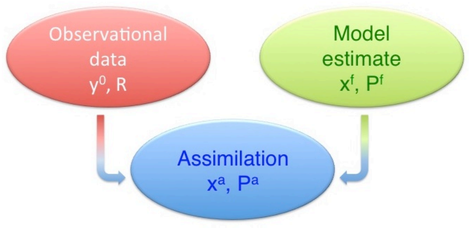
Ensemble Data Assimilation System for Forecasting the Red Sea Circulation

Habib Toye[1], Peng Zhan[1], Furrukh Sana[1], Ganesh Gapalakrishnan[2], Aditya Kartadikaria[1], Ibrahim Hoteit[1]
1 King Abdullah University of Science and Technology
2 Scripps Institution of Oceanography

DATA ASSIMILATION, WHAT IS IT?

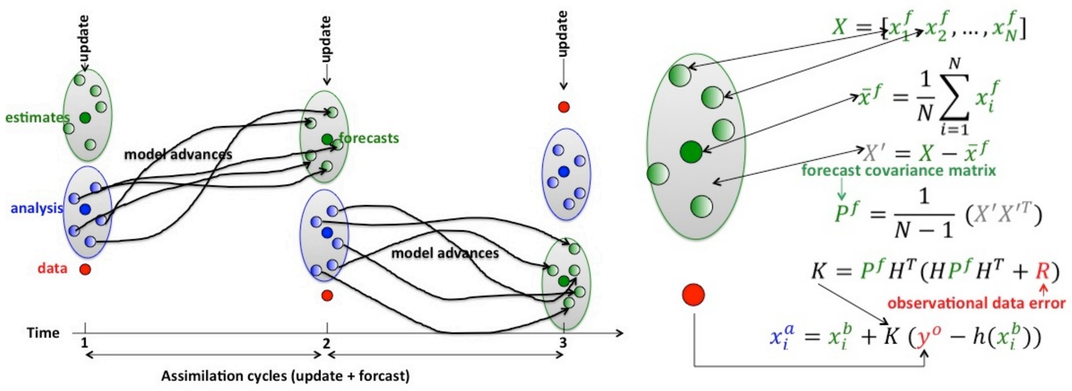
Data assimilation is a state-of-the-art approach for combining observational data (y^0) with model estimate(s) (x^f) in order to compute the best possible representation (x^a) of the system of interest. Not only does it provide the best estimate, but also a quantification of its uncertainties (P^a) derived from the forecast covariance matrix (P^f) and the observational data errors (R).



Data assimilation finds application in many fields, among which, meteorology, weather forecast, motion tracking (of fluids, satellites, airplanes, …).

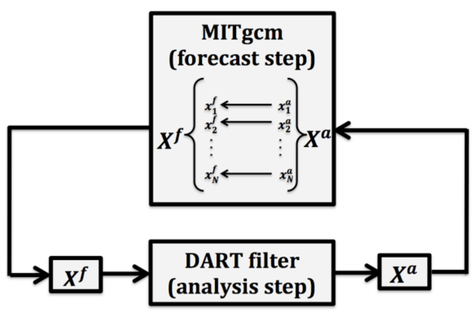
ENSEMBLE DATA ASSIMILATION

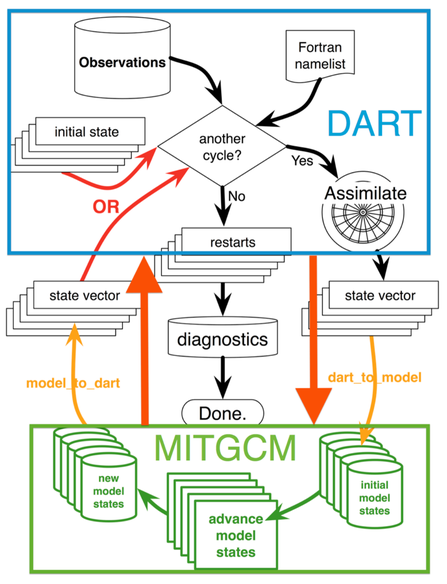
From an ensemble of estimates, once we a new observation becomes available, we compute an ensemble of analysis. We then compute new forecasts by advancing the members with the dynamical model in parallel.



DART-MITGCM FORECASTING SYSTEM FOR THE RED SEA

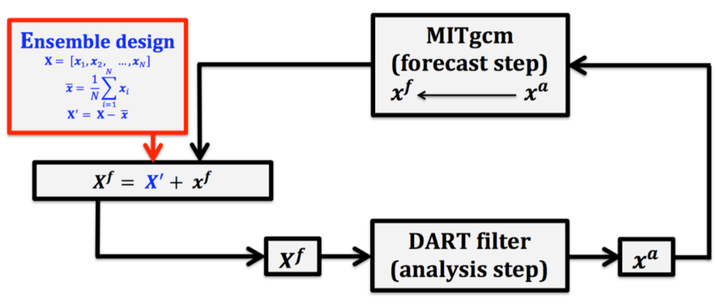
The Data Assimilation Research Testbed (DART) along with the MIT general circulation model (MITgcm) are used and configured for the Red Sea. DART filter performs the assimilation update before handling the ensemble of analysis to MITgcm. Many MITgcm instances are then advanced in parallel to produce a new forecast ensemble. This ensemble of forecast feed DART filter inputs and we go for another assimilation cycle. In this configuration the anomalies are dynamically propagated through the model advances.





ENSEMBLE DESIGN AND ANOMALIES MANAGEMENT

In order to reduce the computational cost and to exploit the dominant seasonal variability of the Red Sea, we implemented new schemes in which we advance only one MITgcm model and build a new ensemble X from a dictionary of model simulations. Within the so-called EnOI scheme, the same ensemble of anomalies is used. For the Seasonal EnOI, one ensemble is used for each season. The Dynamic Ensemble Update (DEU) scheme computes the ensemble from the last forecast and the dictionary.

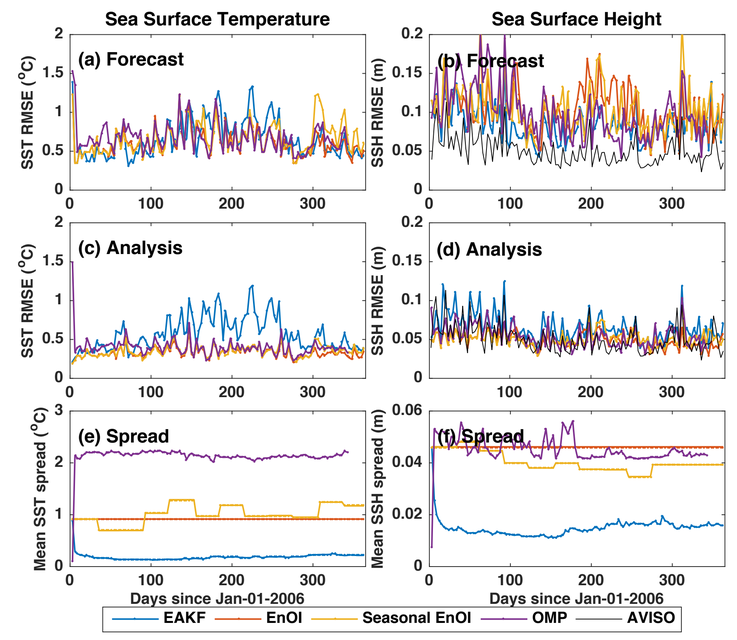


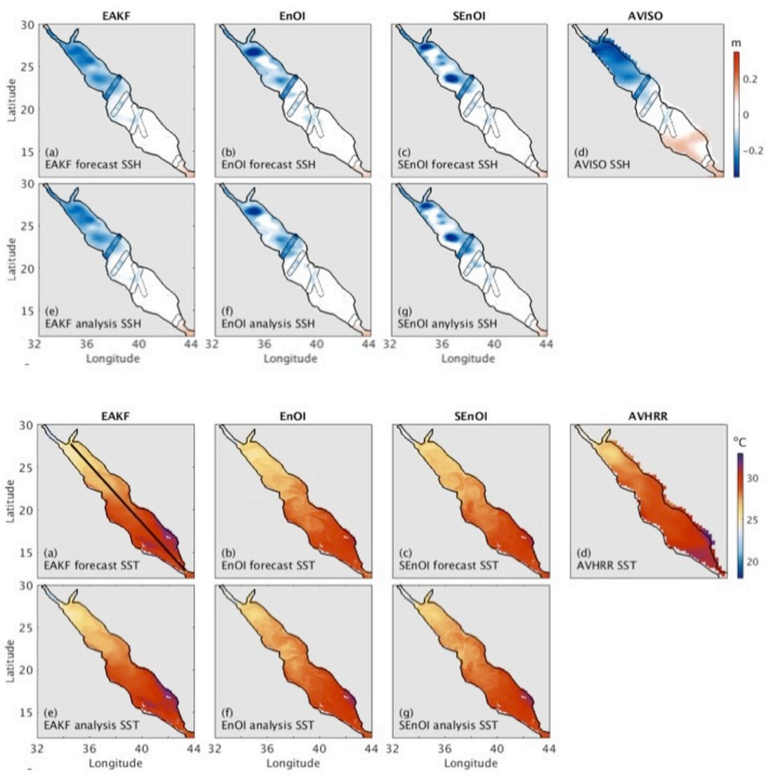
DYNAMIC ENSEMBLE UPDATE SCHEME

Estimation quality depends on the identification of the correct ensemble members from the dictionary based on seasonal data. The scheme utilizes the Orthogonal Matching Pursuit (OMP) algorithm to select the best ensemble from a large dictionary of model estimates that takes into account all seasonal variabilities. The DEU scheme enables changing the ensemble members during estimation cycles to better represent the anomalies resulting from the seasonal variations in the Red Sea.

RMSES, SSH 2D PLOTS AND SST 2D PLOTS

The spatial distributions of the forecast and analysis states on June-6- 2006 as estimated by four ensemble assimilation schemes are compared with remote sensing observations of SSH and SST/temperature profile. The SSH and SST observations are extracted from gridded AVISO and the AVHRR products, respectively. Forecasts from all four schemes agreed well with the remote sensing data, and additionally provided more detailed mesoscale and sub-mesoscale features in the basin than the gridded products.





References:

• http://www.image.ucar.edu/DAReS/DART/index.php
• Sana, Furrukh, et al. "Orthogonal Matching Pursuit for Enhanced Recovery of Sparse Geological Structures With the Ensemble Kalman Filter," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 9, no. 4, pp. 1710-1724, April 2016.
• Toye, Habib, et al. “Ensemble Data Assimilation in the Red Sea: Sensitivity to Ensemble Selection and Atmospheric Forcing” submitted to Ocean Dynamics, Topical collection JONSMOD 2016

Acknowledgements: This research work was supported by King Abdullah University of Science and Technology (KAUST), Saudi Arabia and the Saudi ARAMCO-KAUST Marine Environmental Research Center (SAMERCK). The research made use of the resources of the Super computing Laboratory and computer clusters at KAUST.