High Resolution WRF Regional Climate Modeling for the Andes-Amazon Transition Region: Model Validation Early Results

Juan Pablo Sierra, Clementine Junquas, Jhan Carlo Espinoza, Hans Segura, Thierry Lebel, Miguel Saavedra, Jorge Molina-Carpio, Marcos Andrade, Thomas Condom, Laura Ticona, Jean-Emmanuel Sicart, Daniel Espinoza.

Université Grenoble Alpes, Grenoble, France

juan-pablo.sierra-perez@univ-grenoble-alpes.fr

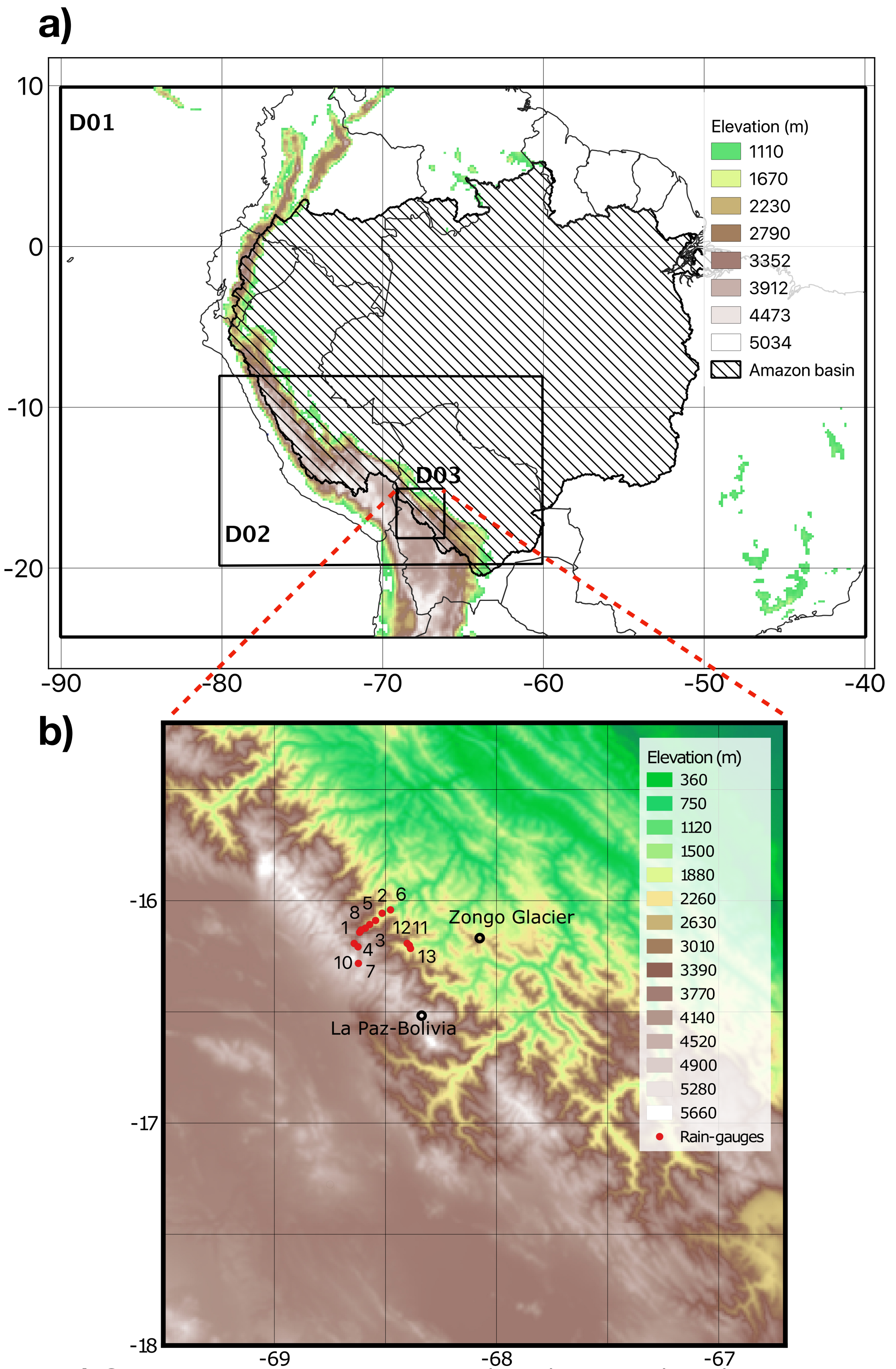
MAKE OUR PLANET GREAT AGAIN

Motivation

- Western Amazon and eastern flank of the Andes (a.k.a. Amazon-Andes transition region) is the rainiest area in the Amazon basin and is one of the most species-rich terrestrial ecosystems.
- The mechanisms controlling rainfall patterns in this region are poorly understood.
- Andes-Amazon accelerated deforestation rates threat the biodiversity hotspots and can induce alterations in surface energy and water balances.

Objectives

- Gain a better understanding in the mechanisms explaining precipitation over the Amazon-Andes transition region.
- Assess the impacts of Amazon deforestation on spatial and temporal rainfall variability during austral summer.



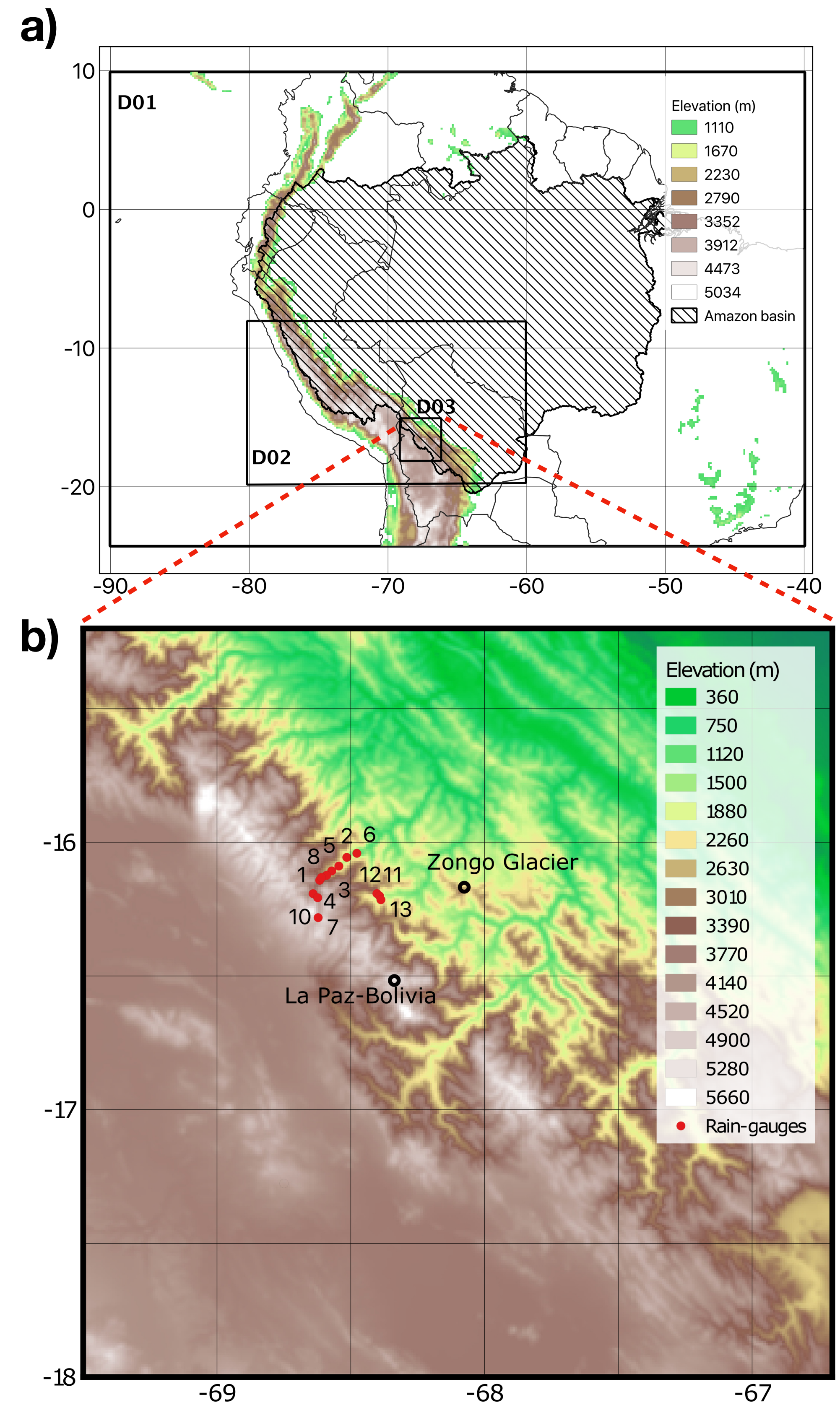
a) Simulation nests at 15 km (D01), 5 km (D02) and 1 km (D03) grid spacing. Regions above 1000m shaded. Hatched region correspond to the Amazon basin. **b)** Rain gauges inside domain 3 used for validation.

Data and Model Configuration

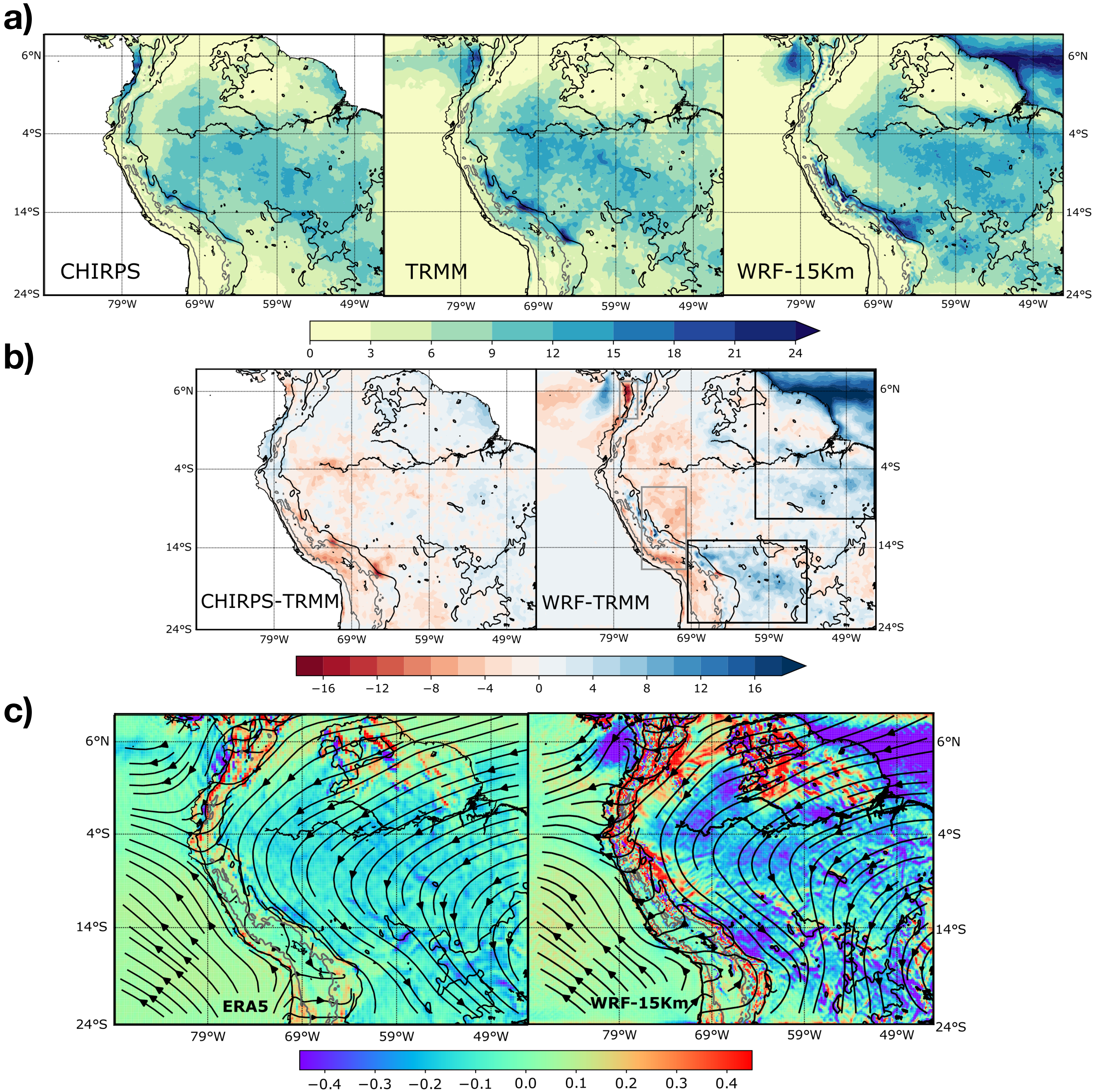
- Regional climate model WRF version 4.1 with 3 nested (one way nesting) domains. The domains grid sizes are 15 km, 5 km and 1 km. Time resolution each 3h for domains 1-2 and 1h for domain 3.
- Initial and lateral boundary conditions derived from ERA5 reanalysis.
- Land use data from Eva et al. 2004, a land cover map produced for South America.

	Parametrizations
Cumulus	Grell-Devenyi
Microphysics	Lin
PBL	YSU
Land surface	Noah
Surface layer	MM5
Radiation	RRTM

- ERA5 (27 km horizontal resolution, 6 h time resolution)reanalysis data for the evaluation of moisture fluxes.
- CHIRPS, TRMM 3B42 and 13 rain-gauge for rainfall assessment from the Peru meteorologic center SENAMHI , the Institut de Recherche pour le Developpement (IRD) and SNO GreatIce.
- **Preliminary study:** Analysis for the wet season 2001-2002 (December-January-February DJF). One month for spin-up is used.



a) Simulation nests at 15 km (D01), 5 km (D02) and 1 km (D03) grid spacing. Regions above 1000m shaded. Hatched region correspond to the Amazon basin. **b)** Rain gauges inside domain 3 used for validation.



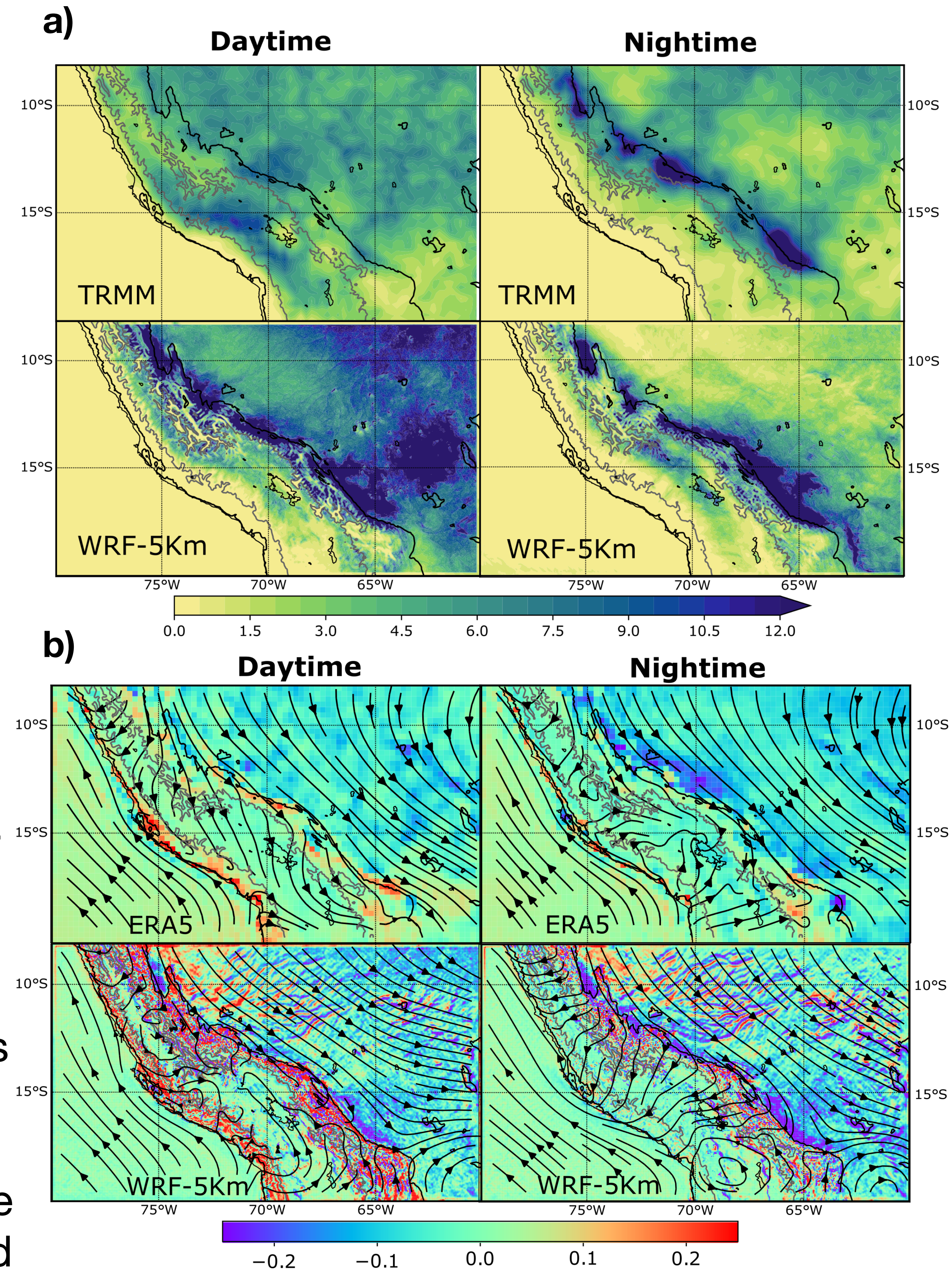
a) Seasonal DJF average precipitation (mm/day) from CHIRPS, TRMM and WRF for domain 1. **b)** Precipitation differences with respect to TRMM (mm/day). **c)** Seasonal average vertically integrated moisture flux divergence (shaded)(g/kg*kg/m2s) and moisture flux streamlines from ERA5 and WRF domain 1. Black and grey contours show 500 and 3500m orography.

Validation Domain 1 (15Km)

- **Well represented rainfall spatial pattern** (Fig a) and moisture fluxes (Fig c).
- Strong rainfall overestimation over the tropical Atlantic Convergence Zone, Bolivian Andes eastern flank and southern Brazil (Fig b black solid squares).
- Rainfall underestimation over the Colombian Pacific coast, northeastern Peru lowlands and Peruvian Andes highlands (Fig b gray solid squares).
- **Stronger convergence/ divergence respect to ERA5** (Fig c).
- **Matching between zones with overestimated (underestimated) precipitation and stronger convergence (divergence).**

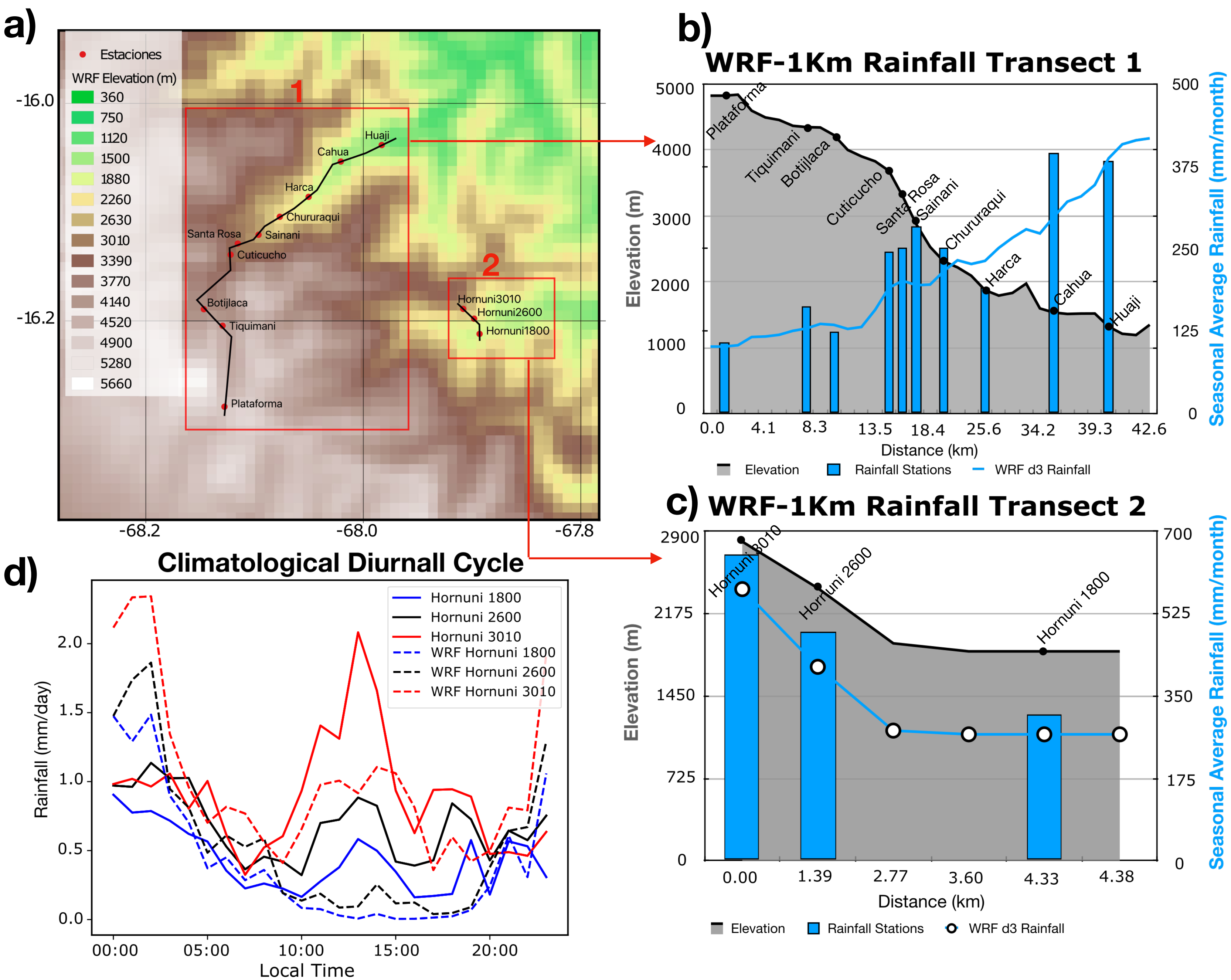
Validation Domain 2 (5Km)

- More precipitation during daytime (nightime) over the Andes highlands (lowlands) in both TRMM and WRF in agreement with previous studies (Garreaud 1999, Kikuchi and Wang 2008).
- Strong rainfall overestimation by WRF over Amazon lowlands and eastern Andes hillsides.
- Increased moisture convergence (divergence) during nightime (daytime) over the eastern piedmont (Andean hillsides) in both ERA5 and WRF.
- Daytime precipitation over Andes highlands is a consequence of solar heating which drives upslope flow. ERA5 and WRF represent this process as strong divergence in both eastern-western hillsides (Zangl and Egger 2005, Junquas et al. 2018).



a) Seasonal average precipitation for daytime and nightime (mm/day) from TRMM and WRF for domain 2. **b)** Seasonal average vertically integrated moisture flux divergence (shaded)(g/kg*kg/m2s) and moisture flux streamlines for daytime and nightime. Data from ERA5 and WRF domain 2.

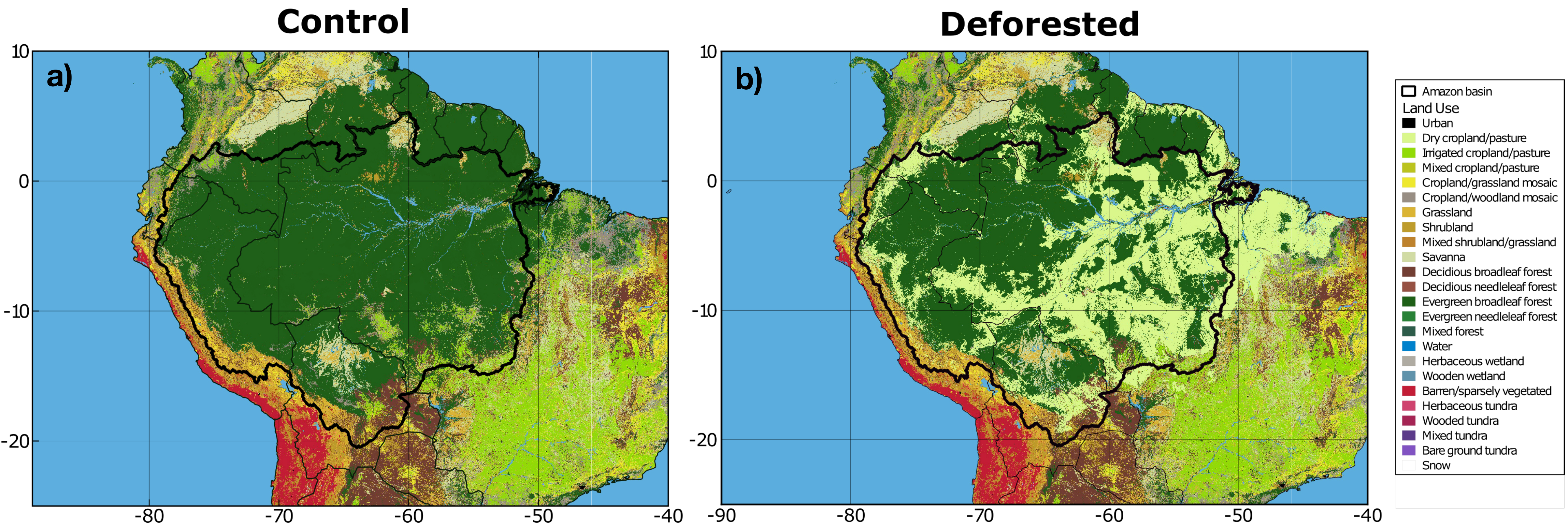
Validation Domain 3 (1Km)



a) WRF topography subsection in domain 3.The black line represents the axis of the cross-section illustrated in figures b and c. Elevation profile (gray) in m, and seasonal rainfall average for rainfall stations (blue bars) and WRF (blue line) in mm/month for transects 1 and 2 **(b,c)**. The x axis represents the horizontal distance along transects in km. **d)** Seasonal diurnal cycle mean for Hornuni rain-gauges and WRF corresponding grid points.

- Clear **inverse relation (transect 1) between terrain elevation and rainfall** with peaks around 1000 m.a.s.l. linked to the South American Low Level Jet maximum moisture flux as previous studies report (Chavez and Takahashi 2017) (Fig b).
- Opposite behavior is observed in transect 2 with **maximum rainfall over high elevations** as a result of the thermally-driven anabatic winds and the lee side location of the rain stations (Molina-Carpio et al. 2019) (Fig c).
- **The model exhibit a realistic representation of the altitude-rainfall relation and rainfall magnitude for both transects.**
- The **model** is able to **represent the observed diurnal cycle with peaks in the early afternoon and midnight overestimating the latter** (Fig d).
- WRF differentiate the behavior of the diurnal cycle over high and medium-low elevations.

Deforestation Scenario



a) Land use map used in control simulation. Database developed for Eva et al. 2004 and adapted by Saavedra et al. 2019.
b) Deforestation scenario from Soares-Filho et al. 2006.

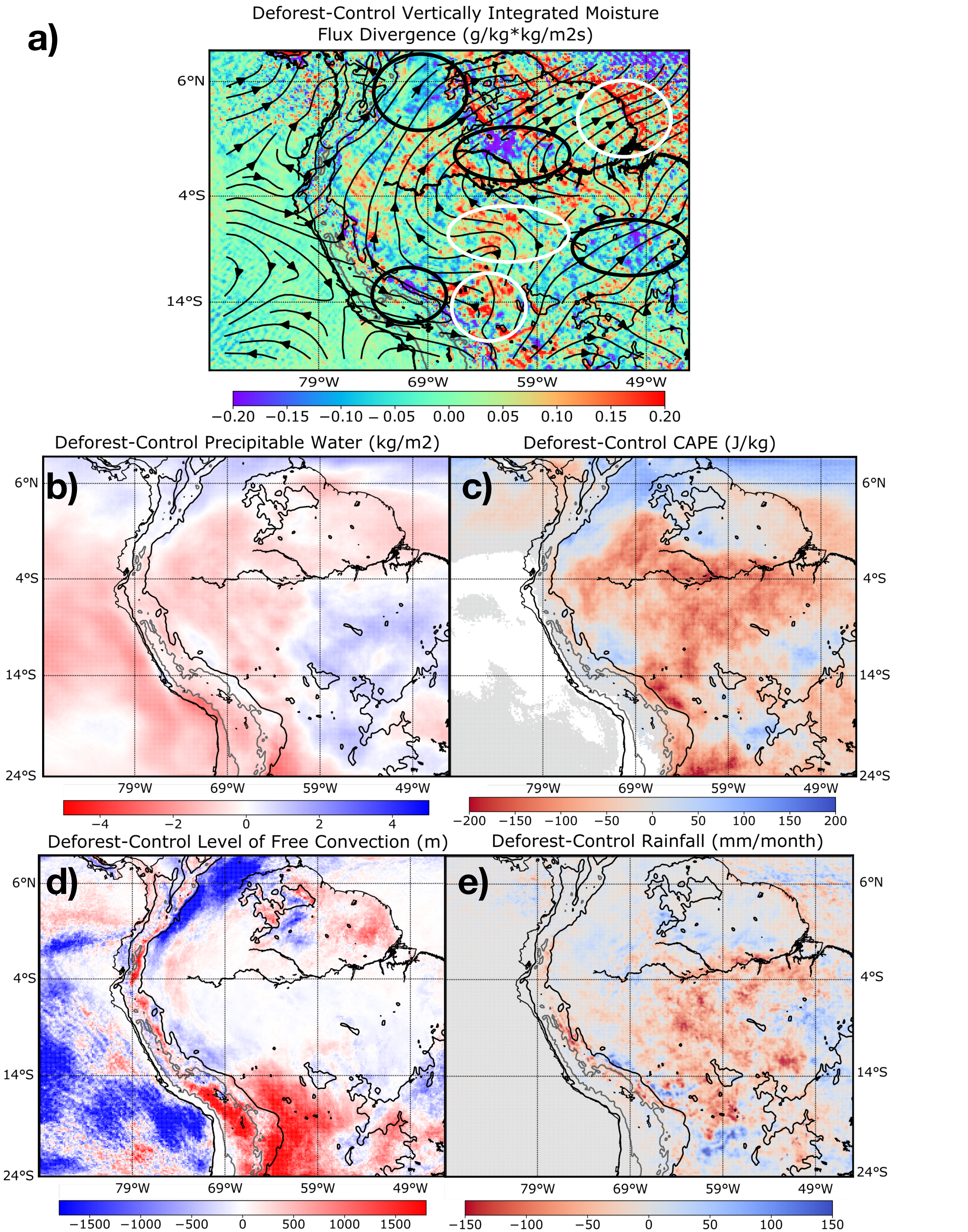
- Deforestation scenario "Bussiness as usual 2050" from Soares-Filho et al. 2006. The assumptions behind this scenario include a continuation of observed deforestation trends in the period 1997-2002 , building of all planned highways and no creation of new protected areas.

- We define "**deforestation**" as the **change of** "natural vegetation" (all kind of **forests, shrubland, grassland and savannas**) **to cropland/grassland mosaic** inside the deforestation polygon.

- **Land cover modifications** leads to an **increase in the albedo and emissivity, and a decrease in soil moisture availability, roughness length, thermal inertia and surface heat capacity over the deforested zone.**

Deforestation Scenario: **Differences** Deforested-Control

- **Decreasing** of the **southward moisture transport** from Amazon basin towards southern latitudes (Fig a).
- Increased moisture convergence over northern South America, central Venezuela, eastern Brazil and south-eastern Peru (Fig a, black solid circles).
- Increased moisture divergence over central and northern Brazil and Bolivia (Fig a, white circles).
- A **boost** in **moisture convergence leads** to a **gain** in **precipitable water** (water vapor) in these areas (Fig b). The opposite is true for increased divergence zones.
- Since moister air is less dense, regions with an **increasing precipitable water** experiment an increasing in the buoyant force which **enlarges CAPE** (Fig c). Similarly, areas with less water vapor suffer a decreasing in CAPE.
- **More humid air needs to rise less to reach the lift condensation level**, which in turn, **diminishes the level of free convection** (Fig d).
- **More CAPE and a lower level of free convection eases rainfall formation over these zones** (Fig e).



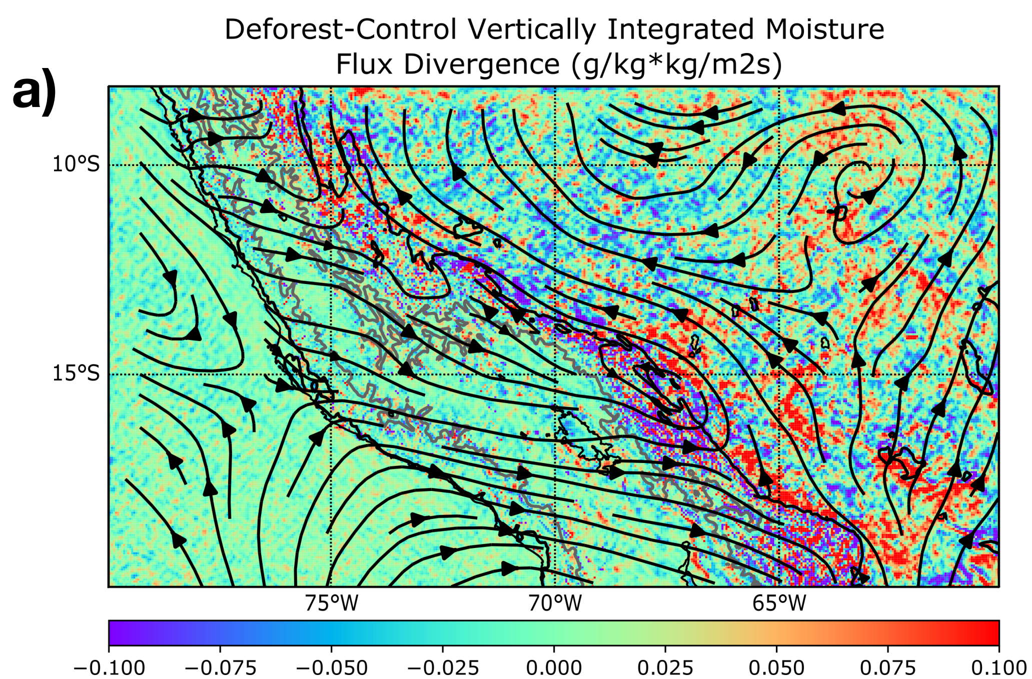
Seasonal mean **differences** between deforestation and control for **a)** Vertically integrated moisture flux divergence (shaded) and moisture flux streamlines. **b)** Precipitable water. **c)** Convective available potential energy. **d)** Level of free convection. **e)** Rainfall. Domain 1 (15Km)

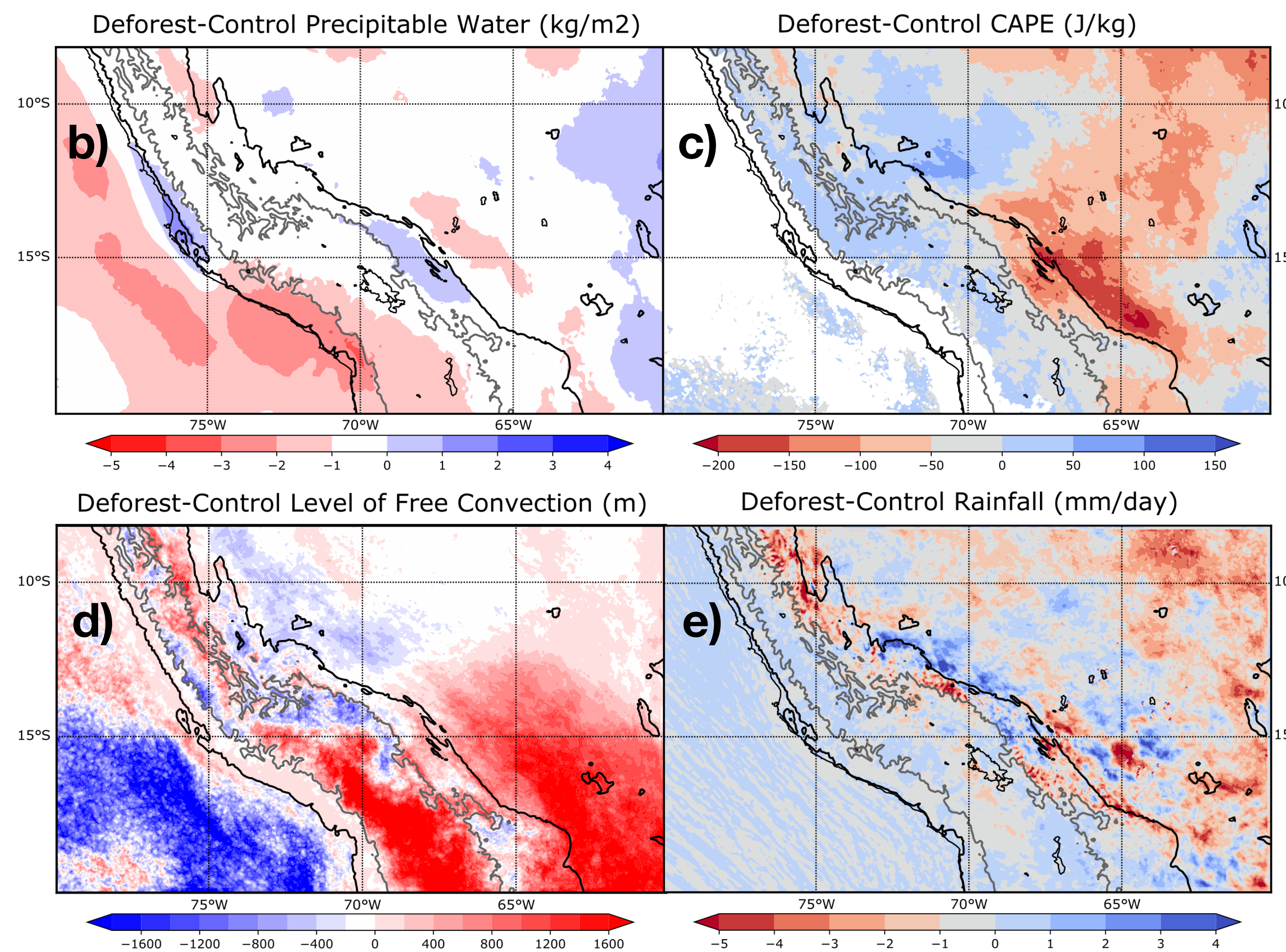
Deforestation Scenario: **Differences Deforested-Control**

- More air entering from Pacific Ocean or less air moving from eastern Andes flank toward Pacific coasts in Deforestation scenario (Fig a). **The new circulation increases moisture divergence over the southeast and moisture divergence over the northwest.**

- Although there is no significant changes in precipitable water in the region (Fig b), **the convergence-divergence dipole leads to the development of an area with low CAPE and deep level of free convection (high CAPE and shallow level of free convection) in the southeastern (northwestern) part of the domain** (Figs c-d).

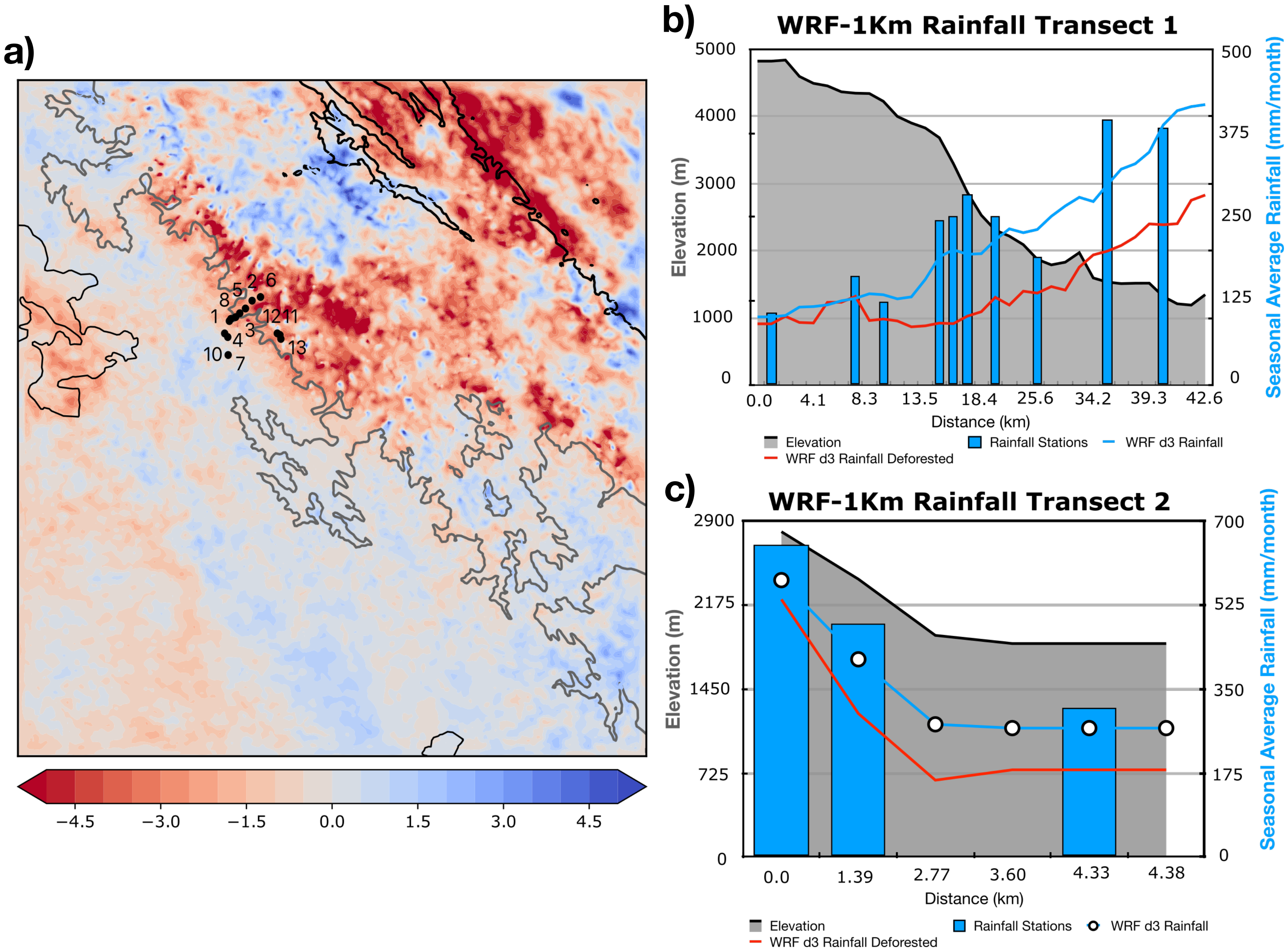
- Rainfall is similar but a noisier southeast-northwest dipole is formed with more rainfall over the Peruvian piedmont and less over Bolivian Andes eastern flank and Amazon lowlands.





Seasonal mean **differences** between deforestation and control for **a)** Vertically integrated moisture flux divergence (shaded) and moisture flux streamlines. **b)** Precipitable water. **c)** Convective available potential energy. **d)** Level of free convection. **e)** Rainfall. Domain 2 (5Km)

Deforestation Scenario: **Differences** Deforested-Control



a) Seasonal mean rainfall **difference** between deforestation and control scenarios for domain 3 (1 km) in mm/day. WRF-1km rainfall (blue and red lines for control and deforested scenarios) and rainfall stations (blue bars) in mm/month, elevation profile (gray line) in m for transects 1 **(b)** and 2 **(c)** (see slide 6). The x axis represents the horizontal distance along transects in km.

- Changes in circulation generates a strong **decreasing in seasonal accumulated precipitation** over most of the domain 3.
- **Rainfall reduction reaches around 30% of total seasonal cumulative rainfall** over dry zones and over most of rainfall gauges (black circles).
- These changes seems to be the result of less moisture transport coming from Amazon basin (see slides 8-9) and more air entering from Pacific Ocean (not shown).

Conclusions

- **WRF exhibit a realistic representation of the seasonal rainfall mean spatial pattern at regional and local scales.** However, the model overestimate precipitation over tropical Atlantic Ocean and over the eastern Andean piedmont.

- WRF reproduces the seasonal mean moisture paths but **strongly overestimate moisture convergence / divergence at a regional level.**

- **Strong rainfall overestimation/underestimation is linked to stronger convergence/divergence in simulated circulation.**

- **The model is able to represent the diurnal and nocturnal behavior of rainfall and moisture flux,** with more rainfall during the afternoon (after midnight) along Andean highlands (eastern piedmont).

- **High resolution WRF** simulation (1 km) p**roperly represent rainfall-elevation link** reported by previous studies and precipitation observed magnitudes. **The diurnal cycle peaks during the early afternoon and midnight are represented but nocturnal (diurnal) maximum is strong overestimated (underestimated)**.

- Our preliminary results suggest a **decreasing of moisture transport from Amazon basin toward southern latitudes as a consequence of deforestation over Amazon basin.** Moisture convergence increases over northern South America and eastern Brazil and Peruvian Andes piedmont, **leading to a rise in CAPE and a lower level of free convection over these zones which favors precipitation along these areas.** However, **rainfall decreasing is simulated over Bolivian Andes eastern flank possibly caused by more dry/cold air masses coming from Pacific Ocean and less moisture transport coming from the Amazon basin.**

Institut de Recherche pour le Développement FRANCE

MAKE OUR PLANET GREAT AGAIN

UGA Université Grenoble Alpes

IGE

EGU