VORtech Computing

Software voor Simulatie en Technisch Rekenwerk

Parallel computing and model coupling in OpenDA

Nils van Velzen

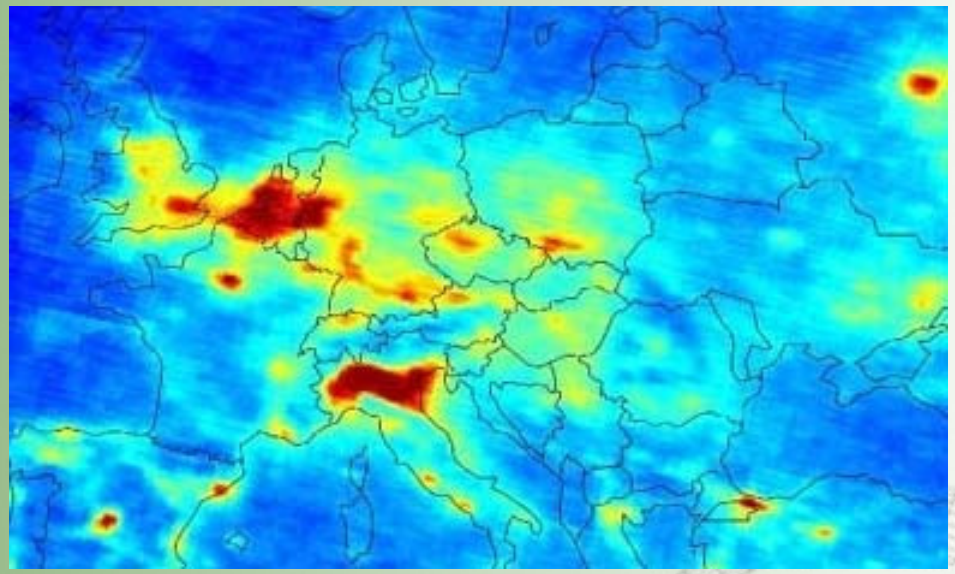
Deltares DA-meeting
Feb 18 2010

Overview

- Backround and motivation for OpenDA
- Object oriented design and model component
- Automatic parallelization in OpenDA
- Coupling with Parallel models in OpenDA
- Conclusions

Backround and motivation for OpenDA

- Simulation models
  - Weather forecast
  - Air quality
  - Shallow water
  - Ocean modeling
- Predictions are not perfect!



Backround and motivation for OpenDA

- Measurements:
  - Satellites
  - Buoys
  - Radar
  - Weather stations

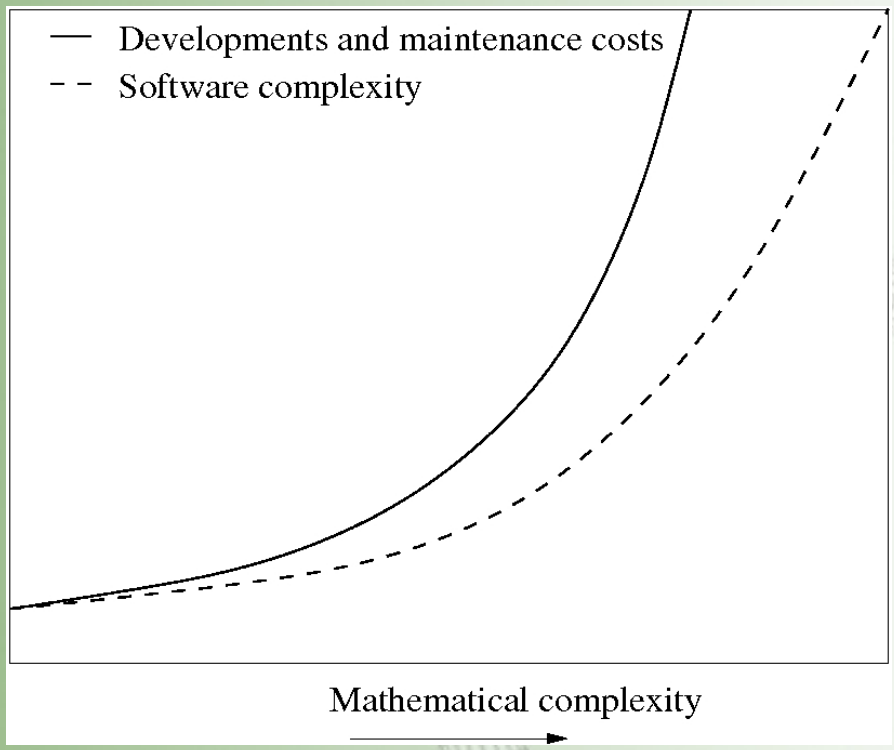
- Measurements are not perfect!

Backround and motivation for OpenDA

- Make model perform better using the available observations:
  - Data assimilation: combine the model forecast and observations into a mixed forecast
  - Calibration: change model parameters in order to reduce the difference between the model predictions and observations

Backround and motivation for OpenDA

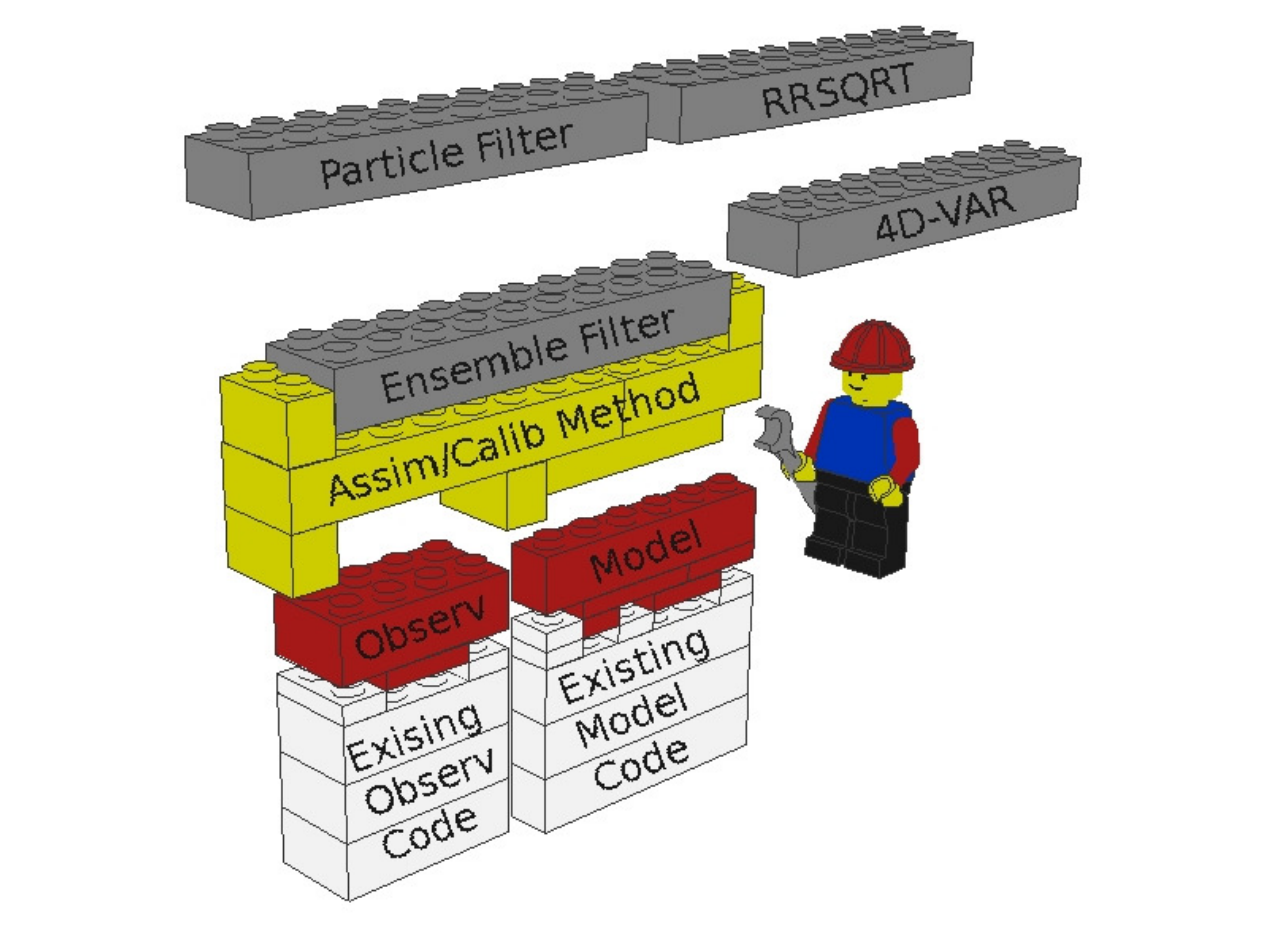
- Simulation software can be (extremely) complex
- More complex is combined with Data assimilation and or Calibration methods
- Expensive to develop and maintain



Backround and motivation for OpenDA

- Split complex software systems up in (well defined!) parts
  - Re-use of code
  - Less errors in software
  - Less complex building blocks
  - Possible to replace parts of the system
  - Cooperation between researchers and institutes

Backround and motivation for OpenDA



Object oriented design and model component

- Object oriented design
  - Classes, software building blocks
  - State (variables) of a class is NOT accessible from outside
  - State can be indirectly accessed/changed using the methods from the interface

Object oriented design and model component

- Model in OpenDA (formal)

$$\frac{d\mathbf{x}(t)}{dt} = M\left(\mathbf{x}(t), \mathbf{p}, \mathbf{u}(t), \mathbf{w}(t)\right)$$

- State of a model instance $\mathbf{x}, \mathbf{u}, \mathbf{p}, \mathbf{w}, t$
- Methods to get or change the model-state

Object oriented design and model component

- Propagate the model state-vector

$$\mathbf{x}(t) = \int_{t}^{t+\Delta t} M\left(\mathbf{x}(t), \mathbf{p}, \mathbf{u}(t), \mathbf{w}(t)\right) dt$$

- Get, set, axpy for $\mathbf{x}, \mathbf{u}, \mathbf{p}, \mathbf{w}, t$

- GetObsValues: $y(t) = H\left(\mathbf{x}(t)\right)$

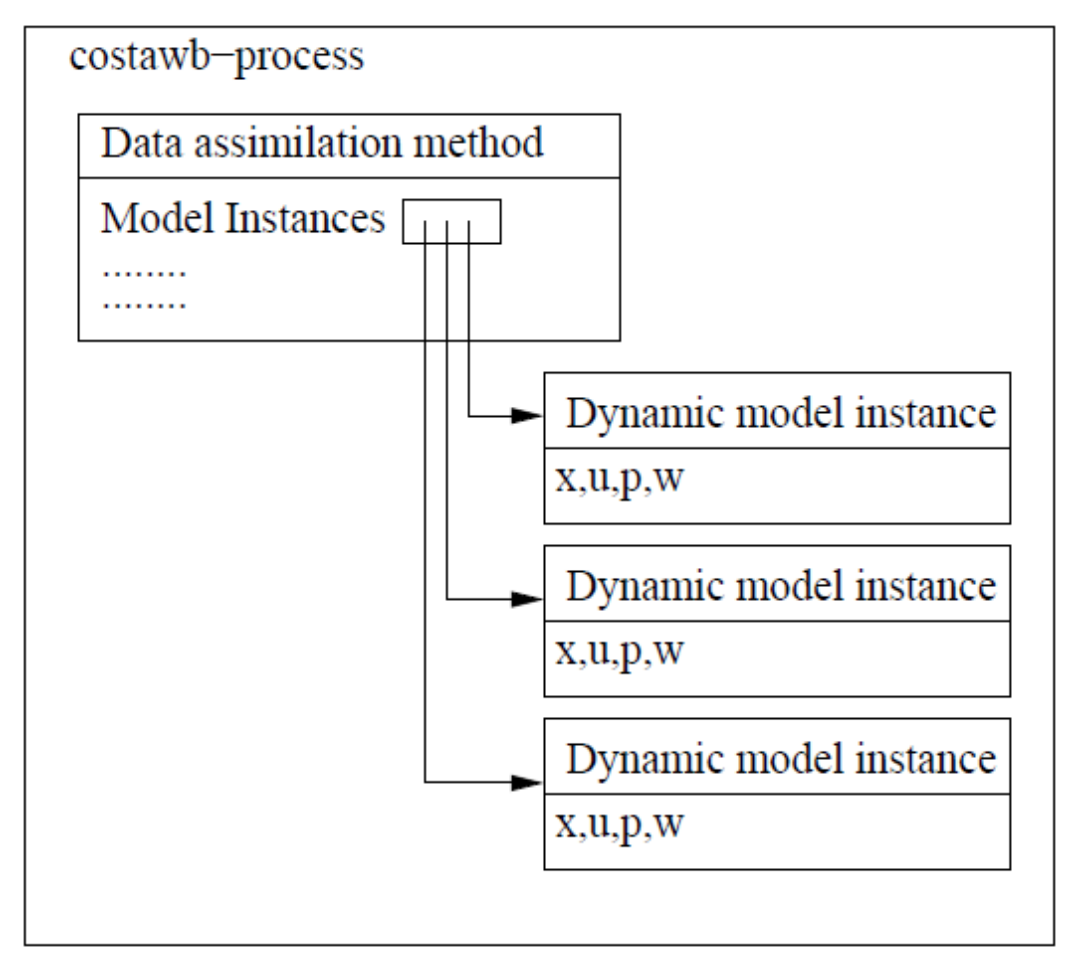
Automatic parallelization in OpenDA

- Recall:
  - Multiple model instances for multiple states
  - State of model is NOT directly accessible
  - Propagating of state is *NON-BLOCKING*
- Propagating multiple modes can be done in parallel
- Interface of all models is the same in OpenDA
  - One generic way to support parallelism for all models

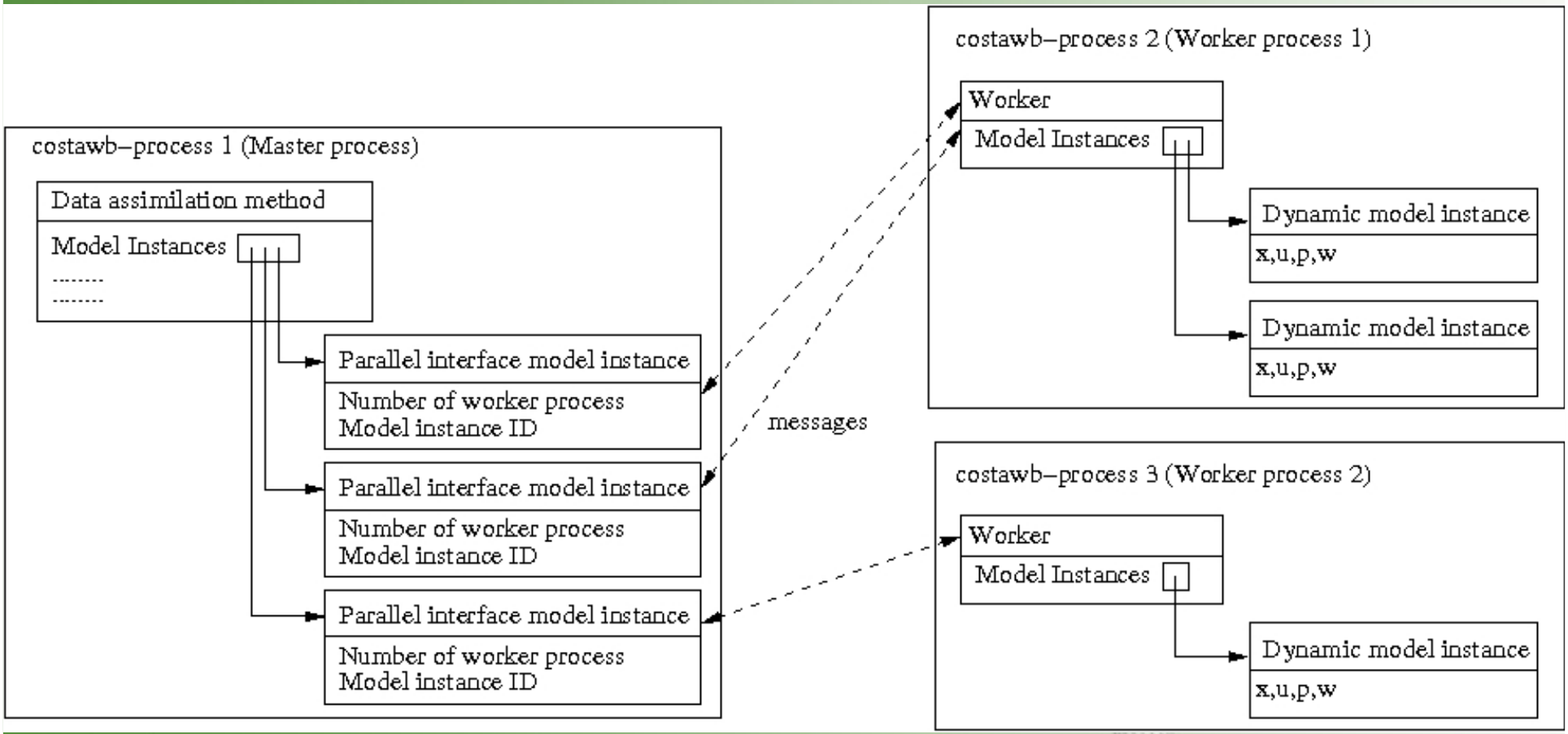
Automatic parallelization in OpenDA

- Relevant for many algorithms
  - EnKF
  - RRSQRT
  - Ensrf
  - Finite difference gradients
- Often propagating states takes the most time

Automatic parallelization in OpenDA



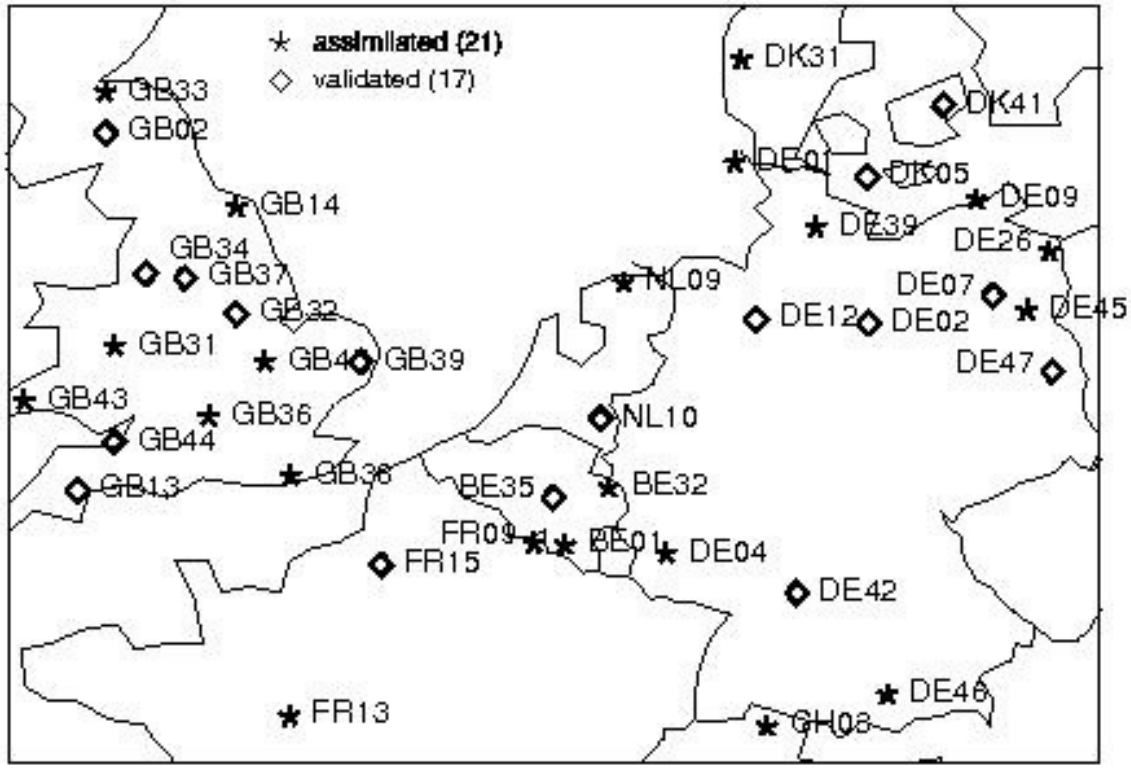
Automatic parallelization in OpenDA



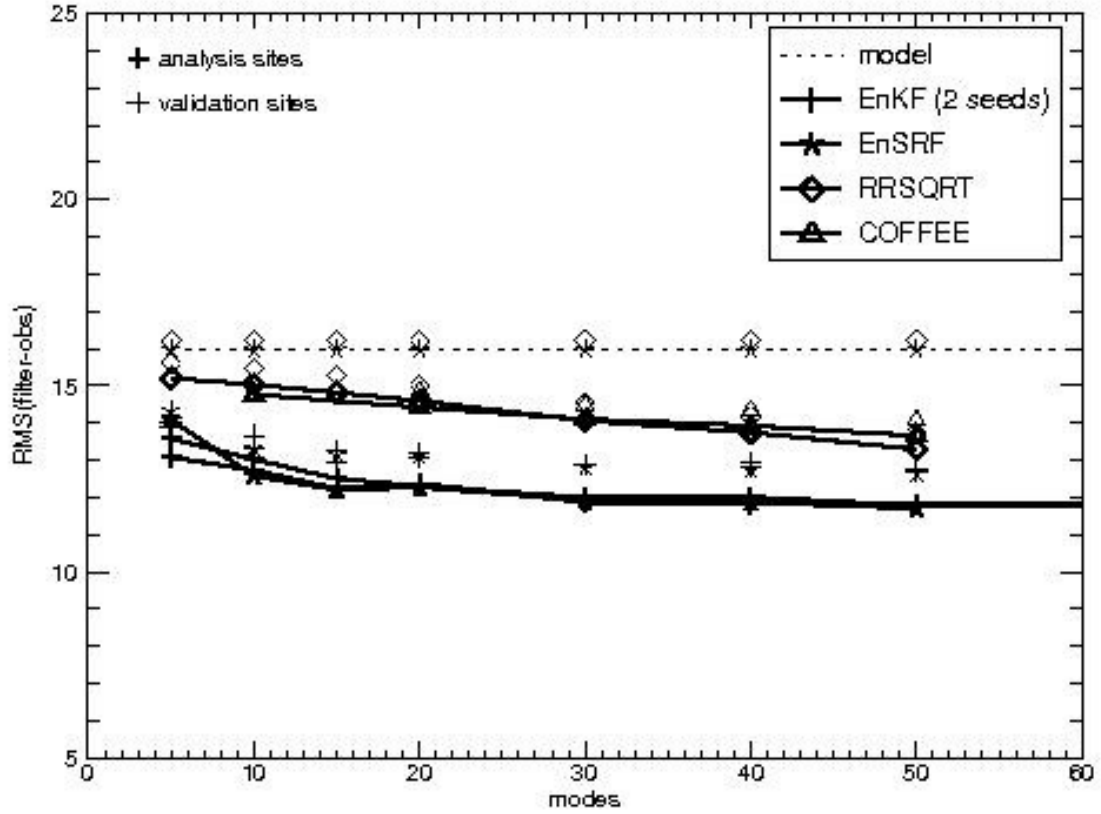
Automatic parallelization in OpenDA

- Testcase with LOTOS-EUROS air quality model
- Compare various DA methods
- Investigate impact of automatic parallelism
- Set up an ozone test-case
- 38 observation stations

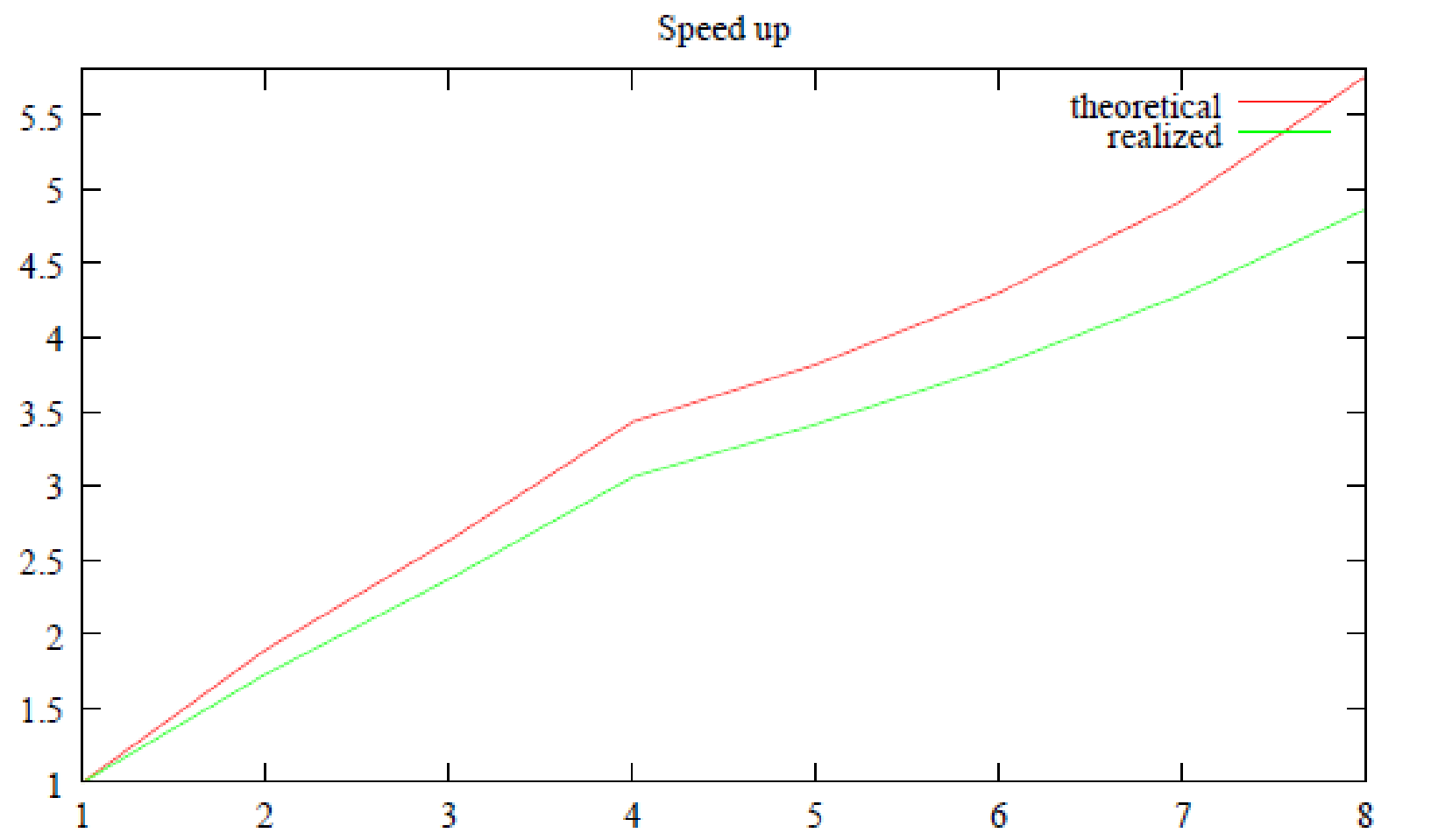
Automatic parallelization in OpenDA



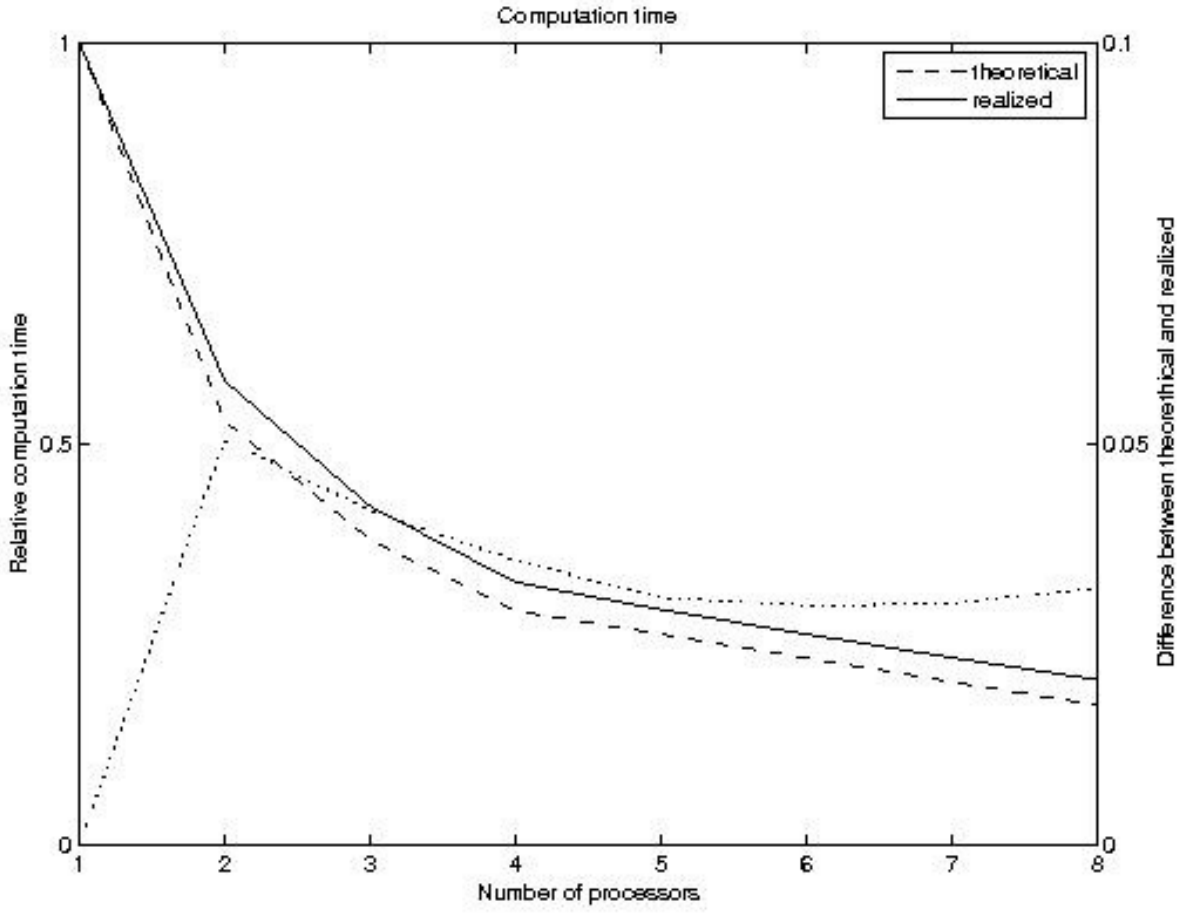
Automatic parallelization in OpenDA



Automatic parallelization in OpenDA



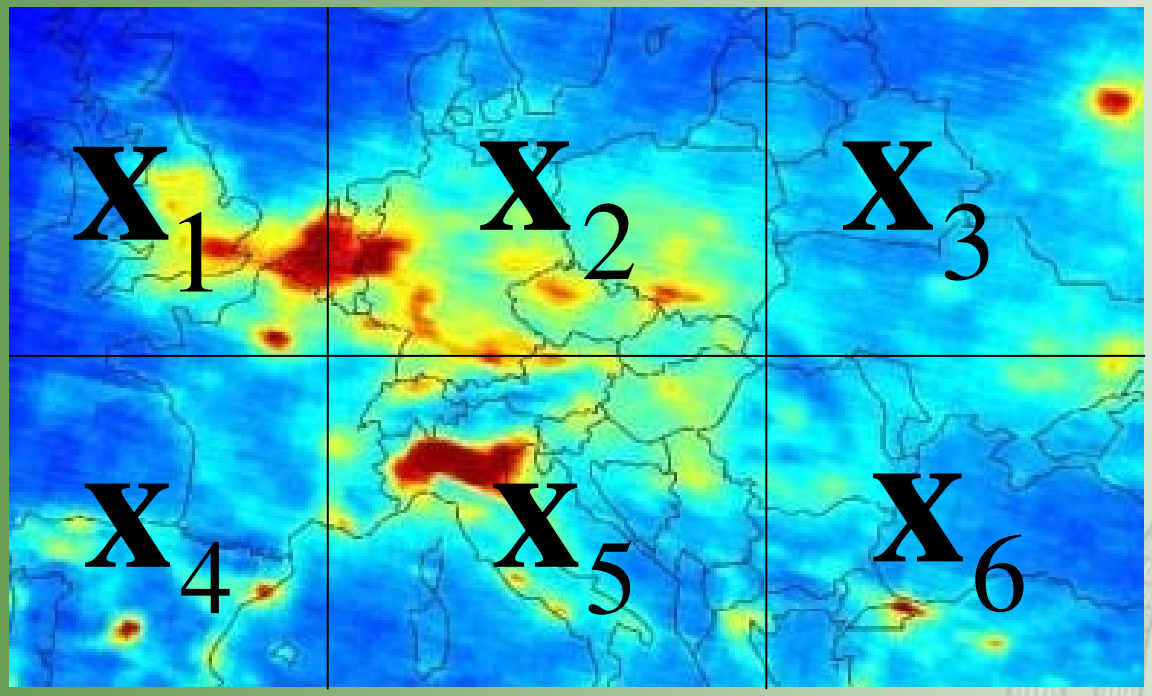
Automatic parallelization in OpenDA



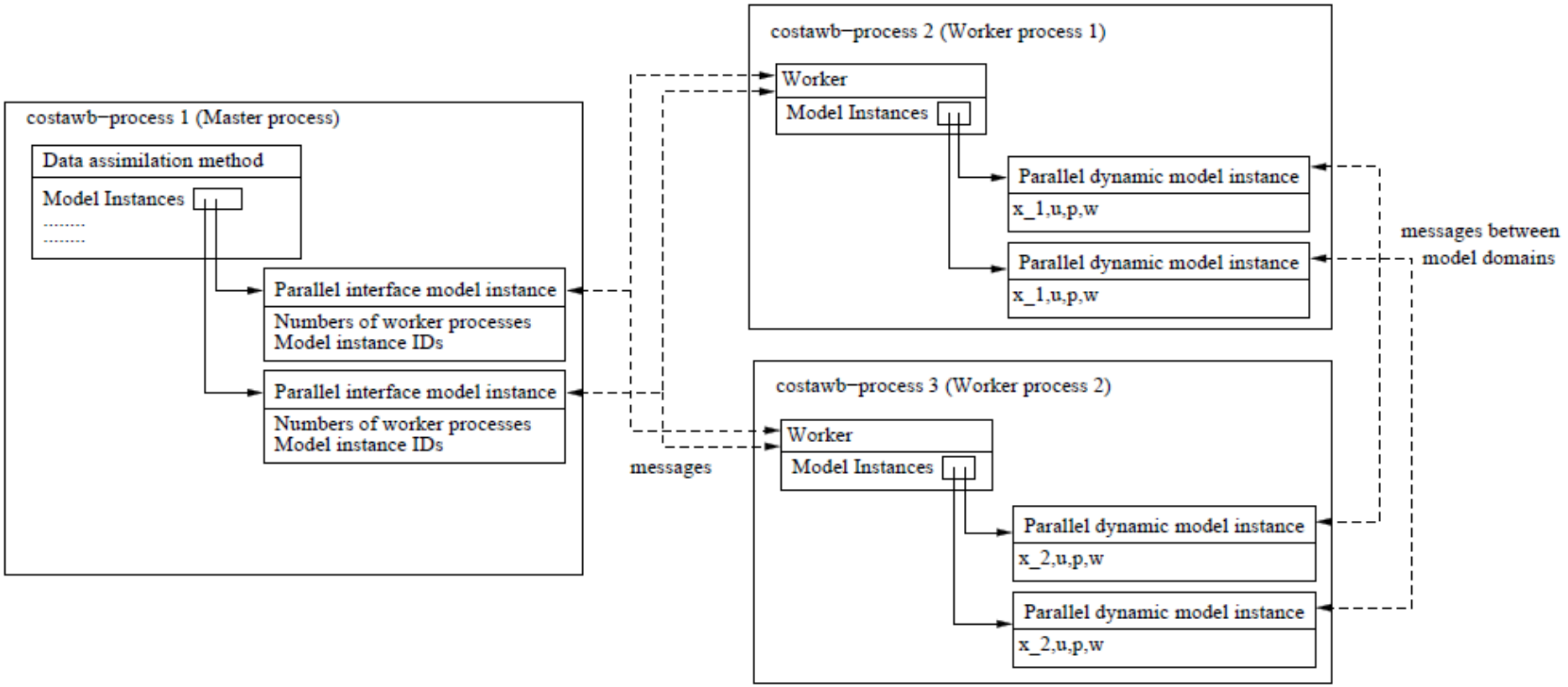
Coupling with Parallel models in OpenDA

- Various forms of parallel computing
  - parallelized using threads
  - Multiple processes
    - master-worker programming model
      - Master represents the whole model
    - Worker-worker programming model
      - The model is a concatenation of sub (worker) models

Coupling with Parallel models in OpenDA

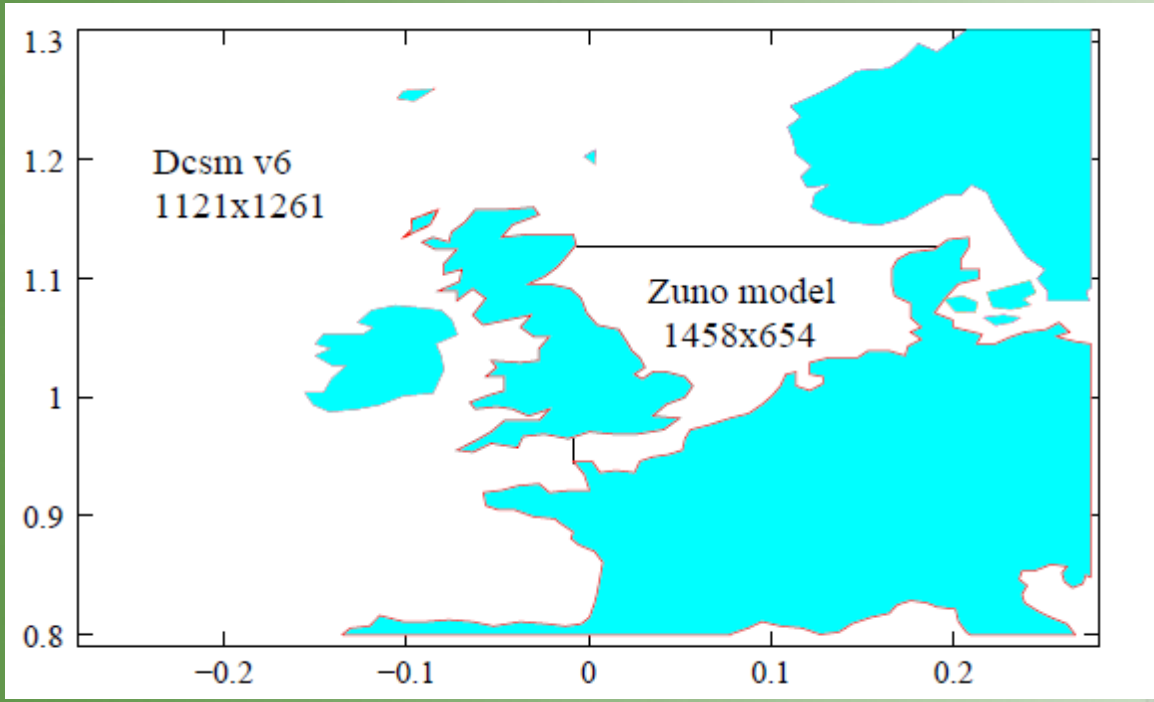


Automatic parallelization in OpenDA

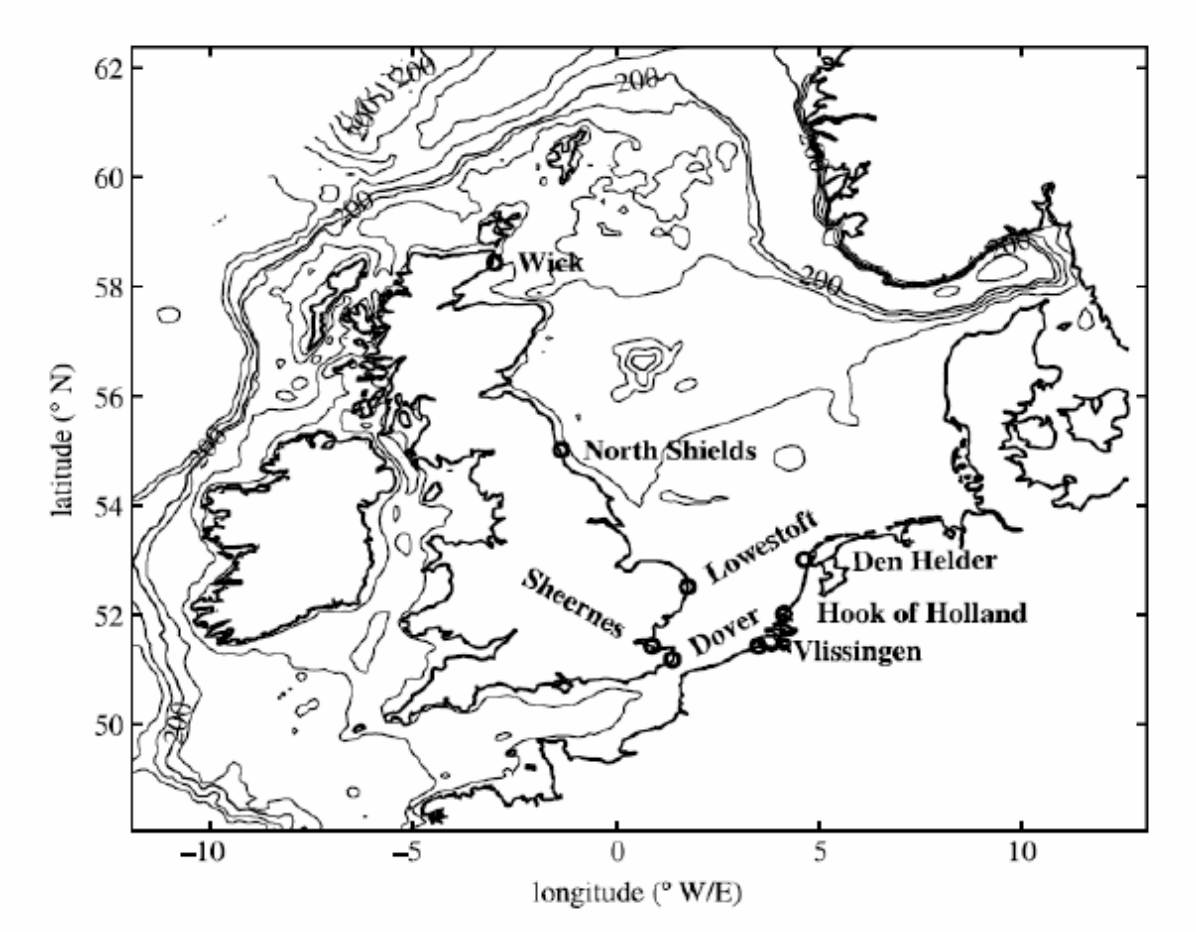


Automatic parallelization in OpenDA

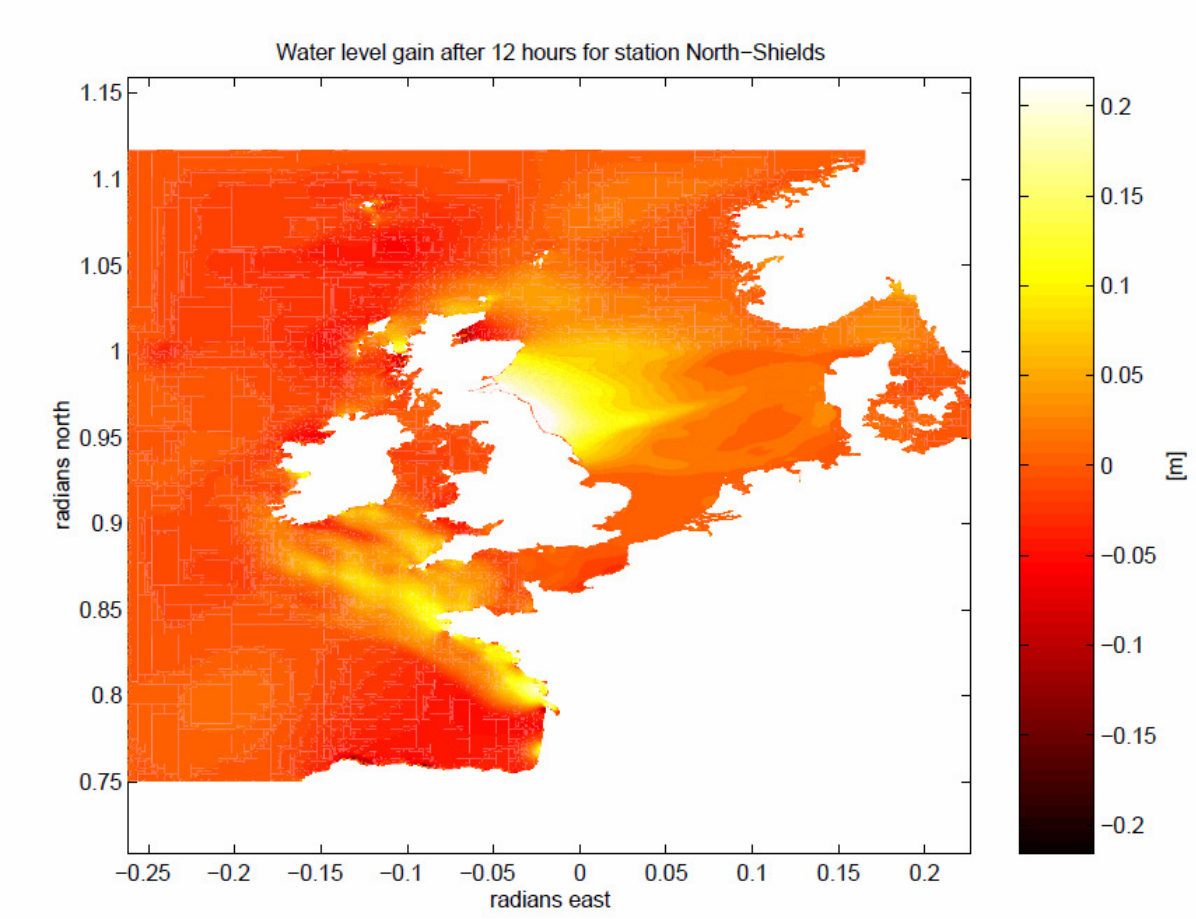
- Proof of concept: WAQUA/TRIWAQ DDHOR (parallel) CZUNO model



Automatic parallelization in OpenDA



Automatic parallelization in OpenDA



Conclusions

- OpenDA is a flexible framework for data assimilation and model calibration
- Easy to experiment with various DA-methods
- Automatic parallelization to improve performance
- Parallel models can be used in OpenDA as well
- Illustrated using real operational models

Questions ?!?