



# **Modelling of Regional Climate in South Asian Region and Future Climate Scenarios**

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# **Climate Applications and Services : WMO Perspectives**

# The World Climate Programme (WCP)

- An authoritative international scientific voice on the Earth's Climate System and on Climate Change.
- The WCP helps countries collect and use climate information and knowledge to benefit their national economies and improve human well-being.

# Major Areas of Interest to WCP

- Monitoring and understanding the global climate system
- Collection, rescue and management of climate data
- Detection & assessment of climate variability and change
- Applications of climate knowledge and information & climate services
- Guide to Climatological Practices
- Prediction of climate variations and improving prediction skill
- Impacts of climate variability and change
- Early warning and climate alert systems
- Guidance, techniques and methodologies for climate information
- Capacity building, transfer of knowledge, techniques and guidance
- Climate services for sustainable development and human well-being

# World Climate Applications and Services Programme

- Applications of climate information and prediction services to support human activities and sustainable development: economic efficiency
  - human health and well being
  - food production, food security
  - prudent use of water resources
  - use of renewable energies
  - sustainable tourism
  - Living in the urban and built environment

# Value of Climate Information and Services to Society

- the nature of the dependence of socio-economic activities on climatic factors
- reliability of climate products including awareness of the associated uncertainties and their implications to decision-making
- accessibility of credible and useful climate information for decision making
- liaison between users and climate information providers
- the ability of users to act on the basis of climate information

# WCASP Long-term Objectives

- Development of climate services
- Services for national sustainable development
- Methods of adapting to, and mitigating, the adverse impacts of climate and its variations
- Increased awareness of potential benefits
- Particular emphasis on public safety and welfare
- Development of practical methods and techniques including climate prediction products

# CLIPS is an implementing project of the World Climate Applications Programme (WCASP)

Climate Services

**Past: Analyzing Past Climate Records**

**Present: Monitoring Current State of Climate**

**Future: Predicting Future Climate Conditions**

The ultimate goal of the CLIPS Project is to develop climate services and their applications in various socio-economic sectors in all Member countries of WMO





# CLIPS Project Goals

- Develop the infrastructure for Seasonal to Interannual Prediction
- Develop and facilitate the concept of a global network of Regional Climate Centers (RCCs)
- Promote the science and the application of Seasonal to Interannual Prediction products, and
- Promote capacity building of producers and users of Seasonal to Interannual Prediction.

# CLIPS Objectives

- To demonstrate the value and eventual socio-economic benefits of climate information and prediction;
- To provide an international framework to enhance and promote climate information and prediction, including the establishment of criteria to measure forecast quality and to permit model inter-comparison;
- To encourage the development of operational climate prediction;
- To facilitate the definition, development and the strengthening of a global network of regional/national climate centres.

# CLIPS Focal Points



Participants of the CLIPS Training Workshop for Eastern and Southern Africa, August 2002

- WMO Members are developing a global network of climate scientists specially trained in climate science, statistical modelling and prediction, applications and project management.
- These CLIPS Focal Points ensure national and regional coordination of climate information and prediction products.

# Capacity Building

- Establish and update CLIPS Focal Points;
- Networking and Coordination of Focal Points;
- Development of CLIPS training Curriculum;
- CLIPS Training Workshops;
- Training end-users through workshops, projects and Climate Outlook Forums.

# Infrastructure and Forecasting

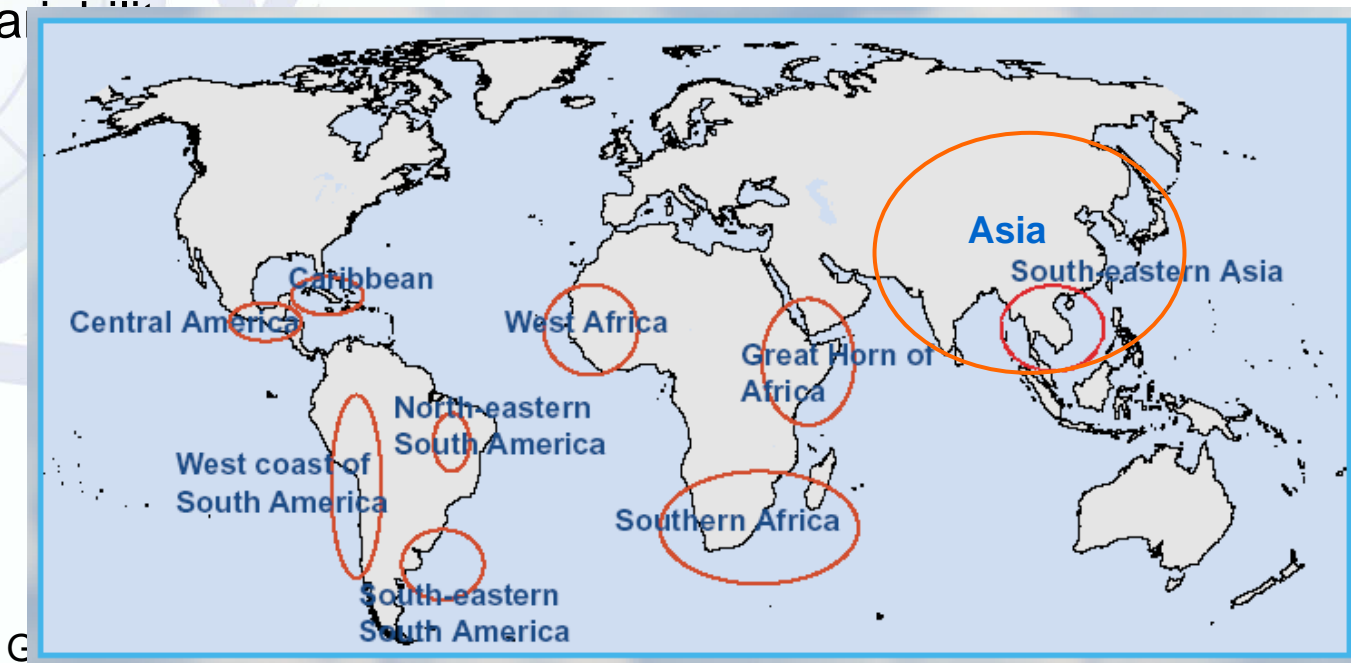
- Regional Climate Centres;
- Examination of forecast presentation methods;
- Best practices;
- Regional Climate Models;
- Regional Climate Outlook Forums;
- Joint activities with research programmes such as WCRP.

# Applications

- Coordination of demonstration and pilot projects;
- Involvement of Focal Points in demonstration and pilot projects;
- Examination of improved project design;
- Examination of impacts of climate services on applications;
- Examination of data requirements.

# Regional Climate Outlook Forums (RCOFs)

- RCOFs, initiated just prior to the major 1997–1998 El Niño event, constitute an important vehicle in developing regions for providing advance information on the likely climate features of the upcoming season, and for developing a consensus product from amongst the multiple available individual predictions.
- RCOFs stimulate the development of climate capacity in the National Meteorological and Hydrological Services of the area, and do much to generate decisions and activities that mitigate adverse impacts of climate and help communities adapt to climate variability.





# Global producers of long-range forecasts

- Centre for Weather Prediction and Climate Studies/National Institute for Space Research (CPTEC/INPE)
- Climate Prediction Center, National Centres for Environmental Prediction (CPC/NCEP/NWS/NOAA)
- European Centre for Medium-range Weather Forecasts (ECMWF)
- International Research Institute for climate and society (IRI)
- Japan Meteorological Agency (JMA)
- Met Office (United Kingdom)
- Météo-France
- Meteorological Service of Canada (MSC)
- Korean Meteorological Administration (KMA)
- National Climate Centre of the China Meteorological Administration (NCC/CMA)
- South African Weather Service (SAWS)
- World Meteorological Centre Melbourne
- World Meteorological Centre Moscow



# Applications and Services Activities

- Climate and Health
  - Heat/Health Warning Systems
  - Climate Indices (UTCI)
  - Climate and Disease
- Climate and Energy
  - Use of renewable energy:
    - Wind
    - solar
  - Data, instrument needs
- Climate and Tourism
  - Impacts of Climate variability, change on tourism
  - Tourism impact on Climate
  - Climatotherapy
- Urban, Building Climatology
  - Effect of urbanization on historical climate data
  - Model development
  - Science curriculum

# Fourteenth Session of WMO Technical Commission for Climatology (CCI XIV) Beijing, China, 3-10 November 2005

- Adopted new working structure and expert teams:
  - One Management Team, One ICT
  - 4 OPAGs
    - Climate and Data Management
    - Monitoring and Analysis of Climate Variability and Change
    - CLIPS
    - Climate Applications and Services
  - Rapporteurs reporting to MG:
    - Climate-related hazards
    - Guide to Climatological Practices
    - GEOSS
    - Gender focal point

# WMO COMMISSION FOR CLIMATOLOGY (CCI)

MANAGEMENT GROUP (MG)

**Regional Representatives:**  
 RA III: Luis Molion (*Brazil*)  
 RA V: Michael Coughlan (*Australia*)

**President**  
**Pierre Bessemoulin**  
*(France)*

**Vice-president**  
**Wang, Shourong**  
*(China)*

**World Data Centres:**  
 Aleksandr Sterin  
*(Russian Federation)*

**OPAG 1**  
**Climate Data and Data Management**  
  
*Chair: Raino Heino (Finland)*

**OPAG 2**  
**Monitoring and Analysis of Climate Variability and Change**  
  
*Chair: Thomas Peterson (USA)*

**OPAG 3**  
**Climate Information and Prediction Services (CLIPS)**  
  
*Chair: Abdallah Mokssit (Morocco)*

**OPAG 4**  
**Climate Applications and Services**  
  
*Chair: Dong, Wenjie (China)*

*Co-chair: Peter Ambenje (Kenya)*

*Co-chair: Manola Brunet India (Spain)*

*Co-chair: José Luis Santos (Ecuador)*

*Co-chair: Muhammed Kadi (Algeria)*

**1.1 ET for Climate Data Management including Metadata**  
*Radim Tolasz (Czech Republic)*

**2.1: CCI/CLIVAR/JCOMM ET on Climate Change Detection and Indices**  
 CCI: Albert KleinTank (Netherlands)  
 CLIVAR: TBD

**3.1: ET on Research Needs for Intraseasonal, Seasonal & Interannual Prediction**  
*Jean-Pierre Ceron (France)*

**4.1: ET on Climate and Health**  
*Glenn McGregor (UK)*

**1.2: ET on Observing Requirements and Standards for Climate**  
*William Wright (Australia)*

**2.2: ET on Climate Monitoring including the use of Satellite and Marine Data and Products**  
*Zhang, Zuqiang (China)*

**3.2: ET on CLIPS Operations, Verification and Applications Services**  
 Operations: Philbert Tibaijuka (Tanzania)  
 Verification: Simon Mason (USA)  
 User Liaison: Jaakko Helminen (Finland)

**4.2: ET on Climate and Energy**  
*David Wratt (New Zealand)*

**1.3: ET on Rescue, Preservation and Digitization of Climate Records**  
*Joe Elms (USA)*

**2.3: Rapporteur on Climate Extremes**  
*Randall Cerveny (USA)*

**3.3: ET on El Niño and La Niña**  
*Luc Maitrepierre (New Caledonia)*

**4.3: ET on Climate and Tourism**  
*Dan Scott (Canada)*

**4.4: ET on Urban and Building Climatology**  
*Sue Grimmond (UK)*

**Reporting to the President or Management Group:**

5.1: Rapporteur on Climate-related Hazards (*Member of the MG, TBD*)  
 5.2: ET on the Guide to Climatological Practices (*Ned Guttman, USA*)  
 5.3: Gender Focal Point (*Juliana Ukeje, Nigeria*)  
 5.4: Rapporteur on GEOS (Stephan Roesner, Germany)

7. Implementation/Coordination Team (ICT): CCI VP; Co-Chairs of OPAGs 1, 2, 3, 4; Chairpersons of the Working Groups on Climate-related Matters for RAs I, II, III, IV, V and VI.

**3.4: Rapporteur on Climate And Water**  
*Nakaegawa Tosiyuki (Japan)*

**3.5: Rapporteur on Climate and Agrometeorology**  
*Roger Stone (Australia)*

**Reporting to the OPAG Chairs:**  
 6. CCI Experts serving on teams of other  
**Technical Commissions**

OPAG: Open Programme Area Group  
 ET: Expert Team

# WCASP Deliverables

## COMPLETED

- Catalogue of Indices and Definitions of El Niño and La Niña in Operational Use by WMO Members. (**Horsfall et al.**), June 2006. *Evolutive web doc*
- Climate Information Needs for the Use of Renewable Energy Systems in Developing Countries. (**Robles-Gil**), September 2005
- Weather derivatives. (**Wratt**), August 2005.
- Guideline on health-related climate indices: the thermal environment. (**Jendritzky et al.**), 2004
- The Aral Sea: Water, Climate and Environmental Change in Central Asia. (**Glantz and Zonn**), 2005
- Glossary of verification terms published in *Forecast Verification: A Practitioner's Guide in Atmospheric Science*, (**Jolliffe and Stephenson**, Eds.), Wiley.

## UNDER DEVELOPMENT

### **Guides/Guidelines**

- Heat-Health Warning Systems (**McGregor et al.**) : jointly with WHO/Europe
- Climatological Practices (**Gutman et al.**)
- Operational Practices (**ET 3.2**)
- Best Practices (**Helminen et al.**)

### **Updating of Technical Notes**

- TN 134: Review of Urban Climatology: With **IAUC**
- TN 145: The socio-economic benefit of Climatological services. (**Helminen et al.**)
- TN 149: Urban and Building Climate. (**Grimmond et al.**)
- TN 150: Applications of Building Climatology to the problem of housing and building for human settlements. (**John Page**)
- TN 172: Meteorological Aspects of the Utilization of Solar Radiation as an Energy Source (**ET 4.2**)
- TN 175: Meteorological Aspects of the Utilization of Wind as an Energy Source (**ET4.2**)

# Continued User Focus for Climate Services

- WCASP/CLIPS will continue to promote the development of climate services with active participation of application sectors.
- CLIPS Focal Point activity to be revitalized and expanded to accomplish better involvement of application sectors
- CCI Expert Teams charged with re-focused strategies to help develop the regional/national capacities in developing climate services
- It is most important for the application sectors to help the climate information providers in qualifying the value of climate services, and also in optimally packaging the climate information products.
- We need to leverage climate information to exploit opportunities afforded by the climate as well as to manage the risks associated with adverse climate situations.



# Climate Change in South Asia

# South Asia :

## Population Pressure on Resources

- Total land area: 3.0% of global
- Population (present): 21.3% of global
- Population (projected-2025): 23.6% of global



# Monsoon in a changing world

- We know the earth's atmosphere is undergoing unprecedented warming
- Much of the warming is convincingly attributed to human activities
- How does the monsoon behave in a warmer atmosphere-ocean coupled system ?
- More atmospheric moisture → More intense hydrological cycle → More intense monsoon ?
- More intense/frequent ENSO anomalies ? More monsoon variability ?
- Which are the sub-regions likely to be affected ?
- Are land-use and land-cover changes associated with monsoon changes ?
- How do we distinguish between natural and anthropogenic changes in monsoon patterns ?
- Do we have global/regional policy options to deal with perceived monsoon changes ?



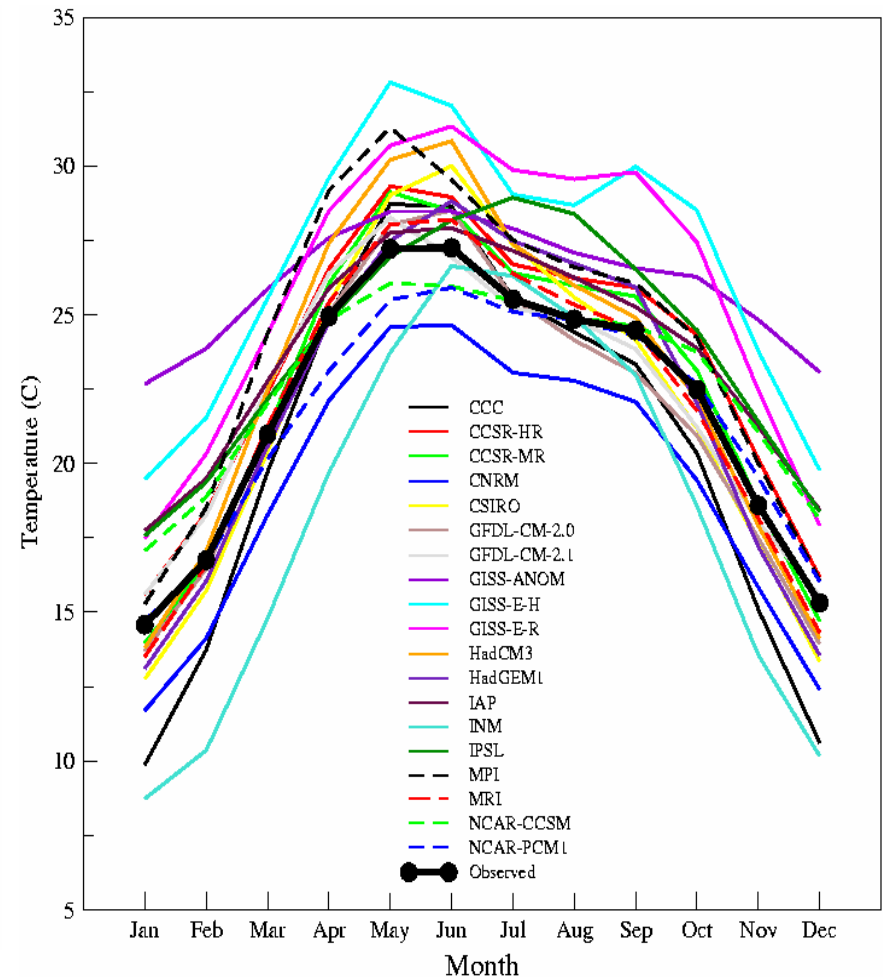
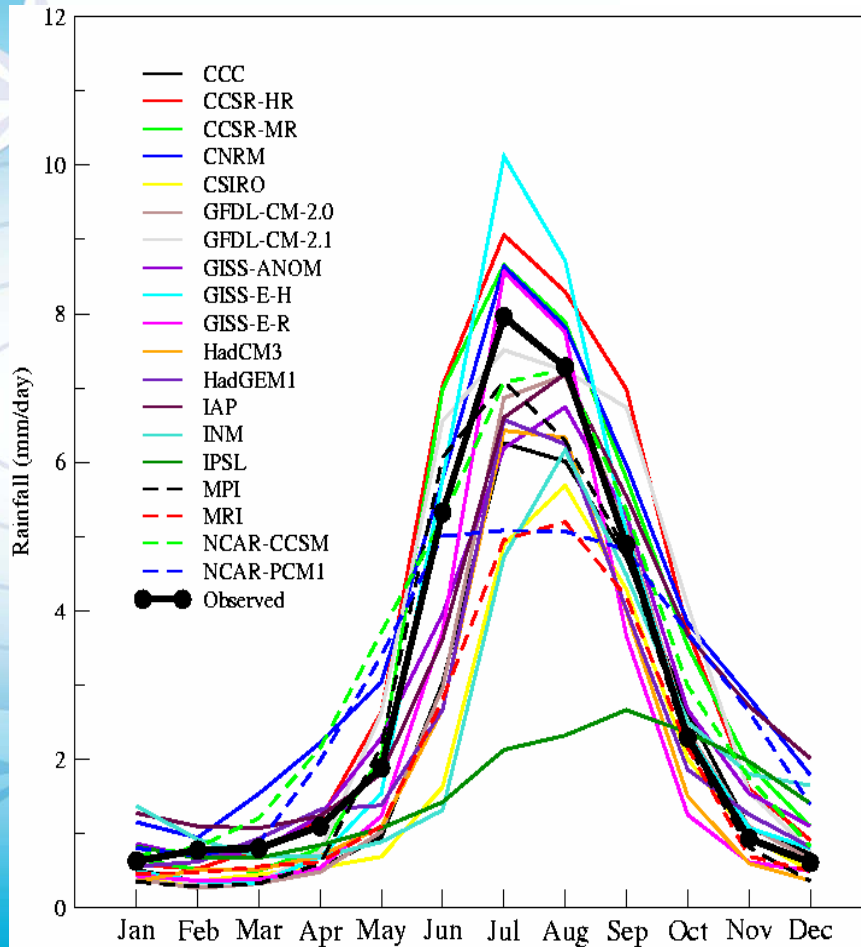
# How monsoon can change...

- Spatio-temporal patterns of rainfall
- Frequency of extreme seasonal anomalies
- Monsoon onset/withdrawal
- Timing and duration of active/break periods
- Frequency of severe rainstorms
- Teleconnections (e.g., ENSO-Monsoon)
- Predictability of monsoon

# Modelling Monsoon Changes

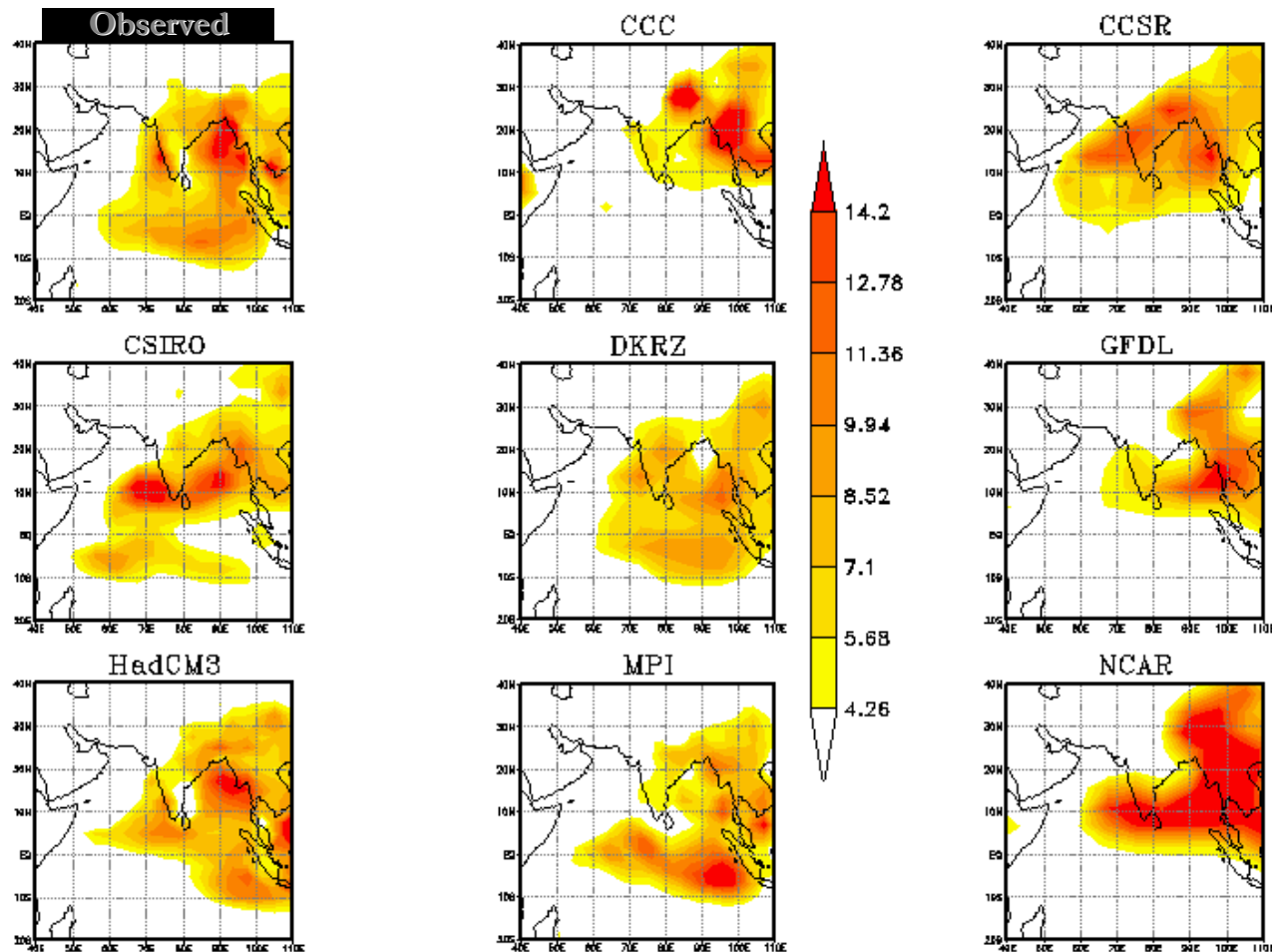
- Atmosphere-Ocean coupled models have made rapid strides over the past decade
- Global models are relatively better in reproducing large-scale monsoon features, but problems with regional details are yet to be overcome
- Regional models provide good tools to downscale global model predictions
- High-resolution climate change scenarios for the monsoon are available for impact assessments
- Yet, human behaviour being the most unpredictable forcing factor for climate change, models can only be used for policy guidance, and NOT to PREDICT future changes

# Annual Cycles of Rainfall and Temperature in the 20<sup>th</sup> century simulations of AR4 models



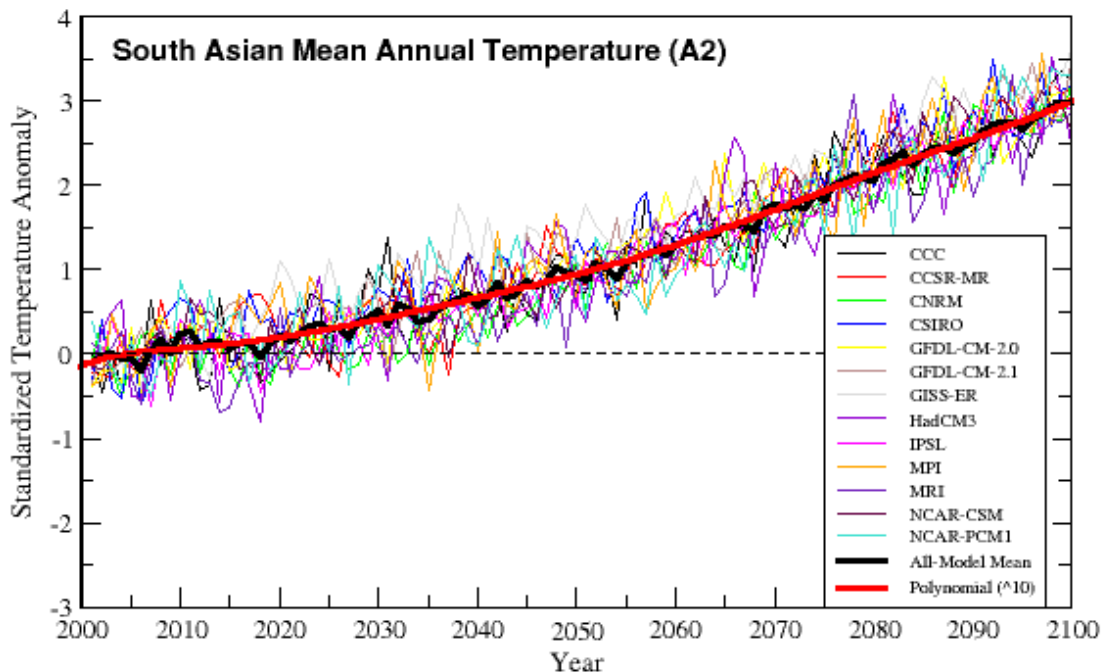
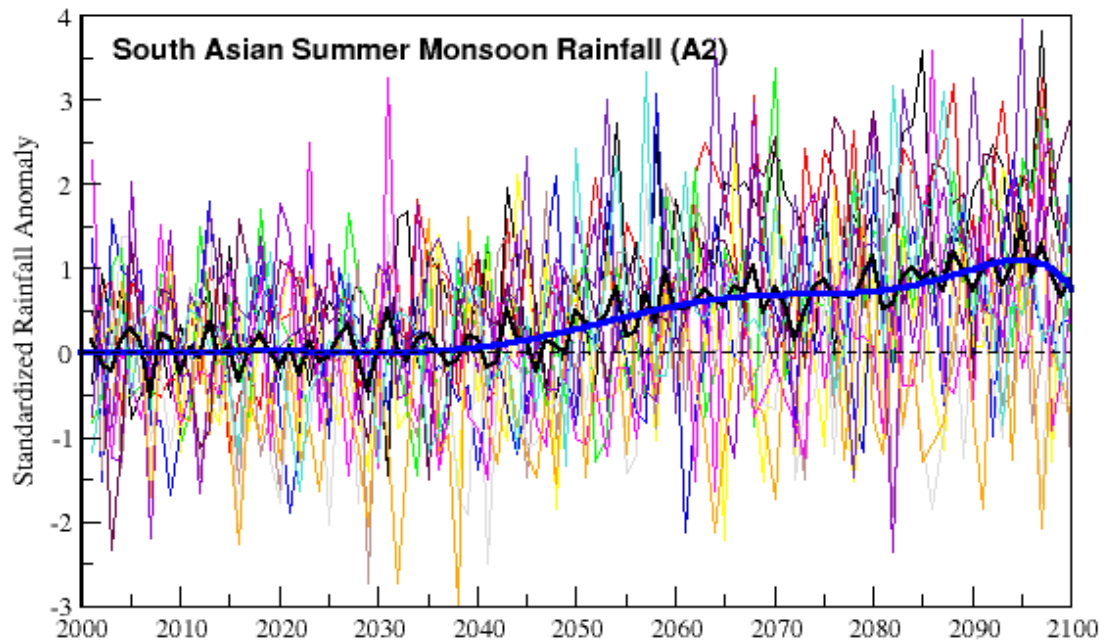
Global models provide inadequate and even inaccurate information on regional scales, more strikingly in the case of the Indian summer monsoon variability patterns.

Summer Monsoon Rainfall (mm/day) Simulation by AOGCMs

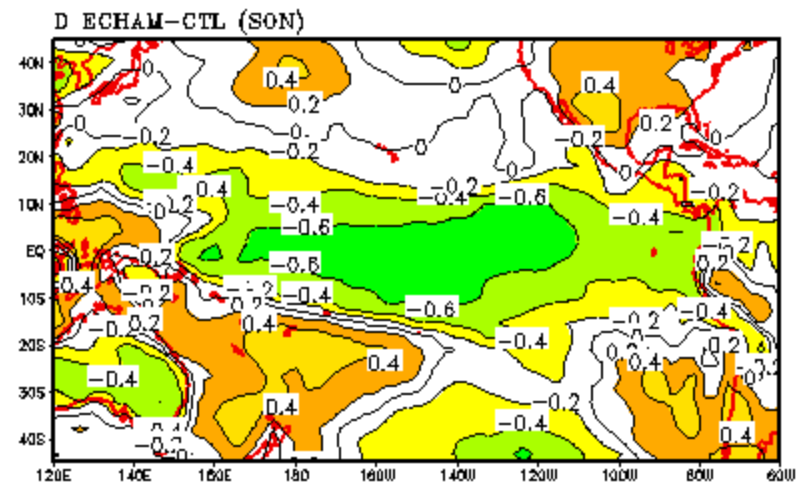
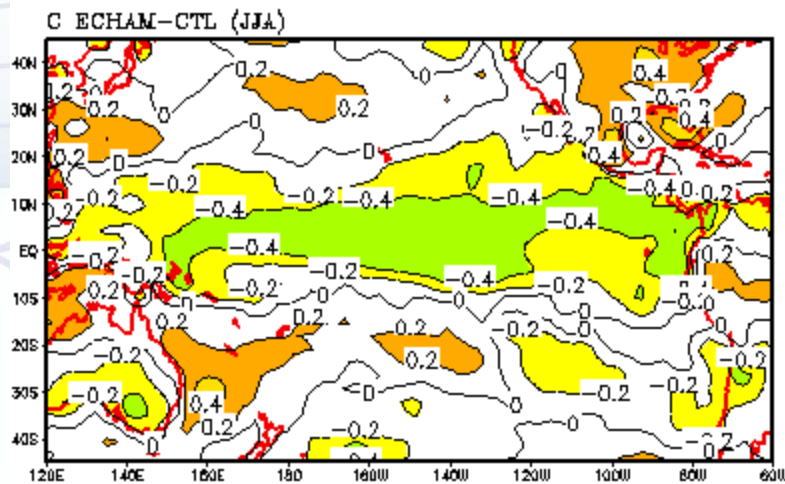
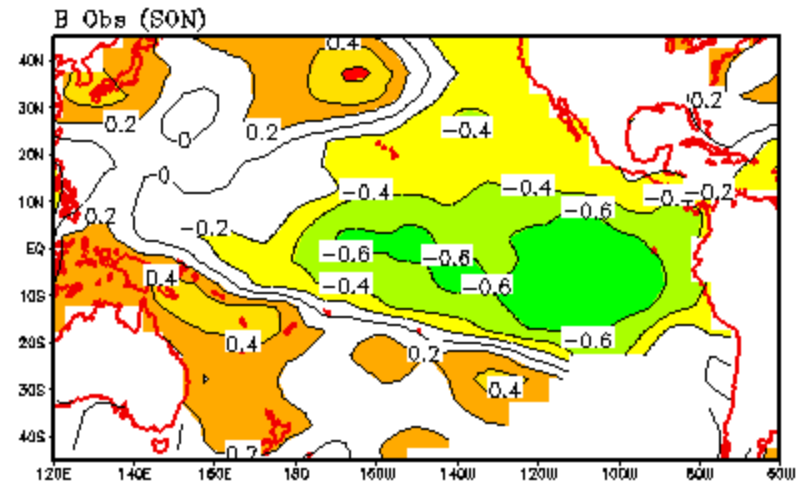
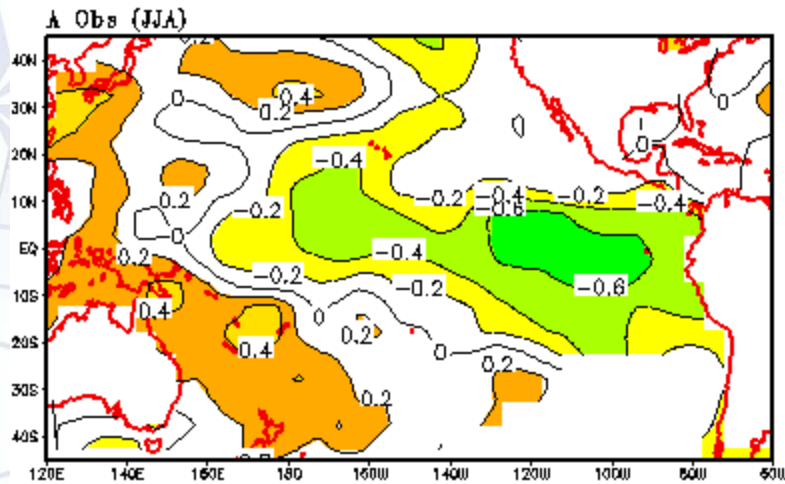


# Future Scenarios for Summer Monsoon Rainfall and Annual Temperature over South Asia under A2 Scenario (High Emissions) based on IPCC AR4 Simulations of AOGCMs

(Anomalies relative to current period)



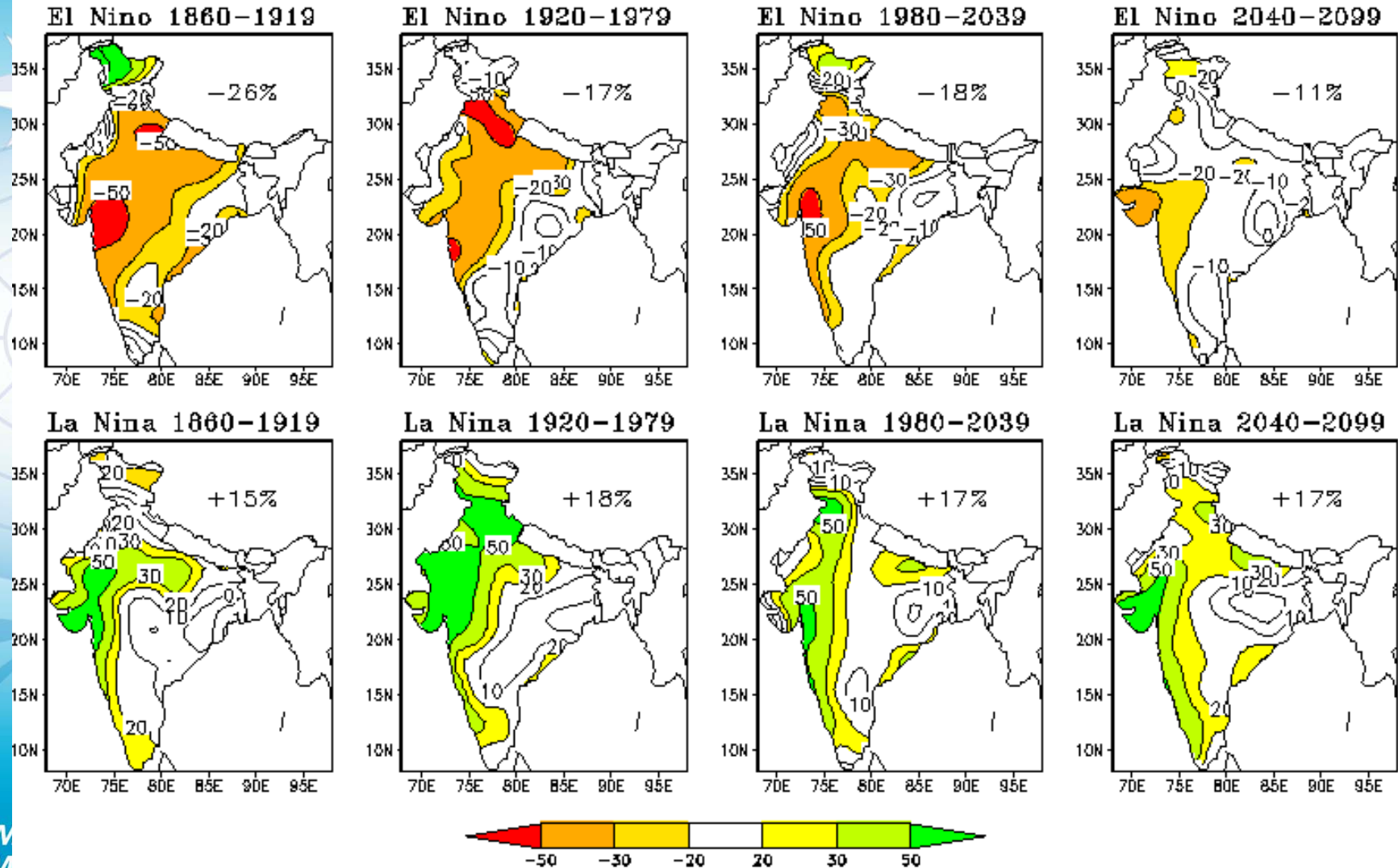
# ENSO-Monsoon Correlations – Observations & Modelling



Global Change Conference, Islamabad, Pakistan, November 16-17, 2006

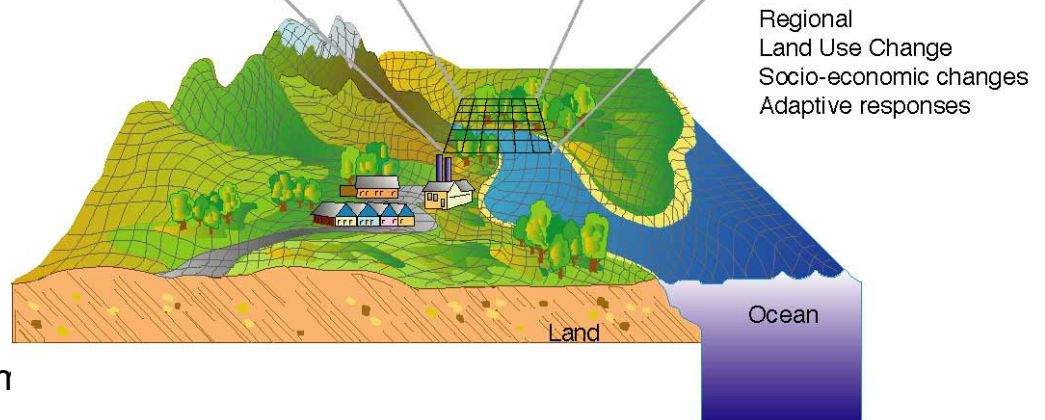
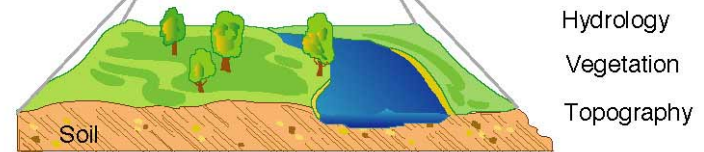
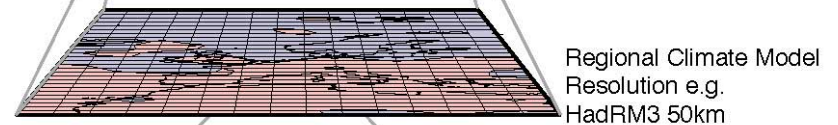
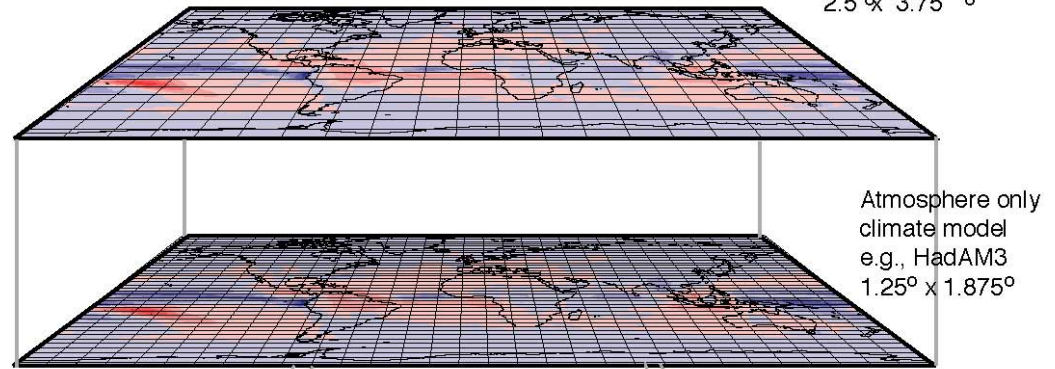


# Projected Changes in ENSO-Monsoon Relationships due to Transient increase in Greenhouse Gas Concentrations (ECHAM4/OPYC3)



# GCMs to Regional Adaptive Responses : Modelling Path

Global Coupled  
Climate  
Model Resolution  
e.g. HadCM3  
2.5° x 3.75°

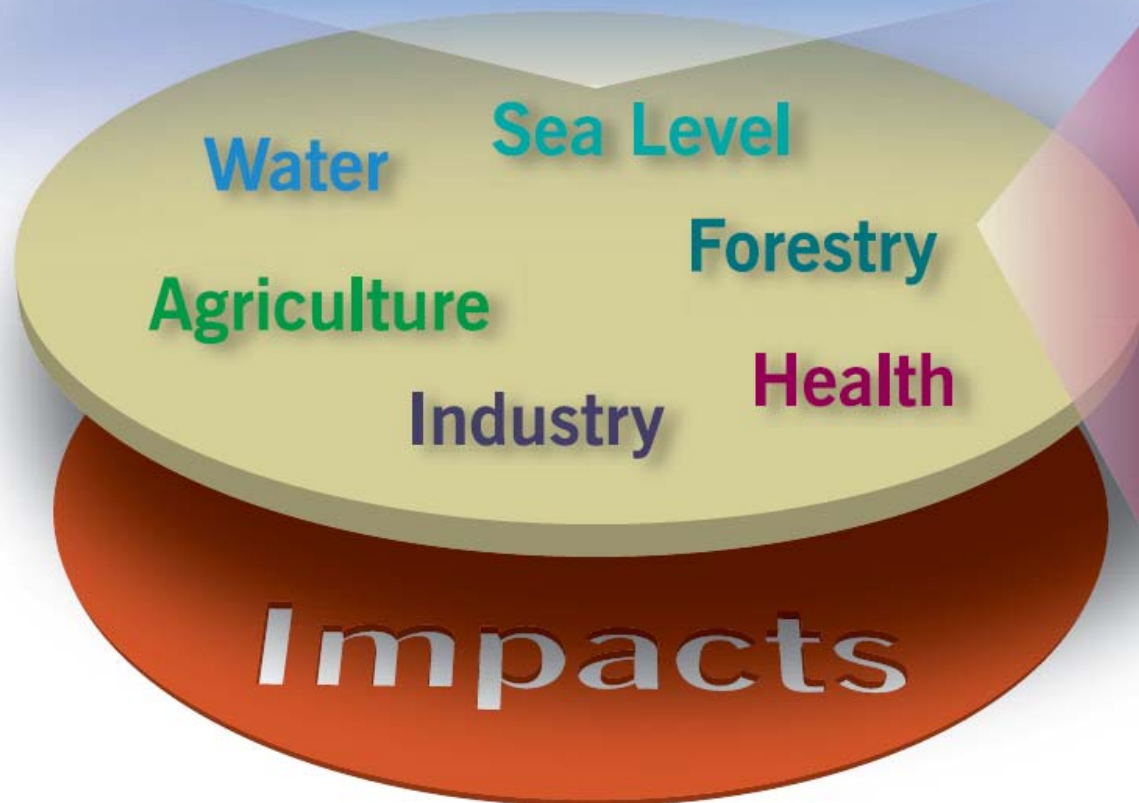




# Joint Indo-UK Programme on Climate Change Impacts in India (2001-2004)

## CLIMATE CHANGE SCENARIOS

(temperature, precipitation and extreme events)



### SOCIO-ECONOMIC SCENARIOS

(in terms of future changes in land use, economy, population, governance)

# Impacts

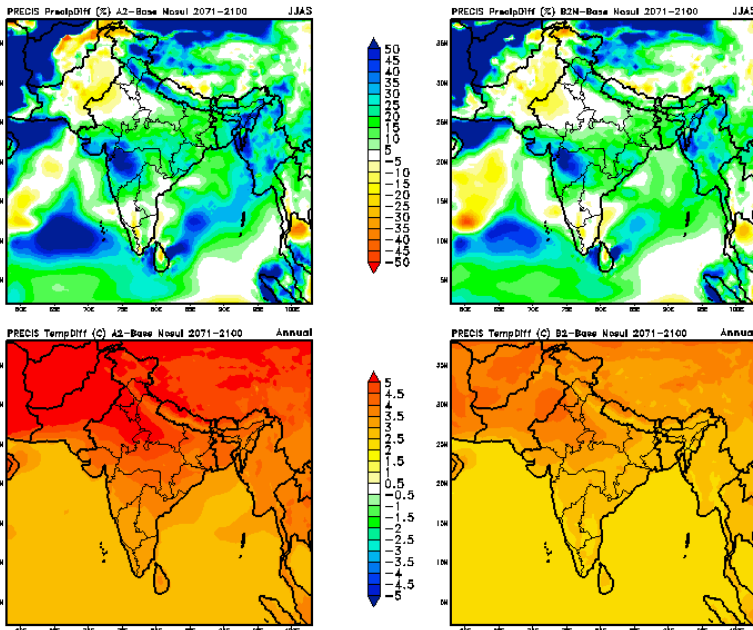
# Research Packages

<i>Themes</i>	<i>Investigating Institutions</i>
Indian climate change scenarios for impact assessment	Indian Institute of Tropical Meteorology (IITM), Pune (Dr. Rupa Kumar Kolli, PI)
Socio-economic scenarios for India	The Energy and Resources Institute (TERI), New Delhi (Ms. Preety Bhandari, PI)
Impacts of climate change on sea-level variability along the coast of India	National Institute of Oceanography (NIO), Goa (Dr. A.S. Unikrishnan, PI)
Impacts of climate change on water resources	Indian Institute of Tropical Meteorology (IITM), Pune (Dr. G.B. Pant, PI)
Impacts of climate change on agriculture	Indian Agricultural Research Institute (IARI), New Delhi (Dr. N. Kalra, PI)
Impacts of climate change on forests	Indian Institute of Science (IISc), Bangalore (Dr. N.H. Ravindranath, PI)
Impacts of climate change on industries, energy and transport	Indian Institute of Management (IIMA), Ahmedabad (Dr. P.R. Shukla, PI)
Impacts of climate change on human health	National Physical Laboratory (NPL), New Delhi (Dr. A.P. Mitra, PI)

# Climate Change Scenarios for India

IITM, Pune

- Climate change scenarios developed using Hadley Centre Regional Climate Models.
- Model simulations performed for the current period (1961-90), A2 (high emissions) and B2 (low emissions) scenarios for the future period (2071-2100).
- Temperatures projected to increase by as much as 3° to 4°C towards the end of 21<sup>st</sup> century.
- Large-scale increase in monsoon rainfall (10 to 30%), but substantial spatial differences.

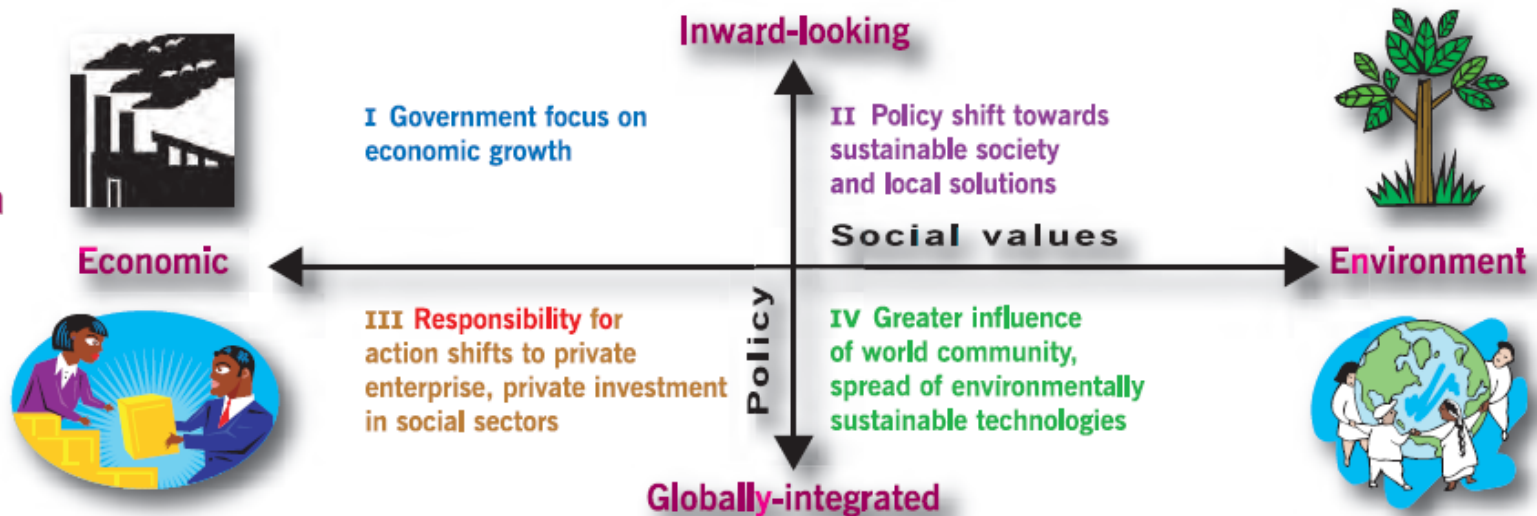


# Socio-economic Scenarios

TERI, New Delhi

- Four potential development scenarios outlined for India based on two central dimensions of policy and social values, along with their associated population and economic growth projections.
- These scenarios are consistent with national growth plans in the short and medium term and sit within the overall context of the long-term socio-economic scenarios developed by the IPCC.
- The research gathered data on factors that are relevant to the six topical projects, such as water use, timber demand, and food demand.

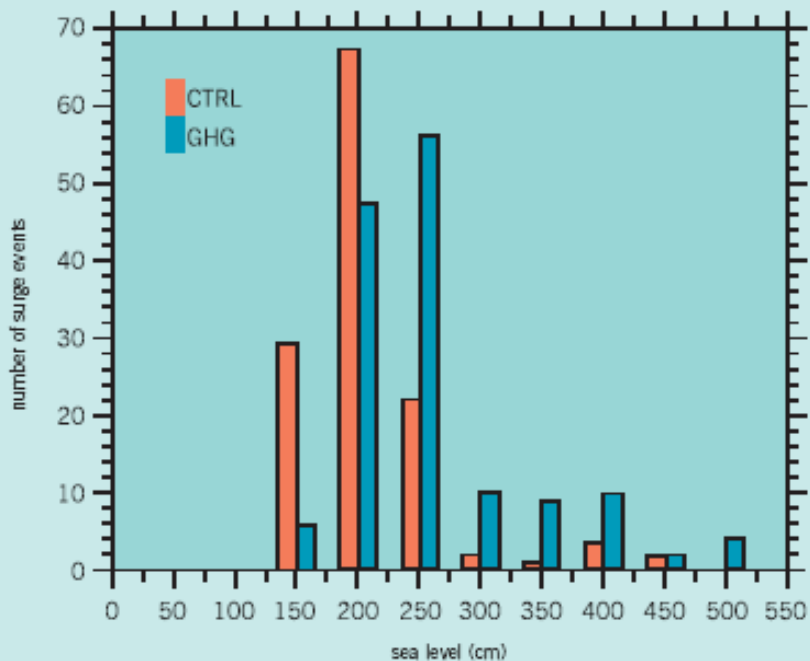
Framework for visions of socio-economic change for India



# Impacts on Sea Level

NIO, Goa

Frequency Distribution of Maximum Surges



- A storm surge model developed for the Bay of Bengal.
- Possible increases projected in the intensity of cyclonic storms leading to more extreme sea-level events.
- Case studies of expected sea-level changes for three locations on the east coast of India suggest that the southern peninsular coast will be the most vulnerable to sea-level rise.



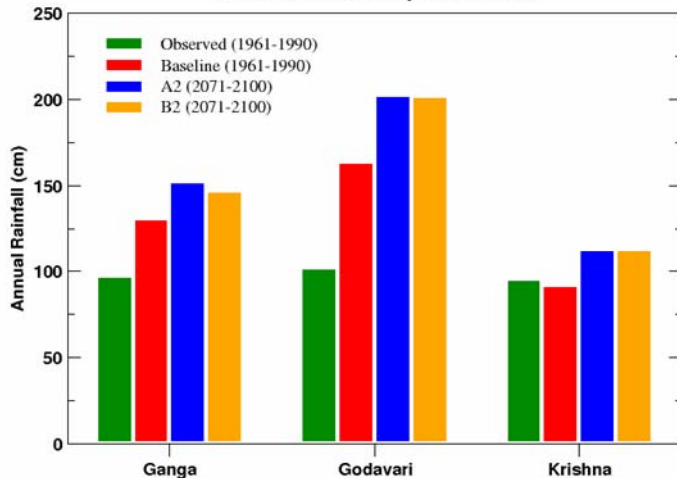
# Impacts on Water Resources

IITM, Pune

- The project focused on an impact assessment of climate change on the country's three major river basins: the Krishna, the Ganga, and the Godavari.
- The hydrological cycle is projected to be more intense, in a greenhouse warming scenario, with expected increase in extremes and intensities.
- Model simulations indicate a general increase (about 20%) in precipitation over the three river basins, with consequent increases in surface water availability.

PRECIS Simulations of Present and Future Precipitation

Annual Rainfall over Major River Basins



# Impacts on Agriculture

IARI, New Delhi

## Boundary Changes for Productivity of Irrigated Wheat

Impact under 425ppm CO<sub>2</sub> concentration and 2°C temperature rise

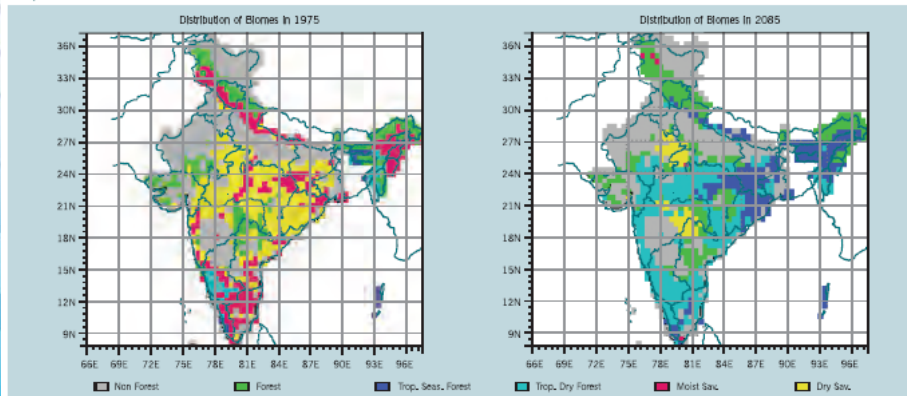


- Crop growth models used to evaluate potential climate change impacts on yield of wheat, rice, sorghum and maize.
- Increases in temperature reduced potential wheat/rice yields in most places, but predicted changes vary greatly by region and crop.
- Reductions in yields predicted to be more pronounced for rain fed crops under limited water supply situations.
- Climate change also predicted to lead to changes in areas suitable for growing certain crops.

# Impacts on Forests

IISc, Bangalore

Impact on forest biomes (B2 scenario)



- Large-scale shifts projected for forest types; the dominant forest cover of Moist and Dry Savanna is projected to give way to Tropical Dry Forest and Seasonal Forest.
- This projected shift in vegetation type may lead to large-scale forest dieback and loss of biodiversity, adversely affecting forest-dependant communities.
- Net Primary Productivity (NPP), a measure of the amount of vegetation matter produced, is likely to increase due to carbon fertilization, with some increase in wood supply in the medium term.

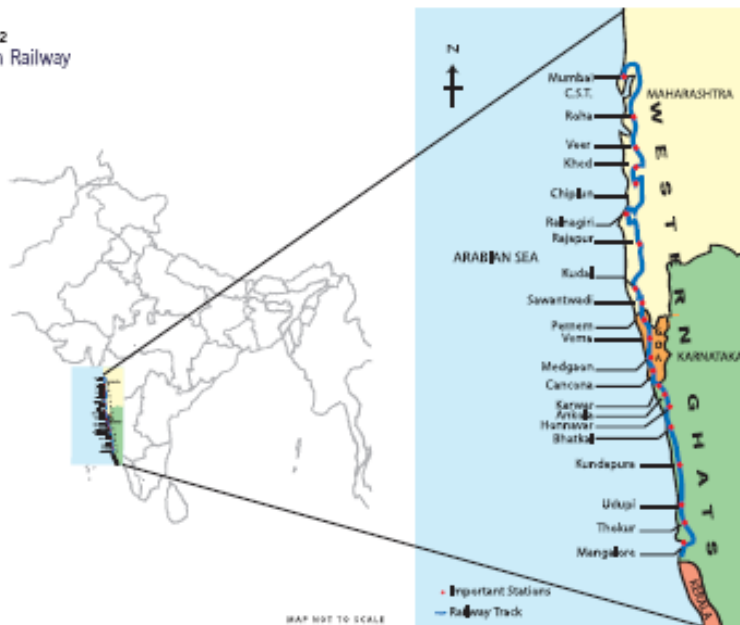


# Impacts on Industries, Energy and Transport

IIM, Ahmedabad

- Two case studies provided a level of focus to the study: transportation infrastructure (Konkan Railway), and national energy demand.
- Climate change projected to increase disruption to Konkan Railway due to increased incidence of extreme events with significant social and economic consequences.
- An additional 1.5% power generation capacity projected to be required due to climate change alone.

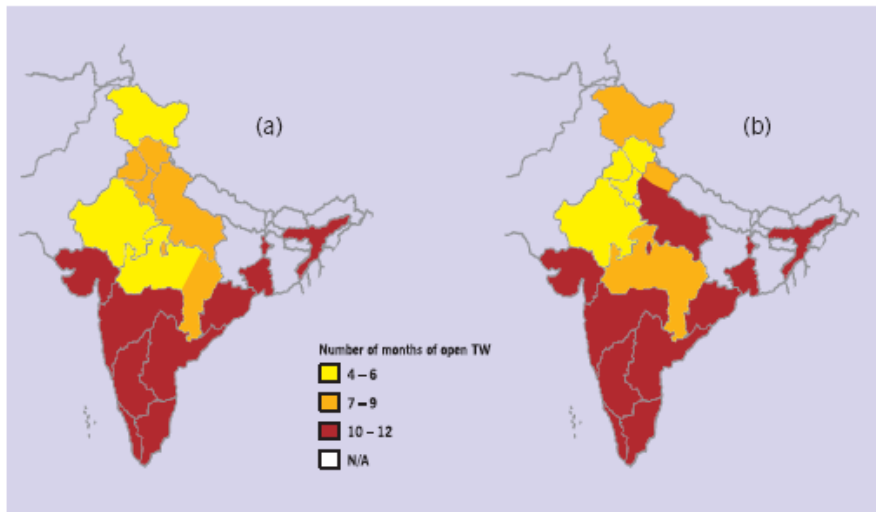
Figure 8.2  
Konkan Railway



# Impacts on Human Health

NPL, New Delhi

Transmission Window of Malaria in Different States of India  
(a) for base case and (b) under projected climate change scenario



- The study focused on malaria, a vector borne disease, because of its prevalence in India.
- The project considered the present and future malaria scenario in vulnerable states, using climate determinants conducive to malaria parasite growth and transmission.
- Transmission windows for malaria are predicted to increase with climate change, particularly in the north.

# Key Benefits

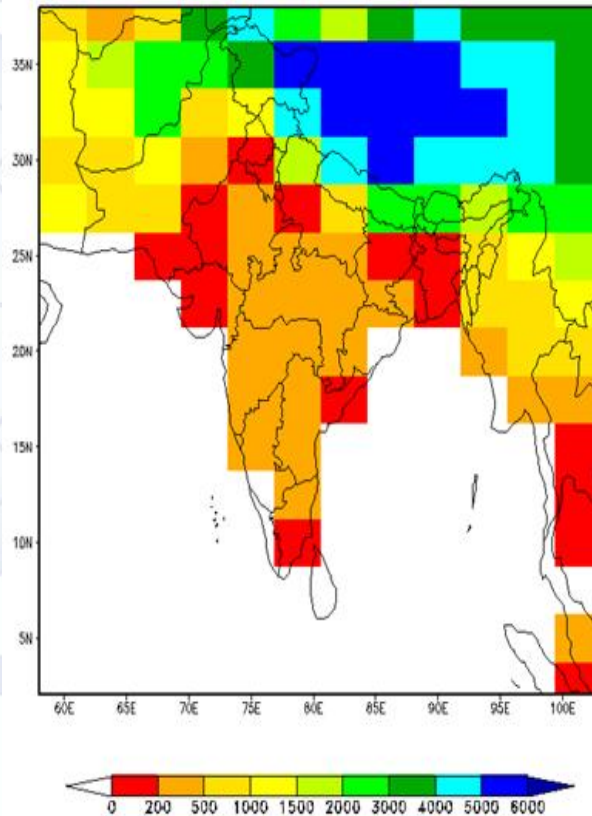
- Establishment of the framework for multi-disciplinary research in climate change impacts.
- Successful application of state-of-art modelling tools and capacity building.
- Comprehensive picture of impacts of climate change, reported in National Communication to the UNFCCC.
- A large database on scenarios and impacts, that can feed more detailed studies for many years to come, and underpin future adaptation strategies.
- Interactions between Indian and UK researchers to share their experiences and perspectives in the area.
- Facilitated climate networking in South Asia, and helped the South Asian countries in sharing information on climate change assessments.

# PRECIS

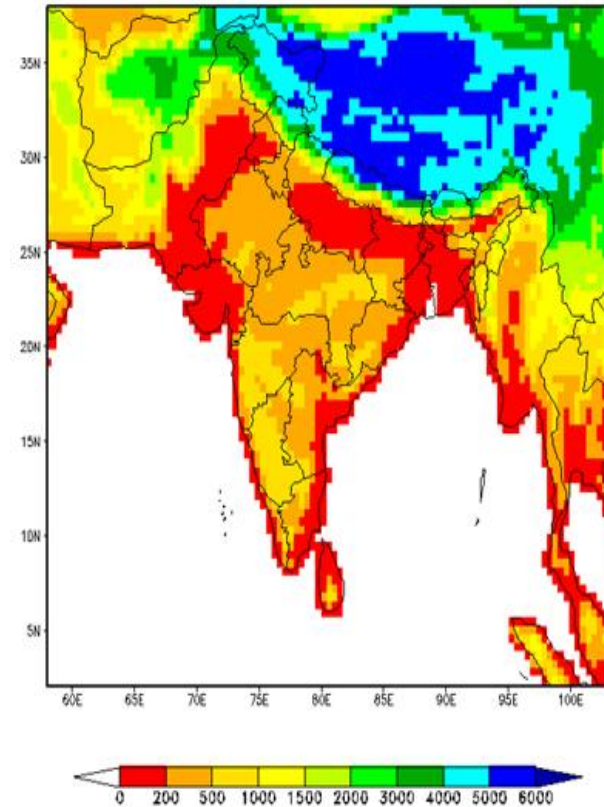
- Providing **REgional Climates for Impacts Studies**
- High-resolution limited area model driven at its lateral and sea-surface boundaries by output from HadCM
- PRECIS runs on a Linux PC (horizontal resolutions currently available: 50 x 50 and 25 x 25 km).
- Needs data for the selected domain on lateral boundary conditions (LBC) from the driving GCM (e.g., HadCM3/HadAM3) and the associated ancillary files (e.g., sea surface temperatures, vegetation, topography, etc.).
- Hadley Centre, UK has been providing PRECIS as well as the driving data to several regional groups.
- Baseline (1961-90), A2 and B2 scenarios (2071-2100). Reanalysis-driven runs provide comprehensive regional data sets representing current conditions, which can assist model evaluation as well as assessment of vulnerability to current climate variability.
- Ensembles to estimate model-related uncertainties.

# Model Orography

## HadCM3



## PRECIS



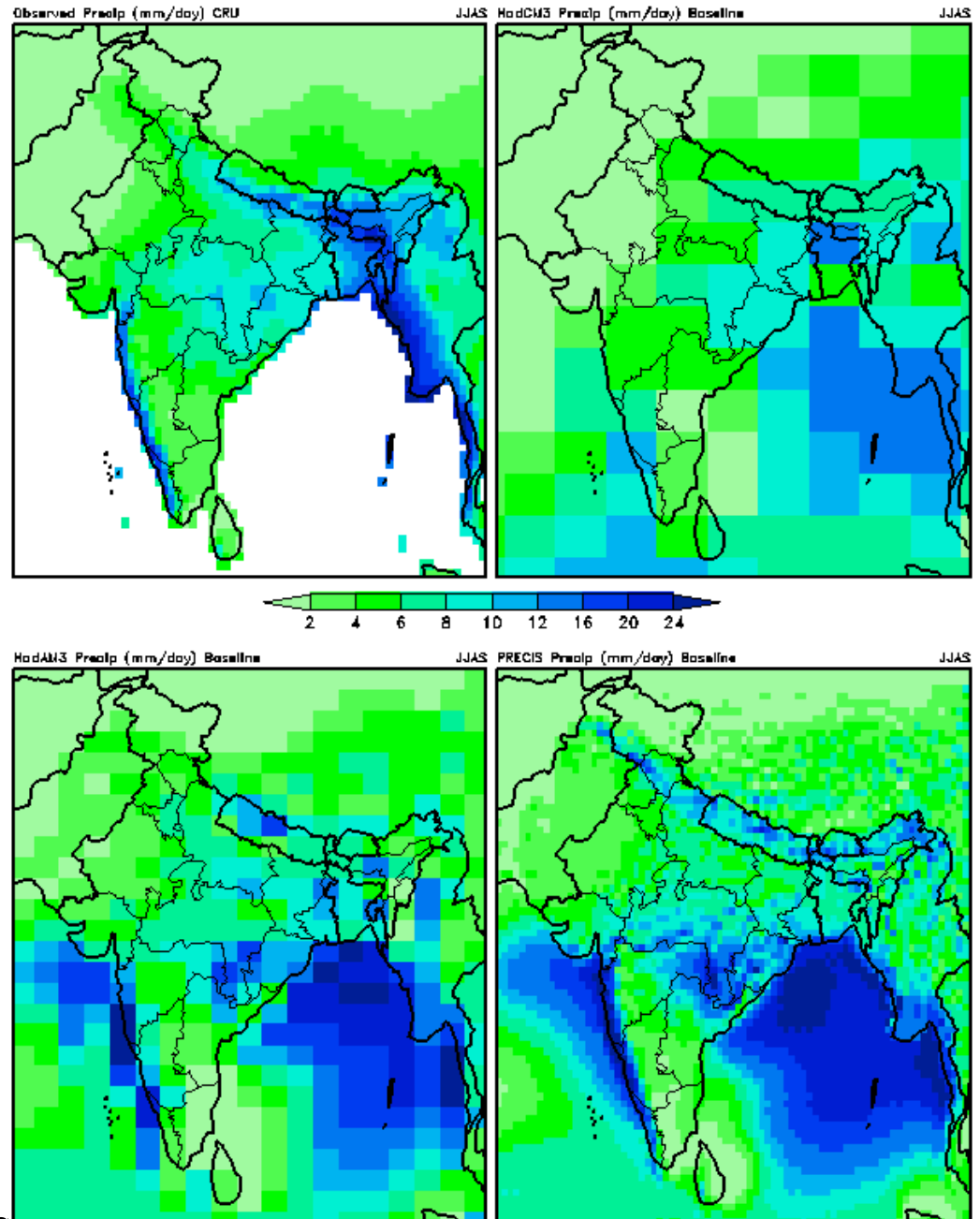


# PRECIS Runs at IITM

- Evaluation experiment using LBCs derived from ERA-15 (1979-93)
- Several scenario runs of PRECIS performed simultaneously on an array of PCs
- Runs (3 ensembles in each experiment) already 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
- Scenarios for intermediate time slices by pattern scaling approaches

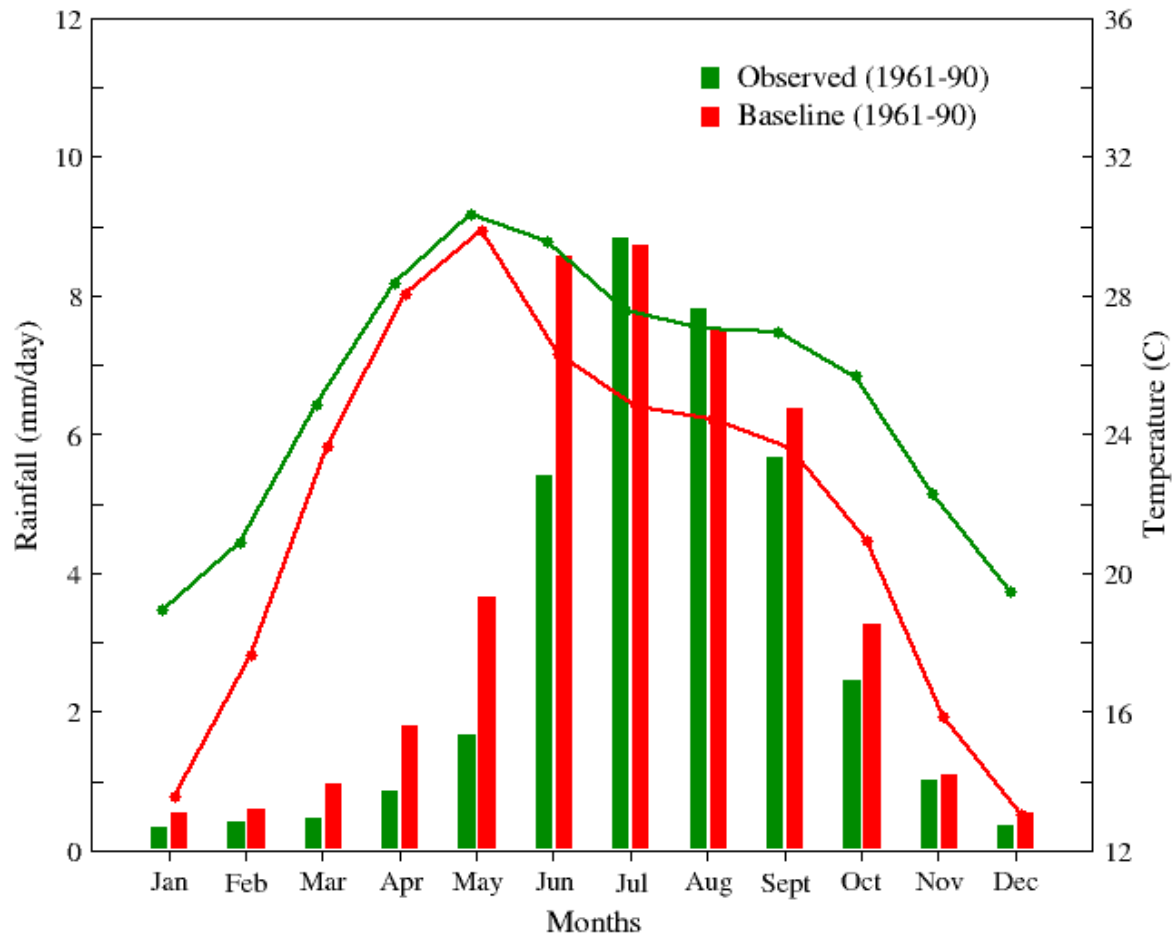


PRECIS captures important regional information on summer monsoon rainfall missing in its parent GCM simulations.



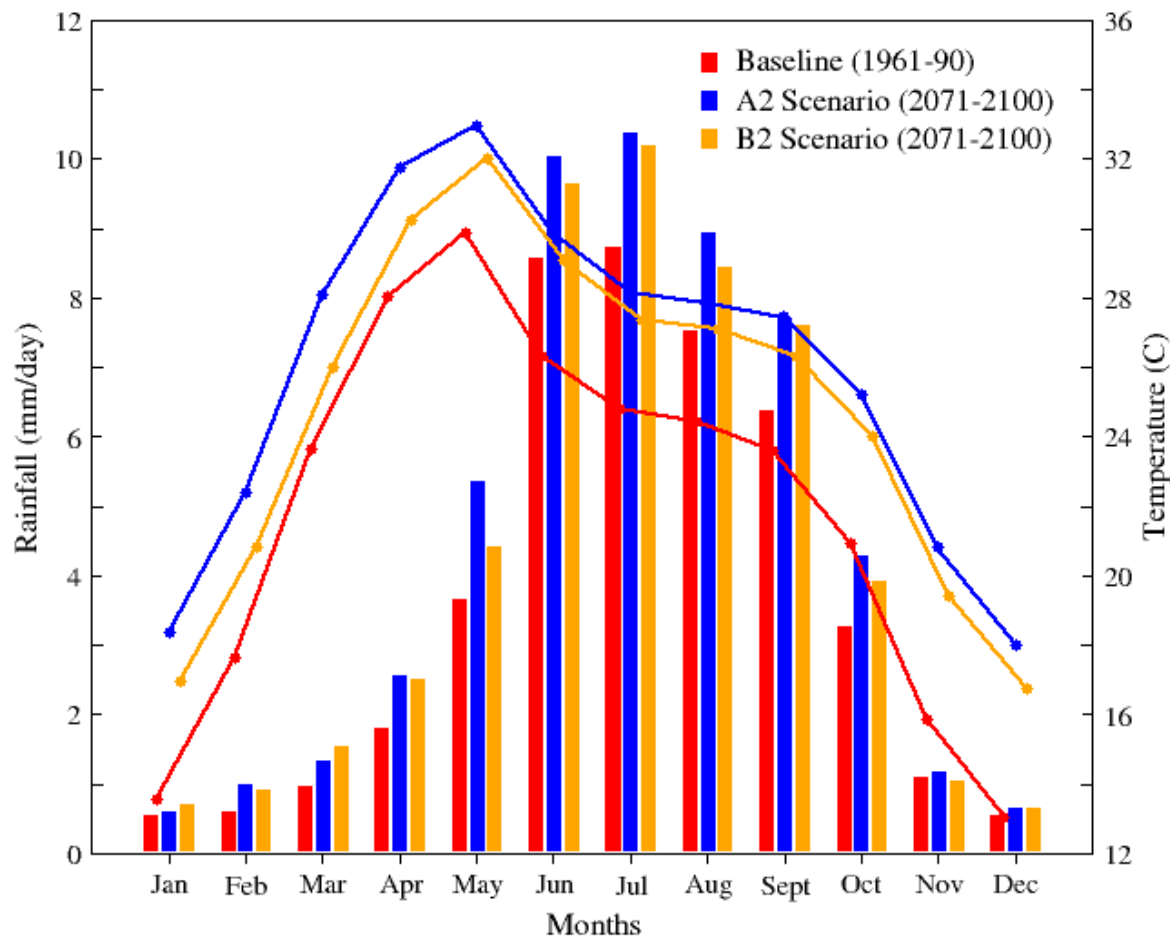
# PRECIS Simulations of Present Climate

## Mean Annual Cycles of All-India Rainfall and Temperature

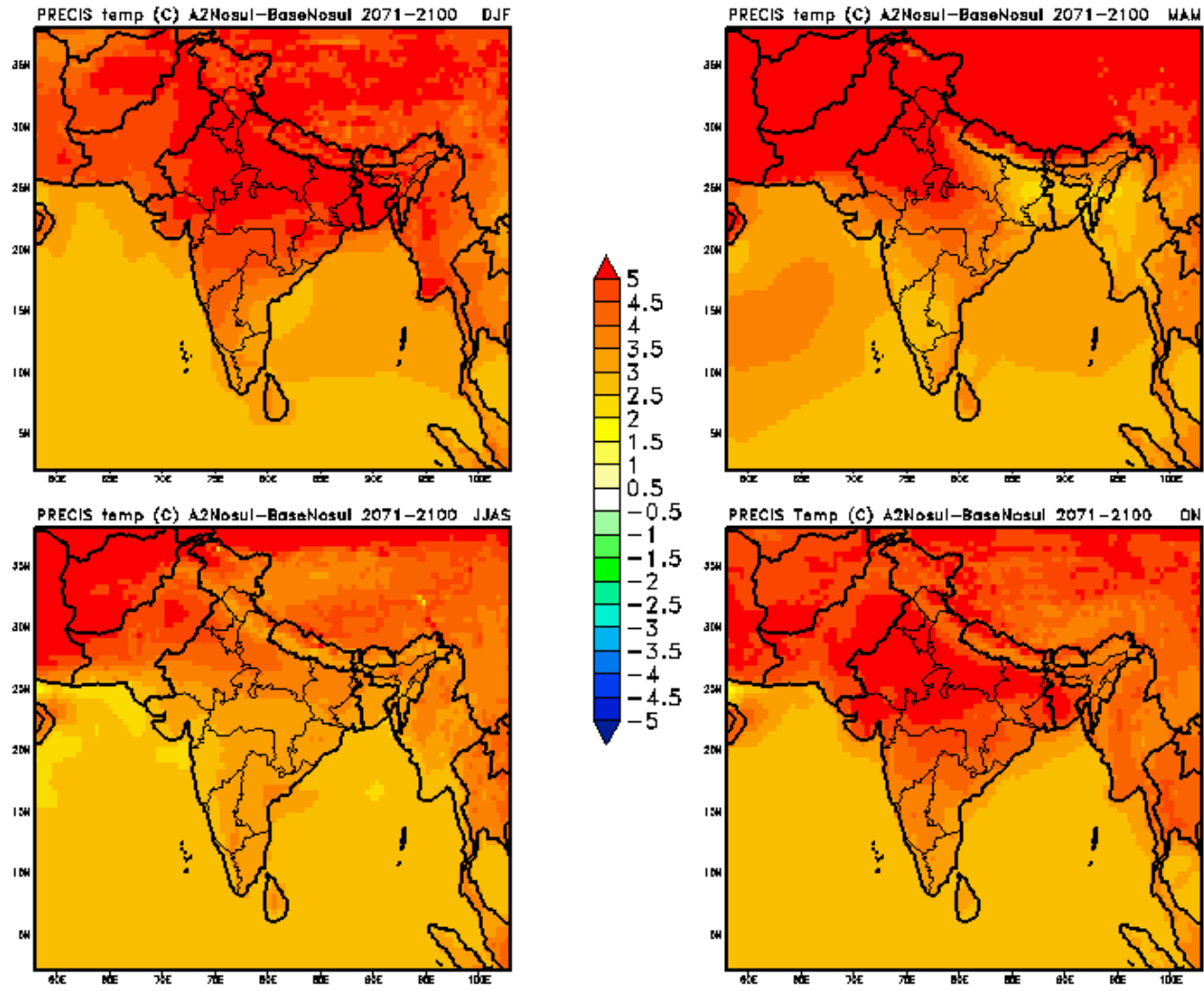


# PRECIS Simulations of Future Climate

## Mean Annual Cycles of All-India Rainfall and Temperature

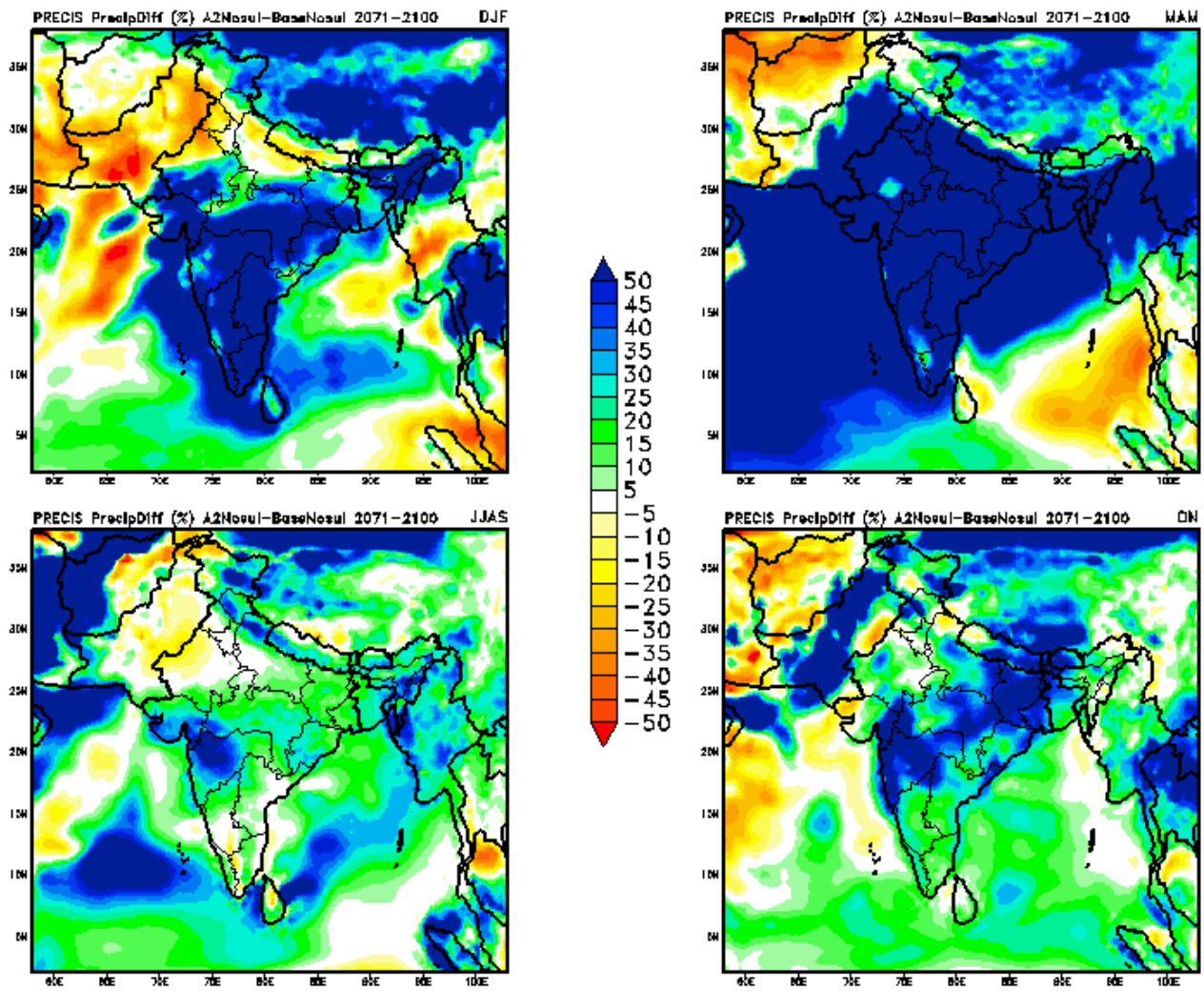


# PRECIS Surface Temperature, A2-Baseline, 2071-2100

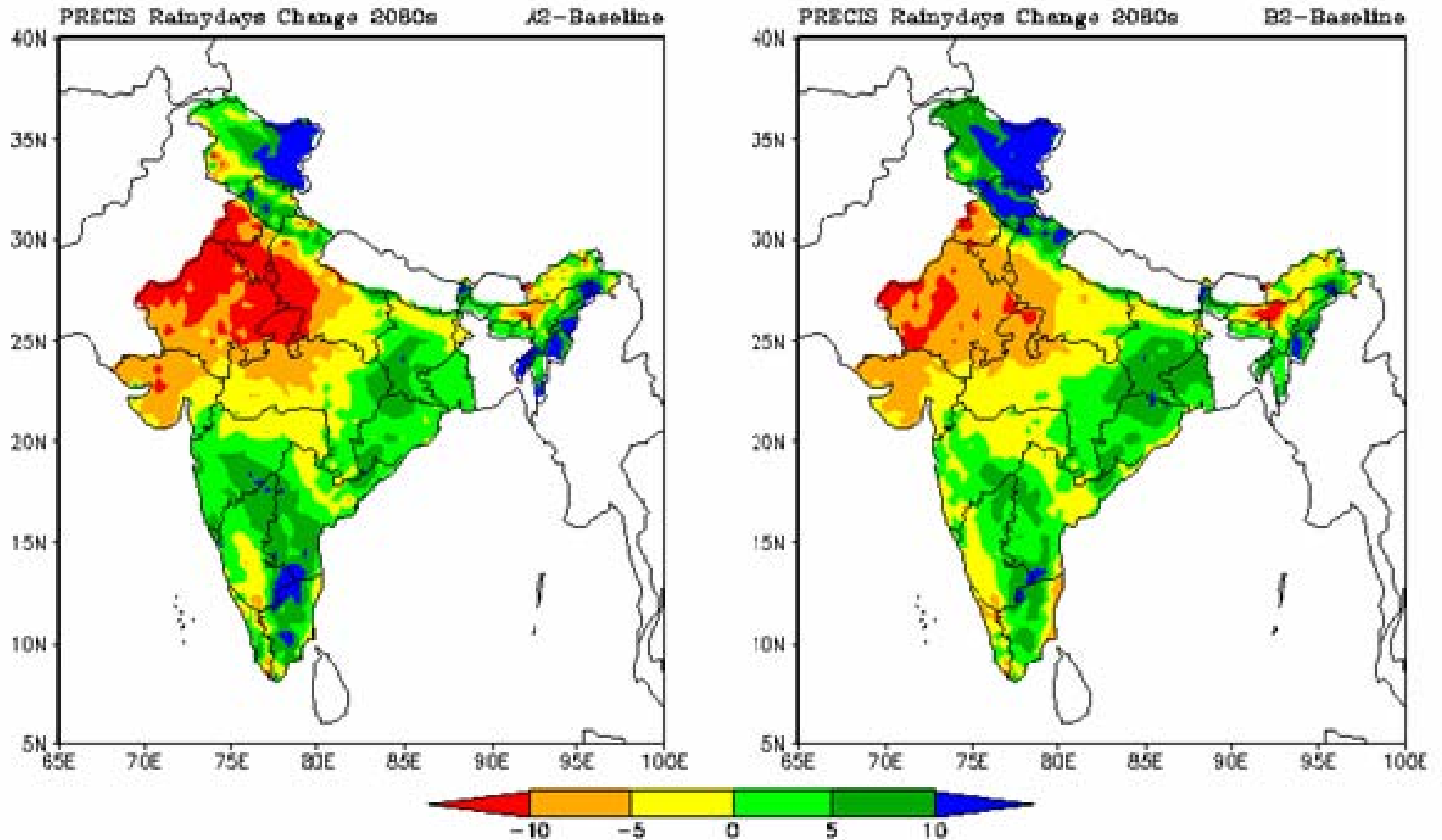


Global Change Conference, Islamabad, Pakistan, November 16-17, 2006

# PRECIS Precipitation, A2-Baseline, 2071-2100



# PRECIS Projected Change in Rainydays



Global Change Conference, Islamabad, Pakistan, November 16-17, 2006

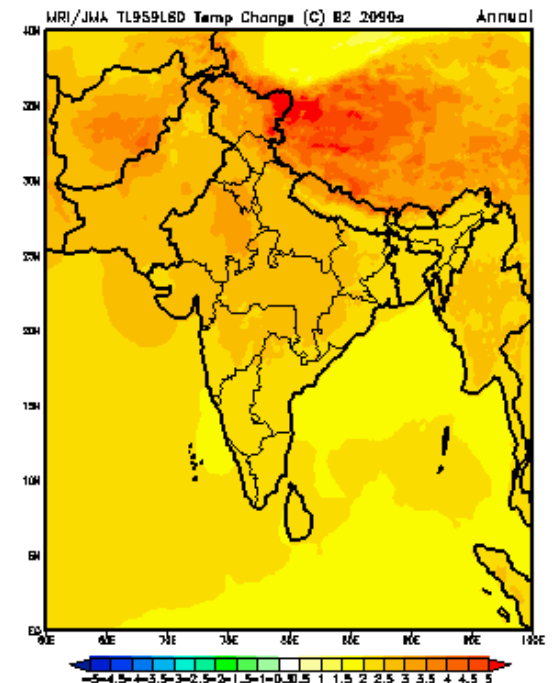
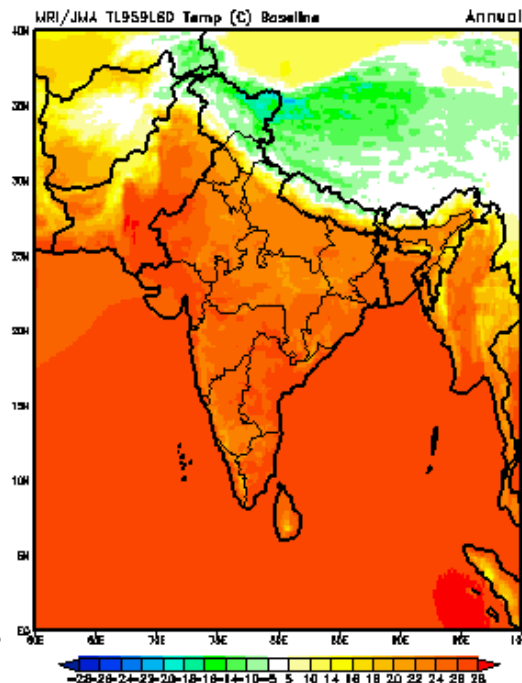
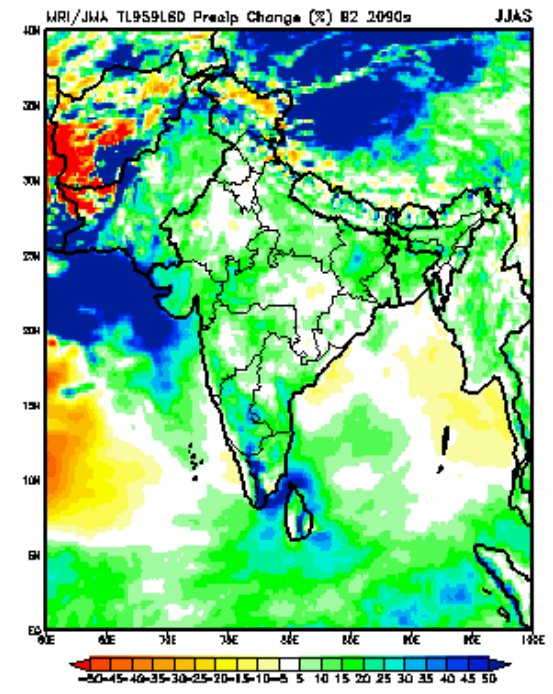
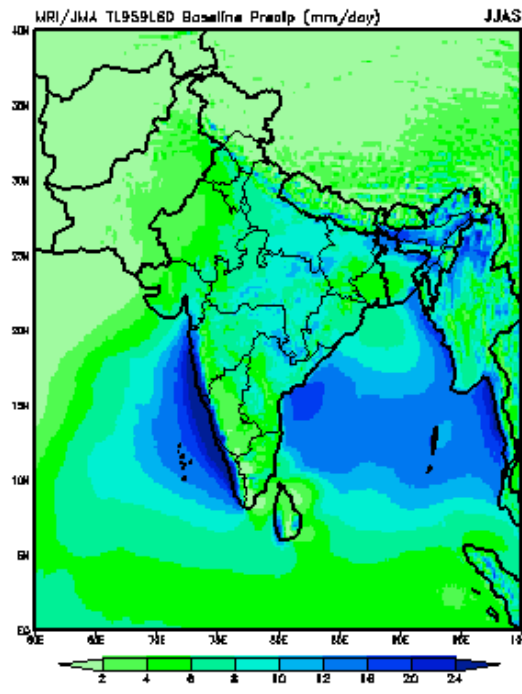


# Regional PRECIS collaboration

- Training workshop for South Asia organized by Hadley Centre in July 2004 at Thimphu, Bhutan, and at IITM, India in January 2005; 6 countries have participated.
- Extensive data on 10 experiments at 50km resolution for all South Asian countries available at IITM; access can be provided to individual country groups.
- PRECIS available in institutes in Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka
- IITM identified as the regional centre for PRECIS application and data coordination for South Asia
- Configuration and operation of a system to distribute data being pursued at IITM with help from the Hadley Centre.

# MRI/JMA TL959L60 Global Model with 20 km x 20 km resolution

Baseline, 1990s (left)  
B2 Scenario, 2090s  
(right)



# To sum up...

- Global warming is happening NOW, with unambiguous regional signatures, and may have implications for the South Asian monsoons
- Observed data indicates that the South Asian summer monsoon has been stable as a large-scale system over the past 200 years
- Most models simulate enhanced monsoon precipitation in a global warming scenario
- Large uncertainties still persist in future projections of monsoon.
- More work needed to understand local manifestations of monsoon changes and the possible role of land-surface changes/processes
- Regional models are quite useful in generating more detailed regional information, seem to inherit some of the biases seen in the driving GCMs.
- The robustness of monsoon projections based on time-slice experiments is constrained by the lack of air-sea interactions in the Indian Ocean. High-resolution coupled GCMs, at least incorporating a slab ocean model, are essential to regionalize the impact of global warming over the monsoon region.