Journal of Marine Systems 162 (2016) 126–136

Contents lists available at ScienceDirect

Journal of Marine Systems

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

Assimilation experiments for the Fishery Observing System in the Adriatic Sea

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A R T I C L E I N F O

Article history:
Received 21 June 2015
Received in revised form 11 December 2015
Accepted 6 March 2016
Available online 8 March 2016

Keywords:
Fishery observing system
Observing system experiment
Observing system simulation experiment
The Adriatic Sea

A B S T R A C T

An impact assessment of a Fishery Observing System (FOS) network in the Adriatic Sea was carried out with an ocean circulation model fully-coupled with a data assimilation system. The FOS data are single point vertical values of temperature collected in 2007. In this study, we used the Observing System Experiment (OSE) and Observing System Simulation Experiment (OSSE) methodologies to estimate the impact of different FOS design and sensors implementation. OSEs were conducted to evaluate real observations and they show that the FOS network improves the analysis significantly, especially during the stratification season. Root mean square (RMS) of temperature errors are reduced by about 44% and 36% in the upper and lower layers respectively. We also demonstrated that a similar impact can be obtained with a reduced number of vessels if the spatial coverage of the data points does not change significantly. In the OSSE, the impact of the implementation of a CTD (conductivity–temperature–depth) sensor in place of the existing temperature sensor was tested with identical twin approaches between January and April 2007. The results imply that the assimilation of salinity does not improve the analysis significantly during the winter and spring seasons.

1. Introduction

Integrating new types of coastal observing systems into high resolution shelf and coastal ocean models is important for forecasting and obtaining best estimates of the essential marine variables in the shelf and coastal areas of the world's oceans. Since the real time global ocean observing system has become a reality in support of ocean forecasting in the open ocean regions (Dombrowski et al., 2009), the challenge is now to define the strategy of the observing system for shelf and coastal areas.

There are various methods to analyze the impact of observing systems (Oke and O'Kane, 2011) on ocean dynamical field reconstructions. One of these is the Observing System Experiment (OSE) which is widely used in the atmospheric and oceanic community. It is a data-denial approach evaluating the impact of the excluded set of observations with a reference to a best estimate that assimilates all the data.

Another methodology is the Observing System Simulation Experiment (OSSE). The rationale is similar to the OSE but the OSSE evaluates the possible impact of a future observing system or various design strategies of the existing system together with new ones. In atmospheric research, the OSSE methodology has been used for the last three decades (Arnold and Dey, 1986; Masutani et al., 2010). For the Mediterranean Sea, Raicich (2006) used an 'identical twin' approach in which a model simulation was used as the 'truth' or 'nature' run from which the synthetic observations are generated, and a perturbed model simulation is generated that differs from the nature run. Synthetic observations are assimilated in the perturbed model simulation and the estimated field variables are intercompared with the nature run. Masuda (2014) studied the effectiveness of concentrated observations for an ocean state estimation in a region remote from the observation site in the North Pacific with the same approach. On the other hand, Alvarez and Mourre (2014) studied the design of a glider network with a 'fraternal twin' approach, in which the nature run and the forecast model are the same but with different physical configurations. Finally, Halliwell et al. (2014, 2015) used the fraternal twin approach and extensively validated their OSSE by comparing it with the reference OSEs.

We focus on the Adriatic Sea where a Fishery Observing System (FOS) has been developed to collect in-situ environmental data using fishing vessels (Falco et al., 2007). The FOS is one of the most notable

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http://dx.doi.org/10.1016/j.jmarsys.2016.03.002
0924-7963/

vessels of opportunity networks along with the RECOPESCA program (Leblond et al., 2010). Designing a ship-of-opportunity optimal network is challenging and alternative strategies for collecting vertical temperature profiles on fishing vessels in the coastal and open ocean are being evaluated (Kourafalou et al., 2015).

In this study, we use a high-resolution ocean circulation model coupled to a data assimilation system in order to assess the impact of specific FOS observations. In our case, FOS data are single vertical point measurements rather than profiles, and it is important to evaluate their impact on quality analyses since this ship-of-opportunity measurement system is cheap and does not impact on fishing activities. We performed Fishery Observing System Experiments (FOSE) to evaluate the impact of the geographical network and the temperature measurement depth distribution. We then designed a Fishery Observing System Simulation Experiment (FOSSE) to estimate the impact of the implementation of a CTD sensor instead of the temperature-only sensor that currently exists.

The paper is organized as follows: Section 2 introduces the model and data assimilation system and the FOS observations provided in 2007 are detailed. Section 3 presents the FOSE design and results. Section 4 is devoted to FOSSE, and the overall results are discussed in Section 5.

2. Materials

2.1. Model description

The model configuration is described in detail by Gunduz et al. (2013) and will only be outlined here. The model uses the NEMO (Nucleus for European Modeling of the Ocean, Madec, 2008) code in its explicit free surface, linear formulation. It has a constant horizontal grid resolution of 1/48° corresponding to 1.8 and 2.3 km in longitudinal and latitudinal directions, respectively, and 120 unevenly spaced z-levels with partial cells at the bottom. The vertical grid is 1 m in the top 60 m, increasing to 9 m at a depth of 100 m and to 50 m at the deepest point in the Adriatic Sea. The largest spacing of 70 m is in the Ionian Sea at the deepest point (2800 m, Fig. 1).

Atmospheric surface momentum, heat and water fluxes are computed using European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim surface fields and bulk formulas. However, precipitation is taken from the Merged Analysis of Precipitation (CMAP) observational dataset (Xie and Arkin, 1997). The ERA-Interim atmospheric forcing fields are available at a 6-hour frequency and horizontal resolution of 0.25°.

The model domain has one open boundary that communicates with the Mediterranean Sea positioned south of the Otranto Strait (Fig. 1). The boundary conditions for temperature, salinity, sea surface height, zonal and meridional currents are provided daily from the large-scale MFS (Pinardi and Coppini, 2010).

The initial conditions of the model were taken from the simulation by Gunduz et al. (2013) in order to coincide with 1 January 2007, and the simulation period is up to December 2007.

2.2. Data assimilation scheme

The OceanVar data assimilation scheme (Dobricic and Pinardi, 2008) is implemented in the Adriatic Sea using a new description of the vertical background error covariances. As described in Dobricic et al. (2005), part of the background error covariance is represented by vertical multivariate Empirical Orthogonal Functions (EOFs) for temperature and salinity. In our study the vertical EOFs were calculated at each model grid point and monthly, using a 10 year-long simulation (Gunduz et al., 2013), and the salinity and temperature variances as a departure from a monthly mean seasonal climatology.

The horizontal part of background error covariance is assumed to be Gaussian isotropic, depending only on distance. It is modeled by the successive application of the recursive filter in longitudinal and latitudinal directions, which provides a high computational efficiency in each iteration of the algorithm. The rapidly evolving part of the background error covariance, consisting of the sea level and the barotropic velocity components, is modeled using a barotropic model forced by the vertically-integrated pressure innovations resulting from temperature and salinity variations. The assimilation scheme of Dobricic and Pinardi (2008) is multivariate, i.e. temperature, salinity and sea surface height observations produce corrections not only in the corresponding state variables but also in the vertically correlated state variables, in particular the velocity fields. The assumption that the horizontal error correlation structure is homogeneous and isotropic is an important limitation of the scheme. This correlation structure is not adequate for strongly anisotropic flow fields as they exist along the western boundary of the

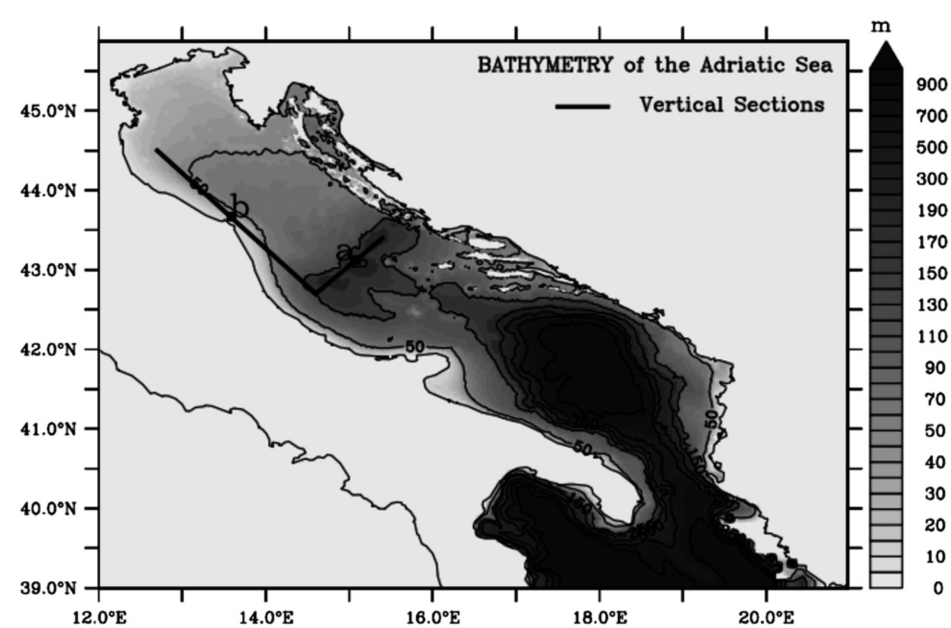

Fig. 1. Bathymetry of the Adriatic Sea. The section indicated with the line segments are used for studying vertical structure of the water column. The locations (a) and (b) are the reference points for the black and green lines, respectively, in the vertical cross-sections.