

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

**CESM Annual Workshop**

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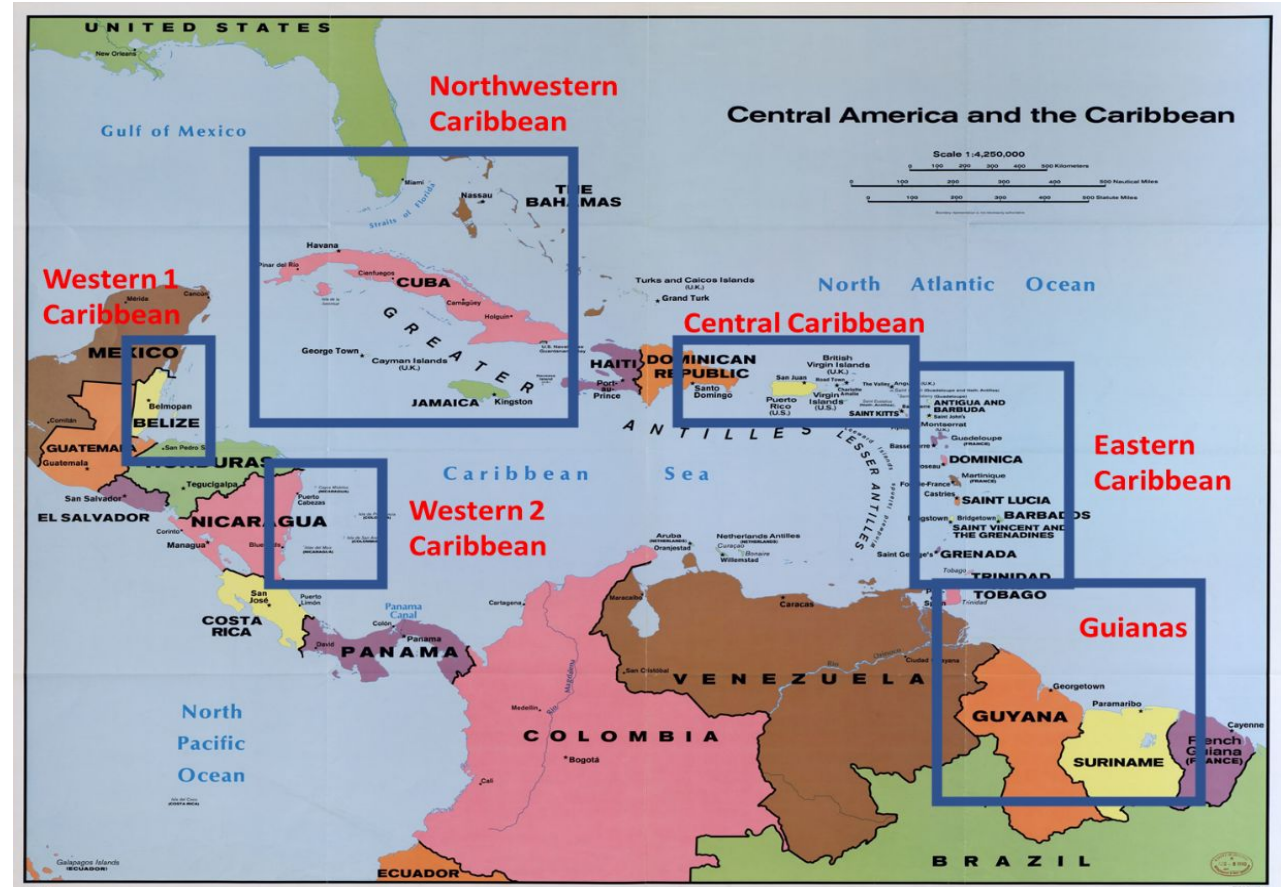


# The Caribbean: A highly vulnerable region to Climate Variability and Change

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

## 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**

# 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

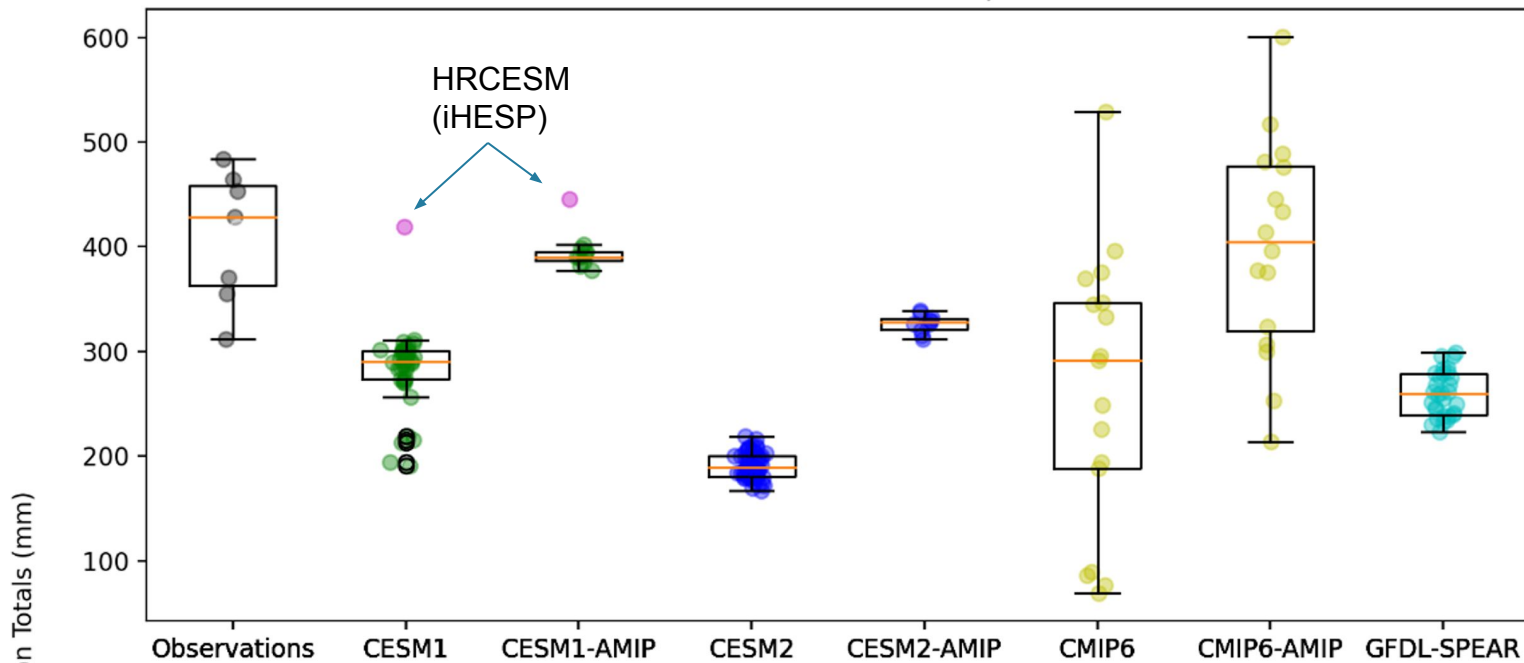
Gridded Precipitation	
PERSIANN-CDR	0.25x0.25 deg
PERSIANN-CCS-CDR	0.04x0.04 deg
MSWEPv2	0.1x0.1 deg
CHIRPSv2	0.05x0.05deg
GPCC	0.25x0.25 deg
ERA5	0.25x0.25deg
Station Precipitation	
CIMH/GHCN	46 stations

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

*(Focus on the Early-Rainy Season (April-June))*  
*Original Resolutions*

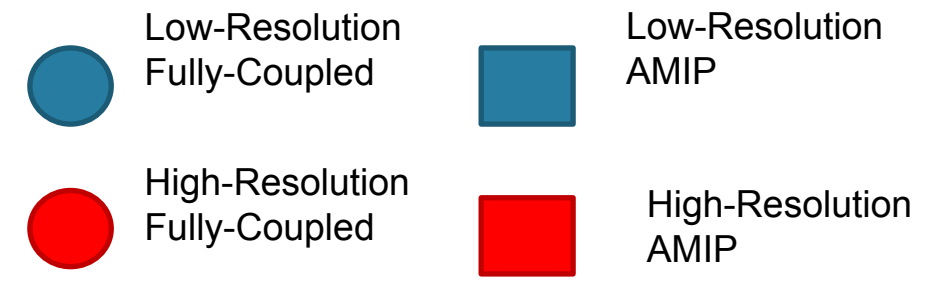
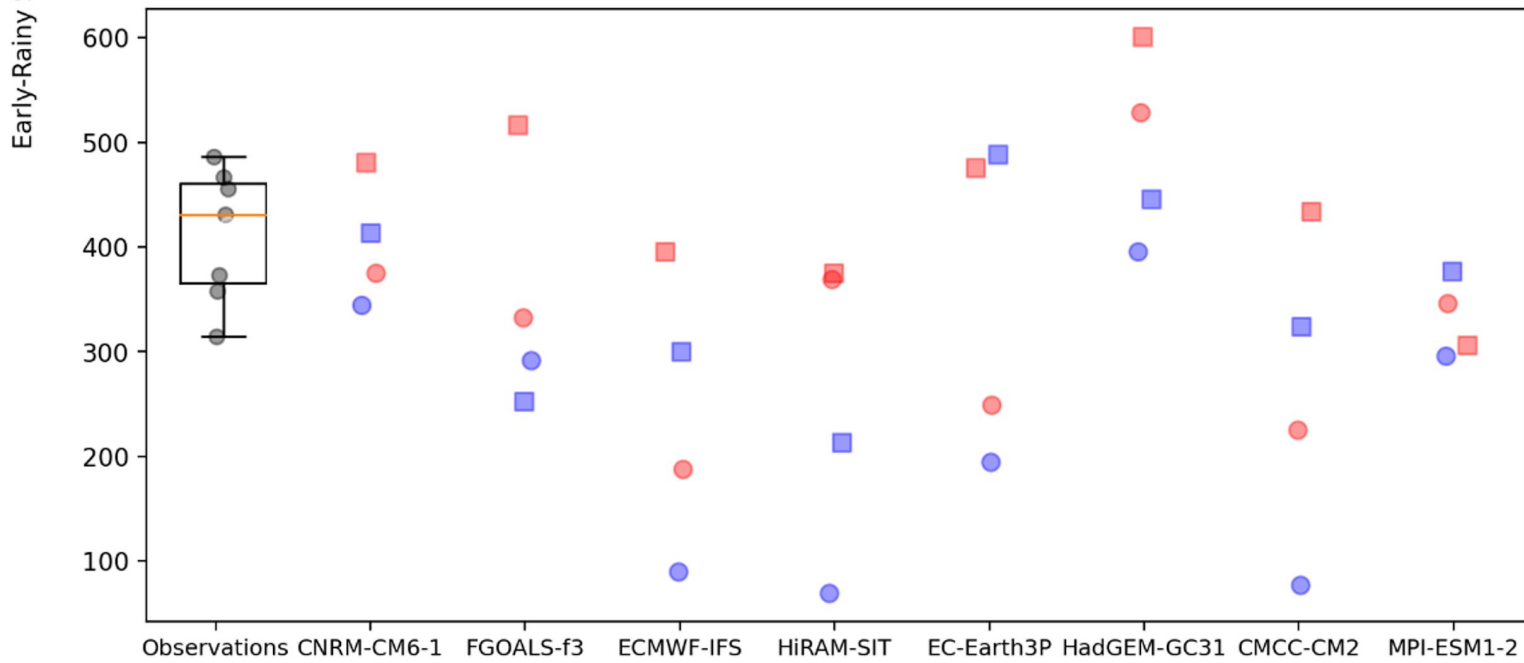
Central Caribbean Land ERS Precipitation Totals



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.

Under each CMIP6 LR vs. HR



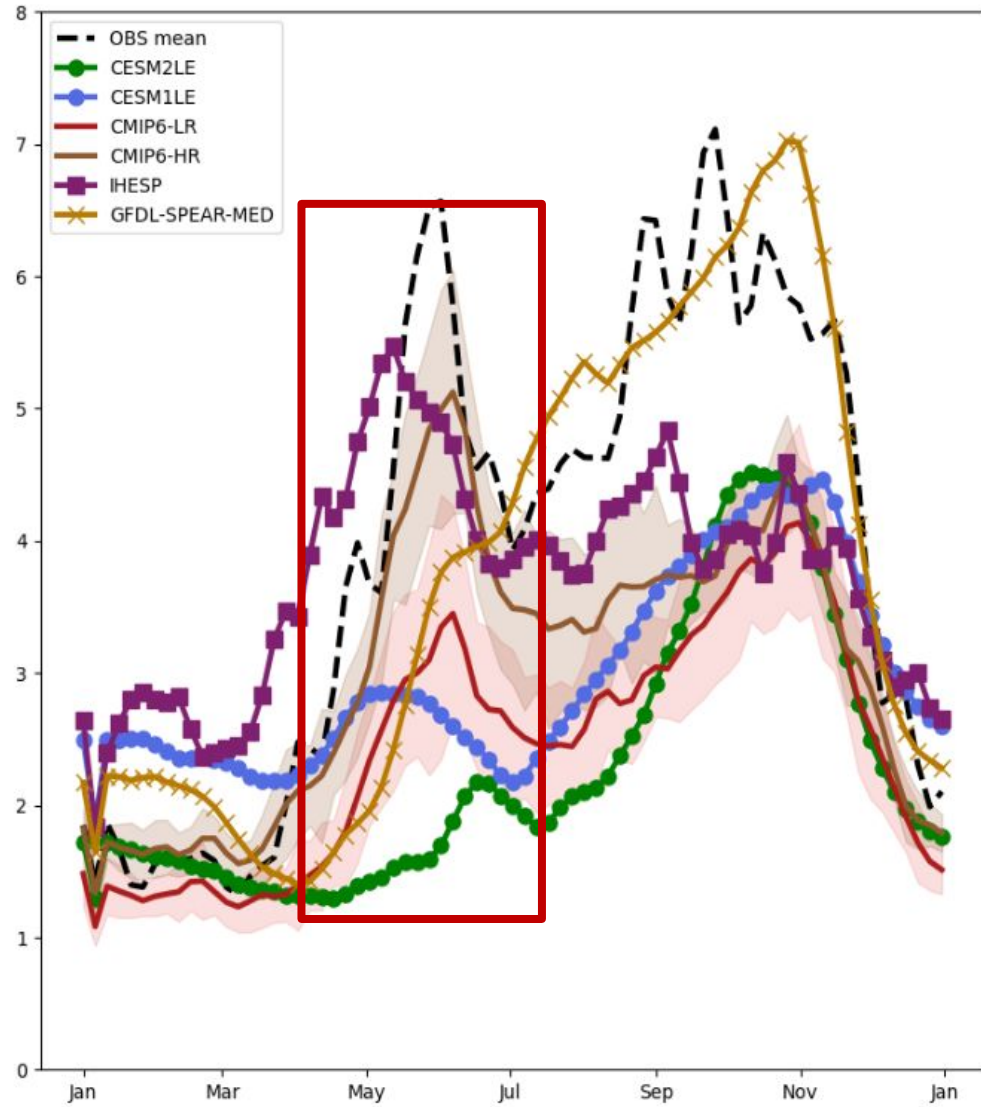
Shows estimates from HR runs are closer to observational spread than their LR counterpart.



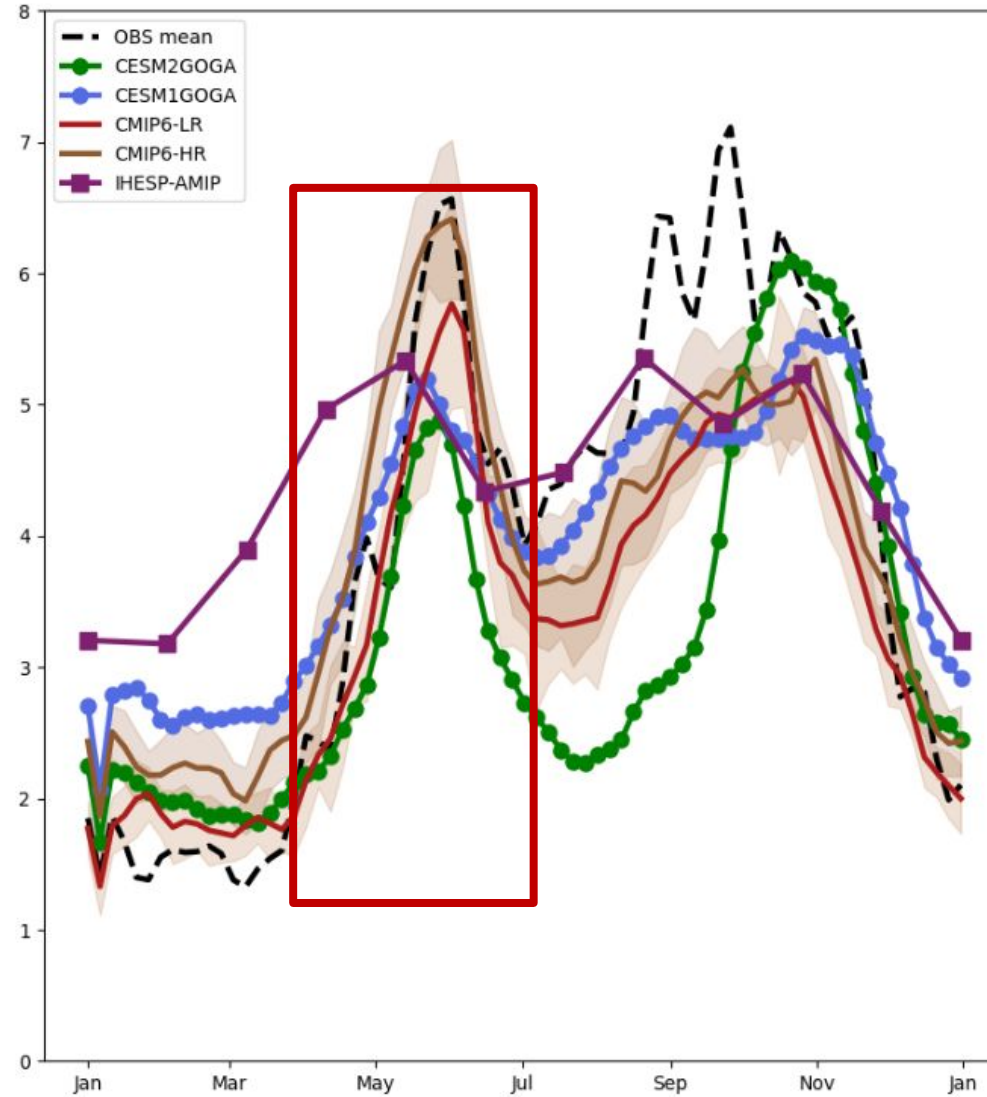


# Central Caribbean (Land-Only Precipitation)

## Fully Coupled



## AMIP



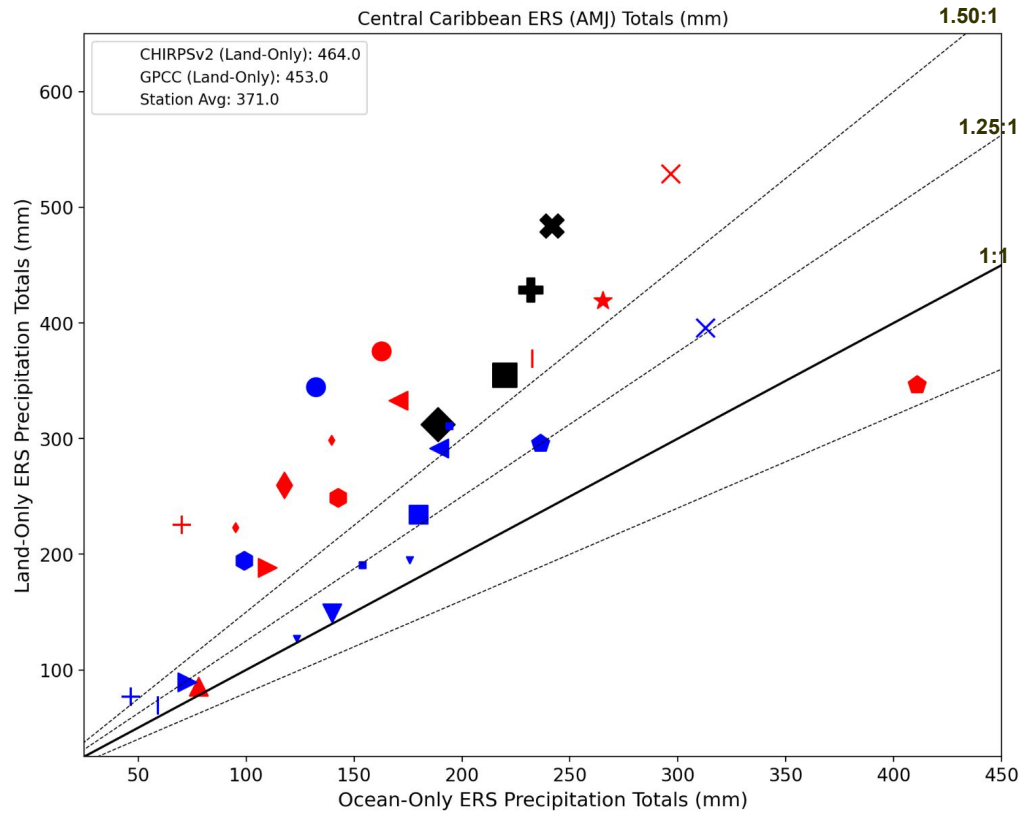
Fully-Coupled runs underestimate hydroclimate over the Caribbean (e.g., CESM1,2 completely miss ERS)

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

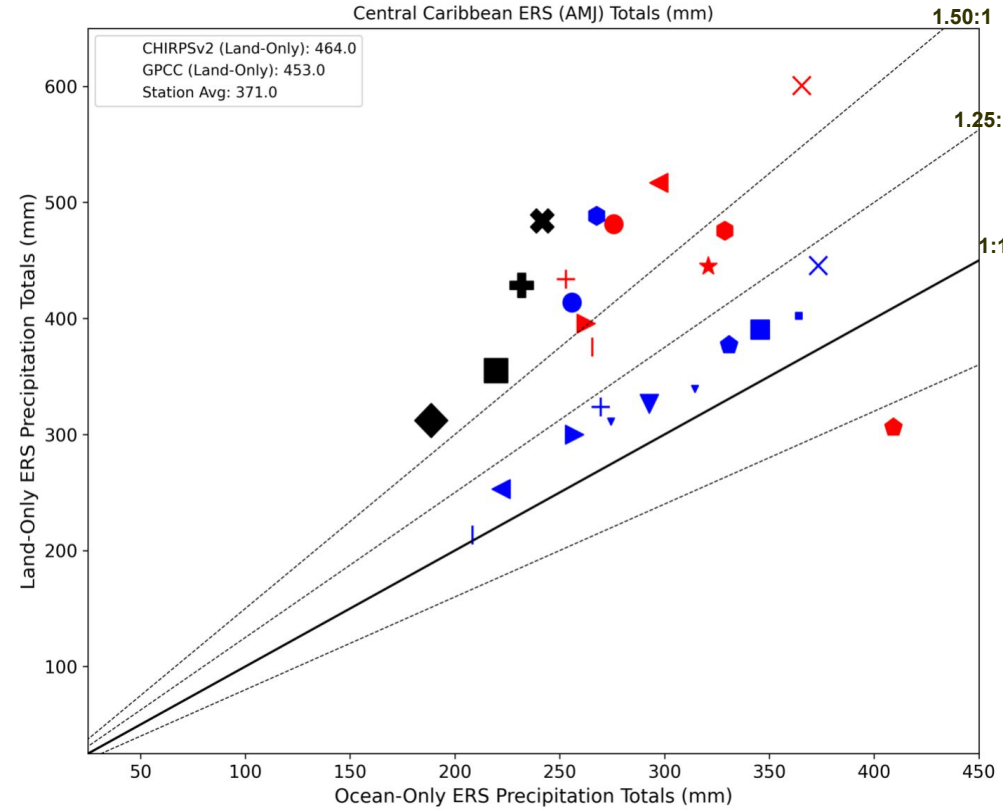
# Land vs. Ocean Precipitation Scatterplots



# Fully Coupled



# AMIP



● Low-Res ● High-Res

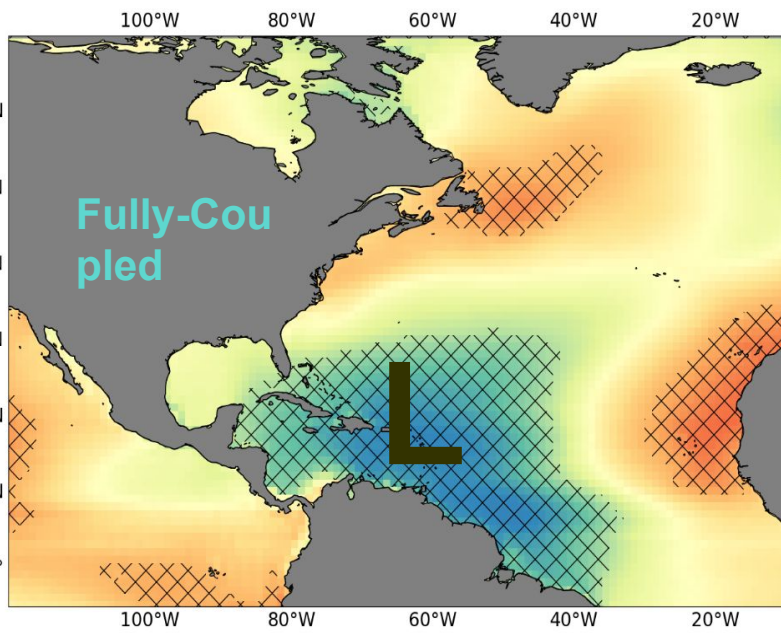
- ERA5
- GPCC
- + MSWEPv2
- × PERSIANN-CDR
- ◆ PERSIANN-CCS-CDR
- ▲ CHIRPSv2
- ◆ GFDL-SPEAR-MED
- ▼ CESM2LE
- CESM1LE
- ★ HRCESM
- ▲ BCC
- CNRM-LR
- CNRM-HR
- ▲ FGOALS-LR
- ▲ FGOALS-HR
- ▲ ECMWF-LR
- ▲ ECMWF-HR
- ┆ HIRAM-LR
- ┆ HIRAM-HR
- ⬡ EARTH-LR
- ⬡ EARTH-HR
- × HADGEM3-MM
- × HADGEM3-HH
- + CMCC-HR
- + CMCC-VHR
- ⬡ MPI-HR
- ⬡ MPI-XR

# Model Coefficients / Scatterplots of Dynamical Variables onto Precipitation Index

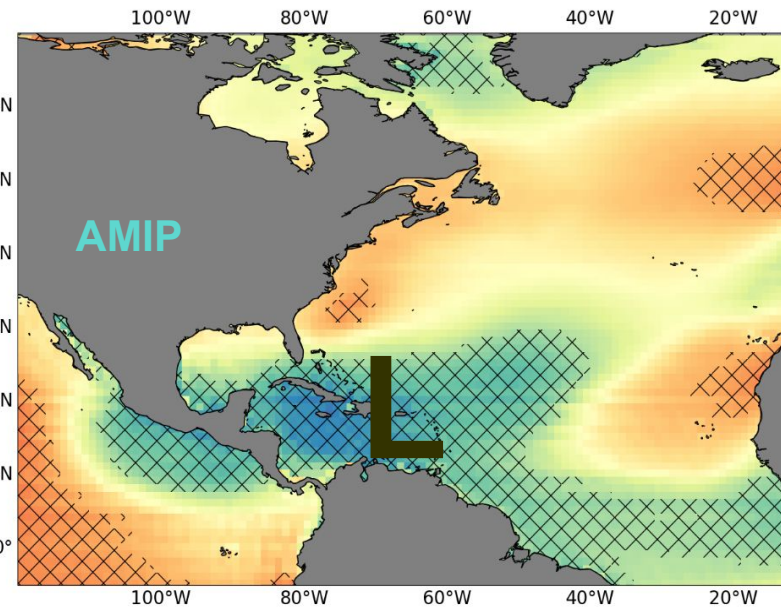
All models regridded to 1.0x1.0-degree resolution



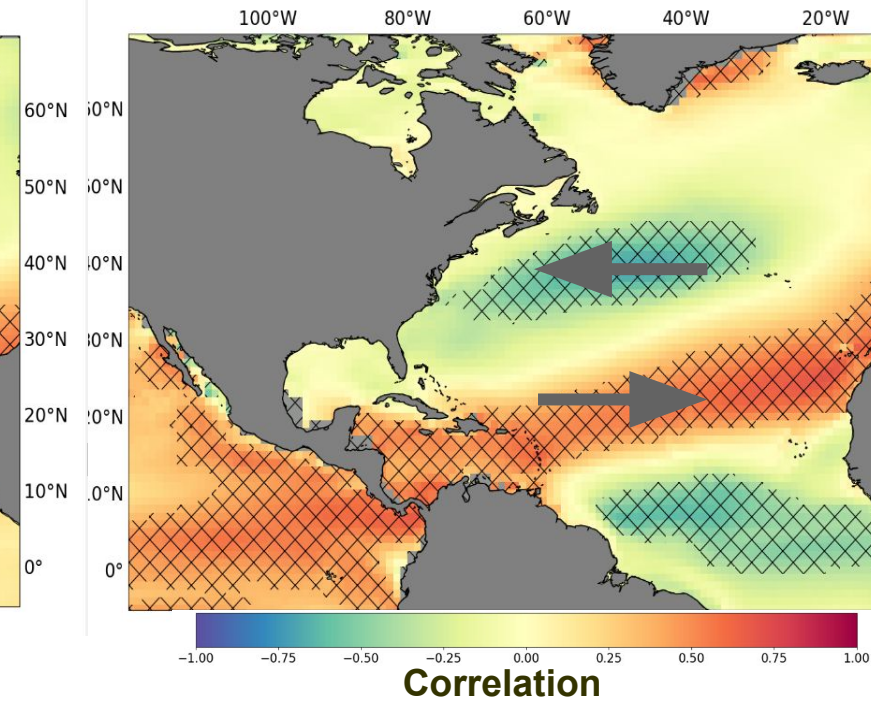
SLP (Zonal Mean May Removed) Correlation onto May Precipitation



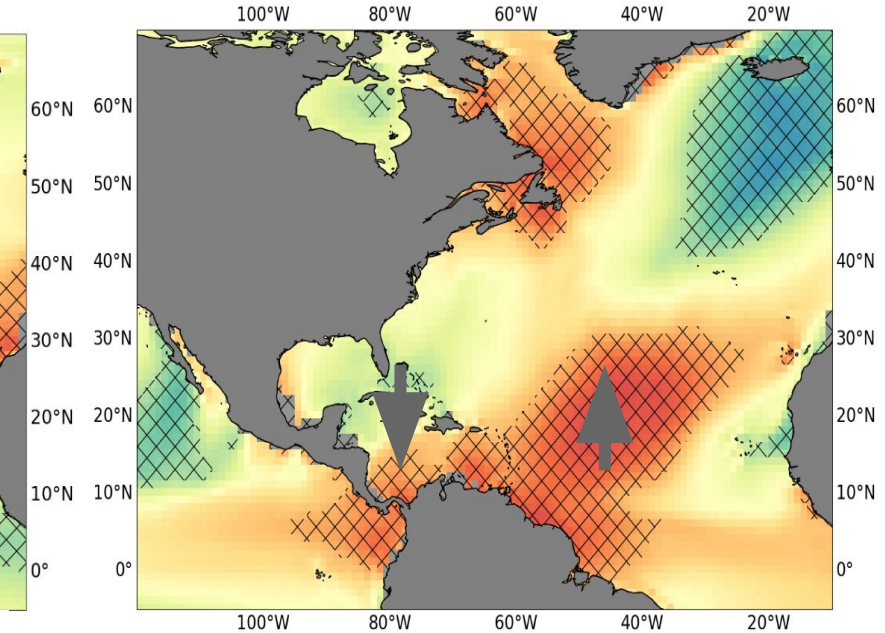
Lower SLP over Caribbean Sea/TNA = More Precipitation



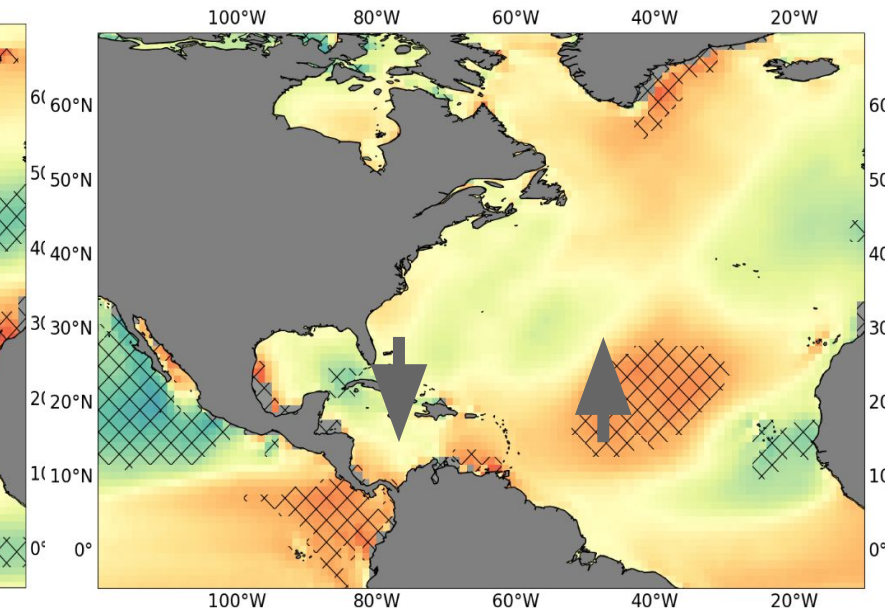
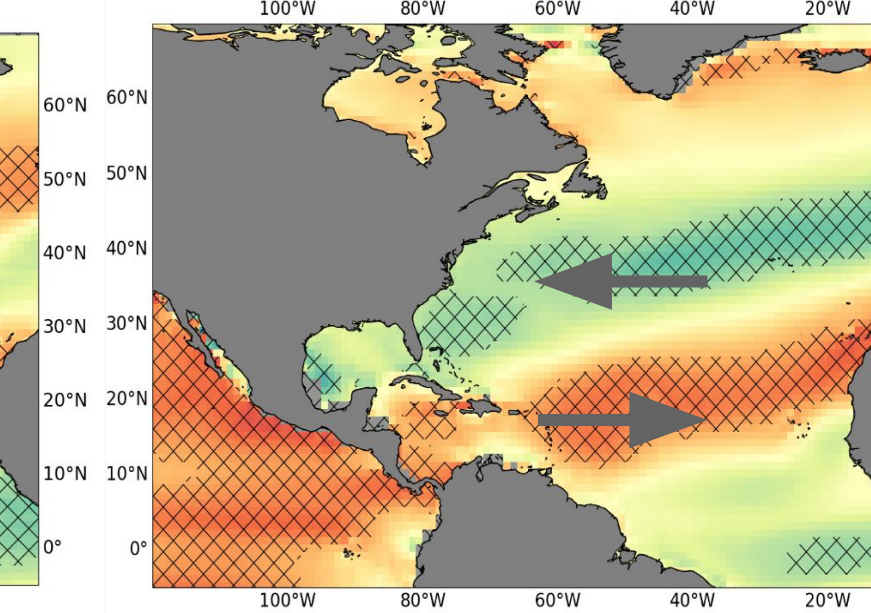
Zonal 925mb Wind Correlation onto May Precipitation



Meridional 925mb Wind Correlation onto May Precipitation



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



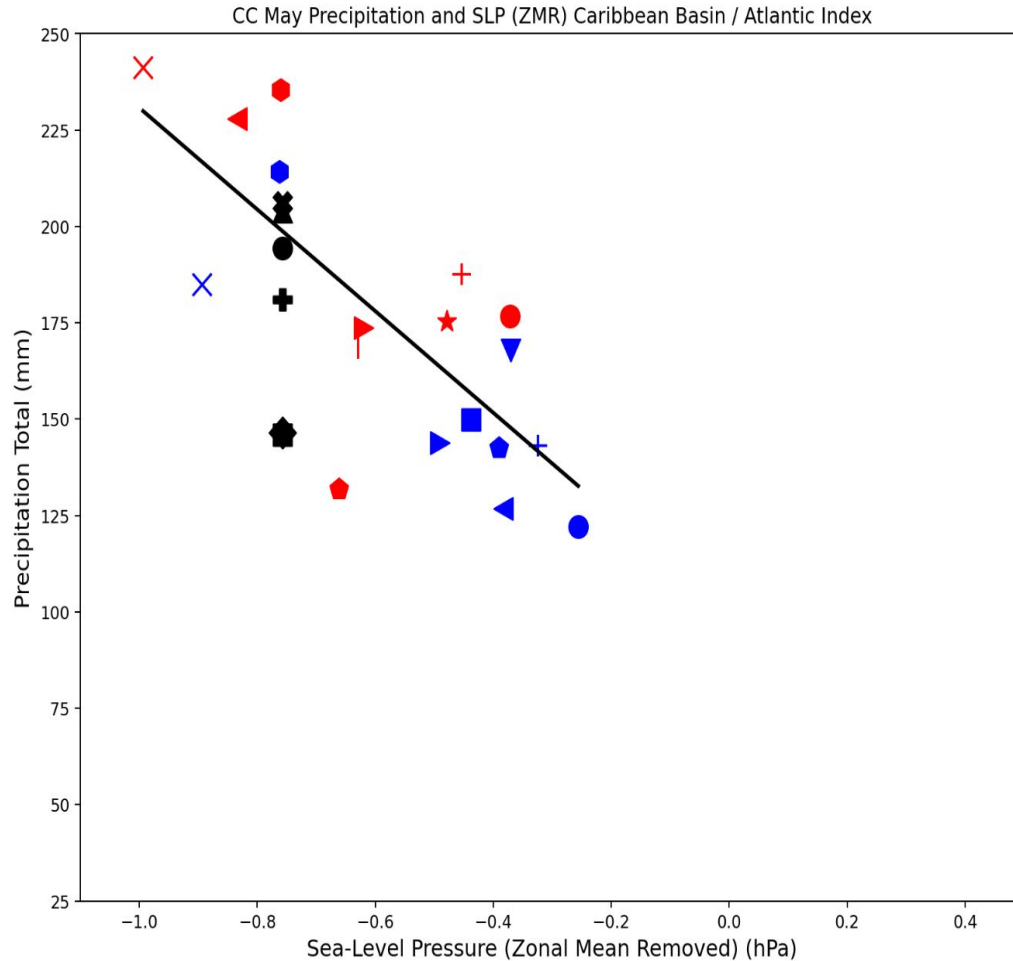
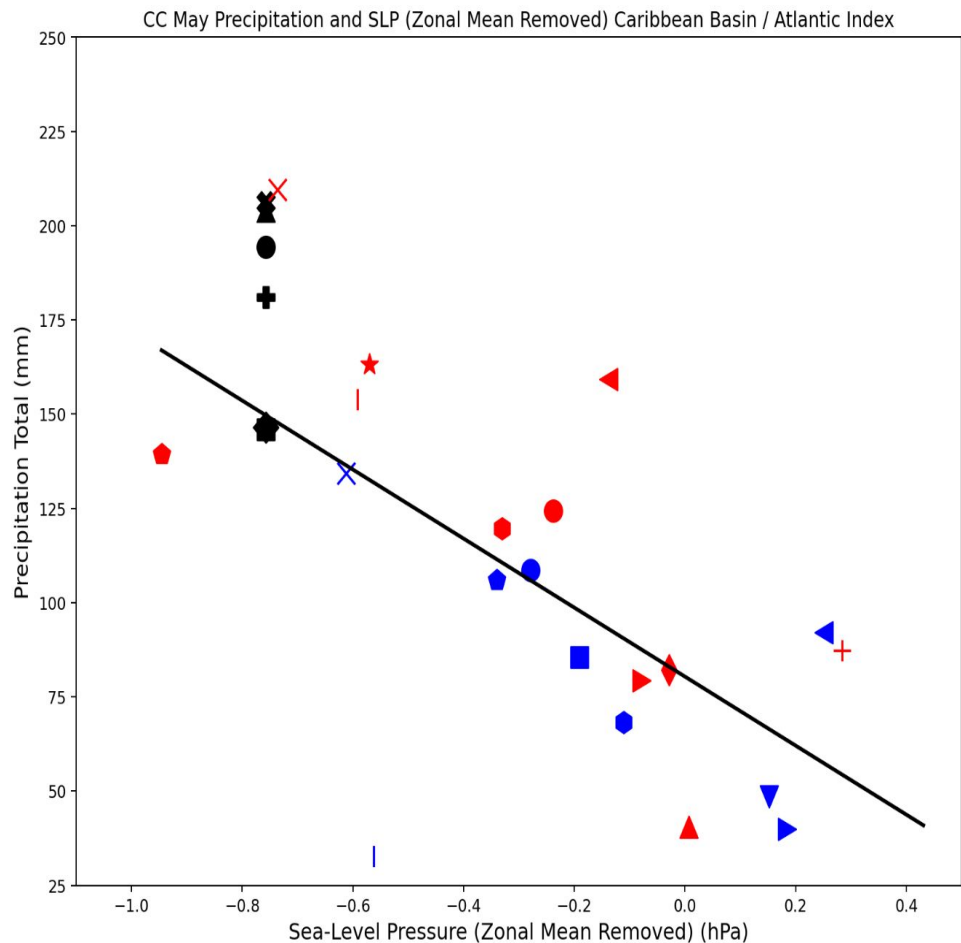
# SLP (Zonal Mean Removed) over the Caribbean Basin/ Tropical North Atlantic Regression and Central Caribbean

Low-Res High-Res

Fully Coupled

Precipitation May Totals

AMIP



Less SLP = More Precipitation Totals

- ERA5
- GPCP
- 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



# June Center of NASH in Fully-Coupled Runs

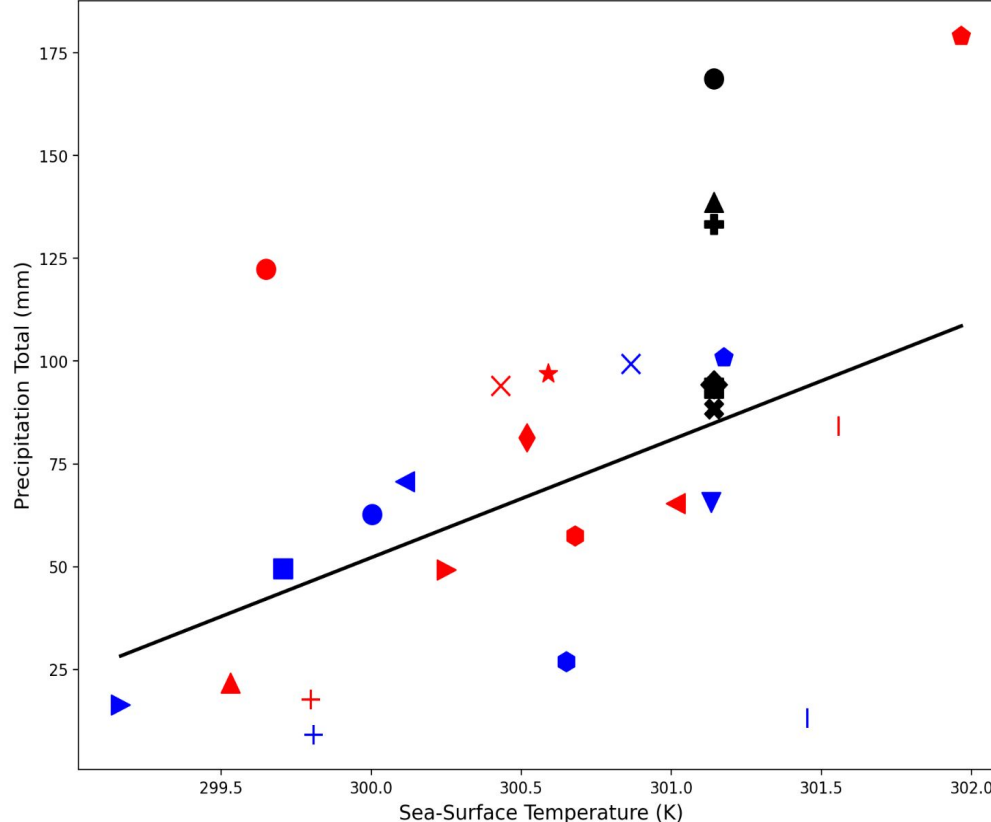
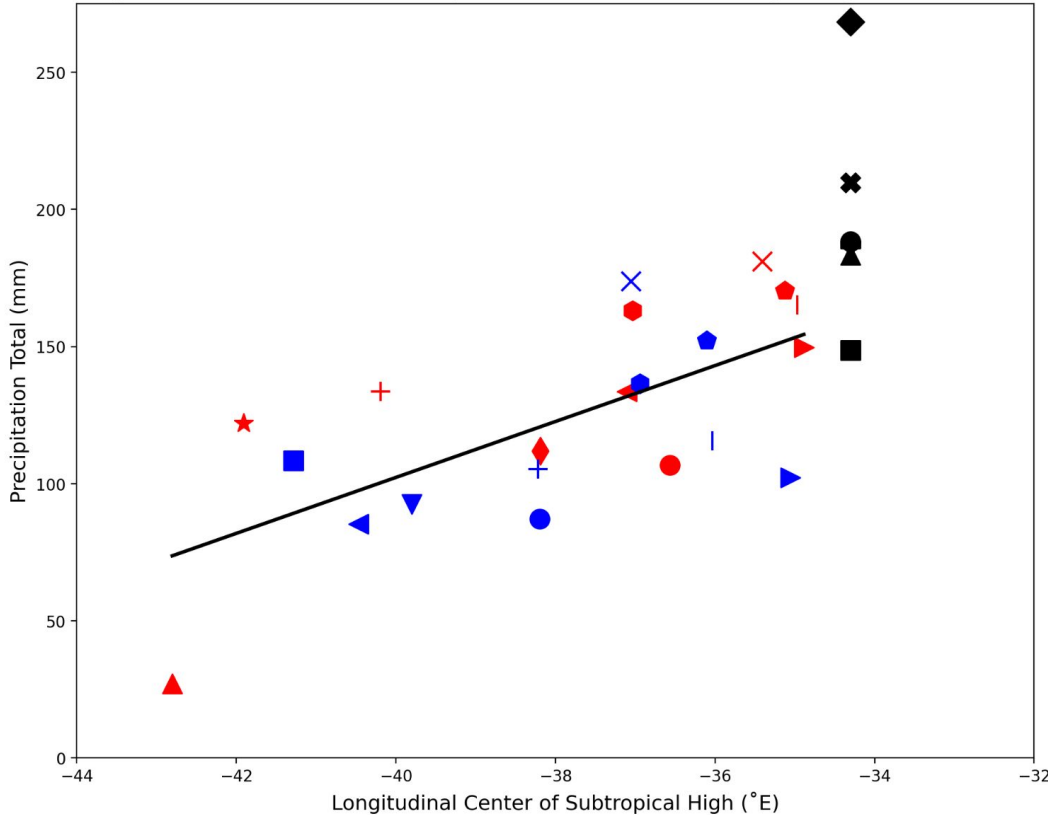
# June SSTs

● Low-Res 
 ● High-Res

- ERA5
- GPCP
- + MSWEPv2
- × PERSIANN-CDR
- ◆ PERSIANN-CCS-CDR
- ▲ CHIRPSv2
- ◇ GFDL-SPEAR-MED
- ▼ CESM2LE
- CSM1LE
- ★ 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

June Northwestern Caribbean Precipitation and North Atlantic Subtropical High Center Index

Eastern Caribbean June Precipitation and SST Caribbean Sea Index

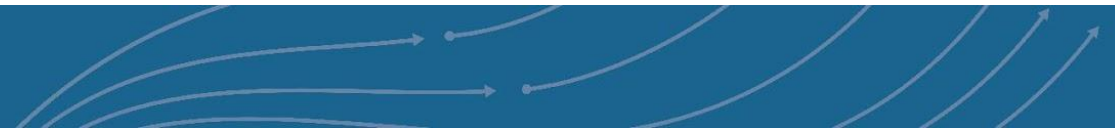


Further west the Subtropical High Center is = less ERS precipitation

Warmer SSTs = more precipitation

Similar findings across the other subregions

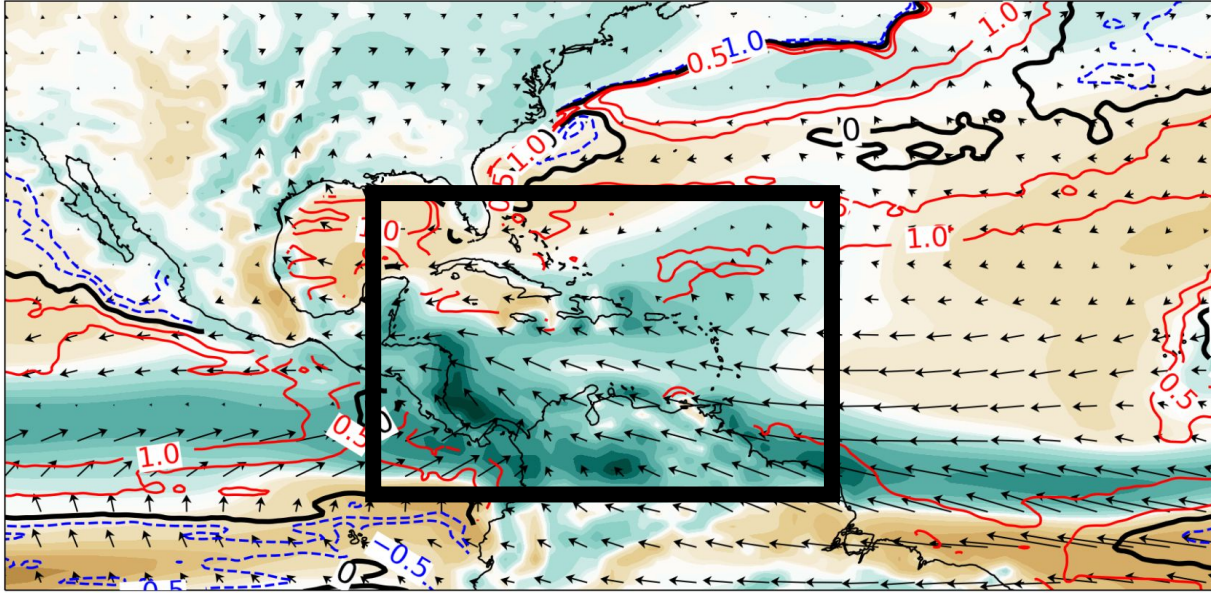
# Total Moisture Budget Analysis



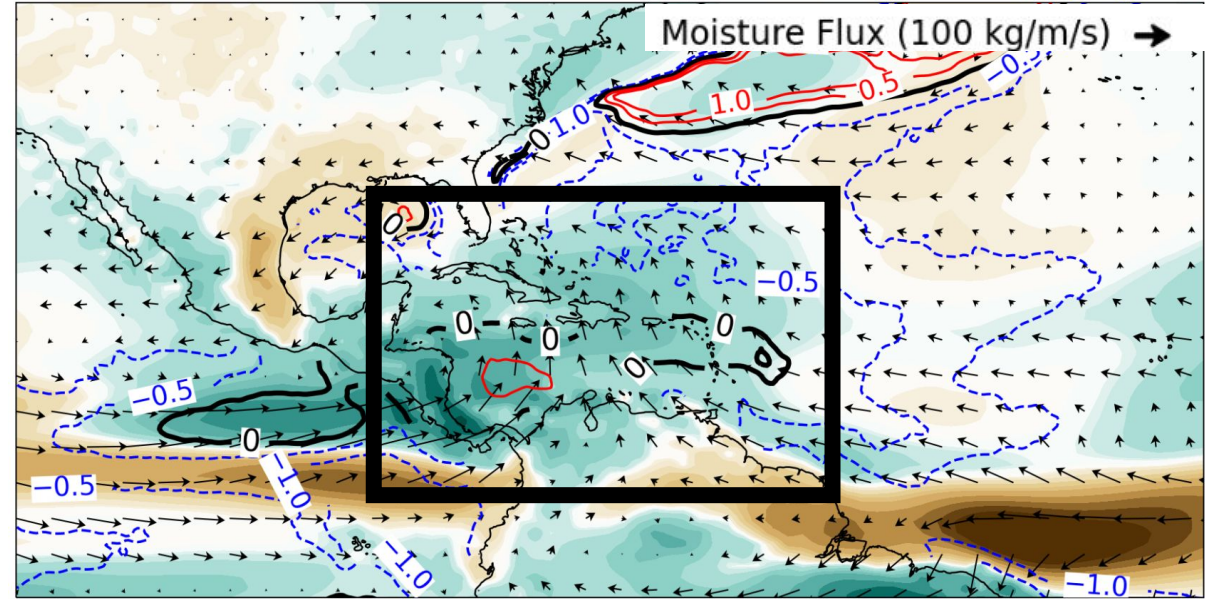


# AMIP minus Fully Coupled May Moisture Flux and SST Composite

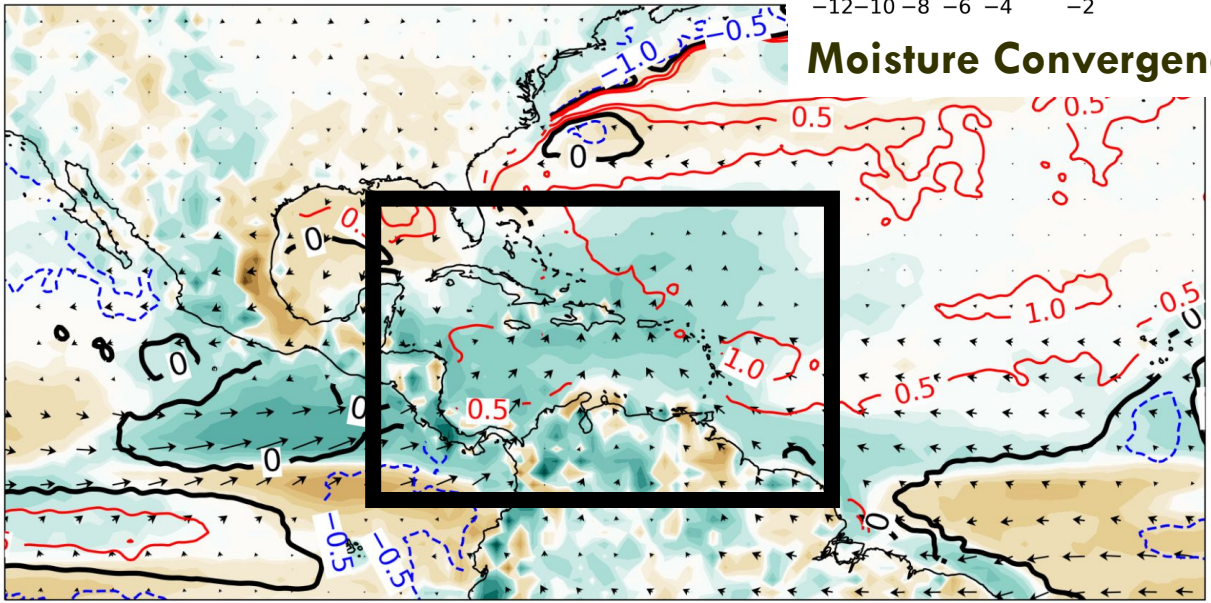
## CESM1 AMIP minus CESM1



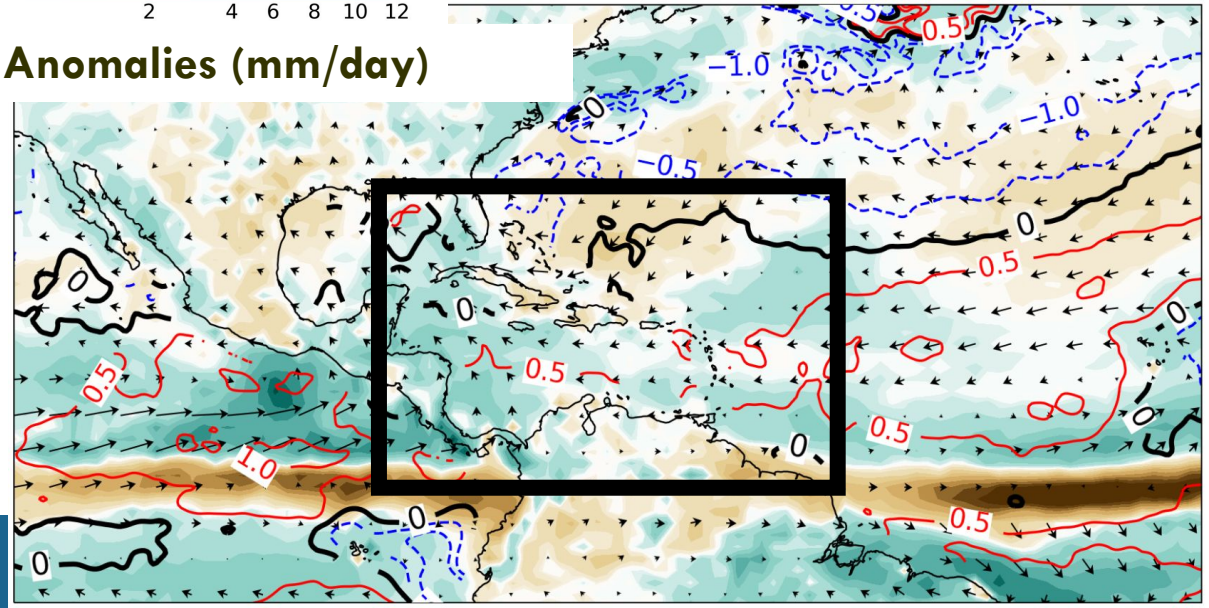
## CESM2 AMIP minus CESM2



## CMIP6 AMIP minus CMIP6



## HRCESM AMIP minus HRCESM



Moisture Convergence Anomalies (mm/day)





# Conclusions/Summary

- Generally, most coupled models underestimate ERS land and ocean precipitation across the Caribbean (*and to an extent during the Mid-Summer Drought and Late-Rainy Season*)
- There is improvement when SSTs are prescribed to the model (AMIP) and in some cases under a higher spatial resolution.
- Dynamical Linkages (stronger NASH, cold SSTs) with dry precipitation bias.