Deciphering forcing mechanisms for dynamic sea level variations off the northeast US coast

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Motivation:

- Sea level (SL) change along the US east coast, being societal relevant, has been a subject to significant interest of late.
- Forcing mechanisms not well understood.
- Hindering evaluations of the fidelity of climate models & projections.
- ECCO (ecco.jpl.nasa.gov) state estimation system and its adjoint sensitivity tool provide a way to systematically decipher the relative contributions & regional contributions of wind & surface buoyancy forcing on dynamic SL.
- Here we provide an example to study forcing mechanisms for dynamic SL at the Nantucket tide gauge station off New England (Fig.1).

Figure 1. Studied location

Method:

- ECCO adjoint enables the calculation of SL sensitivity to forcing as a function of space & lead time (see selected examples in Fig.2).
- Convolution of forcing anomalies with the respective adjoint sensitivity provides the "reconstruction" of the SL anomalies (SLA) estimated by ECCO:

$$SL'(t) = \iiint_{-10\,yrs}^{0} \partial SL/\partial F(x,y,-\tau) \times F'(x,y,t-\tau)\, d\tau\, dx\, dy \quad \text{(Eqn.1)}$$

- Eqn.1 allows ones to decipher the relative contributions of different forcings across various time scales and regions, and quantify the respective contributions to SL variations.

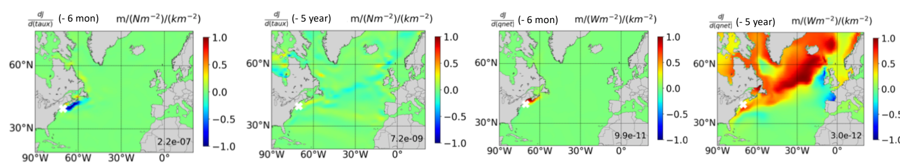


Figure 2. Examples of the sensitivities of Nantucket SL to forcings computed by the ECCO adjoint: response of Nantucket SL to a unit positive perturbation of zonal wind stress at different locations with 6-month (a) and 5-year (b) lead times. (c) & (d) are the equivalent maps for SL response to air-sea heat flux. All maps were normalized by the respective maximum sensitivity value for each lead time (shown in the lower right corner of each panel).

Highlight of selected results:

- SLA at Nantucket estimated by ECCO Version-4 (ECCOv4) solution compare well with altimetry (assimilated) & tide gauge (independent) data, in fact, closer to the independent tide gauge data at this location (Fig.3c).
- The reconstructed SLA using Eqn.1 are close to the ECCOv4 SLA (Fig.3a).
- Winds explains most of higher-frequency (intraseasonal-interannual) SLA (Fig.3b).
- Air-sea heat and freshwater fluxes important for decadal SLA (Fig.3b).
- Air-sea heat flux responsible for the bi-decadal SL rise (Fig.3b).
- Regional wind forcing primarily comes from NE of Nantucket off New England & Newfoundland (Fig.4), reflecting the influence of wind-generated coastal trapped waves (not shown).

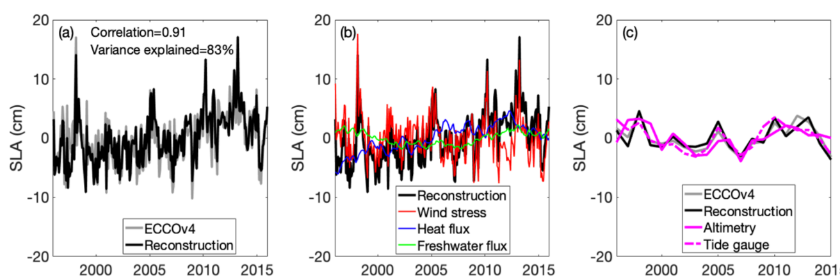
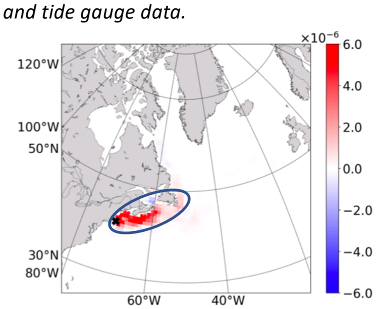


Figure 3. (a) Non-seasonal SLA from ECCOv4 & adjoint reconstruction. (b) Decomposition of reconstructed SLA into contributions by winds & air-sea heat/freshwater fluxes. (c) detrended annually averaged SLA from ECCOv4, reconstruction, altimetry, and tide gauge. Atmospheric pressure effect were removed from ECCOv4, altimetry, and tide gauge data.

Figure 4. Regional Forcing Influence Map for winds, calculated as the fraction of non-seasonal SL variance at Nantucket explained by wind forcing per unit km² at different locations. Wind variability in the oval region accounts for ~80% of Nantucket SLA variance.



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