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Theme 4: Data Assimilation

Session 3: Coastal/regional data assimilation and observation impact

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Development of a Pan-Canadian Operational Regional Ocean Data Assimilation System

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In order to provide Canada with short-term ice-ocean predictions and hazard warnings in ice-infested regions the Government of Canada CONCEPTS initiative (Canadian Operational Network of Coupled Environmental Prediction Systems) has developed a Regional Ice-Ocean Prediction System (RIOPS). The domain covers the Arctic and North Atlantic regions at roughly 5km resolution and produces 48 hr forecasts 4 times a day. RIOPS uses the NEMO-CICE ice-ocean model and includes explicit tides, a landfast ice parametrization based on the effect of grounded ice ridges (for improved representation over shallow waters), and an increased resistance to tension and shear in the ice rheology (for improved representation in land-locked areas). The ocean analysis component of the system was originally based on a spectral nudging approach and is updated here to use a multivariate reduced-order Kalman filter that assimilates sea level anomaly, sea surface temperature and in situ profiles of temperature and salinity. The model domain is also extended to cover the Canadian west coast. The ocean analysis is blended with a 3DVar ice analysis that assimilates SSM/I, SSMIS, AMSR2, ASCAT, as well as manual analyses from the Canadian Ice Service (daily and regional ice charts, and Radarsat image analyses). Here we demonstrate the improvements in the analysis system as compared to both the spectral nudging approach as well as comparable global analysis systems, including the Canadian Global Ice Ocean Prediction System (GIOPS). Particular improvements with respect to GIOPS are found due to higher resolution error modes and a modified observation operator for online tidal filtering for SLA.

Keywords: DA - Shelf-seas and coastal data assimilation, DA - Background and observation error covariances, DA - Fundamentals and methodologies of data assimilation, Systems - Implementation of Ocean Prediction Systems,

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The impact of data assimilation into a tidally driven model for the representation of Cape São Tomé Eddies

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Ocean eddies play an important role by providing energy for lateral and vertical mixing, and exchange water and properties between different oceanic regions. The Brazil Current (BC) has a well-marked mesoscale downstream Vitria-Trindade seamount chain (20S). The BC intensely meanders and generates the well-documented Vitria, Cape So Tom and Cape Frio eddies. The realistic simulation of observed mesoscale features needs high-resolution modeling and data assimilation. The inclusion of tidal forcing in the model simulation may be important because it provides a significant fraction of available energy for mixing, which affects the ocean circulation and mesoscale features. This study investigates the impact of data assimilation and tidal forcing on the Cape So Tom Eddies (CSTE) simulation.

The HYCOM tidal configuration has 1/24 of horizontal resolution and 21 vertical layers. The model was forced on the surface by atmospheric fields from the CFSR. On the lateral boundaries, the outputs of a 1/12 HYCOM run were imposed. Both simulations employed the EnOI-based REMO Ocean Data Assimilation System that assimilates Sea Surface Temperature (SST), Temperature (T) and Salinity (S) profiles from Argo and Sea Level Anomaly (SLA) data. A set of 5 OSEs were performed to evaluate the systems behavior. The OSEs assimilated: (i) only SST (A_SST); (ii) only T/S profiles from Argo (A_TS); (iii) only SLA (A_SLA); (iv) all aforementioned observations (A_ALL); and (v) and all observations but without tides (A_ALL_NOTIDES). An eddy tracking algorithm was used to evaluate the simulated mesoscale activity in comparison to AVISO.

Six CSTE were observed between 2010 and 2011 with an average duration of 53 days. The experiment A_ALL, A_SLA,and A_ALL_NOTIDES represented the eddies 58.1%, 54.0% and 50.7% of the time with an average distance to the observed eddies center of 27.1 km, 28.8 km,and 30.8 km, respectively. A well-describe CSTE, ratified with in situ data, was formed on March 6th 2011. The A_ALL was the only experiment capable of simulating both the eddy increased amplitude on April 22 of 2011 and its northward migration during May 12 of 2011. Those phenomena can be explained by the higher energetic level provided by the tides and the T/S data assimilation which is the most responsible for correcting thermohaline structure, respectively. The CSTE lasted 117 days and was simulated in 79%, 55 % and 68% of the observation period by the A_ALL, A_SLA,and A_ALL_NOTIDES, respectively. The average distances were 27.7 km, 27.0 km,and 26.3 km, accordingly. The six eddies observed were well simulated by the assimilative runs, however, the A_ALL presented best results probably due to the most complete data set assimilated and the inclusion of tides.

Keywords: DA - Data assimilation applications, DA - Observation impact assessment methods, Models - Model assessments and verification, Models - Ocean model configurations, Applications - Environmental assessment

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A data assimilation and forecasting system for the Red Sea

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We present our efforts to build a high-resolution data assimilation and forecasting system developed for the Red Sea. The system is composed of the MIT general circulation model (MITgcm) to simulate ocean circulation and of the Data Assimilation Research Testbed (DART) for data assimilation. In this implementation, the MITgcm is configured with a horizontal resolution of 4 km and 50 depth-varying vertical layers. The model is forced with real-time atmospheric products from the European Centre for Medium-Range Weather Forecasts (ECMWF). DART has been configured with an Ensemble Adjustment Kalman Filter (EAKF) and an invariant ensemble, i.e. an ensemble Optimal Interpolation (EnOI). Observations of Sea surface height (SSH) and sea surface temperature (SST) are assimilated every three days. The behaviors of the different ensemble sampling schemes are examined and their performances in different settings are compared. We assess the ensemble under-sampling errors by conducting assimilation experiments employing thousands of ensemble members with a fault-tolerant ensemble data assimilation system that runs MITgcm fully in parallel. In addition, we further implement the system based on a hybrid (dynamicstatic ensembles) data assimilation formulation of the filter background covariance and the performance is evaluated and discussed.

Keywords: DA - Performance and cost of data assimilation, DA - Background and observation error covariances, DA - Ensemble data assimilation

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Impact of HF Radar Data Assimilation on Surface Currents in the Ibiza Channel

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High frequency (HF) radars are key elements of Coastal Ocean Observing Systems, providing valuable measurements of surface currents in coastal areas. As part of its multi-platform observational approach, SOCIB continuously monitors the Ibiza Channel (Western Mediterranean Sea), operating since 2012 a CODAR HF radar system with two antennas in Ibiza and Formentera islands. The Ibiza Channel, as a transition area between different water masses, represents a very challenging region from the point of view of modelling and prediction.

In this context, several experiments have been carried out to evaluate the impacts on model forecasts of the assimilation of HFR measurements, in addition to multiplatform observations from satellite and ARGO floats, with the perspective of an implementation in the operational system. A multimodel Ensemble Optimal Interpolation scheme has been coupled to the SOCIB Western Mediterranean Operational Model (WMOP) to recursively assimilate observations including HFR surface velocities. WMOP is a 2-km resolution configuration of the ROMS model using CMEMS numerical products as initial and boundary conditions and high-resolution surface forcing from AEMET.

The sensitivity to different configurations and initialization methods has been evaluated, including in particular the consideration of radial and total HF Radar velocities. Results are compared to a control simulation assimilating multiplatform observations without including HFR velocities. The realism of model simulations is assessed comparing against HFR fields and independent surface drifter buoys. Our results indicate a better local performance in representing surface currents, resulting in a decrease in RMSD against observations without degrading other variables. Improvement in the prediction of lagrangian trajectories is also achieved, materialized by a reduction of the mean distance between drifters and virtual model particles.

Keywords: DA - Shelf-seas and coastal data assimilation, DA - Performance and cost of data assimilation, Applications - Search and rescue, Applications - Coastal protection, Systems - Integration of coastal systems in large-scale systems

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Assimilation of SMOS SSS into HYCOM with the REMO Ocean Data Assimilation System in the South Atlantic

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SMOS sea surface salinity (SSS) data was assimilated for the first time into the Hybrid Coordinate Ocean Model (HYCOM) with the Oceanographic Modelling and Observation Network (REMO) data assimilation system, called RODAS. The assimilation scheme is a multivariate Ensemble Optimal Interpolation, in which the ensemble members are selected from a free run according to the assimilation day. RODAS is able to assimilate sea surface temperature data, along-track or gridded sea level anomalies and vertical profiles of temperature (T) and salinity (S) from Argo, XBTs and CTDs. A preliminary SSS assimilation experiment was conducted only with the HYCOM 1/12 grid over the domain 46S-10N, 60W-20W. The model was forced by NOAA/NCEP CFSR fields each 6 h from January 1 to December 31, 2010. The initial condition was taken from the free model run (CONTROL). Only SSS was assimilated each 4 days. Two runs were performed, one in which analysis increments were produced only for salinity in the first 3 vertical z-layers reaching about 11 m depth (A_SSS_3Z), and another in which increments were produced for all model variables in the whole model column (A_SSS_ALL). The goal here was to learn about impacts of SSS assimilation in the model to guide the inclusion of SSS data into HYCOM+RODAS. In general, the A_SSS_3Z run produced very similar SSTs, SSSs and subsurface thermohaline structure with respect to CONTROL, but the A_SSS_ALL produced substantial differences. For instance, the vertically averaged SSS (SST) root mean square deviation (RMSD) over the domain up to 2000 m with respect to 3762 Argo T/S profiles were 0.30 g/kg (2.45 C) and 0.31 g/kg (2.47 C) for the A_SSS_3Z and the CONTROL run, respectively. On the other hand, the A_SSS_ALL run produced larger SST RMSD, by about 0.2 C, and smaller SSS, by about 0.2 g/kg, than the A_SSS_3Z and CONTROL runs. In the subsurface, the skill of the A_SSS_ALL run varied a lot in space. Close to the mouth of the Amazon River, the A_SSS_ALL damaged the thermohaline structure, while In the Brazil-Malvinas Confluence region the A_SSS_ALL improved it. Another run from January 1 to December 31, 2012 was performed with A_SSS_ALL strategy, and it is under evaluation. During this period, there was a large Amazon river discharge. The main conclusion so far is that SSS alone is not able to improve the model state in general. The best performance should be achieved when assimilated SSS together with other data.

Keywords: DA - Assimilation of new observation types, DA - Ensemble data assimilation, Evolution - End to end operational oceanography systems, Observations - Observation impacts,

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Assessing the Impact of Ocean Observing Systems for Analysis-Forecast Systems in Support of U.S. IOOS

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Ocean data assimilation and forecasting is now a routine activity for several of the Regional Associations (RAs) that comprise the U.S. Integrated Ocean Observing System (IOOS). Routine monitoring of the impact of each component of the ocean observing systems on different aspects of the circulation analyses has also been implemented as part of the real-time analysis-forecast suite by several RAs based on the Regional Ocean Modeling System (ROMS) 4-dimensional variational (4D-Var) data assimilation tools. The impact of each observation on a set of circulation metrics is computed using an adjoint-based approach that is similar to that used operationally in numerical weather prediction. The integrated approach to 4D-Var analysis and observation impact assessment will be described, and examples presented from three different real-time analysis-forecast systems that will highlight similarities and differences in the utility of different observation platforms across a range of circulation regimes.

Keywords: DA - Observation impact assessment methods, DA - Data assimilation applications, DA - Variational data assimilation, Observations - Observation impacts,

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