Case Study of subseasonal variability of rainfall over Sahel

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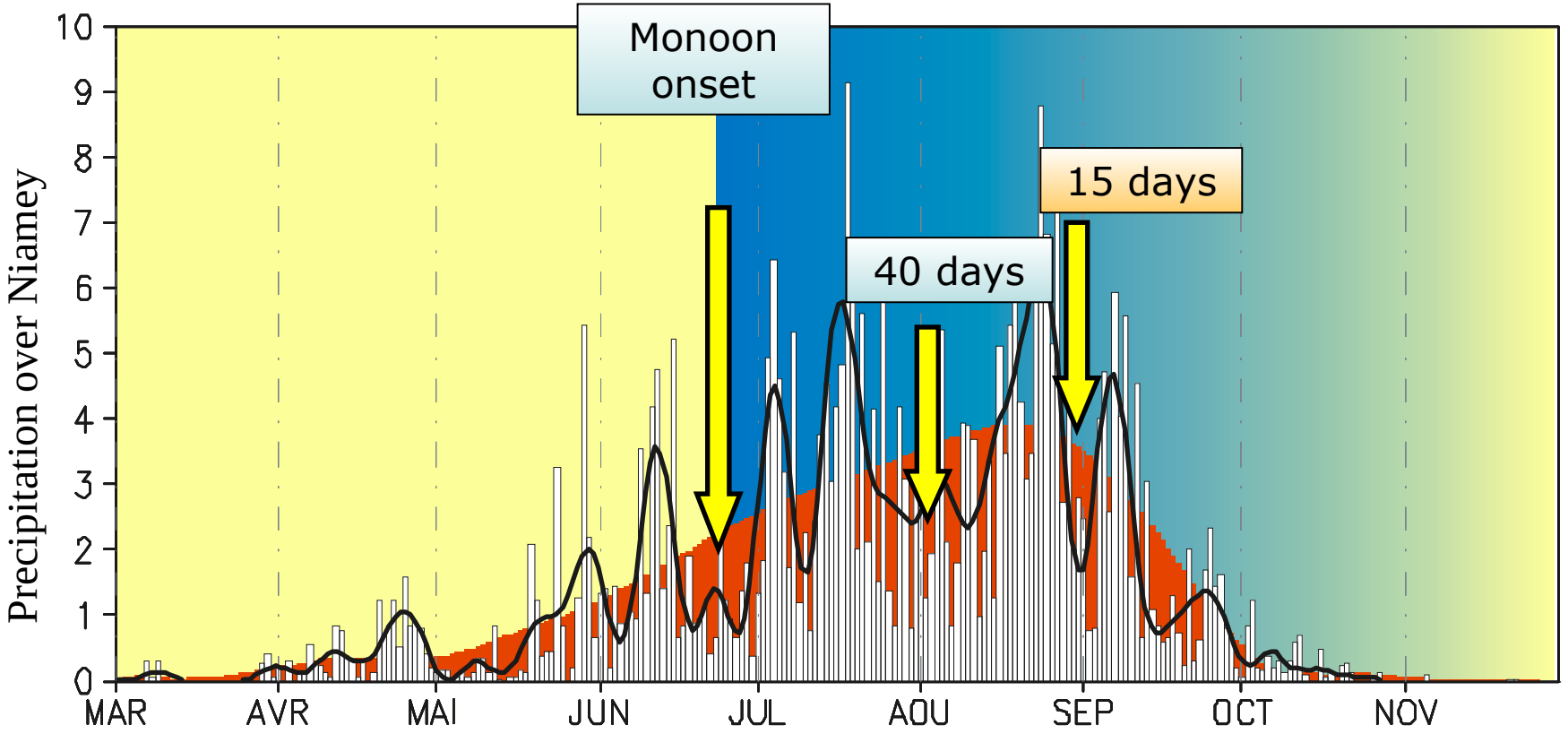
ONLINE TRAINING WORKSHOP ON SUBSEASONAL TO SEASONAL (S2S) PREDICTION OF MONSOONS
2 NOVEMBER 2021

Outline

1. **First view of rainfall variability of rainfall over West Africa**
2. Subseasonal variability and seasonal cycle
3. Case study of the wet phase in core 2019 monsoon

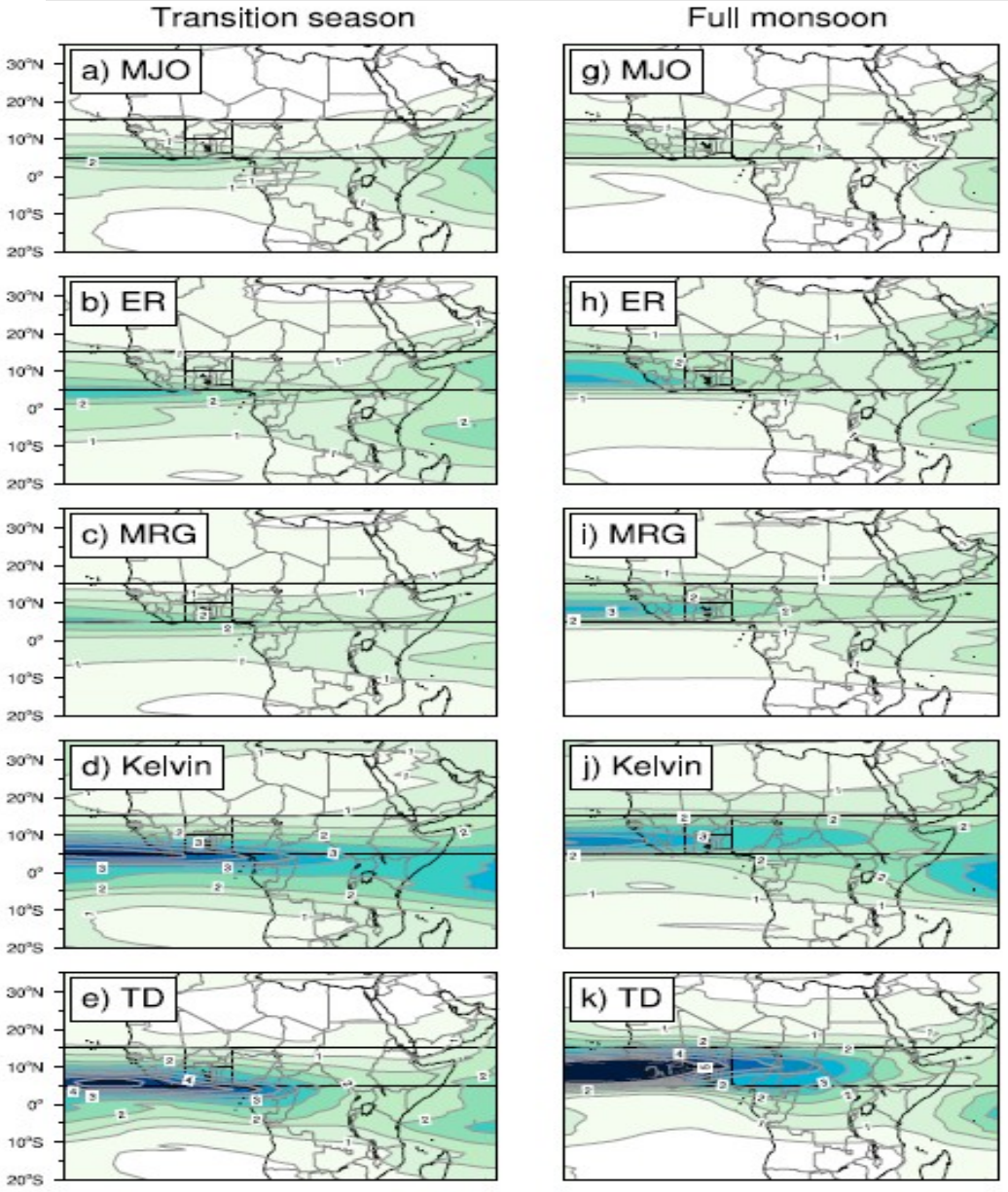
A first view of rainfall variability over the Sahel



- Rainfall variaibility occurs at specific period :
  - ~ 6-10 days : synoptic variability (African Easterly waves)
  - 10-30 days : short subseasonal
  - 30-90 days : long subseasonal (MJO)
- **MISVA** : Monitor subseasonal Variability of rainfall and its drivers (https://misva.aeris-data.fr)

Rainfall Variability over West Africa and equatorial waves

Rainfall variance associated with each equatorial waves (Schluter et al. 2019)



- Equatorial Waves are important drivers of rainfall variability over a large part of Africa
- 1st Order : African Easterly Waves
- Other waves are also modulating rainfall

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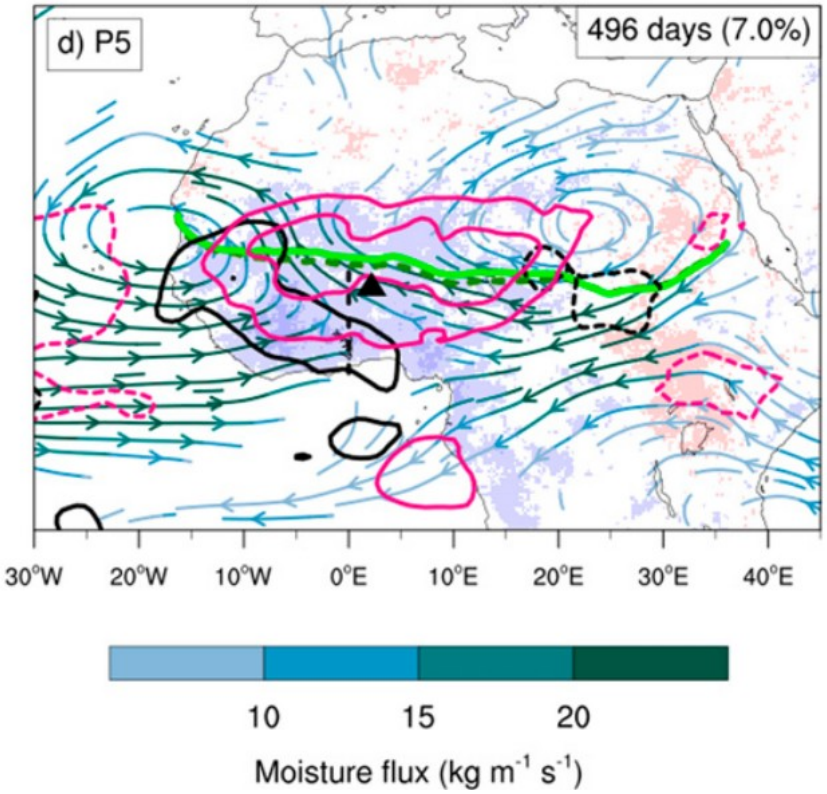
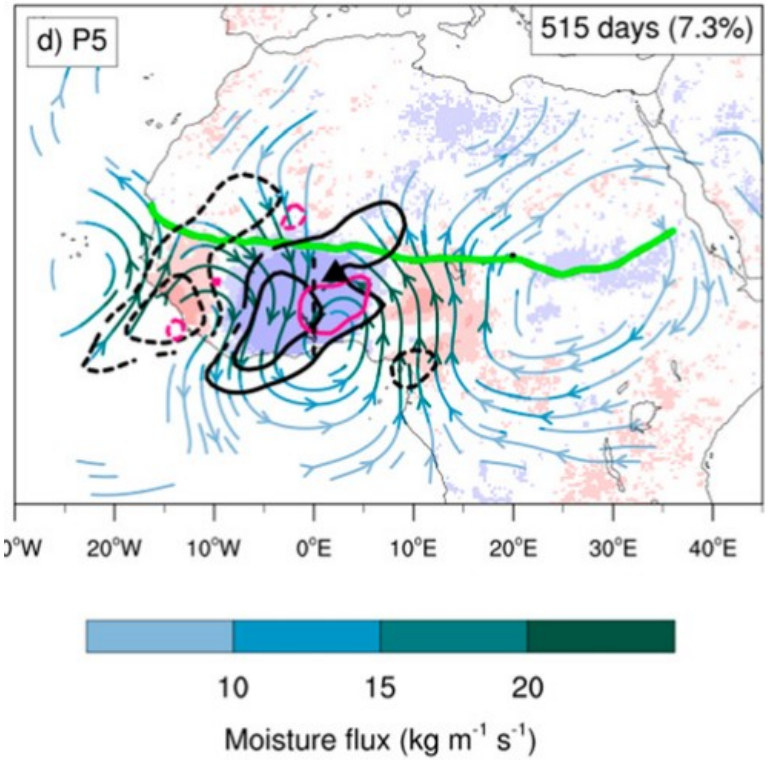
Subseasonal variability of rainfall over West Africa

Focus here on two specific modes of variability :

Equatorial Rossby wave **African Easterly Wave**

Moisture flux, Precipitable Water (Magenta) and wind convergence (solid black) at 850 hPa





Schluter et al. (2019)

- Both waves are marked in meridional wind, vorticity and Precipitable Water (PW)
- Wavelength and period greater for Eq. Rossby wave

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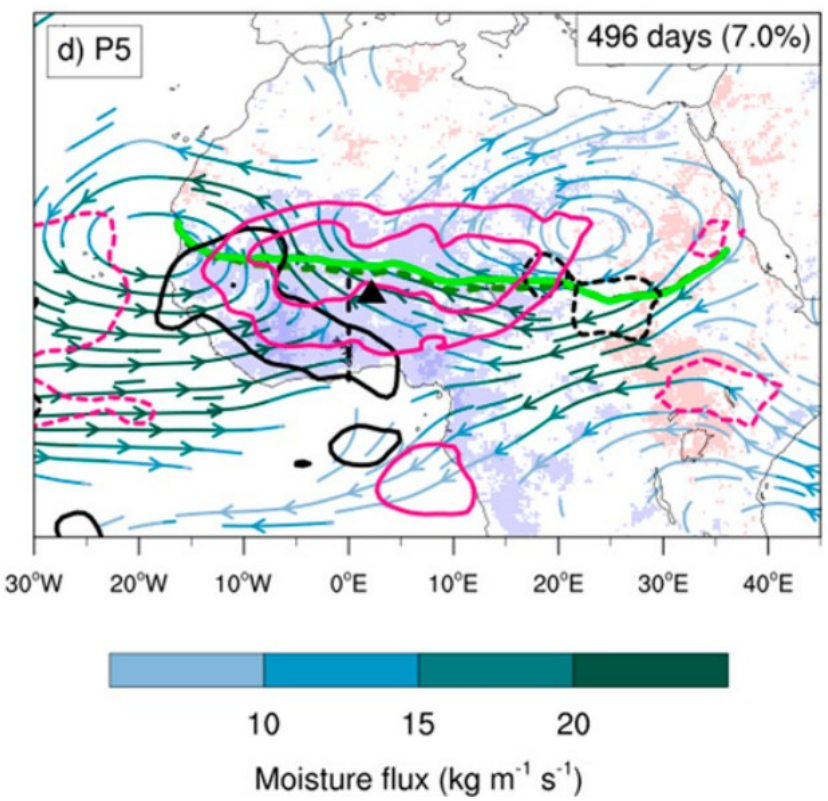

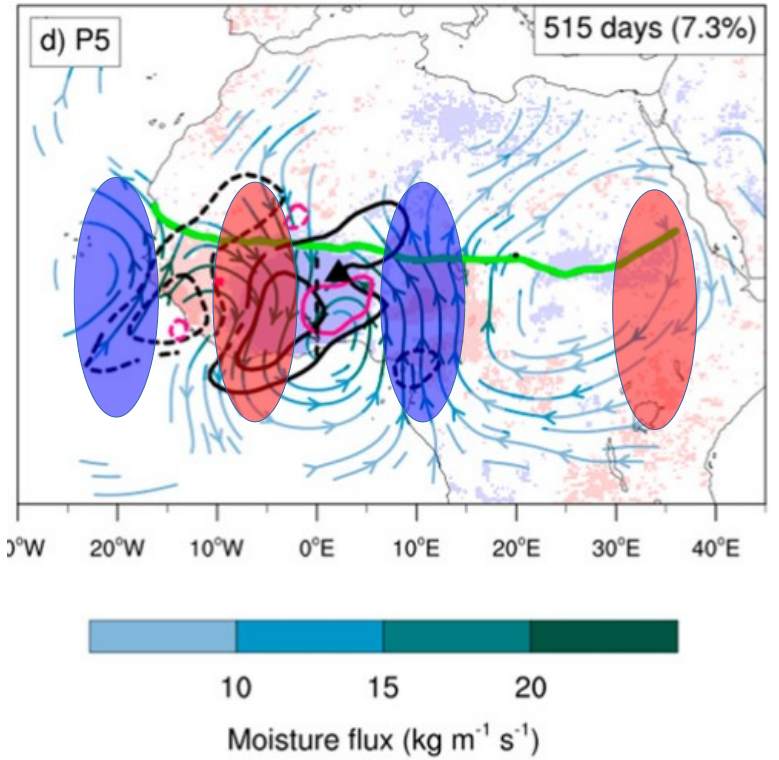

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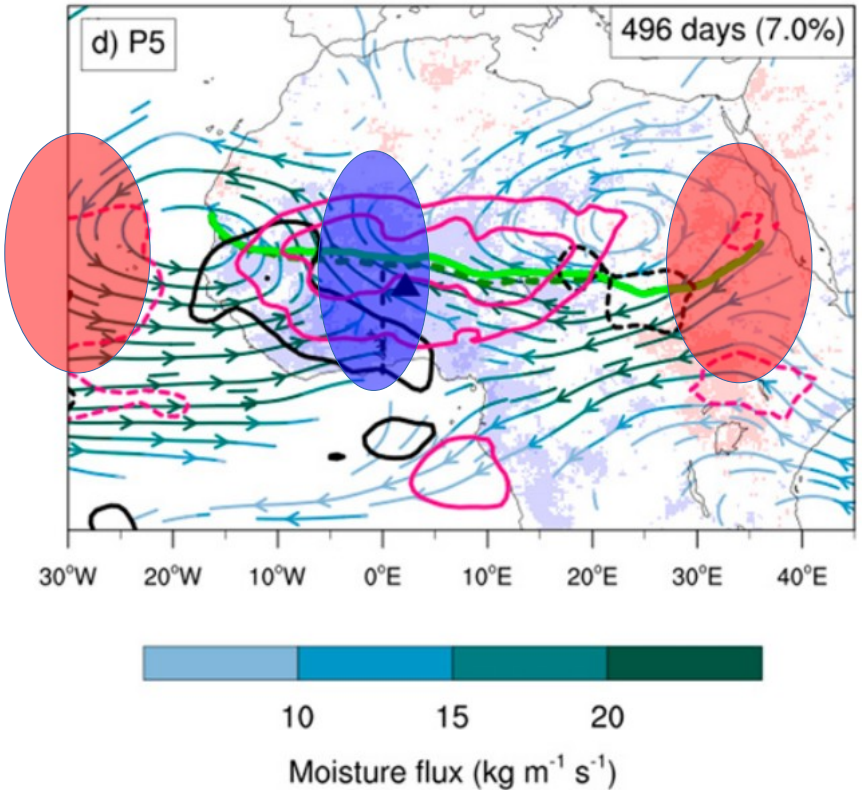

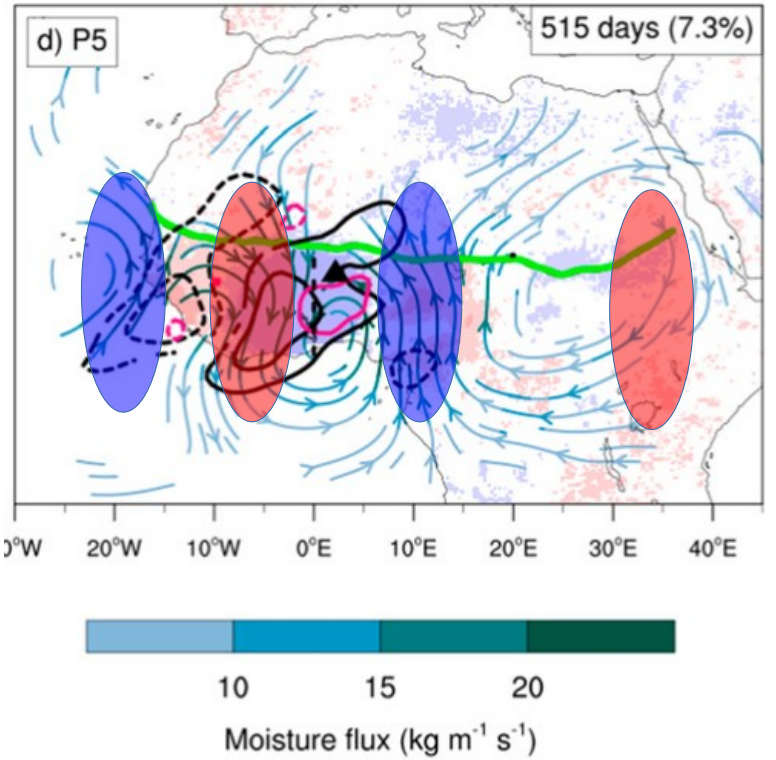

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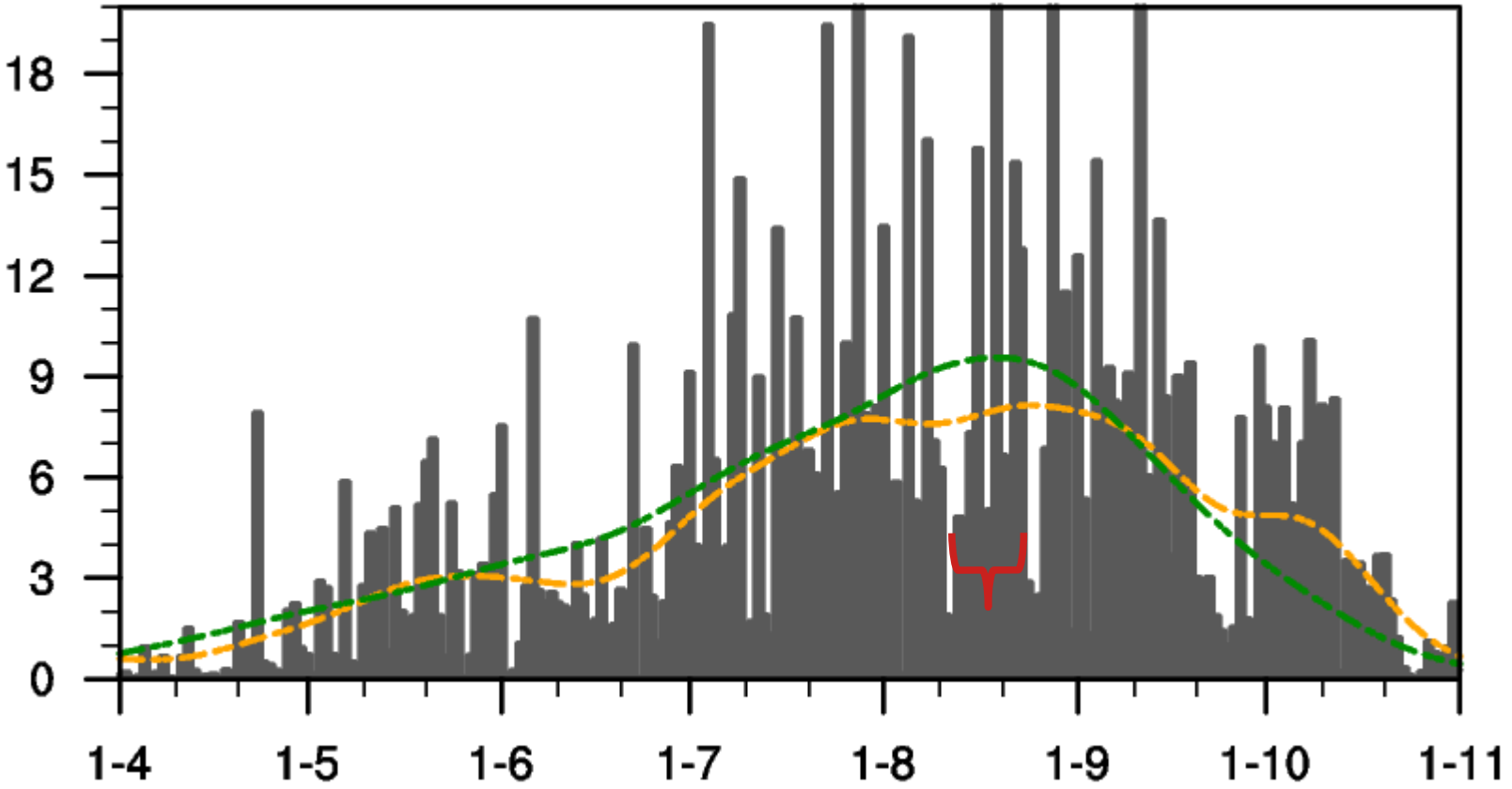
Connnection between subseasonal variability and the annual in 2019 - 1

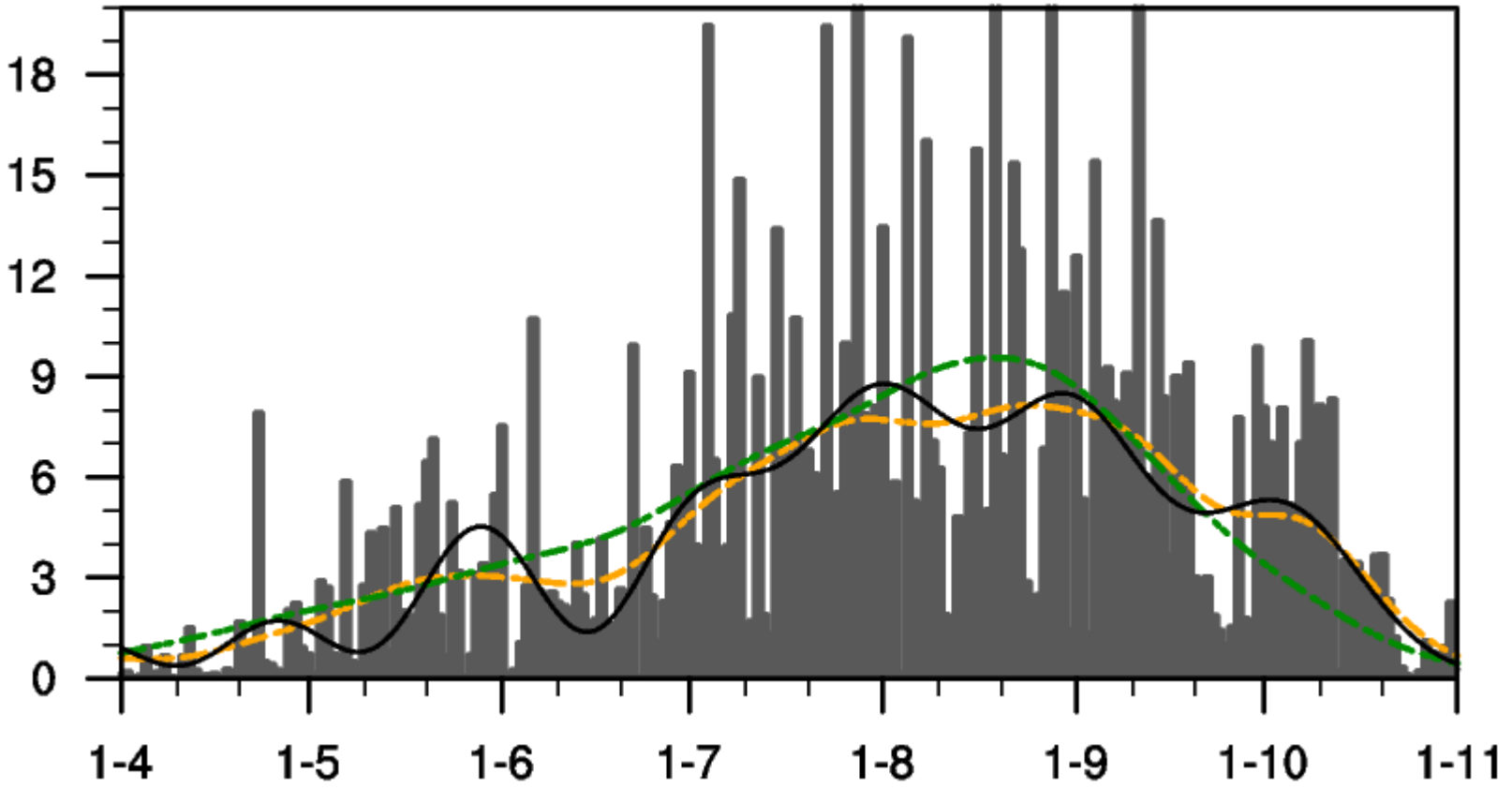
IMERG precipitation (mm/d), 1°x1°,daily
Green : climatology (2000-2020), **orange : annual cycle 2019**, Gray bar : Daily rainfall



- Smooth beginning followed by a 2-week break in June
- Long period of sustained rainfall peaks but August is quite below normal despite several subseasonal events
- The end of the season is remarklby wet

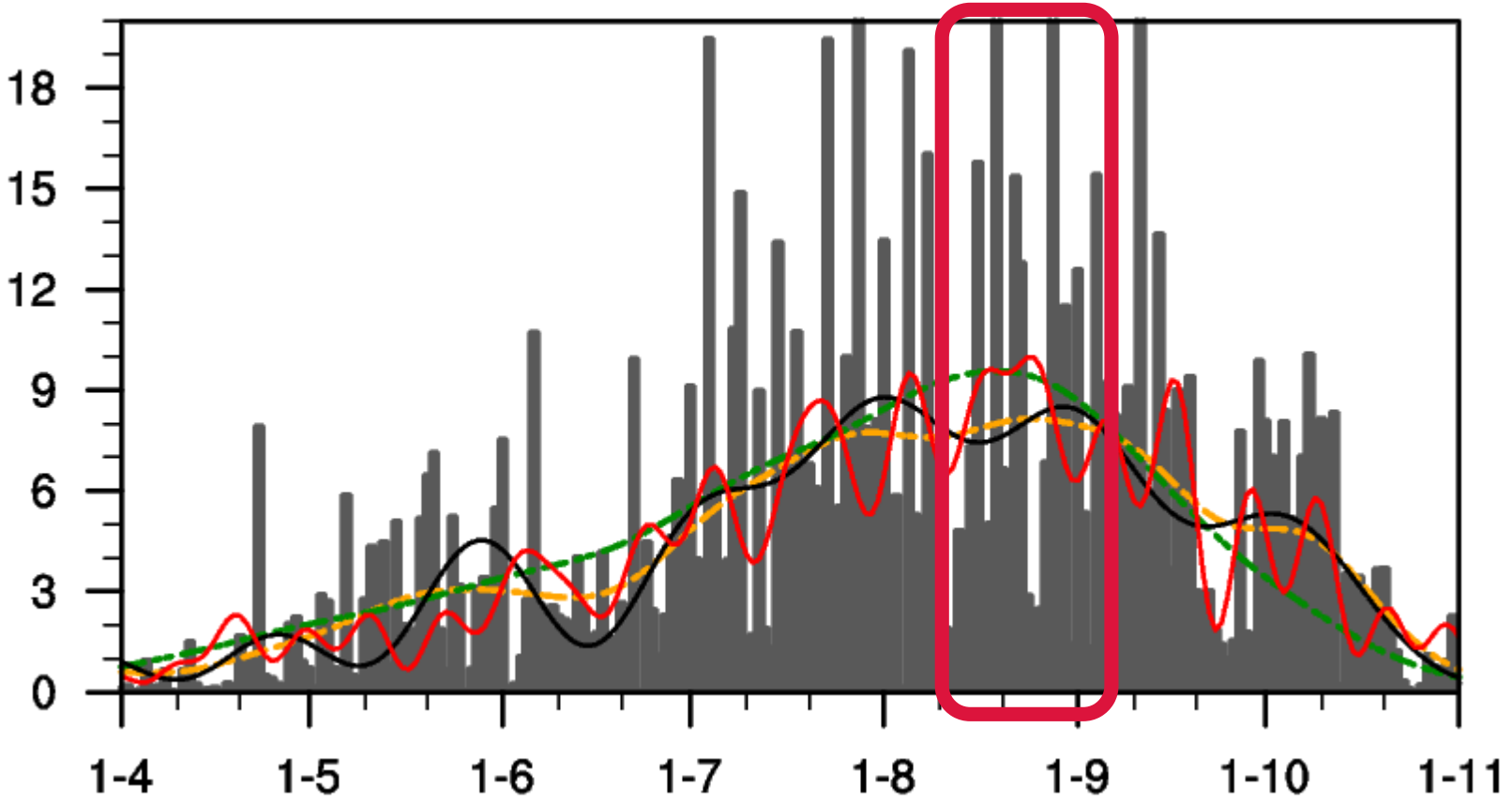
Connnection between subseasonal variability and the annual in 2019 - 2 : MJO

Black : MJO contribution



Connnection between subseasonal variability and the annual in 2019 - 3 : Equatorial Rossby waves

Red: Eq. Rossby contribution



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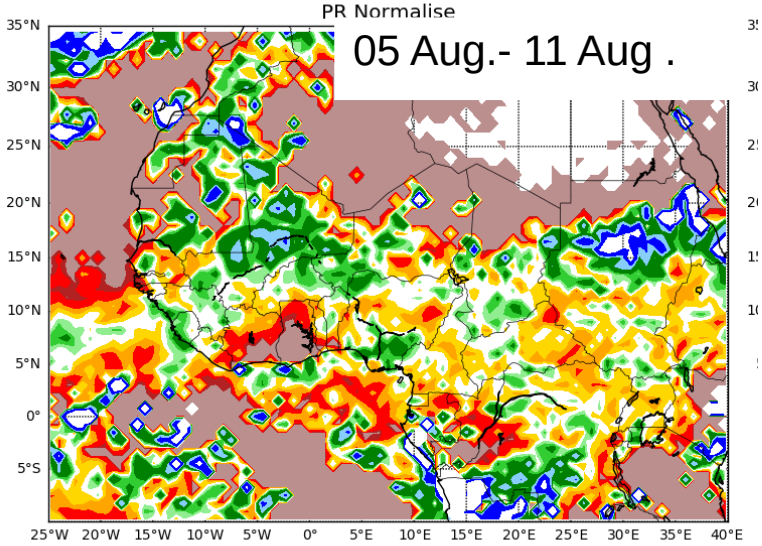
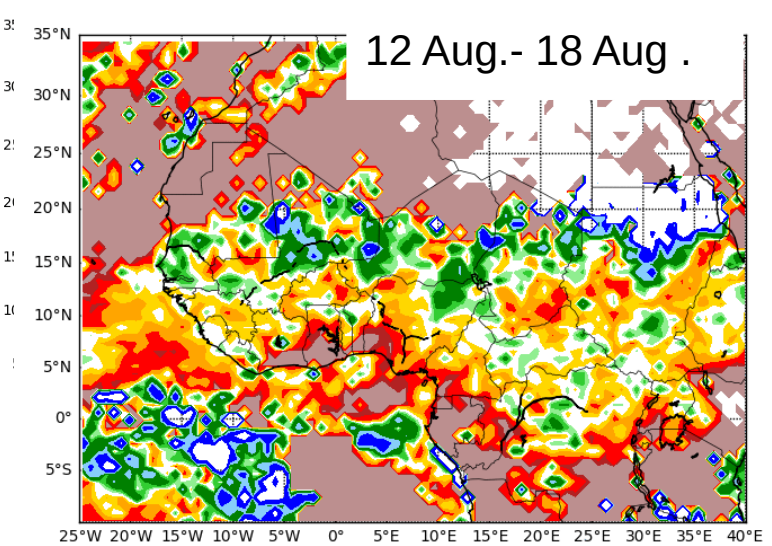
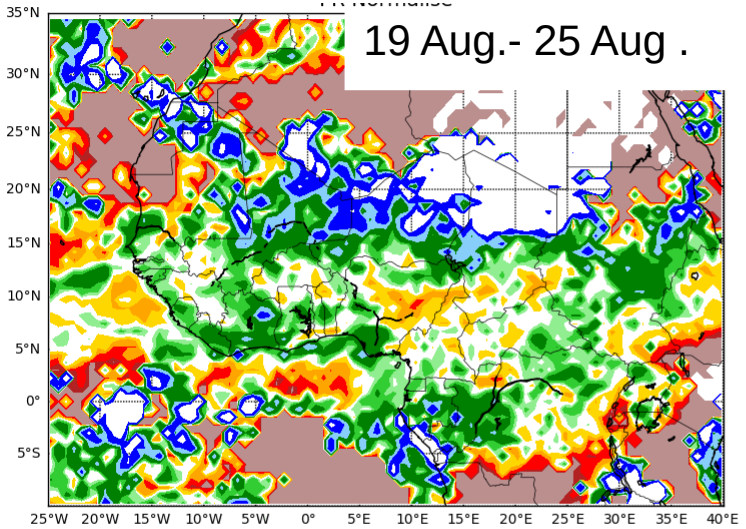
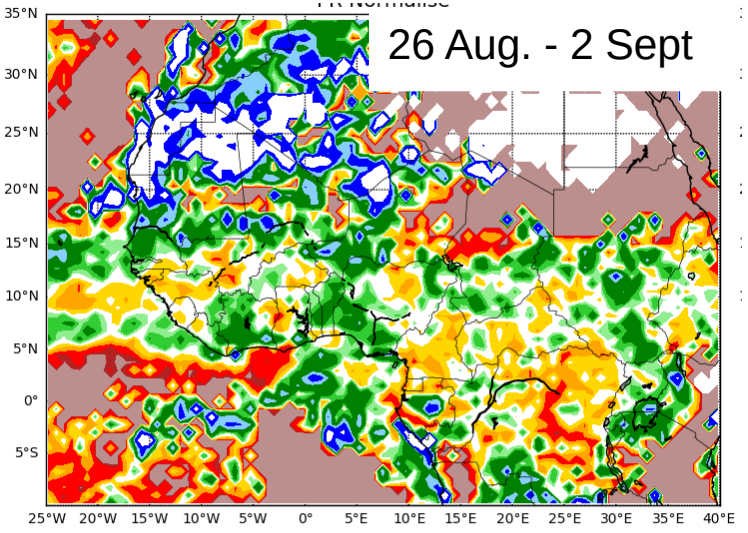
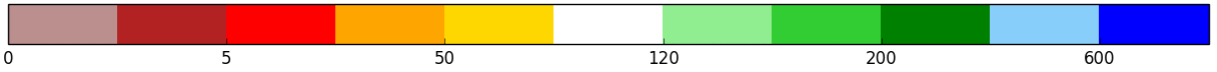
Wet spell from 16 to 26 August 2019 : excedentary weekly rainfall











Percentage of weekly rainfall over the [1999-2018] climatology. TMP3 3B42 rainfall.

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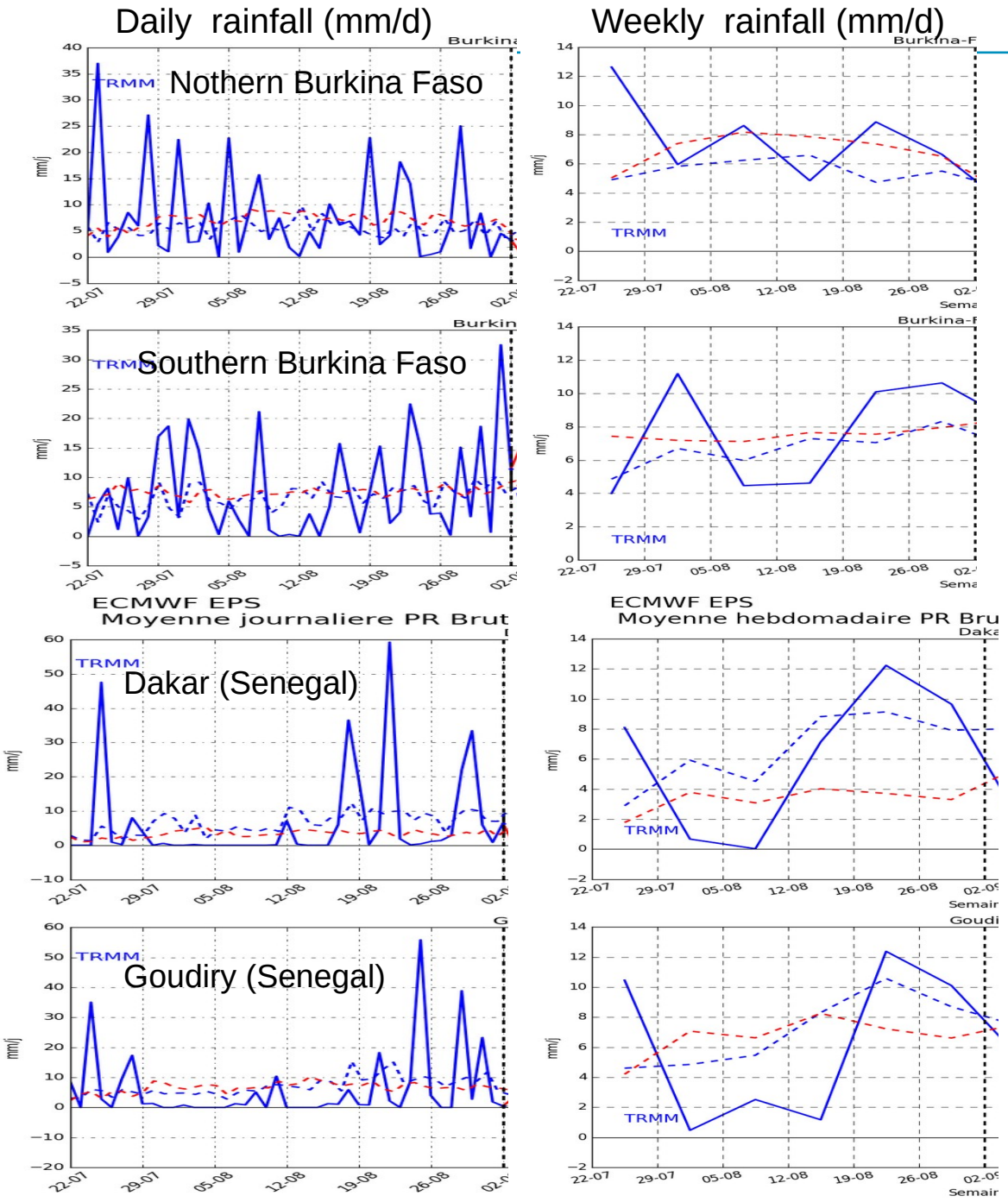
Large impacts of daily and weekly precipitation



TMPA-3B42 precipitation (realtime product) : solid blue and [1998-2018] climatology (dashed blue)

- The wet spell is seen in central and Western Sahel
- It follows a dry period over Senegal and Burkina Faso of 2 to 3 weeks

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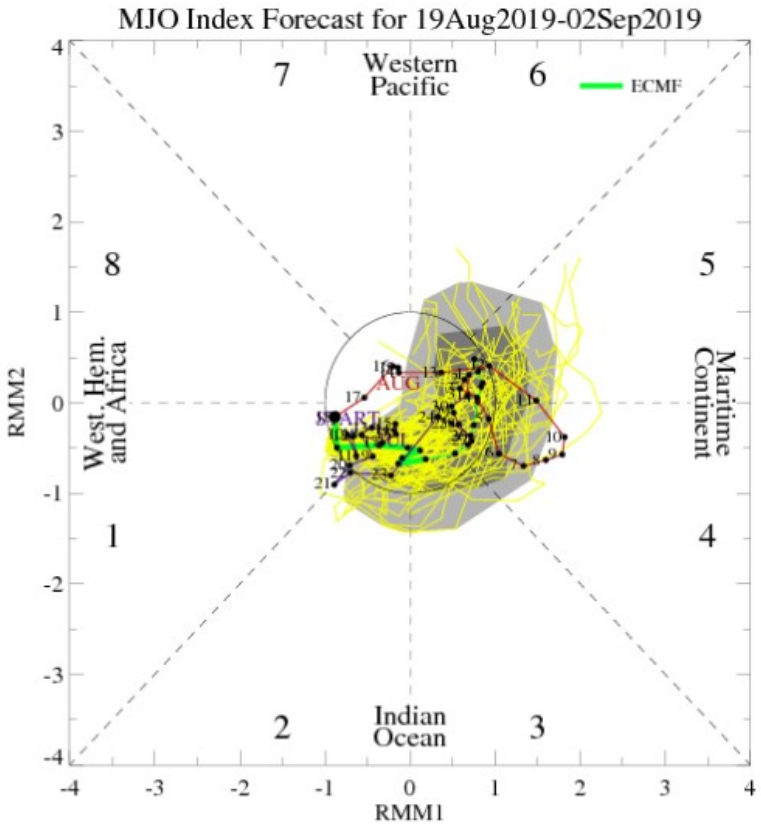
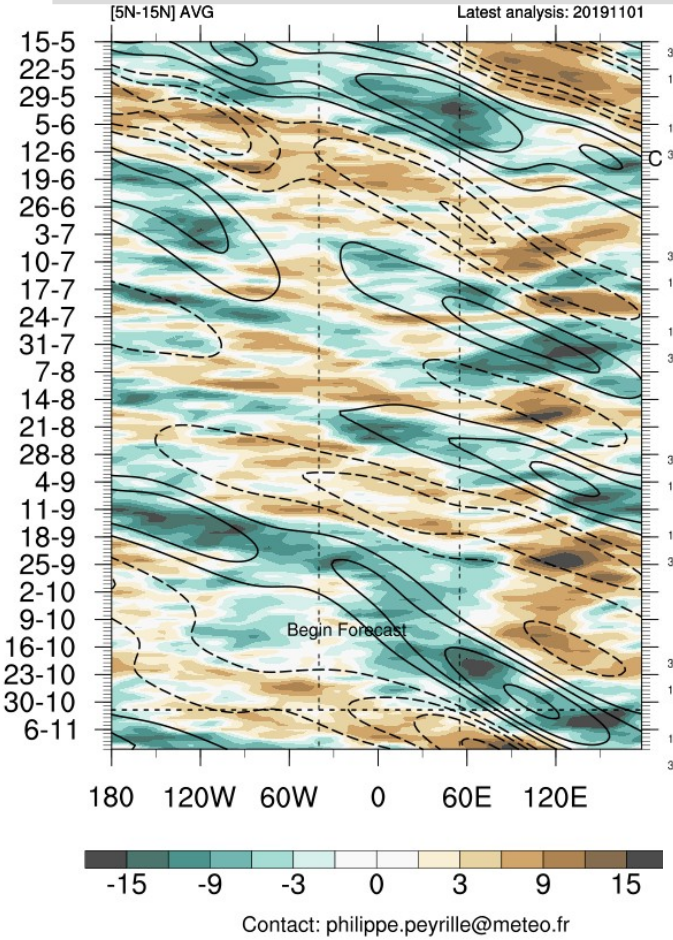
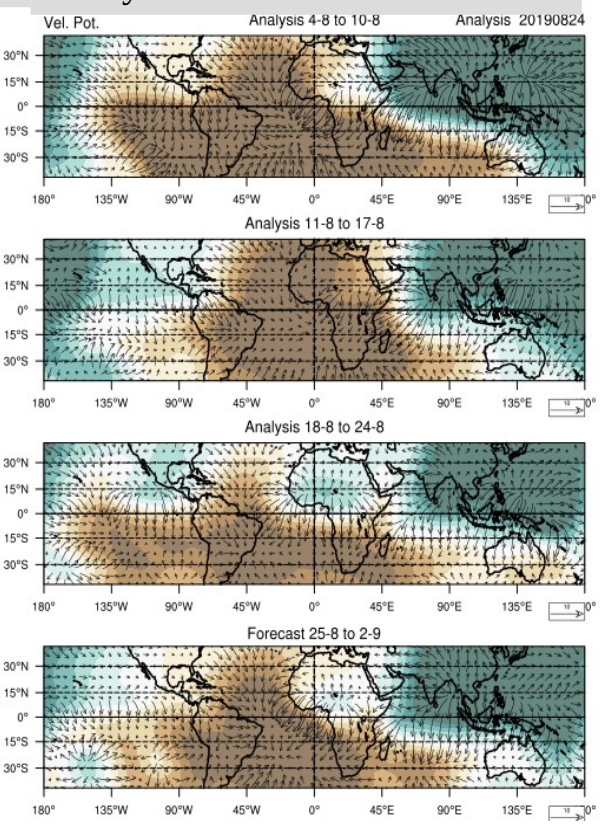
MJO and upper level divergence



5N-15N avg Velocity Potential anomalies at 200 hPa (shading) and MJO (contour) – ECMWF Analysis



Weekly avg Velocity Potential anomalies at 200 hPa – ECMWF Analysis

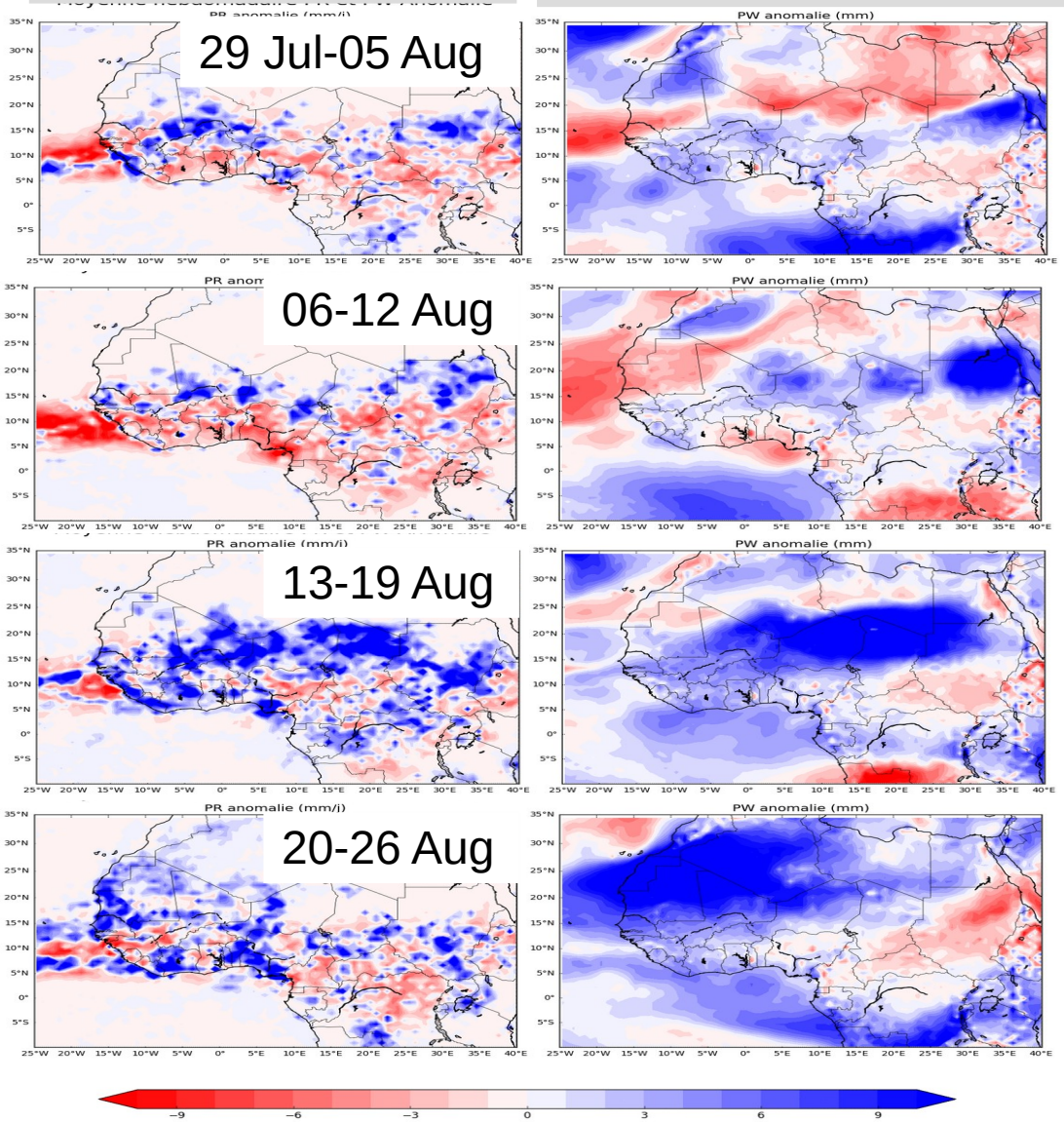


- The RMM Index was slightly out of the circle on 21 August and more emergent after passing West Africa
- Anomaly of Velocity potential at 200 hPa : Proxy for uppel-level divergence
- Bette Signal but the MJO seems also emergent over West Africa ⇒ not so much predictability with the MJO
- Maps of velocity potential : show an intensification of uppel-level divergence on week 18 to 26 August

Wet spell from 16 to 26 August 2019 : A moist enveloppe

weekly-mean anomaly of TMPA precipitation (mm/d)

weekly-mean anomaly of Precipitable Water (mm) ECMWF Analysis



- **Precipitable Water (PW, mm) :** Vertical Integral of water vapour mixing ratio, i.e.: the precipitation one gets if the column water vapour condensates
- A moist anomaly coming from the East can be seen on weekly anomaly of precipitable water (PW)
- It is associate with an increased rainfall

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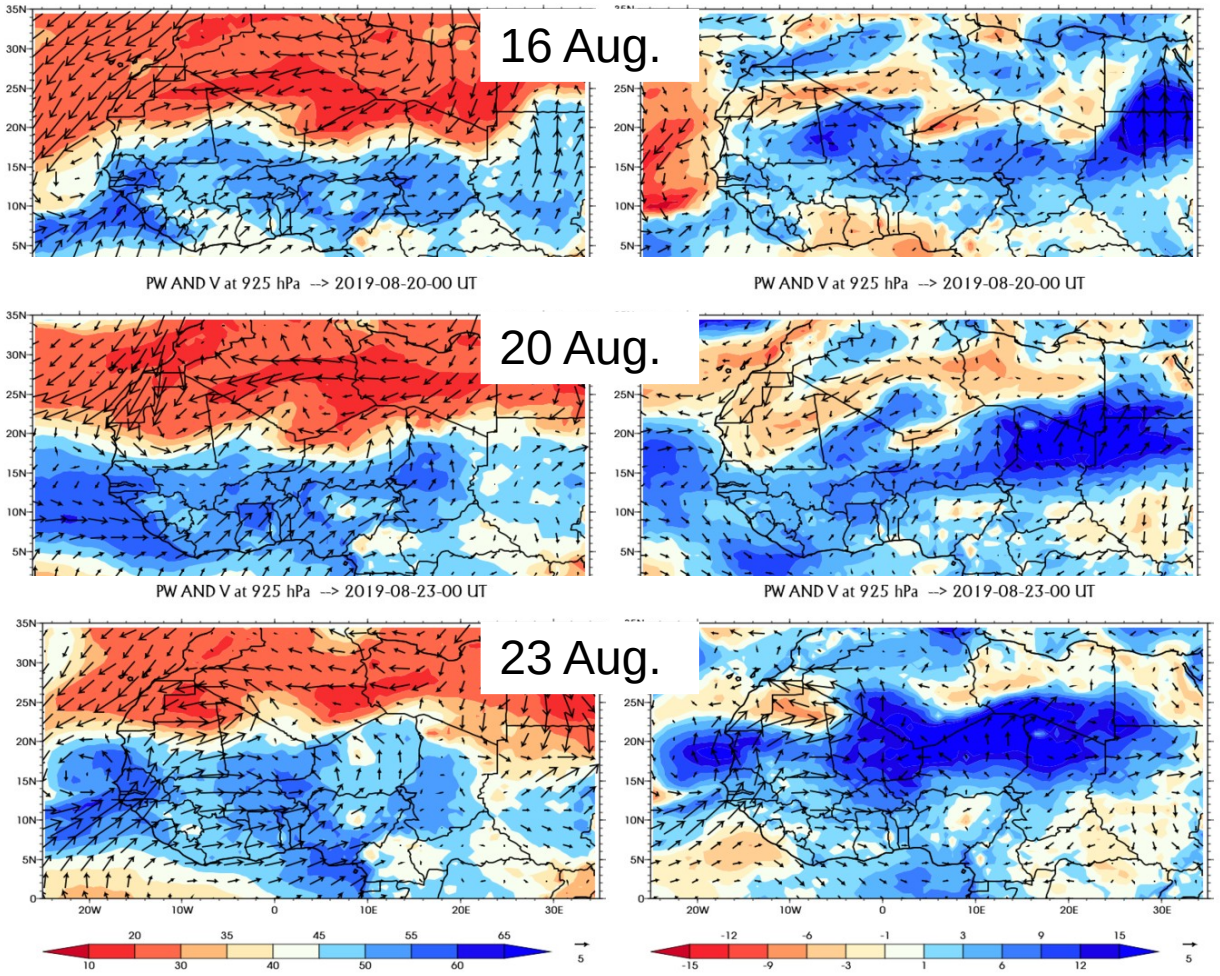
Link with Synoptic variability : Precipitable Water

PW (mm) and 925 hPa winds - ECMWF Analysis

PW and 925 hPa winds Anomalies ECMWF Analysis

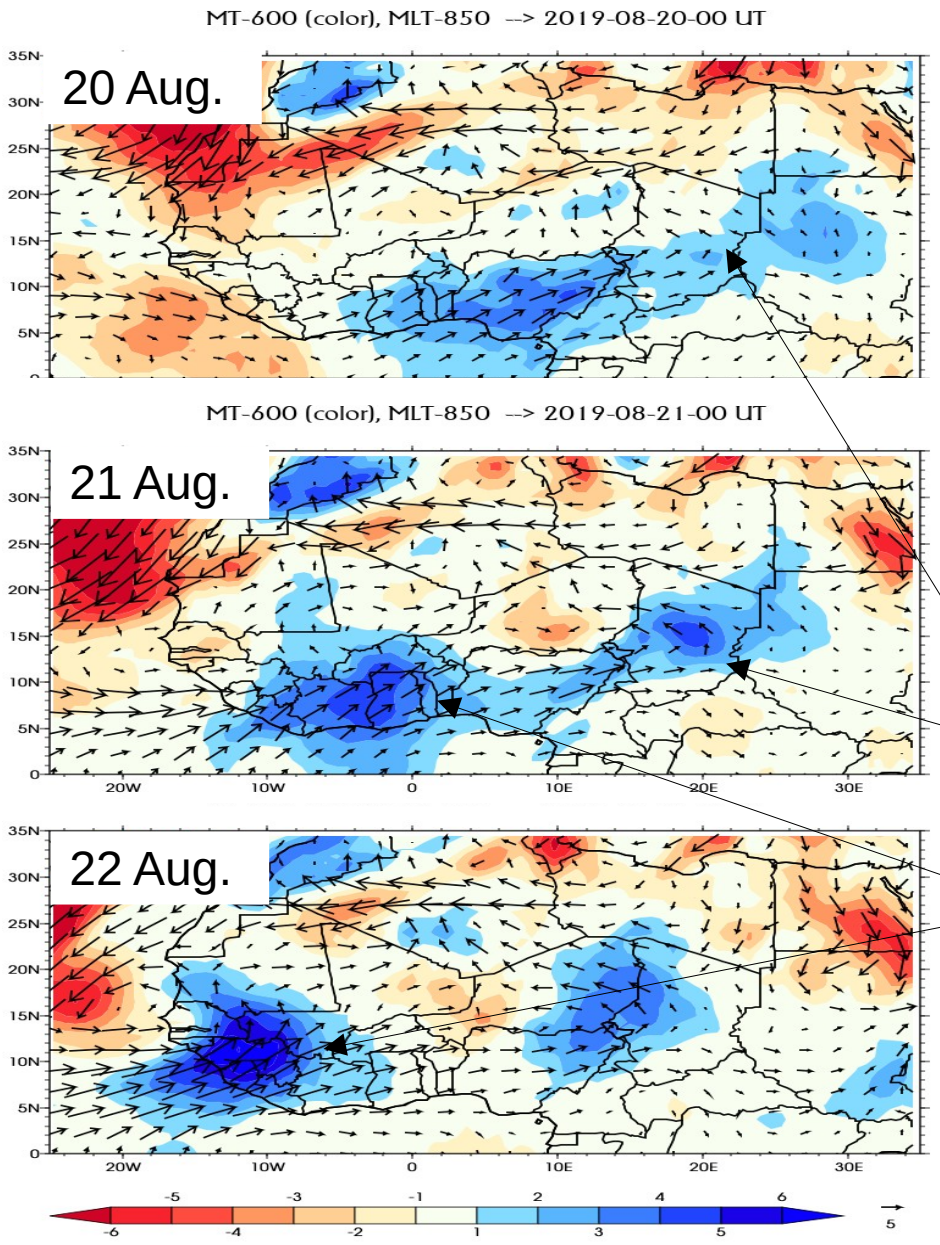


- The large moist anomaly is associated with westerlies on its western flank at 925 hPa

  ⇒ It corresponds to an equatorial Rossby wave pattern

- It increases the monsoon flow

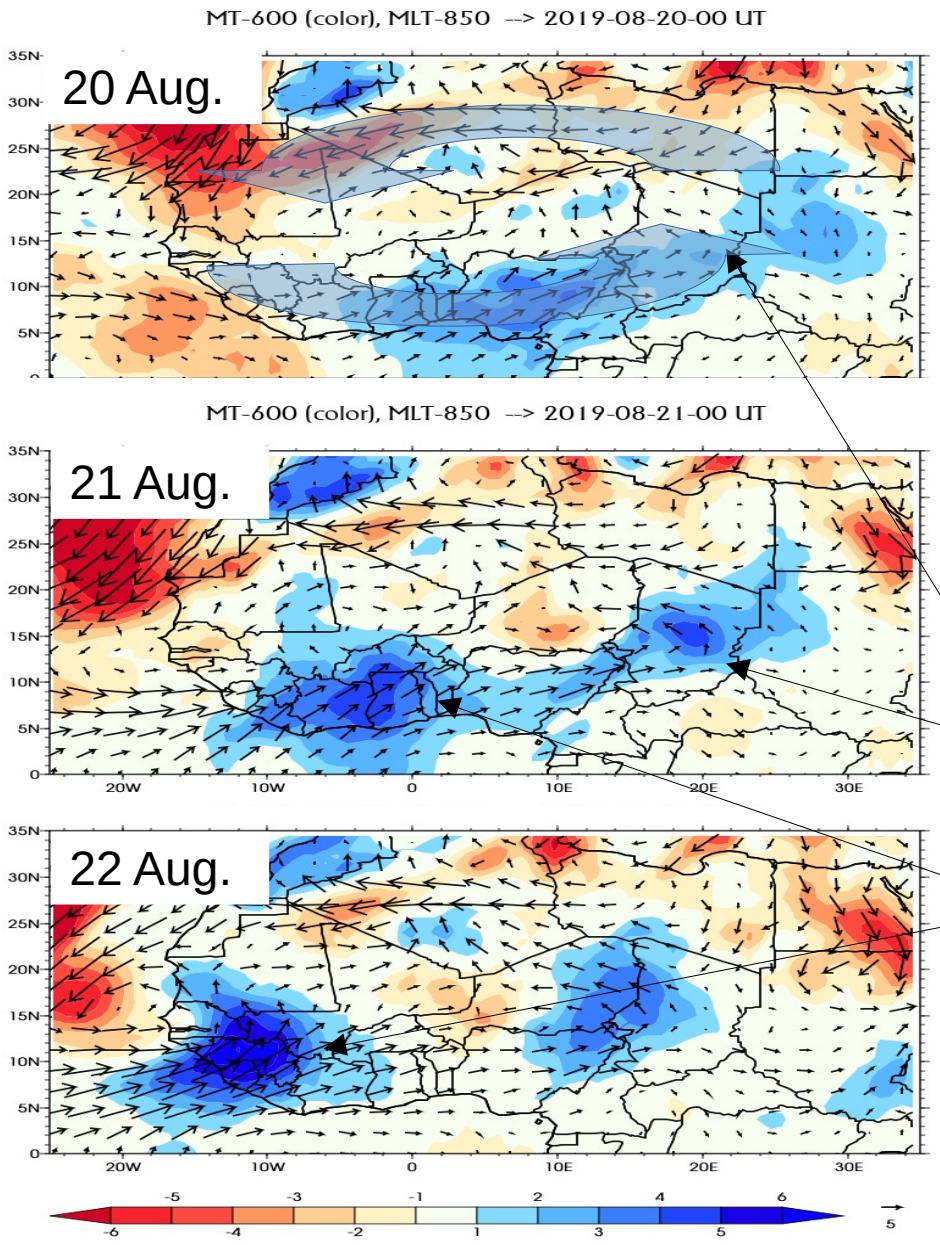
Link with Synoptic variability : Meridional Wind



Mean [925-600] hPa meridional wind (shading), [925-850] mean wind vector ECMWF Analysis

- The large cyclonic gyre is present on 20 August and moves slowly to the west
- The southerly anomaly over Tchad initiated
- Wind convergence over Ivory Coast initates another AEW

Link with Synoptic variability : Meridional Wind



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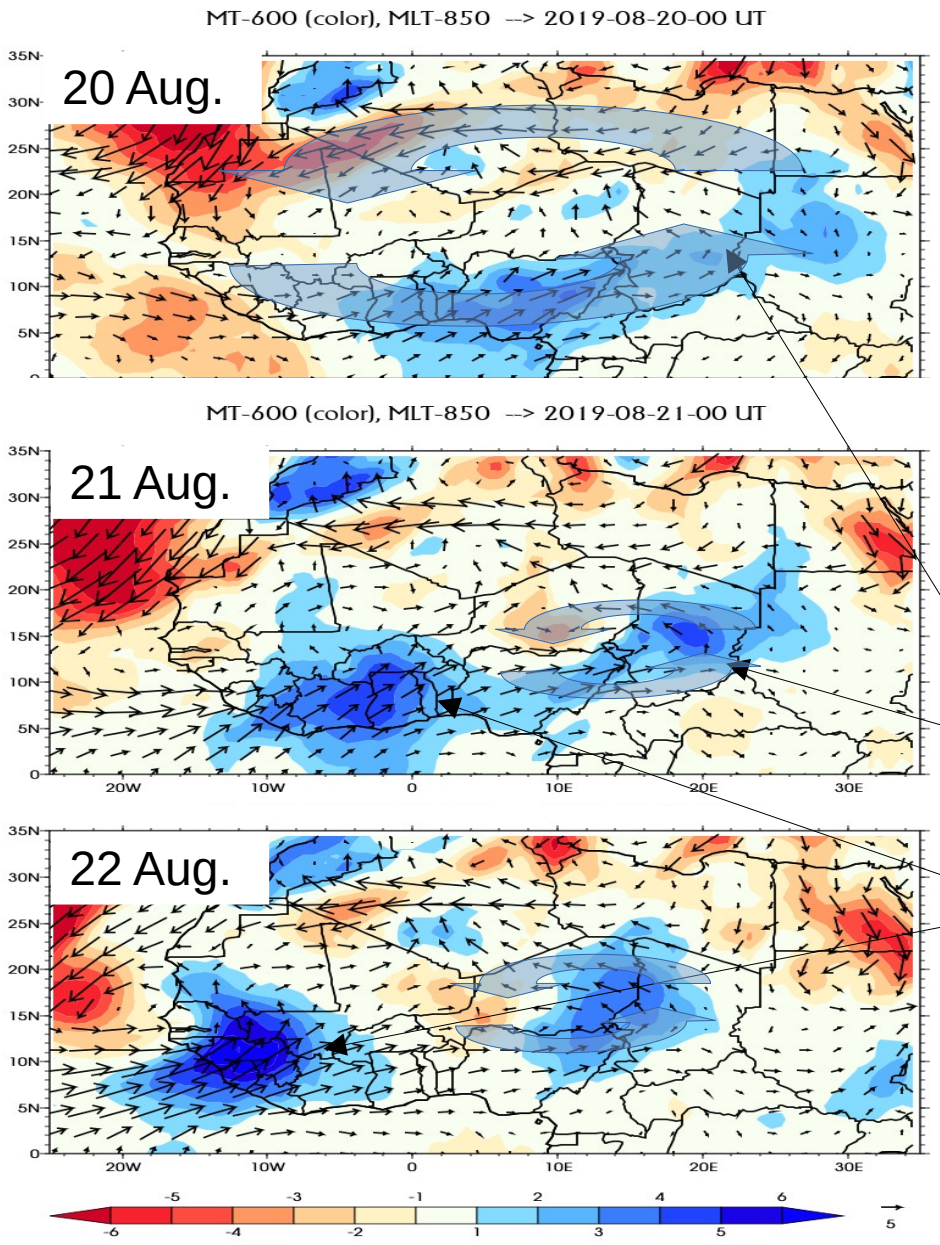

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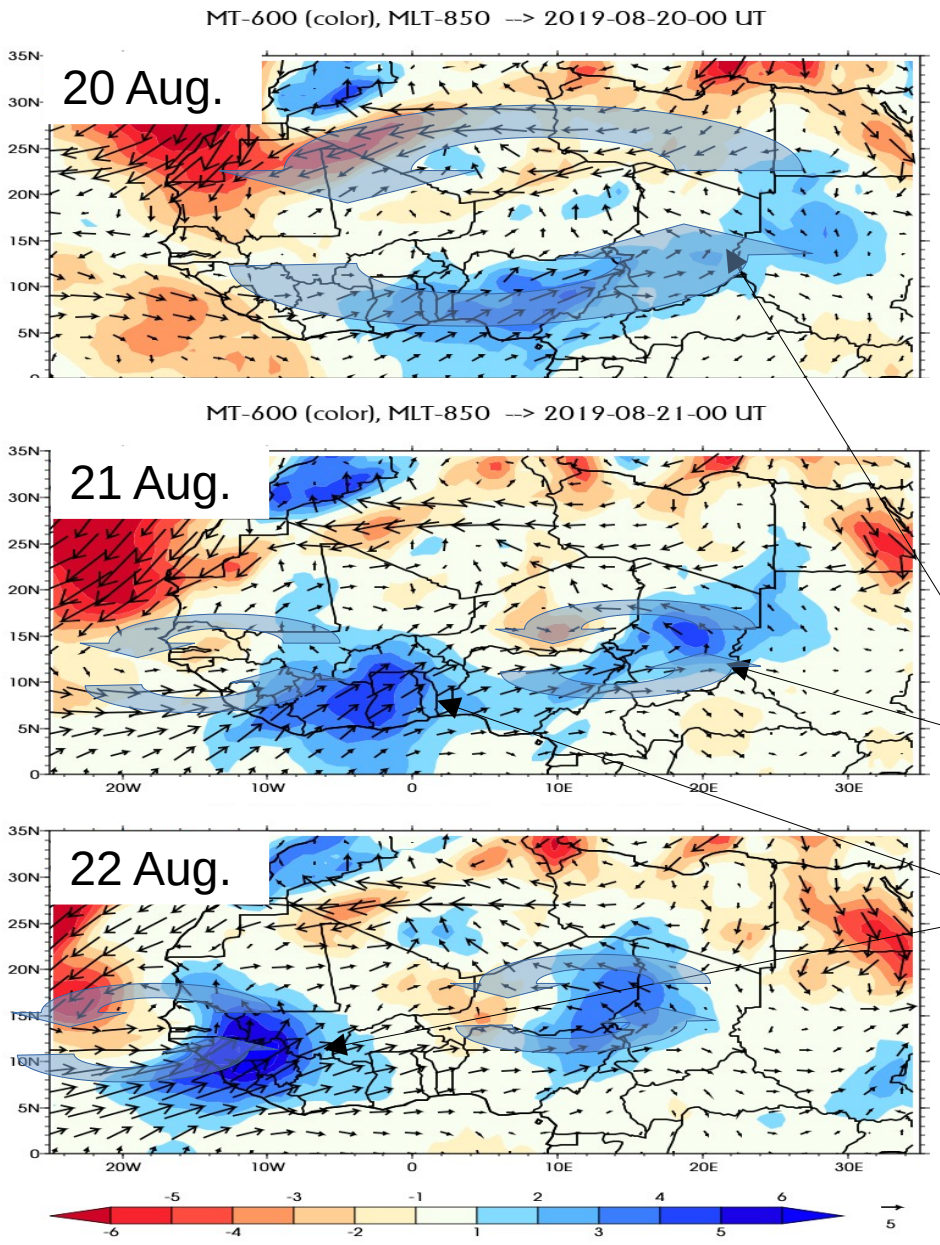

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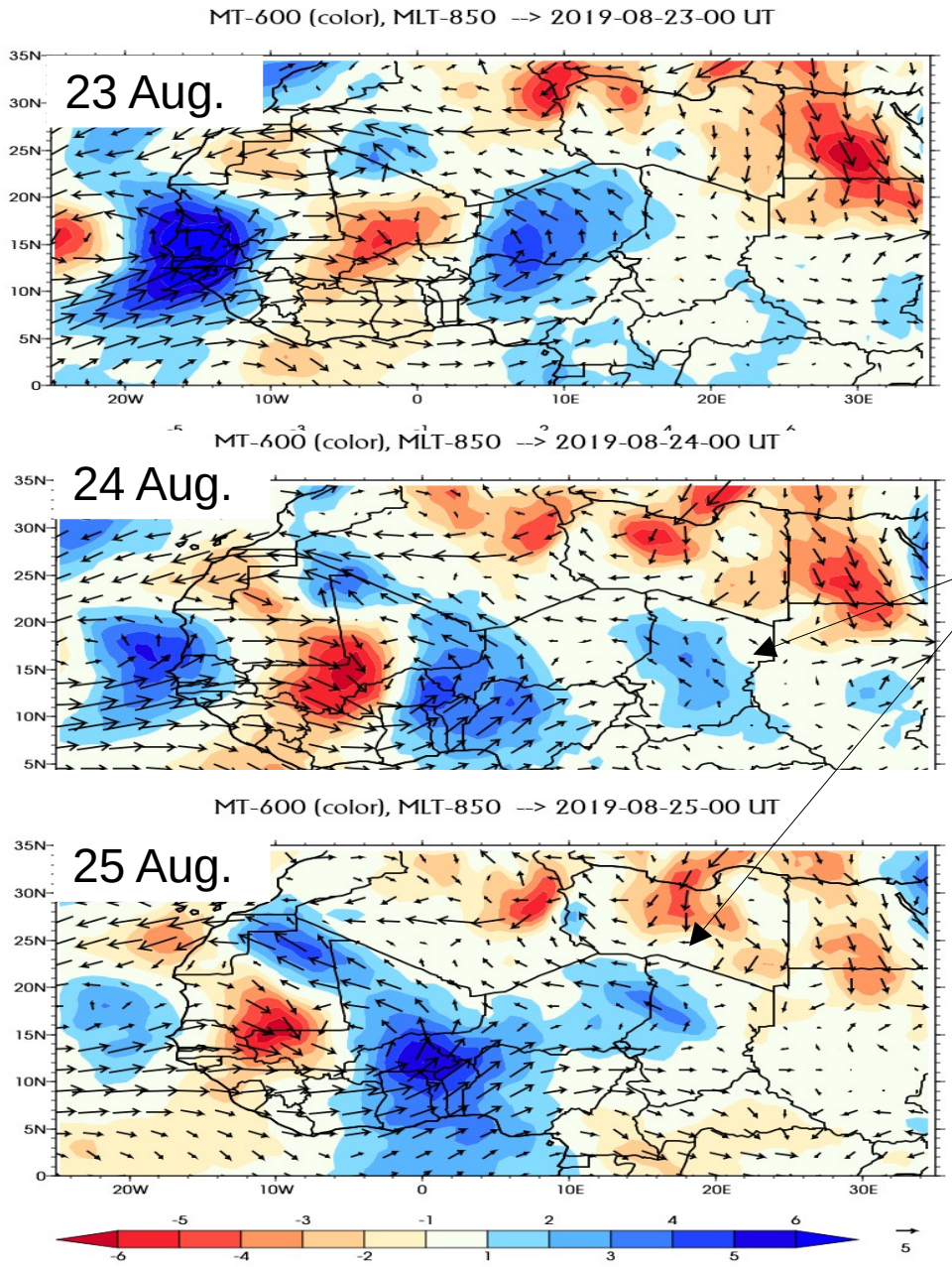

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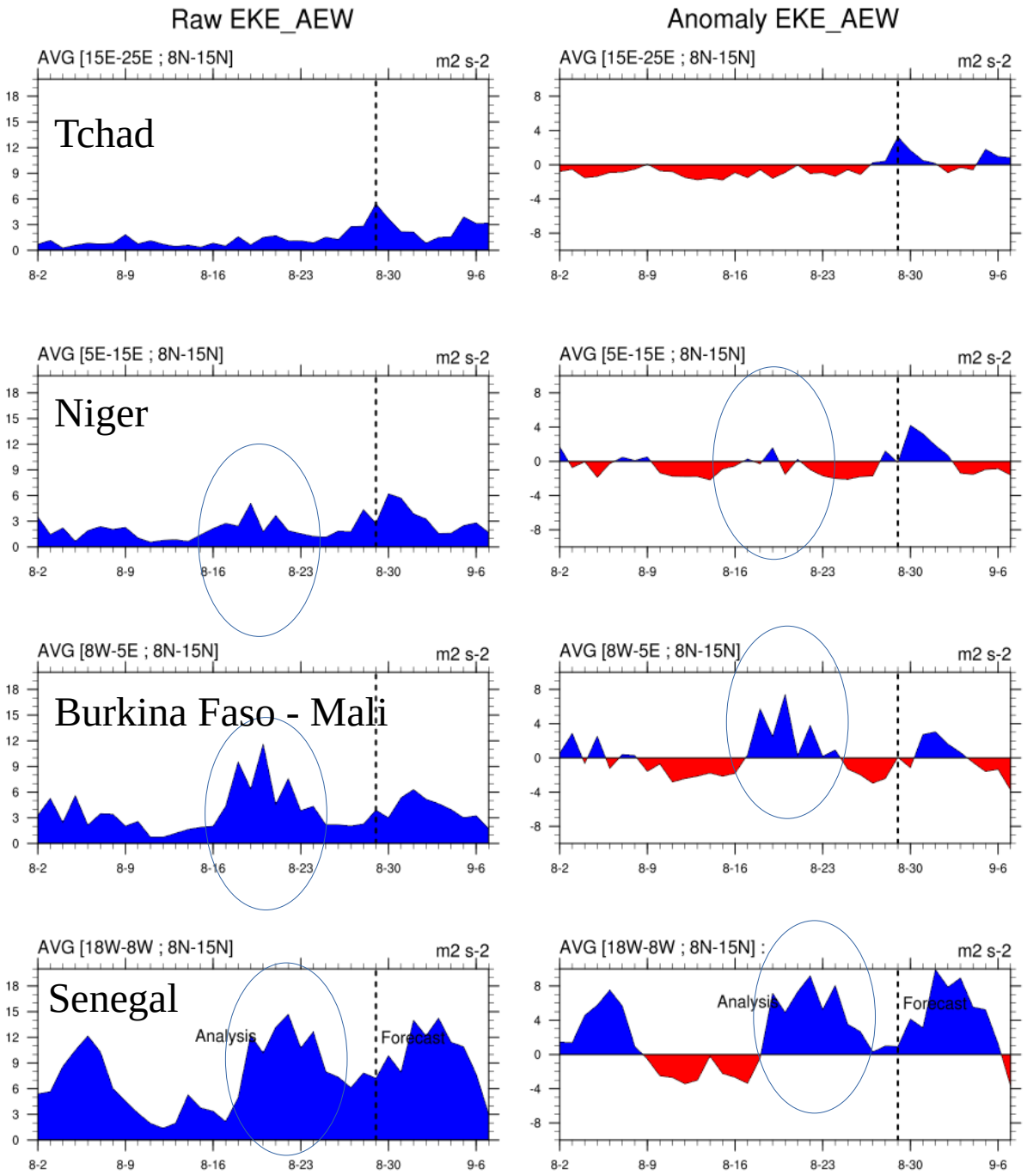
- On 23 August, are embedded :
  - The Equatorial Rossby cyclonic gyre
  - 2 AEWs
- 3rd AEW is growing up on 24 August

  ⇒ Within the cyclonic gyre, 3 AEWs are developing and generate precipitation

Index of AEW Activity



- We define an index for AEW activity based on wind anomaly variance (2-10 day filtered Eddy kinetic energy)
- The greater EKE, the more numerous or vigourous AEW
- The AEW index shows an increase of AEW activity form 18 to 26 August , i.e. during the cyclonic /wet phase of the equatorial Rossby wave

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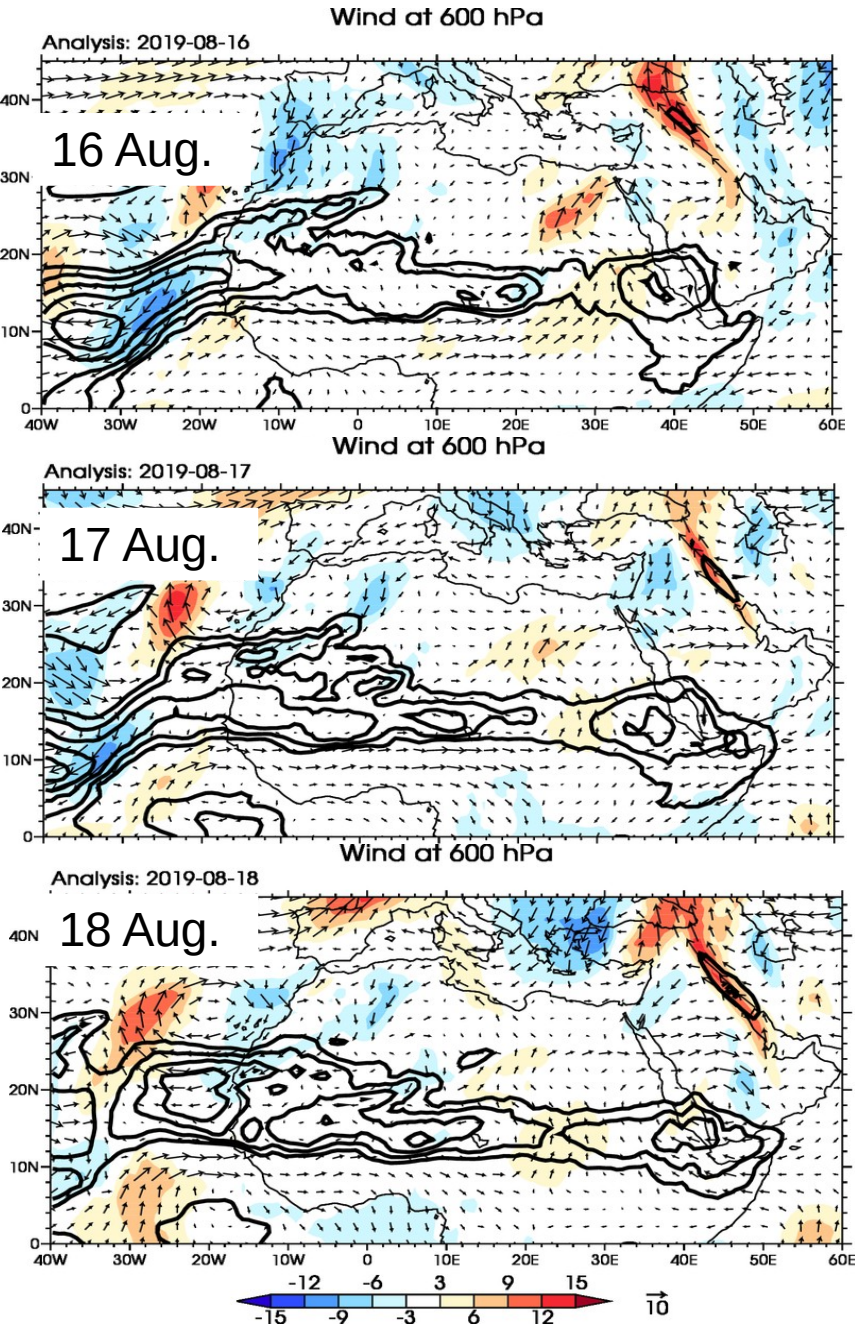
Impact on African Easterly Jet and Instability



600 hPa wind anomaly and African Easterly Jet magnitude (contour 6,9, 12,15 m/s) ECMWF Analysis

- The westerly anomaly is located just south of the African Easterly Jet ⇒ increased horizontal shear and barotropic instability
- The northerly burst of the Equatorial Rossby wave helps the African Easterly Jet to oscillate around Tchad

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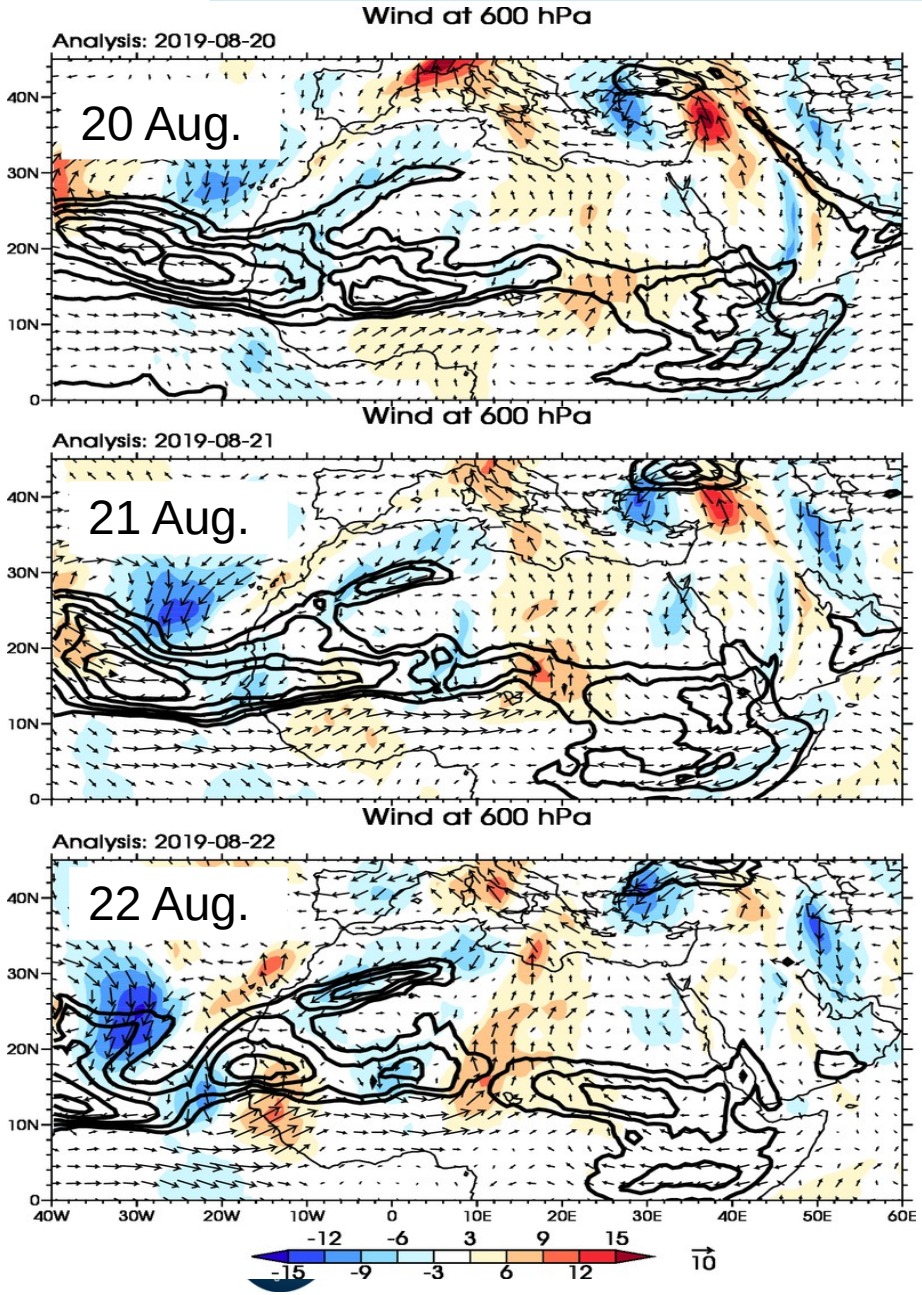
Impact on African Easterly Jet and Instability



600 hPa wind anomaly and African Easterly Jet magnitude (contour 6,9, 12,15 m/s) ECMWF Analysis

- The arrival of the anticyclonic gyre breaks the AEJ into two parts with a second core more to the east and more to the south
- And a strong core to the west

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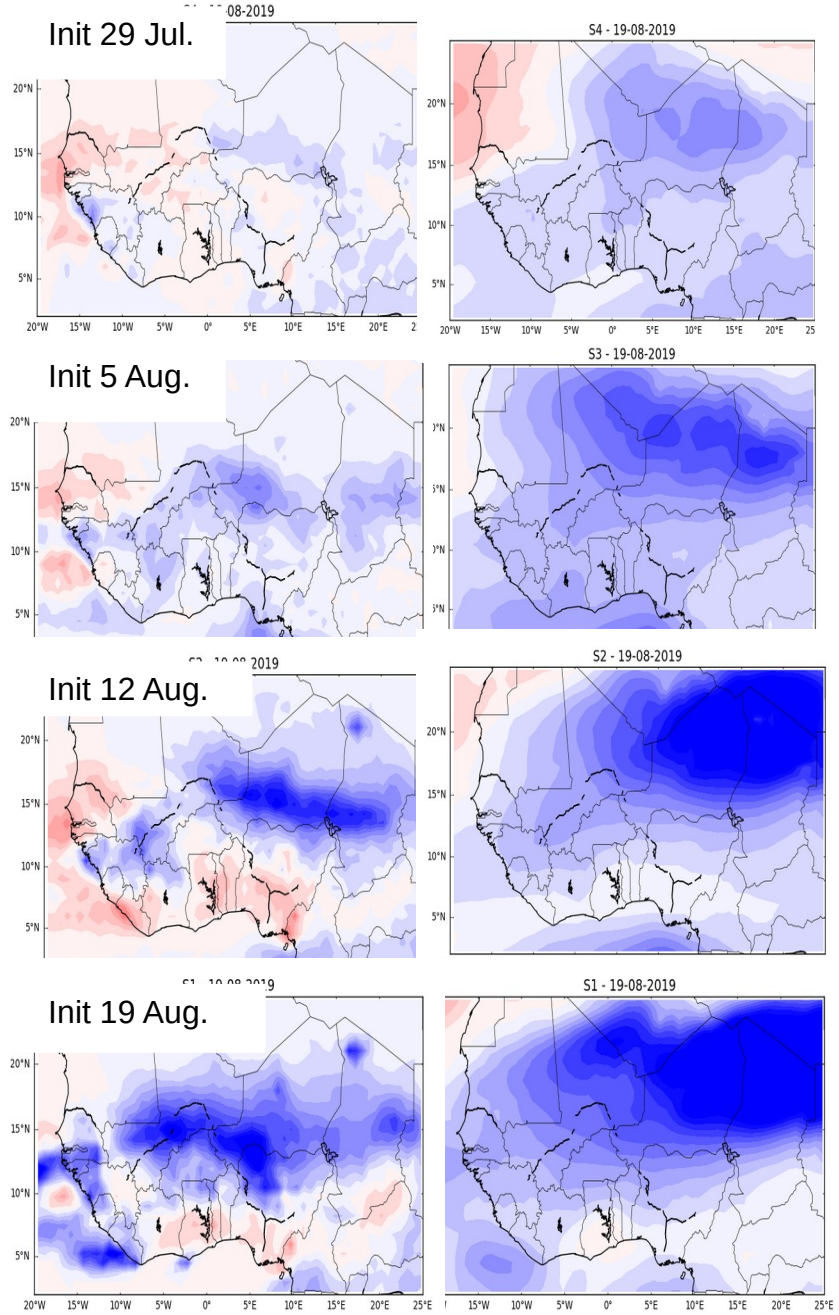
[08/19 - 08/26] weekly-mean Forecast from ECMWF ensemble prediction system at for 4 different initialisations

Forecast 4 weeks in advance within MISVA weekly briefings

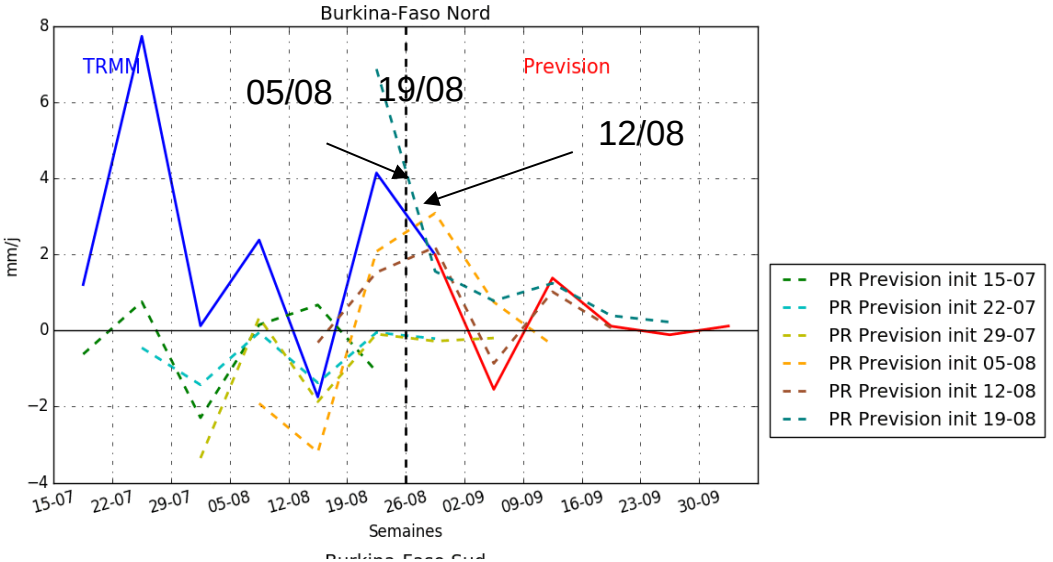
Rainfall anomaly (mm/d) PW anomaly (mm)



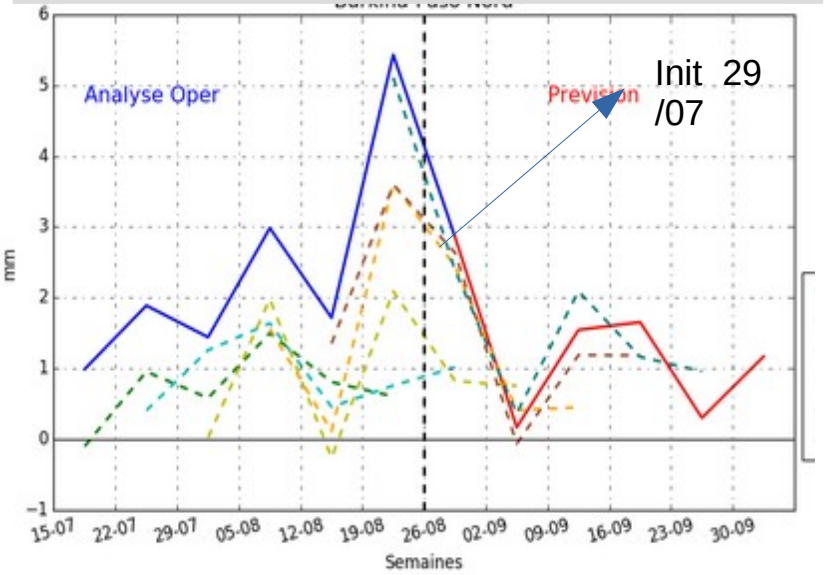
- The PW moist anomaly is seen in the ECMWF forecast model 4 weeks in advance (left)
- The precipitation anomaly really shows a signal 2 weeks in advance.

An example of event forecast 4 weeks in advance within MISVA briefing

Weekly anomaly of precipitation over Burkina Faso from 19 to 26 August : TMPA (blue), and forecast with different initialization dates (dash) for ECMWF forecast



Weekly anomaly of PW over Burkina Faso from 19 to 26 August : TMPA (blue), and forecast with different initialization dates (dash) for ECMWF forecast



- The peak of precipitation can be forecast with the run initialized on August 5 (left) while with PW the initialization of July 29 already shows a moist signal (right).
- It raises significant perspective for the predicatability of these events.

Conclusions

- West African rainfall variability is driven by African Easterly waves (AEW) at synoptic scale : True
- But there is subseasonal variability of rainfall with large impacts
- Large scale drivers such as the MJO and equatorial Rossby waves modulate the AEW activity **at subseasonal scale** and generate subseasonal variability

  ⇒ AEW subseasonal activity is a pathway between the weather and the subseasonal scale

- **This specific case study :**
  - Short after a 2-week relatively dry period over the Sahel :
  - an Equatorial Rossby wave well marked on precipitable water, vorticy and wind modulates the synoptic features of the Sahel (African Easterly Jet, Precipitable Water, vorticity, Instability)
  - Enhances AEW activity and leads to increased rainfall for a period of 2 weeks.
  - **Bonus** : such equatorial Rossby wave have a good predictability and are well captured by ensemble extended range forecast

Thank You

Un exemple sur la phase très humide 19 août- 1er sept. 2019