Diurnal vagaries over the Amazon in CESM

Hedanqiu Bai, Courtney Schumacher, Evandro Anselmo, Luiz Machado

Department of Atmospheric Sciences, Texas A&M University

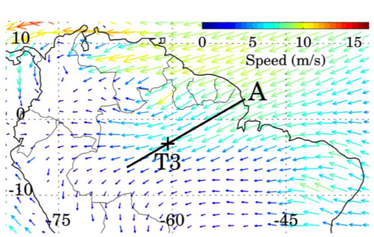
1. Introduction

General circulation models (GCMs) significantly underestimate March-April-May (MAM) precipitation over the northeast coast of Brazil (Richter et al. 2012; 2014) and have difficulties correctly simulating the timing of convection and its growth from shallow to deep over much of the Amazon (e.g., Betts and Jakob 2002). A nocturnal Amazonian low-level jet (ALLJ) was recently diagnosed using reanalysis data (Anselmo et al. 2019). Its inland extent maximizes during the transition from the Amazonian wet to the dry season in MAM.

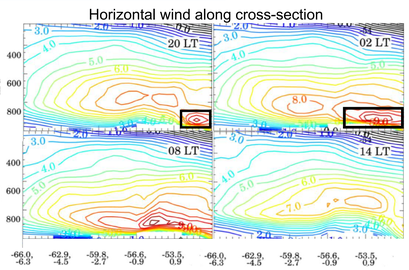
Are GCMs capable of simulating an accurate ALLJ? How does the timing of coastal convection in relation to the ALLJ impact Amazonian rainfall? Are there remote impacts caused by changes in Amazonian convection?

2. The Amazonian low-level jet (ALLJ)

Vertical wind structure

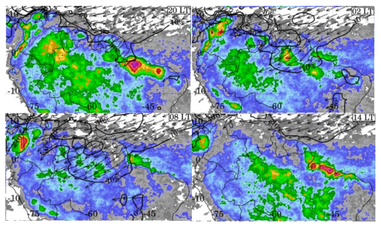


Horizontal wind along cross-section



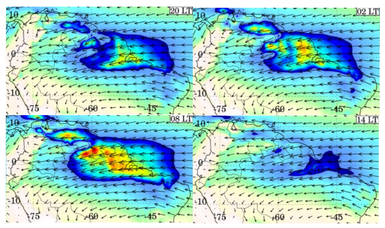
- MERRA2 wind fields from MAM 2014-15 (the years of GoAmazon2014/5) show that a low-level jet initiates in the evening (~20 LT) at the coast and strengthens as it propagates inland. It peaks in strength and extent in the early morning (between 5-8 LT).

Horizontal extent



- Using objective wind criteria, the ALLJ is shown to occur over the central Amazon at least 10% of the time during MAM (solid black contour). It is strong enough to show in the wind climatology above and can be linked to enhanced cloud cover (shading).

Moisture flux

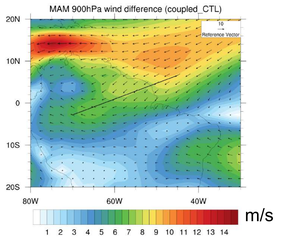


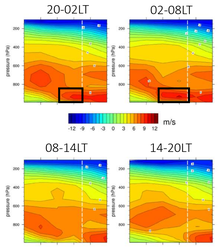
- The vertically integrated moisture flux between 925 and 600 hPa shows a diurnal cycle and horizontal extent that is very similar to that of the ALLJ. We postulate that the nocturnal jet brings moisture in the central Amazon in the evening hours that can then enhance convective development overnight and into the next day.

3. Coastal convection timing

Model experiments

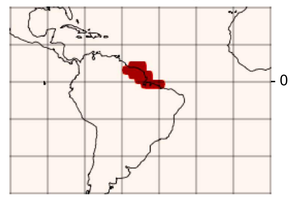
Coupled CTL (5-year average)

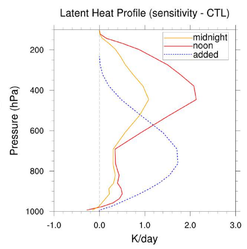




- The fully coupled CESM1.2.2 run at 1.9º x 2.5º resolution produces a realistic ALLJ in MAM (left). However, atmosphere-only CAM5 does not because of land temperature biases (not shown).

Horizontal added heating structure



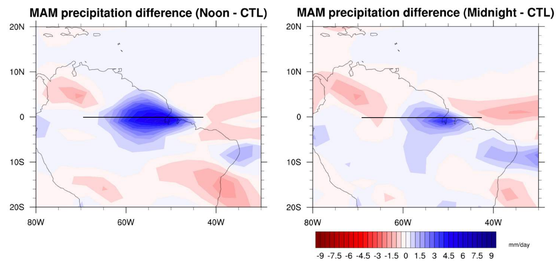


Control (CTL): 5-year CESM1.2.2

Noon (midnight) experiment: same as CTL, but with bottom-heavy heating (equivalent to 3 mm/day of precipitation) added each day at local noon (midnight) along the coast for 2.5 hours during MAM to mimic sea breeze convection.

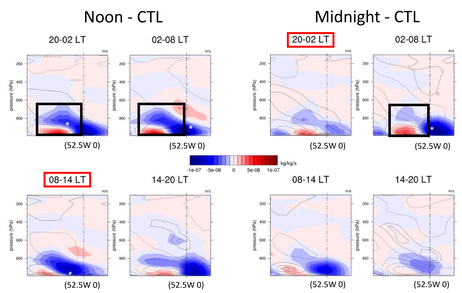
- Heating elevates the following 6 hours in both experiments, but much more so in the noon heating experiment because of the match with the onset of the ALLJ.

Changes in precipitation



- The 5-year MAM rainfall increases more in the noon experiment than in the midnight experiment
- Moreover, the rainfall propagates further inland in the noon experiment

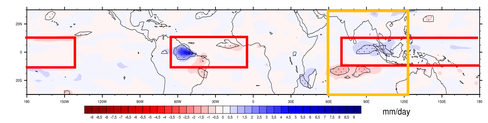
Changes in moisture flux



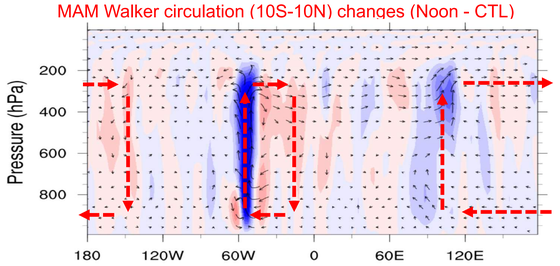
- When low-level heating is added during the early afternoon, the ALLJ transports moisture inland from the ocean, enhancing deep convection development and rainfall across the Amazon basin during the ensuing evening hours
- When low-level heating is added during the night, convection does not deepen as much and the effect of the ALLJ is transient, thus transporting less moisture than in the noon case

4. Remote impacts

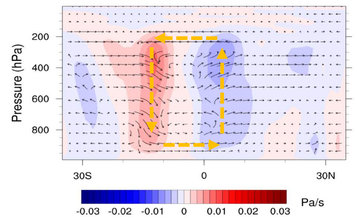
MAM precipitation difference (Noon - CTL)



MAM Walker circulation (10S-10N) changes (Noon - CTL)



MAM Meridional circulation changes over the Indian Ocean



- The noon case (30-year average) shows remote impacts of the enhanced Amazonian convection, including changes in precipitation over southeastern South America, the East Atlantic ITCZ and the Indian Ocean
- The strength of both the Atlantic and Pacific Walker circulations increase, while the Hadley cell over the Indian ocean weakens
- The extra energy added to the model may be redistributed by tropical waves and extratropical wave trains as the model balances itself, thus leading to remote responses outside the Amazon

5. Conclusions

A newly discovered low-level jet over the Amazon helps transport moisture inland from the ocean, thus enhancing deep convection development over the Amazon basin – **this is seen in both observations and CESM1.2.2.**

Diurnal circulations, such as low-level jets and the timing of shallow convection, matter to the organization of convection and overall rain across the Amazon.

Local changes in the representation of diurnal circulations in GCMs can impact the mean climatology of a particular region and cause remote impacts felt across the globe.