Assessment of model skill in the Baltic Sea

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DMI provides meteorological, oceanographic and related services for the community within the large geographical area of the Kingdom of Denmark (Denmark, the Faroe Islands and Greenland), including surrounding waters and airspace.

Contents

Summary

Regional hindcast simulations for the period 1990-2009 have been made using the OPEC regional model systems for both the biogeochemical and HTL model components. This document records the assessment of the model system's performance. The hindcast skill is evaluated using the benchmark tool developed in the framework of OPEC.

The results indicate that all regional model systems demonstrate a range of skill, depending on the variables chosen. Physical variables (e.g. T, S) are generally have the most skill) followed by chemical variables (e.g. O_2, Nutrients) then plankton variables (e.g. chlorophyll) for the coupled hydrodynamic LTL models. The HTL models have more skill for small pelagic fish (e.g. Sprat in the Baltic and Anchovy in the Aegean) than the plankton model that drives them. However the skill for larger pelagic and demersal fish is generally poor.

Introduction

A primary objective of OPEC was to set-up the ecological model system for the next generation GMES marine ecological service in European Seas. Each regional model system comprises a core coupled hydrodynamic-plankton model, a HTL component, a representation of the carbon chemistry and a data assimilation system. These have been used to perform 20yr hindcast of each region and to benchmark model performance. This document focuses on assessing the performance of the hindcast model systems with an emphasis on evaluating the performance of key policy relevant metrics. The goal is to benchmark the quality of the regional hindcasts, firstly to inform users of the data products about the skill and hence usefulness of the simulations, secondly to provide a benchmark against which future model development can be assessed.

Model skill scores are colour coded to give an indication of model skill as follows; Good = green, Moderate = Black, Poor = Red; correlation r Good > 0.75, poor < 0.20, M good = > 0.75, Poor = < 0, Reliability index Good 0.8-1.2, Poor > 2 or –ve. PBias, Good = < 20%, Poor = > 100%.

1. Baltic Sea

1.1 Description of the hindcast simulation experiment

Long term (1990-2009) hindcast in the Baltic Sea uses the physical-biogeochemical coupled model HBM-ERGOM. The model used to implement the hindcast is the operational model system operated in Danish Meteorological Institute (DMI) which provides operational forecast for the Baltic Sea. The technical details of the circulation model HBM were reported by Perg and Poulsen (2012). The biogeochemical model ERGOM was developed by Neumann (2000) and Neumann et al. (2002). The adoption of ERGOM to the DMI operational system includes the development in three aspects. First, the parameters were recalibrated. Second, the model included an extra parameterization to reflect the impacts of suspended particulate matter (SPM) on light attenuation, which improves spring bloom timing in coastal regions (depth < 50m) (Wan et al., 2013). Third, the model used the varying N/P ratios, which improves spring bloom timing in coastal regions (depth < 50m) (Wan et al., 2014). The model setup for this hindcast used the 6nmx6nm horizontal grid with 50 vertical layers. The model performance was comprehensively assessed in Wan et al. (2012).

The initial fields for ammonia, nitrate, DIP and DO are extrapolated from the winter means of data (2001~2009) at 16 off-shore long-term monitoring stations from the International Council for the Exploration of the Sea (ICES) website (http://www.ices.dk/indexfla.asp). The initial fields for biological state variables are manipulated through repetitive runs. The open boundary conditions are configured with the data from the World Ocean Atlas 2001 (WOA01, Conkright et al., 2002) for nitrate, phosphate and DO, and the remaining state variables are set to zero. River loadings and runoffs are derived from outputs of the operational hydrological model. Atmospheric nutrient deposition values are based on Langner et al. (2009) and Eilola et al. (2009).

River runoff and nutrient loads are set with the daily averaged data derived from river measurements for 5 German rivers, operational outputs for 43 Baltic catchments by a hydrological model HBV run by the Swedish Meteorological Hydrological Institute (SMHI) (Bergström, 1976 and 1992), and climatology for the remaining rivers.

1.2 Results of lower trophic level

The overviews of the hindcast products are displayed through their climateologies. The climateologies based on the hindcast results are snapshotted for the distributions of Chl, DIN, DIP and DO in the surface (Figure 1) and their profiles along the section of 20 °E (Figure 2). Five offshore observational stations (Figure 3 for location) are selected for the point-to-point comparison in the surface (Figure 4-9). As we can see, the model results can nicely reproduce the features of seasonal evolutions. The quality of data products are evaluated through the comprehensive model validation scheme (Wan et al., 2011). The results using the comprehensive model validation scheme are displayed in Figure 7. Table 1.1 lists the statistic metrics for Chl, DIN, DIP and Oxygen according to the scheme described in D2.3 (www.marine-opec.eu/downloads/OPEC_D2.3_tech.v1.pdf). Taylor diagram visually shows the standard deviation, correlation coefficient, centralized root mean error for Chl, DIN, DIP and Oxygen (Figure 10).

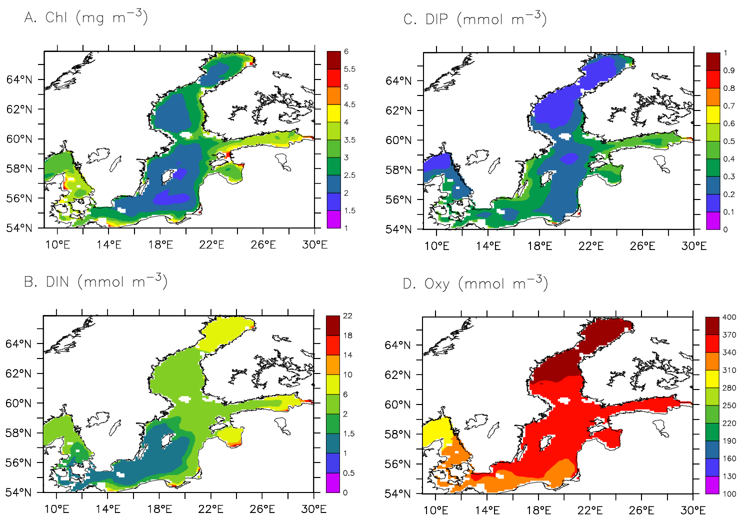


Figure 1. Climatological distributions in the surface for Chl (A), DIN(B), DIP(C) and Oxy(D).

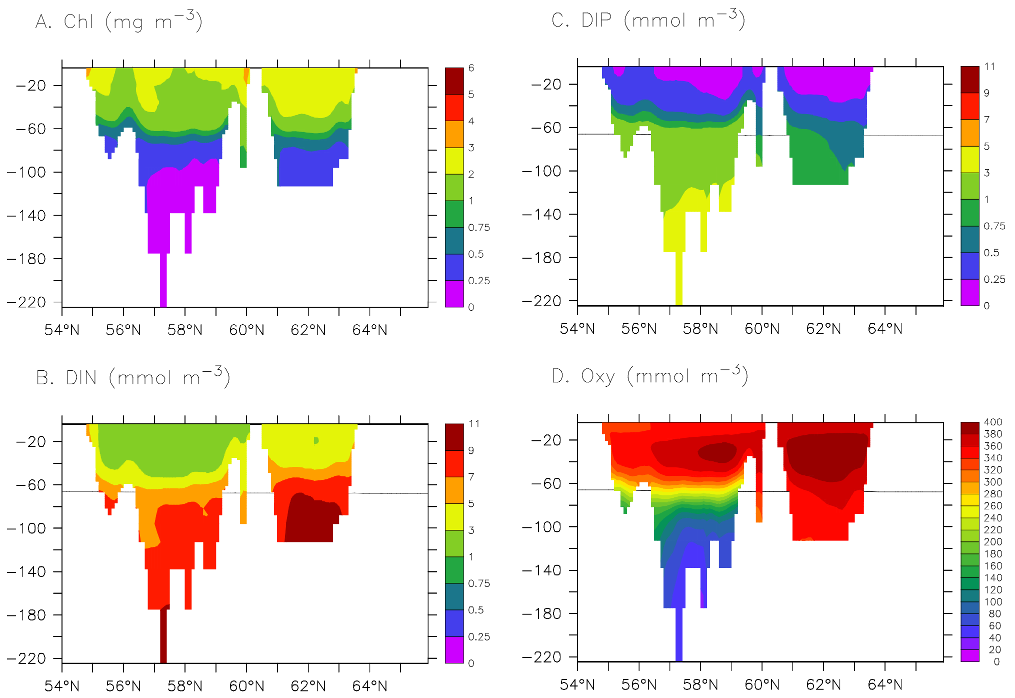


Figure 2. Climatological profiles along the section 20 °E for Chl (A), DIN(B), DIP(C) and Oxy(D).

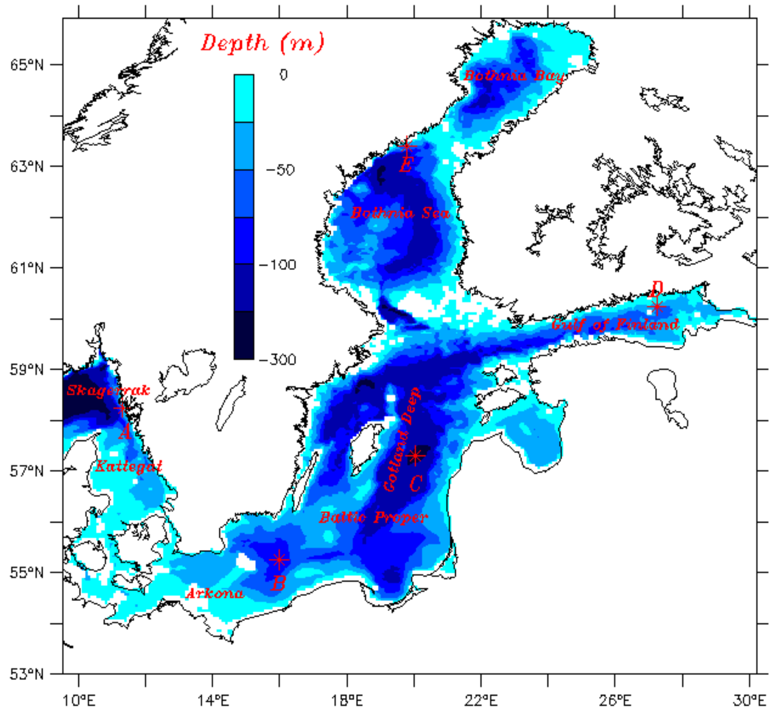


Figure 3. Topography of model domain and locations of 5 observational stations.

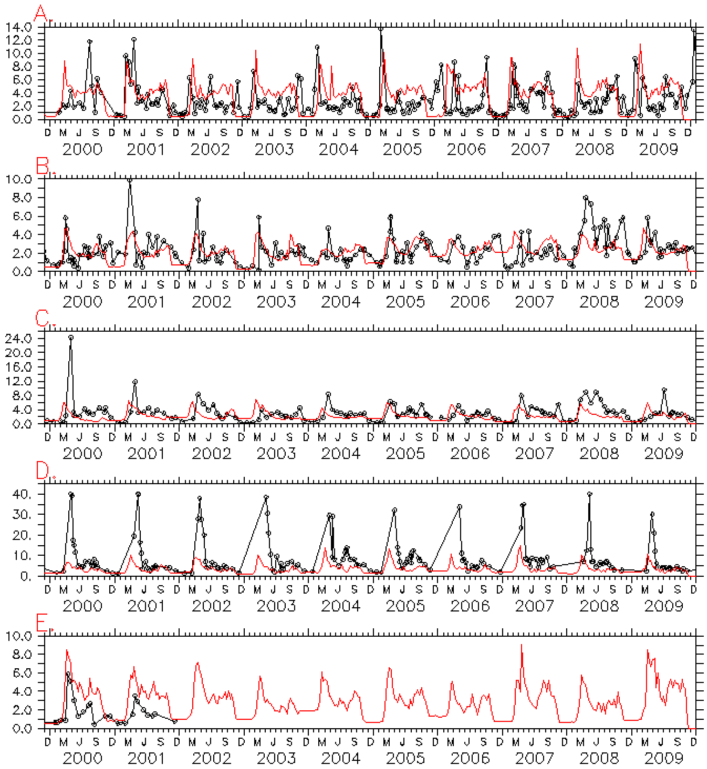


Figure 4. Seasonal evolution of Chl in the surface. Black cycles for observations and red curves for model results. Unit: mg m^{-3}. A-E for the stations labelled in Figure 3.

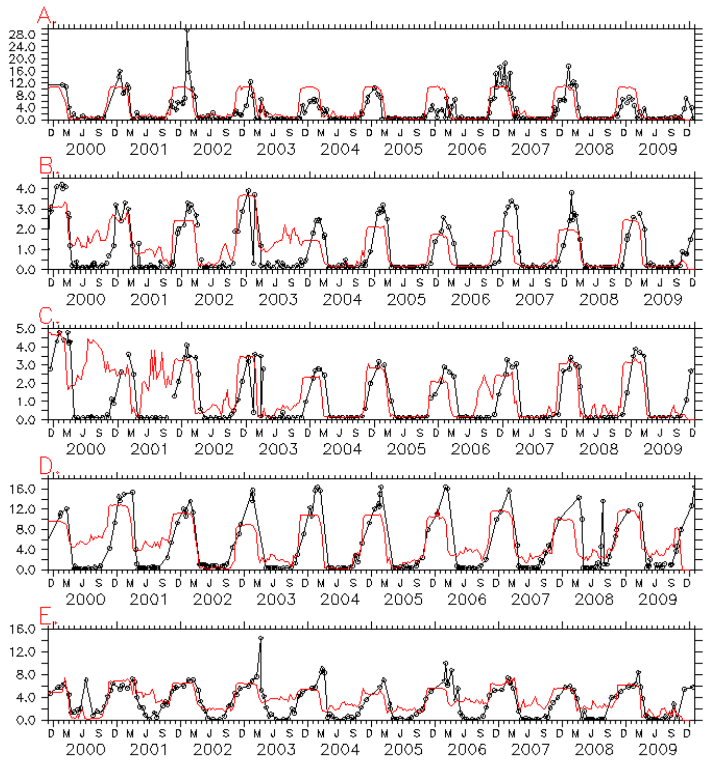


Figure 5. Seasonal evolution of DIN in the surface. Black cycles for observations and red curves for model results. Unit: mmol m^{-3}. A-E for the stations labelled in Figure 3.

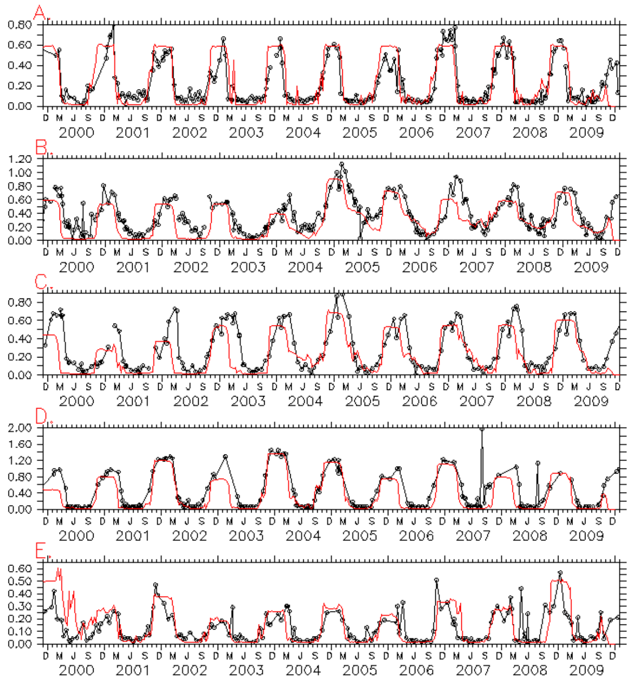


Figure 6. Seasonal evolution of DIP in the surface. Black cycles for observations and red curves for model results. Unit: mmol m^{-3}. A-E for the stations labelled in Figure 3.

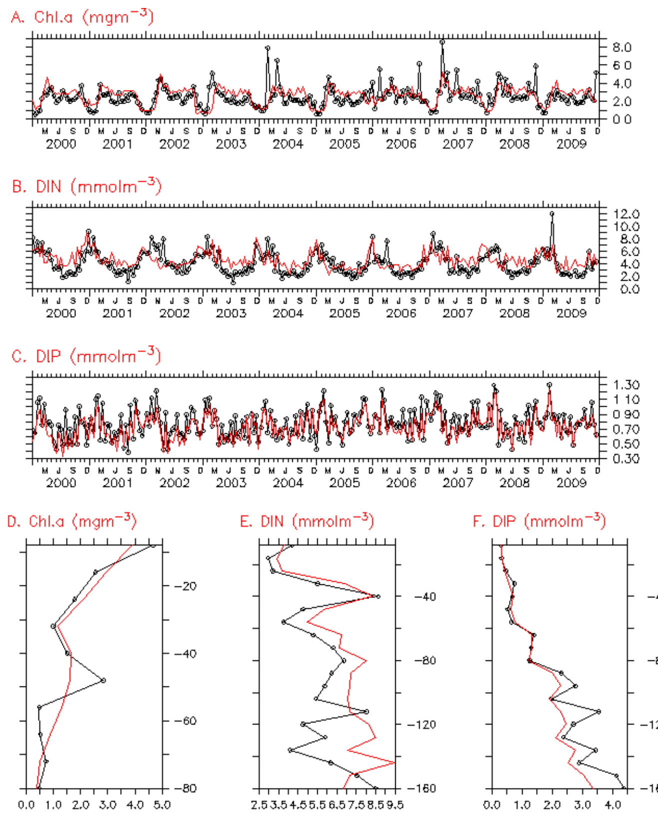


Figure 7. Comprehensive comparison between model (red curves) and observations (black cycles). Panels A-C depict the seasonal pattern of model biases for Chl, DIN and DIP, respectively, and Panels D-F show their vertical profiles (vertical axes for depth, unit: m).

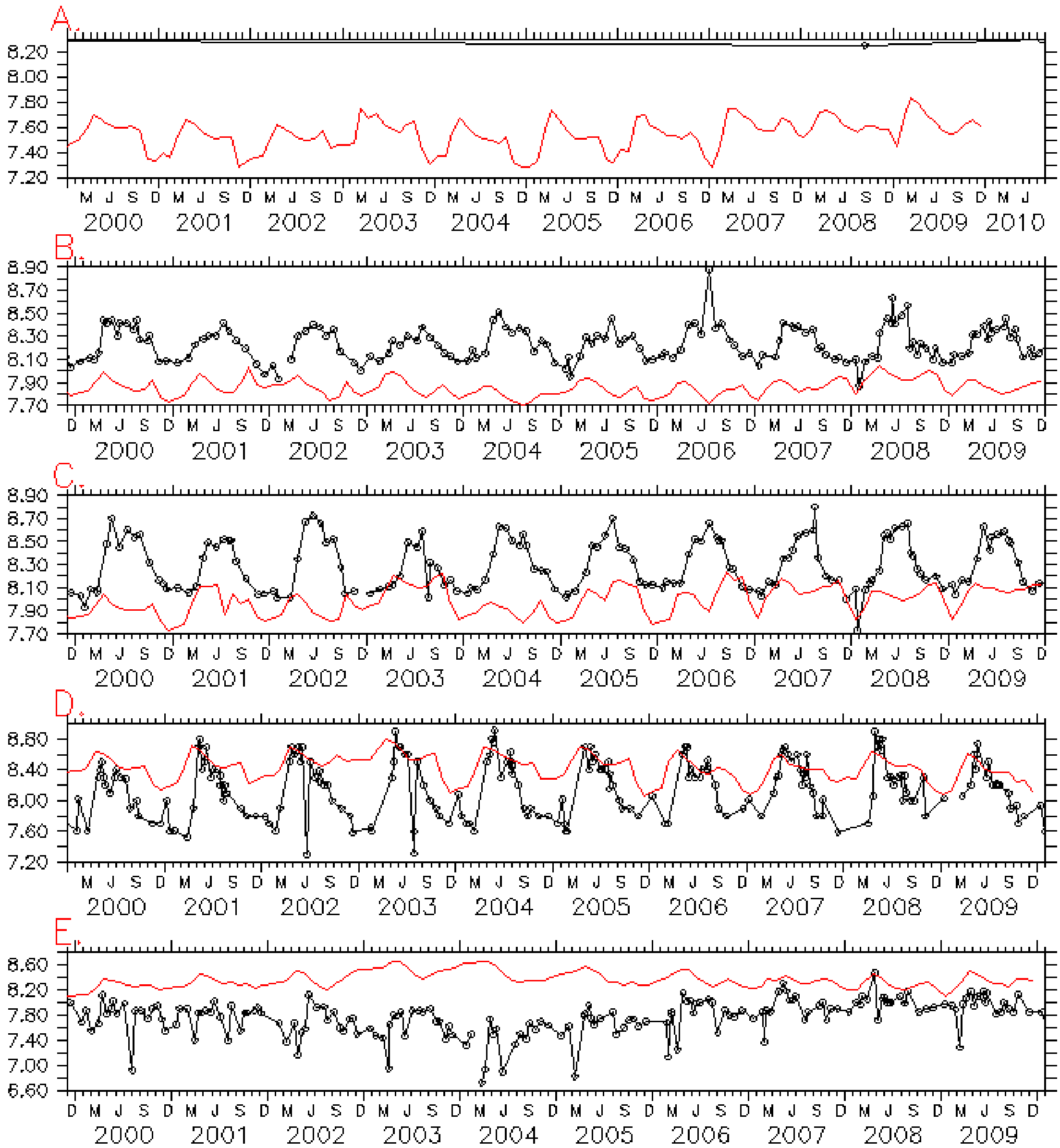


Figure 8. Seasonal evolution of PH in the surface. Black cycles for observations and red curves for model results. A-E for the stations labelled in Figure 3.

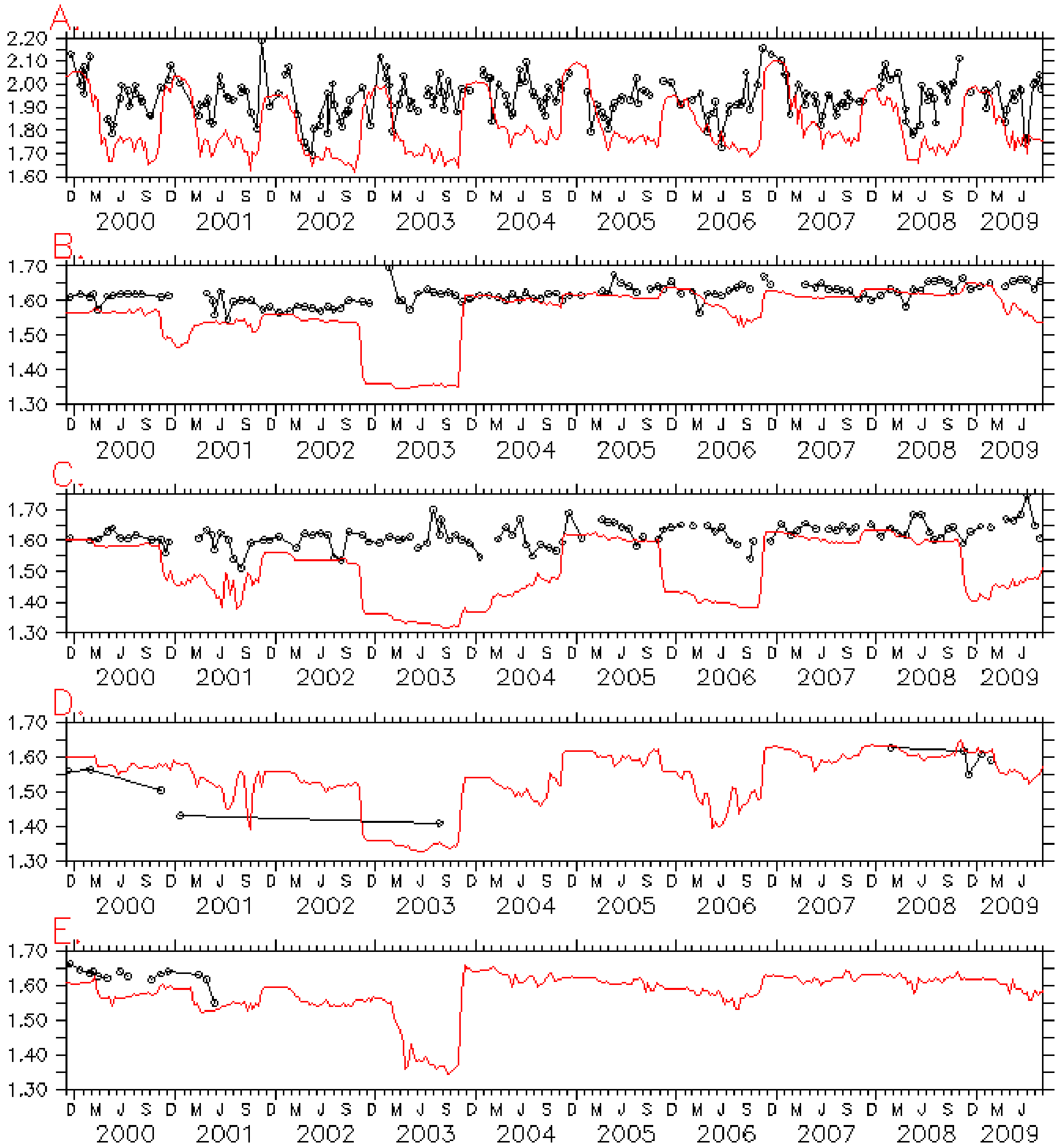


Figure 9. Seasonal evolution of Alkalinity in the surface. Black cycles for observations and red curves for model results. Unit: 1000 mmol m^{-3} . A-E for the stations labelled in Figure 3.

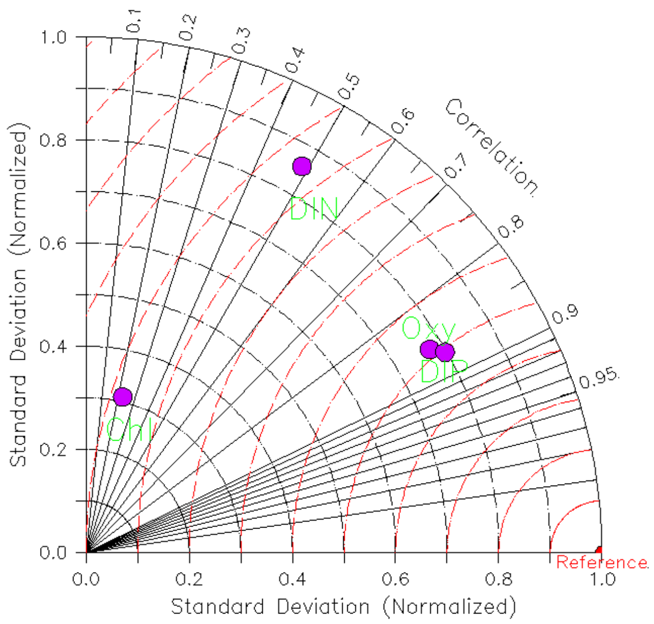


Figure 10. Taylor diagram for Chl, DIN, DIP and Oxygen.

Table 1.1 Model skill for core metrics. Model skill scores are colour coded to give an indication of model skill as follows; Good = green, Moderate = Black, Poor = Red; correlation r good > 0.75, poor < 0.20, ME good = > 0.5, Poor = < 0, Reliability index good 0.8-1.2, poor > 2 or –ve. PBias, good = < 20%, poor = > 100%.

Region: Baltic
Model: ERGOM
Met forcing: DMI regional hindcast
Hindcast time period: 1990-2009
Contact: Zhenwen Wan zw@dmi.dk

		Hindcast					
Variable	**Unit**	**Model Efficiency**	**% Model Bias**	**Pearson Correlation Coefficient**	**RMSE**	**Unbiased RMSE**	**Reliability Index**
Chl	mg m^{-3}	0.04	**10**	**0.23**	4.99	4.98	2.01
DIN	mmol m^{-3}	0.08	**14**	0.49	4.15	4.11	1.37
DIP	mmol m^{-3}	**0.75**	**-6**	**0.87**	0.53	0.52	0.45
Oxygen	mmol m^{-3}	**0.71**	**7**	**0.86**	63.21	63.11	0.95

1.3 Baltic Higher Trophic Level hindcast

1.3.1 Description of the hindcast simulation experiment

The Stochastic Multi Species model (SMS) for higher trophic levels in the Baltic was run in a standard stable version which resolved the major fish species cod, sprat and herring. The simulations were made for the whole basin as the current data availability precludes running at higher resolution and with quarterly time resolution. The commercially important species cod, sprat and herring also dominate the HTL biomass in the Baltic region. The model setup runs with quarterly time steps and resolves dominating species in adult age cohorts, for cod ages 2-5 years, herring ages 1-8 years and sprat ages 1-8 years. Below this are juveniles and early life stages which in the model are handled implicitly via the stock-recruitment component in the SMS model. The model output data available on the OPEC webserver is sprat and herring resolved into age groups and biomass for cod.

Table 1.2 Model skill for core metrics. Model skill scores are colour coded to give an indication of model skill as follows; Good = green, Moderate = Black, Poor = Red; correlation r good > 0.75, poor < 0.20, ME good = > 0.5, Poor = < 0, Reliability index good 0.8-1.2, poor > 2 or –ve. PBias, good = < 20%, poor = > 100%.

Region: Baltic Model: SMS Met forcing: DMI regional hindcast Hindcast time period: 1990-2009 Contact: asc@aqua.dtu.dk							
		Hindcast					
Variable	**Unit**	**Model Efficiency**	**% Model Bias**	**Pearson Correlation Coefficient**	**RMSE**	**Unbiased RMSE**	**Reliability Index**
cod_2	ton	**-1.08**	95.78	**0.81**	1081852	744069	**3.50**
cod_3	ton	**-0.51**	79.42	0.58	452521	357093	1.86
cod_4	ton	**-0.21**	54.64	0.37	122972	105980	1.53
cod_5	ton	0.03	**6.12**	0.26	34063	34018	1.64
herring_1	ton	**-0.14**	-21.67	0.44	134694	126394	1.27
herring_2	ton	**-0.25**	**8.57**	**0.25**	167563	165286	1.25
herring_3	ton	**-0.29**	32.70	0.37	188410	156034	1.31
herring_4	ton	**-0.13**	37.79	0.50	160784	133508	1.30
herring_5	ton	**-0.44**	41.39	0.43	94343	71076	1.35
herring_6	ton	**-0.27**	30.07	0.59	33840	24680	1.27
herring_7	ton	**-0.14**	22.94	0.46	20546	18045	1.28

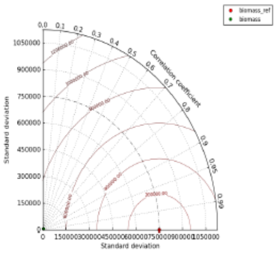
herring_8	ton	-0.27	-26.29	0.53	25241	23049	1.32
sprat_1	ton	**0.71**	**1.01**	**0.87**	208052	207985	1.29
sprat_2	ton	**0.72**	**12.39**	**0.91**	214046	205135	1.25
sprat_3	ton	0.35	29.34	**0.77**	212061	181867	1.25
sprat_4	ton	**0.63**	**18.14**	**0.84**	79369	71831	**1.19**
sprat_5	ton	**0.54**	30.28	**0.90**	65053	54356	1.25
sprat_6	ton	**0.63**	25.09	**0.89**	27171	22574	1.21
sprat_7	ton	0.44	**18.44**	0.74	13151	12053	1.28

No direct measurements of HTL biomasses are feasible for obvious reasons; however representative sampling surveys are conducted regularly, where sampling stations are trawled and analysed or the biomasses is assessed via acoustic surveys. Both these observational techniques gives an index proportional to the species resolved biomasses, where the multiplications factors are assumed time independent but species dependent and must be estimated independently; in this benchmark, the multiplications factors were estimated so that the ratio biomass(model) = biomass(observed) over the hindcast period. In other words, the benchmark will test the models ability to predict observed variability patterns (rather than absolute variability). For cod, a trawling index was applied, whereas for sprat and herring an acoustic-based index was applied.

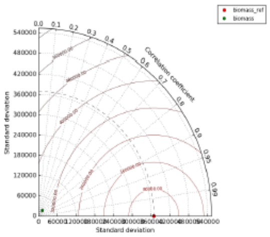
1.3.2 Results of higher trophic level

Table 1.2 shows the SMS model for higher trophic levels in the Baltic benchmarked using the standard OPEC metrics defined in D2.3. Model variables in the table are named as <species>_<age>. The model showed decent performance with quite high correlation coefficients, given the inherent uncertainties associated with modelling higher trophic levels. Sprat and herring seems to have no abundance bias when comparing to surveys, however cod seems to have a slight bias in the model/observation regression, indicating that the SMS model may underestimate in periods with high abundance and overestimate in periods with low abundance; the reason underlying this apparent bias is currently unknown and under investigation. A time series of the stock biomasses is shown below, displaying major interannual fluctuations.

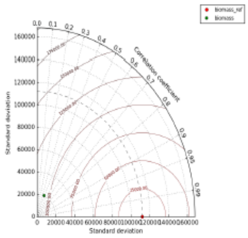
The Taylor diagrams (figures 11-13) indicate a general tendency to underestimate the magnitude of interanual fluctuations even though the correlation coefficient is quite high, demonstrating the models ability to reproduce the trend in interannual variability; this underestimation is most prominent for cod, moderate for sprat and least for herring, where RMS variability comes relative close to observational indices. Potentially the underestimation for cod may be associated with the survey type (trawling), compared to sprat and herring, where acoustic surveys were used to generate reference time series. There are many factors that may add uncertainty to trawl-based survey indices, e.g. the choice of positions for sampling stations and spatial heterogeneity of the cod biomass in relation to biomass abundance. The SMS model is on the other hand has a statistical foundation and therefore a tendency smoothing should be expected.



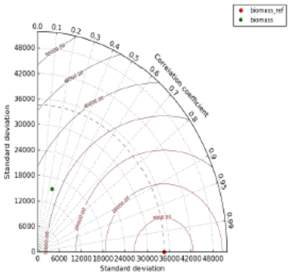
cod age 2



cod age 3



cod age 4



cod age 5

Figure 11. Taylor diagrams for cod biomass time series

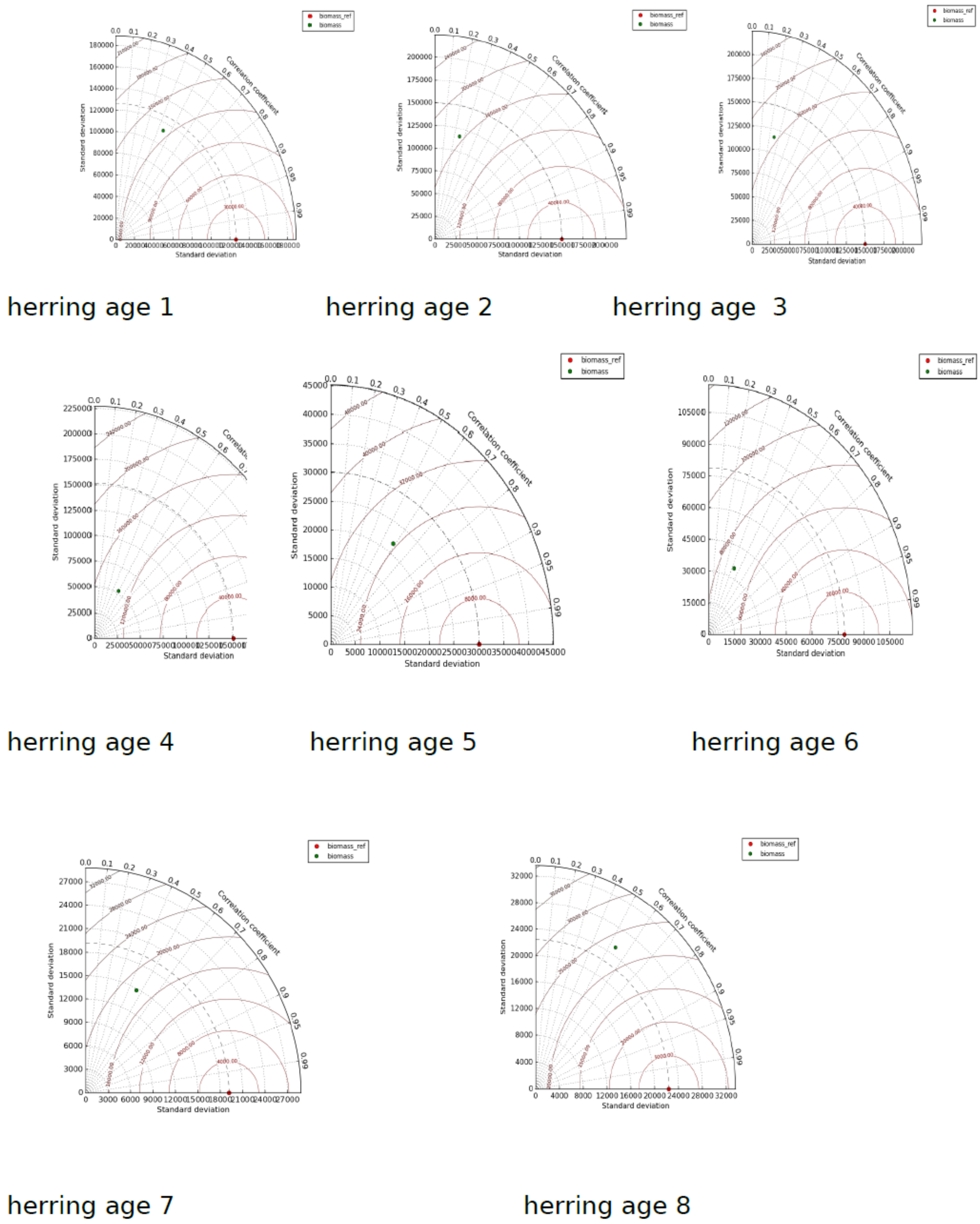


Figure 12. Taylor diagrams for herring biomass time series

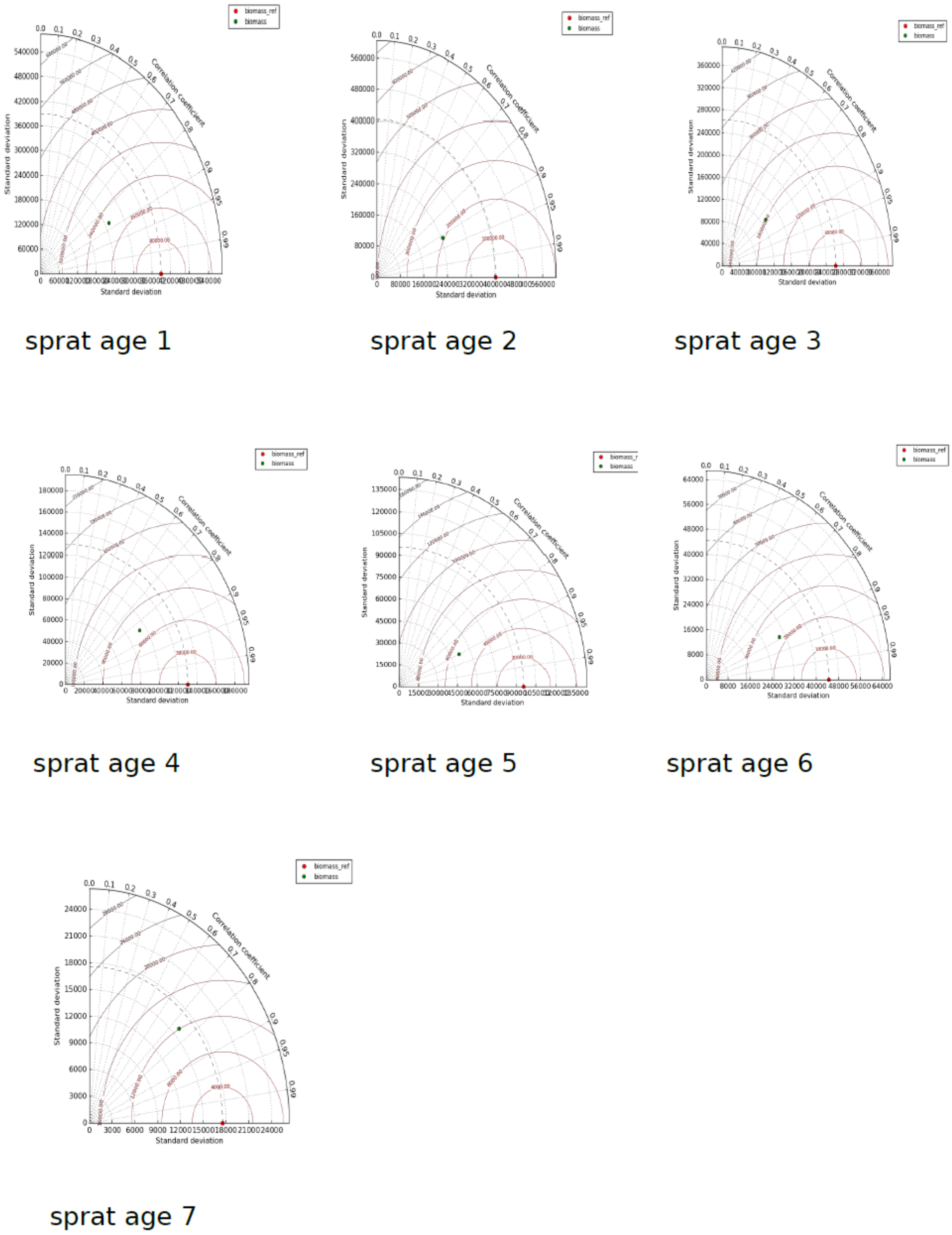


Figure 13. Taylor diagrams for sprat biomass time series

1.4 Summary of hindcast experiment and lessons learnt

The model results were compared with available data collated from the data from the International Council for the Exploration of the Sea (ICES http://www.ices.dk/indexfla.asp). The model results can reasonably reproduce the seasonal evolution of phytoplankton blooms and nutrient dynamics in the surface and can also reproduces the overall features of vertical profiles. To reproduce synoptic variations of pelagic ecosystem is a common challenge for ecological modelling. We have no detailed observations to check the model robustness for synoptic variations. The model ERGOM, like most of others, parameterising some slow biogeochemical processes e.g. remineralisation and denitrification, includes uncertainty for long term simulation.

1.5 Reference

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