Journal of Marine Systems 91 (2012) 34–40

Contents lists available at SciVerse ScienceDirect

Journal of Marine Systems

journal homepage: www.elsevier.com/locate/jmarsys

Using observations of bottom temperature to calibrate the output of an ocean model

J.F. Middleton [a,b,*], R. McGarvey [a], A. Linnane [a], S.M. Middleton [b], C.E.P. Teixeira [a,c], P. Hawthorne [a]

[a] Aquatic Sciences, South Australian Research and Development Institute, Adelaide, S.A., Australia
[b] School of Mathematical Sciences, University of Adelaide, S.A., Australia
[c] School of Mathematics and Statistics, University of New South Wales, N.S.W., Australia

ARTICLE INFO

Article history:
Received 24 September 2010
Received in revised form 10 September 2011
Accepted 13 September 2011
Available online 1 October 2011

Keywords:
South Australia
Bluelink
Rock lobster
Bottom temperature
Model validation

ABSTRACT

In order to understand the effects of environmental variables, such as temperature, on commercial fish species, long time series (>10 years) of data are required. We show that bottom temperature output (1992–2008) from the semi-global ocean circulation model Bluelink, can be corrected for a coastal region off southern Australia using relatively short, non-continuous time series of observed temperature. The correction involves a simple linear regression, but with coefficients that are determined on a monthly basis so as to allow for consistent seasonal errors in the model temperature fields. For one site (Southend), the application of the correction increased the explained variance from 26% to 73%. The bottom temperature data is found to be serially correlated and two methodologies for computing the effective degrees of freedom and confidence limits for the regression model are adopted. Both result in almost identical confidence limits. These results are thought to be robust since around 95% of scatter pairs (temperature data and model output) are found to lie within the 95% confidence limits computed.

1. Introduction

This note results from an Australian Fisheries Research and Development Corporation project that is designed to statistically determine the relative importance of a variety of possible environmental and anthropogenic factors on the catch rate of lobsters along the Bonney coast region of South Australia, (Fig. 1). This region hosts one of Australia's iconic upwelling systems during the austral summer (December to March) that is thought to be important to sustaining the rock lobster resource (Lewis, 1981; Middleton and Bye, 2007; Schahinger, 1987). A long time series of daily catch per unit effort (CPUE) extending back to 1970 exists for the fishery (Linnane et al., 2010) and in order to examine the possible relationship, a similar time series for bottom temperature is required. For the Bonney Coast, some 5 years of bottom temperature data have been collected (Table 1) from Southend (Fig. 1), but the data are not continuous in time. Shorter time series have also been collected from Port MacDonnell and Robe, but are inadequate for a statistically reliable analysis with CPUE.

However, global and semi-global ocean circulation models can provide the long time series of daily estimates of bottom temperature needed, although the resolution in space is necessarily relatively coarse. The Bluelink model has a 0.1 degree resolution in the horizontal (~10 km) and fixed 10 m vertical layers between the surface and 100 m depth (Oke et al., 2008; Schiller et al., 2008). The model output considered here is from version 2p1 and 2p2 of the Bluelink ReANalysis (BRAN), spanning 10/1992-4/2008. These BRAN experiments assimilate satellite-derived and in situ observations of sea-level anomaly, temperature and salinity from a variety of sources — see Oke et al. (2008) for details.

In the following, we show that the Bluelink bottom temperature estimates are not by themselves reliable for the Bonney Coast and explain only 26% of the variance of observed bottom temperature at Southend. However, we find that the model temperatures generally under-estimate (over-estimate) events during summer (winter). This suggests that the model output is subject to a consistent error which may be corrected using a simple regression model.

2. Overview

Daily averages of observed bottom temperature (50–55 m) were obtained from the bottom loggers located on the Bonney Coast off Southend, Port MacDonnell and Robe (Fig. 1). Details of the available time series are listed in Table 1. The bottom loggers used were onset® StowAway®TidbiT® TBI32-05 + 37 with an accuracy of $\pm 0.2°$ at 20 °C and response time of 60 min. These are certainly adequate to resolve daily changes in temperature of 1–2 °C observed for the region.

The daily averaged temperature data for Southend covering a typical year 1999 (Fig. 2) are shown (upper panels, thick curves) along with the Bluelink estimates obtained from the nearest cell to this logger (see Table 2). The logger data show several pronounced upwelling events over the austral summer period, when bottom temperatures can fall by 2–3 °C over a period of 5–10 days (December to March). Overlying this cold water is a surface mixed layer (typically 20–30 m depth), that is 2–3 °C warmer than that at the bottom

* Corresponding author at: Aquatic Sciences, South Australian Research and Development Institute, Adelaide, S.A., Australia.

0924-7963/$ – see front matter. Crown Copyright © 2011 Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.jmarsys.2011.09.006

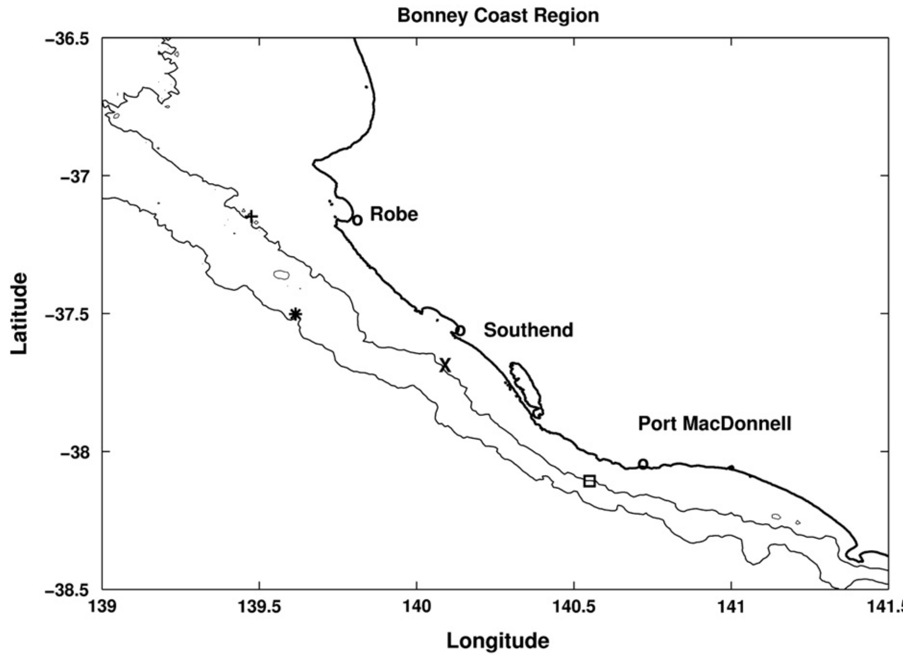

Fig. 1. The Bonney Coast region. The logger sites are indicated by the + (Robe), x (Southend) and box (Port MacDonnell). The 50 m and 100 m isobaths are shown. The * indicates the location of the CTD cast taken on February 7th 2008.

(Schahinger, 1987; Middleton and Bye, 2007; — see also Fig. 4). During autumn (April to June), the south-easterly upwelling winds are replaced by westerlies, and from Fig. 2, bottom temperatures rise by 4–5 °C, as warm surface layer water is mixed to the bottom. During winter, the westerly winds, in conjunction with cooling, lead to downwelling and a vertically well-mixed water column. This state persists until November/December, when upwelling favourable winds again drive cold water onto the shelf (e.g., Fig. 2; 27th November 1999).

Comparing the logger data with the estimates from the Bluelink model, the latter correctly predict the occurrence and timing of high and low-temperature events. Correlation functions of Bluelink versus measured bottom temperature, over a daily time step, showed peaks in correlation at exactly lag = 0. This implies daily precision in the agreement of model with data, specifically in the timing of temperature increases and decreases relative to their respective overall means.

Discrepancies between model and data were, however, apparent in the seasonal mean levels of bottom temperature. During the summer of 1999, the Bluelink output consistently underestimates the reduction in temperature due to observed upwelling events by 2 °C or so. During the remainder of the year, weekly changes in both model and observed temperature are smaller than in summer and the agreement better: the model estimates are often cooler than the data by around 1 °C. The fraction of variance (r^2) of the observed temperature data that is explained by the Bluelink temperature is only 26%.

These observations are reinforced by the plot of monthly averaged logger data (1999–2008) and Bluelink output (Fig. 3). The logger data are typically 1–2 °C cooler than the Bluelink output (thin curves) during summer. During the remainder of the year, when the water column is well mixed, the agreement is better, but the Bluelink temperatures are generally warmer than the observations.

Our initial thought was that the differences between the observations and Bluelink output were a result of poor model resolution in the vertical (10 m layers) coupled with a surface mixed layer scheme (adopted in Bluelink) that does not incorporate a turbulence closure scheme (Chen et al., 1994). During summer, intense atmospheric heating at the surface coupled with cold upwelled water at the bottom leads to a sharp thermocline as illustrated by the CTD cast for temperature (Fig. 4) taken in February 2008: a period of intense upwelling. This thermocline might not be properly resolved by the 10 m deep layers of the model leading to an artificial vertical diffusion of surface heat into the cold upwelled bottom water: warmer (model) bottom temperature would result. A comparison of the CTD cast with the Bluelink output (thin curve; Fig. 4) indicates that the thermocline at depths of 30–40 m is not well resolved by the model. However, the discrepancy between the model and observations also appears to be due to the differences in the surface temperature since those from Bluelink are 2 °C warmer than the data. The discrepancy here may result from errors in the surface heat fluxes used to force the model.

Whatever the reason for the discrepancy, the aforementioned results do indicate that the differences are generally consistent and change on a seasonal or monthly basis: during summer, the model bottom temperatures are too warm and in winter slightly too cold.

Table 1
Details of the bottom logger data.

	Southend	Port MacDonnell	Robe
Depth (m)	63	60	52
Latitude	−37.6665	−38.1072	−37.1482
Longitude	140.1468	140.5499	139.4746
Available data (dd/mm/yyy)	16/12/1998 to 05/10/2001 09/10/2001 to 27/02/2002 07/01/2003 to 25/11/2003 18/05/2007 to 22/11/2007 30/01/2008 to 22/05/2008	27/11/1998 to 01/04/1999 13/01/2000 to 09/10/2000 11/12/2002 to 21/04/2004	09/12/1998 to 04/01/2001 15/11/2001 to 01/12/2001 03/12/2001 to 06/11/2002 15/05/2006 to 20/01/2007
~No. days of data	1760	887	1319