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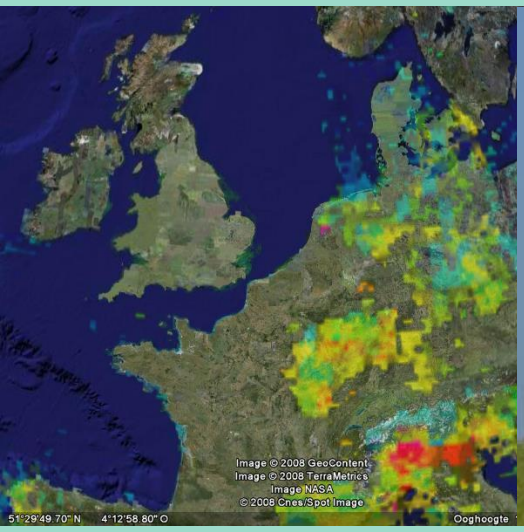
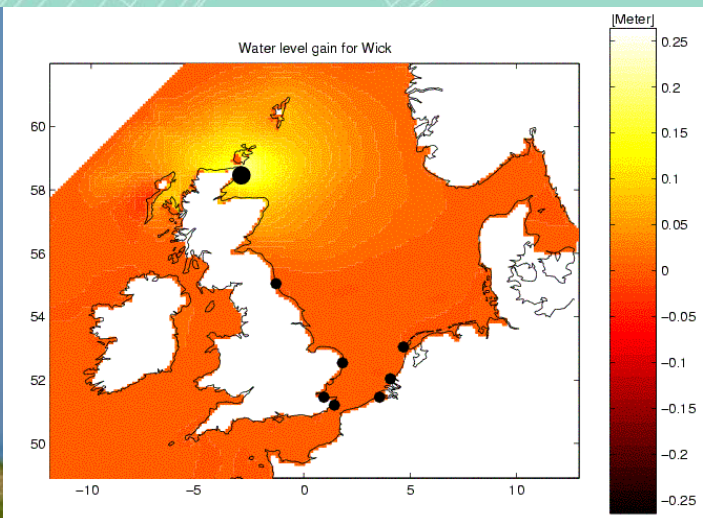
OpenDA





Data assimilation with OpenDA

Deltares
Enabling Delta Life

Jerico Summer School

June 19 2014

TU Delft

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Outline

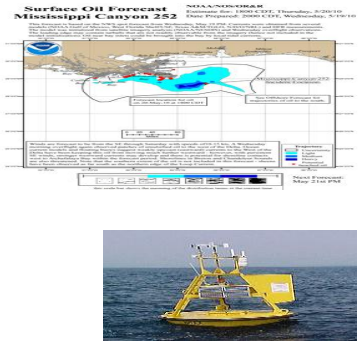
- Data assimilation and model calibration
- What is OpenDA?
- OpenDA architecture
- Coupling models into OpenDA
- Example of Calibration
- Example of Data assimilation
- OpenDA and parallel computing
- Summary

Data assimilation

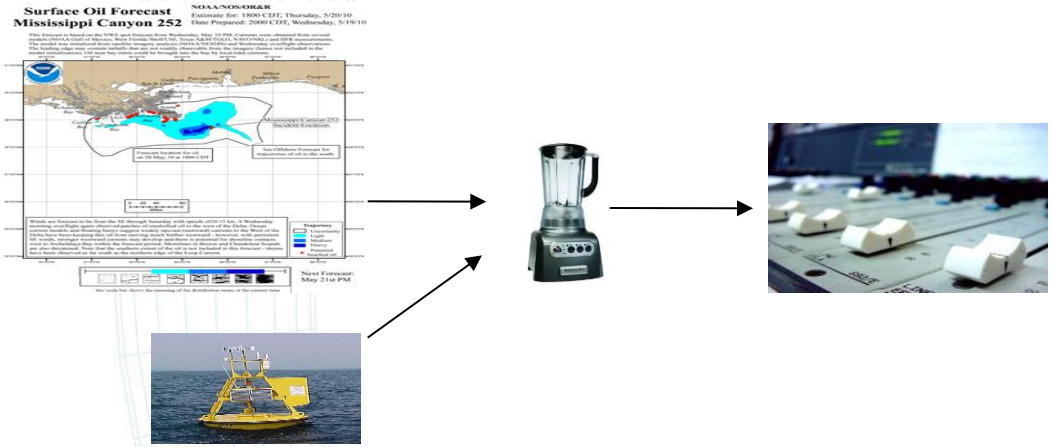
- (real time) data assimilation

Data assimilation and model calibration

- (real time) data assimilation

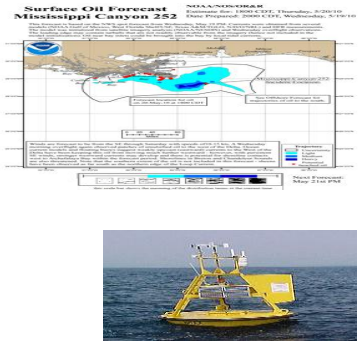


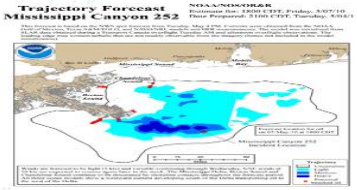
- model calibration



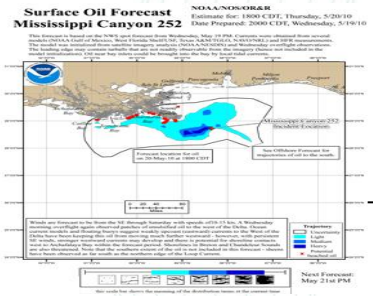
Data assimilation and model calibration

- (real time) data assimilation





- model calibration
- impact of observations
- reconstruction of sources



What is data assimilation

Generic model formulation

$$\frac{dx}{dt} = M[x(t), u(t), p, w(t)]$$

State: $x(t)$ — Parameters: p — Forcings: $u(t)$ — Noise: $w(t)$

Improve the model outcome by applying systematic perturbations to [*x,u,p,w*]

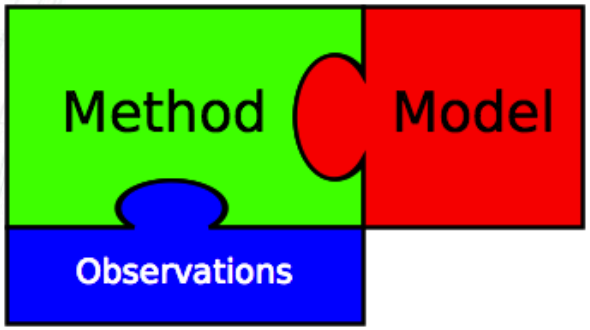
Optimization through knowledge of model uncertainty (multiple instances)
What is systematic? DA method
What is the reference? observations + observation error/uncertainty

What is OpenDA

OpenDA is an open source toolbox for data assimilation and parameter calibration in a generic modeling context

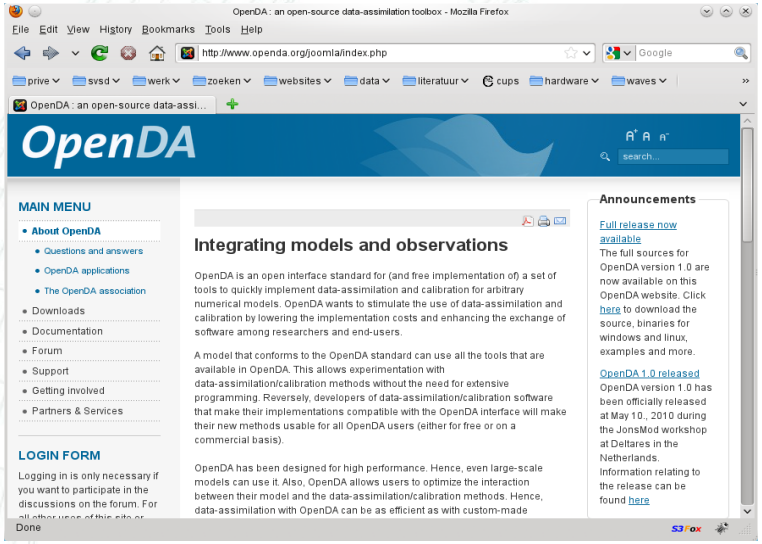
It encompasses:

- An architecture for applying (stochastic) data assimilation algorithms to deterministic models
- A set of interfaces that define interactions between components
- A library of data assimilation and calibration methods:
  - ensemble KF, ensemble square root KF, 3DVar, …
  - Dud, Simplex, Powell, Conjugate Gradient, …



What is OpenDA

- Open source (LGPL)
- Written in Java / C / Fortran
- Current version: OpenDA 2.1
- Available for Windows, Linux & Mac
- Website: www.openda.org with downloads, documentation, support
- The OpenDA Association:



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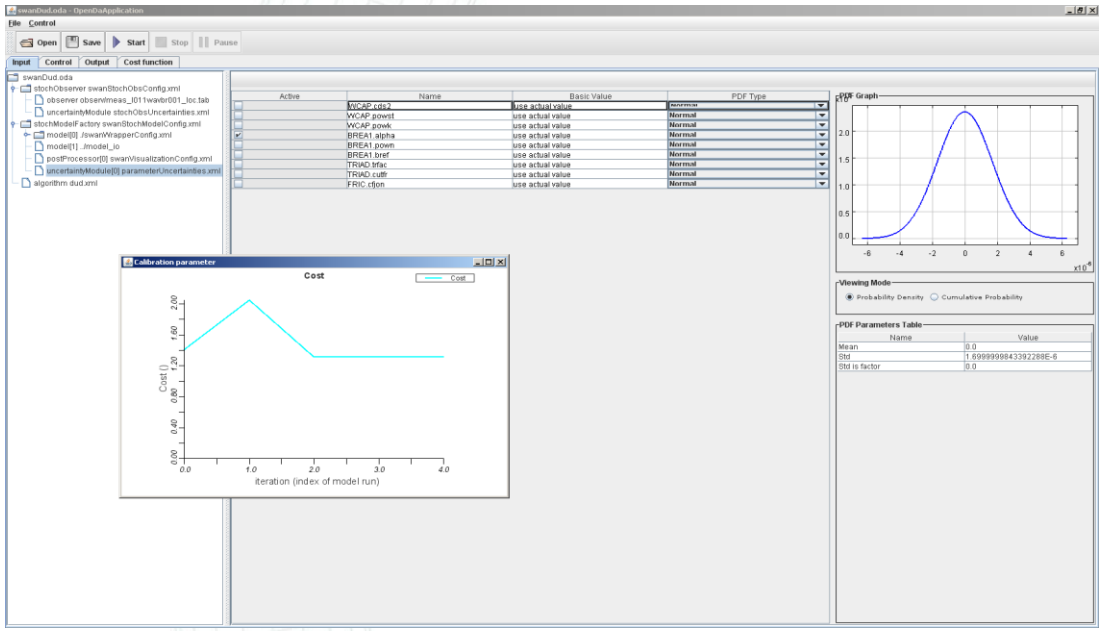
Why OpenDA?

- More efficient than development for individual applications
- Shared knowledge between applications
- Development of algorithms with e.g. universities
- Easier to change algorithm
- Easier to test, which should result in fewer bugs
- Optimized building blocks
- Development template

OpenDA Main Application

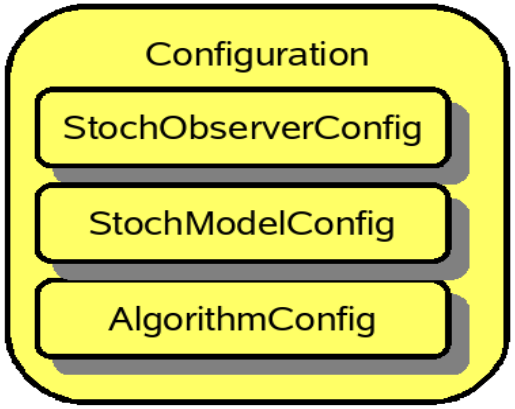
Single program

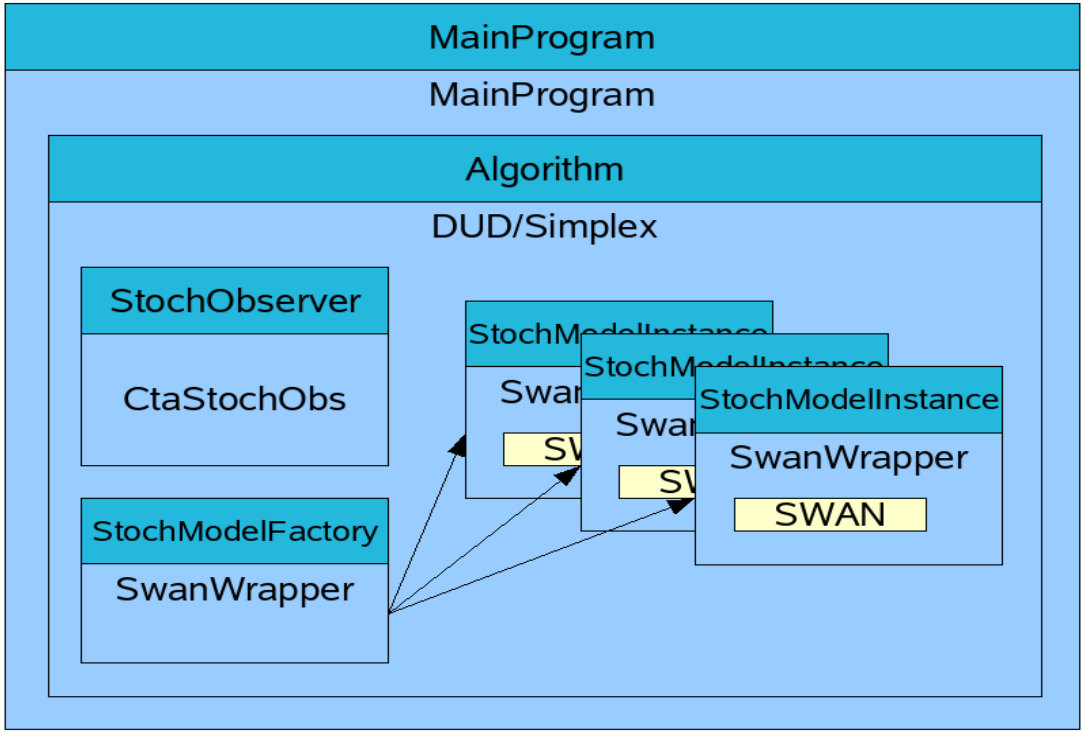
- GUI and command line
- Multiple configuration files
- Calibration and Filtering
- ‘All’ models
- ‘All’ observation sources
- Sequential and parallel



OpenDA architecture

Object Oriented Approach

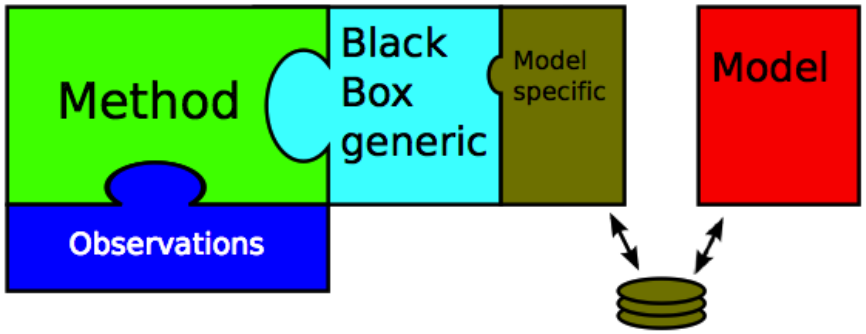




Model coupling: two approaches

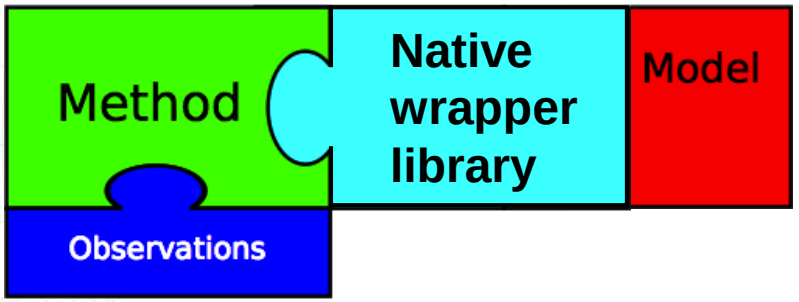
BlackBox coupling:

- model executable (no source required)
- use model input/output files
- $TIME wildcards in configuration
- model requirements:
  - ✓ accurate restart
  - ✓ good documentation of files
  - ✓ run from the command line
- disadvantage: not optimal if IO heavy

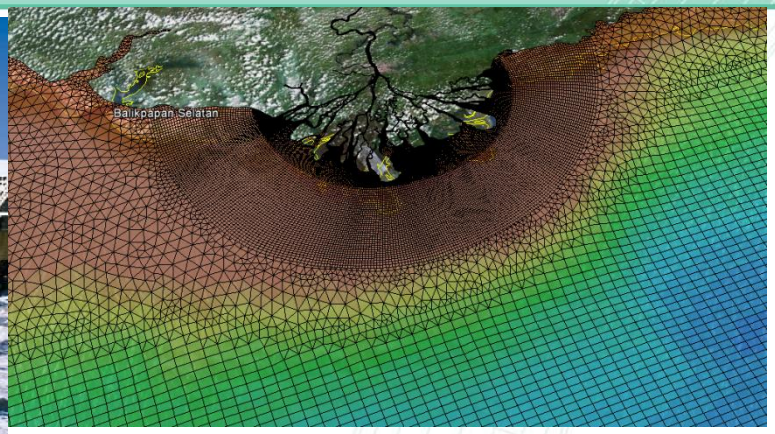


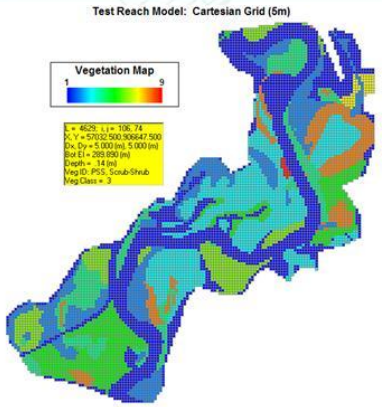
Native model wrapper

- model as a library
- communicate directly with model data objects (double precision arrays)
- model library requirements:
  - ✓ accurate restart (or fix it)
  - ✓ good code documentation
  - ✓ go back in time / instance management / time management
- disadvantage : more complex



Models using OpenDA

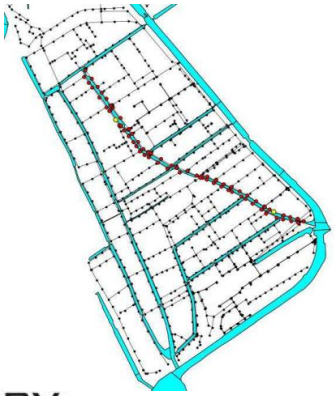


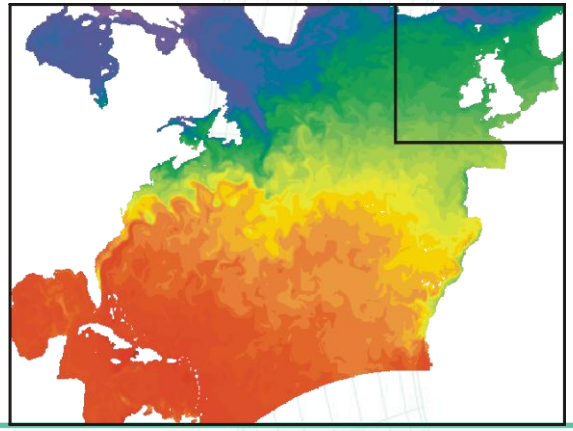


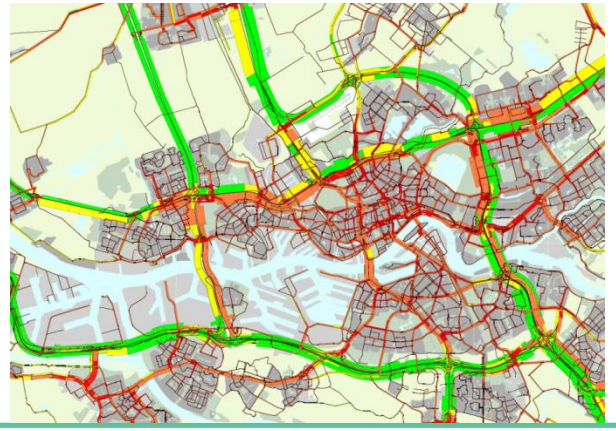
SIMONA Delft3D D-FlowFM SWAN EFDC CE-QUAL-W2

Lotos-euros SOBEK MIKESHE NEMO OmniTRANS OpenTraffic

(OpenFOAM)







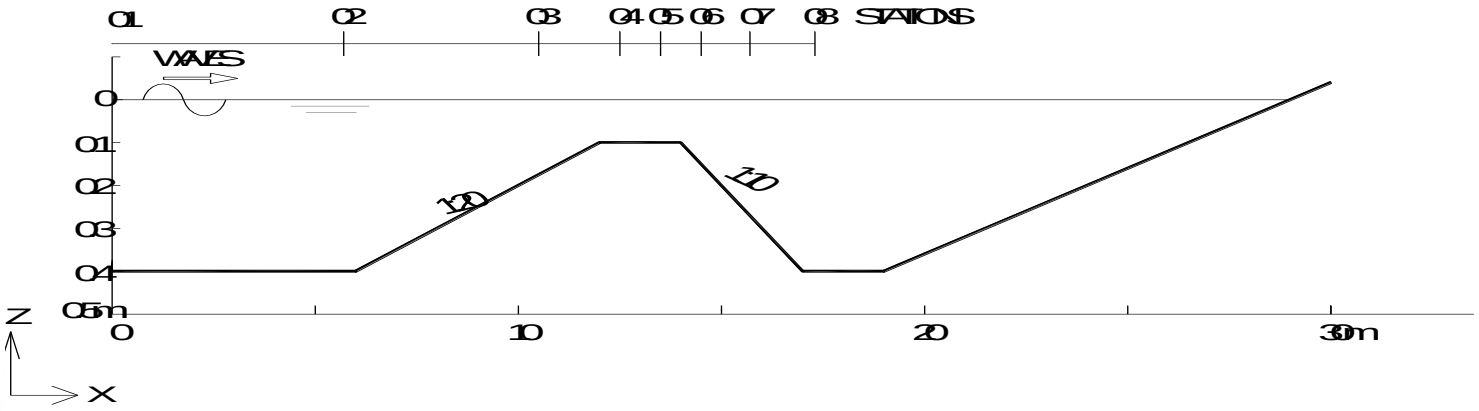
Example of calibration

SWAN 3rd generation wave model

OpenDA

Wave breaking and interaction over a bar

S_{tot} = wind input
+ non-linear interactions (quadruplets & triads)
+ whitecapping
+ bottom friction
+ depth induced wave breaking



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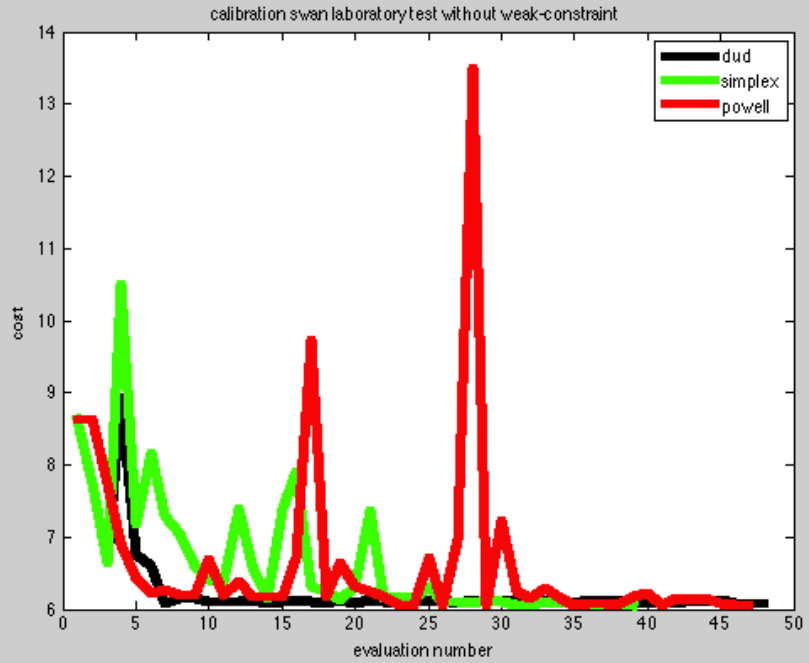
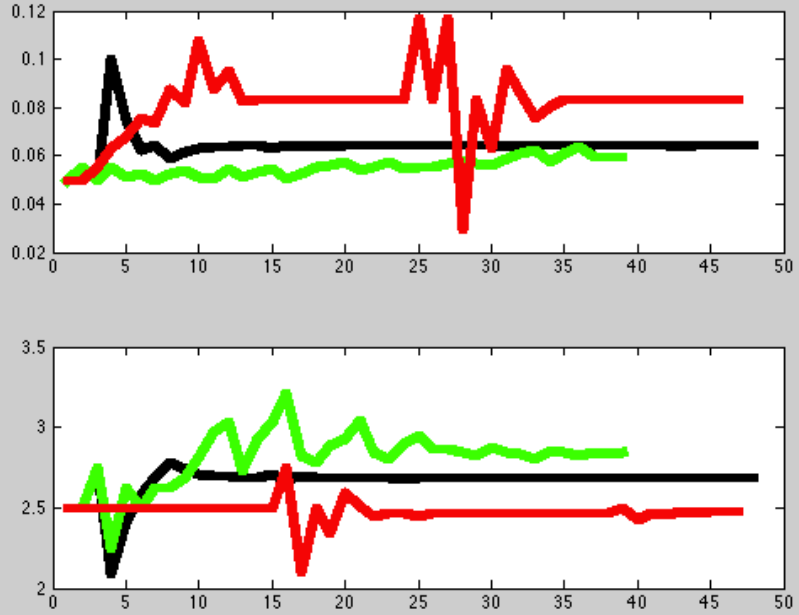
Example of calibration

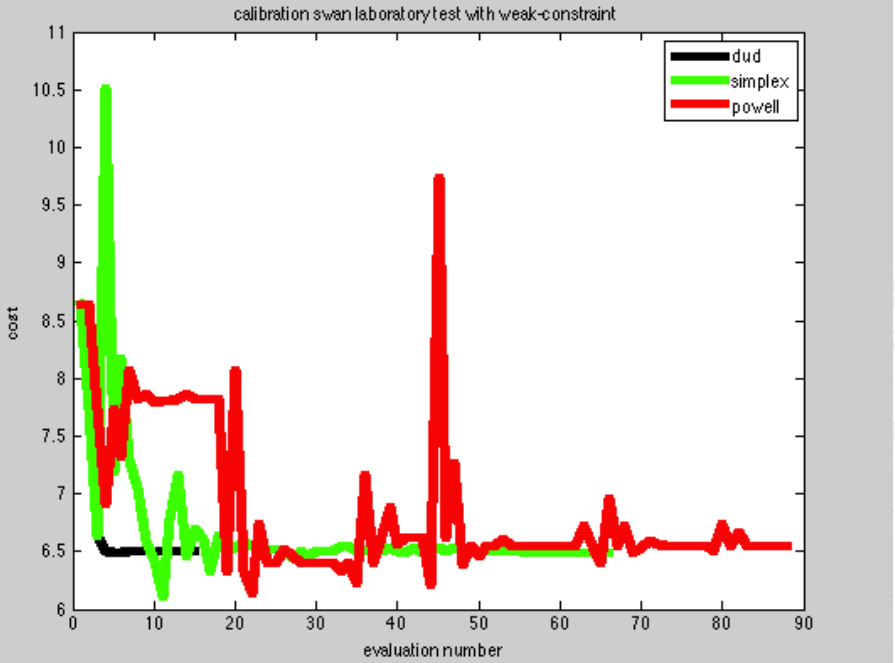
SWAN 3rd generation wave model

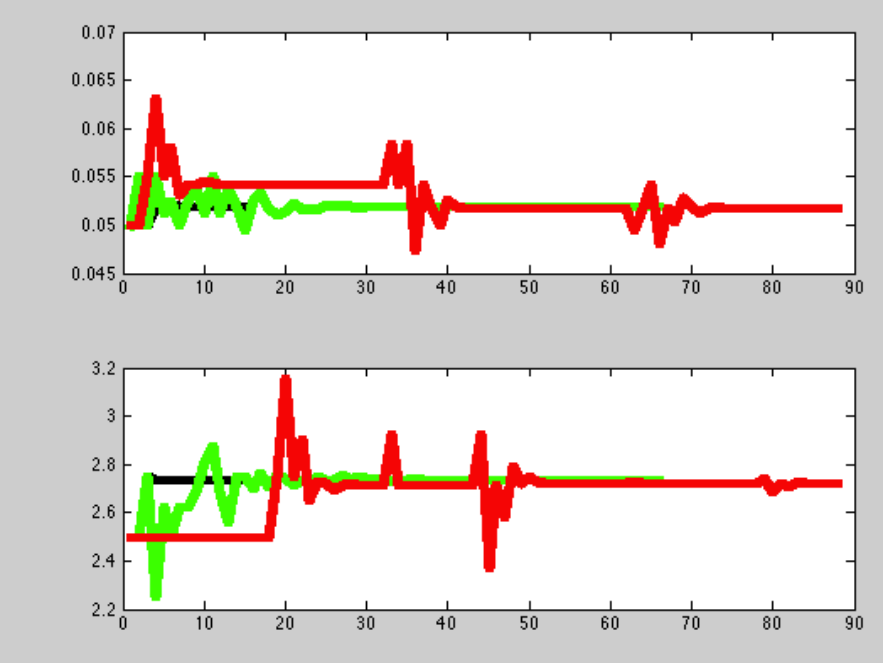




Example of model calibration

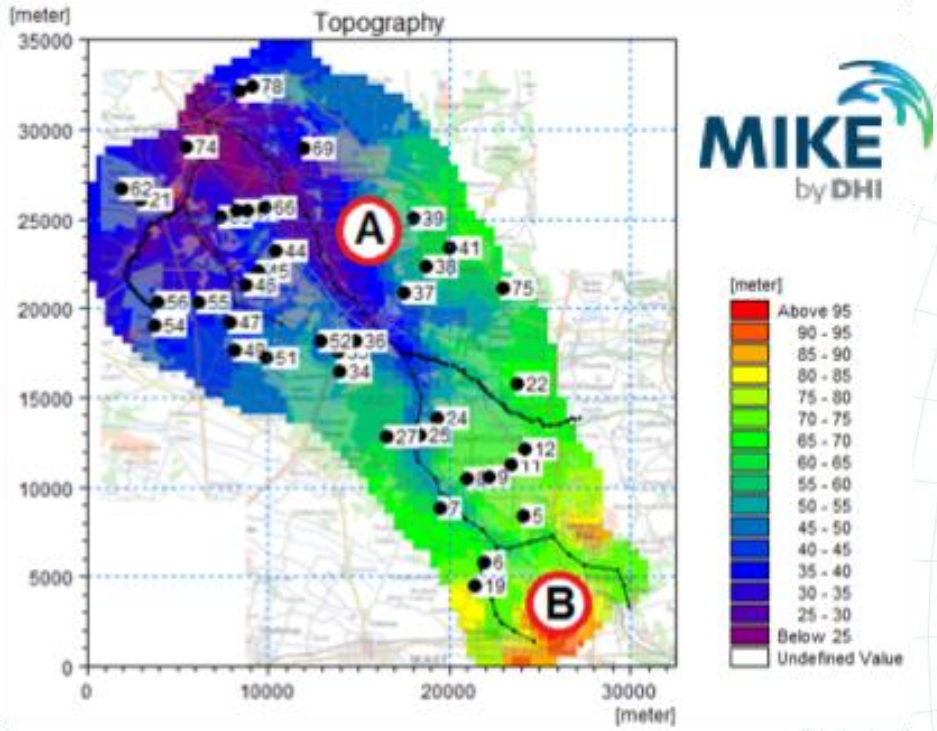
SWAN 3rd generation wave model





Example of data assimilation

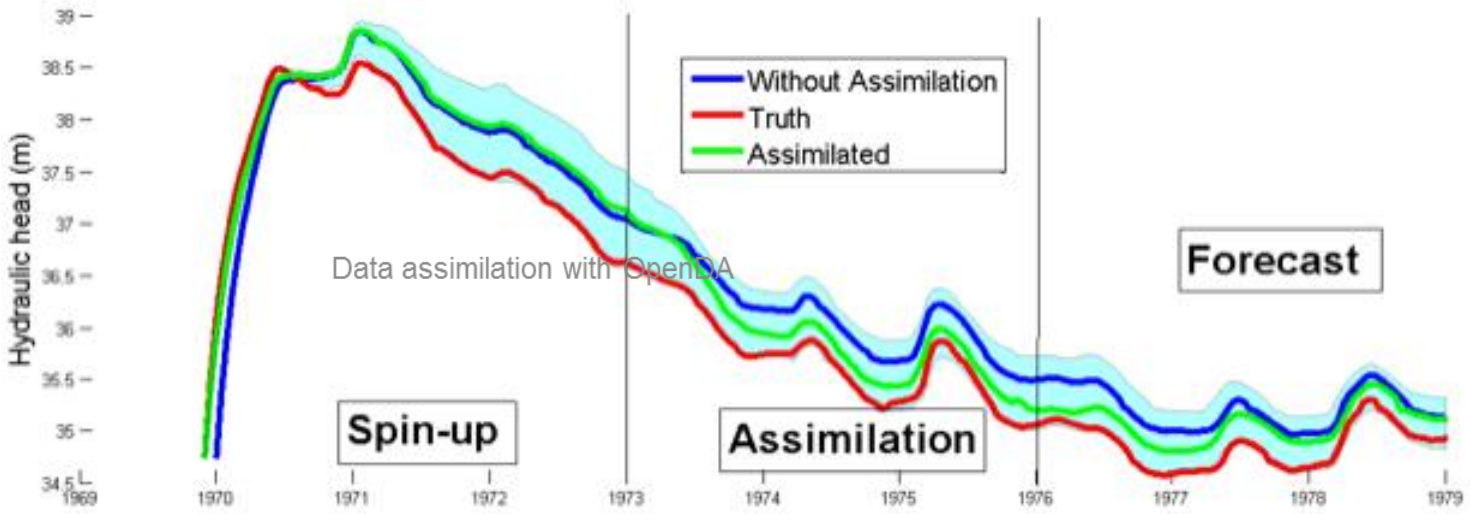
Karup catchment



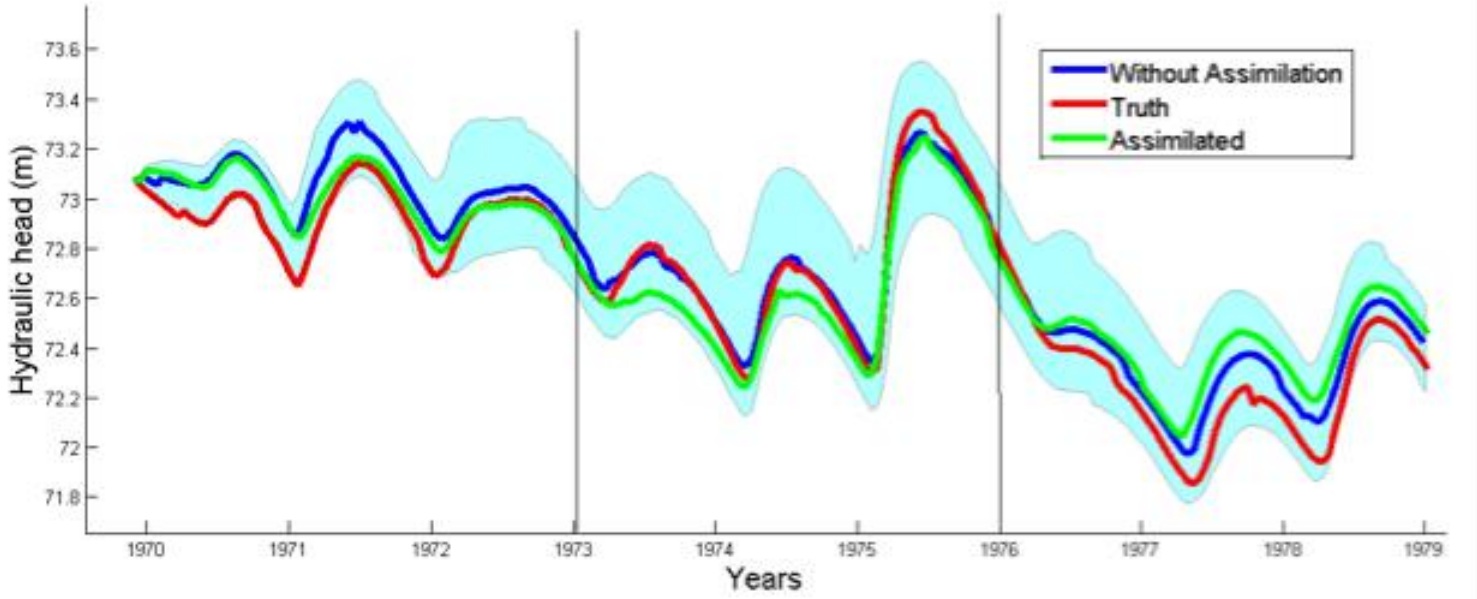
Ensemble Kalman filter

- 30 Ensemble members
- Daily hydraulic head observations (m = 35). Synthetic
- State updating (n = 522)
- Localization

Karup point A

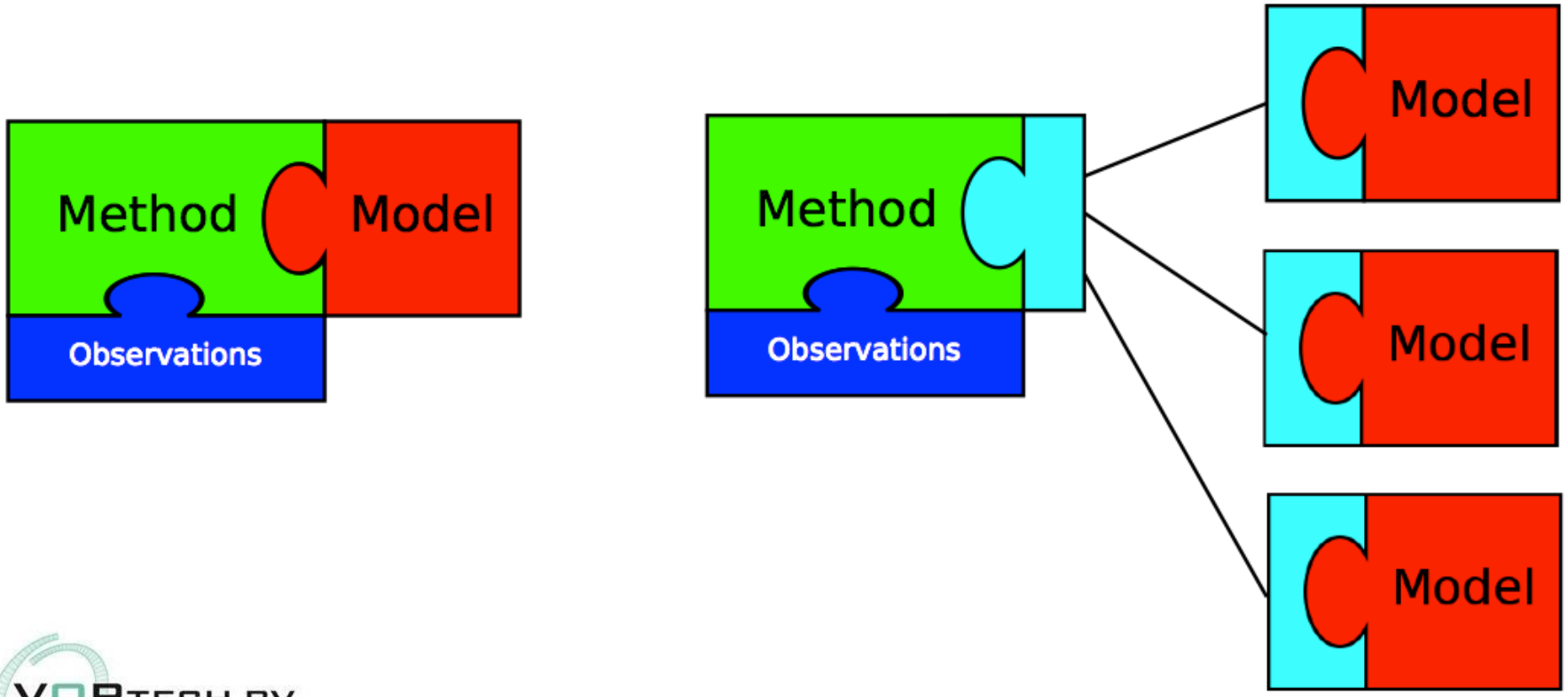


Karup point B



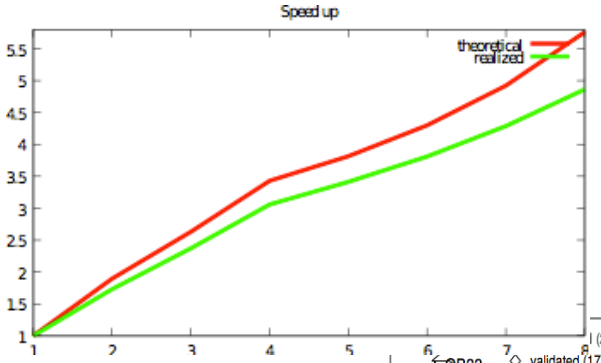
OpenDA and parallel computing

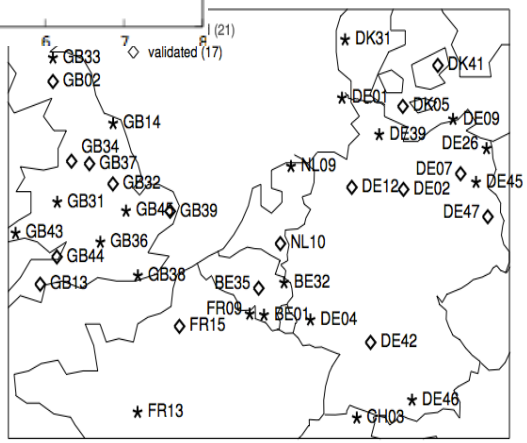
- Generic semi parallel due to OO concepts

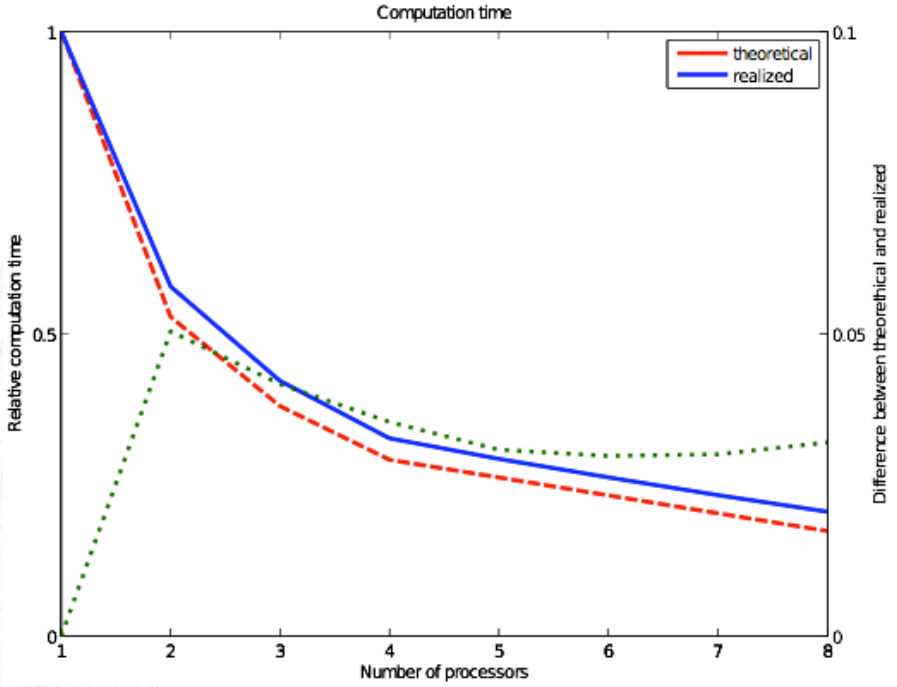


EnKF semi parallel

Lotos-euros air quality model







Summary

- OpenDA: Data assimilation toolbox for real-time data assimilation and model calibration.
- Modular, object oriented design allows easy exchange of building blocks.
- End users do not need to do any programming for experimenting.
- Approaches for integrating your model in OpenDA: Black Box, Native, Java.
- Conceptual support for all kinds of parallel computing.
- More info: www.openda.org