Ensemble Data Assimilation and block methods

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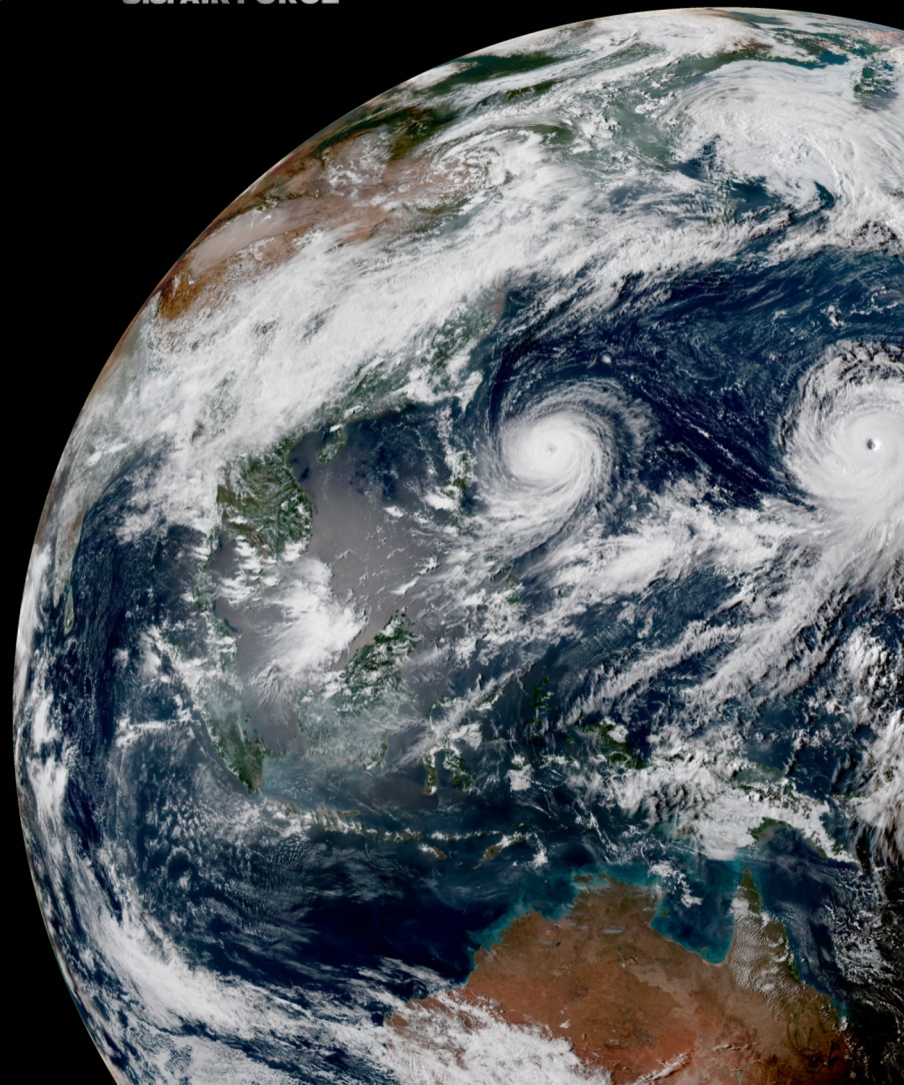


JCSDA workshop – June 2021

Outline

- Ensemble Applications in JEDI
- Block Lanczos algorithm
- Results: convergence, ensemble spread and eigen-structure

Ensemble Applications in JEDI

- One common `EnsembleApplication<APP>` class templated on an application (can be HofX, variational or forecast)

  → Splits `MPI_WORLD` in different, separate communicators (one communicator per member)

  → Launches the specified `APP` on each communicator

  → Runs all the members simultaneously

- One yaml file per member, allowing to specify different backgrounds, observations and their perturbations, outputs, …

Ensemble Applications in JEDI

Main yaml file (e.g. EDA):

```
files:
- "testinput/eda_3dvar_1.yaml"
- "testinput/eda_3dvar_2.yaml"
- "testinput/eda_3dvar_3.yaml"
- "testinput/eda_3dvar_4.yaml"

test:
reference filename: testoutput/eda_3dvar.test
```

Then, each yaml file in the list is similar to the one for the application (HofX, variational or forecast)

Block Lanczos algorithm

Many almost identical optimization problems are solved, so far solved independently

Use information from all the members to construct a better approximation of the eigen-structure of our matrix

→ Accelerate the convergence

Block Lanczos algorithm

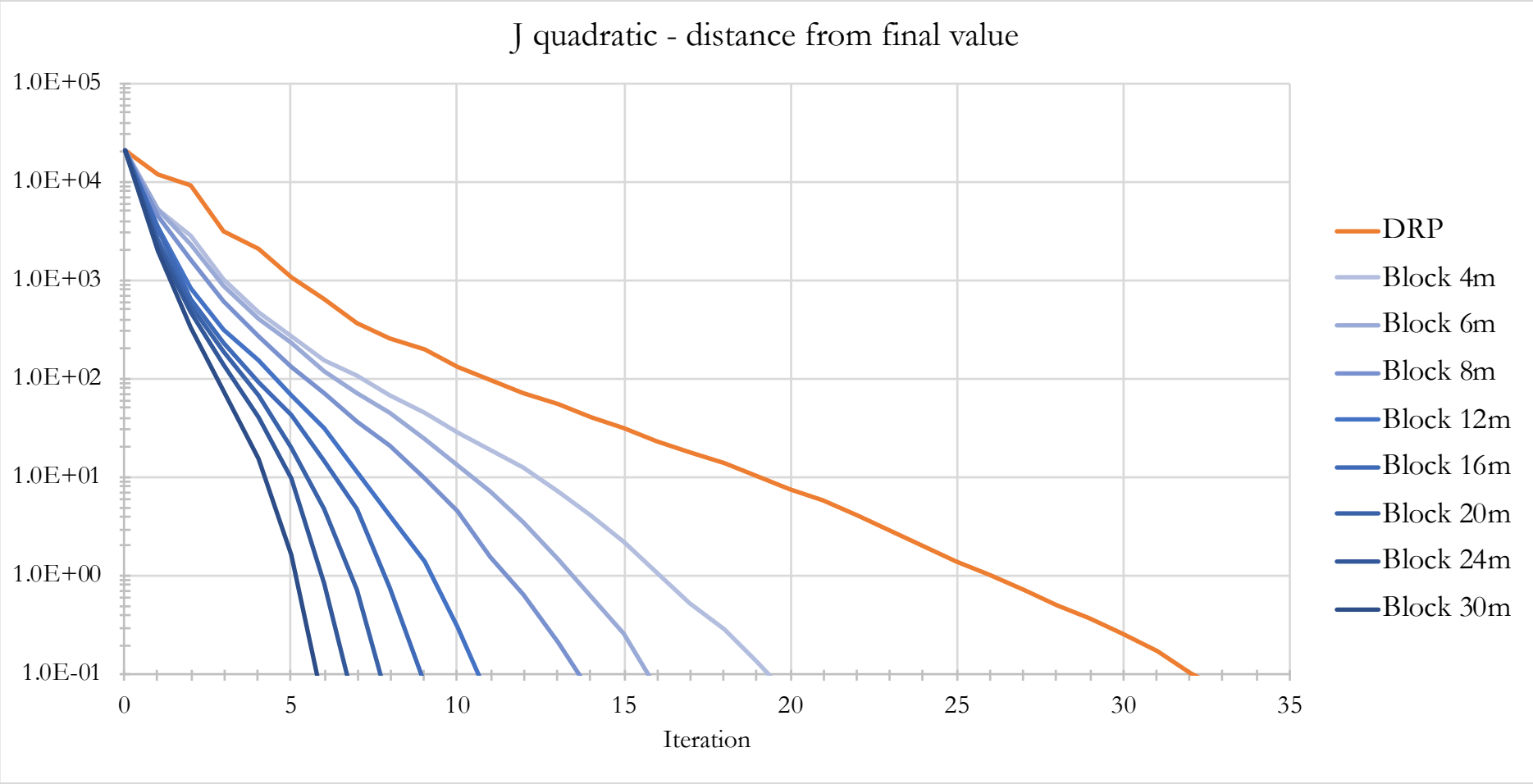
$$(I + H^T R^{-1} HB)\underline{x} = \underline{b}$$

- $(x_1, \ldots, x_m)$ the solution and $(b_1, \ldots, b_m)$ the rhs for each member
- H the linearized observation operator for member 0 (non-perturbed)

Communicator 0	Communicator 1
Initialization of problem 0	Initialization of problem 1
Minimization of 0 (Lanczos)	Minimization of 1 (Lanczos)
Solution 0	Solution 1

Communicator 0	Communicator 1
Initialization of problem 0	Initialization of problem 1
Minimization of 0 and 1 (block Lanczos)	
Solution 0	Solution 1

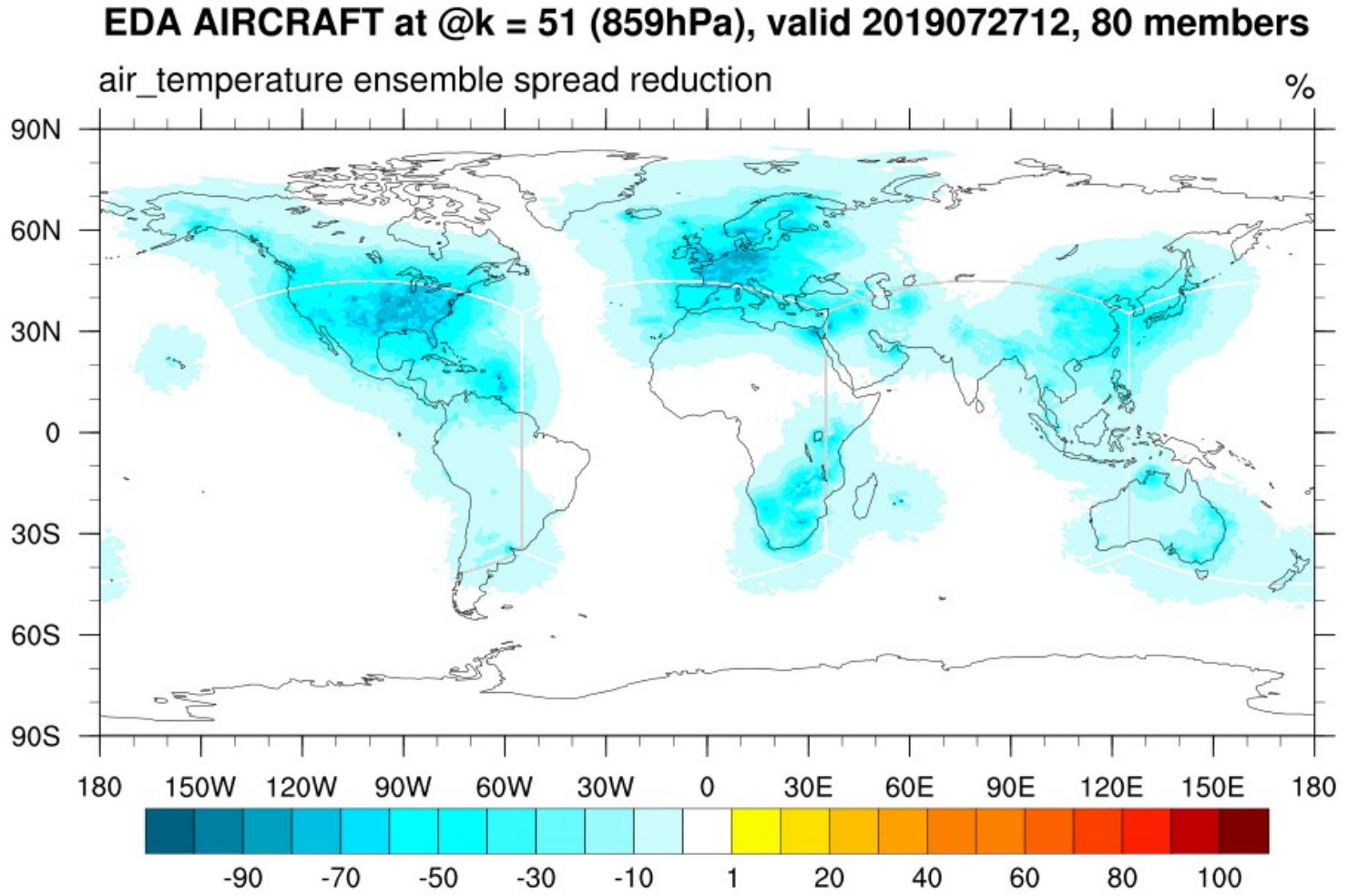
Results – convergence for toy model QG



Results – Ensemble spread

$$\frac{Spread\ reduction = (prior - posterior)}{prior}$$

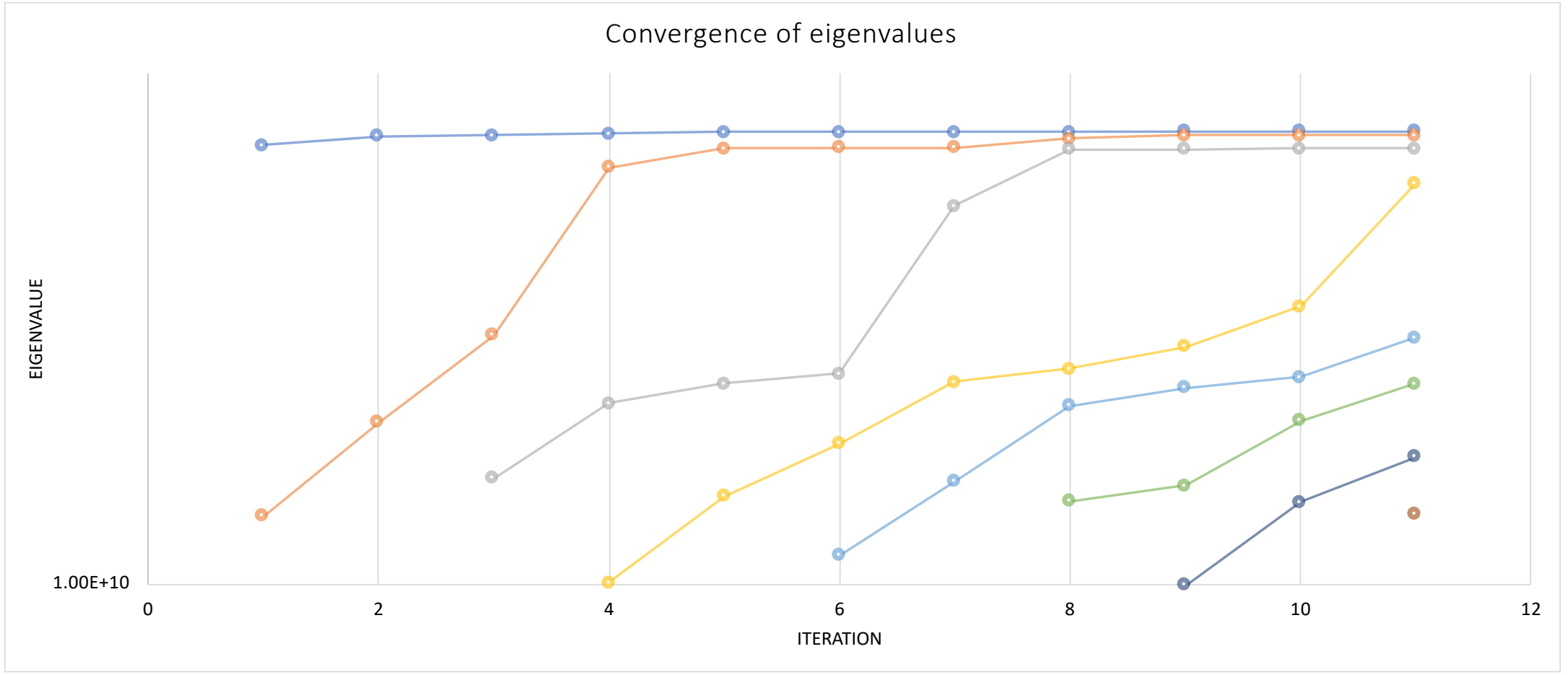
- 80 members
- aircraft observations
- c96 resolution



Results – Eigen-structure of Hessian matrix

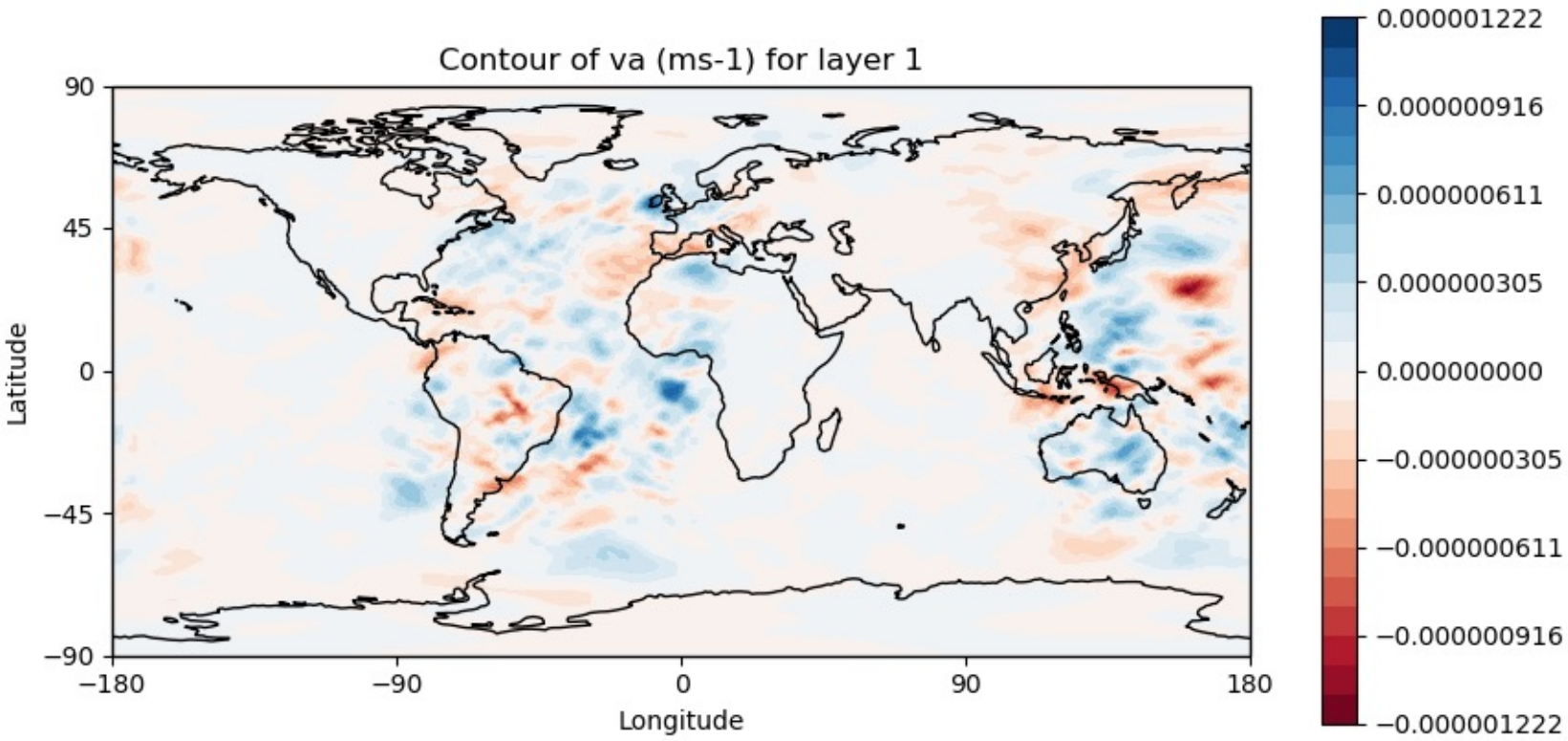
- 3dvar, member 1
- Aircraft, Amsua, ATMS, CRIS, IASI, MHS, OMI, Satwind, SSMIS, Vatwind
- Non perturbed
- C96 resolution
- 25 December 2021
- 30 inner iterations, 1 outer iteration

Results – Eigen-structure of Hessian matrix



Results – Eigen-structure of Hessian matrix

x eigenvector of T, then $y = Vx$ eigenvector of $I + H^T R^{-1} HB$



Conclusion and future work

- Quadratic J converges faster, at the cost of higher computational resources
- Spread is reduced between background and analysis

→ More on eigenvectors and eigenvalues (convergence)

→ Comparison with eigen structure given by block Lanczos

→ More observations

→ Full resolution