Validation of Buoy and Satellite Data for Near-Real Time Assessment of Changes on Bio-Optical Properties on Coastal Waters (English Channel)

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LONG-TERM GOAL

The long-term goal is to quantify the controls of primary productivity in shelf seas, and develop methods to detect and assess the possible anthropogenic impact on shelf-seas. This research requires the development and validation of models that derive predictions of hydrographic and biological variability from estimates of external physical forcing.

OBJECTIVES

The objectives of this project are; to demonstrate that hydrographic variability in shelf waters can be hind-cast, to a quantifiable degree, using a simple 1 dimensional physical model. To demonstrate that the model can be used to interpret the regional variability of ocean colour in terms of the mechanisms of physical forcing on phytoplankton growth. The effects of tidal front dynamics and the stability of the seasonal thermocline are of specific interest.

APPROACH

The approach follows the premise that the distribution of in-water variables (e.g. temperature, chlorophyll concentration) will reflect the distribution of the external forcing variables (e.g. heat budget, tidal speed). Additionally, it is assumed that external forcing controls in-water distribution through heating, mixing and light, which are all dependent on depth.

External forcing displays distinctive frequencies of variability. An observational programme was therefore designed that resolved in-water distribution over similar periods, for a discrete study region. The frequencies are classified as follows; one year, containing the period of seasonal heating, one month, containing the typical periods of meteorological events and the spring-neap tidal cycle, and one day, containing the periods of diurnal heating and the semidiurnal tidal cycle.

The distribution of in-water variables was resolved over the top 40 m of the watercolumn to determine, for instance, the vertical extent of the mixed layer, seasonal thermocline and deep layer. Spatial distribution over repeated transects (approx. 20 km) was also resolved to observe the effect of horizontal variability of tidal mixing and bathymetry.

As no single sampling platform could resolve all the listed scales of variability, a combination was used (see table 1); AVHRR satellite sensors, the Plymouth Marine Bio-Optical Data Buoy (PlyMBODy, Pinkerton & Aiken, 1997), and the towed Undulating Oceanographic Recorder (UOR, Aiken & Bellan 1990). An existing physical-biological model, described by Prestidge & Taylor (1995), was employed. This is a simple 1-dimensional, three-layer watercolumn model. The model uses estimates of external forcing to predict chlorophyll concentration and temperature. Model predictions were compared with field observations for each of the scales of variability.

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	Model	UOR	PlyMBODy	Satellite
1 year	✓	✓	✓	✓
1 month	✓	✗	✓	✓
1 day	✓	✗	✓	✗
20 km horizontal	✓	✓	✗	✗
40 m vertical	✓	✓	✗	✓

Table 1 - Analysis of the variability resolved by each observational platform used during the study. ✓ indicates that the scale was resolved, ✗ indicates that the scale was not resolved.

The approach to the project has developed over the last 3 years. This has mainly been as a response to the late launch of the SeaWiFS sensor, and the corresponding delay to the deployment of the PlyMBODy (optical data buoy) system. As bio-optical algorithms have not, as yet, been developed for the study region, the bio-optical model proposed in last year's (FY97) report has not been developed. Instead, recent work has concentrated developing a procedure for the objective validation of the 1 dimensional physical model of Prestidge & Taylor (1995). As high temporal resolution biological observations are not available, the emphasis of the project has changed from biological to hydrographic system modelling.

WORK COMPLETED

All observational data required for the project have been collected, processed and analysed. The physical-biological model is operational. The final integration of the measured and predicted variability is ongoing, and example analyses are presented in the results section.

RESULTS

Example field data were presented in last years' (FY97) report, which demonstrated that horizontal variability of mixing caused the formation of a tidal front within the study region, with resulting chlorophyll enhancement adjacent to the front. This report, however, presents observations that demonstrate the temporal variability observed at sampling station E1 (50°03'N 4°22'W), during 1997.

The seasonal cycle of heating and the formation of a seasonal thermocline (separation of mixed layer and deep layer temperature) are clear features of the temperature record (figure 1). Observations of

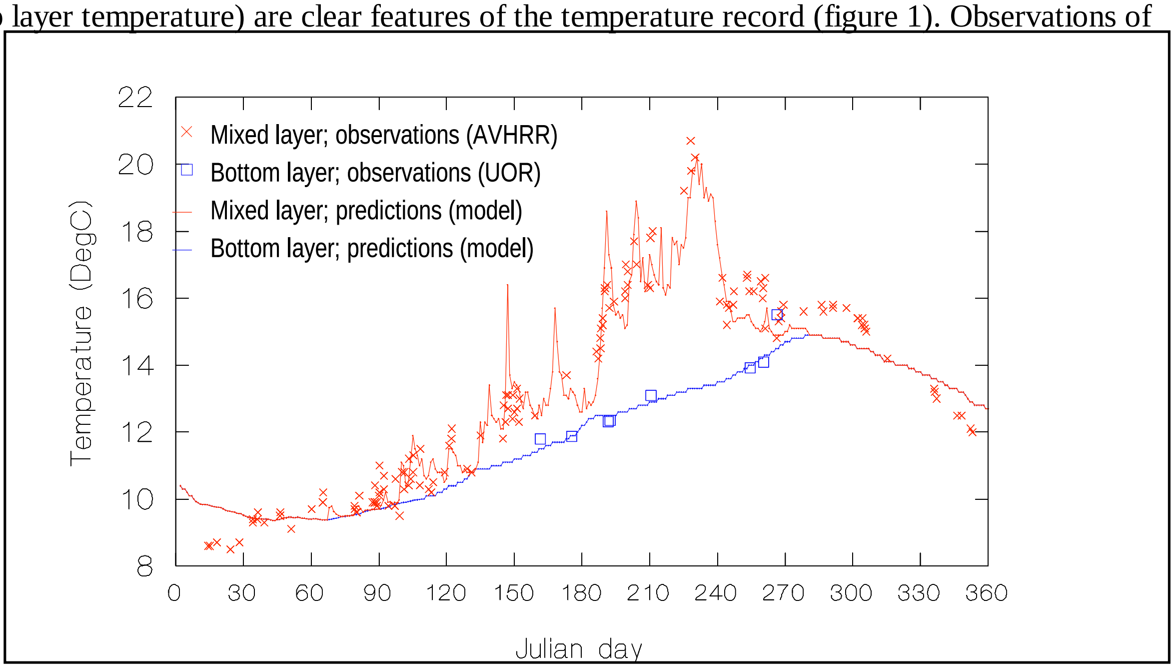

Figure 1 – Observations and predictions of temperature variability at E1 during 1997.

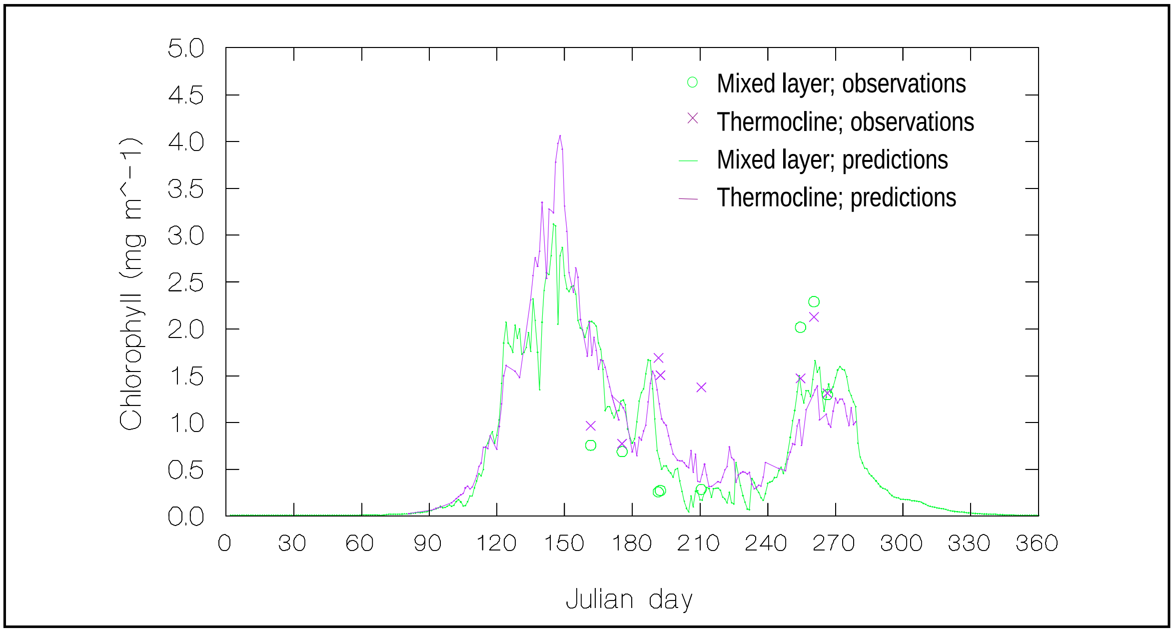

Figure 2 – Observations and predictions of chlorophyll variability at E1 during 1997.

chlorophyll concentration over this period are sparse, but do indicate low summer chlorophyll concentrations with a thermocline maximum, and an elevation of autumn concentrations (figure 2), consistent with examples found in the scientific literature (e.g. Holligan & Harbour, 1977).

Model predictions of temperature are overlaid on the observations in figure 1. The high correlation (R^2>0.9) suggests that vertical processes of heat exchange and mixing were dominant in controlling the temperature distribution at station E1 during 1997. Model predictions of chlorophyll concentration are overlaid on figure 2. Far less (<30%) of the observed variability is explained, However, the number of comparisons was low (n=8) and the model had not been optimised to fit the data set. Whilst the correlation is numerically poor, the model predicted the occurrence of an autumn bloom and a thermocline chlorophyll maxima whose timing appeared consistent with observations. One can therefore

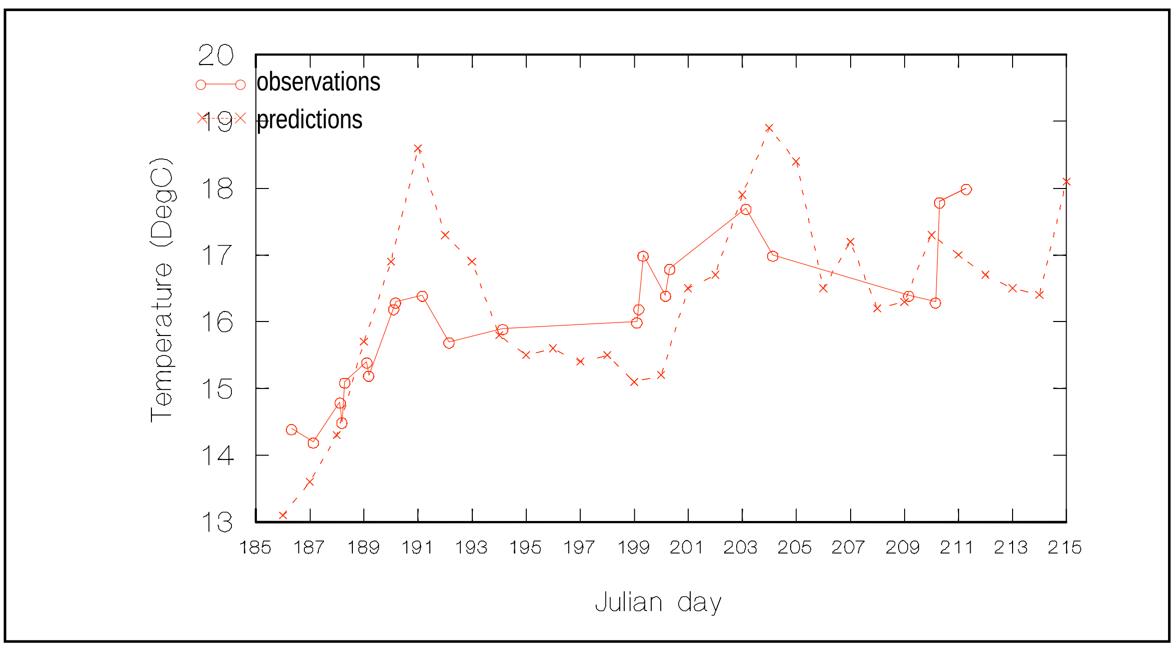

Figure 3 – Temperature variability at E1 during July 1997.

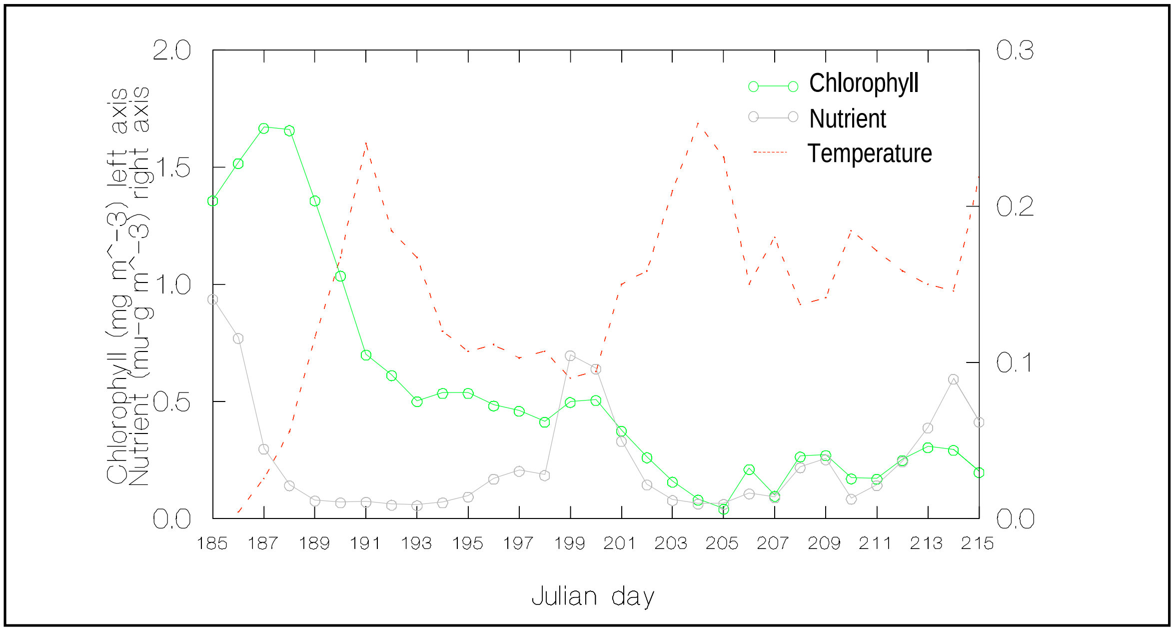

Figure 4 Predictions of chlorophyll and nutrient variability at E1 during June 1997. Temperature predictions from figure 3 have been overlaid.

conclude that vertical processes control the main features of the seasonal chlorophyll distribution.

Over shorter time scales, the model predicted that water column structure responded to individual meteorological events, typically 5-20 days in length. Similar responses are also apparent in observational data. An example from 1997, station E1, is presented in figure 3, which plots predictions and observations of mixed layer temperature over a 30 day period (corresponding to June 1997). The model correctly predicts the frequency and phase of the observed variability, but, because the model physics underestimate surface layer mixing during calm weather, the amplitude is overestimated by up to 1.5°C, leading to a low numerical correlation (R^2~0.5). Work is underway to understand correct the model physics over this scale. The fluctuations in temperature shown by figure 2 are due to variations in mixing causing cooler bottom water to be 'pumped' into the surface layer. As the bottom water is nutrient replete, the model predicts that variable mixing results in a supply of nutrients to the mixed layer, enhancing summer chlorophyll concentrations (see figure 4).

PlyMBODy was deployed in September 1997, corresponding with the launch of SeaWiFS. Measurements, not presented here, revealed significant variability of both temperature and chlorophyll over periods of less than 1 day. Analysis revealed that diurnal heating was a contributing factor. The present model, however, predicted that this variation was minimal (R^2~0). The significance of this error in terms of longer scale variability (e.g. monthly, seasonal) is being investigated. At times, semi-diurnal tidal advection caused additional variability. The model, however, is not capable of predicting any advective effects.

In conclusion, the accurate hind casting of both mixed and deep layer temperatures suggests that the mixing processes, vital to the control of primary productivity, were correctly modelled. Objective validation implies that the distribution of each of the output variables over all of the scales predicted by the model can be resolved by the observational data set. For the 1 dimensional model used here, the temporal resolution of temperature provided by satellite remote sensing, was appropriate for seasonal and monthly variability of mixed layer temperature. A general limitation of this technique is that it does not provide any information on the distribution with respect to depth. This data can be gathered using profilers deployed from boats, as demonstrated by the deep layer temperature observations presented in figure 1. Generally, the maximum temporal resolution achieved from boats is too coarse to resolve high frequency (e.g. monthly) variability.

Work is ongoing on assessing the ability of the model to hind-cast the observations of spatial variability. Preliminary results are encouraging, and demonstrate, for instance, how comparing temporal and spatial analyses can be used to de-couple forcing mechanisms which vary over different horizontal scales (e.g. tidal mixing, which is horizontally variable over scales of 20 km, and wind mixing, which is approximately constant). For the study region, a resolution of 1 km proved adequate to resolve the main spatial features, which was achieved using AVHRR or UOR data for the surface layer, and UOR data for the sub-surface layers.

IMPACT / APPLICATIONS

On conclusion, the limitations of both the modelling and observational components of the project will be understood. This knowledge will be of use in the design/implementation of future integrated observational/modelling programmes.

Estimates are available of the processes controlling the biological and bio-optical distribution within the study region. This knowledge will allow the variability observed in ocean colour data to be related to the prevailing conditions of external forcing, such as wind speed and tidal current.

A physical model optimised for the study region is available. This provides a tool that can predict near-real time hydrographic variability. It can be used operationally to predict, for instance, the transition between water types of differing optical characteristics.

With the availability of high temporal resolution biological observations (from satellites or remote buoys, for example) it will be possible to objectively validate the biological component of the physical/biological. As this only becomes possible after the physical component has been thoroughly validated, it is a logical extension of this project.

TRANSITIONS

none

RELATED PROJECTS

Remote Sensing Data Analysis Service (RSDAS). S. Groom (sbg@wpo.nerc.ac.uk). Responsible for processing all remote sensed data used during this project.

Plymouth Marine Bio-Optical Data Buoy (PlyMBODy). M. Pinkerton (mjp@wpo.nerc.ac.uk). Responsible for processing all optical buoy data used during this project.

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