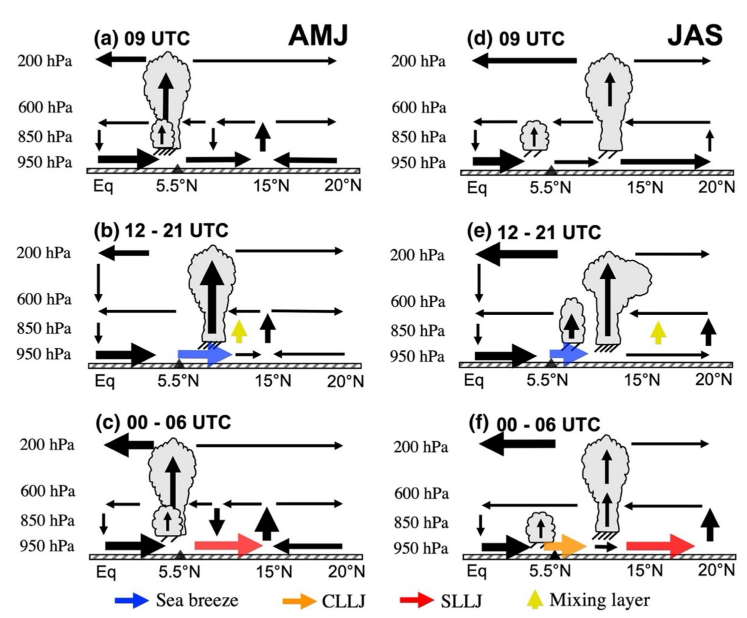
Seasonal and Diurnal Variations in the Meridional Overturning Circulation over West Africa and the East Atlantic and the Associated Convective Cloud Structures

Jonathan Lewis & Courtney Schumacher[1]
[1]*Department of Atmospheric Science*
Texas A&M University, College Station, TX

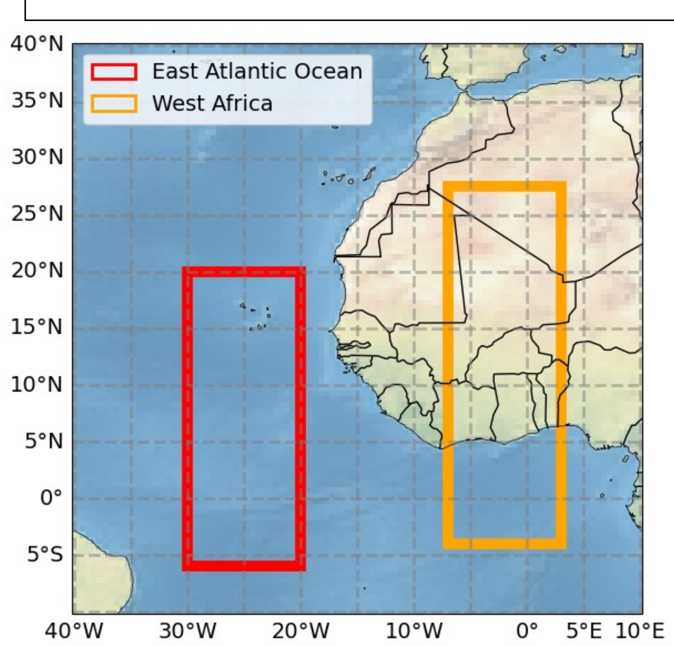
Introduction

The meridional overturning circulation (MOC) over West Africa has been shown to have strong seasonal and diurnal variations via changes in the low-level northerly winds and large-scale vertical motion. The Atlantic ITCZ acts as another important regional upward branch of the Hadley cell but does not undergo the same strong diurnal and seasonal variations as over West Africa.

Huaman et al. (2023) showed that the large-scale circulation variations associated with the West African MOC (including the sea breeze and coastal and Sahara low-level jets) are correlated with rain types observed by the GPM and TRMM radars. This study further investigates the vertical MOC and storm structures over West Africa and the Atlantic.



Data and Methods



Regions of Interest:
1. West Africa
   4°S-27.5°N, 7°W-3°E
2. East Atlantic Ocean
   6°S-20°N, 30°W-20°W

Seasons:
1. Pre-monsoon
   April - June (AMJ)
2. Monsoon
   July - September (JAS)

- GPM Dual-Frequency Precipitation Radar (DPR) 3-D reflectivity (2014-2021) separated into shallow convective, deep convective, and stratiform rain categories
- MERRA-2 MOC (2014-2021) defined by stream function:

$$\Psi(p, \varphi) = \frac{2\pi a \cos(\varphi)}{g} \int_{p}^{p_s} [v(p, \varphi)] dp$$

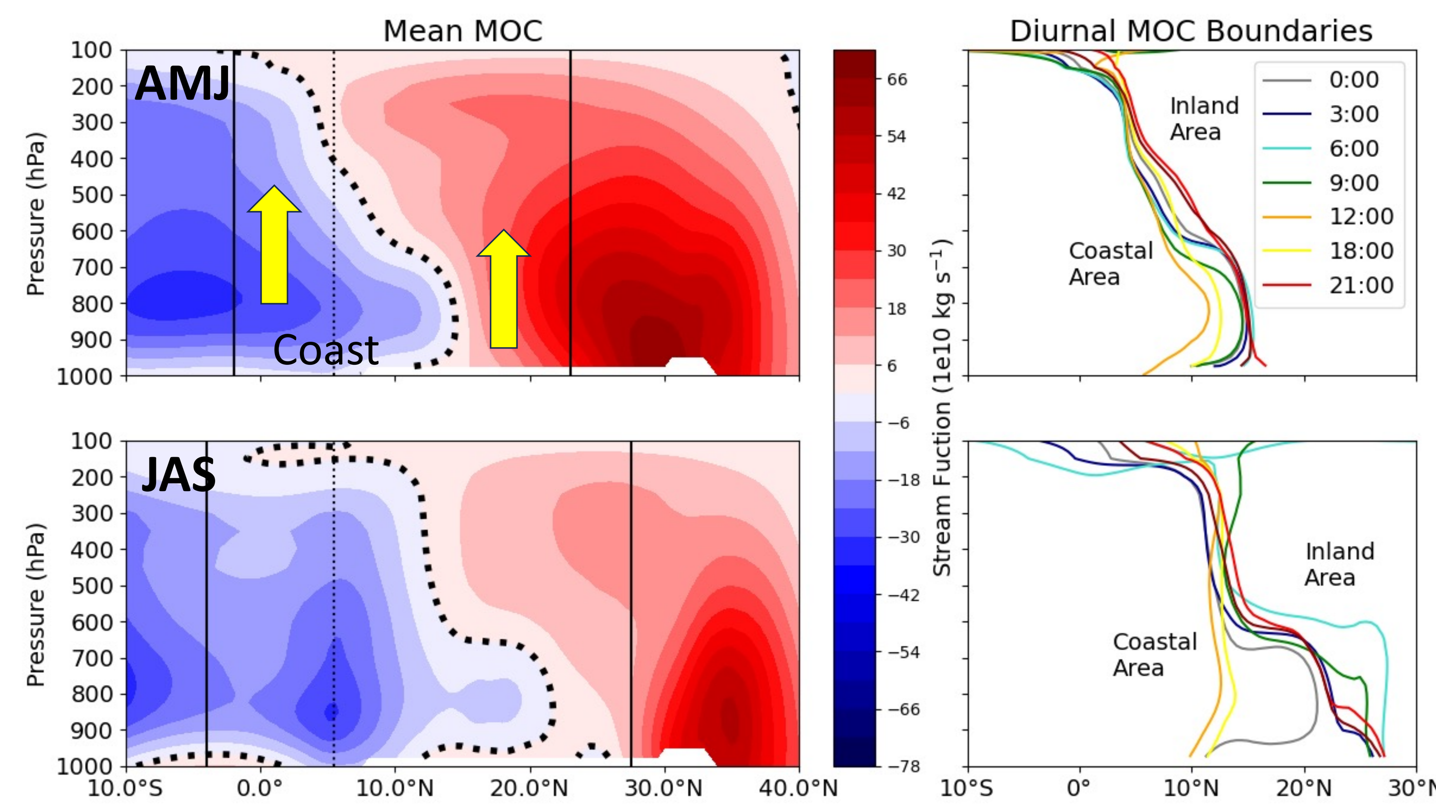
a = planetary radius, φ = latitude

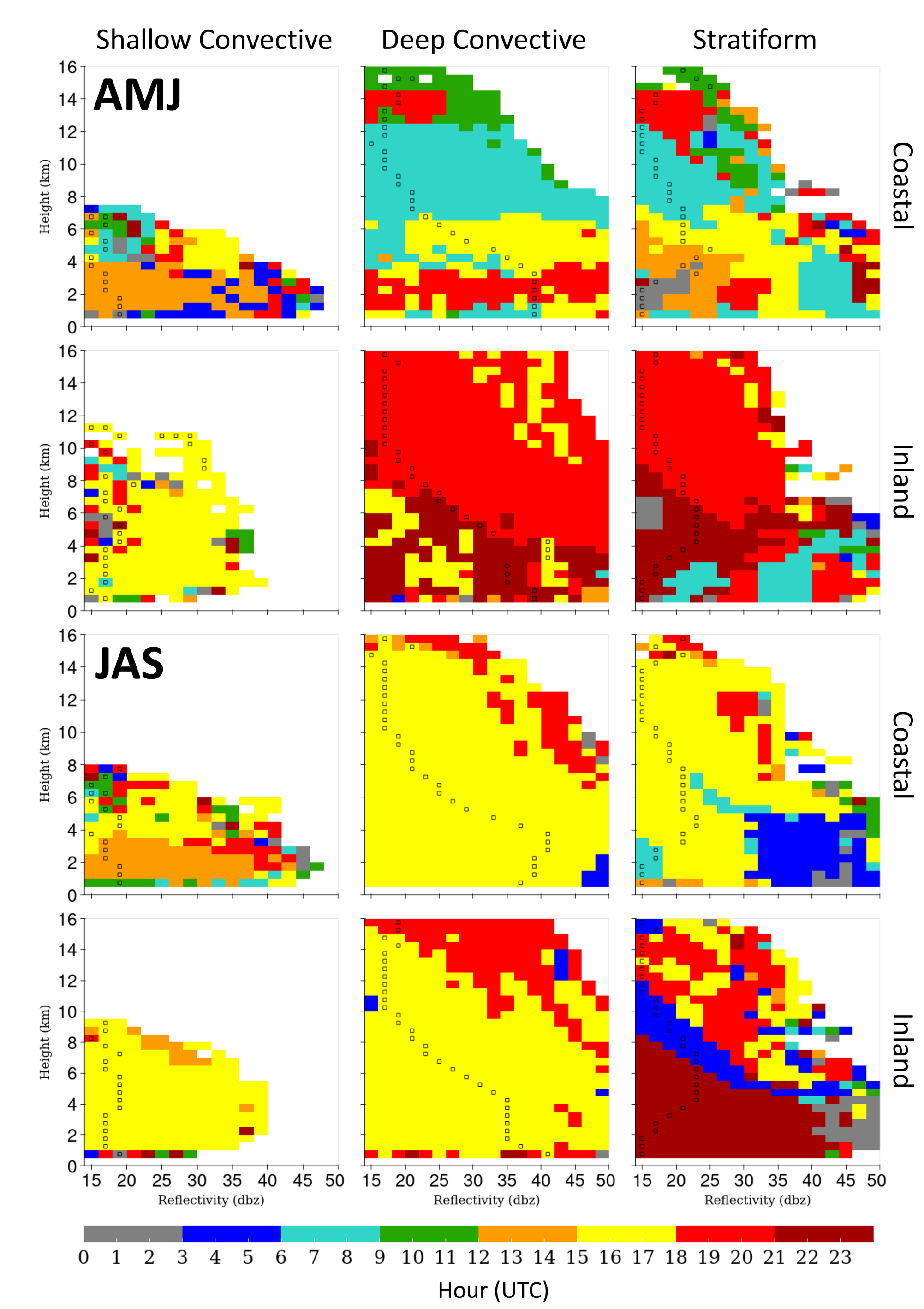
- CAM5 (0.25° resolution) MOC and rain rates (2017-2019)
- IMERGv7 rain rates (2017-2019)

Objectives

1. Analyze the seasonal and diurnal variations in the MOC and vertical reflectivity structures for West Africa and the East Atlantic during the pre-monsoon and monsoon seasons
2. Assess the simulated MOC and total rainfall from CAM5 over West Africa and the East Atlantic

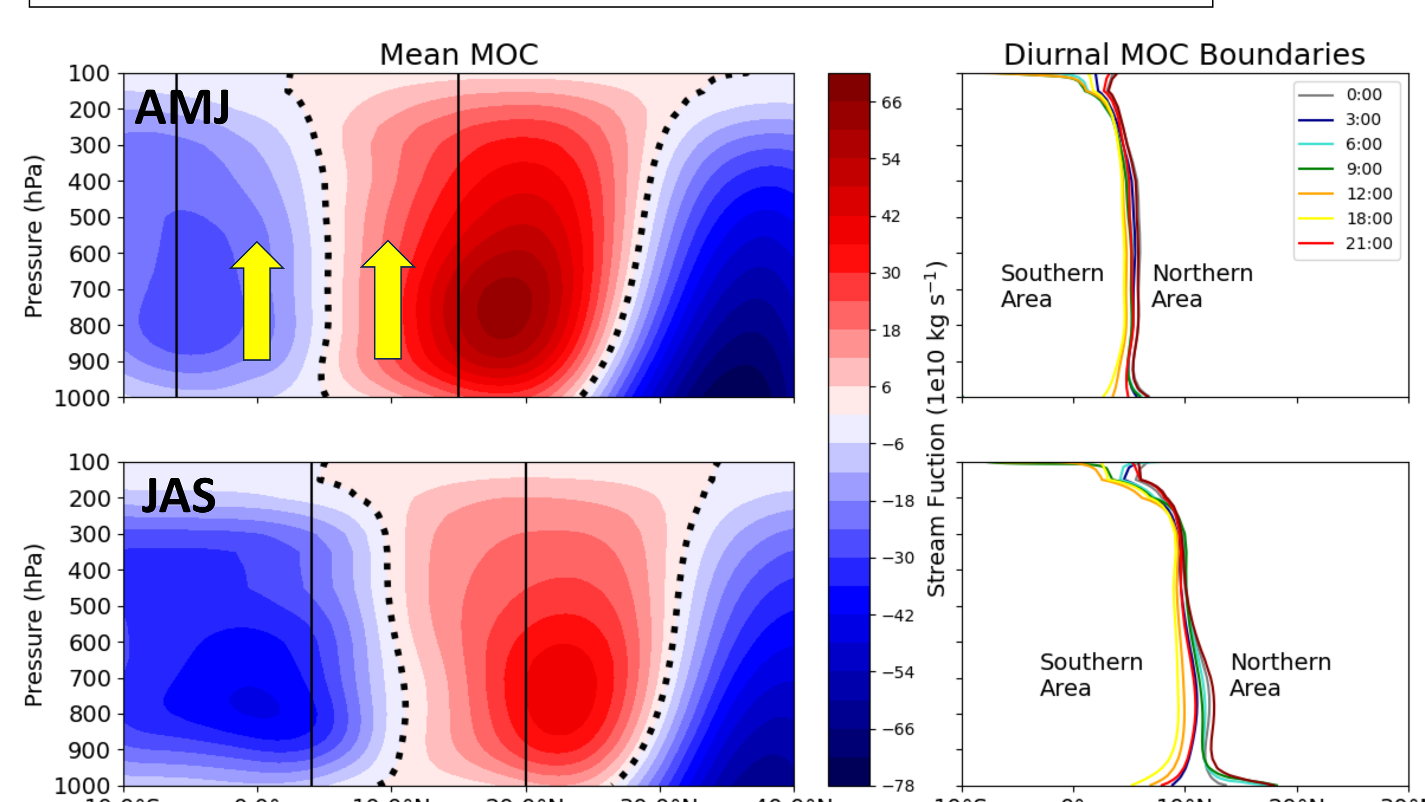
West Africa

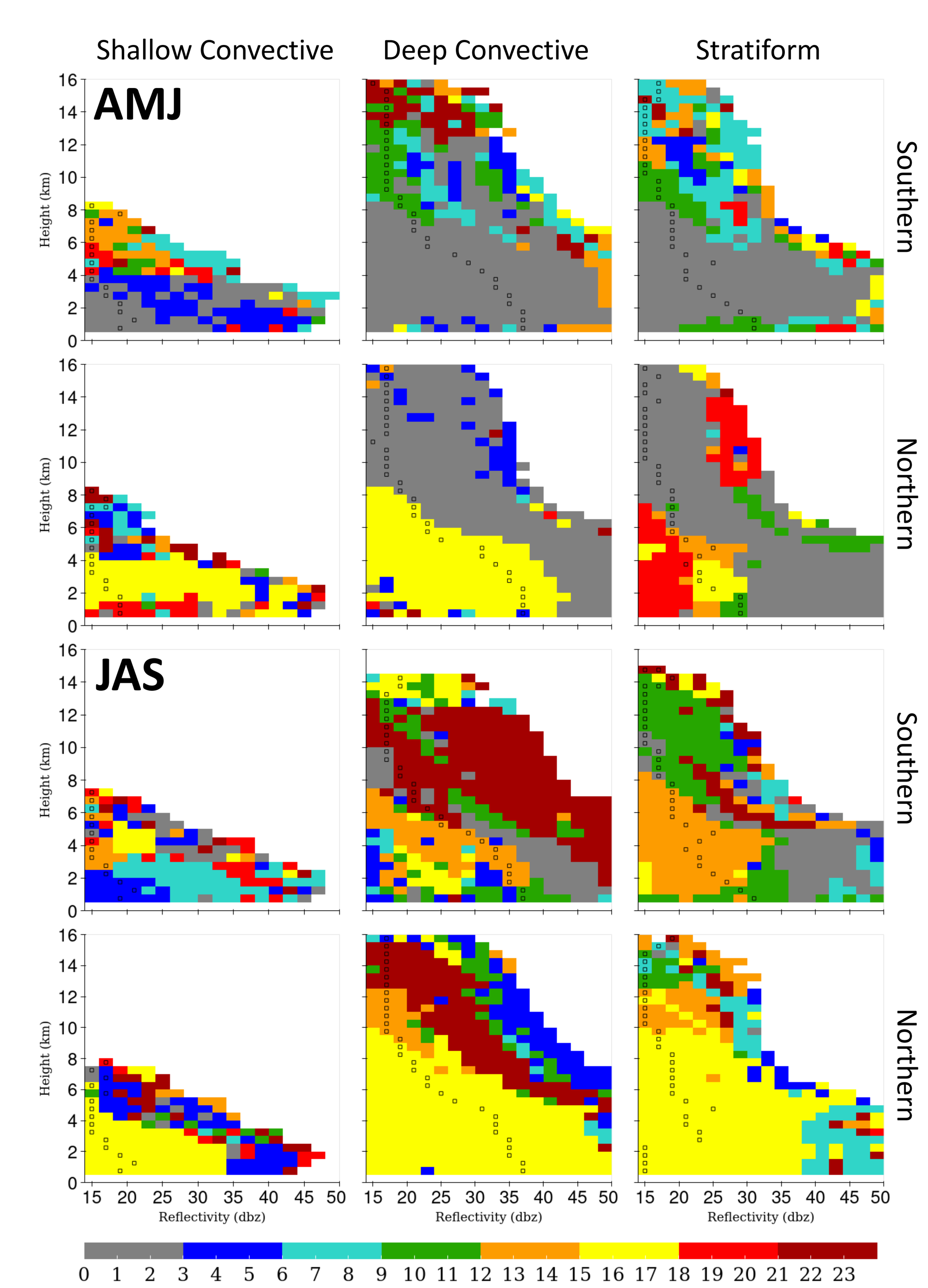




- MOC shows strongly slanted vertical structure over West Africa
- MOC shallow nose (below 700 hPa) closest to the coast at noon and rapidly transitions north, more extreme transition in JAS
- Inland shallow convective rain occurs later and deepens more quickly than coastal area, promoting evolution of shallow nose in both seasons
- More gradual evolution of deep convective and stratiform rain in AMJ causes more vertically-oriented boundary in late evening
- Rapid deep convective growth in the afternoon deepens nose in JAS

East Atlantic Ocean

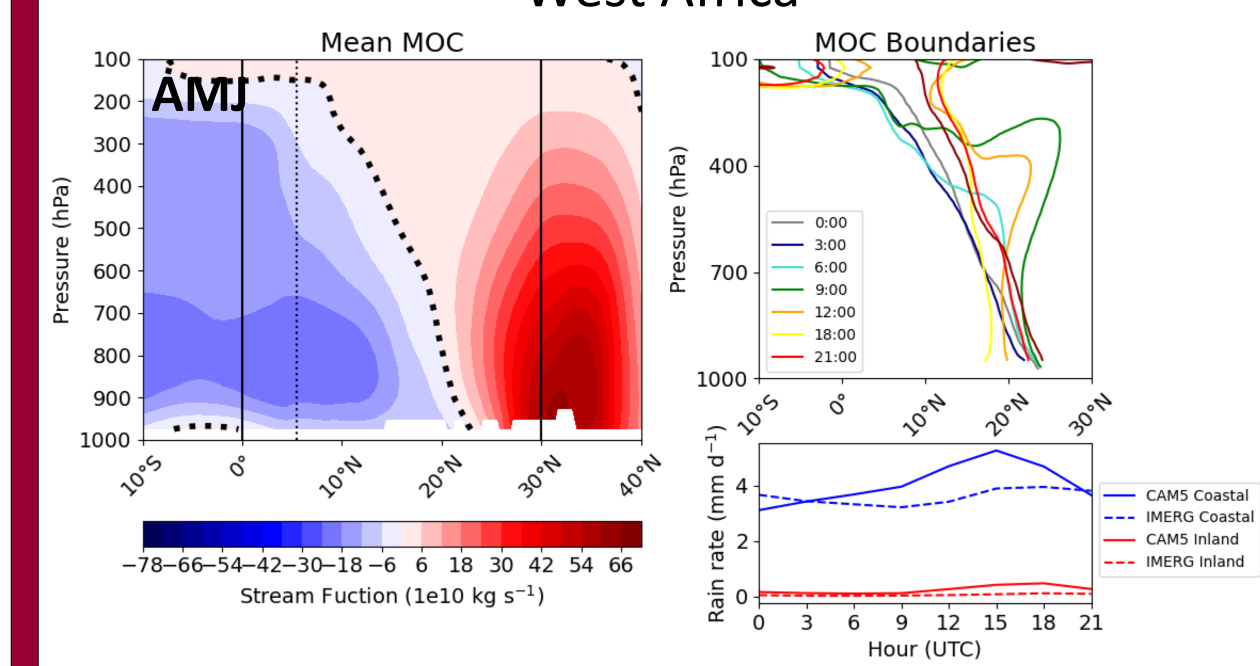




- MOC is vertically oriented over tropical East Atlantic
- Very little diurnal variability in MOC boundary except near surface in JAS
- Southern area storms (i.e., not influenced by land) evolve gradually in height during night, associated with more vertical boundary
- Proximity to West Africa causes northern area storms to maximize in the afternoon at low levels, esp. in JAS, but deeper clouds occur at night
- Ongoing work is linking the strength of the MOC to the 3D reflectivity structure and timing

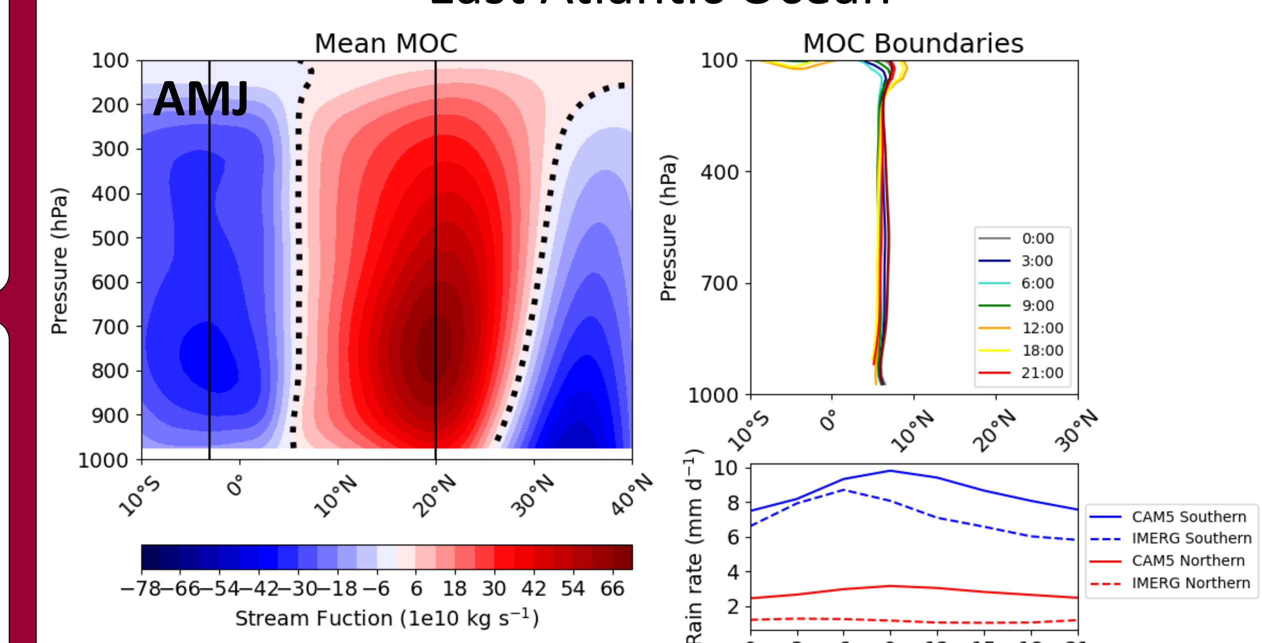
CAM5 (AMJ)

West Africa



- CAM5 has weak MOC aloft + boundary too far north
- Weak low-level/strong upper-level diurnal boundary changes
- CAM5 overestimates afternoon peak in rainfall, when upper-level MOC boundary is too vertical from 9-12 UTC

East Atlantic Ocean



- CAM5 MOC oceanic structure generally similar to MERRA-2
- Stronger MOC in CAM5 may be associated with rainfall over-overestimation

Conclusions

- The MOC over West Africa shows strong diurnal variability, with extreme latitudinal and vertical variations likely linked to storm type development
- The MOC over the East Atlantic has much less seasonal and diurnal variability, although influences from West Africa affect the MOC and storm structures in JAS
- While CAM5 captures elements of the regional MOCs, issues remain with location, diurnal timing, and strength

Acknowledgements

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Huaman, L., C. Schumacher, A. H. Fink, and E. Buttitta, 2023: Diurnal variations of the meridional overturning circulations over West Africa during the premonsoon and monsoon seasons. *Quart J Royal Meteoro Soc*, qj.4533. https://doi.org/10.1002/qj.4533.