Improved seasonal prediction skill for U.S. Atlantic Coast and Gulf Coast Sea Level Using ECCO-based Ocean Dynamic Persistence

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Motivation

Seasonal prediction skill from coupled models ← Accuracy of initial ocean state + Fidelity of coupled models in depicting air-sea coupling

How much predictability does the initial ocean state provide w/o considering subsequent air-sea coupling?

Coupled-model bias & initialization shock can hinder the positive contribution of an accurate initial ocean state to prediction skill.

Method (to address that question)

- Perform a set of 12-month forward runs of the **ECCO** (https://ecco-group.org) global ocean model forced by climatological seasonal atmospheric forcings, initialized monthly from ECCO ocean state estimate from 1994 to 2017.
- Ocean anomalies in these 12-month hindcasts are due to the evolution of initial ocean state without air-sea coupling, referred to as **ocean dynamic persistence (ODP)**.
- It contrasts damped persistence, a common baseline metrics for evaluating prediction skill, where initial anomaly is damped statistically as a function of prediction lead time (using a 1st-order autoregressive model).

Key Results & Messages

- **ODP outperforms altimetry-based damped persistence and state-of-the-art ECMWF SEAS5 climate forecast in predicting U.S. East Coast and Gulf Coast sea level anomalies (SLA) at multi-month (2-12 months) lead times (see examples in Fig.1 & 2).**
- **ODP is a more stringent baseline metrics for evaluating predictions than the commonly used damped persistence.**
- **ODP skill comes from dynamic memory of steric anomalies caused by forcings months before, esp. open-ocean winds off the southeast U.S. coast (causing Rossby wave propagation) & buoyancy forcing in the Gulf & Caribbean Sea (causing advection of steric anomaly) (see example/illustration in Fig.3).**

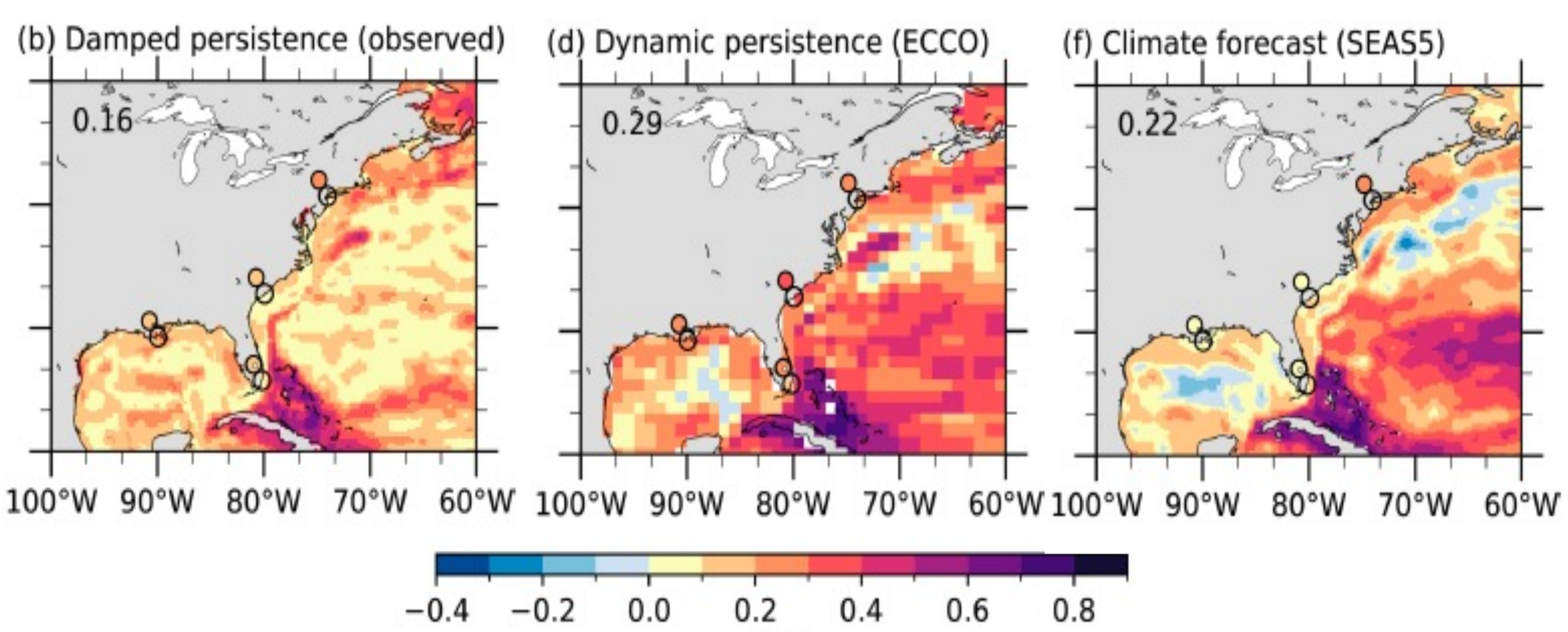

Figure 1. Anomaly correlation coefficient (ACC) between altimetry-observed SLA & predicted SLA at 4-month lead time from (left) altimetry-based damped persistence, (middle) ECCO ocean dynamic persistence (ODP), and (right) ECMWF SEAS5 forecast. **ECCO ODP has the best skill along the U.S. Southeast Coast & Gulf Coast.**

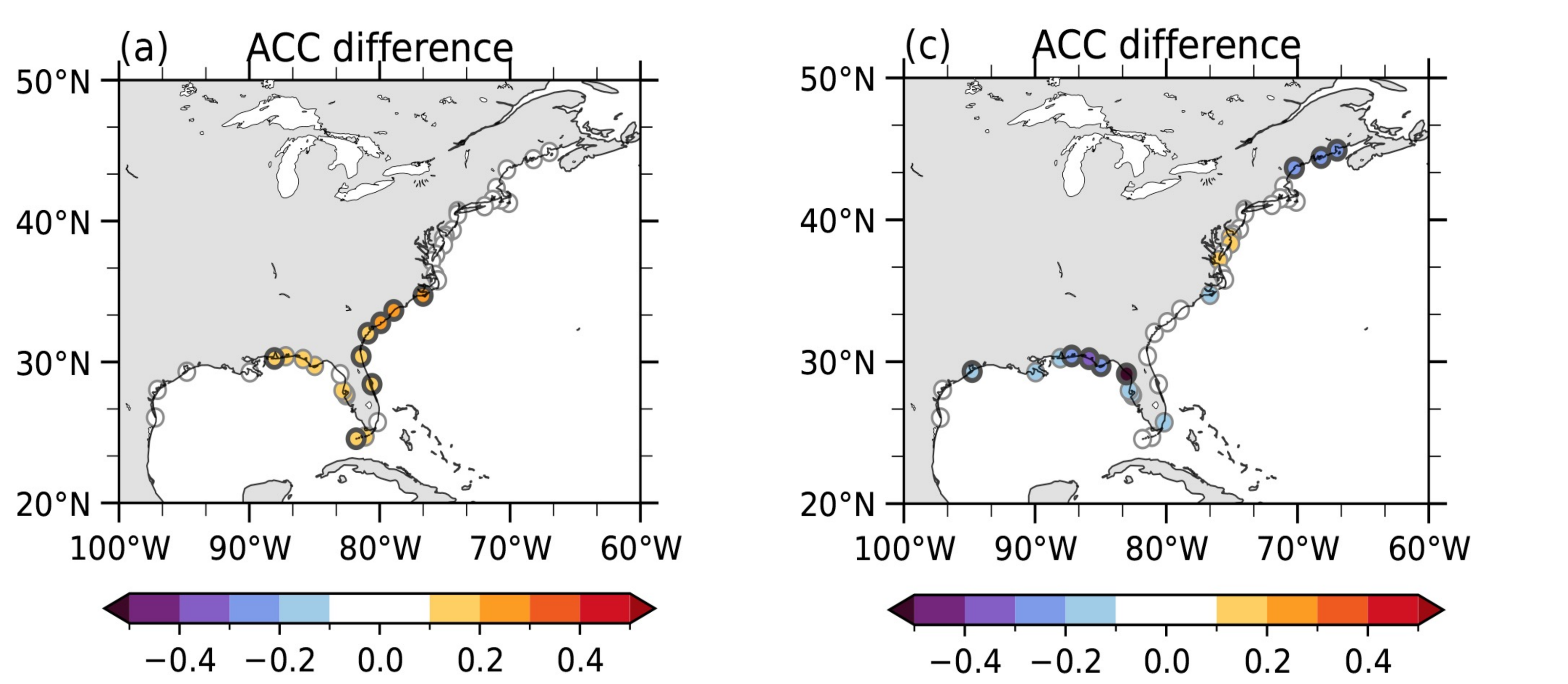

Figure 2. Difference of anomaly correlation coefficient (ACC) for 4-month lead time at tide-gauge locations: (left) ECCO ODP minus altimetry-based damper persistence; (right) ECMWF SEAS5 forecast minus altimetry-based damper persistence.
ECCO ODP improves over altimetry-based damper persistence prediction in the southeast U.S. Coast and Eastern Gulf Coast (as indicated by positive ACC difference).

Forcing Influence Maps at 4-month lead time for Charleston or Nantucket sea level

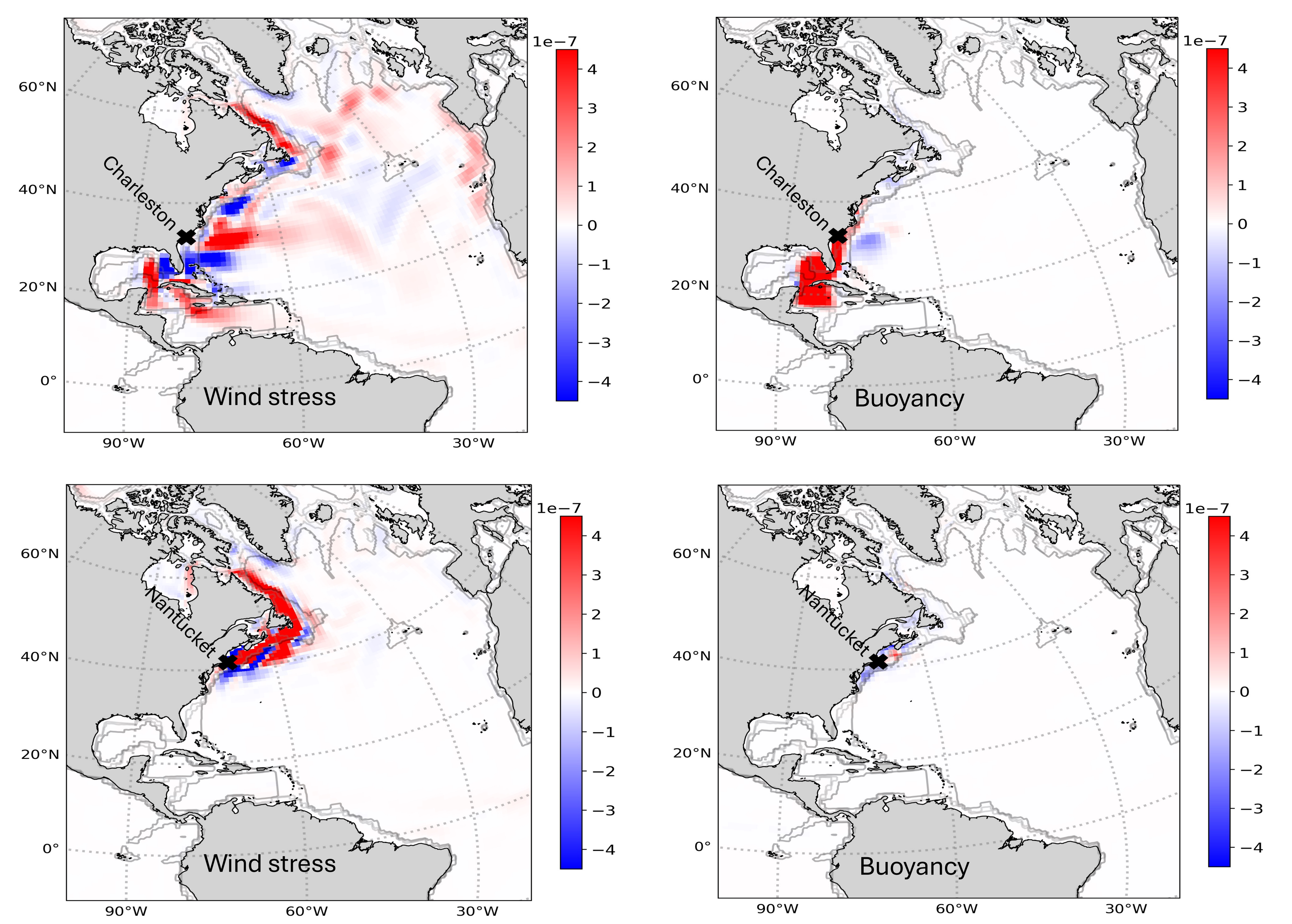

Figure 3. Example showing what forcing type/region is important for predicting Charleston SLA (upper panels) & Nantucket SLA (lower panels) 4 months ahead. The values show fraction of Charleston or Nantucket SLA variance explained by wind (left panels) & buoyancy (right panels) forcing 4 months before, computed by convolving ECCO adjoint sensitivity of Charleston or Nantucket SLA to forcing with forcing anomalies. Red color regions indicate where forcing is particularly important.

- **Open-ocean winds off the southeast U.S. Coast cause Rossby waves that propagate towards the coast, providing multi-month predictability.**
- **After reaching the coast, the signal also propagates into the Gulf Coast as coastally trapped waves, lending predictability for Gulf Coast SLA.**
- **Buoyancy forcing in the Gulf & Caribbean Sea is also important.**

Related references:

Wang, O., T. Lee, T. Frederikse, et al., 2024: What forcing mechanisms affect the interannual sea level co-variability between the Northeast and Southeast Coasts of the United States? J. Geophys. Res., 129, e2023JC019873, https://doi.org/10.1029/2023JC019873.

Feng, X., M.-J. Widlansky, & T. Lee, et al., 2025: Indications of improved seasonal sea level forecasts for the United States Gulf and East Coasts using ocean-dynamic persistence. Ocean Science. https://doi.org/10.5194/egusphere-2025-98.

Delman, A., O. Wang, & T. Lee, et al. 2025: Forcing of subannual-to-decadal sea level varioability and the recent rapid rise along the U.S. Gulf Coast. J. Geophys. Res., in review.