

Study of Changes in Climate Parameters at Regional Level: Indian Scenarios

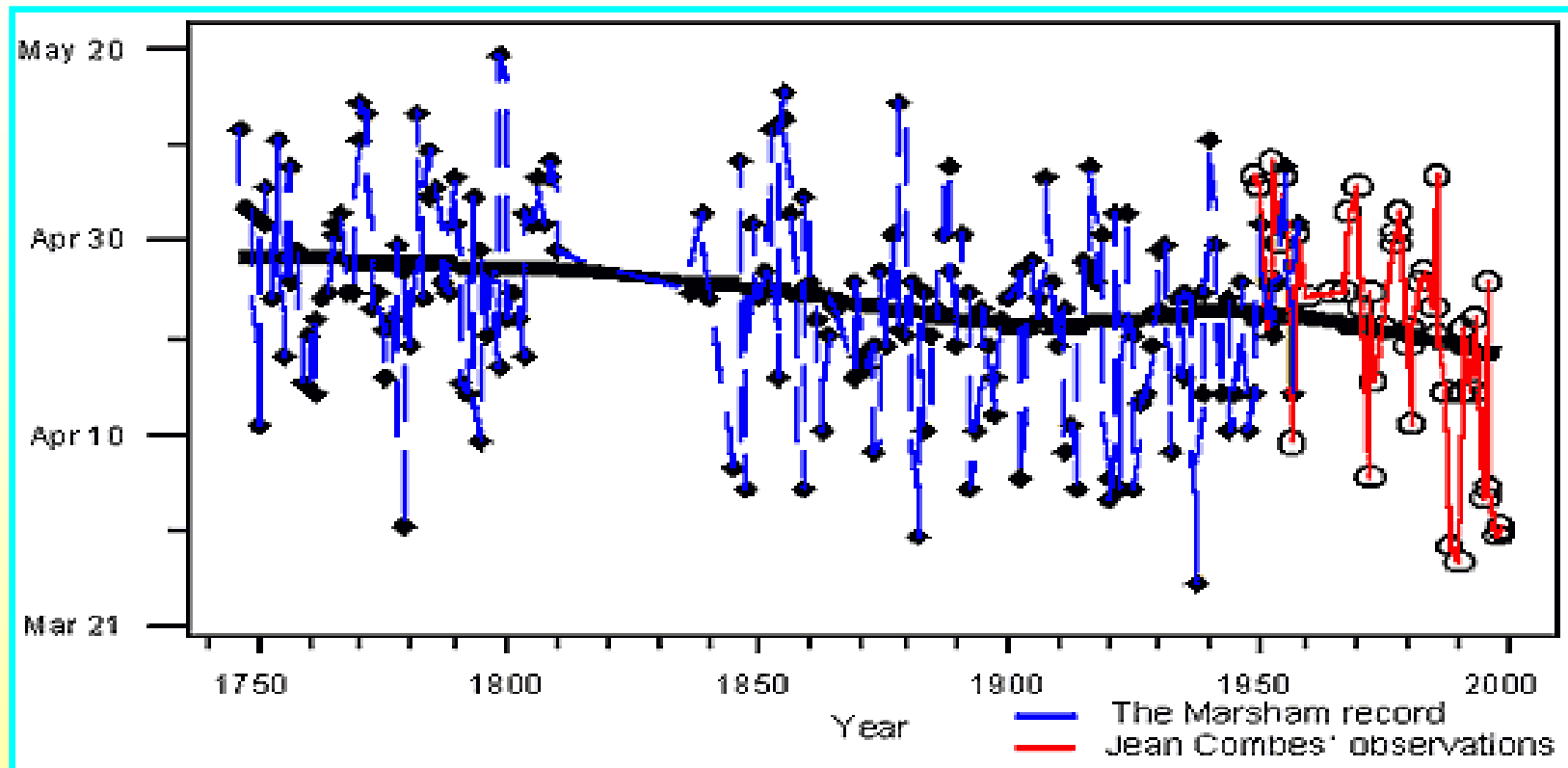
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Indian Institute of Technology Delhi

HABITAT OF THE GOLDEN TOAD



Climate Change and Animal Populations - The golden toad, last seen in Costa Rica's cloud forest in 1989, is believed to be extinct. The ecology of the cloud forest depends on the frequent formation of clouds and mist. Warming of the oceans and atmosphere has contributed to declines in mist formation. This has, in turn, affected species native to the area



Leafing Dates of Oak (1746–present) - This graph shows how the leafing dates of oaks in southeastern England have changed over the past 256 years.

What climate information is available and what can be done?

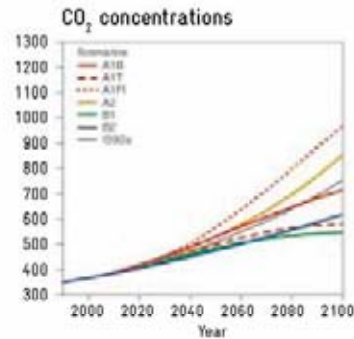
- *Climate science has grown using historical observed data and model output.*
- ***Past temperature and rainfall at several places are available from number of sources.***
- ***Climate models also give the future values into the next century.***
- ***The above information can be utilized to know the future state of climate.***

Challenging Future!

Connecting climate change and societal parameters:

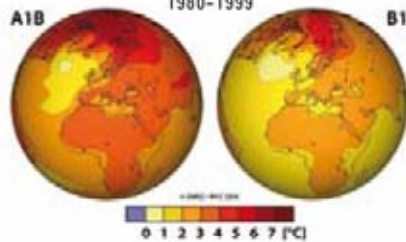
- Extreme rainfall events to the area and number of people to be affected by flood.
- Change in land use pattern to increase in temperature.
- Increase in temperature to enhanced use of power.
- Extreme temperature and rainfall events and air pollution to health issues such as heat stress, lungs, heart and water diseases.

Vulnerability assessments need to involve a cascade of analytical steps

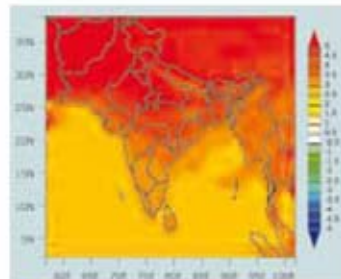


Global emissions scenarios

Temperature Change for 2080-2099 compared with 1980-1999



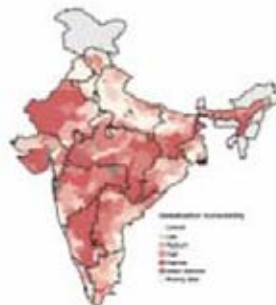
Global Climate Models
(23 in IPCC)



Regional Climate Models

Knowledge from Historical Events →

Local Knowledge and Experiences →



Impact,
Vulnerability
& Adaptation
Analysis

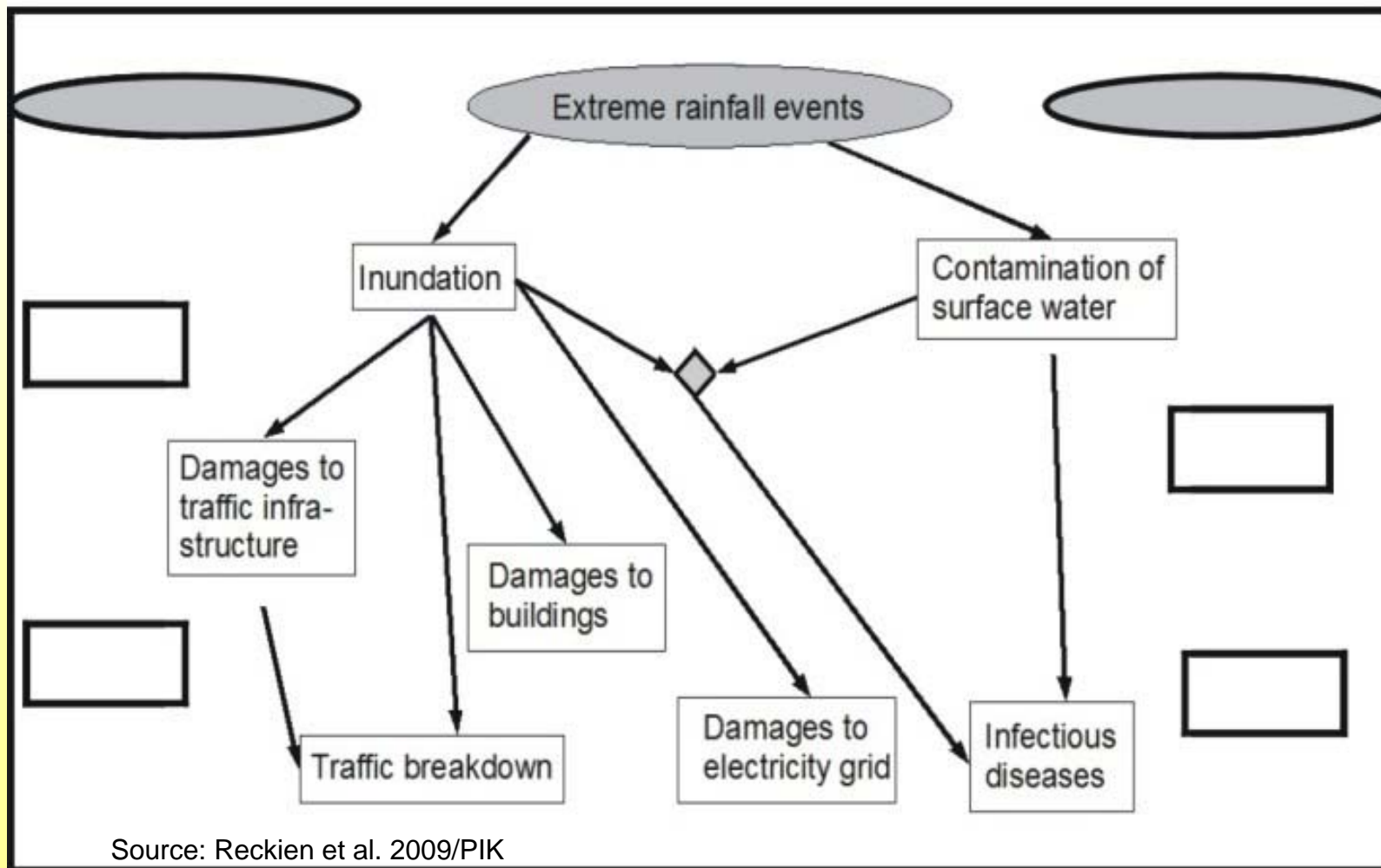
For a management of future risks

...you need to understand mechanisms
...you need to identify intervention points
...you need to know where are the hot spots located

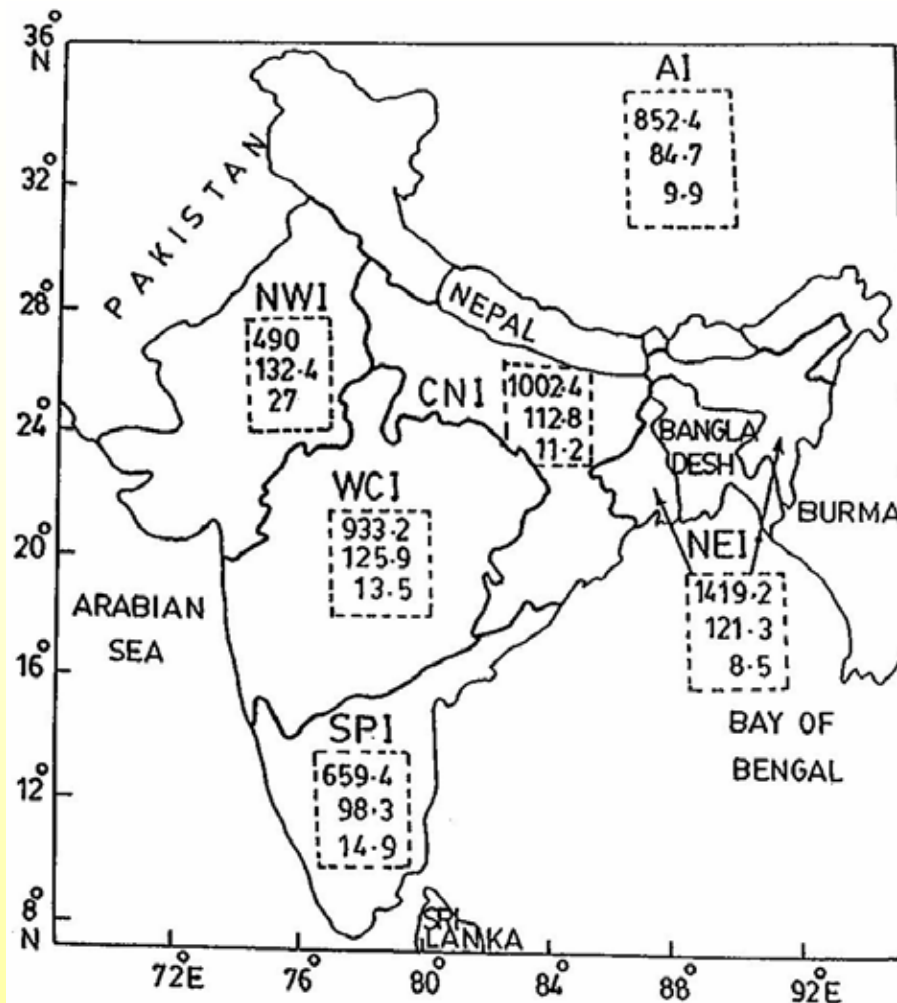
Climate Impact Science **cannot** provide planning tools.
Climate Impact Science **can** outline potential options and their potential effectiveness.

**Impact chains are useful for the analysis
of effects: starting points for action and transformation**

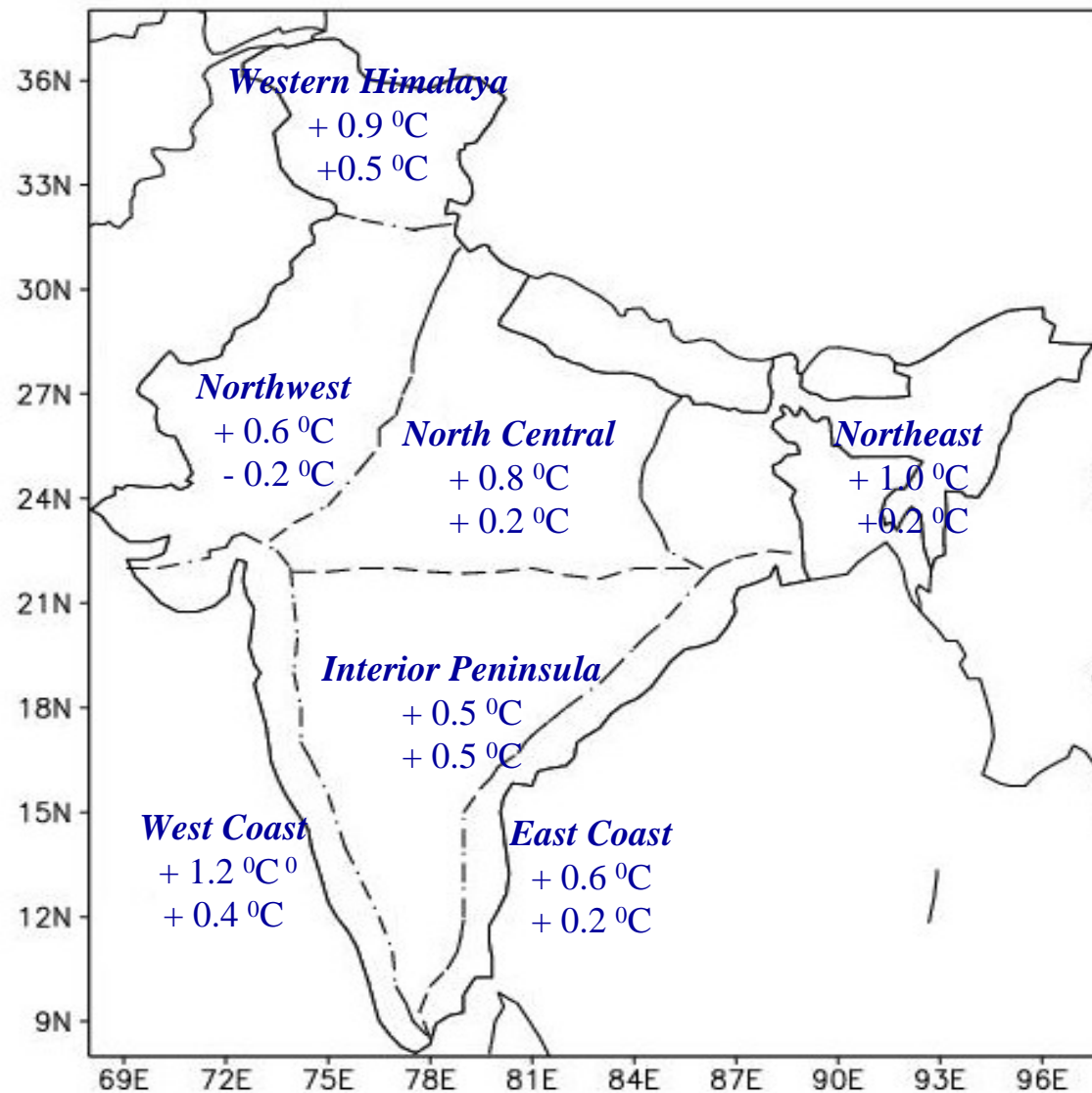
Impact Paths Network



Source: Reckien et al. 2009/PIK



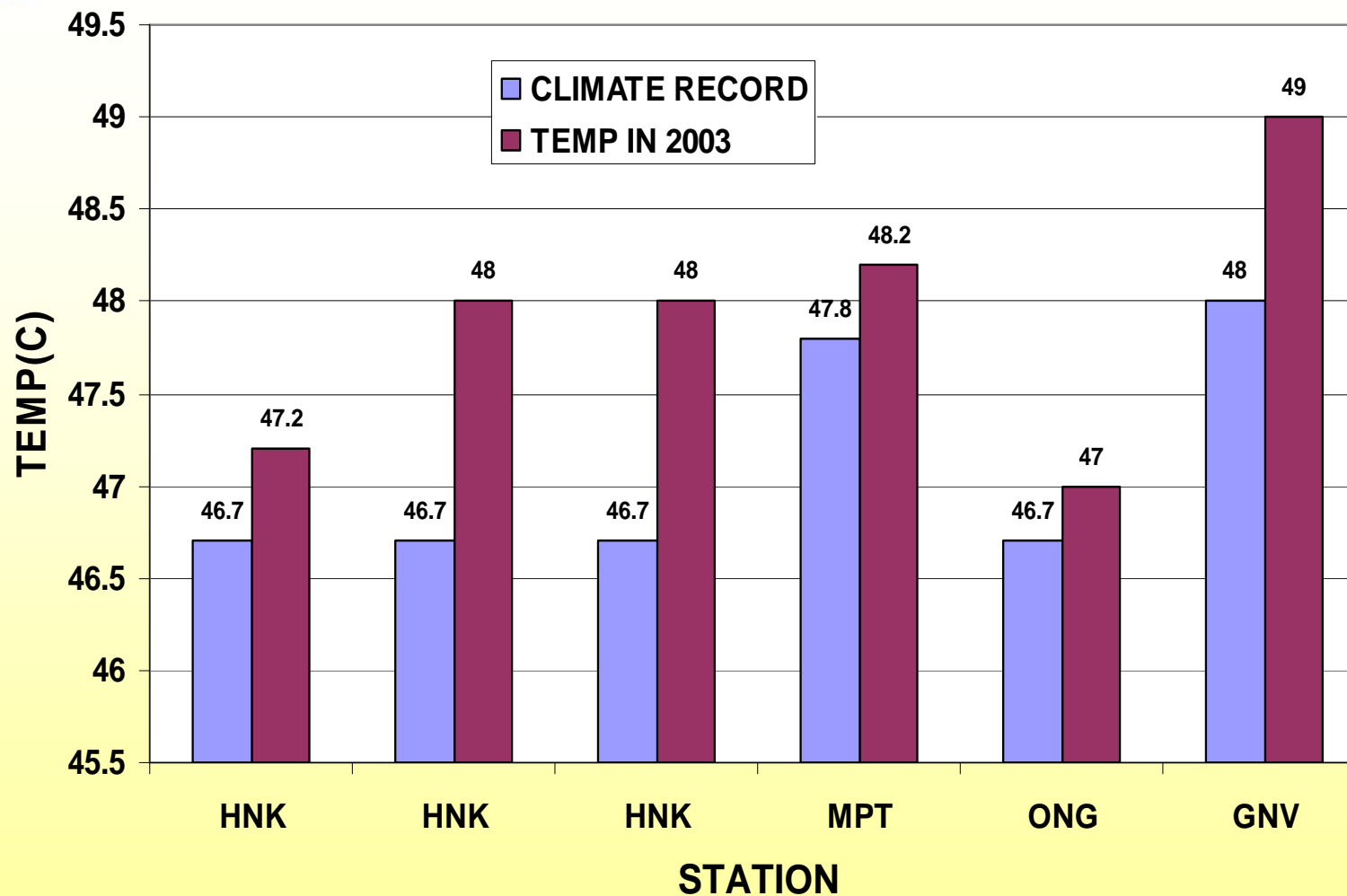
Homogeneous rainfall zones of India. The numbers inside the zones indicate mean monsoon rainfall (mm), standard deviation (mm) and coefficient of variation (%) from top to bottom respectively



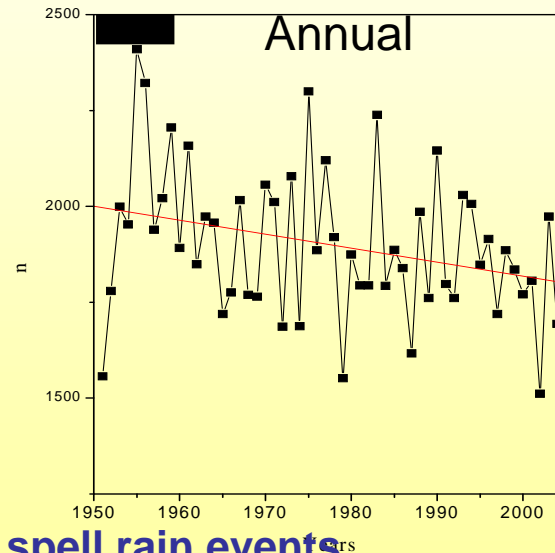
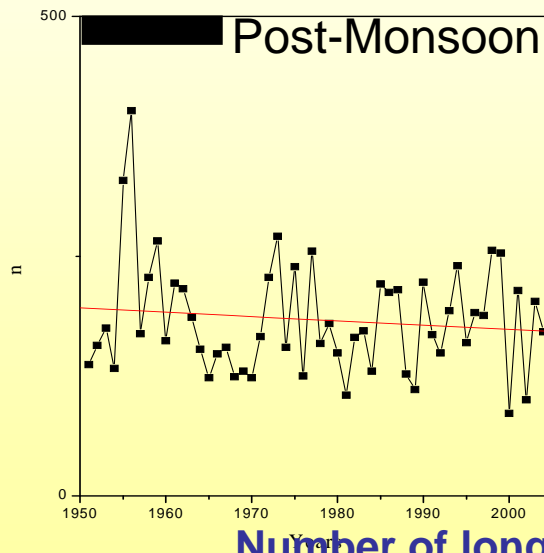
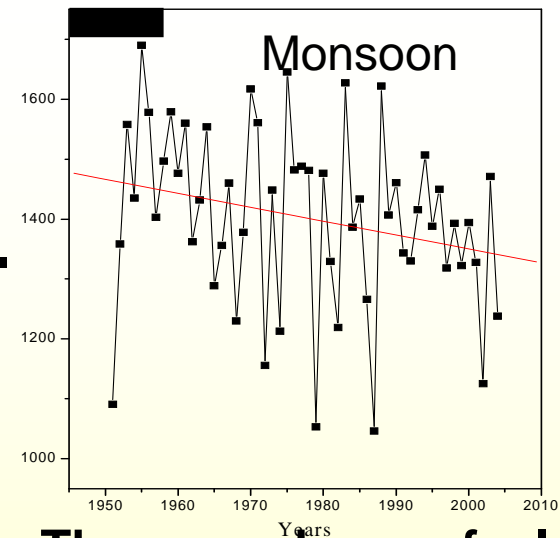
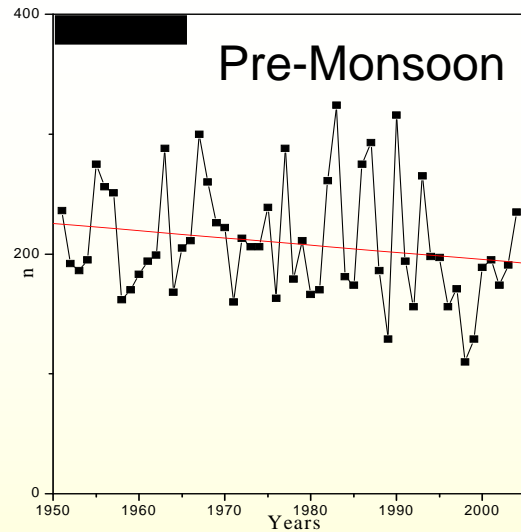
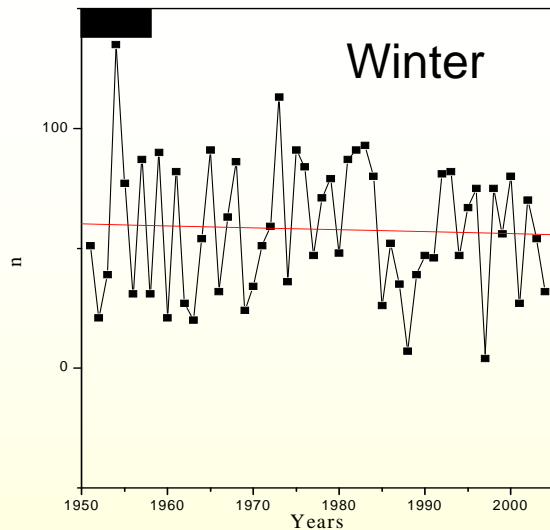
Changes in the maximum and minimum temperatures in different temperature zones during the last century. The upper numbers indicate maximum and lower ones represent minimum temperatures. Also + sign is for an increase and – is for decrease. The map of seven zones has been obtained from <http://www.tropmet.res.in>

Surface air temperature ($^{\circ}\text{C}$) changes during different seasons averaged over the whole of India (+ sign indicates an increase and – represents decrease)

| Months | Mean ($^{\circ}\text{C}$) | Maximum ($^{\circ}\text{C}$) | Minimum ($^{\circ}\text{C}$) |
|--|---|--|--|
| Jan & Feb (Winter) | +1.0 | +1.0 – +1.2 | +0.2 – +0.7 |
| March-May (Pre-monsoon) | +0.3 | +0.6 – +0.8 | - 0.1 – +0.2 |
| June- September | +0.4 | +0.4 – +0.6 | -0.2 – +0.4 |
| October- December (Post- monsoon) | +1.1 | +1.1 – +1.3 | +0.6 – +0.8 |

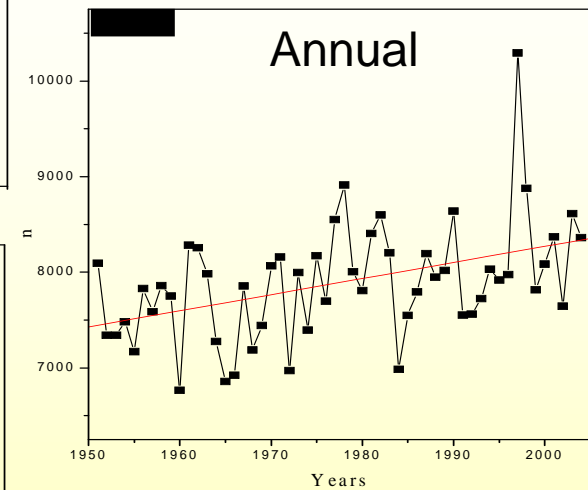
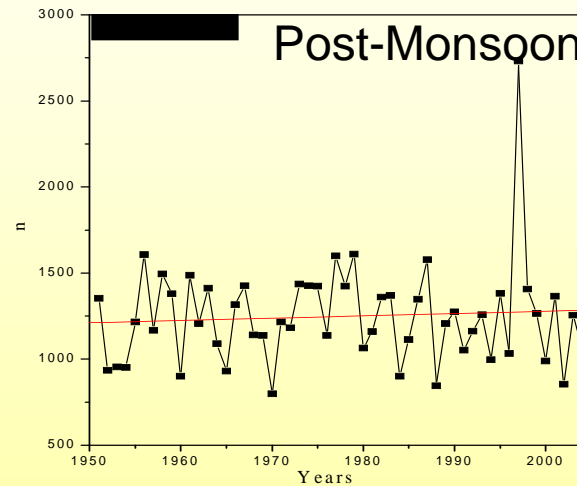
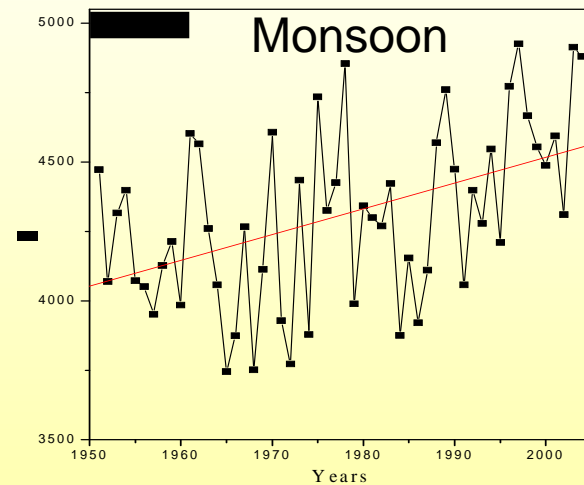
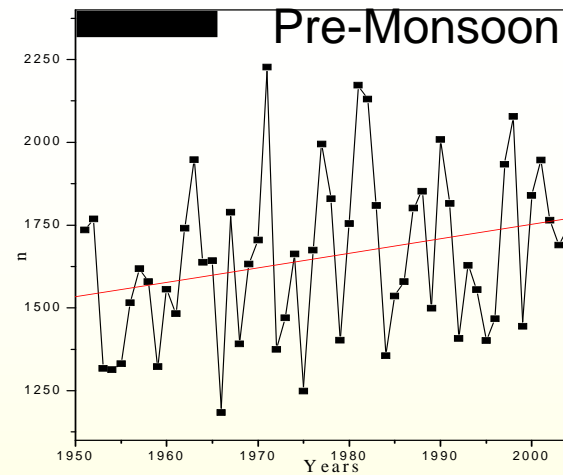
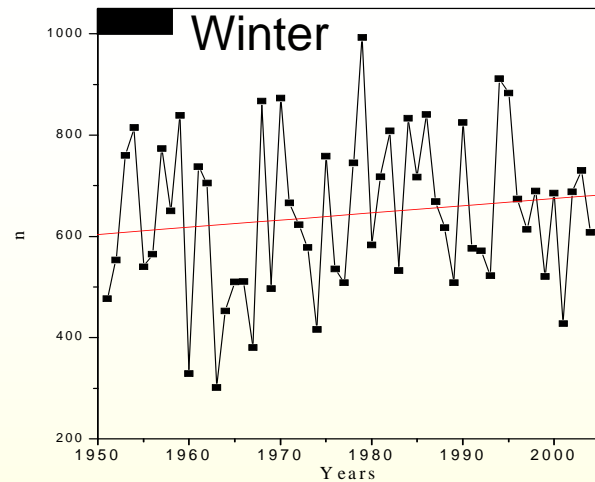


Highest maximum temperature recorded at some stations during heat wave of Andhra Pradesh in May & June 2003 and the earlier recorded highest maximum temperature.



The number of long spell rainfall events shows decreasing trend in monsoon season in last 54 years. This suggests that planetary scale motions, may be southwest monsoon over the country is weakening.

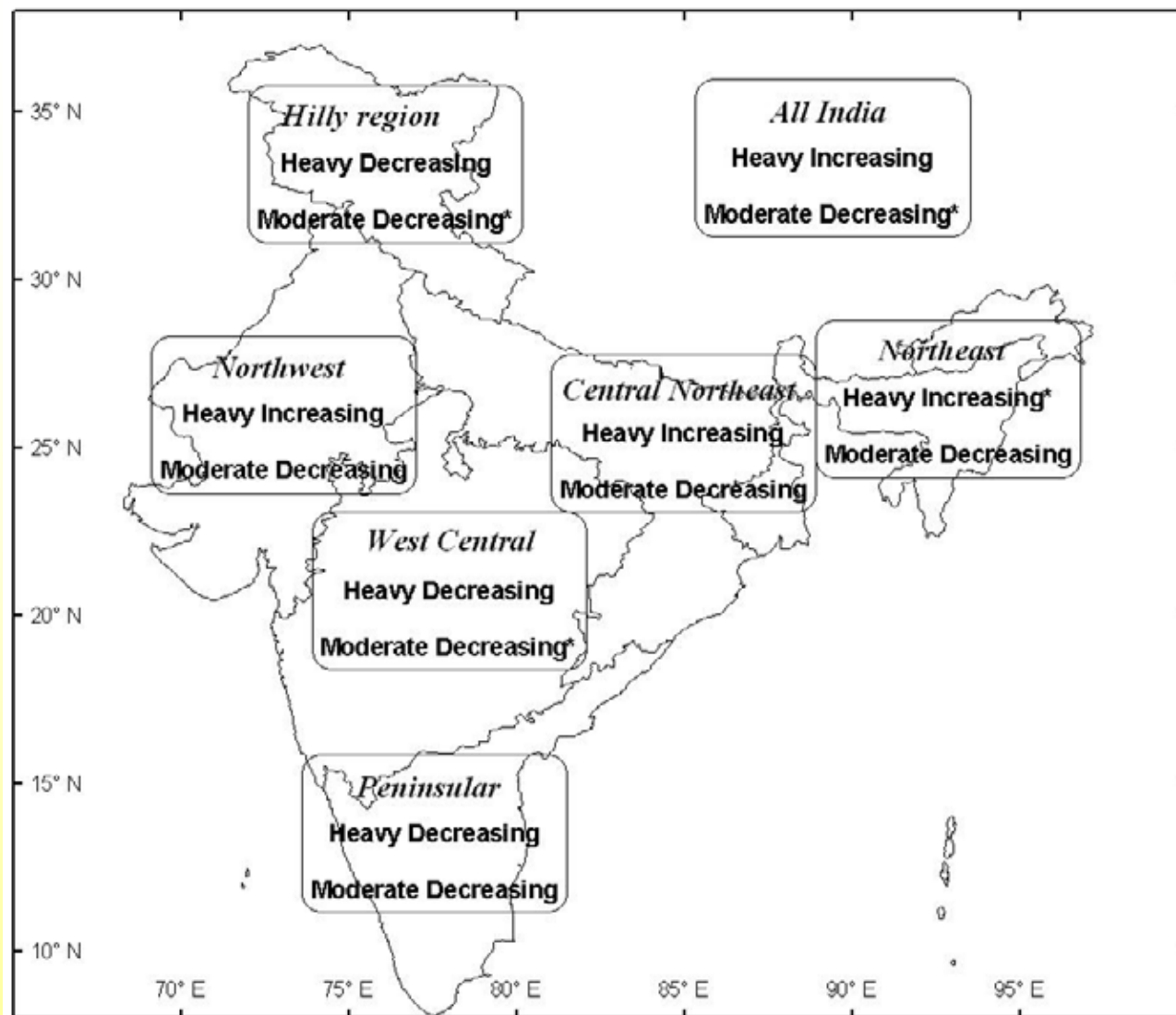
**Number of long spell rain events.
Continuous rainfall for ≥ 4 days over all India
in different seasons.
The red line is linear trend line.**



Number of short spell rain events (Continuous rainfall for < 4 days) over all India in different seasons. The red line is linear trend line.

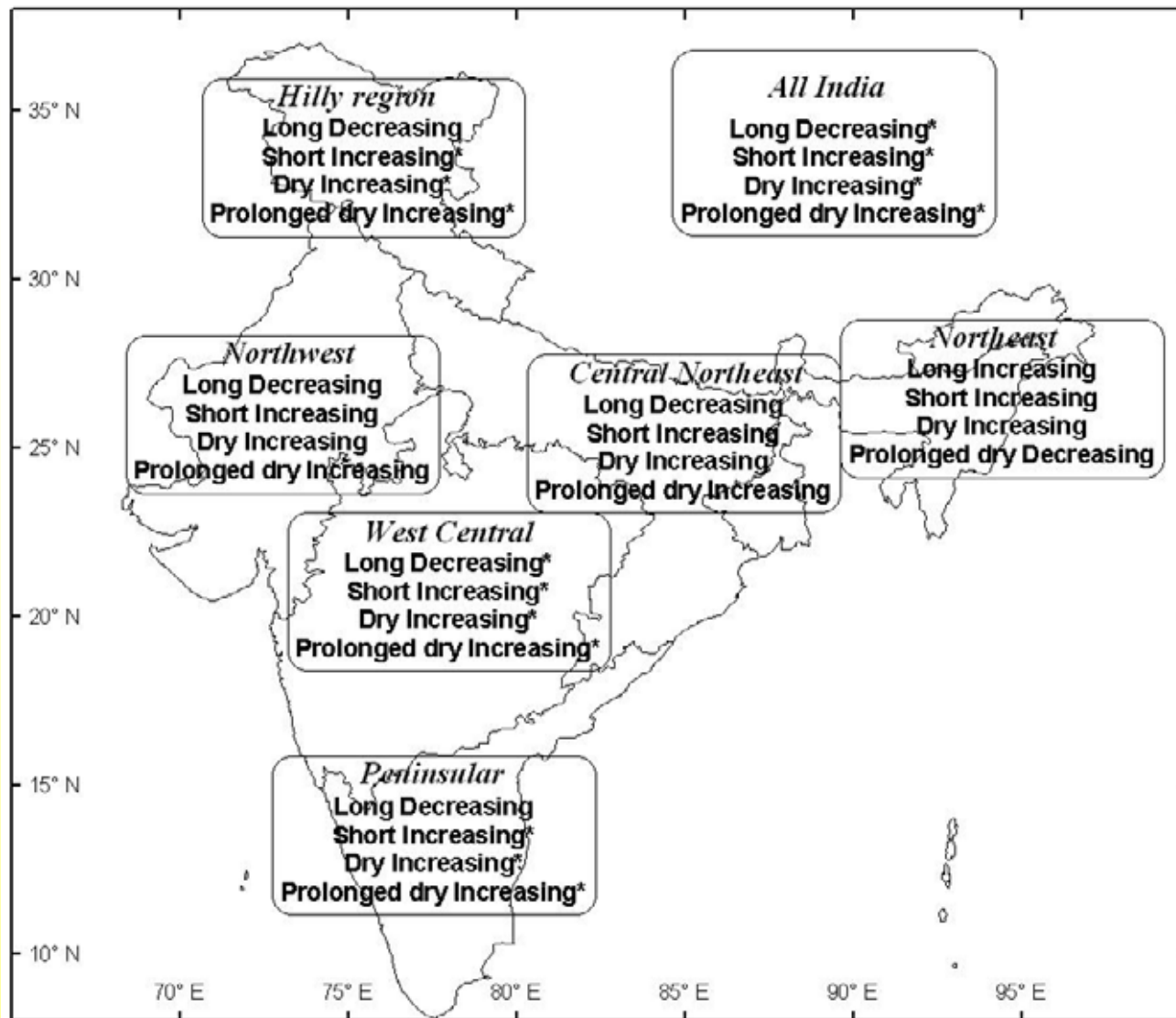
Short spell rainfall events over India show increasing trend. This is an indication of increasing or intensifying of meso-scale convections.

Dash et al. 2009 J. Geophys. Res. Vol. 114



Summary of trends in heavy and moderate rain events in different Indian regions for the summer monsoon season. Asterisks denote significant trend at 5% level.

Dash et al. 2009 J. Geophys. Res. Vol.114



Summary of trends in long, short, dry and prolonged dry spells of rainfall in different Indian regions for the monsoon season. Asterisks denote significant trend at 5% level.

Extreme temperature indices used



| Temperature Indices | Names | Definitions |
|---------------------|---------------------------|---|
| TX90p, TX95p, TX99p | Warm days | Count of days where maximum temperature TX > 90 th , 95 th and 99 th percentile respectively |
| TN90p, TN95p, TN99p | Warm nights | Count of days where minimum temperature TN > 90 th , 95 th and 99 th percentile respectively |
| TX10p, TX05p, TX01p | Cold days | Count of days where maximum temperature TX < 10 th , 5 th and 1 th percentile respectively |
| TN10p, TN05p, TN01p | Cold nights | Count of days where minimum temperature TN < 10 th , 5 th and 1 th percentile respectively |
| WSDI | Warm Spell Duration Index | Count of events where maximum temperature TX > 90 th percentile for at least six days continuously |
| CSDI | Cold Spell Duration Index | Count of events where minimum temperature TN < 10 th percentile for at least six nights continuously |

IETCCDI Klein Tank et al. (2009) <http://www.clivar.org/organization/etccdi/etccdi.php>

Summary of trends in annual and seasonal means of maximum and minimum temperatures with trends in different categories of warm days and nights in summer

| Regions | Mean of Maximum Temperature | | | Categories of Warm Days | | | Mean of Minimum Temperature | | | Categories of Warm Nights | | |
|---------|-----------------------------|-----|------|-------------------------|-------|-------|-----------------------------|-----|------|---------------------------|-------|--------|
| | Annual | MAM | JJAS | TX90p | TX95p | TX99p | Annual | MAM | JJAS | TN90p | TN95p | TN99p |
| AI | ▲ | | ▲ | | | DL▲ | ▲ | ▲ | ▲ | | | |
| WH | | | | | | | △ | | △ | | | |
| NW | ▲ | | | | | | ▲ | △ | ▲ | ▲, DL△ | ▲ | ▲ |
| NC | | | | SS▲ | | | ▲ | | | | | |
| NE | | ▽ | | SS▽ | | | ▲ | ▲ | ▲ | ▲ | ▲ | |
| WC | ▲ | △ | ▲ | WSDI△, SS▽ | | DL△ | ▲ | | ▲ | | | △, DL△ |
| IP | △ | | | WSDI△ | △ | | | | | | | △ |
| EC | △ | | | | | | △ | | △ | | | |

DL-Decadal WSDI-Warm Spell Duration Index SS-Short Spells

Summary of trends in annual and seasonal mean of maximum and minimum temperatures with trends in different categories of cold days and nights in winter

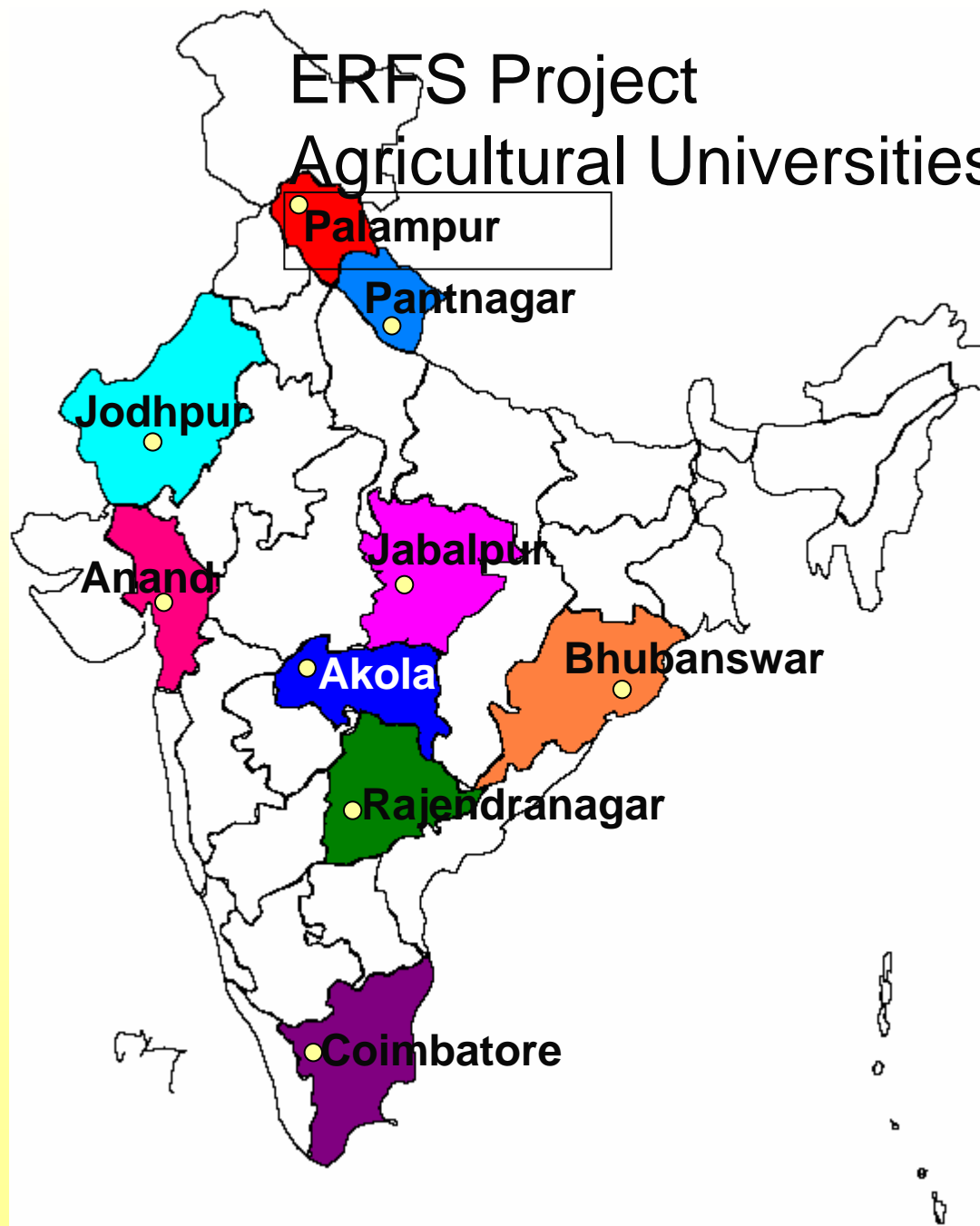
| Regions | Mean of Maximum Temperature | | | Categories of Cold Days | | | Mean of Minimum Temperature | | | Categories of Cold Nights | | |
|---------|-----------------------------|----|-----|-------------------------|--------|--------|-----------------------------|----|-----|---------------------------|--------|-------|
| | Annual | ON | DJF | TX10p | TX05p | TX01p | Annual | ON | DJF | TN10p | TN05p | TN01p |
| AI | ▲ | | | DL▲ | DL▲ | | ▲ | ▲ | ▲ | ▼, SS▼ | ▼ | ▼ |
| WH | | | | DL▼ | ▼, DL▼ | | ▲ | | ▲ | | | |
| NW | ▲ | | | | | | ▲ | ▲ | ▲ | ▼, DL▼, SS▼ | ▼, DL▼ | ▼ |
| NC | | | | ▲ | ▲ | ▲, DL▲ | ▲ | | ▲ | ▼, SS▼ | ▼, DL▼ | ▼ |
| NE | | | | ▲, DL▲ | | | ▲ | ▲ | ▲ | ▼, DL▼, SS▼ | | |
| WC | ▲ | ▲ | ▲ | ▼ | ▼ | | ▲ | | ▲ | ▼, CSDI▼, SS▼ | ▼ | ▼ |
| IP | ▲ | | ▲ | | | | | | | | | |
| EC | ▲ | | ▲ | ▼ | ▼ | | ▲ | | | | ▼ | ▼ |

DL-Decadal CSDI-Cold Spell Duration Index SS-Short Spells

Classification of Rain Events

- HL: High intensity Long spell
- ML: Moderate intensity Long spell
- LL: Low intensity Long spell
- HS: High intensity Short spell
- MS: Moderate intensity Short spell
- LS: Low intensity Short spell

ERFS Project Agricultural Universities



Trends in the contributions of heavy, moderate, and low-intensity rainfall categories to total respective rainfall in All India, homogeneous zones, and agro-met divisions

| Regions | Heavy | | | | | Moderate | | | | | Low | | | | |
|---------------------------|-------|---|---|---|------|----------|---|---|---|------|-----|---|---|---|------|
| | J | J | A | S | JJAS | J | J | A | S | JJAS | J | J | A | S | JJAS |
| Homogeneous zones | | | | | | | | | | | | | | | |
| AI | ▲ | ▲ | ● | ● | ▲ | ▼ | ▼ | ● | ● | ▼ | ● | ● | ● | ● | ● |
| PI | ▲ | ■ | ■ | ▲ | ● | ▼ | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| WCI | ▲ | ● | ● | ● | ▲ | ● | ● | ● | ● | ▼ | ● | ● | ● | ● | ● |
| NWI | ▲ | ■ | ■ | ● | ▲ | ● | ● | ▼ | ● | ▼ | ▼ | ● | ● | ● | ● |
| NEI | ▲ | ▲ | ▲ | ● | ▲ | ▼ | ▼ | ▼ | ● | ▼ | ● | ▼ | ▼ | ● | ▼ |
| Hilly | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| CNEI | ● | ▲ | ▲ | ● | ▲ | ● | ▼ | ● | ● | ▼ | ● | ● | ● | ● | ● |
| Agro-met divisions | | | | | | | | | | | | | | | |
| HP | ● | ● | ● | ● | ● | ● | ● | ▲ | ● | ▲ | ● | ● | ● | ● | ● |
| Uttarakhand | ● | ▲ | ▲ | ● | ▲ | ● | ● | ● | ● | ▼ | ● | ● | ● | ● | ● |
| Gujarat | ● | ● | ● | ● | ● | ● | ● | ● | ● | ▼ | ▼ | ● | ● | ● | ▼ |
| WR | ● | ● | ● | ● | ● | ▲ | ● | ▼ | ● | ● | ▼ | ● | ● | ● | ● |
| Orissa | ▲ | ● | ● | ● | ● | ● | ● | ● | ● | ● | ▼ | ● | ● | ● | ● |
| Telangana | ● | ● | ▲ | ● | ▲ | ● | ● | ● | ● | ▼ | ● | ● | | ● | ● |
| East MP | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Vidharbha | ● | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Tamilnadu and Pondicherry | ● | ▼ | ● | ● | ● | ● | ● | ● | ● | ● | ● | ▲ | ● | ● | ▲ |

Symbols: triangles and inverted triangles indicate increasing and decreasing trends, respectively, each at 5% significance level. Circles show no statistical significance

Contributions of different spells of rain to total summer monsoon rainfall

| Regions | 1IS \rightarrow T | 1IL \rightarrow T | ML \rightarrow T | MS \rightarrow T | LL \rightarrow T | LS \rightarrow T |
|---------------------------|---------------------|---------------------|--------------------|--------------------|--------------------|--------------------|
| Homogeneous zones | | | | | | |
| AI | ▲ | ● | ▼ | ▲ | ● | ▼ |
| PI | ● | ● | ▼ | ● | ● | ● |
| WCI | ▲ | ● | ▼ | ▲ | ● | ▼ |
| NWI | ▲ | ● | ▼ | ● | ● | ▼ |
| NEI | ● | ● | ● | ● | ▼ | ● |
| Hilly | ● | ● | ● | ● | ● | ● |
| CNEI | ▲ | ● | ● | ● | ● | ▼ |
| Agro-met divisions | | | | | | |
| HP | ● | ● | ● | ▲ | ● | ● |
| Uttarakhand | ● | ● | ● | ● | ● | ▼ |
| Gujarat | ▲ | ● | ▼ | ● | ▼ | ▼ |
| WR | ● | ● | ▼ | ● | ● | ● |
| Orissa | ● | ● | ● | ● | ● | ● |
| Telangana | ▲ | ● | ▼ | ● | ● | ▼ |
| East MP | ● | ● | ▼ | ● | ● | ▼ |
| Vidharbha | ▲ | ● | ▼ | ● | ● | ● |
| Tamilnadu and Pondicherry | ● | ● | ● | ● | ● | ● |

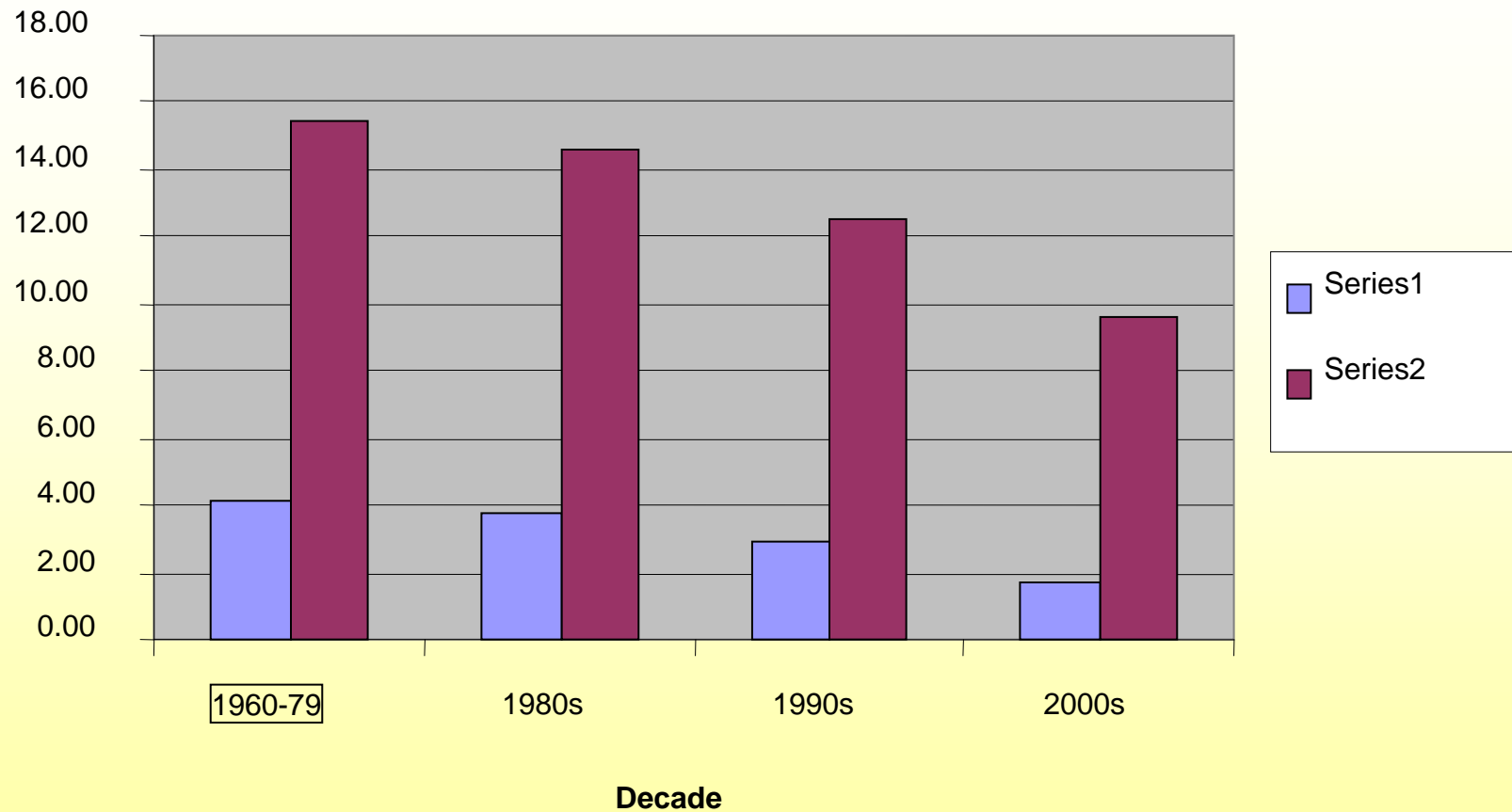
Percentage changes in various categories of long and short spells in the decade 1991-2000 compared with the 1951-1960 decade

| Regions | IIS | IIL | ML | MS | LL | LS |
|---------------------------|-------|-------|-------|------|-------|-------|
| Homogeneous zones | | | | | | |
| AI | 19.8 | 27.7 | 17.6 | 0.7 | 4.5 | 11.6 |
| PI | 22.3 | 11.0 | 6.7 | 7.0 | 2.0 | 5.9 |
| WCI | 13.0 | -46.0 | -24.2 | -3.0 | -3.6 | -19.2 |
| NWI | 14.6 | 0.0 | -28.3 | -4.1 | -11.7 | -21.9 |
| NEI | 0.7 | -4.9 | -7.9 | 6.2 | -4.9 | 0.7 |
| IIlly | 5.4 | 9.4 | 24.7 | 11.6 | 3.9 | 14.5 |
| CNEI | 26.4 | 0.0 | -12.6 | -0.7 | -1.8 | -11.5 |
| Agro-met Divisions | | | | | | |
| HP | -22.8 | 6.7 | -6.2 | 13.2 | 6.8 | 3.4 |
| Uttarakhand | -0.1 | 0.0 | -3.7 | -6.9 | 2.3 | -32.4 |
| Gujarat | 50.2 | 0.0 | 27.2 | 4.6 | 25.3 | 31.1 |
| WR | 61.6 | 0.0 | 45.5 | 2.7 | 3.7 | 16.6 |
| Orissa | 4.8 | 0.0 | -27.6 | -7.8 | 2.3 | -22.2 |
| Telangana | 25.4 | 0.0 | -34.8 | -3.5 | -2.8 | -25.8 |
| Tamilnadu and Pondicherry | 2.8 | -20.7 | -5.8 | 14.7 | -3.1 | 18.1 |
| East MP | 70.5 | 0.0 | 18.1 | 2.5 | 8.2 | 25.2 |
| Vidharbha | 18.0 | 0.0 | 34.5 | 0.1 | 0.6 | 19.7 |

Some rainfall facts for Agriculture

- High intensity Short spells increase and Moderate and Low intensity Long spells decrease.
- Contribution of Moderate Long spells to total rain decreases and Moderate Short spells increases.
- Contribution of Heavy categories to total rain increases and that of Moderate decreases.

Number of workable days



Fully workable days out of 30 by decade at Delhi in the month of June. (Series 1 is heavy labour; Series 2 is light factory work)

Climate change in cities

- Numerous cities in South and Southeast Asia are highly vulnerable to climate change.
- In India, the expected increase in extreme rainfall events and changes to seasonal monsoon patterns will increase the risk of major floods and the likelihood of drought, with severe consequences for the health and livelihoods of millions of people.





Climate change in cities



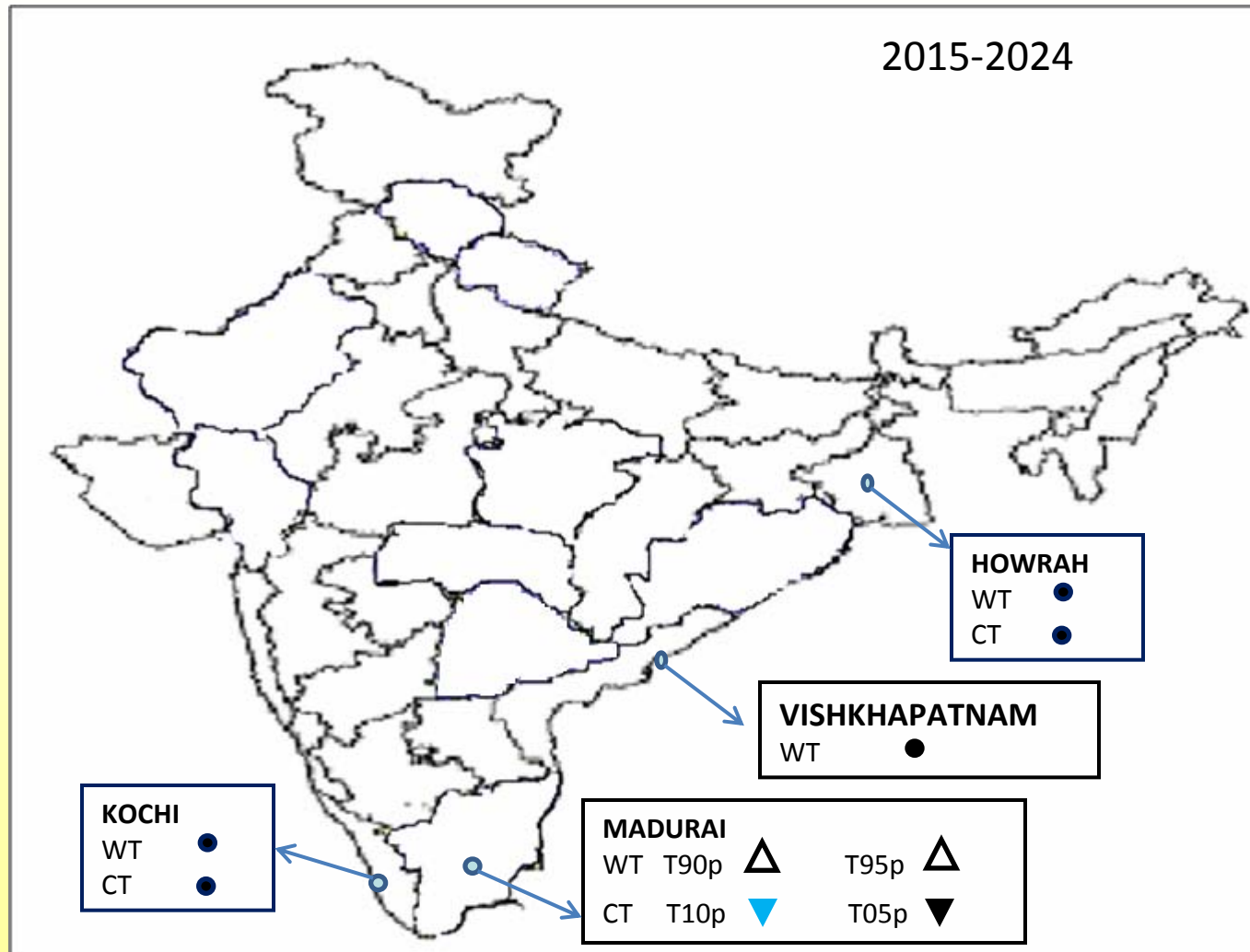
objectives

- (1) to identify generic climate change parameters in four selected cities in India and
- (2) to scientifically contribute in the local climate adaptation plans.



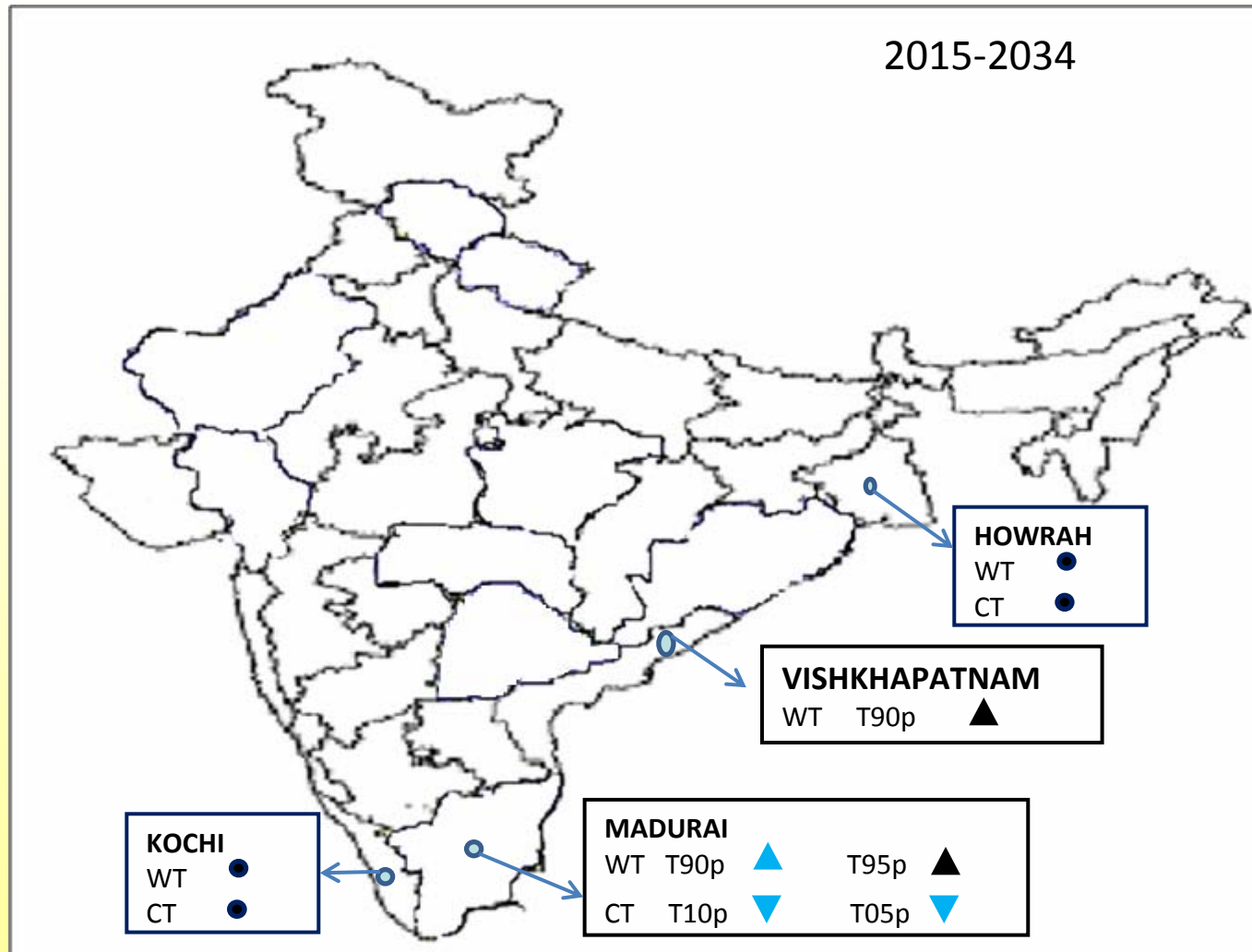
- The four selected cities in India are Howrah, Kochi, Madurai and Visakhapatnam.
- For each of the above cities its local indicators for climate change adaptation are being developed.

WARM TEMPERATURE (WT) & COLD TEMPERATURE (CT) EVENTS



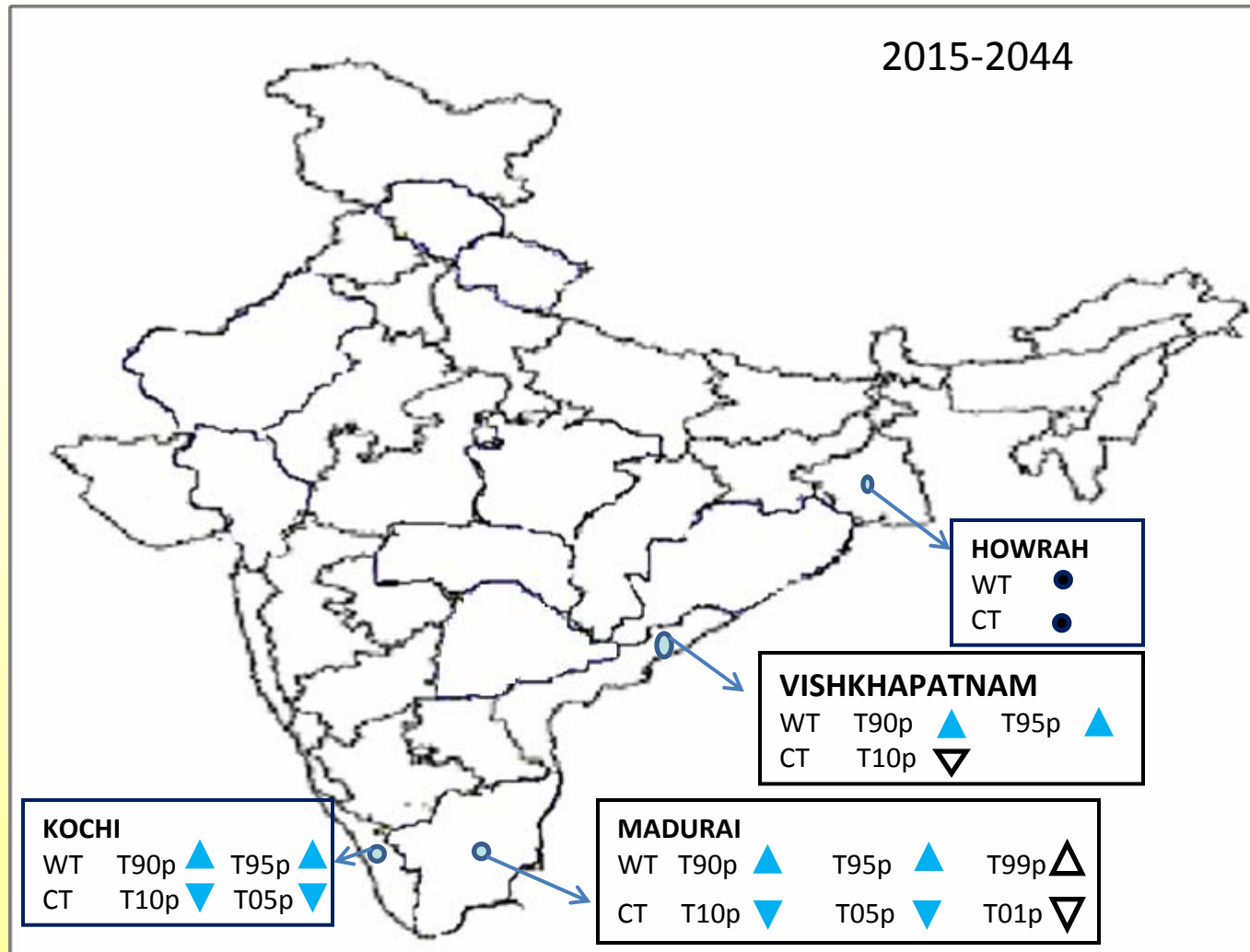
Increasing (Decreasing) trends at 10%,5% and 1% significant levels are marked by the symbol \triangle , \blacktriangle and \blacktriangle (∇ , \blacktriangledown and \blacktriangledown) respectively and \bullet represent no statistical significance.

WARM TEMPERATURE (WT) & COLD TEMPERATURE (CT) EVENTS



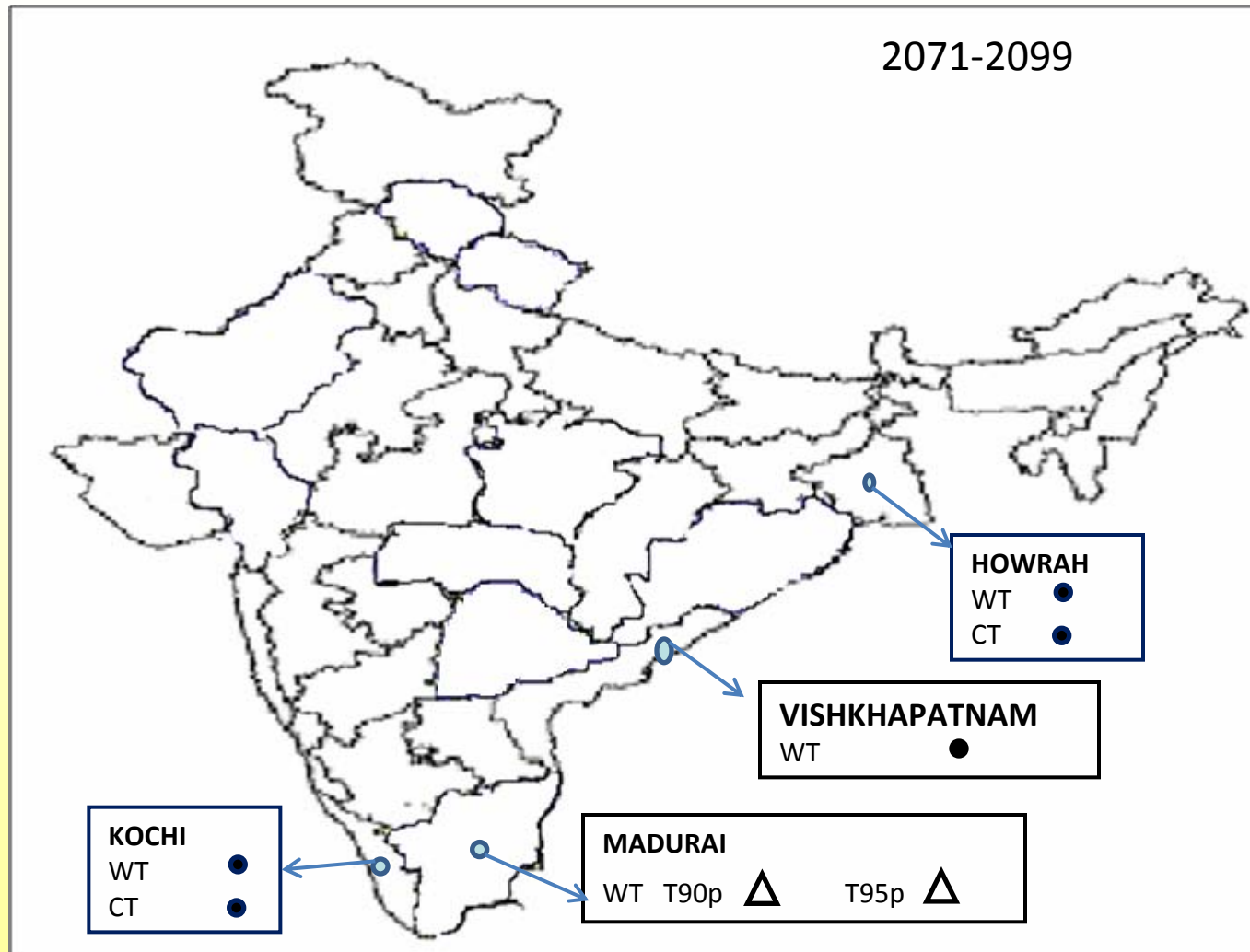
Increasing (Decreasing) trends at 10%,5% and 1% significant levels are marked by the symbol ▲, ▲ and ▲ (▼, ▼ and ▼) respectively and ● represent no statistical significance.

WARM TEMPERATURE (WT) & COLD TEMPERATURE (CT) EVENTS



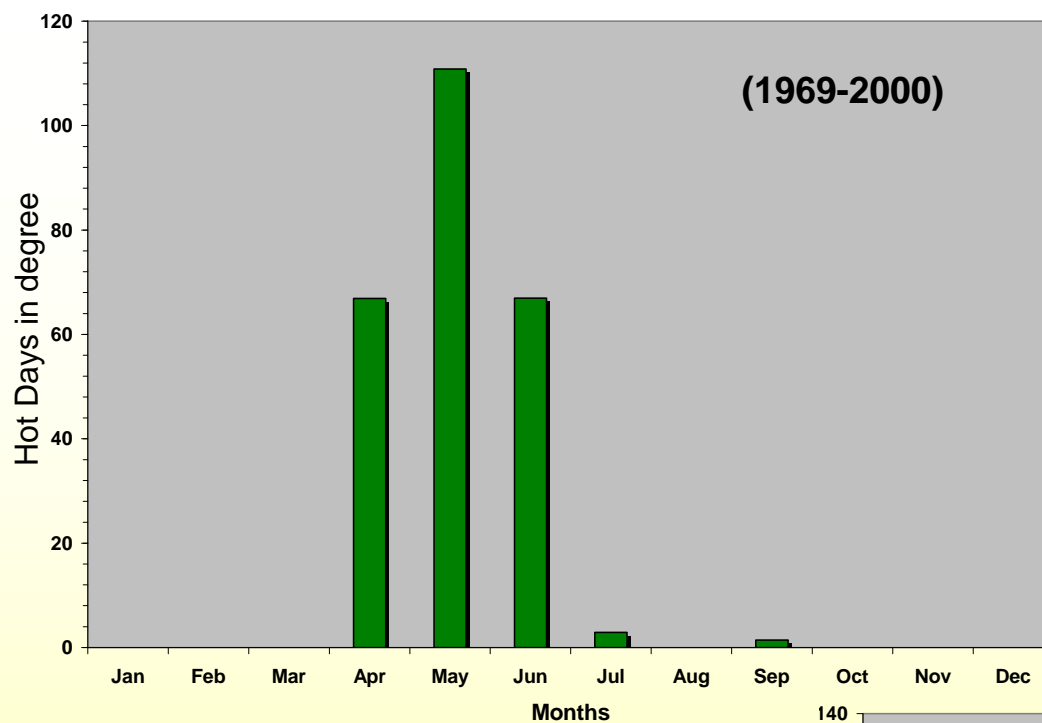
Increasing (Decreasing) trends at 10%,5% and 1% significant levels are marked by the symbol ▲, ▲ and ▲ (▼, ▼ and ▼) respectively and ● represent no statistical significance.

WARM TEMPERATURE (WT) & COLD TEMPERATURE (CT) EVENTS



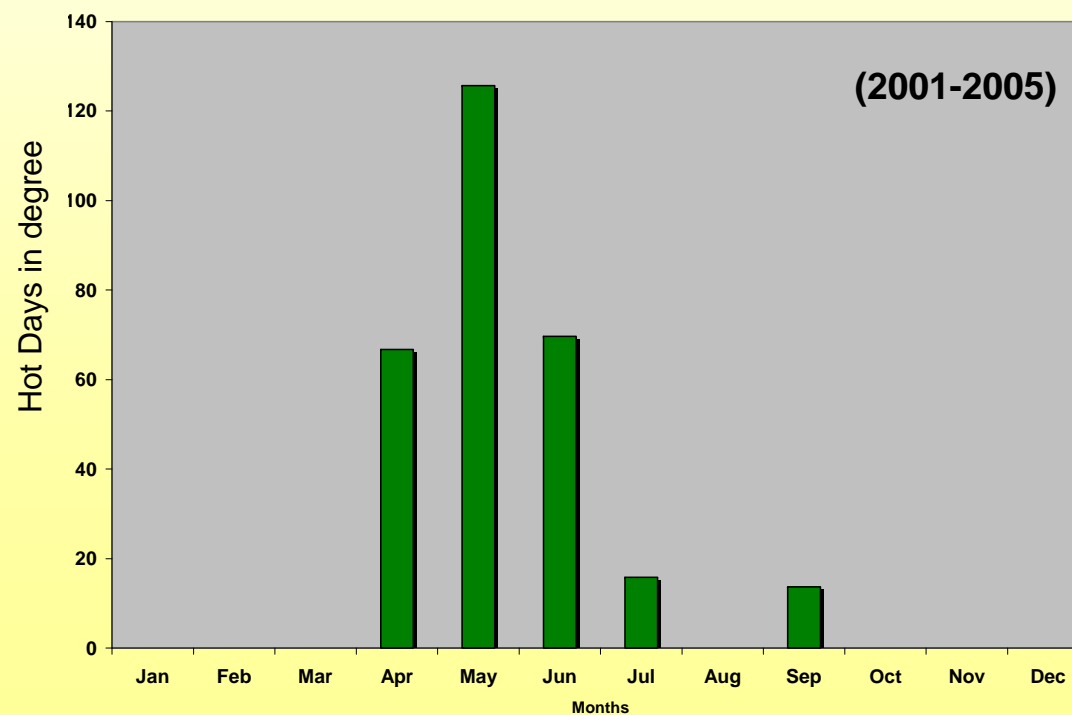
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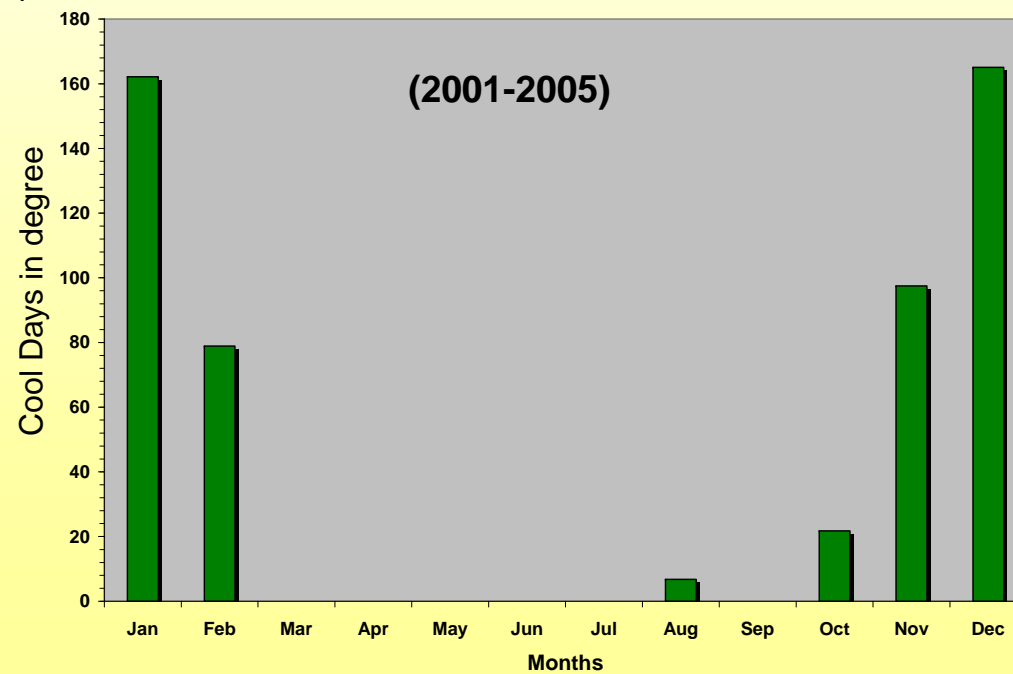
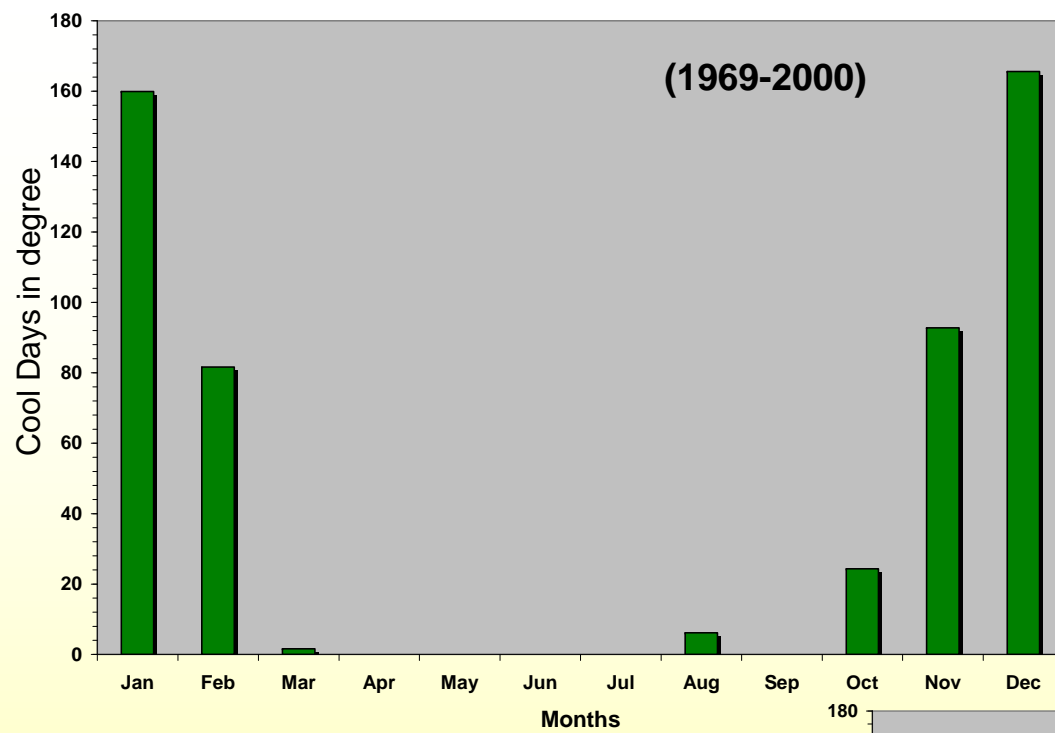
- ✓ **Hot and Cool** days are the quantitative indices calculated from daily mean air temperature.
- ✓ These indices are widely used to describe the energy consumption of heating (cooling) so as to defend against temperature changing.
- ✓ **Hot Day** (in degree) is defined as the accumulated Celsius degrees difference between the threshold temperature and daily mean temperature when the daily mean temperature is higher than the threshold value.
- ✓ **Cool Day** (in degree) is defined as the accumulated Celsius degrees difference between the daily mean temperature and the threshold temperature when the daily mean temperature is lower than the threshold value.
- ✓ The threshold value taken at Howrah is 26.71°C.

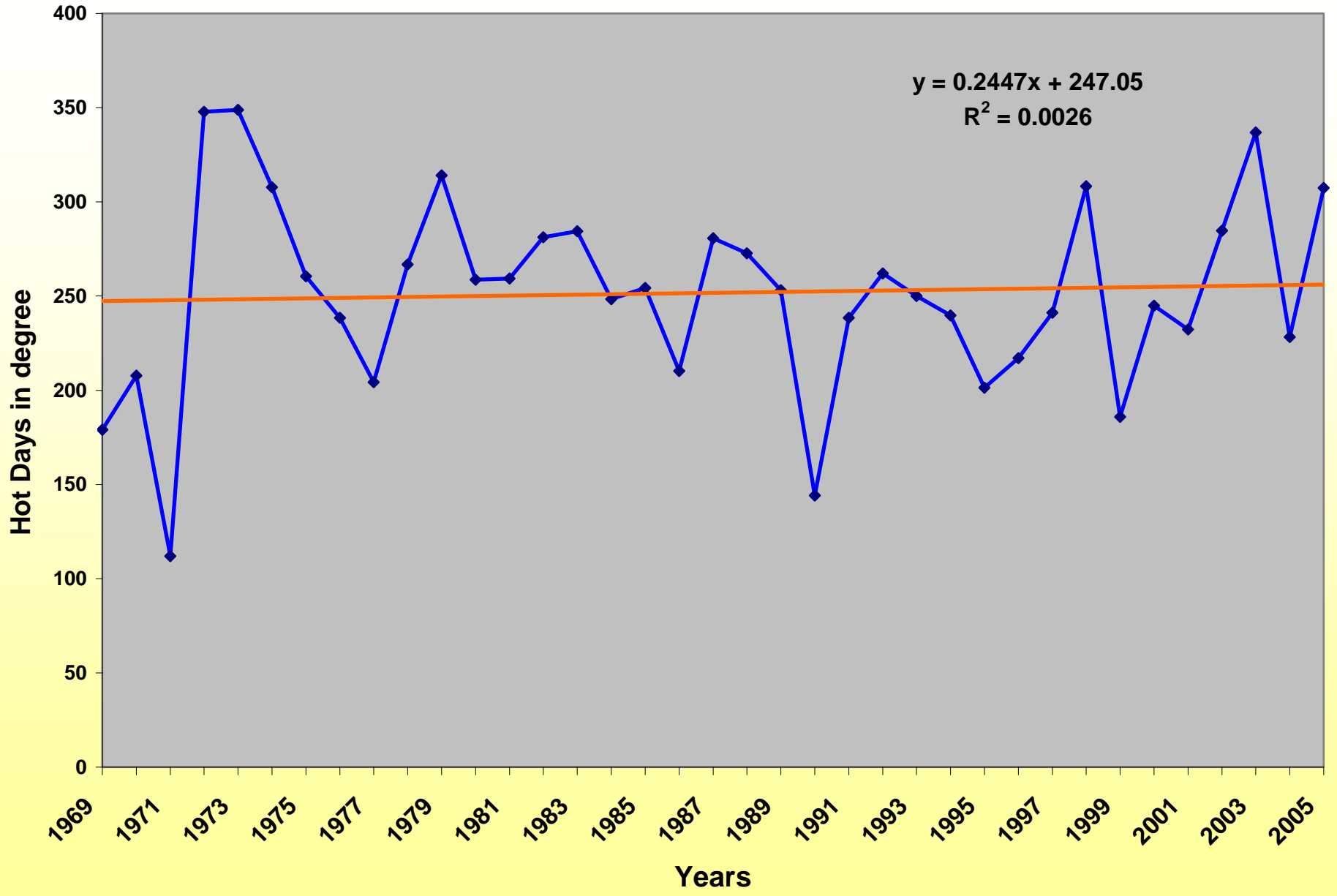


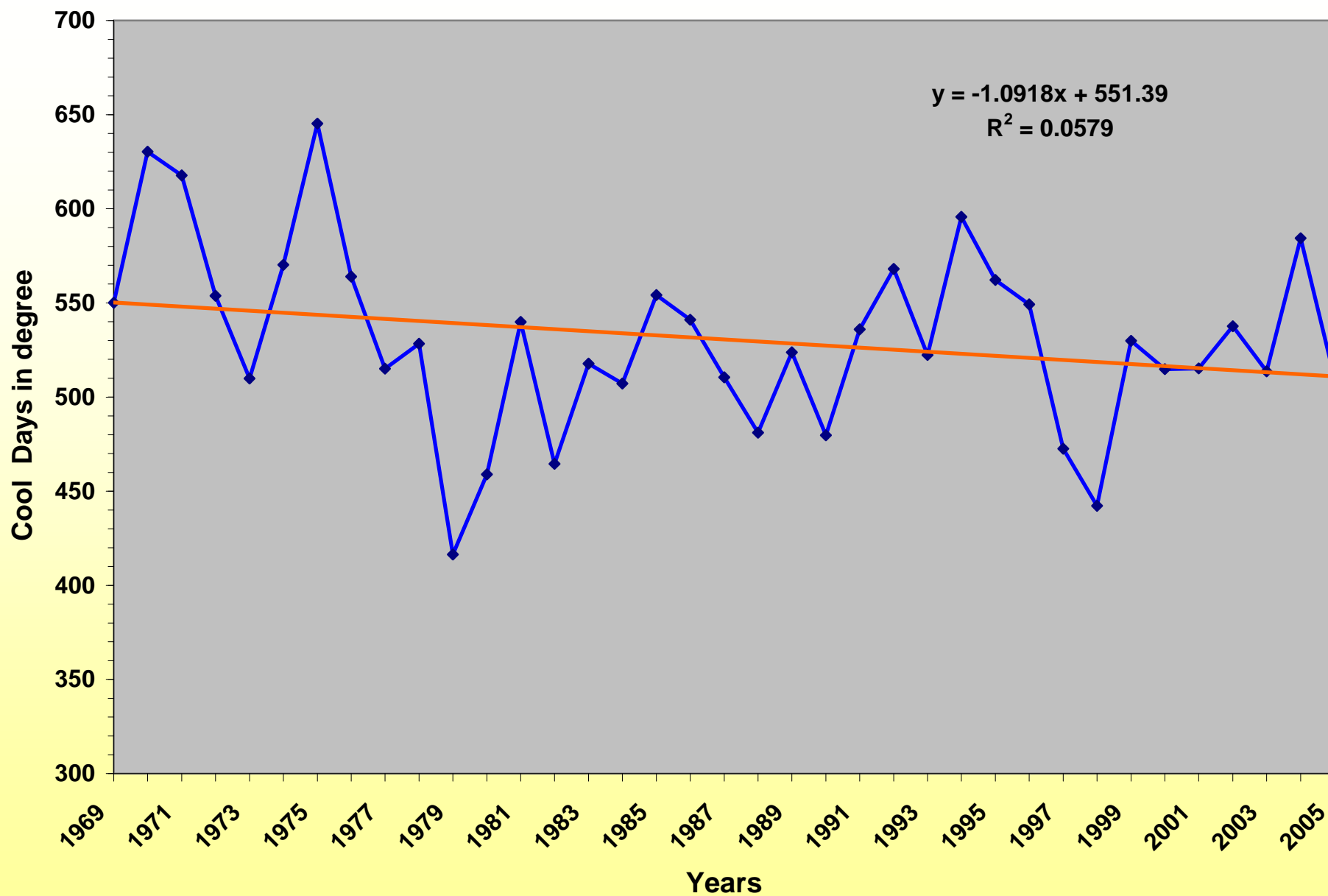
City: VISAKHAPATNAM

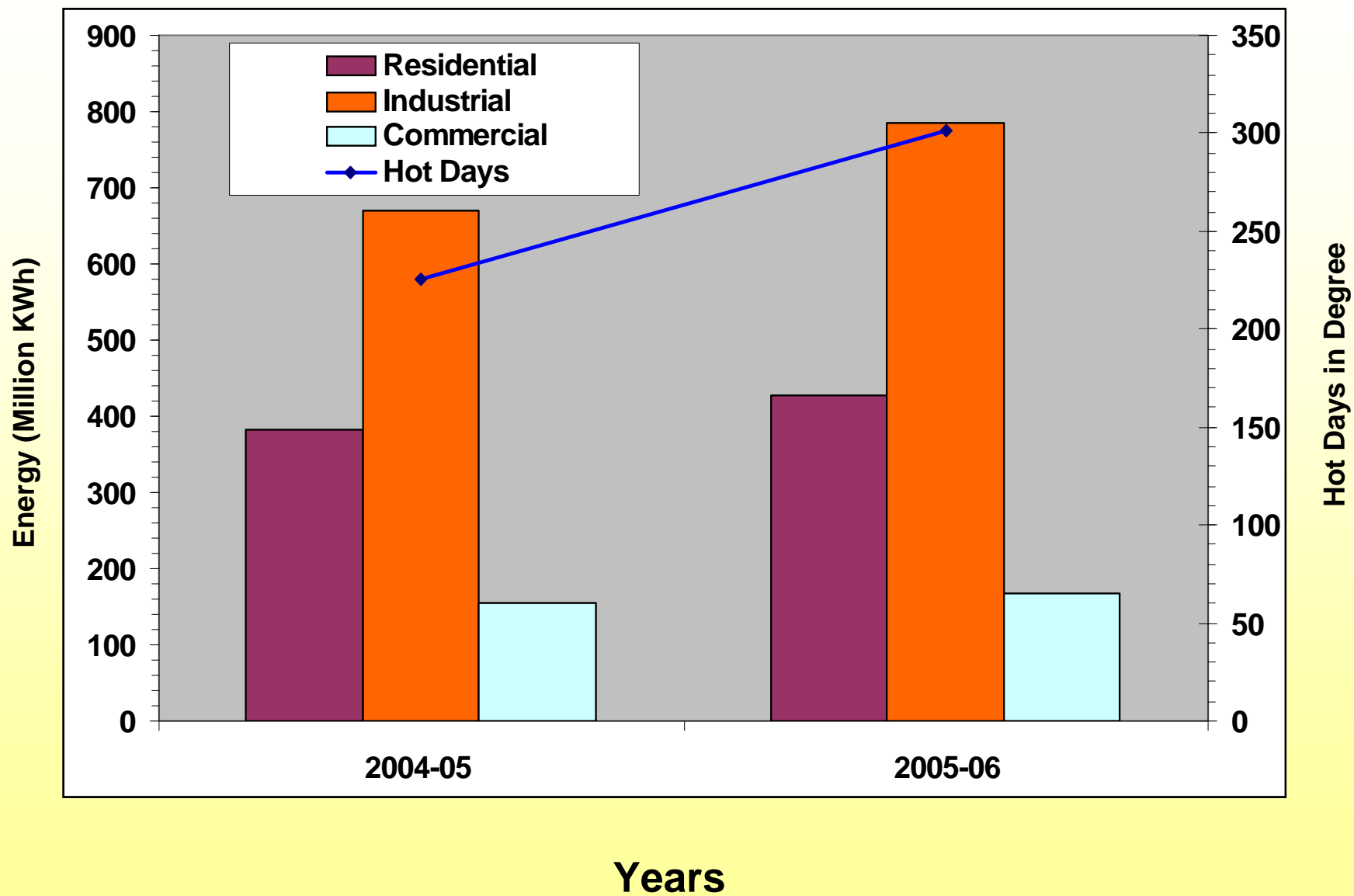
**Data: IMD Gridded Mean Temperature
0.5x0.5 resolution**

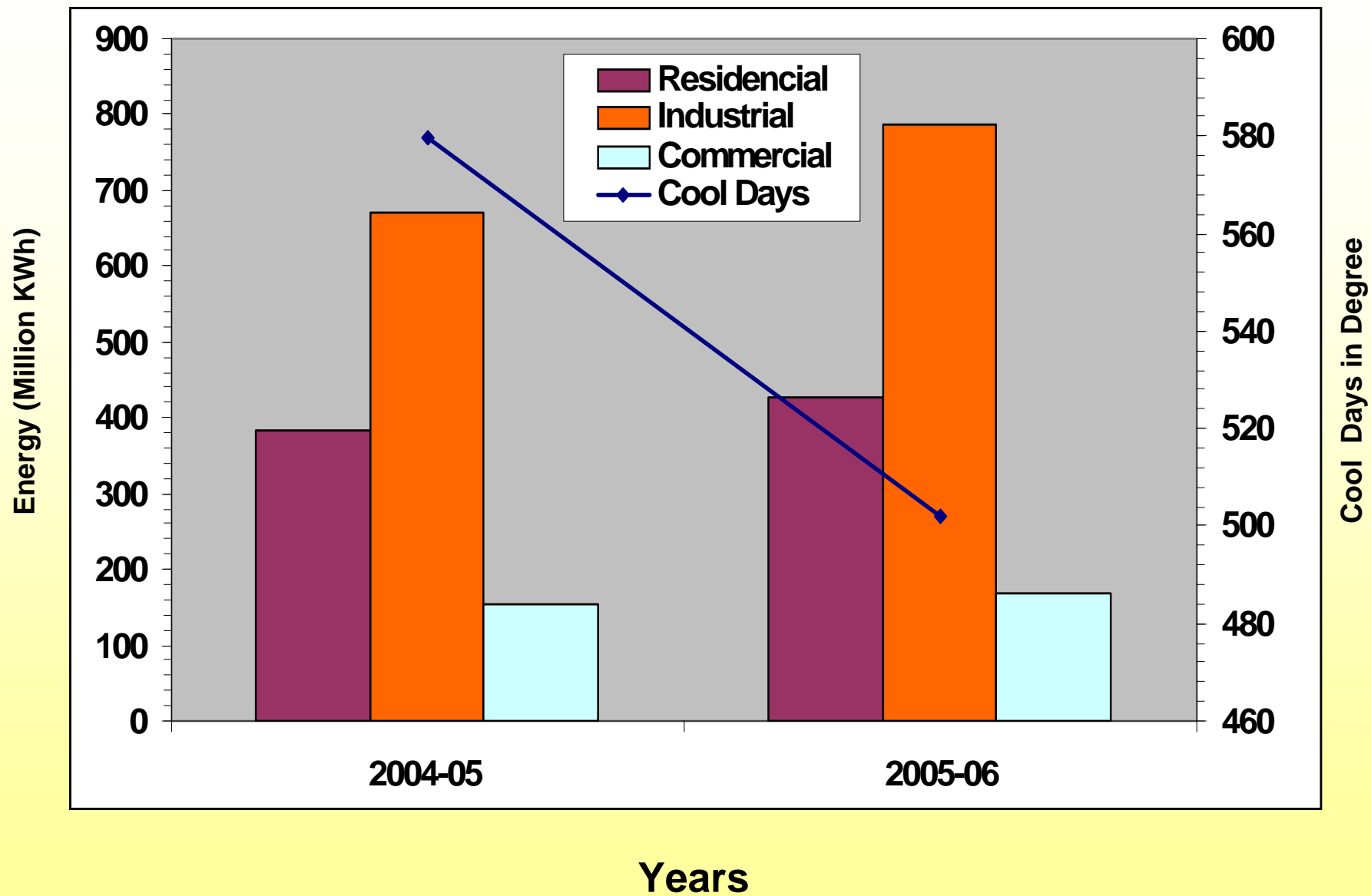












Immediate Goals

- **Validating Regional Climate Models at all the homogeneous regions in India, especially over the Himalayas.**
- **Downscaling surface temperature and rainfall to the resolutions of impact assessments.**
- **Determining the climate uncertainties in temperature and rainfall for applications in Agriculture, Health and City Amenities.**