# Assessment of model skill in the Mediterranean Sea

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## 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. Description**

The Mediterranean (0.1 x 0.1) coupled hydrodynamic/biogeochemical model (POM-ERSEM) along with the model setup (initial conditions, river inputs, open boundary conditions) are described in deliverable D2.4 (www.marine-opec.eu/downloads/OPEC_D2.4.pdf). The atmospheric forcing for the hindcast simulation was obtained from the regional climate model HIRHAM5 simulation, provided by DMI (see D2.2 www.marine-opec.eu/documents/deliverables/D2.2.pdf).

The coupled hydrodynamic/biogeochemical model (POM-ERSEM) has been downscaled in the Aegean Sea (0.15x0.15) and has been coupled to a full life cycle Individual Based Model (IBM) for anchovy (see D2.4; www.marine-opec.eu/downloads/OPEC_D2.4.pdf).

The main goal of this work is to validate the hindcast simulation (1990-2009) for the benchmark variables using available data. These include Chl-a (satellite and in situ), dissolved inorganic nutrients (NO3, PO4, NH4, SiO3), dissolved oxygen, sea surface temperature (SST), sea surface salinity (SSS). In situ data have been collated from SeaDatanet database. The anchovy IBM model results are validated against biomass data derived from acoustic surveys and egg abundance data over 2003-2006 period.

## 2. Results

### *2.1 Comparison against Satellite Chl-a*

In Figure 1, taylor and target diagrams for model simulated monthly Chl-a against satellite (SeaWiFS) over 1998-1999 period is shown. The model presents a total RMSE <1, being characterized as reasonable. A correlation coefficient of 0.38 is found and a small overestimation with PBIAS=-6% (Table 1). The model standard deviation (0.19) is about half of the SeaWiFS Std (0.37), showing a weaker spatial variability.

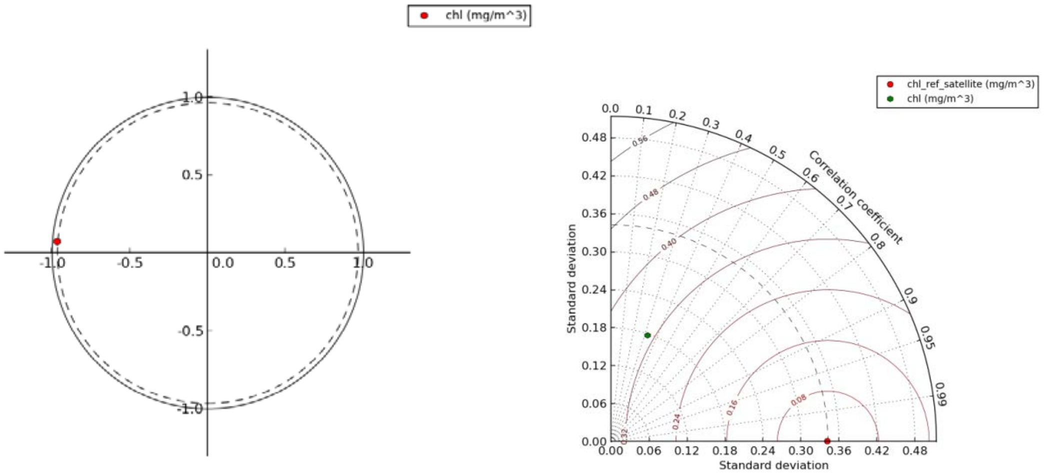


*Figure 1. Target (left) and taylor (right) diagrams for model simulated monthly Chl-a against satellite (SeaWiFS) over 1998-1999 period.*

### *2.2 Comparison with in situ data (SeaDatanet)*

The model results (average 0-50m) were compared with available data collated from SeaDatanet database over 1990-2009 period. The comparison was performed on seasonal windows in order to have a statistically significant number of observations in each period. In Figure 2, an example is shown for model simulated and in situ nitrates in the summer period, while Figure 2 presents the entire model-data series, where statistics are calculated. In Figures 4-9, the taylor and target diagrams for model simulated nitrates (Figure 4), phosphates (Figure 5), ammonia (Figure 6), silicates (Figure 7), chl-a (Figure 8), dissolved oxygen (Figure 9), sea surface temperature (Figure 33) and sea surface salinity (Figure 34). All the statistics of the comparisons may be seen in Table 3.1.

As expected, the model skill is much higher for SST and SSS, showing correlation coefficients of 0.85 and 0.7 respectively. From the target diagrams, the model performance for the SST is characterized as “good” (<0.74) and for the SSS it is “reasonable” (0.74<RMSE<1).

Ammonia, chlorophyll-a (in situ) and nitrates present the better scores, showing a higher Model Efficiency (ME) (NH4=0.23, Chl=0.15, NO3=0.1), correlation coefficients (NH4=0.49, Chl=0.45, NO3=0.36) and a standard deviation that is closer to the data variability (NH4=0.39std, Chl=0.19std, NO3=0.27std). Phosphates present a relatively high correlation coefficient (0.26), but show an increased underestimation (PBIAS=-43%) and low variability (0.16 std) as compared to the data, which results in a slightly negative (-0.03) ME. Silicates present a worse ME (-0.52) mostly due to the relatively low correlation coefficient (0.16).

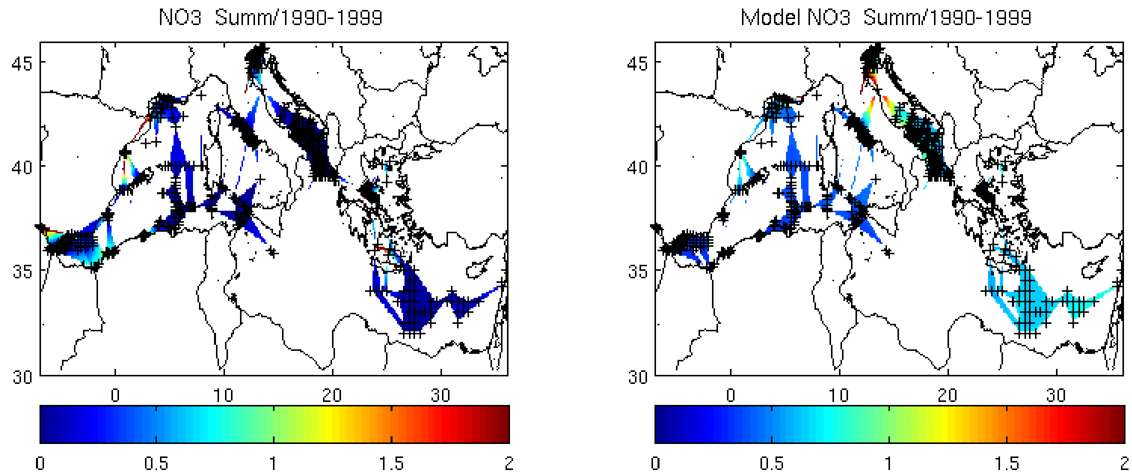


*Figure 2. In situ (left) and model simulated (right) nitrates over summer 1990-1999 periods. In situ data were collated from SeaDatanet database*

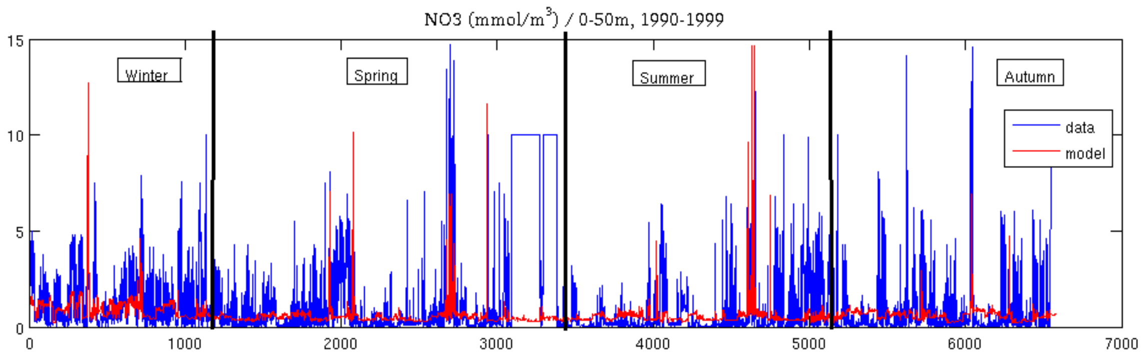


*Figure 3. In situ (blue) and model simulated (red) nitrates over 1990-1999 period. In situ data were collated from SeaDatanet database.*

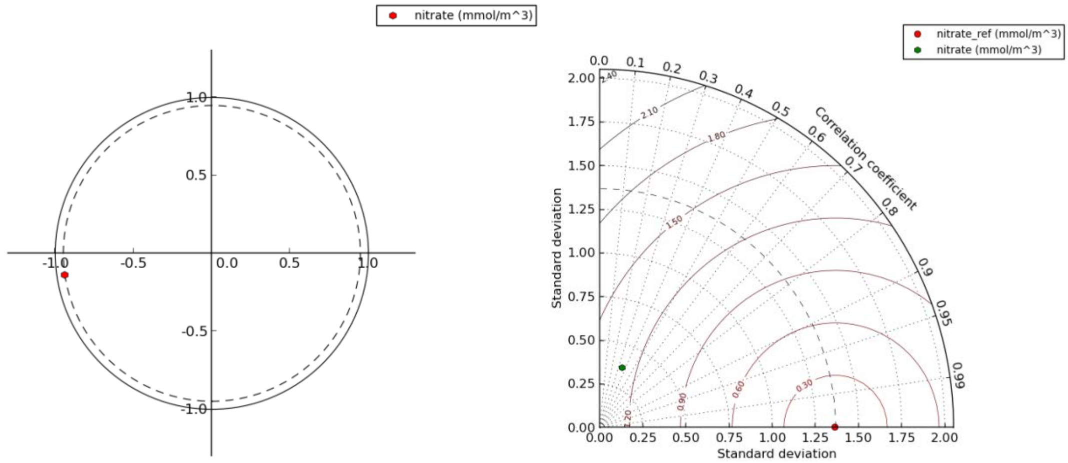


*Figure 4. Target (left) and taylor (right) diagrams for model simulated nitrates against in situ (SeaDatanet) data over 1990-1999 period.*

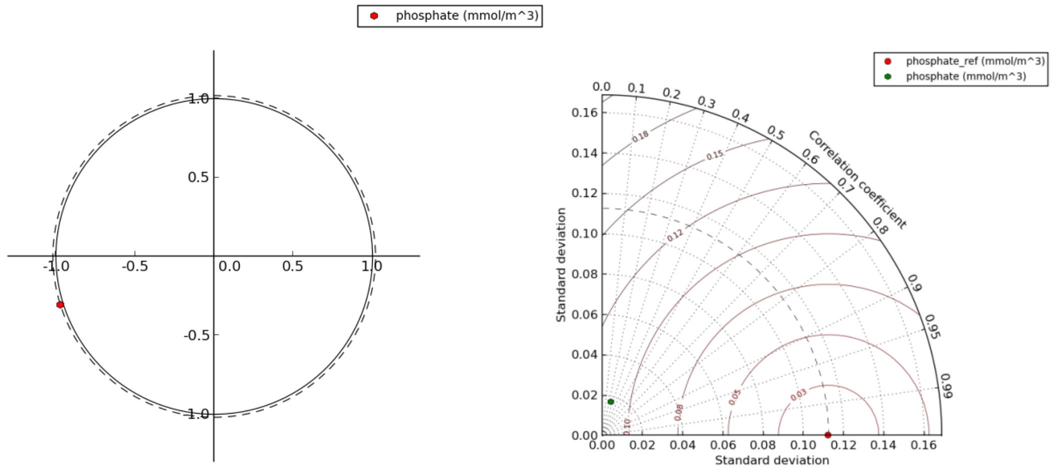


*Figure 5. Target (left) and taylor (right) diagrams for model simulated phosphates against in situ (SeaDatanet) data over 1990-1999 period.*

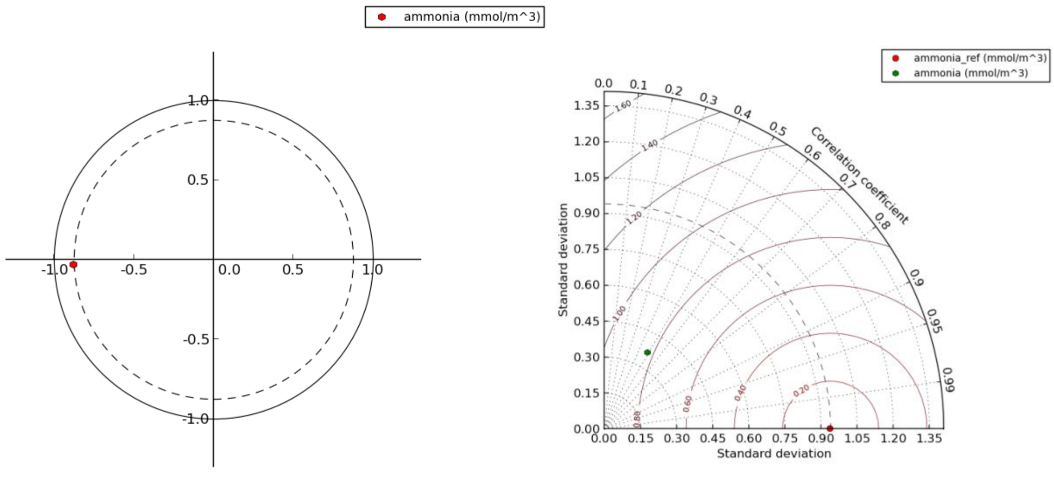


*Figure 6. Target (left) and taylor (right) diagrams for model simulated ammonia against in situ (SeaDatanet) data over 1990-1999 period.*

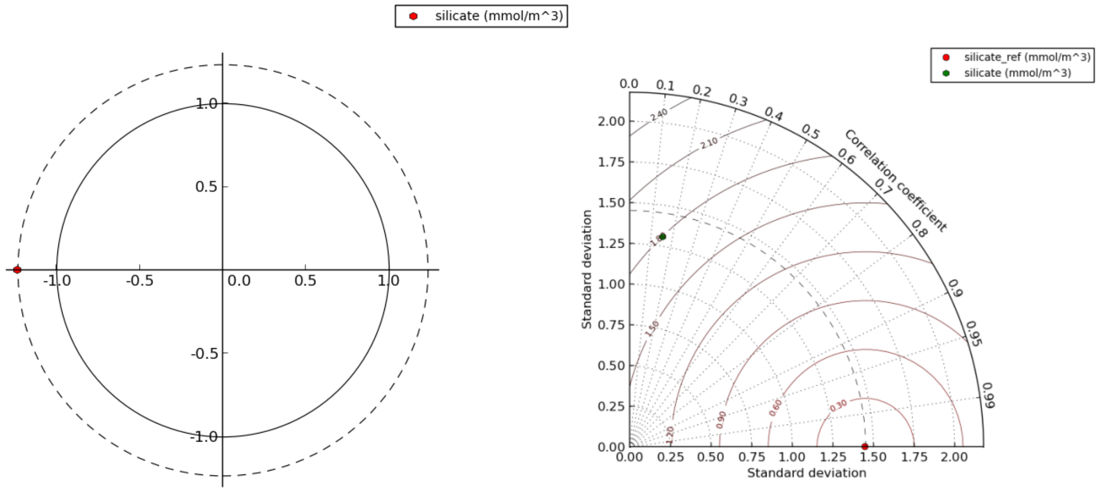


*Figure 7. Target (left) and taylor (right) diagrams for model simulated silicates against in situ (SeaDatanet) data over 1990-1999 period.*

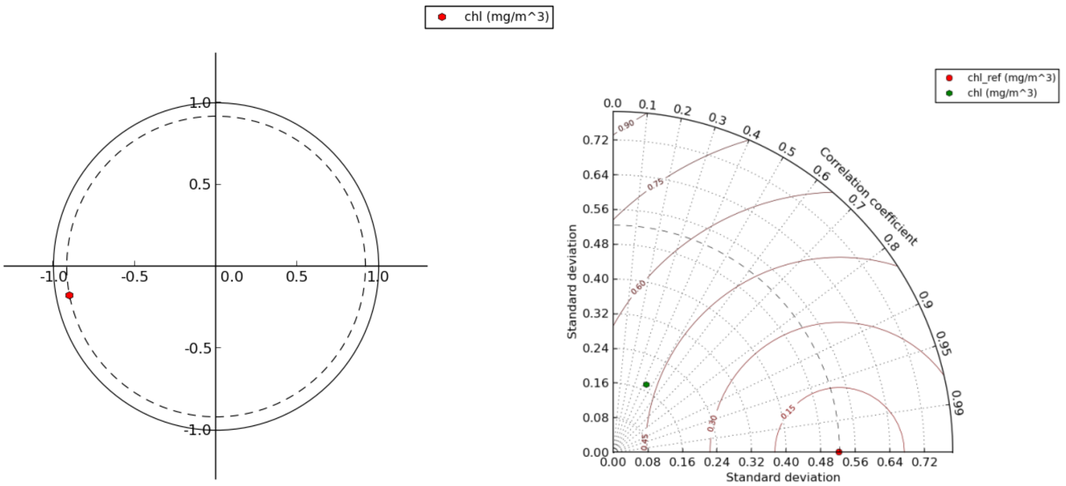


*Figure 8. Target (left) and taylor (right) diagrams for model simulated Chl-a against in situ (SeaDatanet) data over 1990-1999 period.*

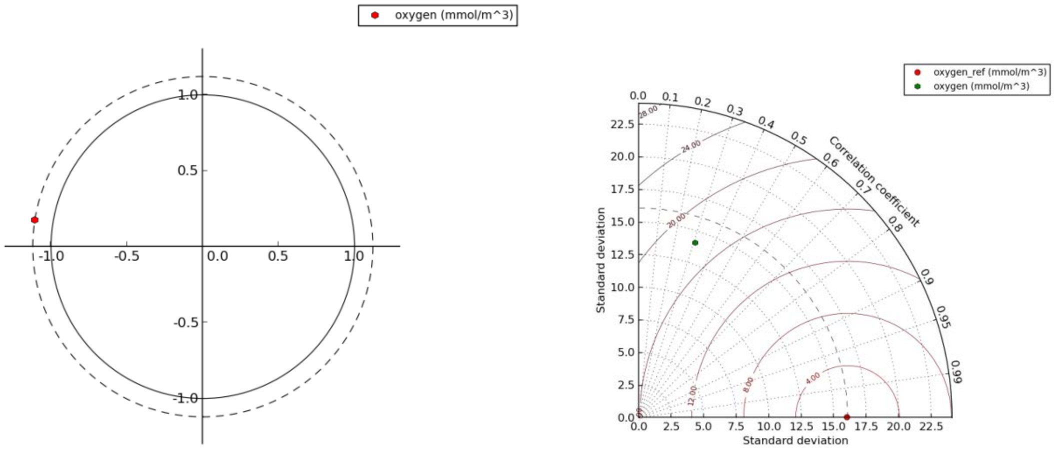


*Figure 9. Target (left) and taylor (right) diagrams for model simulated dissolved oxygen against in situ (SeaDatanet) data over 1990-1999 period.*

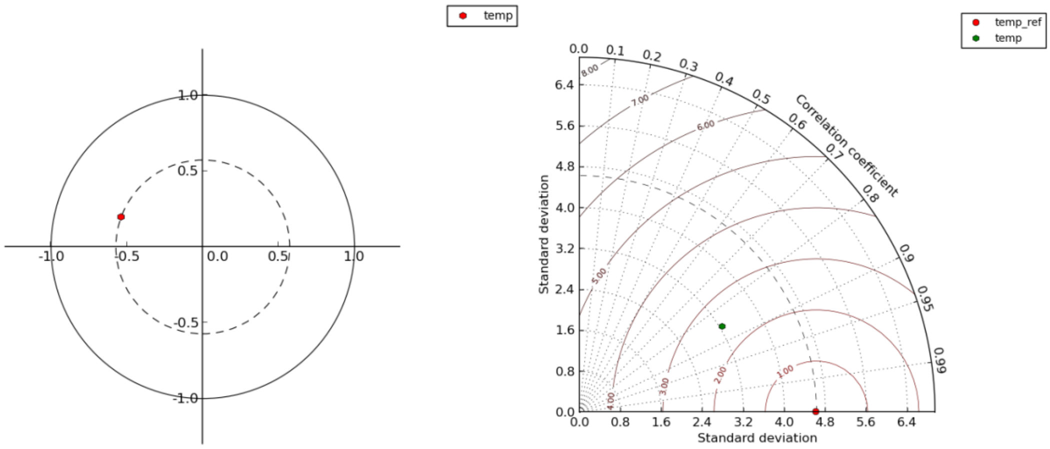


*Figure 10. Target (left) and taylor (right) diagrams for model simulated sea surface temperature (SST) against in situ (SeaDatanet) data over 1990-1999 period.*

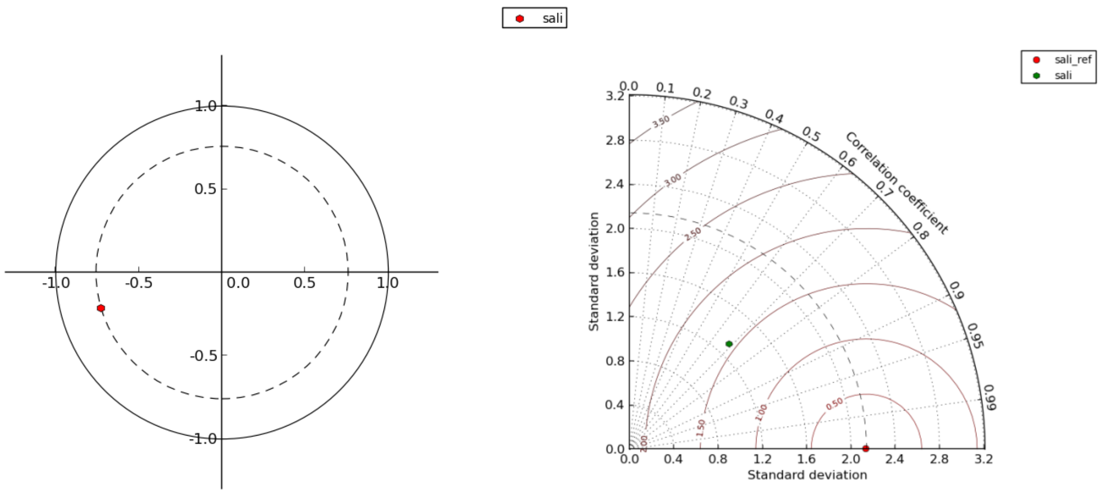


*Figure 11. Target (left) and taylor (right) diagrams for model simulated sea surface temperature (SST) against in situ (SeaDatanet) data over 1990-1999 period.*

### *2.3 Validation of the carbonate system*

Given the scarcity of available data, the model simulated pCO2 and dissolved inorganic carbon (TCO2), was qualitatively validated against available data at DYFAMED (Figure 12), and the Aegean/Ionian Sea (Figure 13), showing a good agreement with the observed seasonal and spatial variability. A quantitative validation of the simulated pH was also performed, using the benchmark tool, comparing with available data collated from SeaDatanet database over 1990-1999 period on a seasonal basis. In Figure 14, an example is shown for model simulated and in situ pH for the summer period, while Figure 15 presents the entire model-data series, where statistics are calculated. In Figure 16, the taylor and target diagrams for model simulated pH (see also Table 1). The simulated pH presents a correlation coefficient (0.23) that is comparable with that of inorganic nutrients, given its underestimated spatial variability (0.25 std) and a slight underestimation (PBIAS=-1.4%) that result in a slightly negative (-0.09) ME.

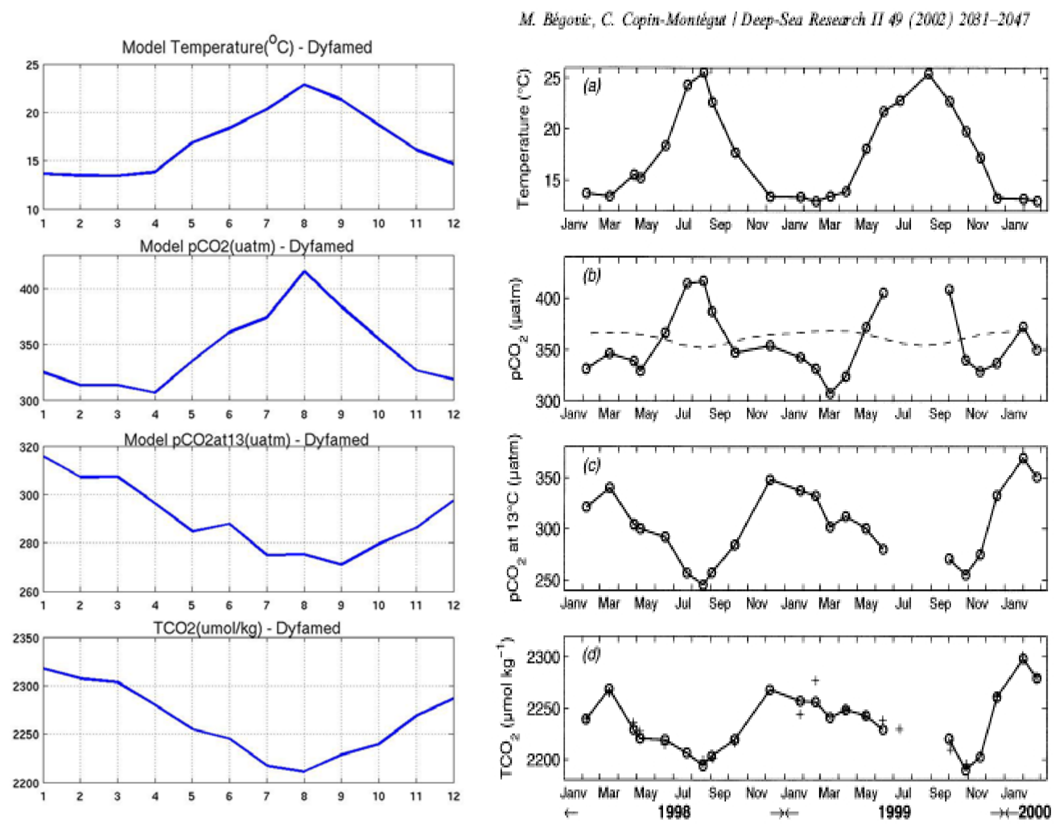


*Figure 12: Model simulated (left) near surface temperature, pCO2(uatm), pCO2@13C(uatm) and TCO2 (umol/Kg) against in-situ data (Begovic and Copin-Montegut, 2002) at DYFAMED site.*

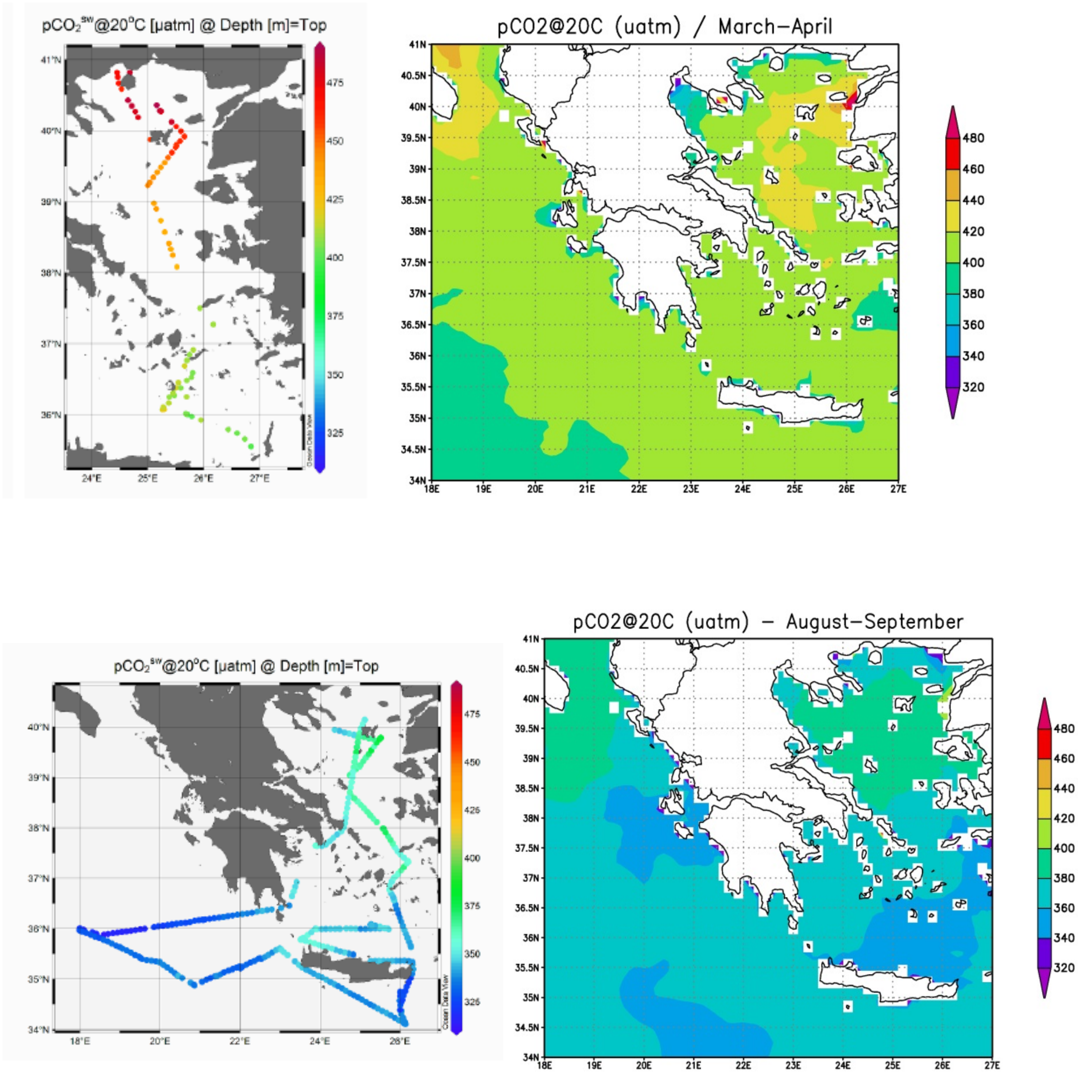


*Figure 13: Model simulated (right) near surface pCO2@20C (uatm) against in-situ data (E. Krasakopoulou, unpublished data) for March-April and August-September periods.*

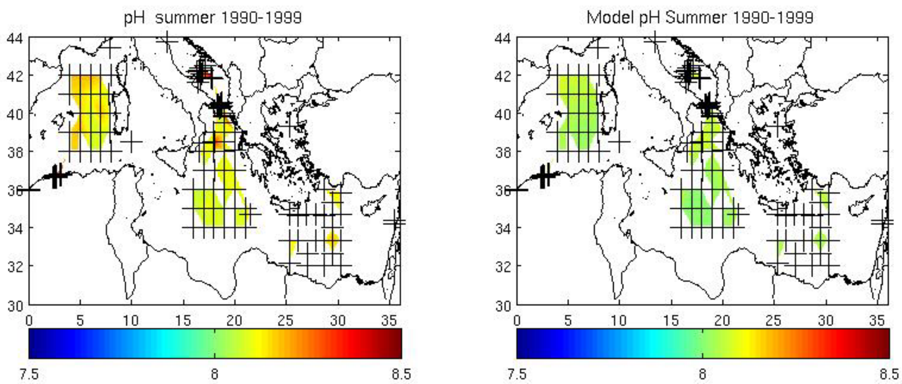


*Figure 14: In situ (left) and model simulated (right) pH over summer 1990-1999 periods. In situ data were collated from SeaDatanet database.*

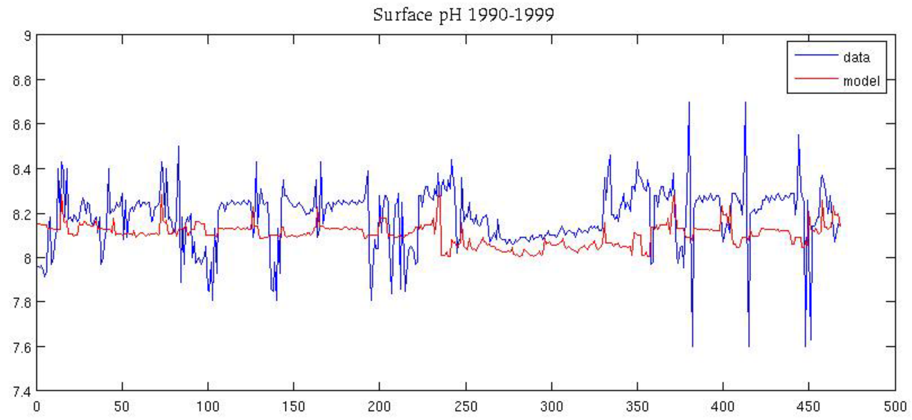


*Figure 15: In situ (blue) and model simulated (red) pH over 1990-1999 period. In situ data were collated from SeaDatanet database.*

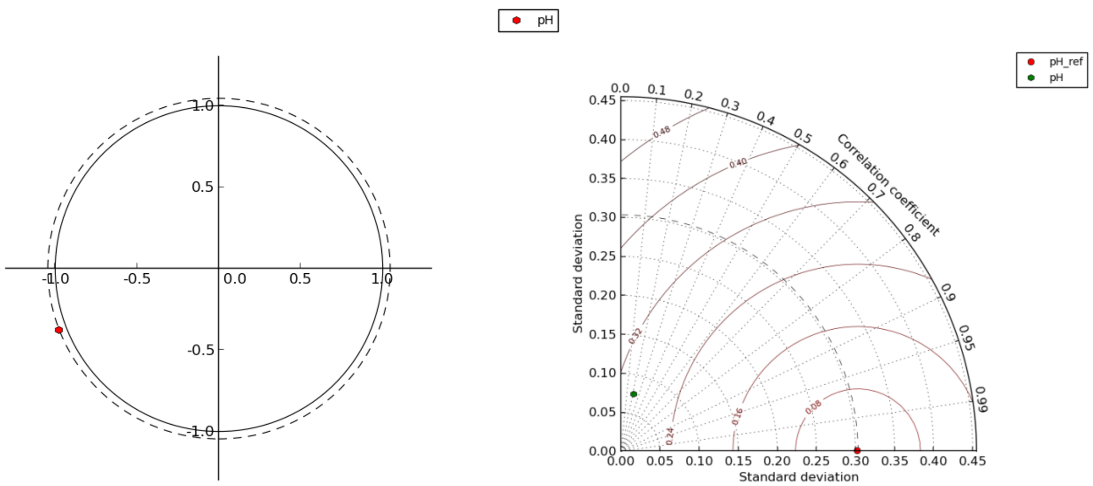


*Figure 16: Target (left) and taylor (right) diagrams for model simulated sea surface pH against in situ (SeaDatanet) data over 1990-1999 period.*

### *2.4. High Trophic Level validation*

In Figure 17, the anchovy biomass mean distribution for 2003-2006 period is compared with biomass estimates from acoustic surveys. The model distribution is in good agreement with the observations, showing an increase in coastal more productive areas, particularly Thermaikos gulf, Strymonikos gulf and Thracian Sea. The model underestimates the anchovy biomass in the Limnos Island area that is influenced by the BSW discharge. In figure 18, the target and taylor diagrams for the comparison below (Figure 40) are shown. Given the significant gradient of model and data values, a logarithm transformation has been applied to both model and data distributions for the taylor diagram, following Stow et al. (2009). The model presents the same variability with the data. The correlation coefficient of ~0.46 and the RMS error is ~1std. As shown in the target diagram, the model underestimates the mean and the total RMSE is >1.

In Figure 19, the simulated mean egg abundance distribution for 2003-2006 period is compared against observations. As shown in Figure 20, a significant correlation (0.42) is found and the RMS error is close to 1. The model STD is slightly higher (0.95std) than the data. In Figure 21, the inter-annual variability of the anchovy total adult biomass and the average weight for different age classes are shown. The simulated total biomass lies within the range of the observations, although there are some discrepancies in certain years. Similarly, the simulated anchovy mean weight is in good agreement with the data. For 1st year adults the model simulated weight falls within the data range. For the 2nd and 3rd year adults, there is also a reasonable agreement, although for some years the simulated weight falls outside the data range.

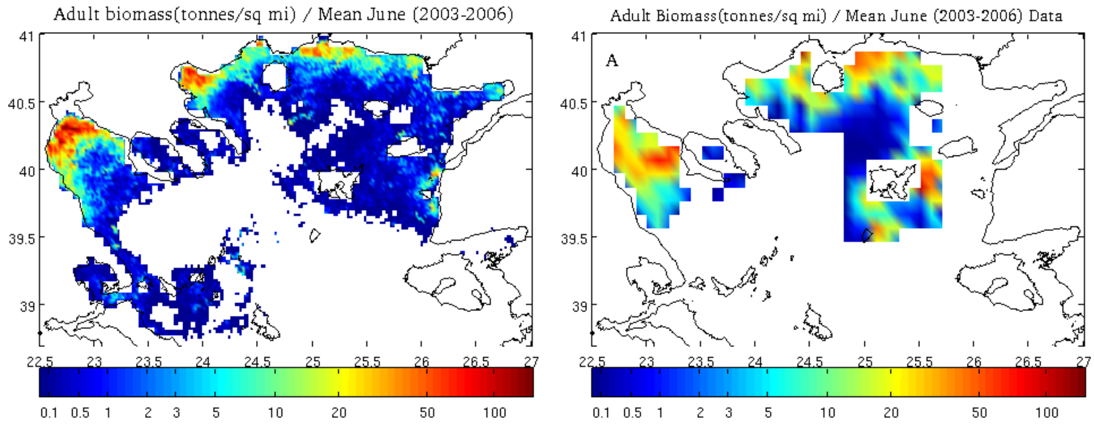


*Figure 17. Model simulated (left) and derived from acoustic surveys (right) adult anchovy biomass (tons/square mile), average over June 2003-2006.*

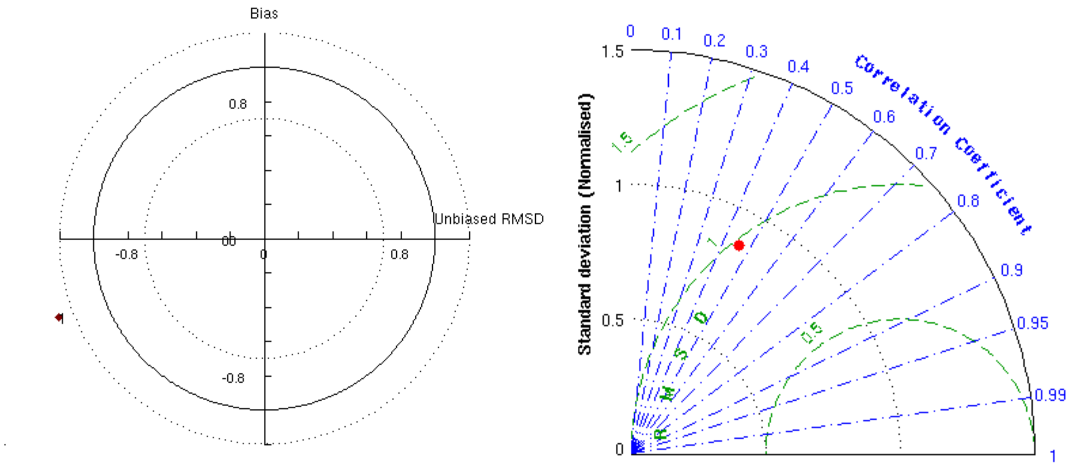


*Figure 18. Target (left) and taylor (right) diagrams for model simulated against derived from acoustic surveys adult anchovy biomass, average over June 2003-2006. A log-transformation has been applied for the Taylor diagram.*

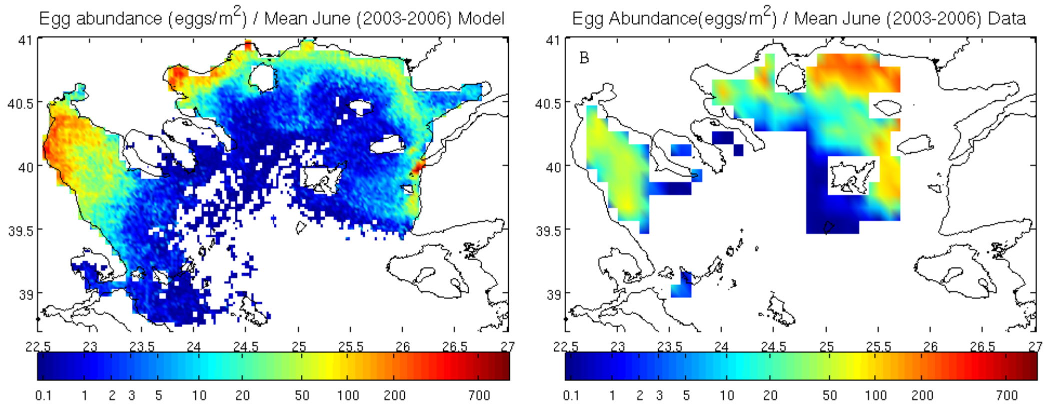


*Figure 19. Model simulated (left) and data derived (right) mean egg abundance (eggs/m2), averaged over June 2003-2006.*

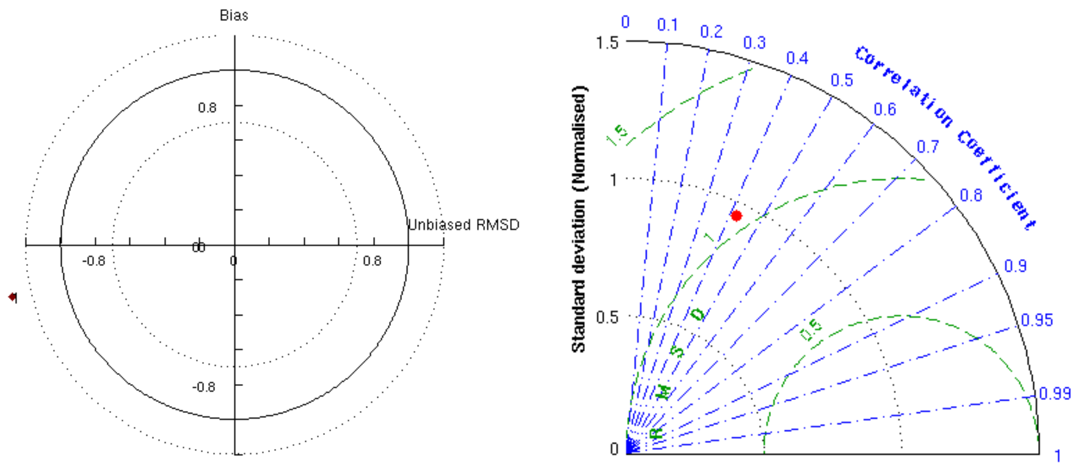


*Figure 20. Target (left) and taylor (right) diagrams for model simulated egg abundance against in situ data, average over June 2003-2006. A log-transformation has been applied for the Taylor diagram.*

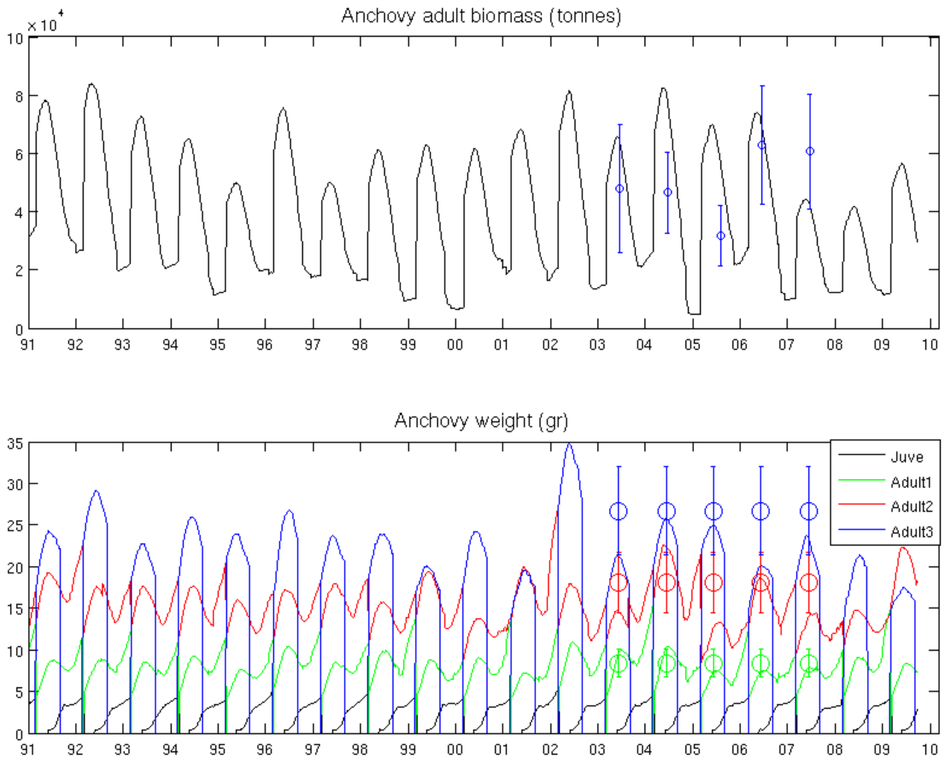


*Figure 21. Inter-annual variability of total anchovy adult biomass (top) and anchovy weight-at-age (bottom). Bars indicate data estimates during June 2003-2006.*

**Table 1**. 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: Mediterranean (HCMR)
Model: POM-ERSEM, Anchovy IBM
Met forcing: DMI regional hindcasat
Hindcast time period: 1990-2009
Contact: ktsiaras@hcmr.gr (Kostas Tsiaras), gt@hcmr.gr (George Triantafyllou)

| | | Hindcast | | | | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **Unit** | **Model Efficiency** | **% Model Bias*** | **Pearson Correlation Coefficient** | **RMSE** | **Unbiased RMSE** | **Reliability Index** |
| Nitrate | Mmol/m3 | 0.1 | 22.5 | 0.36 | 1.29 | 1.28 | **2.11** |
| Phosphate | Mmol/m3 | **-0.03** | 43.4 | 0.26 | 0.115 | 0.109 | 1.45 |
| Ammonia | Mmol/m3 | 0.23 | **-6.62** | 0.49 | 0.823 | 0.822 | **2.05** |
| Silicate | Mmol/m3 | **-0.52** | **0.09** | **0.16** | 1.79 | 1.79 | 1.52 |
| d. oxygen | Mmol/m3 | **-0.25** | **-1.15** | 0.31 | 18.02 | 17.8 | **1.03** |
| Chl-a | Mg/m3 | 0.16 | 21.87 | 0.45 | 0.48 | 0.47 | 1.51 |
| Chl-a/satellite | Mg/m3 | 0.07 | -11.85 | 0.33 | 0.33 | 0.33 | **13.79** |
| Anchovy egg abundance | Log(#) | **-0.13** | **5** | 0.6 | 1.32 | 1.28 | N/A |
| Anchovy adult biomass | Log(tonnes) | **-1.88** | 59<br>-15** | 0.38 | 1.32 | 0.88 | N/A |

*PBIAS=(data-model)/data*100 (positive=underestimation)

**based on estimated total biomass (Figure 17)

### *2.5 Summary of hindcast experiment and lessons learnt*

The model results were compared with available data collated from SeaDatanet database over 1990-2009 period and SeaWiFS satellite Chl-a.

A significant effort was allocated for the in situ data (Seadatanet) collection and their processing in order to be compared with model results.  In some variables the model shows a reasonable agreement with the observations in contrast to some other where the model was not able to follow in magnitude and variability. We have to note however that the point-to-point comparison may be considered as a difficult test for the model, given the significant variability and uncertainty of the observations.