

Using GNU Fortran

For GCC version 16.0.0 (pre-release)

(GCC)

The gfortran team

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1 Introduction

This manual documents the use of `gfortran`, the GNU Fortran compiler. You can find in this manual how to invoke `gfortran`, as well as its features and incompatibilities.

Warning: This document, and the compiler it describes, are still under development. While efforts are made to keep it up-to-date, it might not accurately reflect the status of the most recent GNU Fortran compiler.

1.1 About GNU Fortran

The GNU Fortran compiler is the successor to `g77`, the Fortran 77 front end included in GCC prior to version 4 (released in 2005). While it is backward-compatible with most `g77` extensions and command-line options, `gfortran` is a completely new implementation designed to support more modern dialects of Fortran. GNU Fortran implements the Fortran 77, 90 and 95 standards completely, most of the Fortran 2003 and 2008 standards, and some features from the 2018 standard. It also implements several extensions including OpenMP and OpenACC support for parallel programming.

The GNU Fortran compiler passes the NIST Fortran 77 Test Suite (http://www.fortran-2000.com/ArnaudRecipes/fcvs21_f95.html), and produces acceptable results on the LAPACK Test Suite (<https://www.netlib.org/lapack/faq.html>). It also provides respectable performance on the Polyhedron Fortran compiler benchmarks (https://polyhedron.com/?page_id=175) and the Livermore Fortran Kernels test (<https://www.netlib.org/benchmark/livermore>). It has been used to compile a number of large real-world programs, including the HARMONIE and HIRLAM weather forecasting code (<http://hirlam.org/>) and the Tonto quantum chemistry package (<https://github.com/dylan-jayatilaka/tonto>); see <https://gcc.gnu.org/wiki/GfortranApps> for an extended list.

GNU Fortran provides the following functionality:

- Read a program, stored in a file and containing *source code* instructions written in Fortran 77.
- Translate the program into instructions a computer can carry out more quickly than it takes to translate the original Fortran instructions. The result after compilation of a program is *machine code*, which is efficiently translated and processed by a machine such as your computer. Humans usually are not as good writing machine code as they are at writing Fortran (or C++, Ada, or Java), because it is easy to make tiny mistakes writing machine code.
- Provide information about the reasons why the compiler may be unable to create a binary from the source code, for example if the source code is flawed. The Fortran language standards require that the compiler can point out mistakes in your code. An incorrect usage of the language causes an *error message*.

The compiler also attempts to diagnose cases where your program contains a correct usage of the language, but instructs the computer to do something questionable. This kind of diagnostic message is called a *warning message*.

- Provide optional information about the translation passes from the source code to machine code. This can help you to find the cause of certain bugs which may not be

obvious in the source code, but may be more easily found at a lower level compiler output. It also helps developers to find bugs in the compiler itself.

- Provide information in the generated machine code that can make it easier to find bugs in the program (using a debugging tool, called a *debugger*, such as the GNU Debugger *gdb*).
- Locate and gather machine code already generated to perform actions requested by statements in the program. This machine code is organized into *modules* and is located and *linked* to the user program.

The GNU Fortran compiler consists of several components:

- A version of the `gcc` command (which also might be installed as the system's `cc` command) that also understands and accepts Fortran source code. The `gcc` command is the *driver* program for all the languages in the GNU Compiler Collection (GCC); With `gcc`, you can compile the source code of any language for which a front end is available in GCC.
- The `gfortran` command itself, which also might be installed as the system's `f95` command. `gfortran` is just another driver program, but specifically for the Fortran compiler only. The primary difference between the `gcc` and `gfortran` commands is that the latter automatically links the correct libraries to your program.
- A collection of run-time libraries. These libraries contain the machine code needed to support capabilities of the Fortran language that are not directly provided by the machine code generated by the `gfortran` compilation phase, such as intrinsic functions and subroutines, and routines for interaction with files and the operating system.
- The Fortran compiler itself, (`f951`). This is the GNU Fortran parser and code generator, linked to and interfaced with the GCC backend library. `f951` “translates” the source code to assembler code. You would typically not use this program directly; instead, the `gcc` or `gfortran` driver programs call it for you.

1.2 GNU Fortran and GCC

GNU Fortran is a part of GCC, the *GNU Compiler Collection*. GCC consists of a collection of front ends for various languages, which translate the source code into a language-independent form called *GENERIC*. This is then processed by a common middle end which provides optimization, and then passed to one of a collection of back ends which generate code for different computer architectures and operating systems.

Functionally, this is implemented with a driver program (`gcc`) which provides the command-line interface for the compiler. It calls the relevant compiler front-end program (e.g., `f951` for Fortran) for each file in the source code, and then calls the assembler and linker as appropriate to produce the compiled output. In a copy of GCC that has been compiled with Fortran language support enabled, `gcc` recognizes files with `.f`, `.for`, `.ftn`, `.f90`, `.f95`, `.f03` and `.f08` extensions as Fortran source code, and compiles it accordingly. A `gfortran` driver program is also provided, which is identical to `gcc` except that it automatically links the Fortran runtime libraries into the compiled program.

Source files with `.f`, `.for`, `.fpp`, `.ftn`, `.F`, `.FOR`, `.FPP`, and `.FTN` extensions are treated as fixed form. Source files with `.f90`, `.f95`, `.f03`, `.f08`, `.F90`, `.F95`, `.F03` and `.F08` extensions are treated as free form. The capitalized versions of either form are run through

preprocessing. Source files with the lower case `.fpp` extension are also run through preprocessing.

This manual specifically documents the Fortran front end, which handles the programming language's syntax and semantics. The aspects of GCC that relate to the optimization passes and the back-end code generation are documented in the GCC manual; see Section "Introduction" in *Using the GNU Compiler Collection (GCC)*. The two manuals together provide a complete reference for the GNU Fortran compiler.

1.3 Standards

Fortran is developed by the Working Group 5 of Sub-Committee 22 of the Joint Technical Committee 1 of the International Organization for Standardization and the International Electrotechnical Commission (IEC). This group is known as WG5 (<http://www.nag.co.uk/sc22wg5/>). Official Fortran standard documents are available for purchase from ISO; a collection of free documents (typically final drafts) are also available on the wiki (<https://gcc.gnu.org/wiki/GFortranStandards>).

The GNU Fortran compiler implements ISO/IEC 1539:1997 (Fortran 95). As such, it can also compile essentially all standard-compliant Fortran 90 and Fortran 77 programs. It also supports the ISO/IEC TR-15581 enhancements to allocatable arrays.

GNU Fortran also supports almost all of ISO/IEC 1539-1:2004 (Fortran 2003) and ISO/IEC 1539-1:2010 (Fortran 2008). It has partial support for features introduced in ISO/IEC 1539:2018 (Fortran 2018), the most recent version of the Fortran language standard, including full support for the Technical Specification **Further Interoperability of Fortran with C** (ISO/IEC TS 29113:2012). More details on support for these standards can be found in the following sections of the documentation.

1.3.1 Fortran 95 status

The Fortran 95 standard specifies in Part 2 (ISO/IEC 1539-2:2000) varying length character strings. While GNU Fortran currently does not support such strings directly, there exist two Fortran implementations for them, which work with GNU Fortran. One can be found at <http://user.astro.wisc.edu/~townsend/static.php?ref=iso-varying-string>.

Deferred-length character strings of Fortran 2003 supports part of the features of `ISO_VARYING_STRING` and should be considered as replacement. (Namely, allocatable or pointers of the type `character(len=:)`.)

Part 3 of the Fortran 95 standard (ISO/IEC 1539-3:1998) defines Conditional Compilation, which is not widely used and not directly supported by the GNU Fortran compiler. You can use the program `coco` to preprocess such files (<http://www.daniellnagle.com/coco.html>).

1.3.2 Fortran 2003 status

GNU Fortran implements the Fortran 2003 (ISO/IEC 1539-1:2004) standard except for finalization support, which is incomplete. See the wiki page (<https://gcc.gnu.org/wiki/Fortran2003>) for a full list of new features introduced by Fortran 2003 and their implementation status.

1.3.3 Fortran 2008 status

The GNU Fortran compiler supports almost all features of Fortran 2008; the wiki (<https://gcc.gnu.org/wiki/Fortran2008Status>) has some information about the current implementation status. In particular, the following are not yet supported:

- `DO CONCURRENT` and `FORALL` do not recognize a type-spec in the loop header.
- The change to permit any constant expression in subscripts and nested implied-do limits in a `DATA` statement has not been implemented.

1.3.4 Fortran 2018 status

Fortran 2018 (ISO/IEC 1539:2018) is the most recent version of the Fortran language standard. GNU Fortran implements some of the new features of this standard:

- All Fortran 2018 features derived from ISO/IEC TS 29113:2012, “Further Interoperability of Fortran with C”, are supported by GNU Fortran. This includes assumed-type and assumed-rank objects and the `SELECT RANK` construct as well as the parts relating to `BIND(C)` functions. See also Section 6.1.6 [Further Interoperability of Fortran with C], page 78.
- GNU Fortran supports a subset of features derived from ISO/IEC TS 18508:2015, “Additional Parallel Features in Fortran”:
 - The new atomic `ADD`, `CAS`, `FETCH` and `ADD/OR/XOR`, `OR` and `XOR` intrinsics.
 - The `CO_MIN` and `CO_MAX` and `SUM` reduction intrinsics, and the `CO_BROADCAST` and `CO_REDUCE` intrinsic, except that those do not support polymorphic types or types with allocatable, pointer or polymorphic components.
 - Events (`EVENT POST`, `EVENT WAIT`, `EVENT_QUERY`).
 - Failed images (`FAIL IMAGE`, `IMAGE_STATUS`, `FAILED_IMAGES`, `STOPPED_IMAGES`).
- An `ERROR STOP` statement is permitted in a `PURE` procedure.
- GNU Fortran supports the `IMPLICIT NONE` statement with an `implicit-none-spec-list`.
- The behavior of the `INQUIRE` statement with the `RECL=` specifier now conforms to Fortran 2018.

Part I: Invoking GNU Fortran

2 GNU Fortran Command Options

The `gfortran` command supports all the options supported by the `gcc` command. Only options specific to GNU Fortran are documented here.

See Section “GCC Command Options” in *Using the GNU Compiler Collection (GCC)*, for information on the non-Fortran-specific aspects of the `gcc` command (and, therefore, the `gfortran` command).

All GCC and GNU Fortran options are accepted both by `gfortran` and by `gcc` (as well as any other drivers built at the same time, such as `g++`), since adding GNU Fortran to the GCC distribution enables acceptance of GNU Fortran options by all of the relevant drivers.

In some cases, options have positive and negative forms; the negative form of `-ffoo` would be `-fno-foo`. This manual documents only one of these two forms, whichever one is not the default.

2.1 Option summary

Here is a summary of all the options specific to GNU Fortran, grouped by type. Explanations are in the following sections.

Fortran Language Options

See Section 2.2 [Options controlling Fortran dialect], page 9.

```
-fall-intrinsics -fallow-argument-mismatch -fallow-invalid-boz
-fbackslash -fcray-pointer -fd-lines-as-code -fd-lines-as-comments
-fdec -fdec-char-conversions -fdec-structure -fdec-intrinsic-ints
-fdec-static -fdec-math -fdec-include -fdec-format-defaults
-fdec-blank-format-item -fdefault-double-8 -fdefault-integer-8
-fdefault-real-8 -fdefault-real-10 -fdefault-real-16 -fdollar-ok
-ffixed-line-length-n -ffixed-line-length-none -fpad-source
-ffree-form -ffree-line-length-n -ffree-line-length-none
-fimplicit-none -finteger-4-integer-8 -fmax-identifier-length
-fmodule-private -ffixed-form -fno-range-check -fopenacc -fopenmp
-fopenmp-allocators -fopenmp-simd -freal-4-real-10 -freal-4-real-16
-freal-4-real-8 -freal-8-real-10 -freal-8-real-16 -freal-8-real-4
-std=std -ftest-forall-temp -funsigned
```

Preprocessing Options

See Section 2.3 [Enable and customize preprocessing], page 14.

```
-A-question[=answer]
-Aquestion=answer -C -CC -Dmacro[=defn]
-H -P
-Umacro -cpp -dD -dI -dM -dN -dU -fworking-directory
-imultilib dir
-iprefix file -iquote -isysroot dir -isystem dir -nocpp
-nostdinc
-undef
```

Error and Warning Options

See Section 2.4 [Options to request or suppress errors and warnings], page 18.

```
-Waliasing -Wall -Wampersand -Warray-bounds
-Wc-binding-type -Wcharacter-truncation -Wconversion
-Wdo-subscript -Wfunction-elimination -Wimplicit-interface
```

```
-Wimplicit-procedure -Wintrinsic-shadow -Wuse-without-only
-Wintrinsic-std -Wline-truncation -Wno-align-commons
-Wno-overwrite-recursive -Wno-tabs -Wreal-q-constant -Wsurprising
-Wunderflow -Wunused-parameter -Wrealloc-lhs -Wrealloc-lhs-all
-Wfrontend-loop-interchange -Wtarget-lifetime -fmax-errors=n
-fsyntax-only -pedantic
-pedantic-errors
```

Debugging Options

See Section 2.5 [Options for debugging your program], page 22.

```
-fbacktrace -fdebug-aux-vars -ffpe-trap=list
-ffpe-summary=list
```

Directory Options

See Section 2.6 [Options for directory search], page 24.

```
-Idir -Jdir -fintrinsic-modules-path dir
```

Link Options

See Section 2.7 [Options for influencing the linking step], page 24.

```
-static-libgfortran -static-libquadmath
```

Runtime Options

See Section 2.8 [Options for influencing runtime behavior], page 24.

```
-fconvert=conversion -fmax-subrecord-length=length
-frecord-marker=length -fsign-zero
```

Interoperability Options

See Section 2.11 [Options for interoperability], page 34.

```
-fc-prototypes -fc-prototypes-external
```

Code Generation Options

See Section 2.10 [Options for code generation conventions], page 26.

```
-faggressive-function-elimination -fbblas-matmul-limit=n
-fbounds-check -ftail-call-workaround -ftail-call-workaround=n
-fcheck-array-temporaries
-fcheck=<all|array-temps|bits|bounds|do|mem|pointer|recursion>
-fcoarray=<none|single|lib> -fexternal-blas -fexternal-blas64 -ff2c
-ffrontend-loop-interchange -ffrontend-optimize
-finit-character=n -finit-integer=n -finit-local-zero
-finit-derived -finit-logical=<true|false>
-finit-real=<zero|inf|-inf|nan|snan>
-finline-intrinsics[=<minloc,maxloc>]
-finline-matmul-limit=n
-finline-arg-packing -fmax-array-constructor=n
-fmax-stack-var-size=n -fno-align-commons -fno-automatic
-fno-protect-parens -fno-underscoring -fsecond-underscore
-fpack-derived -frealloc-lhs -frecursive -frepack-arrays
-fshort-enums -fstack-arrays
```

Developer Options

See Section 2.9 [GNU Fortran Developer Options], page 25.

```
-fdump-fortran-global -fdump-fortran-optimized
-fdump-fortran-original -fdump-parse-tree -save-temps
```

2.2 Options controlling Fortran dialect

The following options control the details of the Fortran dialect accepted by the compiler:

-ffree-form

-ffixed-form

Specify the layout used by the source file. The free form layout was introduced in Fortran 90. Fixed form was traditionally used in older Fortran programs. When neither option is specified, the source form is determined by the file extension.

-fall-intrinsics

This option causes all intrinsic procedures (including the GNU-specific extensions) to be accepted. This can be useful with **-std=** to force standard compliance but get access to the full range of intrinsics available with **gfortran**. As a consequence, **-Wintrinsics-std** is ignored and no user-defined procedure with the same name as any intrinsic is called except when it is explicitly declared **EXTERNAL**.

-fallow-argument-mismatch

Some code contains calls to external procedures with mismatches between the calls and the procedure definition, or with mismatches between different calls. Such code is nonconforming, and is usually flagged with an error. This options degrades the error to a warning that can only be disabled by disabling all warnings via **-w**. Only a single occurrence per argument is flagged by this warning. **-fallow-argument-mismatch** is implied by **-std=legacy**.

Using this option is *strongly* discouraged. It is possible to provide standard-conforming code that allows different types of arguments by using an explicit interface and **TYPE(*)**.

-fallow-invalid-boz

A BOZ literal constant can occur in a limited number of contexts in standard conforming Fortran. This option degrades an error condition to a warning, and allows a BOZ literal constant to appear where the Fortran standard would otherwise prohibit its use.

-fd-lines-as-code

-fd-lines-as-comments

Enable special treatment for lines beginning with **d** or **D** in fixed form sources. If the **-fd-lines-as-code** option is given they are treated as if the first column contained a blank. If the **-fd-lines-as-comments** option is given, they are treated as comment lines.

-fdec

DEC compatibility mode. Enables extensions and other features that mimic the default behavior of older compilers (such as DEC). These features are non-standard and should be avoided at all costs. For details on GNU Fortran's implementation of these extensions see the full documentation.

Other flags enabled by this switch are: **-fdollar-ok** **-fcray-pointer**
-fdec-char-conversions **-fdec-structure** **-fdec-intrinsic-ints**
-fdec-static **-fdec-math** **-fdec-include** **-fdec-blank-format-item**
-fdec-format-defaults

If `-fd-lines-as-code/-fd-lines-as-comments` are unset, then `-fdec` also sets `-fd-lines-as-comments`.

-fdec-char-conversions

Enable the use of character literals in assignments and `DATA` statements for non-character variables.

-fdec-structure

Enable `DEC STRUCTURE` and `RECORD` as well as `UNION`, `MAP`, and dot (`'.'`) as a member separator (in addition to `'%'`). This is provided for compatibility only; Fortran 90 derived types should be used instead where possible.

-fdec-intrinsic-ints

Enable `B/I/J/K` kind variants of existing integer functions (e.g. `BIAND`, `IIAND`, `JIAND`, etc...). For a complete list of intrinsics see Chapter 8 [Intrinsic Procedures], page 119.

-fdec-math

Obsolete flag. The purpose of this option was to enable legacy math intrinsics such as `COTAN` and degree-valued trigonometric functions (e.g. `TAND`, `ATAND`, etc...) for compatibility with older code. This option is no longer operable. The trigonometric functions are now either part of Fortran 2023 or GNU extensions.

-fdec-static

Enable DEC-style `STATIC` and `AUTOMATIC` attributes to explicitly specify the storage of variables and other objects.

-fdec-include

Enable parsing of `INCLUDE` as a statement in addition to parsing it as `INCLUDE` line. When parsed as `INCLUDE` statement, `INCLUDE` does not have to be on a single line and can use line continuations.

-fdec-format-defaults

Enable format specifiers `'F'`, `'G'` and `'I'` to be used without width specifiers; default widths are used instead.

-fdec-blank-format-item

Enable a blank format item at the end of a format specification i.e. nothing following the final comma.

-fdollar-ok

Allow `'$'` as a valid non-first character in a symbol name. Symbols that start with `'$'` are rejected since it is unclear which rules to apply to implicit typing as different vendors implement different rules. Using `'$'` in `IMPLICIT` statements is also rejected.

-fbackslash

Change the interpretation of backslashes in string literals from a single backslash character to “C-style” escape characters. The following combinations are expanded: `'\a'`, `'\b'`, `'\f'`, `'\n'`, `'\r'`, `'\t'`, `'\v'`, `'\\'`, and `'\0'` to the ASCII characters alert, backspace, form feed, newline, carriage return, horizontal tab, vertical tab, backslash, and NUL, respectively. Additionally, `'\xnn'`, `'\unnnn'`

and ‘\Unnnnnnnn’ (where each *n* is a hexadecimal digit) are translated into the Unicode characters corresponding to the specified code points. All other combinations of a character preceded by ‘\’ are unexpanded.

-fmodule-private

Set the default accessibility of module entities to **PRIVATE**. Use-associated entities are not accessible unless they are explicitly declared as **PUBLIC**.

-ffixed-line-length-n

Set column after which characters are ignored in typical fixed-form lines in the source file, and, unless **-fno-pad-source**, through which spaces are assumed (as if padded to that length) after the ends of short fixed-form lines.

Popular values for *n* include 72 (the standard and the default), 80 (card image), and 132 (corresponding to “extended-source” options in some popular compilers). *n* may also be ‘none’, meaning that the entire line is meaningful and that continued character constants never have implicit spaces appended to them to fill out the line. **-ffixed-line-length-0** means the same thing as **-ffixed-line-length-none**.

-fno-pad-source

By default fixed-form lines have spaces assumed (as if padded to that length) after the ends of short fixed-form lines. This is not done either if **-ffixed-line-length-0**, **-ffixed-line-length-none** or if **-fno-pad-source** option is used. With any of those options continued character constants never have implicit spaces appended to them to fill out the line.

-ffree-line-length-n

Set column after which characters are ignored in typical free-form lines in the source file. The default value is 132. *n* may be ‘none’, meaning that the entire line is meaningful. **-ffree-line-length-0** means the same thing as **-ffree-line-length-none**.

-fmax-identifier-length=n

Specify the maximum allowed identifier length. Typical values are 31 (Fortran 95) and 63 (Fortran 2003 and later).

-fimplicit-none

Specify that no implicit typing is allowed, unless overridden by explicit **IMPLICIT** statements. This is the equivalent of adding **implicit none** to the start of every procedure.

-fcray-pointer

Enable the Cray pointer extension, which provides C-like pointer functionality.

-fopenacc

Enable handling of OpenACC directives ‘!\$acc’ in free-form Fortran and ‘!\$acc’, ‘c\$acc’ and ‘*\$acc’ in fixed-form Fortran. When **-fopenacc** is specified, the compiler generates accelerated code according to the OpenACC Application Programming Interface v2.6 <https://www.openacc.org>. This option implies **-pthread**, and thus is only supported on targets that have support for **-pthread**. The option **-fopenacc** implies **-frecursive**.

-fopenmp Enable handling of OpenMP directives ‘`!$omp`’ in Fortran. It additionally enables the conditional compilation sentinel ‘`!$`’ in Fortran. In fixed source form Fortran, the sentinels can also start with ‘`c`’ or ‘`*`’. When **-fopenmp** is specified, the compiler generates parallel code according to the OpenMP Application Program Interface v4.5 <https://www.openmp.org>. This option implies **-pthread**, and thus is only supported on targets that have support for **-pthread**. **-fopenmp** implies **-fopenmp-simd** and **-frecursive**.

-fopenmp-allocators

Enables handling of allocation, reallocation and deallocation of Fortran allocatable and pointer variables that are allocated using the ‘`!$omp allocators`’ and ‘`!$omp allocate`’ constructs. Files containing either directive have to be compiled with this option in addition to **-fopenmp**. Additionally, all files that might deallocate or reallocate a variable that has been allocated with an OpenMP allocator have to be compiled with this option. This includes intrinsic assignment to allocatable variables when reallocation may occur and deallocation due to either of the following: end of scope, explicit deallocation, ‘`intent(out)`’, deallocation of allocatable components etc. Files not changing the allocation status or only for components of a derived type that have not been allocated using those two directives do not need to be compiled with this option. Nor do files that handle such variables after they have been deallocated or allocated by the normal Fortran allocator.

-fopenmp-simd

Enable handling of OpenMP’s **simd**, **declare simd**, **declare reduction**, **assume**, **ordered**, **scan** and **loop** directive, and of combined or composite directives with **simd** as constituent with `!$omp` in Fortran. It additionally enables the conditional compilation sentinel ‘`!$`’ in Fortran. In fixed source form Fortran, the sentinels can also start with ‘`c`’ or ‘`*`’. Other OpenMP directives are ignored. Unless **-fopenmp** is additionally specified, the **loop** region binds to the current task region, independent of the specified **bind** clause.

-fno-range-check

Disable range checking on results of simplification of constant expressions during compilation. For example, GNU Fortran gives an error at compile time when simplifying `a = 1. / 0.` With this option, no error is given and `a` is assigned the value `+Infinity`. If an expression evaluates to a value outside of the relevant range of `[-HUGE():HUGE()]`, then the expression is replaced by `-Inf` or `+Inf` as appropriate. Similarly, `DATA i/Z'FFFFFFFF'/` results in an integer overflow on most systems, but with **-fno-range-check** the value “wraps around” and `i` is initialized to `-1` instead.

-fdefault-integer-8

Set the default integer and logical types to an 8 byte wide type. This option also affects the kind of integer constants like `42`. Unlike **-finteger-4-integer-8**, it does not promote variables with explicit kind declaration.

-fdefault-real-8

Set the default real type to an 8 byte wide type. This option also affects the kind of non-double real constants like 1.0. This option promotes the default width of DOUBLE PRECISION and double real constants like 1.d0 to 16 bytes if possible. If **-fdefault-double-8** is given along with **fdefault-real-8**, DOUBLE PRECISION and double real constants are not promoted. Unlike **-freal-4-real-8**, **fdefault-real-8** does not promote variables with explicit kind declarations.

-fdefault-real-10

Set the default real type to an 10 byte wide type. This option also affects the kind of non-double real constants like 1.0. This option promotes the default width of DOUBLE PRECISION and double real constants like 1.d0 to 16 bytes if possible. If **-fdefault-double-8** is given along with **fdefault-real-10**, DOUBLE PRECISION and double real constants are not promoted. Unlike **-freal-4-real-10**, **fdefault-real-10** does not promote variables with explicit kind declarations.

-fdefault-real-16

Set the default real type to an 16 byte wide type. This option also affects the kind of non-double real constants like 1.0. This option promotes the default width of DOUBLE PRECISION and double real constants like 1.d0 to 16 bytes if possible. If **-fdefault-double-8** is given along with **fdefault-real-16**, DOUBLE PRECISION and double real constants are not promoted. Unlike **-freal-4-real-16**, **fdefault-real-16** does not promote variables with explicit kind declarations.

-fdefault-double-8

Set the DOUBLE PRECISION type and double real constants like 1.d0 to an 8 byte wide type. Do nothing if this is already the default. This option prevents **-fdefault-real-8**, **-fdefault-real-10**, and **-fdefault-real-16**, from promoting DOUBLE PRECISION and double real constants like 1.d0 to 16 bytes.

-finteger-4-integer-8

Promote all INTEGER(KIND=4) entities to an INTEGER(KIND=8) entities. If KIND=8 is unavailable, then an error is issued. This option should be used with care and may not be suitable for your codes. Areas of possible concern include calls to external procedures, alignment in EQUIVALENCE and/or COMMON, generic interfaces, BOZ literal constant conversion, and I/O. Inspection of the intermediate representation of the translated Fortran code, produced by **-fdump-tree-original**, is suggested.

-freal-4-real-8**-freal-4-real-10****-freal-4-real-16****-freal-8-real-4****-freal-8-real-10****-freal-8-real-16**

Promote all REAL(KIND=M) entities to REAL(KIND=N) entities. If REAL(KIND=N) is unavailable, then an error is issued. The **-freal-4-** flags also affect the de-

fault real kind and the `-freal-8-` flags also the double-precision real kind. All other real-kind types are unaffected by this option. The promotion is also applied to real literal constants of default and double-precision kind and a specified kind number of 4 or 8, respectively. However, `-fdefault-real-8`, `-fdefault-real-10`, `-fdefault-real-10`, and `-fdefault-double-8` take precedence for the default and double-precision real kinds, both for real literal constants and for declarations without a kind number. Note that for `REAL(KIND=KIND(1.0))` the literal may get promoted and then the result may get promoted again. These options should be used with care and may not be suitable for your codes. Areas of possible concern include calls to external procedures, alignment in `EQUIVALENCE` and/or `COMMON`, generic interfaces, `BOZ` literal constant conversion, and I/O and calls to intrinsic procedures when passing a value to the `kind=` dummy argument. Inspection of the intermediate representation of the translated Fortran code, produced by `-fdump-fortran-original` or `-fdump-tree-original`, is suggested.

-std=std Specify the standard to which the program is expected to conform, which may be one of 'f95', 'f2003', 'f2008', 'f2018', 'f2023', 'gnu', or 'legacy'. The default value for *std* is 'gnu', which specifies a superset of the latest Fortran standard that includes all of the extensions supported by GNU Fortran, although warnings are given for obsolete extensions not recommended for use in new code. The 'legacy' value is equivalent but without the warnings for obsolete extensions, and may be useful for old nonstandard programs. The 'f95', 'f2003', 'f2008', 'f2018', and 'f2023' values specify strict conformance to the Fortran 95, Fortran 2003, Fortran 2008, Fortran 2018 and Fortran 2023 standards, respectively; errors are given for all extensions beyond the relevant language standard, and warnings are given for the Fortran 77 features that are permitted but obsolescent in later standards. The deprecated option '`-std=f2008ts`' acts as an alias for '`-std=f2018`'. It is only present for backwards compatibility with earlier gfortran versions and should not be used any more. '`-std=f202y`' acts as an alias for '`-std=f2023`' and enables proposed features for testing Fortran 202y. As the Fortran 202y standard develops, implementation might change or the experimental new features might be removed.

-ftest-forall-temp

Enhance test coverage by forcing most forall assignments to use temporary.

-funsigned

Allow the experimental unsigned extension.

2.3 Enable and customize preprocessing

Many Fortran compilers including GNU Fortran allow passing the source code through a C preprocessor (CPP; sometimes also called the Fortran preprocessor, FPP) to allow for conditional compilation. In the case of GNU Fortran, this is the GNU C Preprocessor in the traditional mode. On systems with case-preserving file names, the preprocessor is automatically invoked if the filename extension is `.F`, `.FOR`, `.FTN`, `.fpp`, `.FPP`, `.F90`, `.F95`, `.F03` or `.F08`. To manually invoke the preprocessor on any file, use `-cpp`, to disable preprocessing on files where the preprocessor is run automatically, use `-nocpp`.

If a preprocessed file includes another file with the Fortran `INCLUDE` statement, the included file is not preprocessed. To preprocess included files, use the equivalent preprocessor statement `#include`.

If GNU Fortran invokes the preprocessor, `__GFORTRAN__` is defined. The macros `__GNUC__`, `__GNUC_MINOR__` and `__GNUC_PATCHLEVEL__` can be used to determine the version of the compiler. See Section “Overview” in *The C Preprocessor* for details.

GNU Fortran supports a number of `INTEGER` and `REAL` kind types in addition to the kind types required by the Fortran standard. The availability of any given kind type is architecture dependent. The following predefined preprocessor macros can be used to conditionally include code for these additional kind types: `__GFC_INT_1__`, `__GFC_INT_2__`, `__GFC_INT_8__`, `__GFC_INT_16__`, `__GFC_REAL_10__`, and `__GFC_REAL_16__`.

While CPP is the de facto standard for preprocessing Fortran code, Part 3 of the Fortran 95 standard (ISO/IEC 1539-3:1998) defines Conditional Compilation, which is not widely used and not directly supported by the GNU Fortran compiler.

The following options control preprocessing of Fortran code:

- cpp**
- nocpp** Enable preprocessing. The preprocessor is automatically invoked if the file extension is `.fpp`, `.FPP`, `.F`, `.FOR`, `.FTN`, `.F90`, `.F95`, `.F03` or `.F08`. Use this option to manually enable preprocessing of any kind of Fortran file.
 To disable preprocessing of files with any of the above listed extensions, use the negative form: `-nocpp`.
 The preprocessor is run in traditional mode. Any restrictions of the file format, especially the limits on line length, apply for preprocessed output as well, so it might be advisable to use the `-ffree-line-length-none` or `-ffixed-line-length-none` options.
- dM** Instead of the normal output, generate a list of `'#define'` directives for all the macros defined during the execution of the preprocessor, including predefined macros. This gives you a way of finding out what is predefined in your version of the preprocessor. Assuming you have no file `foo.f90`, the command
 `touch foo.f90; gfortran -cpp -E -dM foo.f90`
 shows all the predefined macros.
- dD** Like `-dM` except in two respects: it does not include the predefined macros, and it outputs both the `#define` directives and the result of preprocessing. Both kinds of output go to the standard output file.
- dN** Like `-dD`, but emit only the macro names, not their expansions.
- dU** Like `dD` except that only macros that are expanded, or whose definedness is tested in preprocessor directives, are output; the output is delayed until the use or test of the macro; and `'#undef'` directives are also output for macros tested but undefined at the time.
- dI** Output `'#include'` directives in addition to the result of preprocessing.
- fworking-directory**
 Enable generation of linemarkers in the preprocessor output that let the compiler know the current working directory at the time of preprocessing. When

this option is enabled, the preprocessor emits, after the initial linemark, a second linemark with the current working directory followed by two slashes. GCC uses this directory, when it is present in the preprocessed input, as the directory emitted as the current working directory in some debugging information formats. This option is implicitly enabled if debugging information is enabled, but this can be inhibited with the negated form `-fno-working-directory`. If the `-P` flag is present in the command line, this option has no effect, since no `#line` directives are emitted whatsoever.

-idirafter *dir*

Search *dir* for include files, but do it after all directories specified with `-I` and the standard system directories have been exhausted. *dir* is treated as a system include directory. If *dir* begins with `=`, then the `=` is replaced by the sysroot prefix; see `--sysroot` and `-isysroot`.

-imultilib *dir*

Use *dir* as a subdirectory of the directory containing target-specific C++ headers.

-iprefix *prefix*

Specify *prefix* as the prefix for subsequent `-iwithprefix` options. If the *prefix* represents a directory, you should include the final `'/'`.

-isysroot *dir*

This option is like the `--sysroot` option, but applies only to header files. See the `--sysroot` option for more information.

-iquote *dir*

Search *dir* only for header files requested with `#include "file"`; they are not searched for `#include <file>`, before all directories specified by `-I` and before the standard system directories. If *dir* begins with `=`, then the `=` is replaced by the sysroot prefix; see `--sysroot` and `-isysroot`.

-isystem *dir*

Search *dir* for header files, after all directories specified by `-I` but before the standard system directories. Mark it as a system directory, so that it gets the same special treatment as is applied to the standard system directories. If *dir* begins with `=`, then the `=` is replaced by the sysroot prefix; see `--sysroot` and `-isysroot`.

-nostdinc

Do not search the standard system directories for header files. Only the directories you have specified with `-I` options (and the directory of the current file, if appropriate) are searched.

-undef

Do not predefine any system-specific or GCC-specific macros. The standard predefined macros remain defined.

-Apredicate=*answer*

Make an assertion with the predicate *predicate* and answer *answer*. This form is preferred to the older form `-A predicate(answer)`, which is still supported, because it does not use shell special characters.

-A-predicate=answer

Cancel an assertion with the predicate *predicate* and answer *answer*.

-C

Do not discard comments. All comments are passed through to the output file, except for comments in processed directives, which are deleted along with the directive.

You should be prepared for side effects when using **-C**; it causes the preprocessor to treat comments as tokens in their own right. For example, comments appearing at the start of what would be a directive line have the effect of turning that line into an ordinary source line, since the first token on the line is no longer a '#'.
 Warning: this currently handles C-Style comments only. The preprocessor does not yet recognize Fortran-style comments.

-CC

Do not discard comments, including during macro expansion. This is like **-C**, except that comments contained within macros are also passed through to the output file where the macro is expanded.

In addition to the side-effects of the **-C** option, the **-CC** option causes all C++-style comments inside a macro to be converted to C-style comments. This is to prevent later use of that macro from inadvertently commenting out the remainder of the source line. The **-CC** option is generally used to support lint comments.

Warning: this currently handles C- and C++-Style comments only. The preprocessor does not yet recognize Fortran-style comments.

-Dname

Predefine name as a macro, with definition 1.

-Dname=definition

The contents of *definition* are tokenized and processed as if they appeared during translation phase three in a '#define' directive. In particular, the definition is truncated by embedded newline characters.

If you are invoking the preprocessor from a shell or shell-like program you may need to use the shell's quoting syntax to protect characters such as spaces that have a meaning in the shell syntax.

If you wish to define a function-like macro on the command line, write its argument list with surrounding parentheses before the equals sign (if any). Parentheses are meaningful to most shells, so you need to quote the option. With sh and csh, **-D'name(args...)=definition'** works.

-D and **-U** options are processed in the order they are given on the command line. All **-imacros** file and **-include** file options are processed after all **-D** and **-U** options.

-H

Print the name of each header file used, in addition to other normal activities. Each name is indented to show how deep in the '#include' stack it is.

-P

Inhibit generation of linemarkers in the output from the preprocessor. This might be useful when running the preprocessor on something that is not C code, and is sent to a program that might be confused by the linemarkers.

-Uname Cancel any previous definition of *name*, either built in or provided with a **-D** option.

2.4 Options to request or suppress errors and warnings

Errors are diagnostic messages that report that the GNU Fortran compiler cannot compile the relevant piece of source code. The compiler continues to process the program in an attempt to report further errors to aid in debugging, but does not produce any compiled output.

Warnings are diagnostic messages that report constructions that are not inherently erroneous but that are risky or suggest there is likely to be a bug in the program. Unless **-Werror** is specified, they do not prevent compilation of the program.

You can request many specific warnings with options beginning **-W**, for example **-Wimplicit** to request warnings on implicit declarations. Each of these specific warning options also has a negative form beginning **-Wno-** to turn off warnings; for example, **-Wno-implicit**. This manual lists only one of the two forms, whichever is not the default.

These options control the amount and kinds of errors and warnings produced by GNU Fortran:

-fmax-errors=n

Limits the maximum number of error messages to *n*, at which point GNU Fortran bails out rather than attempting to continue processing the source code. If *n* is 0, there is no limit on the number of error messages produced.

-fsyntax-only

Check the code for syntax errors, but do not actually compile it. This generates module files for each module present in the code, but no other output file.

-Wpedantic

-pedantic

Issue warnings for uses of extensions to Fortran. **-pedantic** also applies to C-language constructs where they occur in GNU Fortran source files, such as use of `'\e'` in a character constant within a directive like `#include`.

Valid Fortran programs should compile properly with or without this option. However, without this option, certain GNU extensions and traditional Fortran features are supported as well. With this option, many of them are rejected.

Some users try to use **-pedantic** to check programs for conformance. They soon find that it does not do quite what they want—it finds some nonstandard practices, but not all. However, improvements to GNU Fortran in this area are welcome.

This should be used in conjunction with **-std=f95**, **-std=f2003**, **-std=f2008**, **-std=f2018** or **-std=f2023**.

-pedantic-errors

Like **-pedantic**, except that errors are produced rather than warnings.

-Wall

Enables commonly used warning options pertaining to usage that we recommend avoiding and that we believe are easy to avoid. This currently includes **-Waliasing**, **-Wampersand**, **-Wconversion**, **-Wsurprising**,

`-Wc-binding-type`, `-Wintrinsics-std`, `-Wtabs`, `-Wintrinsic-shadow`,
`-Wline-truncation`, `-Wtarget-lifetime`, `-Winteger-division`,
`-Wreal-q-constant`, `-Wunused` and `-Wundefined-do-loop`.

`-Waliasing`

Warn about possible aliasing of dummy arguments. Specifically, it warns if the same actual argument is associated with a dummy argument with `INTENT(IN)` and a dummy argument with `INTENT(OUT)` in a call with an explicit interface.

The following example triggers the warning.

```
interface
  subroutine bar(a,b)
    integer, intent(in) :: a
    integer, intent(out) :: b
  end subroutine
end interface
integer :: a

call bar(a,a)
```

`-Wampersand`

Warn about missing ampersand in continued character constants. The warning is given with `-Wampersand`, `-pedantic`, `-std=f95`, `-std=f2003`, `-std=f2008`, `-std=f2018` and `-std=f2023`. Note: With no ampersand given in a continued character constant, GNU Fortran assumes continuation at the first non-comment, non-whitespace character after the ampersand that initiated the continuation.

`-Warray-temporaries`

Warn about array temporaries generated by the compiler. The information generated by this warning is sometimes useful in optimization, in order to avoid such temporaries.

`-Wc-binding-type`

Warn if the a variable might not be C interoperable. In particular, warn if the variable has been declared using an intrinsic type with default kind instead of using a kind parameter defined for C interoperability in the intrinsic `ISO_C_Binding` module. This option is implied by `-Wall`.

`-Wcharacter-truncation`

Warn when a character assignment truncates the assigned string.

`-Wline-truncation`

Warn when a source code line is truncated. This option is implied by `-Wall`. For free-form source code, the default is `-Werror=line-truncation` such that truncations are reported as error.

`-Wconversion`

Warn about implicit conversions that are likely to change the value of the expression after conversion. Implied by `-Wall`.

`-Wconversion-extra`

Warn about implicit conversions between different types and kinds. This option does *not* imply `-Wconversion`.

-Wexternal-argument-mismatch

Warn about argument mismatches for dummy external procedures. This is implied by `-fc-prototypes-external` because generation of a valid C23 interface is not possible in such a case. Also implied by `-Wall`.

-Wextra Enables some warning options for usages of language features that may be problematic. This currently includes `-Wcompare-reals`, `-Wunused-parameter` and `-Wdo-subscript`.

-Wfrontend-loop-interchange

Warn when using `-ffrontend-loop-interchange` for performing loop interchanges.

-Wimplicit-interface

Warn if a procedure is called without an explicit interface. Note this only checks that an explicit interface is present. It does not check that the declared interfaces are consistent across program units.

-Wimplicit-procedure

Warn if a procedure is called that has neither an explicit interface nor has been declared as `EXTERNAL`.

-Winteger-division

Warn if a constant integer division truncates its result. As an example, $3/5$ evaluates to 0.

-Wintrinsics-std

Warn if `gfortran` finds a procedure named like an intrinsic not available in the currently selected standard (with `-std`) and treats it as `EXTERNAL` procedure because of this. `-fall-intrinsics` can be used to never trigger this behavior and always link to the intrinsic regardless of the selected standard.

-Wno-overwrite-recursive

Do not warn when `-fno-automatic` is used with `-frecursive`. Recursion is broken if the relevant local variables do not have the attribute `AUTOMATIC` explicitly declared. This option can be used to suppress the warning when it is known that recursion is not broken. Useful for build environments that use `-Werror`.

-Wreal-q-constant

Produce a warning if a real-literal-constant contains a `q` exponent-letter.

-Wsurprising

Produce a warning when “suspicious” code constructs are encountered. While technically legal these usually indicate that an error has been made.

This currently produces a warning under the following circumstances:

- An `INTEGER`-typed `SELECT CASE` construct has a `CASE` that can never be matched as its lower value is greater than its upper value.
- A `LOGICAL`-typed `SELECT CASE` construct has three `CASE` statements.
- A `TRANSFER` specifies a source that is shorter than the destination.

- The type of a function result is declared more than once with the same type. If `-pedantic` or standard-conforming mode is enabled, this is an error.
 - A `CHARACTER` variable is declared with negative length.
 - With `-fopenmp`, for fixed-form source code, when an `omx` vendor-extension sentinel is encountered. (The equivalent `omp`, used in free-form source code, is diagnosed by default.)
 - With `-fopenacc`, when using named constances with clauses that take a variable as doing so has no effect.
- Wtabs** By default, tabs are accepted as whitespace, but tabs are not members of the Fortran Character Set. For continuation lines, a tab followed by a digit between 1 and 9 is supported. `-Wtabs` causes a warning to be issued if a tab is encountered. Note, `-Wtabs` is active for `-pedantic`, `-std=f95`, `-std=f2003`, `-std=f2008`, `-std=f2018`, `-std=f2023` and `-Wall`.
- Wundefined-do-loop**
Warn if a `DO` loop with step either 1 or -1 yields an underflow or an overflow during iteration of an induction variable of the loop. This option is implied by `-Wall`.
- Wunderflow**
Produce a warning when numerical constant expressions that yield an underflow are encountered during compilation. Enabled by default.
- Wintrinsic-shadow**
Warn if a user-defined procedure or module procedure has the same name as an intrinsic; in this case, an explicit interface or `EXTERNAL` or `INTRINSIC` declaration might be needed to get calls later resolved to the desired intrinsic/procedure. This option is implied by `-Wall`.
- Wuse-without-only**
Warn if a `USE` statement has no `ONLY` qualifier and thus implicitly imports all public entities of the used module.
- Wunused-dummy-argument**
Warn about unused dummy arguments. This option is implied by `-Wall`.
- Wunused-parameter**
Contrary to `gcc`'s meaning of `-Wunused-parameter`, `gfortran`'s implementation of this option does not warn about unused dummy arguments (see `-Wunused-dummy-argument`), but about unused `PARAMETER` values. `-Wunused-parameter` is implied by `-Wextra` if also `-Wunused` or `-Wall` is used.
- Walign-commons**
By default, `gfortran` warns about any occasion of variables being padded for proper alignment inside a `COMMON` block. This warning can be turned off via `-Wno-align-commons`. See also `-falign-commons`.
- Wfunction-elimination**
Warn if any calls to impure functions are eliminated by the optimizations enabled by the `-ffrontend-optimize` option. This option is implied by `-Wextra`.

-Wrealloc-lhs

Warn when the compiler might insert code to for allocation or reallocation of an allocatable array variable of intrinsic type in intrinsic assignments. In hot loops, the Fortran 2003 reallocation feature may reduce the performance. If the array is already allocated with the correct shape, consider using a whole-array array-spec (e.g. `(:,:,:)`) for the variable on the left-hand side to prevent the reallocation check. Note that in some cases the warning is shown, even if the compiler optimizes reallocation checks away. For instance, when the right-hand side contains the same variable multiplied by a scalar. See also **-frealloc-lhs**.

-Wrealloc-lhs-all

Warn when the compiler inserts code to for allocation or reallocation of an allocatable variable; this includes scalars and derived types.

-Wcompare-reals

Warn when comparing real or complex types for equality or inequality. This option is implied by **-Wextra**.

-Wtarget-lifetime

Warn if the pointer in a pointer assignment might be longer than the its target. This option is implied by **-Wall**.

-Wzerotrip

Warn if a DO loop is known to execute zero times at compile time. This option is implied by **-Wall**.

-Wdo-subscript

Warn if an array subscript inside a DO loop could lead to an out-of-bounds access even if the compiler cannot prove that the statement is actually executed, in cases like

```

      real a(3)
      do i=1,4
        if (condition(i)) then
          a(i) = 1.2
        end if
      end do

```

This option is implied by **-Wextra**.

-Werror Turns all warnings into errors.

See Section “Options to Request or Suppress Errors and Warnings” in *Using the GNU Compiler Collection (GCC)*, for information on more options offered by the back end shared by **gfortran**, **gcc** and other GNU compilers.

Some of these have no effect when compiling programs written in Fortran.

2.5 Options for debugging your program

GNU Fortran has various special options that are used for debugging your program.

-fdebug-aux-vars

Renames internal variables created by the **gfortran** front end and makes them accessible to a debugger. The name of the internal variables then start with

uppercase letters followed by an underscore. This option is useful for debugging the compiler's code generation together with `-fdump-tree-original` and enabling debugging of the executable program by using `-g` or `-ggdb3`.

`-ffpe-trap=list`

Specify a list of floating point exception traps to enable. On most systems, if a floating point exception occurs and the trap for that exception is enabled, a SIGFPE signal is sent and the program being aborted, producing a core file useful for debugging. *list* is a (possibly empty) comma-separated list of either `'none'` (to clear the set of exceptions to be trapped), or of the following exceptions: `'invalid'` (invalid floating point operation, such as `SQRT(-1.0)`), `'zero'` (division by zero), `'overflow'` (overflow in a floating point operation), `'underflow'` (underflow in a floating point operation), `'inexact'` (loss of precision during operation), and `'denormal'` (operation performed on a denormal value). The first five exceptions correspond to the five IEEE 754 exceptions, whereas the last one (`'denormal'`) is not part of the IEEE 754 standard but is available on some common architectures such as x86.

The first three exceptions (`'invalid'`, `'zero'`, and `'overflow'`) often indicate serious errors, and unless the program has provisions for dealing with these exceptions, enabling traps for these three exceptions is probably a good idea.

If the option is used more than once in the command line, the lists are joined: `'ffpe-trap=list1 ffpe-trap=list2'` is equivalent to `ffpe-trap=list1,list2`.

Note that once enabled an exception cannot be disabled (no negative form), except by clearing all traps by specifying `'none'`.

Many, if not most, floating point operations incur loss of precision due to rounding, and hence the `ffpe-trap=inexact` is likely to be uninteresting in practice.

By default no exception traps are enabled.

`-ffpe-summary=list`

Specify a list of floating-point exceptions, whose flag status is printed to `ERROR_UNIT` when invoking `STOP` and `ERROR STOP`. *list* can be either `'none'`, `'all'` or a comma-separated list of the following exceptions: `'invalid'`, `'zero'`, `'overflow'`, `'underflow'`, `'inexact'` and `'denormal'`. (See `-ffpe-trap` for a description of the exceptions.)

If the option is used more than once in the command line, only the last one is used.

By default, a summary for all exceptions but `'inexact'` is shown.

`-fno-backtrace`

When a serious runtime error is encountered or a deadly signal is emitted (segmentation fault, illegal instruction, bus error, floating-point exception, and the other POSIX signals that have the action `'core'`), the Fortran runtime library tries to output a backtrace of the error. `-fno-backtrace` disables the backtrace generation. This option only has influence for compilation of the Fortran main program.

See Section "Options for Debugging Your Program or GCC" in *Using the GNU Compiler Collection (GCC)*, for more information on debugging options.

2.6 Options for directory search

These options affect how GNU Fortran searches for files specified by the `INCLUDE` directive and where it searches for previously compiled modules.

It also affects the search paths used by `cpp` when used to preprocess Fortran source.

-I*dir* These affect interpretation of the `INCLUDE` directive (as well as of the `#include` directive of the `cpp` preprocessor).

Also note that the general behavior of `-I` and `INCLUDE` is pretty much the same as of `-I` with `#include` in the `cpp` preprocessor, with regard to looking for `header.gcc` files and other such things.

This path is also used to search for `.mod` files when previously compiled modules are required by a `USE` statement.

See Section “Options for Directory Search” in *Using the GNU Compiler Collection (GCC)*, for information on the `-I` option.

-J*dir* This option specifies where to put `.mod` files for compiled modules. It is also added to the list of directories to searched by an `USE` statement.

The default is the current directory.

-fintrinsic-modules-path *dir*

This option specifies the location of pre-compiled intrinsic modules, if they are not in the default location expected by the compiler.

2.7 Influencing the linking step

These options come into play when the compiler links object files into an executable output file. They are meaningless if the compiler is not doing a link step.

-static-libgfortran

On systems that provide `libgfortran` as a shared and a static library, this option forces the use of the static version. If no shared version of `libgfortran` was built when the compiler was configured, this option has no effect.

-static-libquadmath

On systems that provide `libquadmath` as a shared and a static library, this option forces the use of the static version. If no shared version of `libquadmath` was built when the compiler was configured, this option has no effect.

Please note that the `libquadmath` runtime library is licensed under the GNU Lesser General Public License (LGPL), and linking it statically introduces requirements when redistributing the resulting binaries.

2.8 Influencing runtime behavior

These options affect the runtime behavior of programs compiled with GNU Fortran.

-fconvert=*conversion*

Specify the representation of data for unformatted files. Valid values for *conversion* on most systems are: `'native'`, the default; `'swap'`, swap between big- and little-endian; `'big-endian'`, use big-endian representation for unformatted files; `'little-endian'`, use little-endian representation for unformatted files.

On POWER systems that support `-mabi=ieeelongdouble`, there are additional options, which can be combined with others with commas. Those are

`-fconvert=r16_ieee` Use IEEE 128-bit format for `REAL(KIND=16)`.

`-fconvert=r16_ibm` Use IBM long double format for `REAL(KIND=16)`.

This option has an effect only when used in the main program. The `CONVERT` specifier and the `GFORTRAN_CONVERT_UNIT` environment variable override the default specified by `-fconvert`.

`-frecord-marker=length`

Specify the length of record markers for unformatted files. Valid values for *length* are 4 and 8. Default is 4. *This is different from previous versions of gfortran*, which specified a default record marker length of 8 on most systems. If you want to read or write files compatible with earlier versions of `gfortran`, use `-frecord-marker=8`.

`-fmax-subrecord-length=length`

Specify the maximum length for a subrecord. The maximum permitted value for *length* is 2147483639, which is also the default. Only really useful for use by the `gfortran` testsuite.

`-fsign-zero`

When enabled, floating point numbers of value zero with the sign bit set are written as negative number in formatted output and treated as negative in the `SIGN` intrinsic. `-fno-sign-zero` does not print the negative sign of zero values (or values rounded to zero for I/O) and regards zero as positive number in the `SIGN` intrinsic for compatibility with Fortran 77. The default is `-fsign-zero`.

2.9 GNU Fortran Developer Options

GNU Fortran has various special options that are used for debugging the GNU Fortran compiler.

`-fdump-fortran-global`

Output a list of the global identifiers after translating into middle-end representation. Mostly useful for debugging the GNU Fortran compiler itself. The output generated by this option might change between releases. This option may also generate internal compiler errors for features that have only recently been added.

`-fdump-fortran-optimized`

Output the parse tree after front-end optimization. Mostly useful for debugging the GNU Fortran compiler itself. The output generated by this option might change between releases. This option may also generate internal compiler errors for features that have only recently been added.

`-fdump-fortran-original`

Output the internal parse tree after translating the source program into internal representation. This option is mostly useful for debugging the GNU Fortran compiler itself. The output generated by this option might change between

releases. This option may also generate internal compiler errors for features that have only recently been added.

-fdump-parse-tree

Output the internal parse tree after translating the source program into internal representation. Mostly useful for debugging the GNU Fortran compiler itself. The output generated by this option might change between releases. This option may also generate internal compiler errors for features that have only recently been added. This option is deprecated; use **-fdump-fortran-original** instead.

-save-temps

Store the usual “temporary” intermediate files permanently; name them as auxiliary output files, as specified described under GCC **-dumpbase** and **-dumpdir**.

```
gfortran -save-temps -c foo.F90
```

preprocesses input file `foo.F90` to `foo.fii`, compiles to an intermediate `foo.s`, and then assembles to the (implied) output file `foo.o`, whereas:

```
gfortran -save-temps -S foo.F
```

saves the preprocessor output in `foo.fi`, and then compiles to the (implied) output file `foo.s`.

2.10 Options for code generation conventions

These machine-independent options control the interface conventions used in code generation.

Most of them have both positive and negative forms; the negative form of **-ffoo** would be **-fno-foo**. In the table below, only one of the forms is listed—the one that is not the default. You can figure out the other form by either removing **no-** or adding it.

-fno-automatic

Treat each program unit (except those marked as **RECURSIVE**) as if the **SAVE** statement were specified for every local variable and array referenced in it. Does not affect common blocks. (Some Fortran compilers provide this option under the name **-static** or **-save**.) The default, which is **-fautomatic**, uses the stack for local variables smaller than the value given by **-fmax-stack-var-size**. Use the option **-frecursive** to use no static memory.

Local variables or arrays having an explicit **SAVE** attribute are silently ignored unless the **-pedantic** option is added.

-ff2c

Generate code designed to be compatible with code generated by **g77** and **f2c**. The calling conventions used by **g77** (originally implemented in **f2c**) require functions that return type default **REAL** to actually return the C type **double**, and functions that return type **COMPLEX** to return the values via an extra argument in the calling sequence that points to where to store the return value. Under the default GNU calling conventions, such functions simply return their results as they would in GNU C—default **REAL** functions return the C type **float**, and **COMPLEX** functions return the GNU C type **complex**. Additionally, this option implies the **-fsecond-underscore** option, unless **-fno-second-underscore** is explicitly requested.

This does not affect the generation of code that interfaces with the `libgfortran` library.

Caution: It is not a good idea to mix Fortran code compiled with `-ff2c` with code compiled with the default `-fno-f2c` calling conventions as, calling `COMPLEX` or default `REAL` functions between program parts that were compiled with different calling conventions will break at execution time.

Caution: This breaks code that passes intrinsic functions of type default `REAL` or `COMPLEX` as actual arguments, as the library implementations use the `-fno-f2c` calling conventions.

`-fno-underscoring`

Do not transform names of entities specified in the Fortran source file by appending underscores to them.

With `-funderscoring` in effect, GNU Fortran appends one underscore to external names. This is done to ensure compatibility with code produced by many UNIX Fortran compilers. Note this does not apply to names declared with `C` binding, or within a module.

Caution: The default behavior of GNU Fortran is incompatible with `f2c` and `g77`, please use the `-ff2c` option if you want object files compiled with GNU Fortran to be compatible with object code created with these tools.

Use of `-fno-underscoring` is not recommended unless you are experimenting with issues such as integration of GNU Fortran into existing system environments (vis-à-vis existing libraries, tools, and so on).

For example, with `-funderscoring`, and assuming that `j()` and `max_count()` are external functions while `my_var` and `lvar` are local variables, a Fortran statement like

```
I = J() + MAX_COUNT (MY_VAR, LVAR)
```

is implemented as something akin to the C code:

```
i = j_() + max_count_(&my_var, &lvar);
```

With `-fno-underscoring`, the same statement is implemented as:

```
i = j() + max_count(&my_var, &lvar);
```

Use of `-fno-underscoring` allows direct specification of user-defined names while debugging and when interfacing GNU Fortran code with other languages.

Note that just because the names match does *not* mean that the interface implemented by GNU Fortran for an external name matches the interface implemented by some other language for that same name. That is, getting code produced by GNU Fortran to link to code produced by some other compiler using this or any other method can be only a small part of the overall solution—getting the code generated by both compilers to agree on issues other than naming can require significant effort, and, unlike naming disagreements, linkers normally cannot detect disagreements in these other areas.

Also, note that with `-fno-underscoring`, the lack of appended underscores introduces the very real possibility that a user-defined external name conflicts with a name in a system library, which could make finding unresolved-reference

bugs quite difficult in some cases—they might occur at program run time, and show up only as buggy behavior at run time.

See Section 6.4 [Naming and argument-passing conventions], page 85, for more information. Also note that declaring symbols as `bind(C)` is a more robust way to interface with code written in other languages or compiled with different Fortran compilers than the command-line options documented in this section.

`-fsecond-underscore`

By default, GNU Fortran appends an underscore to external names. If this option is used, GNU Fortran appends two underscores to names with underscores and one underscore to names with no underscores.

For example, an external name such as `MAX_COUNT` is implemented as a reference to the link-time external symbol `max_count__`, instead of `max_count_`. This is required for compatibility with `g77` and `f2c`, and is implied by use of the `-ff2c` option.

This option has no effect if `-fno-underscoring` is in effect. It is implied by the `-ff2c` option.

`-fcoarray=<keyword>`

- `'none'` Disable coarray support; using coarray declarations and image-control statements produces a compile-time error. (Default)
- `'single'` Single-image mode, i.e. `num_images()` is always one.
- `'lib'` Library-based coarray parallelization; a suitable GNU Fortran coarray library such as <http://opencoarrays.org> needs to be linked. Alternatively, GCC's `libcaf_single` library can be linked, albeit it only supports a single image.

`-fcheck=<keyword>`

Enable the generation of run-time checks; the argument shall be a comma-delimited list of the following keywords. Prefixing a check with `no-` disables it if it was activated by a previous specification.

- `'all'` Enable all run-time test of `-fcheck`.
- `'array-temps'`
Warns at run time when for passing an actual argument a temporary array had to be generated. The information generated by this warning is sometimes useful in optimization, in order to avoid such temporaries.
Note: The warning is only printed once per location.
- `'bits'` Enable generation of run-time checks for invalid arguments to the bit manipulation intrinsics.
- `'bounds'` Enable generation of run-time checks for array subscripts and against the declared minimum and maximum values. It also checks array indices for assumed and deferred shape arrays against the actual allocated bounds and ensures that all string lengths

are equal for character array constructors without an explicit typespec.

Some checks require that `-fcheck=bounds` is set for the compilation of the main program.

Note: In the future this may also include other forms of checking, e.g., checking substring references.

- ‘do’ Enable generation of run-time checks for invalid modification of loop iteration variables.
- ‘mem’ Enable generation of run-time checks for memory allocation. Note: This option does not affect explicit allocations using the `ALLOCATE` statement, which are always checked.
- ‘pointer’ Enable generation of run-time checks for pointers and allocatables.
- ‘recursion’ Enable generation of run-time checks for recursively called subroutines and functions that are not marked as recursive. See also `-frecursive`. Note: This check does not work for OpenMP programs and is disabled if used together with `-frecursive` and `-fopenmp`.

Example: Assuming you have a file `foo.f90`, the command

```
gfortran -fcheck=all,no-array-temps foo.f90
```

compiles the file with all checks enabled as specified above except warnings for generated array temporaries.

`-fbounds-check`

Deprecated alias for `-fcheck=bounds`.

`-ftail-call-workaround`

`-ftail-call-workaround=n`

Some C interfaces to Fortran codes violate the gfortran ABI by omitting the hidden character length arguments as described in See Section 6.4.2 [Argument passing conventions], page 85. This can lead to crashes because pushing arguments for tail calls can overflow the stack.

To provide a workaround for existing binary packages, this option disables tail call optimization for gfortran procedures with character arguments. With `-ftail-call-workaround=2` tail call optimization is disabled in all gfortran procedures with character arguments, with `-ftail-call-workaround=1` or equivalent `-ftail-call-workaround` only in gfortran procedures with character arguments that call implicitly prototyped procedures.

Using this option can lead to problems including crashes due to insufficient stack space.

It is *very strongly* recommended to fix the code in question. The `-fc-prototypes-external` option can be used to generate prototypes that conform to gfortran’s ABI, for inclusion in the source code.

Support for this option will likely be withdrawn in a future release of gfortran.

The negative form, `-fno-tail-call-workaround` or equivalent `-ftail-call-workaround=0`, can be used to disable this option.

Default is currently `-ftail-call-workaround`, this will change in future releases.

`-fcheck-array-temporaries`

Deprecated alias for `-fcheck=array-temps`.

`-fmax-array-structor=n`

This option can be used to increase the upper limit permitted in array constructors. The code below requires this option to expand the array at compile time.

```
program test
  implicit none
  integer j
  integer, parameter :: n = 100000
  integer, parameter :: i(n) = (/ (2*j, j = 1, n) /)
  print '(10(I0,1X))', i
end program test
```

Caution: This option can lead to long compile times and excessively large object files.

The default value for *n* is 65535.

`-fmax-stack-var-size=n`

This option specifies the size in bytes of the largest array that is put on the stack; if the size is exceeded static memory is used (except in procedures marked as `RECURSIVE`). Use the option `-frecursive` to allow for recursive procedures that do not have a `RECURSIVE` attribute or for parallel programs. Use `-fno-automatic` to never use the stack.

This option currently only affects local arrays declared with constant bounds, and may not apply to all character variables. Future versions of GNU Fortran may improve this behavior.

The default value for *n* is 65536.

`-fstack-arrays`

Adding this option makes the Fortran compiler put all arrays of unknown size and array temporaries onto stack memory. If your program uses very large local arrays it is possible that you have to extend your runtime limits for stack memory on some operating systems. This flag is enabled by default at optimization level `-Ofast` unless `-fmax-stack-var-size` is specified.

`-fpack-derived`

This option tells GNU Fortran to pack derived type members as closely as possible. Code compiled with this option is likely to be incompatible with code compiled without this option, and may execute slower.

`-frepack-arrays`

In some circumstances GNU Fortran may pass assumed shape array sections via a descriptor describing a noncontiguous area of memory. This option adds code to the function prologue to repack the data into a contiguous block at runtime.

This should result in faster accesses to the array. However it can introduce significant overhead to the function call, especially when the passed data is noncontiguous.

-fshort-enums

This option is provided for interoperability with C code that was compiled with the `-fshort-enums` option. It makes GNU Fortran choose the smallest `INTEGER` kind a given enumerator set fits in, and give all its enumerators this kind.

-finline-arg-packing

When passing an assumed-shape argument of a procedure as actual argument to an assumed-size or explicit size or as argument to a procedure that does not have an explicit interface, the argument may have to be packed; that is, put into contiguous memory. An example is the call to `foo` in

```
subroutine foo(a)
  real, dimension(*) :: a
end subroutine foo
subroutine bar(b)
  real, dimension(:) :: b
  call foo(b)
end subroutine bar
```

When `-finline-arg-packing` is in effect, this packing is performed by inline code. This allows for more optimization while increasing code size.

`-finline-arg-packing` is implied by any of the `-O` options except when optimizing for size via `-Os`. If the code contains a very large number of argument that have to be packed, code size and also compilation time may become excessive. If that is the case, it may be better to disable this option. Instances of packing can be found by using `-Warray-temporaries`.

-fexternal-blas

This option makes `gfortran` generate calls to BLAS functions for some matrix operations like `MATMUL`, instead of using our own algorithms, if the size of the matrices involved is larger than a given limit (see `-fblas-matmul-limit`). This may be profitable if an optimized vendor BLAS library is available. The BLAS library has to be specified at link time. This option specifies a BLAS library with integer arguments of default kind (32 bits). It cannot be used together with `-fexternal-blas64`.

-fexternal-blas64

makes `gfortran` generate calls to BLAS functions for some matrix operations like `MATMUL`, instead of using our own algorithms, if the size of the matrices involved is larger than a given limit (see `-fblas-matmul-limit`). This may be profitable if an optimized vendor BLAS library is available. The BLAS library has to be specified at link time. This option specifies a BLAS library with integer arguments of `KIND=8` (64 bits). It cannot be used together with `-fexternal-blas`, and requires a 64-bit system. This option also requires `-ffrontend-optimize`.

-fblas-matmul-limit=n

Only significant when `-fexternal-blas` or `-fexternal-blas64` are in effect. Matrix multiplication of matrices with size larger than or equal to `n` is performed

by calls to BLAS functions, while others are handled by `gfortran` internal algorithms. If the matrices involved are not square, the size comparison is performed using the geometric mean of the dimensions of the argument and result matrices.

The default value for n is 30.

`-finline-intrinsics`

`-finline-intrinsics=intr1,intr2,...`

Prefer generating inline code over calls to libgfortran functions to implement intrinsics.

Usage of intrinsics can be implemented either by generating a call to the libgfortran library function or by directly generating inline code. For most intrinsics, only a single variant is available, and there is no choice of implementation. However, some intrinsics can use a library function or inline code, where inline code typically offers opportunities for additional optimization over a library function. With `-finline-intrinsics=...` or `-fno-inline-intrinsics=...`, the choice applies only to the intrinsics present in the comma-separated list provided as argument.

For each intrinsic, if no choice of implementation was made through either of the flag variants, a default behavior is chosen depending on optimization: library calls are generated when not optimizing or when optimizing for size; otherwise inline code is preferred.

The set of intrinsics allowed as argument to `-finline-intrinsics=` is currently limited to `MAXLOC` and `MINLOC`. The effect of the flag is moreover limited to calls of those intrinsics without `DIM` argument and with `ARRAY` of a non-`CHARACTER` type. The case of rank-1 argument and `DIM` argument present, i.e. `MAXLOC(A(:),DIM=1)` or `MINLOC(A(:),DIM=1)` is inlined unconditionally for numeric rank-1 array argument `A`.

`-finline-matmul-limit=n`

When front-end optimization is active, some calls to the `MATMUL` intrinsic function are inlined. This may result in code size increase if the size of the matrix cannot be determined at compile time, as code for both cases is generated. Setting `-finline-matmul-limit=0` disables inlining in all cases. Setting this option with a value of n produces inline code for matrices with size up to n . If the matrices involved are not square, the size comparison is performed using the geometric mean of the dimensions of the argument and result matrices.

The default value for n is 30. The `-fblas-matmul-limit` can be used to change this value.

`-frecursive`

Allow indirect recursion by forcing all local arrays to be allocated on the stack. This flag cannot be used together with `-fmax-stack-var-size=` or `-fno-automatic`.

```

-finit-local-zero
-finit-derived
-finit-integer=n
-finit-real=<zero|inf|-inf|nan|snan>
-finit-logical=<true|false>
-finit-character=n

```

The `-finit-local-zero` option instructs the compiler to initialize local `INTEGER`, `REAL`, and `COMPLEX` variables to zero, `LOGICAL` variables to false, and `CHARACTER` variables to a string of null bytes. Finer-grained initialization options are provided by the `-finit-integer=n`, `-finit-real=<zero|inf|-inf|nan|snan>` (which also initializes the real and imaginary parts of local `COMPLEX` variables), `-finit-logical=<true|false>`, and `-finit-character=n` (where *n* is an ASCII character value) options.

With `-finit-derived`, components of derived type variables are initialized according to these flags. Components whose type is not covered by an explicit `-finit-*` flag are treated as described above with `-finit-local-zero`.

These options do not initialize

- objects with the `POINTER` attribute
- allocatable arrays
- variables that appear in an `EQUIVALENCE` statement.

(These limitations may be removed in future releases).

Note that the `-finit-real=nan` option initializes `REAL` and `COMPLEX` variables with a quiet NaN. For a signalling NaN use `-finit-real=snan`; note, however, that compile-time optimizations may convert them into quiet NaN and that trapping needs to be enabled (e.g. via `-ffpe-trap`).

The `-finit-integer` option parses the value into an integer of type `INTEGER(kind=C_LONG)` on the host. Said value is then assigned to the integer variables in the Fortran code, which might result in wraparound if the value is too large for the kind.

Finally, note that enabling any of the `-finit-*` options silences warnings that would have been emitted by `-Wuninitialized` for the affected local variables.

```

-falign-commons

```

By default, `gfortran` enforces proper alignment of all variables in a `COMMON` block by padding them as needed. On certain platforms this is mandatory, on others it increases performance. If a `COMMON` block is not declared with consistent data types everywhere, this padding can cause trouble, and `-fno-align-commons` can be used to disable automatic alignment. The same form of this option should be used for all files that share a `COMMON` block. To avoid potential alignment issues in `COMMON` blocks, it is recommended to order objects from largest to smallest.

```

-fno-protect-parens

```

By default the parentheses in expression are honored for all optimization levels such that the compiler does not do any reassociation. Using `-fno-protect-parens` allows the compiler to reorder `REAL` and `COMPLEX` expressions to produce

faster code. Note that for the reassociation optimization `-fno-signed-zeros` and `-fno-trapping-math` need to be in effect. The parentheses protection is enabled by default, unless `-Ofast` is given.

`-frealloc-lhs`

An allocatable left-hand side of an intrinsic assignment is automatically (re)allocated if it is either unallocated or has a different shape. The option is enabled by default except when `-std=f95` is given. See also `-wrealloc-lhs`.

`-faggressive-function-elimination`

Functions with identical argument lists are eliminated within statements, regardless of whether these functions are marked `PURE` or not. For example, in

```
a = f(b,c) + f(b,c)
```

there is only a single call to `f`. This option only works if `-ffrontend-optimize` is in effect.

`-ffrontend-optimize`

This option performs front-end optimization, based on manipulating parts of the Fortran parse tree. Enabled by default by any `-O` option except `-O0` and `-Og`. Optimizations enabled by this option include:

- inlining calls to `MATMUL`,
- elimination of identical function calls within expressions,
- removing unnecessary calls to `TRIM` in comparisons and assignments,
- replacing `TRIM(a)` with `a(1:LEN_TRIM(a))` and
- short-circuiting of logical operators (`.AND.` and `.OR.`).

It can be deselected by specifying `-fno-frontend-optimize`.

`-ffrontend-loop-interchange`

Attempt to interchange loops in the Fortran front end where profitable. Enabled by default by any `-O` option. At the moment, this option only affects `FORALL` and `DO CONCURRENT` statements with several forall triplets.

See Section “Options for Code Generation Conventions” in *Using the GNU Compiler Collection (GCC)*, for information on more options offered by the back end shared by `gfortran`, `gcc`, and other GNU compilers.

2.11 Options for interoperability with other languages

`-fc-prototypes`

This option generates C prototypes from `BIND(C)` variable declarations, types and procedure interfaces and writes them to standard output. `ENUM` is not yet supported.

The generated prototypes may need inclusion of an appropriate header, such as `<stdint.h>` or `<stdlib.h>`. For types that are not specified using the appropriate kind from the `iso_c_binding` module, a warning is added as a comment to the code.

For function pointers, a pointer to a function returning `int` without an explicit argument list is generated.

Example of use:

```
$ gfortran -fc-prototypes -fsyntax-only foo.f90 > foo.h
```

where the C code intended for interoperating with the Fortran code then uses `#include "foo.h"`.

-fc-prototypes-external

This option generates C prototypes from external functions and subroutines and writes them to standard output. This may be useful for making sure that C bindings to Fortran code are correct. This option does not generate prototypes for `BIND(C)` procedures; use `-fc-prototypes` for that.

The generated prototypes may need inclusion of an appropriate header, such as `<stdint.h>` or `<stdlib.h>`.

This is primarily meant for legacy code to ensure that existing C bindings match what `gfortran` emits. The generated C prototypes should be correct for the current version of the compiler, but may not match what other compilers or earlier versions of `gfortran` need. For new development, use of the `BIND(C)` features is recommended.

Example of use:

```
$ gfortran -fc-prototypes-external -fsyntax-only foo.f > foo.h
```

where the C code intended for interoperating with the Fortran code then uses `#include "foo.h"`.

2.12 Environment variables affecting gfortran

The `gfortran` compiler currently does not make use of any environment variables to control its operation above and beyond those that affect the operation of `gcc`.

See Section “Environment Variables Affecting GCC” in *Using the GNU Compiler Collection (GCC)*, for information on environment variables.

See Chapter 3 [Runtime], page 37, for environment variables that affect the run-time behavior of programs compiled with GNU Fortran.

3 Runtime: Influencing runtime behavior with environment variables

The behavior of the `gfortran` can be influenced by environment variables.

Malformed environment variables are silently ignored.

3.1 TMPDIR—Directory for scratch files

When opening a file with `STATUS='SCRATCH'`, GNU Fortran tries to create the file in one of the potential directories by testing each directory in the order below.

1. The environment variable `TMPDIR`, if it exists.
2. On the MinGW target, the directory returned by the `GetTempPath` function. Alternatively, on the Cygwin target, the `TMP` and `TEMP` environment variables, if they exist, in that order.
3. The `P_tmpdir` macro if it is defined, otherwise the directory `/tmp`.

3.2 GFORTRAN_STDIN_UNIT—Unit number for standard input

This environment variable can be used to select the unit number preconnected to standard input. This must be a positive integer. The default value is 5.

3.3 GFORTRAN_STDOUT_UNIT—Unit number for standard output

This environment variable can be used to select the unit number preconnected to standard output. This must be a positive integer. The default value is 6.

3.4 GFORTRAN_STDERR_UNIT—Unit number for standard error

This environment variable can be used to select the unit number preconnected to standard error. This must be a positive integer. The default value is 0.

3.5 GFORTRAN_UNBUFFERED_ALL—Do not buffer I/O on all units

This environment variable controls whether all I/O is unbuffered. If the first letter is 'y', 'Y' or '1', all I/O is unbuffered. This slows down small sequential reads and writes. If the first letter is 'n', 'N' or '0', I/O is buffered. This is the default.

3.6 GFORTRAN_UNBUFFERED_PRECONNECTED—Do not buffer I/O on preconnected units

The environment variable named `GFORTRAN_UNBUFFERED_PRECONNECTED` controls whether I/O on a preconnected unit (i.e. `STDOUT` or `STDERR`) is unbuffered. If the first letter is 'y', 'Y' or '1', I/O is unbuffered. This slows down small sequential reads and writes. If the first letter is 'n', 'N' or '0', I/O is buffered. This is the default.

3.7 GFORTRAN_SHOW_LOCUS—Show location for runtime errors

If the first letter is 'y', 'Y' or '1', filename and line numbers for runtime errors are printed. If the first letter is 'n', 'N' or '0', do not print filename and line numbers for runtime errors. The default is to print the location.

3.8 GFORTRAN_OPTIONAL_PLUS—Print leading + where permitted

If the first letter is ‘y’, ‘Y’ or ‘1’, a plus sign is printed where permitted by the Fortran standard. If the first letter is ‘n’, ‘N’ or ‘O’, a plus sign is not printed in most cases. Default is not to print plus signs.

3.9 GFORTRAN_LIST_SEPARATOR—Separator for list output

This environment variable specifies the separator when writing list-directed output. It may contain any number of spaces and at most one comma. If you specify this on the command line, be sure to quote spaces, as in

```
$ GFORTRAN_LIST_SEPARATOR=' , ' ./a.out
```

when `a.out` is the compiled Fortran program that you want to run. Default is a single space.

3.10 GFORTRAN_CONVERT_UNIT—Set conversion for unformatted I/O

By setting the `GFORTRAN_CONVERT_UNIT` variable, it is possible to change the representation of data for unformatted files. The syntax for the `GFORTRAN_CONVERT_UNIT` variable for most systems is:

```
GFORTRAN_CONVERT_UNIT: mode | mode ';' exception | exception ;
mode: 'native' | 'swap' | 'big_endian' | 'little_endian' ;
exception: mode ':' unit_list | unit_list ;
unit_list: unit_spec | unit_list unit_spec ;
unit_spec: INTEGER | INTEGER '-' INTEGER ;
```

The variable consists of an optional default mode, followed by a list of optional exceptions, which are separated by semicolons from the preceding default and each other. Each exception consists of a format and a comma-separated list of units. Valid values for the modes are the same as for the `CONVERT` specifier:

NATIVE Use the native format. This is the default.

SWAP Swap between little- and big-endian.

LITTLE_ENDIAN Use the little-endian format for unformatted files.

BIG_ENDIAN Use the big-endian format for unformatted files.

For POWER systems that support `-mabi=ieeelongdouble`, there are additional options, which can be combined with the others with commas. Those are

R16_IEEE Use IEEE 128-bit format for `REAL(KIND=16)`.

R16_IBM Use IBM long double format for `REAL(KIND=16)`.

A missing mode for an exception is taken to mean **BIG_ENDIAN**. Examples of values for `GFORTRAN_CONVERT_UNIT` are:

`'big_endian'` Do all unformatted I/O in big-endian mode.

`'little_endian;native:10-20,25'` Do all unformatted I/O in little-endian mode, except for units 10 to 20 and 25, which are in native format.

`'10-20'` Units 10 to 20 are big-endian, the rest is native.

`'big_endian,r16_ibm'` Do all unformatted I/O in big-endian mode and use IBM long double for output of `REAL(KIND=16)` values.

Setting the environment variables should be done on the command line or via the `export` command for `sh`-compatible shells and via `setenv` for `csh`-compatible shells.

Example for `sh`:

```
$ gfortran foo.f90
$ GFORTRAN_CONVERT_UNIT='big_endian;native:10-20' ./a.out
```

Example code for `csh`:

```
% gfortran foo.f90
% setenv GFORTRAN_CONVERT_UNIT 'big_endian;native:10-20'
% ./a.out
```

Using anything but the native representation for unformatted data carries a significant speed overhead. If speed in this area matters to you, it is best if you use this only for data that needs to be portable.

See Section 5.1.17 [CONVERT specifier], page 55, for an alternative way to specify the data representation for unformatted files. See Section 2.8 [Runtime Options], page 24, for setting a default data representation for the whole program. The CONVERT specifier overrides the `-fconvert` compile options.

Note that the values specified via the `GFORTRAN_CONVERT_UNIT` environment variable override the CONVERT specifier in the OPEN statement. This is to give control over data formats to users who do not have the source code of their program available.

3.11 GFORTRAN_ERROR_BACKTRACE—Show backtrace on run-time errors

If the `GFORTRAN_ERROR_BACKTRACE` variable is set to 'y', 'Y' or '1' (only the first letter is relevant) then a backtrace is printed when a serious run-time error occurs. To disable the backtracing, set the variable to 'n', 'N', '0'. Default is to print a backtrace unless the `-fno-backtrace` compile option was used.

3.12 GFORTRAN_FORMATTED_BUFFER_SIZE—Set buffer size for formatted I/O

The `GFORTRAN_FORMATTED_BUFFER_SIZE` environment variable specifies buffer size in bytes to be used for formatted output. The default value is 8192.

3.13 GFORTRAN_UNFORMATTED_BUFFER_SIZE—Set buffer size for unformatted I/O

The `GFORTRAN_UNFORMATTED_BUFFER_SIZE` environment variable specifies buffer size in bytes to be used for unformatted output. The default value is 131072.

Part II: Language Reference

4 Compiler Characteristics

This chapter describes certain characteristics of the GNU Fortran compiler that are not specified by the Fortran standard, but which might in some way or another become visible to the programmer.

4.1 KIND Type Parameters

The KIND type parameters supported by GNU Fortran for the primitive data types are:

INTEGER 1, 2, 4, 8*, 16*, default: 4**

LOGICAL 1, 2, 4, 8*, 16*, default: 4**

REAL 4, 8, 10*, 16*, default: 4***

COMPLEX 4, 8, 10*, 16*, default: 4***

DOUBLE PRECISION
4, 8, 10*, 16*, default: 8***

CHARACTER
1, 4, default: 1

* not available on all systems

** unless `-fdefault-integer-8` is used

*** unless `-fdefault-real-8` is used (see Section 2.2 [Fortran Dialect Options], page 9)

The KIND value matches the storage size in bytes, except for **COMPLEX** where the storage size is twice as much (or both real and imaginary part are a real value of the given size). It is recommended to use the Section 8.246 [SELECTED_CHAR_KIND], page 278, Section 8.247 [SELECTED_INT_KIND], page 279, Section 8.248 [SELECTED_LOGICAL_KIND], page 279, and Section 8.249 [SELECTED_REAL_KIND], page 280, intrinsics or the INT8, INT16, INT32, INT64, REAL32, REAL64, and REAL128 parameters of the ISO_FORTRAN_ENV module instead of the concrete values. The available kind parameters can be found in the constant arrays CHARACTER_KINDS, INTEGER_KINDS, LOGICAL_KINDS and REAL_KINDS in the Section 9.1 [ISO_FORTRAN_ENV], page 311, module. For C interoperability, the kind parameters of the Section 9.2 [ISO_C_BINDING], page 313, module should be used.

4.2 Internal representation of LOGICAL variables

The Fortran standard does not specify how variables of **LOGICAL** type are represented, beyond requiring that **LOGICAL** variables of default kind have the same storage size as default **INTEGER** and **REAL** variables. The GNU Fortran internal representation is as follows.

A **LOGICAL**(KIND=N) variable is represented as an **INTEGER**(KIND=N) variable, however, with only two permissible values: 1 for **.TRUE.** and 0 for **.FALSE.** Any other integer value results in undefined behavior.

See also Section 6.4.2 [Argument passing conventions], page 85, and Section 6.1 [Interoperability with C], page 73.

4.3 Evaluation of logical expressions

The Fortran standard does not require the compiler to evaluate all parts of an expression, if they do not contribute to the final result. For logical expressions with `.AND.` or `.OR.` operators, in particular, GNU Fortran optimizes out function calls (even to impure functions) if the result of the expression can be established without them. However, since not all compilers do that, and such an optimization can potentially modify the program flow and subsequent results, GNU Fortran throws warnings for such situations with the `-Wfunction-elimination` flag.

4.4 MAX and MIN intrinsics with REAL NaN arguments

The Fortran standard does not specify what the result of the `MAX` and `MIN` intrinsics are if one of the arguments is a `NaN`. Accordingly, the GNU Fortran compiler does not specify that either, as this allows for faster and more compact code to be generated. If the programmer wishes to take some specific action in case one of the arguments is a `NaN`, it is necessary to explicitly test the arguments before calling `MAX` or `MIN`, e.g. with the `IEEE_IS_NAN` function from the intrinsic module `IEEE_ARITHMETIC`.

4.5 Thread-safety of the runtime library

GNU Fortran can be used in programs with multiple threads, e.g. by using OpenMP, by calling OS thread handling functions via the `ISO_C_BINDING` facility, or by GNU Fortran compiled library code being called from a multi-threaded program.

The GNU Fortran runtime library, (`libgfortran`), supports being called concurrently from multiple threads with the following exceptions.

During library initialization, the C `getenv` function is used, which need not be thread-safe. Similarly, the `getenv` function is used to implement the `GET_ENVIRONMENT_VARIABLE` and `GETENV` intrinsics. It is the responsibility of the user to ensure that the environment is not being updated concurrently when any of these actions are taking place.

The `EXECUTE_COMMAND_LINE` and `SYSTEM` intrinsics are implemented with the `system` function, which need not be thread-safe. It is the responsibility of the user to ensure that `system` is not called concurrently.

For platforms not supporting thread-safe POSIX functions, further functionality might not be thread-safe. For details, please consult the documentation for your operating system.

The GNU Fortran runtime library uses various C library functions that depend on the locale, such as `strtod` and `snprintf`. In order to work correctly in locale-aware programs that set the locale using `setlocale`, the locale is reset to the default “C” locale while executing a formatted `READ` or `WRITE` statement. On targets supporting the POSIX 2008 per-thread locale functions (e.g. `newlocale`, `uselocale`, `freelocale`), these are used and thus the global locale set using `setlocale` or the per-thread locales in other threads are not affected. However, on targets lacking this functionality, the global `LC_NUMERIC` locale is set to “C” during the formatted I/O. Thus, on such targets it’s not safe to call `setlocale` concurrently from another thread while a Fortran formatted I/O operation is in progress. Also, other threads doing something dependent on the `LC_NUMERIC` locale might not work correctly if a formatted I/O operation is in progress in another thread.

4.6 Data consistency and durability

This section contains a brief overview of data and metadata consistency and durability issues when doing I/O.

With respect to durability, GNU Fortran makes no effort to ensure that data is committed to stable storage. If this is required, the GNU Fortran programmer can use the intrinsic `FNUM` to retrieve the low level file descriptor corresponding to an open Fortran unit. Then, using e.g. the `ISO_C_BINDING` feature, one can call the underlying system call to flush dirty data to stable storage, such as `fsync` on POSIX, `_commit` on MinGW, or `fcntl(fd, F_FULLSYNC, 0)` on macOS. The following example shows how to call `fsync`:

```
! Declare the interface for POSIX fsync function
interface
  function fsync (fd) bind(c,name="fsync")
    use iso_c_binding, only: c_int
    integer(c_int), value :: fd
    integer(c_int) :: fsync
  end function fsync
end interface

! Variable declaration
integer :: ret

! Opening unit 10
open (10,file="foo")

! ...
! Perform I/O on unit 10
! ...

! Flush and sync
flush(10)
ret = fsync(fnum(10))

! Handle possible error
if (ret /= 0) stop "Error calling FSYNC"
```

With respect to consistency, for regular files GNU Fortran uses buffered I/O in order to improve performance. This buffer is flushed automatically when full and in some other situations, e.g. when closing a unit. It can also be explicitly flushed with the `FLUSH` statement. Also, the buffering can be turned off with the `GFORTRAN_UNBUFFERED_ALL` and `GFORTRAN_UNBUFFERED_PRECONNECTED` environment variables. Special files, such as terminals and pipes, are always unbuffered. Sometimes, however, further things may need to be done in order to allow other processes to see data that GNU Fortran has written, as follows.

The Windows platform supports a relaxed metadata consistency model, where file metadata is written to the directory lazily. This means that, for instance, the `dir` command can show a stale size for a file. One can force a directory metadata update by closing the unit, or by calling `_commit` on the file descriptor. Note, though, that `_commit` forces all dirty data to stable storage, which is often a very slow operation.

The Network File System (NFS) implements a relaxed consistency model called open-to-close consistency. Closing a file forces dirty data and metadata to be flushed to the server, and opening a file forces the client to contact the server in order to revalidate cached data. `fsync` also forces a flush of dirty data and metadata to the server. Similar to `open`

and `close`, acquiring and releasing `fcntl` file locks, if the server supports them, also forces cache validation and flushing dirty data and metadata.

4.7 Files opened without an explicit ACTION= specifier

The Fortran standard says that if an `OPEN` statement is executed without an explicit `ACTION=` specifier, the default value is processor dependent. GNU Fortran behaves as follows:

1. Attempt to open the file with `ACTION='READWRITE'`
2. If that fails, try to open with `ACTION='READ'`
3. If that fails, try to open with `ACTION='WRITE'`
4. If that fails, generate an error

4.8 File operations on symbolic links

This section documents the behavior of GNU Fortran for file operations on symbolic links, on systems that support them.

- Results of `INQUIRE` statements of the “inquire by file” form relate to the target of the symbolic link. For example, `INQUIRE(FILE="foo",EXIST=ex)` sets `ex` to `.true.` if `foo` is a symbolic link pointing to an existing file, and `.false.` if `foo` points to a non-existing file (“dangling” symbolic link).
- Using the `OPEN` statement with a `STATUS="NEW"` specifier on a symbolic link results in an error condition, whether the symbolic link points to an existing target or is dangling.
- If a symbolic link was connected, using the `CLOSE` statement with a `STATUS="DELETE"` specifier causes the symbolic link itself to be deleted, not its target.

4.9 File format of unformatted sequential files

Unformatted sequential files are stored as logical records using record markers. Each logical record consists of one or more subrecords.

Each subrecord consists of a leading record marker, the data written by the user program, and a trailing record marker. The record markers are four-byte integers by default, and eight-byte integers if the `-fmax-subrecord-length=8` option (which exists for backwards compatibility only) is in effect.

The representation of the record markers is that of unformatted files given with the `-fconvert` option, the Section 5.1.17 [`CONVERT` specifier], page 55, in an `OPEN` statement or the Section 3.10 [`GFORTRAN_CONVERT_UNIT`], page 38, environment variable.

The maximum number of bytes of user data in a subrecord is 2147483639 (2 GiB - 9) for a four-byte record marker. This limit can be lowered with the `-fmax-subrecord-length` option, although this is rarely useful. If the length of a logical record exceeds this limit, the data is distributed among several subrecords.

The absolute of the number stored in the record markers is the number of bytes of user data in the corresponding subrecord. If the leading record marker of a subrecord contains a negative number, another subrecord follows the current one. If the trailing record marker contains a negative number, then there is a preceding subrecord.

In the most simple case, with only one subrecord per logical record, both record markers contain the number of bytes of user data in the record.

The format for unformatted sequential data can be duplicated using unformatted stream, as shown in the example program for an unformatted record containing a single subrecord:

```
program main
  use iso_fortran_env, only: int32
  implicit none
  integer(int32) :: i
  real, dimension(10) :: a, b
  call random_number(a)
  open (10,file='test.dat',form='unformatted',access='stream')
  inquire (iolength=i) a
  write (10) i, a, i
  close (10)
  open (10,file='test.dat',form='unformatted')
  read (10) b
  if (all (a == b)) print *, 'success!'
end program main
```

4.10 Asynchronous I/O

Asynchronous I/O is supported if the program is linked against the POSIX thread library. If that is not the case, all I/O is performed as synchronous. On systems that do not support pthread condition variables, such as AIX, I/O is also performed as synchronous.

On some systems, such as Darwin or Solaris, the POSIX thread library is always linked in, so asynchronous I/O is always performed. On other systems, such as Linux, it is necessary to specify `-pthread`, `-lpthread` or `-fopenmp` during the linking step.

4.11 Behavior on integer overflow

Integer overflow is prohibited by the Fortran standard. The behavior of gfortran on integer overflow is undefined by default. Traditional code, like linear congruential pseudo-random number generators in old programs that rely on specific, nonstandard behavior may generate unexpected results. The `-fsanitize=undefined` option can be used to detect such code at runtime.

It is recommended to use the intrinsic subroutine `RANDOM_NUMBER` for random number generators or, if the old behavior is desired, to use the `-fwrapv` option. Note that this option can impact performance.

5 Extensions

The two sections below detail the extensions to standard Fortran that are implemented in GNU Fortran, as well as some of the popular or historically important extensions that are not (or not yet) implemented. For the latter case, we explain the alternatives available to GNU Fortran users, including replacement by standard-conforming code or GNU extensions.

5.1 Extensions implemented in GNU Fortran

GNU Fortran implements a number of extensions over standard Fortran. This chapter contains information on their syntax and meaning. There are currently two categories of GNU Fortran extensions, those that provide functionality beyond that provided by any standard, and those that are supported by GNU Fortran purely for backward compatibility with legacy compilers. By default, `-std=gnu` allows the compiler to accept both types of extensions, but to warn about the use of the latter. Specifying either `-std=f95`, `-std=f2003`, `-std=f2008`, or `-std=f2018` disables both types of extensions, and `-std=legacy` allows both without warning. The special compile flag `-fdec` enables additional compatibility extensions along with those enabled by `-std=legacy`.

5.1.1 Old-style kind specifications

GNU Fortran allows old-style kind specifications in declarations. These look like:

```
TYPESPEC*size x,y,z
```

where `TYPESPEC` is a basic type (`INTEGER`, `REAL`, etc.), and where *size* is a byte count corresponding to the storage size of a valid kind for that type. (For `COMPLEX` variables, *size* is the total size of the real and imaginary parts.) The statement then declares `x`, `y` and `z` to be of type `TYPESPEC` with the appropriate kind. This is equivalent to the standard-conforming declaration

```
TYPESPEC(k) x,y,z
```

where `k` is the kind parameter suitable for the intended precision. As kind parameters are implementation-dependent, use the `KIND`, `SELECTED_INT_KIND`, `SELECTED_LOGICAL_KIND` and `SELECTED_REAL_KIND` intrinsics to retrieve the correct value, for instance `REAL*8 x` can be replaced by:

```
INTEGER, PARAMETER :: dbl = KIND(1.0d0)
REAL(KIND=dbl) :: x
```

5.1.2 Old-style variable initialization

GNU Fortran allows old-style initialization of variables of the form:

```
INTEGER i/1/,j/2/
REAL x(2,2) /3*0.,1./
```

The syntax for the initializers is as for the `DATA` statement, but unlike in a `DATA` statement, an initializer only applies to the variable immediately preceding the initialization. In other words, something like `INTEGER I,J/2,3/` is not valid. This style of initialization is only allowed in declarations without double colons (`::`); the double colons were introduced in Fortran 90, which also introduced a standard syntax for initializing variables in type declarations.

Examples of standard-conforming code equivalent to the above example are:

```
! Fortran 90
```

```

      INTEGER :: i = 1, j = 2
      REAL :: x(2,2) = RESHAPE((/0.,0.,0.,1./),SHAPE(x))
! Fortran 77
      INTEGER i, j
      REAL x(2,2)
      DATA i/1/, j/2/, x/3*0.,1./

```

Note that variables that are explicitly initialized in declarations or in DATA statements automatically acquire the SAVE attribute.

5.1.3 Extensions to namelist

GNU Fortran fully supports the Fortran 95 standard for namelist I/O including array qualifiers, substrings and fully qualified derived types. The output from a namelist write is compatible with namelist read. The output has all names in upper case and indentation to column 1 after the namelist name. The following extensions are permitted:

- Old-style use of '\$' instead of '&'

```

$MYNML
  X(:)%Y(2) = 1.0 2.0 3.0
  CH(1:4) = "abcd"
$END

```

It should be noted that the default terminator is '/' rather than '&END'.

- Querying of the namelist when inputting from stdin. After at least one space, entering '?' sends to stdout the namelist name and the names of the variables in the namelist:

```

?

&mynml
  x
  x%y
  ch
&end

```

Entering '=?' outputs the namelist to stdout, as if WRITE(*,NML = mynml) had been called:

```

=?

&MYNML
  X(1)%Y=  0.000000      ,  1.000000      ,  0.000000      ,
  X(2)%Y=  0.000000      ,  2.000000      ,  0.000000      ,
  X(3)%Y=  0.000000      ,  3.000000      ,  0.000000      ,
  CH=abcd,  /

```

To aid this dialog, when input is from stdin, errors send their messages to stderr and execution continues, even if IOSTAT is set.

- PRINT namelist is permitted. This causes an error if -std=f95 is used.

```

PROGRAM test_print
  REAL, dimension (4)  :: x = (/1.0, 2.0, 3.0, 4.0/)
  NAMELIST /mynml/ x
  PRINT mynml
END PROGRAM test_print

```

- Expanded namelist reads are permitted. This causes an error if -std=f95 is used. In the following example, the first element of the array is given the value 0.00 and the two succeeding elements are given the values 1.00 and 2.00.

```

&MYNML

```

```

      X(1,1) = 0.00 , 1.00 , 2.00
/

```

When writing a namelist, if no `DELIM=` is specified, by default a double quote is used to delimit character strings. With `-std=f95` or later, the `delim` status is set to `'none'`. Defaulting to quotes ensures that namelists with character strings can be subsequently read back in accurately.

5.1.4 X format descriptor without count field

To support legacy codes, GNU Fortran permits the count field of the `X` edit descriptor in `FORMAT` statements to be omitted. When omitted, the count is implicitly assumed to be one.

```

      PRINT 10, 2, 3
10      FORMAT (I1, X, I1)

```

5.1.5 Commas in FORMAT specifications

To support legacy codes, GNU Fortran allows the comma separator to be omitted immediately before and after character string edit descriptors in `FORMAT` statements. A comma with no following format descriptor is permitted if the `-fdec-blank-format-item` is given on the command line. This is considered non-conforming code and is discouraged.

```

      PRINT 10, 2, 3
10      FORMAT ('FOO=' I1' BAR=' I2)
      print 20, 5, 6
20      FORMAT (I3, I3,)

```

5.1.6 Missing period in FORMAT specifications

To support legacy codes, GNU Fortran allows missing periods in format specifications if and only if `-std=legacy` is given on the command line. This is considered non-conforming code and is discouraged.

```

      REAL :: value
      READ(*,10) value
10      FORMAT ('F4')

```

5.1.7 Default widths for 'F', 'G' and 'I' format descriptors

To support legacy codes, GNU Fortran allows width to be omitted from format specifications if and only if `-fdec-format-defaults` is given on the command line. Default widths are used. This is considered non-conforming code and is discouraged.

```

      REAL :: value1
      INTEGER :: value2
      WRITE(*,10) value1, value1, value2
10      FORMAT ('F, G, I')

```

5.1.8 I/O item lists

To support legacy codes, GNU Fortran allows the input item list of the `READ` statement, and the output item lists of the `WRITE` and `PRINT` statements, to start with a comma.

5.1.9 'Q' exponent-letter

GNU Fortran accepts real literal constants with an exponent-letter of `'Q'`, for example, `1.23Q45`. The constant is interpreted as a `REAL(16)` entity on targets that support this

type. If the target does not support `REAL(16)` but has a `REAL(10)` type, then the real-literal-constant is interpreted as a `REAL(10)` entity. In the absence of `REAL(16)` and `REAL(10)`, an error occurs.

5.1.10 BOZ literal constants

Besides decimal constants, Fortran also supports binary ('b'), octal ('o') and hexadecimal ('z') integer constants. The syntax is: `'prefix quote digits quote'`, where the prefix is either 'b', 'o' or 'z', quote is either ' or " and the digits are 0 or 1 for binary, between 0 and 7 for octal, and between 0 and F for hexadecimal. (Example: `b'01011101'`.)

Up to Fortran 95, BOZ literal constants were only allowed to initialize integer variables in `DATA` statements. Since Fortran 2003 BOZ literal constants are also allowed as actual arguments to the `REAL`, `DBLE`, `INT` and `CMPLX` intrinsic functions. The BOZ literal constant is simply a string of bits, which is padded or truncated as needed, during conversion to a numeric type. The Fortran standard states that the treatment of the sign bit is processor dependent. Gfortran interprets the sign bit as a user would expect.

As a deprecated extension, GNU Fortran allows hexadecimal BOZ literal constants to be specified using the 'X' prefix. That the BOZ literal constant can also be specified by adding a suffix to the string, for example, `Z'ABC'` and `'ABC'X` are equivalent. Additionally, as extension, BOZ literals are permitted in some contexts outside of `DATA` and the intrinsic functions listed in the Fortran standard. Use `-fallow-invalid-boz` to enable the extension.

5.1.11 Real array indices

As an extension, GNU Fortran allows the use of `REAL` expressions or variables as array indices.

5.1.12 Unary operators

As an extension, GNU Fortran allows unary plus and unary minus operators to appear as the second operand of binary arithmetic operators without the need for parenthesis.

```
X = Y * -Z
```

5.1.13 Implicitly convert LOGICAL and INTEGER values

As an extension for backwards compatibility with other compilers, GNU Fortran allows the implicit conversion of `LOGICAL` values to `INTEGER` values and vice versa. When converting from a `LOGICAL` to an `INTEGER`, `.FALSE.` is interpreted as zero, and `.TRUE.` is interpreted as one. When converting from `INTEGER` to `LOGICAL`, the value zero is interpreted as `.FALSE.` and any nonzero value is interpreted as `.TRUE.`.

```
LOGICAL :: l
l = 1
INTEGER :: i
i = .TRUE.
```

However, there is no implicit conversion of `INTEGER` values in `if`-statements, nor of `LOGICAL` or `INTEGER` values in I/O operations.

5.1.14 Hollerith constants support

GNU Fortran supports Hollerith constants in assignments, `DATA` statements, function and subroutine arguments. A Hollerith constant is written as a string of characters preceded

by an integer constant indicating the character count, and the letter H or h, and stored in bitwise fashion in a numeric (INTEGER, REAL, or COMPLEX), LOGICAL or CHARACTER variable. The constant is padded with spaces or truncated to fit the size of the variable in which it is stored.

Examples of valid uses of Hollerith constants:

```
complex*16 x(2)
data x /16Habcdefghijklmnop, 16Hqrstuvwxyz012345/
x(1) = 16HABCDEFGHJKLMNOP
call foo (4h abc)
```

Examples of Hollerith constants:

```
integer*4 a
a = 0H           ! Invalid, at least one character is needed.
a = 4HAB12       ! Valid
a = 8H12345678   ! Valid, but the Hollerith constant is truncated.
a = 3Hxyz        ! Valid, but the Hollerith constant is padded.
```

In general, Hollerith constants were used to provide a rudimentary facility for handling character strings in early Fortran compilers, prior to the introduction of CHARACTER variables in Fortran 77; in those cases, the standard-compliant equivalent is to convert the program to use proper character strings. On occasion, there may be a case where the intent is specifically to initialize a numeric variable with a given byte sequence. In these cases, the same result can be obtained by using the TRANSFER statement, as in this example.

```
integer(kind=4) :: a
a = transfer ("abcd", a)      ! equivalent to: a = 4Habcd
```

The use of the -fdec option extends support of Hollerith constants to comparisons:

```
integer*4 a
a = 4hABCD
if (a .ne. 4habcd) then
  write(*,*) "no match"
end if
```

Supported types are numeric (INTEGER, REAL, or COMPLEX), and CHARACTER.

5.1.15 Character conversion

Allowing character literals to be used in a similar way to Hollerith constants is a nonstandard extension. This feature is enabled using -fdec-char-conversions and only applies to character literals of kind=1.

Character literals can be used in DATA statements and assignments with numeric (INTEGER, REAL, or COMPLEX) or LOGICAL variables. Like Hollerith constants they are copied bitwise fashion. The constant is padded with spaces or truncated to fit the size of the variable in which it is stored.

Examples:

```
integer*4 x
data x / 'abcd' /

x = 'A'           ! Is padded.
x = 'ab1234'      ! Is truncated.
```

5.1.16 Cray pointers

Cray pointers are part of a nonstandard extension that provides a C-like pointer in Fortran. This is accomplished through a pair of variables: an integer “pointer” that holds a memory address, and a “pointee” that is used to dereference the pointer.

Pointer/pointee pairs are declared in statements of the form:

```
pointer ( <pointer> , <pointee> )
```

or,

```
pointer ( <pointer1> , <pointee1> ), ( <pointer2> , <pointee2> ), ...
```

The pointer is an integer that is intended to hold a memory address. The pointee may be an array or scalar. If an assumed-size array is permitted within the scoping unit, a pointee can be an assumed-size array. That is, the last dimension may be left unspecified by using a `*` in place of a value. A pointee cannot be an assumed shape array. No space is allocated for the pointee.

The pointee may have its type declared before or after the pointer statement, and its array specification (if any) may be declared before, during, or after the pointer statement. The pointer may be declared as an integer prior to the pointer statement. However, some machines have default integer sizes that are different than the size of a pointer, and so the following code is not portable:

```
integer ipt
pointer (ipt, iarr)
```

If a pointer is declared with a kind that is too small, the compiler issues a warning; the resulting binary will probably not work correctly, because the memory addresses stored in the pointers may be truncated. It is safer to omit the first line of the above example; if explicit declaration of `ipt`’s type is omitted, then the compiler ensures that `ipt` is an integer variable large enough to hold a pointer.

Pointer arithmetic is valid with Cray pointers, but it is not the same as C pointer arithmetic. Cray pointers are just ordinary integers, so the user is responsible for determining how many bytes to add to a pointer in order to increment it. Consider the following example:

```
real target(10)
real pointee(10)
pointer (ipt, pointee)
ipt = loc (target)
ipt = ipt + 1
```

The last statement does not set `ipt` to the address of `target(1)`, as it would in C pointer arithmetic. Adding 1 to `ipt` just adds one byte to the address stored in `ipt`.

Any expression involving the pointee is translated to use the value stored in the pointer as the base address.

To get the address of elements, this extension provides an intrinsic function `LOC()`. The `LOC()` function is equivalent to the `&` operator in C, except the address is cast to an integer type:

```
real ar(10)
pointer(ipt, arpte(10))
real arpte
ipt = loc(ar) ! Makes arpte is an alias for ar
arpte(1) = 1.0 ! Sets ar(1) to 1.0
```

The pointer can also be set by a call to the `MALLOC` intrinsic (see Section 8.190 [MALLOC], page 244).

Cray pointees often are used to alias an existing variable. For example:

```
integer target(10)
integer iarr(10)
pointer (ipt, iarr)
ipt = loc(target)
```

As long as `ipt` remains unchanged, `iarr` is now an alias for `target`. The optimizer, however, does not detect this aliasing, so it is unsafe to use `iarr` and `target` simultaneously. Using a pointee in any way that violates the Fortran aliasing rules or assumptions is invalid. It is the user's responsibility to avoid doing this; the compiler works under the assumption that no such aliasing occurs.

Cray pointers work correctly when there is no aliasing (i.e., when they are used to access a dynamically allocated block of memory), and also in any routine where a pointee is used, but any variable with which it shares storage is not used. Code that violates these rules may not run as the user intends. This is not a bug in the optimizer; any code that violates the aliasing rules is invalid. (Note that this is not unique to GNU Fortran; any Fortran compiler that supports Cray pointers "incorrectly" optimizes code with invalid aliasing.)

There are a number of restrictions on the attributes that can be applied to Cray pointers and pointees. Pointees may not have the `ALLOCATABLE`, `INTENT`, `OPTIONAL`, `DUMMY`, `TARGET`, `INTRINSIC`, or `POINTER` attributes. Pointers may not have the `DIMENSION`, `POINTER`, `TARGET`, `ALLOCATABLE`, `EXTERNAL`, or `INTRINSIC` attributes, nor may they be function results. Pointees may not occur in more than one pointer statement. A pointee cannot be a pointer. Pointees cannot occur in equivalence, common, or data statements.

A Cray pointer may also point to a function or a subroutine. For example, the following excerpt is valid:

```
implicit none
external sub
pointer (subptr,subpte)
external subpte
subptr = loc(sub)
call subpte()
[...]
subroutine sub
[...]
end subroutine sub
```

A pointer may be modified during the course of a program, and this changes the location to which the pointee refers. However, when pointees are passed as arguments, they are treated as ordinary variables in the invoked function. Subsequent changes to the pointer do not change the base address of the array that was passed.

5.1.17 CONVERT specifier

GNU Fortran allows the conversion of unformatted data between little- and big-endian representation to facilitate moving of data between different systems. The conversion can be indicated with the `CONVERT` specifier on the `OPEN` statement. See Section 3.10 [GFORTRAN_CONVERT_UNIT], page 38, for an alternative way of specifying the data format via an environment variable.

Valid values for `CONVERT` on most systems are:

`CONVERT='NATIVE'` Use the native format. This is the default.

`CONVERT='SWAP'` Swap between little- and big-endian.

`CONVERT='LITTLE_ENDIAN'` Use the little-endian representation for unformatted files.

`CONVERT='BIG_ENDIAN'` Use the big-endian representation for unformatted files.

On POWER systems that support `-mabi=ieeelongdouble`, there are additional options, which can be combined with the others with commas. Those are

`CONVERT='R16_IEEE'` Use IEEE 128-bit format for `REAL(KIND=16)`.

`CONVERT='R16_IBM'` Use IBM long double format for `REAL(KIND=16)`.

Using the option could look like this:

```
open(file='big.dat',form='unformatted',access='sequential', &
      convert='big_endian')
```

The value of the conversion can be queried by using `INQUIRE(CONVERT=ch)`. The values returned are `'BIG_ENDIAN'` and `'LITTLE_ENDIAN'`.

`CONVERT` works between big- and little-endian for `INTEGER` values of all supported kinds and for `REAL` on IEEE systems of kinds 4 and 8. Conversion between different “extended double” types on different architectures such as m68k and x86_64, which GNU Fortran supports as `REAL(KIND=10)` and `REAL(KIND=16)`, probably does not work.

Note that the values specified via the `GFORTTRAN_CONVERT_UNIT` environment variable overrides the `CONVERT` specifier in the `OPEN` statement. This is to give control over data formats to users who do not have the source code of their program available.

Using anything but the native representation for unformatted data carries a significant speed overhead. If speed in this area matters to you, it is best if you use this only for data that needs to be portable.

5.1.18 OpenMP

OpenMP (Open Multi-Processing) is an application programming interface (API) that supports multi-platform shared memory multiprocessing programming in C/C++ and Fortran on many architectures, including Unix and Microsoft Windows platforms. It consists of a set of compiler directives, library routines, and environment variables that influence run-time behavior.

GNU Fortran implements all of the OpenMP Application Program Interface v4.5 (<https://openmp.org/specifications/>), and many features from later versions of the OpenMP specification. See Section “OpenMP Implementation Status” in *GNU Offloading and Multi Processing Runtime Library*, for more details about currently supported OpenMP features.

To enable the processing of the OpenMP directive `!$omp` in free-form source code; the `c$omp`, `*$omp` and `!$omp` directives in fixed form; the `!$` conditional compilation sentinels in free form; and the `c$`, `*$` and `!$` sentinels in fixed form, `gfortran` needs to be invoked with the `-fopenmp` option. This option also arranges for automatic linking of the OpenMP runtime library. See *GNU Offloading and Multi Processing Runtime Library*.

The OpenMP Fortran runtime library routines are provided both in a form of a Fortran 90 module named `omp_lib` and in a form of a Fortran `include` file named `omp_lib.h`.

An example of a parallelized loop taken from Appendix A.1 of the OpenMP Application Program Interface v2.5:

```
SUBROUTINE A1(N, A, B)
  INTEGER I, N
  REAL B(N), A(N)
  !$OMP PARALLEL DO !I is private by default
  DO I=2,N
    B(I) = (A(I) + A(I-1)) / 2.0
  ENDDO
  !$OMP END PARALLEL DO
END SUBROUTINE A1
```

See Section “OpenMP and OpenACC Options” in *Using the GNU Compiler Collection (GCC)*, for additional options useful with `-fopenmp`.

Please note:

- `-fopenmp` implies `-frecursive`, i.e., all local arrays are allocated on the stack. When porting existing code to OpenMP, this may lead to surprising results, especially segmentation faults if the stack size is limited.
- On glibc-based systems, OpenMP-enabled applications cannot be statically linked due to limitations of the underlying pthreads implementation. It might be possible to get a working solution if `-Wl,--whole-archive -lpthread -Wl,--no-whole-archive` is added to the command line. However, this is not supported by GCC and thus not recommended.

5.1.19 OpenACC

OpenACC is an application programming interface (API) that supports offloading of code to accelerator devices. It consists of a set of compiler directives, library routines, and environment variables that influence run-time behavior.

GNU Fortran strives to be compatible with the OpenACC Application Programming Interface v2.6 (<https://www.openacc.org/>).

To enable the processing of the OpenACC directive `!$acc` in free-form source code; the `c$acc`, `*$acc` and `!$acc` directives in fixed form; the `!$` conditional compilation sentinels in free form; and the `c$`, `*$` and `!$` sentinels in fixed form, `gfortran` needs to be invoked with the `-fopenacc` option. This option also arranges for automatic linking of the OpenACC runtime library. See *GNU Offloading and Multi Processing Runtime Library*.

The OpenACC Fortran runtime library routines are provided both in a form of a Fortran 90 module named `openacc` and in a form of a Fortran `include` file named `openacc_lib.h`.

See Section “OpenMP and OpenACC Options” in *Using the GNU Compiler Collection (GCC)*, for additional options useful with `-fopenacc`.

5.1.20 Argument list functions %VAL, %REF and %LOC

GNU Fortran supports argument list functions `%VAL`, `%REF` and `%LOC` statements, for backward compatibility with g77. It is recommended that these should be used only for code that is accessing facilities outside of GNU Fortran, such as operating system or windowing facilities. It is best to constrain such uses to isolated portions of a program—portions that deal specifically and exclusively with low-level, system-dependent facilities. Such portions

might well provide a portable interface for use by the program as a whole, but are themselves not portable, and should be thoroughly tested each time they are rebuilt using a new compiler or version of a compiler.

%VAL passes a scalar argument by value, **%REF** passes it by reference and **%LOC** passes its memory location. Since gfortran already passes scalar arguments by reference, **%REF** is in effect a do-nothing. **%LOC** has the same effect as a Fortran pointer.

An example of passing an argument by value to a C subroutine foo.:

```
C
C prototype      void foo_ (float x);
C
      external foo
      real*4 x
      x = 3.14159
      call foo (%VAL (x))
      end
```

For details refer to the g77 manual <https://gcc.gnu.org/onlinedocs/gcc-3.4.6/g77/index.html#Top>.

Also, `c_by_val.f` and its partner `c_by_val.c` of the GNU Fortran testsuite are worth a look.

5.1.21 Read/Write after EOF marker

Some legacy codes rely on allowing **READ** or **WRITE** after the EOF file marker in order to find the end of a file. GNU Fortran normally rejects these codes with a run-time error message and suggests the user consider **BACKSPACE** or **REWIND** to properly position the file before the EOF marker. As an extension, the run-time error may be disabled using `-std=legacy`.

5.1.22 STRUCTURE and RECORD

Record structures are a pre-Fortran-90 vendor extension to create user-defined aggregate data types. Support for record structures in GNU Fortran can be enabled with the `-fdec-structure` compile flag. If you have a choice, you should instead use Fortran 90's "derived types", which have a different syntax.

In many cases, record structures can easily be converted to derived types. To convert, replace **STRUCTURE** */structure-name/* by **TYPE** *type-name*. Additionally, replace **RECORD** */structure-name/* by **TYPE**(*type-name*). Finally, in the component access, replace the period (.) by the percent sign (%).

Here is an example of code using the non portable record structure syntax:

```
! Declaring a structure named ``item'' and containing three fields:
! an integer ID, an description string and a floating-point price.
STRUCTURE /item/
  INTEGER id
  CHARACTER(LEN=200) description
  REAL price
END STRUCTURE

! Define two variables, an single record of type ``item''
! named ``pear'', and an array of items named ``store_catalog''
```

```

RECORD /item/ pear, store_catalog(100)

! We can directly access the fields of both variables
pear.id = 92316
pear.description = "juicy D'Anjou pear"
pear.price = 0.15
store_catalog(7).id = 7831
store_catalog(7).description = "milk bottle"
store_catalog(7).price = 1.2

! We can also manipulate the whole structure
store_catalog(12) = pear
print *, store_catalog(12)

```

This code can easily be rewritten in the Fortran 90 syntax as following:

```

! ``STRUCTURE /name/ ... END STRUCTURE'' becomes
! ``TYPE name ... END TYPE''
TYPE item
  INTEGER id
  CHARACTER(LEN=200) description
  REAL price
END TYPE

! ``RECORD /name/ variable'' becomes ``TYPE(name) variable''
TYPE(item) pear, store_catalog(100)

! Instead of using a dot (.) to access fields of a record, the
! standard syntax uses a percent sign (%)
pear%id = 92316
pear%description = "juicy D'Anjou pear"
pear%price = 0.15
store_catalog(7)%id = 7831
store_catalog(7)%description = "milk bottle"
store_catalog(7)%price = 1.2

! Assignments of a whole variable do not change
store_catalog(12) = pear
print *, store_catalog(12)

```

GNU Fortran implements structures like derived types with the following rules and exceptions:

- Structures act like derived types with the `SEQUENCE` attribute. Otherwise they may contain no specifiers.
- Structures may contain a special field with the name `%FILL`. This creates an anonymous component that cannot be accessed but occupies space just as if a component of the same type was declared in its place, useful for alignment purposes. As an example, the following structure consists of at least sixteen bytes:

```

structure /padded/

```

```

        character(4) start
        character(8) %FILL
        character(4) end
    end structure

```

- Structures may share names with other symbols. For example, the following is invalid for derived types, but valid for structures:

```

    structure /header/
    ! ...
    end structure
    record /header/ header

```

- Structure types may be declared nested within another parent structure. The syntax is:

```

    structure /type-name/
    ...
    structure [/<type-name>/] <field-list>
    ...

```

The type name may be omitted, in which case the structure type itself is anonymous, and other structures of the same type cannot be instantiated. The following shows some examples:

```

    structure /appointment/
    ! nested structure definition: app_time is an array of two 'time'
    structure /time/ app_time (2)
    integer(1) hour, minute
    end structure
    character(10) memo
end structure

```

```

! The 'time' structure is still usable
record /time/ now
now = time(5, 30)

```

```

...

```

```

    structure /appointment/
    ! anonymous nested structure definition
    structure start, end
    integer(1) hour, minute
    end structure
    character(10) memo
end structure

```

- Structures may contain UNION blocks. For more detail see the section on Section 5.1.23 [UNION and MAP], page 61.
- Structures support old-style initialization of components, like those described in Section 5.1.2 [Old-style variable initialization], page 49. For array initializers, an initializer may contain a repeat specification of the form `<literal-integer> * <constant-initializer>`. The value of the integer indicates the number of times to repeat the constant initializer when expanding the initializer list.

Unions are an old vendor extension which were commonly used with the nonstandard Section 5.1.22 [STRUCTURE and RECORD], page 58, extensions. Use of UNION and MAP is automatically enabled with `-fdec-structure`.

Here is a small example:

The two maps share memory, and the size of the union is ultimately six bytes:



```

structure /reg/
  union ! U0                                ! rax
    map
      character(16) rx
    end map
    map
      character(8) rh                        ! rah
    union ! U1

```

```

      map
        character(8) rl      ! ral
      end map
      map
        character(8) ex      ! eax
      end map
      map
        character(4) eh      ! eah
        union ! U2
          map
            character(4) el ! eal
          end map
          map
            character(4) x  ! ax
          end map
          map
            character(2) h  ! ah
            character(2) l  ! al
          end map
        end union
      end map
    end union
  end map
end union
end structure
record /reg/ a

! After this assignment...
a.rx    =    'AAAAAAAA.BBB.C.D'

! The following is true:
a.rx === 'AAAAAAAA.BBB.C.D'
a.rh === 'AAAAAAAA'
a.rl === '.BBB.C.D'
a.ex === '.BBB.C.D'
a.eh === '.BBB'
a.el === '.C.D'
a.x  === '.C.D'
a.h  === '.C'
a.l  === '.D'

```

5.1.24 Type variants for integer intrinsics

Similar to the D/C prefixes to real functions to specify the input/output types, GNU Fortran offers B/I/J/K prefixes to integer functions for compatibility with DEC programs. The types implied by each are:

B - INTEGER(kind=1)

I - INTEGER(kind=2)
 J - INTEGER(kind=4)
 K - INTEGER(kind=8)

GNU Fortran supports these with the flag `-fdec-intrinsic-ints`. Intrinsic for which prefixed versions are available and in what form are noted in Chapter 8 [Intrinsic Procedures], page 119. The complete list of supported intrinsics is here:

Intrinsic	B	I	J	K
Section 8.3 [ABS], page 120	BABS	IIABS	JIABS	KIABS
Section 8.55 [BTEST], page 155	BBTEST	BITEST	BJTEST	BKTEST
Section 8.143 [IAND], page 215	BIAND	IIAND	JIAND	KIAND
Section 8.146 [IBCLR], page 217	BBCLR	IIBCLR	JIBCLR	KIBCLR
Section 8.147 [IBITS], page 218	BBITS	IIBITS	JIBITS	KIBITS
Section 8.148 [IBSET], page 218	BBSET	IIBSET	JIBSET	KIBSET
Section 8.151 [IEOR], page 221	BIEOR	IIEOR	JIEOR	KIEOR
Section 8.158 [IOR], page 225	BIOR	IIOR	JIOR	KIOR
Section 8.165 [ISHFT], page 229	BSHFT	IISHFT	JISHFT	KISHFT
Section 8.166 [ISHFTC], page 230	BSHFTC	IISHFTC	JISHFTC	KISHFTC
Section 8.206 [MOD], page 253	BMOD	IMOD	JMOD	KMOD
Section 8.214 [NOT], page 259	BNOT	INOT	JNOT	KNOT
Section 8.235 [REAL], page 272	--	FLOATI	FLOATJ	FLOATK

5.1.25 AUTOMATIC and STATIC attributes

With `-fdec-static` GNU Fortran supports the DEC extended attributes `STATIC` and `AUTOMATIC` to provide explicit specification of entity storage. These follow the syntax of the Fortran standard `SAVE` attribute.

`STATIC` is exactly equivalent to `SAVE`, and specifies that an entity should be allocated in static memory. As an example, `STATIC` local variables retain their values across multiple calls to a function.

Entities marked `AUTOMATIC` are stack automatic whenever possible. `AUTOMATIC` is the default for local variables smaller than `-fmax-stack-var-size`, unless `-fno-automatic` is given. This attribute overrides `-fno-automatic`, `-fmax-stack-var-size`, and blanket `SAVE` statements.

Examples:

```
subroutine f
  integer, automatic :: i  ! automatic variable
  integer x, y             ! static variables
  save
  ...
endsubroutine

subroutine f
  integer a, b, c, x, y, z
  static :: x
  save y
  automatic z, c
  ! a, b, c, and z are automatic
  ! x and y are static
endsubroutine

! Compiled with -fno-automatic
subroutine f
  integer a, b, c, d
  automatic :: a
  ! a is automatic; b, c, and d are static
endsubroutine
```

5.1.26 Form feed as whitespace

Historically, legacy compilers allowed insertion of form feed characters (`'\f'`, ASCII 0xC) at the beginning of lines for formatted output to line printers, though the Fortran standard does not mention this. GNU Fortran supports the interpretation of form feed characters in source as whitespace for compatibility.

5.1.27 TYPE as an alias for PRINT

For compatibility, GNU Fortran interprets `TYPE` statements as `PRINT` statements with the flag `-fdec`. With this flag asserted, the following two examples are equivalent:

```
TYPE *, 'hello world'
PRINT *, 'hello world'
```

5.1.28 %LOC as an rvalue

Normally %LOC is allowed only in parameter lists. However the intrinsic function LOC does the same thing, and is usable as the right-hand-side of assignments. For compatibility, GNU Fortran supports the use of %LOC as an alias for the builtin LOC with `-std=legacy`. With this feature enabled the following two examples are equivalent:

```
integer :: i, l
l = %loc(i)
call sub(l)

integer :: i
call sub(%loc(i))
```

5.1.29 .XOR. operator

GNU Fortran supports `.XOR.` as a logical operator with `-std=legacy` for compatibility with legacy code. `.XOR.` is equivalent to `.NEQV..` That is, the output is true if and only if the inputs differ.

5.1.30 Bitwise logical operators

With `-fdec`, GNU Fortran relaxes the type constraints on logical operators to allow integer operands, and performs the corresponding bitwise operation instead. This flag is for compatibility only, and should be avoided in new code. Consider:

```
INTEGER :: i, j
i = z'33'
j = z'cc'
print *, i .AND. j
```

In this example, compiled with `-fdec`, GNU Fortran replaces the `.AND.` operation with a call to the intrinsic [Section 8.143 \[IAND\], page 215](#) function, yielding the bitwise-and of `i` and `j`.

Note that this conversion occurs if at least one operand is of integral type. As a result, a logical operand is converted to an integer when the other operand is an integer in a logical operation. In this case, `.TRUE.` is converted to 1 and `.FALSE.` to 0.

Here is the mapping of logical operator to bitwise intrinsic used with `-fdec`:

Operator	Intrinsic	Bitwise operation
<code>.NOT.</code>	NOT	complement (see Section 8.214 [NOT], page 259)
<code>.AND.</code>	IAND	intersection (see Section 8.143 [IAND], page 215)
<code>.OR.</code>	IOR	union (see Section 8.158 [IOR], page 225)
<code>.NEQV.</code>	IEOR	exclusive or (see Section 8.151 [IEOR], page 221)
<code>.EQV.</code>	NOT IEO	complement of exclusive or (see Section 8.151 [IEOR], page 221)

5.1.31 Extended I/O specifiers

GNU Fortran supports the additional legacy I/O specifiers `CARRIAGECONTROL`, `READONLY`, and `SHARE` with the compile flag `-fdec`, for compatibility.

CARRIAGECONTROL

The `CARRIAGECONTROL` specifier allows a user to control line termination settings between output records for an I/O unit. The specifier has no meaning for

readonly files. When `CARRIAGECONTROL` is specified upon opening a unit for formatted writing, the exact `CARRIAGECONTROL` setting determines what characters to write between output records. The syntax is:

```
OPEN(..., CARRIAGECONTROL=cc)
```

where `cc` is a character expression that evaluates to one of the following values:

'LIST'	One line feed between records (default)
'FORTRAN'	Legacy interpretation of the first character (see below)
'NONE'	No separator between records

With `CARRIAGECONTROL='FORTRAN'`, when a record is written, the first character of the input record is not written, and instead determines the output record separator as follows:

Leading character	Meaning	Output character(s) separating
'+'	Overprinting	Carriage return only
'-'	New line	Line feed and carriage return
'0'	Skip line	Two line feeds and carriage return
'1'	New page	Form feed and carriage return
'\$'	Prompting	Line feed (no carriage return)
CHAR(0)	Overprinting (no advance)	None

READONLY The `READONLY` specifier may be given upon opening a unit, and is equivalent to specifying `ACTION='READ'`, except that the file may not be deleted on close (i.e. `CLOSE` with `STATUS="DELETE"`). The syntax is:

```
OPEN(..., READONLY)
```

SHARE The `SHARE` specifier allows system-level locking on a unit upon opening it for controlled access from multiple processes/threads. The `SHARE` specifier has several forms:

```
OPEN(..., SHARE=sh)
OPEN(..., SHARED)
OPEN(..., NOSHARED)
```

Where `sh` in the first form is a character expression that evaluates to a value as seen in the table below. The latter two forms are aliases for particular values of `sh`:

Explicit form	Short form	Meaning
<code>SHARE='DENYRW'</code>	<code>NOSHARED</code>	Exclusive (write) lock
<code>SHARE='DENYNONE'</code>	<code>SHARED</code>	Shared (read) lock

In general only one process may hold an exclusive (write) lock for a given file at a time, whereas many processes may hold shared (read) locks for the same file.

The behavior of locking may vary with your operating system. On POSIX systems, locking is implemented with `fcntl`. Consult your corresponding operating system's manual pages for further details. Locking via `SHARE=` is not supported on other systems.

5.1.32 Legacy PARAMETER statements

For compatibility, GNU Fortran supports legacy `PARAMETER` statements without parentheses with `-std=legacy`. A warning is emitted if used with `-std=gnu`, and an error is acknowledged with a real Fortran standard flag (`-std=f95`, etc...). These statements take the following form:

```
implicit real (E)
parameter e = 2.718282
real c
parameter c = 3.0e8
```

5.1.33 Default exponents

For compatibility, GNU Fortran supports a default exponent of zero in real constants with `-fdec`. For example, `9e` would be interpreted as `9e0`, rather than an error.

5.2 Extensions not implemented in GNU Fortran

The long history of the Fortran language, its wide use and broad userbase, the large number of different compiler vendors and the lack of some features crucial to users in the first standards have lead to the existence of a number of important extensions to the language. While some of the most useful or popular extensions are supported by the GNU Fortran compiler, not all existing extensions are supported. This section aims at listing these extensions and offering advice on how best make code that uses them running with the GNU Fortran compiler.

5.2.1 ENCODE and DECODE statements

GNU Fortran does not support the `ENCODE` and `DECODE` statements. These statements are best replaced by `READ` and `WRITE` statements involving internal files (`CHARACTER` variables and arrays), which have been part of the Fortran standard since Fortran 77. For example, replace a code fragment like

```
INTEGER*1 LINE(80)
REAL A, B, C
c ... Code that sets LINE
DECODE (80, 9000, LINE) A, B, C
9000 FORMAT (1X, 3(F10.5))
```

with the following:

```
CHARACTER(LEN=80) LINE
REAL A, B, C
c ... Code that sets LINE
READ (UNIT=LINE, FMT=9000) A, B, C
9000 FORMAT (1X, 3(F10.5))
```

Similarly, replace a code fragment like

```
INTEGER*1 LINE(80)
REAL A, B, C
c ... Code that sets A, B and C
ENCODE (80, 9000, LINE) A, B, C
9000 FORMAT (1X, 'OUTPUT IS ', 3(F10.5))
```

with the following:

```
CHARACTER(LEN=80) LINE
REAL A, B, C
```

```

c      ... Code that sets A, B and C
      WRITE (UNIT=LINE, FMT=9000) A, B, C
9000 FORMAT (1X, 'OUTPUT IS ', 3(F10.5))

```

5.2.2 Variable FORMAT expressions

A variable FORMAT expression is format statement that includes angle brackets enclosing a Fortran expression: `FORMAT(I<N>)`. GNU Fortran does not support this legacy extension. The effect of variable format expressions can be reproduced by using the more powerful (and standard) combination of internal output and string formats. For example, replace a code fragment like this:

```

      WRITE(6,20) INT1
20    FORMAT(I<N+1>)

```

with the following:

```

c      Variable declaration
      CHARACTER(LEN=20) FMT
c
c      Other code here...
c
      WRITE(FMT,'("(I", I0, ")")') N+1
      WRITE(6,FMT) INT1

```

or with:

```

c      Variable declaration
      CHARACTER(LEN=20) FMT
c
c      Other code here...
c
      WRITE(FMT,*) N+1
      WRITE(6,"(I" // ADJUSTL(FMT) // ")") INT1

```

5.2.3 Alternate complex function syntax

Some Fortran compilers, including `g77`, let the user declare complex functions with the syntax `COMPLEX FUNCTION name*16()`, as well as `COMPLEX*16 FUNCTION name()`. Both are nonstandard legacy extensions. `gfortran` accepts the latter form, which is more common, but not the former.

5.2.4 Volatile COMMON blocks

Some Fortran compilers, including `g77`, let the user declare `COMMON` with the `VOLATILE` attribute. This is invalid standard Fortran syntax and is not supported by `gfortran`. Note that `gfortran` accepts `VOLATILE` variables in `COMMON` blocks since revision 4.3.

5.2.5 OPEN(... NAME=)

Some Fortran compilers, including `g77`, let the user declare `OPEN(... NAME=)`. This is invalid standard Fortran syntax and is not supported by `gfortran`. `OPEN(... NAME=)` should be replaced with `OPEN(... FILE=)`.

5.2.6 Q edit descriptor

Some Fortran compilers provide the `Q` edit descriptor, which transfers the number of characters left within an input record into an integer variable.

A direct replacement of the `Q` edit descriptor is not available in `gfortran`. How to replicate its functionality using standard-conforming code depends on what the intent of the original code is.

Options to replace `Q` may be to read the whole line into a character variable and then counting the number of non-blank characters left using `LEN_TRIM`. Another method may be to use formatted stream, read the data up to the position where the `Q` descriptor occurred, use `INQUIRE` to get the file position, count the characters up to the next `NEW_LINE` and then start reading from the position marked previously.

5.3 Experimental features future Fortran versions

GNU Fortran supports some experimental features that have been proposed and accepted by the J3 standards committee. These exist to give users a chance to try them out, and to provide a reference implementation.

As these features have not been included in the worklist for Fortran 202Y by WG5, there is a chance that a version in any upcoming standard will differ from what GNU Fortran currently implements. These features are therefore currently classified as an extension.

5.3.1 Unsigned integers

If the `-funsigned` option is given, GNU Fortran supports unsigned integers according to J3/24-116 (<https://j3-fortran.org/doc/year/24/24-116.txt>). The data type is called `UNSIGNED`. For an unsigned type with `n` bits, it implements integer arithmetic modulo 2^{**n} , comparable to the `unsigned` data type in C.

The data type has `KIND` numbers comparable to other Fortran data types, which can be selected via the `SELECTED_UNSIGNED_KIND` function.

Mixed arithmetic, comparisons and assignment between `UNSIGNED` and other types are only possible via explicit conversion. Conversion from `UNSIGNED` to other types is done via type conversion functions like `INT` or `REAL`. Conversion from other types to `UNSIGNED` is done via `UINT`. Unsigned variables cannot be used as index variables in `DO` loops or as array indices.

Unsigned numbers have a trailing `u` as suffix, optionally followed by a `KIND` number separated by an underscore.

Input and output can be done using the ‘I’, ‘B’, ‘O’ and ‘Z’ descriptors, plus unformatted I/O.

Here is a small, somewhat contrived example of their use:

```
program main
  use iso_fortran_env, only : uint64
  unsigned(kind=uint64) :: v
  v = huge(v) - 32u_uint64
  print *,v
end program main
```

which outputs the number 18446744073709551583.

Arithmetic operations work on unsigned integers, also for exponentiation. As an extension to J3/24-116.txt, unary minus and exponentiation of unsigned integers are permitted unless `-pedantic` is in force.

In intrinsic procedures, unsigned arguments are typically permitted for arguments for the data to be processed, analogous to the use of `REAL` arguments. Unsigned values are prohibited as index variables in `DO` loops and as array indices.

Unsigned numbers can be read and written using list-directed, formatted and unformatted I/O. For formatted I/O, the ‘B’, ‘I’, ‘O’ and ‘Z’ descriptors are valid. Negative values and values that would overflow are rejected with `-pedantic`.

`SELECT CASE` is supported for unsigned integers.

The following intrinsics take unsigned arguments:

- `BGE`, see Section 8.50 [`BGE`], page 152,
- `BGT`, see Section 8.51 [`BGT`], page 153,
- `BIT_SIZE`, see Section 8.52 [`BIT_SIZE`], page 153,
- `BLE`, see Section 8.53 [`BLE`], page 154,
- `BLT`, see Section 8.54 [`BLT`], page 154,
- `CMPLX`, see Section 8.66 [`CMPLX`], page 162,
- `CSHIFT`, see Section 8.85 [`CSHIFT`], page 176,
- `DIGITS`, see Section 8.90 [`DIGITS`], page 180,
- `DOT_PRODUCT`, see Section 8.92 [`DOT_PRODUCT`], page 181,
- `DSHIFTL`, see Section 8.95 [`DSHIFTL`], page 183,
- `DSHIFTR`, see Section 8.96 [`DSHIFTR`], page 183,
- `EOSHIFT`, see Section 8.98 [`EOSHIFT`], page 185,
- `FINDLOC`, see Section 8.113 [`FINDLOC`], page 195,
- `HUGE`, see Section 8.139 [`HUGE`], page 212,
- `IALL`, see Section 8.142 [`IALL`], page 214,
- `IAND`, see Section 8.143 [`IAND`], page 215,
- `IANY`, see Section 8.144 [`IANY`], page 216,
- `IBCLR`, see Section 8.146 [`IBCLR`], page 217,
- `IBITS`, see Section 8.147 [`IBITS`], page 218,
- `IBSET`, see Section 8.148 [`IBSET`], page 218,
- `IEOR`, see Section 8.151 [`IEOR`], page 221,
- `INT`, see Section 8.155 [`INT`], page 223,
- `IOR`, see Section 8.158 [`IOR`], page 225,
- `IPARITY`, see Section 8.159 [`IPARITY`], page 225,
- `ISHFT`, see Section 8.165 [`ISHFT`], page 229,
- `ISHFTC`, see Section 8.166 [`ISHFTC`], page 230,
- `MATMUL`, see Section 8.193 [`MATMUL`], page 245,
- `MAX`, see Section 8.194 [`MAX`], page 246,
- `MAXLOC`, see Section 8.196 [`MAXLOC`], page 247,
- `MAXVAL`, see Section 8.197 [`MAXVAL`], page 248,
- `MERGE`, see Section 8.200 [`MERGE`], page 250,

- `MERGE_BITS`, see Section 8.201 [`MERGE_BITS`], page 250,
- `MIN`, see Section 8.202 [`MIN`], page 251,
- `MINLOC`, see Section 8.204 [`MINLOC`], page 252,
- `MINVAL`, see Section 8.205 [`MINVAL`], page 253,
- `MOD`, see Section 8.206 [`MOD`], page 253,
- `MODULO`, see Section 8.207 [`MODULO`], page 254,
- `MVBITS`, see Section 8.209 [`MVBITS`], page 256,
- `NOT`, see Section 8.214 [`NOT`], page 259,
- `OUT_OF_RANGE`, see Section 8.218 [`OUT_OF_RANGE`], page 262,
- `PRODUCT`, see Section 8.226 [`PRODUCT`], page 266,
- `RANDOM_NUMBER`, see Section 8.231 [`RANDOM_NUMBER`], page 269,
- `RANGE`, see Section 8.233 [`RANGE`], page 271,
- `REAL`, see Section 8.235 [`REAL`], page 272,
- `SHIFTA`, see Section 8.253 [`SHIFTA`], page 282,
- `SHIFTL`, see Section 8.254 [`SHIFTL`], page 283,
- `SHIFTR`, see Section 8.255 [`SHIFTR`], page 283,
- `SUM`, see Section 8.272 [`SUM`], page 294,
- `TRANSPOSE`, see Section 8.287 [`TRANSPOSE`], page 304,
- `TRANSFER`, see Section 8.286 [`TRANSFER`], page 303,

The following intrinsics are enabled with `-funsigned`:

- `UINT`, see Section 8.292 [`UINT`], page 306,
- `UMASKL`, see Section 8.294 [`UMASKL`], page 307,
- `UMASKR`, see Section 8.295 [`UMASKR`], page 307,
- `SELECTED_UNSIGNED_KIND`, see Section 8.250 [`SELECTED_UNSIGNED_KIND`], page 281,

The following constants have been added to the intrinsic `ISO_C_BINDING` module: `c_unsigned`, `c_unsigned_short`, `c_unsigned_char`, `c_unsigned_long`, `c_unsigned_long_long`, `c_uintmax_t`, `c_uint8_t`, `c_uint16_t`, `c_uint32_t`, `c_uint64_t`, `c_uint128_t`, `c_uint_fast8_t`, `c_uint_fast16_t`, `c_uint_fast32_t`, `c_uint_fast64_t`, `c_uint_fast128_t`, `c_uint_least8_t`, `c_uint_least16_t`, `c_uint_least32_t`, `c_uint_least64_t` and `c_uint_least128_t`.

The following constants have been added to the intrinsic `ISO_FORTRAN_ENV` module: `uint8`, `uint16`, `uint32` and `uint64`.

6 Mixed-Language Programming

This chapter is about mixed-language interoperability, but also applies if you link Fortran code compiled by different compilers. In most cases, use of the C Binding features of the Fortran 2003 and later standards is sufficient.

For example, it is possible to mix Fortran code with C++ code as well as C, if you declare the interface functions as `extern "C"` on the C++ side and `BIND(C)` on the Fortran side, and follow the rules for interoperability with C. Note that you cannot manipulate C++ class objects in Fortran or vice versa except as opaque pointers.

You can use the `gfortran` command to link both Fortran and non-Fortran code into the same program, or you can use `gcc` or `g++` if you also add an explicit `-lgfortran` option to link with the Fortran library. If your main program is written in C or some other language instead of Fortran, see Section 6.3 [Non-Fortran Main Program], page 81, below.

6.1 Interoperability with C

Since Fortran 2003 (ISO/IEC 1539-1:2004(E)) there is a standardized way to generate procedure and derived-type declarations and global variables that are interoperable with C (ISO/IEC 9899:1999). The `BIND(C)` attribute has been added to inform the compiler that a symbol shall be interoperable with C; also, some constraints are added. Note, however, that not all C features have a Fortran equivalent or vice versa. For instance, neither C's unsigned integers nor C's functions with variable number of arguments have an equivalent in Fortran.

Note that array dimensions are reversely ordered in C and that arrays in C always start with index 0 while in Fortran they start by default with 1. Thus, an array declaration `A(n,m)` in Fortran matches `A[m][n]` in C and accessing the element `A(i,j)` matches `A[j-1][i-1]`. The element following `A(i,j)` (C: `A[j-1][i-1]`; assuming $i < n$) in memory is `A(i+1,j)` (C: `A[j-1][i]`).

6.1.1 Intrinsic Types

In order to ensure that exactly the same variable type and kind is used in C and Fortran, you should use the named constants for kind parameters that are defined in the `ISO_C_BINDING` intrinsic module. That module contains named constants of character type representing the escaped special characters in C, such as newline. For a list of the constants, see Section 9.2 [ISO_C_BINDING], page 313.

For logical types, please note that the Fortran standard only guarantees interoperability between C99's `_Bool` and Fortran's `C_Bool`-kind logicals and C99 defines that `true` has the value 1 and `false` the value 0. Using any other integer value with GNU Fortran's `LOGICAL` (with any kind parameter) gives an undefined result. (Passing other integer values than 0 and 1 to GCC's `_Bool` is also undefined, unless the integer is explicitly or implicitly casted to `_Bool`.)

6.1.2 Derived Types and struct

For compatibility of derived types with `struct`, use the `BIND(C)` attribute in the type declaration. For instance, the following type declaration

```
USE ISO_C_BINDING
```

```

TYPE, BIND(C) :: myType
  INTEGER(C_INT) :: i1, i2
  INTEGER(C_SIGNED_CHAR) :: i3
  REAL(C_DOUBLE) :: d1
  COMPLEX(C_FLOAT_COMPLEX) :: c1
  CHARACTER(KIND=C_CHAR) :: str(5)
END TYPE

```

matches the following `struct` declaration in C

```

struct {
  int i1, i2;
  /* Note: "char" might be signed or unsigned. */
  signed char i3;
  double d1;
  float _Complex c1;
  char str[5];
} myType;

```

Derived types with the C binding attribute shall not have the `sequence` attribute, type parameters, the `extends` attribute, nor type-bound procedures. Every component must be of interoperable type and kind and may not have the `pointer` or `allocatable` attribute. The names of the components are irrelevant for interoperability.

As there exist no direct Fortran equivalents, neither unions nor structs with bit field or variable-length array members are interoperable.

6.1.3 Interoperable Global Variables

Variables can be made accessible from C using the C binding attribute, optionally together with specifying a binding name. Those variables have to be declared in the declaration part of a `MODULE`, be of interoperable type, and have neither the `pointer` nor the `allocatable` attribute.

```

MODULE m
  USE myType_module
  USE ISO_C_BINDING
  integer(C_INT), bind(C, name="_MyProject_flags") :: global_flag
  type(myType), bind(C) :: tp
END MODULE

```

Here, `_MyProject_flags` is the case-sensitive name of the variable as seen from C programs while `global_flag` is the case-insensitive name as seen from Fortran. If no binding name is specified, as for `tp`, the C binding name is the (lowercase) Fortran binding name. If a binding name is specified, only a single variable may be after the double colon. Note of warning: You cannot use a global variable to access `errno` of the C library as the C standard allows it to be a macro. Use the `IERRNO` intrinsic (GNU extension) instead.

6.1.4 Interoperable Subroutines and Functions

Subroutines and functions have to have the `BIND(C)` attribute to be compatible with C. The dummy argument declaration is relatively straightforward. However, one needs to be careful because C uses call-by-value by default while Fortran behaves usually similar to call-by-reference. Furthermore, strings and pointers are handled differently.

To pass a variable by value, use the `VALUE` attribute. Thus, the following C prototype

```
int func(int i, int *j)
```

matches the Fortran declaration

```
integer(c_int) function func(i,j)
  use iso_c_binding, only: c_int
  integer(c_int), VALUE :: i
  integer(c_int) :: j
```

Note that pointer arguments also frequently need the `VALUE` attribute, see Section 6.1.5 [Working with C Pointers], page 76.

Strings are handled quite differently in C and Fortran. In C a string is a NUL-terminated array of characters while in Fortran each string has a length associated with it and is thus not terminated (by e.g. NUL). For example, if you want to use the following C function,

```
#include <stdio.h>
void print_C(char *string) /* equivalent: char string[] */
{
  printf("%s\n", string);
}
```

to print “Hello World” from Fortran, you can call it using

```
use iso_c_binding, only: C_CHAR, C_NULL_CHAR
interface
  subroutine print_c(string) bind(C, name="print_C")
    use iso_c_binding, only: c_char
    character(kind=c_char) :: string(*)
  end subroutine print_c
end interface
call print_c(C_CHAR_"Hello World"//C_NULL_CHAR)
```

As the example shows, you need to ensure that the string is NUL terminated. Additionally, the dummy argument *string* of `print_C` is a length-one assumed-size array; using `character(len=*)` is not allowed. The example above uses `c_char_"Hello World"` to ensure the string literal has the right type; typically the default character kind and `c_char` are the same and thus `"Hello World"` is equivalent. However, the standard does not guarantee this.

The use of strings is now further illustrated using the C library function `strncpy`, whose prototype is

```
char *strncpy(char *restrict s1, const char *restrict s2, size_t n);
```

The function `strncpy` copies at most *n* characters from string *s2* to *s1* and returns *s1*. In the following example, we ignore the return value:

```
use iso_c_binding
implicit none
character(len=30) :: str, str2
interface
  ! Ignore the return value of strncpy -> subroutine
  ! "restrict" is always assumed if we do not pass a pointer
  subroutine strncpy(dest, src, n) bind(C)
    import
    character(kind=c_char), intent(out) :: dest(*)
    character(kind=c_char), intent(in)  :: src(*)
    integer(c_size_t), value, intent(in) :: n
  end subroutine strncpy
end interface
str = repeat('X',30) ! Initialize whole string with 'X'
call strncpy(str, c_char_"Hello World"//C_NULL_CHAR, &
             len(c_char_"Hello World",kind=c_size_t))
```

```
print '(a)', str ! prints: "Hello WorldXXXXXXXXXXXXXXXXXXXX"
end
```

The intrinsic procedures are described in Chapter 8 [Intrinsic Procedures], page 119.

6.1.5 Working with C Pointers

C pointers are represented in Fortran via the special opaque derived type `type(c_ptr)` (with private components). C pointers are distinct from Fortran objects with the `POINTER` attribute. Thus one needs to use intrinsic conversion procedures to convert from or to C pointers. For some applications, using an assumed type (`TYPE(*)`) can be an alternative to a C pointer, and you can also use library routines to access Fortran pointers from C. See Section 6.1.6 [Further Interoperability of Fortran with C], page 78.

Here is an example of using C pointers in Fortran:

```
use iso_c_binding
type(c_ptr) :: cptr1, cptr2
integer, target :: array(7), scalar
integer, pointer :: pa(:), ps
cptr1 = c_loc(array(1)) ! The programmer needs to ensure that the
                        ! array is contiguous if required by the C
                        ! procedure
cptr2 = c_loc(scalar)
call c_f_pointer(cptr2, ps)
call c_f_pointer(cptr2, pa, shape=[7])
```

When converting C to Fortran arrays, the one-dimensional `SHAPE` argument has to be passed.

If a pointer is a dummy argument of an interoperable procedure, it usually has to be declared using the `VALUE` attribute. `void*` matches `TYPE(C_PTR)`, `VALUE`, while `TYPE(C_PTR)` alone matches `void**`.

Procedure pointers are handled analogously to pointers; the C type is `TYPE(C_FUNPTR)` and the intrinsic conversion procedures are `C_F_PROCPTR` and `C_FUNLOC`.

Let us consider two examples of actually passing a procedure pointer from C to Fortran and vice versa. Note that these examples are also very similar to passing ordinary pointers between both languages. First, consider this code in C:

```
/* Procedure implemented in Fortran. */
void get_values (void (*)(double));

/* Call-back routine we want called from Fortran. */
void
print_it (double x)
{
    printf ("Number is %f.\n", x);
}

/* Call Fortran routine and pass call-back to it. */
void
foobar ()
{
    get_values (&print_it);
}
```

A matching implementation for `get_values` in Fortran that correctly receives the procedure pointer from C and is able to call it, is given in the following `MODULE`:

```
MODULE m
```

```

    IMPLICIT NONE

    ! Define interface of call-back routine.
    ABSTRACT INTERFACE
        SUBROUTINE callback (x)
            USE, INTRINSIC :: ISO_C_BINDING
            REAL(KIND=C_DOUBLE), INTENT(IN), VALUE :: x
        END SUBROUTINE callback
    END INTERFACE

CONTAINS

    ! Define C-bound procedure.
    SUBROUTINE get_values (cproc) BIND(C)
        USE, INTRINSIC :: ISO_C_BINDING
        TYPE(C_FUNPTR), INTENT(IN), VALUE :: cproc

        PROCEDURE(callback), POINTER :: proc

        ! Convert C to Fortran procedure pointer.
        CALL C_F_PROCPTR (cproc, proc)

        ! Call it.
        CALL proc (1.0_C_DOUBLE)
        CALL proc (-42.0_C_DOUBLE)
        CALL proc (18.12_C_DOUBLE)
    END SUBROUTINE get_values

END MODULE m

```

Next, we want to call a C routine that expects a procedure pointer argument and pass it a Fortran procedure (that clearly must be interoperable!). Again, the C function may be:

```

int
call_it (int (*func)(int), int arg)
{
    return func (arg);
}

```

It can be used as in the following Fortran code:

```

MODULE m
    USE, INTRINSIC :: ISO_C_BINDING
    IMPLICIT NONE

    ! Define interface of C function.
    INTERFACE
        INTEGER(KIND=C_INT) FUNCTION call_it (func, arg) BIND(C)
            USE, INTRINSIC :: ISO_C_BINDING
            TYPE(C_FUNPTR), INTENT(IN), VALUE :: func
            INTEGER(KIND=C_INT), INTENT(IN), VALUE :: arg
        END FUNCTION call_it
    END INTERFACE

CONTAINS

    ! Define procedure passed to C function.
    ! It must be interoperable!
    INTEGER(KIND=C_INT) FUNCTION double_it (arg) BIND(C)
        INTEGER(KIND=C_INT), INTENT(IN), VALUE :: arg
        double_it = arg + arg
    END FUNCTION double_it

```

```

END FUNCTION double_it

! Call C function.
SUBROUTINE foobar ()
  TYPE(C_FUNPTR) :: cproc
  INTEGER(KIND=C_INT) :: i

  ! Get C procedure pointer.
  cproc = C_FUNLOC (double_it)

  ! Use it.
  DO i = 1_C_INT, 10_C_INT
    PRINT *, call_it (cproc, i)
  END DO
END SUBROUTINE foobar

END MODULE m

```

6.1.6 Further Interoperability of Fortran with C

GNU Fortran implements the Technical Specification ISO/IEC TS 29113:2012, which extends the interoperability support of Fortran 2003 and Fortran 2008 and is now part of the 2018 Fortran standard. Besides removing some restrictions and constraints, the Technical Specification adds assumed-type (`TYPE(*)`) and assumed-rank (`DIMENSION(..)`) variables and allows for interoperability of assumed-shape, assumed-rank, and deferred-shape arrays, as well as allocatables and pointers. Objects of these types are passed to `BIND(C)` functions as descriptors with a standard interface, declared in the header file `<ISO_Fortran_binding.h>`.

Note: Currently, GNU Fortran does not use internally the array descriptor (dope vector) as specified in the Technical Specification, but uses an array descriptor with different fields in functions without the `BIND(C)` attribute. Arguments to functions marked `BIND(C)` are converted to the specified form. If you need to access GNU Fortran's internal array descriptor, you can use the Chasm Language Interoperability Tools, <http://chasm-interop.sourceforge.net/>.

6.1.7 Generating C prototypes from Fortran

The options `-fc-prototypes` can be used to write out C declarations and function prototypes for `BIND(C)` entities. The same can be done for writing out prototypes for external procedures using `-fc-prototypes-external`, see Section 2.11 [Interoperability Options], page 34.

Standard Fortran does not specify an interoperable type for C's `unsigned` integer types. For interoperability with unsigned types, GNU Fortran provides unsigned integers, see Section 5.3.1 [Unsigned integers], page 69.

6.2 GNU Fortran Compiler Directives

6.2.1 ATTRIBUTES directive

The Fortran standard describes how a conforming program shall behave; however, the exact implementation is not standardized. In order to allow the user to choose specific implementation details, compiler directives can be used to set attributes of variables and

procedures that are not part of the standard. Whether a given attribute is supported and its exact effects depend on both the operating system and on the processor; see Section “C Extensions” in *Using the GNU Compiler Collection (GCC)* for details.

For procedures and procedure pointers, the following attributes can be used to change the calling convention:

- **CDECL** – standard C calling convention
- **STDCALL** – convention where the called procedure pops the stack
- **FASTCALL** – part of the arguments are passed via registers instead using the stack

Besides changing the calling convention, the attributes also influence the decoration of the symbol name, e.g., by a leading underscore or by a trailing at-sign followed by the number of bytes on the stack. When assigning a procedure to a procedure pointer, both should use the same calling convention.

On some systems, procedures and global variables (module variables and **COMMON** blocks) need special handling to be accessible when they are in a shared library. The following attributes are available:

- **DLEXPOR**T – provide a global pointer to a pointer in the DLL
- **DLLIMPO**R – reference the function or variable using a global pointer

For dummy arguments, the **NO_ARG_CHECK** attribute can be used; in other compilers, it is also known as **IGNORE_TKR**. For dummy arguments with this attribute actual arguments of any type and kind (similar to **TYPE(*)**), scalars and arrays of any rank (no equivalent in Fortran standard) are accepted. As with **TYPE(*)**, the argument is unlimited polymorphic and no type information is available. Additionally, the argument may only be passed to dummy arguments with the **NO_ARG_CHECK** attribute and as argument to the **PRESENT** intrinsic function and to **C_LOC** of the **ISO_C_BINDING** module.

Variables with **NO_ARG_CHECK** attribute shall be of assumed-type (**TYPE(*)**; recommended) or of type **INTEGER**, **LOGICAL**, **REAL** or **COMPLEX**. They shall not have the **ALLOCATE**, **CODIMENSION**, **INTENT(OUT)**, **POINTER** or **VALUE** attribute; furthermore, they shall be either scalar or of assumed-size (**dimension(*)**). As **TYPE(*)**, the **NO_ARG_CHECK** attribute requires an explicit interface.

- **NO_ARG_CHECK** – disable the type, kind and rank checking
- **DEPRECATED** – print a warning when using a such-tagged deprecated procedure, variable or parameter; the warning can be suppressed with **-Wno-deprecated-declarations**.
- **NOINLINE** – prevent inlining given function.
- **NORETURN** – add a hint that a given function cannot return.
- **WEAK** – emit the declaration of an external symbol as a weak symbol rather than a global. This is primarily useful in defining library functions that can be overridden in user code, though it can also be used with non-function declarations. The overriding symbol must have the same type as the weak symbol.

The attributes are specified using the syntax

```
!GCC$ ATTRIBUTES attribute-list :: variable-list
```

where in free-form source code only whitespace is allowed before **!GCC\$** and in fixed-form source code **!GCC\$**, **cGCC\$** or ***GCC\$** shall start in the first column.

For procedures, the compiler directives shall be placed into the body of the procedure; for variables and procedure pointers, they shall be in the same declaration part as the variable or procedure pointer.

6.2.2 UNROLL directive

The syntax of the directive is

```
!GCC$ unroll N
```

You can use this directive to control how many times a loop should be unrolled. It must be placed immediately before a **DO** loop and applies only to the loop that follows. *N* is an integer constant specifying the unrolling factor. The values of 0 and 1 block any unrolling of the loop.

For **DO CONCURRENT** constructs the unrolling specification applies only to the first loop control variable.

6.2.3 BUILTIN directive

The syntax of the directive is

```
!GCC$ BUILTIN (B) attributes simd FLAGS IF('target')
```

You can use this directive to define which middle-end built-ins provide vector implementations. *B* is name of the middle-end built-in. *FLAGS* are optional and must be either (**inbranch**) or (**notinbranch**). **IF** statement is optional and is used to filter multilib ABIs for the built-in that should be vectorized. Example usage:

```
!GCC$ builtin (sinf) attributes simd (notinbranch) if('x86_64')
```

The purpose of the directive is to provide an API among the GCC compiler and the GNU C Library which would define vector implementations of math routines.

6.2.4 IVDEP directive

The syntax of the directive is

```
!GCC$ ivdep
```

This directive tells the compiler to ignore vector dependencies in the following loop. It must be placed immediately before a **DO** loop and applies only to the loop that follows.

Sometimes the compiler may not have sufficient information to decide whether a particular loop is vectorizable due to potential dependencies between iterations. The purpose of the directive is to tell the compiler that vectorization is safe.

For **DO CONCURRENT** constructs this annotation is implicit to all loop control variables.

This directive is intended for annotation of existing code. For new code it is recommended to consider OpenMP SIMD directives as potential alternative.

6.2.5 VECTOR directive

The syntax of the directive is

```
!GCC$ vector
```

This directive tells the compiler to vectorize the following loop. It must be placed immediately before a **DO** loop and applies only to the loop that follows.

For **DO CONCURRENT** constructs this annotation applies to all loops specified in the concurrent header.

6.2.6 NOVECTOR directive

The syntax of the directive is

```
!GCC$ novector
```

This directive tells the compiler to not vectorize the following loop. It must be placed immediately before a DO loop and applies only to the loop that follows.

For DO CONCURRENT constructs this annotation applies to all loops specified in the concurrent header.

6.3 Non-Fortran Main Program

Even if you are doing mixed-language programming, it is very likely that you do not need to know or use the information in this section. Since it is about the internal structure of GNU Fortran, it may also change in GCC minor releases.

When you compile a PROGRAM with GNU Fortran, a function with the name `main` (in the symbol table of the object file) is generated, which initializes the libgfortran library and then calls the actual program that uses the name `MAIN__`, for historic reasons. If you link GNU Fortran compiled procedures to, e.g., a C or C++ program or to a Fortran program compiled by a different compiler, the libgfortran library is not initialized and thus a few intrinsic procedures do not work properly, e.g. those for obtaining the command-line arguments.

Therefore, if your PROGRAM is not compiled with GNU Fortran and the GNU Fortran compiled procedures require intrinsics relying on the library initialization, you need to initialize the library yourself. Using the default options, gfortran calls `_gfortran_set_args` and `_gfortran_set_options`. The initialization of the former is needed if the called procedures access the command line (and for backtracing); the latter sets some flags based on the standard chosen or to enable backtracing. In typical programs, it is not necessary to call any initialization function.

If your PROGRAM is compiled with GNU Fortran, you shall not call any of the following functions. The libgfortran initialization functions are shown in C syntax but using C bindings they are also accessible from Fortran.

6.3.1 `_gfortran_set_args` — Save command-line arguments

Synopsis: `void _gfortran_set_args (int argc, char *argv[])`

Description:

`_gfortran_set_args` saves the command-line arguments; this initialization is required if any of the command-line intrinsics is called. Additionally, it shall be called if backtracing is enabled (see `_gfortran_set_options`).

Arguments:

<code>argc</code>	number of command line argument strings
<code>argv</code>	the command-line argument strings; <code>argv[0]</code> is the pathname of the executable itself.

Example:

```
int main (int argc, char *argv[])
{
```

```

    /* Initialize libgfortran. */
    _gfortran_set_args (argc, argv);
    return 0;
}

```

6.3.2 `_gfortran_set_options` — Set library option flags

Synopsis: `void _gfortran_set_options (int num, int options[])`

Description:

`_gfortran_set_options` sets several flags related to the Fortran standard to be used, whether backtracing should be enabled and whether range checks should be performed. The syntax allows for upward compatibility since the number of passed flags is specified; for non-passed flags, the default value is used. See also see Section 2.10 [Code Gen Options], page 26. Please note that not all flags are actually used.

Arguments:

<code>num</code>	number of options passed
<code>argv</code>	The list of flag values

option flag list:

<code>option[0]</code>	Allowed standard; can give run-time errors if e.g. an input-output edit descriptor is invalid in a given standard. Possible values are (bitwise or-ed) <code>GFC_STD_F77</code> (1), <code>GFC_STD_F95_OBS</code> (2), <code>GFC_STD_F95_DEL</code> (4), <code>GFC_STD_F95</code> (8), <code>GFC_STD_F2003</code> (16), <code>GFC_STD_GNU</code> (32), <code>GFC_STD_LEGACY</code> (64), <code>GFC_STD_F2008</code> (128), <code>GFC_STD_F2008_OBS</code> (256), <code>GFC_STD_F2018</code> (512), <code>GFC_STD_F2018_OBS</code> (1024), <code>GFC_STD_F2018_DEL</code> (2048), <code>GFC_STD_F2023</code> (4096), and <code>GFC_STD_F2023_DEL</code> (8192). Default: <code>GFC_STD_F95_OBS GFC_STD_F95_DEL GFC_STD_F95 GFC_STD_F2003 GFC_STD_F2008 GFC_STD_F2008_OBS GFC_STD_F77 GFC_STD_F2018 GFC_STD_F2018_OBS GFC_STD_F2018_DEL GFC_STD_F2023 GFC_STD_F2023_DEL GFC_STD_GNU GFC_STD_LEGACY</code> .
<code>option[1]</code>	Standard-warning flag; prints a warning to standard error. Default: <code>GFC_STD_F95_DEL GFC_STD_LEGACY</code> .
<code>option[2]</code>	If non zero, enable pedantic checking. Default: off.
<code>option[3]</code>	Unused.
<code>option[4]</code>	If non zero, enable backtracing on run-time errors. Default: off. (Default in the compiler: on.) Note: Installs a signal handler and requires command-line initialization using <code>_gfortran_set_args</code> .
<code>option[5]</code>	If non zero, supports signed zeros. Default: enabled.

option[6] Enables run-time checking. Possible values are (bitwise or-ed): GFC_RTCKECK_BOUNDS (1), GFC_RTCKECK_ARRAY_TEMPS (2), GFC_RTCKECK_RECURSION (4), GFC_RTCKECK_DO (8), GFC_RTCKECK_POINTER (16), GFC_RTCKECK_MEM (32), GFC_RTCKECK_BITS (64). Default: disabled.

option[7] Unused.

option[8] Show a warning when invoking STOP and ERROR STOP if a floating-point exception occurred. Possible values are (bitwise or-ed) GFC_FPE_INVALID (1), GFC_FPE_DENORMAL (2), GFC_FPE_ZERO (4), GFC_FPE_OVERFLOW (8), GFC_FPE_UNDERFLOW (16), GFC_FPE_INEXACT (32). Default: None (0). (Default in the compiler: GFC_FPE_INVALID | GFC_FPE_DENORMAL | GFC_FPE_ZERO | GFC_FPE_OVERFLOW | GFC_FPE_UNDERFLOW.)

Example:

```
/* Use gfortran 4.9 default options. */
static int options[] = {68, 511, 0, 0, 1, 1, 0, 0, 31};
_gfortran_set_options (9, &options);
```

6.3.3 `_gfortran_set_convert` — Set endian conversion

Synopsis: `void _gfortran_set_convert (int conv)`

Description:

`_gfortran_set_convert` set the representation of data for unformatted files.

Arguments:

conv Endian conversion, possible values:
 GFC_CONVERT_NATIVE (0, default),
 GFC_CONVERT_SWAP (1), GFC_CONVERT_BIG
 (2), GFC_CONVERT_LITTLE (3).

Example:

```
int main (int argc, char *argv[])
{
  /* Initialize libgfortran. */
  _gfortran_set_args (argc, argv);
  _gfortran_set_convert (1);
  return 0;
}
```

6.3.4 `_gfortran_set_record_marker` — Set length of record markers

Synopsis: `void _gfortran_set_record_marker (int val)`

Description:

`_gfortran_set_record_marker` sets the length of record markers for unformatted files.

Arguments:

`val` Length of the record marker; valid values are 4 and 8. Default is 4.

Example:

```
int main (int argc, char *argv[])
{
    /* Initialize libgfortran. */
    _gfortran_set_args (argc, argv);
    _gfortran_set_record_marker (8);
    return 0;
}
```

6.3.5 `_gfortran_set_fpe` — Enable floating point exception traps

Synopsis: `void _gfortran_set_fpe (int val)`

Description:

`_gfortran_set_fpe` enables floating point exception traps for the specified exceptions. On most systems, this results in a SIGFPE signal being sent and the program being aborted.

Arguments:

`option[0]` IEEE exceptions. Possible values are (bitwise or-ed) zero (0, default) no trapping, `GFC_FPE_INVALID` (1), `GFC_FPE_DENORMAL` (2), `GFC_FPE_ZERO` (4), `GFC_FPE_OVERFLOW` (8), `GFC_FPE_UNDERFLOW` (16), and `GFC_FPE_INEXACT` (32).

Example:

```
int main (int argc, char *argv[])
{
    /* Initialize libgfortran. */
    _gfortran_set_args (argc, argv);
    /* FPE for invalid operations such as SQRT(-1.0). */
    _gfortran_set_fpe (1);
    return 0;
}
```

6.3.6 `_gfortran_set_max_subrecord_length` — Set subrecord length

Synopsis: `void _gfortran_set_max_subrecord_length (int val)`

Description:

`_gfortran_set_max_subrecord_length` set the maximum length for a subrecord. This option only makes sense for testing and debugging of unformatted I/O.

Arguments:

`val` the maximum length for a subrecord; the maximum permitted value is 2147483639, which is also the default.

Example:

```
int main (int argc, char *argv[])
{
    /* Initialize libgfortran. */
    _gfortran_set_args (argc, argv);
    _gfortran_set_max_subrecord_length (8);
    return 0;
}
```

6.4 Naming and argument-passing conventions

This section gives an overview about the naming convention of procedures and global variables and about the argument passing conventions used by GNU Fortran. If a C binding has been specified, the naming convention and some of the argument-passing conventions change. If possible, mixed-language and mixed-compiler projects should use the better defined C binding for interoperability. See Section 6.1 [Interoperability with C], page 73.

6.4.1 Naming conventions

According the Fortran standard, valid Fortran names consist of a letter between A to Z, a to z, digits 0, 1 to 9 and underscores (_) with the restriction that names may only start with a letter. As vendor extension, the dollar sign (\$) is additionally permitted with the option `-fdollar-ok`, but not as first character and only if the target system supports it.

By default, the procedure name is the lowercased Fortran name with an appended underscore (_); using `-fno-underscoring` no underscore is appended while `-fsecond-underscore` appends two underscores. Depending on the target system and the calling convention, the procedure might be additionally dressed; for instance, on 32bit Windows with `stdcall`, an at-sign @ followed by an integer number is appended. For the changing the calling convention, see Section 6.2 [GNU Fortran Compiler Directives], page 78.

For common blocks, the same convention is used, i.e. by default an underscore is appended to the lowercased Fortran name. Blank commons have the name `__BLNK__`.

For procedures and variables declared in the specification space of a module, the name is formed by `__`, followed by the lowercased module name, `_MOD_`, and the lowercased Fortran name. Note that no underscore is appended.

6.4.2 Argument passing conventions

Subroutines do not return a value (matching C99's `void`) while functions either return a value as specified in the platform ABI or the result variable is passed as hidden argument to the function and no result is returned. A hidden result variable is used when the result variable is an array or of type `CHARACTER`.

Arguments are passed according to the platform ABI. In particular, complex arguments might not be compatible to a struct with two real components for the real and imaginary part. The argument passing matches the one of C99's `_Complex`. Functions with scalar complex result variables return their value and do not use a by-reference argument. Note that with the `-ff2c` option, the argument passing is modified and no longer completely matches the platform ABI. Some other Fortran compilers use `f2c` semantic by default; this might cause problems with interoperability.

GNU Fortran passes most arguments by reference, i.e. by passing a pointer to the data. Note that the compiler might use a temporary variable into which the actual argument has been copied, if required semantically (copy-in/copy-out).

For arguments with `ALLOCATABLE` and `POINTER` attribute (including procedure pointers), a pointer to the pointer is passed such that the pointer address can be modified in the procedure.

For dummy arguments with the `VALUE` attribute: Scalar arguments of the type `INTEGER`, `LOGICAL`, `REAL` and `COMPLEX` are passed by value according to the platform ABI. (As vendor extension and not recommended, using `%VAL()` in the call to a procedure has the same effect.) For `TYPE(C_PTR)` and procedure pointers, the pointer itself is passed such that it can be modified without affecting the caller.

For Boolean (`LOGICAL`) arguments, please note that GCC expects only the integer value 0 and 1. If a GNU Fortran `LOGICAL` variable contains another integer value, the result is undefined. As some other Fortran compilers use `-1` for `.TRUE.`, extra care has to be taken – such as passing the value as `INTEGER`. (The same value restriction also applies to other front ends of GCC, e.g. to GCC's C99 compiler for `_Bool` or GCC's Ada compiler for `Boolean`.)

For arguments of `CHARACTER` type, the character length is passed as a hidden argument at the end of the argument list, except when the corresponding dummy argument is declared as `TYPE(*)`. For deferred-length strings, the value is passed by reference, otherwise by value. The character length has the C type `size_t` (or `INTEGER(kind=C_SIZE_T)` in Fortran). Note that this is different to older versions of the GNU Fortran compiler, where the type of the hidden character length argument was a C `int`. In order to retain compatibility with older versions, one can e.g. for the following Fortran procedure

```
subroutine fstrlen (s, a)
  character(len=*) :: s
  integer :: a
  print*, len(s)
end subroutine fstrlen
```

define the corresponding C prototype as follows:

```
#if __GNUC__ > 7
typedef size_t fortran_charlen_t;
#else
typedef int fortran_charlen_t;
#endif

void fstrlen_ (char*, int*, fortran_charlen_t);
```

In order to avoid such compiler-specific details, for new code it is instead recommended to use the `ISO_C_BINDING` feature.

Note with C binding, `CHARACTER(len=1)` result variables are returned according to the platform ABI and no hidden length argument is used for dummy arguments; with `VALUE`, those variables are passed by value.

For `OPTIONAL` dummy arguments, an absent argument is denoted by a `NULL` pointer, except for scalar dummy arguments of intrinsic type or derived type (but not `CLASS`) and that have the `VALUE` attribute. For those, a hidden Boolean argument (`logical(kind=C_bool),value`) is used to indicate whether the argument is present.

Arguments that are assumed-shape, assumed-rank or deferred-rank arrays or, with `-fcoarray=lib`, allocatable scalar coarrays use an array descriptor. All other arrays pass

the address of the first element of the array. With `-fcoarray=lib`, the token and the offset belonging to nonallocatable coarrays dummy arguments are passed as hidden argument along the character length hidden arguments. The token is an opaque pointer identifying the coarray and the offset is a passed-by-value integer of kind `C_PTRDIFF_T`, denoting the byte offset between the base address of the coarray and the passed scalar or first element of the passed array.

The arguments are passed in the following order

- Result variable, when the function result is passed by reference
- Character length of the function result, if it is a of type `CHARACTER` and no C binding is used
- The arguments in the order in which they appear in the Fortran declaration
- The present status for optional arguments with value attribute, which are internally passed by value
- The character length and/or coarray token and offset for the first argument which is a `CHARACTER` or a nonallocatable coarray dummy argument, followed by the hidden arguments of the next dummy argument of such a type

7 Coarray Programming

7.1 Type and enum ABI Documentation

7.1.1 caf_token_t

Typedef of type `void *` on the compiler side. Can be any data type on the library side.

7.1.2 caf_register_t

Indicates which kind of coarray variable should be registered.

```
typedef enum caf_register_t {
    CAF_REGTYPE_COARRAY_STATIC,
    CAF_REGTYPE_COARRAY_ALLOC,
    CAF_REGTYPE_LOCK_STATIC,
    CAF_REGTYPE_LOCK_ALLOC,
    CAF_REGTYPE_CRITICAL,
    CAF_REGTYPE_EVENT_STATIC,
    CAF_REGTYPE_EVENT_ALLOC,
    CAF_REGTYPE_COARRAY_ALLOC_REGISTER_ONLY,
    CAF_REGTYPE_COARRAY_ALLOC_ALLOCATE_ONLY
}
caf_register_t;
```

The values `CAF_REGTYPE_COARRAY_ALLOC_REGISTER_ONLY` and `CAF_REGTYPE_COARRAY_ALLOC_ALLOCATE_ONLY` are for allocatable components in derived type coarrays only. The first one sets up the token without allocating memory for allocatable component. The latter one only allocates the memory for an allocatable component in a derived type coarray. The token needs to be set up previously by the `REGISTER_ONLY`. This allows having allocatable components unallocated on some images. The status of whether an allocatable component is allocated on a remote image can be queried by `_caf_is_present` which used internally by the `ALLOCATED` intrinsic.

7.1.3 caf_deregister_t

```
typedef enum caf_deregister_t {
    CAF_DEREGTYPE_COARRAY_DEREGISTER,
    CAF_DEREGTYPE_COARRAY DEALLOCATE_ONLY
}
caf_deregister_t;
```

Allows to specify the type of deregistration of a coarray object. The `CAF_DEREGTYPE_COARRAY DEALLOCATE_ONLY` flag is only allowed for allocatable components in derived type coarrays.

7.1.4 caf_reference_t

The structure used for implementing arbitrary reference chains. A `CAF_REFERENCE_T` allows to specify a component reference or any kind of array reference of any rank supported by gfortran. For array references all kinds as known by the compiler/Fortran standard are supported indicated by a `MODE`.

```
typedef enum caf_ref_type_t {
    /* Reference a component of a derived type, either regular one or an
       allocatable or pointer type. For regular ones idx in caf_reference_t is
```

```

        set to -1. */
CAF_REF_COMPONENT,
/* Reference an allocatable array. */
CAF_REF_ARRAY,
/* Reference a non-allocatable/non-pointer array. I.e., the coarray object
   has no array descriptor associated and the addressing is done
   completely using the ref. */
CAF_REF_STATIC_ARRAY
} caf_ref_type_t;

typedef enum caf_array_ref_t {
/* No array ref. This terminates the array ref. */
CAF_ARR_REF_NONE = 0,
/* Reference array elements given by a vector. Only for this mode
   caf_reference_t.u.a.dim[i].v is valid. */
CAF_ARR_REF_VECTOR,
/* A full array ref (:). */
CAF_ARR_REF_FULL,
/* Reference a range on elements given by start, end and stride. */
CAF_ARR_REF_RANGE,
/* Only a single item is referenced given in the start member. */
CAF_ARR_REF_SINGLE,
/* An array ref of the kind (i:), where i is an arbitrary valid index in the
   array. The index i is given in the start member. */
CAF_ARR_REF_OPEN_END,
/* An array ref of the kind (:i), where the lower bound of the array ref
   is given by the remote side. The index i is given in the end member. */
CAF_ARR_REF_OPEN_START
} caf_array_ref_t;

/* References to remote components of a derived type. */
typedef struct caf_reference_t {
/* A pointer to the next ref or NULL. */
struct caf_reference_t *next;
/* The type of the reference. */
/* caf_ref_type_t, replaced by int to allow specification in fortran FE. */
int type;
/* The size of an item referenced in bytes. I.e. in an array ref this is
   the factor to advance the array pointer with to get to the next item.
   For component refs this gives just the size of the element referenced. */
size_t item_size;
union {
    struct {
        /* The offset (in bytes) of the component in the derived type.
           Unused for allocatable or pointer components. */
        ptrdiff_t offset;
        /* The offset (in bytes) to the caf_token associated with this
           component. NULL, when not allocatable/pointer ref. */
        ptrdiff_t caf_token_offset;
    } c;
    struct {
        /* The mode of the array ref. See CAF_ARR_REF*. */
        /* caf_array_ref_t, replaced by unsigned char to allow specification in
           fortran FE. */
        unsigned char mode[GFC_MAX_DIMENSIONS];
        /* The type of a static array. Unset for array's with descriptors. */
        int static_array_type;
        /* Subscript refs (s) or vector refs (v). */
        union {
            struct {

```

```

        /* The start and end boundary of the ref and the stride. */
        index_type start, end, stride;
    } s;
    struct {
        /* nvec entries of kind giving the elements to reference. */
        void *vector;
        /* The number of entries in vector. */
        size_t nvec;
        /* The integer kind used for the elements in vector. */
        int kind;
    } v;
    } dim[GFC_MAX_DIMENSIONS];
    } a;
    } u;
} caf_reference_t;

```

The references make up a single linked list of reference operations. The `NEXT` member links to the next reference or `NULL` to indicate the end of the chain. Component and array refs can be arbitrarily mixed as long as they comply to the Fortran standard.

Notes: The member `STATIC_ARRAY_TYPE` is used only when the `TYPE` is `CAF_REF_STATIC_ARRAY`. The member gives the type of the data referenced. Because no array descriptor is available for a descriptorless array and type conversion still needs to take place the type is transported here.

At the moment `CAF_ARR_REF_VECTOR` is not implemented in the front end for descriptorless arrays. The library `caf_single` has untested support for it.

7.1.5 `caf_team_t`

Opaque pointer to represent a team-handle. This type is a stand-in for the future implementation of teams. It is about to change without further notice.

7.2 Function ABI Documentation

7.2.1 `_gfortran_caf_init` — Initialization function

Synopsis: `void _gfortran_caf_init (int *argc, char ***argv)`

Description:

This function is called at startup of the program before the Fortran main program, if the latter has been compiled with `-fcoarray=lib`. It takes as arguments the command-line arguments of the program. It is permitted to pass two `NULL` pointers as argument; if non-`NULL`, the library is permitted to modify the arguments.

Arguments:

<code>argc</code>	intent(inout) An integer pointer with the number of arguments passed to the program or <code>NULL</code> .
<code>argv</code>	intent(inout) A pointer to an array of strings with the command-line arguments or <code>NULL</code> .

Notes: The function is modelled after the initialization function of the Message Passing Interface (MPI) specification. Due to the way coarray registration works, it might not be the first call to the library. If the main program is not written

in Fortran and only a library uses coarrays, it can happen that this function is never called. Therefore, it is recommended that the library does not rely on the passed arguments and whether the call has been done.

7.2.2 `_gfortran_caf_finish` — Finalization function

Synopsis: `void _gfortran_caf_finish (void)`

Description:

This function is called at the end of the Fortran main program, if it has been compiled with the `-fcoarray=lib` option.

Notes: For non-Fortran programs, it is recommended to call the function at the end of the main program. To ensure that the shutdown is also performed for programs where this function is not explicitly invoked, for instance non-Fortran programs or calls to the system's `exit()` function, the library can use a destructor function. Note that programs can also be terminated using the `STOP` and `ERROR STOP` statements; those use different library calls.

7.2.3 `_gfortran_caf_this_image` — Querying the image number

Synopsis: `int _gfortran_caf_this_image (caf_team_t team)`

Description:

Return the current image number in the *team*, or in the current team, if no *team* is given.

Arguments:

team intent(in), optional; The team this image's number is requested for. If null, the image number in the current team is returned.

Notes: Available since Fortran 2008 without argument; Since Fortran 2018 with optional *team* argument. Fortran 2008 uses 0 as argument for *team*, which is permissible, because a team handle is always an opaque pointer, which as a special case can be null here.

7.2.4 `_gfortran_caf_num_images` — Querying the maximal number of images

Synopsis: `int _gfortran_caf_num_images (caf_team_t team, int32_t *team_number)`

Description:

This function returns the number of images in the team given by *team* or *team_number*, if either one is present. If both are null, then the number of images in the current team is returned.

Arguments:

team intent(in), optional; The team the number of images is requested for. If null, the number of images in the current team is returned.

team_number intent(in), optional; The team id for which the number of teams is requested; if unset, then number of images in the current team is returned.

Notes: When both argument are given, then it is caf-library dependent which argument is examined first. Current implementations prioritize the *team* argument, because it is easier to retrieve the number of images from it.

Fortran 2008 or later, with no arguments; Fortran 2018 or later with two arguments.

7.2.5 `_gfortran_caf_image_status` — Query the status of an image

Synopsis: `int _gfortran_caf_image_status (int image, caf_team_t * team)`

Description:

Get the status of the image given by the id *image* of the team given by *team*. Valid results are zero, for image is ok, `STAT_STOPPED_IMAGE` from the `ISO_FORTRAN_ENV` module to indicate that the image has been stopped and `STAT_FAILED_IMAGE` also from `ISO_FORTRAN_ENV` to indicate that the image has executed a `FAIL IMAGE` statement.

Arguments:

<i>image</i>	the positive scalar id of the image in the current TEAM.
<i>team</i>	optional; team on the which the inquiry is to be performed.

Notes: This function follows TS18508. Because team-functionality is not yet implemented a null pointer is passed for the *team* argument at the moment.

7.2.6 `_gfortran_caf_failed_images` — Get an array of the indexes of the failed images

Synopsis: `int _gfortran_caf_failed_images (caf_team_t * team, int * kind)`

Description:

Get an array of image indexes in the current *team* that have failed. The array is sorted ascendingly. When *team* is not provided the current team is to be used. When *kind* is provided then the resulting array is of that integer kind else it is of default integer kind. The returns an unallocated size zero array when no images have failed.

Arguments:

<i>team</i>	optional; team on the which the inquiry is to be performed.
<i>image</i>	optional; the kind of the resulting integer array.

Notes: This function follows TS18508. Because team-functionality is not yet implemented a null pointer is passed for the *team* argument at the moment.

7.2.7 `_gfortran_caf_stopped_images` — Get an array of the indexes of the stopped images

Synopsis: `int _gfortran_caf_stopped_images (caf_team_t * team, int * kind)`

Description:

Get an array of image indexes in the current *team* that have stopped. The array is sorted ascendingly. When *team* is not provided the current team is to be used. When *kind* is provided then the resulting array is of that integer kind else it is of default integer kind. The returns an unallocated size zero array when no images have failed.

Arguments:

team optional; team on the which the inquiry is to be performed.
image optional; the kind of the resulting integer array.

Notes: This function follows TS18508. Because team-functionality is not yet implemented a null pointer is passed for the *team* argument at the moment.

7.2.8 `_gfortran_caf_register` — Registering coarrays

Synopsis: `void _gfortran_caf_register (size_t size, caf_register_t type, caf_token_t *token, gfc_descriptor_t *desc, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Registers memory for a coarray and creates a token to identify the coarray. The routine is called for both coarrays with `SAVE` attribute and using an explicit `ALLOCATE` statement. If an error occurs and *STAT* is a `NULL` pointer, the function shall abort with printing an error message and starting the error termination. If no error occurs and *STAT* is present, it shall be set to zero. Otherwise, it shall be set to a positive value and, if not-`NULL`, *ERRMSG* shall be set to a string describing the failure. The routine shall register the memory provided in the *DATA*-component of the array descriptor *DESC*, when that component is non-`NULL`, else it shall allocate sufficient memory and provide a pointer to it in the *DATA*-component of *DESC*. The array descriptor has rank zero, when a scalar object is to be registered and the array descriptor may be invalid after the call to `_gfortran_caf_register`. When an array is to be allocated the descriptor persists.

For `CAF_REGTYPE_COARRAY_STATIC` and `CAF_REGTYPE_COARRAY_ALLOC`, the passed size is the byte size requested. For `CAF_REGTYPE_LOCK_STATIC`, `CAF_REGTYPE_LOCK_ALLOC` and `CAF_REGTYPE_CRITICAL` it is the array size or one for a scalar.

When `CAF_REGTYPE_COARRAY_ALLOC_REGISTER_ONLY` is used, then only a token for an allocatable or pointer component is created. The *SIZE* parameter is not used then. On the contrary when `CAF_REGTYPE_COARRAY_ALLOC_ALLOCATE_ONLY` is specified, then the *token* needs to be registered by a previous call with regtype `CAF_REGTYPE_COARRAY_ALLOC_REGISTER_ONLY` and either the memory specified in the *DESC*'s data-ptr is registered or allocate when the data-ptr is `NULL`.

Arguments:

<i>size</i>	For normal coarrays, the byte size of the coarray to be allocated; for lock types and event types, the number of elements.
<i>type</i>	one of the <code>caf_register_t</code> types.
<i>token</i>	intent(out) An opaque pointer identifying the coarray.
<i>desc</i>	intent(inout) The (pseudo) array descriptor.
<i>stat</i>	intent(out) For allocatable coarrays, stores the <code>STAT=</code> ; may be <code>NULL</code>
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be <code>NULL</code>
<i>errmsg_len</i>	the buffer size of <code>errmsg</code> .

Notes: Nonallocatable coarrays have to be registered prior use from remote images. In order to guarantee this, they have to be registered before the main program. This can be achieved by creating constructor functions. That is what GCC does such that also for nonallocatable coarrays the memory is allocated and no static memory is used. The token permits to identify the coarray; to the processor, the token is a nonaliasing pointer. The library can, for instance, store the base address of the coarray in the token, some handle or a more complicated struct. The library may also store the array descriptor *DESC* when its rank is nonzero. For lock types, the value shall only be used for checking the allocation status. Note that for critical blocks, the locking is only required on one image; in the locking statement, the processor shall always pass an image index of one for critical-block lock variables (`CAF_REGTYPE_CRITICAL`). For lock types and critical-block variables, the initial value shall be unlocked (or, respectively, not in critical section) such as the value `false`; for event types, the initial state should be no event, e.g. `zero`.

7.2.9 `_gfortran_caf_deregister` — Deregistering coarrays

Synopsis: `void _gfortran_caf_deregister (caf_token_t *token, caf_deregister_t type, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Called to free or deregister the memory of a coarray; the processor calls this function for automatic and explicit deallocation. In case of an error, this function shall fail with an error message, unless the *STAT* variable is not null. The library is only expected to free memory it allocated itself during a call to `_gfortran_caf_register`.

Arguments:

<i>token</i>	the token to free.
<i>type</i>	the type of action to take for the coarray. A <code>CAF_DEREGTYPE_COARRAY_DEALLOCATE_ONLY</code> is allowed only for allocatable or pointer components of derived type coarrays. The action only deallocates the local memory without deleting the token.

stat intent(out) Stores the STAT=; may be NULL
errmsg intent(out) When an error occurs, this is set to an
 error message; may be NULL
errmsg_len the buffer size of errmsg.

Notes: For nonallocatable coarrays this function is never called. If a cleanup is required, it has to be handled via the finish, stop and error stop functions, and via destructors.

7.2.10 `_gfortran_caf_register_accessor` — Register an accessor for remote access

Synopsis: `void _gfortran_caf_register_accessor (const int hash, void (*accessor)(void **, int32_t *, void *, void *, size_t *, size_t *))`

Description:

Identification of access functions across images is done using a unique hash. For each given hash an accessor has to be registered. This routine is expected to register an accessor function pointer for the given hash in nearly constant time. I.e. it is expected to add the hash and accessor to a buffer and return. Sorting shall be done in `_gfortran_caf_register_accessors_finish`.

Arguments:

hash intent(in) The unique hash value this accessor is to
 be identified by.
accessor intent(in) A pointer to the function on this
 image. The function has the signature `void
 accessor (void **dst_ptr, int32_t *free_dst,
 void *src_ptr, void *get_data, size_t
 *opt_src_charlen, size_t *opt_dst_charlen)`.
 GFortran ensures that functions provided to
 `_gfortran_caf_register_accessor` adhere to this
 interface.

Notes: This function is required to have a nearly constant runtime complexity, because it will be called to register multiple accessor in a sequence. GFortran ensures that before the first remote accesses commences `_gfortran_caf_register_accessors_finish` is called at least once. It is valid to register further accessors after a call to `_gfortran_caf_register_accessors_finish`. It is invalid to call `_gfortran_caf_register_accessor` after the first remote access has been done. See also Section 7.2.11 [`_gfortran_caf_register_accessors_finish`], page 96, and Section 7.2.12 [`_gfortran_caf_get_remote_function_index`], page 97,

7.2.11 `_gfortran_caf_register_accessors_finish` — Finish registering accessor functions

Synopsis: `void _gfortran_caf_register_accessors_finish ()`

Description:

Called to finalize registering of accessor functions. This function is expected to prepare a lookup table that has fast lookup time for the hash supplied to

`_gfortran_caf_get_remote_function_index` and constant access time for indexing operations.

Arguments:

No arguments.

Notes: This function may be called multiple times with and without new hash-accessors- pairs being added. The post-condition after each call has to be that hashes can be looked up quickly and indexing on the lookup table of hash-accessor-pairs is a constant time operation.

7.2.12 `_gfortran_caf_get_remote_function_index` — Get the index of an accessor

Synopsis: `int _gfortran_caf_get_remote_function_index (const int hash)`

Description:

Return the index of the accessor in the lookup table build by Section 7.2.10 [`_gfortran_caf_register_accessor`], page 96, and Section 7.2.11 [`_gfortran_caf_register_accessors_finish`], page 96. This function is expected to be fast, because it may be called often. A $\log(N)$ lookup time for a given hash is preferred. The reference implementation uses `bsearch()`, for example. The index returned shall be an array index to be used by Section 7.2.13 [`_gfortran_caf_get_from_remote`], page 97, i.e. a constant time operation is mandatory for quick access.

The GFortran compiler ensures that `_gfortran_caf_get_remote_function_index` is called once only for each hash and the result be stored in a static variable to prevent future redundant lookups.

Arguments:

`hash` intent(in) The hash of the accessor desired.

Result: The zero based index to access the accessor function in a lookup table. On error, -1 can be returned.

Notes: The function's complexity is expected to be significantly smaller than N , where N is the number of all accessors registered. Although returning -1 is valid, will this most likely crash the Fortran program when accessing the -1-th accessor function. It is therefore advised to terminate with an error message, when the hash could not be found.

7.2.13 `_gfortran_caf_get_from_remote` — Getting data from a remote image using a remote side accessor

Synopsis: `void _gfortran_caf_get_from_remote (caf_token_t token, const gfc_descriptor_t *opt_src_desc, const size_t *opt_src_charlen, const int image_index, const size_t dst_size, void **dst_data, size_t *opt_dst_charlen, gfc_descriptor_t *opt_dst_desc, const bool may_realloc_dst, const int getter_index, void *get_data, const size_t get_data_size, int *stat, caf_team_t *team, int *team_number)`

Description:

Called to get a scalar, an array section or a whole array from a remote image identified by the *image_index*.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>opt_src_desc</i>	intent(in) A pointer to the descriptor when the object identified by <i>token</i> is an array with a descriptor. The parameter needs to be set to NULL, when <i>token</i> identifies a scalar.
<i>opt_src_charlen</i>	intent(in) When the object to get is a char array with deferred length, then this parameter needs to be set to point to its length. Else the parameter needs to be set to NULL.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number. this_image () is valid.
<i>dst_size</i>	intent(in) The size of data expected to be transferred from the remote image. If the data type to get is a string or string array, then this needs to be set to the byte size of each character, i.e. 4 for a CHARACTER (KIND=4) string. The length of the string is then returned in opt_dst_charlen (also for string arrays).
<i>dst_data</i>	intent(inout) A pointer to the address the data is stored. To prevent copying of data into an output buffer the address to the live data is returned here. When a descriptor is provided also its data-member is set to that address. When <i>may_realloc_dst</i> is set, then the memory may be reallocated by the remote function, which needs to be replicated by this function.
<i>opt_dst_charlen</i>	intent(inout) When a char array is returned, this parameter is set to the length where applicable. The value can also be read to prevent reallocation in the accessor.
<i>opt_dst_desc</i>	intent(inout) When a descriptor array is returned, it is stored in the memory pointed to by this optional parameter. When <i>may_realloc_dst</i> is set, then the descriptor may be changed, i.e. its bounds, but upto now not its rank.
<i>may_realloc_dst</i>	intent(in) Set when the returned data may require reallocation of the output buffer in <i>dst_data</i> or <i>opt_dst_desc</i> .
<i>getter_index</i>	intent(in) The index of the accessor to execute as returned by _gfortran_caf_get_remote_function_index ().

<i>get_data</i>	intent(inout) Additional data needed in the accessor. I.e., when an array reference uses a local variable <i>v</i> , it is transported in this structure and all references in the accessor are rewritten to access the member. The data in the structure of <i>get_data</i> may be changed by the accessor, but these changes are lost to the calling Fortran program.
<i>get_data_size</i>	intent(in) The size of the <i>get_data</i> structure.
<i>stat</i>	intent(out) When non-NULL give the result of the operation, i.e., zero on success and non-zero on error. When NULL and an error occurs, then an error message is printed and the program is terminated.
<i>team</i>	intent(in) The opaque team handle as returned by <code>FORM TEAM</code> .
<i>team_number</i>	intent(in) The number of the team this access is to be part of.

Notes: It is permitted to have `image_index` equal the current image; the memory to get and the memory to store the data may (partially) overlap. The implementation has to take care that it handles this case, e.g. using `memmove` which handles (partially) overlapping memory.

7.2.14 `_gfortran_caf_is_present_on_remote` — Check that a coarray or a part of it is allocated on the remote image

Synopsis: `int32_t _gfortran_caf_is_present_on_remote (caf_token_t token, const int image_index, const int is_present_index, void *add_data, const size_t add_data_size)`

Description:

Check if an allocatable coarray or a component of a derived type coarray is allocated on the remote image identified by the *image_index*. The check is done by calling routine on the remote side.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number. <code>this_image ()</code> is valid.
<i>is_present_index</i>	intent(in) The index of the accessor to execute as returned by <code>_gfortran_caf_get_remote_function_index ()</code> .
<i>add_data</i>	intent(inout) Additional data needed in the accessor. I.e., when an array reference uses a local variable <i>v</i> , it is transported in this structure and all references in the accessor are rewritten to access the member. The data in the structure of <i>add_data</i> may be changed by the accessor, but these changes are lost to the calling Fortran program.
<i>add_data_size</i>	intent(in) The size of the <i>add_data</i> structure.

7.2.15 `_gfortran_caf_send_to_remote` — Send data to a remote image using a remote side accessor to store it

Synopsis: `void _gfortran_caf_send_to_remote (caf_token_t token, gfc_descriptor_t *opt_dst_desc, const size_t *opt_dst_charlen, const int image_index, const size_t src_size, const void *src_data, size_t *opt_src_charlen, const gfc_descriptor_t *opt_src_desc, const int setter_index, void *add_data, const size_t add_data_size, int *stat, caf_team_t *team, int *team_number)`

Description:

Called to send a scalar, an array section or a whole array to a remote image identified by the *image_index*. The call modifies the memory of the remote image.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>opt_dst_desc</i>	intent(inout) A pointer to the descriptor when the object identified by <i>token</i> is an array with a descriptor. The parameter needs to be set to NULL, when <i>token</i> identifies a scalar or is an array without a descriptor.
<i>opt_dst_charlen</i>	intent(in) When the object to send is a char array with deferred length, then this parameter needs to be set to point to its length. Else the parameter needs to be set to NULL.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number. <code>this_image ()</code> is valid.
<i>src_size</i>	intent(in) The size of data expected to be transferred to the remote image. If the data type to get is a string or string array, then this needs to be set to the byte size of each character, i.e. 4 for a CHARACTER (KIND=4) string. The length of the string is then given in <i>opt_src_charlen</i> (also for string arrays).
<i>src_data</i>	intent(in) A pointer the data to be send to the remote image. When a descriptor is provided in <i>opt_src_desc</i> then this parameter can be ignored by the library implementing the coarray functionality.
<i>opt_src_charlen</i>	intent(in) When a char array is send, this parameter is set to its length.
<i>opt_src_desc</i>	intent(in) When a descriptor array is send, then this parameter gives the handle.
<i>setter_index</i>	intent(in) The index of the accessor to execute as returned by <code>_gfortran_caf_get_remote_function_index ()</code> .

add_data intent(inout) Additional data needed in the accessor. I.e., when an array reference uses a local variable *v*, it is transported in this structure and all references in the accessor are rewritten to access the member. The data in the structure of *add_data* may be changed by the accessor, but these changes are lost to the calling Fortran program.

add_data_size intent(in) The size of the *add_data* structure.

stat intent(out) When non-NULL give the result of the operation, i.e., zero on success and non-zero on error. When NULL and an error occurs, then an error message is printed and the program is terminated.

team intent(in) The opaque team handle as returned by **FORM TEAM**.

team_number intent(in) The number of the team this access is to be part of.

Notes: It is permitted to have *image_index* equal the current image; the memory to send the data to and the memory to read for the data may (partially) overlap. The implementation has to take care that it handles this case, e.g. using **memmove** which handles (partially) overlapping memory.

7.2.16 **_gfortran_caf_transfer_between_remotes** — Initiate data transfer between to remote images

Synopsis: `void _gfortran_caf_transfer_between_remotes (caf_token_t dst_token, gfc_descriptor_t *opt_dst_desc, size_t *opt_dst_charlen, const int dst_image_index, const int dst_access_index, void *dst_add_data, const size_t dst_add_data_size, caf_token_t src_token, const gfc_descriptor_t *opt_src_desc, const size_t *opt_src_charlen, const int src_image_index, const int src_access_index, void *src_add_data, const size_t src_add_data_size, const size_t src_size, const bool scalar_transfer, int *dst_stat, int *src_stat, caf_team_t *dst_team, int *dst_team_number, caf_team_t *src_team, int *src_team_number)`

Description:

Initiates a transfer of data from one remote image to another remote image. The call modifies the memory of the receiving remote image given by *dst_image_index*. The *src_image_index*'s memory is not modified. The call returns when the transfer has commenced.

Arguments:

dst_token intent(in) An opaque pointer identifying the coarray on the receiving image.

- opt_dst_desc* intent(inout) A pointer to the descriptor when the object identified by *dst_token* is an array with a descriptor. The parameter needs to be set to NULL, when *dst_token* identifies a scalar or is an array without a descriptor.
- opt_dst_charlen* intent(in) When the object to modify on the receiving image is a char array with deferred length, then this parameter needs to be set to point to its length. Else the parameter needs to be set to NULL.
- dst_image_index* intent(in) The ID of the receiving/destination remote image; must be a positive number. `this_image ()` is valid.
- dst_access_index* intent(in) The index of the accessor to execute on the receiving image as returned by `_gfortran_caf_get_remote_function_index ()`.
- dst_add_data* intent(inout) Additional data needed in the accessor on the receiving side. I.e., when an array reference uses a local variable *v*, it is transported in this structure and all references in the accessor are rewritten to access the member. The data in the structure of *dst_add_data* may be changed by the accessor, but these changes are lost to the calling Fortran program.
- dst_add_data_size* intent(in) The size of the *dst_add_data* structure.
- src_token* intent(in) An opaque pointer identifying the coarray on the sending image.
- opt_src_desc* intent(inout) A pointer to the descriptor when the object identified by *src_token* is an array with a descriptor. The parameter needs to be set to NULL, when *src_token* identifies a scalar or is an array without a descriptor.
- opt_src_charlen* intent(in) When the object to get from the source image is a char array with deferred length, then this parameter needs to be set to point to its length. Else the parameter needs to be set to NULL.
- src_image_index* intent(in) The ID of the sending/source remote image; must be a positive number. `this_image ()` is valid.
- src_access_index* intent(in) The index of the accessor to execute on the sending image as returned by `_gfortran_caf_get_remote_function_index ()`.

<i>src_add_data</i>	intent(inout) Additional data needed in the accessor on the sending side. I.e., when an array reference uses a local variable <i>v</i> , it is transported in this structure and all references in the accessor are rewritten to access the member. The data in the structure of <i>src_add_data</i> may be changed by the accessor, but these changes are lost to the calling Fortran program.
<i>src_add_data_size</i>	intent(in) The size of the <i>src_add_data</i> structure.
<i>src_size</i>	intent(in) The size of data expected to be transferred between the images. If the data type to get is a string or string array, then this needs to be set to the byte size of each character, i.e. 4 for a CHARACTER (KIND=4) string. The length of the string is then given in <i>opt_src_charlen</i> and <i>opt_dst_charlen</i> (also for string arrays).
<i>scalar_transfer</i>	intent(in) Is set to true when the data to be transferred between the two images is not an array with a descriptor.
<i>dst_stat</i>	intent(out) When non-NULL give the result of the operation on the receiving side, i.e., zero on success and non-zero on error. When NULL and an error occurs, then an error message is printed and the program is terminated.
<i>src_stat</i>	intent(out) When non-NULL give the result of the operation on the sending side, i.e., zero on success and non-zero on error. When NULL and an error occurs, then an error message is printed and the program is terminated.
<i>dst_team</i>	intent(in) The opaque team handle as returned by FORM TEAM.
<i>dst_team_number</i>	intent(in) The number of the team this access is to be part of.
<i>src_team</i>	intent(in) The opaque team handle as returned by FORM TEAM.
<i>src_team_number</i>	intent(in) The number of the team this access is to be part of.

Notes: It is permitted to have both *dst_image_index* and *src_image_index* equal the current image; the memory to send the data to and the memory to read for the data may (partially) overlap. The implementation has to take care that it handles this case, e.g. using *memmove* which handles (partially) overlapping memory.

7.2.17 `_gfortran_caf_sendget_by_ref` — Sending data between remote images using enhanced references on both sides

Synopsis: `void _gfortran_caf_sendget_by_ref (caf_token_t dst_token, int dst_image_index, caf_reference_t *dst_refs, caf_token_t src_token, int src_image_index, caf_reference_t *src_refs, int dst_kind, int src_kind, bool may_require_tmp, int *dst_stat, int *src_stat, int dst_type, int src_type)`

Description:

Called to send a scalar, an array section or a whole array from a remote image identified by the `src_image_index` to a remote image identified by the `dst_image_index`.

Arguments:

<code>dst_token</code>	intent(in) An opaque pointer identifying the destination coarray.
<code>dst_image_index</code>	intent(in) The ID of the destination remote image; must be a positive number.
<code>dst_refs</code>	intent(in) The references on the remote array to store the data given by the source. Guaranteed to have at least one entry.
<code>src_token</code>	intent(in) An opaque pointer identifying the source coarray.
<code>src_image_index</code>	intent(in) The ID of the source remote image; must be a positive number.
<code>src_refs</code>	intent(in) The references to apply to the remote structure to get the data.
<code>dst_kind</code>	intent(in) Kind of the destination argument
<code>src_kind</code>	intent(in) Kind of the source argument
<code>may_require_tmp</code>	intent(in) The variable is false when it is known at compile time that the <code>dest</code> and <code>src</code> either cannot overlap or overlap (fully or partially) such that walking <code>src</code> and <code>dest</code> in elementwise order (honoring the stride value) does not lead to wrong results. Otherwise, the value is true .
<code>dst_stat</code>	intent(out) when non-NULL give the result of the send-operation, i.e., zero on success and nonzero on error. When NULL and an error occurs, then an error message is printed and the program is terminated.
<code>src_stat</code>	intent(out) When non-NULL give the result of the get-operation, i.e., zero on success and nonzero on error. When NULL and an error occurs, then an error message is printed and the program is terminated.
<code>dst_type</code>	intent(in) Give the type of the destination. When the destination is not an array, than the precise type, e.g. of a component in a derived type, is not known, but provided here.

src_type intent(in) Give the type of the source. When the source is not an array, than the precise type, e.g. of a component in a derived type, is not known, but provided here.

Notes: It is permitted to have the same image index for both *src_image_index* and *dst_image_index*; the memory of the send-to and the send-from might (partially) overlap in that case. The implementation has to take care that it handles this case, e.g. using `memmove` which handles (partially) overlapping memory. If *may_require_tmp* is true, the library might additionally create a temporary variable, unless additional checks show that this is not required (e.g. because walking backward is possible or because both arrays are contiguous and `memmove` takes care of overlap issues).

Note that the assignment of a scalar to an array is permitted. In addition, the library has to handle numeric-type conversion and for strings, padding and different character kinds.

Because of the more complicated references possible some operations may be unsupported by certain libraries. The library is expected to issue a precise error message why the operation is not permitted.

7.2.18 `_gfortran_caf_lock` — Locking a lock variable

Synopsis: `void _gfortran_caf_lock (caf_token_t token, size_t index, int image_index, int *acquired_lock, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Acquire a lock on the given image on a scalar locking variable or for the given array element for an array-valued variable. If the *acquired_lock* is NULL, the function returns after having obtained the lock. If it is non-NULL, then *acquired_lock* is assigned the value true (one) when the lock could be obtained and false (zero) otherwise. Locking a lock variable that has already been locked by the same image is an error.

Arguments:

token intent(in) An opaque pointer identifying the coarray.
index intent(in) Array index; first array index is 0. For scalars, it is always 0.
image_index intent(in) The ID of the remote image; must be a positive number.
acquired_lock intent(out) If not NULL, it returns whether lock could be obtained.
stat intent(out) Stores the STAT=; may be NULL.
errmsg intent(out) When an error occurs, this is set to an error message; may be NULL.
errmsg_len intent(in) the buffer size of errmsg

Notes: This function is also called for critical blocks; for those, the array index is always zero and the image index is one. Libraries are permitted to use other images for critical-block locking variables.

7.2.19 `_gfortran_caf_lock` — Unlocking a lock variable

Synopsis: `void _gfortran_caf_unlock (caf_token_t token, size_t index, int image_index, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Release a lock on the given image on a scalar locking variable or for the given array element for an array-valued variable. Unlocking a lock variable that is unlocked or has been locked by a different image is an error.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>index</i>	intent(in) Array index; first array index is 0. For scalars, it is always 0.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number.
<i>stat</i>	intent(out) For allocatable coarrays, stores the STAT=; may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of errmsg

Notes: This function is also called for critical block; for those, the array index is always zero and the image index is one. Libraries are permitted to use other images for critical-block locking variables.

7.2.20 `_gfortran_caf_event_post` — Post an event

Synopsis: `void _gfortran_caf_event_post (caf_token_t token, size_t index, int image_index, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Increment the event count of the specified event variable.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>index</i>	intent(in) Array index; first array index is 0. For scalars, it is always 0.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number; zero indicates the current image, when accessed noncoindexed.
<i>stat</i>	intent(out) Stores the STAT=; may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of errmsg

Notes: This acts like an atomic add of one to the remote image's event variable. The statement is an image-control statement but does not imply sync memory. Still, all preceding push communications of this image to the specified remote image have to be completed before `event_wait` on the remote image returns.

7.2.21 `_gfortran_caf_event_wait` — Wait that an event occurred

Synopsis: `void _gfortran_caf_event_wait (caf_token_t token, size_t index, int until_count, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Wait until the event count has reached at least the specified *until_count*; if so, atomically decrement the event variable by this amount and return.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>index</i>	intent(in) Array index; first array index is 0. For scalars, it is always 0.
<i>until_count</i>	intent(in) The number of events that have to be available before the function returns.
<i>stat</i>	intent(out) Stores the STAT=; may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of errmsg

Notes: This function only operates on a local coarray. It acts like a loop checking atomically the value of the event variable, breaking if the value is greater or equal the requested number of counts. Before the function returns, the event variable has to be decremented by the requested *until_count* value. A possible implementation would be a busy loop for a certain number of spins (possibly depending on the number of threads relative to the number of available cores) followed by another waiting strategy such as a sleeping wait (possibly with an increasing number of sleep time) or, if possible, a futex wait.

The statement is an image-control statement but does not imply sync memory. Still, all preceding push communications of this image to the specified remote image have to be completed before `event_wait` on the remote image returns.

7.2.22 `_gfortran_caf_event_query` — Query event count

Synopsis: `void _gfortran_caf_event_query (caf_token_t token, size_t index, int image_index, int *count, int *stat)`

Description:

Return the event count of the specified event variable.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>index</i>	intent(in) Array index; first array index is 0. For scalars, it is always 0.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number; zero indicates the current image when accessed noncoindexed.
<i>count</i>	intent(out) The number of events currently posted to the event variable.
<i>stat</i>	intent(out) Stores the STAT=; may be NULL.

Notes: The typical use is to check the local event variable to only call `event_wait` when the data is available. However, a coindexed variable is permitted; there is no ordering or synchronization implied. It acts like an atomic fetch of the value of the event variable.

7.2.23 `_gfortran_caf_sync_all` — All-image barrier

Synopsis: `void _gfortran_caf_sync_all (int *stat, char *errmsg, size_t errmsg_len)`

Description:

Synchronization of all images in the current team; the program only continues on a given image after this function has been called on all images of the current team. Additionally, it ensures that all pending data transfers of previous segment have completed.

Arguments:

<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of <i>errmsg</i>

7.2.24 `_gfortran_caf_sync_images` — Barrier for selected images

Synopsis: `void _gfortran_caf_sync_images (int count, int images[], int *stat, char *errmsg, size_t errmsg_len)`

Description:

Synchronization between the specified images; the program only continues on a given image after this function has been called on all images specified for that image. Note that one image can wait for all other images in the current team (e.g. via `sync images(*)`) while those only wait for that specific image. Additionally, `sync images` ensures that all pending data transfers of previous segments have completed.

Arguments:

<i>count</i>	intent(in) The number of images that are provided in the next argument. For a zero-sized array, the value is zero. For <code>sync images (*)</code> , the value is <code>-1</code> .
<i>images</i>	intent(in) An array with the images provided by the user. If <i>count</i> is zero, a NULL pointer is passed.
<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of <i>errmsg</i>

7.2.29 `_gfortran_caf_atomic_define` — Atomic variable assignment

Synopsis: `void _gfortran_caf_atomic_define (caf_token_t token, size_t offset, int image_index, void *value, int *stat, int type, int kind)`

Description:

Assign atomically a value to an integer or logical variable.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>offset</i>	intent(in) The number of bytes the actual data is shifted compared to the base address of the coarray.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number; zero indicates the current image when used noncoindexed.
<i>value</i>	intent(in) the value to be assigned, passed by reference
<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be <code>NULL</code> .
<i>type</i>	intent(in) The data type, i.e. <code>BT_INTEGER</code> (1) or <code>BT_LOGICAL</code> (2).
<i>kind</i>	intent(in) The kind value (only 4; always <code>int</code>)

7.2.30 `_gfortran_caf_atomic_ref` — Atomic variable reference

Synopsis: `void _gfortran_caf_atomic_ref (caf_token_t token, size_t offset, int image_index, void *value, int *stat, int type, int kind)`

Description:

Reference atomically a value of a kind-4 integer or logical variable.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>offset</i>	intent(in) The number of bytes the actual data is shifted compared to the base address of the coarray.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number; zero indicates the current image when used noncoindexed.
<i>value</i>	intent(out) The variable assigned the atomically referenced variable.
<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be <code>NULL</code> .
<i>type</i>	the data type, i.e. <code>BT_INTEGER</code> (1) or <code>BT_LOGICAL</code> (2).
<i>kind</i>	The kind value (only 4; always <code>int</code>)

7.2.31 `_gfortran_caf_atomic_cas` — Atomic compare and swap

Synopsis: `void _gfortran_caf_atomic_cas (caf_token_t token, size_t offset, int image_index, void *old, void *compare, void *new_val, int *stat, int type, int kind)`

Description:

Atomic compare and swap of a kind-4 integer or logical variable. Assigns atomically the specified value to the atomic variable, if the latter has the value specified by the passed condition value.

Arguments:

<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>offset</i>	intent(in) The number of bytes the actual data is shifted compared to the base address of the coarray.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number; zero indicates the current image when used noncoindexed.
<i>old</i>	intent(out) The value the atomic variable had just before the cas operation.
<i>compare</i>	intent(in) The value used for comparison.
<i>new_val</i>	intent(in) The new value for the atomic variable, assigned to the atomic variable, if compare equals the value of the atomic variable.
<i>stat</i>	intent(out) Stores the status STAT= and may be NULL.
<i>type</i>	intent(in) the data type, i.e. BT_INTEGER (1) or BT_LOGICAL (2).
<i>kind</i>	intent(in) The kind value (only 4; always int)

7.2.32 _gfortran_caf_atomic_op — Atomic operation

Synopsis: `void _gfortran_caf_atomic_op (int op, caf_token_t token, size_t offset, int image_index, void *value, void *old, int *stat, int type, int kind)`

Description:

Apply an operation atomically to an atomic integer or logical variable. After the operation, *old* contains the value just before the operation, which, respectively, adds (GFC_CAF_ATOMIC_ADD) atomically the **value** to the atomic integer variable or does a bitwise AND, OR or exclusive OR between the atomic variable and *value*; the result is then stored in the atomic variable.

Arguments:

<i>op</i>	intent(in) the operation to be performed; possible values GFC_CAF_ATOMIC_ADD (1), GFC_CAF_ATOMIC_AND (2), GFC_CAF_ATOMIC_OR (3), GFC_CAF_ATOMIC_XOR (4).
<i>token</i>	intent(in) An opaque pointer identifying the coarray.
<i>offset</i>	intent(in) The number of bytes the actual data is shifted compared to the base address of the coarray.
<i>image_index</i>	intent(in) The ID of the remote image; must be a positive number; zero indicates the current image when used noncoindexed.

<i>old</i>	intent(out) The value the atomic variable had just before the atomic operation.
<i>val</i>	intent(in) The new value for the atomic variable, assigned to the atomic variable, if <code>compare</code> equals the value of the atomic variable.
<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be NULL.
<i>type</i>	intent(in) the data type, i.e. <code>BT_INTEGER</code> (1) or <code>BT_LOGICAL</code> (2)
<i>kind</i>	intent(in) the kind value (only 4; always <code>int</code>)

7.2.33 `_gfortran_caf_co_broadcast` — Sending data to all images

Synopsis: `void _gfortran_caf_co_broadcast (gfc_descriptor_t *a, int source_image, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Distribute a value from a given image to all other images in the team. Has to be called collectively.

Arguments:

<i>a</i>	intent(inout) An array descriptor with the data to be broadcasted (on <i>source_image</i>) or to be received (other images).
<i>source_image</i>	intent(in) The ID of the image from which the data should be broadcasted.
<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of <i>errmsg</i> .

7.2.34 `_gfortran_caf_co_max` — Collective maximum reduction

Synopsis: `void _gfortran_caf_co_max (gfc_descriptor_t *a, int result_image, int *stat, char *errmsg, int a_len, size_t errmsg_len)`

Description:

Calculates for each array element of the variable *a* the maximum value for that element in the current team; if *result_image* has the value 0, the result shall be stored on all images, otherwise, only on the specified image. This function operates on numeric values and character strings.

Arguments:

<i>a</i>	intent(inout) An array descriptor for the data to be processed. On the destination image(s) the result overwrites the old content.
<i>result_image</i>	intent(in) The ID of the image to which the reduced value should be copied to; if zero, it has to be copied to all images.

<i>stat</i>	intent(out) Stores the status STAT= and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>a_len</i>	intent(in) the string length of argument <i>a</i>
<i>errmsg_len</i>	intent(in) the buffer size of <i>errmsg</i>

Notes: If *result_image* is nonzero, the data in the array descriptor *a* on all images except of the specified one become undefined; hence, the library may make use of this.

7.2.35 `_gfortran_caf_co_min` — Collective minimum reduction

Synopsis: `void _gfortran_caf_co_min (gfc_descriptor_t *a, int result_image, int *stat, char *errmsg, int a_len, size_t errmsg_len)`

Description:

Calculates for each array element of the variable *a* the minimum value for that element in the current team; if *result_image* has the value 0, the result shall be stored on all images, otherwise, only on the specified image. This function operates on numeric values and character strings.

Arguments:

<i>a</i>	intent(inout) An array descriptor for the data to be processed. On the destination image(s) the result overwrites the old content.
<i>result_image</i>	intent(in) The ID of the image to which the reduced value should be copied to; if zero, it has to be copied to all images.
<i>stat</i>	intent(out) Stores the status STAT= and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>a_len</i>	intent(in) the string length of argument <i>a</i>
<i>errmsg_len</i>	intent(in) the buffer size of <i>errmsg</i>

Notes: If *result_image* is nonzero, the data in the array descriptor *a* on all images except of the specified one become undefined; hence, the library may make use of this.

7.2.36 `_gfortran_caf_co_sum` — Collective summing reduction

Synopsis: `void _gfortran_caf_co_sum (gfc_descriptor_t *a, int result_image, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Calculates for each array element of the variable *a* the sum of all values for that element in the current team; if *result_image* has the value 0, the result shall be stored on all images, otherwise, only on the specified image. This function operates on numeric values only.

Arguments:

<i>a</i>	intent(inout) An array descriptor with the data to be processed. On the destination image(s) the result overwrites the old content.
<i>result_image</i>	intent(in) The ID of the image to which the reduced value should be copied to; if zero, it has to be copied to all images.
<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of <i>errmsg</i>

Notes: If *result_image* is nonzero, the data in the array descriptor *a* on all images except of the specified one become undefined; hence, the library may make use of this.

7.2.37 `_gfortran_caf_co_reduce` — Generic collective reduction

Synopsis: `void _gfortran_caf_co_reduce (gfc_descriptor_t *a, void * (*opr) (void *, void *), int opr_flags, int result_image, int *stat, char *errmsg, int a_len, size_t errmsg_len)`

Description:

Calculates for each array element of the variable *a* the reduction value for that element in the current team; if *result_image* has the value 0, the result shall be stored on all images, otherwise, only on the specified image. The *opr* is a pure function doing a mathematically commutative and associative operation.

The *opr_flags* denote the following; the values are bitwise ored. `GFC_CAF_BYREF` (1) if the result should be returned by reference; `GFC_CAF_HIDDENLEN` (2) whether the result and argument string lengths shall be specified as hidden arguments; `GFC_CAF_ARG_VALUE` (4) whether the arguments shall be passed by value, `GFC_CAF_ARG_DESC` (8) whether the arguments shall be passed by descriptor.

Arguments:

<i>a</i>	intent(inout) An array descriptor with the data to be processed. On the destination image(s) the result overwrites the old content.
<i>opr</i>	intent(in) Function pointer to the reduction function
<i>opr_flags</i>	intent(in) Flags regarding the reduction function
<i>result_image</i>	intent(in) The ID of the image to which the reduced value should be copied to; if zero, it has to be copied to all images.
<i>stat</i>	intent(out) Stores the status <code>STAT=</code> and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.

a_len intent(in) the string length of argument *a*
errmsg_len intent(in) the buffer size of *errmsg*

Notes: If *result_image* is nonzero, the data in the array descriptor *a* on all images except of the specified one become undefined; hence, the library may make use of this.

For character arguments, the result is passed as first argument, followed by the result string length, next come the two string arguments, followed by the two hidden string length arguments. With C binding, there are no hidden arguments and by-reference passing and either only a single character is passed or an array descriptor.

7.2.38 `_gfortran_caf_form_team` — Team creation function

Synopsis: `void _gfortran_caf_form_team (int team_id, caf_team_t *team, int
 new_index, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Create a team. All images giving the same *team_id* in a call to `FORM TEAM` will form a new team addressable by the opaque handle *team* which is of type `team_type` from the intrinsic module Section 9.1 [ISO_FORTRAN_ENV], page 311. In the team the image gets the image index given by *new_index* if present. If *new_index* is absent, then an implementation specific index is assigned.

Arguments:

team_id intent(in) A unique id for each team to form. Images giving the same *team_id* in a call to `FORM TEAM` belong to the same team.
team intent(out) The opaque pointer to the newly formed team
new_index intent(in) If non-null gives the unique index of this image in the newly formed team. When no *new_index* is given, the caf-library is free to choose a unique index.
stat intent(out) Stores the status `STAT=` and may be `NULL`.
errmsg intent(out) When an error occurs, this is set to an error message; may be `NULL`.
errmsg_len intent(in) the buffer size of *errmsg*

Notes: The id given in *team_id* has to be unique in all subsequent calls to `FORM TEAM` on the same image. That id is the same used in `TEAM_NUMBER=` of coarray indexes, which motivates the uniqueness.

The index given in *new_index* needs to be unique among all members of team to create. Failing uniqueness may lead to misbehaviour, which depends on the caf-library's implementation. The library is free to implement checks for this, which imposes overhead and therefore may be avoided.

7.2.39 `_gfortran_caf_change_team` — Team activation function

Synopsis: `void _gfortran_caf_change_team (caf_team_t team, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Activates the team given by *team*, which must be formed but not active yet. This routine starts a new epoch on the coarray memory pool. All coarrays registered from now on, will be freed once the team is terminated.

Arguments:

<i>team</i>	intent(inout) The opaque pointer to an already formed team
<i>stat</i>	intent(out) Stores the status STAT= and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of errmsg

Notes: When an error occurs and *stat* is non-null, it will be set. Nevertheless will the Fortran program continue with the first statement in the change team block.

7.2.40 `_gfortran_caf_end_team` — Team termination function

Synopsis: `void _gfortran_caf_end_team (int *stat, char *errmsg, size_t errmsg_len)`

Description:

Terminates the last team changed to. The coarray memory epoch is terminated and all coarrays allocated since the execution of `CHANGE TEAM` are freed.

Arguments:

<i>stat</i>	intent(out) Stores the status STAT= and may be NULL.
<i>errmsg</i>	intent(out) When an error occurs, this is set to an error message; may be NULL.
<i>errmsg_len</i>	intent(in) the buffer size of errmsg

7.2.41 `_gfortran_caf_sync_team` — Synchronize all images of a given team

Synopsis: `void _gfortran_caf_sync_team (caf_team_t team, int *stat, char *errmsg, size_t errmsg_len)`

Description:

Blocks execution of the image calling `SYNC TEAM` until all images of the team given by *team* have joined the synchronisation call.

Arguments:

<i>team</i>	intent(in) The opaque pointer to an active team
<i>stat</i>	intent(out) Stores the status STAT= and may be NULL.

errmsg intent(out) When an error occurs, this is set to an error message; may be NULL.
errmsg_len intent(in) the buffer size of *errmsg*

7.2.42 `_gfortran_caf_get_team` — Get the opaque handle of the specified team

Synopsis: `caf_team_t _gfortran_caf_get_team (int32_t *level)`

Description:

Get the current team, when *level* is null, or the team specified by *level* set to `INITIAL_TEAM`, `PARENT_TEAM` or `CURRENT_TEAM` from the `ISO_FORTRAN_ENV` intrinsic module. When being on the `INITIAL_TEAM` and requesting its `PARENT_TEAM`, then the initial team is returned.

Arguments:

level intent(in) If set to one of the levels specified in the `ISO_FORTRAN_ENV` module, the function returns the handle of the given team. Values different from the allowed ones lead to a runtime error.

7.2.43 `_gfortran_caf_team_number` — Get the unique id of the given team

Synopsis: `int _gfortran_caf_team_number (caf_team_t team)`

Description:

The team id given when forming the team Section 7.2.38 [`_gfortran_caf_form_team`], page 115, of the team specified by *team*, if given, or of the current team, if *team* is absent. It is a runtime error to specify a non-existing team. The team has to be formed, i.e., it is not necessary that it is changed into to get the team number. The initial team has the team number -1.

Arguments:

team intent(in) The team for which the team id is desired.

