The CU Airborne SOF Instrument: Developing Techniques to Quantify Wildfire Emissions

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CIRES Cooperative Institute for Research in Environmental Sciences

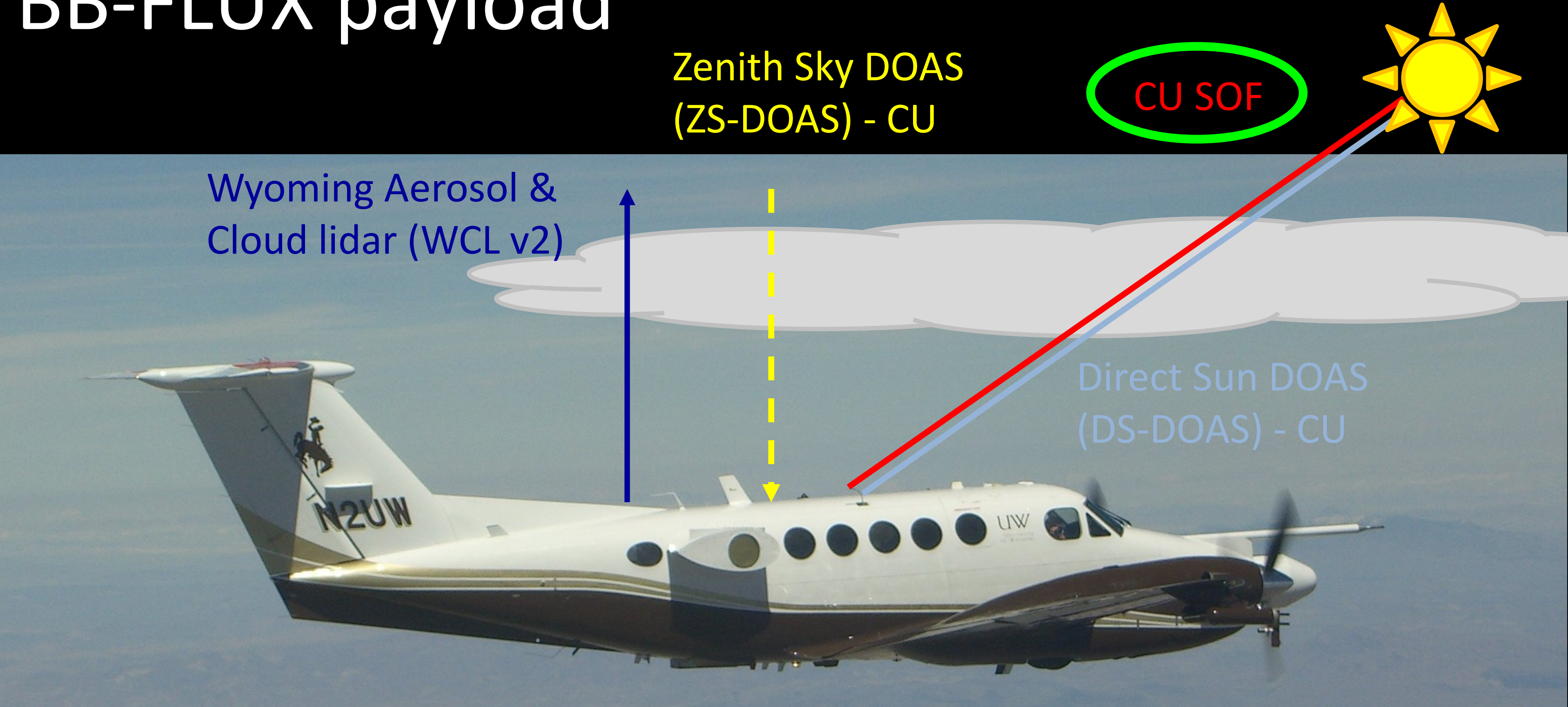
University of Colorado Boulder

University of Wyoming

NCAR National Center for Atmospheric Research

NSF

BB-FLUX payload



in-situ sampling:
- CO, CO_2, H_2O
- O_3 (KIT)
- Aerosol size distribution
- Cloud size distributions

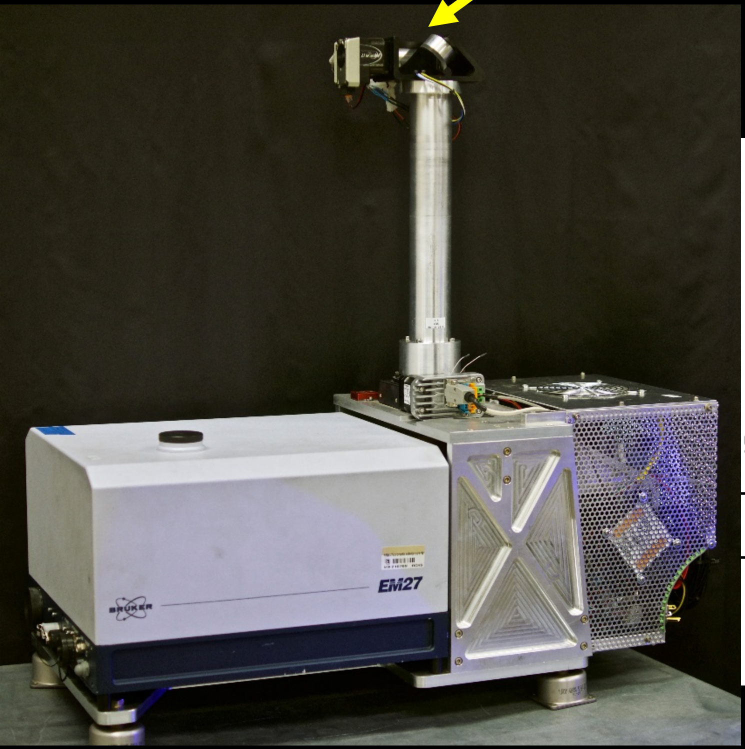
Auxiliary :
- Radiation (up- and downwelling)
- Video (forward & downward)

CU airborne SOF: emission flux & chemistry

University of Colorado airborne
Solar Occultation Flux

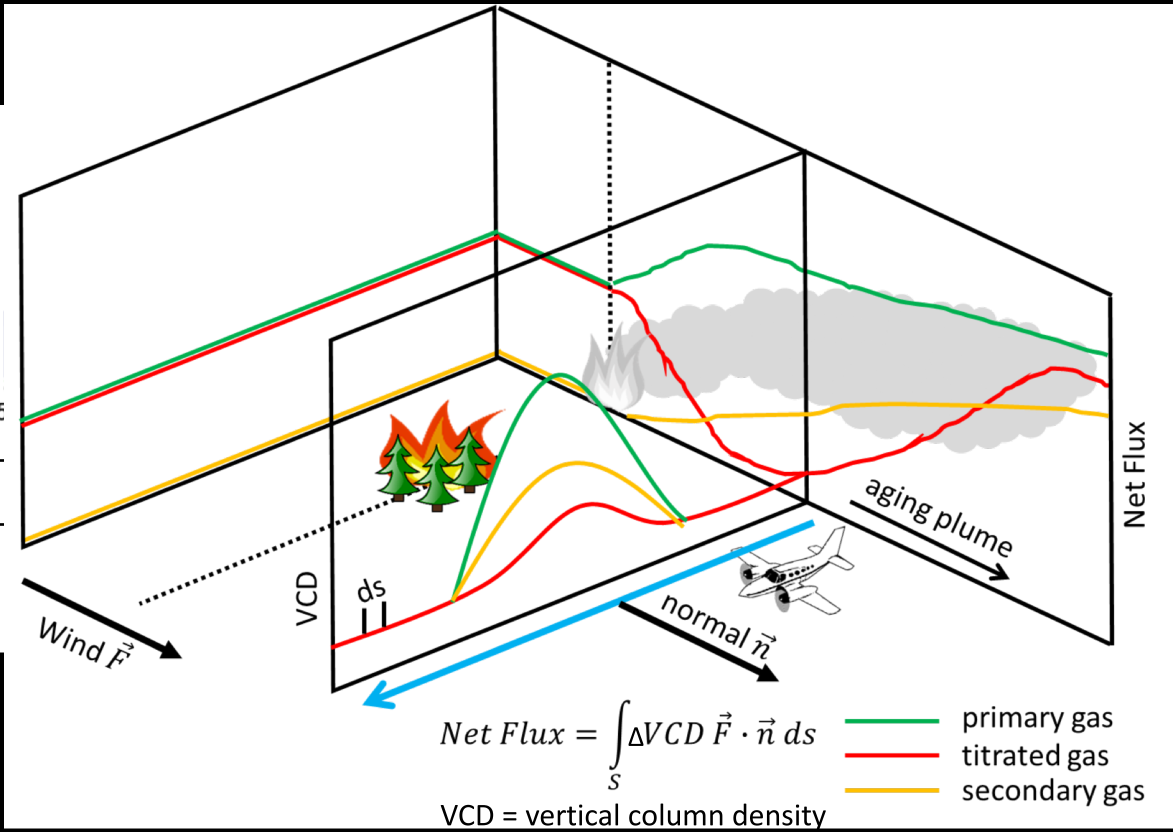
Direct sunlight
observation

Column measurements are independent of PBLH



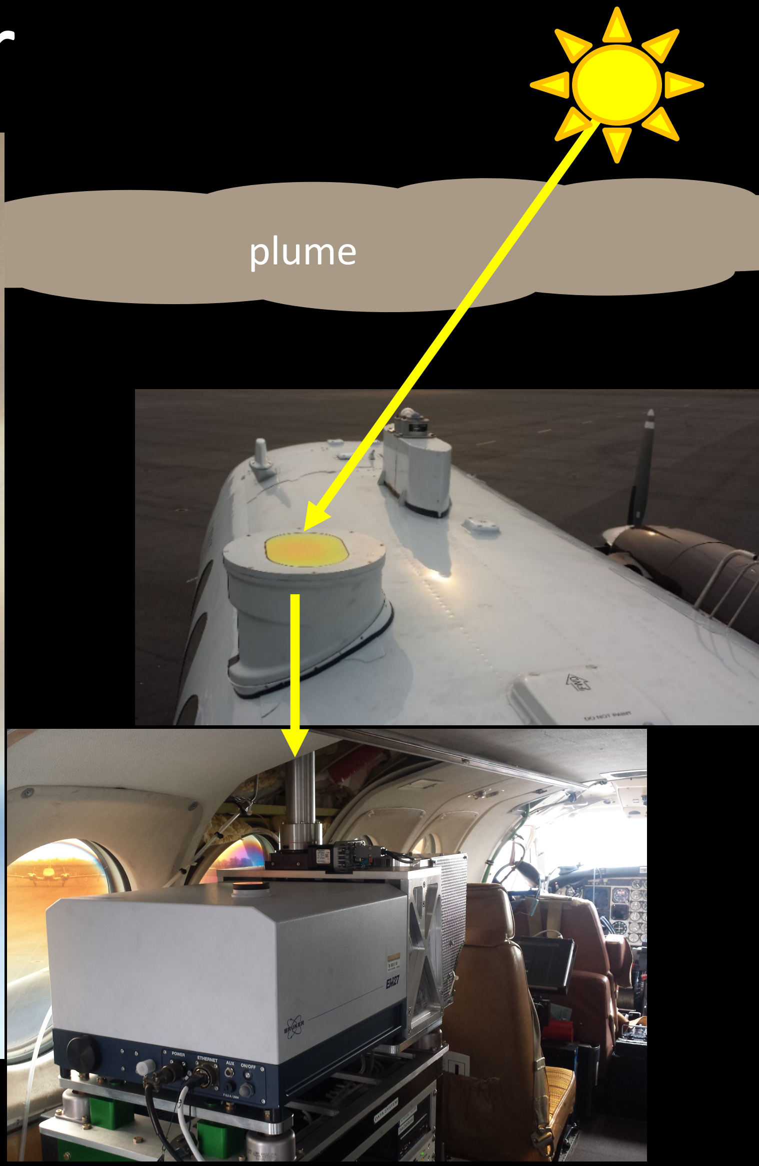
Weight: ~38 kg
Size: 356 mm x 750 mm (W x L)

Kille et al., 2017, AMT



Hypothesis: It is possible to quantify trace gas fluxes at the scale of wildfires.

Digital mobile solar tracker



Access to Euler Angles of the sun

Active control to correct for vehicle motion

→ Less time adjusting & more time measuring

Works under optically thick plumes & partly cloudy skies

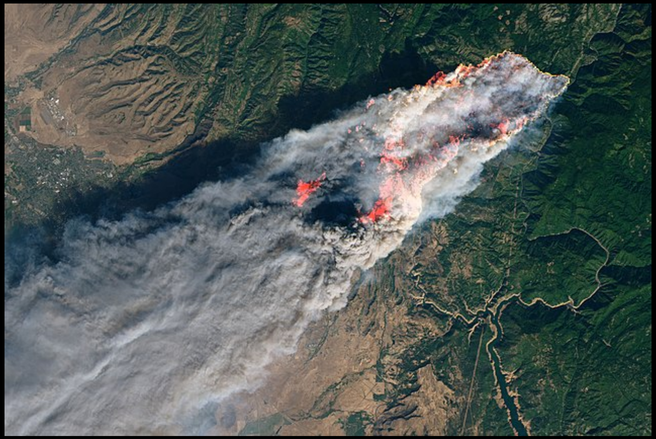
Baidar et al., 2016, AMT

Quantifying impacts on the atmosphere

Need to know what and how much is emitted from wildfires

Bottom up method: $E = A \cdot F \cdot \beta \cdot EF$

Top down method: $E = FRE \cdot c \cdot EF$



E = emission (g)
A = area burned (km^2)
F = fuel load (kg/km^2)
β = combustion completeness (0-1)
EF = emission factor (g/kg)
FRE = fire radiative energy (MJ)
c = conversion factor (kg/MJ)

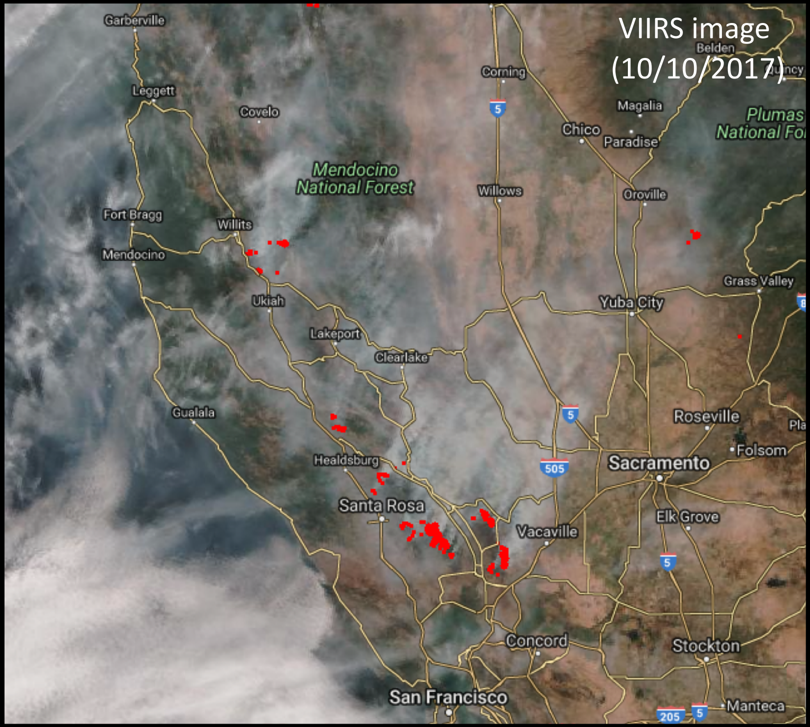
San Francisco Chronicle

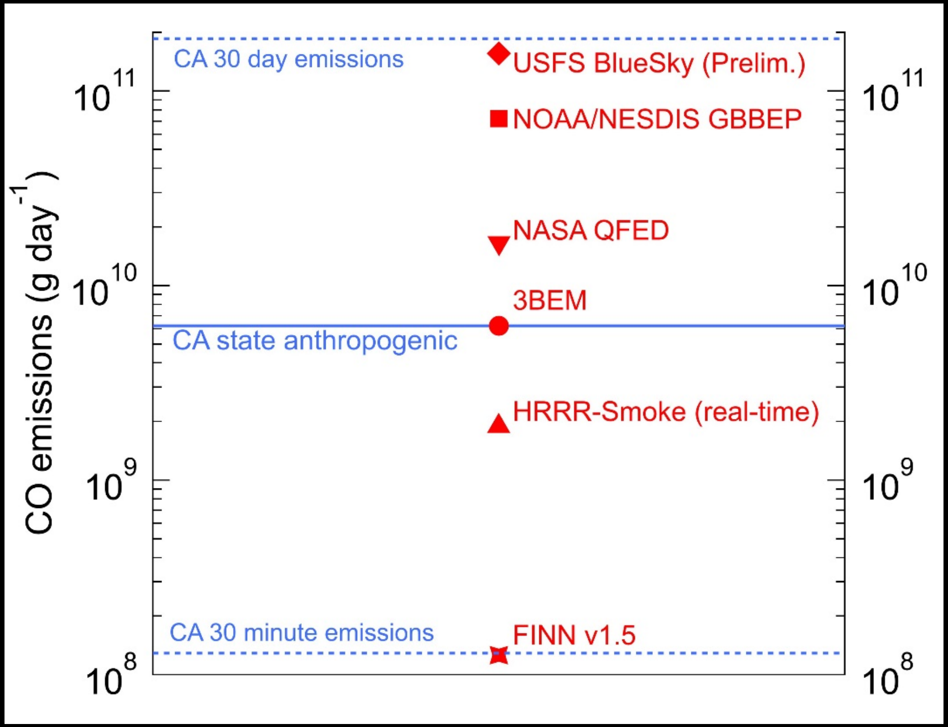
Camp Fire's climate toll: Greenhouse gases equal about a week of California auto emissions

Kurtis Alexander | Nov. 30, 2018 | Updated: Nov. 30, 2018 4 a.m.

Analytical challenge: lack of measurement techniques to evaluate emissions from wildfires.

October 2017 Northern California fires



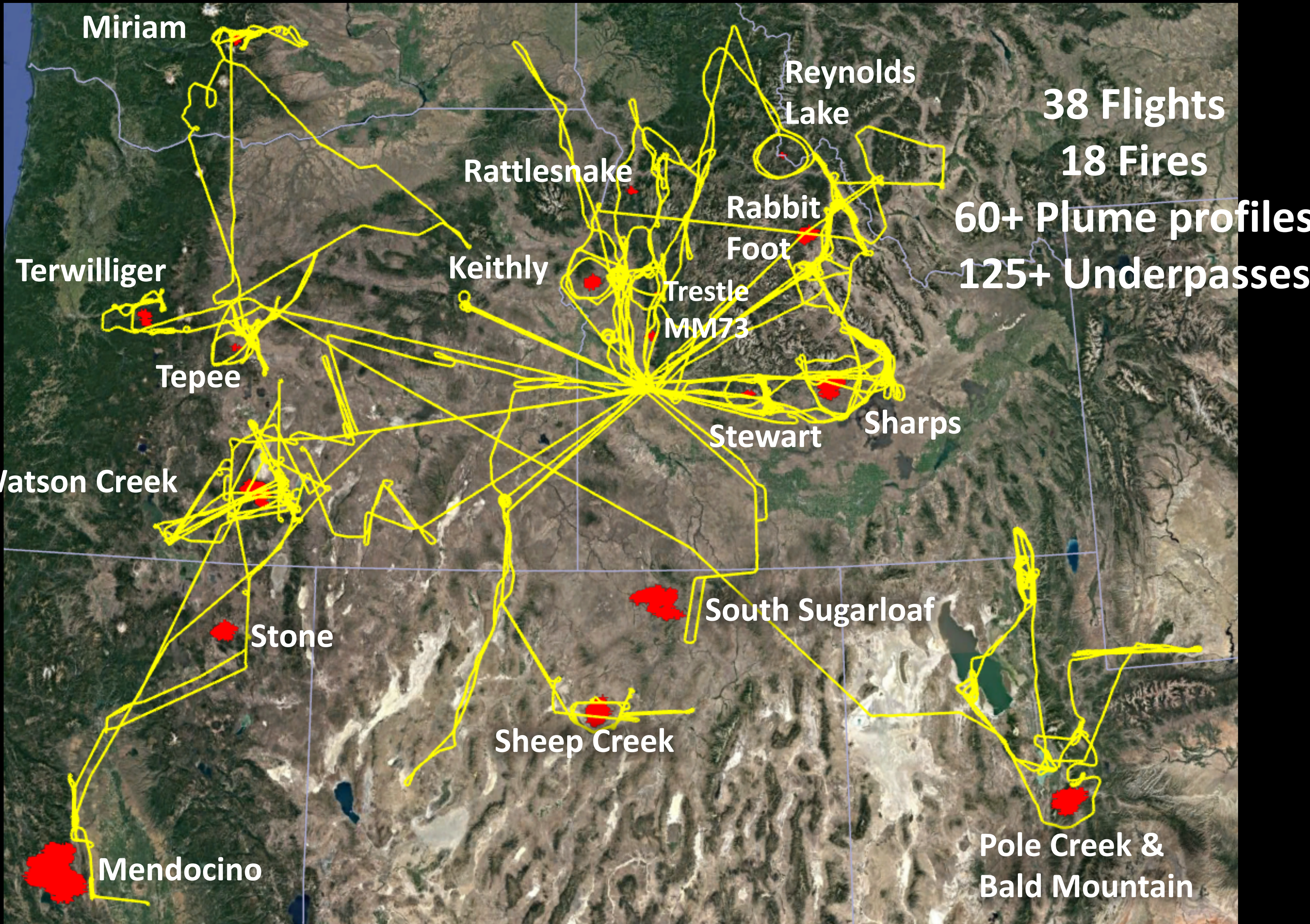


Emissions estimates for Santa Rosa fires vary by >3 orders of magnitude!

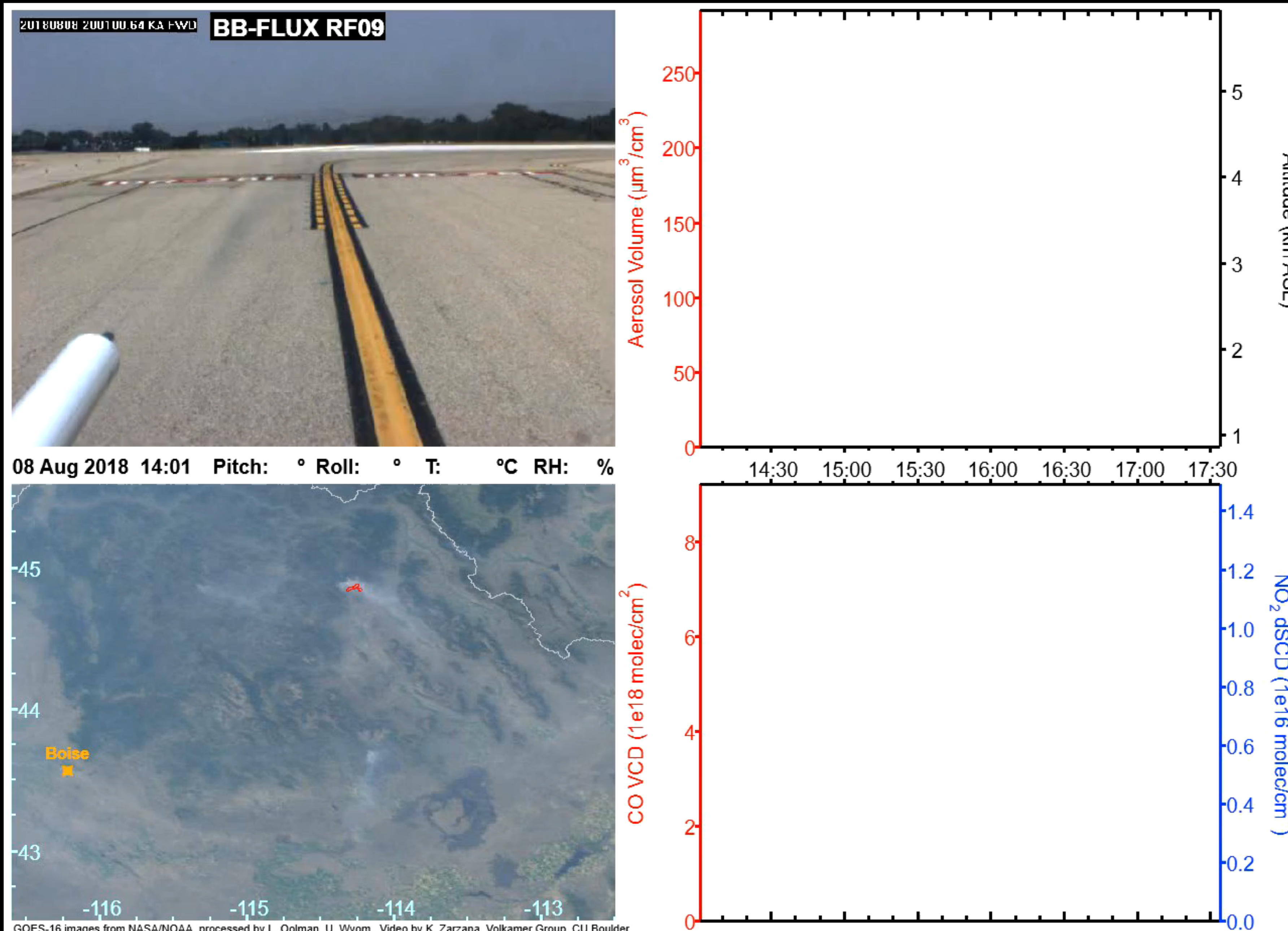
Variability is driven by uncertainty in amount of fuel burned.

Hypothesis: It is possible to quantify trace gas fluxes at the scale of wildfires.

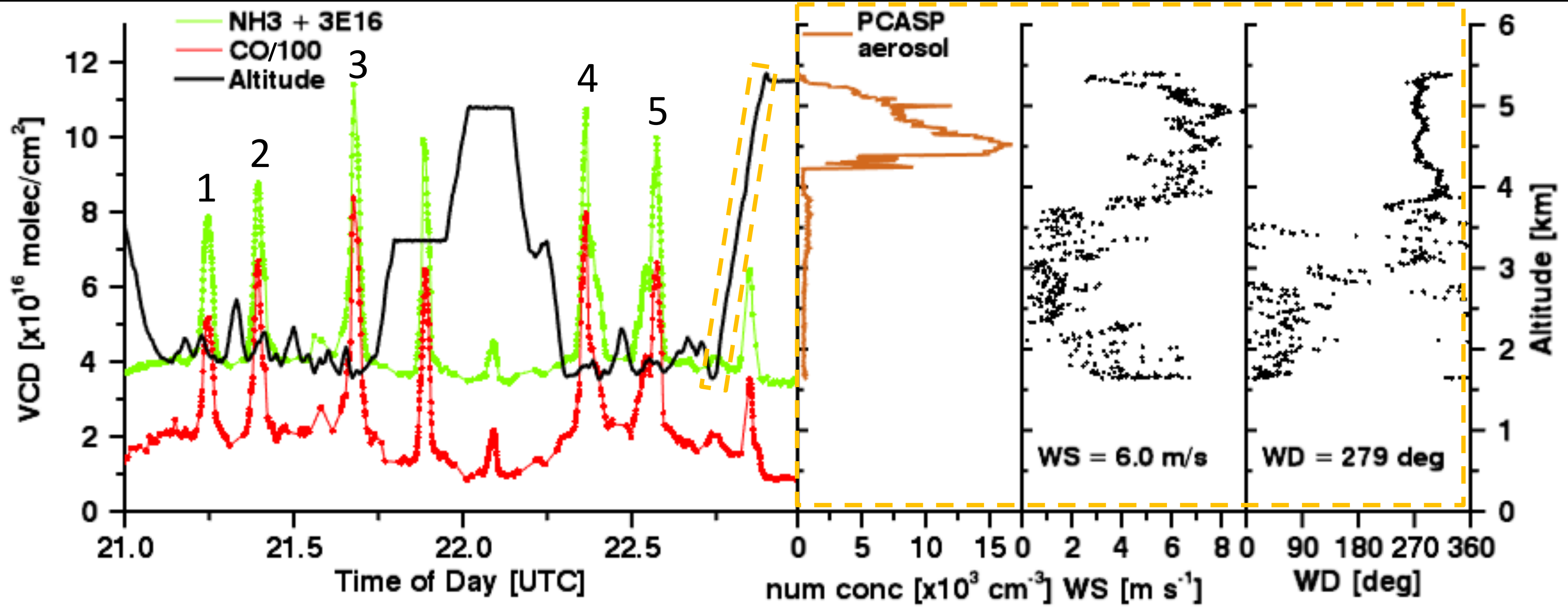
BB-FLUX 2018


Miriam
Reynolds
Lake
38 Flights
18 Fires
60+ Plume profiles
125+ Underpasses
Rattlesnake
Rabbit
Foot
Terwilliger
Keithly
Trestle
MM73
Tepee
Stewart
Sharps
Watson Creek
South Sugarloaf
Stone
Sheep Creek
Pole Creek &
Bald Mountain
Mendocino

Rabbit Foot Fire, ID



Emission Fluxes from CU SOF



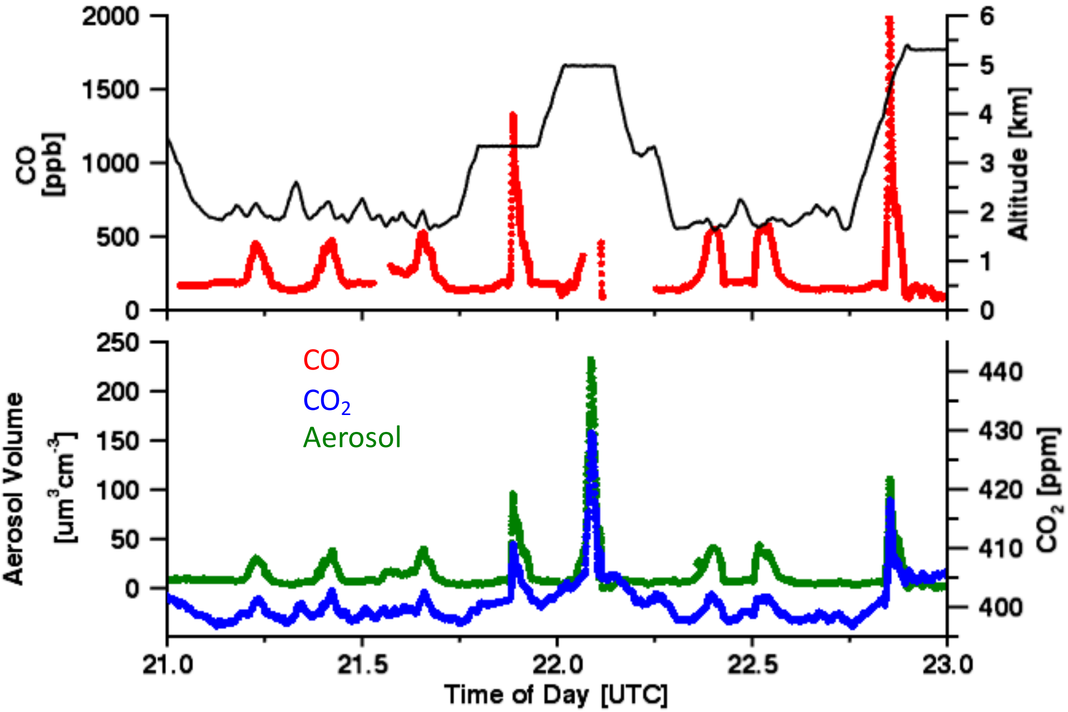
$$Flux = \int_S \Delta VCD \; \vec{n} \cdot \vec{F} \, ds$$

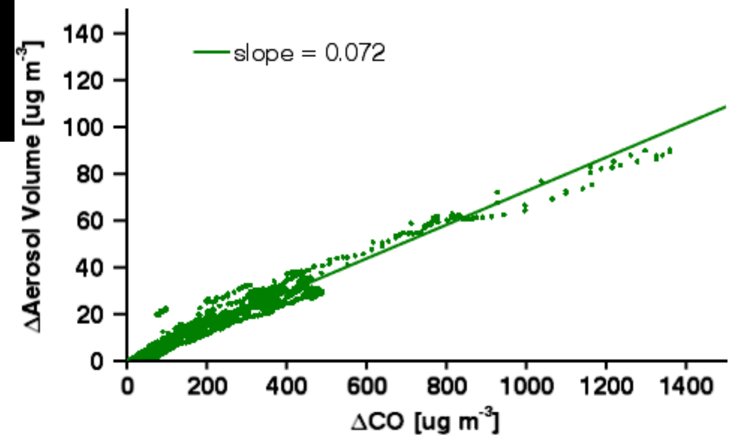
$\Delta VCD = VCD - VCD_{BKG}$

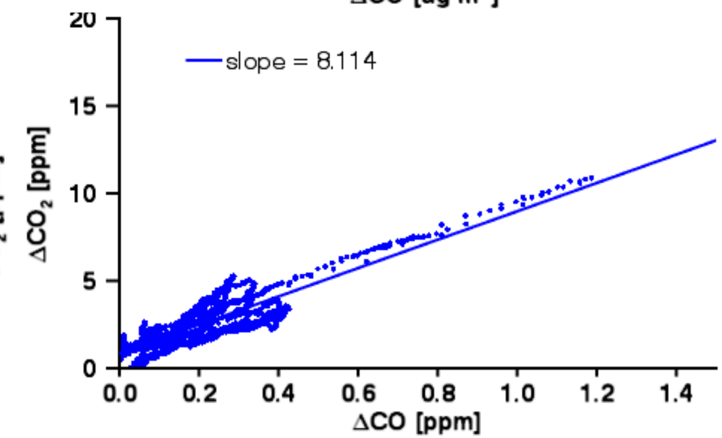
$\vec{F}$ = wind $\vec{n}$ = normal to flight direction

	1	2	3	4	5
CO [t/hr]	382 - 409	476 - 508	663 - 709	749 - 800	622 – 665
NH_3 [t/hr]	2.8 - 3.0	3.3 - 3.6	4.4 - 4.8	4.8 - 5.1	4.2 - 4.5

Total Carbon Fluxes







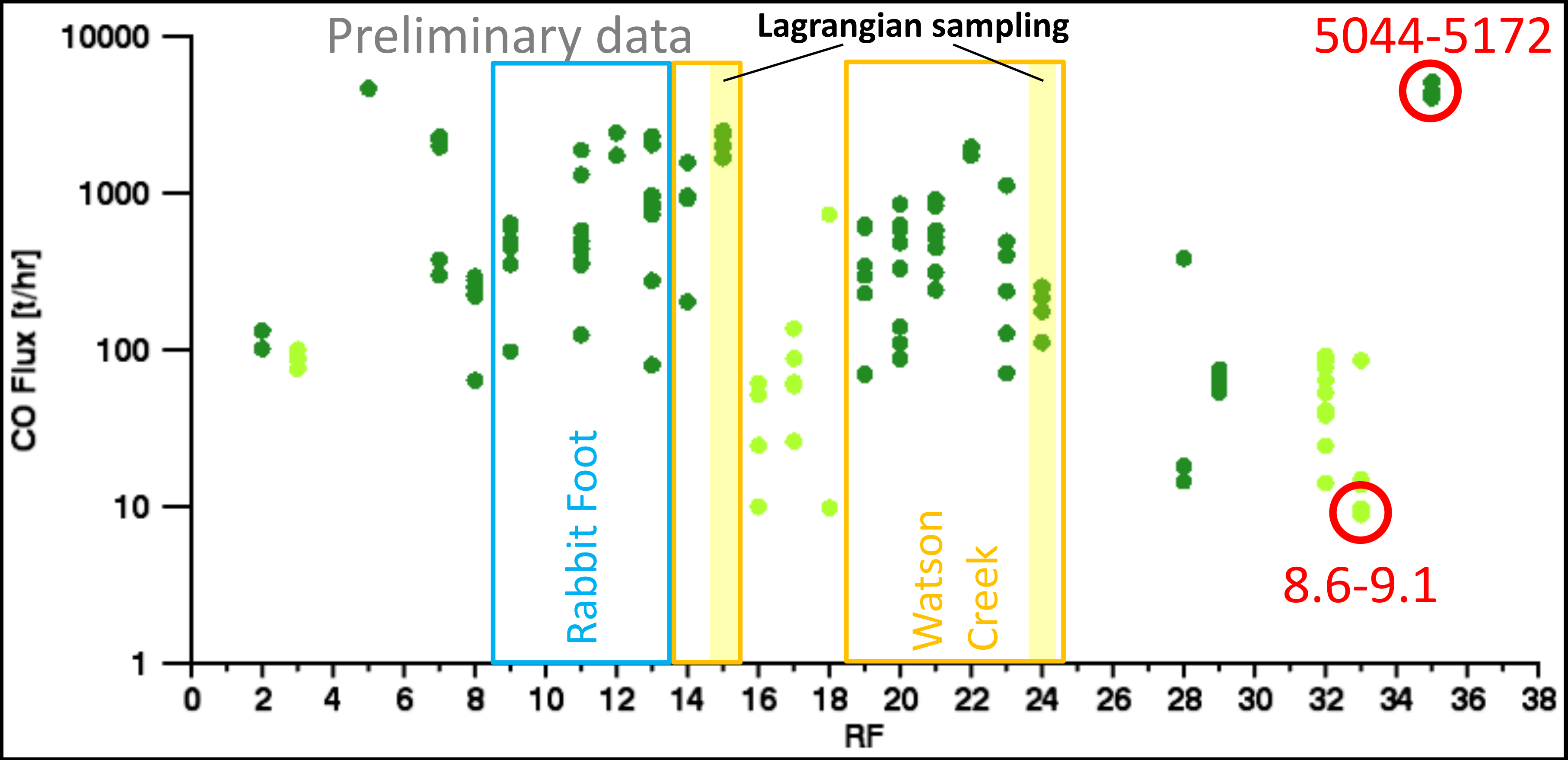
$$Flux(Z) = ER_{w/w}(Z) \cdot CO\ Flux$$

$$ER_{w/w}(Z) = \frac{\Delta Z}{\Delta CO}$$

Z = CO_2, …

	1	2	3	4	5
CO [t/hr]	382 - 409	476 - 508	663 - 709	749 - 800	622 - 665
CO_2 [t/hr]	3100 - 3319	3862 - 4122	5380 - 5753	6077 - 6491	5047 - 5396
Aerosol[1] [t/hr]	28 - 29	34 - 37	48 - 51	54 - 58	45 - 48

SOF perspective of BB-FLUX

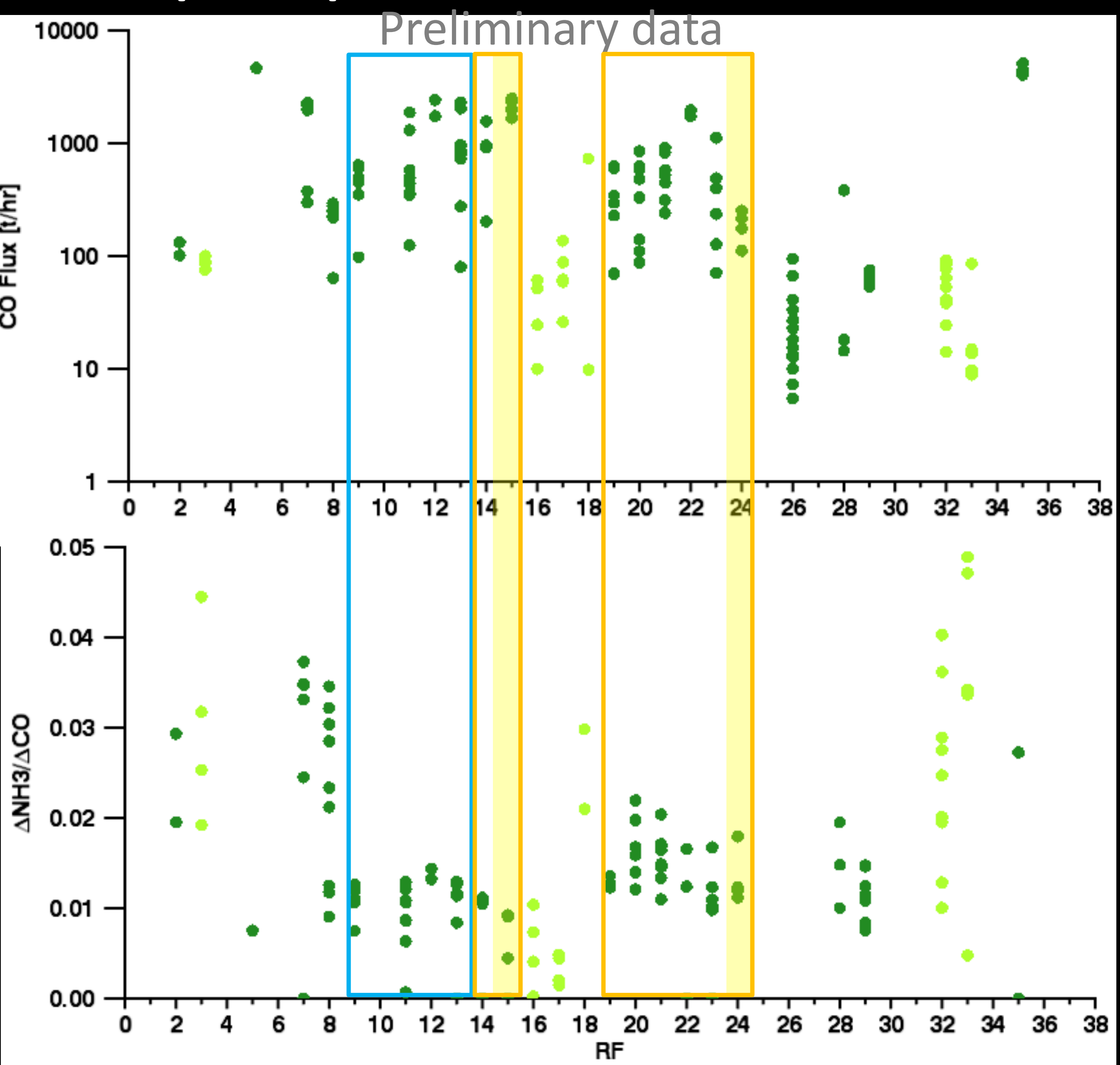


Primary fuel type

- grass
- tree

SOF captures fluxes in large dynamic range

SOF perspective of BB-FLUX



Primary fuel type

- grass
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Conclusions

- Airborne SOF is a new tool to quantitatively evaluate fire emissions
  - Measured CO fluxes from 8.6 to 5200 t/hr
- Synergistic application of SOF and ERs (in situ or column) is powerful to quantify and speciate trace gas and aerosol fluxes
  - Total carbon flux dominated by CO_2 and CO, smaller contributions from aerosol and VOCs
- SOF observed $\Delta NH_3/\Delta CO$ <0.01 to 0.05
- Outlook:
  - Develop new SOF retrievals
  - Characterize time evolution of emission fluxes and ratios

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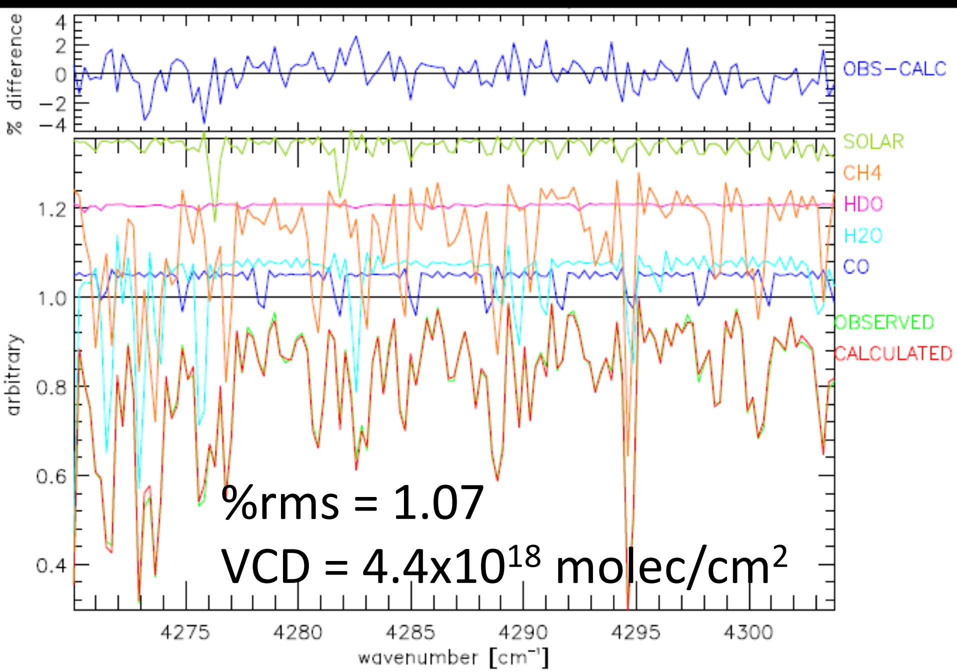
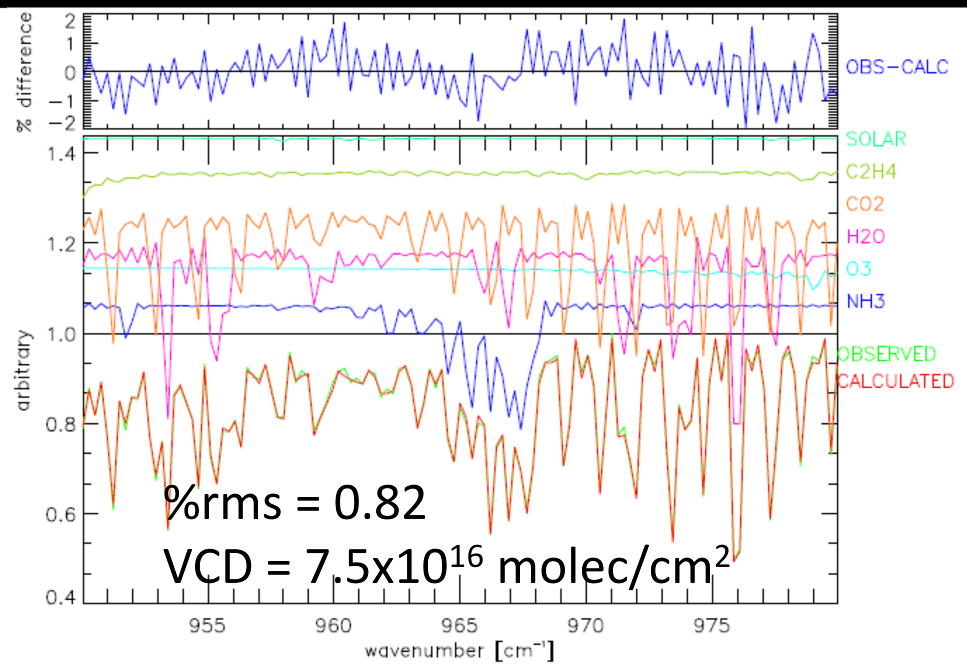
NSF AGS 1754019

Retrieval windows

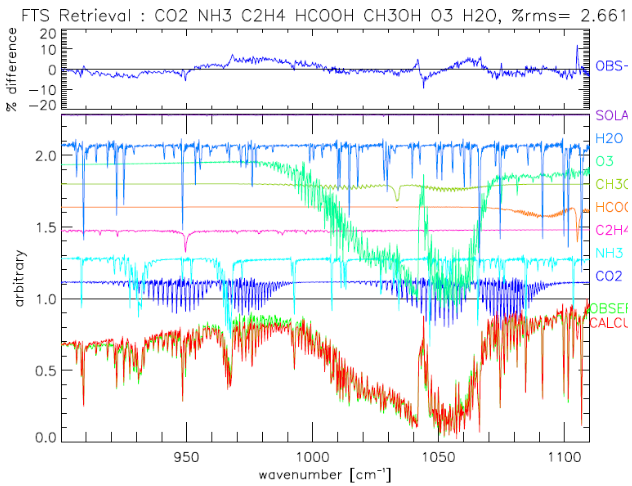
CO



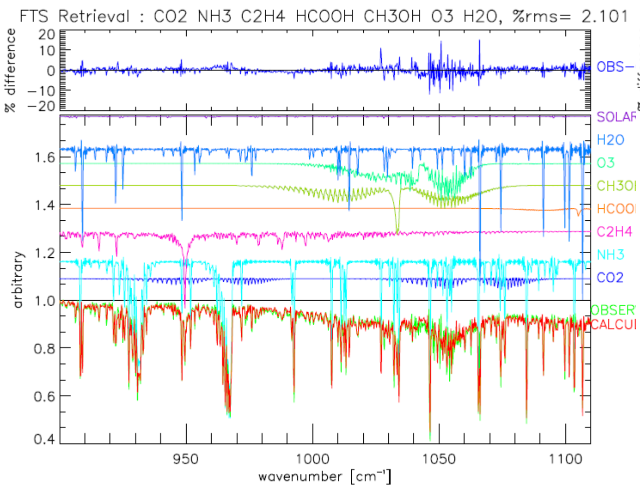
NH_3



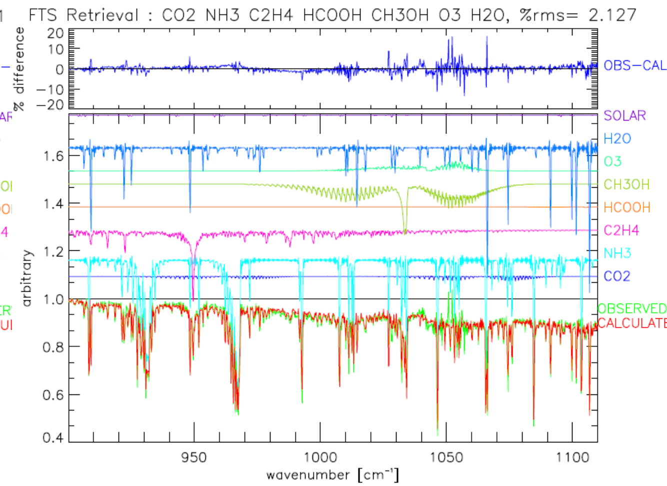
2sec in plume spectrum



(2sec in plume)/(2sec outside)



(16sec in plume)/(16sec outside)



Running retrieval as usual.

Comparison:

	2 se spec	Ratio	Avg, ratio
Iterations	7	25	28
CO_2 [x10^{21} molec/cm^2]	5.7	0.5	0.2
O_3 [x10^{18} molec/cm^2]	9.0	0.1	Negative (-0.3)
H_2O [x10^{22} molec/cm^2]	2.0	0.6	0.6
CH_3OH [x10^{16} molec/cm^2]	6.2	11.2	11.7