Review of the WRF AR5 downscaling results for Latin America and the Caribbean

A High-Resolution Modeling Strategy to Assess Impacts of Climate Change for Mesoamerica and the Caribbean

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Climate Change Impacts for Mesoamerica Using WRF

1) Three-year control run, forced by NCEP reanalyses - for evaluation of model uncertainties and biases (made using previous domains)

2) Five year run for the ‘present-day’ (2006-2010) forced by the NCAR CCSM GCM (new)

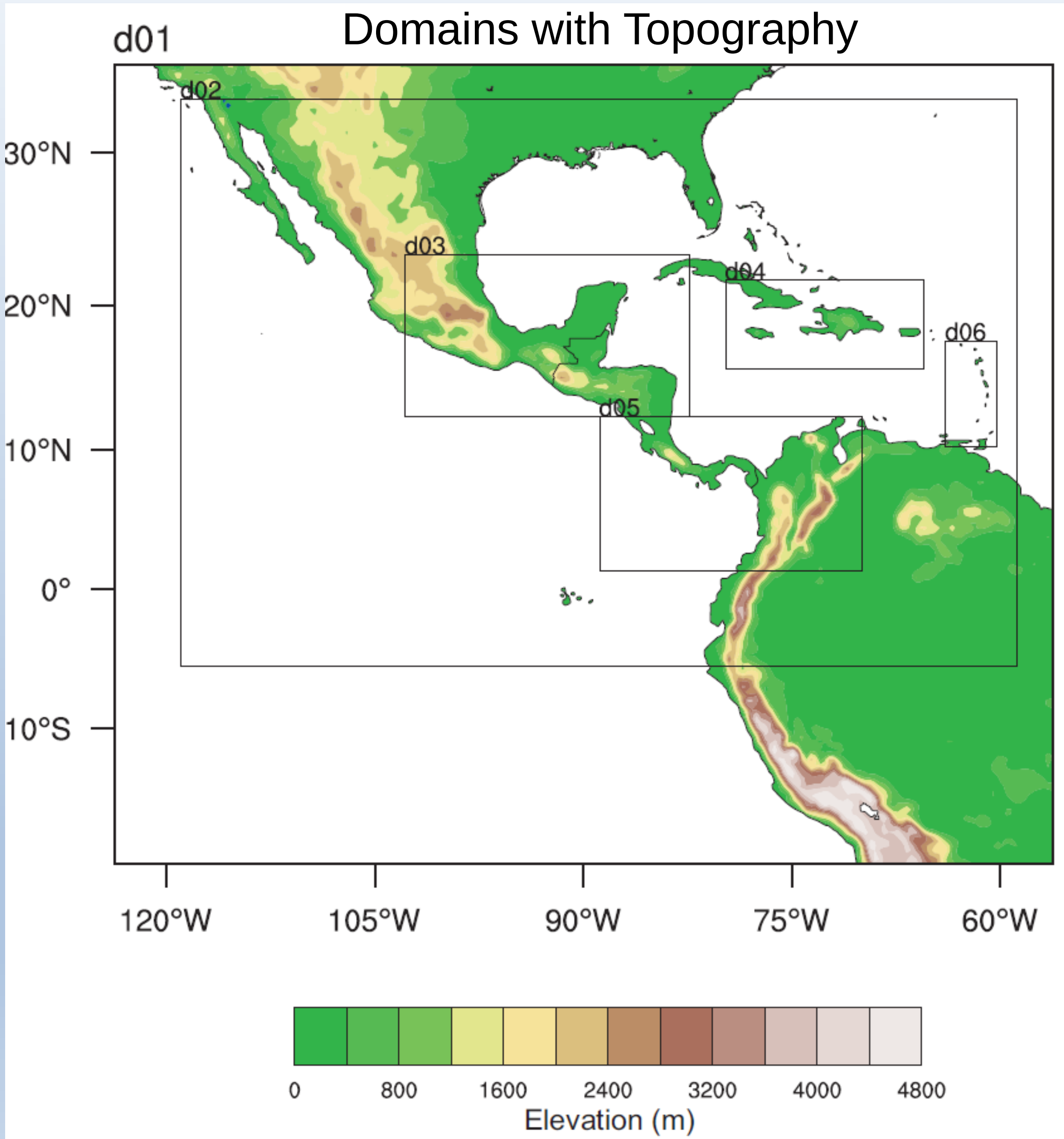
3) Five year climate change run for 2056-2060 using the RCP8.5 ensemble Member #6 (MOAR) ‘business as usual’ scenario (new)

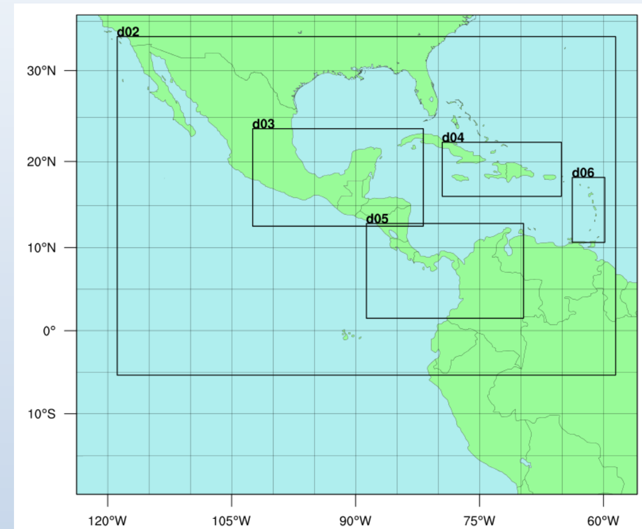
4) Outer domain of 36 km primarily intended to step down the large-scale forcing

5) All of Mesoamerica covered by 12 km domain

6) As much as possible covered at 4 km, focusing on regions of complex topography/land use

Domains for the WRF Runs





Resolution of domains:

d01 – 36 km

d02 – 12 km

d03-06 – 4 km

Verifying Model Results Against Observations

- The most basic question of any model:

  How well does it do what we want it to?

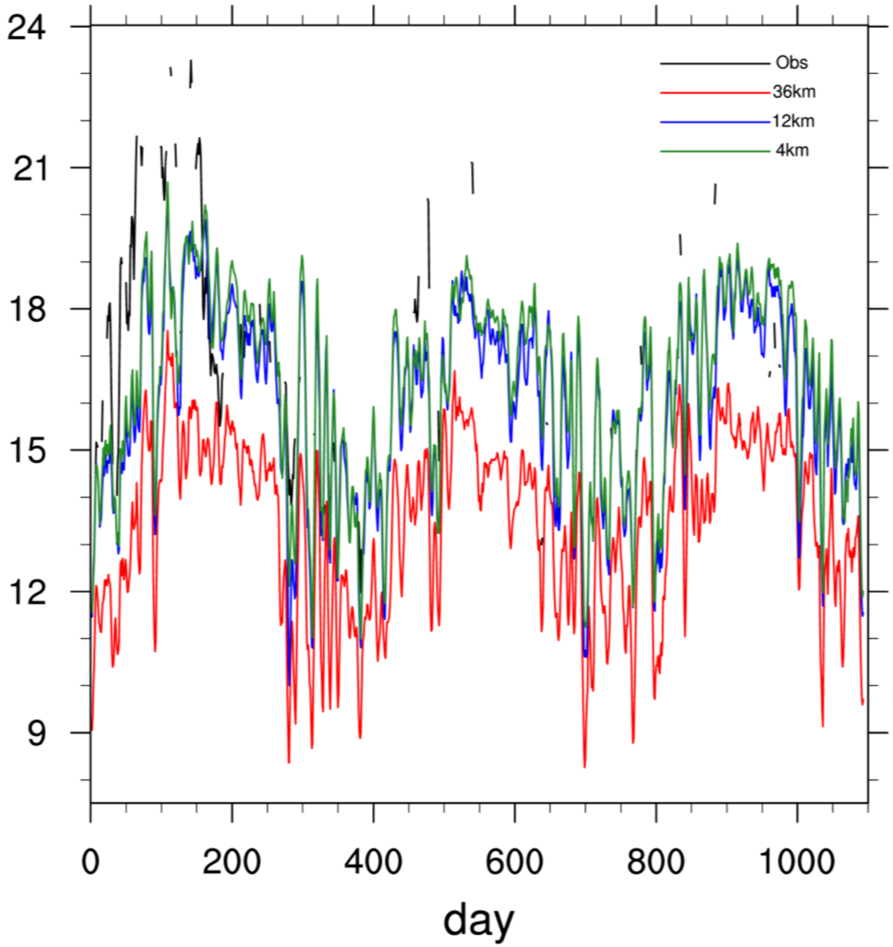
This tells us

- How much confidence we can have in the model results
- How well we understand the problem at hand
- What in the model needs to be improved

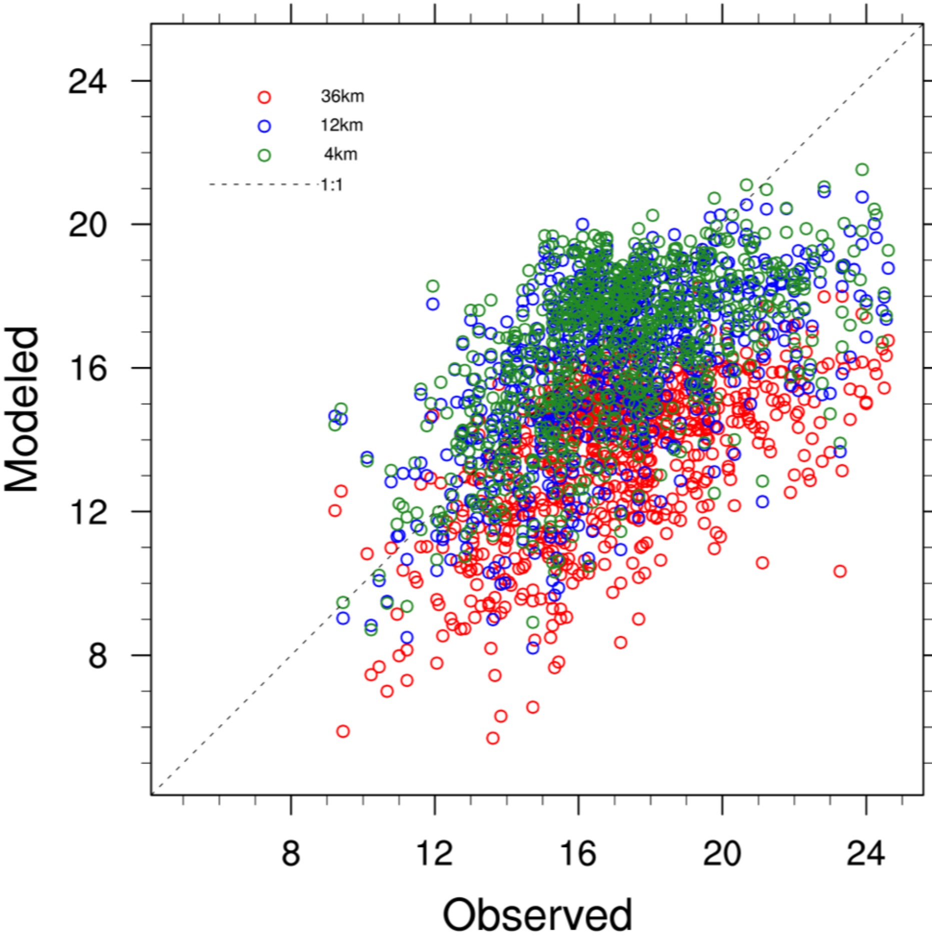
- Because the point to regional modeling is to better simulate local controls on climate, we focus on using station observations to evaluate the WRF control simulation (forced by NCEP reanalyses)

Mexico City, Mexico: Temperature

a) time series (5-day running average)



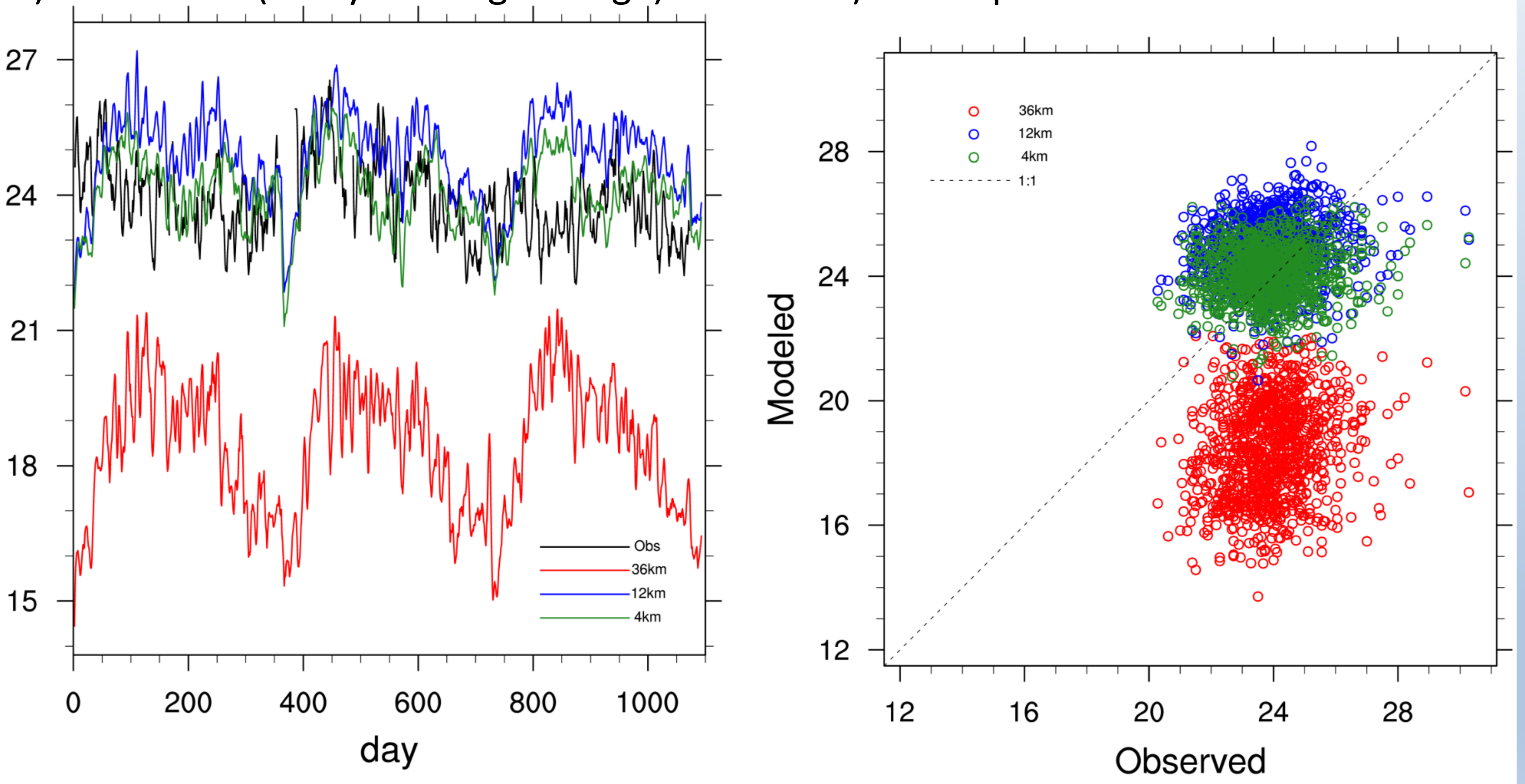
b) scatterplot.



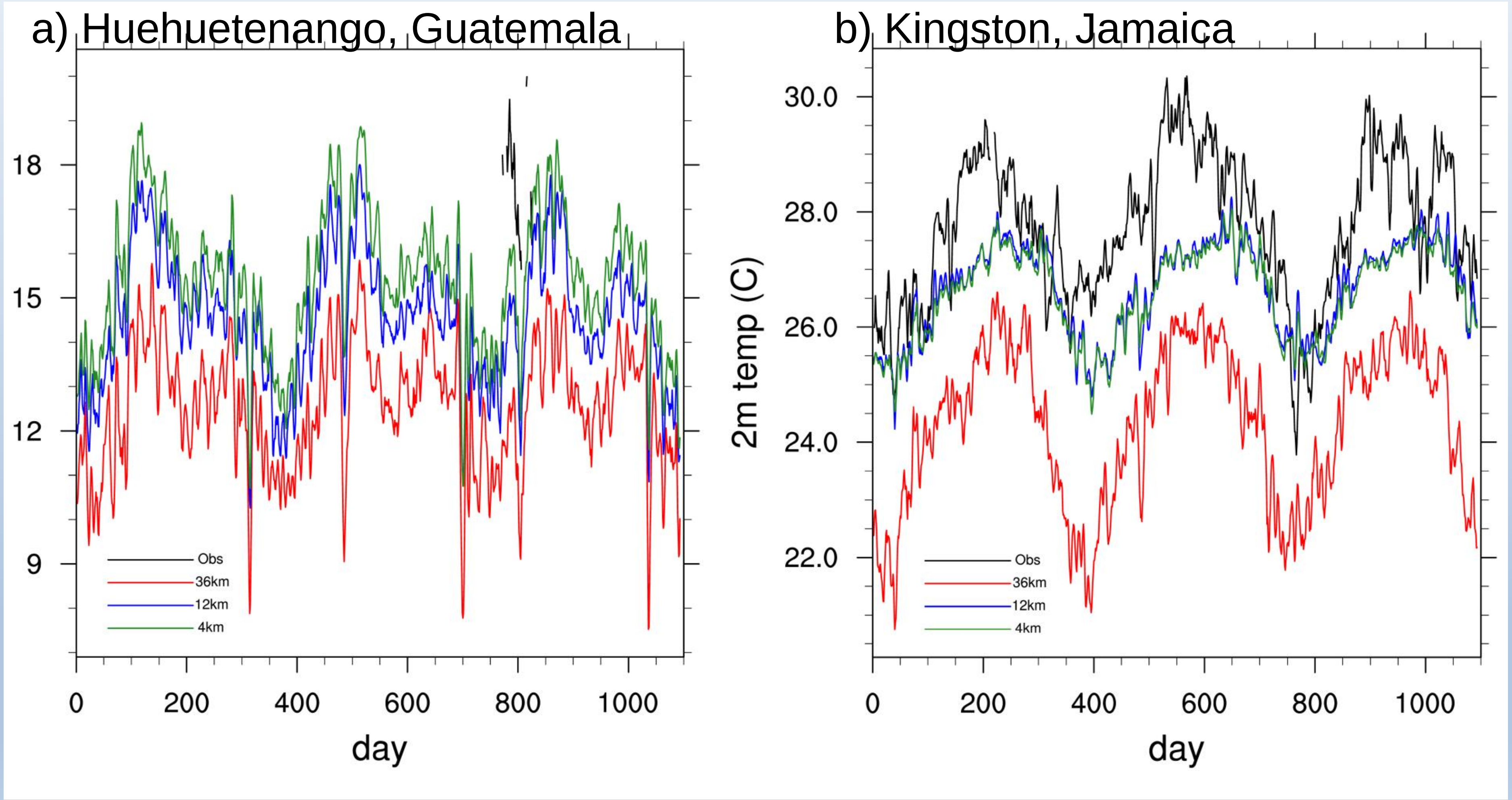
Cali, Colombia: Temperature

a) time series (5-day running average)

b) scatterplot.



Temperature Time Series (5-day running average)

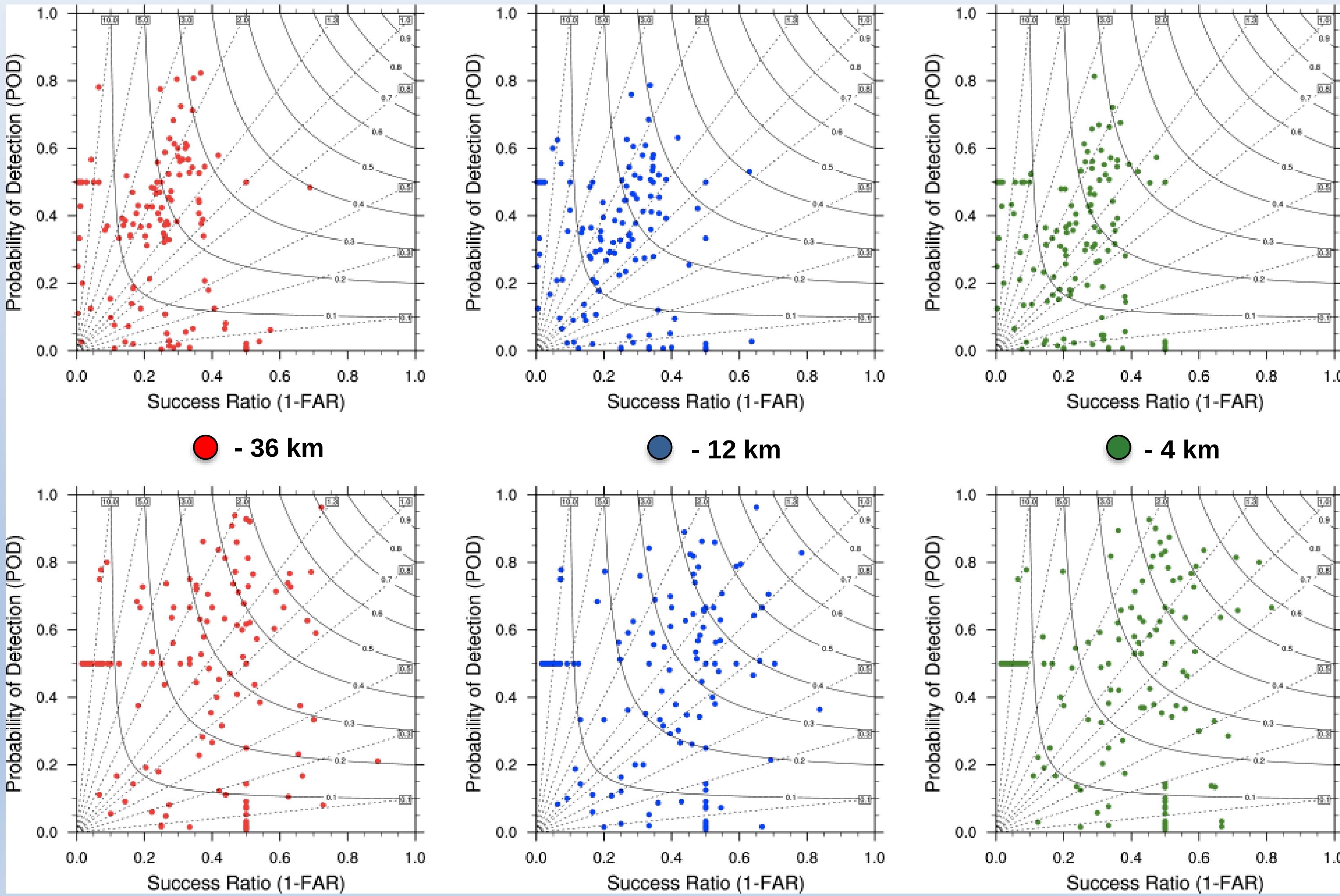


Skill scores

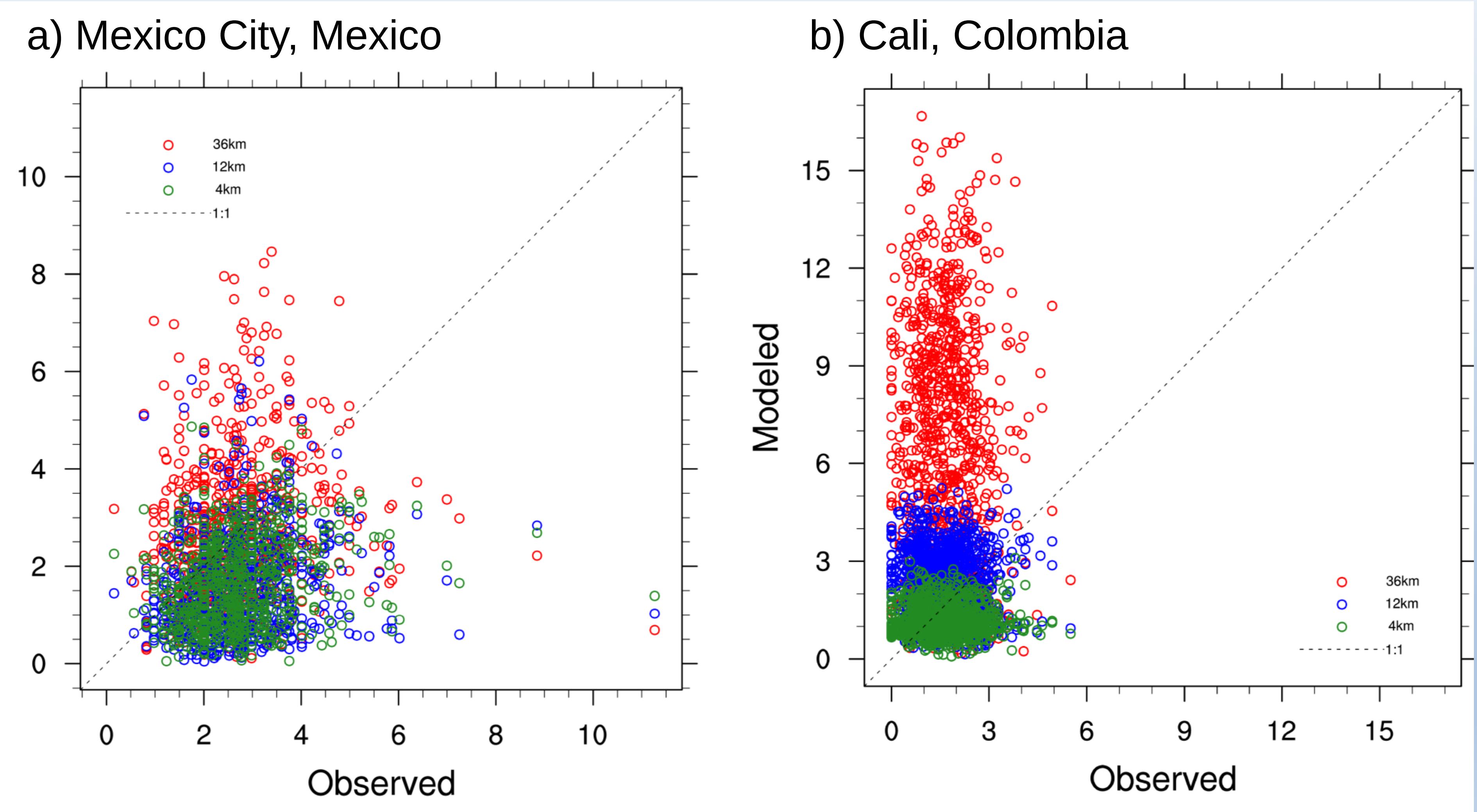
For all stations with more than 200 non-missing observations of precipitation

1-day precipitation > 2 mm

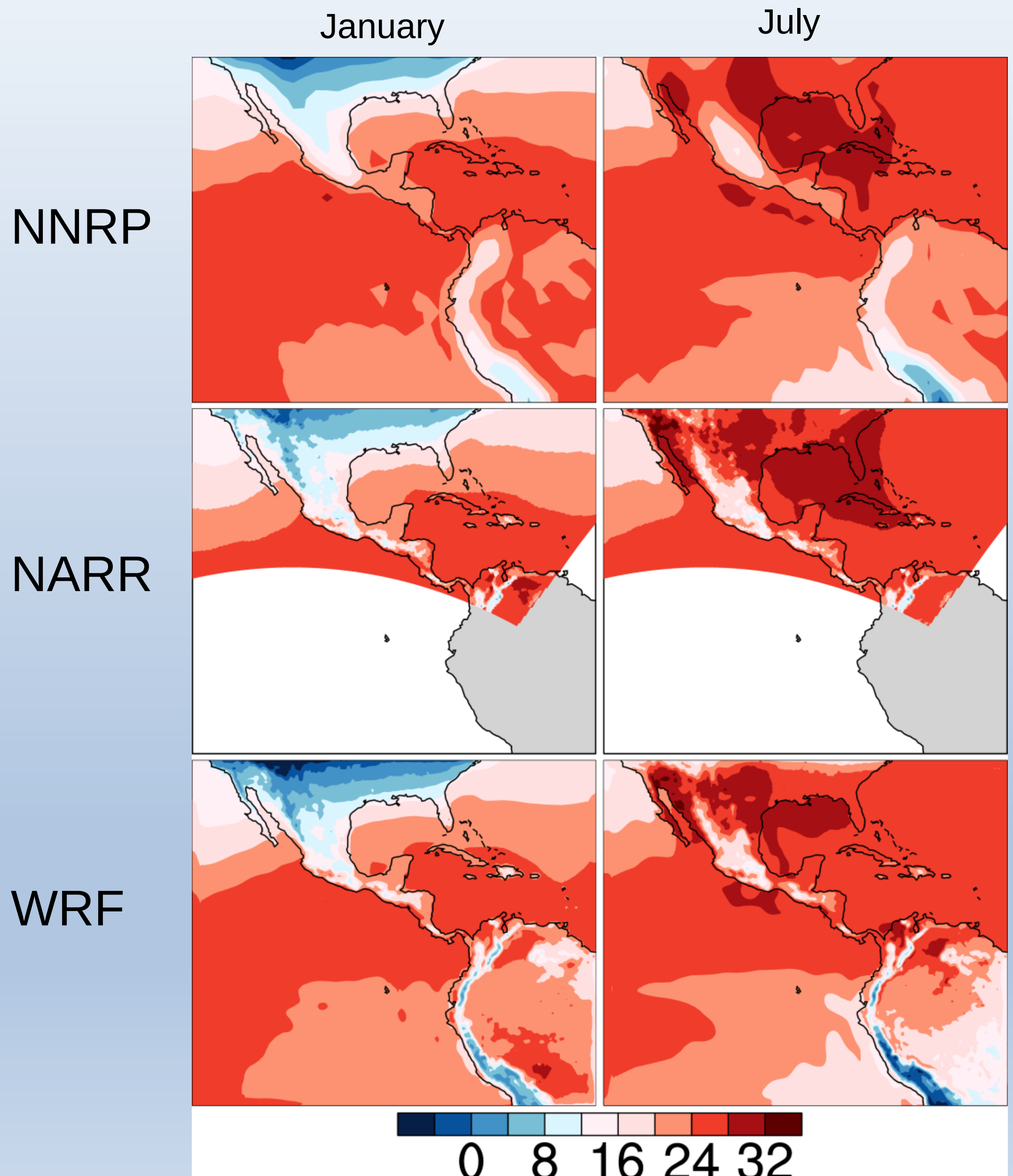
5-day precipitation > 10 mm



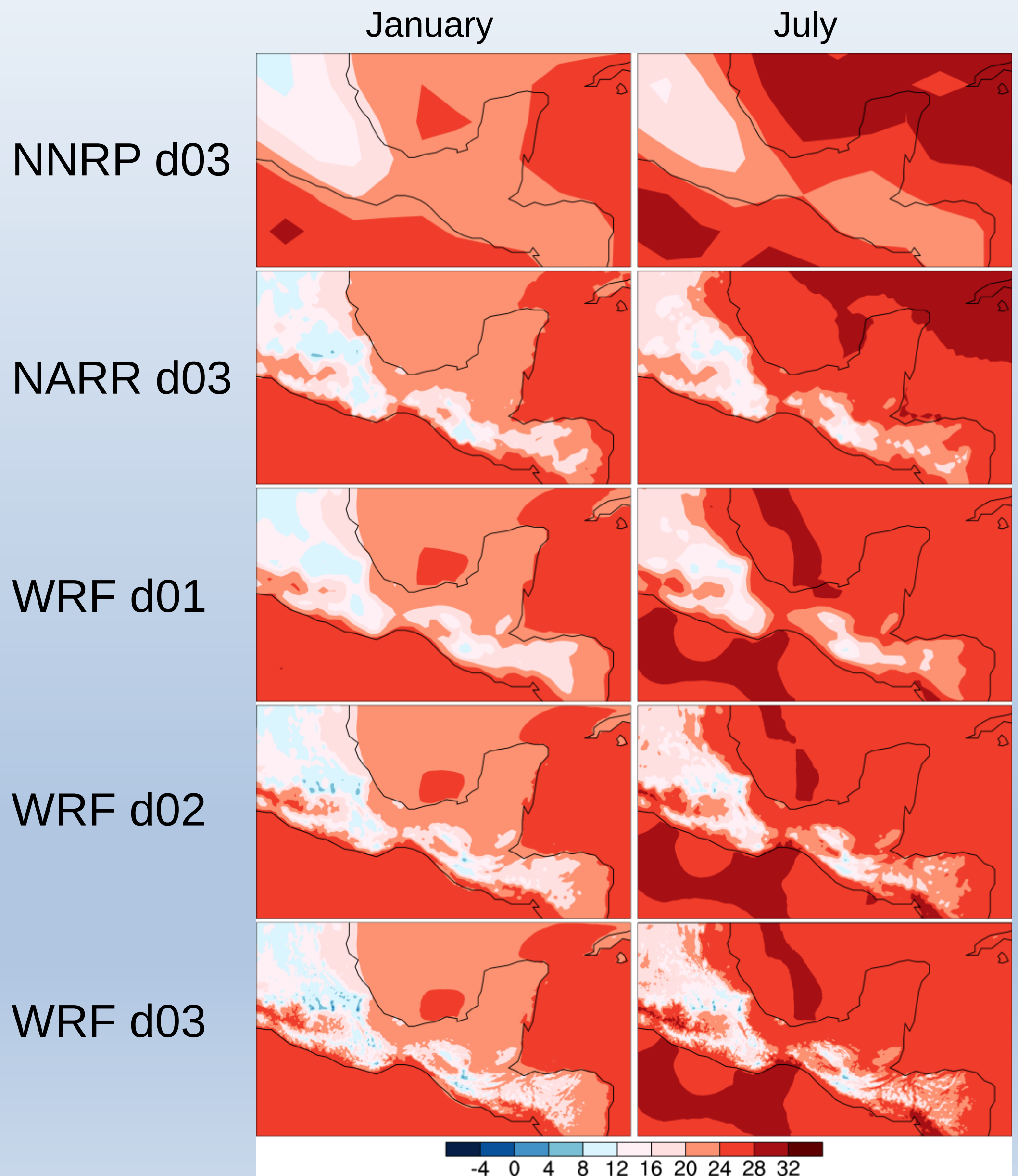
Wind Scatterplots



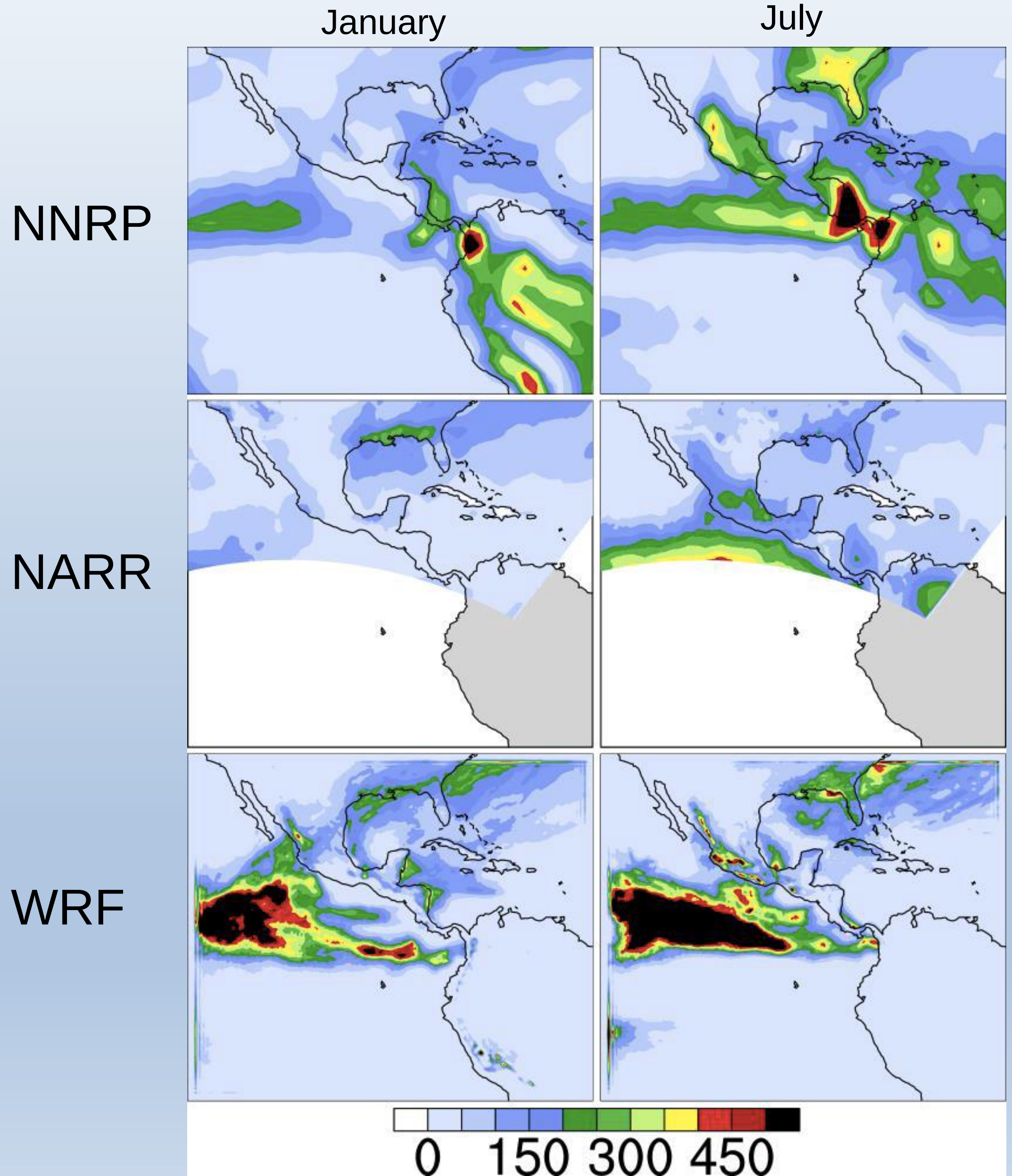
Monthly climatological mean temperature for 1991-1993 plotted over domain 01



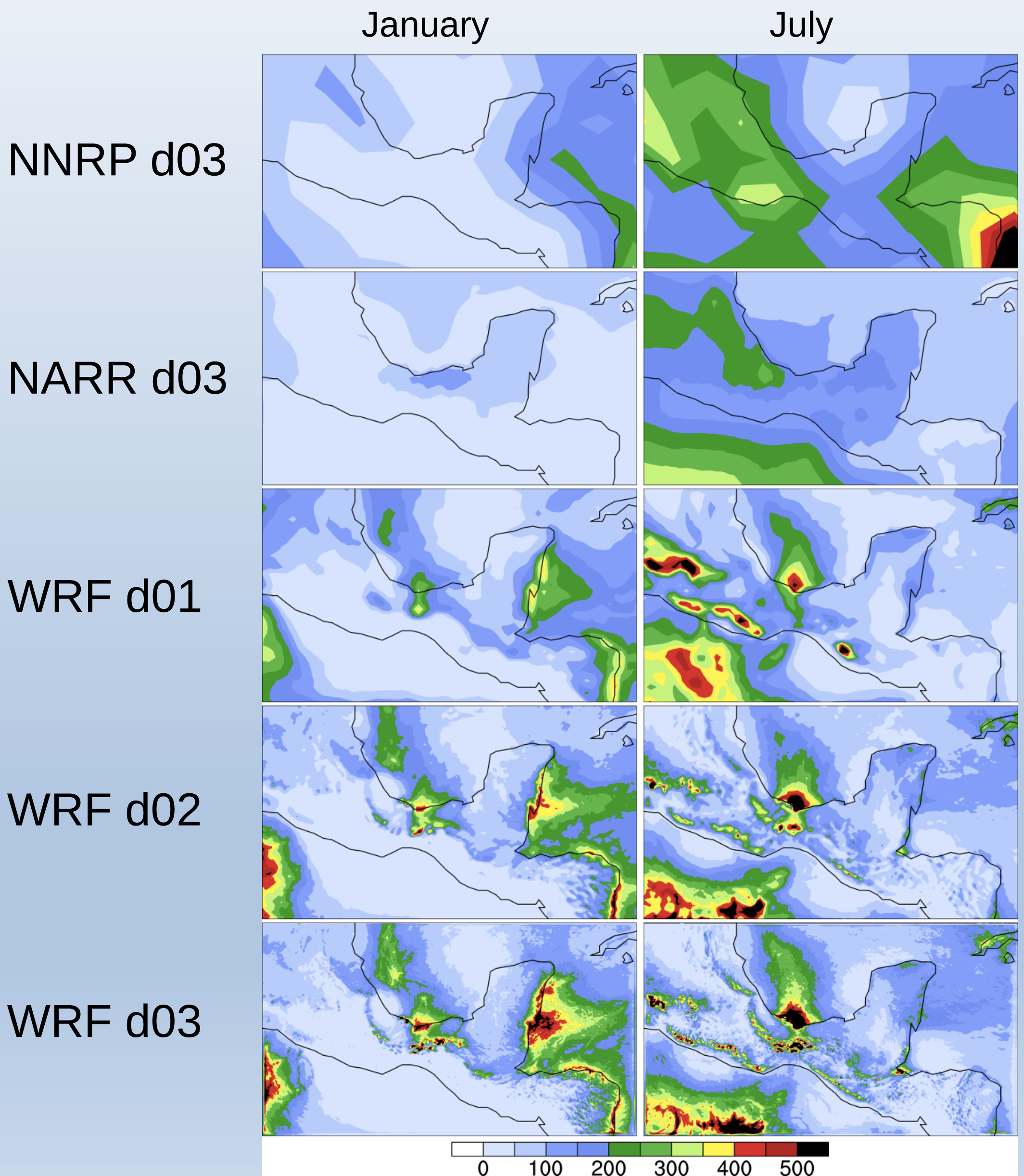
Monthly climatological mean temperature for 1991-1993



Monthly climatological total precipitation for 1991-1993 plotted over domain 01



Monthly climatological total precipitation for 1991-1993



KEY RESULTS – VERIFICATION

1) Accuracy of the temperature simulation is strongly dependent on altitude. In regions of complex topography a resolution of 4 km is required. In larger, more homogeneous regions, such as the Mexico City basin, 12 km may be sufficient.

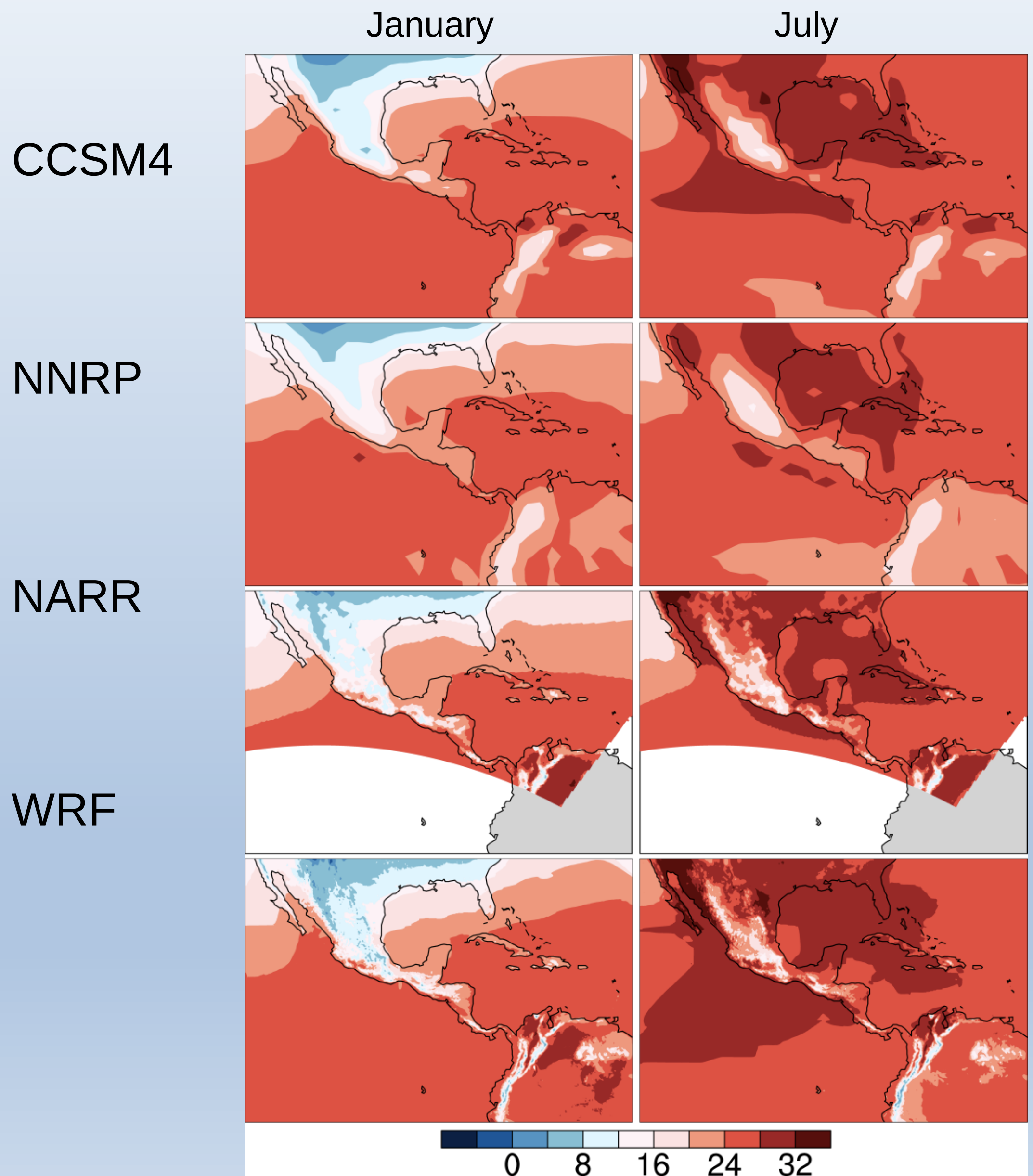
2) Precipitation and wind are complex fields and more difficult to simulate. Lack of sufficient observational data at small spatial scale, is an impediment for verification. The CCSM4 broadly captures overall precipitation features, but spatial details are lacking, and magnitudes are generally underestimated.

3) Evaluation of the winds points to a problem - due to insufficient resolution of topography along the Atlantic coast, trade winds blow unimpeded across Central America towards the Pacific. This will be of major significance when evaluating model simulations of future climate change for the region.

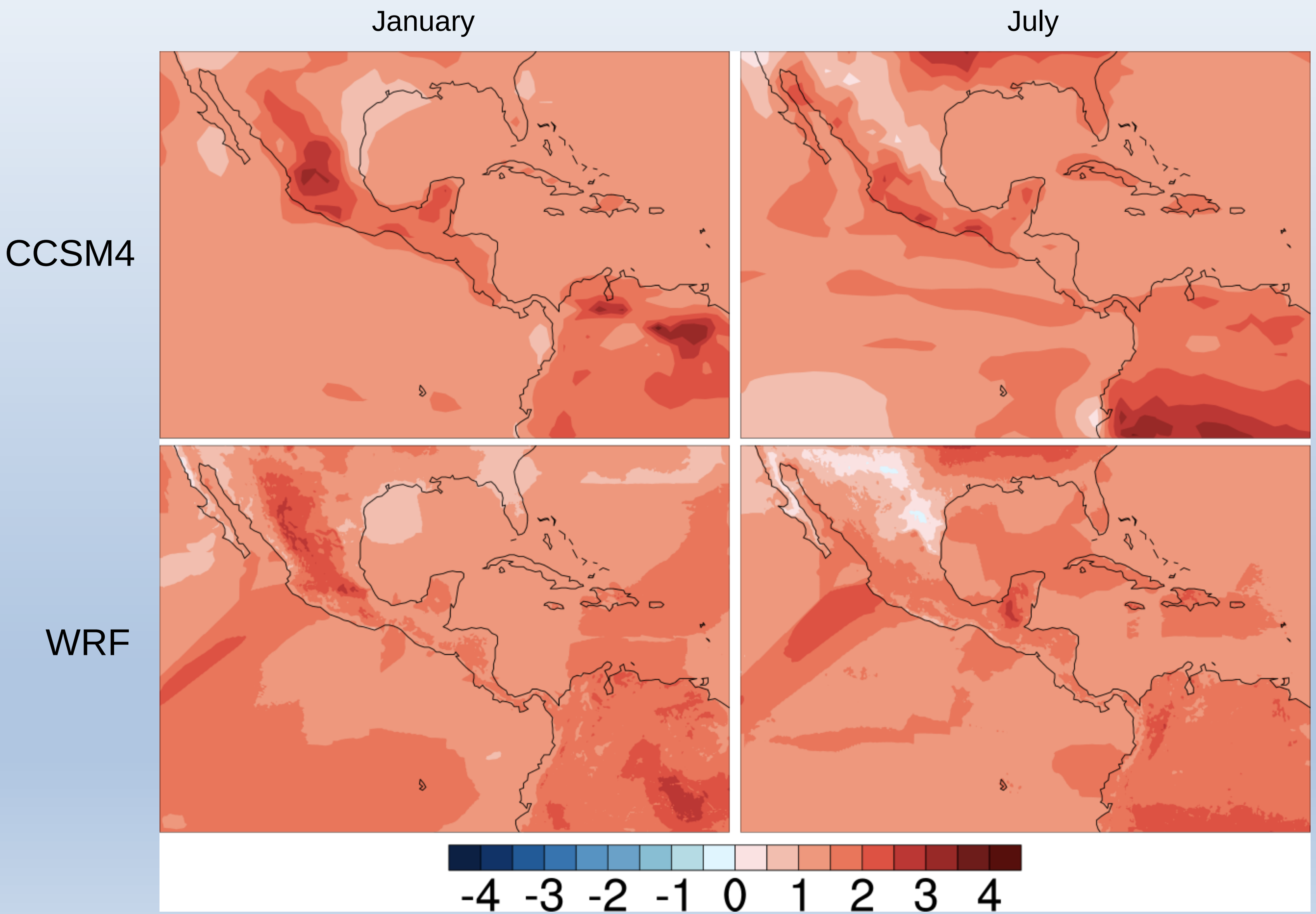
4) The comparison of actual weather events to mean climate for the region helps support the robustness of the model results. WRF was able to simulate quite well actual station surface temperatures observed from 1991-1993, especially when the station elevation was properly resolved. Precipitation was also generally well simulated.

5) The climate simulated by CCSM4 is not as robust as that provided by the quasi-observational NNRP.

Monthly climatological mean temperature for 2006-2010 plotted over domain 02



Monthly climatological mean temperature difference for January (left) and July (right) plotted over domain 02



KEY RESULTS – FUTURE CLIMATE CHANGES

TEMPERATURE

1) CCSM4 results show warming over all of Mesoamerica between the present and the 2050's, ranging from less than 1°C to more than 3°C, The largest warming occurs over interior and highland regions; coastal regions show the least change.

2) The same general patterns hold with WRF downscaling, though additional detail and changes are seen. Effects of topography are much better resolved, with patterns of surface temperature difference largely follow the topography.

3)Coastal regions show lesser change, presumably because of the strong ocean influence.

Monthly climatological total precipitation for 2006-2010 plotted over domain 02

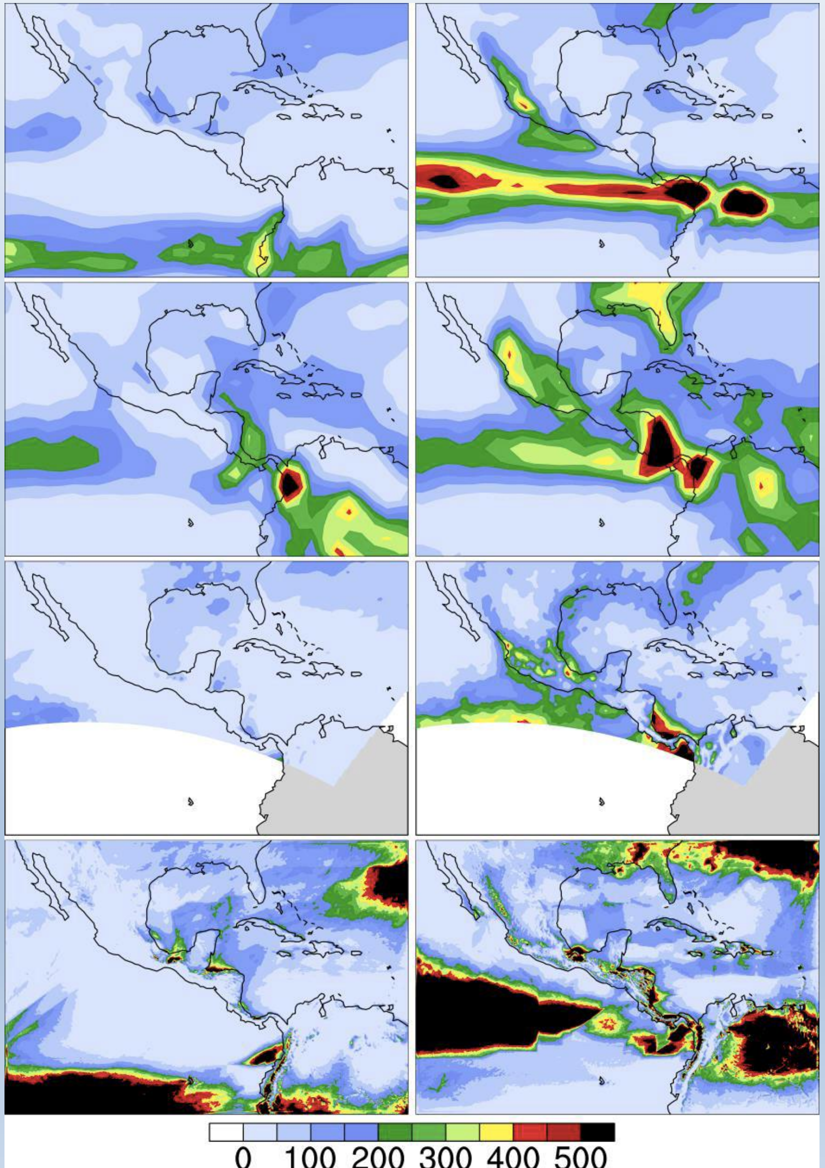
January July

CCSM4

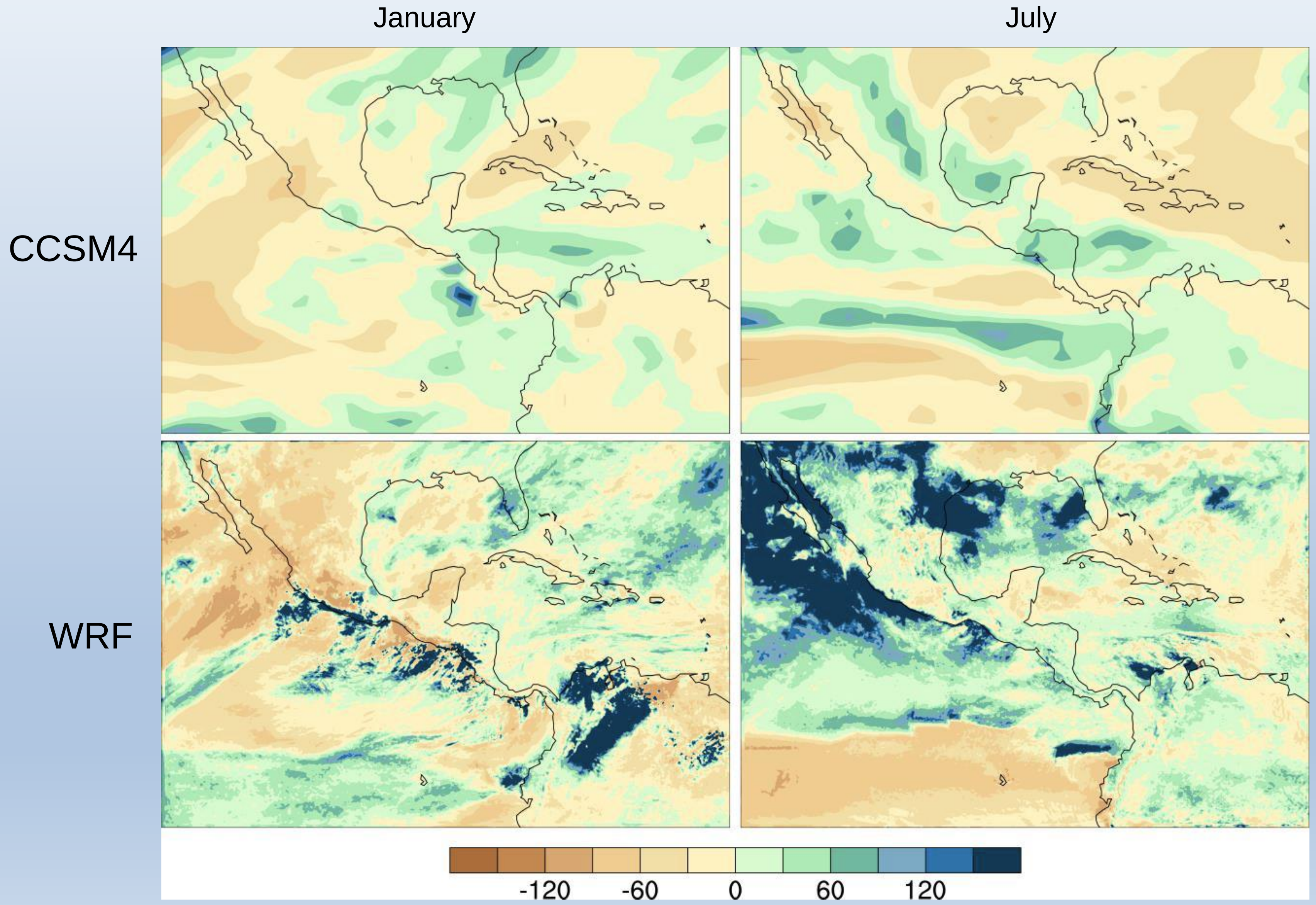
NNRP

NARR

WRF



Monthly climatological percentage precipitation difference for January (left) and July (right) plotted over domain 02



KEY RESULTS – FUTURE CLIMATE CHANGES, cont.

PRECIPITATION

1) The global model results for precipitation are at odds with those from WRF, indicating a complex situation.

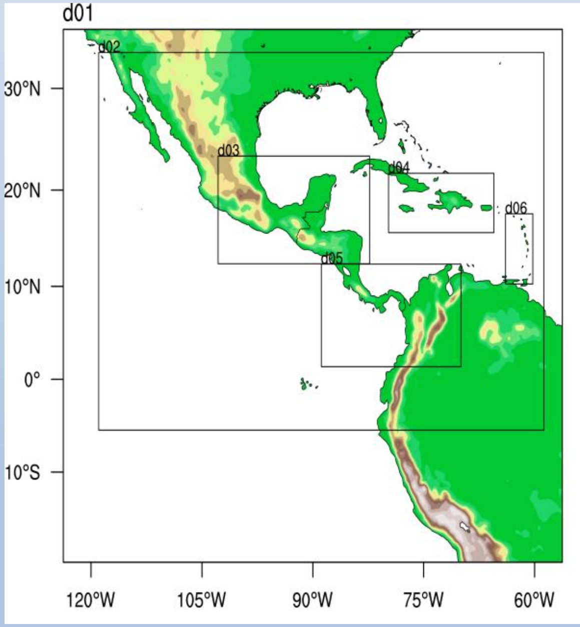
2) Topography has a strong influence on precipitation. Over windward slopes air is forced to rise, enhancing condensation and precipitation; over leeward slopes, air descends, inhibiting precipitation.

3) Changes in the wind regime are also important. Observed trade wind precipitation is restricted to the immediate Atlantic coast, while in GCM simulations it spreads across all of Central America from the Gulf of Tehuantepec to the Darien Gap.

4) Results for precipitation from WRF are very different than those from the GCM, and are consistent with better resolution of topographic effects, especially along the Atlantic coast.

5) WRF is able to take a large-scale forcing associated with changes in the trade winds and simulate instead a very different precipitation regime for inland and Pacific coast regions of Mesoamerica.

CONCLUSIONS



CONCLUSIONS: Verification

- Because of the very strong impact of topography on surface temperature, the results clearly demonstrate the need for high resolution in order for it to be properly simulated.
- Precipitation is more difficult to evaluate, being composed of discrete events highly variable in time and space (as opposed to the much smoother, continuous temperature).
- Simulation of the surface winds tends to be too strong at 36 km resolution and much improved at 12 km and, especially, 4 km.
- A suite of standard verification statistics were computed and show that the biases are sharply reduced at higher resolutions, while standard errors are little changed
- Overall, the CCSM4/WRF combination appears to adequately simulate the preset-day climate of Mesoamerica, lending credence to its ability to simulate future climate change in coming decades

CONCLUSIONS: Climate Change

Temperature

- All regions will warm.
  - In general the warming is larger with higher topographic elevations and distance from the coast, such as the western Amazon basin. Surrounding ocean waters moderate the warming over the Caribbean islands.

Precipitation

- The results for precipitation are less straightforward. In general a decrease occurs along the Atlantic coast
  - pressure and wind changes suggest a weakening of trade wind-induced precipitation.

- Elsewhere, most of the region sees little difference, or even a slight increase.
  - This is at odds with the GCM and 36 km WRF results, but at these lower resolutions, the trade winds blow from the Atlantic to the Pacific, instead of being blocked by mountains near the Atlantic coast. A resolution of 12 km appears sufficient to resolve this latter effect.

NEXT STEPS

1. Global warming due to increased greenhouse gas emissions not the only agent of climate change.
   - Temperature changes due to land use alterations, especially deforestation, may be as large, at least locally.

2. Further evaluation of topographic complexity – is 4 km resolution sufficient? What is the relationship between explicit resolution of convection and microphysics parameterization schemes at higher resolutions?

3. Can our modeling strategy be fine-tuned, or adapted to the changing software and hardware configurations prevalent in climate modeling?

4. How best to use these results to provide robust input into regional and national climate assessments? Such usage ultimately is the primary purpose of this research.