FIREX-AQ ER-2: A Summary of Scanning High-resolution Interferometer Sounder (S-HIS) Observations

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Introduction

The FIREX-AQ (Fire Influence on Regional to Global Environments and Air Quality) is a joint venture led by NOAA and NASA, and provides comprehensive observations to investigate the impact on air quality and climate from wildfires and agricultural fires across the continental United States. FIREX-AQ brought together scientists from NOAA, NASA and more than 40 partners to explore the chemistry and fate of trace gases and aerosols in smoke with instrumented aircraft, satellites, UAVs and ground-based instrumentation in the northwestern and southeastern U.S. during the summer of 2019.

2019-08-01	Engineering test flight
2019-08-02	Mills and Dixon Fires
2019-08-06	Williams Flats Fire
2019-08-07	Williams Flats Fire
2019-08-08	Williams Flats Fire
2019-08-12	Calibration Flight (cut short) Intended target: Railroad Valley
2019-08-13	Springs Fire, Railroad Valley
2019-08-15	Boulin, Sheridan, Castle, Trumbill Fires, Railroad Valley
2019-08-16	Castle, Ikes, Sheridan Fires
2019-08-19	Flight cut short due to weather Intended targets: Fresno AERONET, Springs Fire
2019-08-20	Little Bear, Castle, Ikes Fires
2019-08-21	FASMEE burn area, Sheridan, Little Bear, Castle, Ikes Fires

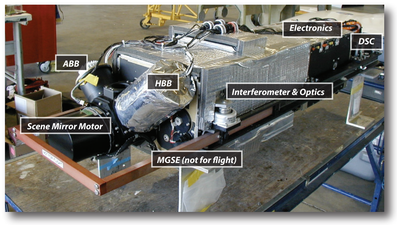
The overarching objective of FIREX-AQ is to provide measurements of trace gas and aerosol emissions for wildfires and prescribed fires in great detail, relate them to fuel and fire conditions at the point of emission, characterize the conditions relating to plume rise, follow plumes downwind to understand chemical transformation and air quality impacts, and assess the efficacy of satellite detections for estimating the emissions from sampled fires.

The airborne component of the FIREX-AQ effort was centered on the deployment of the NASA DC-8, with two complementarily outfitted NOAA Twin Otters, and sampled wildfire plumes from near the point of emission to downwind on a regional scale. The NASA ER-2 was also deployed for FIREX-AQ and played a key role in the experiment. The goal for the NASA ER-2 was to serve as a bridge between in-situ and satellite datasets by using an airborne remote sensing instrument suite to help characterize fire development, emission processes, plume evolution, and downwind impacts on air quality, and evaluate and validate recently developed remote sensing approaches and algorithms.

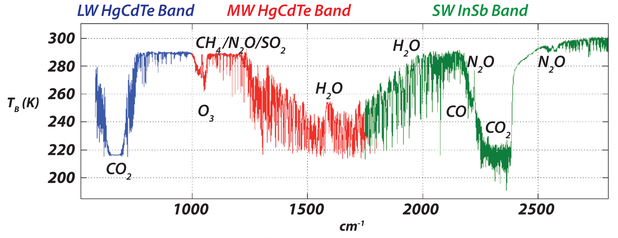
FIREX-AQ ER-2 Payload (courtesy Olga Kalashnikova, NASA JPL)

Instrument	Satellite analogs	Description	Spectral range	Spectral resolution	Nominal spatial resolution 20km/65k alt.	Nominal swath 20km/65k alt.	Products
AirMSPI	MISR, MAIA	Multiangle Spectro-Polarimetric Imager	355-935 nm	8 bands	25m	11km	AOD; size distribution; SSA Research: Smoke plume rise and BC content;
AVIRIS-C	EMIT, SBG	Hyperspectral Vis-SWIR spectrometer	370-2550 nm	9.8 nm	20m	11km	Vegetation/soil/albedo info; fire temperature, H_2O, (research CO_2, CH_4, AOD)
CPL	CALIPSO	3-channel backscatter lidar with polarization	355, 532, 1064 nm	-	20m	(30m vertical)	Smoke plume and cloud top heights, aerosol extinction profiles
eMAS	MODIS, VIIRS	Vis-IR scanning spectrometer	445-2400 nm, 3.7 µm, 6.7-14.0 µm	>40nm 38 bands	50m	37km	Cloud and aerosol properties, fire temperature
GCAS	TROPOMI, TEMPO	UV-Vis-NIR hyperspectral spectrometer	300-890 nm	0.2 -0.4nm	500m	16km	NO_2, HCHO, SO_2, CHOCHO
NAST-I	AIRS, CrIS, IASI	Cross-track Scanning IR interferometer	3.5-16 µm	0.25 cm^{-1}	2600m	40km	Calibrated radiances, temperature and water vapor vertical profiles, CO, O_3
S-HIS	AIRS, CrIS, IASI	Cross-track Scanning IR interferometer	3.3-18 µm	0.50 cm^{-1}	2000m	40km	Calibrated radiances, temperature and water vapor vertical profiles; CO, N_2O, CH_4, SO_2, O_3 vertical profiles; total column CO_2, O_3, H_2O

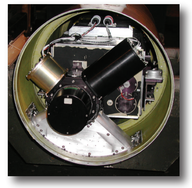
S-HIS



IFOV: 100 mrad (2km @ 20km, nadir)
FOR: Programmable 45° scene mirror nadir ± 40° typical
Spectral Coverage: 580 - 3000 cm^{-1}
Spectral Resolution: 0.5 cm^{-1}



Sample upwelling S-HIS brightness temperature spectra.



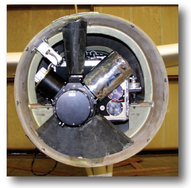
ER-2 centerline pod

Calibration, Calibration Verification, and Traceability

- Pre-integration **calibration of on-board blackbody references** at subsystem level
- **Pre and post deployment end-to-end calibration verification**
- Periodic **end-to-end radiance evaluations under flight like conditions with NIST transfer sensors.**
- Instrument calibration during flight using **two on-board calibration blackbodies**

Geophysical Retrievals (Dual Regression)
Temperature Profiles
Water Vapor Profiles (RH, Mixing Ratio)
CO, N2O, CH4, SO2, O3 Profiles
Total Column CO_2, O_3, H_2O
Surface temperature and emissivity

DC-8



Proteus wing boom

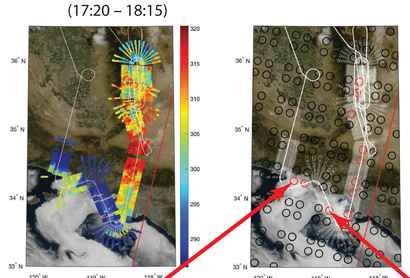
WB-57 wingpod

S-HIS mounted on AV-6, Zone 25

Preliminary Analysis Examples, Data and Quicklooks

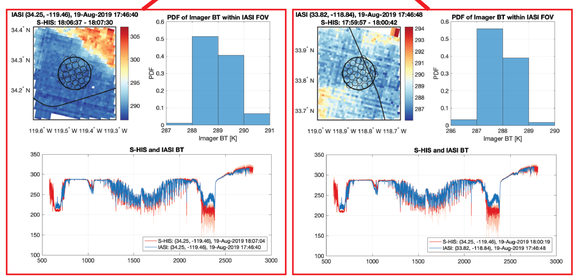
METOP-C Underflight Example (2019-08-19)

895-895 cm^{-1} S-HIS BT (17:20 – 18:15)



S-HIS footprints (white outline)
IASI footprints (black outline)
Complete coverage of IASI footprints by S-HIS (red outline)

IASI Sub-sat line in red
ER-2 flight path in white



Low spatial variability within these IASI FOVs (IASI boresighted IR imager)

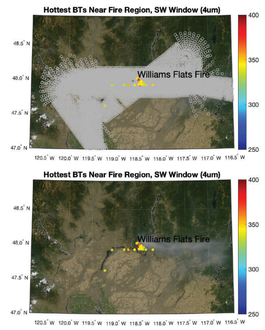
Will use GOES data to assess temporal stability for the these IASI FOV locations

"Blue Spike" Detection Example (2019-08-07)

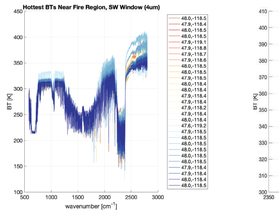
- The blue spike is a spectral feature of a hot gas layer sandwiched between two cooler regions. S-HIS spectra contain the blue spike when the scene below the ER-2 consists of a hot gas layer above a cooler surface with cool air directly below the aircraft.
- A blue spike occurs when the asymmetric stretching mode of carbon dioxide molecules undergo rotational hot band transitions.
- The name blue spike comes from the narrow sharp peak appearing on the blue side of the center of this mode's absorption band (2350 cm^{-1})

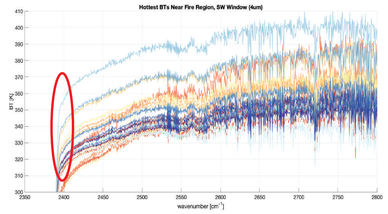
McCourt, M. L., et al. "Using the "blue spike" to characterize biomass-burning sites during Southern African Regional Science Initiative (SAFARI) 2000." Journal of Geophysical Research: Atmospheres 109.D20 (2004)

King, Michael D., et al. "Remote sensing of smoke, land, and clouds from the NASA ER-2 during SAFARI 2000." Journal of Geophysical Research: Atmospheres 108.D13 (2003)

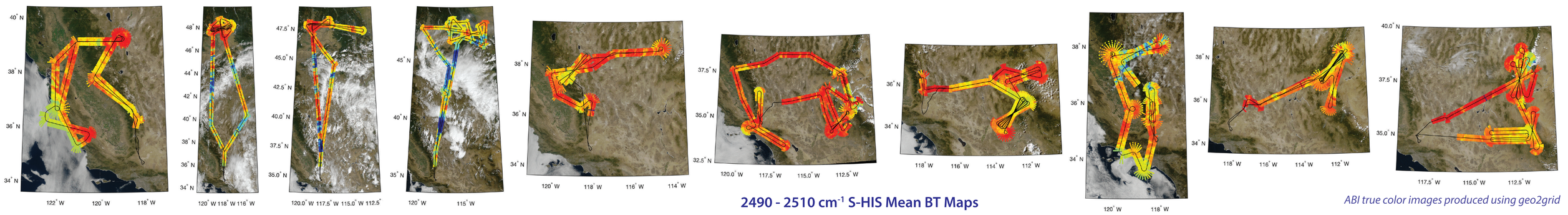


- Grey outlined markers show all S-HIS observations in region
- Hottest FOVs (SW window) shown as solid markers colored by BT
- Overlaid on GOES-W true color image from 20:01UTC
- Spectra associated with hottest SW window FOVs shown at lower left
- 2350 – 2800 cm^{-1} region shown on a tighter y-scale on the lower right
- A very small blue spike may be evident in some of the hottest spectra
- Relatively small radiative power for this fire
- This signature is not evident in the non-fire FOVs





2019-08-02 2019-08-06 2019-08-07 2019-08-08 2019-08-13 2019-08-15 2019-08-16 2019-08-19 2019-08-20 2019-08-21



2490 - 2510 cm^{-1} S-HIS Mean BT Maps

ABI true color images produced using geo2grid

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