

# **NATIONAL AND REGIONAL IMPACTS OF CLIMATE CHANGE ON THE INDIAN ECONOMY**

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# Climate Change and Developing Countries

- Though all countries are affected by climate change, they are affected in different ways and to different extents.
- Developing countries will be particularly badly hit, for three reasons:
  - geography (non-temperate latitudes)
  - stronger dependence on agriculture
  - with their fewer resources comes greater vulnerability

*Stern Review: The Economics of Climate Change  
(2006) p. 29*

# Climate Change and Asia

- Effects of rising temperatures on Asia:
  - declining crop yields; reduced fresh water supplies; rising sea-levels; increased floods, droughts and extreme weather events; biodiversity loss; higher risk of diseases
- India-specific assessments:
  - **NATCOM (2004)**: General country-wide vulnerability assessment; post-2070 scenarios
  - **Indian Network for Climate Change Assessment INCCA (2010)**: Finer-grained 4x4 assessment
  - 2030 time-horizon
  - 4 regions: Western Ghats, Himalayan Region, Coastal India, North-East
  - 4 sectors: Agriculture, Water, Forests, Human Health

# Main points

1. The only certainty is uncertainty
2. Impacts and response at the aggregate level
3. Regional (sub-national) impacts  
(warmer and wetter India? regional variability)
4. Implications for convergence across states
5. Optimal response in a federal framework

# The only certainty is uncertainty

## ***Few facts....***

- There exist heat trapping gases (GHGs)
- Concentrations of GHGs has increased due to human activity (anthropogenic causes)

## ***And many doubts....***

- How much warming will take place?
- How soon?
- By how much will ocean levels rise?
- How likely are cataclysmic events?
- What will be the economic impact?

## e.g., for India...

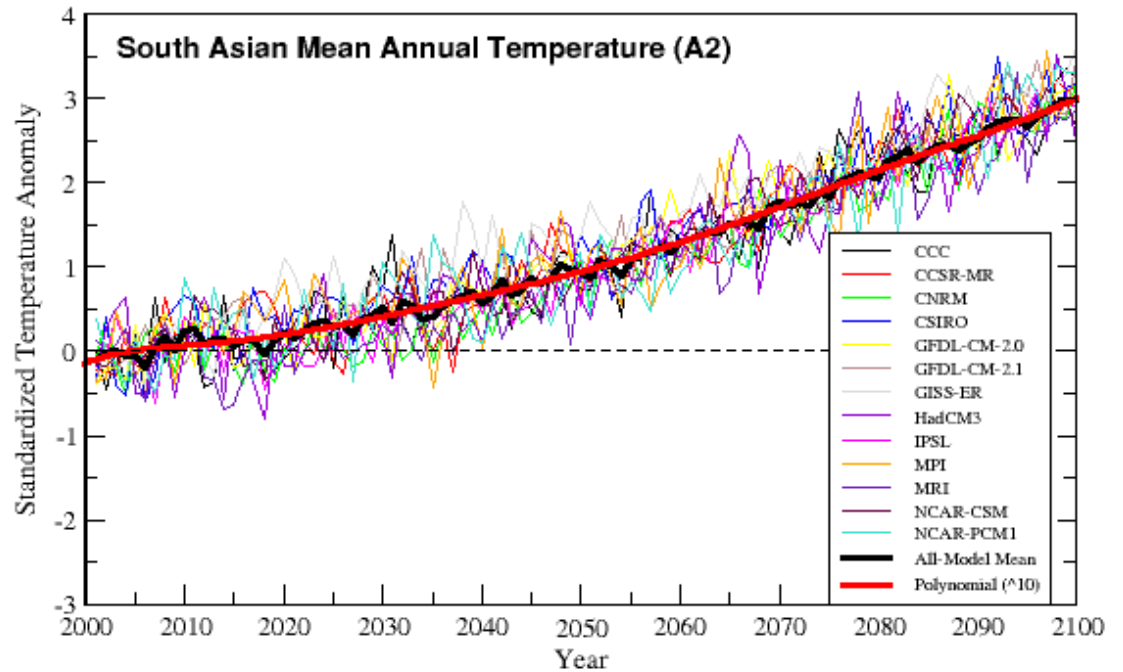
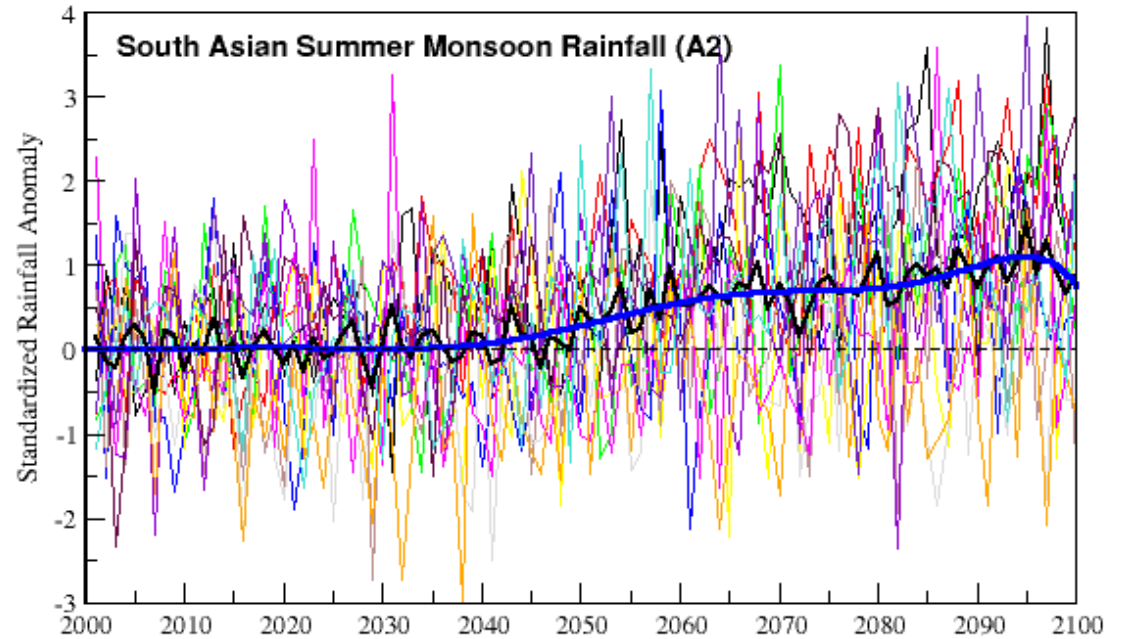
- Global warming is real
- But considerable uncertainty on specifics
  - How much *average* temperature increase
    - In 2030, 2050, 2080, etc.?
    - In Kashmir? In Karnataka?
  - How will a given *average* temperature increase occur?
    - Rise in maximum, minimum or the entire distribution?
    - More hot days, less cold days?
    - More severe summer, less severe winter?
  - Same questions on rainfall, which may rise (or fall)
  - Impact uncertainties
    - More hot days bad in Rajasthan but not in Kashmir
    - More rain be good in Rajasthan but bad in Meghalaya
    - For many crops, heat is bad but CO<sub>2</sub> emissions are good

# Expected climate change in India by 2030

- **Warmer**
  - Avg. temp rise: 2.0 deg C predicted
  - 1.0-4.0 deg C at extreme ranges
- **and wetter - increased annual precipitation, but**
  - lower frequency of rainy days; increased intensity
- **Cyclonic disturbances**
  - lower frequency; increased intensity
  - increased risk of storm surges
- **Sea-level rise**
  - 1.3mm/year on average

**Future scenarios for  
summer monsoon  
rainfall  
and  
annual temperature over  
South Asia  
under A2 Scenario  
(High Emissions)**

**based on IPCC AR4  
simulations of AOGCMs  
(anomalies relative to  
current period)**





## On temperature (NATCOM 2004)

- Warming mainly in the post-monsoon and winter seasons.
- Warming predominantly due to increased maximum temperatures
- A significant warming trend along the west coast, in central India, the interior peninsula and over north-east India,
- A cooling trend in north-west India and a pocket in southern India.

# Expected effects (of expected climate change) for India: examples (INCCA 2010)

- **Agriculture**
  - Up to 50% reduction in maize yields
  - 4-35% reduction in rice yields (with some exceptions)
  - Rise in coconut yields (with some exceptions); reduced apple production
  - Negative impacts on livestock in all regions
- **Fresh water supply**
  - High variability predicted in water yields (from 50% increase to 40-50% fall)
  - 10-30% increased risk of floods; increased risks of droughts
- **Forests and natural ecosystems**
  - Shifting forest borders; species mix; negative impact on livelihoods and biodiversity
- **Human health**
  - Higher morbidity and mortality from heat stress and vector/water-borne diseases
  - Expanded transmission window for malaria

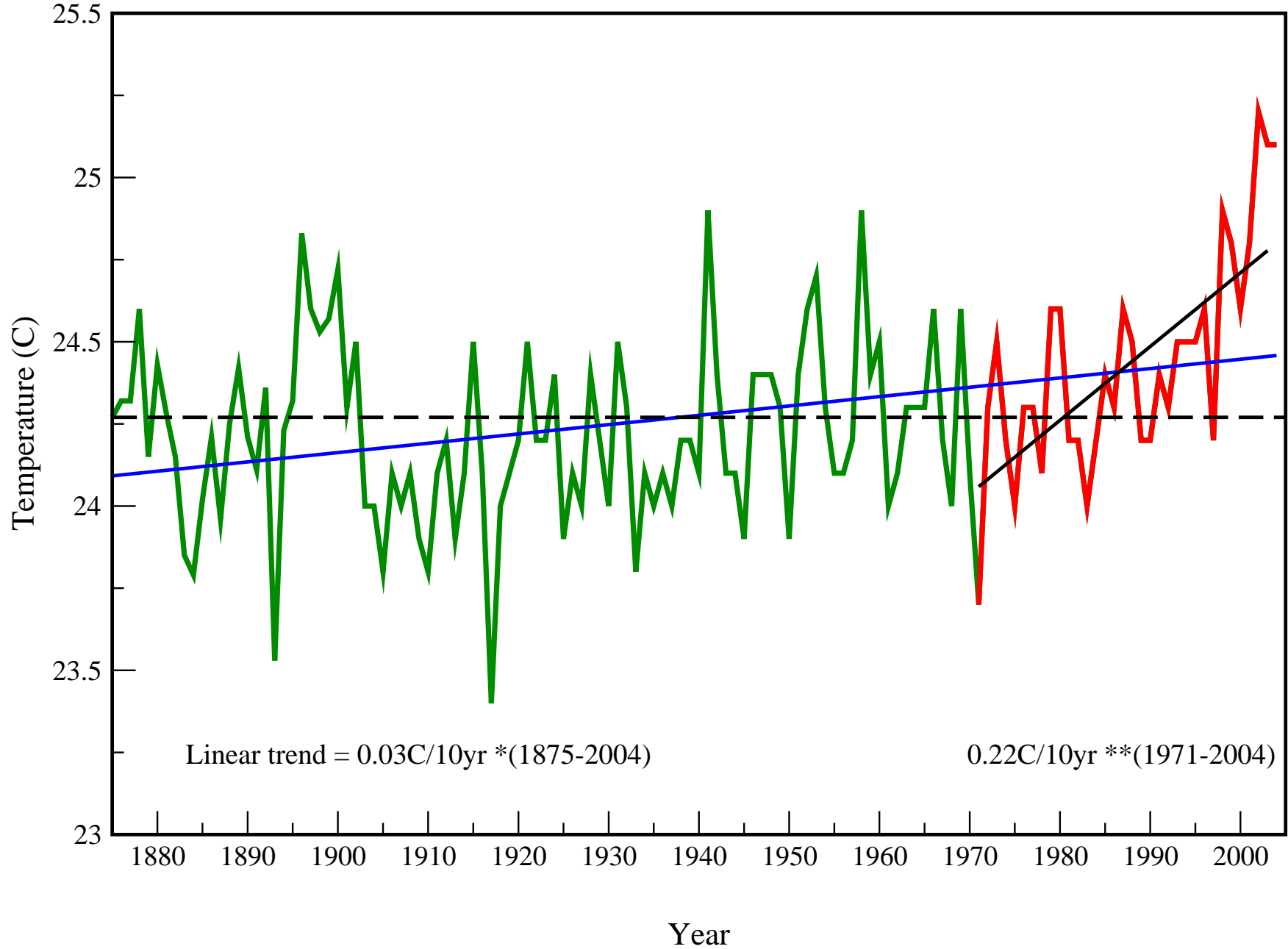
# How will climate change affect India's economy?

At the aggregate level

Analytically three types of effects:

- (a) mean temperatures would rise (see graph)
- (b) climate becomes variable El Nino-type
- (c) tails become 'fatter'

# Variation of All-India mean annual temperature during 1875-2004



## How these effects will affect the economy

- Mean temperature rising means an exogenous technical regress/progress
- Increased climate variability means consumption-smoothing is an issue
- Especially if this is a world-wide phenomenon
- When tails become 'fatter', what does one do? Take evasive action? How much? Tricky because this is self-insurance against a tail event

# Regional climate impacts for India (and their regional economic impact)

- Why of interest?
- Large country, diverse geography, climates
- Makes little sense to focus on (climate) effects at aggregate level when these effects themselves are region specific

## Modeling regional climate impacts

- Atmosphere-ocean general circulation models (AOGCMs) – simulate climate at large continental scale
- Coarse resolution of A-O coupled models (~300 km grids) HadAM3H 150km x 150km
- Ignore unique topographies (e.g. Western Ghats) and fail to reproduce their influence on peninsular monsoon rainfall patterns
- But we need reliable estimates at regional level (esp. for countries with salient primary sector such as India)

# Regional climate models (RCMs)

- High resolution at global scale computationally expensive
- RCMs allow 'zooming in'
  - downscale global model simulations to superimpose regional details of specific regions of interest (eg Western Ghats)
- Hadley Centre (UK Met Office): **Providing Regional Climates for Impact Studies (PRECIS)**
- A second generation RCM – limited area, high-resolution atmosphere-land model
- Locatable over any part of the globe
- Specify boundary conditions at the limits of the model's domain
- Forced at boundary by a high-res global model (HadAM3H 150km grid)



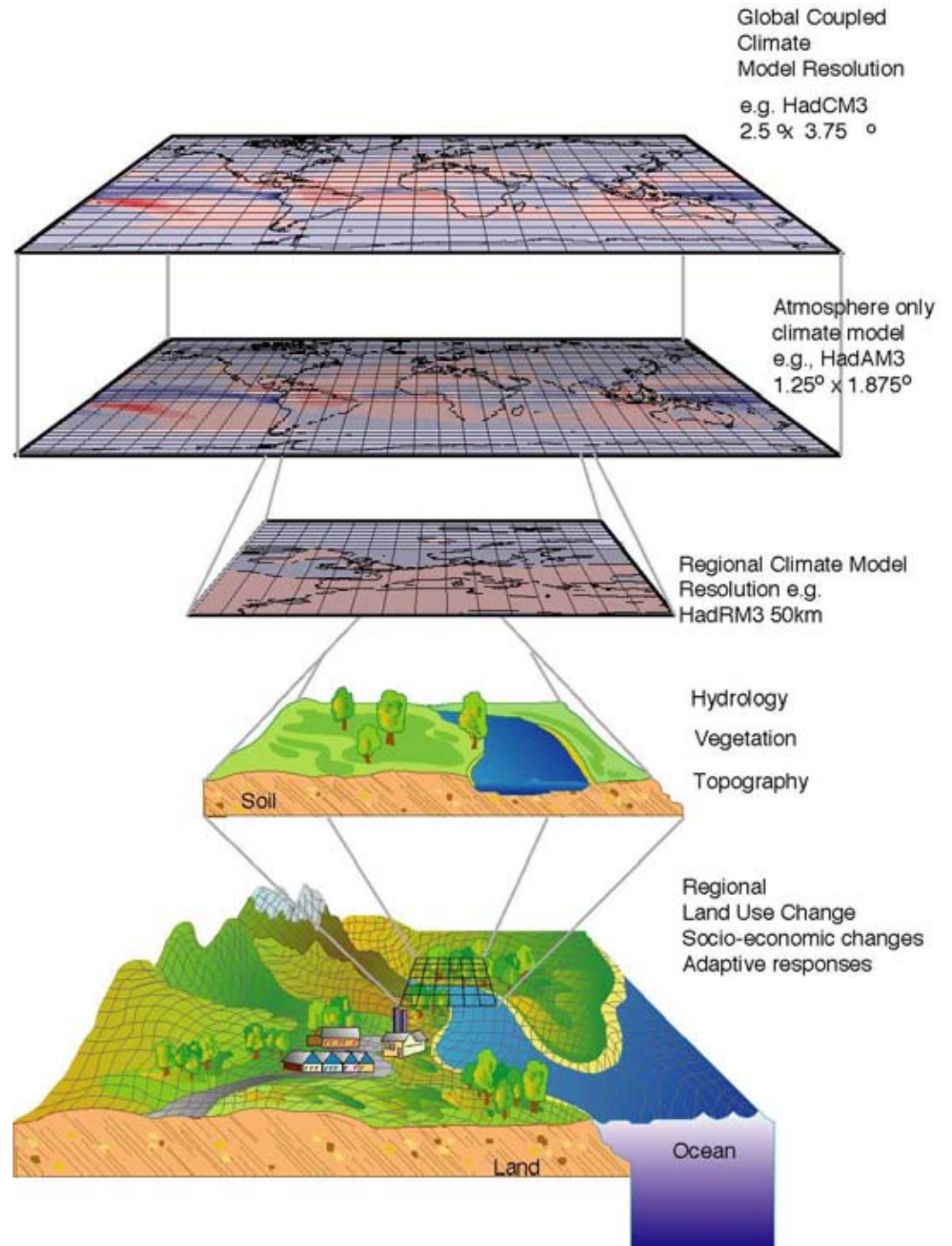
# GCMs to Regional Adaptive Responses: Modelling Path

$$Cs = f(Cl, \emptyset s)$$

Cs - small scale climate

Cl - large scale climate

$\emptyset s$  - physiographic details at small scale



## Running PRECIS for India

- Simulated at Center for Climate Change Research (CCCR), Indian Institute of Tropical Meteorology (IITM), Pune
- Joint Indo-UK collaborative programme on climate change impacts in India
- 50 km x 50 km resolution
- Configured for South Asian domain (1.5°N – 38°N and 56°E-103°E)
- Lacunae--only one estimate of monsoon by one regional model forced by one coupled model output. Uncertainties on the estimate unknown

# PRECIS Runs at IITM

Evaluation experiment using Lateral Boundary Conditions (LBCs) derived from hi-res GCMs such as HadAM3H

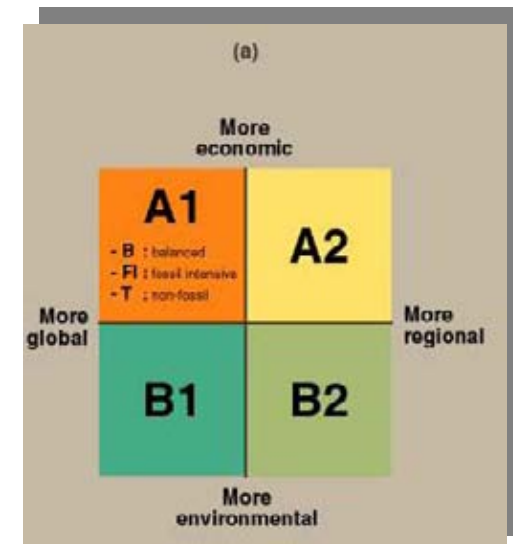
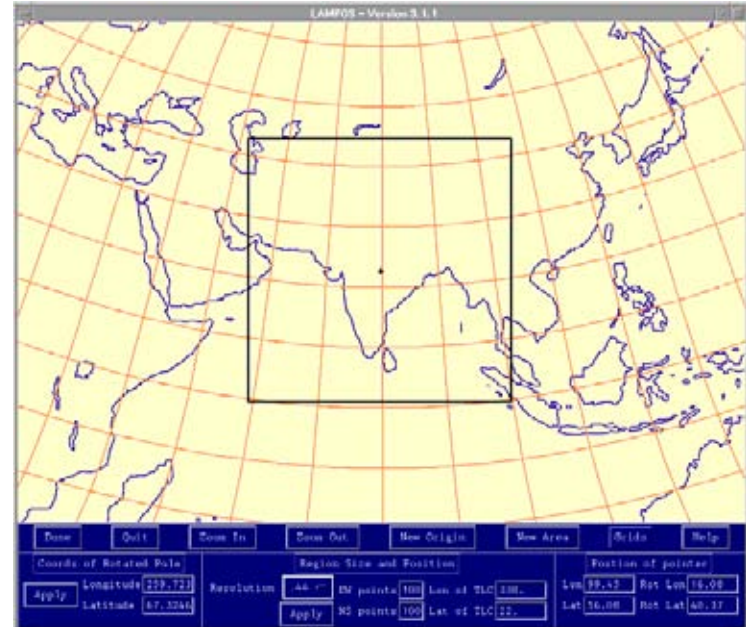
Runs (3 ensembles in each experiment) completed with LBCs having a length of 30 years each, for

**Baseline (1961-90)**

**A2 scenario (2071-2100)**

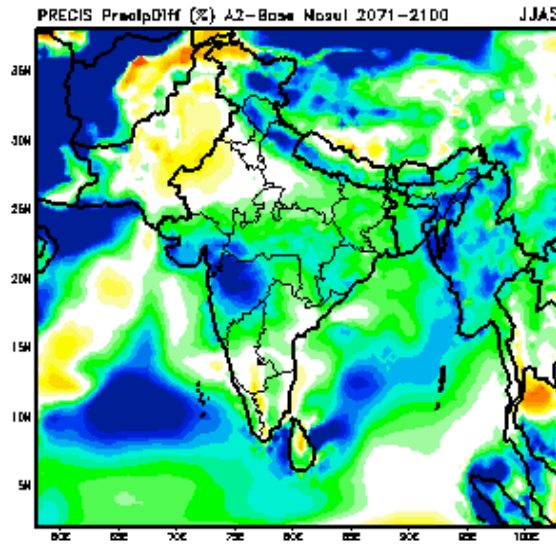
**B2 scenario (2071-2100)**

All runs done both with and without the sulphur cycle

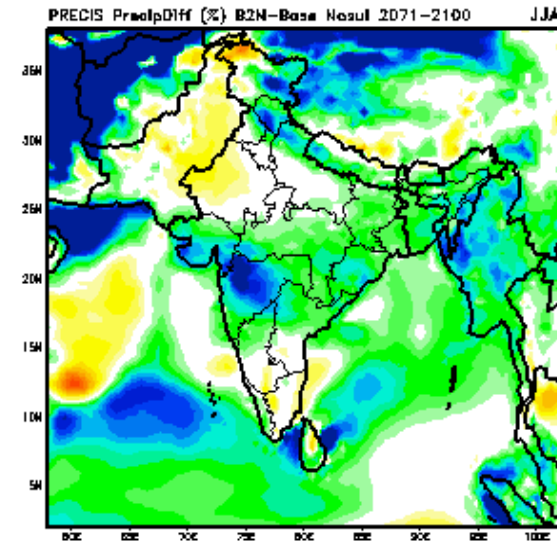


# Spatial Patterns of changes in summer monsoon rainfall (%) and annual mean surface air temperature(°C) for 2071-2100 v-a-v baseline (1961-90)

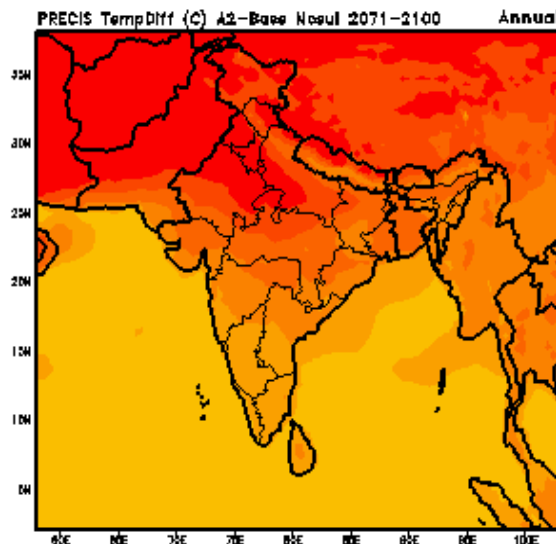
A2-CTL  
Monsoon  
Precip



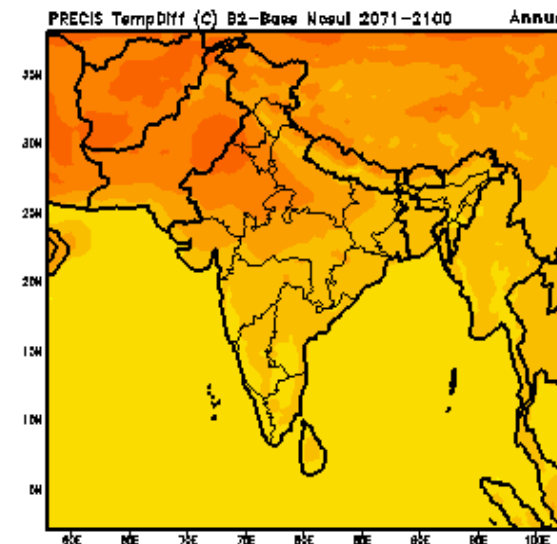
B2-CTL  
Monsoon  
Precip



A2-CTL  
Annual  
Temp



B2-CTL  
Annual  
Temp

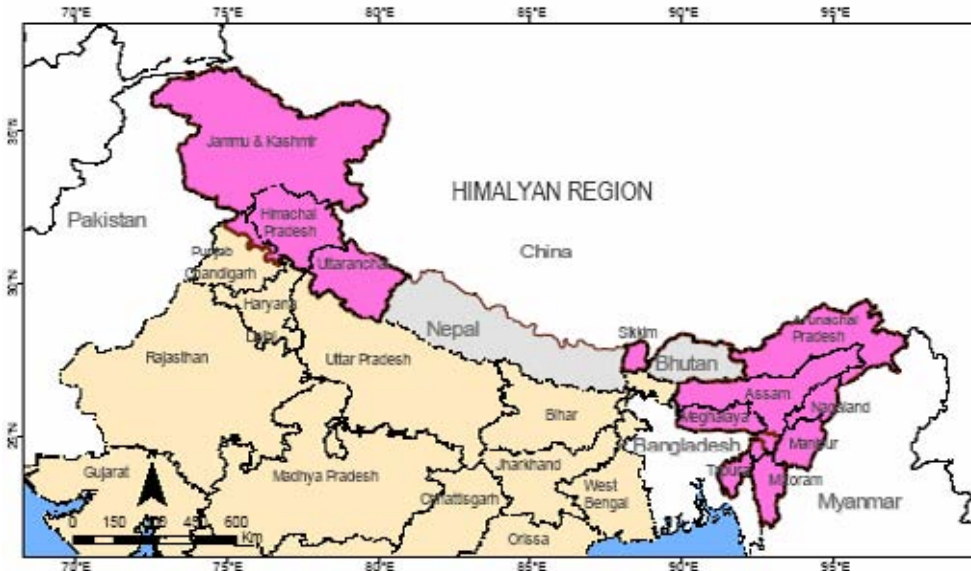


## Regional climate impacts for India: the 4x4 assessment

- Most detailed assessment so far
- Focuses on 4 climate sensitive regions in India:
  - Himalayan Region, North East, Western Ghats, Coastal Region
- Assess likely impacts in 2030s on:
  - Agriculture, Ecosystems and Biodiversity, Water, and human health
- Use IPCC SRES A1B scenario as the emissions 'storyline' (namely, rapid economic growth in a globalised world with energy cons balanced across fossil and non-fossil sources)

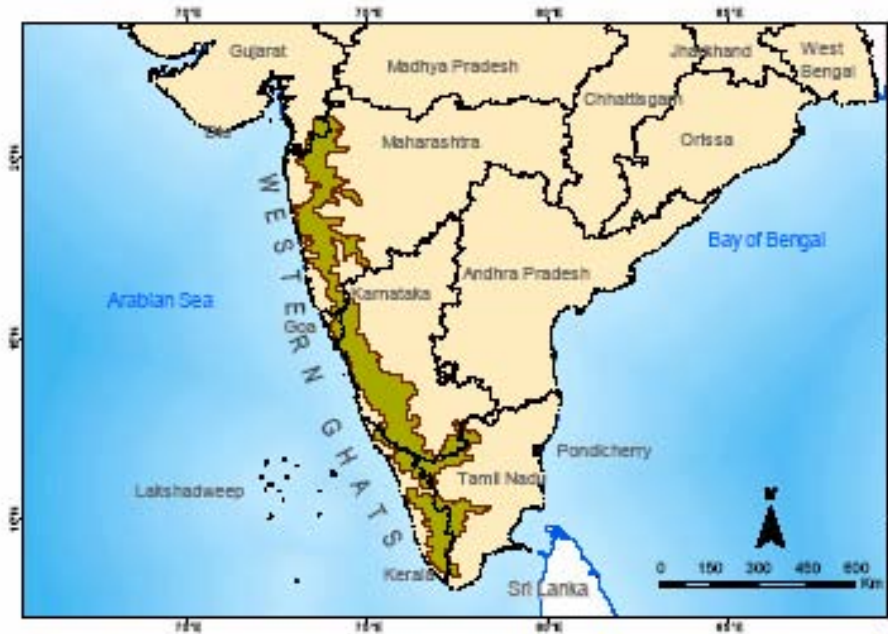
# The Regions

## The Himalayan Region



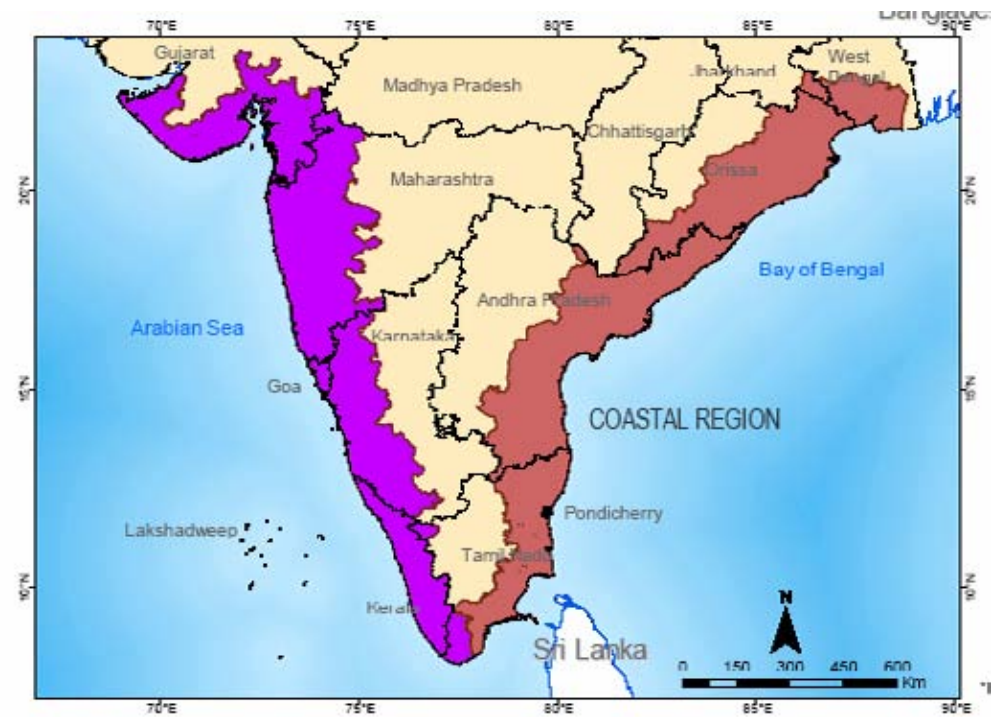
North East

# The Regions



**Western Ghats**

**Coastal Region**





**Agriculture**



**Water**

# The Sectors

**Forest & Biodiversity**



**Health**





## Approach

- Studied the observed climate and simulated the same using PRECIS having a resolution of 50 km x 50 km
- Developed climate change scenarios for 2030s using PRECIS
- Using these climate change scenarios, run biophysical models and/or developed criteria for determining the impacts
- Also used expert judgment to ascertain the likely impacts where modeling not yet possible

# Climate Scenarios

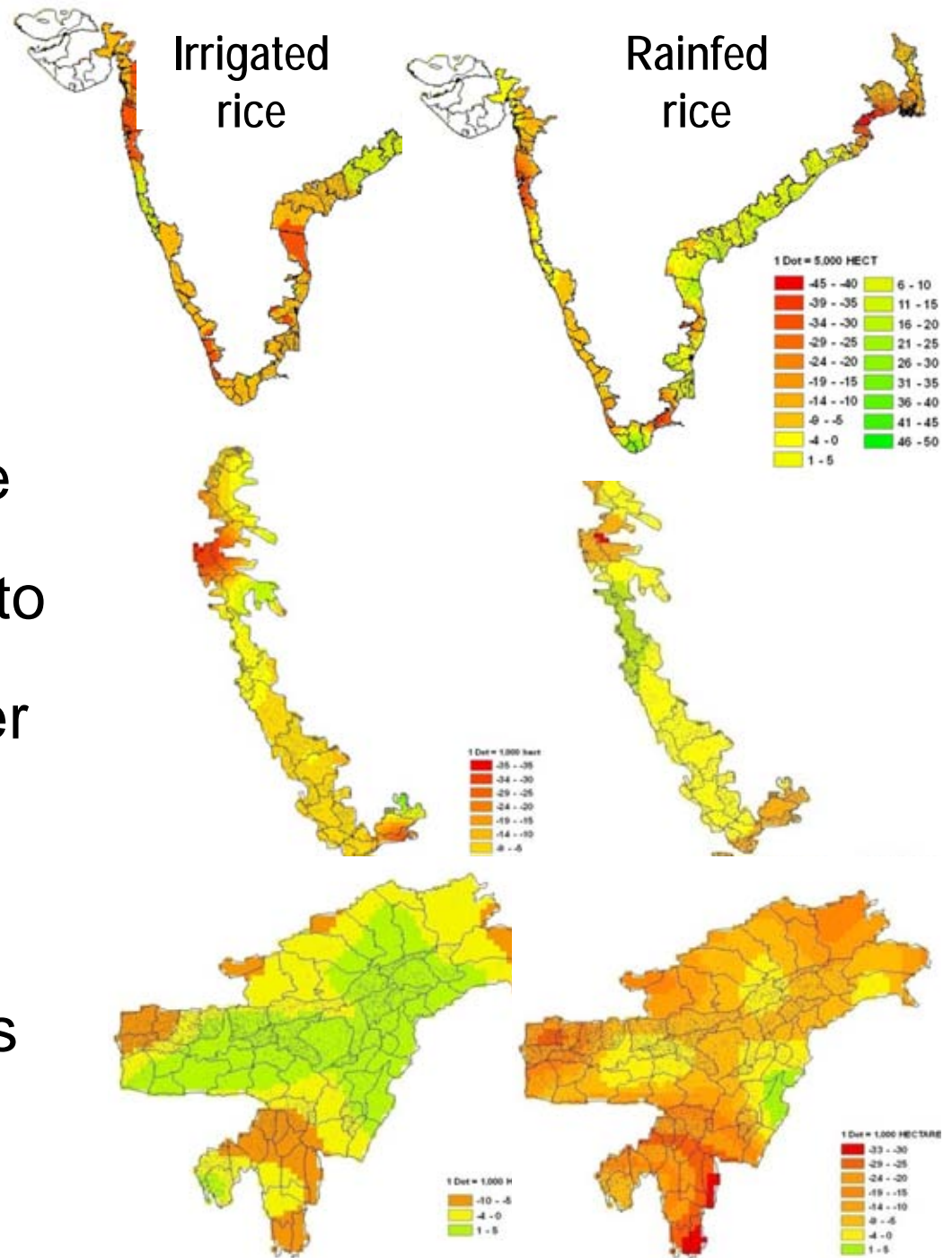
- Generated for 2030s using PRECIS run on SRES A1B
- Parameters studied
  - Temperature
  - Precipitation
  - Extreme events
  - Sea Level rise

# Regional climate impacts: Findings

- Nuanced and complex
- Winners and losers everywhere
- Though on the whole losers

# Agriculture

- General decrease in productivity of crops however cash crops like coconut may increase.
- Some species of marine fisheries likely to have higher catch compared to others as their area of spawning shifts to higher latitudes
- Livestock productivity likely to be affected adversely with increase in extreme temperatures



# Water yield

## Himalayan Region:

likely to increase

## North Eastern

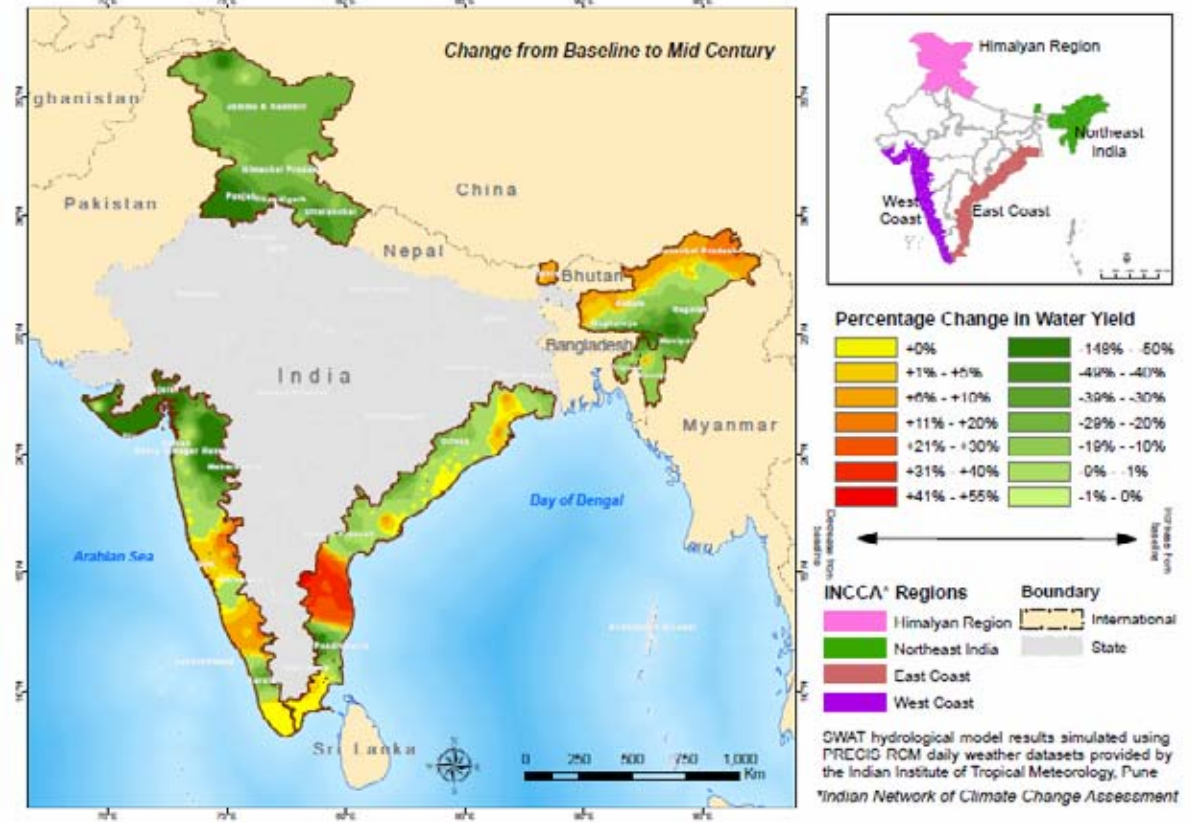
Region: reduction

## Western Ghats:

variable water yield changes projected across the region

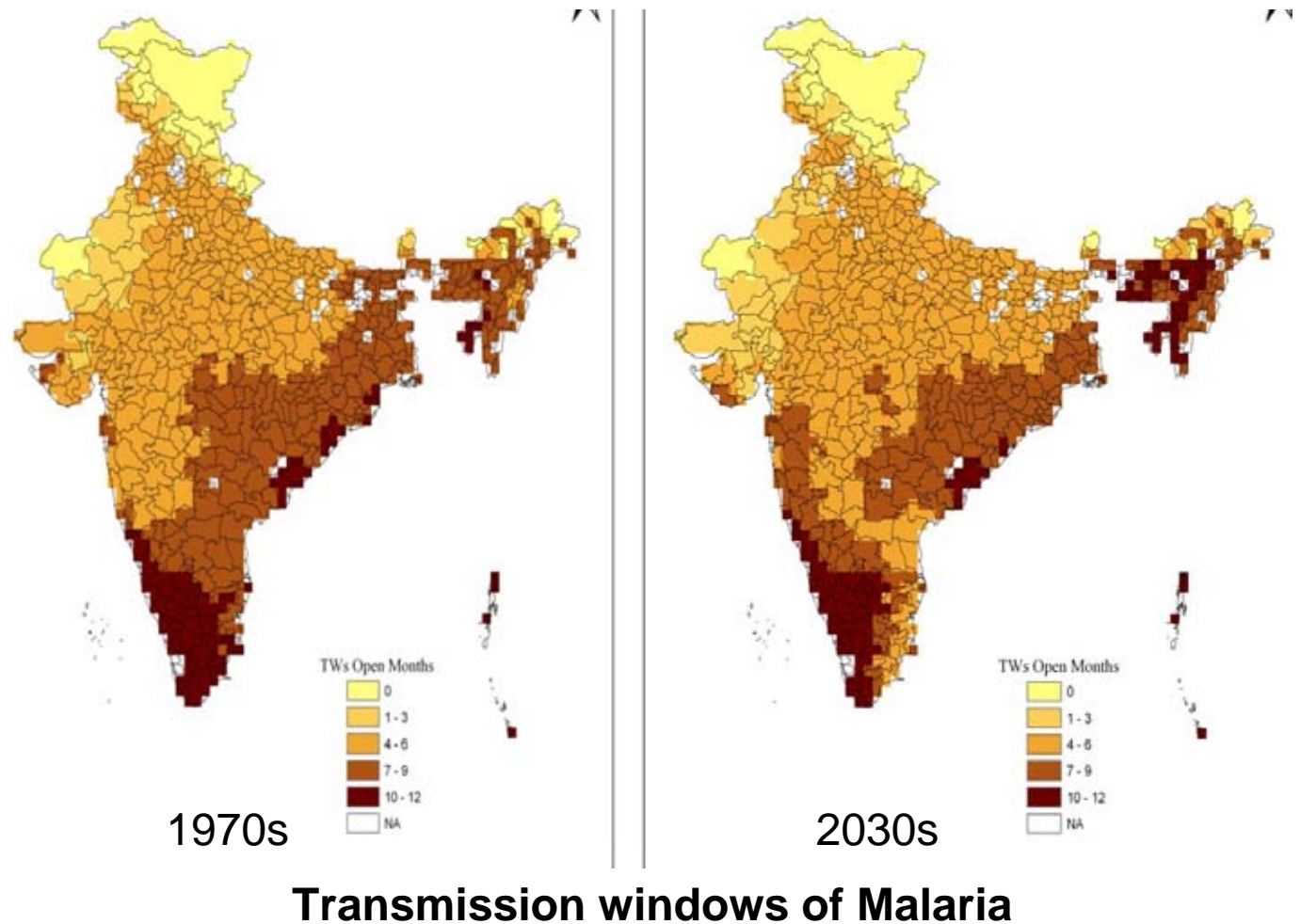
## Coastal Region:

general reduction



# Human Health

- Likely increase in morbidity due to rise in **extreme temperatures**
- Likely increase in morbidity and mortality **due to increase in water borne diseases** (enhanced flooding and SLR)
- Reduced crop yields may raise malnutrition cases (climate)
- Increase in incidence of malaria due to opening up of transmission windows at higher altitudes (climate)



# Implications for Convergence

- (Non)convergence and economic reforms
- No evidence of absolute convergence
- But club convergence
- Impact of climate change incl. extreme events
- Greater dispersion
- New clubs?
- Next steps...
- Need to 'shoehorn' regional climate impacts into state boundaries (units of economic and political analysis) and monetise these impacts
- Why?

## **Optimal response in a federal framework**

- At the aggregate level – should the (fat) tail wag the climate dog?
- At the regional (state) level – a Climate Finance Commission?