Towards an assimilation of MODIS-derived Sea Surface Temperature (SST) by the Optos_nos model

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Abstract

Aiming to use the MODIS-derived SST to improve the surface forcing of the Optos_nos model, our first task consists in a cross-comparison between satellite data, model results and in situ measurements. We note that the accuracy of the model must be improved close to the coast and that the procedure of flagging clouds must be improved before the satellite data can be used as forcing.

Keywords:

SST, North Sea, MODIS, Coherens, validation

1. Introduction

The objective of this study is to assess the capability of MODIS-derived SST to improve the quality of the SST Optos_nos model results.

Comparisons between satellite and Optos_nos modelled SST are carried out to address the weaknesses of the model which may be corrected by the satellite data and/or to determine places where the available satellite data are too sparse or of too bad quality. Satellite and modelled SST are then compared with in situ measurements.

This preliminary work shows that, at this stage, the satellite derived SST must be improved to avoid disturbing the model instead of improving it.

2. Description of the data sources

Our study focuses on the year 2004. Our zone of interest is the North Sea. This study mainly consists in a global cross-comparison between satellite-derived SST, modelled SST and in situ data. Each source is described hereafter.

2.1 Satellite-derived SST

The MODerate resolution Imaging Spectro-radiometer (MODIS) onboard the two satellites EOS AQUA and EOS TERRA retrieve the Sea Surface Temperature (SST) from the radiance measured at 2 infrared bands centered around 11µm and 12µm -called hereafter 11µm SST for daytime SST-, plus a 4µm night-time SST generated from radiances measured in 2 mid-infrared narrow bands centered around 3.9µm and 4.0µm. The 4µm SST algorithm is not used for daytime products because the measured radiance at short wave infrared wavelength is contaminated by reflected sun radiation.

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Daily products of SST are generated using the calibrated algorithm of Brown and Minnett (1999) and Minnett et al. (2003) for daytime and night-time SST:

$$SST=c1+ c2*T_{11}+ c3*(T_{11}-T_{12})*T_{src}+c4*(sec(\theta)-1)*(T_{11}-T_{12})$$

Where T_{11} (resp. T_{12}) is the brightness from channel 11µm (resp. 12µm), θ is the satellite zenith angle and T_{src} is an estimate of the SST, generated using the MultiChannel Linear (MCSST) algorithm of McClain et al. (1985).

For night-time SST, the 4µm algorithm is used:

$$SST4=c1+ c2*T_{3.9}+ c3*(T_{3.4}-T_{4.0})+c4*(sec(\theta)-1)$$

Daily products of mean SST and related Quality Level (QL) data with 4km resolution covering the North Sea area during the year 2004 were downloaded from the Goddard Earth Science Distributed Active Archive Center **(GES DAAC)** Online FTP website (http://disc.gsfc.nasa.gov/data/datapool/). The level of processing of SST is level 3, which refers to atmospherically corrected, re-projected and 4km averaged data. QL data provide an indication of the level of confidence we may give to SST product, ranging from 0 (=good quality) to 3 (=bad quality). QL 2 refers to clouded pixels. These products were available in HDF format.

The downloaded SST and QL data were read and further processed using the ENVI software. SST data have been filtered using QL products keeping only good quality flagged pixels for each map. Data are then re-projected to match the model grid (1/12° intervals for longitudes and 1/24° intervals for latitude).

2.2 Model

The Optos_nos model is the operational implementation of the Coherens code (Luyten et al., 1999) on the North Sea from 4°W up to 10°E and from 48.5°N up to 57°N. The horizontal resolution is about 5 km (1/12° in longitude, 1/24° in latitude). The vertical component is represented by 20 sigma layers.

At the open boundaries, currents and elevation are provided by a 2D model covering the whole continental shelf. Salinity is fixed at 35 along the western boundary and at 34.9 along the northern boundary in inflow conditions. A zero gradient is imposed for the temperature and in outflow conditions for the salinity.

At the river boundaries, discharge based on a climatological mean is imposed. Salinity is set to zero. For the temperature, a zero-gradient is imposed.

At the surface, the UKMO forecasts for wind, atmospheric pressure, cloud cover, rain, humidity and air temperature at 10 m above the sea surface are used to estimate the wind stress and the heat flux.

2.3 In situ measurements

Various sources of in situ data are available for the validation of the SST in the zone of interest : the observations from the R.V. Belgica (available since 2004 on the web site http://www.mumm.ac.be/EN/Monitoring/Belgica/campaigns.php) ; the hourly SST at three fixed stations in the Channel (see http://www.metoffice.com/research/ocean/goos/maws.html) ; the SST maps from the Bundesamt für Seeschifffahrt und Hydrographie (Loewe, 2003) interpolated from ship and station data, also using AVHRR satellite data (see http://www.bsh.de/en/Marine data/Observations/Sea surface temperatures/

index.jsp) ; the observations from the Monitoring Network Flemish Banks (see http://www.vliz.be/Nl/coast/mvb/mvb.htm).

3. Results

Figure 1 shows, for all satellite pictures, averaged values of SST over the whole domain derived from MODIS and computed with the Optos_nos model. The second figure gives time series of SST from satellite, from the model and measured in situ in the Belgian coastal zone (Westhinder station).

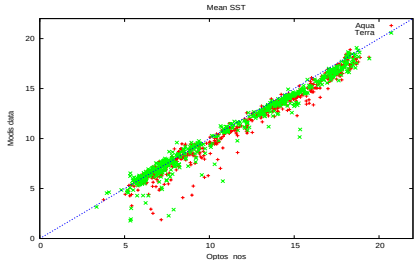

Figure 1: Mean SST (in °C) obtained by the Optos_nos model (X axis) and by Aqua and Terra (Y axis)

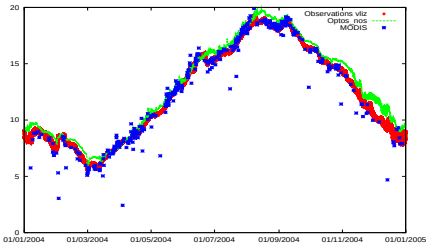

Figure 2: SST (in °C) observed, computed by Optos_nos and derived from Modis at the Westhinder station (51.38°N, 2.44°E)

On Figures 3 and 4, the weekly average difference (and the standard deviation of this difference) of SST between the model and respectively the satellite data and the BSH maps is shown. Again, only grid points where at least one non zero MODIS value over the week are taken in consideration.

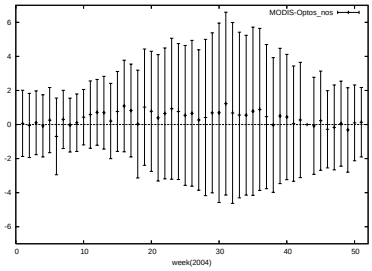

Figure 3: Weekly averaged difference and standard deviation of the difference of SST (°C) between Modis and Optos_nos

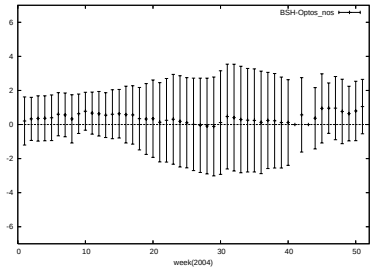

Figure 4: Weekly averaged difference and standard deviation of the difference of SST (°C) between BSH maps and Optos_nos

4. Discussion

The spatial averaged SST (figure 1) computed by the Optos_nos model and obtained by Modis shows the same trend. We have observed that the greater differences corresponded to satellite pictures with less valid values (i.e. with more clouds). Globally, the mean difference of SST is 0.55° (0.65° in absolute value).

At Westhinder station (figure 2) and Sandettie station (not shown here), there is a good fit between the observations, the model results and the satellite data. The Optos_nos simulations are less good (too hot) in late summer. Some of the daytime values of the

satellite are clearly underestimated. All Modis SST "outlier" values come from pixels located in the vicinity of clouds. These pixels are actually contaminated by clouds or cloud shadow but have been missed during the quality control.

The weekly mean difference between the model and the other sources of information is always less that 1.22 °C. We notice that the standard variation is higher in the summer and that the model is closer to the BSH maps (σ maximum 3.13°C) than to the MODIS values (σ maximum 5.36°C).

Spatial repartition of the difference of SST (not shown here) permits us to detect a problem near to the coasts for the model and near to the clouds for the satellite.

5. Conclusion

In summary, MODIS SST products (mean SST and related QL data) could help the model to accurately forecast the SST field provided that the QL is improved over cloud contaminated pixels. A spatial filter may also be used to roughly eliminate any abrupt spatial variation of SST which can disturb the model. This confirms the SST validation made by the MODIS processing team which pointed out the necessity to improve the procedure of flagging cirrus and low level clouds or fogs (Evans, 1999).

In the next steps, the observations of the Ferrybox project will be used to determine the source of the differences of SST. The algorithm for detection of clouds will be improved. The Optos_nos model will be improved near to the coasts. Finally the impact of the use of the Modis-derived SST as forcing of the Optos_nos model will be tested.

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