# An Evaluation of the Seasonal Caribbean Hydroclimate under various CESM and other CMIP6 Models

**CVWG Winter Meeting**

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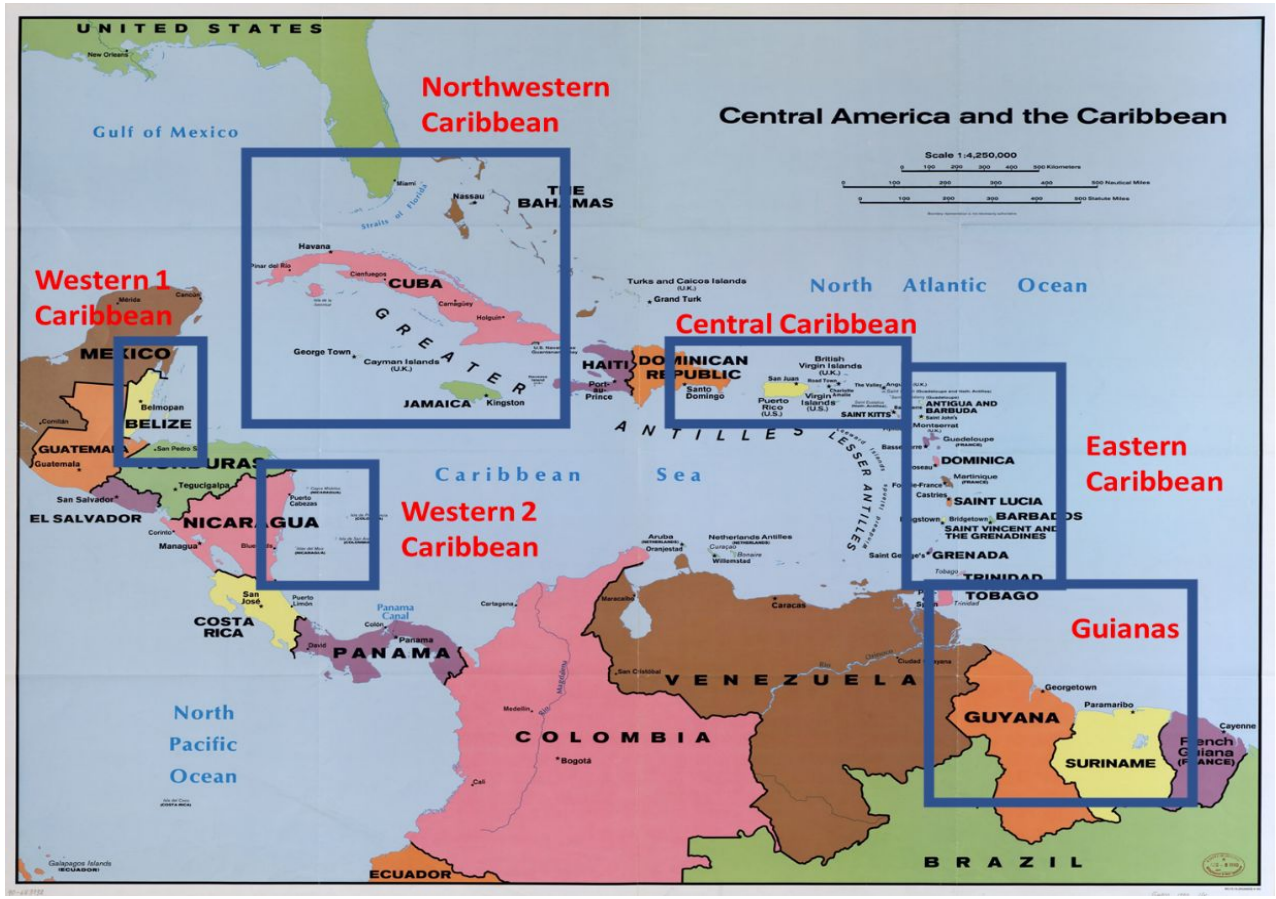
# The Caribbean: A highly vulnerable region to Climate Variability and Change

Between 1970 and 2000, the Caribbean region suffered direct and indirect losses estimated between $700 million and $3.3 billion due to natural disasters associated with weather and climate events - Food and Agricultural Organization (FAO, 2016)

Farmers, tourism industry, etc. look to their local weather and climate service for forecasts on rainfall

Recent work developed a refined and comprehensive understanding of the Caribbean Rainfall Cycle




Subregions of the Caribbean from Martinez et al. 2019 and 2020

# Main Ingredients:

Intertropical Convergence Zone (ITCZ)
(Henderson-Sellers and Robinson, 1986),

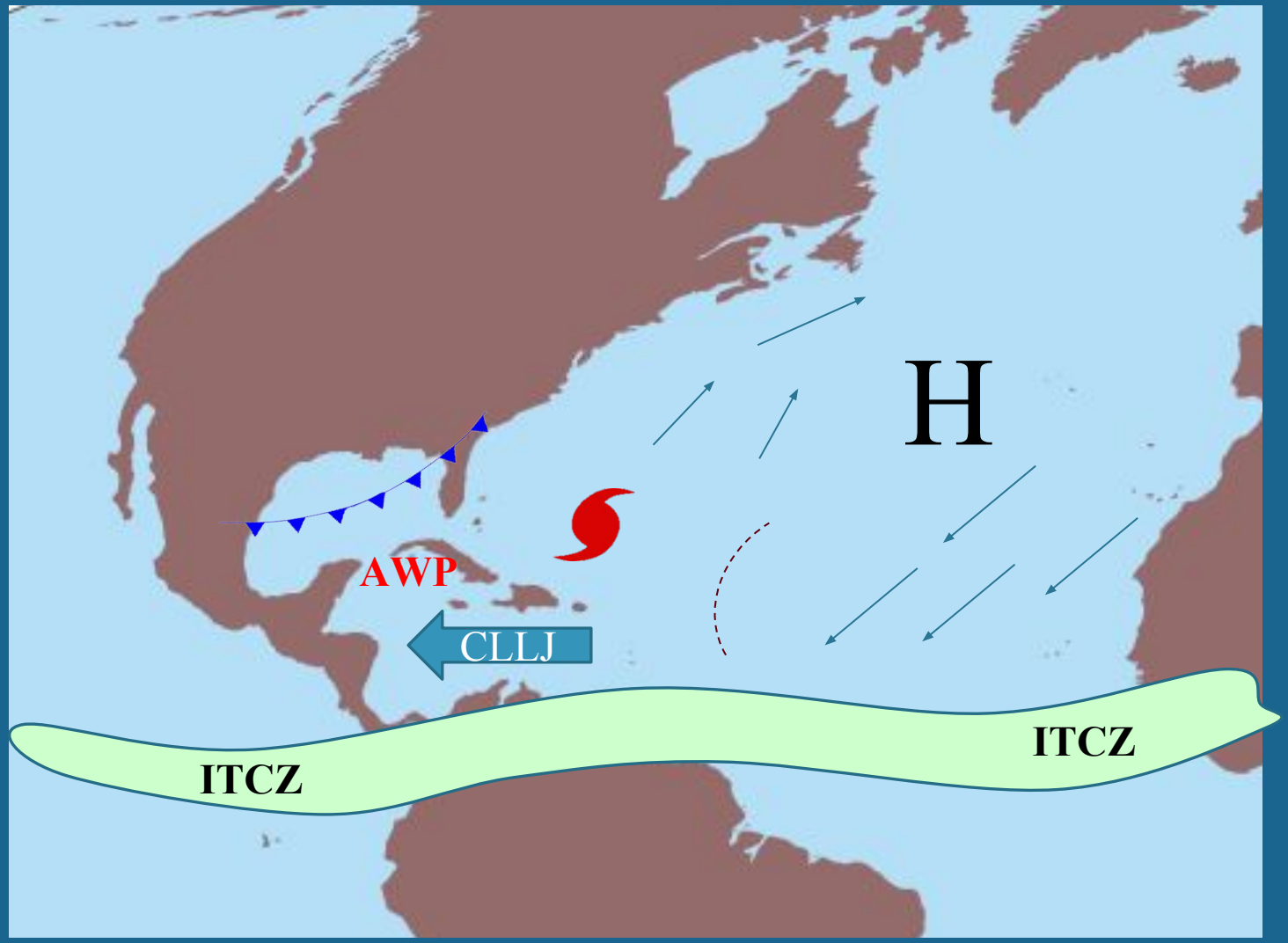
North Atlantic Subtropical High (NASH) / Trade Winds (Davis et al. 1997)

Regional Modifiers:
Atlantic Warm Pool (AWP) (Wang et al. 2006)

Caribbean Low-Level Jet (CLLJ)
(Amador, 1998)

Easterly Waves / Tropical Cyclones, Frontal Systems (Burpee 1972)

Local forces (i.e. orographic lifting, sea breezes, etc).



# Mission

**This refined understanding has yet to be explored in modeling studies over the Caribbean/Central America (e.g., looking at the region on a subregional and seasonal lens)**

**Has yet to be a model evaluation study in the Caribbean that uses the new simulations of CESM and CMIP6**

# Questions and Objectives

- How well do global circulation models (GCMs) simulate the Caribbean rainfall cycle and its dynamical mechanisms?
- Do the models perform better over ocean-only grid spaces (where there is less complexity such as topography) than land-only grid spaces? Vice versa?
- Are any biases specific to a sub-region of the Caribbean? Or general to the entire basin?
- Is there a relationship between model resolution and precipitation estimates when comparing the observed precipitation values?

# Datasets

- CESM
  - CESM1 and 2LENS and AMIP (GOGA) runs
  - High-Resolution CESM (iHESP) and AMIP

  AMIP = Sea-Surface Temperature was prescribed into model (Atmospheric Response only)

  Fully-Coupled = Ocean and Atmosphere Response

- CMIP6HighResMIP
  - Low-Resolution and High-Resolution versions of the same model

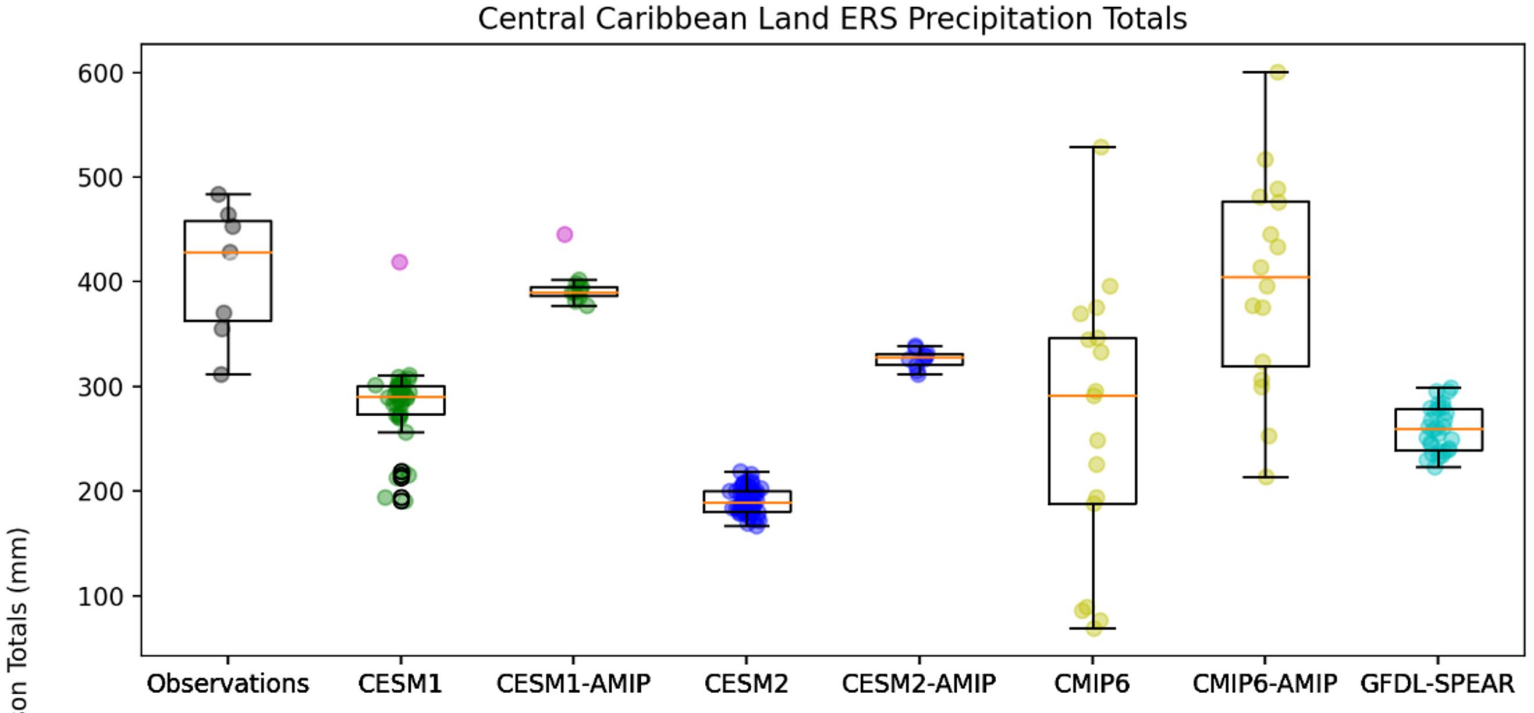
- Observations

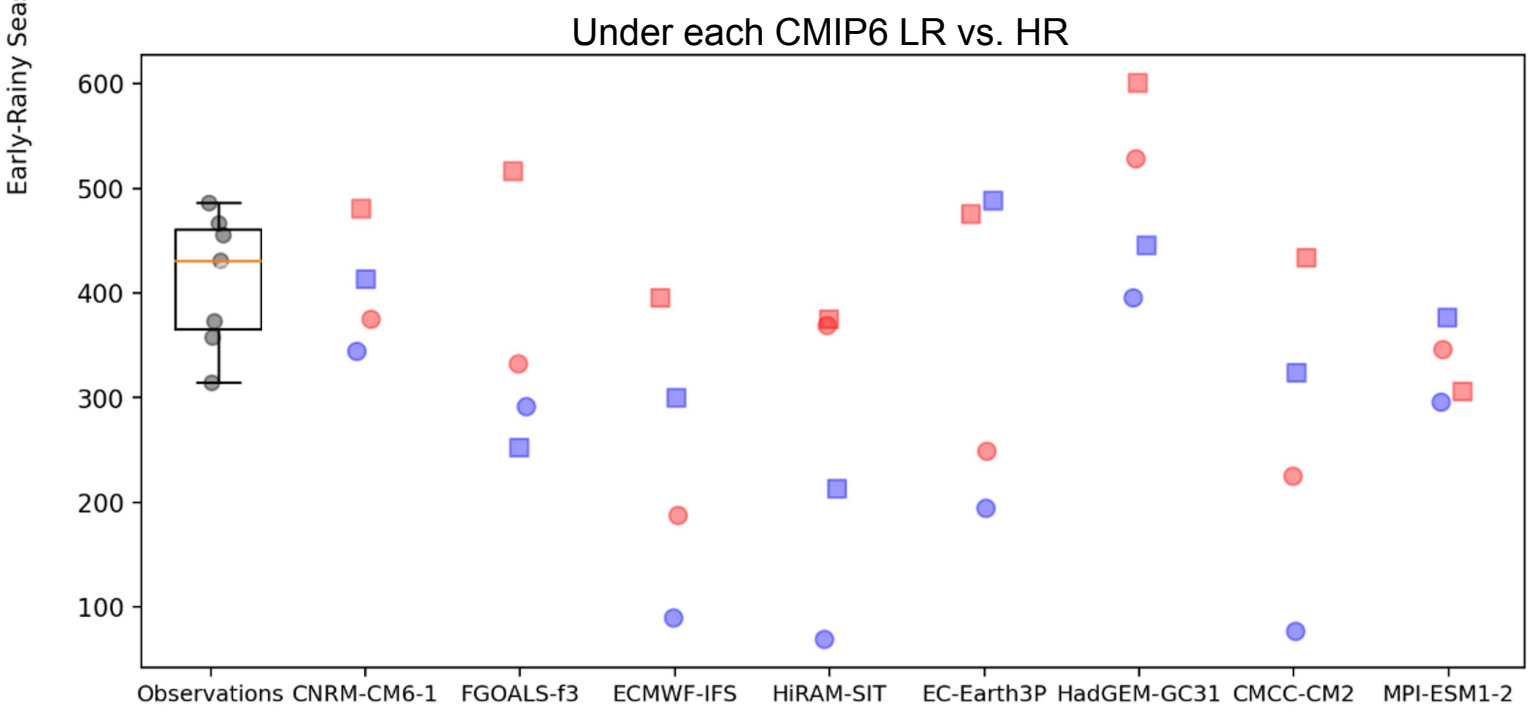
| Gridded Precipitation | |
|---|---|
| PERSIANN-CDR | 0.25x0.25 deg |
| PERSIANN-CCS-CDR | 0.04x0.04 deg |
| MSWEPv2 | 0.1x0.1 deg |
| CHIRPSv2 | 0.05x0.05deg |
| GPCC | 0.25x0.25 deg |
| ERA5 | 0.25x0.25deg |
| Station Precipitation | |
| CIMH/GHCN | 46 stations |

| CESM | # of Members used | Resolution (Atmospheric Model) | Atmospheric Model |
|---|---|---|---|
| CESM1LENS | 40 | 0.90x1.25 deg | CAM5 |
| CESM1GOGA | 10 | 0.90x1.25 deg | CAM5 |
| CESM2LENS (CMIP6) | 50 | 0.90x1.25 deg | CAM6 |
| CESM2GOGA | 10 | 0.90x1.25 deg | CAM6 |
| HRCESM (IHESP) | 1 | 0.25x0.25 deg | (CESM1.3) CAM5 |
| HRCESM-AMIP (IHESP) | 1 | 0.25x0.25 deg | (CESM1.3) CAM5 |
| | | | |
| **CMIP6HighResMIP** | # of Members used | Resolution (Atmospheric Model) | |
| CNRM-CM6-1 | 1 | 1.40x1.40 deg | ARPEGE6.3 |
| CNRM-CM6-1-HR | 1 | 0.50x0.50 deg | ARPEGE6.3 |
| FGOALS-f3-L | 1 | 1.00x1.25 deg | FAMIL2.2 |
| FGOALS-f3-H | 1 | 0.25x0.25 deg | FAMIL2.2 |
| HIRAM-SIT-LR | 1 | 0.50x0.50deg | GFDL-HiRAM |
| HIRAM-SIT-HR | 1 | 0.25x0.25 deg | GFDL-HiRAM |
| EC-Earth3P | 1 | 0.70x0.70 deg | IFS cy36r4 |
| EC-Earth3P-HR | 1 | 0.35x0.35 deg | IFS cy36r4 |
| ECMWF-IFS-LR | 1 | 1.00x1.00 deg | IFS cyc43r1 |
| ECMWF-IFS-HR | 1 | 0.50x0.50 deg | IFS cyc43r1 |
| HadGEM3-GC31-MM | 1 | 0.56x0.83 deg | MetUM |
| HadGEM3-GC31-HH | 1 | 0.23x0.35 deg | MetUM |
| CMCC-CM2-HR | 1 | 1.00x1.00 deg | CAM4 |
| CMCC-CM2-VHR | 1 | 0.25x0.25 deg | CAM4 |
| MPI-ESM1-2-HR | 1 | 1.00x1.00 deg | ECHAM6.3 |
| MPI-ESM1-2-XR | 1 | 0.5x0.5 deg | ECHAM6.3 |
| BCC-CSM2-HR | 1 | 0.45x0.45 deg | BCC_AGCM3_HR |
| | | | |
| **Other** | | | |
| GFDL-SPEAR-MED | 30 | 0.50x0.50 deg | GFDL-AM4C192 |

# Land vs. Ocean Caribbean Hydroclimate between observations and models

*(Focusing on the Early-Rainy Season (April-June))*




Fully-Coupled Runs show a dry bias in precipitation estimates.

Estimates from AMIP runs improve, indicating that when sea-surface temperatures are prescribed into the model, the model improves its precipitation estimates.

Low-Resolution Fully-Coupled

Low-Resolution AMIP

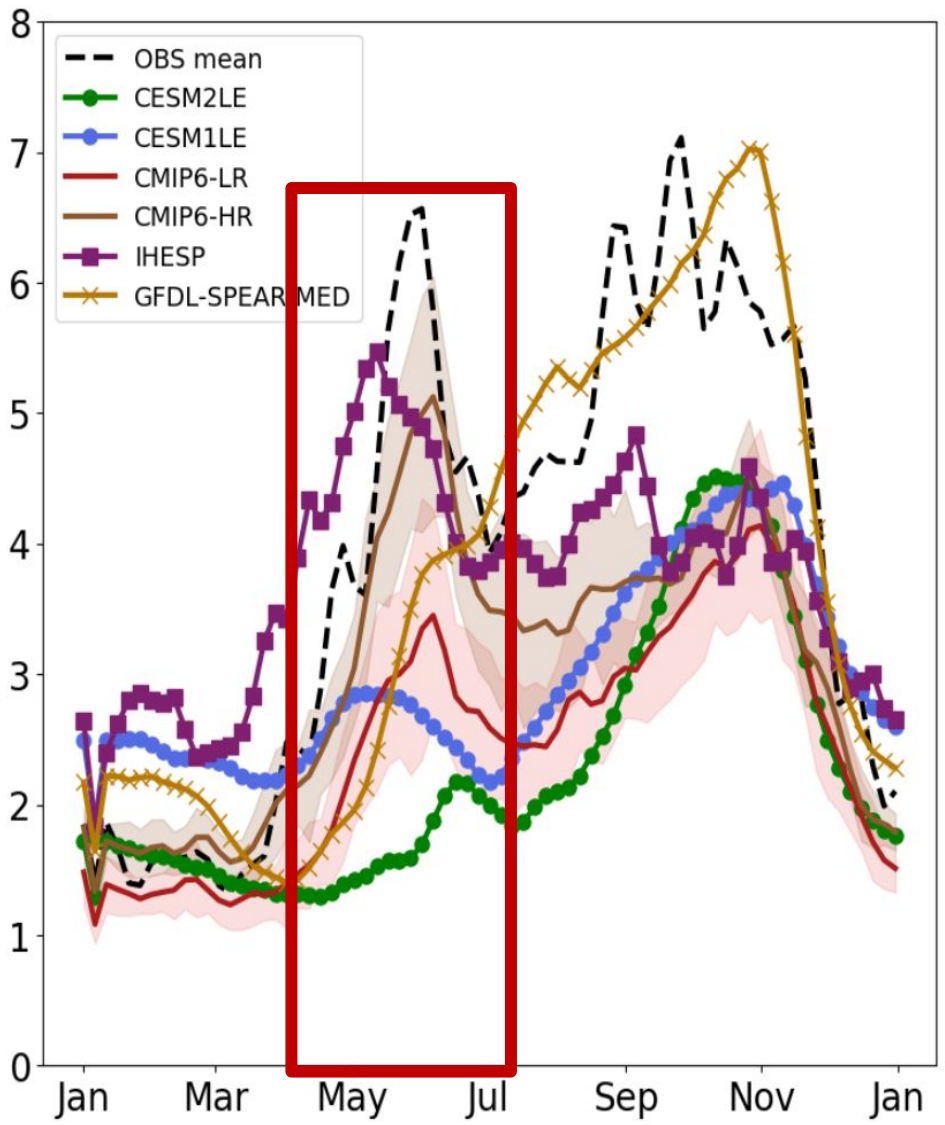
High-Resolution Fully-Coupled

High-Resolution AMIP

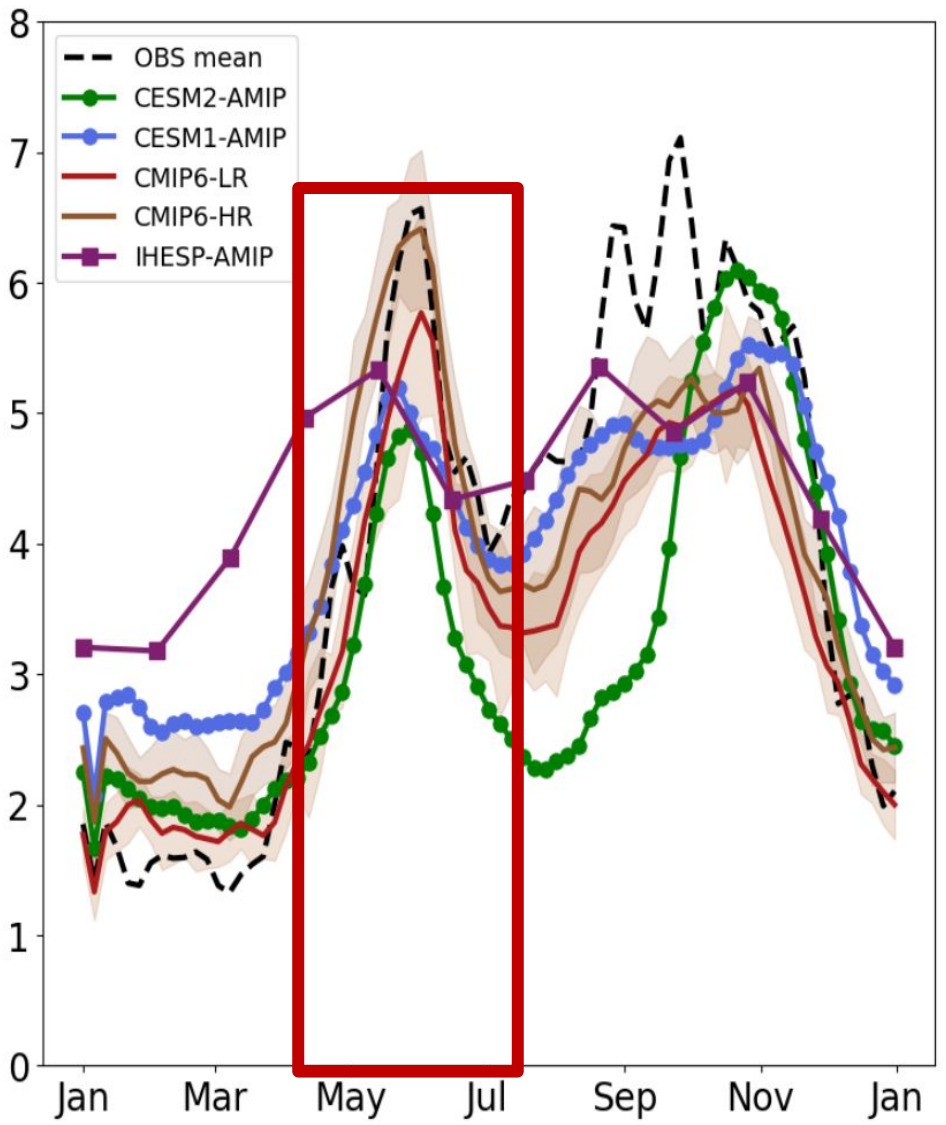
Shows estimates from HR runs are closer to observational spread than their LR counterpart.

Central Caribbean (Land-Only Precipitation)

**Fully Coupled**




**AMIP**

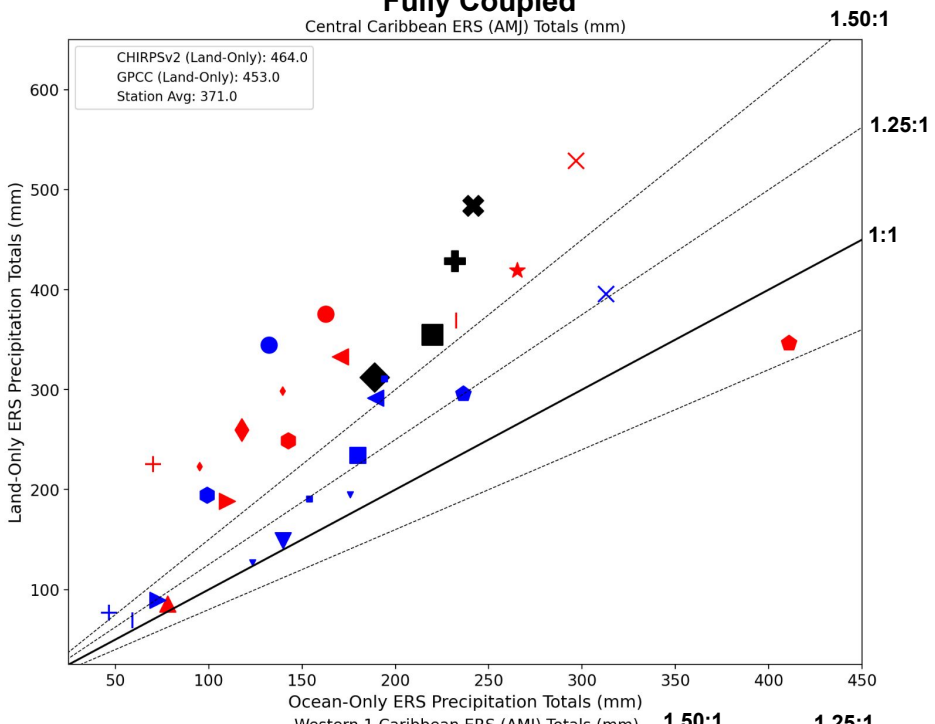


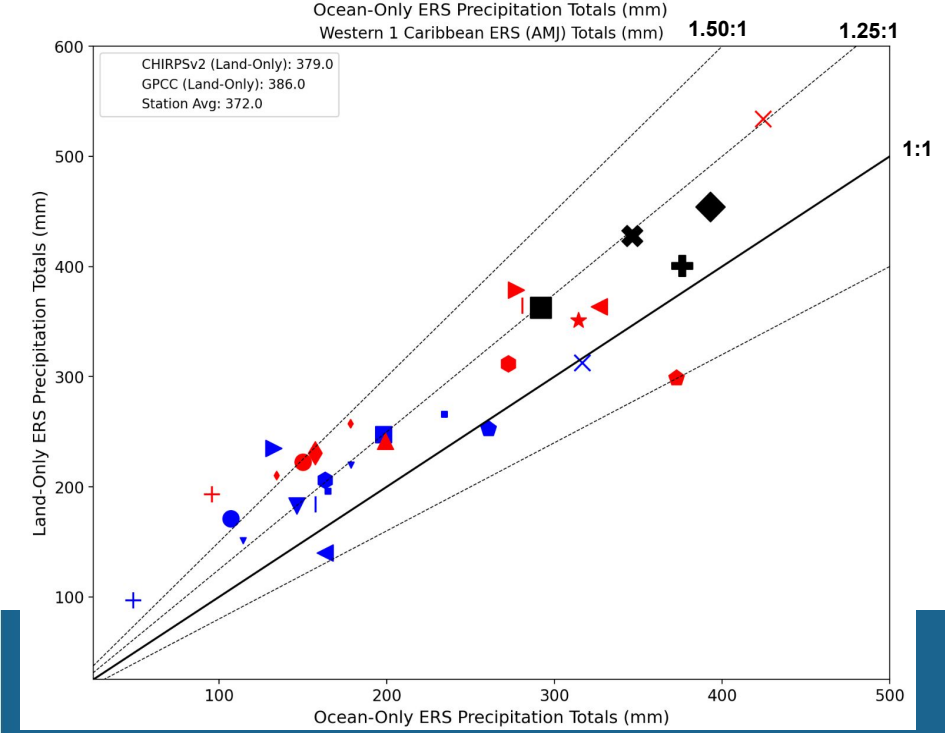

Fully-Coupled runs underestimate hydroclimate over the Caribbean (e.g., CESM1,2 completely miss ERS)

When SSTs are prescribed (AMIP), the models perform better.

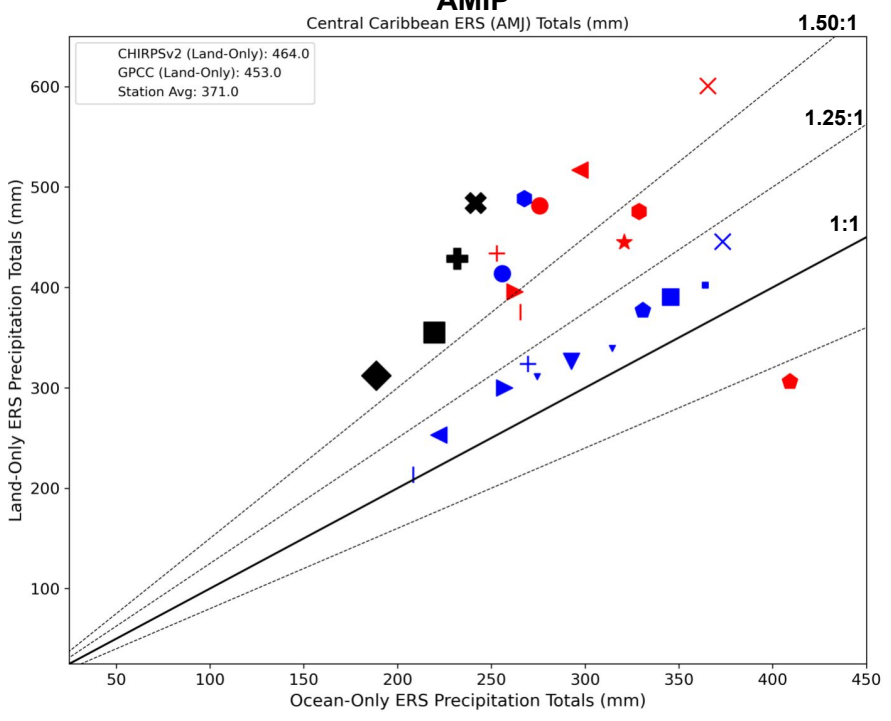
# Land vs. Ocean Precipitation Scatterplots

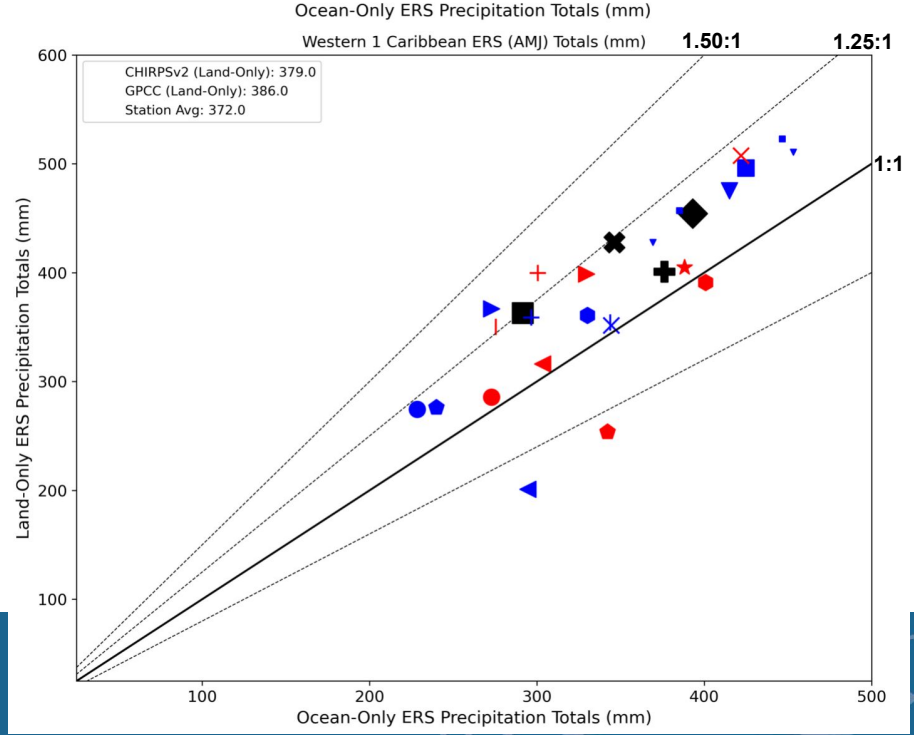
## Fully Coupled




## AMIP




Low-Res

High-Res

- ERA5
- GPCC
- MSWEPv2
- PERSIANN-CDR
- PERSIANN-CCS-CDR
- CHIRPSv2
- GFDL-SPEAR-MED
- CESM2LE
- CESM1LE
- HRCESM
- BCC
- CNRM-LR
- CNRM-HR
- FGOALS-LR
- FGOALS-HR
- ECMWF-LR
- ECMWF-HR
- HIRAM-LR
- HIRAM-HR
- EARTH-LR
- EARTH-HR
- HADGEM3-MM
- HADGEM3-HH
- CMCC-HR
- CMCC-VHR
- MPI-HR
- MPI-XR

Generally, most FC models underestimate ocean and land-only precipitation.

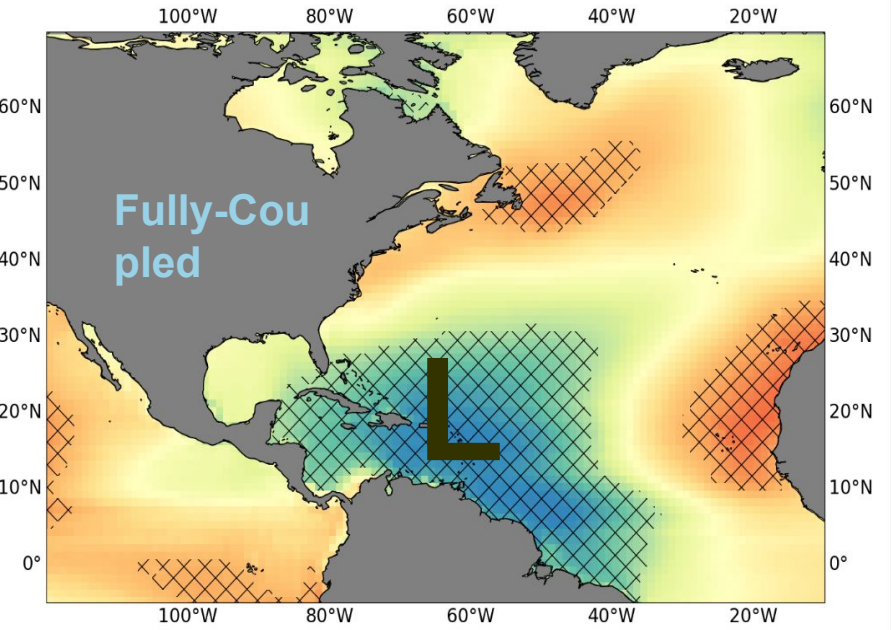
Comparing FC LR (blue) to HR (red), the HR values are closer to the observed spread.

AMIP runs show values closer or within the observational spread.

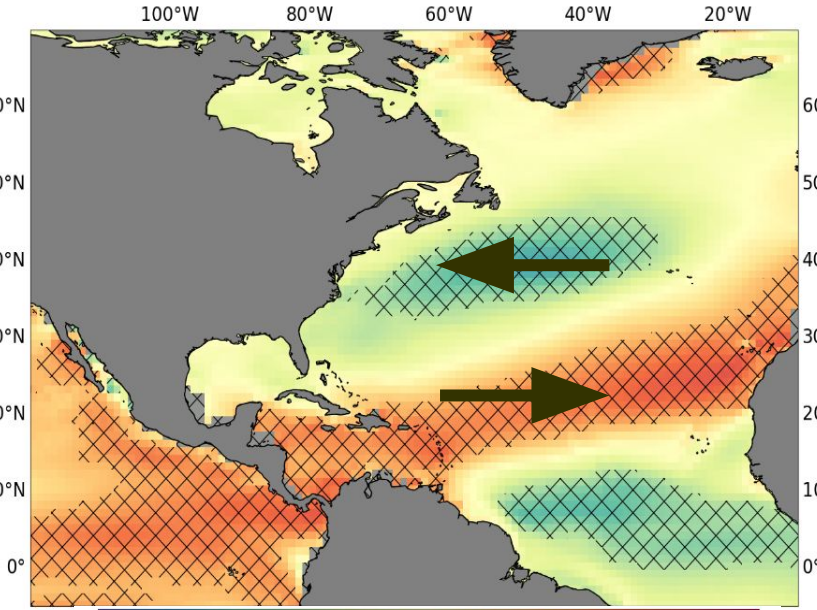
# Model Spatial Regression / Scatterplots of Dynamical Variables onto Precipitation Index

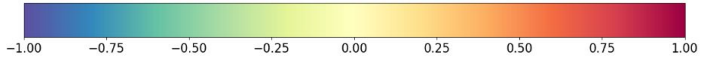
All models regridded to 0.25x0.25-degree resolution

SLP (Zonal Mean Removed) Regressed onto May Precipitation

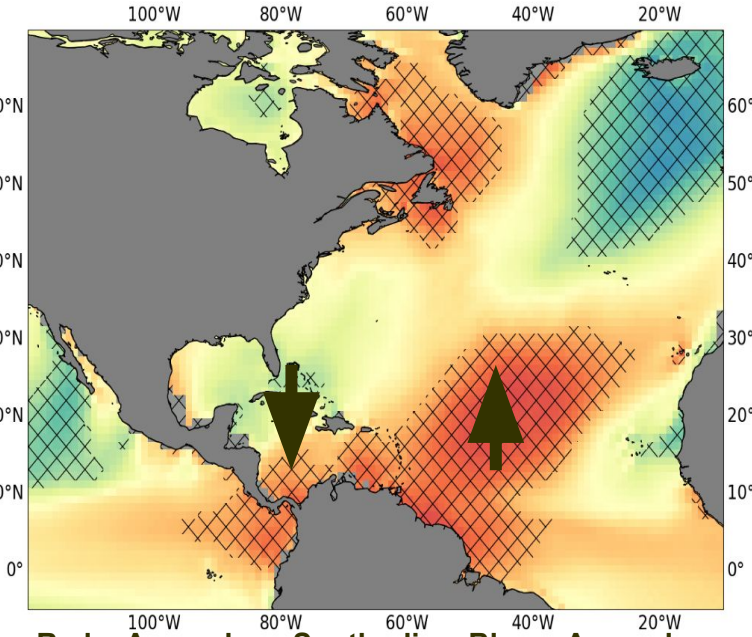



Zonal 850mb Wind Regressed onto May Precipitation



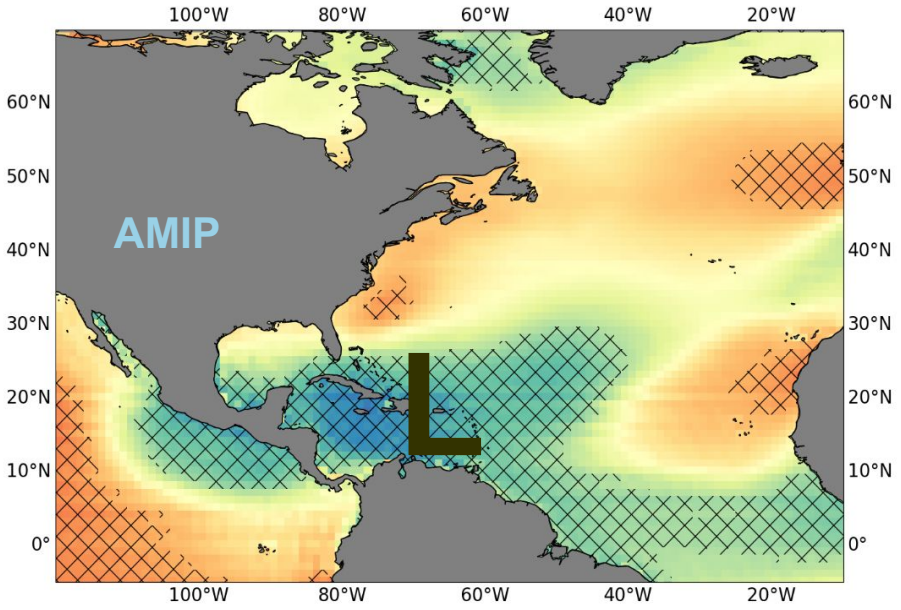


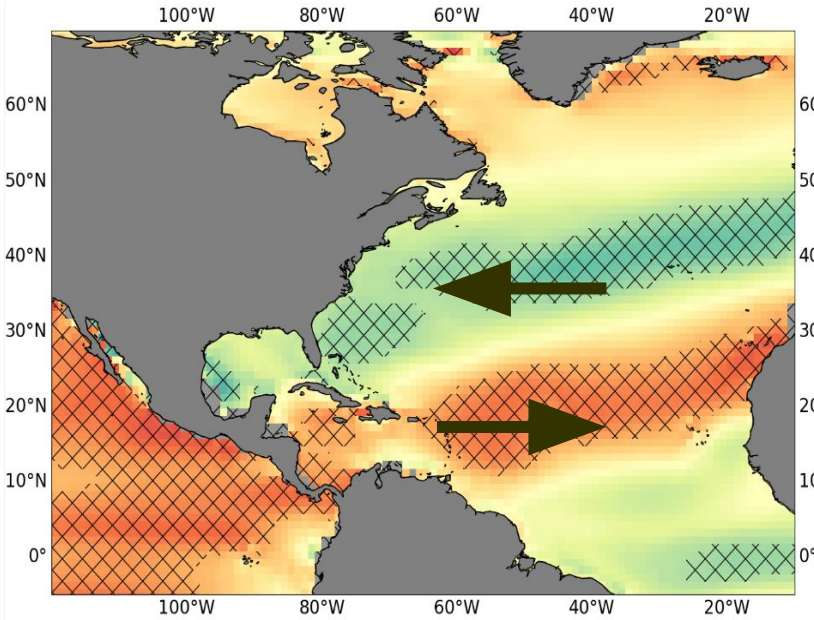

Meridional 850mb Wind Regressed onto May Precipitation

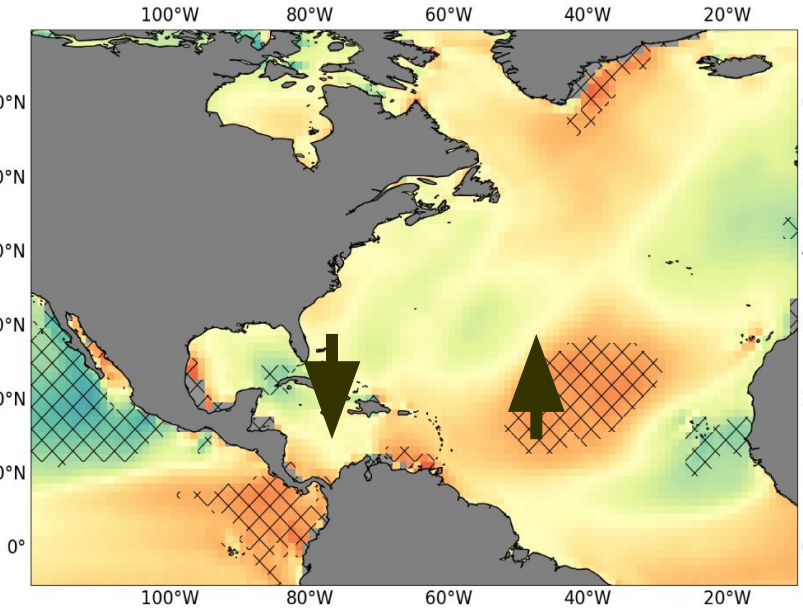


Red = Anomalous Southerlies Blue = Anomalous Northerlies. Show an Anomalous Low Circulation or weaker NASH Circulation

Lower SLP over Caribbean Sea/TNA = More Precipitation

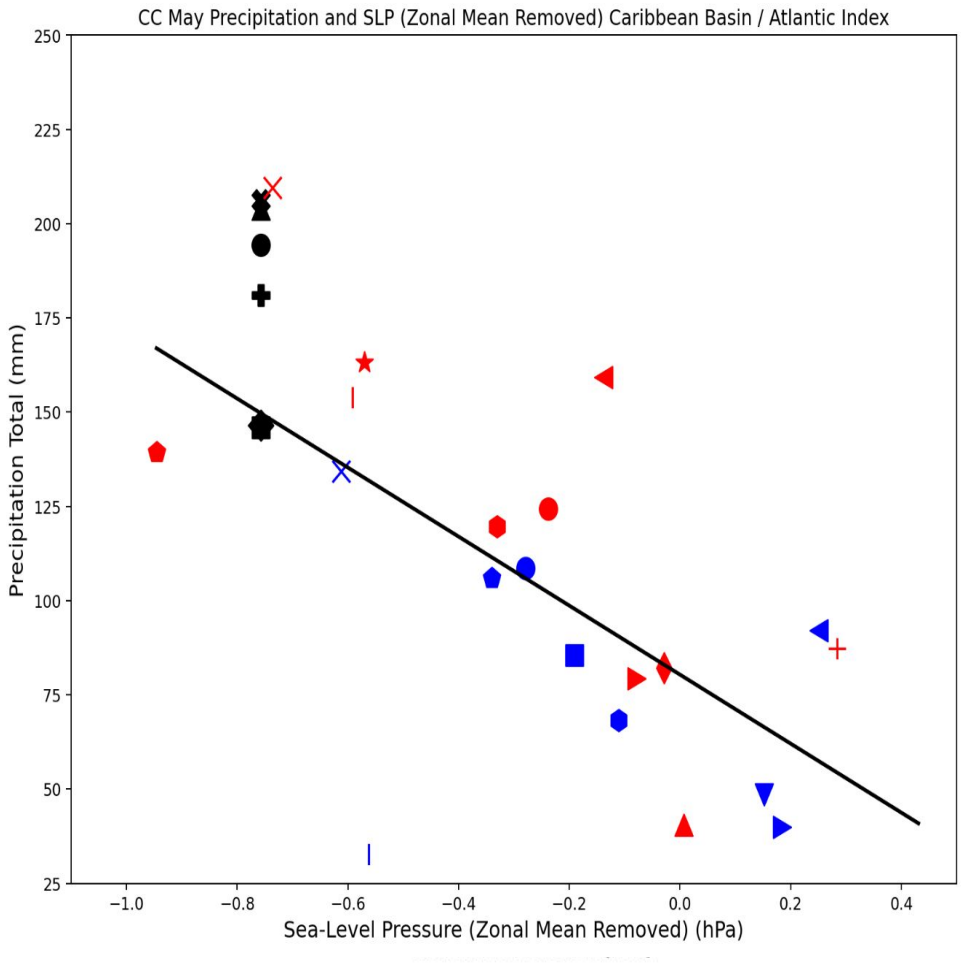


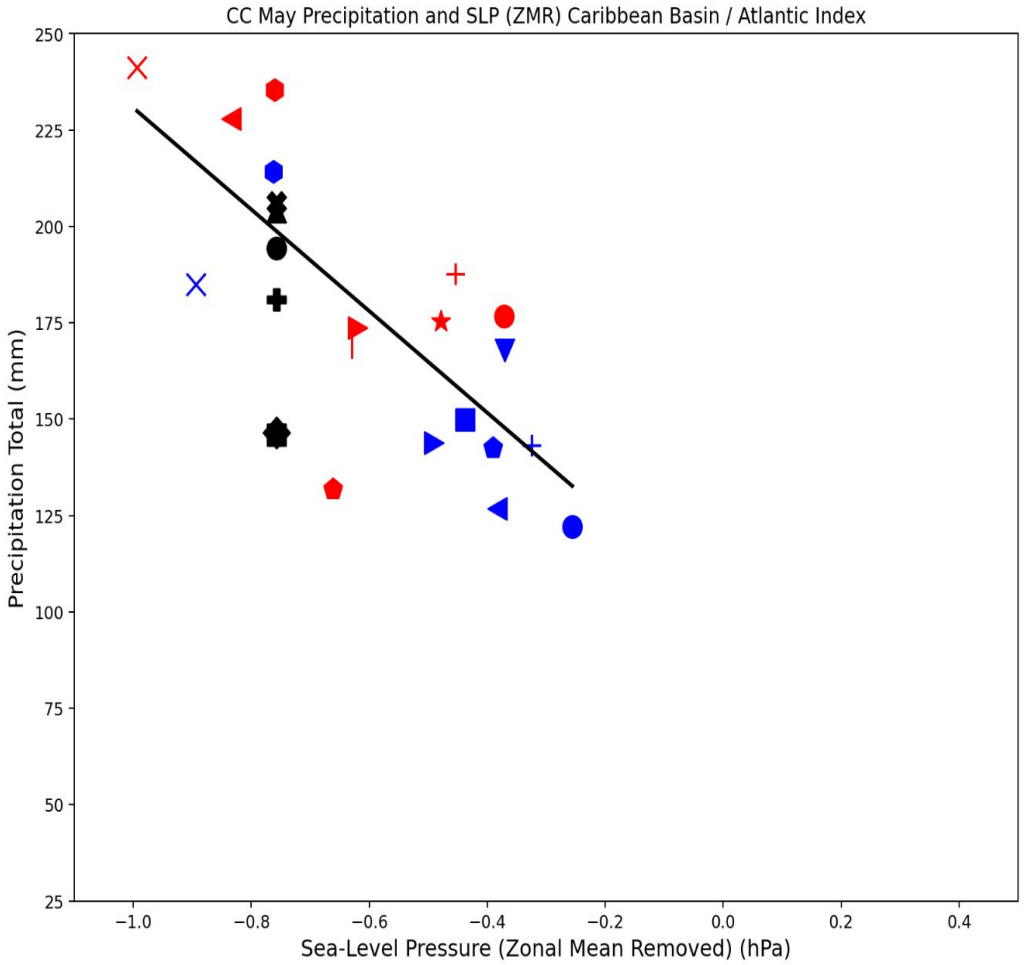


# SLP (Zonal Mean Removed) over the Caribbean Basin/ Tropical North Atlantic Regression and Central Caribbean Precipitation May Totals

## Fully Coupled




## AMIP




- ERA5
- GPCC
- MSWEPv2
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- ECMWF-HR
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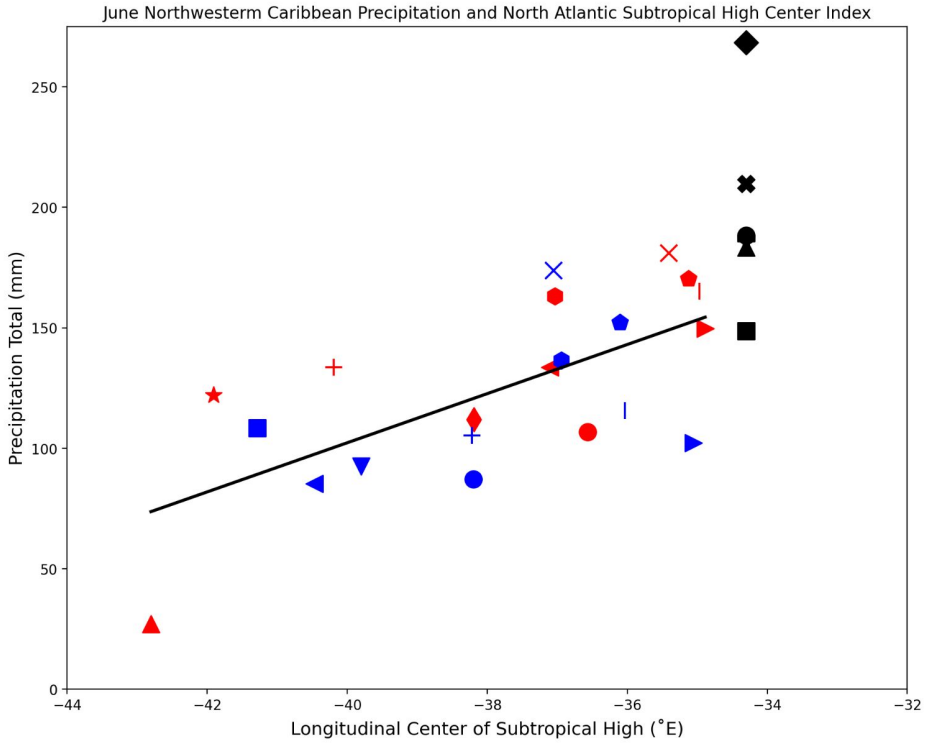
- HIRAM-HR
- EARTH-LR
- EARTH-HR
- HADGEM3-MM
- HADGEM3-HH
- CMCC-HR
- CMCC-VHR
- MPI-HR
- MPI-XR

Less SLP = More Precipitation Totals

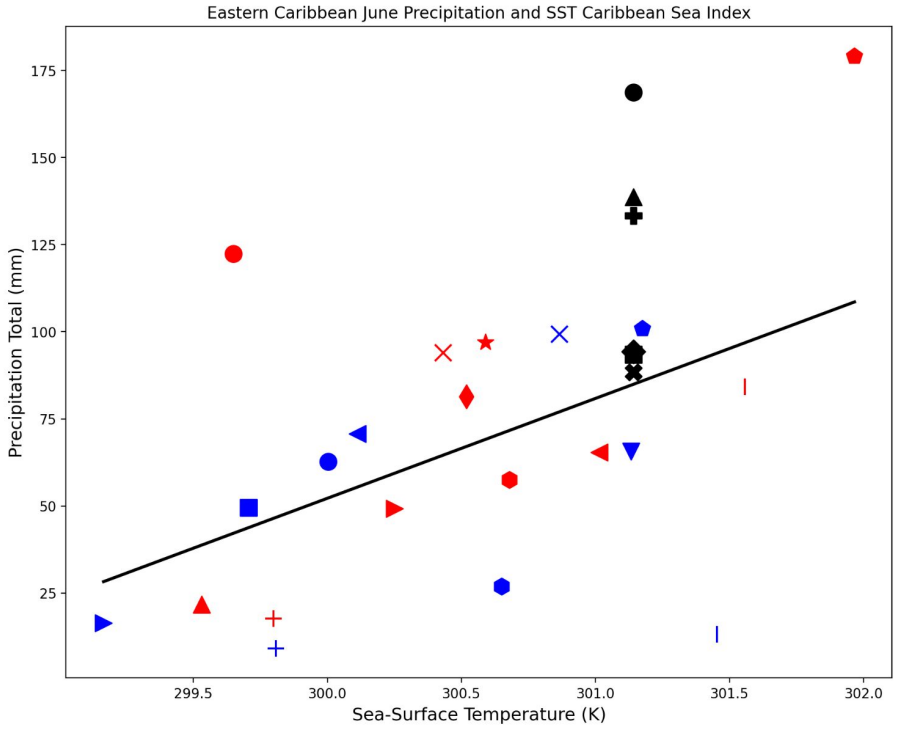
# Other Intermodal Differences

## June Center of NASH in Fully-Coupled Runs




Further west the Subtropical High Center is = less ERS precipitation

## June SSTs




Warmer SSTs = more precipitation

Similar findings across the other subregions

- ERA5
- GPCC
- MSWEPv2
- PERSIANN-CDR
- PERSIANN-CCS-CDR
- CHIRPSv2
- GFDL-SPEAR-MED
- CESM2LE
- CESM1LE
- HRCESM
- BCC
- CNRM-LR
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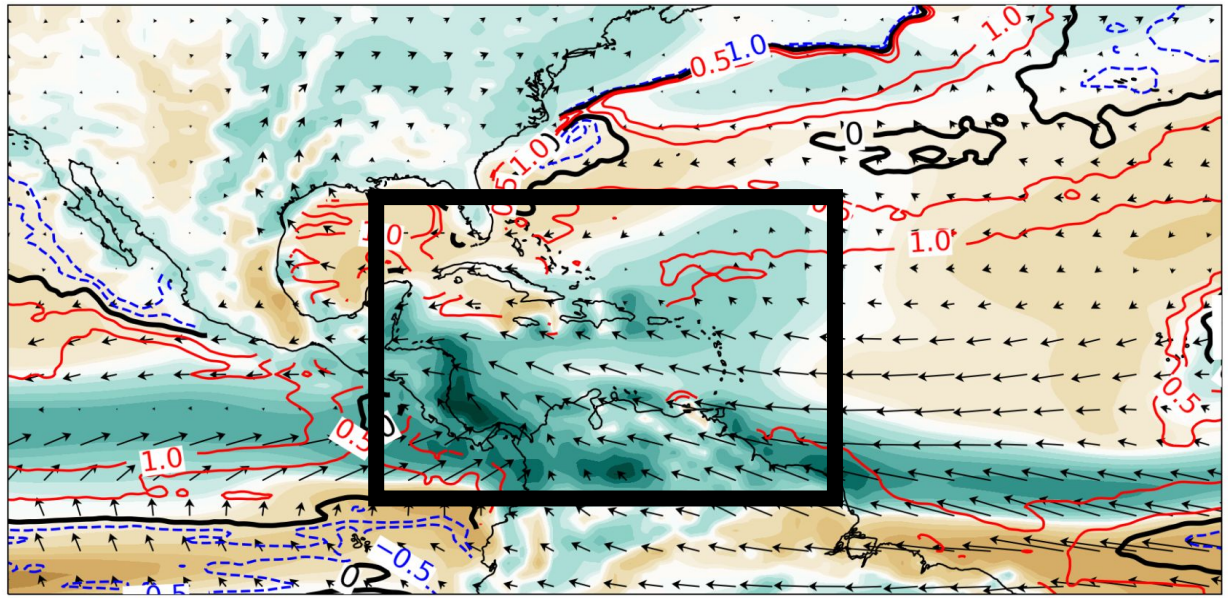
- HIRAM-LR
- HIRAM-HR
- EARTH-LR
- EARTH-HR
- HADGEM3-MM
- HADGEM3-HH
- CMCC-HR
- CMCC-VHR
- MPI-HR
- MPI-XR

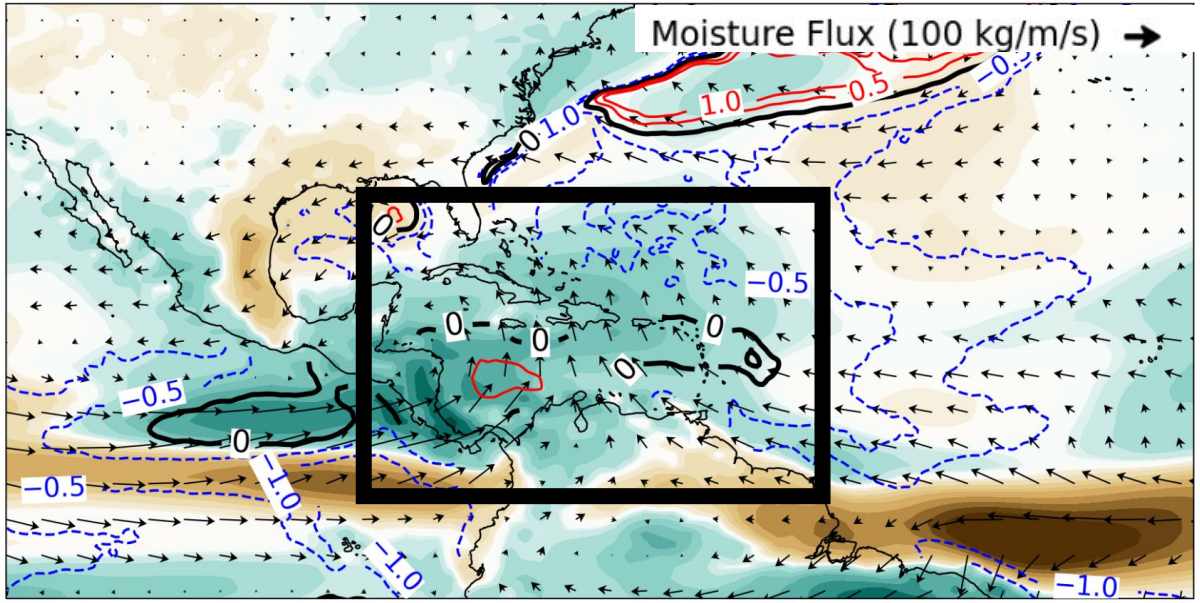
# Total Moisture Budget Analysis

# AMIP minus Fully Coupled May Moisture Flux and SST Composite

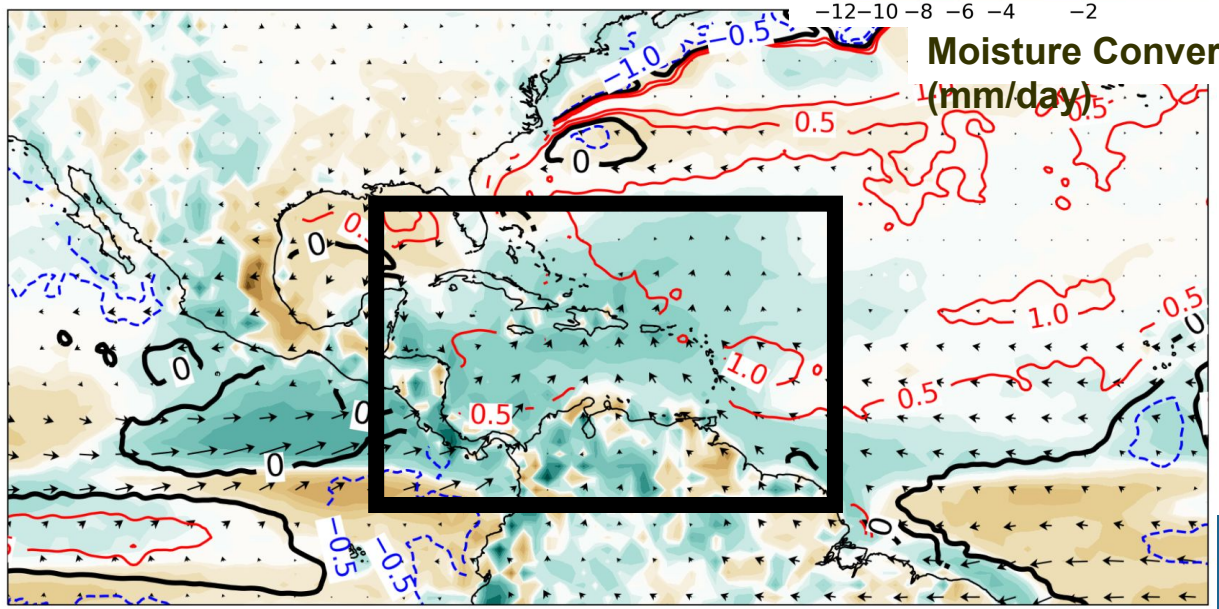
## CESM1 AMIP minus CESM1



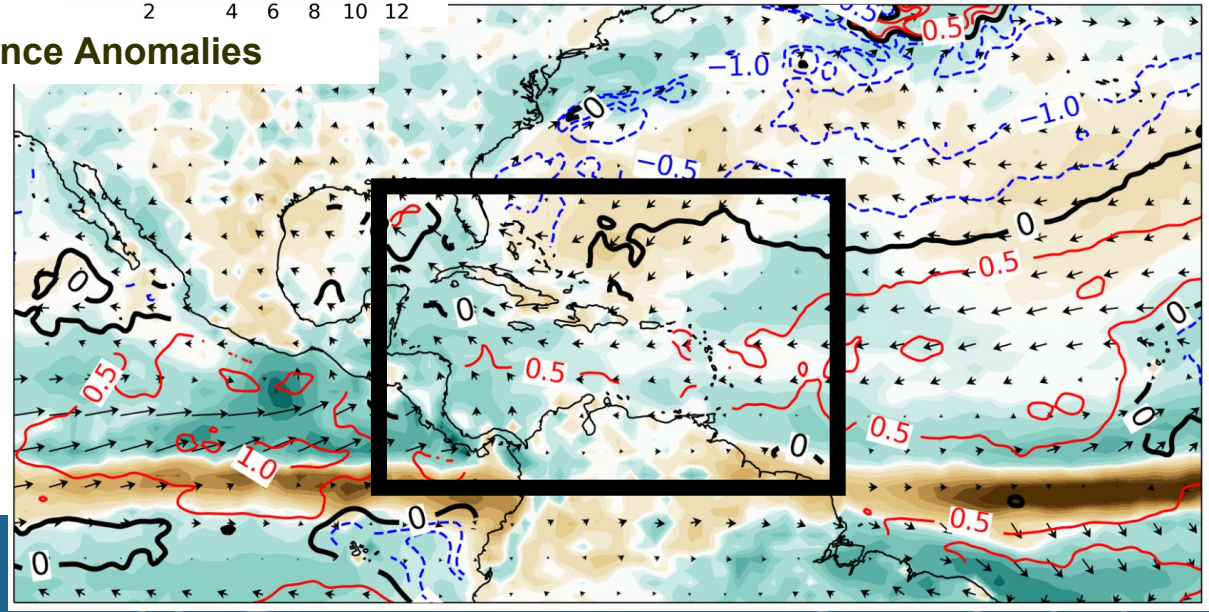
## CESM2 AMIP minus CESM2

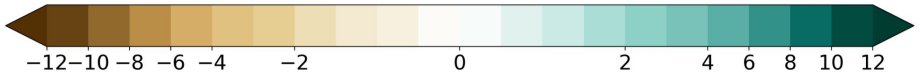



## CMIP6 AMIP minus HRCESM



## HRCESM AMIP minus HRCESM





# Conclusions/Summary

- Generally, most coupled models underestimate ERS land and ocean precipitation across the Caribbean.
- Coupled models also show a stronger and/or westward shift of the North Atlantic Subtropical High, which causes enhanced easterlies/divergence over the Caribbean basin.
- There is improvement of precipitation and large-scale dynamics when SSTs are prescribed to the model (AMIP).
- In several cases, High-Resolution estimate precipitation and dynamical variables closer to the observations/ERA5 than their Low-Resolution counterpart.
- *These findings are similar during the Mid-Summer Drought and Late-Rainy Seasons*

# Model – AMIP October Composite