CESM Insights Into Drivers of Regional Sea Level Rise in Recent Decades

(Fasullo and Nerem 2018 PNAS; Hamlington et al. 2019 GRL)

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Trends over the altimeter era (1993-2018) exhibit strong spatial structure. What drives these patterns? How will they evolve?
Early in the altimeter record, trends were shown to be strongly influenced by ENSO.

A) Trends in the first half are influenced by El Niño in its early years and La Niña later in the era. ∴ **Trend is La Niña-like**

B) Trends in the second half are influenced strongly by La Niña in early years and strong El Niño events late in the era. ∴ **Trend is El Niño-like**
Later, an influence of the PDO similar to that of ENSO (A) was also identified (B).

A transition in the PDO from strong positive values (1990s) to negative values (2000-13) – are plausible explanations of the trend pattern, which resembles the inverse of the PDO regression.

But are the full altimeter-era trends in fact dominated by the noise of internal variability?
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The magnitude of the FRs is sizeable; doubling rates of rise in some regions; eliminating rise in others.

Some model dependence exists in the FR, particularly in the deep tropical Pacific Ocean (10N/S, Walker cell) but many common features exist: western subtropical and Atlantic Ocean maxima; eastern Pacific, Southern Ocean minima.
Patterns of the forced response evolve over time / can be correlated with trends of individual members to assess emergence.

Key findings:
1) FRs evolve as a function of time (f(time))
2) FR has emerged for the altimeter era: correlations for 1993-2018 for every LE member exceed the 95% threshold of those from the 1800 yr control run (r=0.25)
3) A similar FR persists and strengthens in coming decades.

Single Forcing Runs show:
Regional trends during the altimeter era include important contributions from ozone, aerosols, O₃.
In coming decades, western subtropical Pacific maxima extend further eastward and patterns in other basins intensify.

Thus, in addition to acceleration in the global mean rate of sea level rise, many regions that have exhibited elevated rates of rise in the altimeter era should expect those elevated rates to persist rather than reverse.

Antarctica, west coast of South America should expected past lower rates of rise to persist (also due to gravitational fingerprints).
Correlation between early and late era trends are negative…

When modes are removed, correlation with each other and background trend is strong.

Correlation: -0.31

Correlation with 1993-2018 rate pattern: 0.70 and 0.75
With internal modes removed, altimeter era trends remain highly correlated with raw trends.
Conclusions

Large Ensembles are a useful tool for evaluating the emergence of the patterns of forced response over discrete intervals (e.g. satellite records).

Regional sea level trends in every member of the CESM and ESM2M large ensembles correlate with their respective forced responses to a degree that exceeds the 95% confidence limit (estimated from their piControl runs). **On average the FR explains about 30% of the spatial variance of trends in the altimeter era.**
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The forced response is transient. It evolves over time and often is not well-characterized by the 1850-2100 trend (particularly true in fields with slow adjustment – e.g. ocean).

SLR emergence has now been corroborated in recent observational studies. This also allows for an estimation of the anticipated trends over the next several decades. How best to do so remains an active research question.

**Manuscripts:**
END
Ocean heat content is a primary driver of SSH trend patterns. Regions of greater warming exhibit greater rates of rise.

In addition, the coefficient of expansion is greater for warm water and thus SSH rise is greater in warm oceans for a given warming.
Drivers of Altimeter SSH Trends Inferred from Single-Forcing LENS

Key Findings:
• O$_3$, aerosols, GHG important
• SH dipole driven by GHG, O$_3$
• Atlantic dominated by aerosols
• GHG influence in North Atlantic
• Pacific trends from all 3.