Contrasting Eastern North American coastal sea level variability in salt marsh proxies and CESM

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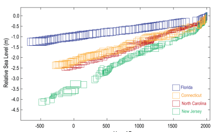
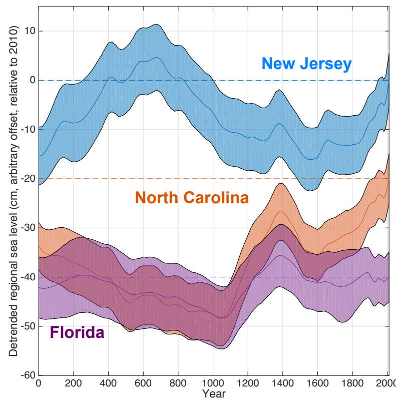
Motivation

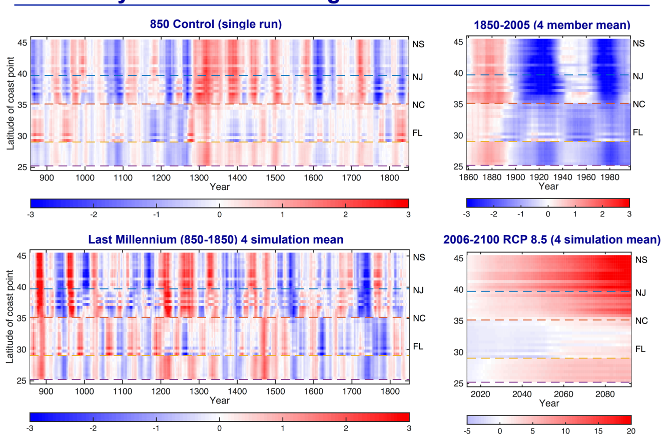
Detrended salt marsh proxies along the Eastern North American coastline reveal regional variability that has been interpreted to reflect changes in ocean dynamics (e.g. Kemp et al. 2013). Here, we analyze the CESM Last Millennium Ensemble to determine whether comparable departures in coastal sea level are evident in simulations at any time between 850-2100, and the possible role of variations in Atlantic Meridional Overturning Circulation (AMOC) strength.





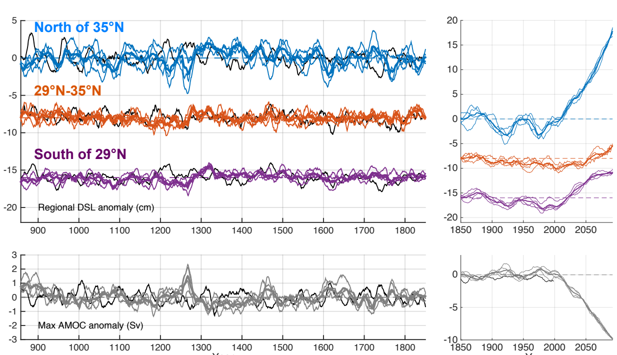
Salt marsh proxy-derived sea level, relative to 2010 (dashed lines), at three locations, after detrending and removing the basin-wide signal (raw records are shown at left).

Coastal dynamic sea level regimes in CESM-LME



Dynamic sea level anomaly (in cm), relative to the 850-1850 period, at coastal grid points for various CESM-LME simulations. Locations of selected salt marsh proxy sites are noted on the right axis.

- **CESM exhibits three regions of coherent DSL variability along the Eastern North American coast, in partial agreement with recent instrumental analyses (e.g. McCarthy et al. 2015).**
- **These regions are consistent across control, last millennium, historical, and 21st century simulations.**
- **Florida and North Carolina salt marsh sites are near the boundaries of dynamic regimes.**
- **Some coastal points are subject to local (physical/numerical?) effects.**



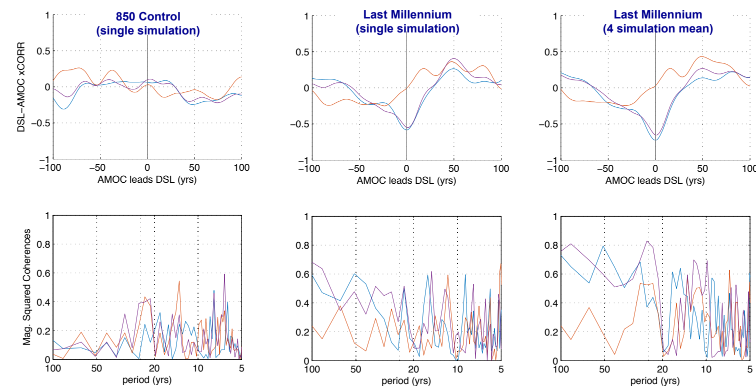
Top: DSL anomaly (in cm), relative to the 850-1850 period, averaged over three coastal regions, with an 8 cm offset between regions. Bottom: Maximum AMOC streamfunction anomaly (Sv) relative to the 850-1850 mean. Black lines show 850 control simulation. Thin lines are 4 individual ensemble members. Thick lines indicate the ensemble mean. Note different scale on pre- and post- 1850 plots.

- **When averaged over three regions, large changes in DSL (>3 cm), alongshore DSL gradient, and AMOC strength (>1.5 Sv) are evident only under RCP forcing**
- **Forced variability is almost completely indistiguishable before 2000 except for a multi-decadal excursion associated with a strengthening AMOC around 1275 CE.**

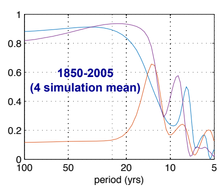
Conclusions

- ✯ **The CESM Last Millennium Ensemble does not exhibit multi-decadal to multi-centennial, 15-30 cm, swings in dynamic sea level (DSL) inferred from salt-marsh proxies.**
- ✯ **However, strong, in-phase, anticorrelations of DSL with AMOC strength suggest that much of the variability could be accounted for with 5+ Sv variations in AMOC.**
- ✯ **Other explanations for model-proxy discrepancies include:**
  - **Static-equilibrium effects (unlikely to account for magnitude of changes across sites)**
  - **Local processes/error (also unlikely across all sites)**
  - **Unresolved dynamic changes that are unrelated to AMOC strength**
  - **Other suggestions are appreciated!**

DSL regimes and AMOC strength in CESM-LME

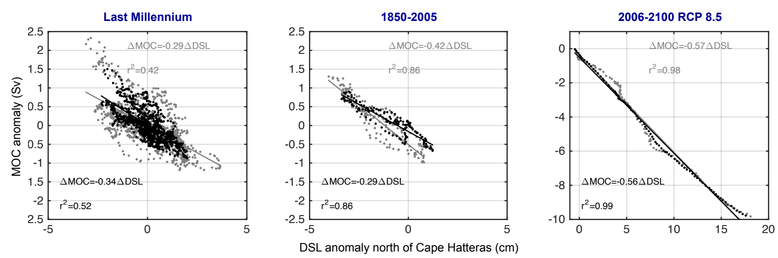


Cross-correlation (top) and magnitude-squared coherence (bottom) of DSL in the three coastal regions and maximum AMOC streamfunction for a single control simulation (left) a single last millennium ensemble member (center) and the ensemble mean (right).



- **Across all climate forcing scenarios, changes in coastal DSL north of Cape Hatteras and south of 29°N are in phase and highly negatively correlated with the maximum strength of the AMOC streamfunction.**
- **Between 29°N and Cape Hatteras, there is little coherence and evidence of a lag.**
- **Unforced variability clouds coherence in individual simulations.**

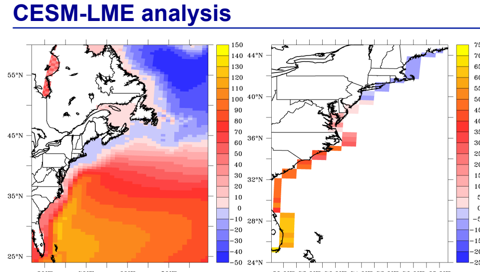
How large would AMOC changes have to be?



Regression of DSL anomalies north of 35°N and maximum AMOC streamfunction for a single ensemble member (grey) and the ensemble mean (black).

- **Dramatic changes in sustained and/or stochastic NAO forcing, absent in these simulations, might lead to underestimated Last Millennium AMOC and DSL variability (Trouet 2009; Otto-Bliesner et al. 2015)**
- **Last Millennium simulations indicate that post-1600 DSL rise in NC and NJ, and pre-1100 DSL rise and fall in NJ could be explained by ~5 Sv changes in AMOC strength (on multi-century timescales)**
- **However, this assumes an AMOC/DSL relationship is stationary: RCP 8.5 simulations show a lower sensitivity. Furthermore, this relationship is not consistent across climate models (not shown here).**

CESM-LME analysis



Mean dynamic topography (in cm) relative to the grid point closest to the NJ salt marsh site in the CESM-LEM 850 control simulation.

- **Community Earth System Model Last Millennium Ensemble (CESM-LME)**
- **850 control simulation, and 4 members of the LME (simulations 2, 3, 8, and 9).**
- **Forced simulations employ a reconstruction of climate forcing pre-1850, then the 1850-2005 forcing as specified in the CMIP5 historical experiments, then 2006-2100 RCP 8.5 forcing.**
- **"SSH" and "MOC" variables smoothed with a 15-year filter**
- **44 coastal grid points between 29°N and 45°N are extracted**

References

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