Evolution of PAN in wildfire smoke plumes detected by the Cross-Track Infrared Sounder (CrIS) over the western US during summer 2018

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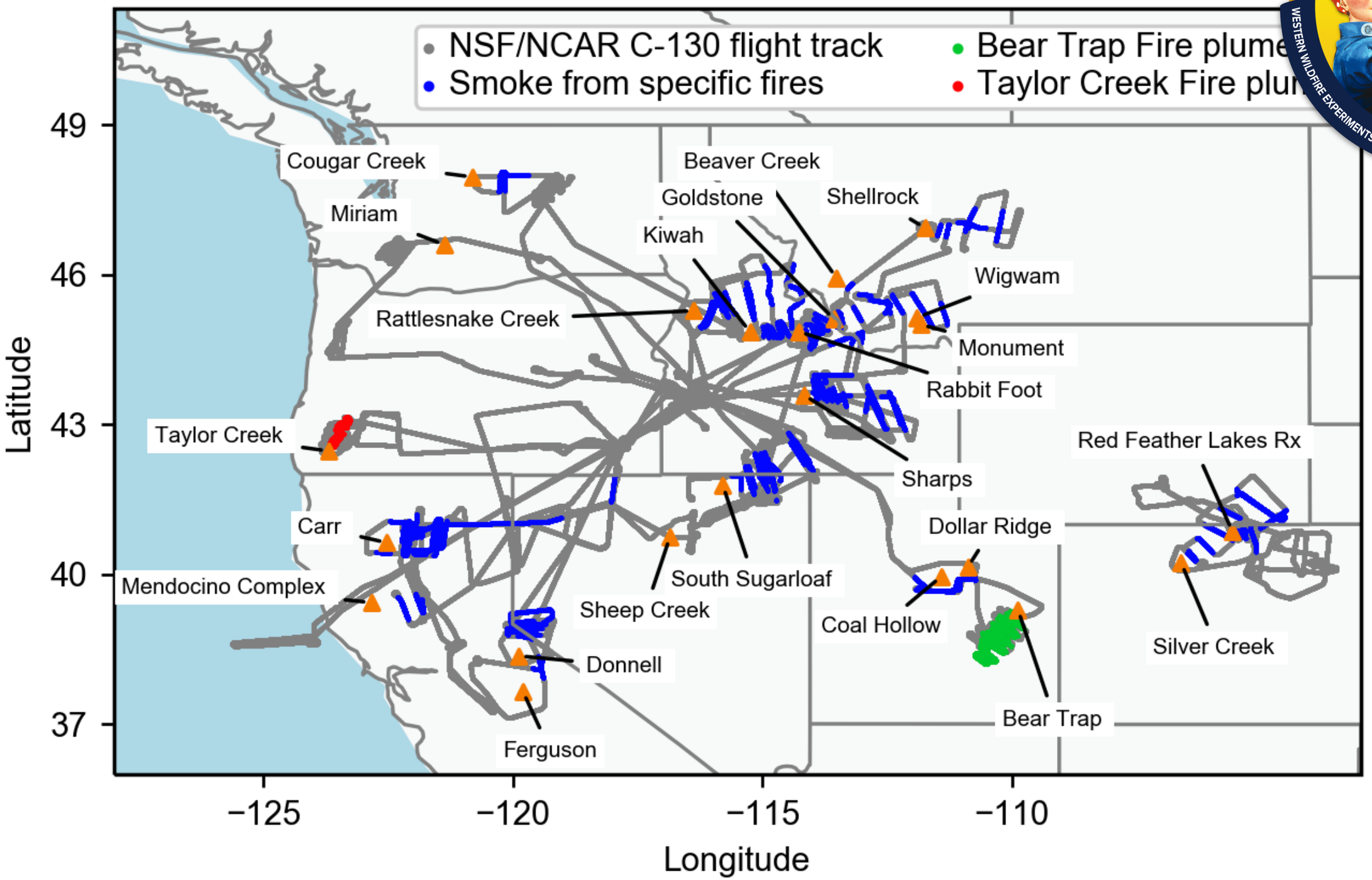
Photo: Ali Akherati
Williams Fork Fire
August 15th, 2020

The Western Wildfire Experiment for Cloud Chemistry, Aerosol Absorption, and Nitrogen (WE-CAN) sampled a large number of wildfire smoke plumes during summer 2018.



Daytime oxidized reactive nitrogen chemistry in smoke plumes is complex.

NO_x sequestration and transport

e.g., Alvarado et al., 2010

PAN

PPN

Others

RO_2NO_2

O_3 formation

e.g., Jaffe and Wigder, 2012

T dependent

RO_2

O_3

hv

OH

HNO_3

NO_2

NO

HONO

OH

RO_2, O_3

OH

hv

RO_2

$RONO_2$

Free NH_3

Oxidative capacity (hazardous air pollutants)

e.g., Peng et al., 2020

Org N

Emissions

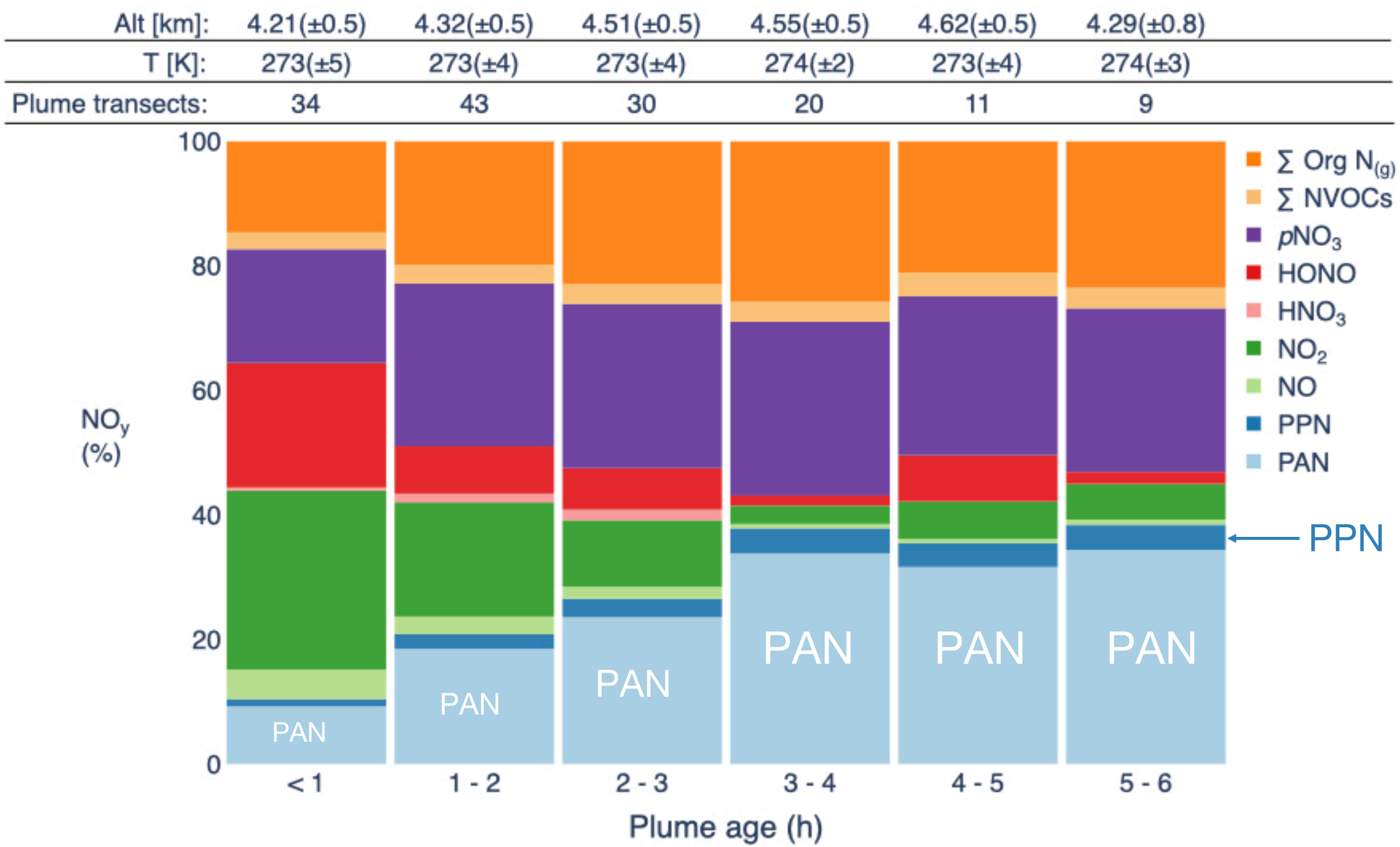
pNO_3

Aerosol formation and climate effects

e.g., Paulot et al., 2017

Omitting dark chemistry

After 3 hours, ~37% of the $\sum NO_y$ is in the form PAN and PPN.

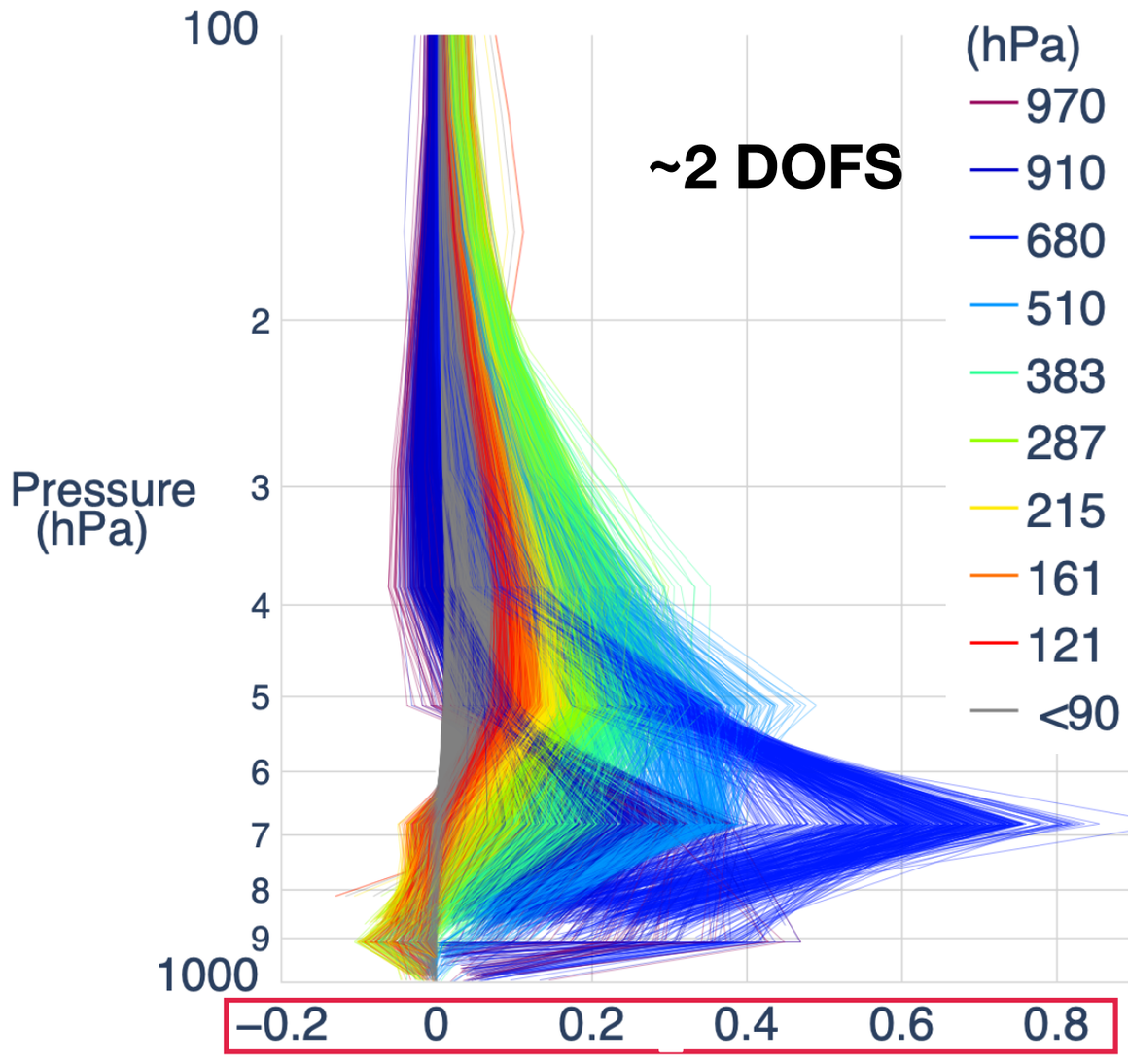


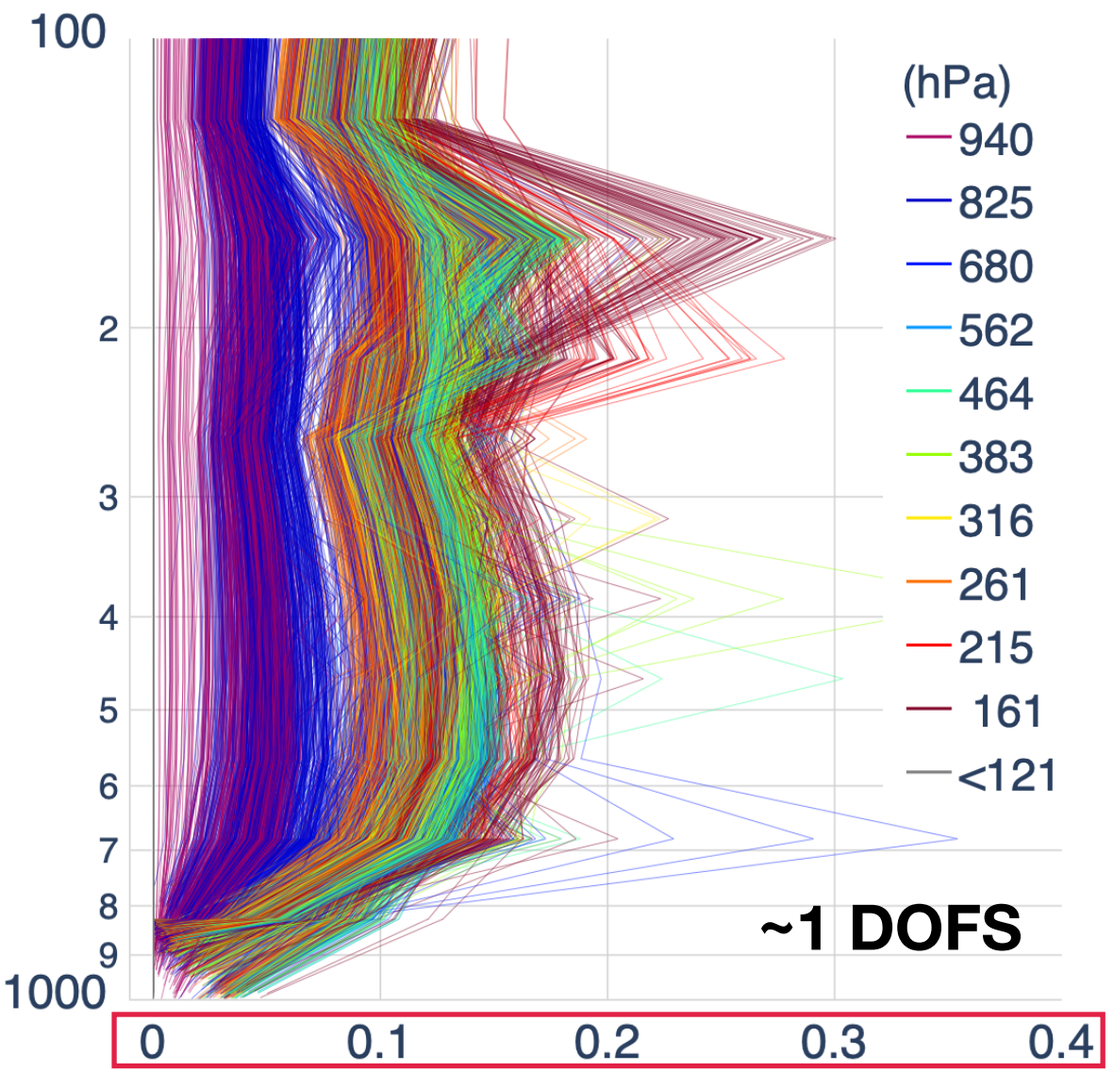
Rapid conversion of NO_x to PANs has been observed in smoke plumes form wildfires and agricultural fires (Alvarado, et al., 2010; Yokelson et al., 2009; Akagi et al., 2011; Liu et al., 2016).

The Cross-Track Infrared Sounder (CrIS) on Suomi-NNP complements the PAN measurements during WE-CAN and continues the PAN satellite record.

CrIS CO has ~2 DOFS while CrIS PAN has only ~1 DOFS.

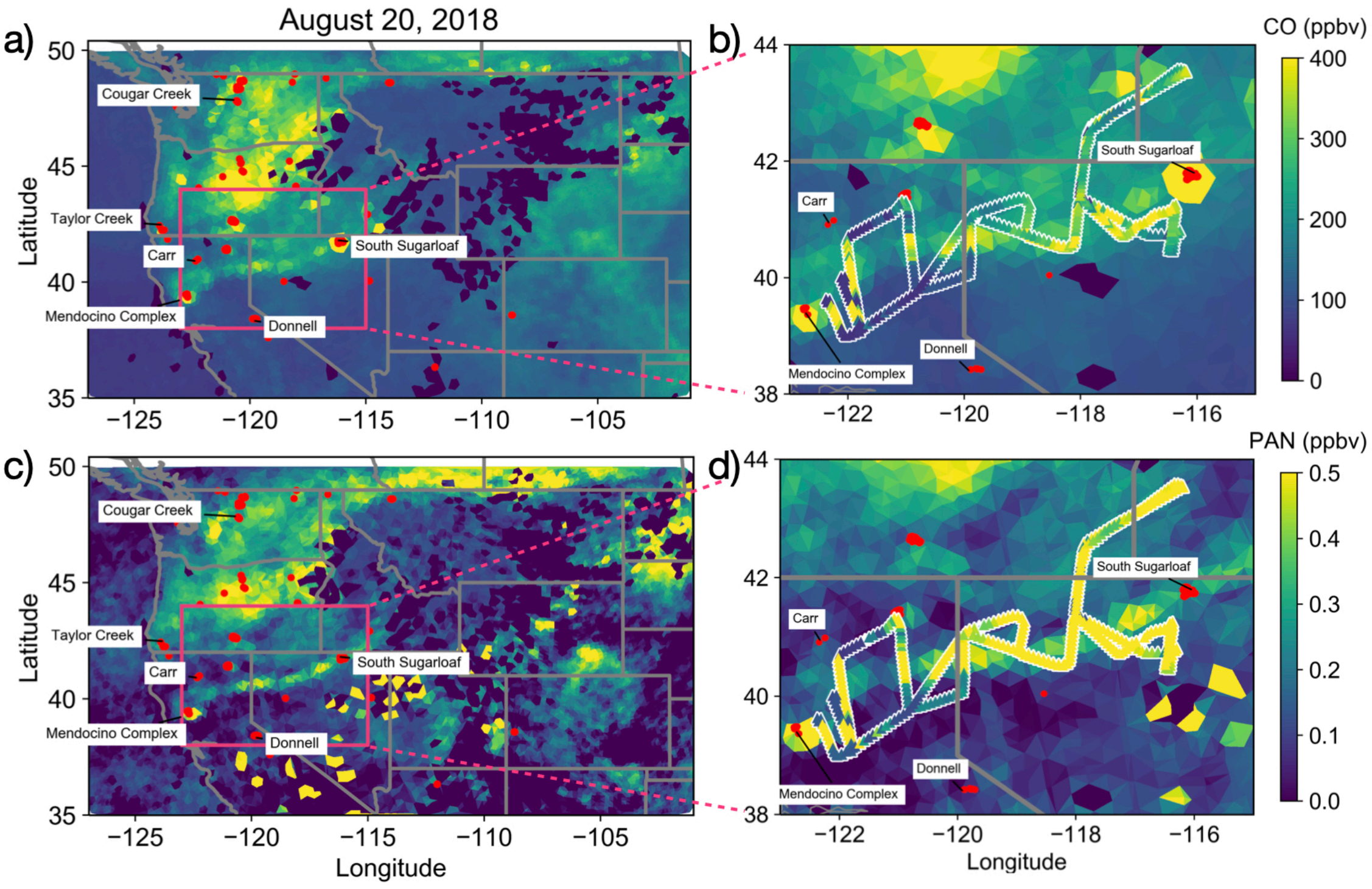
August 20, 2018 (39° - 43° N, 115° - 123° W)
from smoke-impacted retrievals





Note difference
in AK scale

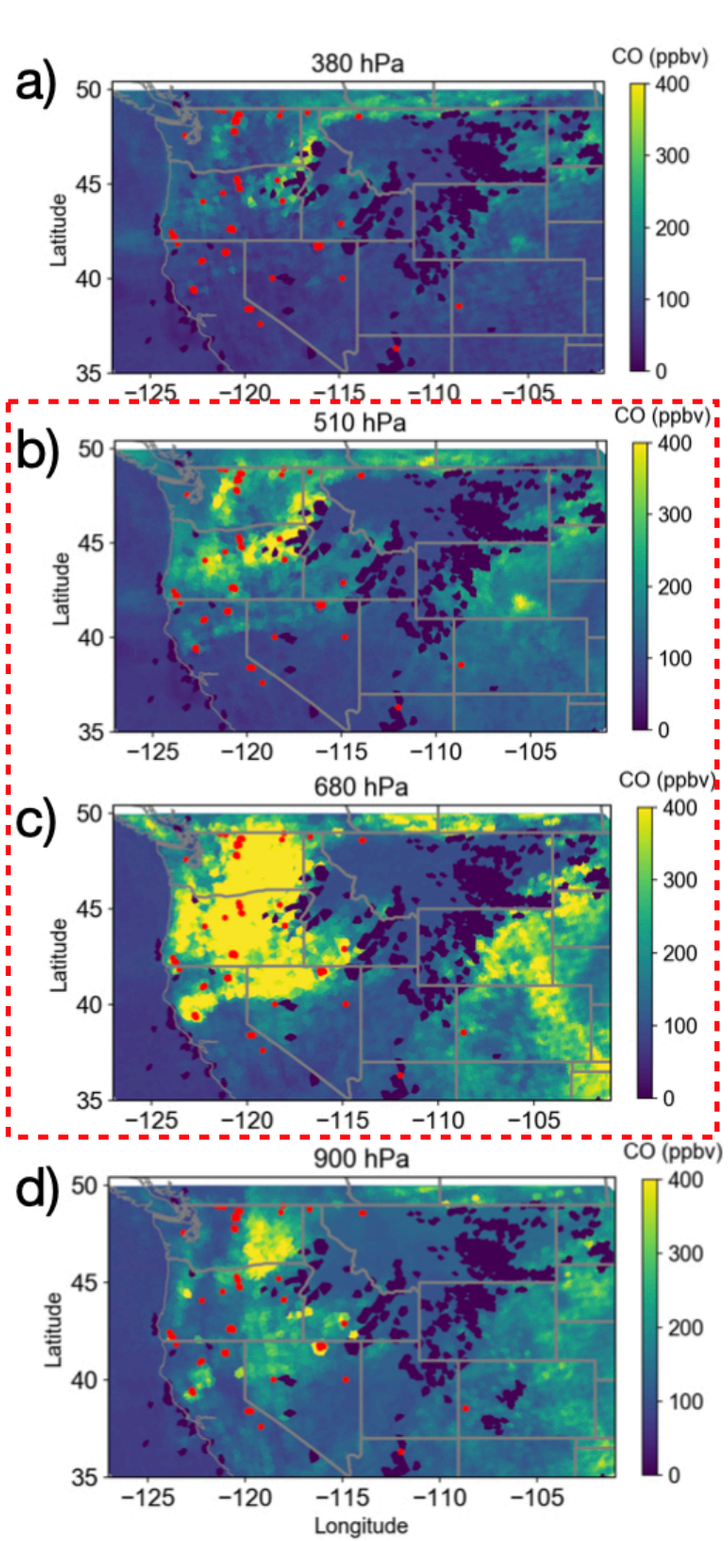
Many smoke plumes sampled during WE-CAN were also detected by CrIS offering an opportunity to extend the WE-CAN data set.

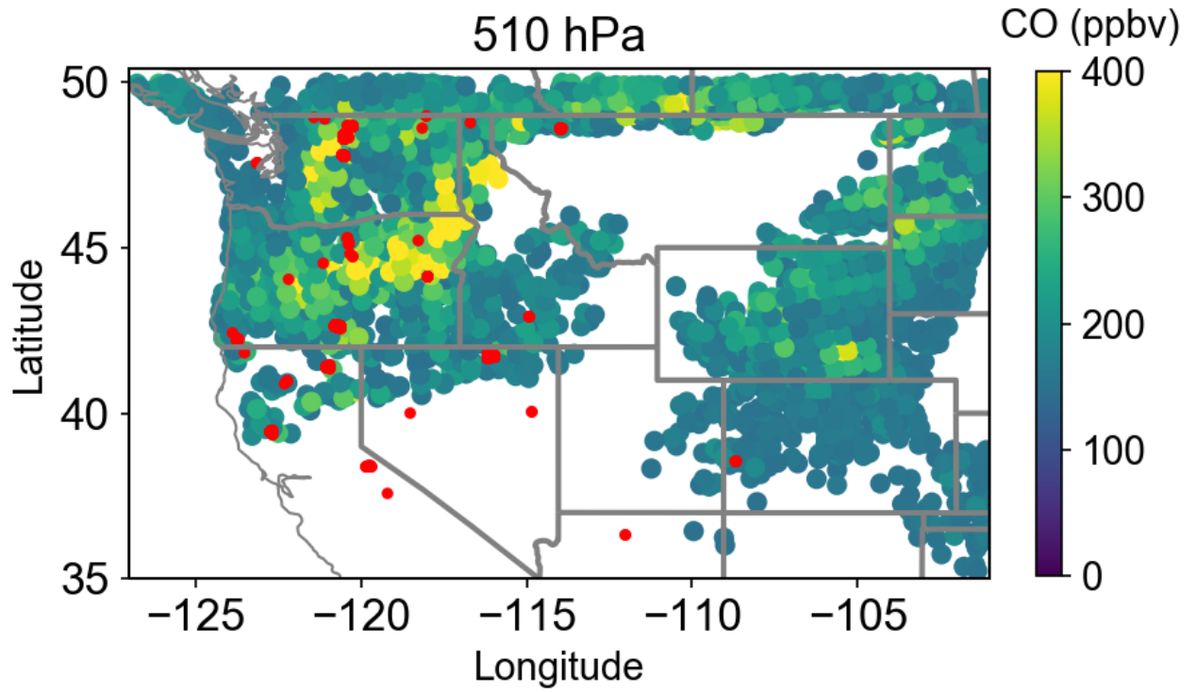


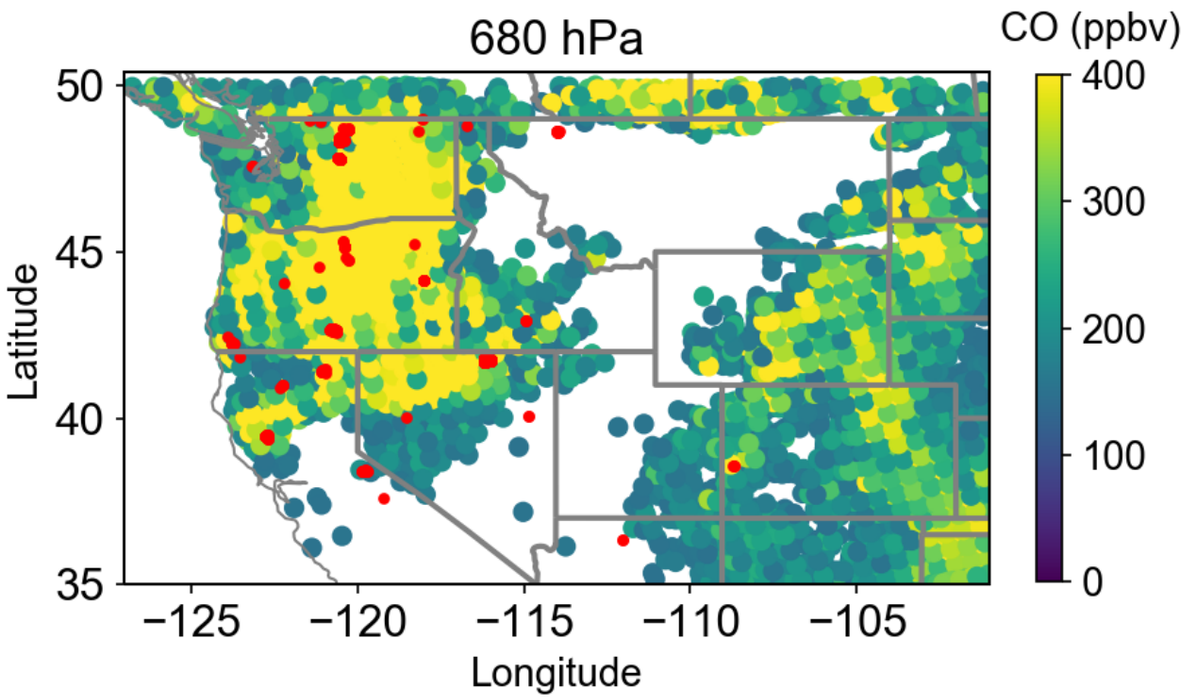
● S-NPP / Visible Infrared Imaging Radiometer Suite (VIIRS) fire detections

We use two techniques to classified a specific retrieval as smoke-impacted or smoke-free:

1. CO > 150 ppbv at the 510 or 680 hPa level.







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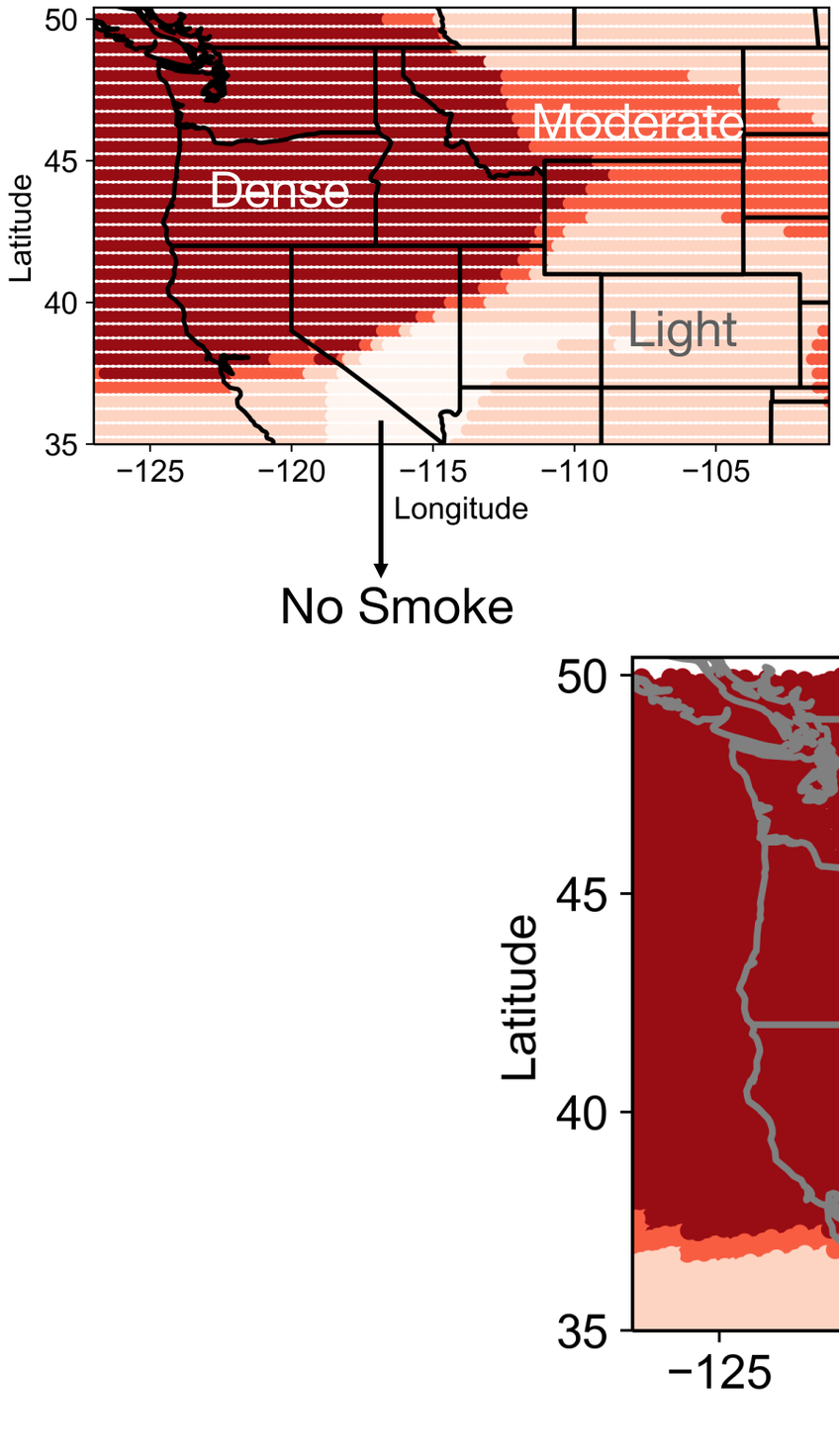
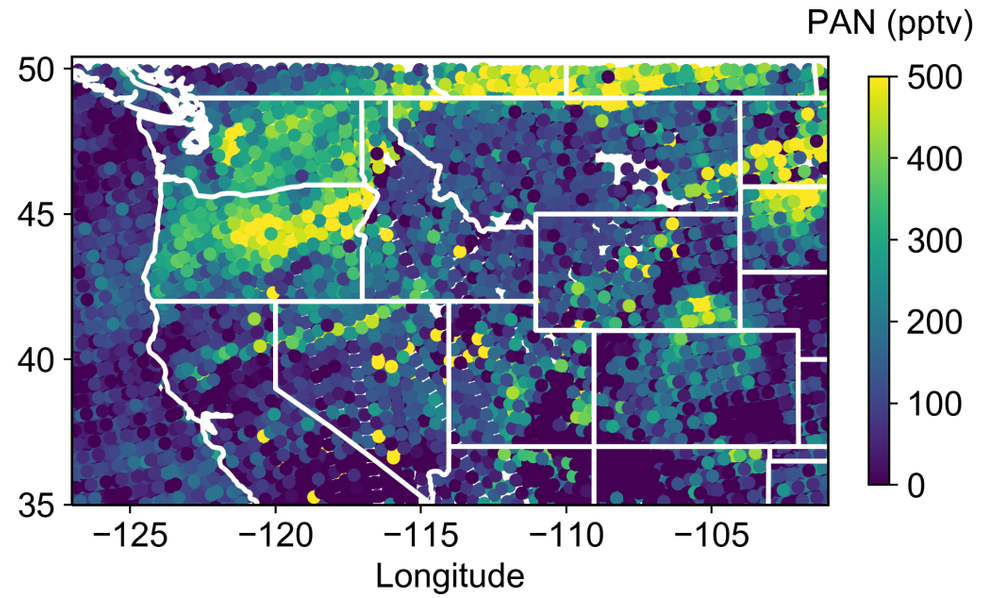
2. NOAA Hazard Mapping System (HMS) indicates smoke in column

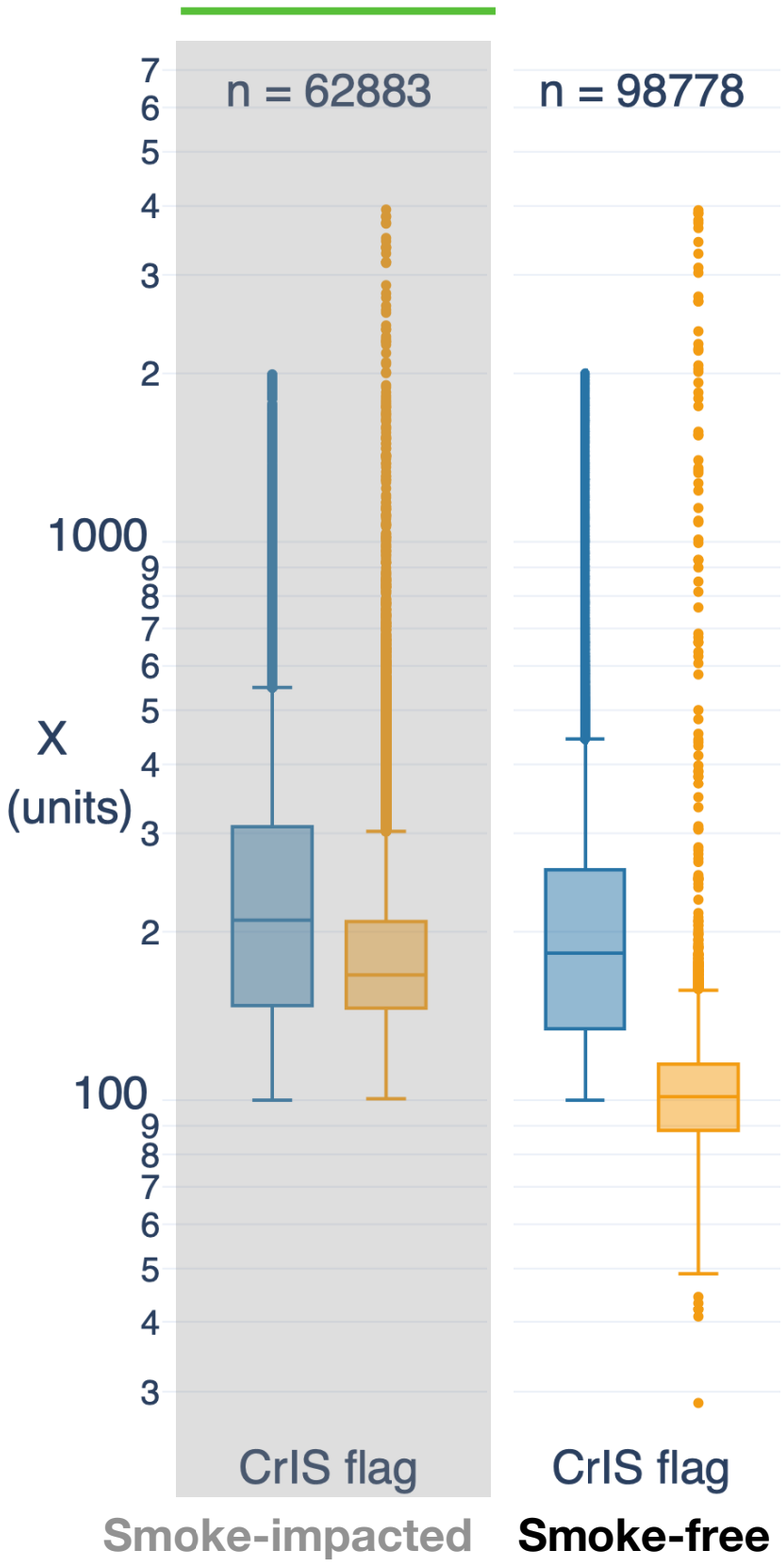


Collocation



Thanks to Bonne Ford for the HMS data

Smoke-impacted retrievals contain more PAN and CO than smoke-free retrievals.



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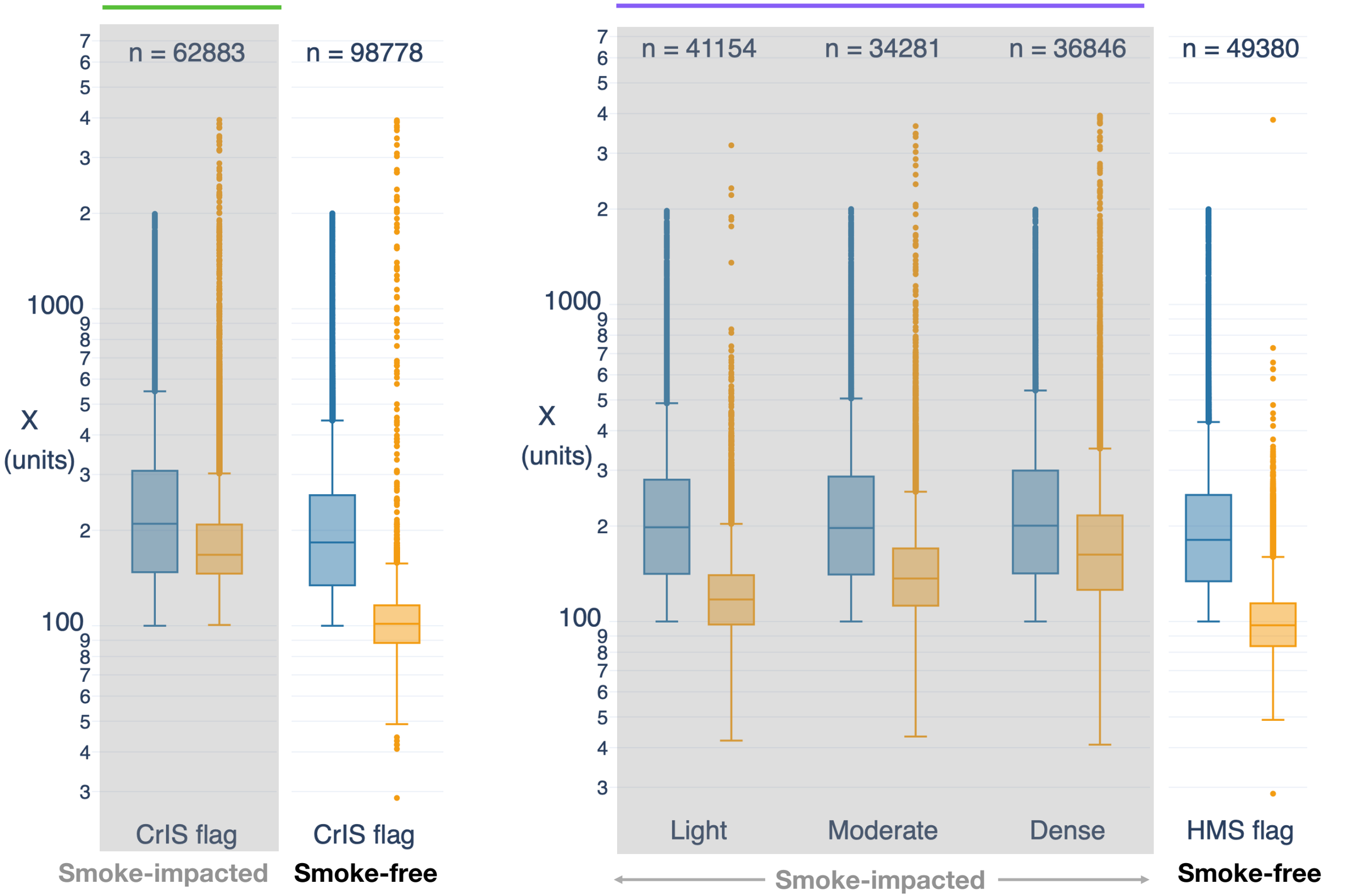
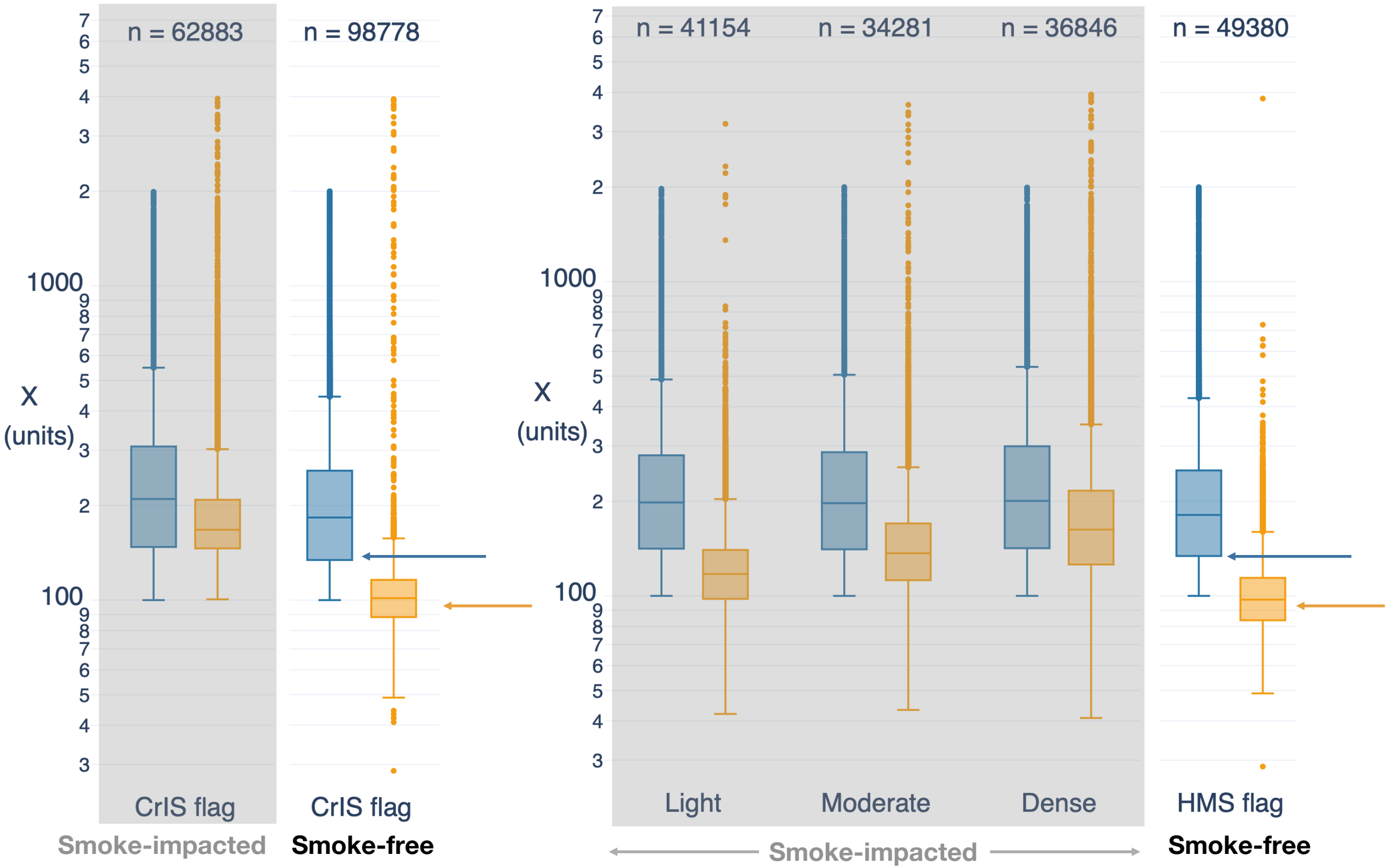


For the analysis that follows, we use background values of 130 pptv for PAN and 95 ppbv for CO.



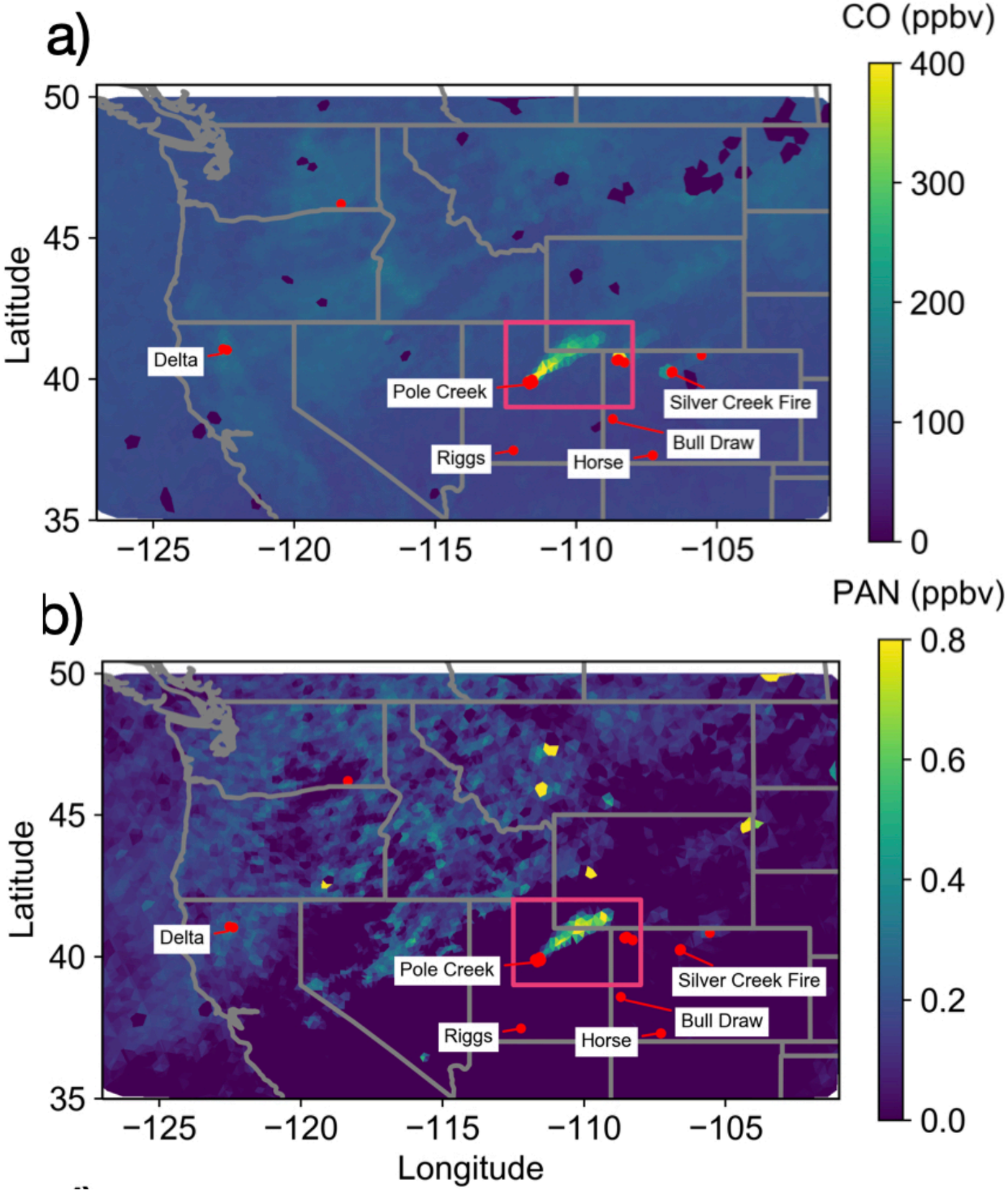
Pole Creek Fire

Utah

September 13, 2018

Photo: Inciweb

CrIS detects CO and PAN from the Pole Creek smoke plume on September 13, 2018.



The combined spatial resolution and sensitivity of CrIS is sufficient to detect the chemical evolution in plumes when background conditions are favorable.

$$NEMR = \frac{PAN_{plume} - PAN_{background}}{CO_{plume} - CO_{background}}$$

*NEMR: normalized excess mixing ratio

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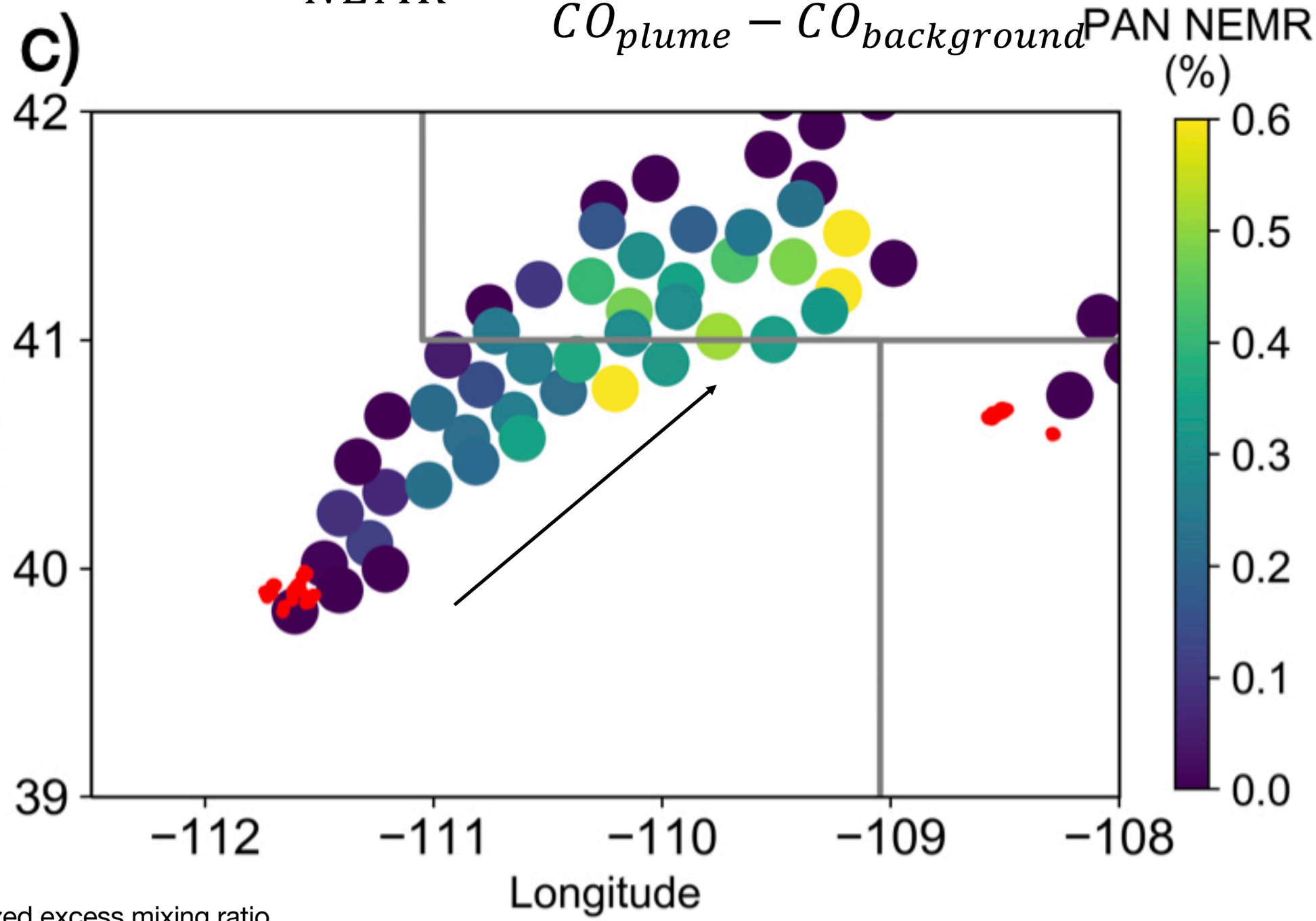

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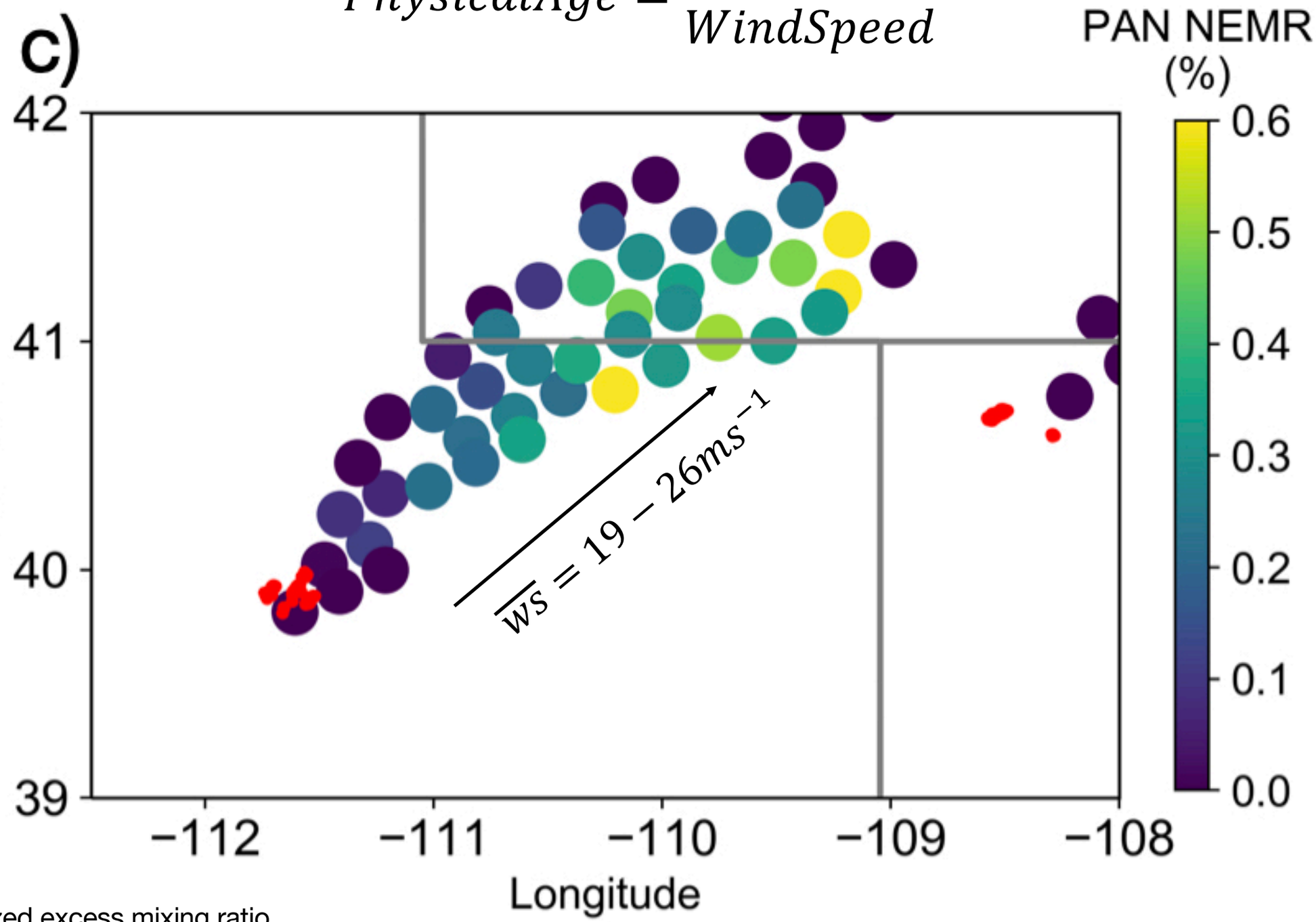
$$PhysicalAge = \frac{Distance}{WindSpeed}$$



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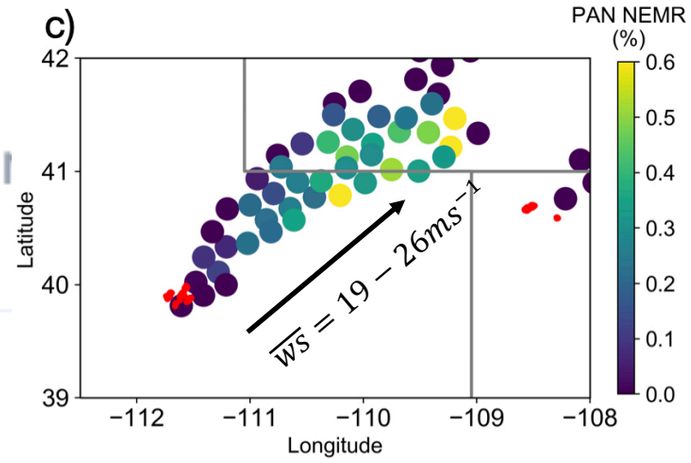
The evolution of PAN in the Pole Creek Fire is comparable to the that of the fresh plumes sampled during WE-CAN.



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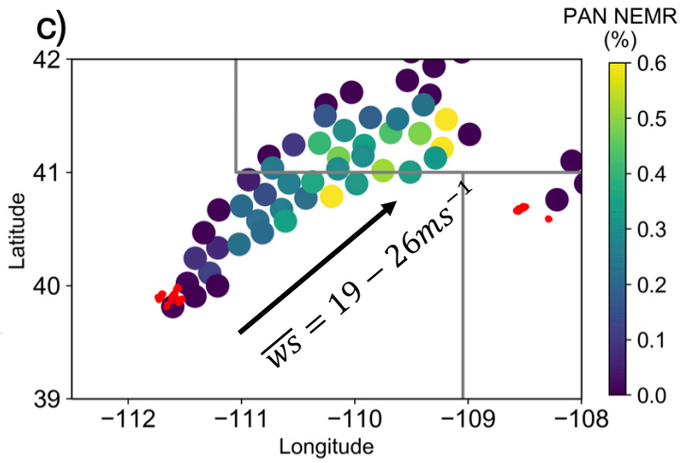

Take away

- CrIS is able to detect PAN and CO enhancements in smoke plumes from many individual wildfires.
- The spatial resolution of CrIS combined with favorable background conditions is sufficient to observe the chemical evolution of PAN.

Discussion

- What overarching science questions would you like to address with long-term sounder composition records, given what you know about their quality and uncertainty?
  - Calculate emissions of trace gases from fires (*e.g.,* CO, PAN, NH_3)
  - Estimate the contribution of PAN to ozone (O_3) production in smoke.

- What should be the highest priorities when developing new trace gas products for air quality / climate monitoring?
  - Fine spatial resolution and coverage. These allow to “see” chemical changes within a particular smoke plume and track smoke plume chemical changes as the plume is transported downwind from the fire source.

- Given that the LEO sounders (IASI, IASI-NG, CrIS) will continue to be in orbit till ~2040s, what, in your mind, are the key observational gaps?
  - Nighttime data would be nice. Fires extent during nighttime but airborne measurement are hard to do at night. Satellite nighttime data and at other time throughout the day would facilitate continuity in monitoring plumes
  - Geostationary CrIS!!!

Thank you!

Questions?