Precipitation and temperature projections for the Indus River basin of Pakistan during 21st century using statistical downscaling

Session CL4.17

(Mountain Climatology and Meteorology)

By

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EGU2020- Sharing Geosciences online

4th May 2020, Vienna-Austria

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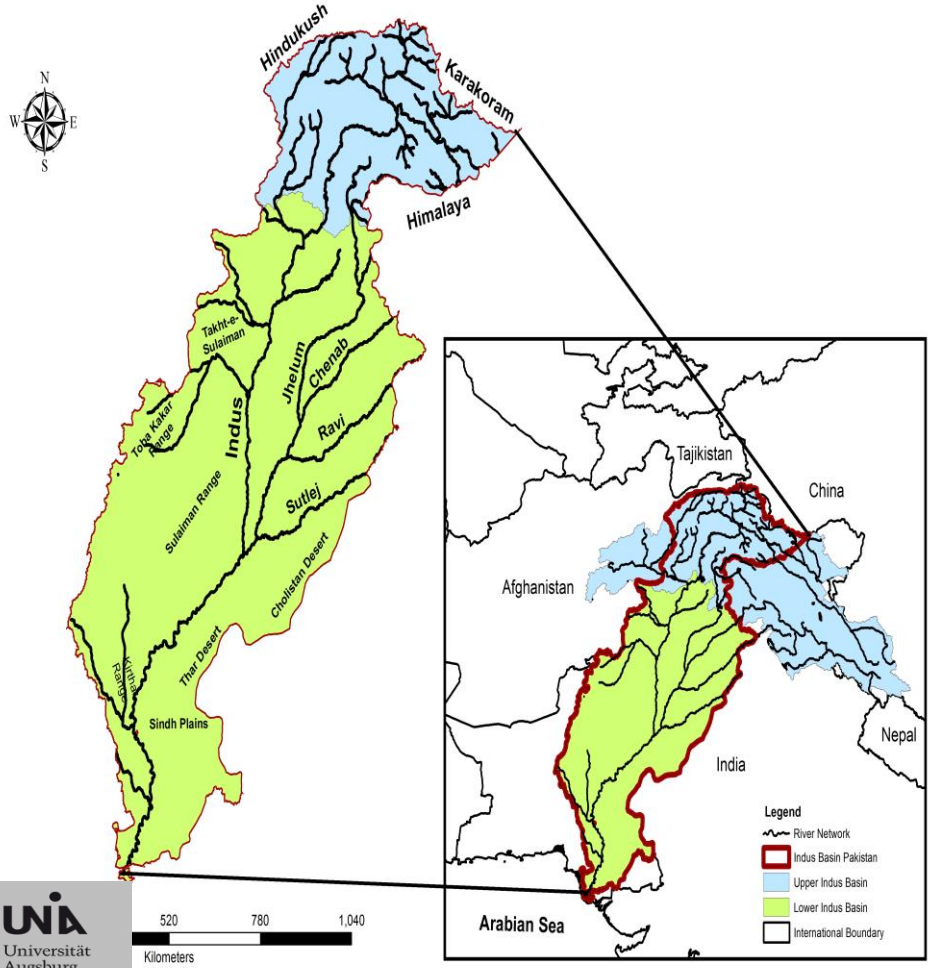
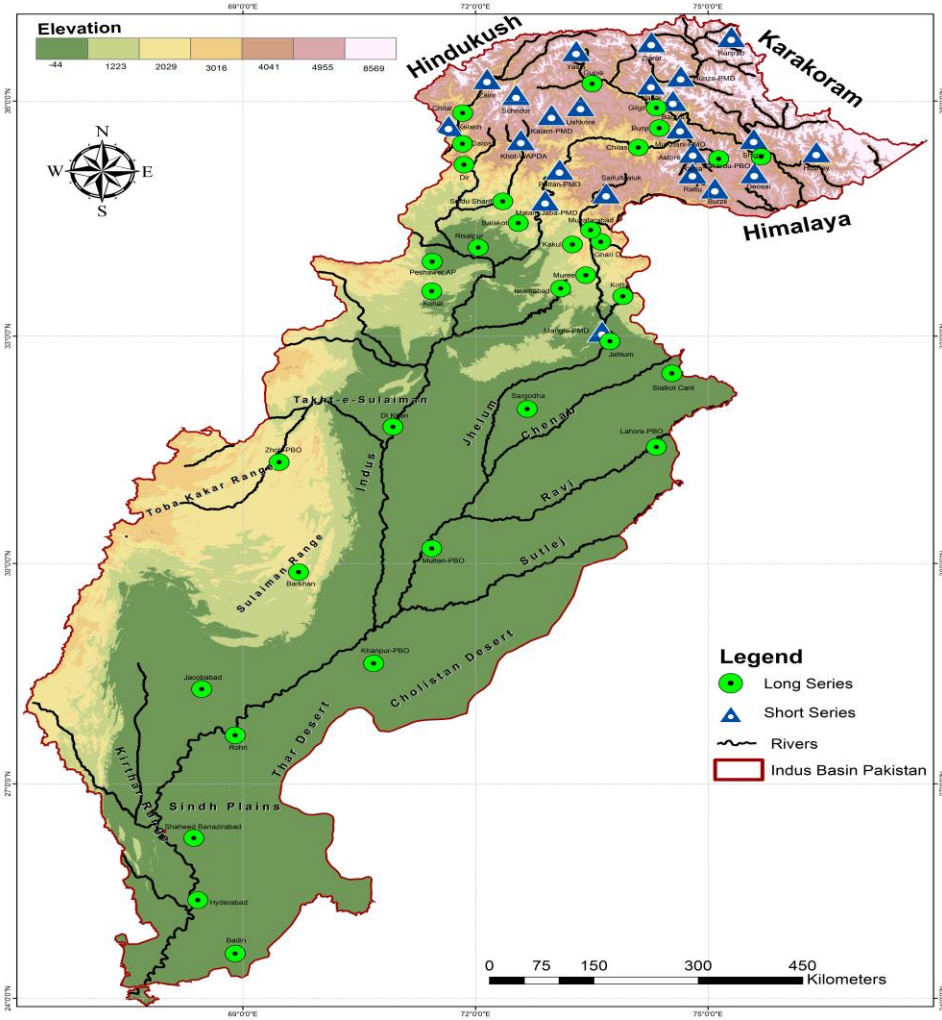
The Indus River Basin: A Complex Climate Hotspot

Can relatively-low altitude stations explain orographic climate structure within the UIB?
What observations tell us?

IRB and Study area



Study stations



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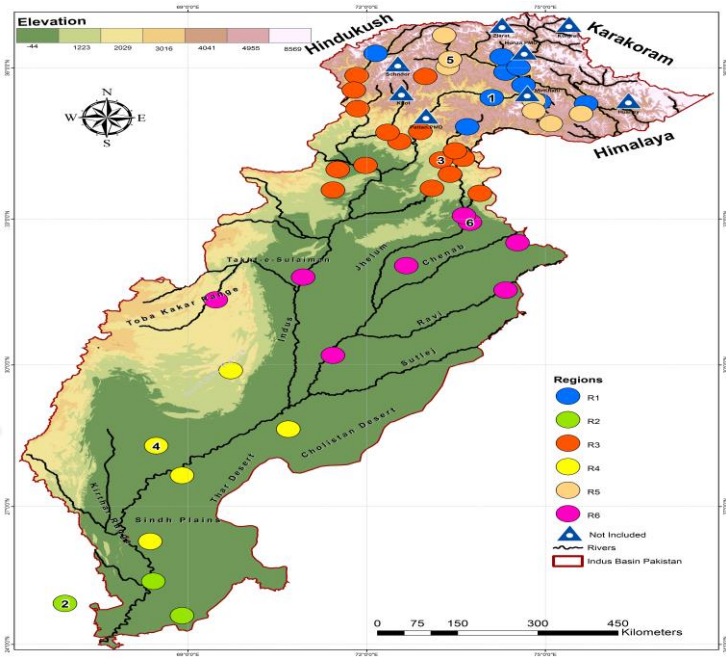
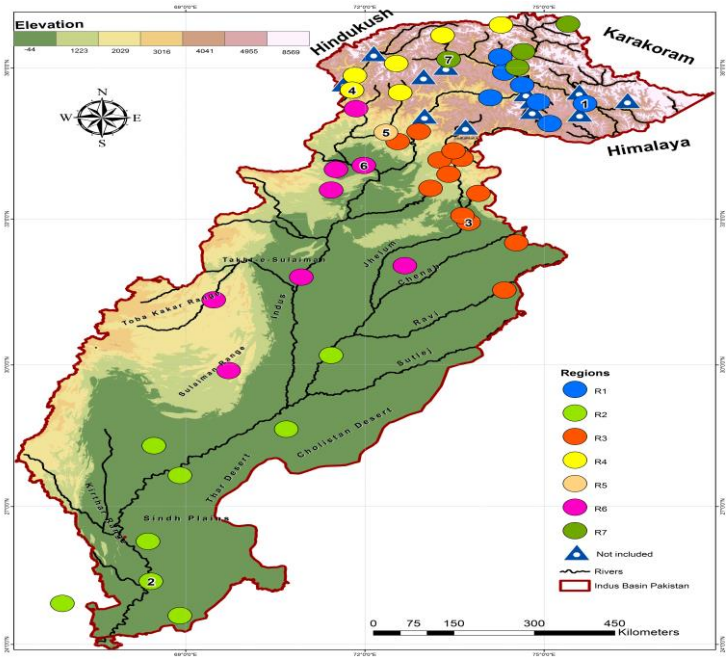
K-Means Precipitation Clustering using Correlation

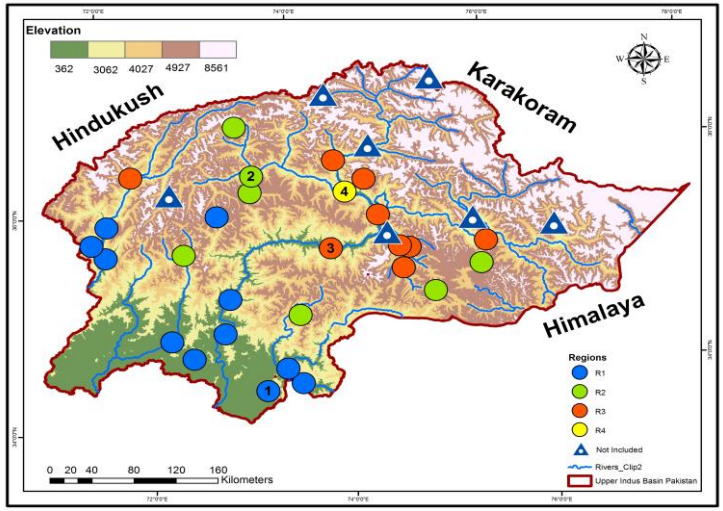
Clustering of HA stations around low-altitude stations

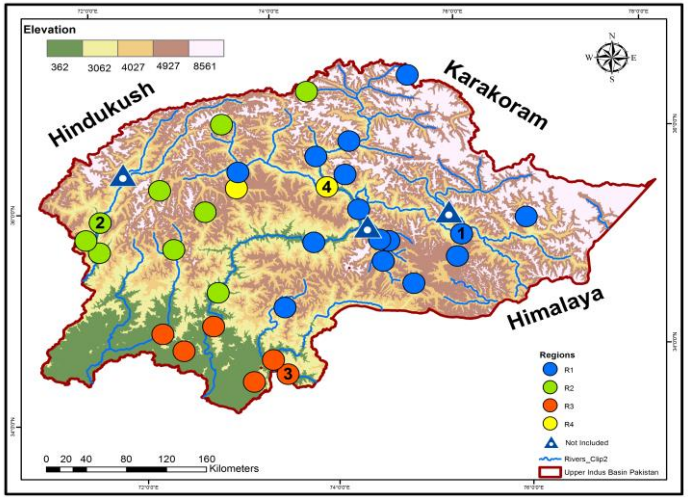
Basin-wide regionalization





HA-UIB regionalization





WS-DJFM)

MS-JAS)

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Predictand-Predictor Modeling and Performance

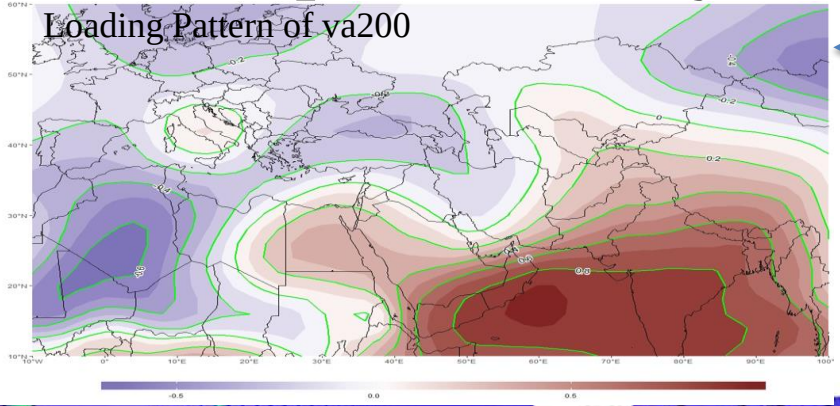
- *Time-series of selected regionally representative stations serve as* ***Predictands***
- *GLM with gamma and Tweedie distributions used for precipitation regression models within a robust cross- validation framework by minimizing (maximizing)errors (MSESS) in 1000 random iterations.*
- *MLR for modeling Tmax and Tmin on seasonal scales.*
- *Final models show significant statistical skills*

- *PC scores derived from S-mode PCA on selected dynamic and thermodynamic predictors of a reanalysis serve as* ***Predictors***

Precipitation Modeling performance

Season Spatial Scale	No. of Regions	Avg. Val. MSESS (Range) in %)
MS (UIB)	5	**32.73** (20.71 to 52.541)
MS (LI)	2	**36.19** (32.06 to 40.32)
PMS (UIB)	4	**43.90** (28.83 to 50.42)
PMS (LI)	2	**38.88** (37.64 to 40.11)
WS (UIB)	3	**34.69** (26.10 to 49.57)
WS (LI)	2	**32.69** (28.75 to 36.63)

Anomalous MS Precipitation: Physical Mechanisms

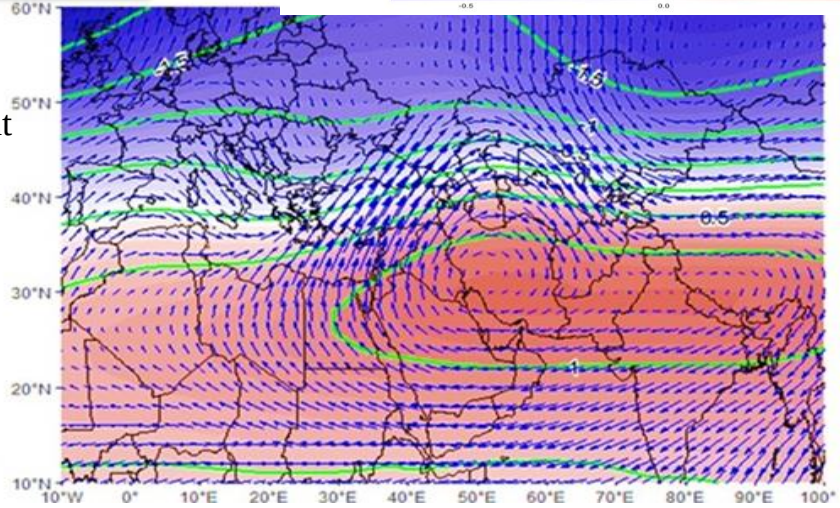


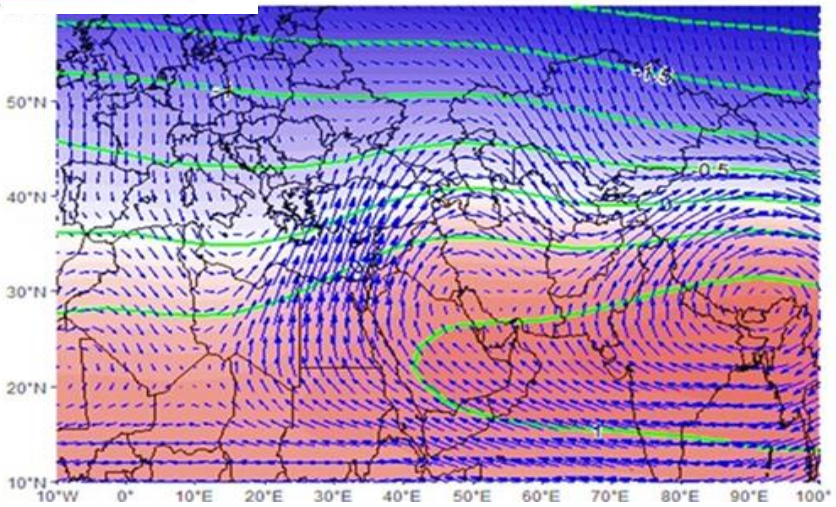
a) 181 mm/m

a) 344 mm/m

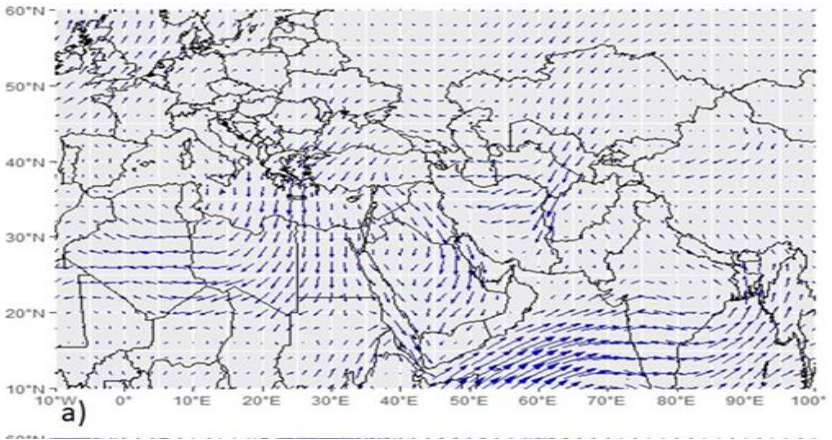
b) 69 mm/m

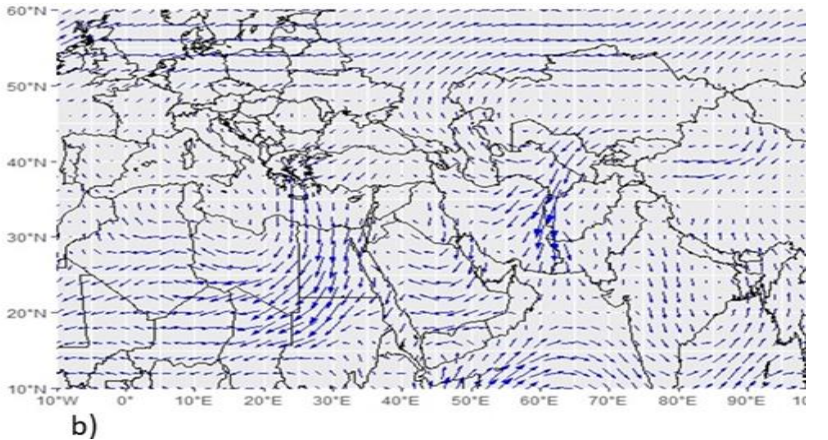
wind and zg at 200hPa





wind at 850hPa





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Circulation-based GCM Selections

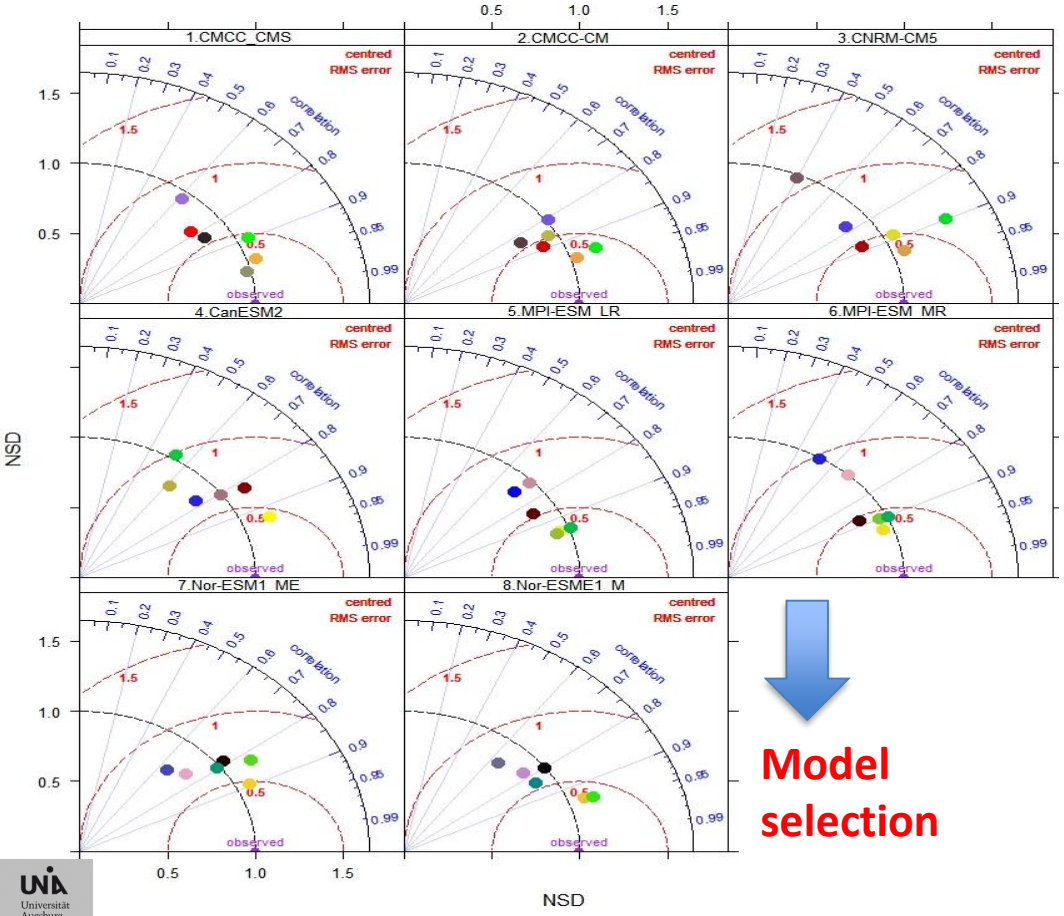
PS = abs (CR) – abs (NSD – 1)

Where,

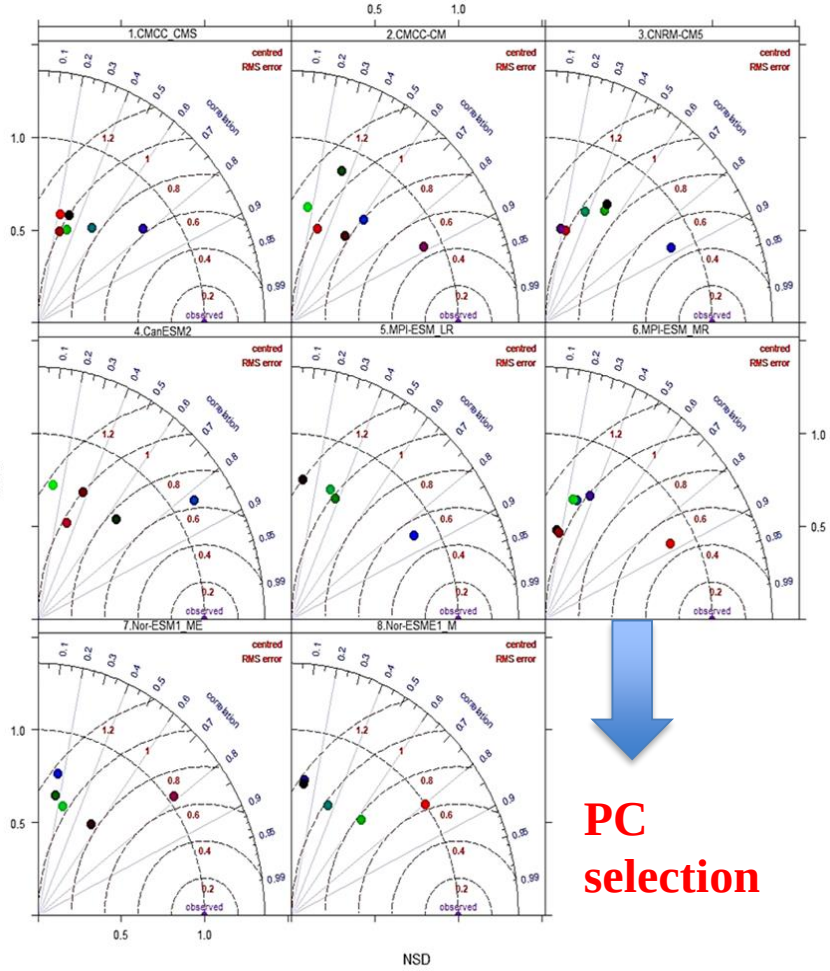
CR = Pattern correlation, NSD = Normalized Ratio of variance

For an ideal match → PS = 1 → Zero errors

Regression coefficients are used as weights



Model selection



PC selection

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Quantifying Reference (Model) Uncertainties: Spatiotemporal Perspective

Uncertainty = (1- PS)*100

Seasons	Regions	Reanalysis		GCMs							
		ERA5	NCEP-NCAR-II	CMCC-CMS	CMCC-CM	CNRM-CM5	Can-ESM2	MPI-ESM-LR	MPI-ESM-MR	Nor-ESM1-ME	Nor-ESM1-M
MS	**UIB**										
	R1	0.76	0.59	**0.40**	0.30	***0.37***	0.33	0.31	*0.13*	0.36	0.20
	R3	0.96	0.82	**0.70**	0.56	0.58	0.40	*0.38*	0.54	***0.66***	0.62
	R4	0.91	0.76	***0.53***	0.52	0.45	0.41	0.36	0.51	*0.36*	**0.58**
	R5	0.77	0.67	0.41	**0.53**	0.45	0.38	***0.46***	0.39	0.41	*0.37*
	R7	0.81	0.74	0.48	***0.52***	**0.55**	0.43	0.40	0.45	*0.35*	0.42
	Avg. UIB	***0.84***	***0.72***	**0.50**	***0.49***	0.48	0.39	*0.38*	0.40	0.43	0.44
	Avg. UIB-Uncer. (%)	***16***	***28***	***50***	***51***	***52***	***61***	***62***	***60***	***57***	***56***
	LI										
	R2	0.87	0.79	0.50	0.42	***0.62***	0.33	**0.69**	0.56	0.45	*0.30*
	R6	0.75	0.60	***0.37***	**0.41**	0.36	*0.26*	0.34	0.36	**0.41**	0.40
	Avg.LI	***0.81***	***0.70***	***0.44***	***0.42***	***0.49***	***0.30***	***0.52***	***0.46***	***0.43***	***0.35***
	Avg. LI Uncer. (%)	***18.72***	***30.50***	***56.50***	***58.50***	***51.00***	***70.50***	***48.50***	***54.00***	***57.00***	***65.00***
WS	**UIB**										
	R1	0.89	0.72	0.58	0.60	***0.62***	0.48	**0.69**	0.46	0.51	*0.42*
	R3	0.84	0.73	0.56	**0.67**	0.46	0.48	***0.64***	0.45	0.31	*0.30*
	R5	0.77	0.77	0.55	0.57	0.59	*0.47*	**0.68**	0.56	0.59	***0.66***
	Avg. UIB	**0.83**	**0.74**	**0.56**	**0.61**	**0.56**	**0.48**	**0.67**	**0.49**	**0.47**	**0.46**
	Avg. UIB-Uncer. (%)	**16.82**	**26.00**	**43.67**	**38.67**	**44.33**	**52.33**	**33.00**	**51.00**	**53.00**	**54.00**
	LI										
	R4	0.94	0.91	0.58	0.62	**0.71**	0.58	*0.43*	0.61	***0.67***	0.60
	R6	0.51	0.72	0.72	**0.78**	0.63	0.66	***0.76***	0.72	*0.60*	0.66
	Avg.LI	***0.73***	***0.82***	***0.65***	***0.70***	***0.67***	***0.62***	***0.60***	***0.67***	***0.64***	***0.63***
	Avg. LI Uncer. (%)	***27***	***19***	***35***	***30***	***33***	***38***	***41***	***34***	***37***	***37***

Green color	1st best model
Blue color	second best model
Red color	worst regional model

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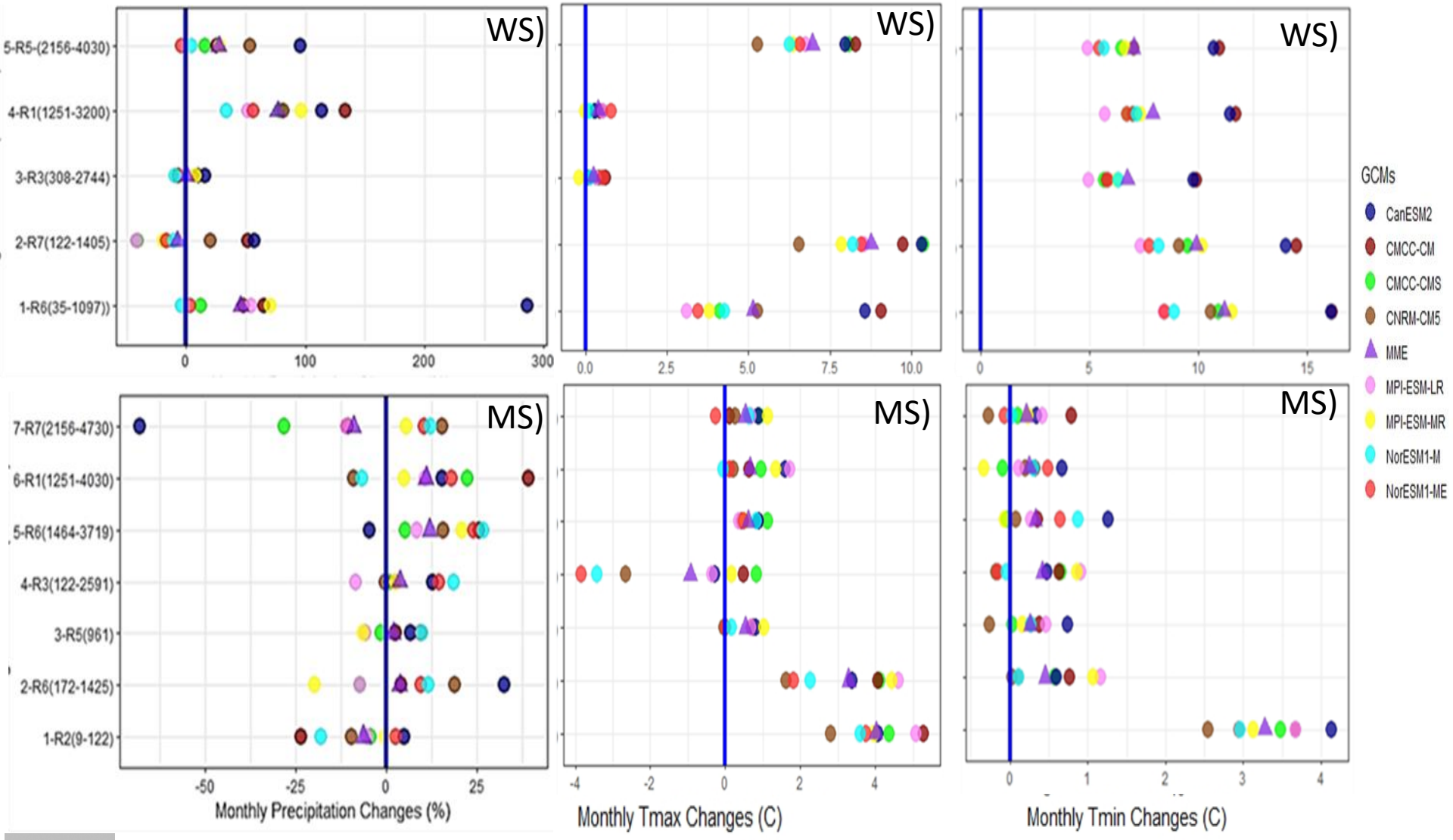
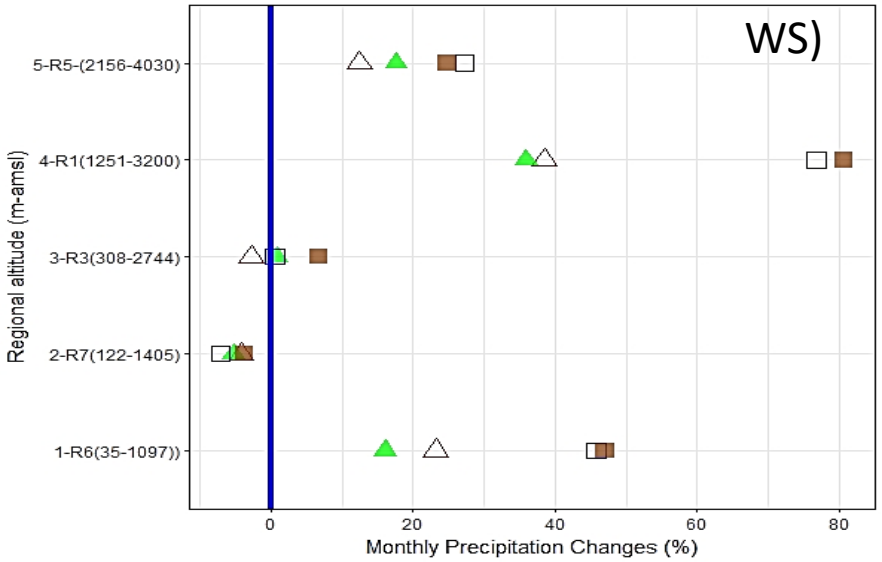
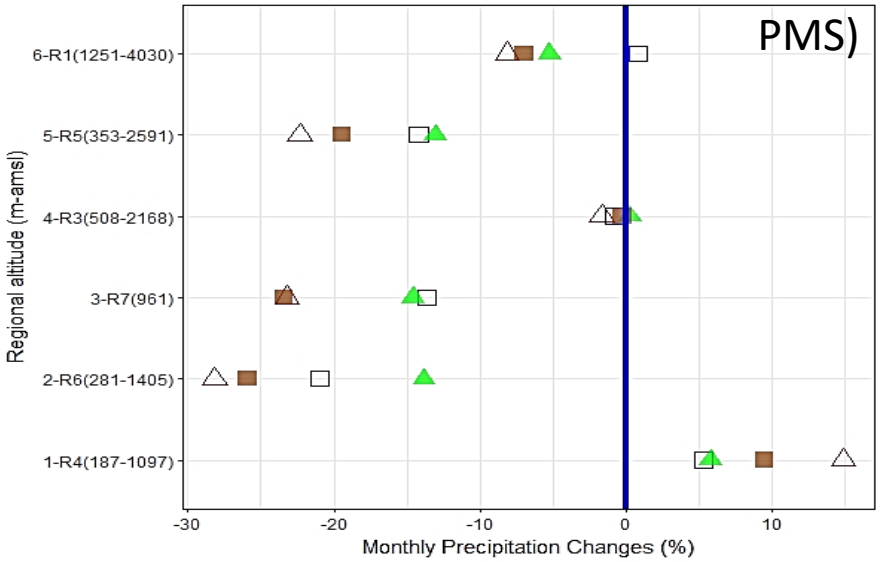
RCP8.5 Projections (2071-2100 minus 1976-2005)

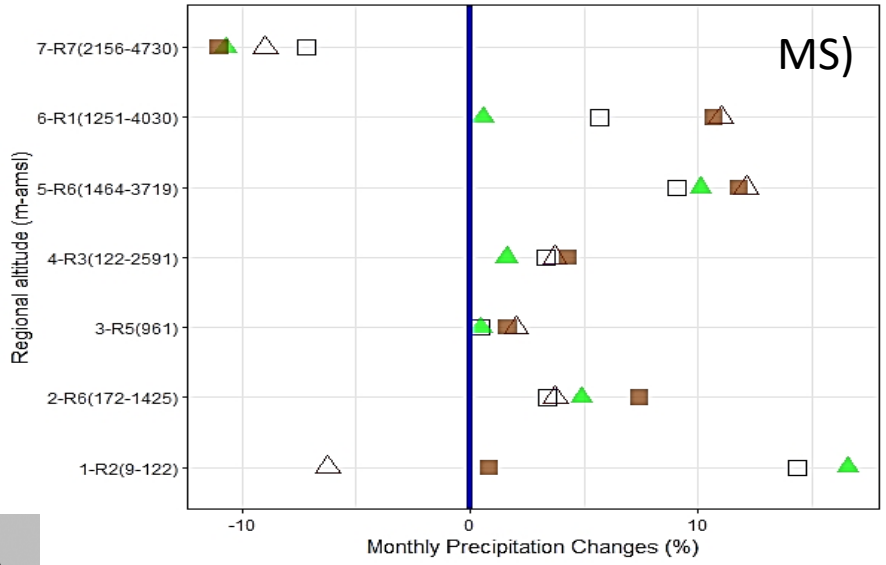


MME = median of the multi-model ensemble

Impact of Model Weights on Precipitation (MME) Signals







unw_rcp = unweighted change signal of the rcp

w_rcp = weighted change signal of the rcp

RCPs unw_rcp85 uw_rcp45 w_rcp45 w_rcp85

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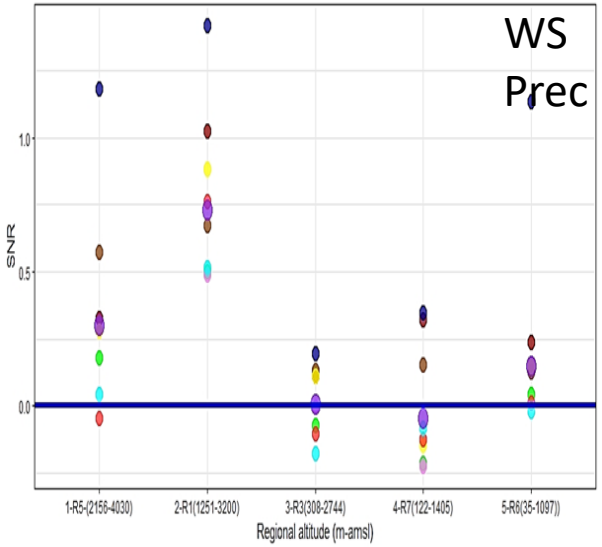
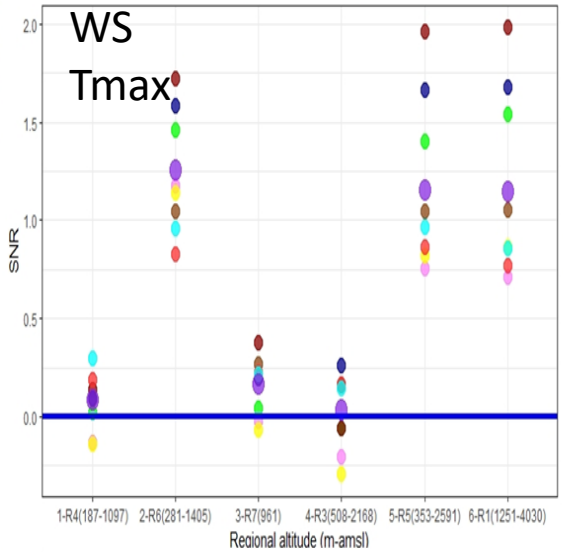
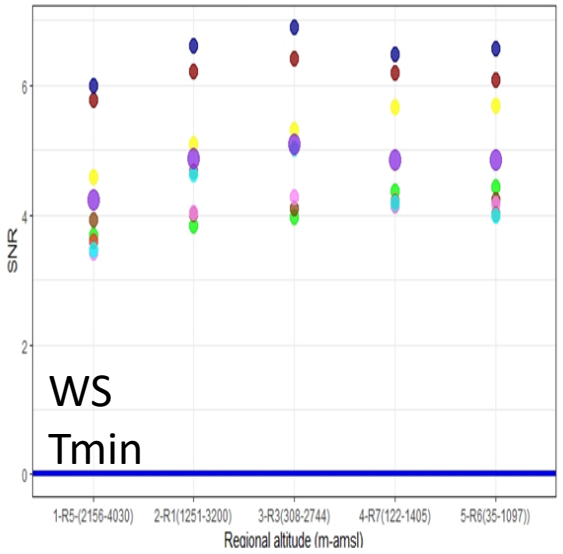
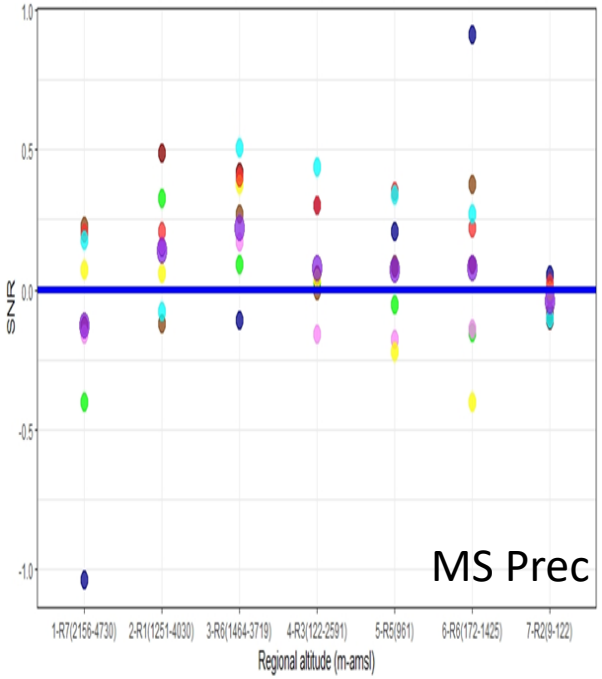
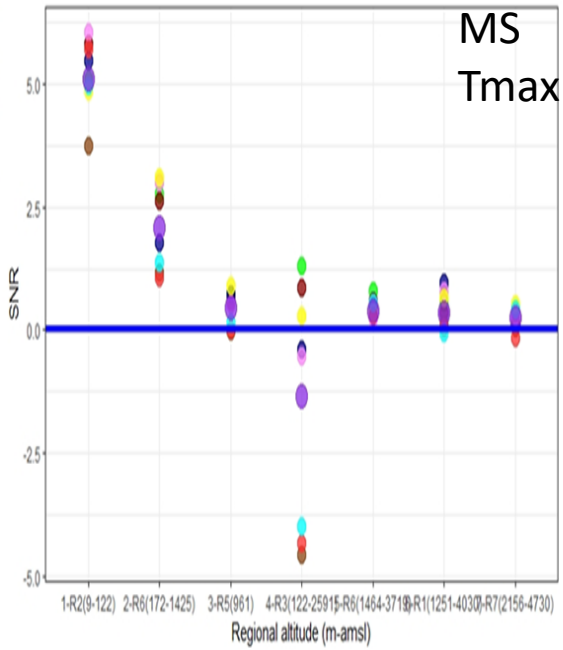
SNR= Robustness of RCP8.5 Change Signals (2080s)

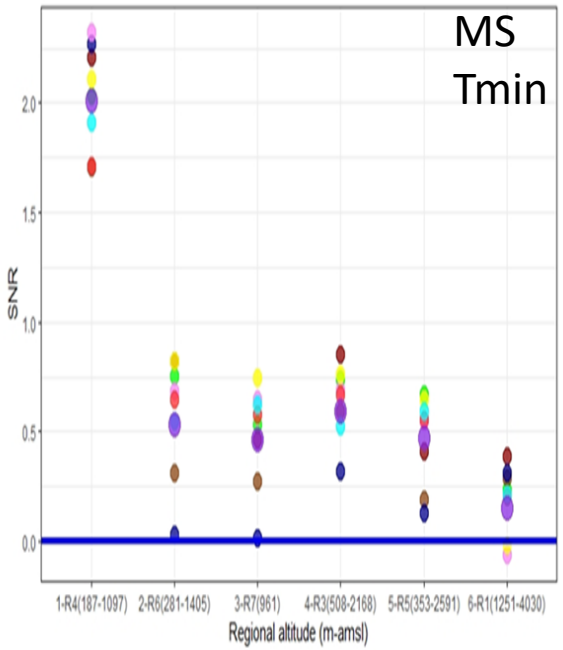


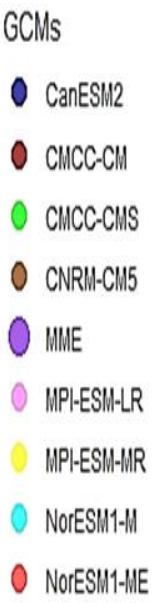












Conclusions

- Relatively low-altitudes stations can explain orography within the UIB
- Atmospheric circulations can resolve observed (fine-scale) patterns, explain governing mechanisms and help to select GCMs
- Precipitation during the WS (MS) increases but decreases during the PMS (over northwestern regions) and better performing models intensify these signals
- Spatial patterns suggest more northward penetrations of westerlies and MS regimes under RCP8.5 particularly over the central Karakoram
- Basin will warm, but increase in Tmin is more profound- a decrease in DTR. The WS (PMS) will warm significantly and follow EDW in UIB.
- ***A large portion of UIB will show MS cooling*** with less warming over the HA of the UIB.
- LI will exhibit more demand (rise in temp) in future for all seasons.
- Overall water supply (and base flow) may increase but seasonal supply-demand will pose serious water-management challenges

A new dimension for future regional research