Evaluating the Performance of VR-CESM for Modeling Precipitation in Southeast Asia

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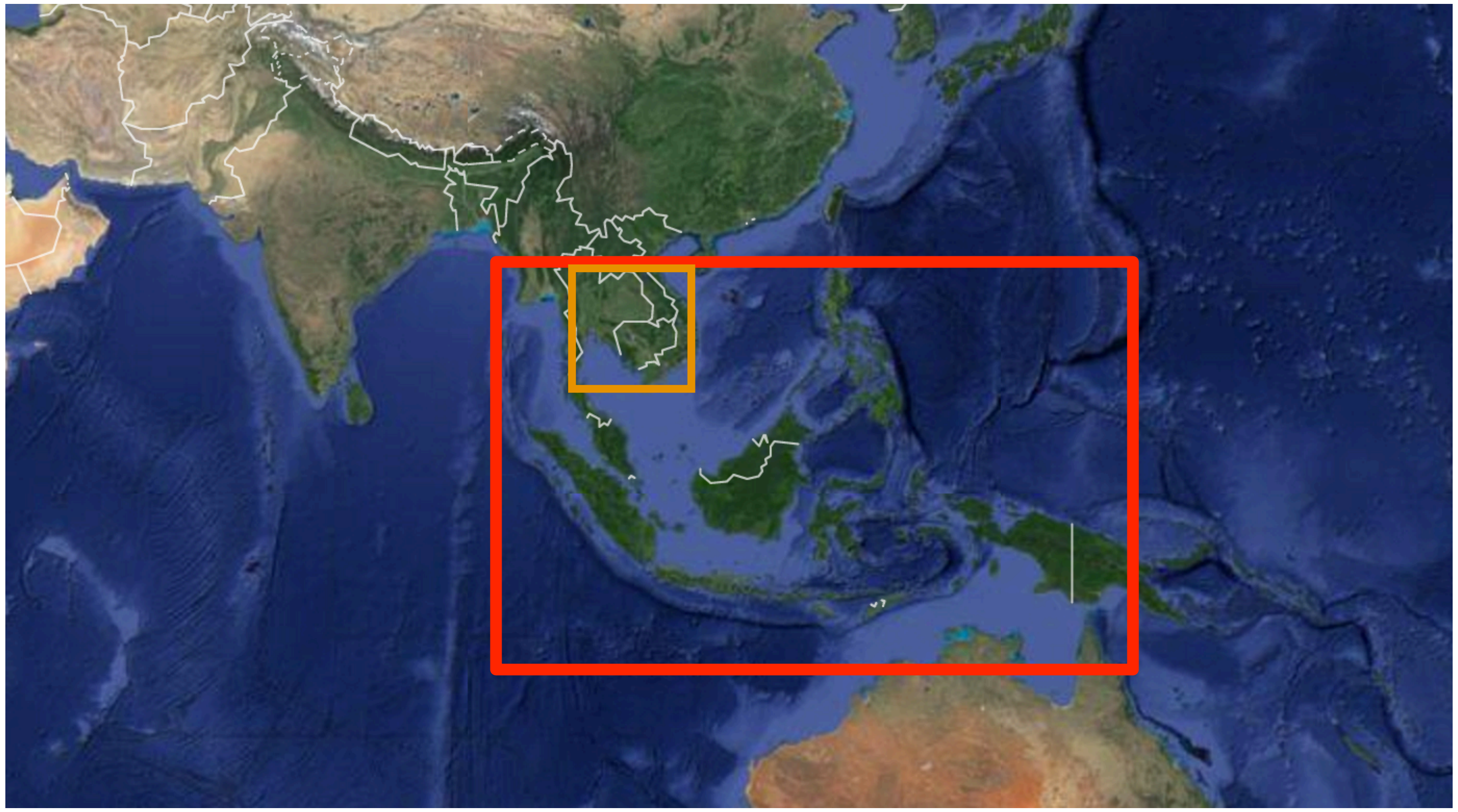
Southeast Asia

- Southeast Asia (SEA) extends from about 12°S-22°N and 94°E-140°E consists of 11 countries including Cambodia, Laos, Myanmar, Thailand, Vietnam, Laos, Brunei, East Timor, Indonesia, Malaysia, Philippines and Singapore
- The region has a total population of more than six hundred million (more than 8% of the global population).
- We focus on mainland southeast Asia, which is the region from 10°N-25°N and 100°E-110°E, also called the Indochinese Peninsula.



Motivation

- Agriculture and industries in Southeast Asia are particularly vulnerable to changes in the hydrological cycle.

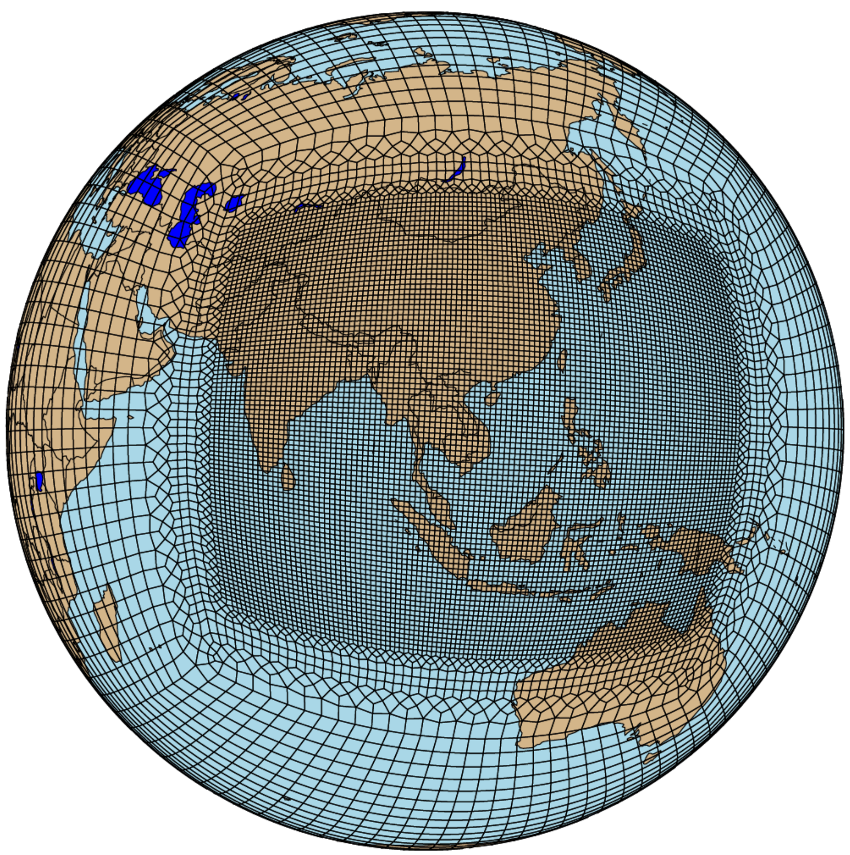
- The global economy is sensitive to weather-related impacts on the region's economy due to the supply chains linking the region to the global economy.
  - ➡ Widespread flooding in Thailand in 2011 resulted in $46.5 billion in damages to Thailand's economy and contributed to a 2.5% decrease in global industrial production (*Haraguchi and Lall*, 2015).

- Simulating weather extremes in the region requires high-resolution modeling to better capture the complex topography in the region.

BANGKOK (Oct. 22, 2011) (U.S. Navy photo by Mass Communication Specialist 1st Class Jennifer A. Villalovos/Released)

Model and Experiments

- We use CESM1.2 with variable resolution (VR-CESM, CAM5.3), which has a fine resolution of 0.25º over Southeast Asia and a coarser resolution of 1º globally.
- Conducted 27 year simulations with an AMIP configuration from 1979 to 2005.
- Compared the VR-CESM simulation with the three coarse resolution CESM simulations listed in the table below.



VRseasia refined grid

CESM version	Description
VRseasia	Spectral element 0.25°x0.25° in SEA ~1°x1° globally
ne30	Spectral element ~1°x1° globally
fv0.9x1.25	Finite volume ~1°x1° globally
fv1.9x2.5	Finite volume ~2°x2° globally

Observations for Model Evaluation

Observations	Period	Frequency	Coverage	References
CRU-TS3.21	1901-2012	monthly	Gauge, gridded	Harris, et al., 2014
GPCC-v7	1901-2010	monthly	Gauge, gridded	Becker, et al., 2011
APHRODITE-MA	1951-2007	daily	Gauge, gridded	Yatagai, et al., 2012
SA-OBS	Depend on stations	daily	stations	Van den Besselaar, et al., 2017

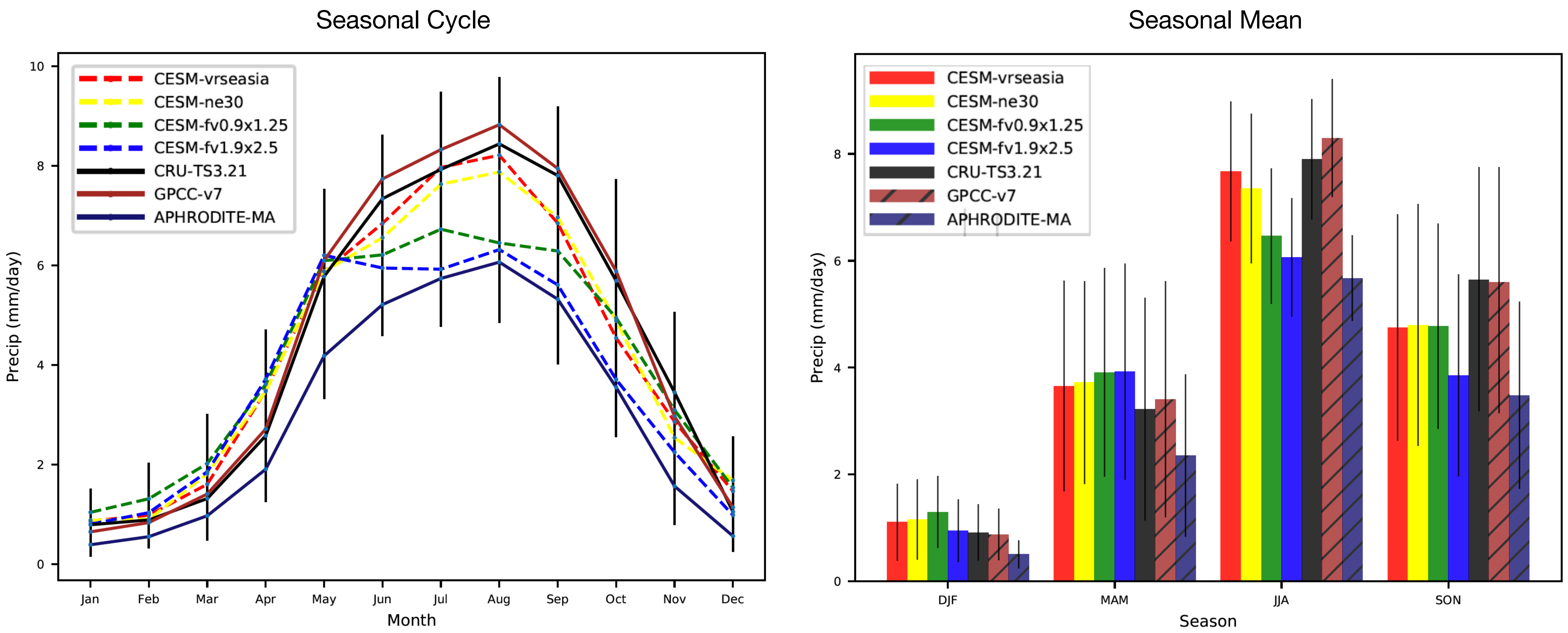
Other Model Simulations for Comparison: CORDEX-SEA

- The Southeast Asia Regional Climate Downscaling (SEACLID) / Coordinated Regional climate Downscaling Experiment (CORDEX) Southeast Asia Project published high-resolution climate change scenarios (25 km x 25 km) for the Southeast Asia region.

Experiments	GCMs	RCMs	Resolution
1970-2005 historical	ICHEC-EC-EARTH	ICTP-RegCM4.3	25km x 25km
1970-2005 historical	IPSL-IPSL-CM5A-LR	ICTP-RegCM4.3	25km x 25km
1970-2005 historical	MPI-M-MPI-ESM-MR	ICTP-RegCM4.3	25km x 25km
1951-2005 historical	MOHC-HadGEM2-ES	SMHI-RCA4	25km x 25km

SEACLID/CORDEX Southeast Asia Project

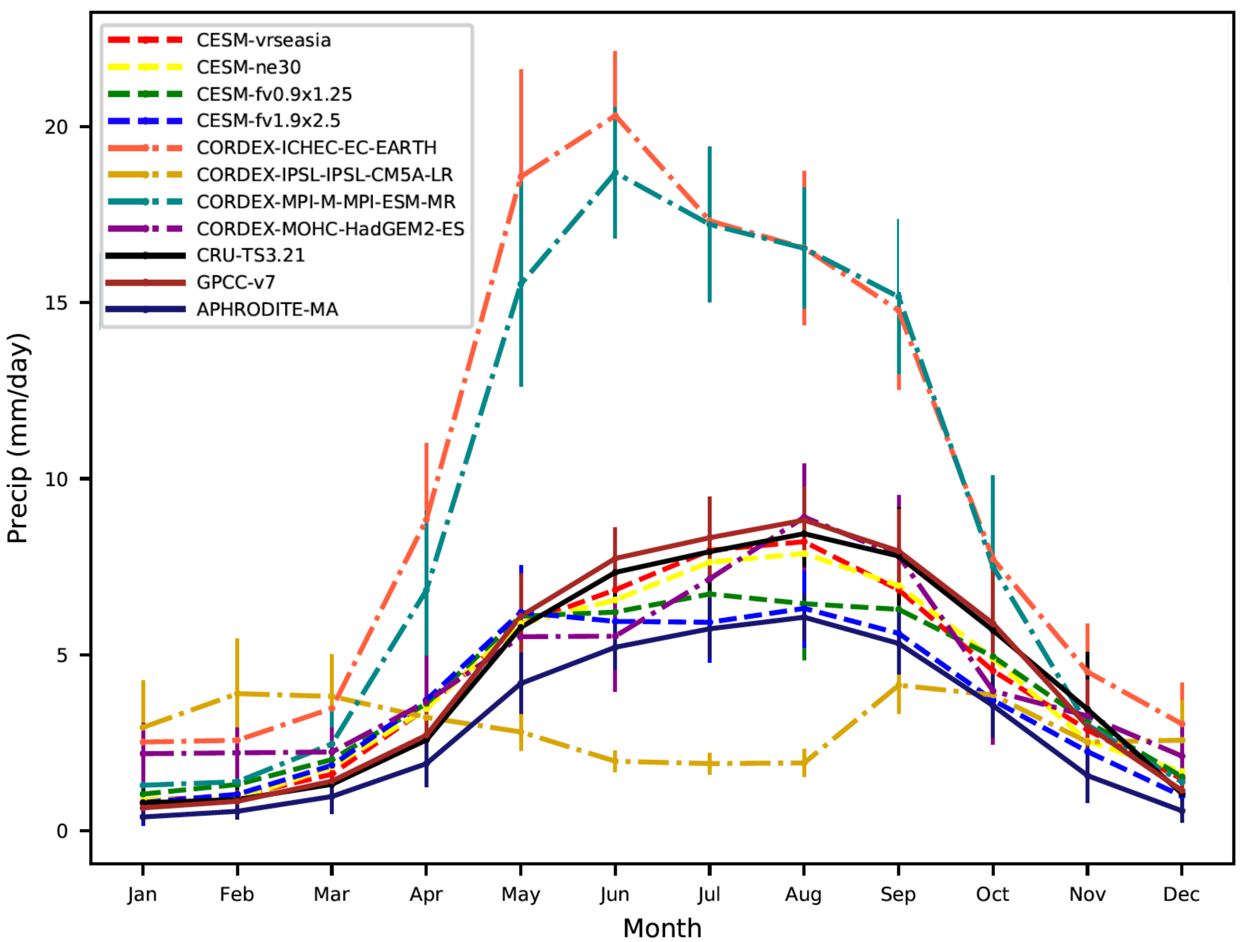
Seasonal Variation in Precipitation



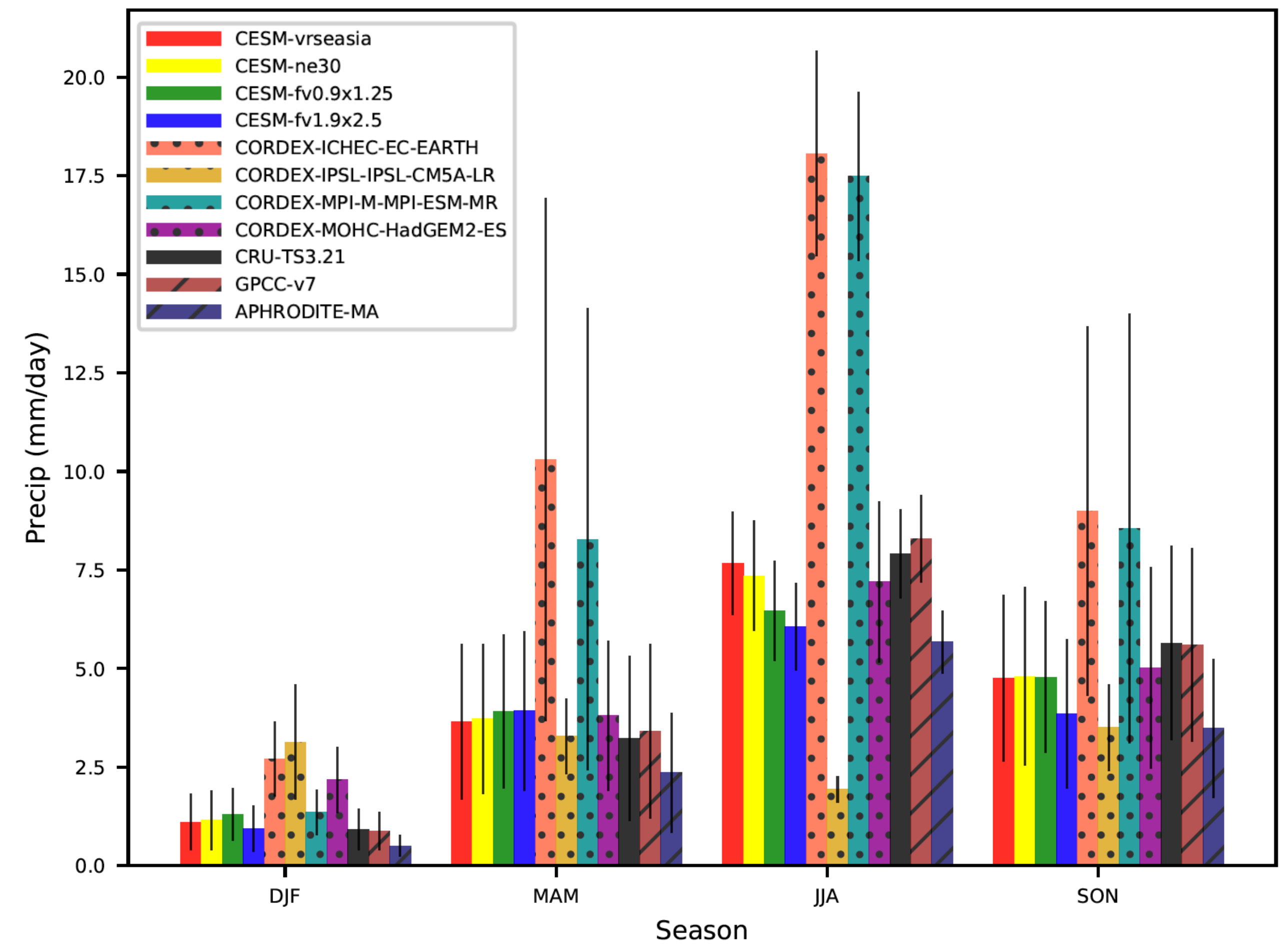
- The spectral element models (VRseasia and ne30) best simulate the seasonal cycle in the CRU and GPCC data.
- Overall, VR-CESM produced the best agreement with CRU and GPCC data, with the smallest bias (especially in summer).
- The APHRODITE-MA data suggest much lower precipitation rates than the CRU and GPCC data.

Seasonal Variation in Precipitation

Seasonal Cycle

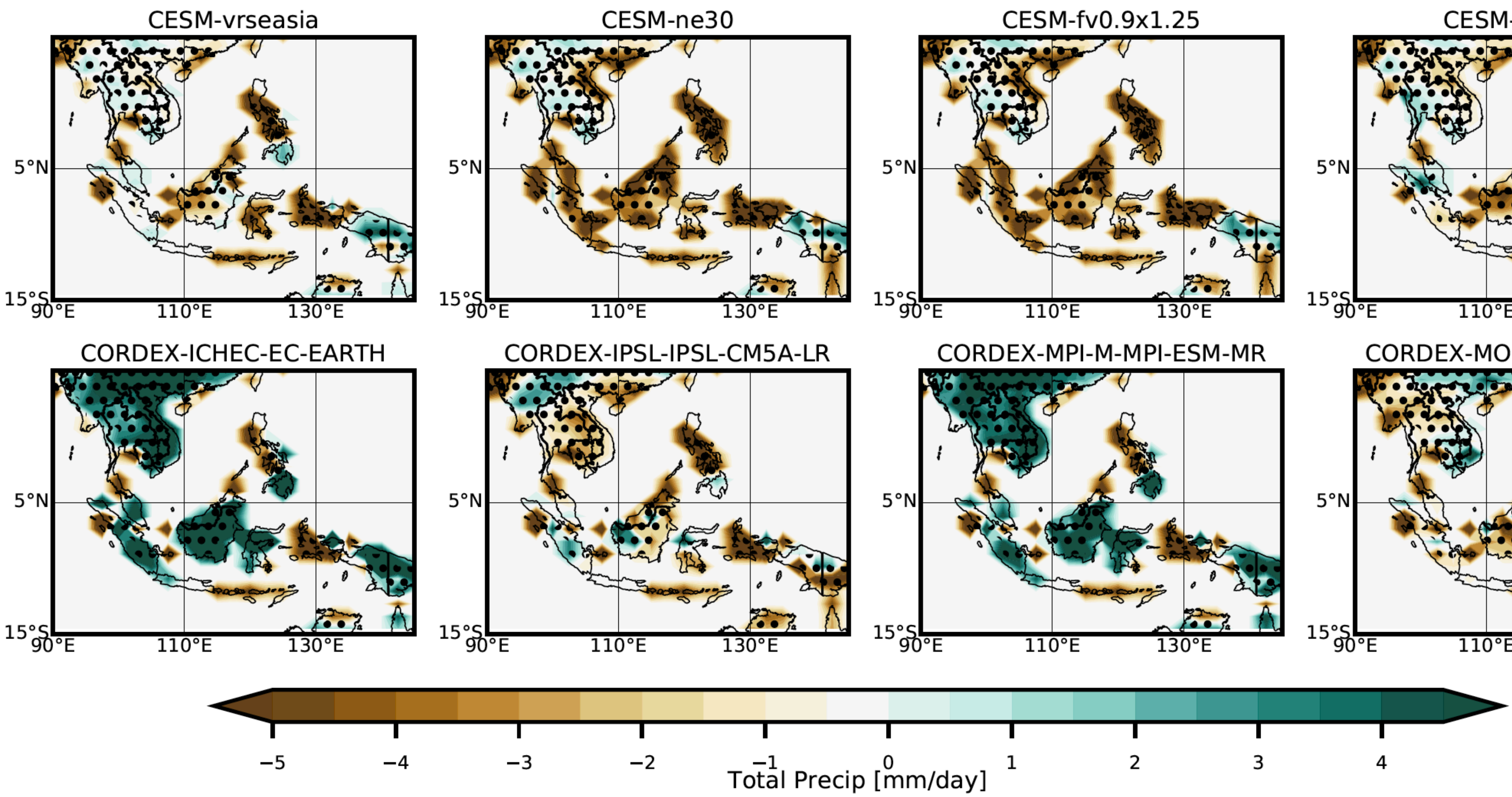


Seasonal Mean



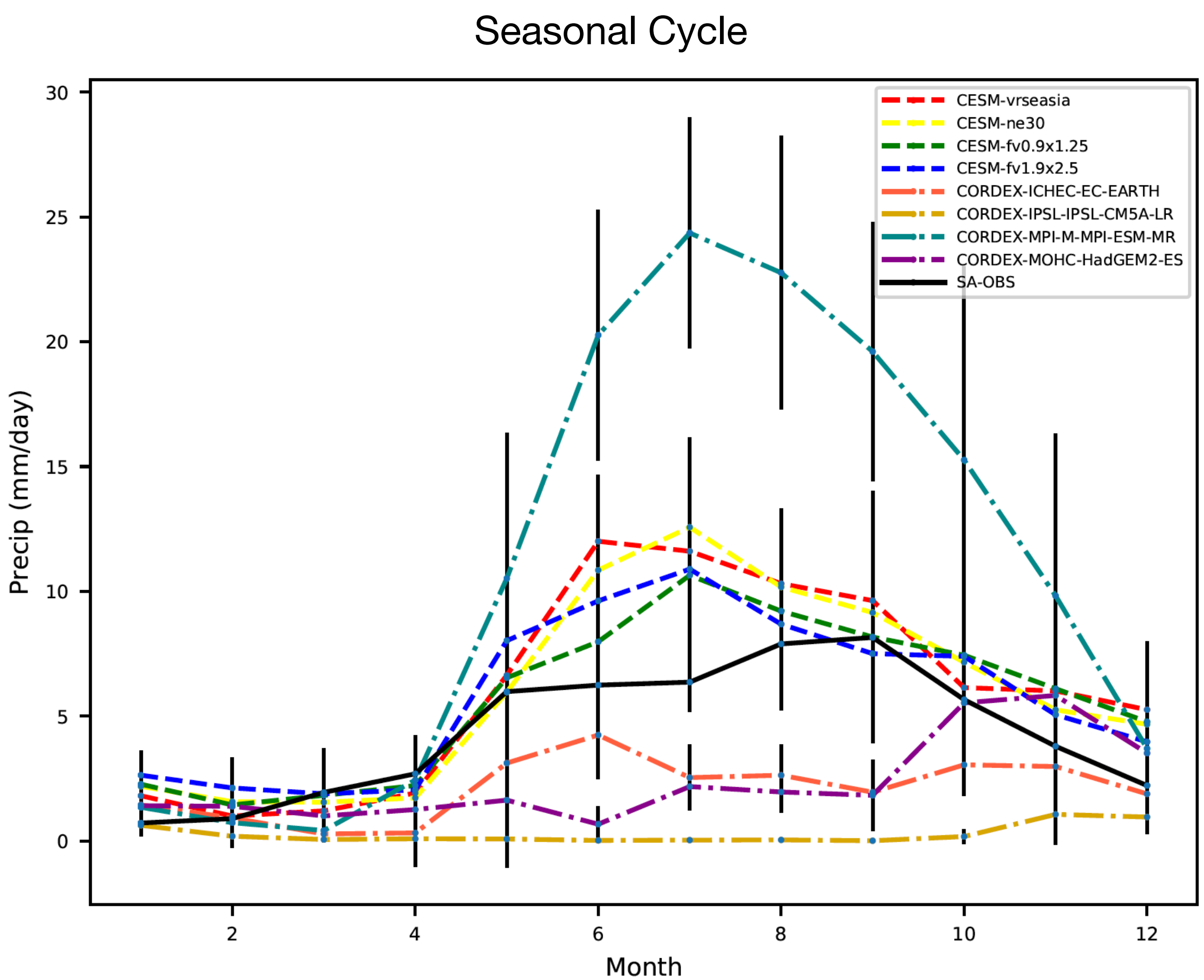
- Two CORDEX-SEA models significantly overestimate the summer precipitation, whereas a third one fails to capture the seasonal cycle in precipitation in SEA.
- The HadGEM2 with RCA4 CORDEX simulation was most consistent with the CESM simulations.

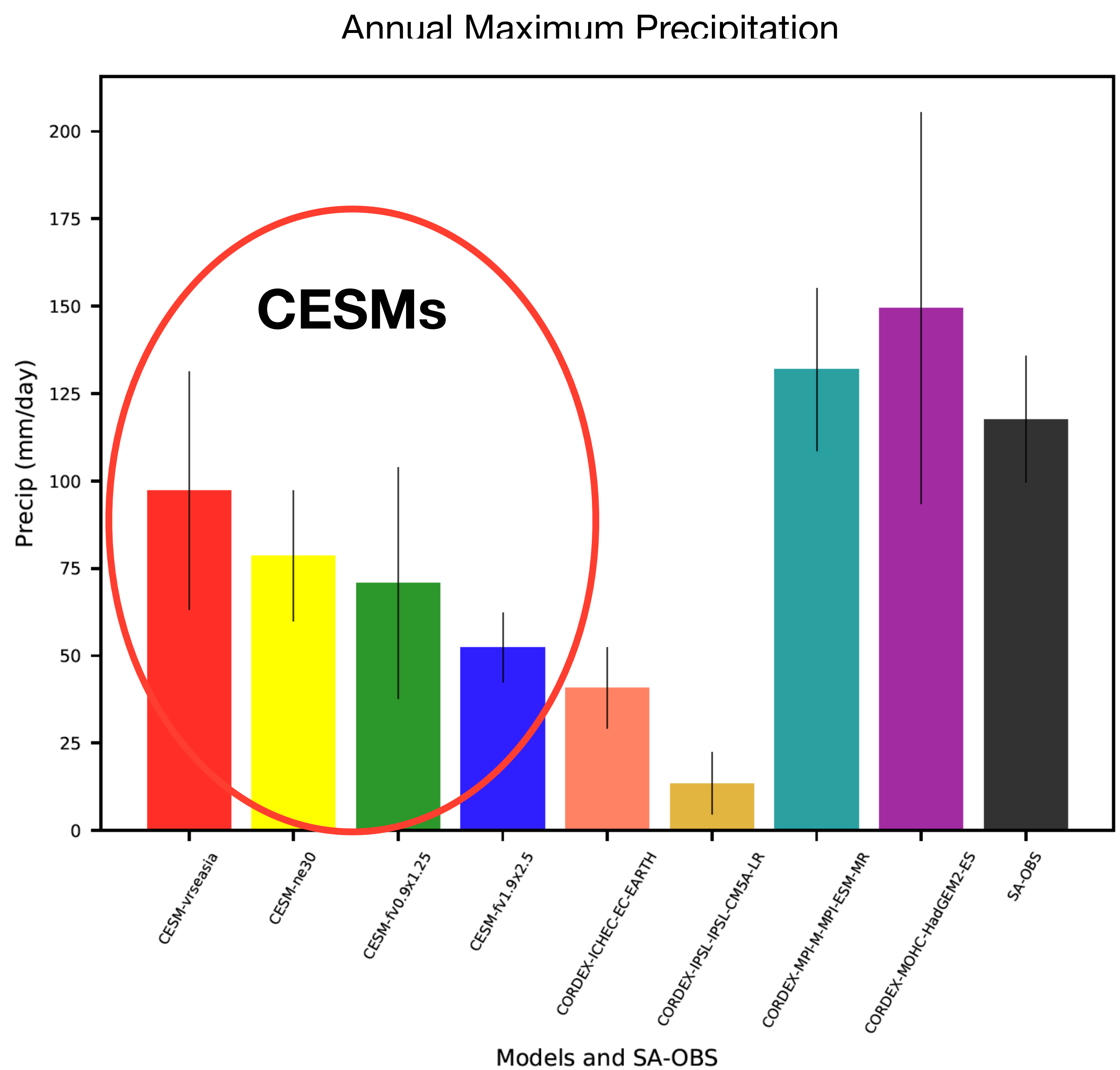
Annual Mean Precipitation Bias (GPCC)



- Although the CESM simulations are drier than the observations, the models have much smaller biases than the CORDEX models.
- VR-CESM has the smallest biases across all the CESM models, especially in northern Vietnam and across maritime Southeast Asia.

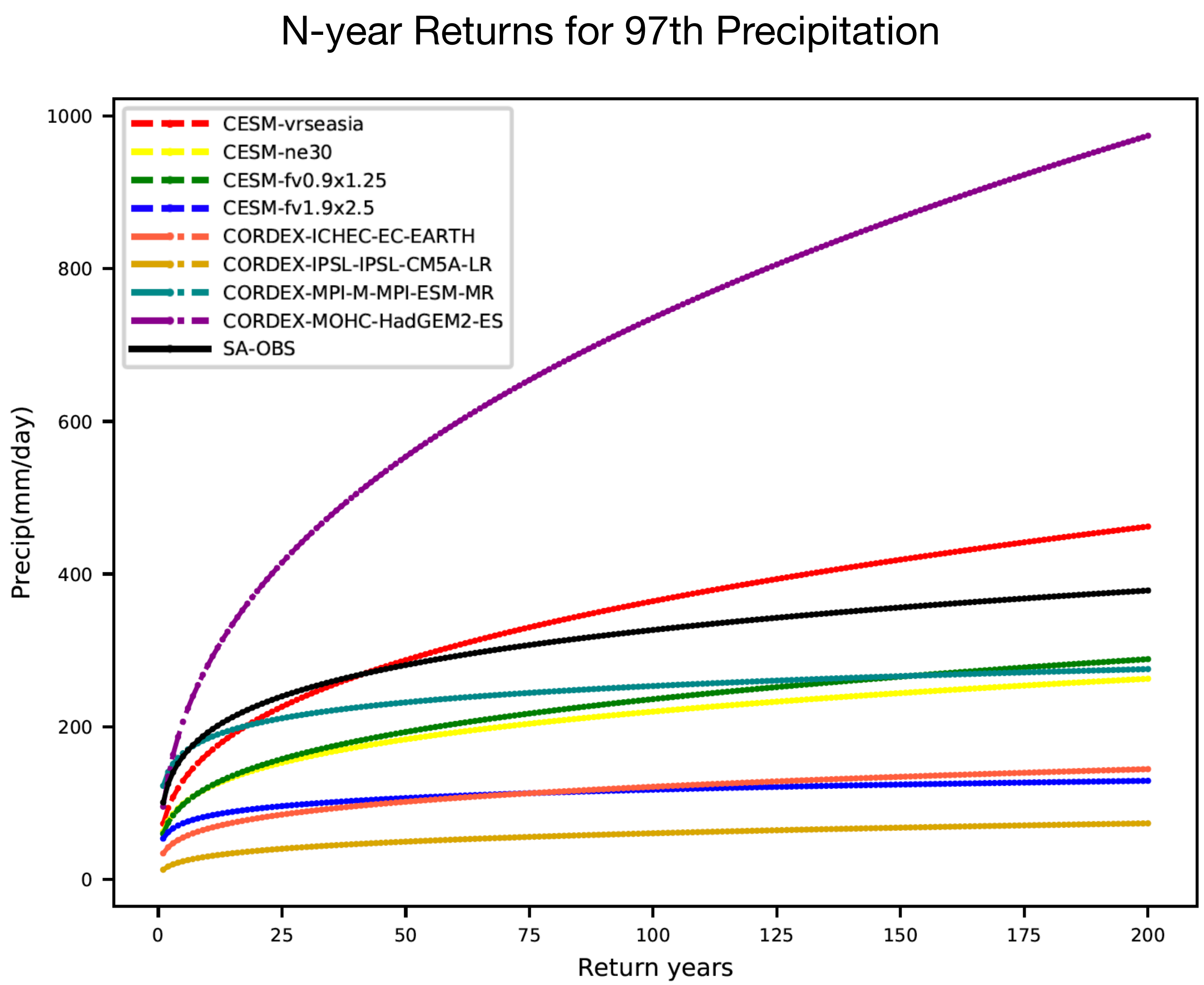
Comparison with Station Observations (SA-OBS)

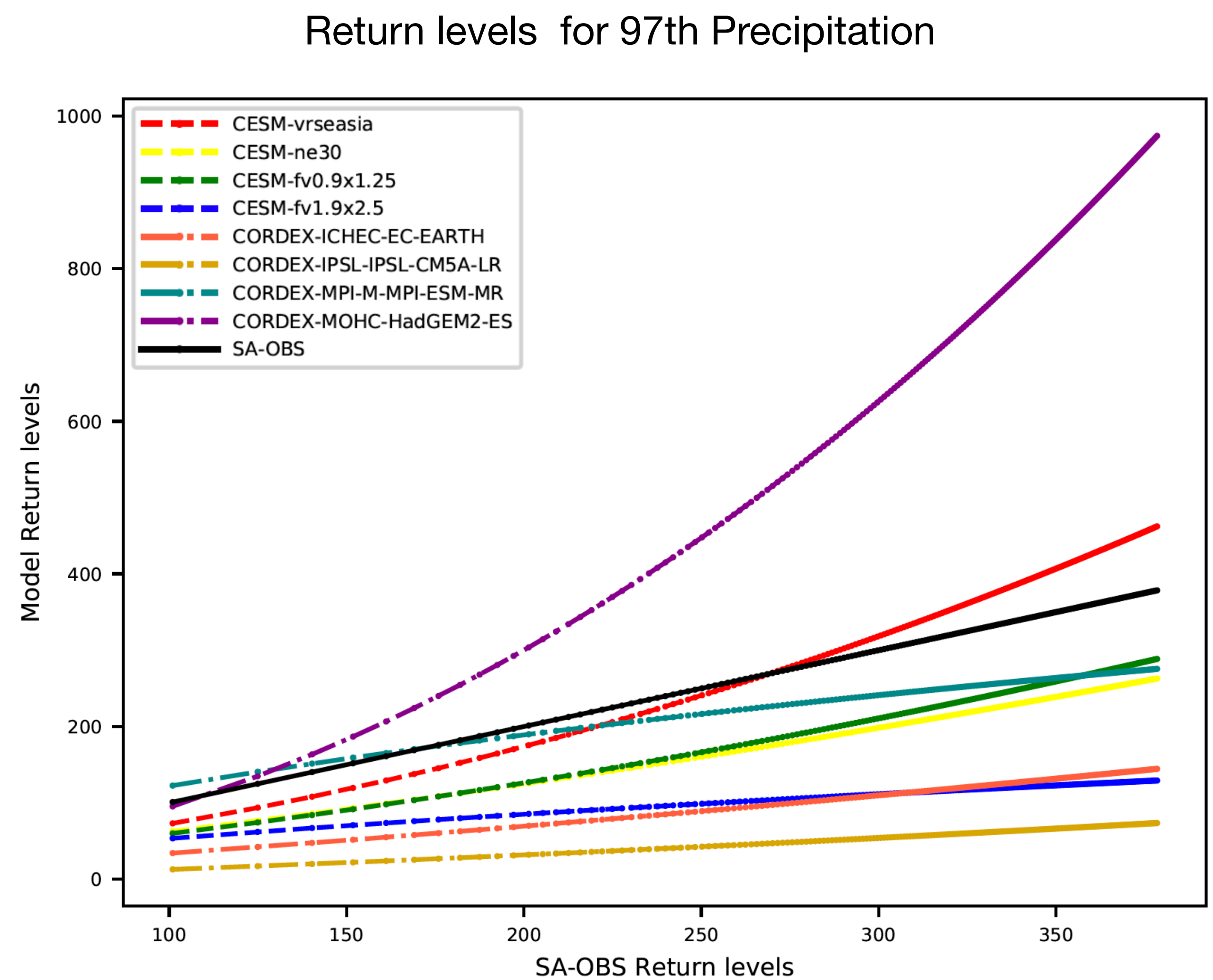




- All CESM simulations are bias high in summer, resulting in greater annual mean precipitation (not shown).
- Of all the CESM models, VR-CESM simulated the annual maximum precipitation the best.
- Two of the CORDEX models simulate the maximum precipitation better, but produce a much more biased seasonal cycle.

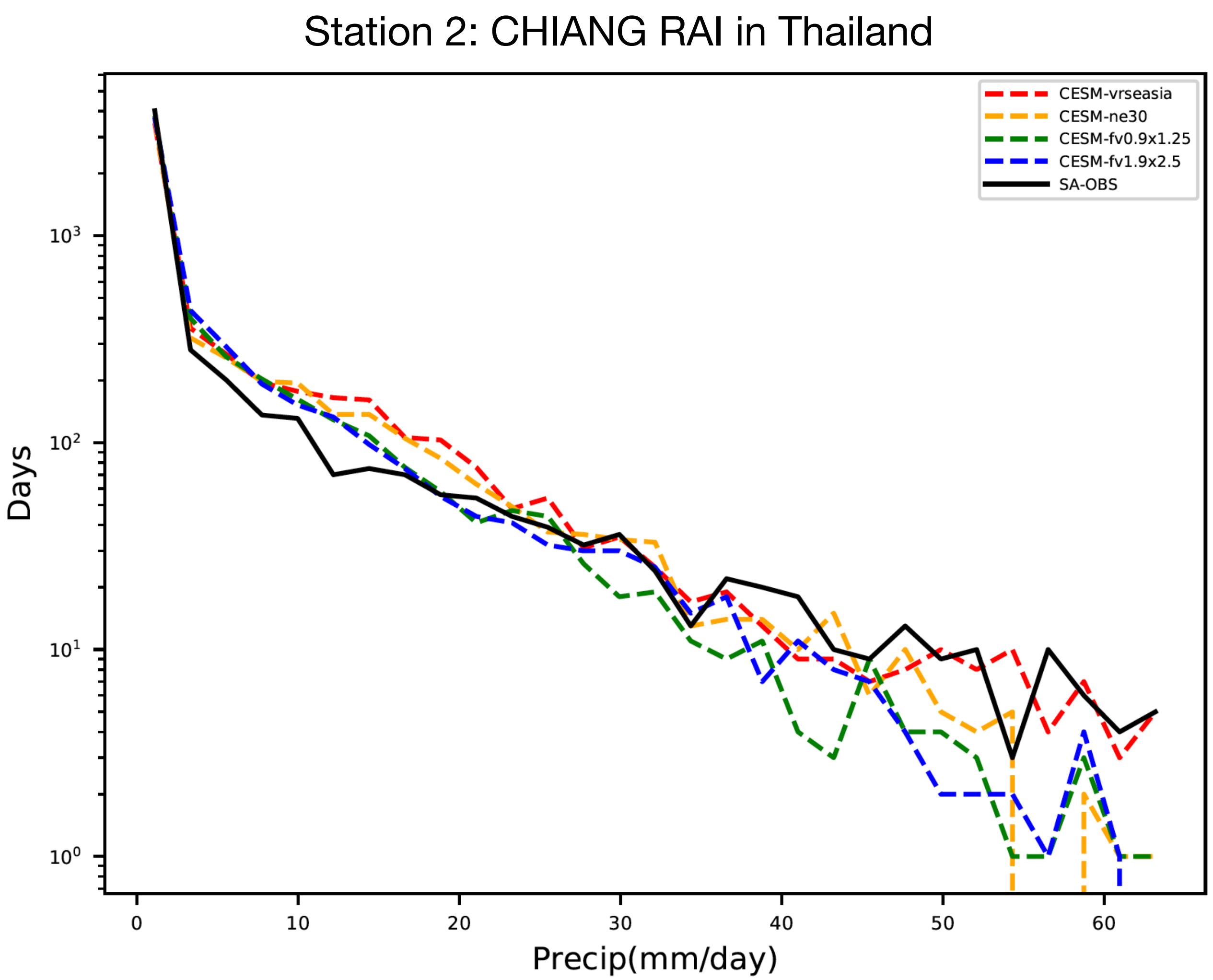
Extreme Analysis Across all Stations

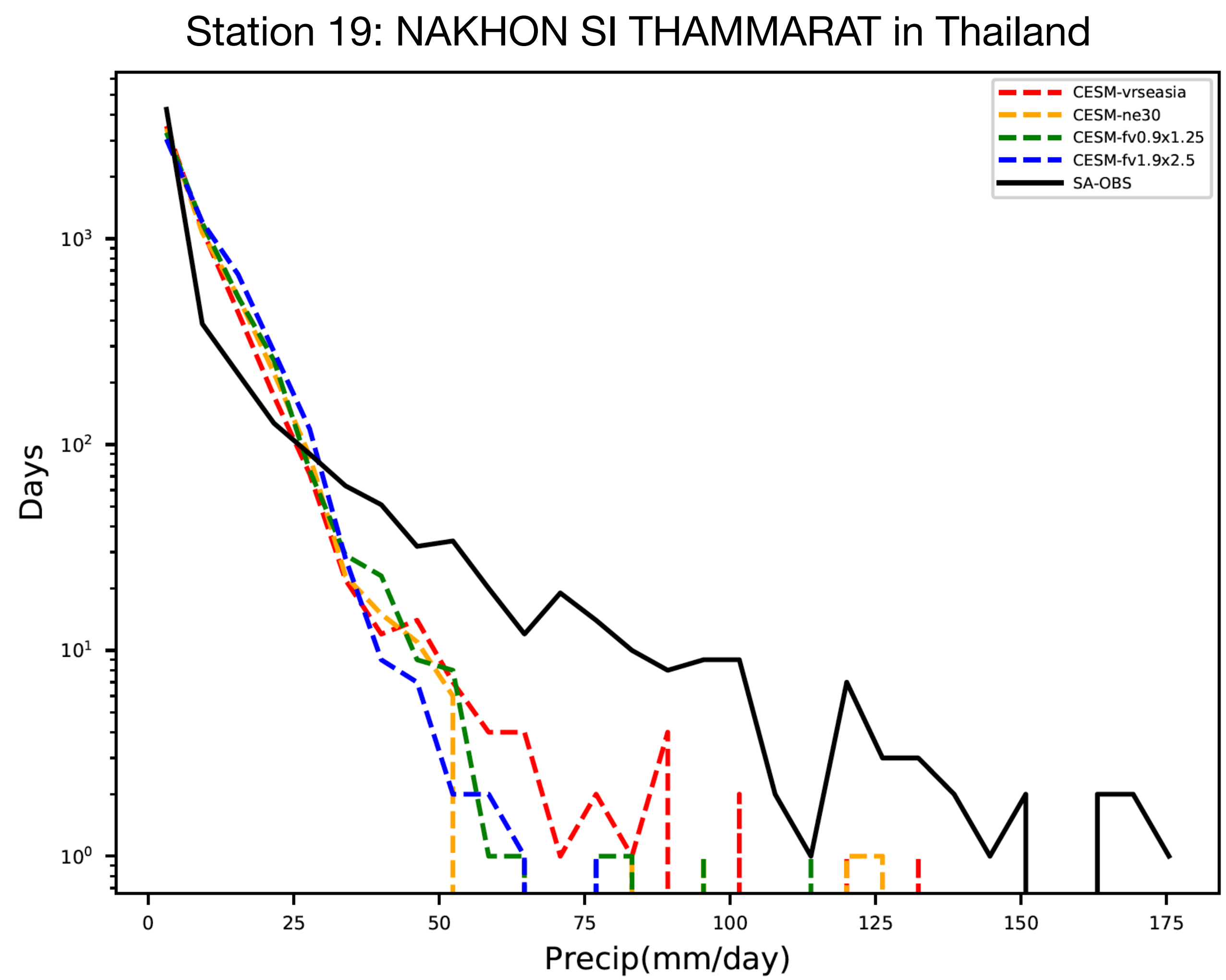




- As expected, increasing the resolution in CESM has a great impact on simulating the distribution of precipitation extremes;
  - ➡ VR-CESM best captures the observed N-year precipitation returns.
- Although HadGem2 with RCA4 was consistent with the CESM simulations in reproducing the seasonal cycle in the CRU and GPCC data, the N-year returns in HadGem2 is much higher than in the all station observations.

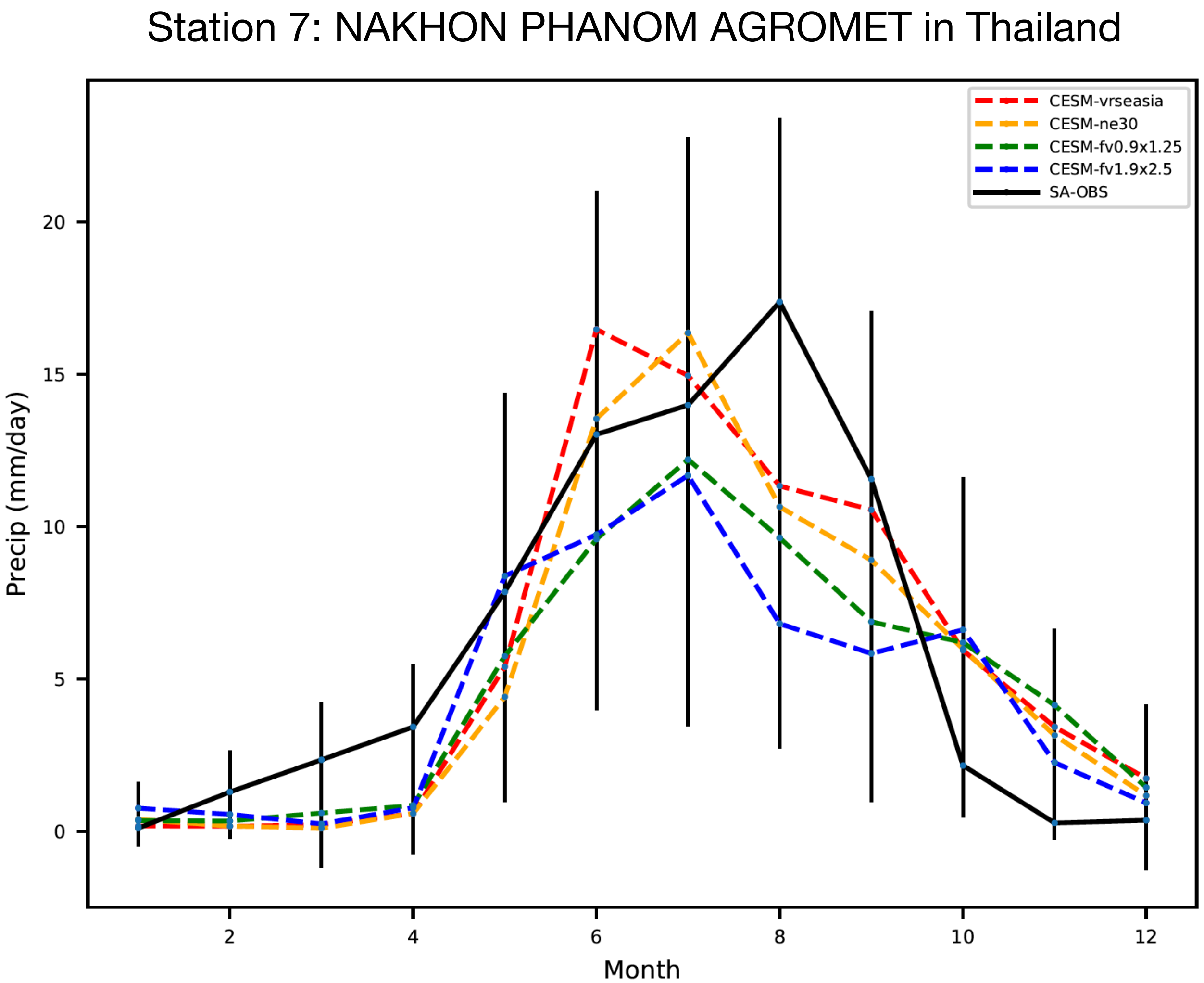
Heterogeneity in the Station Data: Precipitation Distribution

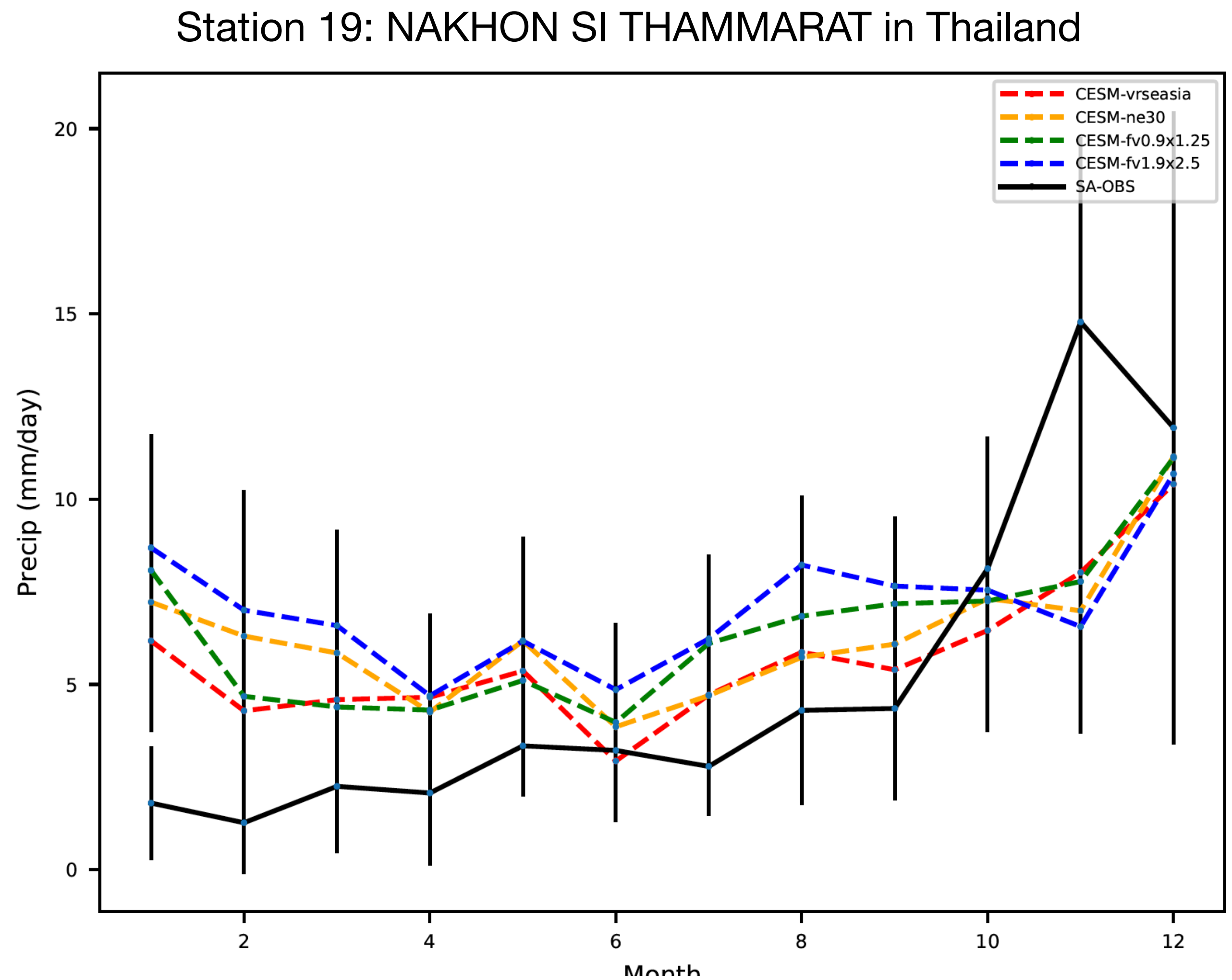




- There are significant differences in the precipitation distribution across the stations.

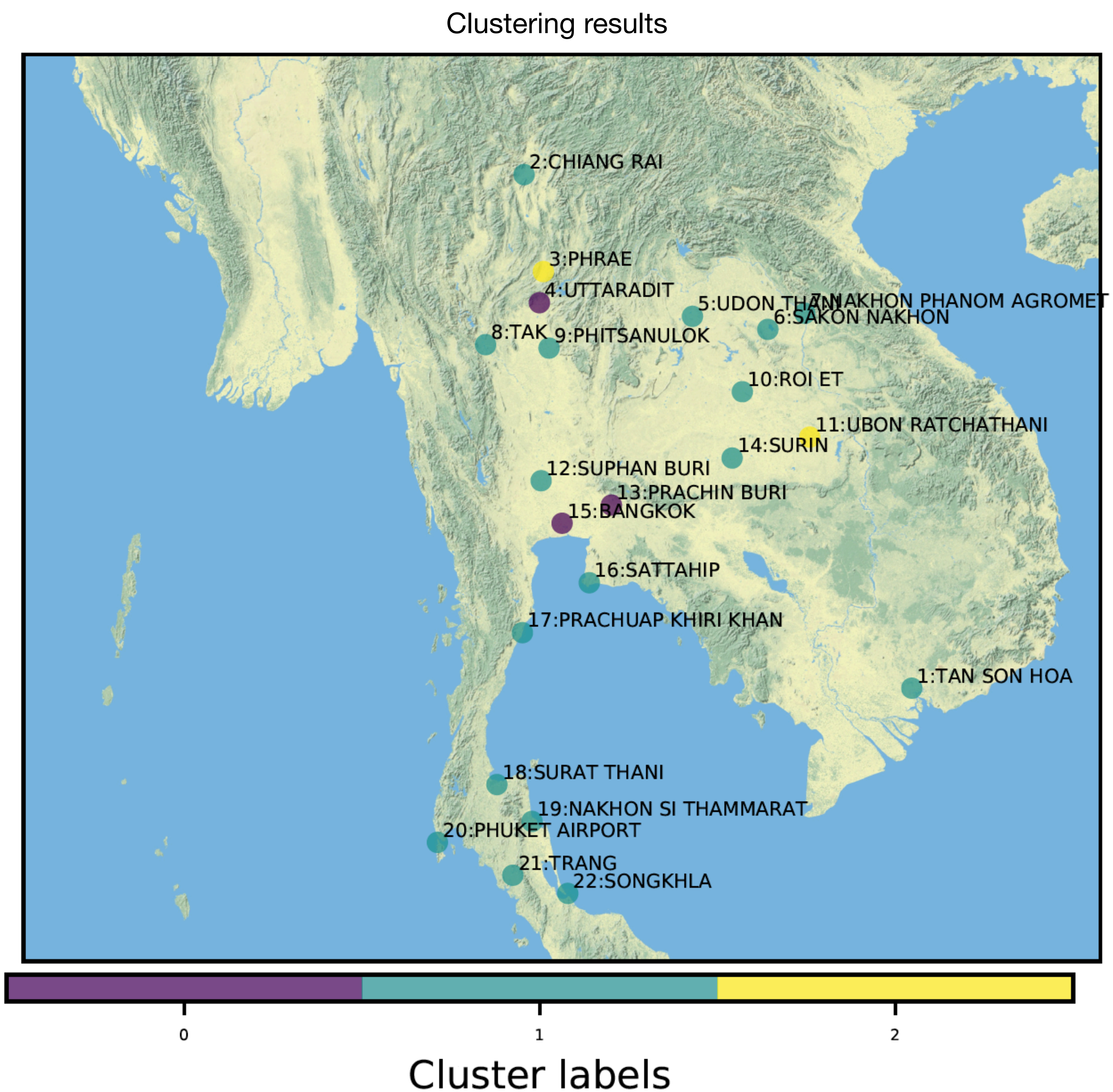
Heterogeneity in the Station Data: Seasonal Cycle





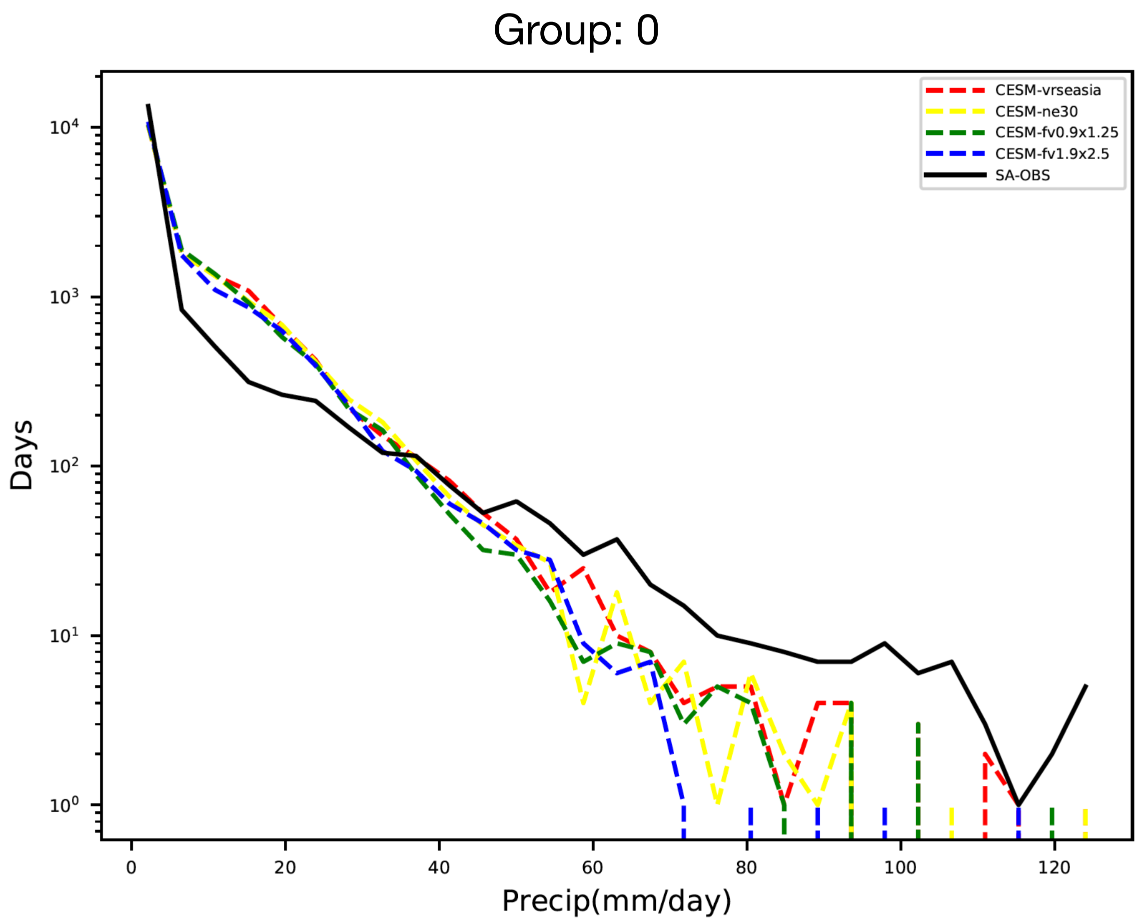
- The seasonal cycles can be also very different across the stations!

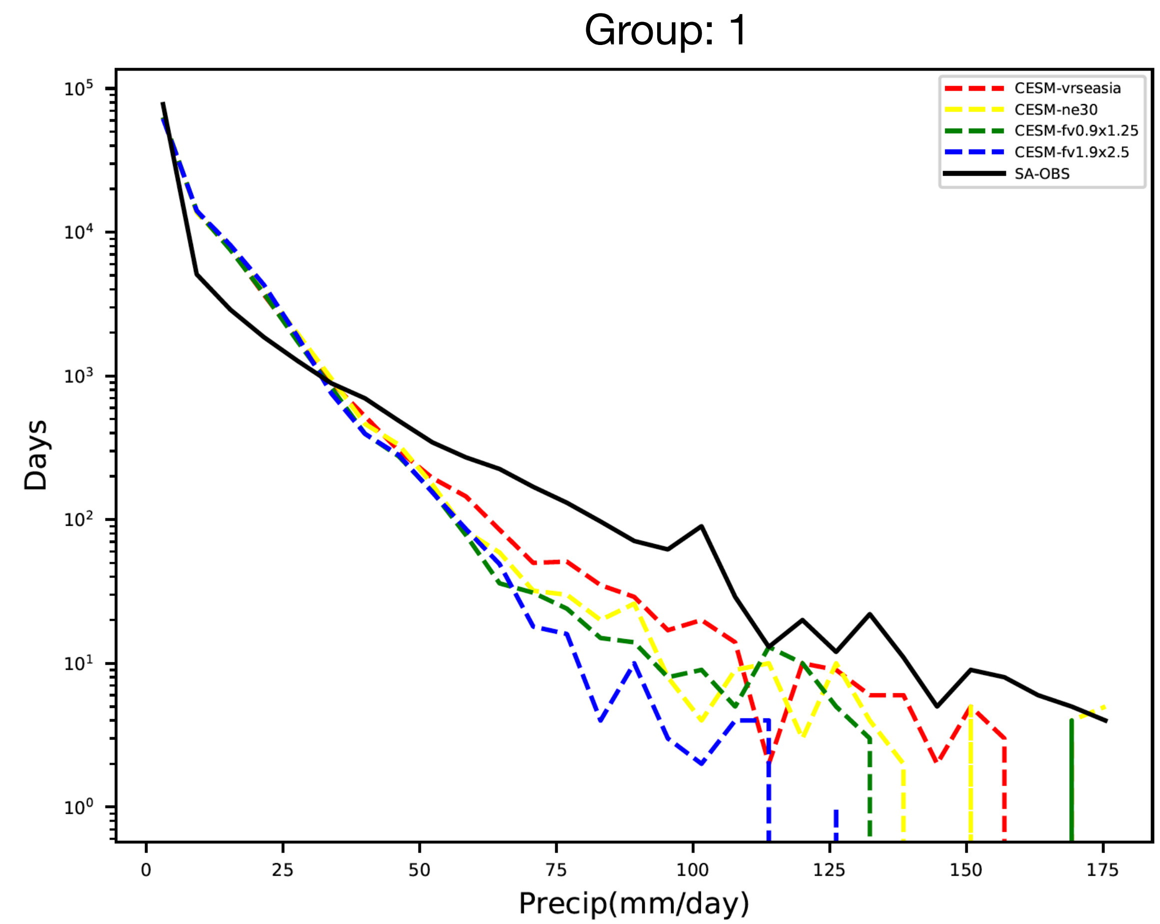
Clustering the Station Data

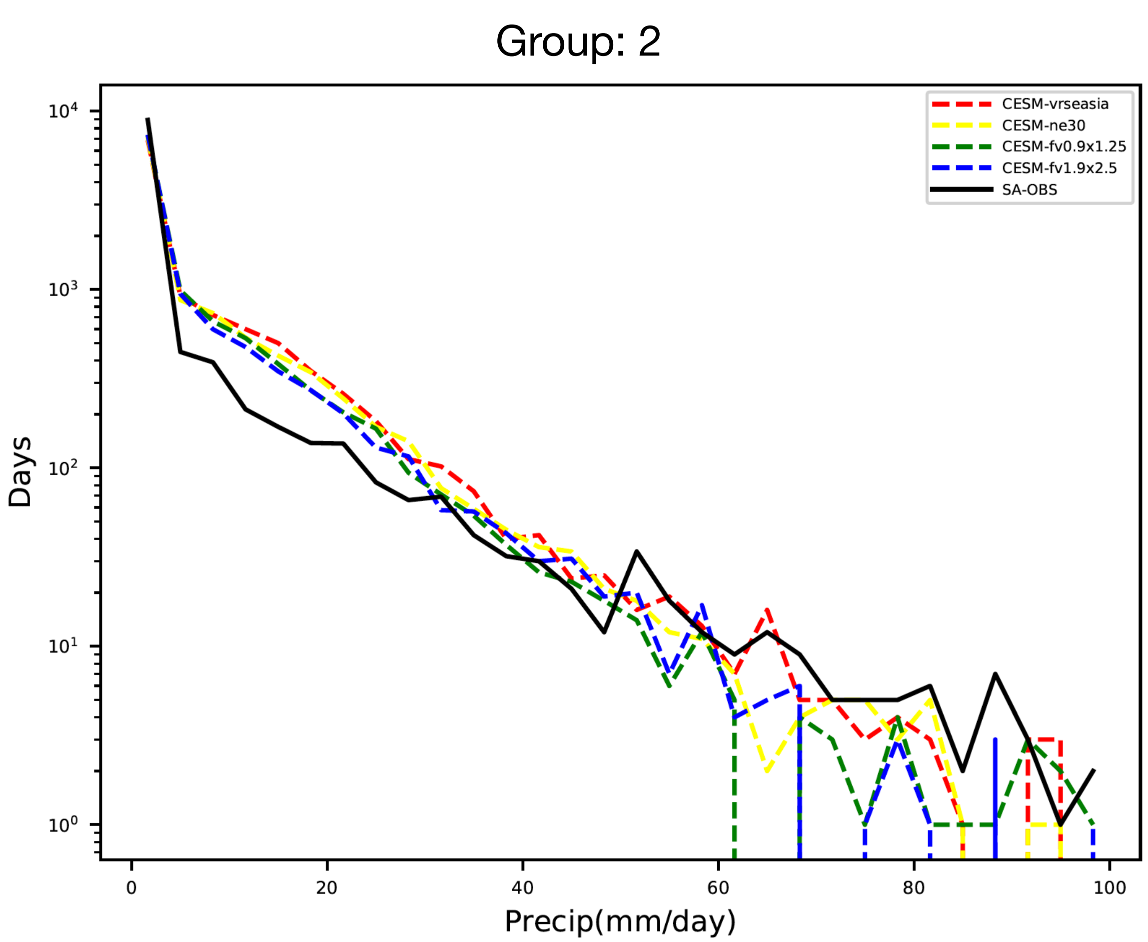


- All 22 stations are divided into 3 groups based on the differences in daily precipitation time series using K-Means clustering.
- The members in each cluster can be geographically distant.

Histogram of Total Precipitation in the 3 Groups



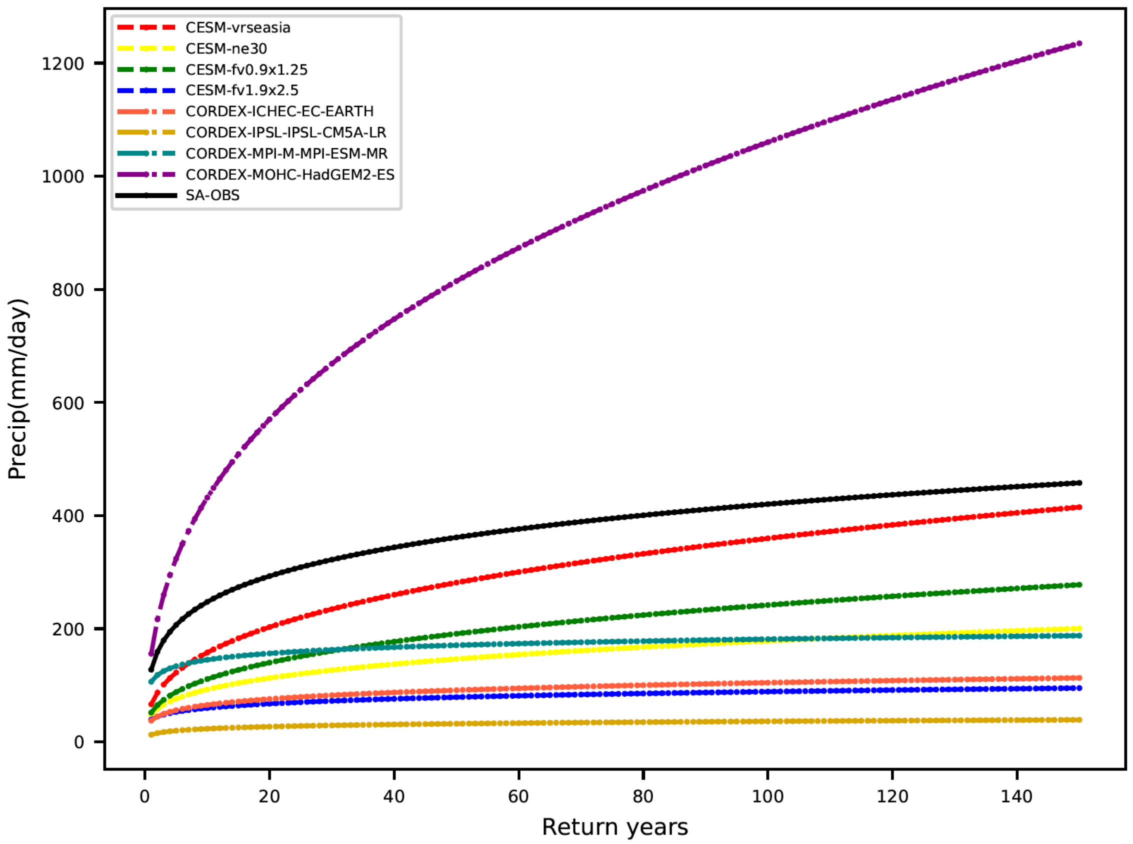




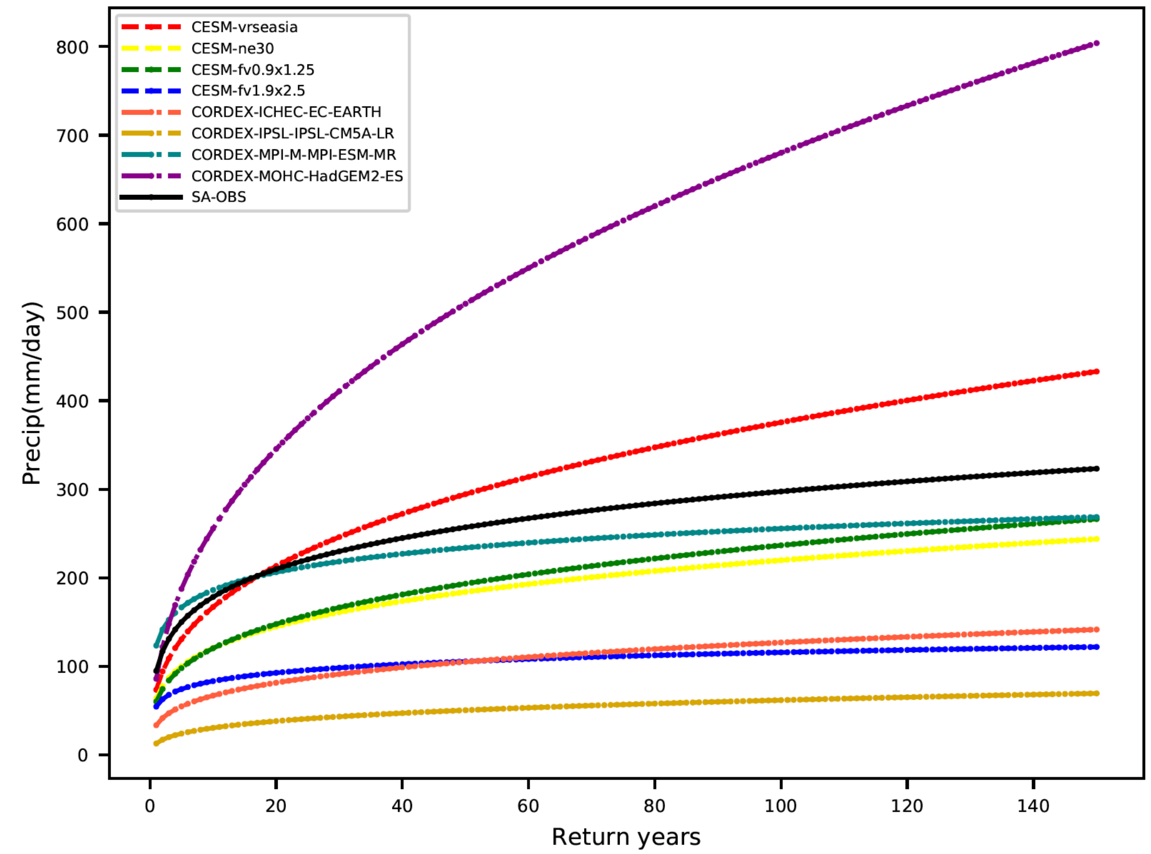
- In Group 1, which contains the most stations, VR-CESM matches the observations better.
- In Group 2 (containing Station 3 and 11), all CESM simulations fit the observations well except for the 2° runs.

97th Precipitation Return levels in the 3 Groups

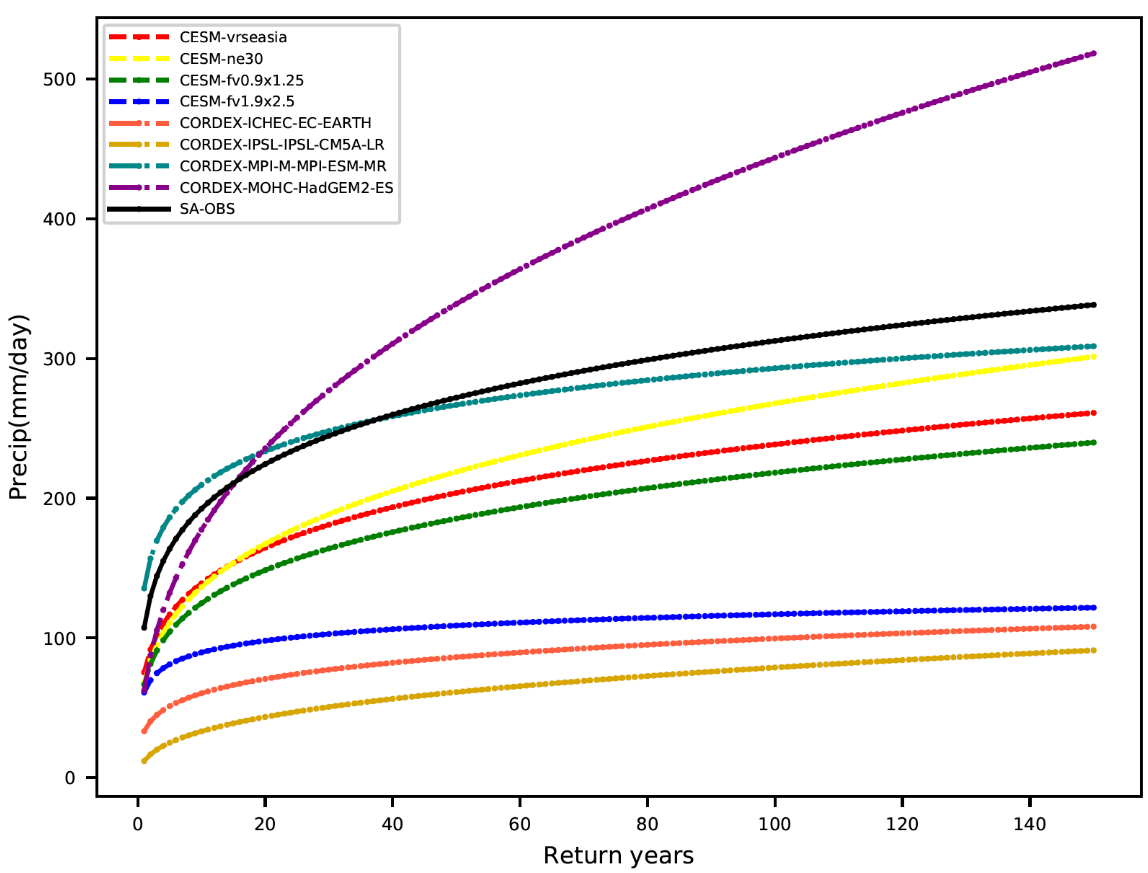
Group 0: N-year returns for 97th precipitation



Group 1: N-year returns for 97th precipitation



Group 2: N-year returns for 97th precipitation



- VR-CESM generally performs better than the other CESM simulations in simulating very high precipitation extremes.
- The MPI with RegCM4.3 CORDEX model also agrees with the extremes in the observations, but it has a significant high biases in mean precipitation.

Summary

- The CESM simulations generally perform better than the CORDEX simulations in capturing precipitation over mainland Southeast Asia.

- VR-CESM best simulates the seasonal cycle in precipitation over mainland Southeast Asia, as seen in the CRU and GPCC data.

- VR-CESM improves the simulation of the precipitation extremes in the region (measured by the station data), though the year-to-year variability is not necessarily improved.

Acknowledgement

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- We thank the SEACLID/CORDEX Southeast Asia Project team for making available the regional climate model data.

References

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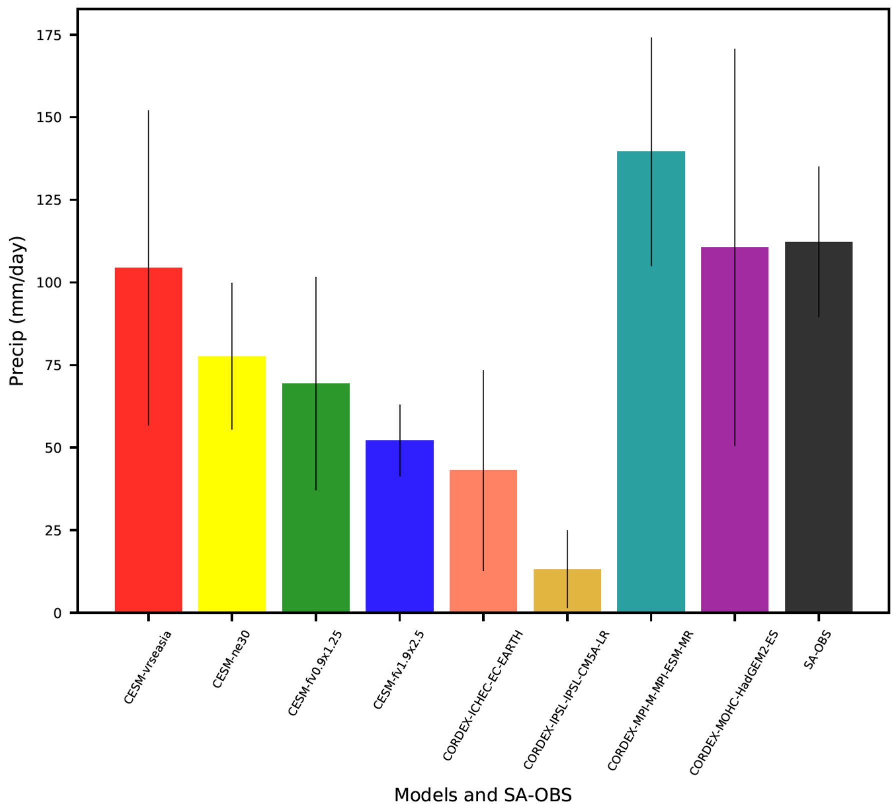
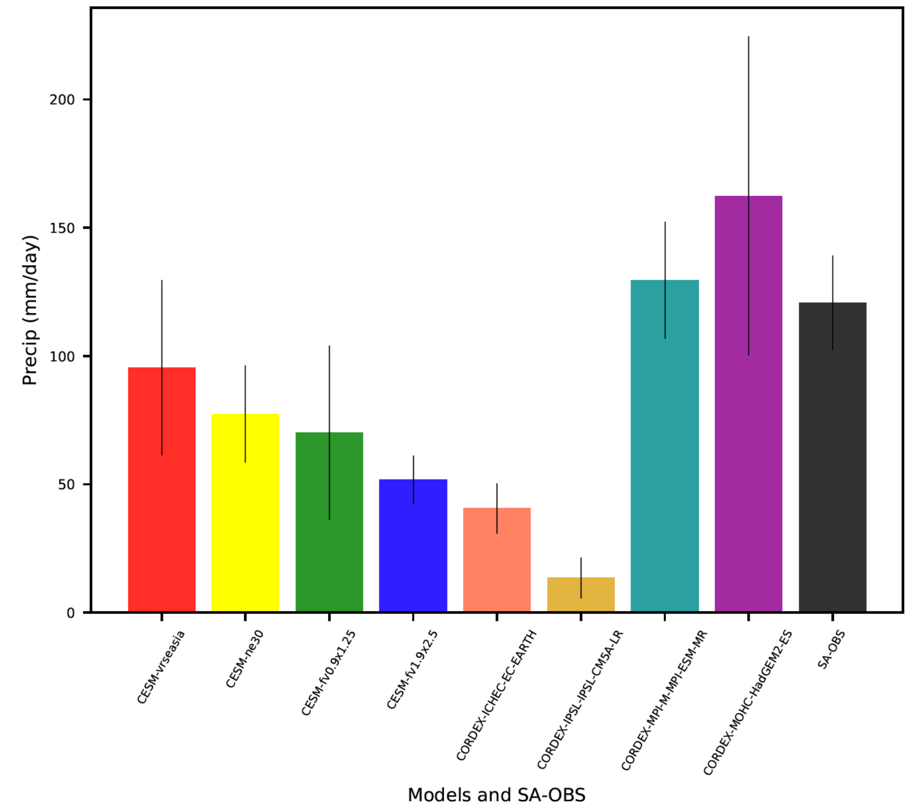
Supplementary slides

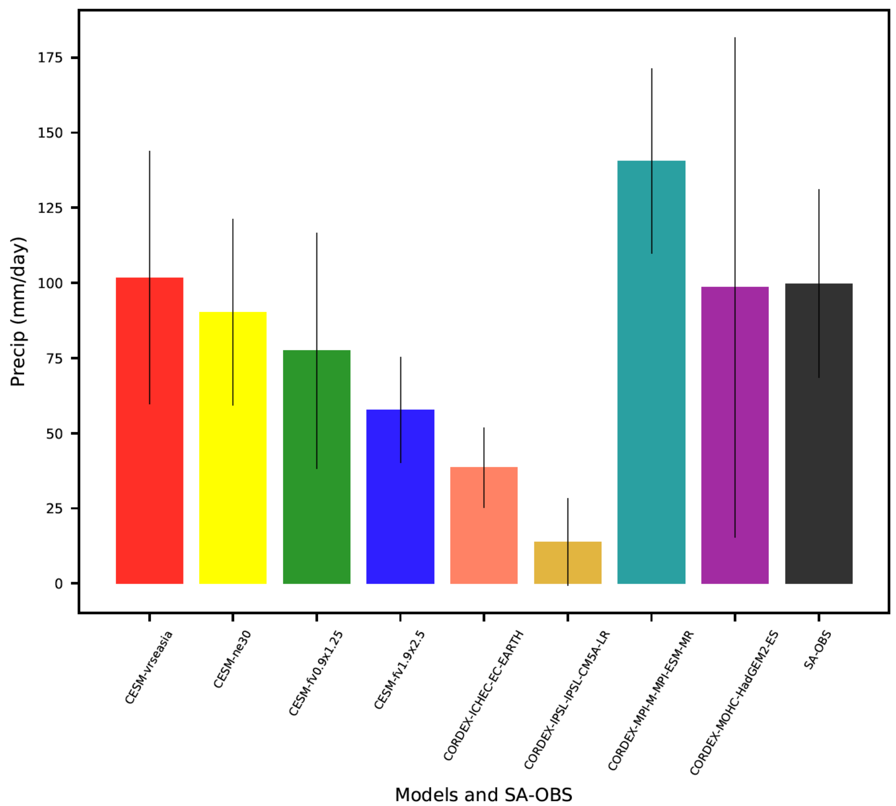
Group 0: Annual maximum precipitation



Group 1: Annual maximum precipitation

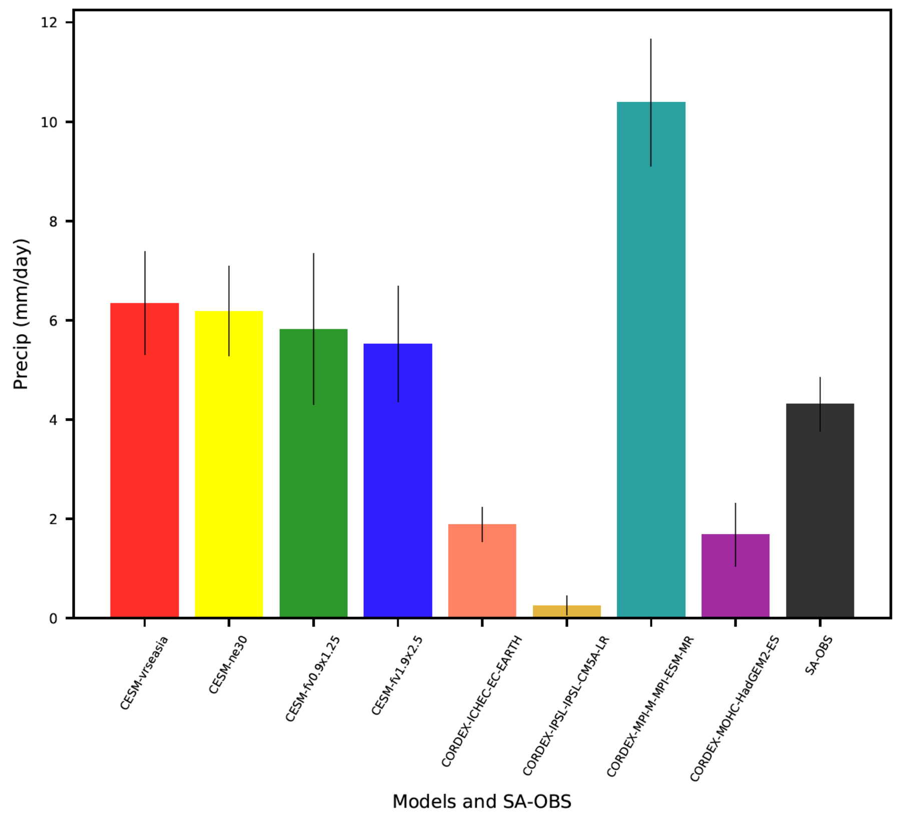


Group 2: Annual maximum precipitation



Supplementary slides

Group 0: Annual mean precipitation



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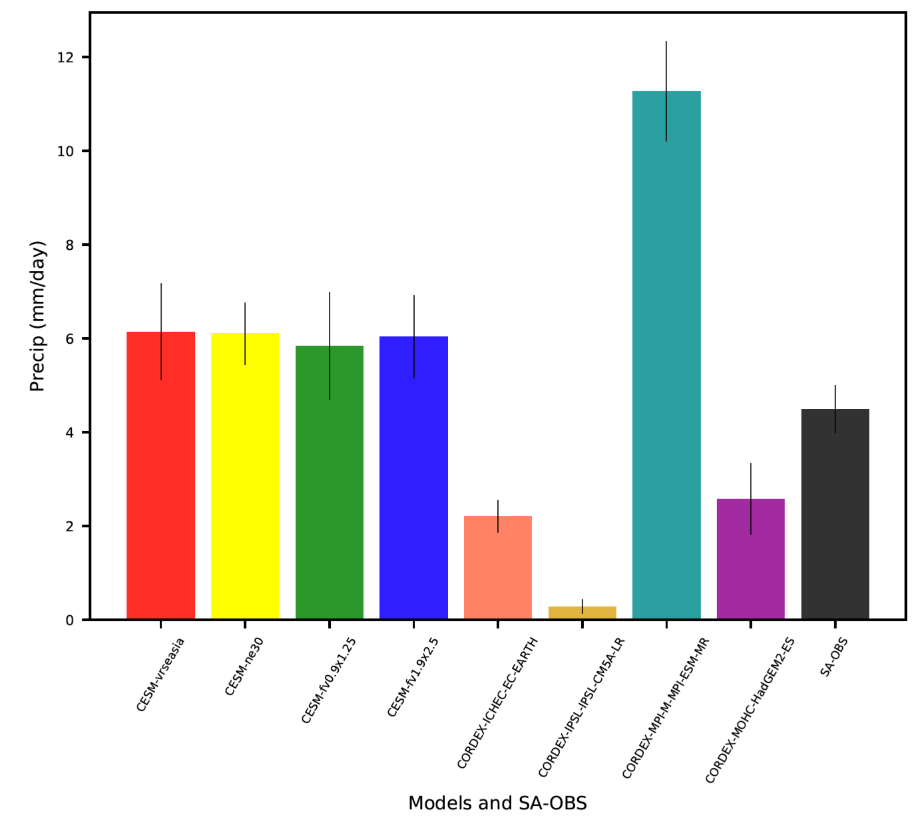
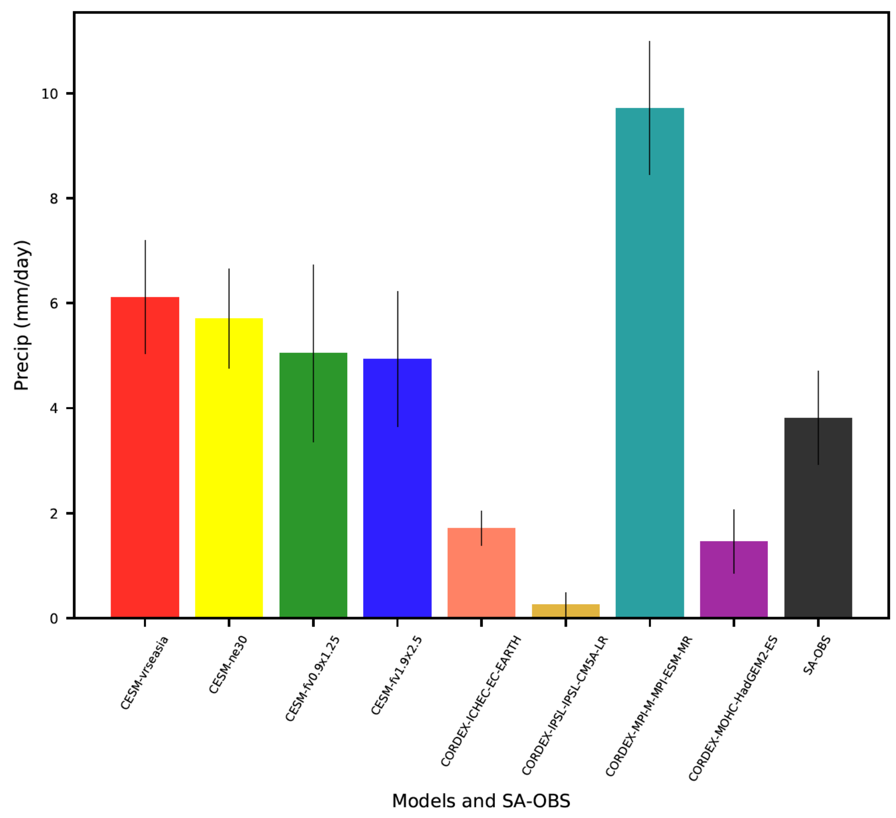
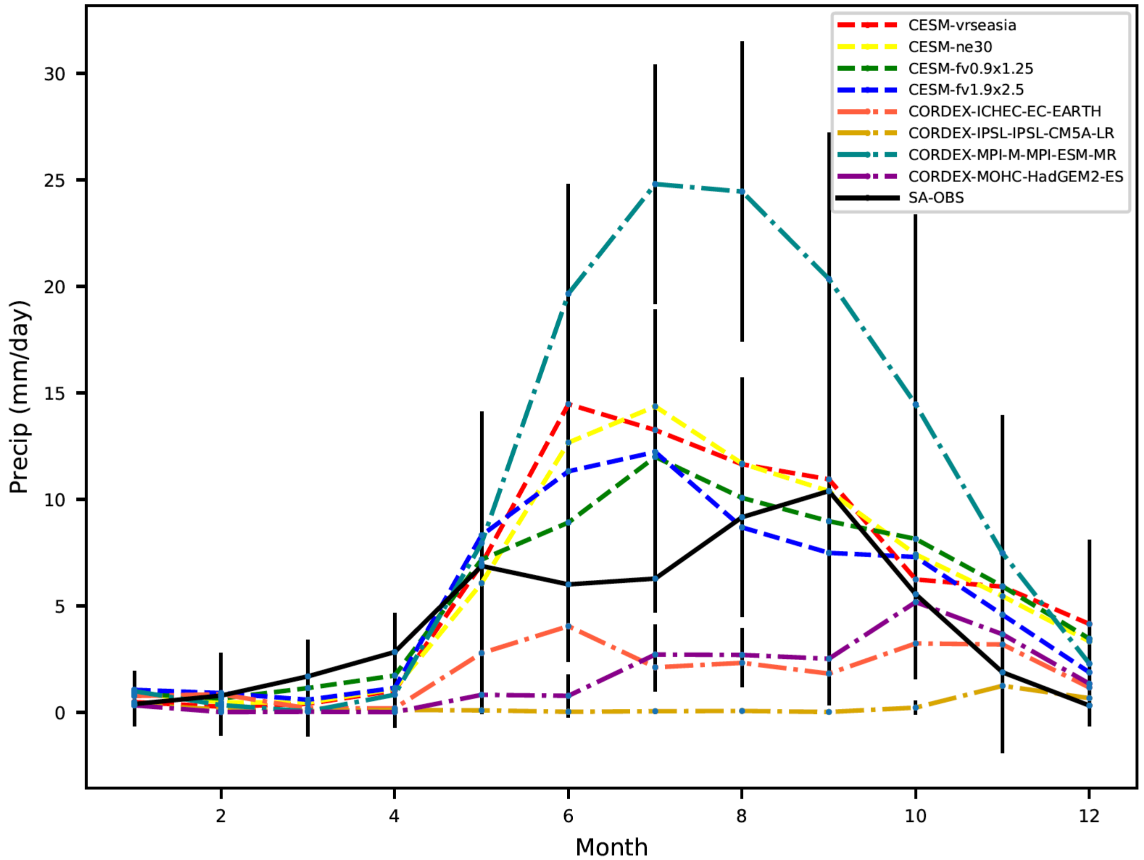


Group 2: Annual mean precipitation



Supplementary slides

Group 0: Seasonal cycle



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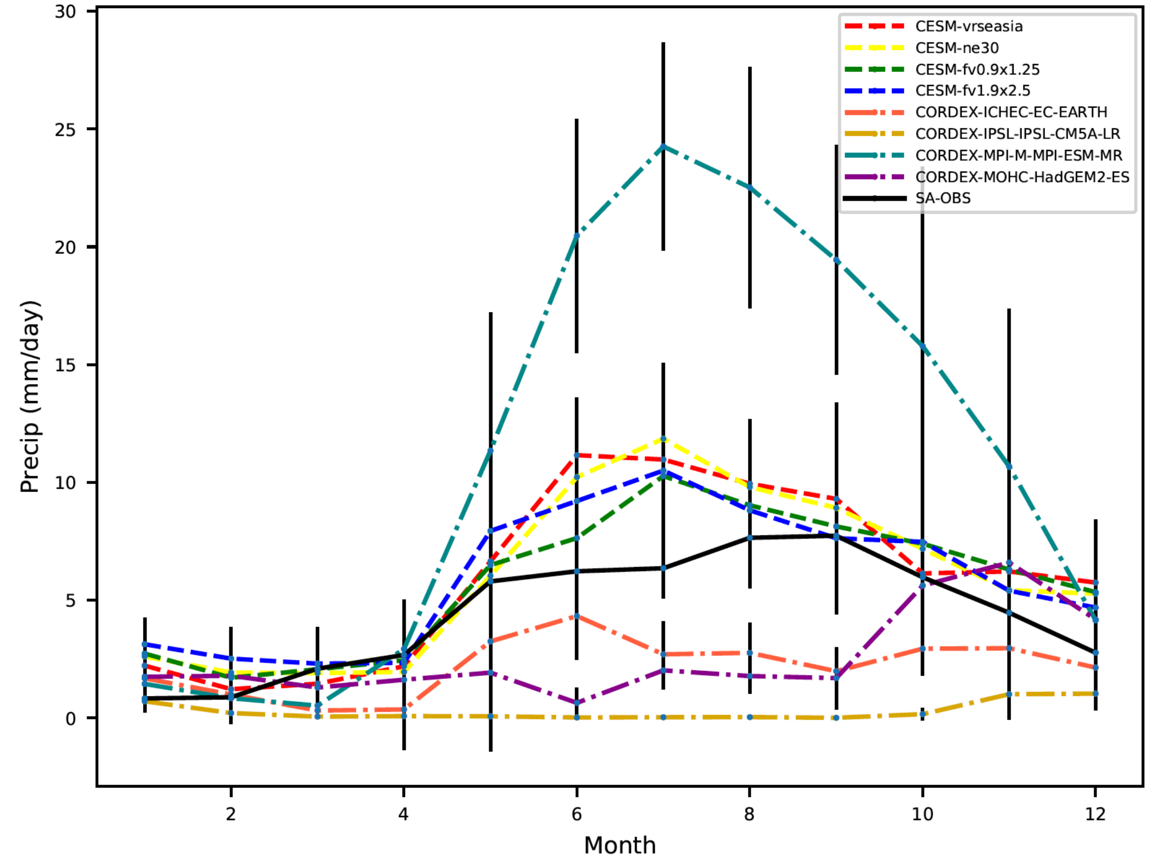
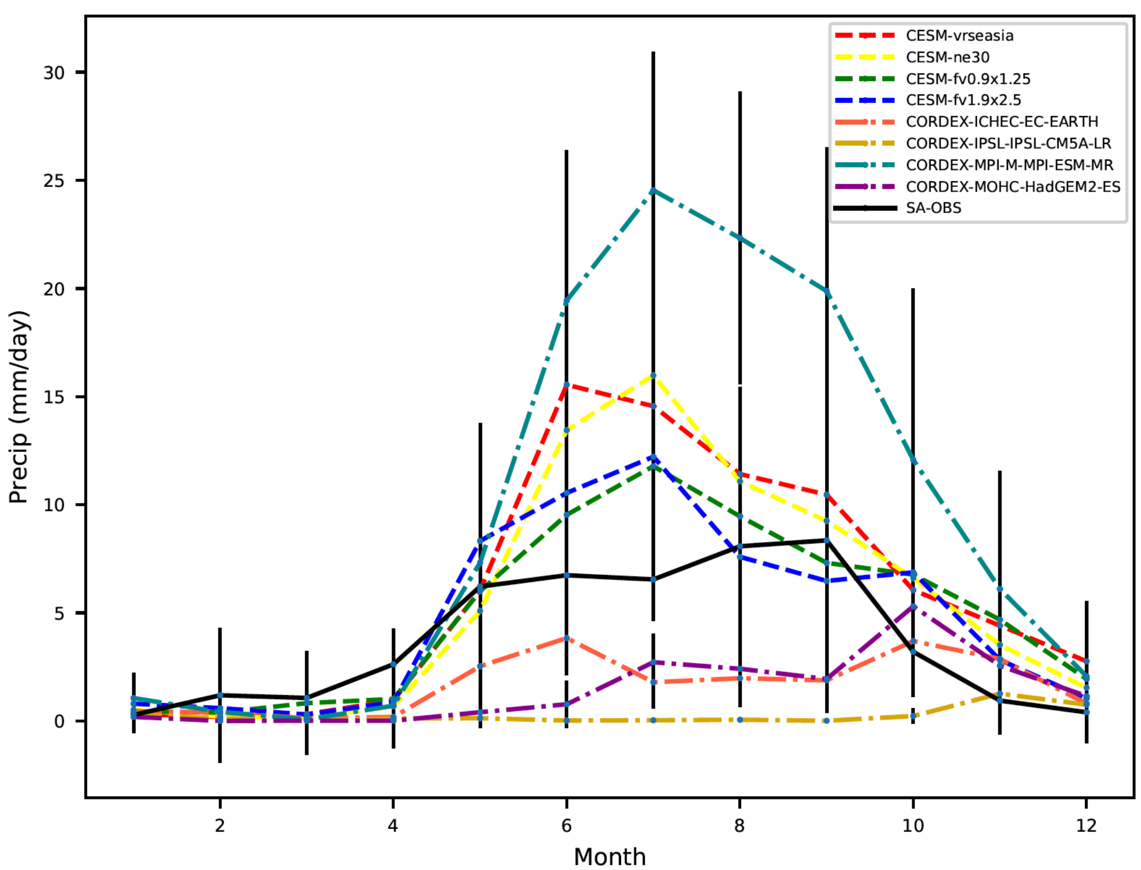


Group 2: Seasonal cycle



Supplementary slides

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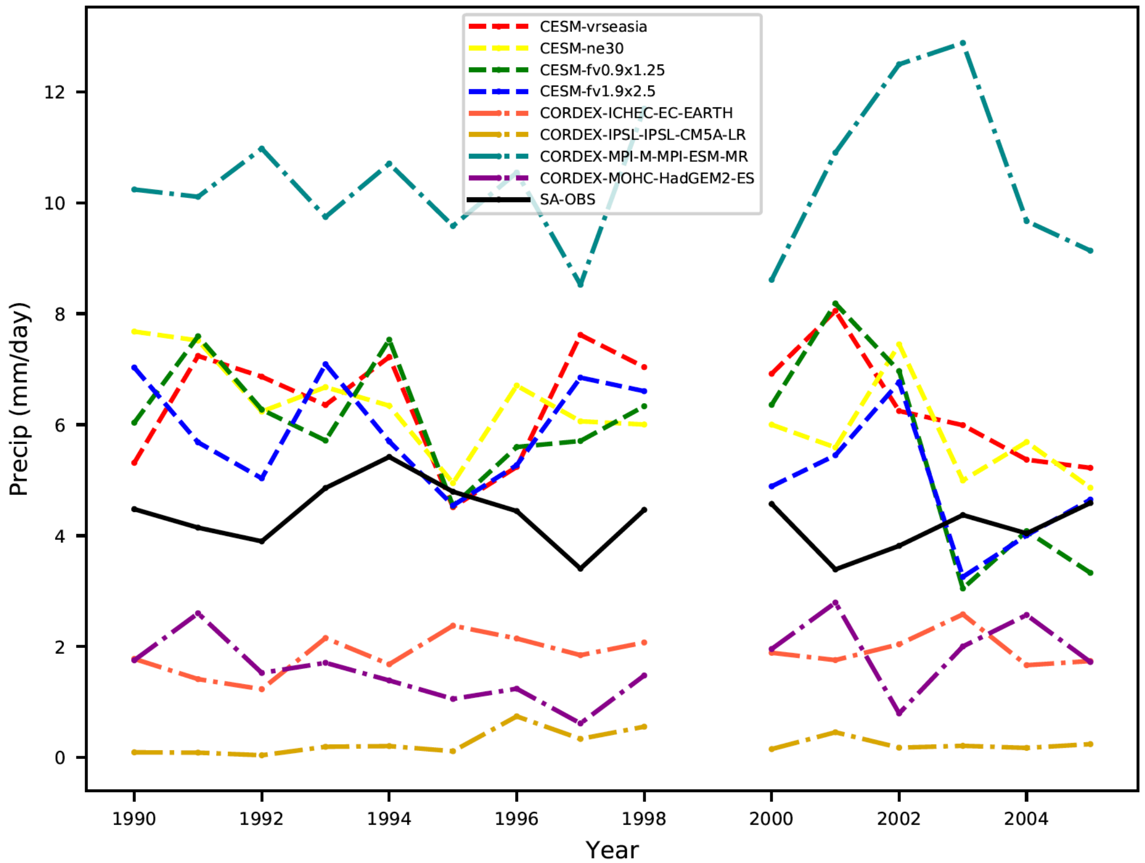

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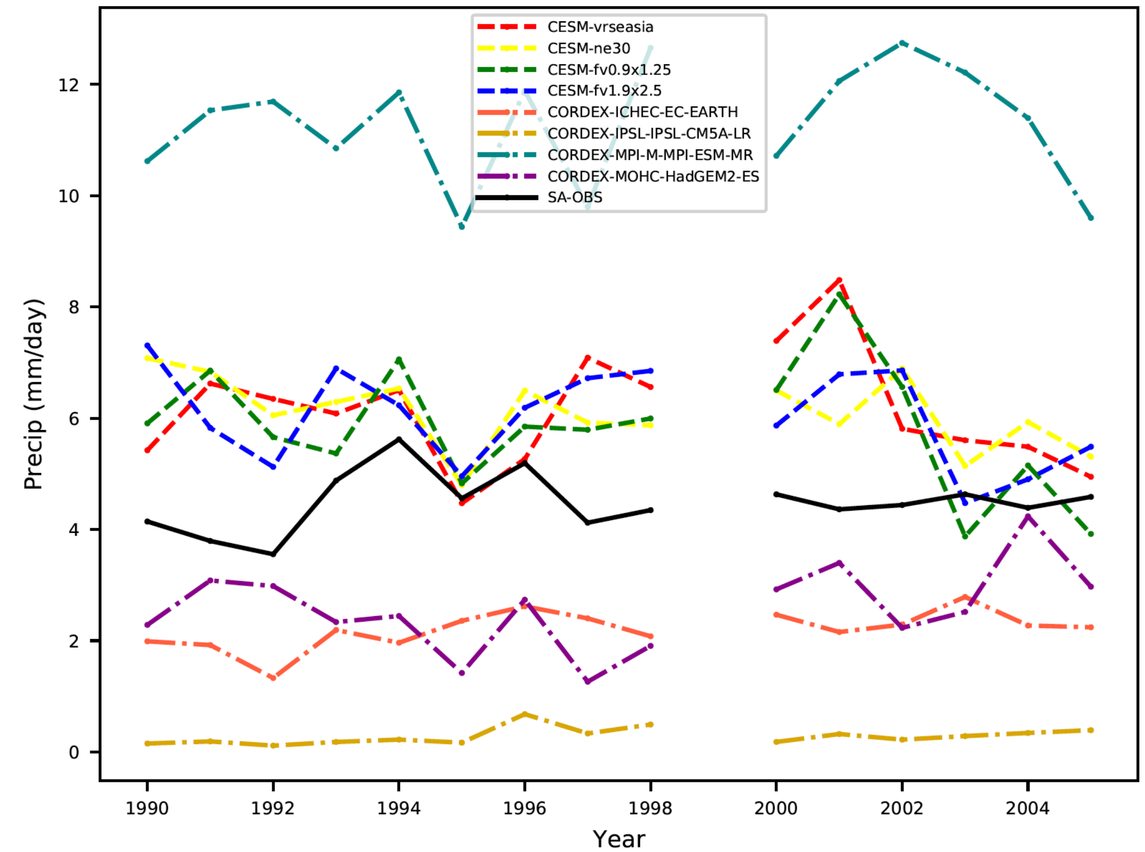
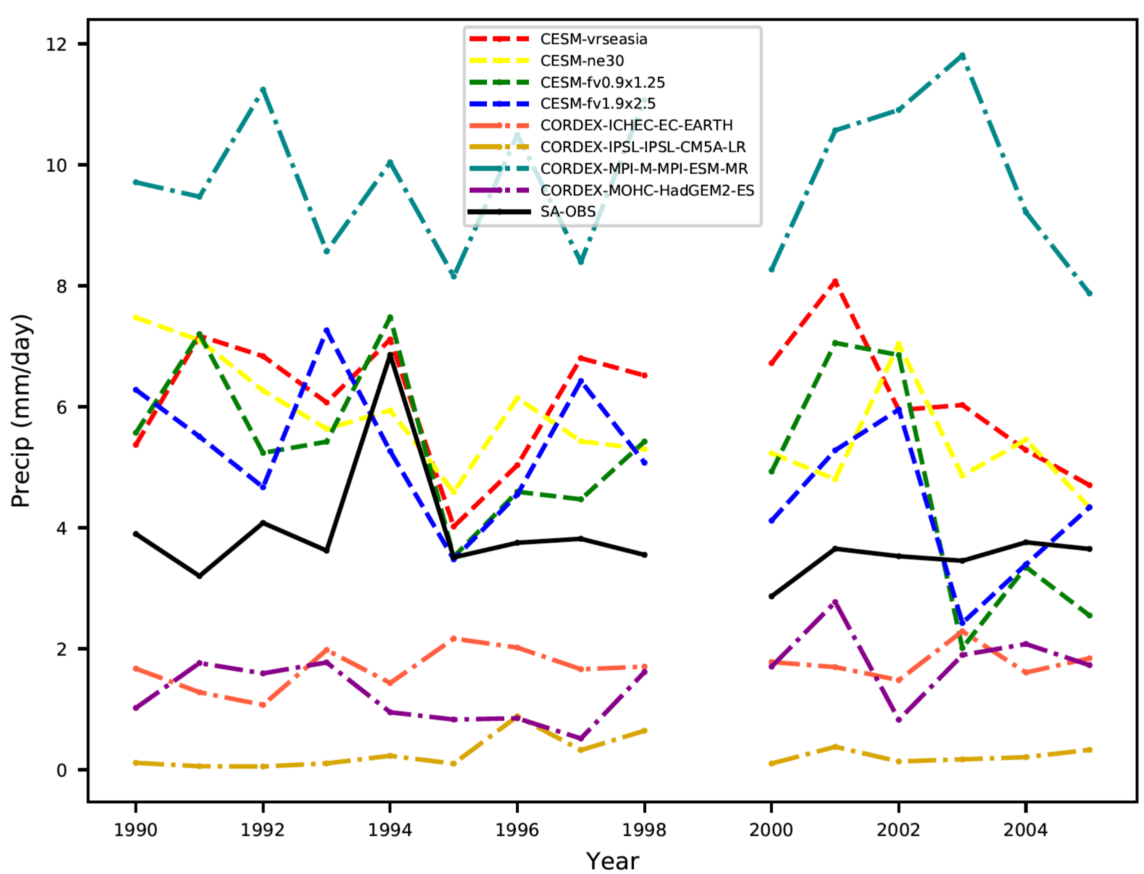
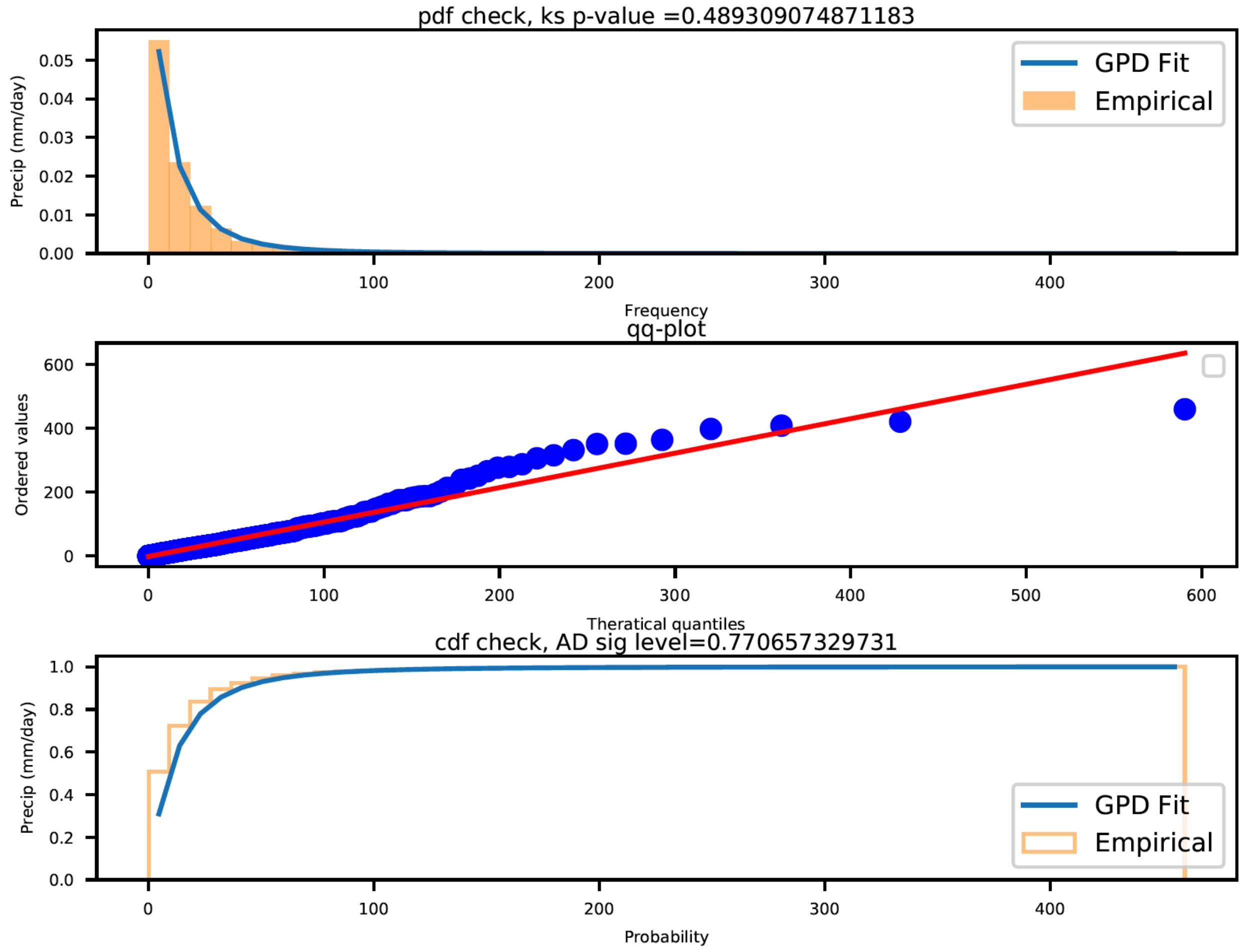


Group 2: Annual mean precipitation

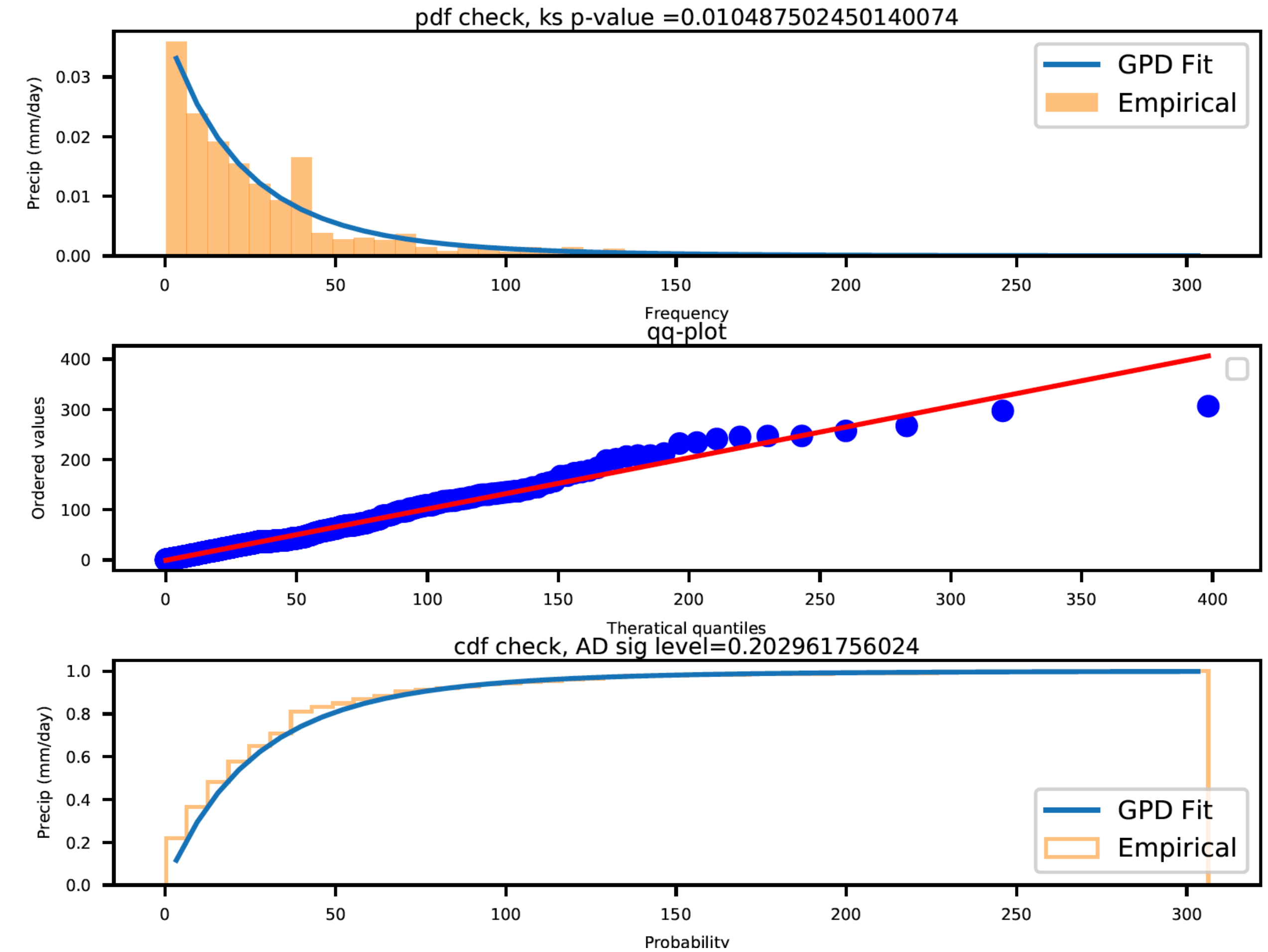


Supplementary slides

Goodness of GPD fitting: 97th precipitation

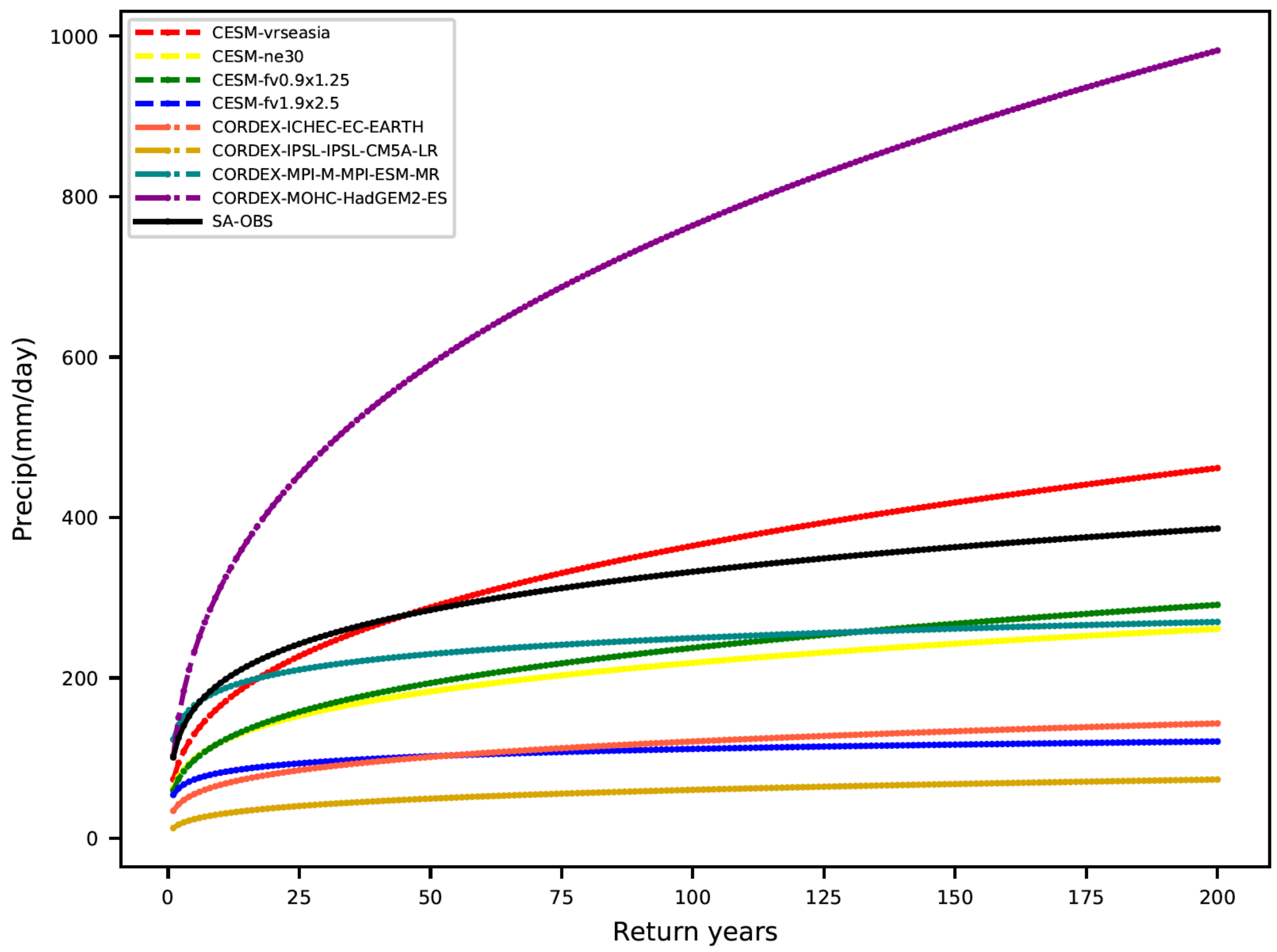


Goodness of GPD fitting: 99th precipitation



Supplementary slides

N-year returns for 99th precipitation



return levels for 99th precipitation