The Crew Earth Observations Experiment: Earth System Science from the ISS

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Overview

- **The Data**
  - Basic Remote Sensing Theory
  - Astronaut Photography Data Characteristics

- **Astronaut Training and Operations**
  - Crew Earth Observations Group
  - Targeting Sites and Acquisition
  - Cataloging and Database

- **Analysis and Applications for ESS**
  - Image Analysis
  - Urban Areas, Megafans, Deltas, Reefs

* all images in this presentation courtesy of NASA unless otherwise noted*
**Basic Theory**

- Earth’s atmosphere defines “windows” useable for remote sensing
- Different information is obtained using different wavelengths
- Most sensors are passive (radar and LIDAR are active)
- Information obtained is directly related to material chemistry and physics

**Electromagnetic Spectrum**

```
<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>10^6</td>
<td></td>
</tr>
<tr>
<td>10^5</td>
<td></td>
</tr>
<tr>
<td>10^4</td>
<td></td>
</tr>
<tr>
<td>10^3</td>
<td></td>
</tr>
<tr>
<td>10^2</td>
<td>410-440 nm</td>
</tr>
<tr>
<td>10^1</td>
<td>440-540 nm</td>
</tr>
<tr>
<td>10^0</td>
<td>540-650 nm</td>
</tr>
<tr>
<td>10^-1</td>
<td>650-770 nm</td>
</tr>
<tr>
<td>10^-2</td>
<td>770 nm</td>
</tr>
</tbody>
</table>
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Speed of light \( c = 299,792,458 \text{ m/sec} \)

Frequency \( = \frac{c}{\text{wavelength}} \)
• Incident energy is reflected, transmitted, or emitted from surficial materials, water, and atmosphere (clouds, dust); sensor sees mixture of energy from multiple surface materials and atmosphere

• For passive systems, information is obtained from only the uppermost surface (~130 microns); no depth profiles!
Data Characteristics

- AP acquired since 1960s as part of Apollo, Skylab, Mir, Shuttle, and ISS missions

- System response for current Kodak 760 Digital Still Camera (DSC) is comprised of CCD response, optical filters (NIR) and transmissivity of ISS window

- 3060 x 2036 pixel CCD, RGBG array

- Response curves exhibit significant band overlap below 60 % incident energy

- Predicted maximum resolution approaching 4 m/pixel recently observed in image of Munich airport

### Station Altitude

<table>
<thead>
<tr>
<th>Camera</th>
<th>Lens (mm)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hasselblad</td>
<td>110</td>
<td>35.4</td>
<td>37.1</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>15.6</td>
<td>16.3</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>11.1</td>
<td>11.6</td>
</tr>
<tr>
<td>Nikon</td>
<td>300</td>
<td>13.0</td>
<td>13.6</td>
</tr>
<tr>
<td></td>
<td>400</td>
<td>9.7</td>
<td>10.2</td>
</tr>
<tr>
<td>DSC</td>
<td>300</td>
<td>11.0</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>400</td>
<td>8.3</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>4.2</td>
<td>4.4</td>
</tr>
</tbody>
</table>
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**Crew Earth Observations (CEO)**

- Science and operations team based at NASA Johnson Space Center; currently tasked with performance of Crew Earth Observations experiment payload aboard the ISS.

- Provide astronaut training for specific science objectives (includes urban areas, ecological monitoring sites, glaciers, deltas, megafans, internal waves, impact craters, atmospheric phenomena).

- Download and cataloging of images for entry into database, curation of astronaut photography database.

- Distribution of data to collaborating scientists and performance of research.


- Gateway to Astronaut Photography of Earth (http://eol.jsc.nasa.gov) provides free access to data.

- Astronaut photography will be featured in upcoming Google Earth release of NASA data.
Payload Workflow

Crew Training

- Astronauts and cosmonauts are given briefing on science objectives and photographic technique by CEO scientist prior to Expeditions

Operational Summary

- Lenses/orientation
  - 50 mm or 180 mm for general context images
  - 250 mm or 600 mm (not zoom lens) may be requested for point locations within specific sites
  - ISS/site area of interest intersection time and coordinates; descriptive text and specific photographic instructions; and supporting data formatted into CEO Target List message

Slide excerpts from CEO “Long Term Ecological Research” crew briefing.

Mission Operations

- Daily determination of potential CEO LTER target visibility using ISS orbit ephemeris data
- Screening of potential target list by crew activity schedule, sun elevation, ISS orientation (determines nadir versus oblique imagery)
- Predicted cloud cover (24 hrs. out) favorable?
  - YES
    - ISS/site area of interest intersection time and coordinates; descriptive text and specific photographic instructions; and supporting data formatted into CEO Target List message
  - NO
    - CEO Target List message reviewed by Operations Controller and Payload Operations Director; uploaded to crew prior to waking

Image Database

- Geographic center coordinates and descriptive metadata are determined for each image by CEO staff using georeferenced remotely sensed data and maps.
- Images are then added to the online searchable astronaut photography database “Gateway to Astronaut Photography of Earth”: http://eol.jsc.nasa.gov.
- Online database can be searched by geographic coordinates, date/time, mission, keyword, illumination and look angle parameters, lenses, etc. using Technical Search tools (left) @ http://eol.jsc.nasa.gov/sseop/sql.htm.
- Query results include links to full metadata for each image (right). Images can be downloaded at full resolution free of charge.
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ASTER-Astronaut Photography (AP) Image Comparison, Paris, France

Methodology

1) AP registered to ASTER L1B data using 4th order polynomial (RMS = 0.002)

2) Supervised classification of AP using visually-defined vegetated and non-vegetated classes

3) AP/ASTER DN comparison points obtained for each class using classified results; at least 30 points taken for each class, distributed throughout image area

4) Correlation analyses performed for various AP/ASTER band combinations

Field Validation Methodology

• 15 points inclusive of all visual AP classes selected in Paris area using AP image
• Field visits to points to observe and record:
  - dominant vegetation type and phenology
  - if fallow field, presence/absence of plant material, bare soil color
  - degree of surface soil moisture
Image Classes

<table>
<thead>
<tr>
<th>AP Visual Image Class</th>
<th>ASTER Land Cover Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow (Y)</td>
<td>Vegetation, high productivity</td>
</tr>
<tr>
<td>Dark Green1 (DG1)</td>
<td>Vegetation, moderate to low productivity</td>
</tr>
<tr>
<td>Dark Green2 (DG2)</td>
<td>Vegetation, non-canopied</td>
</tr>
<tr>
<td>Tan (T)</td>
<td>Bare Soil</td>
</tr>
<tr>
<td>Olive1 (O)</td>
<td>Sparsely vegetation soil</td>
</tr>
<tr>
<td>White (W)</td>
<td>Light-colored soils and built materials</td>
</tr>
</tbody>
</table>

0 4 km
Paris, France metropolitan area acquired April 2002; Photograph ISS004-E-10414
Class O                Class DG1    Class T

Class Y                              Class Y

“colza” (*Brassica napus* L. var. oleifera)?

Group 4 - Field Photographs
(Ozoir-la-Ferrière)
Use of astronaut photography for urban ecological LU/LC classification

Object-oriented approach compensates for relatively low spectral information content of data, takes advantage of high spatial information content.
Use of astronaut photography for urban ecological LU/LC classification

Object-oriented approach compensates for relatively low spectral information content of data, takes advantage of high spatial information content

Object-Oriented Classification
Phoenix, AZ

ASTER-based visible-near infrared expert system classification
Coral Reef Mapping and Monitoring

- Coral reefs are sensitive indicators of ecosystem health in shallow marine areas.

- CEO collecting time-series data for reefs around the world; contributor to Reefbase online database.

- Blue and green bands can be used to obtain quantitative estimates of water depths by using spectral attenuation with depth (left).

- Astronaut photography also useful to augment cloud-covered satellite imagery in time-series analysis.

Pearl and Hermes Reefs, Hawaii; 400 mm lens.
Coral Reef Mapping and Monitoring

Nukuoro Atoll, Federated States of Micronesia; 800 mm lens
**Deltas**

Yellow River delta changes 1976 - 2003

1989-2000
build out of \( \approx 400 \text{ km}^2 \)
erosion of \( \approx 250 \text{ km}^2 \)

- host wetlands important for storm surge protection and surface/groundwater purification
- critical habitat for numerous estuarine, oceanic, and migratory flora and fauna
- significant component of local economies from fishing and recreational use
- deltas worldwide under stress from land use change, sea level rise, and upstream dams
Megafans

- mean radius 100 - 300 km
- areas from 7000 - 200,000 km²
- river-made
- 96 probable fans identified at present
- fan-shaped, cone of sediment (convex contour elevation lines)

- Kosi River avulsions—
  - cross entire surface of fan
  - average rate ~19 yr between switching events
- Slowest switching rate encountered is > 30,000 yr between switching events

Kosi R. fan, India
Mechanisms for fish speciation based on megafan model

- **River switching** leads to —
  - division of single fish populations
  - connection of minor and major watersheds

- **Climate change**, common on old large fans, leads to —
  - break up of river systems
  - consequent dividing of single fish populations

- **Avulsion/incision** process —
  - also applicable to petroleum exploration
  - exploration technique using astronaut photography patented
**International Polar Year (IPY)**

- Goal is to study polar regions and their role/interaction with ongoing global climate change
- ISS crew targets include aurora, polar clouds, plankton blooms, sea ice, glaciers, and volcanoes
- CEO collaborating with IPY scientists to coordinate observations with field campaigns, and make data quickly available through our web site
Selected References


