Diurnal variation of rainfall and the meridional overturning over West Africa during the pre-monsoon season

Department of ATMOSPHERIC SCIENCES, COLLEGE OF GEOSCIENCES

Lidia Huaman[1], Courtney Schumacher[1], Erin Buttitta[1] and Andreas Fink[2]

1 Department of Atmospheric Sciences, Texas A&M University, 2 Karlsruhe Institute of Technology, Karlsruhe, Germany

1. Introduction

- West African precipitation mainly depends on the moisture transported inland from the Gulf of Guinea at seasonal and daily scales.
- During the pre-monsoon season, from April to June (AMJ), deep cloud systems with strong precipitation are predominant offshore in the Gulf of Guinea at around 5°N and are accompanied by a deep meridional circulation. Inland, at 15°N, a dry shallow meridional circulation is observed (Fig. 1).
- Two main features play important roles in the diurnal cycle of the West African vertical motion and precipitation climatology: the nocturnal low-level jet (NLLJ, Parker et al. 2005) and the sea-breeze front (Grams et al. 2010).

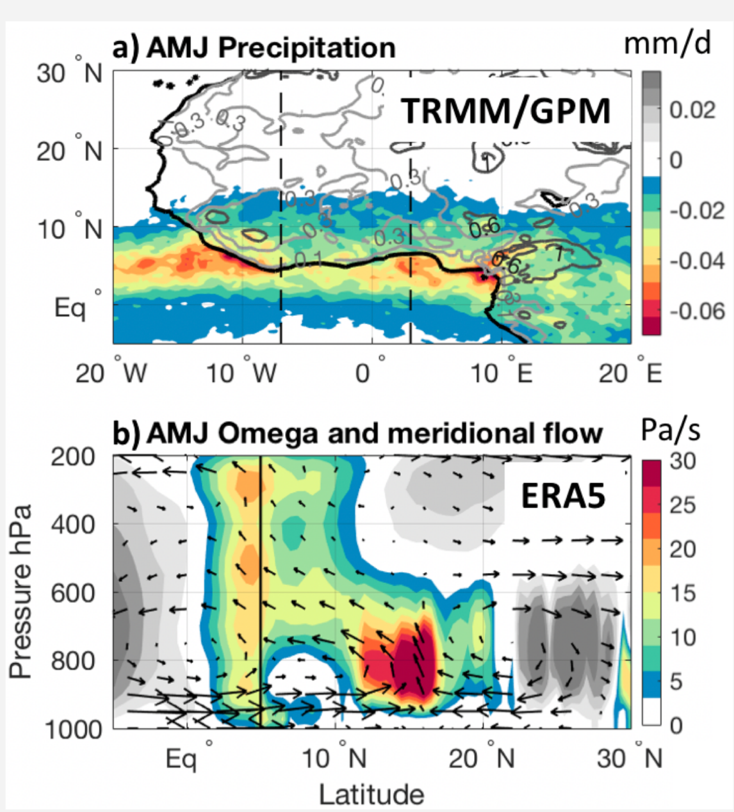

***Fig. 1** a) PR-DPR precipitation during AMJ for 1998-2019, and b) ERA5 latitudinal cross section from 7°W-3°E (i.e., between vertical dashed lines in a) for omega and meridional flow.*

2. Data

- Horizontal and vertical wind fields from ERA5 and MERRA-2 reanalyses interpolated to 0.5° resolution
- TRMM and GPM satellite radar precipitation gridded at 0.25° and categorized as (deep) convective, stratiform, and shallow (convective) from 2APR and 2ADPR products
- All data shown is during AMJ (the pre-monsoon) for 1998-2019

3. Results

3.1 Diurnal cycle of vertical velocity from ERA5

Diurnal Features:

a) Sea Breeze
b) Nocturnal low-level jet (NLLJ)
c) Mixing Layer

00 – 03 UTC

- NLLJ very active, enhances Saharan shallow meridional circulation
- Deep upward motion over ocean

06 – 09 UTC

- NLLJ and shallow meridional circulation decaying
- Deep upward motion over ocean strengthening

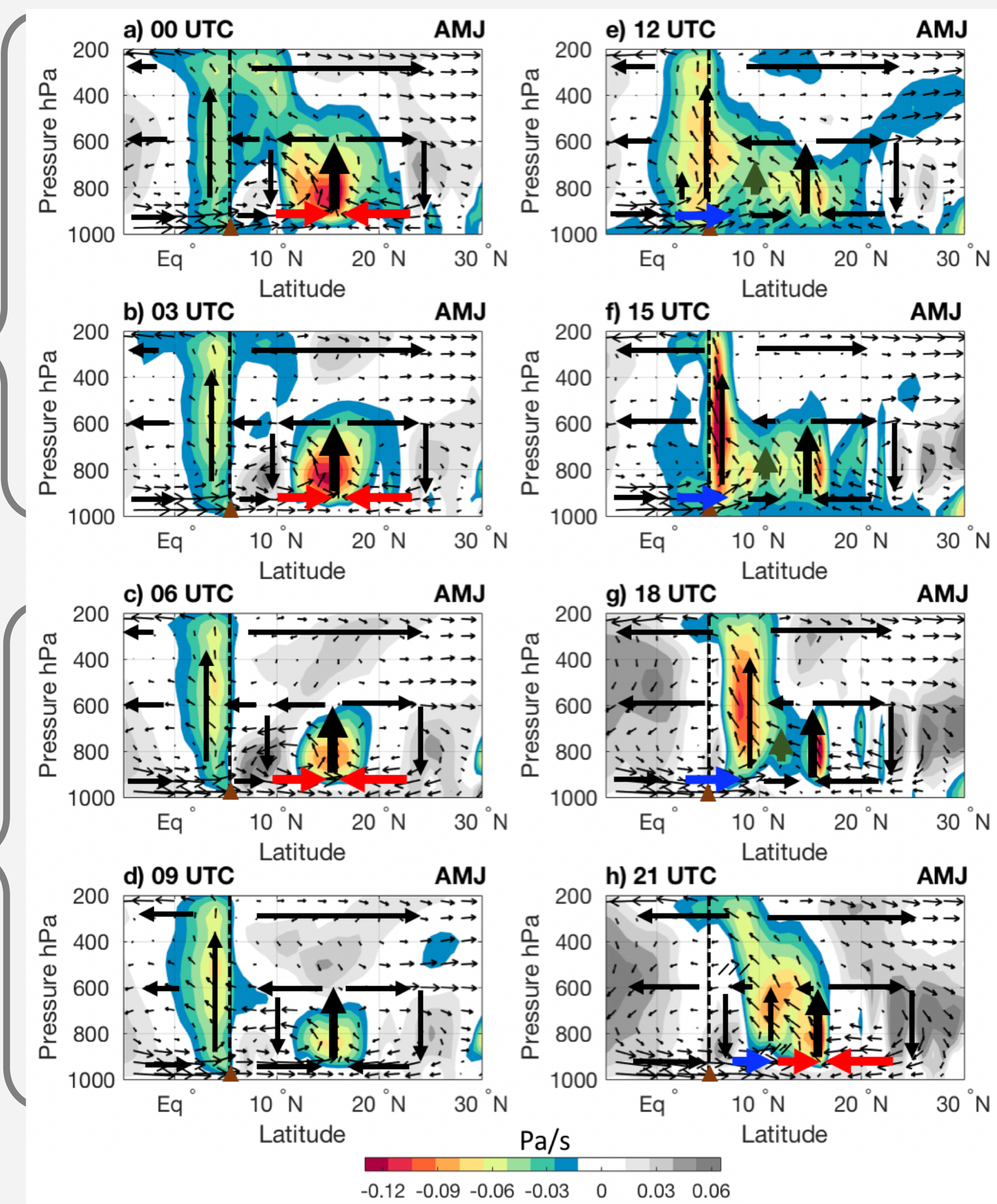

***Fig. 2** Diurnal variation of vertical motion (Pa/s) and meridional flow in latitudinal cross sections from 7°W-3°E during AMJ. The solid line at 5.5°N highlights the coastline.*

12 – 15 UTC

- Deep upward motion propagates onto land due to sea-breeze front (11.5 m/s)
- Well-mixed air in planetary boundary layer
- Shallow meridional circulation is weak

18 – 21 UTC

- Deep upward motion propagates inland (10°N) due to sea-breeze front
- Deep convection interacts with the southern part of dry Saharan shallow meridional circulation

3.2 TRMM-GPM rain types

Deep convective and stratiform rain propagates inland from 12 to 18 UTC due to sea-breeze front. Shallow convective rain stays closer to coast.

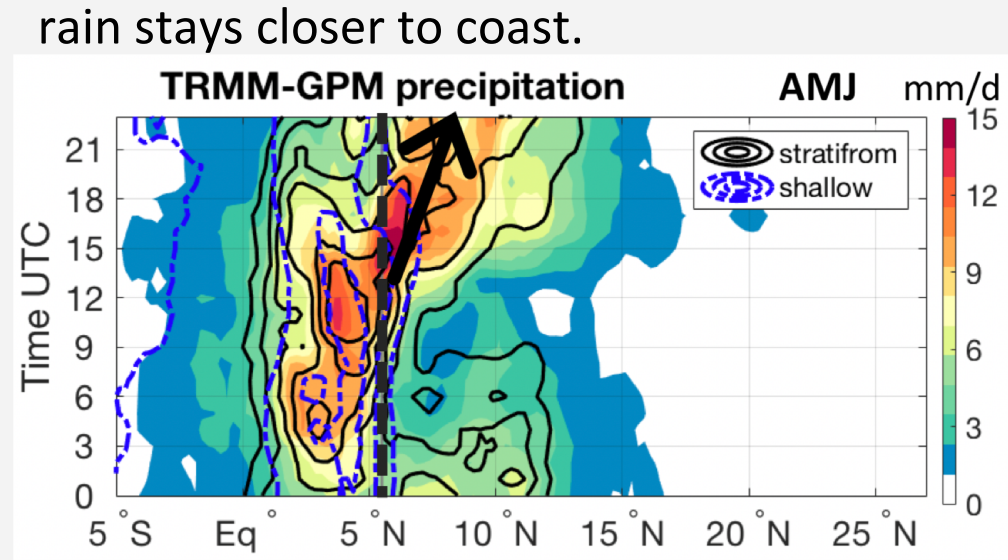

***Fig. 3** Convective (shaded), stratiform (black contours each 1 mm/d starting at 2 mm/d), and shallow (blue contours each 0.5 mm/d starting at 0.5 mm/d) rain in mm/d from PR-DPR during AMJ.*

3.3 MERRA-2 vs ERA5

- MERRA-2 doesn't show inland propagation of deep convection (represented by 400-hPa omega) between 12 to 21 UTC as suggested by ERA5
- MERRA-2 shows sea breeze (represented by 850-hPa omega) with slower phase speed than ERA5 and is not linked to 400-hPa omega and deep convection

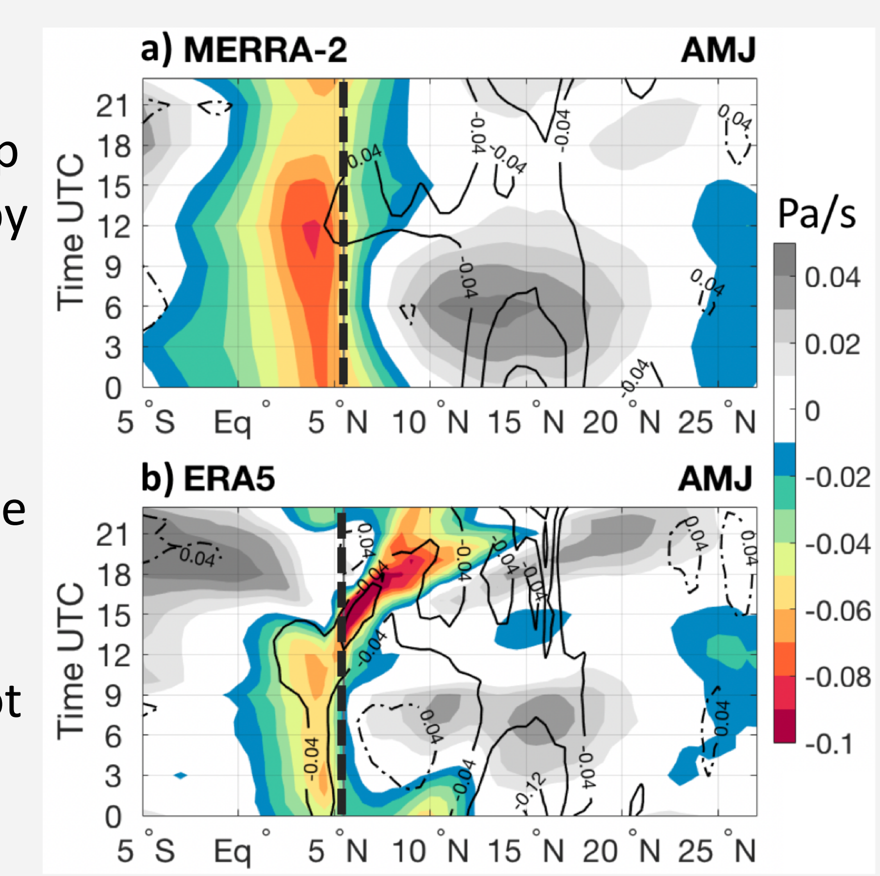

***Fig. 4** Latitude-time diagrams of vertical velocity at 400 hPa (shading) and 850 hPa (contours) in Pa/s from a) MERRA-2 and b) ERA5 during AMJ.*

4. Conclusions

- The meridional overturning circulation over West Africa during AMJ has strong diurnal cycle linked to the sea breeze and NLLJ.
- The sea breeze drives deep convection from the coast into land during the early afternoon.
- The continental NLLJ produces large low level-convergence and strengthens the dry shallow cell at night.
- MERRA-2 overestimates convection over coastal region and does not show inland propagation of deep convection, while ERA5 captures this well.

5. Acknowledgments

This project was funded by NASA PMM grant 80NSSC19K0734 and by NASA NESSF grant 80NSSC18K1402.

6. References

- Parker et al. 2005. The diurnal cycle of the West African monsoon circulation. *Quarterly Journal of the Royal Meteorological Society*, *131*(611), 2839-2860.
- Grams et al. 2010. The Atlantic inflow to the Saharan heat low: Observations and modelling. *Quarterly Journal of the Royal Meteorological Society*, *136*(S1), 125-140.