National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Climatology of Krishna River Basin

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National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

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The Centres for Krishna River Basin Management Studies (cKrishna) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by NIT Warangal and NIT Surathkal, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cKrishna is committed to restoring and conserving the Krishna River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

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Acknowledgment

This report is a comprehensive outcome of the project jointly executed by NIT Warangal (Lead Institute) and NIT Surathkal (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

Disclaimer

This report is a preliminary version prepared as part of the ongoing Condition Assessment and Management Plan (CAMP) project. The analyses, interpretations and data presented in the report are subject to further validation and revision. Certain datasets or assessments may contain provisional or incomplete information, which will be updated and refined in the final version of the report after comprehensive review and verification.

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Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

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Abbreviations and Acronyms

ENSO	El Niño–Southern Oscillation
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
ITCZ	Intertropical Convergence Zone
KRB	Krishna River Basin
NASA	National Aeronautics and Space Administration
RH	Relative Humidity
SSP	Shared Socioeconomic Pathway
SWAT	Soil and Water Assessment Tool
Tmax	Maximum Temperature
Tmin	Minimum Temperature
WEAP	Water Evaluation and Planning System
WS	Wind Speed
WD	Wind Direction

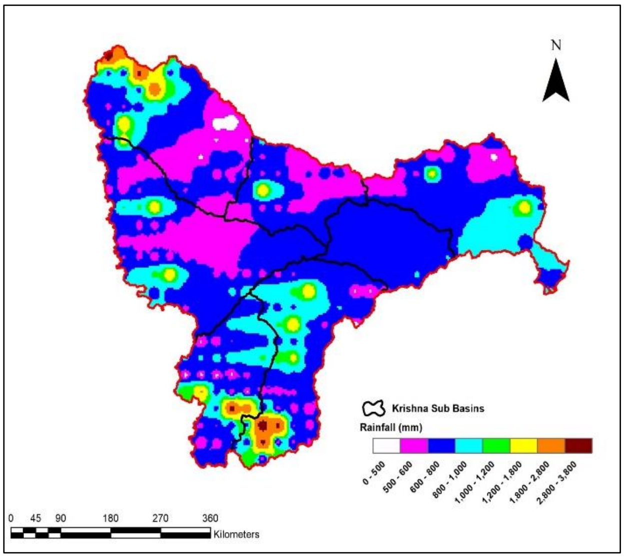
1. Introduction

The Krishna River Basin drains roughly 258,900 km² across Maharashtra, Karnataka, Telangana and Andhra Pradesh and has a predominantly tropical monsoon climate strongly seasonal and topography driven. The basin's rainfall is dominated by the southwest monsoon (June–September), which supplies the majority of annual precipitation. There is strong spatial variability: the Western Ghats and windward highlands receive very high rainfall (locally >2000 mm/yr), while interior Deccan and rain-shadow zones can receive on the order of a few hundred mm/year. Recent basin-scale studies report regionally variable trends, with some sub-basins showing decreases in annual rainfall and changes in extremes. Coming to temperature, seasonal minima occur in winter (Dec–Jan) and maxima in late pre-monsoon months (Apr–May). Mean minimum temperatures in cooler plateau/highland zones can fall below ~10°C in winter; coastal and low-lying areas remain milder (~15–18°C). Pre-monsoon maxima in interior plateau regions commonly exceed 40°C during heat spells. Observational and modelling work indicates a basin-wide warming trend (higher average Tmax and Tmin) consistent with regional climate change projections. Relative Humidity (RH) shows a pronounced seasonal cycle: very high RH (>80%) during the monsoon months across much of the basin, and substantially lower RH (often <40–50%) during the dry pre-monsoon and post-monsoon seasons in interior areas. Coastal sectors retain higher humidity year-round due to maritime influence. Large-scale wind patterns are governed by the monsoon: southwesterlies (from Arabian Sea / west coast) prevail during the southwest monsoon delivering moisture inland, while the post-monsoon / winter period sees northeasterly flow (from the Bay of Bengal / inland). Typical basin mean wind speeds (near surface, daily averages) are moderate (a few m/s), but can increase markedly during storms or cyclonic incursions. Satellite/reanalysis datasets (e.g., NASA POWER) provide gridded time series of wind speed and direction suitable for basin-scale analysis. Multiple studies find basin-scale warming and complex rainfall changes (spatially heterogeneous, some subbasins showing declines in mean rainfall, others changes in extremes). These shifts affect runoff, reservoir inflows, water availability and agriculture which motivates integrated water resources planning that accounts for both mean and extreme climate behaviour. The detailed analysis is presented in the following sections.

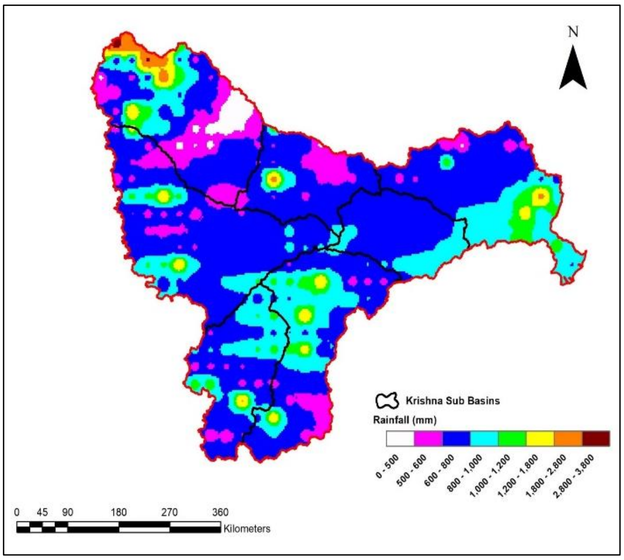
2. Precipitation and Temperature

2.1 Precipitation Anomaly

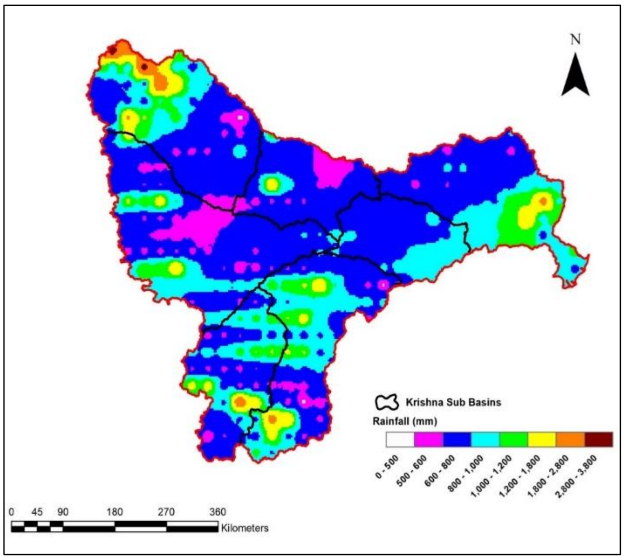
The India Meteorological Department (IMD) provides essential climate data, including temperature and precipitation (rainfall), which are widely used for research, agriculture, water resource management, and climate modeling. IMD offers gridded datasets for daily rainfall at a resolution of 0.25° x 0.25° from 1901 onwards, and daily maximum and minimum temperatures at a resolution of 1.0° x 1.0° from 1951 onwards. These datasets are typically available in NetCDF format and are suitable for spatial and temporal analysis across India. The data can be accessed through the official IMD. These data-sets serve as a critical foundation for applications in hydrological modeling, trend analysis, agricultural forecasting, and climate change impact assessments across India. The Krishna River Basin (KRB) exhibits a slight but consistent increase in average annual precipitation over the past century. During 1901–1950, the basin's mean precipitation hovered around 860 mm, rising to about 890 mm in the period 1951–2000, and reaching approximately 920 mm in the early 21st century (2001–2024). While the average rainfall has edged upward, spatial variability remains notable, with certain western and coastal grids consistently recording very high rainfall exceeding 3000 mm, likely influenced by the Western Ghats, and central or rain-shadow regions remaining drier with less than 600 mm. Interestingly, although the basin experienced higher average precipitation in recent decades, the maximum recorded annual grid-wise rainfall slightly declined compared to mid-century peaks, suggesting fewer extreme wet years but broader increases across moderate rainfall zones. Overall, these patterns indicate both a gradual intensification of precipitation and a possible spatial redistribution within the basin, which may have significant implications for water resource planning and management in the region. The basin's mean precipitation hovered reaching approximately 920 mm in the early 21st century (2001–2024). While the average rainfall has edged upward, spatial variability remains notable, with certain western and coastal grids consistently recording very high rainfall exceeding 3000 mm, likely influenced by the Western Ghats, and central or rain-shadow regions remaining drier with less than 600 mm. Interestingly, although the basin experienced higher average precipitation in recent decades, the maximum recorded annual grid-wise rainfall slightly declined compared to mid-century peaks, suggesting fewer extreme wet years but broader increases across moderate rainfall zones. Overall, these patterns indicate both a gradual intensification of precipitation and a possible spatial redistribution within the basin. Figure 2.1 represents spatial variations of annual average precipitation (a) 1901-1950 (b) 1951-2000 (c) 2001-2024.



(a)



(b)



(c)

Figure 2. 1 Spatial variations of annual average precipitation over Krishna River Basin for the periods (a) 1901-1950 (b) 1951-2000 (c) 2001-2024

The analysis of the dataset from 1901 to 2024 shows a slight upward trend with a slope of +0.4653 units/year; however, the R^2 value of 0.0168 and a p-value of 0.1519 indicate that this trend is weak and not statistically significant at the 5% level. While the overall movement is marginally increasing, strong short-term fluctuations and spikes overshadow this slow rise, and year-to-year variations dominate the pattern. Figure 2. 2 represents the temporal variation of annual average minimum temperature (1951–2024) over Krishna River Basin.

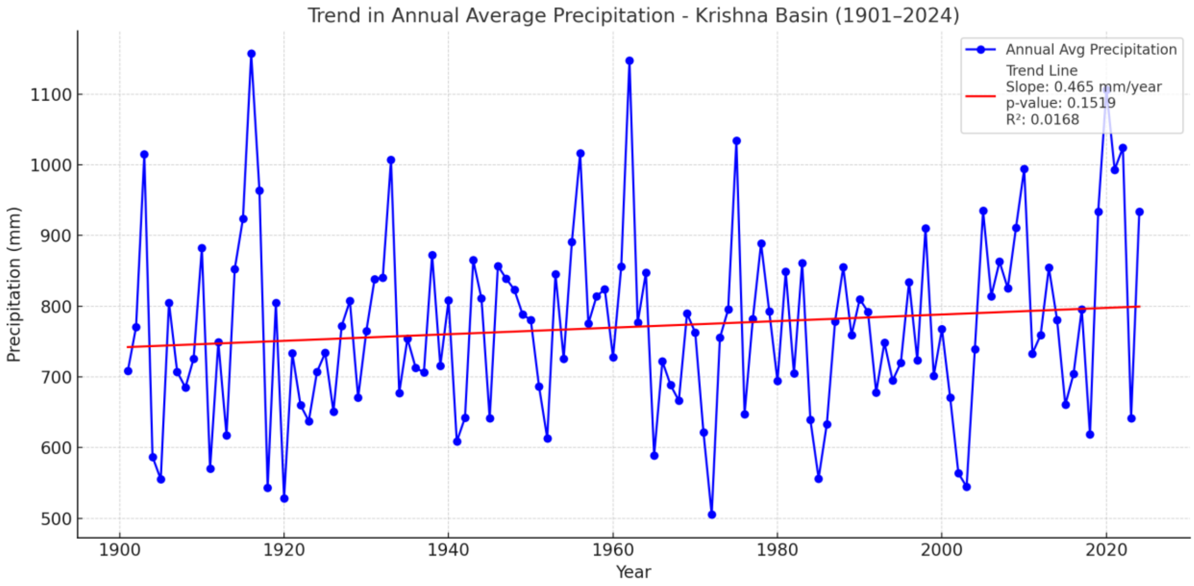
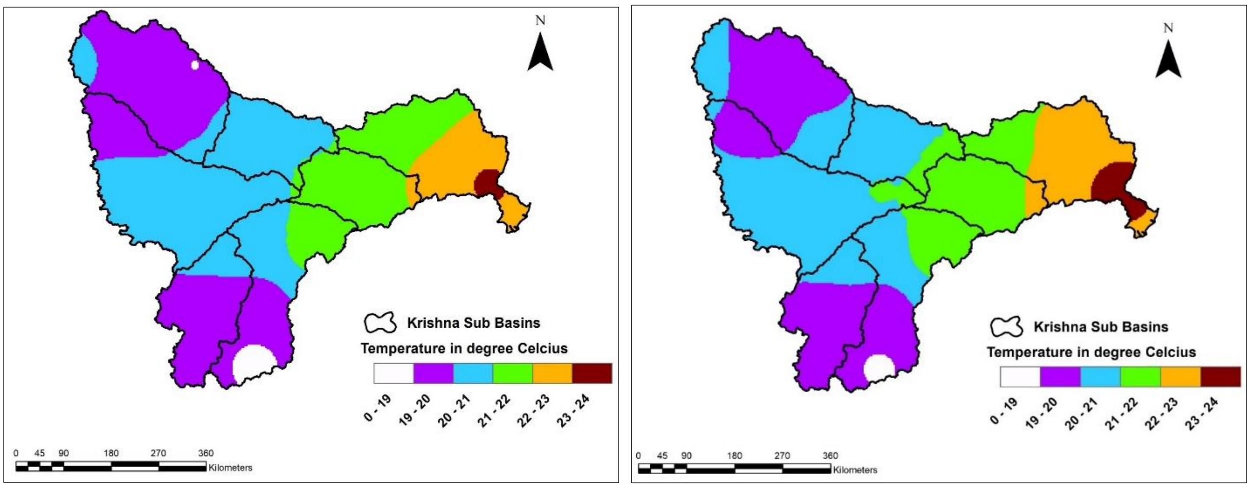


Figure 2. 2 Temporal Variation of Annual Average Precipitation (1901–2024) over Krishna River Basin

2.2 Minimum Temperature Anomaly

The annual average minimum temperature over the study period (1951–2000) shows relatively small interannual variability, generally fluctuating between 19.92 °C and 21.10 °C. The lowest value was recorded in 1971 (19.92 °C), while the highest occurred in 1998 (21.10 °C). The 1950s and 1960s exhibit moderate variations, with temperatures mostly around 20.2–20.8 °C. A slight dip is observed during the early 1970s, followed by a gradual recovery in the late 1970s and 1980s. From the late 1980s to the 1990s, the minimum temperature tends to remain slightly above 20.3 °C, with a few warmer years (e.g., 1979, 1987, 1998) indicating possible warming tendencies toward the end of the century. Overall, the dataset suggests a modest long-term warming pattern in minimum temperatures, consistent with broader climatic warming trends. The annual average minimum temperature across the Krishna River Basin shows a consistent warming trend between 2001–2024. In nearly all grid cells, minimum temperatures increased slightly typically by about 0.1°C to 0.4°C. For instance, average values rose from around 19.28°C to 19.38°C in some cooler grids, and from about 23.22°C to 23.58°C in warmer grids. Though the absolute increase is smaller compared to maximum temperatures, the steady upward shift in minimum temperatures still has important implications for agricultural planning and hydrological balance in the basin. Figure 2.3 represents spatial variation of average annual minimum temperature (2001-2024). The trend analysis for the annual average minimum temperature in the Krishna Basin from 1951 to 2024 reveals a slope of 0.0035 °C per year, with a p-value of 0.0344, indicating statistical significance at the 5% level. The coefficient of determination (R^2) is 0.0606, meaning that the trend explains approximately 6% of the observed variability in the data. Overall, the results suggest a gradual warming trend in minimum temperatures, equivalent to an increase of about 0.35 °C per century. Figure 2. 4 represents the temporal variation of annual average minimum temperature (1951–2024) over Krishna River Basin.



(a) **(b)**

Figure 2. 3 Spatial Variation of Average Annual Minimum Temperature (a) 1951-2000 and (b) (2001-2024)

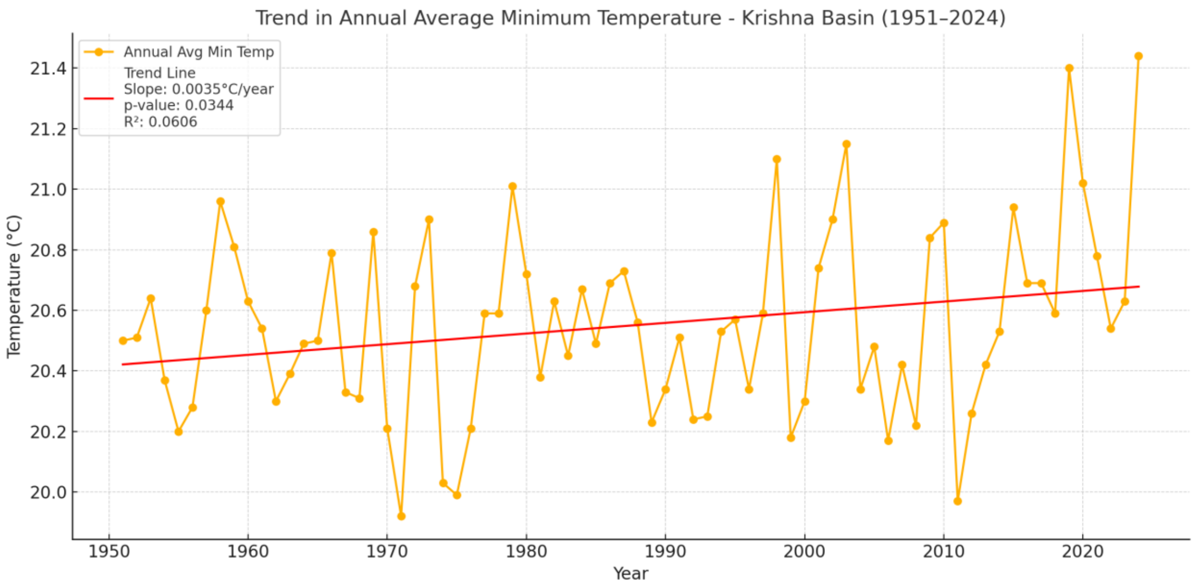
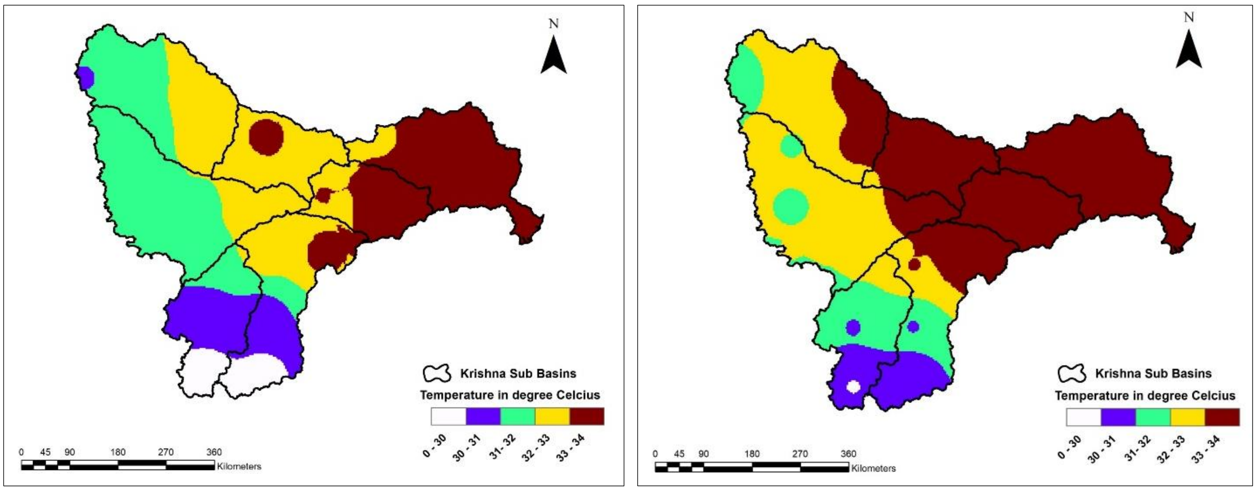


Figure 2. 4 Temporal Variation of Annual Average Minimum Temperature (1951–2024) over Krishna River Basin

2.3 Maximum Temperature Anomaly

The analysis of annual average maximum temperatures over the Krishna Basin for the period 1951–2000 shows a statistically significant warming trend of approximately 0.0156 °C per year ($R^2 = 0.36$, $p < 0.001$), equivalent to an overall rise of about 0.78 °C in five decades. Decadal averages indicate a consistent increase from 31.64 °C in the 1950s to 31.94 °C in the 1960s, 32.01 °C in the 1970s, and peaking at 32.27 °C in both the 1980s and 1990s, with a slight levelling during the latter. The warmest individual years include 1972, 1980, and 1998, each exceeding 32.7 °C in maximum annual average temperature. Periods of relative cooling are evident in the mid-1950s, early 1960s, mid-1970s, and early 1990s, but the long-term trajectory remains upward, aligning with regional warming patterns reported by IMD and NASA POWER datasets. This steady increase in maximum temperatures suggests heightened thermal stress in the basin, with potential implications for evapotranspiration rates, crop water requirements, and hydrological balance in the context of integrated water resources management. The analysis of annual average maximum temperature over the Krishna River Basin shows a clear increasing trend from the period 2001–2024. Across almost all grid cells, temperatures increased by about 0.5°C to 1°C, with basin-wide average maximum temperatures rising from roughly 31–32°C in the latter half of the 20th century to above 32–33°C in the early 21st century. This increase suggests a basin-wide intensification of heat, which could have significant implications for water resources, agriculture, and evapotranspiration rates. Overall, this reflects the broader impact of climate change across the region, highlighting the need for adaptation strategies in water and land management. Figure 2.5 represents spatial variation of average annual maximum temperature for the periods (a) 1951-2000 and (b) (2001-2024). The trend analysis for the Krishna Basin's annual average maximum temperature over the 1951–2024 period reveals a statistically significant warming trend, with a slope of +0.0154 °C/year, amounting to approximately 1.12 °C of warming across the 73-year span. The coefficient of determination ($R^2 = 0.529$) indicates a stronger correlation than observed in the 1951–2000 analysis, suggesting that over half of the variability in annual maximum temperatures can be explained by the long-term trend. The p-value of 2.19×10^{-13} confirms that this upward trend is highly statistically significant. While there is noticeable year-to-year variability, marked by sharp peaks in 2003, 2015, and 2016 and cooler dips during the mid-1950s, early 1990s, and 2021, the overall trajectory remains consistently upward, underscoring a clear long-term warming pattern in the basin. Figure 2.6 represents the temporal variation of annual average maximum temperature (1951–2024) over Krishna River Basin.



(a) **(b)**

Figure 2. 5 Spatial Variation of Average Annual Maximum Temperature for the periods (a) 1951-2000 and (b) (2001-2024)

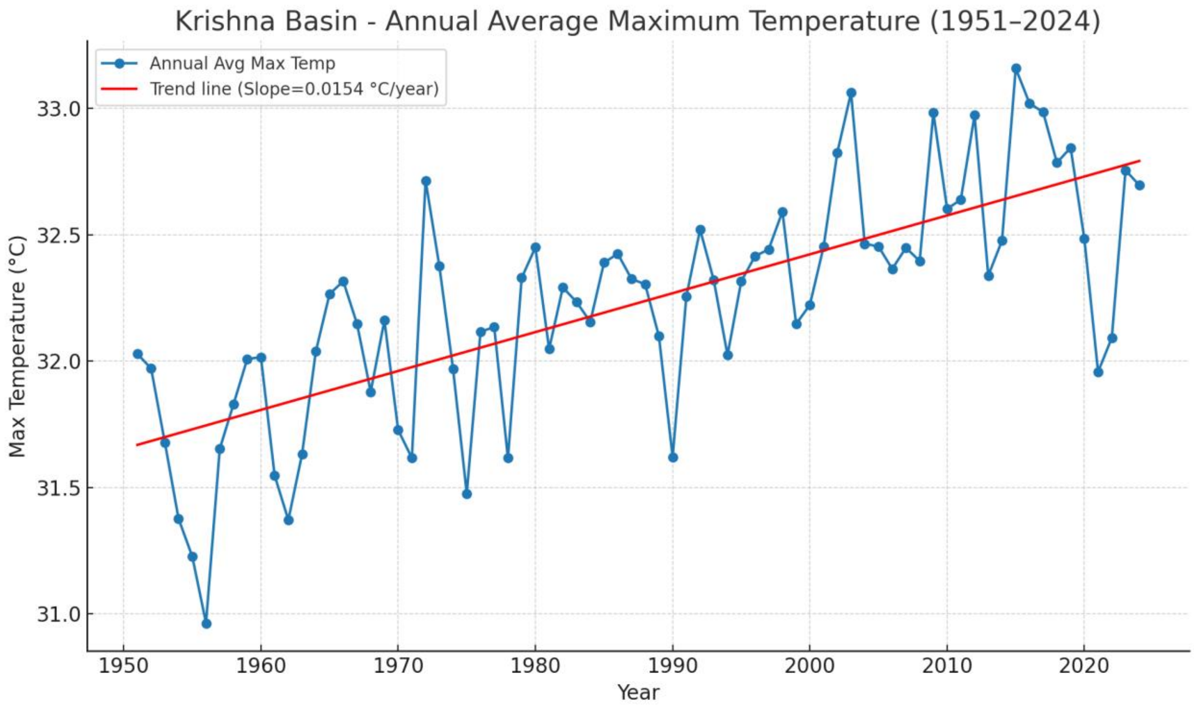


Figure 2. 6 Temporal Variation of Annual Average Maximum Temperature (1951–2024) over Krishna Basin

2.4 Future Projections

The future projections for monthly mean precipitation over the KRB from multiple climate model scenarios states that the monsoon months (June–September) dominate the rainfall contribution across all scenarios, with the highest monthly means typically occurring in July and August. Notably, high-emission scenarios (SSP5-8.5) generally predict larger peaks, especially in models like CANESM5_SSP-585 and NORESM2-LM_SSP-585, where August precipitation can exceed 600 mm and 300 mm respectively, reflecting a potential intensification of monsoon extremes. The inter-model spread is wide: models like CANESM5 project particularly high rainfall peaks, while MPI-ESM1-2-HR shows relatively moderate monsoon peaks and drier pre-monsoon periods. Figure 2.7 represents monthly mean precipitation (2015-2100). The future projections of monthly mean maximum temperature over the Krishna River Basin show a consistent seasonal cycle and a gradual increase under higher emission scenarios. Across all models and scenarios, the highest temperatures are projected in the pre-monsoon months (April–May), with mean monthly maxima typically reaching around 38–40 °C. Under SSP5-8.5, slightly higher peaks are evident, for example, EC-EARTH3_SSP-585 and ACCESS-CM2_SSP-585 show April–May temperatures exceeding ~40 °C. During the monsoon months (June–September), temperatures decrease modestly, remaining mostly between ~31–37 °C, reflecting the cooling effect of rainfall and cloud cover. Figure 2.8 represents monthly mean maximum temperature (2015-2100). The projected monthly mean minimum temperature KRB show a clear seasonal cycle and a consistent warming trend under both moderate (SSP2-4.5) and high (SSP5-8.5) emission scenarios. Notably, high emission scenarios consistently produce warmer nighttime conditions throughout the year, typically by about 0.5–1.5 °C compared to SSP2-4.5, especially during summer and post-monsoon months. While the models generally agree on the warming pattern, there is inter-model variation: models like ACCESS-CM2 and CANESM5 tend to project slightly higher night-time temperatures, while MRI-ESM2-0 and MPI-ESM1-2-HR project slightly cooler conditions. This warming of minimum temperatures implies warmer nights and reduced diurnal temperature ranges, which could exacerbate heat stress, impact crop growth, and influence water demand in the basin. Figure 2.9 represents monthly mean minimum temperature (2015-2100).

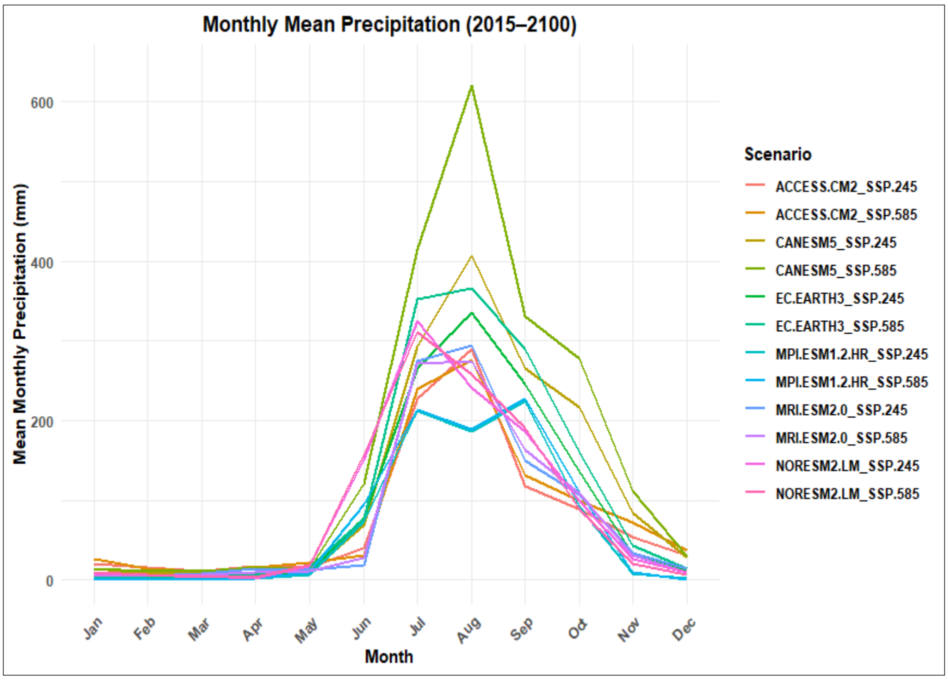


Figure 2. 7 Monthly Mean Precipitation (2015-2100)

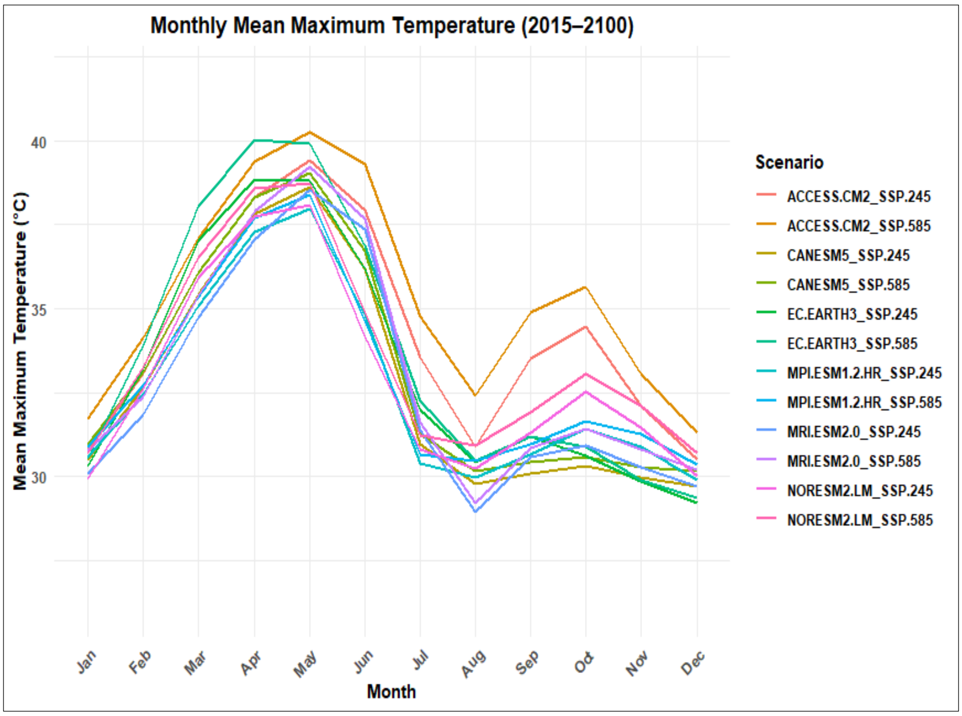


Figure 2. 8 Monthly Mean Maximum Temperature (2015-2100)

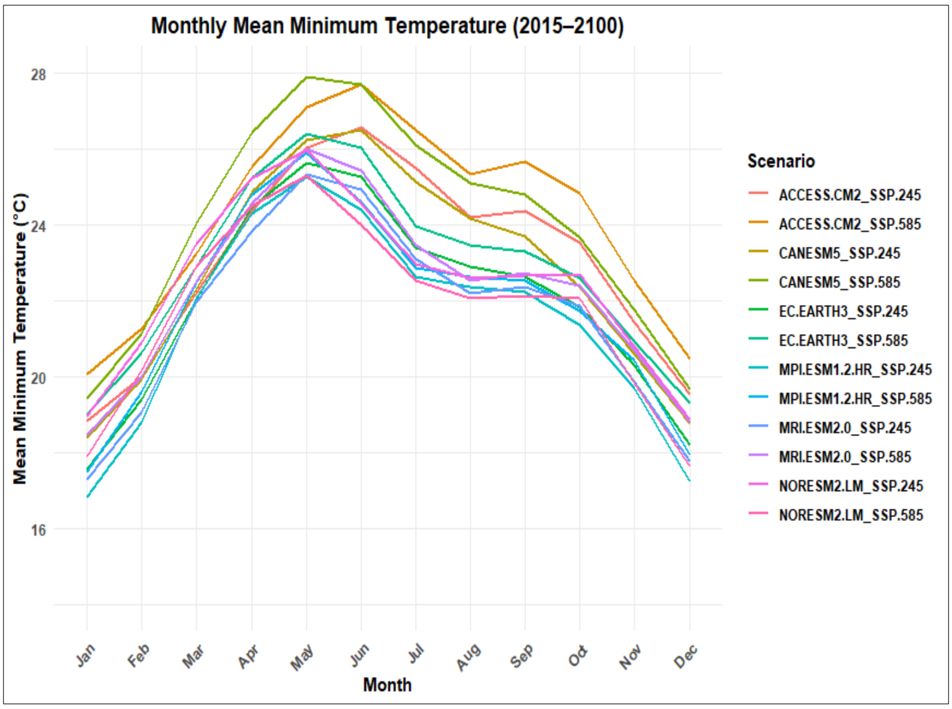


Figure 2. 9 Monthly Mean Minimum Temperature (2015-2100)

3. Relative Humidity

Spatial pattern of Relative Humidity over Krishna River Basin is presented in Figure 3.1 is as follows:

Coastal Eastern Zone (High RH: 75–80%): Eastern parts of the basin, particularly in Andhra Pradesh near the Krishna Delta, exhibit the highest relative humidity. Proximity to the Bay of Bengal ensures year-round maritime moisture inflow, with peak values during the Southwest and Northeast Monsoons. These areas benefit from intense monsoon rainfall and deltaic irrigation networks, resulting in sustained soil moisture and higher atmospheric humidity.

Central Plateau Zone (Moderate RH: 65–75%): Much of the middle basin, covering Telangana and northern Karnataka, falls in this range. While monsoon winds still bring moisture, these areas are farther from the coast, and rainfall is more seasonal. Post-monsoon, RH declines moderately due to reduced cloud cover and increased evaporation.

Western Ghats & Rain-Shadow Regions (Low RH: 52–65%): The western upper catchment, particularly in Maharashtra and parts of Karnataka, shows the lowest RH values. While the windward side of the Western Ghats receives heavy rainfall and short-term spikes in humidity, the leeward (rain-shadow) interior zones—such as parts of Solapur, Vijayapura, and northern Raichur districts—are drier. Persistent sunshine, high evapotranspiration, and limited surface moisture reduce average RH values.

From 1985 to 2024, seasonal relative humidity (RH) patterns in the Krishna River Basin show distinct climatic influences. During the Southwest Monsoon (June–September), basin-wide RH peaks, particularly in coastal and central regions, driven by moist south-westerly winds. In the Post-Monsoon and Winter months (October–January), the eastern coastal belt retains high RH due to the Northeast Monsoon, while interior areas experience a gradual decline. The Pre-Monsoon period (March–May) records the sharpest RH drop in the central and western interiors, where dust storms and dry heat are common. These variations have direct hydrological and agricultural implications: high RH in the Krishna Delta supports water-intensive crops such as paddy and sugarcane, whereas low-RH interiors favour drought-tolerant crops like millets and pulses. For water resources planning, RH significantly affects evapotranspiration estimates in hydrological models like SWAT and WEAP, influencing basin-scale water allocation. Climate adaptation strategies must account for the stark contrast between humid deltaic zones and semi-arid interiors, with tailored approaches for water transfer, irrigation scheduling, and crop selection. RH data also play a vital role in estimating evaporation losses from key reservoirs like Nagarjuna Sagar, Srisailam, and Almatti, forecasting drought risks in semi-arid sub-basins, designing efficient irrigation schedules for diverse agro-climatic zones, and supporting climate impact assessments to anticipate changes in monsoon intensity and dry-season severity.

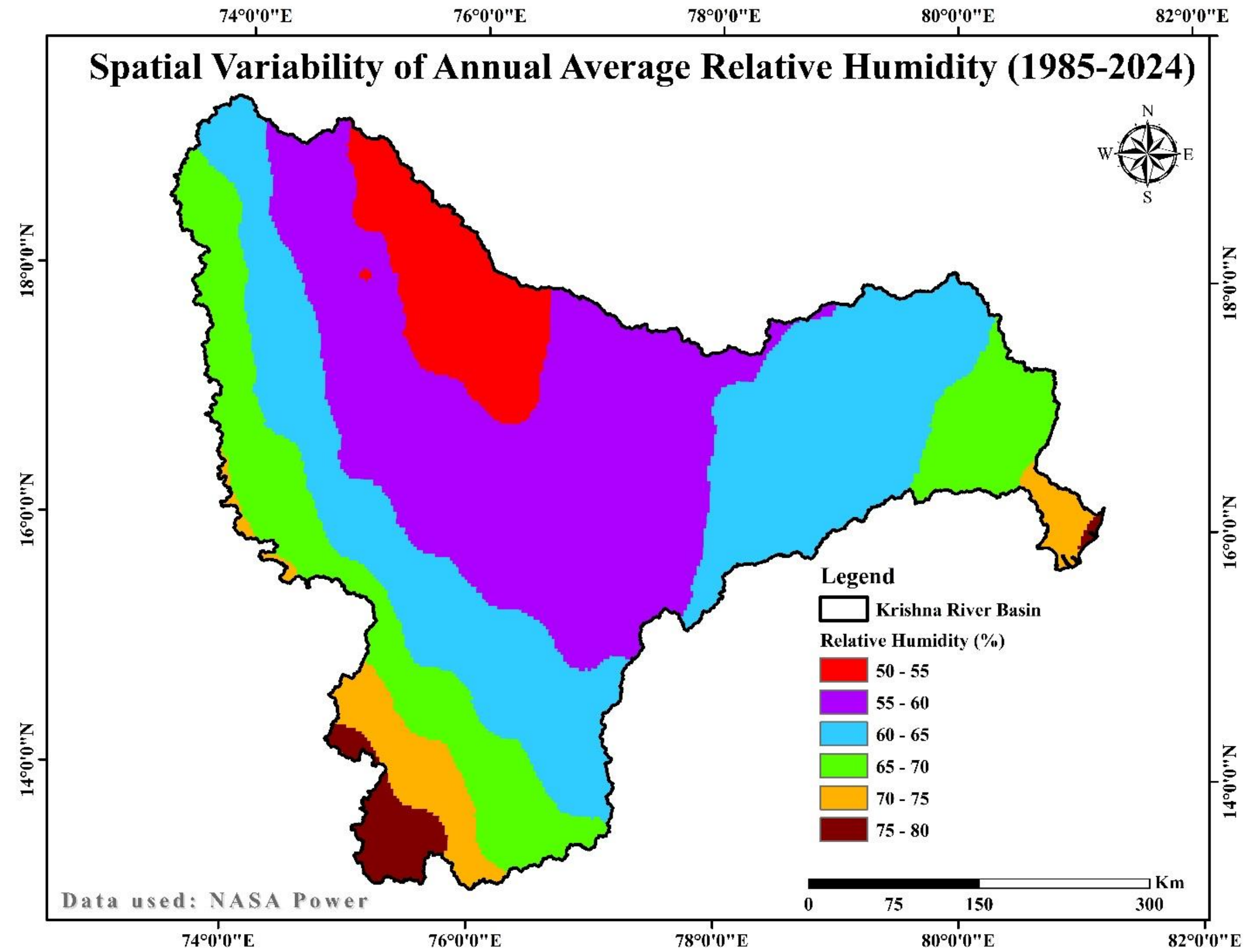


Figure 3. 1 Spatial variation of annual average relative humidity (in %) over Krishna River Basin (1985-2024)

4. Wind Speed

The wind speed (WS) values across 240 grid points covering the Krishna River Basin for the period 1985–2024, the spatial variation in wind patterns is clearly evident as presented in Figure 4.1. The wind speeds range roughly from below 1 m/s in sheltered inland and leeward regions to above 5 m/s in certain coastal and elevated areas. Higher wind speeds are observed predominantly along the eastern coastal stretch of the basin (latitudes ~13° N to 15.5° N, longitudes 80.5° E to 82.5° E) where the influence of the Bay of Bengal results in stronger and more consistent winds. Inland plateau and hilly regions in the western part, especially near the Western Ghats, also record relatively elevated wind speeds (around 4–4.6 m/s) due to orographic effects. In contrast, interior lowland areas and rain-shadow zones (particularly in central and north-eastern parts of the basin) show significantly lower average wind speeds, often falling between 1.5–2.8 m/s. The spatial gradient indicates a general east–west and coastal–inland variation, with coastal and windward hill slopes experiencing stronger winds, while leeward and inland plains remain calmer. Over the 1985–2024 period, these spatial patterns likely remained consistent, although interannual variability and seasonal monsoon dynamics would have modulated the magnitude. Such wind speed characteristics are important for assessing evaporation rates, wind-driven hydrological processes, and potential renewable energy applications in the basin.

Expanding on the analysis, the 1985–2024 wind speed dataset for the Krishna River Basin highlights not only the spatial differences but also the underlying geographical and climatic controls shaping the wind regime. The southern and south-eastern coastal zones of the basin consistently record the highest wind speeds (often exceeding 5 m/s), driven by the interaction of sea–land breeze systems and the seasonal monsoon flow from the Bay of Bengal. These regions are particularly influenced during the southwest monsoon onset and retreat phases, when pressure gradients between land and sea intensify. The western boundary of the basin, adjacent to the Western Ghats, shows moderately high wind speeds (~4.2–4.6 m/s), which can be attributed to orographic channelling and the funnelling effect of mountain passes, especially during the monsoon season.

Inland central parts of the basin, stretching across Karnataka and parts of Telangana, exhibit moderate wind speeds (2.5–3.2 m/s) that reflect their position in the rain-shadow zone, where the terrain shields them from direct high-velocity monsoon winds. The northern basin sectors, especially towards Maharashtra, record some of the lowest wind speeds (<2.0 m/s), largely due to reduced monsoon penetration and the dominance of stable atmospheric conditions outside the rainy season.

Temporally, while this dataset is averaged over nearly four decades, it’s reasonable to infer that interannual variability in wind speeds would correlate with variations in monsoon strength, El Niño–Southern Oscillation (ENSO) events, and tropical cyclone activity in the Bay of Bengal. Stronger monsoon years and cyclone-prone periods likely enhance seasonal peaks in wind speeds, particularly in the coastal and windward regions, whereas drought years or weak monsoons may suppress these peaks.

From a hydrological perspective, these spatial wind patterns directly influence evaporation rates from reservoirs, soil moisture loss, and the microclimate over agricultural zones. From an energy standpoint, the eastern coastal and western highland regions emerge as potential hotspots for wind energy development due to their consistently higher wind speeds, while central and northern interiors may be less favourable for large-scale wind power generation.

This wind speed climatology thus forms a crucial component for integrated water resources management, climate adaptation planning, and renewable energy feasibility studies in the Krishna River Basin.

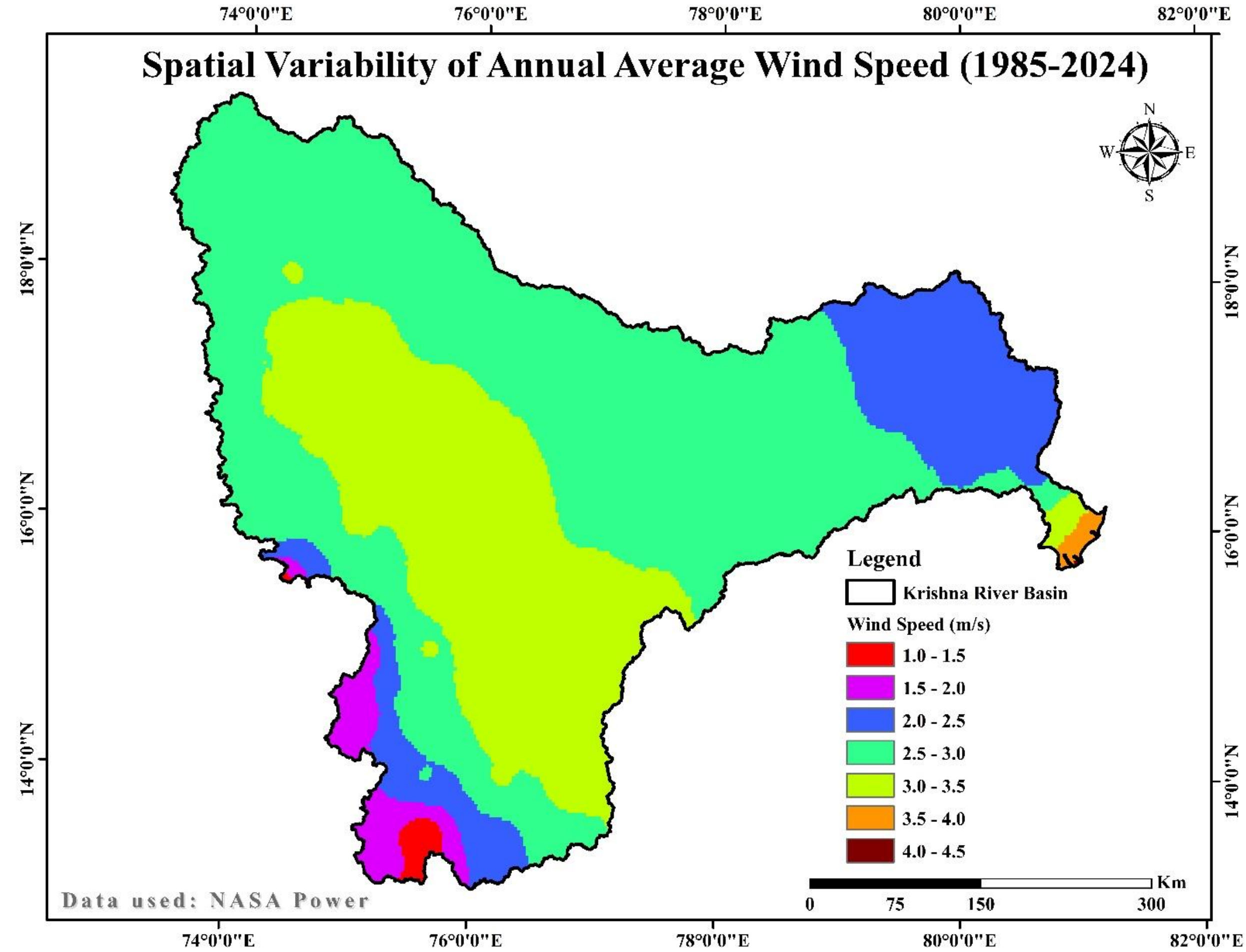


Figure 4. 1 Spatial variation of annual average wind speed (in m/sec) over Krishna River Basin (1985-2024)

5. Wind Direction

The mean wind direction patterns over the Krishna River Basin from 1985 to 2024 reveal a distinct spatial variation that aligns closely with the basin's topography and climatic influences as shown in Figure 5.1. In the coastal and western parts of the basin, particularly near the Arabian Sea fringe of Karnataka and Goa, wind directions predominantly align with south-westerly to westerly flows. This is strongly linked to the southwest monsoon regime, where moisture-laden winds from the Arabian Sea dominate during the rainy season.

Moving inland towards the central plateau regions of Karnataka and Telangana, the wind direction begins to show a more southerly to south-easterly orientation, reflecting the influence of the Deccan Plateau's thermal low-pressure systems during pre-monsoon and monsoon months. The central basin acts as a transitional zone where the maritime influence diminishes, and local pressure gradients start to dominate.

In the eastern parts of the basin, particularly in Andhra Pradesh towards the Krishna delta, mean wind directions are more easterly to north-easterly, especially during post-monsoon and winter months when the northeast monsoon winds influence the coastal plains. Here, the seasonal reversal of wind direction is more prominent, as the northeast monsoon supplements the general circulation pattern with winds from the Bay of Bengal.

The spatial consistency of these patterns over the four-decade period suggests that large-scale atmospheric drivers—such as the Indian monsoon system, the Intertropical Convergence Zone (ITCZ) shifts, and basin-scale pressure gradients—have remained dominant in shaping wind directions. Local features, including the Western Ghats barrier effect and river valley alignment, add finer-scale deviations to the wind flow, especially in the mid and lower basin.

Overall, the Krishna River Basin exhibits a clear west-to-east transition in prevailing wind direction, moving from strong monsoon-driven westerlies in the west to seasonally reversing easterlies near the coast. This wind climatology has significant implications for moisture transport, rainfall distribution, evapotranspiration patterns, and renewable energy planning (particularly wind power potential).

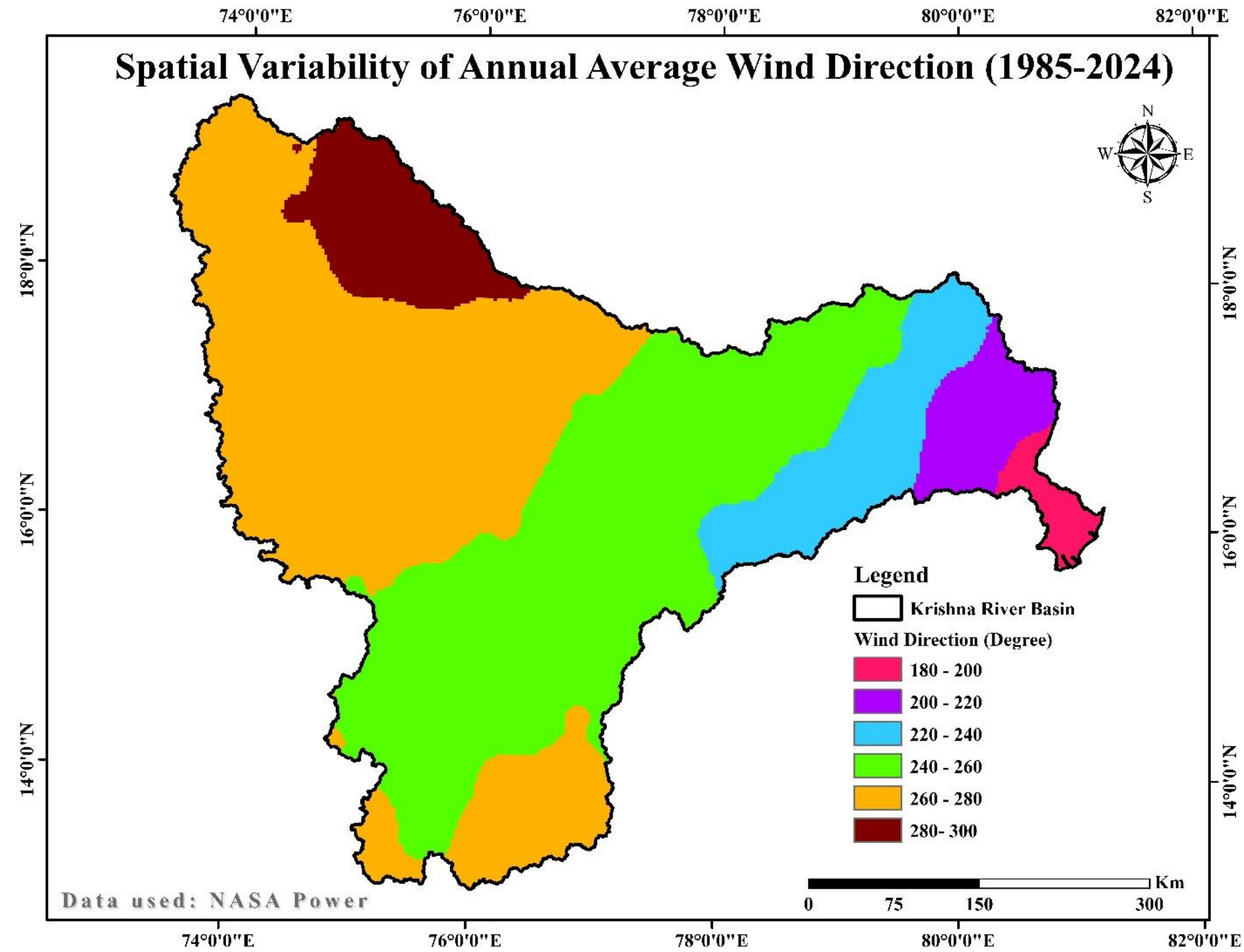


Figure 5. 1 Spatial variation of annual average wind direction (in degrees) over Krishna River Basin (1985-2024)

The wind direction data across the Krishna River Basin shows a spatially coherent but regionally variable wind regime, reflecting both the basin's complex topography and the influence of large-scale monsoon circulation. In the western coastal belt, closer to the Arabian Sea, mean wind directions are predominantly from the west-southwest to southwest, consistent with the summer monsoon inflow during June–September. This orientation suggests that maritime air masses dominate here, bringing moisture-laden winds inland. Moving eastward across the basin, especially into the central Deccan Plateau, the mean wind direction gradually shifts toward the south or southeast, indicating a partial deflection of the monsoon flow by the Western Ghats and the local terrain-induced channelling effects. In the eastern fringes of the basin, closer to the Bay of Bengal influence, mean directions exhibit a more pronounced easterly or northeast component, which may be linked to post-monsoon and winter season winds, as well as occasional cyclonic systems.

Seasonal variability embedded in this 40-year mean implies that while the summer monsoon dominates the overall pattern, other seasonal wind systems — such as the northeast monsoon (October–December) and dry season easterlies — contribute to the observed long-term average. The directional gradients across the basin may also influence evaporation rates, dust transport, and localized convection patterns, which are important for integrated water resources management. Furthermore, these prevailing directions have implications for wind energy site selection, agro-meteorology, and hydrological modelling, since wind direction affects evapotranspiration, sediment transport, and even reservoir evaporation losses.

The combined wind speed–direction analysis highlights the basin's dual-season wind regime, strongly tied to India's monsoon system, with higher energy winds in the southwest monsoon period and lower, more variable winds in the post-monsoon and winter months. These wind characteristics have implications for evapotranspiration rates, water balance modelling, sediment transport, and renewable energy potential in the basin. In hydrological simulations, this spatio-temporal wind variability is particularly important for accurate Integrated Water Resources Management (IWRM), as it influences open water evaporation, reservoir operation planning, and agro-climatic zoning.

6. Conclusions

The climatological assessment of the Krishna River Basin for the period 1985–2024 reveals distinct spatial and temporal patterns in precipitation, temperature, relative humidity, wind speed, and wind direction that are closely linked to the basin's monsoon-dominated climate and varied topography. Precipitation shows a gradual basin-wide increase over the past century, with strong spatial gradients—from very high rainfall zones along the Western Ghats and coastal Andhra Pradesh to semi-arid interiors in Karnataka, Telangana, and Maharashtra. Minimum and maximum temperatures both exhibit consistent warming trends, with sharper increases in maximum temperatures, particularly during the pre-monsoon months. Relative humidity peaks during the southwest monsoon across the basin, remains high in the eastern coastal belt during the northeast monsoon, and drops sharply in interior regions during the pre-monsoon dry season. Wind speeds are highest in the eastern coastal areas and the western windward highlands, and lowest in interior rain-shadow zones; wind directions follow a clear seasonal reversal, from southwesterlies in the monsoon to northeasterlies in the post-monsoon/winter season. These climatic features have significant implications for water resources management, agriculture, reservoir operations, and climate adaptation planning. The results underscore the importance of integrating long-term climate variability and change into hydrological modelling, irrigation scheduling, and drought/flood preparedness strategies for sustainable basin management.

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