BOOS national activities in 2016

part1 - Modelling

BOOS STG
CMEMS Product Development last year: Waves

Set up:
- WAM 4.5.4 + few Baltic modifications
- Grid: 1 nmi
- 2 days forecast 2/day: hourly instantaneous values
- Atm: FMI-HARMONIE (2.5 km) / Estonian Weather Service 11 km)
- BDY: ECMWF wave spectra
- Product: 17 variables.

Pre-Qualification:
- 2 years: June 2014 – May 2016 at FMI

- Good forecast: storm event Jan 2017:
  \[ Hs \text{ obs}: 8.0 \text{ m} \text{ (record: 8.2 m)} \]
CMEMS Upgraded 3D ocean PHY & BIO forecast product: HBM-ERGOM

Sea ice module
Coastal-fast ice (freely drifting ice vs. immovable ice)
Ice dynamics (simple)

Turbulence scheme
new set of structure functions
(Canuto part III)

Atmospheric deposition:
upgraded to include spatial varying data
(oxidised and reduced nitrogen) (EMEP)

N/P ratio:
local quality improved by spatial variable N/P ratio
Ice ridging in shallow waters might lead to the development of anchor points that support the condition of rigidity.

In the context of plasticity, ice ridging is implemented as additional load compensating stress term.

Ridged fast ice yields to stresses that exceed critical limits. It can also be moved when it loses its bottom contact and gets afloat.

A ice ridging model has been implemented that describes the development of ice ridge thickness and ice ridge density (Mikko Lensu, IRIS project, Lars Axel, HIRLAM)

Jens Murawski, Eckhard Kleine, BOOS, Copenhagen, 23-rd May
Ice Ridging and Fast ice

When ice ridging occurs:

- The **number of ice ridges** per characteristic length scale (blue) increases, dependent on the convergence of the currents and a characteristic length scale.

- The **thickness of the ridged ice** (blue dots) grows, as a function of the ice volume, i.e. thickness.

- The **thickness of the ice-ridges** (sail-to-kiel) (red) increases, with a rate that depends on the level ice thickness (available ice volume); and reduces with the number of ice ridges per length scale. → saturation eqn.

**From Ridging to Fast Ice**

- Ridging has been implemented in the plasticity calculus
- When the kiel depth equals the total water depth, the ridged ice sticks to the ground and is transformed to fast ice.

Jens Murawski, Eckhard Kleine, BOOS, Copenhagen, 23-rd May
Model comparison with satellite data

The ice model is well able to predict the sea ice covered area, both the maximum extent and the change during the melting phase.

Modelled sea ice thickness is somewhat lower than observed values, even when the thickness of the ridged ice is considered. The analysis on the next page indicates that the observations do not only represent level ice, but also to some extent rafted or ridged ice.

Comparison at ice covered points
Product Quality Assessment: CMEMS Priority – continuous development

"online":
- Quarterly
- Work in progress...

pre-qualification
Multi-model-ensemble for BOOS & NOOS

BOOS: www.boos.org
NOOS: www.noos.cc

MME Community: BSH, DMI, FCOO, FMI, SMHI, IOPAN, MSI, UK MetOffice, Met.no, RBINS

Parameter
- sea surface temperature (SST)
- sea surface salinity (SSS)
- sea surface currents (SSC)
- sea bottom temperature (SBT)
- sea bottom salinity (SBS)
- mass transport (TRA)
- Water level

Download
ftp://ftp.bsh.de/outgoing/opmodel/my_ocean/MME

ben@bsh.de
Seamless modelling: coastal-estuary continuum

New DKSS
Storm Surge Setup

Logstoer, 500m resolution

Logstoer, 185m resolution

≈1nm (1’x1.66’)

≈3nm (3’x5’)

≈0.5nm (30’’x50’’)

185m resolution
River Data
E-hype3

public download page
http://hypeweb.smhi.se/europehype/time-series/

- Forecast data is used operationally
- Daily delivery of 10 days: yesterday, today, 8-day forecast run-off [m3/s] sanity checked
- 30-day accumulated nutrient load [T/30d] Total-N, Total-P
- Annual calender day climatology generated from 30 years of daily run-off (1980-2010) and 11 years of bioloads (2000-2010)
- 3032 coastal segments / rivers
- 846 North / Baltic sea river
- 31 Limfjord river (30 outlets)

E-Hype3 vs. HBV
~10x more outlet points
Test of HBM’s capabilities to run extensive set-ups

<table>
<thead>
<tr>
<th>Domain</th>
<th>Grid resolution</th>
<th>N3D points (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Sea (NS)</td>
<td>5km</td>
<td>0.48</td>
</tr>
<tr>
<td>Waddensea (WS)</td>
<td>2km</td>
<td>0.1</td>
</tr>
<tr>
<td>Danish Straits (DS)</td>
<td>1km</td>
<td>6.2</td>
</tr>
<tr>
<td>Baltic Sea Fine (BS²)</td>
<td>500m</td>
<td>103.64</td>
</tr>
<tr>
<td>Baltic Sea Nest (BS²ⁿ)</td>
<td>2 km</td>
<td>4.3</td>
</tr>
<tr>
<td>Gulf of Finland (GoF)</td>
<td>500m</td>
<td>10.72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nested Setup</th>
<th>Fine Setup</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS, WS, DS, BS²ⁿ, GoF</td>
<td>NS, WS, BS²</td>
</tr>
<tr>
<td>Number of 3D points (in million)</td>
<td>21.8</td>
</tr>
<tr>
<td>Expected memory use</td>
<td>10.81</td>
</tr>
<tr>
<td>Maximum run time ratio N-to-F</td>
<td>6.43</td>
</tr>
</tbody>
</table>
Nutrient tagging

- **Goal:** estimate of contribution of anthropogenic nutrient input to algea blooms and eutrophication
  - > Simulations with tagged nitrate input
ERGOM development

- Implementation of bio-optical module (Neumann, 2015) > interface to data assimilation
- Calculation of Secchi depth from $K_{par}$ > indicator for water quality
Drift modelling – Stokes drift
Downscaling forecast for GoR and 12 lakes
Vilnis Frishfelds, Uldis Bethers, Juris Sennikovs
University of Latvia

Resolution: blue ~ 2nmi, red ~ 1nmi
Bathimetry: EMODnet
Boundary conditions, atmospheric forcing, waves: DMI
River run-off: climatological
Ephemeris: NASA
Operational on UL cluster node with 32 cores ~5 days forecast
http://www.modlab.lv/meteo

HBM3D (left)
Swevolver 2D (right)
Prognose for oversvømmelse: projekt Varsko

Eksempel: Stormfloden Bodil, 6. december 2013

Sammenligning med forsikrings-information om oversvømmede huse
RCP8.5

2046-2065

2081-2100

delta change for 10 year return heights [cm]

Lower significance

Significant, 68% level

Significant, 90% level

Delta change for 10 year return heights [cm]
HBM-ERGOM (AU-BIOS)

A) The North Sea - Baltic Sea

B) Transition area

6nm-1nm set-up
DK river loads from AU
Waiting for E-hype data from DMI
• PP can occur even though there few nutrients:

\[ \mu C = \max \times T \times L_{\text{lim}} \times (\min (N_{\text{lim}}, P_{\text{lim}}, Si_{\text{lim}}) + \mu_{\text{min}}) \]

• C:N-ratio of phytoplankton varies with N-limitation from 0.04-0.15:

\[ CN = (0.036 + 0.115 \times N_{\text{lim}})^{-1} \]

• PP can now be estimated from phytoplankton biomass (BN), carbon growth rate (\(\mu C\)), C:N-ratio and C-mol weight (CW):

\[ PP_C = BN \times \mu C \times CN \times CW \]

**PRIMARY PRODUCTION (PP)**
PRIMARY PRODUCTION

Monthly means 2001-2009
- Data ± SD (●)
- Model (black line)
- Model mean ±SD (grey lines)

All stations: $R^2 = 0.59$, PMB= 1%, nSD=0.83
For at få punktopstilling på teksten (flere niveauer findes), brug 'Forøg listeniveau'.

For at få venstrestillet tekst uden punktopstilling, brug 'Formindsk listeniveau'.

Ændr 2. linje i overskriften til AU Passata Light.

Hydrodynamic model

Time averaged fluxes in original computational grid

Flexsem tool

Fluxes in Flexsem computational mesh

Pelagic equation solver

Sources

Light

HD offline

Advection-diffusion

Benthic equation solver

HDlite

Output

Post processing

Visualization

Calculations

- C++ and text files as input
- Fast, runs on normal pc

Offline system that can be used for local set-ups e.g. support the use of Copernicus products
NEMO-Nordic

- Name of the specific version used at SMHI (and other institutes), including...
  - ...namelist settings
  - ...bathymetries
  - ...minor code changes
- Ocean dynamics:
  - NEMO-3.6; "3.6_stable" from Paris trunk (r5628)
  - Included patch from UK Met. Office to be able to run four times a day
- Ice dynamics:
  - LIM-3.6
  - Five ice categories used
  - Fast ice parameterization added
  - Temporary fix for ice thickness (awaiting new advection scheme)
- Setups: See Adam's presentation ...
NEMO-Nordic

- NEMO-Nordic 60 hour forecast, operational since 2016-05-10
  - 1 Nautical mile resolution
  - 56 depth levels
  - Forced by:
    - Arome 2.5 km and ECMWF 9km
    - E-Hype
  - Runs four times a day, 00z, 06z, 12z and 18z
  - Output:
    - Netcdf
    - Grib
    - Surface and 3D-files
- Available on ftp until end of June. We will then transfer to SMHI open data/web service
NEMO-Nordic-SCOBI

• Biogeochemistry model developed at SMHI
  – Coupled to NEMO-Nordic ("NEMO-SCOBI")
  – Coupled to NEMO via TOP module
  – Reference version under evaluation now
  – Operational October 2017!

• Data assimilation adapted for NEMO-Nordic (physics)
  – 3D EnVar
  – LSEIK filter (based on PDAF)

• Data assimilation adapted for SCOBI (biogeochemistry)
  – May 2017: 3D EnVar (needs more development)
  – Summer 2017: LSEIK
NEMO-Nordic

Data assimilation
What happens next

• **NEMO-Nordic**
  • Data assimilation of ice (runs in test)
  • Improve grid
  • S and T at the open boundaries
  • Wind wave coupling
  • Ensemble forecast using MEPS 2018? (pre-study)

• **NEMO-Nordic-SCOBI** (biogeochemical) is tested in semi-operational mode. Operational version in October 2017

• **SWAN:**
  – Tests with Krill-forcing
  – Possibilities for longer forecasts
Future of oceanographic modelling at FMI using NEMO

Global version of NEMO is used in climate simulations.

For the Baltic Sea, three setups are used:
- 2 nmi setup for the North Sea - Baltic Sea (NEMO-Nordic, co-operation with SMHI)
- 1nmi setup for the Gulf of Bothnia (SmartSea project)
- 0.25 nmi setup for the Gulf of Finland (EXOSYSTEM project).

FMI also has a NEMO setup for the Kara Sea, which is currently being run in pre-operational mode. (KAMON project).
Nested NEMO Experiments Setups Summary

Three nested configuration runs and one reference model simulation run (2010-01-01 to 2010-12-31)

<table>
<thead>
<tr>
<th>North Sea Vert. Grid</th>
<th>Baltic Sea Vert. Grid</th>
<th>Danish Straits Resolution</th>
<th>Nesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-level</td>
<td>S-level</td>
<td>Coarse (2nm)</td>
<td>N/A</td>
</tr>
<tr>
<td>S-level</td>
<td>Z-level</td>
<td>Coarse (2nm)</td>
<td>N to B</td>
</tr>
<tr>
<td>S-level</td>
<td>Z-level</td>
<td>Fine (0.5nm)</td>
<td>N to D to B</td>
</tr>
</tbody>
</table>

Nesting consists of linear interpolated hourly forcing in the Danish Strait area via Flow-Relaxation-Scheme (FRS) for temperature and salinity and via Flather-Condition-Scheme (FCS) at the outer boundary of the nest for sea surface elevation and barotropic velocities.
Unstructured model of the North Sea and Baltic Sea

SCHISM
(Semi-implicit Cross-scale Hydroscience Integrated System Model)

- Horizontal triangular mesh consists of ~400k nodes
- Shaved sigma layers with max. 59 layers in the Norwegian trench
- Forcing at the open boundaries by CMEMS reanalysis (AMM7-Nemo) with horizontal, vertical tides; salinity, temperature
- Climatological river run-off based on SMHI ehype product
- Meteorological forcing from DWD (Ecosmo-EU model)
- Model integration starts 1 March 2014, covers the MBI of December 2014
Data Assimilation cooperation
PDAF - a software environment for ensemble assimilation
http://pdaf.awi.de/trac/wiki

**Partners & Role**
- DMI: HBM-PAF offline system
- BSH: HBM-PDAF online system
- SMHI: NEMO-PDAF offline system
- AWI: Developer, host repository

**Supporting groups:**
- HBM CDG (Thorger), Cal/Val (Simon)
SST assimilation improves subsurface in Baltic Sea
T/S errors for October / November 2012