GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
EARTH SYSTEM SCIENCE ORGANISATION
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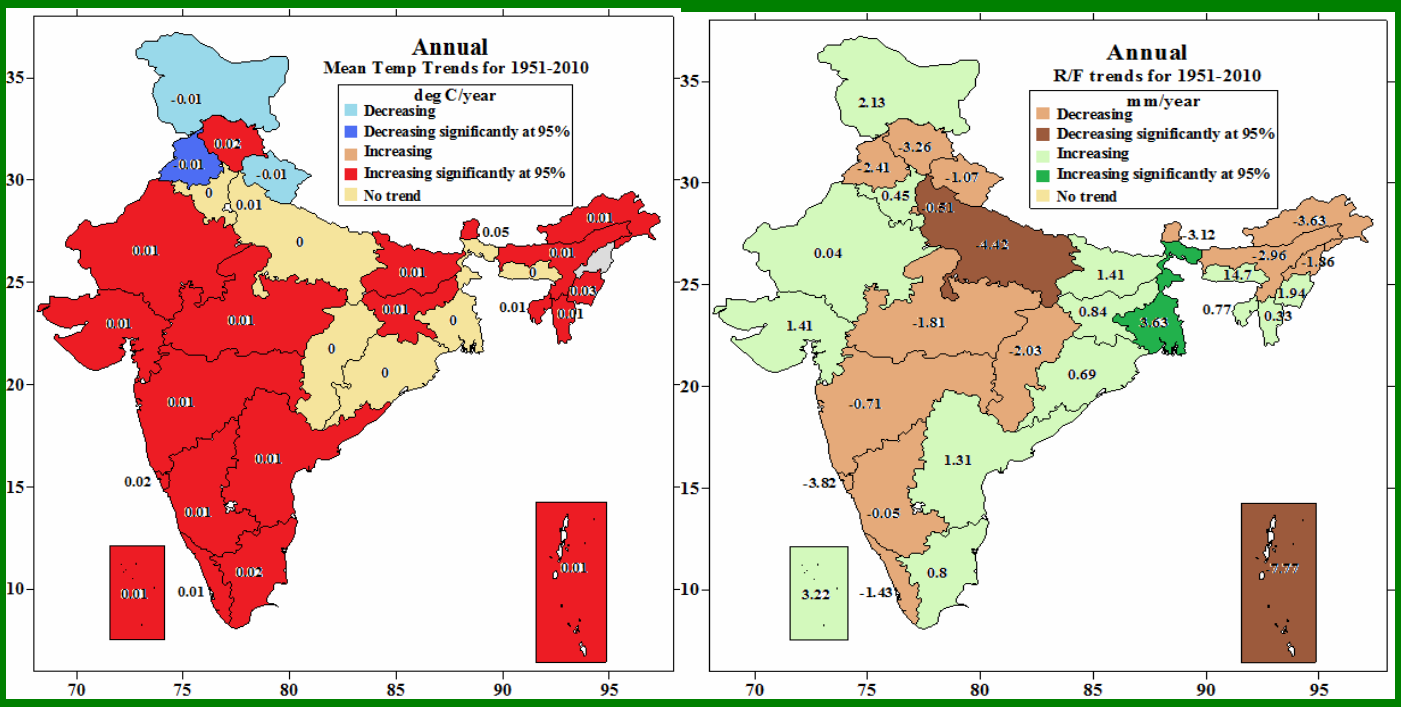
# STATE LEVEL CLIMATE CHANGE TRENDS IN INDIA

*Meteorological Monograph No. ESSO/IMD/EMRC/02/2013*




**L S Rathore, S D Attri and A K Jaswal**

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Published in India
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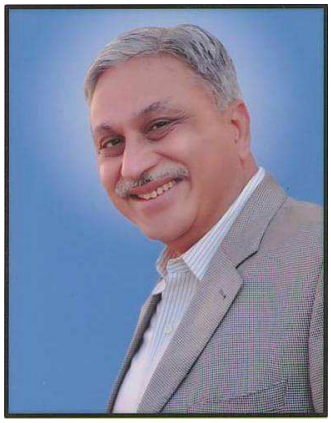

## FOREWORD

**I have great pleasure in introducing the "State Level Climate Change Trends in India" under the Meteorological Monograph Series. The Meteorological Monographs have been brought on relevant topics concerning meteorological and allied sciences. It is for the first time that such comprehensive, long-term assessment of the climate change during 1951-2010 has been undertaken for each state of the country. The publication contains assessment of the annual, seasonal and monthly climate change trends in maximum, minimum and average temperatures, diurnal temperature range and precipitation at state level.**

**I am sure that climate change trends and regional impact assessments provided in this monograph at state level will be extremely useful to plan adaptation and mitigation strategies. I compliment Dr. L.S. Rathore, Dr.S.D. Attri and Shri A.K. Jaswal in bringing out this important publication.**

(Shailesh Nayak)

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**INDIA METEOROLOGICAL DEPARTMENT**
**DOCUMENT AND DATA CONTROL SHEET**

| | | |
|---|---|---|
| 1. | Document title | State Level Climate Change Trends in India |
| 2. | Document type | Met Monograph |
| 3. | Issue No. | Environment Meteorology-02/2013 |
| 4. | Issue date | December 2013 |
| 5. | Security Classification | Unclassified |
| 6. | Control Status | Uncontrolled |
| 7. | No. of Pages | 147 |
| 8. | No. figures | 88 |
| 9. | No. of reference | 46 |
| 10. | Distribution | Unrestricted |
| 11. | Language | English |
| 12. | Authors | L S Rathore, S D Attri and A K Jaswal |
| 13. | Originating Division/Group | EMRC |
| 14. | Reviewing and Approving Authority | DGM |
| 15. | End users | Ministries / Departments of Central and State Governments, Research organisations, Universities, Planners, Scientific community, Public etc. |
| 16. | Abstract | State level climate change trends over India during last 60 years have been presented here. The publication contains quantification of climate change trends with latest data (1951-2010) in respect of temperatures (Maximum, Minimum and Average), Daily temperature range and rainfall for each state of the country. The publication is also intended to provide requisite details for Government, scientific community and planners to address climate change issues particularly at state level. |
| 17. | Key words | Climate Change, State, Rainfall, DTR, Temperatures |

# *CONTENTS*

# CHAPTER 1

## 1. Introduction

Climate is a critical factor in the lives and livelihoods of the people and socio-economic development as a whole. Climate has shown warming of 0.89 [0.69 to 1.08] °C over the period 1901–2012 which is mainly attributed to anthropogenic activities (IPCC 2013). Further, it has projected that the global mean surface temperature and sea level may increase by 0.3°C to 1.7°C and 0.26 to 0.54 m for RCP2.6, 1.1°C to 2.6°C and 0.32 to 0.62m for RCP 4.5, 1.4°C to 3.1°C and 0.33 to 0.62 m for RCP6.0 and 2.6°C to 4.8°C and 0.45 to 0.81 m for RCP 8.5 respectively by 2181-2100. The newer findings indicate that warming is more pronounced than expected. The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India (Sathaye, Shukla & Ravindranath, 2006). Increasing temperature trends of the order of 0.60°C during last 112 years (IMD 2012) and increase in heavy rainfall events and decrease in low and medium rainfall events (Goswami *et al*. 2006) over India have been observed. Changes in rainfall and temperatures have also been reported by Dash *et al.* (2009), Arora *et al.* (2005), De *et al.* (2005), Guhathakurta and Rajeevan (2008), MoEF (2010), Jones and Briffa (1992), Kothawale *et al.* (2010), Tyagi and Goswami (2009) and others.

India has to face the challenge of sustaining its rapid economic growth in the era of rapidly changing global climate. The problem has emanated from accumulated greenhouse gas emissions in the atmosphere, anthropogenically generated through long-term and intensive industrial growth and high consumption lifestyles in developed countries. Though, there is need to continuously engage international community to collectively and cooperatively deal with this threat, India needs a strong national strategy to firstly, adapt to climate change and secondly, to further enhance the ecological sustainability of its development path. This path is based on its unique resource endowments, the overriding priority of economic and social development and poverty eradication, and its adherence to its civilization legacy that places a high value on the environment and the maintenance of ecological balance. In its journey to developmental pathway, the country has a wider spectrum of choices precisely because it is at an early stage of development. The national vision

is to create a prosperous, but not wasteful society, an economy that is self-sustaining in terms of its ability to unleash the creative energies of our people and is mindful of our responsibilities to both present and future generations. This is in tune with global vision inspired by Mahatma Gandhi's wise dictum – *"The earth has enough resources to meet people's needs, but will never have enough to satisfy people's greed"*. As such, promotion of sustainable production processes along with but equally, sustainable lifestyles across the globe should be the focus point of our efforts.

India needs to emerge as responsible and enlightened member of the international community, ready to make our contribution to the solution of a global challenge, which impacts on humanity as a whole. It should concentrate on efforts of global agreement for transfer of new and additional financial resources and climate friendly technologies to support both adaptation and mitigation in developing countries. The principle of equity that must underline the global approach must allow each inhabitant to the earth an equal entitlement to the global atmospheric resource. In such scenario, India's per capita greenhouse gas emissions will at no point exceed that of developed countries even as we pursue our development objectives. Our response to the climate change threat lies in National Action Plan on Climate change containing 8 Missions launched by Hon'ble Prime Minister of India in 2008 (GOI, 2008).

Global warming /Climate change, rapidly increasing population, depletion of natural habitats and resources are important global challenges having direct impacts on livelihoods and raising concerns for food security, water supply, health and energy. To address these issues, there is need to mobilize the capabilities to facilitate the mounting societal demand for in changing climate, fully knowing that climate has both physical aspects which can shape the availability of natural resources, such as in particular renewable energies, as well as informational aspects that may be used, at least potentially, to support socio-economic decision-making.

Governments and global research communities have strongly indicated their desire that the earth must be preserved for posterity and "live and let live" slogans need to become the role model leading to sustainable development. United Nations Framework Convention on Climate Change (UNFCCC) is playing a major a role in

mitigating greenhouse gases emissions by bringing developed and developing countries at some common platform so that climate change can be kept at reasonable safe level. But reasonable agreement is still elusive in spite of 18 annual meetings of Conference of Parties. Government of India has taken a number of policy and technological initiatives for safeguarding the earth and resources and addressing climate change implications. There is also need for the sensitization at the grassroot levels and major initiatives at the national level to develop a culture for greener environment, a well-coordinated environment protection protocol between the government and citizens and the passion for protection and conservation on the whole.

India Meteorological Department (IMD) has been maintaining a well distributed network of more than 500 stations in the country for more than a century. It has provided climatic observations and products to the national and international requirements National Communication (NATCOM), WMO, UNFCCC and IPCC. It is in process of augmenting its weather and climate-related observation systems that underpins analytical and predictive capability which is critical for minimising extreme climate variability impacts and quantify climate change trends in the country as well at state level to plan adaptation and mitigation strategies.

IMD brought out Met. Monograph No 01/2010 on “Climate Profile of India” (Attri and Tyagi, 2010) containing national level trends as contribution to the “India’s Second National Communication-II” and submitted to UNFCCC in May 2012 and for providing inputs to NAPCC, which was widely acclaimed. NATCOM (2012) has delineated current status of climate change and future predictions in India including sectoral vulnerability assessments and systematic observations and research in climate science. *Govt of India has emphasised on all the States to prepare SLAPCC (State* Level APCC) like NAPCC. This publication consisting of long term and latest data (1951-2010) of well distributed 282 stations for temperatures and 1451 stations for rainfall series in India, will provide insight into climate change occurring over smaller areas and will also assist the Sates in formulation of their adaptation and Mitigation strategies in light of rapidly changing climate trends.

# Chapter 2

# METHODOLOGY

## 2.0 Data and Methodology

One of the best ways of understanding how climate may change in future is to examine how it has changed in the past based upon long-term observational records. Recent long-term meteorological data for 1951-2010 period were obtained from National Data Centre of India Meteorological Department (IMD) located at Pune where all quality controlled climatological data are archived. Climatological trend analysis for a 60-year period is of sufficient duration to reflect natural climatic variability on a multi-decadal timescale, which is important in considering long-term impacts of climate change. There are more than 500 surface meteorological stations and more than 2500 rainfall stations maintained by Central and state Governments in IMD's network. However, temperature data are selected for those stations having 48 years or more data available during 1951-2010. Further, stations having less than 80% data availability during 1951-2010 are rejected. To obtain sufficient number of stations for calculating state averages, exceptions are made for stations in the Northeast and Jammu and Kashmir where stations having 35 years or more with 75% data availability during 1951-2010 are also considered. Due to strict station selection criterion, some states are represented by few stations only. No station from Nagaland could qualify for temperature analysis. The number of meteorological stations whose data are used for analyzing surface temperature and rainfall trends are 282 and 1451 respectively. The locations of these meteorological stations are shown in Figures 1 and 2 respectively. It is important to note that state averages of temperature and rainfall are calculated as simple arithmetic means of number of stations in the state.

In addition to mean maximum temperature and mean minimum temperature, mean temperature (average of maximum and minimum temperature) and diurnal temperature range (difference of maximum and minimum temperature) for each month of the year were also computed. From the monthly values, annual (January-December) and seasonal (Winter: December, January, February; Summer: March-

May; Monsoon: June-September; Post monsoon: October-November) time series of mean maximum temperature, mean minimum temperature, mean temperature, mean diurnal temperature range and rainfall were prepared. State annual, seasonal and monthly time series of maximum temperature, minimum temperature, mean temperature, diurnal temperature range (DTR) and rainfall were computed by averaging the stations series in the respective state. Total 282 surface meteorological stations are used for preparing state temperature series. Similarly, 1451 rainfall stations spread across all over the country were used for preparing state average rainfall series. The number of stations used for preparing state level temperature and rainfall time-series for 1951-2010 is given in Table 1.

Behaviour of annual, seasonal and monthly state time series of temperature and rainfall is studied by subjecting them to non-parametric Mann-Kendall test and increasing or decreasing slope of trends in the time series is determined by using Sen's method (Sen, 1968). The Mann-Kendall test consists of comparing each value of the time-series with the others remaining, always in sequential order. The number of times that the remaining terms are greater than that under analysis is counted.

The Mann–Kendall statistic is given by:

$$S=\sum_{i=2}^{n}\sum_{j=1}^{i-1} sign(x_i - x_j) \qquad (1)$$

where n is the length of the data set, $x_i$ and $x_j$ are two generic sequential data values.

The function sign($x_i - x_j$) assumes the following values:

$$sign(x_i - x_j) = \begin{cases} +1, if\ (x_i - x_j) > 0 \\ 0, if\ (x_i - x_j) = 0 \\ -1, if\ (x_i - x_j) < 0 \end{cases} \qquad (2)$$

Under the hypothesis of independent and randomly distributed variables when n≥8, the statistic *S* is approximately normally distributed with zero mean and the variance Var(*S*) as follows:

$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5)\right] \quad (3)$$

where *n* is the length of the times-series.

The standardized test statistic *Z* is given by:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & if \ S > 0 \\ 0 & if \ S = 0 \\ \dfrac{S-1}{\sqrt{Var(S)}} & if \ S < 0. \end{cases} \quad (4)$$

The presence of a statistically significant trend is evaluated using the *Z* value. This statistic is used to test the null hypothesis such that no trend exists. A positive *Z* indicates an increasing trend in the time-series, while a negative *Z* indicates a decreasing trend. In this study, if $Z > +1.96$ or $Z < -1.96$, the null hypothesis ($H_o$) is rejected at the 95% significance level. The estimate for the magnitude of the slope of trend *b* is calculated using non-parametric Sen's method, which is the median of slopes of all data value pairs.

$$b = median\left[\frac{(X_j - X_i)}{(j-i)}\right], \ for\ all\ i < j \quad (5)$$

where *b* is the slope between data points $X_j$ and $X_i$ measured at times j and i respectively.

The results of trend analysis are presented in Figures 3 to 87 where statistically significant trends at 95% level and non-significant trends are shown in different colours. State level annual, seasonal and monthly trend values of mean maximum temperature, minimum temperature, mean temperature, diurnal temperature range and rainfall for 1951-2010 are given in Tables 2 to 11 where increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign.

# CHAPTER 3

# CLIMATE CHANGE TRENDS

Long-term changes in surface temperature and precipitation in India were analyzed using observational records of IMD from 1951 to 2010. In this study, 282 stations free from highly influence of urbanization and having continuous temperature records from 1951 onwards were selected to estimate long term temperature trends. However, for precipitation trends, 1451 stations having continuous records from 1951 onwards were selected. The locations of these meteorological stations are shown in Figures 1 and 2 respectively and the stations used for preparing state level temperature and rainfall time-series for 1951-2010 is presented in Table 1.

## 3.1 ANNUAL CLIMATE CHANGE TRENDS

### 3.1.1 Annual mean maximum temperature trends

State wise averaged annual mean maximum temperature time series has shown increasing trends over many states of India except Bihar, Chhattisgarh, Delhi, Haryana, Jammu and Kashmir, Meghalaya, Punjab, Tripura and Uttar Pradesh (Figure 3). The increasing trends were significant over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Orissa, Rajasthan, Sikkim, Tamil Nadu and Uttarakhand. The highest increase in annual mean maximum temperatures was observed over Himachal Pradesh (+0.06 $^{o}$C/year) followed by Goa (+0.04 $^{o}$C/year), Manipur, Mizoram and Tamil Nadu (+0.03 $^{o}$C/year each) as given in Table 2. The decreasing trends were significant over Punjab (-0.01 $^{o}$C/year) and Haryana (-0.02 $^{o}$C/year). However, no trends were observed over Bihar, Chhattisgarh, Delhi, Meghalaya, Tripura and Uttar Pradesh during 1951-2010.

### 3.1.2 Annual mean minimum temperature trends

State averaged annual mean minimum temperatures have shown significantly increasing trends over Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Kerala, Lakshadweep, Manipur, Meghalaya, Rajasthan, Sikkim, Tamil Nadu and Tripura (Figure 4). The highest increase in annual mean minimum temperature was observed for Sikkim (+0.07 $^{o}$C/year) followed by Arunachal Pradesh, Bihar, Delhi, Gujarat, Manipur, Tamil Nadu and Tripura (+0.02 $^{o}$C/year each) during the study period (Table 3). Annual mean minimum temperature trends are significantly decreasing over Chhattisgarh (-0.01 $^{o}$C/year), Orissa (-0.02 $^{o}$C/year), Punjab (-0.01 $^{o}$C/year) and Uttarakhand (-0.03 $^{o}$C/year). However, Goa, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Mizoram, Uttar Pradesh and West Bengal do not indicate any trend in annual mean minimum temperature during last six decades.

### 3.1.3 Annual mean temperature trends

Annual mean temperatures have increased significantly over all the states of India except Chhattisgarh, Haryana, Jammu and Kashmir, Meghalaya, Orissa, Punjab, Uttar Pradesh, Uttarakhand and West Bengal. The highest increase in annual mean temperature was obtained for Sikkim (+0.05 $^{o}$C/year) followed by Manipur (+0.03 $^{o}$C/year), Goa, Himachal Pradesh and Tamil Nadu (+0.02 $^{o}$C/year each) as given in Table 4. Punjab (-0.01 $^{o}$C/year) has shown significant decreasing trends in annual mean temperature while no trends were observed in Chhattisgarh, Haryana, Meghalaya, Orissa, Uttar Pradesh and West Bengal during 1951-2010.

### 3.1.4 Annual mean DTR trends

Significant increase in annual mean DTR trends have been observed over Andaman and Nicobar, Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Maharashtra, Mizoram, Orissa, Tamil Nadu and Uttarakhand during 1951-2010 (Figure 6). The highest increase in annual mean DTR was obtained over Himachal Pradesh (+0.06 $^{o}$C/year) followed by Goa and Mizoram and Goa (+0.04 $^{o}$C/year each) as presented in Table 5. Annual mean DTR trends have significantly decreased over Arunachal Pradesh (-0.01 $^{o}$C/year), Bihar (-0.02 $^{o}$C/year), Delhi (-0.01 $^{o}$C/year), Gujarat (-0.01 $^{o}$C/year),

Haryana (-0.02 $^{o}$C/year), Sikkim (-0.04 $^{o}$C/year), Tripura (-0.02 $^{o}$C/year) and Uttar Pradesh (-0.01 $^{o}$C/year). However, averaged annual mean DTR did not indicate any trends in Assam, Madhya Pradesh, Manipur, Meghalaya, Rajasthan and West Bengal.

### 3.1.5 Annual average rainfall trends

State averaged annual rainfall trends have increased over Andhra Pradesh, Bihar, Gujarat, Haryana, Jammu and Kashmir, Jharkhand, Lakshadweep, Manipur, Meghalaya, Mizoram, Orissa, Rajasthan, Tamil Nadu, Tripura and West Bengal during 1951-2010 (in Figure 7). However, annual rainfall has decreased over Andaman and Nicobar, Arunachal Pradesh, Assam, Chhattisgarh, Delhi, Goa, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Nagaland, Punjab, Sikkim and Uttar Pradesh. The highest increase and decrease in annual rainfall were observed over Meghalaya (+14.68 mm/year) and Andaman and Nicobar (-7.77 mm/year) respectively (Table 6). However, annual rainfall trends have been significantly increasing over West Bengal (+3.63 mm/year) and significantly decreasing over Andaman and Nicobar (-7.77 mm/year) and Uttar Pradesh (-4.42 mm/year).

## 3.2 STATE LEVEL SEASONAL CLIMATE CHANGE TRENDS

### 3.2.1 WINTER CLIMATE CHANGE TRENDS

#### 3.2.1.1 Winter mean maximum temperature trends

The study indicates increasing trend in winter mean maximum temperatures over all States of India except Bihar, Chhattisgarh, Delhi, Haryana, Madhya Pradesh, Meghalaya, Punjab, Rajasthan, Tripura, Uttar Pradesh and West Bengal (Figure 8). The increasing trends were significant over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Goa, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Maharashtra, Manipur, Mizoram, Sikkim, Tamil Nadu and Uttarakhand. The highest increase in winter mean maximum temperature was obtained for Himachal Pradesh (+0.06 $^{o}$C/year) followed by Goa (+0.05 $^{o}$C/year), Manipur, Mizoram and Tamil Nadu (+0.04 $^{o}$C/year each) as given in Table 2. Winter mean maximum temperature for Bihar (-0.01 $^{o}$C/year), Haryana (-0.03 $^{o}$C/year) and Punjab (-0.02 $^{o}$C/year) have shown significant decreasing trends. However, Chhattisgarh, Madhya Pradesh, Meghalaya, Rajathan and West Bengal showed no trend in winter mean maximum temperature during 1951-2010.

#### 3.2.1.2 Winter mean minimum temperature trends

State averaged winter mean minimum temperatures have shown significantly increasing trends over Arunachal Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Lakshadweep, Manipur, Meghalaya, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal as depicted in Figure 9. The highest increase in annual mean minimum temperature was obtained for Sikkim (+0.08 $^{o}$C/year) followed by Gujarat, Manipur and Tripura (+0.033 $^{o}$C/year each) as given in Table 3. Winter mean minimum temperature trends have significantly decreased over Chhattisgarh (-0.01 $^{o}$C/year), Goa (-0.01 $^{o}$C/year) and Himachal Pradesh (-0.02 $^{o}$C/year). However, no trends in winter mean minimum temperature during last 60 years were observed in Jammu and Kashmir, Jharkhand, Madhya Pradesh, Maharashtra, Mizoram, Punjab and Uttarakhand.

#### 3.2.1.3 Winter mean temperature trends

Winter mean temperatures have increased over all states of India except Bihar, Chhattisgarh, Haryana, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Orissa, Punjab, Uttar Pradesh and West Bengal (Figure 10). The increasing trends

were significant over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Kerala, Lakshadweep, Manipur, Meghalaya, Mizoram, Rajasthan, Sikkim, Tamil Nadu and Tripura. The highest increase in winter mean temperature was obtained over Sikkim (+0.05 $^{o}$C/year) followed by Manipur (+0.04 $^{o}$C/year) and Tamil Nadu (+0.03 $^{o}$C/year) as given in Table 4. Winter mean temperatures for Punjab have decreased significantly by -0.02 $^{o}$C/year. However, no trends were seen over Bihar, Chhattisgarh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh and West Bengal during 1951-2010.

### 3.2.1.4 Winter mean DTR trends

Winter DTR time series has shown significant increasing trends for Andaman and Nicobar (+0.02 $^{o}$C/year), Goa (+0.06 $^{o}$C/year), Himachal Pradesh (+0.09 $^{o}$C/year), Jammu and Kashmir (+0.02 $^{o}$C/year), Karnataka (+0.03 $^{o}$C/year), Maharashtra (+0.02 $^{o}$C/year), Mizoram (+0.04 $^{o}$C/year), Orissa (+0.02 $^{o}$C/year), Tamil Nadu (+0.01 $^{o}$C/year) and Uttarakhand (+0.03 $^{o}$C/year) as depicted in Figure 11. Winter DTR has decreased significantly over Bihar (-0.04 $^{o}$C/year), Delhi (-0.03 $^{o}$C/year), Gujarat (-0.03 $^{o}$C/year), Haryana (-0.05 $^{o}$C/year), Rajasthan (-0.01 $^{o}$C/year), Sikkim (-0.05 $^{o}$C/year), Tripura (-0.04 $^{o}$C/year), Uttar Pradesh (-0.03 $^{o}$C/year) and West Bengal (-0.01 $^{o}$C/year). However, DTR did not indicate any trend in winter over Arunachal Pradesh, Assam and Lakshadweep during last 6 decades as given in Table 5.

### 3.2.1.5 Winter season rainfall trends

Winter season rainfall has shown increasing trends over Andhra Pradesh, Assam, Chhattisgarh, Delhi, Haryana, Jammu and Kashmir, Karnataka, Maharashtra, Manipur, Meghalaya, Nagaland, Orissa, Punjab, Rajasthan, Tripura and West Bengal (Figure 12). Winter rainfall trends have decreased over Andaman and Nicobar, Arunachal Pradesh, Bihar, Himachal Pradesh, Jharkhand, Kerala, Lakshadweep, Madhya Pradesh, Mizoram, Sikkim, Tamil Nadu, Uttar Pradesh and Uttarakhand. However, annual rainfall trends have significantly increased over Jammu and Kashmir (+1.88 mm/year) and Meghalaya (+0.52 mm/year) and significantly decreased over Andaman and Nicobar (-2.70 mm/year) as presented in Table 6. However, Goa and Gujarat showed no trend in state averaged winter rainfall during 1951-2010.

### 3.2.2 SUMMER CLIMATE CHANGE TRENDS

#### 3.2.2.1 Summer mean maximum temperature trends

State averaged summer mean maximum temperatures have increased over all states of India except Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Jammu and Kashmir, Jharkhand, Meghalaya, Punjab, Tripura, Uttar Pradesh, Uttarakhand and West Bengal (Figure 13). The increasing trends were significant over Andaman and Nicobar, Andhra Pradesh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Maharashtra, Mizoram, Rajasthan, Sikkim and Tamil Nadu. The highest increase has been obtained over Himachal Pradesh (+0.06 $^{o}$C/year) followed by Goa (+0.04 $^{o}$C/year), Sikkim and Tamil Nadu (+0.030 $^{o}$C/year each) as given in Table 2. Bihar (-0.02 $^{o}$C/year), Tripura (-0.02 $^{o}$C/year) and West Bengal (-0.01 $^{o}$C/year) have observed significant decreasing trends. However, Arunachal Pradesh, Assam, Chhattisgarh, Gujarat, Jharkhand, Meghalaya, Punjab and Uttarakhand showed no trend during last 60 years.

#### 3.2.2.2 Summer mean minimum temperature trends

Summer mean minimum temperatures have shown significant increasing trends over Arunachal Pradesh, Assam, Bihar, Delhi, Gujarat, Haryana, Lakshadweep, Manipur, Rajasthan, Sikkim and Tamil Nadu (Figure 14). The highest increase in summer mean minimum temperature was obtained for Sikkim (+0.07 $^{o}$C/year) followed by Manipur (+0.03 $^{o}$C/year), Arunachal Pradesh, Delhi, Gujarat, Haryana, Rajasthan and Tamil Nadu (+0.02 $^{o}$C/year each) as presented in Table 3. Summer mean minimum temperature trends have significantly decreased over Chhattisgarh (-0.02 $^{o}$C/year), Goa (-0.01 $^{o}$C/year), Himachal Pradesh (-0.03 $^{o}$C/year), Karnataka (-0.01 $^{o}$C/year), Mizoram (-0.01 $^{o}$C/year), Orissa (-0.02 $^{o}$C/year) and Uttarakhand (-0.03 $^{o}$C/year). However, no trends have been observed over Andaman and Nicobar, Andhra Pradesh, Jharkhand, Kerala, Madhya Pradesh, Meghalaya, Punjab, Tripura, Uttar Pradesh and West Bengal in summer mean minimum temperature during 1951-2010.

#### 3.2.2.3 Summer mean temperature trends

Summer mean temperatures have significantly increased over Andaman and Nicobar, Andhra Pradesh, Delhi, Goa, Kerala, Lakshadweep, Manipur, Rajasthan,

Sikkim and Tamil Nadu (Figure 15). The highest increase in summer mean temperature has been seen over Sikkim (+0.05 $^{o}$C/year) followed by Tamil Nadu (+0.03 $^{o}$C/year), Goa, Lakshadweep, Manipur and Rajasthan (+0.02 $^{o}$C/year each) as given in Table 4. Summer mean temperatures have shown significant decreasing trends over Tripura and West Bengal (-0.01 $^{o}$C/year each). However, Assam, Bihar, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Meghalaya, Mizoram and Punjab showed no trend in summer mean minimum temperature during last 6 decades.

#### 3.2.2.4 Summer mean DTR trends

State averaged summer DTR time series has shown significant increasing trends for Andaman and Nicobar (+0.01 $^{o}$C/year), Andhra Pradesh (+0.01 $^{o}$C/year), Chhattisgarh (+0.02 $^{o}$C/year), Goa (+0.05 $^{o}$C/year), Himachal Pradesh (+0.09 $^{o}$C/year), Jammu and Kashmir (+0.03 $^{o}$C/year), Karnataka (+0.02 $^{o}$C/year), Kerala (+0.01 $^{o}$C/year), Lakshadweep (+0.01 $^{o}$C/year), Madhya Pradesh (+0.01 $^{o}$C/year), Maharashtra (+0.02 $^{o}$C/year), Mizoram (+0.02 $^{o}$C/year), Orissa (+0.02 $^{o}$C/year), Tamil Nadu (+0.01 $^{o}$C/year) and Uttarakhand (+0.03 $^{o}$C/year) during 1951-2010 (Figure 16). Summer DTR showed significantly decreasing trends over Arunachal Pradesh (-0.02 $^{o}$C/year), Assam (-0.01 $^{o}$C/year), Bihar (-0.03 $^{o}$C/year), Delhi (-0.01 $^{o}$C/year), Gujarat (-0.02 $^{o}$C/year), Haryana (-0.02 $^{o}$C/year), Sikkim (-0.04 $^{o}$C/year) and Tripura (-0.02 $^{o}$C/year) as given in Table 5.

#### 3.2.2.3 Summer mean rainfall trends

Summer season rainfall has increased over Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Haryana, Himachal Pradesh, Jharkhand, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Tripura, Uttar Pradesh, Uttarakhand and West Bengal (Figure 17). The increasing trends have been significant over Bihar (+0.59 mm/year), Delhi (+0.40 mm/year), Haryana (+0.39 mm/year), Orissa (+0.65 mm/year), Rajasthan (+0.17 mm/year) and West Bengal (+1.34 mm/year). Mizoram, Meghalaya and Manipur showed highest increase in summer rainfall, while maximum decline has taken place over Kerala and Jammu and Kashmir (Table 6). Summer rainfall trends have decreased over Andaman and Nicobar, Assam, Goa, Gujarat, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Maharashtra, Sikkim and Tamil Nadu. However, Arunachal Pradesh and Madhya Pradesh did not indicate any trends in summer season rainfall during 1951-2010.

### 3.2.3 MONSOON CLIMATE CHANGE TRENDS

#### 3.2.3.1 Monsoon season mean maximum temperature trends

State averaged monsoon season mean maximum temperatures have shown increasing trends over all states of India except Arunachal Pradesh, Chhattisgarh, Delhi, Haryana, Jammu and Kashmir, Jharkhand, Orissa, Punjab and Uttar Pradesh (Figure 18). The increasing trends were significant over Andaman and Nicobar, Andhra Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Sikkim, Tamil Nadu, Tripura and West Bengal. The highest increase in monsoon mean maximum temperatures has been obtained for Himachal Pradesh (+0.06 $^{o}$C/year) followed by Mizoram (+0.05 $^{o}$C/year), Goa, Manipur, Sikkim and Tamil Nadu (+0.03 $^{o}$C/year each) as given in Table 2. Haryana (-0.01 $^{o}$C/year), Jammu and Kashmir (-0.04 $^{o}$C/year) and Punjab (-0.02 $^{o}$C/year) have shown significant decreasing trends in monsoon season mean maximum temperature. However, no trends during 1951-2010 were seen over Arunachal Pradesh, Chhattisgarh, Delhi, Jharkhand, Orissa and Uttar Pradesh.

#### 3.2.3.2 Monsoon season mean minimum temperature trends

Monsoon mean minimum temperatures have increased significantly over Andhra Pradesh, Arunachal Pradesh, Assam, Delhi, Goa, Gujarat, Kerala, Manipur, Sikkim, Tamil Nadu and Tripura (Figure 19). The highest increase in monsoon mean minimum temperature occurred over Sikkim (+0.06 $^{o}$C/year) followed by Tamil Nadu and Manipur (+0.02 $^{o}$C/year each) as given in Table 3. Monsoon mean minimum temperature over Chhattisgarh (-0.01 $^{o}$C/year), Jammu and Kashmir (-0.03 $^{o}$C/year), Madhya Pradesh (-0.01 $^{o}$C/year), Orissa (-0.02 $^{o}$C/year), Punjab (-0.01 $^{o}$C/year), Uttar Pradesh (-0.01 $^{o}$C/year) and Uttarakhand (-0.04 $^{o}$C/year) have shown significant decreasing trends. However, no trends were observed over Andaman and Nicobar, Bihar, Himachal Pradesh, Jharkhand, Kerala, Karnataka, Lakshadweep, Maharashtra, Mizoram, Rajasthan and West Bengal during last 60 years.

#### 3.2.3.3 Monsoon season mean temperature trends

Monsoon mean temperatures have increased significantly over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Manipur, Mizoram, Sikkim, Tamil Nadu, Tripura and West Bengal during 1951-2010 (Figure 20). The highest

increase in monsoon mean temperature has been seen over Sikkim (+0.05 $^{o}$C/year) followed by Himachal Pradesh (+0.03 $^{o}$C/year) as presented in Table 4. Monsoon mean temperatures over Haryana (-0.01 $^{o}$C/year), Jammu and Kashmir (-0.02 $^{o}$C/year), Orissa (-0.01 $^{o}$C/year), Punjab (-0.01 $^{o}$C/year) and Uttarakhand (-0.02 $^{o}$C/year) have shown significant decreasing trends. However, no trends were observed over Chhattisgarh, Jharkhand, Madhya Pradesh, Meghalaya and Uttar Pradesh during last 60 years.

### 3.2.3.4 Monsoon season mean DTR trends

Monsoon season mean DTR has shown increasing trend over all states of India except Arunachal Pradesh, Assam, Delhi, Gujarat, Haryana, Jammu and Kashmir, Jharkhand, Meghalaya, Punjab, Sikkim and Tripura (Figure 21). The increasing trends were significant over Andaman and Nicobar, Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal. The highest increase in monsoon mean DTR has been obtained for Himachal Pradesh (+0.05 $^{o}$C/year) followed by Mizoram and Uttarakhand (+0.040 $^{o}$C/year each) as given in Table 5. Arunachal Pradesh (-0.02 $^{o}$C/year), Haryana (-0.01 $^{o}$C/year), Punjab (-0.01 $^{o}$C/year) and Sikkim (-0.03 $^{o}$C/year) have shown significant decreasing trends in monsoon season DTR. However, no trends have been observed over Assam, Gujarat, Jammu and Kashmir, Jharkhand, Meghalaya and Tripura during 1951-2010.

### 3.2.3.5 Monsoon season rainfall trends

State averaged monsoon season rainfall has increased over Bihar, Gujarat, Jharkhand, Karnataka, Lakshadweep, Meghalaya, Mizoram and West Bengal during 1951-2010 (Figure 22). The highest increase (non-significant) in rainfall was found over Meghalaya and Mizoram (Table 6). Decreasing trend in monsoon rainfall have been observed over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Chhattisgarh, Delhi, Goa, Haryana, Himachal Pradesh, Jammu and Kashmir, Kerala, Madhya Pradesh, Maharashtra, Manipur, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and Uttarakhand. Andaman and Nicobar and Himachal Pradesh have shown highest decline trends (non-significant) in monsoon season rainfall, while significantly decrease has been observed over Tamil Nadu (-1.35 mm/year) and Uttar Pradesh (-3.52 mm/year).

### 3.2.4 POST- MONSOON CLIMATE CHANGE TRENDS

#### 3.2.4.1 Post-monsoon mean maximum temperature trends

State averaged post monsoon mean maximum temperatures have increased over all states of India except Haryana, Jammu and Kashmir, Punjab and Uttar Pradesh (Figure 23). The increasing trends are significant over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Orissa, Tamil Nadu, Tripura, Uttarakhand and West Bengal. The highest increase in post monsoon mean maximum temperature has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Mizoram and Goa (+0.05 $^{o}$C/year each) as depicted in Table 2. Jammu and Kashmir has shown decreasing trends, while no trend were observed in post monsoon mean maximum temperature over Haryana, Punjab and Uttar Pradesh during 1951-2010.

#### 3.2.4.2 Post-monsoon mean minimum temperature trends

Post monsoon mean minimum temperatures have shown significantly increasing trends over Arunachal Pradesh, Assam, Bihar, Delhi, Goa, Gujarat, Kerala, Lakshadweep, Madhya Pradesh, Manipur, Meghalaya, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal (Figure 24). The highest increase was obtained for Sikkim (+0.08 $^{o}$C/year) followed by Gujarat, Madhya Pradesh, Manipur, Rajasthan and Tripura (+0.03 $^{o}$C/year each) as given in Table 3. Post monsoon mean minimum temperatures have decreased significantly over Himachal Pradesh and Jammu and Kashmir (-0.03 $^{o}$C/year each). However, no trends have been observed over Andaman and Nicobar, Chhattisgarh, Karnataka, Mizoram and Punjab during last 60 years.

#### 3.2.4.3 Post-monsoon mean temperature trends

Increasing trends in post monsoon mean temperatures have been observed over all states of India except Jammu and Kashmir and Punjab (Figure 25). The increasing trends are significant over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Delhi, Goa, Gujarat, Himachal Pradesh,

Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal. The highest increase in post monsoon mean temperature has been seen over Sikkim (+0.04 $^{o}$C/year) followed by Goa, Manipur, Madhya Pradesh and Tripura (+0.03 $^{o}$C/year each) as presented in Table 4. While Jammu and Kashmir has shown significant decreasing trend (-0.02 $^{o}$C/year), Punjab has shown no trend in post monsoon mean temperature during 1951-2010.

#### 3.2.4.4 Post-monsoon mean DTR trends

Post monsoon season mean DTR has significantly increased over Andaman and Nicobar, Goa, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Mizoram, Orissa and Uttarakhand (Figure 26). The highest increase in post monsoon mean DTR was obtained for Himachal Pradesh (+0.90 $^{o}$C/year) followed by Mizoram (+0.06 $^{o}$C/year) and Goa (+0.04 $^{o}$C/year) as given in Table 5. Gujarat (-0.02 $^{o}$C/year), Sikkim (-0.08 $^{o}$C/year), Tripura (-0.01 $^{o}$C/year) and Uttar Pradesh (-0.02 $^{o}$C/year) have shown significant decreasing trends in post monsoon season DTR. However, no trends were found over Assam, Meghalaya, Punjab and Tamil Nadu in last six decades.

#### 3.2.4.5. Post-monsoon season rainfall trends

State averaged post monsoon season rainfall has shown increasing trends over Andhra Pradesh, Bihar, Chhattisgarh, Goa, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Manipur, Meghalaya, Nagaland, Tamil Nadu, and West Bengal (Figure 27). The highest increase (non-significant) in rainfall was found over Meghalaya, Kerala and Tamil Nadu (Table 6). Post monsoon rainfall has decreased over Andaman and Nicobar, Arunachal Pradesh, Assam, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Maharashtra, Mizoram, Orissa, Punjab, Rajasthan, Sikkim, Tripura Uttar Pradesh and Uttarakhand. However, rainfall trends have decreased significantly over Haryana (-0.23 mm/year) during 1951-2010.

## 3.3 MONTHLY CLIMATE CHANGE TRENDS

### 3.3.1 JANUARY

#### 3.3.1.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of January have shown significantly increasing trends over Himachal Pradesh, Uttarakhand, Jharkhand, Mizoram, Manipur, Maharashtra, Goa, Karnataka, Andhra Pradesh, Kerala, Tamil Nadu, Lakshadweep and Andaman and Nicobar Islands during 1951-2010 (Figure 28). The highest increase in January mean maximum temperature occurred over Himachal Pradesh (+0.08 $^{o}$C/year) followed by Mizoram and Goa (+0.05 $^{o}$C/year each) as given in Table 7. Mean maximum temperature trends for January were significantly lower in Haryana (-0.04 $^{o}$C/year), Punjab (-0.03 $^{o}$C/year), Bihar and Delhi (-0.02 $^{o}$C/year each). Chhattisgarh has shown no trend during 1951-2010.

#### 3.3.1.2 Minimum temperature trends

Mean minimum temperatures for January showed significantly increasing trends over Arunachal Pradesh, Assam, Gujarat, Lakshadweep, Manipur, Meghalaya, Sikkim, Tamil Nadu and Tripura during 1951-2010 (Figure 29). The highest increase in January mean minimum temperature was observed over Sikkim (+0.08 $^{o}$C/year) followed by Gujarat, Tripura and Manipur (+0.03 $^{o}$C/year each) as presented in Table 8. Mean minimum temperature trends for January have decreased (non-significantly) in Jammu and Kashmir, Punjab, Himachal Pradesh, Jharkhand, West Bengal, Chhattisgarh, Orissa, Maharashtra, Goa and Karnataka. However, Andaman and Nicobar, Andhra Pradesh, Kerala, Madhya Pradesh, Mizoram, Uttarakhand, Uttar Pradesh and West Bengal showed no trends in mean minimum temperature for January during 1951-2010.

#### 3.3.1.3 Mean temperature trends

Significantly increasing trends in state averaged mean temperatures over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Kerala, Lakshadweep, Manipur, Meghalaya, Mizoram, Sikkim and Tamil Nadu were observed for January during 1951-2010 (Figure 30). The

highest increase in January mean temperature has occurred over Sikkim (+0.05 $^{o}$C/year) followed by Manipur (+0.04 $^{o}$C/year), Himachal Pradesh, Mizoram and Tamil Nadu (+0.03 $^{o}$C/year each) as depicted in Table 9. Significant decreasing trends in mean temperatures for January were found over Punjab (-0.02 $^{o}$C/year) and Haryana (-0.01 $^{o}$C/year). No trends in mean temperatures over Jammu and Kashmir, Jharkhand, Madhya Pradesh, Maharashtra and Orissa were observed for January during last six decades.

#### 3.3.1.4 DTR trends

State averaged mean DTR for January have shown significantly increasing trends over Andaman and Nicobar, Goa, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Maharashtra, Mizoram, Orissa, Tamil Nadu and Uttarakhand during 1951-2010 (Figure 31). The highest increase in mean DTR of January month has occurred over Himachal Pradesh (+0.10 $^{o}$C/year) followed by Goa (+0.05 $^{o}$C/year), Jammu and Kashmir, Jharkhand, Karnataka, Mizoram and Uttarakhand (+0.03 $^{o}$C/year each) as given in Table 10. Mean DTR for January has decreased significantly in Bihar (-0.04 $^{o}$C/year), Delhi (-0.03 $^{o}$C/year), Gujarat (-0.02 $^{o}$C/year), Haryana (-0.05 $^{o}$C/year), Rajasthan (-0.02 $^{o}$C/year), Sikkim (-0.06 $^{o}$C/year), Tripura (-0.04 $^{o}$C/year) and Uttar Pradesh (-0.03 $^{o}$C/year). Arunachal Pradesh, Kerala and Lakshadweep showed no trends in mean DTR for January during last 60 years.

#### 3.3.1.5 Rainfall trends

Figure 32 shows increasing month rainfall trends over Andhra Pradesh, Chhattisgarh, Jammu and Kashmir, Karnataka, Lakshadweep, and Orissa. The increasing trends are significant over Karnataka (+0.01 mm/year). Decreasing trends in rainfall of January month have been observed over Andaman and Nicobar, Arunachal Pradesh, Assam, Bihar, Delhi, Haryana, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Manipur, Meghalaya, Nagaland, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and Uttarakhand. The decreasing trends in rainfall are significant for Himachal Pradesh (-0.69 mm/year), Uttar Pradesh (+0.24 mm/year) and Andaman and Nicobar (+0.94 mm/year) as presented in Table 11. However, Gujarat, Maharashtra, Goa, West Bengal and Tripura showed no trend in rainfall during 1951-2010.

### 3.3.2 FEBRUARY

#### 3.3.2.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of February have shown significantly increasing over Andaman and Nicobar Islands, Arunachal Pradesh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Manipur, Mizoram and Tamil Nadu (Figure 33). The highest increase in February mean maximum temperature has occurred over Himachal Pradesh and Goa (+0.05 $^{o}$C/year each) followed by Manipur and Tamil Nadu (+0.04 $^{o}$C/year each) as given in Table 7. Mean maximum temperature trends have decreased but not significantly in Bihar, Chhattisgarh, Delhi, Haryana, Madhya Pradesh, Punjab, Tripura, Uttar Pradesh and West Bengal states. Gujarat Jammu and Kashmir and Meghalaya showed no trend in mean maximum temperature during 1951-2010.

#### 3.3.2.2 Minimum temperature trends

Mean minimum temperatures have shown significantly increasing trends over Arunachal Pradesh, Assam, Bihar, Gujarat, Delhi, Jharkhand, Lakshadweep, Manipur, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal during 1951-2010 (Figure 34). The highest increase in February mean minimum temperature was observed over Sikkim (+0.08 $^{o}$C/year) followed by Bihar, Delhi, Gujarat, Manipur, Rajasthan, Tamil Nadu, Tripura and Uttar Pradesh (+0.03 $^{o}$C/year each) as depicted in Table 8. Mean minimum temperature trends have decreased significantly in Goa (-0.02 $^{o}$C/year) and Mizoram (-0.03 $^{o}$C/year). No trends in mean minimum temperature were found over Maharashtra and Punjab during last 60 years.

#### 3.3.2.3 Mean temperature trends

Significantly increasing trends in mean temperatures for February were observed over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Goa, Jharkhand, Kerala, Lakshadweep, Manipur, Sikkim and Tamil Nadu during 1951-2010 (Figure 35). The highest increase in February mean temperature has occurred over Sikkim (+0.05 $^{o}$C/year) followed by Manipur (+0.04 $^{o}$C/year), Arunachal Pradesh and Tamil Nadu (+0.03 $^{o}$C/year each) as given in Table 9. Mean temperature trends for February have decreased (non-significantly) in Punjab and Chhattisgarh.

However, Haryana, Jammu and Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Mizoram, Orissa, Uttarakhand and West Bengal showed no trend in mean temperature for February during last six decades.

### 3.3.2.4 DTR trends

State averaged mean DTR for February has shown significantly increasing trends over Goa, Himachal Pradesh, Karnataka, Mizoram and Uttarakhand during 1951-2010 (Figure 36). The highest increase in mean DTR of February month has occurred over Himachal Pradesh (+0.09 $^{o}$C/year) followed by Goa (+0.06 $^{o}$C/year) and Mizoram (+0.04 $^{o}$C/year) as presented in Table 10. Mean DTR for February has decreased significantly in Bihar (-0.04 $^{o}$C/year), Delhi (-0.03 $^{o}$C/year), Gujarat (-0.03 $^{o}$C/year), Haryana (-0.04 $^{o}$C/year), Sikkim (-0.04 $^{o}$C/year), Tripura (-0.04 $^{o}$C/year), Uttar Pradesh (-0.03 $^{o}$C/year) and West Bengal (-0.02 $^{o}$C/year). However, Andhra Pradesh, Chhattisgarh, Jharkhand and Lakshadweep have shown no trend in mean DTR for February during 1951-2010.

### 3.3.2.5 Rainfall trends

State averaged February month rainfall trends have increased over Andhra Pradesh, Assam, Bihar, Delhi, Haryana, Himachal Pradesh, Madhya Pradesh, Maharashtra, Meghalaya, Nagaland, Punjab, Rajasthan, Sikkim, Tripura, Uttar Pradesh, Uttarakhand and West Bengal (Figure 37). The increasing trends were significant over Delhi (+0.21 mm/year), Maharashtra (+0.02 mm/year) and Meghalaya (+0.48 mm/year). Rainfall of February month has decreased over Andaman and Nicobar, Arunachal Pradesh, Chhattisgarh, Jammu and Kashmir, Jharkhand, Kerala, Lakshadweep, Manipur, Mizoram and Orissa. The decreasing trends in rainfall were not significant for any of the state as given in Table 11. However, Gujarat, Goa, Karnataka and Tamil Nadu showed no trend in rainfall during 1951-2010.

### 3.3.3 MARCH

#### 3.3.3.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of March have significantly increased over Andaman and Nicobar, Andhra Pradesh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep and Tamil Nadu (Figure 38). The highest increase in March mean maximum temperature has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Goa and Tamil Nadu (+0.04 $^{o}$C/year each) as given in Table 7. While mean maximum temperature trends for March have decreased but not significantly over Arunachal Pradesh, Haryana, Jammu and Kashmir, Punjab, Uttar Pradesh and West Bengal, they have significantly decreased over Tripura (-0.02 $^{o}$C/year) only. However, Assam, Bihar, Delhi, Gujarat, Meghalaya, Mizoram, Sikkim and Uttar Pradesh showed no trends in mean maximum temperature during 1951-2010.

#### 3.3.3.2 Minimum temperature trends

Mean minimum temperatures for March have showing significantly increasing trends over Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Lakshadweep, Manipur, Rajasthan, Sikkim and Tamil Nadu during 1951-2010 (Figure 39). The highest increase in mean minimum temperature for March has occurred over Sikkim (+0.07 $^{o}$C/year) followed by Manipur (+0.05 $^{o}$C/year) and Tamil Nadu (+0.03 $^{o}$C/year) as presented in Table 8. Mean minimum temperature trends for March have decreased significantly over Goa (-0.02 $^{o}$C/year), Himachal Pradesh (-0.03 $^{o}$C/year), Karnataka (-0.01 $^{o}$C/year), Mizoram (-0.02 $^{o}$C/year) and Uttarakhand (-0.03 $^{o}$C/year). However, no trends in mean minimum temperature were observed over Andaman and Nicobar, Maharashtra, Meghalaya and Uttar Pradesh.

#### 3.3.3.3 Mean temperature trends

Mean temperatures for March have showing significantly increasing trends over Andhra Pradesh, Goa, Kerala, Lakshadweep, Manipur, Rajasthan, Sikkim and Tamil Nadu during 1951-2010 (Figure 40). The highest increase in March mean temperature has occurred over Sikkim (+0.04 $^{o}$C/year) followed by Manipur and Tamil Nadu (+0.03 $^{o}$C/year) as given in Table 9. Mean temperature trends for March

have decreased (non-significantly) over Haryana, Jammu and Kashmir, Punjab, Uttarakhand and Tripura. However, the decreasing trend were significant in Mizoram (-0.02 $^{o}$C/year) only. Arunachal Pradesh, Chhattisgarh, Karnataka, Meghalaya, Orissa, Uttar Pradesh and West Bengal states did not find any trend in mean temperature during 1951-2010.

#### 3.3.3.4 DTR trends

Significantly increasing trends in mean DTR for March have been observed over Chhattisgarh, Goa, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Mizoram, Orissa and Uttarakhand during 1951-2010 (Figure 41). The highest increase in mean DTR of March month has been seen over Himachal Pradesh (+0.11 $^{o}$C/year) followed by Goa (+0.05 $^{o}$C/year) and Uttarakhand (+0.03 $^{o}$C/year) as presented in Table 10. Mean DTR for March has decreased significantly over Haryana (-0.03 $^{o}$C/year), Delhi (-0.02 $^{o}$C/year), Bihar (-0.03 $^{o}$C/year), Sikkim (-0.06 $^{o}$C/year), Arunachal Pradesh (-0.03 $^{o}$C/year), Assam (-0.02 $^{o}$C/year), Tripura (-0.04 $^{o}$C/year), Gujarat (-0.02 $^{o}$C/year) and West Bengal (-0.02 $^{o}$C/year). However, Andhra Pradesh, Lakshadweep, Madhya Pradesh, Meghalaya and Rajasthan states show no trends in mean DTR for March during 1951-2010.

#### 3.3.3.5 Rainfall trends

State averaged monthly rainfall trends for March have increased over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Himachal Pradesh, Karnataka, Kerala, Manipur, Meghalaya, Sikkim and Tamil Nadu (Figure 42). Rainfall of March month has decreased over Bihar, Delhi, Haryana, Jammu and Kashmir, Jharkhand, Madhya Pradesh, Mizoram, Orissa, Punjab, Uttar Pradesh, Uttarakhand and West Bengal. However, neither increasing nor decreasing trends in March rainfall were significant for any of the state (Table 11). No trends in rainfall over Rajasthan, Gujarat, Maharashtra, Goa, Chhattisgarh, Tripura, Nagaland and Lakshadweep were observed during 1951-2010.

### 3.3.4 APRIL

#### 3.3.4.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of April have significantly increased over Andaman and Nicobar Islands, Andhra Pradesh, Goa, Himachal Pradesh, Karnataka, Lakshadweep, Maharashtra, Rajasthan and Tamil Nadu (Figure 43). The highest increase in April mean maximum temperature has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Goa (+0.05 $^{o}$C/year) and Tamil Nadu (+0.04 $^{o}$C/year) as given in Table 7. While mean maximum temperature trends for April have decreased but not significantly over Jammu and Kashmir, Bihar, West Bengal, Meghalaya, but have significantly decreased over Arunachal Pradesh (-0.03 $^{o}$C/year), Assam (-0.02 $^{o}$C/year) and Tripura (-0.04 $^{o}$C/year). However, no trends in mean maximum temperature for April during 1951-2010 were observed in Chhattisgarh, Manipur and Mizoram states.

#### 3.3.4.2 Minimum temperature trends

Mean minimum temperatures for April have shown significantly increasing trends over Arunachal Pradesh, Bihar, Delhi, Gujarat, Lakshadweep, Manipur, Rajasthan, Sikkim and Tamil Nadu during 1951-2010 (Figure 44). The highest increase in mean minimum temperature for April has occurred over Sikkim (+0.07 $^{o}$C/year) followed by Delhi (+0.03 $^{o}$C/year), Arunachal Pradesh, Gujarat, Manipur, Rajasthan and Tamil Nadu (+0.02 $^{o}$C/year each) as presented in Table 8. Mean minimum temperature trends for April have decreased significantly over Jammu and Kashmir (-0.03 $^{o}$C/year), Himachal Pradesh (-0.03 $^{o}$C/year), Orissa (-0.02 $^{o}$C/year) and Mizoram (-0.02 $^{o}$C/year). However, Kerala, Madhya Pradesh, Meghalaya, Tripura, Uttar Pradesh, Madhya Pradesh, Jharkhand, Goa, Andhra Pradesh, Andaman and Nicobar Islands and West Bengal states showed no trend in mean minimum temperature.

#### 3.3.4.3 Mean temperature trends

Significantly increasing trends in mean temperature for April have been observed over Delhi, Goa, Gujarat, Lakshadweep, Rajasthan, Sikkim and Tamil Nadu during 1951-2010 (Figure 45). The highest increase in April mean temperature has occurred over Sikkim (+0.04 $^{o}$C/year) followed by Delhi, Rajasthan and Tamil

Nadu (+0.03 $^{o}$C/year) as depicted in Table 9. Mean temperature trends for April have decreased (non-significantly) in Arunachal Pradesh, Assam, Jammu and Kashmir, Meghalaya, Orissa, Uttarakhand and West Bengal, the decreasing trend was significant over Tripura and Mizoram (-0.02 $^{o}$C/year each) only. Andaman and Nicobar, Bihar, Chhattisgarh, Jharkhand, Karnataka, Kerala and Uttar Pradesh states did not indicate any trend in mean temperature during 1951-2010.

#### 3.3.4.4 DTR trends

Mean DTR for April has shown significantly increasing trends over Andaman and Nicobar, Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Lakshadweep, Madhya Pradesh, Maharashtra, Mizoram, Orissa, Rajasthan, Tamil Nadu and Uttarakhand during 1951-2010 (Figure 46). The highest increase in mean DTR of April month has occurred over Himachal Pradesh (+0.10 $^{o}$C/year) followed by Goa (+0.05 $^{o}$C/year), Jammu and Kashmir, Maharashtra, Orissa and Uttarakhand (+0.03 $^{o}$C/year each) as given in Table 10. Mean DTR for April has been decreasing significantly over Arunachal Pradesh (-0.04 $^{o}$C/year), Assam (-0.03 $^{o}$C/year), Bihar (-0.03 $^{o}$C/year), Gujarat (-0.01 $^{o}$C/year), Manipur (-0.03 $^{o}$C/year), Sikkim (-0.04 $^{o}$C/year) and Tripura (-0.03 $^{o}$C/year) during the study period. However, Delhi and Haryana states have no trends in DTR during 1951-2010.

#### 3.3.4.5 Rainfall trends

State averaged monthly rainfall trends for April have increased over Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Delhi, Haryana, Himachal Pradesh, Jharkhand, Manipur, Meghalaya, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tripura, Uttar Pradesh, Uttarakhand and West Bengal (Figure 47). The increasing trends have been significant over Sikkim (+3.51 mm/year), Meghalaya (+2.15 mm/year) and West Bengal (+0.44 mm/year). Rainfall of April month has decreased over Andaman and Nicobar, Chhattisgarh, Goa, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra and Tamil Nadu. However, the decreasing trends in April month rainfall were not found significant for any of the state as depicted in Table 11. No trends in rainfall during 1951-2010 were observed over Gujarat.

### 3.3.5 MAY

#### 3.3.5.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of May have significantly increased over Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Maharashtra, Mizoram, Sikkim and Tamil Nadu as shown in Figure 48. The highest increase in mean maximum temperature has occurred over Himachal Pradesh and Goa (+0.05 $^{o}$C/year each) followed by Sikkim (+0.04 $^{o}$C/year) as given in Table 7. While mean maximum temperature trends for May have decreased non-significantly over Chhattisgarh, Gujarat, Haryana, Jammu and Kashmir, Tripura, Uttarakhand and West Bengal, the trends have significantly decreased over Uttar Pradesh (-0.03 $^{o}$C/year), Bihar (-0.04 $^{o}$C/year) and Jharkhand (-0.03 $^{o}$C/year). However, Delhi, Madhya Pradesh, Meghalaya, Orissa and Punjab did not show any trend in mean maximum temperature during last six decades.

#### 3.3.5.2 Minimum temperature trends

Mean minimum temperatures for May have shown significantly increasing trends over Arunachal Pradesh, Assam, Delhi, Gujarat, Manipur, Rajasthan, Sikkim and Tamil Nadu during 1951-2010 as shown in Figure 49. The highest increase in mean minimum temperature for May has occurred over Sikkim (+0.07 $^{o}$C/year) followed by Arunachal Pradesh (+0.03 $^{o}$C/year), Delhi, Rajasthan and Tami Nadu (+0.02 $^{o}$C/year each) as presented in Table 8. Mean minimum temperature trends have decreased significantly over Chhattisgarh (-0.03 $^{o}$C/year), Himachal Pradesh (-0.04 $^{o}$C/year), Jammu and Kashmir (-0.04 $^{o}$C/year), Jharkhand (-0.01 $^{o}$C/year), Orissa (-0.030 $^{o}$C/year) and Uttarakhand (-0.04 $^{o}$C/year). However, no trends in mean minimum temperature for May during 1951-2010 were found over Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Kerala, Lakshadweep, Madhya Pradesh, Meghalaya, Mizoram and Tripura states during 1951-2010.

#### 3.3.5.3 Mean temperature trends

Mean temperatures for May have significantly increased over Andaman and Nicobar, Arunachal Pradesh, Assam, Goa, Lakshadweep, Mizoram, Rajasthan, Sikkim and Tamil Nadu during 1951-2010 as shown in Figure 50. The highest increase in May mean temperature has occurred over Sikkim (+0.05 $^{o}$C/year)

followed by Arunachal Pradesh (+0.03 $^{o}$C/year), Goa, Lakshadweep, Rajasthan and Tamil Nadu (+0.02 $^{o}$C/year each) as presented in Table 9. Mean temperature trends have decreased significantly over Bihar, Chhattisgarh, Jammu and Kashmir, Jharkhand, Orissa, Uttar Pradesh and Uttarakhand. The highest significant decrease in mean temperature was obtained for Jammu and Kashmir, Jharkhand and Uttarakhand (-0.03 $^{o}$C/year each). However, Gujarat, Haryana, Madhya Pradesh, Maharashtra and Meghalaya states did not show any trend in mean temperature for May during 1951-2010.

### 3.3.5.4 DTR trends

Significantly increasing trends in mean DTR for May have been observed over Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Maharashtra, Mizoram, Orissa, Tamil Nadu and Uttarakhand during 1951-2010 as shown in Figure 51. The highest increase in mean DTR of May month has occurred over Himachal Pradesh (+0.09 $^{o}$C/year) followed by Goa (+0.05 $^{o}$C/year), Mizoram and Orissa (+0.03 $^{o}$C/year each) as given in Table 10. Mean DTR for May has decreased significantly over Bihar (-0.03 $^{o}$C/year), Delhi (-0.02 $^{o}$C/year), Gujarat (-0.02 $^{o}$C/year), Haryana (-0.02 $^{o}$C/year) and Sikkim (-0.03 $^{o}$C/year). However, no trends in mean DTR were observed over Arunachal Pradesh, Meghalaya, Punjab and Rajasthan during last six decades.

### 3.3.5.5 Rainfall trends

State averaged monthly rainfall trends for May have increased over in Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Haryana, Himachal Pradesh, Jharkhand, Madhya Pradesh, Manipur, Mizoram, Orissa, Punjab, Rajasthan, Tripura, Uttar Pradesh, Uttarakhand and West Bengal as shown in Figure 52. The increasing trends were significant over Bihar (+0.59 mm/year), Chhattisgarh (+0.31 mm/year), Delhi (+0.38 mm/year), Haryana (+0.26 mm/year), Jharkhand (+0.42 mm/year), Orissa (+0.50 mm/year), Uttar Pradesh (+0.15 mm/year) and West Bengal (+0.44 mm/year). May month rainfall has decreased over Andaman and Nicobar, Arunachal Pradesh, Assam, Goa, Gujarat, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Maharashtra, Meghalaya, Sikkim and Tamil Nadu. However, the decreasing trends in May month rainfall have been significant over Assam (--1.16 mm/year) and Karnataka (-0.58 mm/year) as depicted in Table 11. Nagaland did not show showing no trend in rainfall.

### 3.3.6 JUNE

#### 3.3.6.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of June have significantly increased over Andaman and Nicobar Islands, Assam, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Manipur, Mizoram, Tamil Nadu and Tripura as shown in Figure 53. The highest increase in mean maximum temperature of the month of June has occurred over Himachal Pradesh and Goa (+0.04 $^{o}$C/year each) followed by Manipur and Mizoram (+0.03 $^{o}$C/year) as given in Table 7. Mean maximum temperature trends have decreased significantly over Haryana (-0.04 $^{o}$C/year), Jammu and Kashmir (-0.06 $^{o}$C/year) and Punjab (-0.05 $^{o}$C/year). However, Arunachal Pradesh, Bihar and Madhya Pradesh did not show any trend in mean maximum temperature for June during 1951-2010.

#### 3.3.6.2 Minimum temperature trends

Mean minimum temperatures for June have shown significantly increasing trends over Arunachal Pradesh, Assam, Goa, Gujarat, Manipur, Meghalaya, Rajasthan, Sikkim, Tamil Nadu and Tripura during 1951-2010 as shown in Figure 54. The highest increase in mean minimum temperature for June has occurred over Sikkim (+0.06 $^{o}$C/year) followed by Arunachal Pradesh (+0.02 $^{o}$C/year), Assam, Goa, Gujarat, Manipur, Manipur, Meghalaya, Tami Nadu and Tripura (+0.01 $^{o}$C/year each) as given in Table 8. Mean minimum temperature trends for June have decreased significantly over Chhattisgarh, Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Orissa, Punjab, Uttar Pradesh and Uttarakhand. The highest decrease in mean minimum temperature for June has occurred over Uttarakhand (-0.06 $^{o}$C/year) followed by Jammu and Kashmir (-0.05 $^{o}$C/year), Haryana, Himachal Pradesh, Orissa and Uttar Pradesh (-0.03 $^{o}$C/year each). However, no trends in mean minimum temperature for June during 1951-2010 were observed over Andaman and Nicobar, Andhra Pradesh, Bihar, Karnataka, Kerala, Lakshadweep, Maharashtra, Mizoram and West Bengal.

#### 3.3.6.3 Mean temperature trends

Mean temperatures for June have significantly increased over Andaman and Nicobar, Assam, Goa, Gujarat, Kerala, Lakshadweep, Manipur, Meghalaya,

Mizoram, Sikkim, Tripura and Tamil Nadu during 1951-2010 as shown in Figure 55. The highest increase in June mean temperature has occurred over Sikkim (+0.05 $^{o}$C/year) followed by Assam, Goa, Manipur, Mizoram, Tamil Nadu and Tripura (+0.02 $^{o}$C/year each) as given in Table 9. Mean temperatures for June have decreased significantly over Haryana, Jammu and Kashmir, Orissa, Punjab, Uttar Pradesh and Uttarakhand. The highest significant decrease in mean temperature for June was obtained for Jammu and Kashmir (-0.05 $^{o}$C/year) followed by Uttarakhand (-0.04 $^{o}$C/year), Haryana and Punjab (-0.03 $^{o}$C/year each). However, Andhra Pradesh, Bihar, Himachal Pradesh, Maharashtra, Rajasthan and West Bengal did not indicate any trend in mean temperature for June during 1951-2010.

### 3.3.6.4 DTR trends

Significantly increasing trends in mean DTR for June have been observed over Andaman and Nicobar, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Mizoram, Orissa, Rajasthan, Tamil Nadu and Uttarakhand during 1951-2010 as shown in Figure 56. The highest increase in mean DTR of June month has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Goa, Mizoram and Uttarakhand (+0.03 $^{o}$C/year each) as presented in Table 10. Mean DTR for June has decreased significantly over Arunachal Pradesh (-0.02 $^{o}$C/year) and Punjab (-0.03 $^{o}$C/year). However, Bihar, Gujarat, Meghalaya and Tripura showed no trend in mean DTR for June during last six decades.

### 3.3.6.5 Rainfall trends

State averaged monthly rainfall trends for June have increased over Bihar, Chhattisgarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Lakshadweep, Madhya Pradesh, Maharashtra, Mizoram, Orissa, Punjab, Rajasthan, Uttar Pradesh, Uttarakhand and West Bengal as shown in Figure 57. The increasing trends have been significant over Punjab (+0.51 mm/year), Haryana (+0.57 mm/year) and Delhi (+0.88 mm/year. June month rainfall has decreasing over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Jammu and Kashmir, Kerala, Manipur, Meghalaya, Nagaland, Sikkim, Tamil Nadu and Tripura. However, the decreasing trends in June month rainfall were significant for Andaman and Nicobar (-1.91 mm/year), Assam (-1.59 mm/year), Manipur (-1.45 mm/year) and Nagaland (-1.38 mm/year) as given in Table 11.

### 3.3.7 JULY

#### 3.3.7.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of July have increased all over the country except Arunachal Pradesh, Delhi, Haryana, Jammu and Kashmir, Meghalaya Punjab, Rajasthan and Uttar Pradesh. These increasing trends have been found significant over Andaman and Nicobar Islands, Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Maharashtra, Manipur, Mizoram, Orissa, Sikkim, Tamil Nadu Tripura and West Bengal as shown in Figure 58. The highest increase in mean maximum temperature of July has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Tamil Nadu (+0.04 $^{o}$C/year) and Goa (+0.03 $^{o}$C/year) as given in Table 7. While Arunachal Pradesh, Haryana and Punjab showed non-significant decrease in mean maximum temperature, the trend has been significant for Jammu and Kashmir (-0.04 $^{o}$C/year) only. However, Delhi, Meghalaya, Rajasthan and Uttar Pradesh states showed no trend in mean maximum temperature for July during 1951-2010.

#### 3.3.7.2 Minimum temperature trends

Mean minimum temperature for July has shown significantly increasing trends over Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Kerala, Manipur, Sikkim, Tamil Nadu and Tripura during 1951-2010 as shown in Figure 59. The highest increase in mean minimum temperature for July has occurred over Sikkim (+0.06 $^{o}$C/year) followed by Himachal Pradesh, Manipur and Tamil Nadu (+0.02 $^{o}$C/year each) as depicted in Table 8. Mean minimum temperature trends for July have decreased significantly over Jammu and Kashmir, Uttarakhand, Uttar Pradesh and Orissa. The highest decrease in mean minimum temperature for July has occurred over Uttarakhand (-0.04 $^{o}$C/year) followed by Jammu and Kashmir (-0.03 $^{o}$C/year) and Orissa (-0.02 $^{o}$C/year). Chhattisgarh, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Punjab, Rajasthan and West Bengal states found no trend in mean minimum temperature during last six decades.

#### 3.3.7.3 Mean temperature trends

Mean temperature for July ha s significantly increased over Andaman and Nicobar, Andhra Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Jharkhand,

Karnataka, Kerala, Lakshadweep, Maharashtra, Manipur, Sikkim, Tamil Nadu, Tripura and West Bengal during 1951-2010 as shown in Figure 60. The highest increase in July mean temperature has occurred over Himachal Pradesh and Sikkim (+0.04 $^{o}$C/year each) followed by Tamil Nadu (+0.03 $^{o}$C/year) as given in Table 9. Mean temperature trends for July have decreased significantly in Jammu and Kashmir (-0.03 $^{o}$C/year) and Uttarakhand (-0.01 $^{o}$C/year) only. However, no trends in mean temperature for July during 1951-2010 were observed over Arunachal Pradesh, Meghalaya, Orissa, Rajasthan and Uttar Pradesh states.

### 3.3.7.4 DTR trends

Significantly increasing trends in mean DTR for July have been found over Andaman and Nicobar, Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Mizoram, Orissa, Tamil Nadu, Uttarakhand and West Bengal during 1951-2010 as shown in Figure 61. The highest increase has occurred over Himachal Pradesh and Uttarakhand (+0.05 $^{o}$C/year each) followed by Mizoram and Orissa (+0.03 $^{o}$C/year each) as presented in Table 10. Mean DTR has decreased significantly over Arunachal Pradesh (-0.02 $^{o}$C/year), Haryana (-0.01 $^{o}$C/year), Punjab (-0.02 $^{o}$C/year) and Sikkim (-0.03 $^{o}$C/year). However, Assam, Bihar, Gujarat, Jharkhand, Meghalaya and Tripura did not indicate any trend in mean DTR during 1951-2010.

### 3.3.7.5 Rainfall trends

State averaged monthly rainfall trends for July have increased over Arunachal Pradesh, Bihar, Gujarat, Haryana, Jammu and Kashmir, Lakshadweep, Madhya Pradesh, Meghalaya, Mizoram, Rajasthan and West Bengal as shown in Figure 62. However, the increasing trends have not been found significant for any of the state. July month rainfall has decreased over Andaman and Nicobar, Andhra Pradesh, Assam, Chhattisgarh, Delhi, Goa, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Maharashtra, Manipur, Nagaland, Orissa, Punjab, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and Uttarakhand. The decreasing trends in July month rainfall have been significant for Himachal Pradesh (-1.72 mm/year) and Tamil Nadu (-0.65 mm/year) only as given in Table 11.

### 3.3.8 AUGUST

#### 3.3.8.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of August have shown increasing trends all over the country except Arunachal Pradesh, Haryana, Jammu and Kashmir, Meghalaya and Punjab. The increasing trends have been found significant over many states like Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Delhi, Goa, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Manipur, Mizoram, Orissa, Rajasthan, Tamil Nadu Tripura, Uttar Pradesh, Uttarakhand and West Bengal as shown in Figure 63. The highest increase has occurred over Himachal Pradesh (+0.08 $^{o}$C/year) followed by Mizoram (+0.06 $^{o}$C/year), Delhi, Goa, Manipur and Tamil Nadu (+0.03 $^{o}$C/year) as given in Table 7. The mean maximum temperature trend has decreased significantly over Jammu and Kashmir (-0.02 $^{o}$C/year) only. However, Arunachal Pradesh, Haryana, Meghalaya and Punjab did not show any trend in mean maximum temperature for August during 1951-2010.

#### 3.3.8.2 Minimum temperature trends

Mean minimum temperature for August has showing significantly increasing trends over Andhra Pradesh, Arunachal Pradesh, Assam, Delhi, Gujarat, Himachal Pradesh, Manipur, Sikkim, Tamil Nadu and Tripura during 1951-2010 as shown in Figure 64. The highest increase in mean minimum temperature for August has occurred over Sikkim (+0.06 $^{o}$C/year) followed by Arunachal Pradesh, Delhi, Himachal Pradesh, Tamil Nadu and Tripura (+0.02 $^{o}$C/year each) as depicted in Table 8. Mean minimum temperature trends for August have decreased significantly over Jammu and Kashmir (-0.03 $^{o}$C/year), Orissa (-0.02 $^{o}$C/year) and Uttarakhand (-0.04 $^{o}$C/year). However, no trends in mean minimum temperature for August during 1951-2010 were observed in Andaman and Nicobar, Chhattisgarh, Goa, Haryana, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Punjab, Rajasthan, Uttar Pradesh and West Bengal.

#### 3.3.8.3 Mean temperature trends

Significantly increasing trends in mean temperature for August have been observed over Andaman and Nicobar, Andhra Pradesh, Assam, Bihar, Delhi, Goa,

Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Manipur, Mizoram, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal during 1951-2010 as shown in Figure 65. The highest increase in August mean temperature has occurred over Himachal Pradesh and Sikkim (+0.05 $^{o}$C/year each) followed by Mizoram (+0.03 $^{o}$C/year) as given in Table 9. Mean temperature trends for August have decreased significantly over Jammu and Kashmir (-0.03 $^{o}$C/year) and Orissa (-0.01 $^{o}$C/year) only. However, Chhattisgarh, Maharashtra, Meghalaya and Punjab did not observe any trend in mean temperature for August during 1951-2010.

#### 3.3.8.4 DTR trends

Mean DTR for August has shown significantly increasing trends over Andaman and Nicobar, Bihar, Chhattisgarh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Orissa, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal during 1951-2010 as shown in Figure 66. The highest increase in mean DTR of August month has occurred over Himachal Pradesh, Uttarakhand and Mizoram (+0.05 $^{o}$C/year each) followed by Goa and Orissa (-0.03 $^{o}$C/year each) as presented in Table 10. Mean DTR for August has decreased significantly over Sikkim (-0.03 $^{o}$C/year) only. However, no trends in mean DTR for August during 1951-2010 were found over Assam, Gujarat, Haryana, Jammu and Kashmir, Meghalaya and Punjab states.

#### 3.3.8.5 Rainfall trends

State averaged monthly rainfall trends for August have increased over Andhra Pradesh, Goa, Gujarat, Karnataka, Lakshadweep, Maharashtra, Meghalaya, Mizoram, and Sikkim as shown in Figure 67. The increasing trends were not significant for any state. August month rainfall has decreased over Andaman and Nicobar, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Kerala, Madhya Pradesh, Manipur, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and Uttarakhand. However, the decreasing trends in August month rainfall have been found significant for Chhattisgarh (-1.78 mm/year) and Uttar Pradesh (-1.88 mm/year) as given in Table 11. However, no trends in August rainfall were observed over Nagaland and West Bengal.

### 3.3.9 SEPTEMBER

#### 3.3.9.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of September have increased all over the country except Arunachal Pradesh, Assam, Delhi, Haryana, Jammu and Kashmir, Meghalaya and Punjab. The increasing trends are significant over Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Chhattisgarh, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Orissa, Rajasthan, Sikkim, Tamil Nadu and West Bengal as shown in Figure 68. The highest increase has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Mizoram (+0.05 $^{o}$C/year), Goa, Rajasthan and Sikkim (+0.03 $^{o}$C/year each) as given in Table 7. The mean maximum temperature trend has decreased significantly over Jammu and Kashmir (-0.03 $^{o}$C/year) and Punjab (-0.02 $^{o}$C/year) only. However, Assam, Delhi and Meghalaya states did not show any trend in mean maximum temperature for September during 1951-2010.

#### 3.3.9.2 Minimum temperature trends

Mean minimum temperatures for September have shown significantly increasing trends over Andhra Pradesh, Arunachal Pradesh, Assam, Delhi, Gujarat, Kerala, Manipur, Sikkim, Tamil Nadu and Tripura during 1951-2010 as shown in Figure 69. The highest increase in mean minimum temperature for September has occurred over Sikkim (+0.07 $^{o}$C/year) followed by Delhi, Gujarat, Manipur and Tamil Nadu and (+0.02 $^{o}$C/year each) as depicted in Table 8. Mean minimum temperature trends have decreased significantly over Jammu and Kashmir (-0.03 $^{o}$C/year), Orissa (-0.02 $^{o}$C/year), Punjab (-0.02 $^{o}$C/year) and Uttarakhand (-0.03 $^{o}$C/year). However, no trends in mean minimum temperature for September during 1951-2010 were found over Andaman and Nicobar, Bihar, Chhattisgarh, Goa, Haryana, Karnataka, Lakshadweep, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram and Uttar Pradesh states.

#### 3.3.9.3 Mean temperature trends

Significantly increasing trends in mean temperatures for September were found over Andaman and Nicobar, Andhra Pradesh, Goa, Gujarat, Himachal

Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Rajasthan, Sikkim, Tamil Nadu and Tripura during 1951-2010 as shown in Figure 70. The highest increase in mean temperature of September month has occurred over Sikkim (+0.05 $^{o}$C/year) followed by Himachal Pradesh (+0.03 $^{o}$C/year each), Goa, Gujarat, Manipur, Mizoram and Tamil Nadu (+0.02 $^{o}$C/year each) as given in Table 9. Mean temperature trends for September have decreased significantly over Jammu and Kashmir (-0.04 $^{o}$C/year) and Punjab (-0.02 $^{o}$C/year) only. However, Chhattisgarh, Meghalaya, Orissa, Uttar Pradesh and West Bengal states did not show any trend in mean temperature during last six decades.

#### 3.3.9.4 DTR trends

Mean DTR for September has shown significantly increasing trends over Andaman and Nicobar, Andhra Pradesh, Chhattisgarh, Goa, Himachal Pradesh, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Mizoram, Orissa, Uttarakhand and West Bengal during 1951-2010 as shown in Figure 71. The highest increase in mean DTR of September month has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Mizoram (+0.05 $^{o}$C/year) and Uttarakhand (+0.04 $^{o}$C/year) as presented in Table 10. Mean DTR for September has decreased significantly over Sikkim (-0.03 $^{o}$C/year) only. However, no trends were found over Assam, Gujarat, Jharkhand, Meghalaya, Tamil Nadu and Tripura states during 1951-2010.

#### 3.3.9.5 Rainfall trends

State averaged monthly rainfall trends for September have increased over Arunachal Pradesh, Delhi, Haryana, Karnataka, Kerala, Lakshadweep, Maharashtra, Manipur, Meghalaya, Nagaland, Punjab, Tripura, Uttarakhand and West Bengal as shown in Figure 72. September month rainfall has decreased over Andaman and Nicobar, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Madhya Pradesh, Mizoram, Orissa, Rajasthan, Sikkim, Tamil Nadu and Uttar Pradesh. The increasing/decreasing trends in September month rainfall have not been found significant for any state as given in Table 11. However, no trends in September month rainfall during 1951-2010 were observed over Andhra Pradesh.

### 3.3.10 OCTOBER

#### 3.3.10.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of October have increased all over the country except Haryana, Jammu and Kashmir, Punjab and Uttar Pradesh. The increasing trends have been significant over Andaman and Nicobar Islands, Andhra Pradesh, Assam, Goa, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Mizoram, Orissa, Tamil Nadu, Tripura, Uttarakhand and West Bengal as shown in Figure 73. The highest increase in mean maximum temperature has occurred over Himachal Pradesh (+0.07 $^{o}$C/year) followed by Goa and Mizoram (+0.04 $^{o}$C/year each) as given in Table 7. The mean maximum temperature trends have decreased but not significantly over Jammu and Kashmir and Punjab. However, Haryana and Uttar Pradesh states showed no trend in mean maximum temperature for October during 1951-2010.

#### 3.3.10.2 Minimum temperature trends

Significantly increasing trends in mean minimum temperature for October have been observed over Arunachal Pradesh, Assam, Gujarat, Rajasthan, Sikkim, Tamil Nadu and Tripura during 1951-2010 as shown in Figure 74. The highest increase in mean minimum temperature for October has occurred over Sikkim (+0.08 $^{o}$C/year) followed by Gujarat (+0.03 $^{o}$C/year each), Arunachal Pradesh, Rajasthan, Tamil Nadu and Tripura (+0.02 $^{o}$C/year each) as depicted in Table 8. Mean minimum temperature trends for October have decreased significantly over Himachal Pradesh, Jammu and Kashmir, Mizoram, Orissa and Uttarakhand. The highest decrease in mean minimum temperature for October has occurred over Jammu and Kashmir and Himachal Pradesh (-0.04 $^{o}$C/year) followed by Uttarakhand and Orissa (-0.02 $^{o}$C/year each). Andaman and Nicobar, Andhra Pradesh, Goa, Haryana, Jharkhand, Karnataka, Kerala, Maharashtra and West Bengal states did not have and trend in mean minimum temperature for October during 1951-2010.

#### 3.3.10.3 Mean temperature trends

Mean temperatures for October have significantly increased over Andaman and Nicobar, Andhra Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh,

Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Manipur, Mizoram, Rajasthan, Sikkim, Tamil Nadu and Tripura during 1951-2010 as shown in Figure 75. The highest increase in October mean temperature has occurred over Sikkim (+0.05 $^{o}$C/year) followed by Manipur (+0.03 $^{o}$C/year), Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Madhya Pradesh, Rajasthan, Tamil Nadu and Tripura (+0.02 $^{o}$C/year each) as given in Table 9. Mean temperature trends for October have decreased significantly over Jammu and Kashmir (-0.03 $^{o}$C/year) only. However, Chhattisgarh, Haryana, Orissa and Uttarakhand states did not indicate any trend in mean temperature during last six decades.

### 3.3.10.4 DTR trends

Significantly increasing trends in mean DTR for October have been observed over Andaman and Nicobar, Chhattisgarh, Goa, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Maharashtra, Mizoram, Orissa and Uttarakhand during 1951-2010 as shown in Figure 76. The highest increase in mean DTR of October month has occurred over Himachal Pradesh (+0.10 $^{o}$C/year) followed by Mizoram (+0.06 $^{o}$C/year), Goa, Jammu and Kashmir, Orissa and Uttarakhand (+0.04 $^{o}$C/year each) as presented in Table 10. Mean DTR for October has decreased significantly over Sikkim (-0.06 $^{o}$C/year) only. However, no trends in mean DTR were seen over Bihar, Madhya Pradesh, Meghalaya, Punjab, Rajasthan and Tamil Nadu states during 1951-2010.

### 3.3.10.5 Rainfall trends

State averaged monthly rainfall trends for October have increased over Bihar, Goa, Gujarat, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Nagaland and West Bengal as shown in Figure 77. The increasing trends in rainfall were not found significant for any state. October month rainfall has decreased over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Chhattisgarh, Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Lakshadweep, Mizoram, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and Uttarakhand. However, the decreasing trend in October month rainfall has been significant for Haryana (-0.11 mm/year) only as given in Table 11. Jharkhand and Karnataka showed no trend in October month rainfall during 1951-2010.

### 3.3.11 NOVEMBER

#### 3.3.11.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of November have increased all over the country except Delhi, Haryana, Jammu and Kashmir, Sikkim and Uttar Pradesh. The increasing trends have been significant over Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Maharashtra, Manipur, Mizoram, Orissa, Tamil Nadu, Tripura, Uttarakhand and West Bengal as shown in Figure 78. The highest increase in mean maximum temperature has occurred over Mizoram and Himachal Pradesh (+0.06 $^{o}$C/year each) followed by Goa (+0.05 $^{o}$C/year), Jharkhand, Manipur and Uttarakhand (+0.03 $^{o}$C/year each) as given in Table 7. The mean maximum temperature trend has decreased but not significantly in Haryana only. However, Delhi, Jammu and Kashmir, Sikkim and Uttar Pradesh did not have any trend in mean maximum temperature for November during 1951-2010.

#### 3.3.11.2 Minimum temperature trends

Significantly increasing trends in mean minimum temperature for November have been observed over Arunachal Pradesh, Assam, Bihar, Delhi, Goa, Gujarat, Haryana, Jharkhand, Kerala, Lakshadweep, Madhya Pradesh, Manipur, Meghalaya, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal during 1951-2010 as shown in Figure 79. The highest increase in mean minimum temperature for November has occurred over Sikkim (+0.08 $^{o}$C/year) followed by Bihar, Madhya Pradesh, Manipur, Tripura and Uttar Pradesh (+0.04 $^{o}$C/year each) as depicted in Table 8. Mean minimum temperature trends for November have decreased significantly over Himachal Pradesh and Jammu and Kashmir (-0.03 $^{o}$C/year each) only. However, no trends in mean minimum temperature for November during 1951-2010 were found over Mizoram and Uttarakhand states.

#### 3.3.11.3 Mean temperature trends

Mean temperatures have increased over all states except Jammu and Kashmir. The increasing trends in mean temperature are significant in Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Delhi, Goa, Gujarat,

Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Orissa, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal during 1951-2010 as shown in Figure 80. The highest increase in November mean temperature has occurred over Goa, Manipur, Mizoram and Sikkim (+0.04 $^{o}$C/year each) followed by Gujarat, Jharkhand, Madhya Pradesh and Tripura (+0.03 $^{o}$C/year each) as given in Table 9.

### 3.3.11.4 DTR trends

Mean DTR for November has shown significantly increasing trends over Goa, Himachal Pradesh, Jammu and Kashmir, Mizoram and Uttarakhand during 1951-2010 as shown in Figure 81. The highest increase in mean DTR of November month has occurred over Himachal Pradesh (+0.10 $^{o}$C/year) followed by Mizoram (+0.06 $^{o}$C/year), Goa, Jammu and Kashmir and Uttarakhand (+0.03 $^{o}$C/year each) as depicted in Table 10. Mean DTR for November has decreased significantly in Bihar (-0.02 $^{o}$C/year), Delhi (-0.02 $^{o}$C/year), Gujarat (-0.02 $^{o}$C/year), Haryana (-0.02 $^{o}$C/year), Madhya Pradesh (-0.03 $^{o}$C/year), Sikkim (-0.09 $^{o}$C/year), Tripura (-0.02 $^{o}$C/year) and Uttar Pradesh (-0.03 $^{o}$C/year). However, no trends in mean DTR were found over Andhra Pradesh, Assam, Chhattisgarh, Kerala, Lakshadweep, Maharashtra, Manipur, Meghalaya, Punjab, Tamil Nadu and West Bengal states during last six decades.

### 3.3.11.5 Rainfall trends

State averaged monthly rainfall trends for November have increased over Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Manipur, Meghalaya, Orissa, Sikkim, Tamil Nadu, Uttar Pradesh and West Bengal as shown in Figure 82. The increasing trends have been found significant for Chhattisgarh (+0.11 mm/year) and Tamil Nadu (+1.54 mm/year) as given in Table 11. November month rainfall has decreased over Andaman and Nicobar, Arunachal Pradesh, Assam, Goa, Jammu and Kashmir, Maharashtra, Mizoram, Nagaland, Rajasthan and Tripura. The decreasing trends in November month rainfall were not significant for any state. However, Bihar, Delhi, Gujarat, Haryana, Punjab and Uttarakhand did not find any trend in November month rainfall during 1951-2010.

### 3.3.12 DECEMBER

#### 3.3.12.1 Maximum temperature trends

State averaged mean maximum temperatures for the month of December have increased significantly over Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep, Maharashtra, Manipur, Meghalaya, Mizoram, Tamil Nadu, Uttarakhand and West Bengal as shown in Figure 83. The highest increase in mean maximum temperature has occurred over Goa and Himachal Pradesh (+0.05 $^{o}$C/year each) followed by Mizoram (+0.04 $^{o}$C/year) as given in Table 7. December mean maximum temperature trend has decreased significantly over Haryana (-0.02 $^{o}$C/year) only. However, Bihar, Delhi, Jammu and Kashmir and Uttar Pradesh states did not indicate any trend in mean maximum temperature for December during 1951-2010.

#### 3.3.12.2 Minimum temperature trends

Mean minimum temperature for December has shown significantly increasing trends over Arunachal Pradesh, Assam, Bihar, Gujarat, Lakshadweep, Manipur, Meghalaya, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal during 1951-2010 as shown in Figure 84. The highest increase in mean minimum temperature for December has occurred over Sikkim (+0.08 $^{o}$C/year) followed by Manipur and Tripura (+0.04 $^{o}$C/year each) as presented in Table 8. Mean minimum temperature trends for December have decreased significantly over Himachal Pradesh (-0.03 $^{o}$C/year) only. However, no trends in mean minimum temperature for December during 1951-2010 were observed over Jharkhand, Punjab and Uttarakhand states.

#### 3.3.12.3 Mean temperature trends

Significantly increasing trends in mean temperatures for December have been observed over Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Gujarat, Kerala, Lakshadweep, Manipur, Meghalaya, Mizoram, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand and West Bengal during 1951-2010 as shown in Figure 85. The highest increase in December mean temperature has occurred over Sikkim (+0.05 $^{o}$C/year) followed by Manipur (+0.04 $^{o}$C/year),

Mizoram, Tamil Nadu and Tripura (+0.03 $^{o}$C/year each) as given in Table 9. Mean temperature trends for December have decreased (non-significantly) over Haryana and Punjab. However, Chhattisgarh, Jammu and Kashmir and Orissa states did not show any trend in mean temperature for December during last six decades.

### 3.3.12.4 DTR trends

Mean DTR for December has shown significantly increasing trends over Andaman and Nicobar, Andhra Pradesh, Goa, Himachal Pradesh, Jharkhand, Karnataka, Maharashtra, Mizoram, Orissa and Uttarakhand during 1951-2010 as shown in Figure 86. The highest increase in mean DTR of December month has occurred over Himachal Pradesh (+0.10 $^{o}$C/year) followed by Goa (+0.06 $^{o}$C/year) and Mizoram (+0.04 $^{o}$C/year) as depicted in Table 10. Mean DTR for December has decreased significantly over Bihar (-0.03 $^{o}$C/year), Delhi (-0.02 $^{o}$C/year), Gujarat (-0.02 $^{o}$C/year), Haryana (-0.04 $^{o}$C/year), Sikkim (-0.07 $^{o}$C/year), Tripura (-0.03 $^{o}$C/year) and Uttar Pradesh (-0.02 $^{o}$C/year) during 1951-2010. However, no trends in mean DTR for December were found over Arunachal Pradesh, Assam, Lakshadweep and Madhya Pradesh during last sixty years.

### 3.3.12.5 Rainfall trends

State averaged monthly rainfall trends for December have increased over Andhra Pradesh, Jharkhand, Karnataka, Lakshadweep, Madhya Pradesh, Tamil Nadu and West Bengal as shown in Figure 87. December month rainfall has decreased over Andaman and Nicobar, Arunachal Pradesh, Assam, Himachal, Jammu and Kashmir, Kerala, Meghalaya, Mizoram, Punjab, Sikkim and Uttarakhand as given in Table 11. However, the increasing/decreasing trends in December month rainfall were not found significant for any state of India. However, Bihar, Chhattisgarh, Delhi, Goa, Gujarat, Haryana, Maharashtra, Manipur, Nagaland, Orissa, Rajasthan, Tripura and Uttar Pradesh did not indicate any trend in December month rainfall during 1951-2010.

# CHAPTER 4

# CONCLUSIONS

The results revealed that many states in India have indeed experienced significant state-wide warming in both maximum and minimum temperatures over the last six decades. However, the changes are not equal for all states of India, spatially and temporally. Trends in temperatures showed a much higher degree of spatial coherence and statistically significant warming, reflecting increases in both maximum and minimum temperatures. Though rainfall trends are not significant in many states, spatially coherent decrease in rainfall in most of the states in India particularly in monsoon season is a cause of worry. Details of periodic trends during 1951-2010 are summarized as under:

**Annual climate change trends**

- Significant increasing trends were found in the mean maximum temperature over all states in India except those in the Indo-Gangetic plains wherein spatially coherent decreasing trends were observed in the annual mean maximum temperature with significant decrease over Haryana (-0.02 $^{o}$C/year) and Punjab (-0.01 $^{o}$C/year).
- The maximum increase in annual mean maximum temperature was observed in Himachal Pradesh where the rate of change is +0.06 $^{o}$C/year.
- Annual mean maximum temperature has significantly increased over Lakshadweep and Andaman and Nicobar islands by 0.02 $^{o}$C/year.
- Annual mean minimum temperatures have significantly increased in states of northwest, northeast and southeast parts of India while extreme northern states have shown decreasing trends. The rate of increase in annual mean minimum temperature is highest in Sikkim (0.07 $^{o}$C/year) while the rate of decrease is highest in Uttarakhand (-0.03 $^{o}$C/year).
- Spatially coherent increasing and decreasing trends in annual rainfall are found in many states of India, though not statistically significant. However, annual rainfall is significantly increasing in West Bengal (+3.63 mm/year) and significantly decreasing in Uttar Pradesh (-4.42 mm/year) and Andaman and Nicobar (-7.77 mm/year) during 1951-2010.
- Mean temperatures show a significantly increasing trends over all the states of India except Chhattisgarh, Haryana, Jammu and Kashmir, Meghalaya, Orissa, Punjab, Uttarakhand and West Bengal. Punjab (-0.01 $^{o}$C/year) has shown significant decreasing trends in mean temperature, while no trends were observed in Chhattisgarh, Haryana, Meghalaya, Orissa, Uttar Pradesh and West Bengal during 1951-2010.

**Seasonal climate change trends**

- Significant coherent increasing trends in mean maximum temperature are found in southern states for all seasons, while northern states are having mixed trends both spatially and temporally.
- The highest increase in seasonal mean maximum temperature in southern states has occurred in Goa ranging between +0.03 $^{o}$C/year in monsoon to +0.05 $^{o}$C/year in winter season.
- States in the Indo-Gangetic plains are having spatially coherent decrease in mean maximum temperature in winter and summer seasons with highest significant decrease in Haryana by -0.03$^{o}$C/year and in Bihar by -0.02 $^{o}$C/year respectively.
- While many states have significant spatially coherent increasing trends in mean minimum temperature during winter and post monsoon seasons, there is spatially coherent decrease in mean minimum temperature in monsoon season in many states in northern and central India. The highest decrease in mean minimum temperature in monsoon season is observed in Uttarakhand (-0.04 $^{o}$C/year).
- The increase in summer rainfall is spatially coherent over many states in north, northwest, east and southeast parts of India. However, summer rainfall is significantly increasing in Rajasthan (+0.17 mm/year), Haryana (+0.39 mm/year), Delhi (+0.40 mm/year), Bihar (+0.59 mm/year), Orissa (+0.65 mm/year) and West Bengal (+1.34 mm/year). While monsoon season rainfall is significantly decreasing in Uttar Pradesh (-3.52 mm/year) and Tamil Nadu (-1.35 mm/year), post monsoon season rainfall is significantly decreasing in Haryana (-0.23 mm/year) only.
- Even though decrease in monsoon rainfall is spatially coherent but not significant in most of the states of India, it is still a concern for the rain-fed agriculture and water resources of the country.

**Monthly climate change trends**

- Monthly state-wide trends in mean maximum temperature reveal significant increase in states in south India in most of the months. Goa and Tamil Nadu in southern India are having highest increase in monthly mean maximum temperature in November (+0.05 $^{o}$C/year) and January (+0.04 $^{o}$C/year) respectively.
- States in northern half of India are exhibiting mixed trends in maximum temperature. States in the Indo-Gangetic plains are having decrease in mean maximum temperatures in January, February, March, May and June.
- While Himachal Pradesh and Uttarakhand have shown significant increase in mean maximum temperature in most of the months, Jammu & Kashmir is showing decrease in maximum temperature. The magnitude of increase in maximum temperature is highest over Himachal Pradesh in January and August (+0.08 $^{o}$C/year each) and in Uttarakhand in January, November and December (+0.03 $^{o}$C/year each). Jammu and Kashmir showed highest significant decrease in mean maximum temperature in June (-0.06 $^{o}$C/year).
- Compared to mean minimum temperature trends, a large number of states are exhibiting significantly increasing trends in monthly mean maximum temperature during monsoon months June to September.
- Spatially coherent significant increase (decrease) in mean minimum temperature in many states of India is found in November (June). While monthly mean minimum temperature is increasing in states in central India in March, April, October-December, it is decreasing in many states in May and June. Monthly highest increase in mean minimum temperature is observed in Sikkim in January, February, October, November and December (+0.08 $^{o}$C/year each) while highest decrease is found in Uttarakhand in June (-0.06 $^{o}$C/year).
- Spatially coherent increasing trends in monthly rainfall are observed in February, May and June, while decreasing trends are found in January, March, July-September in most of the states in India.
- The significant change in winter months rainfall is found in January, where it is decreasing in states of Himachal Pradesh (-0.69 mm/year), Uttar Pradesh (-0.24

mm/year) and Andaman and Nicobar (-0.94 mm/year) and significantly increasing in Karnataka (+0.01 mm/year).

- The prominent change in summer months rainfall is found in May where it is significantly increasing in states of Haryana (+0.26 mm/year), Delhi (+0.38 mm/year), Uttar Pradesh (+0.15 mm/year), Bihar (+0.59 mm/year), Chhattisgarh (+0.31 mm/year), Jharkhand (+0.42 mm/year), West Bengal (+0.77 mm/year) and Orissa (+0.50 mm/year) and significantly decreasing in Assam (-1.46 mm/year) and Karnataka (-0.58 mm/year).
- Spatially coherent increase in monthly rainfall in June and decrease in monthly rainfall in August in most of the states was observed. Monthly rainfall trends are significantly increasing in June month in Punjab (+0.51 mm/year), Haryana (+0.57 mm/year) and Delhi (+0.88 mm/year). Besides Andaman and Nicobar (-1.91 mm/year), states in northeast India also showed significant decrease in rainfall in June viz. Assam (-1.59 mm/year), Manipur (-1.45 mm/year) and Nagaland (-1.38 mm/year). The highest significant decrease in monsoon months rainfall in July is in Himachal Pradesh (-1.72 mm/year) and Tamil Nadu (-0.65 mm/year) and in August in Uttar Pradesh (-1.88 mm/year) and Chhattisgarh (-1.78 mm/year) during the 1951-2010 period.

## REFERENCES


1. Arora, M., Goel, N.K. and Singh, P., 2005. “Evaluation of temperature trends over India”. Hydrological Sciences Journal, **50,** 81-93.
2. Attri, S.D. and Tyagi, A., 2010. “Climate Profile of India”. Met. Monograph Environmental Meteorology No 1/2010, pp. 1-122.
3. Dash, S.K., Kulkarni, M.A., Mohanty, U.C. and Prasad, K., 2009. “Changes in the characteristics of rain events in India”. J. Geophys. Res., **114**, D10109, doi:10.1029/2008JD010572
4. De, U.S., Dube, R.K. and Prakasa Rao, G.S., 2005. “Extreme weather events over India in last 100 years”. J. Indian Geophys. Union, **9**, 173–187.
5. Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodanan, M.S. and Xavier, P. K., 2006 “Increasing trend of Extreme Rain Events over India in a Warming Environment”. Science, **314**, 5804, 1442-1445.
6. Government of India, 2008. “National Action Plan on Climate Change”, Ministry of Environment and Forests, Government of India, New Delhi.
7. Guhathakurta, P. and Rajeevan, M., 2008. “Trends in the rainfall pattern over India”. Int. J. Clamoto., **28**, 1453-1469
8. IMD, 2012. “Annual Climate Summary 2012”. National Climate Centre, Pune.
9. Jones, P.D., and Briffa, K.R., 1992. “Global surface air temperature variations during the 20th century: Part 1, Spatial, temporal and seasonal details”. Holocene, **2**, 165–179
10. IPCC, 2013. “Climate Change 2013 - The Physical Science Basis”. Cambridge University Press, U.K.
11. Kothawale, D.R., Munot, A.A. and Krishna Kumar, K., 2010. “Surface air temperature variability over India during 1901–2007 and its association with ENSO”. Climate Res., **42**, 89–104.
12. MoEF, 2010. “Climate Change and India: A 4x4 assessment: A Sectoral, and Regional Analysis for 2030s”. Ministry of Environment and Forests, Government of India, New Delhi
13. NATCOM, 2012. “India’s Second National Communication to the United Nations Frame Work Convention on Climate change”. Ministry of Environment and Forests, Government of India, New Delhi
14. Sen, P.K., 1968. “Estimates of the regression coefficient based on Kendall's Tau”. J. Am. Stat. Assoc., **63**, 1379-1389.
15. Tyagi, A. and Goswami, B.N., 2009. “Assessment of Climate change and adaptation in India”. Climate Sense, 68-70

## SUGGESTED READINGS


- Alexander, L.V and Co-authors, 2006. “Global observed changes in daily climate extremes of temperature and precipitation”. J. Geophys. Res., 111,D05109, doi:10.1029/2005JD006290
- Attri, S.D., and Rathore, L.S., 2003. “Simulation of Impact of Projected Climate Change on Wheat in India”. International Journal of Climatology, 23, 693–705.
- Attri, S.D., 2006. “Climate Change and Agriculture-An overview”. Vayu Mandal, 32, 3-4, 10-26.
- Bhatia, M.S., 2005. “Viability of Rainfed Agriculture in Semi-Arid Regions”. NABARD Occasional Paper No. 40, Department of Economic Analysis and Research, National Bank for Agriculture and Rural Development, Mumbai.
- Caesar, J., Alexandar, L. and Vose, R., 2006. “Large-scale changes in observed daily maximum and minimum temperatures: Creation and analysis of a new gridded data set”. J. Geophys. Res., 111, D05101, doi:10.1029/2005JD006280
- Dash, S.K., Jenamani, R.K., Kalsi, S.R. and Panda, S.K., 2007. “Some evidence of climate change in twentieth-century India”. Climatic Change 85, 299-321.
- Dash, S.K., Mamgain, A., 2011. “Changes in the Frequency of Different Categories of Temperature Extremes in India”. J. Appl. Meteor. Climatol., 50, 1842–1858.
- Dash, S.K., Kulkarni, M.A., Mohanty, U.C. and Prasad, K., 2009. “Changes in the characteristics of rain events in India”. J. Geophys. Res., 114
- De, U.S. and Mukhopadhyay, R.K., 1998. “Severe heat wave over the Indian subcontinent in 1998, in perspective of global climate”. Curr. Sci., 75,1308–1315
- De, U.S., Khole, M. and Dandekar, M., 2004. “Natural hazards associated with meteorological extreme events”. Nat. Hazards, 31, 487–497
- Goswami, B.N., Wheeler, M.C., Gottschalck, J.C. and Waliser, D.E., 2011. “Interdecadal Variability and forecasting: A review of recent research”. In: The Global Monsoon System: Research and Forecast (2nd edition) Eds. C.-P. Chang, Y.H. Ding N.-C. Lau, R. Johnson, B. Wang and T. Yasunari, Volume 5, pp 389-407.
- Fisher, R.A. and Tippett, L.H.C., 1928. “Limiting forms of the frequency distributions of the largest or smallest members of a sample”. Proc. Cambridge Philos. Soc., 24, 180–190.
- Frich, P., Alexander, L.V., Della-Marta, P., Gleason, B., Haylock, M., Klein Tank, A.M.G. and Peterson, T., 2002. “Observed coherent changes in climatic extremes during the second half of the twentieth century”. Climate Res., 19, 193–212.
- Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodanan, M.S., Xavier, P.K., 2006. “Increasing trend of Extreme Rain Events over India in a Warming Environment”. Science, 314, 5804, 1442-1445.
- IMD, 2006, “Trends in precipitation extremes over India”. NCC Research Report No. 3/2006

- Jaswal, A.K., 2009. “Sunshine duration climatology and trends in association with other climatic factors over India for 1970-2006”. Mausam, 60, 4, 437-454.
- Jaswal, A.K., 2010. “Recent winter warming over India – spatial and temporal characteristics of monthly maximum and minimum temperature trends for January to March”. Mausam, 61, 2, 163-174.
- Jaswal, A.K. and Prakasa Rao, G.S., 2010. “Recent trends in meteorological parameters over Jammu and Kashmir”. Mausam, 61, 3, 369-382.
- Jaswal, A.K., 2010. “Changes in total cloud cover over India based upon 1961-2007 surface observations”. Mausam, 61, 4, 455-468.
- Jaswal, A.K., Prakasa Rao, G.S. and De, U.S., 2008. “Spatial and temporal characteristics of evaporation trends over India during 1971-2000”. Mausam, 59, 2, 149-158.
- Kothawale, D.R., Revadekar, J.V. and Rupa Kumar, K., 2010. “Recent trends in pre-monsoon daily temperature extremes over India”. J. Earth Syst. Sci., 119, 51–65
- Krishna Kumar, K., 2009. “Impact of Climate Change on India’s Monsoonal Climate and Development of High Resolution Climate Change Scenarios for India”. MoEF, New Delhi.
- Kumar, V., Jain, S.K. and Singh, Y., 2010. “Analysis of long-term rainfall trends in India”. Hydrological Sciences Journal, 55, 484-496.
- Mall, R.K., Singh, R., Gupta, A., Srinivasan, G., and Rathore, L.S., 2006. “Impact of Climate Change on Indian Agriculture: A Review,” Climatic Change, 78, 2–4, 445–78.
- Mooley, D.A. and Parthasarthy, B., 1984. “Fluctuations of all India summer monsoon rainfall during 1871-1978”. Climatic Change 6, 287-301.
- Pant, G.B. and Kumar, K.R., 1997. “Climates of South Asia”. Wiley, Chichester, United Kingdom.
- Prakasa Rao, G.S., Jaswal, A.K. and Kumar, M.S., 2004. “Effects of urbanization on meteorological parameters”. Mausam, 55, 429–440.
- Rajeevan, M., and Nanjundiah, R.S., 2009, “Coupled Model Simulations of Twentieth Century Climate of the Indian Summer Monsoon,” in N. Mukunda (ed.), Current Trends in the Sciences, Platinum Jubilee Special of the Indian Academy of Sciences.
- Rao, G.S.P, Murthy, M.K. and Joshi, U.R., 2005. “Climate change over India as revealed by critical extreme temperature analysis”. Mausam, 56, 601–608.
- Sathaye, J., Shukla, P.R. and Ravindranath, N.H., 2006. “Climate change, sustainable development and India: Global and national concerns”. Current Science, 90, 3, 314-325.
- Thapliyal, V. and Kulshrestha, S.M., 1991. “Decadal changes and trends over India”. Mausam 42, 333-338.

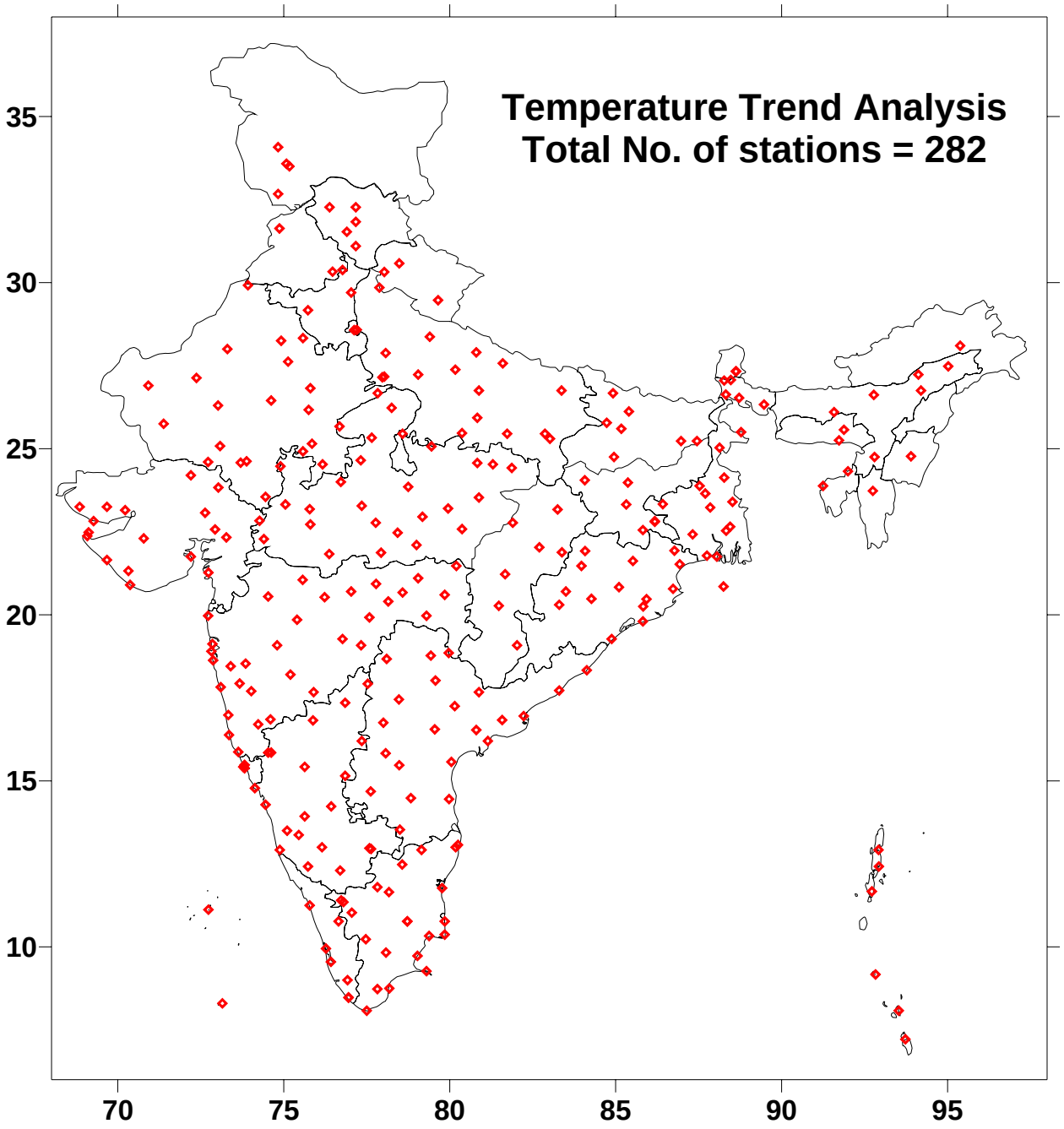


Figure 1: Distribution of 282 surface meteorological stations used for state level temperature trend analysis for 1951-2010.

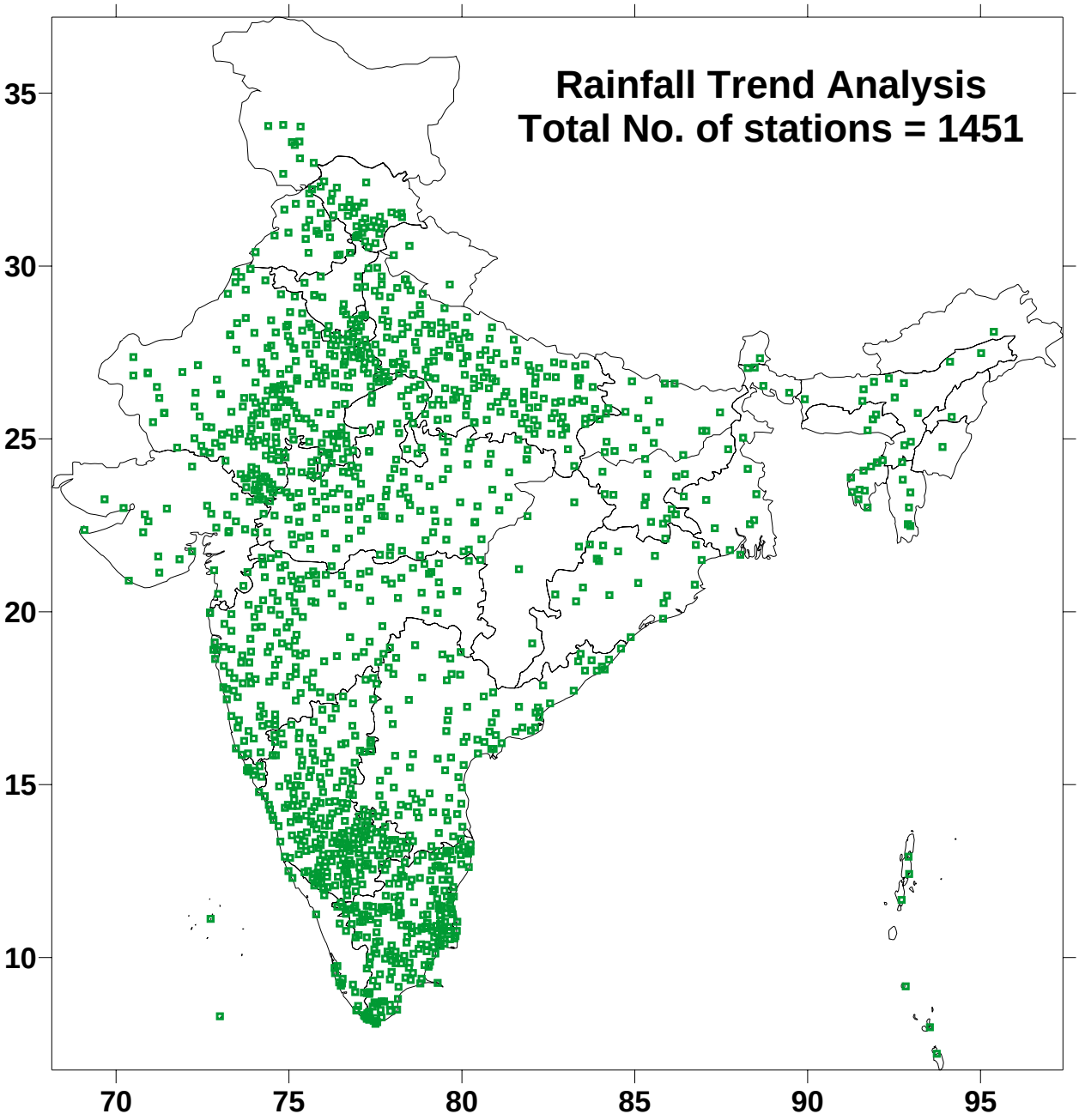


Figure 2: Distribution of 1451 stations used for state level rainfall trend analysis for 1951-2010.

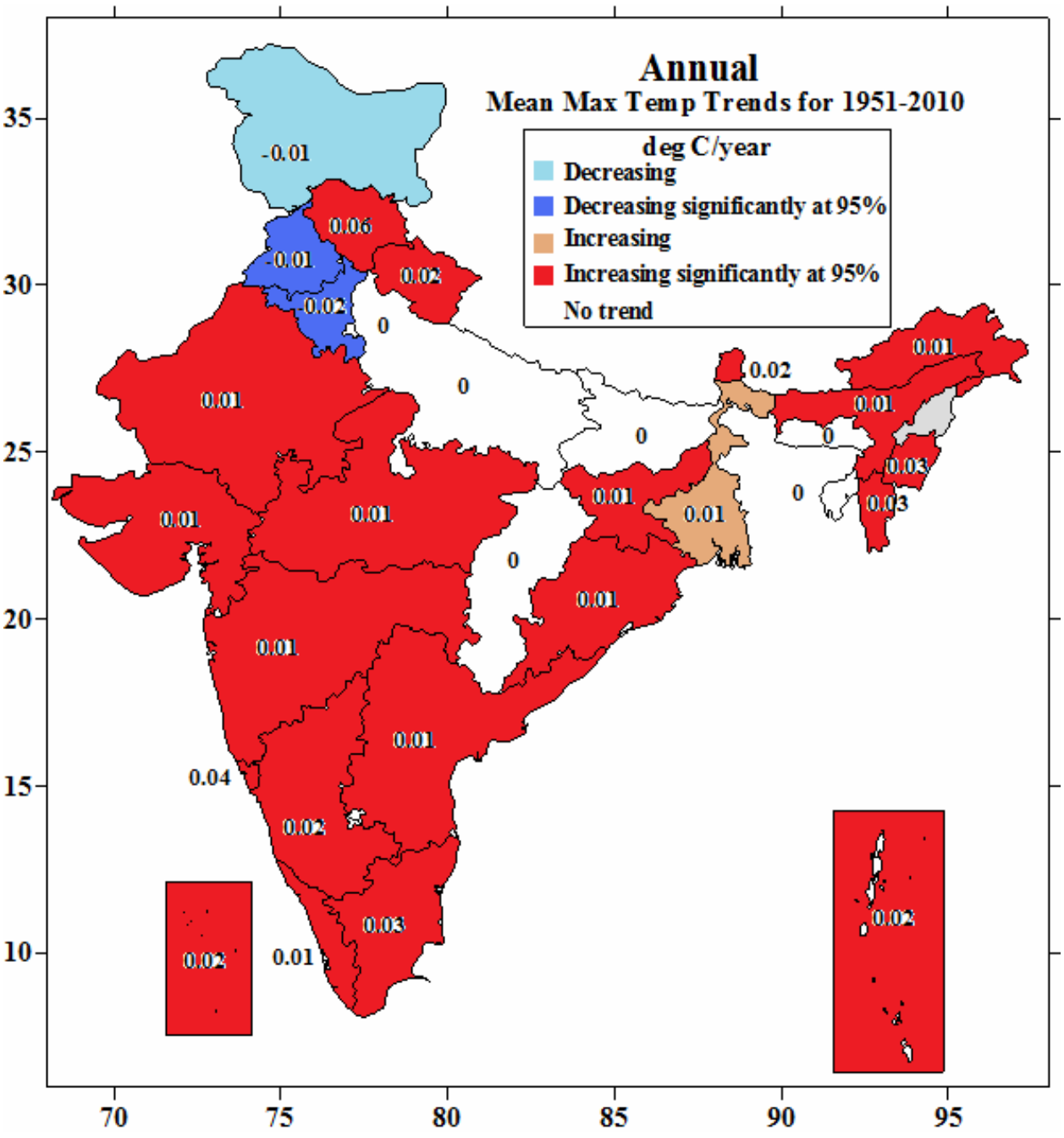


Figure 3: State level annual mean maximum temperature trends.

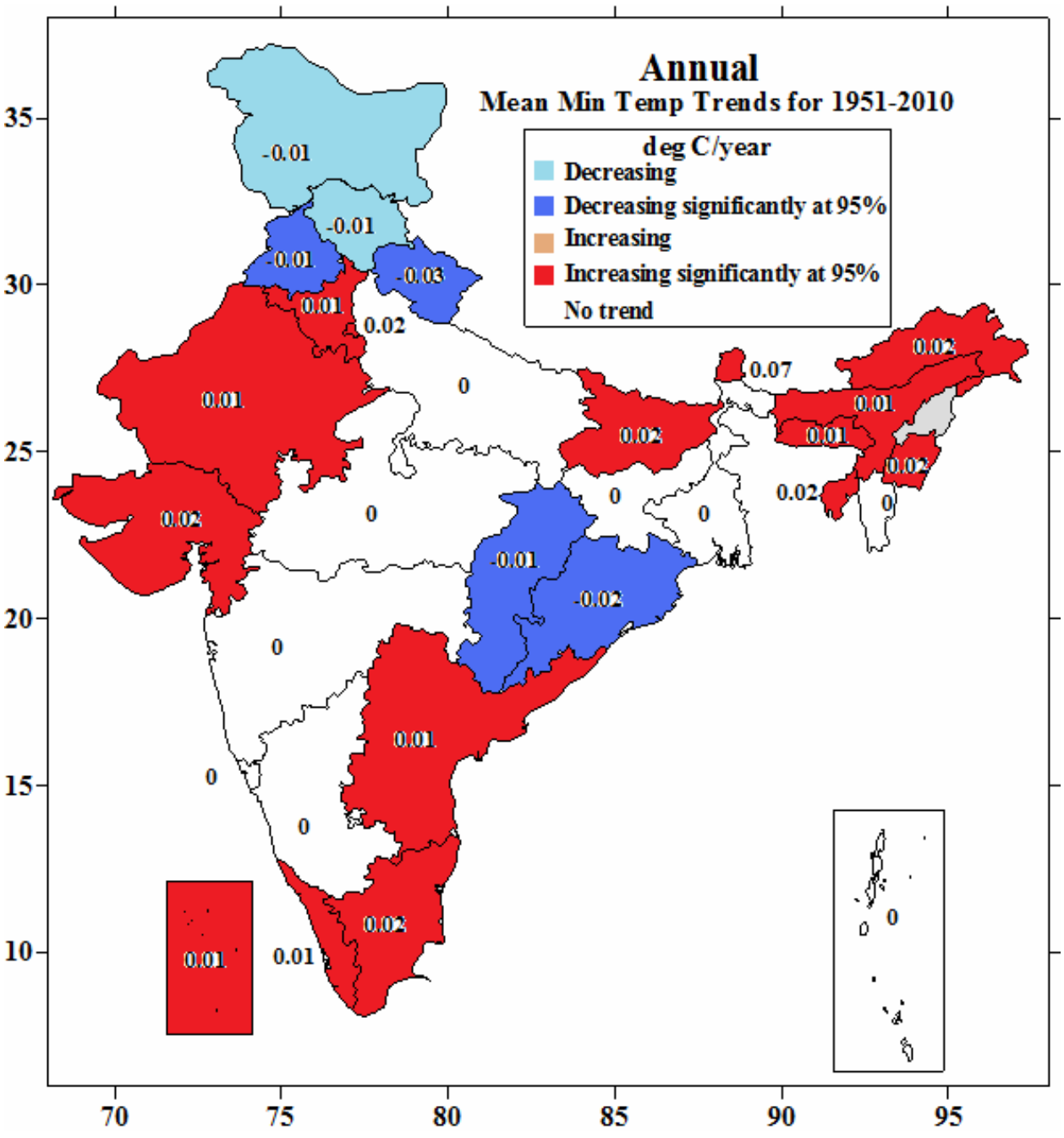


Figure 4: State level annual mean minimum temperature trends.

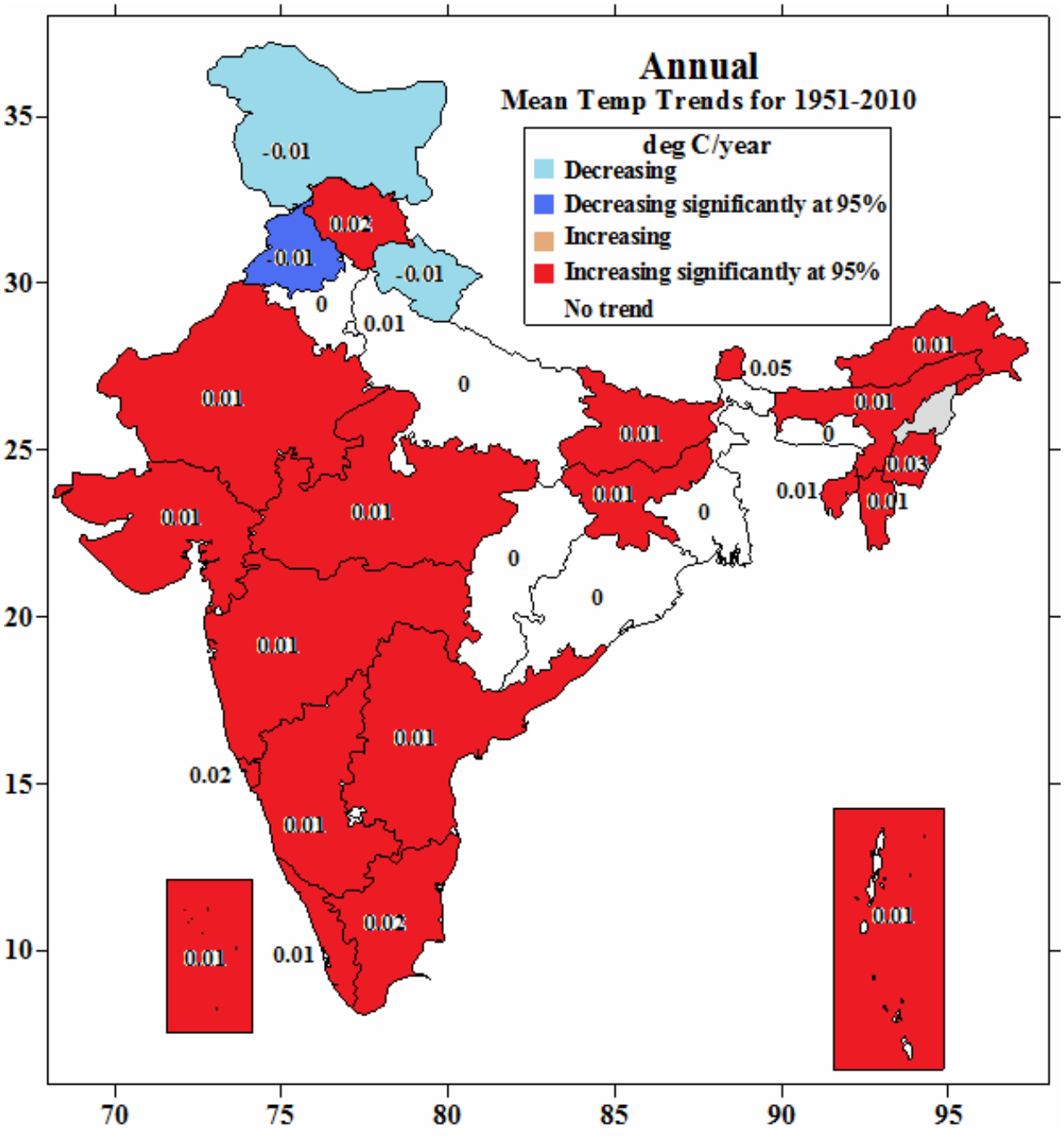


Figure 5: State level annual mean temperature trends.

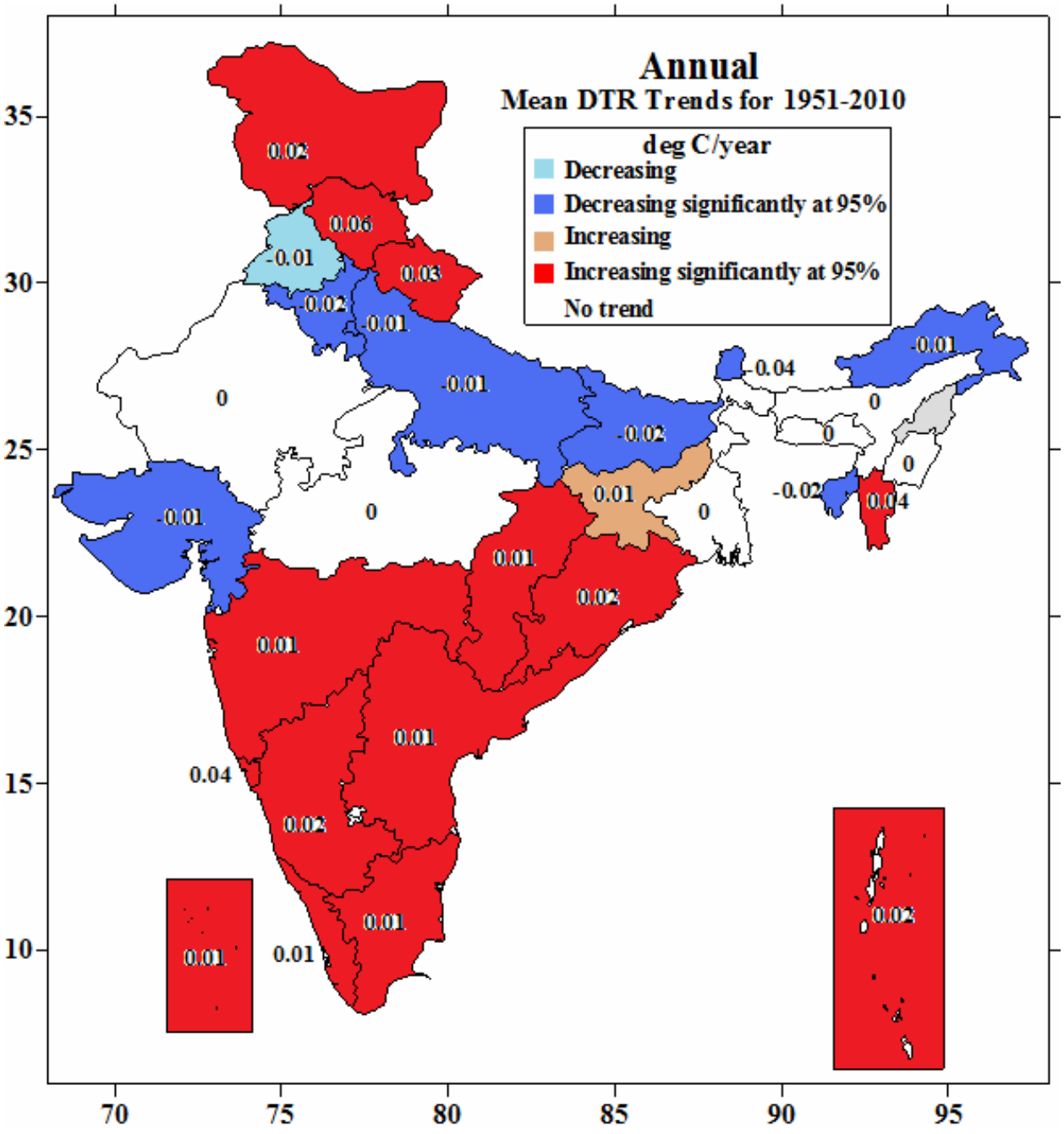


Figure 6: State level annual mean diurnal temperature range (DTR) trends.

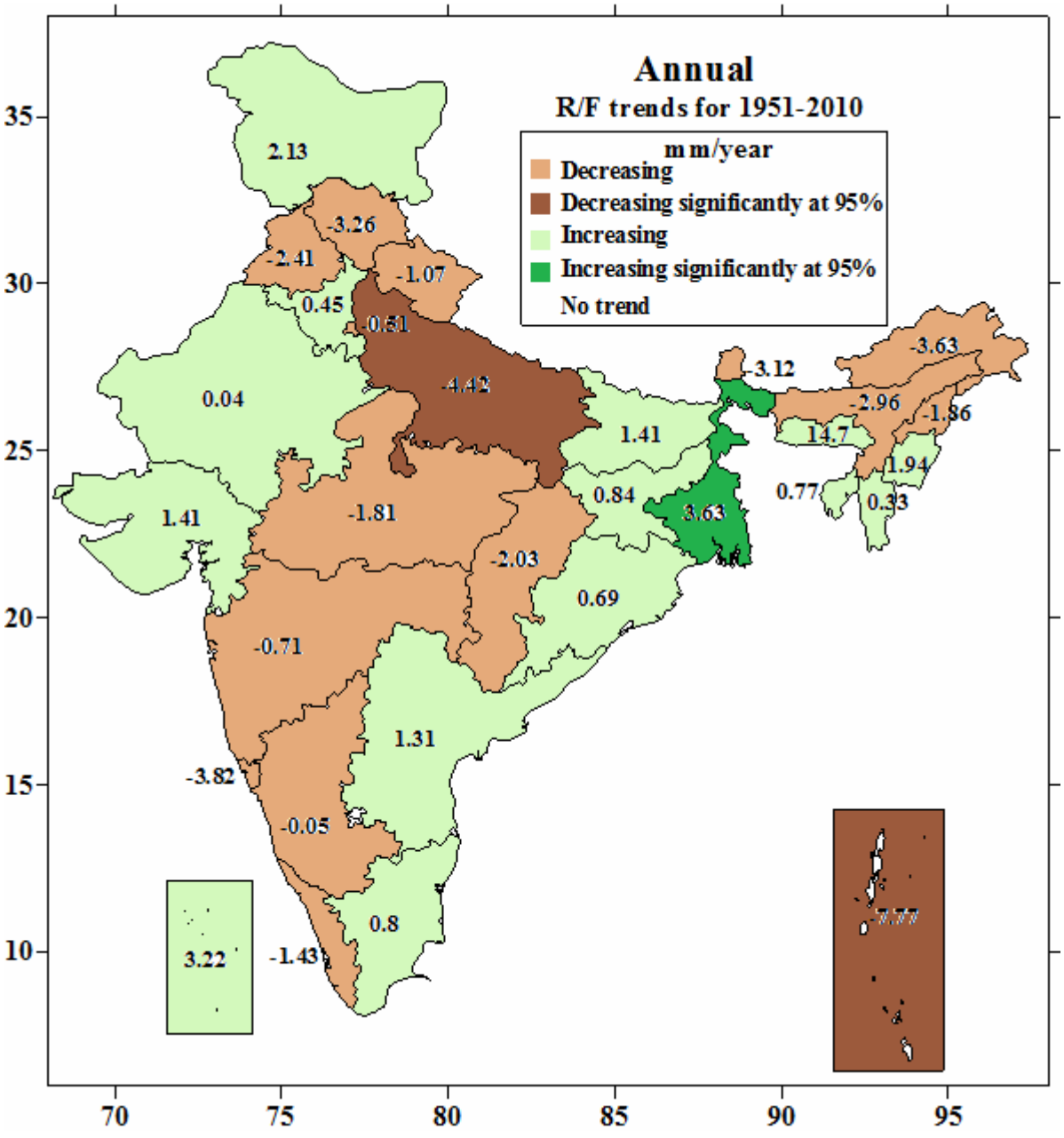


Figure 7: State level annual rainfall trends.

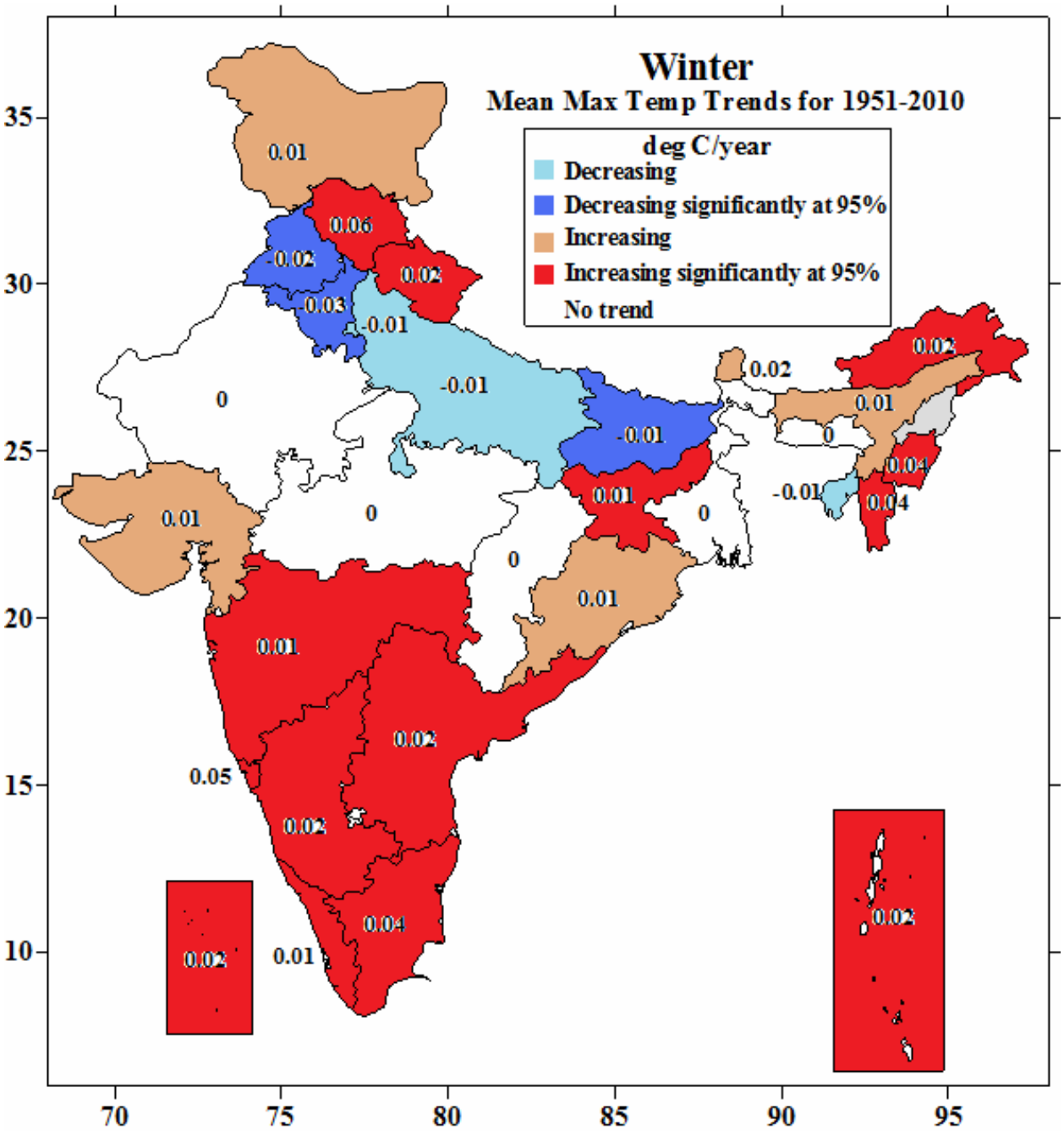


Figure 8: State level mean maximum temperature trends for winter season.

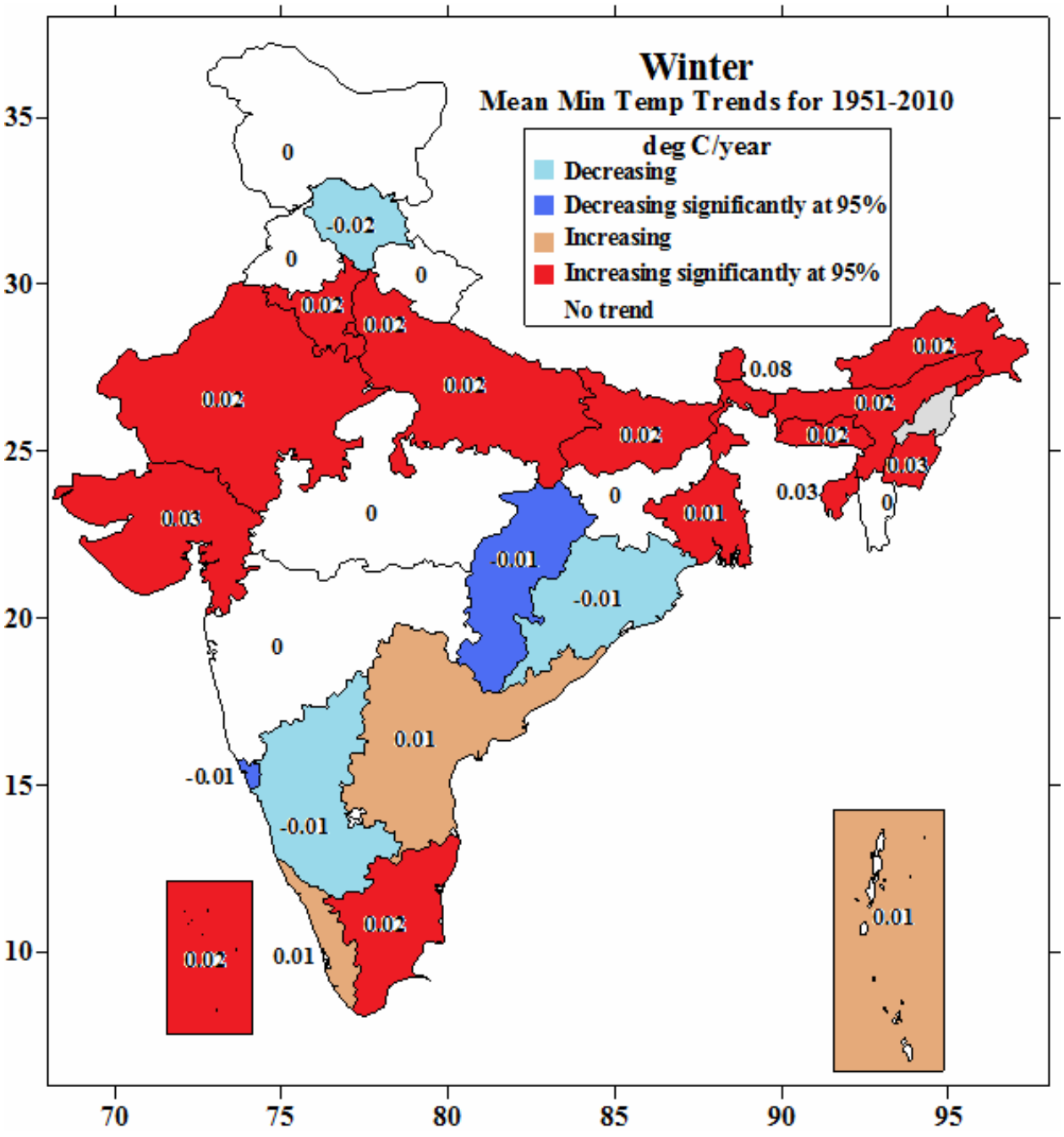


Figure 9: State level mean minimum temperature trends for winter season.

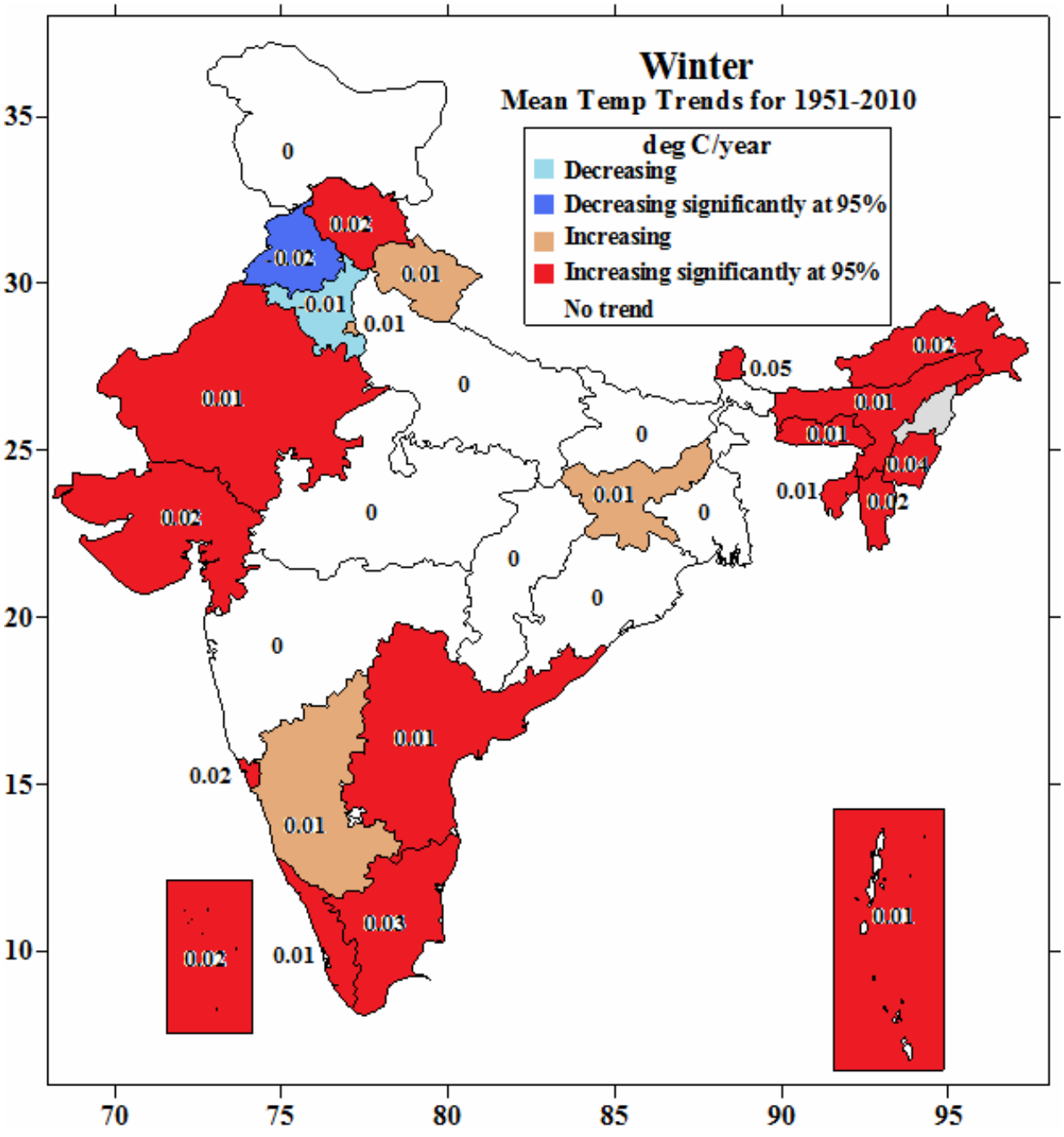


Figure 10: State level mean temperature trends for winter season.

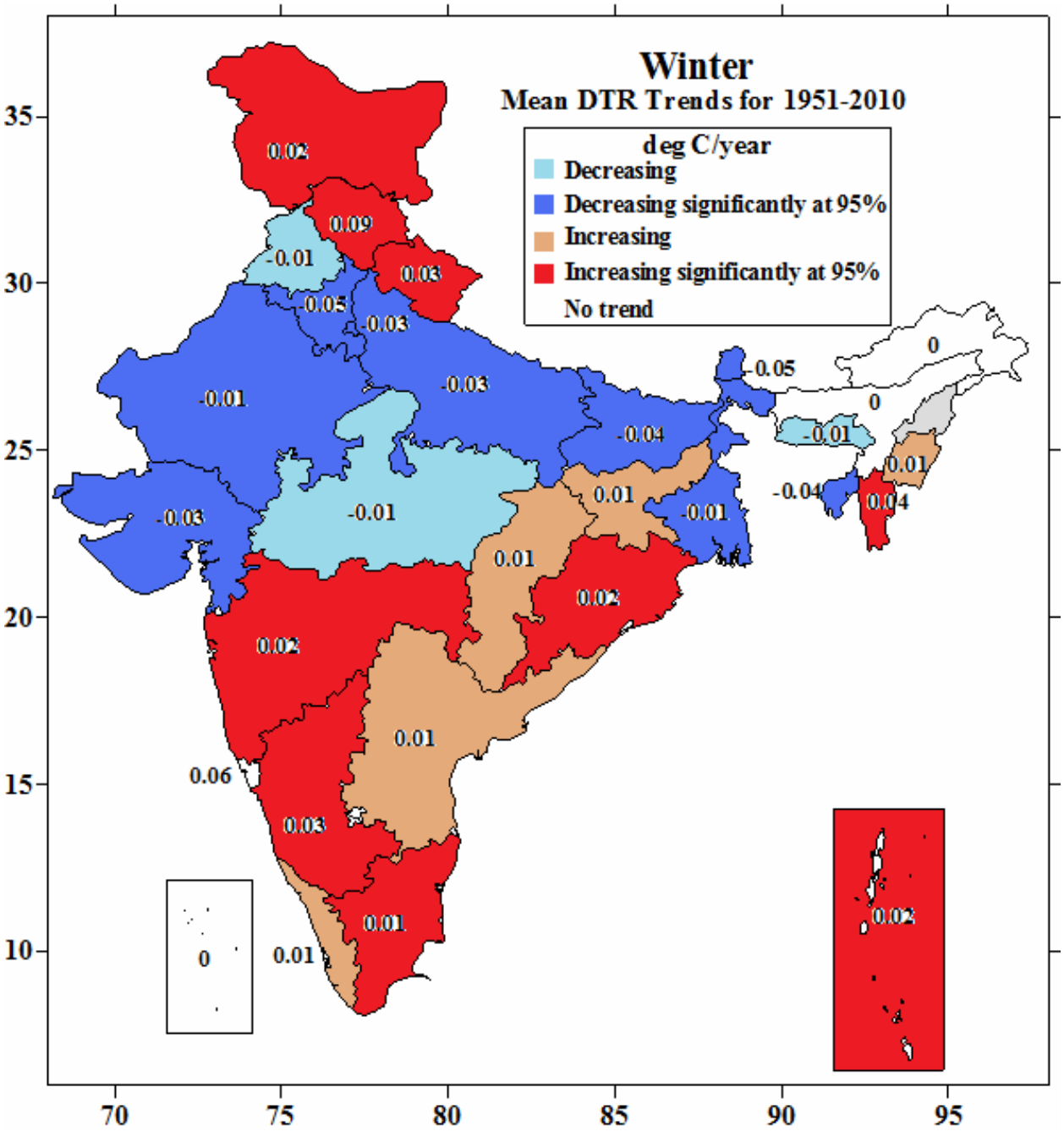


Figure 11: State level mean diurnal temperature range (DTR) trends for winter season.

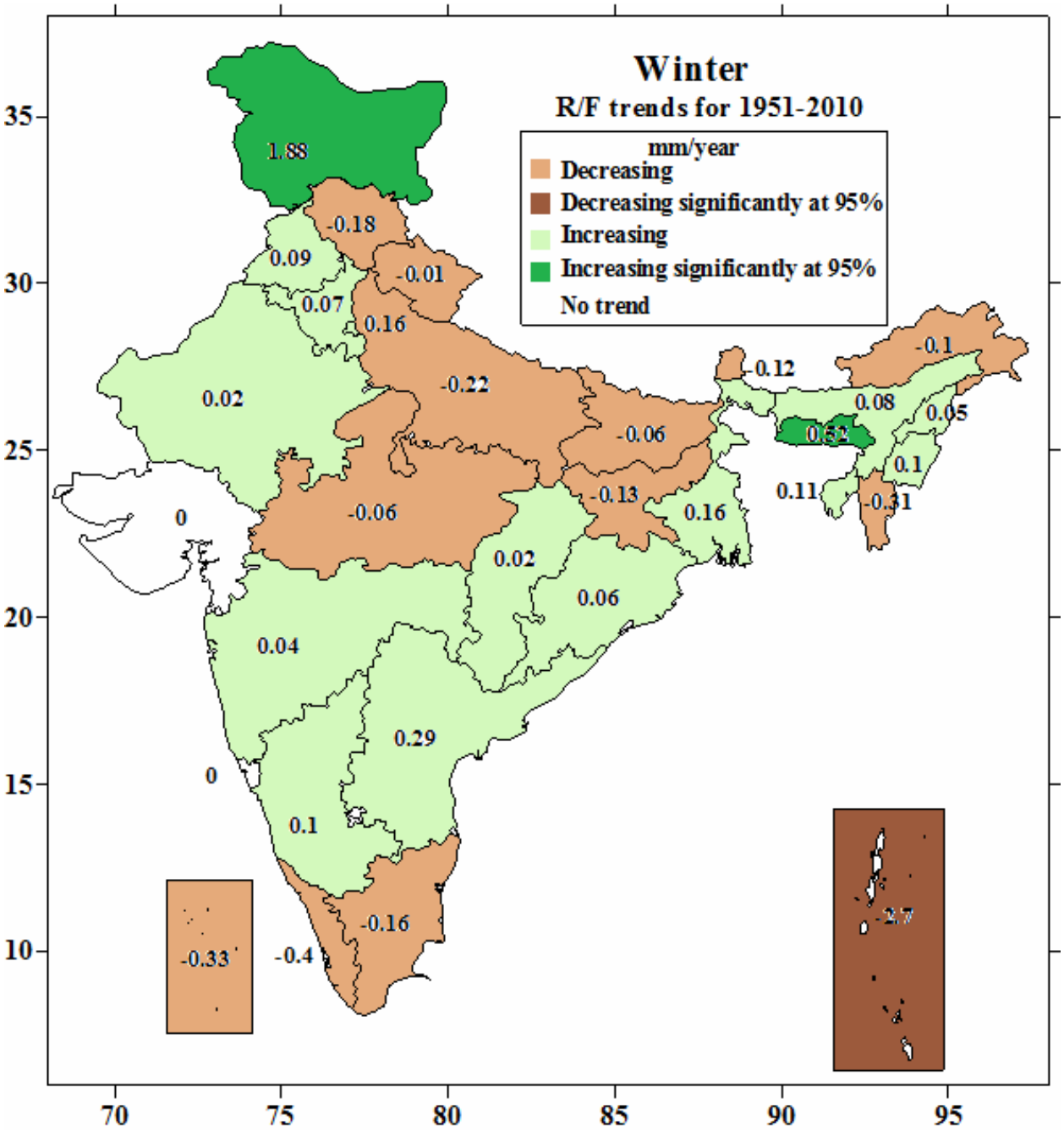


Figure 12: State level rainfall trends for winter season.

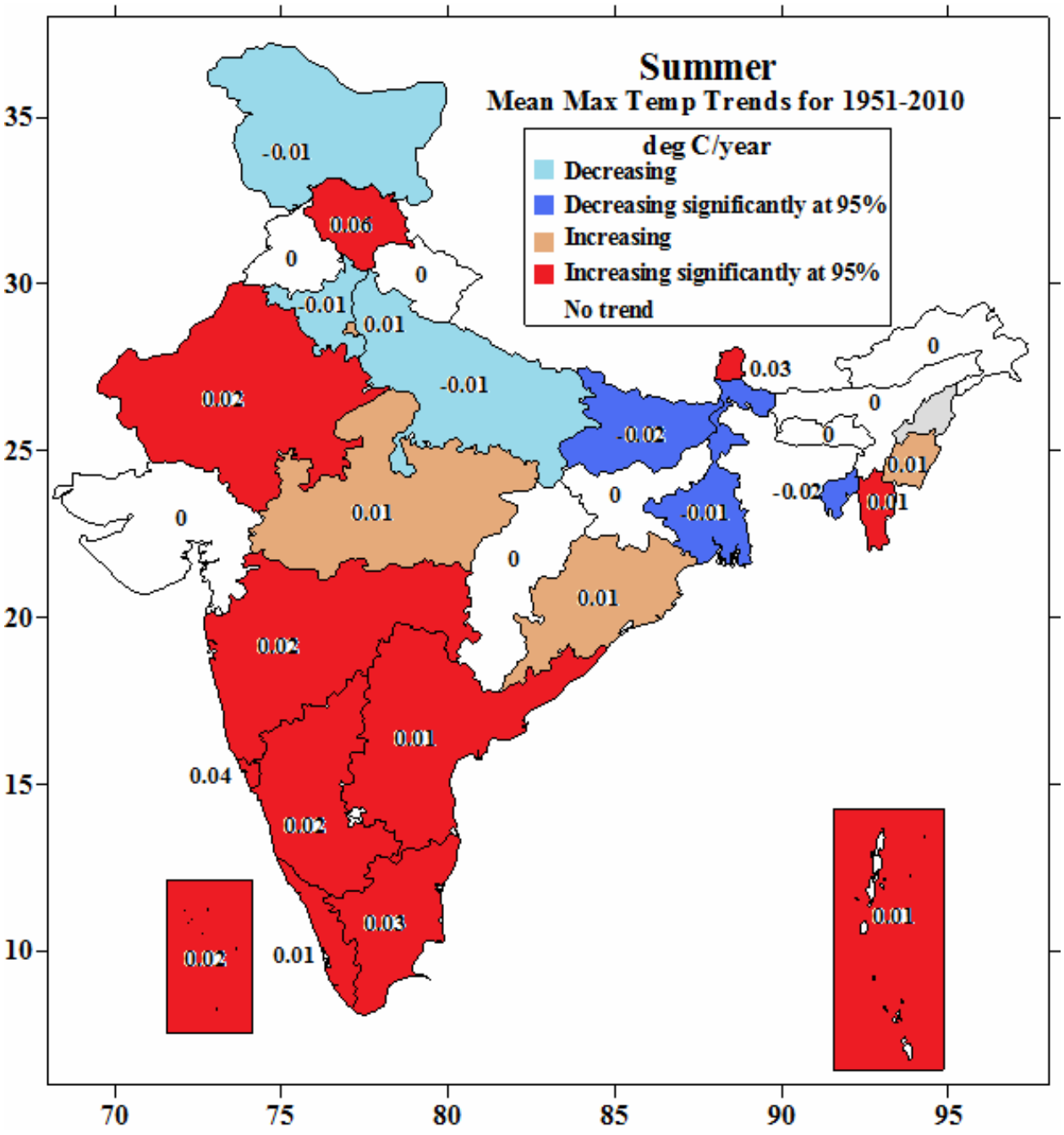


Figure 13: State level mean maximum temperature trends for summer season.

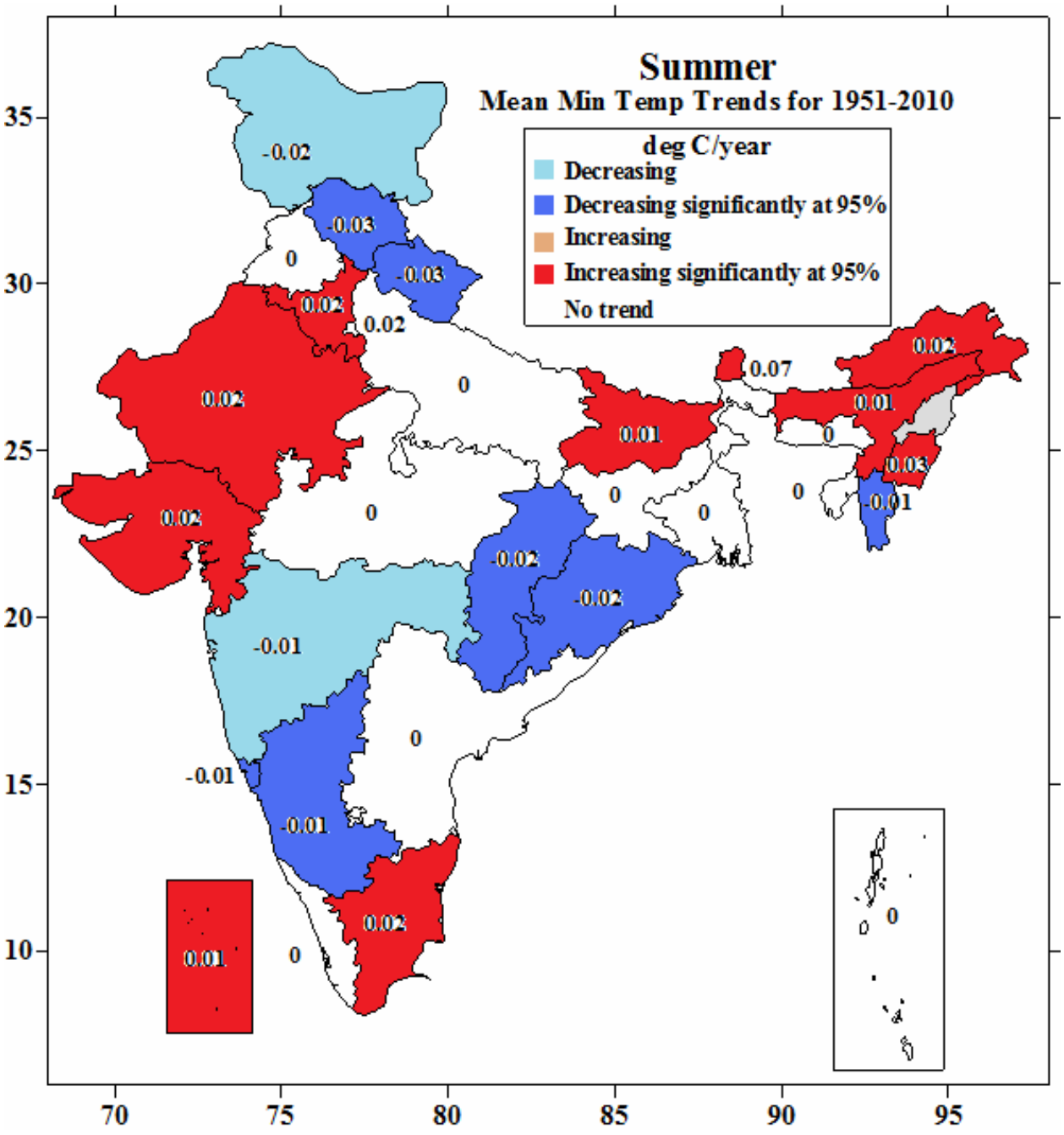


Figure 14: State level mean minimum temperature trends for summer season.

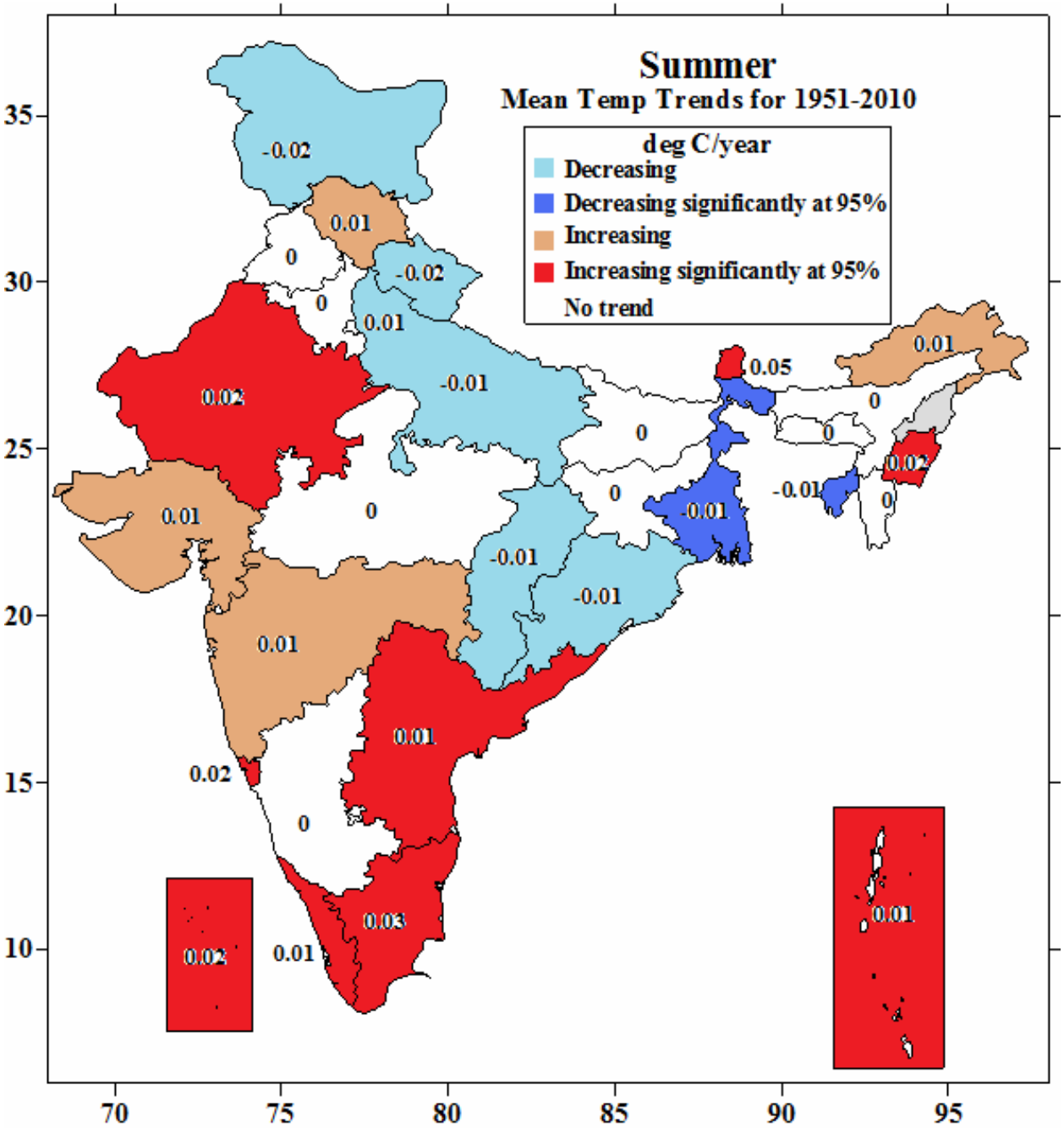


Figure 15: State level mean temperature trends for summer season.

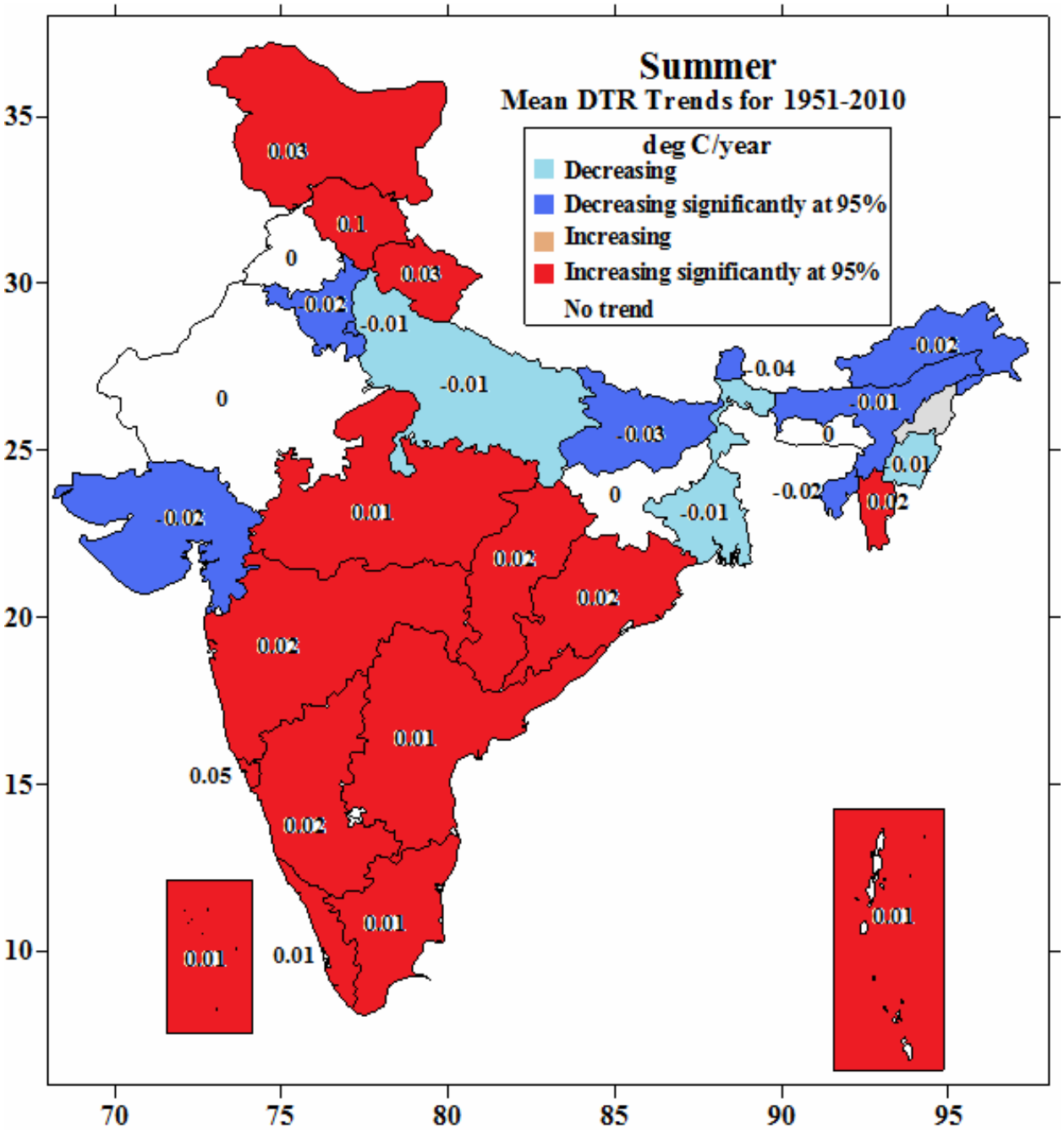


Figure 16: State level mean diurnal temperature range (DTR) trends for summer.

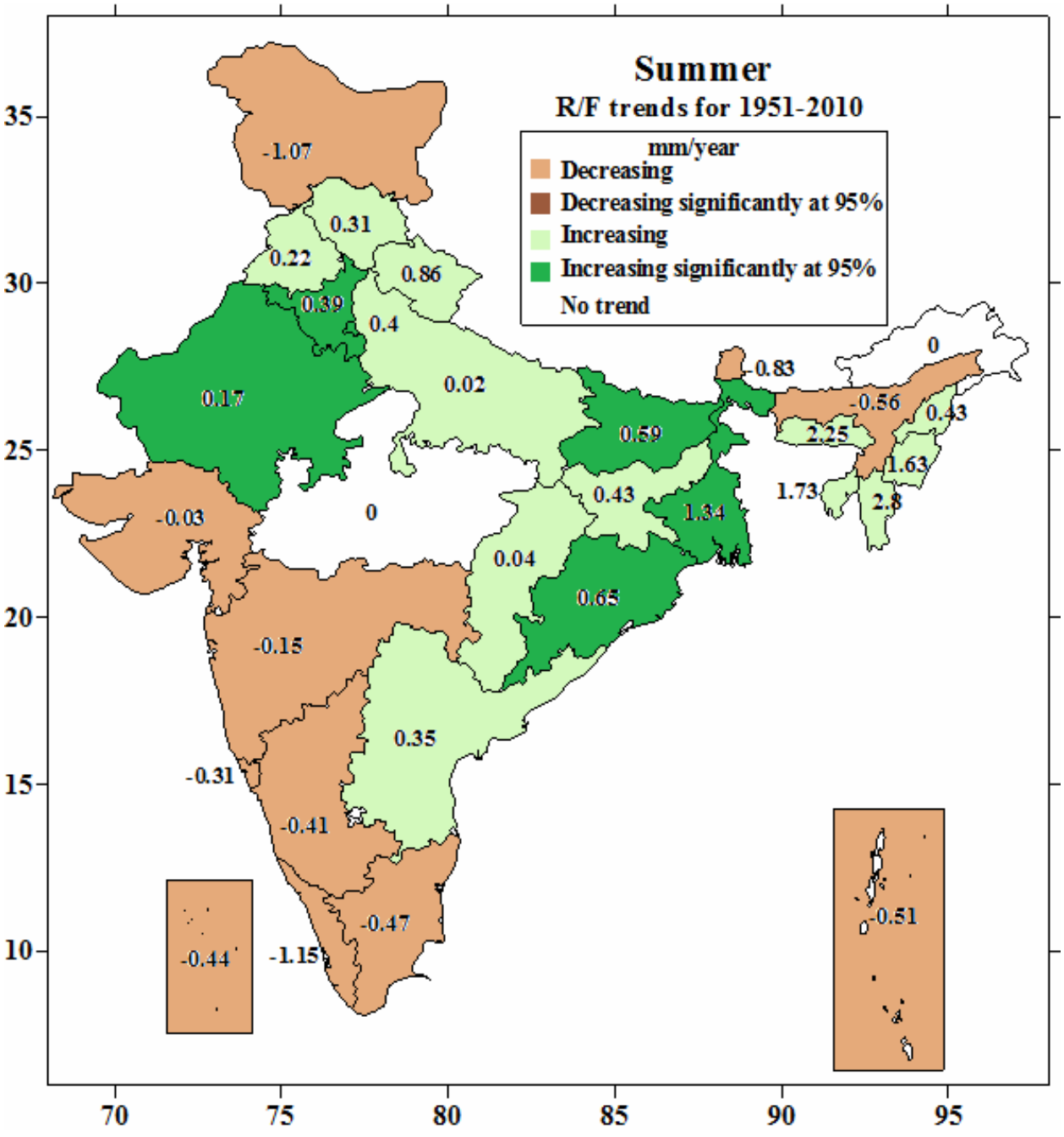


Figure 17: State level rainfall trends for summer season.

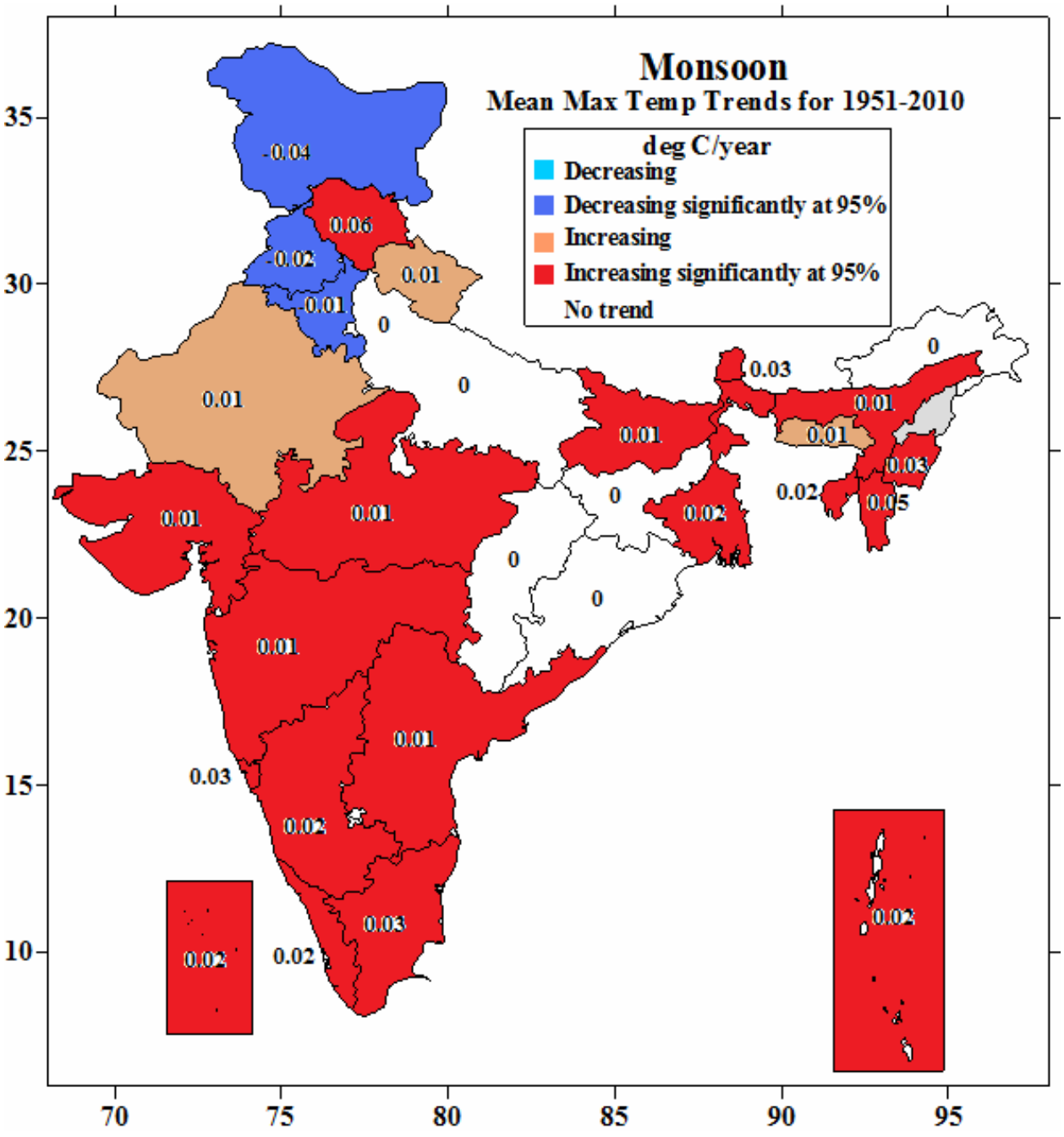


Figure 18: State level mean maximum temperature trends for monsoon season.

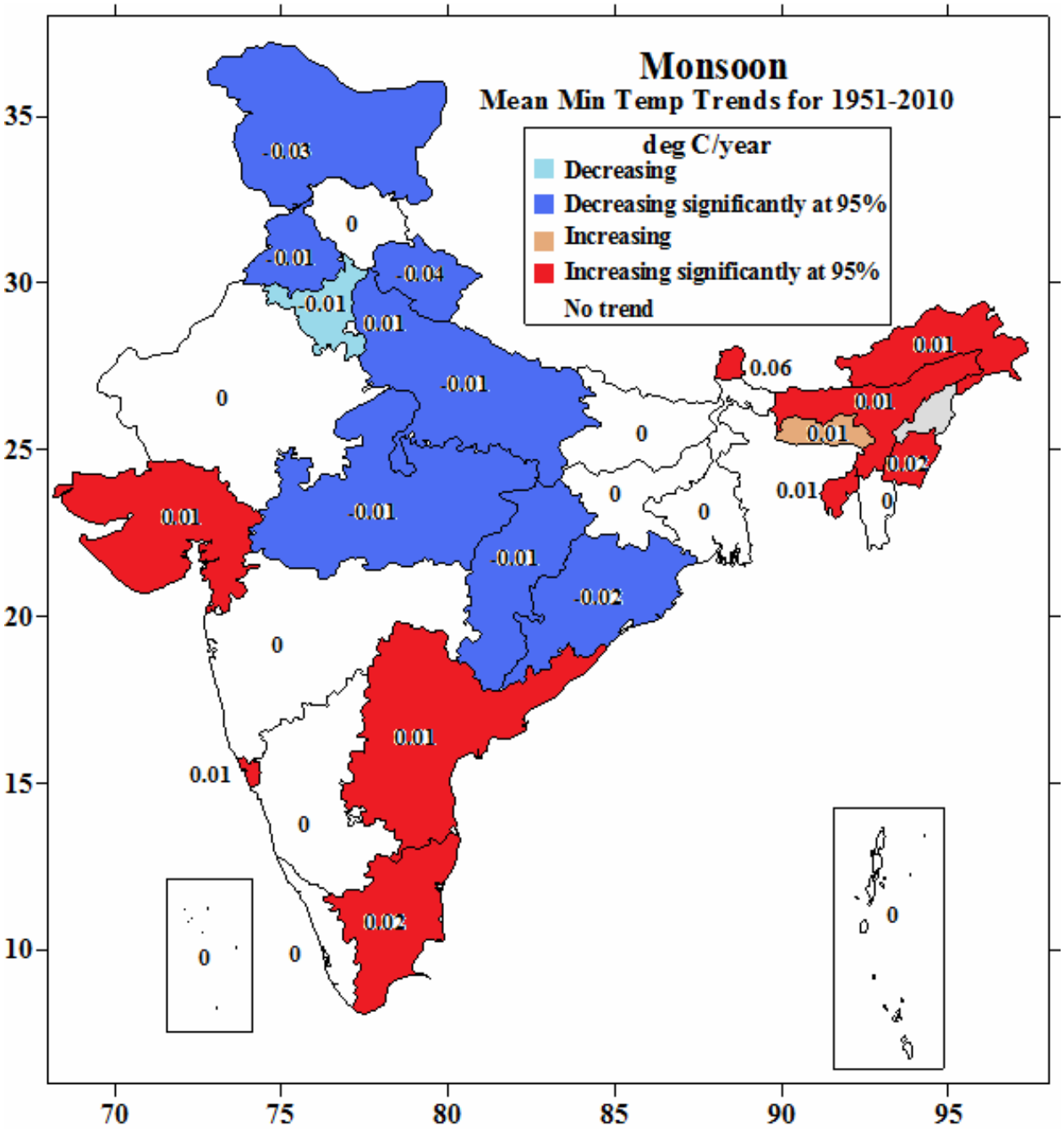


Figure 19: State level mean minimum temperature trends for monsoon season.

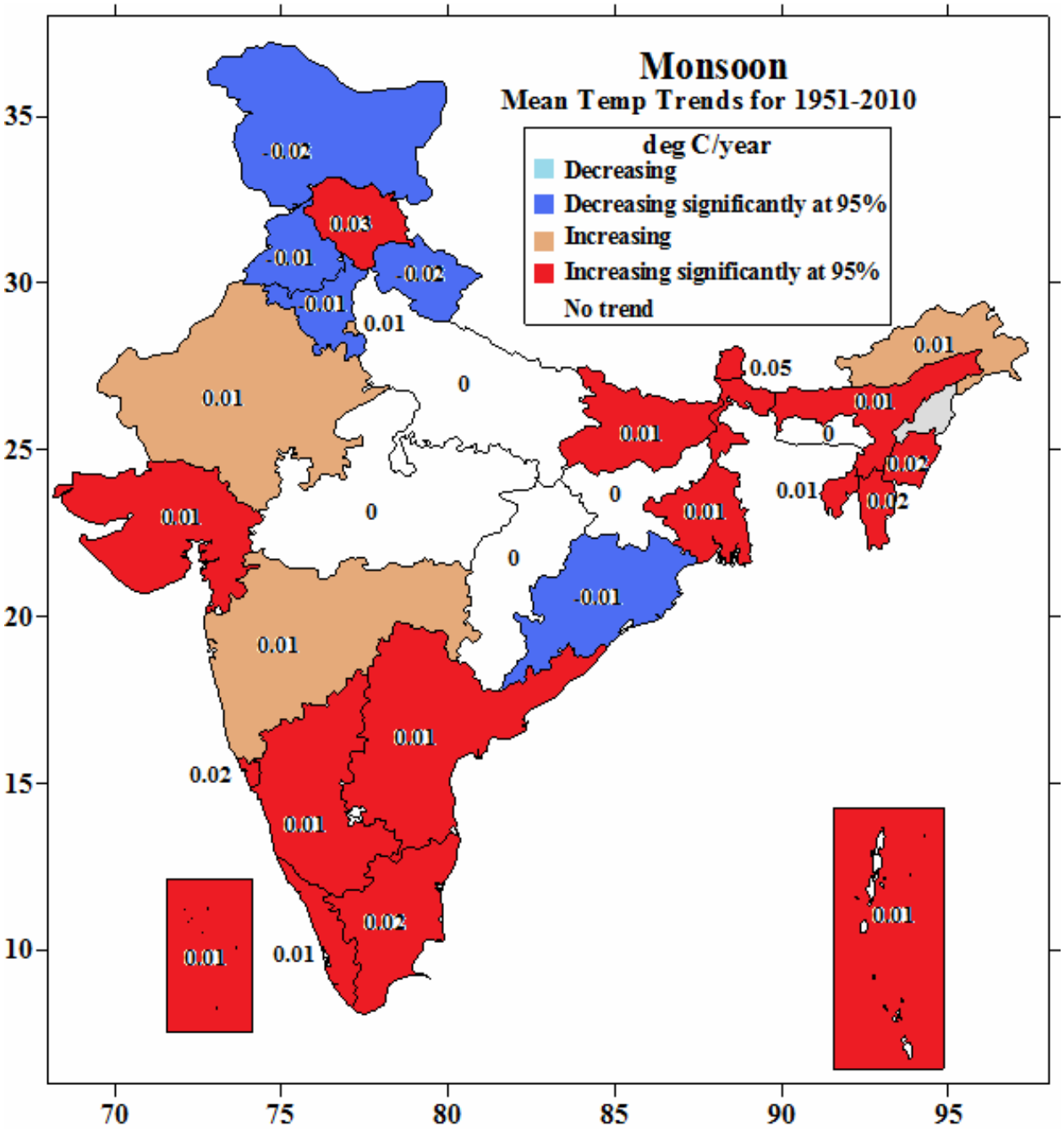


Figure 20: State level mean temperature trends for monsoon season.

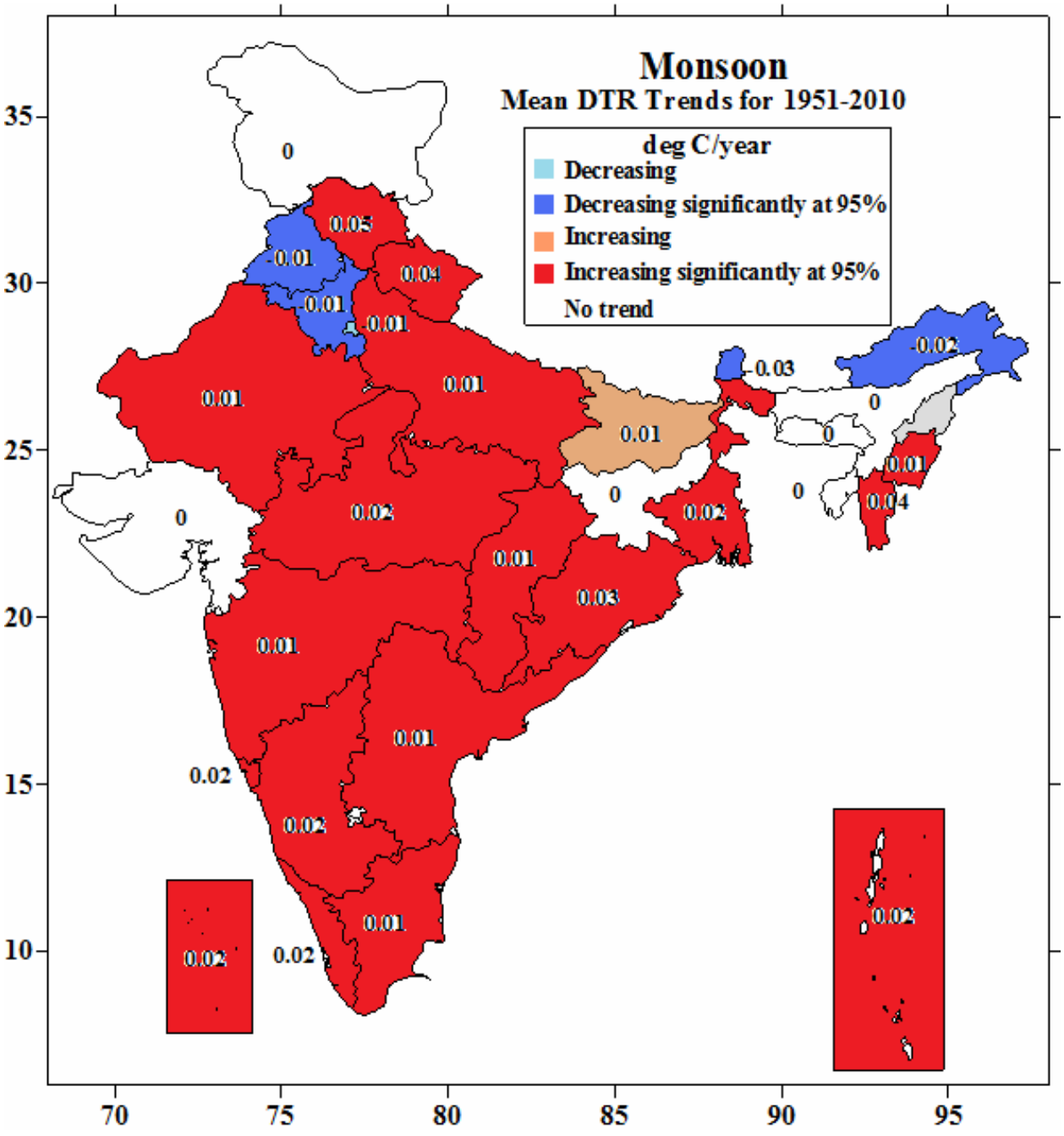


Figure 21: State level mean diurnal temperature range (DTR) trends for monsoon.

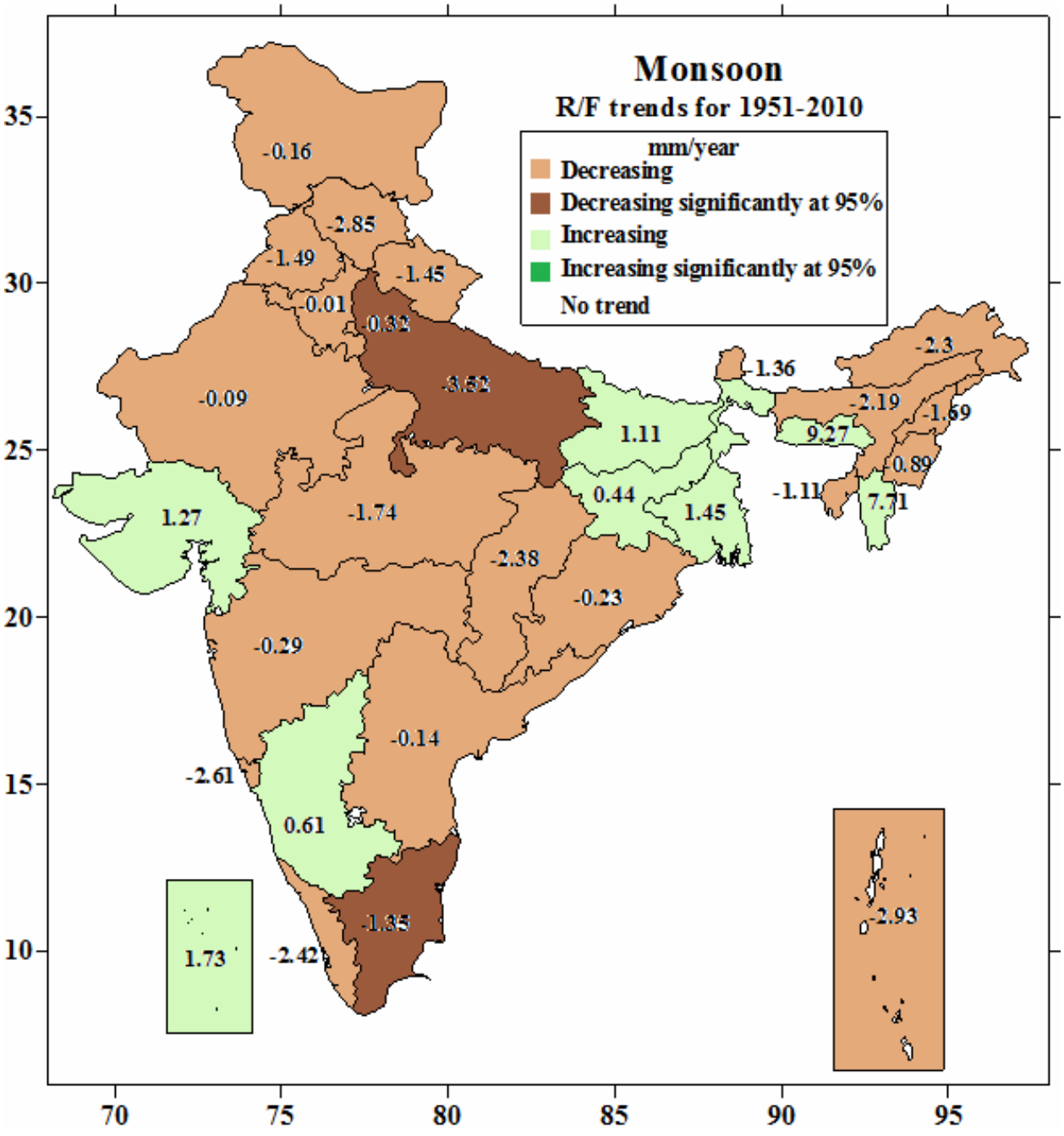


Figure 22: State level rainfall trends for monsoon season.

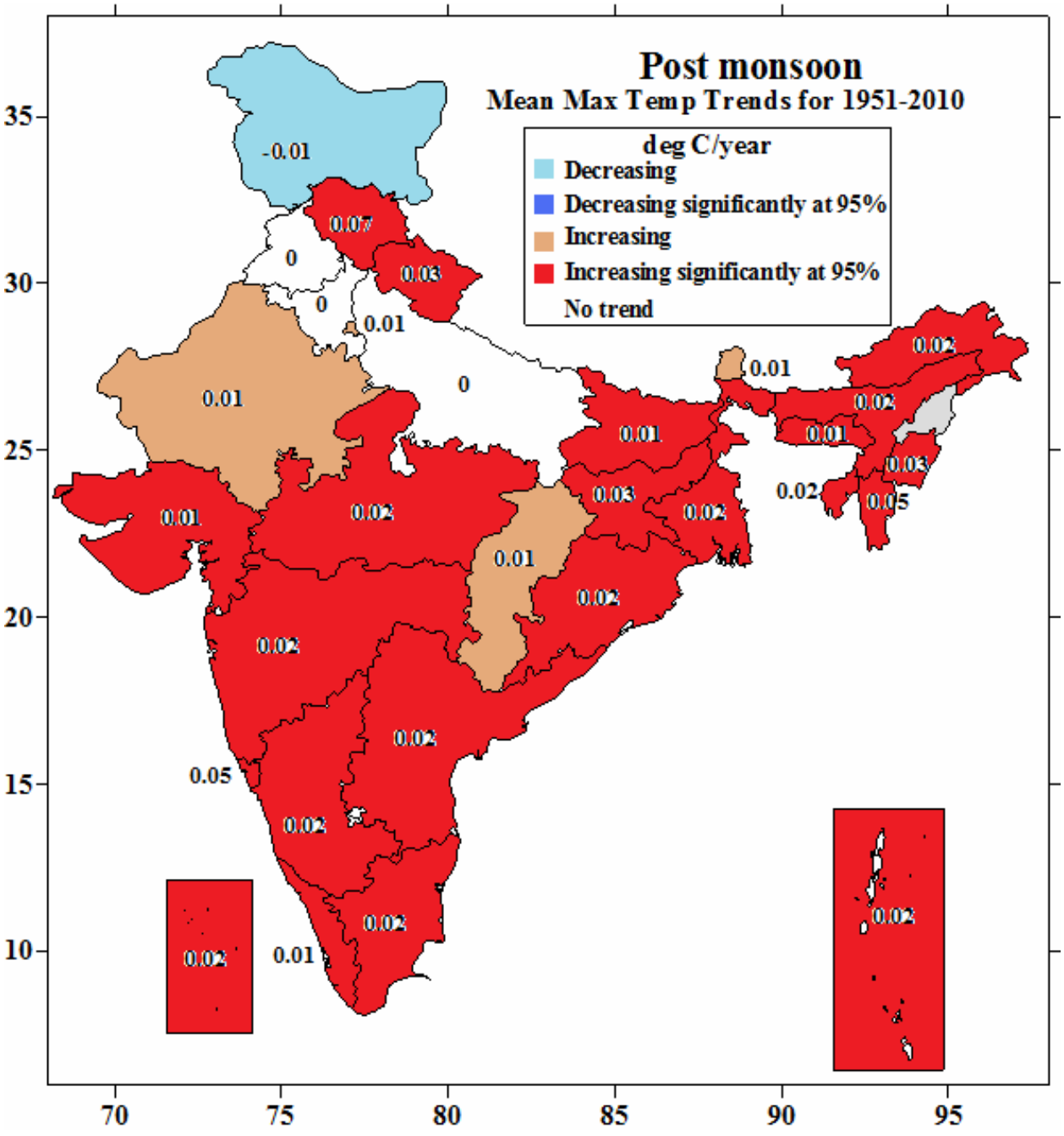


Figure 23: State level mean maximum temperature trends for post monsoon season.

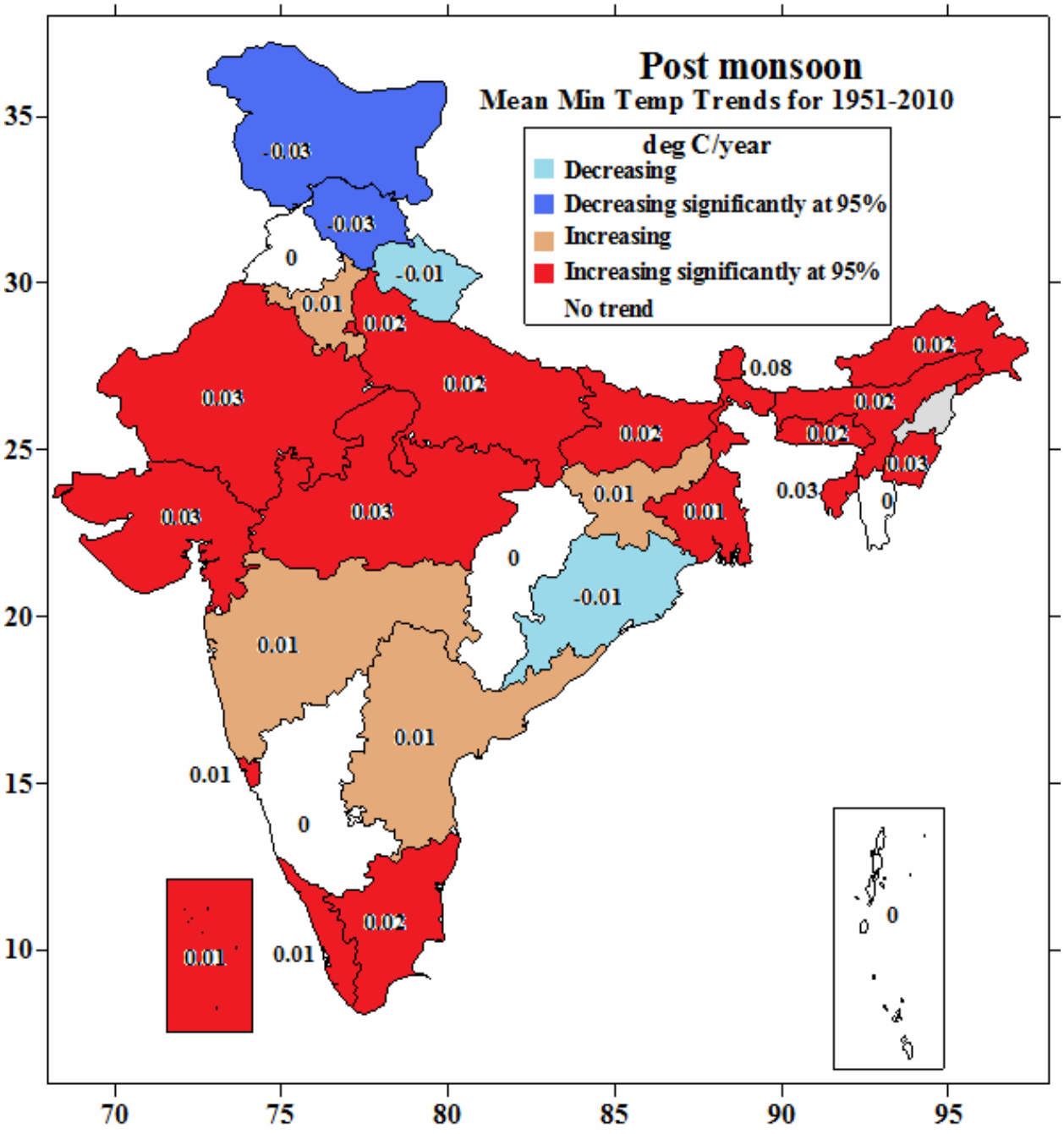


Figure 24: State level mean minimum temperature trends for post monsoon season.

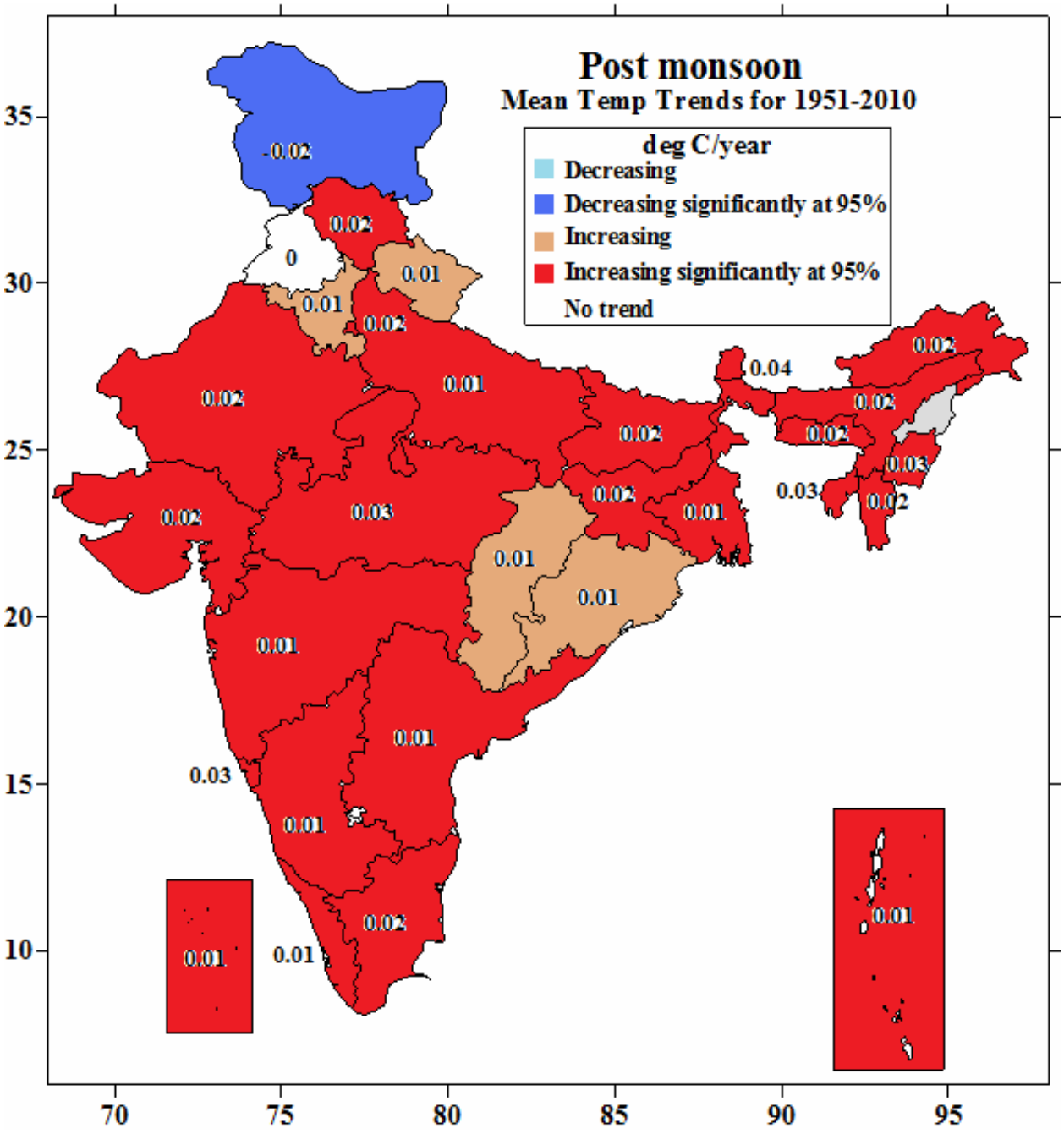


Figure 25: State level mean temperature trends for post monsoon season.

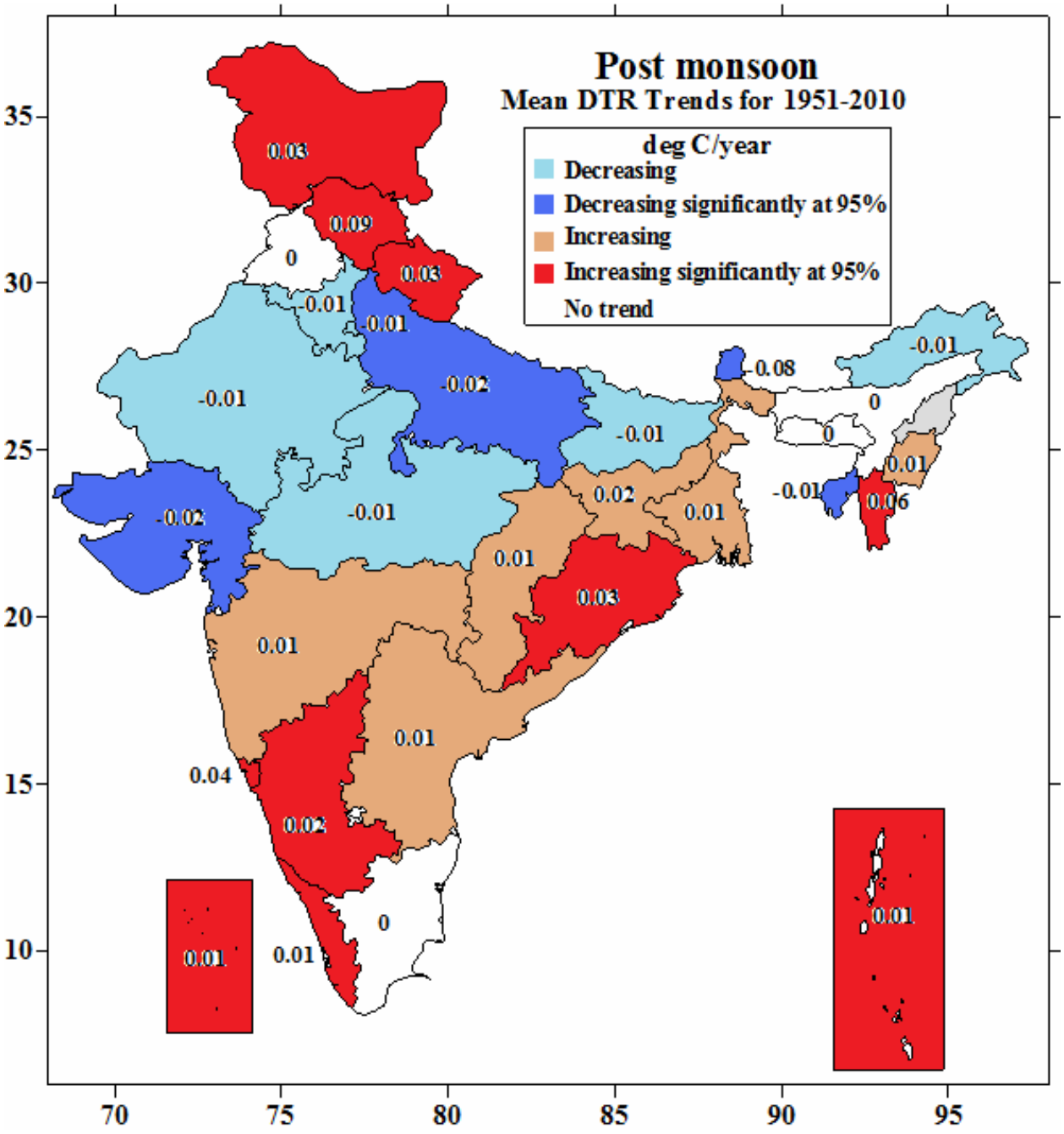


Figure 26: State level mean diurnal temperature range (DTR) trends for post monsoon.

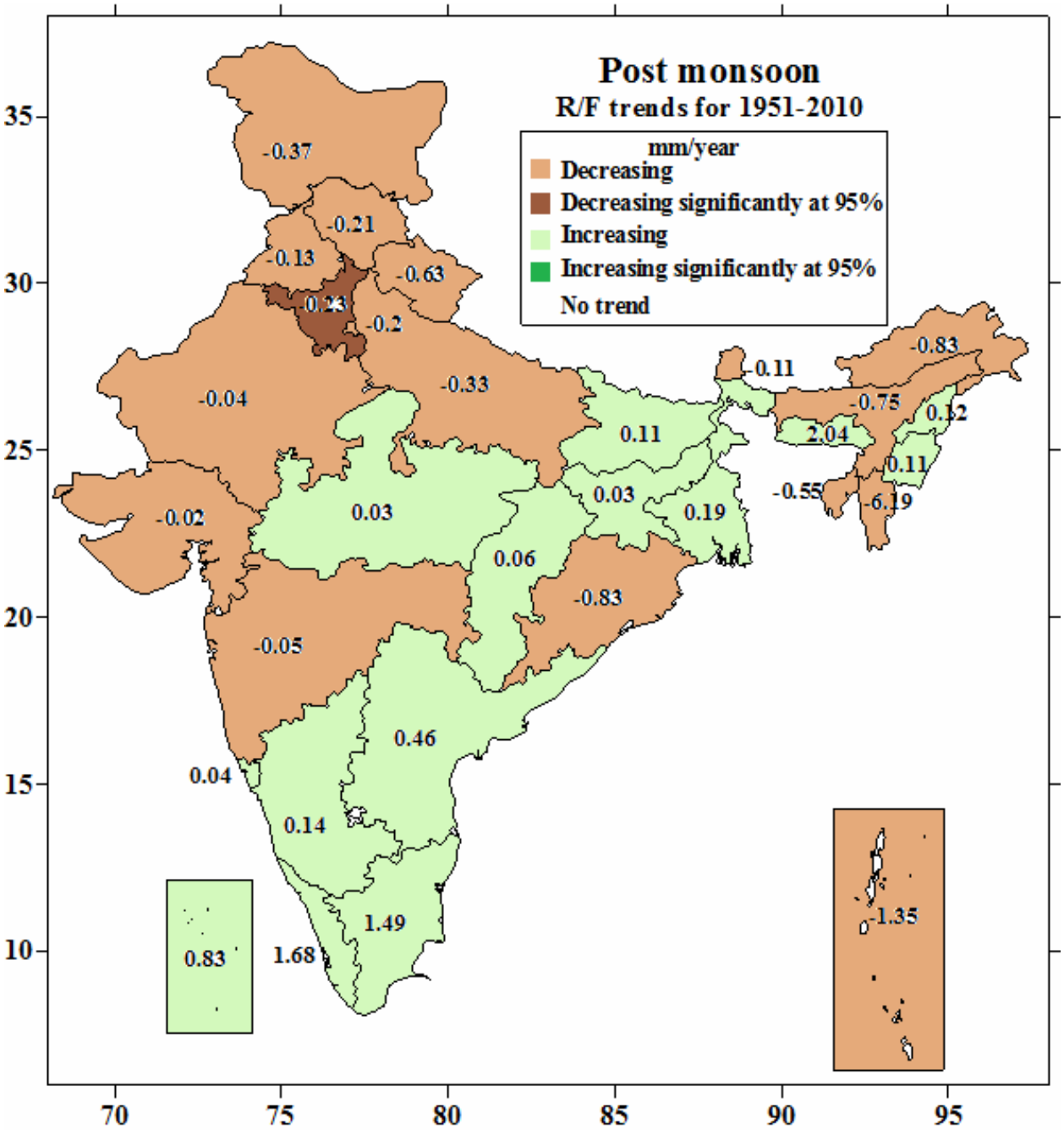


Figure 27: State level rainfall trends for post monsoon season.

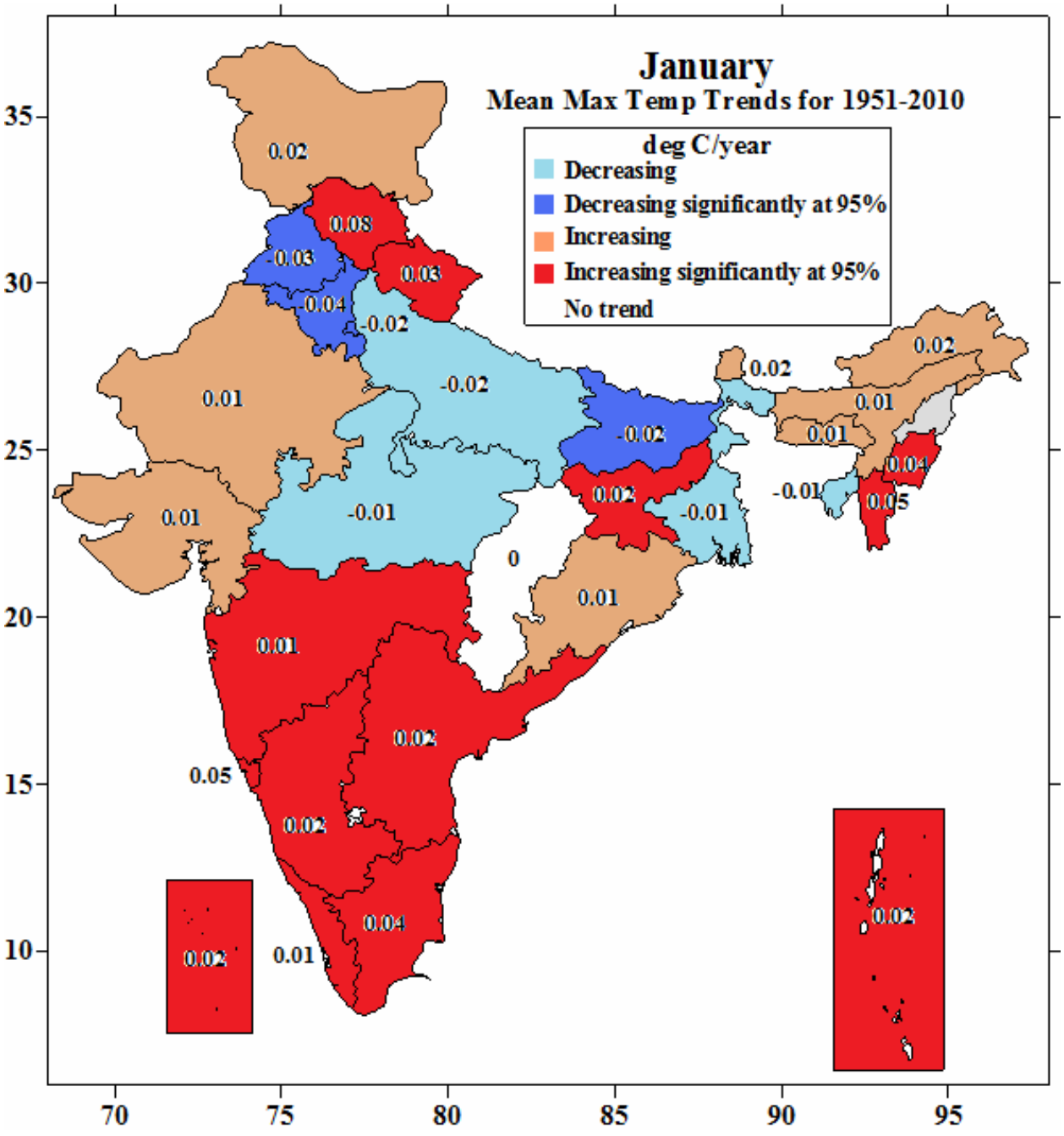


Figure 28: State level mean maximum temperature trends for January.

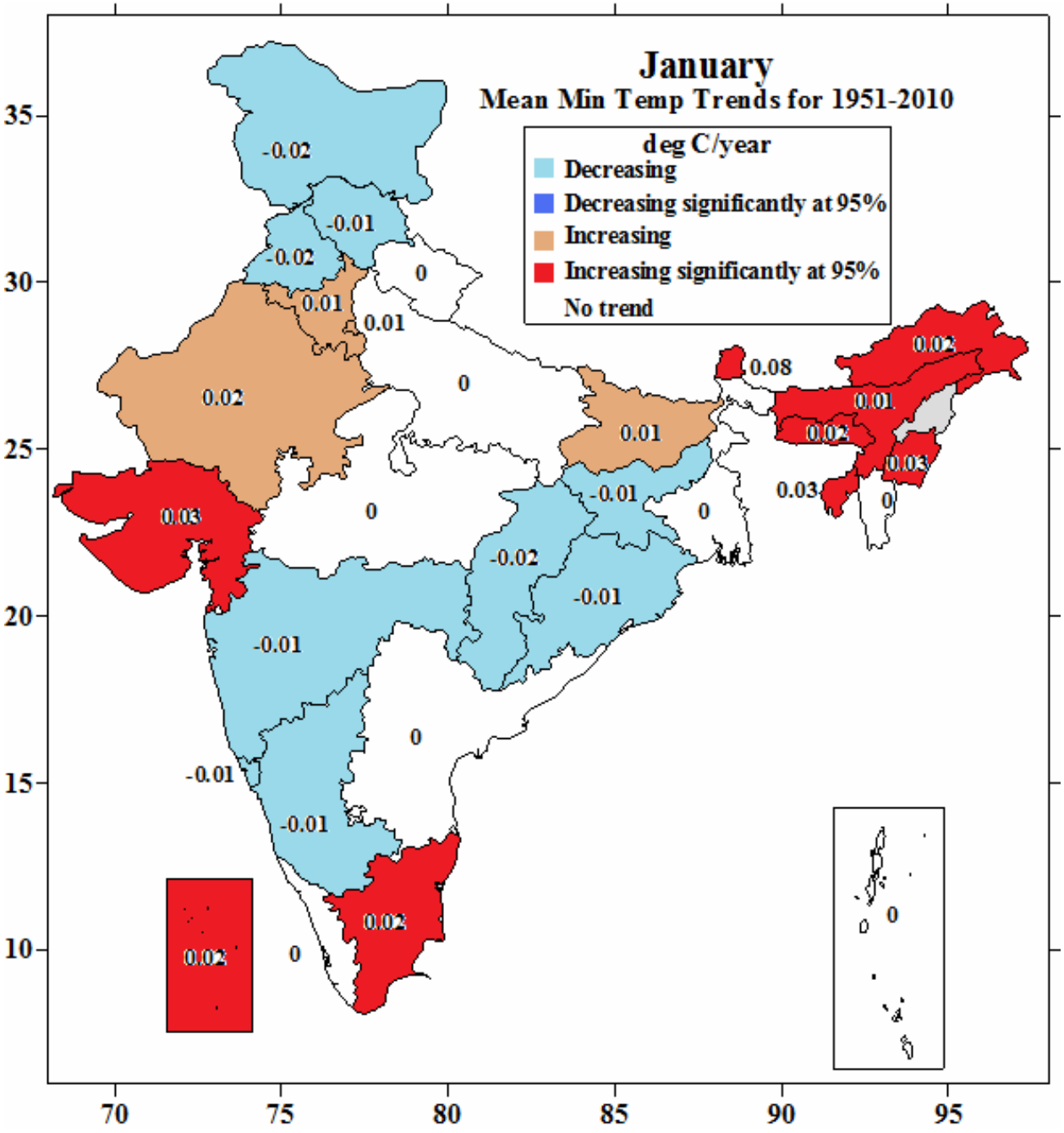


Figure 29: State level mean minimum temperature trends for January.

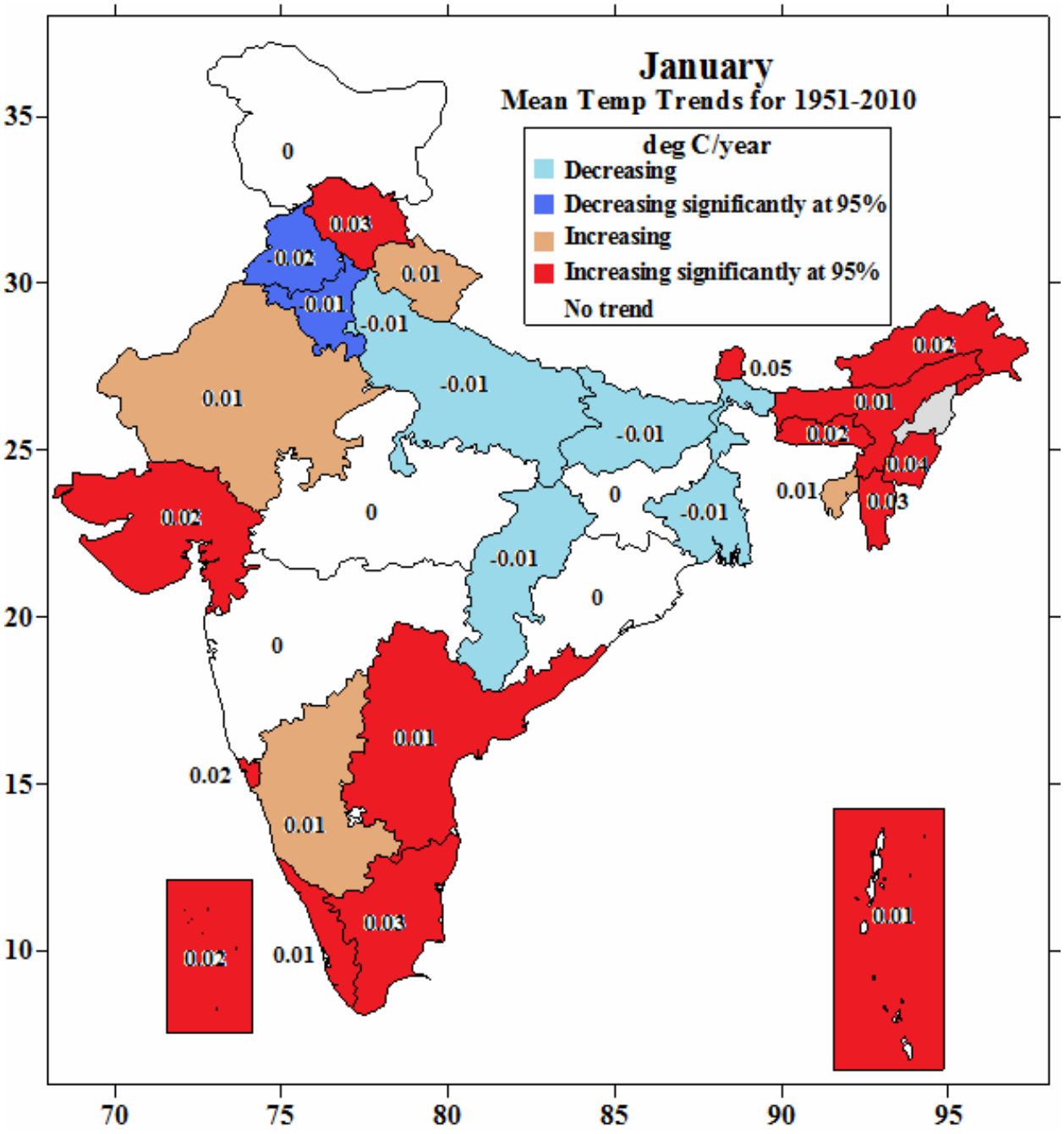


Figure 30: State level annual mean temperature trends for January.

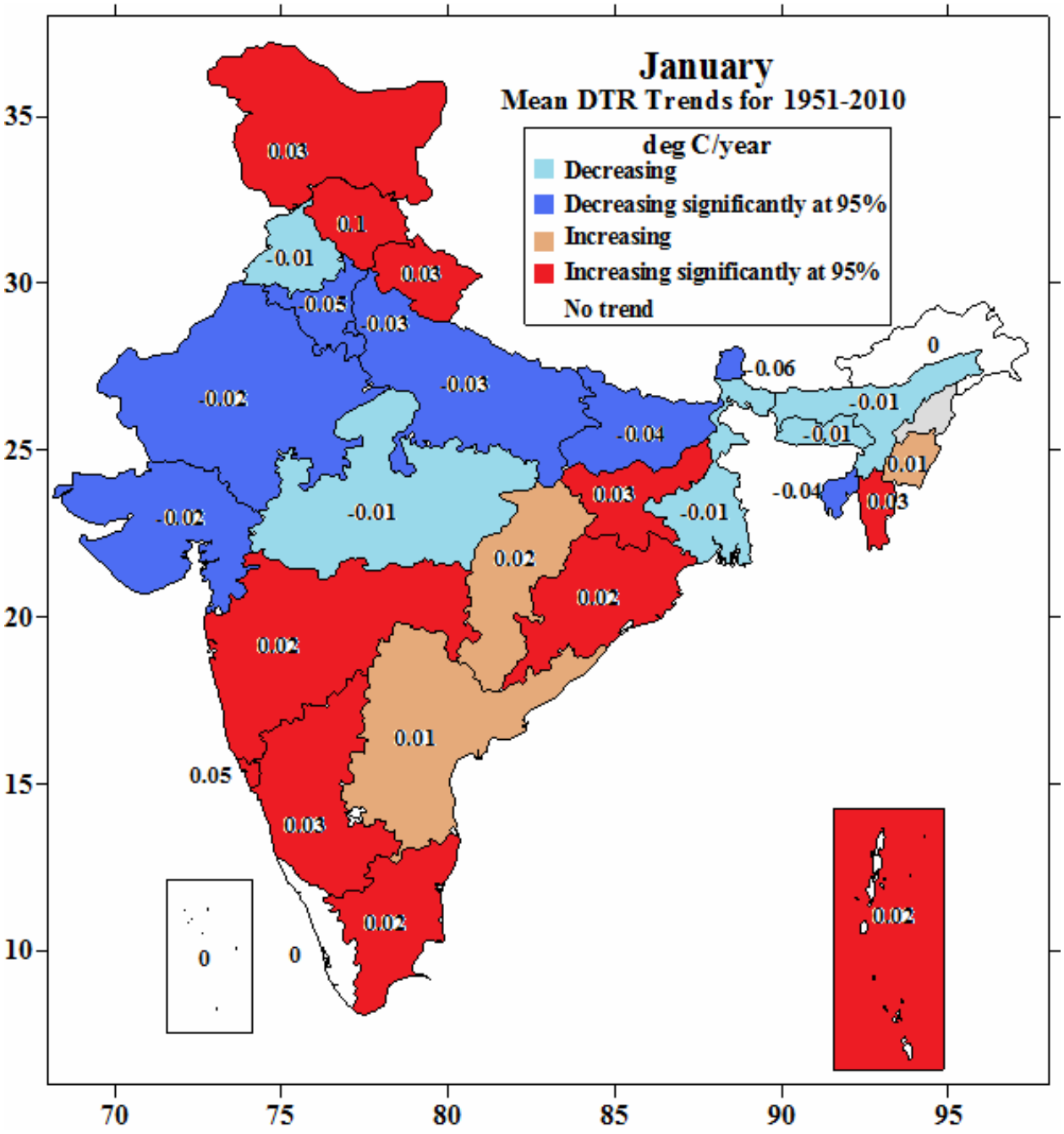


Figure 31: State level mean diurnal temperature range (DTR) trends for January.

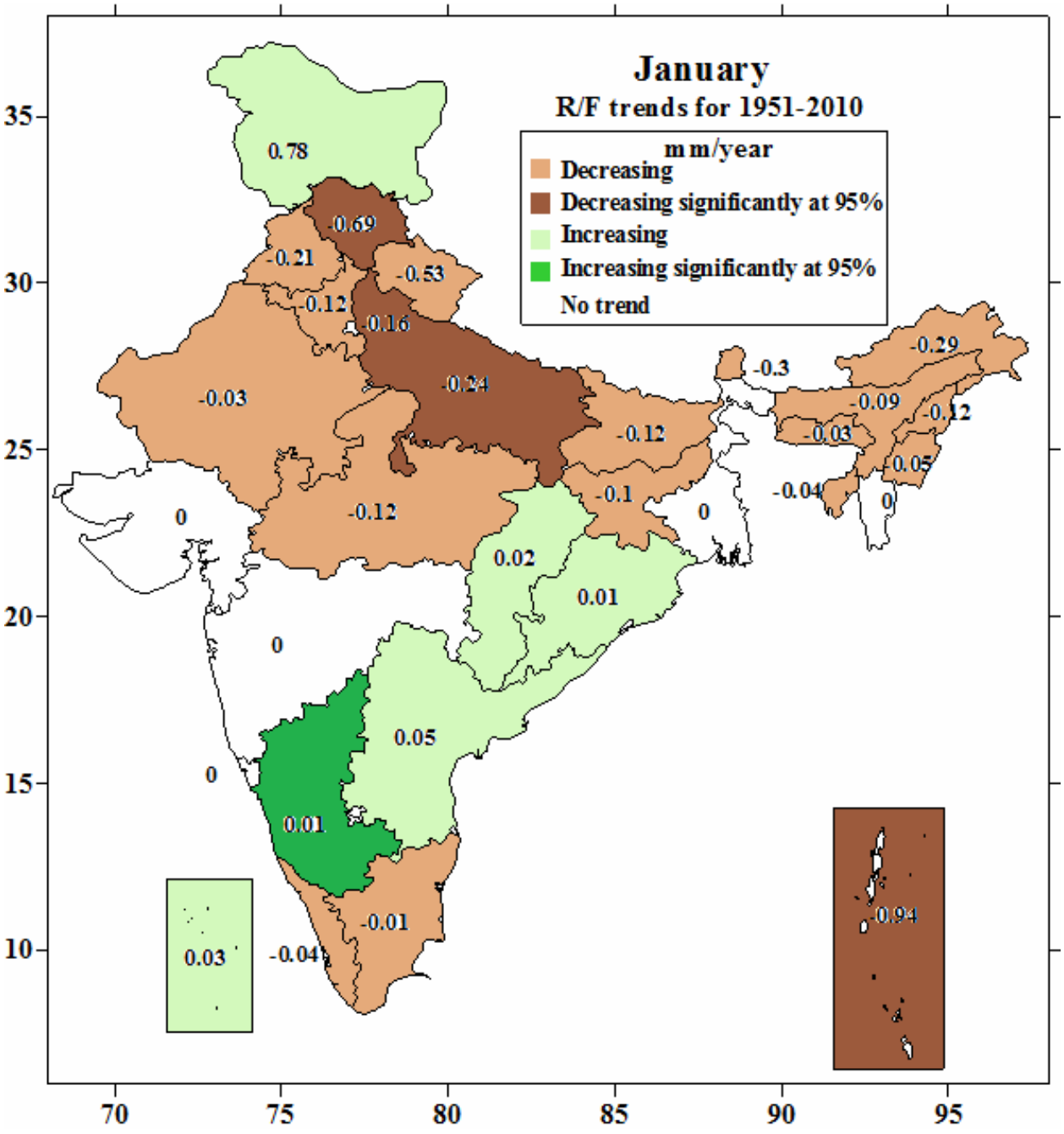


Figure 32: State level rainfall trends for January.

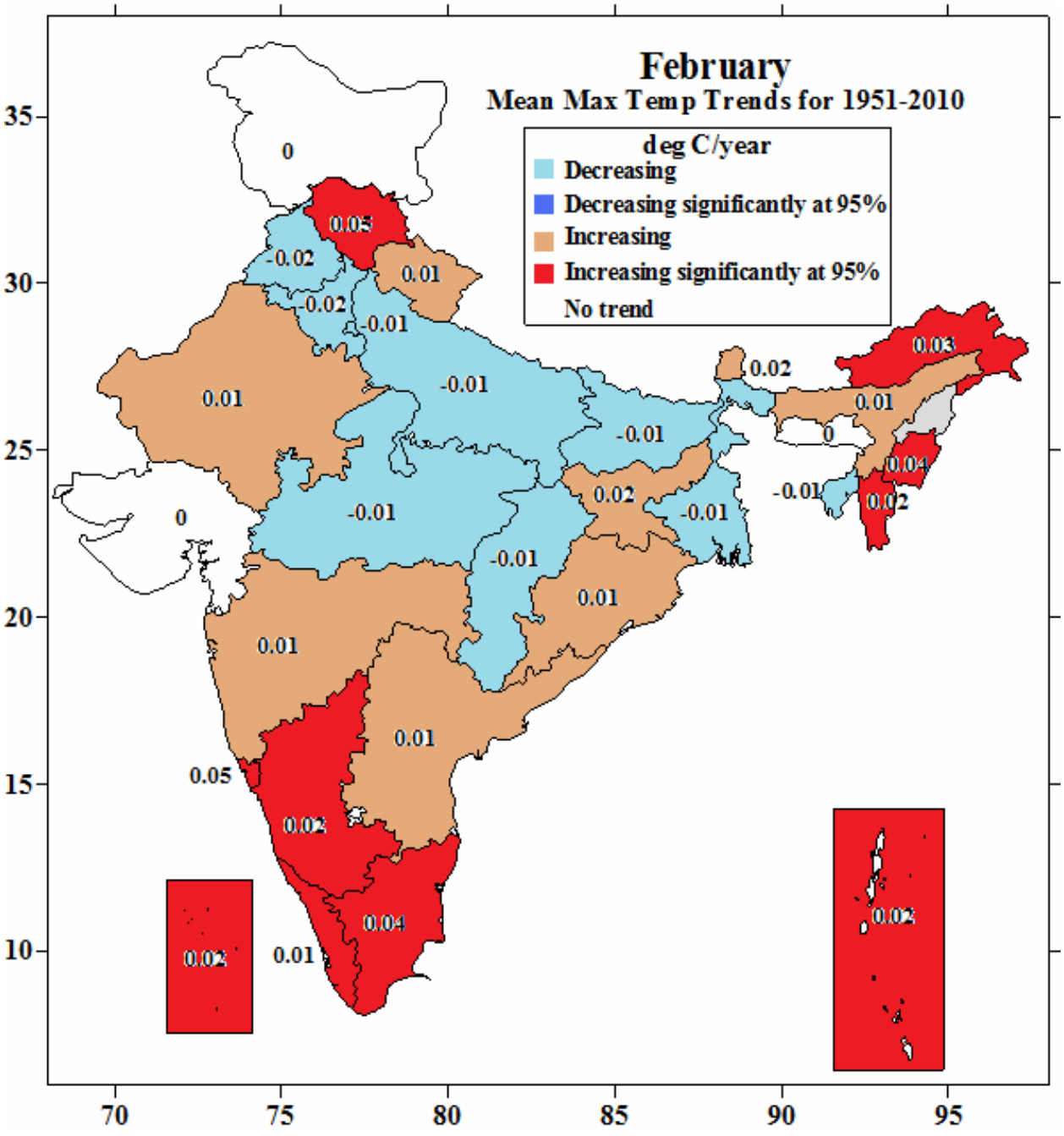


Figure 33: State level mean maximum temperature trends for February.

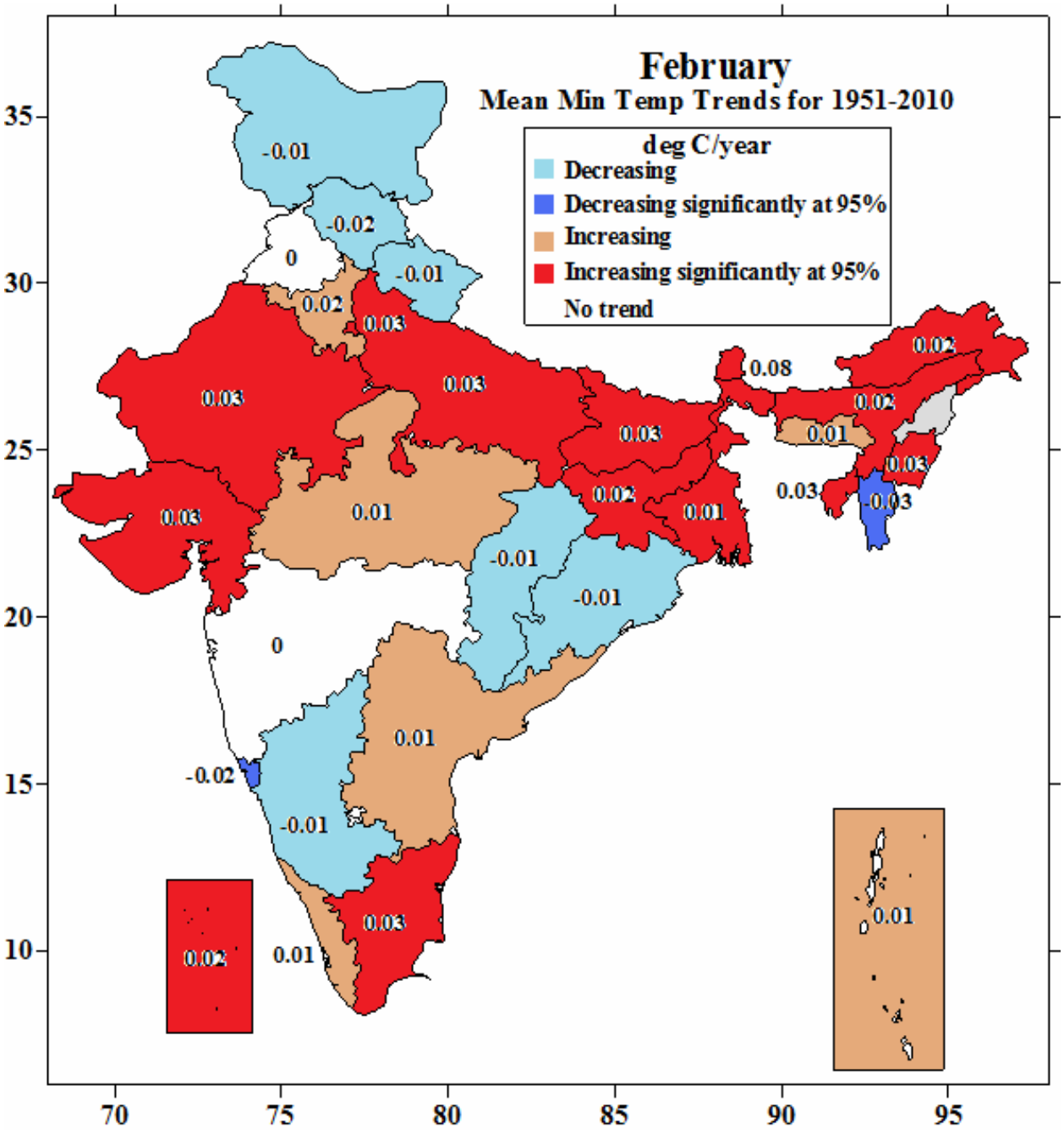


Figure 34: State level mean minimum temperature trends for February.

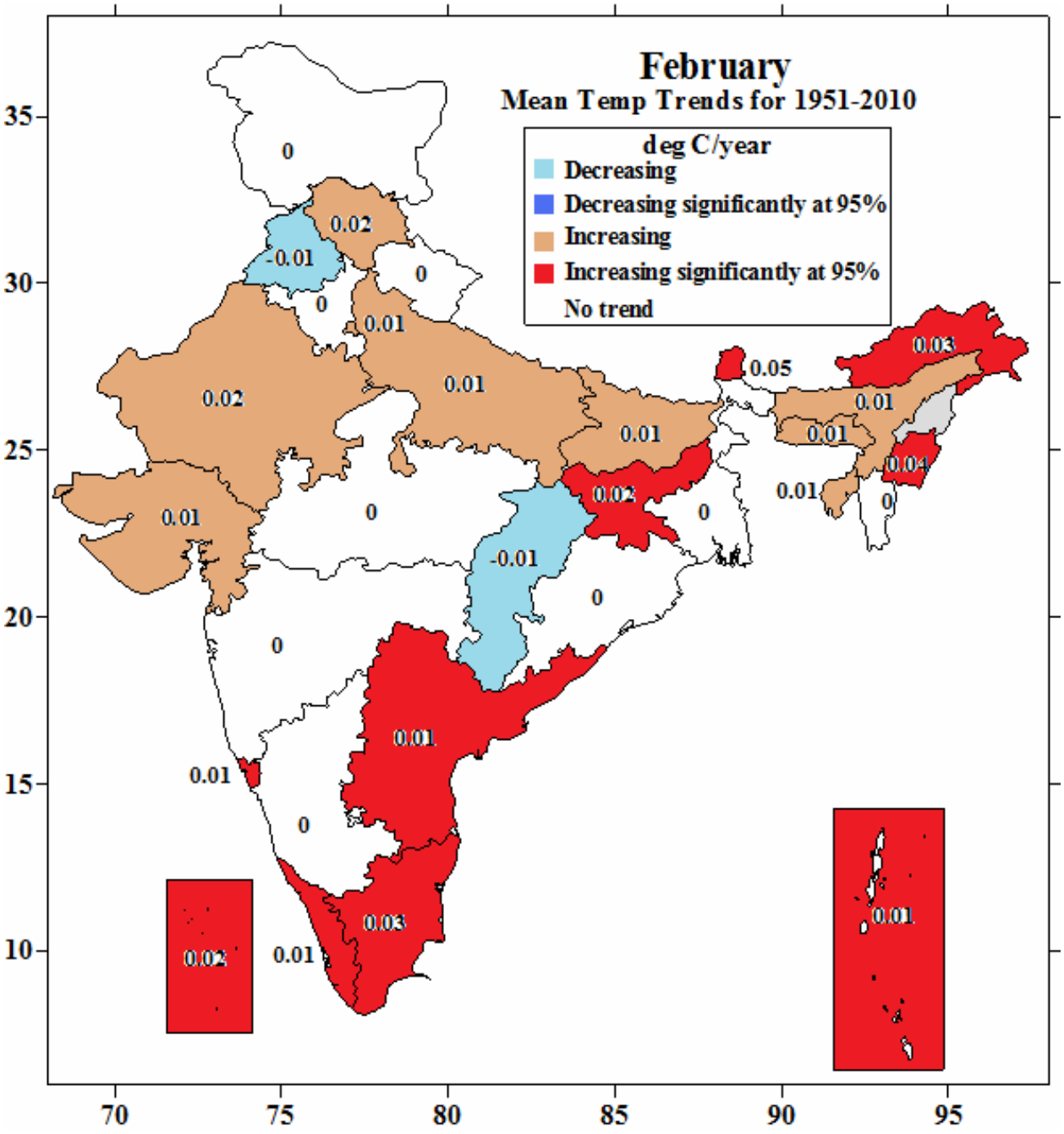


Figure 35: State level mean temperature trends for February.

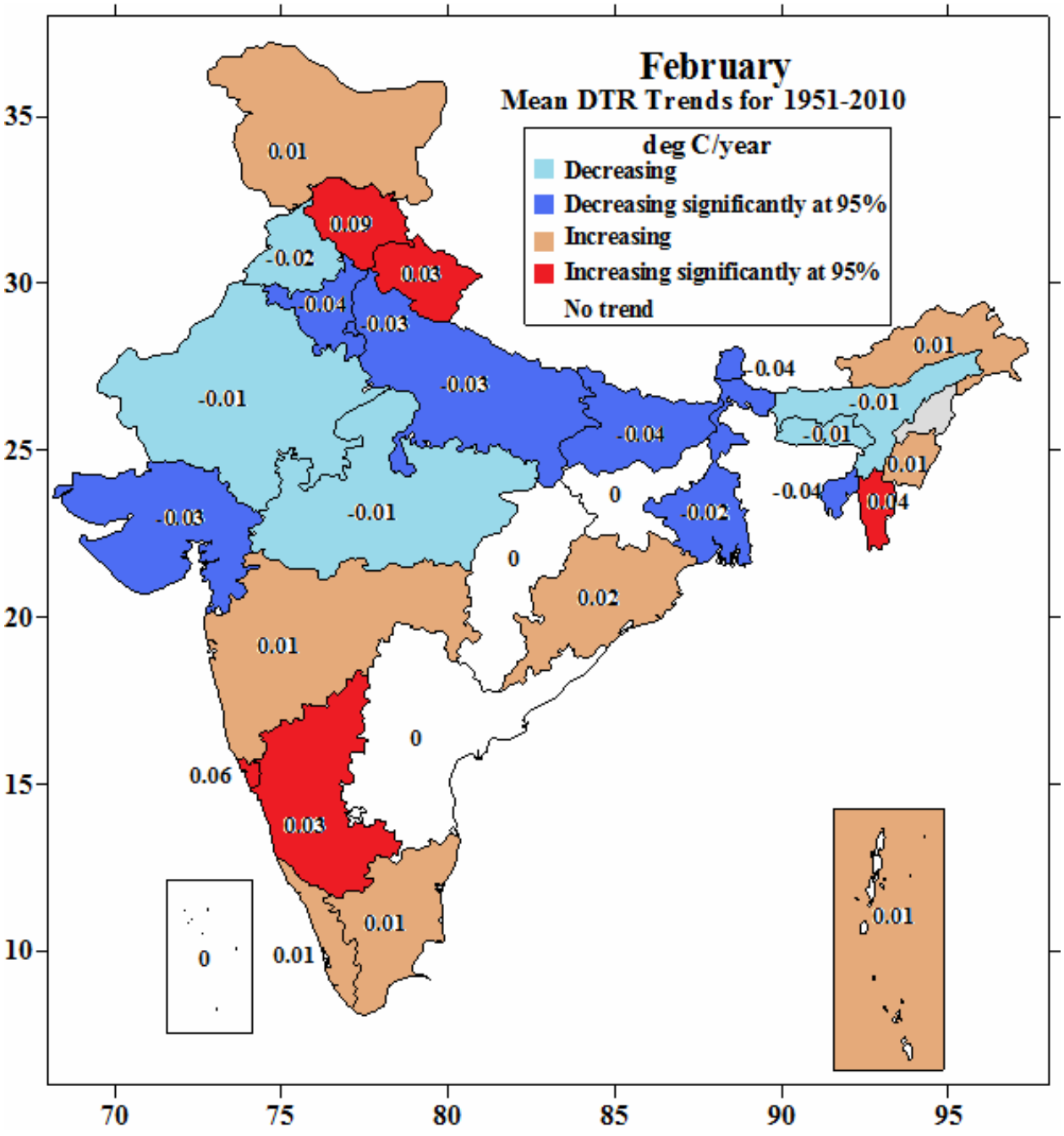


Figure 36: State level mean diurnal temperature range (DTR) trends for February.

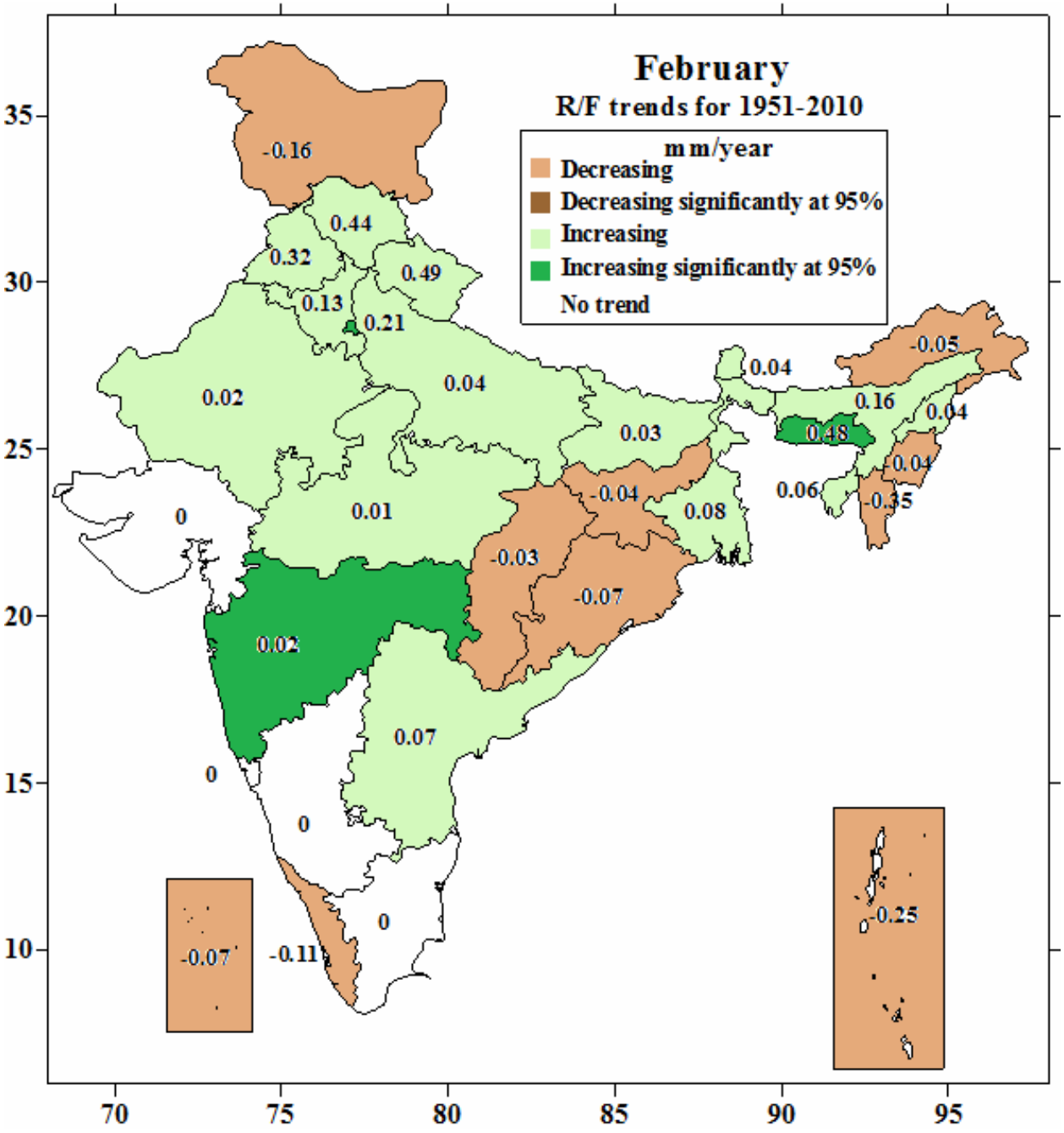


Figure 37: State level rainfall trends for February.

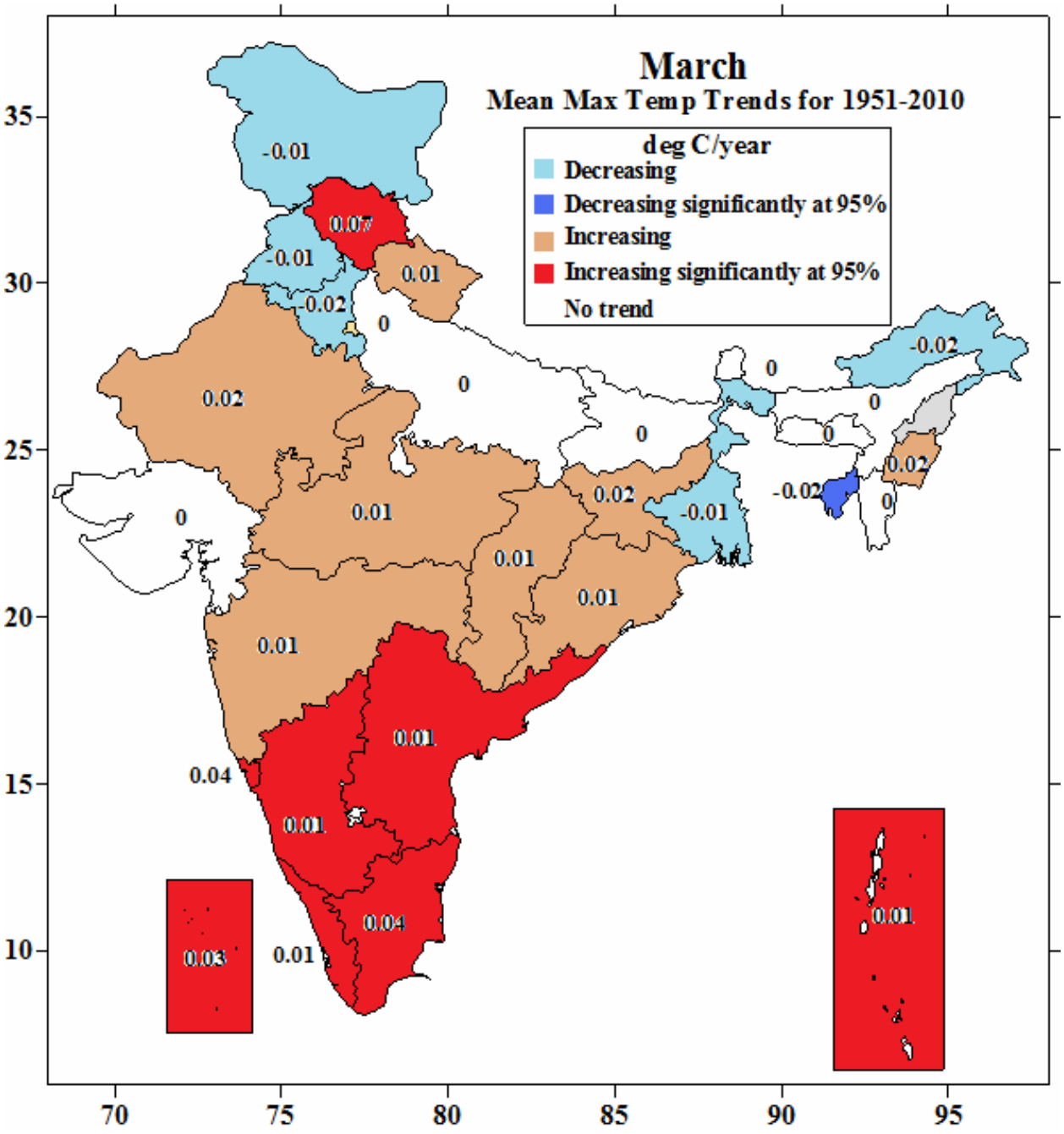


Figure 38: State level mean maximum temperature trends for March.

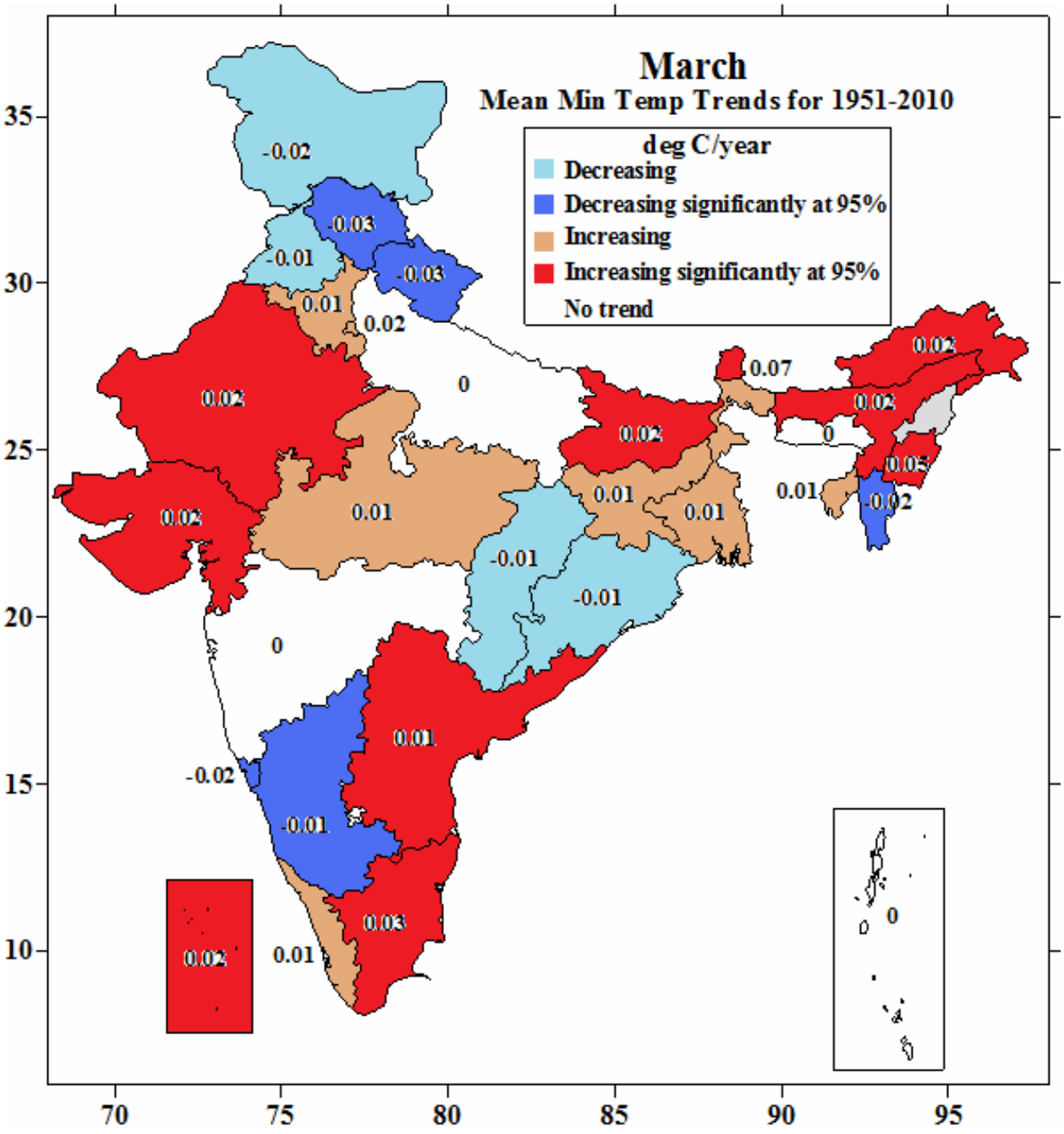


Figure 39: State level mean minimum temperature trends for March.

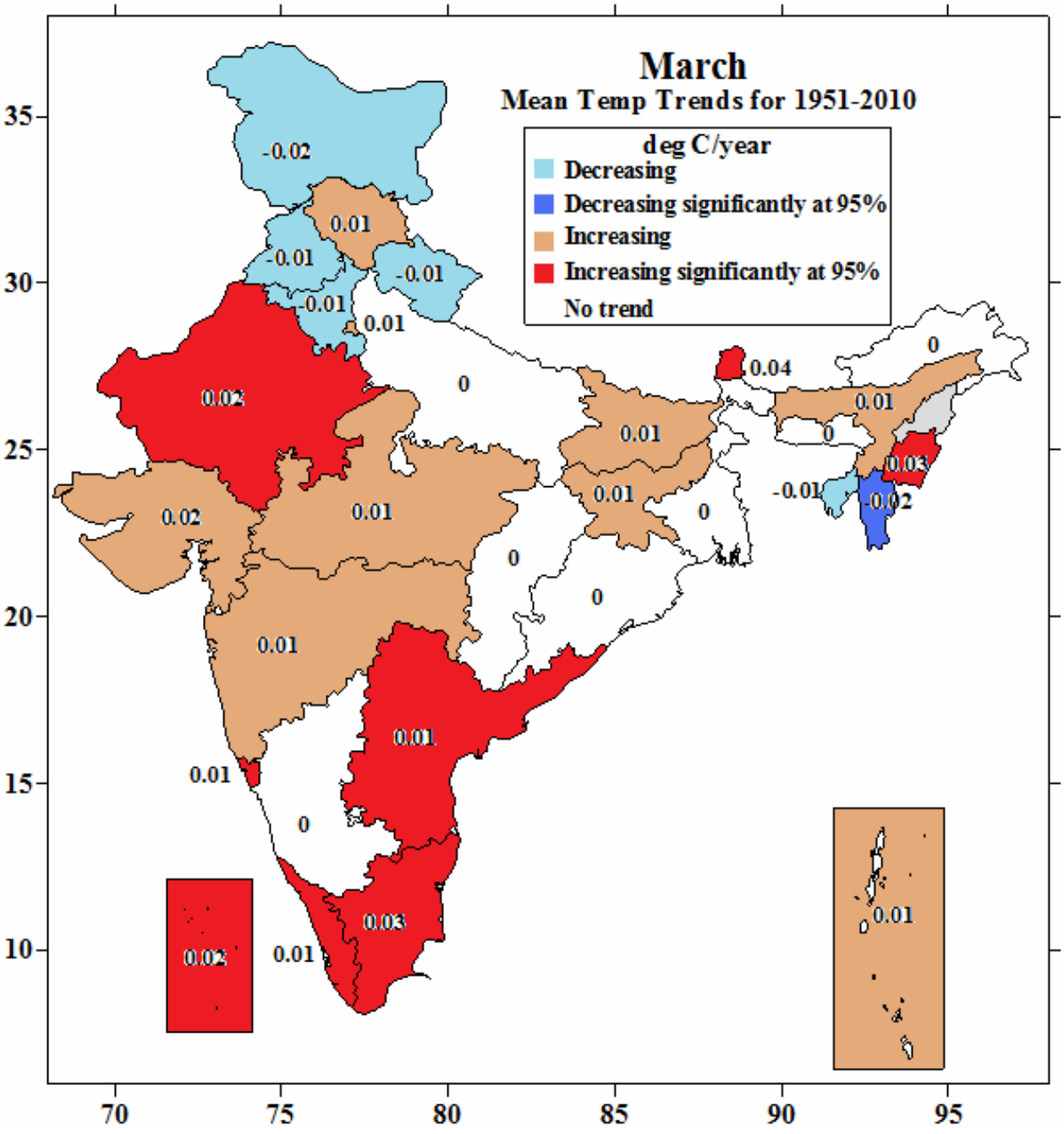


Figure 40: State level annual mean temperature trends for March.

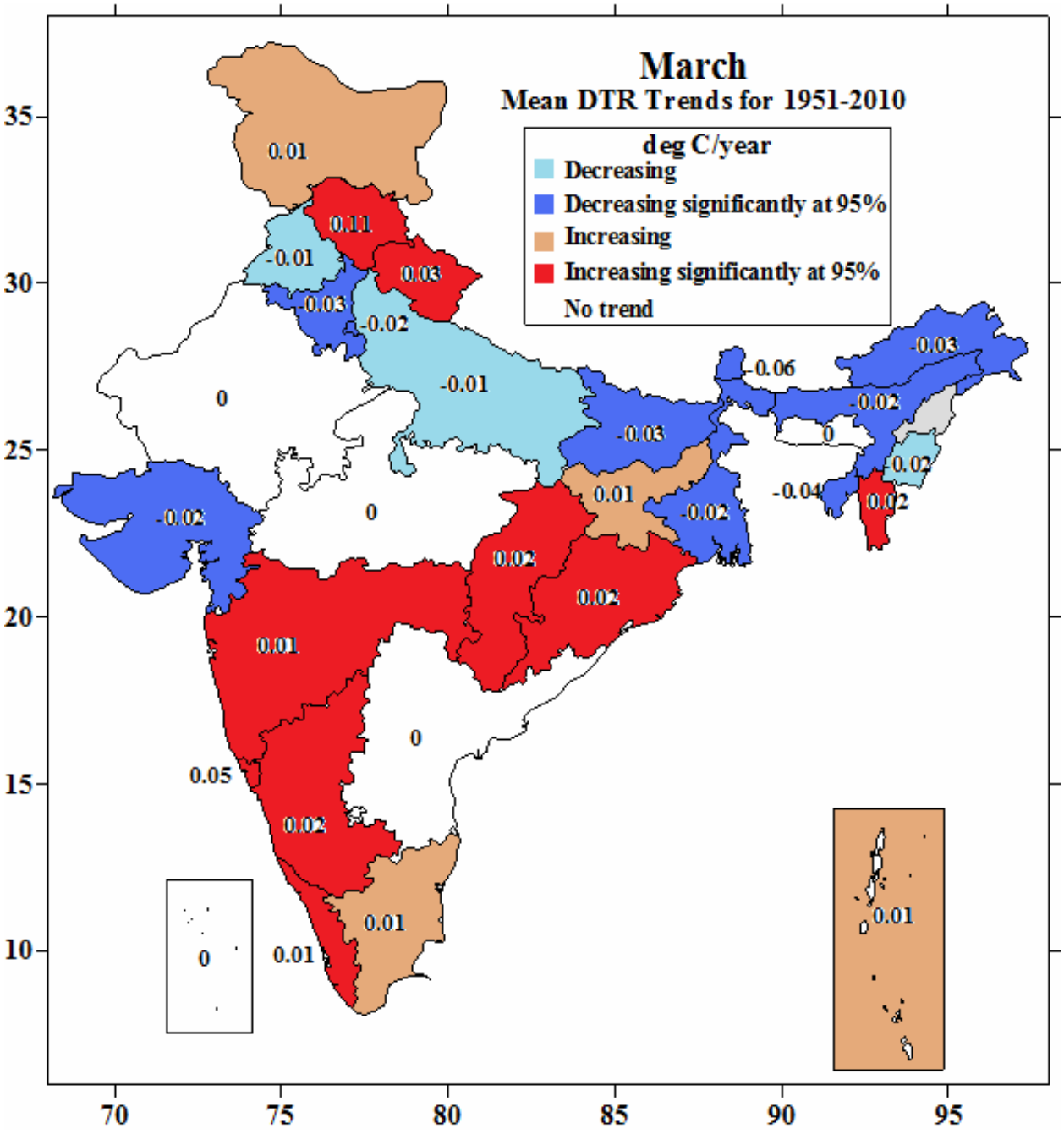


Figure 41: State level mean diurnal temperature range (DTR) trends for March.

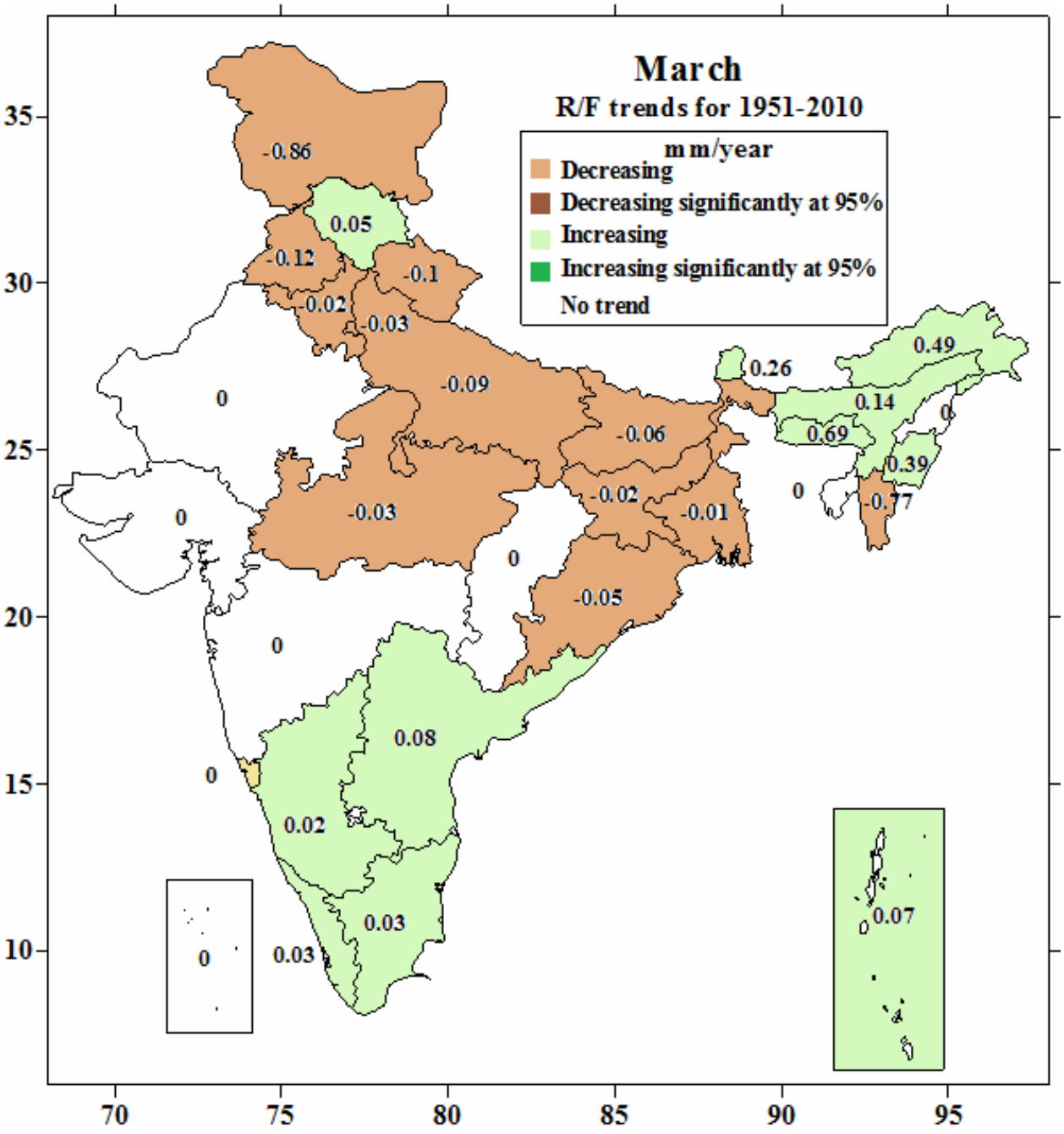


Figure 42: State level rainfall trends for March.

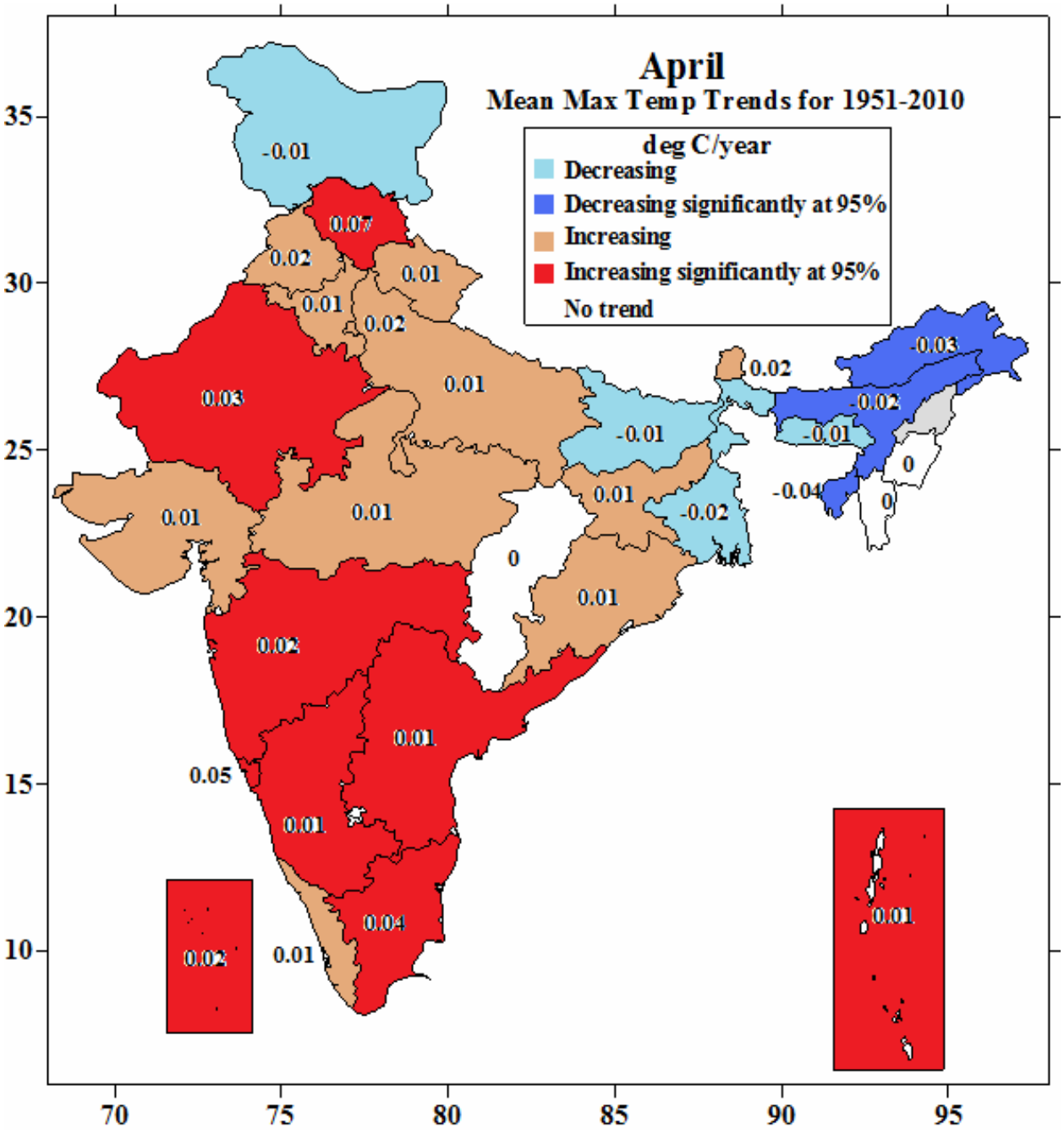


Figure 43: State level mean maximum temperature trends for April.

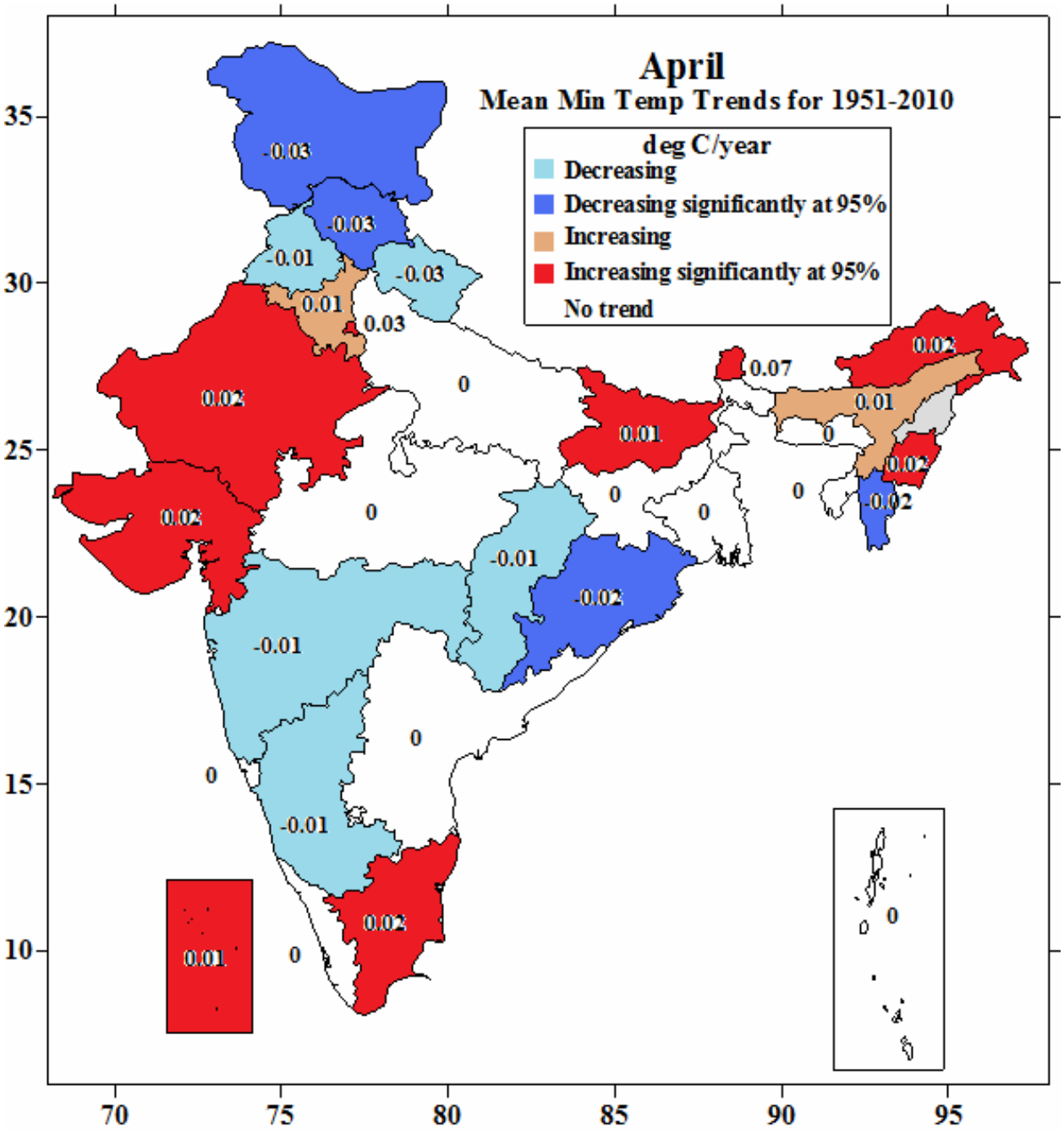


Figure 44: State level mean minimum temperature trends for April.

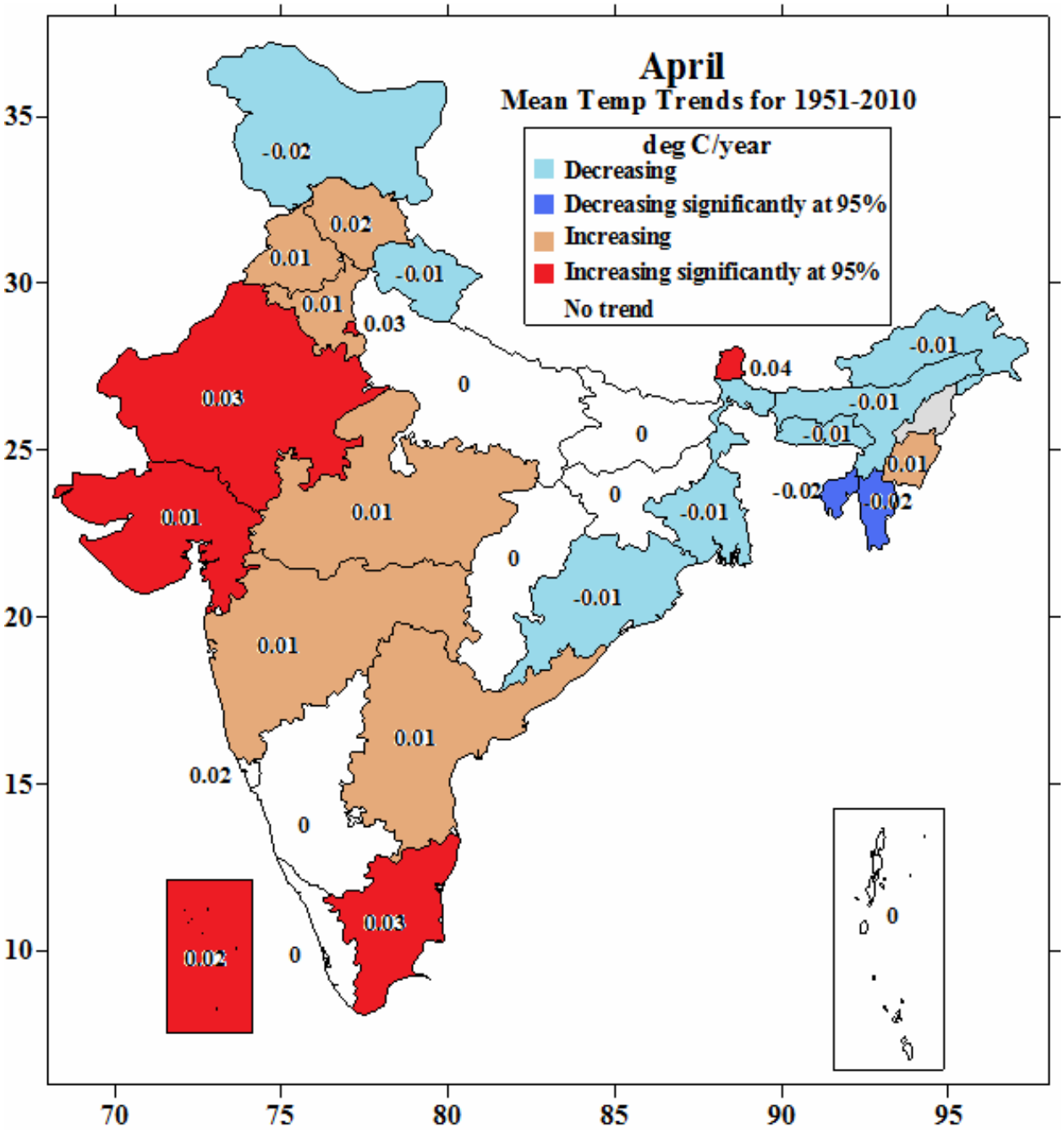


Figure 45: State level mean temperature trends for April.

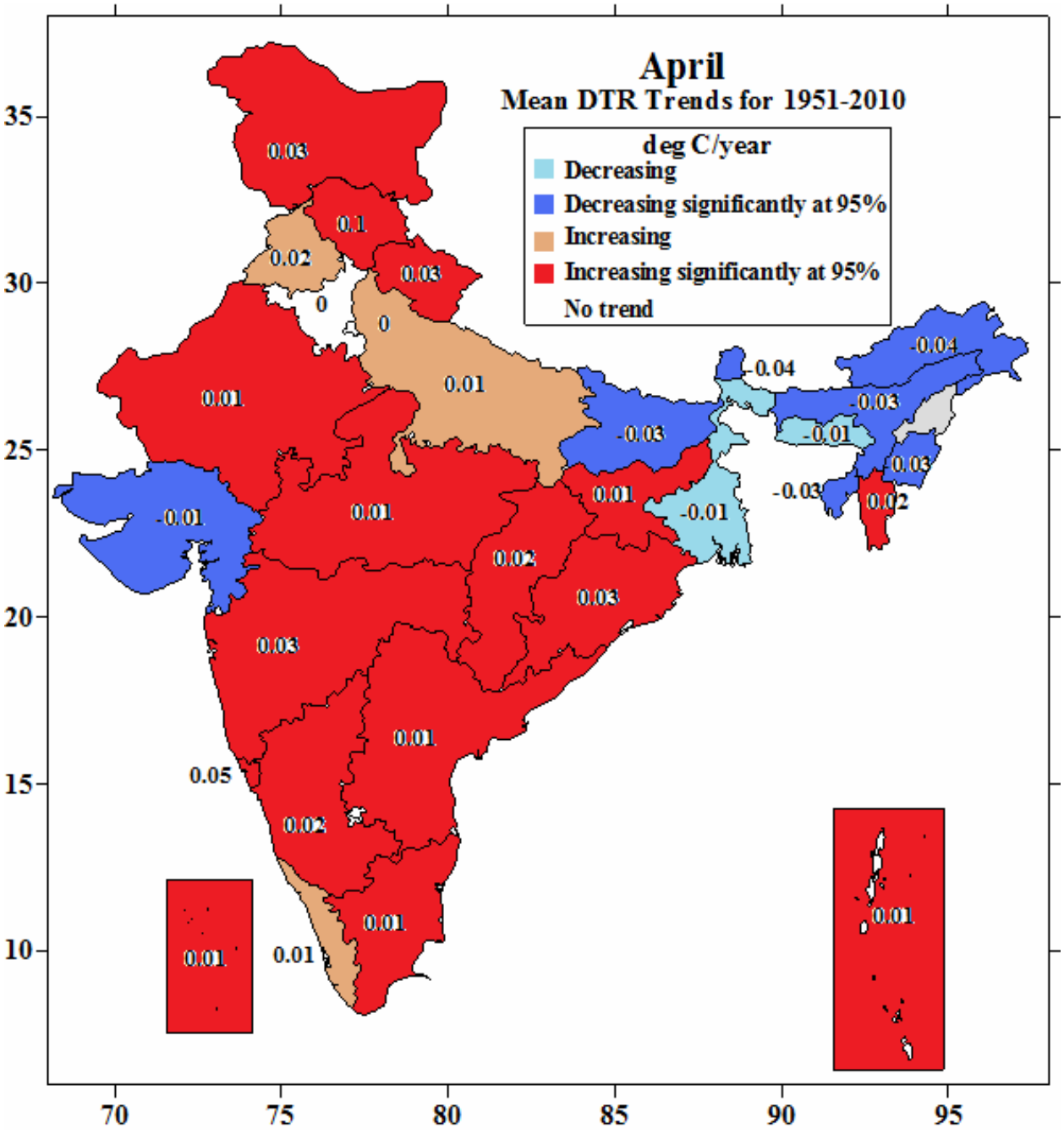


Figure 46: State level mean diurnal temperature range (DTR) trends for April.

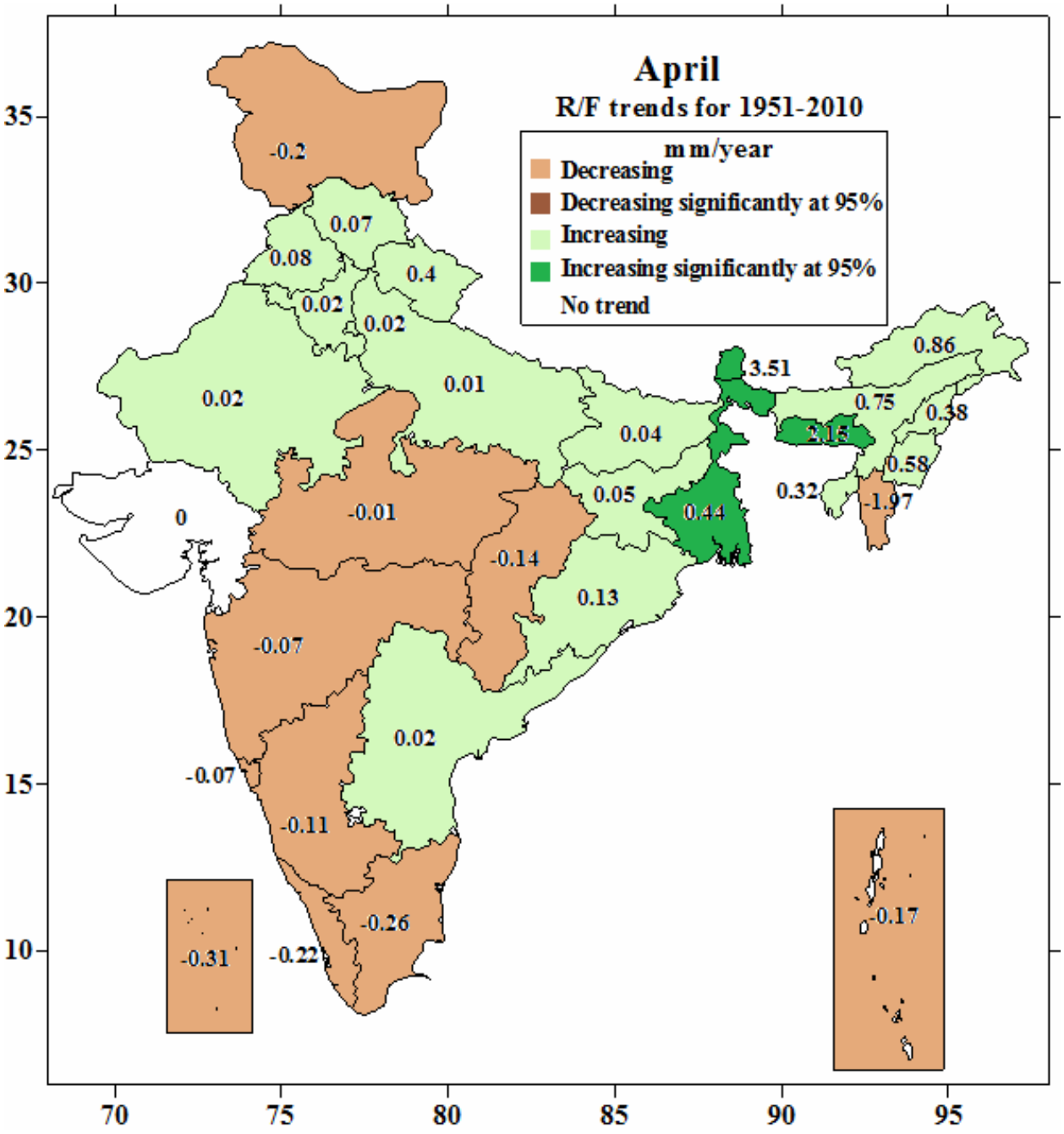


Figure 47: State level rainfall trends for April.

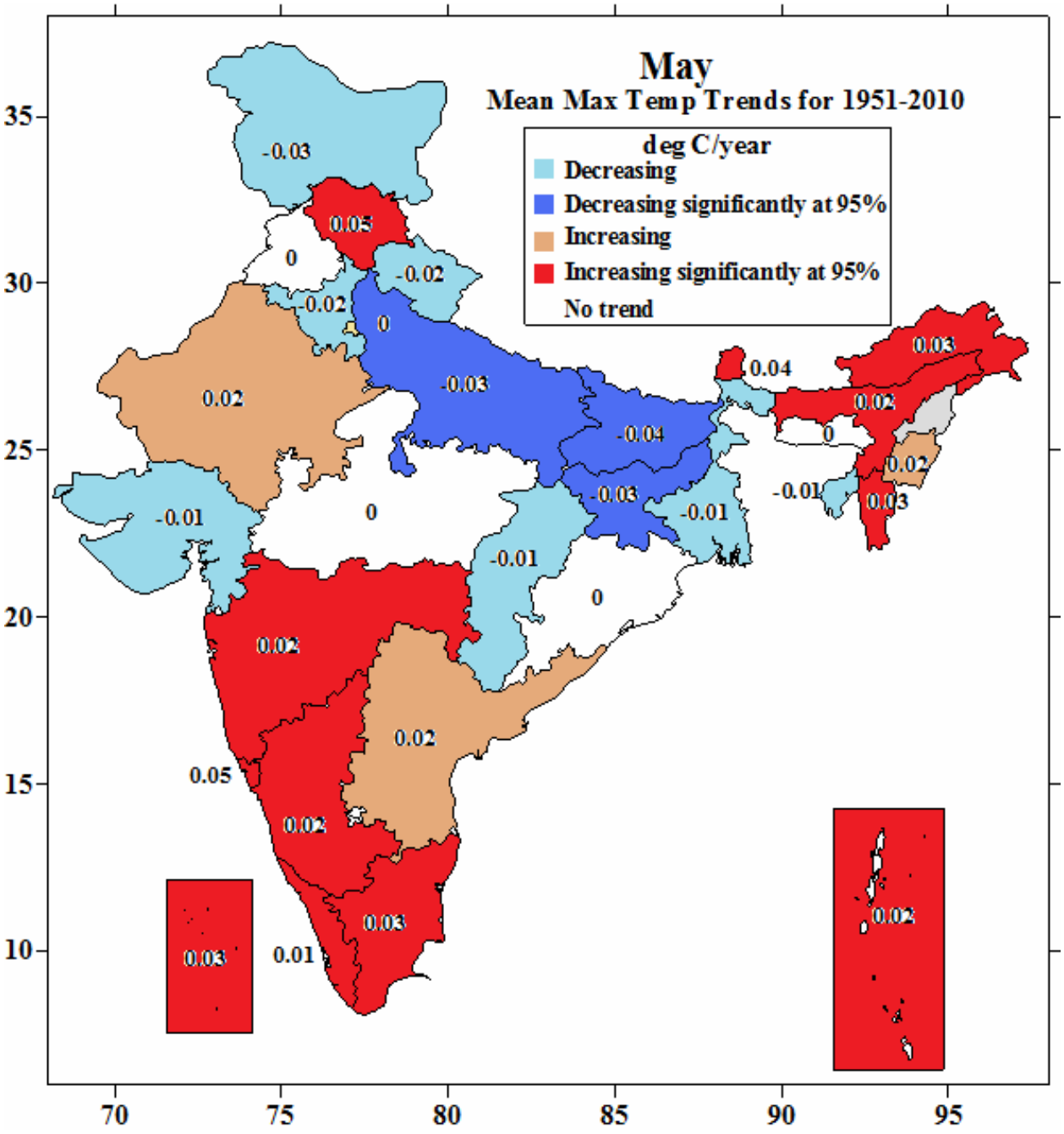


Figure 48: State level mean maximum temperature trends for May.

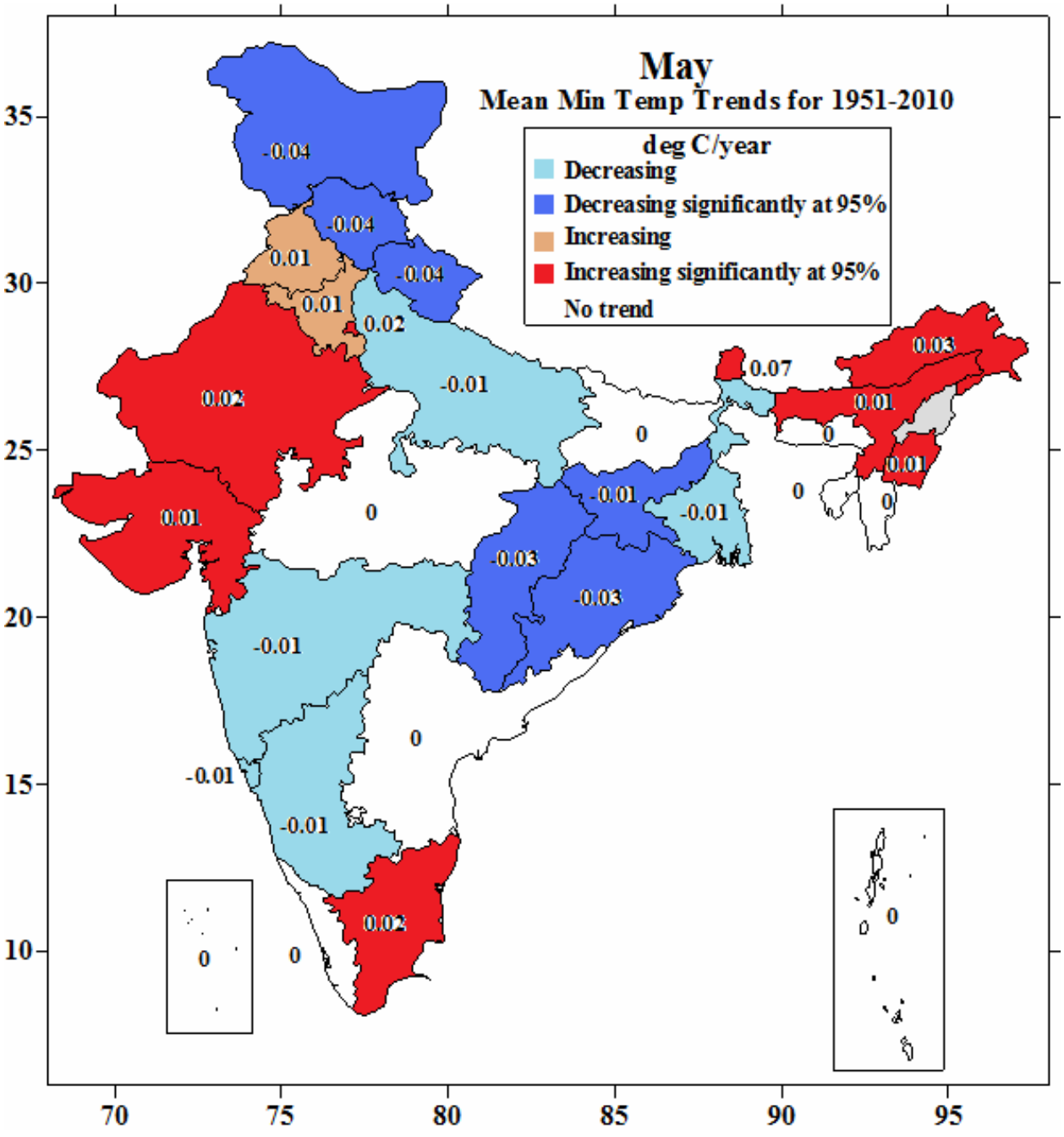


Figure 49: State level mean minimum temperature trends for May.

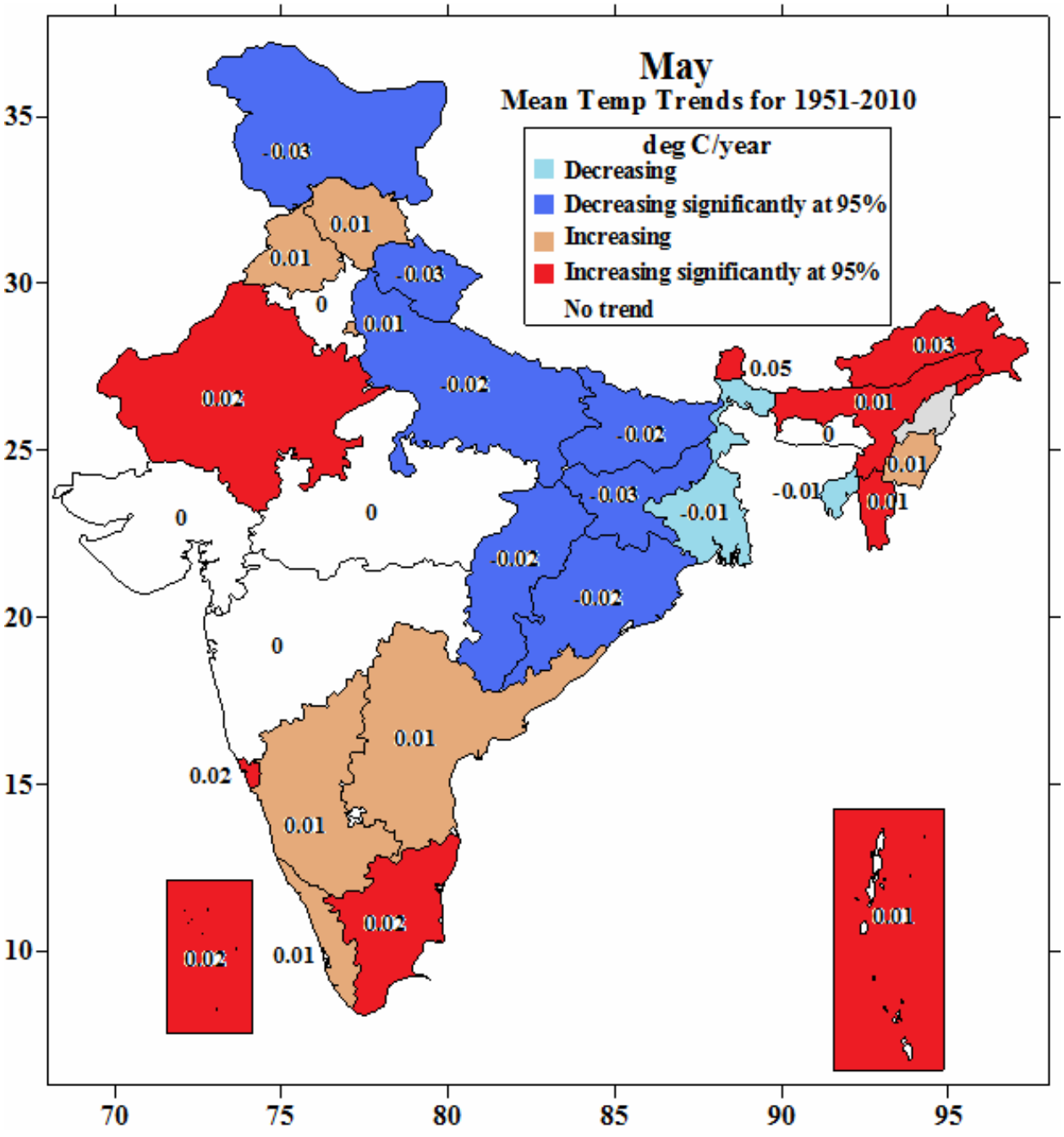


Figure 50: State level mean temperature trends for May.

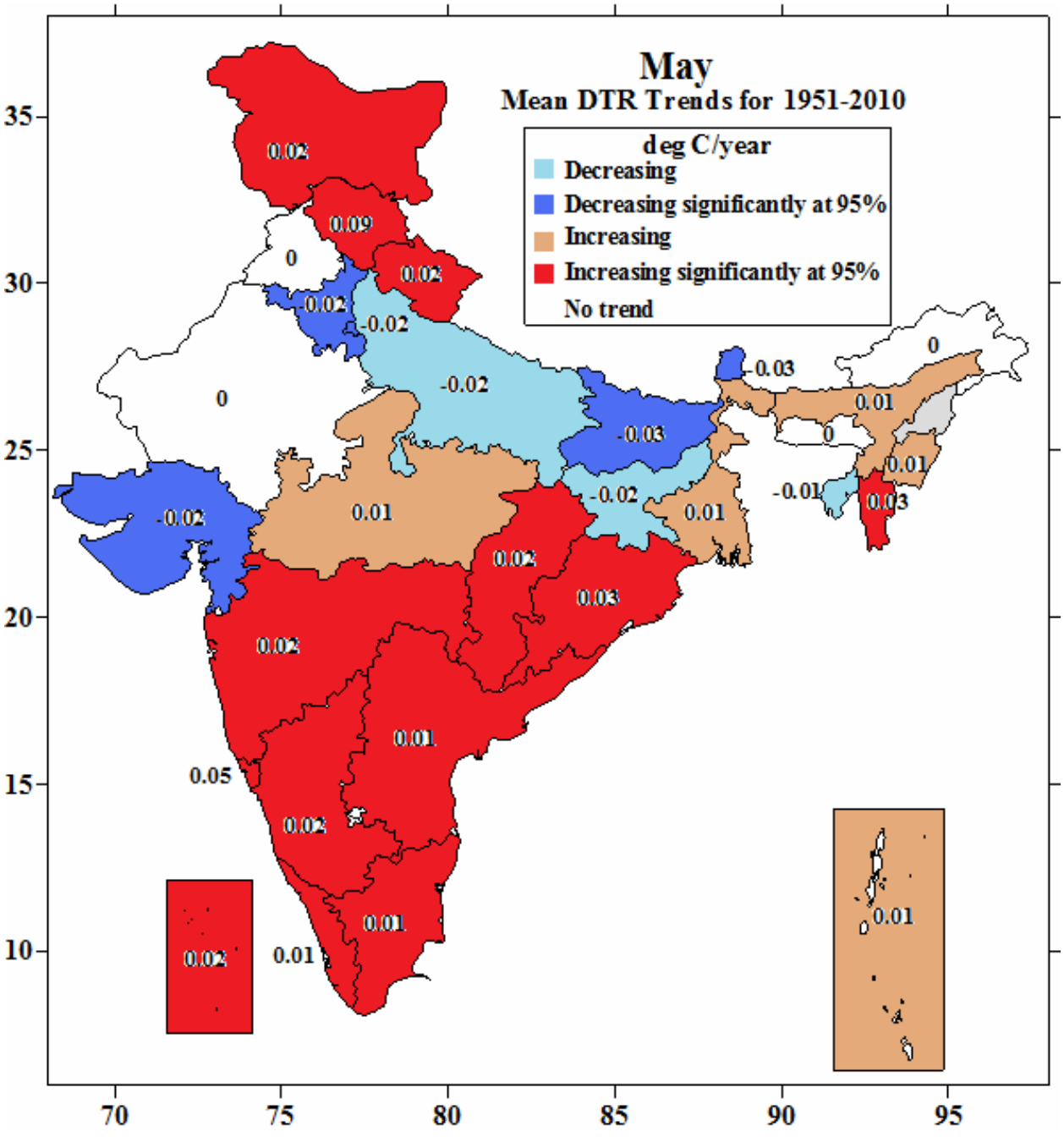


Figure 51: State level mean diurnal temperature range (DTR) trends for May.

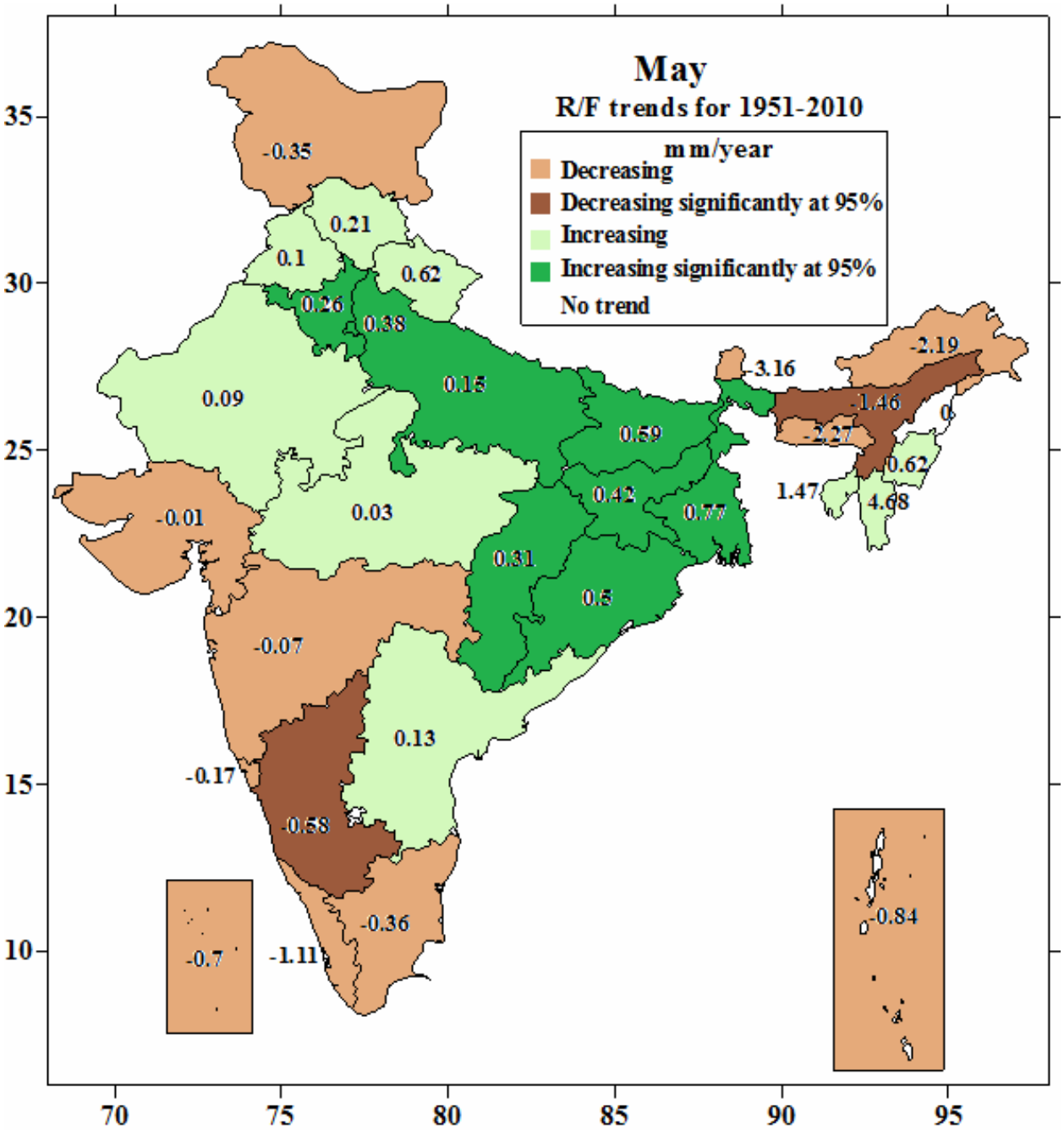


Figure 52: State level rainfall trends for May.

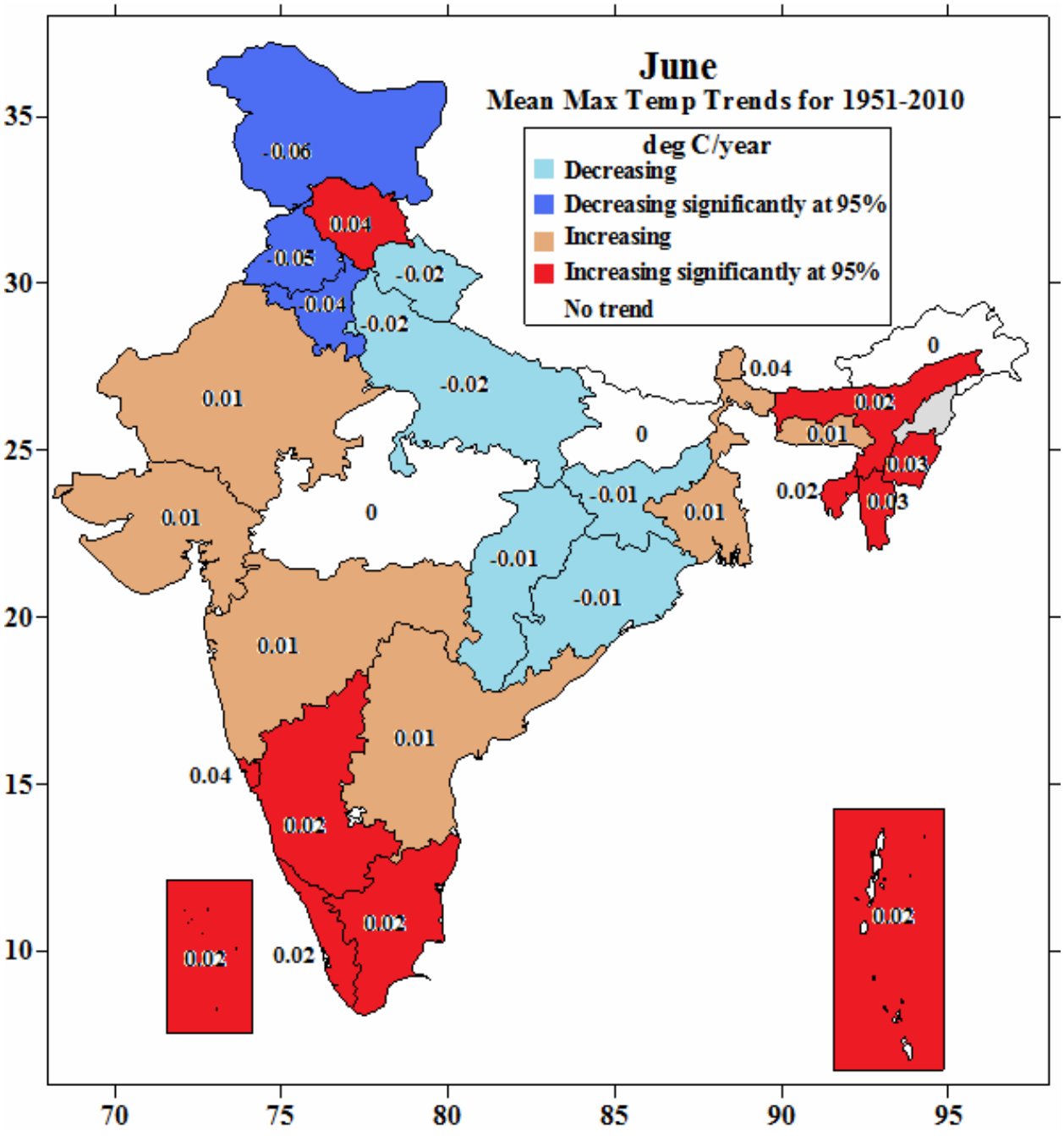


Figure 53: State level mean maximum temperature trends for June.

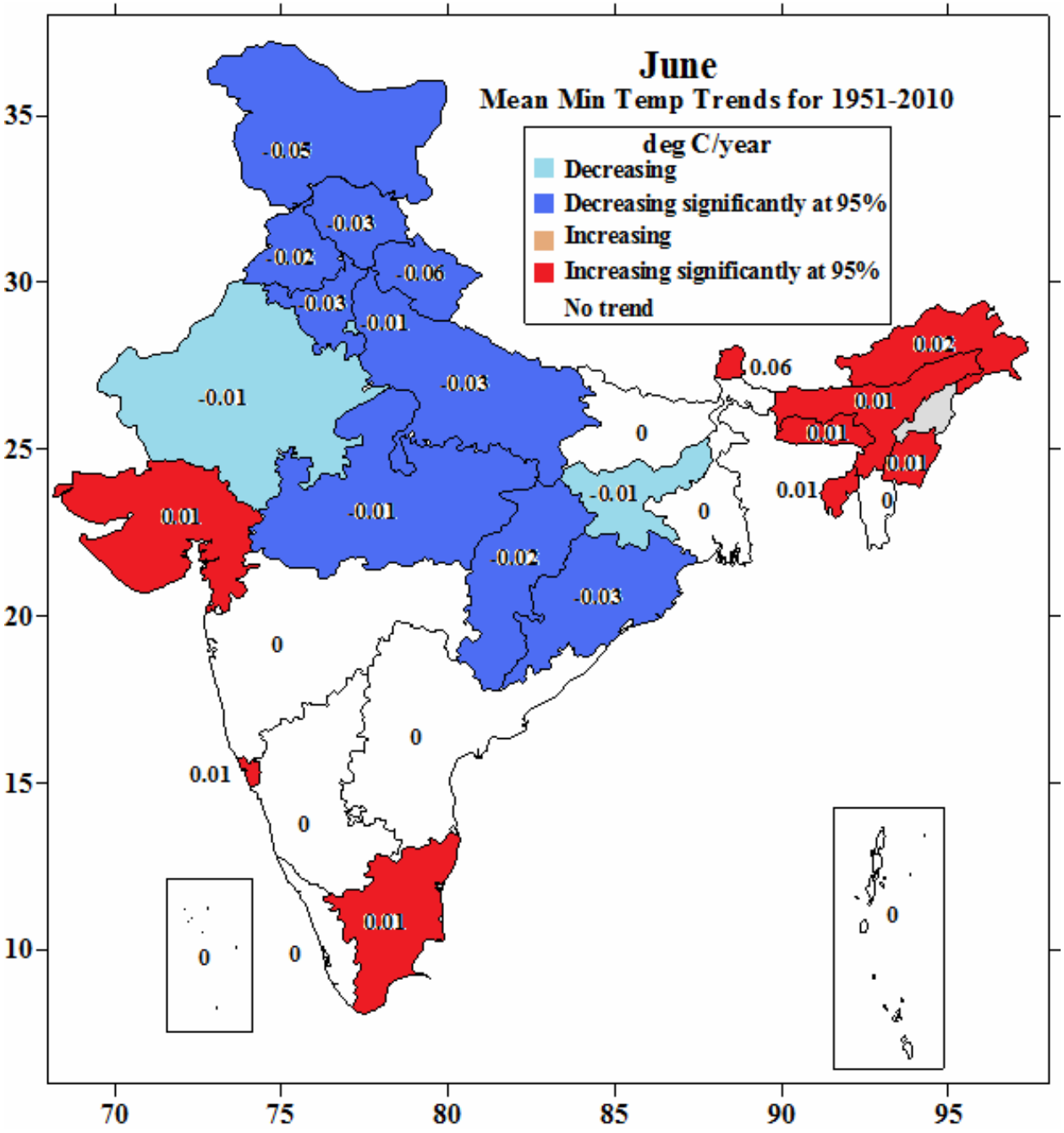


Figure 54: State level mean minimum temperature trends for June.

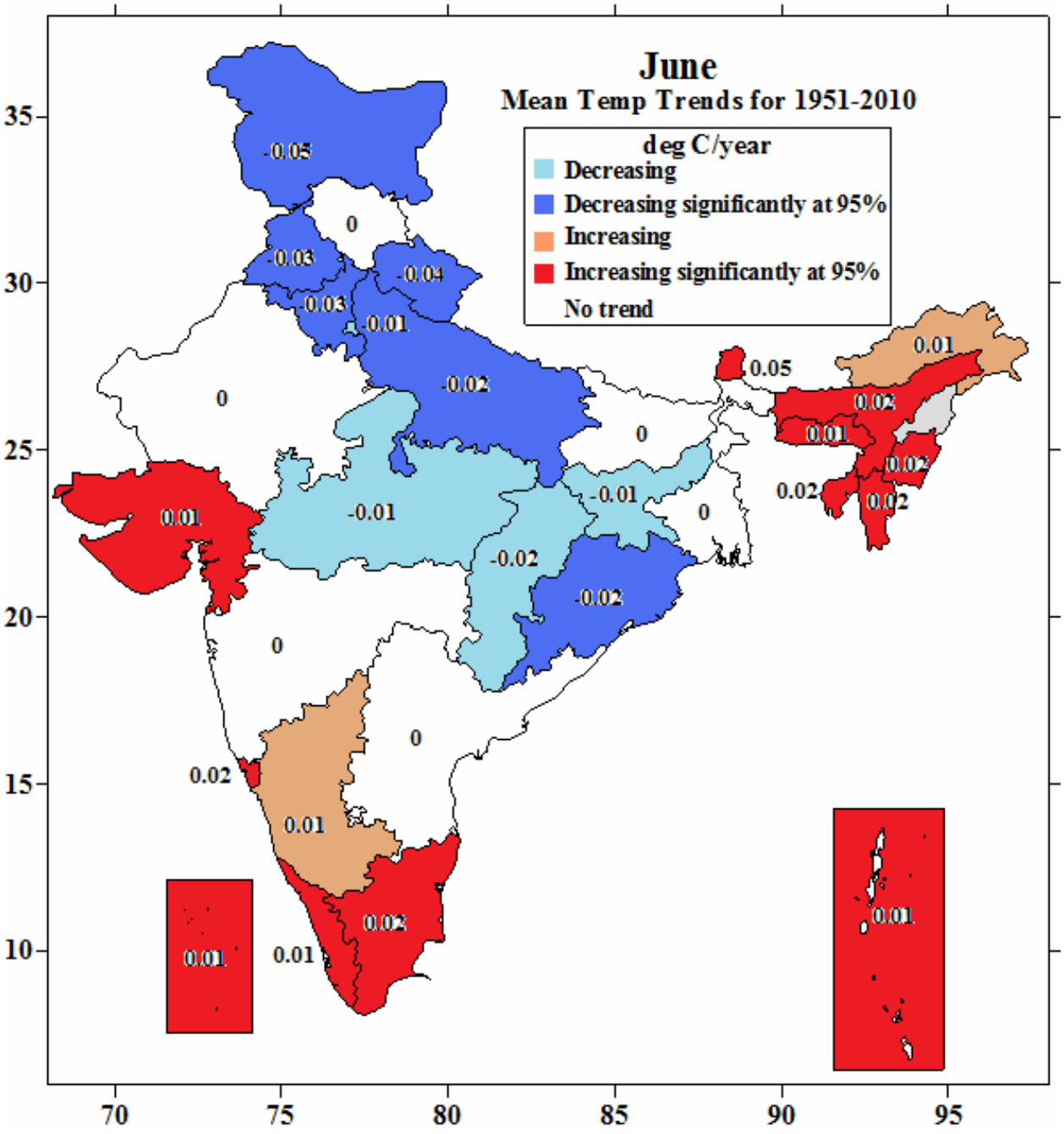


Figure 55: State level mean temperature trends for June.

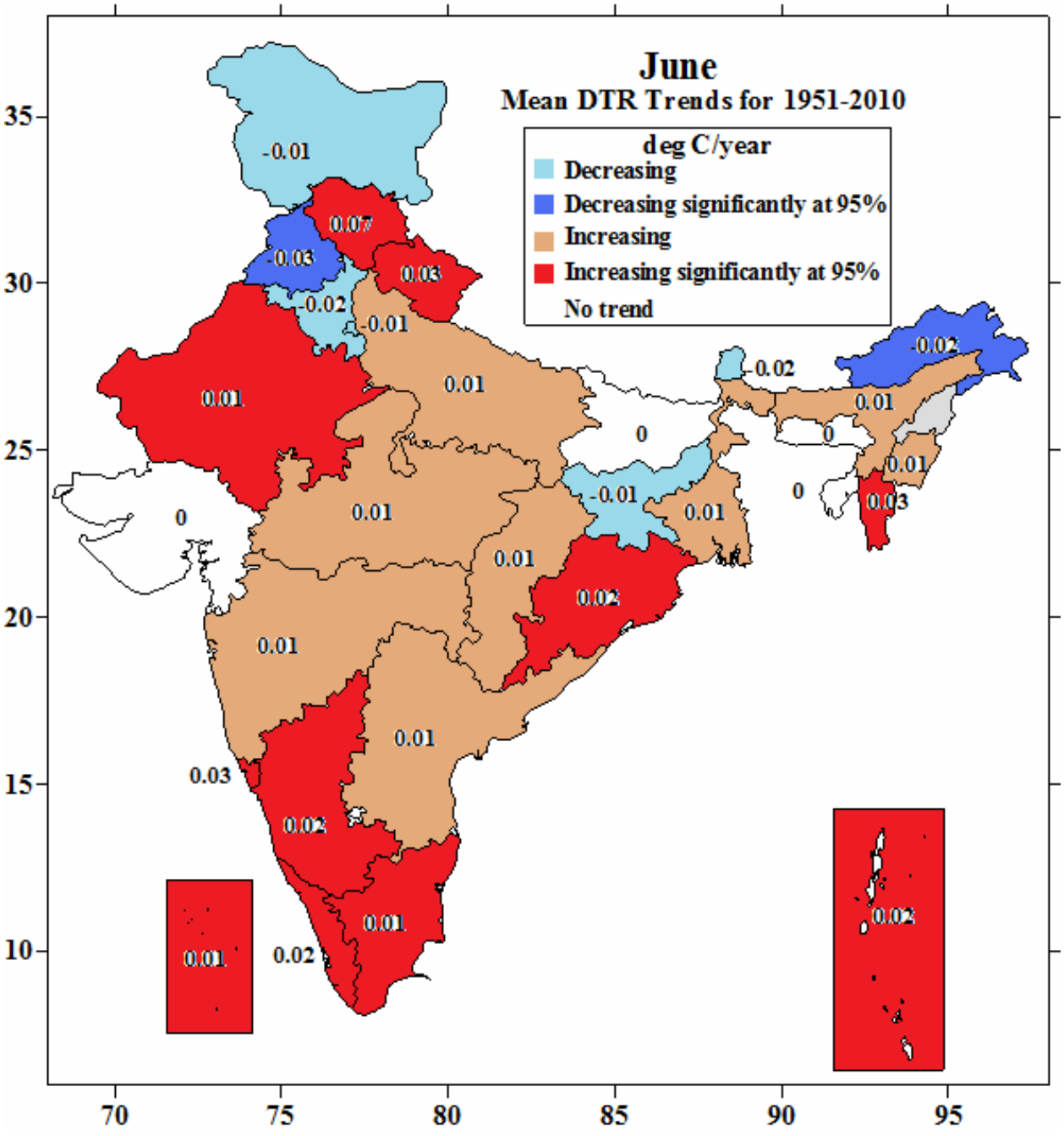


Figure 56: State level mean diurnal temperature range (DTR) trends for June.

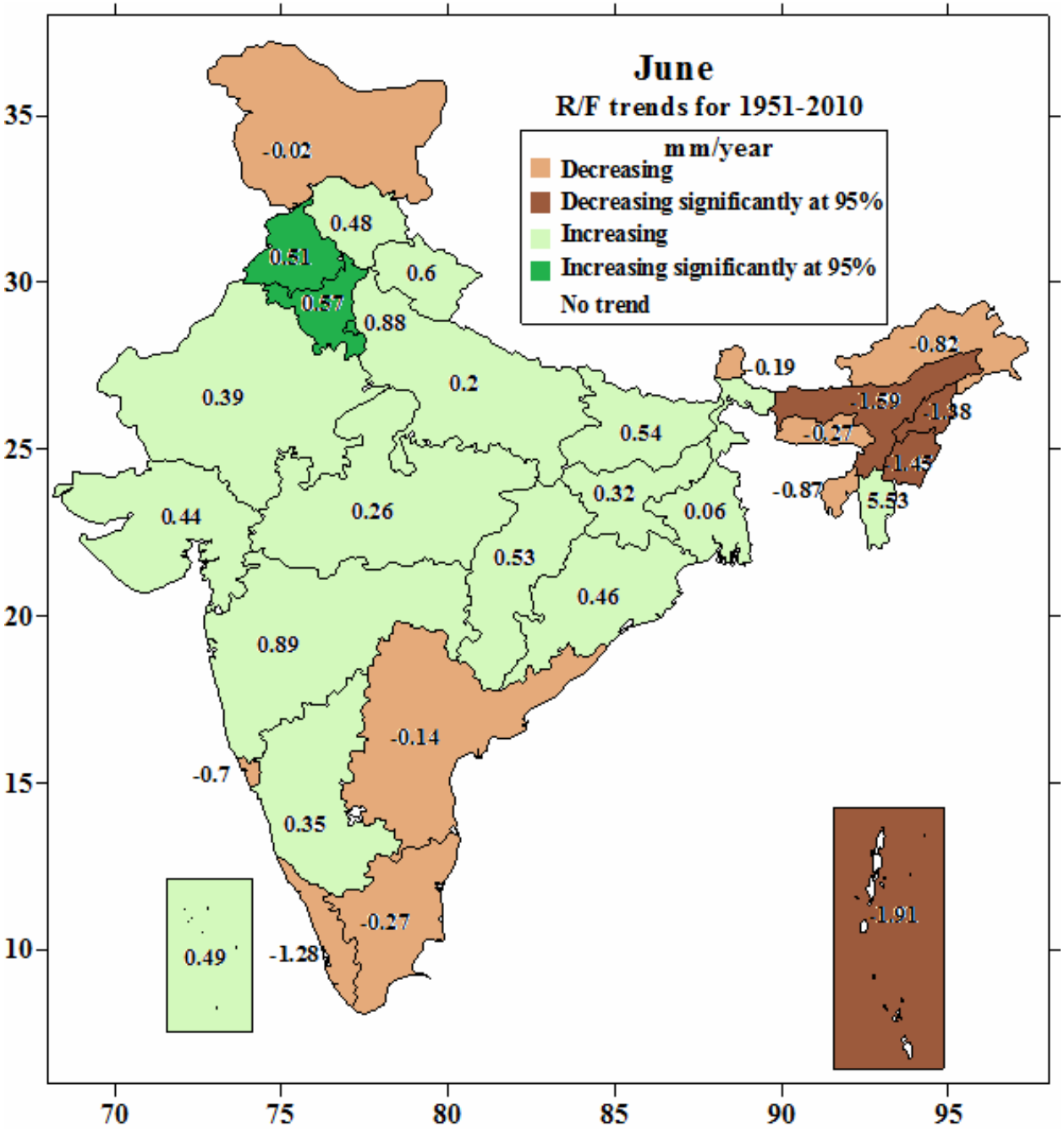


Figure 57: State level rainfall trends for June.

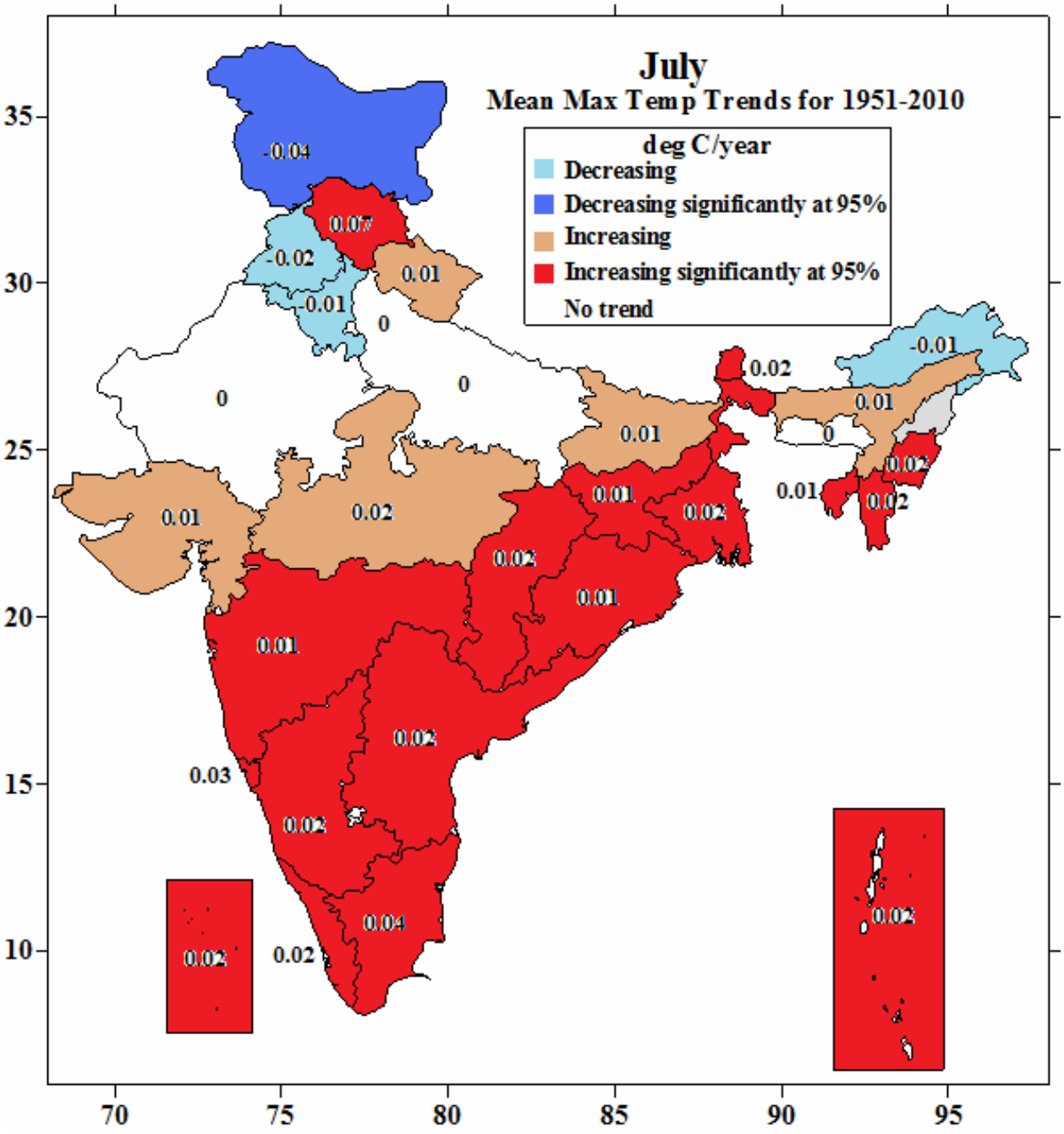


Figure 58: State level mean maximum temperature trends for July.

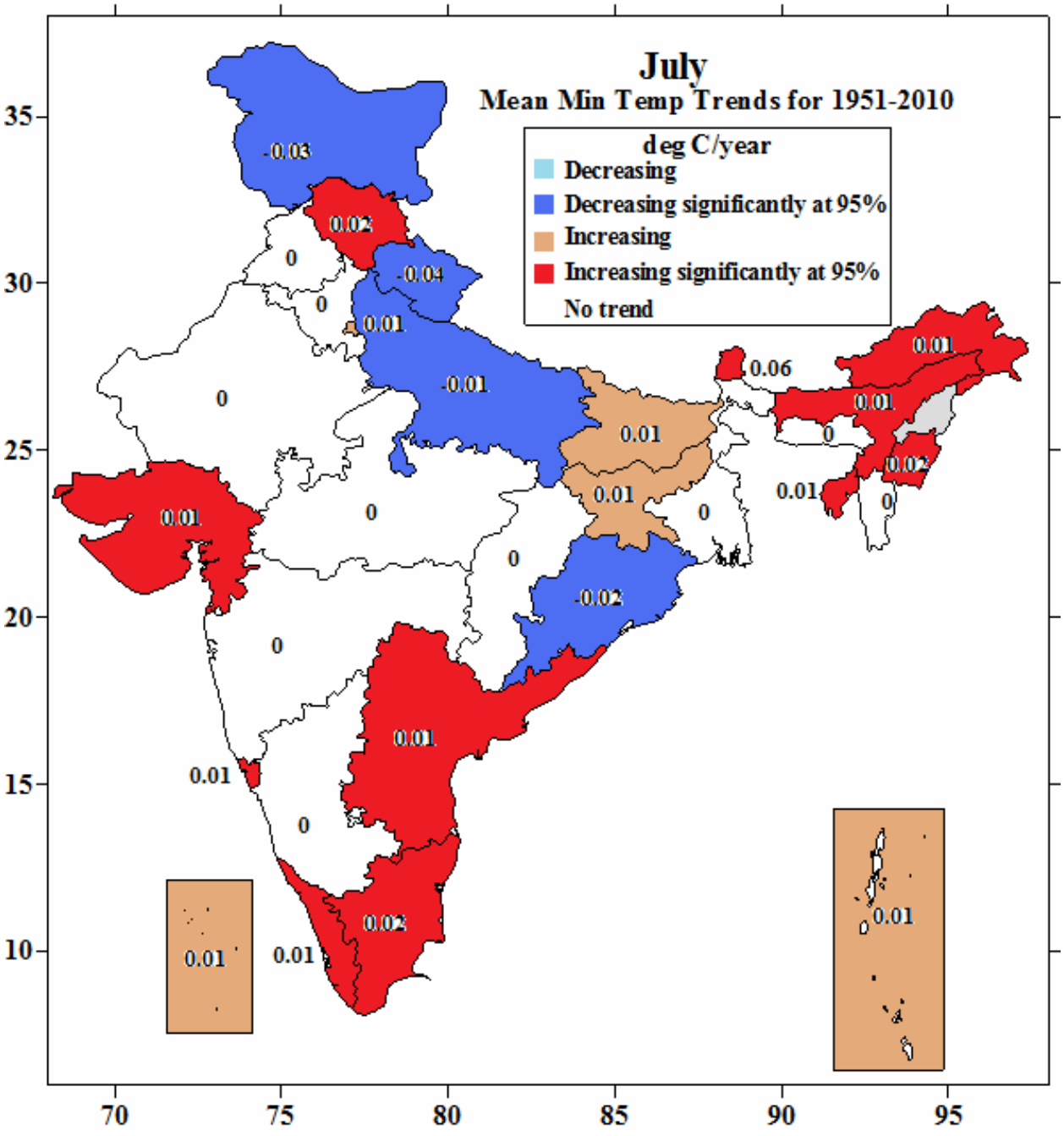


Figure 59: State level mean minimum temperature trends for July.

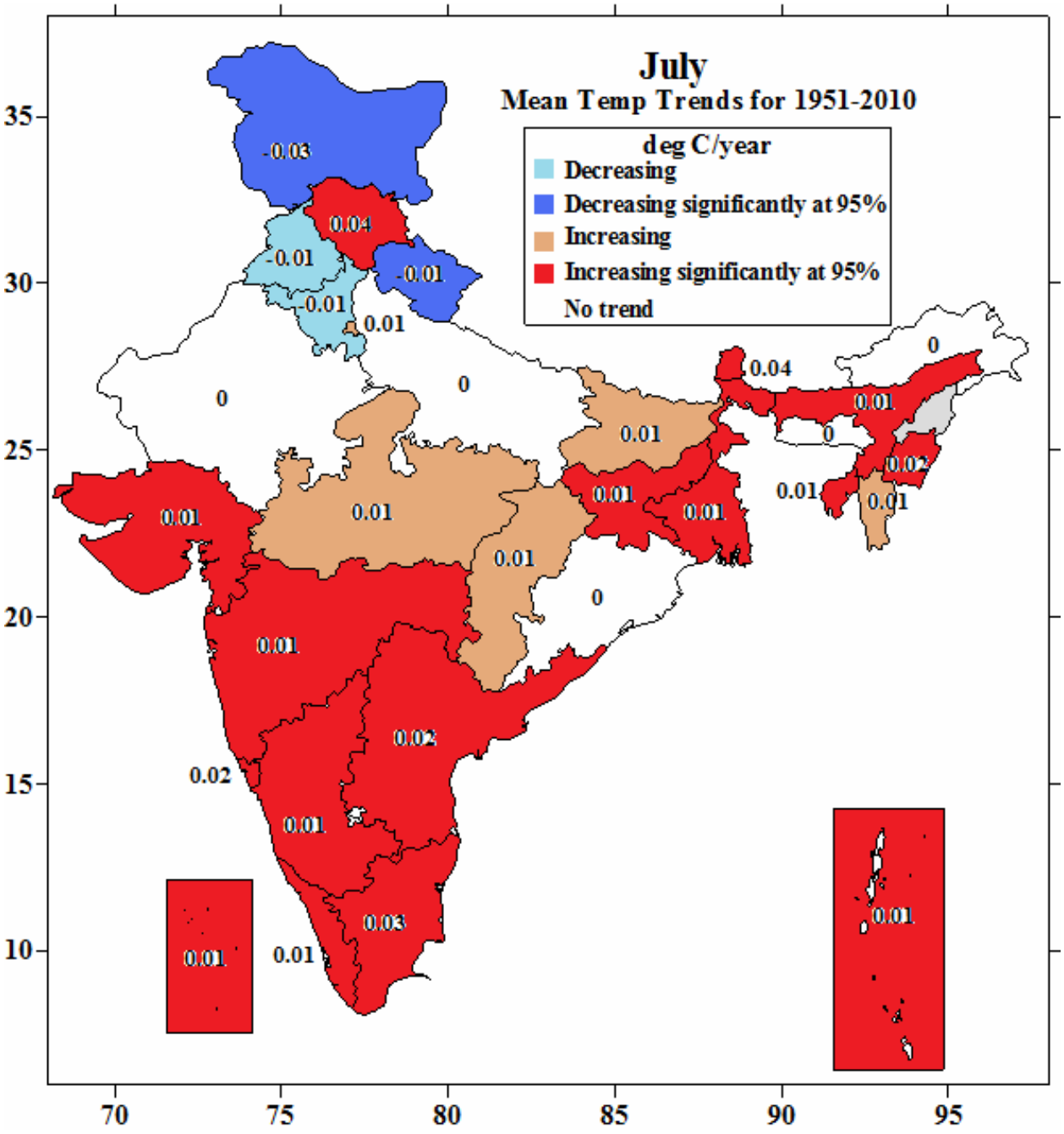


Figure 60: State level mean temperature trends for July.

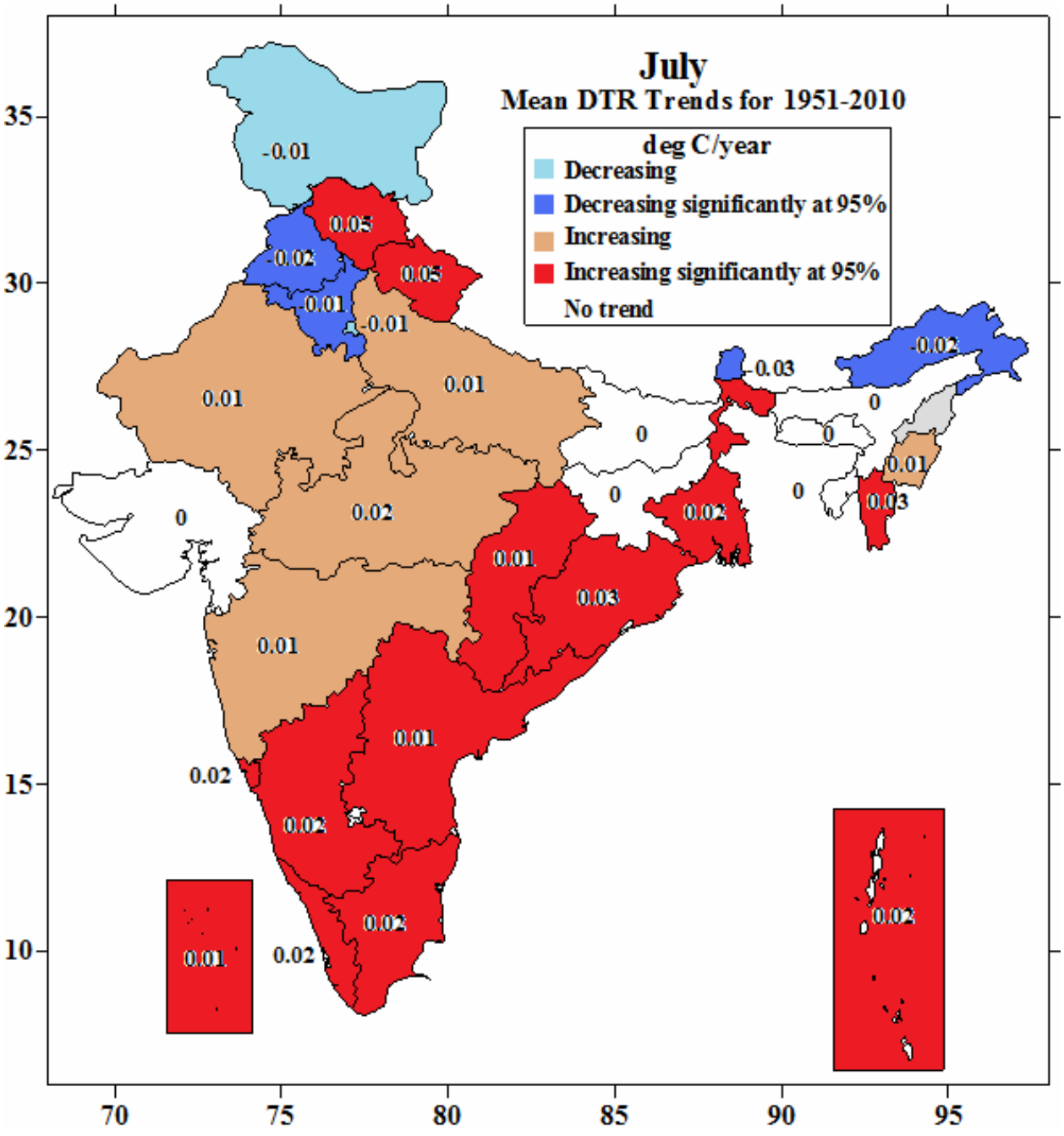


Figure 61: State level mean diurnal temperature range (DTR) trends for July.

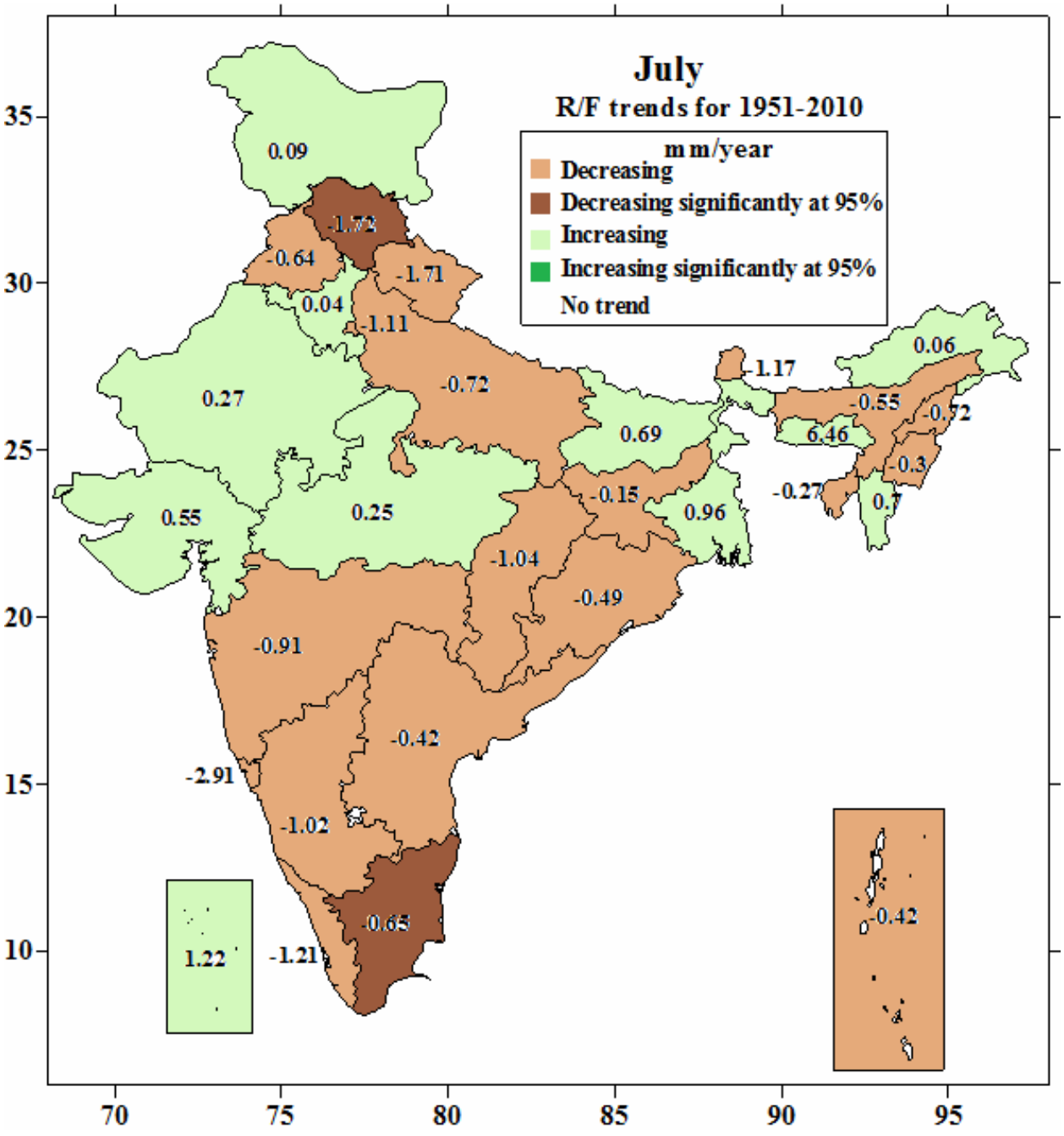


Figure 62: State level rainfall trends for July.

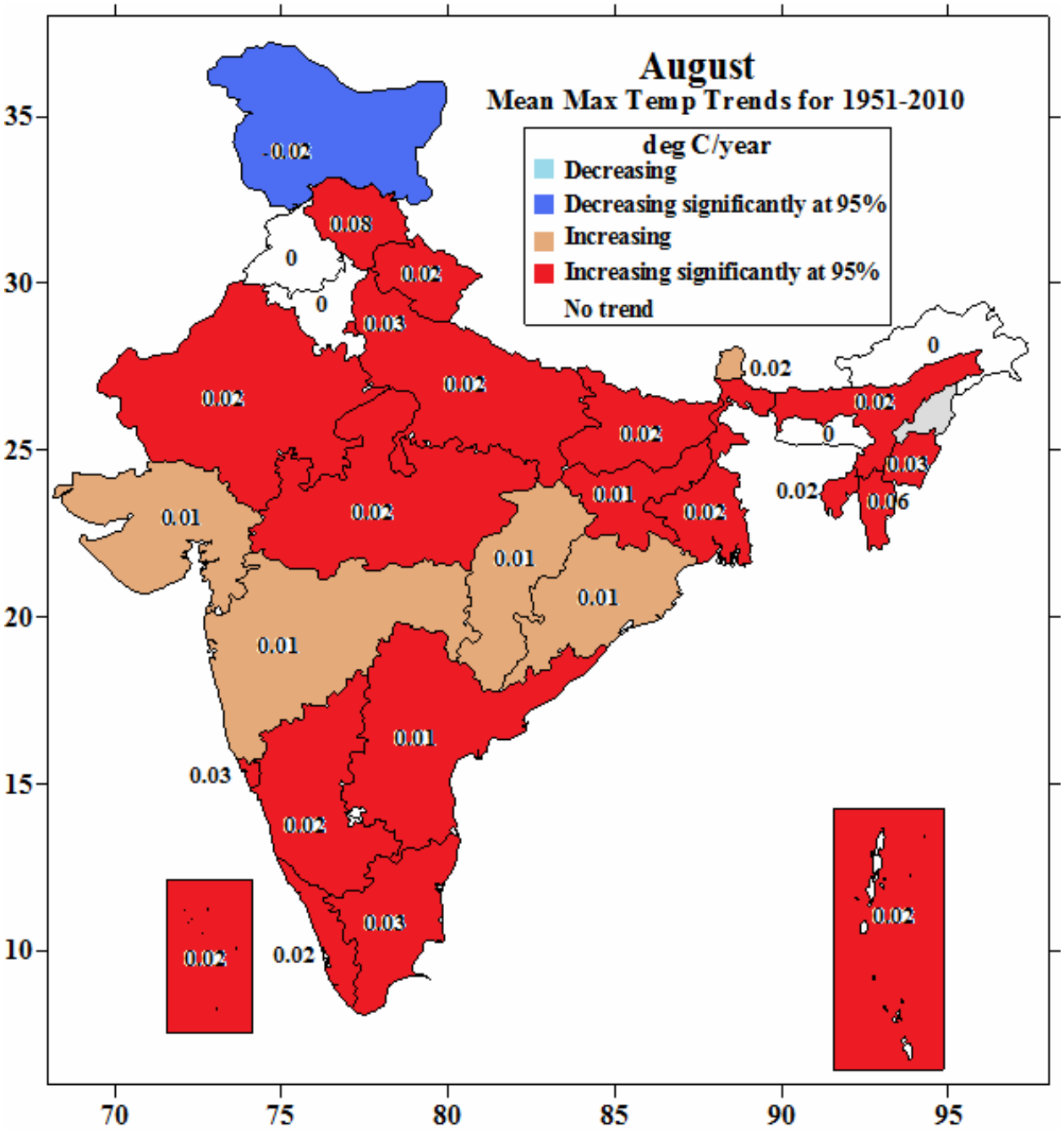


Figure 63: State level mean maximum temperature trends for August.

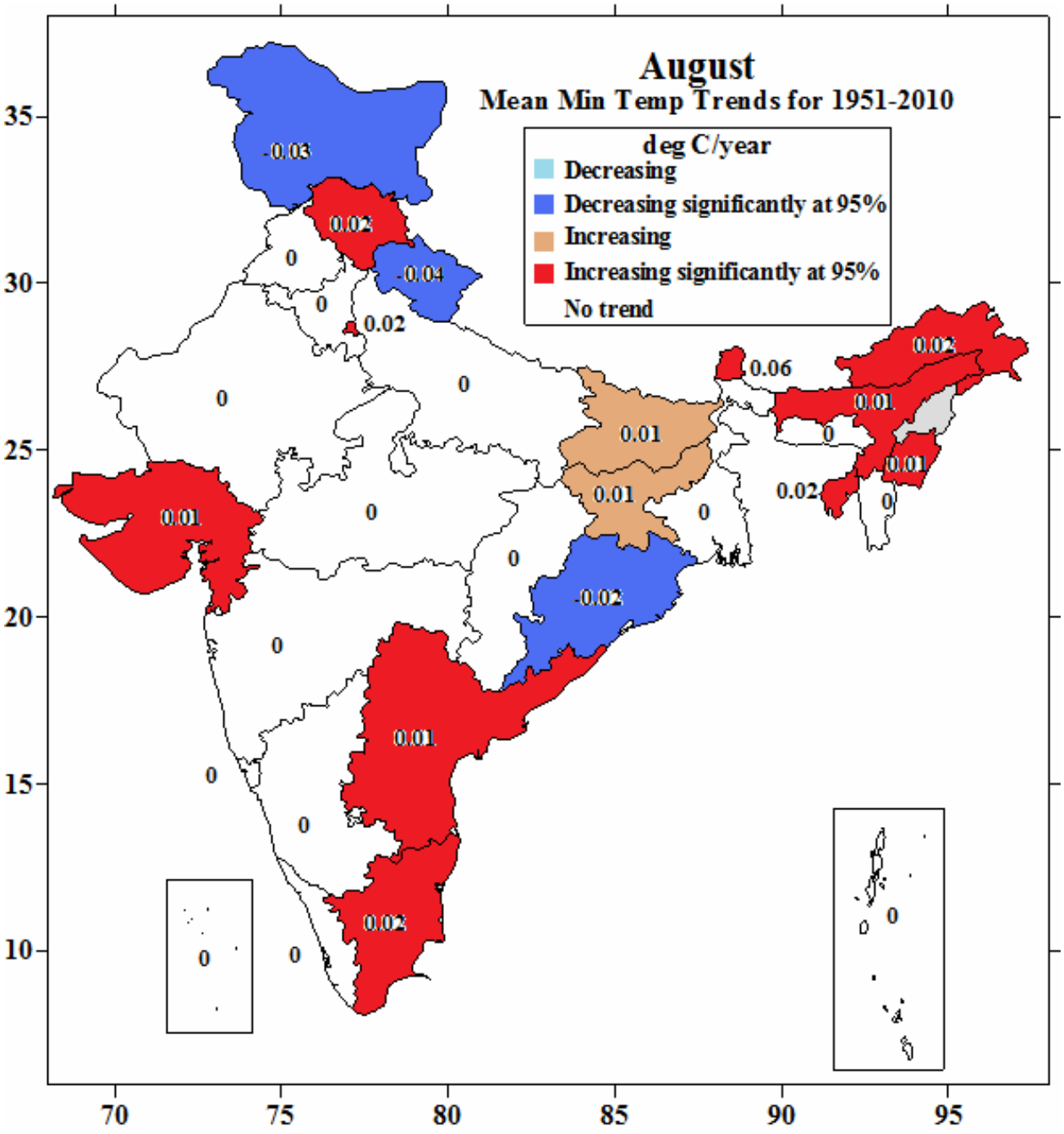


Figure 64: State level mean minimum temperature trends for August.

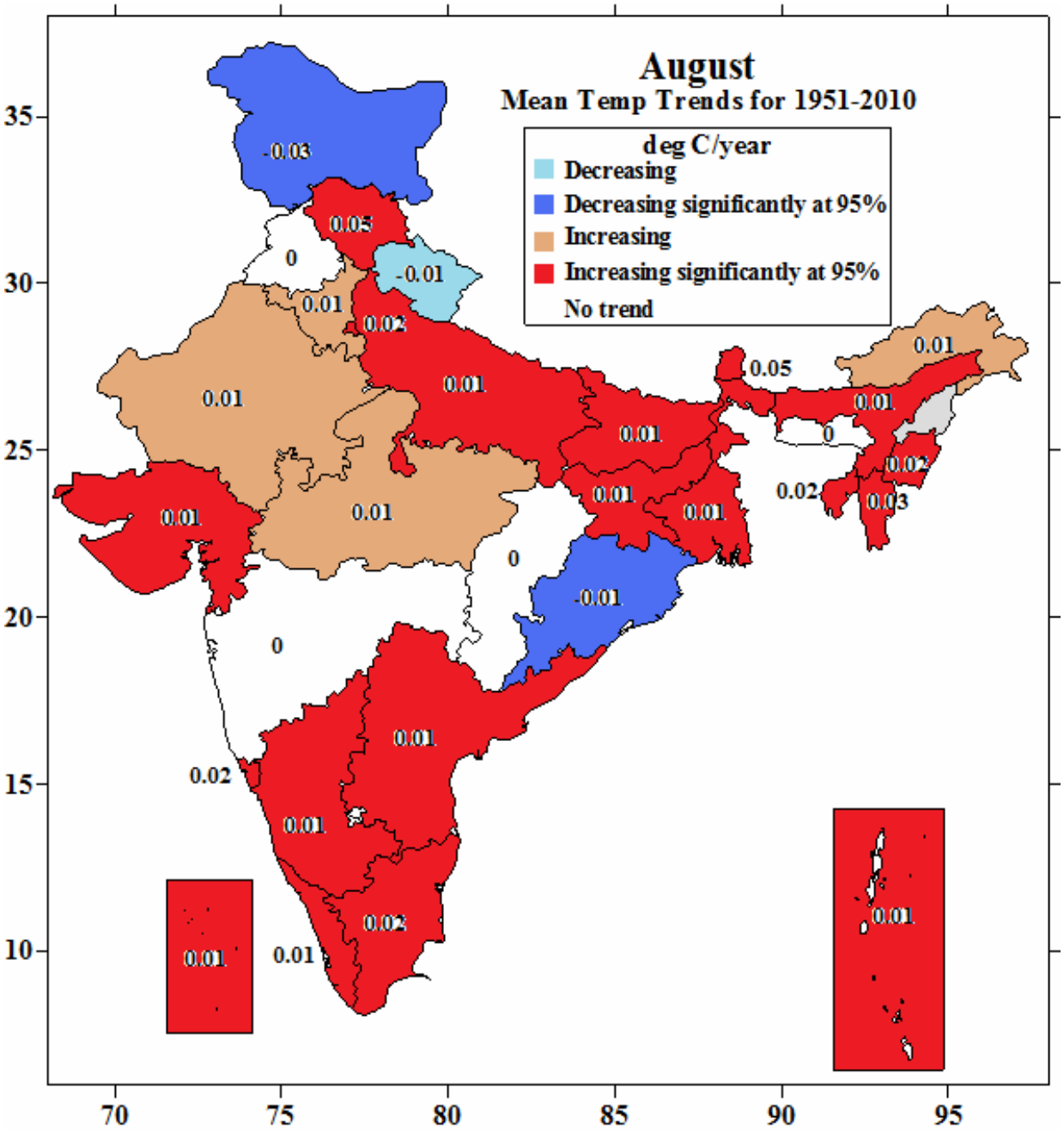


Figure 65: State level mean temperature trends for August.

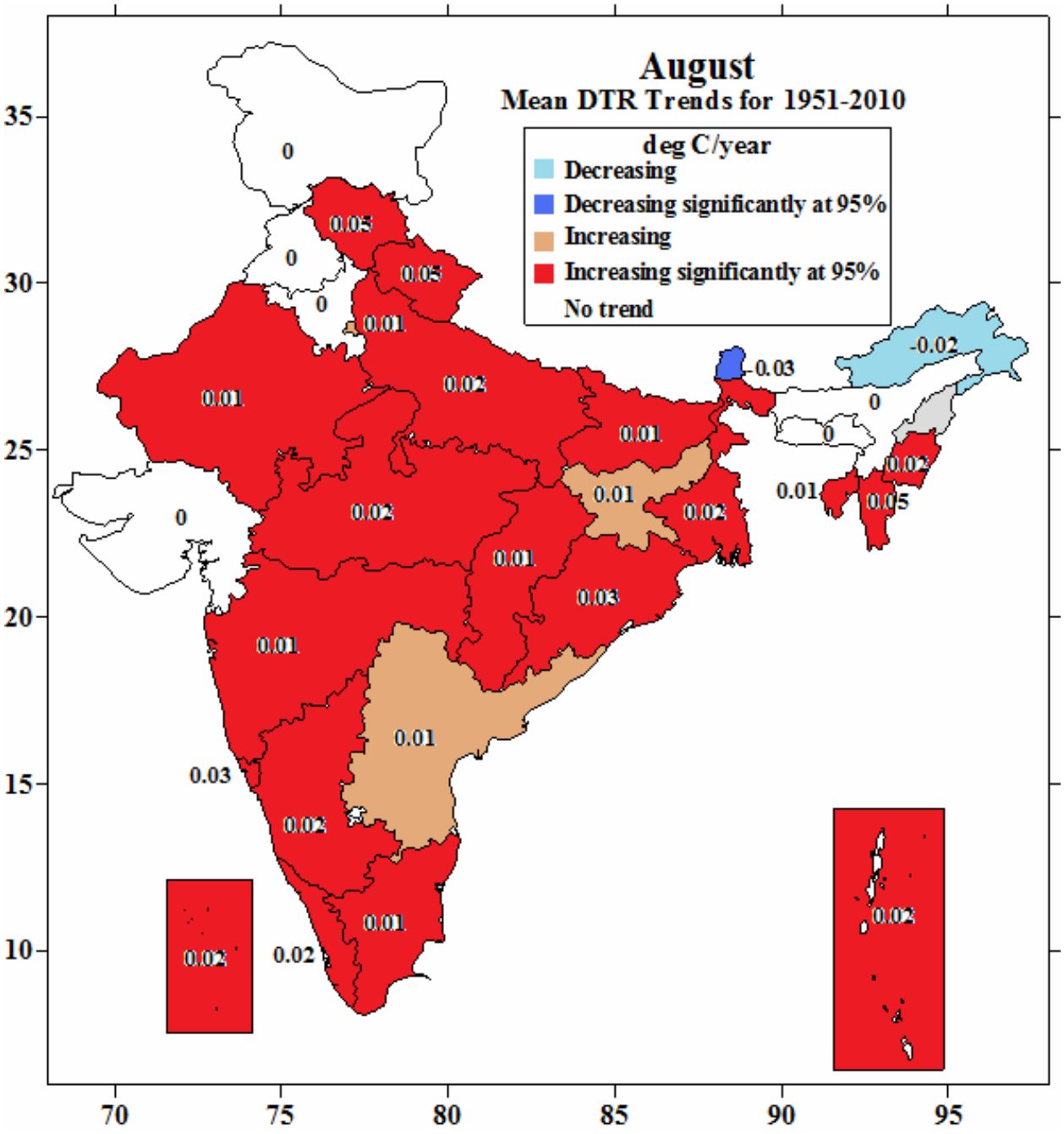


Figure 66: State level mean diurnal temperature range (DTR) trends for August.

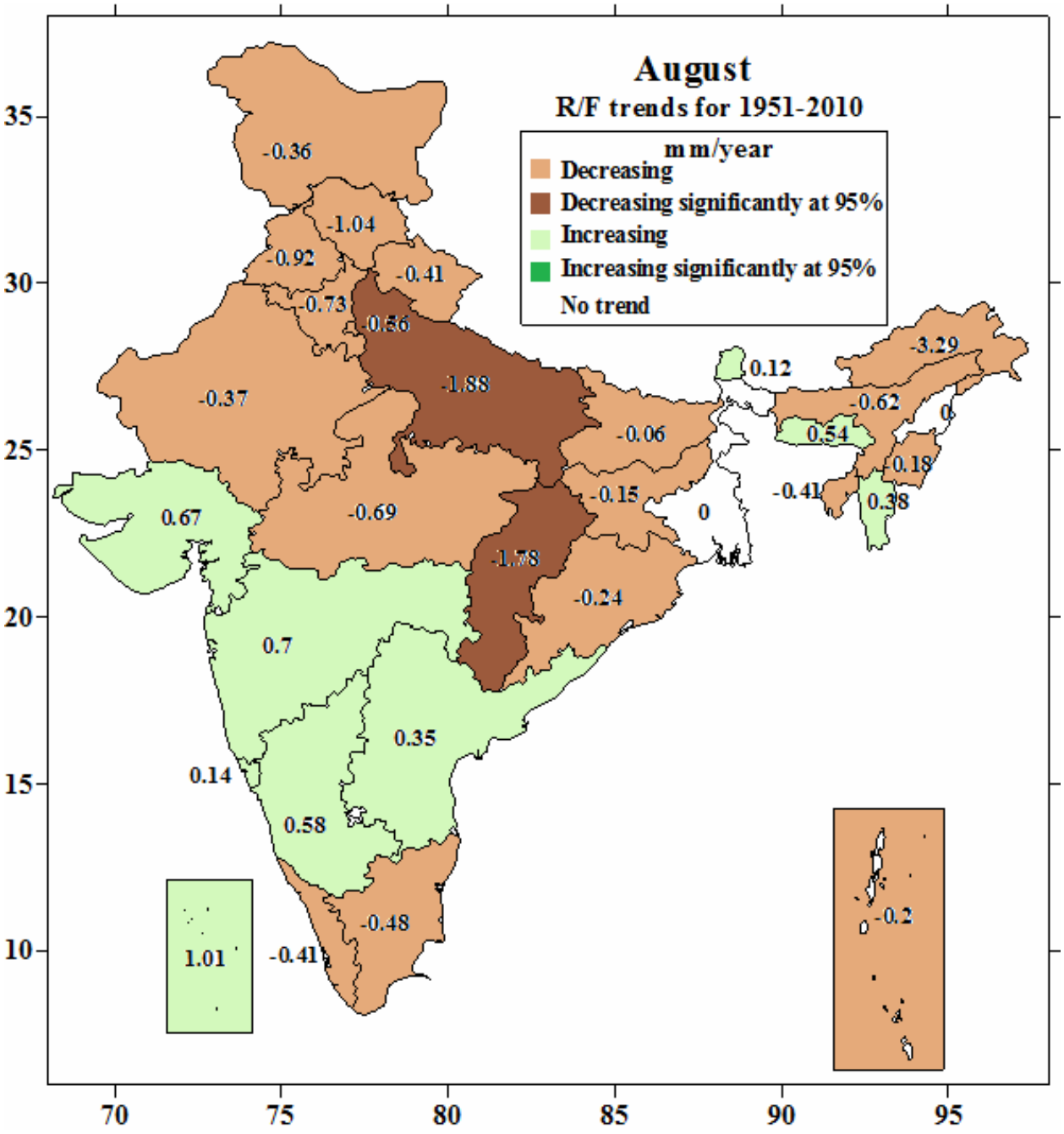


Figure 67: State level rainfall trends for August.

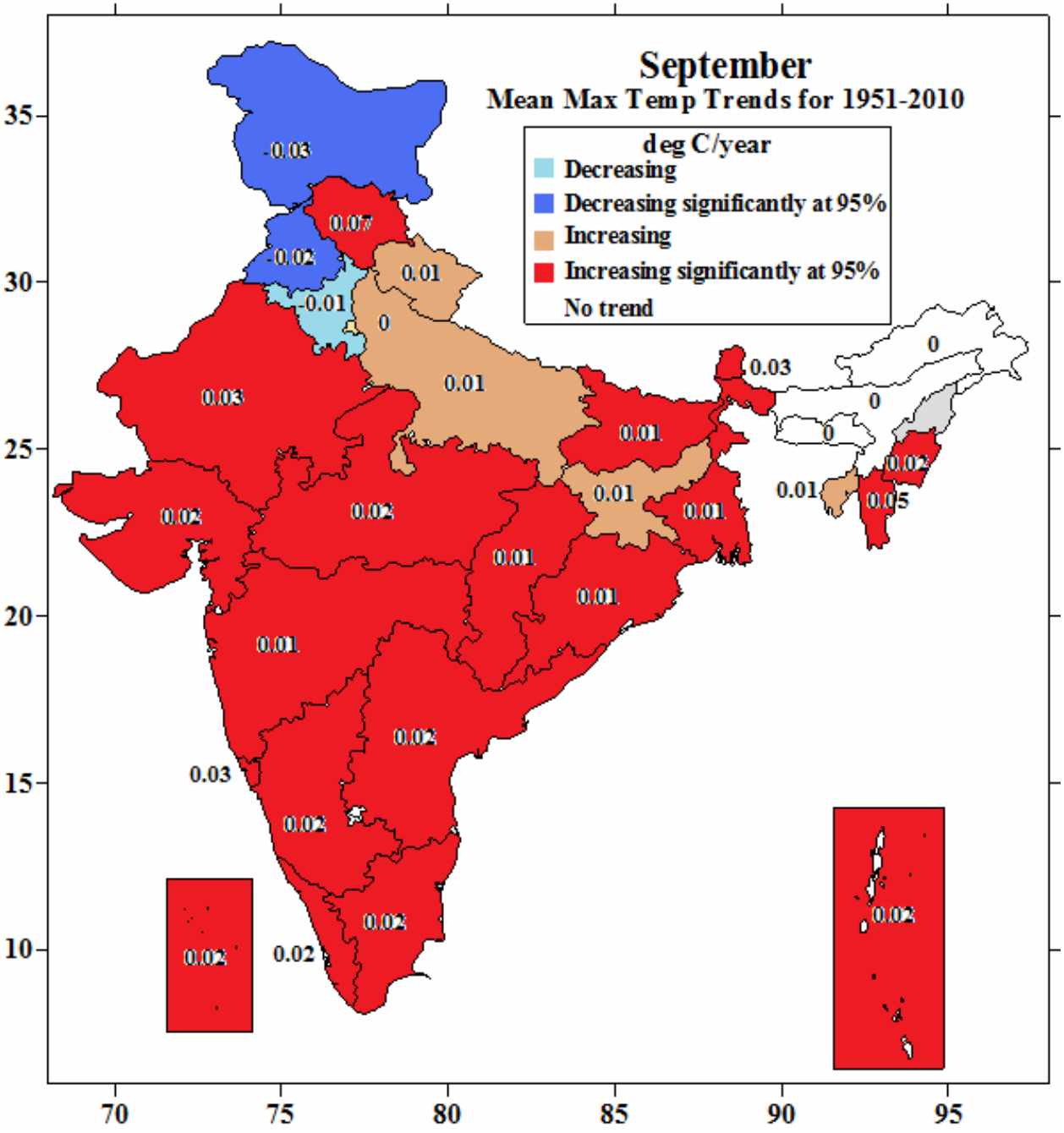


Figure 68: State level mean maximum temperature trends for September.

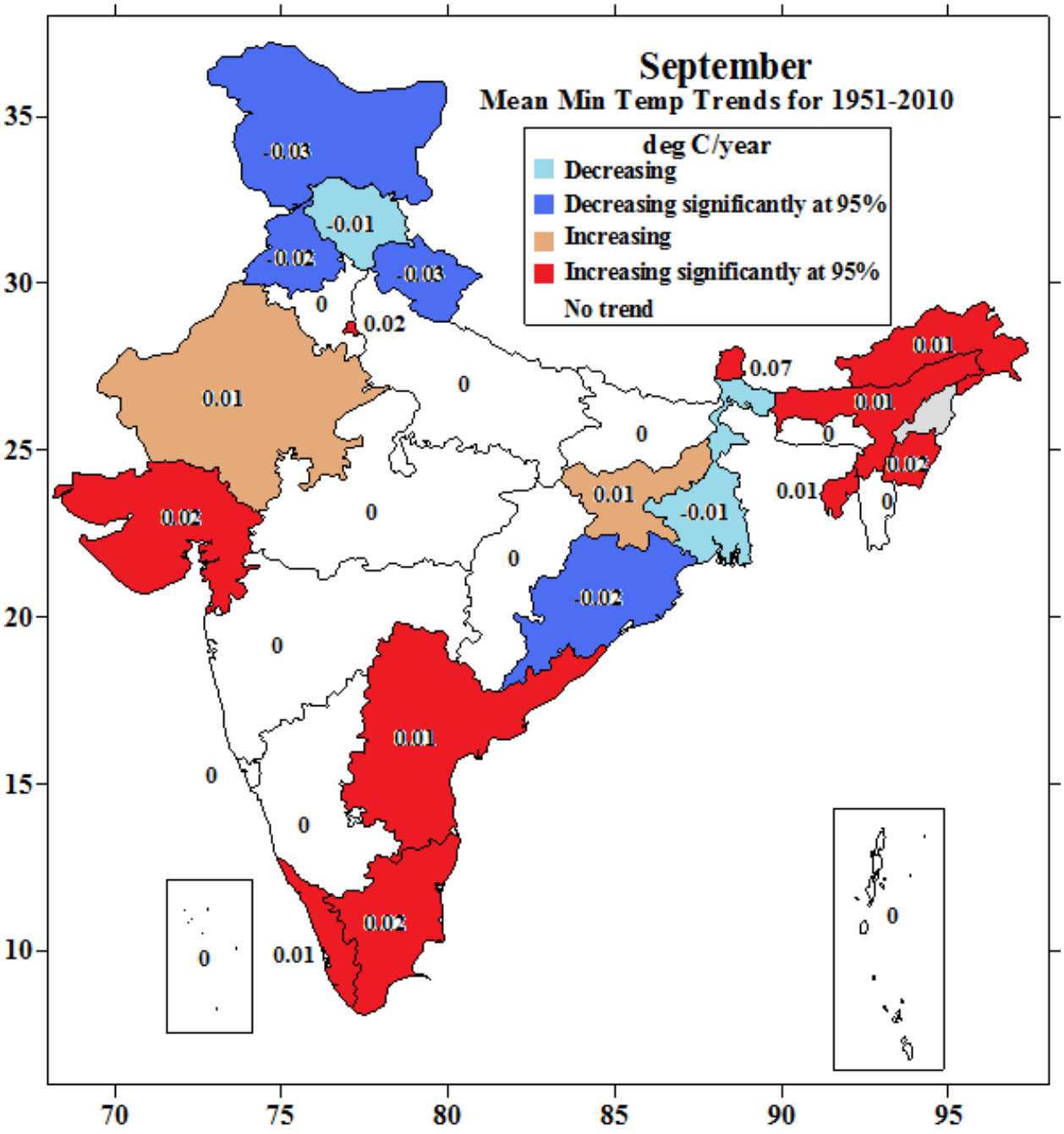


Figure 69: State level mean minimum temperature trends for September.

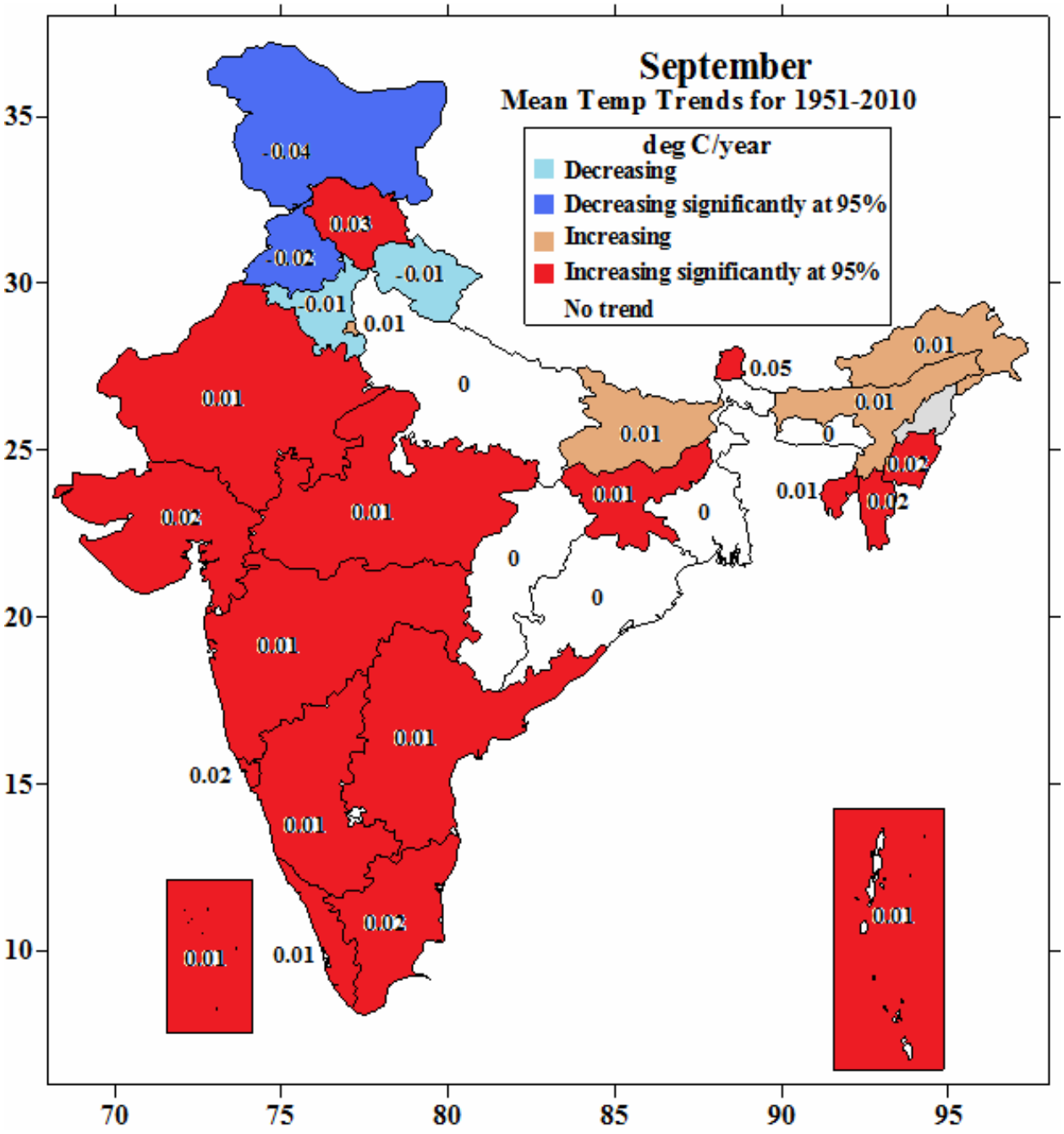


Figure 70: State level mean temperature trends for September.

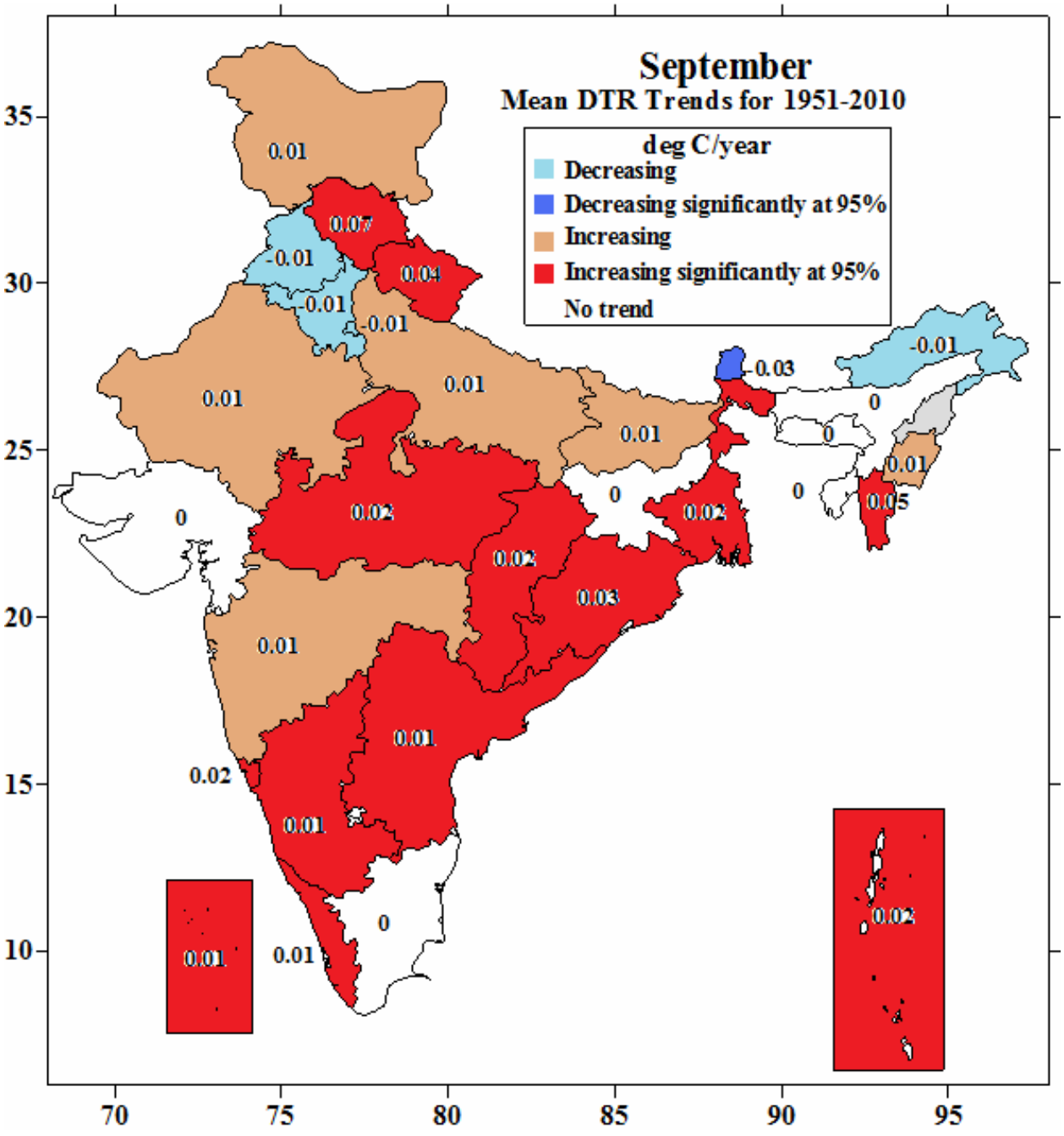


Figure 71: State level mean diurnal temperature range (DTR) trends for September.

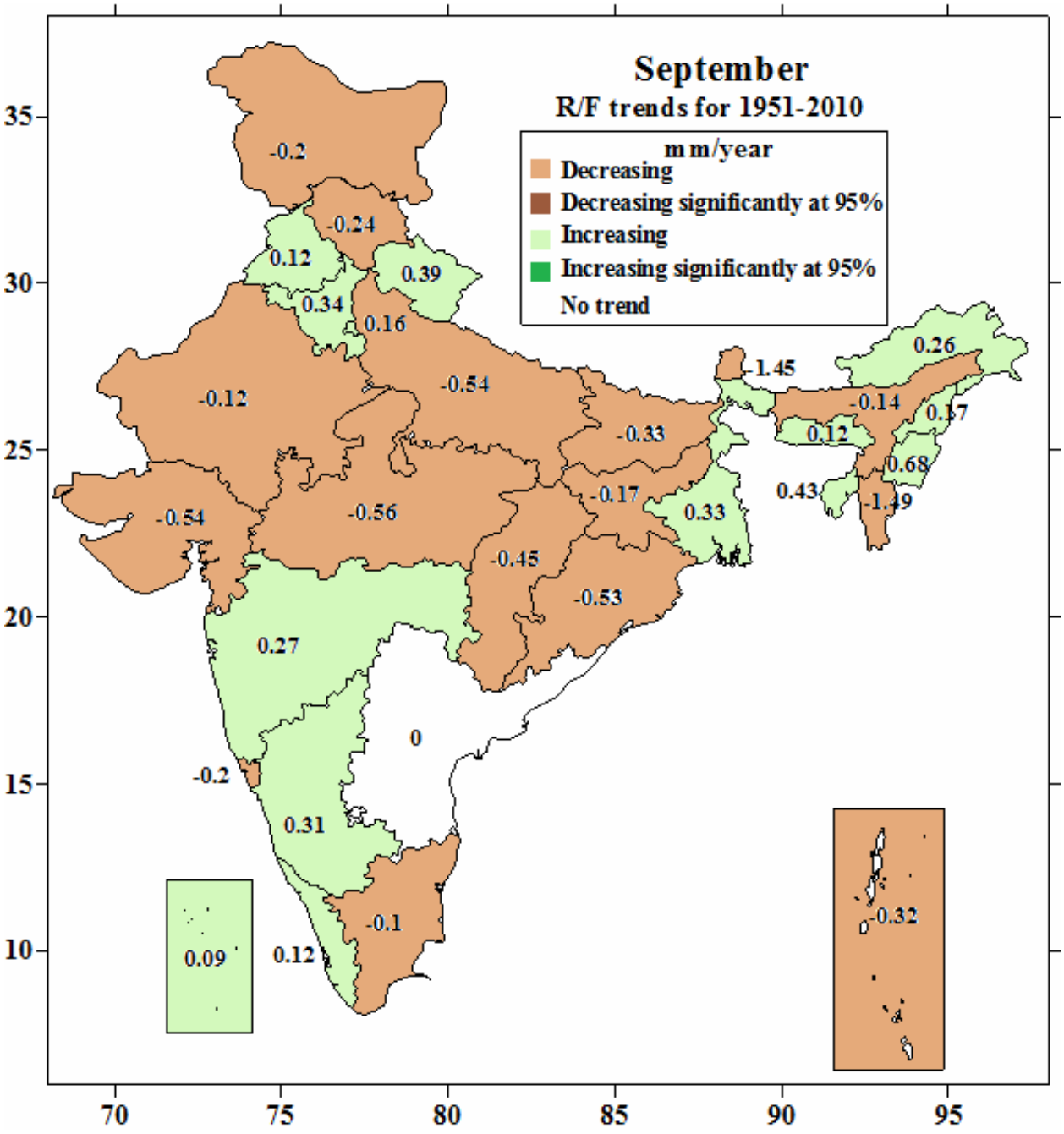


Figure 72: State level rainfall trends for September.

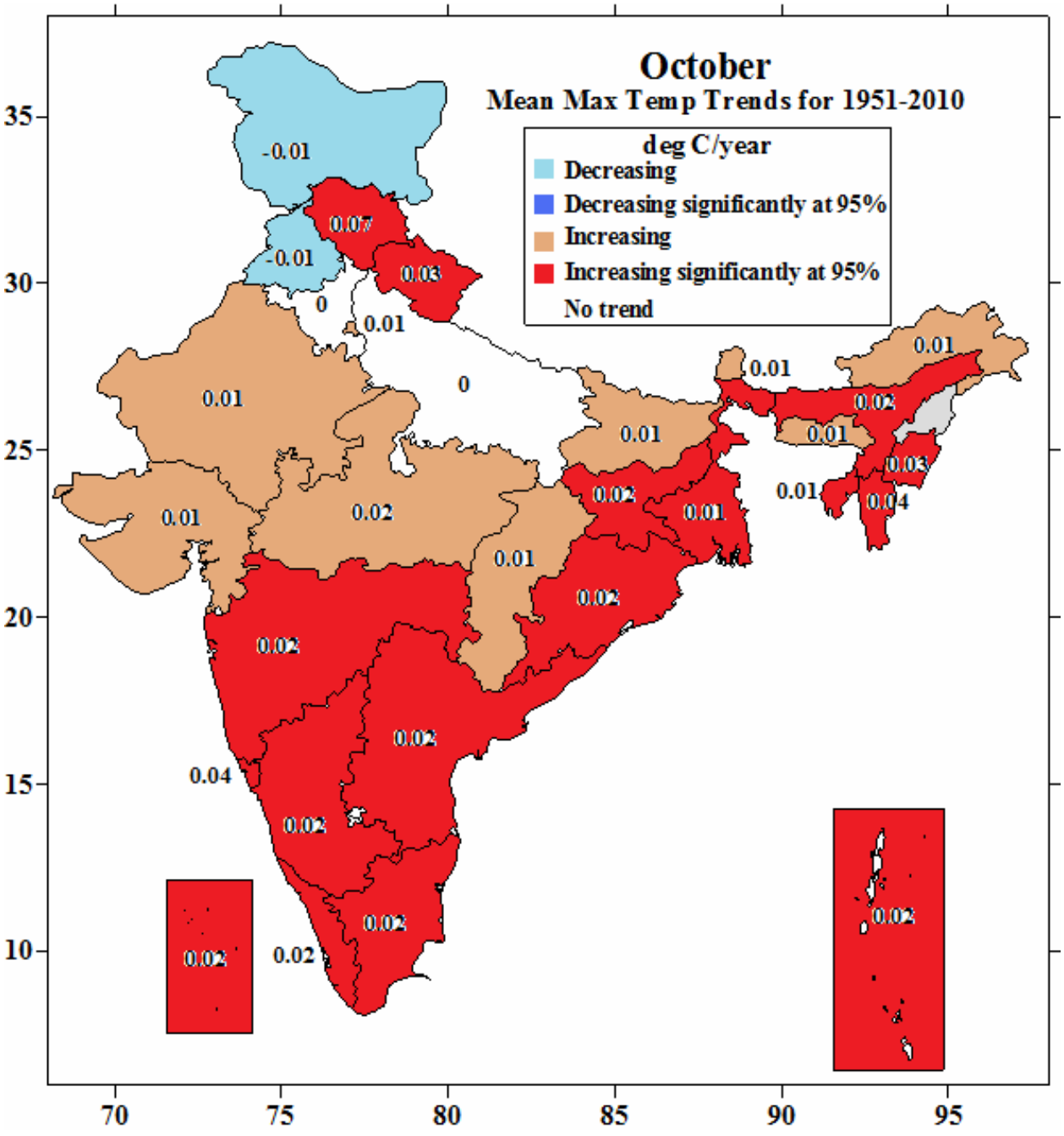


Figure 73: State level mean maximum temperature trends for October.

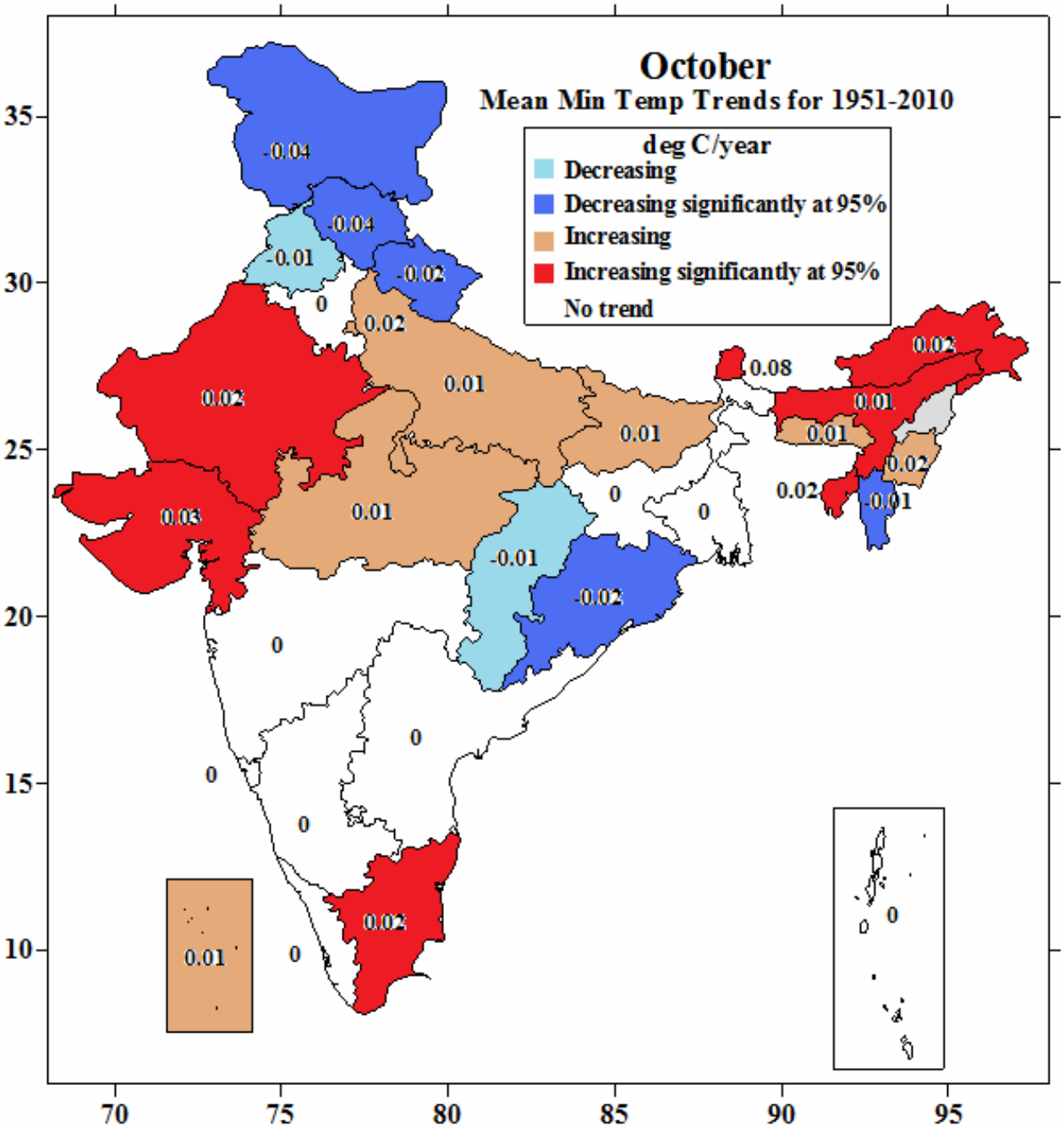


Figure 74: State level mean minimum temperature trends for October.

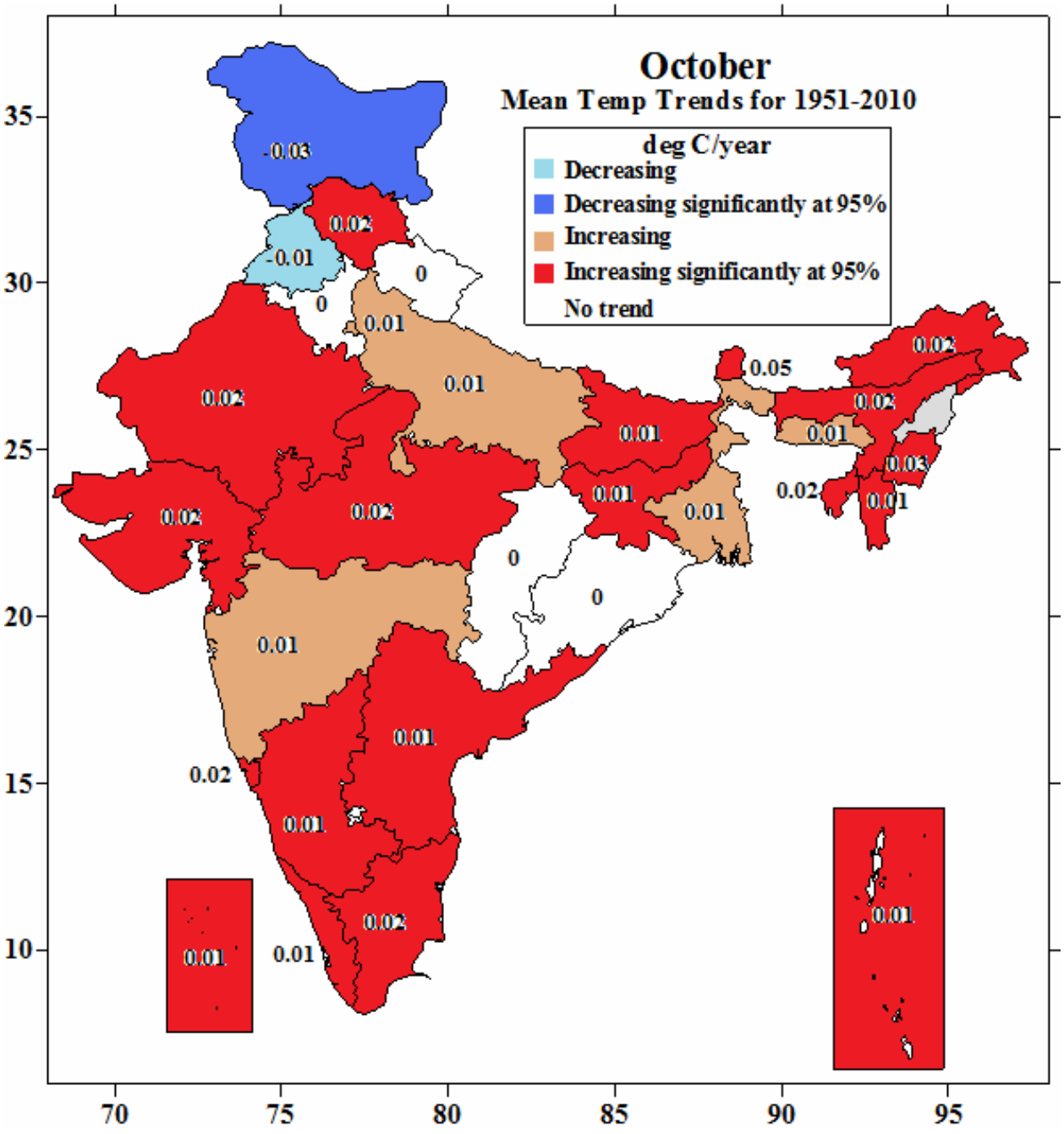


Figure 75: State level mean temperature trends for October.

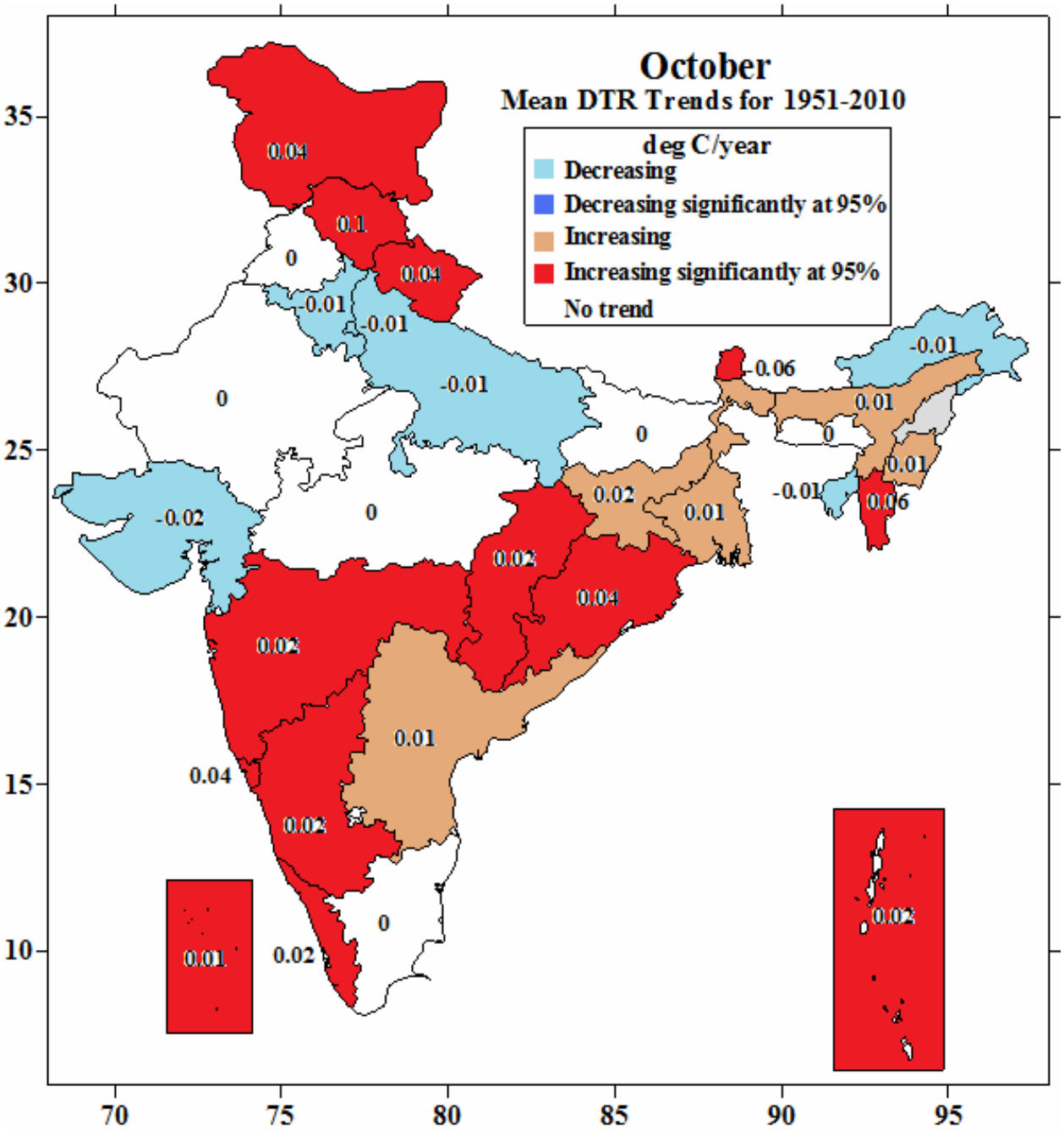


Figure 76: State level mean diurnal temperature range (DTR) trends for October.

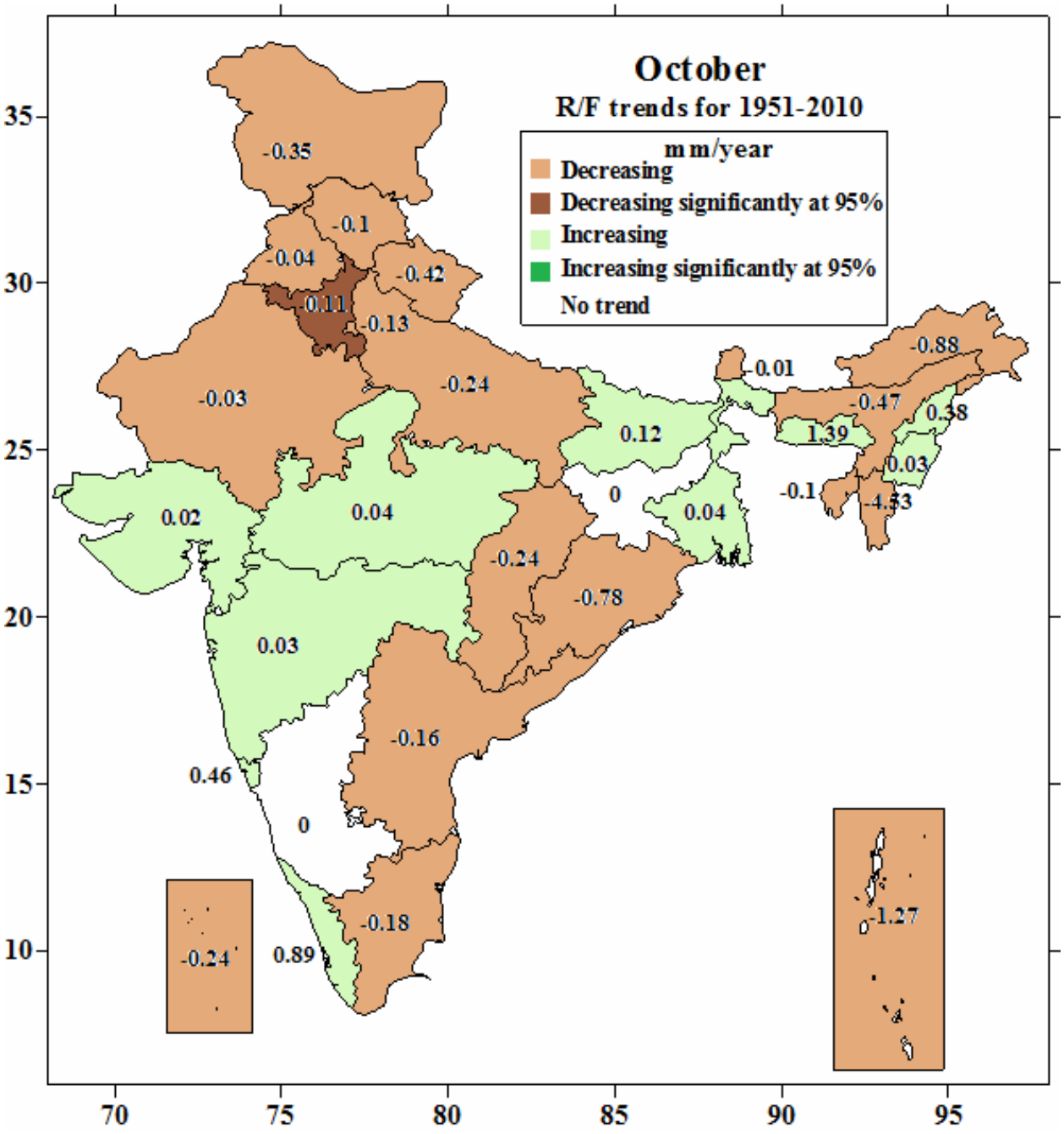


Figure 77: State level rainfall trends for October.

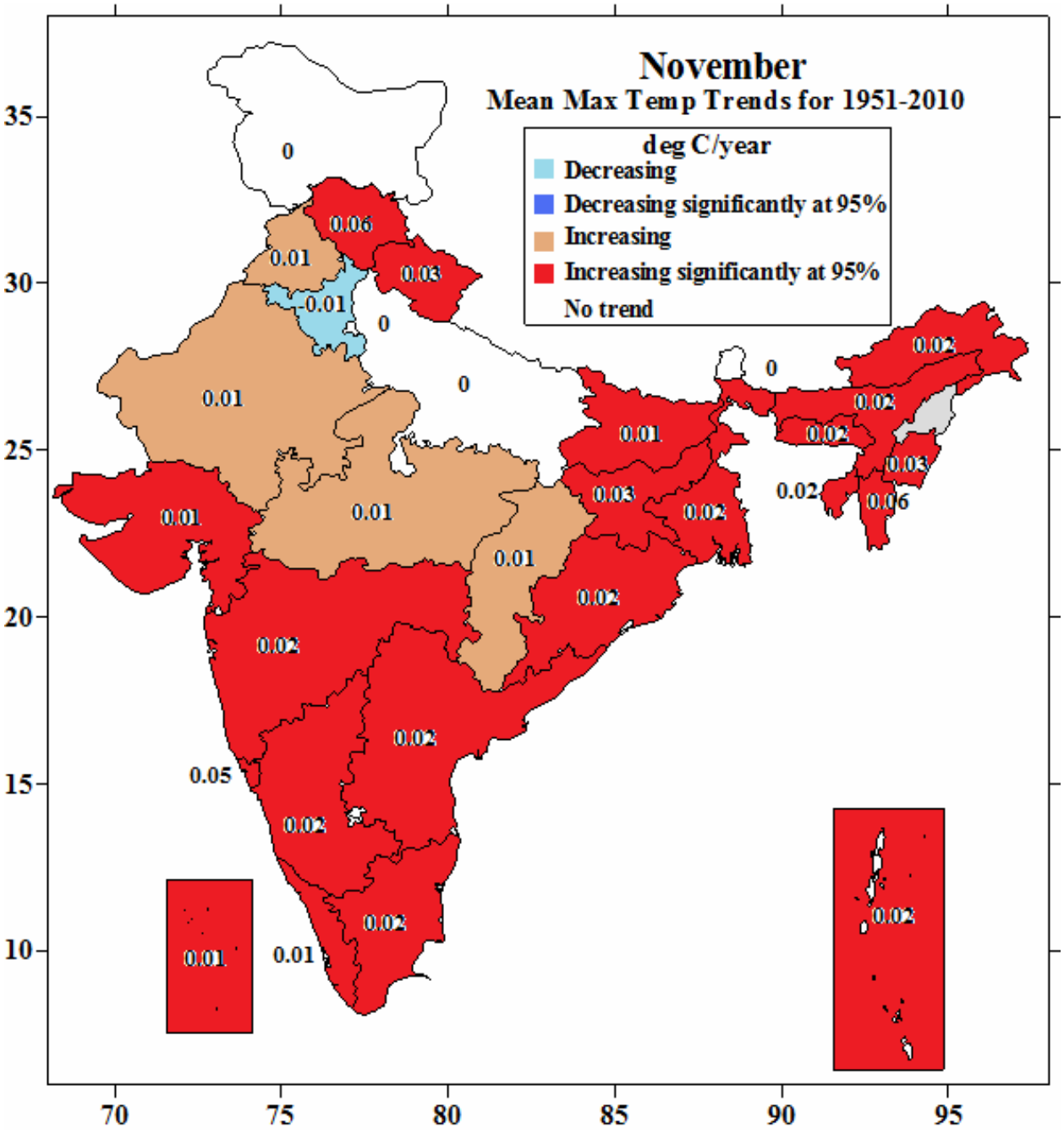


Figure 78: State level mean maximum temperature trends for November.

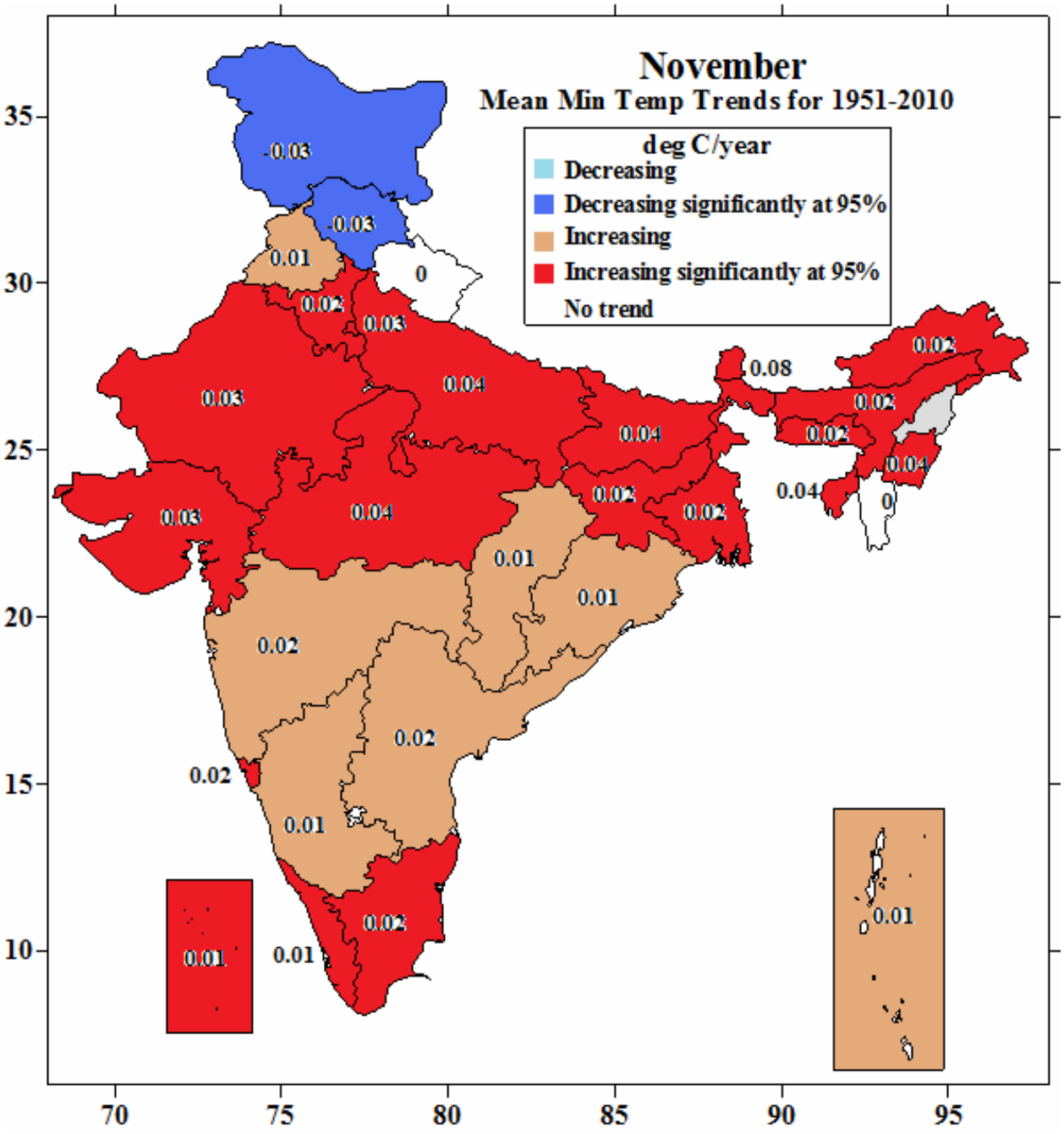


Figure 79: State level mean minimum temperature trends for November.

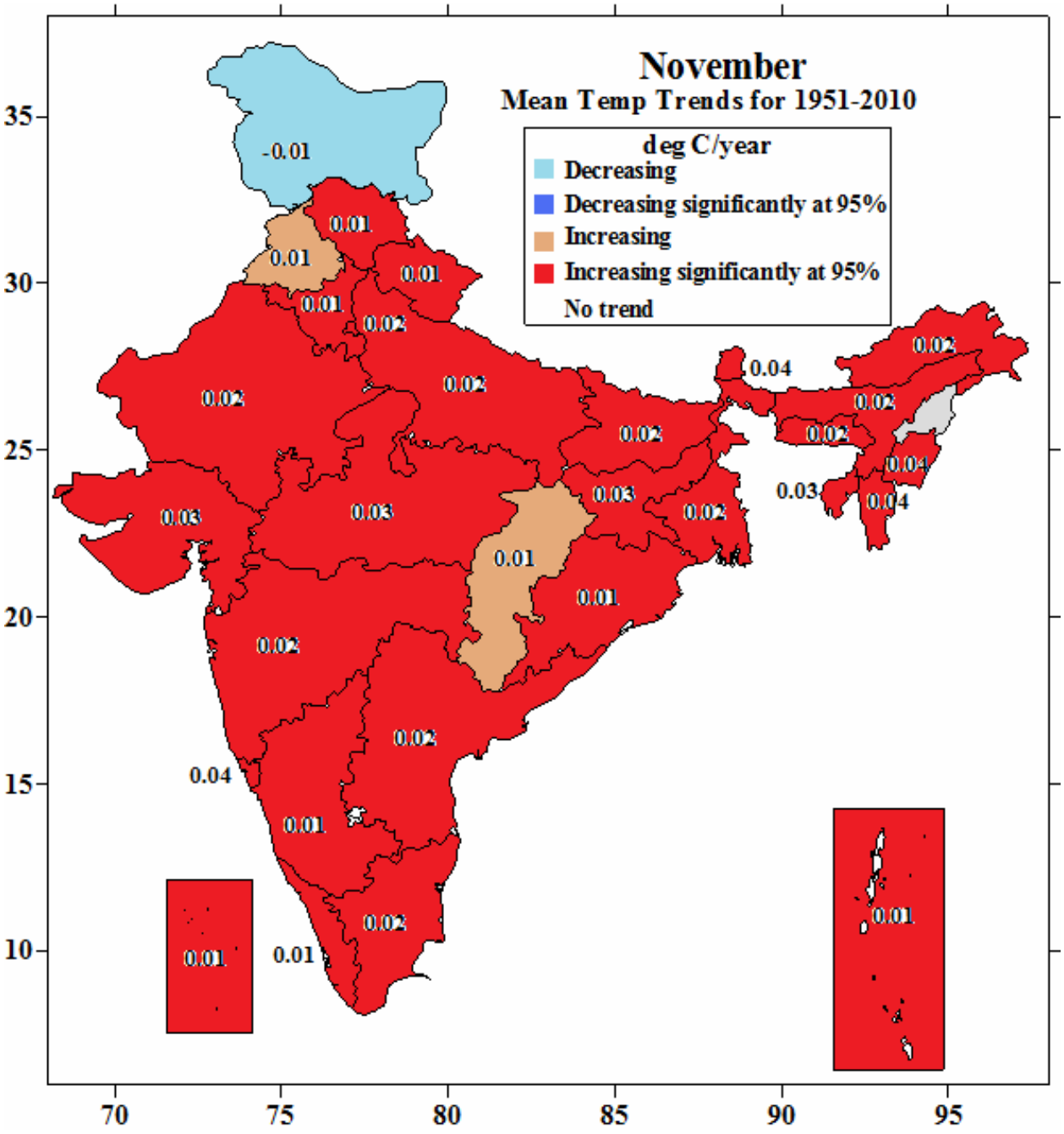


Figure 80: State level mean temperature trends for November.

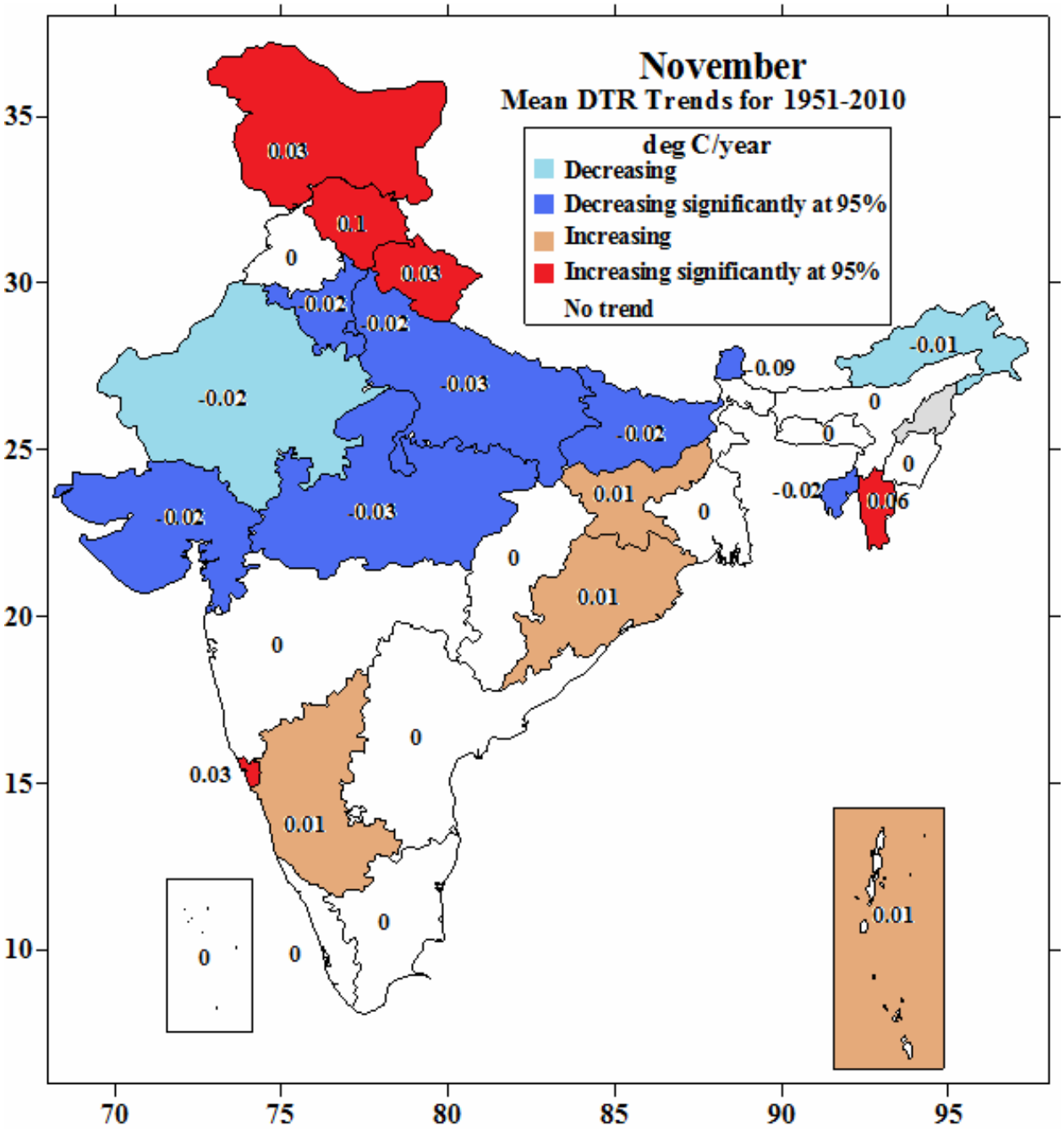


Figure 81: State level mean diurnal temperature range (DTR) trends for November.

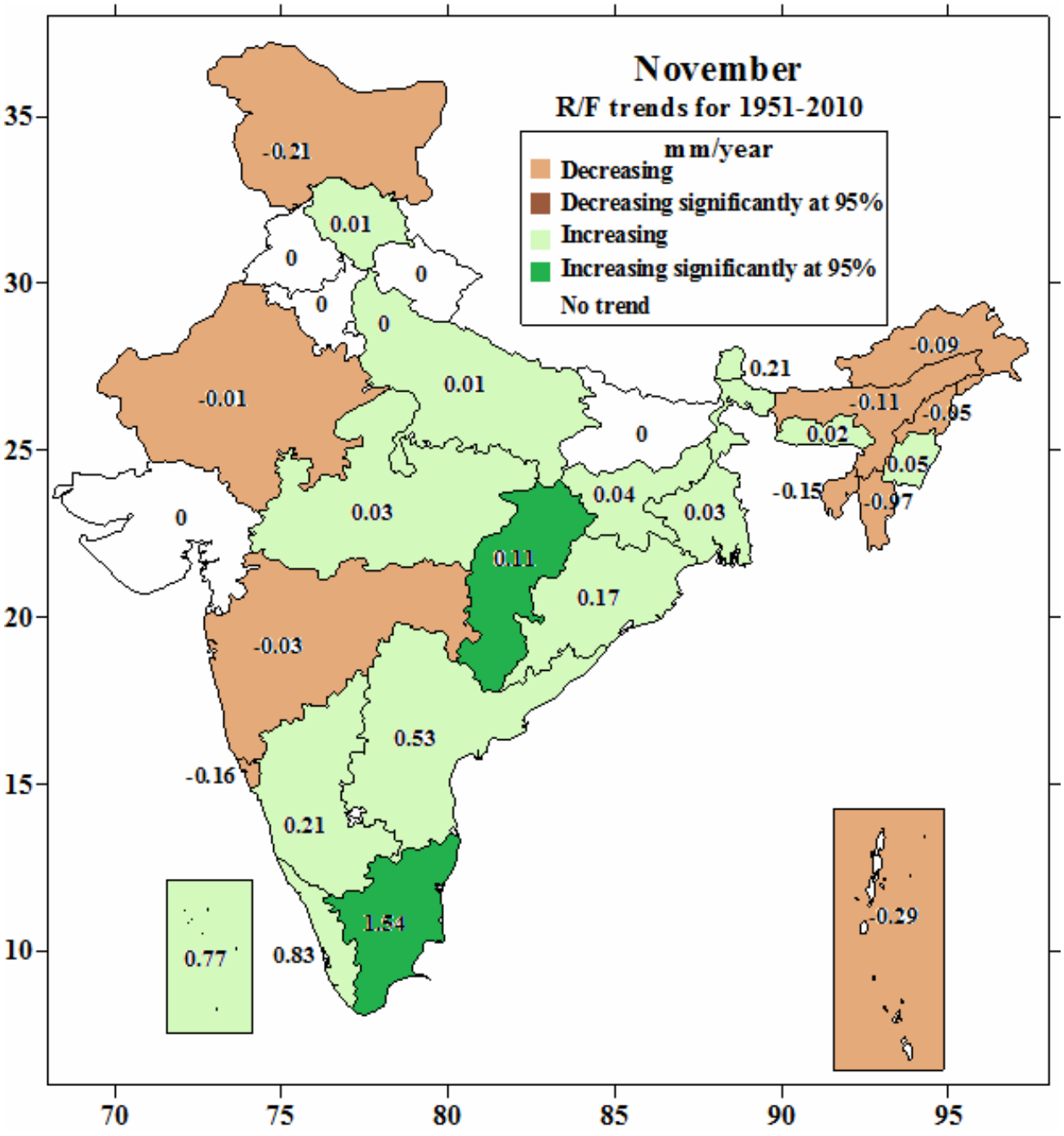


Figure 82: State level rainfall trends for November.

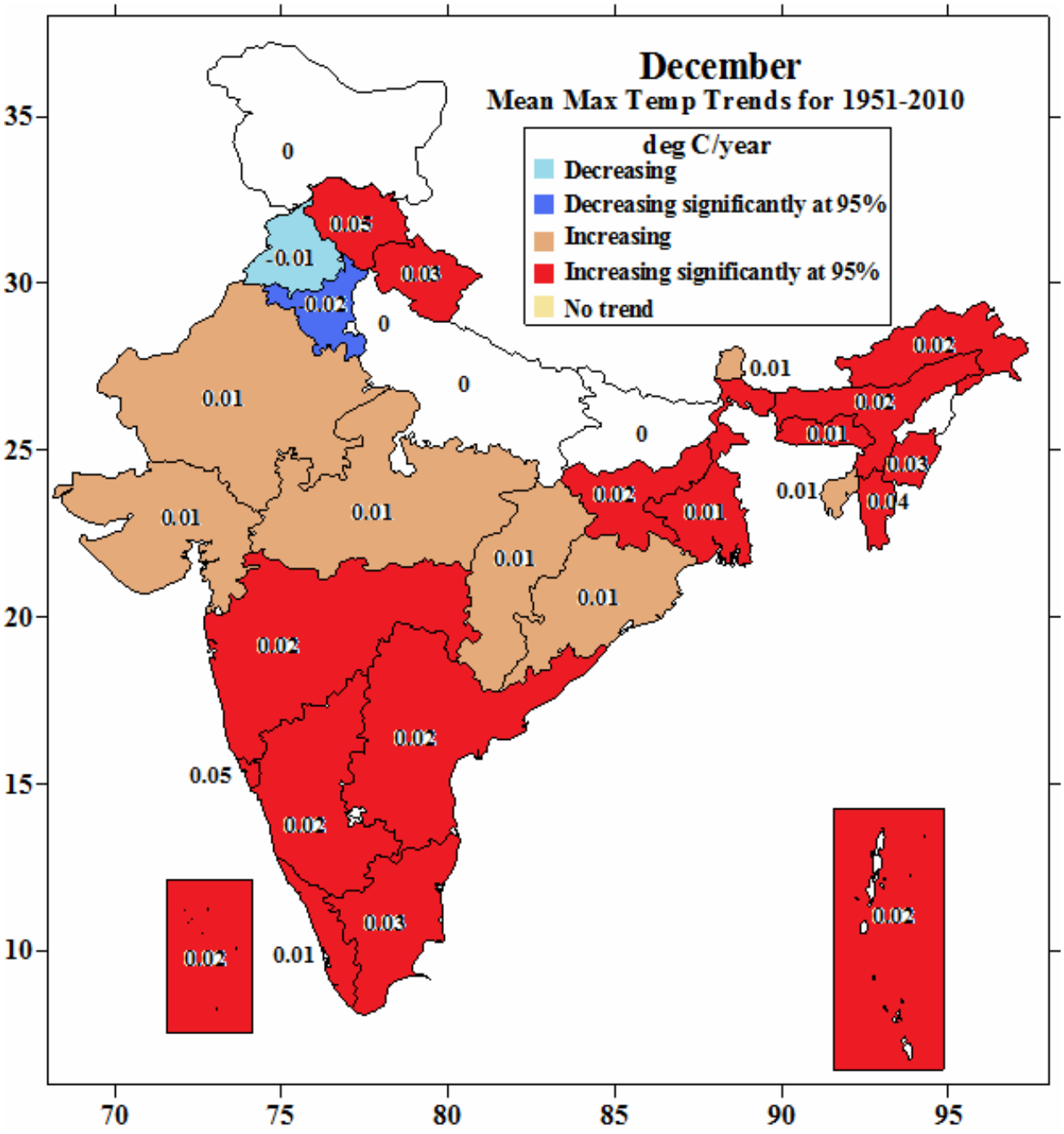


Figure 83: State level mean maximum temperature trends for December.

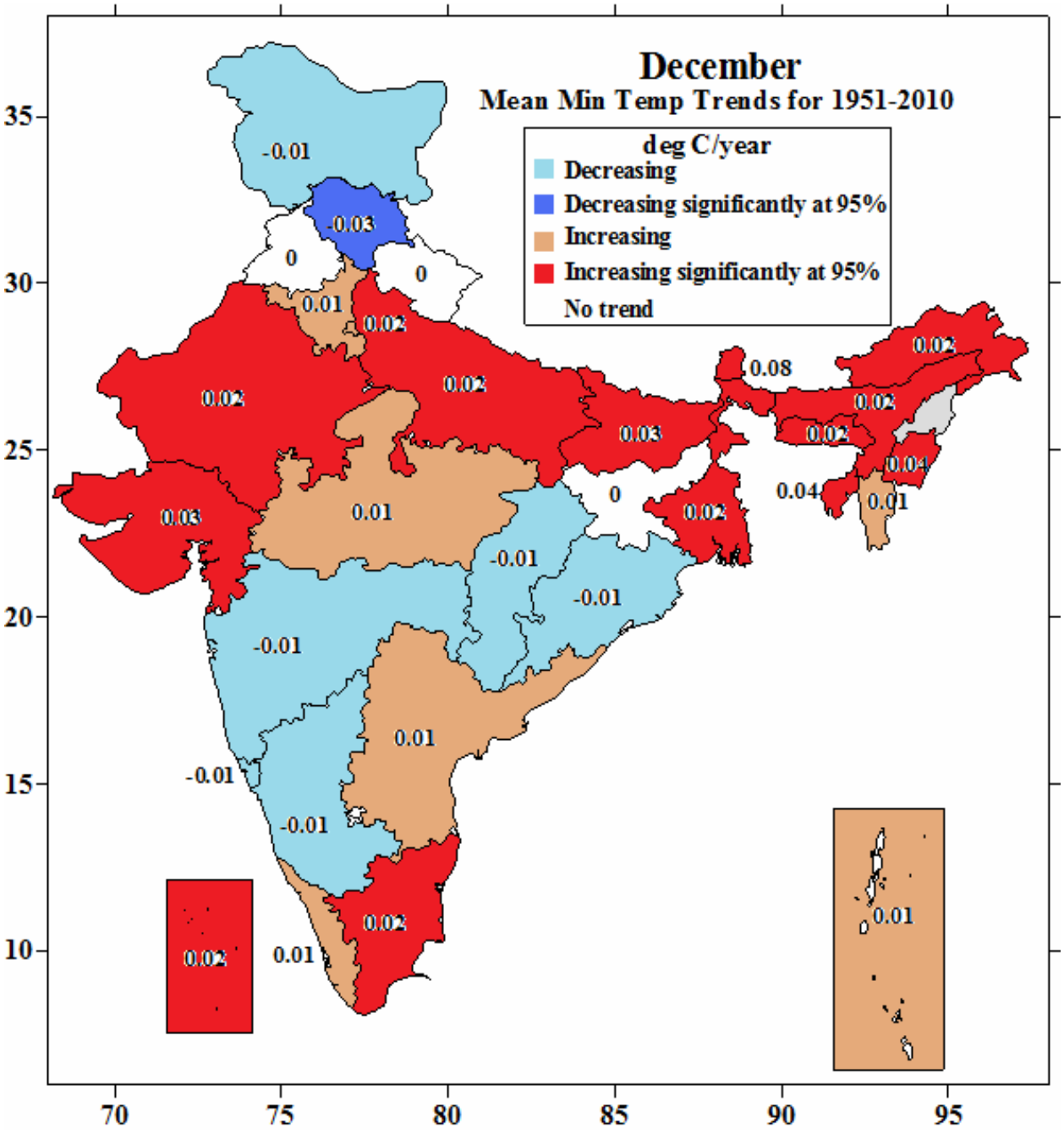


Figure 84: State level mean minimum temperature trends for December.

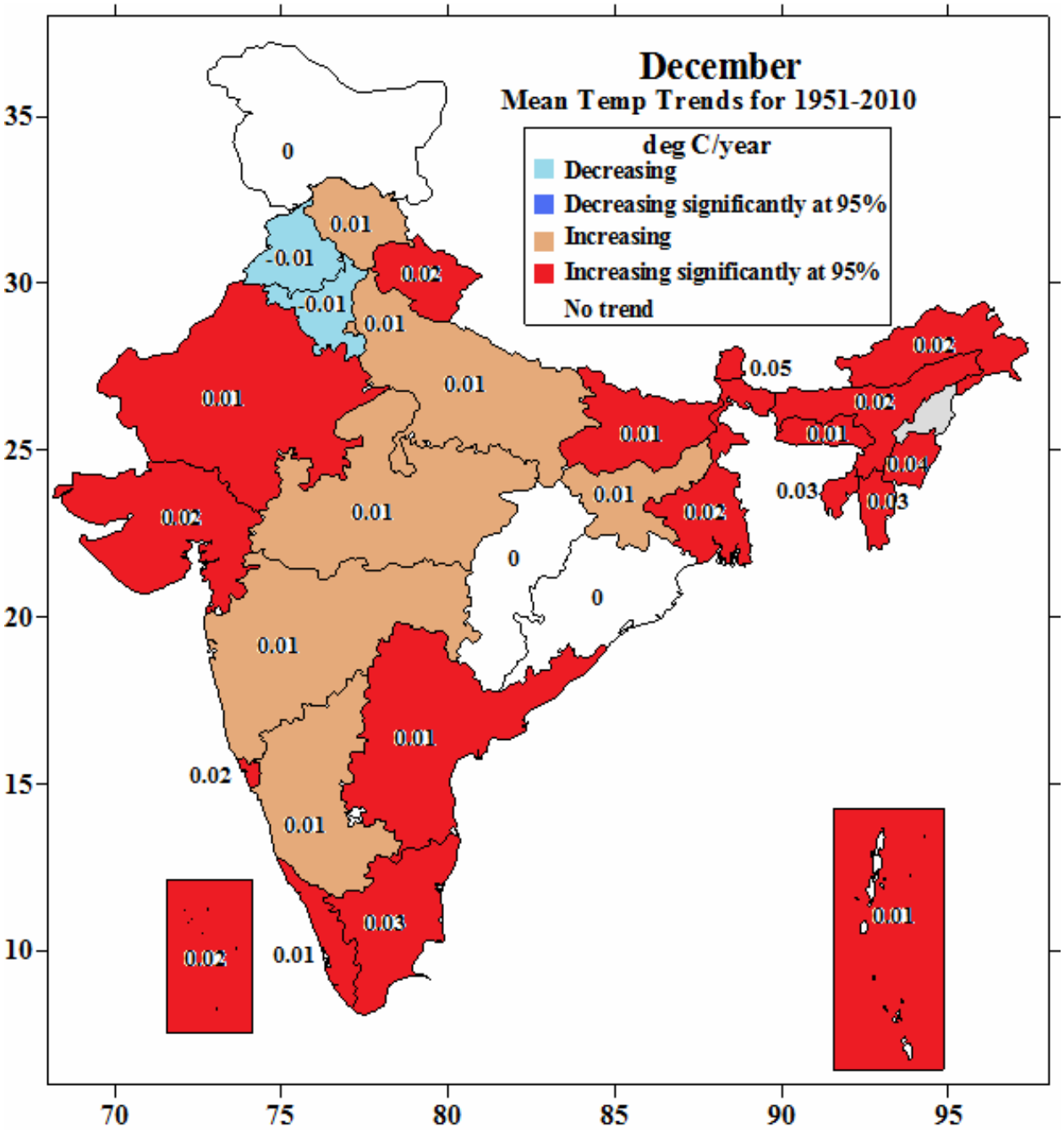


Figure 85: State level mean temperature trends for December.

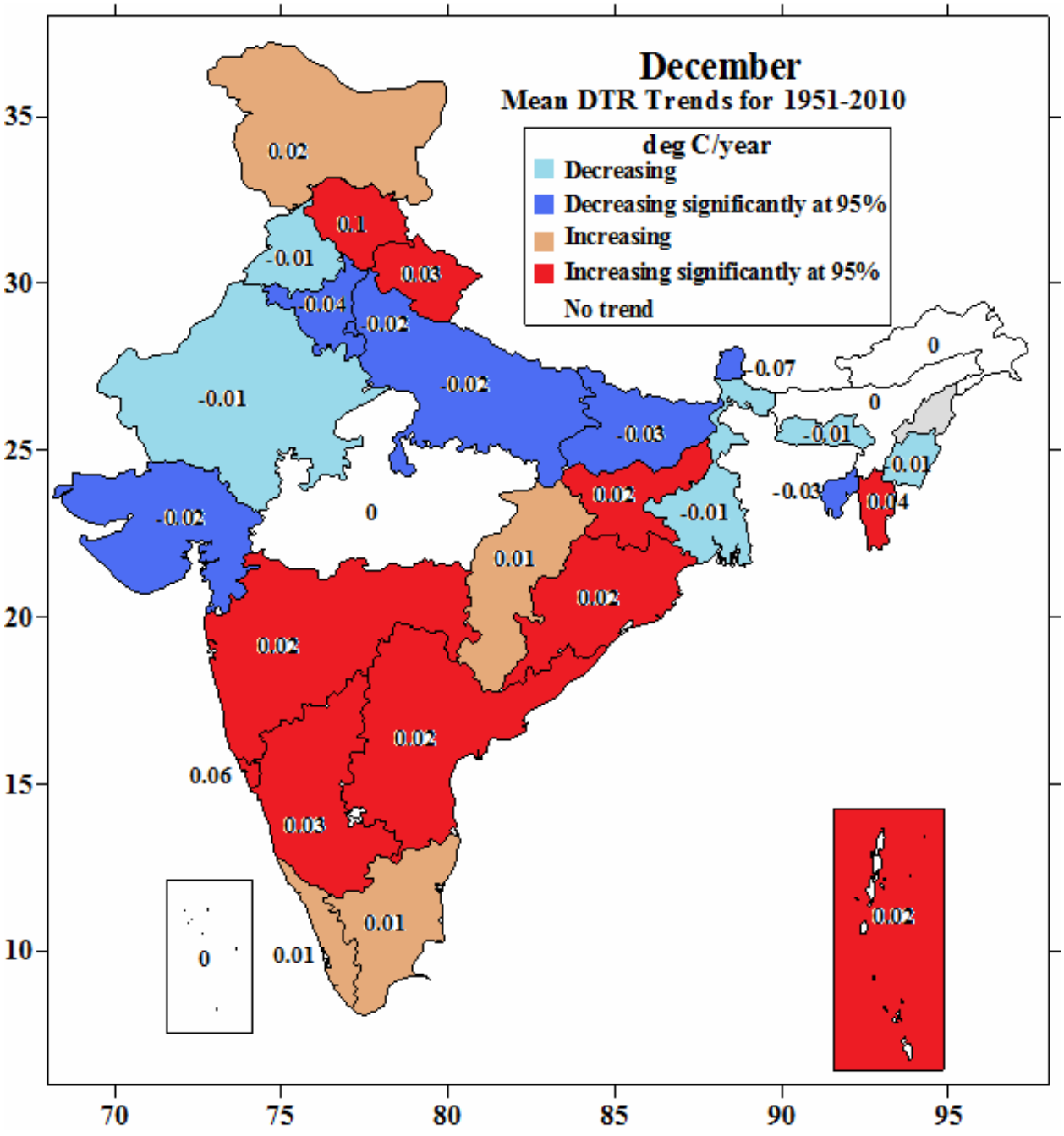


Figure 86: State level mean diurnal temperature range (DTR) trends for December.

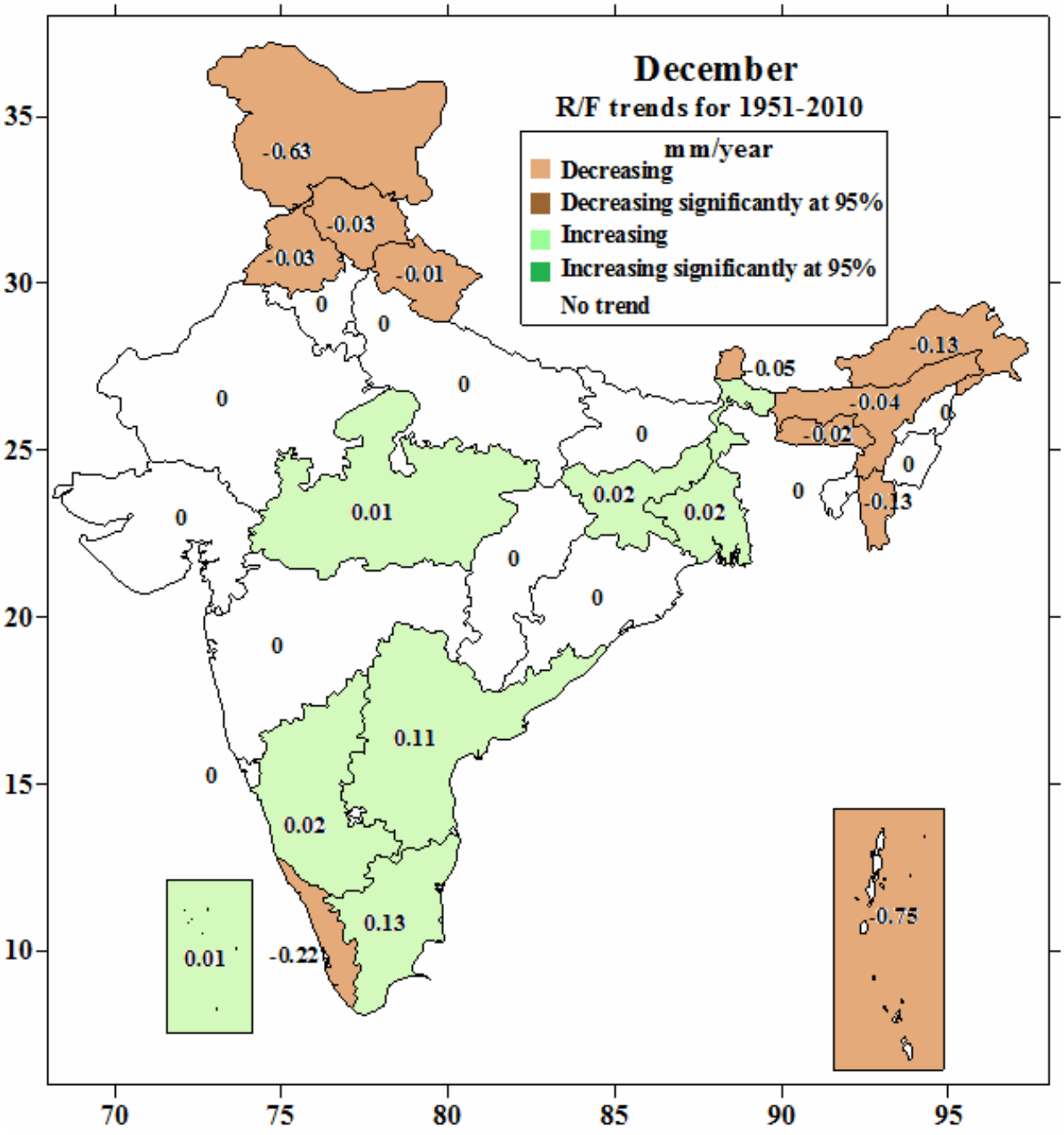


Figure 87: State level rainfall trends for December.

**TABLE 1**

Number of stations whose data are used for preparing state time series of temperature and rainfall for 1951-2010.

| S. No. | State Name | No. of Stations Used | |
|---|---|---|---|
| | | Temperature | Rainfall |
| 1 | Andaman & Nicobar | 6 | 6 |
| 2 | Andhra Pradesh | 21 | 94 |
| 3 | Arunachal Pradesh | 1 | 1 |
| 4 | Assam | 6 | 12 |
| 5 | Bihar | 7 | 18 |
| 6 | Chhattisgarh | 7 | 5 |
| 7 | Delhi | 2 | 3 |
| 8 | Goa | 3 | 7 |
| 9 | Gujarat | 18 | 27 |
| 10 | Haryana | 3 | 22 |
| 11 | Himachal Pradesh | 5 | 36 |
| 12 | Jammu & Kashmir | 4 | 9 |
| 13 | Jharkhand | 6 | 17 |
| 14 | Karnataka | 20 | 222 |
| 15 | Kerala | 7 | 18 |
| 16 | Lakshadweep | 2 | 2 |
| 17 | Madhya Pradesh | 25 | 120 |
| 18 | Maharashtra | 33 | 142 |
| 19 | Manipur | 1 | 1 |
| 20 | Meghalaya | 2 | 4 |
| 21 | Mizoram | 1 | 6 |
| 22 | Nagaland | 0 | 1 |
| 23 | Orissa | 14 | 18 |
| 24 | Punjab | 2 | 20 |
| 25 | Rajasthan | 21 | 241 |
| 26 | Sikkim | 2 | 1 |
| 27 | Tamil Nadu | 22 | 207 |
| 28 | Tripura | 2 | 12 |
| 29 | Uttarakhand | 4 | 3 |
| 30 | Uttar Pradesh | 16 | 162 |
| 31 | West Bengal | 19 | 14 |
| | Total | 282 | 1451 |

## TABLE 2

State level annual and seasonal mean maximum temperature trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign.

| | Mean Maximum Temperature Trends in °C per year | | | | |
|---|---|---|---|---|---|
| State | Annual | Winter | Summer | Monsoon | Post monsoon |
| Andaman & Nicobar | **+0.02*** | **+0.02*** | **+0.01*** | **+0.02*** | **+0.02*** |
| Andhra Pradesh | **+0.01*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.02*** |
| Arunachal Pradesh | **+0.02*** | **+0.02*** | No trend | No trend | **+0.02*** |
| Assam | **+0.02*** | +0.01 | No trend | **+0.01*** | **+0.02*** |
| Bihar | No trend | **-0.01*** | **-0.02*** | **+0.01*** | **+0.01*** |
| Chhattisgarh | No trend | No trend | No trend | No trend | +0.01 |
| Delhi | No trend | -0.01 | +0.01 | No trend | +0.01 |
| Goa | **+0.04*** | **+0.05*** | **+0.04*** | **+0.03*** | **+0.05*** |
| Gujarat | **+0.01*** | +0.01 | No trend | **+0.01*** | **+0.01*** |
| Haryana | **-0.02*** | **-0.03*** | -0.01 | **-0.01*** | No trend |
| Himachal Pradesh | **+0.06*** | **+0.06*** | **+0.06*** | **+0.06*** | **+0.07*** |
| Jammu & Kashmir | -0.01 | +0.01 | -0.01 | **-0.04*** | -0.01 |
| Jharkhand | **+0.01*** | **+0.01*** | No trend | No trend | **+0.03*** |
| Karnataka | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Kerala | **+0.01*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.01*** |
| Lakshadweep | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Madhya Pradesh | **+0.01*** | No trend | +0.01 | **+0.01*** | **+0.02*** |
| Maharashtra | **+0.01*** | **+0.01*** | **+0.02*** | **+0.01*** | **+0.02*** |
| Manipur | **+0.03*** | **+0.04*** | +0.01 | **+0.03*** | **+0.03*** |
| Meghalaya | No trend | No trend | No trend | +0.01 | **+0.01*** |
| Mizoram | **+0.03*** | **+0.04*** | **+0.01*** | **+0.05*** | **+0.05*** |
| Orissa | **+0.01*** | +0.01 | +0.01 | No trend | **+0.02*** |
| Punjab | **-0.01*** | **-0.02*** | No trend | **-0.02*** | No trend |
| Rajasthan | **+0.01*** | No trend | **+0.02*** | +0.01 | +0.01 |
| Sikkim | **+0.02*** | +0.02 | **+0.03*** | **+0.03*** | +0.01 |
| Tamil Nadu | **+0.03*** | **+0.04*** | **+0.03*** | **+0.03*** | **+0.02*** |
| Tripura | No trend | -0.01 | **-0.02*** | **+0.02*** | **+0.02*** |
| Uttar Pradesh | No trend | -0.01 | -0.01 | No trend | No trend |
| Uttarakhand | **+0.02*** | **+0.02*** | No trend | +0.01 | **+0.03*** |
| West Bengal | +0.01 | No trend | **-0.01*** | **+0.02*** | **+0.02*** |

## TABLE 3

State level annual and seasonal mean minimum temperature trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign.

| State | Mean Minimum Temperature Trends in °C per year | | | | |
|---|---|---|---|---|---|
| | Annual | Winter | Summer | Monsoon | Post monsoon |
| Andaman & Nicobar | No trend | +0.01 | No trend | No trend | No trend |
| Andhra Pradesh | **+0.01*** | +0.01 | No trend | **+0.01*** | +0.01 |
| Arunachal Pradesh | **+0.02*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.02*** |
| Assam | **+0.01*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.02*** |
| Bihar | **+0.02*** | **+0.02*** | **+0.01*** | No trend | **+0.02*** |
| Chhattisgarh | **-0.01*** | **-0.01*** | **-0.02*** | **-0.01*** | No trend |
| Delhi | **+0.02*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.02*** |
| Goa | No trend | **-0.01*** | **-0.01*** | **+0.01*** | **+0.01*** |
| Gujarat | **+0.02*** | **+0.03*** | **+0.02*** | **+0.01*** | **+0.03*** |
| Haryana | **+0.01*** | **+0.02*** | **+0.02*** | -0.01 | +0.01 |
| Himachal Pradesh | -0.01 | -0.02 | **-0.03*** | No trend | **-0.03*** |
| Jammu & Kashmir | -0.01 | No trend | -0.02 | **-0.03*** | **-0.03*** |
| Jharkhand | No trend | No trend | No trend | No trend | +0.01 |
| Karnataka | No trend | -0.01 | **-0.01*** | No trend | No trend |
| Kerala | **+0.01*** | +0.01 | No trend | No trend | **+0.01*** |
| Lakshadweep | **+0.01*** | **+0.02*** | **+0.01*** | No trend | **+0.01*** |
| Madhya Pradesh | No trend | No trend | No trend | **-0.01*** | **+0.03*** |
| Maharashtra | No trend | No trend | -0.01 | No trend | +0.01 |
| Manipur | **+0.02*** | **+0.03*** | **+0.03*** | **+0.02*** | **+0.03*** |
| Meghalaya | **+0.01*** | **+0.02*** | No trend | +0.01 | **+0.02*** |
| Mizoram | No trend | No trend | **-0.01*** | No trend | No trend |
| Orissa | **-0.02*** | -0.01 | **-0.02*** | **-0.02*** | -0.01 |
| Punjab | **-0.01*** | No trend | No trend | **-0.01*** | No trend |
| Rajasthan | **+0.01*** | **+0.02*** | **+0.02*** | No trend | **+0.03*** |
| Sikkim | **+0.07*** | **+0.08*** | **+0.07*** | **+0.06*** | **+0.08*** |
| Tamil Nadu | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Tripura | **+0.02*** | **+0.03*** | No trend | **+0.01*** | **+0.03*** |
| Uttar Pradesh | No trend | **+0.02*** | No trend | **-0.01*** | **+0.02*** |
| Uttarakhand | **-0.03*** | No trend | **-0.03*** | **-0.04*** | -0.01 |
| West Bengal | No trend | **+0.01*** | No trend | No trend | **+0.01*** |

## TABLE 4

State level annual and seasonal mean temperature trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign.

| | Mean Temperature Trends in °C per year | | | | |
|---|---|---|---|---|---|
| State | Annual | Winter | Summer | Monsoon | Post monsoon |
| Andaman & Nicobar | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** |
| Andhra Pradesh | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** |
| Arunachal Pradesh | **+0.01*** | **+0.02*** | +0.01 | +0.01 | **+0.02*** |
| Assam | **+0.01*** | **+0.01*** | No trend | **+0.01*** | **+0.02*** |
| Bihar | **+0.01*** | No trend | No trend | **+0.01*** | **+0.02*** |
| Chhattisgarh | No trend | No trend | -0.01 | No trend | +0.01 |
| Delhi | **+0.01*** | +0.01 | **+0.01*** | +0.01 | **+0.02*** |
| Goa | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.03*** |
| Gujarat | **+0.01*** | **+0.02*** | +0.01 | **+0.01*** | **+0.02*** |
| Haryana | No trend | -0.01 | No trend | **-0.01*** | +0.01 |
| Himachal Pradesh | **+0.02*** | **+0.02*** | +0.01 | **+0.03*** | **+0.02*** |
| Jammu & Kashmir | -0.01 | No trend | -0.02 | **-0.02*** | **-0.02*** |
| Jharkhand | **+0.01*** | +0.01 | No trend | No trend | **+0.02*** |
| Karnataka | **+0.01*** | +0.01 | No trend | **+0.01*** | **+0.01*** |
| Kerala | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** |
| Lakshadweep | **+0.01*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.01*** |
| Madhya Pradesh | **+0.01*** | No trend | No trend | No trend | **+0.03*** |
| Maharashtra | **+0.01*** | No trend | +0.01 | +0.01 | **+0.01*** |
| Manipur | **+0.03*** | **+0.04*** | **+0.02*** | **+0.02*** | **+0.03*** |
| Meghalaya | No trend | **+0.01*** | No trend | No trend | **+0.02*** |
| Mizoram | **+0.01*** | **+0.02*** | No trend | **+0.02*** | **+0.02*** |
| Orissa | No trend | No trend | -0.01 | **-0.01*** | +0.01 |
| Punjab | **-0.01*** | **-0.02*** | No trend | **-0.01*** | No trend |
| Rajasthan | **+0.01*** | **+0.01*** | **+0.02*** | +0.01 | **+0.02*** |
| Sikkim | **+0.05*** | **+0.05*** | **+0.05*** | **+0.05*** | **+0.04*** |
| Tamil Nadu | **+0.02*** | **+0.03*** | **+0.03*** | **+0.02*** | **+0.02*** |
| Tripura | **+0.01*** | **+0.01*** | **-0.01*** | **+0.01*** | **+0.03*** |
| Uttar Pradesh | No trend | No trend | -0.01 | No trend | **+0.01*** |
| Uttarakhand | -0.01 | +0.01 | -0.02 | **-0.02*** | +0.01 |
| West Bengal | No trend | No trend | **-0.01*** | **+0.01*** | **+0.01*** |

## TABLE 5

State level annual and seasonal mean diurnal temperature range (DTR) trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign.

| | Mean Diurnal Temperature Range Trends in °C per year | | | | |
|---|---|---|---|---|---|
| State | Annual | Winter | Summer | Monsoon | Post monsoon |
| Andaman & Nicobar | **+0.02*** | **+0.02*** | **+0.01*** | **+0.02*** | **+0.01*** |
| Andhra Pradesh | **+0.01*** | +0.01 | **+0.01*** | **+0.01*** | +0.01 |
| Arunachal Pradesh | **-0.01*** | No trend | **-0.02*** | **-0.02*** | -0.01 |
| Assam | No trend | No trend | **-0.01*** | No trend | No trend |
| Bihar | **-0.02*** | **-0.04*** | **-0.03*** | +0.01 | -0.01 |
| Chhattisgarh | **+0.01*** | +0.01 | **+0.02*** | **+0.01*** | +0.01 |
| Delhi | **-0.01*** | **-0.03*** | **-0.01*** | -0.01 | -0.01 |
| Goa | **+0.04*** | **+0.06*** | **+0.05*** | **+0.02*** | **+0.04*** |
| Gujarat | **-0.01*** | **-0.03*** | **-0.02*** | No trend | **-0.02*** |
| Haryana | **-0.02*** | **-0.05*** | **-0.02*** | **-0.01*** | -0.01 |
| Himachal Pradesh | **+0.06*** | **+0.09*** | **+0.10*** | **+0.05*** | **+0.09*** |
| Jammu & Kashmir | **+0.02*** | **+0.02*** | **+0.03*** | No trend | **+0.03*** |
| Jharkhand | +0.01 | +0.01 | No trend | No trend | +0.02 |
| Karnataka | **+0.02*** | **+0.03*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Kerala | **+0.01*** | +0.01 | **+0.01*** | **+0.02*** | **+0.01*** |
| Lakshadweep | **+0.01*** | No trend | **+0.01*** | **+0.02*** | **+0.01*** |
| Madhya Pradesh | No trend | -0.01 | **+0.01*** | **+0.02*** | -0.01 |
| Maharashtra | **+0.01*** | **+0.02*** | **+0.02*** | **+0.01*** | +0.01 |
| Manipur | No trend | +0.01 | -0.01 | **+0.01*** | +0.01 |
| Meghalaya | No trend | -0.01 | No trend | No trend | No trend |
| Mizoram | **+0.04*** | **+0.04*** | **+0.02*** | **+0.04*** | **+0.06*** |
| Orissa | **+0.02*** | **+0.02*** | **+0.02*** | **+0.03*** | **+0.03*** |
| Punjab | -0.01 | -0.01 | No trend | **-0.01*** | No trend |
| Rajasthan | No trend | **-0.01*** | No trend | **+0.01*** | -0.01 |
| Sikkim | **-0.04*** | **-0.05*** | **-0.04*** | **-0.03*** | **-0.08*** |
| Tamil Nadu | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | No trend |
| Tripura | **-0.02*** | **-0.04*** | **-0.02*** | No trend | **-0.01*** |
| Uttar Pradesh | **-0.01*** | **-0.03*** | -0.01 | **+0.01*** | **-0.02*** |
| Uttarakhand | **+0.03*** | **+0.03*** | **+0.03*** | **+0.04*** | **+0.03*** |
| West Bengal | No trend | **-0.01*** | -0.01 | **+0.02*** | +0.01 |

## TABLE 6

State level annual and seasonal rainfall trends based upon 1451 rainfall stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign.

| | Rainfall trends in mm per year | | | | |
|---|---|---|---|---|---|
| State | Annual | Winter | Summer | Monsoon | Post monsoon |
| Andaman & Nicobar | **-7.77*** | **-2.70*** | -0.51 | -2.93 | -1.35 |
| Andhra Pradesh | +1.31 | +0.29 | +0.35 | -0.14 | +0.46 |
| Arunachal Pradesh | -3.63 | -0.10 | No trend | -2.30 | -0.83 |
| Assam | -2.96 | 0.08 | -0.56 | -2.19 | -0.75 |
| Bihar | +1.41 | -0.06 | **+0.59*** | +1.11 | +0.11 |
| Chhattisgarh | -2.03 | +0.02 | +0.04 | -2.38 | +0.06 |
| Delhi | -0.51 | +0.16 | **+0.40*** | -0.32 | -0.20 |
| Goa | -3.82 | No trend | -0.31 | -2.61 | +0.04 |
| Gujarat | +1.41 | No trend | -0.03 | +1.27 | -0.02 |
| Haryana | +0.45 | +0.07 | **+0.39*** | -0.01 | **-0.23*** |
| Himachal Pradesh | -3.26 | -0.18 | +0.31 | -2.85 | -0.21 |
| Jammu & Kashmir | +2.13 | **+1.88*** | -1.07 | -0.16 | -0.37 |
| Jharkhand | +0.84 | -0.13 | +0.43 | +0.44 | +0.03 |
| Karnataka | -0.05 | +0.10 | -0.41 | +0.61 | +0.14 |
| Kerala | -1.43 | -0.40 | -1.15 | -2.42 | +1.68 |
| Lakshadweep | +3.22 | -0.33 | -0.44 | +1.73 | +0.83 |
| Madhya Pradesh | -1.81 | -0.06 | No trend | -1.74 | +0.03 |
| Maharashtra | -0.71 | +0.04 | -0.15 | -0.29 | -0.05 |
| Manipur | +1.94 | +0.10 | +1.63 | -0.89 | +0.11 |
| Meghalaya | 14.68 | **+0.52*** | +2.25 | +9.27 | +2.04 |
| Mizoram | +0.33 | -0.31 | +2.80 | +7.71 | -6.19 |
| Nagaland | -1.86 | +0.05 | +0.43 | -1.69 | +0.12 |
| Orissa | +0.69 | +0.06 | **+0.65*** | -0.23 | -0.83 |
| Punjab | -2.41 | +0.09 | +0.22 | -1.49 | -0.13 |
| Rajasthan | +0.04 | +0.02 | **+0.17*** | -0.09 | -0.04 |
| Sikkim | -3.12 | -0.12 | -0.83 | -1.36 | -0.11 |
| Tamil Nadu | +0.80 | -0.16 | -0.47 | **-1.35*** | +1.49 |
| Tripura | +0.77 | +0.11 | +1.73 | -1.11 | -0.55 |
| Uttar Pradesh | **-4.42*** | -0.22 | +0.02 | **-3.52*** | -0.33 |
| Uttarakhand | -1.07 | -0.01 | +0.86 | -1.45 | -0.63 |
| West Bengal | **+3.63*** | +0.16 | **+1.34*** | +1.45 | +0.19 |

## TABLE 7

State level monthly mean maximum temperature trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign. No trend is indicated by abbreviation NT.

| | Monthly mean maximum temperature trends in °C per year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Andaman & Nicobar | **+0.02*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Andhra Pradesh | **+0.02*** | +0.01 | **+0.01*** | **+0.01*** | +0.02 | +0.01 | **+0.02*** | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Arunachal Pradesh | +0.02 | **+0.03*** | -0.02 | **-0.03*** | **+0.03*** | NT | -0.01 | NT | NT | +0.01 | **+0.02*** | **+0.02*** |
| Assam | +0.01 | +0.01 | NT | **-0.02*** | **+0.02*** | **+0.02*** | +0.01 | **+0.02*** | NT | **+0.02*** | **+0.02*** | **+0.02*** |
| Bihar | **-0.02*** | -0.01 | NT | -0.01 | **-0.04*** | NT | +0.01 | **+0.02*** | **+0.01*** | +0.01 | **+0.01*** | NT |
| Chhattisgarh | NT | -0.01 | +0.01 | NT | -0.01 | -0.01 | **+0.02*** | +0.01 | **+0.01*** | +0.01 | +0.01 | +0.01 |
| Delhi | **-0.02*** | -0.01 | NT | +0.02 | NT | -0.02 | NT | **+0.03*** | NT | +0.01 | NT | NT |
| Goa | **+0.05*** | **+0.05*** | **+0.04*** | **+0.05*** | **+0.05*** | **+0.04*** | **+0.03*** | **+0.03*** | **+0.03*** | **+0.04*** | **+0.05*** | **+0.05*** |
| Gujarat | +0.01 | NT | NT | +0.01 | -0.01 | +0.01 | +0.01 | +0.01 | **+0.02*** | +0.01 | **+0.01*** | +0.01 |
| Haryana | **-0.04*** | -0.02 | -0.02 | +0.01 | -0.02 | **-0.04*** | -0.01 | NT | -0.01 | NT | -0.01 | **-0.02*** |
| Himachal Pradesh | **+0.08*** | **+0.05*** | **+0.07*** | **+0.07*** | **+0.05*** | **+0.04*** | **+0.07*** | **+0.08*** | **+0.07*** | **+0.07*** | **+0.06*** | **+0.05*** |
| Jammu & Kashmir | +0.02 | NT | -0.01 | -0.01 | -0.03 | **-0.06*** | **-0.04*** | **-0.02*** | **-0.03*** | -0.01 | NT | NT |
| Jharkhand | **+0.02*** | +0.02 | +0.02 | +0.01 | **-0.03*** | -0.01 | **+0.01*** | **+0.01*** | +0.01 | **+0.02*** | **+0.03*** | **+0.02*** |
| Karnataka | **+0.02*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Kerala | **+0.01*** | **+0.01*** | **+0.01*** | +0.01 | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.01*** |
| Lakshadweep | **+0.02*** | **+0.02*** | **+0.03*** | **+0.02*** | **+0.03*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.02*** |
| Madhya Pradesh | -0.01 | -0.01 | +0.01 | +0.01 | NT | NT | +0.02 | **+0.02*** | **+0.022*** | +0.02 | +0.01 | +0.01 |
| Maharashtra | **+0.01*** | +0.01 | +0.01 | **+0.02*** | **+0.02*** | +0.01 | **+0.01*** | +0.01 | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Manipur | **+0.04*** | **+0.04*** | +0.02 | NT | +0.02 | **+0.03*** | **+0.02*** | **+0.03*** | **+0.02*** | **+0.03*** | **+0.03*** | **+0.03*** |
| Meghalaya | +0.01 | NT | NT | -0.01 | NT | +0.01 | NT | NT | NT | +0.01 | **+0.02*** | **+0.01** |
| Mizoram | **0.05*** | **+0.02*** | NT | NT | **+0.03*** | **+0.03*** | **+0.02*** | **+0.06*** | **+0.05*** | **+0.04*** | **+0.06*** | **+0.04*** |
| Orissa | +0.01 | +0.01 | +0.01 | +0.01 | NT | -0.01 | **+0.01*** | +0.01 | **+0.01*** | **+0.02*** | **+0.02*** | +0.01 |
| Punjab | **-0.03*** | -0.02 | -0.01 | +0.02 | NT | **-0.05*** | -0.02 | NT | **-0.02*** | -0.01 | +0.01 | -0.01 |
| Rajasthan | +0.01 | +0.01 | +0.02 | **+0.03*** | +0.02 | +0.01 | NT | **+0.02*** | **+0.03*** | +0.01 | +0.01 | +0.01 |
| Sikkim | +0.02 | +0.02 | NT | +0.02 | **+0.04*** | +0.04 | **+0.02*** | +0.02 | **+0.03*** | +0.01 | NT | +0.01 |
| Tamil Nadu | **+0.04*** | **+0.04*** | **+0.04*** | **+0.04*** | **+0.03*** | **+0.02*** | **+0.04*** | **+0.03*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.03*** |
| Tripura | -0.01 | -0.01 | **-0.02*** | **-0.04*** | -0.01 | **+0.02*** | **+0.01*** | **+0.02*** | +0.01 | **+0.01*** | **+0.02*** | +0.01 |
| Uttar Pradesh | -0.02 | -0.01 | NT | +0.01 | **-0.03*** | -0.02 | NT | **+0.02*** | +0.01 | NT | NT | NT |
| Uttarakhand | **+0.03*** | +0.01 | +0.01 | +0.01 | -0.02 | -0.02 | +0.01 | **+0.02*** | +0.01 | **+0.03*** | **+0.03*** | **+0.03*** |
| West Bengal | -0.01 | -0.01 | -0.01 | -0.02 | -0.01 | +0.01 | **+0.02*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.01*** |

## TABLE 8

State level monthly mean minimum temperature trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign. No trend is indicated by abbreviation NT.

| | Monthly mean minimum temperature trends in °C per year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Andaman & Nicobar | NT | +0.01 | NT | NT | NT | NT | +0.01 | NT | NT | NT | +0.01 | +0.01 |
| Andhra Pradesh | NT | +0.01 | **+0.01*** | NT | NT | NT | **+0.01*** | **+0.01*** | **+0.01*** | NT | +0.02 | +0.01 |
| Arunachal Pradesh | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.03*** | **+0.02*** | **+0.01*** | **+0.02*** | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Assam | **+0.01*** | **+0.02*** | **+0.02*** | +0.01 | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.02*** |
| Bihar | +0.02 | **+0.03*** | **+0.02*** | **+0.01*** | NT | NT | +0.01 | +0.01 | NT | +0.01 | **+0.04*** | **+0.03*** |
| Chhattisgarh | -0.02 | -0.01 | -0.01 | -0.01 | **-0.03*** | **-0.02*** | NT | NT | NT | -0.01 | +0.01 | -0.01 |
| Delhi | +0.01 | **+0.03*** | +0.02 | **+0.03*** | **+0.02*** | -0.01 | +0.01 | **+0.02*** | **+0.02*** | +0.02 | **+0.03*** | +0.02 |
| Goa | -0.01 | **-0.02*** | **-0.02*** | NT | -0.01 | **+0.01*** | **+0.01*** | NT | NT | NT | **+0.02*** | -0.01 |
| Gujarat | **+0.03*** | **+0.03*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.03*** | **+0.03*** | **+0.03*** |
| Haryana | +0.01 | +0.02 | +0.01 | +0.01 | +0.01 | **-0.03*** | NT | NT | NT | NT | **+0.02*** | +0.01 |
| Himachal Pradesh | -0.01 | -0.02 | **-0.03*** | **-0.03*** | **-0.04*** | **-0.03*** | **+0.02*** | **+0.02*** | -0.01 | **-0.04*** | **-0.03*** | **-0.03*** |
| Jammu & Kashmir | -0.02 | -0.01 | -0.02 | **-0.03*** | **-0.04*** | **-0.05*** | **-0.03*** | **-0.03*** | **-0.03*** | **-0.04*** | **-0.03*** | -0.01 |
| Jharkhand | -0.01 | **+0.02*** | +0.01 | NT | **-0.01*** | -0.01 | +0.01 | +0.01 | +0.01 | NT | **+0.02*** | NT |
| Karnataka | -0.01 | -0.01 | **-0.01*** | -0.01 | -0.01 | NT | NT | NT | NT | NT | +0.01 | -0.01 |
| Kerala | NT | +0.01 | +0.01 | NT | NT | NT | **+0.01*** | NT | **+0.01*** | NT | **+0.01*** | +0.01 |
| Lakshadweep | **+0.02*** | **+0.02*** | **+0.02*** | **+0.01*** | NT | NT | +0.01 | NT | NT | +0.01 | **+0.01*** | **+0.02*** |
| Madhya Pradesh | NT | +0.01 | +0.01 | NT | NT | **-0.01*** | NT | NT | NT | +0.01 | **+0.04*** | +0.01 |
| Maharashtra | -0.01 | NT | NT | -0.01 | -0.01 | NT | NT | NT | NT | NT | +0.02 | -0.01 |
| Manipur | **+0.03*** | **+0.03*** | **+0.05*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.01*** | **+0.02*** | +0.02 | **+0.04*** | **+0.04*** |
| Meghalaya | **+0.02*** | +0.01 | NT | NT | NT | **+0.01*** | NT | NT | NT | +0.01 | **+0.02*** | **+0.02*** |
| Mizoram | NT | **-0.03*** | **-0.02*** | **-0.02*** | NT | NT | NT | NT | NT | **-0.01*** | NT | +0.01 |
| Orissa | -0.01 | -0.01 | -0.01 | **-0.02*** | **-0.03*** | **-0.03*** | **-0.02*** | **-0.02** | **-0.02*** | **-0.02*** | +0.01 | -0.01 |
| Punjab | -0.02 | NT | -0.01 | -0.01 | +0.01 | **-0.02*** | NT | NT | **-0.02*** | -0.01 | +0.01 | NT |
| Rajasthan | +0.02 | **+0.03*** | **+0.02*** | **+0.02*** | **+0.02*** | -0.01 | NT | NT | +0.01 | **+0.02*** | **+0.03*** | **+0.02*** |
| Sikkim | **+0.08*** | **+0.08*** | **+0.07*** | **+0.07*** | **+0.07*** | **+0.06*** | **+0.06*** | **+0.06*** | **+0.07*** | **+0.08*** | **+0.08*** | **+0.08*** |
| Tamil Nadu | **+0.02*** | **+0.03*** | **+0.03*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** |
| Tripura | **+0.03*** | **+0.03*** | +0.01 | NT | NT | **+0.01*** | **+0.01*** | **+0.02*** | **+0.01*** | **+0.02*** | **+0.04*** | **+0.04*** |
| Uttar Pradesh | NT | **+0.03*** | NT | NT | -0.01 | **-0.03*** | **-0.01*** | NT | NT | +0.01 | **+0.04*** | **+0.02*** |
| Uttarakhand | NT | -0.01 | **-0.03*** | -0.03 | **-0.04*** | **-0.06*** | **-0.04*** | **-0.04*** | **-0.03*** | **-0.02*** | NT | NT |
| West Bengal | NT | **+0.01*** | +0.01 | NT | -0.01 | NT | NT | NT | -0.01 | NT | **+0.02*** | **+0.02*** |

## TABLE 9

State level monthly mean temperature trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign. No trend is indicated by abbreviation NT.

| | Monthly mean temperature trends in °C per year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Andaman & Nicobar | **+0.01*** | **+0.01*** | +0.01 | NT | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** |
| Andhra Pradesh | **+0.01*** | **+0.01*** | **+0.01*** | +0.01 | +0.01 | NT | **+0.02*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.01*** |
| Arunachal Pradesh | **+0.02*** | **+0.03*** | NT | -0.01 | **+0.03*** | +0.01 | NT | +0.01 | +0.01 | **+0.02*** | **+0.02*** | **+0.02*** |
| Assam | **+0.01*** | +0.01 | +0.01 | -0.01 | **+0.01*** | **+0.02*** | **+0.01*** | **+0.01*** | +0.01 | **+0.02*** | **+0.02*** | **+0.02*** |
| Bihar | -0.01 | +0.01 | +0.01 | NT | **-0.02*** | NT | +0.01 | **+0.01*** | +0.01 | **+0.01*** | **+0.02*** | **+0.01*** |
| Chhattisgarh | -0.01 | -0.01 | NT | NT | **-0.02*** | -0.02 | +0.01 | NT | NT | NT | +0.01 | NT |
| Delhi | -0.01 | +0.01 | +0.01 | **+0.03*** | +0.01 | -0.01 | +0.01 | **+0.02*** | +0.01 | +0.01 | **+0.02*** | +0.01 |
| Goa | **+0.02*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.04*** | **+0.02*** |
| Gujarat | **+0.02*** | +0.01 | +0.02 | **+0.01*** | NT | **+0.01*** | **+0.01*** | **+0.01*** | **+0.02*** | **+0.02*** | **+0.03*** | **+0.02*** |
| Haryana | **-0.01*** | NT | -0.01 | +0.01 | NT | **-0.03*** | -0.01 | +0.01 | -0.01 | NT | **+0.01*** | -0.01 |
| Himachal Pradesh | **+0.03*** | +0.02 | +0.01 | +0.02 | +0.01 | NT | **+0.04*** | **+0.05*** | **+0.03*** | **+0.02*** | **+0.01*** | +0.01 |
| Jammu & Kashmir | NT | NT | -0.02 | -0.02 | **-0.03*** | **-0.05*** | **-0.03*** | **-0.03*** | **-0.04*** | **-0.03*** | -0.01 | NT |
| Jharkhand | NT | **+0.02*** | +0.01 | NT | **-0.03*** | -0.01 | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.03*** | +0.01 |
| Karnataka | +0.01 | NT | NT | NT | +0.01 | +0.01 | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | +0.01 |
| Kerala | **+0.01*** | **+0.01*** | **+0.01*** | NT | +0.01 | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** |
| Lakshadweep | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.01*** | **+0.02*** |
| Madhya Pradesh | NT | NT | +0.01 | +0.01 | NT | -0.01 | +0.01 | +0.01 | **+0.01*** | **+0.02*** | **+0.03*** | +0.01 |
| Maharashtra | NT | NT | +0.01 | +0.01 | NT | NT | **+0.01*** | NT | **+0.01*** | +0.01 | **+0.02*** | +0.01 |
| Manipur | **+0.04*** | **+0.04*** | **+0.03*** | +0.01 | +0.01 | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.03*** | **+0.04*** | **+0.04*** |
| Meghalaya | **+0.02*** | +0.01 | NT | -0.01 | NT | **+0.01*** | NT | NT | NT | +0.01 | **+0.02*** | **+0.01*** |
| Mizoram | **+0.03*** | NT | **-0.02*** | **-0.02*** | **+0.01*** | **+0.02*** | +0.01 | **+0.03*** | **+0.02*** | **+0.01*** | **+0.04*** | **+0.03*** |
| Orissa | NT | NT | NT | -0.01 | **-0.02*** | **-0.02*** | NT | **-0.01*** | NT | NT | **+0.01*** | NT |
| Punjab | **-0.02*** | -0.01 | -0.01 | +0.01 | +0.01 | **-0.03*** | -0.01 | NT | **-0.02*** | -0.01 | +0.01 | -0.01 |
| Rajasthan | +0.01 | +0.02 | **+0.02*** | **+0.03*** | **+0.02*** | NT | NT | +0.01 | **+0.01*** | **+0.02*** | **+0.02*** | **+0.01*** |
| Sikkim | **+0.05*** | **+0.05*** | **+0.04*** | **+0.04*** | **+0.05*** | **+0.05*** | **+0.04*** | **+0.05*** | **+0.05*** | **+0.05*** | **+0.04*** | **+0.05*** |
| Tamil Nadu | **+0.03*** | **+0.03*** | **+0.03*** | **+0.03*** | **+0.02*** | **+0.02*** | **+0.03*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | **+0.03*** |
| Tripura | +0.01 | +0.01 | -0.01 | **-0.02*** | -0.01 | **+0.02*** | **+0.01*** | **+0.02*** | **+0.01*** | **+0.02*** | **+0.03*** | **+0.03*** |
| Uttar Pradesh | -0.01 | +0.01 | NT | NT | **-0.02*** | **-0.02*** | NT | **+0.01*** | NT | +0.01 | **+0.02*** | +0.01 |
| Uttarakhand | +0.01 | NT | -0.01 | -0.01 | **-0.03*** | **-0.04*** | **-0.01*** | -0.01 | -0.01 | NT | **+0.01*** | **+0.02*** |
| West Bengal | -0.01 | NT | NT | -0.01 | -0.01 | NT | **+0.01*** | **+0.01*** | NT | +0.01 | **+0.02*** | **+0.02*** |

## TABLE 10

State level monthly mean diurnal temperature range (DTR) trends based upon 282 surface meteorological stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign. No trend is indicated by abbreviation NT.

| | Monthly mean DTR trends in °C per year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Andaman & Nicobar | **+0.02*** | +0.01 | +0.01 | **0.01*** | 0.01 | **0.02*** | **0.02*** | **+0.02*** | **+0.02*** | **+0.02*** | +0.01 | **+0.02*** |
| Andhra Pradesh | +0.01 | NT | NT | **0.01*** | **0.01*** | 0.01 | **0.01*** | +0.01 | **+0.01*** | +0.01 | NT | **+0.02*** |
| Arunachal Pradesh | NT | +0.01 | **-0.03*** | **-0.04*** | NT | **-0.02*** | **-0.02*** | -0.02 | -0.01 | -0.01 | -0.01 | NT |
| Assam | -0.01 | -0.01 | **-0.02*** | **-0.03*** | 0.01 | 0.01 | NT | NT | NT | +0.01 | NT | NT |
| Bihar | **-0.04*** | **-0.04*** | **-0.03*** | **-0.03*** | **-0.03*** | NT | NT | **+0.01*** | +0.01 | NT | **-0.02*** | **-0.03*** |
| Chhattisgarh | +0.02 | NT | **+0.02*** | **0.02*** | **0.02*** | 0.01 | **0.01*** | **+0.01*** | **+0.02*** | **+0.02*** | NT | +0.01 |
| Delhi | **-0.03*** | **-0.03*** | **-0.02*** | NT | **-0.02*** | -0.01 | -0.01 | +0.01 | -0.01 | -0.01 | **-0.02*** | **-0.02*** |
| Goa | **+0.05*** | **+0.06*** | **+0.05*** | **0.05*** | **0.05*** | **0.03*** | **0.02*** | **+0.03*** | **+0.02*** | **+0.04*** | **+0.03*** | **+0.06*** |
| Gujarat | **-0.02*** | **-0.03*** | **-0.02*** | **-0.01*** | **-0.02*** | NT | NT | NT | NT | -0.02 | **-0.02*** | **-0.02*** |
| Haryana | **-0.05*** | **-0.04*** | **-0.03*** | NT | **-0.02*** | -0.02 | **-0.01*** | NT | -0.01 | -0.01 | **-0.02*** | **-0.04*** |
| Himachal Pradesh | **+0.10*** | **+0.09*** | **+0.11*** | **0.10*** | **0.09*** | **0.07*** | **0.05*** | **+0.05*** | **+0.07*** | **+0.10*** | **+0.10*** | **+0.10*** |
| Jammu & Kashmir | **+0.03*** | +0.01 | +0.01 | **0.03*** | **0.02*** | -0.01 | -0.01 | NT | +0.01 | **+0.04*** | **+0.03*** | +0.02 |
| Jharkhand | **+0.03*** | NT | +0.01 | **0.01*** | -0.02 | -0.01 | NT | +0.01 | NT | +0.02 | +0.01 | **+0.02*** |
| Karnataka | **+0.03*** | **+0.03*** | **+0.02*** | **0.02*** | **0.02*** | **0.02*** | **0.02*** | **+0.02*** | **+0.01*** | **+0.02*** | +0.01 | **+0.03*** |
| Kerala | NT | +0.01 | **+0.01*** | 0.01 | **0.01*** | **0.02*** | **0.02*** | **+0.02*** | **+0.01*** | **+0.02*** | NT | +0.01 |
| Lakshadweep | NT | NT | NT | **0.01*** | **0.02*** | **0.01*** | **0.01*** | **+0.02*** | **+0.01*** | **+0.01*** | NT | NT |
| Madhya Pradesh | -0.01 | -0.01 | NT | **0.01*** | 0.01 | 0.01 | 0.02 | **+0.02*** | **+0.02*** | NT | **-0.03*** | NT |
| Maharashtra | **+0.02*** | +0.01 | **+0.01*** | **+0.03*** | **+0.02*** | +0.02 | +0.01 | **+0.01*** | +0.01 | **+0.02*** | NT | **+0.02*** |
| Manipur | +0.01 | +0.01 | -0.02 | **-0.03*** | +0.01 | +0.01 | +0.01 | **+0.02*** | +0.01 | +0.01 | NT | -0.01 |
| Meghalaya | -0.01 | -0.01 | NT | -0.01 | NT | NT | NT | NT | NT | NT | NT | -0.01 |
| Mizoram | **+0.03*** | **+0.04*** | **+0.02*** | **+0.02*** | **+0.03*** | **+0.03*** | **+0.03*** | **+0.05*** | **+0.05*** | **+0.06*** | **+0.06*** | **+0.04*** |
| Orissa | **+0.02*** | +0.02 | **+0.02*** | **+0.03*** | **+0.03*** | **+0.02*** | **+0.03*** | **+0.03*** | **+0.03*** | **+0.04*** | +0.01 | **+0.02*** |
| Punjab | -0.01 | -0.02 | -0.01 | +0.02 | NT | **-0.03*** | **-0.02*** | NT | -0.01 | NT | NT | -0.01 |
| Rajasthan | **-0.02*** | -0.01 | NT | **+0.01*** | NT | **+0.01*** | +0.01 | **0.01*** | +0.01 | NT | -0.02 | -0.01 |
| Sikkim | **-0.06*** | **-0.04*** | **-0.06*** | **-0.04*** | **-0.03*** | -0.02 | **-0.03*** | **-0.03*** | **-0.03*** | **-0.06*** | **-0.09*** | **-0.07*** |
| Tamil Nadu | **+0.02*** | +0.01 | +0.01 | **+0.01*** | **+0.01*** | **+0.01*** | **+0.02*** | **0.01*** | NT | NT | NT | +0.01 |
| Tripura | **-0.04*** | **-0.04*** | **-0.04*** | **-0.03*** | -0.01 | NT | NT | **0.01*** | NT | -0.01 | **-0.02*** | **-0.03*** |
| Uttar Pradesh | **-0.03*** | **-0.03*** | -0.01 | +0.01 | -0.02 | +0.01 | +0.01 | **0.02*** | +0.01 | -0.01 | **-0.03*** | **-0.02*** |
| Uttarakhand | **+0.03*** | **+0.03*** | **+0.03*** | **+0.03*** | **+0.02*** | **+0.03*** | **+0.05*** | **0.05*** | **+0.04*** | **+0.04*** | **+0.03*** | **+0.03*** |
| West Bengal | -0.01 | **-0.02*** | **-0.02*** | -0.01 | +0.01 | +0.01 | **+0.02*** | **0.02*** | **+0.02*** | +0.01 | NT | -0.01 |

## TABLE 11

State level trends in monthly rainfall based upon 1451 rainfall stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with '*' sign. No trend is indicated by abbreviation NT.

| | Monthly rainfall trends in mm per year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Andaman & Nicobar | **-0.94*** | -0.25 | +0.07 | -0.17 | -0.84 | **-1.91*** | -0.42 | -0.20 | -0.32 | -1.27 | -0.29 | -0.75 |
| Andhra Pradesh | +0.05 | +0.07 | +0.08 | +0.02 | +0.13 | -0.14 | -0.42 | +0.35 | NT | -0.16 | +0.53 | +0.11 |
| Arunachal Pradesh | -0.29 | -0.05 | +0.49 | +0.86 | -2.19 | -0.82 | +0.06 | -3.29 | +0.26 | -0.88 | -0.09 | -0.13 |
| Assam | -0.09 | +0.16 | +0.14 | +0.75 | **-1.46*** | **-1.59*** | -0.55 | -0.62 | -0.14 | -0.47 | -0.11 | -0.04 |
| Bihar | -0.12 | +0.03 | -0.06 | +0.04 | **+0.59*** | +0.54 | +0.69 | -0.06 | -0.33 | +0.12 | NT | NT |
| Chhattisgarh | +0.02 | -0.03 | NT | -0.14 | **+0.31*** | +0.53 | -1.04 | **-1.78*** | -0.45 | -0.24 | **+0.11** | NT |
| Delhi | -0.16 | **+0.21*** | -0.03 | +0.02 | **+0.38*** | **+0.88*** | -1.11 | -0.56 | +0.16 | -0.13 | NT | NT |
| Goa | NT | NT | NT | -0.07 | -0.17 | -0.70 | -2.91 | +0.14 | -0.20 | +0.46 | -0.16 | NT |
| Gujarat | NT | NT | NT | NT | -0.01 | +0.44 | +0.55 | +0.67 | -0.54 | +0.02 | NT | NT |
| Haryana | -0.12 | +0.13 | -0.02 | +0.02 | **+0.26*** | **0.57*** | +0.04 | -0.73 | +0.34 | **-0.11*** | NT | NT |
| Himachal Pradesh | **-0.69*** | +0.44 | +0.05 | +0.07 | +0.21 | +0.48 | **-1.72*** | -1.04 | -0.24 | -0.10 | +0.01 | -0.03 |
| Jammu & Kashmir | +0.78 | -0.16 | -0.86 | -0.20 | -0.35 | -0.02 | +0.09 | -0.36 | -0.20 | -0.35 | -0.21 | -0.63 |
| Jharkhand | -0.10 | -0.04 | -0.02 | +0.05 | **+0.42*** | +0.32 | -0.15 | -0.15 | -0.17 | NT | +0.04 | +0.02 |
| Karnataka | **+0.01*** | NT | +0.02 | -0.11 | **-0.58*** | +0.35 | -1.02 | +0.58 | +0.31 | NT | +0.21 | +0.02 |
| Kerala | -0.04 | -0.11 | +0.03 | -0.22 | -1.11 | -1.28 | -1.21 | -0.41 | +0.12 | +0.89 | +0.83 | -0.22 |
| Lakshadweep | +0.03 | -0.07 | NT | -0.31 | -0.70 | +0.49 | +1.22 | +1.01 | +0.09 | -0.24 | +0.77 | +0.01 |
| Madhya Pradesh | -0.12 | +0.01 | -0.03 | -0.01 | +0.03 | +0.26 | +0.25 | -0.69 | -0.56 | +0.04 | +0.03 | +0.01 |
| Maharashtra | NT | **+0.02*** | NT | -0.07 | -0.07 | +0.89 | -0.91 | +0.70 | +0.27 | +0.03 | -0.03 | NT |
| Manipur | -0.05 | -0.04 | +0.39 | +0.58 | +0.62 | **-1.45*** | -0.30 | -0.18 | +0.68 | +0.03 | +0.05 | NT |
| Meghalaya | -0.03 | **+0.48*** | +0.69 | **+2.15*** | -2.27 | -0.27 | +6.46 | +0.54 | +0.12 | +1.39 | +0.02 | -0.02 |
| Mizoram | NT | -0.35 | -0.77 | -1.97 | +4.68 | +5.53 | +0.70 | +0.38 | -1.49 | -4.53 | -0.97 | -0.13 |
| Nagaland | -0.12 | +0.04 | NT | +0.38 | NT | **-1.38*** | -0.72 | NT | +0.17 | +0.38 | -0.05 | NT |
| Orissa | +0.01 | -0.07 | -0.05 | +0.13 | **+0.50*** | +0.46 | -0.49 | -0.24 | -0.53 | -0.78 | +0.17 | NT |
| Punjab | -0.21 | +0.32 | -0.12 | +0.08 | +0.10 | **+0.51*** | -0.64 | -0.92 | +0.12 | -0.04 | NT | -0.03 |
| Rajasthan | -0.03 | +0.02 | NT | +0.02 | +0.09 | +0.39 | +0.27 | -0.37 | -0.12 | -0.03 | -0.01 | NT |
| Sikkim | -0.30 | +0.04 | +0.26 | **+3.51*** | -3.16 | -0.19 | -1.17 | +0.12 | -1.45 | -0.01 | +0.21 | -0.05 |
| Tamil Nadu | -0.01 | NT | +0.03 | -0.26 | -0.36 | -0.27 | **-0.65*** | -0.48 | -0.10 | -0.18 | **+1.54** | +0.13 |
| Tripura | -0.04 | +0.06 | NT | +0.32 | +1.47 | -0.87 | -0.27 | -0.41 | +0.43 | -0.10 | -0.15 | NT |
| Uttar Pradesh | **-0.24*** | +0.04 | -0.09 | +0.01 | **+0.15*** | +0.20 | -0.72 | **-1.88*** | -0.54 | -0.24 | +0.01 | NT |
| Uttarakhand | -0.53 | +0.49 | -0.10 | +0.40 | +0.62 | +0.60 | -1.71 | -0.41 | +0.39 | -0.42 | NT | -0.01 |
| West Bengal | NT | +0.08 | -0.01 | **+0.44*** | **+0.77*** | +0.06 | +0.96 | NT | +0.33 | +0.04 | +0.03 | +0.02 |