Use of EO inputs for Climate Change studies in India

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Climate Change Research in India

- Ministry of Environment, Forest and Climate Change is responsible for climate change coordination, including policy and international cooperation
  - UNFCCC, IPCC, ...
- Ministry of Earth Sciences has established Centre for Climate Change Research in IITM, Pune
  - Earth System Model & a computing facility established at CCCR
- Universities & Institutions also have a large climate research program
- ISRO supports climate research program through
  - Space Segment comprising satellites & sensors
  - ISRO Geosphere Biosphere Research Program
  - National Information System of Climate & Environmental Studies
  - Climate Change Research Programs at ISRO (SAC, NRSC, IIRS, SPL/VSSC) as well as DOS centres:
    - PHYSICAL RESEARCH LABORATORY
    - NATIONAL ATMOSPHERIC RES. LAB
ISRO GEOSPHERE-BIOSPHERE PROGRAM

• Multi-institutional & national scale programs:
  - National Carbon Project
  - Aerosol Radiative Forcing in India
  - Aerosol Chemistry
  - Trace Gases & dynamics
  - Atmospheric Boundary Layers
  - Energy & Mass Exchange in Vegetation
  - Land Use & Hydrology
  - Multi-proxy paleo-climate studies
Black Carbon emissions are decreasing.

Elevated Aerosol Layers

No Acid Rains in India (N West)
ISRO Observation Infrastructure for CC

- **AEROSOLS**
  - Multiwavelength radiometer network, aetholometers
- **BOUNDARY LAYER**
  - LIDARS, Agromet Towers
- **GREEN HOUSE GASES**
  - FTIR, GHG Observations
- **HIMALAYA GLACIERS**
  - Field Campaigns
- **OCEAN**
  - Ship Cruises for ocean biogeochemistry, air sampling, Aircraft
- **TERRESTRIAL BIOSPHERE**
  - Eddy-covariance Flux tower network
Carbon Cycle of India

- **Scientific Questions for Carbon Cycle are**
  - Quantify Carbon pools, fluxes and net C balance
  - Estimate temporal pattern as affected by human activities
  - Predict carbon source-sink in future climate and human influence
  - ...

- **Challenge is to**
  - Capture large spatial variability
  - Detect small differences over large variability & uncertainty
  - ..

- **Science Program**
  - National Carbon Project under ISRO GEOSPHERE BIOSPHERE PROGRAM
    - FLUX TOWERS FOR NET C EXCHANGE
    - LAND USE CHANGE; DEFORESTATION; FOREST BIOMASS
    - OCEAN & COAST; SOIL POOLS & FLUXES;
    - MODEL NPP ;
Long-term (1930-2013) spatial forest change
Phytomass C density change analysis (1994-2010)

- **Phytomass C**: 3911 TgC in 1994, 4368 TgC in 2010
- **C in dense forest**: 2895 TgC in 1994, 3176 TgC in 2010
- **C in open forest**: 1016 TgC in 1994, 1192 TgC in 2010
- **5km C density range**: 0.29 - 240.14 t/ha in 1994, 0.10 - 326.32 t/ha in 2010
- **Open forest C density**: 38.47 t/ha in 1994, 41.69 t/ha in 2010
- **Dense forest C density**: 77.08 t/ha in 1994, 80.24 t/ha in 2010
- **Forest Cover**: 61.14 Mha in 1994, 64.08 Mha in 2010
Improving Forest Phytomass estimates

- **Approach I: High Resolution + LIDAR (aerial)**
  - Uppangla Forest, Very High Biomass, Multi-tier canopy, Western Ghats, INDIA

  **Model Indices: Directional Metrics**
  - FOTO (HR Data)
  - Terrain Complexity Indices

  - \[ R^2 = 0.95; \]
  - \[ \text{RMSE} = 28\% (446 + 140 \text{ t/ha}) \]

  - Tree Height – upto 70 m
  - DBH - upto 160 cm
  - Tree Biomass – 690 t/ha
  - Pushpagiri Wildlife Sanctuary
Soil Carbon Pool: Geospatial Modeling

**Approach**
- Sampling plan with land use, soil map, slope & AEZ
- Consistent 1200 samples analysed by CHN
- Modelling & Prediction by Data Mining (Random Forest) uses additional weather & VI
- Predicted SOC, SIC & TOC maps at 250m spatial resolution
Forest Flux towers – Betul & Sundarbans

**Location**

Betul (Dry Deciduous)  
21.86 N 77.42 E

Sundarbans (Mangrove)  
21.82 N 88.62 E
Diurnal Average variation of CO$_2$ Flux – Betul, M.P

**Net Annual Production**

2012.87 g CO$_2$ m$^{-2}$
(or)
548.46 g C m$^{-2}$.

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Diurnal Average variation of CO$_2$ Flux – Sundarbans, W.B.

**Net Annual Production**

1005.32 g CO$_2$ m$^{-2}$
(or)
273.93 g C m$^{-2}$.
Large decline of NPP over the Indo-Gangetic plains

Climate has Significant control

NPP budget is 1.56 PgC yr\(^{-1}\) & is increasing at the rate of 5 Tg C yr\(^{-2}\)

India is the region of net sink of atmospheric CO\(_2\) during most of the years after 1985.

Annual uptake is 9.5 Tg C yr\(^{-1}\) during 1981-2006

& is 19 Tg C yr\(^{-1}\) during 1991-2006
Integrated CO₂ Model

- GEOS-CHEM Implementation for Comprehensive Analysis of Carbon Cycle over the Indian Region
  - Presently at 20x2.50 for the globe, Years: 2006 and 2013 at 3 hourly interval

- Meteorological Fields (U,V, T, Q etc) based on GEOS analysis
- Anthropogenic sources of CO₂
  - Bio fuel+ Fossil fuel+ Ship emissions + etc.

- GEOS-CHEM Atmospheric Transport Model
  - Solve 3D chemical continuity equations on global Eulerian grid
  - Time series of NDVI, AirTemp, Precipitation, Solar Radiation

- CASA-Ecosystem model
  - NPP, NEP, NEE

- LULC & Soil maps
- Scaling & model parameters

- Wind speed
- SST
- Salinity
- CO₂ gas transfer velocity
- Solubility of CO₂ in sea-water
- Delta PCO₂

- Air-sea CO₂ flux exchange

- OCEAN MODULE
- LAND MODULE

- 3D fields of Atmospheric CO₂
GEOS-CHEM: Simulated Atmospheric CO$_2$
Himalayas : Climate Change studies

• Himalayas are highly populated hilly region with a significant anthropogenic impacts, respond to climate variability and also have potential to influence regional climate

• Himalayan Cryosphere

• EO inputs is the only approach to characterise large spatio-temporal variability, limited by parameters estimated by EO

• Important parameters of interest are
  – Snow cover, inter-seasonal & interannual variability, trends ?
  – Glaciers, inventory & characteristics
  – Glacier mass balance, snout retreat/advance, ice sheet thickness, glacier velocity, trends/future ?
  – Implications on snowmelt, runoff, long-term societal effects
Glacier Monitoring

• Glacier Inventory
  – Total Glaciers: 34,919 (Indus: 18,576; Ganga: 6,237; Brahmaputra: 10,106)
  – Glaciated area: 75,779 sq km (Indus: 36,843; Ganga: 18,393; Brahmaputra: 20,543 sq km)

• Glacier Retreat
  – Total 2018 glaciers
  – 1752 shows no change,
  – 248 Retreat & 18 Advance
  – [Bahuguna et al. (2014)]

• Glacier Mass Balance

• Glacier Hazard - GLOF
Treeline Shift in Himalayias

- Treeline upward shift of $388\pm 80m$ (~11m/year) in Uttarakhand has been reported during year 1970s–2006 in study conducted for Indian Himalaya using satellite remote sensing technique (Panigrahy et al., 2010; Singh et al., 2012)
Sea Level : Rise & Coastal Interactions

- Regional Vulnerability of the Indian Coast due to 1 m Sea Level Rise

- Vulnerable low slope regions along Gujarat coast
Ocean

- SST Trends (Deg C / year) from NOAA OISST during 1990-July 2014

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


Chlorophyll-a concentration (mg m\(^{-3}\))
Thank You

http://www.isro.org
http://www.isro.gov.in

http://bhuwan.nrsc.gov.in