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Moist singular vector sensitivity analysis applied to understanding African easterly wave evolution and predictability

Rosalind Cornforth and Brian Hoskins
NCAS-Climate, Walker Institute for Climate System Research, University of Reading, Reading, Berkshire, UK

Moist singular vectors (MSV) have been applied successfully to predicting mid-latitude storms growing in association with latent heat of condensation. Tropical cyclone sensitivity has also been assessed. There is now considerable interest in its application for singular vector computation in the tropics and tropical perturbations for the ensemble system on a wider basis than targeting tropical cyclones. Extending this approach to more general tropical weather systems, MSVs are evaluated here for understanding African easterly waves (AEWs) and associated rainfall. These are arguably, the tropical systems that exhibit dynamical organization in a manner that is most similar to extra-tropical weather systems, and yet provide the context for convection that is of great importance both in their development and their subsequent behaviour, and in yielding ideas on the interaction between physics and dynamics in the tropical atmosphere that may have more general relevance.

The systematic errors that can plague the forecast skill in this region may be improved by process studies aimed at understanding the fundamental dynamics governing the WAM. Here we present results from a study that aims to use MSVs to build on our recently gained theoretical insights from normal mode studies of the moist AEJ-AEW system, and to learn for practical purposes, whether MSVs targeted on W. Africa could be suitable as perturbations to the ECMWF ensemble system for improving AEW prediction and associated rainfall. Comparison is made of AEW-like singular perturbations that develop in consecutive wet and dry spells of the WAM during August 2006 of the AMMA SOP. The full physics linearised SV package developed at ECMWF, used in conjunction with the ECMWF Integrated Forecasting System, allows the use of moisture during SV evolution, but not initial humidity perturbations. Emphasis is thus placed on examination of the perturbation structures and growth mechanisms during these contrasting spells and the subsequent sensitivity of short-range forecasts. ECMWF assimilation experiments constructed to assess the impact of the well-known dry humidity bias in specific radiosondes, were used to further test the sensitivity of the perturbation growth mechanisms.

Results suggest MSVs may be used advantageously in this region. AEW-like perturbations grow rapidly over 24 h in association with moist processes. Perturbations bear similar structural and energy profiles consistent with previous normal mode non-linear idealised studies and observations. The crucial ingredient for MSV perturbation growth is diabatic heating set against a background of enhanced baroclinicity. During the dry spell, the MSVs tend to occur in regions of higher baroclinicity around the jet entrance. During the moist spell however, their initiation and subsequent growth is influenced both by surface temperature gradients and the availability of moisture. New structures and genesis locations result and MSV growth is reduced as competing growth mechanisms emerge. The difficulty in interpreting the MSV growth lies however in the opposing lower tropospheric potential temperature and moisture gradients and uncertainty in whether sustained growth can thus occur. Non-linear integrations showed that inclusion of these moist perturbations led to some but not a significant spread in predictability for AEWs. This suggests that whilst initial structures are sensitive to these perturbations, the assumption of linear growth may not be valid in a region where highly non-linear, moist processes are likely to be important. In view of the results, new light will be shed on the triggering paradigm debated in previously published work for the genesis of AEWs which has consequences for the variability and predictability of AEWs at weather and climate time scales.