
# Virtual Research Presentation Conference

## 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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# Tutorial Introduction

**Abstract**

This is an effort under the “Linkages in the Earth System” Initiative.

The objective is to introduce time-varying cryospheric and hydrologic forcings into the ECCO global ocean state estimation system so as to enhance the capabilities to quantify the relative contributions of cryospheric, hydrologic, and atmospheric forcings to regional changes of sea level (SL) and ocean circulation and to support the related missions.

ECCO is an international consortium effort led by JPL to synthesize existing satellite and in-situ ocean observations with a state-of-the-art global ocean model. The ECCO estimation system produces estimates of the ocean state that satisfy the physical principles of the model while being consistent with the observations to within their uncertainties. The observation-model synthesis (or assimilation) approach is based on an inverse estimation method.

# Problem Description

- Oceanic changes, including SL, are influenced by time-varying atmospheric forcing (such as momentum, heat, and freshwater fluxes through the ocean surface), hydrologic forcing (such as river discharge), and cryospheric forcing (such as the melting of ice shelves and ice sheets).
- State-of-the-art global ocean modeling and assimilation systems (including ECCO) have included time-varying atmospheric forcing, but not time-varying hydrologic and cryospheric forcings. Including the latter two forcings will significantly enhance our ability to understand why regional SL has changed in the past and project how it will change in the future.
- The effort under this SRTD addresses one of the strategic areas of JPL’s Earth Science: SL change, and supports a multi-agency effort led by JPL: the RISE project.
- The effort also addresses one of the Most Important Objectives of the 2017-2027 Decadal Survey: SL rise.

# Methodology

- To accomplish the objective, we derive estimates of the time-varying hydrologic and cryospheric forcings from reanalysis-based and observation-based products and implement these forcings into the ECCO ocean model.
- The estimates of the hydrologic and cryospheric forcings as well as the atmospheric forcings have errors. An important **innovation** of the work is the ability to account for and correct these errors.
- This is accomplished by treating these forcing variables as adjustable variables or control variables, the latter being a terminology used in control theory for system optimization. This will allow the prior estimates of the control variables to be optimized through ECCO's inverse estimation procedure using the constraints of ocean observations and model dynamics.

# Results

**Accomplishments:**

- Introduced reanalysis-based estimates of daily river discharge around the world ocean as prior values of time-varying hydrologic forcing for ECCO, which improved the ocean state near major river mouths against observations; we also used the improved simulation to identify limitations of a theory that relates river discharge to SL variation.
- Developed a box model of Antarctic ice shelves and coupled it with the ECCO ocean model to simulate the time-varying ice-shelf melt rates in response to ambient ocean temperature changes.
- Derived estimates of seasonally and geographically dependent melt rates of icebergs in the Southern Ocean based on observations of iceberg trajectories and mass fluxes.
- Included these forcing variables as control variables in ECCO's inverse estimation system to allow the optimization of the prior values of these forcings to account for their errors in the future.

**Significance:** strengthened our ability to support the science for ongoing and upcoming missions (e.g., ICESat-2, GRACE-FO, and SWOT) and to compete for ROSES and Earth Venture Sub-orbital mission proposals.

**Next steps:** (1) introduce Greenland ice sheet melt water forcing; (2) improve Antarctic ice-shelf cavity representation; (3) include ice-shelf observations to constrain the time-varying melt rates simulated by the ice-shelf box model coupled to ECCO ocean model; (4) complete ongoing papers to report scientific findings via publications.

# Publications and References


[A] Hrishikesh Chandanpurkar , Tong Lee, Xiaochun Wang, Hong Zhang, Severine Fournier, Ian Fenty, Ichiro Fukumori, Dimitris Menemenlis, Chris Piecuch, J.T. Reager, Ou Wang, and John Worden, “Influence of nonseasonal river discharge on seas surface salinity and height”, J. Geophys. Res., submitted. 2020.

[B] Hong Zhang, Ian Fenty, Ichiro Fukumori, Tong Lee, Dimitris Menemenlis, and Ou Wang, “Studying atmospheric forcing mechanisms for regional sea level changes using ECCO adjoint”, AGU Ocean Sciences Meeting, San Diego, CA, February 2020.

[C] Hrishikesh Chandanpurkar , Tong Lee, Xiaochun Wang, Hong Zhang, Severine Fournier, Ian Fenty, Ichiro Fukumori, Dimitris Menemenlis, Chris Piecuch, J.T. Reager, Ou Wang, and John Worden. “Influence of nonseasonal river discharge on seas surface salinity and height”, AGU Ocean Sciences Meeting, San Diego, CA, February 2020.

[D] Ou Wang, Tong Lee, Hong Zhang, Ian Fenty, and Ichiro Fukumori, “Deciphering forcing mechanisms for dynamic se level variations off the northeast US coast”, EGU General Assembly, Virtual, May 2020.