WMO TPRCC-Network
Third Pole Regional Climate Centre Network

Observed and Reanalysis data, products and services for Third Pole Region

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TPRCC Southern Node: Developments so far

Institutions	Role
India Meteorological Department	**Southern TP Node** Coordination with Consortia Members Operational Data Services, to support operational LRF and climate monitoring Develop quality controlled regional climate datasets, gridded where applicable Collection the data of the integrated observing network and their quality assessment **Other Functions** Long Range Forecast Operational Activities for Climate Monitoring Climate Applications Training and capacity building Research and Development
Support Role	
Indian Institute of Tropical Meteorology	**High-resolution global climate modeling for the Himalayan region, CORDEX South Asia-Downscaled climate change Projections for the Hindu Kush Himalayan region**
NCMRWF	**Modelling Activities for Long Range Mountain Weather Forecast**
MoEF&CC, Mountain Division	**Meteorological Data Network, RCC Users involvement**
SAC (ISRO), IMD	**Himalayan Cryospheric Applications using Space based Observations**
NCPOR, WIHG	**Monitoring of Himalayan Glaciers using Space and Ground based Observations**
Cryosphere Studies in the Himalaya	**Jawaharlal Nehru University, University of Kashmir, IISER**
National Centre for Disease Control, New Delhi	**Climate Change and Health over the Mountain regions**

Data and Products

- Climate normal for observational precipitation and temperature data over Third Pole 1981-2020.
- Analysing the temperature and precipitation temporal and spatial distribution using all available reanalysis dataset. Analysis completed for the period 1981-2020.

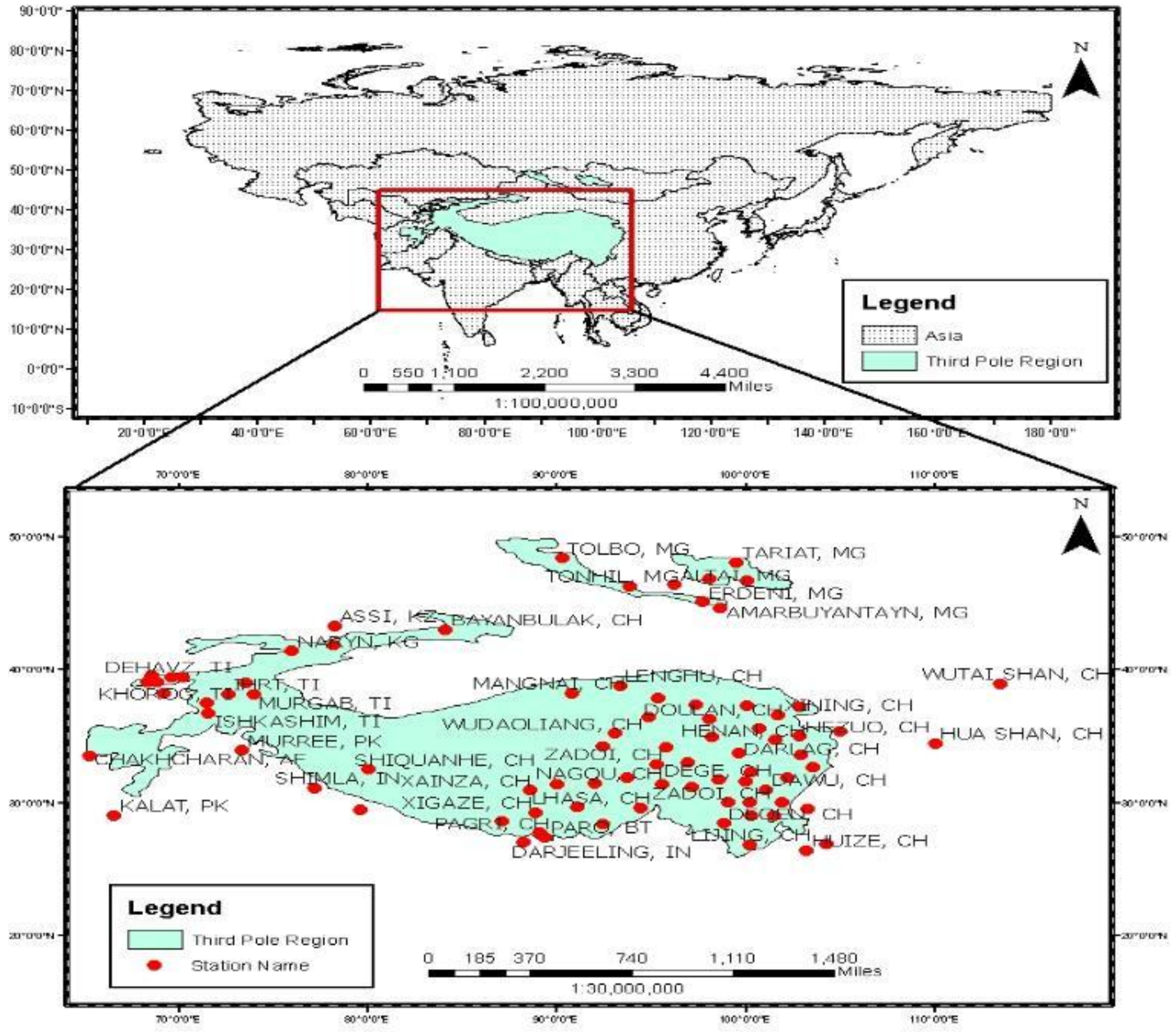
Observational Data: Observed dataset from 82 station (>2000m altitude) in TP region have been organized and prepared time series.

Reanalysis data:
Precipitation: CHIRPS, CMAP, CRU, ERA5, GPCC, MERRA2, CPC, JRA55 and NCEP-NCAR
Temperature: CRU, ERA5, CPC, JRA55 and NCEP-NCAR
Snow Cover: ERA5

Analysis

- Long term changes in meteorological variables
- Validation of reanalysis data against observations (also at different elevation)

LOCATION OF STATIONS IN THE THIRD POLE REGION (ELEVATION > 2000 m)



Countries	No. of Stations
China	53
Tajikistan	11
Mongolia	8
India	3
Pakistan	2
Kyrgyztan	2
Afghanistan	1
Kazakhstan	1
Bhutan	1

82 Stations lie with elevation >2000m

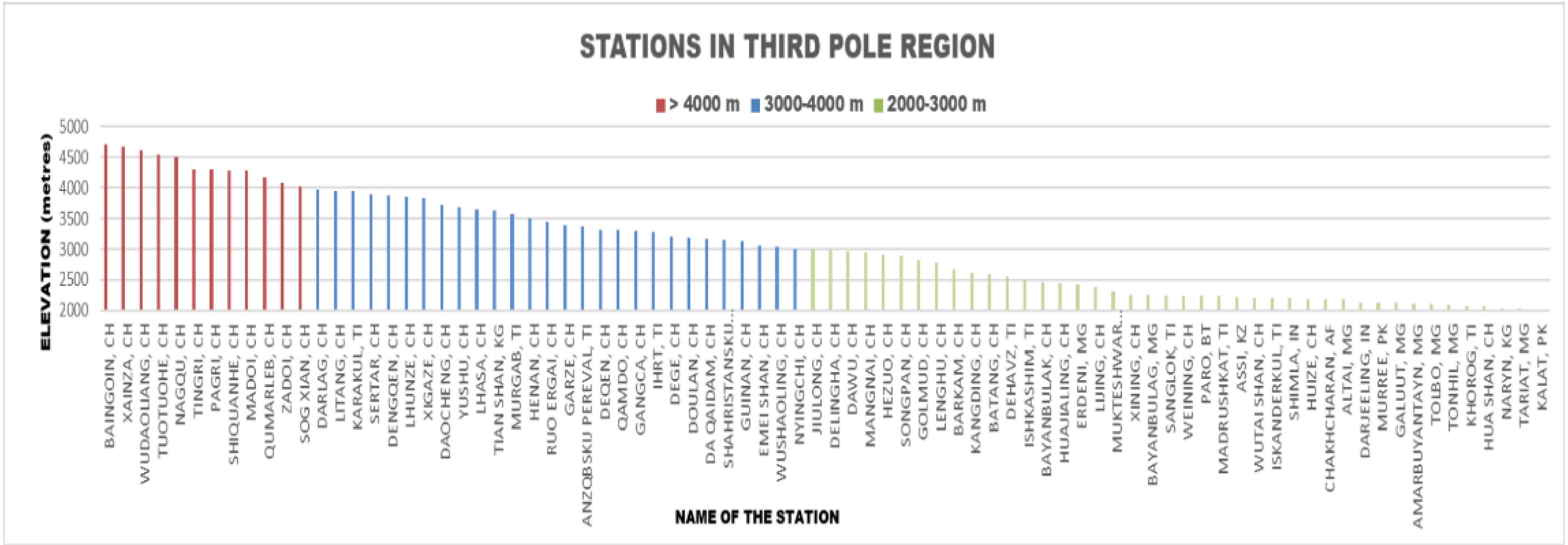
Total ~698 Stations

Stations with more than 2000m elevation

S No.	NAME	LATITUDE	LONGITUDE	ELEVATION
1	ASSI, KZ	43.32	78.25	2216
2	NARYN, KG	41.43	76.00	2041
3	TIAN SHAN, KG	41.88	78.23	3639
4	SHAHRISTANSKIJ PEREVAL, TI	39.57	68.58	3143
5	ISKANDERKUL, TI	39.10	68.38	2204
6	ANZQBSKIJ PEREVAL, TI	39.08	68.87	3373
7	MADRUSHKAT, TI	39.43	69.67	2234
8	DEHAVZ, TI	39.45	70.20	2561
9	SANGLOK, TI	38.25	69.23	2239
10	IHRT, TI	38.17	72.63	3276
11	KARAKUL, TI	39.02	73.55	3940
12	MURGAB, TI	38.17	73.97	3576
13	KHOROG, TI	37.50	71.50	2077
14	ISHKASHIM, TI	36.72	71.60	2523
15	CHAKHCHARAN, AF	33.53	65.27	2183
16	MURREE, PK	33.92	73.38	2127
17	KALAT, PK	29.03	66.58	2017
18	**SHIMLA, IN**	31.10	77.17	2202
19	**MUKTESHWAR KUMAON, IN**	29.47	79.65	2311
20	**DARJEELING, IN**	27.05	88.27	2128
21	PARO, BT	27.40	89.42	2234.79
22	TOLBO, MG	48.42	90.30	2101
23	TARIAT, MG	48.08	99.55	2041
24	TONHIL, MG	46.32	93.90	2095
25	BAYANBULAG, MG	46.83	98.08	2255
26	ALTAI, MG	46.40	96.25	2181
27	GALUUT, MG	46.70	100.13	2126
28	ERDENI, MG	45.15	97.77	2417
29	AMARBUYANTAYN, MG	44.62	98.70	2103
30	BAYANBULAK, CH	43.03	84.15	2459
31	MANGNAI, CH	38.25	90.85	2945
32	LENGHU, CH	38.83	93.38	2771
33	DA QAIDAM, CH	37.85	95.37	3174
34	DELINGHA, CH	37.37	97.37	2982
35	GANGCA, CH	37.33	100.13	3302
36	WUSHAOLING, CH	37.20	102.87	3044
37	GOLMUD, CH	36.42	94.90	2809
38	DOULAN, CH	36.30	98.10	3190
39	XINING, CH	36.62	101.77	2262
48	XIGAZE, CH	29.25	88.88	3837
49	LHASA, CH	29.67	91.13	3650
50	TINGRI, CH	28.63	87.08	4300
51	LHUNZE, CH	28.42	92.47	3861
52	PAGRI, CH	27.73	89.08	4300
53	TUOTUOHE, CH	34.22	92.43	4535
54	ZADOI, CH	32.90	95.30	4068
55	QUMARLEB, CH	34.13	95.78	4176
56	YUSHU, CH	33.02	96.95	3682
57	MADOI, CH	34.92	98.22	4273
58	DARLAG, CH	33.75	99.65	3968
59	HENAN, CH	34.73	101.60	3501
60	RUO ERGAI, CH	33.58	102.97	3441
61	HEZUO, CH	35.00	102.90	2910
62	SOG XIAN, CH	31.88	93.78	4024
63	DENGQEN, CH	31.42	95.60	3874
64	QAMDO, CH	31.15	97.17	3307
65	DEGE, CH	31.73	98.57	3201
66	GARZE, CH	31.62	100.00	3394
67	SERTAR, CH	32.28	100.33	3896
68	DAWU, CH	30.98	101.12	2959
69	BARKAM, CH	31.90	102.23	2666
70	SONGPAN, CH	32.67	103.60	2882.5
71	BATANG, CH	30.00	99.10	2589
72	LITANG, CH	30.00	100.27	3950
73	NYINGCHI, CH	29.57	94.47	3001
74	DAOCHENG, CH	29.05	100.30	3729
75	KANGDING, CH	30.05	101.97	2617
76	EMEI SHAN, CH	29.52	103.33	3049
77	DEQEN, CH	28.45	98.88	3320
78	JIULONG, CH	29.00	101.50	2994
79	LIJING, CH	26.83	100.22	2382
80	HUIZE, CH	26.40	103.25	2189.3
81	WEINING, CH	26.87	104.28	2236
82	HUA SHAN, CH	34.48	110.08	2063

82 Stations lie with elevation >2000m

Total ~698 Stations



- Total 82 stations in the third pole region which have an Elevation > 2000 m

- Latitudinal extent : 20°N- 50°N
- Longitudinal extent: 60°-115°E

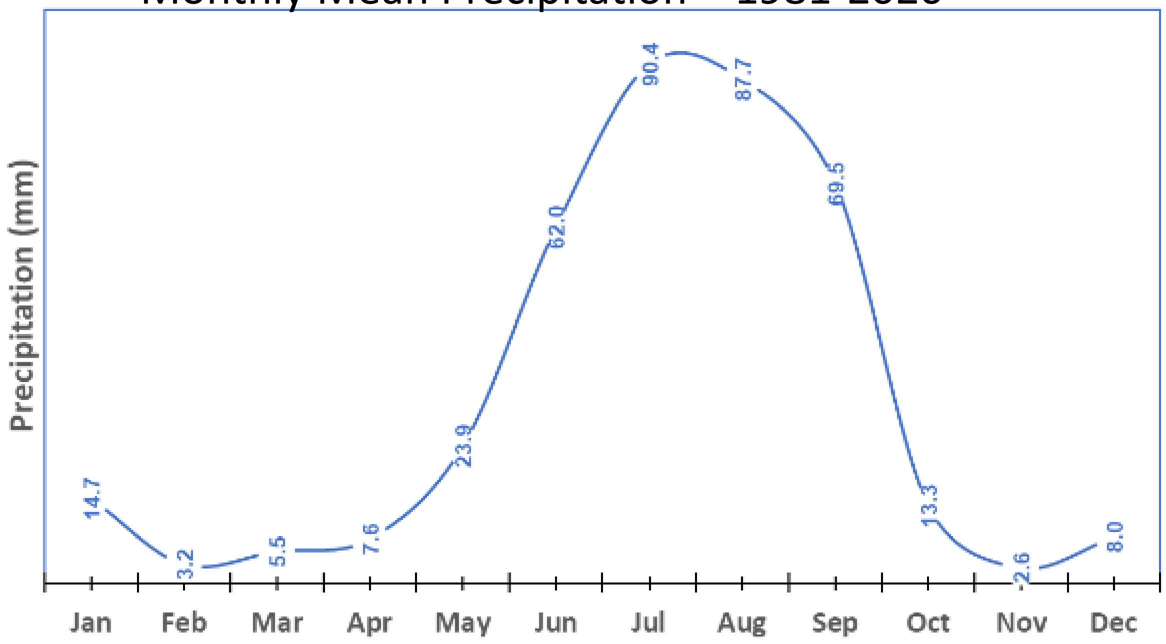
- Altitudinal Zonation
    - > 4000 m : 12 stations
    - 3000-4000 m : 28 stations
    - 2000-3000 m : 42 stations

Reanalysis Database

Data	Description	Variable used	Spatial Coverage	Source
CHIRPS Climate Hazards Group Infrared Precipitation with Station data	Reanalysis products NASA and NOAA, UC Santa Barbara, CA,USA	Precipitation	0.05^0 x 0.05^0	https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_daily/netcdf/p05/chirps-v2.0.${i}.days_p05.nc
CMAP Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP)	Reanalysis data from NOAA PSL, Boulder, Colorado, USA	Precipitation	2.5^0 x 2.5^0	*https://psl.noaa.gov*
CRU Climatic Research Unit	University of East Anglia and Met Office	Precipitation and Temperature	0.5^0 x 0.5^0	https://doi.org/10.1038/s41597-020-0453-3
ERA5 European Environment Agency.	climate data from ECMWF, Reading, UK, with additional sites in Bologna, Italy, and Bonn, Germany	Precipitation and Temperature	0.25^0 x 0.25^0 .	https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels-monthly-means?tab=overview
MERRA2	MDISC, managed by the NASA Goddard Earth Sciences (GES), DISC, USA	Precipitation	0.5 ° x 0.625 °	https://disc.gsfc.nasa.gov/datasets/M2IMNPASM_5.12.4/summary

Data	description	Variable used	Spatial Coverage	Source
CPC Climate prediction center	Global Unified Gauge-Based Analysis data *provided by the NOAA PSL, Boulder, Colorado, USA, from their website at*	Precipitation and Temperature	0.5^0 x 0.5^0	*https://psl.noaa.gov/data/gridded/data.cpc.globalprecip.html*
JRA55	*Japanese 55-year Reanalysis data (JRA-55) project carried out by the Japan Meteorological Agency (JMA)*	Precipitation and Temperature	1.25° x 1.25°	https://rda.ucar.edu/datasets/ds628.1/
NCEP-NCAR	NCEP-NCAR Reanalysis *data provided by the NOAA PSL, Boulder, Colorado, USA, from their website at https://psl.noaa.gov*	Temperature	2.5° x 2.5°	*https://psl.noaa.gov*
GPCC	*Global Precipitation Climatology Centre (GPCC) data provided by the NOAA PSL, Boulder, Colorado, USA, from their website at https://psl.noaa.gov*	Precipitation	0.5^0 x 0.5^0	https://psl.noaa.gov/data/gridded/data.gpcc.html

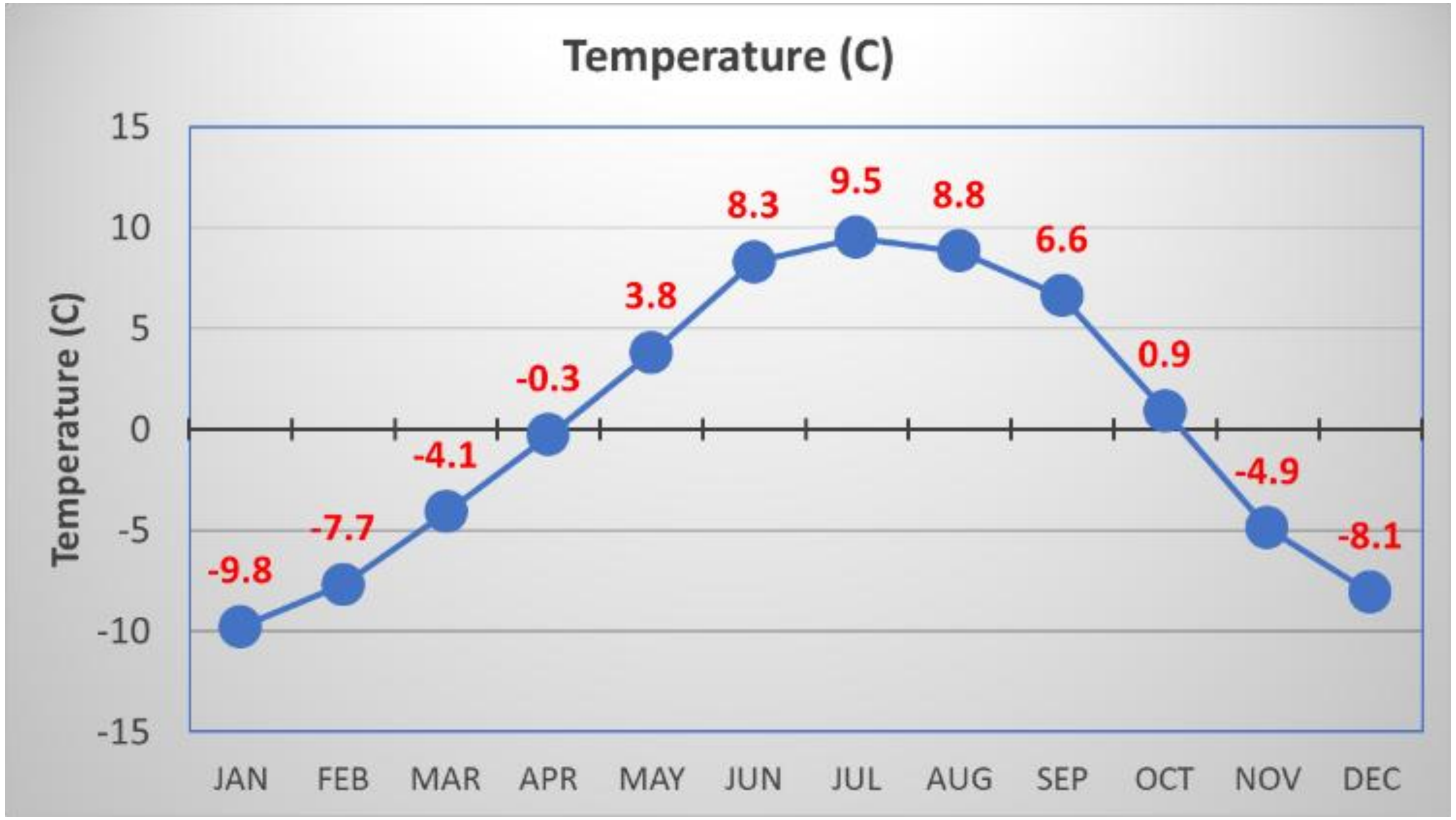
Monthly Mean Precipitation – 1981-2020



Based on observed data of 82 stations
Total annual mean Precipitation = 388.3 mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	14.7	3.2	5.5	7.6	23.9	62.0	90.4	87.7	69.5	13.3	2.6	8.0
%	4	1	1	2	6	16	23	23	18	3	1	2

JJAS	309.6
%	80



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (C)	**-9.8**	**-7.7**	**-4.1**	**-0.3**	**3.8**	**8.3**	**9.5**	**8.8**	**6.6**	**0.9**	**-4.9**	**-8.1**

Lowest Monthly Mean Temp = -33.7 C, BAYANBULAK, CH (2459 m) January, 1984

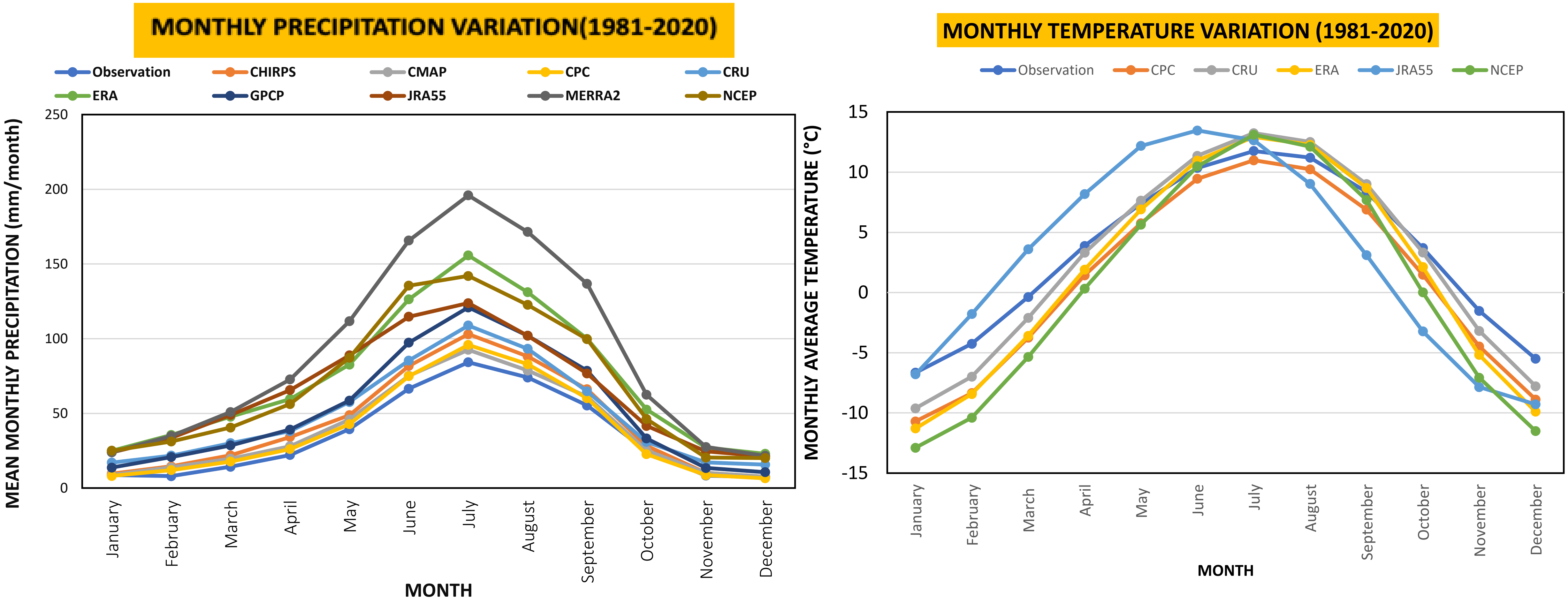
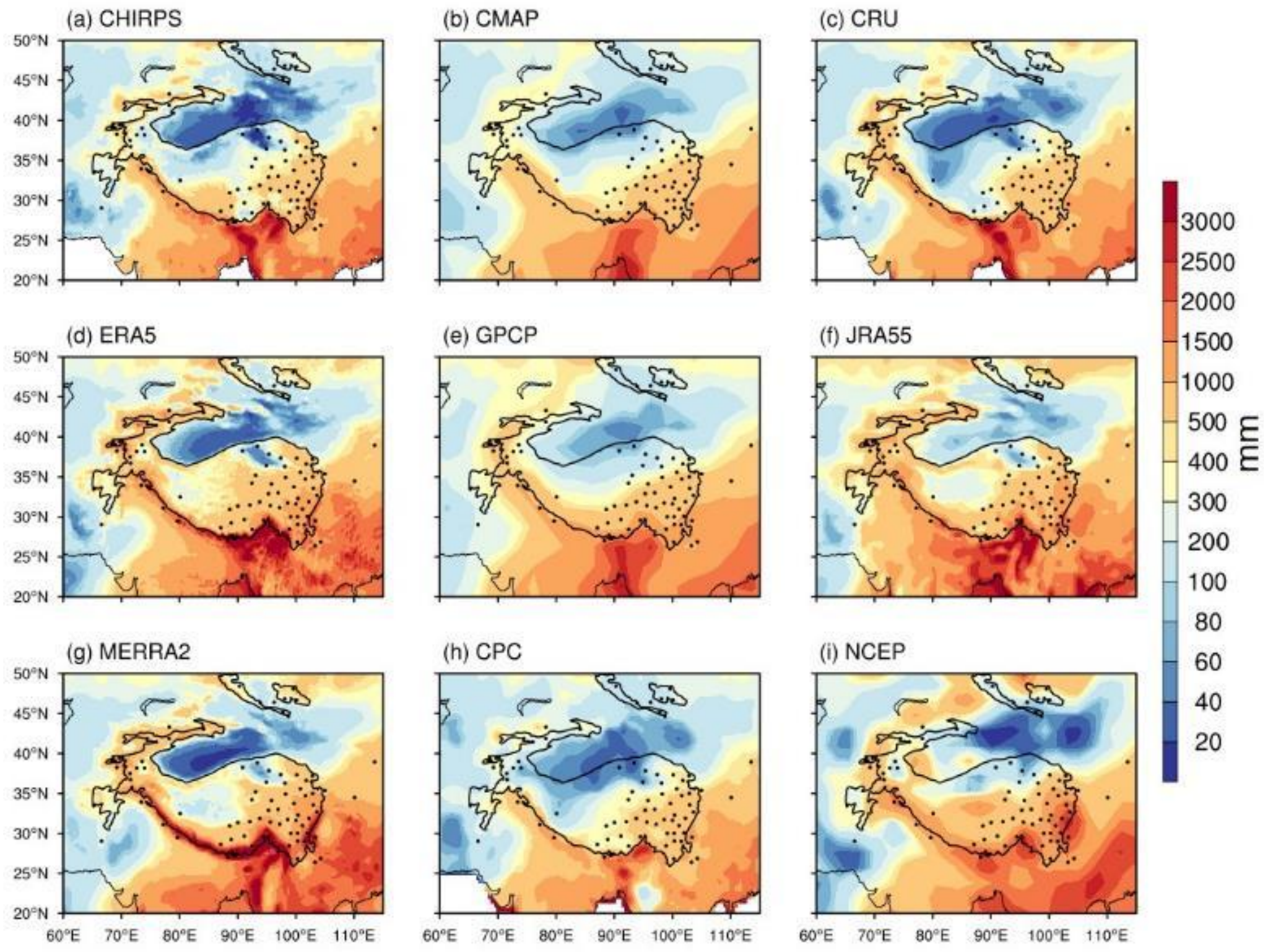
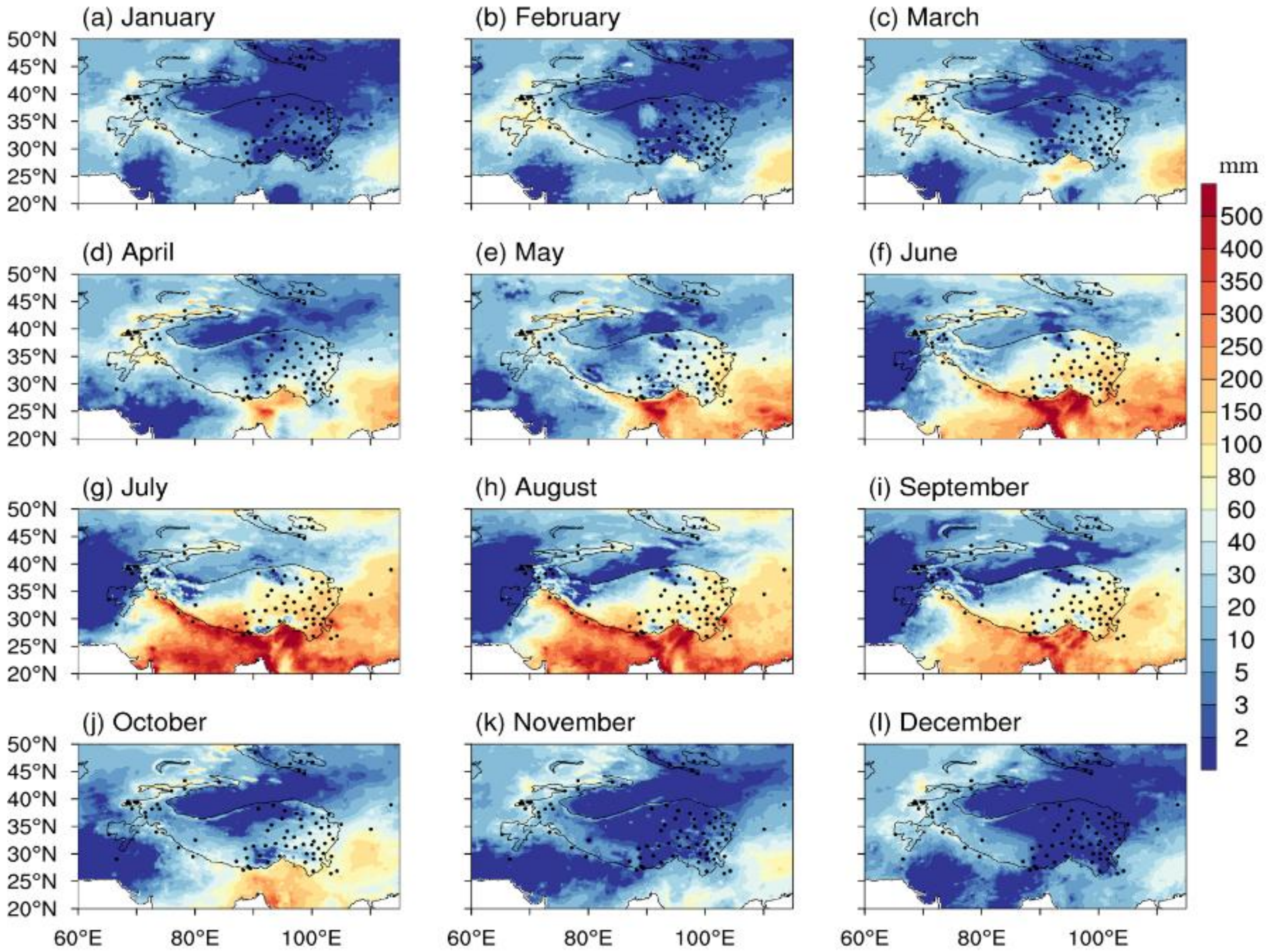


Figure 3: Distribution of monthly variation of precipitation and temperature for 82 stations (elevation > 2000 m) in the Third Pole Region for 40 years (1981-2020). The observation data taken from GTS along with CHIRPS, CMAP, CRU, ERA5, GPCP, JRA55, MERRA2, CPC and NCEP

Spatial distribution of Annual precipitation climatology from CHIRPS, CMAP, CRU, ERA5, GPCP,, JRA55, MERRA2 and CPC over third-pole regions from 1981-2020.



Spatial distribution of monthly precipitation climatology from CHIRPS 1981-2020.



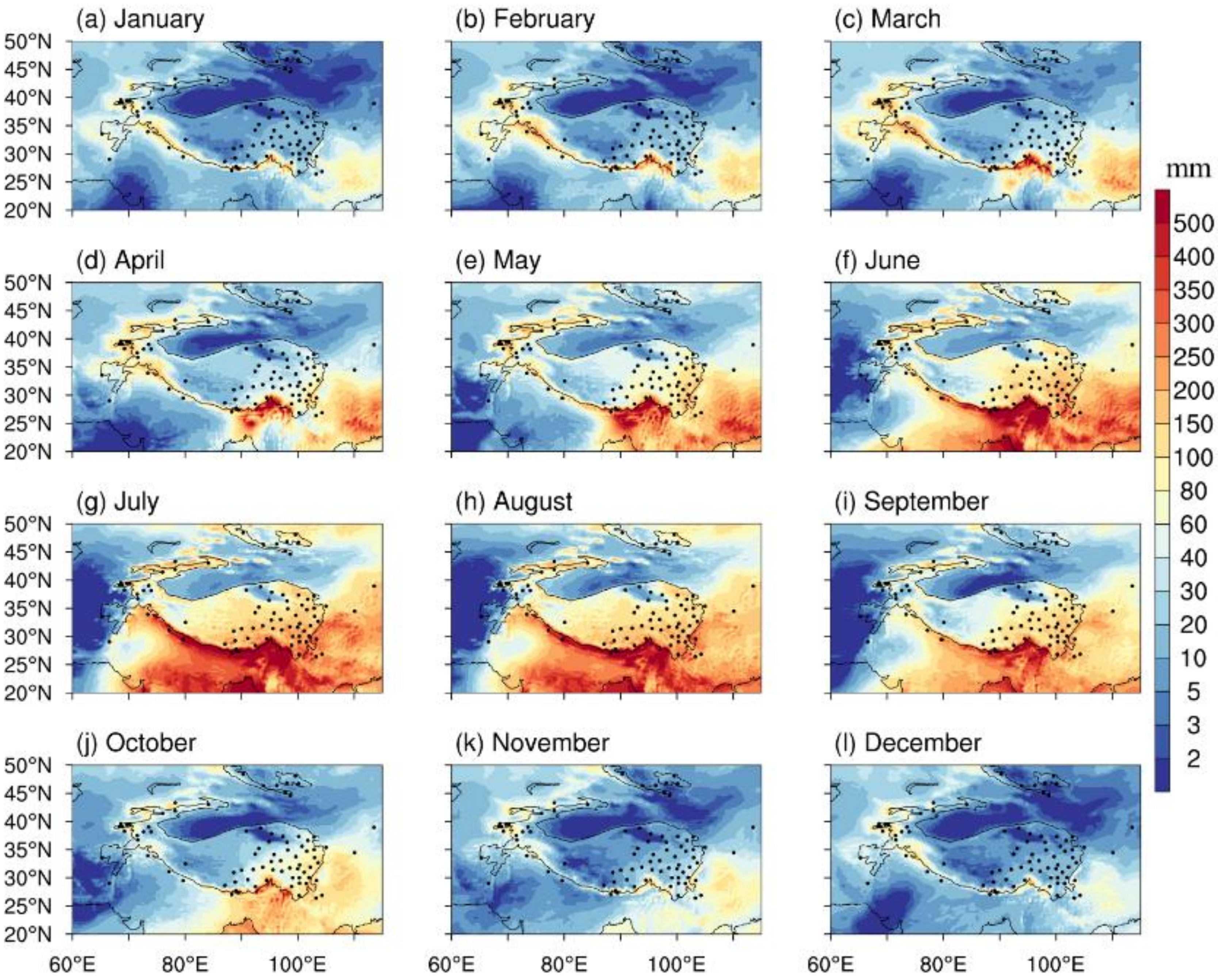
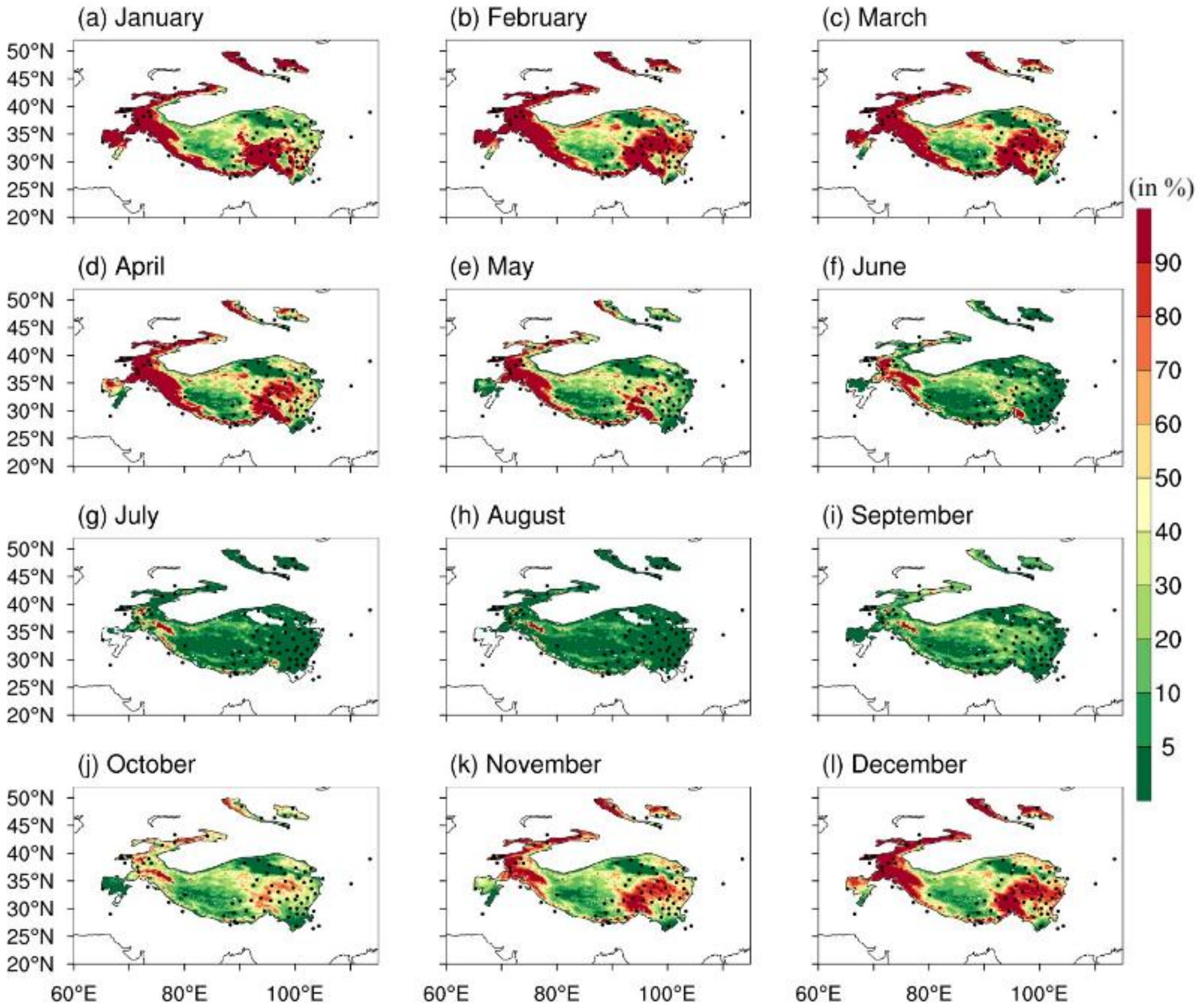


Figure : Spatial distribution of monthly precipitation climatology from ERA5 data over third-pole regions from 1981-2020.

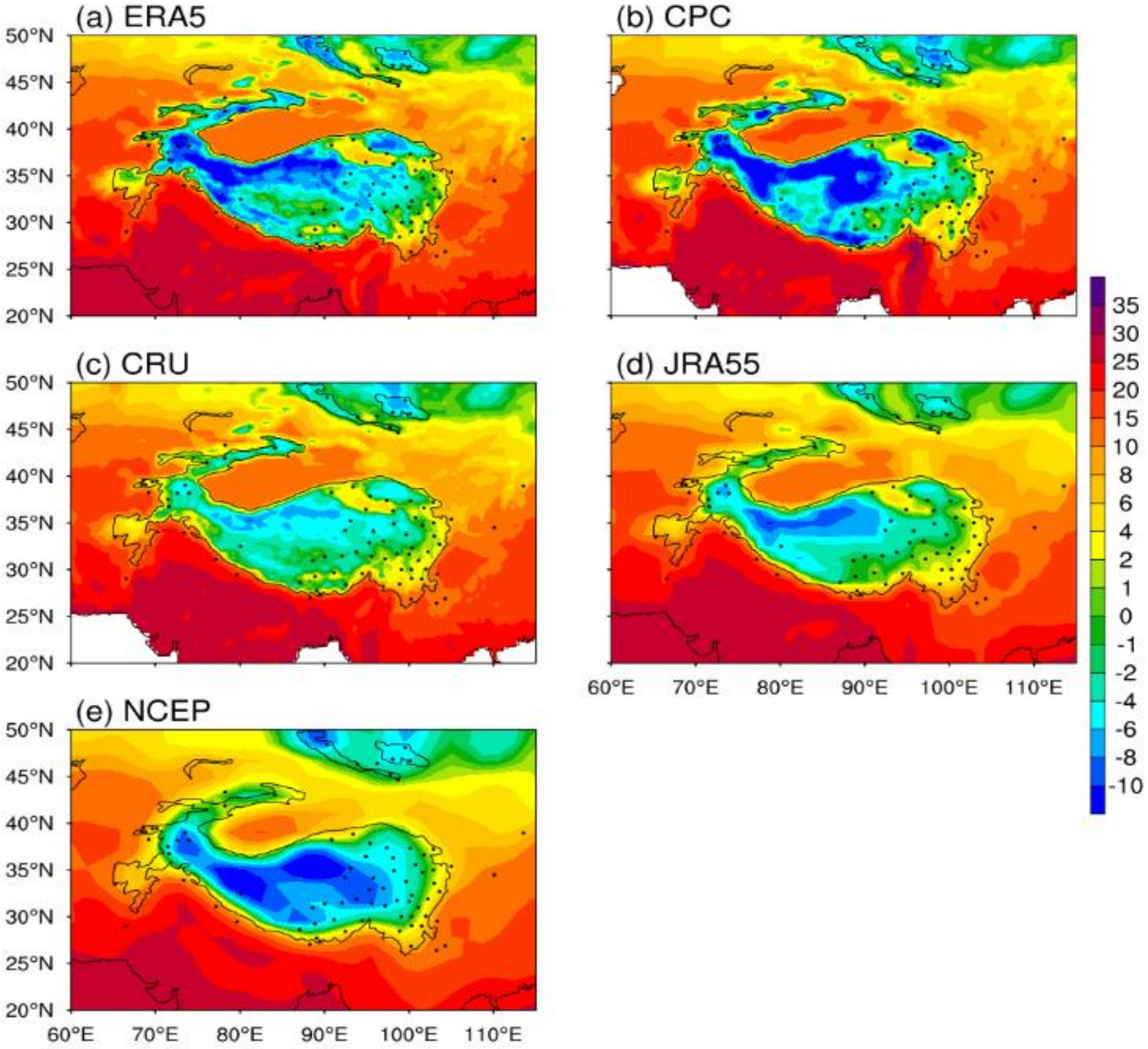
Snow cover (%) Climatology: 1981-2020 ERA5



Snow cover (%)

It represents the fraction (0-1) of the cell / grid-box occupied by snow (similar to the cloud cover fields of ERA5).

Spatial distribution of Annual mean surface air temperature (C) from ERA5, CPC, CRU, JRA55 and NCEP over third-pole regions from 1981-2020 .



Performance matrix (PM)of reanalysis precipitation and temperature data with respect to observation

Data	Precipitation				
	CC	RMSE	MAE	Z-score	E-Score
CHIRPS	0.88	39.48	20.06	0.02	0.45
CMAP	0.85	43.68	23.36	-0.04	0.48
CPC	0.90	35.77	16.20	-0.02	0.37
CRU	0.84	47.91	27.32	0.12	0.50
ERA5	0.82	61.84	42.48	0.51	0.49
GPCP	0.84	48.16	28.42	0.17	0.49
JRA55	0.77	216.33	186.03	1.37	0.94
MERRA2	0.75	79.27	55.62	-3.38	1.33
NCEP	0.78	239.34	207.64	1.45	0.99
	Temperature				
	CC	RMSE	MAE	Z-score	E-Score
ERA5	0.98	4.62	4.22	-0.33	0.5
CPC	0.99	5.22	5.02	-0.08	0.52
CRU	0.99	3.69	3.48	0.02	0.45
JRA55	0.83	6.64	5.63	0.23	0.78
NCEP	0.91	7.02	6.4	-0.26	0.64

Performance matrix of reanalysis precipitation data according to elevation

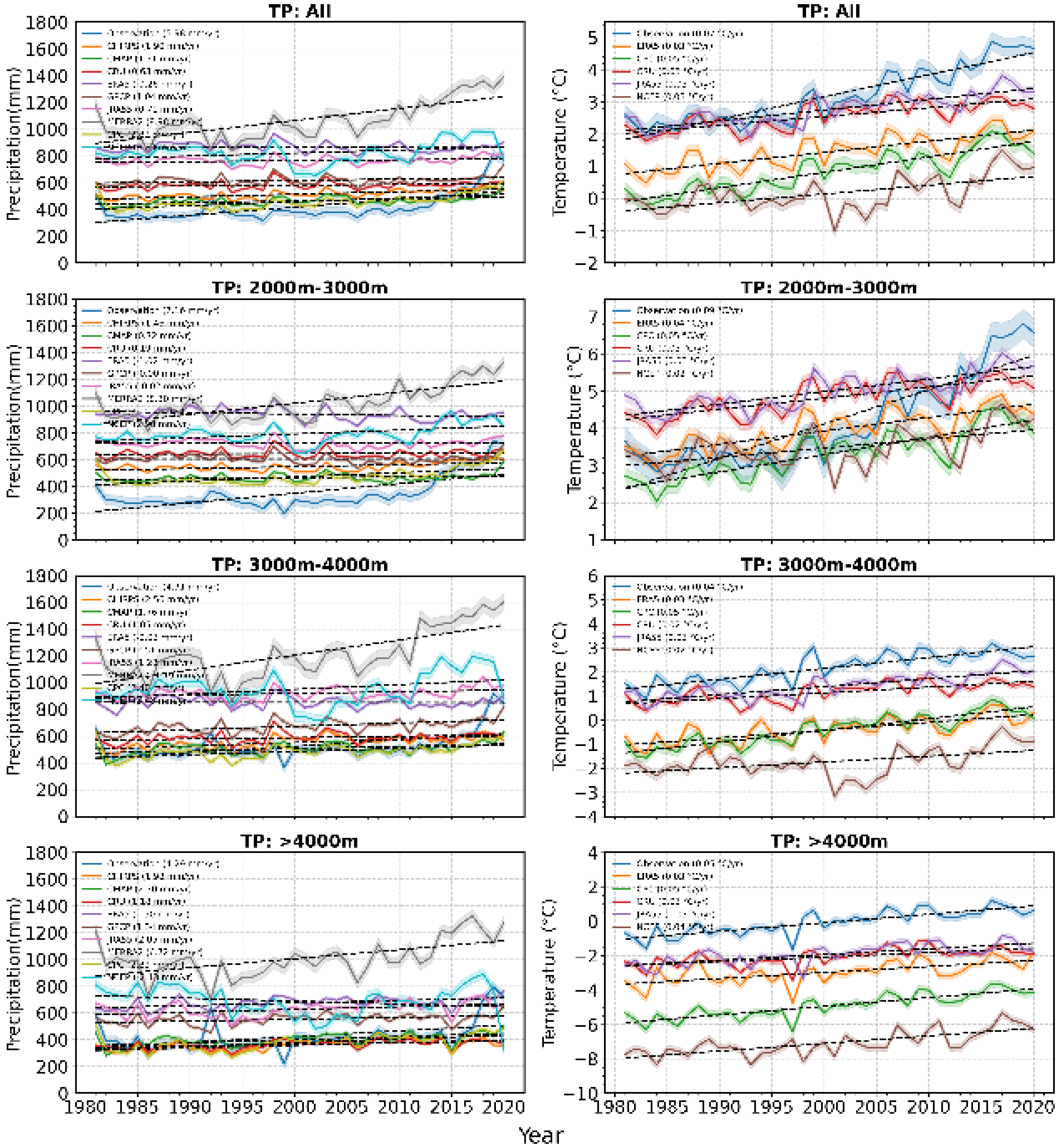
	TP-All		2000-3000m		3000-4000m		>4000 m	
	CC	STDEV	CC	STDEV	CC	STDEV	CC	STDEV
CHIRPS	0.88	0.77	0.84	0.71	0.8	0.81	0.76	0.9
CMAP	0.85	0.74	0.83	0.71	0.78	0.75	0.74	0.84
CPC	0.9	0.8	0.87	0.77	0.75	0.81	0.81	0.91
CRU	**0.84**	**0.71**	**0.81**	**0.67**	**0.77**	**0.72**	**0.75**	**0.82**
ERA5	0.82	0.6	0.8	0.57	0.64	0.61	0.72	0.68
GPCP	0.84	0.67	0.82	0.65	0.64	0.69	0.74	0.73
JRA55	0.67	0.44	0.56	0.4	0.54	0.47	0.53	0.55
MERRA2	0.65	1.15	0.65	1.11	0.55	1.18	0.6	1.19
NCEP	0.68	1.05	0.63	1.38	0.57	1.5	0.61	1.01

Performance matrix of reanalysis temperature data according to elevation

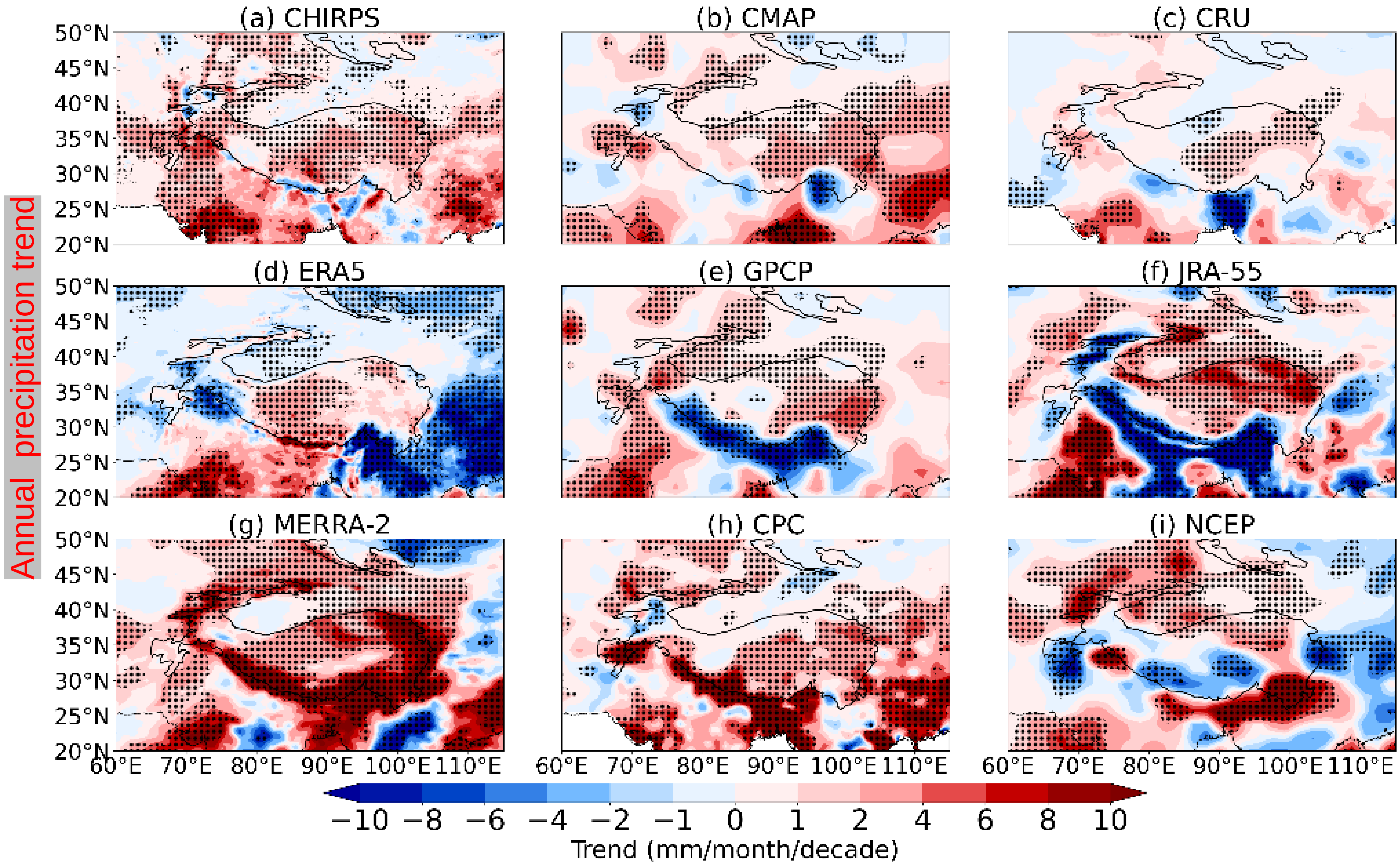
	TP-All		2000-3000m		3000-4000m		>4000 m	
	CC	STDEV	CC	STDEV	CC	STDEV	CC	STDEV
ERA5	0.98	0.76	0.98	0.36	0.90	0.51	0.96	1.24
CPC	0.99	0.84	0.97	0.11	0.92	1.05	0.95	0.97
CRU	0.99	1.05	0.99	0.33	0.96	1.26	0.98	1.30
JRA55	0.85	1.46	0.84	0.80	0.80	1.59	0.83	1.40
NCEP	0.79	0.25	0.86	1.01	0.84	1.21	0.86	0.50

- JRA55, MERRA2, NCEP show poor agreement with observations.
- CHIRPS, CMAP, CRU and CPC, ERA5, and GPCP data are comparable against observation

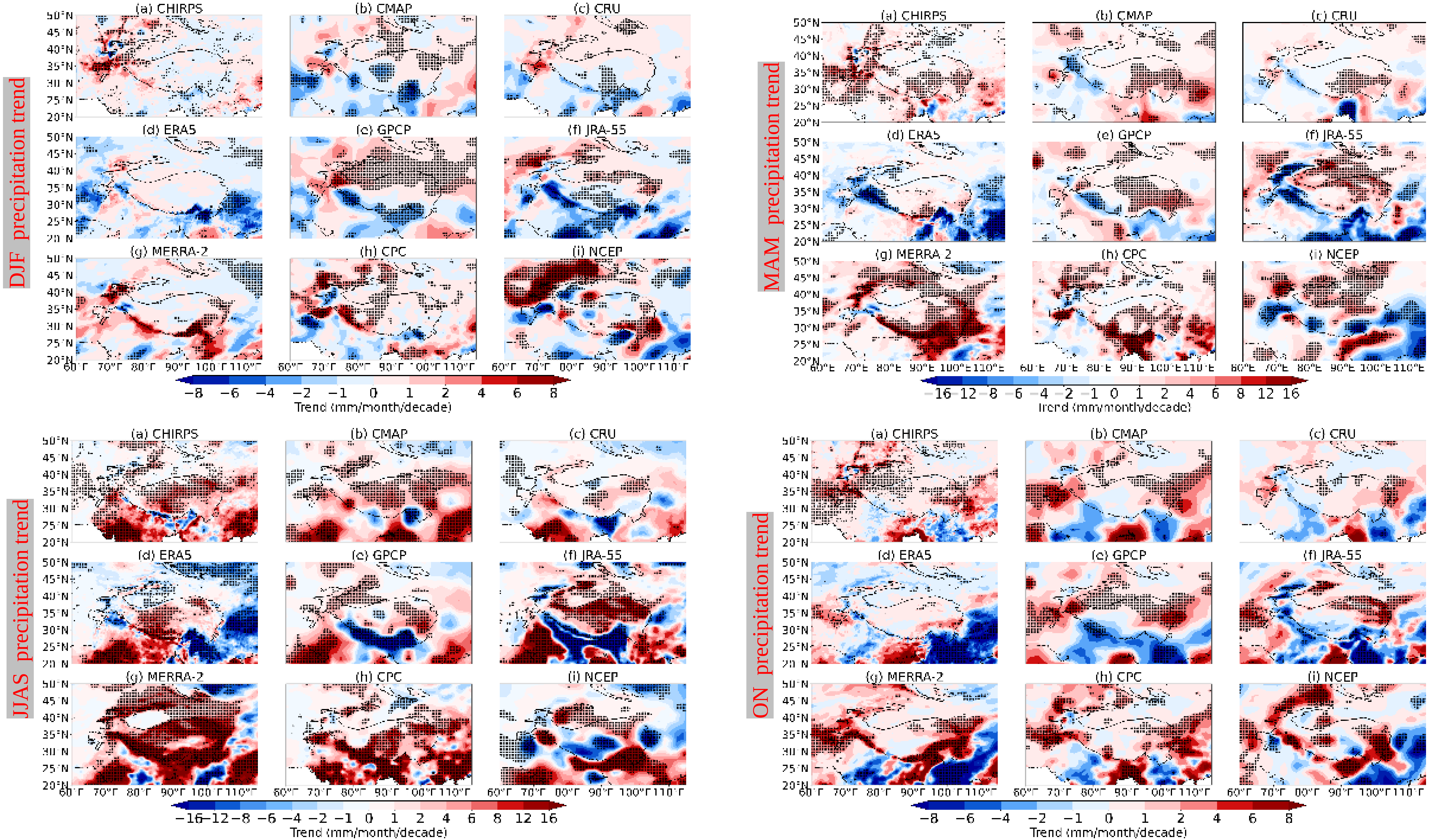
Annual



- The Third Pole is experiencing a warming trend and increasing precipitation, with notable variations across its regions. Temperature increases are generally more pronounced in the central, eastern, and northwestern parts of the plateau, particularly during the winter season.
- Warming over TP region 0.34 °C/decade which exceeds the rates for the Northern Hemisphere (0.29 °C/decade) and the global means (0.19 °C/decade)
- The TP is experiencing a warming trend at a rate that is about twice the global mean, a phenomenon known as "Tibetan Amplification (You et al., 2020)".
- Precipitation in the TP is showing an increasing trend overall, especially in the summer months, and with a significant increase in precipitation with increasing elevation. However, this increase is not uniform, with some regions, particularly the southern and southeastern parts, showing slightly decreasing trends in annual precipitation.



Stippling show significant trend at 95%


DJF precipitation trend
(a) CHIRPS
(b) CMAP
(c) CRU
(d) ERA5
(e) GPCP
(f) JRA-55
(g) MERRA-2
(h) CPC
(i) NCEP
−8 −6 −4 −2 −1 0 1 2 4 6 8
Trend (mm/month/decade)
MAM precipitation trend
(a) CHIRPS
(b) CMAP
(c) CRU
(d) ERA5
(e) GPCP
(f) JRA-55
(g) MERRA-2
(h) CPC
(i) NCEP
−16 −12 −8 −6 −4 −2 −1 0 1 2 4 6 8 12 16
Trend (mm/month/decade)
JJAS precipitation trend
(a) CHIRPS
(b) CMAP
(c) CRU
(d) ERA5
(e) GPCP
(f) JRA-55
(g) MERRA-2
(h) CPC
(i) NCEP
−16 −12 −8 −6 −4 −2 −1 0 1 2 4 6 8 12 16
Trend (mm/month/decade)
ON precipitation trend
(a) CHIRPS
(b) CMAP
(c) CRU
(d) ERA5
(e) GPCP
(f) JRA-55
(g) MERRA-2
(h) CPC
(i) NCEP
−8 −6 −4 −2 −1 0 1 2 4 6 8
Trend (mm/month/decade)

In the Himalayan regions of northwest India, the primary weather systems responsible for wintertime precipitation are the Western Disturbances, westerly upper tropospheric synoptic-scale waves, that can undergo orographic capture and intensification as they pass over south central Asia.

- Major snowfall events in the central Himalayas are primarily caused by Western Disturbances.

- Orographic forcing is the dominant factor in precipitation in the central Himalayas.

- Significant precipitation in this region only occurs when the large-scale flow evolves to a favorable geometry with respect to the mountains.
-
- Observations from a meteorological network (Marsyandi River basin) suggest that snowfall contributes up to 25– 35% of annual precipitation at high elevations (> 3000 m MSL) in the central Himalayas. This percentage increases with altitude and tends to mitigate differences in annual precipitation between very-high-altitude stations (> 4000 m MSL) and lower-elevation ridge stations (3000–4000 m MSL). The snow contribution can be up to 100 cm or more, liquid water equivalent. However, these amounts are strongly modulated by interannual variability, which can exceed 20–30% of annual totals. Low-elevation stations (< 3000 m MSL) stay above 0C and receive little rain during the winter months (generally < 20 cm over the entire Jan–Mar period).

Summary

- **CPC, CRU and ERA-5 Reanalysis data provide the better performance over TP region when compared with observed data for Temperature and Precipitation.**
- **CRU and CPC have spatial resolution of 0.5^0 x 0.5^0 and ERA-5 have spatial resolution of 0.25^0 x 0.25^0**
- **Observed Data are available (Jan 1981- April 2025) on TPRCC - Southern Node website.**
- **Reanalysis date are available on TPRCC - Southern Node website.**

The contribution of snow, to annual total precipitation remains largely unknown.
There also is a lack of understanding of the weather systems that are important for winter precipitation in the central Himalayas.

Recent landslide, cloudburst and associated flash flood events recorded in the Indian Himalayan Region (IHR)

Events	Date	Area	Period
Rainfall-induced landslide[a]	20 July 1970	Belakuchi (Birahi River), Uttarakhand	M
Rainfall-induced landslide[a]	August 1981	Mandakhal Pauri Garhwal, Uttarakhand	M
Cloudburst[w]	22-July 1983	Karmi Village, Almora, Uttarakhand	M
Cloudburst-flash flood[c]	29 September 1988	Soldan Khad, Sutlej Valley, Himachal Pradesh	WM
Rainfall-induced landslide[a]	July 1990	Neelkanth, Uttarakhand	M
Landslide-flash flood[c]	31 July - 2 August 1991	Maling, Spiti Valley, Himachal Pradesh	M
Cloudburst-landslide[c]	8 July 1993	Nathpa, Sutlej Valley, Himachal Pradesh	OM
Cloudburst-landslide[c]	24 February 1993	Jhakri, Sutlej Valley, Himachal Pradesh	
Cloudburst-flash flood[c]	11 August 1997	Chirgaon, Himachal Pradesh	M
Rainfall-induced landslide[d, e]	11–19 August 1998	Malpa and Okhimath Rishikesh-Mana, Uttarakhand	M
Cloudburst-flash flood[c]	30 July 2000	Sutlej Valley, Himachal Pradesh	M
Cloudburst-flash flood[f]	5–10 June 2000	Gangotri Glacier, Uttarakhand	OM
Cloudburst-landslide[g]	31 August 2001	Gona Village, Uttarakhand	M
Cloudburst-landslide[h, i]	16 July 2001	Phata Byung, Rudraprayag, Uttarakhand	M
Cloudburst-landslide[j]	10 August 2002	Budha Kedar, Tehri, Uttarakhand	M
Rainfall-induced landslide[a]	16 July 2003	Shilagarh, Garsa Valley, Kullu, Himachal Pradesh	M
Cloudburst-flash flood[k]	16 July 2003	PuliyaNal, Kullu, Himachal Pradesh	M
Rainfall-induced landslide[l]	23 September 2003	Varunavat, Uttarkashi district, Uttarakhand	WM
Rainfall-induced landslide[c]	July 2005	Dhanyau village, Rudraprayag, Uttarakhand	M
Cloudburst-flash flood[m]	June 2005, 1 August 2006	Phyang, Igu, and LehNalla, Jammu and Kashmir	OM
Rainfall-induced landslide[a]	July 2007	Mandakini river basin, Uttarakhand	M
Rainfall-induced landslide[g]	July 2007, September 2007	Sikkim, Darjeeling	M, WM
Cloudburst-landslide[g]	July 12 2007	Devpuri, Chamoli, Uttarakhand	M
Rainfall-induced landslide[n]	8 August 2009	Kuity Village, Berinag-Munsiyari, Uttarakhand	M
Cloudburst-landslide[o]	4–6 August 2010	Leh, Jammu and Kashmir	M
Rainfall-induced landslide[d, e]	18–21 September 2010	Malpa and Okhimath Rishikesh-Mana highway, Uttarakhand	WM
Cloudburst-landslide[o]	25 July 2011	Leh, Jammu and Kashmir	M
Rainfall-induced flash flood[p]	15–25 August 2010 15–25 August 2011	Dokriani Glacier, Uttarakhand	M
Cloudburst-flash flood[q]	3 August 2012	Asiganga, Uttarkashi, Uttarakhand	M
Cloudburst-flash flood[r]	13 September 2012 14 September 2012	Okhimath, Uttarakhand	WM
Cloudburst-flash flood[s]	16–17 June 2013	Kedarnath, Uttarakhand	OM
Cloudburst-flash flood[t]	16–17 June 2013	Gangotri Glacier, Uttarakhand	OM
Cloudburst-flashflood[u]	5–6 September, 2014	Udhampur, Jammu and Kashmir	WM
Cloudburst-flash flood[v]	1 July 2016	Bastadi Narula, Uttarakhand	OM

M = Monsoon (July–August), OM = Pre-monsoon (June), and WM = Withdrawal of Indian Summer Monsoon (September).

Thanks

TP Region LRF: Temp and precipitation anomaly as well as probability based on multi model ensemble climate forecasting system

MMCFS Model Details

- Atmospheric Component: Global Forecast System (GFS) with spectral resolution of T382 and 64 hybrid vertical levels
- Ocean Component: Geophysical Fluid Dynamics Laboratory (GFDL) Flexible Modeling System (FMS) & Modular Ocean Model version 4 (MOM4; Griffies et al. 2004). The horizontal resolution of the ocean component (MOM4) is 0.25° between 10°S to 10°N latitude band and 0.5° elsewhere.
- In addition to the atmosphere and ocean component, the CFSv2 also employs a four-layer NOAH land surface model [*Ek et al*., 2003] with dynamic vegetation as well as a three-layer (one layer of snow and two layers of sea ice) interactive sea ice model [*Winton*, 2000].
- The ocean and atmosphere are coupled without flux correction.

- **Model resolution**: T328L64
- **Ensemble size**: 12 members for Hindcast and 40 members for forecast
- **Forecasts period**: 9 months
- Initial Condition:
  - Ocean Initial Condition: From INCOIS
  - Atmospheric Initial Condition: From NCMRWF