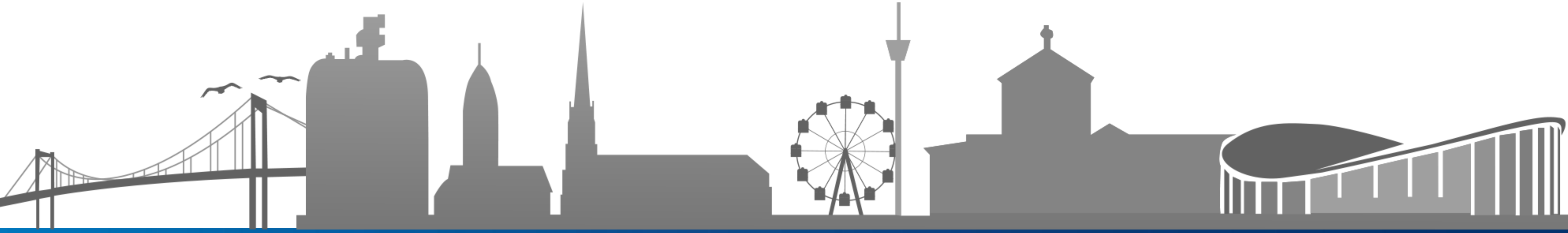
Climate change impact on water security of India based on coupled model intercomparison project phase 6 experiments

DEVENDRA KUMAR SHARMA,

INDIA

Chairman, Himachal Pradesh Electricity Regulatory Commission



Introduction:

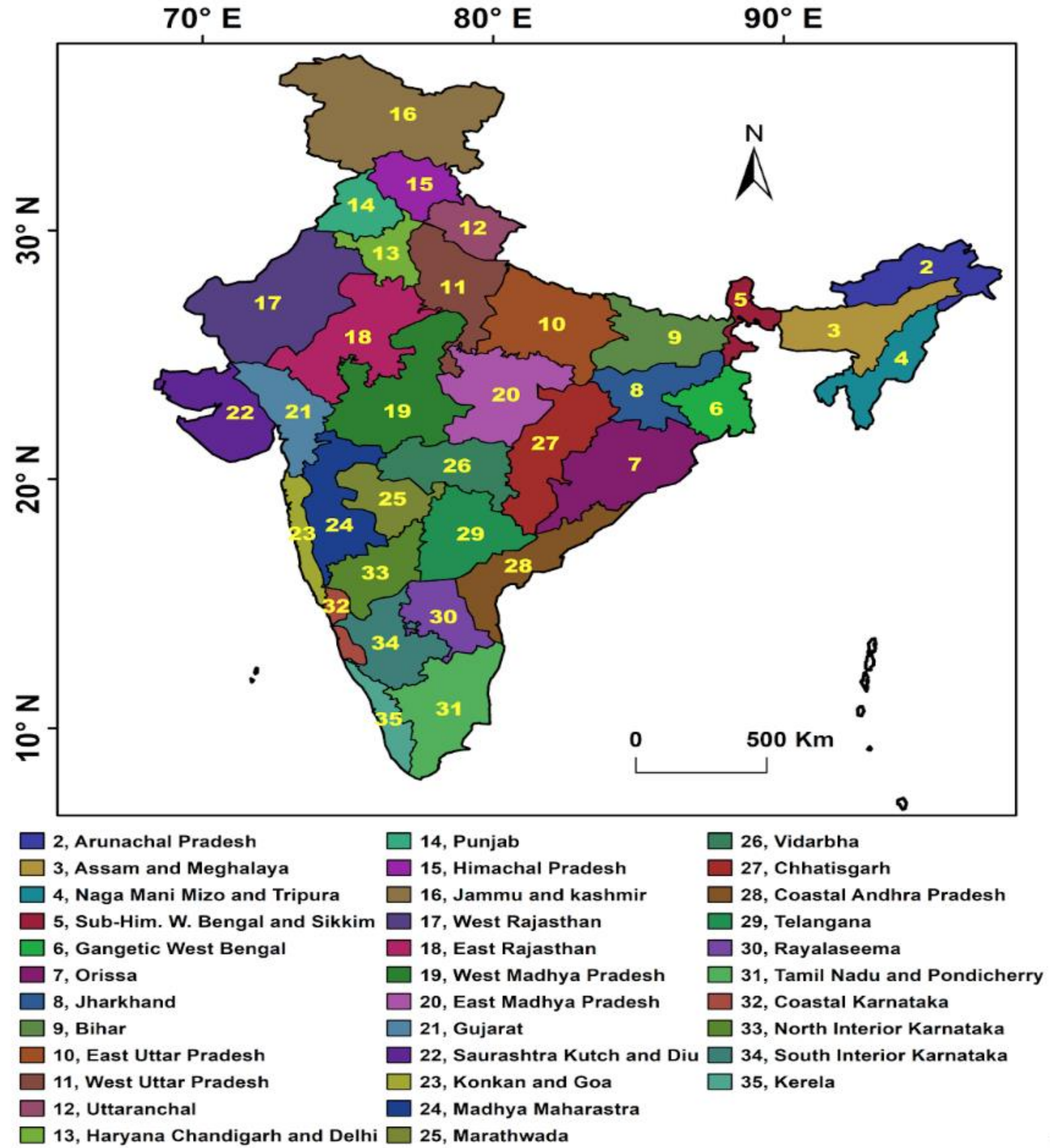
- Climate Change is projected to impact water resources in India due to meteorological variables like precipitation and temperature. Growing water demand in India is a challenge which has been aggravated by the climate change.
- Coupled Model Intercomparison Project 6 (CMIP6) has been used to project change of precipitation and temperature till 2100.
- Objectives of the study include the following:
  - Detection of climate change signals in precipitation and temperature in over India as well as 34 meteorological sub-divisions in India (in total 36 volumes including an executive summary).
  - Projection of precipitation and temperatures in near future (2021-2060) and far future (2061-2100) by downscaling from CMIP6 for Shared socio-economic pathways (watts per square meter), SSP1-2.6 (sustainability and balance growth), SSP2-4.5 (middle path), SSP3-7.0 (fragmented world of resurgent nationalism) and SSP4-8.5 (unconstrained growth).
  - Examining the characteristics of precipitation (monthly, seasonal and annual) and temperature (maximum, minimum and mean at monthly time scales) under all four SSPs.
  - Assessment of extreme precipitation over India under all SSPs
  - Adaptation needed against heat waves, flood hazards, reduced agriculture yield, optimum water use etc. have been discussed. Short term and long term measures to ensure water security have been presented in the paper.

Downscaling Methods:

- Hybrid delta (HD) method has been selected for determining the future projections of precipitation and temperature over all 34 meteorological sub-divisions of India. This method is hybrid of simple delta method and bias-correction and statistical downscaling (BCSD) method.
- Projected future series in HD method borrows spatial and temporal variability from observed series while their probability distributions (mean, variance, skewness, kurtosis etc.) match with the climate model distribution.

Study Area and Data Used:

- Coupled Model Intercomparison Project, CMIP 6 dataset by World Climate Research Program (WCRP) for 11 GCMs has been considered for all four SSPs. The projections of precipitation and temperature from CGMs has been done at the resolution of India Meteorological Department (IMD). CGMs have very coarse resolution.



70° E
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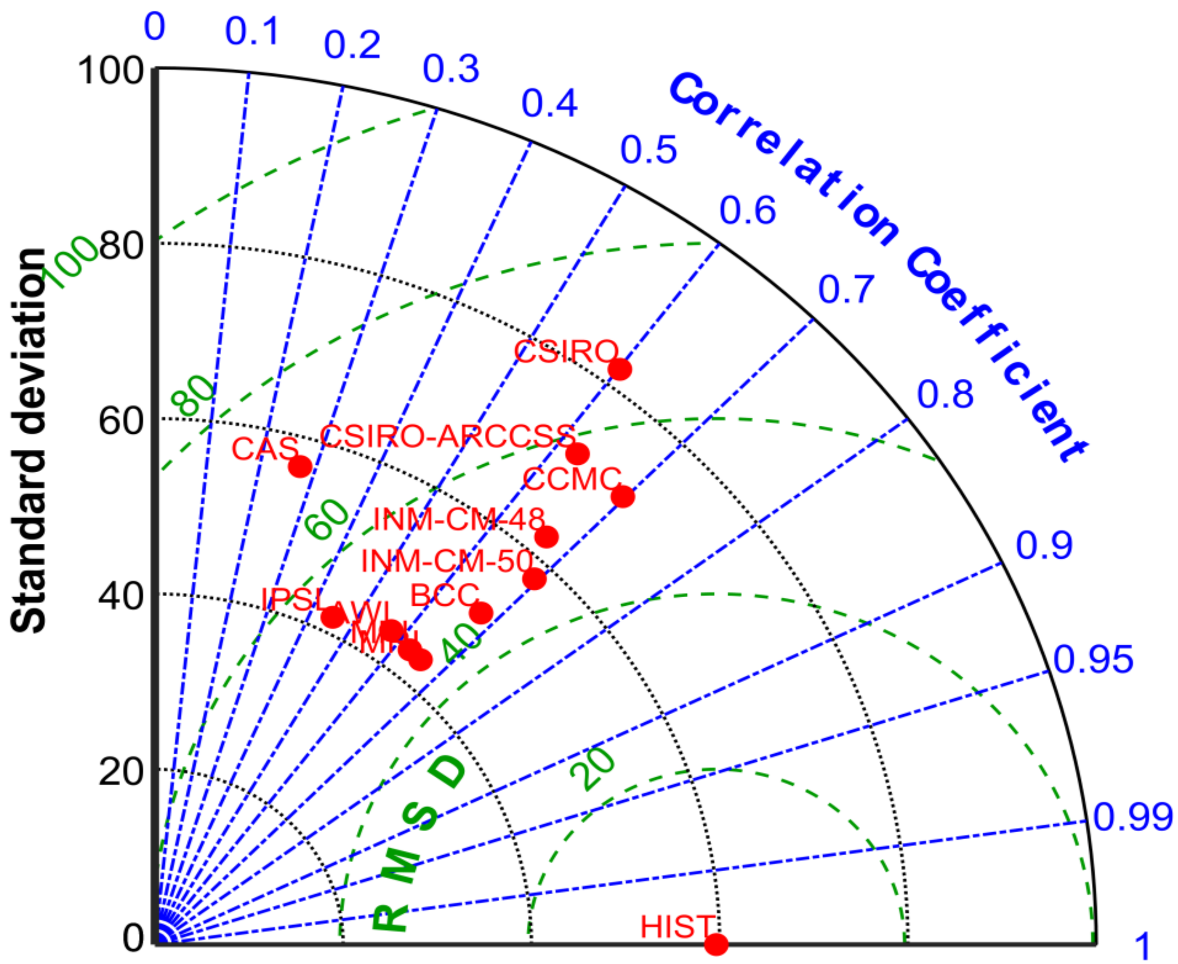
2, Arunachal Pradesh
3, Assam and Meghalaya
4, Naga Mani Mizo and Tripura
5, Sub-Him. W. Bengal and Sikkim
6, Gangetic West Bengal
7, Orissa
8, Jharkhand
9, Bihar
10, East Uttar Pradesh
11, West Uttar Pradesh
12, Uttaranchal
13, Haryana Chandigarh and Delhi
14, Punjab
15, Himachal Pradesh
16, Jammu and kashmir
17, West Rajasthan
18, East Rajasthan
19, West Madhya Pradesh
20, East Madhya Pradesh
21, Gujarat
22, Saurashtra Kutch and Diu
23, Konkan and Goa
24, Madhya Maharastra
25, Marathwada
26, Vidarbha
27, Chhatisgarh
28, Coastal Andhra Pradesh
29, Telangana
30, Rayalaseema
31, Tamil Nadu and Pondicherry
32, Coastal Karnataka
33, North Interior Karnataka
34, South Interior Karnataka
35, Kerela

Uncertainty with GCM Data:

- Climatic projections generated by GCMs are highly uncertain for precipitation and its extremes. Future emissions, internal climate variability and model uncertainty lead to uncertainties in the data which hinder the application of climate projections in impact and change studies. Simplest technique is correcting the long term climatological mean bias between observations and simulations.
- Taylor diagram quantitatively measures how well simulated and observed patterns match each other in terms of spatial correlation factor, root-mean-square error and the ratio of standard deviation.



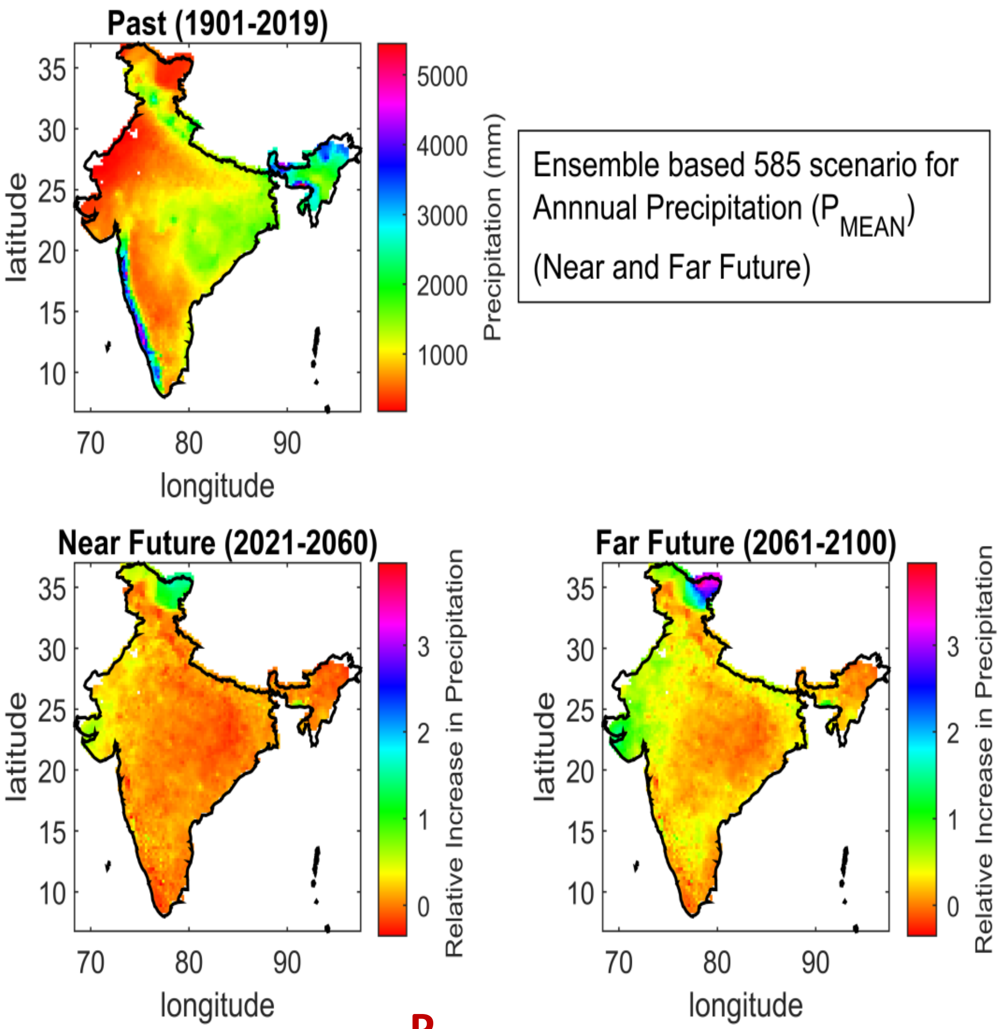
Taylor Diagram for determination of suitable GCMs for analyzing Precipitation data over India

Table 1. Global Climate Models used in this study.

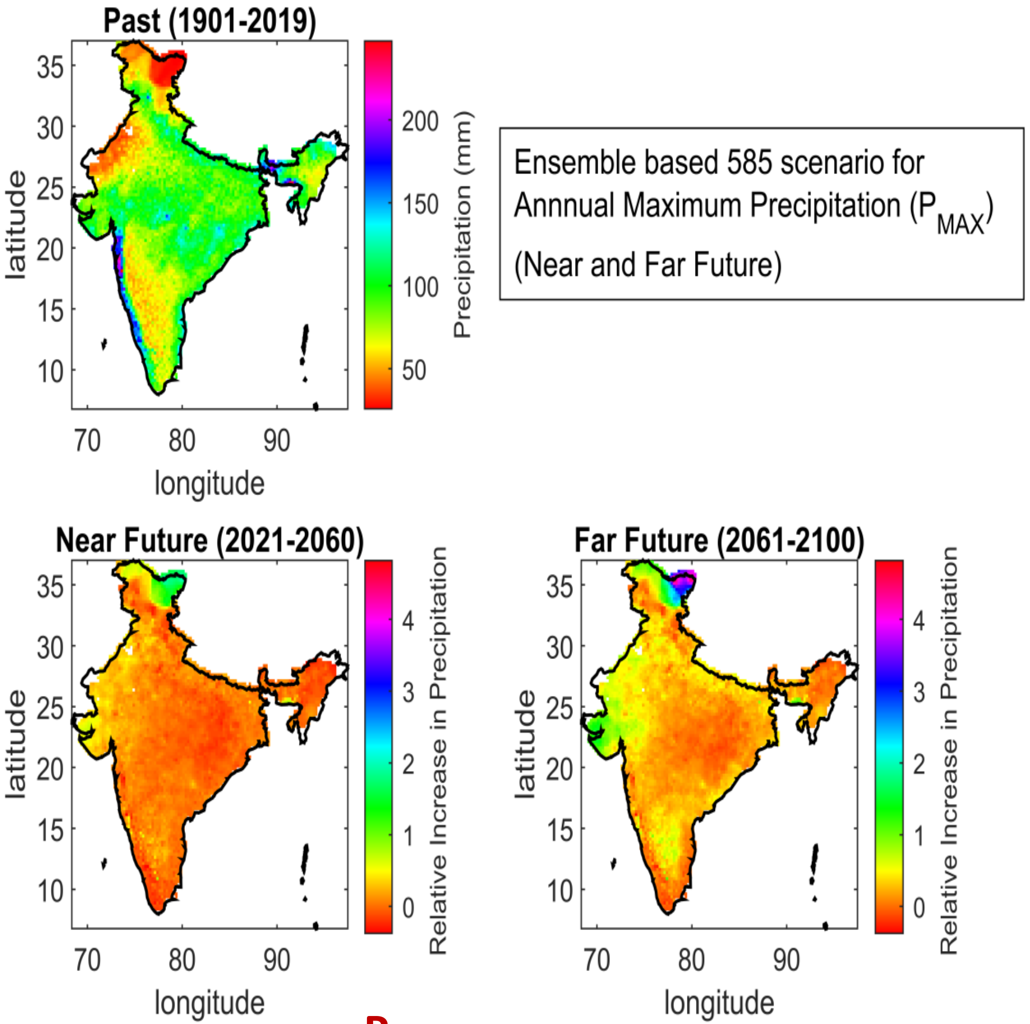
S. No.	Model	Nominal Resolu-tion	Dimen-sions(Latitude × Longitude)	Institute Name
1	AWI	100 km	192×384	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany
2	BCC	100 km	160×320	Beijing Climate Center, Beijing 100081, China
3	CAS	250 km	80×180	Chinese Academy of Sciences, Beijing 100029, China
4	CCMC	100 km	192×288	Fondazione Centro Euro-Mediterraneo sui Cam-biamenti Climatici, Lecce 73100, Italy
5	CSIRO	250 km	145×192	Commonwealth Scientific and Industrial Re-search Organisation, Aspendale, Victoria 3195, Australia
6	CSIRO_ARCCSS	250 km	144×192	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Aspendale, Victoria 3195, Australia), ARCCSS (Australian Research Council Centre of Excellence for Climate System Science)
7	INMCM4-8	100 km	120×180	Institute for Numerical Mathematics, Russian Academy of Science, Moscow 119991, Russia
8	INMCM5-0	100 km	120×180	Institute for Numerical Mathematics, Russian Academy of Science, Moscow 119991, Russia
9	IPSL	100 km	143×144	Institut Pierre Simon Laplace, Paris 75252, France
10	MPI	250 km	96×192	Max Planck Institute for Meteorology, Ham-burg 20146, Germany
11	MRI	100 km	160×320	Meteorological Research Institute, Tsu-kuba, Ibaraki 305-0052, Japan

Precipitation

- Coupled Model Intercomparison Project 6 (CMIP 6)
- Shared Socioeconomic Pathways (SSPs) SSP 126 (low), SSP 245 (medium), SSP370 (high) and SSP 850 (very high)



P_{mean}

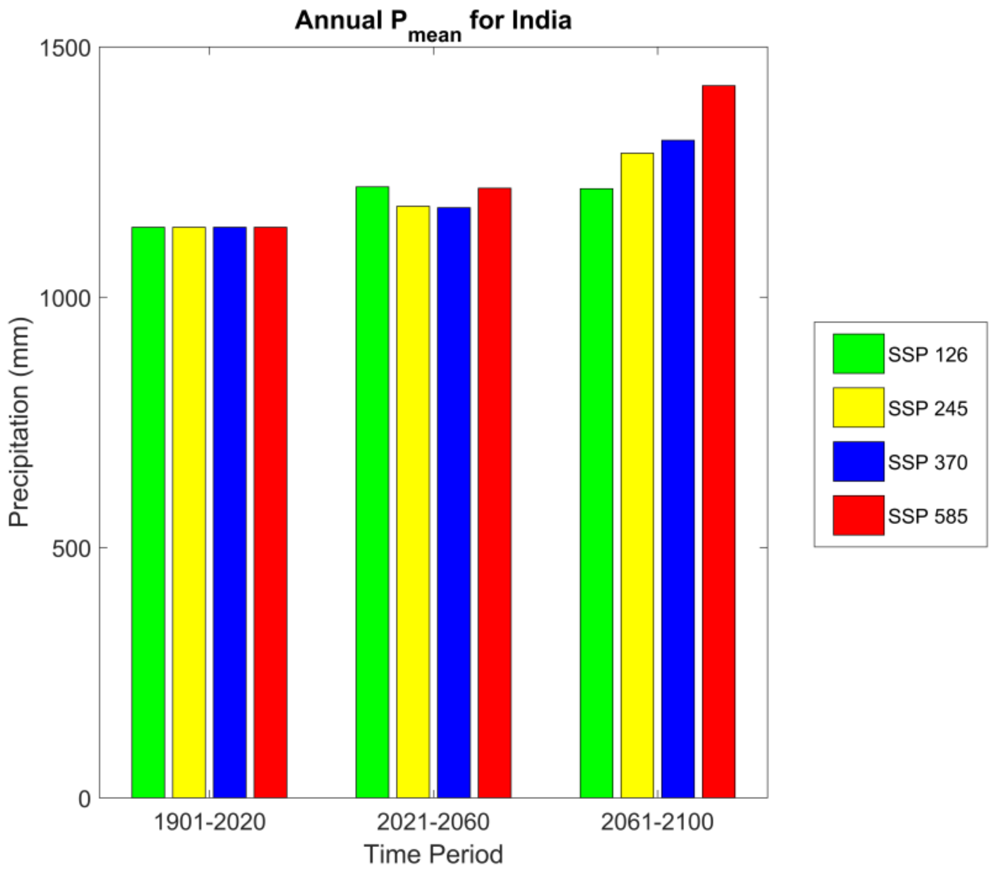


P_{max}

Change in Annual P_{mean} and P_{max} Over India Corresponding to SSP585 Scenario

Precipitation

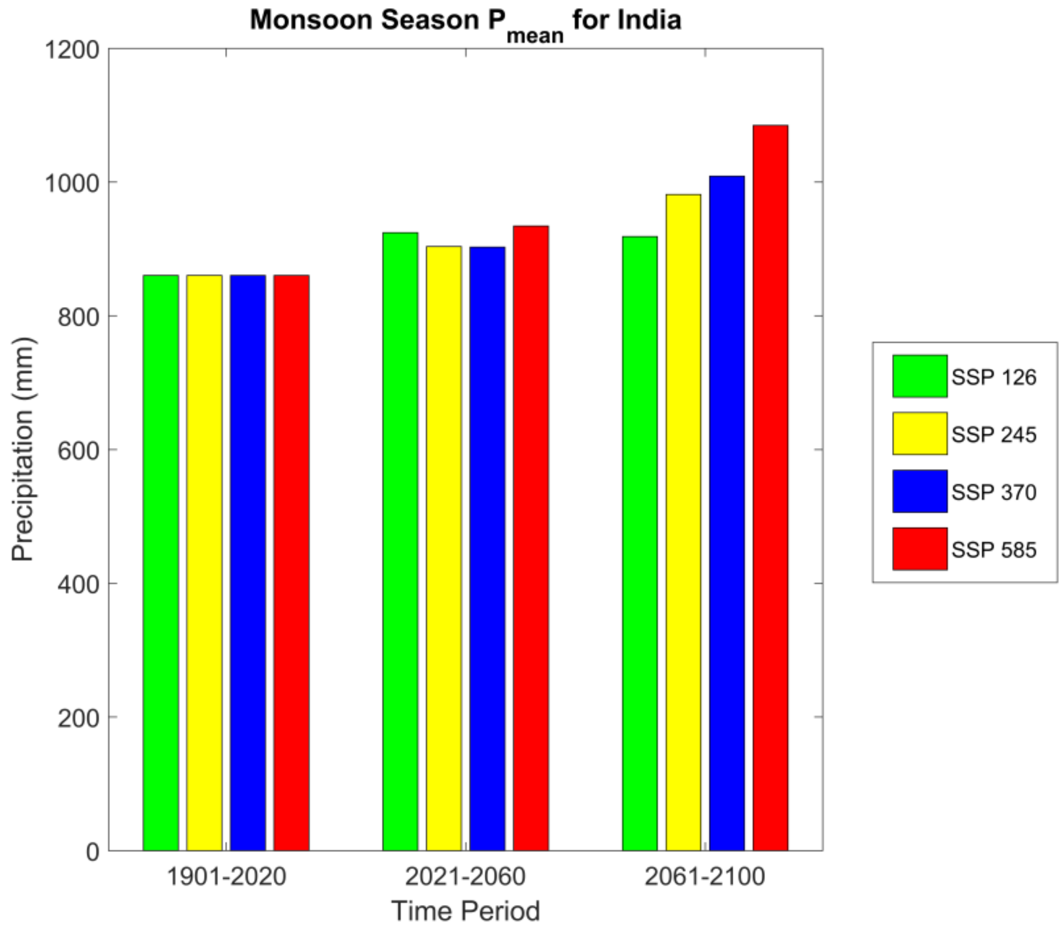
Paris Agreement adopted in 2015, goal is to **keep the rise in mean global temperature to well below 2° C (3.6 °F) above pre-industrial levels, and preferably limit the increase to 1.5° C (2.7 °F).** This has been signed by 196 countries.

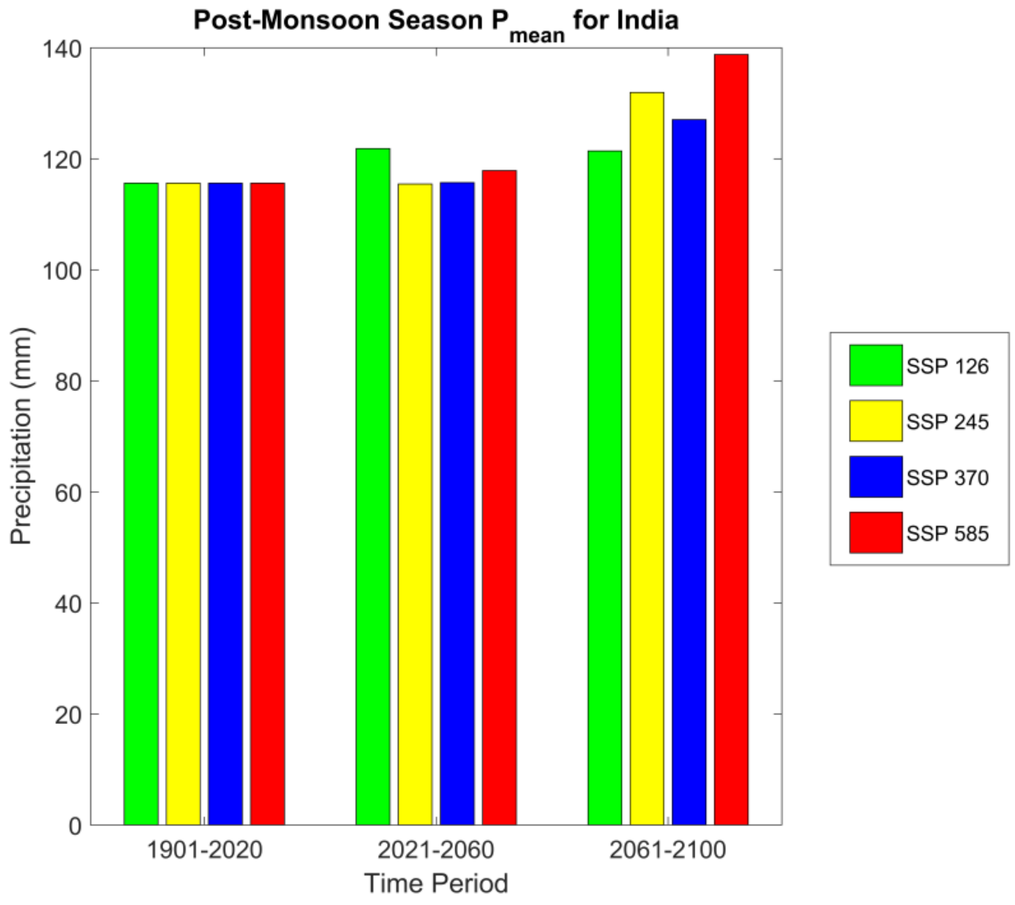


The Climate change study depicts wetter climate up to 7% in near future and 29% (maximum) in far future by 2100.

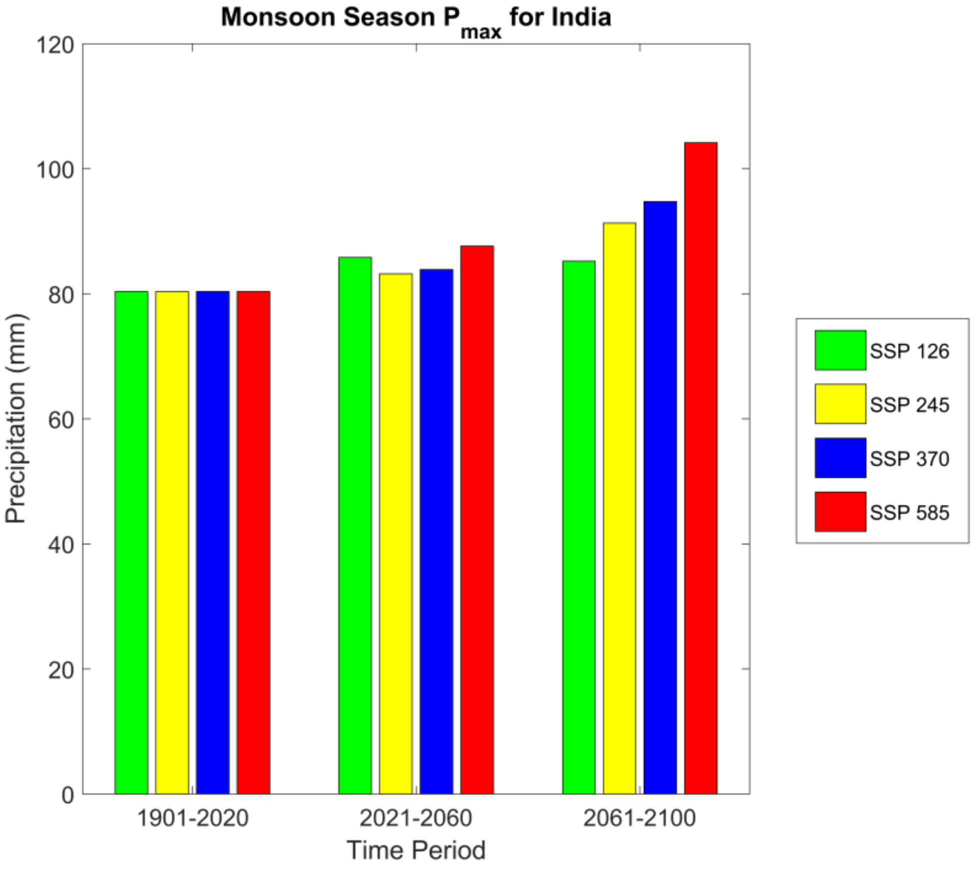
To achieve a target of 2^0C by 2050 we need to add 850 GW of hydropower globally. To achieve increase of 1.5^0 C by 2050 we need to add 1200 GW of hydropower.

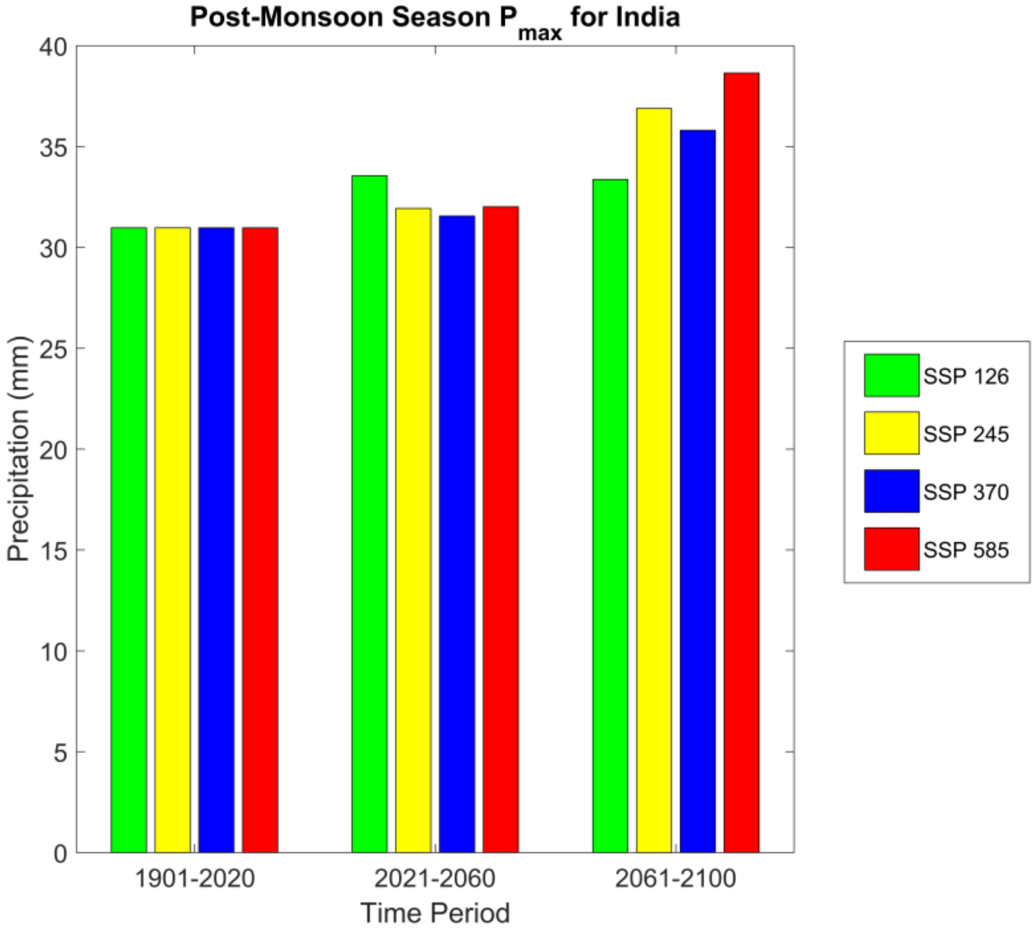
Precipitation



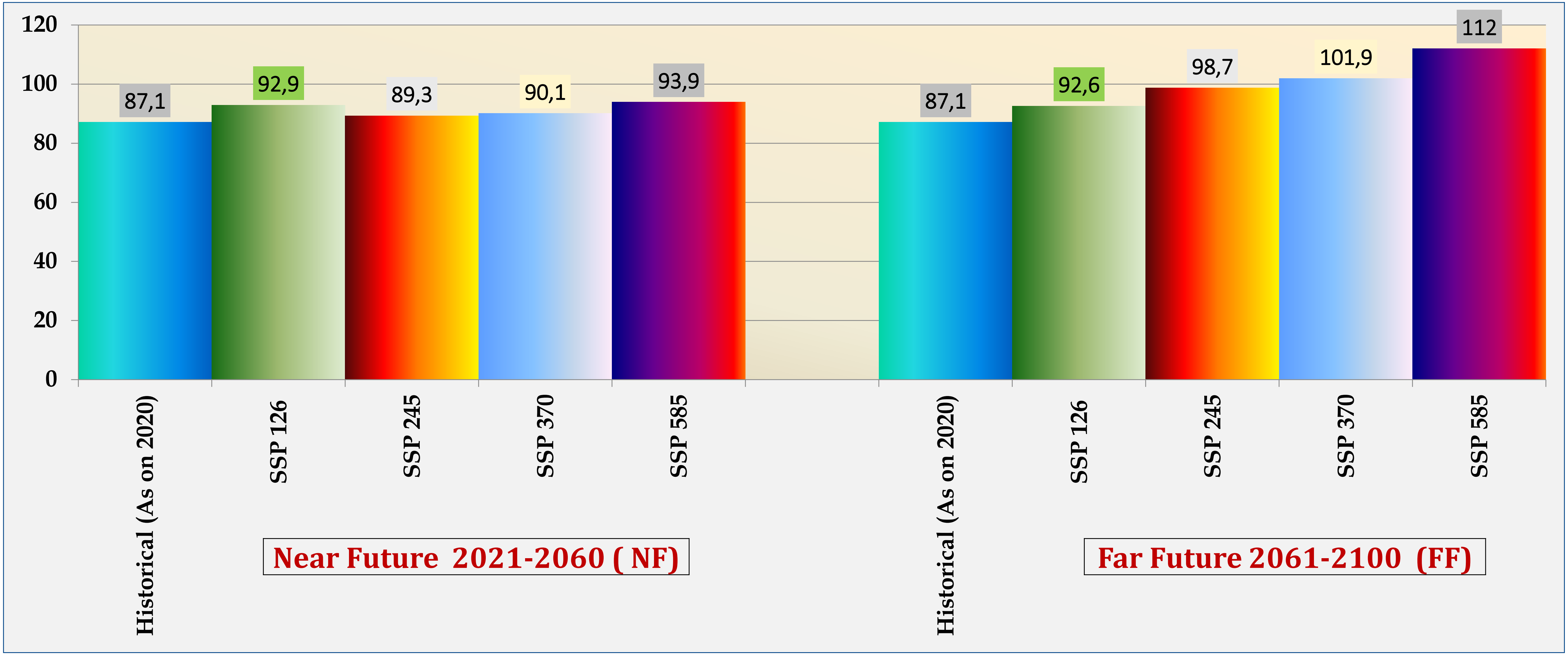


Precipitation

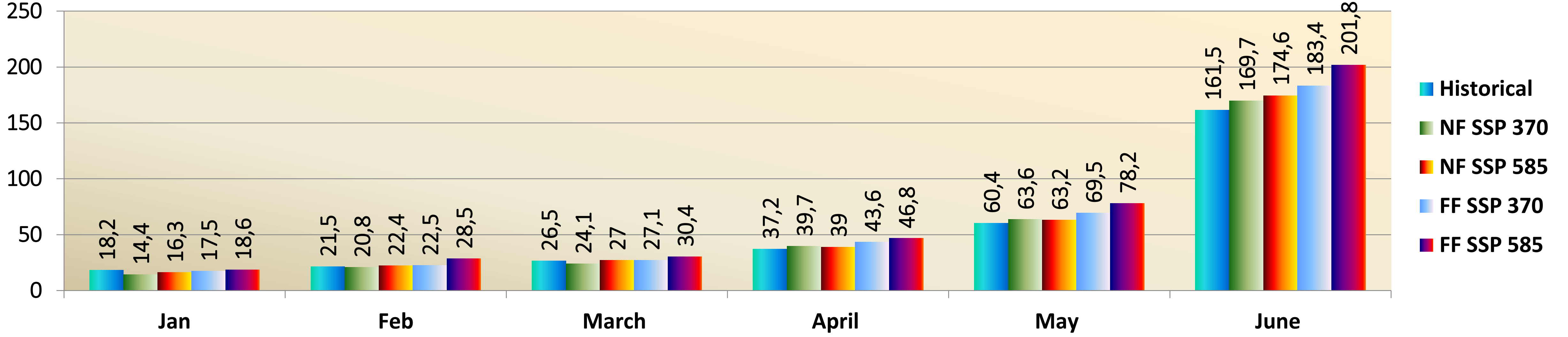




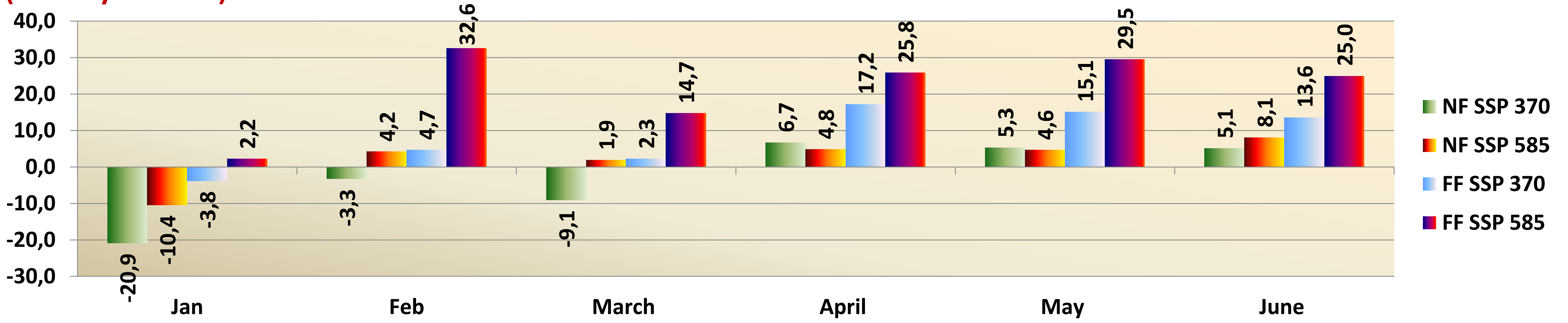
Summary of Historical and Future Projections of Maximum Precipitation (in mm) over India



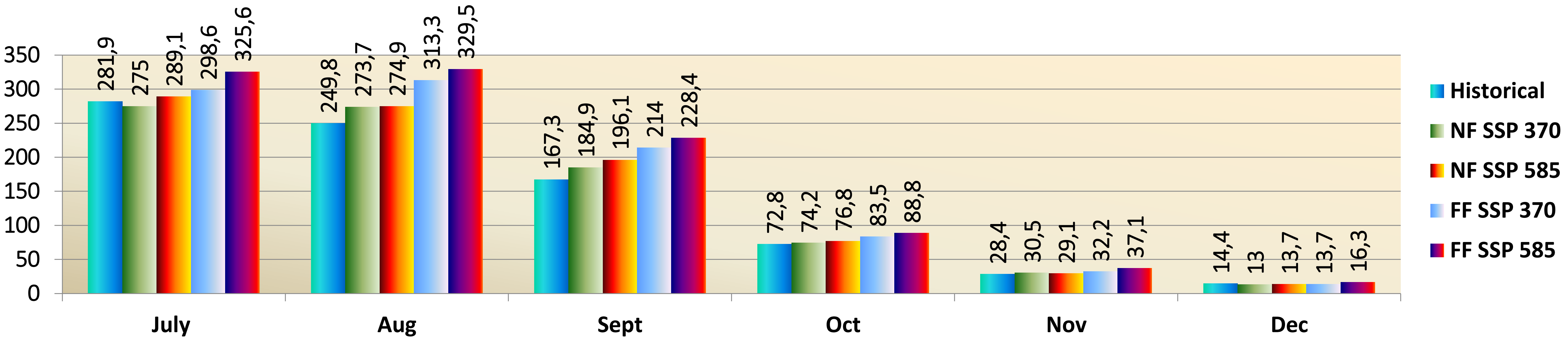
Comparison of Month wise Near and Far Future Projections of Average Precipitation (in mm) over India (January to June)



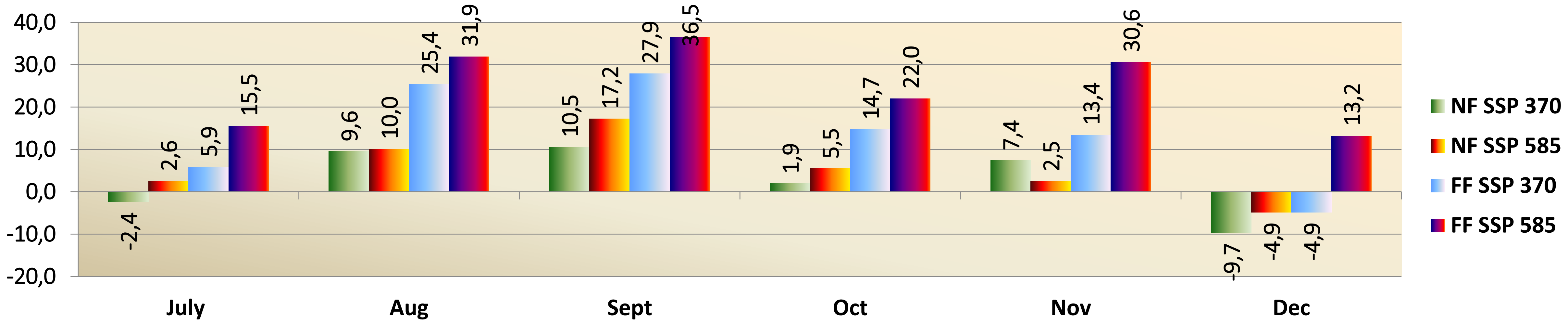
% age change in Near and Far Future projections of Precipitation (in mm) vis-a-vis Historical Average Precipitation over India (January to June)



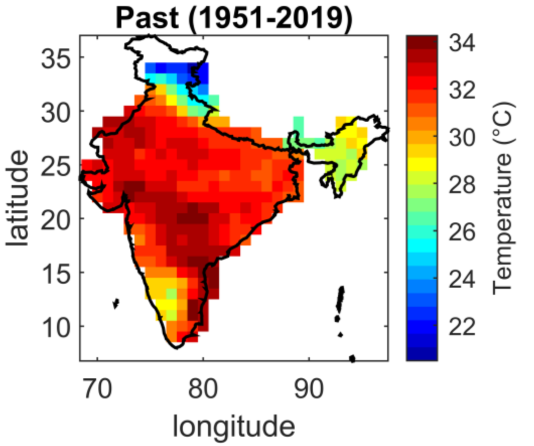
Comparison of Month wise Near and Far Future Projections of Average Precipitation (in mm) over India (July to Dec.)



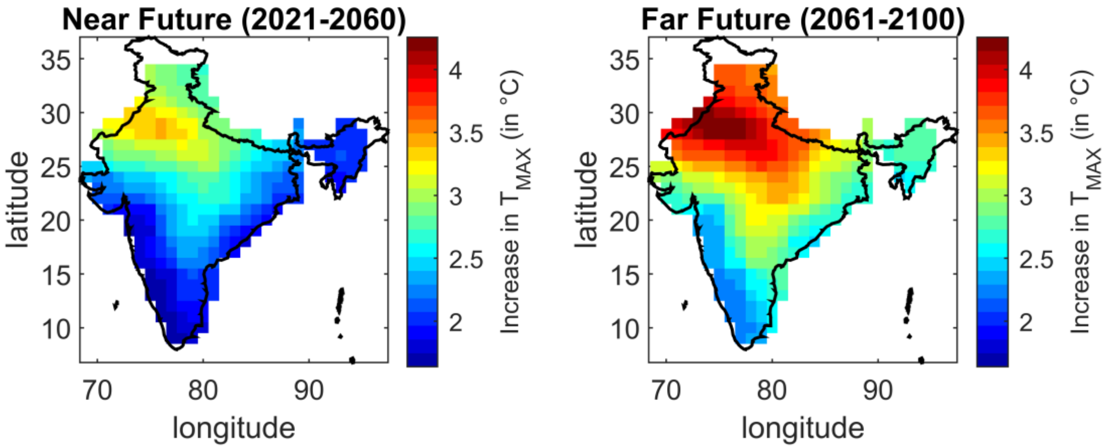
% age change in Near and Far Future projections of Precipitation (in mm) vis-a-vis Historical Average Precipitation over India (July to Dec.)



Temperature

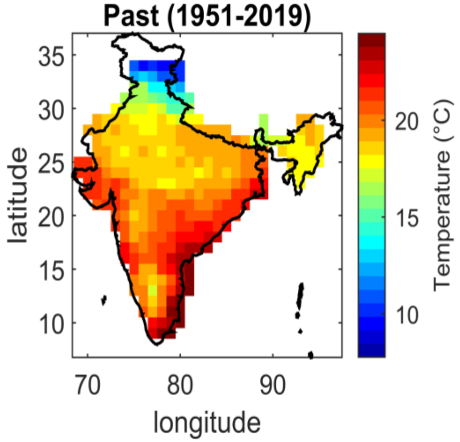


Ensemble based 585 scenario for Mean Annual T_{MAX} (Near and Far Future)

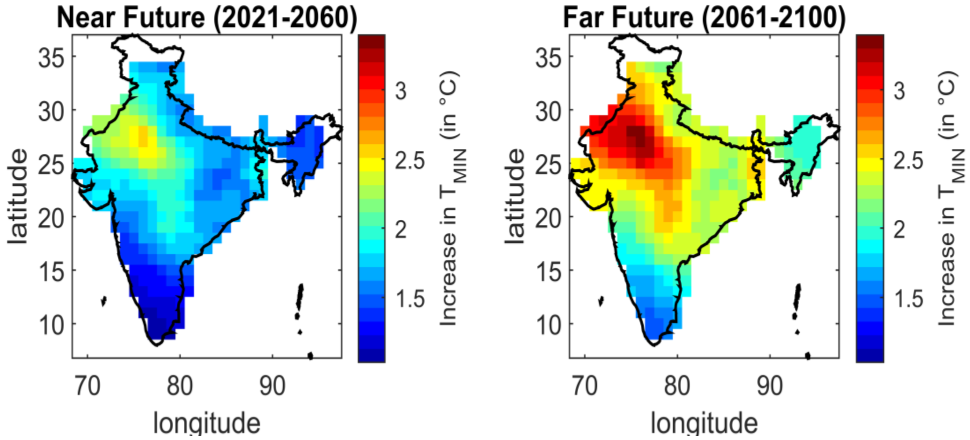


T_{max}

T_{max}



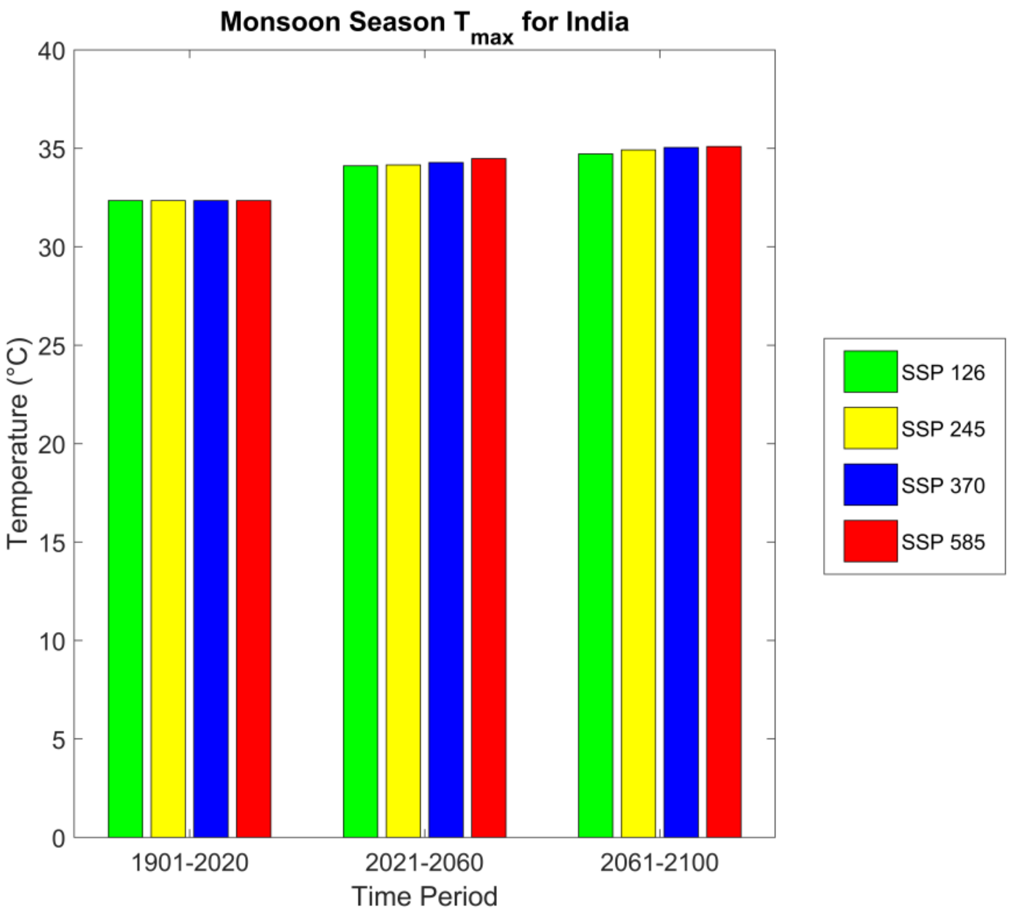
Ensemble based 585 scenario for Mean Annnual T_{MIN} (Near and Far Future)

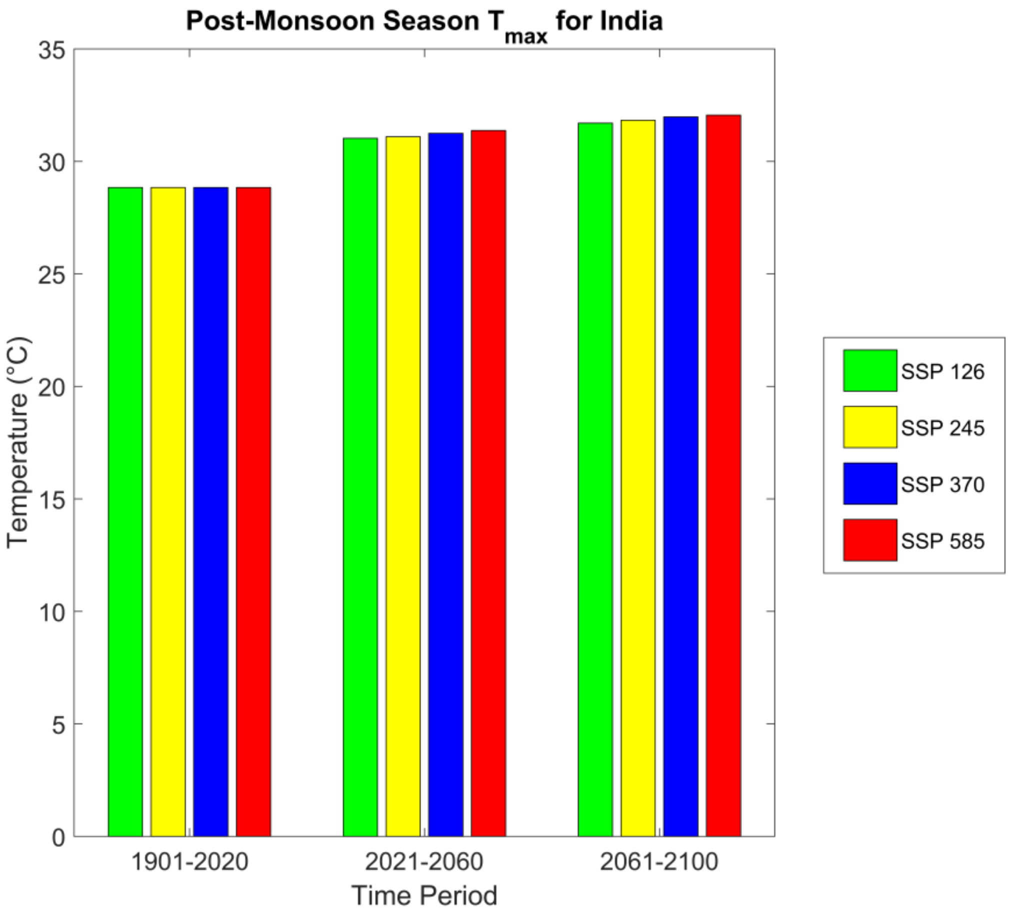


T_{min}

Change in Annual T_{max} and T_{min} over India Corresponding to SSP585 Scenario

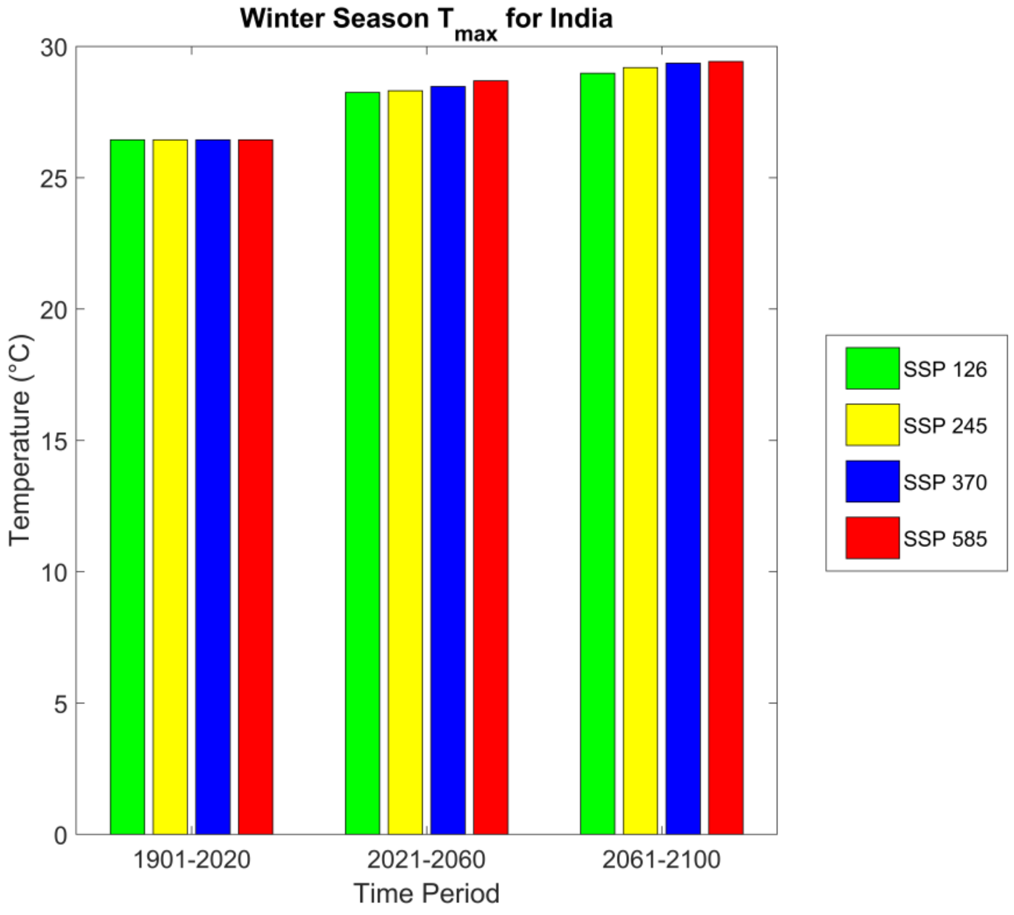
Temperature

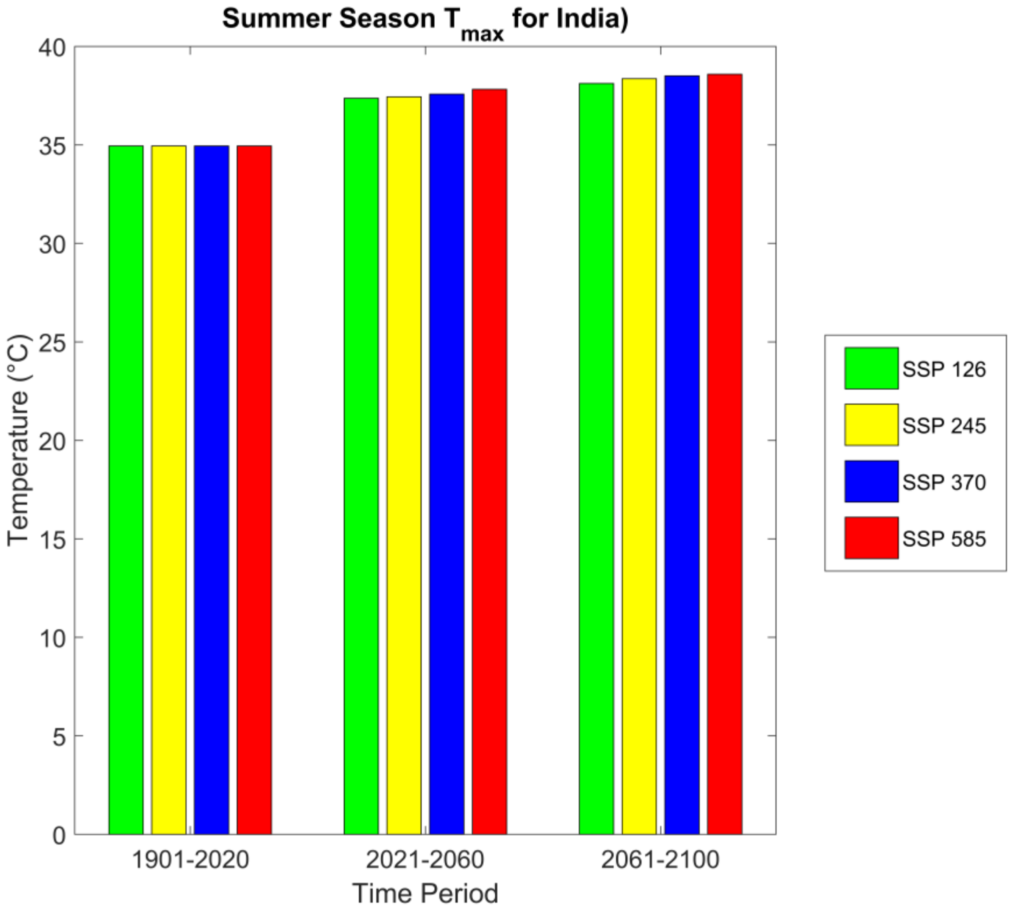




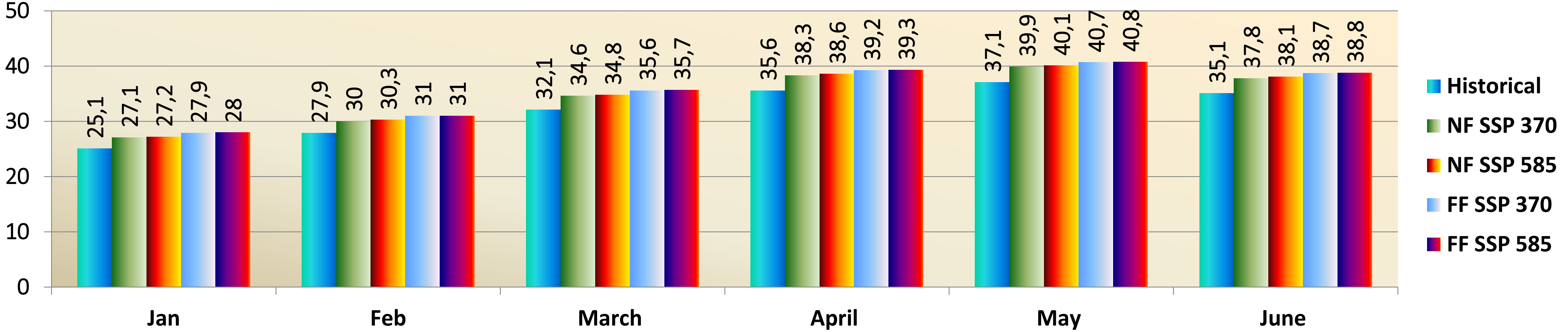
The Climate change study in India depicts a warmer temperature by 1.5° to 3°C in near future by the year 2060 and 2.5° to 4°C rise in far future by 2100.

Temperature

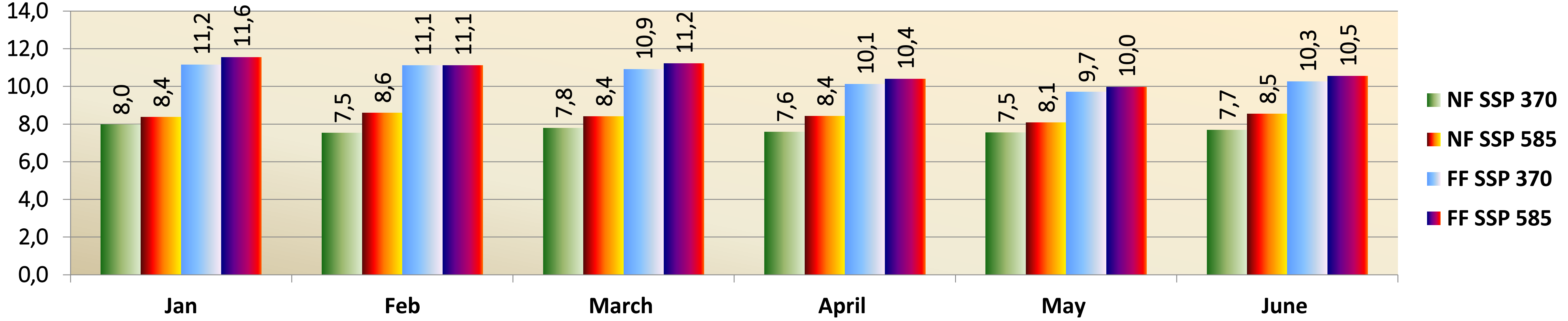




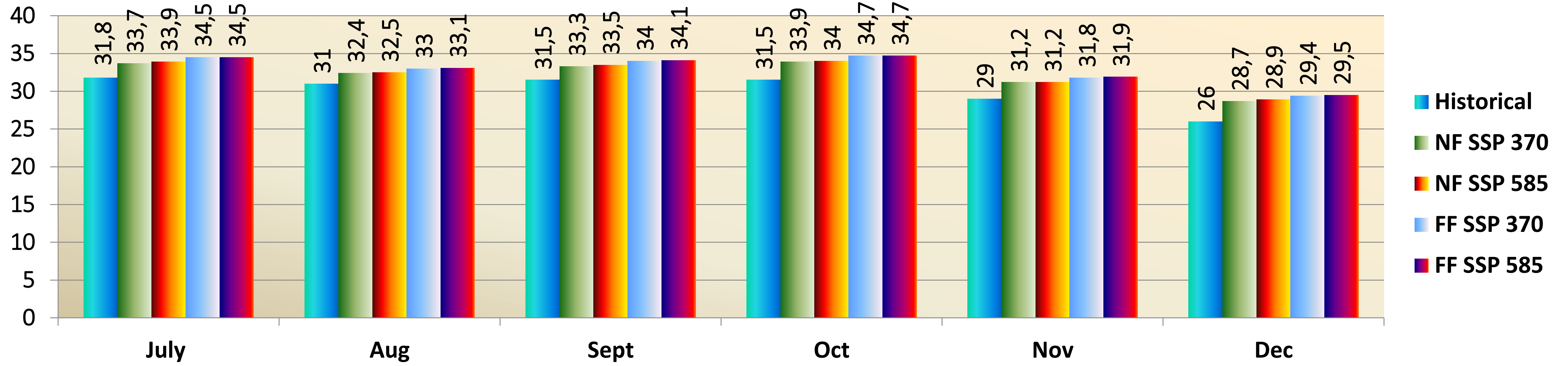
Comparison of Month wise Near and Far Future Projections of Maximum Temperature (in °C) over India (Jan. to June)



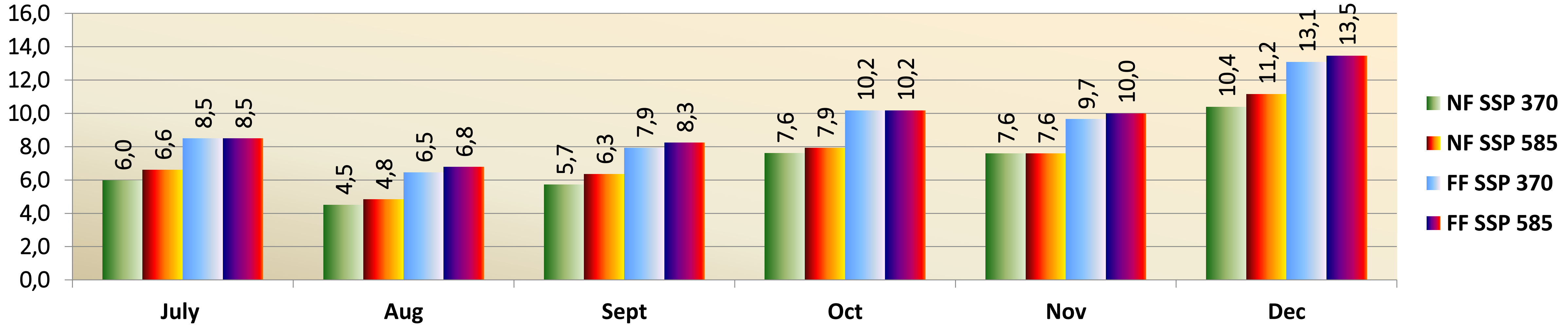
% age change in Near and Far Future projections of Maximum Temperature (in °C) vis-a-vis Historical Average Temperature over India (Jan. to June)



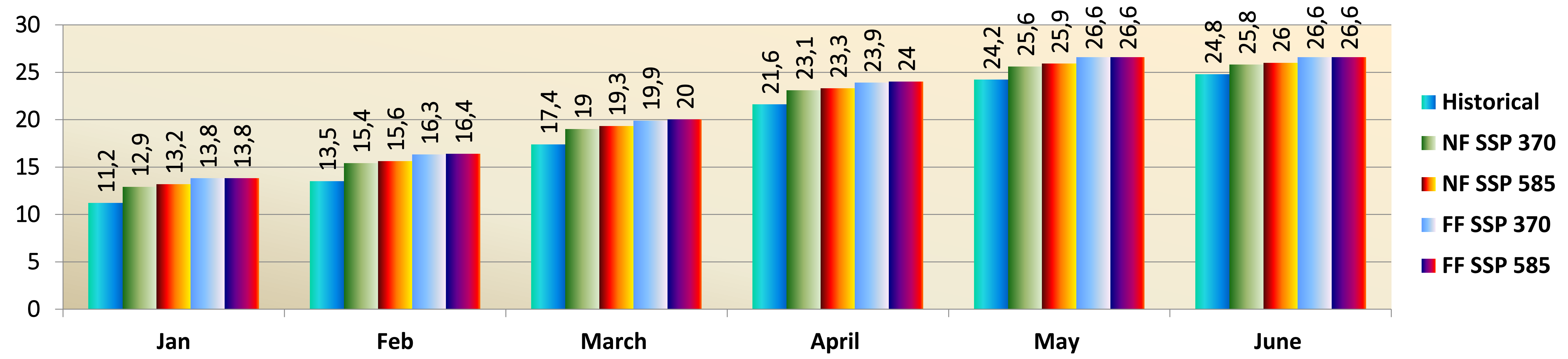
Comparison of Month wise Near and Far Future Projections of Maximum Temperature (in °C) over India (July to Dec.)



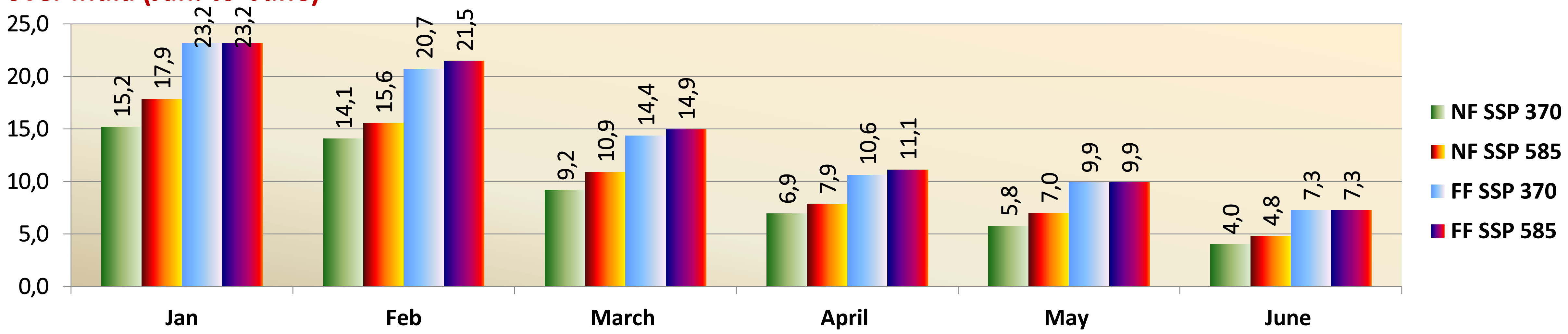
% age change in Near and Far Future projections of Maximum Temperature (in °C) vis-a-vis Historical Average Temperature over India (July to Dec.)



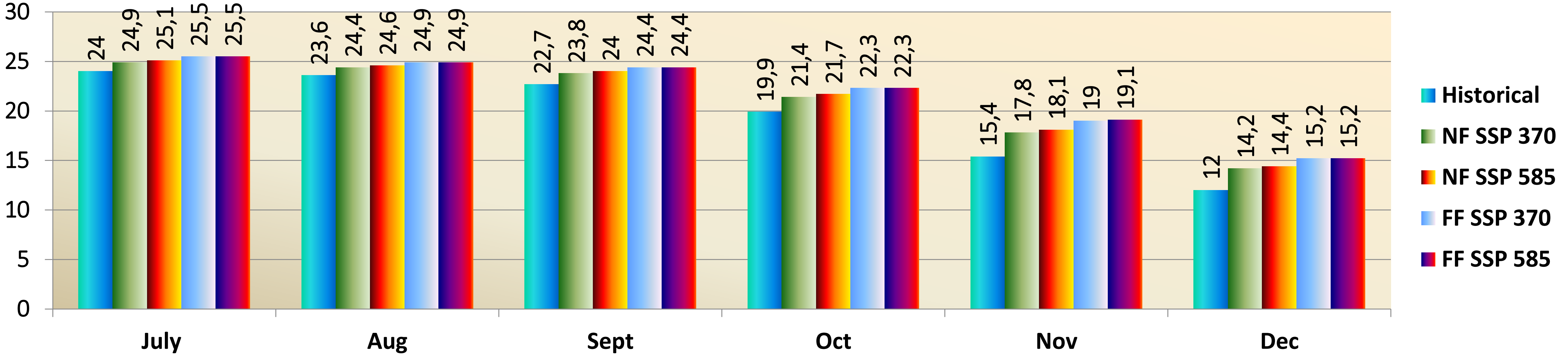
Comparison of Month wise Near and Far Future Projections of Minimum Temperature (in °C) over India (Jan. to June)



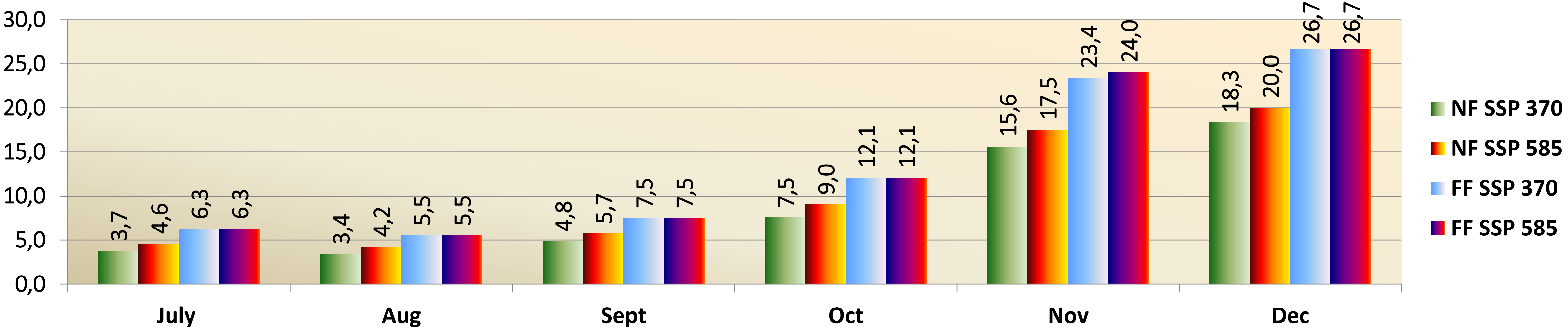
% age change in Near and Far Future projections of Minimum Temperature (in °C) vis-a-vis Historical Average Temperature over India (Jan. to June)



Comparison of Month wise Near and Far Future Projections of Minimum Temperature (in °C) over India (July to Dec.)



% age change in Near and Far Future projections of Minimum Temperature (in °C) vis-a-vis Historical Average Temperature over India (July to Dec.)



- IN **Way Froward**
- IN Develop scientific adaptation strategy to reduce adaptation costs and to ensure national water security. It will improve agricultural productivity, innovation, health and well being, food security, livelihood and biodiversity conservation. Prepare action plan to ‘work with nature’ and ‘to live with water’.
- IN **Short Term Measures**
- ▪ Spatial and temporal distribution of precipitation is changing fast due to climate change. **Water storage in small, medium and big storage need to be assigned priority.**
- ▪ Construction of new ponds, rejuvenation of existing ponds/lakes in every district. Each village to have its own pond.
- ▪ Prepare emergency action plan with floods, heat waves etc. Monitoring of these ponds for long term sustainability to be undertaken through remote sensing.
- ▪ Improve utility of surface and ground water. Bring in efficiency in use of water.
- ▪ To reduce wastage of water, carry out repair of irrigation canals. Design efficient water conveyance systems.
- ▪ Promote research to find out climate resilient crops which require les water and can sustain high temperature.

IN **Short Term Measures (Contd.)**

- Reduce evaporation from water bodies due to rising heat through physical and chemical methods.
- Designing and implementing laws and regulations to guarantee water security at local as well as national level. Develop more stringent water resources management measures and policing of pollutes discharge management.

IN **Long Term Measures**

- Water availability distribution will change in magnitude and time in rivers due to climate change. Store excessive run-off. Construct water retaining structures i.e. dams and check dams for creation of small, medium and large storage reservoirs at appropriate locations.
- Enhance ground water levels through check dams and ponds etc. Raising water level of river even by few meters such that it remains confined within river banks would ensure water availability during lean season.
- Weakening of soil health and ecosystem will require large scale irrigation systems coupled with supportive public policies to enhance water and food security.

IN

Long Term Measures (contd.)

- River linking is useful way to prevent flooding and in some parts of the country and bypassing the excess discharge through river links to water stressed areas.
- To minimize damage due to floods carry out flood plain zoning. Combination of non-structural measures such as early warning, flood plain zoning, watershed management, emergency action plan and insurance etc and structural measures like levees, improved channelization, embankment protection and construction of dams will reduce loss of lives and property.
- Hot heat waves will increase extreme demand for energy from few weeks to few months. Example of Sinchua province in August, 2022 is well known to all.
- Research on water desalination methods need to be carried out so as to produce affordable water for drinking as well as for industrial purpose.
- Study of water balance affected by climate change is required to be undertaken for all major river in the country.
- Exorbitant losses to economy due to catastrophic events is likely to create unrest in minds of people. It might destabilize a country and can pose a serious threat to National Security. Any destabilization in a country or a neighbouring country might have serious geopolitical issues.

IN **CONCLUSION**

- With the increasing global warming, losses or damages are becoming very difficult to avoid. Adaptation strategies do not prevent all losses and damages even though they are implemented effectively. Implementation of adaptive measures depend upon capacity and effectiveness of governance and decision making processes. Overall findings of the study highlight the need to implement adaptive/mitigation strategies ensuring the water security of India.

Let us work unitedly for energy transition and against an existential threat of climate change

email: dks.Shimla@gmail.com