On the coupling between the meridional overturning circulation, alongshore wind stress, and United States coastal sea level

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Abstract. By the late 21st century, climate models project enhanced dynamic sea level (DSL) rise along the western boundary of the North Atlantic that is associated with a decline in the Atlantic Meridional Overturning Circulation (AMOC). However, many studies – both observation and model-based – have argued that changes in DSL over the last few decades are driven primarily by local alongshore winds. These seemingly contradictory explanations have led to conflicting interpretations of historical sea level variability, even as recent work has begun to utilize DSL gradients derived from tide gauges as a proxy of AMOC strength. The lack of clarity also clouds the assessment of climate model reliability, which is particularly important given large, but highly uncertain, projections of 21st century regional DSL rise.

Here, we analyze the coupling between local winds, AMOC strength, and DSL in 40 simulations performed using the Community Earth System Model Large Ensemble (CESM-LE) over the 1920-2100 period. We first demonstrate that, although the phasing of multidecadal AMOC variability can vary quite widely due to atmospheric initial conditions, DSL variability evident in detrended annual Northeast US tide gauge records is well-represented in CESM-LE. We then partition DSL variability into alongshore wind and AMOC-coupled, and internal and externally-forced, components.

We find a "crossover timescale" of approximately 5-15 years partitioning a local wind-driven coastal sea level regime from a basin-scale, overturning-related regime. Processes unrelated to either AMOC strength and local winds introduce noise at interannual to decadal timescales. As the climate system transitions to an externally forced state, DSL variability associated with the overturning circulation becomes dominant. While the largely externally-forced, AMOC-coupled, component explains only 29±12% (ensemble mean± ensemble standard deviation) of DSL variance over the 1920-2010 period, it explains 89±3% of the variance in the 2011-2100 period. We discuss the implications of these results on the reliability of climate model projections of regional DSL, the use of coastal sea level data as a proxy for AMOC, and the origins of multidecadal variability in coastal sea level.