A parallel implementation of En-4DEnVar

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Introduction

- **4DEnVar at Météo-France**

Motivations

Flow-dependent error covariances from beginning of assimilation period.
Avoids the difficult development and maintenance of TL and AD models.
Potentially better background error covariances with NL forecasts.
Localisation in state space.

Implementation

δ**x** control variable and Double Preconditioned CG (Desroziers et al, 2014) instead of **α** variables (Lorenc, 2003; Buehner, 2005).
Use of optimal localisation diagnostics (Ménétrier et al, 2015).
Advection of the localisation (Desroziers et al, 2016).

- **En-4DEnVar**

Motivations

Use same approach for ensemble and deterministic analyses.

Problematics

Each ensemble analysis needs ensemble perturbations:
potential I/O and memory problems.

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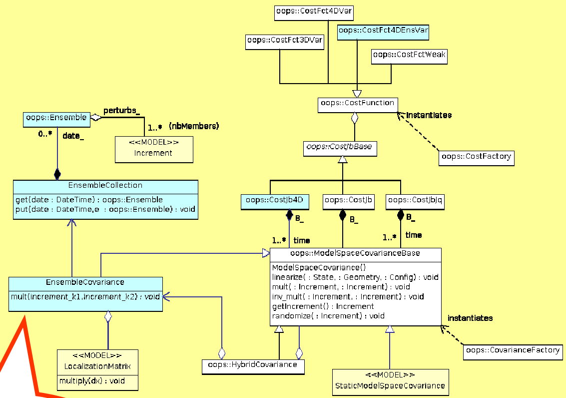
4DEnVar under OOPS



$$\mathbf{Bg} = \sum_{l=1}^{L} \mathbf{x}_l^{b'} \circ (\mathbf{1 L 1}^T (\mathbf{x}_l^{b'} \circ \mathbf{g}))$$

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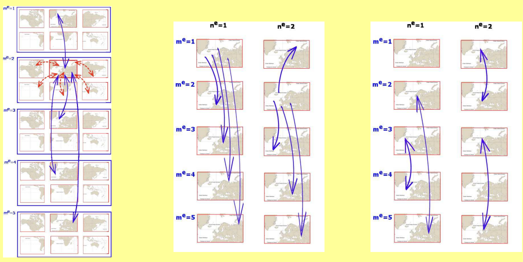
En-4DEnVar under OOPS

Rationale

Use MPI C++ library to distribute minimizations and perturbations over different MPI tasks, while keeping the FORTRAN MPI geographical parallelization.
Perturbations are read and stored only once but can be exchanged between different minimizations.



MPI tasks **parallel broadcast** **point-to-point**

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Tests with the 4DEnVar ARPEGE system

- **Configuration of the minimizations**

T149 spectral resolution, 10^6 observations, 25 members.
Run on Météo-France Bull with 1800 nodes of 40 Broadwell cores.

- **2 types of communication of perturbations**

Parallel broadcast or point-to-point MPI communication.

- **3 possible strategies**

- A fully parallel implementation of En-4DEnVar (a single application is run).
- A set of 5 loops of 5 sequential minimizations.
- A single loop of 25 sequential minimizations.
- Fixed total number of nodes (160) to compare different strategies.

- **Different configurations**

- 160 / 80 nodes.
- For each node: 5 MPI tasks (8 threads) / 10 MPI tasks (4 threads).

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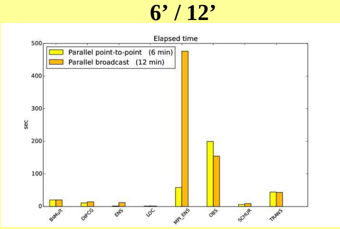
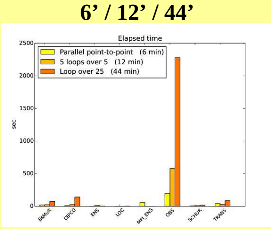
Results (Elapse time)

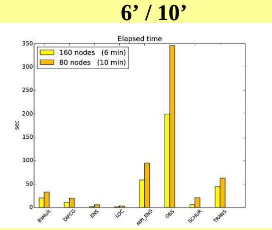
point-to-point / broadcast
6' / 12'



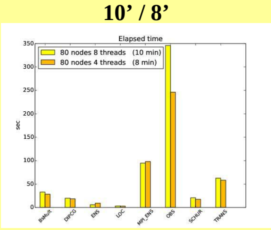
parallel / partly seq. / sequential
6' / 12' / 44'



160 / 80 nodes
6' / 10'



5 / 10 MPI tasks per node
10' / 8'



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Conclusions

- **En-4DEnVar design**

- The OOPS C++ upper layer offers the possibility to distribute ensemble minimizations and perturbations over MPI tasks, while keeping the FORTRAN level of geographical parallelization.
- δ**x** formulation a priori better than **α** formulation: twice fewer exchanges.

- **First real size tests with the global ARPEGE 4DEnVar system**

- Point-to-point commmunication is the most pertinent strategy.
- Fully parallel En-4DEnVar is quicker than other strategies
- This advantage is likely to increase with ensemble size.
- Perturbation communication is not prohibitive.
- Extrapolation to 200 members indicates that such a configurationt is tractable.

E. Arbogast, G. Desroziers, 2016: A parallel implementation of En-4DEnVar. Q. J. R. Meteor. Soc. To be submitted.

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