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Near real-time ocean circulation assimilation and prediction in the Intra-Americas Sea with ROMS

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ABSTRACT

We present the feasibility of a prototype, near real-time assimilation and ensemble prediction system for the Intra-Americas Sea run autonomously aboard a ship of opportunity based on the Regional Ocean Modeling System (ROMS). Predicting an ocean state depends upon numerical models that contain uncertainties in their modeled physics, initial conditions, and model state. An advanced model, four-dimensional variational assimilation, and ensemble forecasting techniques are used to account for each of these uncertainties. Every 3 days, data from the previous 7 days period were assimilated to generate an estimate of the circulation and to create an ensemble of 2 weeks forecasts of the ocean state. This paper presents the methods and results for a multi-resolution assimilation system and ensemble forecasts of surface fields and dominant surface circulation features. When compared to post-processed science quality observations, the state estimates suffer from our reliance on real-time, quick-look satellite observations of the ocean surface. Despite a number of issues, the ensemble forecast estimate is often superior to observational persistence. This proof-of-concept prototype performed well enough to reveal deficiencies, provide useful insights, valuable lessons, and guidance for future improvements in real-time ocean forecasting.

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1. Introduction

Prediction of the ocean or atmosphere involves a complex, nonlinear system with imperfect physics, and uncertainties in the model state and boundary and initial conditions. Since the 1970s, significant progress against each of these issues has improved model predictive skill in numerical weather prediction (Kalnay et al., 1998; Buizza et al., 2000; Simmons and Hollingsworth, 2002). Advancements in computational power and numerical schemes have helped reduce the uncertainties in model physics. Advanced variational data assimilation techniques have done much to address the errors in the current state estimate (Le Dimet and Talagrand, 1986; Talagrand and Courtier, 1987; Courtier et al., 1994; Chua and Bennett, 2001). Ensemble techniques provide forecast estimates of probability distribution functions that are consistent with the estimates of the model state errors (Lewis, 2005). The practice of using numerical weather forecasting in the ocean is relatively new and actively under development (Pinardi and Woods, 2002; Chassignet and Verron, 2006). We present a near real-time ocean prediction system that incorporates an advanced primitive equation model, multi-resolution four-dimensional variational (4DVAR) data assimilation, and ensemble prediction methods running aboard a ship at sea. Our previous work, Powell et al. (2008) (hereafter P2008), presented the theory and application results of the incremental 4DVAR assimilation method in ROMS. This paper presents an operational forecasting system comprised of a multi-resolution assimilation scheme, a method for ensemble forecasts using information derived from the assimilation procedure, and serving to elucidate the challenges, issues and options available with respect to real-time ocean forecasts of surface fields while operating at sea.

The focus of this study is the Intra-Americas Sea (IAS), shown in Fig. 1, which encompasses the Gulf of Mexico (GOM) and Caribbean Sea and contains five deep basins separated by relatively shallow sills (<2000 m). The IAS circulation is an important component of the western boundary current system of the North Atlantic sub-tropical gyre (Lee et al., 1996) and is fed by ocean transport through the Antilles island passages. This flow converges in the northwest Caribbean as the Yucatan Current to become the Loop Current (LC), the energetic jet entering the Gulf of Mexico through the Yucatan Channel and separating from the Campeche Bank. The LC is the dominant source of energy, variability, and momentum that drives much of the circulation within the Gulf of Mexico (Ohlmann et al., 2001; Schmitz et al., 2005). The LC exits through the Florida Straits and proceeds north as the Gulf Stream. The circulation is characterized by a richly varied dynamical structure of energetic, large-scale, mesoscale and submesoscale eddies (Mooers and Maul, 1998; Schmitz et al., 2005).

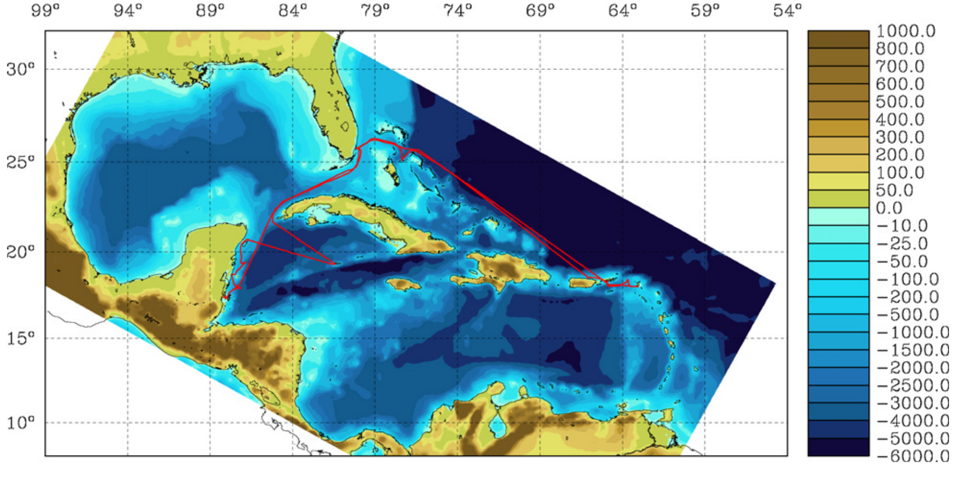

Fig. 1. The model domain encompasses the entirety of the IAS and portions of the North Atlantic. The western and eastern cruise tracks followed by the Royal Caribbean International *Explorer of the Seas* are indicated by the red lines.