Understanding Sea Level as a Constraint on Climate Variability and Sensitivity

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Take Home Messages

Q: Do sea level reconstructions provide guidance as to whether the Grand Hiatus (1945-75) was forced?

A: Yes, the reconstructions suggest it was likely not primarily forced (i.e. persistent energy imbalance when TWS, cryo. terms considered).

What are the implications?

Larger uncertainty for ECS estimates from the instrumental record? Confirmation of Stevens et al. 2015?

Also: NCAR is involved in multiple projects aimed at promoting understanding of internal variability in the community. Ask for access.
NCAR Community Resources

1. CESM1-CAM5 Large Ensemble (LE): 30-mem 1920-2100

2. CESM1-CAM5 Last Millennium Ensemble (LME): 33-mem w/ single forcing 850-2005

3. Climate Variability Diagnostics Package (CVDP)

4. Climate Data Guide (CDG)
• Motivated by an apparent discrepancy between various methods of estimating ECS and thus no single “best estimate” was provided in AR5

• instrumental: Lewis; models: Fasullo; paleo: Annan
In retrospect, AR5 maybe not correct in lowering the lower bound of ECS to 1.5

- The planetary imbalance went largely unchanged during the hiatus. The hiatus offers no evidence of a weaker net positive climate feedback.

- While novel “instrumental” methods were published since AR4 suggesting lower ECS, their robustness (sensitivity to internal variability) was largely unexplored. Uncertainty estimates vary widely.

**Update:** Since last summer, a new global Ts record was set, the PDO has flipped sign and NOAA has expanded the vertical scale on its OHC plots to accommodate additional warming.
Sea Level from Altimetry

- provided both an early and powerful suggestion of a persisting planetary imbalance. ("missing energy", Trenberth and Fasullo 2010 Science)

- changes in 2010-11 suggested initially that this may not be the case. The drop is now known to have resulted from ↑TWS and a unique combination of internal variability. (Fasullo et al 2013 GRL)

- a main feature of the hiatus is that surface temperature and the planetary imbalance can diverge for over a decade and that GMSL can be a useful indicator of the imbalance
How well do models simulate internal variability?

By how much, and for how long, can surface temperature diverge from the planetary imbalance?
Challenges in Model Evaluation: Limited Observation Period (CVDP)

PDO Tropical Power
(based on 1901-2010)
- LE is close (varies by member)
- 2° may be too strong (#2 OK)
- EC-Earth too weak
- GISS-E2 too weak

LME suggests that runs of 1000+ yrs yield stable PDO tropical statistics
GMSL as a Constraint on OHC?

Key Uncertainties

Glaciers
extent? melt rate?
surface forcing?
P-E?

Greenland
ice sheet dyn.?

Antarctica
subsurface melt?

Aquifers
timescales/mag? groundwater var?

Soils
resistance
depth of interaction
ext.

Reservoirs
The “Grand” Hiatus: 1945-1975

Net $\Delta T_s \approx 0$ 1945-1975

PDO existed in a coincident and prolonged negative phase

CMIP models have reproduced the hiatus largely with aerosol forcing.

Indicative of internal or forced variability?
What are the implications of GMSL for Grand Hiatus?

C+W record (also others) suggests that GMSL rise during the hiatus was 1.6 mm/yr and was greater than in the preceding or subsequent decades.

≈5 cm rise

How can this occur with near-zero planetary imbalance? ΔTWS?
CLM Estimates of TWS: GRACE Period

Improvements in forcing data and model physics have led to strong agreement between forced CLM4.5+ and GRACE TWS.
CLM Estimates of Global TWS

CLM shows only very small changes in TWS during 1945-1975

Best estimate (GPCC) suggests a GMSL contribution of +0.1 mm/yr.
Conclusions

- Interpreting climate sensitivity from the instrumental record depends critically on separating forced changes from internal variability - assumptions regarding internal variability are key, model dependent, and challenging to validate.

- The unprecedented observing system in place during the 2000's hiatus provides a unique opportunity to understand its causes and evaluate the fidelity of simulated internal variability - though challenges remain.

- Strong parallels exist between the Grand Hiatus and the 2000's (PDO, GMSL). While multiple generations of climate models have reproduced the hiatus mainly as a forced response, sea level reconstructions suggest that the planetary imbalance was persistent during the event.

- TWS cannot account for the sustained increase in GMSL during the Grand Hiatus. *Estimation of cryospheric melt using MDD also does not suggest a major cryospheric contribution.*
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