Introduction to the Use of NCEP GEFS and CFSv2 for sub-seasonal forecasting

First WMO RCC-Washington Training Workshop
Washington DC, USA,
30 September 2019 – 4 October 2019

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NOAA/CPC/International Desks

1. NCEP Ensemble Models

- GEFS - Global Ensemble Forecast System
  - A weather forecast model made up of 21 separate forecasts, or ensemble members.
- CFSv2 - Climate Forecast System (version 2)
  - A coupled model - representing the global interaction between Earth's oceans, land, and atmosphere.

2. Terminologies

- Ensemble Mean – Average of the ensemble member forecasts
  - Average of 20 members for GEFS
  - Average of 32 members for CFSv2
- Raw Forecasts - no bias correction/calibration
- Model Climatology – Average of model reforecasts over the reference hindcast period (1999 – 2018)

2. Terminologies (cont.)

- Raw forecast anomalies are computed by removing model climatology from the ensemble mean forecast:

GEFS raw Forecast Anomaly = GEFS Ens. Mean – GEFS Model Climo

CFSv2 raw Forecast Anomaly = CFsv2 Ens. Mean – CFsv2 Model Climo

3. Post Processing

- The skill of NWP models decreases with forecast lead time.
  - Larger model errors for forecasts beyond week-2

➢ A need for forecast correction methods:

  - From simple linear bias removal (bi = fi –oi) based on recent forecasts, to
  - Complicated algorisms (e.g NCEP combination of decaying average (over recent forecasts), and knowledge on reforecast period errors).

3. Post Processing (cont.)

- Linear Ensemble Regression Calibration

$$y = mx + b$$

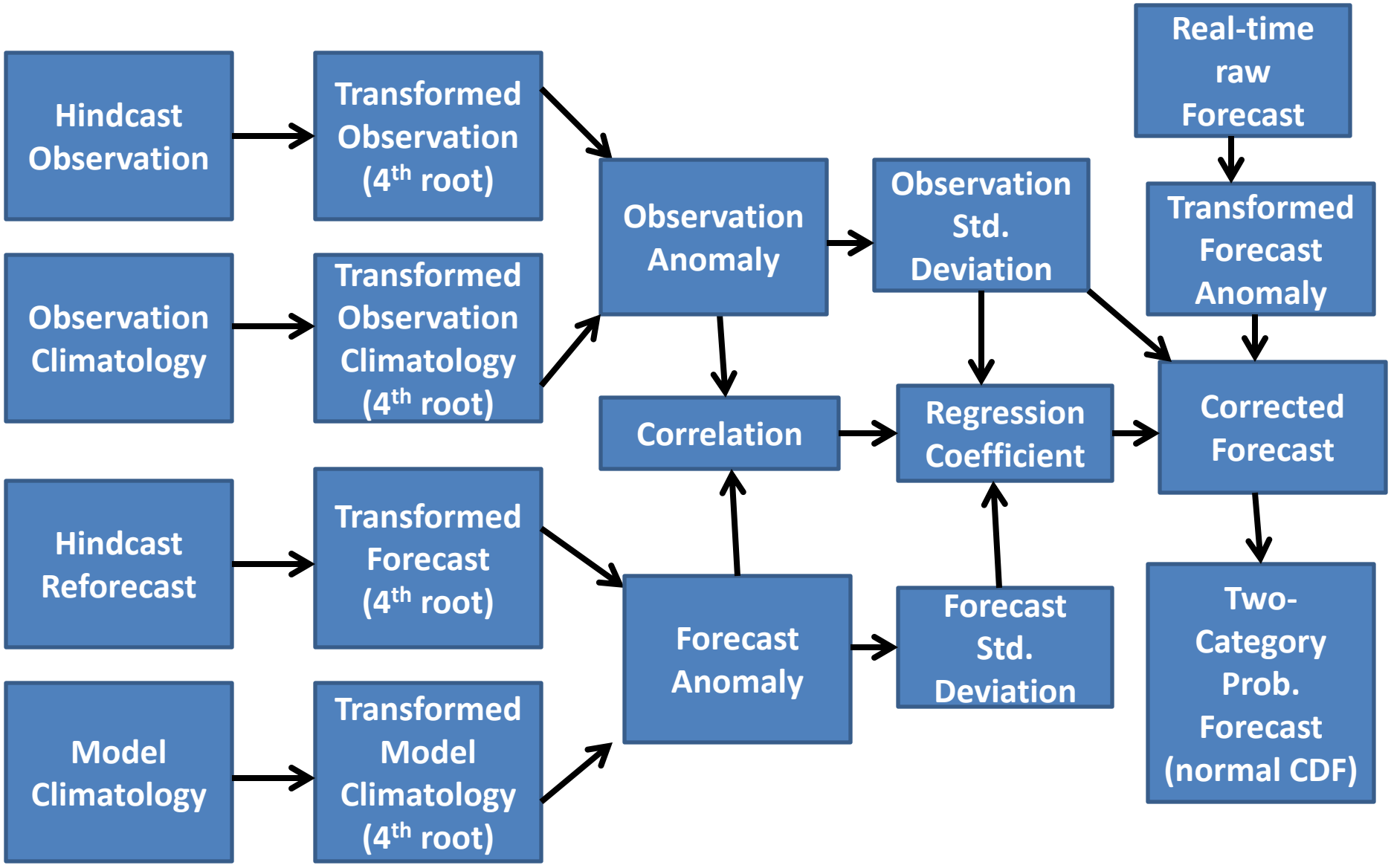
- Where y is forecast anomaly, and x is observation anomaly

- Build relationship between observation and reforecast data in the hindcast period (1999 – 2018)
  - calculate the regression coefficient
  - Use the regression coefficient to correct your current raw forecast

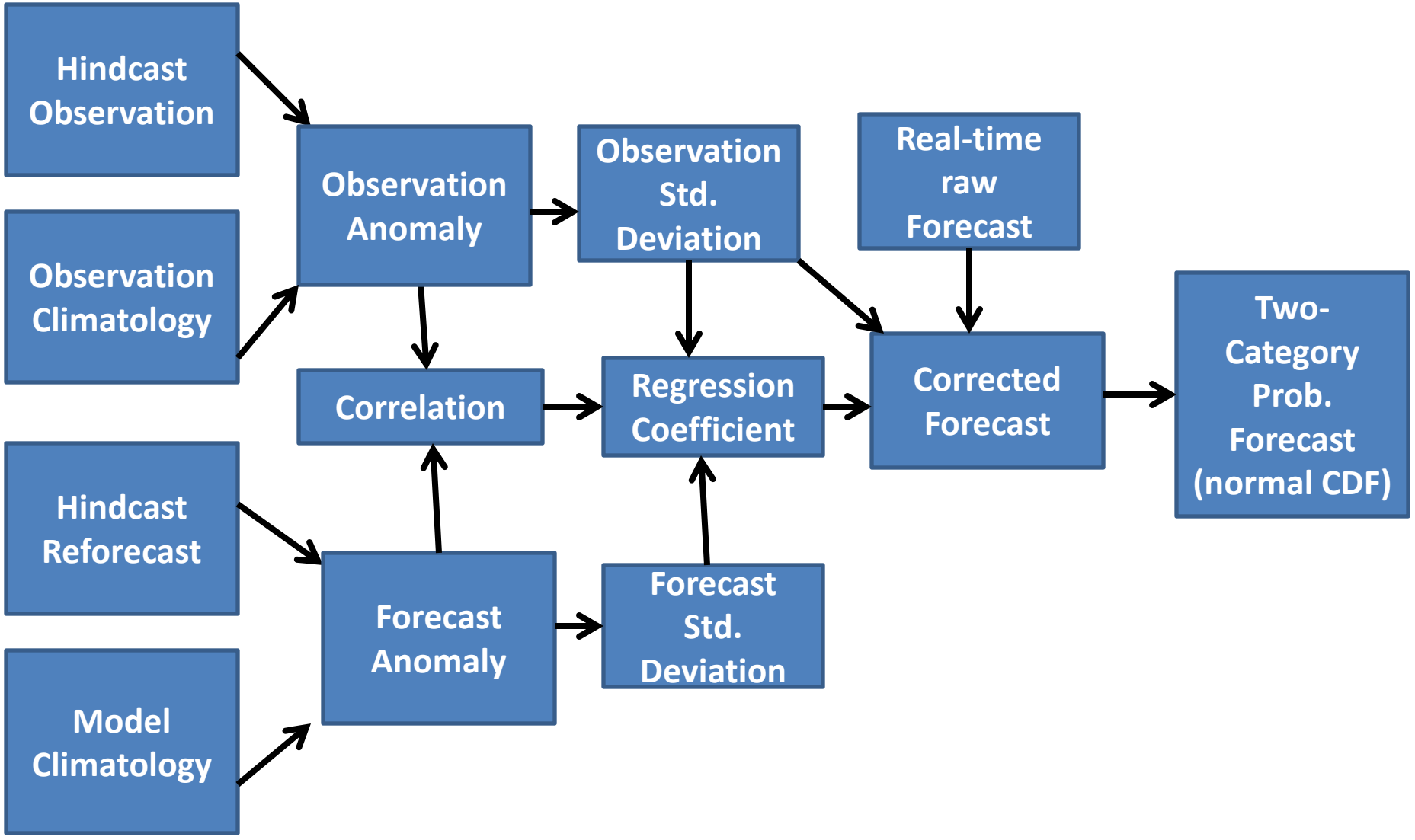
4. Data Used to Generate the Calibration Statistics

- Observation Data:
  - 20 years (1999-2018) CPC Blended rainfall for week-1/2 target periods
  - 20 years (1999-2018) CPC Gridded 2m Temperature for the week-1/2 target periods
- Reforecast Data:
  - 20 years (1999-2018) GEFS and CFSv2 Reforecast of rainfall for week-1/2 target periods
  - 20 years (1999-2018) GEFS & CFSv2 Reforecast of 2m temperature for week-1/2 target periods

6. Ensemble Regression Calibration Process - Rainfall



7. Ensemble Regression Calibration Process – 2m Temperature



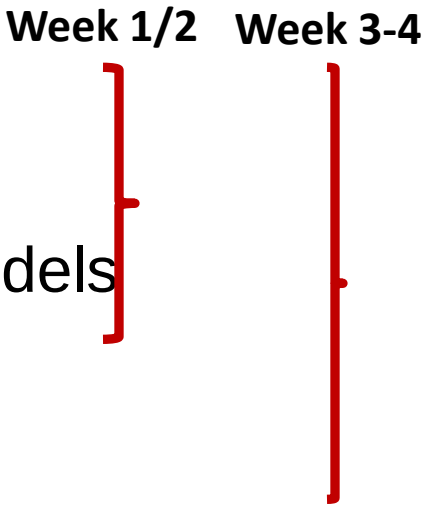
Creating Diagnostics for Subseasonal Forecast
Week-1/2 Outlook Tools

1. Tools for Operational Sub-Seasonal Forecasting

a) Madden Julian Oscillation

b) Numerical Weather and climate models

c) El Nino Southern Oscillation



2. Week-1 and Week-2 Forecasts

a. State of the MJO

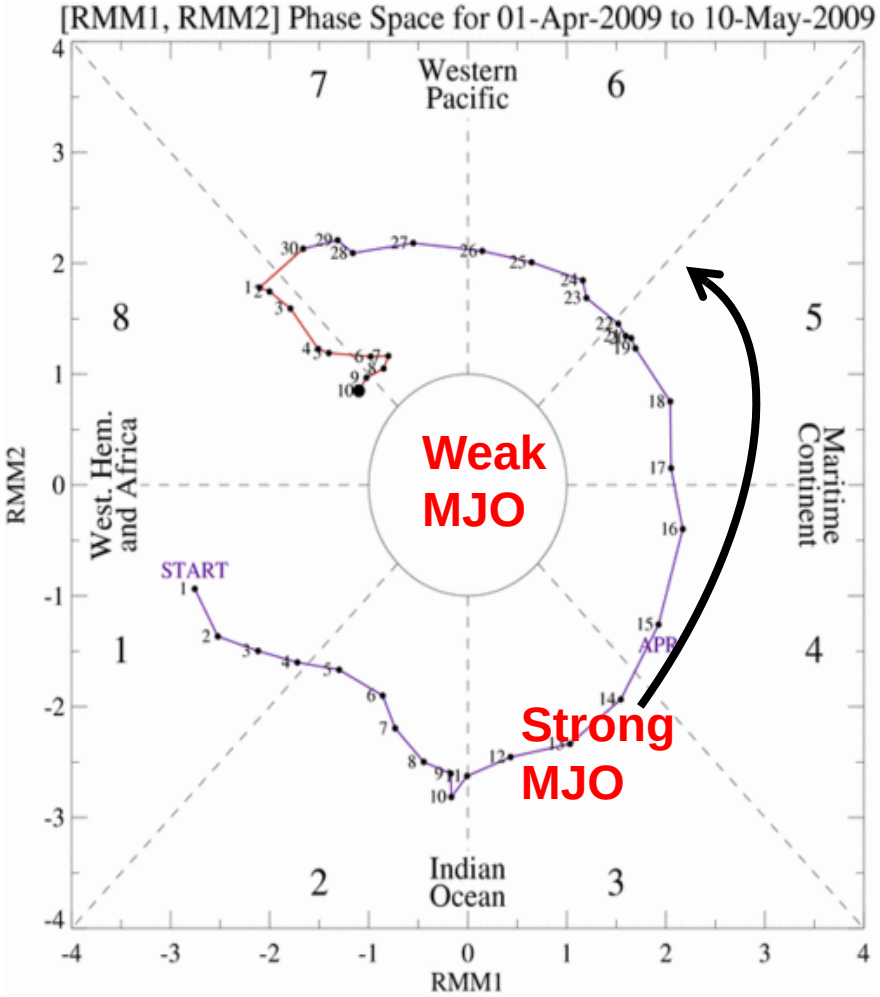
- Much emphasis is given to the state of the MJO and its projected phases on the Wheeler-Hendon diagram at the moment of the forecasts.
- Refer to the MJO monitoring and prediction tools to determine if an active MJO is present

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml#

2. Week-1 and Week-2 Forecasts

b. State of the MJO (The Wheeler-Hendon Diagram)

Each dot/number represents a single day and location of the MJO enhanced rainfall.



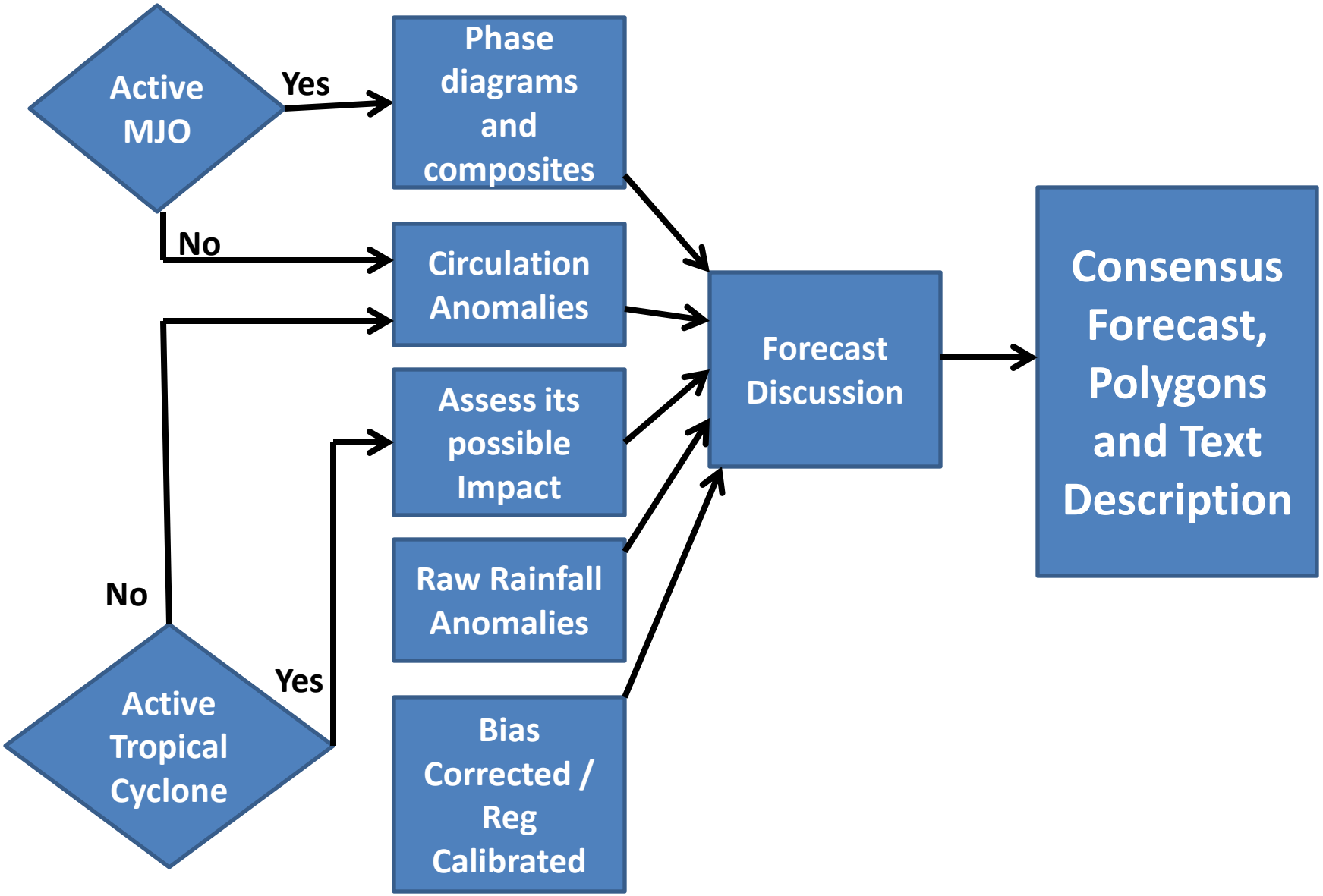
MJO exists when there is counterclockwise movement on diagram

2. Week-1 and Week-2 Forecasts

c. NWP Guidance

- The MJO is present, but projected to weaken considerably during the week-1 and/or week-2 outlook period.
  - NWP outputs are the primary tools for guiding the week-1 and week-2 forecasts.
  - NWP output tools include quantitative precipitation forecasts, ensemble bias corrected precipitation forecasts from the GFS, the GEFS, CFS, and ECMWF.
  - Examine the predicted circulation features associated with the predicted rainfall anomalies.
  - More weight will be given to the NWP precipitation outlook tools that are more consistent with the predicted rainfall anomalies.
  - Examine the weekly SST patterns and tendency, as well as tropical cyclone activities

3. Week-1/2 Forecast Process



4. Example, Week-1 Outlook for Africa

- Week 1 Forecast, valid **25 Sep – 01 Oct, 2019**
- Tools
  - MJO
  - NWP Guidance
  - Tropical Cyclone?

Current State of the Climate

- Active MJO?
- Active tropical cyclone/Hurricane/typhoon activity?
- Significant SST and circulation anomaly patterns?

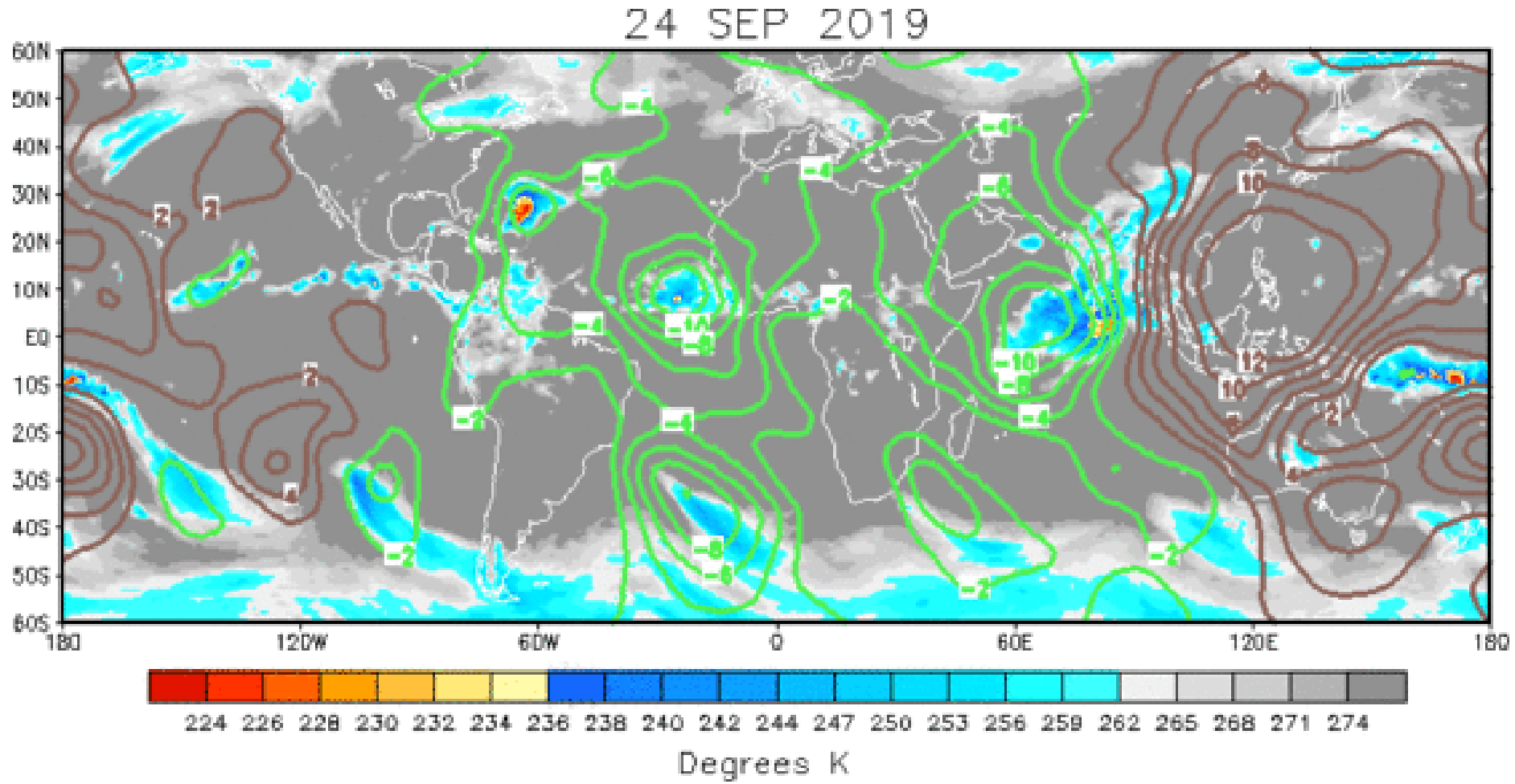
Current State of the Climate

- Active MJO?

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml#discussion

200 hPa Velocity Potential Anomaly

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/ir_anim_monthly.shtml

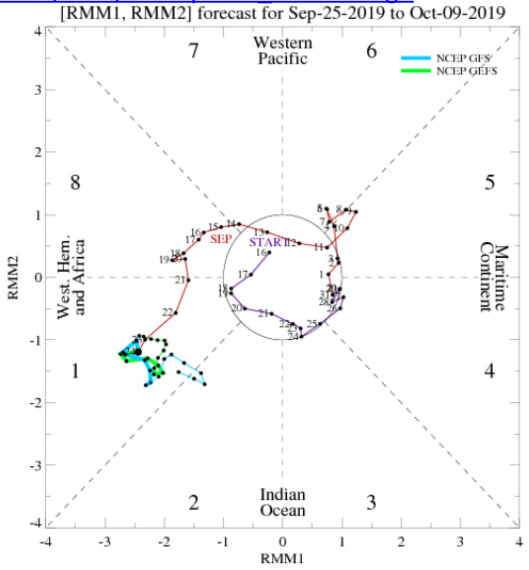


•Green shade indicates areas of upper level divergence and convection or precipitation at surface. Brown contours indicate areas of upper level convergence or subsidence and suppressed precipitation at surface.

Wheeler-Hendon Index - Forecasts

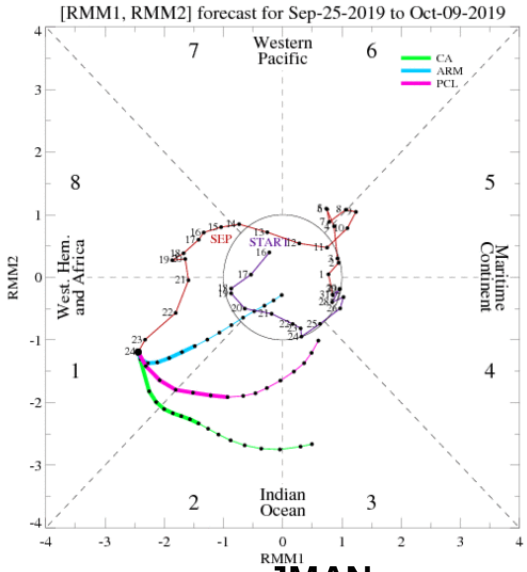
GFS/GEFS

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/combphase_noCFSfull.gif



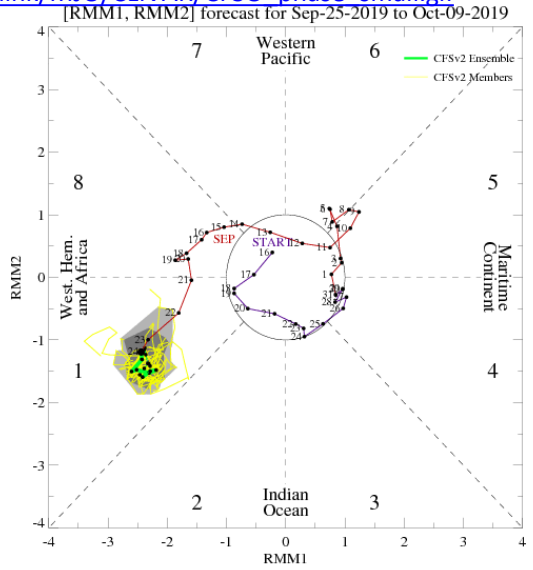
Statistical

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/statphase_full.gif



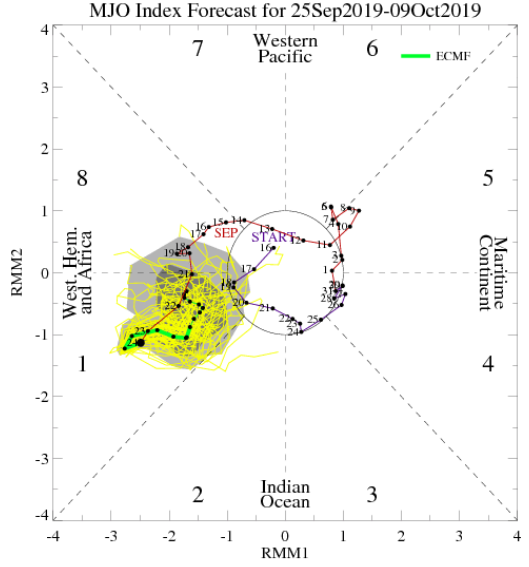
CFSv2

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/CFSO_phase_small.gif



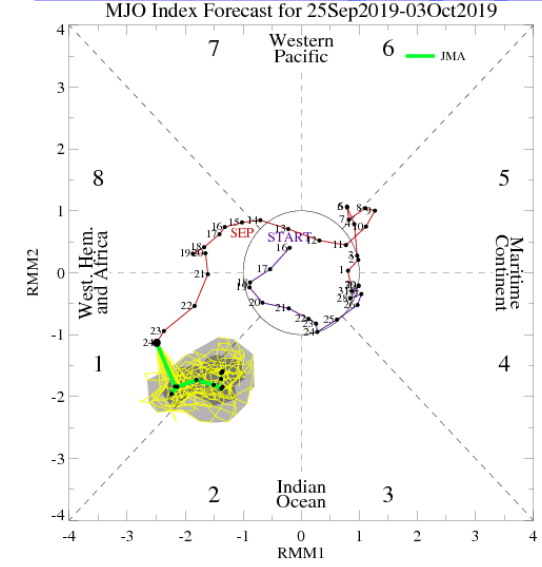
ECMWF

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/ECMF_phase_MANOM_51m_small.gif



JMAN

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/JMAN_phase_51m_small.gif



CMET

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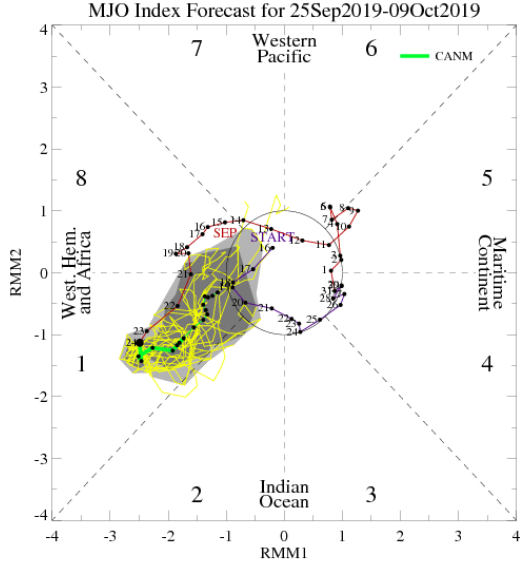
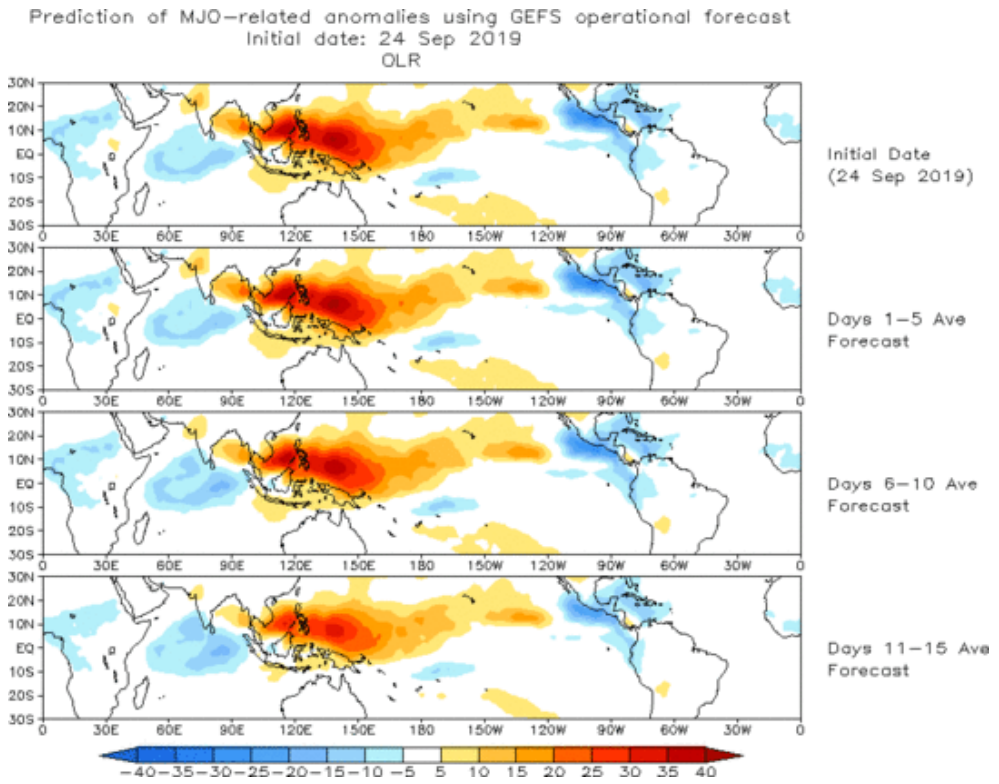


Evolution of MJO-related anomalies

Initial date: 24 September 2019

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/spatial_olrmap_full.gif



Red shade indicate areas of suppressed convection

Blue shade indicate areas of enhanced convection

1 - 5 days ave. Forecast

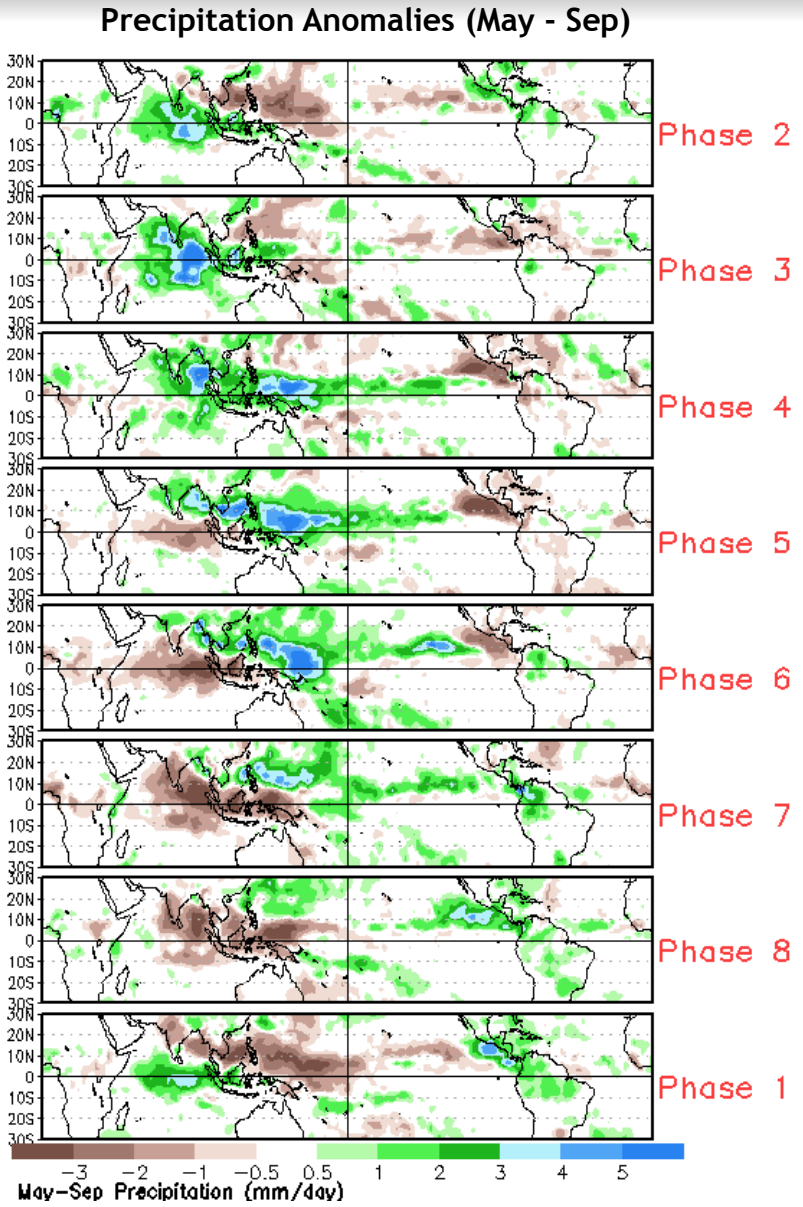
6-10 days ave. Forecast

11-15 days ave. Forecast

MJO Rainfall Composites – Global Tropics

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/plot_pcp_tvalue_8pan_maysep.gif (May - Sep Season)

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/plot_pcp_tvalue_8pan_novmar.gif (Nov - Mar Season)

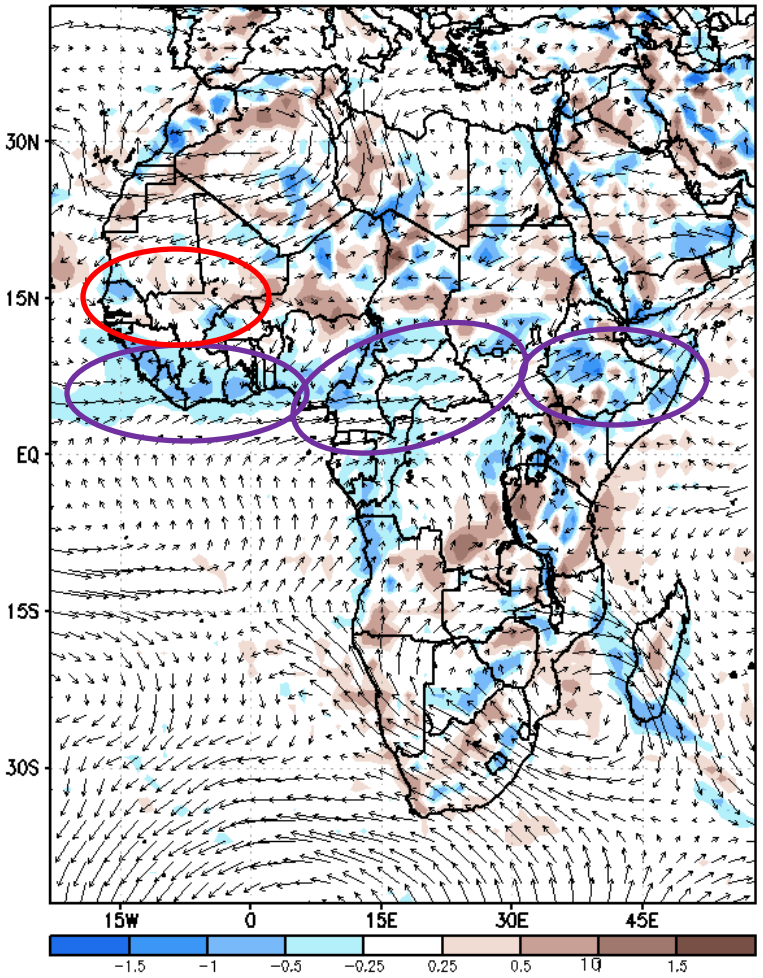


MJO Contribution?

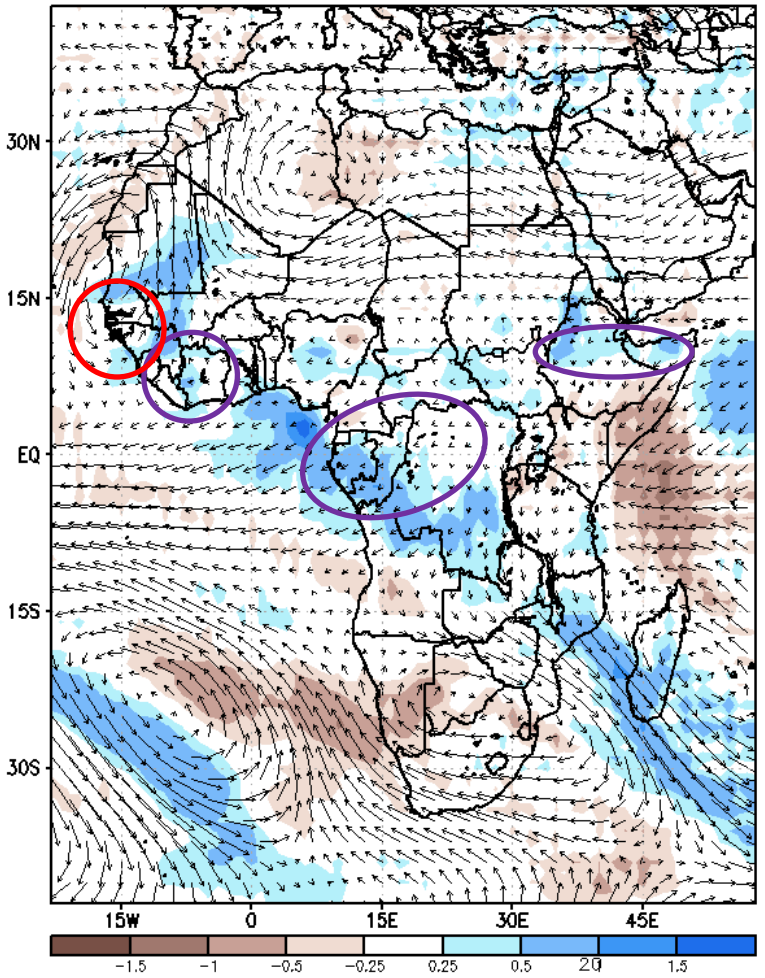
- Do the MJO predictions suggest enhanced/suppressed rainfall?
  - **Enhanced rainfall across eastern Gulf of Guinea and Central Africa**

NCEP GEFS Wind and Divergence Anomaly Forecast Week-1, Valid: 25 Sep – 01 Oct, 2019

700-hPa



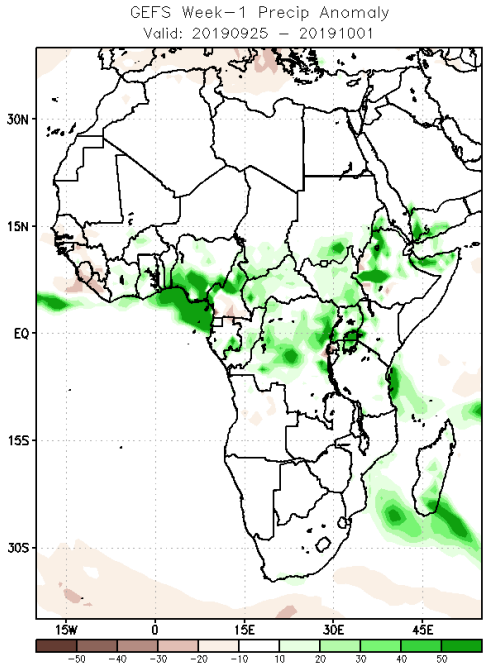
200-hPa



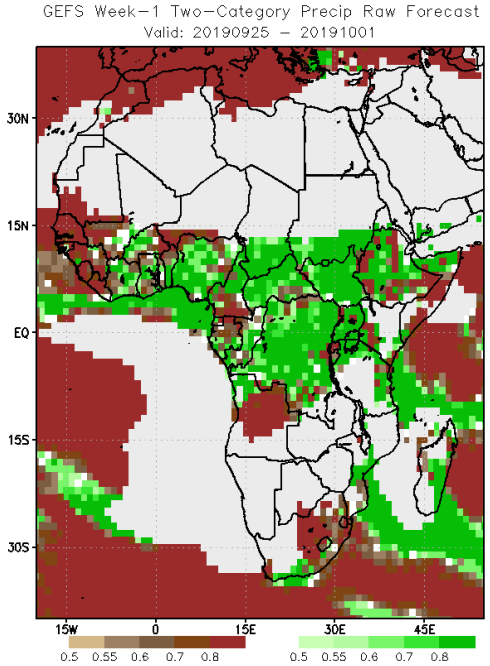
NCEP GEFS/CFSv2 Precip forecasts for Week-1, Valid: 25 Sep – 01 Oct, 2019

GEFS

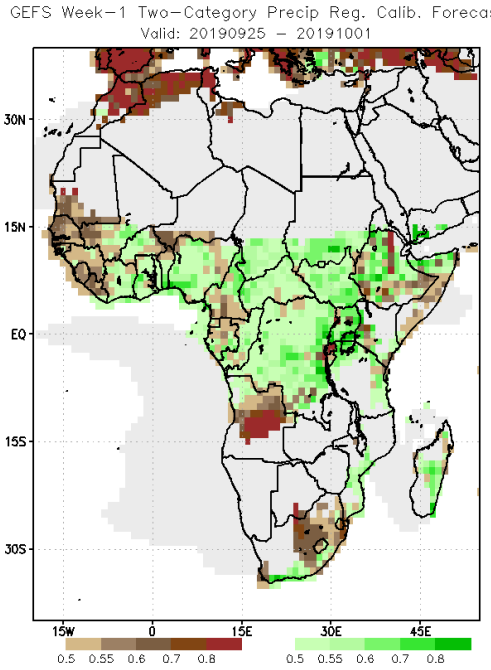
Ensemble Mean Anomaly



Two-category Probabilistic Forecast - Raw

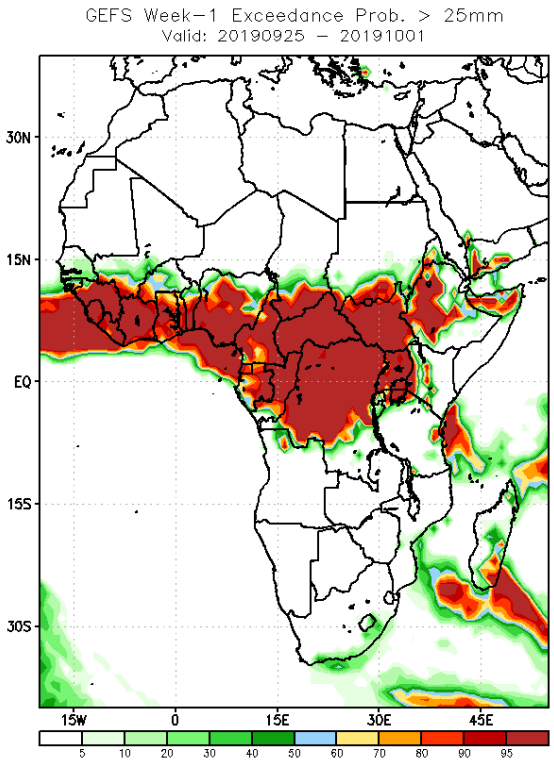


Two-category Probabilistic Forecast – Reg - Calibrated

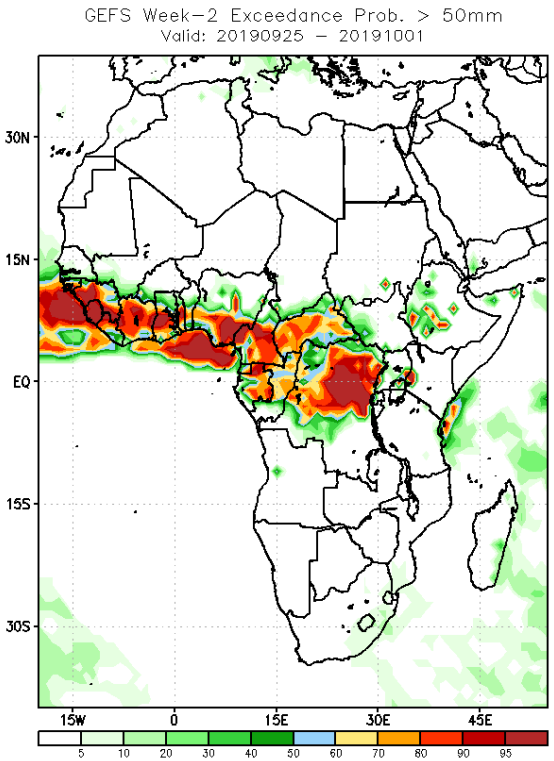


GEFS Week-2 Exceedance Probability, Valid: 25 Sep – 01 Oct, 2019

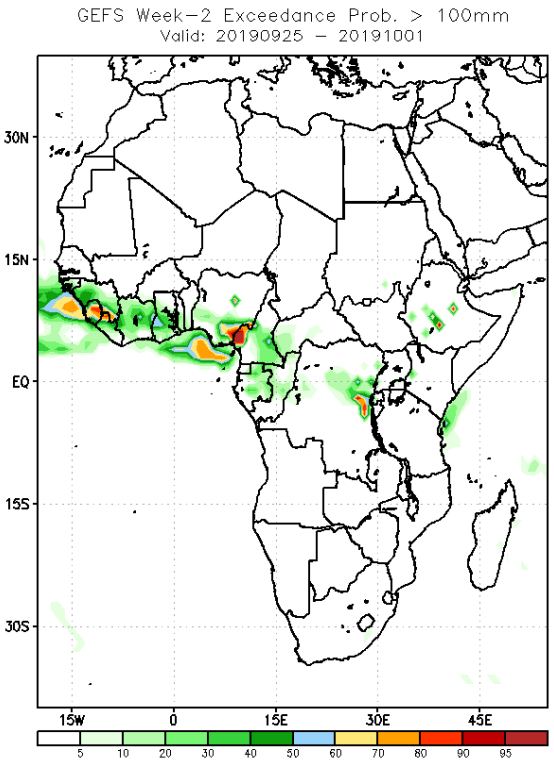
>25mm



>50mm



>100mm

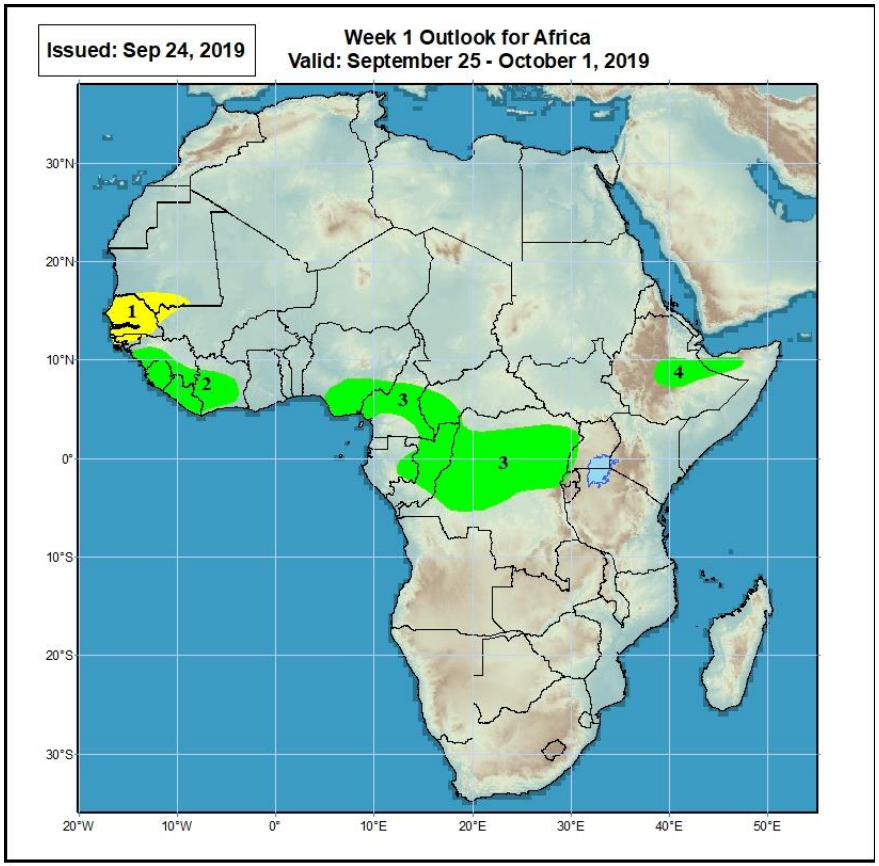


Week-1, Convergence of Evidence?

- **Wet**
  - MJO ->
  - Lower/upper-level wind/divergence anomalies ->
  - Rainfall Model Guidance ->
  - Exceedance Probability ->

- **Dry**
  - MJO ->
  - Lower/upper-level wind/divergence anomalies ->
  - Rainfall Model Guidance ->
  - Exceedance Probability ->

Week-1 Rainfall Outlook, 25 Sep – 01 Oct, 2019



1. **There is an increased chance for below-average rainfall over Senegal, Guinea-Bissau, Gambia, and southwestern Mauritania:** An area of anomalous lower-level dry northerly flow is expected to suppress rainfall in the region.
2. **There is an increase chance for above-average rainfall over Guinea, Sierra Leone, Liberia, and Cote d'Ivoire:** An area of anomalous lower-level dry northerly flow is expected to suppress rainfall in the region.
3. **There is an increased chance for above-average rainfall over southern Nigeria, Cameroon, western CAR, eastern Gabon, Congo, and DRC:** An area of anomalous upper-level divergence along with influence from the MJO is expected to enhance rainfall in the region.
4. **There is an increased chance for above-average rainfall over eastern Ethiopia and parts of northern Somalia:** An area of anomalous lower-level convergence and moist onshore flow is expected to enhance rainfall in the region.

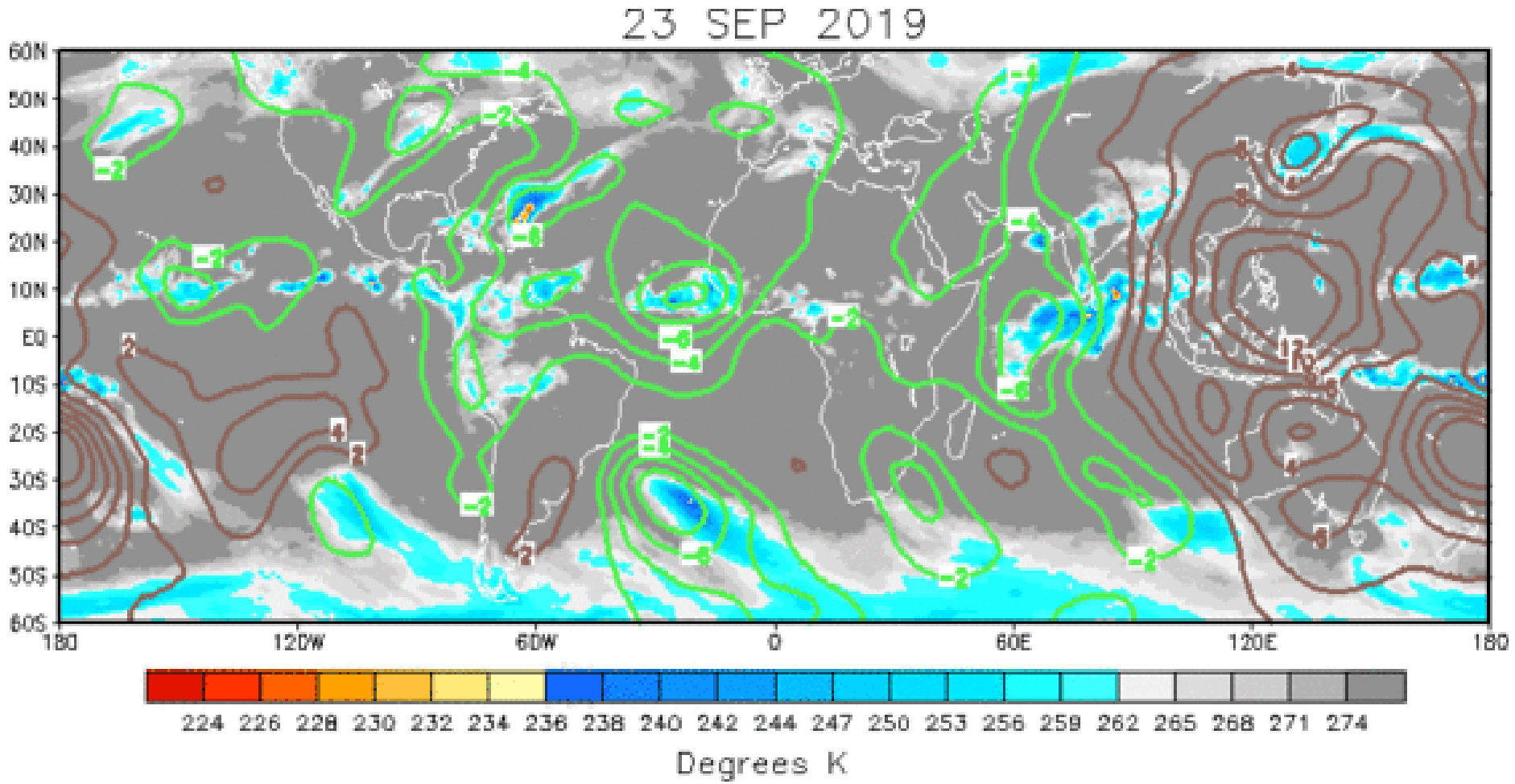
Exercise, Week-2 Rainfall Outlook

Exercise, Week-2 Outlook for Africa

- Week-2 Forecast, valid **2 – 8 October, 2019**
- Tools
  - MJO
  - NWP Guidance

200 hPa Velocity Potential Anomaly

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/ir_anim_monthly.shtml

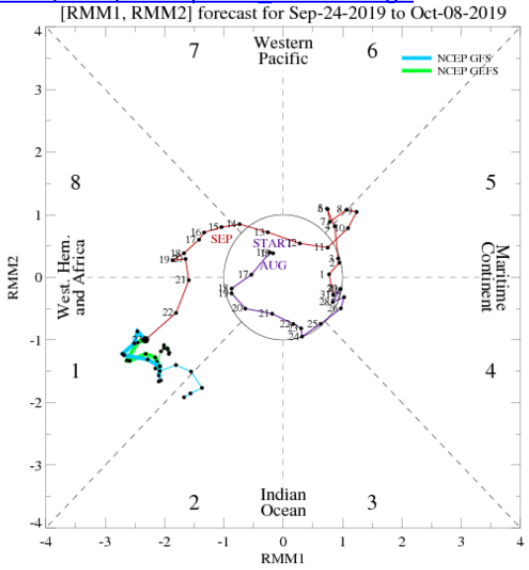


•Green shade indicates areas of upper level divergence and convection or precipitation at surface. Brown contours indicate areas of upper level convergence or subsidence and suppressed precipitation at surface.

Wheeler-Hendon Index - Forecasts

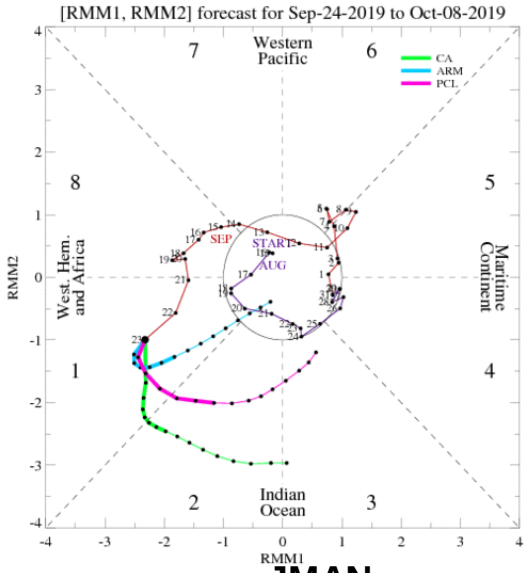
GFS/GEFS

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/combphase_noCFSfull.gif



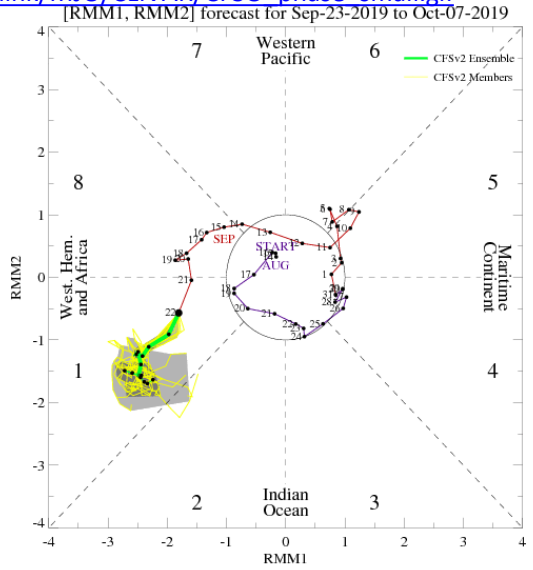
Statistical

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/statphase_full.gif



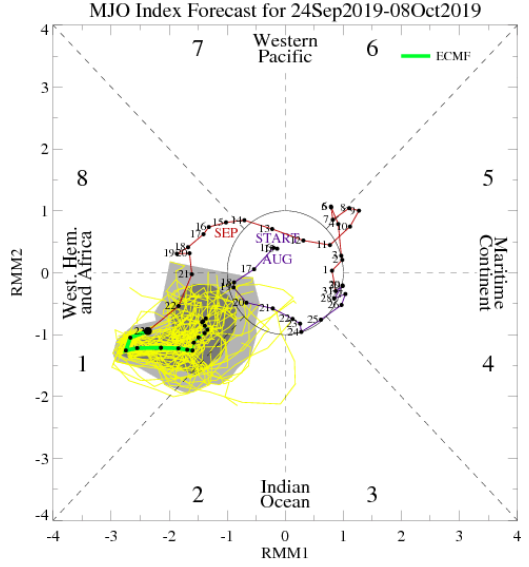
CFSv2

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/CFSO_phase_small.gif



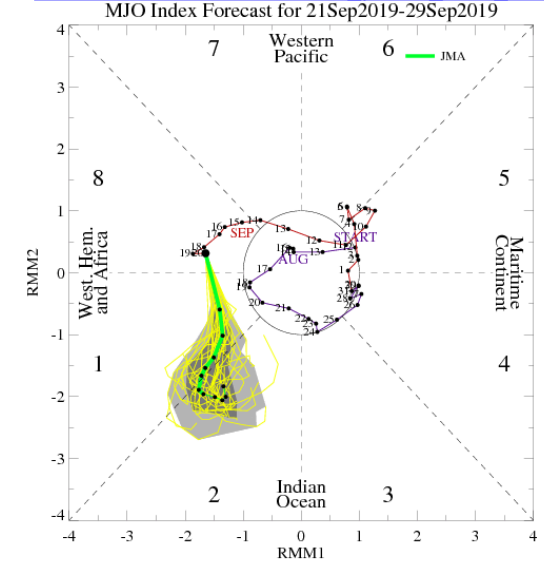
ECMWF

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/ECMF_phase_MANOM_51m_small.gif



JMAN

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/JMAN_phase_51m_small.gif



CMET

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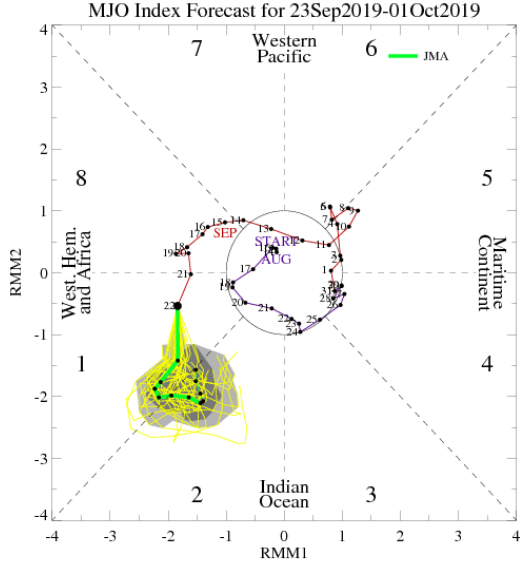
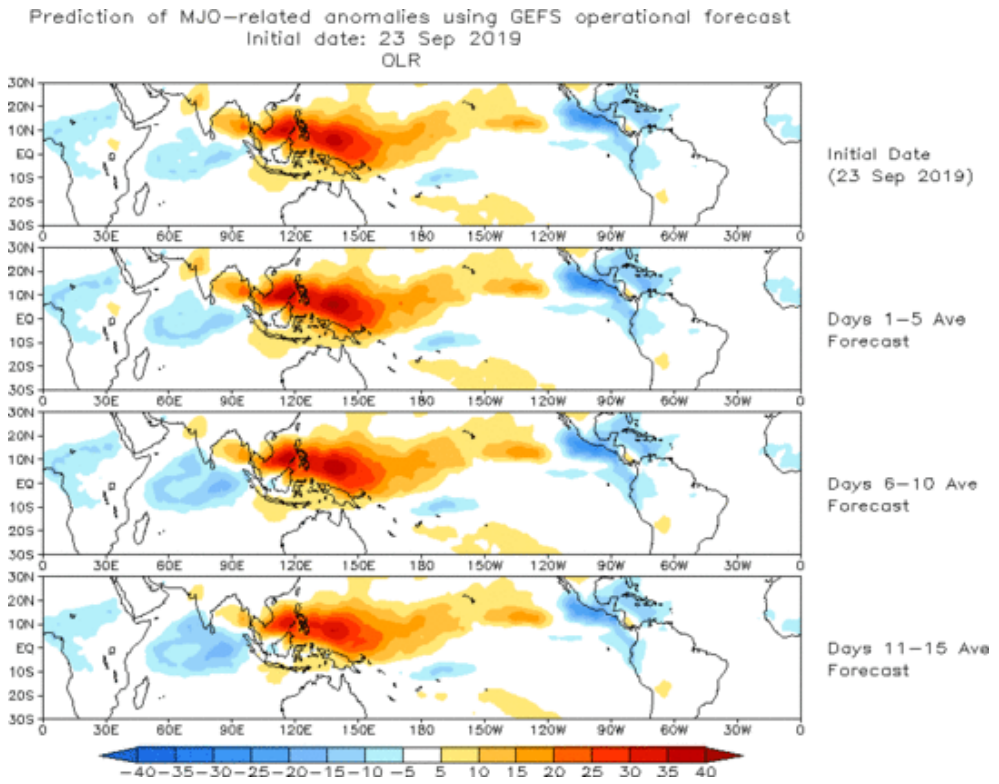


Evolution of MJO-related anomalies

Initial date: 23 September 2019

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/spatial_olrmap_full.gif



Red shade indicate areas of suppressed convection

Blue shade indicate areas of enhanced convection

1 - 5 days ave. Forecast

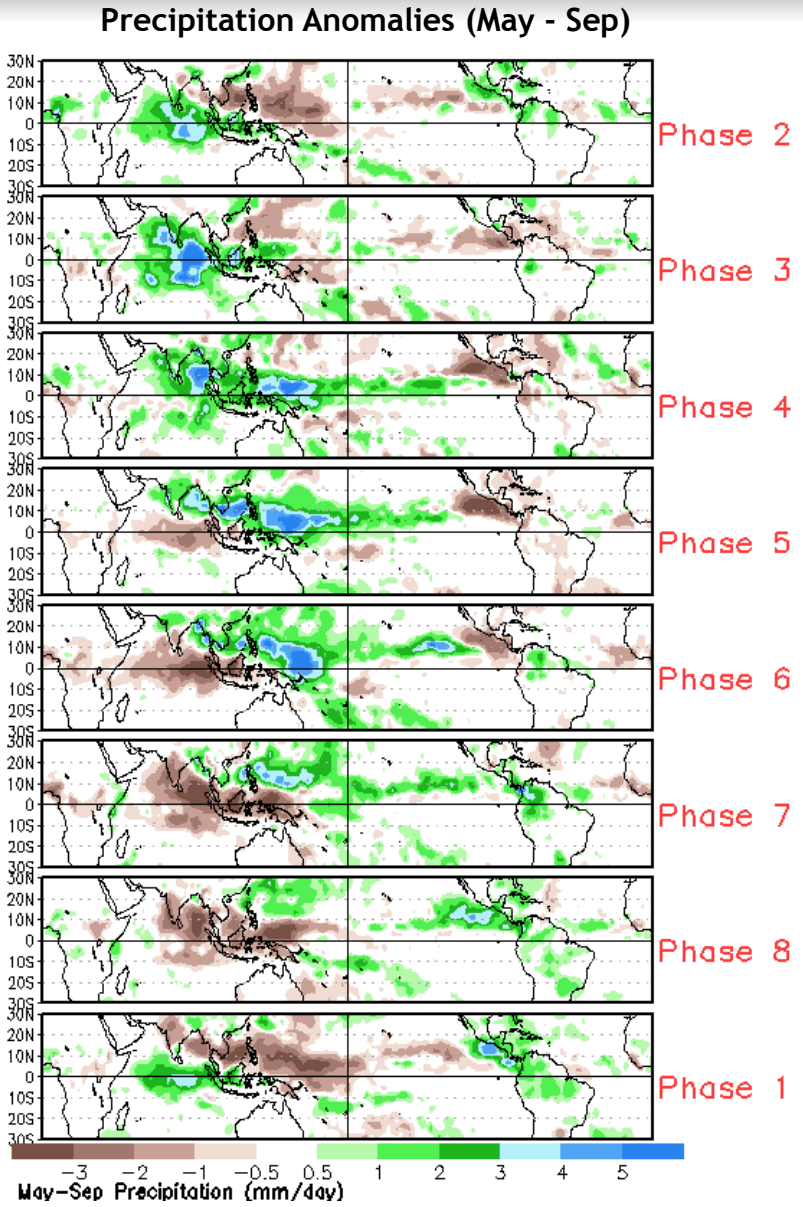
6-10 days ave. Forecast

11-15 days ave. Forecast

MJO Rainfall Composites – Global Tropics

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/plot_pcp_tvalue_8pan_maysep.gif (May - Sep Season)

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/plot_pcp_tvalue_8pan_novmar.gif (Nov - Mar Season)

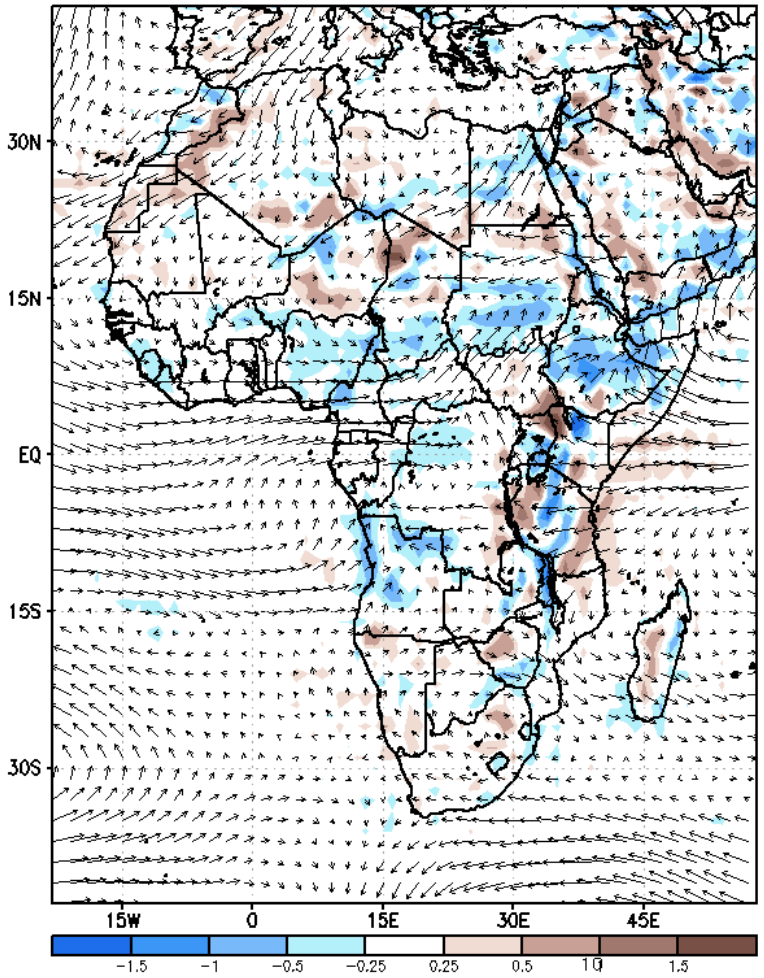


Week2, MJO Contribution?

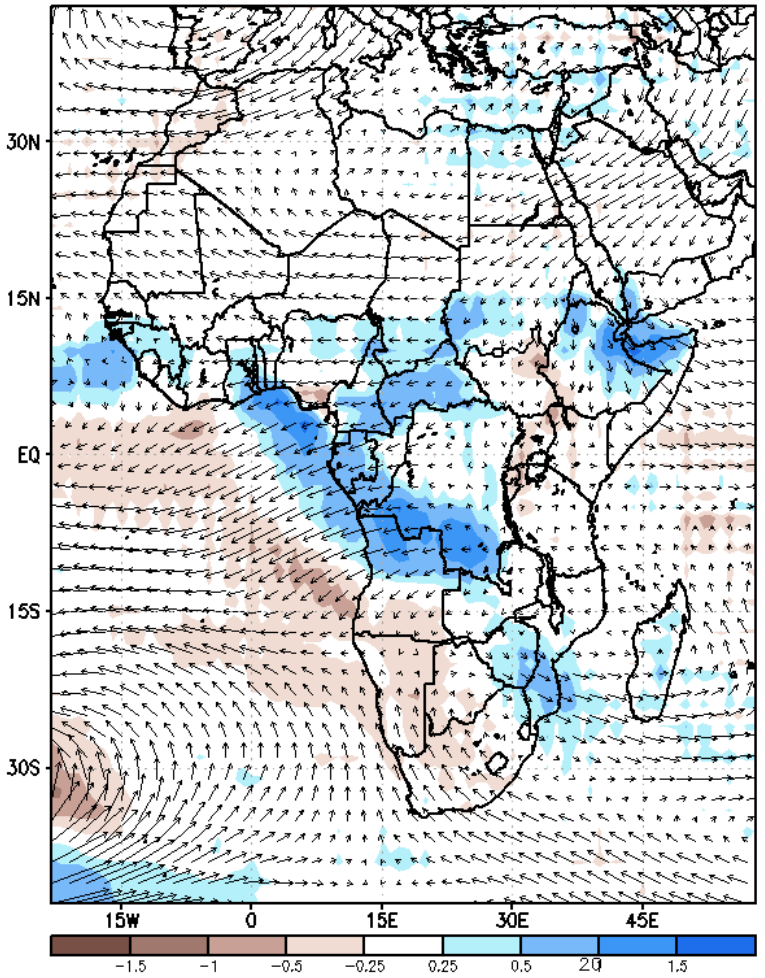
- Do the MJO predictions suggest enhanced/suppressed rainfall?

NCEP GEFS Wind and Divergence Anomaly Forecast Week-2, Valid: 2 - 8 October, 2019

700-hPa



200-hPa



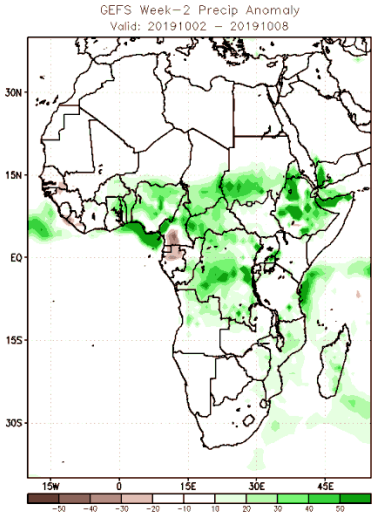
NCEP GEFS/CFSv2 Precip forecasts for Week-2, Valid: 2 - 8 October, 2019

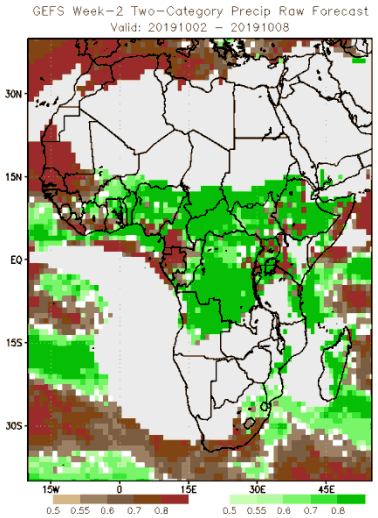
Ensemble Mean Anomaly

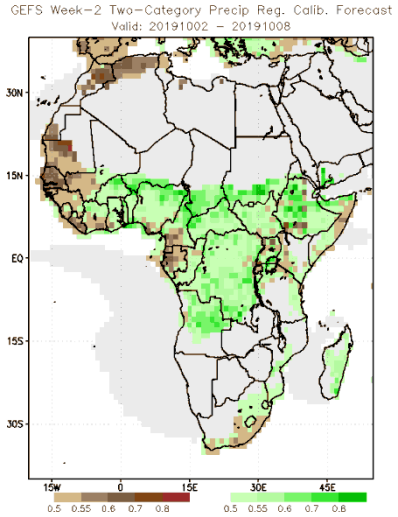
Two-category Probabilistic Forecast - Raw

Two-category Probabilistic Forecast – Reg - Calibrated

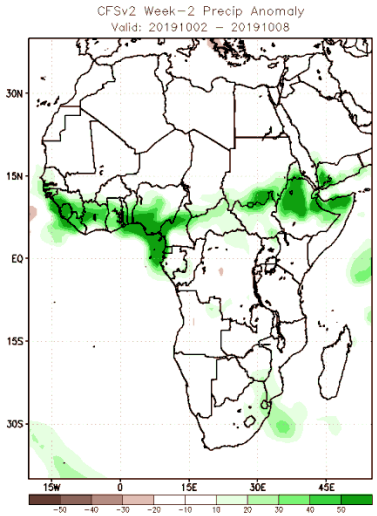
GEFS

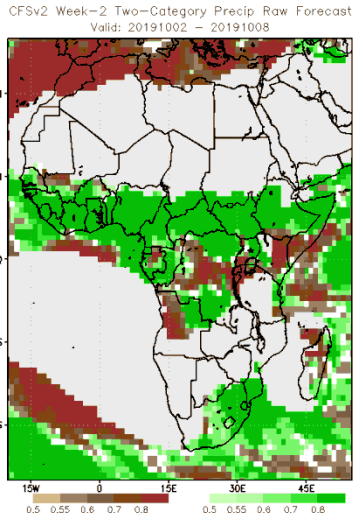


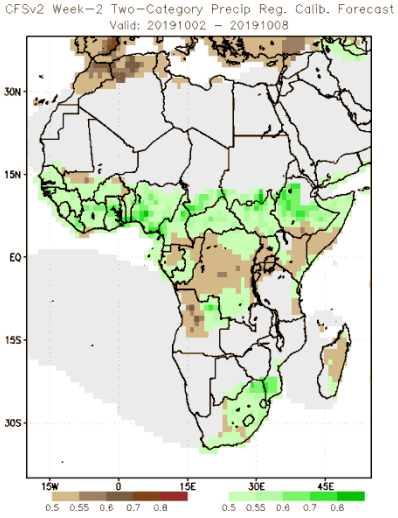




CFSv2

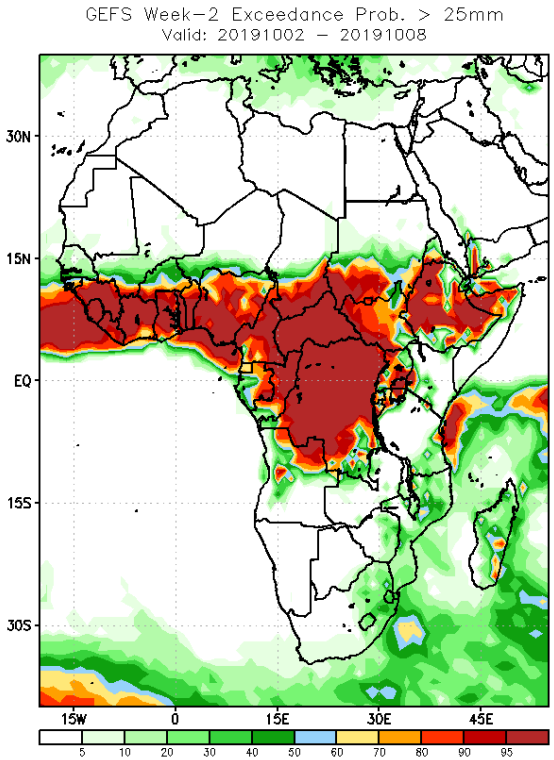






GEFS Week-2 Exceedance Probability, Valid: 2 - 8 October, 2019

>25mm



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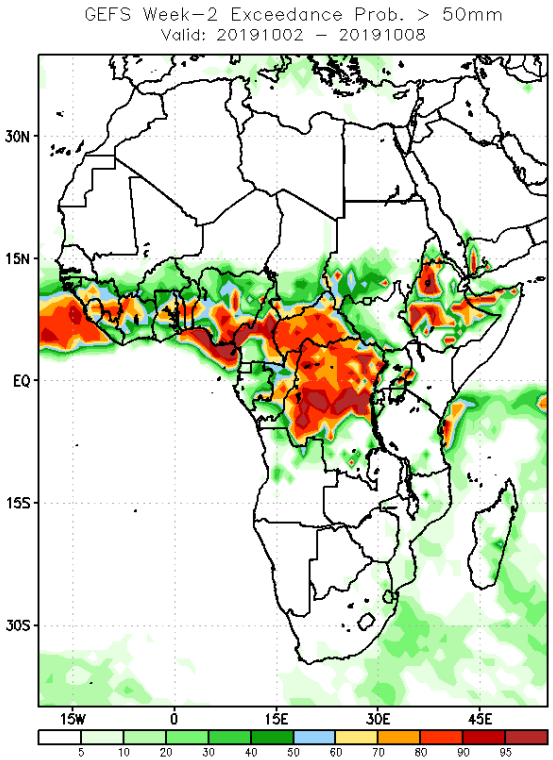

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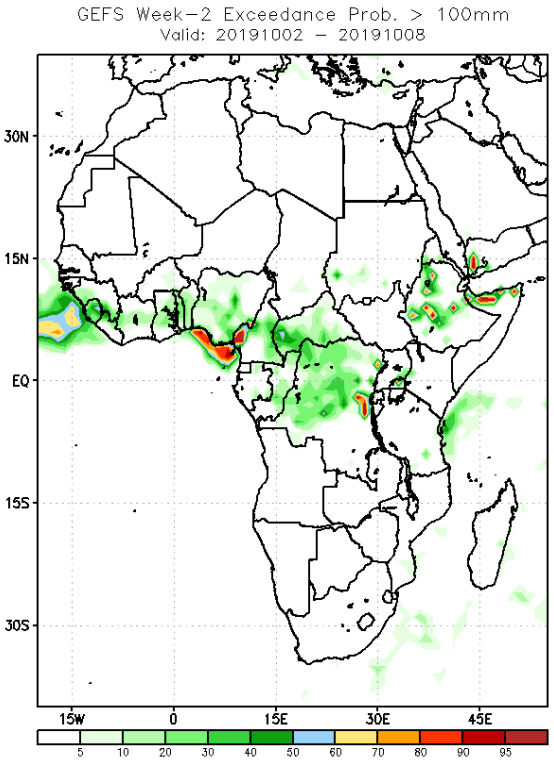
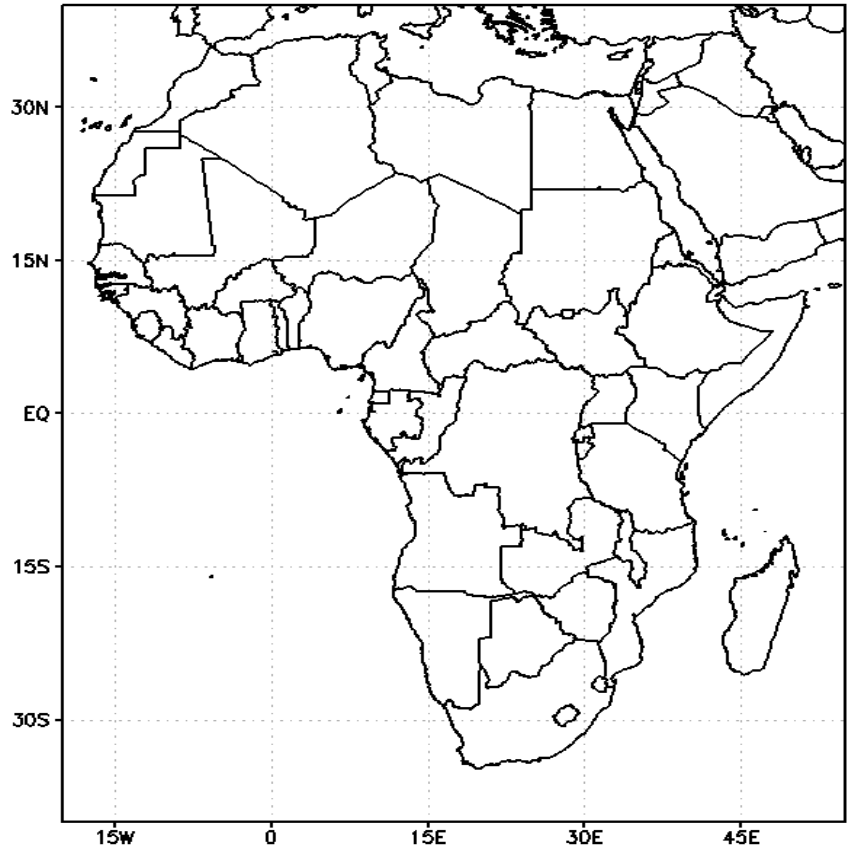


Week-2, Convergence of Evidence?

- **Wet**
  - MJO ->
  - Lower/upper-level wind/divergence anomalies ->
  - Rainfall Model Guidance ->
  - Exceedance Probability ->

- **Dry**
  - MJO ->
  - Lower/upper-level wind/divergence anomalies ->
  - Rainfall Model Guidance ->
  - Exceedance Probability ->

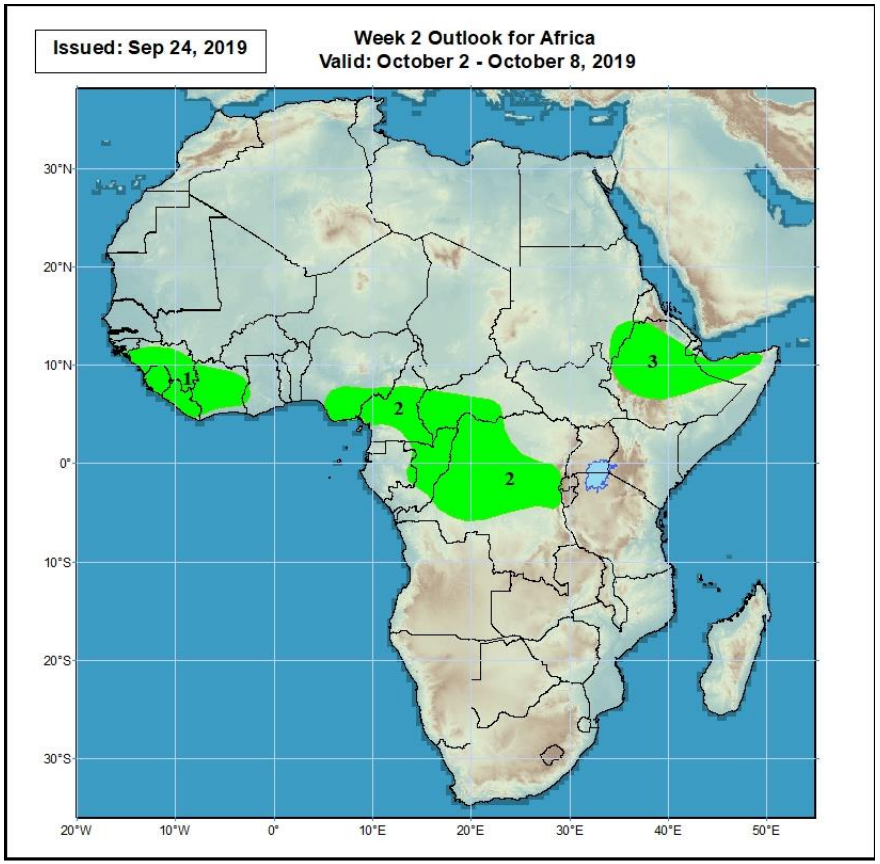
Week-2 Rainfall Outlook, 2 – 8 October 2019



1. **Forecast:** Reason.

2. **Forecast:** Reason.
3. **Forecast:** Reason.
4. **Forecast:** Reason.

Week-2 Rainfall Outlook, 2 – 8 October 2019



1. **Forecast:** Reason.

2. **Forecast:** Reason.
3. **Forecast:** Reason.
4. **Forecast:** Reason.