Sensitivity of precipitation and atmospheric low-level circulation patterns to domain size in RegCM.v.4.4 over Central America

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Scientific Rationale

Central America and Mexico (CAM) are very vulnerable regions to extreme climatic events that cause socio-economical and natural disasters (Amador 2011). Specifically, Central America is a **"hot spot"** for climate change impacts (Giorgi, 2006), being one of the most vulnerable regions in the world to climate change.

Coarse resolution global dynamical models have a relatively poor representation of CAM regional climate features. Therefore, dynamical downscaling techniques and the use of limited area climate models are useful alternatives to approach the problem of modeling regional climate variability and climate change.

The Coordinated Regional climate Downscaling Experiment (CORDEX) **vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.** **ICTP and RegCM.**

CIGEFI-UCR RegCM model simulations

Objectives

In this research, the CORDEX Central America domain at 50 km horizontal resolution (simply CCA), with a relaxation zone of 10º around it (CCA+), was taken as the basis to increase and decrease domain size in the RegCM4.4 hydrostatic model (Giorgi et al. 2015).

The objective of the work is to test the sensitivity of precipitation distribution and some of its basic statistical attributes, and of the atmospheric low-level circulation patterns within CCA, to domain size changes in the RegCM4.4 model.

By changing the size of the domain it will also be possible to assess if the specified CCA domain has the correct size so that all winter/summer processes affecting the Central America region can be better represented by regional models (Cerezo-Mota et al 2015).

An additional objective is to compare Diro et al. (2012) results for the CA región within the “CCA+” domain, but for a different period.

Diro et al. (2012) model basic configuration:

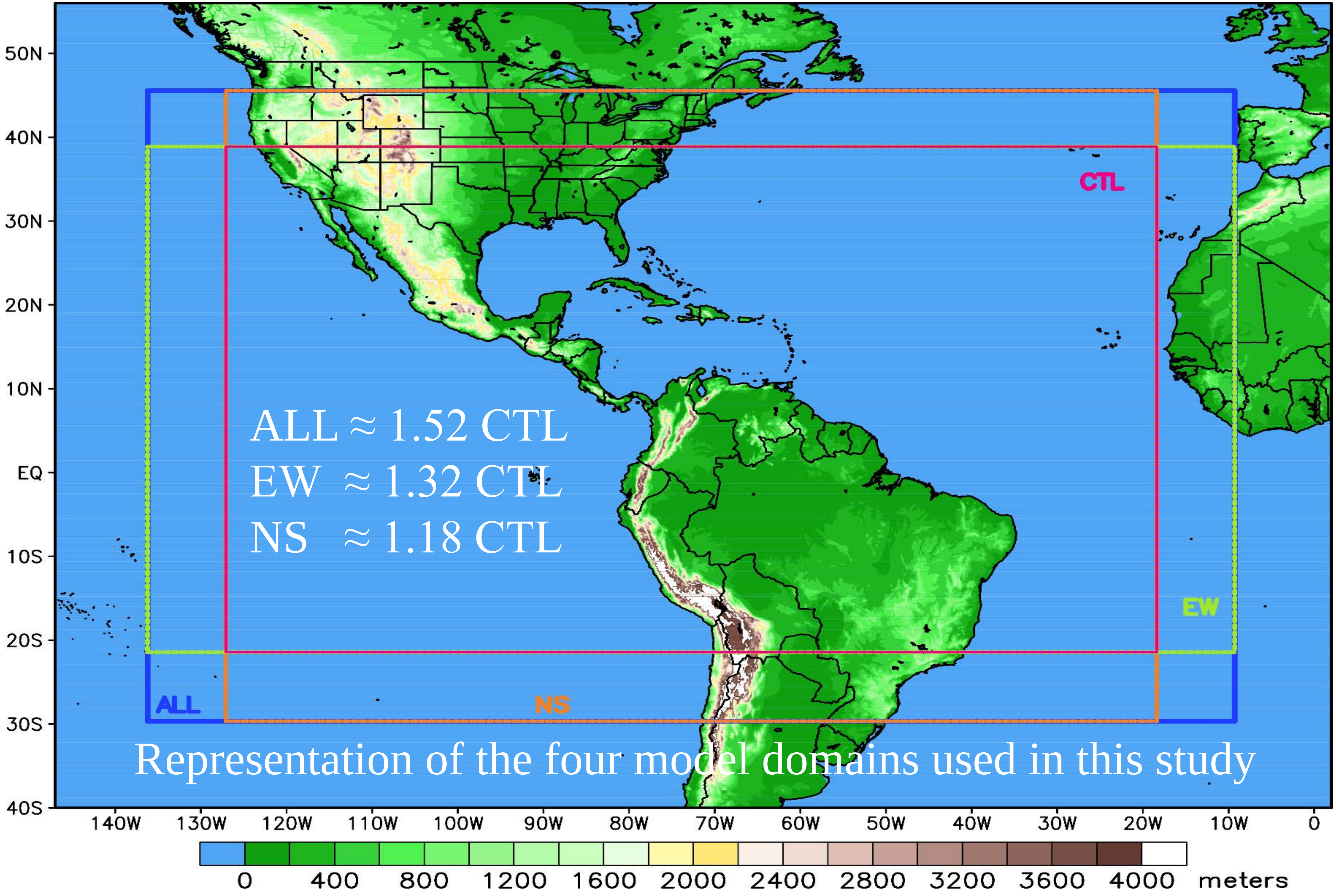
Planetary boundary layer scheme of Holtslag et al. (1990). [Ri]

Mixed convection scheme using the MIT convection parameterization of Emanuel (1991) over ocean areas and the scheme of Grell (1993) over land areas.

Six hourly fields from ERA-interim reanalysis (boundary conditions).

Optimal interpolation weekly SST data (Reynolds et al. 2002) from 00:00 UTC on 1 January 1997 and run continuously for 6 years until 1 January 2003

Daniel Martínez-Castro1, Alejandro Vichot-Llano1, Arnoldo Bezanilla-Morlot1, Abel Centella-Artola1, Jayaka Campbell2 and Cecilia Viloria-Holguin. 2016. Performance of RegCM-4.3 over the Caribbean region using different configurations of the Tiedtke convective parameterization scheme, *Rev Clim*, 16 (2016): 77-98.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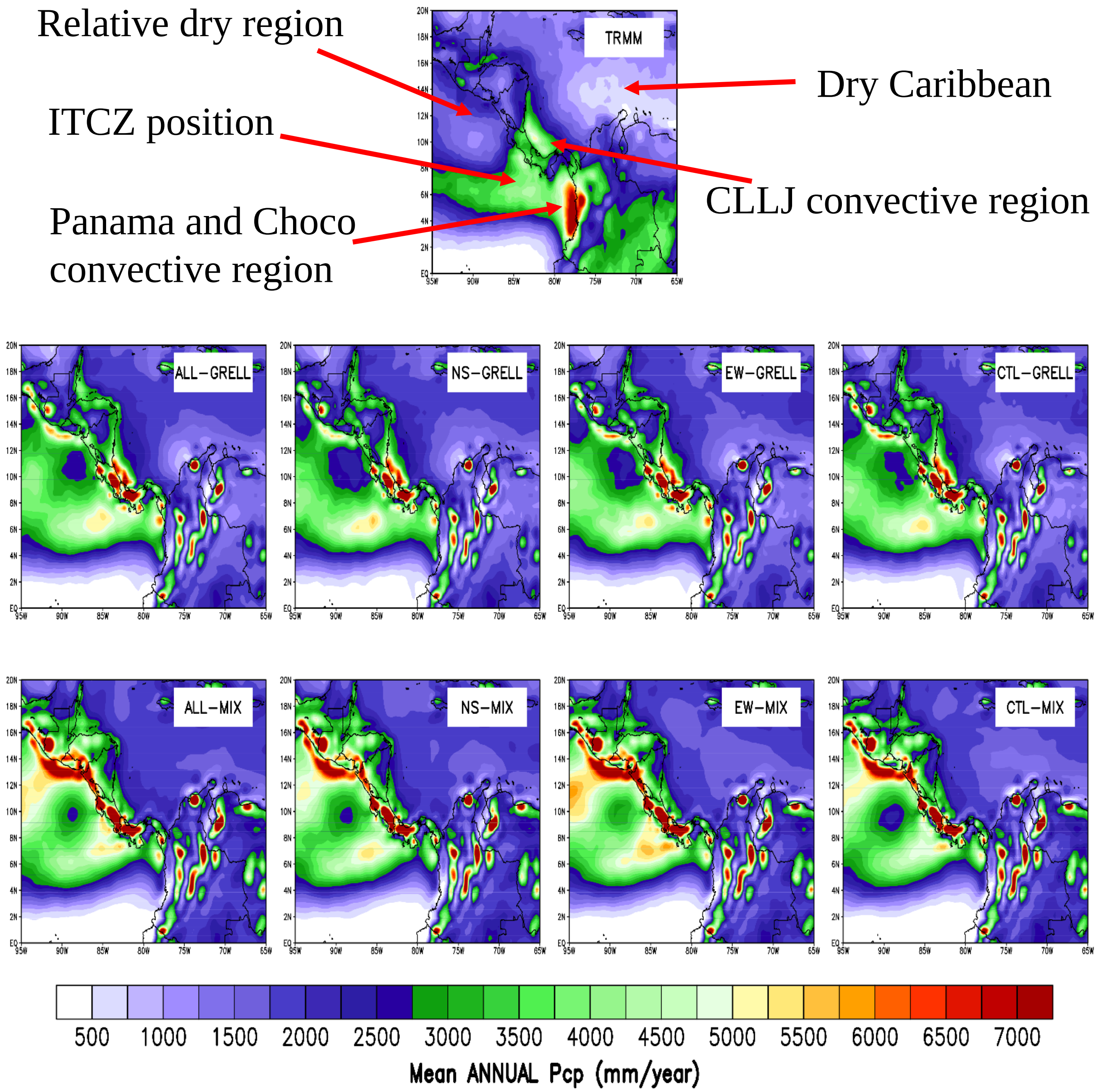
10W
0
CTL
EW
ALL
NS
ALL ≈ 1.52 CTL
EW ≈ 1.32 CTL
NS ≈ 1.18 CTL
Representation of the four model domains used in this study
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
meters

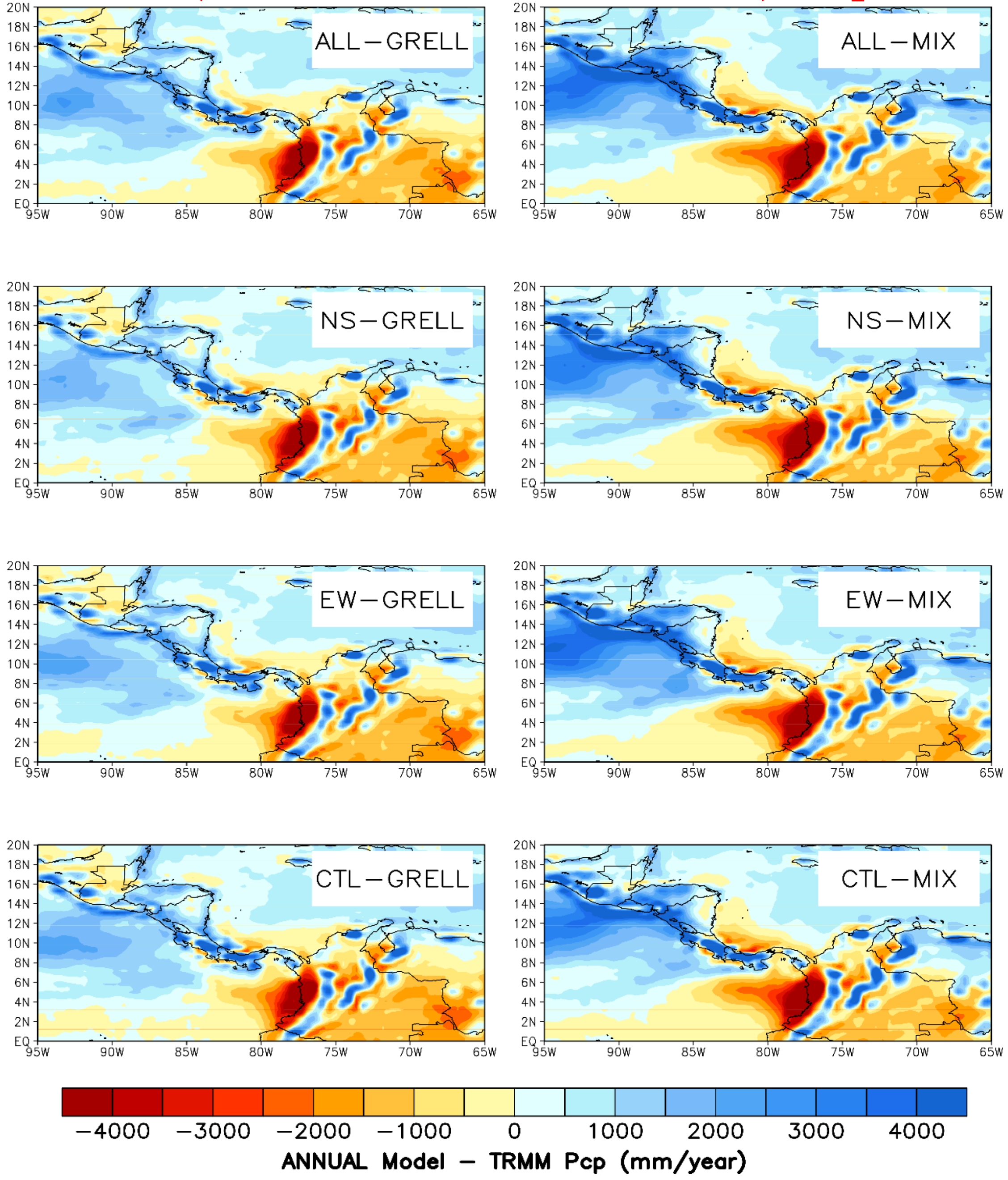
Results for Precipitation

Annual and seasonal scales

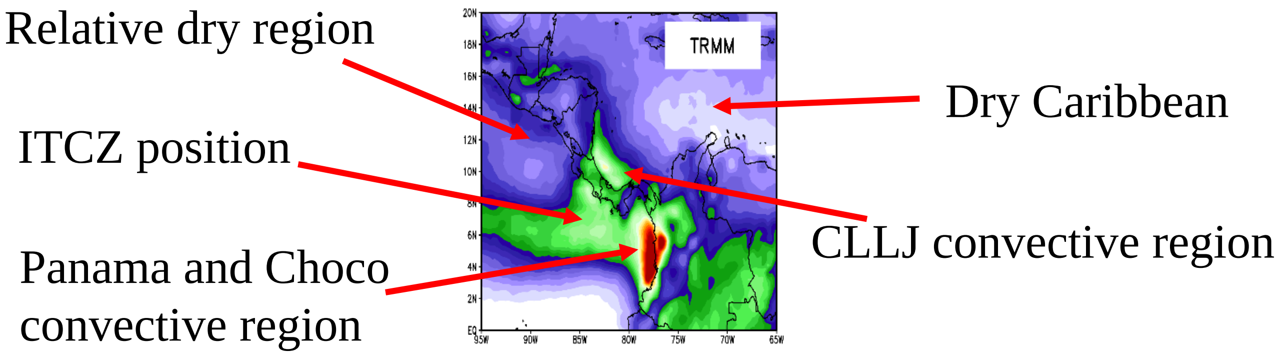
"Observed" TRMM Pcp

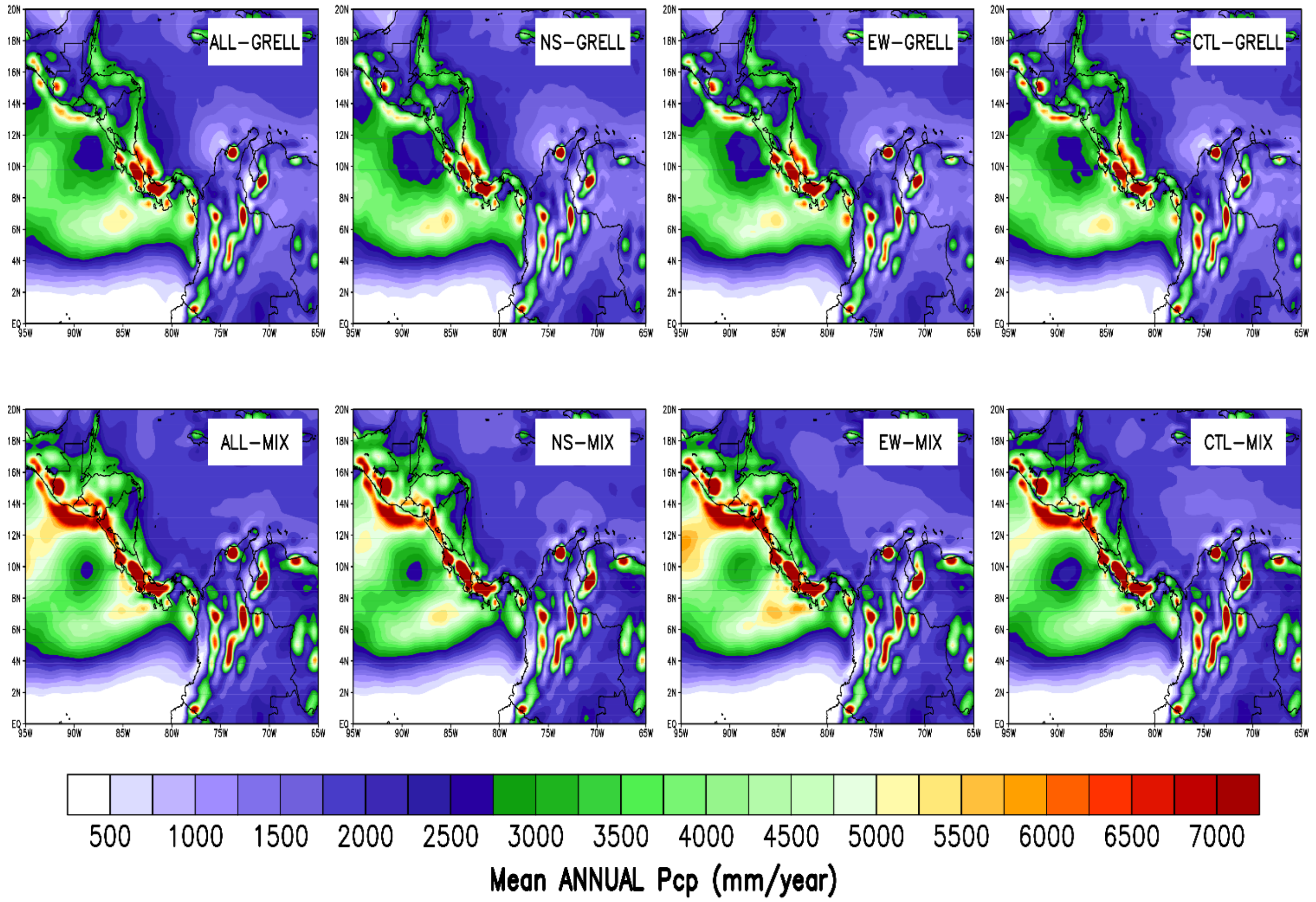


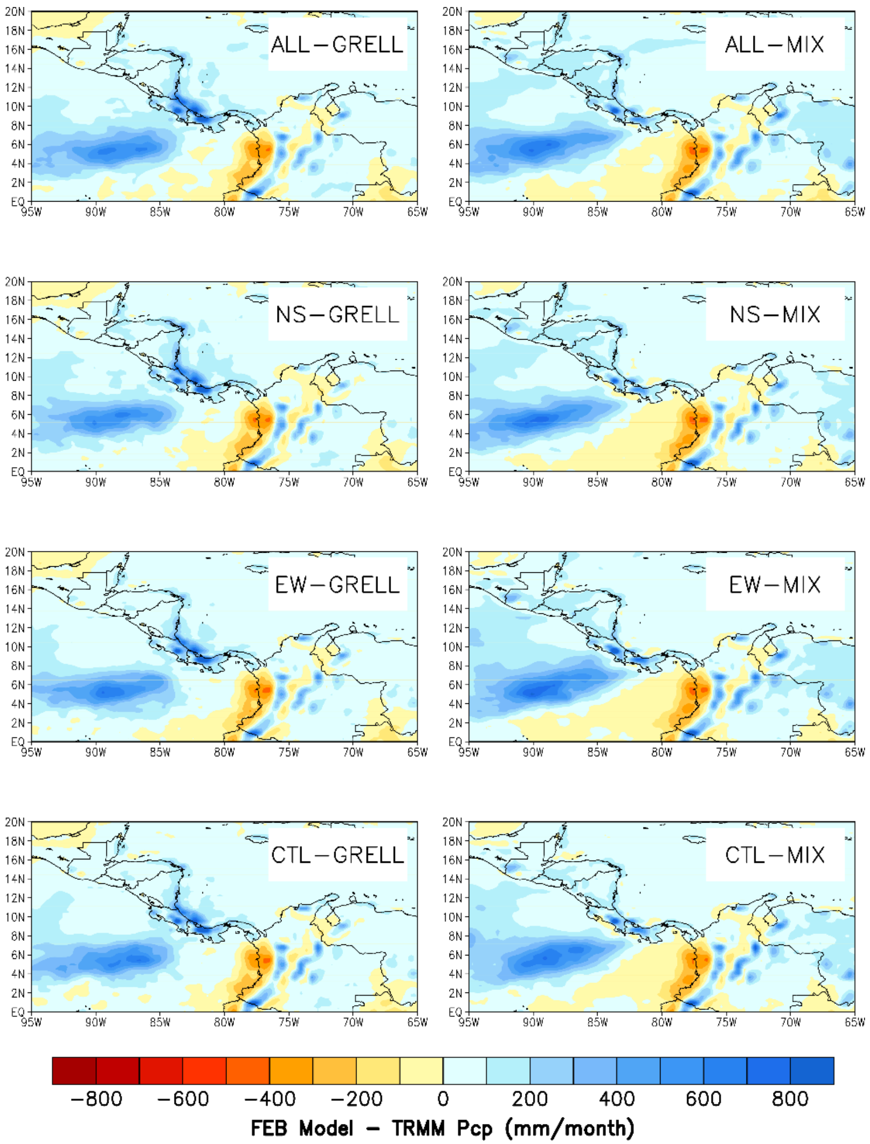
(Annual model – TRMM) Pcp

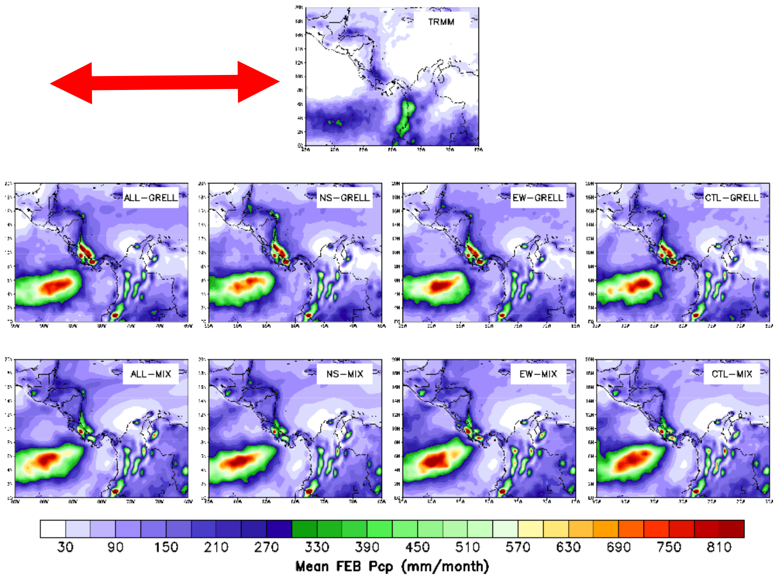


“Observed” TRMM Pcp

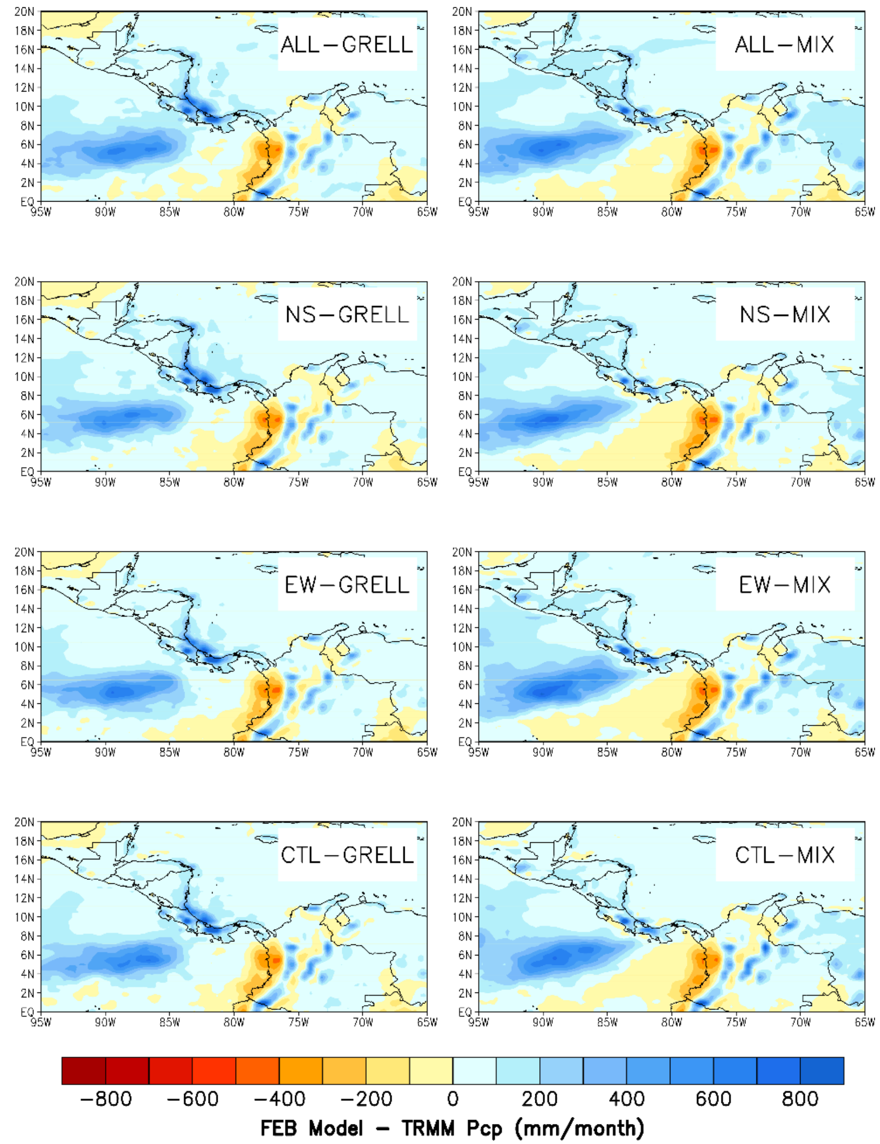


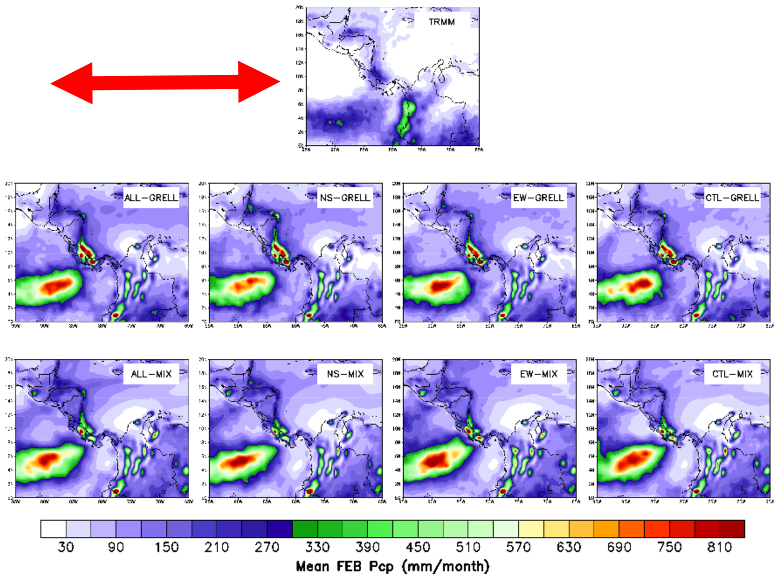




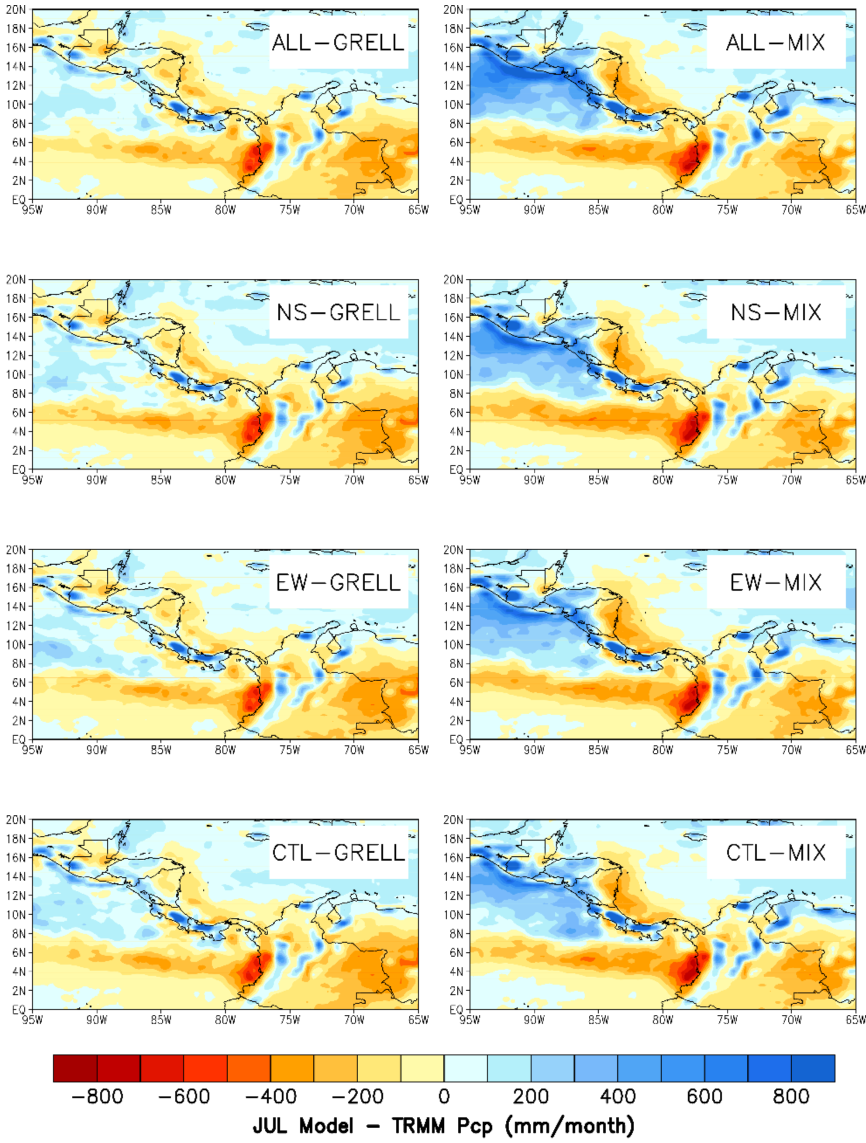


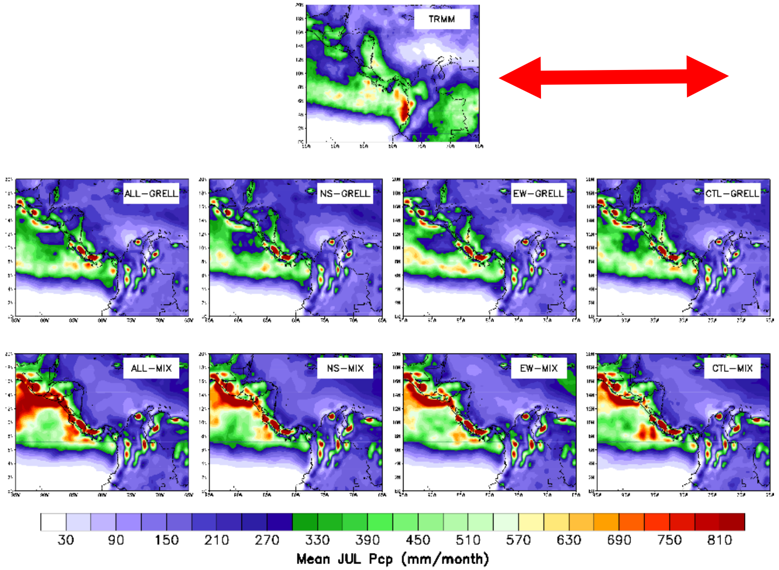
February
(Annual model – TRMM) Pcp





July
(Annual model – TRMM) Pcp





February
(Annual model – TRMM) Pcp

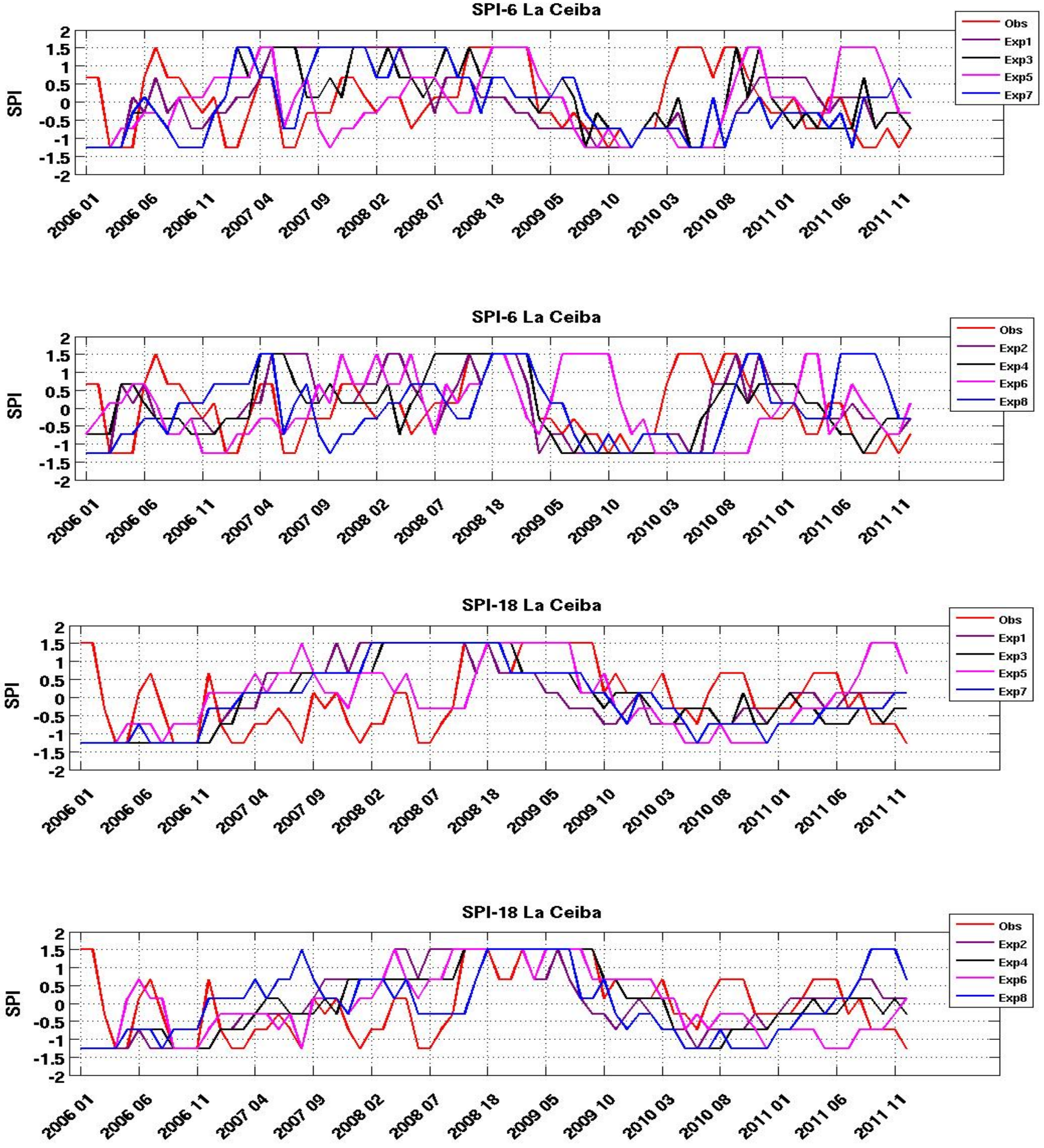
SPI

The **Standardized Precipitation Index** (SPI; McKee 1993) is the number of **standard** deviations that observed cumulative **precipitation** deviates from the climatological average.

To study extreme values of the SPI a long-term time series should be used.

In this work the aim is to see if this index has the skill to capture “normal” dry and wet periods in the monthly scales.

G


SPI-6 La Ceiba
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2006 01
2006 06
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2011 06
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SPI-6 La Ceiba
Obs
Exp2
Exp4
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SPI-18 La Ceiba
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SPI-18 La Ceiba
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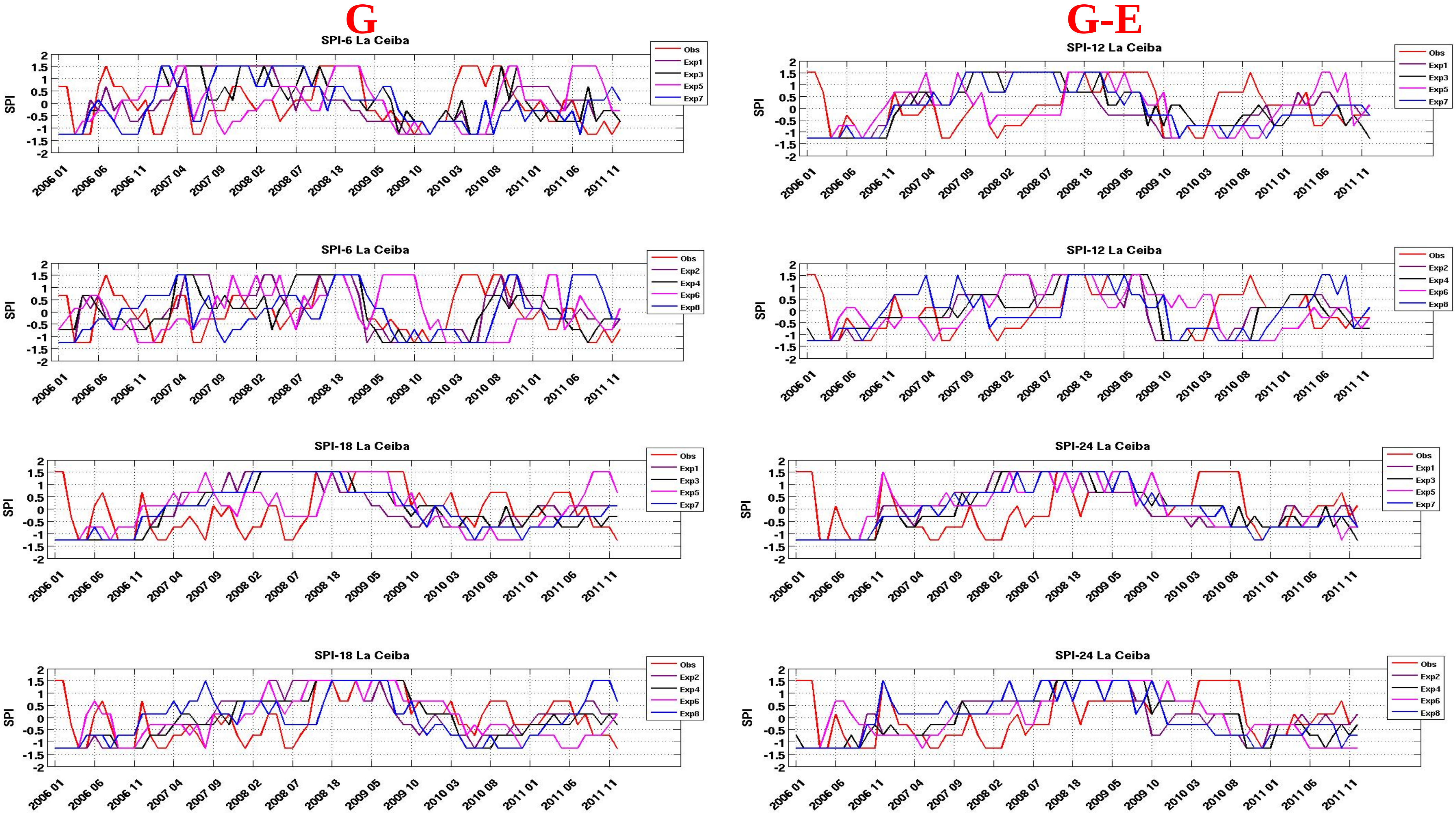
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G-E
SPI-6 La Ceiba
SPI-12 La Ceiba
SPI-18 La Ceiba
SPI-24 La Ceiba
SPI
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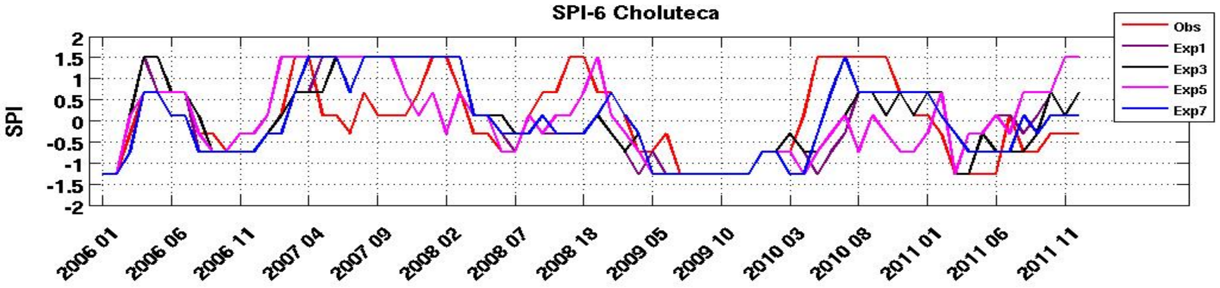
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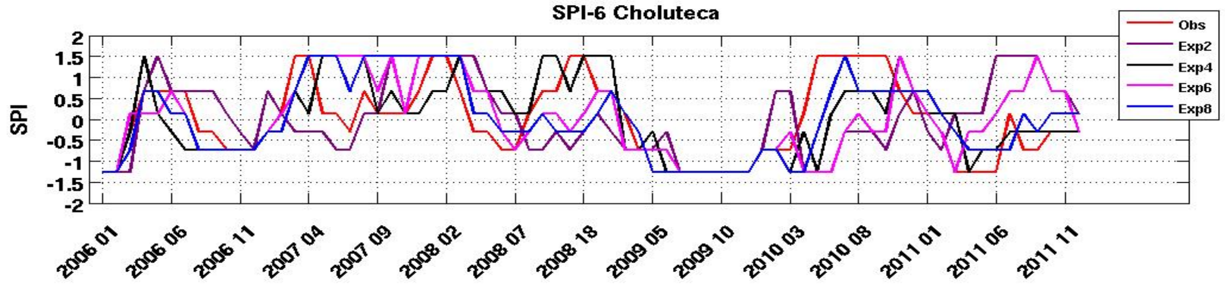
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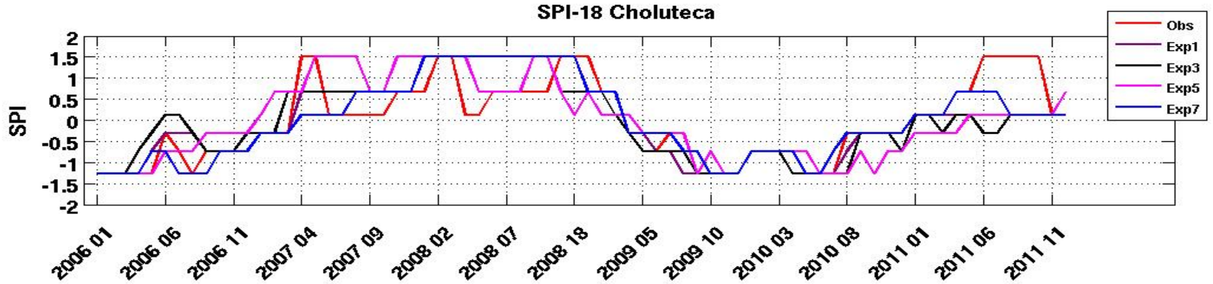
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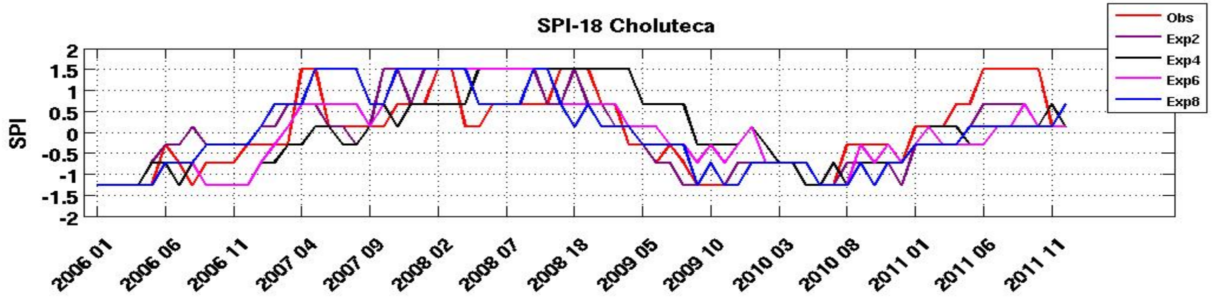
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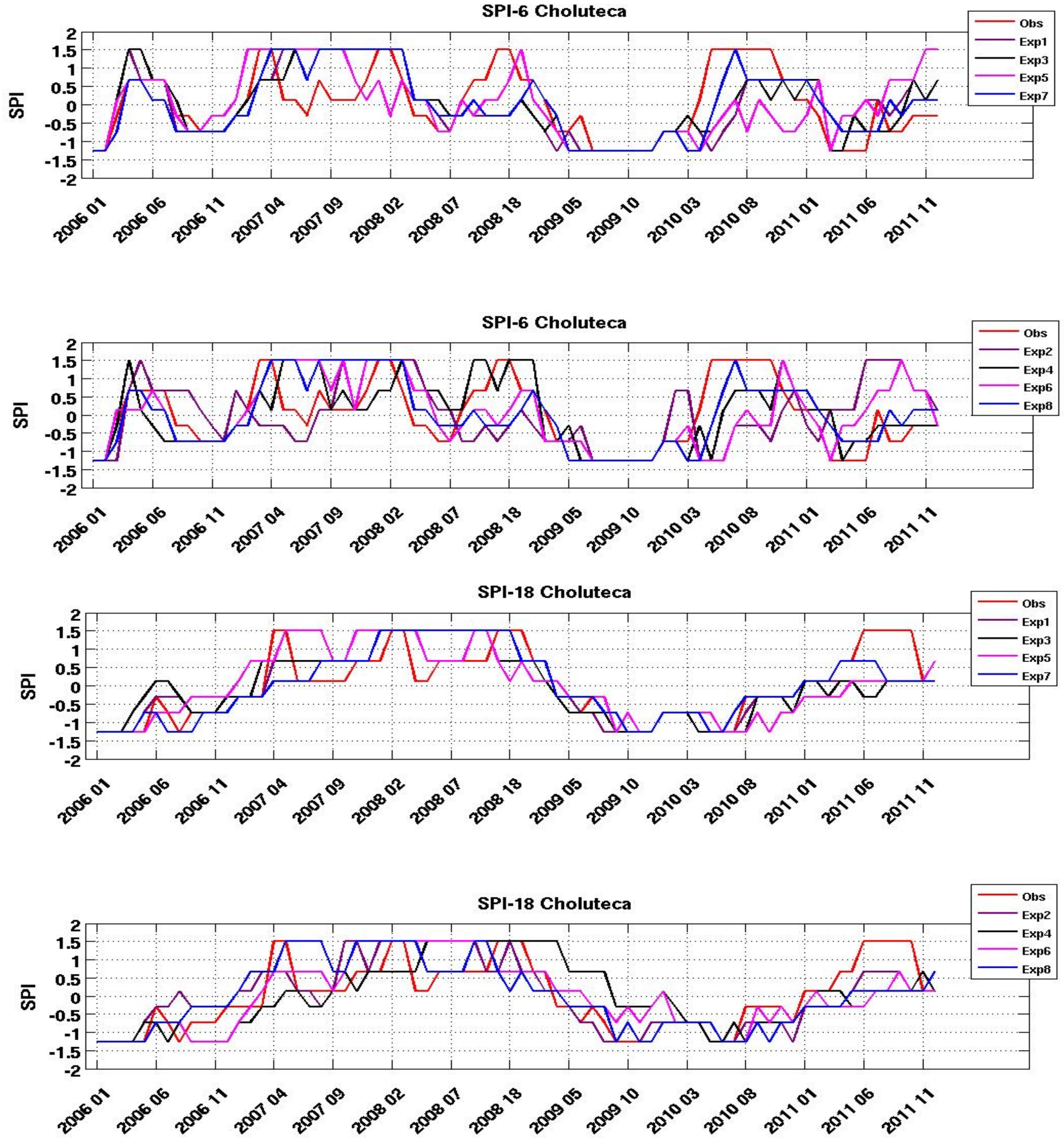
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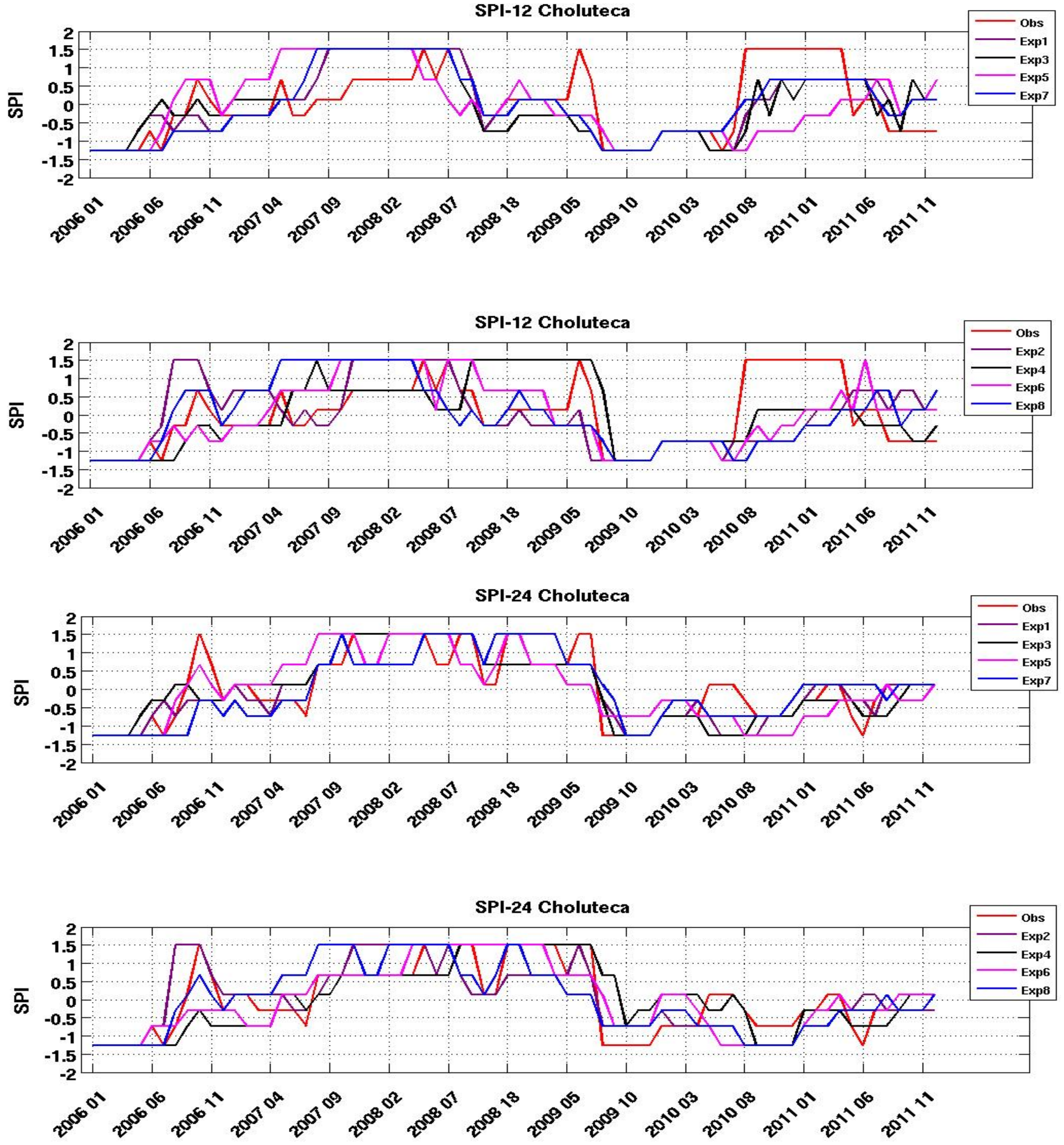
SPI-12 Choluteca
Obs
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SPI-12 Choluteca
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SPI-24 Choluteca
Obs
Exp1
Exp3
Exp5
Exp7
SPI-24 Choluteca
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Exp4
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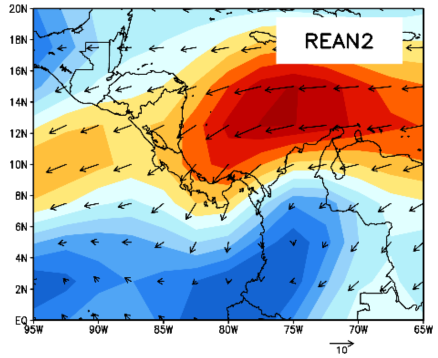
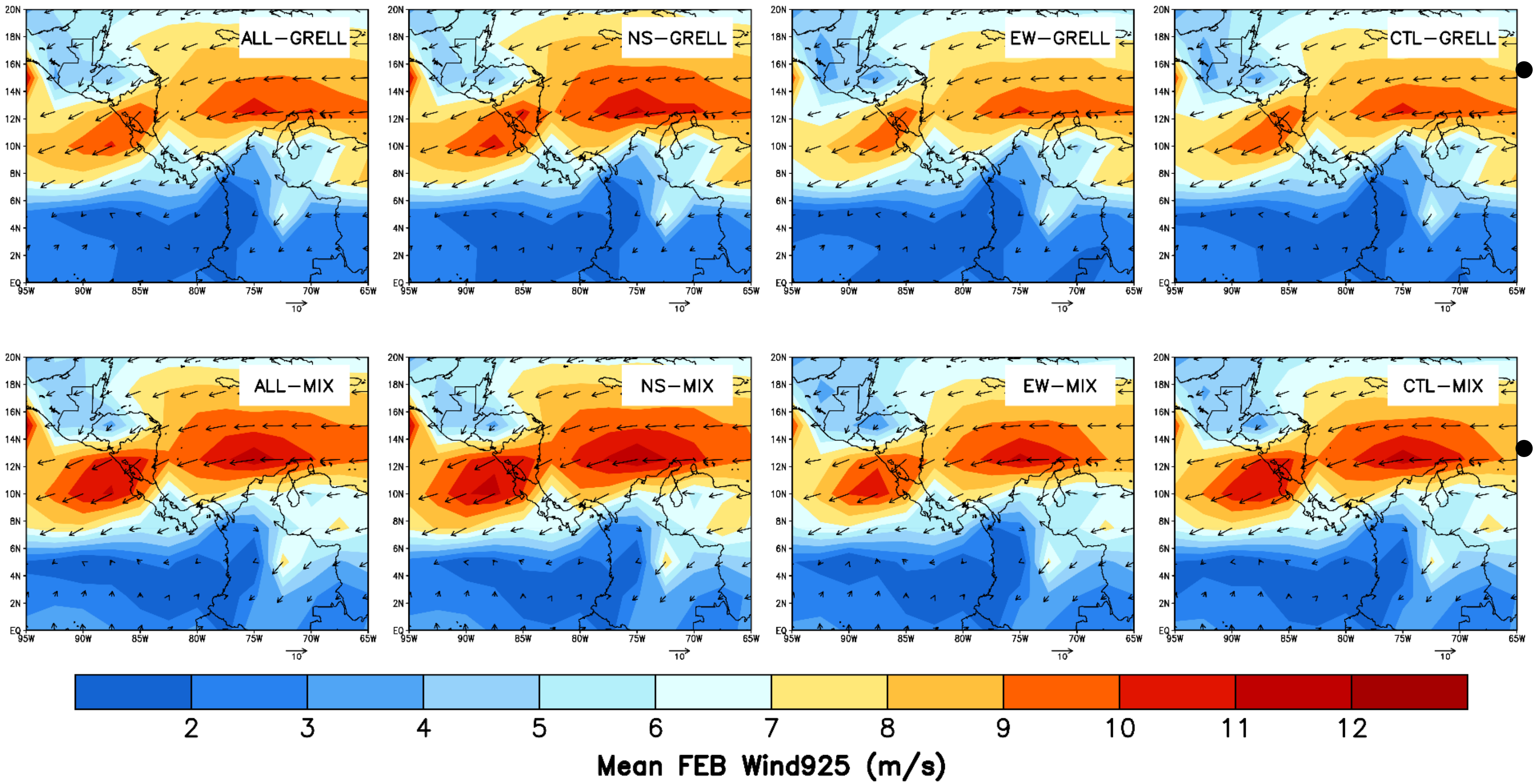
Results for wind fields

Mean February
925 hPa winds
Reanalysis 2

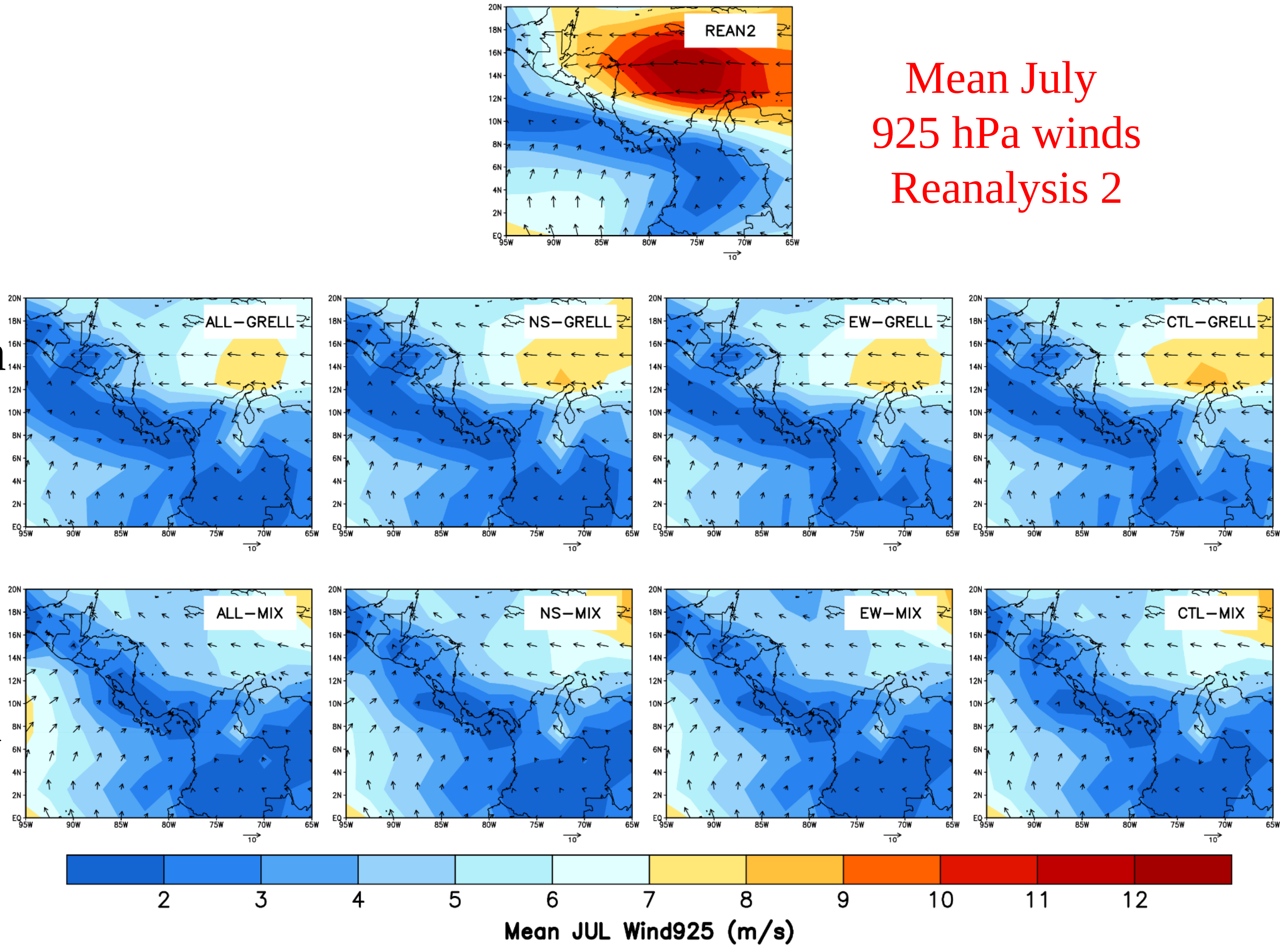




- The model captures reasonably well the **Winter** maximum of the CLLJ.
- As in the case of precipitation, there is no clear dependence on the domain size.
- Intensity of the CLLJ is greater in the simulations using mixed convective schemes.

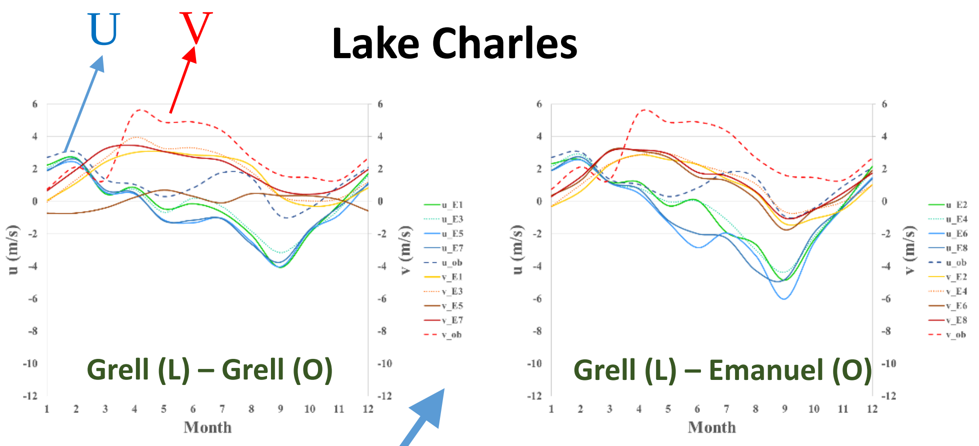
- The model underestimates the **Summer** maximum of the CLLJ.
- Better representation in the simulations that used only the Grell scheme.
- Much weaker winds over the Caribbean Sea in the simulations with mixed convective schemes.

Mean July 925 hPa winds Reanalysis 2

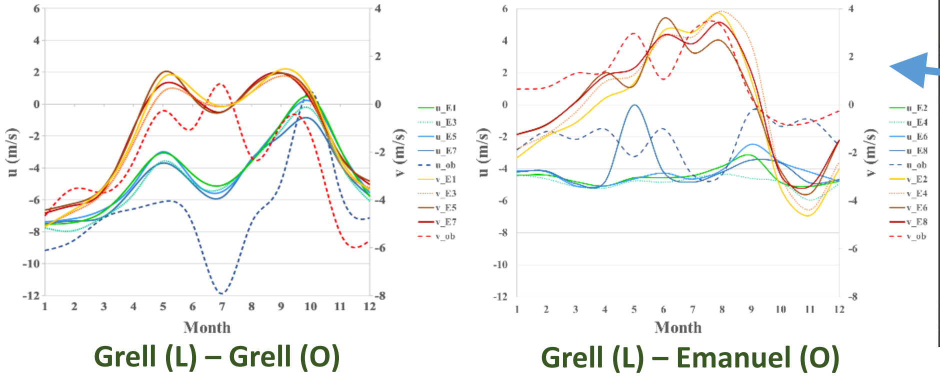


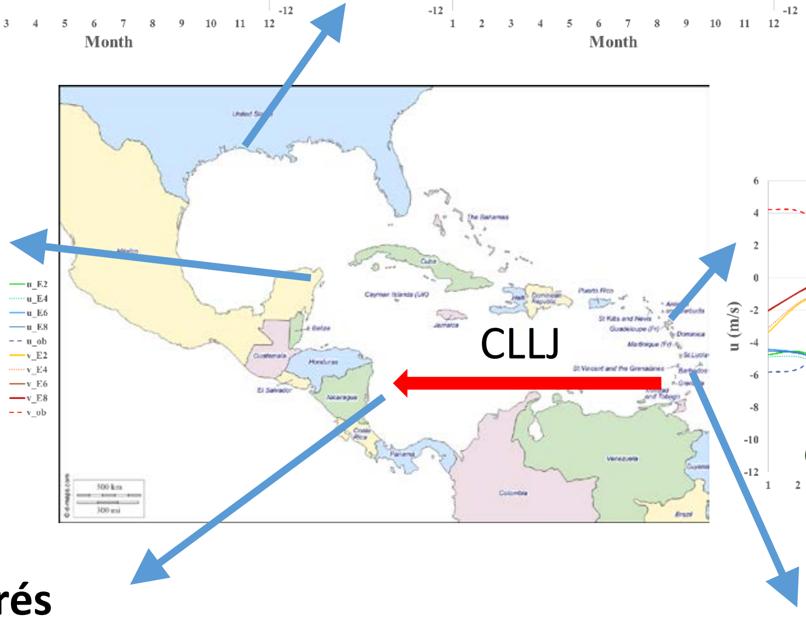
Model results vs. wind observations (soundings at 925 hPa)

Lake Charles

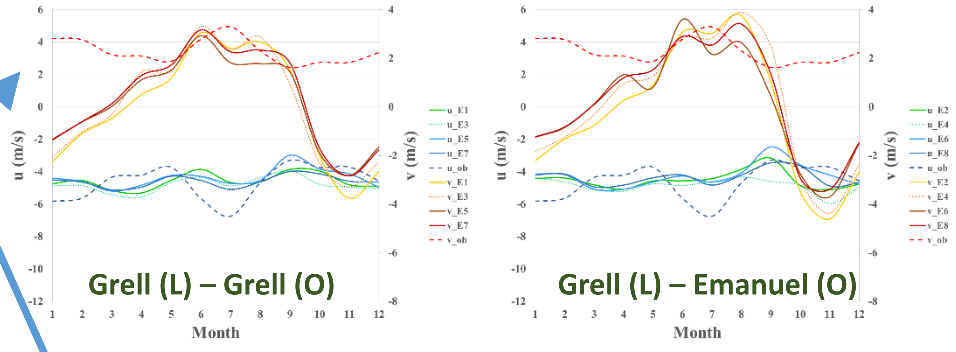


Yucatán

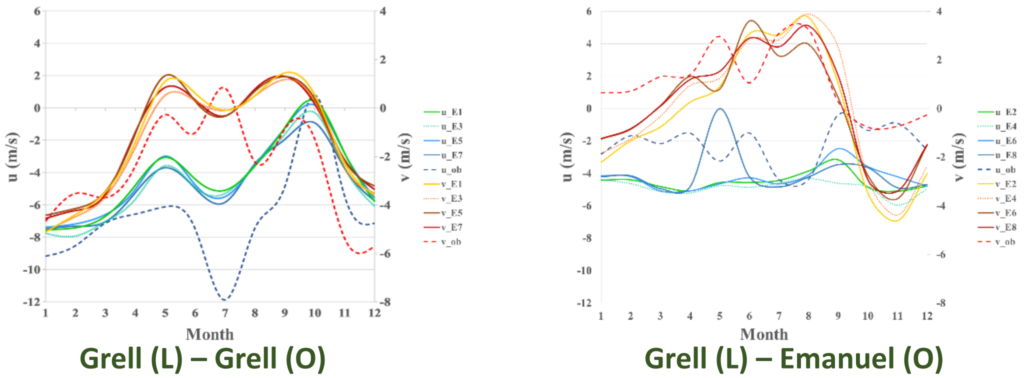




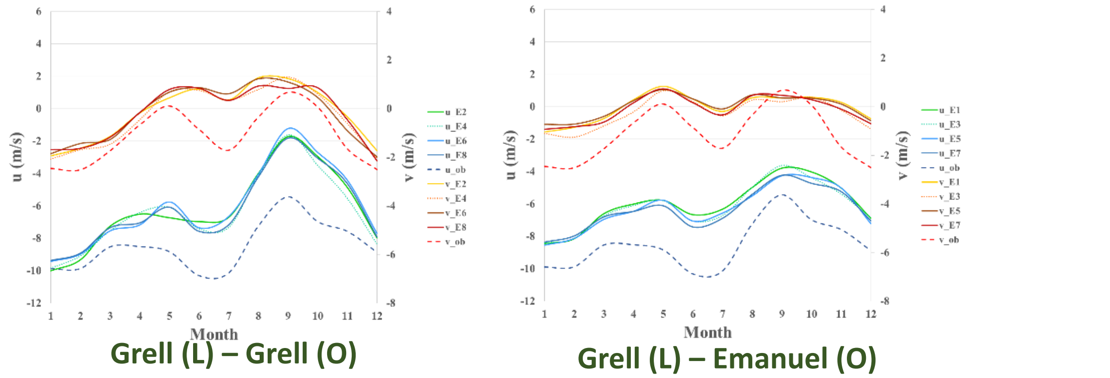
Guadalupe



San Andrés



Barbados



Results I

Precipitation and low-level circulations do not show observable sensitivity to domain size changes for an area increment of 18, 32 and 52 % with respect to the size of the control domain (CCA CORDEX domain).

RegCM4.4 model under both Grell and Enmanuel parameterizations do not capture well precipitation patterns, especially regional extremes, such as the MSD, the Choco and southwestern Caribbean maxima, however, in general Grell performs better that Enmanuel. These results contrast with those of Diro et al (2012) and are not in agreement with the scheme of a MIT convection parameterization of Emanuel (1991) over ocean areas and the scheme of (Grell 1993) over land areas as an effective scheme for most CORDEX domains (Giorgi 2012).

SPI periods of dry and wet spells using modeled data during the period analyzed appear to respond better above the 12 month frequencies, however, their correlations with precipitation data for several stations are not statisticaly significant (5%) for frequencies up to 24 months.

Results II

Simulated winds over the Caribbean associated with the CLLJ show some features of its seasonal behaviour, such as, the máxima in summer in the U component, but in general the intensity of this peak is underestimated, which has enormous implications for the position of the ITCZ and moisture transport to Central America, the Gulf of Mexico and the USA Great Planes.

This condition also affects the representation of cold air intrusions to Central America during NH Winter, an important mechanism for precipitation distribution over the Caribbean slope of this región.

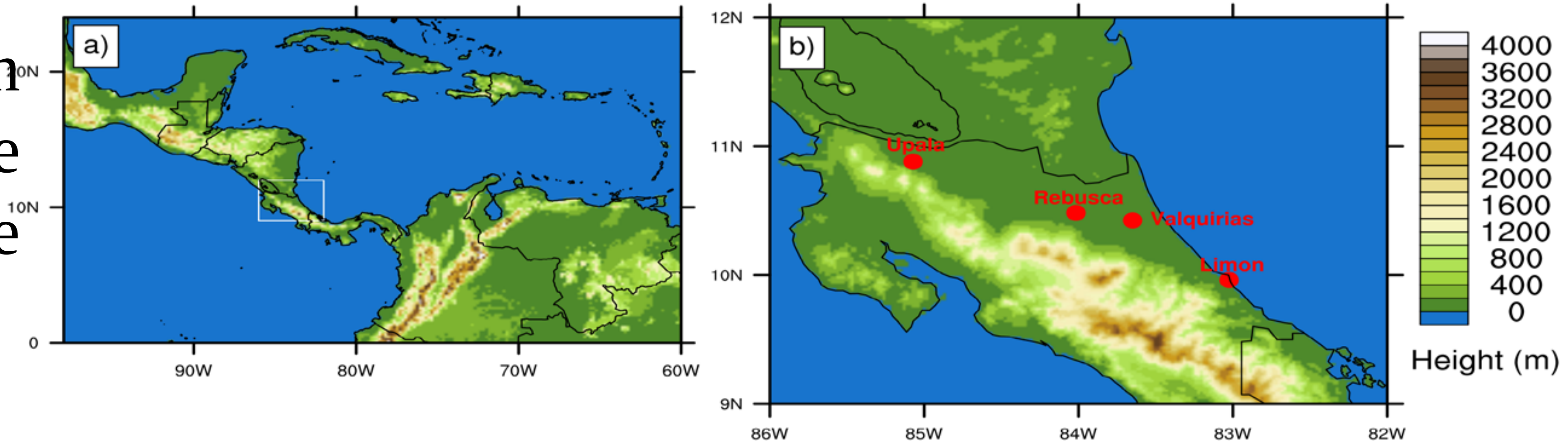
The modeled meridional wind field fails to represent the correct sign (+) in the Gulf of Mexico and (-) in the eastern Caribbean near the CLLJ entrance. This underestimates moisture transport to the Grandes Llanos low-level jet and its connection with the SALLJ.

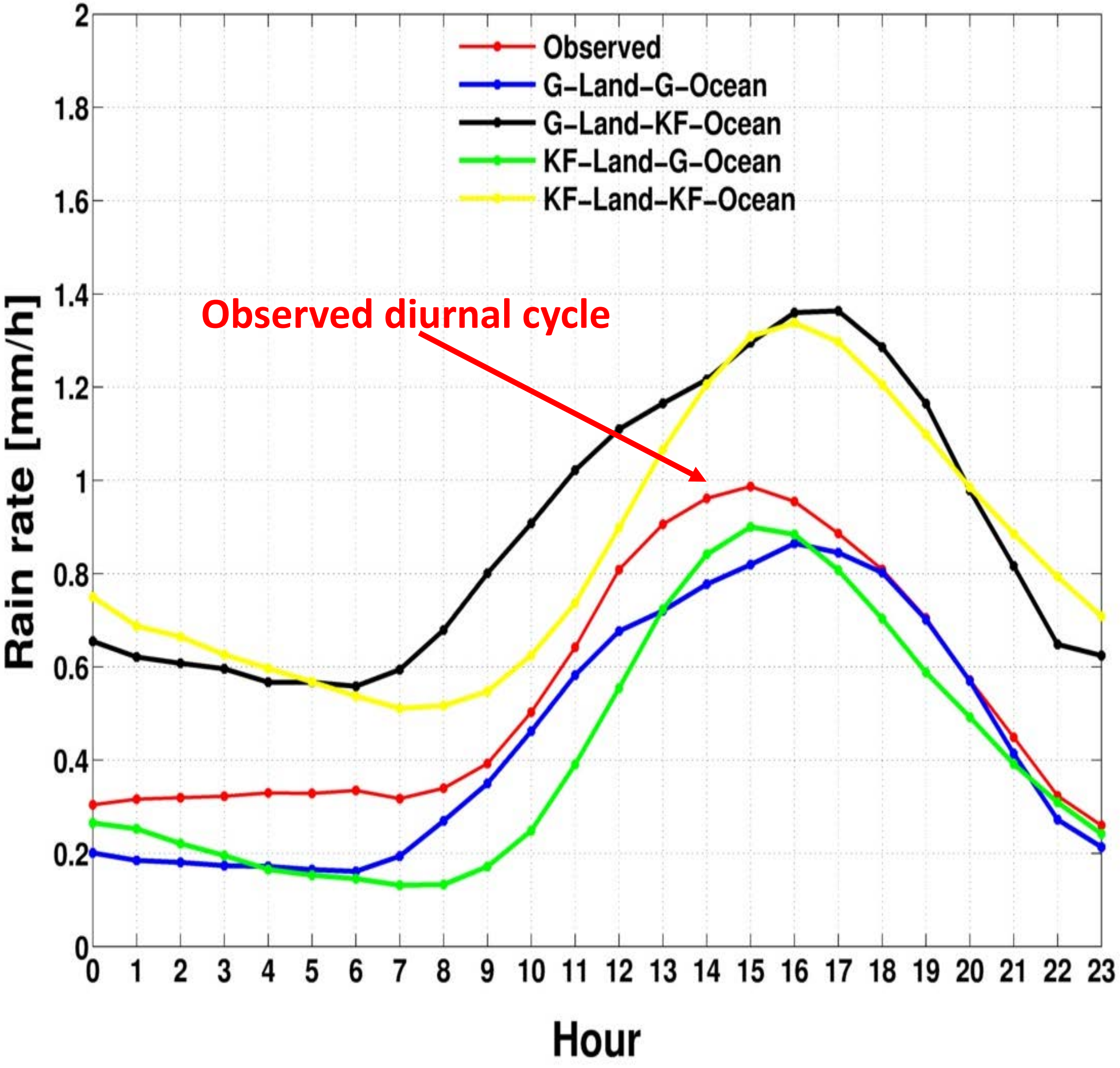
III- Downscaling of RegCM CORDEX CA domain (Saenz et al. 2017 ….)

The **Fixed model configuration** (the control simulation with Grell scheme over the entire domain) was downscaled to 25 Km resolution to test the sensitivity to convection schemes. All model configurations from this experiment were kept as before except for convection schemes and downscaled domain.

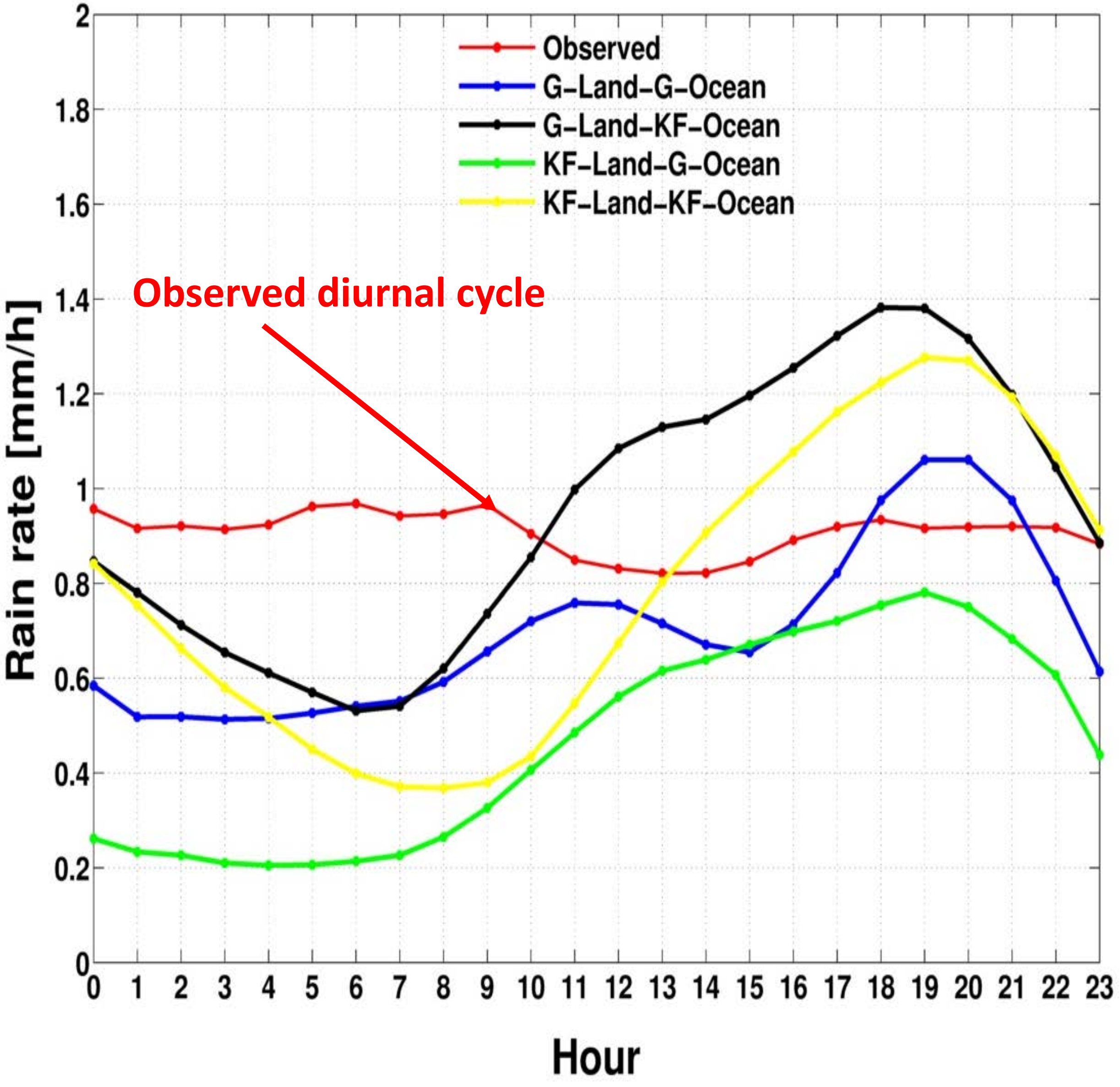
Grell (G) and Kain-Fritsch (KF) schemes and their combination over land-ocean (a total of 4 simulations) were tested for their ability to reproduce observed diurnal cycle of precipitation on the Caribbean slope of Costa Rica, a region with four types of diurnal precipitation regimes (Saenz and Amador 2016).

a) Downscaled domain and b) Caribbean slope and stations used in the study

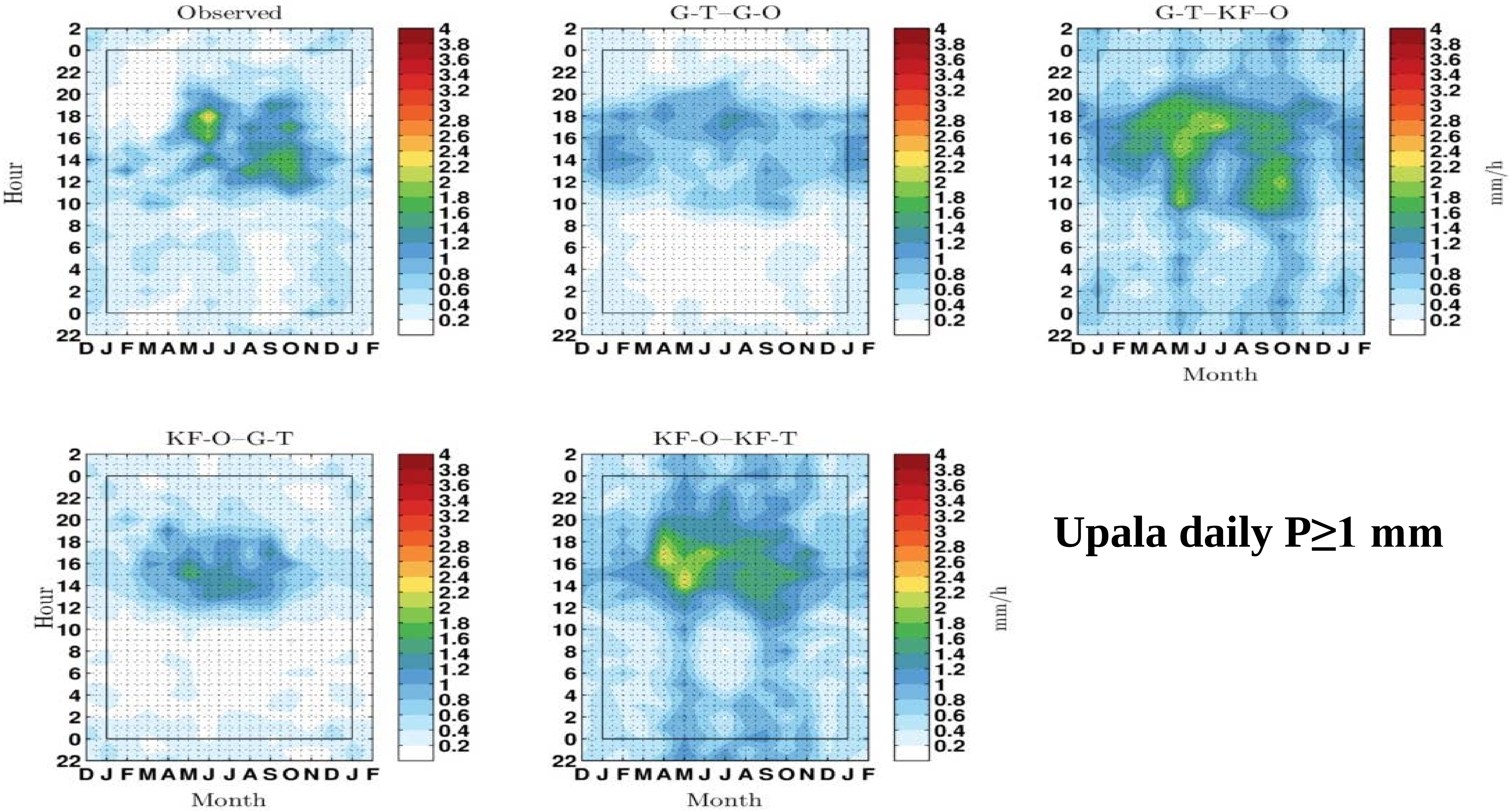




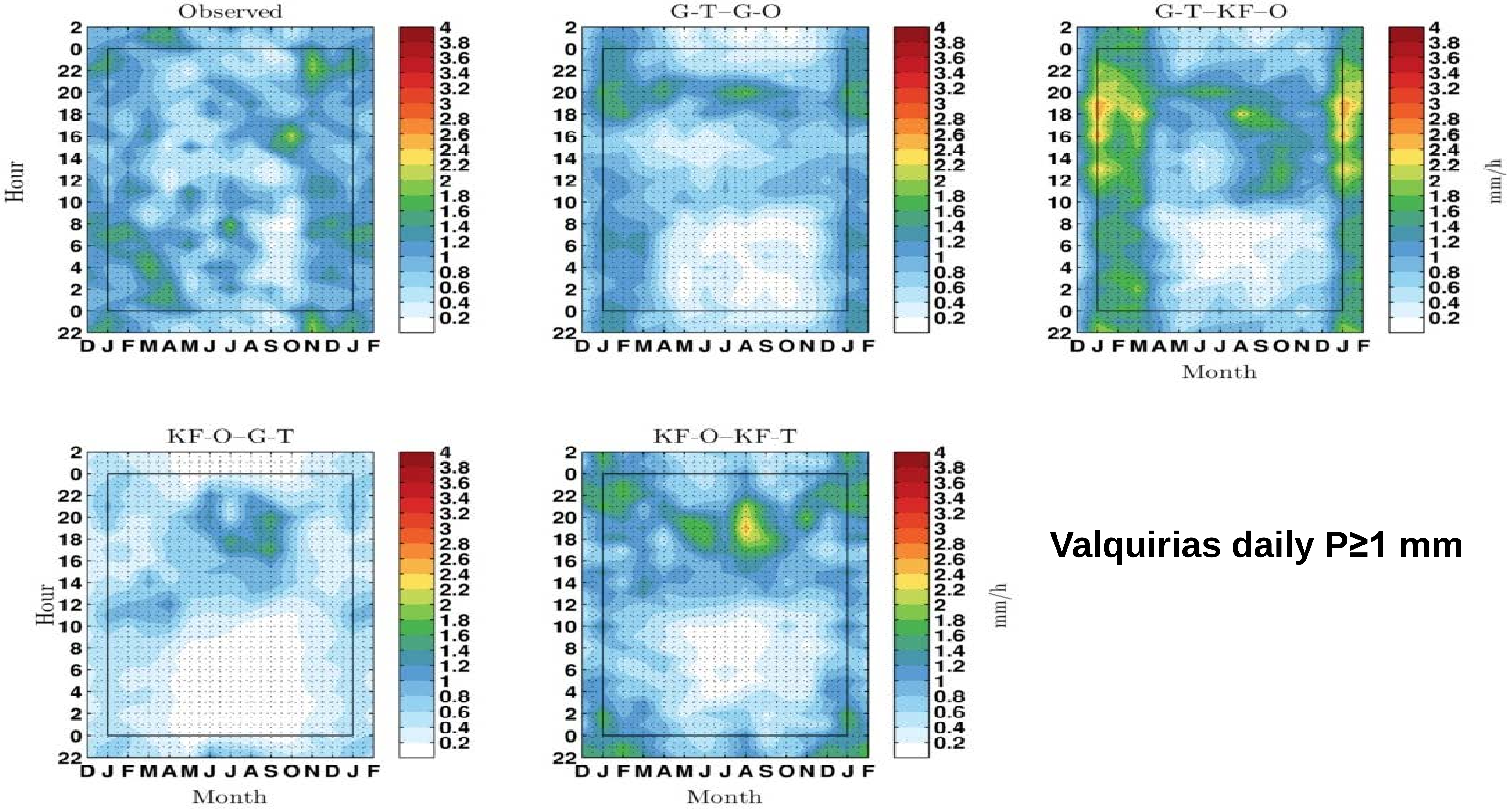
Upala daily P ≥ 1 mm



Valquirias daily P ≥ 1 mm



Upala daily P≥1 mm



Valquirias daily P≥1 mm

Results III

All simulations capture diurnal cycle's shape in land regions far from the coast (continental diurnal cycle; Kikuchi and Wang 2008) but the peaks are simulated later than observed, in contrast with Diro et al. 2012 when compared to TRMM data.

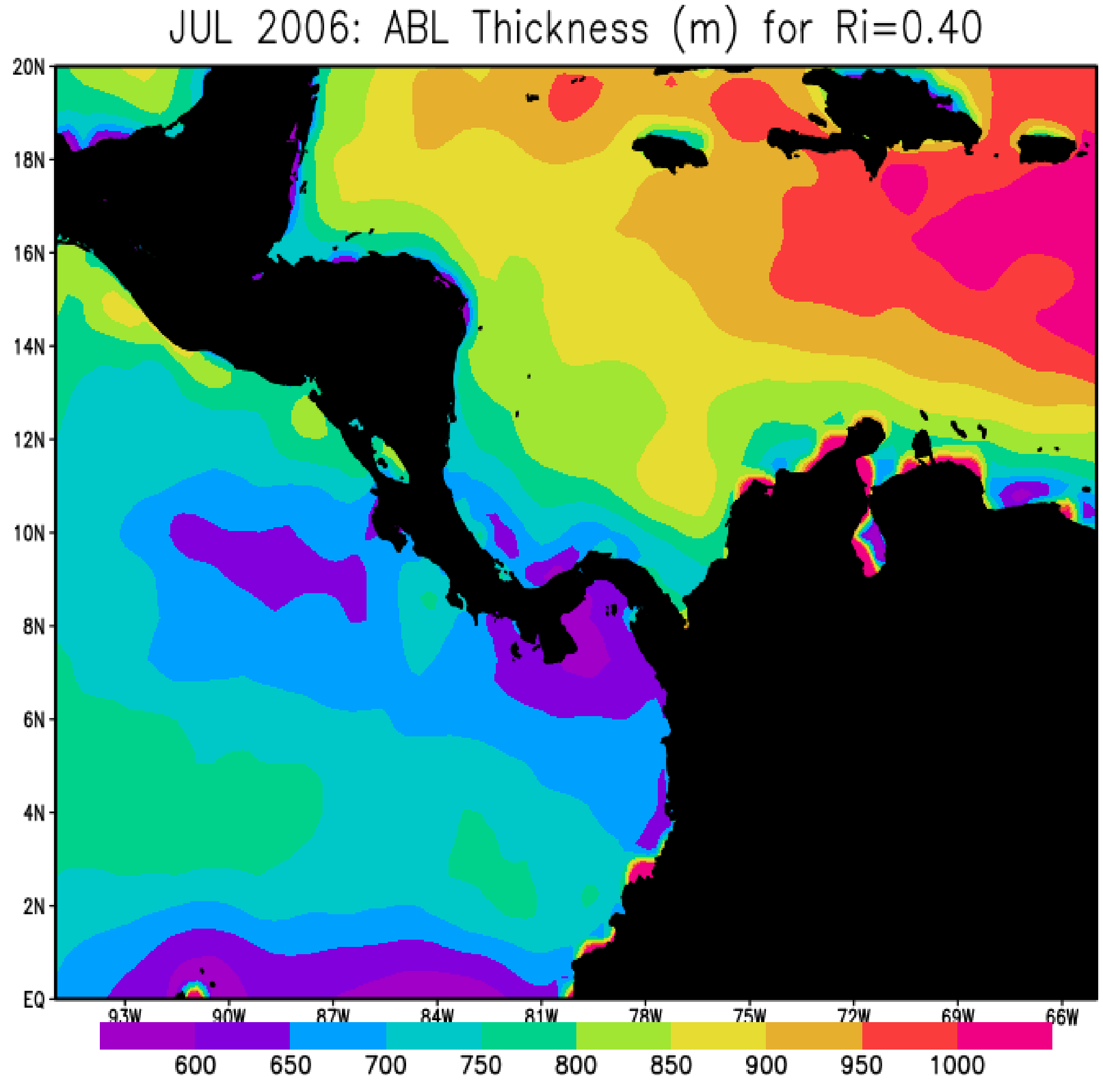
On coastal regions where observed diurnal cycles are complex, most model simulations show a more defined diurnal cycle, indicating that the model is not simulating the wealth of precipitation producing mechanisms in coastal regions (Resolution? Sure, what else?)

Simulations of the seasonal variations of the diurnal cycle are less satisfactory, analysis show that the model has problems representing some larger scale features (e.g., CLLJ) that are relevant to diurnal cycle of precipitation in this region, which is modulated by multi-scale interactions.

Heigth of the PBL in the IAS as estimated from the Holstlag scheme

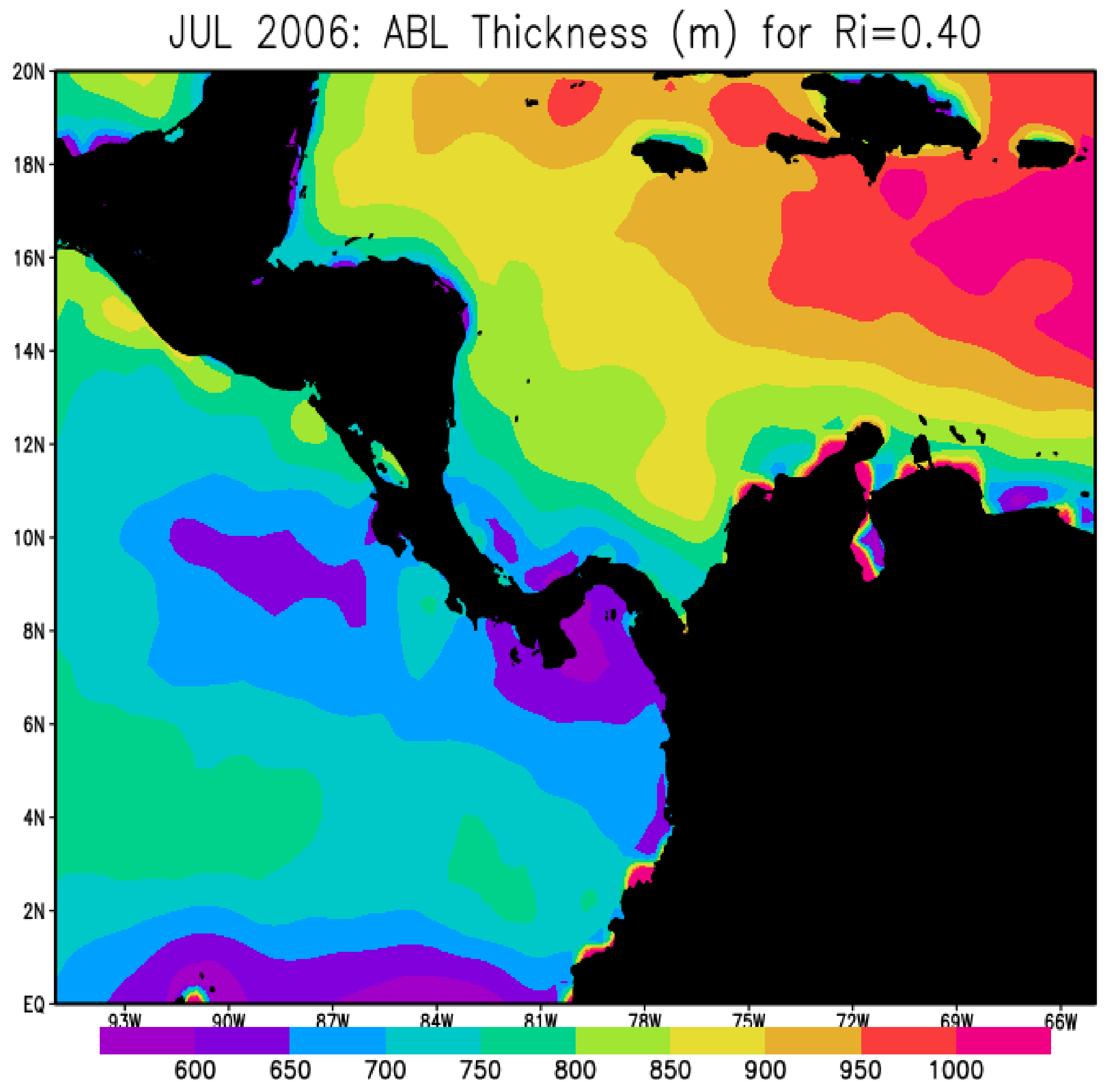
Ri = (0.1, 0,2, 0,25, 0,3, 0.4)

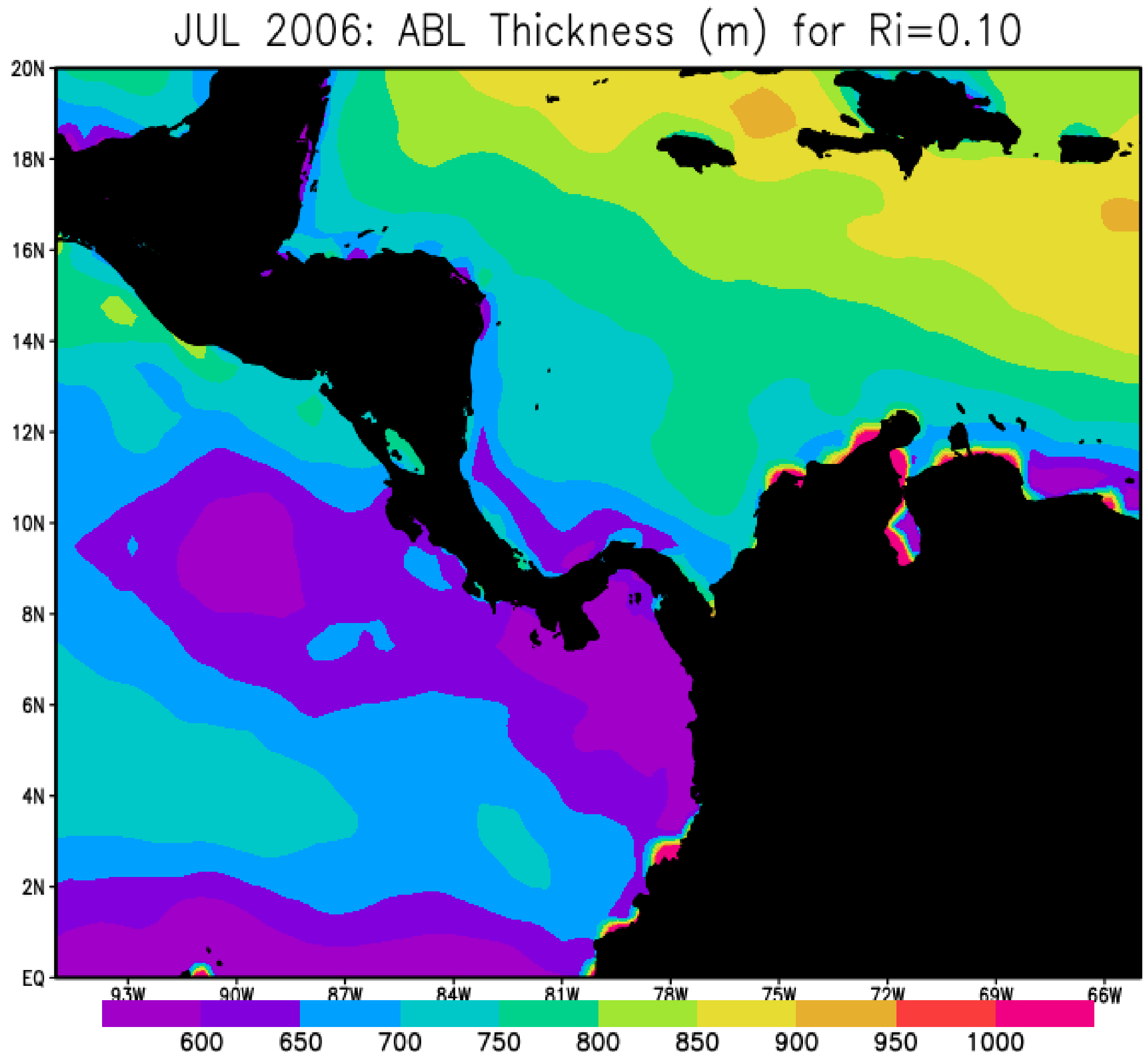
Heigth of the PBL in the IAS as estimated from the Holstlag scheme
Ri = (0.1, 0,2, 0,25, 0,3, 0.4)



Heigth of the PBL in the IAS as estimated from the Holstlag scheme

Ri = (0.1, 0,2, 0,25, 0,3, 0.4)





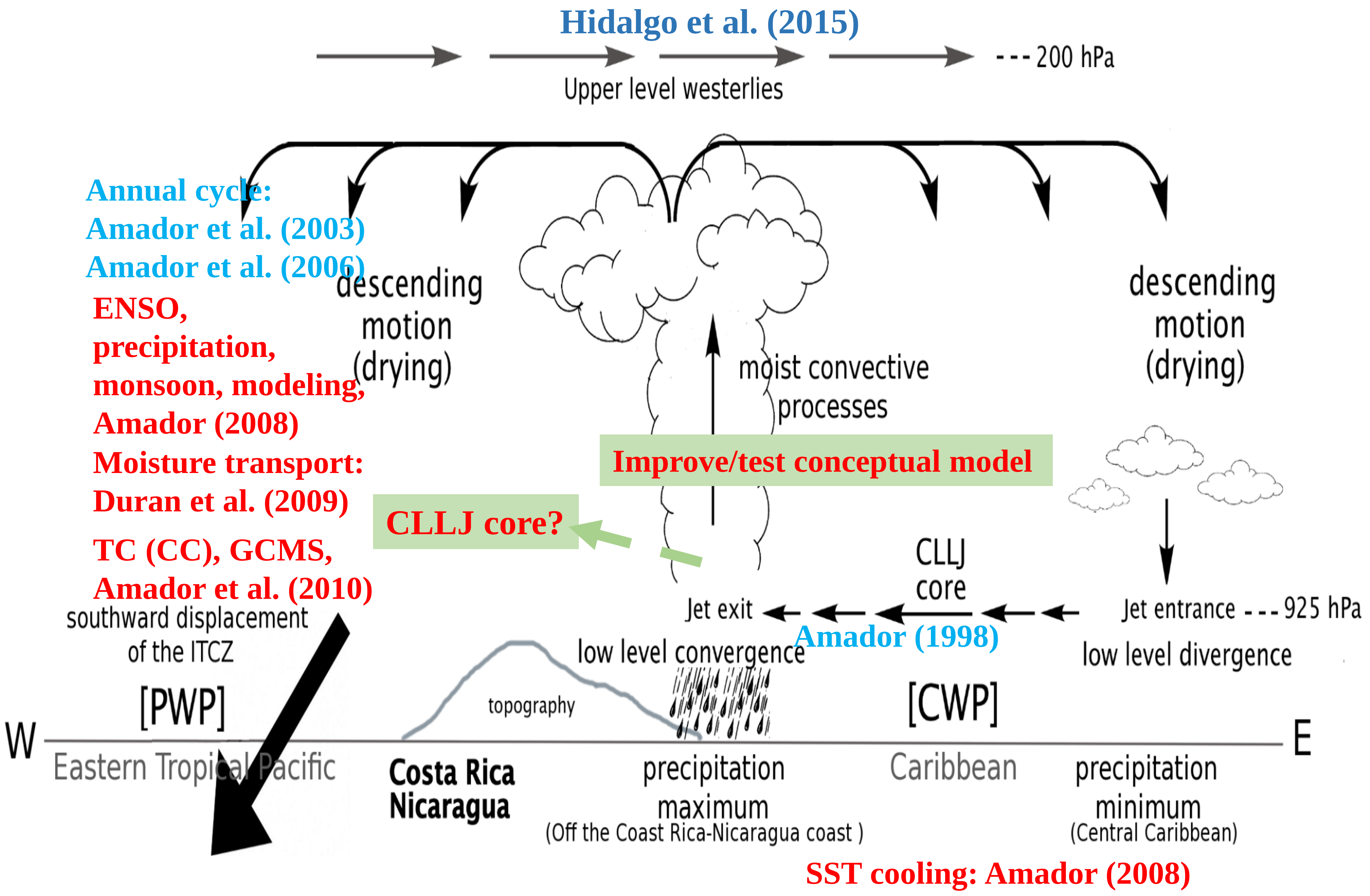
Work in progress Big Brother Experiment

Isolate the effect of domain size by seeing if a small domain can reproduce the results from a large domain when using the same RegCM4.4 model.
The Big Brother results (50 km resolution) will be smoothed to imitate a coarse resolution driving model (200 km resolution). The filtered output will serve as the initial and lateral boundary conditions for a smaller domain with a resolution of 50 km.

Downscaling experiments

An objective frame for evaluation of the shown experiments is being developed.
More simulations with smaller resolutions will be performed.

Also the new non-hydrostatic version of RegCM will be incorporated to the analysis, if model stability is satisfactory.



Hidalgo et al. (2015)
200 hPa
Upper level westerlies
Annual cycle:
Amador et al. (2003)
Amador et al. (2006)
ENSO,
precipitation,
monsoon, modeling,
Amador (2008)
Moisture transport:
Duran et al. (2009)
TC (CC), GCMS,
Amador et al. (2010)
descending
motion
(drying)
moist convective
processes
descending
motion
(drying)
Improve/test conceptual model
CLLJ core?
CLLJ
core
Jet exit
Jet entrance
925 hPa
Amador (1998)
southward displacement
of the ITCZ
low level convergence
low level divergence
[PWP]
topography
[CWP]
W
E
Eastern Tropical Pacific
Costa Rica
Nicaragua
precipitation
maximum
(Off the Coast Rica-Nicaragua coast)
Caribbean
precipitation
minimum
(Central Caribbean)
SST cooling: Amador (2008)

References

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