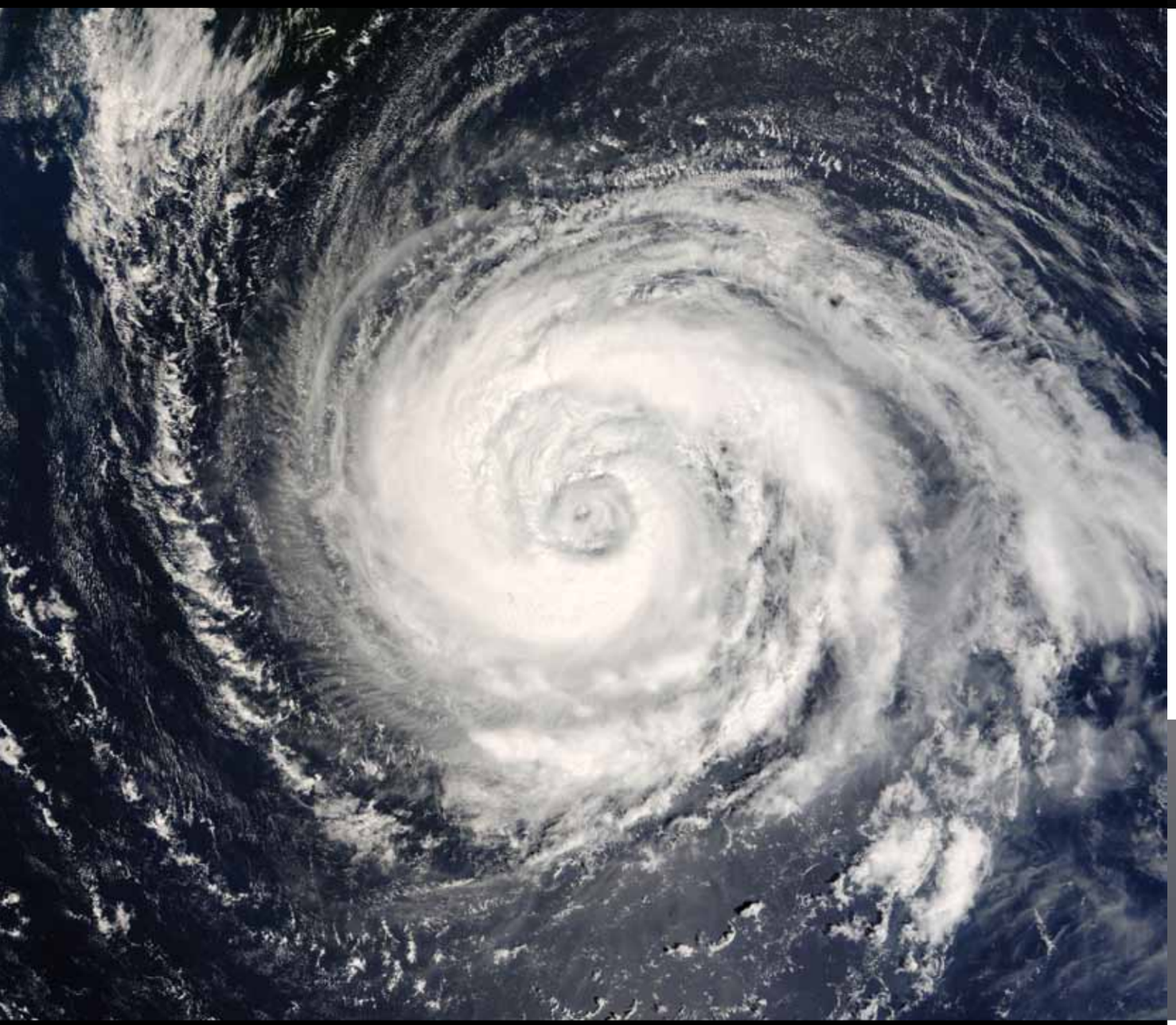
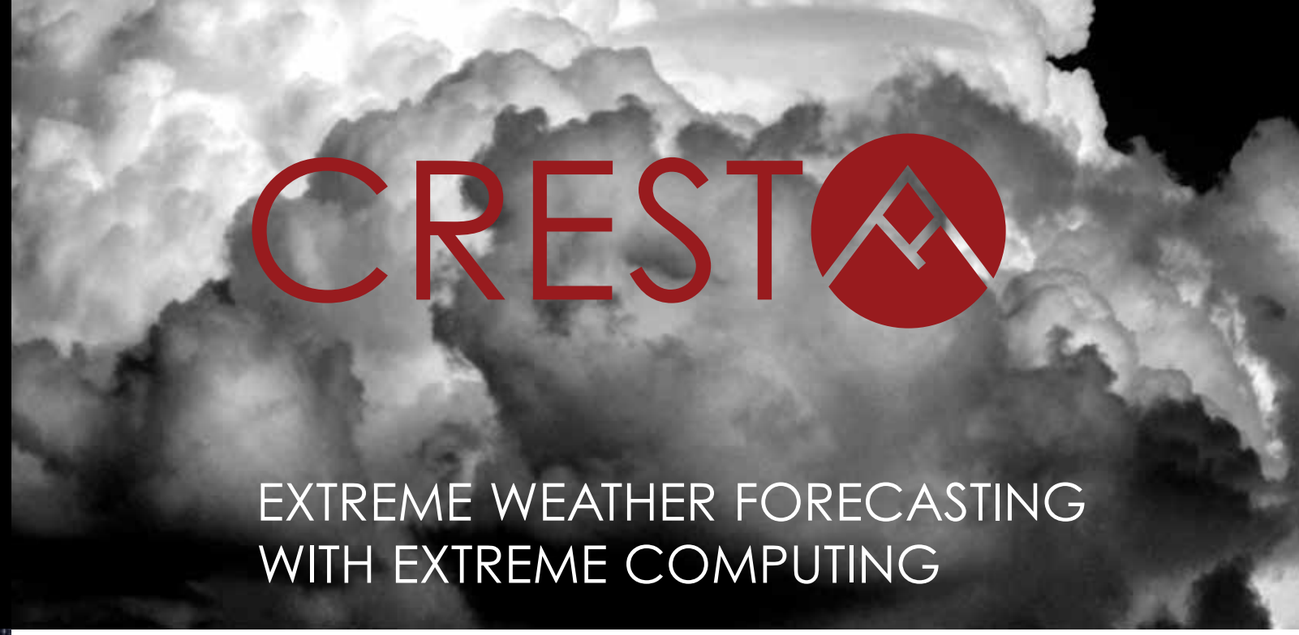
Coarray Fortran (CAF), was created by Robert Numrich in the 1990s and coarrays are now part of the Fortran 2008 standard.

> "you have produced a very important example of a production code.... You guys are using the coarray model the way it was intended to be used" – Bob Numrich, UMN.

CAF allows asynchronous execution of replicated copies, termed images, of a program. These contain their own sets of data objects and use extended Fortran array syntax to reference data spread across images.

The coarrays model has allowed IFS to experiment with exposing parallelism at the fine scale for both computation and communication.





CRESTA

EXTREME WEATHER FORECASTING WITH EXTREME COMPUTING

Weather-related natural disasters have, over the last two decades, caused the loss of thousands of lives and caused damage totaling billions of Euros annually. Floods, droughts, windstorms, tropical cyclones, all can be devastating.

Forecasts of severe weather events provide vital early warning for authorities and the public, giving time to allow contingency plans to be put into place.

The European Centre for Medium-Range Weather Forecasts (ECMWF) provides forecasts to its Member States and Co-operating States. These are used by the national weather services to provide early warnings of severe weather to their customers, including civil protection agencies and the general public.

Hurricane Sandy hit New Jersey on 30th October 2012, causing over 100 fatalities and significant damage to property. From the 23rd October ECMWF's Integrated Forecasting system (IFS) predicted the storm would strike the East Coast of the US, with most other models predicting the storm would move out to sea. This gave essential early warning to government and the general public.

ECMWF is an application partner in CRESTA bringing the IFS application to the project. This forecasting system is a production code used to provide medium-range weather forecast products up to 10 to 15 days ahead. For the IFS model, it is paramount that it completes a 10-day forecast in less than one hour so that forecast products can be delivered on time to ECMWF member states.

ECMWF At shorter range, national weather services issue more detailed warnings, using local observations and additional information from their own regional and local short-range forecast models. ECMWF is an intergovernmental organisation supported by more than 30 states. Its principal objective is to produce operational weather forecasts for up to two weeks ahead and to disseminate this information to the national weather services of its Member States.

While IFS provides a detailed weather forecast for up to ten days ahead, it is also important for users to know how confident they can be in the forecast. For this reason, at ECMWF the high resolution forecast is complemented by an Ensemble Prediction System (EPS). This is a set of 50 low resolution forecasts, each started from a slightly perturbed version of the operational analysis. The perturbed forecasts represent the range of possible future atmospheric states consistent with the small but sometimes significant uncertainty in the initial state.

The EPS suite is a perfect candidate to run on future Exascale systems, with each ensemble member being independent. By increasing the number of members and their resolution it is relatively easy to fill a future Exascale system. What is less clear is whether the IFS model can continue to run efficiently on such systems and continue to meet the operational target of one hour when running on millions of cores which it would have to do.

"Within CRESTA, ECMWF is exploring the use of Fortran2008 coarrays – this is possibly the first time that coarrays have been used in a world leading production application within the context of OpenMP parallel regions." – G Mozdzynski, ECMWF

The resolution of the operational IFS model today is T1279L137 (1279 spectral waves and 137 levels in the atmosphere with 16km resolution). In the future there will be a need to perform model simulations at convection-resolving resolutions of O(1km), which is more challenging to scale.

The evolution of the IFS model from the mid-1980's to the current operational model shows that halving the horizontal grid spacing occurs about every 8 years. Halving the grid spacing typically increases the computational cost by a factor 12. However, in reality the cost can be greater than this, when some non-linear items are included such as the Legendre transforms and Fourier transforms.

Within CRESTA, ECMWF is exploring the use of Fortran2008 coarrays - this is possibly the first time that coarrays have been used in a world leading production application within the context of OpenMP parallel regions.

"The complex hybrid (MPI/OpenMP/coarray) application is a very good test for the Cray compiler and runtime and we have been able to target improvements in the light of the experience gained." – H Richardson, Cray

The purpose of these optimisations is primarily to allow the overlap of computation and communication in the Legendre and Fourier transforms, and further, in the semi-Lagrangian scheme, to reduce the volume of data communicated.

This approach has resulted in an overall 20+ percent performance improvement at 40K cores on the UK National HPC service, HECToR, a Cray XE6. In addition to this improvement, a further 20-30% improvement has been made by a combination of MPI optimization and in the case of a non-hydrostatic model by optimizing the spectral computations.

The importance of these optimisations is clear – they will allow the IFS model to continue to use the spectral transform method to 2030 and beyond on an Exascale sized system.

Photo: John Barker

EXTREME COMPUTING AND CRESTA

Build a supercomputer that can deliver an exaflop – a million million million calculations per second – and preparing the software and applications to exploit such a system, requires research and development on a global scale.

The Collaborative Research into Exascale Systemware, Tools and Applications (CRESTA) project form's part of Europe's exascale research program. This is focused on developing applications with exascale potential and through a co-design process, developing the software required to support these applications at the exascale.

"This work has involved close collaboration between application and systemware developers – ECMWF and Cray. A good example of CRESTA's co-design model, the process has been beneficial to the development of the IFS code and the Cray compiler, as well as showcasing the use of coarrays in a real world application. " – L Smith, EPCC, CRESTA project manager.