“Dynamical downscaling experiments for a tropical region”.

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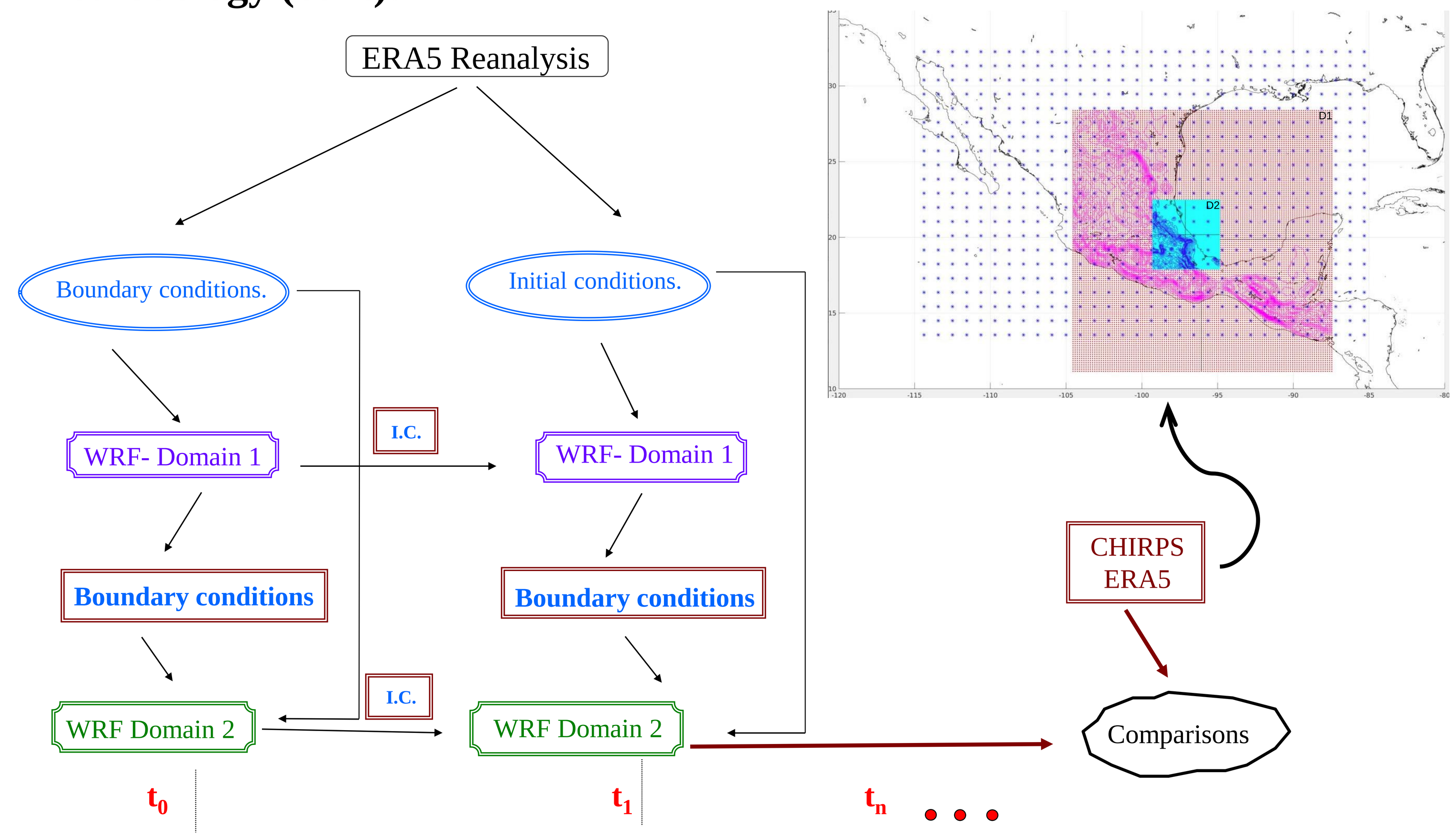
Abstract:. Dynamical downscaling experiments were evaluated using the regional model WRF in the “convection permitting” mode. The simulations were performed for a short period (April 22-30, 2014: during which an extreme precipitation event was registered) and for a longer period: from May to September 2010, in both cases using ERA5 database to force the WRF model evaluating their capabilities. The regional model was running under medium resolution coarse grid (15 km) and high-resolutions (3km, 4 km, 5 km, 6 km and 10 km) nesting grids, covering a domain over a group of river basins located in the tropical zone of Mexico: northern Veracruz. The numerical simulations were evaluated analyzing the spatial distribution of precipitation and surface temperature through comparisons between CHIRPS and ERA5 databases

Rationale: The tropical atmosphere is characterized by weak thermal gradient and intense convective activity, the release of latent heat is the main source of energy in the circulations of the region. In the southeastern Mexico the orographic and oceanic influence in the atmospheric processes modulate convection and precipitation. The resolution of the ESM´s is insufficient to describe the important subcontinental processes at scales smaller than 10 km. This gap is filled up by performing dynamical downscaling. The aim of this study is to improve convection reproduction in high-resolution simulations in the “convection permitting” mode forced by ERA5 Reanalysis to reproduce the impact of intense precipitation with direct influence of the Gulf of Mexico.

Goal:. Compare simulations between the coarse grid and the high-resolution grids, analyzing the performance of the model, identifying the best combination of physical process parameterizations in combination with the convection permitting option for high resolution grids. The implications of the improvement of the model's capacities to reproduce low and high frequency processes, including the “convection permitting” option is analyzed to understand the main local processes and mechanisms at different scales and their relationship. For the next stage of the project, the best ESM´s was chosen to force the WRF model for both historical and future periods under climate change scenarios.

Methodology: To test how well the regional models can reproduce local processes and mechanisms to improve the representation of convection in the tropics at high resolution, the numerical simulations were carried out with the configurations with the best performance (Table I) in several numerical experiments using WRF with the “convection permitting mode” for short-term simulation (April 22-30, 2014) and long-term (May to September 2010).

Methodology (cont):



Configuration		ERA5 / WRF
Coarse Domain		10° N- 29°N, 86°W- 106° W
Resolution	Horizontal	25 km
	Vertical	18 levels. Top: 100 hPa
Nested Domains		17.5° N- 22°N, 94.5°W- 99° W
Resolution	Horizontal	3 km, 4 km, 5 km, 6 km and 10 km
	Vertical	18 levels. Top: 100 hPa
Relaxation zone		12 grids
Parameterisations	Micro Physics	WRF Single–moment 6–class Scheme (2006)
	Cumulus Physics	Grell–Freitas Ensemble Scheme (coarse grid) (2014)
	Boundary Layer	Mellor–Yamada Nakanishi Niino (MYNN) (1994)
	Longwave radiation	RRTM Longwave Scheme (1997)
	Shortwave radiation	Dudhia Shortwave Scheme (1989)
	Surface Layer	MYNN Scheme (2006)
	Land surface	Noah–MP Land Surface Model (2011)
	Periods	April 22-30, 2014. May to Sep 2010

Table I. WRF configuration

R E S U L T S

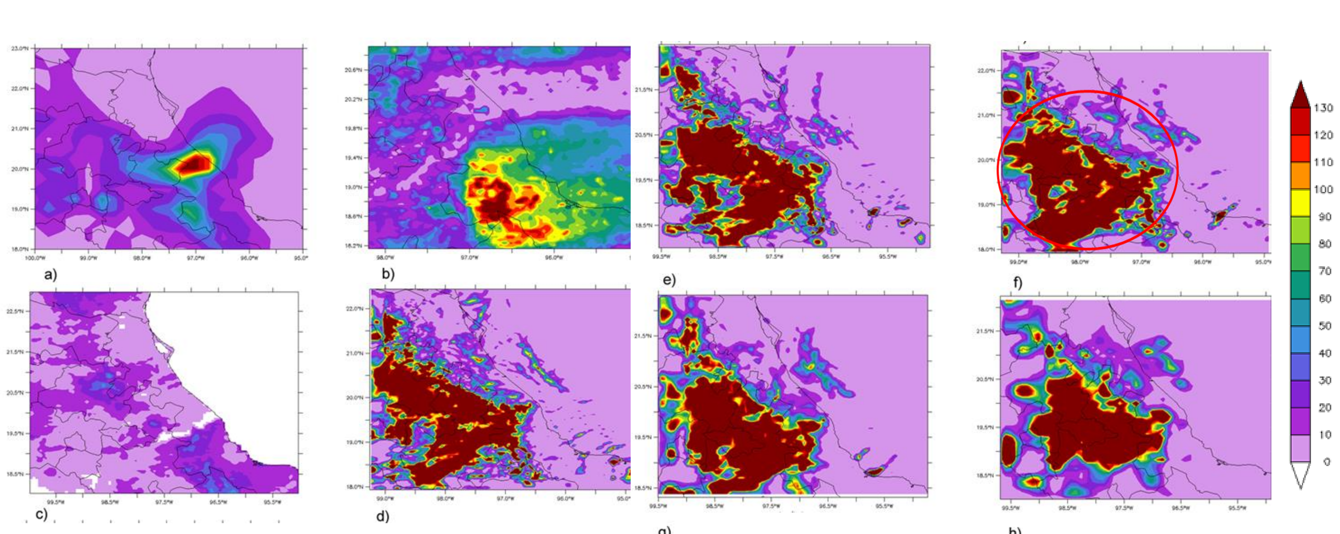


Fig. 1 Accumulated precipitation (mm) April 22-30. 2014. a) ERA 5 25 Km. b) CCS 5 Km. c) CHIRPS 4 Km. d) WRF 3 Km. e) WRF 4 Km. f) WRF 5 Km. g) WRF 6 Km. h) WRF 10 Km.

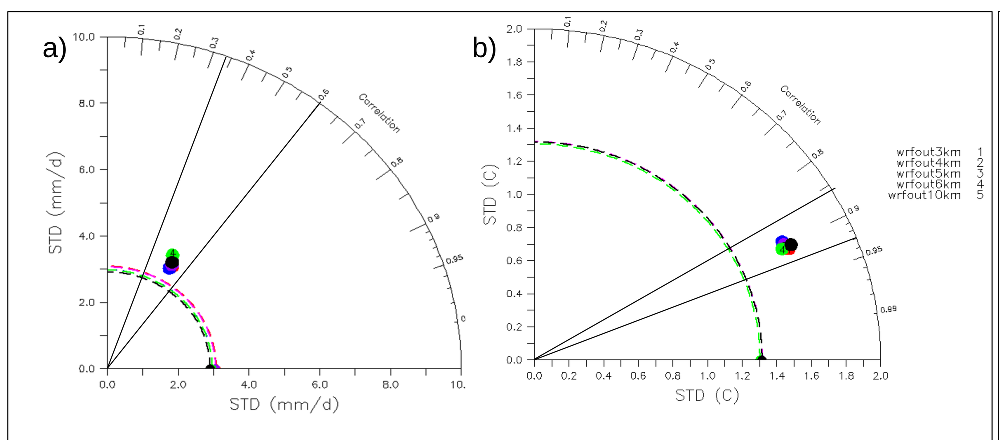


Fig. 2 Comparisons. April 22-30 2014. a) Precipitation. CHIRPS-WRF 2014. b) Surface temperature. ERA5-WRF.

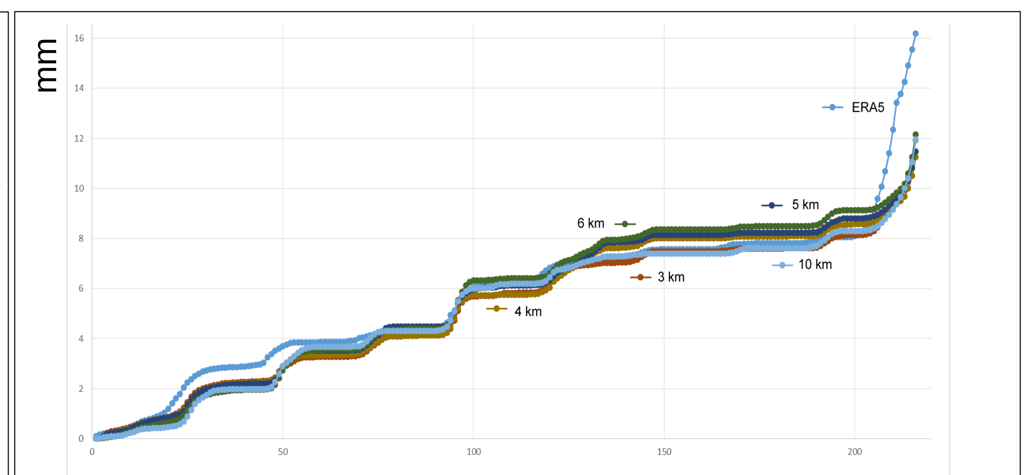


Fig. 3 Accumulated hourly precipitation (mm) WRF and ERA. April 22-30. 2014

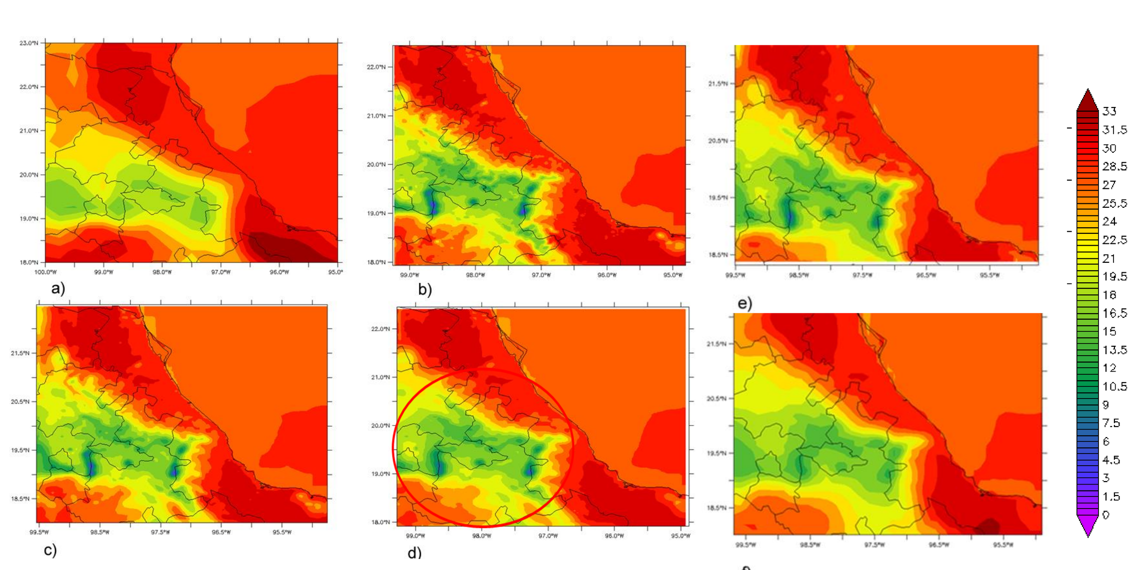


Fig. 4 Surface temperature (°C) April 22-30. 2014. a) ERA 5 25 Km. b) WRF 3 Km. c) WRF 4 Km. d) WRF 5 Km. e) WRF 6 Km. f) WRF 10 Km.

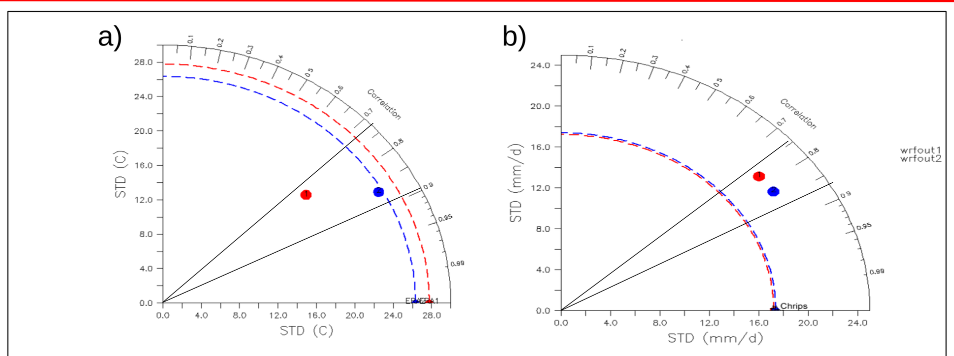


Fig. 5 Precipitation comparison . CHIRPS-WRF. 2010 a) June. b) Sep

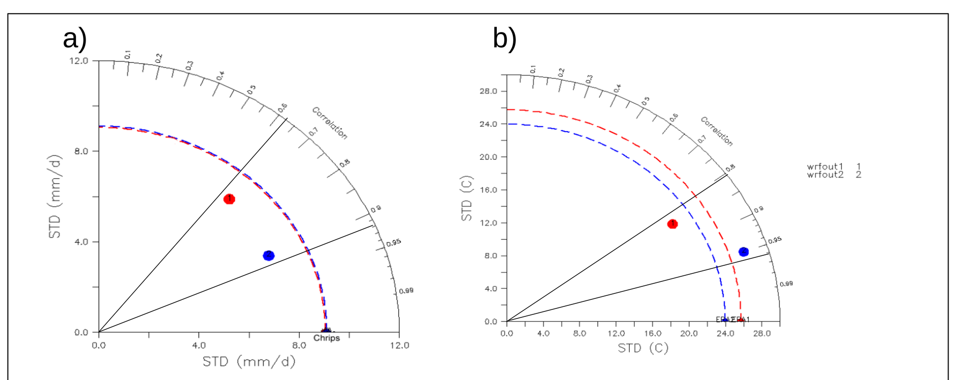


Fig. 6 Temperature comparison. CHIRPS-WRF. 2010 a) June. b) Sep

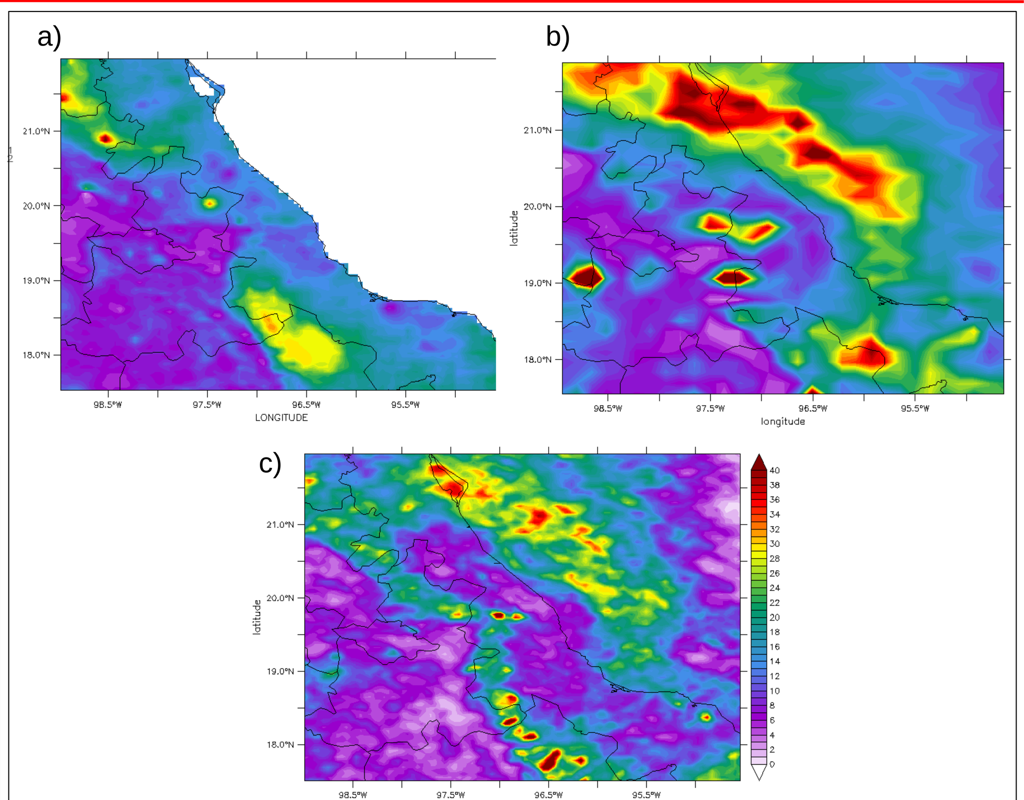


Fig. 7 Long-term precipitation analysis. July 2010. a) CHIRPS. b) 15 Km. resolution c) 3 Km. resolution

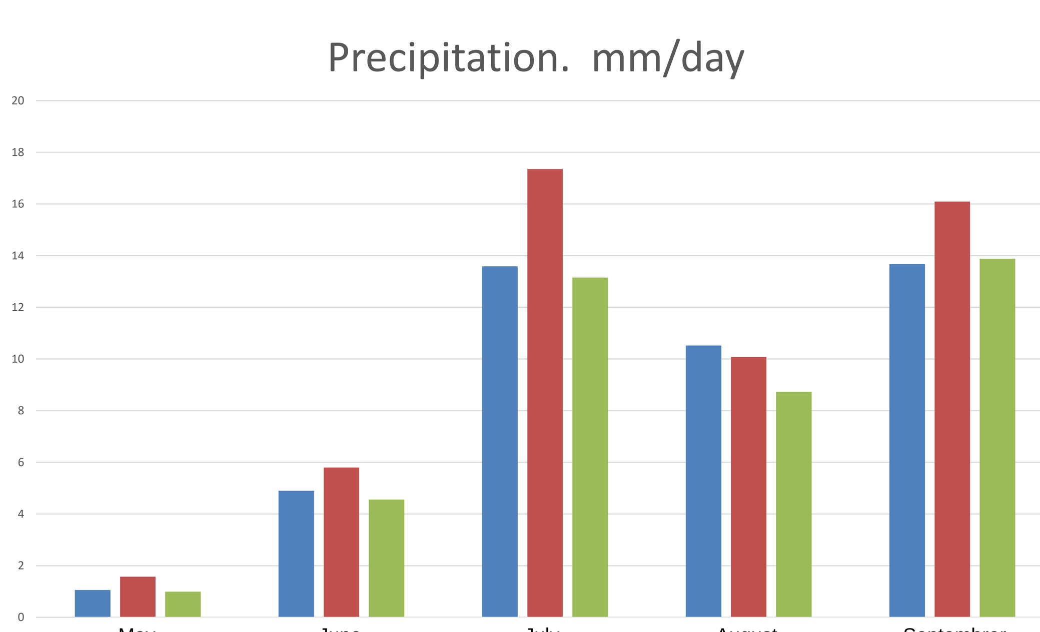


Fig. 8 Monthly accumulated precipitation May-nov 2010.

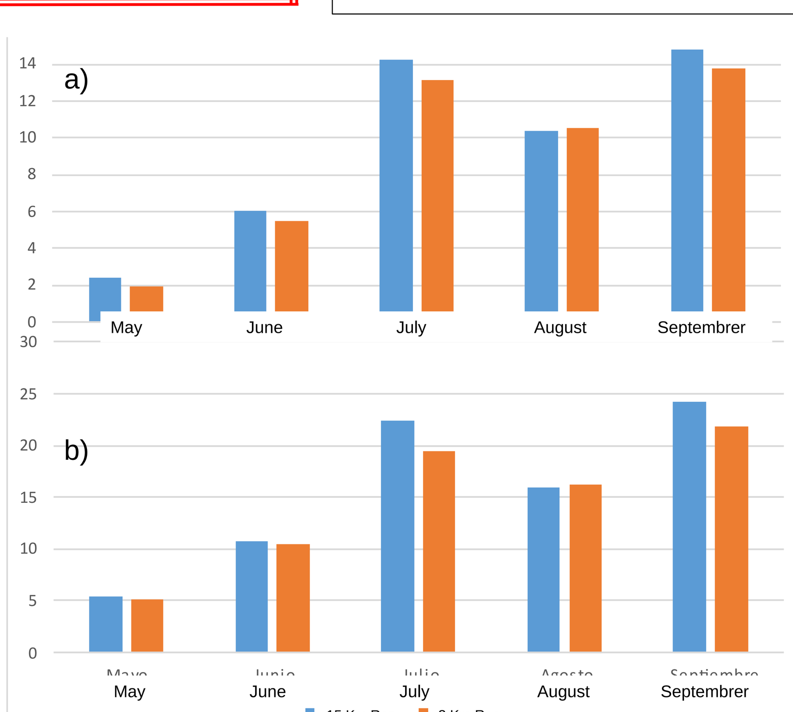


Fig. 9 Precipitation May-nov 2010 a) Mean absolute error (MAE). b) Root mean square error (RMSE).

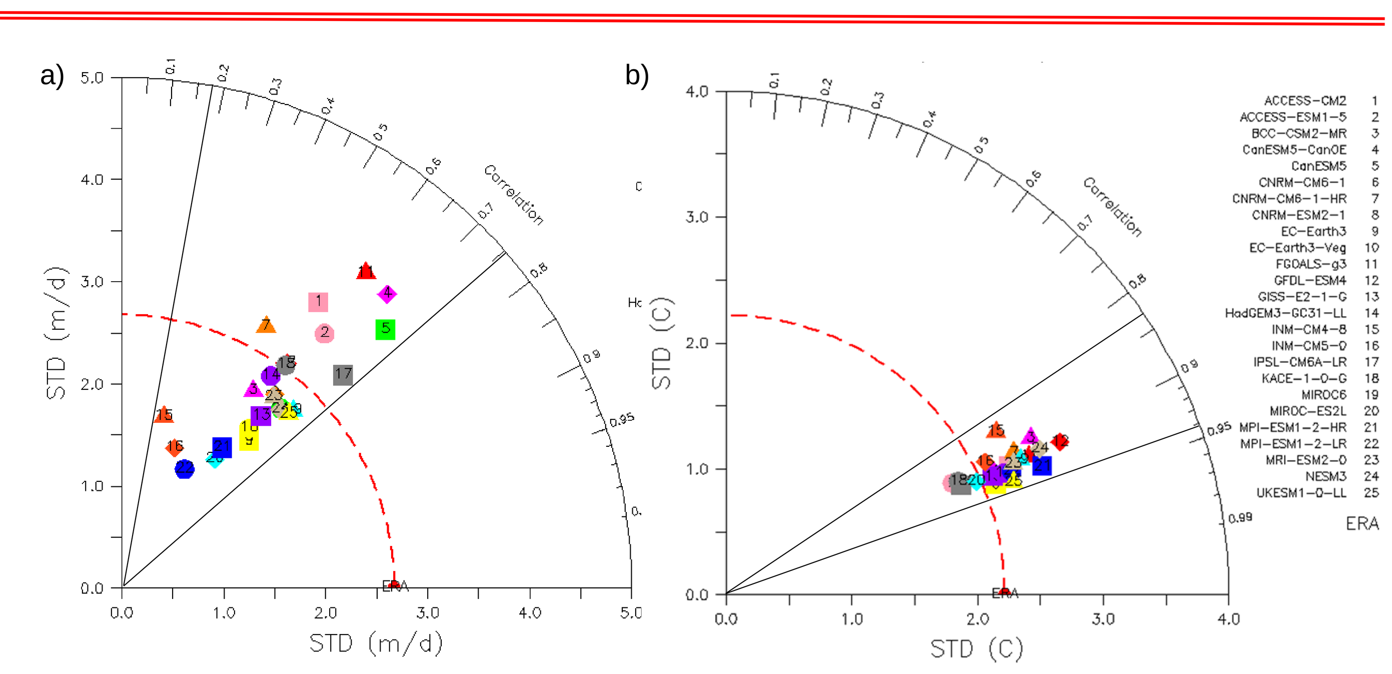


Fig. 10 ESM´s correlation respect to ERA5 and STD. 1989-2018a) Precipitation. b) Surface Temperature.

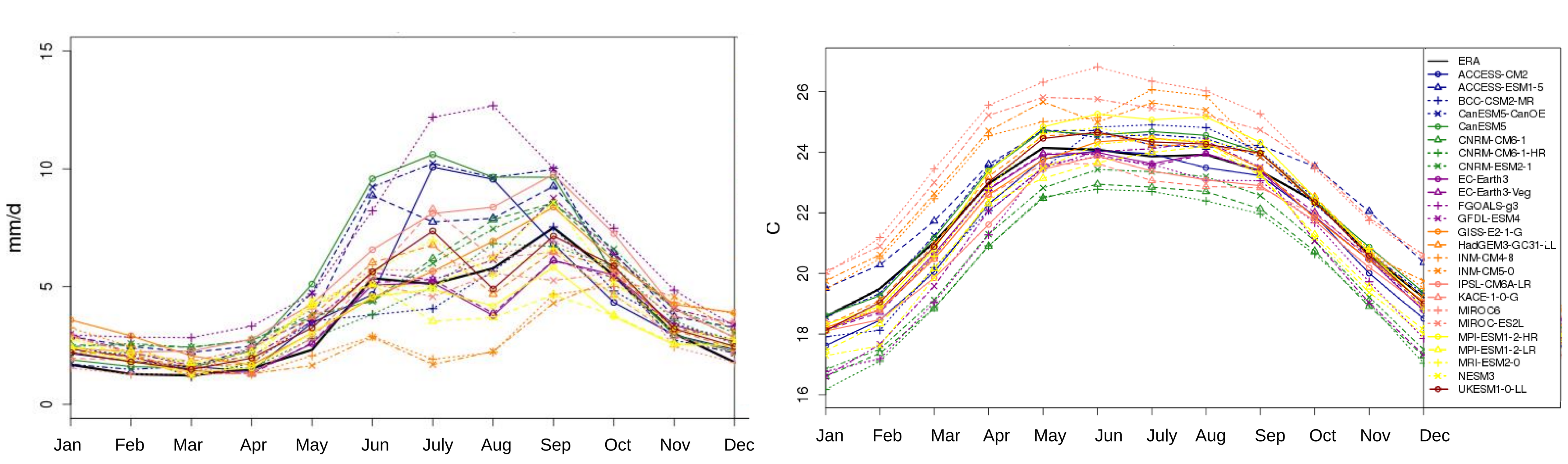


Fig. 11 Annual cycle. a) Precipitation. b) Temperature 1989-2018

Remarks: In the short-term simulations, the spatial distribution of precipitation under an intense event it is not reproduced so well by WRF, it overestimates in all spatial resolutions in the mountain region, the effect of the abrupt orography is more clearly reproduced with the resolution of 3 km. Precipitation has a low correlation: 0.5 with respect to CHIRPS data, however, in all cases, the accumulated hourly precipitation is very well represented, except after 200 hours of simulation, when WRF underestimates the last 24 hours of the intense event.

On the other hand, the spatial distribution of temperature, is better represented in all resolutions, reproducing more clearly the orography effect in the 3 km. resolution, its correlation is very good: 0.9 for all resolutions, highlighting local minima.

In the long-term analysis, the 5 Km, resolution reproduces better the spatial pattern of precipitation in the mountain area. The accumulated monthly precipitation shows the typical time-distribution, with two peaks: July and September, identifying the midsummer drought in August. In all months, the 5 Kms. resolution, is more like CHIRPS data, this is corroborated both in the MAE and the RMSE, which are lower for the 5 km domain.

For the next stage of the project, the best of 25 models was chosen to force the WRF model, in the case of precipitation, the correlation dispersion is wide (from 0.25 to 0.75), with a large variability in standard deviation. On the other hand, surface temperature has a better correlation, (between 0.8 to 0.95) and its range is narrower.

Another criterion for selecting ESM is the annual cycle of precipitation and temperature, for the first case, the models that reproduce the midsummer drought were identified and selected the one that most closely matches the ERA5 data values (MPI-ESM1-2HR) , for the second case, the same model was identified as the best for this region.

Aknowlements: To Mexican Institute of Water Tecnology (IMTA), ICTP for the financial support, and CORDEX for the endorsement.