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## BENEFITS AND APPLICATIONS OF HYPERSPPECTRAL IMAGERY FROM THE SPACE STATION

February 26, 2020

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# Presenters

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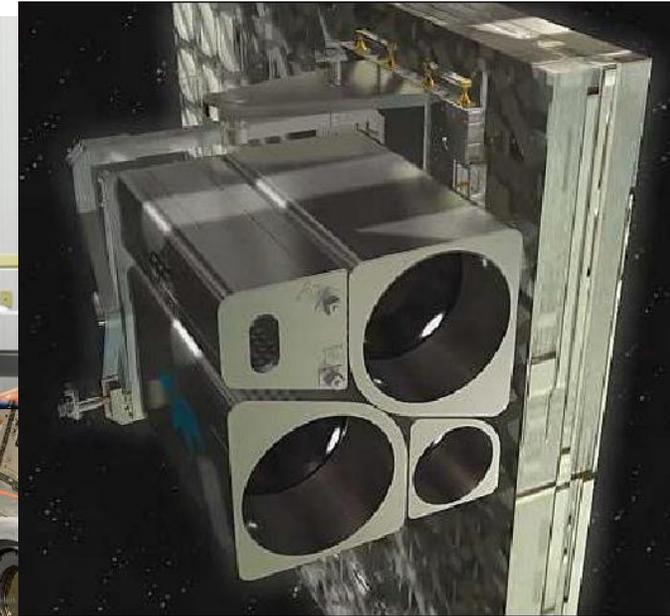
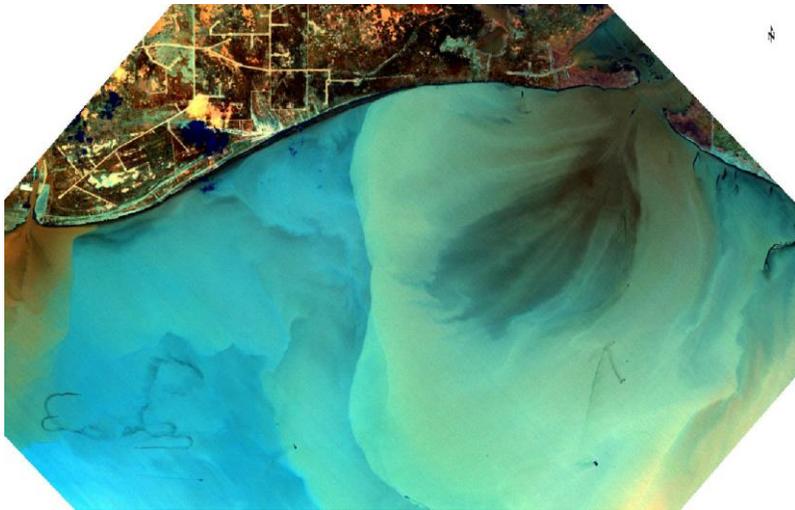


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# Agenda



- The value of hyperspectral imagery
- DESIS-30 specs, collecting on the ISS
- Case Studies with ENVI analytics
- DESIS Access
- Q & A



# Poll Question

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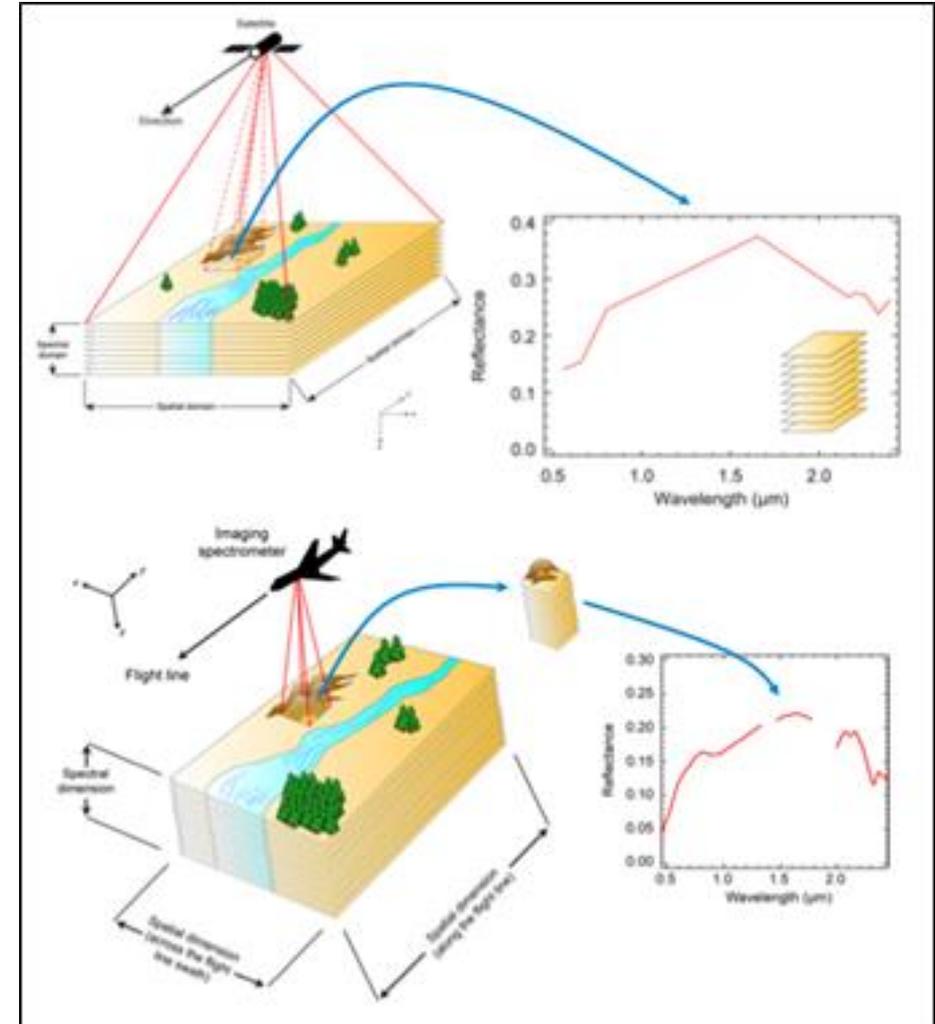
Have you used hyperspectral imagery before?

- Yes
- No

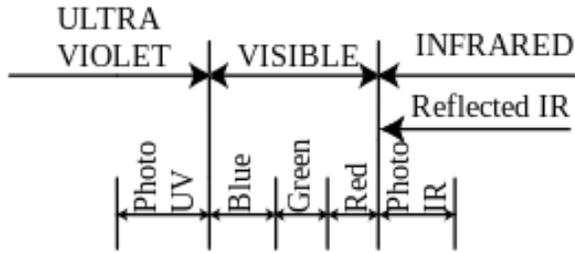
# Hyperspectral Background



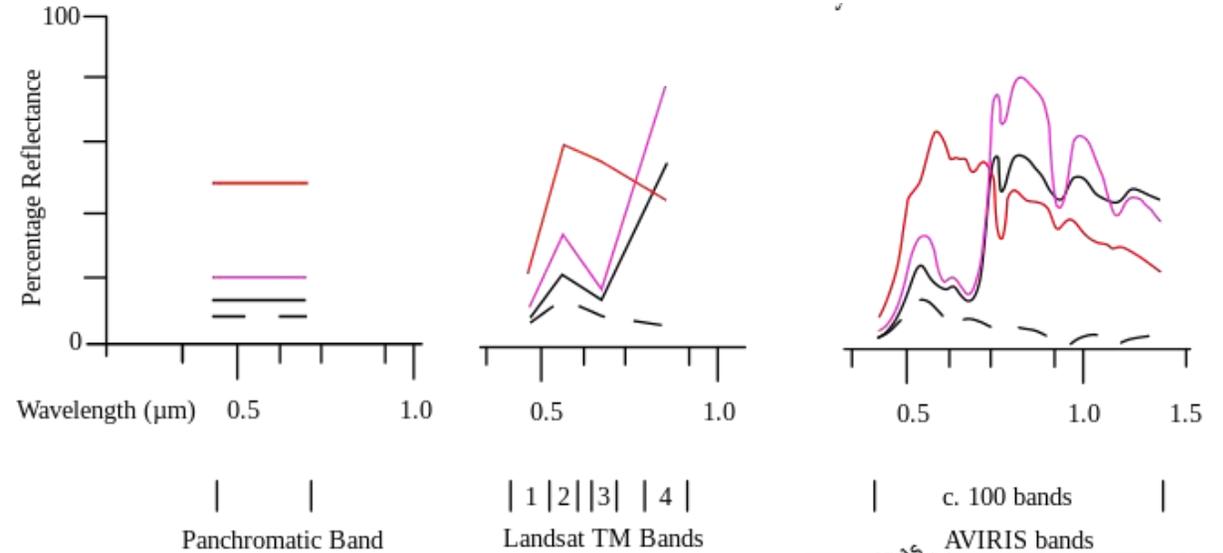
- Capability around for many years, but compute power struggled with large size of data
- That has been overcome and onboard processing is a reality
- Hyperspectral imagery (HSI) usually has at least 30 bands, as compared to multispectral
- Where as multispectral imagery, like a Landsat image, can give you a class like iron bearing minerals, HSI can give the exact type of mineral
- Think of it like a zoom button, multispectral is viewing a very blurred scene, where you can maybe pick out specific objects, with hyperspectral as the zoomed version, where you can much more easily discern what is in the image.



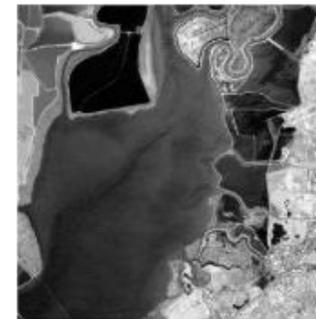
# Hyperspectral Overview



- Pinewood
- Grassland
- Red Sand Pit
- Silty Water



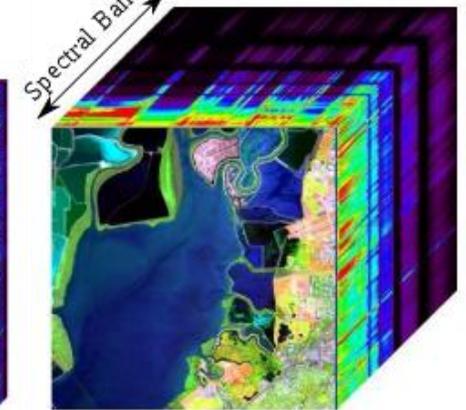
- A panchromatic band usually has higher resolution for less unique wavelength information
- Multispectral usually has lower resolution than pan, but more wavelength information
- Hyperspectral has a great amount of unique spectral information, and used to have lower resolution or much more expensive sensors



Single band



Multispectral

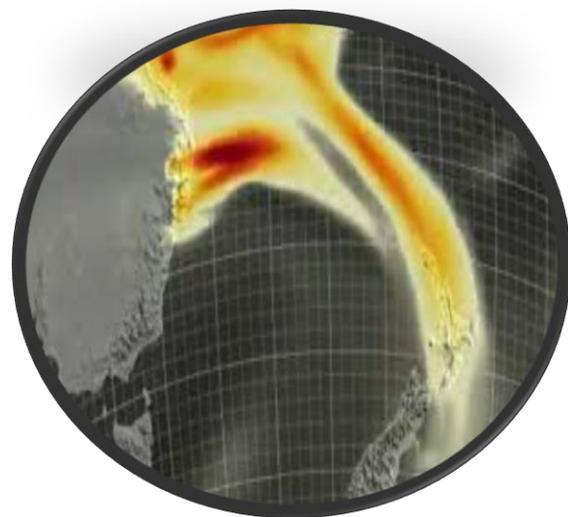
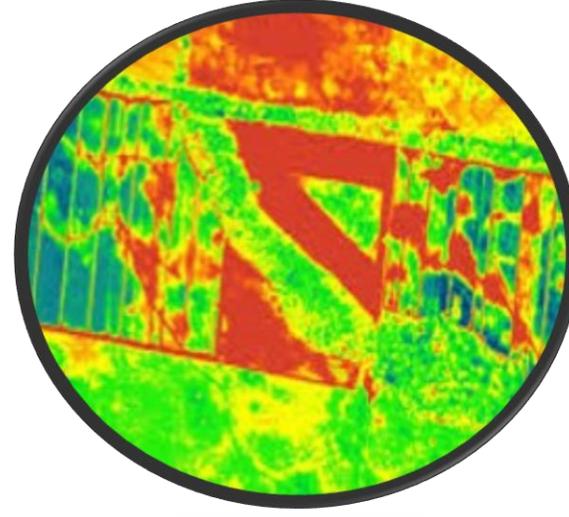
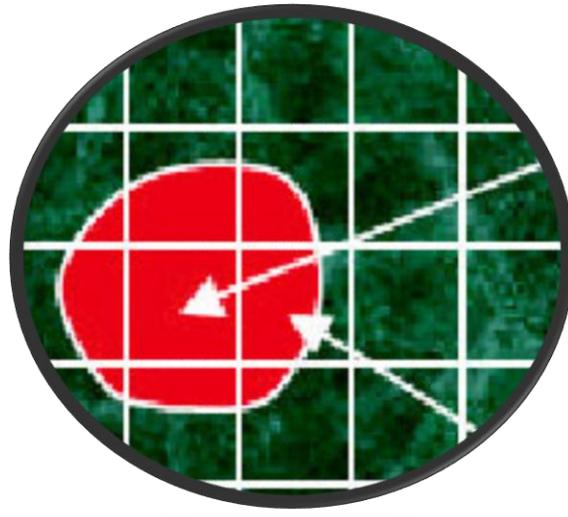


Hyperspectral



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 Author: <http://commons.wikimedia.org/wiki/User:Arbeck>

# Why Hyperspectral?

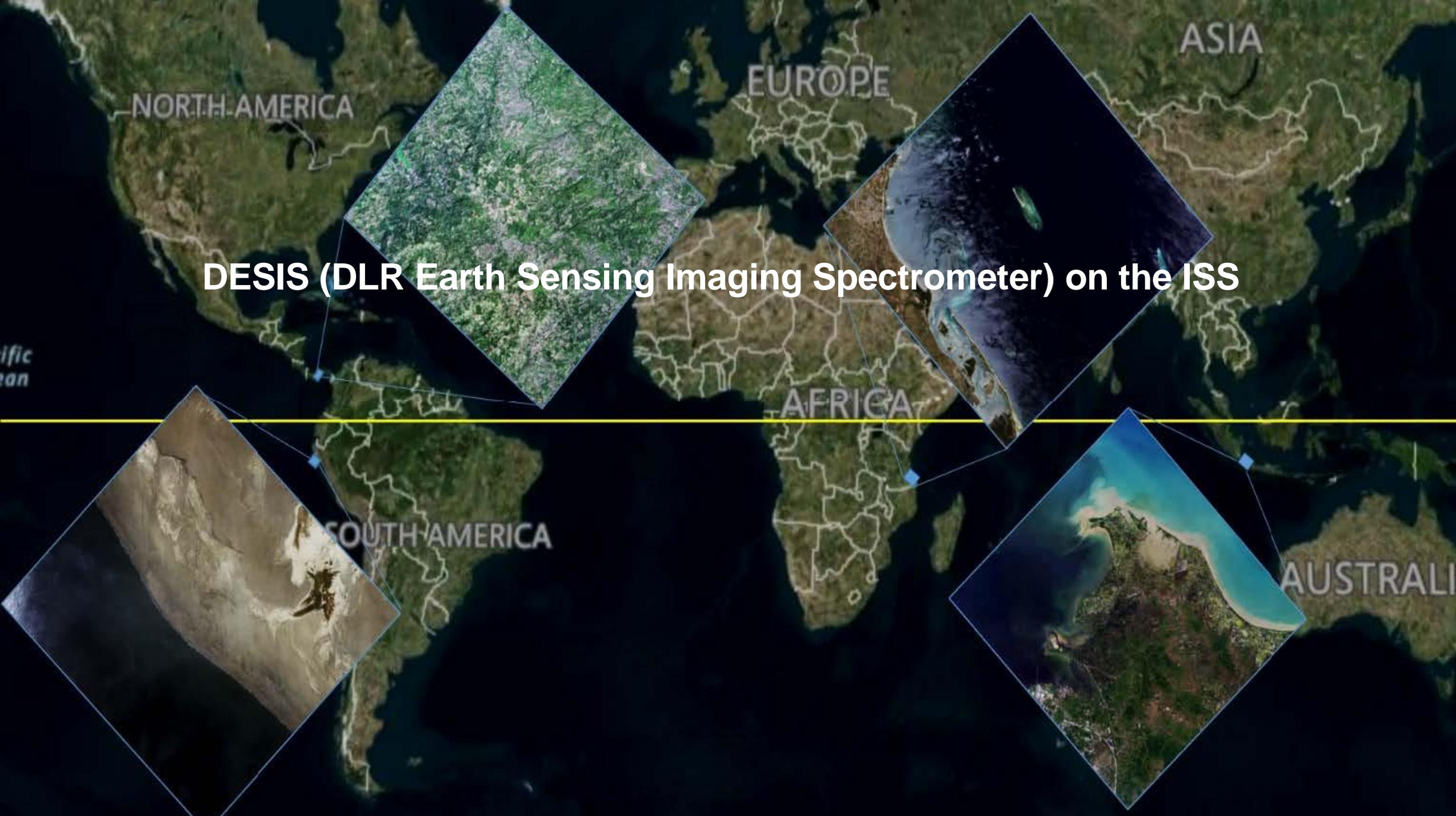




## What other types of imagery/data do you use?

*Select all that apply*

- LiDAR
- SAR
- High resolution commercial satellite imagery
- Medium resolution imagery (e.g. Landsat)
- Imagery from aerial or drones



NORTH-AMERICA

EUROPE

ASIA

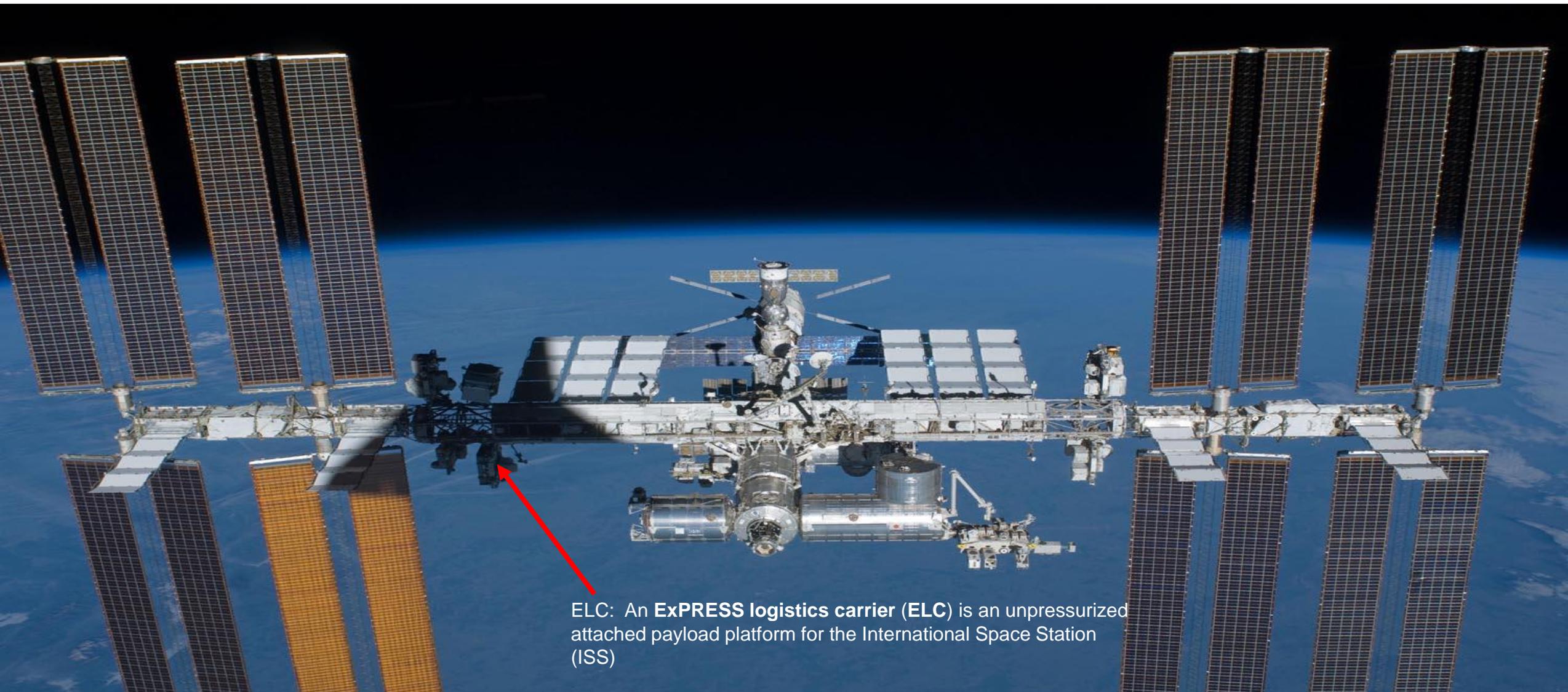
**DEGIS (DLR Earth Sensing Imaging Spectrometer) on the ISS**

AFRICA

SOUTH-AMERICA

AUSTRALIA

# MUSES/DESIS Location on the ISS Express Logistics Carrier 4 (ELC-4)



ELC: An **ExPRESS logistics carrier (ELC)** is an unpressurized attached payload platform for the International Space Station (ISS)

# Multi-User System for Earth Sensing (MUSES)



- DESIS is installed on MUSES (Teledyne developed)
- Precise pointing and Earth surface target tracking
- Up to 4 robotically installed instruments
- Total data downlink ~225 GB/day
- Onboard processing option
- Instruments launched in “soft stowage”, ISS National Lab covers transport cost, Teledyne manages integration, safety, testing, downlink, ops, etc.
- 6-12 months from agreement to installation
- Currently exploring SWIR, other payloads

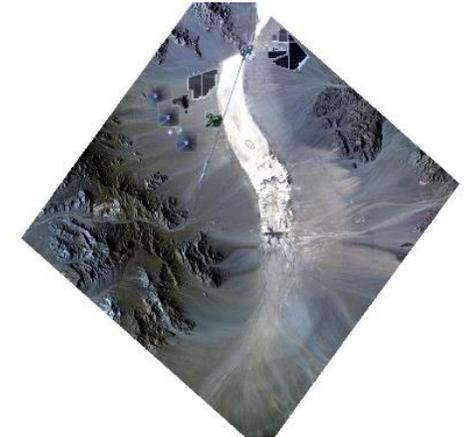
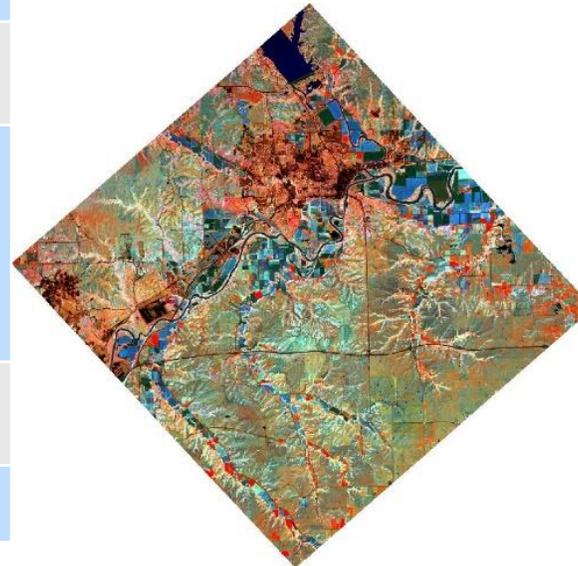
Characteristic	MUSES Performance Target
Field of Regard	Outboard Cross-Track: 5°
	Inboard Cross-Track: 45°
	Along-Track: +/- 25°
Thermal Control	Passive
Star Tracker	Sodern SED26
Inertial Measurement Unit	Honeywell Miniature Inertial Measurement Unit (MIMU)
Precision Time	Sourced from the ISS GPS, $\leq \pm 250 \mu\text{sec}$ to MUSES instruments
Pointing Accuracy	$\leq \pm 60$ arc seconds
Pointing Knowledge	$\leq \pm 30$ arc seconds (~ 60 m on ground from 400 km altitude)
Location knowledge	Sourced from the ISS GPS, $\pm 50$ meters, RMS
Orbit	51.6° Inclination, 400 km altitude $\pm 5\%$ (nominal)
Data Processing	Linux Server on-board ISS with redundant 6 TB storage
Daily Downlink Capacity	225 GB



# DEGIS Specs



Characteristic	DEGIS-30 Features
Ground Sampling Distance	30 m @ 400 km altitude
Ground Swath	30 km @ 400 km altitude
Spectral Range	400 nm – 1000 nm
Spectral Bins	Measured: 235 @ 2.55 nm Programmable binning on-orbit
Quantization	12 bits + 1 gain bit
Signal to Noise Ratio @ 550 nm	205:1 sampled at 2.55 nm 406:1 binned to 10.2 nm
On-board calibration	Dark Field for DSNU LED Array for PRNU
Independent Pointing	Pointing Unit $\pm 15^\circ$ Along Track
Independent Time and Location	On-board GPS



# Earth Observation From the ISS – Why It Works/Challenges



## Benefits

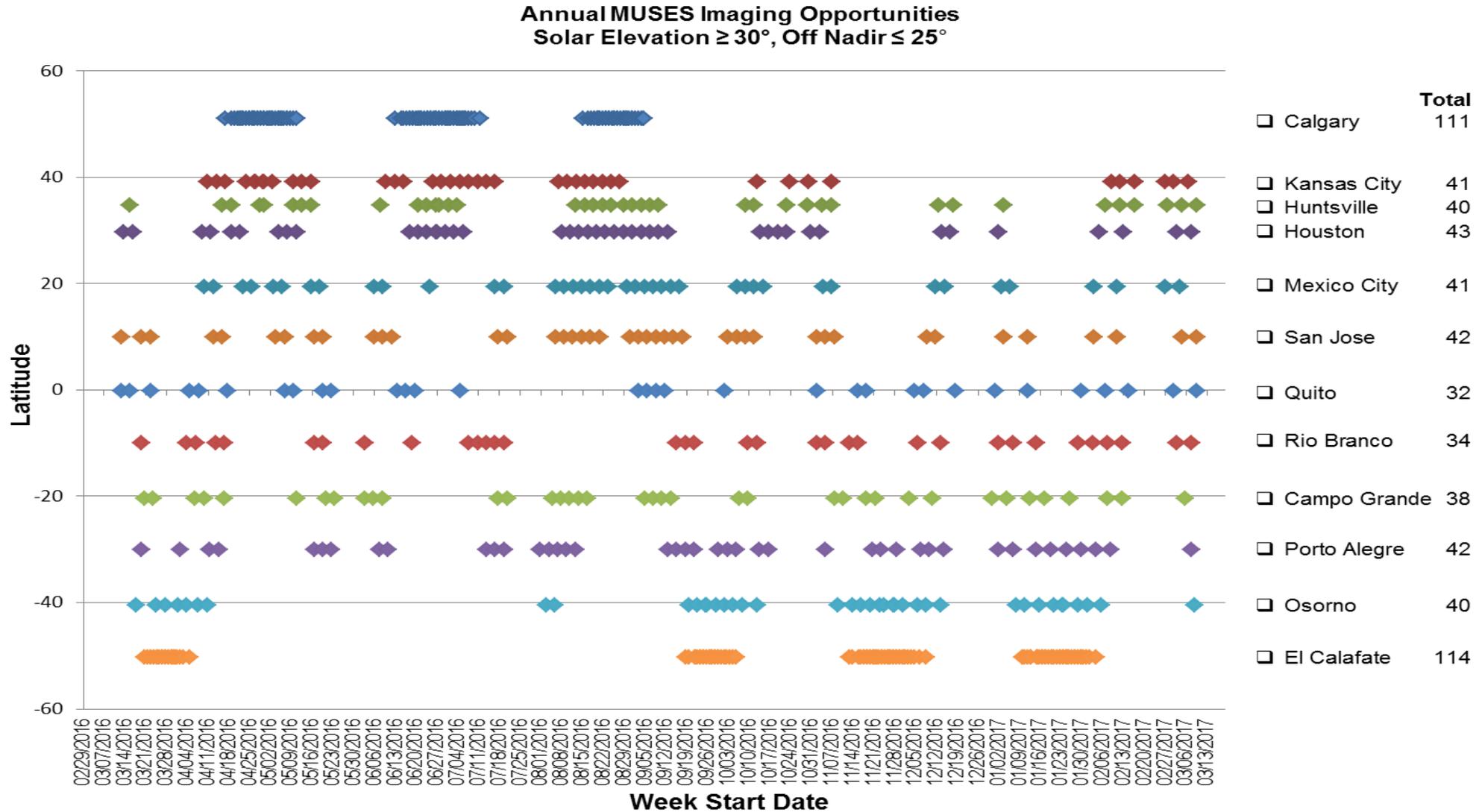
- Coverage of ~90% of populated Earth
- Coverage of 100% of tropics, frequent revisit
- Upgrade, repair and exchange of instruments as technology and/or markets evolution. Traditional barriers to entry are minimized

## Challenges

- Maneuvers, resupplies, spacecraft location can cause missed collects (field coordination)
- 55 degrees N and below 51 degrees S not covered in orbit



# MUSES Imaging Opportunities from the ISS





From a big data perspective, what are most important to you?

*Select all that apply*

- Frequent coverage of one area to study change over time
- Access to broad data catalog for modelling or deep learning analysis
- Ease of fusion for multiple data sources

An aerial hyperspectral image of a landscape. The image is color-coded by spectral data, showing a river on the right side, agricultural fields in the center, and a forested area on the left. The colors range from blue and purple to green and yellow. The text 'Case Studies' is overlaid in the center in a large, white, sans-serif font.

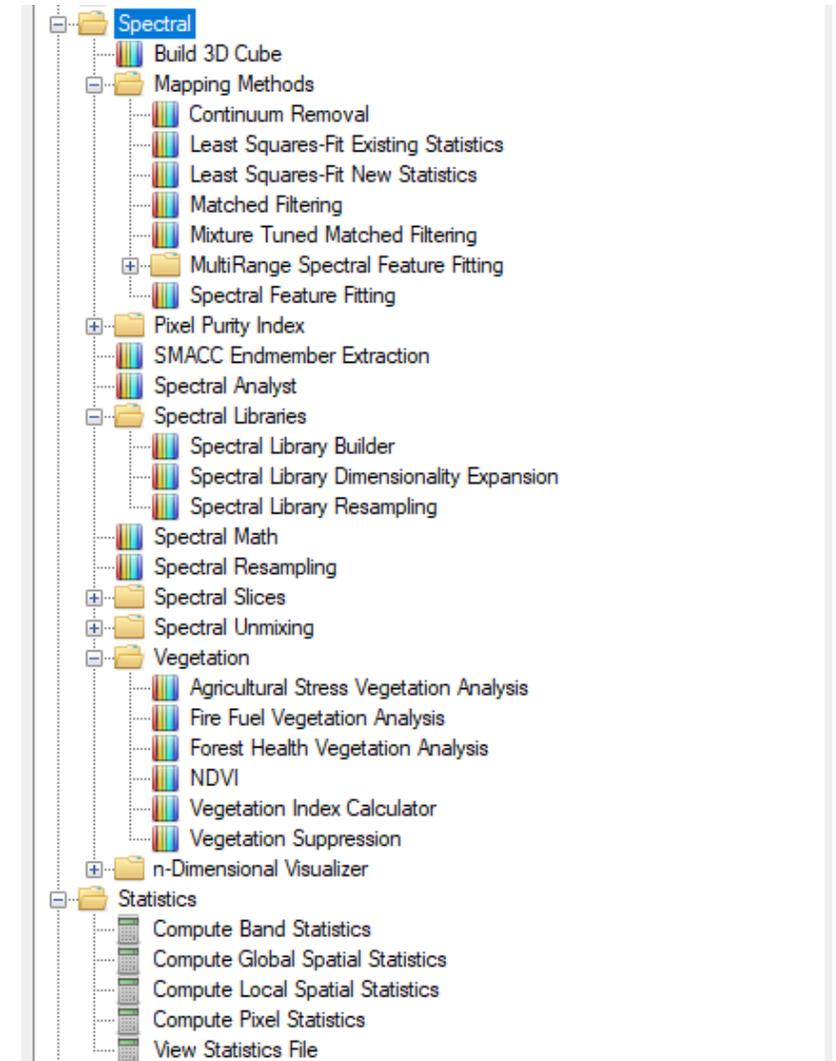
# Case Studies

ENVI Hyperspectral Analytics

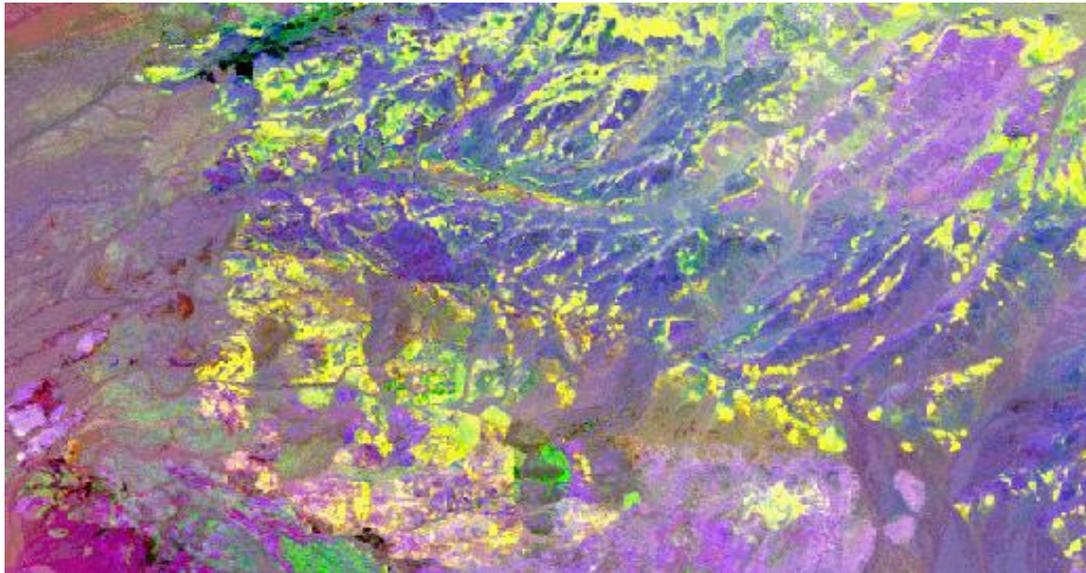
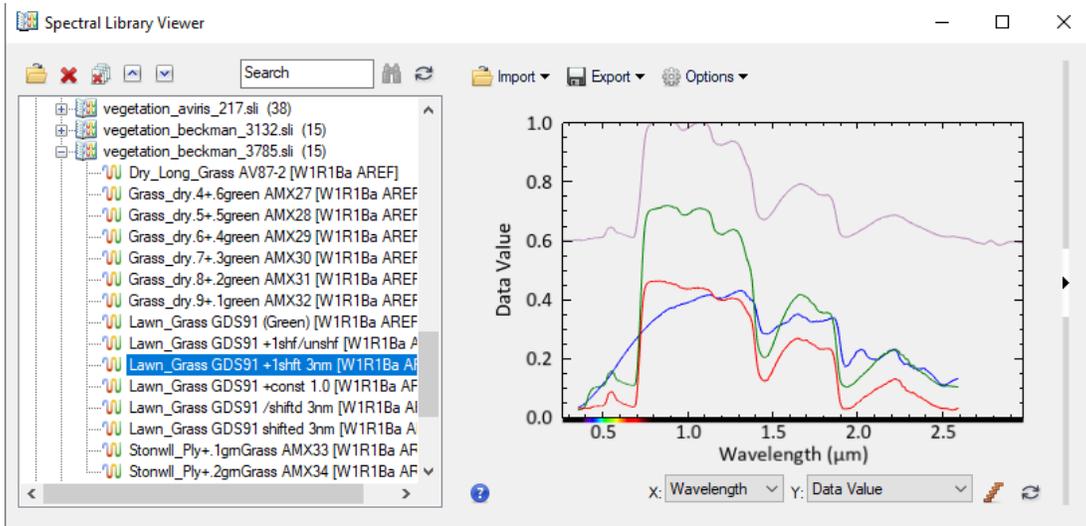
# ENVI and Hyperspectral



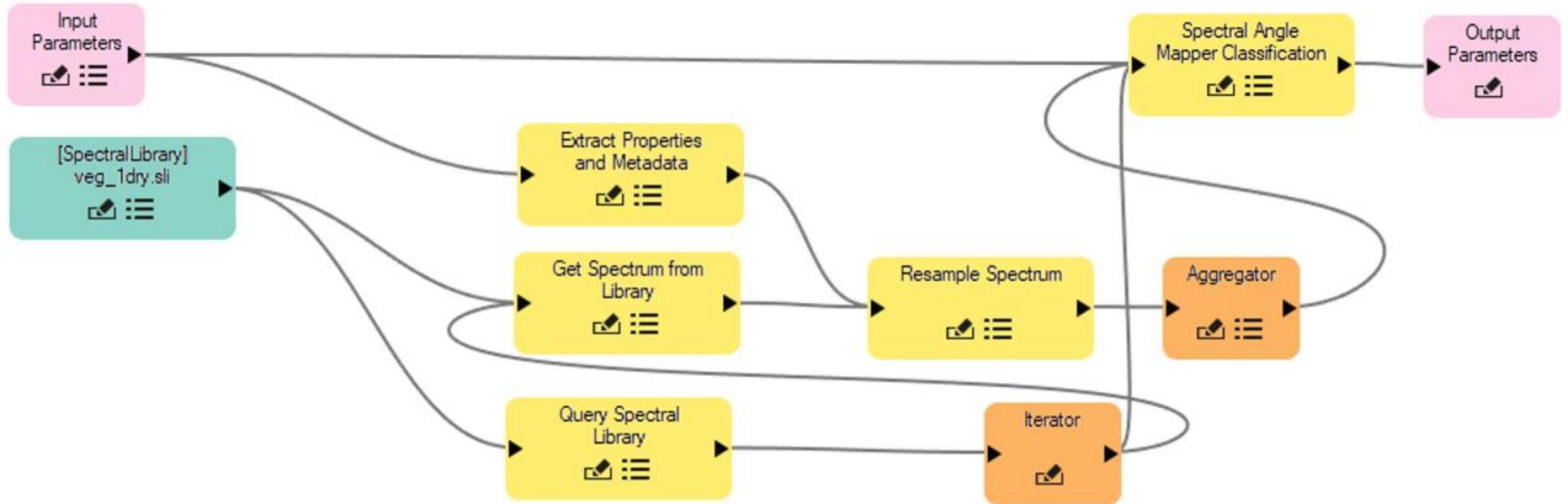
- ENVI was developed originally for working with hyperspectral imagery because it is so fast at processing large data
- ENVI has curated a large number of tools specific to hyperspectral imagery as well as all the pre-processing tools such as:
  - Radiometric calibration
  - Atmospheric correction
  - Careful pixel care—preserve the original signal so spectra aren't muddled



# ENVI and Hyperspectral



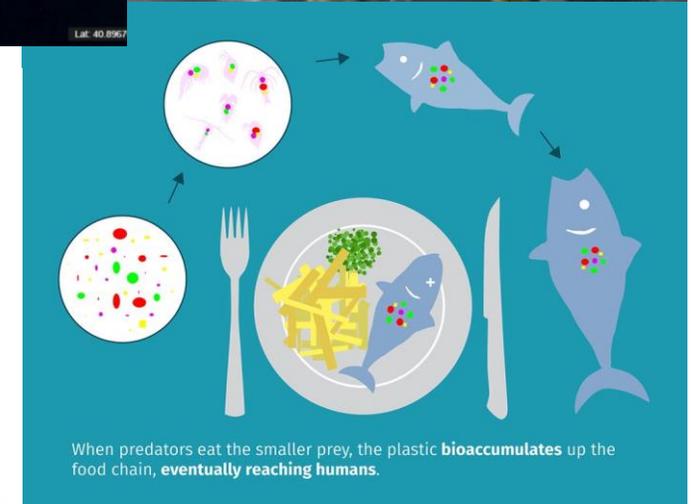
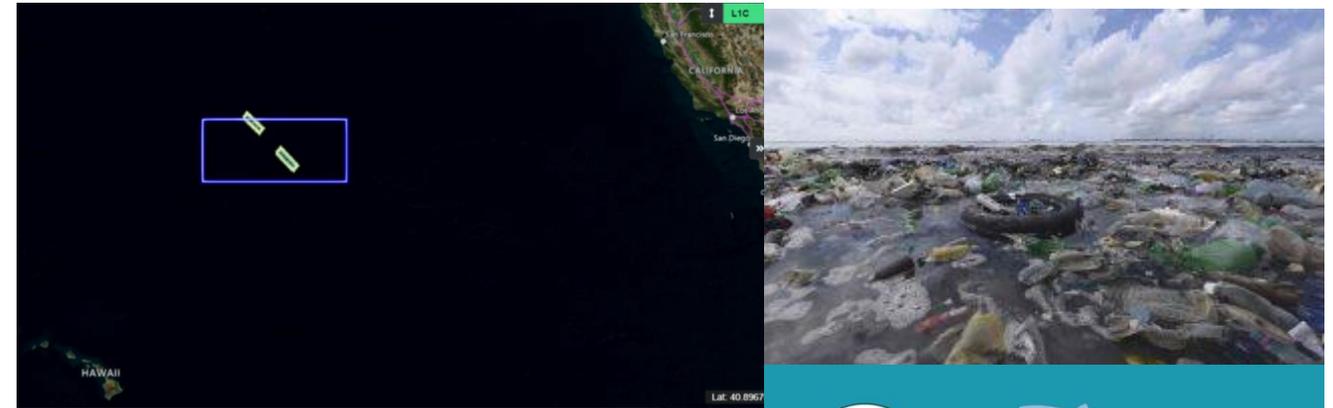
# Automated Workflows with ENVI Modeler



# Marine Debris



- Marine Debris is a major environmental and transportation hazard
- Significant impact to marine food chain and ecological collapse
- DESIS can image these remote gyres, shorelines and sources for debris/plastics flowing into oceans
- Some gyre locations known, find dense debris areas for clean up and transit avoidance
- Different types of debris appear at different times of year. The more we can learn about this global crisis, the more we can mitigate impacts
- Started this kind of work after the Fukushima Earthquake



<https://theoceancleanup.com/great-pacific-garbage-patch/>

# Detecting Marine Debris

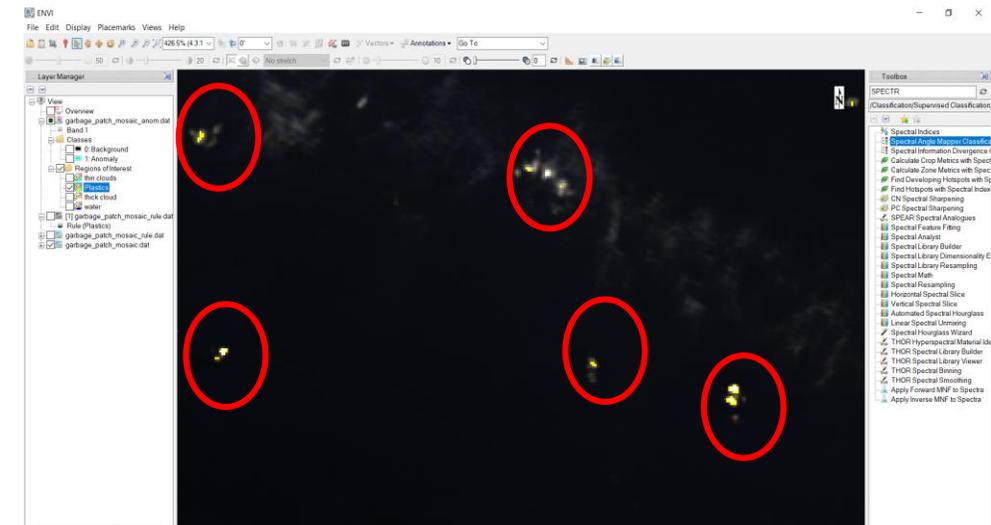
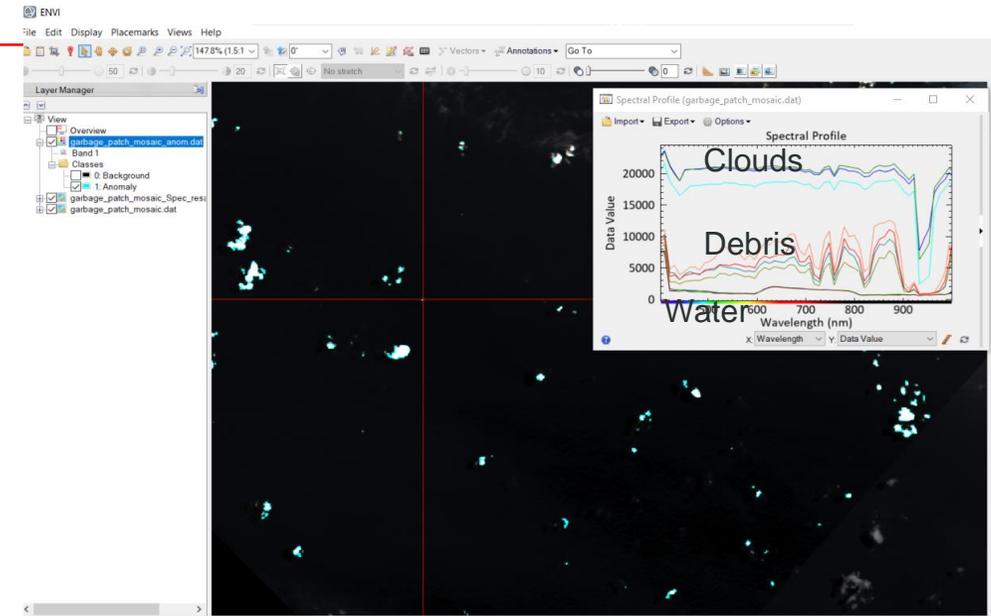


## ENVI Process

- Prepared DESIS imagery
  - Radiometric calibration
- Seamless Mosaic
- RX Anomaly Detection to search a large area
- Viewed anomalous spectral profiles
- Create new spectral signature library and ROIs
- SAM to separate anomalies (cloud fringe) from real plastics

## In the Future

- Fully automate workflow for monitoring
- Automate process for other searches
- On-Board processing to downlink locations



# Oil Slicks and Seeps



- Mississippi Canyon Seep, <https://coastalscience.noaa.gov/news/mc20report/>
- Oil Seeps and spills observable with hyperspectral data and more detailed level, such as oil type and thickness

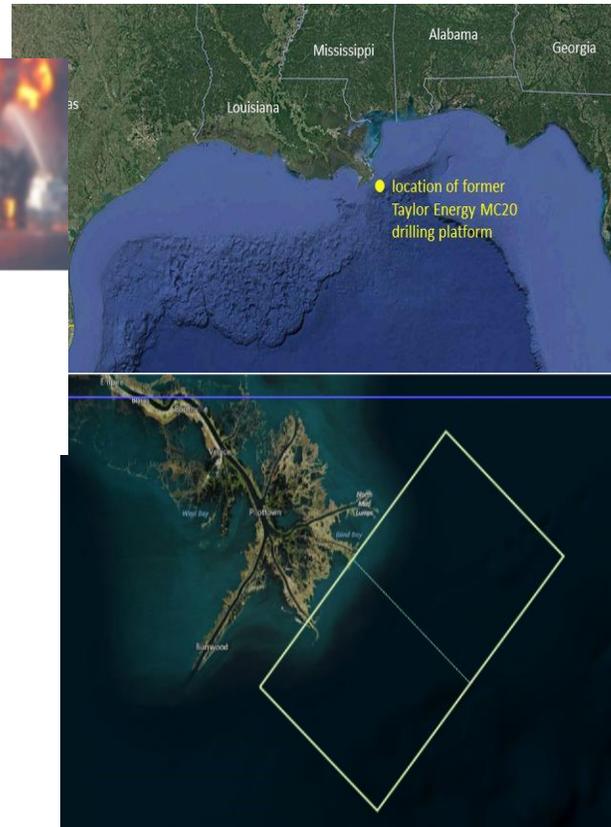
**Taylor Energy Platform "Saratoga"**  
Gulf of Mexico off Mississippi River Delta | 2013-Jul-14

Initial Notification: On 14 July 2013, the USCG Sector New Orleans contacted the NOAA SSC requesting trajectory support for a reported crude oil discharge from the Platform "Saratoga" that was destroyed during Hurricane Ivan in 2004. A bloom of varying colors was reported in lease block Mississippi Canyon 20A. The NRC report number is 1053820.

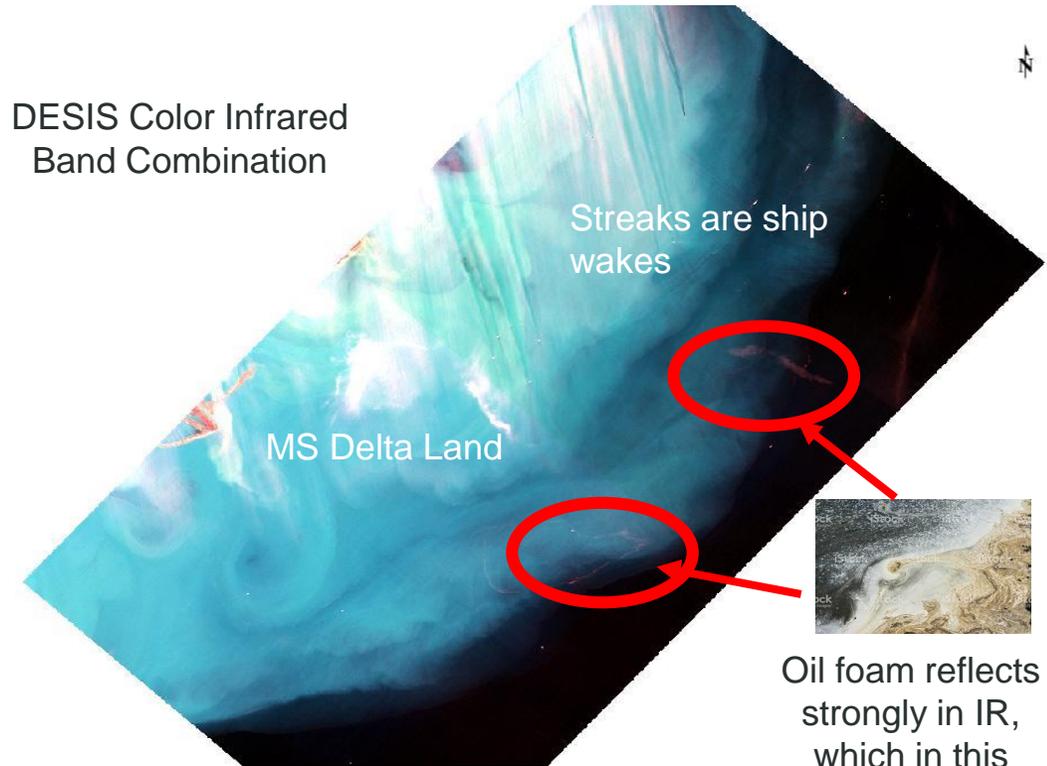
Incident Details	
Primary Threat:	Oil
Products Of Concern:	South LA Sweet Crude
Latitude (Approximate):	28° 56.16' North
Longitude (Approximate):	88° 58.13' West

**Public Information and Incident-Related Links**

On 14 July 2013, the USCG Sector New Orleans contacted the NOAA SSC requesting trajectory support for a reported crude oil discharge from the Platform "Saratoga" that was destroyed during Hurricane Ivan in 2004. A sheen 2mi x 200' of varying colors was reported in lease block Mississippi Canyon 20A. The NRC report number is 1053820.



DESI Color Infrared Band Combination

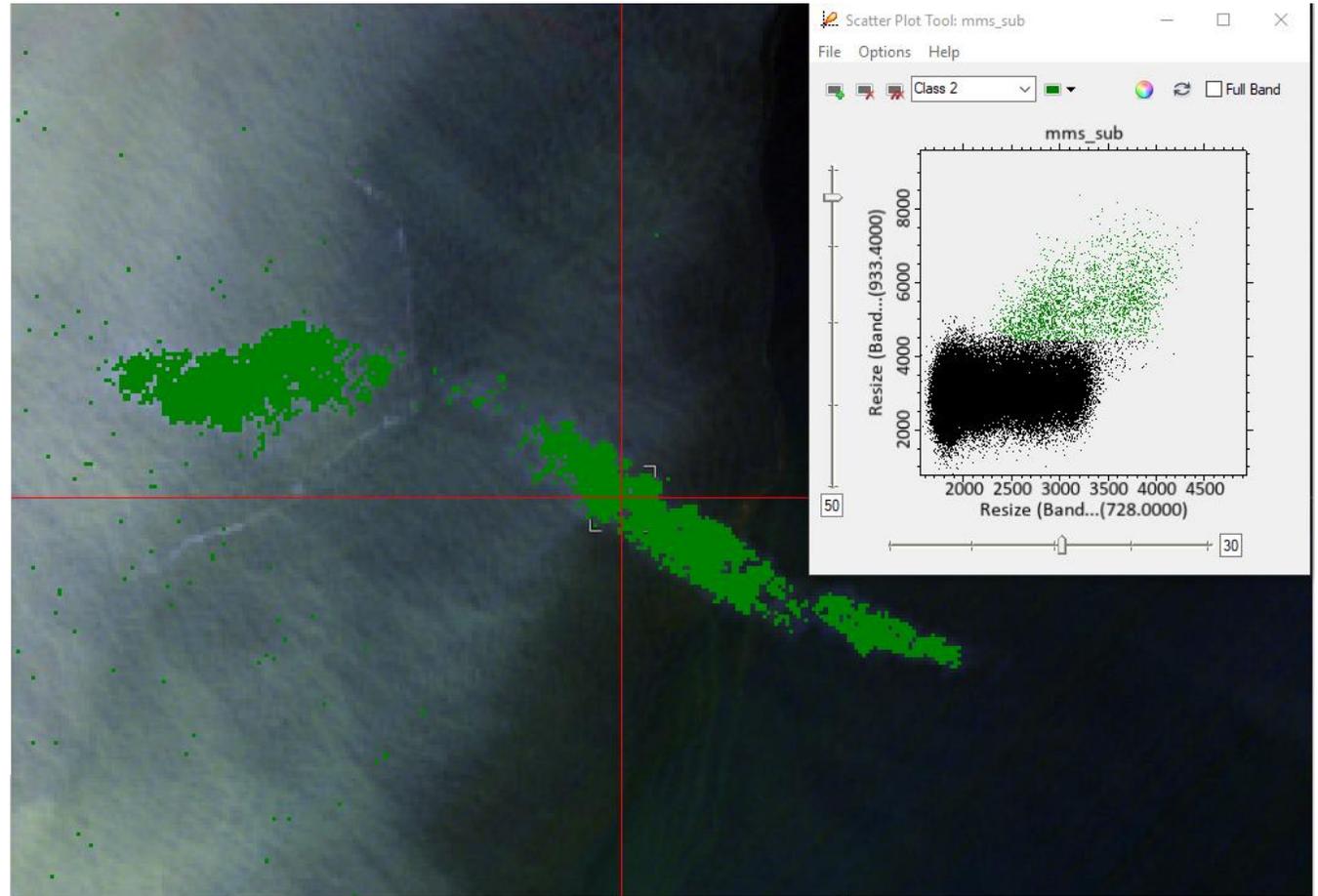
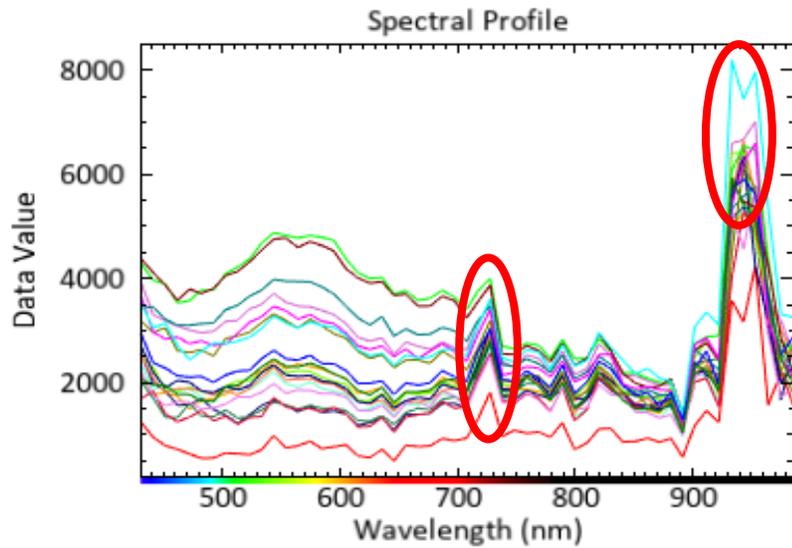


Streaks are ship wakes

MS Delta Land

Oil foam reflects strongly in IR, which in this image shows up as red

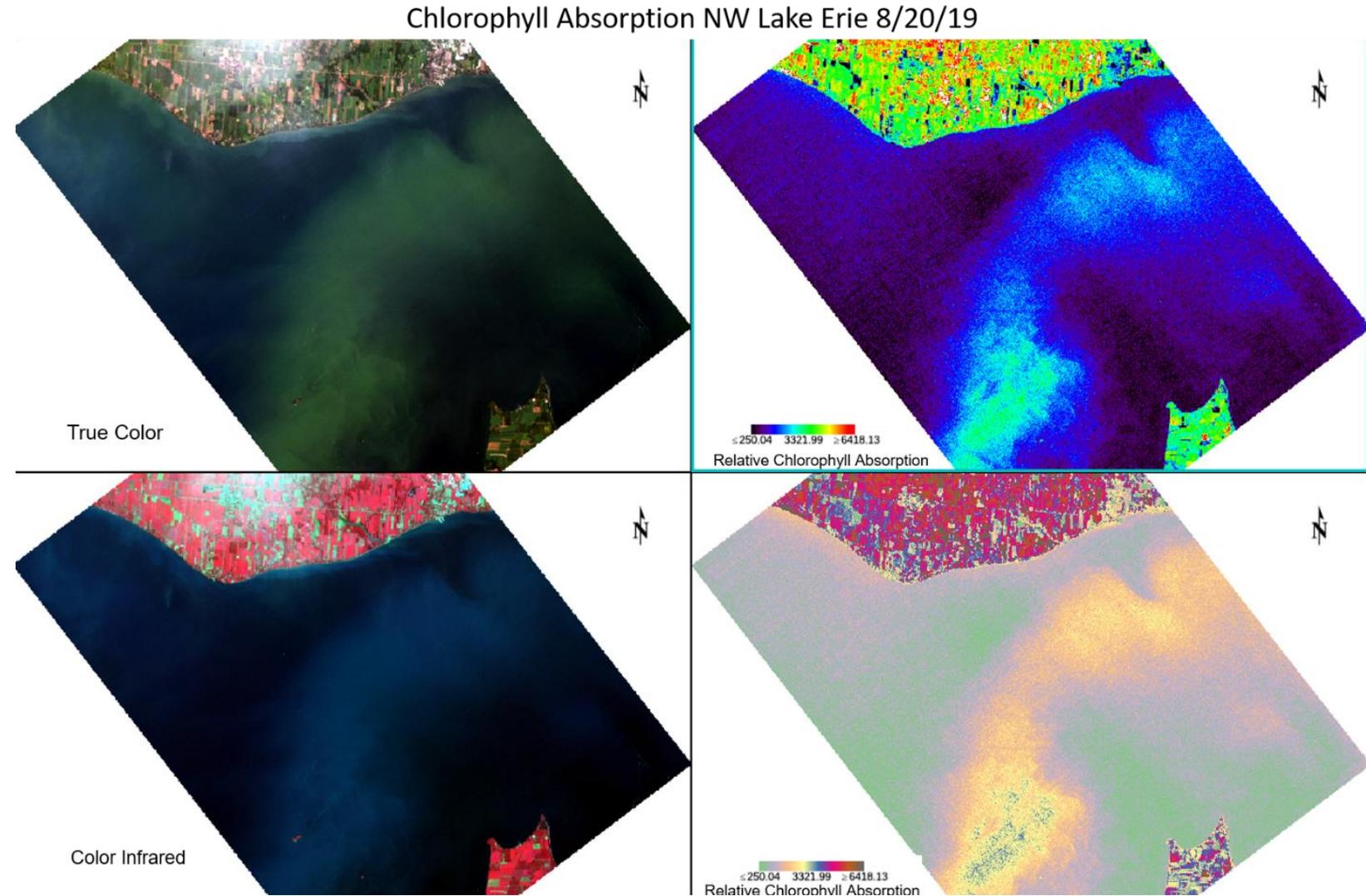
# Spectral Properties to Map Oil Extents



# Water Quality



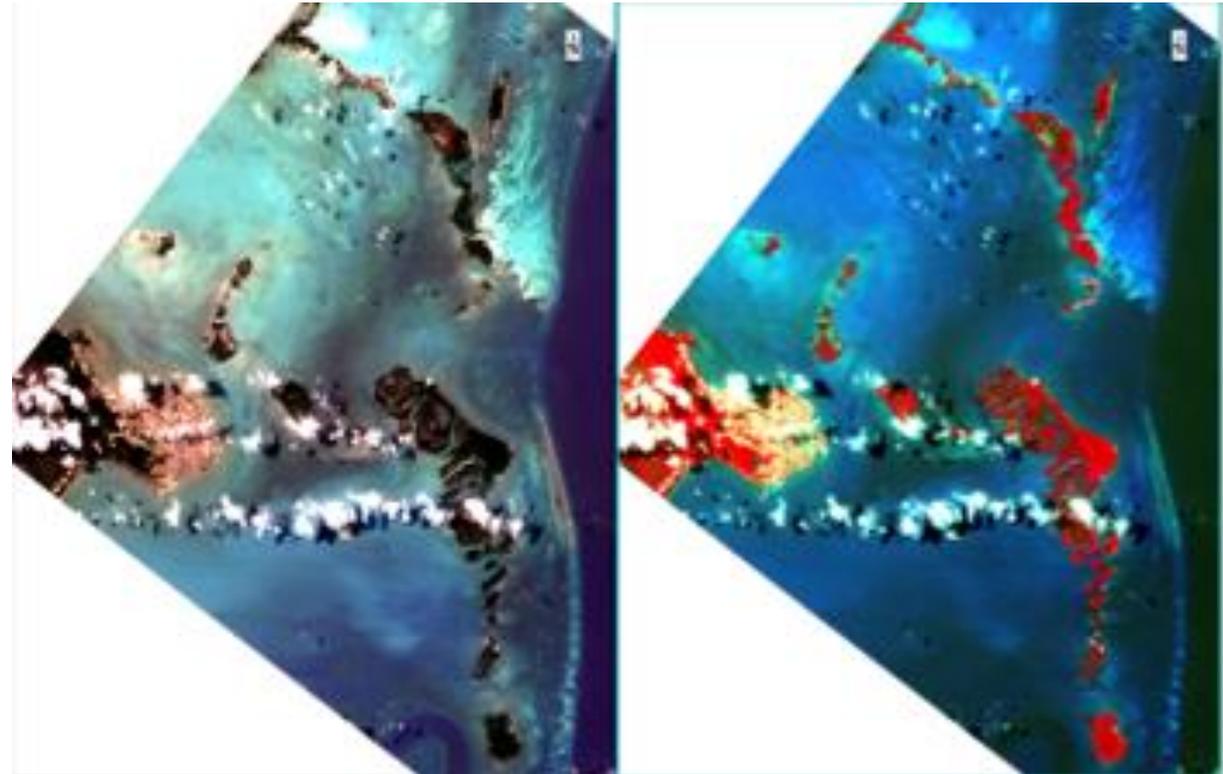
- ENVI provides 60+ spectral indices for detecting different materials, water quality is just one
- Inputs are straight forward so product creation can be automated with ENVI workflows
- Those workflows can also be run in the cloud or inside of ArcGIS





- In dry times, vegetation can behave differently which can reveal the presence of ancient structures
- Ongoing research using DESIS data
- More frequent equatorial repeats mean more chances for clear imagery and comparison
- Collections in coordination with field efforts with ASD spectra collection
  - Because of ISS activities, can't always time correctly, work with Amanda and Teledyne Operations

DESIIS Imagery of Belize City

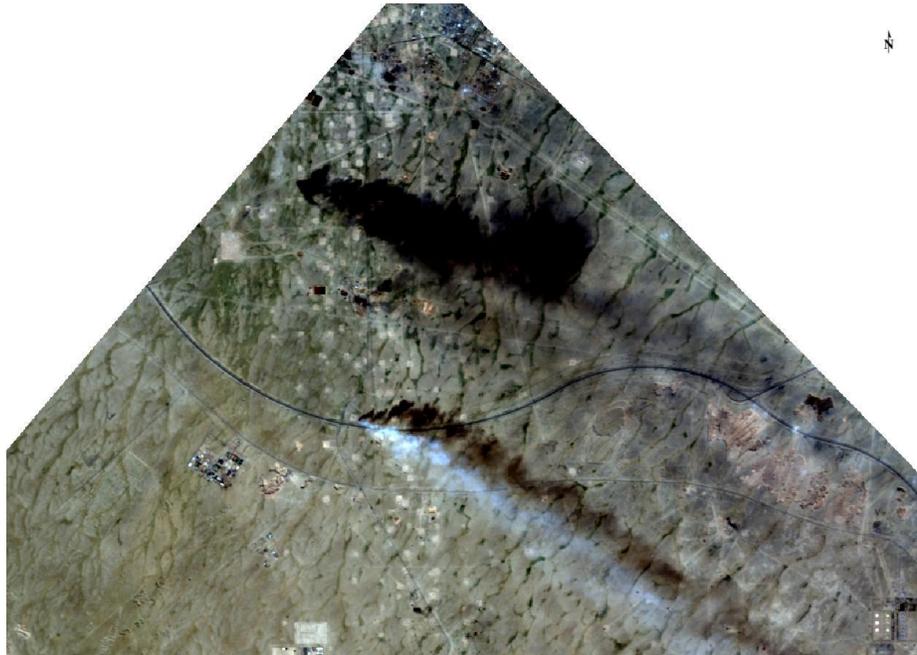


# Oil and Gas

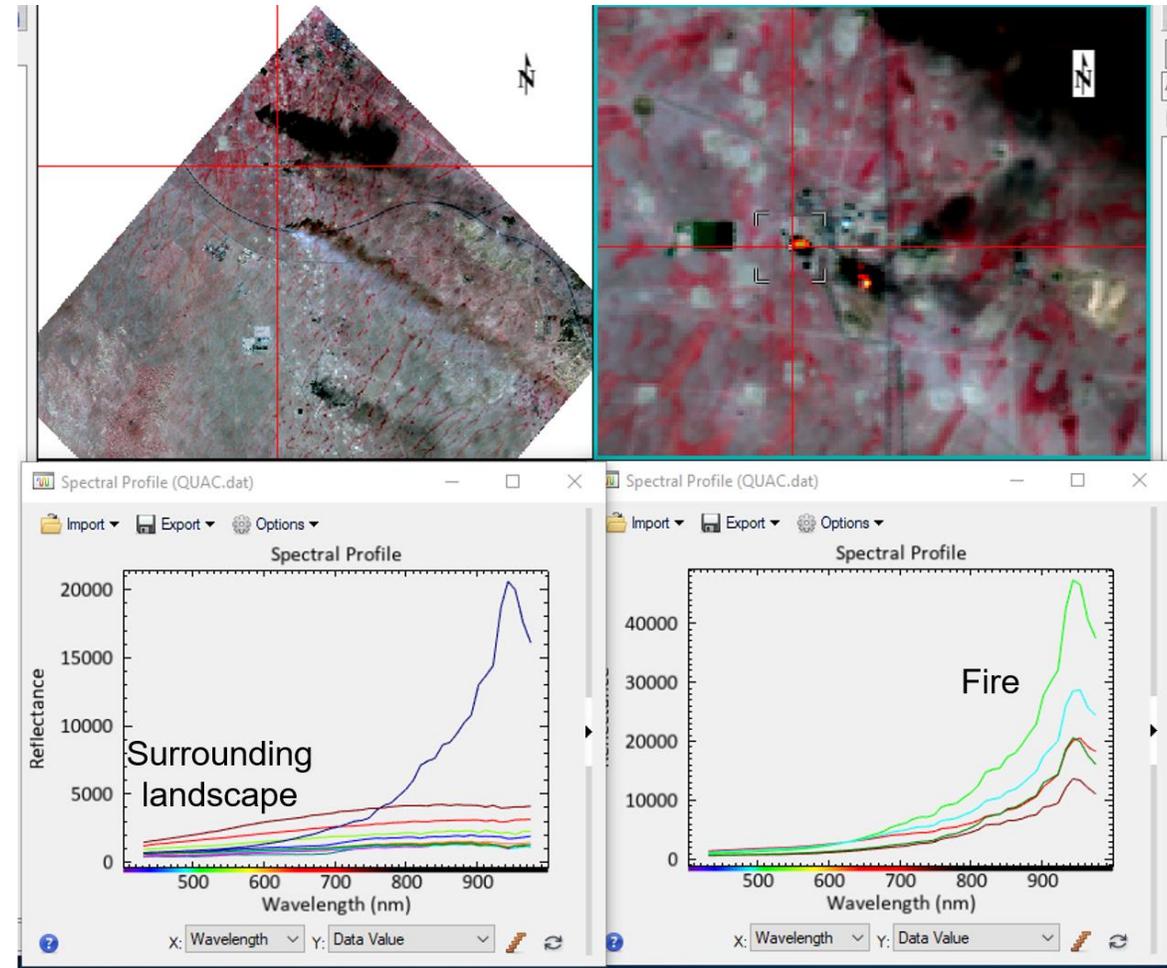


- Observe oil and gas flaring
- Dynamic range large enough to detect fire through plumes

DESIS True Color, no flame visible



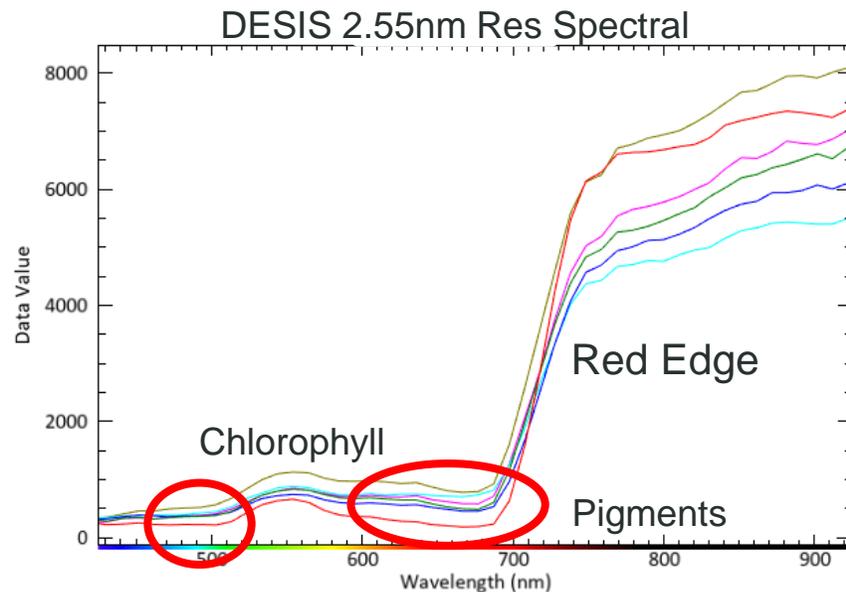
CIR Composite of Oil Wells Near Bagra, Iraq



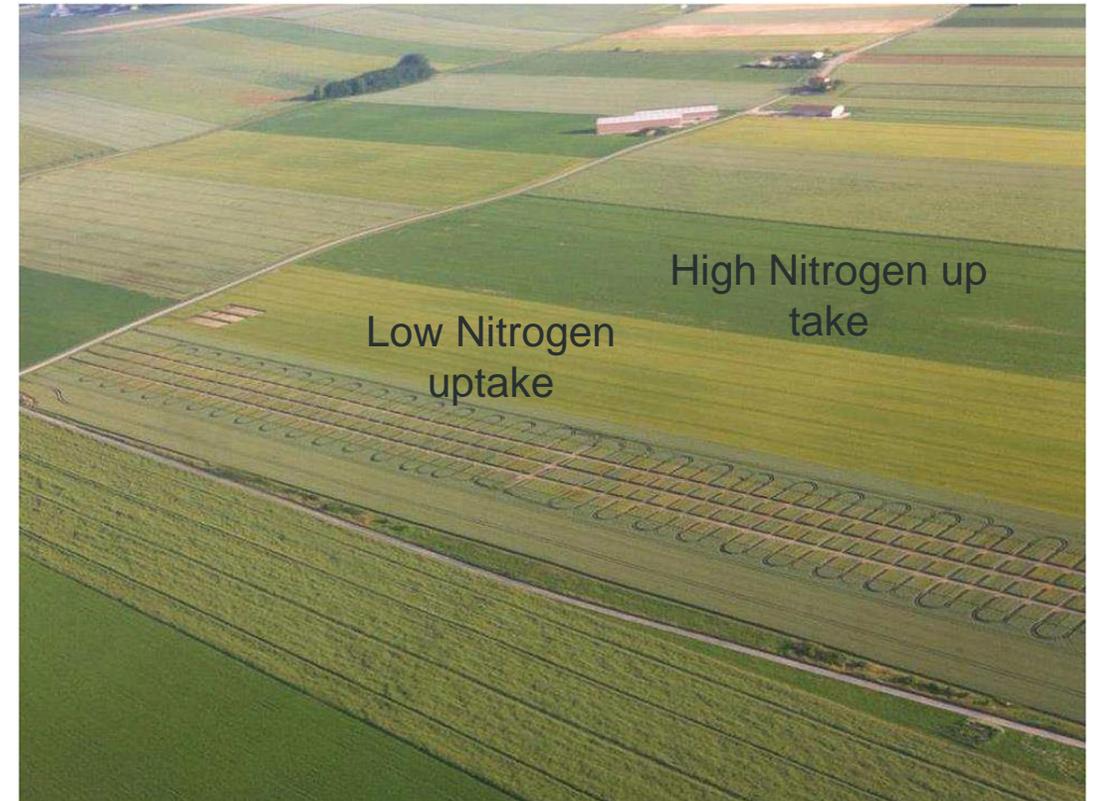
# Vegetation and Food Security



- 30m resolution effective for regional area analysis and trend analysis
- Hyperspectral data sensitive to vegetation pigments that can indicate stress
- Stress over time can create food insecurity and lead to geopolitical instability
- Agriculture companies can use the subtle pigment changes to study the efficacy of treatments



Different Wheat Phenotype Nitrogen absorption

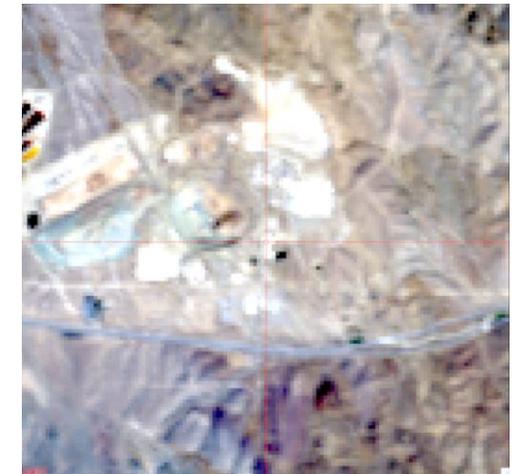
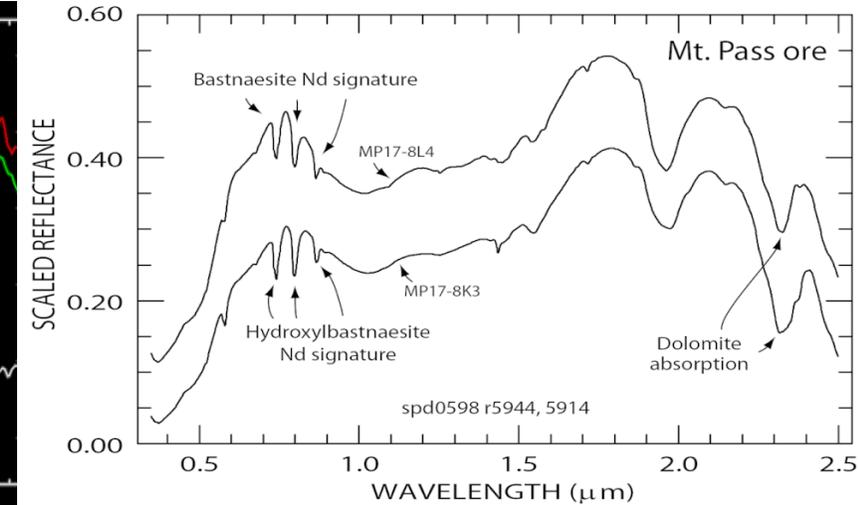
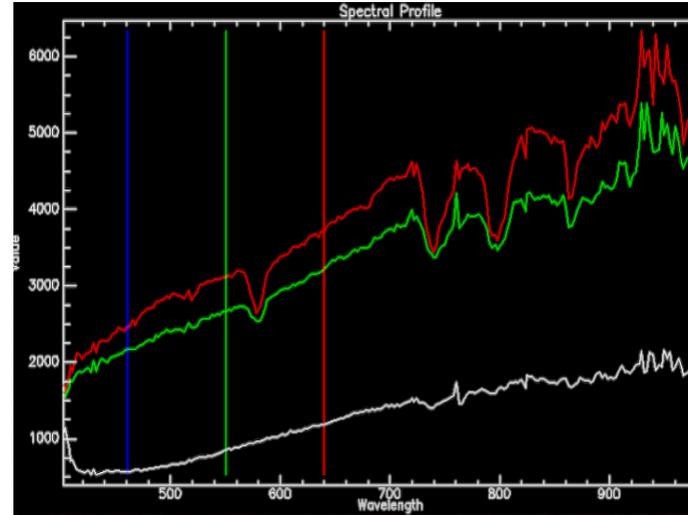


David Gouache, SPIE Newsroom 2016

# Rare Earth Elements



- Most geologic features found in Shortwave Infrared
- REE absorptions are “due to crystal-field transitions involving deep-lying electrons”  
<https://www.usgs.gov/media/images/reflectance-spectra-rare-earth-oxides>
- China is primary source of REEs
- Costs and international politics are changing REE sourcing
- USGS scientist confirm ability to delineate 2 versions of REEs present in 2.55 nm data (bastnaesite from hydroxylbastnaesite)
- The different kinds of REE’s separated OH group



Credit:   
science for a changing world

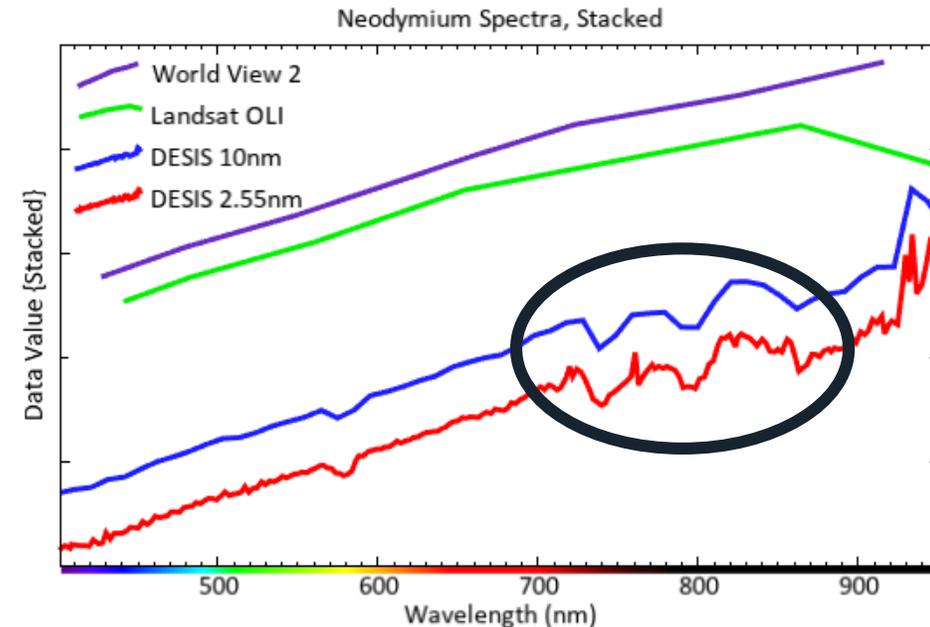
# The Value of Hyperspectral for REE



- Using ENVI's Resampling tools we can see that the absorption features that define REEs disappear
- **Gregg Swayze from USGS SpecLab**

**“So this may be the first demonstration of REE detection from space but may also have high enough resolution and SNR to allow differentiation of individual REE minerals.”**

- Because of DESIS' quality, this application is a reality

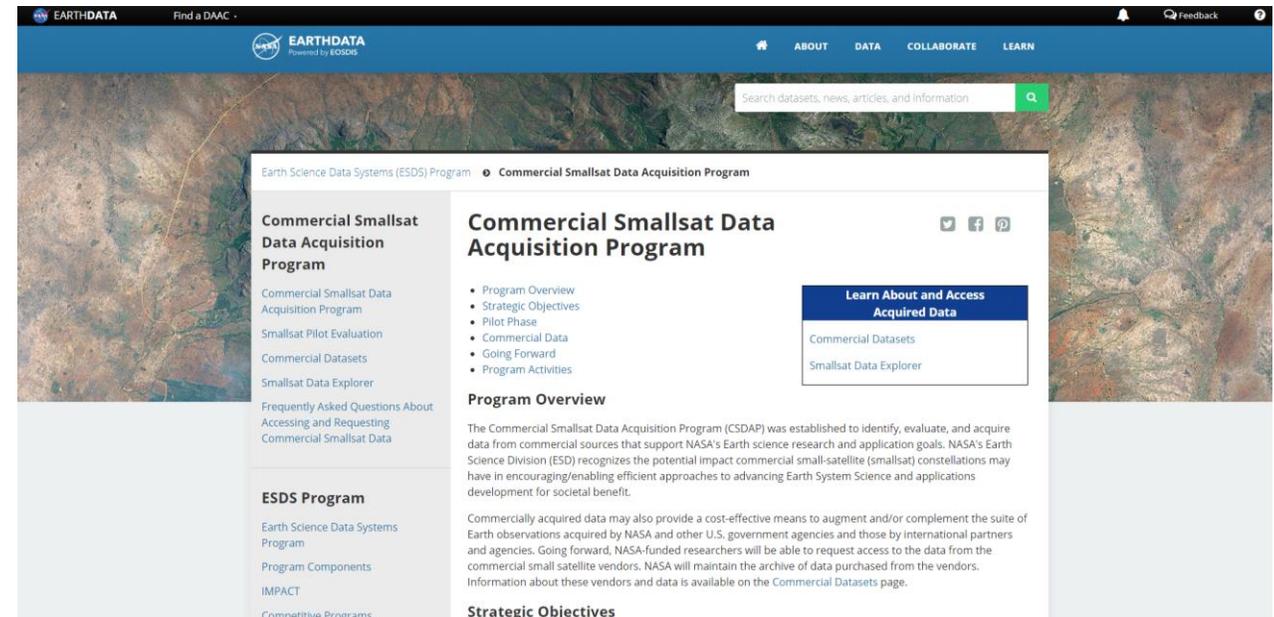
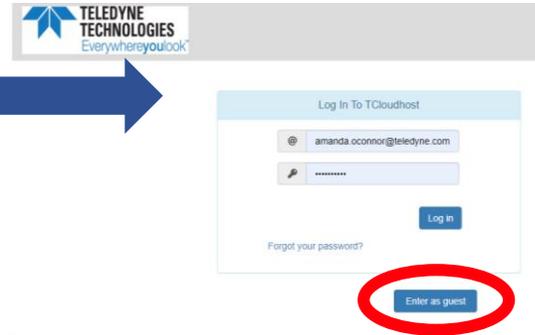


# Data Access



- Catalog can be browsed here:  
[Teledyne.tcloudhost.com](https://Teledyne.tcloudhost.com)
- Catalog data freely available to US federal **Research Scientists** VIA NASA contract.  
[Yvonne Ivey](#) is the POC for catalog access
- DESIS will eventually be available here:  
<https://earthdata.nasa.gov/esds/small-satellite-data-buy-program>
- Academic and NGO small data needs (Several Scenes), contact the DLR  
[https://www.dlr.de/eoc/desktopdefault.aspx/tabid-13629/23675\\_read-54295/](https://www.dlr.de/eoc/desktopdefault.aspx/tabid-13629/23675_read-54295/)
- Commercial, Academic/NGO site access, technical questions, [Amanda O'Connor](#)

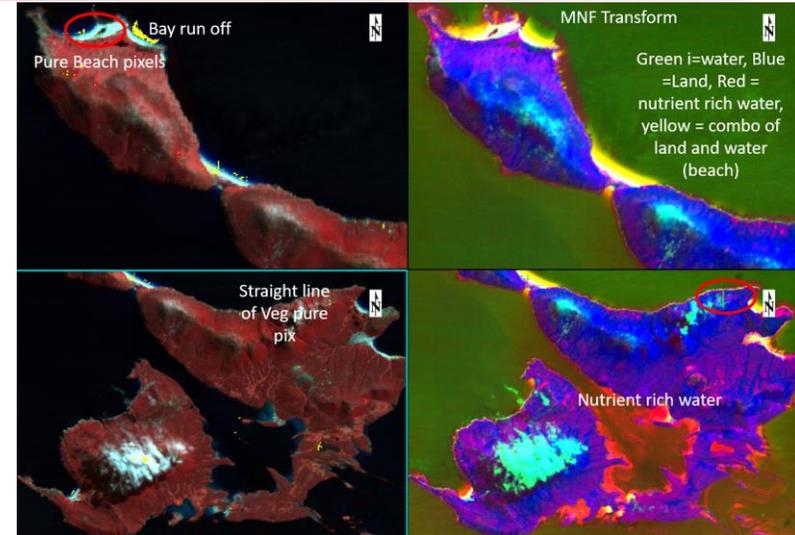
Fine print: 2.55nm resolution only available to US Gov and DLR. Larger commercial or site access may be eligible for a NOAA waiver on a case by case basis



# Every pixel can tell a story.....



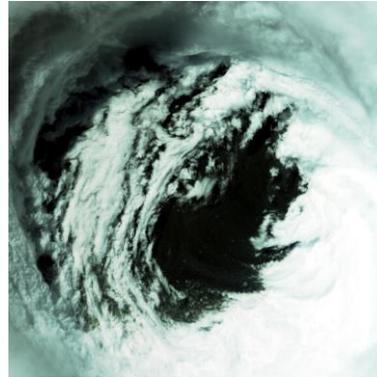
- The questions yet to be asked of hyperspectral are infinite and more and more sensors are coming on line
- Find your rockhopper penguin colony and understand how it changes
- For those interested, Teledyne Brown Engineering will make a DESIS sample image available. Please send Amanda your contact information
  - Name, Address, Country, email, organization
- DESIS Cal/Val information  
[https://tbe.com/\\_documents/PDFs/sensors-19-04471-v2.pdf](https://tbe.com/_documents/PDFs/sensors-19-04471-v2.pdf)
- If you are interested in trying ENVI please email [geospatialinfo@L3Harris.com](mailto:geospatialinfo@L3Harris.com)



# Questions?



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*[NASA ROSES](#) call for Research Opportunities in Space and Earth Sciences, DESIS may be used as a proposal component*