Earth Remote Sensing:
Social Benefits & Challenges

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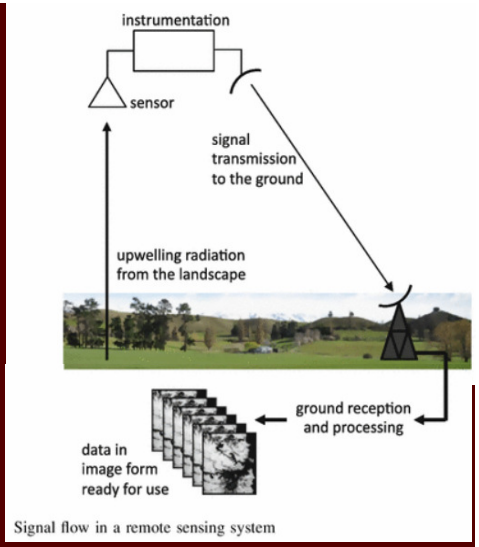
Earth Remote Sensing:

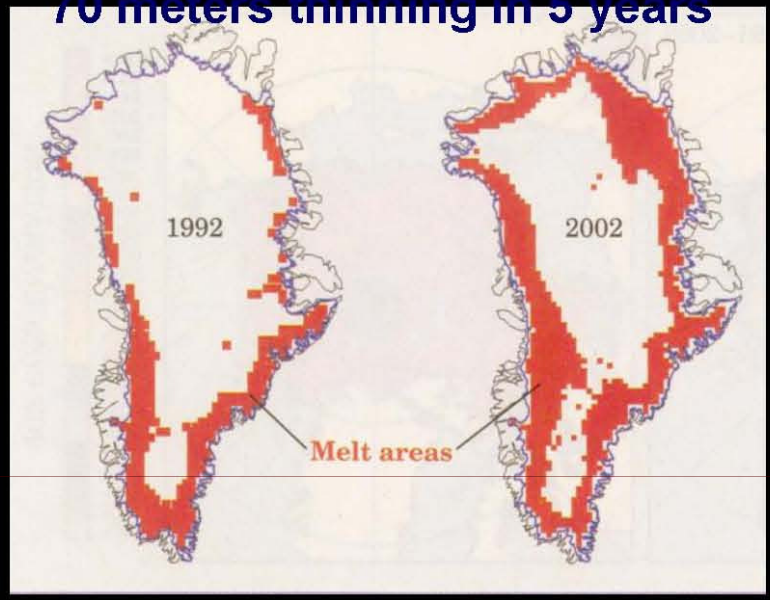
Definition by the United Nations:-



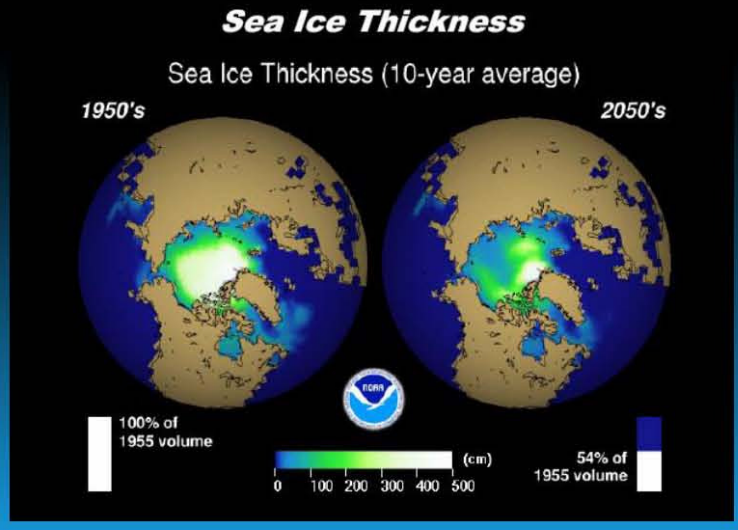
Signal flow in a remote sensing system

`Remote sensing means sensing of the earth's surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed objects, for the purpose of ***improving natural resource management, land use and the protection of the environment.'***

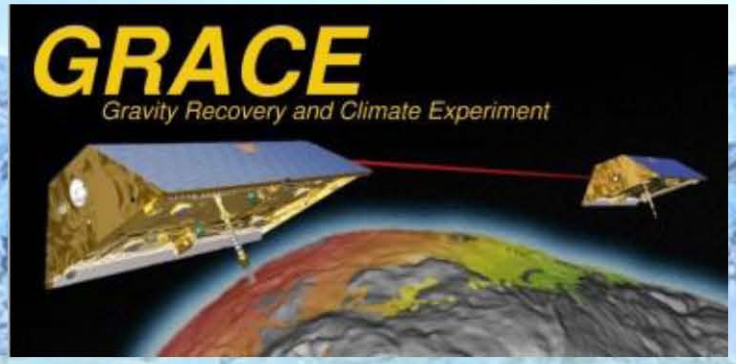
EO monitors Arctic Sea Ice Melting



- Heating faster than anywhere else
- 7 m sea level rise, if fully melt
- Greenland currently losing 100 to 150 cubic km/ year *(Robert Corell , 2007)*
- Indonesia could lose about 2,000 islands by 2030 Island countries like Saint Lucia, Fiji and the Bahamas would likely disappear *(Rachmat Witoelar, Indonesian Environment Minister)*

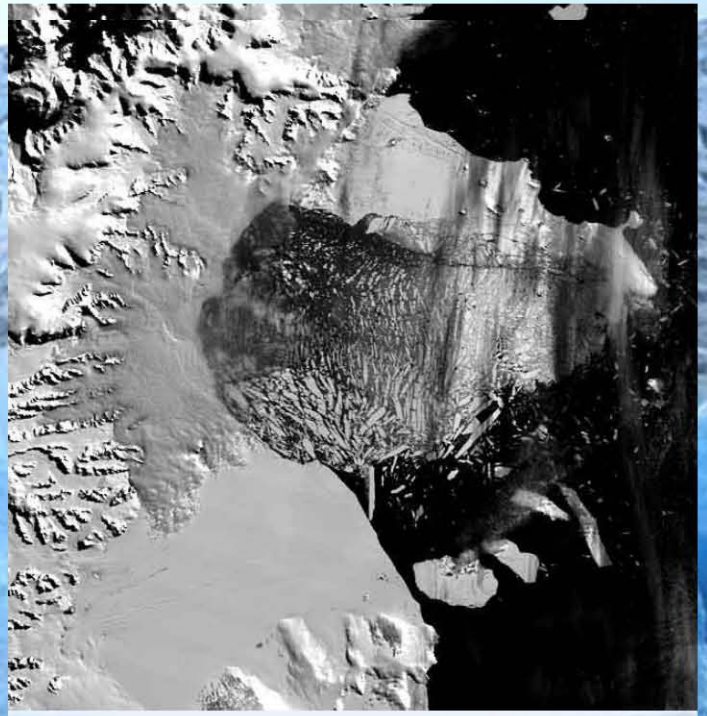


EO monitors Antarctic Sea Ice Melting

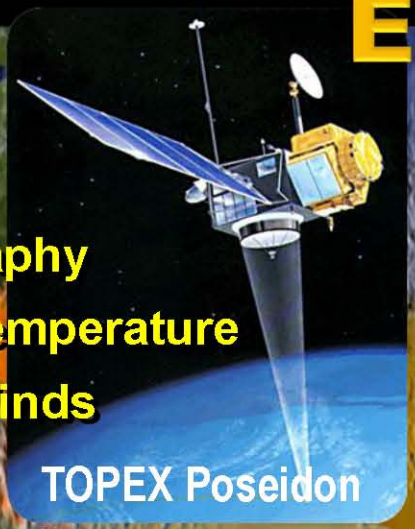


- EO data: Antarctic ice sheet, (harbors 90 % of Earth's ice) has lost significant mass in recent years
- Losing up to 36 cubic miles of ice, or 152 km^3, annually

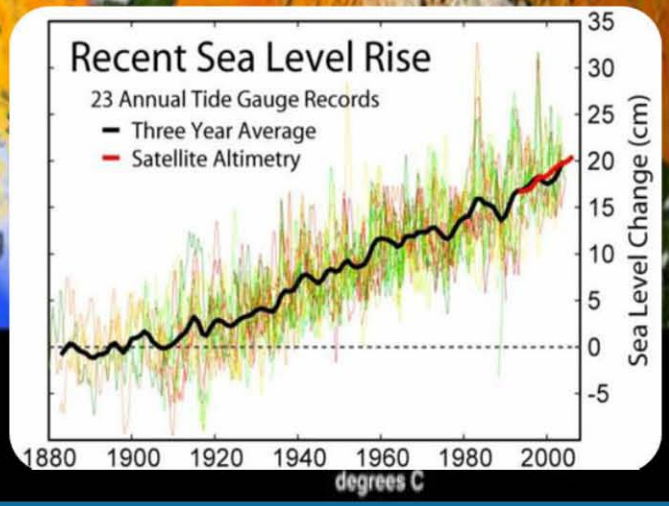
Larsen B Ice Shelf breakup

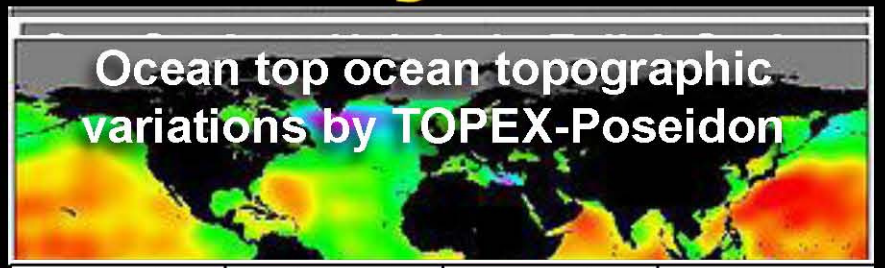


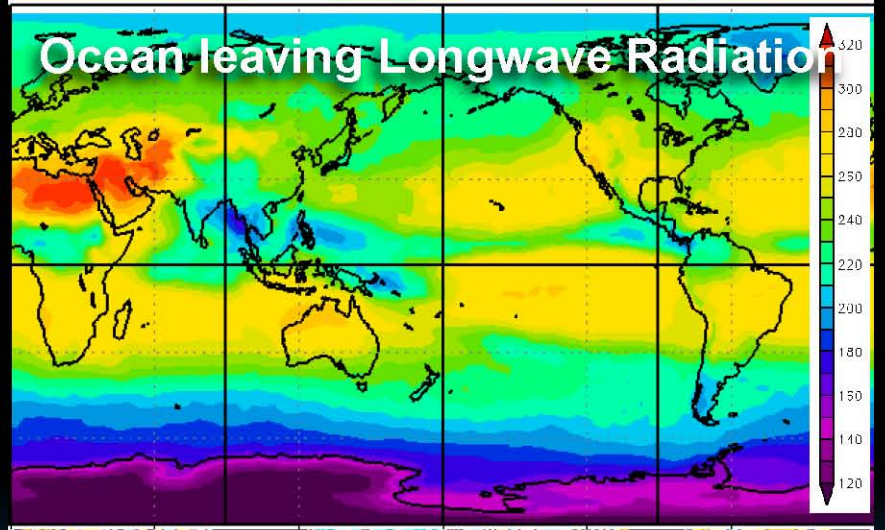
Observations over Oceans: EO the only means



- Ocean topography
- Sea Surface Temperature
- Sea Surface Winds
- Sea salinity
- Ocean Biology/ Chemistry



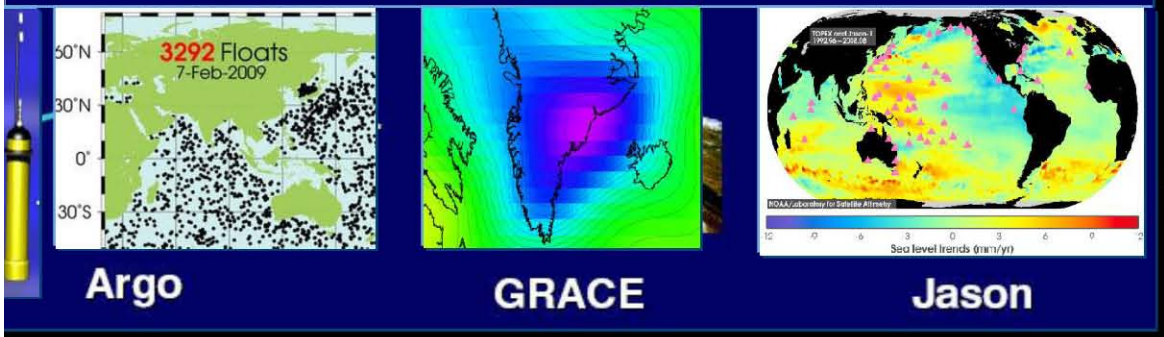




Ocean influenced by mass, energy & momentum exchanges with atmosphere & Global Observations are essential

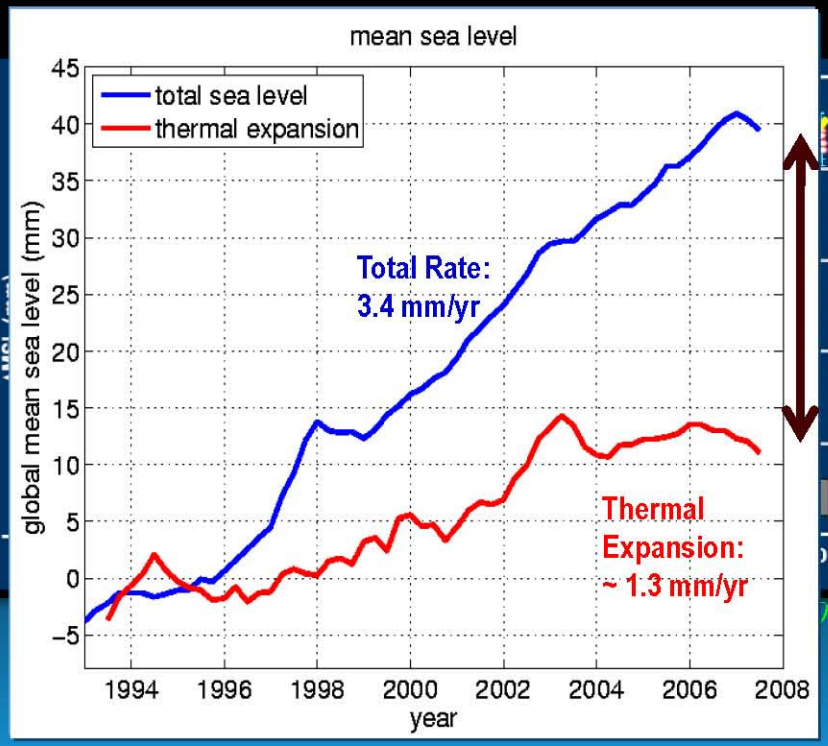
EO monitors Sea level rise

Addition of heat | Addition of freshwater | Total sea level rise



Argo | GRACE | Jason

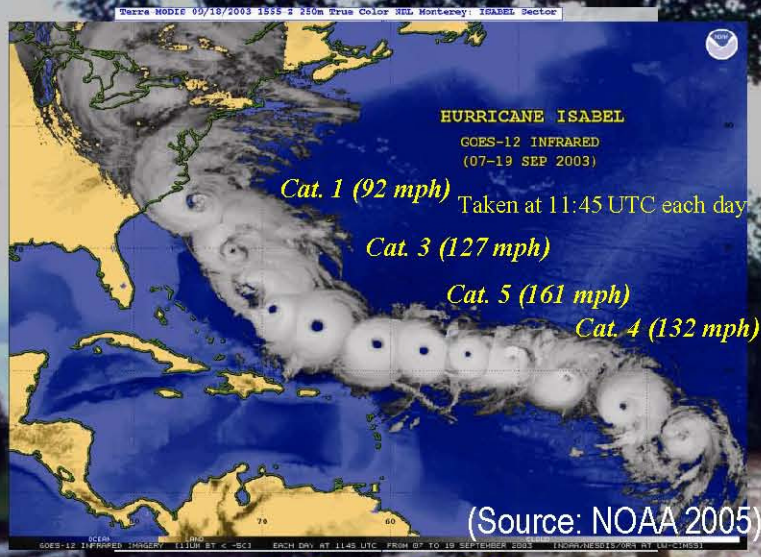
What happens to these islands?



Difference mainly due to melting of ice

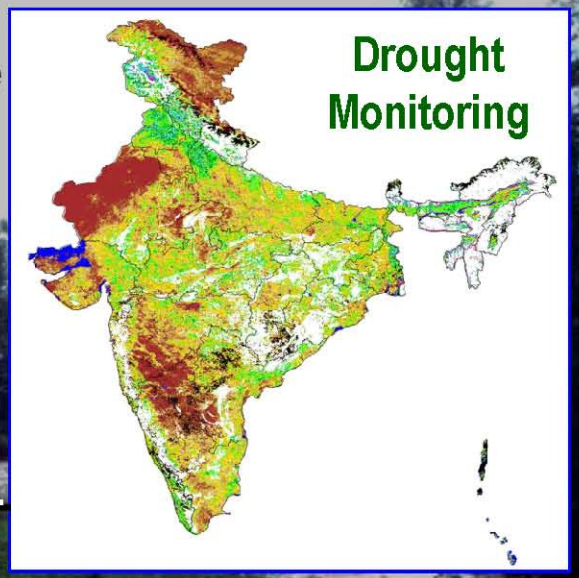
(Source: Josh Willis, JPL)

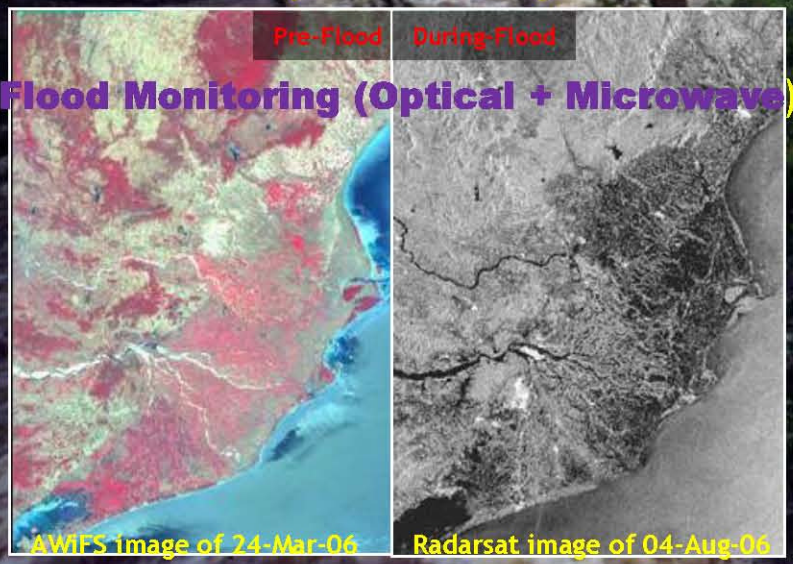
EO in Disaster Management



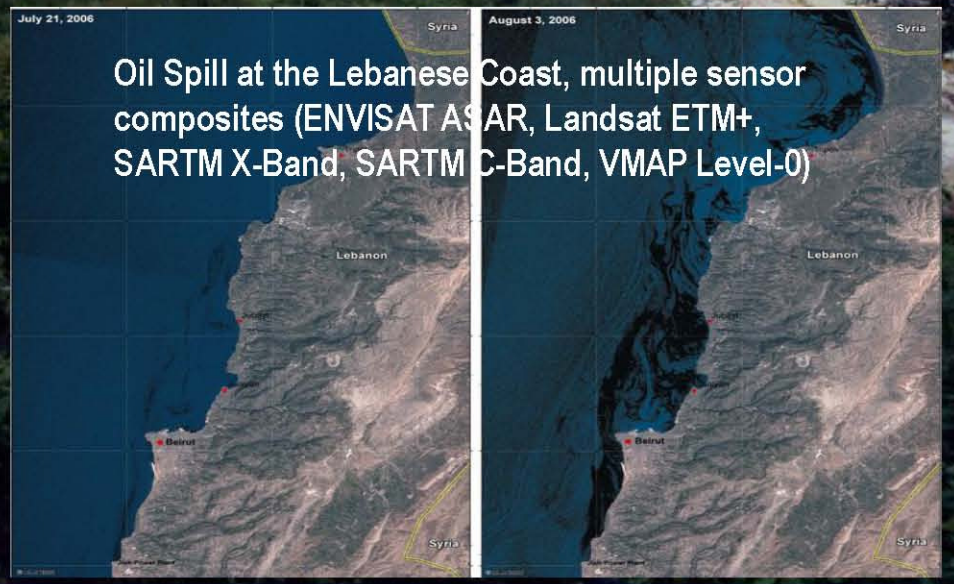
Cyclone Tracking

- Significant increase in Weather related disasters
- Many Global initiatives; International Charter; UN SPIDER; SENTINEL-Asia





Flood Monitoring (Optical + Microwave)

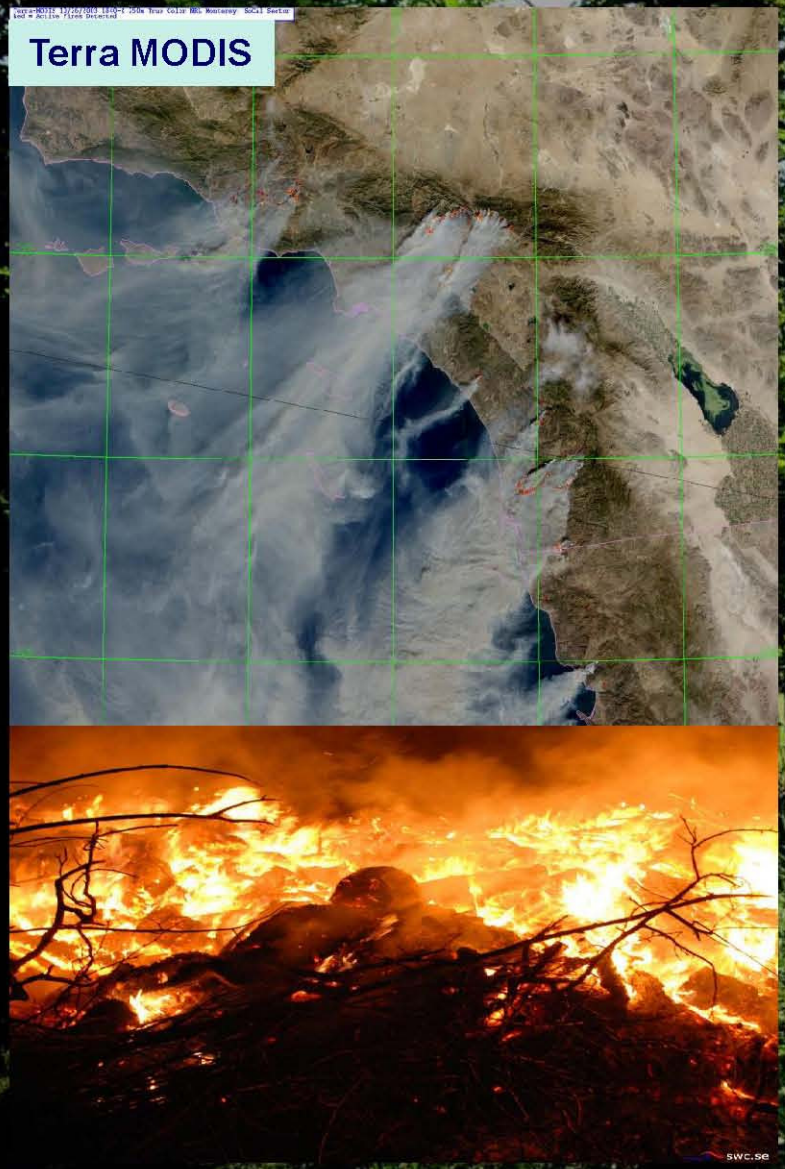


Oil Spill at the Lebanese Coast, multiple sensor composites (ENVISAT ASAR, Landsat ETM+, SARTM X-Band, SARTM C-Band, VMAP Level-0)

Radiometers, Imagers, spectrometers provide inputs

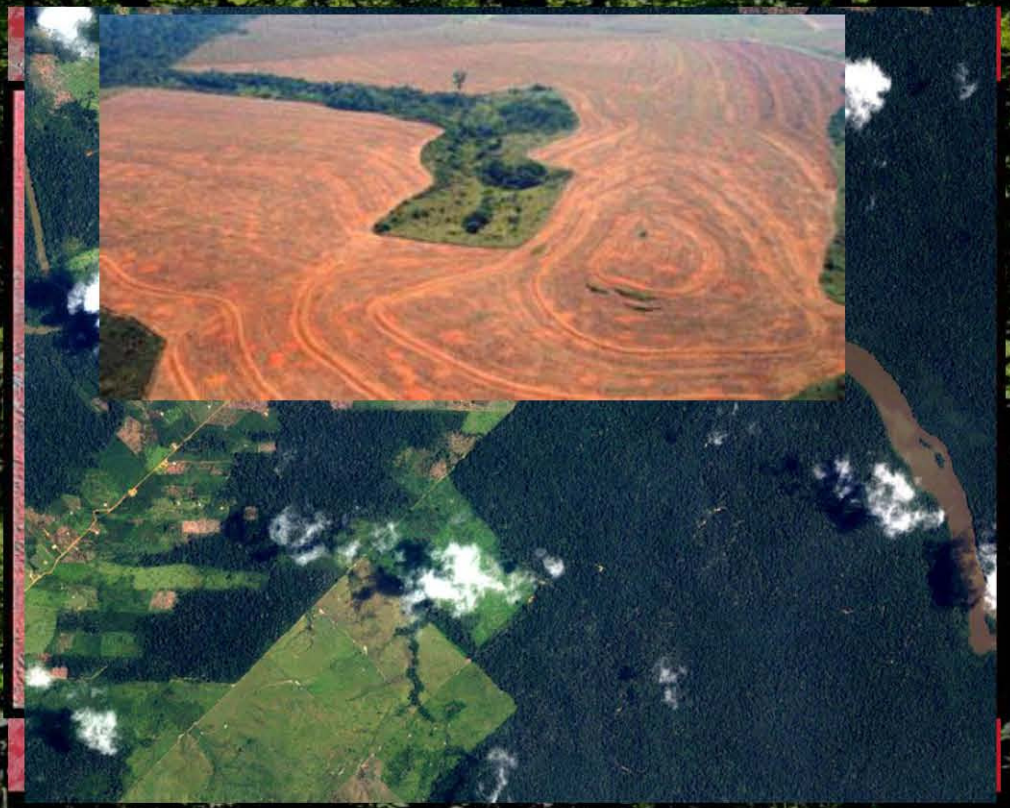
EO in Ecological Disasters

Forest Fire



Large scale Deforestation of Tropical Forest - Amazon

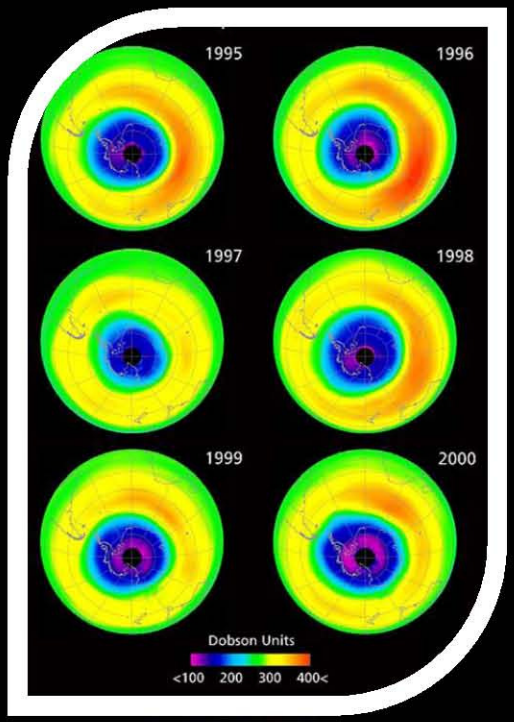
- Amazon has 1/5th of world fresh water; 1/3rd of plant & animal species
- Soyabean (at 14%/ yr expansion) major driver in Amazon
- Global forest cover loss: 32 M ac/ yr

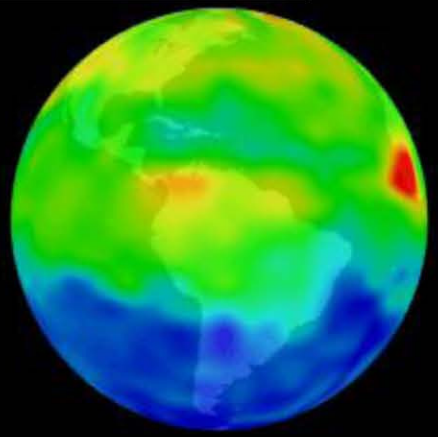


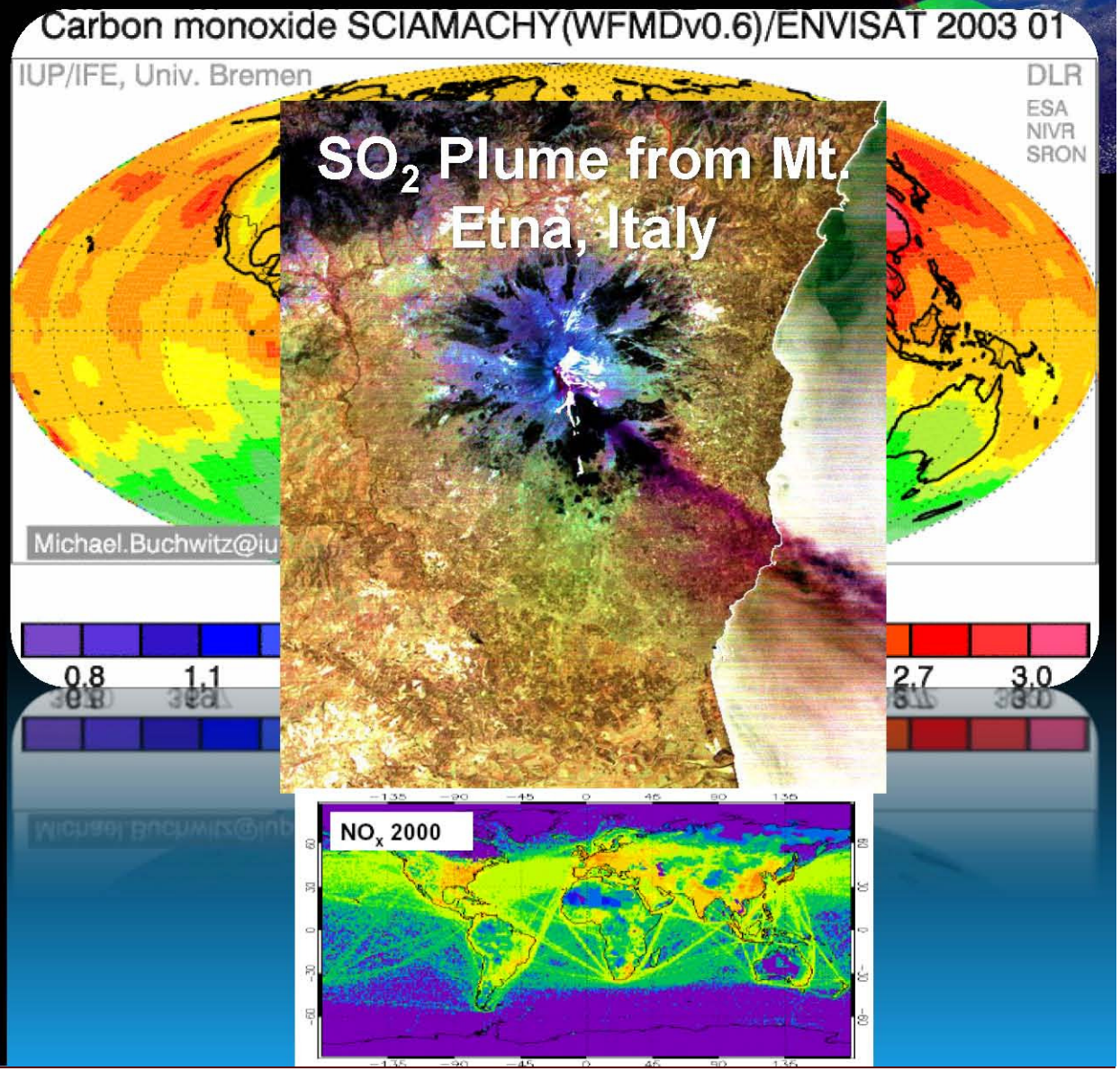
EO in Atmospheric Chemistry

Monitoring GHGs from Space

MOPITT, SCIAMACHY, TOMS

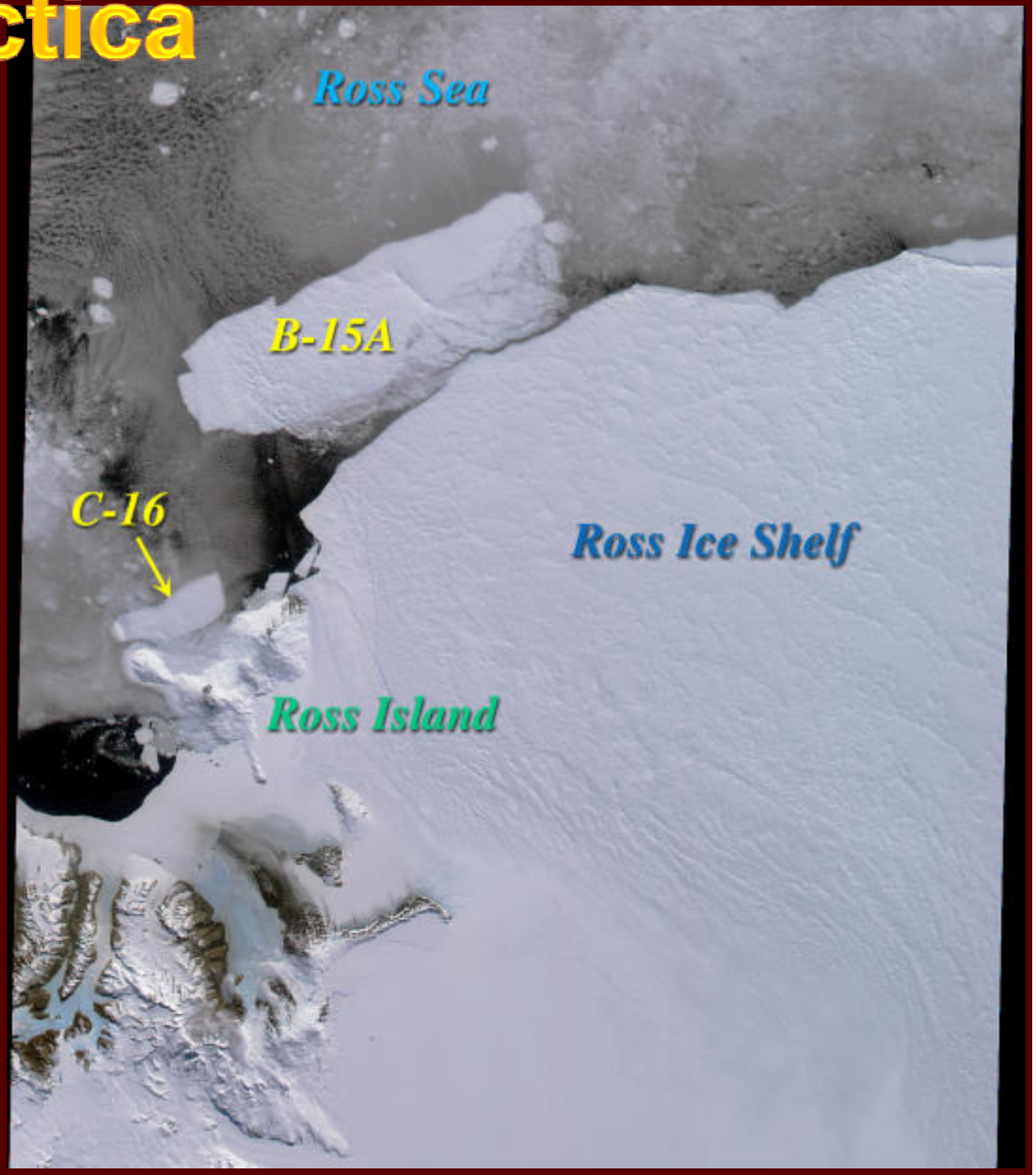






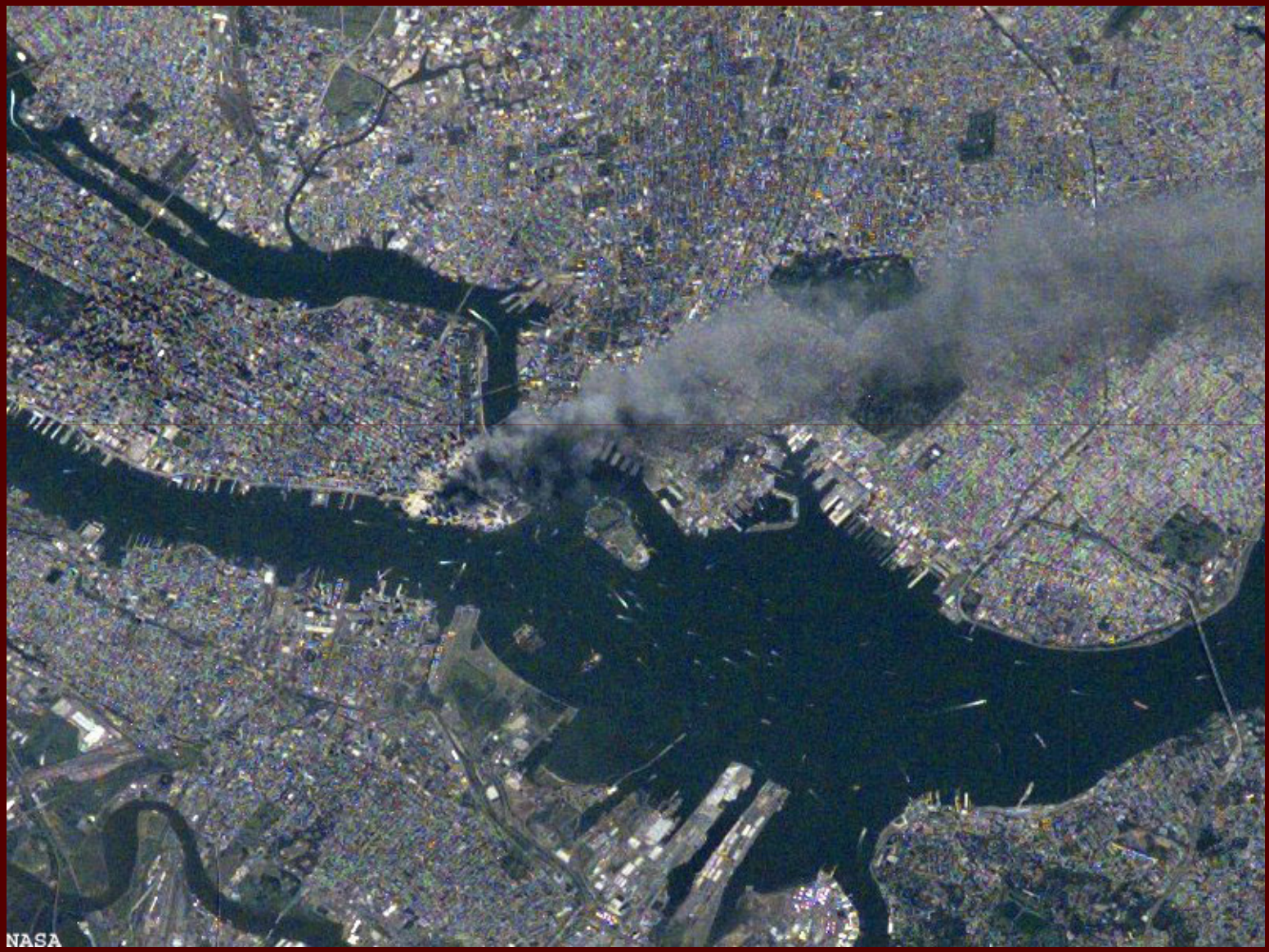
EO for Event Monitoring: Icebergs, Antarctica

Monitoring ice-berg movement for ship routing and climate change analysis



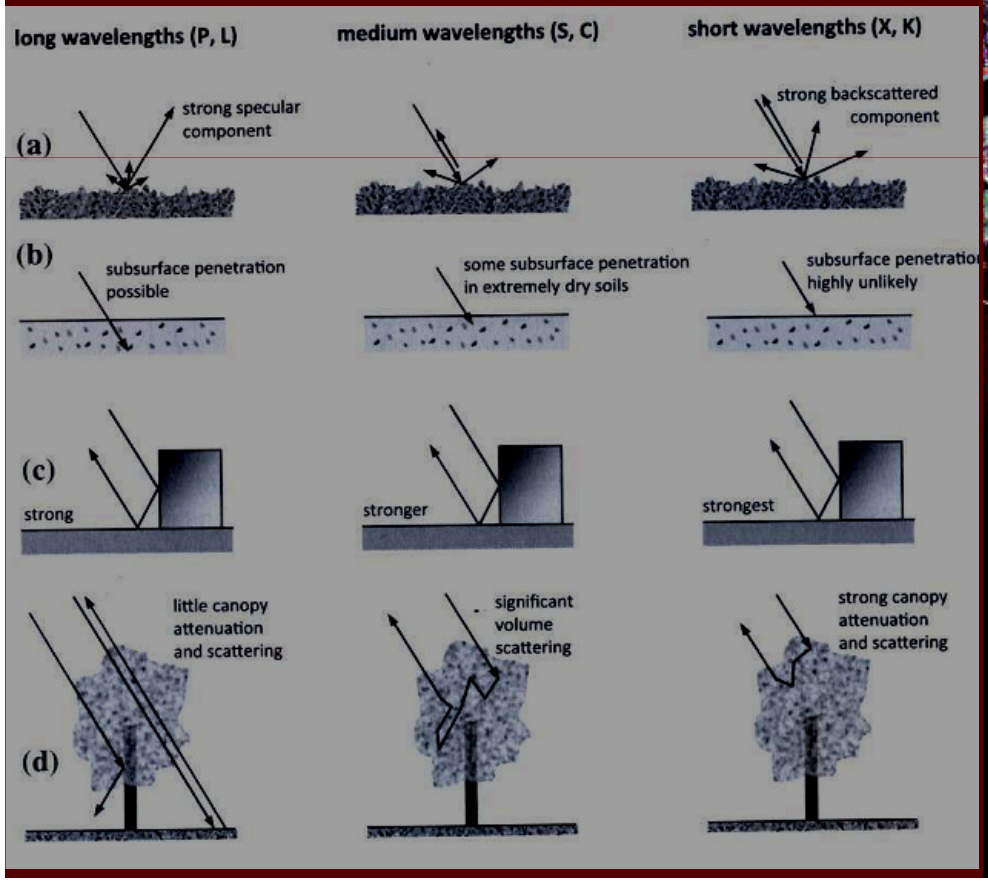
EO for Event Monitoring: Volcano, Alaska

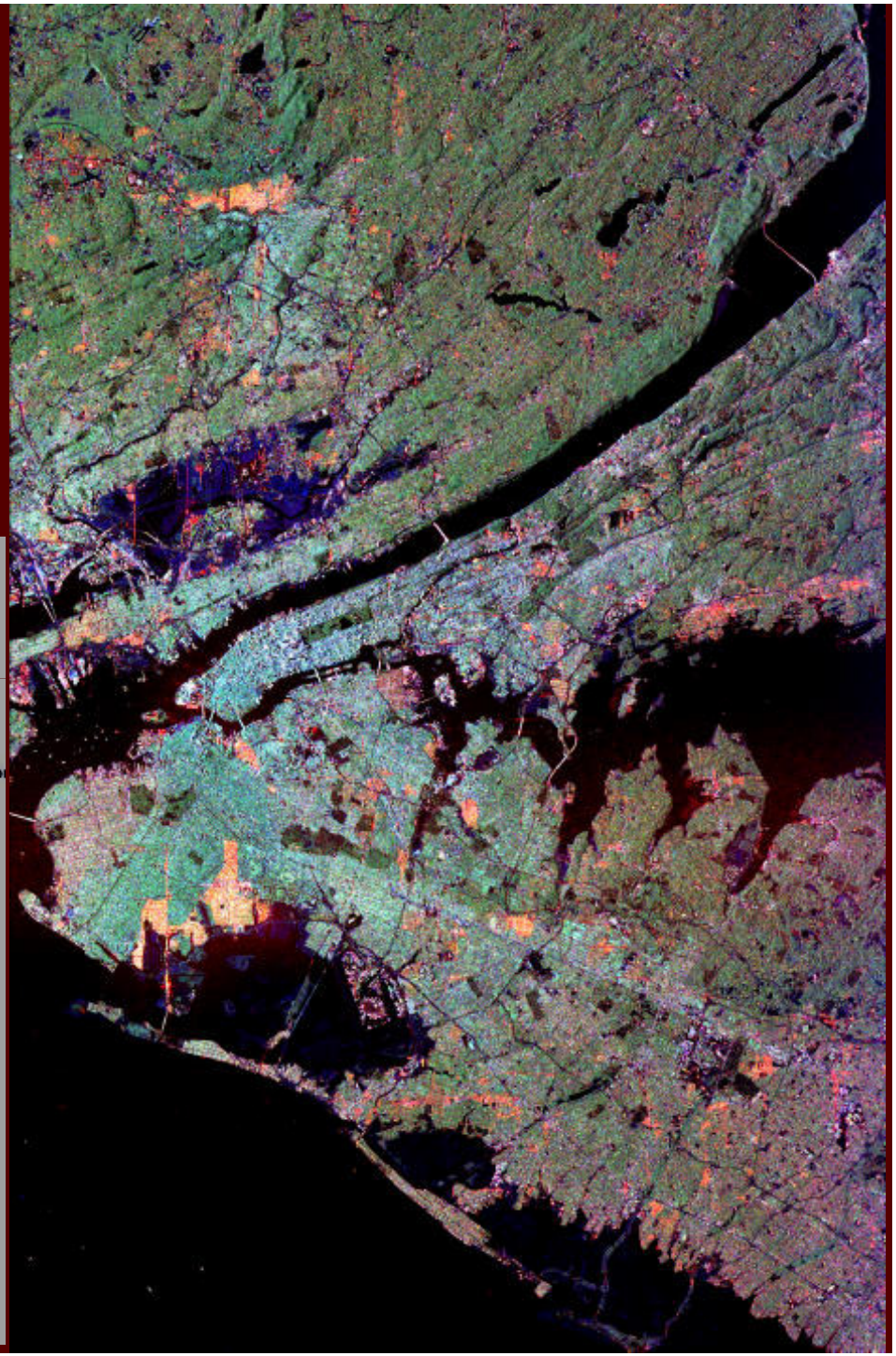
World Trade Center Disaster, Sept.11, 2001



Radar Image of New York City:

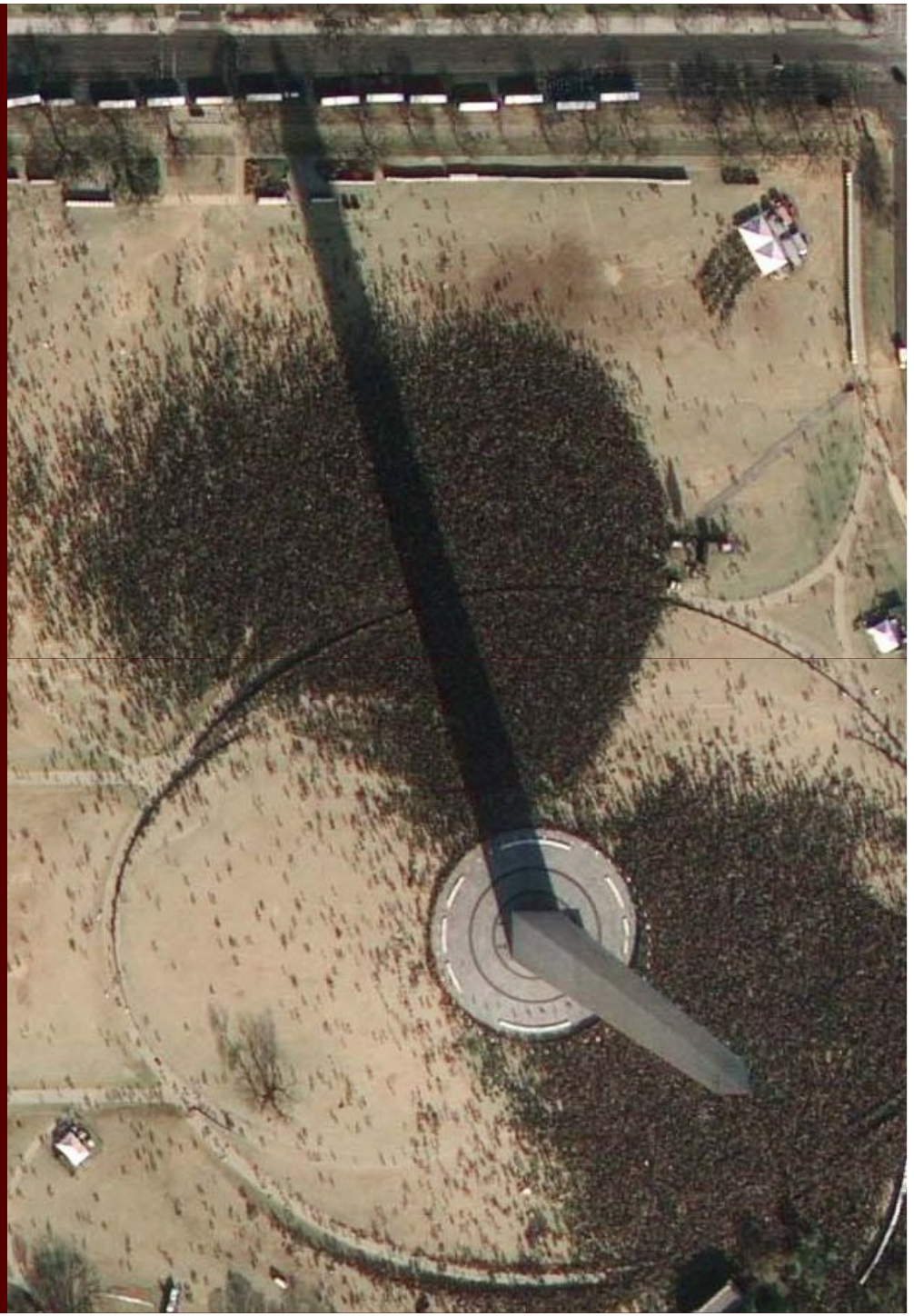
a new dimension to remote sensing



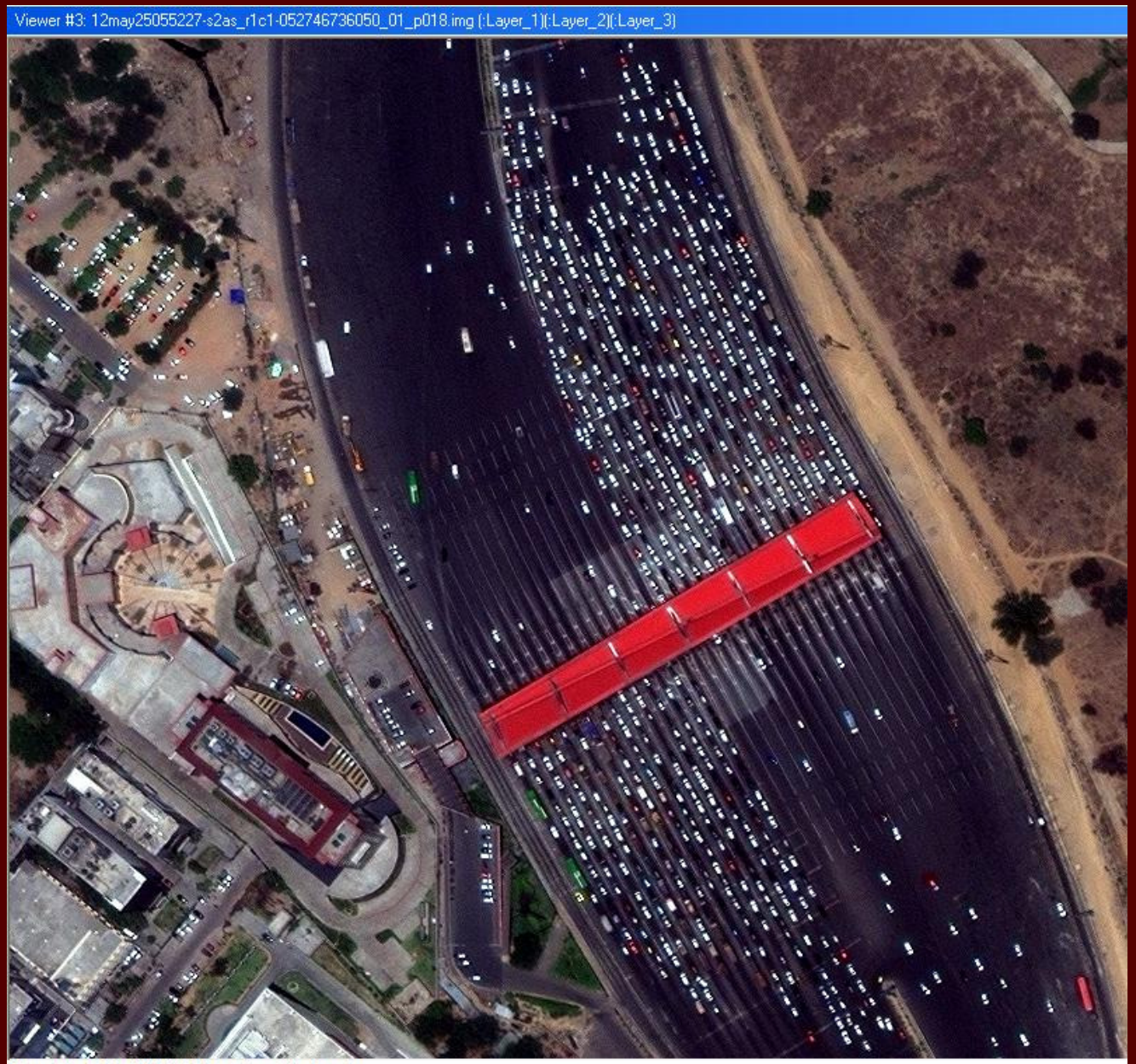


Pope John Paul II Funeral

Barack Obama's Inauguration



Monitoring Vehicles' flow

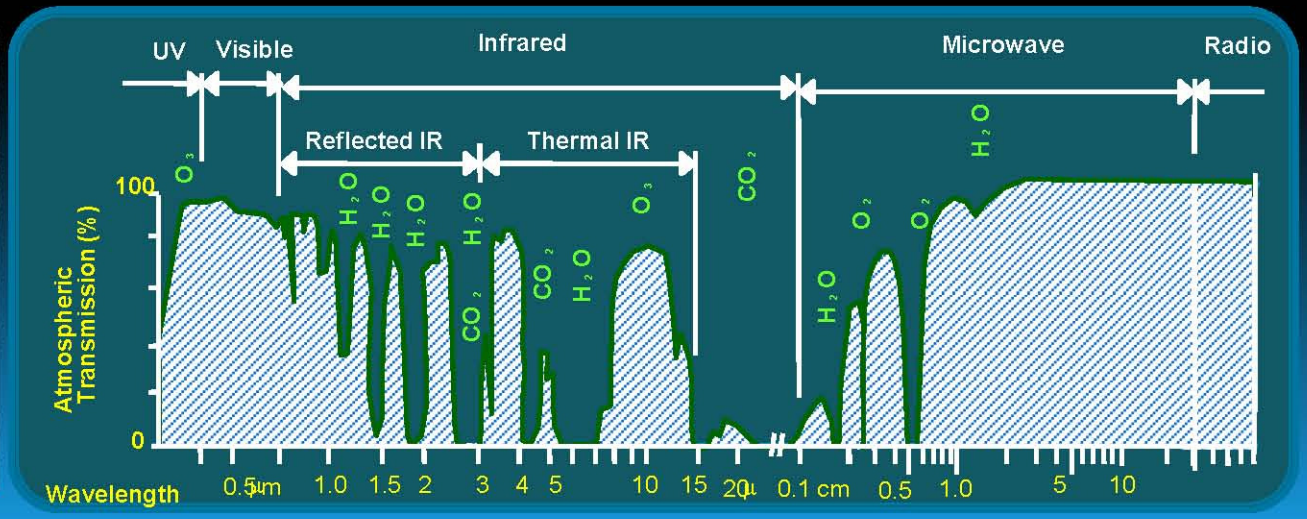


New Delhi in WV PSH data - Tollgate

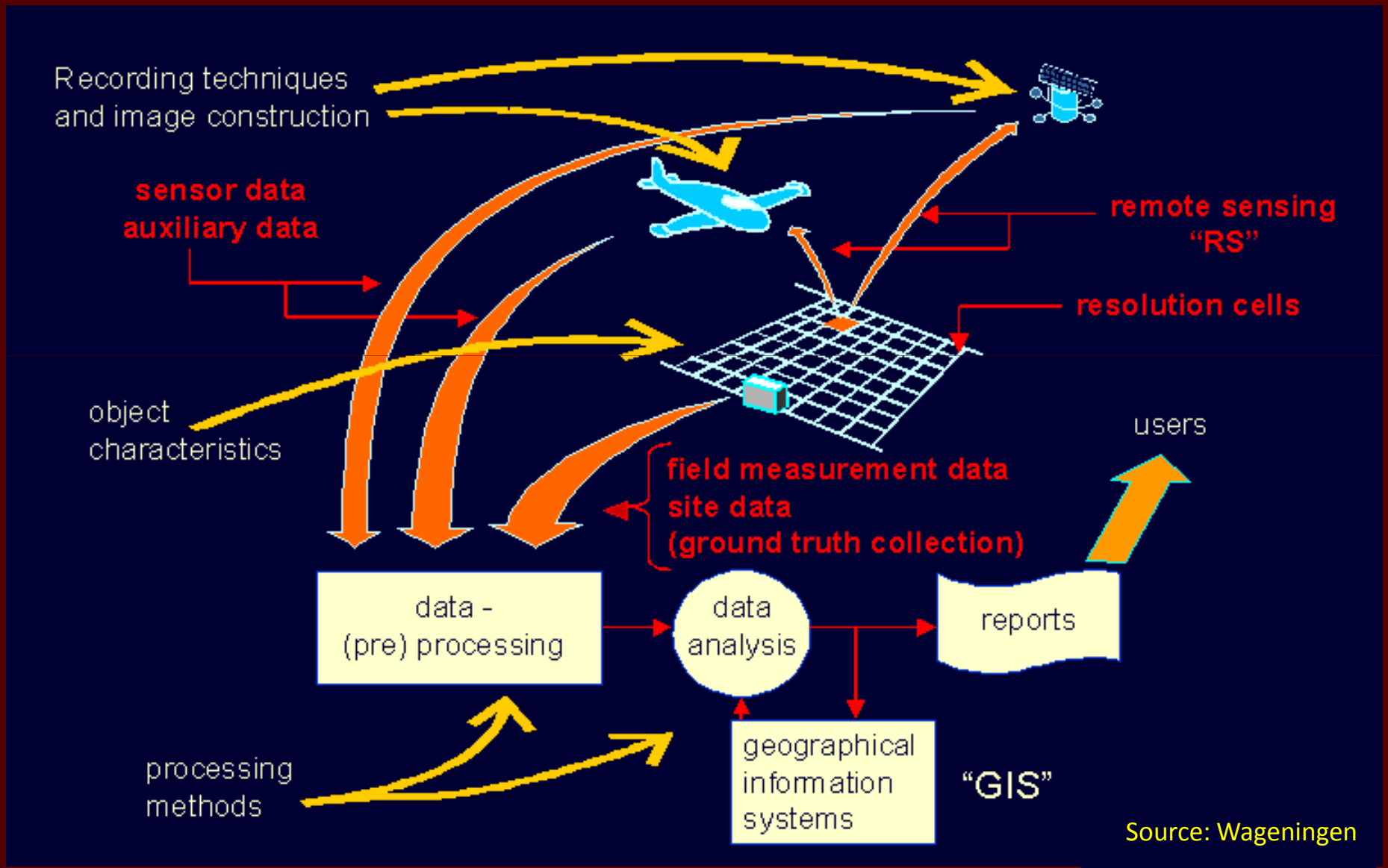
The Sharpness of the image can be clearly perceived here.

What EO Satellites do?

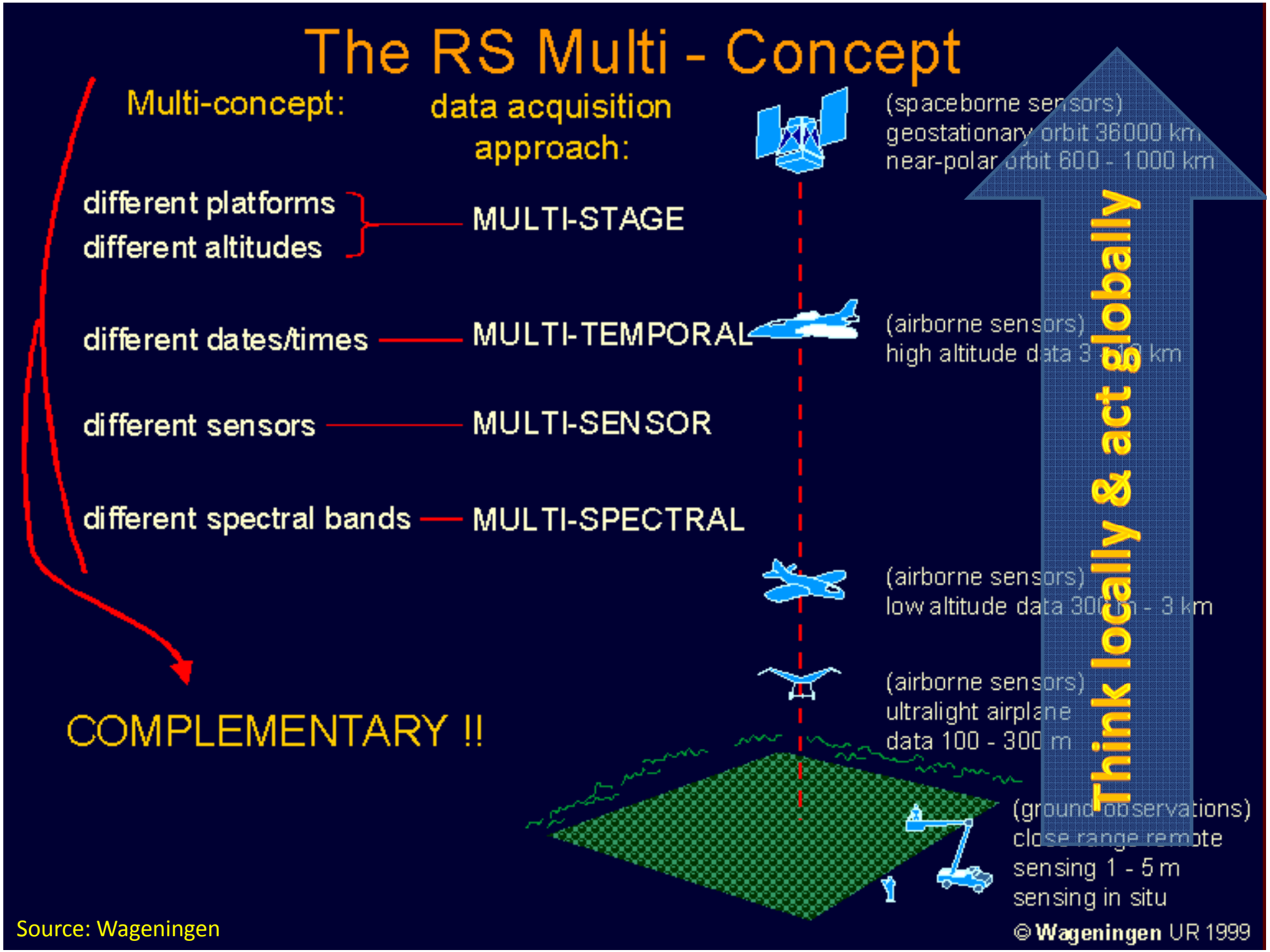
- Characterising Target Signatures with Synoptic coverage across full EM Spectrum
- Spatial domain; Spectral (multi/ hyper); Repeated observations
- Long term quantitative measurements with calibrated instruments
- Global to local applications



RS Data & Information System



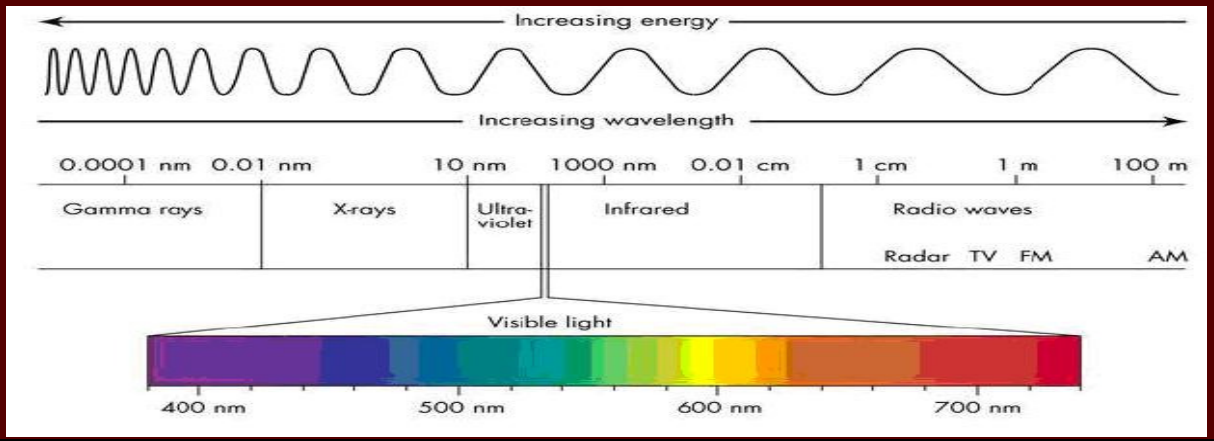
Source: Wageningen

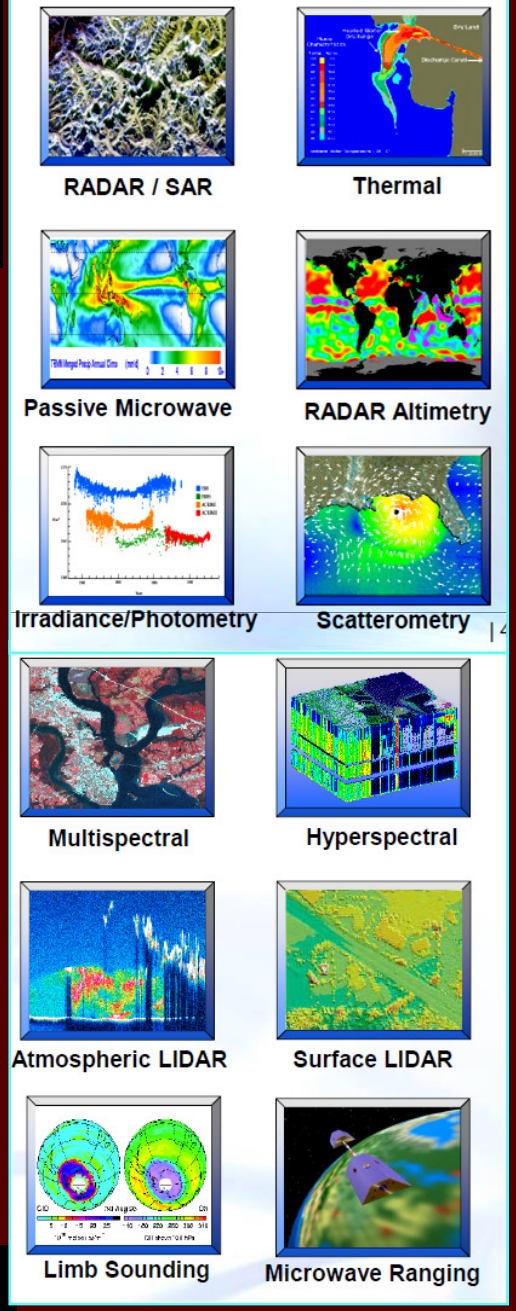


Source: Wageningen

EO Spans across EM Spectrum

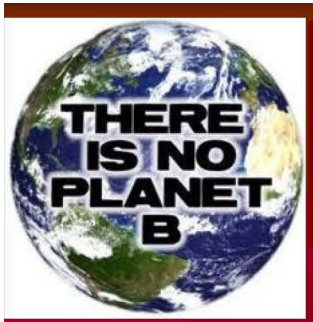
- Atmospheric chemistry instruments
- Atmospheric temperature & humidity sounders
- Cloud Profilers & Rain Radars
- Earth Radiation Budget Radiometers
- High resolution optical imagers
- Imaging multi-spectral radiometers (Visible/IR)
- Imaging multi-spectral radiometers (passive microwave)
- Imaging microwave radars
- LIDARs (Backscatter; Doppler)
- Multiple direction/ polarisation Instruments.
- Ocean Colour instruments
- Radar altimeters
- Scatterometers
- Gravity, magnetic field & geodynamic instruments





Source: NASA Earth Science

EO Transgressing from Qualitative to Quantitative



HOW CLOSE IS THE GLOBAL SCALE TIPPING POINT ?

Drivers for Irreversible change in biosphere

- Population Growth, Degradation / Destruction of Natural Ecosystems and Climate Change
- Population to reach 9 Billion by 1945 with **50% of land surface disturbed by 2025** *, and reservoirs of biodiversity & ecosystem services critically affected

Destructive Consequences of Tipping Point

- Reduction in biodiversity, and severely impacting ecosystem services and Quality of Life.

* Today 43% mark crossed






"As Human pressures on Earth system accelerate, several critical global, regional and local thresholds are close or have been exceeded" – ***UNEP 5th Global Env Outlook***

NASA's Earth Science Programme

Suomi National Polar-orbiting Partnership (NPP) launched
Orbiting Carbon Observatory-2 (OCO-2) , replacement satellite for OCO 1

Accelerated Decadel Survey Tier 1 Missions (2014-2017)

- Soil Moisture , Active and Passive (SMAP)
- ICESat-2
- Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI)
- Climate Absolute Radiance and Refractivity Observatory (CLARREO)

Climate Continuity Missions

- Stratospheric Aerosol and Gas Experiment (SAGE III)
- Gravity Recovery and Climate Experiment Follow-On (GRACE FO)
- Pre-Aerosol, Cloud and Ocean Ecosystem (PACE)

Tier 2 Mission Accelerations (2017-2020)

- Active Sensing of CO_2 Emissions over Nights, Days & Seasons (ASCENDS)
- Surface Water Ocean Topography (SWOT)

Climate-Centric Architecture; Program concentrates on acceleration & expansion of Space-based Observing Systems and Mission-enabling/Data Exploiting Activities. Economic Recession impact on Funding !

ESA's Living Planet Programme & GMES

Earth Explorer Missions

Core Missions

- Gravity Field and steady-state Ocean Circulation Explorer (GOCE)
- Atmospheric Dynamics Mission (ADM-Aeolus)
- Earth Clouds Aerosols and Radiation Explorer (EarthCARE)

Opportunity Missions

- Soil Moisture and Ocean Salinity (SMOS) (2009)
- Cryosat-2 (2010)
- SWARM Constellation (2012-)

Earth Watch element

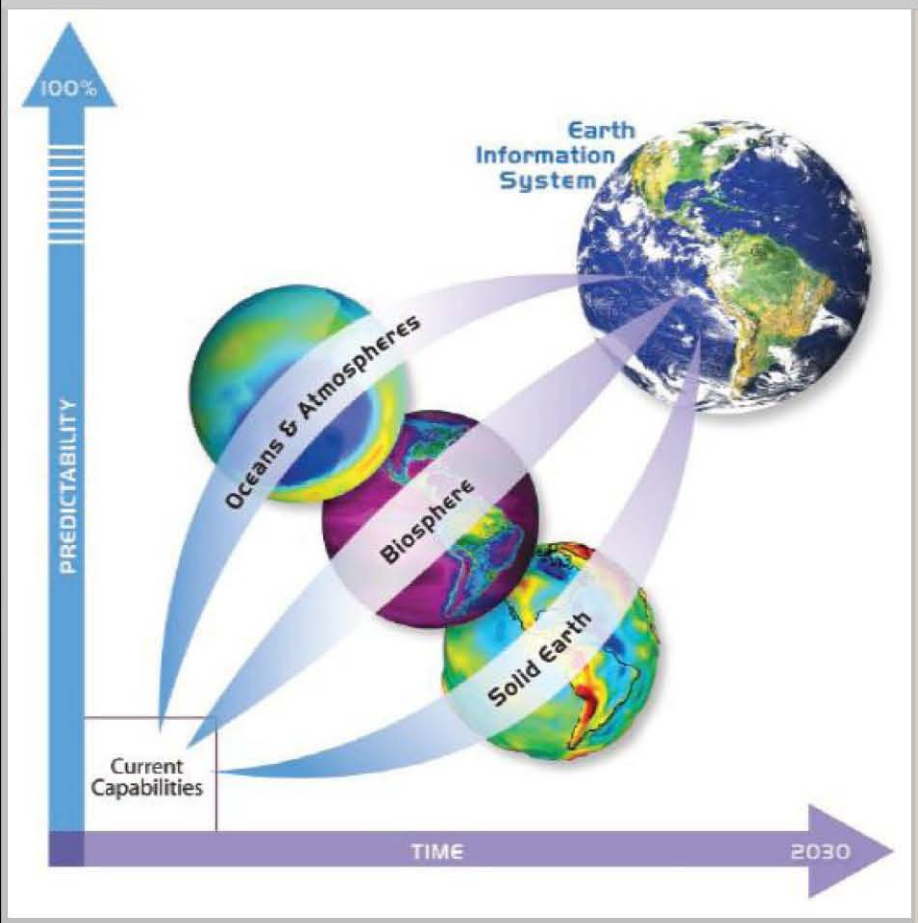
Operational Meteorogy Missions with EUMETSAT

EU's Global Monitoring of Environment and Security (GMES)

Dedicated Five SENTINEL Missions

Climate and Environment as the Prime. Funding issues remain

Vision 2030 - A Prediction Paradigm



Present disciplinary approach to EO and monitoring poorly assesses the feedback between diverse system components

Key attributes of the Integrated Earth Information System:

- Observes the whole Earth system, such that the changes in any component system can be traced to measure the total impact;
- Models the whole Earth system and all its components, such that effects of changes in any component can be predicted;
- Dynamically evolves to define the system behavior that best describes ongoing observations; and
- Yields predictions with quantitative uncertainties that are useful in the public decision-making process.

Earth Science Vision 2030, GSFC/ NASA; 2004

Space Technology Advancements

Satellite Remote Sensing

- Mapping the Earth's Surface: 100+ times more accurate
- Measuring of assets/ infrastructures: 1/100+ of a metre accuracy in surface subsidence
- Disaster warning: 100+ hours advance risk warning
- On-board imaging: 100+ new satellite sensors for sustainable development
- Formation flying; On-board autonomy; Event triggering mission; Constellation

Satellite Meteorology

- Improved computational capabilities
- Predicting El Nino: 100+ days early warning
- Advanced warning of Tornadoes & flash floods

Event	20 years before	In 2000	In 2005
Tornadoes	3 min.	11 min.	15 min.
Flash floods	7.7 min.	15 min.	65 min.

- Weather Forecast
  - Today 3 day 1t 93%; 7 day at 62%
  - In 2010 5 dat >90%; 7-10 day at 75%

Source: NWS; NOAA; ESTO

Satellite Communication

- Satcom capability >100+ new satellites, advent of Ku, Ka bands
- Convergence > 100 times more
- Networks > 100 times more
- Emergency Communication > 100 times
- Emerging Killer Applications: DTH; DARS; HDTV; DMB
- Global Mobile Personal Communication System (GMPCS)
- Satellite broadband internet (may not compete with DSL) can cater to 10-15%

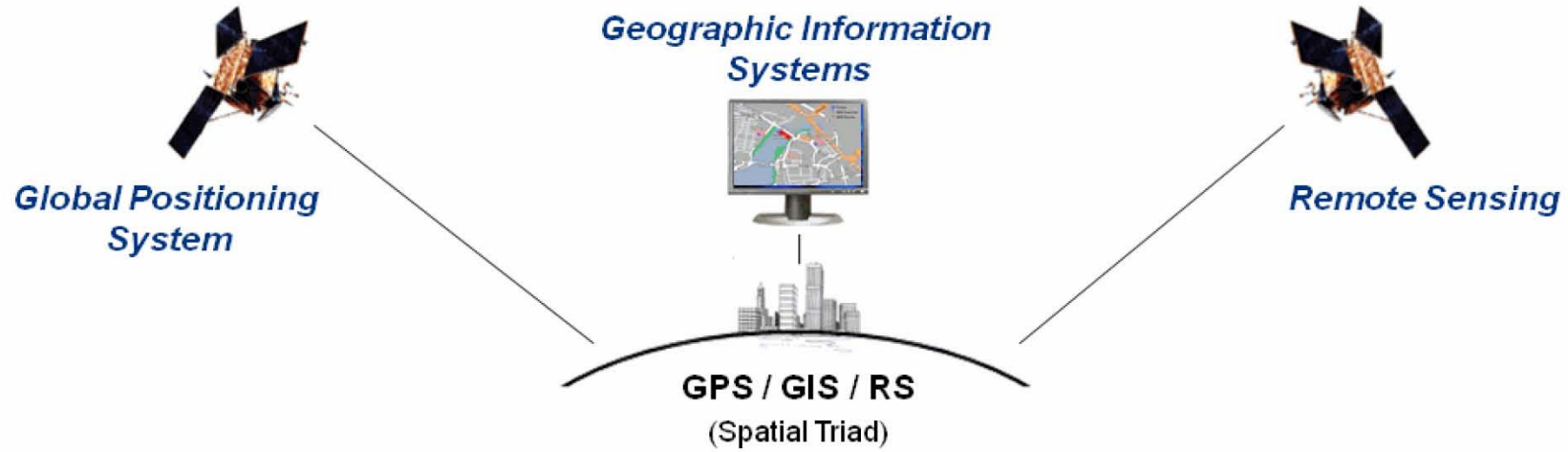
Satellite Navigation

- Moved from warplanes to car navigation to gaming in <10 years
- American Wide Area Augmentation System (WAAS): 350 ft in 2003; 200 ft in 2006
- Commercial operators with WAAS gain access to Cat1 equivalent approach services with no ILS
- Europian EGNOS: Japanese MSAS; Indian GAGAN

Geospatial : a mega technology

(Nanotechnology) **Geotechnology** *(Biotechnology)*

Geotechnology *is one of the three "mega technologies" for the 21st century and promises to forever change how we conceptualize, utilize and visualize spatial information in scientific research, commercial applications and general usage*

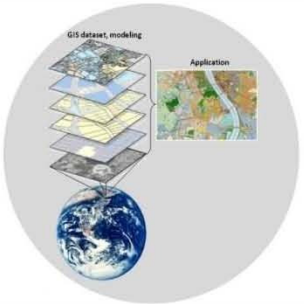


Where *is* **What**

Mapping involves ***precise placement*** *(delineation) of physical features*

(Graphical)

← *Descriptive* **Mapping**



Prescriptive **Modeling** →

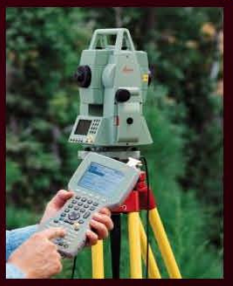
Why *and* **So What**

Analysis involves investigation of ***spatial relationships***

(Numerical)

Source: Joseph K Berry

Geospatial Convergence



GIS

RS

ICT

GPS

LBS

Band width

Photo-grammetry

Convergence

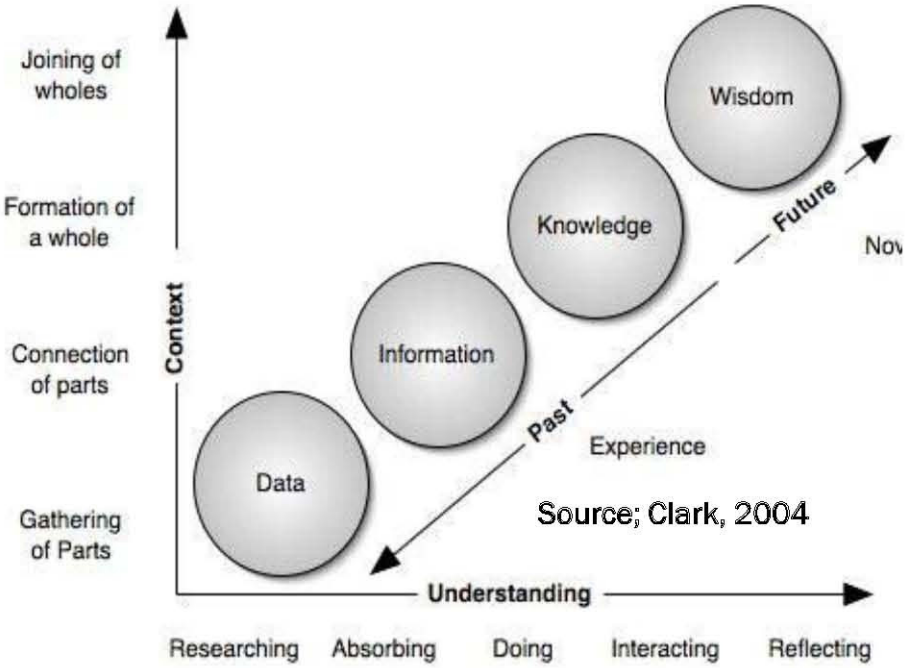
ALTM

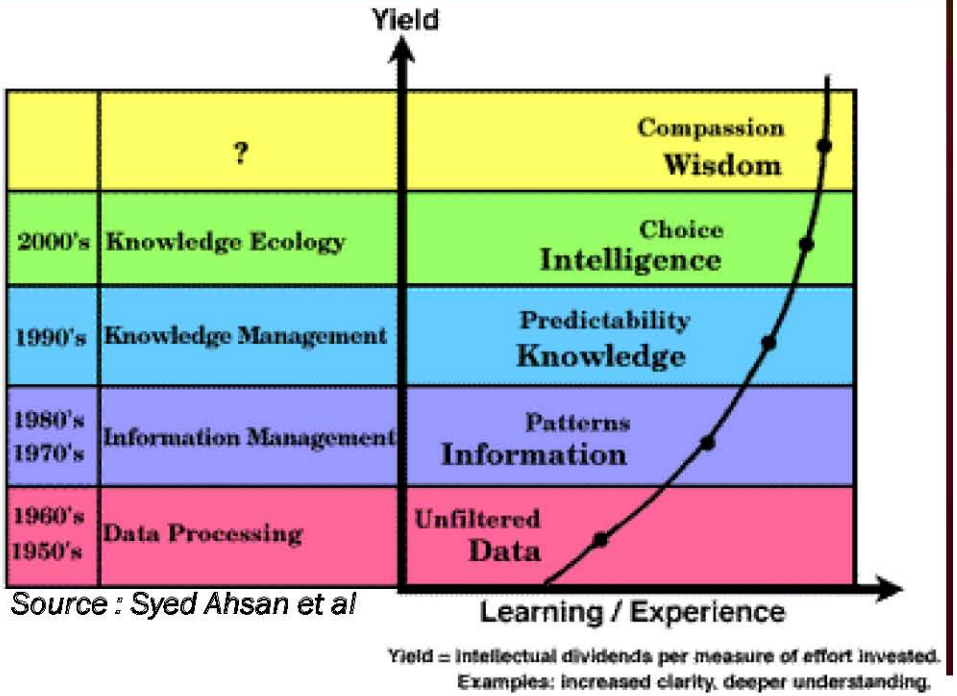
Total Station

Total Turnkey Solutions

… Space tech playing a major role

Understanding the DIKW Chain





Philosopher's Progression of Understanding —

- ✓ **Data** (all facts)
- ✓ **Information** (facts within a context)

  ...**GeoExploration** *emphasizes tools for data access and visualization (general user)*

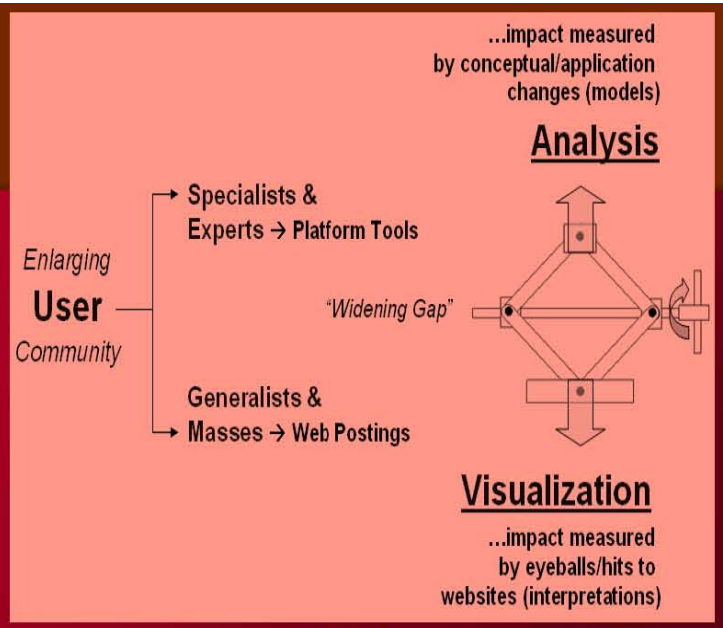
  Mapping focus

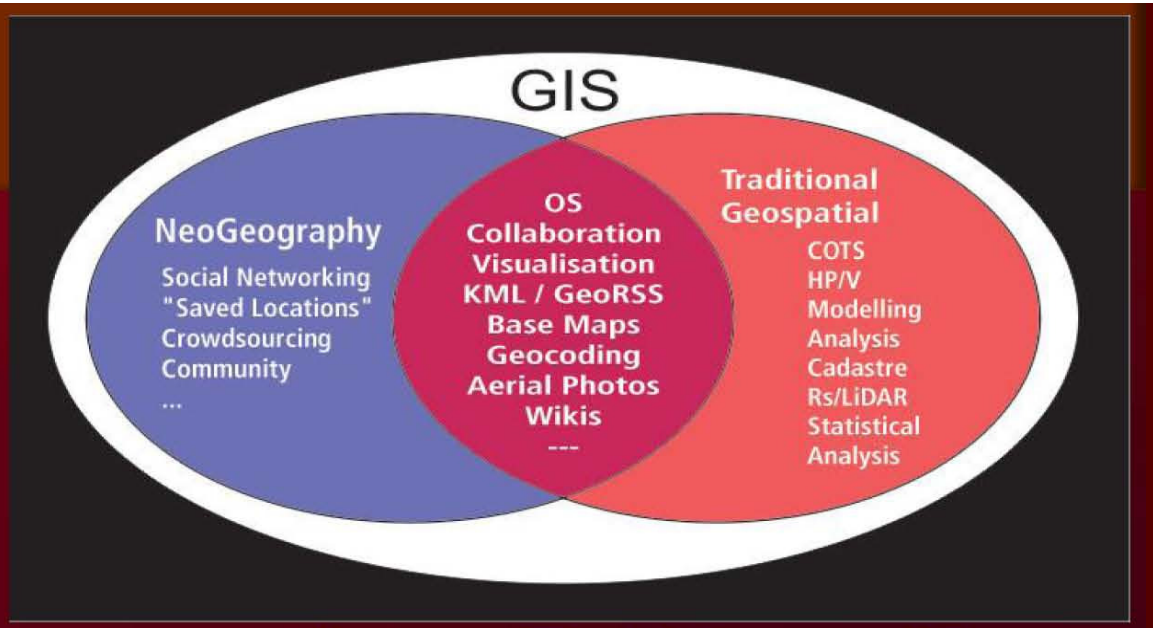
  Data/Structure and Analysis focus

- ✓ **Knowledge** (interrelationships among relevant facts)
- ✓ **Wisdom** (actionable knowledge)

  ...**GeoScience** *emphasizes tools for spatial reasoning and understanding of spatial patterns and relationships (application specialist)*

Source:Joseph K berry



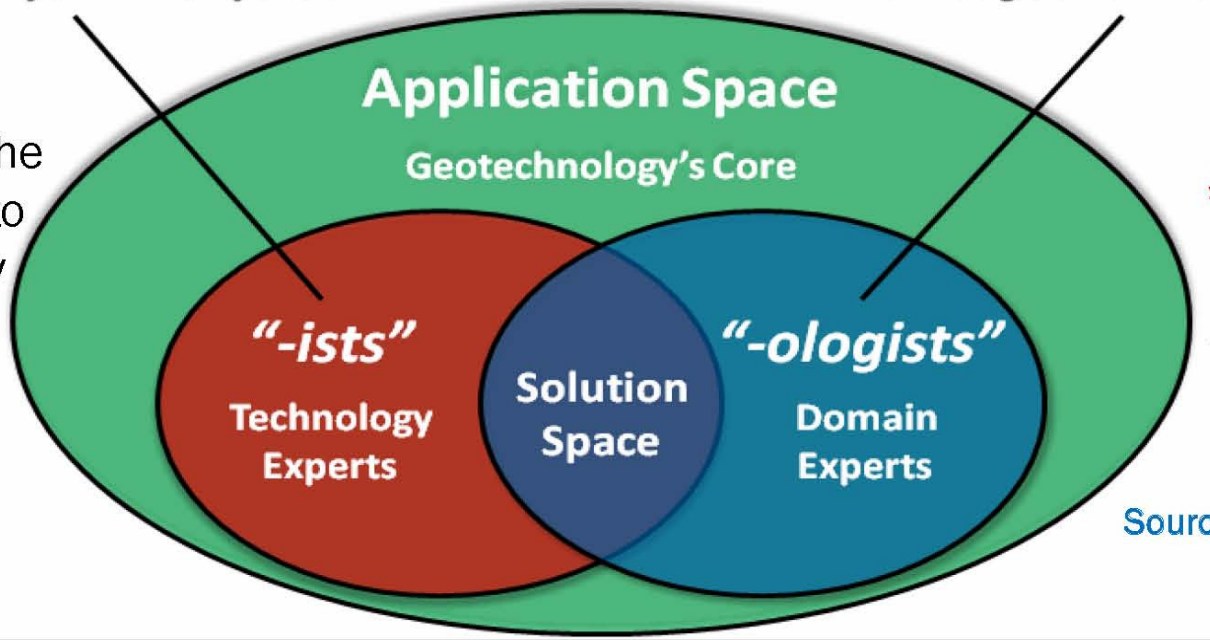


User Perception Differs!!

Data and Information focus

Knowledge and Wisdom focus

Understand the ***'tools '*** used to display, query and analyse spatial data



Understand the ***science*** behind spatial relations used for decision-making

Source: Joseph K Berry

Geospatial – Expanding Spiral

• **Computer Mapping** (1970s) ...automates the map drafting process (*Digital Maps*)

Surveying *Photogrammetry* *Remote Sensing (RS)*

Computer-aided Drafting and Computer-assisted Mapping (CAD/CAM)

Automated Cartography *Image Processing*

• **Spatial Database Management** (1980s) ...links digital maps to descriptive information about map features (*discrete Points, Lines, Polygons*)

Automated Mapping and Facilities Management (AM-FM)

Geographic Information Systems (GIS) *Desktop Mapping*

Geographic Information Science *Enterprise GIS*

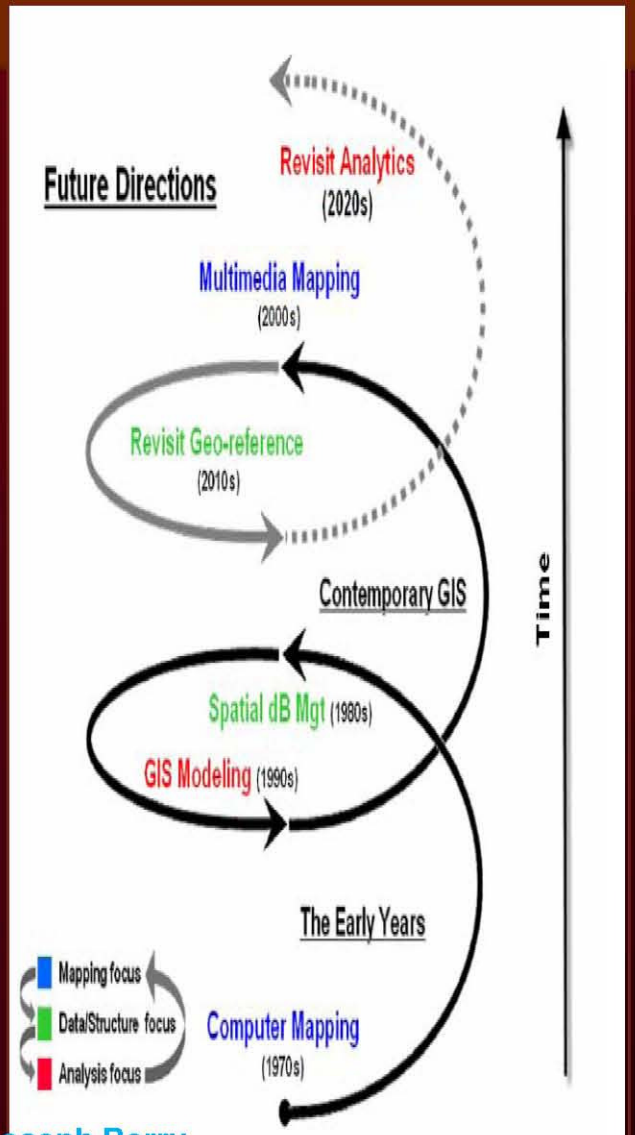
• **Map Analysis and Modeling** (1990s) ...investigates spatial relationships and patterns within and among map layers (*continuous Surfaces*)

Cartographic Modeling *Map Algebra (Map-ematics)* *Geomatics*

• **Multimedia Mapping** (2000s) ...full integration of RS/GIS/GPS with the Internet and other technologies (*Visualization*)

Global Positioning System (GPS) *Mobile GIS*

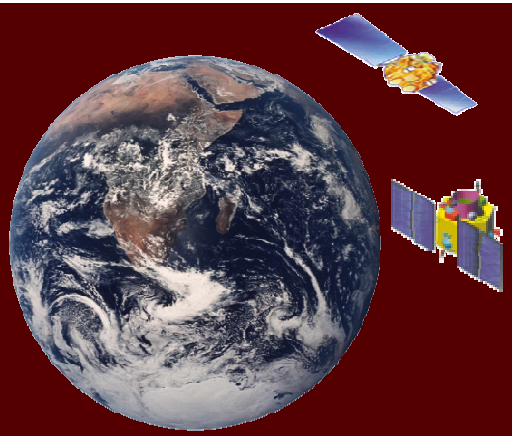
Web Mapping *Virtual Reality* *Geospatial Technology*



Source: Joseph Berry

Mapping , data structures and analysis in multi-dimensional space will be future focus

Pixel to People



Petabytes

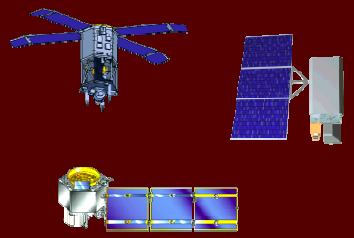
Multi-platform, Multi-Parameter, high spatial and temporal resolution, remote & in-situ sensing

Terrabytes

Gigabytes

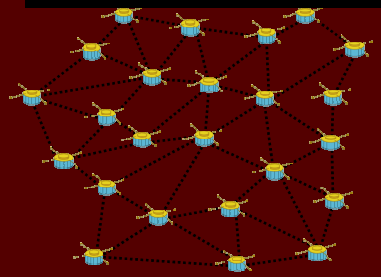
Megabytes

Autonomous; Formation Flights



Autonomous, In-space Calibration and Data Reduction

Sensor Webs



Synergy and convergence of observational networks

Data Fusion/ Advanced Models

Interaction between Modeling/Forecasting and Observation Systems

Seamless Access

Knowledge

Interactive Dissemination

Ultimately, user wants simple interface and Fit for Purpose information without any major policy hurdles. There lies the major Challenge

Global Observational Needs

– *Largely addressed by EO Satellites*

Encompasses

- **Atmospheric Compositions:** CO_2, Water vapour, Ozone, Aerosols
- **Ocean Surface Topography & Physicochemical status:** Sea level rise as well as SST and chemistry trends
- **Precipitation:** studies of rainfall, impact of severe storms & understanding water cycles
- **Land Surface Imaging:** Farm lands, coastlines, deserts, forests & tracking wildfires, floods & volcanic activity

Climate Change Indicators (for scientific analysis)

- Radiation, clouds, water vapour, precipitation & atmospheric circulation
- Ocean circulation, productivity, & exchange with the atmosphere
- Troposphere chemistry & GHGs
- Land ecosystems & hydrology
- Snow, ice & glacier extent
- Ozone & stratospheric chemistry
- Volcanoes & climate effects of aerosol

"Simplicity is the ultimate sophistication."

— Leonardo da Vinci

Think Globally Act locally

Some Indian Experiences…

India: Major Challenges...

Lower adaptive capacity for Climate Change

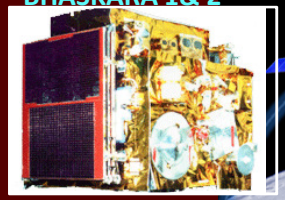
- Eroding land resources (soil, nutrient..)
- Water resources: Scarcity in abundance: Spatially & temporally erratic rainfall
- Depleting groundwater resources
- Demographic pressure: Susceptible coastal areas
- Stagnating agricultural growth: Lower productivity in rain-fed areas
- Disaster prone terrains: Floods., Droughts, earthquakes, landslides
- Increasing Socio economic, knowledge & digital divides
- Illiteracy and health & hygiene

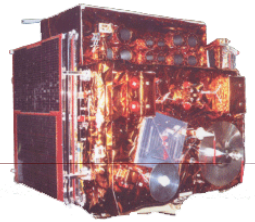
and of course, Population explosion

Priorities: Food Security & Poverty alleviation; Natural Resources Assets Built-up; Infrastructure Development; Disaster Reduction; Weather & Climate; Education & Health

Indian EO Programme

BHASKARA 1& 2



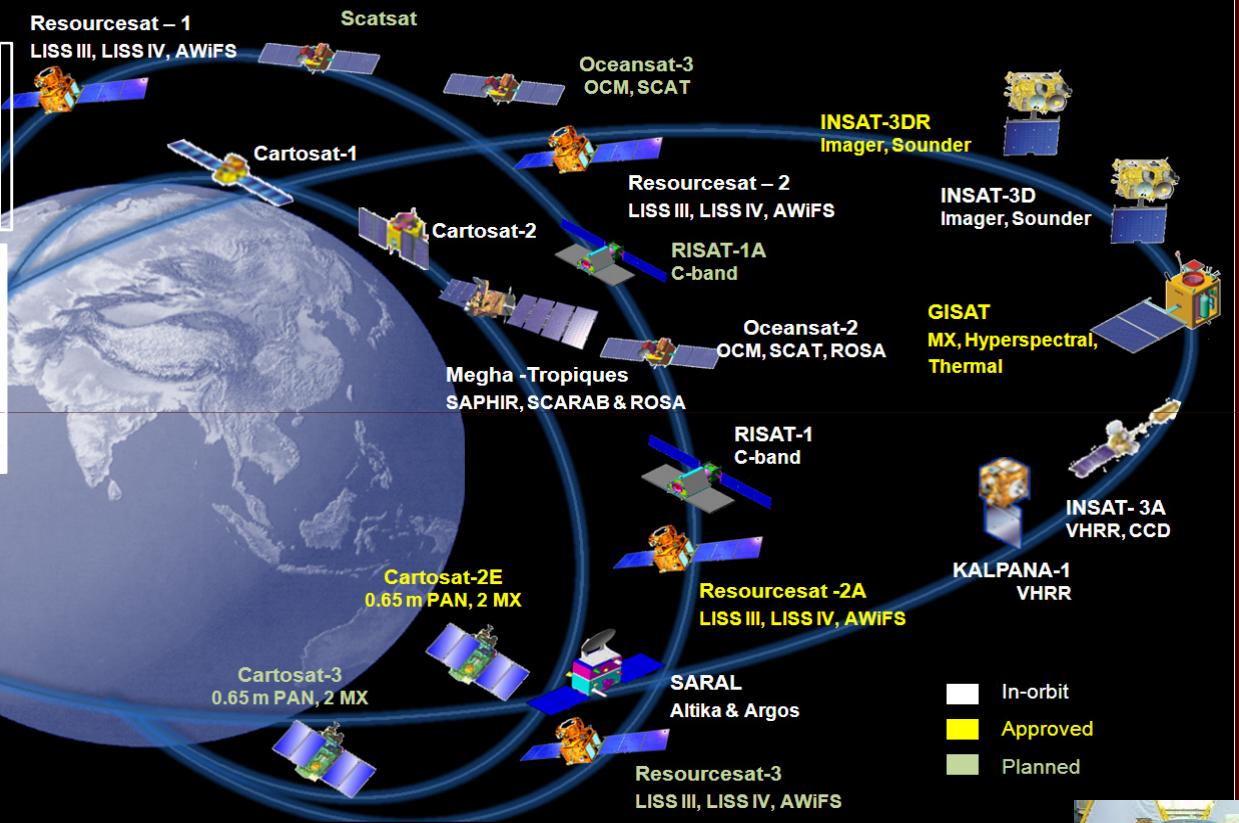


IRS 1A/1B

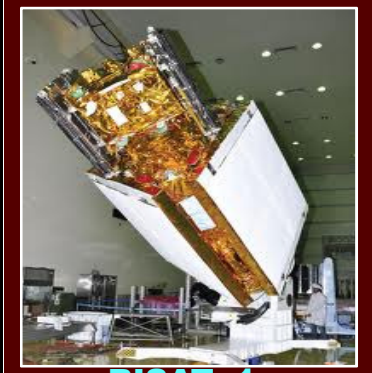
IRS 1C/1D

Oceansat 1 &2

Indian EO Missions



SARAL



RISAT -1

Megha Tropiques

TES

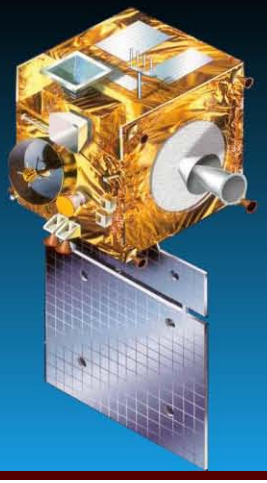
Resourcesat 1 & 2

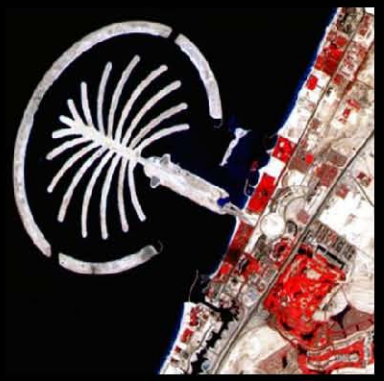
Cartosat 1

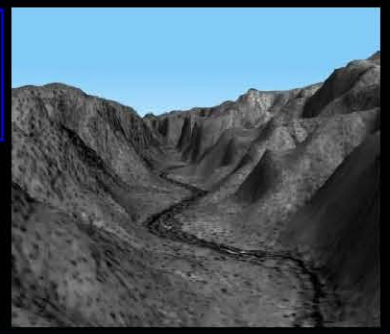
Cartosat 2A

Cartosat 2B

EO Emphasis on Thematic Series







Land & Water

Cartographic

Ocean & Atmospheric

2012
Risat 1
C-band

2010
CARTOSAT-2B
PAN

2009
RISAT 2
X-SAR

2010
RESOURCES AT-2
LISS 3; LISS 4; AWiFS

2007/2008
CARTOSAT-2/2A
PAN

2003
RESOURCESAT-1
LISS 3; LISS 4; AWiFS

2011
Meghatropiques
MADRAS;scarab;SAPHIR

2005
CARTOSAT-1
PAN, F/A

2009
OCEANSAT-2
OCM, SCAT

1995/97 IRS-1C/1D LISS-3, PAN & WiFS

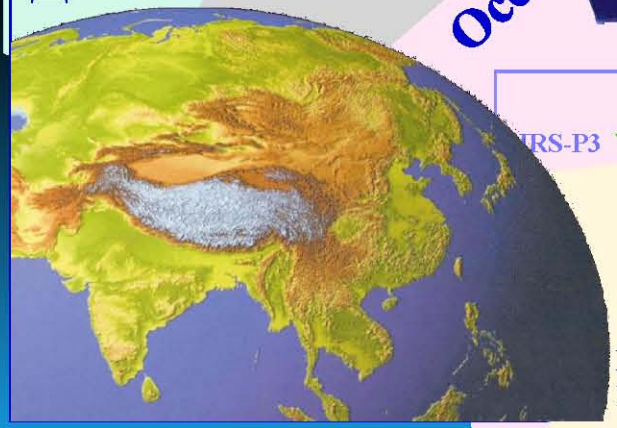
2001
TES
Step& Stare
PAN

1999/2003
INSAT-2E/ 3A
VHRR, CCD

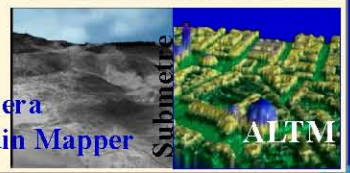
1999
OCEANSAT-1
OCM & MSMR

2002
KALPANA-1
VHRR

1996
IRS-P3 WiFS, MOS-



Aerial

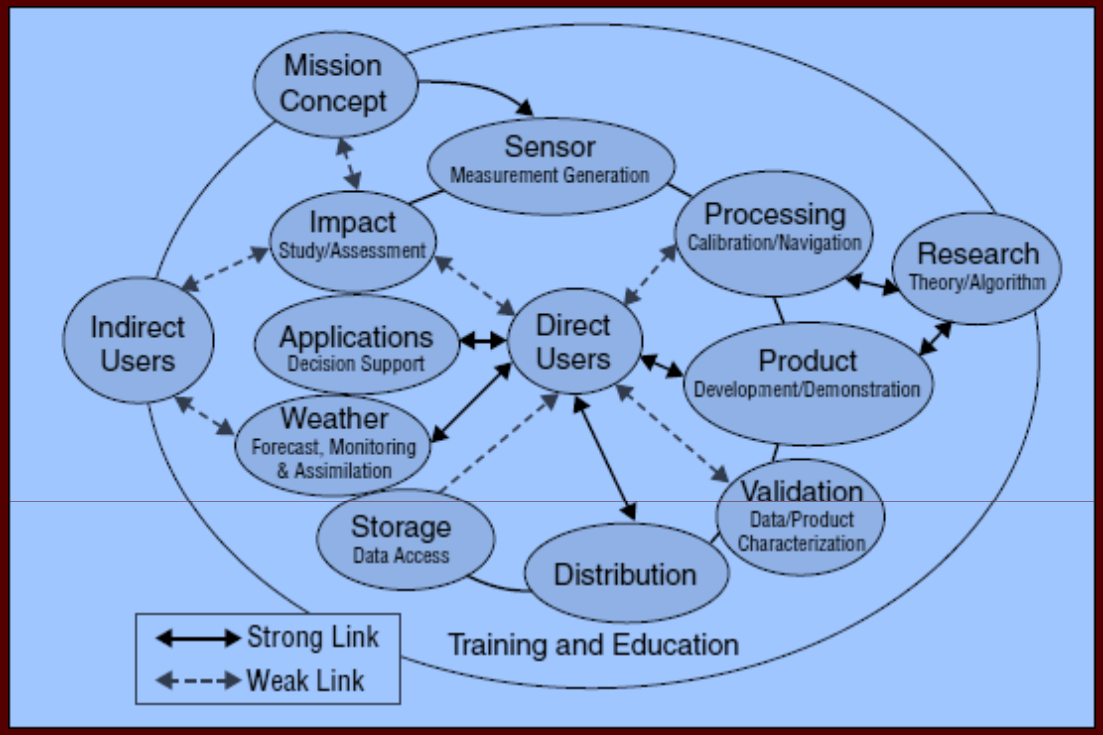


Digital Camera
Laser Terrain Mapper

Submetre

ALTM

Complex process of EO data utilisation

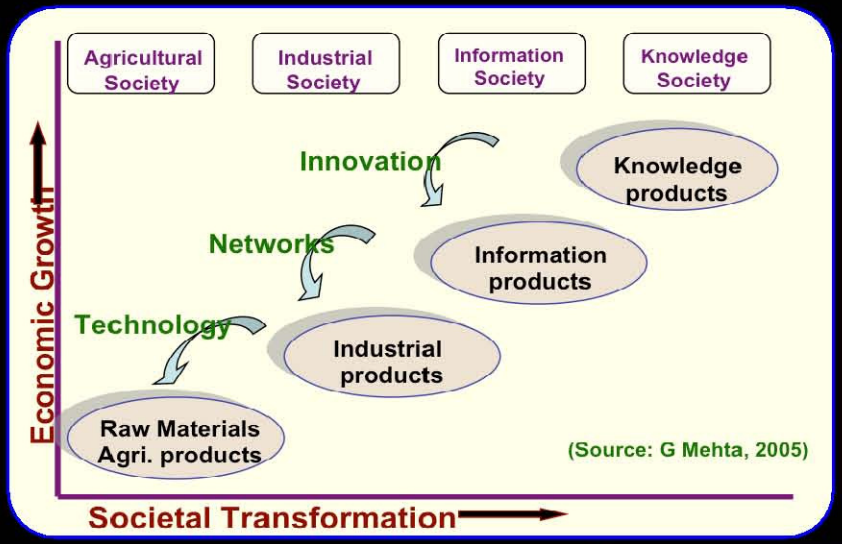


Source: National Academy of Sciences, 2004

- **Multi-disciplinary EO chain**
  - Dynamic technology, multi-disciplinary, multi-dimensional, fast changing
  - End-to-end characterisation from raw data acquisition to data processing and to end-use applications
  - Continuing need for efforts on R&D and challenges to make it operational

Ultimately, value of Information is its ability to reduce uncertainty in decision-making at the user-end.

Transforming Society thru' Space



Strategy for

- **Building Livelihood Assets & Community Resilience**
- **Natural Resources and Disaster Management**
- **e-governance & Empowerment**
- **Targeting Poverty, Vulnerability and Marginality**
- **Tele-medicine/Distance Education/Interactive Training**

Remote Sensing

- Mapping
- Monitoring
- Impact Assessment
- building resilience of Livelihoods & NR base

Satellite Communications

- Info. Access
- "Last mile" Connectivity *(or Is it 'First Mile'?)*

GIS & GPS

- Linking Socio-economic variables
- Focus on Livelihood

Environmental Integrity ⇄ **Natural Resources Assets Building** ⇄ **Incidence of Poverty/ Human Dev. Indicators** ⇔ **Actionable Products and Services**

EO in Developmental Intervention Processes

Food Security & Poverty Alleviation

CAPE/FASAL, Horticulture inventory, Diversification, Intensification, Extensification, Potential Fishing Zone mapping, Rainfed & irrigated area development

Building Infrastructure

Social: Rajiv Gandhi National Drinking Water Mission, National Rural Employment Guarantee Programme

Physical: National Urban Info System, Jawaharlal Nehru National Urban Renewal Mission, Rail/ Road/ Pipeline alignment, Interlinking of Rivers, Hydropower potential harnessing

NR Assets Building

Wasteland inventory, Natural Resources Census, Forest & Environ. Mgt., Mineral Prospecting, Snow/ Glacial studies

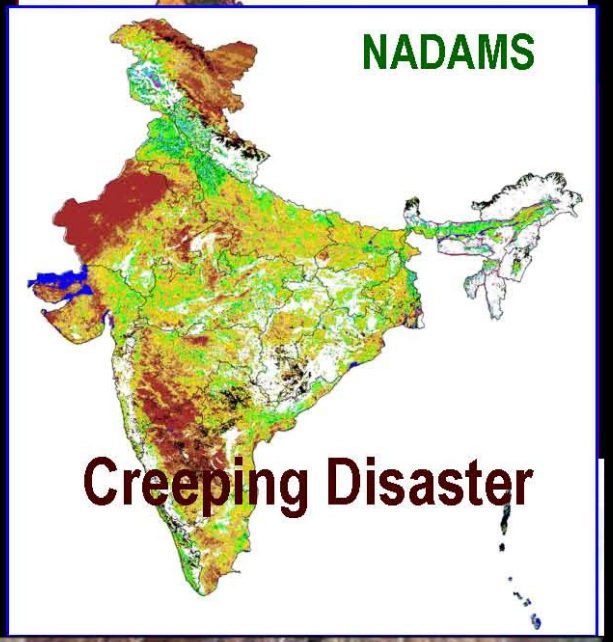
Disaster Management

Flood,cyclone, landslide, drought., Tsunami

Weather & Climate

RCM, ISRO GBP,

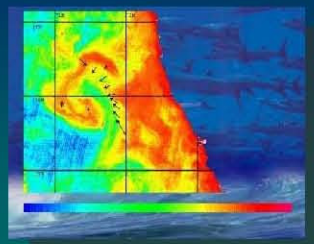
Land use/ Land cover map



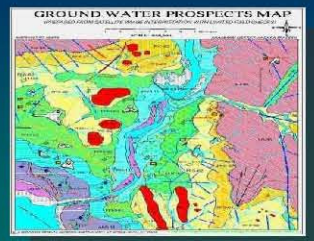
Space to Society: Outreach

Agriculture

Fisheries

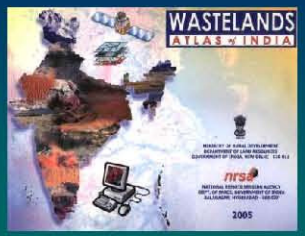


Drinking Water



Watershed Development

Wasteland mapping

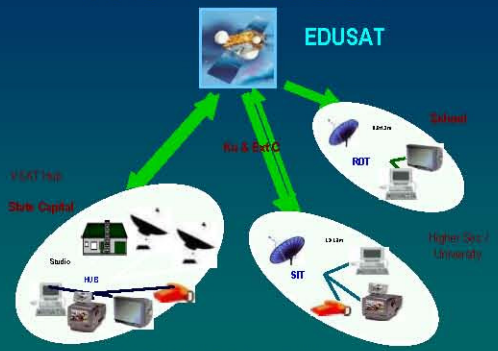


Disaster Management Support (DMS) System

Networking, Early Warning
[CWDS, IOTWS, INFFRAS, ..]

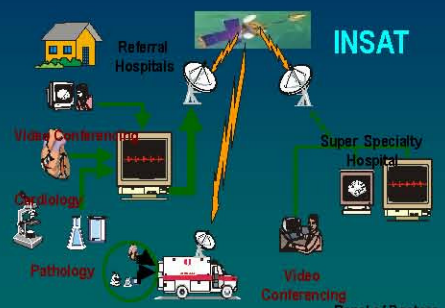
NDEM, Hazard Zonation, Risk Assessment, …

Tele-Education



> 55,000 Virtual Class Rooms

Tele-Medicine



~ 500,000 Patients treated

Village Resources Centre

EO based Info. &
Digital Connectivity

EO: What is in store?

EO Constellation for GEOSS

- Implemented through Committee on Earth Observation Satellites (CEOS)

EO Constellation of satellites for

- Land Surface Imaging (LSI)
- Atmospheric Chemistry (AC)
- Global Precipitation Mission (GPM)
- Ocean Surface Topography (OST)
- Ocean Surface Wind
- Ocean Colour

India's Contribution

- Resourcesat for LSI
- MeghaTropiques for GPM
- SARAL for OST
- Oceansat-2 for Wind & Colour
- I-STAG for AC

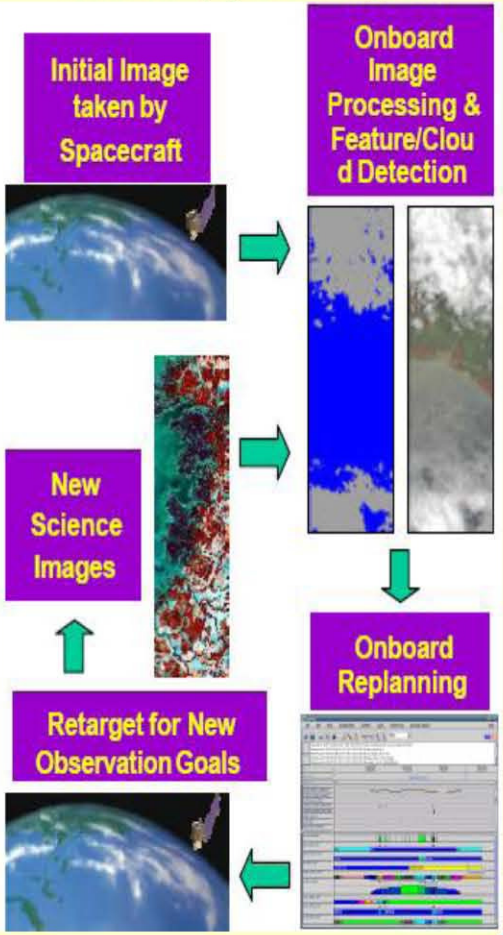
Benefit Areas

- **Disasters** Risk reduction
- **Health:** Understand environmental factors
- **Energy**: Improve management of energy
- **Climate**: Understand, assess, predict, mitigate & adapt
- **Water**: Understand water cycle
- **Weather**: Improve forecasting & warning
- **Ecosystems:** Protect terrestrial, coastal & marine resources
- **Agriculture:** Sustainable agriculture & combating desertification
- **Biodiversity:** Understand, monitor & conserve

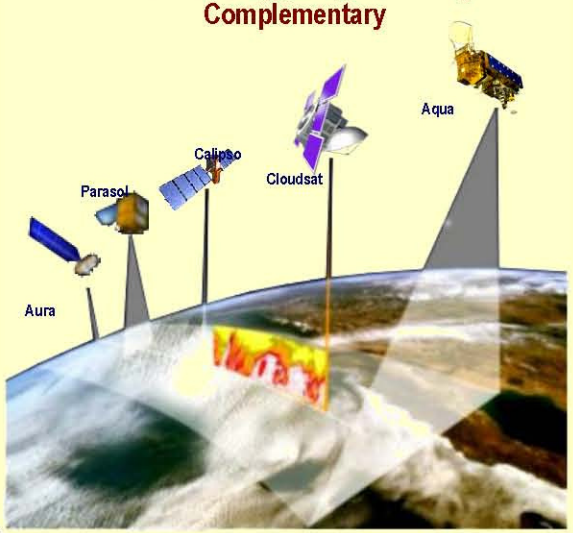
CEOS is the Space arm of GEOSS working through GEO

Emerging Scenario in EO

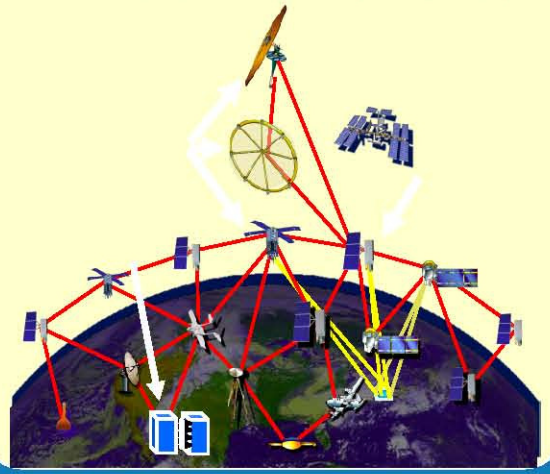
Autonomous Spacecraft:
Onboard Software System to detect the extreme event and respond autonomously by capturing the events and downlink without any ground support

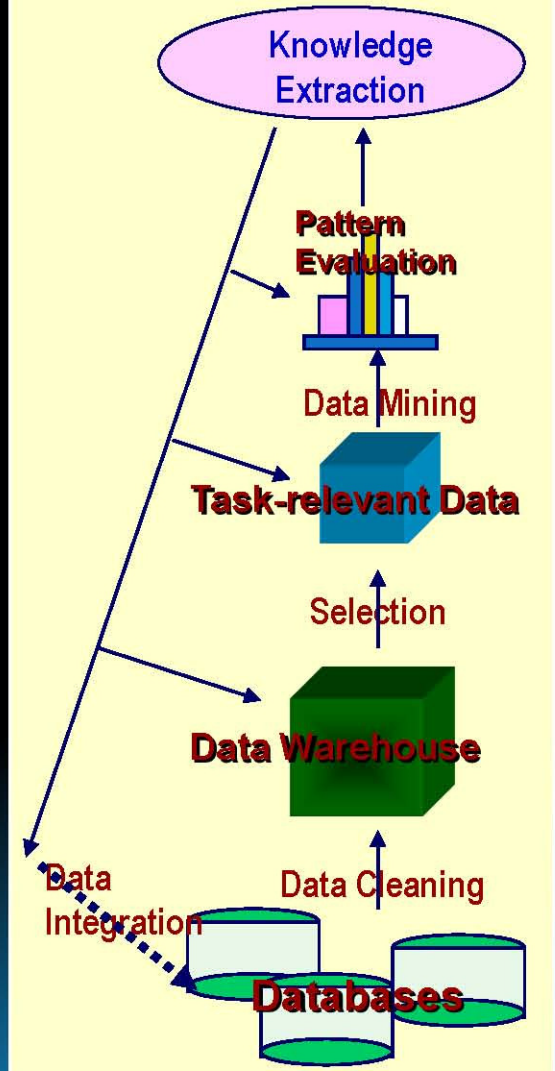


Formation Flying & Event Triggering:
Ensures Synergy, Supplementary & Complementary



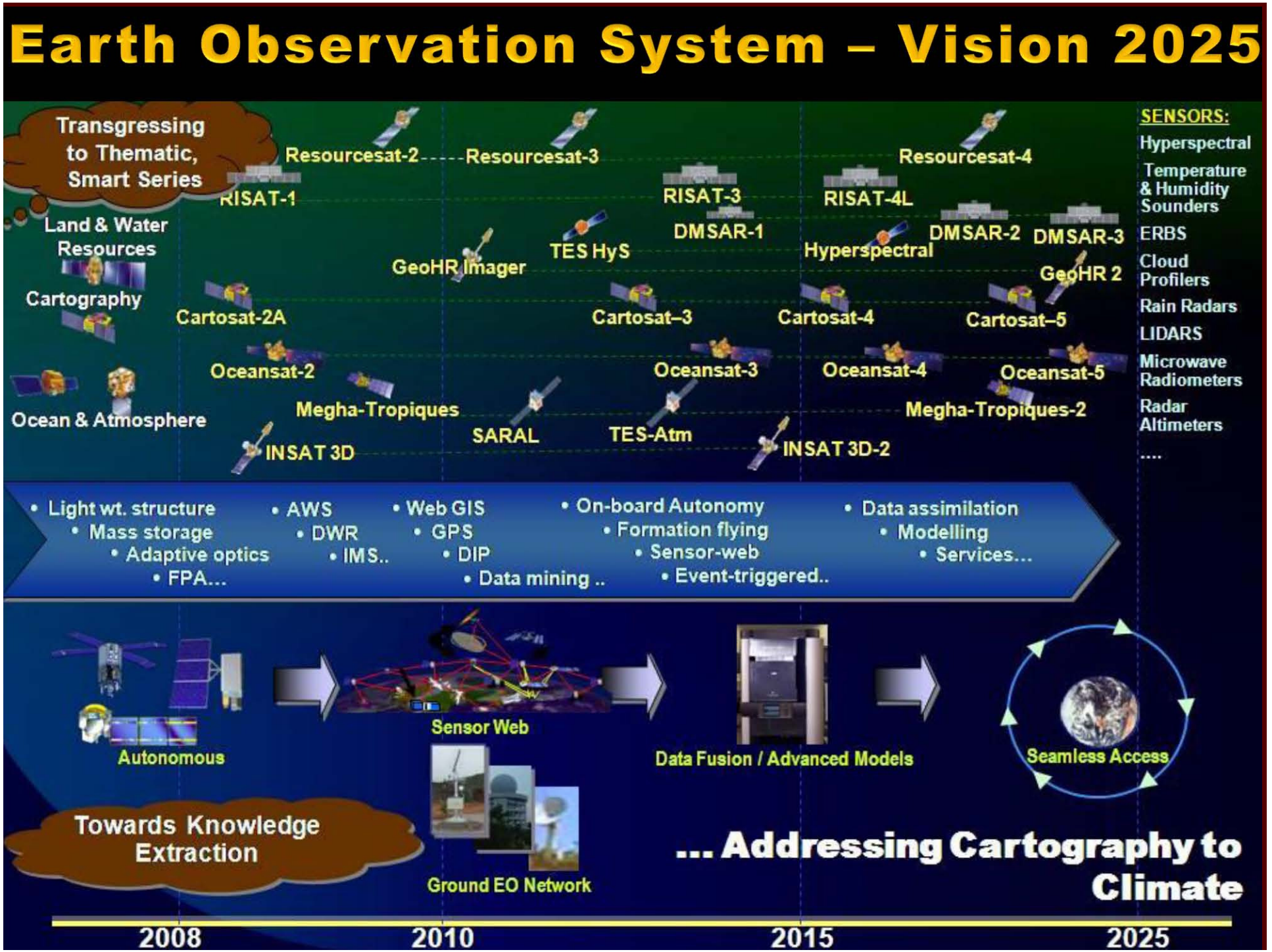
Sensor-Web: Seamlessly networked observing System (*in situ* & space based)





Smaller, Intelligent & Autonomous Missions in the Offing

Earth Observation System – Vision 2025



Space Outreach – Touching Lives

Info for Farmers

Good catch for fishermen

Tele-Education

Disaster Risk Reduction

Providing clean water

Rural Health

Still a long way to go!

References

- Dr. V. Jayaraman's Lectures in Research Gate
  - *www.**researchgate**.net/profile/**Jayaraman_V**/publications*
- Internet is "ever green" book for this topic
-

ıman Impacted World

GEO-TECHNOLOGY

Burgeoning

Populace
Energy exhaustion
Industrialization
Pollution

Dying

Resources
Natural
Areas
Diversity
Civilization

Thank you

ion has caused la
Planet Earth