Key processes associated with diurnal cycle of rainfall over the east Amazon and its representation in HIRES CAM6

Xianan Jiang[1,2], Patrick Callaghan[3], Adam Herrington[3], Julio Bacmeister[3], Rong Fu[1], Joao Teixeira[2], and Rich Neale[3]

[1] University of California, Los Angeles, Los Angeles, CA
[2] Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA
[3] National Center for Atmospheric Research, Boulder, CO

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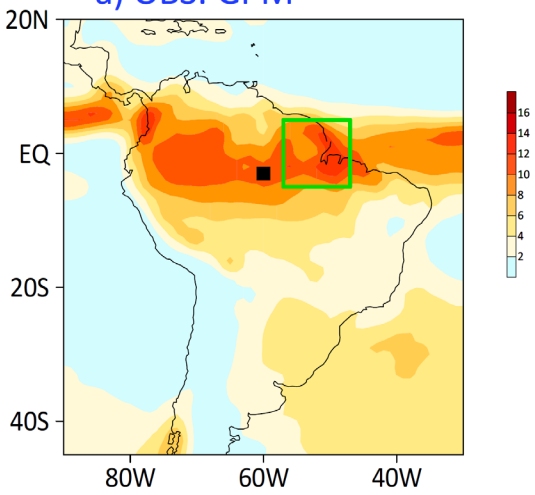
A crucial role of the Amazon River Basin in global hydrological and carbone cycles

Credit: NASA

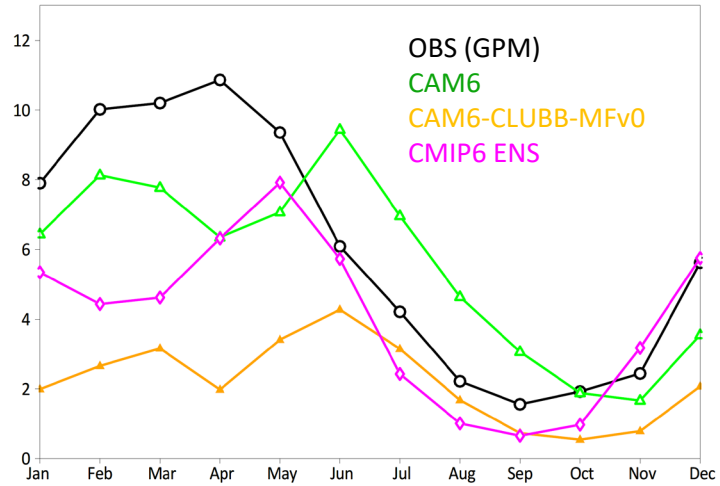
Credit: Neil Palmer/International Center for Tropical Agriculture

Model biases in simulating boreal Spring seasonal mean (March-May, MAM) precipitation over the east Amazon

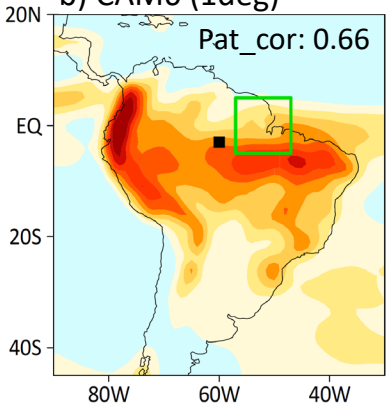
a) OBS: GPM



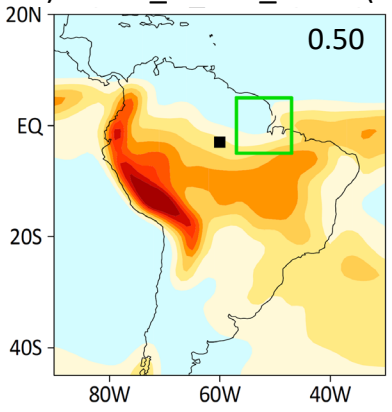
Annual cycle of rainfall over the east Amazon



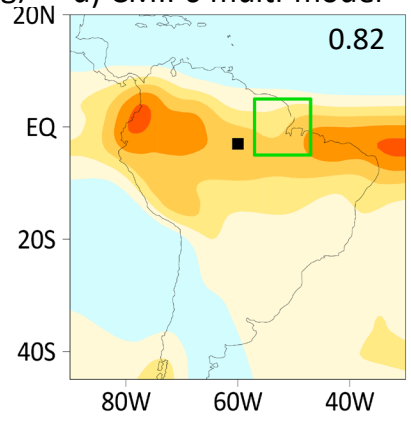
b) CAM6 (1deg)



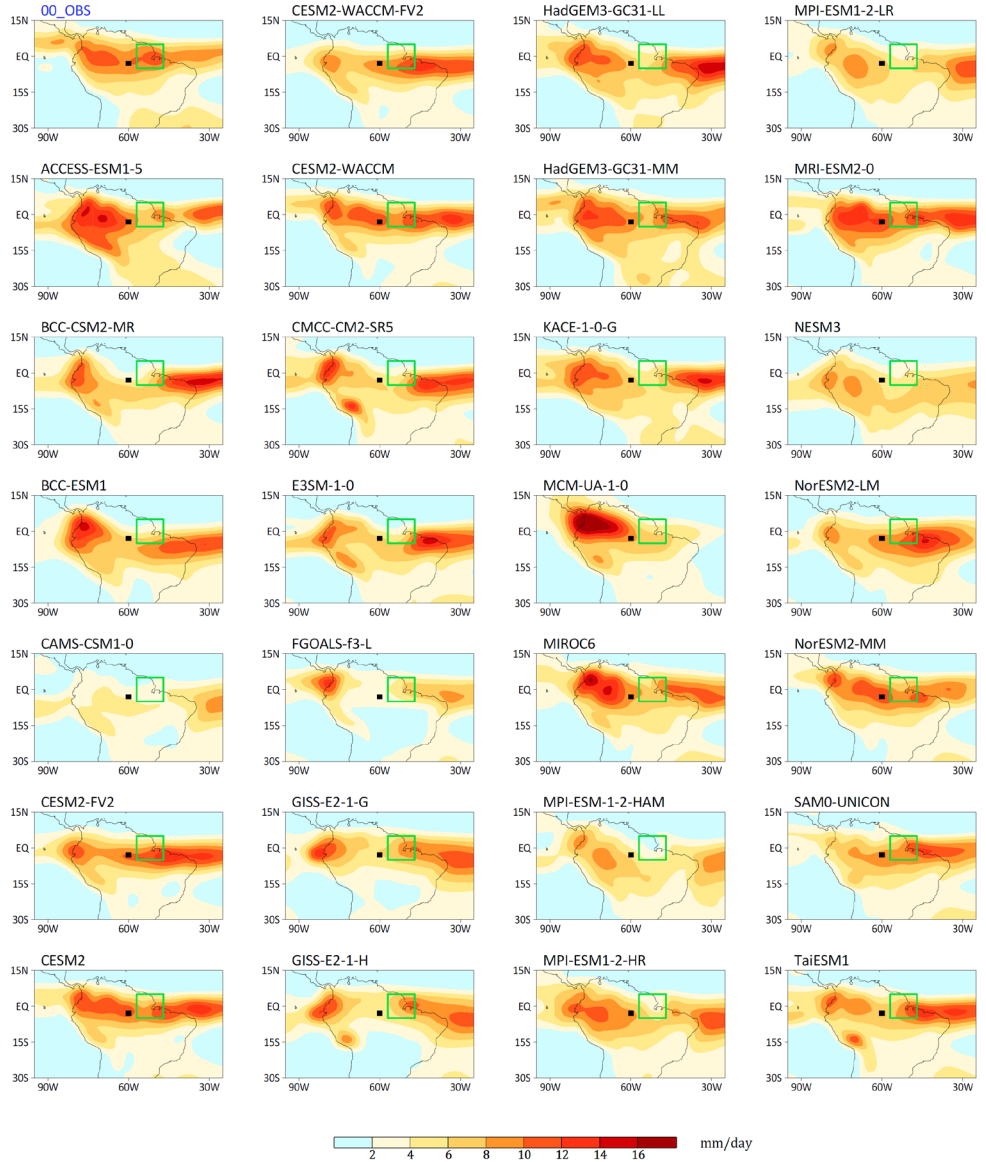
c) CAM6_CLUBB_MFv0 (1deg)



d) CMIP6 multi-model

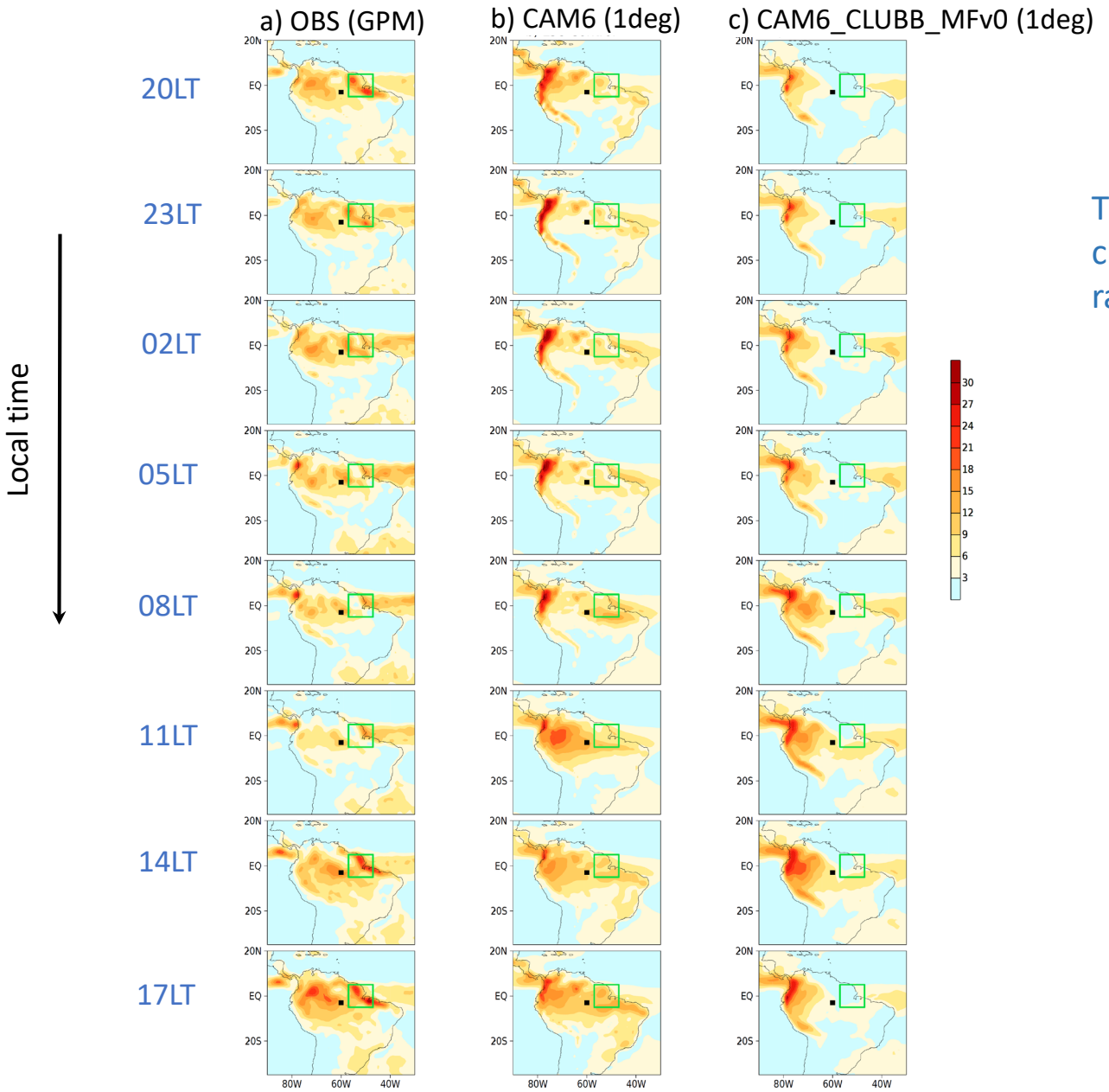


MAM mean precipitation in CMIP6 model simulations



Large model biases in mean precipitation over the Amazon basin, particularly an underestimate of rainfall maximum over east Amazon during boreal Spring (March-May, MAM).

Climatological diurnal cycle of rainfall (March-May; MAM)



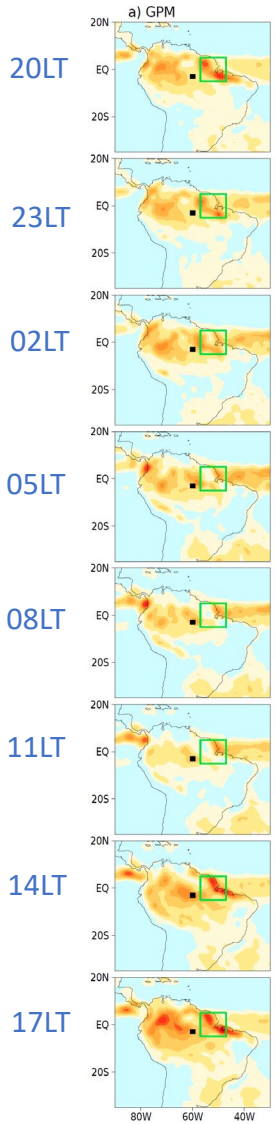
The observed precipitation over the east Amazon is closely associated with diurnal westward propagation rainfall events, but is poorly simulated in CAM6.

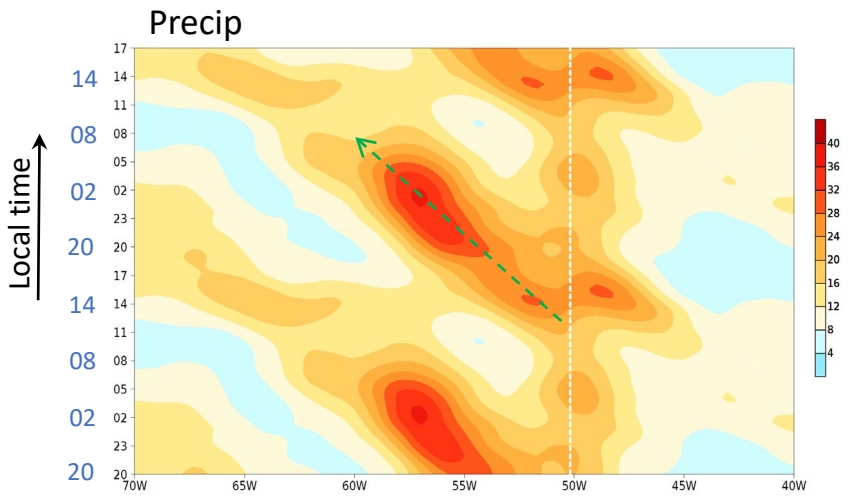
Outline:

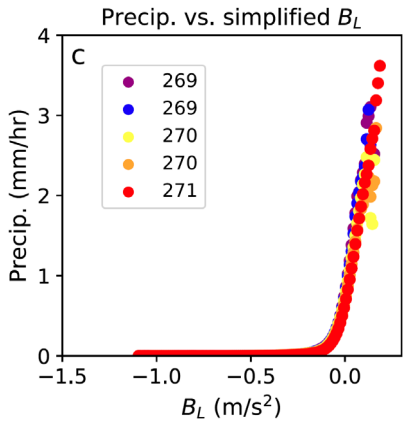
- What are the key processes regulating diurnal cycle of rainfall over the east Amazon?

- Can representation of diurnal cycle of rainfall over the east Amazon be improved in high-resolution CAM6 simulations?

What controls the westward propagation of diurnal rainfall events over the east Amazon?







Precip-Buoyancy framework

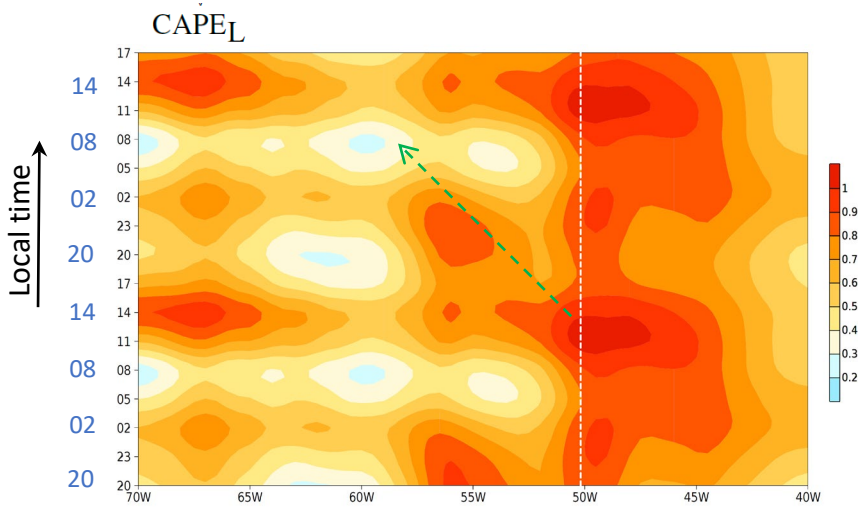
Ahmed et al. (2020)

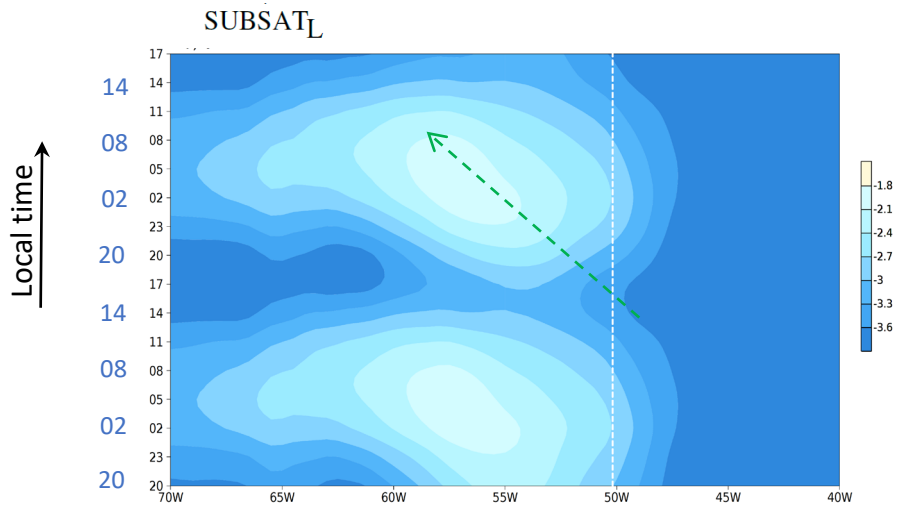
$$B_L = \frac{g}{\overline{\kappa}_L \theta_{e0}} \left[w_B \underbrace{\left(\frac{\theta_{eB} - \theta^*_{eL}}{\theta^*_{eL}} \right) \theta_{e0}}_{\mathrm{CAPE_L}} - w_L \underbrace{\left(\frac{\theta^*_{eL} - \theta_{eL}}{\theta^*_{eL}} \right) \theta_{e0}}_{\mathrm{SUBSAT_L}} \right].$$

PBL: 100hPa above surface

Lower Troposphere: PBL top -500hPa

$\theta_{e0} = 340$ K

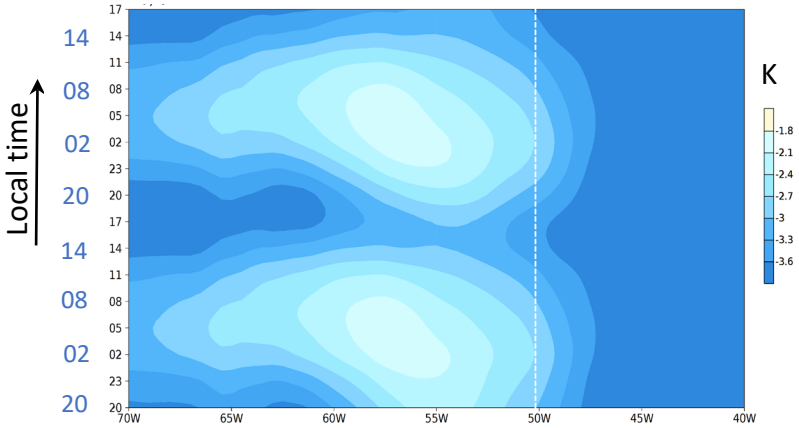




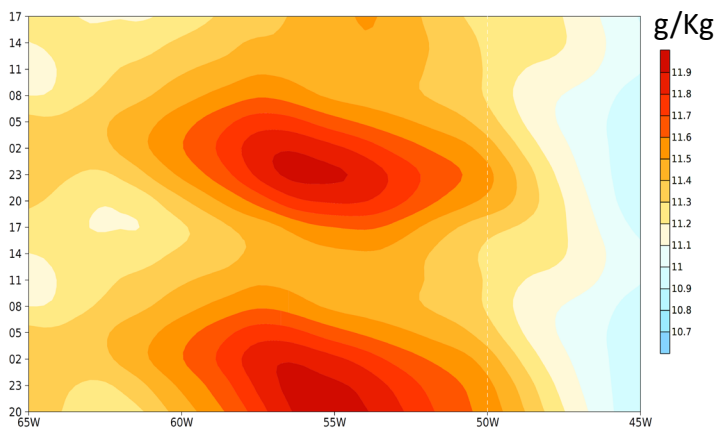
Westward propagation of the diurnal rainfall is collocated with reduced lower-tropospheric moisture deficit ($\mathrm{SUBSAT_L}$).

What controls the westward propagation of diurnal rainfall events?

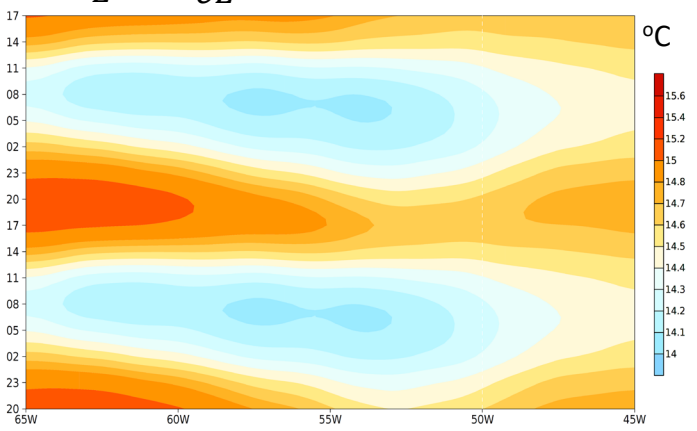
$\mathrm{SUBSAT_L} \sim \theta_{eL}, \theta^*_{eL}$



$q_L \sim \theta_{eL}$

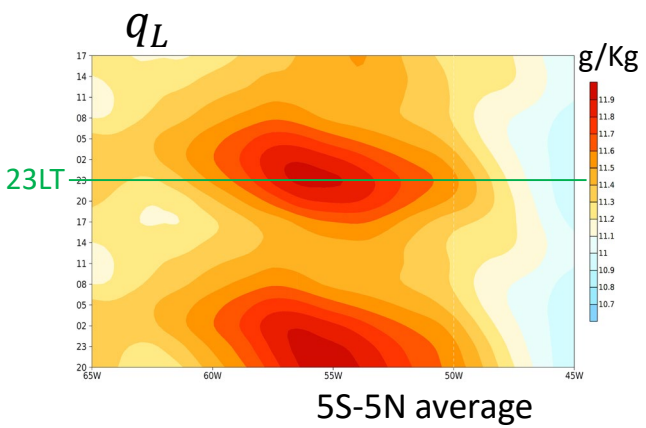


$T_L \sim \theta^*_{eL}$

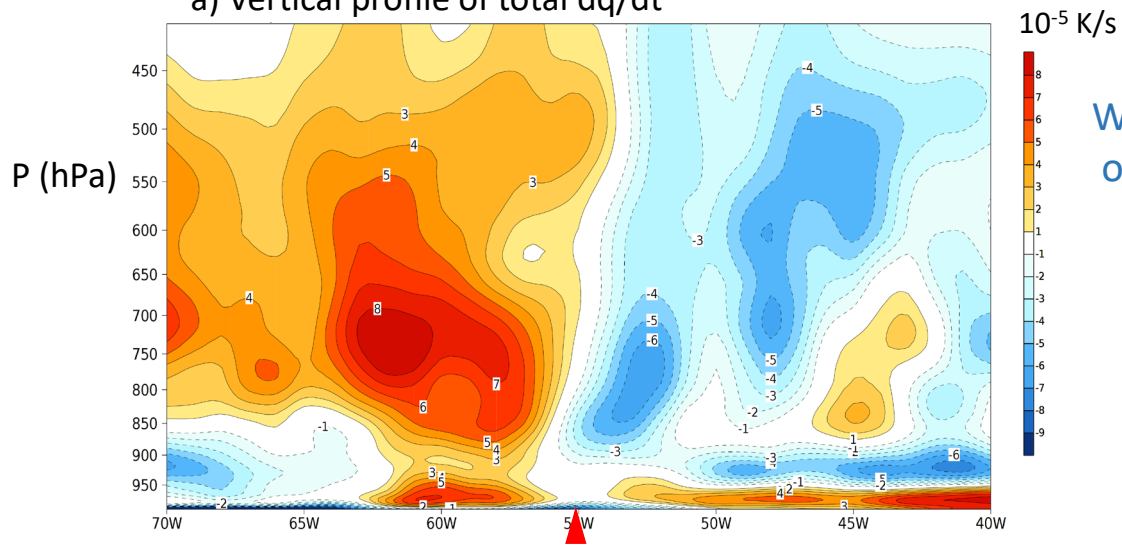


The diurnal westward movement of reduced moisture deficit is mainly controlled by enhanced moisture, and amplified by nighttime cooling over the land region west of convection center.

Moisture budget at 23LT based on EC-IFS: 2018-2019

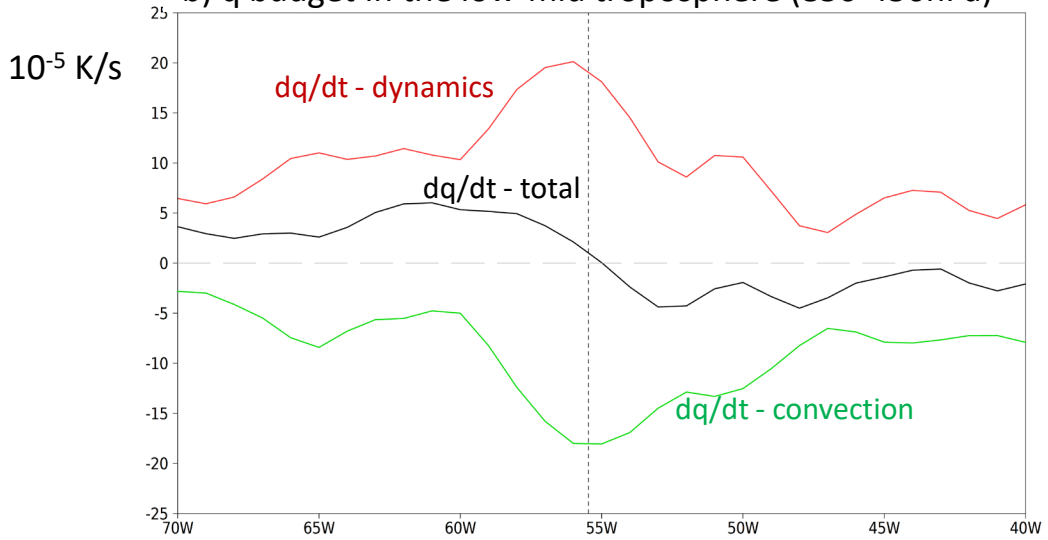


a) Vertical profile of total dq/dt

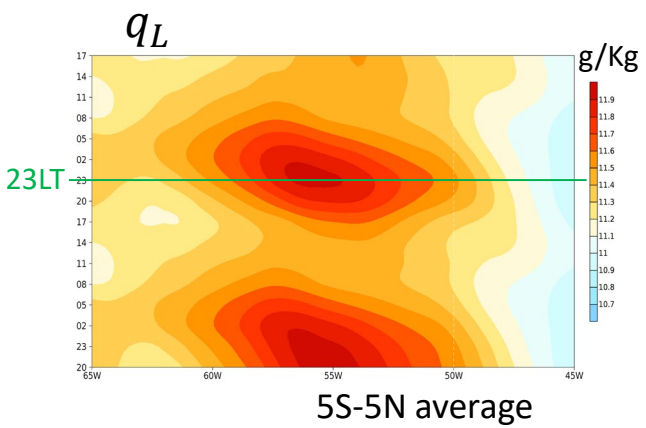


What leads to the westward propagation of lower-tropospheric moisture?

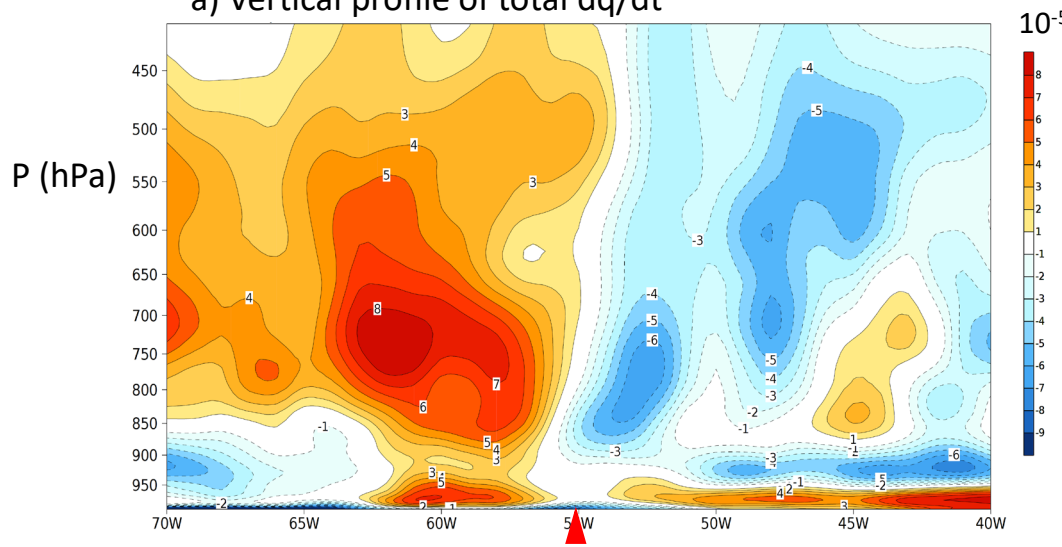
b) q budget in the low-mid troposphere (850-450hPa)



Moisture budget at 23LT based on EC-IFS: 2018-2019



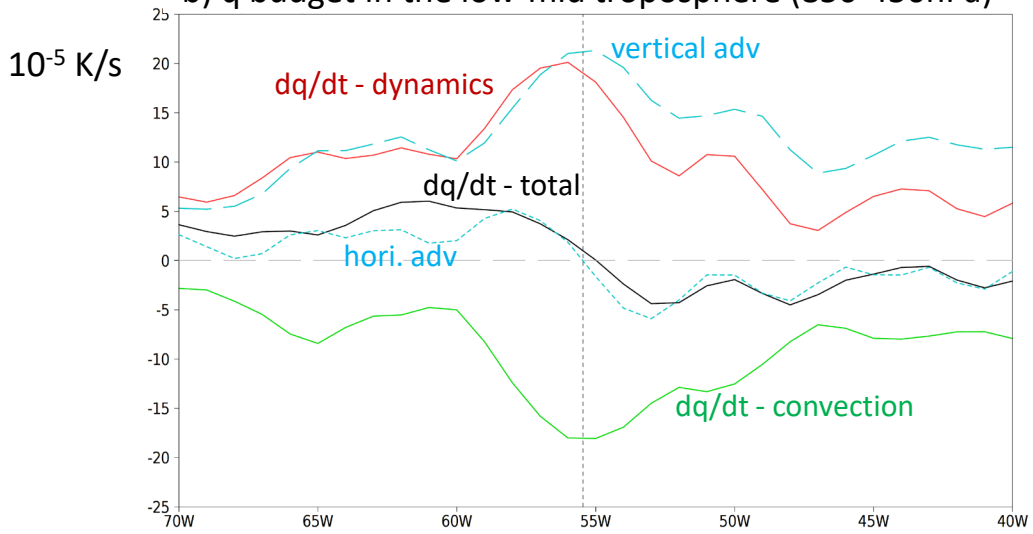
a) Vertical profile of total dq/dt



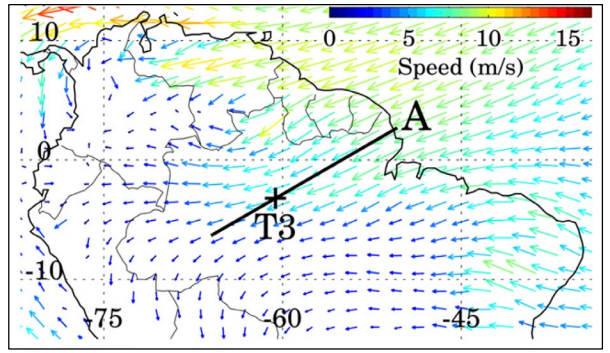
What leads to the westward propagation of lower-tropospheric moisture?

⇒ Horizontal moisture advection by the easterly low-level winds

b) q budget in the low-mid troposphere (850-450hPa)



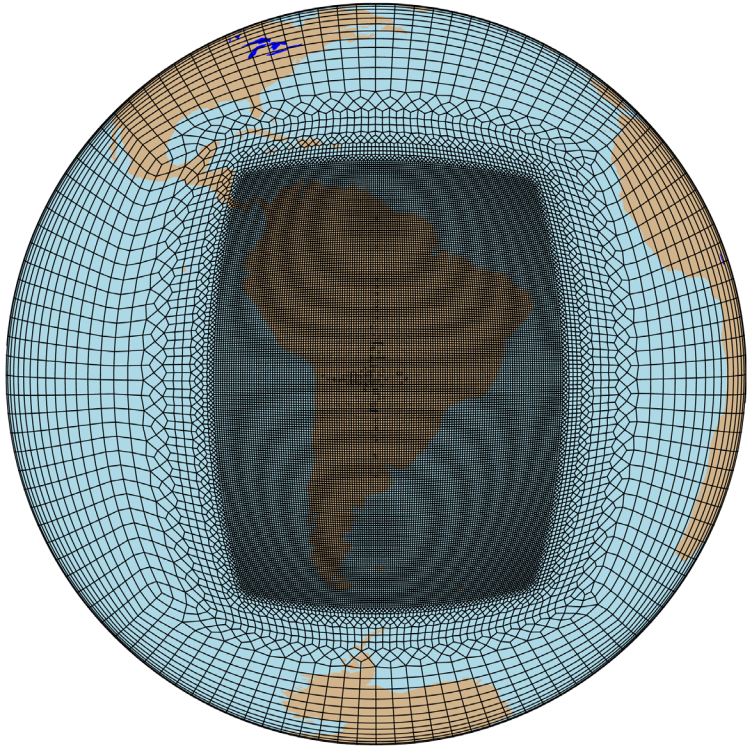
MAM mean 900hPa wind



Anselmo, et al. (2020): "Amazonian Low-Level Jet"

Simulation of diurnal cycle of rainfall over the east Amazon in high-res CAM experiments

Regionally refined grids over South America in CAM6 (details see Patrick's Talk)

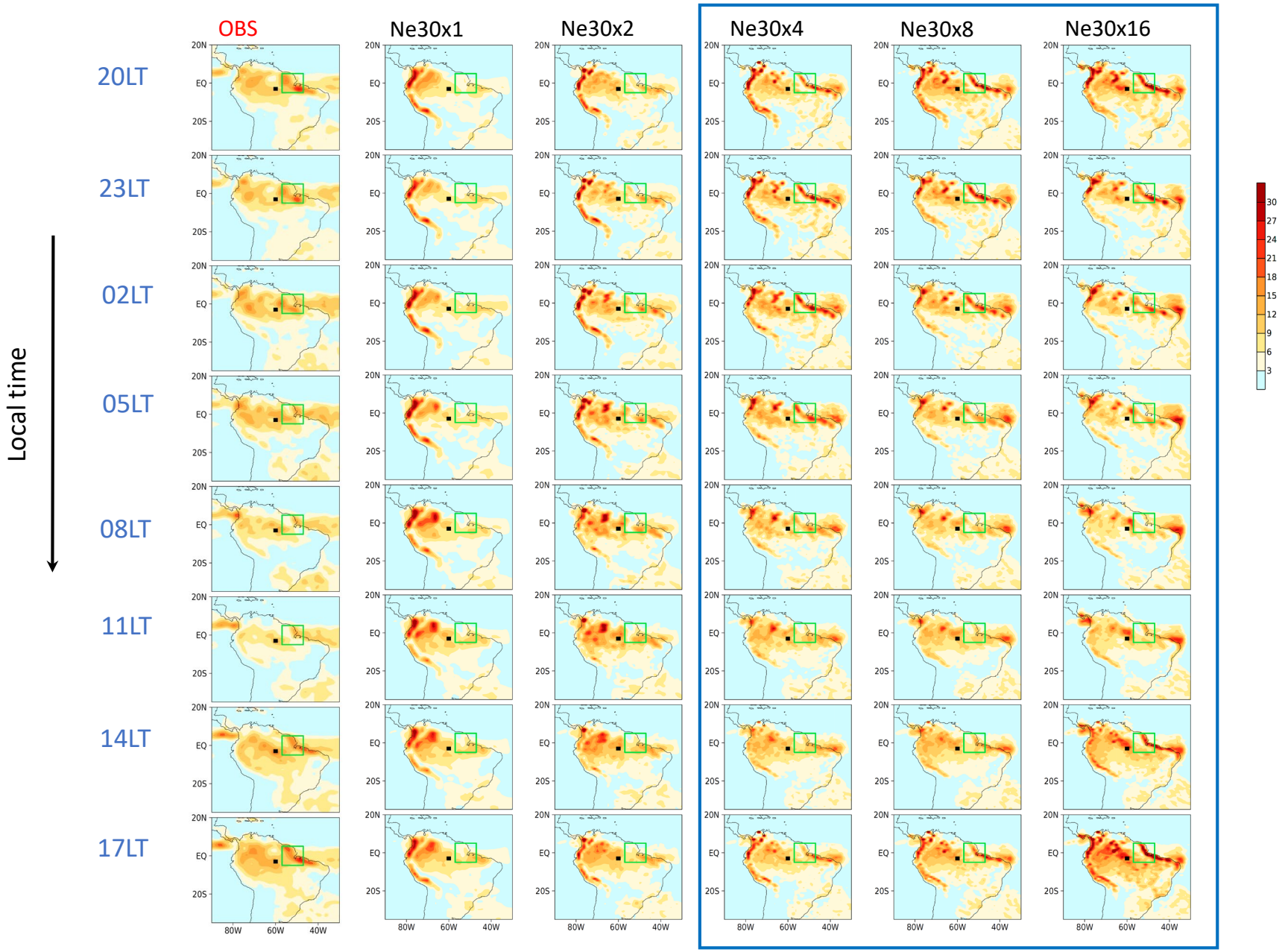


- Ne30x1 ~ 1 deg
- Ne30x2 ~ 0.5deg
- Ne30x4 ~ 0.25deg
- Ne30x8 ~ 14km
- Ne30x16 ~ 7km

Regions beyond the refined grids over SA is nudged to ERA reanalysis.

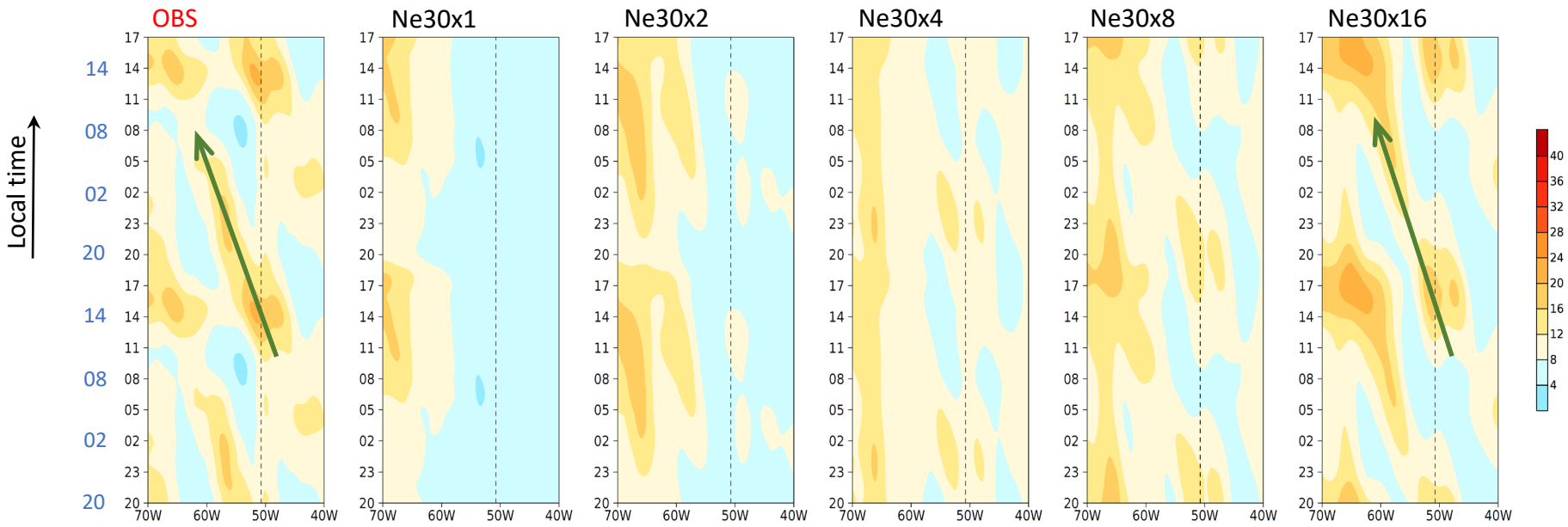
Three years: 2010/11, 2015/16, 2018/19.

Diurnal evolution of precipitation during March-May (2011,2016,2019) in CAM6 simulations



Diurnal rain belt over the east Amazon coast starts to emerge in simulations with horizontal resolutions < 0.25deg (Ne30x4, Ne30x8, Ne30x16).

Diurnal cycle of precipitation along EQ (mm/day; 5S-5N)



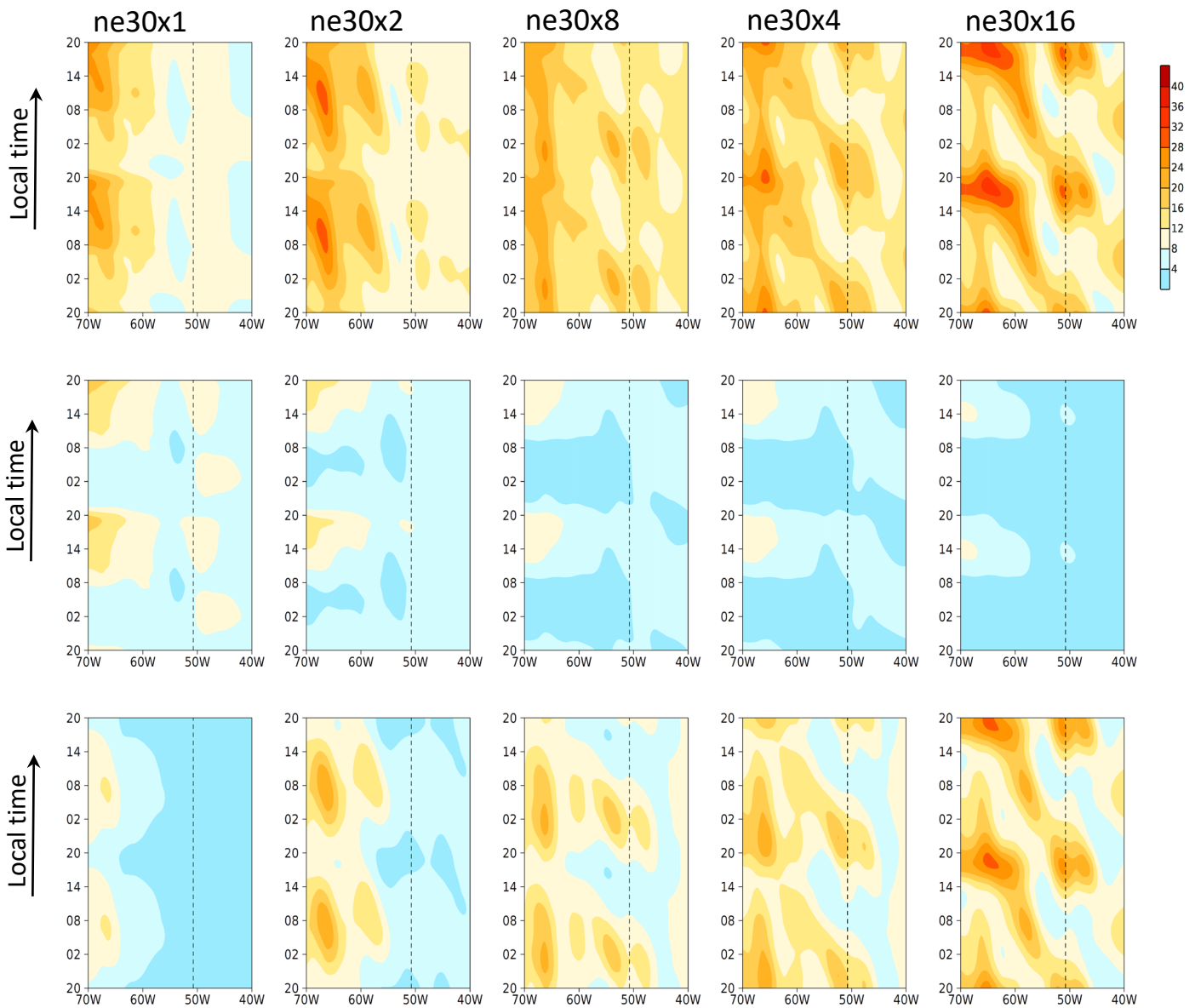
Resolved westward propagation of diurnal rainfall in high resolution runs, particularly in the x16 experiment (~7km).

Total diurnal precipitation by convective vs. large-scale precipitation

Total PREC

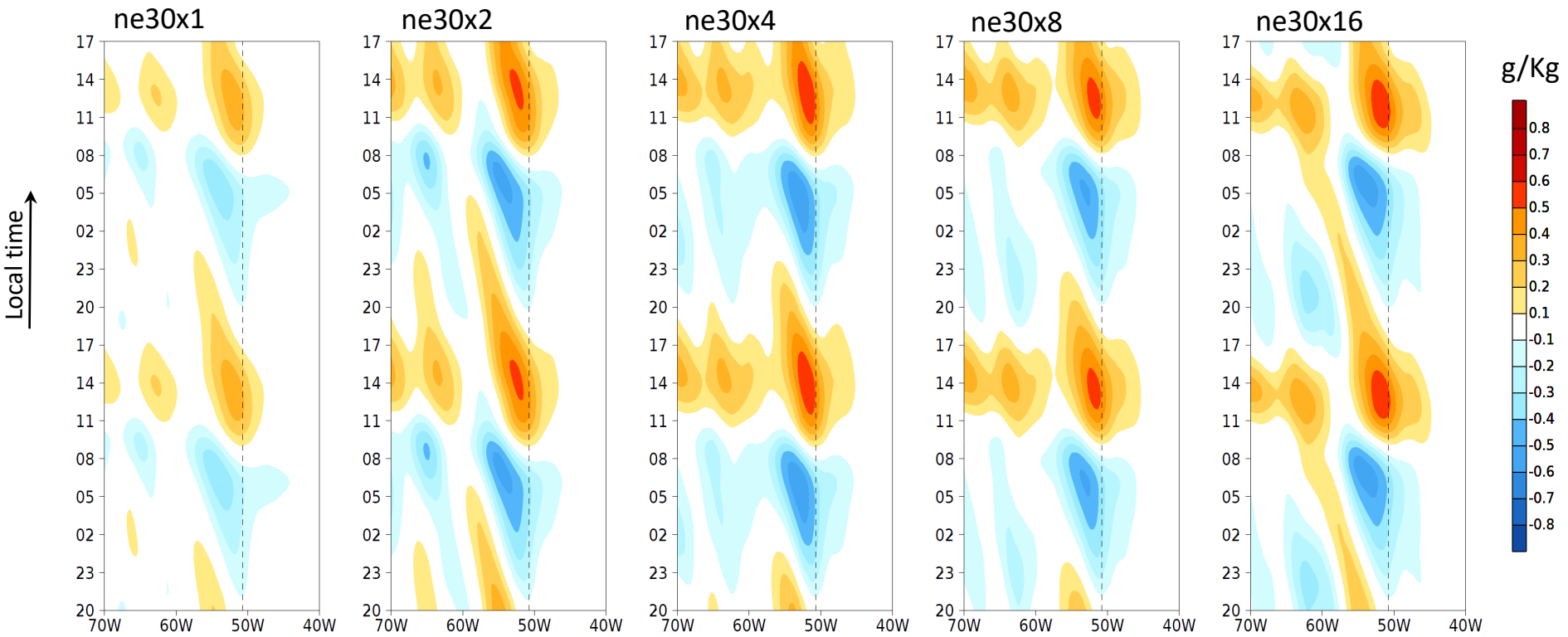
PRECC

PRECL



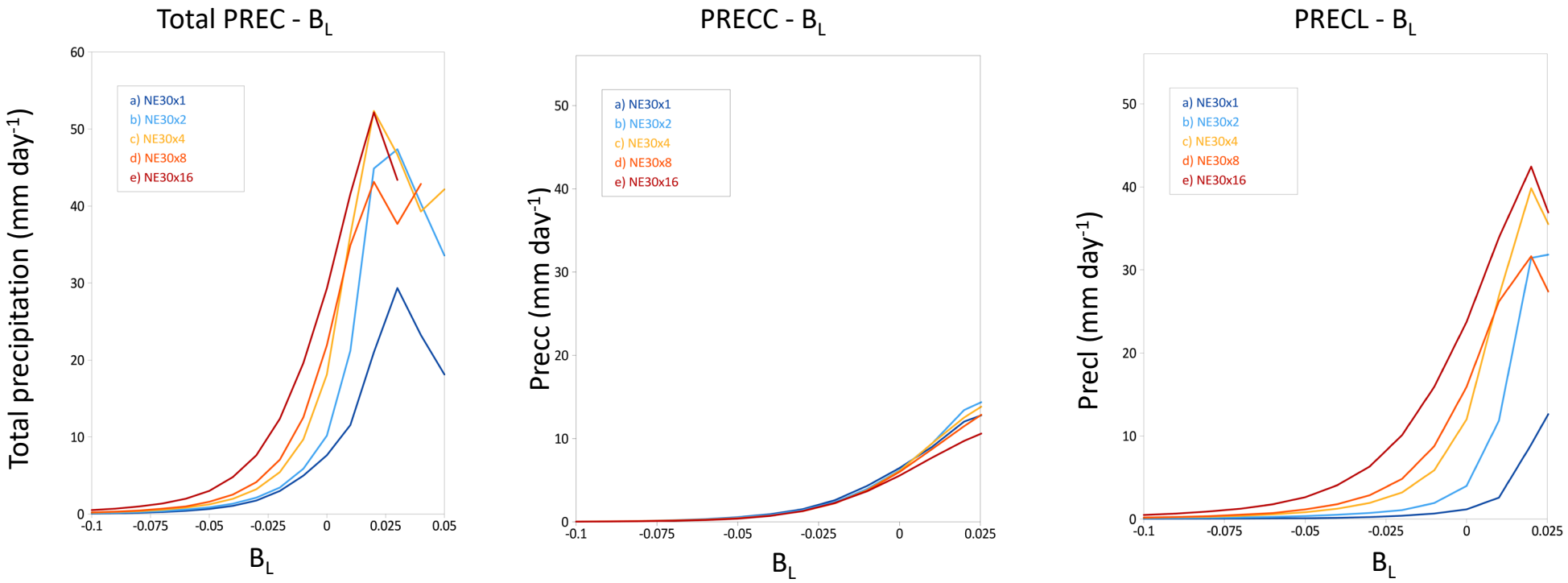
- PRECC decreases with increase of resolution.
- Improved diurnal rainfall is mainly through large-scale precipitation.

Diurnal evolution of 900-700hPa moisture along EQ (5S-5N) – **daily mean removed**



Westward propagation of low-level moisture is captured in all experiments, including low-res runs !

Precipitation versus lower-tropospheric buoyancy (B_L) over the east Amazon in CAM simulations



Improved rainfall in high-resolution CAM simulations is associated with higher sensitivity of PRECL to the lower-tropospheric buoyancy.

Summary:

- Diurnal cycle of rainfall is critical in defining seasonal mean precipitation over the east Amazon;
- The westward propagation of diurnal rainfall events is found to be closely associated with horizontal moisture advection by the easterly low-level winds over the east Amazon, and enhanced by nighttime cooling in the lower-troposphere over the land to the west of convection through reduced moisture deficit.
- CAM experiments suggest that a high-resolution with Δx < 0.25deg is needed to resolve the westward propagating diurnal events. The improvement of diurnal rainfall is mainly through enhanced sensitivity of large-scale precipitation to low-tropospheric buoyancy forcing.