The NOAA Operational High-Resolution CrIS Channel Selection: Impacts On NUCAPS Trace Gas Retrievals

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Introduction

- **The Cross-Track Infrared Sounder (CrIS)** is a Fourier spectrometer covering the longwave (655-1095 cm-1, "LW"), midwave (1210-1750 cm-1, "MW"), and shortwave (2155-2550 cm-1, "SW") infrared spectral regions.

- **NUCAPS Phase I, II and III operations:**
  - Maximum geometrical path difference L = 0.8 cm (LW), 0.4 cm (MW) and 0.2 cm (SW)
  - Nyquist spectral sampling ($1/2L$): 0.625 cm-1, 1.25 cm-1 and 2.5 cm-1
  - Total number of channels: 1305

- **NUCAPS Phase IV operations:**
  - Maximum geometrical path difference L = 0.8 cm in all three bands
  - Nyquist spectral sampling ($1/2L$): 0.625 cm-1 in all three bands
  - Total number of channels: 2211 + 12 guard channels

- **<u>Motivation for a channel selection:</u>**
  - Assimilation of full radiance spectra is not computationally efficient for near real time data processing.
  - A channel selection is required to expedite both data assimilation and retrieval processes.
  - Attention must be paid to minimizing the loss of information content such that the final retrieval quality is not deteriorated.

Channel Selection Methods: Two Schools of Thought

Jacobians or Physical method

- physically-based methodology

  - channels are selected upon their spectral properties

  - each atmospheric species, we perform a spectral sensitivity analysis and retain the spectrally purest channels.

- Other than spectral purity, priority is given to:
  - vertical sensitivity properties,
  - instrumental noise
  - RTA errors.

- Jacobian method is suited for sequential steps retrieval methodologies

- works for simultaneous optimal estimation retrieval techniques.

Rodgers method

- follows a statistical iterative approach
  - channels are incrementally added after being tested against an increase in degree of freedom.

- This methodology is suited for simultaneous optimal estimation retrieval techniques.

Both methods:

- a constant channel selection is normally used

- derived as an average from multiple optimal selections computed over different geophysical regimes (polar, mid latitudes, tropical, land, ocean, desert).

Why do we use the Jacobians method?

- NUCAPS required <u>all sky</u> operational products:
  - Cloud cleared radiances
  - Cloud top pressure and fraction
  - Surface temperature
  - Vertical temperature
  - Water vapor
  - Trace gases: O_3, CH_4, CO, CO_2, SO_2, N_2O, HNO_3
    - Future candidates:
      - NH_3 (Ammonia), HCO_2H (Formic Acid), $CH_3COOONO_2$ ("PAN")

- Most channels are largely contaminated by clouds, temperature and water vapor signals.

- A "**trace gas**" is a gas which makes up less than 1% of the volume of the Earth's atmosphere.

- Trace gas radiative signals are in the range of the instrument noise.

- <u>Answer</u>: *Spectral purity combined with a sequential retrieval approach is essential for the retrieval of the full list of NUCAPS products, particularly for trace gases, under all sky conditions.*

- In depth description available in:

A.Gambacorta and C.Barnet, Methodology and information content of the NOAA NESDIS operational channel selection for the Cross-Track Infrared Sounder (CrIS), IEEE Transaction on geoscience and remote sensing.
Vol. 51, No. 6, 2013. DOI: 10.1109/TGRS.2012.2220369

Spectral Purity Analysis (band 2)

Band 2 Sensitivity Analysis
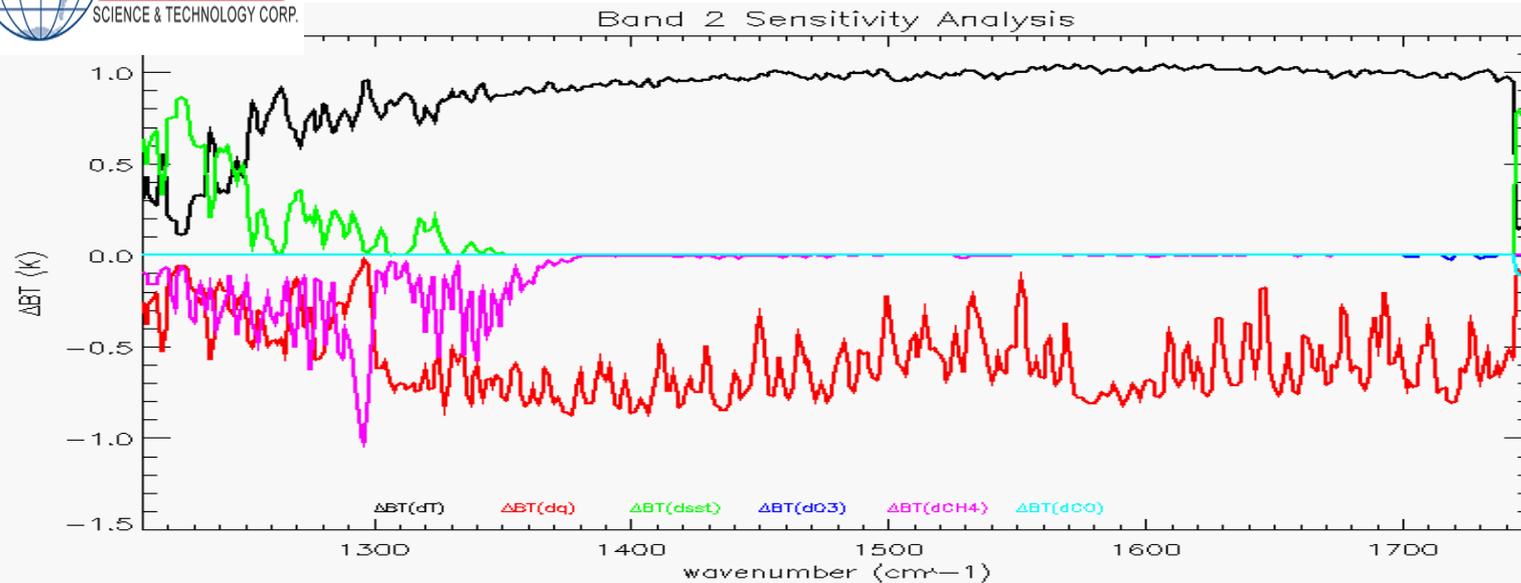
SST	1K
T	1K
H2O	10%
O3	10%
CH4	2%
CO	1%

Brightness temperature difference (ΔBT) terms represent the sensitivity of each channel to a given perturbation species and are indicative of the degree of *"spectral purity"* of each channel.

• Perturb these gases (left column) by that amount or percentage (right column), you obtain a perturbation (ΔBT) in brightness temperature (figure above).

• The magnitude of ΔBT describes how sensitive a channel is to the perturbed species.

• You select those channels that tend to be sensitive to only your species of interest with minimum interference from the other species.

• You still account for the residual interference as an error term in the retrieval measurement error covariance.
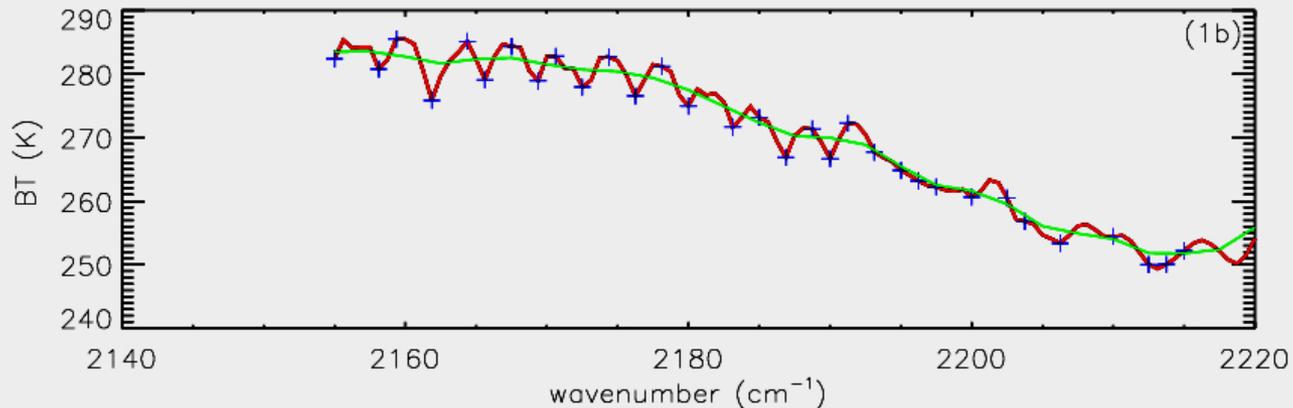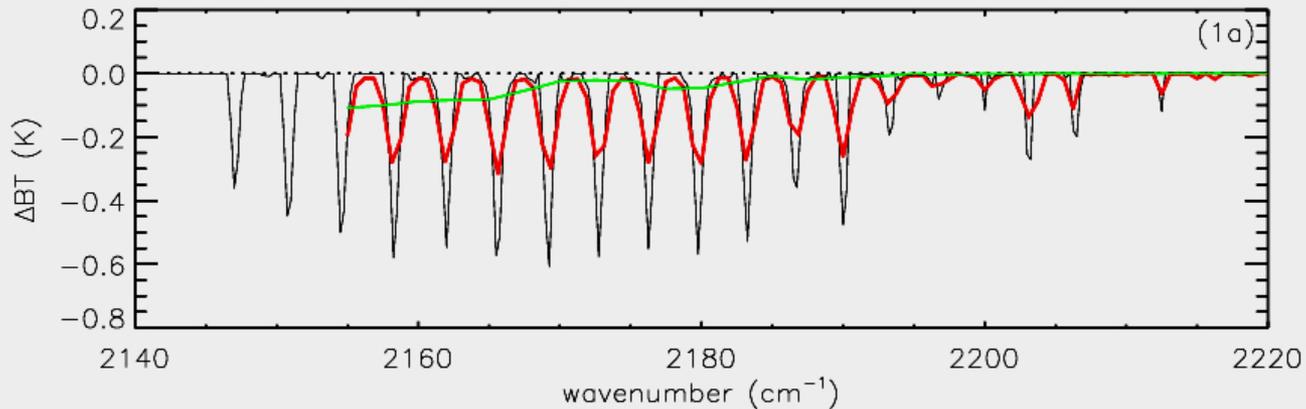
CO Channel Selection

## A test case study from the 1 May 2016 (Ft. McMurray, Alberta Fire Case)

Sensitivity Analysis to 1% CO perturbation

- Why you are showing the CO case?
  - Only when switched to high spectral resolution, CrIS spectrum (red curve, bottom part) shows the distinctive signature of CO absorption (red and black curve, top figure).
  - Blue cross symbols: CO high resolution channel selection.

Fire Case Study

CO$_{RET}$ (at P=496.6) (160507 9UT)
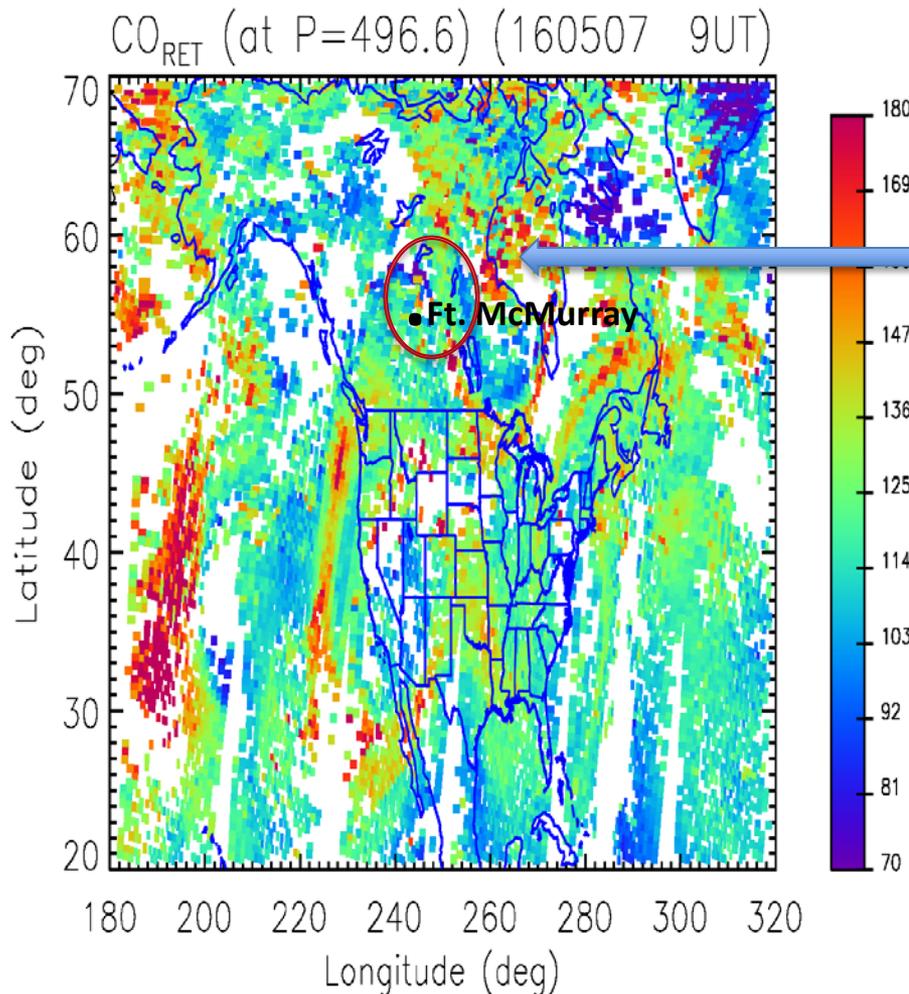
Ft. McMurray

- 7 May 2016 NUCAPS retrieval over North America

- Highlighting the Ft. McMurray, Alberta Fire

- Pressure level: 496.62 hPa

- 120+ ppbv over fire

CO channel selection for Ft. McMurray, Alberta fire case
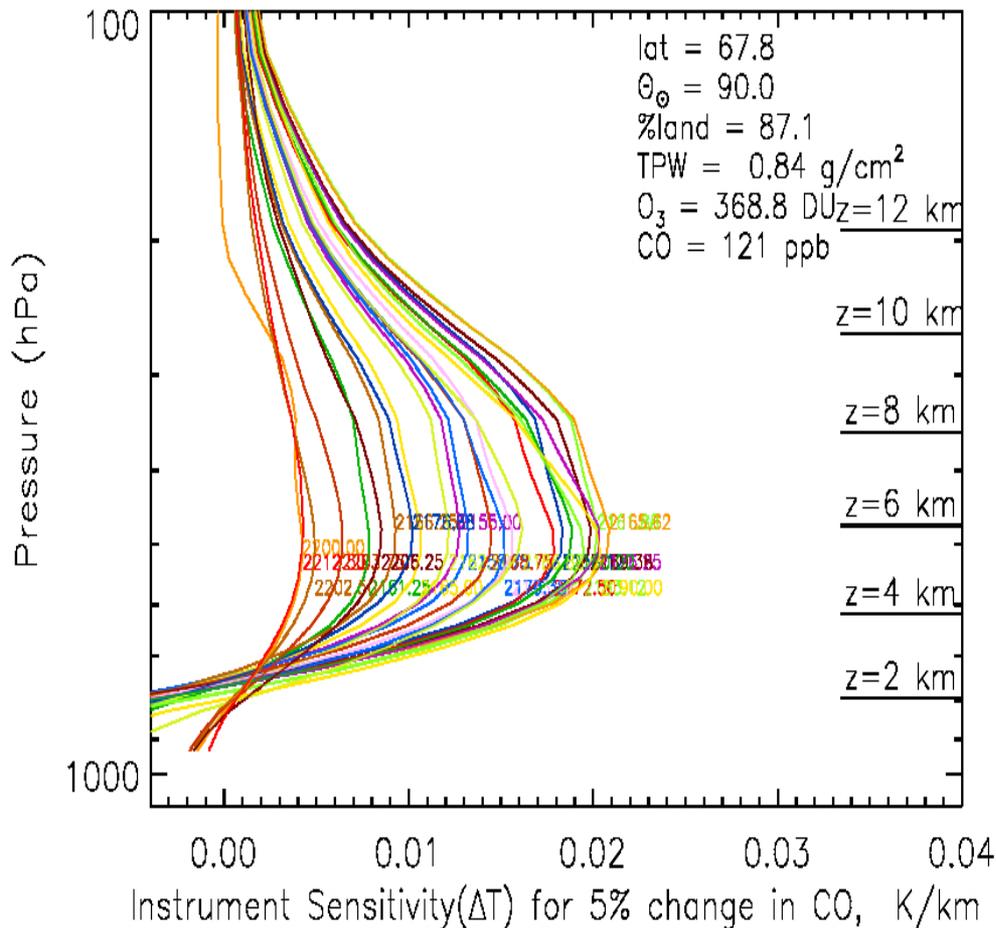
- The selection was made on multiple geophysical regimes (polar, mid-latitude, tropics, and fire) to

  - ensure global applicability.
  - examine polluted vs relatively clear regimes.

- We are testing CO selection over focus areas to ensure global optimality and to serve users needs

NUCAPS High Res Trace Gas Product Evaluation

- Initiative is based on 2 recently funded JPSS proposals.
  1. Greg Frost: "Understanding emissions and tropospheric chemistry using NUCAPS and VIIRS"
  2. Brad Pierce: "High Resolution Trajectory-Based Smoke Forecasts using VIIRS Aerosol Optical Depth and NUCAPS Carbon Monoxide Retrievals "

- Models are used to interpolate the sparse aircraft observations to the satellite temporal, spatial, and vertical sampling characteristics for detailed validation

- NUCAPS (and AOD f/ VIIRS) will be used within IDEA (Infusing Satellite Data into Envir. AQ Applications)
  http://www.star.nesdis.noaa.gov/smcd/spb/aq/

Future Work:
Maintenance and Optimization

- *We will re optimize and deliver the channel selection once the new version of the RTA is delivered*

- Expected improvements
  - NON LTE and water vapor regions

- Continue to run NUCAPS various global cases

- Channel selection for IASI

- Continue to ensure that users obtain the best products

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