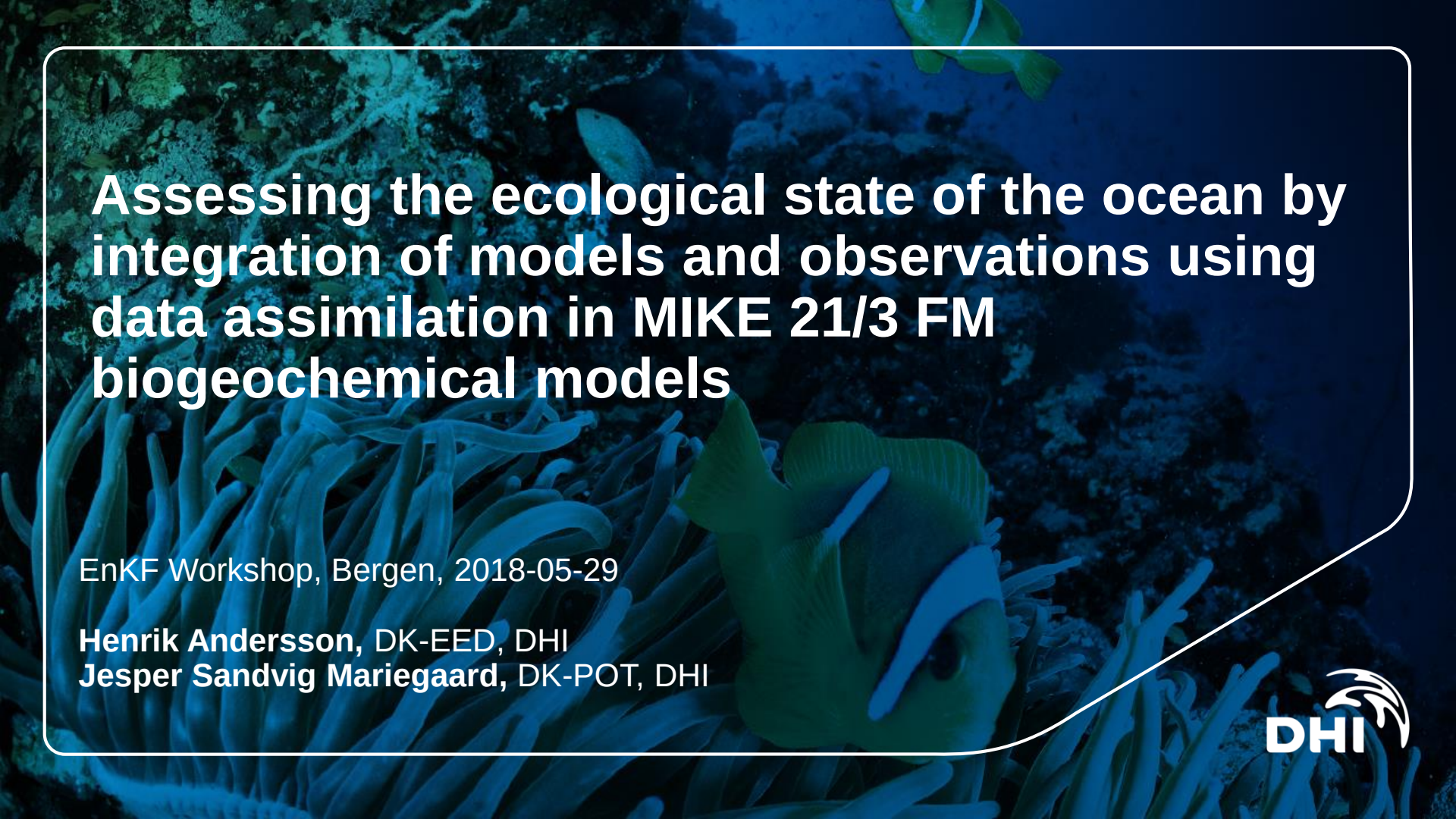


Assessing the ecological state of the ocean by integration of models and observations using data assimilation in MIKE 21/3 FM biogeochemical models

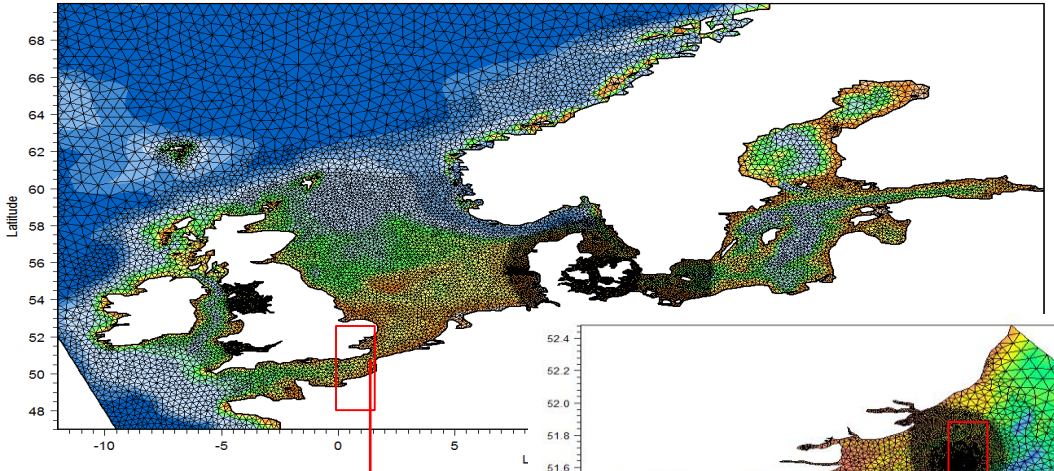
EnKF Workshop, Bergen, 2018-05-29

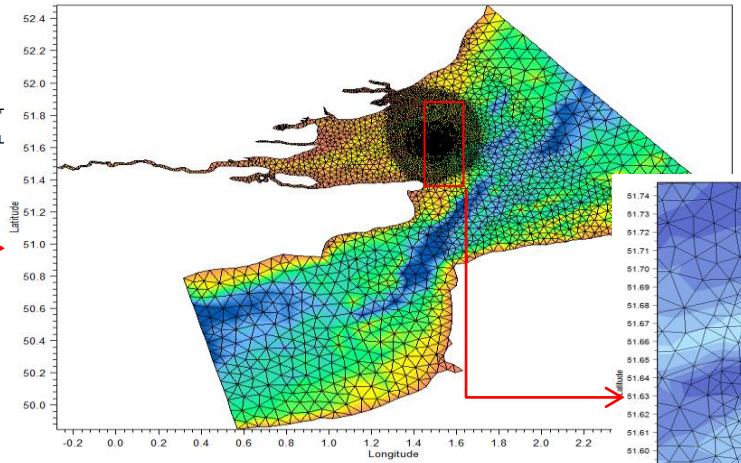
Henrik Andersson, DK-EED, DHI
Jesper Sandvig Mariegaard, DK-POT, DHI

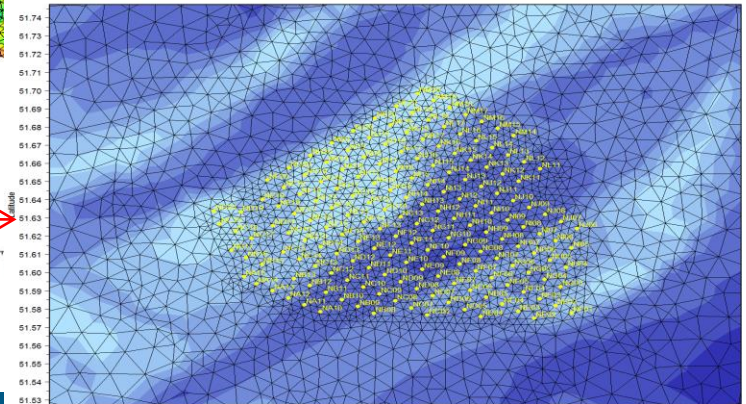
Agenda

- Introducing Mike 21/3 FM
- Data Assimilation applications
- Recent developments
- Data Assimilation in Biogeochemical models
- Future work

Flexible meshes: downscaling from regional to local wave and current models





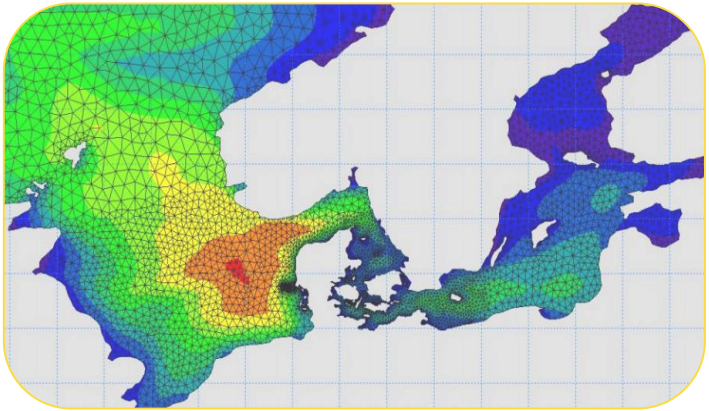


MIKE 21/3 FM system for waves and currents utilizing flexible mesh

Data assimilation in MIKE 21/3

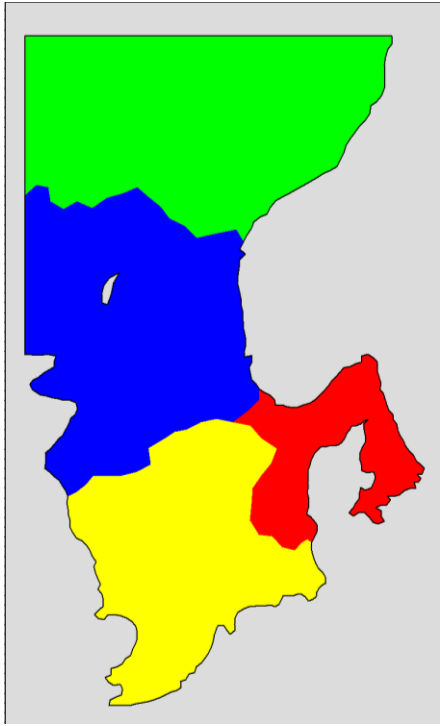
Development started in 1999 in MIKE 21/3 classic, later in MIKE 21/3 FM

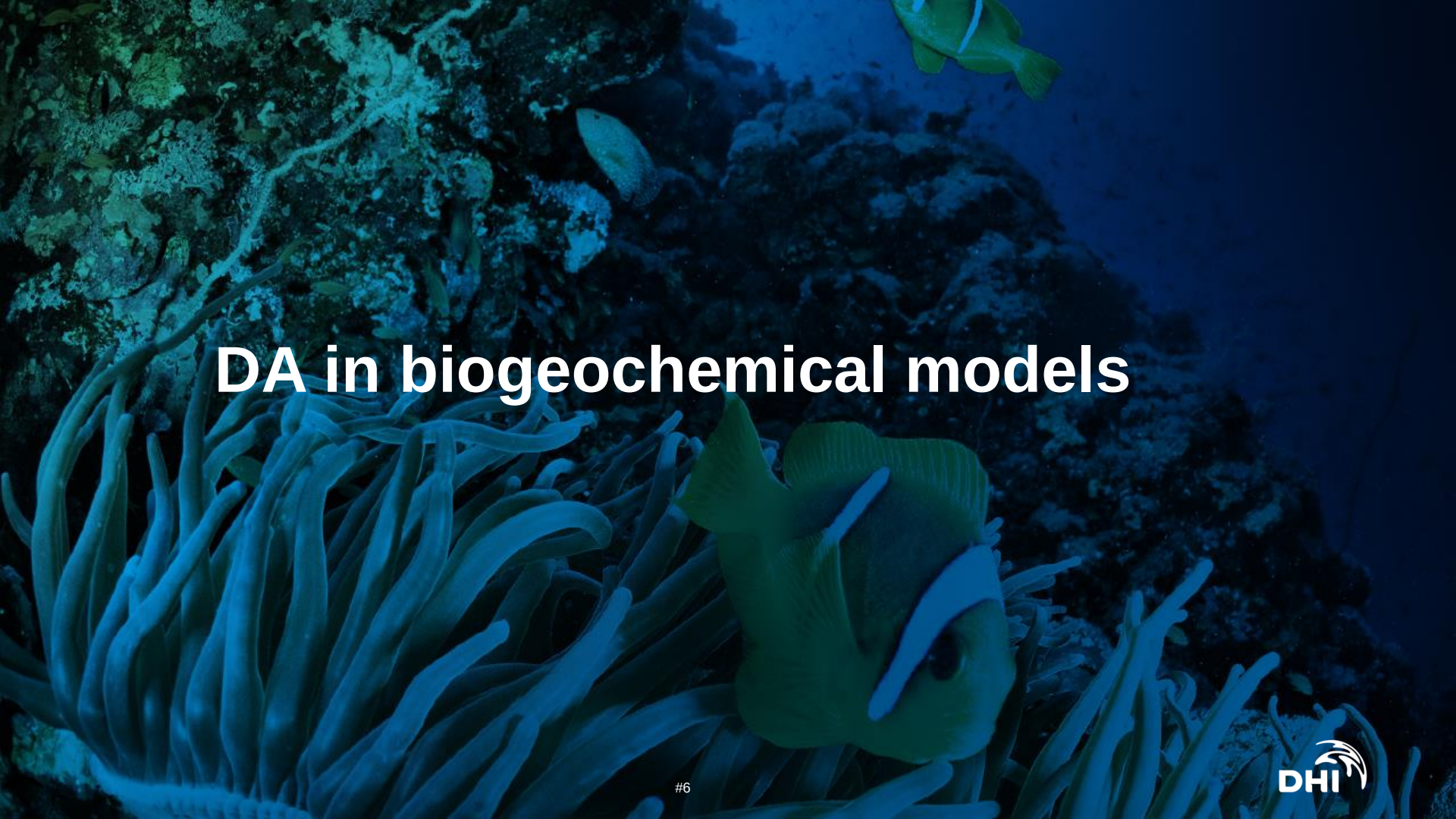
- Sequential DA with Ensemble Kalman filter (EnKF)
- Mostly assimilation of tide gauge station data
- Examples of operational DA models
  - Great Lakes Forecast
  - Caspian Sea Forecast
  - Adriatic Sea (Venice) Forecast



Recent developments in FM DA Module

- Implementation of ETKF and DEnKF
- Localization by Local Analysis
- Reading and processing track data observations (point clouds)
- Correlated observation errors
- Domain decomposed parallelization (MPI)

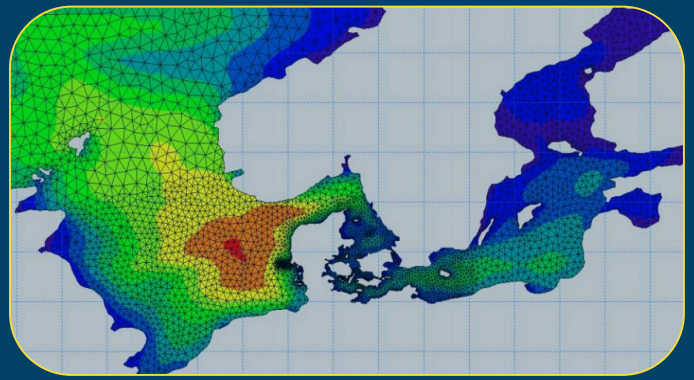




DA in biogeochemical models

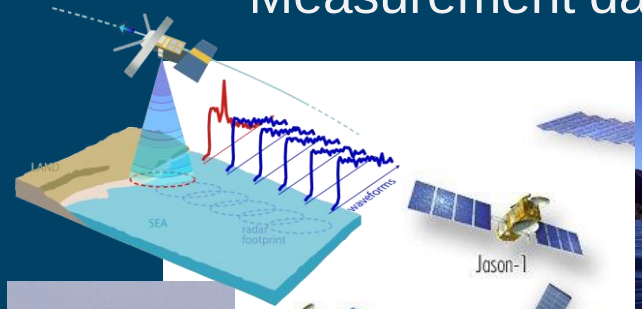
Why data assimilation?

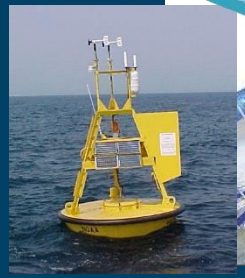
Numerical Models



- Full spatial and temporal description
- Process descriptions
- Correlation between variables
- Lower pointwise accuracy

Measurement data

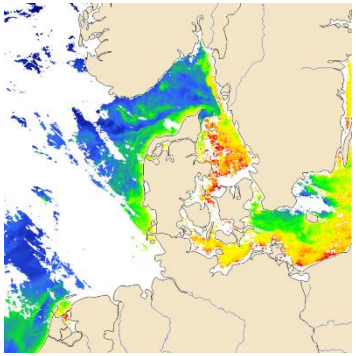




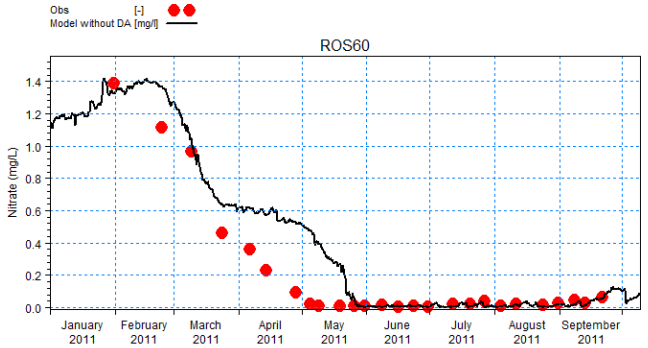
- High pointwise accuracy
- Limited spatial and/or temporal extent

Applications of biogeochemical DA

- Algal bloom forecasting

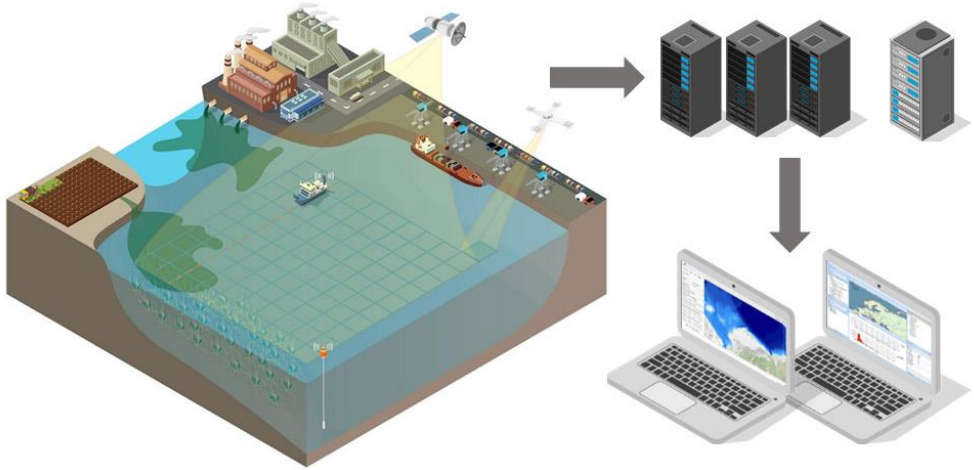


- Water quality reanalysis



SeaStatus (2017-2020)

The aim of SeaStatus is to develop a range of decision support tools for **intelligent marine ecosystem management** allowing for optimal use of marine resources at minimum impact. This is achieved by **combining** novel and traditional **measurement** techniques and data processing algorithms with **models** allowing for a continuous updating of the **environmental status** and improving the information basis for management.



Tools:
- Algorithms for integration of observations
- Stochastic model library
- Linkage between stochastic and mechanistic models
- Ecosystem models and data assimilation

Products:
- Baseline/status data layers and associated uncertainties
- High-quality historical model based data sets and associated uncertainties
- Continuous updating of environmental status

Services:
- Methodology for introducing uncertainty
- Recommendations on methods for specific use-cases
- EIA aligned with new directive
- Intelligent ecosystem management

DA in Mike 21/3 FM ECOLAB - Goal

Create a flexible Data Assimilation framework accessible to ecological modelers with a basic understanding of DA.

Why is the model wrong?

- ~~Missing ecological processes~~
- Ecological model parameters (e.g. growth rate)
- Initial conditions
- Boundary conditions
- Sources
  - Riverine
  - Atmospheric deposition
- Other forcings, e.g. wave height
- Hydrodynamics (Advection/Dispersion)

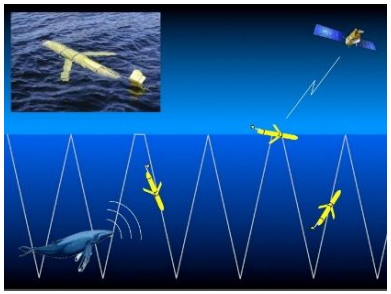
Biogeochemistry DA in Mike 21/3 FM

Transport	Ecolab
Advection/Dispersion	Advection/Dispersion
First order decay	Flexible process model
No interactions between state variables	Interactions, vertical transport, benthic variables, air-sea exchange …
Simple	Complex
Fast	Not so fast

1. Biogeochemical model decoupled from hydrodynamics
2. Joint assimilation of hydrodynamics and biogeochemistry

Observation types

- Fixed locations
  - *Buoy*
  - *Standard ship-based station*
- Point clouds
  - *Ferrybox*
  - *Glider*
  - *Sail-drone*
- Raster
  - *Satellite images*

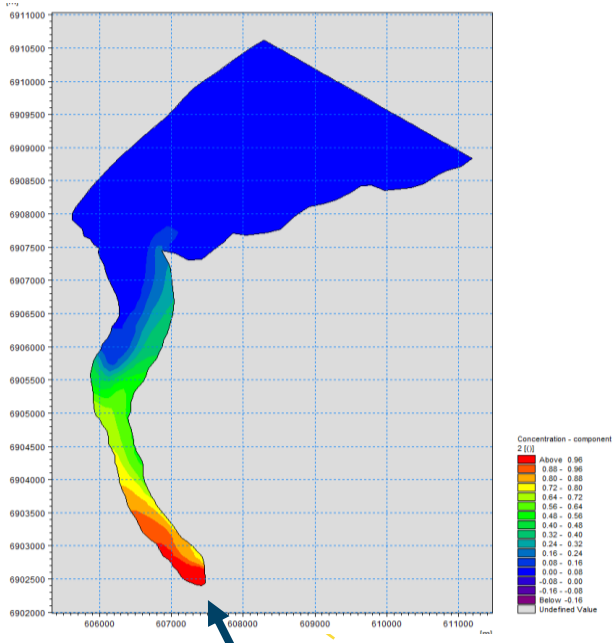


Examples

Test cases

- Transport module
  - Funnings fjord,Faroe islands
- Ecolab
  - Roskilde fjord

TR module - Funnings fjord



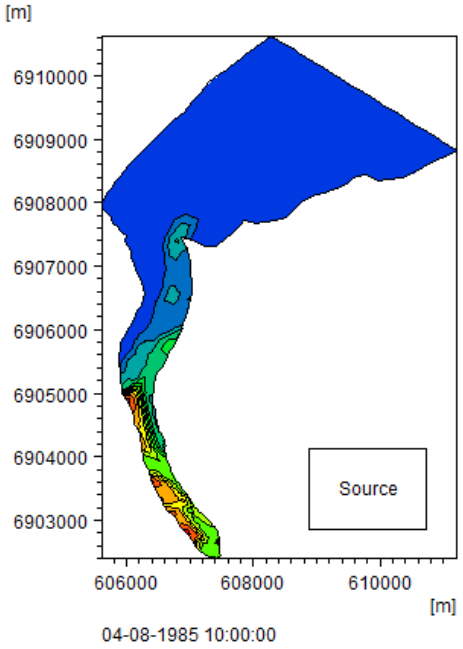
Concentration decreases from the river to the sea by mixing and decay

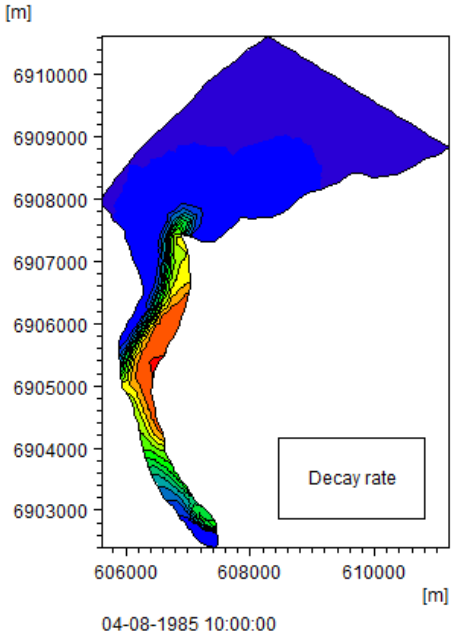
River input constant discharge / constant concentration

Effect of uncertainty formulation

There are many ways to perturb the model.

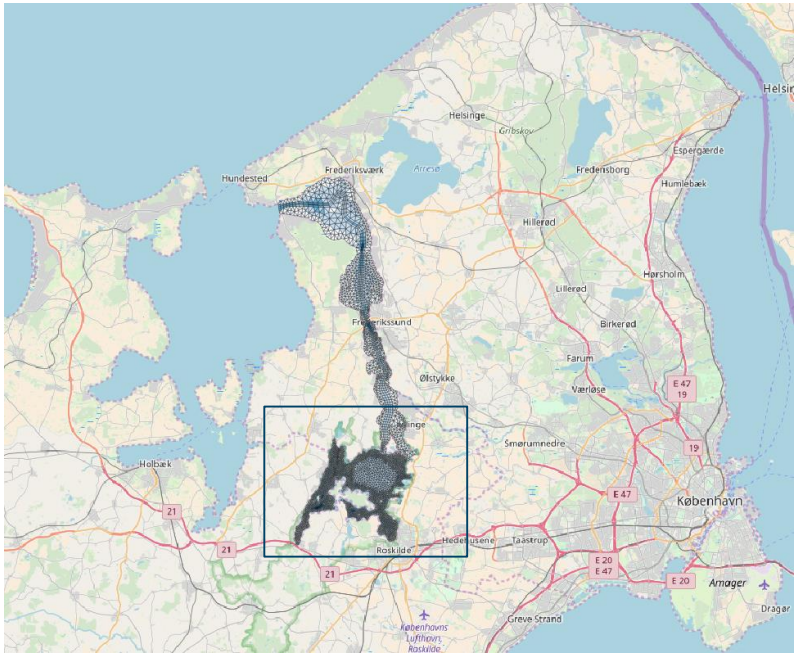
This will determine the actual model uncertainty and correlations both spatially and between variables

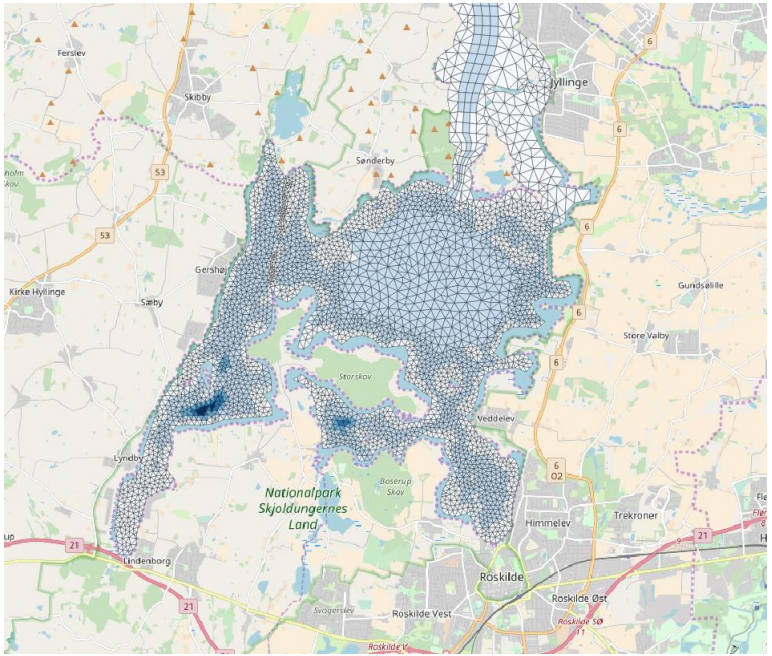




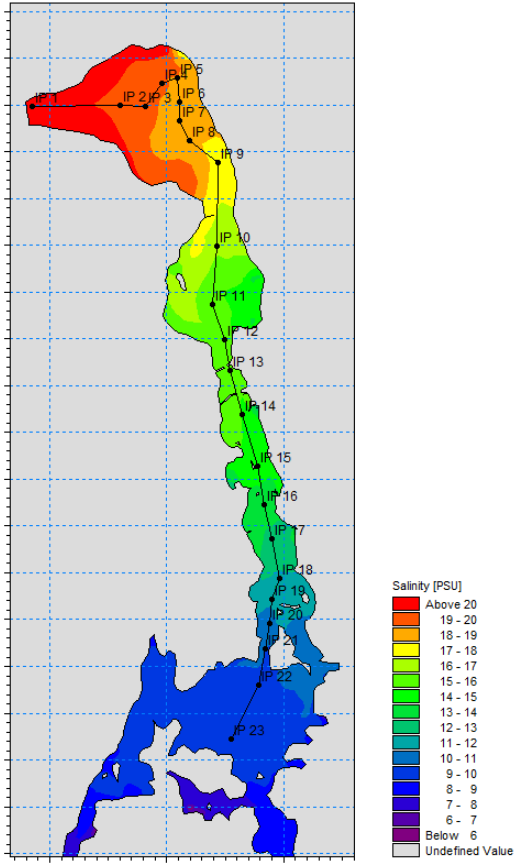
Standard deviation

Roskilde fjord

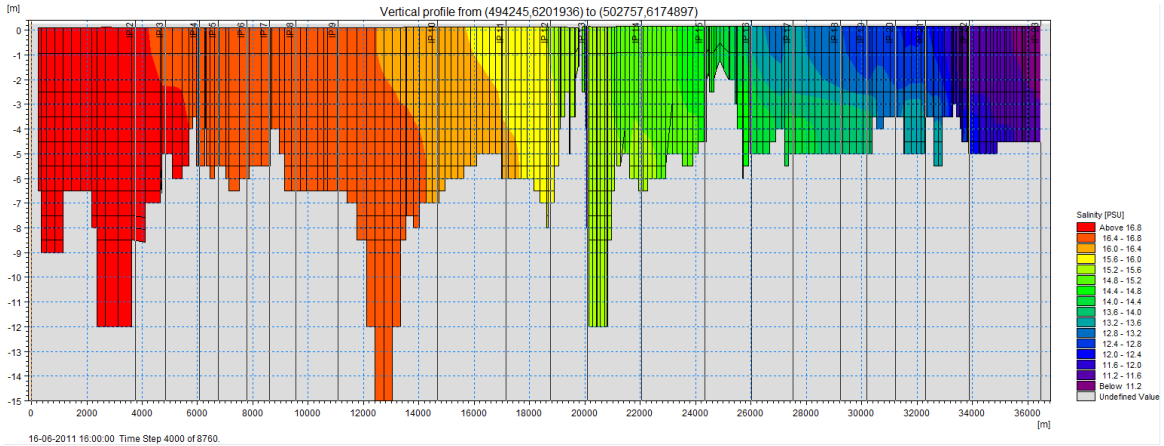




Roskilde fjord - hydrodynamics



- Shallow estuary (avg. depth 3m)
- Tidal amplitude 0.2m
- Horizontal salinity gradient (8-20 psu)
- Well-mixed most of the time



Roskilde fjord – ecosystem model

Variable element ratios (C,N,P)

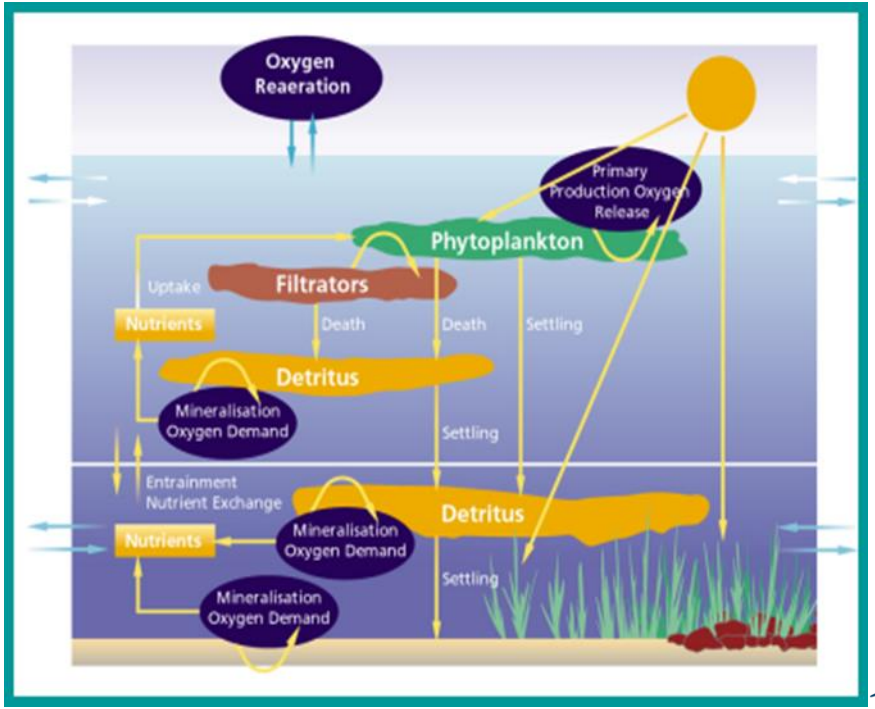
Benthic-pelagic coupling

Resuspension

22 pelagic state variables

30 benthic state variables

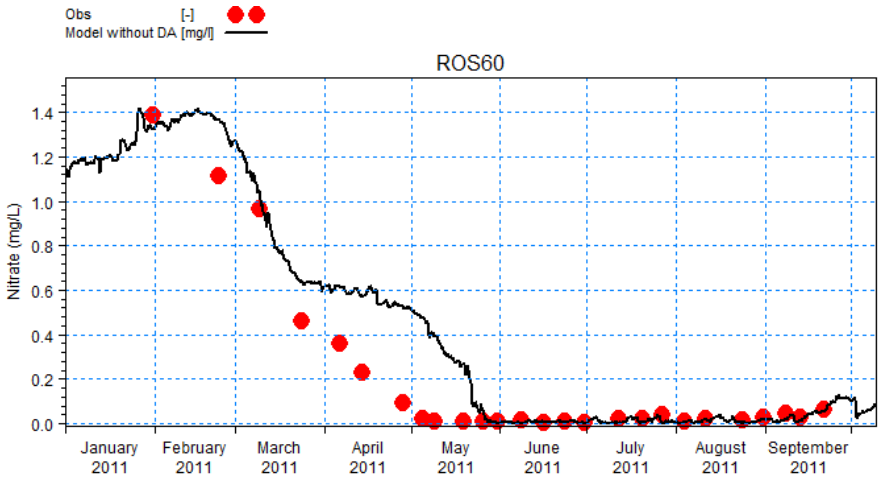
275 process parameters



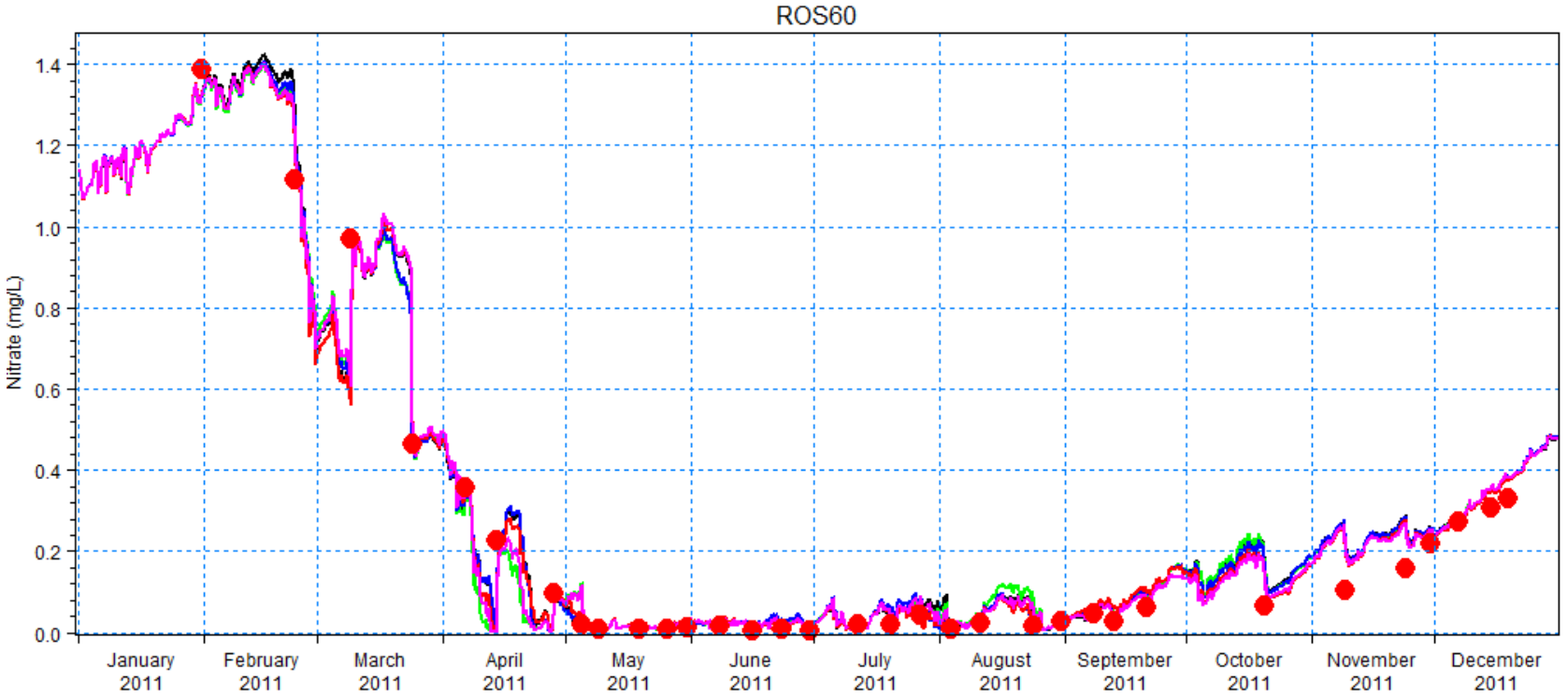
Proof of concept test case

- 5 selected parameters (e.g. max growth rate)
- 10 % error
- 5d temporal correlation

- Nitrate observations

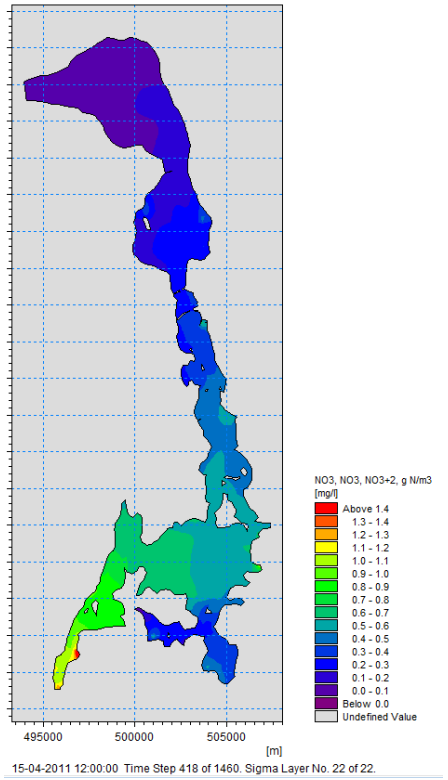


Results

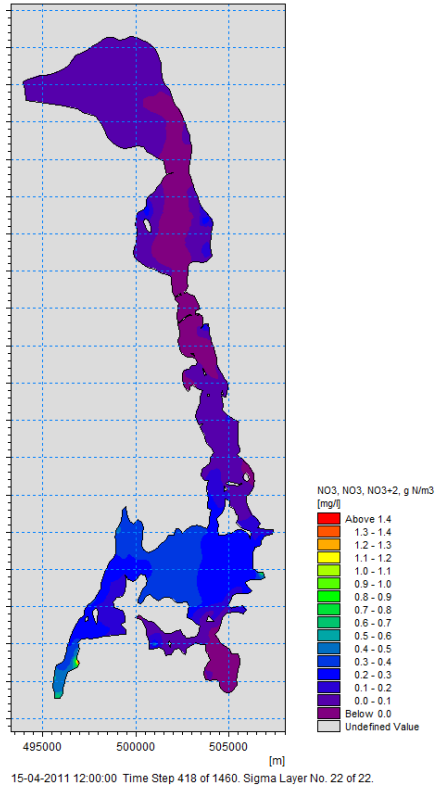

ROS60
Nitrate (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
January 2011
February 2011
March 2011
April 2011
May 2011
June 2011
July 2011
August 2011
September 2011
October 2011
November 2011
December 2011

Results

No DA



DA



Further work

- Rigorous testing of all features
- Include benthic variables in state
- Spatially variable parameters
- Enforce constraints (e.g. positive concentrations)
- …

- Develop a calibrated DA setup for Roskilde Fjord

Thank you