

A Study of Tropical Atlantic Variability with a High-resolution, Regional Coupled Climate Model

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Some important challenges in the study of Tropical Atlantic Variability (TAV) are (i) the prevalence of large systematic biases in the simulation of the tropical Atlantic state in global coupled models, (ii) the lack of adequate horizontal resolution in the deep tropics, and (iii) quantification of the relative importance of dynamic and thermodynamic atmosphere-ocean coupling.

We have developed a regional coupled model of the Atlantic basin, based on the MOM3 ocean model from GFDL, to address the above challenges. The regional coupling approach helps to mitigate the biases in the coupled tropical Atlantic simulation by allowing us to specify the observed SST in other ocean basins, particularly in the eastern equatorial Pacific, and thus capturing remote effects such as the influence of El Niño-Southern Oscillation (ENSO) on TAV accurately. The smaller spatial extent of the regional ocean model also allows us to use significantly higher horizontal resolution for the same cost as a lower resolution global coupled model. We employ this regional model as part of a hierarchy of coupled models, with different degrees of atmosphere-ocean coupling, to test the following hypotheses:

1. In the Atlantic intertropical convergence zone (ITCZ) region, atmospheric convection is affected more by thermodynamic coupling than by dynamic coupling.
2. Along the equator, dynamic coupling is more important than thermodynamic coupling.
3. Improved horizontal resolution will lead to better simulation of the narrow meridional scales associated with the ITCZ and the ocean currents, allowing models to better represent the interactions between the gradient mode, the ITCZ and the equatorial "Atlantic ENSO" mode.

We use the NCAR atmospheric general circulation model, CAM3, in the following configurations: uncoupled, thermodynamically coupled to a slab ocean model and fully coupled to the MOM3 regional ocean model in the Atlantic domain. By comparing the simulated TAV in the different model configurations, we test the hypotheses listed above. We also carry out ensemble hindcast experiments to assess the seasonal predictability of TAV, including hindcast experiments to coincide with the observing period of the proposed Atlantic Marine ITCZ process study.

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Variability in Tropical Depression Formation in the Eastern Atlantic and the Eastern Pacific

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Over the last ten years, an average of three tropical depressions per year have formed in the Atlantic east of 35° W. In the superficially similar region of the eastern Pacific, the rate of tropical depression formation is more than 5 times greater. Given that east Pacific storms are widely thought to form primarily from African easterly waves, which also presumably move through the monsoon trough area of the eastern Atlantic, it is a mystery as to why more such waves do not amplify into tropical depressions, and from there into tropical storms and hurricanes in the Atlantic.

Some hints as to the origin of this suppression comes from the research of William Gray, Chris Landsea, and their colleagues into the natural variability of Atlantic hurricanes. Three major factors appear to affect the frequency of such cyclones: (1) Sahelian rainfall, (2) the phase of ENSO, and (3) the phase of the quasi-biennial oscillation (QBO). In particular, a wet Sahel, La Niña, and westerly 30 hPa stratospheric winds are correlated with increased Atlantic storm activity. The latter two conditions are thought to reduce vertical wind shear in the regions of tropical cyclogenesis, a situation known to favor storm formation. Drought in the Sahel is also thought to increase shear in the eastern Atlantic, but may also have other effects, such as modification of easterly wave structure and more import of dry air.

The EPIC2001 project and other work by Maloney and Hartmann as well as Molinari and colleagues have documented variability in the east Pacific, a variability manifested strongly in changes in tropical storm generation. The predominant intraseasonal switch in this region is the phase of the Madden-Julian oscillation (MJO). EPIC2001 was unique in that it provided intensive in situ observations of tropical cyclogenesis and resulted in a hypothesis for the mechanism whereby the MJO affects this process. It also showed that the variability implied by periodic tropical storm production rectifies strongly onto climate time scales, both in the ocean and in the atmosphere.

Given the highly variable nature of the suppression of tropical storm activity by variable environmental factors in the eastern Atlantic, it would seem important to understand how these suppression mechanisms work there. A process study in this region could throw light on this issue, especially in the context of east Pacific observations, where the suppression of cyclogenesis is much weaker.

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