

# Space Technology Applications for Monitoring Climate Change Impacts on Water Resources



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**Indian Space Research Organization**

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Applications for Climate Change  
12-14 September, 2016**

**Austrian Academy of Sciences, Institute for Space Research  
Schmiedlstrasse 6, Graz, Austria**

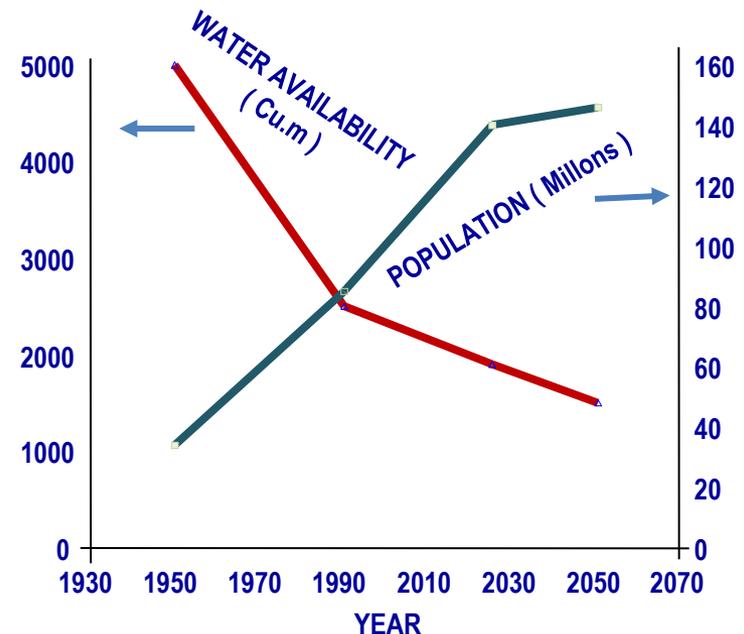
**September 13, 2016**

# Water Resources of India: Some Facts

- **Total Annual Utilizable Water Res. (Ground + Surface) - 1120 bcu.m**
- **Sectoral use: 80% for Agriculture**
- **18% of the world's population with only 4% of the total usable water resources**
- **Uneven Distribution: Dwindling per capita availability**
- **Large Evapotranspiration in Arid/Semiarid Zone**
  - Rain for Less than 3 Months, High Temperature
  - Low Soil Moisture in 8 Months / Year
- **55.0 mha Irrigated land produce 60% Food Grains**
- **Over Use of Ground Water for Irrigation**
- **Drinking Water Problem: 15% Urban ; 21% Rural**
- **Rapid Rate of Reservoir Sedimentation**
- **Deteriorating Water Quality and Environment**
- **Climate Change impacts**

## Per Capita Annual Water Availability (Cu.m / capita / year)

1951 -	5200 Cu.m
2001 -	1816 Cu.m
2011 -	1545 Cu.m
2025 -	1401 Cu.m
2050 -	1191 Cu.m



# Water Resources - What Space Can Do.....

## Remote Sensing

(High Resolution Imaging & Survey)

- Mapping/Monitoring

## Airborne Systems

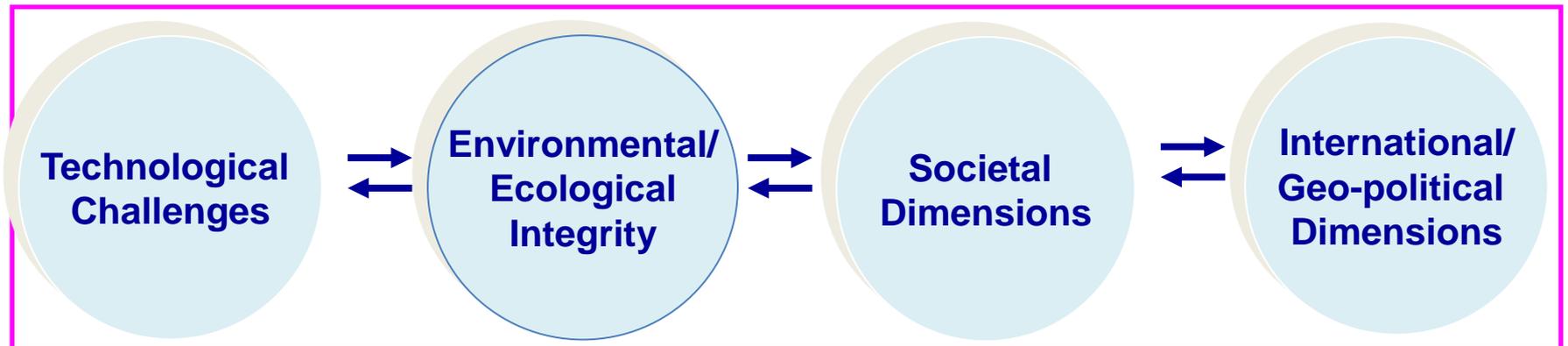
(SAR/LASER/Photogrametry)

- 3D Terrain Modeling

## GIS + Econometric Models

(Linking Socio-economic variables )

- Targeting Beneficiaries



**Scientific Inputs to -  
WATER RESOURCES, PLANNING DESIGN AND MANAGEMENT**

# The Drivers..

## Enabling Policies:

- Integrated Water Management Planning
- Environment Protection and Regulation
- National Water Policy – 2012
  - Equity and social justice
  - Enhancing water use efficiency
  - Stakeholder participation
  - climate changes – coping strategies

## Institutional Base:

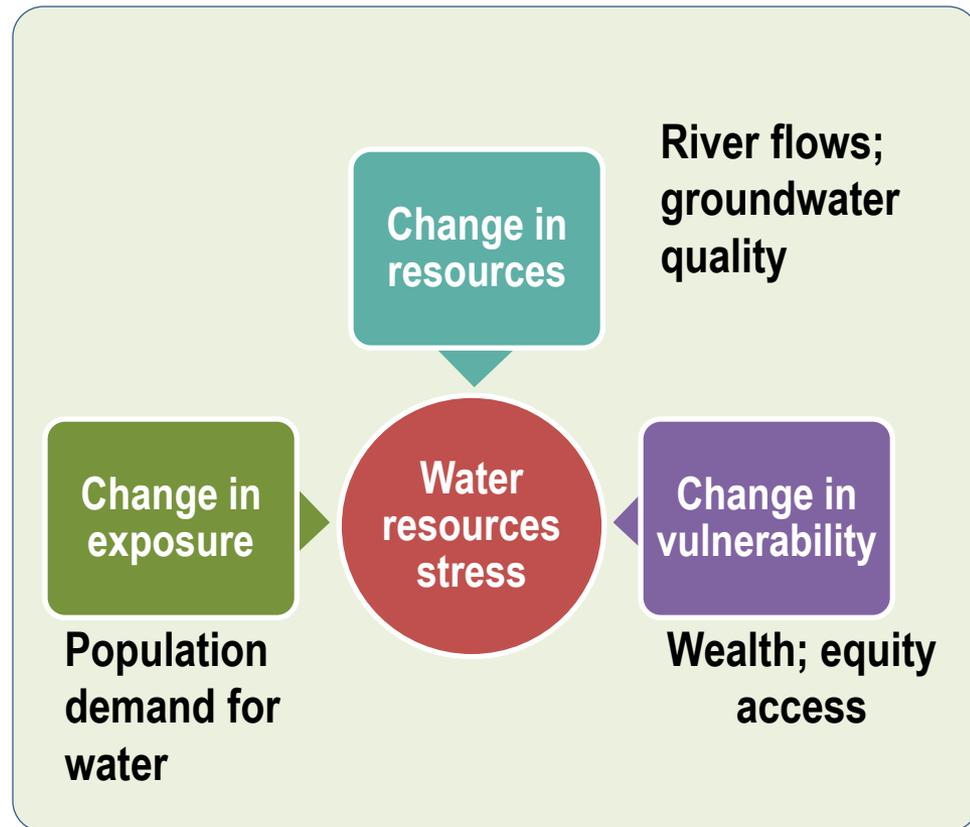
- Networks of End Users
- Institutional Capacity..

## Technological Matrix:

- Access to Core Technologies
- Technological Convergence

## Role of Space technology:

- Catalytic
- Enabler &
- Facilitator



- Indicators of exposure
  - Numbers affected by flood / drought
- Indicators of access
  - Numbers with access to safe water
- Indicators of availability
  - Resources per capita

# Water Resources Applications

In collaboration Ministry of Water Resources

## Water Resources Information System (WRIS)



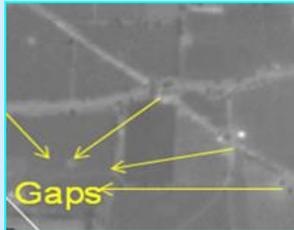
- A comprehensive web based information system for planning & development
- 12 information systems, 95 spatial layers; 4000+ attributes

## Salinity & Water logging Assessment



- Assessment and monitoring of salinity and waterlogged areas - 1701 irrigation commands

## Accelerated Irrigation Benefit Programme (AIBP)



- Mapping and Monitoring of the irrigation infrastructure in the command area
- >100 Commands

## Command Area Development



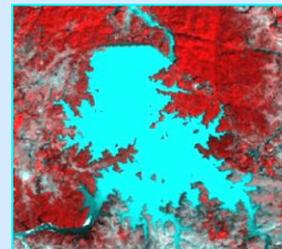
- Alignment of distributaries
- Designing cropping pattern
- Fixing design discharges

## Water Resources Assessment



- Assessment of Water Resources at Basin Scale
- Inputs to Water Resources Planning

## Reservoir Siltation

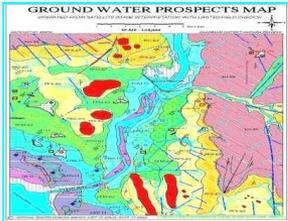


- Reservoir Capacity Assessment – 124 Reservoirs
- Use of Satellite data for elevation contours and water spread areas

# Water Resources Applications

In collaboration with Other User Ministries

## National Drinking Water Mission (Department of Drinking Water & Sanitation)



- Prospective groundwater zones and Recharge structures
- Success rate > 90%; 9000+ Water Harvesting Structures

## Wetland Inventory

(Ministry of Environment and Forests)



- Mapping of entire country at 1: 50K
- Input for conservation and water resources management

## Agricultural Drought Assessment (Ministry of Agriculture)



- Period of monitoring : June to Nov.
- Operationally carried out by Ministry of Agriculture

## Snow & Glaciers

(Ministry of Environment and Forests)



- Snow Cover (selected sub-basins)
- Glacier Inventory
- Glacier Retreat Study
- Glacier Mass Balance

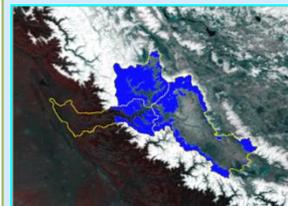
## Flood Mapping & Monitoring (Ministry of Water Resources)



- Flood Inundation information
- Damage Assessment
- Flood controls Monitoring
- Forecasting & warning models

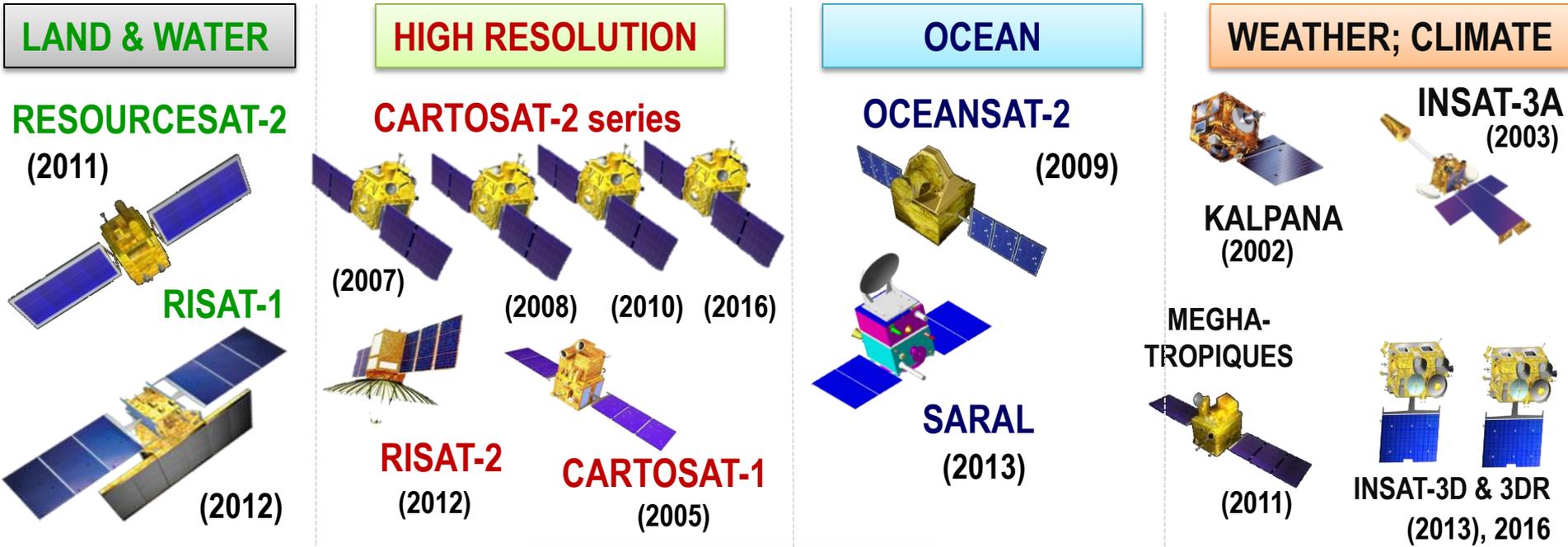
## Snowmelt Runoff

(Ministry of Water Resources)



- 5 Himalayan Basins
- Short term (10 Days) and Seasonal (April – June) Run-off Forecast

# Earth Observation Satellites

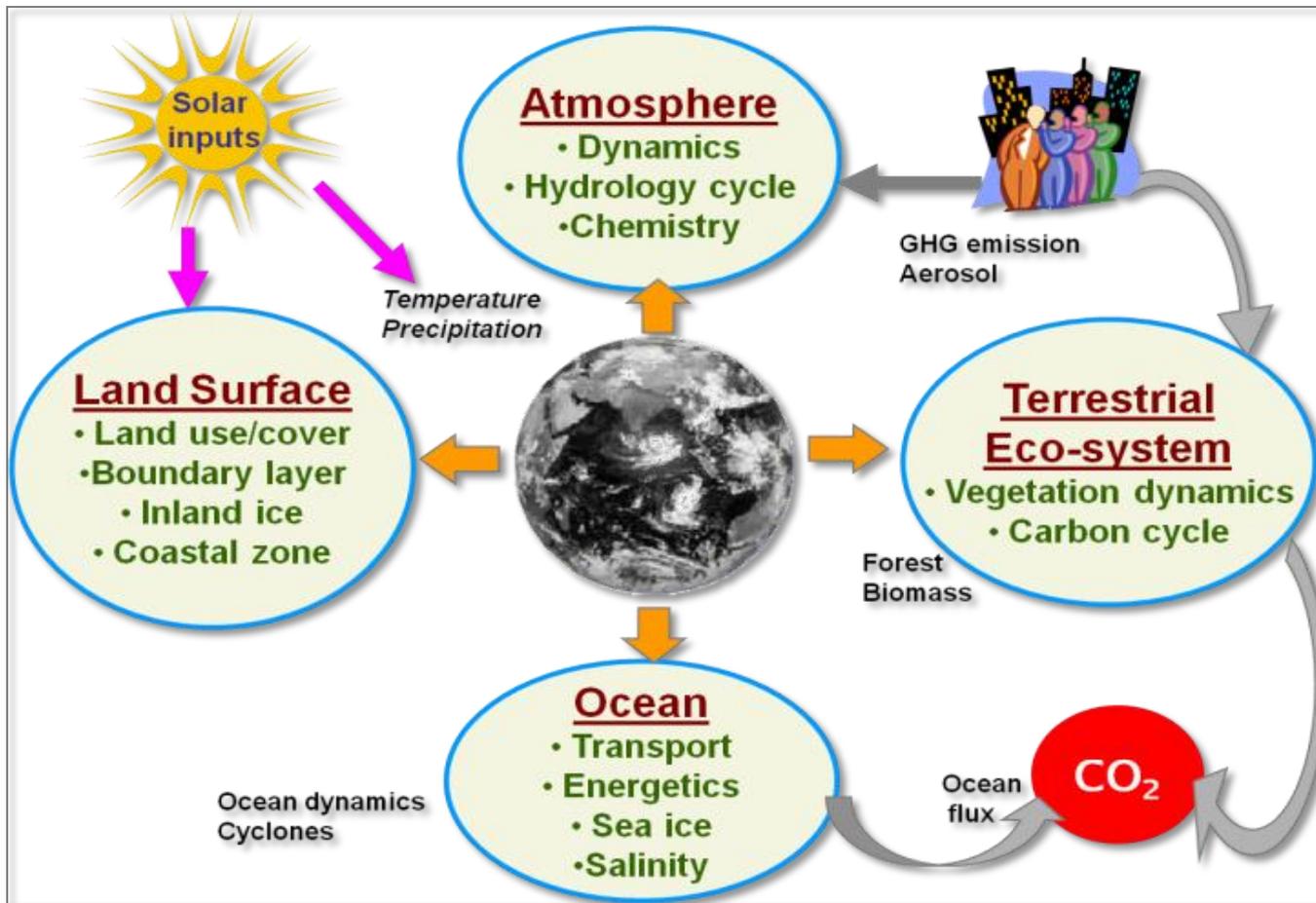


Resourcesat-2A, SCATSAT-1, Cartosat 2 Series, Cartosat-3, Oceansat-3, GISAT being added during 2015-17 for continuity of services and new capability.

# How do we address the Climate Change Issues?

- Understand physical, chemical & biological interactions that regulate Earth System.
- Understand the changes occurring in the system.
- Understand the influence on climate by natural forces and human activities.

## Earth System Processes



Measuring the small changes associated with long-term global climate change

~56 ECVs identified by Global Climate Observing System (GCOS) for monitoring the Earth.

# Climate Change

## Effects

- **Temperature rise:**

Mean earth temperature changed by **0.85°C** (1880 – 2012) and projected temperature increase by 2100 - **2 to 4.5 °C**

- **Precipitation:**

**Increase** of precipitation in mid-latitudes land masses & wet tropical regions; **decrease** in most subtropical regions

- **Sea Level Rise:**

Rise in Global mean sea level at an average rate of **1.7 mm/yr** (1901 - 2010) and Projected sea level rise by 2100 – **26 to 82 cm**

- **Ocean pH:**

Reduce by - **0.10** units since beginning of industrial era

## Impacts

- **Glacier melt & receding snow cover**
- **Increased risk of flash floods during wet season**
- **Decrease in Soil Moisture & Agricultural Productivity**
- **Inundation of low-lying areas, coastal marshes & wetlands**
- **Deltas threatened by flooding, erosion and salt intrusion**
- **Increase in river water salinity**
- **Impact on fisheries due to loss of mangroves**
- **Human health impacts due to changes in temperature & humidity**

# Space based Inputs for Climate Change Studies

## Mapping the Indicators of Climate Change

- Glacial Retreat in Himalayas
- Change in Polar Ice Cover
- Upward Shift in Timberline & Vegetation in Alpine zone
- Bleaching of Coral Reefs
- Desertification
- Disasters - Flood, Drought, etc.

## Monitoring the Agents of Climate Change

- GHGs & Other Gases - Variability of atmospheric CO/ CO<sub>2</sub>/ NO<sub>2</sub>/ CH<sub>4</sub>
- Biomass burning/ forest fire
- Terrestrial Carbon
- Atmospheric Aerosols & Trace gases

## Modeling the impacts of climate change

- Impact on Food Security
- Hydrology
- Coastal Zone
- Ocean Productivity
- Land Surface Changes from Regional Climate Simulations over India
- Role of Indian Ocean in Climate variability

# Indian Satellite Systems for Observing Climate Variables

Satellites	Major Variables
Resourcesat Series	Vegetation, Land Use, Coastal Zone, Glacier
Cartosat Series	Urban Land Use, Urbanization
INSAT Series	Vegetation, Temperature & Humidity Profiles, Ozone, Clouds, Sea surface Temperature, Cloud, Radiation
Oceansat Series	Ice/Snow, Vegetation, Chlorophyll, Ocean Sediments (OCM-II), Surface wind (Scatterometer), Aerosol
SARAL	Sea Surface Height
RISAT-1	Soil Moisture, Vegetation
Megha-Tropiques	Radiation Budget, Water Vapor Profile, Integrated Water Content, Radio Occultation for Temperature and Humidity Profiles

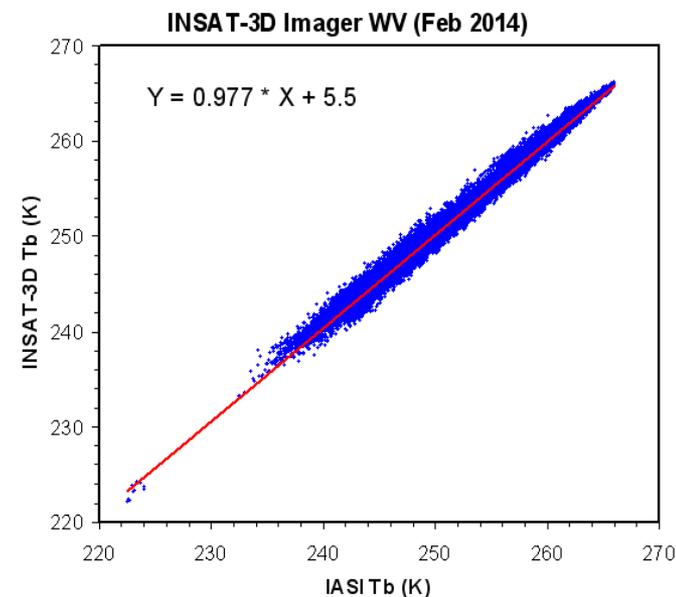
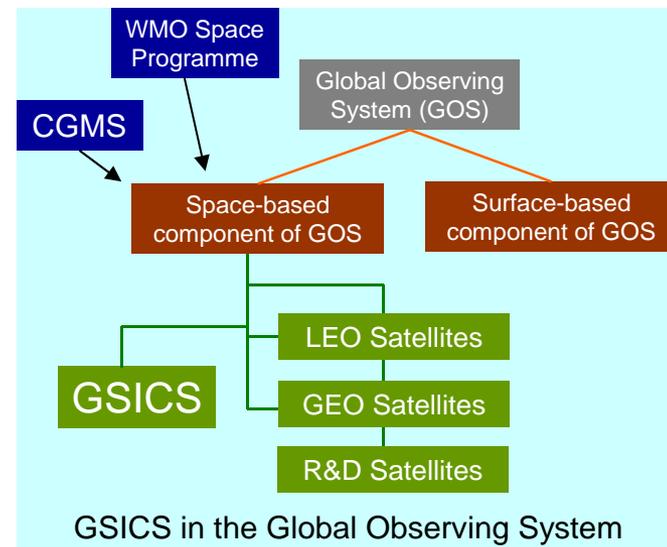
## INSAT-3D Geophysical Products

Outgoing long wave radiation (OLR), Quantitative Precipitation Est. (QPE), Sea Surface Temperature (SST), Snow cover, Snow depth, Fire, Smoke, Aerosol, Cloud Motion Vector, Upper Tropospheric Humidity (UTH), Temperature & Humidity profiles, Total Ozone, Value added products from Sounder payload...

# Global Space-based Inter-Calibration System (GSICS)

GSICS is an international collaborative effort initiated in 2005 by WMO & the Coordination Group for Meteorological Satellites (CGMS)

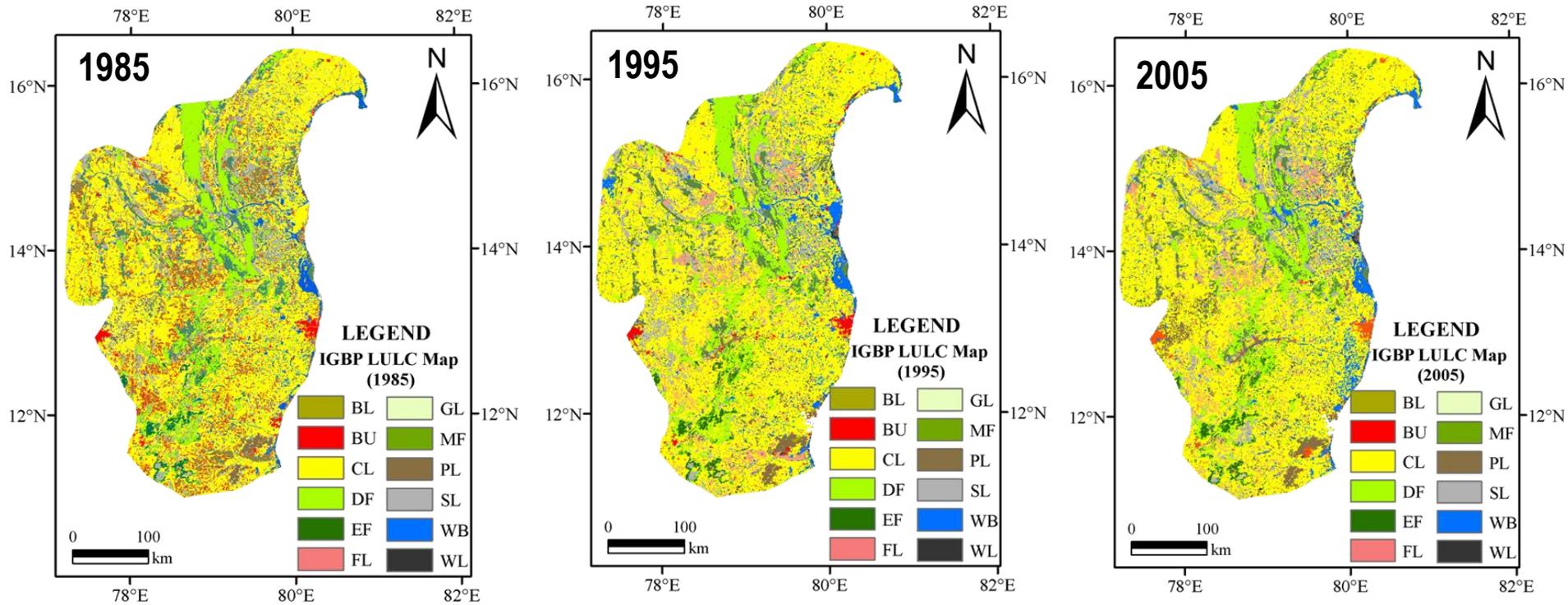
- GSICS contributes to the integration of satellite data within WMO Integrated Global Observing System (WIGOS) and Global Earth Observation System of Systems (GEOSS)
- GSICS delivers calibration corrections needed for accurately integrating data from multiple observing systems
- Ensures consistent observations for climate monitoring, weather forecasting, and environmental applications.



## GSICS-ISRO

Inter-calibration of IR sensors onboard Indian geostationary satellites, Kalpana, INSAT-3A and INSAT-3D Imager/Sounder using state-of-the-art hyperspectral sounding measurements from Metop-IASI, NPP-CrIS and Aqua-AIRS

# Land use/ Land cover Change (Pennar Basin)



LULC Class	Area in Year 1985 km <sup>2</sup>	Area in Year 2005 km <sup>2</sup>	Change 1985 - 2005	% Change 1985-05
Evergreen Forest	1836	1702	-134	<b>-7.30</b>
Decidious Forest	16046	15067	-979	<b>-6.10</b>
Crop Land	80565	79661	-904	<b>-1.12</b>
Built Up	1906	2023	117	<b>6.14</b>

# Glacier Features



Tributary glacier

Lateral moraine

Snout

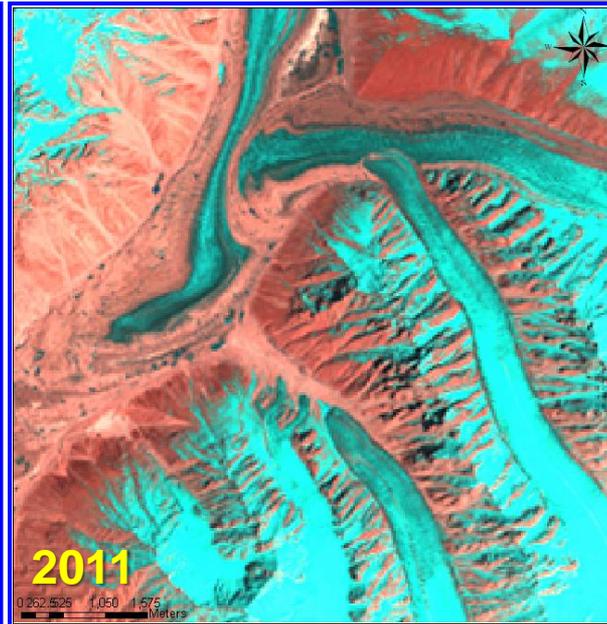
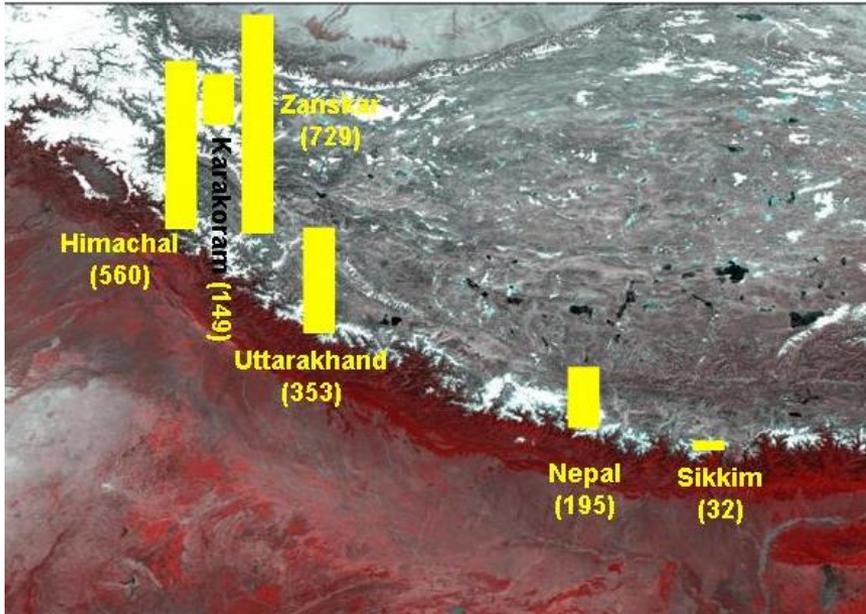
Ablation area

Accumulation area

Snow line

IRS LISS IV  
Zaskar basin  
(J & K)

# Monitoring of Himalayan Glaciers (2000 – 2011)



Advancing Glacier (Panmah Glacier, Karakoram Range)

Total 2018 glaciers  
1752 shows no change,  
248 Retreat & 18 Advance

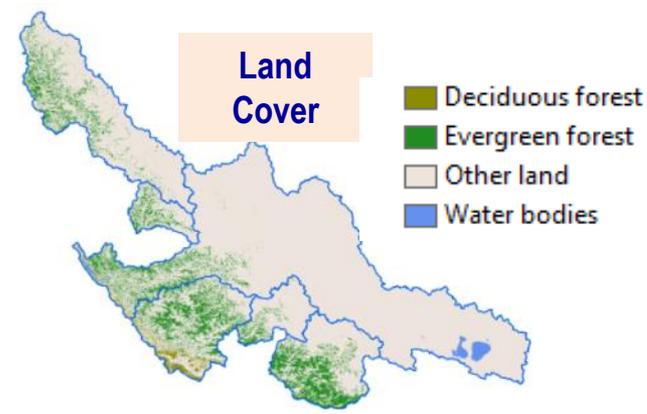
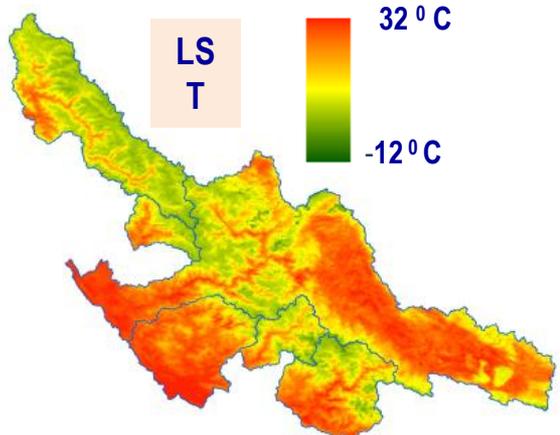
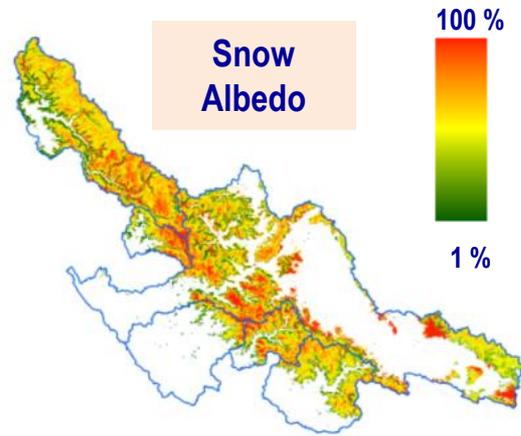
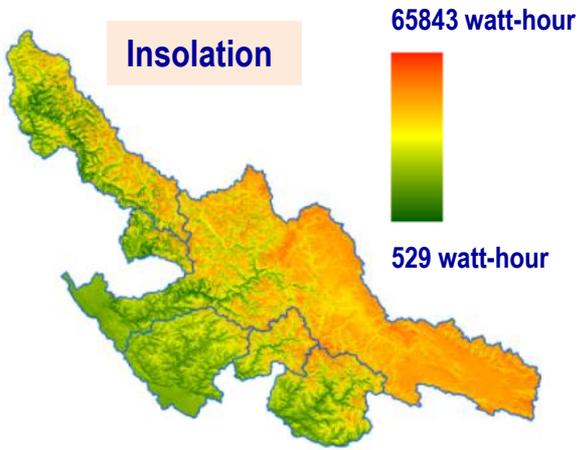
87 % Stable, 12 %  
retreating 1% advance

# Snowmelt Runoff Forecasting in Himalayan basins

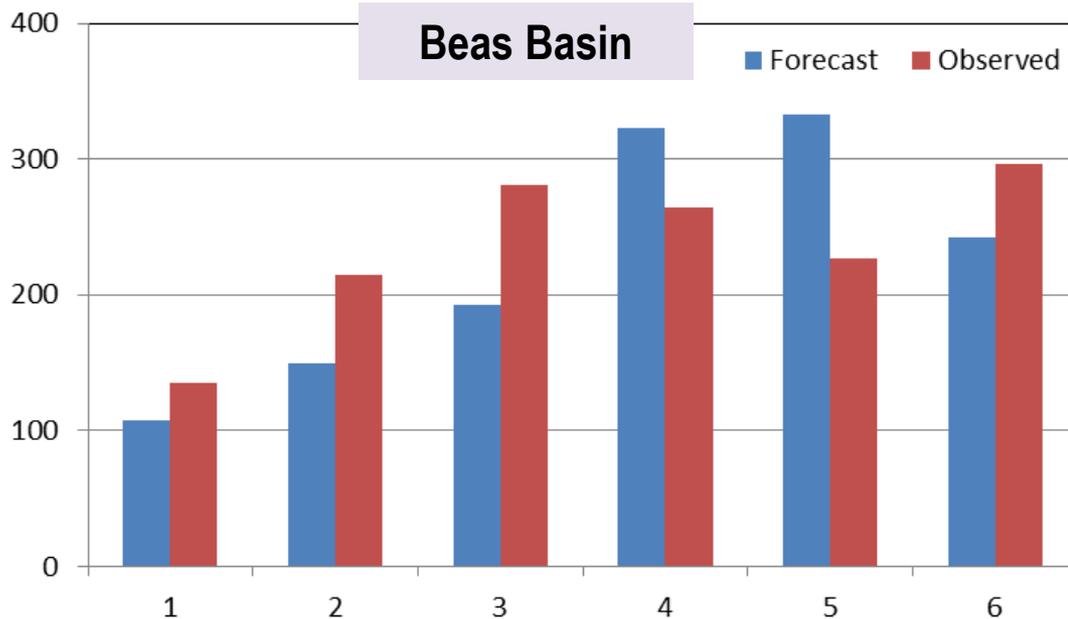
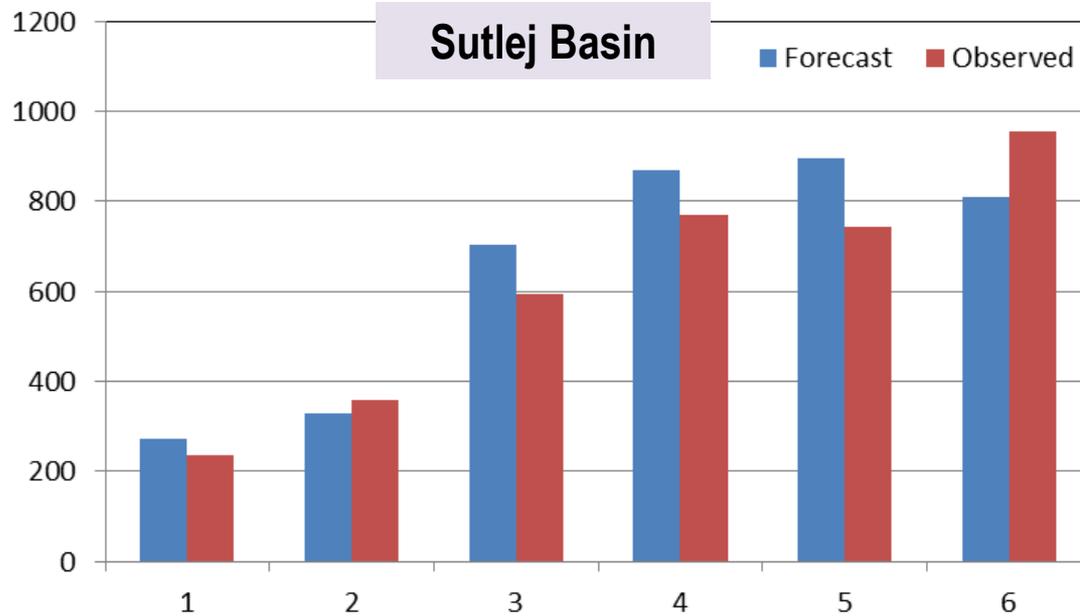
- Snowmelt runoff forecasting based on Energy Balance approach
- Satellite derived inputs for computing net short and long wave radiation
- Calibration and validation of models using observed runoff

## Data Used

- Snow Cover Area
- Glacier Cover Area
- Land Surface Temperature
- Incoming Solar Radiation
- Net Longwave Radiation
- Snow Albedo
- Land Cover
- Snow persistence Index
- Digital Elevation Model, Slope, Aspect
- Field measured discharge and Rainfall data



# Snowmelt Runoff Forecasting in Himalayan basins using RS inputs



## Snowmelt Runoff Forecast issued during April-May-June 2015

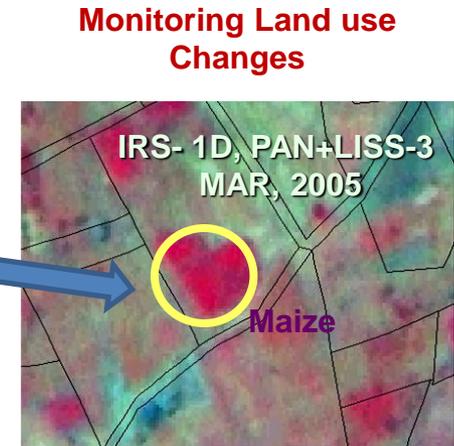
River Basin / Outlet 2015	Observed Runoff (MCM)	Forecasts (MCM)	% deviation
Sutlej at Bhakra	3,656	3,877	6.0
Beas at Bhunter	1,418	1,346	5.0
Chenab at Premnagar	8,046	7,588	-5.6
Yamuna at Hatnikund	1,361	1,167	-14.2
Ganga - Alaknanda at Rudraprayag	3,682	3,391	-7.9
Ganga - Bhagirathi at Uttarkashi	1,333	1,413	6.0

1. 01-Apr-15 to 14-Apr-15
2. 15-Apr-15 to 30-Apr-15
3. 01-May-15 to 16-May-15
4. 17-May-15 to 01-Jun-15
5. 02-Jun-15 to 17-Jun-15
6. 18-Jun-15 to 30-Jun-15

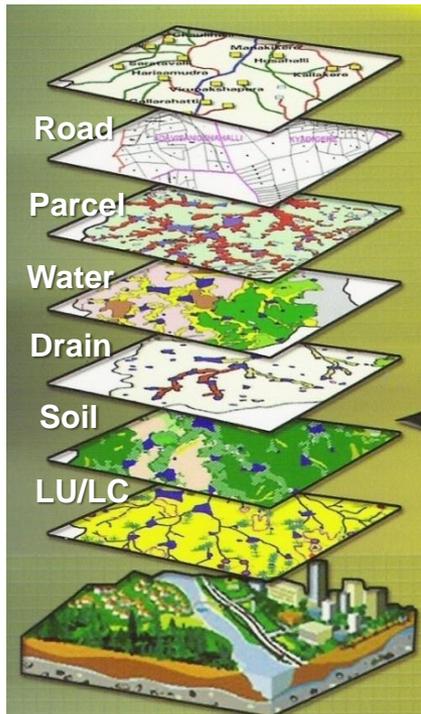
# Improving Productivity in Dry lands

- Phase-wise implementation of Sujala Watershed Project Karnataka
- Work in progress in more than 52 thousand micro watersheds

- Watershed prioritization & Development using EO inputs
- Improve productive potential of degraded watersheds & cropping intensity
- Create alternate livelihood options
- Process Monitoring & Mid-course correction
- Improves the quality of life



Increase in Cropping Intensity



Participatory Implementation



Watershed Community



Nala bund



Farm Pond

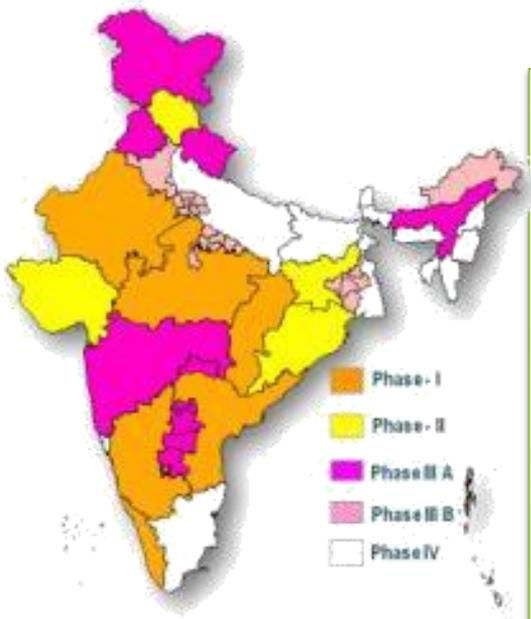


Outcome

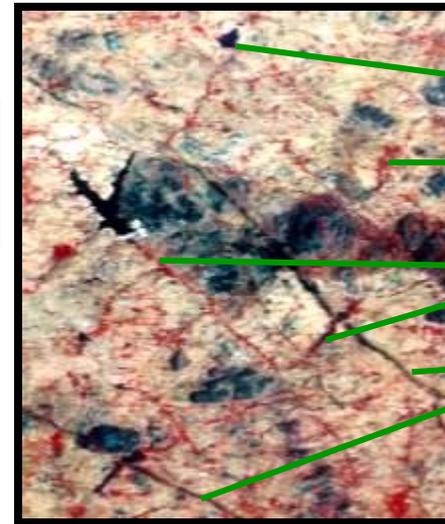
# National Drinking Water Mission

## Groundwater Exploration & Recharge

Identification of potable drinking water sources for problematic habitations.



- Mapping of Rock types, Geomorphology, Structure
- Ground Water Prospects - Depth & Yield
- Carried out in Phases for Entire Country.

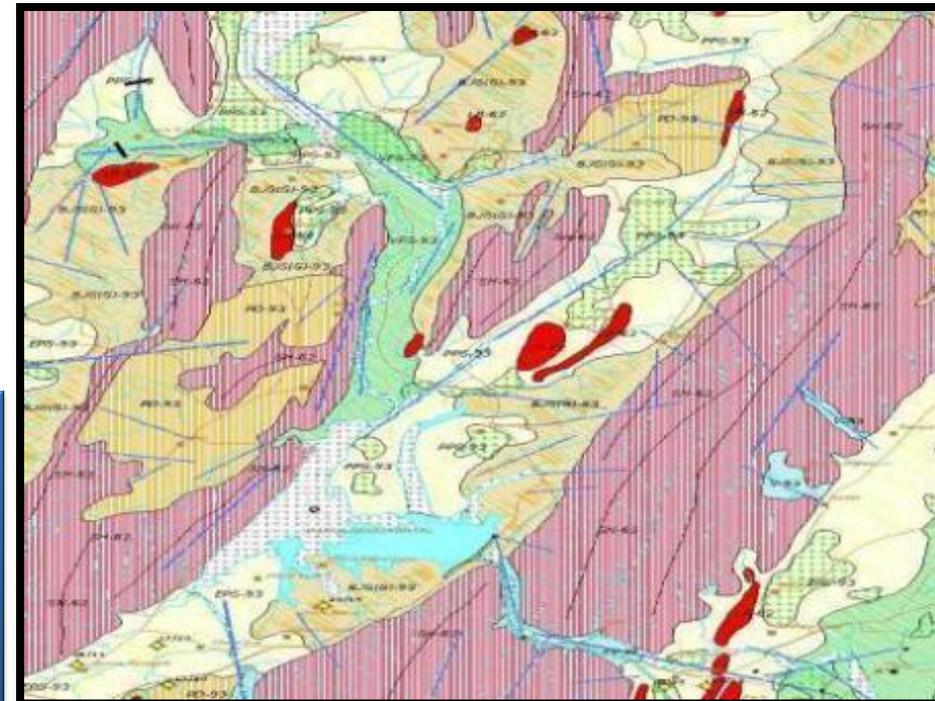


Hydrologic information  
(Surface water bodies)

G.W. exploitation  
(Ground water irrigated area)

Conduits for G.W movement  
(Fracture /Lineament)

Barriers for G. W. movement  
(Dolerite dyke)



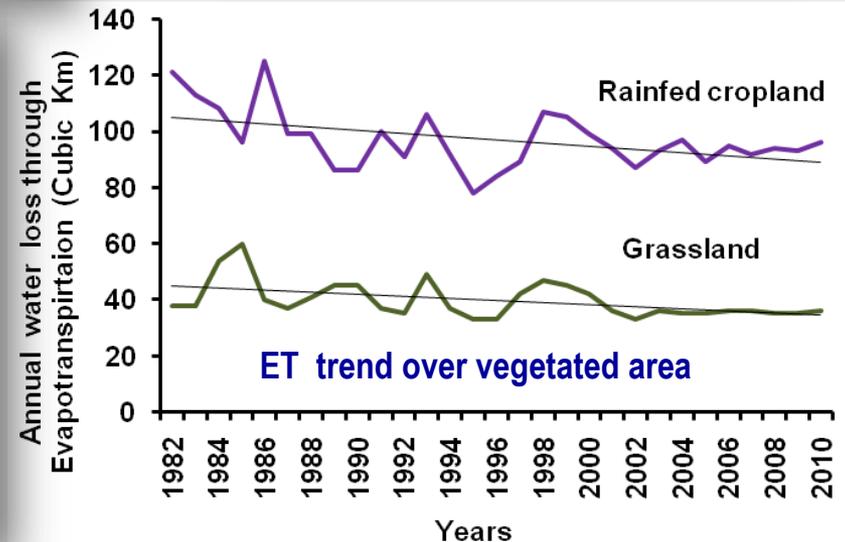
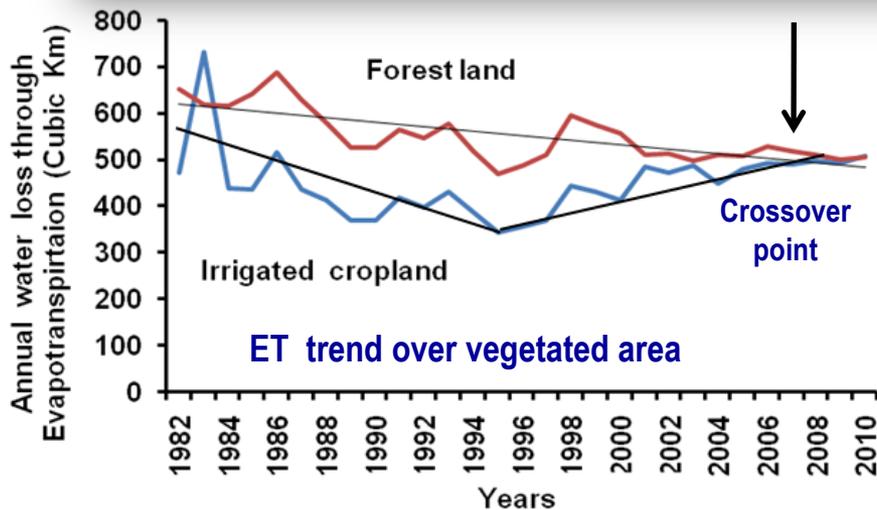
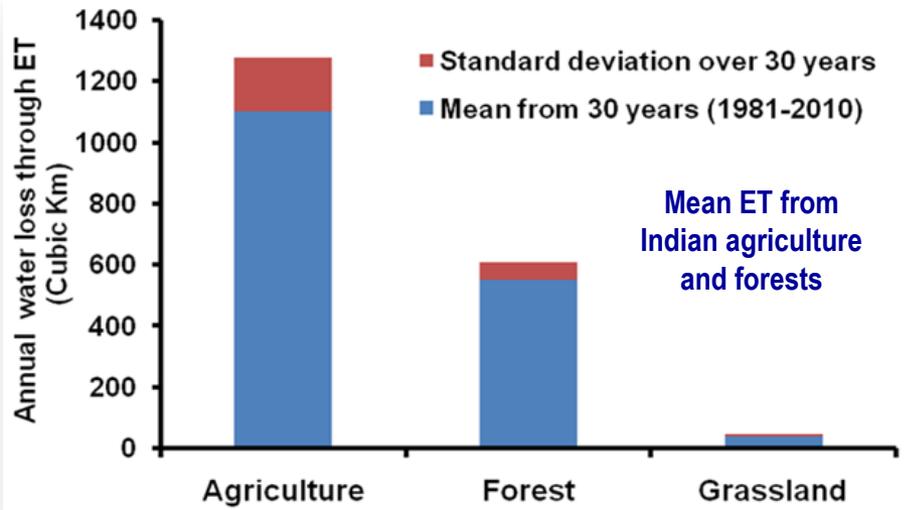
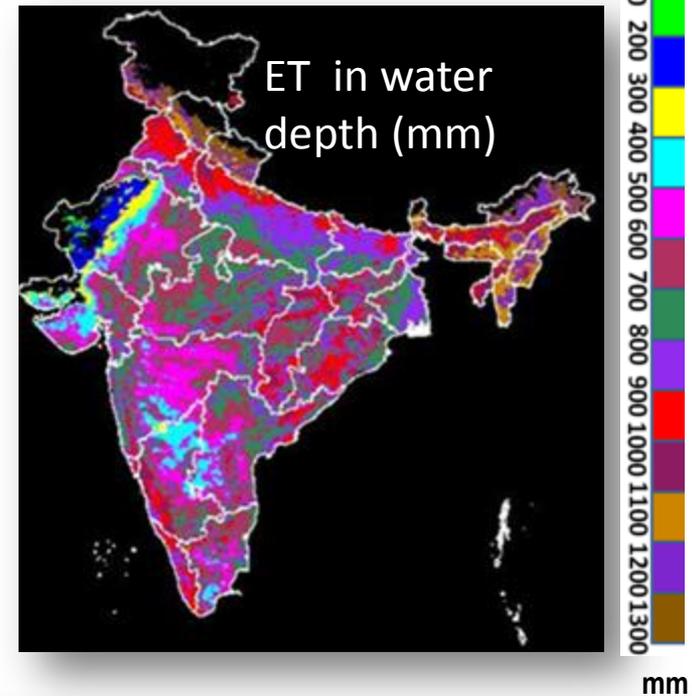
## Success (Based on feedback from 9 States)

- > 2,96,000 Bore wells drilled using Ground Water Potential Maps (93% Success rate).
- > 9,000 Recharge structures constructed.

# Evapotranspiration (ET) over Land

- 30 years satellite observations (NOAA & MODIS) in optical-thermal bands to compute ET
- Total ET loss in agro-ecosystem twice the forest ecosystem
- Regional Analysis: (2000-10) ET increases without increase in rainfall (MP & Bihar) – anthropogenic forcing

Annual loss of water through ET



# Runoff Modeling and Trend Analysis over Main Land of India

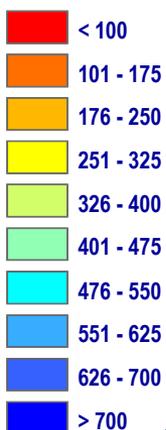
## SATELLITE DERIVED INPUTS:

1. Land Use/ Cover (AWiFS)
2. Rainfall (IMD, IITM)
3. Topography (Cartosat-1)
4. NDVI (SPOT-VGT)

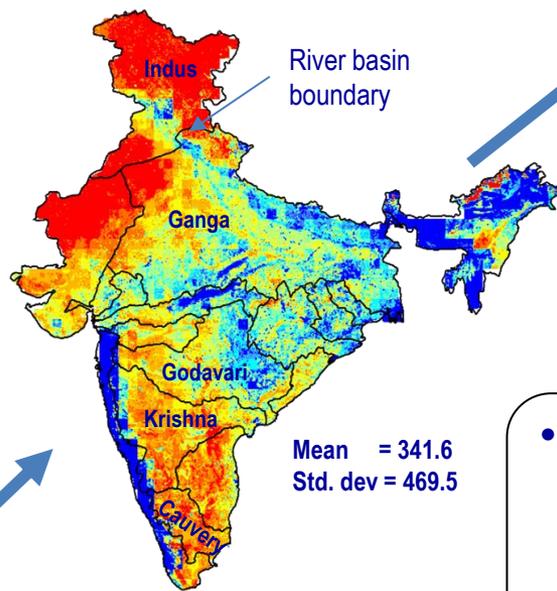
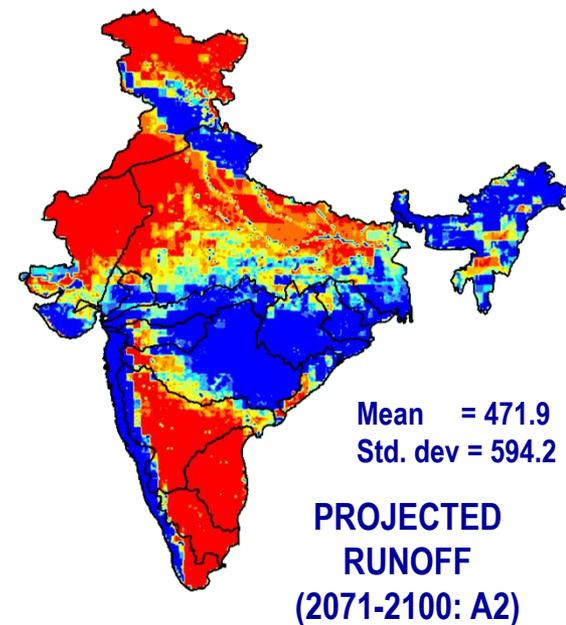
## OTHER INPUTS:

- Soil textures
- Soil properties

## Runoff, mm

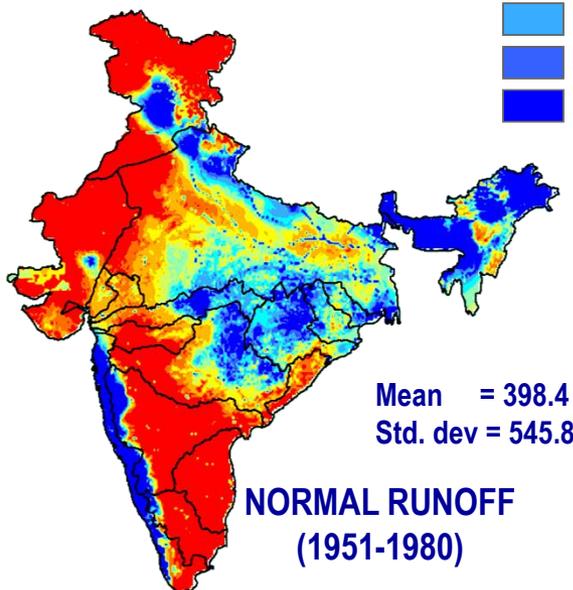


## MODELING SCHEME: Modified curve number model



## RECENT PAST RUNOFF (1971-2005)

## ANALYSIS PERIOD: May to October

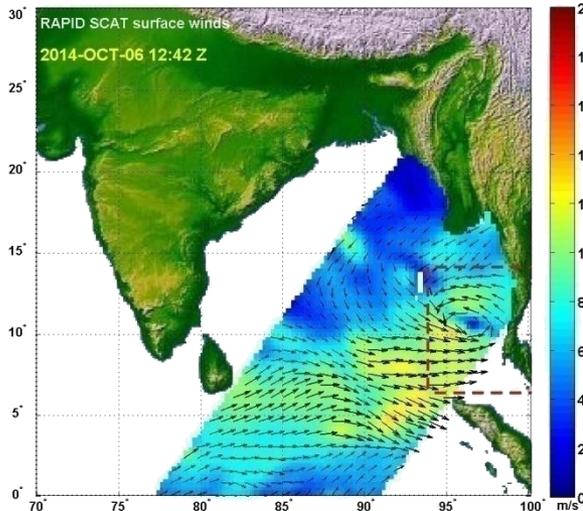


- Reduction in rainfall based runoff water availability (14.3%) during 1951-1980 period to 1971-2005 whereas significant increase (18.4%) observed for future projections over India.
- Western and south-eastern region runoff show increasing trend for future scenario.
- Most of the river basins except Ganga and Cauvery show increase in runoff for future predictions.

# Improved Cyclone Prediction / Warning

## Prediction of Cyclogenesis

Prediction of cyclogenesis of TC HUDHUD

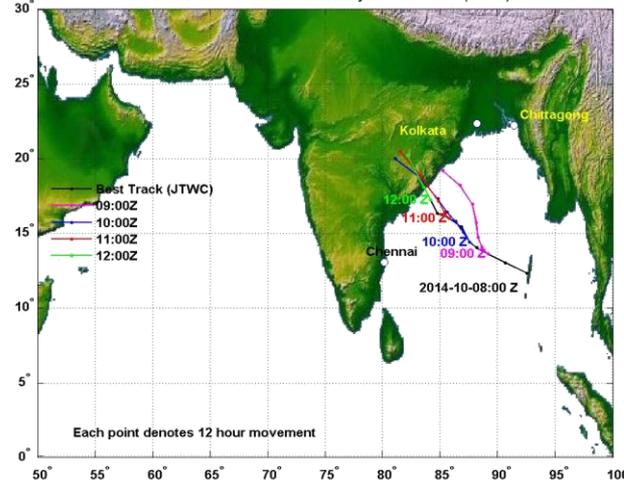


Prediction lead time: 36 hour

## Real-time Track Prediction

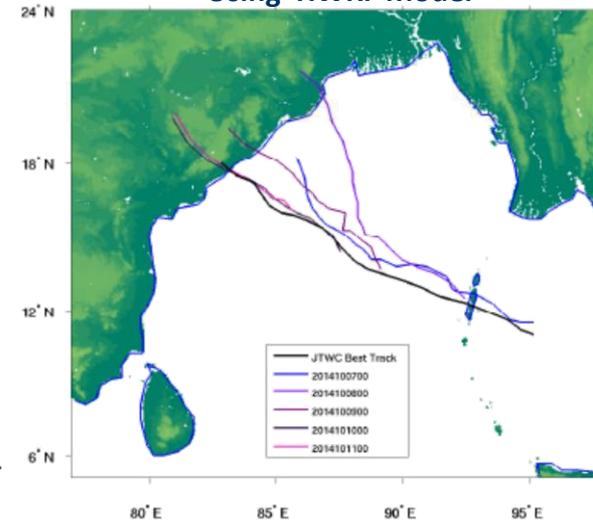
Using SAC-Lagrangian Advection Model

Observed and Predicted Track of Cyclone: HUDHUD (JTWC)



24 hour landfall error: 48 km

Using HWRF Model

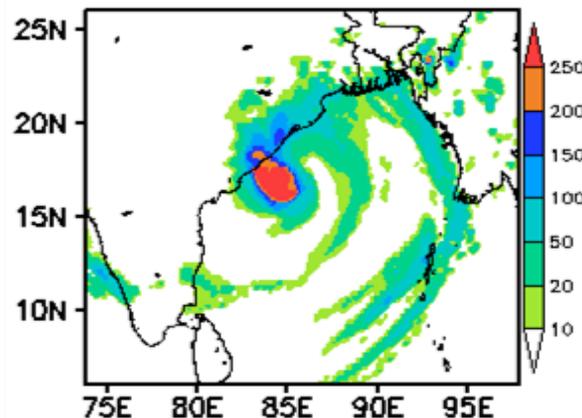


24 hour landfall error: 19 km

Unique technique developed with Space data & genetic algorithm for cyclone track prediction  $\pm 19$  kms for 24 hrs forecast

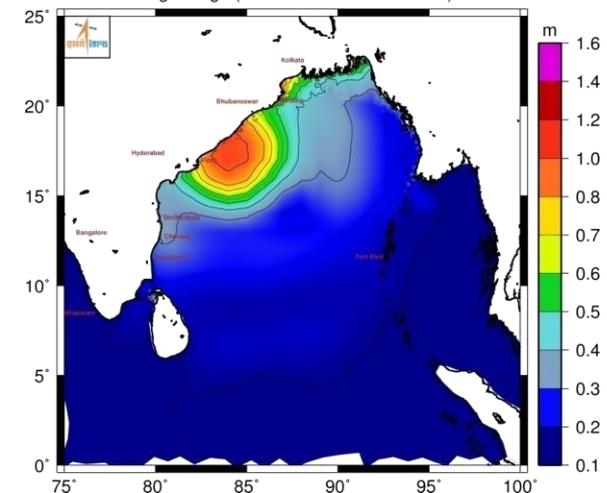
## Prediction of Rainfall

24 h acc. rainfall (mm)  
2014101109 - 2014101209



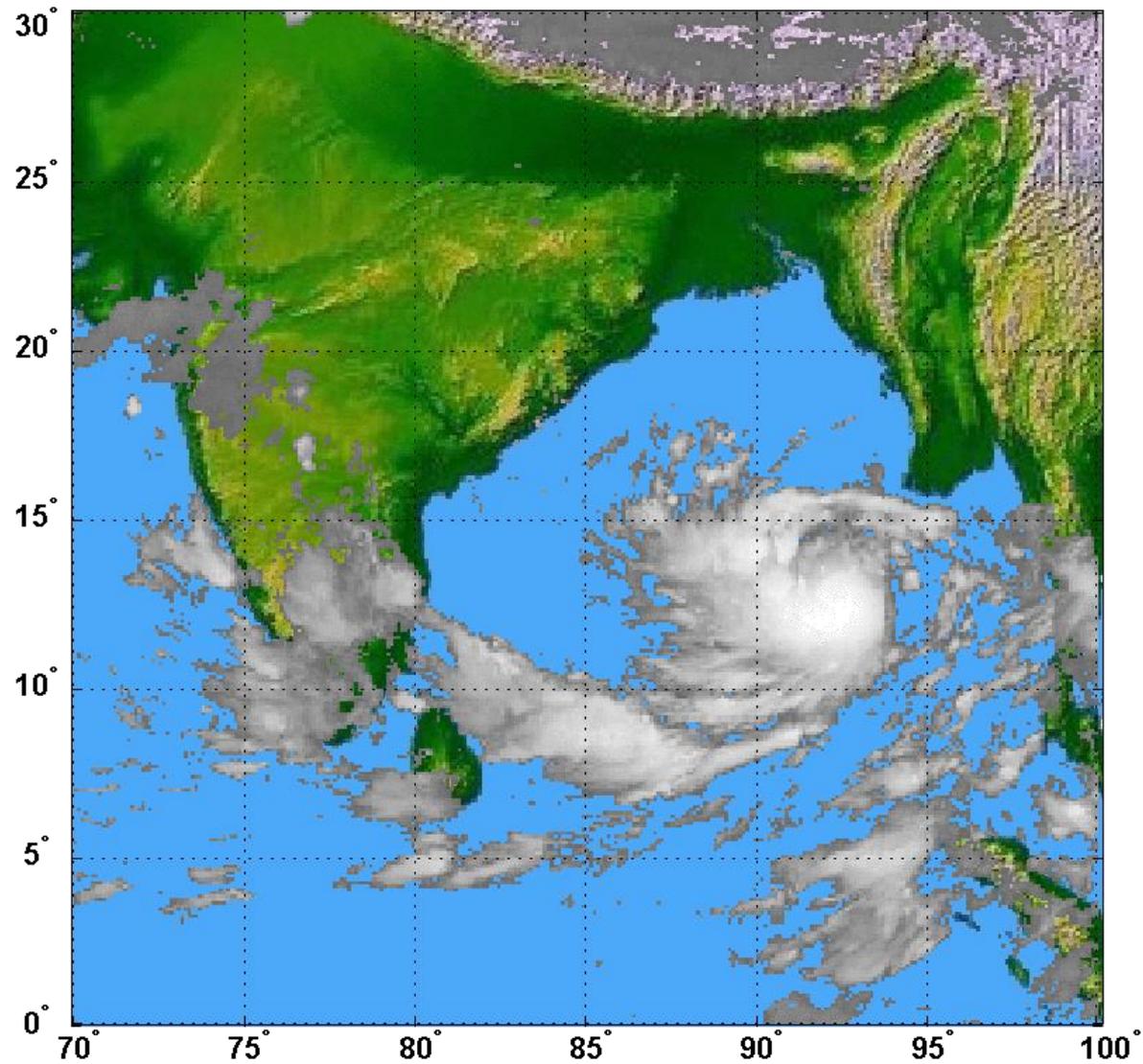
## Prediction of Storm Surge

Surge Height(12-OCT-2014-00:00UTC)



# Tropical Cyclone HUDHUD Track Monitoring by INSAT-3D

08OCT2014 - 0000 Z



# INSAT-3D Applications

## Prediction of thunderstorms

- INSAT-3D imager provides the capabilities to monitor and predict severe weather events like thunderstorms.
- Thunderstorms are characterized by highly reflective and deep convection, that can be detected by visible and infrared channels.

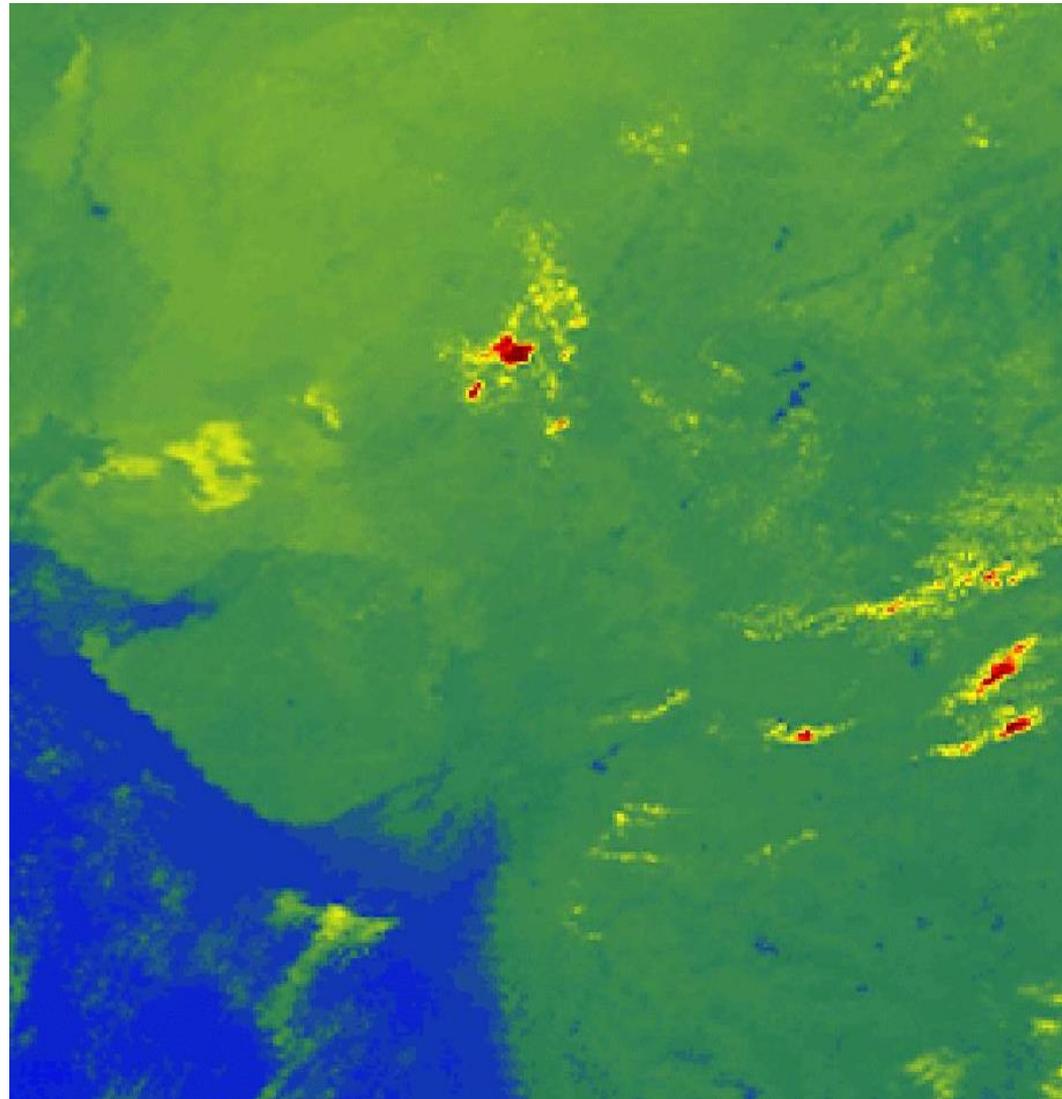
### End Use

- Advance warnings of thunderstorms are being provided operationally for Uttarakhand and Himachal Pradesh.
- National Disaster Management Authority

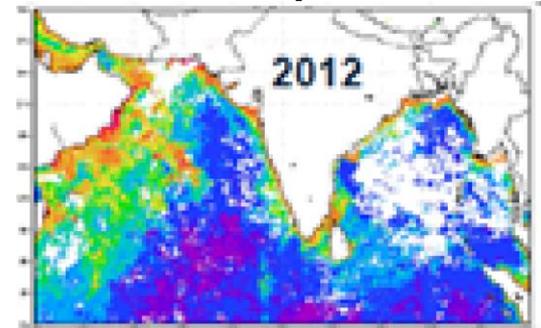
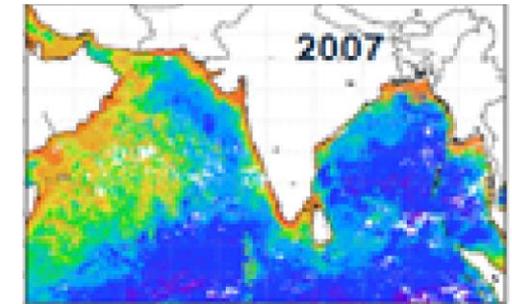
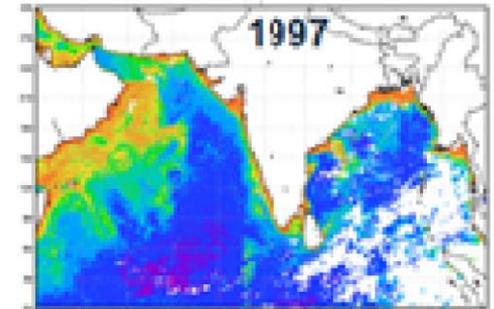
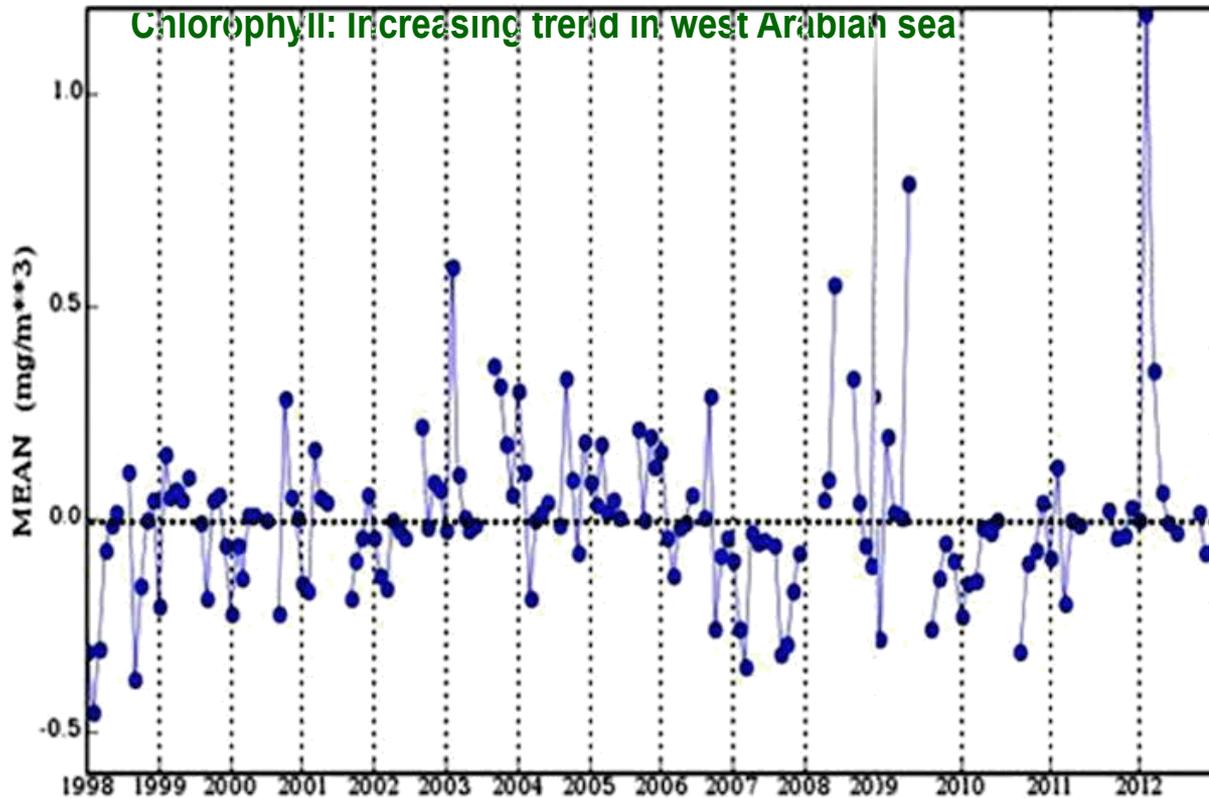
### Details

- Advance warnings for All India region to commence in May 2015 .
- INSAT-3D imager and sounder data

Multi-cellular thunderstorm over Western India  
(20 April 2014)



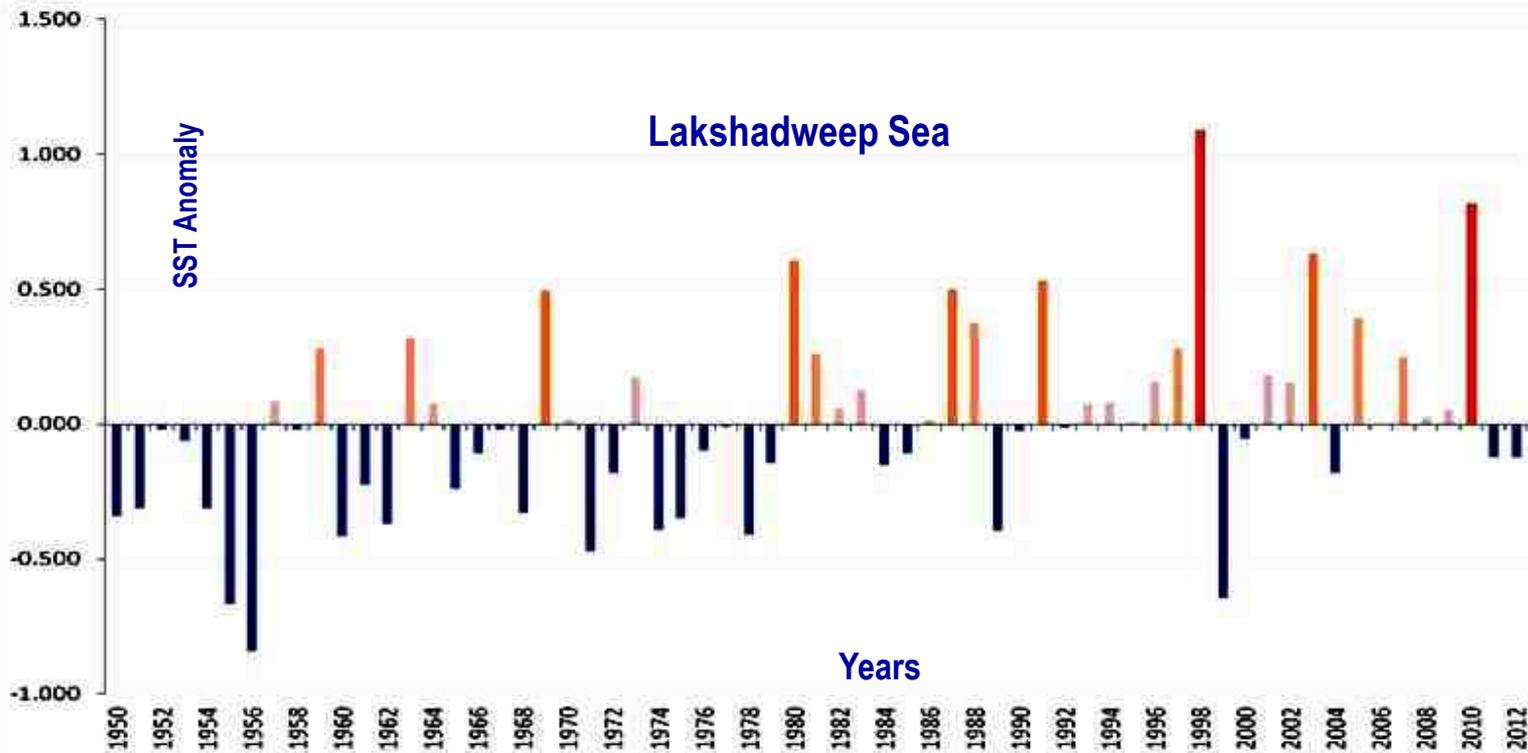
# Chlorophyll-a variability in the Indian Ocean during 1997-2012



## Major Science Issues

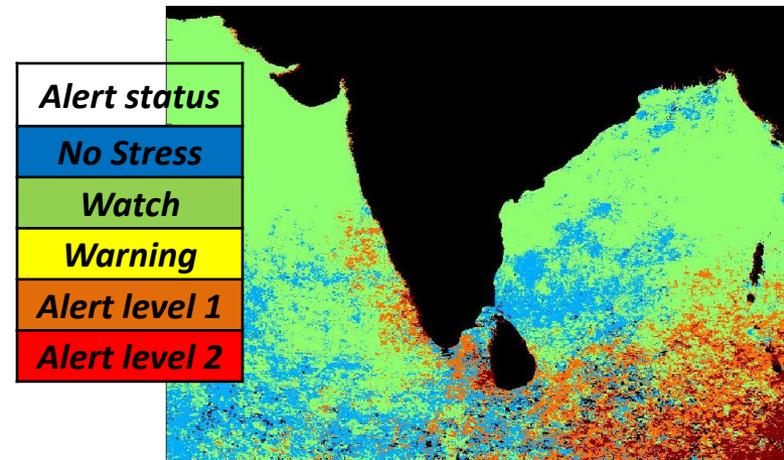
- How the ecosystem of Arabian Sea & Bay of Bengal is responding to increasing SST
- How the fisheries will be affected due to changing ecosystems
- OCEANSAT OCM & other international ocean colour data

# Impact of SST on Coral bleaching

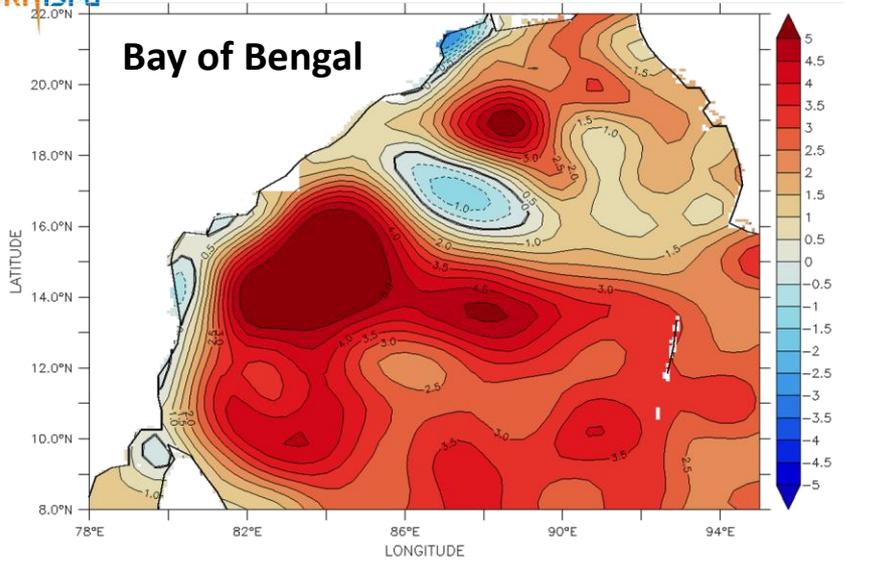


**Coral bleaching alert map for may 1998**

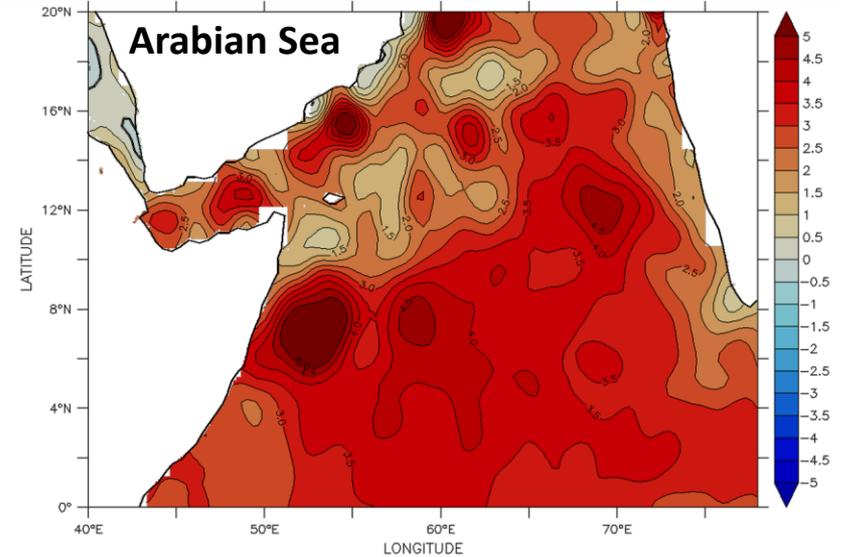
- Coral bleaching - a stress response of coral subjected to warmer than normal sea surface temperature.
- HadISST1 data analysis shows an increasing trend in years with positive SST anomaly
- In 1998 - mass coral bleaching event world wide.
- Coral bleaching alert map based on degree of heating



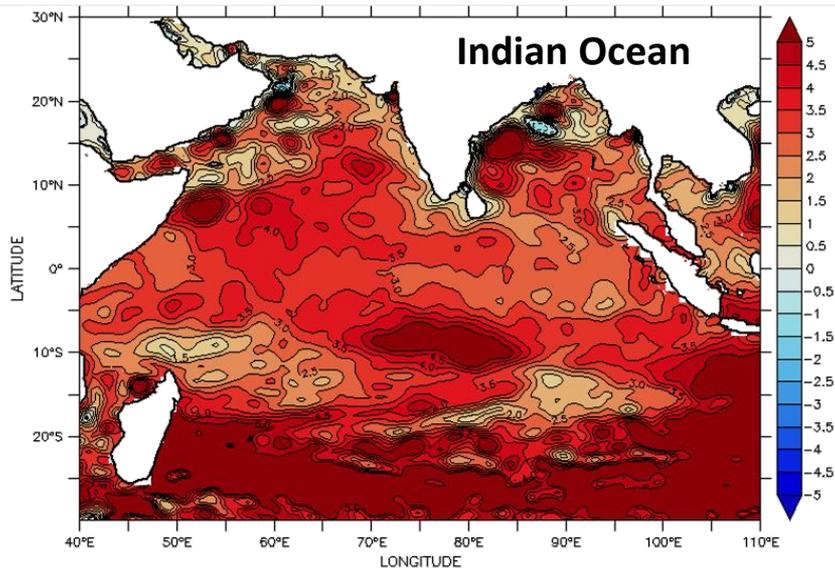
# Sea Level Trends (mm/ year) from Altimeter during 1992-2012



Sea Level Anomaly trend (mm/year)



Sea Level Anomaly trend (mm/year)



Sea Level Anomaly trend (mm/year)

- Overall trends in Bay of Bengal and Arabian Sea indicate rise in sea level.
- The average Indian Ocean Sea Level trend is ~ 3 mm per year

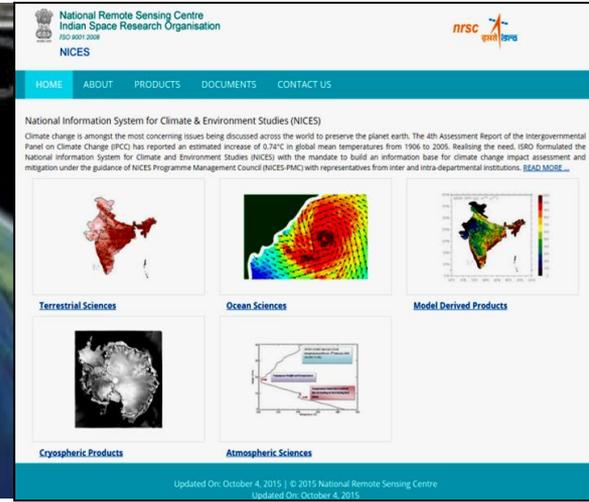
# Web based Information Services



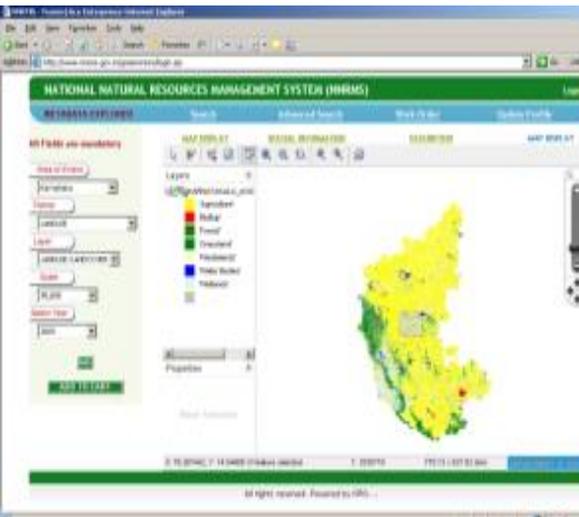
[www.dataportal.isro.gov.in](http://www.dataportal.isro.gov.in)



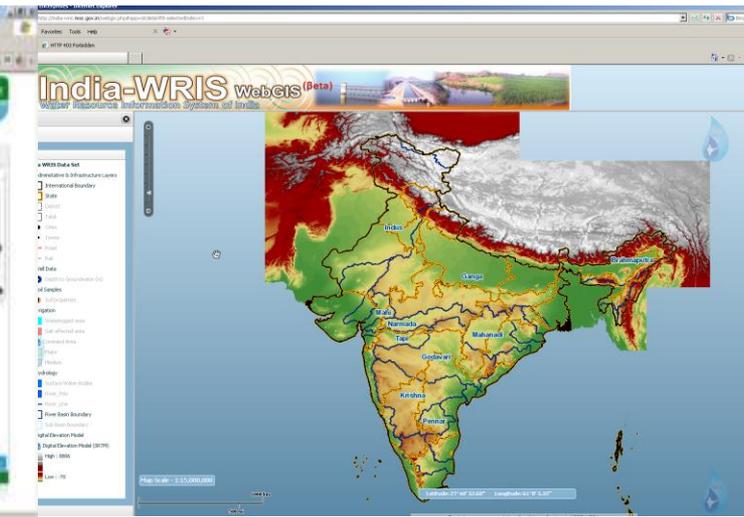
[Bhuvan \(bhuvan.nrsc.gov.in\)](http://bhuvan.nrsc.gov.in)



[NICES \(www.nrsc.gov.in/nices\)](http://www.nrsc.gov.in/nices)



**Natural Resources Database**



**Water Resource Information  
(India-wris.nrsc.gov.in)**



**MOSDAC  
(mosdac.gov.in)**

# Climate Change – Possible Mitigation

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Indicators	Mitigation
Extreme Heat	Optimal urban planning, Improving the use of renewable energy
Changing Rainfall Patterns	Flood early warning and Improvements in hydro-meteorological systems for weather forecasting
Droughts	Drought-resistant crop varieties, Efficient water management
Groundwater	Judicious use of ground water resources and recharge
Glacier Melt	Improvements in water storage capacity would be needed to benefit from increased river flows in spring and compensate for lower flows later on
Sea level rise	Enforcing coastal Regulation Zone codes and adhering to norms for the building codes in the urban areas.
Agriculture and food security	Crop diversification, efficient water use, development of drought-resistant crops, improved soil management practices,
Water Security	Improvements in irrigation systems, water harvesting techniques, watershed based approach

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# Way Forward

- **Continuity and improvement** of operational constellations
- **Sustained observation** of Essential Climate Variables (ECVs) observable from space
- **Calibration/validation sites** and global cooperation for inter comparison of satellite observations
- **Development of merged /blended geophysical fields by integrating space observations, *in-situ* measurements and model outputs.**
- **Newer Observation from Geo & LEO Platforms**

- **Development of local scale data sets and simple climate-linked models.**
- **Climate change impacts on water quality and groundwater** has received little attention as compared to surface water resources.
- **Implementation of adaptation processes** and methods such as improved water-use efficiency, water-demand management, water conservation - essential for coping with climate change.
- **Creation of sharable information is essential for judicious use of water resources through engagement of stakeholders**

**Given the diversity of interests, require integrated approach to arrive at sustainable solutions in managing stressed water resources**

**Thank you**

