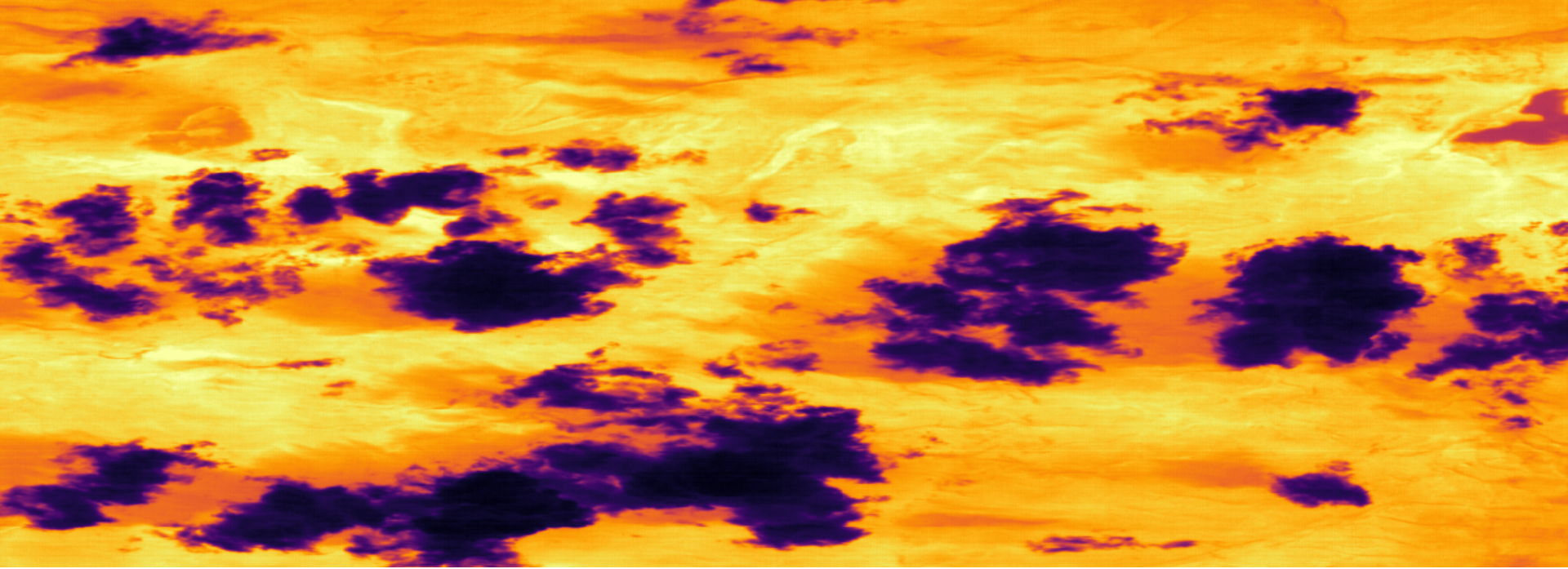

Virtual Research Presentation Conference

Joint VSWIR-TIR Retrieval Using ISOFIT

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Program: Spontaneous Concept

Assigned Presentation #RPC-060

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

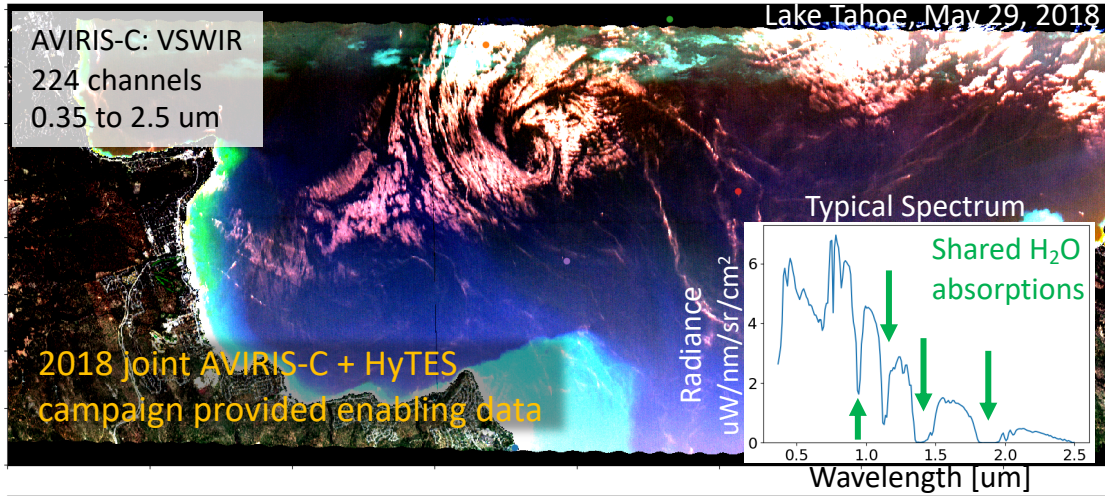
Abstract

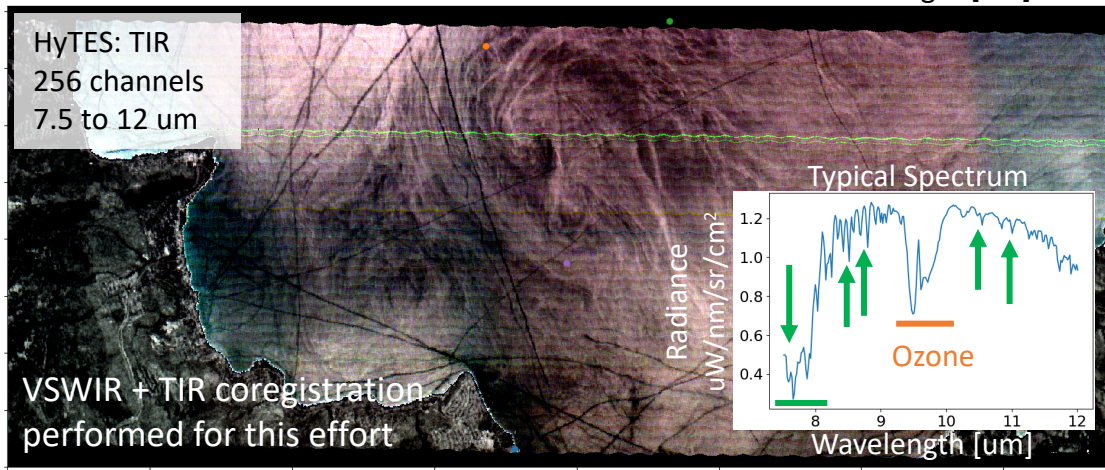
Imaging spectrometers are powerful tools for understanding our planet's surface composition and biome health and facilitate environmental mapping. Mounted on an airplane, these instruments measure the radiance spectrum for a strip of the Earth's surface in various spectral bands, including the Visible/ShortWave InfraRed (VSWIR) or Thermal InfraRed (TIR). Bayesian image processing algorithms then "retrieve" the surface reflectance spectrum along with several parameterized atmospheric quantities, like water vapor content, from the radiance data. Typically, these retrievals are performed for each instrument separately and the independent results combined. Relying on a joint AVIRIS-C (VSWIR) and HyTES (TIR) campaign from 2018, we have developed a new algorithm to instead fuse the data from the VSWIR and TIR into a single, joint retrieval. This process leverages shared information between the two spectral regions, like atmospheric water vapor absorptions, to yield better estimates with less uncertainty. It also enables retrieving new quantities not possible with separate instruments, like simultaneous air and surface temperatures used for constraining energy fluxes in Earth System Models. In this report, we demonstrate the algorithm and provide initial comparisons against JPL calibration sites and the HyTES standard products. The algorithm is implemented in JPL's ISOFIT optimal estimation software (Thompson 2018).

Improved atm. correction and estimation through sensor fusion:

Joint VSWIR + TIR Optimal Estimation

- Remote imaging spectroscopy can use solar-reflected or thermally-emitted photons.
  - Traditionally the two intervals have been treated completely separately.
- For the first time, we have demonstrated a combined retrieval spanning the Ultraviolet through Thermal Infrared wavelengths
  - Leverages the complementary information in both regimes, improving accuracy and enabling new measurements
- Benefits:
  - Surface and atm. measurements with reduced uncertainties
  - Improved evapotranspiration est. for primary productivity
  - Simultaneous air / ground temperature measurements to better constrain energy fluxes in Earth System Models
- This work extracts more and better information for Earth Observation as JPL continues to develop and field imaging spectrometers
  - Could be used in future Surface Biology and Geology concept
  - Recent joint AVIRIS-C and HyTES collection over Bobcat Fire





Bayesian inversion facilitates sensor fusion

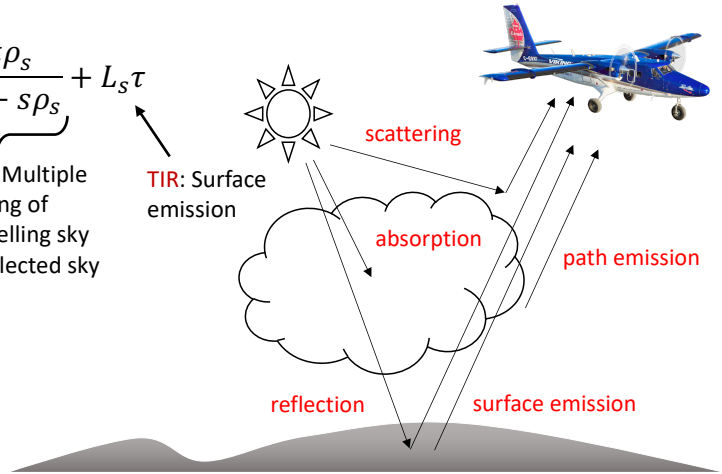
- Optimal Estimation (OE) retrievals use a Bayesian framework to provide a cost function for optimization
  - Straightforward to adapt cost function
  - Based on JPL's ISOFIT OE software for VSWIR https://github.com/isofit/isofit (Thompson 2018)
- Joint OE retrievals required two changes:
  1. Updated "forward model" to include thermal emission from the sky and the surface in the radiative transport model
  2. New Bayesian prior probability distribution based on the ECOSTRESS Spectral Library (https://speclib.jpl.nasa.gov)

$$L_{model} = L_a + L_{\downarrow}\frac{t\rho_s}{1 - s\rho_s} + L_s\tau$$

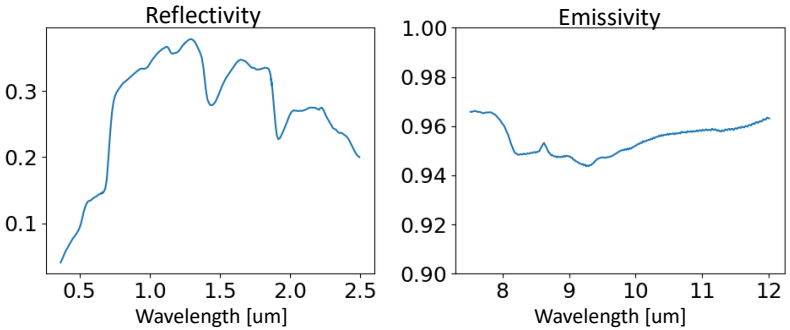
VSWIR: Scattered sun light
TIR: Path radiance

VSWIR: Multiple scattering of downwelling sky
TIR: Reflected sky

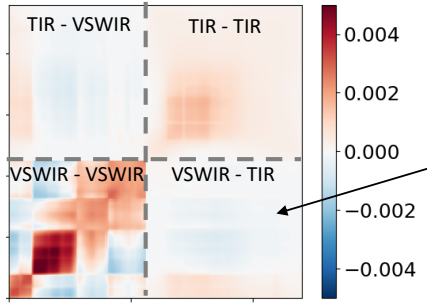
TIR: Surface emission



Example prior means



Example Prior Covariance



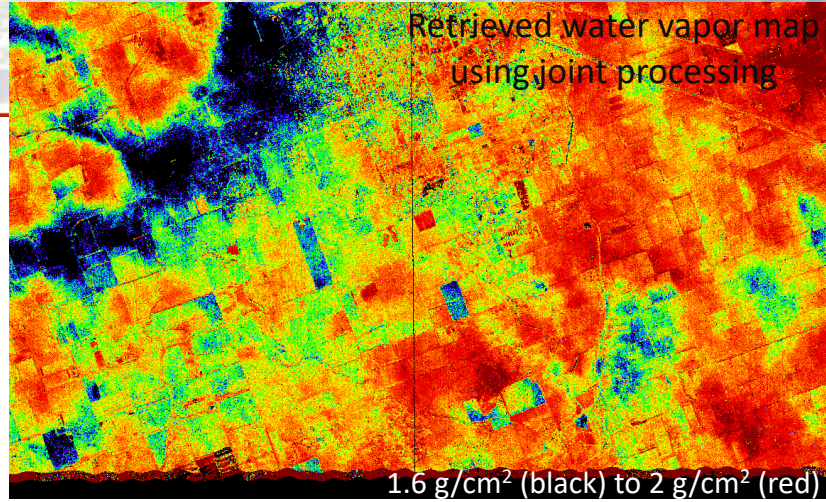
Correlations between bands provide constraints on joint retrieval not present in either individually

Initial results demonstrate algorithm accuracy

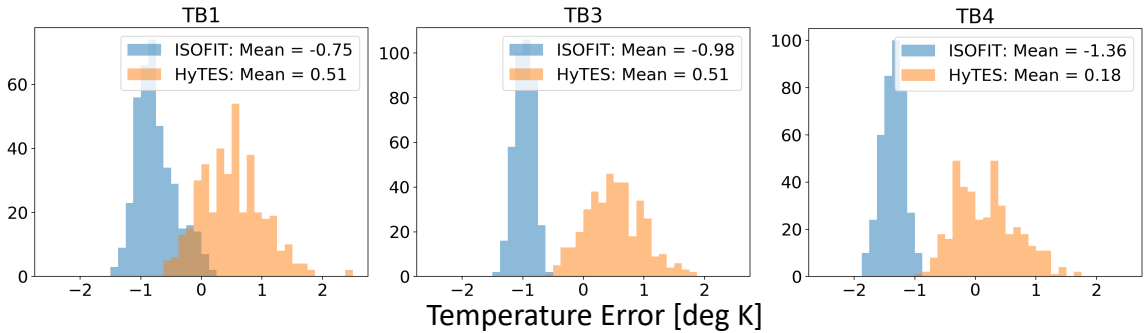
- Achieved all three goals from proposal:
  1. Coregistration of AVIRIS-C and HyTES imagery (slide 3)
  2. New emissive surface and radiative transfer models (slide 4)
  3. Surface and atmospheric joint VSWIR + TIR retrievals (below and right) and increased retrieval degrees of freedom (DOF):

VSWIR	82.081
TIR	4.875
VTIR	85.760

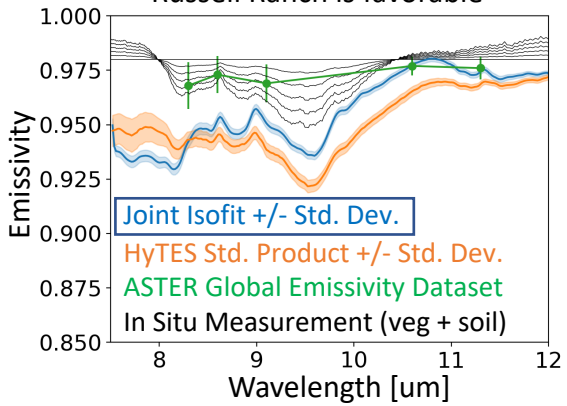
- Demonstrates first known Joint VSWIR + TIR retrieval, allowing two instruments to be treated as a single, enhanced instrument
- Next steps: fully exploit newly available information
  - Simultaneous air & surface temperature
  - Hi res ozone maps
  - Joint H_2O estimates better than VSWIR or TIR alone



Retrieved surface T histograms near JPL's Lake Tahoe cal/val sites TB1, TB3, and TB4



Emissivity comparison at Russell Ranch is favorable



Created during follow-on work under David Thompson's PLUS group motivated by Spon. Con. development.

Publications and References

A paper based on this work has been accepted to the Remote Sensing of Environment's Special Issue on Thermal Remote Sensing for Terrestrial Ecosystem (TIR TE): Characteristics, Monitoring, and Assessment

An AGU presentation of this work has been accepted for the 2020 AGU Fall Meeting

References:

Rodgers, C.D., 2000. Inverse Methods for Atmospheric Sounding: Theory and Practice. 2.

Thompson, David R., Vijay Natraj, Robert O. Green, Mark C. Helmlinger, Bo-Cai Gao, and Michael L. Eastwood. "Optimal Estimation for Imaging Spectrometer Atmospheric Correction." *Remote Sensing of Environment* 216 (October 2018): 355–73. https://doi.org/10.1016/j.rse.2018.07.003.