Evaluations and applications of trace gas retrievals from sounders

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NOAA JPSS Proving Ground & Risk Reduction Program

Summary of talk

- Evaluating CrIS trace gas observations with aircraft observations
- Applications of sounder and other satellite atmospheric composition data
- Discussion about long-term sounder atmospheric composition records

Overview of NOAA CSL's JPSS PGRR projects

JPSS Products

- **Suomi-NPP** (launched in 2011) and **NOAA-20** (launched in 2017) spacecraft
- **NUCAPS** (NOAA Unique Combined Atmospheric Processing System) **science code retrievals** of **CrIS** (Cross-track Infrared Sounder) tropospheric **CO**, **O_3, H_2O**, & other gases
- **VIIRS** (Visible Infrared Imaging Radiometer Suite) **aerosol optical depth** (**AOD**)

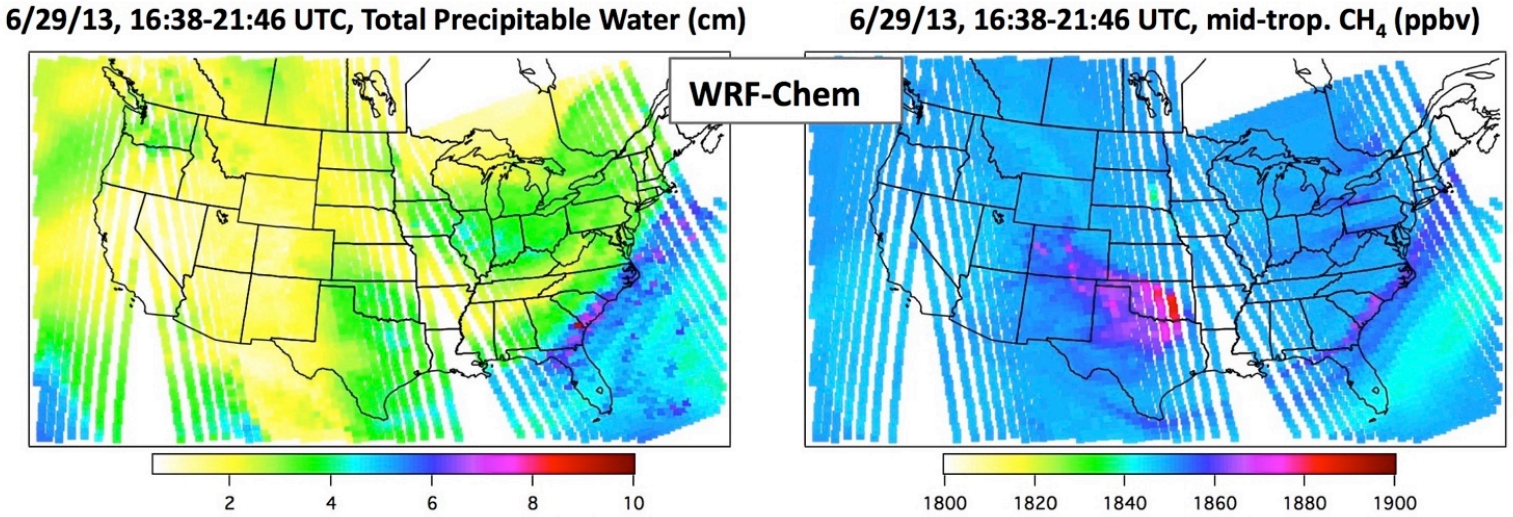
Objectives for these JPSS products

- Improve **retrieval algorithms**
- Assess **spatial averaging**
- Characterize **vertical profiles**
- Evaluate **tropospheric columns**
- Use in **field mission planning and analysis**
- Use to **evaluate** model predictions
- **Assimilate** in operational forecasts

Approach for CSL's JPSS PGRR projects

Aircraft data from NOAA/NASA field research studies are the basis of our CrIS data evaluations, providing…

- high accuracy and precision
- fine horizontal and vertical resolution
- repeated sampling



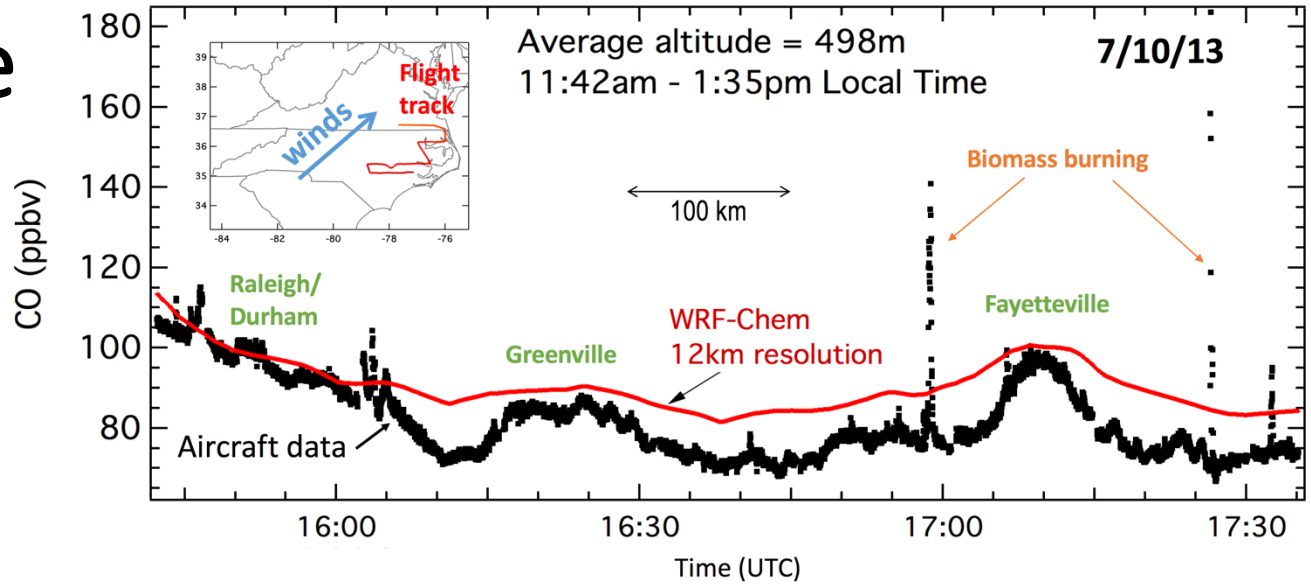
Atmospheric chemical-transport models evaluated and improved by aircraft data enable direct assessment of CrIS trace gases and meteorological products, by…

- Extending temporal and spatial domain beyond sparse aircraft sampling
- Simulating atmospheric quantities to match CrIS retrievals

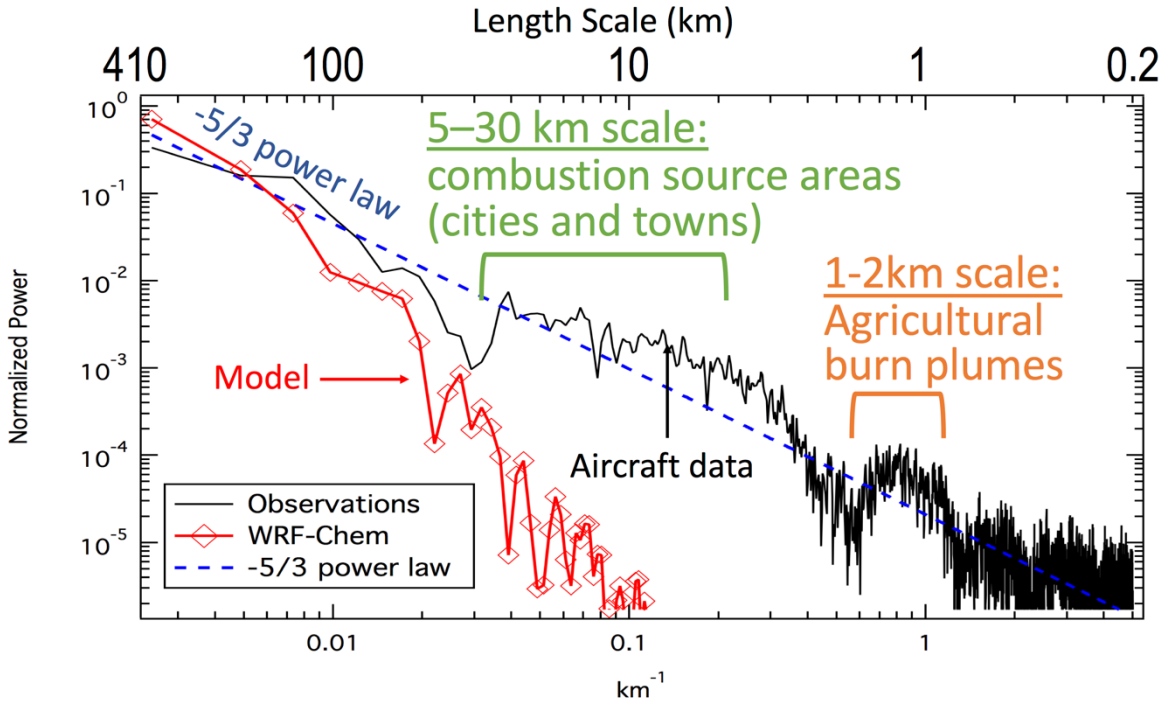
Assessing CrIS Scale Variance

- Characterize CrIS true signals versus noise
- Assess spatial averaging needed to produce meaningful CrIS trace gas data

➢ Use power spectrum analysis of scale variance

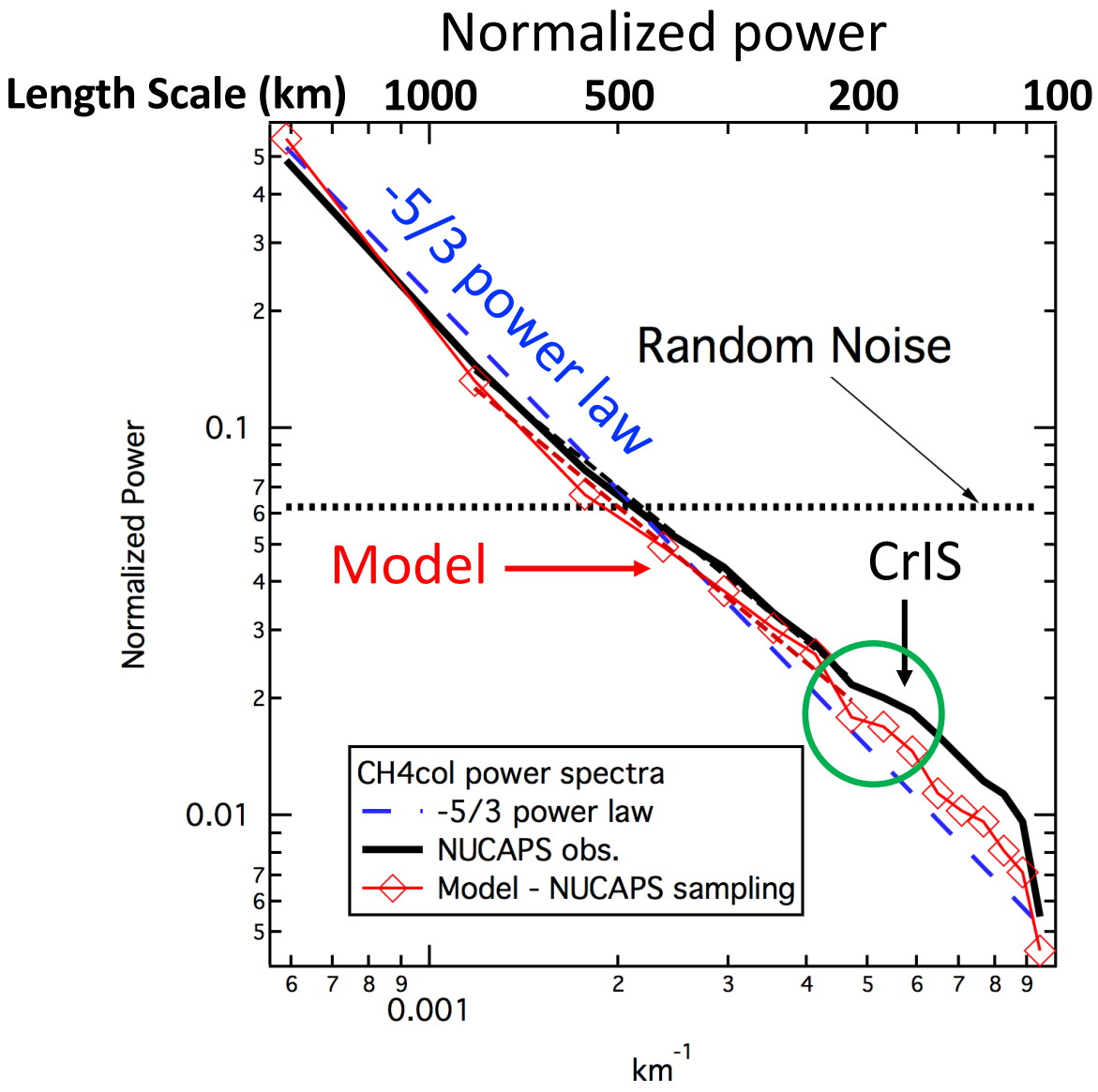


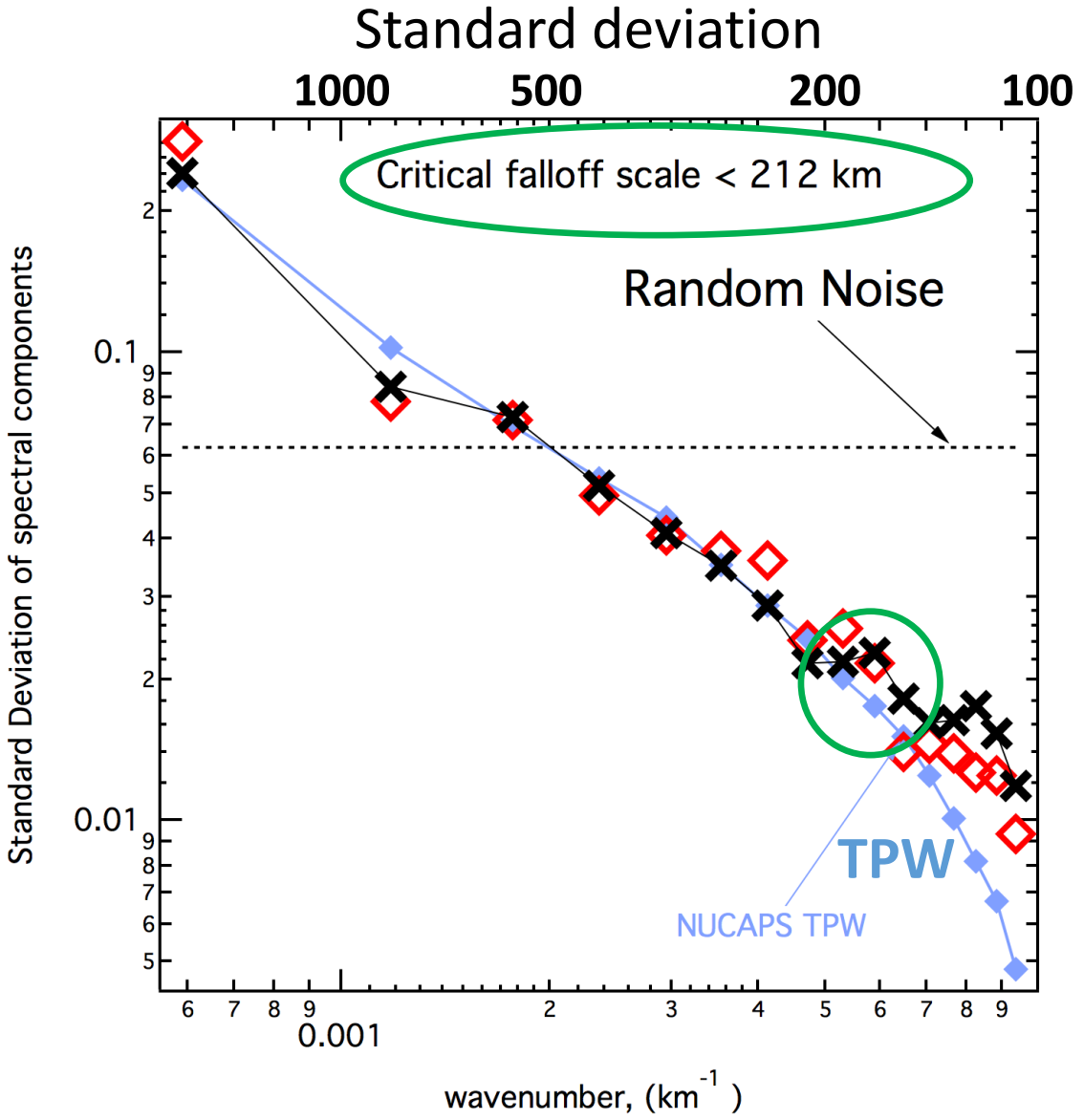
Time series of aircraft data and model output



Power spectra of aircraft data and model output

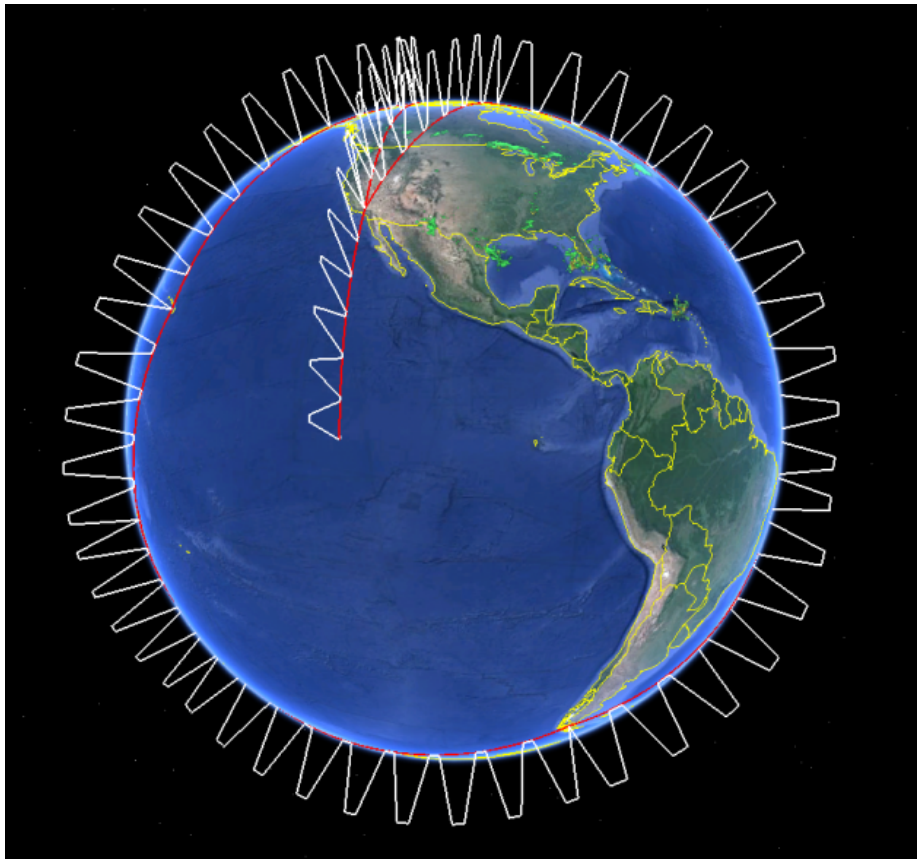
Power spectra: CrIS and model column CH_4

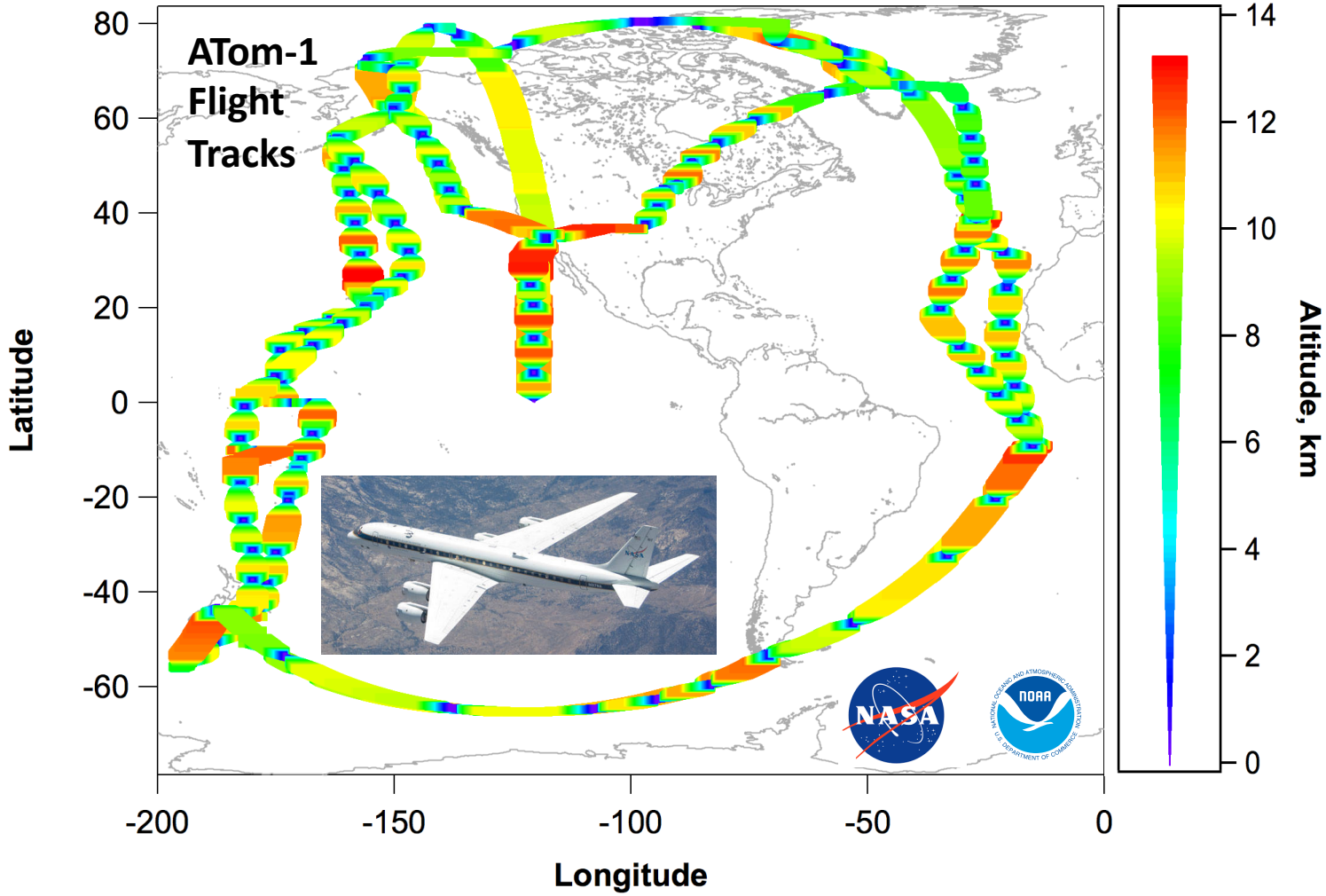




➢ **CrIS tropospheric CH_4 columns should be averaged horizontally at scales ≥ 200 km**

Atmospheric Tomography Mission





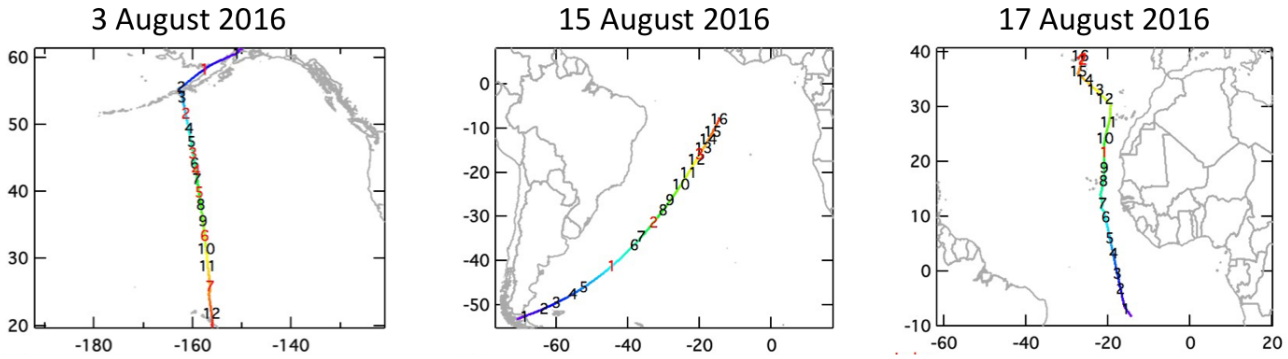
https://espo.nasa.gov/home/atom/content/ATom

NASA DC-8 sampled pole-to-pole tropospheric profiles in each season between 2016 & 2018

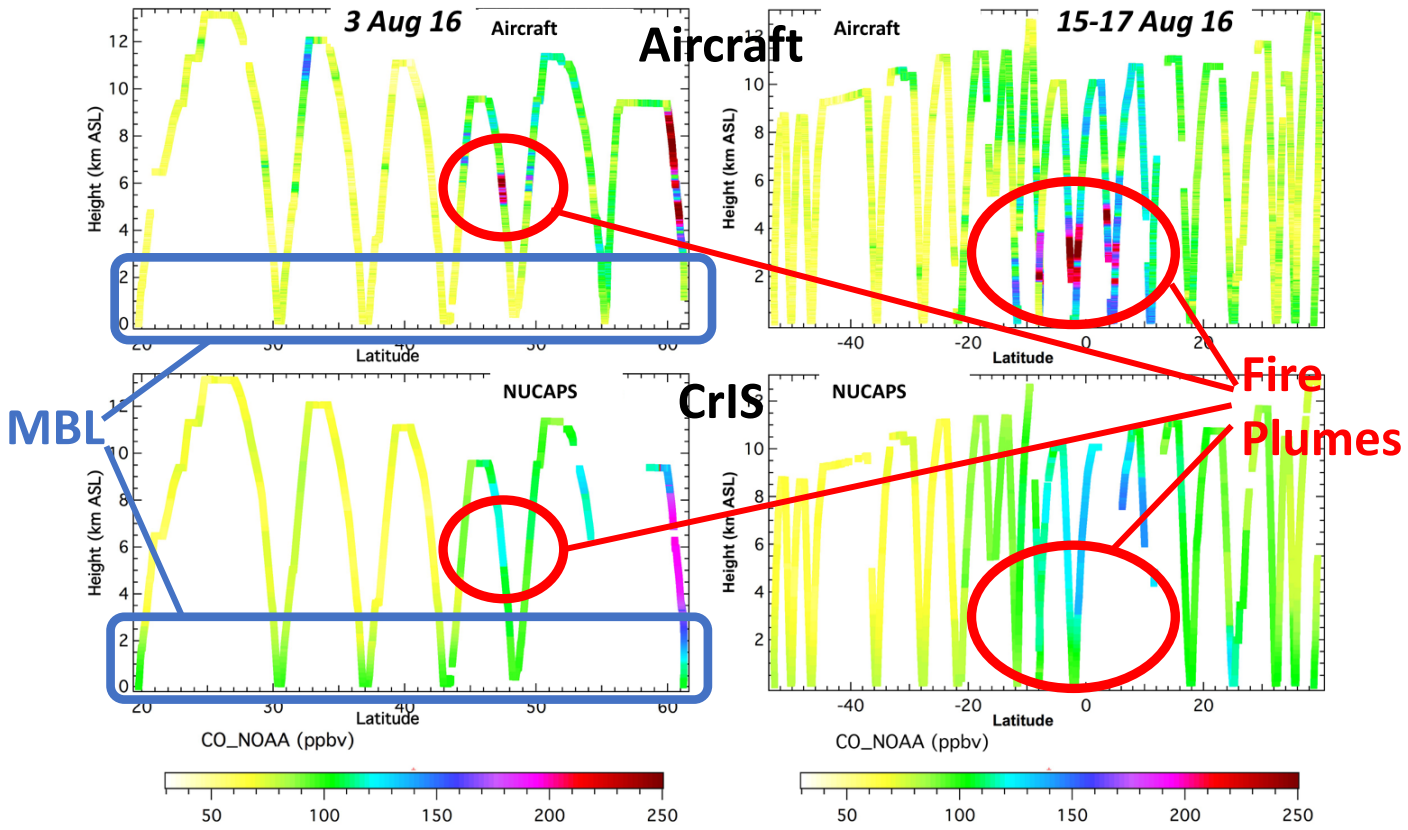
ATom Analysis of CrIS Retrievals

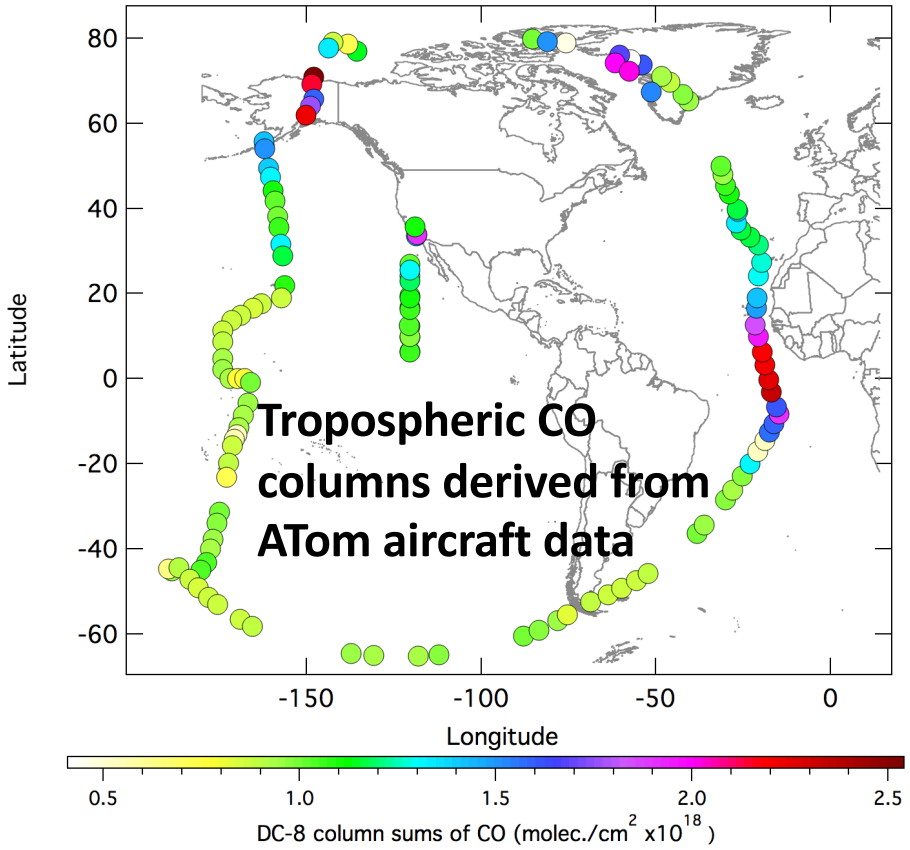
ATom provides evaluation opportunities for JPSS trace gas products

Aircraft Flight Tracks

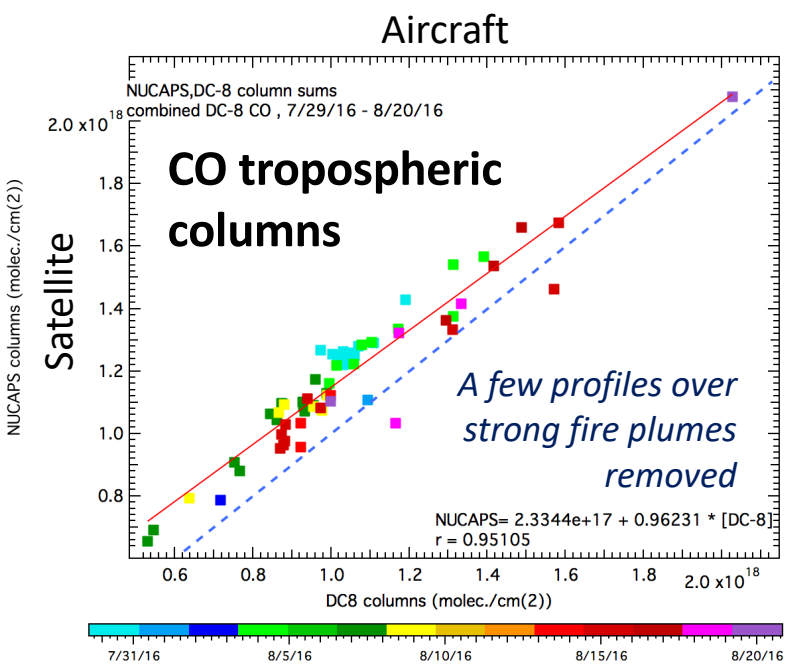


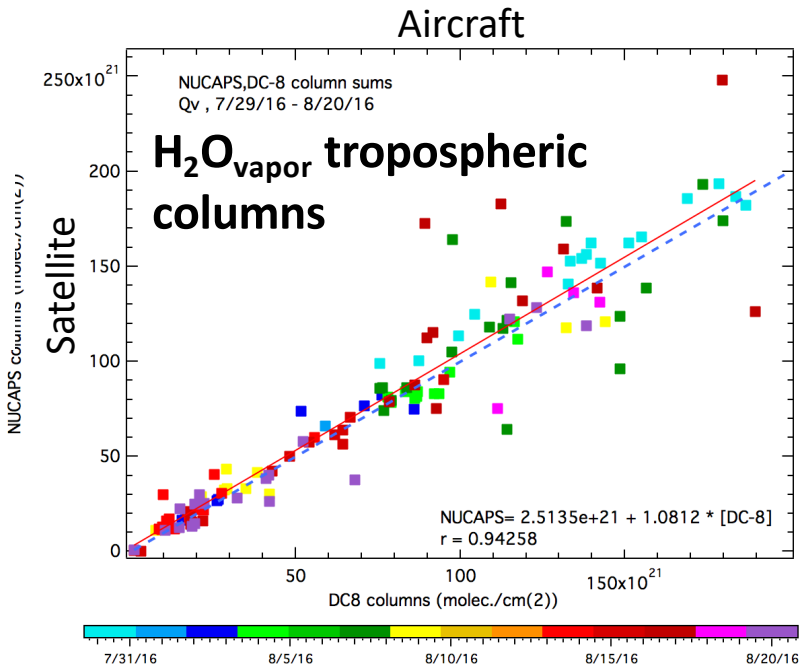
CO Mixing Ratios

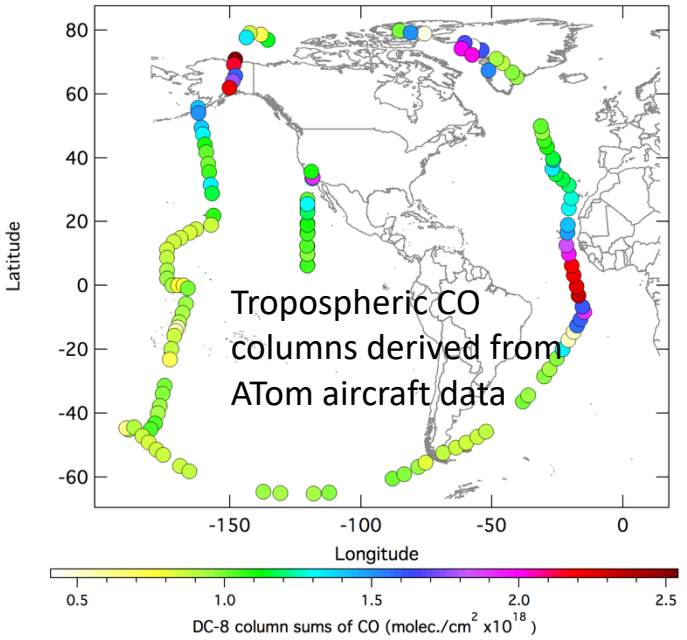


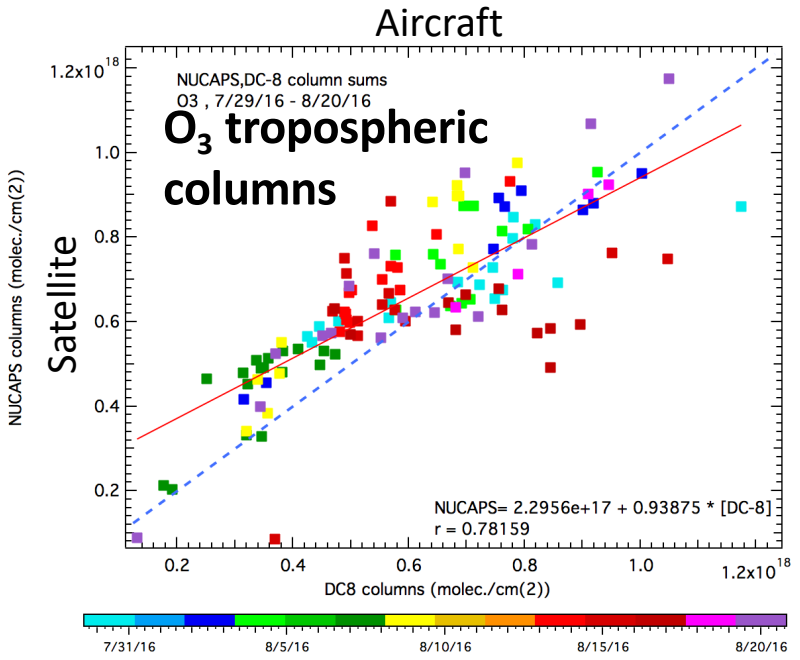


ATom Analysis of CrIS Retrievals









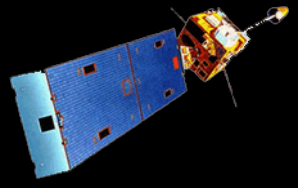
- ATom data give confidence in CrIS trace gas data
- CrIS mid-tropospheric CO and H_2O data are reliable
- CrIS has more limited skill in measuring tropospheric O_3
- CrIS retrievals over fire plumes need additional work

Recent Coordinated U.S. Wildfire Research Activities

Multi-agency collaborations to study complex fire systems

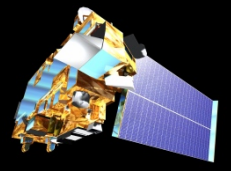
Satellites: Remote Sensing

NOAA GOES-R



NOAA/NASA JPSS

NASA TERRA



NOAA/NASA FIREX-AQ

Laboratory study: 2016
Field intensive: 2019
NOAA CPO funded 20 projects
NASA SMD funded 24 projects

NASA DC-8

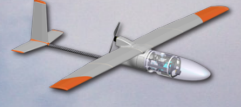
NASA ER-2

Aircraft: Local to Continental In-situ & Remote Sensing

CHEM Twin Otter

MET Twin Otter

NOAA/CU NightFOX

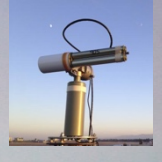


Mobile Ground Sites: Local

Aerodyne Mobile Lab

NOAA Mobile Lab

AERONET DRAGON



NSF WE-CAN

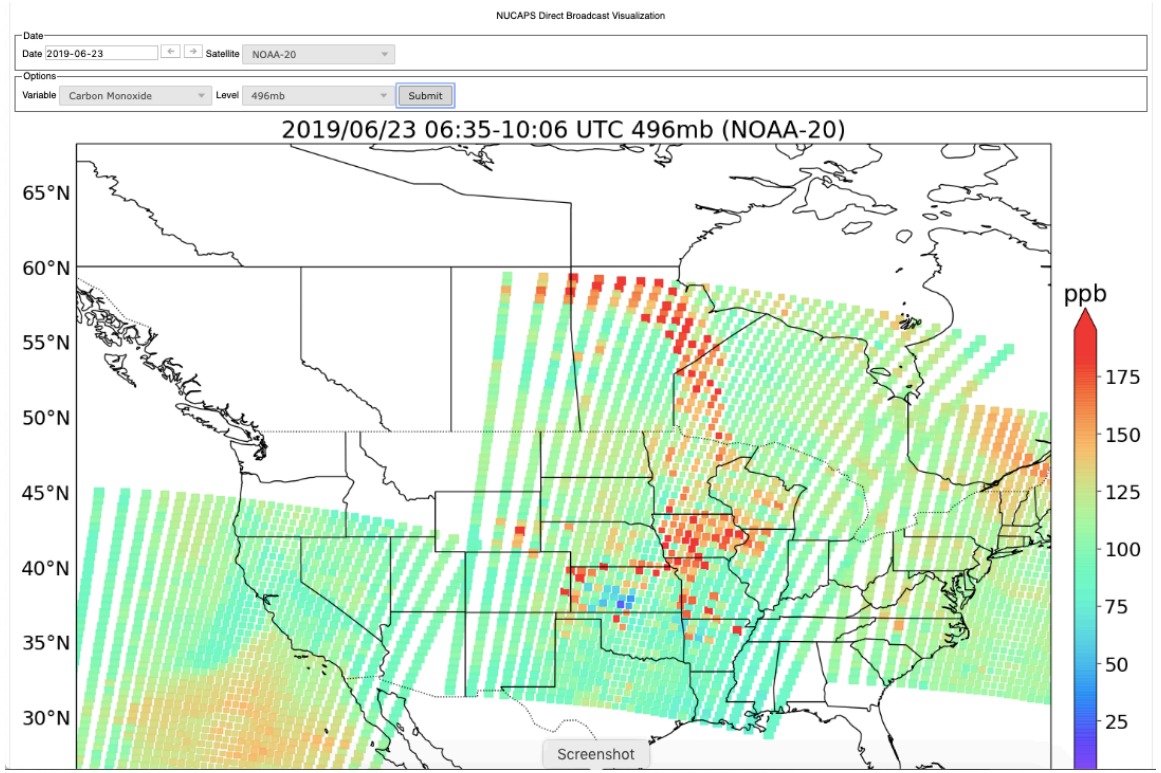
C130 aircraft study: 2018

JFSP Western Wildfire Campaign (FASMEE)
Source fuel fire studies: 2019+

International Biomass Burning Initiative (IGAC): communicate globally what is learned in U.S.

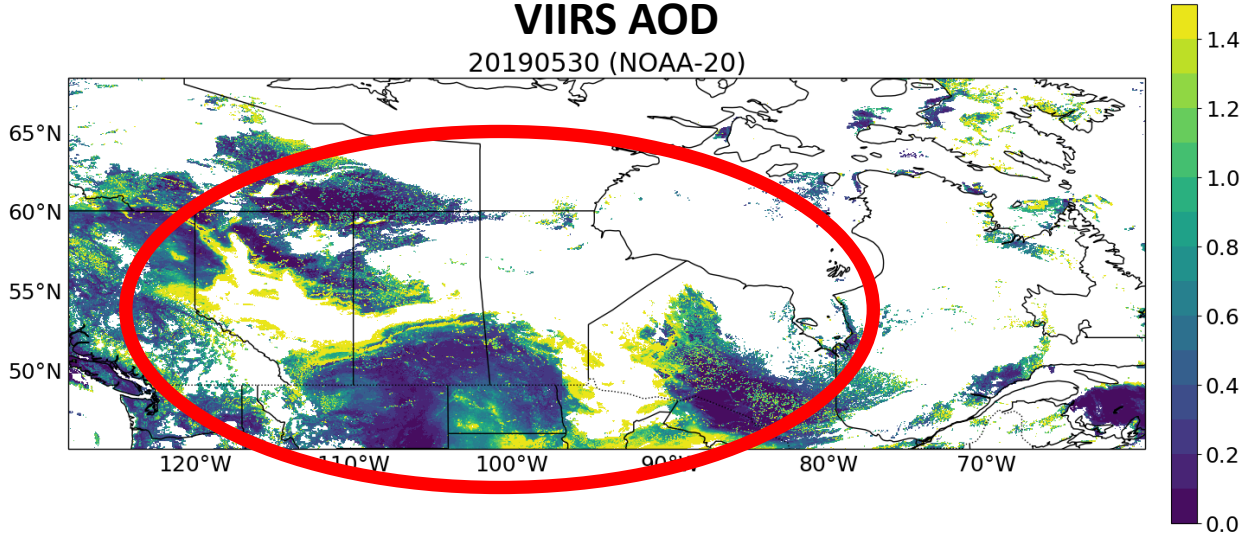
CrIS and VIIRS used for FIREX-AQ mission planning & analysis

NUCAPS Direct Broadcast Viewer

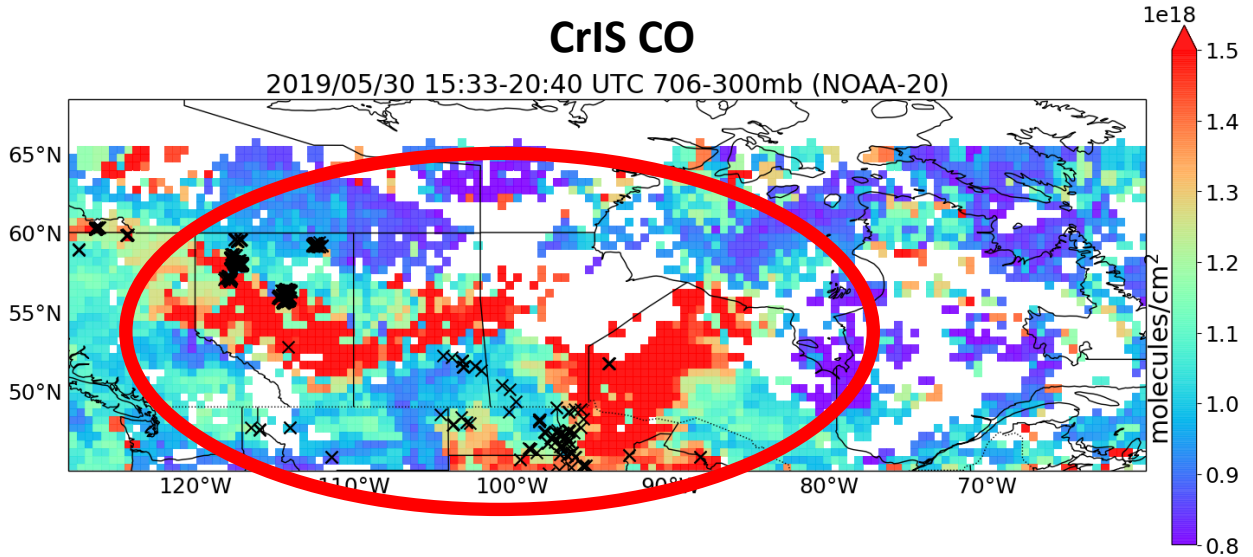


Science & Technology Corp Web Viewer
http://sigma.umd.edu/resmaili/nucaps.html
Rebekah Esmaili et al.

VIIRS AOD



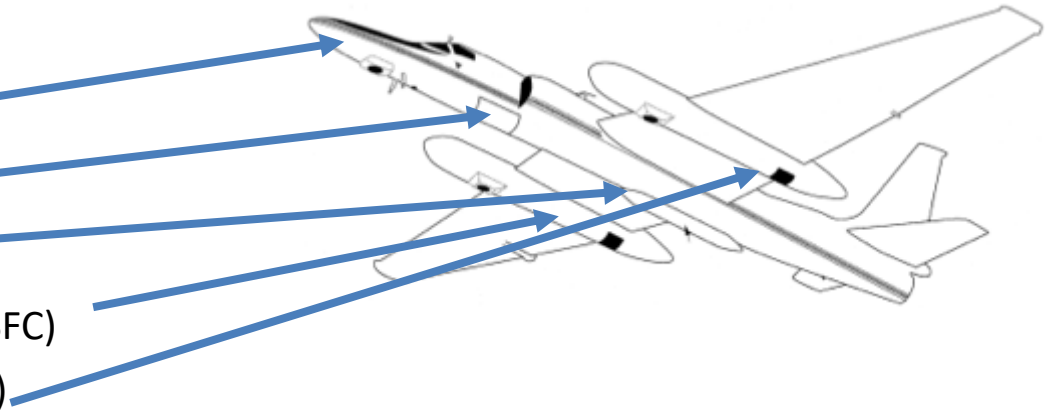
CrIS CO



ER-2 payload in FIREX-AQ 2019

Instruments

- AirMSPI-1 (JPL)
- AVIRIS-C (JPL)
- S-HIS (UW)
- CPL (GSFC) and eMAS (ARC/GSFC)
- GCAS (GSFC) and NAST-I (LaRC)



Thanks to JPSS office for supporting ER-2 deployment in FIREX-AQ!

Relevant Retrieved Geophysical Variables:

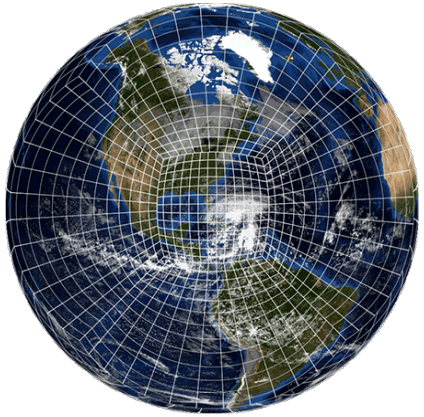
- Effective fire temperature/FRP (AVIRIS-C, eMAS, HyTES)
- Smoke plume structure/heights (CPL and AirMSPI)
- Atmospheric thermodynamic profiles (S-HIS and NAST-I)
- Aerosol amount and properties (eMAS, AirMSPI, CPL)
- Total column trace gas amount in plume and downwind (GCAS, HyTES)
- Trace gas profiles (S-HIS and NAST-I)
- Nearby fuels (AVIRIS-C)
- Winds (from plume displacements in time-resolved imagery)

FIREX-AQ ER-2 Science Scorecard

- Priority 1 objectives = Critical to success of FIREX-AQ science
- Priority 2 objectives = Important to success of FIREX-AQ
- Priority 3 objectives = Useful for science, demonstration, or validation but not directly related to FIREX-AQ

➢ **Overall ~94% of the objectives met!**

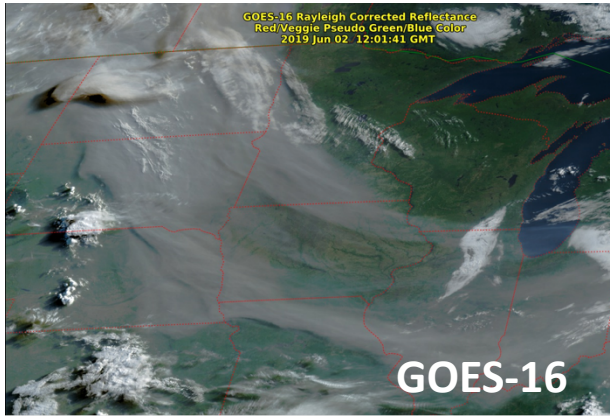
Applications of JPSS data to NOAA forecasting



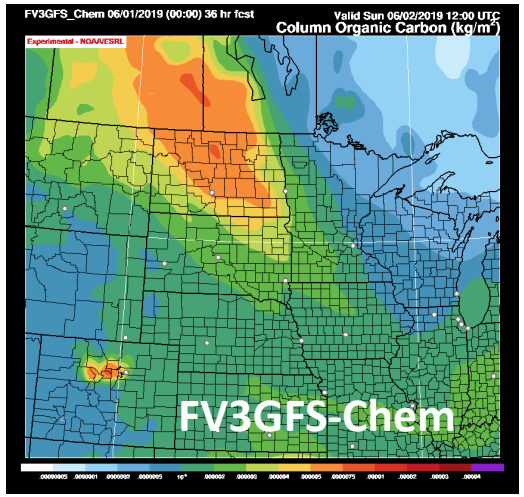
Implementing atmospheric composition into operational FV3GFS

FV3GFS-Chem forecasts fire plume transport

June 2, 2019 – 12:00 UTC

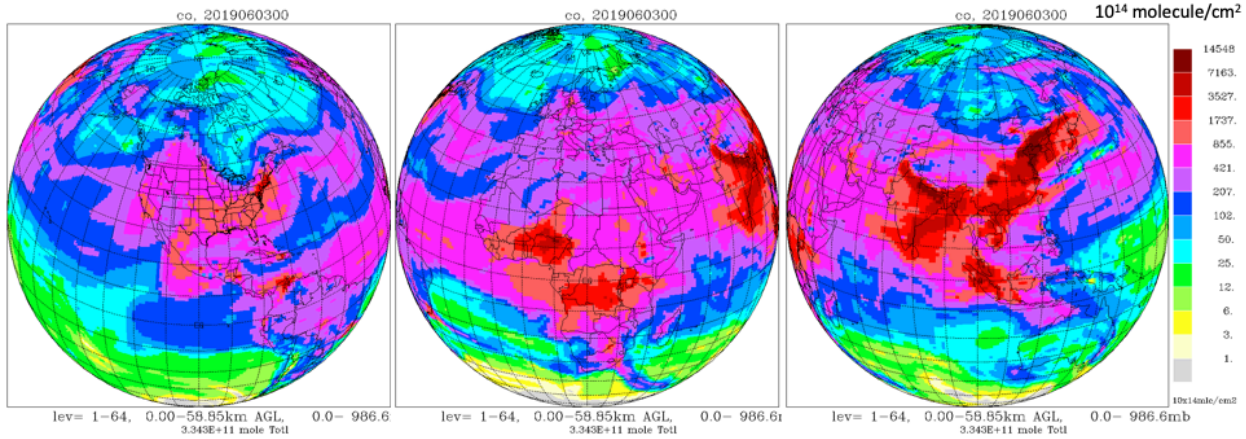


http://dustdevil.aos.wisc.edu/goes16/grb/rgb/mw/goes16_mw.html



https://fim.noaa.gov/FV3chem

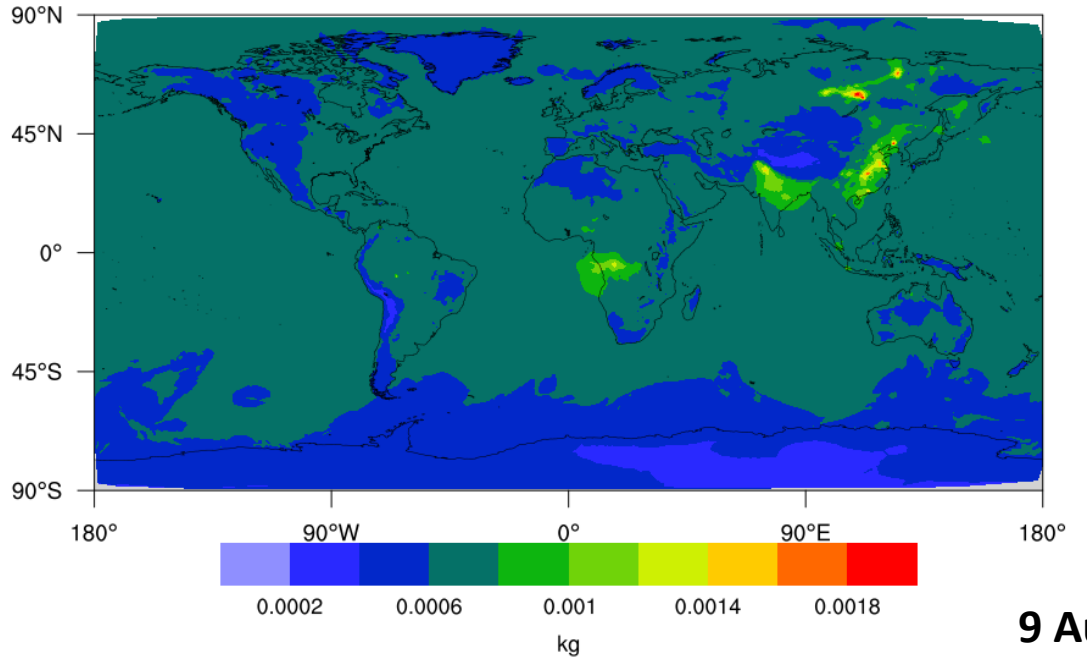
Total column CO, FV3GFS-Aerosols + CO tracer, 6/3/19 00:00 UTC

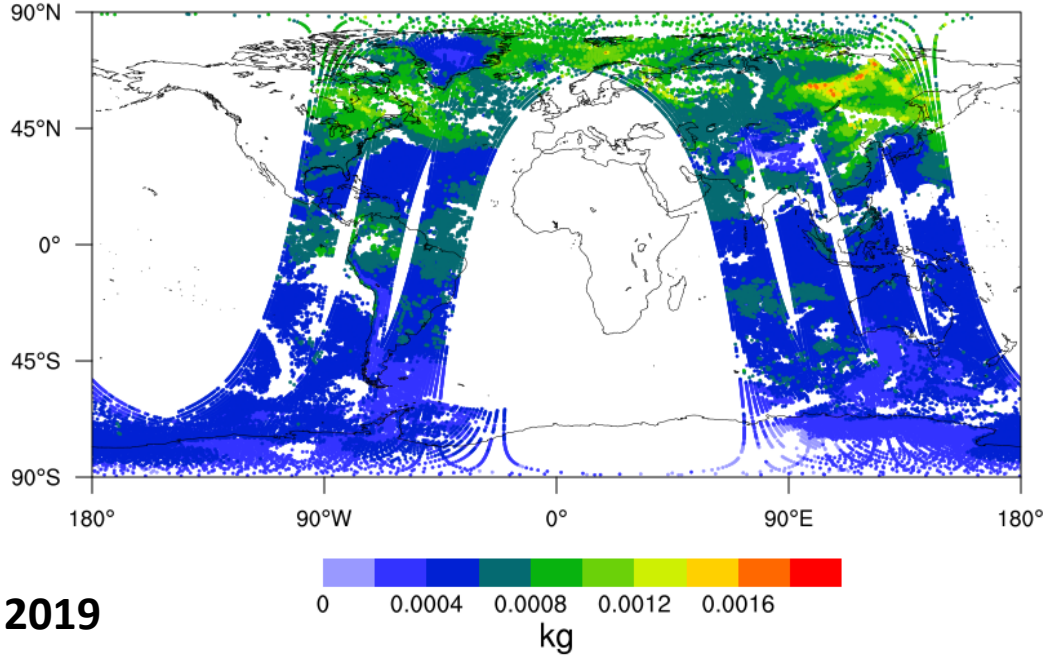


Add CO tracer to FV3GFS-Aerosols model for future effort to assimilate CrIS data and improve forecasts

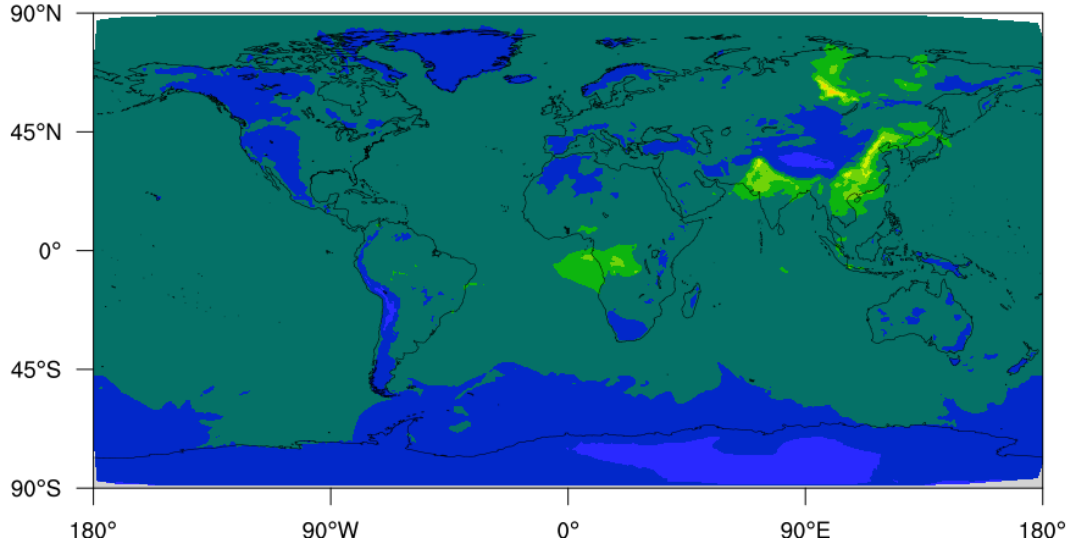
Initial comparisons of FV3GFS-Aerosols+CO model with CrIS

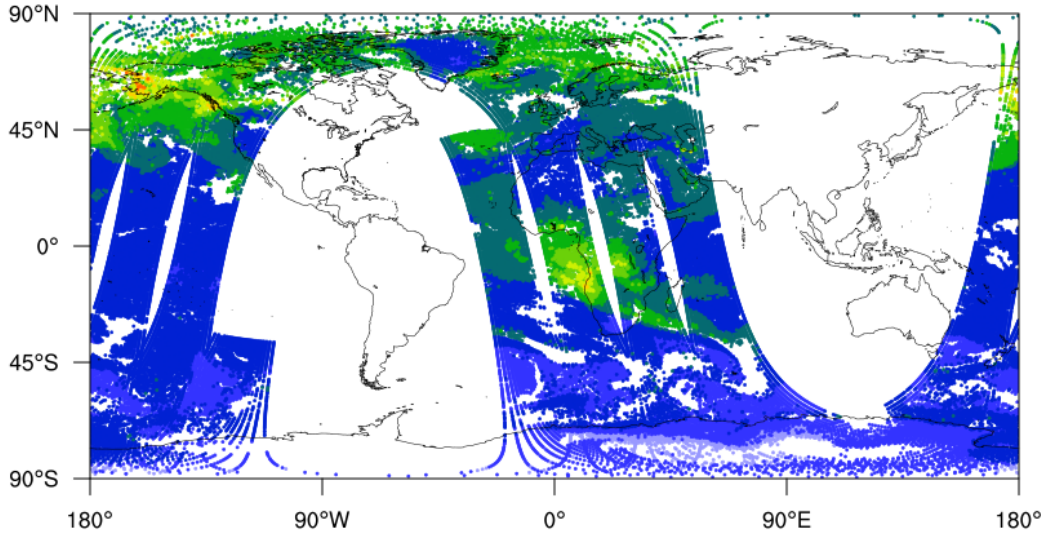
Model **7 August 2019** **CrIS**





9 August 2019





Value of combined instrument records

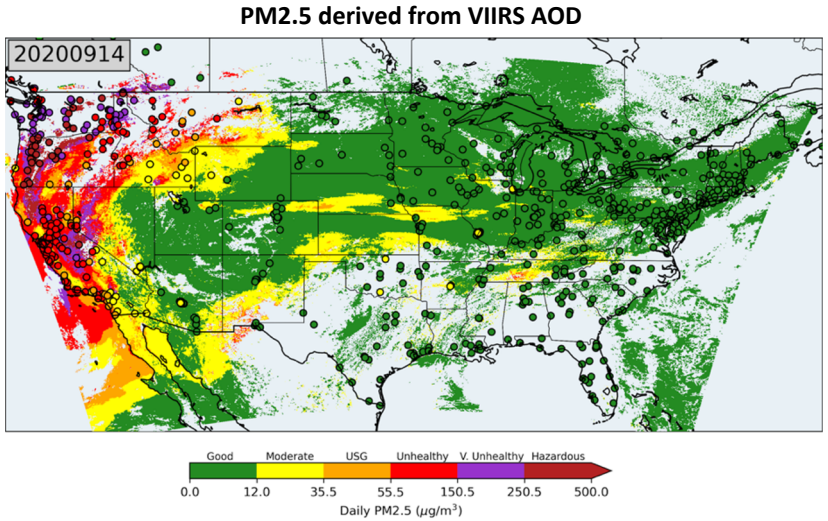
The Washington Post
Democracy Dies in Darkness

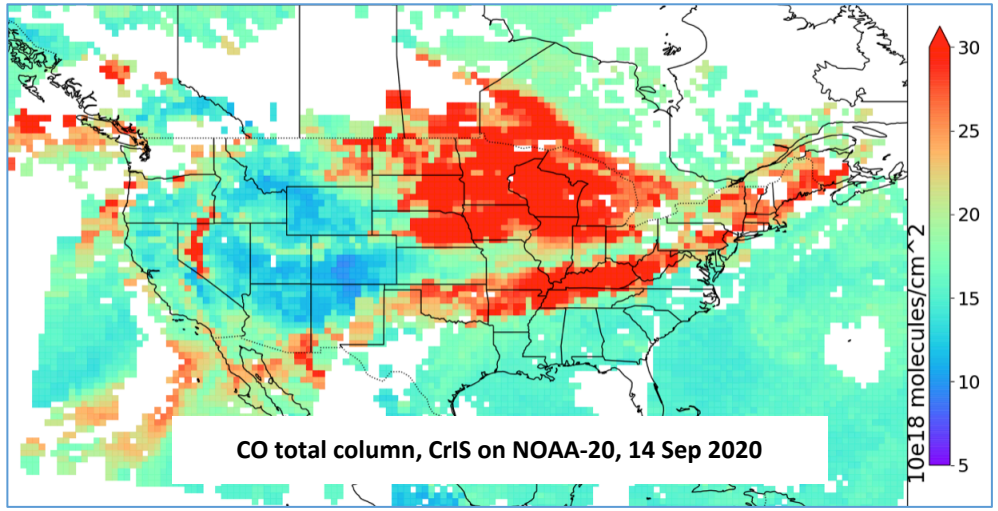
Smoke in D.C.'s skies traveled thousands of miles from the West Coast

By **Ian Livingston**

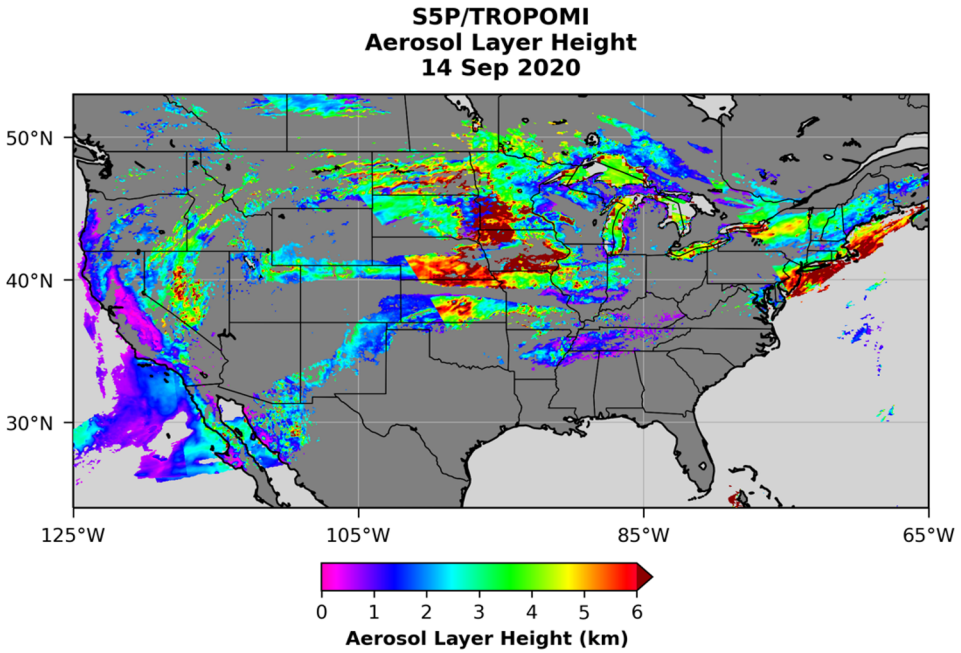
September 15, 2020 at 10:38 a.m. MDT

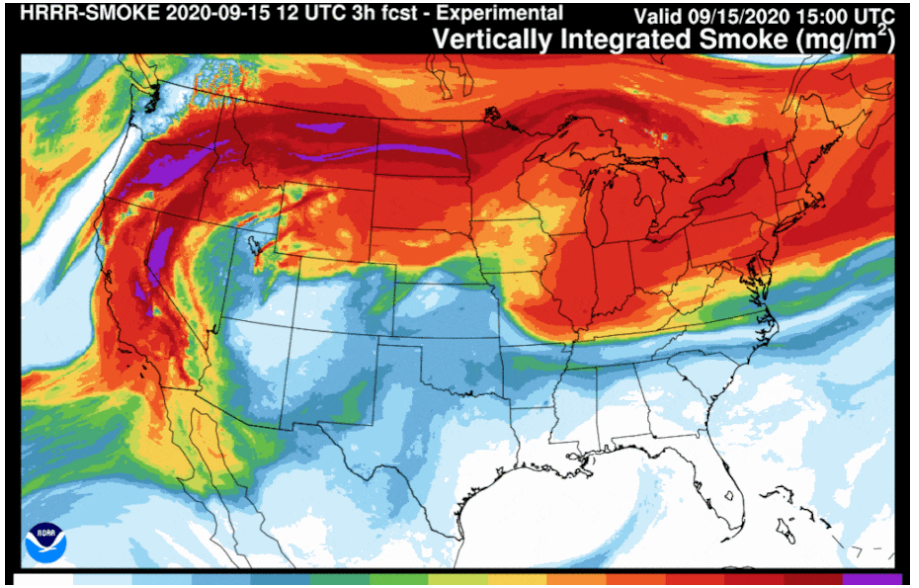
+

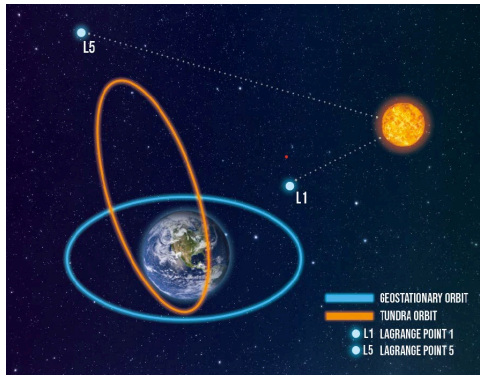




Combination of thermal IR sounder with UV-VIS and near-IR datasets provides powerful dataset for tracking long-range transport and constraining model forecasts







Value Assessment of an Atmospheric Composition Capability on NOAA's Next-Generation Geostationary and Extended Orbits (GEO-XO) Missions

GEO-XO = NOAA missions to follow current GOES-R and Space Weather Follow-On (SWFO) missions in 2030 - 2050 timeframe

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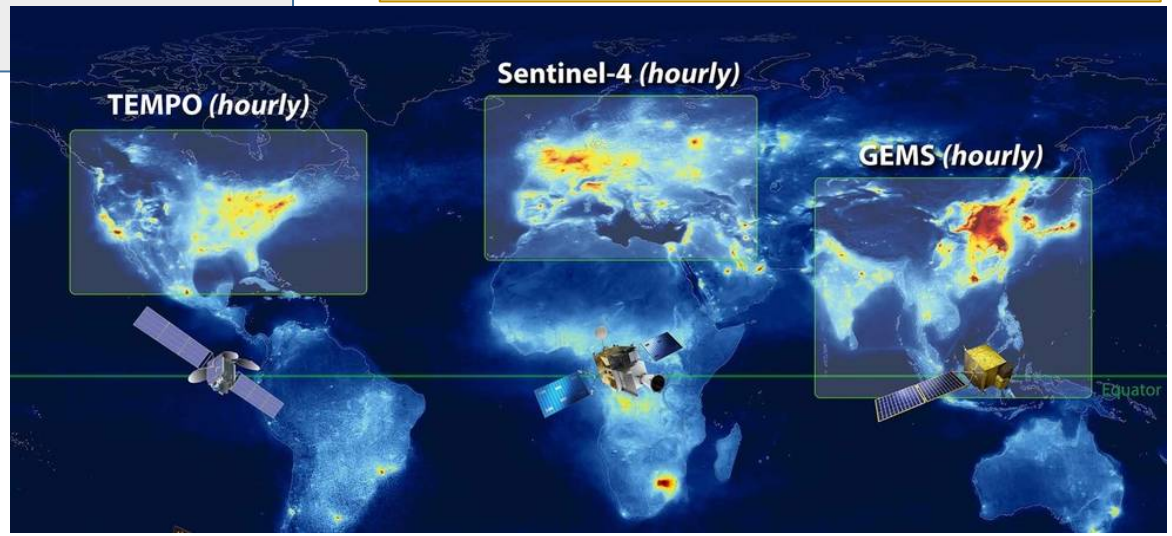
NOAA Technical Report OAR CPO-8
Submitted 9 October 2020
https://doi.org/10.25923/1s4s-t405 (DOI active soon!)

- Executive Summary
- Motivation and Background
- The Value of GEO-XO to NOAA Applications
  1. Air Quality Forecasting
  2. Weather and Climate Forecasting
  3. Fire Weather Forecasting
  4. Hazards Forecasting
  5. Greenhouse Gas Monitoring
  6. Stratospheric Ozone Monitoring
  7. Air Quality Monitoring
- Potential Valuation Use Cases

Proposed GEO-XO atmospheric composition measurement suite

- **Vis/IR Imager:** fires, aerosol type & optical depth
- **Thermal/shortwave IR Sounder:** profiles and tropospheric columns of ozone and greenhouse gases
- **UV/Vis Spectrometer:** tropospheric columns of ozone and air pollutants, aerosol layer height



Discussion

1. Which overarching science questions can be addressed with long-term sounder atmospheric composition records?

- Sounders provide continuous datasets with wide geographic coverage
- Sounders measure under-sampled free troposphere
- Sounders augment other space-based observations
- Sounders can help constrain global tropospheric chemical budgets, which are otherwise under-constrained
- Chemical data assimilation and chemical re-analyses demonstrate usefulness of sounders

Discussion

2. What are the highest priorities and current shortcomings in terms of composition data products, data fields, and information from sounder retrievals?

- Characterize sounder retrievals with in-situ observations, particularly vertical sensitivity and retrievals in complex environments
- Produce consistent long-term sounder datasets to enable detection of real temporal and spatial variability in atmospheric composition
- Strengthen connections between evaluation and retrieval teams, which leads to long-term improvements in retrievals
- Transition retrieval advances into operational datasets
- Increase awareness of the value of atmospheric composition data products

Discussion

3. Given that the IR sounders will be in orbit until ~2040s, what are the key observational gaps?

- Shortwave IR bands extend the vertical extent of thermal IR sounders into the boundary layer
- Combination of UV/VIS and IR retrievals is more powerful than IR alone
- Geostationary hyperspectral TIR+SWIR sounders and UV-VIS observations will add information on temporal variation, enable monitoring of episodic events, and increase cloud-free coverage