The development of a parametrized spectral background error covariance model within JCSDA (Joint Centre for Satellite Data Assimilation) JEDI (Joint Effort for Data assimilation Integration) framework … and beyond.

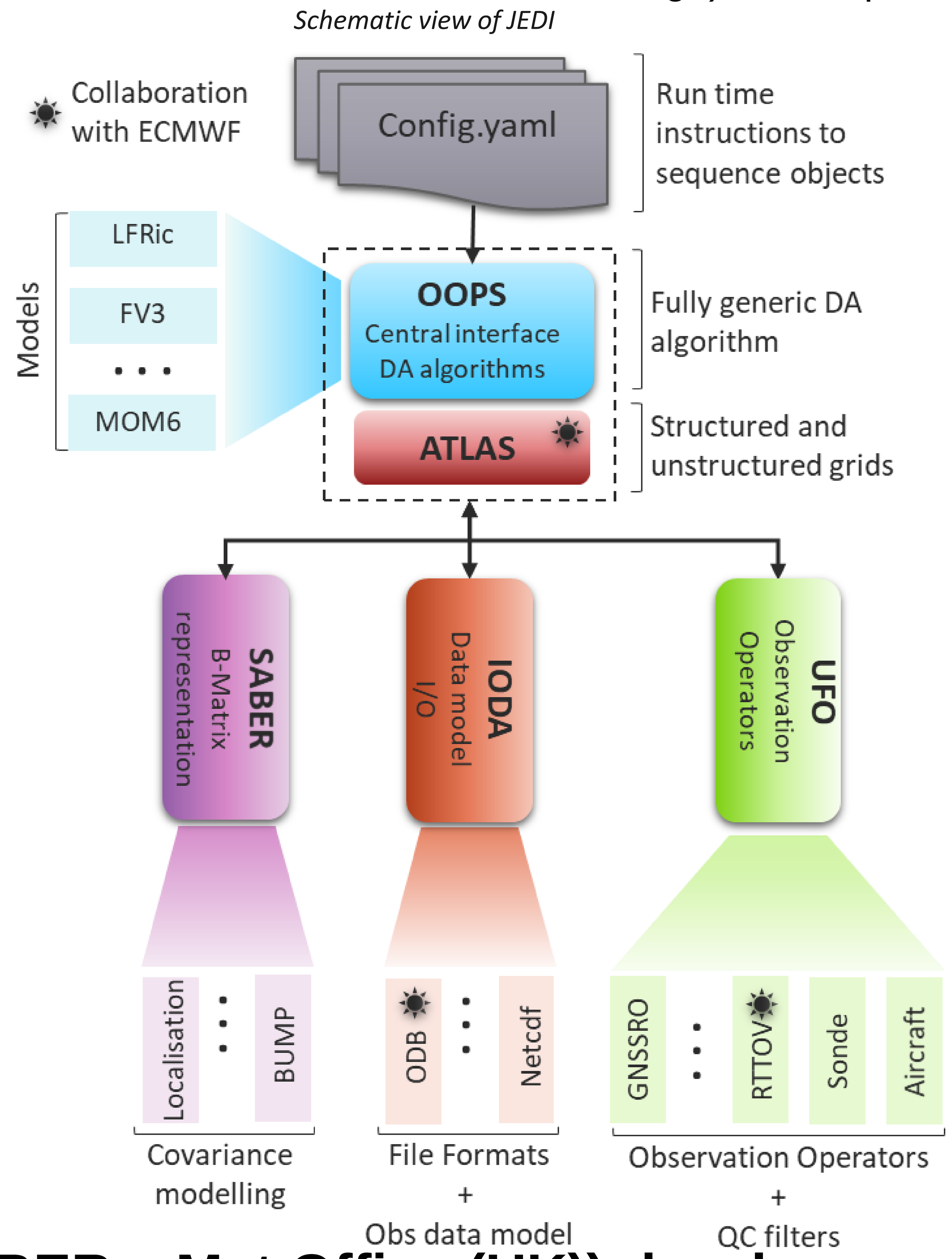
Marek Wlasak (Met Office), Benjamin Ménétrier (Met Norway), Mayeul Destouches (Met Office),
Anna Shlyaeva (JCSDA), Yannick Trémolet (JCSDA), Stefano Migliorini (Met Office)

JEDI (Joint Effort for Data assimilation Integration) and SABER (System Agnostic Background Error Representation)

The Met Office has adopted the C++ JEDI code framework. JEDI is a unified and versatile DA system, providing a variety of different DA schemes, that can be applied to any model. The JEDI framework is being developed for both operational data assimilation and for scientific research, being designed to bring new research quickly into operational data assimilation systems. It is designed to be portable to various computer architectures.

JEDI includes a framework specifically designed for modelling background error covariances called SABER. The aim of SABER is the same as JEDI's. One objective is for it to include all the main operational background covariance models. So far, it has access to GSI (Grid Point Statistical Interpolation) (NCAR) covariance model, BUMP (Background error on an Unstructured Mesh Package) and a spectral background error covariance model.

Schematic view of JEDI



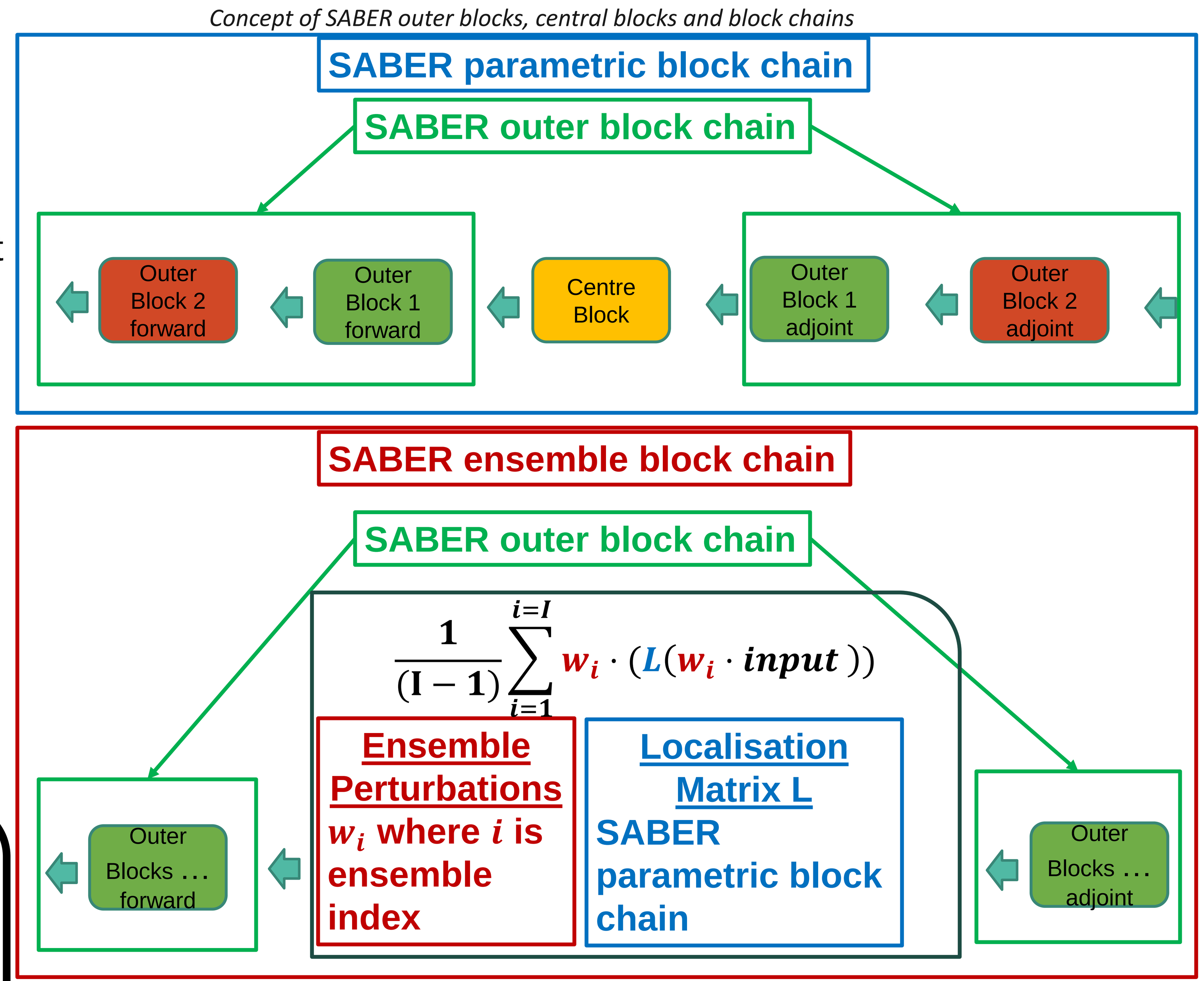
SABER design features

The design involves the creation of "blocks" (SABER blocks) that can be chained together in various ways (as nested SABER block chains) at runtime from a configuration file. The modularisation of components facilitates great flexibility when modelling background covariances.
It can be used for ensemble-localised, parametric and hybrid covariance models.

It is written in C++ and dependent on ECMWF Atlas data structures. Atlas data structures allow flexibility in model geometries and Fortran interfacing.

Hybrid B, $\sum_{j=1}^{j=J} v_j B_j$, *is a* SABER central block where each component j has a weight v and a covariance B and is stored within a SABER block chain. B_j can be represented by either a **SABER parametric block chain** or a **SABER ensemble block chain**.

Concept of SABER outer blocks, central blocks and block chains



(where $input$ refers an increment that comes from the adjoint of the outer blocks)

(SABER – Met Office (UK)) developments

Spectral background covariance model

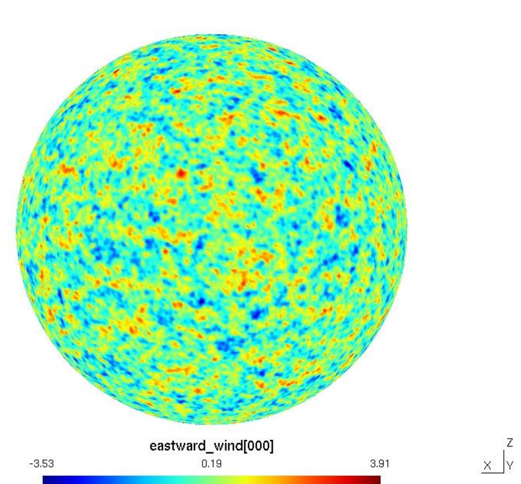
For the Met Office, the first step was to implement the parametric background error covariance model that is close to the operational version used in global NWP (Numerical Weather Prediction) for 6hr to 5-day forecasts. The procedure needs to be different to the current one to take account of the new cubed-sphere geometry of our new atmospheric model, LFRic.

The covariance model uses ECMWF atlas repository as an interface to ECMWF's spherical harmonic library ectrans. The inter variable structure includes dynamical assumptions such as hydrostatic balance and mass/wind law relationships as well as statistically derived relationships. The three-dimensional spatial covariance structure is determined by vertical covariances for each horizontal total wavenumber.

Randomization

SABER has the capability to generate background perturbations by applying the "square root" of the covariance model to a random Gaussian vector with zero mean and unit variance.

Creating the appropriate Met Office spectral SABER blocks to represent the square root of the static covariance model we can generate random background perturbations consistent with the covariance model.

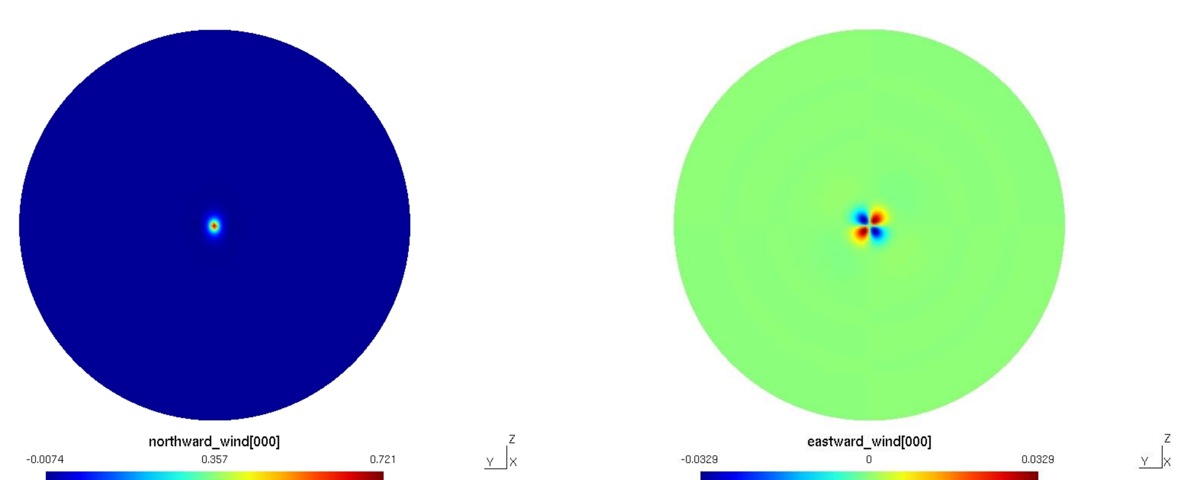


A zonal wind component generated by applying the square root of the spectral covariance model

Testing: Dirac, adjoint tests

All SABER blocks that have been created need to pass adjoint tests before being committed to the repository. SABER includes its own model interface called QUENCH, which is Atlas-based and allows full testing of the background error covariances.

Also, to protect the code from mistakes, numerous Dirac tests are run. The Dirac test involves applying an impulse of size 1 to the background error covariance from a specified model grid point and model variable's field. The result is a column of the background error covariance matrix. Capabilities exist to graphically check the structures and check that variances and cross-covariances do not unexpectedly change.



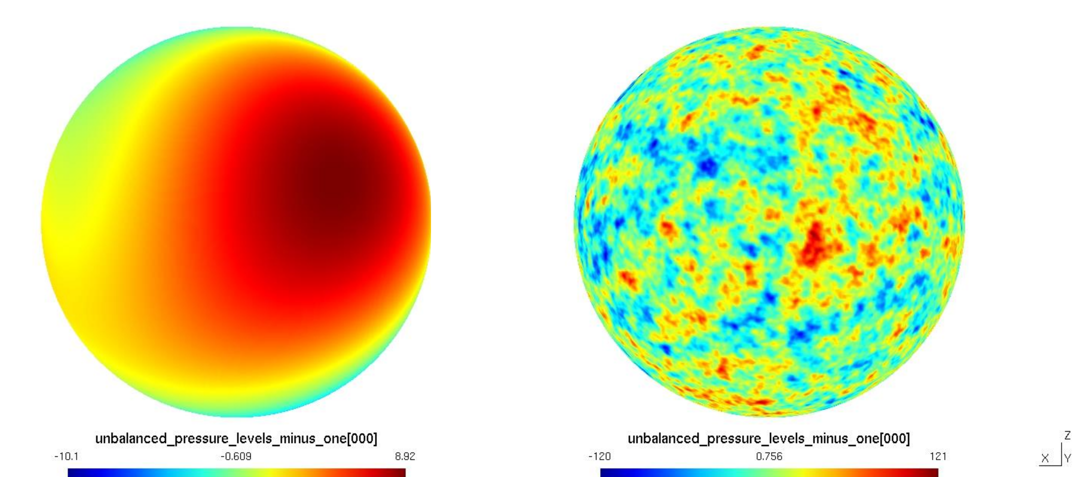
Applying spectral background error covariance to an impulse to the meridional wind component. (Left) the effect on the meridional component (Right) the effect on the zonal component

Covariance Calibration and left-inverse tests.

SABER has been designed with the infrastructure needed to generate the necessary statistics for background error covariance models. We are currently implementing the necessary Met Office calibration code to utilize this infrastructure. So far, we have implemented for all Met Office SABER blocks the required left-inverse operations needed and have automatic testing of these routines. All that we need to do is implement the aggregation of the necessary statistics and check that it works as intended.

Pre-processing background perturbations.

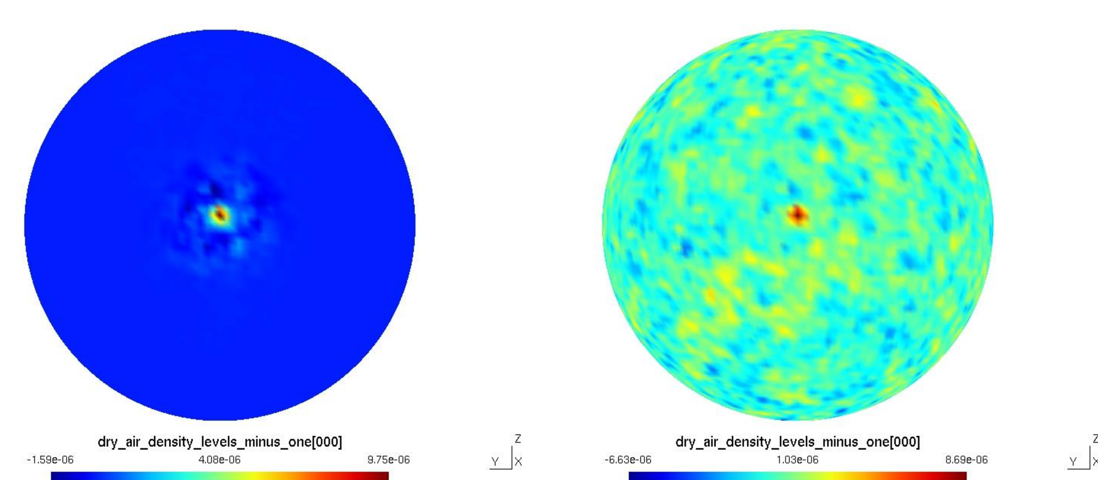
The Met Office background perturbations that we use operationally are broken into waveband components before being used. Before fully implementing this approach, we have implemented a simpler high-pass filter to remove troublesome low-wavenumber component from the perturbations and dump them to file (done via subtraction).



Splitting an ensemble perturbation into low and high wave-bands. (Left) Low-wavenumber part (Right) High wavenumber part.

Localised ensemble B

Saber blocks have been implemented to apply horizontal localization using a spectral analytic Gaussian filter, vertical localization using a vertical mode decomposition.



(Left) Dirac test with localized ensemble B (Right) Dirac test with unlocalized ensemble B. 50 ensemble background perturbations generated from parametrized B using randomization at F24 grid resolution. Ensemble perturbations had high pass filter applied and were limited to 4 control variables. An outer block chain was used to derive dry air density from these variables.

Met Office FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: +44 1392 885680 Fax: +44 1392 885681
Email: marek.wlasak@metoffice.gov.uk or mayeul.destouches@metoffice.gov.uk
SABER reference:: https://github.com/JCSDA/saber