BOOS Modelling Program: Scientific Plan 2016–2021

May, 2016

1. Introduction

In 2014 it was decided on HIROMB and BOOS Steering Group meetings that the HIROMB (High-Resolution Operational Model for the Baltic) cooperation should be a modelling program under BOOS, and simply be called the BOOS Modelling Program (BMP). As a result, the former HIROMB Scientific Plan will live on as the “BOOS Modelling Program Scientific Plan”, or simply the BMP Scientific Plan.

The former HIROMB cooperation started in the early 1990s, following a HELCOM Recommendation regarding development of an oil drift forecasting system, as a cooperation between BSH and SMHI in adapting a model at BSH to a more general Baltic Sea model. To comply with the HELCOM Recommendation, all states with a border to the Baltic Sea were later invited to join the project. Today national institutes from all these states participate in the cooperation. The purpose of the cooperation was to operate, maintain and develop at least one operational model system, and the HIROMB Cooperation Agreement regulated the scope of the cooperation as well as the member’s obligations in their joint efforts to further develop HIROMB and maintain it as an operational tool within the member’s governmental services and/or research activities. The purpose of the BOOS Modelling Program is to continue this joint effort, but instead being carried out as a Modelling Program under the BOOS umbrella.

The Baltic Modelling cooperation is in many respects a success. The original Baltic forecast model HIROMB has been operational at SMHI since 1995 and been developed ever since. Since 1999 there have been annual scientific workshops, where previous efforts and further development have been presented and discussed. Identified shortcomings and possible improvements have led to some scientific goals, which have been the basis for the Work Plan for the coming year. One of the purposes of the present Scientific Plan is to strengthen this process.

There is an increasing number of users of Baltic forecast models, with new requirements on the operational output. For example, in the first few years the main focus areas were oil spill spreading and sea level forecasts. Today, the usage has increased to encompass calculations of e.g. trajectories for larvae, environments for porpoises, sea ice forecasts etc.

This Plan collects existing scientific goals, and together with an overview of the present state describes the arguments and the paths towards reaching the goals. Additionally, the purpose of the Plan is to help stimulate work, spread a clearer view of what ought to be done, be the basis for the annual Work Plan and to stimulate discussions. The Plan covers the coming five years, and will be updated yearly.

The model development work within the BOOS Modelling Program is divided into several branches, developing different circulation models, which should be reflected in this document. The first one is the HIROMB model, which is still run at SMHI and MSI though development of this model has ceased. The second one is the so-called HIROMB-BOOS Model, or HBM for short, which has been developed within the EU funded project My Ocean (http://www.myocean.eu/) and follow-up projects. That code is the result of a merge of the previous model codes BSH-cmod and DMI-cmod, and to some extent also HIROMB. It has been used for daily forecasts at BSH and DMI within My Ocean and is currently used within the framework of Copernicus (http://marine.copernicus.eu/) in the Baltic Marine Forecasting Centre (Baltic MFC). The third circulation model is the GETM (General Estuarine Transport Model, http://www.getm.eu/) which is developed and run at FCOO. The fourth circulation model is the NEMO (Nucleus for European Modelling of the Ocean, http://www.nemo-ocean.eu/) ocean model, recently been put into operational use at SMHI and also tested at FMI. The idea is that this Scientific Plan will cover the development of all these four models, as well as related issues such as data assimilation.

2. Present state of model codes used within BOOS

2.1 HIROMB

2.1.1 Overview

The latest tagged version of HIROMB i version 4.5. Earlier bugs that are fixed in hiromb-4.5 include

- ice drift and melting did not work properly before
- river temperatures were not updated during the forecast
- the time levels of the output of meteorological variables were sometimes incorrect

some problems with the rotated coordinate system

Later changes made in the code, after the tagging of hiromb-4.5, include

- a bug fix regarding salinity in river points
- option to start from a GRIB file instead of unformatted fortran file
- option to read daily river runoff (not from the data_* file)
- option to write smaller surface GRIB files more often than full 3D fields
- new implementation of fast ice
- new namelist parameters:
    - UseDailyRunoff
    - UseGribStartfiles

- removed namelist parameter: DumpInitialField

At present, all HIROMB setups running at SMHI use version 4.5, including the Baltic and North Sea configurations NS03 and BS01 (see Figure 1) as well as the local configurations for Brofjorden on the Swedish west coast and Lake Vänern in Sweden. This is the reccommended version for use, as most known severe problems have now been fixed.

Some problems still remain in version 4.5, e.g.

- ice parallellization with many processors
- occurrence of unrealistically high values of turbulent kinetic energy

It is unclear if these problems will ever be corrected as the development work on the HIROMB model has ceased, in favour of other circulation models (see below). Nevertheless, here follows a list of features that hiromb-4.5 has, as a reference, and possibly also as an inspiration for the development work on other, more modern, circulation models:

- horizontal coordinate systems supported are regular lat/long as well as rotated grids
- vertical coordinate system is z coordinates with partial cells
- horizontal parallelization using Message Passing Interface (MPI) with pre-defined horizontal boxes, except for ice for which the work load is shared between all processors
- data format of input meteorological variables as well as output of ocean variables is GRIB
- data format of input and output of restart files is unformatted fortran
- state-of-the-art turbulence models, including
  - a two-eqwuation k-ω model
  - parameterization for Langmuir circulation
  - parameterization for internal wave energy
  - surface boundary conditions that include breaking surface waves
- viscous-visco-plastic ice reology
- vertical decay of shortwave radiation (non-infrared part)
- wind stress parameterization dependent on atmospheric stability
- possibility to have variable bottom roughness (external file)
- a script system that controls auxiliary programs to make setups in new areas easy
- GRIB output of
  - sea level
  - currents
  - mean currents (as opposed to instantaneous)
  - skin velocity
  - salinity
  - temperature
  - Turbulent Kinetic Energy (TKE)
  - dissipation rate of TKE
  - eddy diffusivity
  - ice drift components
  - ice divergence
  - ice concentration

- level ice thickness
- ridged ice thickness
- ridge density (number of ridges per km)
- ridge sail height
- snow thickness
- snow temperature
- bathymetry
- all meteorological forcing variables

An untagged trunk version of hiromb also exists (version 5.0?), with the following news:

- possibility to start from an output grib file (rather untested)
- can read an ascii file of river runoff in the format latitude, longitude, value, and automatically locate the river in the closest river point
- a slightly improved parameterization of fast ice

This version was used in the reanalysis in MyOcean2.

2.1.2 Known current setups of HIROMB

The nested configurations NS03-BS01 are still run four times a day at SMHI, though as of May 2016 they are no longer operational at SMHI. They are planned to be shut down in January 2017. The forecast length is 60 hours and the meteorological forcing is provided by a Swedish version of HIRLAM (High-Resolution Limited Area Model) with 11 km resolution.

In addition, the NS03 configuration is run twice daily at SMHI, with a forecast length of 10 days. The meteorological forcing is then provided by forecasts from the European Centre for Medium-Range Forecasts (ECMWF), currently with about 16 km resolution.

In late 2006, HIROMB was set up to run as a local model to simulate the circulation in the fjord Brofjorden on the Swedish west coast. It is run in an operational test phase since January 1, 2007. The horizontal resolution is 2”, or about 60 m, in the horizontal. The vertical resolution is 1 m down to 20 m depth, then increasing to 4 m resolution near the maximum depth of 84 m. See Fig. 2 (a). Boundary conditions in terms of sea level and salinity and temperature profiles are obtained from HIROMB-BS01 (1 nm resolution), and the forcing is supplied by a 5.5-km version of HIRLAM.

Since the summer 2011, SMHI also runs a local model for Lake Vänern (Sweden's largest lake). It is run once daily at 00 UTC 48 hours ahead with a horizontal resolution of 0.2 nmi (370 m). The vertical resolution is 1 m near the surface and 4 m near the bottom (about 100 m depth). See Fig. 2 (b).

HIROMB is currently used operationally at the Marine Systems Institute in Estonia, to simulate the circulation in the Gulf of Finland and the Gulf of Riga, with an open western boundary in the Baltic proper. The open boundary conditions are supplied by HIROMB-BS01, and the atmospheric forcing by a regional version of HIRLAM. The horizontal resolution is 0.5 nmi, and the vertical resolution is 3 m near the surface and 5 m near the bottom; see Fig. 2 (c).

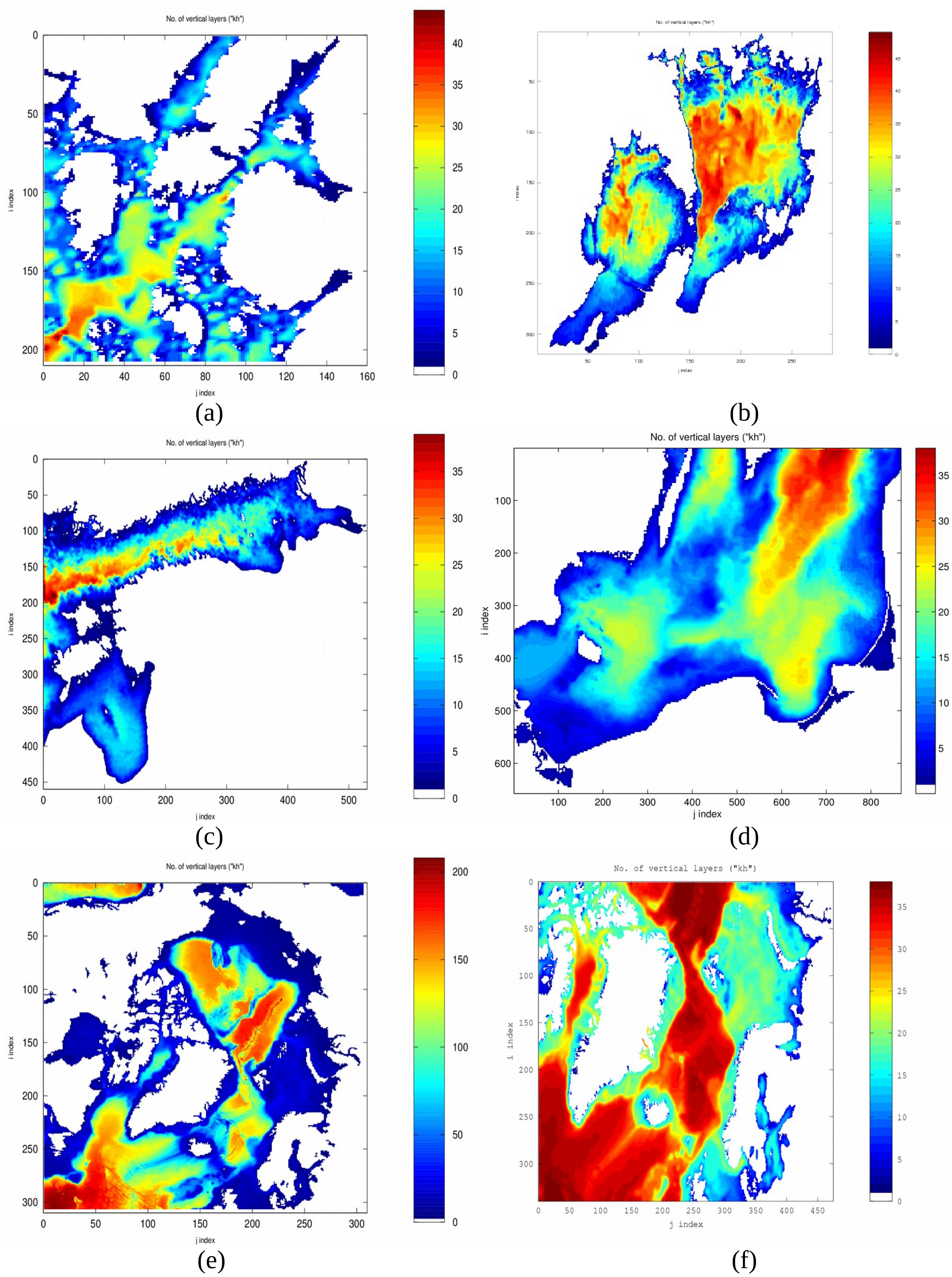

Figure 2. Local or regional setups of HIROMB in (a) Brofjorden , (b) Lake Vänern, (c) the Gulf of Finland and the Gulf of Riga, (d) southern Baltic proper, (e) the Arctic Ocean, and (f) the Atlantic sector of the Arctic Ocean.

At the Maritime Institute in Gdańsk (MIG), HIROMB has been set up in the southern Baltic proper. The configuration has a horizontal resolution of 0.33 nmi and a vertical resolution of 4 to 26 m in 38 vertical layers. See Fig. 2 (d).

Finally, there are two Arctic setups of HIROMB at SMHI. The first one has 12 nmi resolution covering the whole Arctic; see Fig. 2 (e). It has earlier been used in the EU-funded project DAMOCLES together with HIRLAM to make coupled experiments including data assimilation of the atmosphere-ice-ocean system. We completed a three-year reanalysis for the years 2005-2007. This setup of HIROMB required a rotated grid, which was introduced in version 4.0.

The other Arctic setup is from the summer 2012, which is a 6 nmi configuration of HIROMB for the Atlantic sector of the Arctic, including the Norwegian Sea, the Greenland Sea, and Baffin Bay; see Fig. 2 (f). It runs once a day 60 hours ahead on the same grid as the 11-km HIRLAM which is used as forcing. Data assimilation is made using SST and Sea Ice Concentration (SIC) only.

2.1.3 Identified weaknesses and shortcomings

Too shallow surface layer during autumn and winter:

Some data have indicated that the mixed layer thickness in HIROMB is too small during winter. This can have several causes, but the most probable reason is that a turbulence constant related to convection has a too low value and thus could be tuned. No literature value exists for this constant as the buoyancy-extended version of the k-ω model is rather new. Further investigations into this matter are needed.

A bug occurring during severe ice conditions

During severe winters, HIROMB-BS01 may crash in certain ice conditions. We believe this bug is related to the parallelization of the ice part of the code and occurs when different blocks have different ideas whether a certain grid cell has ice or not. It also seems to be related to the open boundary, which in BS01 is located south of Norway. During mild or normal winters there is usually no ice in this area which may explain why it only occurs during severe winters. The bug has temporarily been fixed by forcing the external boundary to have just one single block, thus making MPI communication unnecessary near the boundary. A more permanent bug fix would be welcome.

Limitation on the maximum number of processors

HIROMB uses MPI for parallel computing to decrease the computational time. For the circulation part of the model the parallelization strategy is to divide the domain into hundreds of fixed blocks. The ice is treated differently, as the ice is normally present in only part of the model domain. However, the ice parallelization sometimes has problems when using more than 32 processors, which of course is a limiting factor during the ice season. The reason for this is yet unknown. For the circulation part of the model there is no such upper limit on the number of processors.

3. Present state of HBM

The development of the HIROMB-BOOS Model (HBM) was initiated during the (first) MyOcean project, funded by the EU.

4. Present state of NEMO

NEMO (Nucleus for European Modelling of the Ocean) is a state-of-the-art ocean modelling framework. It consists of the following five major components:

- the blue ocean (ocean dynamics, NEMO-OPA)
- the white ocean (sea ice, NEMO-LIM)
- the green ocean (biogeochemistry, NEMO-TOP)
- the adaptive mesh refinement software (AGRIF)
- the assimilation component (NEMO-TAM)

The NEMO code is freely available under the CeCILL license (public license). As a result, it is used by a large community. As of 2015, it is used in about 100 projects and has about 1000 registered users of which half reside in Europe. The NEMO development is controlled by a European Consortium, which presently is a coopoeration between CNRS (France), Mercator-Ocean (France), NERC (UK), Met Office (UK), CMCC (Italy), and INGV (Italy).

The latest stable release came the summer of 2015 (version 3_6_STABLE) and replaces all earlier versions. More information can be found at http://www.nemo-ocean.eu/.

SMHI has several configurations using NEMO, including two North Sea-Baltic Sea configurations with resolutions of 1 and 2 nmi, respectively, called Nemo-Nordic-NS01 and Nemo-Nordic-NS02 (having the same domain as HIROMB-NS03). The former is used operationally at SMHI since May 10, 2016 whereas the latter one is used for climate simulations, with or without coupling to the biogeochemical model SCOBI. In addition, test configurations exist covering (1) the Persian Gulf, (2) Nares Strait, (3) the Baltic Sea only, and (4) the northern baltic Sea.

There are also two storm-surge configurations, called Nemo-Storm, covering slightly different areas of the northern North Atlantic with 6 nmi resolution.

5. Present state of GETM

The development of the General Estuarine Transport Model (GETM) was started in 1997. It is a 3-D baroclinic circulation model written in modular FORTRAN 90/95 code. It includes an interface to the General Ocean Turbulence Model (GOTM), allows drying and wetting of cells, has general vertical coordinates and horizontal curvi-linear coordinates. The latest stabel release is version 2.4. It is a Public Domain model published under GNU Public Licence. More information can be found at http://getm.eu/.

The Danish Defence Center for Operational Oceanography (FCOO) is running in operational production three nested setups (Büchmann *et al.* 2011) of the General Estuarine Transport Model, GETM (Burchard *et al.* 2009, 2010). GETM is an open-source finite-difference based model, which use the General Ocean Turbulence Model, GOTM (Burchard *et al.*, 1999), and is capable of running both 2D (barotropic) and 3D (barotropic or baroclinic) simulations. For 3D simulations, GETM uses split-mode between 2D and 3D time steps.
The three GETM setups are configured as one-way nesting, with differing horizontal resolutions – ranging from roughly 3nm over 1nm to 600m.
The “outer” 3nm North Atlantic setup is denoted “NA3”, and runs as a (2D) barotropic storm surge model. Boundary conditions for this model are Flather conditions based on so-called inverse-pressure combined with an annual steric effect and zero-velocities, see Büchmann *et al.* (2011). The meteo forcing is delivered by the DMI operational model HIRLAM T15 (Petersen *et al.* 2005) with 4 daily forecasts and 1h temporal resolution. The NA3 surges (elevation and fluxes) are combined with astronomical tide predictions of elevations and velocities (Egbert and Erofeeva 2002; GETM-UTILS) to yield boundary conditions for a 1nm baroclinic North Sea – Baltic Sea setup, denoted “NS1C”. Boundary conditions for salinity and temperature are computed from monthly climatological values. The NS1C setup includes the entire English Channel, and use 60 layers of general vertical coordinates (Hofmeister *et al.*, 2005) with zooming toward surface and sea bed for the vertical discretization. This vertical coordinate description is used also for the 600m Kattegat – Arkona Sea setup, denoted “DK600”. For both NS1C and DK600, the operational DMI HIRLAM S03 is used for meteo forcing. Fresh-water sources (river) data are obtained by the combination of BSH river runoff measurements and SMHI’s operational fresh-water model HBV (Bergström, 1992). All three setups are so-called free-runs without any operational data assimilation. The entire model complex is run in forecast mode four times per day, each forecast providing data for the following 54 hour period.

FCOO provide forecasts to BOOS of sea level at coastal stations, transport along transects, and surface fields of temperature, salinity and currents.

In June 2014 the following updates of the operational setup were done:

- New GETM source code, new subdomain division (and compiler flags).
- Investigated the effect of smoothing the met-forcing between two epochs. In the operational setup there is a linear interpolation of the first six hours, from the previous to the latest met-forecast. For the new operational GETM setup, the time period of interpolation increased from six to nine hours, which will result in decreased amount of energy in the high energy spectra.
- Increased sea level offset at the open boundary of the North Sea - Baltic Sea setup of GETM to better predict sea level in the Danish waters.

Ongoing developments:

- Include a thermodynamic sea ice model
- Shifting vertical coordinate system from general vertical coordinates to adaptive vertical coordinates.
- Examine the model internal variability. The variability are evaluated in relation to results from (slightly) changed model setups to gauge how much information is

needed in order to determine if one model setup is better (or just stochastically significantly different) from another.

6. Data Assimilation

In this section we will summarize the Data Assimilation (DA) methods being used or being developed within the HIROMB community. The list is far from complete, but the aim is to increase the amount of information about DA methods successively with the help from concerned institutes.

6.1 The univariate Optimal Interpolation method (OI)

The univariate Optimal Interpolation (OI) method was used at SMHI since the switch to HIROMB-4.0 in 2009. It succeded the former Successive Corrections Method (SCM) used earlier since HIROMB-3.0. The current OI implementation is included in the HIROMB code distribution since many versions back and is avaialable to anyone who is interested in using it. For best performance it should be used with an auxilliary file with information about horizontal lengthscales and ellipse orientation angles. Such files are also part of the HIROMB distribution for some existing setups, and new ones can easily be constructed using the program `./DataAssimilation/CalcLcoast_alpha.f90`. The lengthscales and the ellipse orientation angles are used to parameterize Background Error Covariances (BECs) for salinity and temperaure.

The OI method, as it is implemented here, is basically univariate (i.e. one variable is assimilated in isolation from the others), but the implementation makes it pseudo multivariate in certain ways as e.g. assimilation of sea ice concentration affects sea ice thickness and vice versa. Further, a certain dependence between temperature and ice is also implemented.

The input/output (I/O) format of the code was originally adapted to the operational HIROMB code. However, since HIROMB-4.4 there is also the possibility to choose I/O format according to the HBM model, as it has been used within the MyOcean project with that model. In the latest tagged version it does not work for nested HBM grids, however, but there is work in progress to fix this.

6.2 The Ensemble Optimal Interpolation method (EnOI)

An ensemble-based OI method (EnOI) has been implemented at SMHI, for use in a reanalysis project for the Baltic Sea. It uses statistics from a multi-year free model run to calculate BECs. The implementation is multivariate, which means that several variables may be affected for each observation. It has been verified mainly for salinity and temperature, but tests have also been made for biogeochemical variables. It has not been tested for sea ice yet.

Currently the implementation only supports the I/O format of the Rossby Centre Ocean (RCO) model used for climate simulations at SMHI. According to future plans it will soon be adapted to the NEMO model as well.

6.3 The Three-Dimensional Ensemble Variational method (3D EnVar)

An ensemble-based variational method (3D EnVar) has been implemented at SMHI during the past few years (Axell and Liu, 2016). Just as in the case of EnOI, it calculates the

BECs from ensemble statistics of previous model runs. The main difference is in the way the analysis is calculated. In EnOI it is calculated by inverting a large matrix, whereas in this method (and any other variational method) it calculates the analysis by minimizing a cost function which depends on the the first guess as well as available observations. Whereas EnOI calculates the assimilation increments locally, En3D-Var is a non-local method which calculates assimilation increments for the whole domain at once.

Just as in the EnOI method, the implementation is multivariate, i.e. many variables are affected at the same time. It was initially developed mainly with sea ice in mind but works well for salinity and temperature as well. Other variables such as currents and sea levels are also included (optional). The implementation currently only supports the I/O formats of HIROMB and NEMO.

When Nemo-Nordic-NS01 became operational on May 10, 2016, the 3D EnVar method became the operational data assimilation method at SMHI as the univariate OI method used operationally with HIROMB has not been adapted for NEMO.

By taking full and explicit account of the time dimension, it is possible to extend the 3D EnVar code to four dimensions, making it 4D EnVar. This development is planned for the near future and is expected to have a positive impact on variables that have short time scales such as surface currents and sea levels.

Another planned development is to include radial velocity components in the observation operator, to make it possible to assimilate radial velocity components from HF radars. So far, only eastward and northward components have been assimilated in tests, calculated from a pair of HF radars on the Swedish west coast during 2015.

7. Model-independent investigations and improvements

7.1 Ensemble forecasts

It has long been recognized that sea level forecasts may benefit from an ensemble approach. Since many years, this has already been used on the Ocean Web page, in the form of a multi-model ensemble. This is all well, but the ensemble concept may be taken further by forcing a (single) model with e.g. the 51 atmospheric forcing ensembles provided by the ECMWF. This has recently been tested at SMHI and may in the future be part of the sea level forecasting system.

An ensemble system was set up for HIROMB ice forecasts in the Polar View project. For technical reasons, these have been discontued since 2015, but as ensemble data assimilation is becoming more popular, it is possible that a new ensemble forecast system may be set up at SMHI in the future, including more variables than just sea ice and SST.

In the meantime, BSH has set up a multi-model ensemble forecast system which can be viewed on the BOOS home page.

7.2 A new model of the mechanics of sea ice

HIROMB's model of sea ice dynamics needs to be replaced. As practical experience has shown, it does not do well in capturing significant features of the sea ice field. It also sometimes requires considerable computing time without producing adequate forecasts. Fundamental revision is in order, concerning both physics and numerics.

The model's purpose is to reproduce the essentials of the sea ice cover at synoptic scale, in a way like ice charts. It is not about minor details or features at fine scale, but an expedient description of sea ice along with some suitably idealised mechanics. The envisioned model is intended to serve general purposes. It should equally well account for both drift ice and coastal fast ice, spanning the entire range of intermediate states in between ideally intact and fully granulated. As a key to improved ice mechanics at synoptic scale, the structure of the ice field must be built into any model. Compared to standard sea ice mechanics models, the description of structure should be significantly and fundamentally enhanced. In addition, the structure is subject to changes among which some are due to mechanics (drift, rearrangement).

According to its aim (synoptic scale), a continuum mechanics model should be appropriate. The approach may be and should be phenomenological inasmuch as suitable modelling tools are ascertained and combined in order to capture the object in its essential features. In particular, the ice field is considered as a rigid-plastic medium. The stress field is made statically determinate by a simple constitutive assumption: minimum stress.

The main problem is to characterise the material's strength and its evolution as the ice field is deformed. To do so, the anisotropy of the material is described in terms of simple deformation modes and their associated strengths. As general concept to accommodate a wide variety of ice forms, consider partially intact material which, at the same time, is partially broken. This very naturally gives rise to frictional behaviour, an essential feature of fractured and fragmented media. In terms of structural strength, pressure-sensitivity of strength a special parameter is appropriate, named intactness. To account for size effects, length scales and moment stresses are built into the model. To close the model, evolution equations for the varying material parameters are required.

7.3 Operational model quality assurance

Continuous daily model validation of parameters that are collected more or less in real time can be implemented operationally to give a clue on how good each day's model forecast is. If possible the quality of the forcing model should be used as well. To be able to do this operationally, good methods for this type of validation/quality assurance must be found. This type of work can be done at any of the institutes involved. Plausible, but not necessary, the final operational daily validation can be made at SMHI. E.g, we could start validating the sealevel forecasts from different institutes used on the Ocean Web (see http://produkter.smhi.se/OceanWeb/).

7.4 The currents and flow rates in the Belts

The first current and flow rate validation was done around 2000, and showed that HIROMB greatly underestimated the current and flow rate magnitude. Validation of version 3.0 showed that this error now was more or less corrected. It is important to confirm that this good behaviour is still present in later versions.

7.5Coordination of validation studies and data requisition

The tasks are performed in two parts, sections *Validation studies* and *Data requisition* below. Detailed specifications are given in section *The Most Important Parameters (MIPs) for validation.*

7.5.1 Validation studies

A comprehensive document should be compiled containing:

a. Compilation of all made validations
b. List of procedures and methods. This must be based on work already reported.
A volunteer is needed for compilation.

Each member institute appoint a contact person for co-ordination of work and data, who should:

- Notify when validations are in progress.
- Spread the word about notifications.

The primary purposes and ways to make validations are known to be:
- Investigation of single extreme events (extreme values for the MIPs, oil spill drift events, ecology, upwelling, etc)
- Validation of products of the individual member institutes
- On-line quick look comparison (OceanWeb)
- Using basic statistics of model performance

7.5.2 Data requisition

This task is performed partly by the Operational Coordinator. Each member institute reports on observations available for validation over the last 3 years. The BMP partners will accept a list of Most Important Parameters (MIPs, see below) as high priority parameters in validation work.

During permission procedures for offshore construction projects, such as the NORDSTREAM Gas pipeline ADCP moorings, the responsible institutes shall demand data. The BMP partners will appoint persons to work on potential measurement campains:

- Validation campaign on currents. This may be performed by the Operational Coordinator.
- HF-radar investment
- Ferrybox on-line quick look comparison (Oceanweb)

7.5.3 The Most Important Parameters (MIPs) for validation

MIPs and user needs that drive basic requirements on validation are:

Parameter	Driver
Sea Level	Warnings
Surface Current	Oil spill and Search and Rescue
Sea surface temperature	Coupling to Meteorology, Sea Ice and the Public
Halo- & thermocline depth	Ecosystem modelling

Ice concentration	Navigation in ice

Some major observational sources for the MIPs are:

Sea Levels:
- Observations are available (on-line cal/val, basic statistics and extreme events)

Currents:
- HF-radar investments needs planning and coordinated actions from BMP partners
- Bottom mounted ADCP sections in areas (up to 1 year)
- Strong needs for campaign validations.
- Coordination within the HIROMB project is performed by the Operational Coordinator,

and the task comprises:

- Ship borne ADCPs (Aranda, Oceania) cross sections
- Complemented with modern Drifters (T. Rossby)
- Should be performed 2009
- Fund rising: Carlson foundation, BONUS+, Interreg programs

Sea surface temperature:
- Ferryboxes (on-line cal/val, basic statistics)
- Research Cruise data (basic statistics)
- Buoys (on-line cal/val, basic statistics)

Halocline/Thermocline depth:
- CTD.data (basic statistics)
- Batfish data (basic statistics)

Ice concentration:
- National ice charts
- Satellite data (AMSR-E, SAR, etc)

8. References

Axell, L. and Liu, Y. (2016) Application of 3-D ensemble variational data assimilation to a Baltic Sea reanalysis 1989-2013, Tellus A, 68, 24220, http://dx.doi.org/10.3402/tellusa.v68.24220.
Axell, L. Weaker Surface Currents in HIROMB 3.1., 9th HIROMB Scientific Workshop 28-31 August 2006, SMHI, Gothenburg, 25 slides, www.environment.fi/syke/hiromb

Bergström, S. (1992) The HBV model - its structure and applications. SMHI Reports RH, No. 4, Norrköping.

Büchmann B., Hansen C. and Söderkvist J. (2011) Improvement of hydrodynamic forecasting of Danish waters: impact of low-frequency North Atlantic barotropic variations, Ocean Dynamics, Vol 61, Issue 10, pp 1611-1617

Burchard, H., K. Bolding, and M. R. Villarreal (1999) GOTM – a general ocean turbulence model. Theory, applications and test cases, Tech. Rep. EUR 18745 EN , European Commission. http://www.gotm.net/pages/documentation/manual/stable/pdf/a4.pdf Accessed 28 May 2014

Burchard H, Janssen F, Bolding K, Umlauf L, Rennau H (2009) Model simulations of dense bottom currents in the Western Baltic Sea. Cont Shelf Res 29:205–220

Burchard H, Bolding K, Umlauf L (2010) GETM Source Code and Test Case Documentation Version pre 2.0.x. http://www.getm.eu/data/getm/doc/getm-doc-devel.pdf. Accessed 28 May 2014

Egbert GD, Erofeeva SY (2002) Efficient inverse modeling of barotropic ocean tides. J Atmos Oceanic Technol 19(2):183– 204

GETM-UTILS. GETM Tidal Boundary Conditions http://sourceforge.net/p/getm-utils/wiki/OtpsTides/. Accessed 28 May 2014

Hofmeister, R., J.-M. Beckers, H. Burchard: Realistic modelling of the exceptional inflows into the central Baltic Sea in 2003 using terrain-following coordinates. Ocean Modelling, Volume 39, 2011, Pages 233-247, doi: 10.1016/j.ocemod.2011.04.007

Petersen C., Kmit M., Woetmann N., Nielsen, Amstrup B. and Huess V. (2005), Performance of DMI-HIRLAM-T15 and DMI-HIRLAM-S05 and the storm surge model in winter storms, DMI Technical Report 05-13, ISSN: 1399-1388, Danish Meteorological Institute