The Red Sea Forecasting System

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Despite its importance to the world community for a variety of socio-economical reasons and the presence of extensive coral reef gardens along its shores, the Red Sea remains one of the most under-studied large marine physical and biological systems in the global ocean. We present our efforts to build advanced modeling, data assimilation, and uncertainty quantification capabilities for the Red Sea, which is part of the newly established Saudi ARAMCO Marine Environmental Research Center aiming at studying and forecasting the circulation and the environment of the Red Sea.

The Red Sea modeling system compromises a regional nested very high resolution MIT general circulation models (MITgcm) to simulate the general circulation at various spatial scales, a 10km resolution Weather Research Forecasting (WRF) model to simulate the atmospheric conditions, a 4km resolution Regional Seas Ecosystem Model (ERSEM) to simulate the ecosystem, and a 1km resolution WAVEWATCH-III model to simulate the wind driven surface waves conditions. We have also implemented an oil spill model, and a probabilistic larval Connectivity Modeling System (CMS) to simulate the wind driven surface waves conditions.

The Red Sea MITgcm, WRF and ERSEM models have also been equipped with advanced fully parallel Ensemble-based Kalman Filtering (EnKF) tools capable of assimilating all multivariate satellite and in-situ data sets that have been collected or will be collected in the future. EnKFs have been proven successful for ocean data assimilation, efficiently propagating and reducing uncertainties of large scales ocean simulations. The important role of uncertainties is now increasingly recognized in the ocean forecasting community for proper decision-making and risk management. In an EnKF, the forecasts and their uncertainties come as ensembles of mode simulations. Incoming ocean observations are then used to quantify and reduce the uncertainties in the forecasts. We have also built an advanced visualization framework to enable users to easily extract and identify the relevant important information from such big data sets.

**System Overview**

**Integrated Monitoring, Modeling and Forecasting System**

**Remote sensing** provides large scale observations from the satellite, including Sea Level Anomaly (SLA), Sea Surface Temperature (SST), Chl-a, Sea Surface Wind and Heat Fluxes.

**Assimilation, Uncertainty Quantification and Visualization**

**WRF with 3DVAR and WAVEWATCH-III**

**Validation of wave height from WAVEWATCH-III forced with WRF**

**MITgcm with EnKF**

**Schematic of the ensemble Bayesian filtering assimilation**

The assimilation scheme consists of two steps: a forecast step in which an ensemble of state vectors representing the uncertainties in the system is integrated with the model forward in time to compute the forecast distribution, and an update step to update the forecast ensemble distribution with incoming data based on the Bayes’ rule.

**Uncertainty Visualization**

Visualization system for exploration of ocean forecast ensembles from multiple perspectives

**Visualization of sea surfaces blended over the current surface and volume rendering of the pdf at a user-selected position**