Water Balance using RegCM4 projections over multiple CORDEX domains

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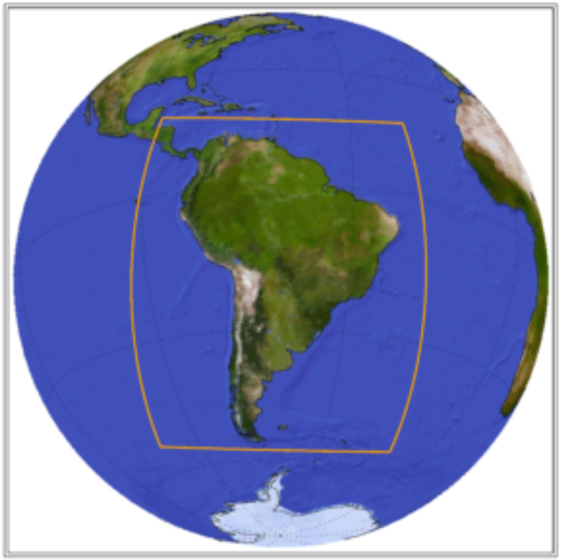
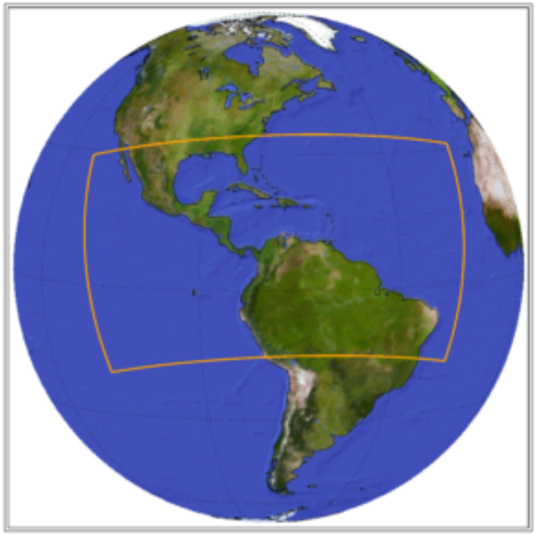
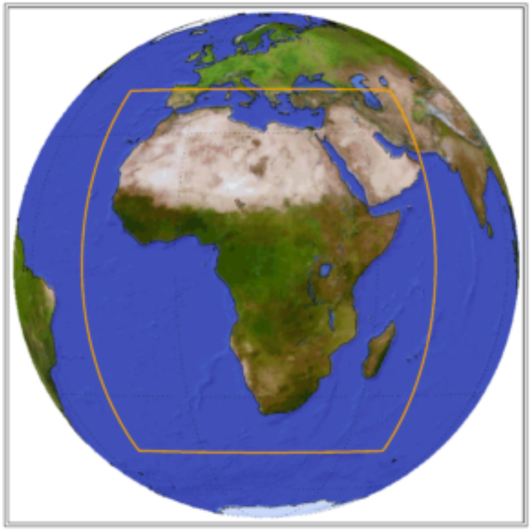
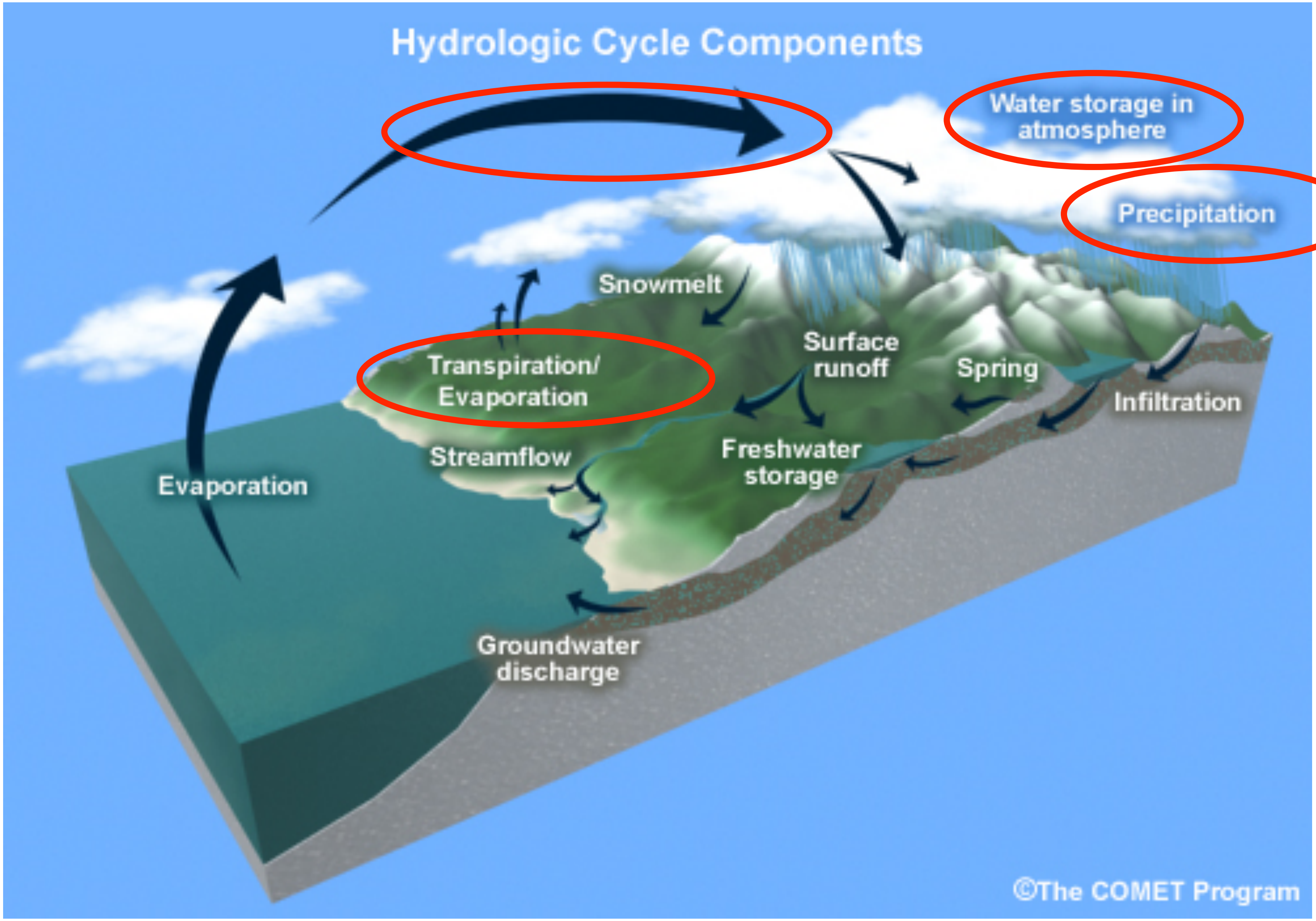
CORDEX domains








Hydrologic Cycle Components
Water storage in atmosphere
Precipitation
Snowmelt
Surface runoff
Spring
Infiltration
Transpiration/ Evaporation
Streamflow
Freshwater storage
Evaporation
Groundwater discharge
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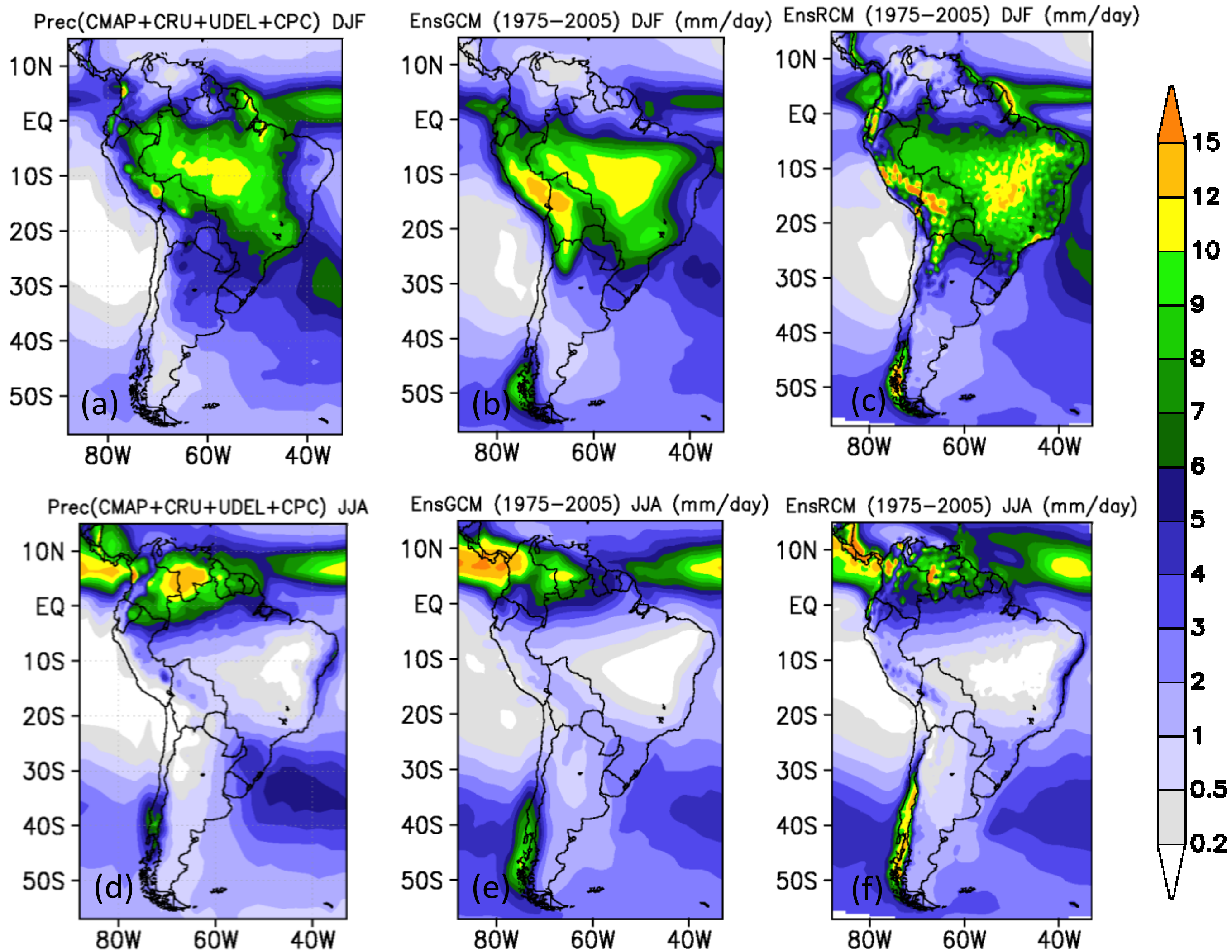
The aim is to...

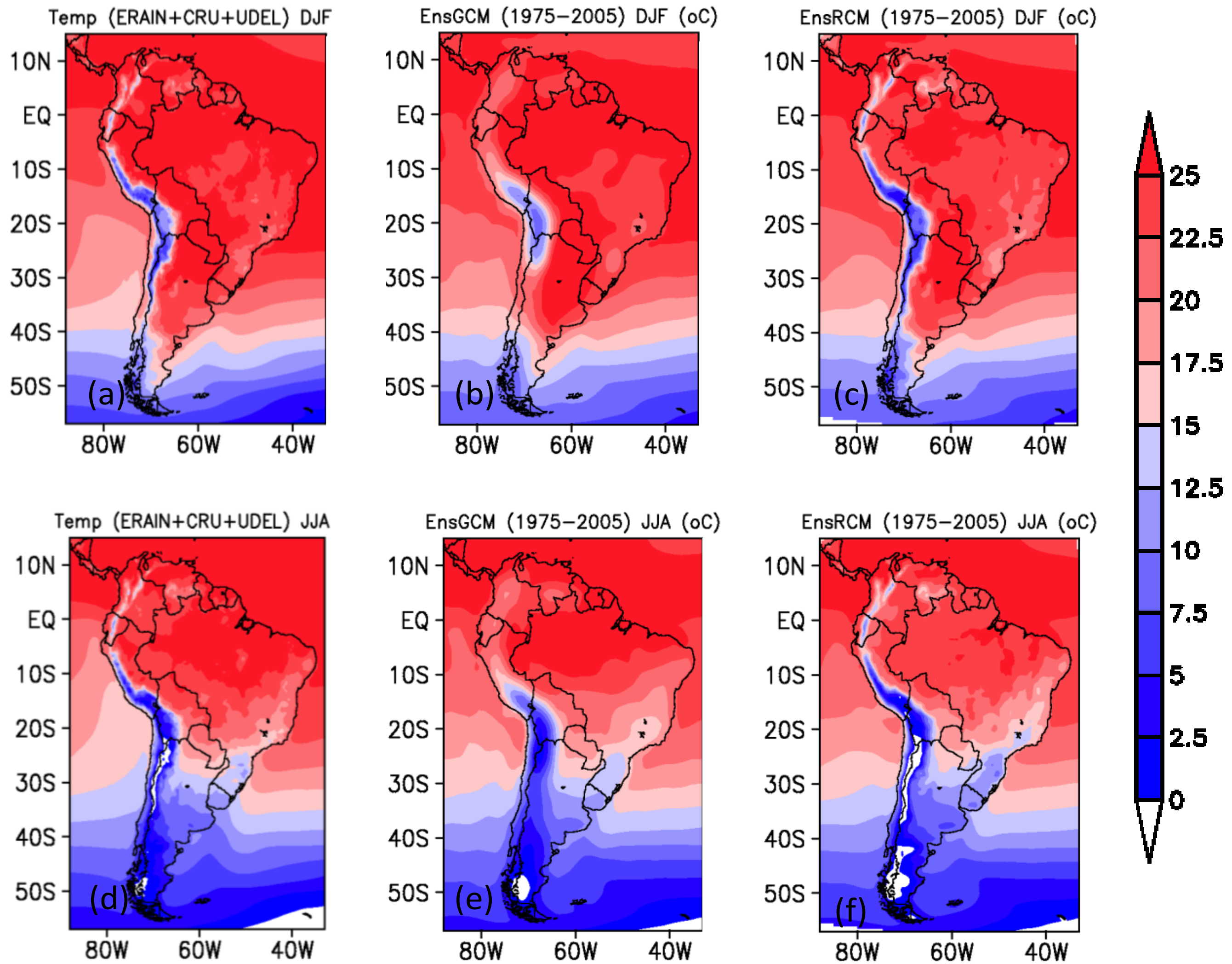
- ✓ Understand the water balance change signal in the future
- ➢ Infer whether the water balance are changing and what would be driving this change

Basic Analysis

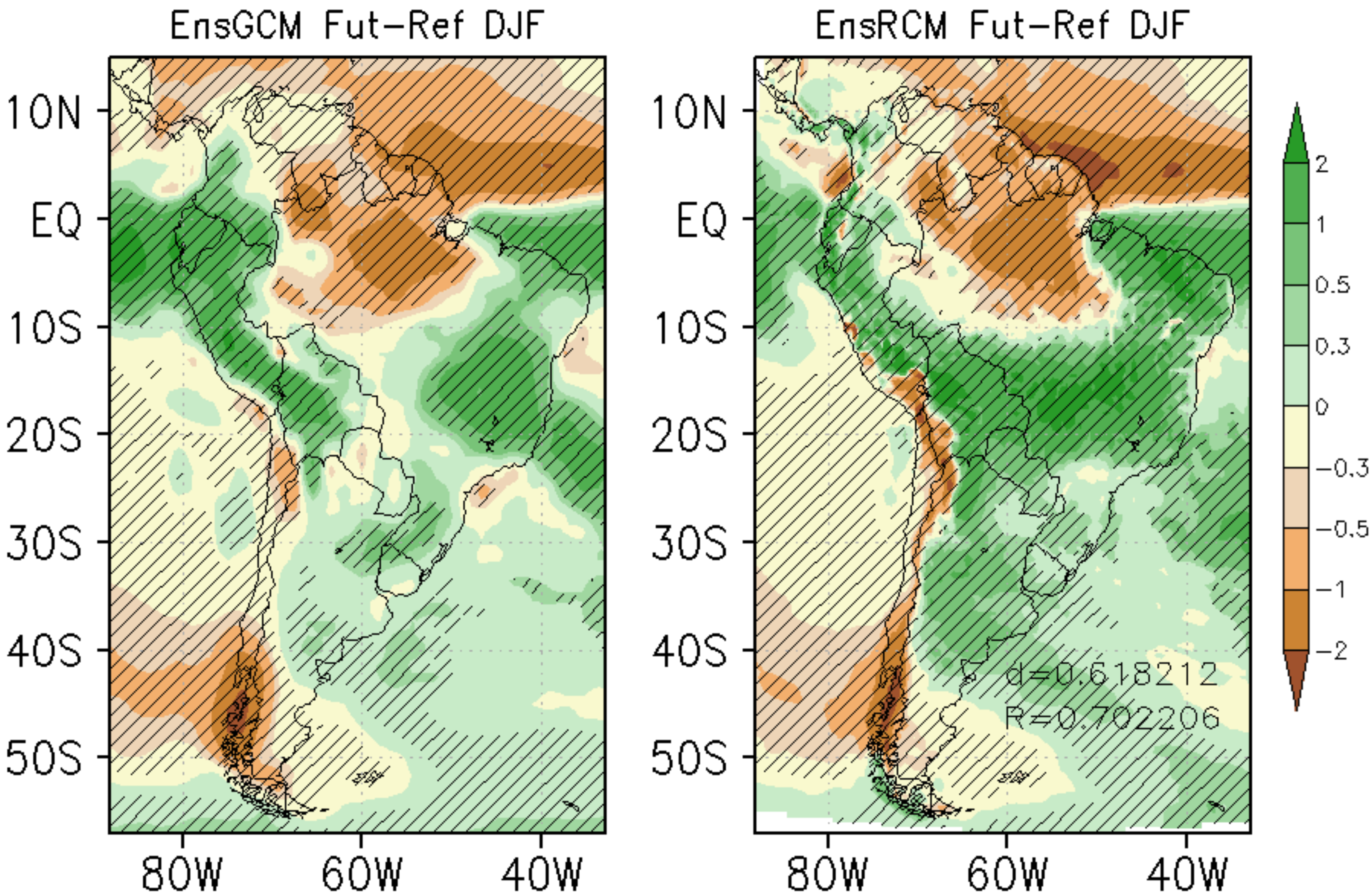
Model Validation (Reference Period)



Model Validation (Reference Period)

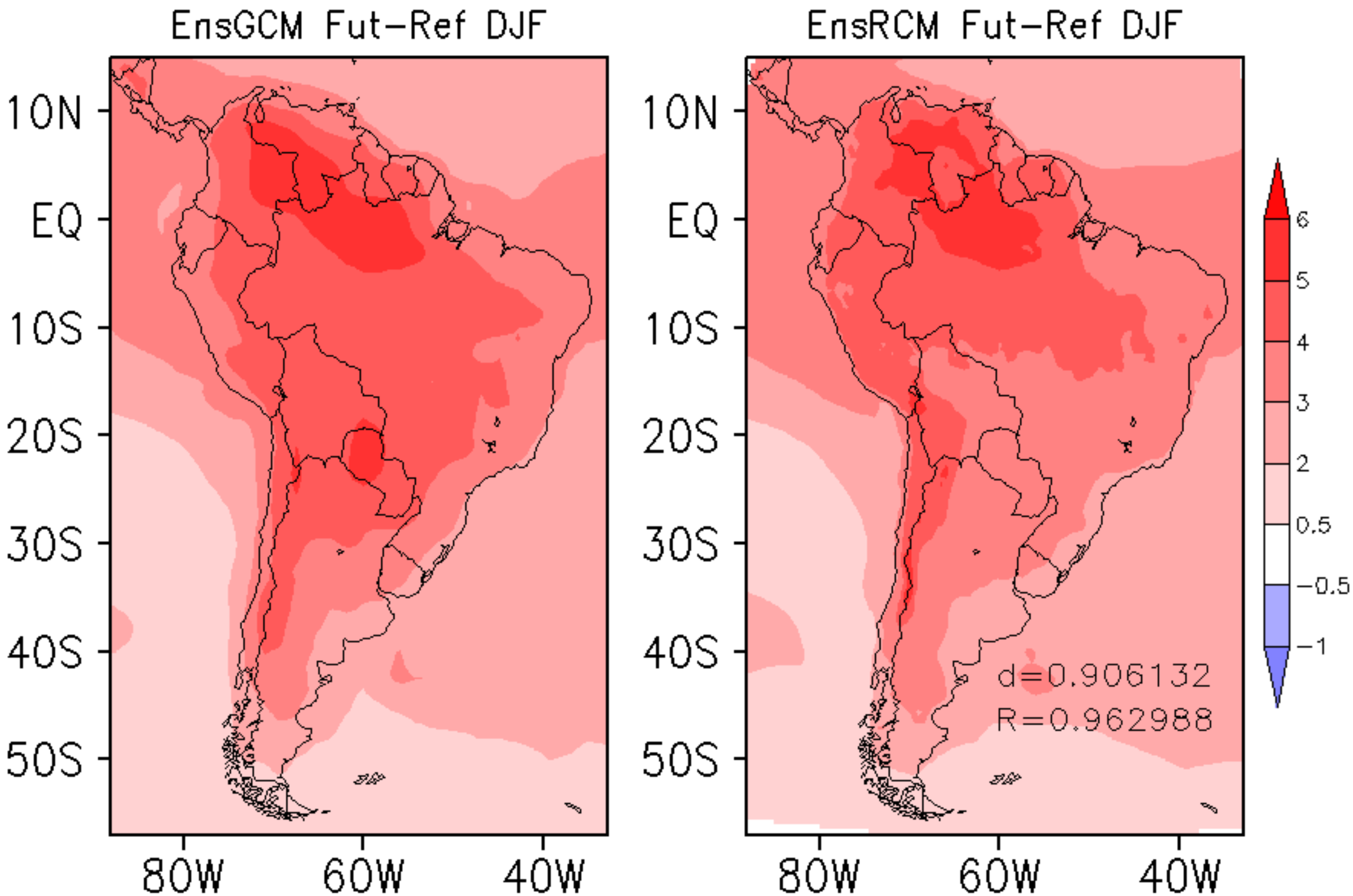


Precipitation Change Signal



Llopart et al. (2019) – under review on Climate Dynamics

Temperature Change Signal



Llopart et al. (2019) – under review on Climate Dynamics

Water Balance

The hydrological cycle describes the cycling of water among land, ocean, and air

The cycle has two branches:

- the terrestrial (inflow, outflow and water storage) and
- the atmospheric (atmospheric water transport, mainly in the vapor phase).

Water Balance

Surface Water Balance

$\Delta S = P - ET - R$

P= Precipitation (mm day^{-1})
ET= Evapotranspiration (mm day^{-1})
R=Total runoff (mm day^{-1})
ΔS = Soil water content variation (mm day^{-1})

In a long term average, ΔS can be ignored:

$$P = ET + R$$

Water Balance

Atmospheric Water Balance

$$\mathbf{dw/dt = -P + C + ET}$$

where dw/dt represents the water stock change (mm day^{-1})

P is the precipitation (mm day^{-1})

ET is the evapotranspiration (mm day^{-1})

C is the vertically integrated moisture flux convergence (mm day^{-1}) between 925 and 100 hPa.

dw/dt can be ignored for longer periods $\rightarrow$ $\boldsymbol{P = ET + C}$

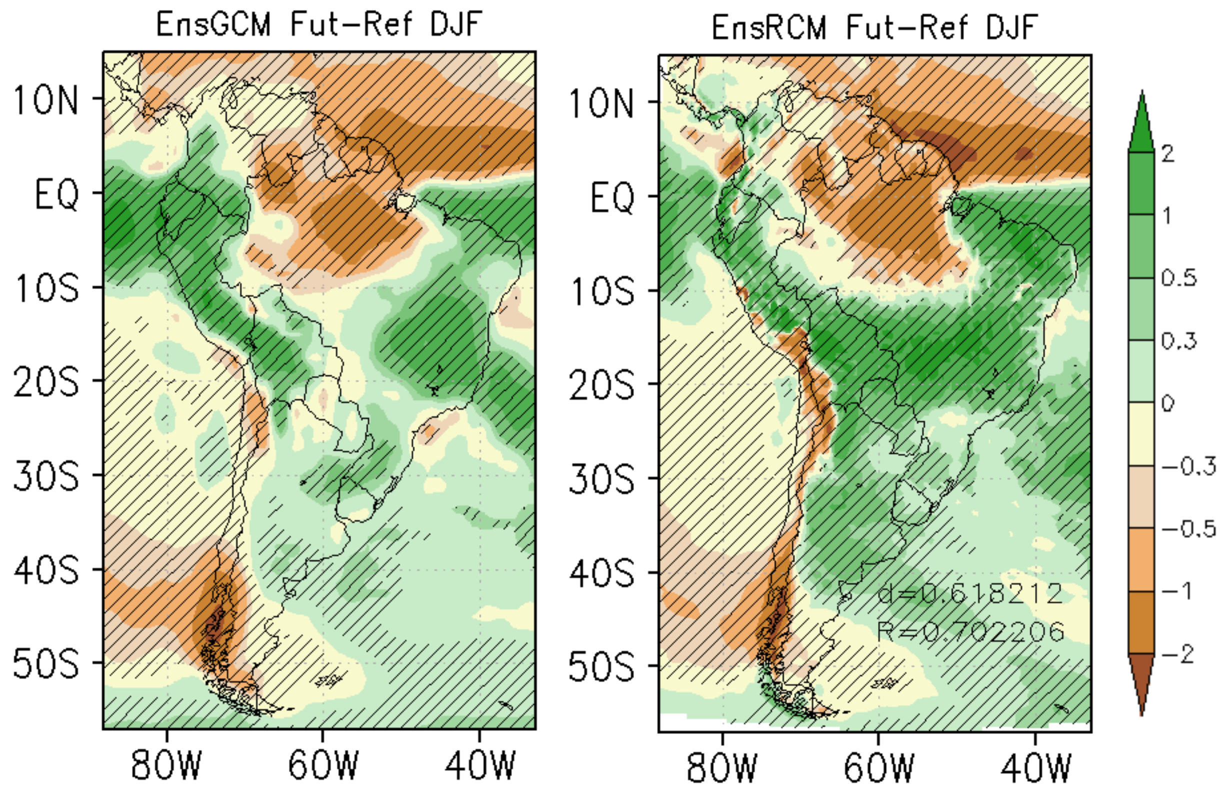
Water Balance

Considering the two branches of the hydrological cycle, the connection between atmosphere and surface is:

$$C = R$$

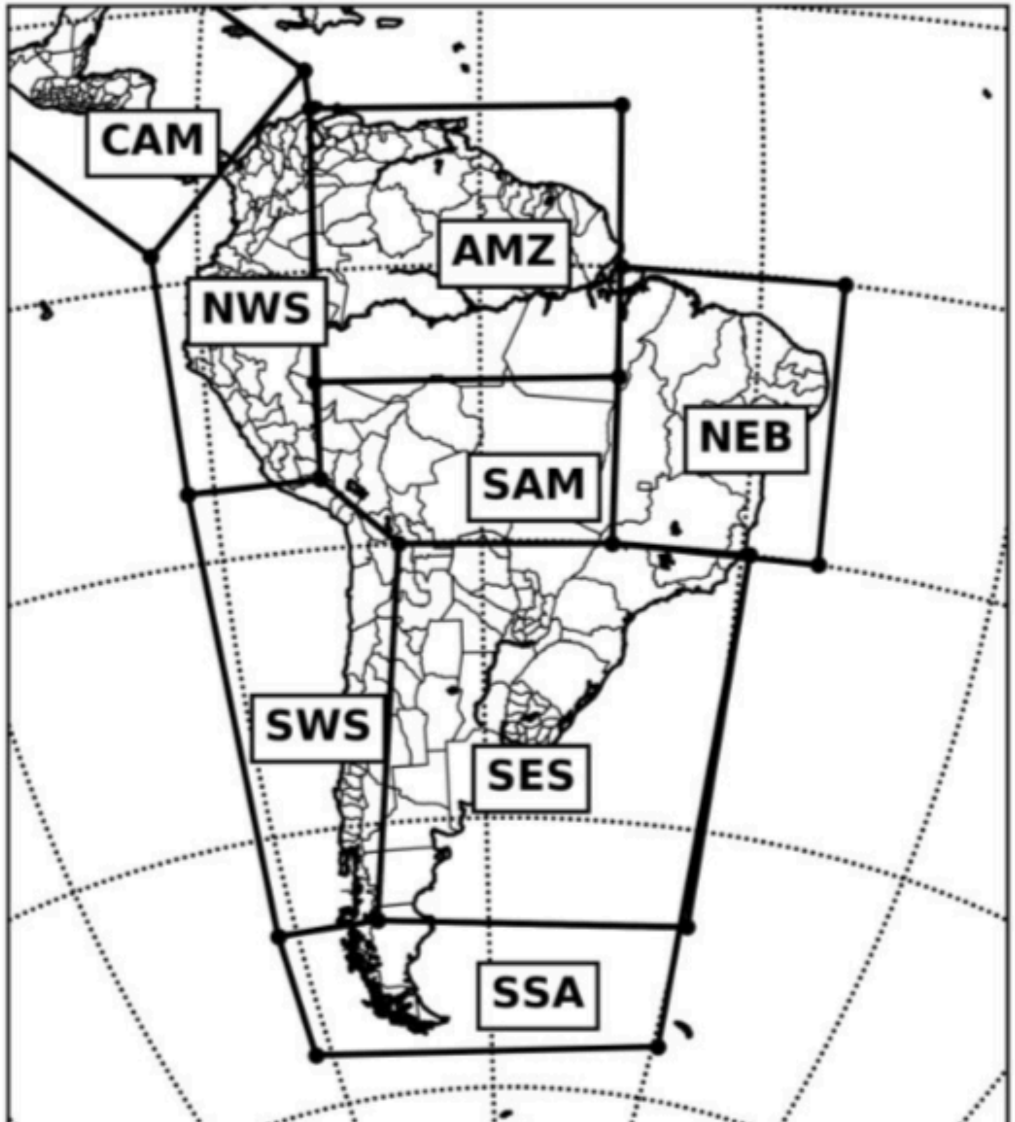
C= moisture flux convergence
R=Runoff

The criteria to define the regions …



- **We will identify the regions where the precipitation, evapotranspiration and moisture flux convergence change signal are significant to perform the analysis**
- **And we will try to figure out the causes of these changes**

NEW South American regions



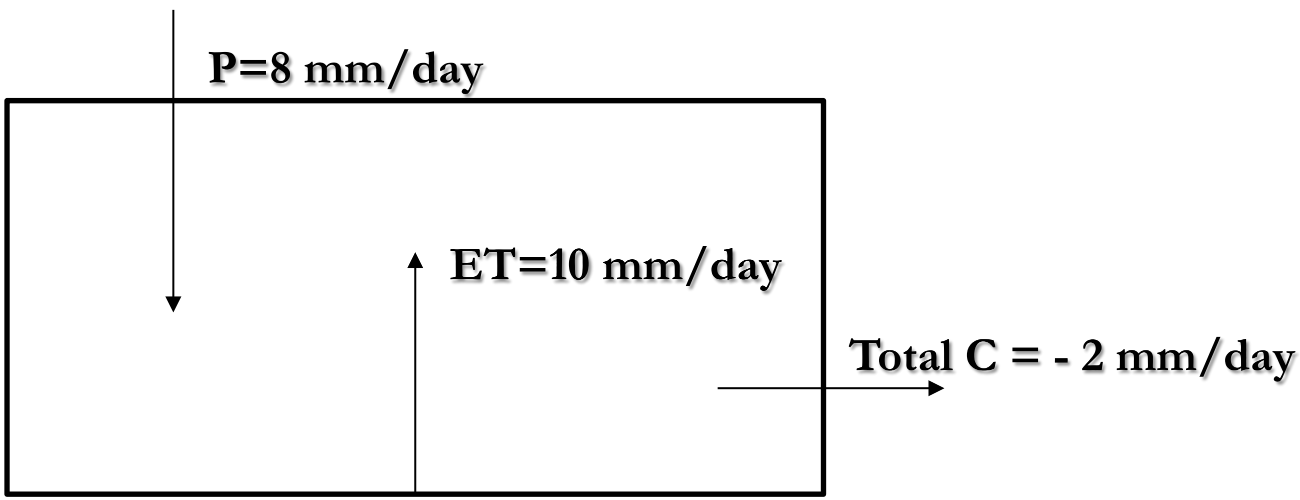
These regions act as moisture sources (sinks) to (from) the atmosphere?

- According to Marengo *et al.* (2006) and Nascimento *et al.* (2016), ET/P ratio is the recycling rate, which indicates how ET contributes to the average rainfall in a given area

- It can be used as a tool for diagnosing the interactions between the surface and the regional climate

Land surface feedbacks

- If ET is greater than P locally (ET > P), the region is a source of moisture to the atmosphere
- To know wheter the precipitation signal is only influenced locally, C must be less than ET (C < ET)
- In this example the region is a source of moisture locally and for other regions



Land surface feedbacks

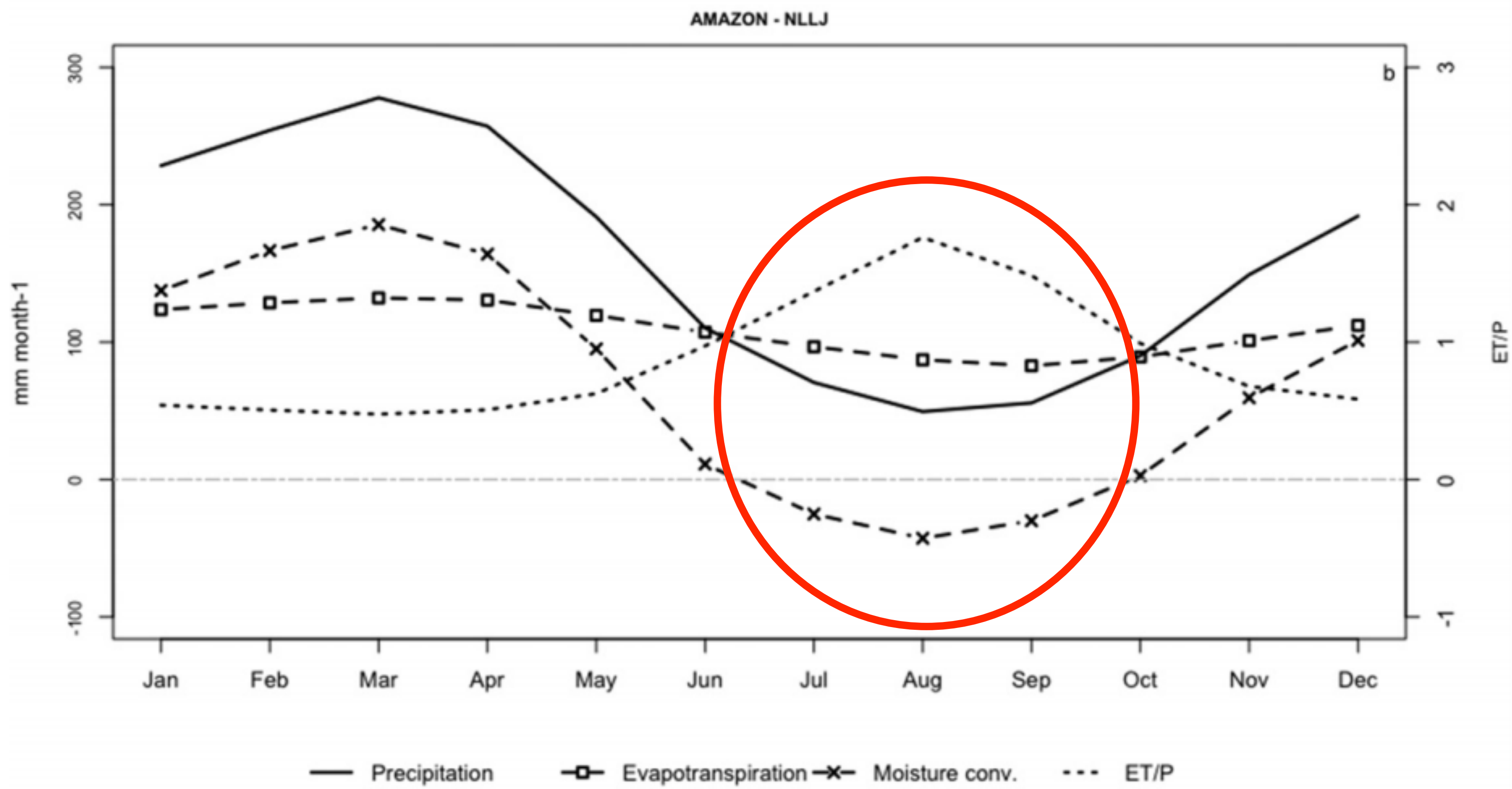


FIG. 9. Water balance variables (mm month^{-1}) over the Amazon region during (a) the LLJ events and (b) non-LLJ events from 1979 to 2008. Primary axis: precipitation, evapotranspiration, and moisture convergence. Secondary axis: ET/*P* ratio.

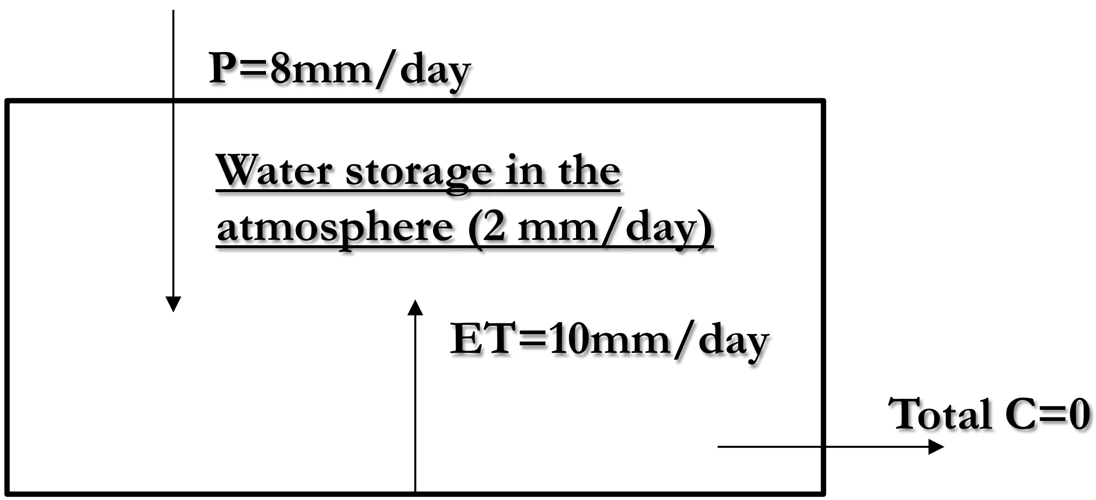
Nascimento *et al.* (2016)

Land surface feedbacks

- If ET is greater than P locally (ET > P), the region is a source of moisture to the atmosphere

- To know whether the precipitation signal is only influenced locally, C must be less than ET (C < ET)

- In this example the region is a source of moisture only locally



Land surface feedbacks

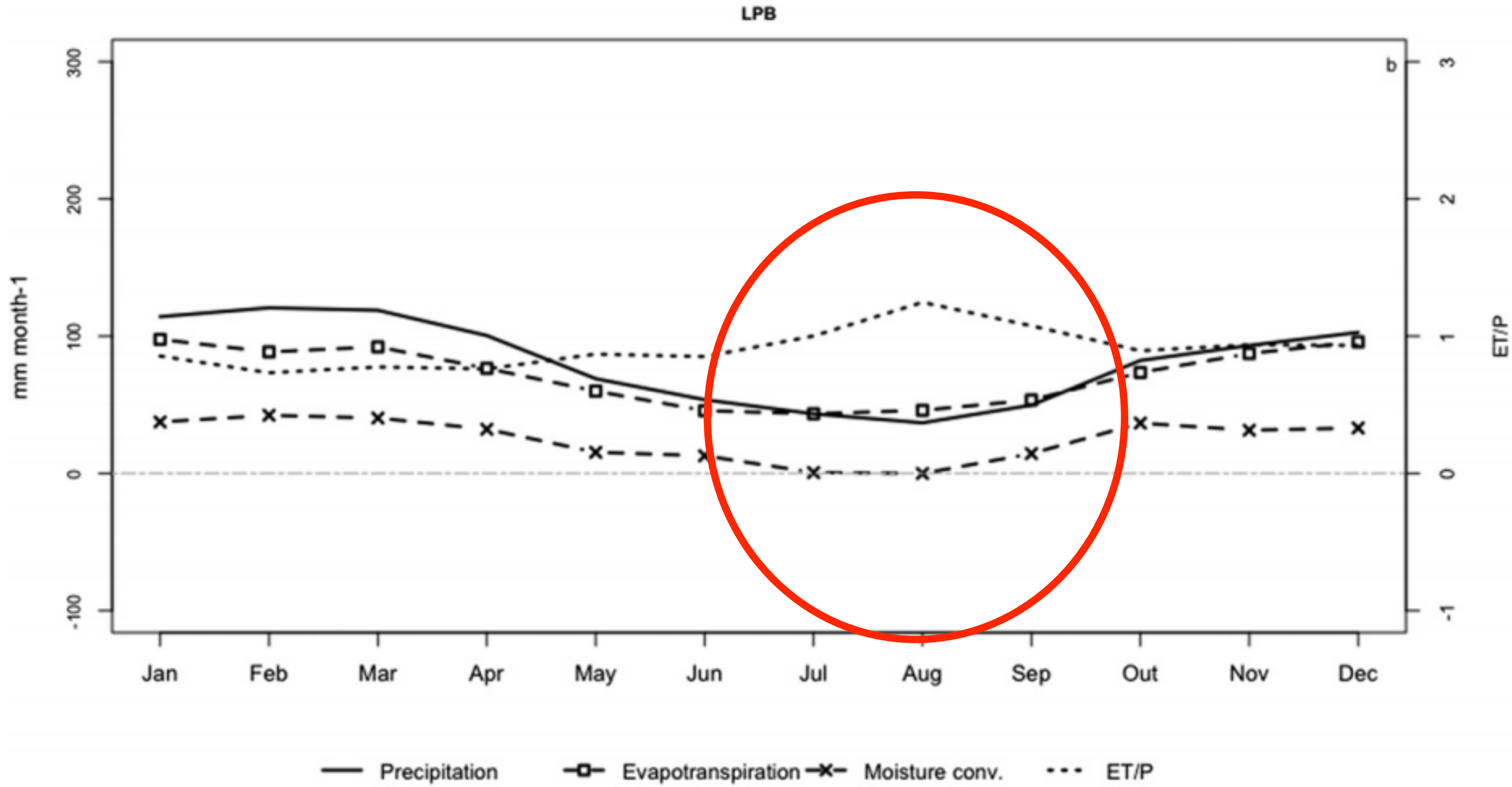
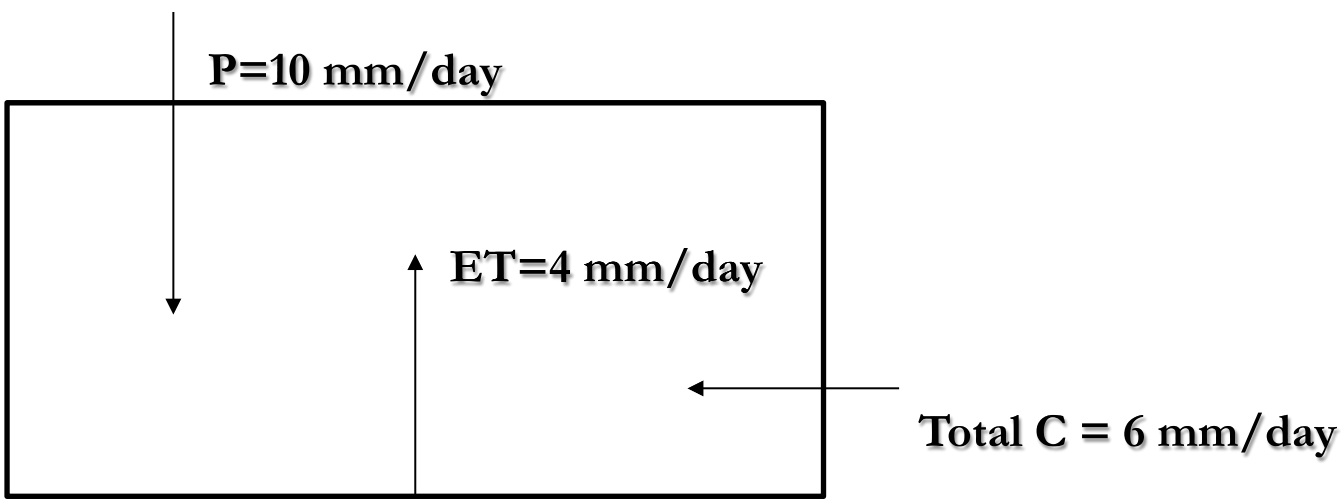


FIG. 2. Water balance variables (mm $month^{-1}$) over the Amazon and LPB regions from 1979 to 2008. Primary axis: precipitation, evapotranspiration, and moisture convergence. Secondary axis: ET/*P* ratio.

Nascimento et al. (2016)

Remote feedbacks

- If **P>ET** locally, the region is a sink of moisture from another region
- It means that the precipitation signal is mainly driven by remote feedbacks



Remote feedbacks

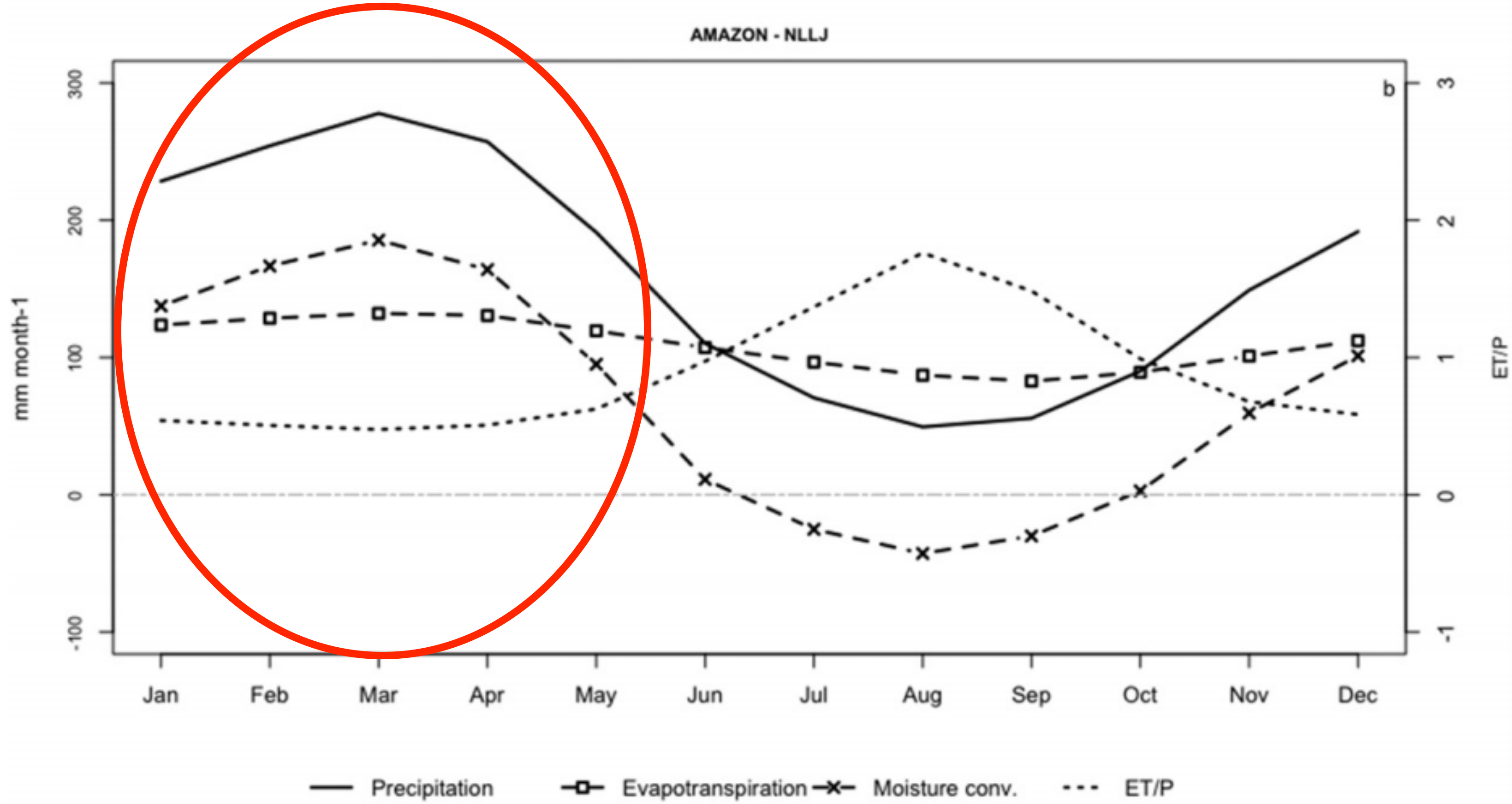
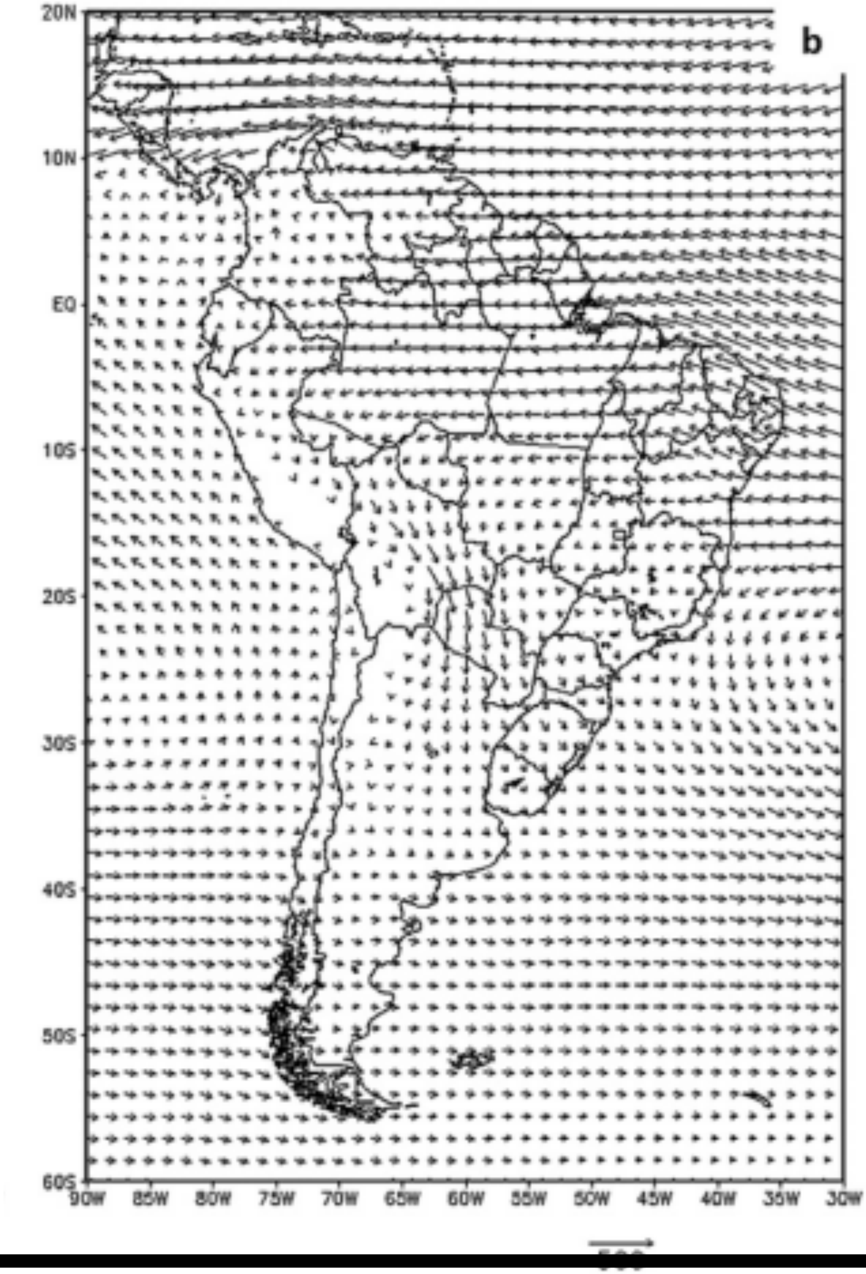


FIG. 9. Water balance variables (mm $month^{-1}$) over the Amazon region during (a) the LLJ events and (b) non-LLJ events from 1979 to 2008. Primary axis: precipitation, evapotranspiration, and moisture convergence. Secondary axis: ET/*P* ratio.

Nascimento et al. (2016)



If a region is a sink of moisture, we can perform a similar analysis to see where the moisture flux is coming from

Integrated Moisture flux

$(V\,q)$

TABLE 1. Water balance variables for the preestablished regions (mm month^{-1}) for the period between 1979 and 2008 [*P*: precipitation, ET: evapotranspiration, *C*: moisture convergence]. The CFSR caption refers to the CFSR data, and the WM caption refers to the Willmott–Matsuura data.

	B 1.1	B 1.2	Amazon	B 2.1	B 2.2	La Plata
P (CFSR)	169.30	150.55	159.92	88.81	75.38	82.10
P (WM)	195.76	163.90	179.83	107.44	93.27	100.35
ET	107.88	112.47	110.17	76.99	66.39	71.69
C	90.06	49.30	69.68	18.51	30.96	24.74
$P - \text{ET} - C$ (CFSR)	−28.64	−11.22	−19.93	−6.69	−21.97	−14.33

$P - \text{ET} - C = 0$ **Residual – to close the water balance**

- Residuals may be related to the uncertainties of the models data;

- In addition, soil moisture must be steady in long periods in order to discard the term ΔS. If it is not fully acessed, the balance does not close!

What can we obtain from these analysis?

How the water balance will behave in the future? What will drive these changes?

How the specific regions in the future will behave? Will they still act as a sink (source) of moisture from (to) the atmosphere?

Thank you

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Equation (12.12) shows that the excess of evaporation over precipitation at the earth's surface is balanced by the local rate of change of water vapor storage $\partial W/\partial t$ and by the inflow or outflow of water vapor, div $\mathbf{Q}$. Averaging of Eq. (12.12) in space over a region bounded by a conceptual vertical wall (e.g., a river-drainage basin or an interior sea) leads to another form of Eq. (12.12):

$$\left\{\frac{\partial \overline{W}}{\partial t}\right\} + \{\text{div}\,\mathbf{Q}\} = \{\overline{E} - \overline{P}\}. \tag{12.13}$$

Using the Gauss theorem, Eq. (12.13) may be rewritten in a form, which is often more useful for regional studies:

$$\left\{\frac{\partial \overline{W}}{\partial t}\right\} + (1/A)\oint(\overline{\mathbf{Q}}\cdot\mathbf{n})d\gamma = \{\overline{E} - \overline{P}\}, \tag{12.14}$$

where A denotes the area of the region and $\mathbf{n}$ the unit vector directed outward, normal to the boundary of the region.

Equations (12.13) and (12.14) describe the atmospheric branch of the hydrological cycle. Except in the case of severe storms and for short intervals of time, the rate of change of precipitable water $\partial W/\partial t$ is very small compared with the other terms. Thus, for sufficiently long periods of time, divergence of water vapor is found over those regions of the globe where evaporation exceeds precipitation, whereas convergence is found where precipitation is greater than evaporation.

The term $\{\overline{E} - \overline{P}\}$ is common to Eqs. (12.2) and (12.13) and establishes the connection between the terrestrial and atmospheric branches of the hydrological cycle. Elimination of $\{\overline{E} - \overline{P}\}$ between these two equations yields

$$\{\overline{R}_0\} + \{\overline{S}\} = -\{\text{div}\,\overline{\mathbf{Q}}\} - \left\{\frac{\partial \overline{W}}{\partial t}\right\}, \tag{12.15}$$

which shows how the two branches of the hydrological cycle are linked together.

If, besides the aerological terms, $\{\overline{R}_0\}$ and $\{\overline{P}\}$ are known over a certain catchment basin from stream flow and precipitation data, one can estimate the rate of change in ground water and the rate of evaporation. Thus, using finite differences as is usually done in hydrology, Eq. (12.15) may be written

$$\{\overline{S}\} = -\{\overline{\Delta W/\Delta t}\} - (1/A)\oint(\overline{\mathbf{Q}}\cdot\mathbf{n})d\gamma - \{\overline{R}_0\}. \tag{12.16}$$

Similarly the mean evaporation can be obtained from Eq. (12.14):

$$\{E\} = \{\overline{\Delta W/\Delta t}\} + (1/A)\oint(\overline{\mathbf{Q}}\cdot\mathbf{n})d\gamma + \{\overline{P}\}. \tag{12.17}$$

Over long periods of time, such as a year, changes in storage in the land and in the atmosphere become small so that, e.g., for a continent the surface and subsurface runoff have to be exactly balanced by the aerial "runoff" into the continent from the surrounding ocean areas.

When the entire global atmosphere is considered over a long period of time, all transport and storage terms vanish, and we can conclude from Eq. (12.12) that the global-mean evaporation has to be equal to the global-mean precipitation.