Internal Variability in the West African Monsoon and 8-Day Rainy Sequences

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Summary

1. Credible dry and moist simulations of the African Easterly Jet (AEJ) and African Easterly Waves (AEWs) that grow on it, show that these core dynamical features of the West African Monsoon are strongly inter-dependent throughout their life cycle, hence “the AEJ-AEW system”.

2. The inter-dependencies impact the evolutions, growth/decay, structures and locations of the moist AEJ-AEW system, which are consistent with observations.

3. These dependencies establish an internal 8-10 day variability between the model rainfall and periods of growth and decay in the AEWs - consistent with intraseasonal observations of rainy day sequences (Fig. 1).

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The Challenge

Predictions of rainfall in sub-Saharan Africa show high uncertainty. Short-range forecasts (up to 2 days) are needed for the public and aviation, and medium-range forecasts (10-30 days) are key for agriculture, hydrology and health information.

AEJ-AEW System is a crucially important component of West African monsoon (WAM) rainfall variability. Many convective systems move with and through AEWs, with periods in which convection intensifies and vice versa (Laing et al, QJ, 2009).

In Fig. 2, convection is modulated on an AEW-like length-scale.

Fig.1: Daily rainfall time series (mm) from June to September 1968 averaged over the grid points from 10W to 10E and 12.5N and 15N (white) and in black the corresponding index filtered above 60 days.

But systematic errors plague the forecast skill in the region and AEWs decay far too quickly in forecasts (Agusti-Panareda et al, ECMWF Newsletter, 2008). Forecasting is still nowcasting.

Atmospheric processes are incorrectly represented. Urgent need for underpinning theoretical framework to amend NWP models.

The Approach: Use Idealised Modelling

1. Reading’s Intermediate Global Circulation Model: idealised yet retains important interactions. Integrated first with dry and then with moist physics to diagnose the impact of moist processes.

2. Prescribed zonally symmetric surface temperature and moisture profiles establish the AEJ through meridional contrasts in dry and moist convection. AEJ is forced not prescribed (Fig. 3).

3. AEWs initialised by breaking zonal symmetry and integrating model with zonal wavenumber 13 symmetry, after randomly perturbing surface pressure coefficients at t=0.

Questions

To what extent is rainfall predictable?
From Figs. 1 and 2 make the hypothesis:

- AEWs are a synoptic system capable of organising convection

Then use the idealised approach to explore:
What impacts AEW evolution, growth/decay, structure and location?

1. Impacts on AEJ-AEW Evolutions

Time-series of (a) AEJ max wind speed in different epochs and (b) 3D moist AEJ wind max and AEW max EKE

(a) Moist processes contribute to faster developments of moist AEJ and AEWs than in dry life cycle. (b) Slow oscillations in moist AEJ time series. Periods of deceleration in AEJ coincide with max AEW growth.

AEW Growth/Decay and Rainfall

Most AEWs have intermittent periods of decay and growth. Growth is preceded by increased mean rainfall.

- Speculation of an external forcing causing observed rainy day sequences (Sultan et al, J Clim, 2003) may well be explained instead by this internal forcing in the moist AEJ-AEW system.

- Significant result from the moist life cycle, providing an alternative explanation for some of the observed intraseasonal variability of the precipitation over West Africa.

- It has implications for the evaluation of weather and climate prediction models for West Africa.

2. Impacts on AEJ-AEW Structures

Diabatic heating in moist life cycle increases meridional PV gradient at red-levels. Model processes in construction of scales.

3. Geographical dependences

Lattitudinal displacements of the dry and moist AEWs correlate with the growth/decay of AEWs. In (a), the dry jet moves equatorwards whilst in (b) the moist jet moves polewards. This is consistent with observations.

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