The Hyperspectral Thermal Emission Spectrometer's (HyTES) July 2014 Science Deployment

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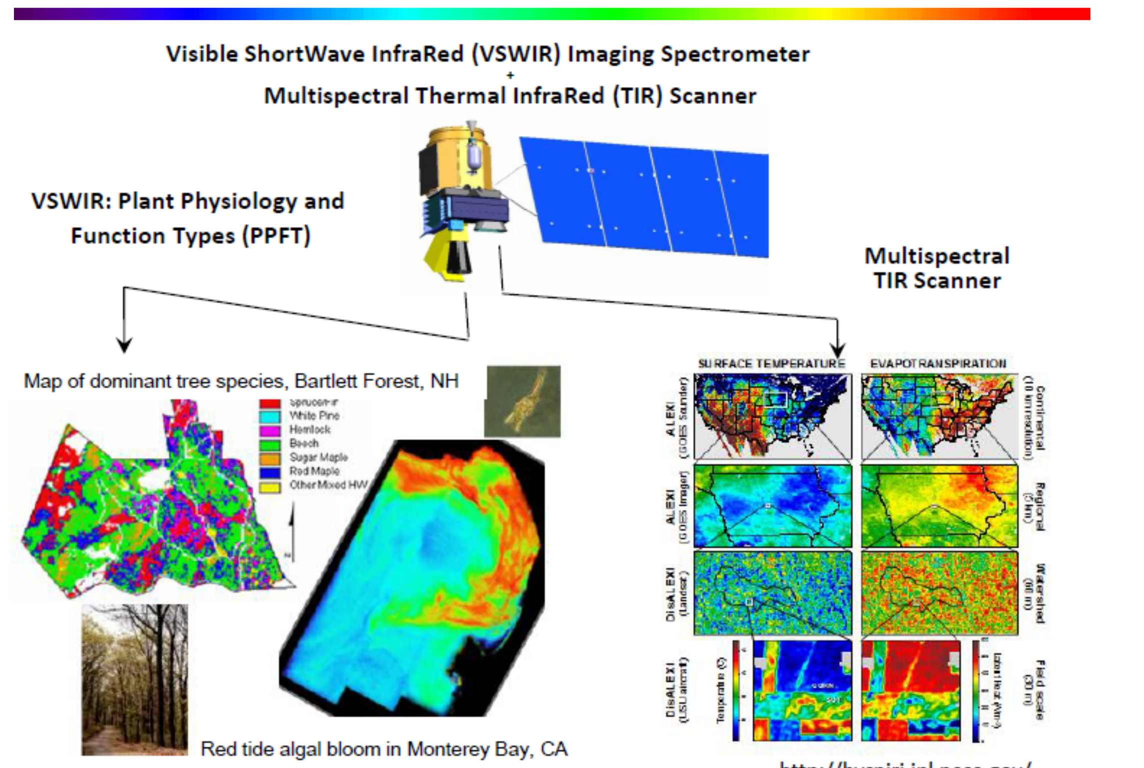
HyspIRI Background



http://hyspiri.jpl.nasa.gov/

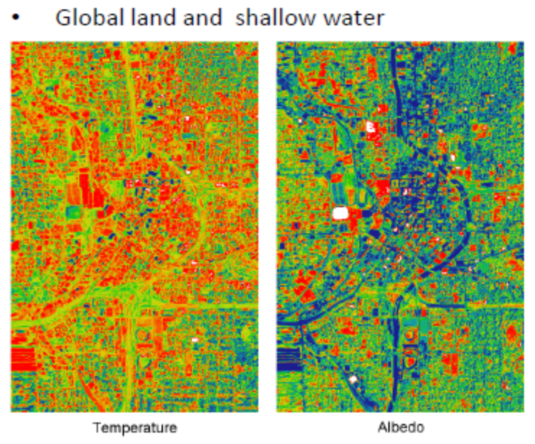
Multispectral Scanner

Schedule: 4 year phase A-D, 3 years operations

High Heritage

Measurement:

- 7 bands between 7.5-12 µm and 1 band at 4 µm
- 60 m resolution, 5 days revisit
- Global land and shallow water



Atlanta, GA - May 1997

Science Questions:

TQ1. Volcanoes/Earthquakes (MA,FF)

– How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

- *TQ2. Wildfires (LG,DR)*

– What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?

- *TQ3. Water Use and Availability, (MA,RA)*

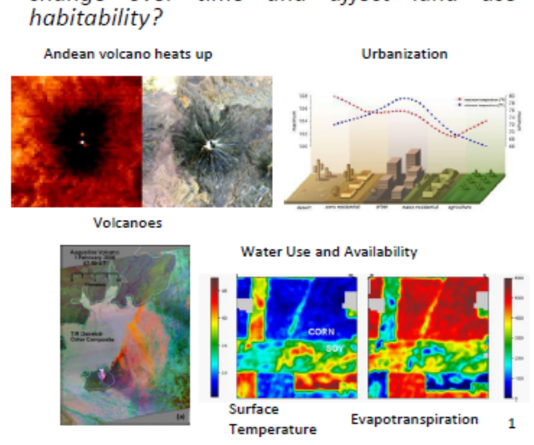
– How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?

- *TQ4. Urbanization/Human Health, (DQ,GG)*

– How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

- *TQ5. Earth surface composition and change, (AP,JC)*

– What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?



HyTES Rational and Objective

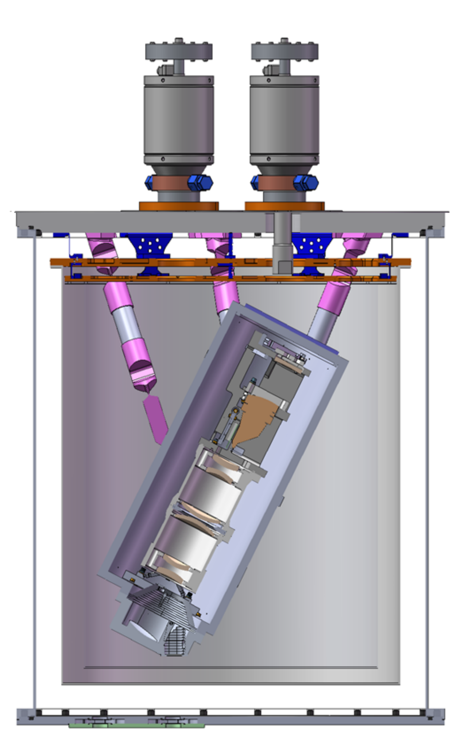
- Develop a thermal infrared imaging spectrometer with high spatial and spectral resolution which will provide precursor thermal infrared data for the NRC Recommended HyspIRI mission.

- Build and deploy an airborne Hyperspectral Thermal Emission Spectrometer (HyTES) with 512 pixels across track with pixel sizes in the range of 5 to 50 m depending on aircraft flying height and 256 spectral channels between 7.5 and 12 µm.

- Key enabling JPL technologies:

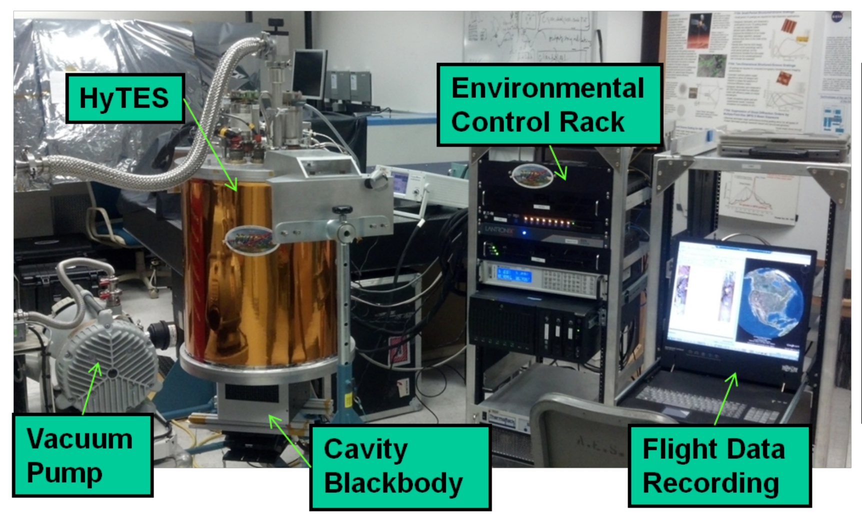
1. Dyson spectrometer: small form factor with high throughput, self-baffling
2. Quantum well Infrared photodetector: high uniformity and yield
3. Precision slit: enables low distortion and provides additional baffling
4. Convex diffraction grating: low scatter, high efficiency

Instrument Characteristic	HyTES
Mass (Scanhead)[1]	12kg
Power	400W
Volume	1m x 0.5m (Cylinder)
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5-12 um
Integration time (1 scanline)	30 ms
Total Field of View	50 degrees
Calibration (preflight)	Full aperture blackbody
QWIP Array Size	1024x512
QWIP Pitch *	19.5um
QWIP Temperature	40K
Spectrometer Temperature	100K
Slit Width	39 µm
Pixel size at 2000 m flight altitude	3.64m
Pixel size at 20,000 m flight altitude	36.4m



HyTES Instrument Layout

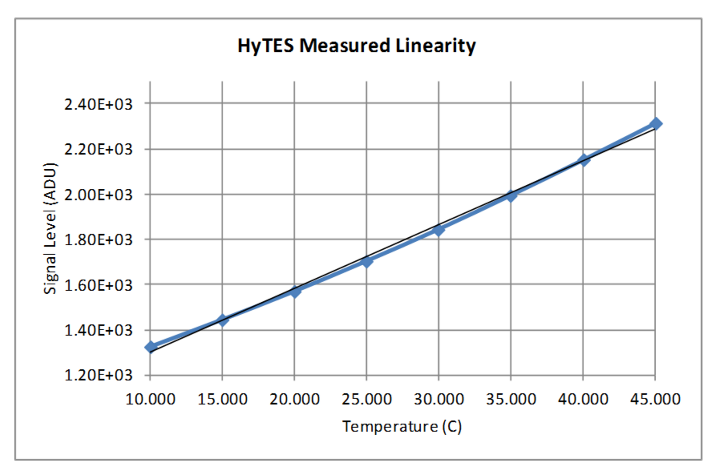
HyTES Laboratory Testing



Lab Test Procedure

- Cycle Blackbody Through Temperatures of 5, 10, 15, 20, 25, 30, 35, 40 and 45 ° C
- Blackbody DN's at 5 and 45 ° C used to Calculate 2-Point Calibration Coefficients
- Calculate Radiance and Brightness Temperature for Blackbody at 25 ° C.

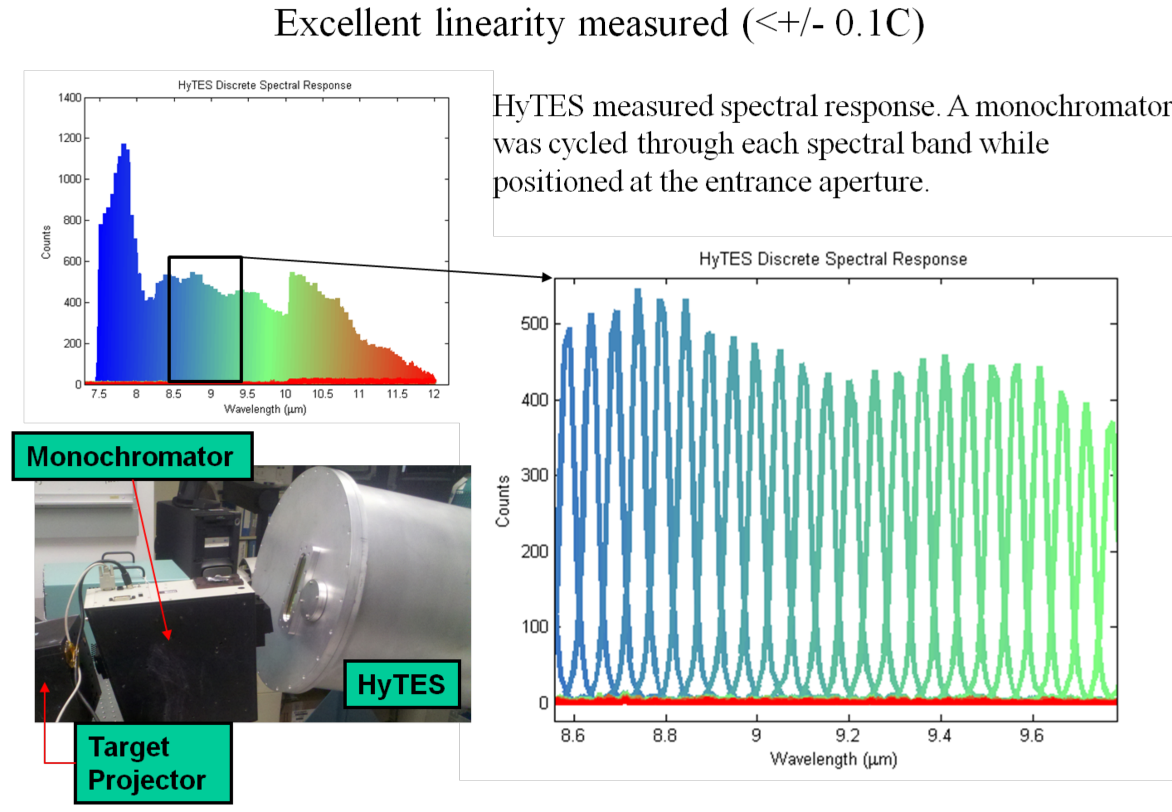
HyTES shown with high accuracy cavity blackbody. This is the set-up used for measuring system linearity, brightness temperature and NEDT.

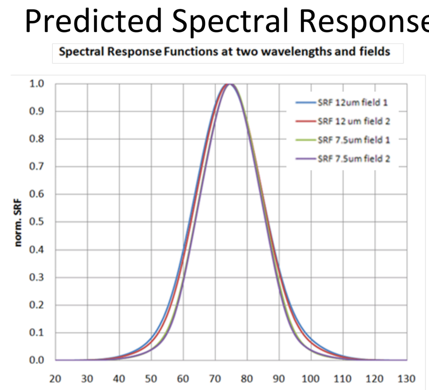


Actual Temp (C)	Measured Temp (C)	ΔT (C)
45	45.00	0
40	40.01	0.0054
35	34.94	-0.0594
30	29.92	-0.0769
25	24.95	-0.05225
20	19.97	-0.02695
15	14.96	-0.03695
10	10.00	0

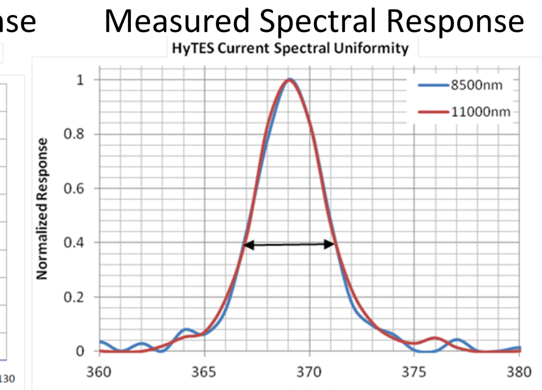
Excellent linearity measured (<+/- 0.1C)

HyTES measured spectral response. A monochromator was cycled through each spectral band while positioned at the entrance aperture.





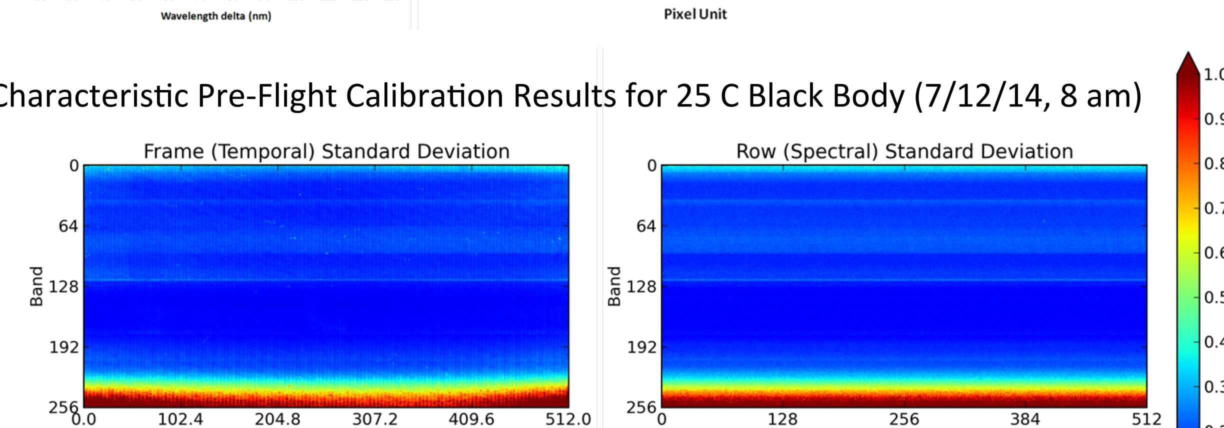
Predicted Spectral Response



Measured Spectral Response

Arrow on measured response shows a FWHM of about 35.2 nm or 4 pixels (2 effective pixels)

Characteristic Pre-Flight Calibration Results for 25 C Black Body (7/12/14, 8 am)



Measured NEdT (temporal and spectral) of approximately 0.2 K

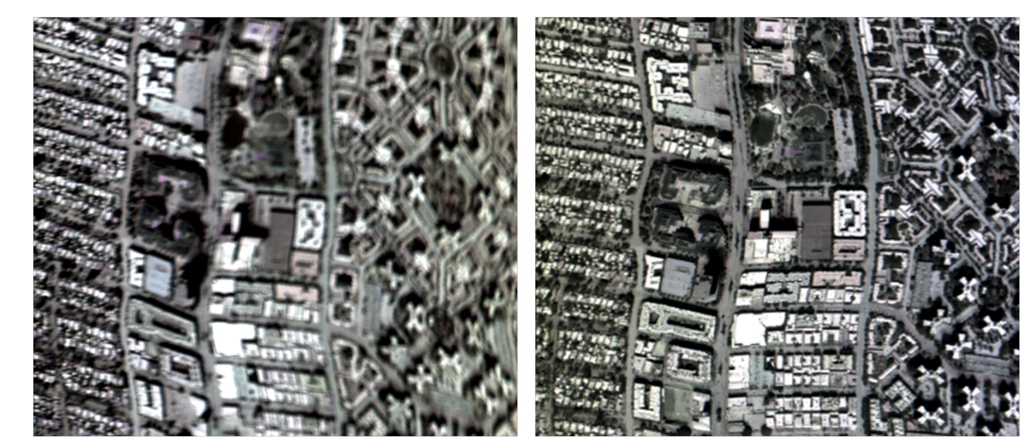
Key Results for 2014

1) Detection of methane over challenging areas, e.g. cities where thermal in-scene clutter makes detection difficult. This includes detection of natural (seeps) and managed systems (e.g. feedlots, pipelines, oil fields, landfills, storage facilities)
2) Detection of additional gases. Can now detect:
   a) Salton Sea (NH3 and H2S)
   b) La Brea Tar Pits (CH4)
   c) Kern River Oil Field (CH4)
   d) Ace Cogeneration Plant (SO2, NO2)
   e) Granada Hills (CH4)
   f) South and North Bakersfield Pipeline (CH4)
3) Acquisition of data over selected HyspIRI sites e.g. Teakettle, Soaproot Saddle, Tonzi Ranch for evaluation with HyspIRI campaign data
4) Acquisition of data over ecological, agricultural and geological sites for performance evaluation

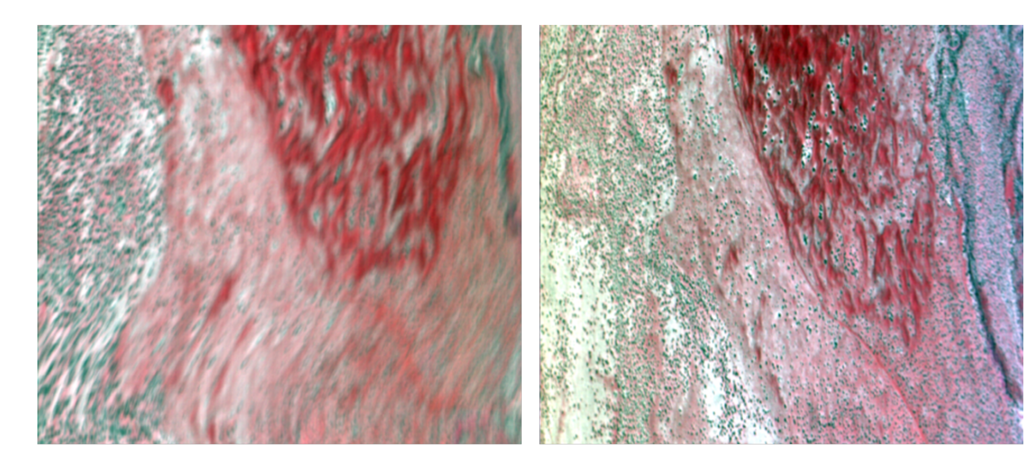
Key Instrument improvements for 2014

1) New diffraction grating that improves spectral alignment
2) Improved instrument focus improved thermal stability
3) Shipped instrument cold reducing time from shipping to first flight by 1 week.
4) Continuous data acquisition and geo-coding throughout the campaign.
5) Single sensor calibration for the entire mission.

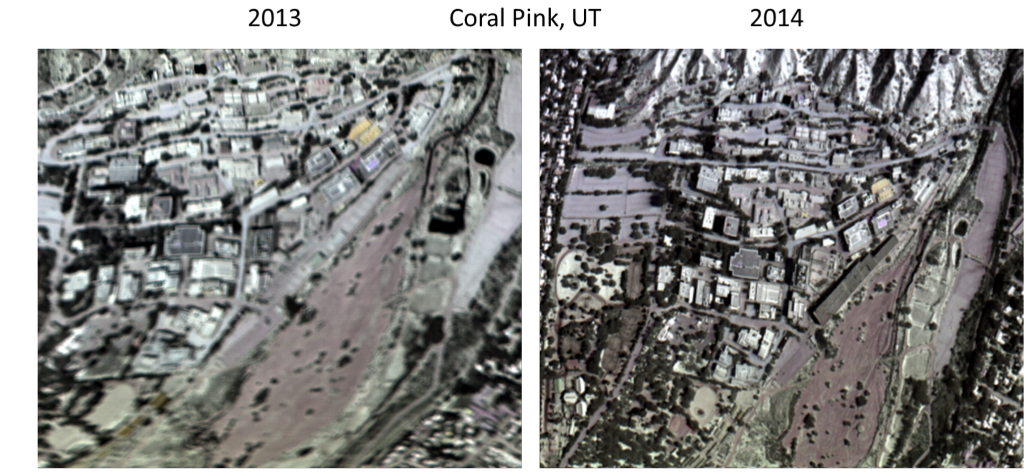
Examples of improved Imagery



2013 La Brea Tar Pits, CA 2014

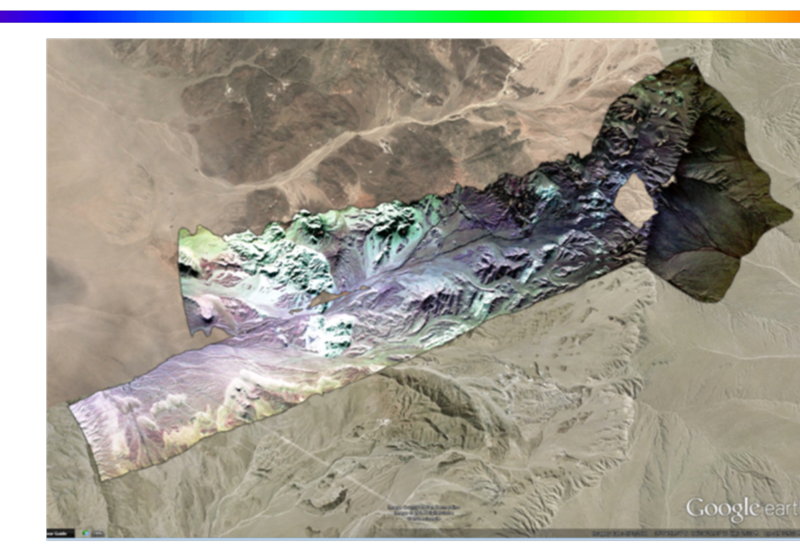


2013 Coral Pink, UT 2014



2013 Jet Propulsion Laboratory 2014

Image Orthorectification – now implemented

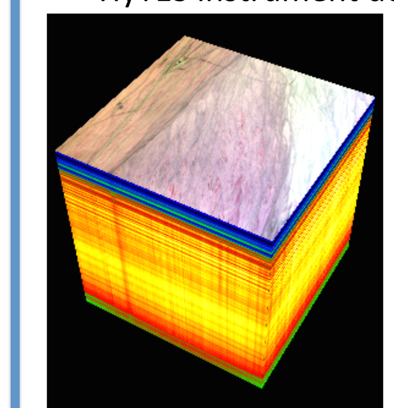


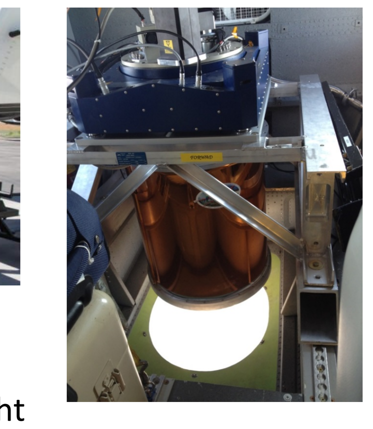
KMZ after correction

L1A before applying geo-correction

HyTES 2014 Science Flights

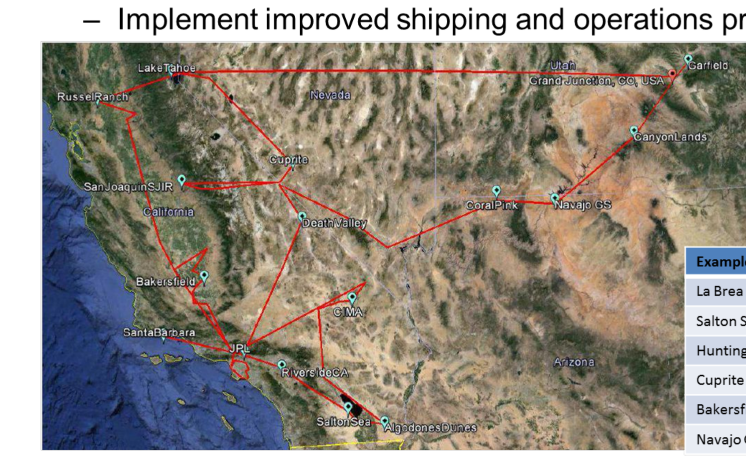
HyTES instrument deployed in June 2014 configured on the Twin Otter aircraft





(Left) HyTES image cube of Cuprite
(Center) Twin Otter aircraft
(Right) HyTES looking NADIR in flight

- Objectives
  - Acquire data from a range of targets for evaluation in various disciplines: Solid Earth, Ecosystems, Atmospheric composition
  - Evaluate upgrades made to instrument after previous campaigns
  - Evaluate improved algorithms for geo-location and gas detection
  - Implement improved shipping and operations procedures



Parameter	Value
Duration	12 days
Hours	50 hours
Area	Southwest USA
Aircraft	Twin Otter (Commercial) – Grand Junction Co

Example Sites	Purpose
La Brea Tarpits	Urban/Methane
Salton Sea	Calibration/Ammonia
Huntington Gardens	Ecosystems
Cuprite	Surface Composition
Bakersfield Oil and livestock	Methane
Navajo Generating Station	Sulfur dioxide

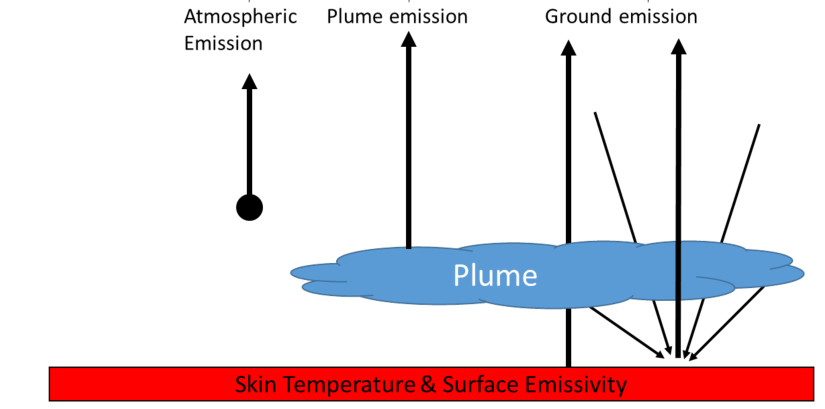
Cuprite Kern River Oil Field Navajo Gen Station Russell Ranch

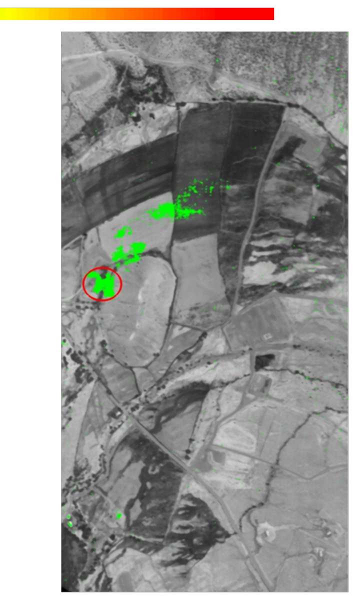
Gas Plume Detection

Thermal Infrared Radiative Transfer

Sensor Radiance

$$L_i(\theta) = \underbrace{L^{path}}_{\text{Atmospheric Emission}} + \underbrace{L^{plume}\tau^{atm}}_{\text{Plume emission}} + \underbrace{L^{gnd}\tau^{atm}\tau^{plume}}_{\text{Ground emission}}$$





Geo-coded gas plume detection: Captured over numerous sites. Example above shows CH_4 leakage at a fracking site. Other data: NH_3, SO_2, N_2O, H_2S.

HyTES July 2014 Summary

The HyTES 2014 campaign was a success. HyTES successfully deployed on a Twin Otter aircraft over various sites in the southwestern USA. Results indicate that HyTES will provide precursor data suitable for the HyspIRI mission as well as data to advance the current understanding of Earth Science.

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