What is coarray Fortran? Why use it?

- Coarray Fortran (CAF) is a collection of features in the Fortran 2008 standard with expanded support in Fortran 2015.
- CAF enables programmers to express parallel algorithms without tying an algorithm’s implementation to a specific, lower level communication library (e.g., MPI) or set of directives (e.g., OpenMP).
- A CAF executable launches one or more images (replicas of itself) in a Single Program Multiple Data (SPMD) fashion.
- Each image manages its own portion of what is logically a Partitioned Global Address Space (PGAS).
- The language rules facilitate one-sided communication: one image may access a second image’s coarray without the second image’s involvement.
- A coarray may be a scalar or an array in statically or dynamically allocated memory and may be of intrinsic or derived type.

Fortran is now a PGAS language that facilitates SPMD parallel programming without direct reference to anything outside the language!

Fortran 2008 CAF at work

```fortran
!real, dimension(10), codimension[*] :: x, y
!integer :: num_img, me
num_img = num_images()
me = this_image()
x(2) = x(3) ! get value from image 7
x(6)[4] = x(1) ! put value on image 4
x(i)[2] = y(i) ! put array on image 2
sync all
x(1:10:2) = y(1:10:2)[4] ! strided get from image 4
```

The Cray and Intel compilers support Fortran 2008 CAF. GCC 5.1 or later use OpenCoarrays to support most Fortran 2008 CAF.

Fortran 2015 Collective Subroutines

- Fortran 2015 adds collective subroutines for efficient global communication and computation: co_sum, co_min, co_max, and co_broadcast perform global summation, minimum, and maximum reductions, and broadcasts.
- The co_reduce collective subroutine allows users to extend the set of collective subroutines by writing a user-defined, functionally pure, binary operator for use in a global reduction.

Intrinsic vs. User-Defined Collectives

- With an OpenCoarrays-aware compiler, such as GCC 5.1 or later, OpenCoarrays functions as an application binary interface (ABI) that the compiler calls for parallel communication, computation and synchronization.
- OpenCoarrays also provides an application programmer interface (API) that provides users access to CAF features even with non-CAF compilers.
- OpenCoarrays provides a compiler wrapper (“caf”) that can translate the image number tally program at the lower left into a program with API calls that non-CAF compilers can process.

Users of GCC 4.9 can compile some CAF codes via the “caf” wrapper, which will eventually support non-GCC compilers as well.

Summary and Conclusions

Fortran 2008 CAF features adds a PGAS capability to the language PGAS facilitates SPMD-style programming within the language. Fortran 2015 adds intrinsic collective subroutines that greatly outperform even reasonably sophisticated collectives that a user might write in Fortran 2008. The OpenCoarrays compiler wrapper translates a subset of CAF features into calls to the OpenCoarrays API for users of non-CAF compilers. Such users invoke the intrinsic collective subroutines through C bindings in the API, whereas OpenCoarrays-aware CAF compilers directly invoke the OpenCoarrays ABI.