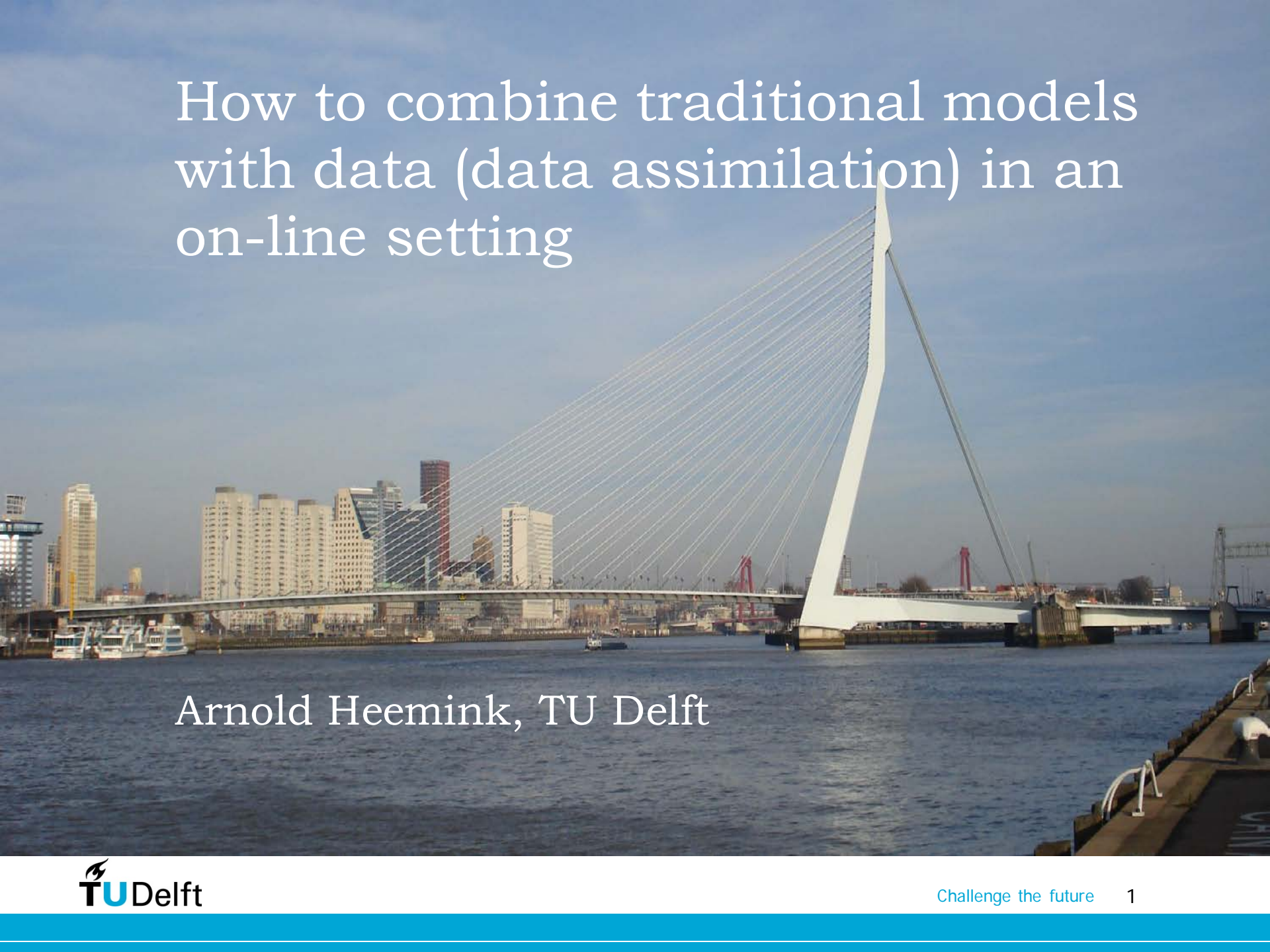
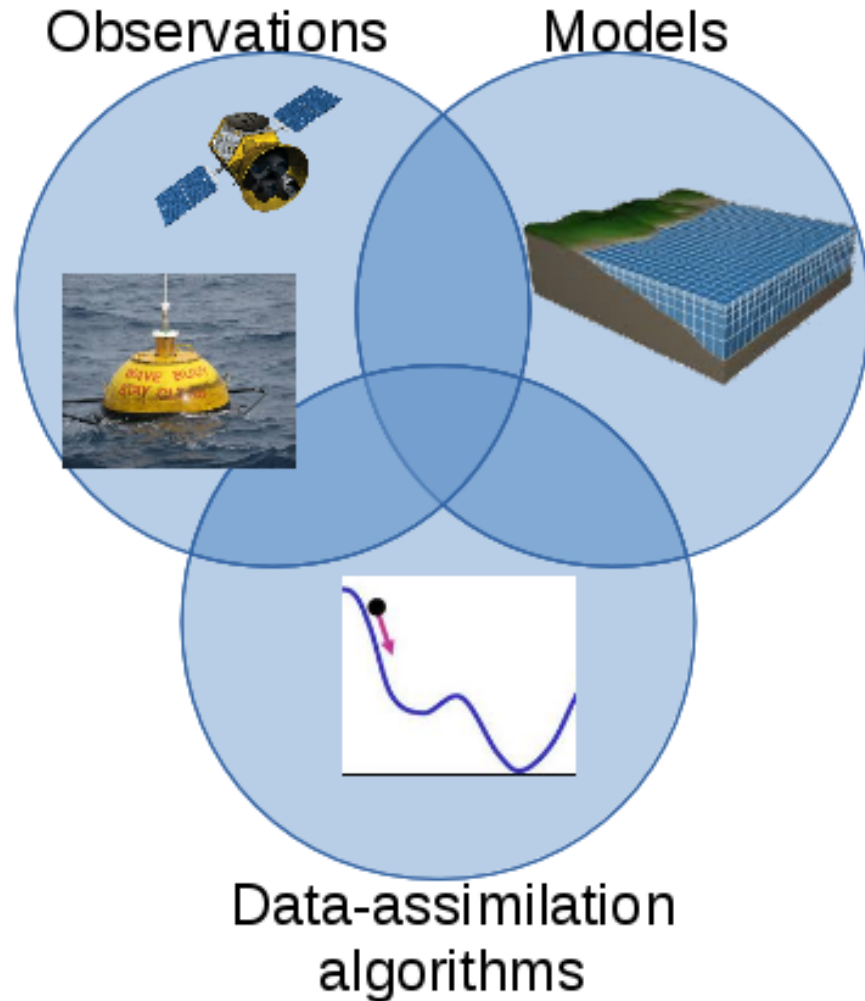


# How to combine traditional models with data (data assimilation) in an on-line setting



Arnold Heemink, TU Delft

**Data Assimilation is the incorporation of measurements into a numerical model to improve the model results**



# Data assimilation

Applications:

- Weather forecasting using numerical models
- Storm surge forecasting
- Reconstructing air pollution emissions
- Estimating permeability patterns in petroleum reservoir models
- .....
- .....

# Data Assimilation algorithms

4D Variational Data Assimilation: The Data Assimilation problem is formulated as a large scale optimization problem. A great challenge here is the development of the adjoint model. Key technologies in developing efficient algorithms that are also not too complicated to implement are Model Order Reduction and High Performance Computing.

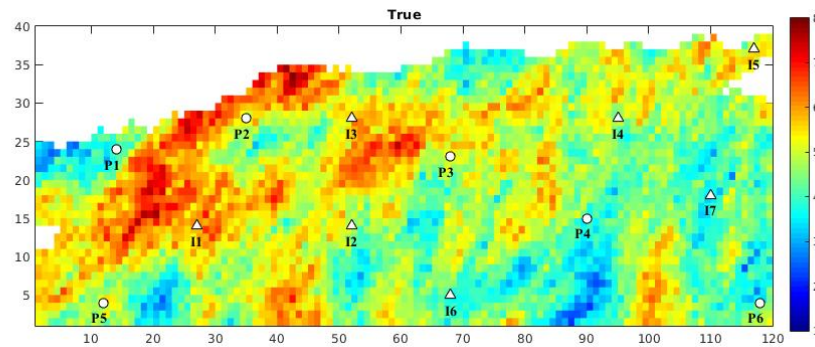
Ensemble Kalman filtering: A Bayesian type recursive algorithm based on an ensemble of model simulations.

Computational effort of data assimilation: 20-200 (!) times the computational effort required by underlying numerical model

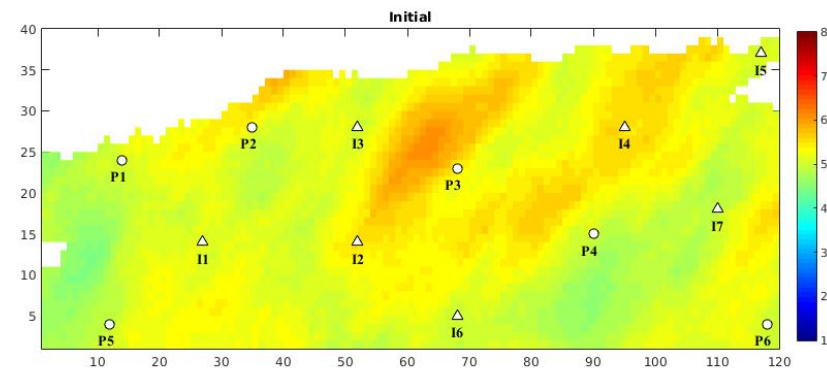
# Application: Estimation of the space varying permeability in a numerical petroleum reservoir model

- A twin experiment where the exact solution is known
- A parameter estimation problem with 282 degrees of freedom solved with a variational Data Assimilation algorithm based on Model Order Reduction techniques and Domain Decomposition
- The solution is obtained using (“only”) 72 model simulations

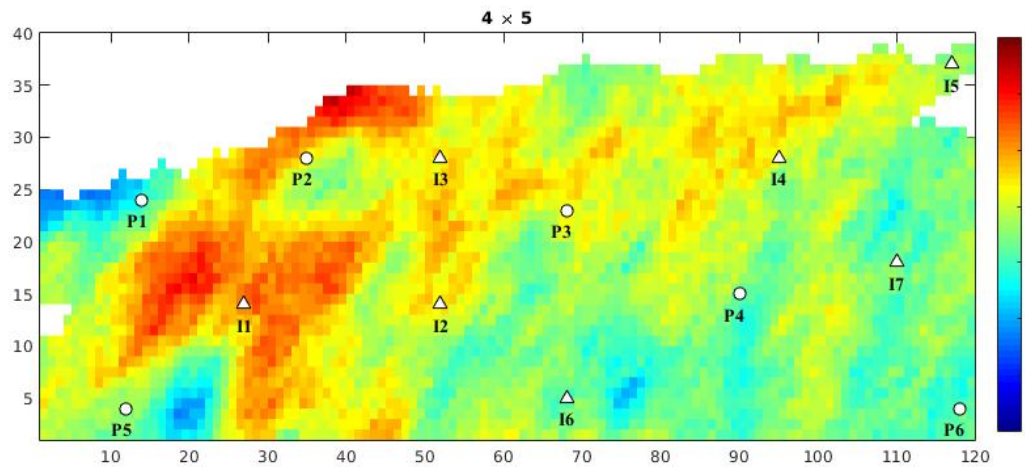
# "true" permeability



# initial permeability



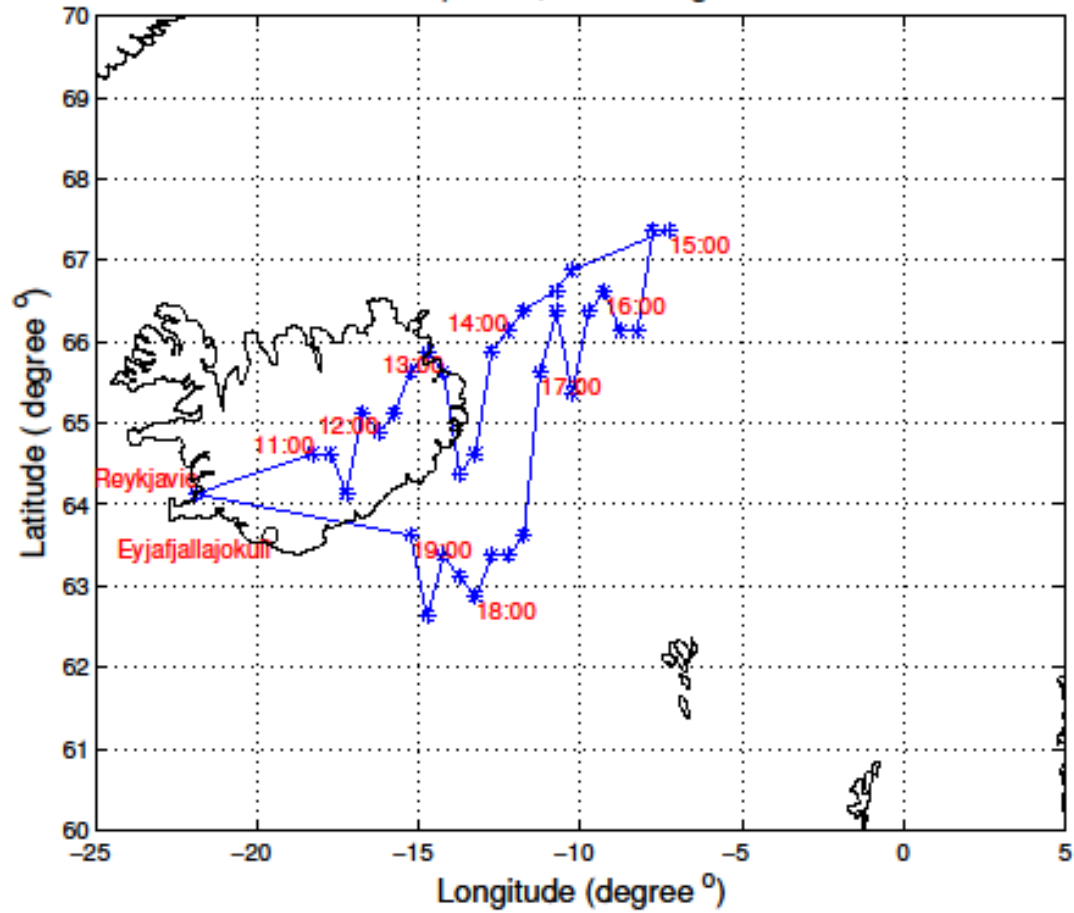
# assimilation results





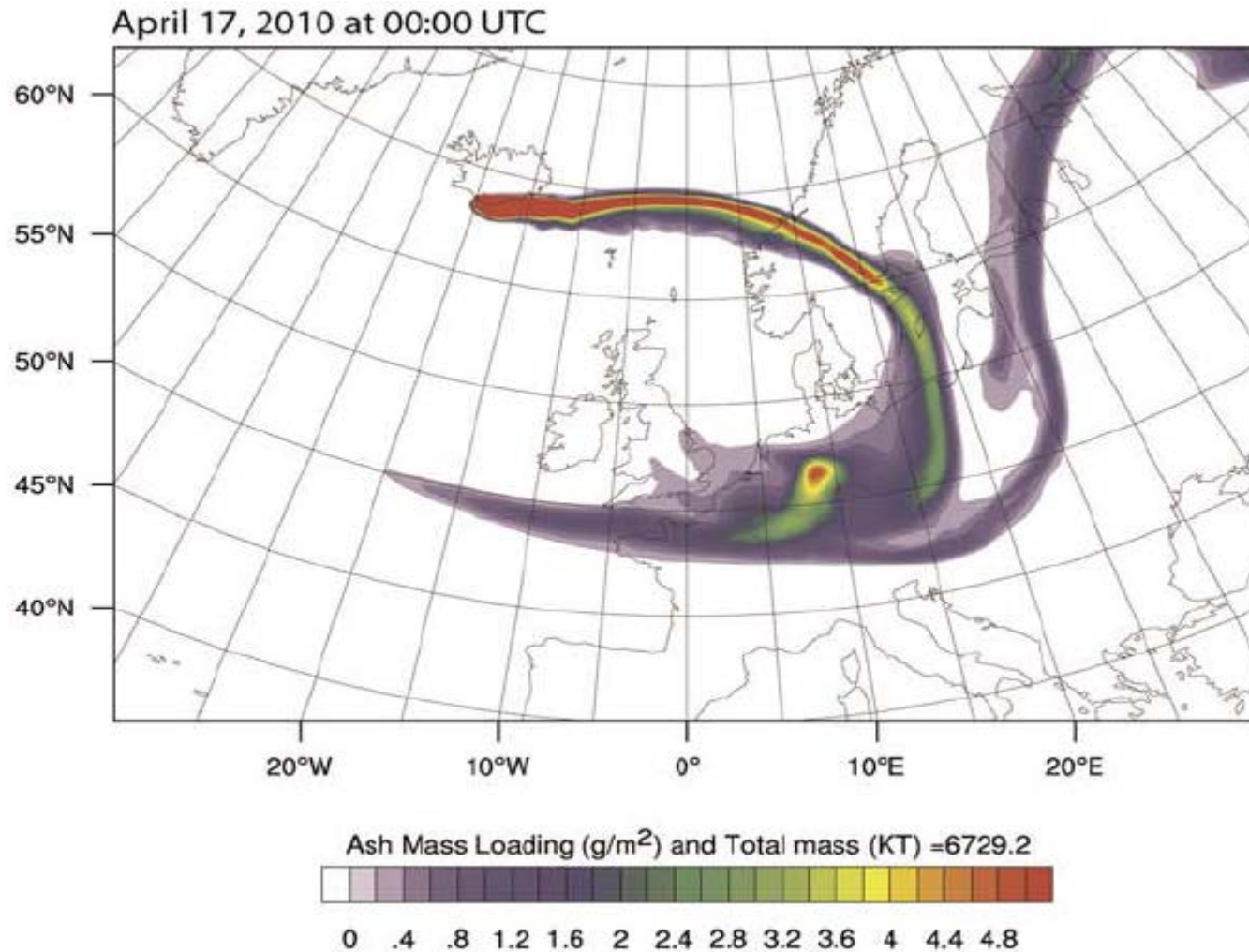
**Another application:  
Real-time forecasting  
of volcanic ash  
concentrations**

Date : April 14 , 2010. Height: 10 km





# Forecast of the 3D atmospheric transport model LOTOS-EUROS after assimilation of the data





## Data assimilation software

Library of data-assimilation algorithms:

Simplex, conjugate gradient, LBFGS, DUD, ...

EnKF, ENSR, steady-state, particle filter, ...

Set of interfaces: models, observations, algorithms

Open source (LGPL)

Platform for cooperation

Association

