Comparison of 4DVAR and EnKF state estimates and forecasts in the Gulf of Mexico

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Experiments were conducted to compare the performances of four-dimensional variational (4DVAR) and ensemble Kalman filter (EnKF) assimilation in the Gulf of Mexico (GoM) using the Massachusetts Institute of Technology general circulation model (MITgcm). The quality of the ocean state estimates and forecasts using both methods were compared including the contribution of ensemble prediction. The MITgcm-Estimating the Circulation and Climate of the Ocean (MITgcm-ECCO) 4DVAR and the MITgcm-Data Assimilation Research Testbed (MITgcm-DART) EnKF systems were used to obtain two month hindcasts by assimilating satellite-derived along-track sea-surface height (SSH) and gridded sea-surface temperature (SST) observations. The model analysis from each method was used to initialize a forecast for two months from the end of the hindcast period. The forecasts provide a cross-validation test of the state estimate by comparing it to independent future observations and are evaluated against analyses for practical Loop Current (LC) predictability. The model forecast was tested for Loop Current Eddy (LCE) separation events, including Eddy Franklin (Eddy-F) in May 2010 during the Deepwater Horizon (DwH) oil spill in the GoM. The model performance was evaluated by computing model-observation root-mean-square-difference (rmsd) during both the hindcast and forecast periods. Both methods outperformed persistence (keeping the initial state fixed), although forecasts initialized from the HYCOM (1/12)° global analysis using Navy Coupled Ocean Data Assimilation (NCODA) also produced competitive forecasts. The 4DVAR has better long-term (longer than 1 month) predictability and lower rmsd compared to EnKF, while EnKF is better than 4DVAR for short-term forecasts (less than 1 month). The EnKF short-term predictability can be enhanced by decreasing the localization length scale (i.e. increasing localization) which enables a better fit with the data. The EnKF also showed enhanced predictability by increasing the number of ensemble members from 25 to 50 and to 100 with identical localization radius and covariance inflation parameters. It is hypothesized that increased long-term forecast performance reflects better initialization, and that this results from retaining more information in the hindcasts, whether by increasing the ensemble size in the EnKF or by using 4DVAR, which is not limited to a subspace of the model control space.