Standoff Thermal Infrared Hyperspectral Imaging for Ground-Based and Airborne Remote Sensing

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Introduction

Thermal infrared imaging represents a highly versatile measurement technique, as experiments can be carried out under various illumination conditions. The inherent self-emission associated with thermal infrared removes the need for an external illumination source. Over the last decade, technological progresses have allowed combining Fourier-Transform spectroradiometer instruments with focal-plane array imaging in order to provide a combination of high spatial, spectral and temporal resolution. Thermal infrared hyperspectral imaging remote sensing can then be used to identify the chemical nature of targets based on their unique infrared spectral signature.

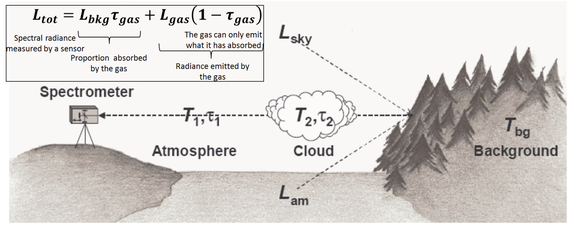
The Hyper-Cam

- FTIR-Based Spectro-Radiophotometer
- Cooled 320x256 pixels FPA (High-Sensitivity)
- 0.25 to 150 cm^{-1} Spectral Resolution
- Available in the MWIR (3-5µm), LWIR (8-12µm) and optimized for methane
- Ground and airborne configurations

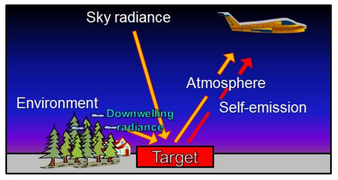
The Radiative Transfer Models

$$L_{tot} = L_{bkg}\tau_{gas} + L_{gas}(1-\tau_{gas})$$

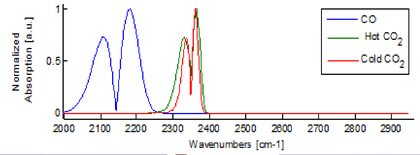
Spectral radiance measured by a sensor; Proportion absorbed by the gas; The gas can only emit what it has absorbed; Radiance emitted by the gas

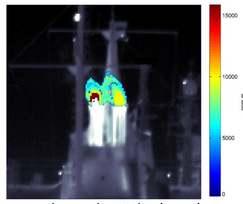


$$L_{tot} = \left[L_{tg}\varepsilon_{tg} + DW(1-\varepsilon_{tg})\right]\tau_{atm} + L_{atm}(1-\tau_{atm})$$

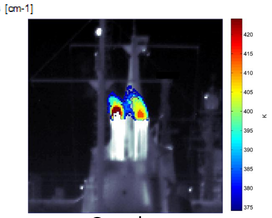


Ship Plumes

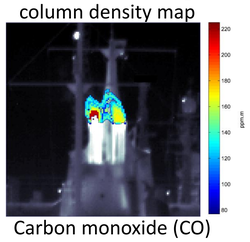




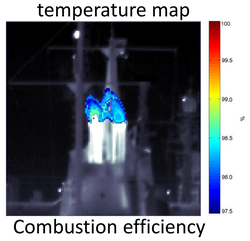
Carbon dioxide (CO_2) column density map



Gas plume temperature map



Carbon monoxide (CO) column density map

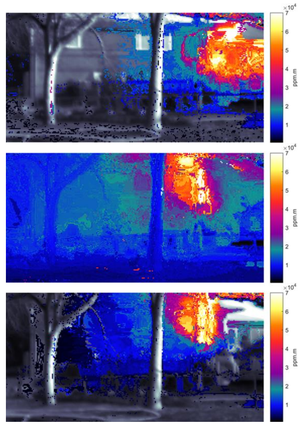


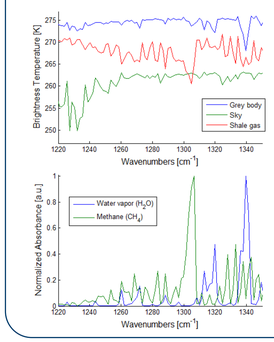
Combustion efficiency map

Shale Gas Leak

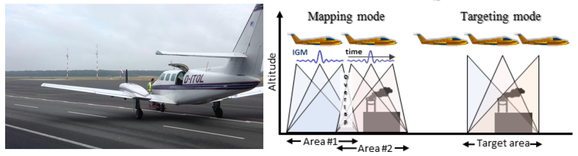
Shale gas leak observed in Québec City (Canada, Dec. 2014)

- Calculated leak rate of 27g/s of methane





Airborne Platform

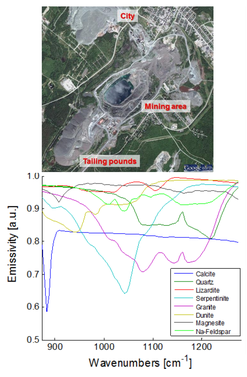


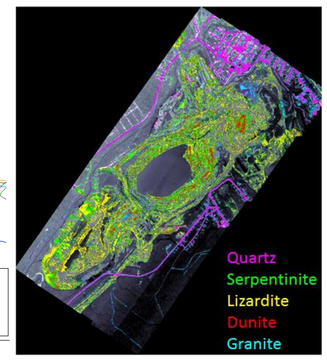
Two operating modes supported: mapping and targeting

Airborne Mineral Survey

Open-pit mine in the Thetford Mines area (Québec, Canada)

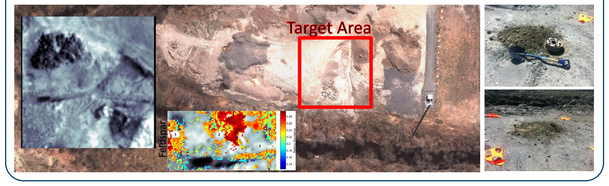
- Thematic map after Temperature-Emissivity Separation





Airborne Buried Objects Detection

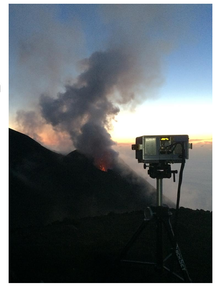
Buried objects areas exhibit higher radiometric temperature and lower contribution for each mineral to the overall spectral emissivity data. In this case, disturbed soils contain a higher proportion of organic materials which behave like grey bodies, i.e. no spectral features from a TIR perspective.

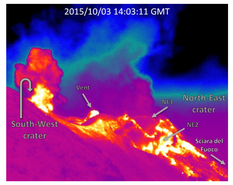


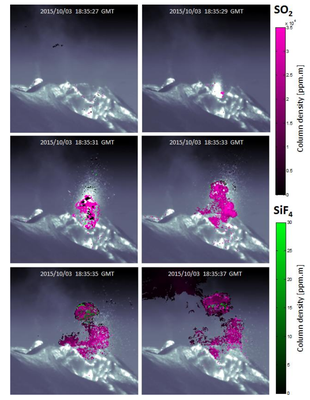
Volcanic Eruption

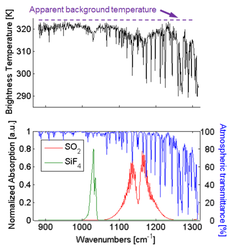
Stromboli volcano (Italy) – In collaboration with Blaise Pascal University (France)

- Standoff distance ~400m
- Measurements during the passive degassing as well as during eruption
- Pre-processing to remove artefacts produced by high-temperature moving particles due to volcanic eruptions
- SO_2 and SiF_4 measured





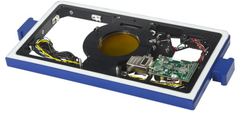


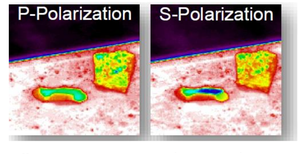


Polarization

A motorized polarizer module can be installed in front of the Hyper-Cam, in-between the entrance window and the dual automated calibration sources. The polarizer orientation is software-controlled and user-selectable with a resolution of 1°.

The measurements with the polarizer get the same high-accuracy radiometric calibration as the standard Hyper-Cam measurements.





Quartz monocrystal + amethyst