Climate change projections with a focus on resolving the US Caribbean Islands

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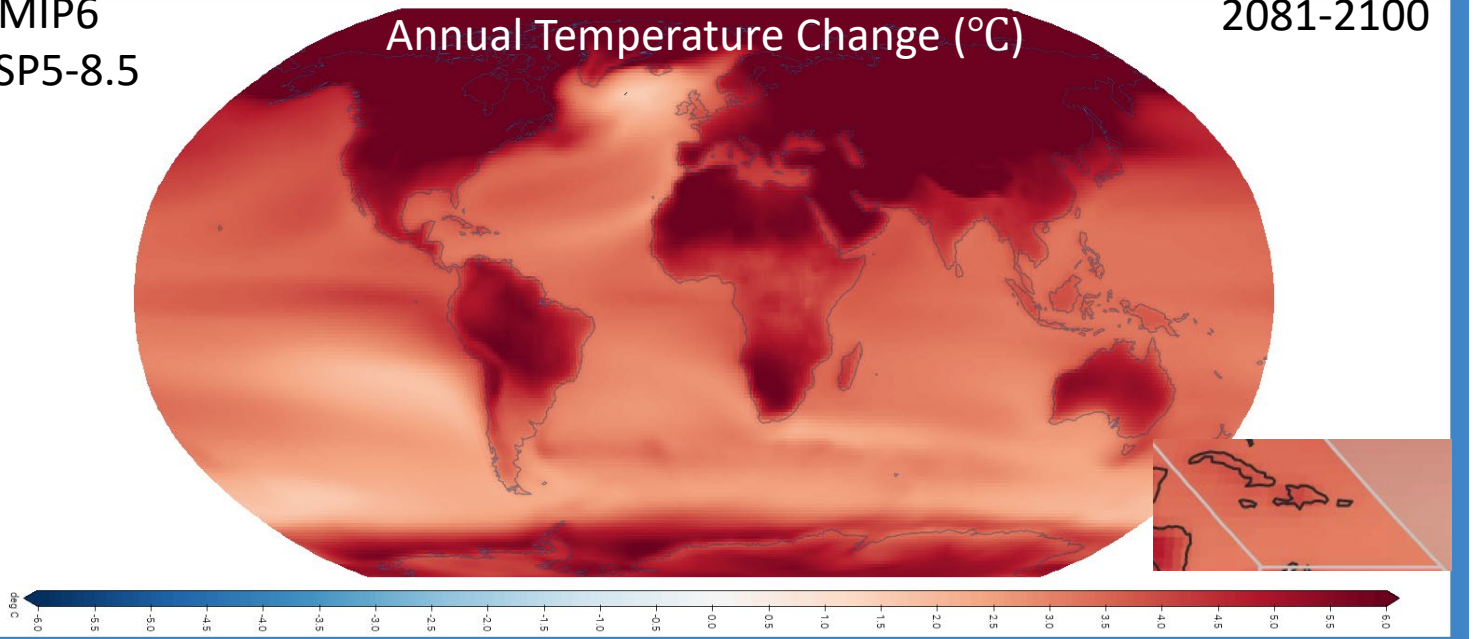
What are the growing risks with respect to climate change for the US Caribbean Islands?

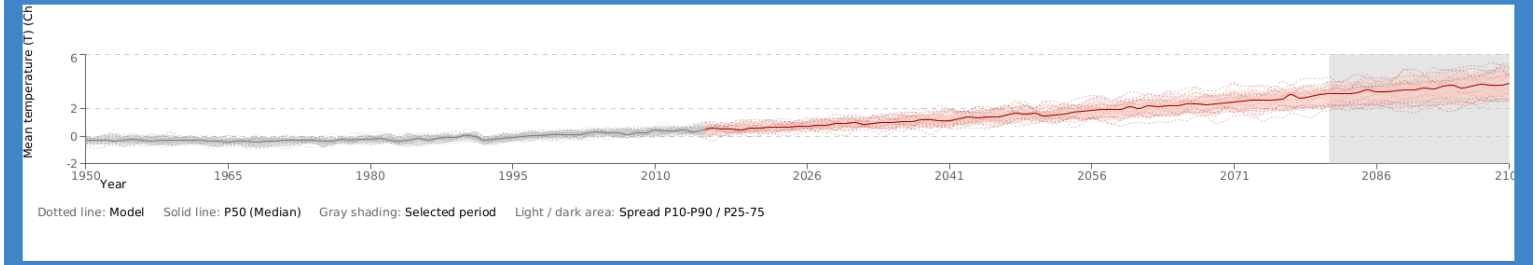
Let’s consider mean changes in the climate for the islands.

CMIP6
SSP5-8.5

Annual Temperature Change (°C)

2081-2100





Mean temperature (T) - Change (deg C)
Long Term (2081-2100) (SSP5-8.5) (rel. to 1986-2005)
CMIP6 - Annual (34 models)-Caribbean

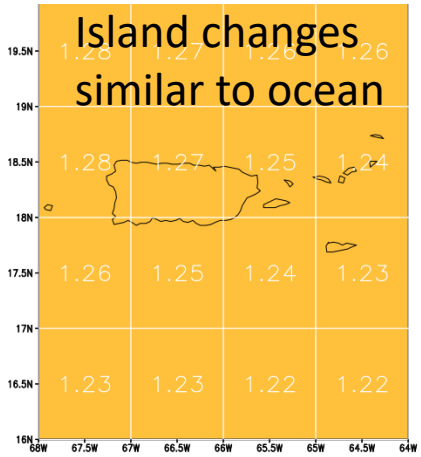
ipcc
INTERGOVERNMENTAL PANEL ON climate change

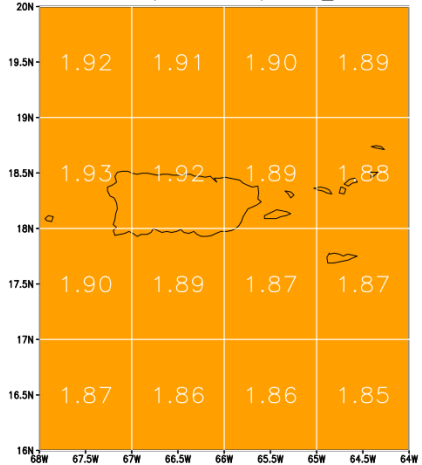
Annual Temperature Change (℃) CMIP6 GCM Ensemble

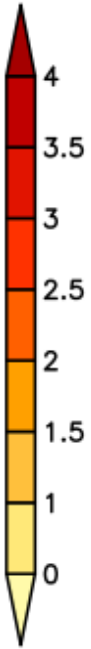
Mid-Century
(2041-2060)
~ +1.25 ℃

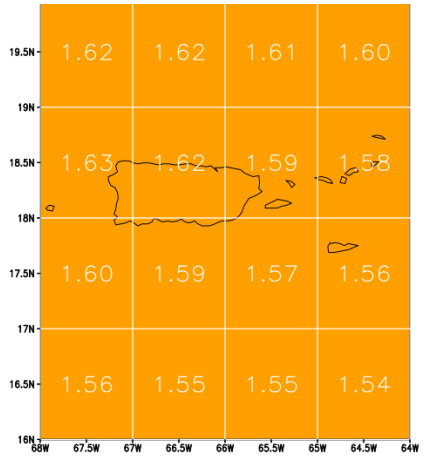
SSP2_4.5

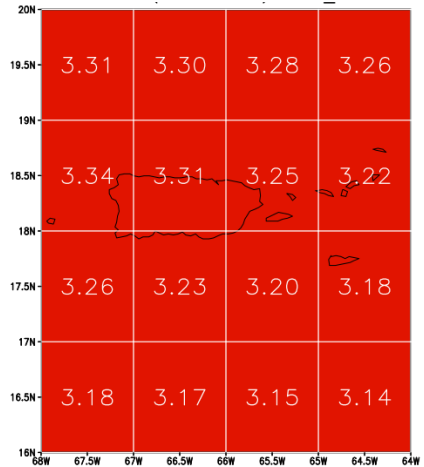
End-Century
(2081-2100)
~ +1.90 ℃









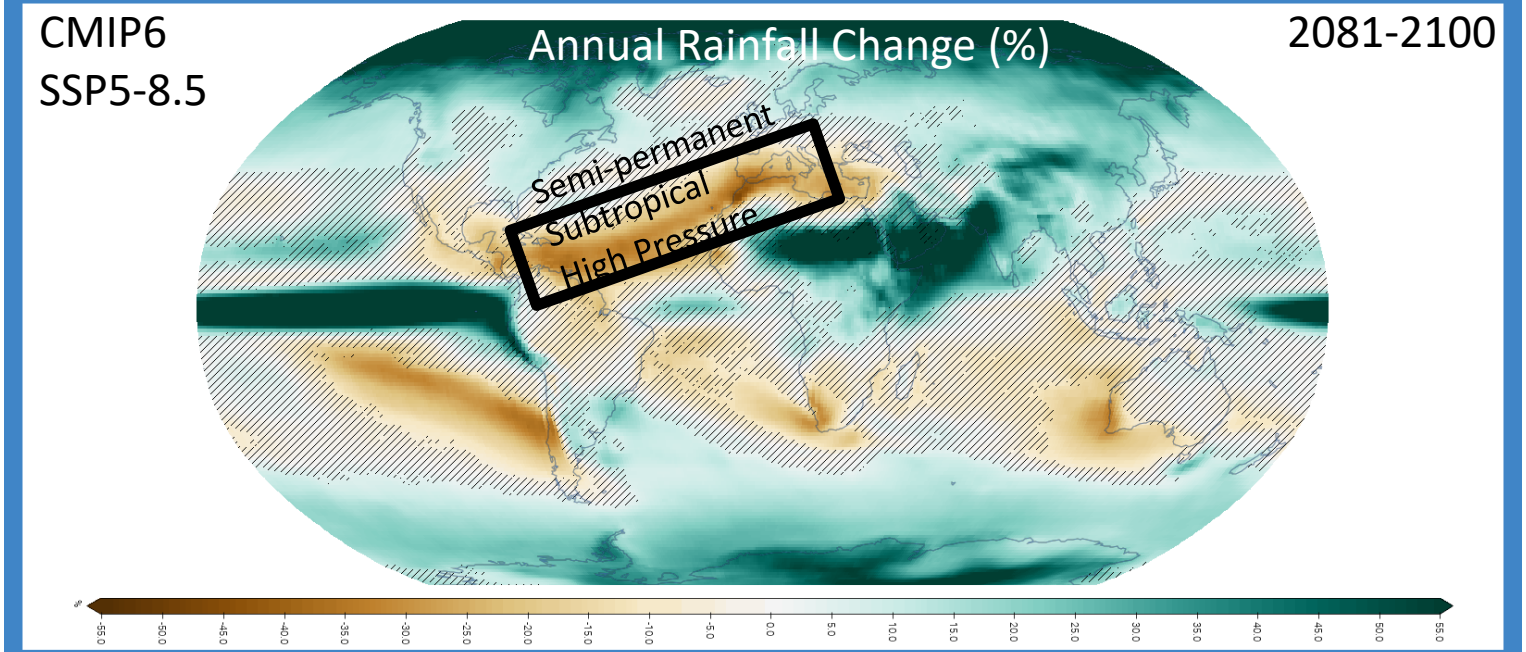


Mid-Century
(2041-2060)
~ +1.60 ℃

SSP5_8.5

End-Century
(2081-2100)
~ +3.25 ℃

CMIP6
SSP5-8.5



Total precipitation (PR) - Change (%)

SSP5-8.5 (rel. to 1986-2005)

CMIP6 - Annual (33 models)-South-Eastern South America, Caribbean

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Annual Precipitation Change (%) CMIP6 GCM Ensemble

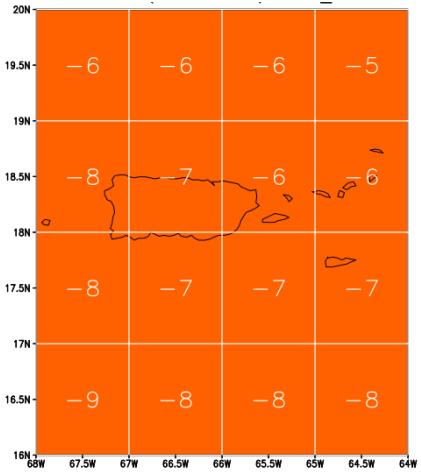
Mid-Century
(2041-2060)

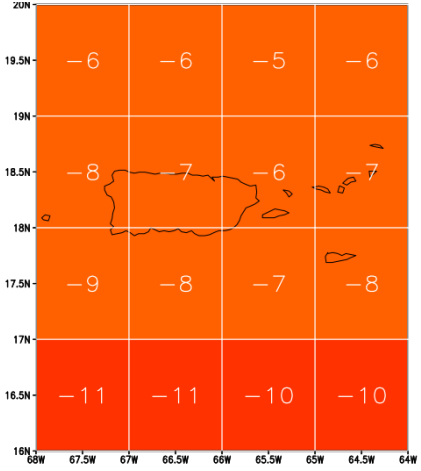
~ -7%

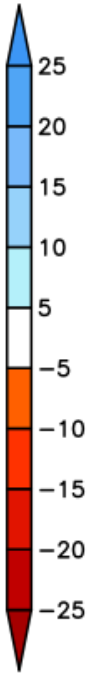
SSP2_4.5

End-Century
(2081-2100)

~ -8%







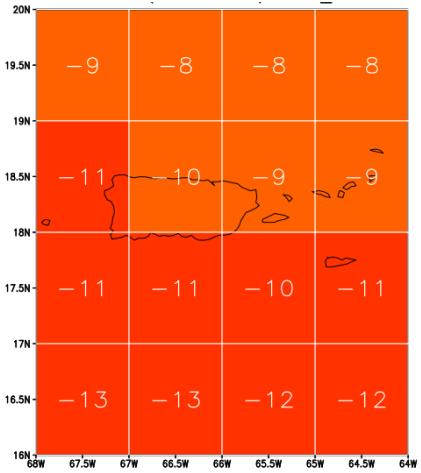
Mid-Century
(2041-2060)

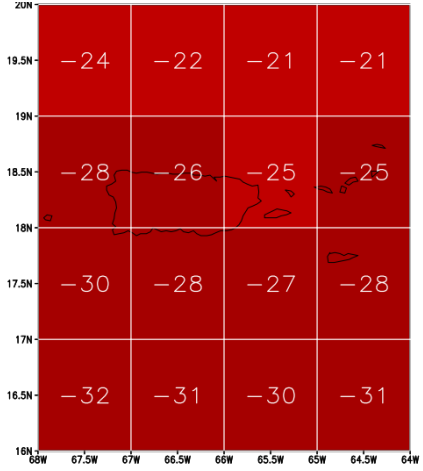
~ -10%

SSP5_8.5

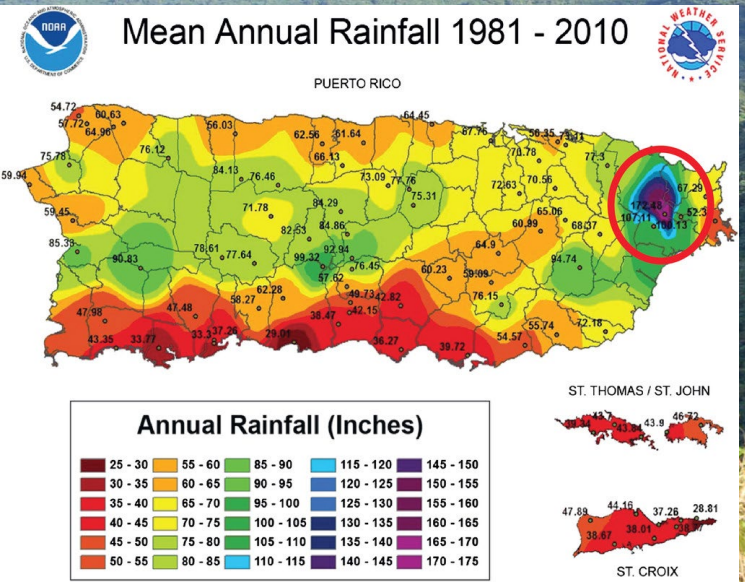
End-Century
(2081-2100)

~-27%





High-resolution climate modeling needed to capture the effects of complex topography and micro-climates



GCM

GCMs & RCMs
Consider Physics &
simulate future changes in the atmosphere as greenhouse gas emissions increase.
GCMs don't resolve island scale climates.

$$\frac{Du}{Dt} - fv = -\frac{\partial \phi}{\partial x} - F_x$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

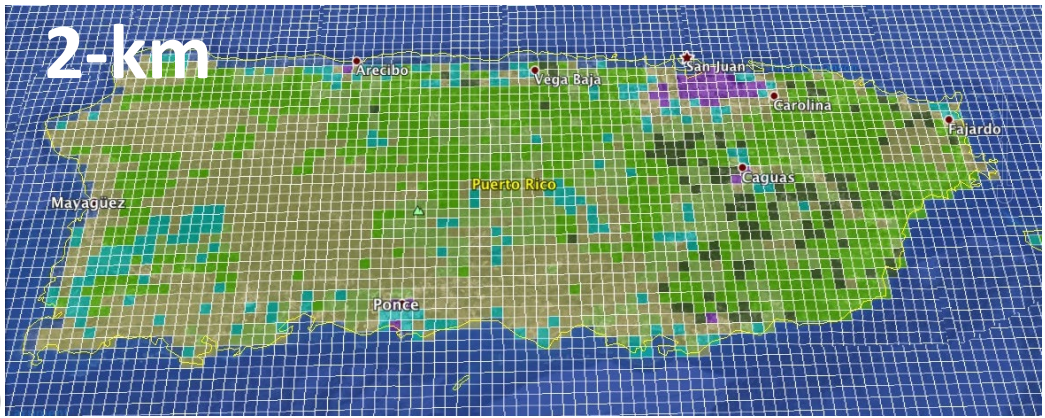
$$\frac{\partial T}{dt} + u\frac{\partial T}{dx} + v\frac{\partial T}{dy} + \omega\left(\frac{\partial T}{\partial p} + \frac{RT}{pc_p}\right) = \frac{J}{c_p}$$

$$p = \rho RT$$

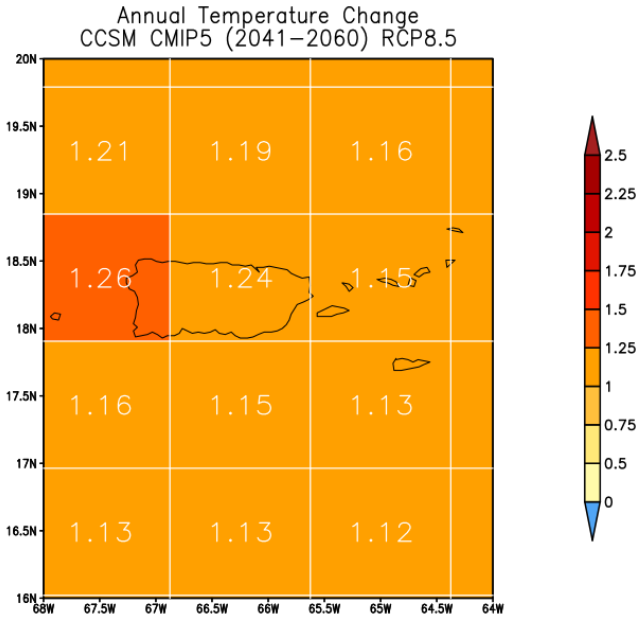
Global Climate Models (GCMs)

Downscale
Two CMIP5 GCMs – RCP8.5

Regional Climate Model
Weather Research Forecasting Model (WRF)



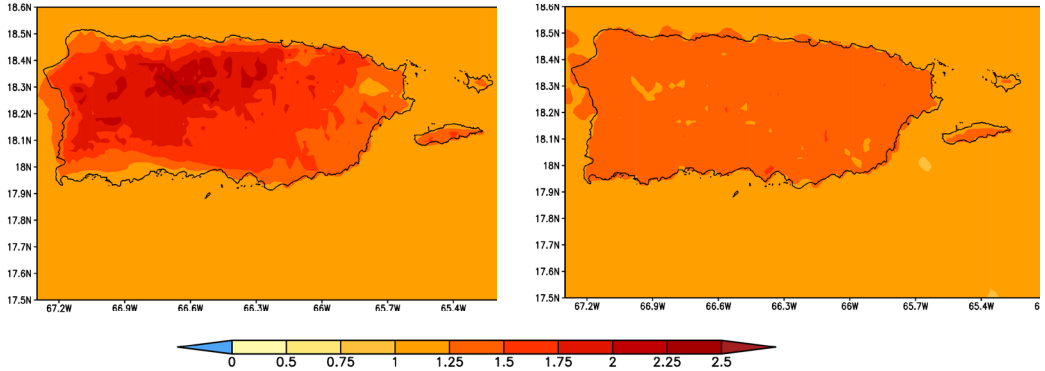
GCM - CCSM
Annual Temperature Change (℃)
Mid-Century
High GHG emission scenario (RCP8.5)



RCM Realization Example (2-km); WRF-CCSM
Max. & Min. Annual Temperature Change (℃)
Mid-Century
High GHG emission scenario (RCP8.5)

Max. Temperature

Min. Temperature

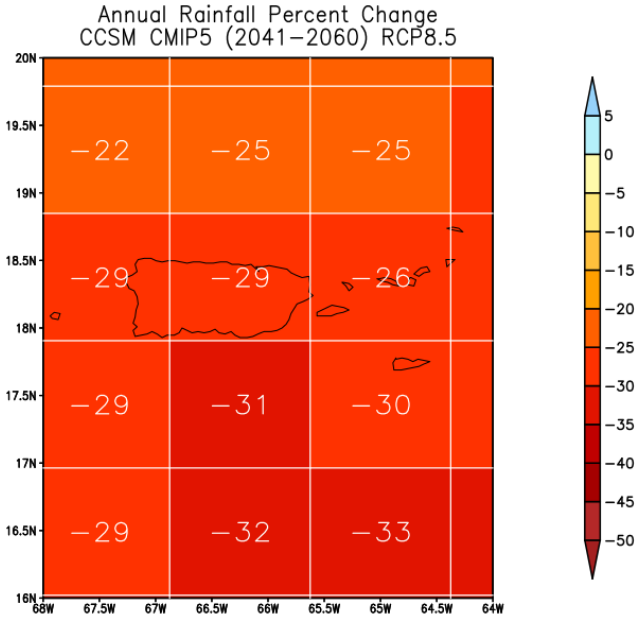


Larger warming over land, especially daytime. Nighttime warming more homogenous than daytime warming, which is associated to rainfall change (shown in upcoming slides).

Key Message for Temperature

- GCMs depict >1℃ differences in mean warming by end-century for middle vs. high GHG emission scenario
  - <2℃ for SSP2-4.5 (CO_2 around current levels till 2050 then reductions)
  - >3 ℃ for SSP5-8.5 (nearly 3-times CO_2 by 2100 compared to current levels)
- Regional climate model (RCM) projections reveal significantly larger increases within the island than the GCMs.
- These differences (RCM vs. GCM) can be larger than differences between scenarios or mid vs. end century.

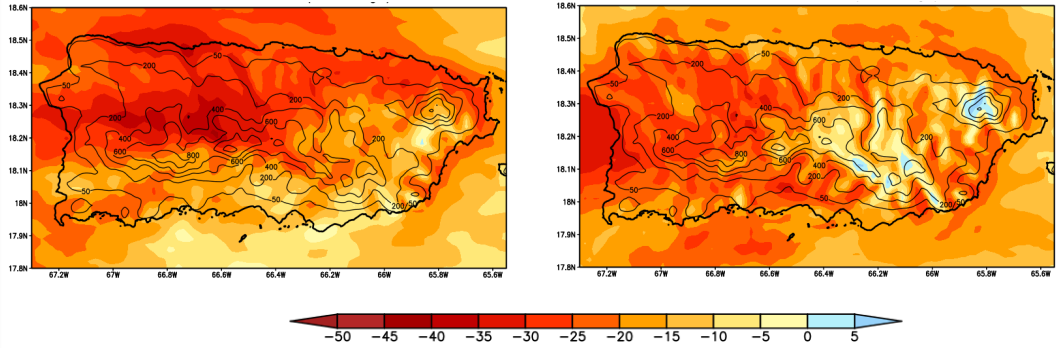
GCM-CCSM
Annual Precipitation Change (%)
Mid-Century
High GHG emission scenario (RCP8.5)



RCM Realization Example (2km); WRF-CCSM
Wet/Dry Season Precipitation Change (%)
Mid-Century
High GHG emission scenario

Dry Season (Nov-Apr)

Wet Season (May-Oct)



Rainfall reductions can be locally smaller for elevated areas (especially eastern half of Puerto Rico)

But also locally larger than the driving GCM

(contours – model terrain height; shaded rainfall change)

Larger temperature increases are related to the rainfall reductions.

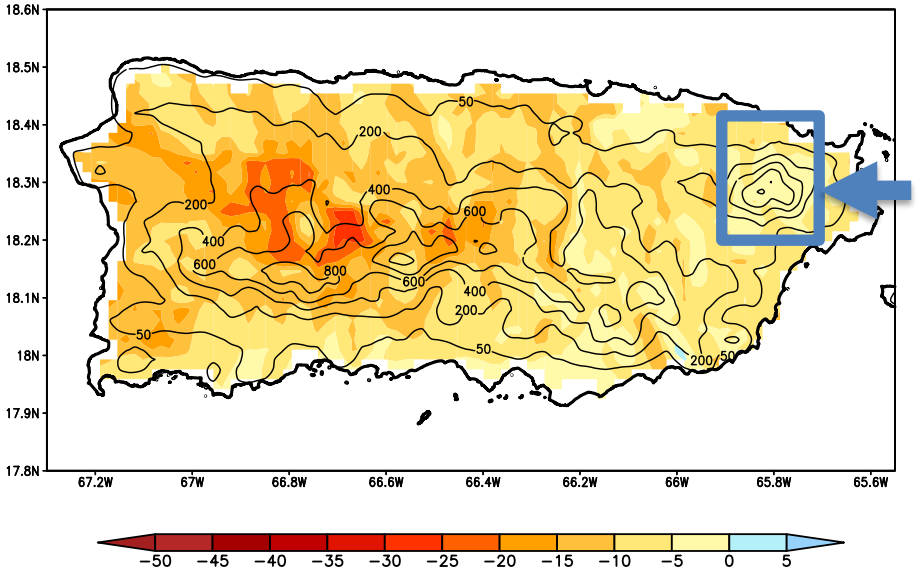
Key Message for Precipitation

- GCMs indicate a large sensitivity in the magnitude of the annual rainfall reductions across the Caribbean by end-century when considering future greenhouse gas emissions.
  - Higher GHG emissions = Larger rainfall reductions; Policy implications

- GCMs underestimate the complexity of regional impacts.
  - RCM projections show plausible larger within island rainfall reductions ; possibly 10-15% larger reductions locally the than GCM.
  - RCM projections indicate rainfall reductions within both the wet and dry seasons.
  - RCM projections depict an elevational sensitivity in the magnitude of the rainfall reductions.

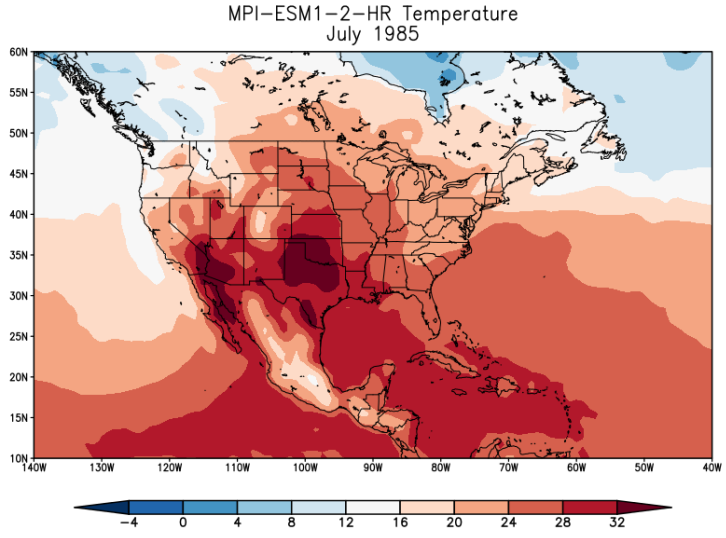
Overall, there is an increasing risk of aridity within the Caribbean islands as greenhouse gas continues to increase.

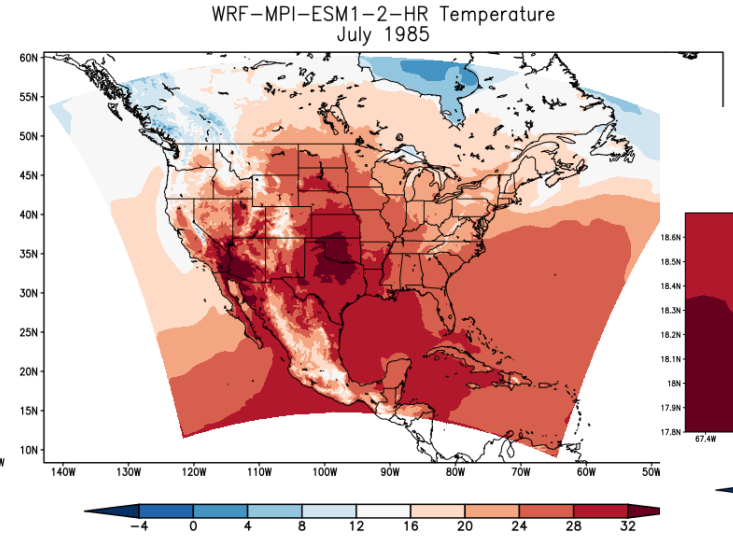
Relative change in soil moisture (%) for top 10cm during the Wet season

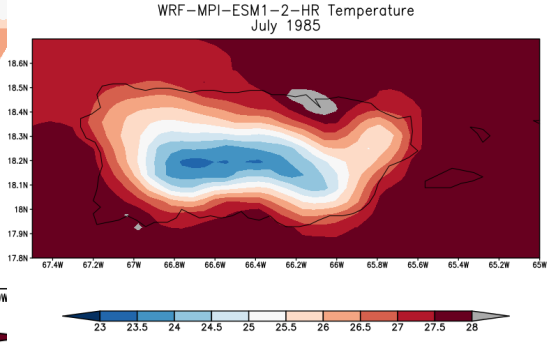


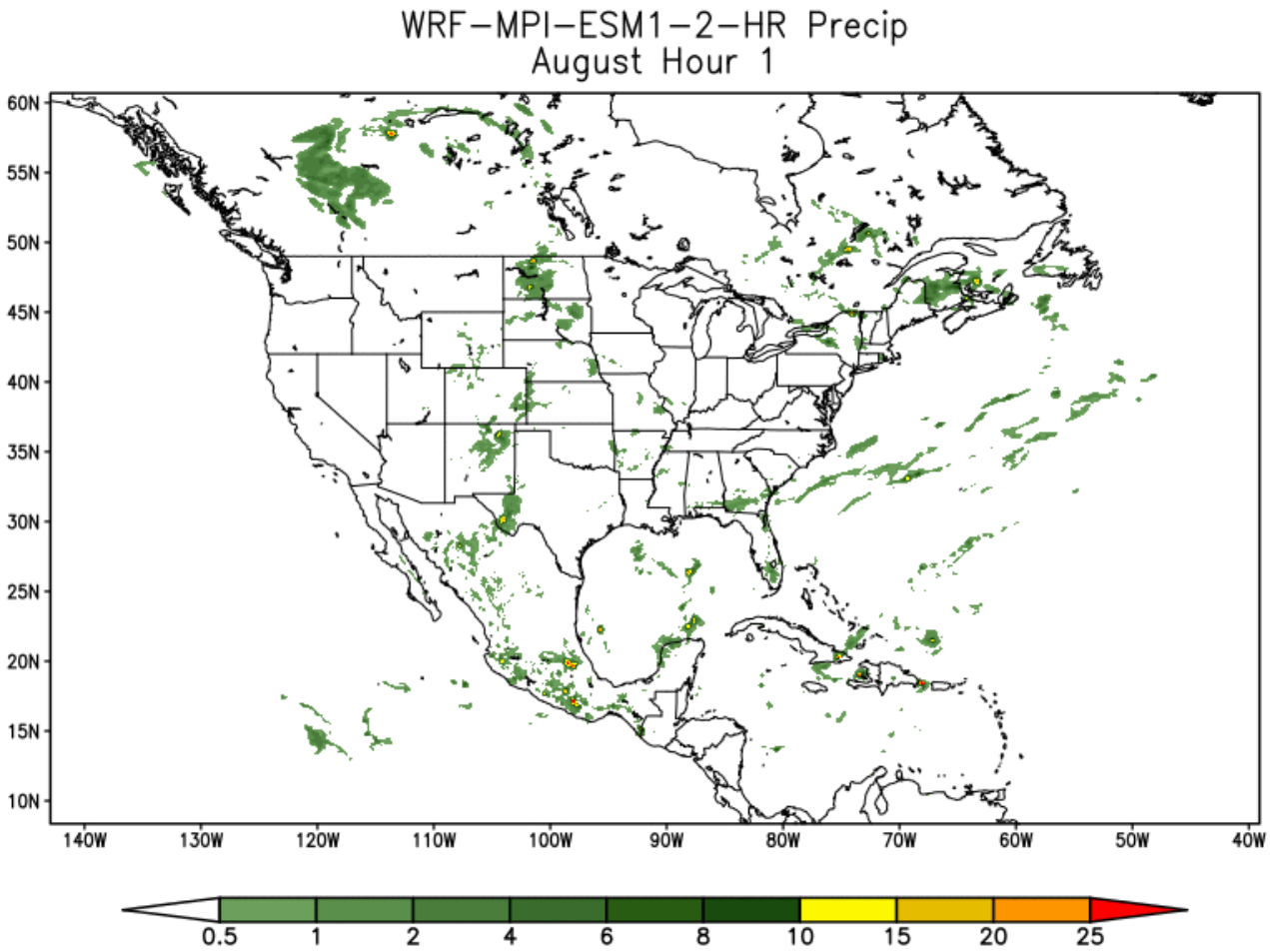
Rainfall increases but evaporation demand is larger.

Are the downscaled simulations robust, such as the elevational sensitivities found? Ongoing research with CMIP6 Downscaling








WRF–MPI–ESM1–2–HR Precip
August Hour 1
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
140W
130W
120W
110W
100W
90W
80W
70W
60W
50W
40W
0.5
1
2
4
6
8
10
15
20
25