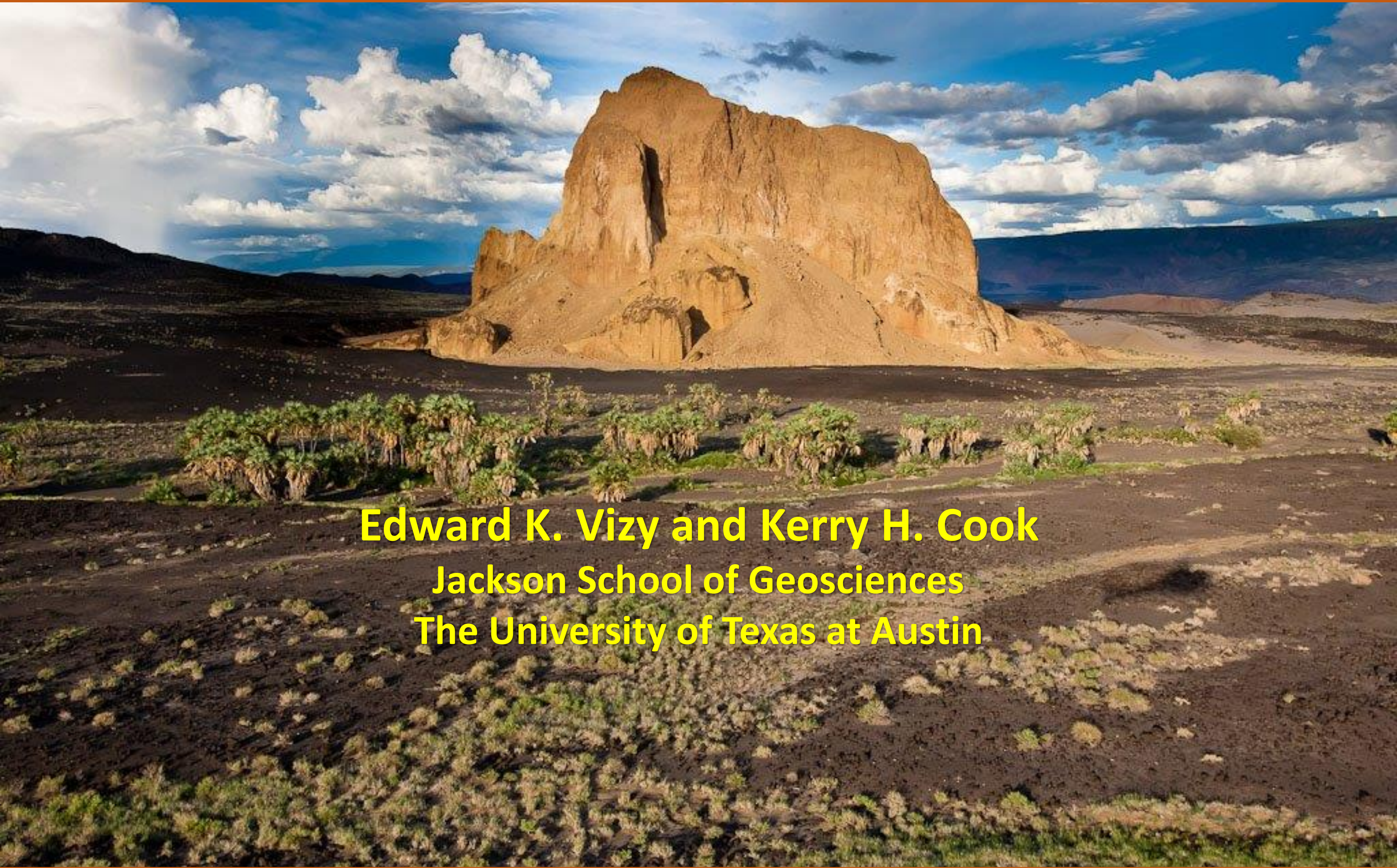
Observed relationship between the Turkana low-level jet and boreal summer convection



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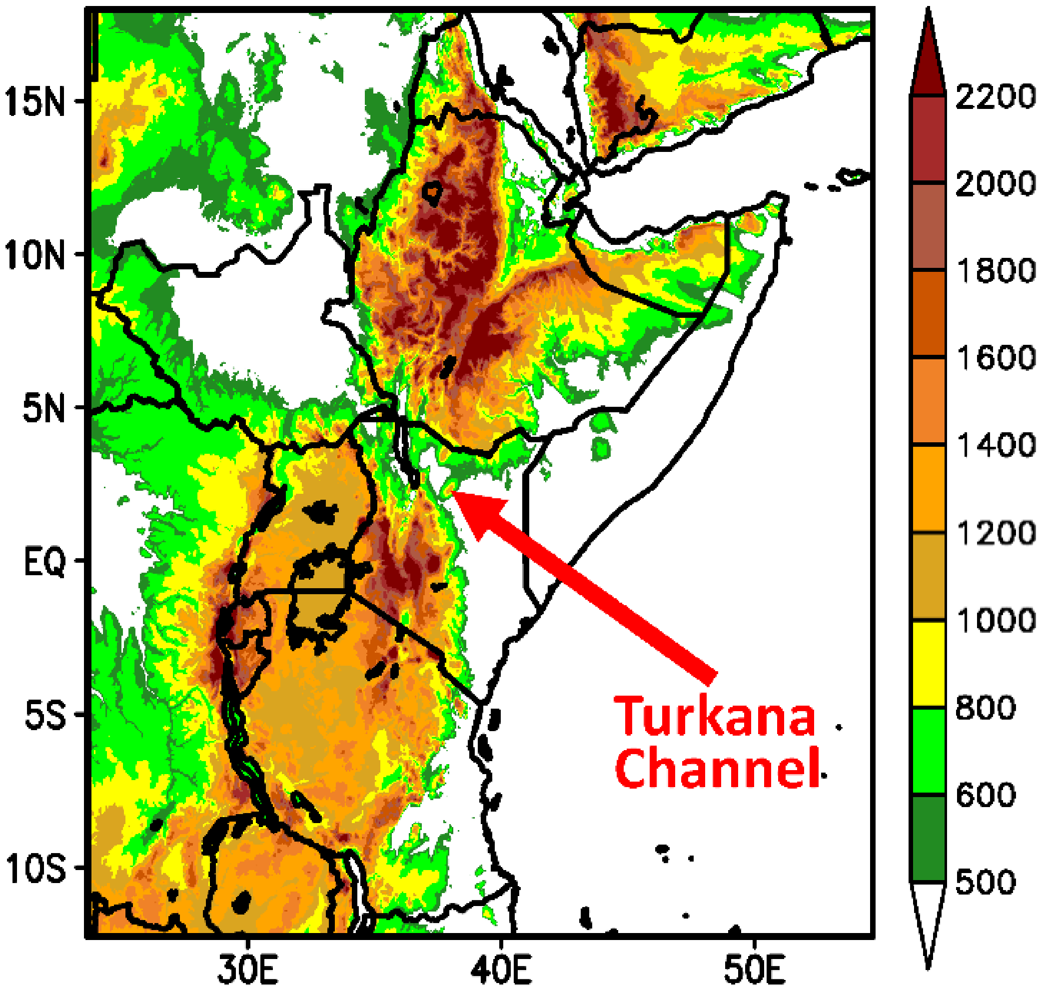
What is the Turkana low-level Jet?

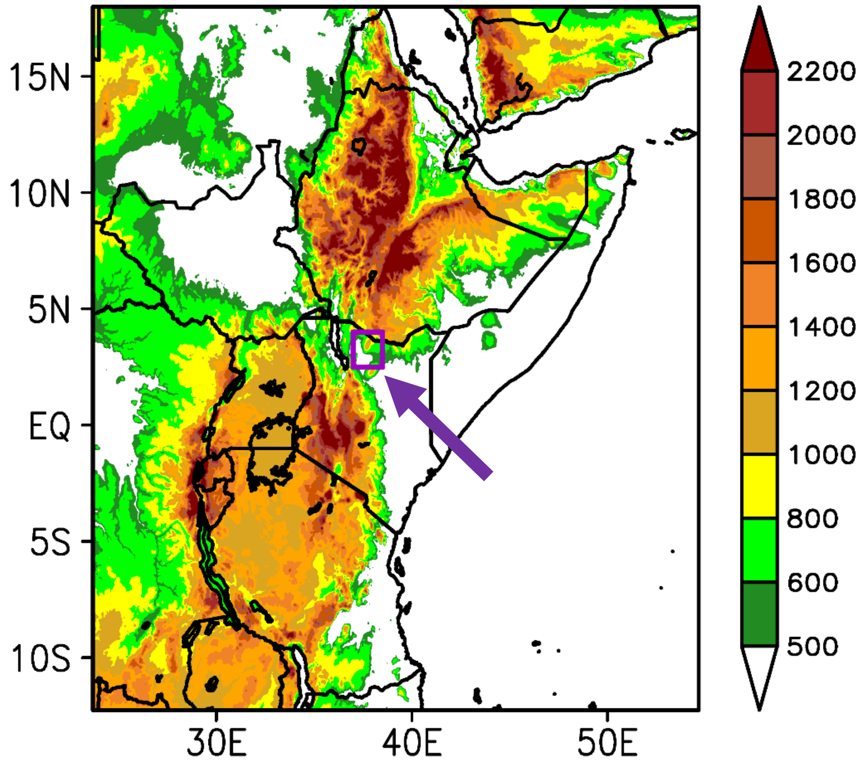
Topography in meters



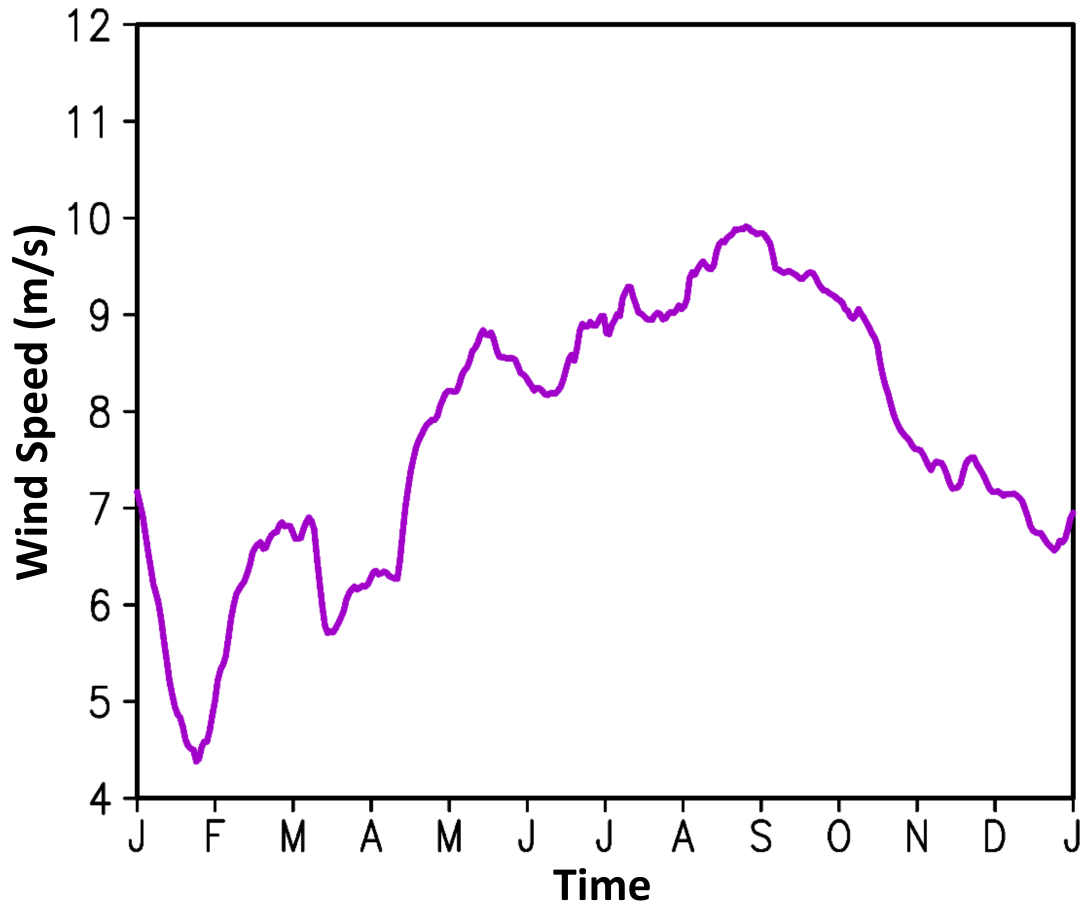
- Low-level flow is orographically channeled through the gap between the Ethiopian and East African Highlands.
- The horizontal height gradient across the channel is important with flow directed down the height gradient and wind speed influenced by the topography consistent with the Bernoulli effect (Indeje et al. 2001)
- Jet strength is also influenced by a variety of processes including frictional and thermal forcing (Sun et al. 1999; Indeje et al. 2001; Hartman 2018)

What is the seasonality of the Turkana Jet?

Location of Averaging Region Used



ERA5 area-averaged 2000 -2017 climatological daily 925 hPa wind speed (m/s)*

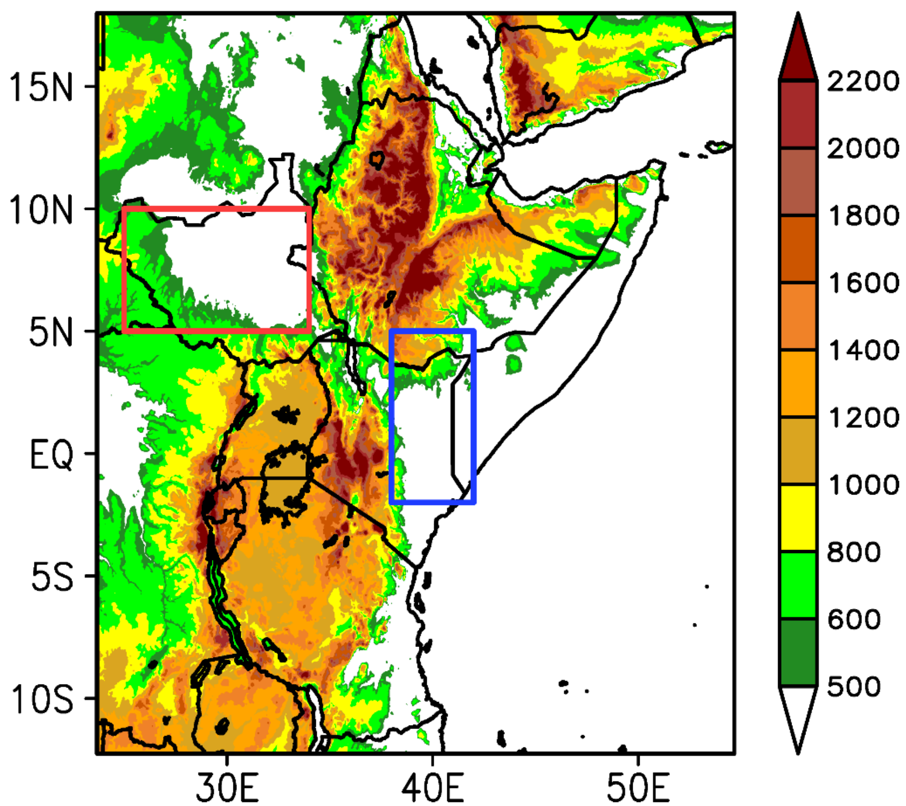


* 30-day smoothing filter is applied to the climatological daily time series

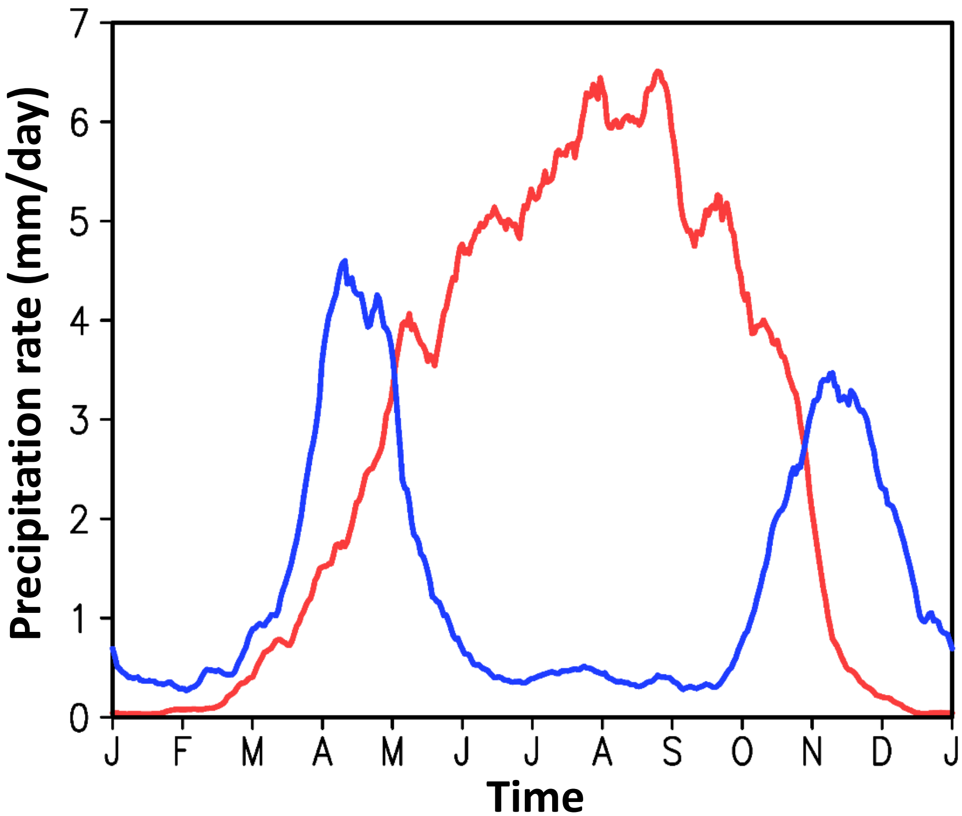
The jet is a year-round feature, but it is strongest during the late boreal summer (August – September)

How does seasonality of jet strength relate to the seasonality of precipitation?

Location of precipitation averaging regions east and west of the Turkana Channel



CHIRPS V2 climatological daily precipitation rate over the east and west averaging regions



- **West of the Turkana Channel rainfall rates peak during the late boreal summer (August), coinciding with when the Turkana jet is at its peak strength**

Purpose & Approach

Purpose:

Improve our understanding of the relationship between the Turkana Jet and the boreal summer rainfall variability in the vicinity of the jet exit region over continental interior Eastern Africa.

Approach:

Utilize high spatio-temporal resolution observational datasets and atmospheric reanalyses for August

Rainfall Datasets

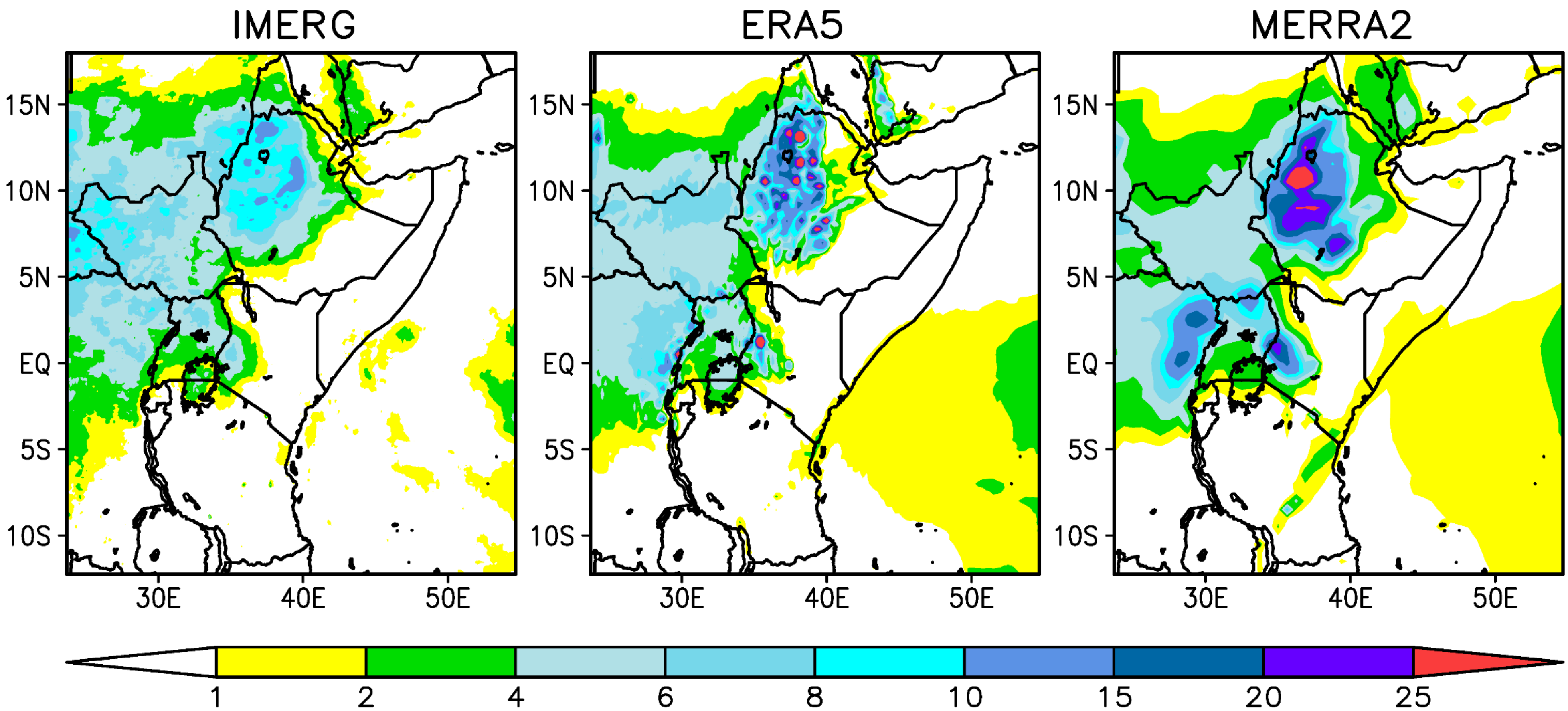
- **NASA TRMM TMPA (Huffman et al. 2007):** 3-hourly, 0.25° resolution
- **CHIRPS V2 (Funk et al. 2015):** daily, 0.1 ° resolution
- **NOAA CMORPH V2 bias-corrected (Xie et al. 2017):** 30-min, 0.07° resolution
- **NASA IMERG (Huffman et al. 2014):** 30-min, 0.1° resolution

Atmospheric Reanalyses

- **ECMWF ERA5 reanalysis (ERA5 2018):** hourly, 0.25° resolution
- **NASA MERRA2 reanalysis (Gelaro et al. 2017):**
  - **Upper air fields** 3-hourly, 0.625° lon ×0.5° lat resolution
  - **Some surface fields** hourly, 0.625° lon ×0.5° lat resolution

To what extent do the reanalyses reproduce the climatological observed rainfall?

Climatological August average precipitation rate (mm/day)



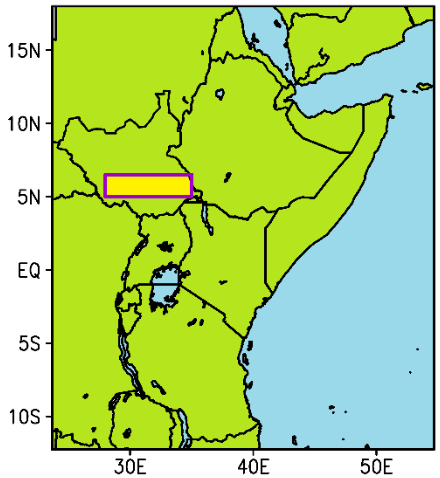
Aside from wet biases over the Ethiopian Highlands, ERA5 reasonably captures the observed climatological August spatial rainfall pattern.

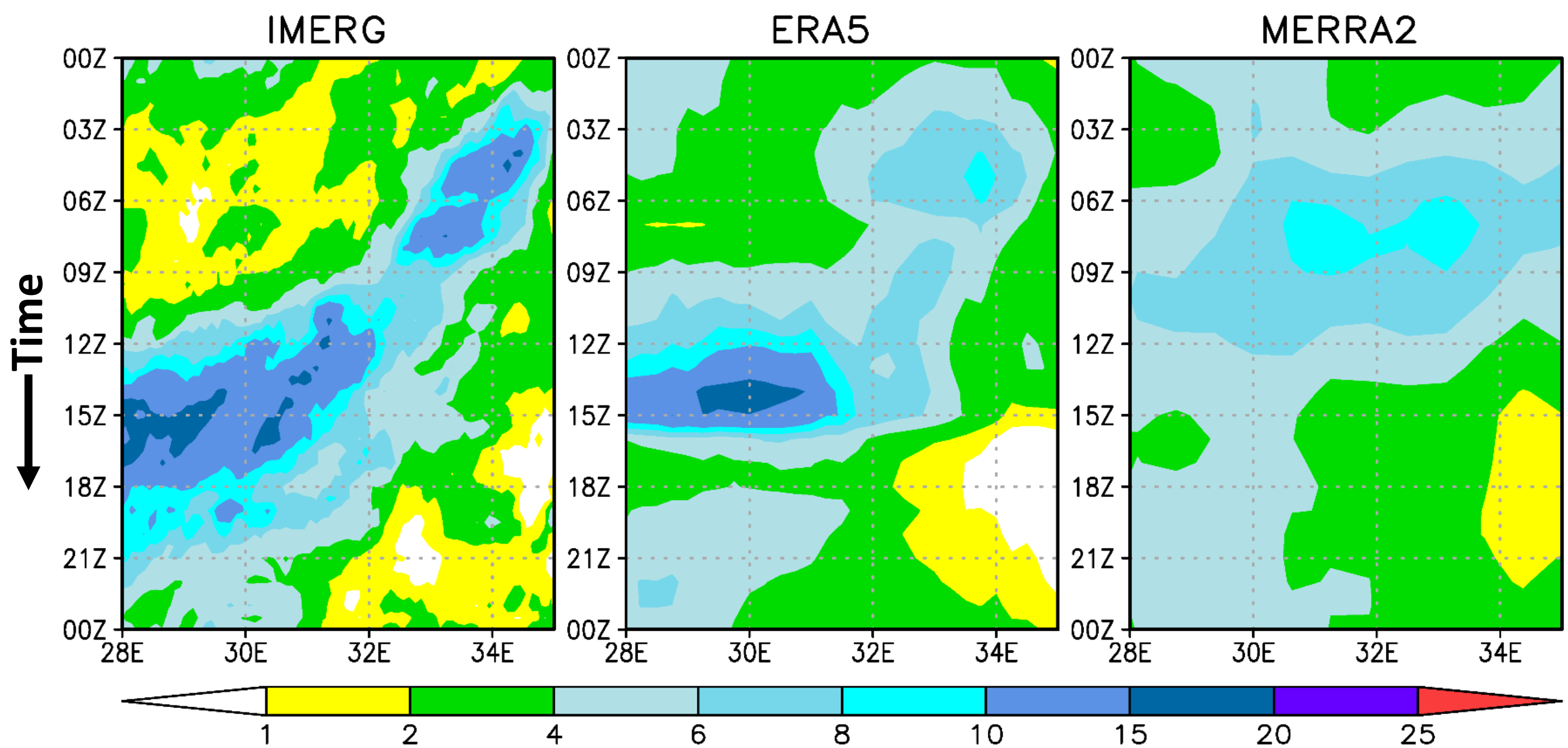
Differences from the observations are more pronounced for MERRA2

To what extent do the reanalyses reproduce the climatological observed rainfall?

Climatological August diurnal cycle of precipitation averaged from 5°N – 6.5°N (shading; mm/day)

Location of region



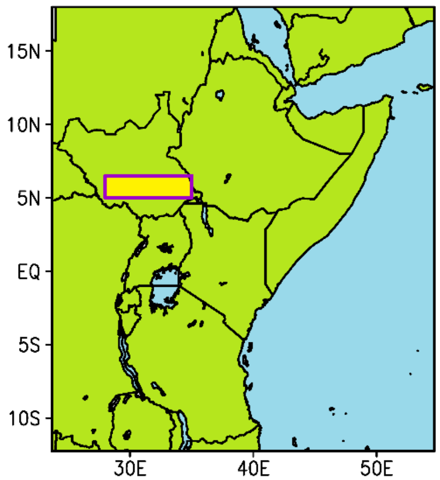


Observations indicate a morning (03Z – 09Z) peak in rainfall near 34°E that appears to propagate westward during the day with the strongest rainfall west of 32°E at 15Z

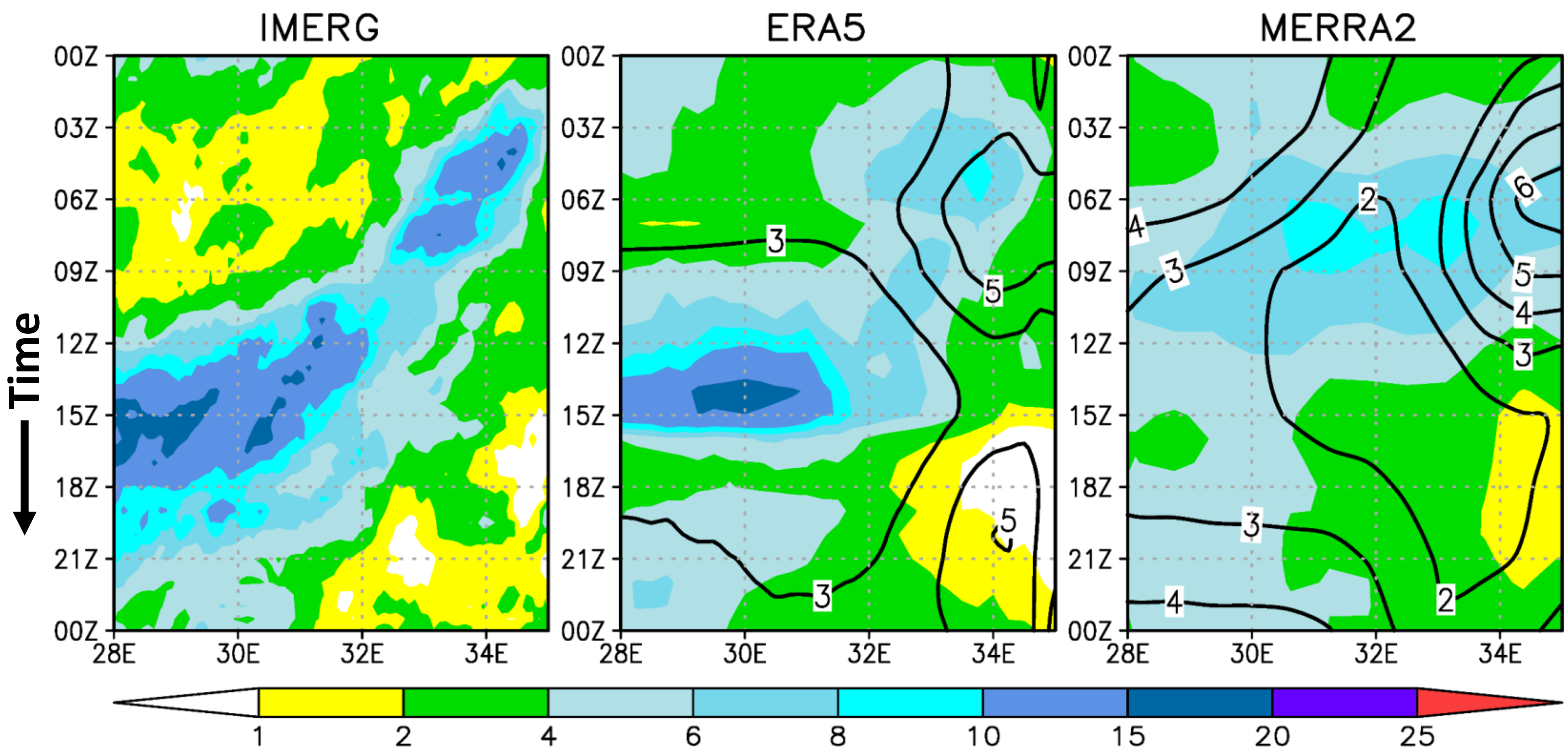
While not perfect, ERA5 represents the observed diurnal cycle of rainfall pattern, but MERRA2 does not

How does this relate to the climatological diurnal cycle of the Turkana Jet strength?

Location of region



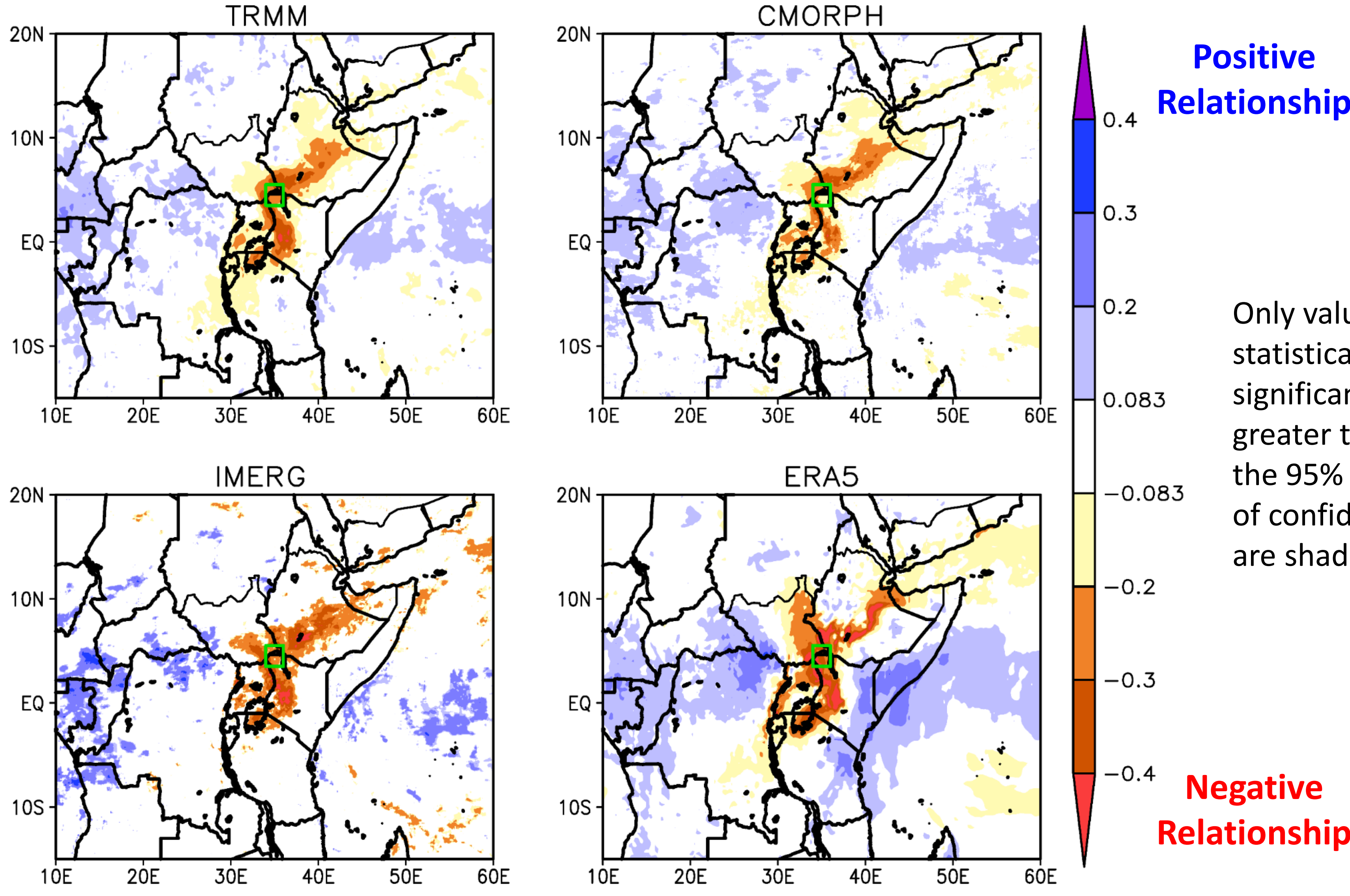
Climatological August diurnal cycle of precipitation averaged from 5°N – 6.5°N (shading; mm/day) and 900 hPa wind speed (black contours; m/s)



Morning peak in rainfall near the jet exit region is associated with a strong Turkana Jet and enhanced low-level wind convergence at this time

What is the relationship between jet strength and precipitation on the daily timescale?

Correlation between daily ERA5 900 hPa Turkana Jet wind speed averaged over the green box and daily precipitation for August



Only values statistically significant at greater than the 95% level of confidence are shaded

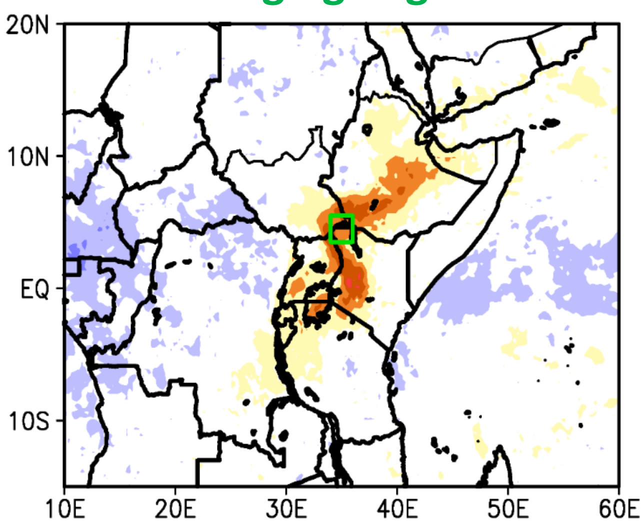
Strong jet associated with reduced rainfall over the East African Highlands and eastern South Sudan, and vice versa

Form Composites for Strong and Weak Jet Days using ERA5

Strong Turkana Jet day is defined as when the daily area-averaged 900 hPa wind speed over the green box is more than 1 standard deviation above the 2000 – 2017 August climatological daily mean. (112 days; 39 independent events)

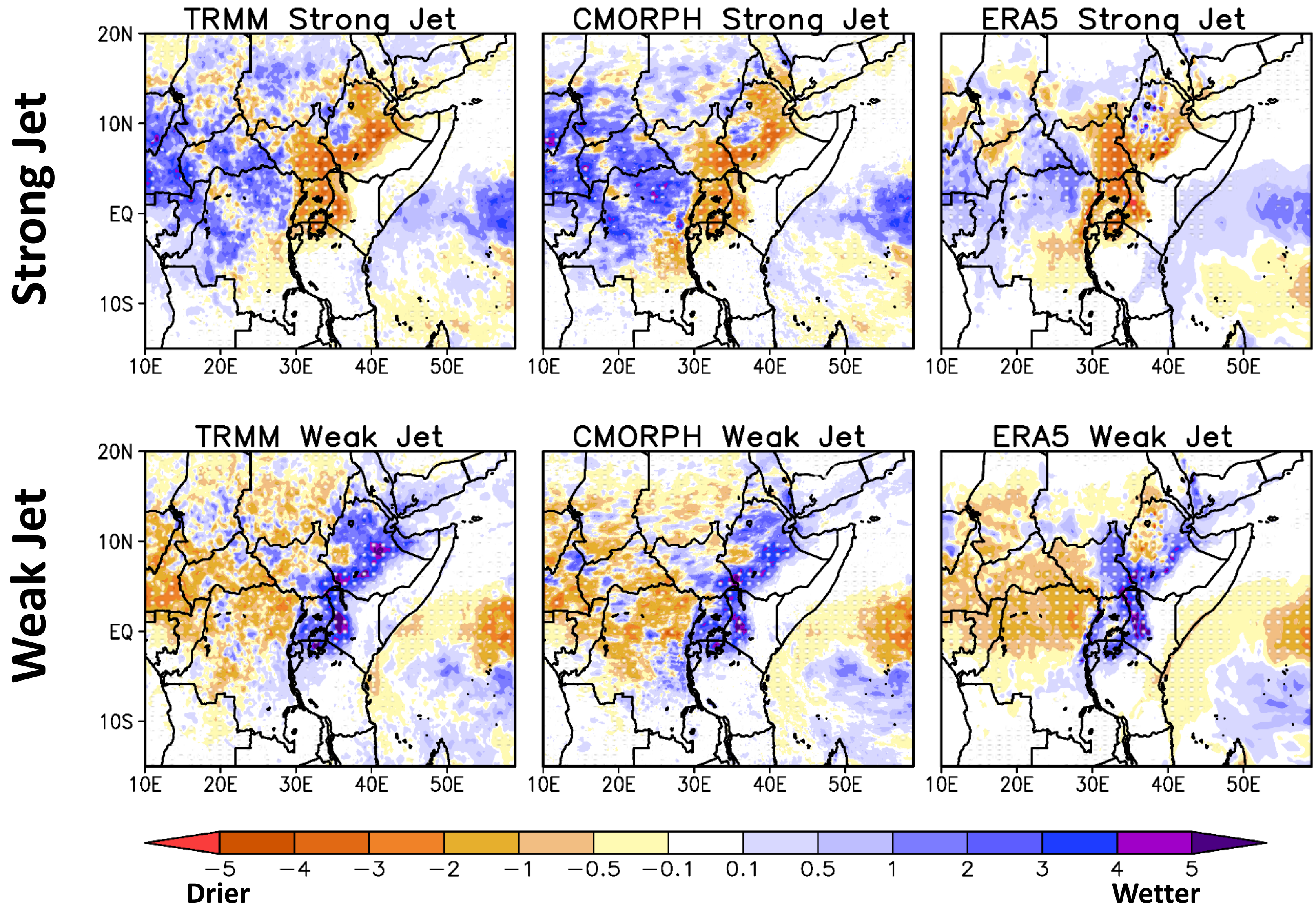
Weak Turkana Jet day is defined as when the daily area-averaged 900 hPa wind speed over the green box is less than 1 standard deviation below the 2000 – 2017 August climatological daily mean. (107 days; 41 independent events)

Averaging Region



These identified days are used to form daily mean (i.e., synoptic) and diurnal cycle composites for strong and weak Turkana jet event types

Composite Daily Precipitation Anomalies (mm/day)

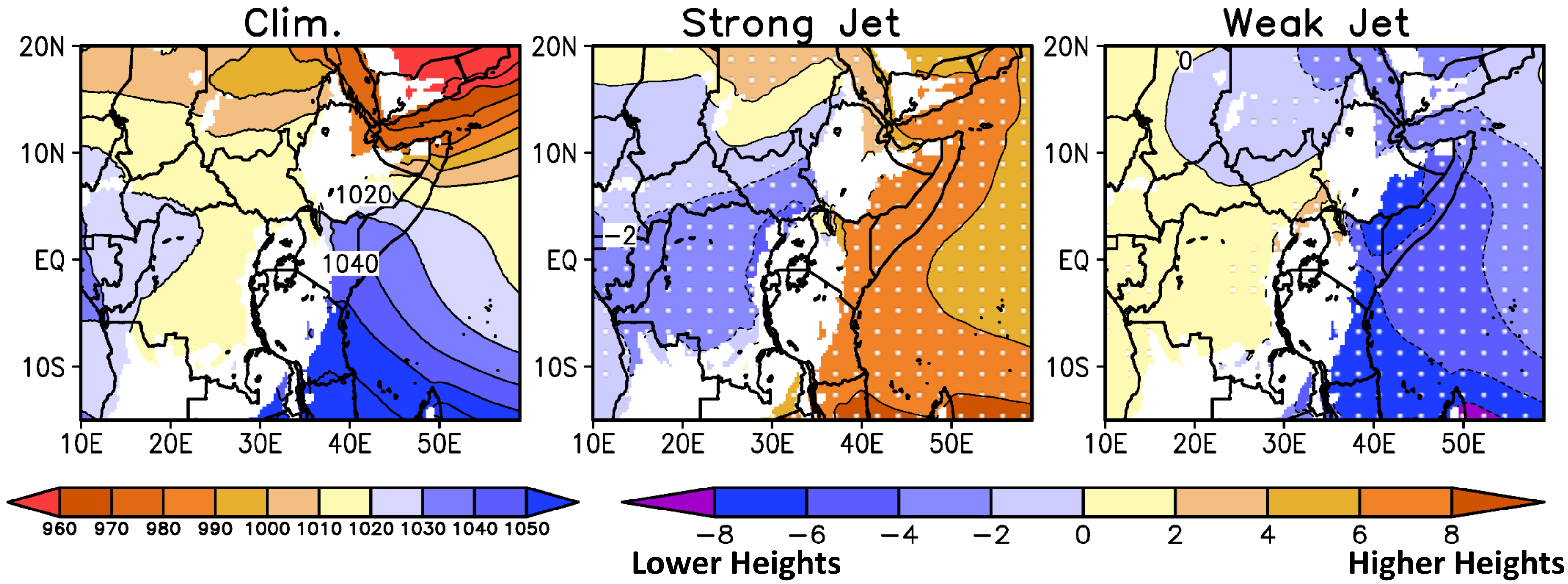


Stippling denotes anomalies significant at the 95% level of confidence

Composite rainfall anomalies are in agreement with correlations

Daily Composite Results

900 hPa Geopotential Heights and Composite Anomalies (m)

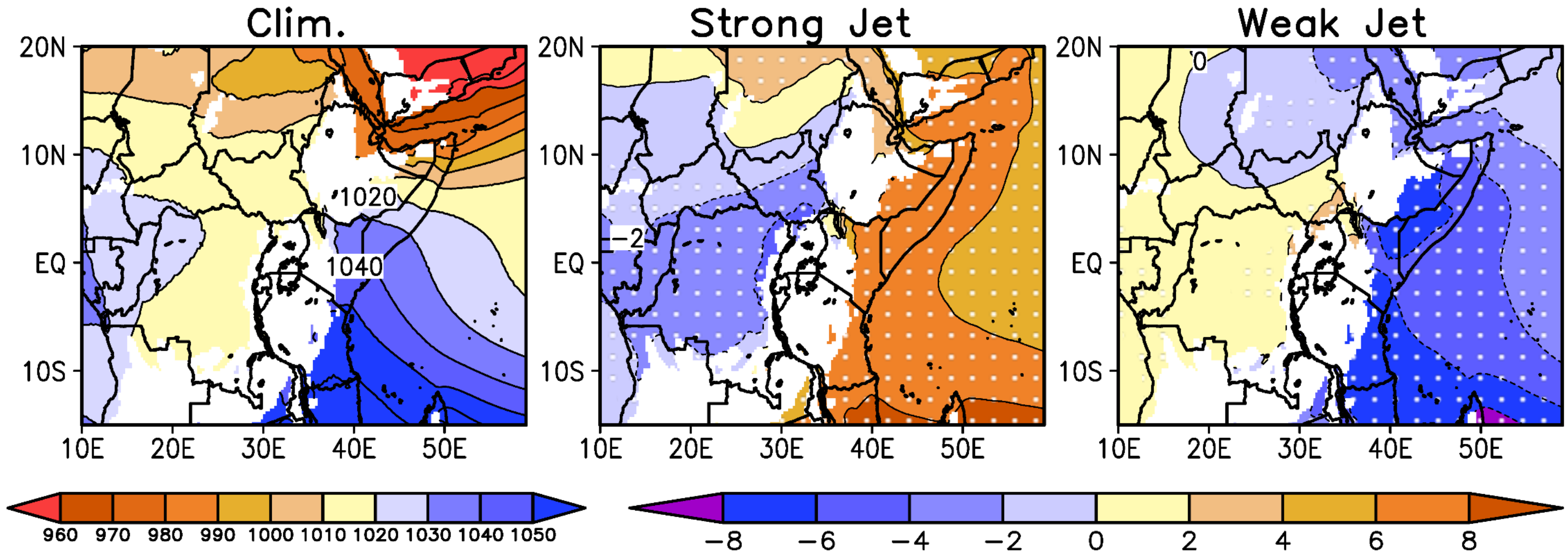


Stippling denotes anomalies significant at the 95% level of confidence

Strong jet case is associated with an enhanced height gradient across the channel, and the opposite occurs for the weak jet case

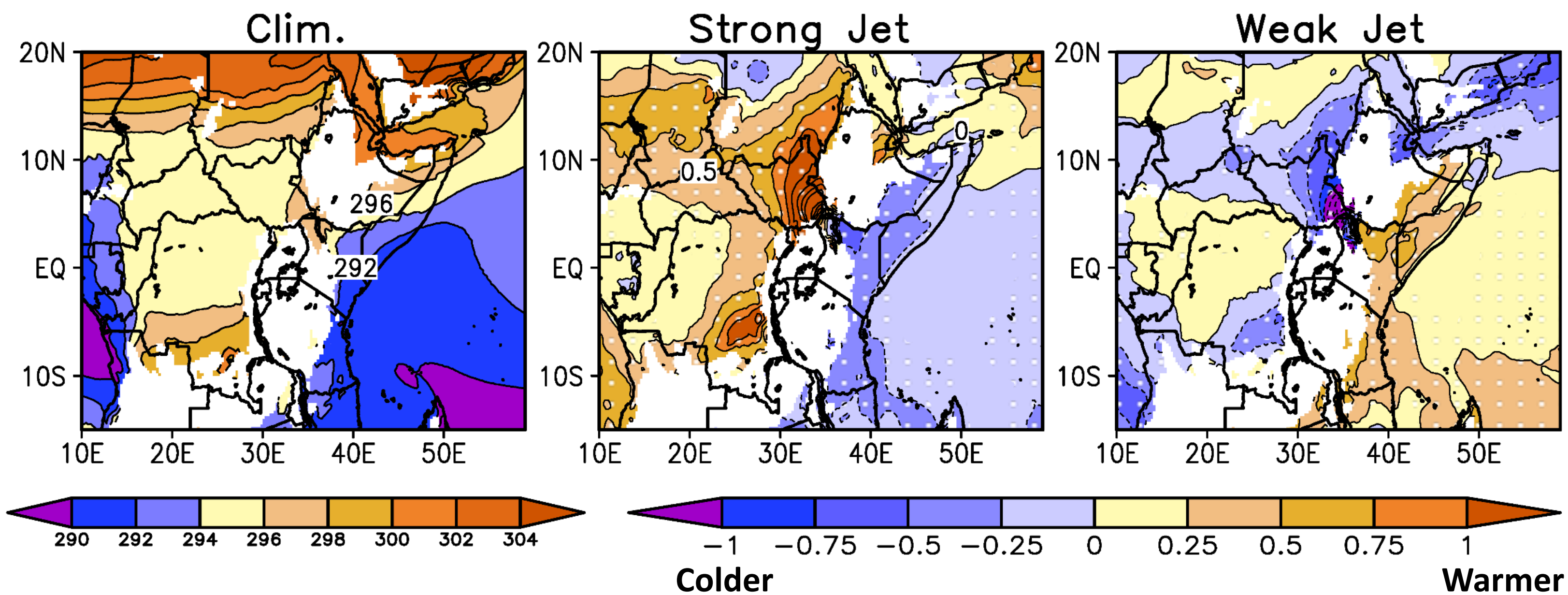
Daily Composite Results

900 hPa Geopotential Heights and Composite Anomalies (m)



Stippling denotes anomalies significant at the 95% level of confidence

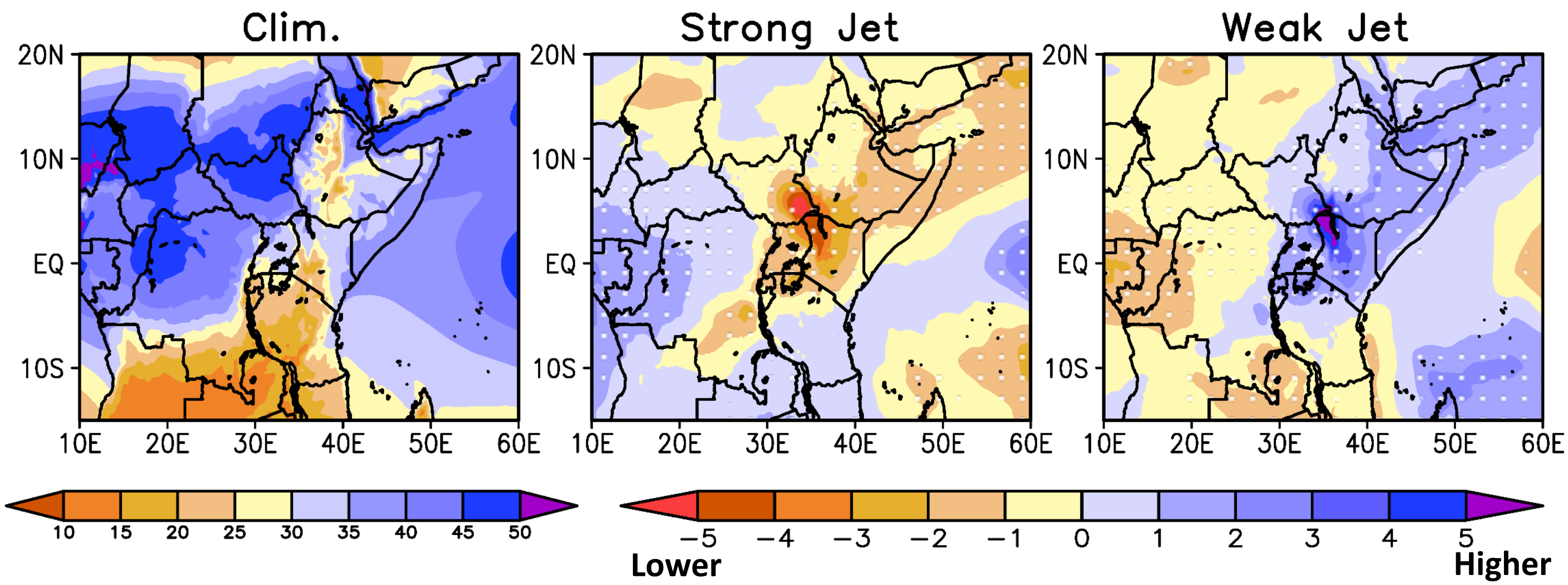
900 hPa Temperature and Composite Anomalies (K)



Strong jet case is also associated with cooler temperatures to the east of the highlands and warmer temperatures to the west. The opposite occurs for the weak jet case.

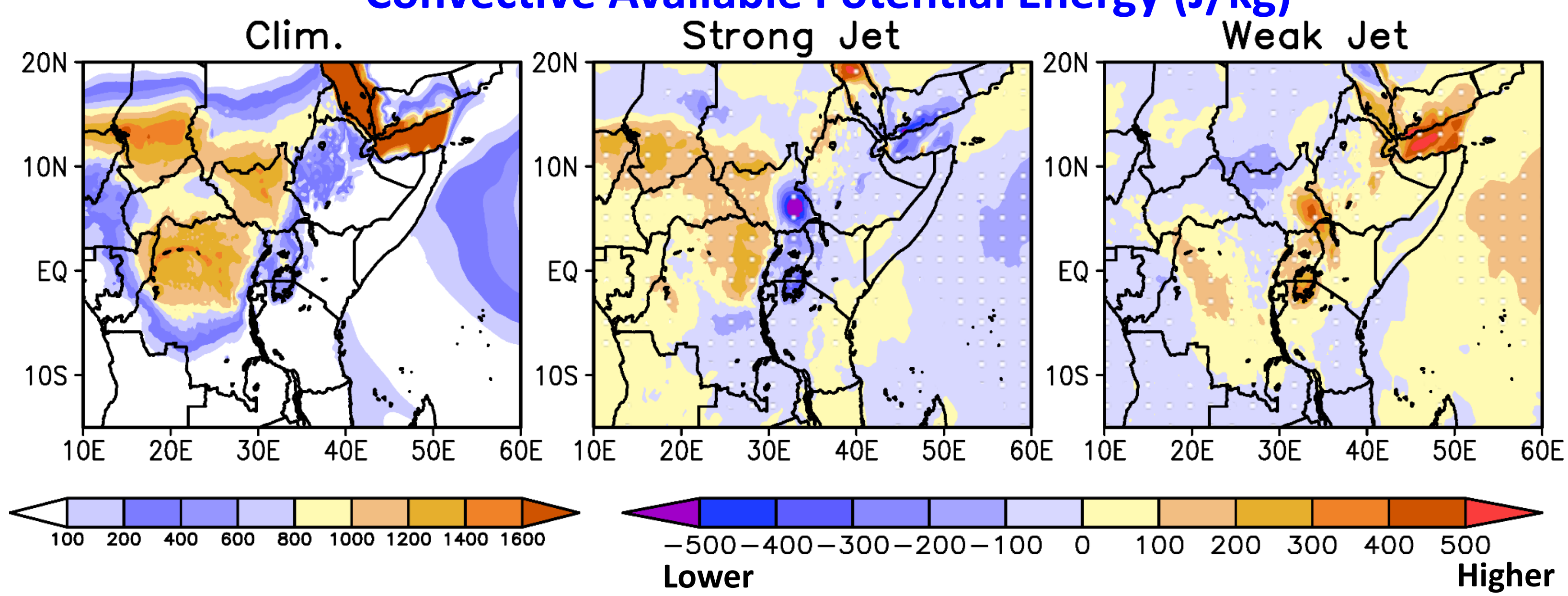
Daily Composite Results

Precipitable Water and Composite Anomalies (mm)



Stippling denotes anomalies significant at the 95% level of confidence

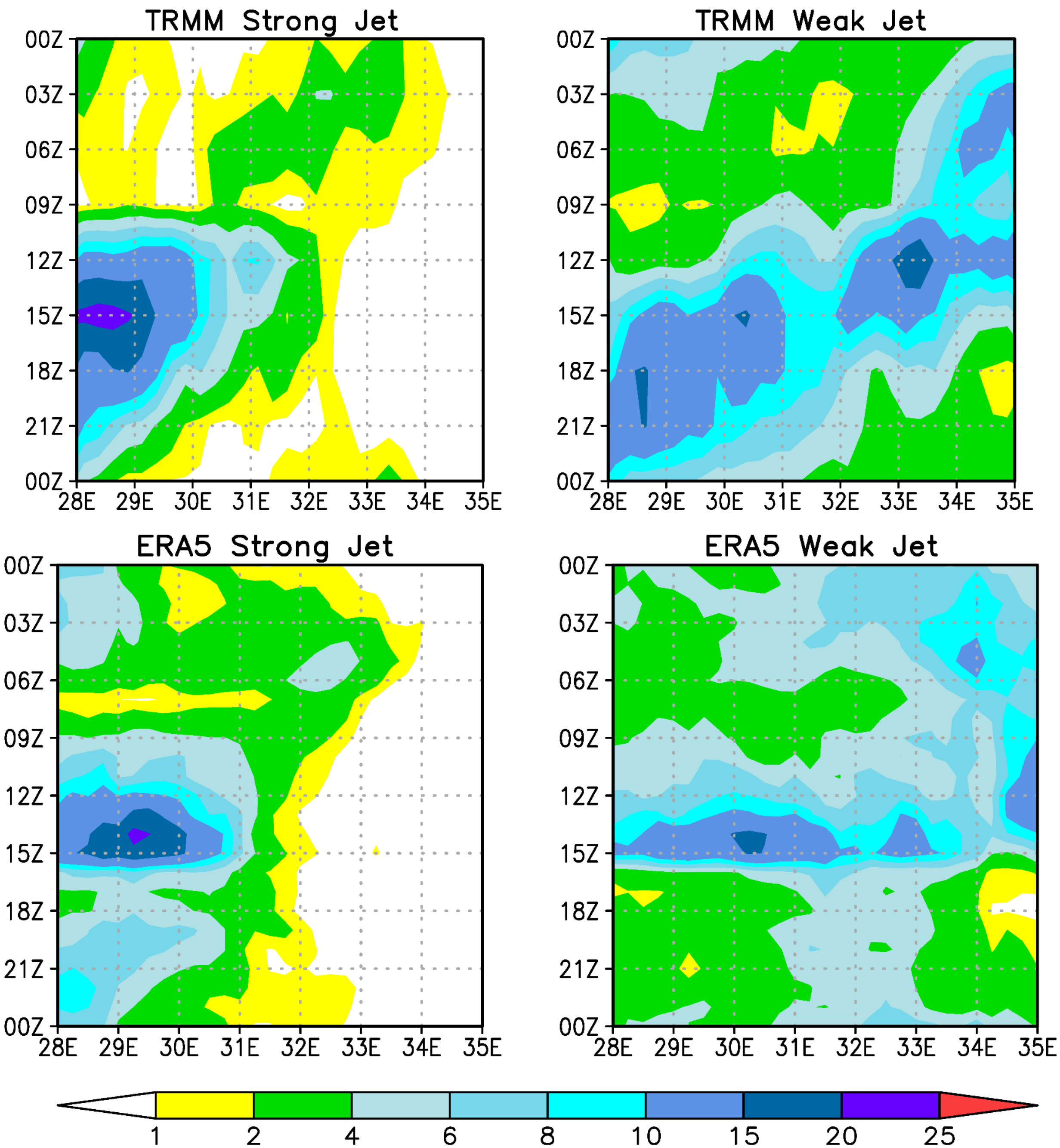
Convective Available Potential Energy (J/kg)



Strong jet case is also associated with drier, more stable conditions in the channel and over the eastern South Sudan. The opposite occurs for the weak jet case.

Composite Diurnal Cycle averaged from 5°N – 6.5°N

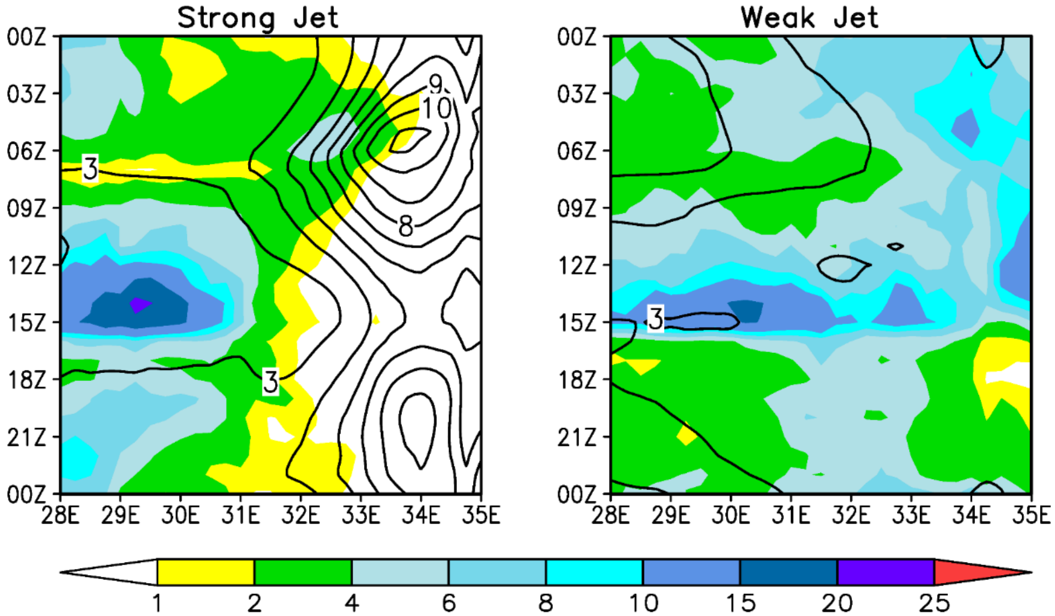
Precipitation (mm/day)



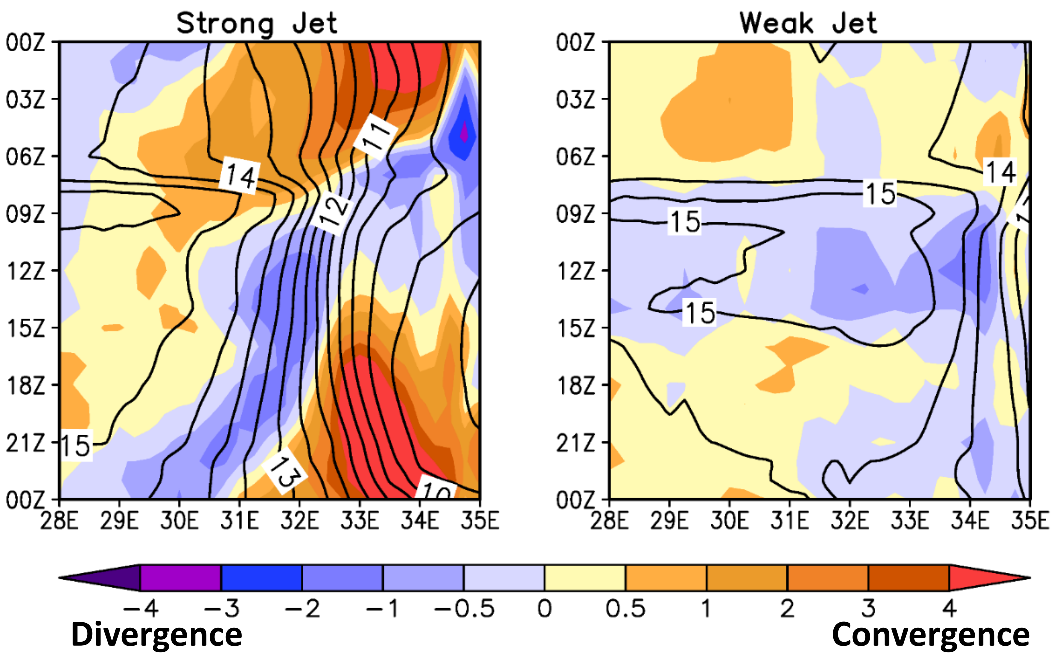
- **Strong Jet composite is relatively dry east of 32°E over entire diurnal cycle**
- **Weak jet composite indicates stronger rainfall east of 32°E before 15Z**
- **ERA5 yields a similar rainfall pattern to TRMM**

Composite Diurnal Cycle averaged from 5°N – 6.5°N (mm/day)

Precipitation (mm/day) & 900 hPa Wind Speed (m/s)



900 hPa Wind Convergence (shading; × 10^{-5} s^{-1}) & Specific Humidity (contours; g/kg)



- **Strong jet composite -** rainfall is reduced east of 32°E over eastern South Sudan due to a decrease in low-level moisture and despite an increase in the low-level wind convergence

- **Weak jet composite -** rainfall is enhanced east of 32°E over eastern South Sudan due to an increase in low-level moisture

Conclusions

- **Composite results indicate that a strong Turkana jet is associated with reduced convective activity over the eastern South Sudan, and vice versa during the late boreal summer.**

- **It is the Turkana jet's influence on the atmospheric moisture content rather than its impact on low-level convergence that appears to be most important during this time of the year.**

- **Synoptic variability of the Turkana jet and South Sudan rainfall is found to be closely associated with low-level ridging along the East African coast south of the equator over the southwestern Indian Ocean.**

- **Finally the apparent contradiction in the relationship between eastern South Sudan rainfall in the jet exit region and the Turkana jet strength in the climatological mean and the strong and weak jet composites is an artifact of the methodology used to process the datasets**

Climatological Approach - considers all types of events and this obscures the relationship
Compositing Approach - separates the strong and weak periods yielding a more complete understanding of the relationship

For more details regarding this work please see:

Vizy, E.K., and K.H. Cook, 2019: Observed relationship between the Turkana low-level jet and boreal summer convection. *Clim. Dyn.*, 53, 4037 – 4058. https://doi.org/10.1007/s00382-019-04769-2