National Aeronautics and Space Administration

Improving the infrastructure for regional sea level studies and related mission formulations by including time-varying cryospheric and hydrological forcings and their uncertainties

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Program: Strategic Initiative

Project Objective:

Over-arching goal: To enhance the capabilities to quantify the relative contributions of forcings from different elements of the Earth system (*cryosphere, hydrology,* and *atmosphere*) on regional sea-level and ocean circulation changes.

Specific objectives:

To enhance JPL's Estimating the Circulation and Climate of the Ocean (ECCO) modeling/ assimilation and Observing System Simulation Experiment (OSSE) tools to (1) study the relative contributions of atmospheric, hydrological, and cryospheric frocings on regional sea level changes and (2) develop the tools to predict/project future sea level changes and quantify the associated uncertainties.

FY18/19 Results and Significance:

Major accomplishments:

- Quantification the impacts of non-seasonal river discharges (deviations from climatological seasonal discharges) on the ocean including on sea level (e.g., Fig.1), which is a major knowledge gap.
- Investigation of the regions of influence by riverine waters (e.g., Fig.2).
- Successful development of an adjoint-based approach for reconstructing past sea level changes and for predicting/projecting future sea level changes (e.g., Fig.3).
- Implementation of iceberg calving forcing and ice shelf forcing on ECCO model.

Significance:

- The enhanced ECCO capability by including time-varying hydrological/cryospheric forcings significantly strengthens JPL's capability to study past sea level changes in terms of attribution of processes, and for prediction/projection of future sea level changes.
- In particular, our results show that non-seasonal discharges (deviation from the seasonal cycle) can impacts coastal sea level significantly, a factor that has not received much attention in studying or predicting/projecting sea level changes.
- The adjoint-based method as demonstrated by the successful reconstruction of sea level variations (Fig.3) can be applied to the prediction/projection of future sea level changes using predicted/projected forcing and the pre-computed adjoint sensitivities. The method also allows Uncertainty Quantification of predicted/projected sea level changes using predicted/projected forcing ensembles. The approach offers a portal tool for sea level prediction/projection for potential stakeholders.

EFFECT OF NON-SEASONAL RIVER DISCHARGE ON SEA LEVEL VARIABILITY

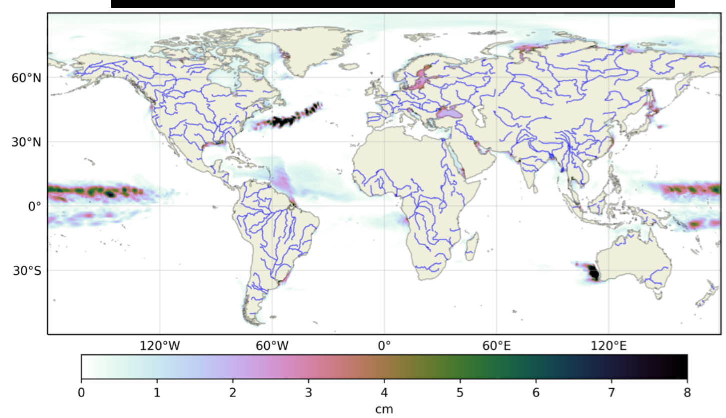

Fig.1: Maximum difference of monthly sea surface height (SSH) variations between 2 forward model runs, using daily and climatological discharges respectively, reflecting the impacts on non-seasonal discharges on SSH. The SSH differences are significant near the mouths of several major rivers (e.g., in the Gulf of Mexico, tropical Atlantic, South Atlantic, and the Arctic Ocean), caused by the effect of riverine waters on ocean density and thus SSH. The SSH differences in the open ocean are caused by fast barotropic waves (unrelated to density changes) that perturb tropical instability waves and Gulf Stream meanders.

MAPPING THE ORIGIN AND IMPACT REGIONS OF TERRESTRIAL RUNOFF ON OCEAN SALINITY

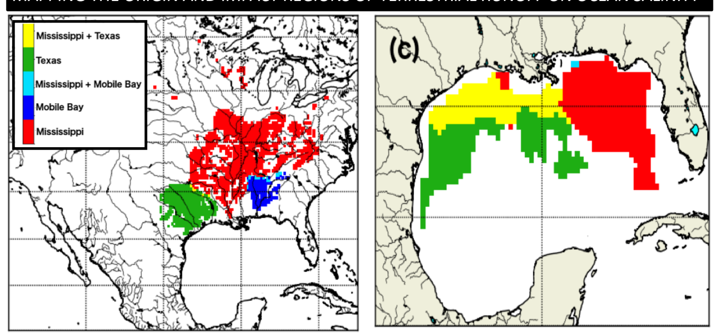

Fig. 2: (left) A map of the regions on land (US mid-west) that have the largest effect on river discharges into the Gulf of Mexico in the southeastern Mississippi basin at 16 days lead time, in the Mobile Bay and Texas basins at 3 days lead time.
(right) The unique contribution of individual river discharge forcing to specific features of river plume structure across the GoM shows regions influenced by each of the three sources of freshwater at lag times from weeks to several months.

RECONSTRUCTION OF SEA LEVEL ANOMALIES USING ECCO ADJOINT & FORCING

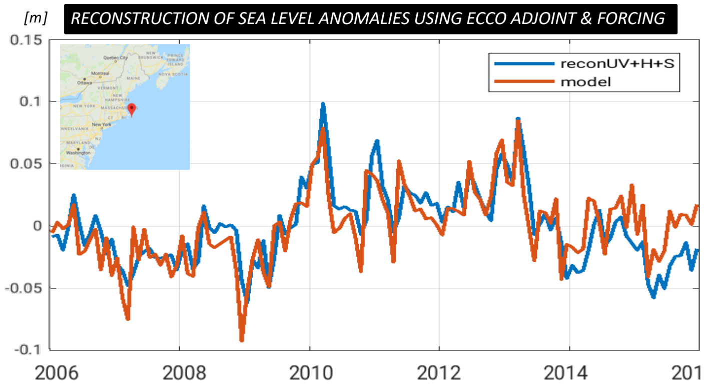

Fig. 3: SSH simulated by forward model (red) and reconstructed using adjoint sensitivity and forcing anomalies (blue) near Nantucket Island. The simulation shows 20 cm of sea level variation over this 10 yr period. The reconstruction is made by convolving a set of adjoint sensitivity functions with atmospheric wind stress, heating, and precipitation and evaporation anomalies. ***The good agreement between the simulated and reconstructed SSH shows that we can use seasonal to decadal atmospheric forecasts to predict interannual coastal sea level changes without running the forward model, thus providing a portal tool for sea level prediction***

Publications and Presentations:

Wang, X., T. Lee, I. Fenty, H. Zhang, H. Chandanpurpar, S. Fournier, I. Fukumori, D. Menemenlis, D. Waliser, O. Wang, J. Worden, J.T. Reager (2019). Developing the Capability to Inversely Constrain the Estimates of Time-Varying River Discharge Using Ocean Observation. AGU Fall Meeting 2018.

Fournier, S., J.T. Reager, B. Dzwonkowski, J., Vazquez-Cuervo, J. (2019). Statistical mapping of freshwater origin and fate signatures as land/ocean 'regions of influence' in the Gulf of Mexico. Journal of Geophysical Research: Oceans, doi.org/10.1029/2018JC014784

Zhang, H, I. Fenty, I. Fukumori, T. Lee, D. Menemenlis, and O. Wang (2020). Studying atmospheric forcing mechanisms for regional sea level changes using ECCO adjoint. AGU Ocean Sciences Meeting, San Diego, CA, February 2020.

Chandanpurkar, H., X. Wang, T. Lee, Z. Hong, I, Fenty, S. Fournier, I. Fukumori, D. Menemenlis, J.T. Reager, O. Wang, J. Worden (2020). Influence of Non-seasonal River Discharge on the Ocean. AGU Ocean Sciences Meeting, San Diego, CA, February 2020.

Chandanpurkar, H., X. Wang, T. Lee, Z. Hong, I, Fenty, S. Fournier, I. Fukumori, D. Menemenlis, J.T. Reager, O. Wang, J. Worden (2019). Influence of Non-seasonal River Discharge on the Ocean. Manuscript in prep.

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