The HICO-RAIDS Experiment Payload Mission (HREP)

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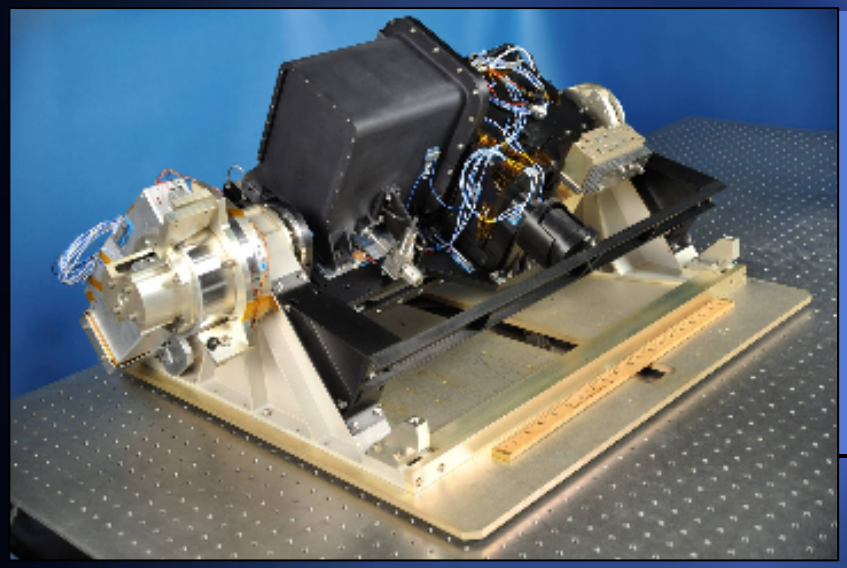
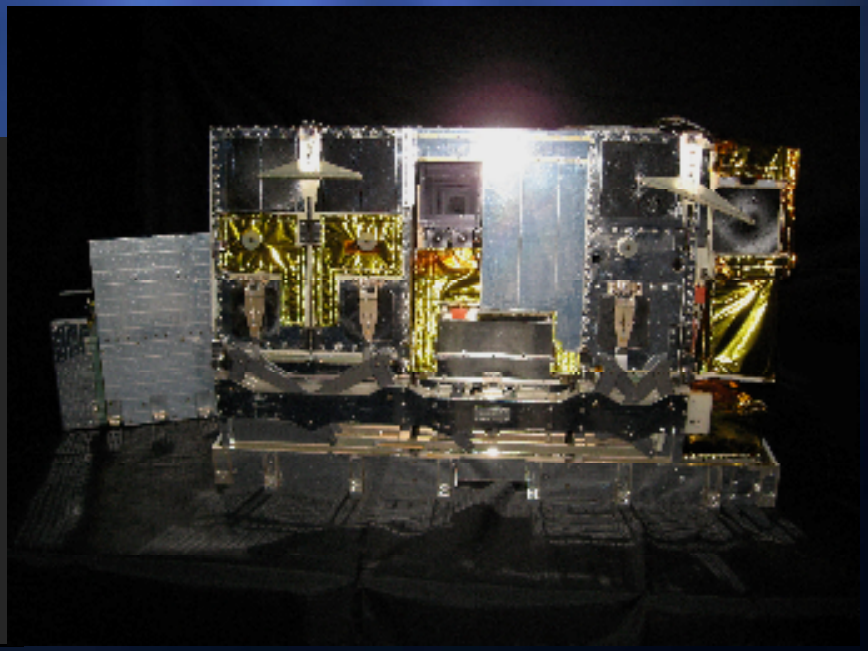
Two Hyperspectral Experiments

- Two Naval Research Laboratory science experiments



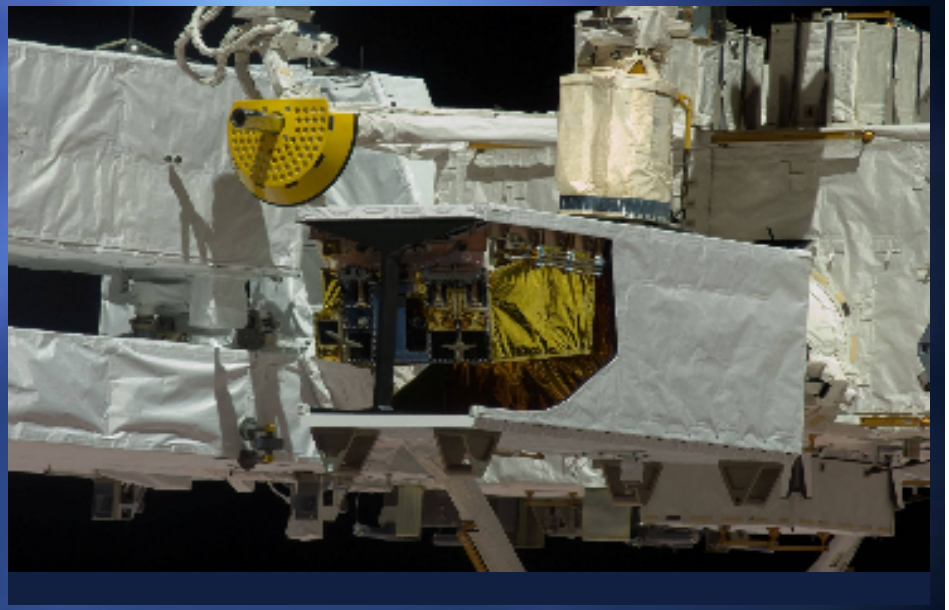
- Hyperspectral Imager for Coastal Ocean (HICO)
  - Innovative prototype mission using COTS components to demonstrate hyperspectral coastal imaging from space

- Remote Atmospheric and Ionospheric Detection System (RAIDS)
  - First EUV/FUV atmospheric remote sensing experiment aboard ISS

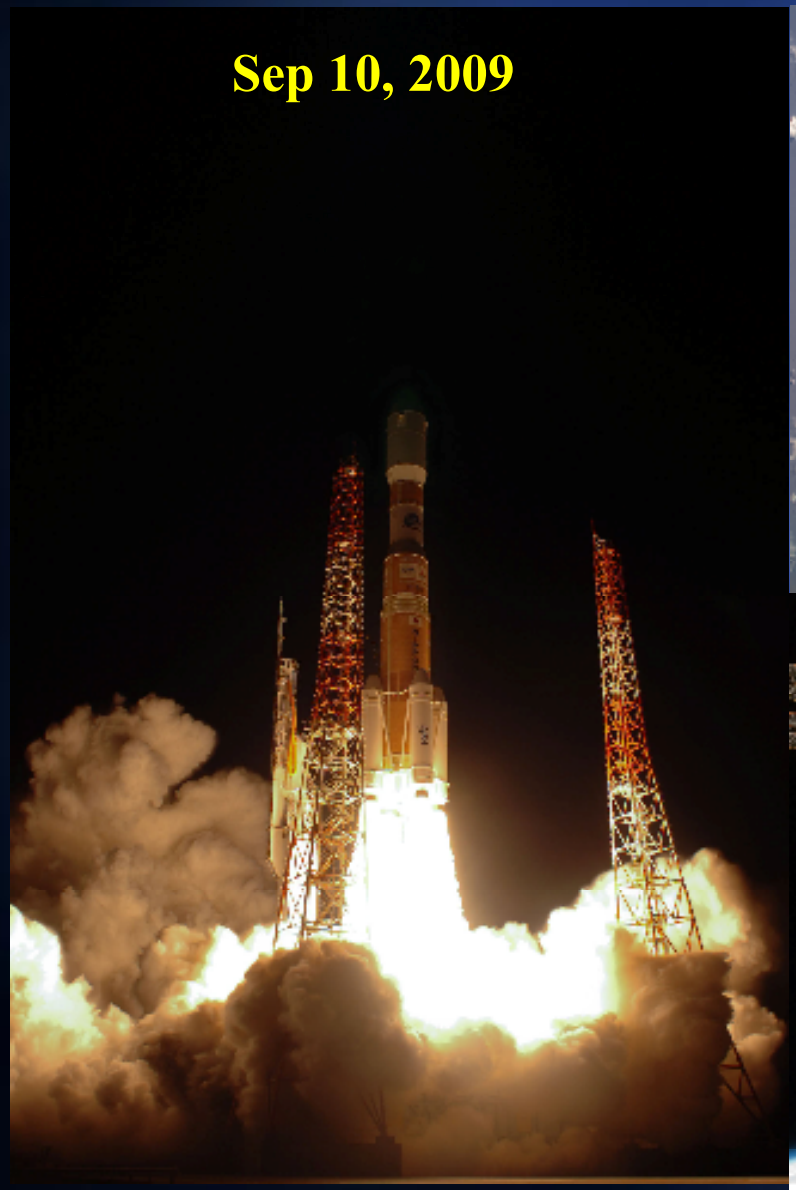


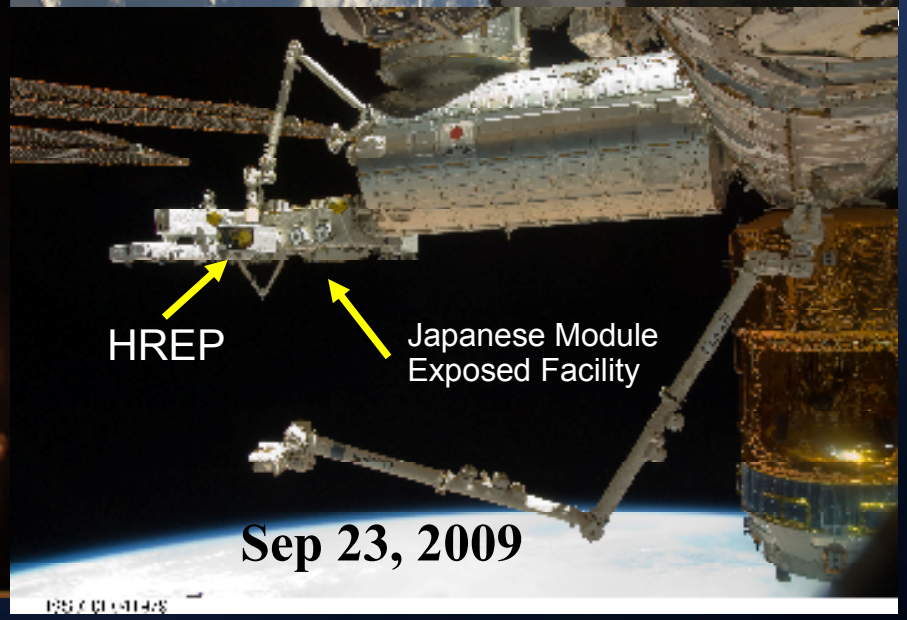
The HREP Mission

- HICO and RAIDS were integrated, flown, and operated on the ISS through the US DoD Space Test Program and NASA
- Program kick-off March 30, 2007
  - Deliver flight-ready experiment in 18-months
    - Significant schedule/budget constraints
  - Demonstration flight of H-IIB rocket and HTV
  - First US Payload to JEM-EF
    - Integration process not fully defined; Contamination environment not well known; Attitude performance loosely constrained for a typical remote sensing science mission



Launch & Installation

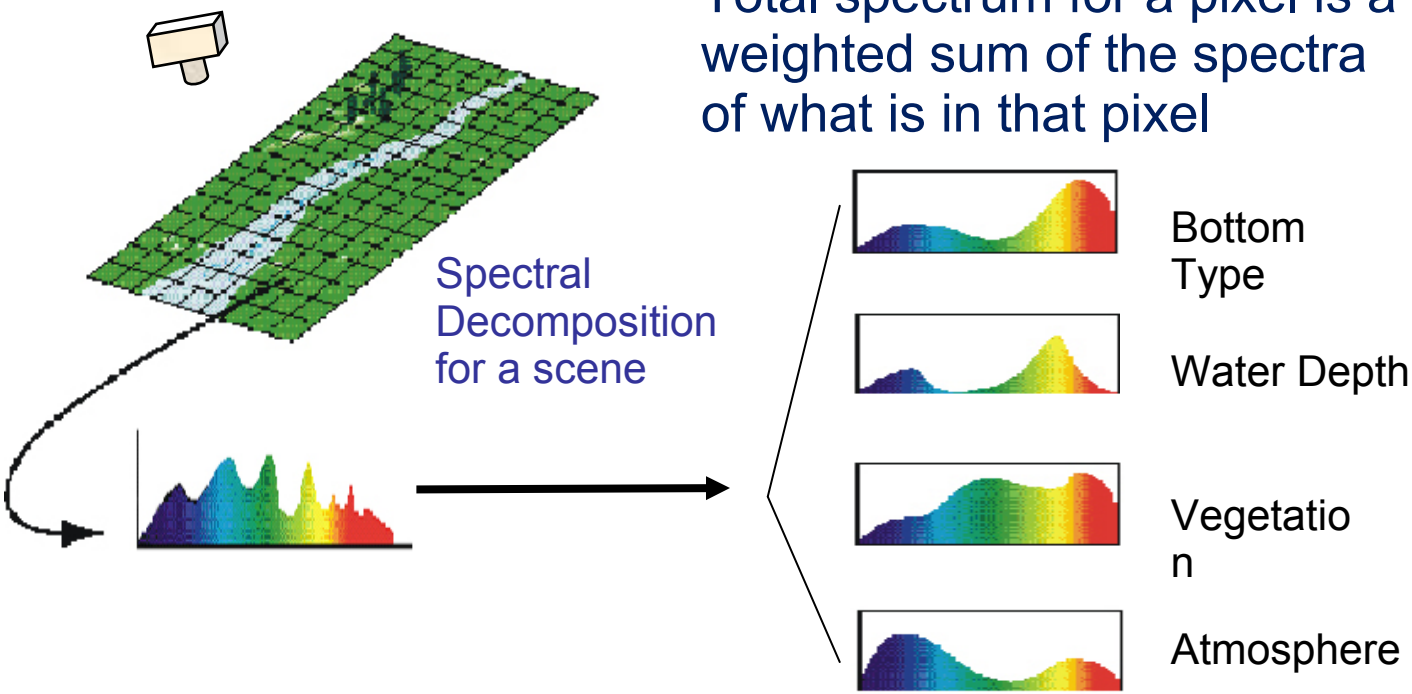




Introduction to Hyperspectral Imaging

- Hyperspectral imagery uses more channels than R-G-B color imaging
- A hyperspectral imager records a spectrum of the light from each pixel in the scene
- Hyperspectral image analysis exploits this extra spectral information

Total spectrum for a pixel is a weighted sum of the spectra of what is in that pixel



The imager and method of exploitation must be tailored to the scene and the desired products.

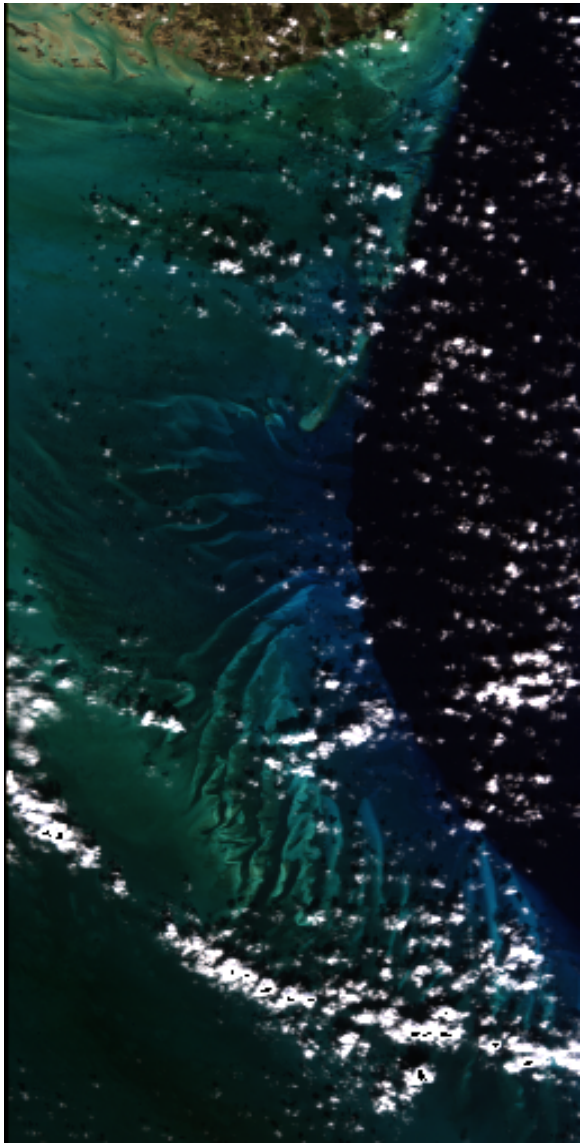
What is the Hyperspectral Imager for the Coastal Ocean (HICO)?

- HICO is an experiment to demonstrate the advantages of imaging the coastal ocean at higher resolution from space.
- The HICO sensor:
  - first spaceborne imaging spectrometer for coastal oceans
  - samples coastal regions at <100 m (400 to 900 nm: at 5.7 nm)
  - high signal-to-noise ratio to resolve the complexity of the coastal ocean
- Sponsored as an Innovative Naval Prototype (INP) by the Office of Naval Research: Goal of reduced cost and a greatly shortened schedule.
  - Start of Project to Sensor Delivery in 16 months
  - Launched to the ISS September 10, 2009

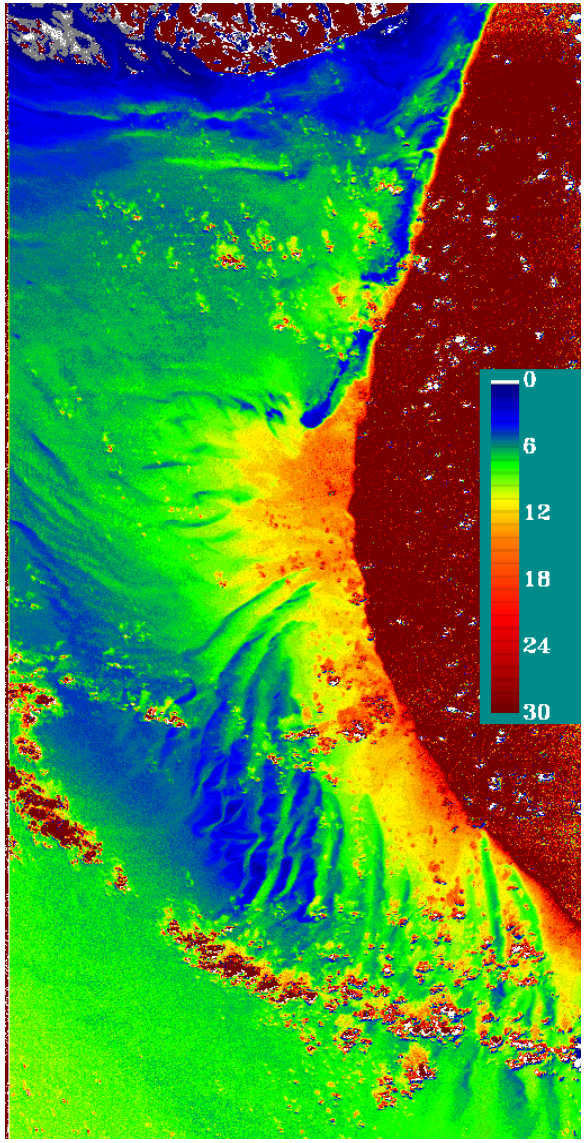
HICO image of Hong Kong, October 2, 2009.

Andros Island, Bahamas, Oct 22, 2009

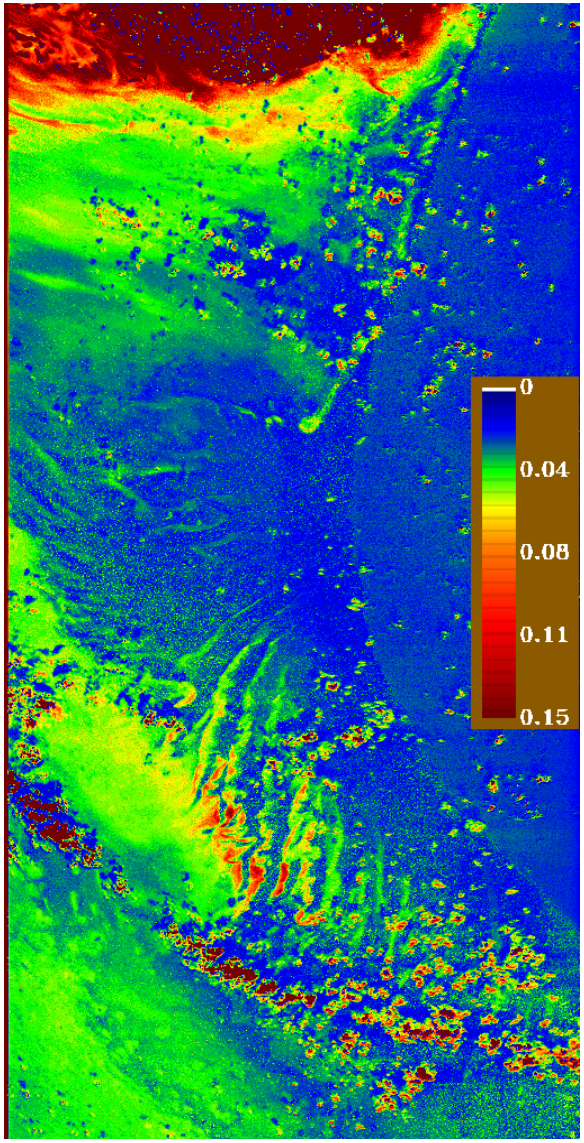
RGB image



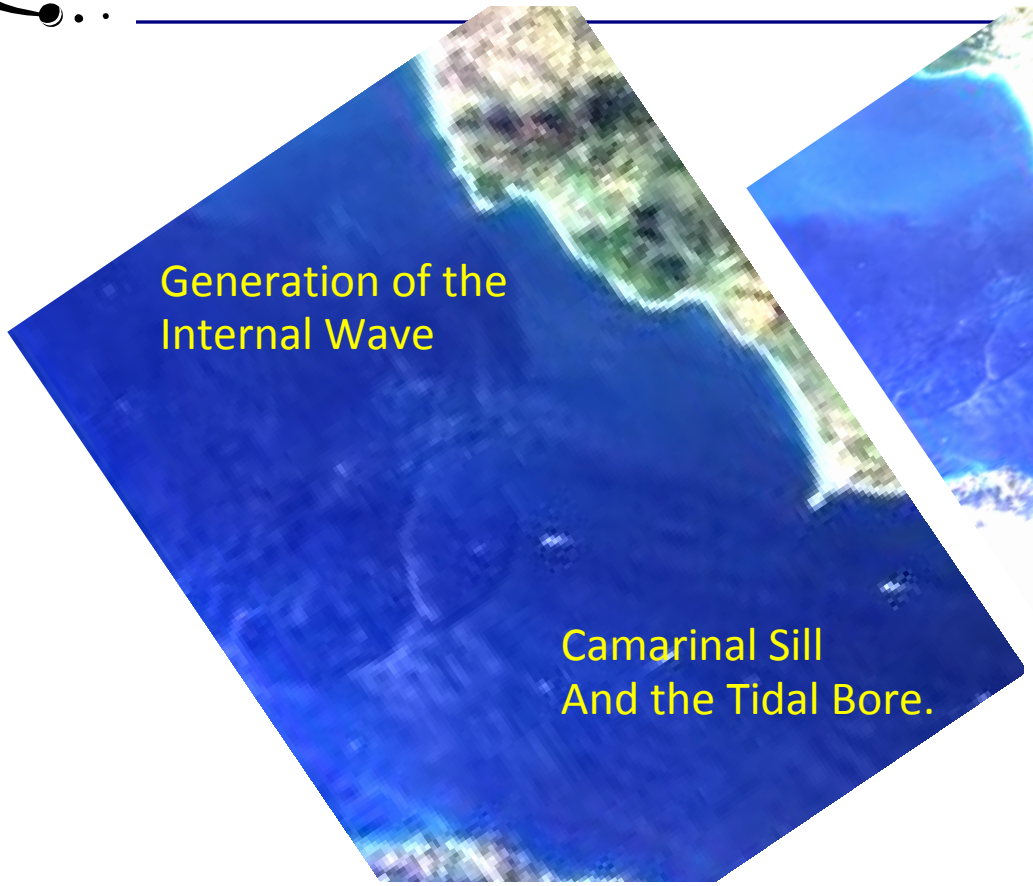
bathymetry

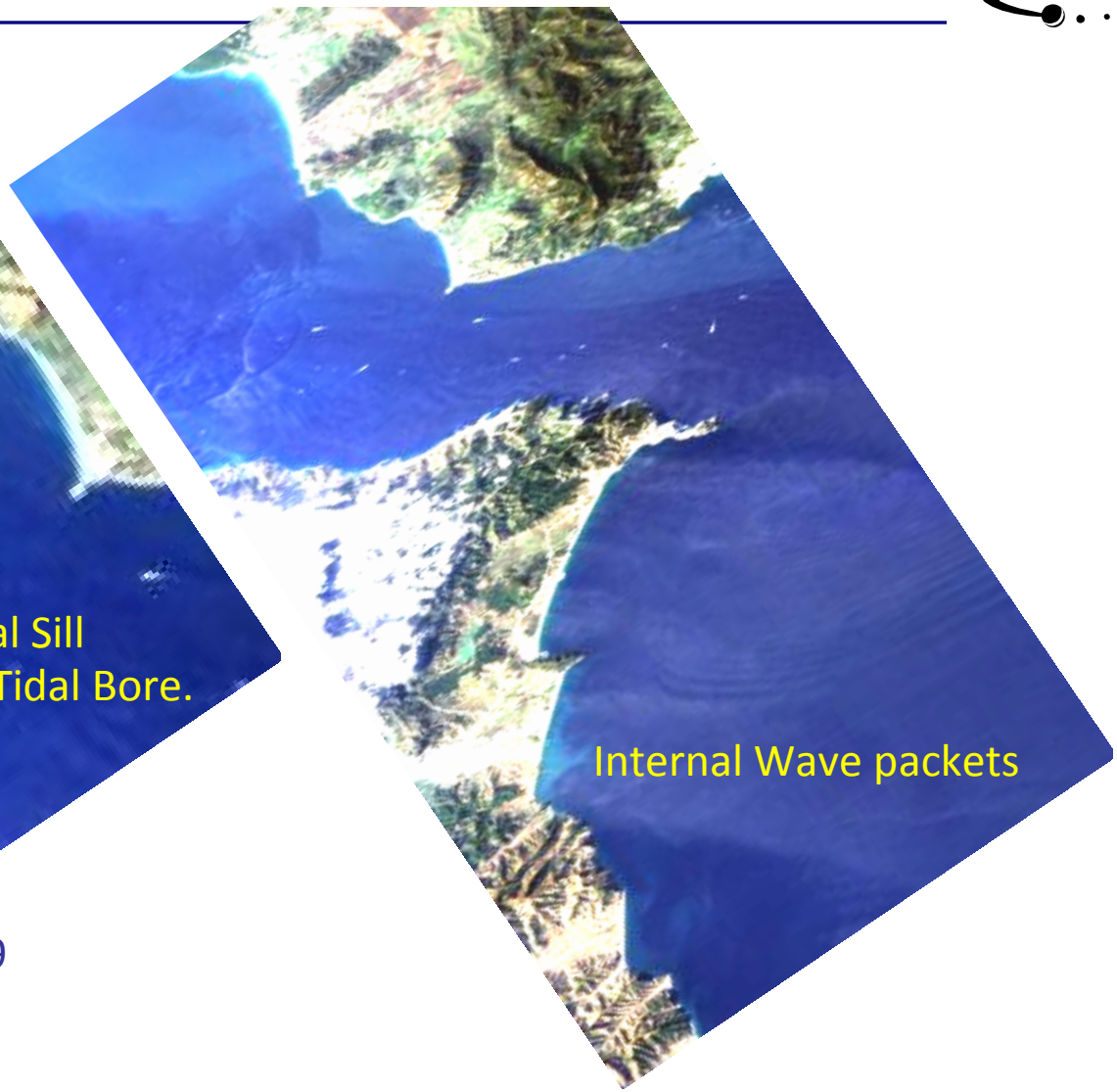


absorption



Internal waves at the Straits of Gibraltar

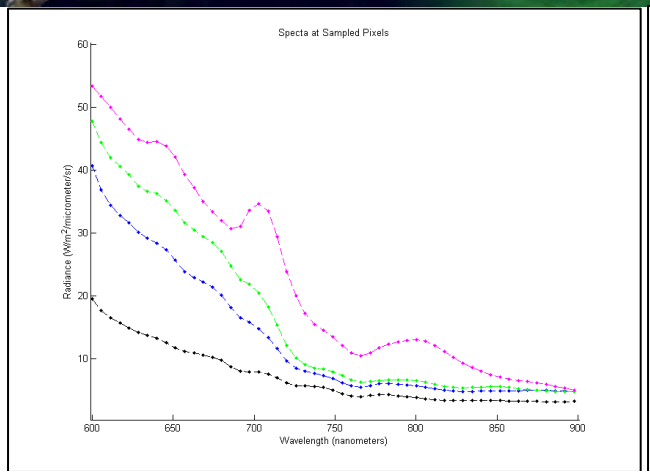


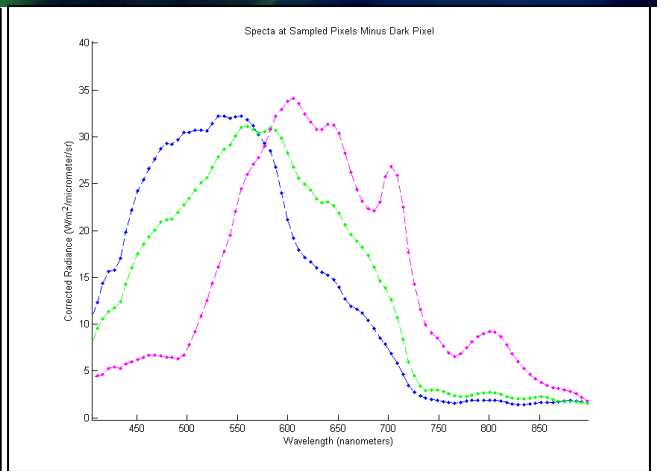


Straits of Gibraltar
HICO Image Dec 5, 2009
(R. Arnone analysis)

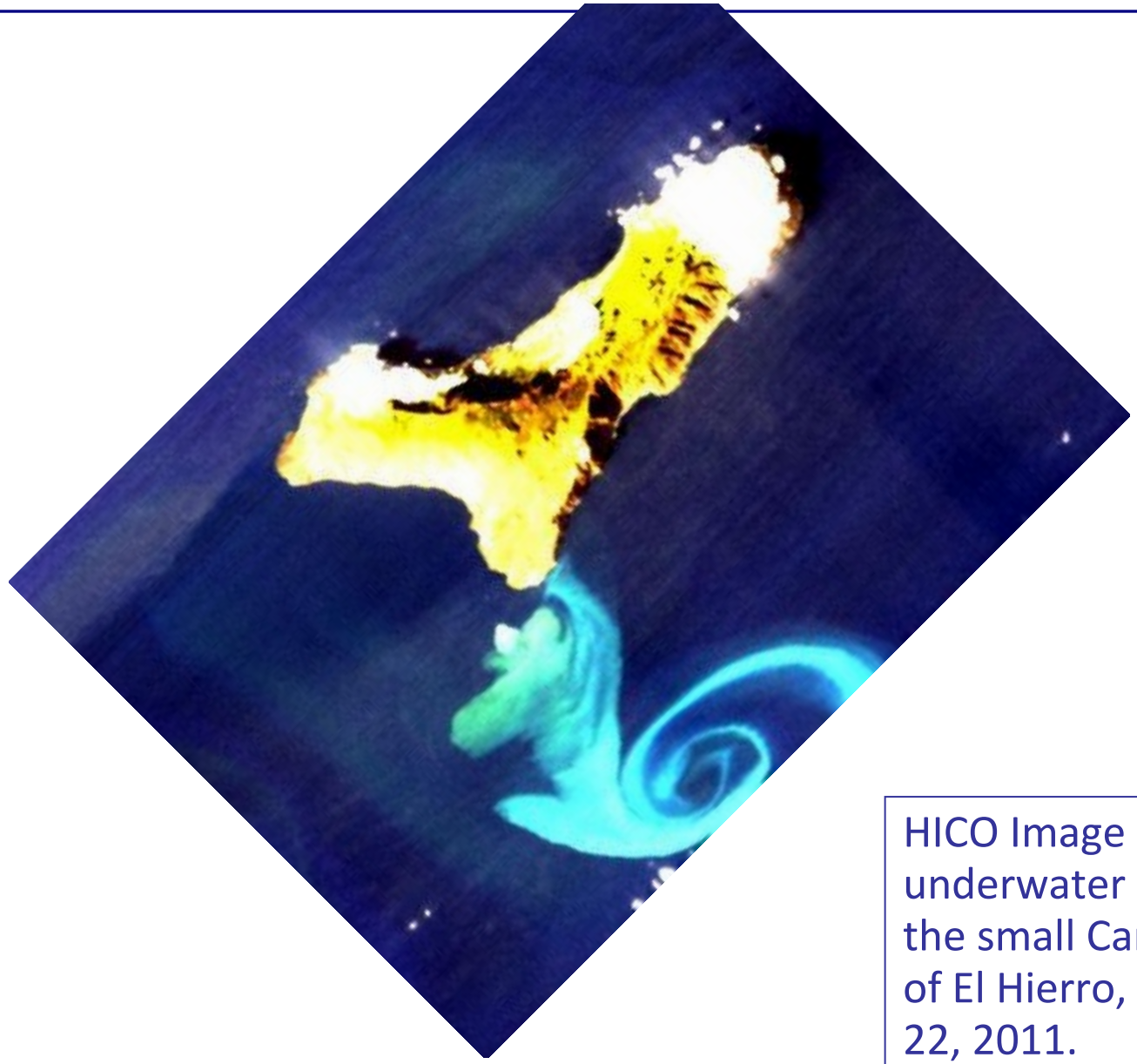
Microcystis bloom in Lake Erie

HICO Image of a massive *Microcystis* bloom in western Lake Erie, September 3, 2011 as confirmed by spectral analysis.





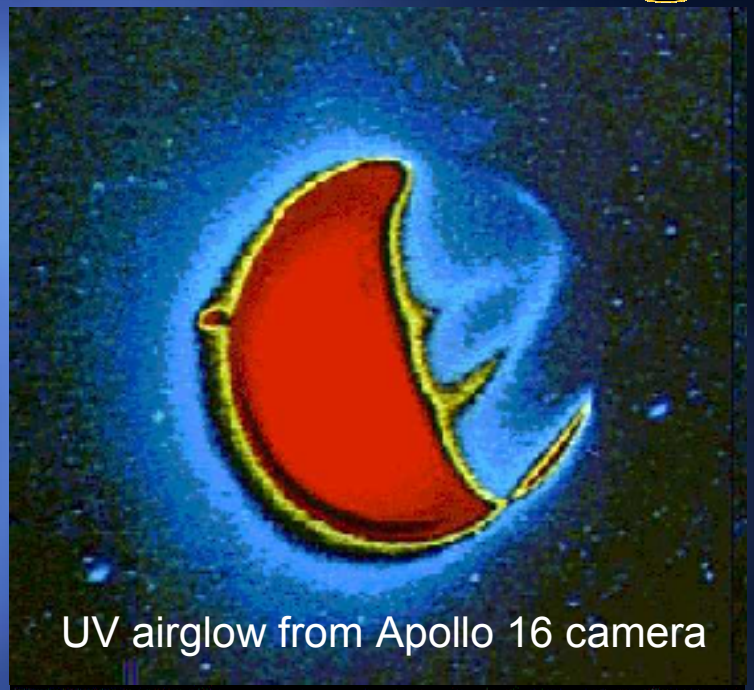
Birth of a New Island, Canary Islands



HICO Image of the new underwater volcano off the small Canary Island of El Hierro, December 22, 2011.

Remote Sensing and Airglow

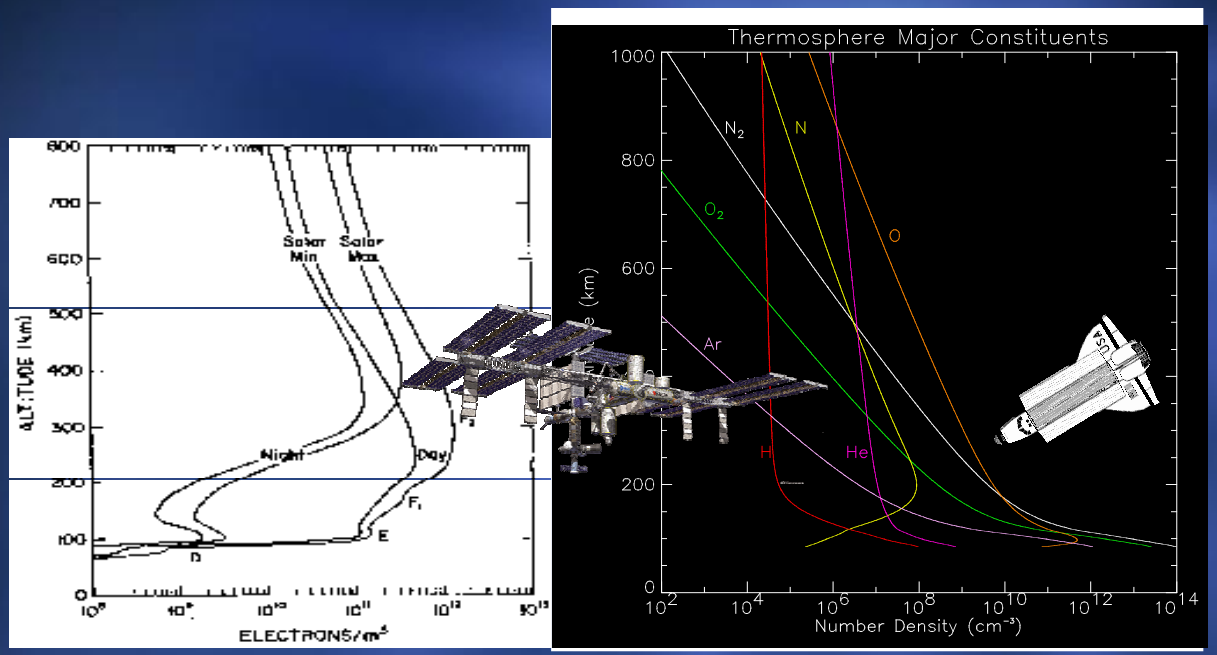
- The upper atmosphere and ionosphere glow day and night
  - Sunlight-driven processes
  - Solar-wind driven processes
  - Chemical processes
- Simply view it
  - Passive UV-Visible remote sensors
  - UV must be observed from space
- And interpret the glow
  - Physics-based data analysis
- To characterize the upper atmosphere
  - Upper mesosphere
  - Lower thermosphere
  - Ionosphere



UV airglow from Apollo 16 camera

Airglow from STS-39

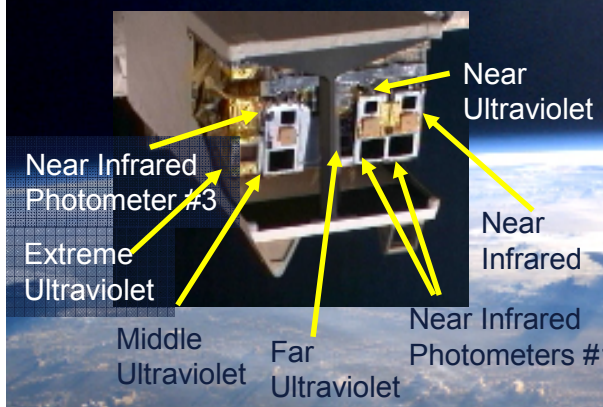
Thermosphere and Ionosphere

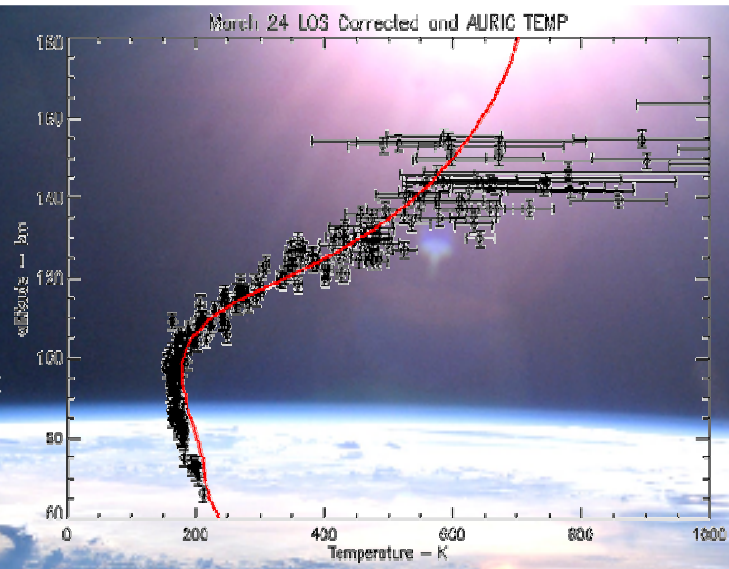


- Ionosphere (F region 200-800 km)
  - Most Variable Component In The Atmosphere
    - Spatial, temporal, solar cycle, time of day variations
- Thermosphere (100-1000 km)
  - Expands with temperature, solar forcing
  - Winds, tides, waves, composition affect ionosphere structure

RAIDS Concept

Measuring atmospheric temperature through the coldest part of near space.





Objective:

✧Describe the thermospheric and ionosphere, and its dynamic variability in response to space weather and forcing from lower atmosphere

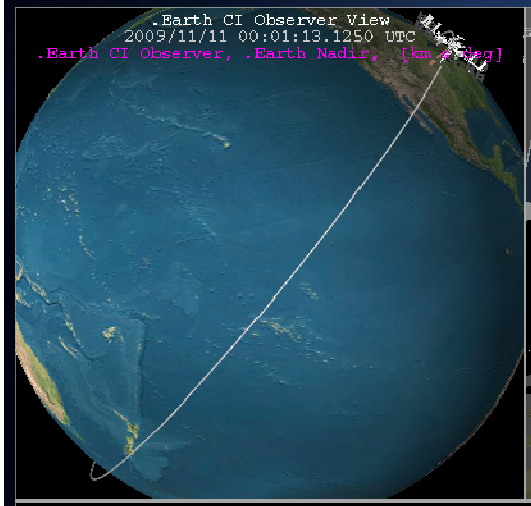
- ✧ Thermospheric temperature profiles
- ✧ Electron density profiles
- ✧ Neutral density, composition (N_2, O_2, O, N, NO)
- ✧ Minor species chemistry and abundance

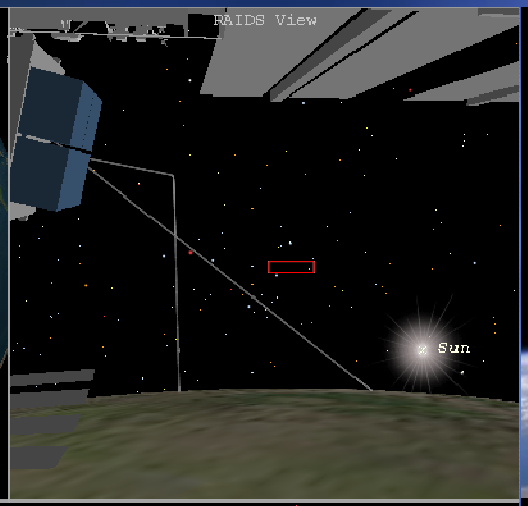
Approach:

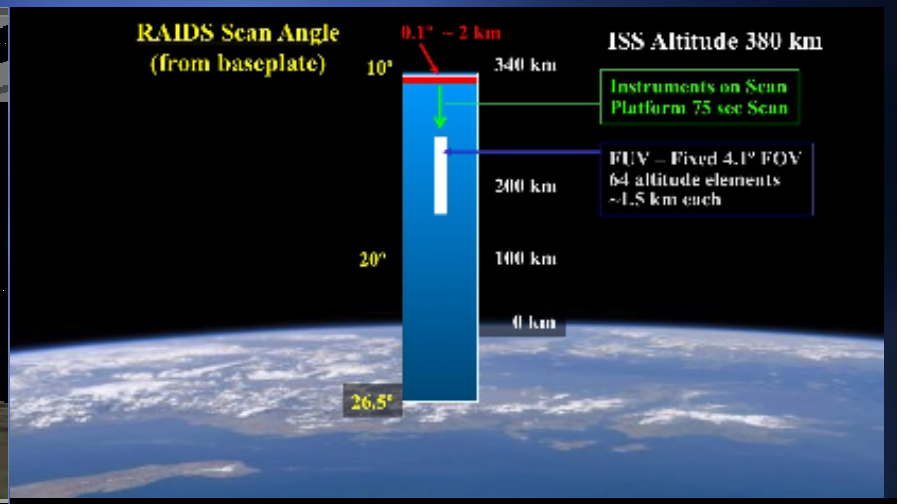
✧Remote sensing of airglow limb radiances from EUV (55nm) to NIR (870nm) covering 90–300 km altitude

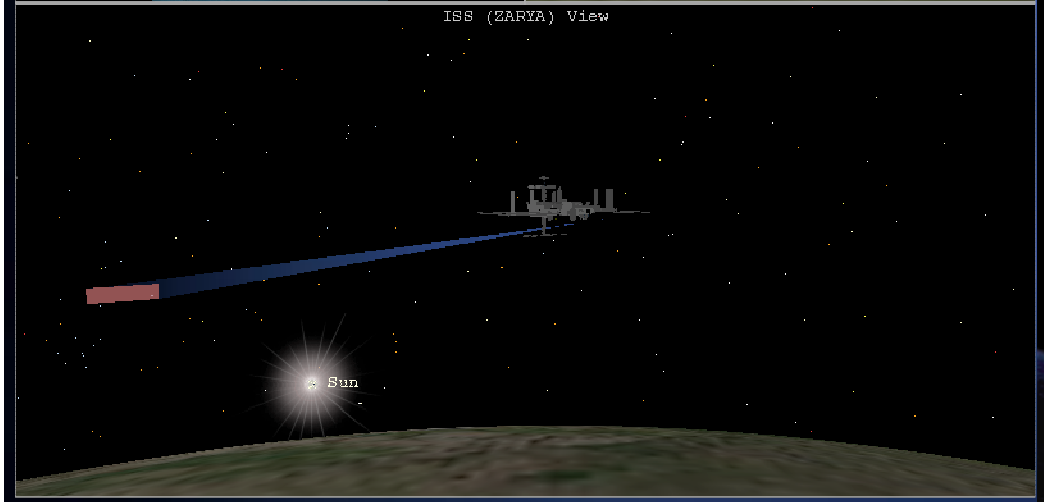
✧Atmospheric state obtained by inverting limb radiances using state-of-the-art science algorithms

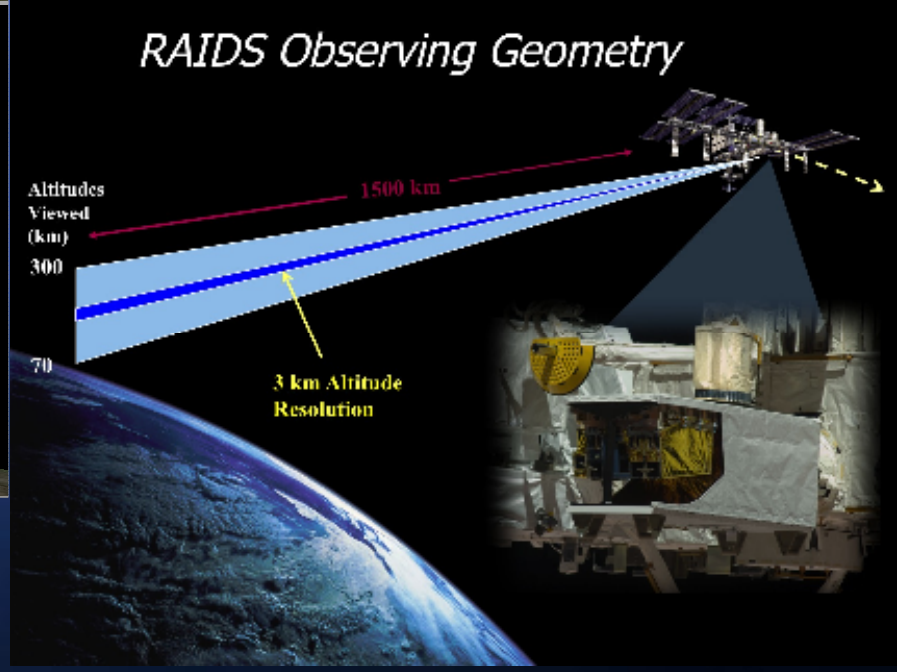
RAIDS Operation and Observations





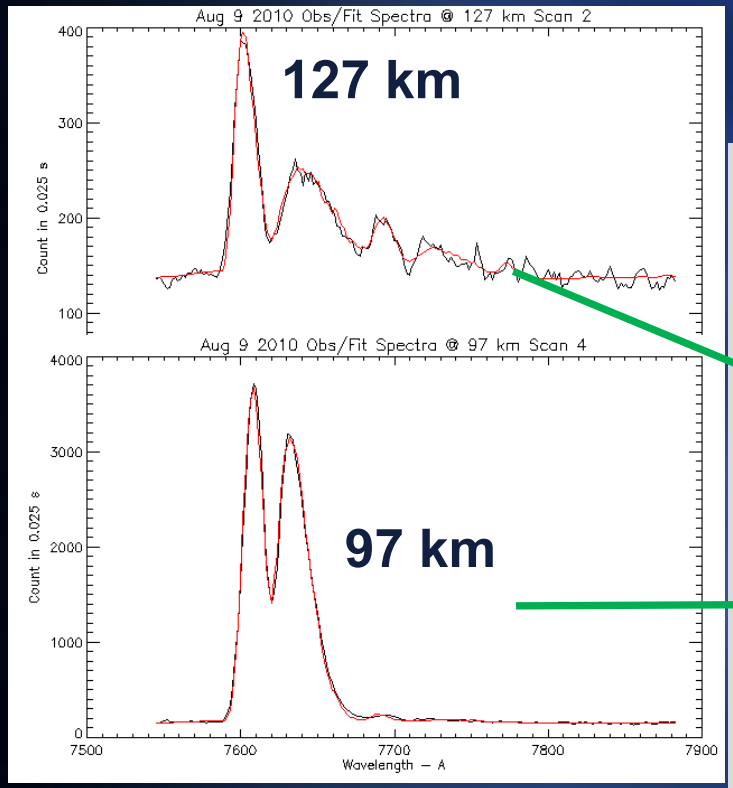




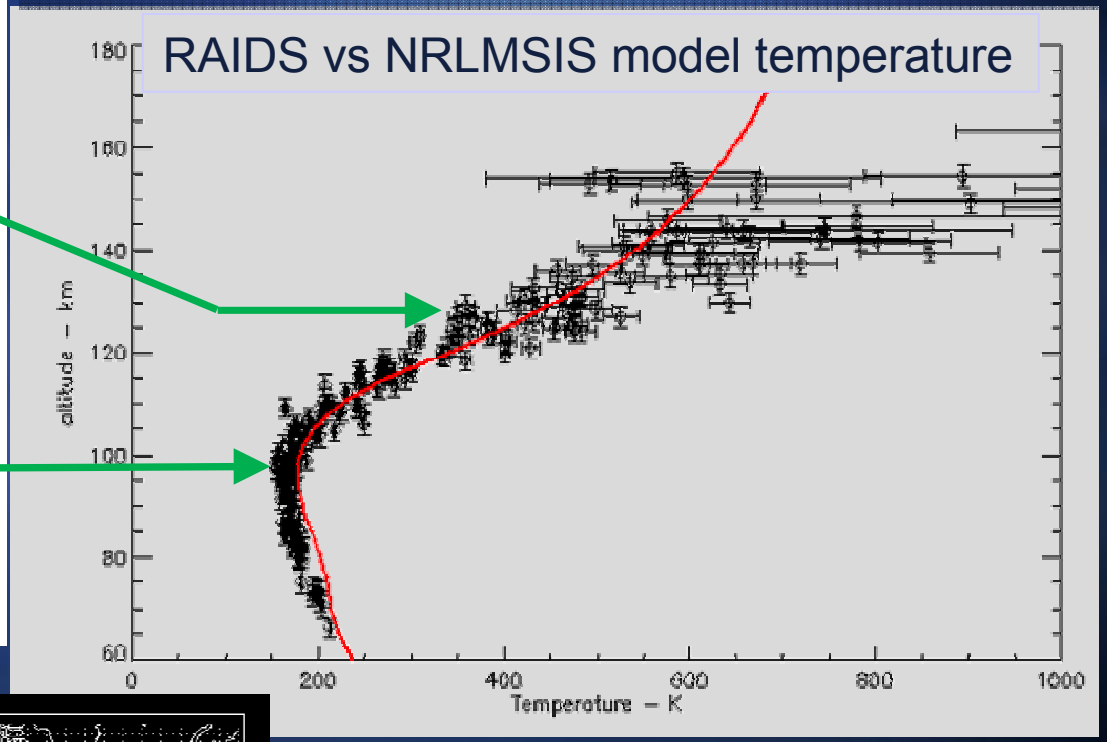


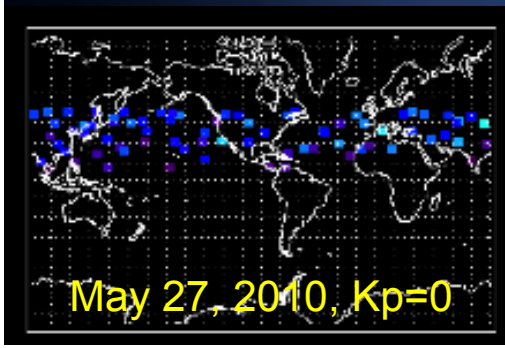
Measuring the coldness of space: O_2-A band

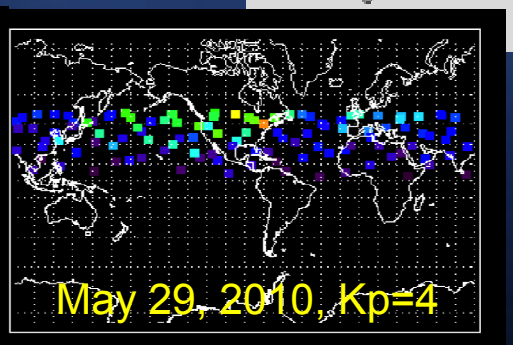
Near-infrared airglow spectra



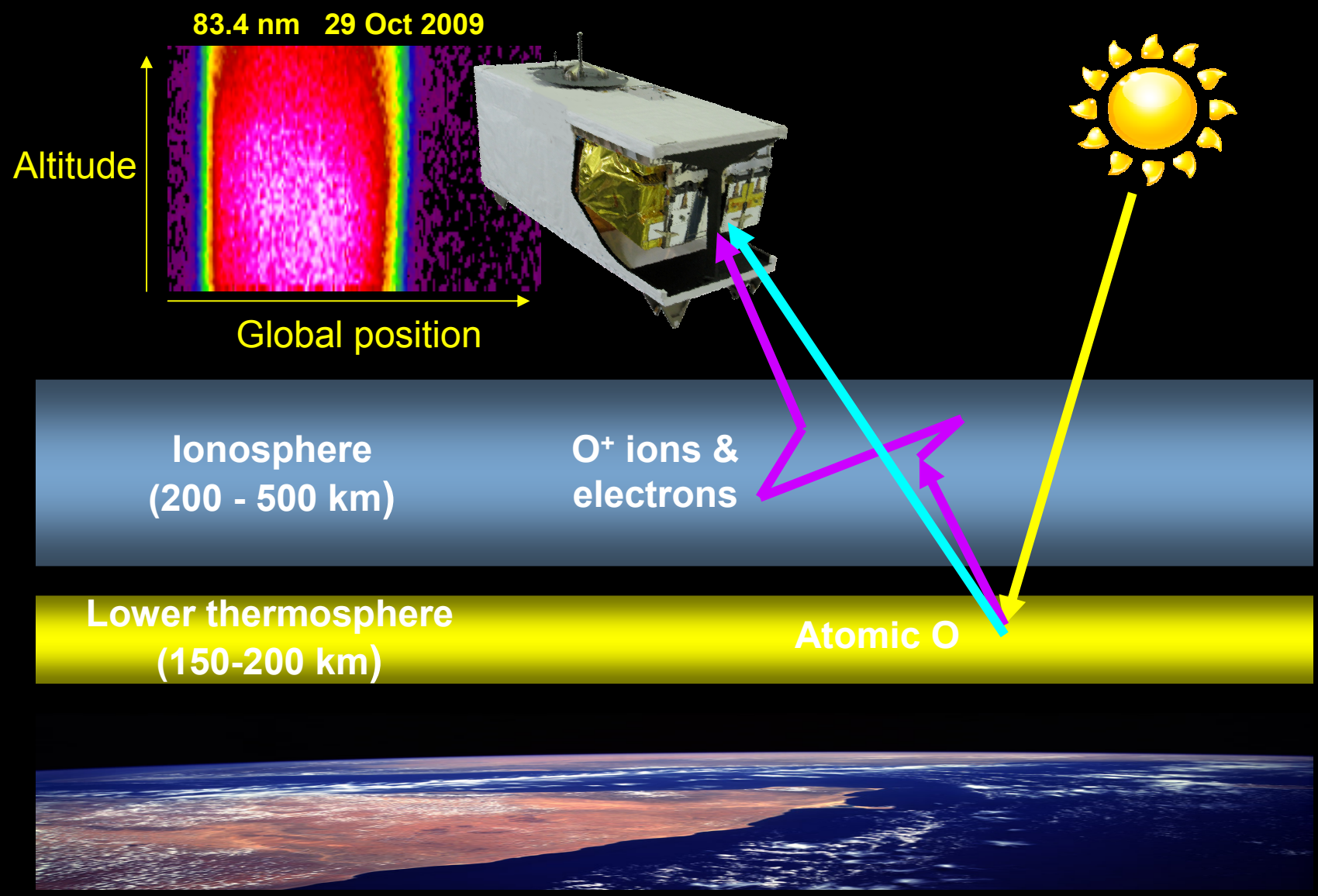
The brightness and spectral shape of O_2 A-band airglow is modeled to retrieve upper atmosphere temperature.





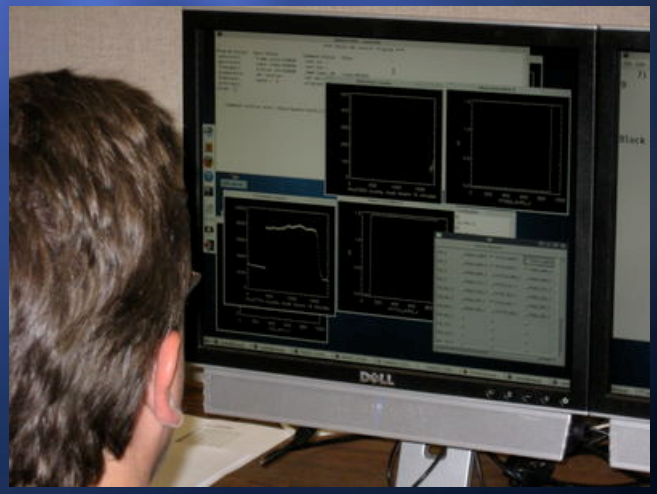


Measuring Dayside Ionosphere



Real-Time Data & Commanding

- TDRSS
  - Daily 4-hour command windows
  - Real-time data 60-70% coverage
  - Very different from typical LEO sats
- Easy troubleshooting & experimentation
  - Use RAIDS in campaign mode
  - Develop advanced observing modes
- RAIDS became an atmospheric observatory on ISS, rather than a fly-and-forget satellite sensor



Summary

ISS is a uniquely capable platform for remote sensing of ocean and atmosphere

- HREP
  - successfully demonstrates low-cost, short schedule payload development
  - served as a pathfinder for follow-on JEM-EF payloads from NASA
- HICO
  - has acquired over 6000 scenes of hyperspectral coastal imagery
  - successfully demonstrates hyperspectral remote sensing using COTS parts in its design
- RAIDS
  - met science objectives for lower thermosphere temperature, ionospheric density, and minor species chemistry
  - demonstrates the utility of the ISS as a platform for atmospheric remote sensing and EUV/FUV observations