Variability of West African Weather Systems

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(1) Convectively Coupled Kelvin waves
(2) African Easterly Waves
Key features of the WAM Climate System during Boreal summer
Data: GPCP (Global Precipitation Climatological Project).
Resolution: pentad on a 2.5° grid.
Averaged from 10°W to 10°E over 23 years (1979-2001).
Eastward and Westward moving Weather Systems

Unfiltered Brightness Temperature

Kiladis et al. (2009)
Annual Cycle of Synoptic Weather Systems

TD-filtered OLR (AEW-activity)
Peaks in Summer

We know little about the nature and causes of AEW-variability

Kelvin-filtered OLR
Peaks in Spring

Key synoptic system for pre-coastal phase and possibly the coastal phase – much weaker in summer
Kelvin wave examples – Flooding in Ghana 2006
While Kelvin wave activity is weaker in Boreal summer in the African region – they can still have a significant influence

Base point for regression analysis
Evolution of Kelvin waves in Boreal Summer

Day 0

Ventrice et al., 2011
Evolution of Kelvin waves in Boreal Summer

Day -6
Evolution of Kelvin waves in Boreal Summer
Evolution of Kelvin waves in Boreal Summer

Day -4
Evolution of Kelvin waves in Boreal Summer

Day -3
Evolution of Kelvin waves in Boreal Summer

Day -2
Evolution of Kelvin waves in Boreal Summer

Day -1
Evolution of Kelvin waves in Boreal Summer

Day 0
Evolution of Kelvin waves in Boreal Summer

Day +1
Evolution of Kelvin waves in Boreal Summer

Day +2
Evolution of Kelvin waves in Boreal Summer

Day +3
Evolution of Kelvin waves in Boreal Summer

Day +4
Evolution of Kelvin waves in Boreal Summer

Day +5
Evolution of Kelvin waves in Boreal Summer

Day +6
Initiation of Kelvin waves that impact West Africa

Initiation from Madden Julian Oscillaton (MJO) – Kiladis et al (2009)

Initiation from Cold fronts – Liebmann et al (2009)
African Easterly Waves

- Primary synoptic modulator of rainfall in summer
- Most Atlantic Tropical Cyclones are triggered by AEWs
OLR and 850 hPa Flow Regressed against TD-filtered OLR (scaled -20 W m²) at 10°N, 10°W for June-September 1979-1993

Day 0

Streamfunction (contours 1 X 10⁵ m² s⁻¹)
Wind (vectors, largest around 2 m s⁻¹)
OLR (shading starts at +/- 6 W s⁻²), negative blue

Kiladis, Thorncroft, Hall (2006)
OLR and 850 hPa Flow Regressed against TD-filtered OLR (scaled -20 W m$^2$) at 10°N, 10°W for June-September 1979-1993

Day-4

Streamfunction (contours 1 X 10$^5$ m$^2$ s$^{-1}$)
Wind (vectors, largest around 2 m s$^{-1}$)
OLR (shading starts at +/- 6 W s$^{-2}$), negative blue
OLR and 850 hPa Flow Regressed against TD-filtered OLR (scaled -20 W m$^2$) at 10°N, 10°W for June-September 1979-1993

Day-3

Streamfunction (contours $1 \times 10^5$ m$^2$ s$^{-1}$)
Wind (vectors, largest around 2 m s$^{-1}$)
OLR (shading starts at +/- 6 W s$^{-2}$), negative blue
OLR and 850 hPa Flow Regressed against TD-filtered OLR (scaled -20 W m$^2$) at 10°N, 10°W for June-September 1979-1993

Streamfunction (contours 1 X 10$^5$ m$^2$ s$^{-1}$)
Wind (vectors, largest around 2 m s$^{-1}$)
OLR (shading starts at +/- 6 W s$^{-2}$), negative blue
OLR and 850 hPa Flow Regressed against TD-filtered OLR (scaled -20 W m$^2$) at 10°N, 10°W for June-September 1979-1993

Day-1

Streamfunction (contours 1 X 10$^5$ m$^2$ s$^{-1}$)
Wind (vectors, largest around 2 m s$^{-1}$)
OLR (shading starts at +/- 6 W s$^{-2}$), negative blue
OLR and 850 hPa Flow Regressed against TD-filtered OLR (scaled -20 W m$^{-2}$) at 10°N, 10°W for June-September 1979-1993

Day 0

Streamfunction (contours 1 X 10$^5$ m$^2$ s$^{-1}$)
Wind (vectors, largest around 2 m s$^{-1}$)
OLR (shading starts at +/- 6 W s$^{-2}$), negative blue
Life-Cycle of an intense MCS

Sep. 7, 1200 Z 2006

- Convection initially developed west of the trough near the Jos Plateau.

Janiga (2013)
Life-Cycle of an intense MCS

Sep. 7, 1800 Z 2006

- At 1800 Z convection was present in most AEW phases.

10.8 μm IR BT (K, shaded), 700 hPa streamfunction (x10^6 m^2 s^-1, contours), and trough/ridge
Life-Cycle of an intense MCS

Sep. 8, 0000 Z 2006

- By 0000Z convection in the northerlies began to organize into a large MCS.

10.8 μm IR BT (K, shaded), 700 hPa streamfunction (x10^6 m^2s^-1, contours), and trough/ridge

Janiga (2013)
Life-Cycle of an intense MCS

Sep. 8, 0600 Z 2006

• The MCS reached peak intensity around 0600 Z.

• IR BTs of 185-190 K were observed.

10.8 μm IR BT (K, shaded), 700 hPa streamfunction (x10^6 m^2 s^-1, contours), and trough/ridge

Janiga (2013)
• To what extent do the most intense MCSs rely on intense AEWs and vice versa?
The West African Monsoon is characterized by significant intraseasonal variability at two distinctive timescales:

- 25-60 days
- 10-25 days

(see Sultan and Janicot, 2003; Maloney and Shaman, 2008).

Is such variability manifested in variability in AEW-activity and related TC-activity?
Variability of AEWs (EKE measure)
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Variability in AEW structures and intensity can arise from:

(i) variability in the regional environment (e.g. AEJ)
(ii) variability in coupling between AEWs and convection
(iii) variability in the triggers of AEWs
(iv) interactions with other synoptic disturbances including extratropical troughs and convectively coupled equatorial waves.
(v) internal AEW-AEJ interactions (Cornforth et al, 2009)
(vi) upstream development (Diaz and Aiyyer, 2012)
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Convective triggering of an intense AEW
MJO and Kelvin waves both modulate convection over tropical North Africa. We therefore expect these phenomena to impact AEW activity.

**MJO:**
- Ventrice et al (2011)
- Alaka and Maloney (2012)

**Kelvin Waves:**
- Ventrice et al (2011)
Variability in AEW Activity: The MJO

RMM Phase 1

RMM Phase 2

RMM Phase 3

RMM Phase 4

RMM Phase 5

RMM Phase 6

RMM Phase 7

RMM Phase 8

Ventrice et al, 2011
Variability in AEW Activity: The MJO

RMM Phase 1

RMM Phase 2

RMM Phase 3

RMM Phase 4

RMM Phase 5

RMM Phase 6

RMM Phase 7

RMM Phase 8

OLR

2-10d filtered 700 hPa EKE
Kelvin wave (shaded), enhanced AEWs (contoured, only one phase shown).

A series of AEWs that were initiated or enhanced in association with Kelvin wave (AEWs are labeled).

AEW-4 became TS Bret, the first tropical storm of the season.

Mekonnen et al, 2008
A time-longitude plot of TRMM 3B42 unfiltered rain rate anomalies (shaded) during 2000 July 20-August 10. Kelvin filtered TRMM anomalies are overlaid. The +/- 2 mm/day Kelvin filtered TRMM anomaly is only contoured. Negative Kelvin filtered TRMM anomalies are dashed.

The Berry and Thorncroft (2005) AEW formed during the passage of the convectively active phase of a CCKW.
Sahel Decadal Rainfall

Martin and Thorncroft (2013)
The AMO: Atlantic Multidecadal Oscillation

A multidecadal pattern of detrended North Atlantic SST variability between the equator and Greenland

Martin and Thornicroft (2013)
Identifying AMO Phases

AMO and Sahel rainfall highly correlated

Warm – wet
Cold – dry

Isolate “warm” and “cold” AMO years

Composite variables based on warm and cold years

Martin and Thorncroft (2013)
AMO – Sahel Rainfall Relationship

Composite by warm and cold AMO years

Rainfall difference between warm and cold AMO years

*Sahel wetter in warm AMO years* when North Atlantic SSTs are increased

Martin and Thornicroft (2013)
**AMO – AEWs Relationship**

EKE difference between warm and cold AMO years

*Increased AEW activity during warm AMO years* when North Atlantic SSTs are increased

Relationship with tropical cyclones?
AMO – Tropical Cyclone Genesis

Increased tropical cyclone frequency in warm AMO years

→ Increased SST

→ Decreased vertical wind shear

→ Increased EKE
Primary synoptic weather system in boreal Spring
May determine monsoon onset on short timescales
Should be monitored on daily timescales

Strong relationship with MJO offers some potential predictability that could be exploited.

Q: Does the “misrepresentation” of Kelvin waves in climate models limit predictability of West African rainfall?
Primary synoptic weather system in summer.
Primary trigger for Atlantic tropical cyclones.

Exhibit substantial variability on daily-to-decadal timescales.

Variability impacted by rainfall variability (triggers, coupling)

Strong relationship with Kelvin waves, MJO, AMO.

Q: How does AEW-variability feedback onto regional environment?