Accessibility of Earth Observation data

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RS-course (GRS-20306)
Long term observations of a changing earth

Lake Chad (Africa):
1973 - 1987

Global change in vegetation productivity (1981-2000)

http://www.nasa.gov/centers/goddard/earthandsun/climate_change.html
Rapid assessment of events

http://earthobservatory.nasa.gov/

Sundarbans, Bangladesh

Stretching across part of southwestern Bangladesh and southeastern India, the Sundarbans is the largest remaining tract of mangrove forest in the world. The Sundarbans is a tapestry of waterways, mudflats, and forested islands at the edge of the Bay of Bengal. Home to the endangered Bengal tiger, sharks, crocodiles, and freshwater dolphins, as well as nearly two hundred bird species, the low-lying plain is part of the Mouth of the Ganges. The area has been protected for decades by the two countries as a
Overview

- Short history of Earth Observation (EO)
- From satellite launch to image on the screen
- Making EO data available
- Developments in access to EO data
Earth observation (EO) refers to the collection, processing, modeling, and dissemination of data about the Earth system (GEO).

Observation of the Earth from orbit by a constellation of specifically designed satellites, similar to reconnaissance satellites but intended for non-military uses, in order to understand and model the impact of natural events and human-induced activities on the earth’s environment (Wikipedia).

source: Kramer, 2002
History of EO

- 1960s: Apollo photo’s, weather satellites
- 1970s: start Landsat program
- 1980s: start SPOT program, SIR-A/B
- 1990s: ERS, RADARSAT, IKONOS
- 2000+: TERRA, AQUA, ENVISAT, Quickbird, satellites India, Nigeria, Korea

- 1999: The Earth Observing System (EOS-NASA)
- 1999: Living Planet Program (ESA)
- 2005: Group on Earth Observation (GEO)
Applications for EO

- Weather forecast
- Land cover and land use monitoring
- Food security and agriculture
- Biodiversity and environmental assessment
- Climate change and carbon cycle
- Disaster monitoring: tsunami, earthquake, volcanoes, forest fires
Developments in EO sensor

Detailed assessments, monitoring with infrequent coverage
- AVIRIS (from 20,000 m)
- HyMap ARES (from 3000 m)
- DAIS 7915 (from 3000 m)
- EnMAP
- Hyperion from space
- TIMS (from 3200 m)
- HRG pan
- LISS-1C ETM pan
- TM thermal

Large scale assessments, monitoring with frequent coverage
- MODIS (reflective, thermal)
- MERIS full spatial resolution
- MERIS red spatial resolution
- AVHRR
- METEOSAT

Spatial resolution (GSD in meter)

Number of spectral bands

1 10 100 1000 10,000
10 100 1000
300

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Summary developments in EO sensors

- Developments in EO satellite sensors:
  - Spectral domain: more bands, narrow bands
  - Temporal domain: higher frequency with more detailed spatial resolution
  - Directional domain: new (CHRIS-PROBA, MSIR)
  - Multi-sensor: optical and LIDAR

- Trigger for new applications, analysis techniques and algorithms

- However, discontinuity problem of sensor missions (e.g., Landsat, MODIS, MERIS)
  - essential for commercial applications
  - loss of long-term time series
From idea to satellite launch to image on the screen

- User requirement
- Definition studies
- Final definition
- Construction
- Launch
- Commission phase: first data
- Operational phase: end-products

10 years
Case MERIS on Envisat

- MERIS (Medium Resolution Imaging Spectrometer)
- 1984: ESA’s Ocean Colour Working Group: idea for IS for ocean applications
- 1987: release of technical specifications for ‘MERIS’
- 1991 – 1997: re-branding from oceanic to environmental sensor (ocean, atmosphere, land)
- 1995: final definition, start of construction by industry (space segment and ground segment)
- March 2002: Launch of MERIS on Envisat platform (10 sophisticated optical and radar instruments)
- 2002: first data (commission phase): intensive global field campaigns; validation phase for level 2 products (NDVI, MGVI, MTCI)
- from 2003: operational phase

source: curran and steele, 2005; http://envisat.esa.int/
# MERIS characteristics

<table>
<thead>
<tr>
<th>Band Nr.</th>
<th>Band center (nm)</th>
<th>Bandwidth (nm)</th>
<th>Potential applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>412.5</td>
<td>10</td>
<td>Yellow substance, turbidity</td>
</tr>
<tr>
<td>2</td>
<td>442.5</td>
<td>10</td>
<td>Chlorophyll absorption max.</td>
</tr>
<tr>
<td>3</td>
<td>490</td>
<td>10</td>
<td>Chlorophyll, other pigments</td>
</tr>
<tr>
<td>4</td>
<td>510</td>
<td>10</td>
<td>Turbidity, suspended sediment, red tides</td>
</tr>
<tr>
<td>5</td>
<td>560</td>
<td>10</td>
<td>Chlorophyll reference, suspended sediment</td>
</tr>
<tr>
<td>6</td>
<td>620</td>
<td>10</td>
<td>Suspended sediment</td>
</tr>
<tr>
<td>7</td>
<td>665</td>
<td>10</td>
<td>Chlorophyll absorption</td>
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<tr>
<td>8</td>
<td>681.25</td>
<td>7.5</td>
<td>Chlorophyll fluorescence</td>
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<tr>
<td>9</td>
<td>705</td>
<td>10</td>
<td>Atmospheric correction</td>
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<tr>
<td>10</td>
<td>753.75</td>
<td>7.5</td>
<td>Oxygen absorption reference</td>
</tr>
<tr>
<td>11</td>
<td>760</td>
<td>2.5</td>
<td>Oxygen absorption R-branch</td>
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<tr>
<td>12</td>
<td>775</td>
<td>15</td>
<td>Aerosols, vegetation</td>
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<tr>
<td>13</td>
<td>865</td>
<td>20</td>
<td>Atmospheric correction ocean</td>
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<tr>
<td>14</td>
<td>890</td>
<td>10</td>
<td>Water vapour absorption reference</td>
</tr>
<tr>
<td>15</td>
<td>900</td>
<td>10</td>
<td>Water vapour absorption, vegetation</td>
</tr>
</tbody>
</table>

source: http://envisat.esa.int/instruments/meris
Example MERIS products

Water: Chlorophyll Concentration

Atmosphere: Aerosol Optical Thickness

Land: Fraction of Absorbed Photosynthetically Active Radiation
Making EO data available

- Starting from first Apollo photographs (1960s)
- Approx. 400 EO space missions
- Huge amounts of data acquired
- EO data only limited amount available

- Statement from Millennium Ecosystem Assessment report:
  
  Although for 30 years remote sensing capacity has been available that could enable rigorous global monitoring of land cover change, financial resources have not been available to process this information, and thus accurate measurements of land cover change are only available on a case study basis.

source: www.maweb.org
Concept of spatial data infrastructure for EO

- SDI is dealing with facilitation and coordination of the exchange and sharing of spatial (EO) data

SDI components:

- users
- technology
- policies
- standards
- EO data/services

source: www.geo-informatie.nl/courses/grs21306
Global Earth Observation System of Systems: GEOSS

- A Global, Coordinated, Comprehensive and Sustained System of Earth Observing Systems
- GEO is a voluntary partnership of 72 governments and the European Commission, 52 intergovernmental organizations (Feb 2008)

- User driven approach
- Interoperability arrangements
- Web portal and clearing house
- Support new observation methods
- Dissemination knowledge

source: www.earthobservations.org
Product levels

Level 0 Product: raw data
- Laboratory Calibration (radiometric and spectral), Vicarious Validation
- Atm. corrected data

Level 1 Product: at-sensor radiance data
- System Correction & Radiometric Calibration
- Geometric Correction
- Atmospheric Correction

Level 2a Product: Atm. corrected data
- Level 2a Product
- Level 2b Product
- Preprocessing
- Radiative Transfer Model, Atmospheric Variables, Topographic Variables

Level 2b Product
- Level 2b Product
- Geometric Correction
- Atmospheric Correction

Level 2 Product: statistical or physical models & validation
- Level 2 Product
- Level 3 Product
- Image analysis
- Variables and application
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Level 3 Product: thematic variables mapped on uniform space-time grid scales
EO data providers

- **Space agencies:**
  - NASA: MODIS (esg.gsfc.nasa.gov)
  - ESA: ENVISAT ([www.eoportal.int](http://www.eoportal.int) or eoli.esa.int)

- **Governmental organizations:** USGS (earthexplorer.usgs.gov)

- **Value adding-companies:** EUimage (www.eurimage.com)

- **Partnerships and collaborations:** (postel.mediasfrance.org)

- **Availability of EO data (selection):**
  - Landsat, SPOT, Hyperion, ERS
  - ‘Free of charge’: MODIS, MERIS, ASTER, AVHRR
NASA EO data portal

- NASA EOS program
- MODIS: The Land Processes Distributed Active Archive Center (LP DAAC)
- Example of combined development of sensor and ground segment (algorithms, calibration, validation)
- Level 2 data + large number of level 3 products
- Automatic preprocessing facilities
- Standardization of data levels (MODIS)
- Mosaics combine different days to get complete image

### Table 2
MOD products, their release dates and their status

<table>
<thead>
<tr>
<th>Product</th>
<th>DAAC</th>
<th>Beta release date</th>
<th>Beta product start date</th>
<th>Provisional status date</th>
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<tbody>
<tr>
<td><strong>Radiation balance product suite</strong></td>
<td></td>
<td></td>
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<tr>
<td>MOD09 Surface reflectance</td>
<td>EDC</td>
<td>8/4/00</td>
<td>6/9/00</td>
<td>10/7/00</td>
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<tr>
<td>MOD11 Surface temperature and emissivity</td>
<td>EDC</td>
<td>9/1/00</td>
<td>6/25/00</td>
<td>10/31/00</td>
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<tr>
<td>MOD43 BRDF/Albedo</td>
<td>EDC</td>
<td>9/29/00</td>
<td>7/11/00</td>
<td>10/31/00</td>
</tr>
<tr>
<td>MOD10 Snow cover</td>
<td>NSIDC</td>
<td>10/13/00</td>
<td>9/13/00</td>
<td>10/31/00</td>
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<tr>
<td>MOD29 Sea ice extent</td>
<td>NSIDC</td>
<td>4/13/01</td>
<td>1/23/01</td>
<td>10/31/00</td>
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<tr>
<td><strong>Vegetation product suite</strong></td>
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<tr>
<td>MOD13 Vegetation indices</td>
<td>EDC</td>
<td>8/4/00</td>
<td>6/9/00</td>
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<td>MOD15 LAI/FPAR</td>
<td>EDC</td>
<td>8/4/00</td>
<td>6/9/00</td>
<td>6/9/00</td>
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<td>MOD17 NPP/PSN</td>
<td>EDC</td>
<td>3/16/01</td>
<td>12/19/00</td>
<td>12/19/00</td>
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<tr>
<td><strong>Land cover product suite</strong></td>
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<td>MOD12 Land cover and change</td>
<td>EDC</td>
<td>4/27/01</td>
<td>10/15/00</td>
<td>7/11/00</td>
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<td>MOD14 Thermal anomalies and fire</td>
<td>EDC</td>
<td>10/13/00</td>
<td>8/20/00</td>
<td>10/31/00</td>
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<td>MOD44 Vegetation cover conversion/continuous fields</td>
<td>UMD GLCF</td>
<td>3/30/01</td>
<td>6/9/00</td>
<td>TBD</td>
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</tbody>
</table>

source: http://edcimswww.cr.usgs.gov/pub/imswelcome/
Terra, MOD09, day 2002194 (07/13/2002), Collection 004

Click to an area in the global image to pop-up a 5km-resolution close-up of this region and the granule information.

Satellites/Collections:
- Terra, Collection 4
- Terra, Collection 3
- Aqua, Collection 3

Products available for day 2002194:
Examples of EO web services (results of RGI)

- ADAGUC: Atmospheric data access for geo-spatial user community

- Real time Productivity: National vegetation productivity using MODIS medium resolution data
  - [http://webgrs.wur.nl/cgi/projects/sensorweb/pmapper/pmapper_gpp/map.phtml](http://webgrs.wur.nl/cgi/projects/sensorweb/pmapper/pmapper_gpp/map.phtml)
Metadata and standards

- Technical Specifications for Collecting, Processing, Storing, and Disseminating Data and Products
- Transparency and reproducibility
- For EO data combined standards for metadata and exchange (e.g., HDF)
Digital Image Data Formats

- Increasing amounts of data, effective storage required
- Web-based access
- Storage devices: tapes or optical disks (cd or dvd)
- Compaction

- Common formats (based on ordering of 3 data dimensions):
  - Band SeQuential (BSQ)
  - Band Interleaved by Line (BIL)
  - Band Interleaved by Pixel (BIP)
  - Run-length encoding
NASA – Google partnership

- Memorandum of understanding (sept. 2005)
- NASA’s strength: scientific exploring, massive amount of information, however for small group of people
- Google’s strength: indexing, distributing, organizing information, large community
- Earth: Google Earth & NASA World Wind
- What’s next: Moon Mineralogy Mapper (M³) and Google Moon
EO in a Sensor Web

- Sensor web: online availability of sensor data:
  - *in situ* sensors
  - RS sensors
- Characteristics:
  - (wireless) communication layer
  - Near real time access

*In Situ Sensor Measurement Assimilation Program (ISSMAP) (Teillet, 2002)*
EO-1/Terra/Aqua Sensorweb Demo Scenario
(Source: NASA EO-1 Mission)

EO-1 is notified and autonomously replans to take a closer look.

1. Science Goal Monitor (SGM) WS
   - High Level Goal: When MODIS detects a forest fire within XX area, take a closer look with EO-1 Hyperion and/or ALI.

2. Request forest fire alert within XX area.

3. Terra/Aqua images wide swath w/MODIS
   - CASPER replans EO-1 tasking by calculating times, slews and momentum management; and sends appropriate real-time commands to C&DH system to execute plan.

4. Downlink Images
   - E-Mail alert within 3 hrs of image acquisition with forest fire lat/lon.

5. Image target
   - Request & coordinated images from EDC & DAAC.

6. Target Lat/Long
   - Automatically coordinate with MOC on following activities:
     - Convert lat/lon to WR8
     - Create LTAP record
     - Calculate ALI frame rate
     - Priority scheme
     - Reformat for ingestion by CASPER (onboard planning)
     - Create and transfer load to ASIF

7. Downlink Images via direct broadcast

8. USGS ERD3 Data Center (EDC)
   - "Rapid-Fire" Workstations

9. MODIS Instrument Center
   - 8/10 Load w/ Lat/Long
## Current developments in EO products and services

- Automated preprocessing and archiving facilities (PAF)
- Development of standards for metadata and data exchange formats (e.g., HDF)
- Use of common and advanced (e.g., smile correction) preprocessing techniques
- Increased attention for product quality assessment and documentation
- Processing on demand (e.g., disaster monitoring)
- Real time integration of EO data in models
- Range from data – product – application – decision support tool
- Requirement: reliable infrastructure: hardware and network
Weblinks

- And many others
Study material

- Read: section 6.18 of Lillesand & Kiefer
- Exercise: from reader exercise 3: EO data search for land use monitoring