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

William L. Stefanov[1]
Cynthia A. Evans[1]
Julie A. Robinson[2]
M. Justin Wilkinson[1]

[1]Image Science & Analysis Laboratory
[2]Space Station Payloads Office
NASA Johnson Space Center
Houston, TX 77058 USA

william.l.stefanov@nasa.gov

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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

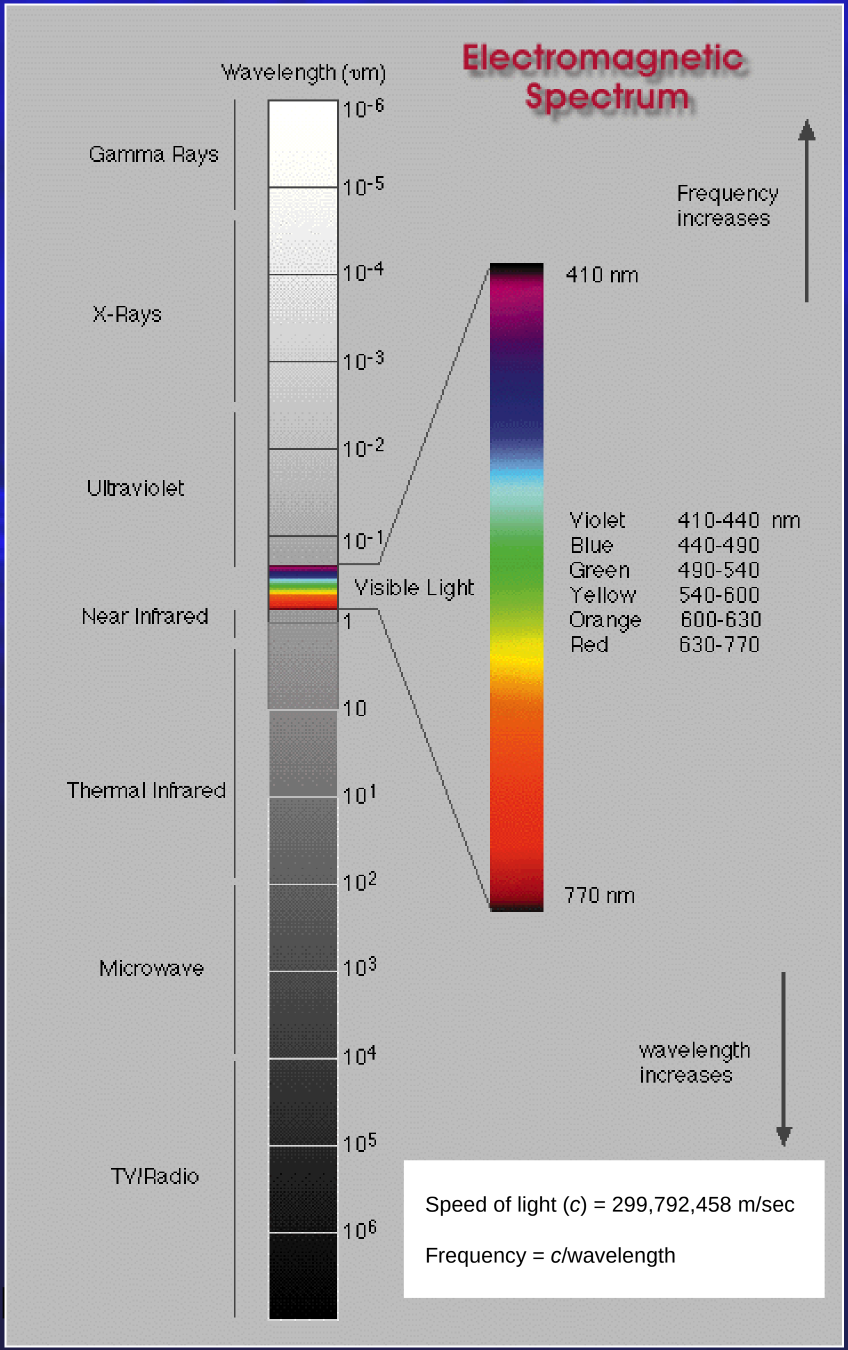
- Analysis and Applications for ESS
  - Image Analysis
  - Urban Areas, Megafans, Deltas, Reefs


ISS013-E-13263

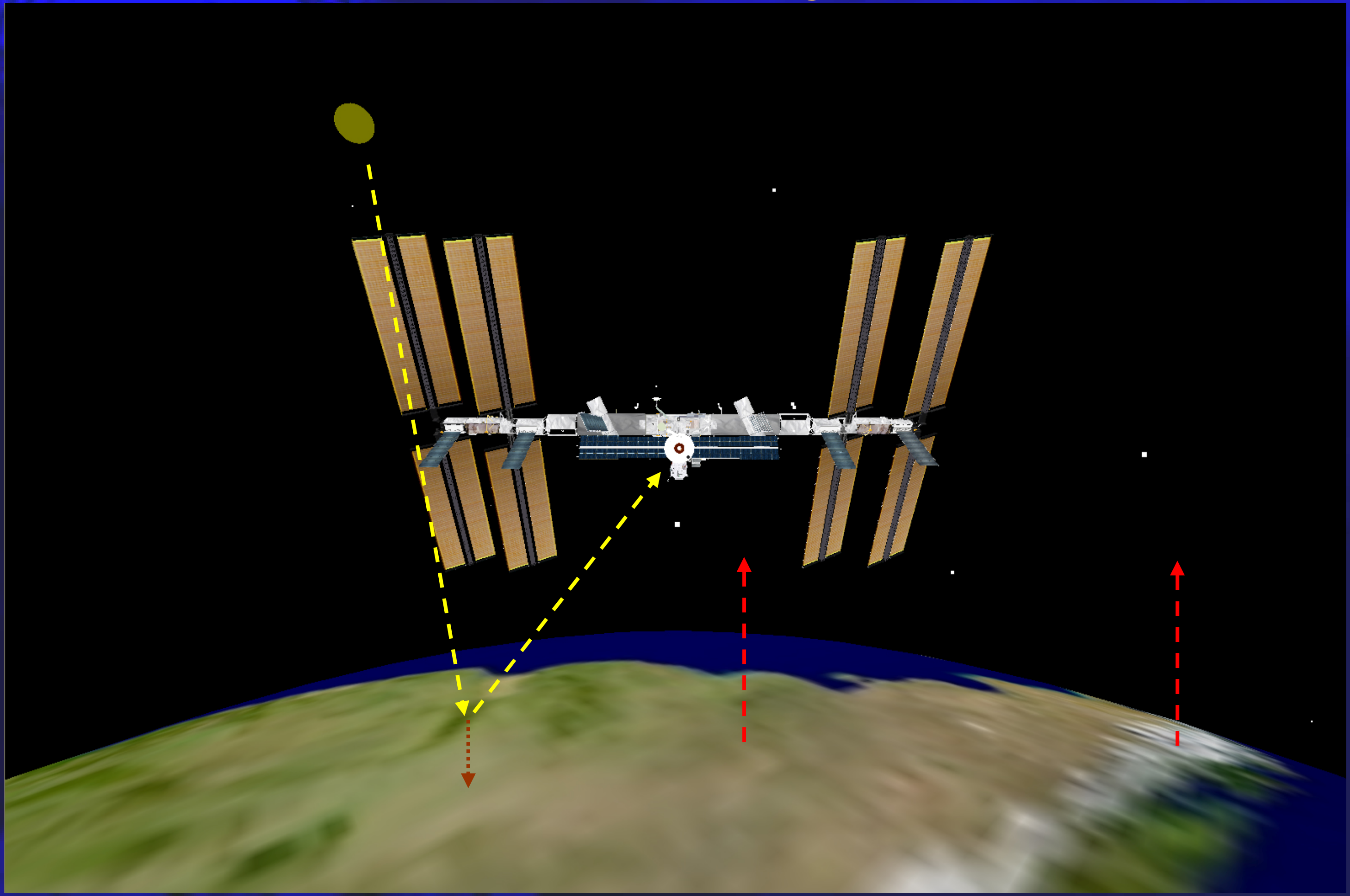
* all images in this presentation courtesy of NASA unless otherwise noted*

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

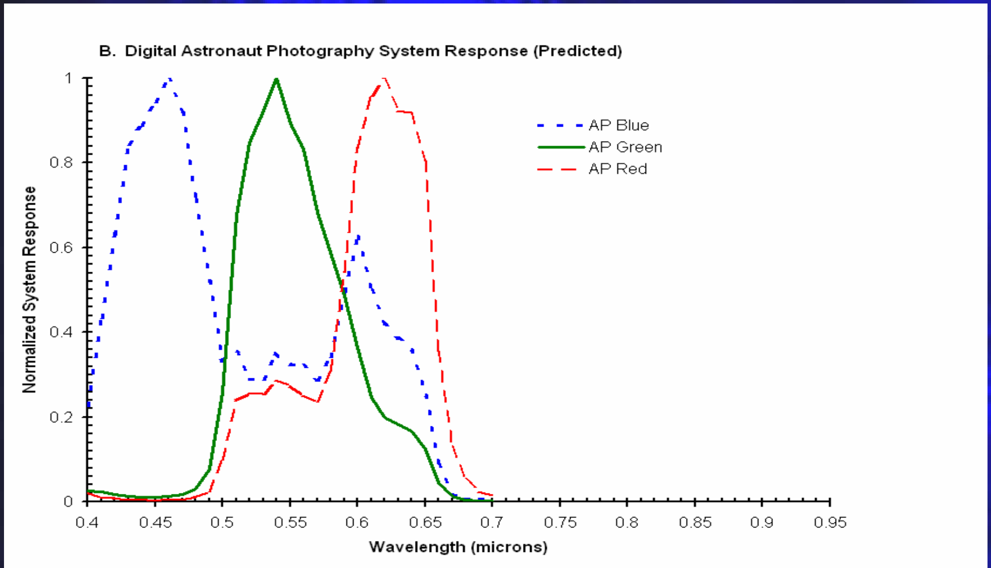


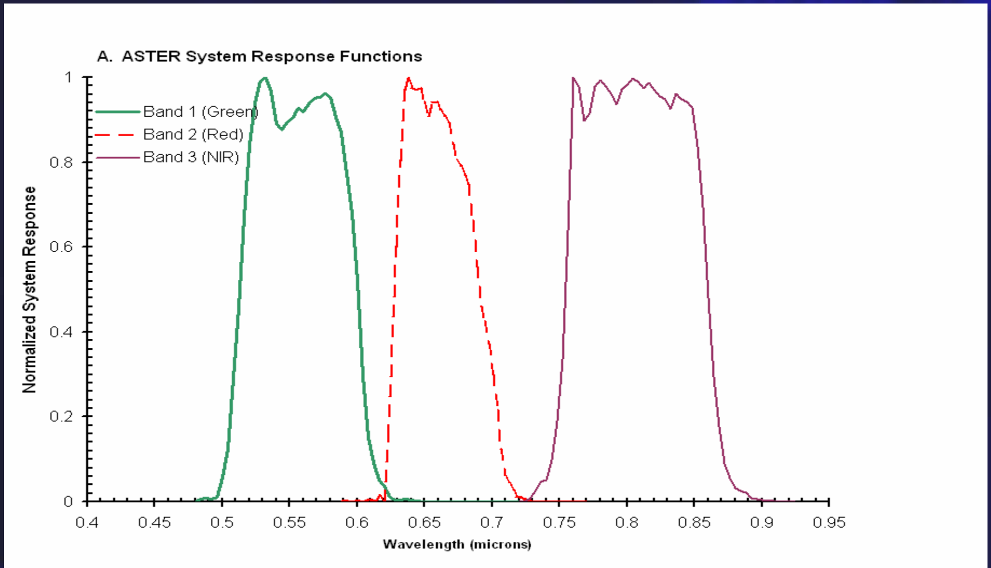
Basic Theory



- 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!

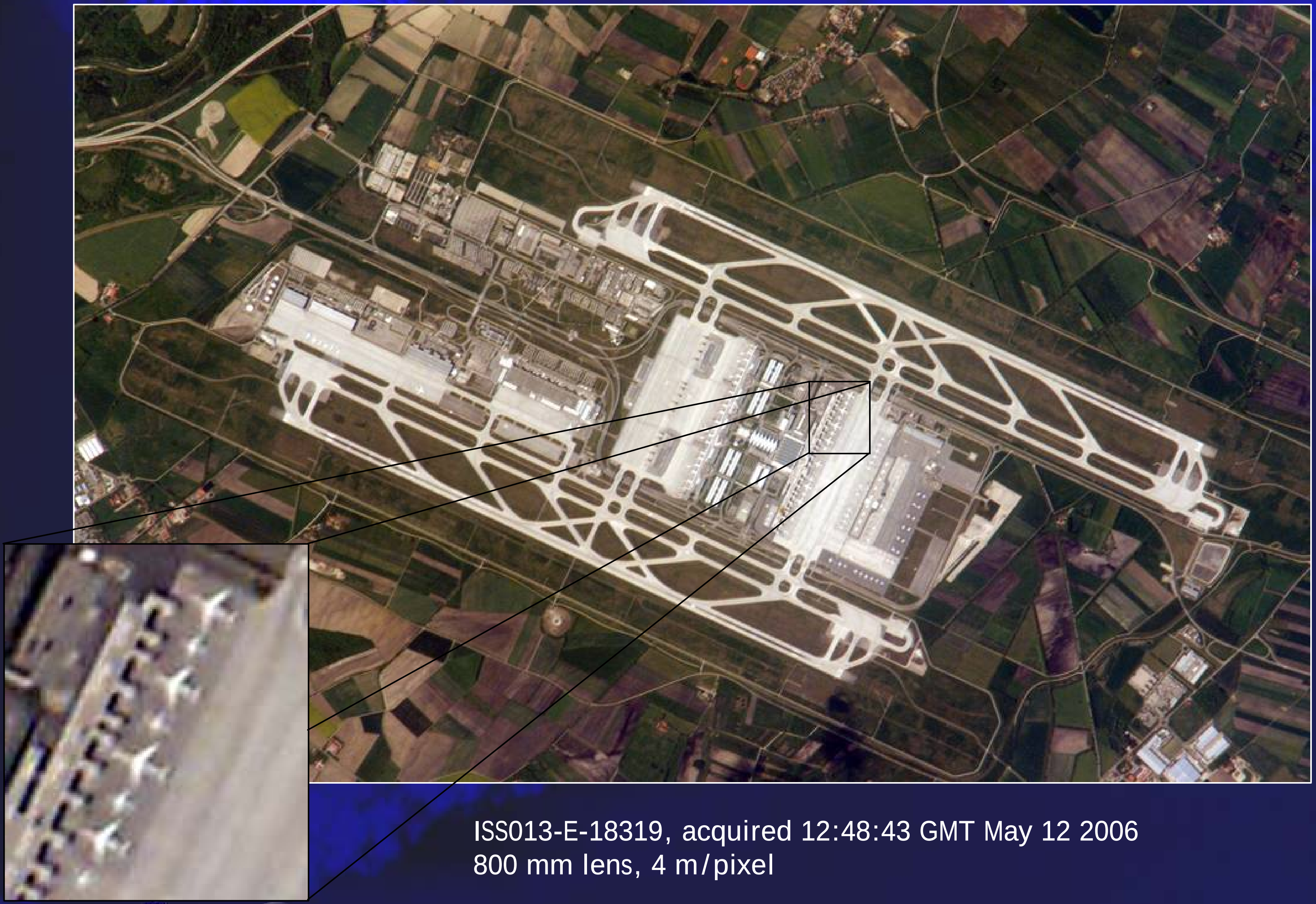
Data Characteristics





- 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	
		Minimum	Maximum
Camera	Lens	368 km	386 km
Hasselblad	110 mm	35.4	37.1
	250 mm	15.6	16.3
	350 mm	11.1	11.6
Nikon	300 mm	13.0	13.6
	400 mm	9.7	10.2
DSC	300 mm	11.0	11.6
	400 mm	8.3	8.7
	800 mm	4.2	4.4



ISS013-E-18319, acquired 12:48:43 GMT May 12 2006
800 mm lens, 4 m/pixel

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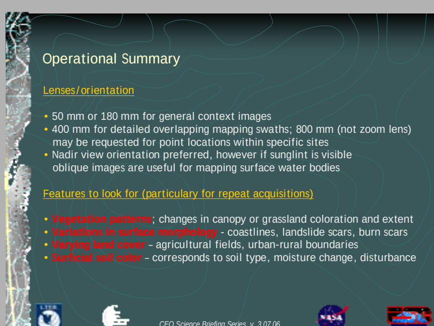
Crew Earth Observations (CEO)

- 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
- Educational outreach (NASA Earth Observatory, Public Affairs Office, NASA Hurricane Resource web site)
- 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



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?

NO (return to screening)

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

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

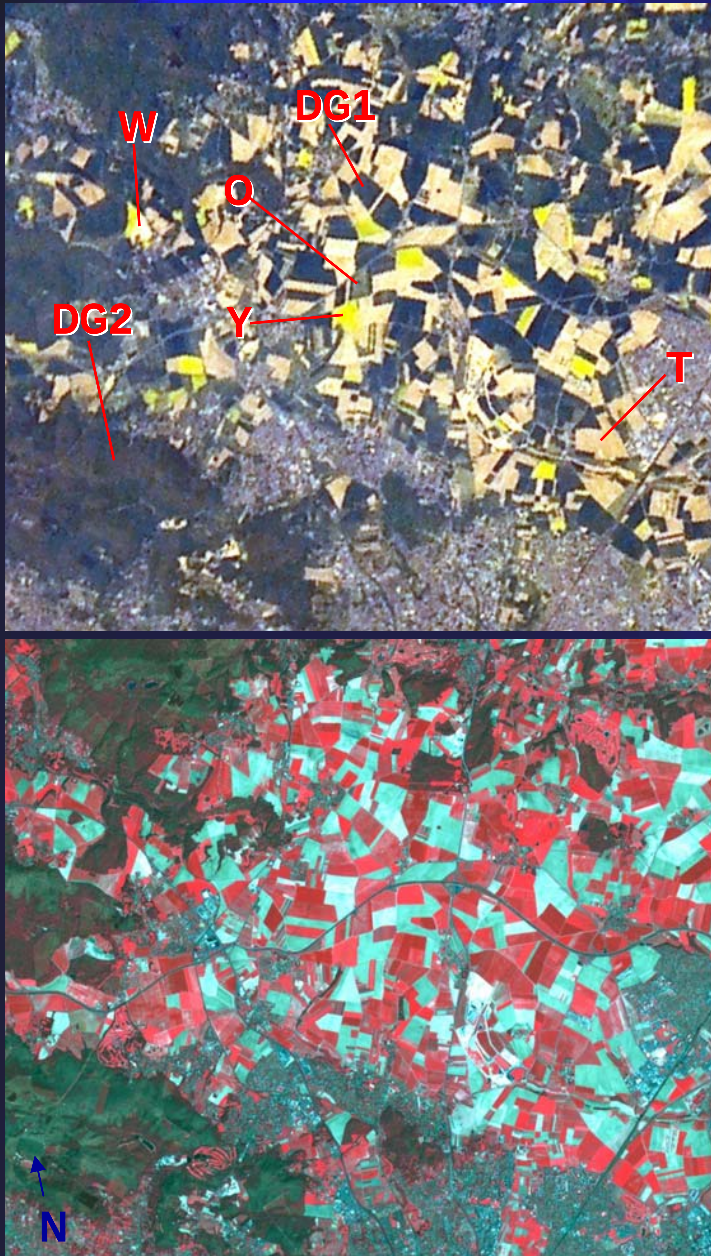
3) AP/ASTER DN comparison points obtained for each class using classified results; at least 30 points taken for each class, distributed throughout image area

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

Field Validation Methodology

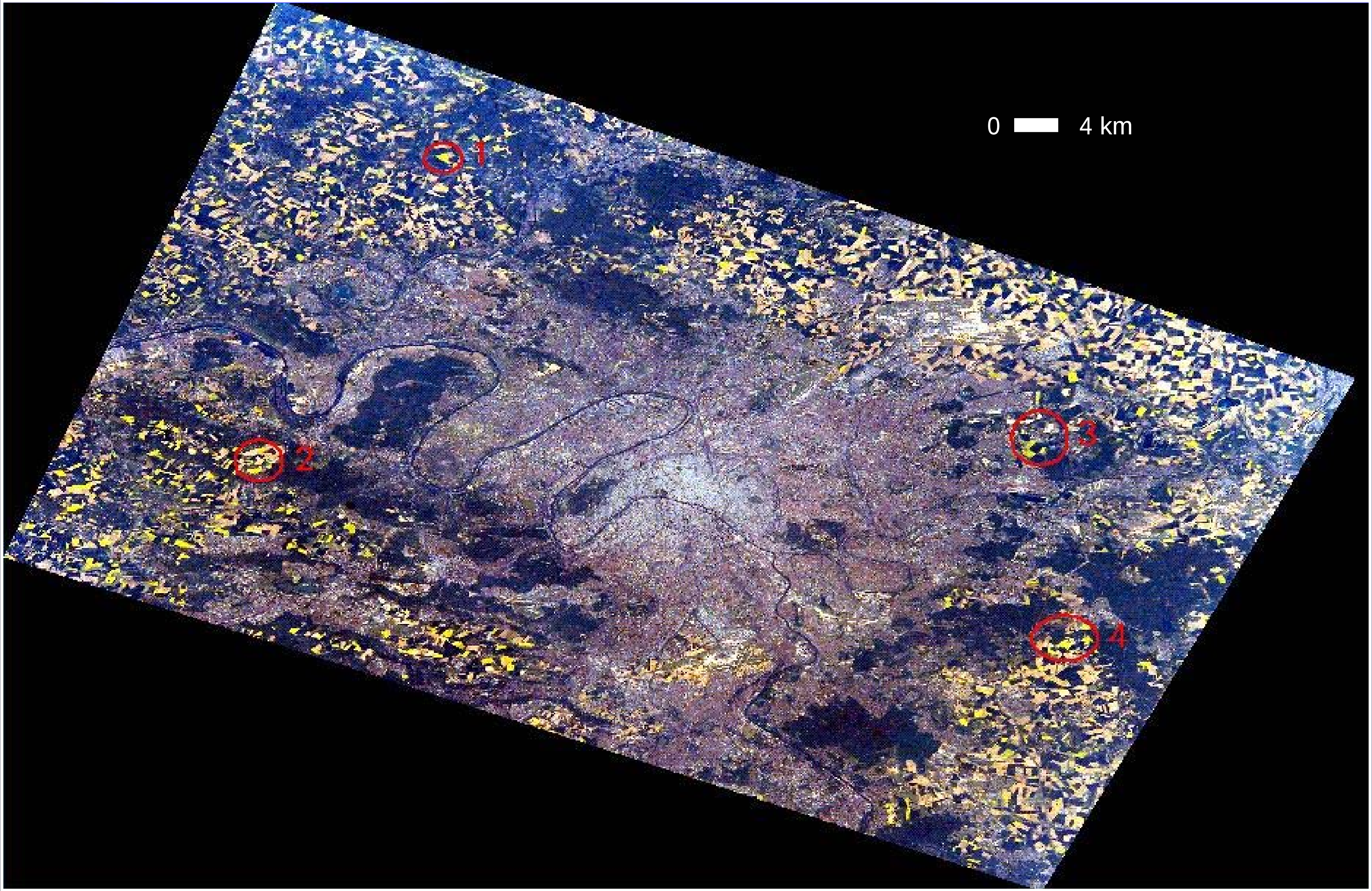
- 15 points inclusive of all visual AP classes selected in Paris area using AP image
- Field visits to points to observe and record:
  - dominant vegetation type and phenology
  - if fallow field, presence/absence of plant material, bare soil color
  - degree of surface soil moisture

Image Classes



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

0 4 km



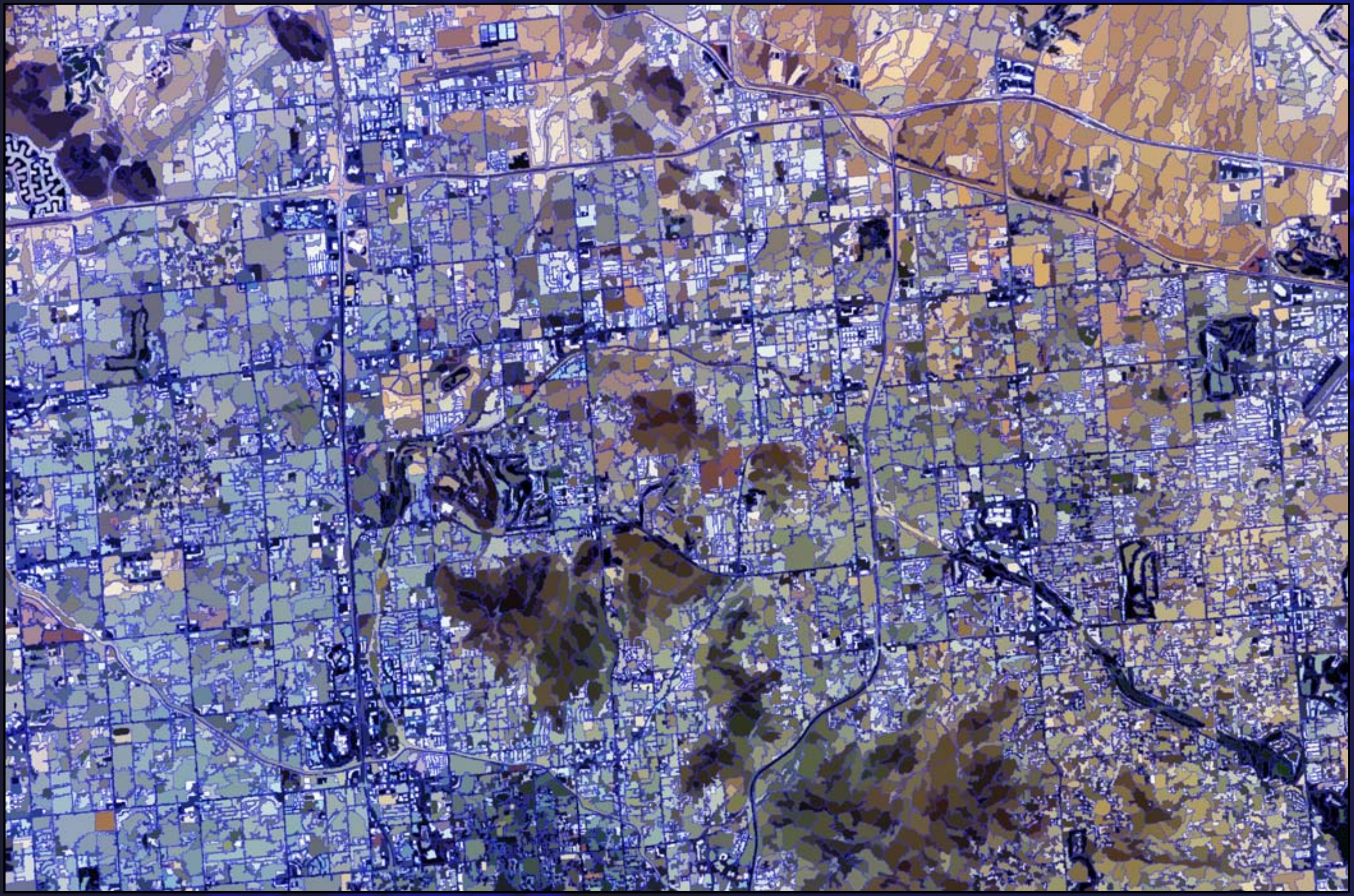
Paris, France metropolitan area acquired April 2002; Photograph ISS004-E-10414

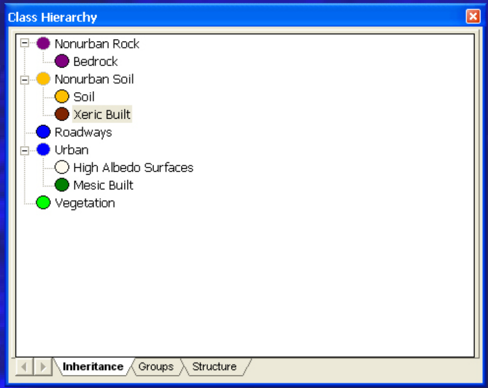
Group 4 – Field Photographs (Ozoir-la-Ferrière)

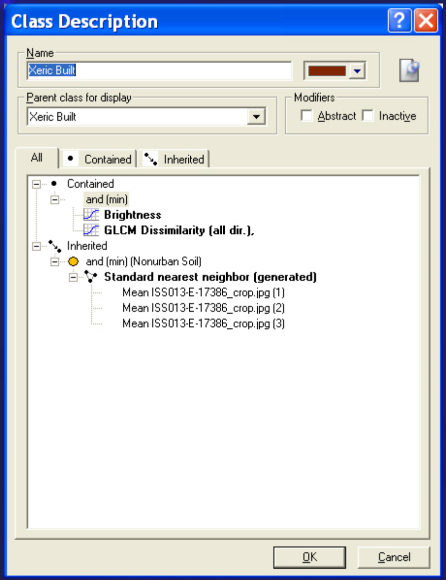
“colza” (*Brassica napus* L. var. oleifera)?

Object-Oriented Classification Phoenix, AZ

- 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





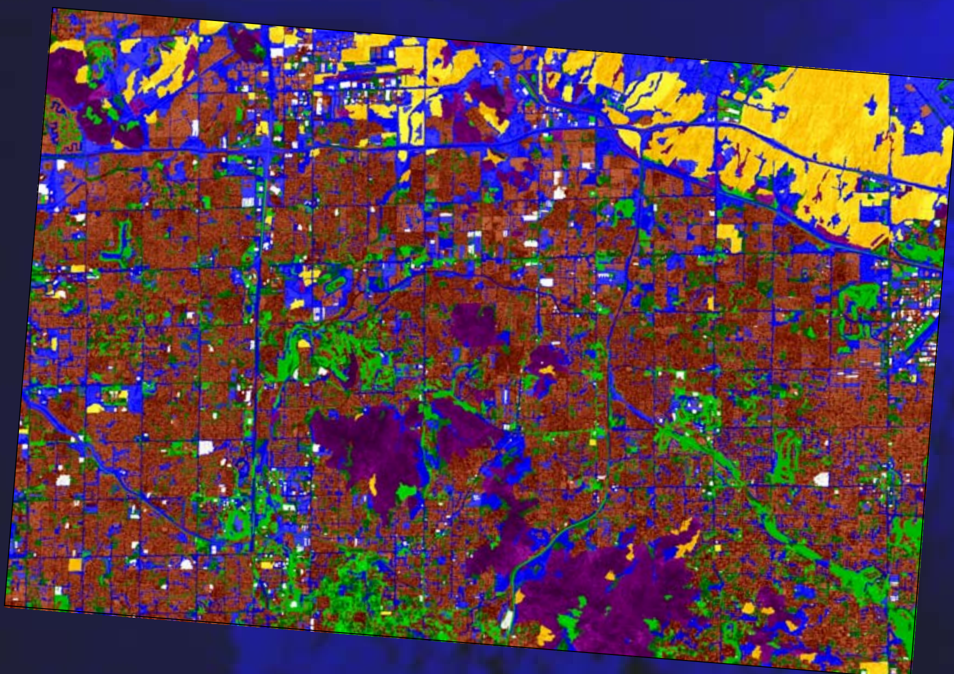


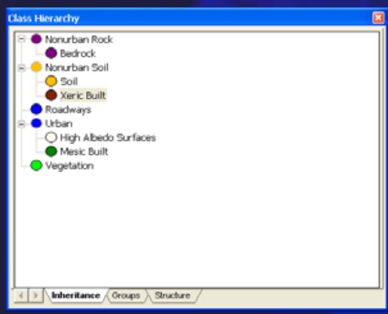
ISS013-E-17836

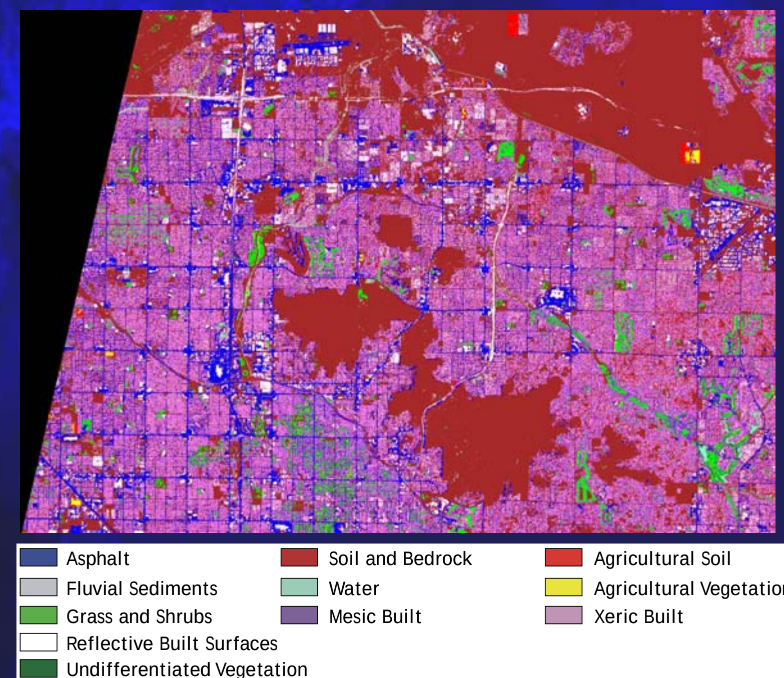
Segmentation Level 0

Object-Oriented Classification
Phoenix, AZ

- **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**

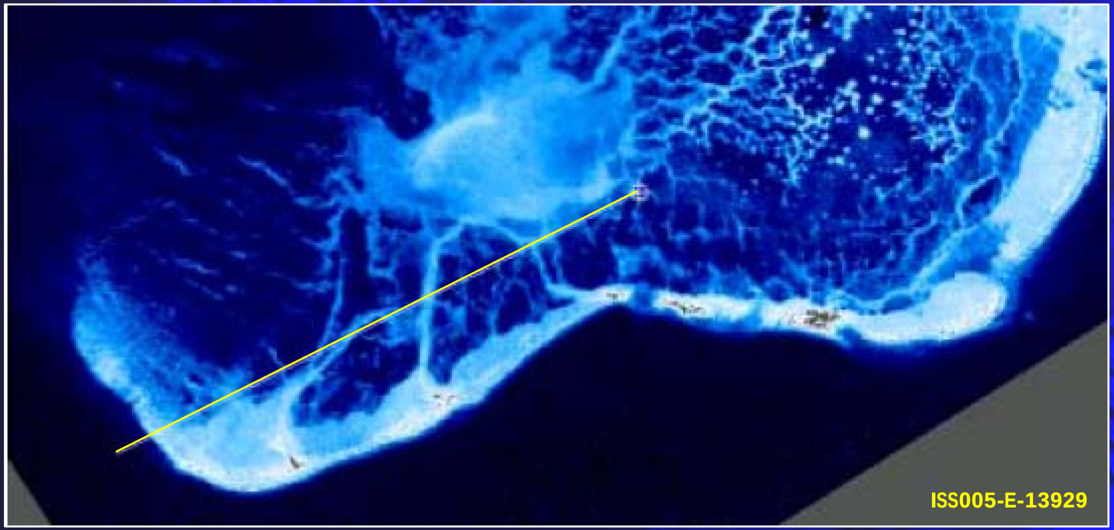




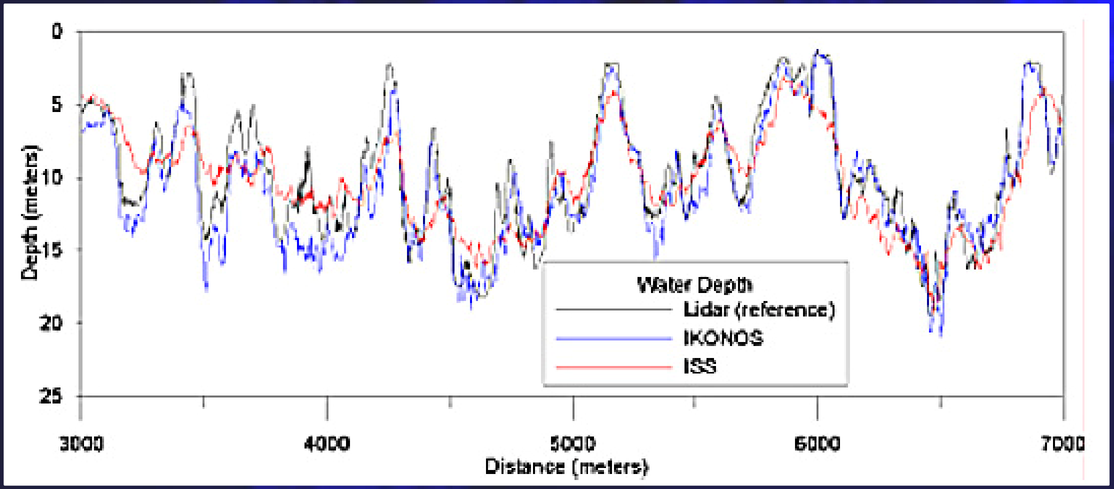


ASTER-based visible-near infrared expert system classification

Coral Reef Mapping and Monitoring



Pearl and Hermes Reefs, Hawaii; 400 mm lens

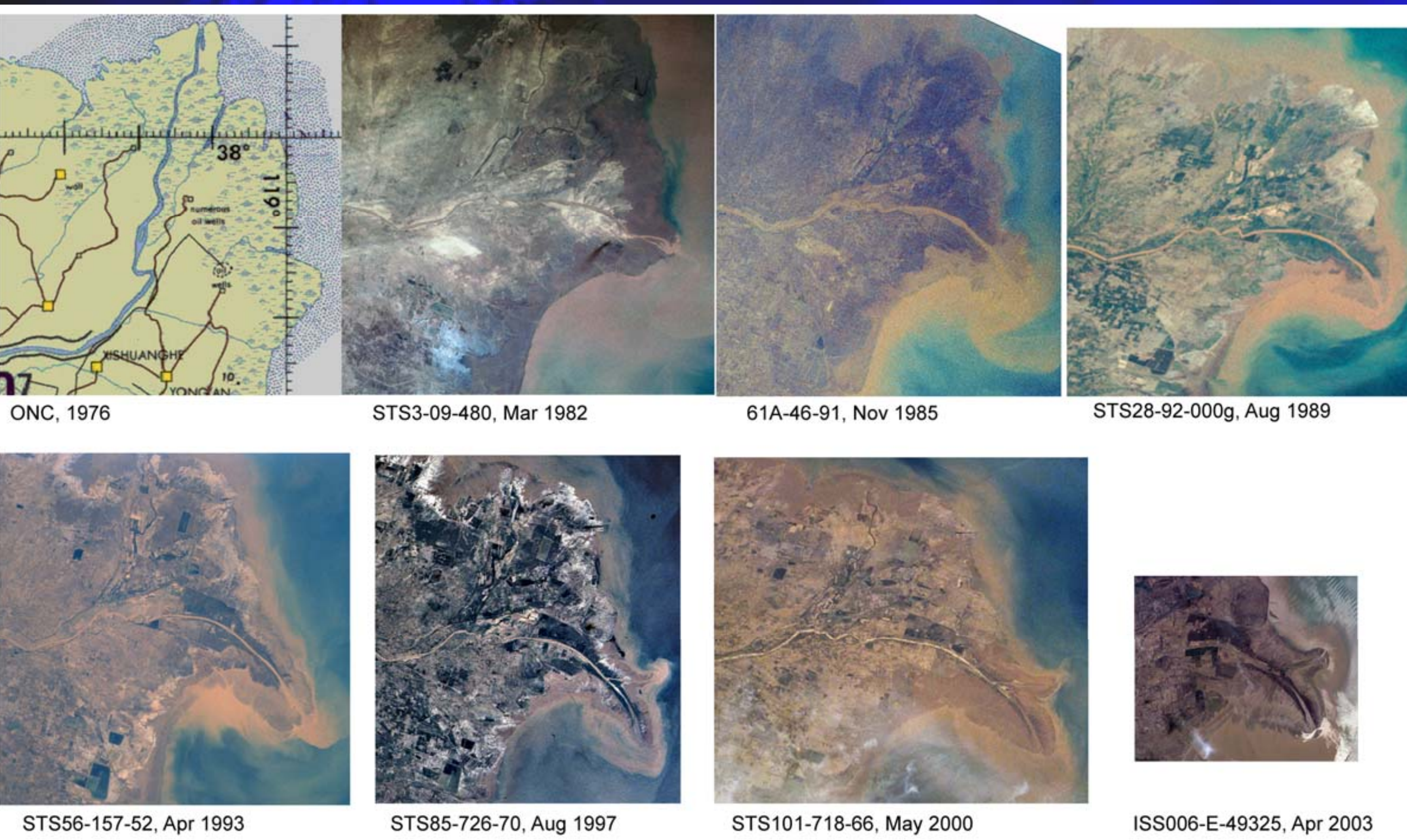


- Coral reefs are sensitive indicators of ecosystem health in shallow marine areas
- CEO collecting time-series data for reefs around the world; contributor to *Reefbase* online database
- Blue and green bands can be used to obtain quantitative estimates of water depths by using spectral attenuation with depth (left)
- astronaut photography also useful to augment cloud-covered satellite imagery in time-series analysis

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 ~400 km^2
erosion of ~250 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 km^2
- river-made
- 96 probable fans identified at present
- fan-shaped, *cone of sediment (convex contour elevation lines)*

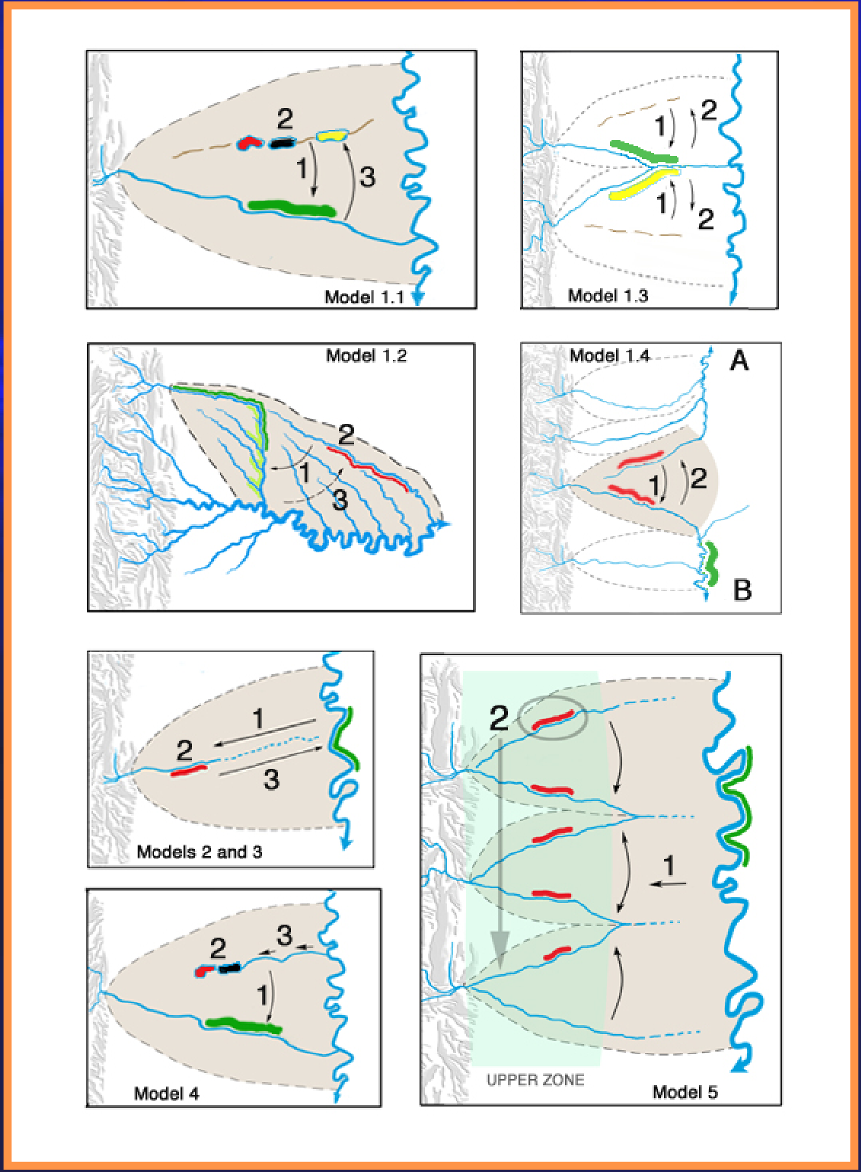
- Kosi River avulsions—
  - cross entire surface of fan
  - average rate ~19 yr between switching events
- Slowest switching rate encountered is > 30,000 yr between switching events

Okavan
R. inla
del
Botswa

Kosi R. fan, India

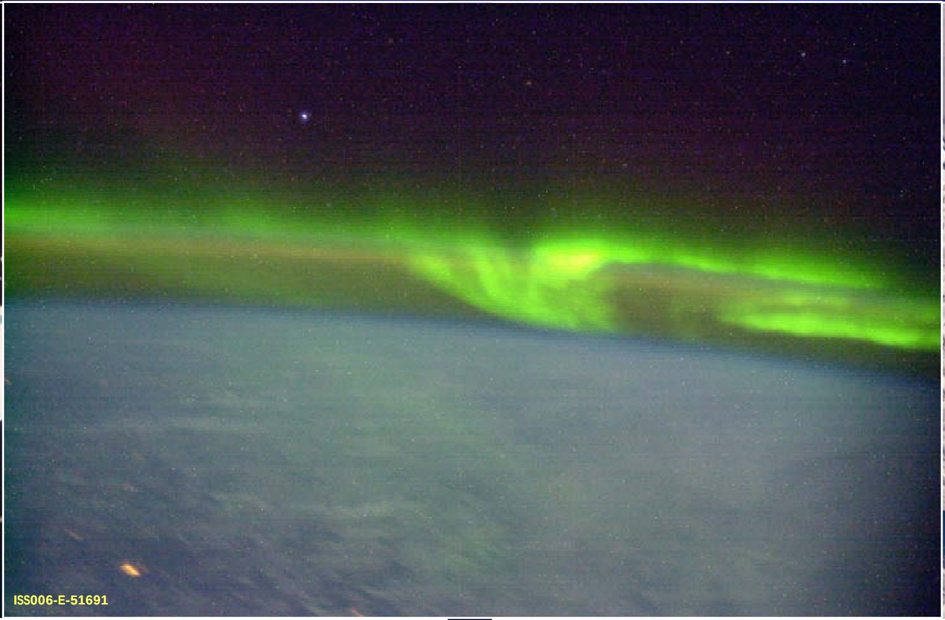
Mechanisms for fish speciation based on megafan model

- *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



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