Remote Sensing for Climate Change Studies

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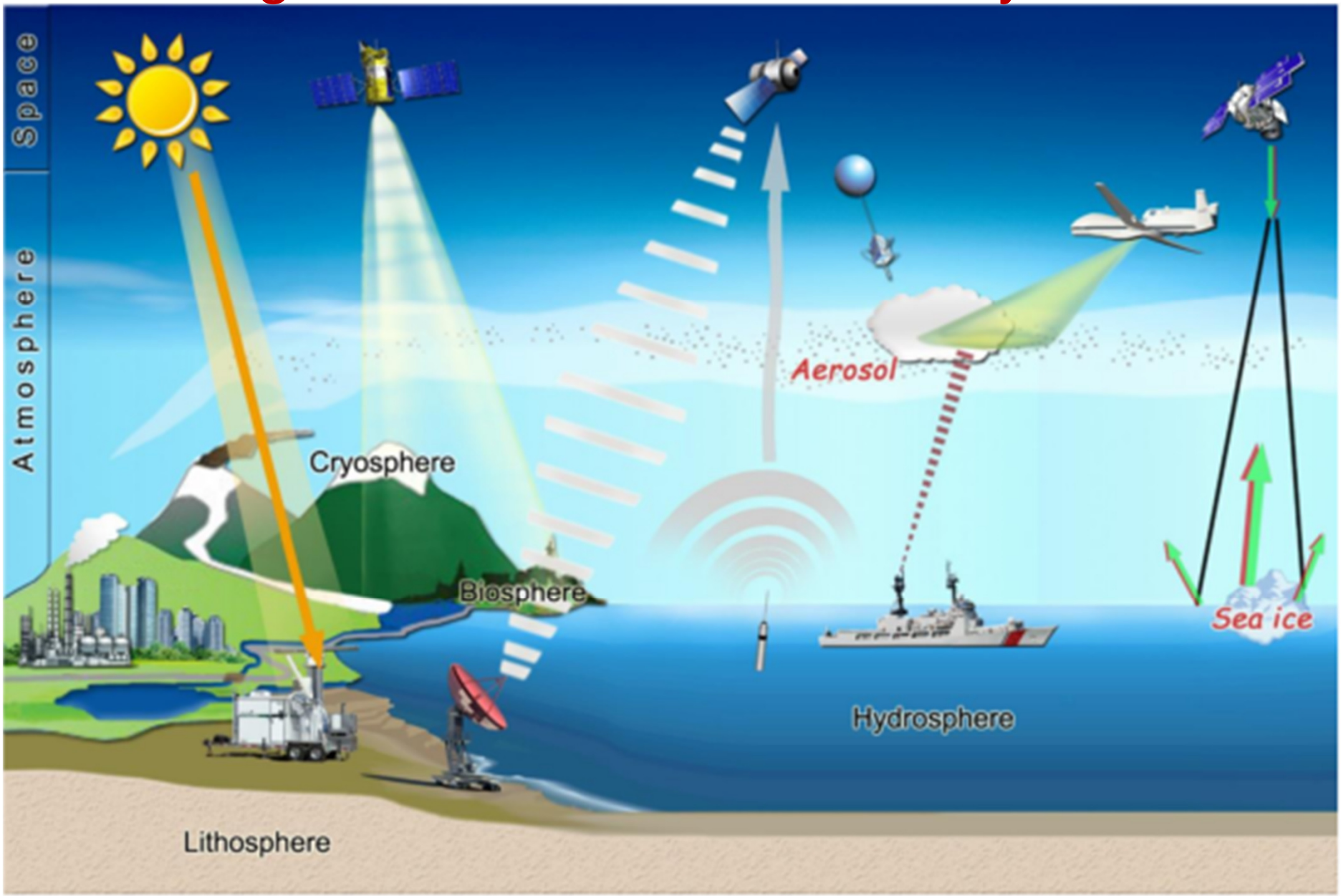
IILS-CIMSANS_Bengaluru_Nov16,2013


c.f. Santella, FG 2008
OBSERVING THE EARTH FROM THE DISTANCE

Integrated Earth Observation System



Yang et al. 2013


OSTM/Jason 2
Jason
QuikSCAT
ACRIMSAT
EO-1
SORCE
TRMM
Aqua
Terra
GRACE
CALIPSO
CloudSat
Aura
c.f. Santella, FG 2008

Observing Systems

Global Earth Observation System of Systems

c.f. Santella, FG 2008

Essential Climatic Variables (ECV)

* 50 ECVs have been identified to support the work of the UNFCCC and the IPCC.
* All ECVs are technically and economically feasible for systematic observation.
* It is for these variables, the international exchange is required for both current and historical observations.

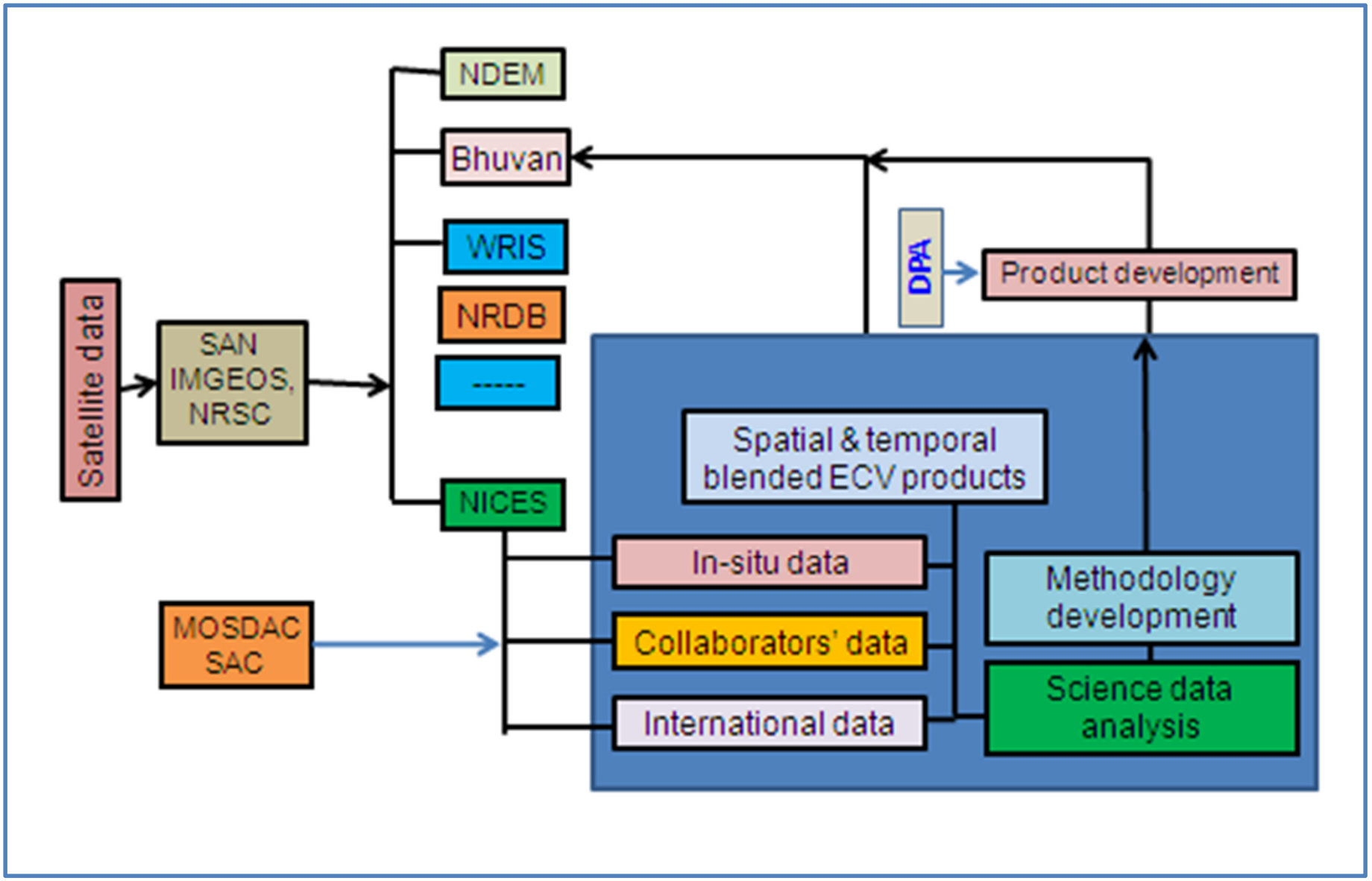
Essential Climatic Variables (ECV)

Domain	GCOS Essential Climate Variables
Atmospheric (over land, sea and ice)	**Surface:** Air temperature, Wind speed and direction**, Water vapour**, Pressure, **Precipitation**, **Surface radiation budget**.
	Upper-air: Temperature, Wind speed and direction, **Water vapour**, **Cloud properties, Earth radiation budget**
	Composition: Carbon dioxide, **Methane**, and other long-lived greenhouse gases, **Ozone and Aerosol**, supported by their precursors.
Oceanic	**Surface: Sea-surface temperature**, **Sea-surface salinity**, **Sea level**, Sea state, Sea ice, **Surface current**, **Ocean colour**, C O2 partial pressure, Ocean acidity, **Phytoplankton.**
	Sub-surface: Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, **Water use**, Groundwater**, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), fAPAR, LAI, Above-ground biomass**, Soil carbon**, Fire disturbance, Soil moisture**.

Global satellite data / products

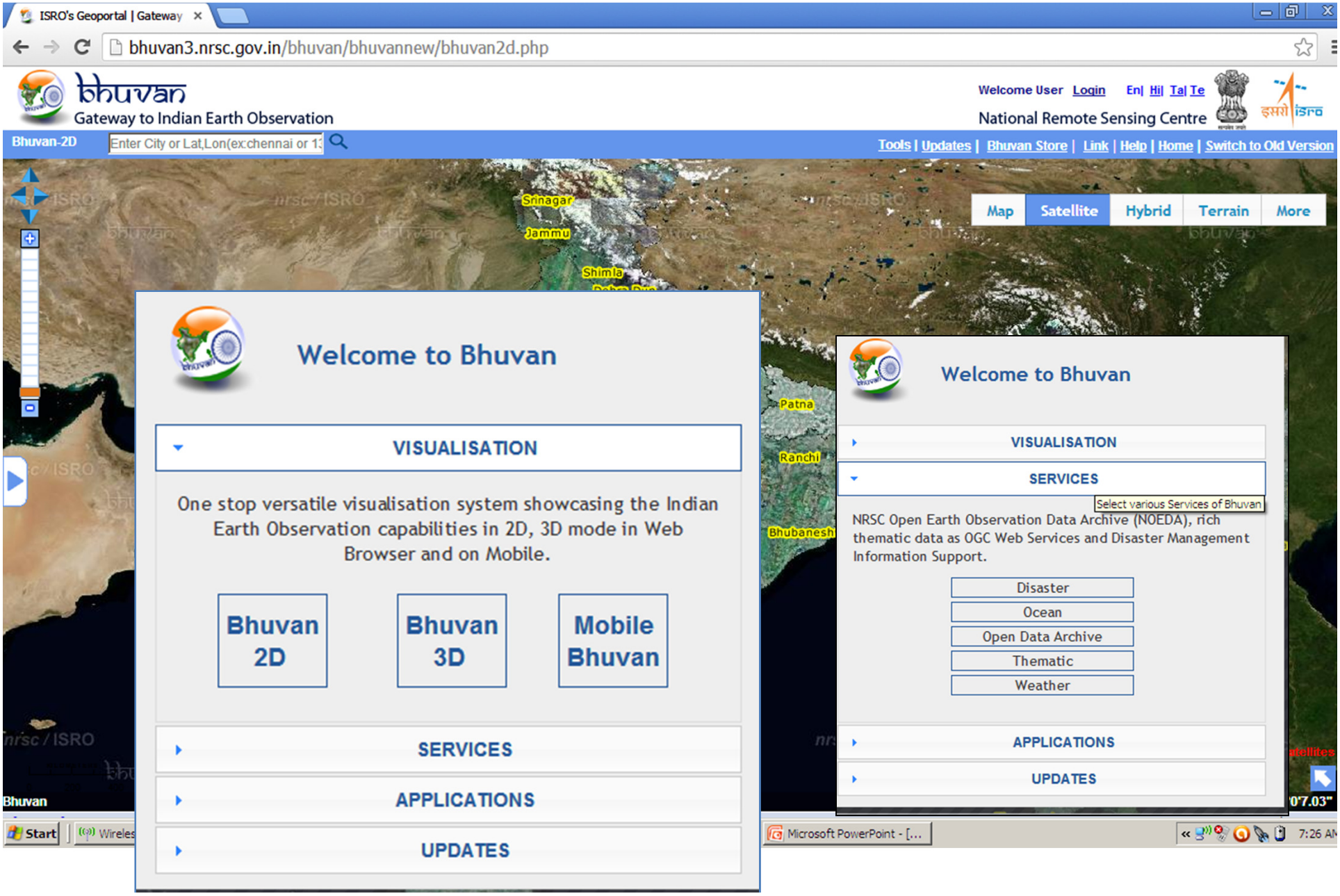
- ✓ NOAA-NASA
- ✓ ESA
- ✓ EUMETSAT
- ✓ CMACAST
- ✓ ISRO
- ✓ **GEO**
- ✓ ……

National Information System for Climate & Environmental Studies (NICES): Product Development and Interfaces



Bhuvan: Geo-portal of ISRO

(www.bhuvan.nrsc.gov.in)

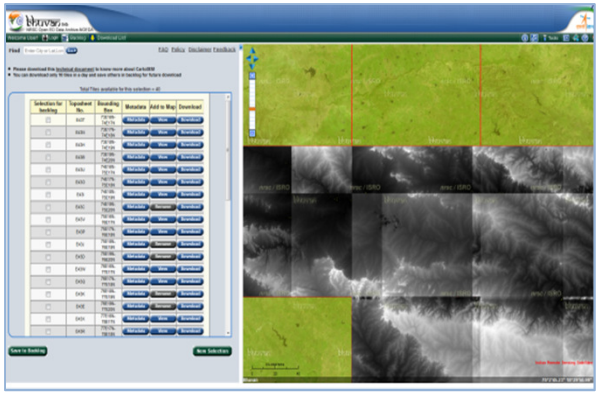


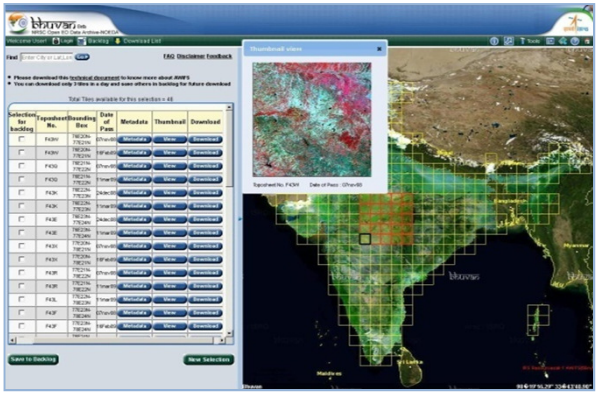
NRSC Open EO Data Archive

http://bhuvan-noeda.nrsc.gov.in

A new initiative to facilitate the users to select, browse and download IRS satellite data products.

- Cartosat-1:DEM: 1 arc Sec (v1(2006-08), v1.1(2008-12)
- Resourcesat-1:AWiFS Ortho (2008K,2009R&K, 2010 R&K):56m
- Resourcesat-1:LISS III Ortho (2008-09, 2011):24m
- IMS-1: HySI: Spectral Binned data: 500m
- Oceansat2:OCM2: Albedo, NDVI, VF (2011,12) – 1 Km
- Tropical Cyclone Heat Potential (TCHP) (near real time & model derived)
- Ocean Heat Content (OHC) (near real time) and model derived D26
- Metadata NSDI 2.0
- Select Area based on *'Bounding box, Mapsheet(SOI), Tiles, Interactive Drawing'*





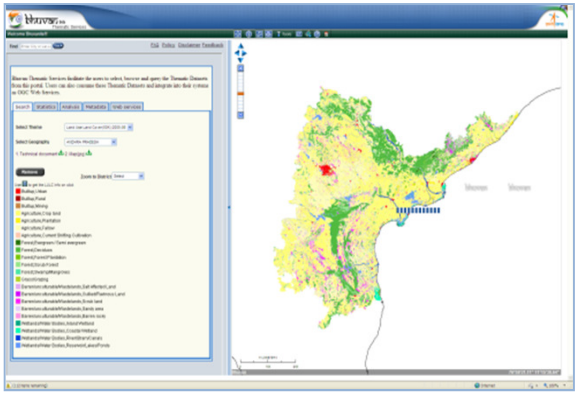
This facility will be extended for other IRS satellite data coarser than 24m in near future.

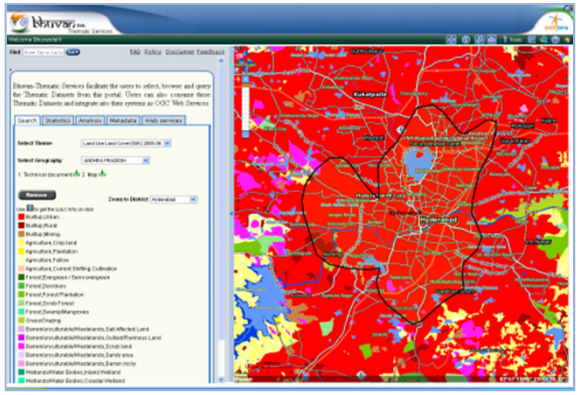
Thematic Services

"OGC Web Services (WMS, WMTS) towards interoperability"

Bhuvan-Thematic Services facilitate the users to select, browse and query the Thematic Datasets from this portal. Users can also consume these Thematic Datasets and integrate into their systems as 'OGC Web Services'.

- Land Use Land Cover -50 K (2005-06, 2011-12)
- Land Use Land Cover -250 K (8 Cycles : 2004-05 to 2011-12)
- Urban Land Use: 10K
- Wasteland: 50K (2008-09)
- Geomorphology:50K (2005-06) & Lineament: 50K
- Flood Annual Layers (1998 to 2010) – Assam & Bihar
- Flood Hazard Layer (1998-2007) – Assam 7 Bihar
- Metadata NSDI 2.0
- Analysis, Statistics, Web services, View based Print, Add WMS Layer, Clip & Ship





http://bhuvan-noeda.nrsc.gov.in/theme

Disaster Services

Disaster Management Information Support : Not an exhaustive list

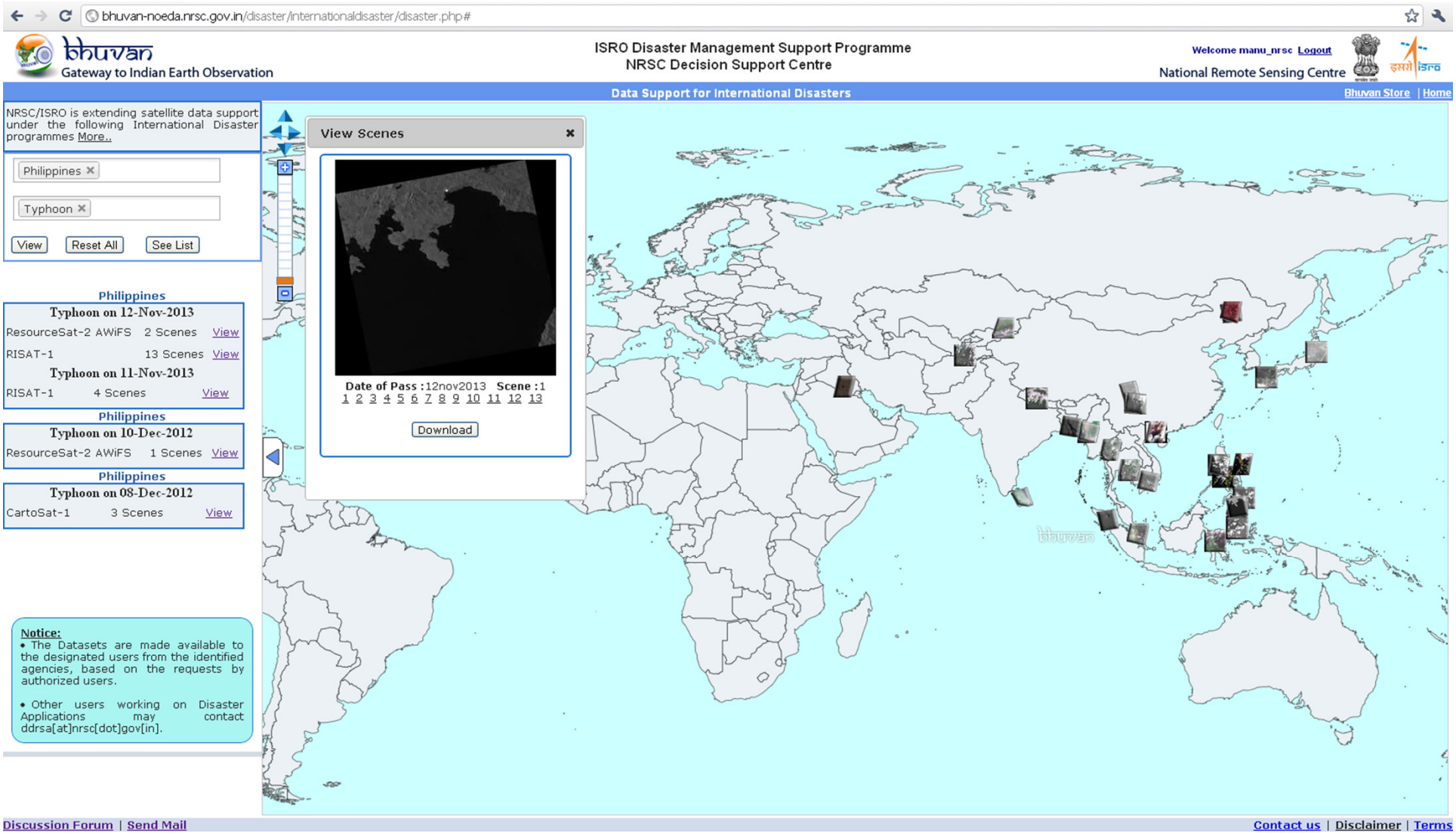
Theme	Availability	Remarks/Source
Drought • Normalized Differential Vegetation Index • Normalized Differential Water Index • Soil Moisture Index • Short Wave Angle Slope Index (SASI)	2008 to 2012	Derived under National Agricultural Drought Assessment and Monitoring System (NADAMS)
Flood Events • 2013 (Andhra Pradesh, Assam, Bihar, Delhi, Gujarat, Maharashtra, Orissa, Uttarakhand, Uttar Pradesh, West Bengal) – Including Cyclone Phailin • 2012 (Andhra Pradesh, Assam, Bihar, Tamil Nadu), 2011 (Assam, Bihar, Orissa, Uttar Pradesh, West Bengal) • 2010 (Punjab), 2009 (Andhra Pradesh) • 2008 (Bihar)	24 events 26 events 46 events 1 event 3 events 1 event	Derived from RADARSAT and RISAT-2/1
Flood Annual Layer: Assam, Bihar	1999 to 2010	Maximum Flood Inundation extent observed in that year
Flood Hazard Layer: Assam, Bihar	1998-2007	Assessment of frequency of inundation.

Disaster Services

Disaster Management Information Support: Not an exhaustive list

Theme	Availability	Remarks/Source
Forest Fire Alert	2008 to 2013	Indian Forest Fire Response and Assessment System (INFFRAS) Updated on daily basis (Day and Night) during Feb to June.
Forest Fire Regime	2003 to 2012	Based on three inputs – Average fire density, Fire period duration and Annual fire deviation.
Landslide • **Inventory** • **Hazard Zone**	 4 (3 Events + 1 Route) 2 (Uttarakhand & HP)	 Kedarnath, Okhimath, Sikkim & Amarnath Sector wise (8 sectors)
Earthquake • **Recent Seismicity** • **Historic Seismicity**	 2013 1819 to 2011	 3 events - USGS Magnitude greater than 6 - IMD
Heat Index	2009 to 2013	Derived based on Temperature and Humidity obtained from AWS stations

http://bhuvan-noeda.nrsc.gov.in/disaster/internationaldisaster/disaster.php#



“Data Support for International Disasters”

“27 events – 94 Data sets including HRS and MRS data”

MOSDAC

Govt. of India

Meteorological & Oceanographic Satellite Data Archival Centre

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SARAL GDR data released on 28-10-2013

MOSDAC OBJECTIVES

Application of Space Technology for the benefit of the comman man. Weather forecasting, cyclone prediction & continuous weather & ocean data availability.

FTP SITES

MOSDAC | MEGHATROPIQUES | CALVAL | PRWONAM | SARAL

ALERTS FROM EXPERIMENTAL FORECAST

Uttarakhand Heavy Rain/Cloudburst image

EVENTS OF OCTOBER 2013

PHAILIN Cyclone - INSAT-3D | MT | OCEANSAT2

EVENTS OF JUNE 2013

This is an experimental run, not an operational forecast

MISSIONS

- KALPANA
- INSAT3A
- OCEANSAT2
- MEGHATROPIQUES(MT)
- SARAL
- INSAT-3D

SERVICES

- PRODUCT CATALOGUE
- METADATA
- SATELLITE DATA
- IN-SITU DATA
- FORECAST
- CYCLONE
- CALVAL
- AWS-MP

TODAY'S FORECAST OF AHMEDABAD

Temperature(°C):30.6(14:30 Hrs)
Rain (mm): No Rain(17:30 Hrs)
Humidity(%):54.6(17:30 Hrs) more ...

ANNOUNCEMENTS

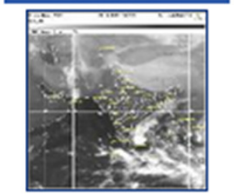
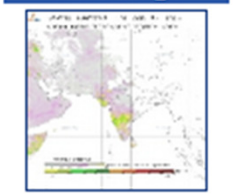
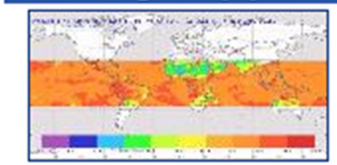
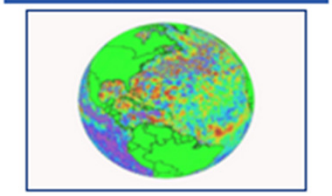
- NEW KALPANA derived Heavy Rain
- NEW SARAL - World Sea State Atlas
- NEW INSAT-3D First Day Products
- NEW Annoucement to MT data users

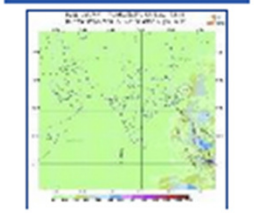
SARAL FULLDAY PRODUCTS PREVIEW

MEGHA-TROPIQUES & SARAL SATELLITES

- Current Position
- Orbit Viewer

KALPANA-1 | NDVI Image | Megha Tropiques | SARAL-SSHA | Heavy Rain | Other Products



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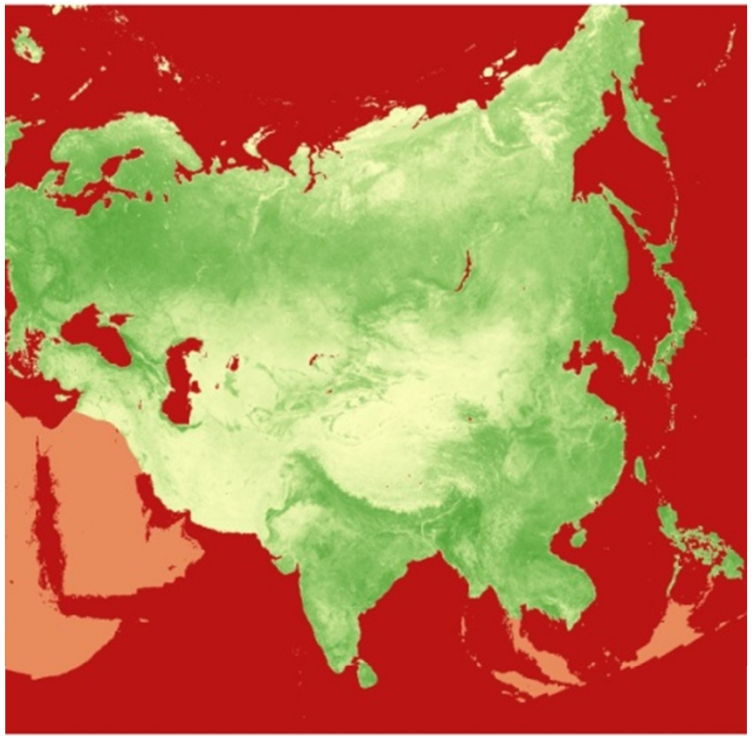
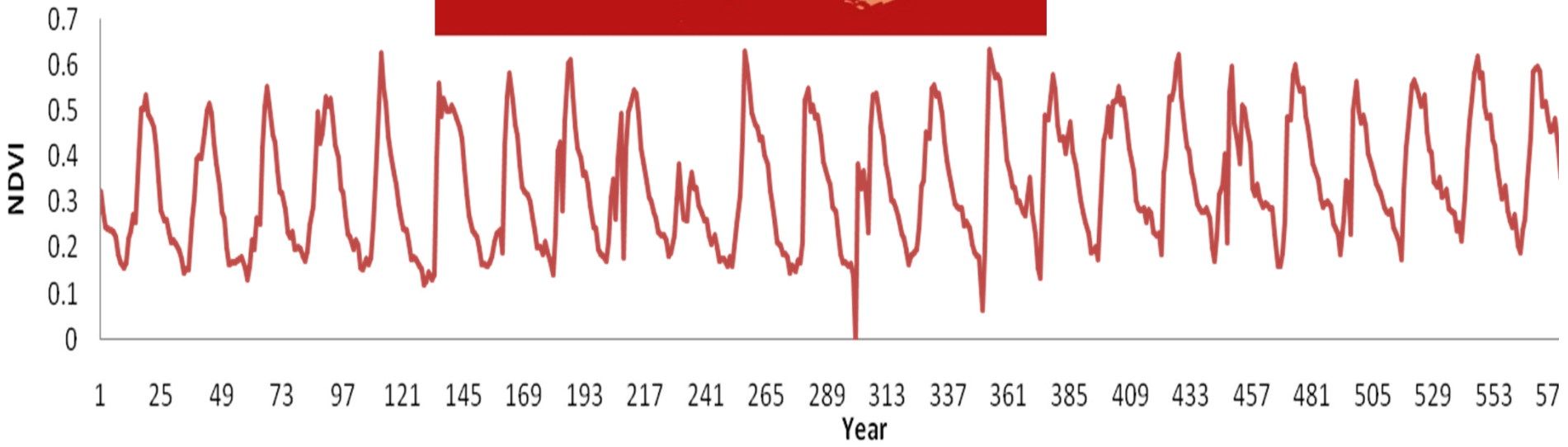
Global Inventory Modeling and Mapping Studies





Global Inventory Modeling and Mapping Studies

Corrected for:

- residual sensor degradation and sensor inter-calibration differences
- distortions caused by persistent cloud cover globally
- solar zenith angle and viewing angle effects due to satellite drift; volcanic aerosols
- missing data in the Northern Hemisphere during winter using interpolation
- due to high solar zenith angles
- low signal to noise ratios due to sub-pixel cloud contamination and water vapor

Salient Features:

- Prepared with NOAA 7, 9, 11, 14, 16
- Spatial coverage: Global except Greenland & Antartica
- Spatial resolution: 8 km, Albert Equal Area Conic projection, Clarke 1866 ellipsoid
- Temporal coverage: July 1981 to December 2006
- Temporal resolution: 15 days
- Scale: -10000 to +10000, Water -10000, no data -5000

Start of growing season (kharif) : Trends

Advanced (days/yr)

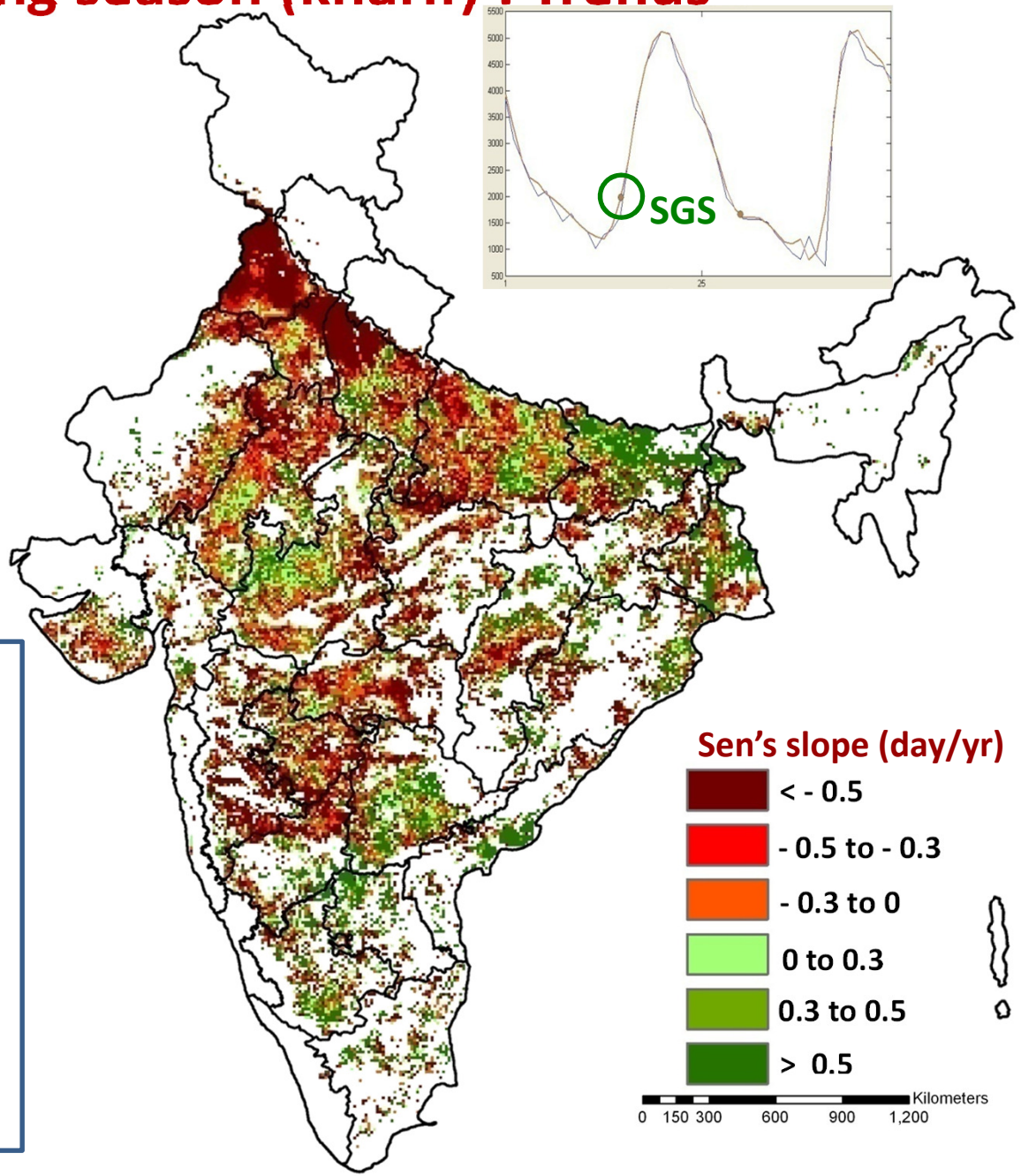
- Punjab (-0.77 days/yr),
- Haryana (-0.57 days/yr),
- Marathwada (-0.75 days/yr),
- Vidarbha (-0.61 days/yr)
- Madhya Maharashtra (-0.1 days/yr).

(Early monsoon rainfall, snow melt irrigation, crop variety/type, cropping pattern)

Delayed (days/yr):

- Rayalaseema (0.94 days/yr)
- Coastal AP (1.2 days/yr)
- Bihar (1.1 days/yr)
- Gangetic WB (0.94 days/yr)
- Sub-Himalayan WB (1.6 days/yr).

(Irrigation from rainfed rivers, delay in monsoon, crop variety/type, cropping pattern)



Kharif seasonal NDVI amplitude (Crop vigour): Trends

Positive trend (0.002-0.007 year $^{-1}$):

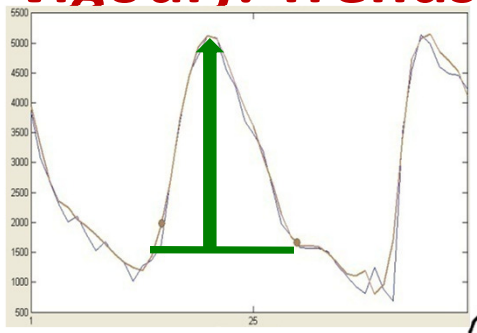
- Punjab
- Haryana
- West & East Rajasthan
- East UP
- West MP
- Bihar
- Sub-Himalayana West Bengal
- Sourashtra & Kutch
- North Interior Karnataka
- Rayalaseema
- Telangana

(Better monsoon, increase in sown area, vigourous crop variety/ type, irrigation)

Negative trend (0.002-0.003 year $^{-1}$):

- Tamil Nadu
- South Interior Karnataka
- Coastal AP
- Marathwada
- Vidarbha
- Madhya Maharashtra
- Orissa
- Gujarat
- Jharkhand
- Chhattisgarh

(Meager monsoon, decrease in sown area, HYV)



Kharif Integrated NDVI (seasonal greenness): Trends

Positive trend (0.02 – 0.05 year^{-1}):

- Punjab
- Haryana
- West & East UP
- West & East Rajasthan
- Bihar
- Sub-Himalayan WB
- West and East MP
- Sourashtra & Kutch
- Rayalaseema

→ Increase in AMP

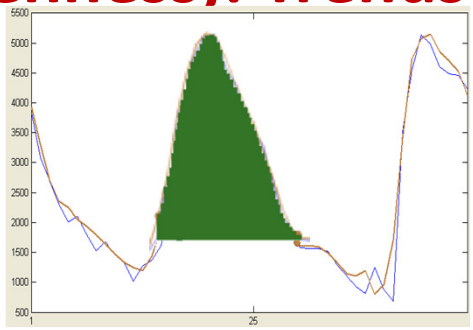
- Marathwada
- Vidarbha

→ Decrease in AMP i.e. increase in LGS

Negative trend (0.02 – 0.04 year^{-1}):

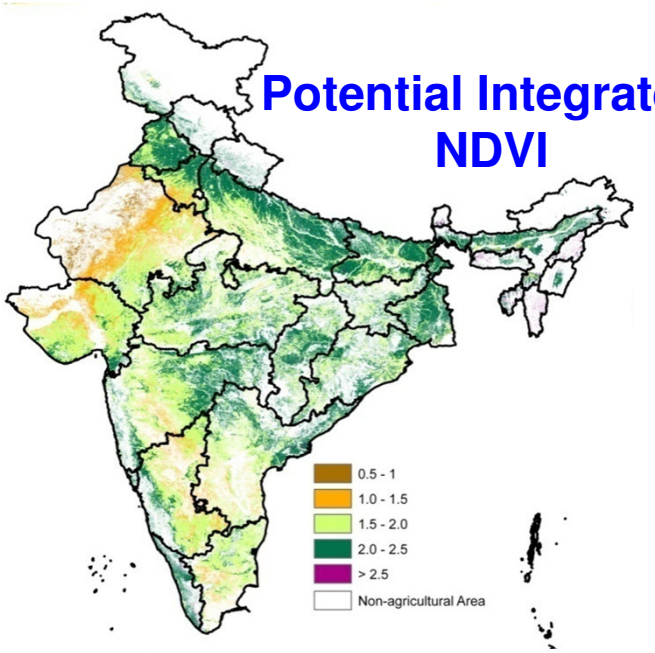
Tamilnadu

- South Interior Karnataka
- Coastal AP
- Madhya Maharashtra
- Chhattisgarh
- Gujarat
- Gangetic WB

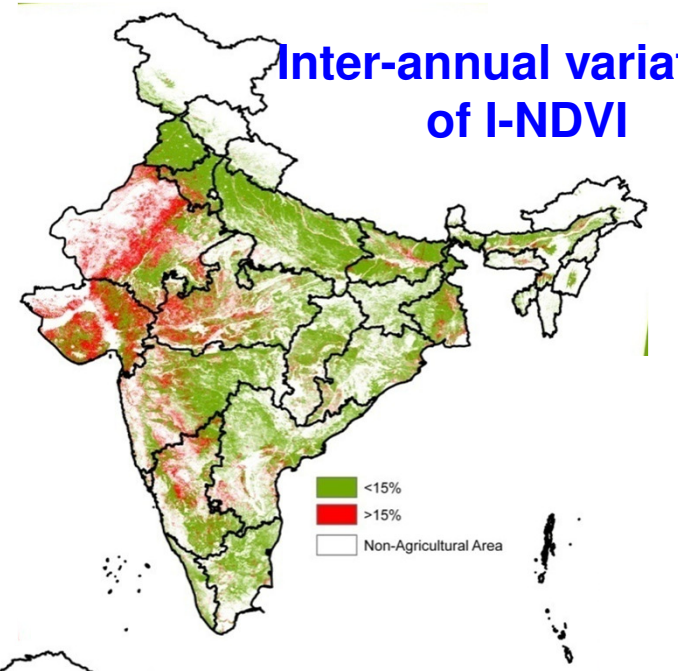


Agricultural drought proneness using iNDVI

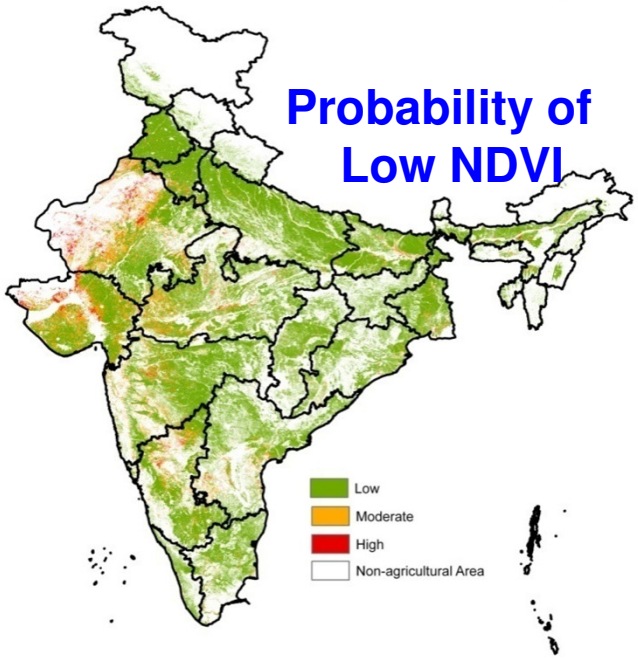
Potential Integrated NDVI



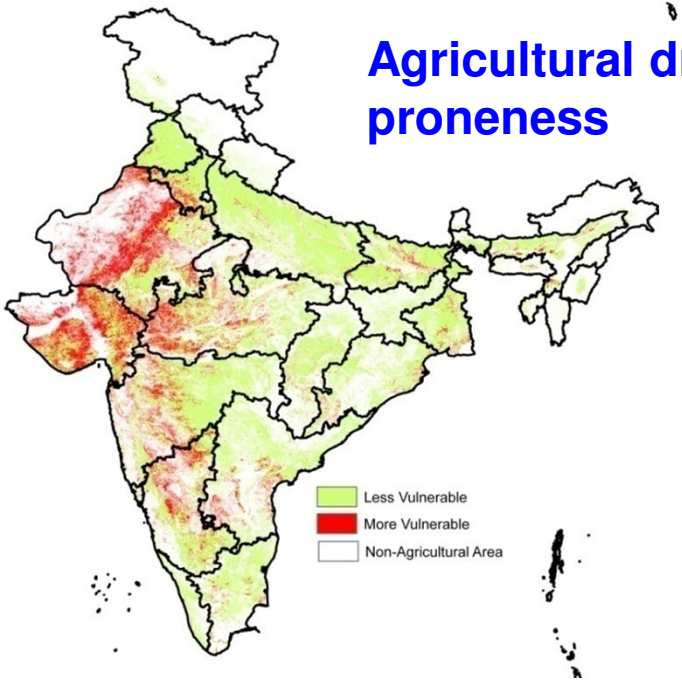
Inter-annual variation of I-NDVI



Probability of Low NDVI



Agricultural drought proneness



ECVs Generation by NICES

Theme	Parameters	Major Contr. Centre
Atmosphere	Aerosol Measurements / RF	SPL
	Satellite AOD Retrieval / Reprocessing	NRSC
	Atm. Profiling & Modeling	NARL
	Atm. & Met. Studies	SAC
	Satellite Met. Data Reprocessing	NRSC
Oceans	Ocean Observations	INCOIS
	Satellite Oceanography	NRSC, SAC
	Cal / Val	SAC
	GPRs	SAC
	Reprocessing of Data	NRSC
Land	LULC	NRSC
	Soil Moisture	NRSC
	Himalayan Snow Cover	NRSC
	NDVI	NRSC
	Surface Water	NRSC
	Glacial Lakes	NRSC
Model / Reanalysis	Climatological Data (Atm.)	NARL, SAC
	NPP	NRSC
	OGCM Climatology	SAC

ECVs Generation by NICES

Sensor	Variable	Spatial Domain	Temporal Re-visit	Resolution
OCM	Chlorophyll-*a*	Global	Monthly	1Km
	NDVI	Global	Monthly	4Km
	Vegetation.Fr	Global	Monthly	5Km
	Albedo	Global	Planned	
	Chlorophyll-*a*	NIO	8-day	1Km
	NDVI	India	14-day	1Km
	Vegetation.Fr	India	15-day	1Km
	Albedo	India	15-day	1Km
	IPAR	NIO	8-day	1Km
	PAR	NIO	8-day	1Km
	K_d-490	NIO	8-day	1Km
	TSM*	NIO	8-day	1Km

ECVs Generation by NICES

Sensor	Variable	Spatial Domain	Temporal Revisit	Resolution (deg.)
OSCAT	Wind Speed	Indian Ocean	Daily	0.5 x 0.5/0.25x0.25
	Wind Stress	Indian Ocean	Daily	0.5 x 0.5/0.25x0.25
	Wind Stress Curl	Indian Ocean	Daily	0.5 x 0.5/0.25x0.25
	Currents	Indian Ocean	monthly	0.5 x 0.5/0.25x0.25
Altimeter	TCHP	Indian Ocean	Daily	0.5 x 0.5/0.25x0.25
	OHC	Indian Ocean	Daily	0.5 x 0.5/0.25x0.25
Model	D26	Indian Ocean	Daily	0.5 x 0.5
	MLD	Indian Ocean	Daily	0.5 x 0.5
	Pressure	Indian Ocean	Planned	

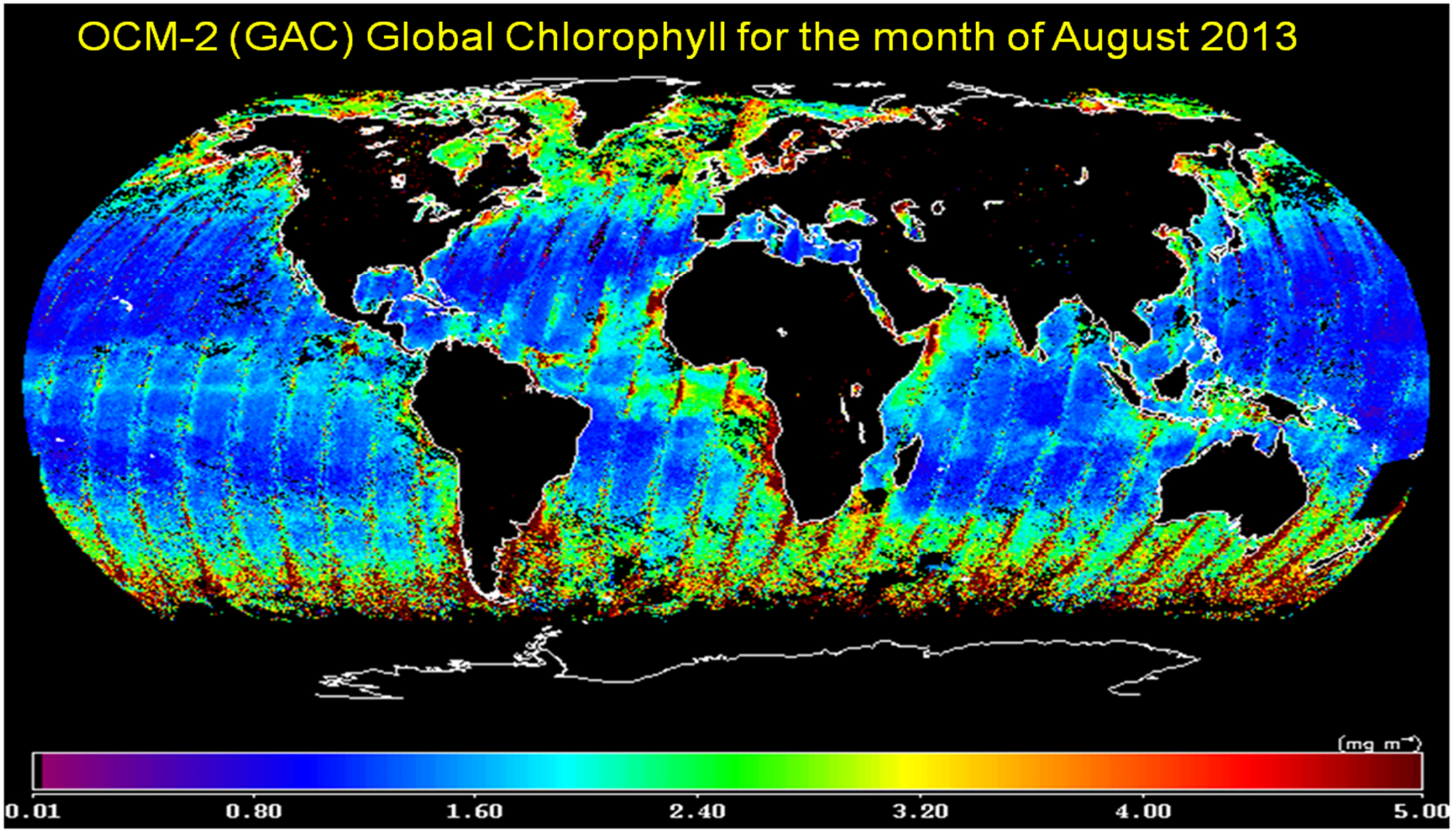
ECVs Generation by NICES

Sensor	Variable	Spatial Domain	Temp. Revisit	Resolution
AWiFS	Fire Damage	India	5-days	50m
	Himalayan Snow Cover	Himalaya	Monthly	50m
	Glacial Lakes	Himalaya	Monthly (Monsoon)	50m
	Surface Water	India	Monthly	50m
	LULC	India	Yearly	250m / 5', 2',30"
NCP	Forest Carbon	India	Yearly	1Km
	Soil Carbon	India	2008-2014	1Km
	pCO2	BoB	Time Series	1Km
	Modeled Carbon	India	Yearly	0.5 x 0.5 deg.

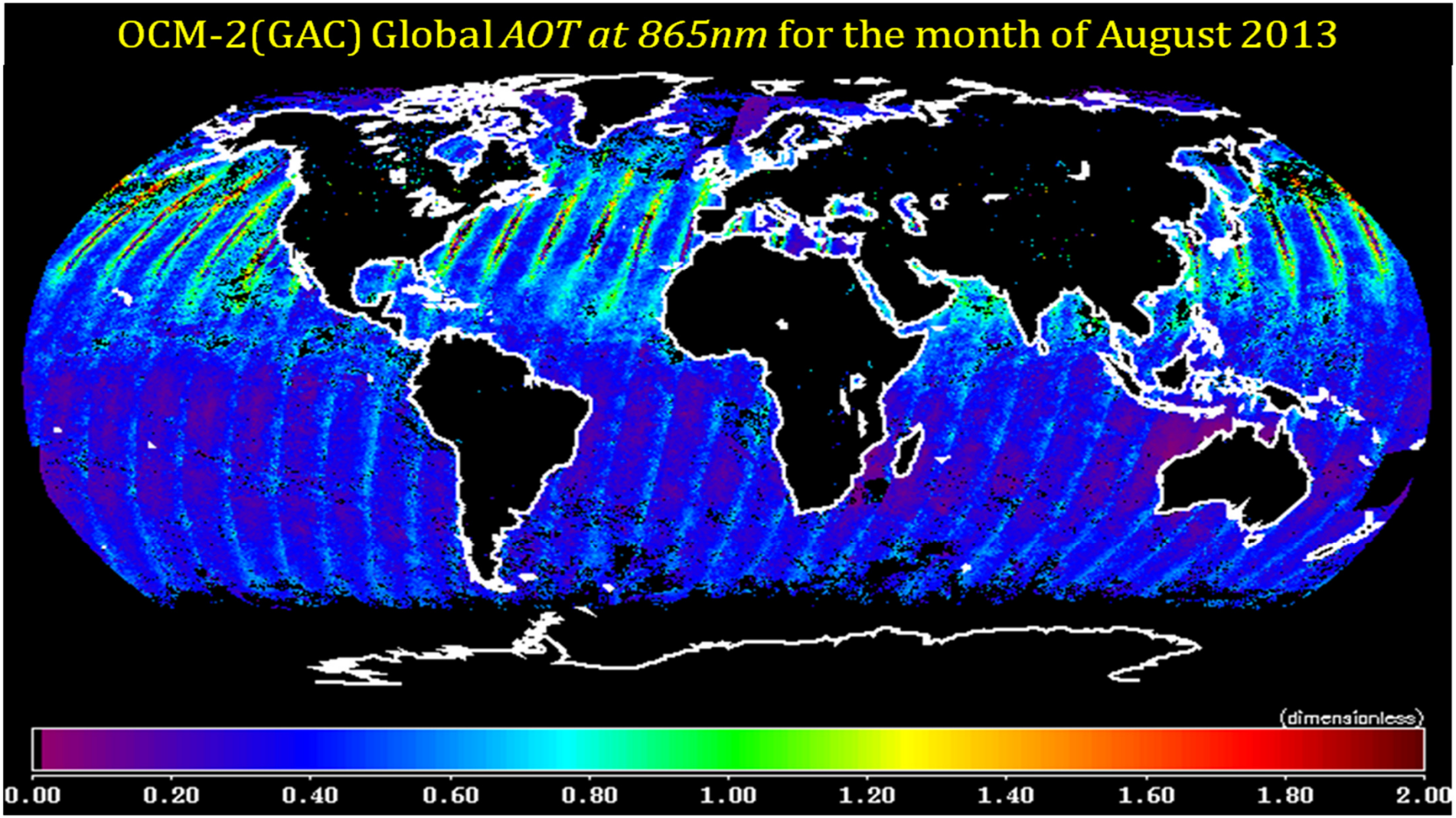
ECVs Generation by NICES

Sensor	Variable	Spatial Domain	Temporal Re-visit	Resolution
RO	T, RH, P	Vertical	Occultation	200m
Ozone	O3	Columnar	Monthly	1Km
	Stratospheric Ozone	India	Daily	25Km
	Trop. Ozone	Troposphere	Monthly	1Km
ARFI	AOD	India	Monthly	0.5 x 0.5 deg.
	RF	India	Monthly	0.5 x 0.5 deg.
LPRM	Soil Moisture	India	Daily	0.25x0.25 deg.

Global Chlorophyll-a reprocessed product, August 2013



Global *AOT* at *865nm* reprocessed - August 2013

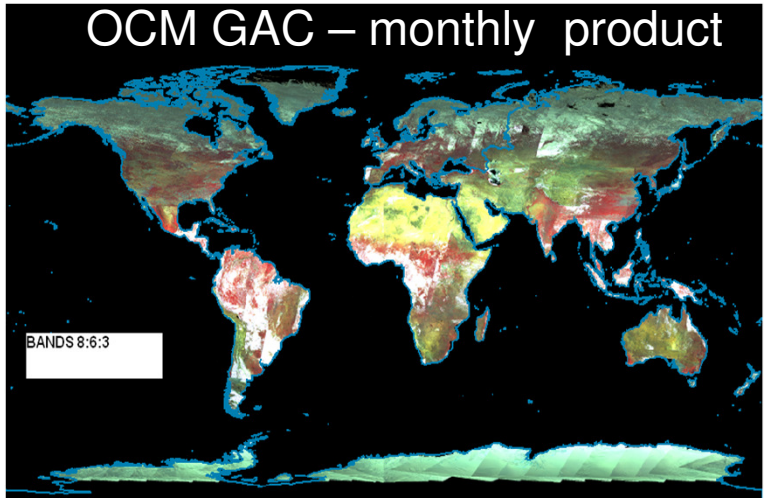


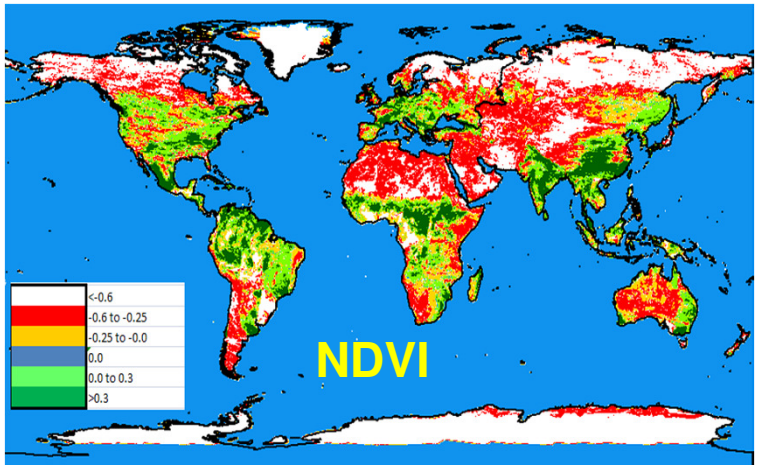
Geophysical Products & Services - Operational

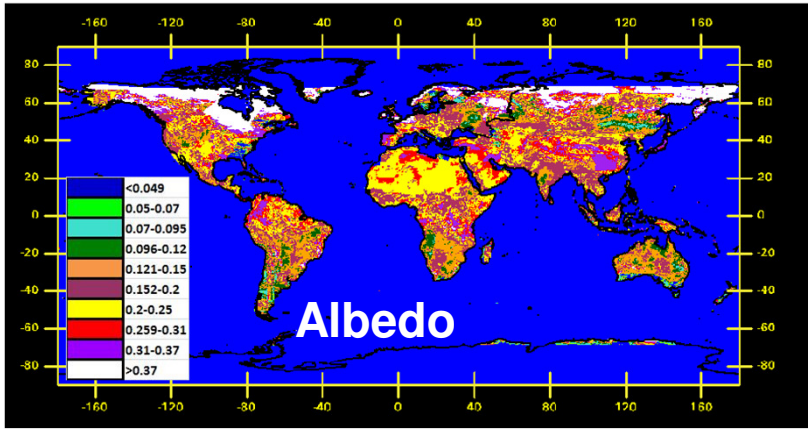
- **National (1 km res – 15day)**
  - NDVI
  - Vegetation Fraction
  - Albedo (Vis)

- **Global (5 km res – monthly)**
  - NDVI
  - Veg. Fraction
  - Albedo (Vis)

No. of downloads from May'12 to Sept.10 → 1345

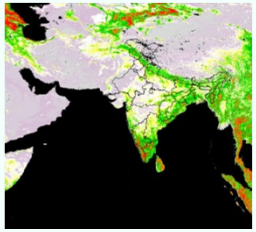




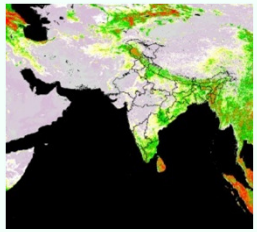


Vegetation Dynamics from INSAT 3A CCD

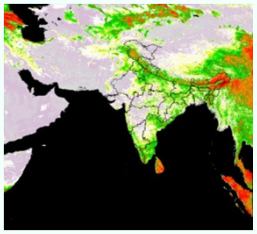
25 May to 9June'08



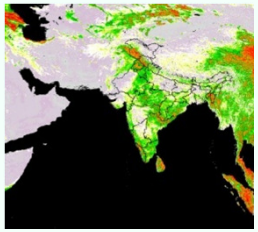
10 June to 25 June'08



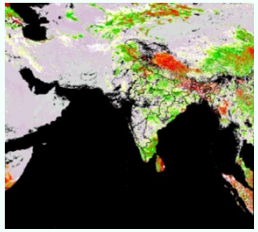
26 June to 11 July'08



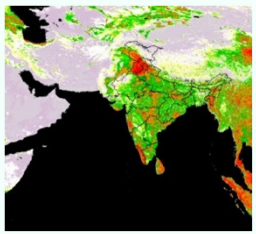
12 July to 27 July'08



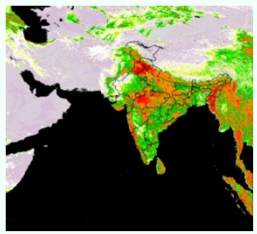
28 July to 12 Aug'08



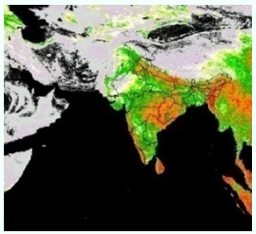
13 Aug to 28 Aug'08



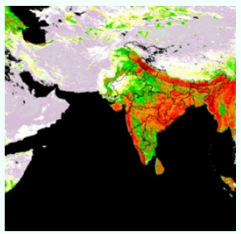
29 Aug to13 Sept'08



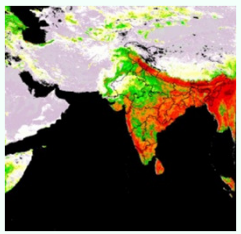
14 Sept to 29 Sept'08



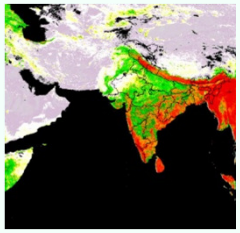
30 Sept to 15 Oct'08



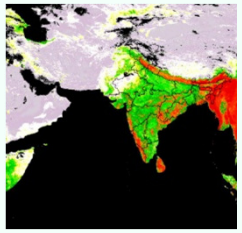
16 Oct to 31Oct'08



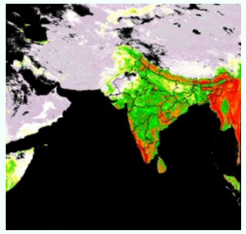
1 Nov to 16 Nov'08



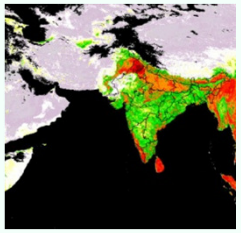
17 Nov to 2 Dec'08



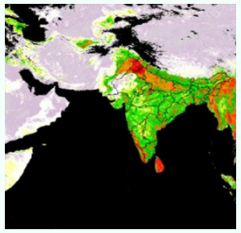
3 Dec to 18 Dec'08



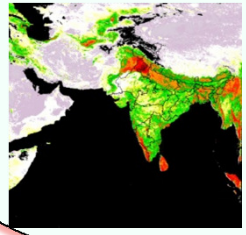
2 Feb to 17 Feb'09



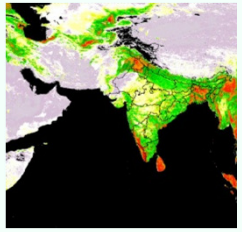
18 Feb to 05 Mar'09



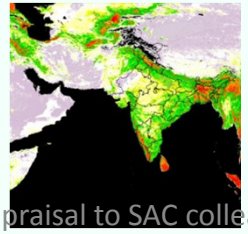
6 Mar to 21Mar'09



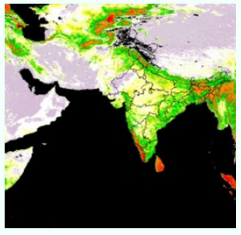
22 Mar to 6 April'09

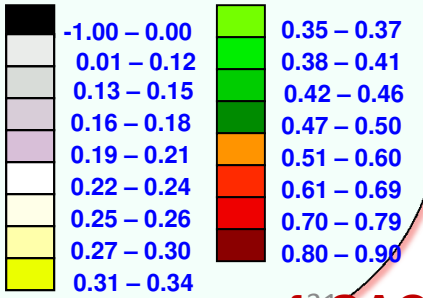


7 April to 22 April'09



23 April to 30 April'09





c.f. SAC

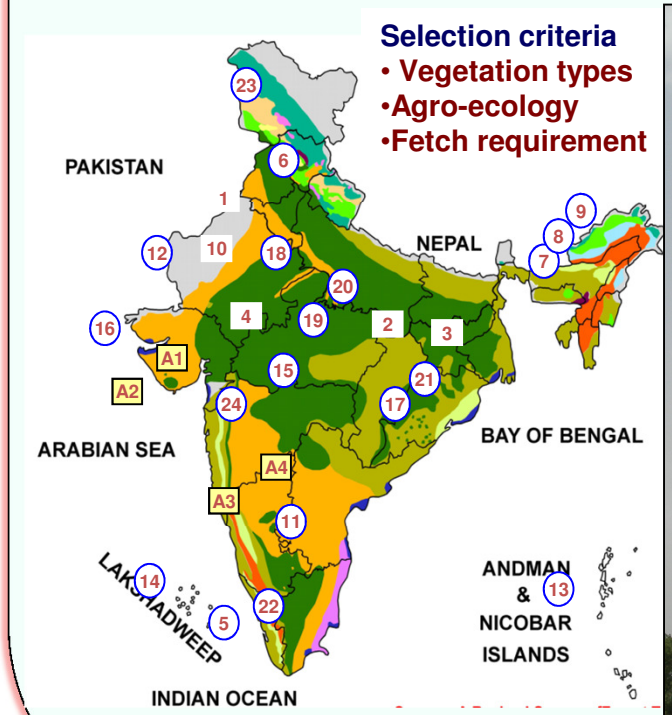
Terrestrial Environment

Agro-Meteorological Stations (AMS) Network

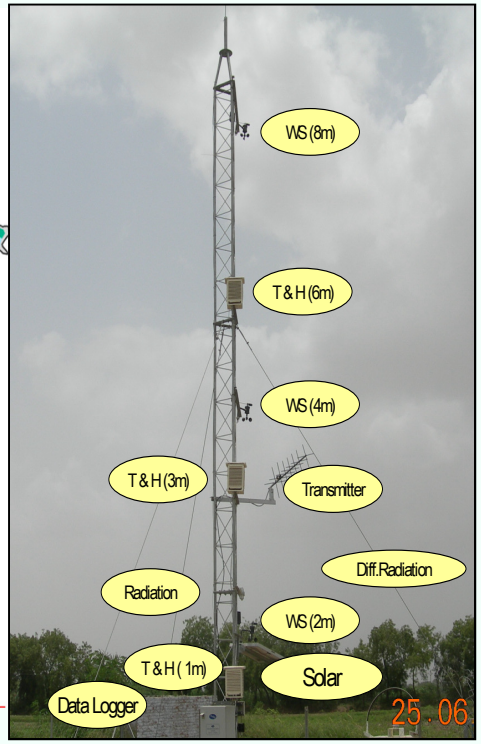
Vegetation Response to Climate and CO_2 Uptake

Network of Micrometeorological (Canopy scale) Measurements

Sensors : Radiation balance, Energy Balance, Water balance



Locations of AMS Net work (24)



ISRO-Agro-Met Station (AMS)
10m for short canopies

Flux Towers 50Metrs

1. Ludhiana
2. Patna
3. Kalyani, WB
4. Madhav Nat. Park MP
5. LPSC, TN
6. Tunganath
7. Guwahati
8. Bomdilla, AP
9. Tonga AP
10. Bharatpur, Raj
11. Shriharikota
12. Jodhpur
13. Andman
14. Nicobar
15. Kanha Nat. Park, MP
16. Banni, Guj.
17. Chilka
18. IISR, UP
19. Bandhavgarh Nat. Park,MP
20. Mirzapur UP
21. Bhitarkanika
22. TNAU, TN
23. Nubra/Leh
24. Maharastra

Terrestrial Environment

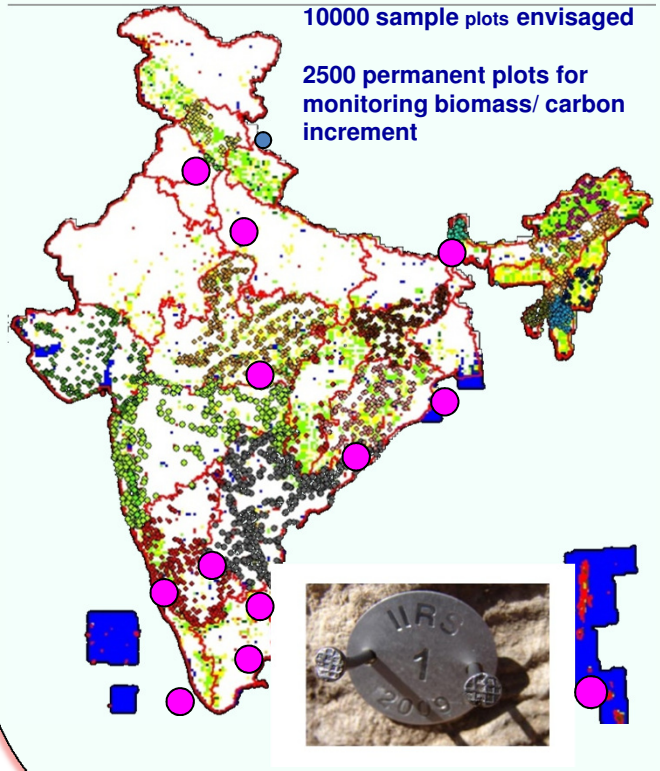
National Carbon Pool Assessment (NCP)

Current spatial vegetation & soils Carbon pool

Quantitative spatial estimates of C flux viz., GPP, NPP & respiration

Fluxes controlled by environmental variables & vegetation types

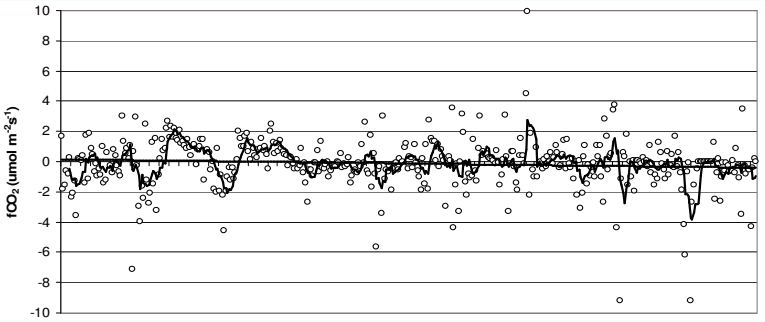
India's Flux net established

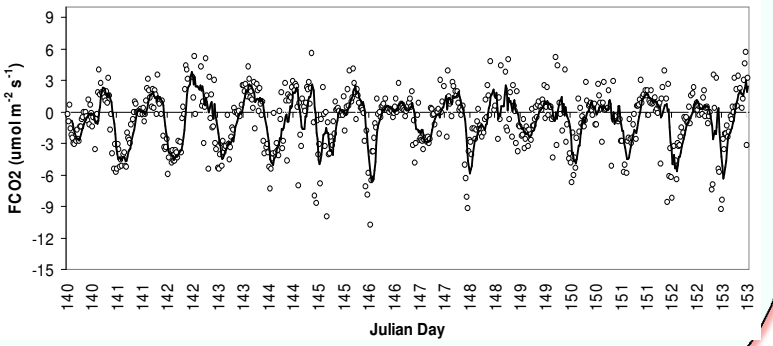


Flux Net sites

Flux Tower

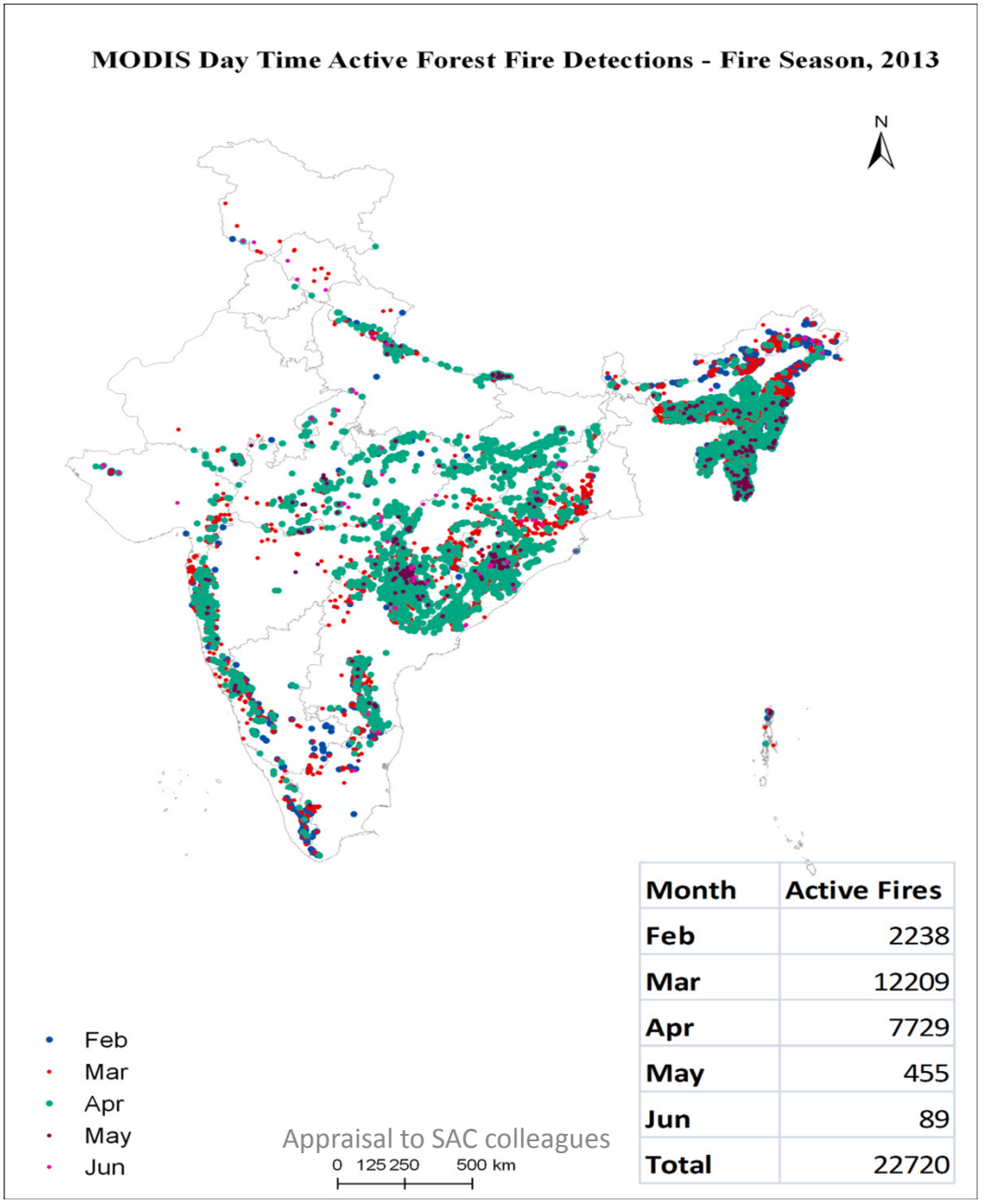
Haldwani tower





Flux of CO_2 during the growing period

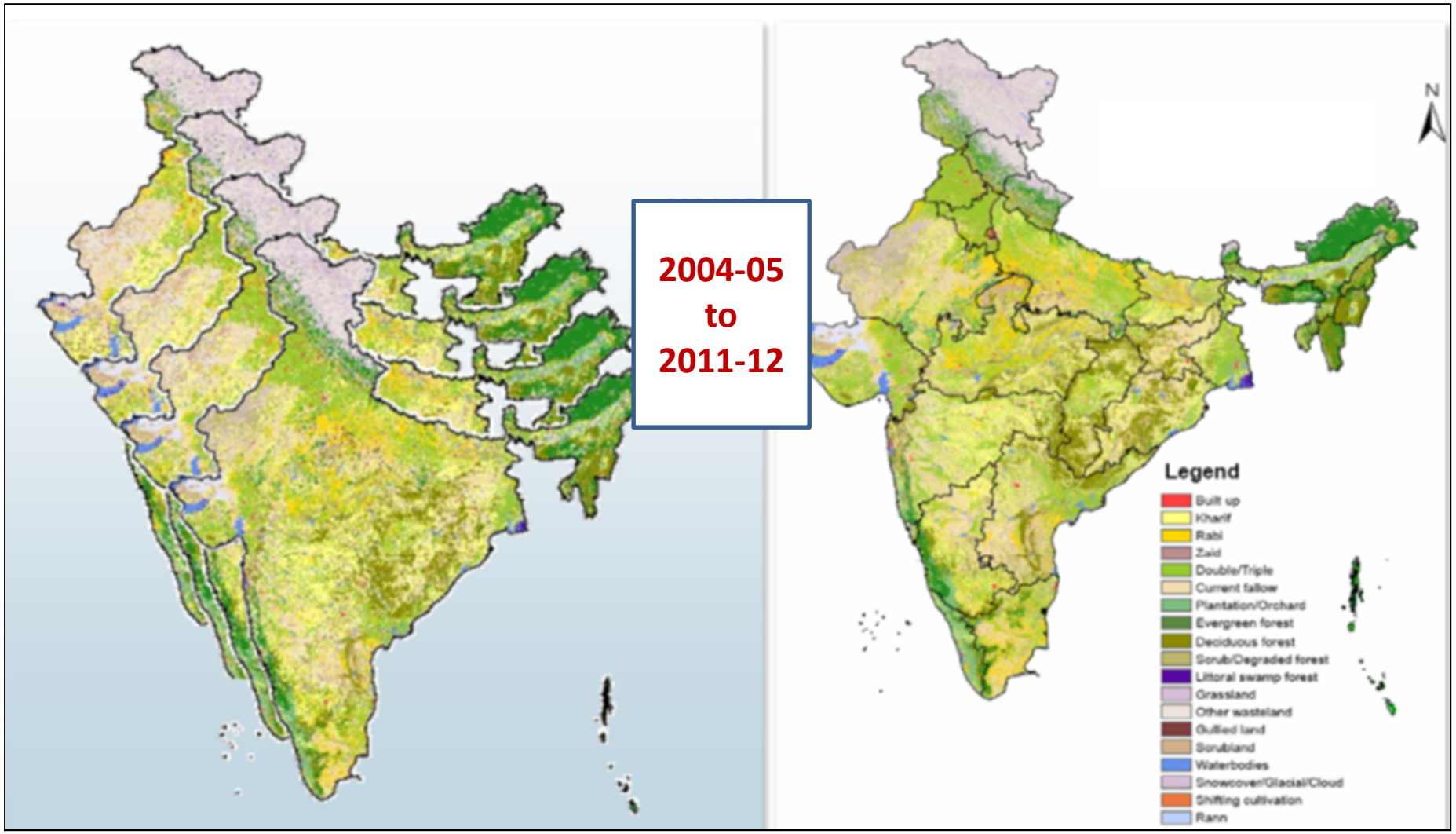
Forest Fire Damage – Satellite Data



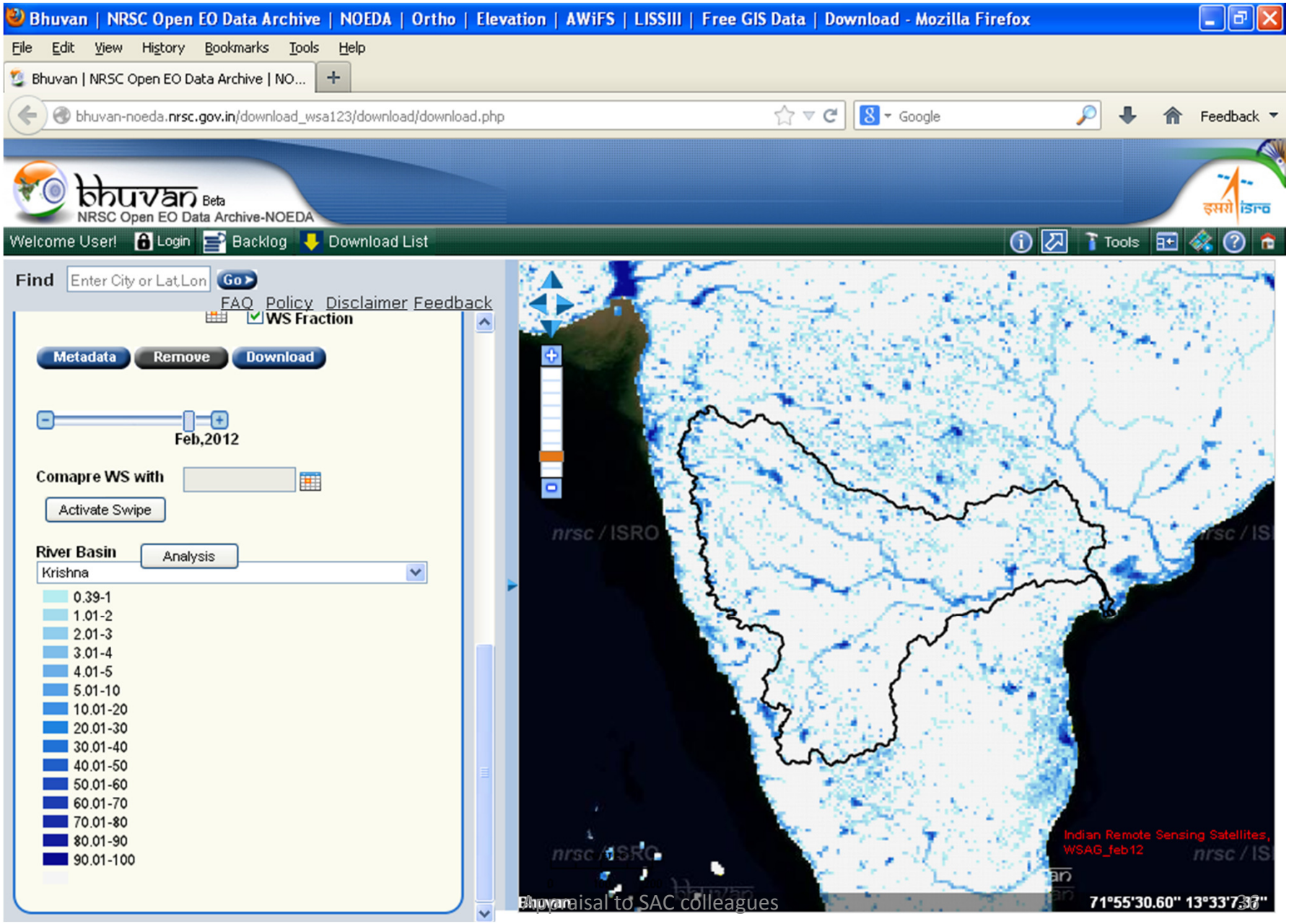
Month	Active Fires
Feb	2238
Mar	12209
Apr	7729
May	455
Jun	89
Total	22720

Appraisal to SAC colleagues

Land Use & Land Cover Dynamics

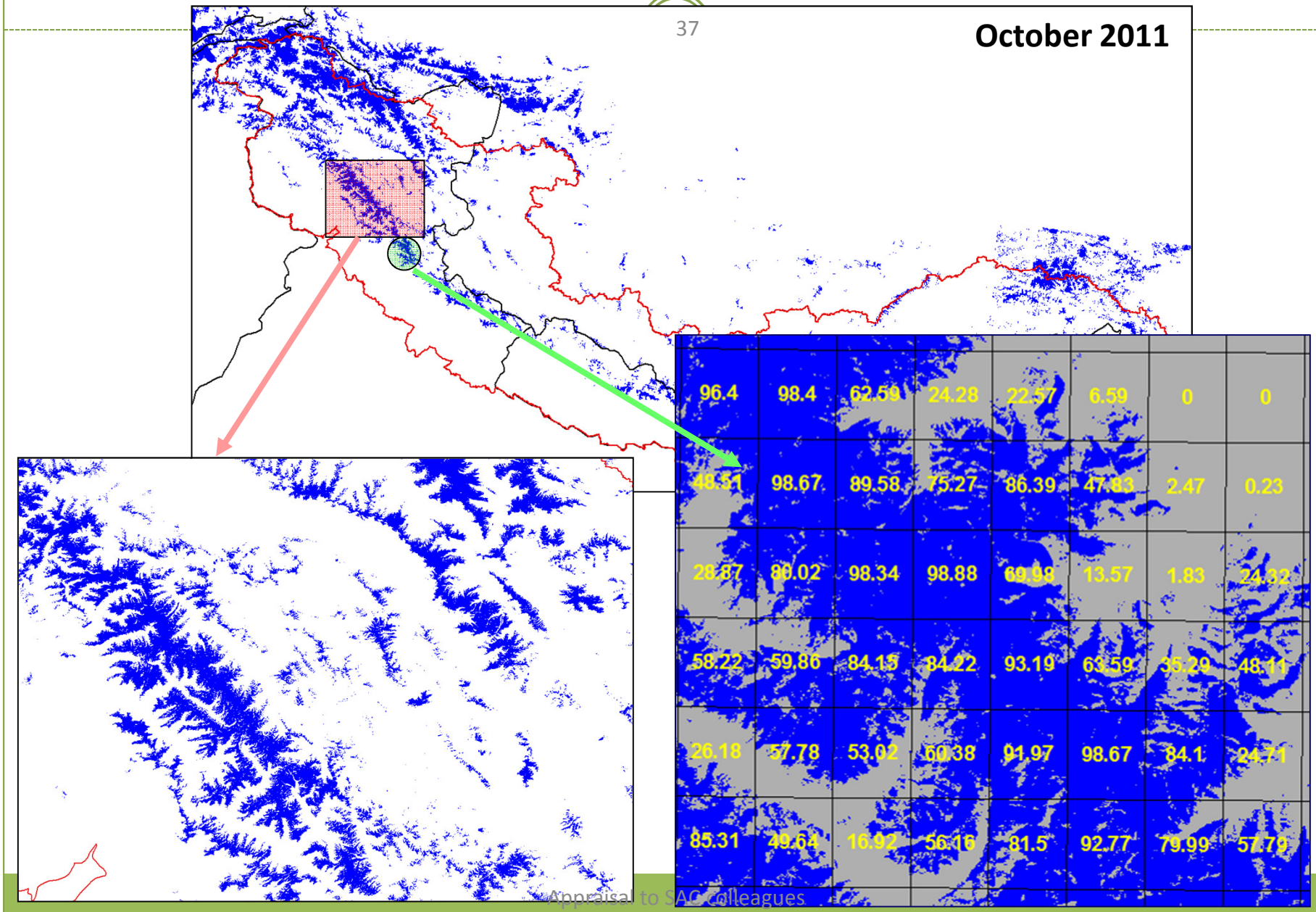


Water Bodies Fraction at 5x5Km Grid

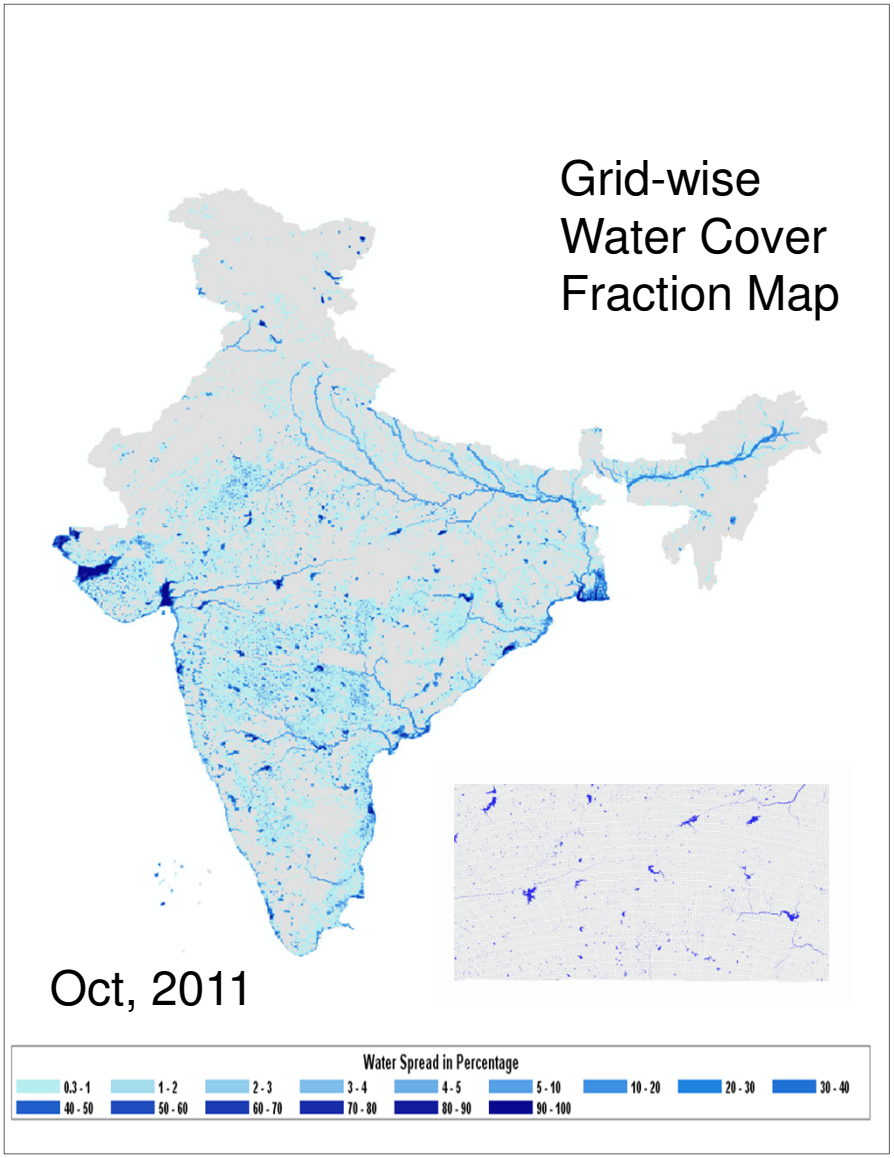


Appraisal to SAC colleagues

Snow Cover Area (SCA) Fraction Product

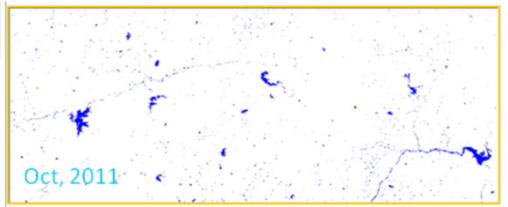


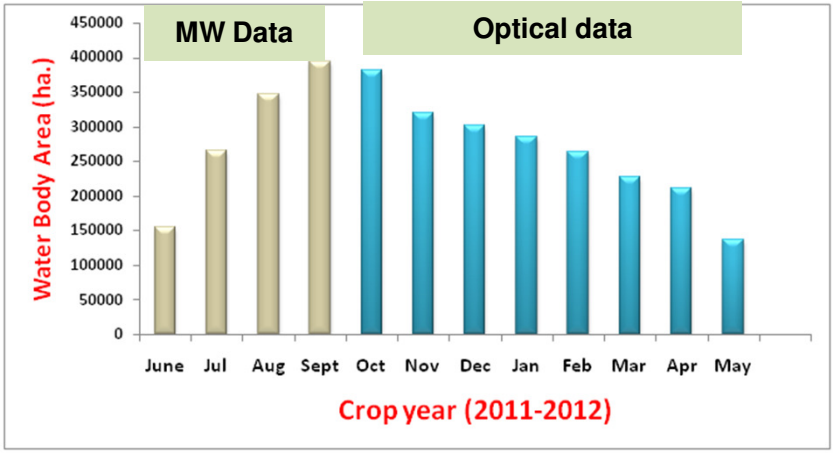
Water Spread Dynamics

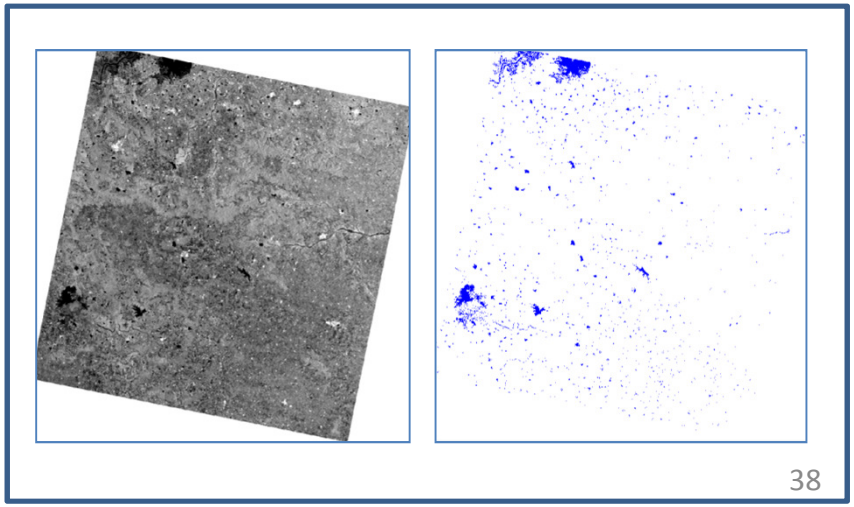


WBA Monthly Variations

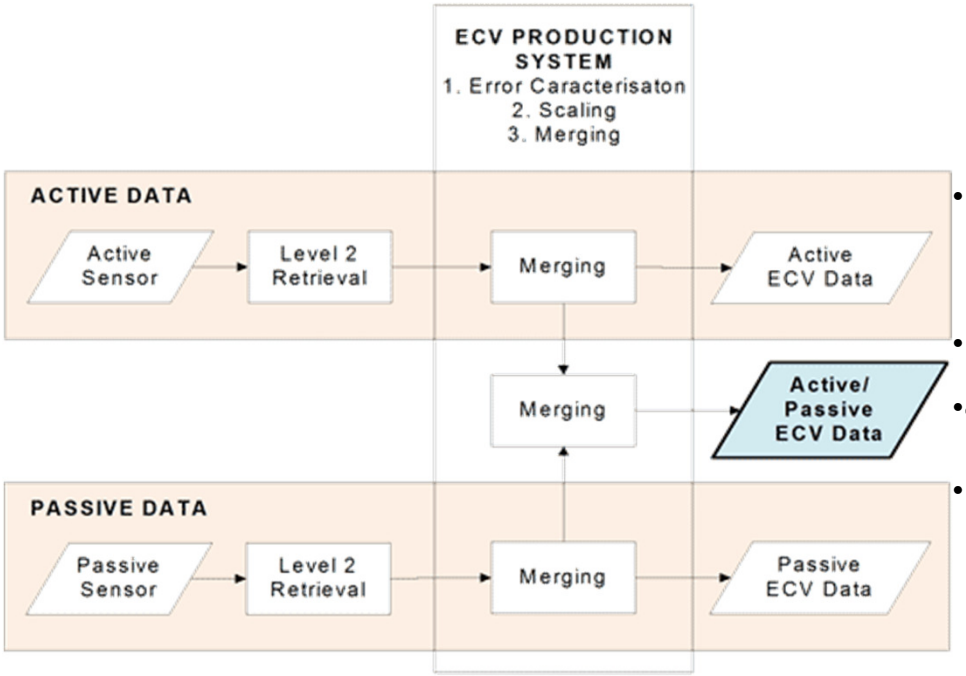
Sample area



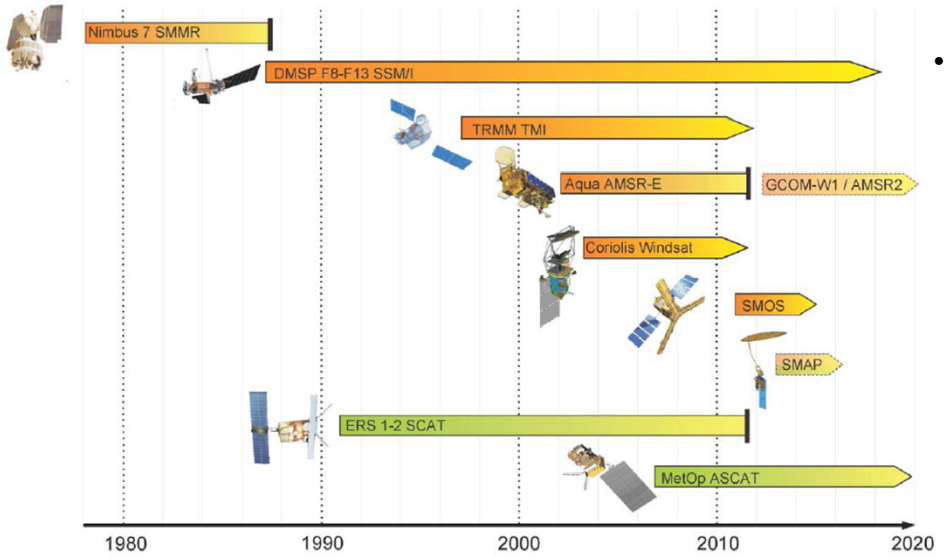


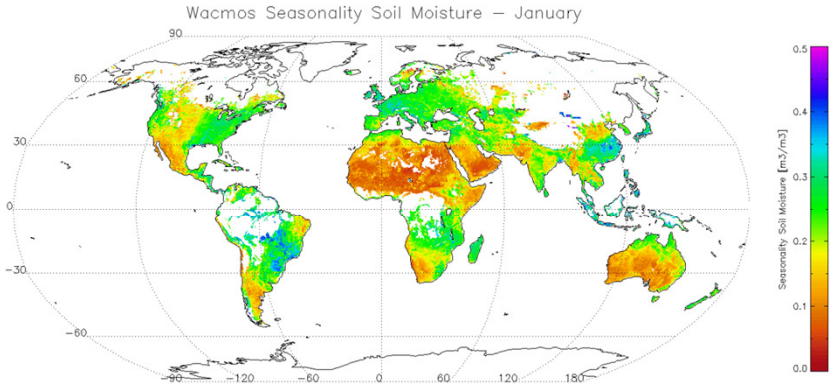


Daily Surface soil moisture data from Climate Change Initiative of ESA (1978-2010)



- **Soil moisture is a critical input to GCM, RCM, Biogeochemical models**
- **Daily soil moisture data at global scale**
- **at 25 km grid from 1978-2010**
- **Merged soil moisture data based of Active and Passive sensors**
  Passive: SMMR, DMSP SSM/I, AMSR-E, ..
  Active: ERS-1 SCAT, Metop ASCAT





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Limitations of Remotely Sensed Satellite Data For Climate Change Studies

- Spatio-temporal mis-matching
- Inadequate Spatial resolutions and Temporal frequencies
- Lack of ready-to-use interfaces
- Short data spans of satellite data
- Biases associated with the sensors
  - Calibration issues
  - Data merger from different systems

Way Forward

- Inter comparison of datasets
- Innovative uses of the existing data
- Rigorous analyses / re-analyses
- Combination of Active and Passive sensors
- High quality validation network
- Dedicated satellite / EO missions
- International cooperation

Thanks
for your kind attention