Attribution of Simulated Atlantic Multidecadal Variability to External Forcing, Internal Coupled Variability, and Weather Noise

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The mechanisms of the Atlantic Multidecadal Variability (AMV) simulated by the CCSM3 CGCM in a 300 year run with constant external forcing and in a 110 year run with 20th century forcing are isolated and compared. The diagnostic procedure employs several auxiliary configurations of the CCSM3 component models:

1) Ensemble of CGCM simulations (in the case of 20th century forcing). The externally forced AMV is the AMV of the ensemble mean of the CGCM simulations.

2) Ensemble runs of the AGCM component forced by the SST and external forcing from a CGCM simulation. The ensemble mean of the AGCM simulations diagnoses the SST and externally forced response of the atmosphere for a CGCM simulation (AMIP-type ensembles). Removal of the diagnosed SST and externally forced response from the CGCM simulation leaves the internal atmospheric variability (weather noise) as a residual.

3) The Interactive Ensemble (IE) version of CCSM3 forced by specified weather noise. The IE is a CGCM in which the ensemble mean of an AGCM ensemble is coupled to an OGCM. Each AGCM ensemble member is forced by the same SST, as produced by the OGCM, while the ocean and its SST are simultaneously forced by the ensemble mean of the AGCM surface fluxes. The IE coupling effectively parameterizes the atmospheric transient eddy fluxes, while suppressing the weather noise forcing of the ocean, leaving SST variability due only to external forcing, coupled atmosphere-ocean feedbacks and ocean internal variability. Due to the suppression of the weather noise, the IE responds quasi-deterministically to specified forcing applied to the IE OGCM. We take advantage of this property by forcing the IE with the weather noise surface fluxes diagnosed from original CGCM simulation in step 2. This specified forcing is applied either globally or regionally, and separately by process (surface heat flux, wind stress, salinity flux), to mechanistically attribute the CGCM simulated AMV response to the noise forcing structures. To complete the attribution, AMV not explained by external or weather noise forcing is attributed to internal variability of the ocean or coupled feedbacks between the atmosphere and ocean in the coupled system.

The results show that all of the potential mechanisms are playing a role in the simulated AMV, with:
-A predominant role for NAO-like weather noise forcing, associated especially with heat flux in the eastern North Atlantic and wind stress in the northwest North Atlantic,
-An ocean dynamical response to the weather noise involving the AMOC and gyre circulations that could be acting as a positive coupled feedback,
-A non-trivial role for 20th century external forcing.

Keywords: climate variability, Atlantic Multidecadal Variability, Interactive Ensemble CGCM, climate simulation