FIREChem

Fire Impacts on Regional Emissions and Chemistry

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https://espo.nasa.gov/FIREChem_White_Paper

FIREChem Timeline

1 February 2017 – White Paper Complete

14 February 2017 – Solicitation for Proposals Released

15 June 2017 – Proposals Due

September 2017 – Proposal Selections Announced

Note: The white paper defines the scientific scope of FIREChem needed to enable science team selection and definition of the scientific payload. Deployment details and sampling strategies, however, remain flexible in response to new information and the realities of conditions encountered during the deployment.

Dates: 25 July – 15 September 2019

Location: Salina, KS

Research Platform: NASA DC-8

FIREChem Objectives

FIREChem flights will contribute to the planned interagency collaboration in three areas:

1 – Sampling of wildfires in coordination with interagency partners to combine near and far-field observations to understand chemical evolution and transport and evaluate downwind impacts.

Accomplishing this goal requires heavy coordination of flights with NOAA along with input and advice from the Joint Fire Science Program. This goal takes priority when wildfires of sufficient size and regional impact are active.

2 – Sampling of small fires to build statistics on emission factors and fuels, plume rise, satellite detectability, and integrated impacts.

Accomplishing this goal requires liaison with state and local authorities to anticipate when and where to expect burning.

3 – Sampling of prescribed burns in coordination with FASMEE

This objective provides the best chance for bridging laboratory and ambient conditions and takes priority when burns are announced.

FIREChem Science Questions

1) What are the emissions of gases, aerosols, aerosol precursors, and greenhouse gases from North American fires? How variable are these emissions due to fuel and fire conditions?

2) How does the composition of fire plumes change as primary species are converted to secondary gas and aerosol tracers?

3) How is local air quality impacted by fires in the continental United States? How well do air quality models capture such impacts?

4) What are the regional impacts of North American fires?

5) What are the climate-relevant properties of biomass burning aerosols? What role do brown carbon and coatings on black carbon particles play in the optical properties? What is the composition of PM2.5?

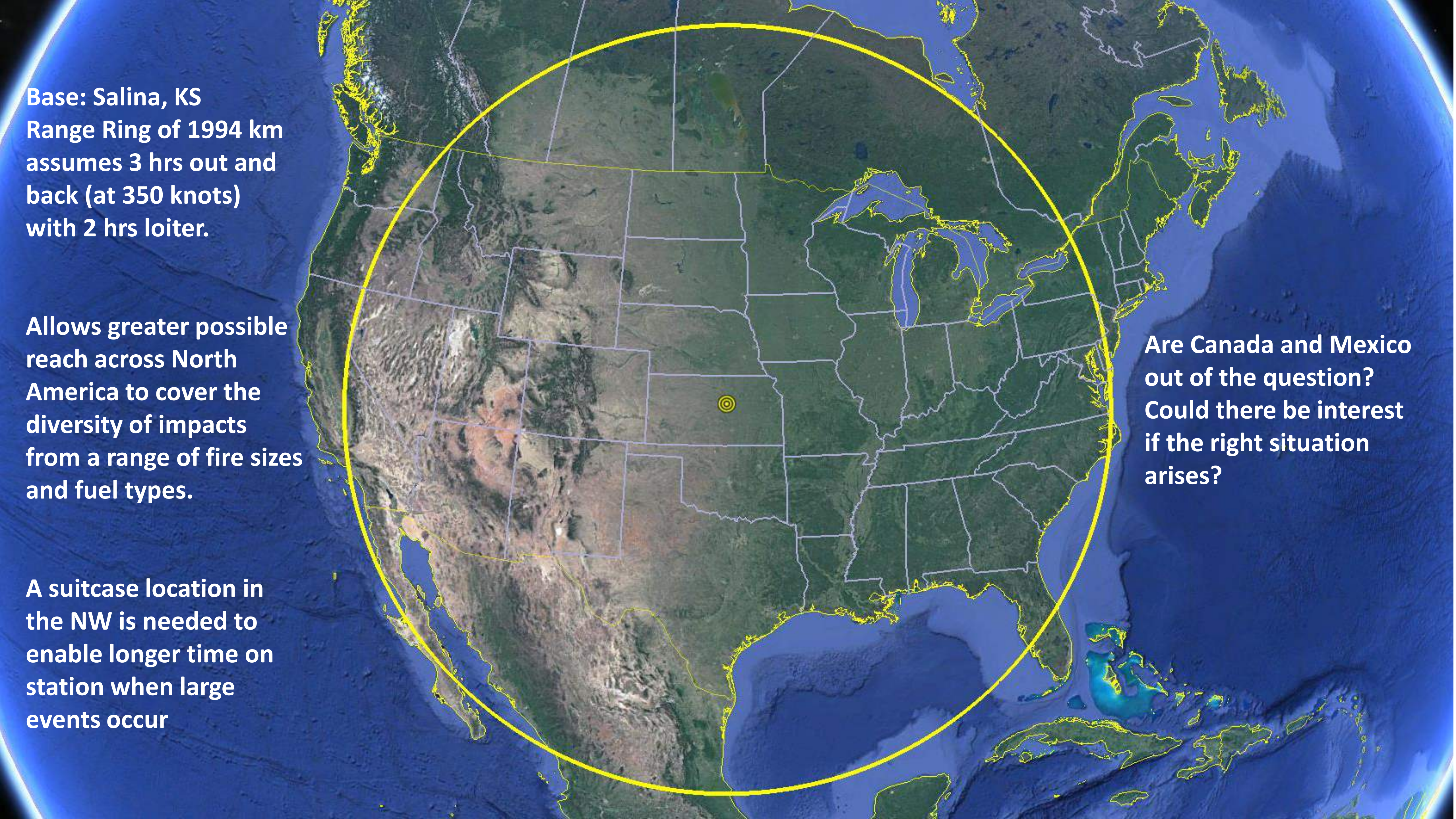
6) How can satellite measurements help with #1-5? And how can we obtain better satellite estimates of plume height, fire intensity, and fire radiative power?

DC-8 Measurement Priorities

Gas Phase In Situ	Priority	Detection Limit	Required Resolution	Desired Resolution
O3	1	1 ppbv	1 s	5 Hz
H2O	1	10 ppmv	1 s	5 Hz
CO	1	5 ppbv	1 s	5 Hz
CH4	1	10 ppbv	1 s	5 Hz
C2H6	1	50 pptv	1 s	5 Hz
CO2	1	0.1 ppm	1 s	5 Hz
NMHCs	1	<10%	1 min	5 Hz
NO	1	10 pptv	1 s	5 Hz
NO2	1	20 pptv	1 s	5 Hz
HCHO	1	50 pptv	1 s	5 Hz
CH3CN	1	10 pptv	1 s	5 Hz
HCN	2	10 pptv	1 s	-
NH3	2	30 pptv	1 s	-
HONO	2	50 pptv	1 s	-
Organic Acids	2	10 pptv	10 s	1 s
H2O2	2	50 pptv	10 s	1 s
ROOH	2	50 pptv	10 s	1 s
NOy	2	50 pptv	1 s	5 Hz
HNO3	2	50 pptv	10 s	1 s
PANs	2	50 pptv	10 s	1 s
RONO2	2	50 pptv	10 s	1 s
SO2	2	10 pptv	1 s	-
OH reactivity	2	1 s^{-1}	10 s	1 s
OH, HO2, RO2	2	0.01/0.1/0.1 pptv	30 s	1 s
Halocarbons	3	variable	1 min	-
N2O	3	1 ppbv	1 s	-

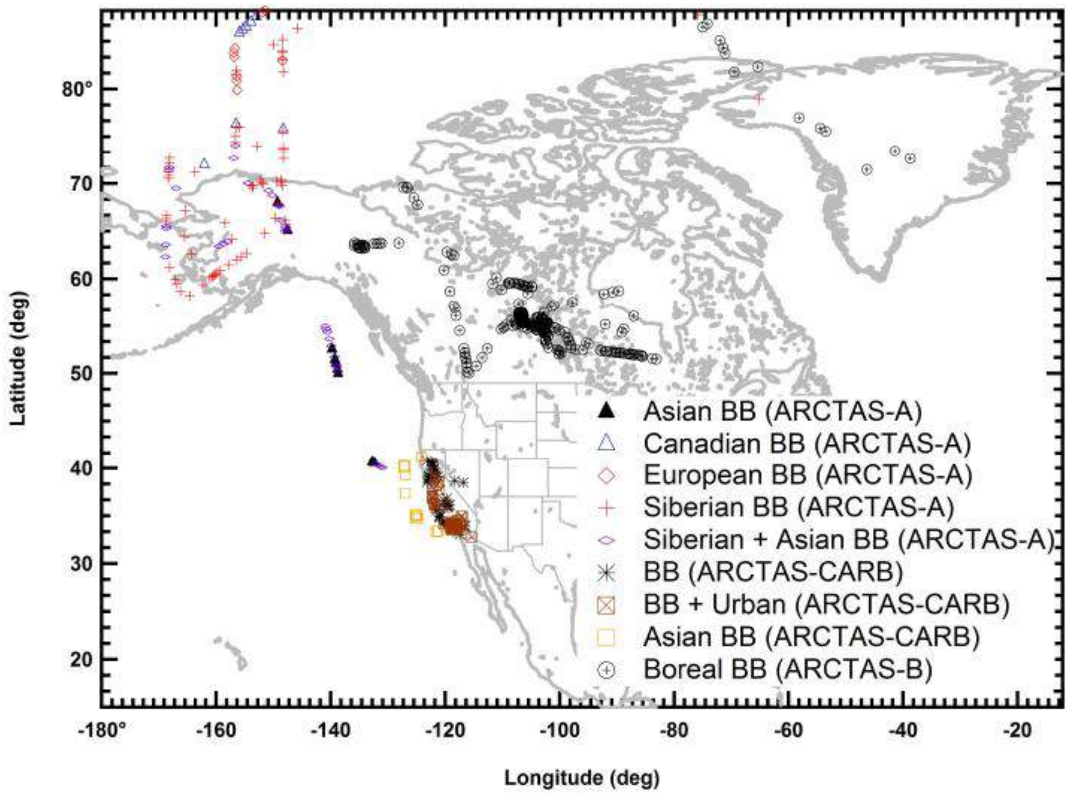
Aerosol In Situ	Priority	Detection Limit	Required Resolution	Desired Resolution
Particle Number	1	NA	1 s	5 Hz
Size Distribution (10 nm – 5 µm)	1	NA	10 s	1 s
Volatility	1	NA	1 s	5 Hz
Scattering	1	1 Mm-1	1 s	-
Scattering Phase Function	1	3 Mm-1	5 s	-
Hygroscopicity	1	NA	10 s	1 s
Absorption	1	0.2 Mm-1	10 s	-
Brown Carbon Absorption	1	1 Mm-1	per plume	30 s
Size-resolved composition	2	100 ng m^{-3}	1 s	-
Organic mass	1	100 ng m^{-3}	10 s	1 s
Black carbon	1	50 ng m^{-3}	1 s	5 Hz
Bulk Composition	2	50 ng m^{-3}	per plume	-
Single particle composition	2	<4 µm dia.	1 s	-
CCN/IN	2	<4 µm dia.	1 s	-
Cloud particle size dist.	2	0.05-1000 µm	1 s	-

Remote Sensing, Radiation, and Met	Priority	Detection Limit	Resolution
Aerosol profiles of extinction	1	10 Mm^{-1} or 10%	300 m
Aerosol profiles of backscatter	1	3%	30 m
Aerosol profiles of depolarization	1	3%	30 m
High Resolution Met (T, P, winds)	1	0.3K, 0.3 mb, 1 ms^{-1}	10 Hz
UV spectral actinic flux (4π sr)	1	80° SZA equivalent	1 s
Surface IR Imaging (FRP)	2	-	-
Ozone lidar (nadir/zenith)	2	5 ppbv or 10%	300 m
Trace Gas Columns (O_3, NO_2, C_2HO)	2	variable	Variable
Multi-spectral optical depth	3	0.01	1 s


Base: Salina, KS
Range Ring of 1994 km assumes 3 hrs out and back (at 350 knots) with 2 hrs loiter.
Allows greater possible reach across North America to cover the diversity of impacts from a range of fire sizes and fuel types.
A suitcase location in the NW is needed to enable longer time on station when large events occur
Are Canada and Mexico out of the question? Could there be interest if the right situation arises?

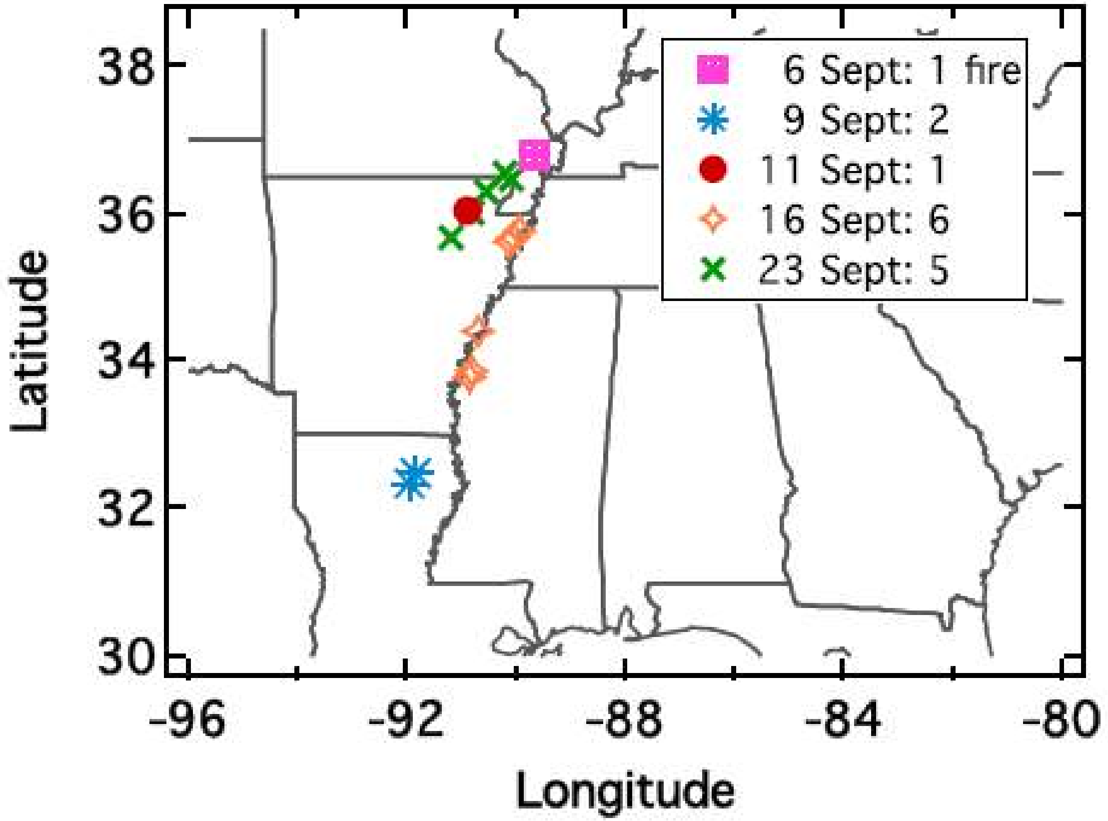
FIREChem challenges us to sample differently.

Hecobian et al., ACP, 2011



495 detections of fire influence

Liu et al., JGR, 2011



15 targeted samples of small fire emissions

Source	SEAC^{4}RS Liu et al.	Stockwell et al. [2015]	Akagi et al. [2011]	Kudo et al. [2014]	Hayashi et al. [2014]	
Crop type	SE U.S. rice straw	Asian rice straw	Unidentified crop residue in Mexico	Chinese wheat	Japanese rice straw	
Approach	Airborne study	Lab study	Airborne study	Ground study	Lab studies	
Moisture content (%)	-	-	-	-	10.6	20.0
MCE	0.930	0.930	0.925	0.930	0.949	0.910
CO_2	1339 (26)	-	1664 (66)	1598 (5)	803 (65)	946 (49)
CO	64.46 (16.57)	-	85.6 (34)	77.2 (6.9)	27.2 (1.7)	59.4 (0.7)
NO	0.251 (0.211)	1.86 (0.28)	2.06 (0.79)	-	-	-
NO_2	2.02 (0.80)	1.70 (0.25)	3.48 (2.11)	-	-	-
NOx as NO	1.58 (0.63)	2.97 (0.32)	3.64 (1.13)	-	-	-
NH_3	-	1.12 (0.77)	1.76 (1.35)	-	0.059 (0.045)	0.025 (0.020)
HCl	0.0181 (0.0144)	0.458 (0.308)	-	-	0.062 (0.003)	0.022 (0.006)
SO_2	0.795 (0.377)	1.22 (0.34)	-	-	-	-
HCN	0.610 (0.479)	0.399 (0.160)	0.16 (0.30)	-	-	-
HCHO	2.63 (1.05)	1.29 (0.61)	1.85 (0.92)	1.07	-	-
CH_3OH	1.41 (1.38)	1.48 (1.56)	2.67 (1.58)	2.94	-	-
Hydroxyacetone	2.06 (0.89)	1.33 (1.47)	-	-	-	-
CH_3CN	0.169 (0.123)	0.230 (0.092)	-	0.20 (0.03)	-	-
Acetaldehyde	1.37 (0.80)	2.09 (1.46)	-	1.02	-	-
Acetone	0.638 (0.417)	0.989 (0.532)	-	0.83	-	-
MVK + MACR	0.449 (0.305)	0.489 (0.398)	-	0.43 (0.02)	-	-
Isoprene	0.411 (0.282)	0.203 (0.104)	-	0.52 (0.01)	-	-
Furan	-	0.325 (0.496)	-	-	-	-
HPALDs	0.406 (0.229)	-	-	-	-	-
Benzene	0.275 (0.139)	0.302 (0.123)	-	0.53 (0.07)	-	-
Monoterpenes	0.258 (0.164)	-	-	-	-	-
Toluene	0.167 (0.091)	0.271 (0.138)	-	0.32	-	-
Ammonium	0.424 (0.261)	-	-	-	0.083 (0.020)	0.245 (0.092)
Nitrate	0.436 (0.337)	-	-	-	0.006 (0.002)	0.008 (0.000)
Chloride	1.07 (0.89)	-	-	-	0.30 (0.02)	0.69 (0.14)
Sulfate	0.160 (0.115)	-	-	-	0.027 (0.000)	0.063 (0.003)
OA	12.9 (6.3)	-	3.67	-	1.6	7.4
BC	0.163 (0.141)	-	0.75	-	-	-

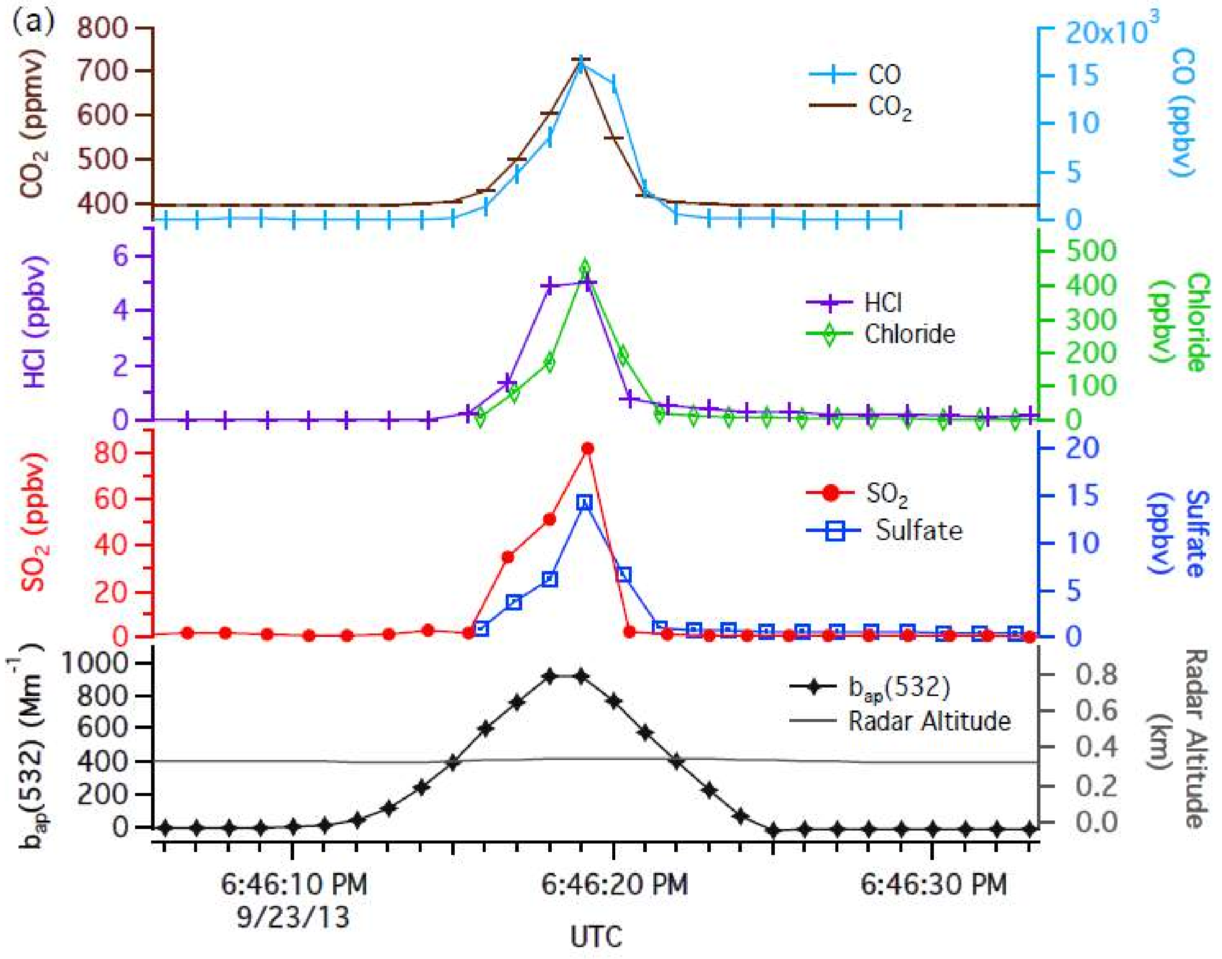
Table from the FIREChem white paper comparing literature estimates for emissions from crop residue fires.

We need to broadly sample fires to improve both the range of species for which emissions are measured as well as the statistical range of observed emissions

Colored values show that when compared to the SEAC4RS values, **BOTH** averages fall outside the uncertainties of the other **(RED)** or **ONE** of the averages fall outside the uncertainty bounds of the other **(ORANGE)**

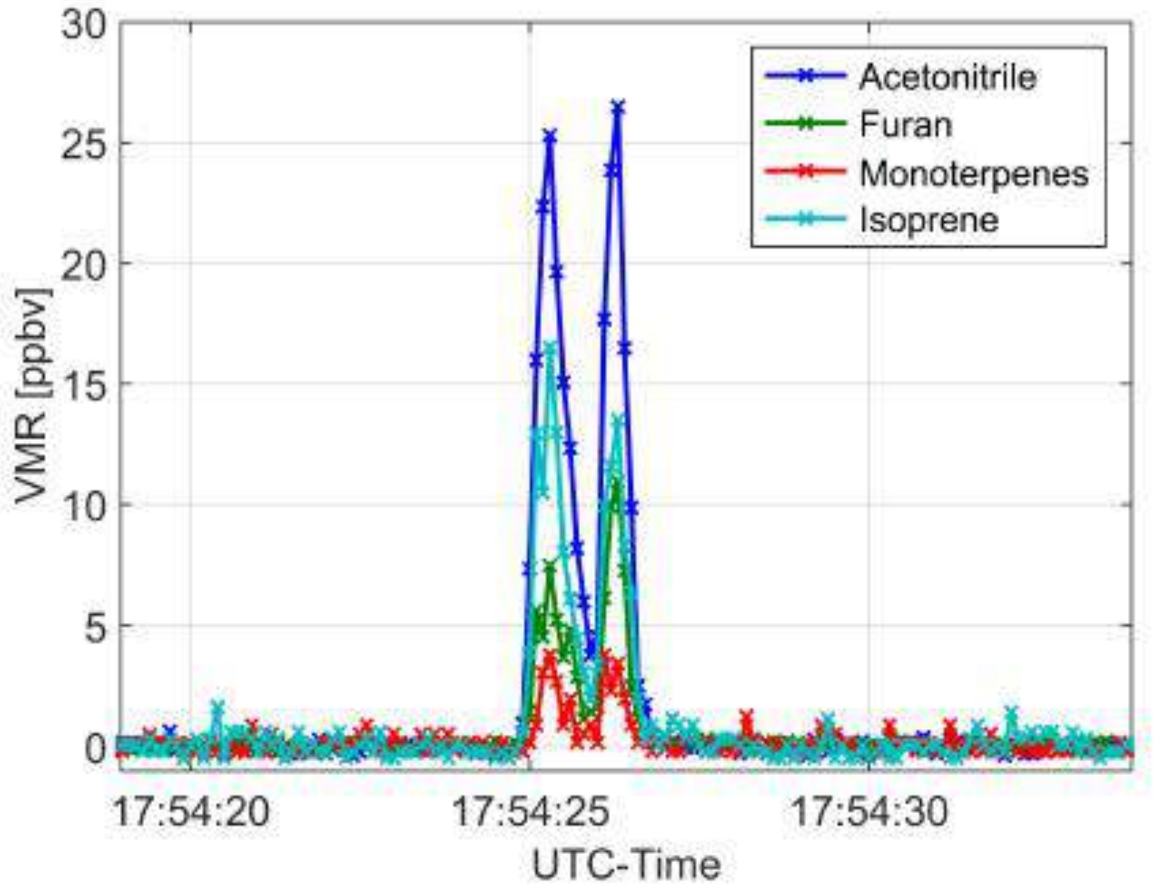
FIREChem challenges us to sample differently.

Liu et al., JGR, 2011



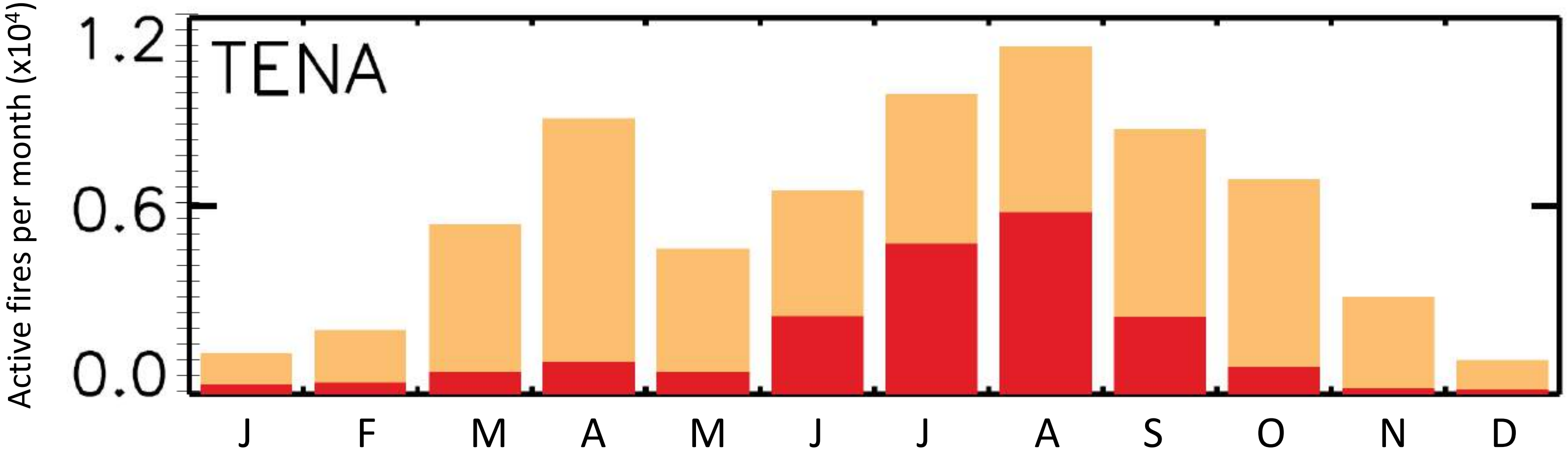
1 Hz sampling of small fire over 5 seconds

Muller et al., ACP, 2016



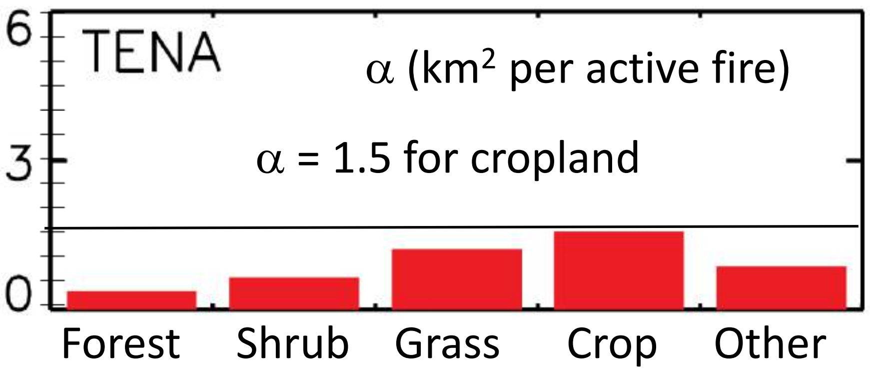
10 hz sampling of small fire over 2 seconds

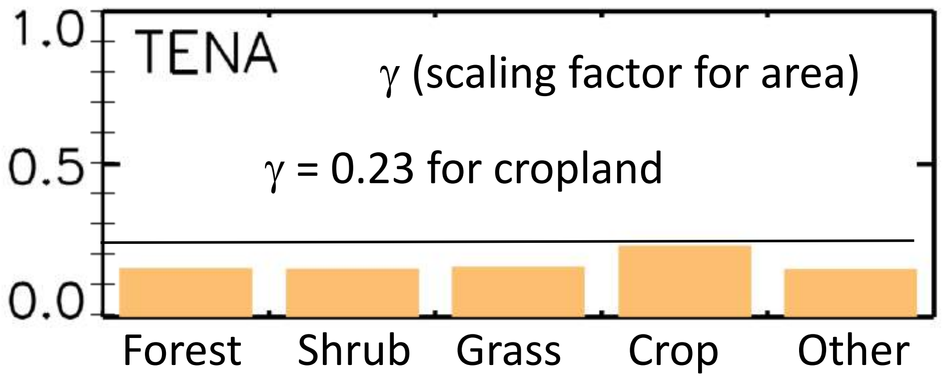
Randerson et al. 2012 suggest large underestimates in the contribution from small fires globally (TENA = CONUS)



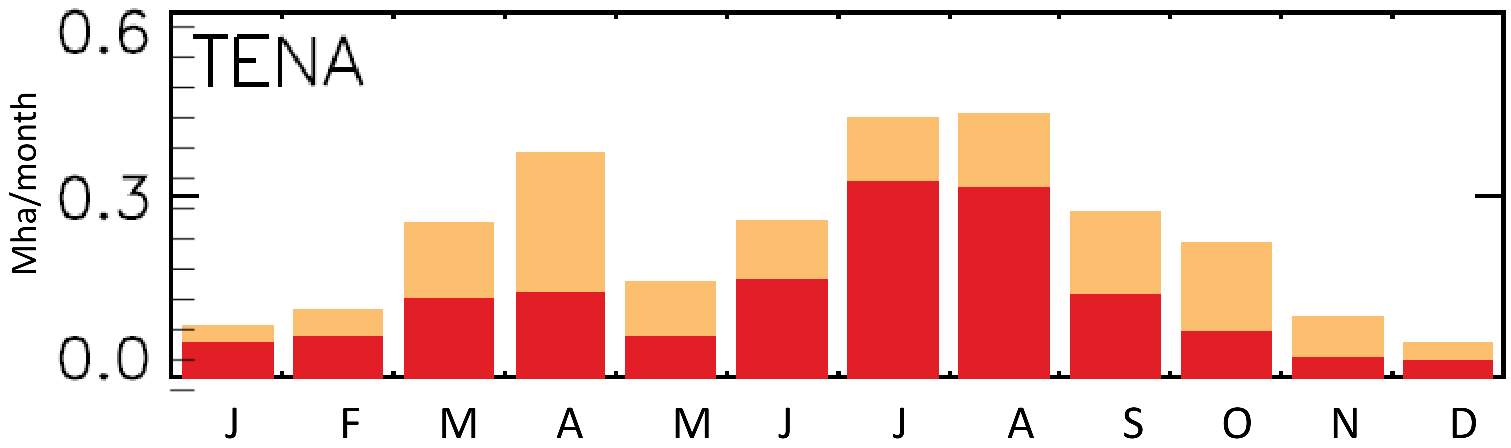
Red = active counts in burn scars
Orange = active counts outside burn scars

Annual counts found within burn scars is 30%, but closer to 50/50 during the planned FireChem period (Jul-Sep)



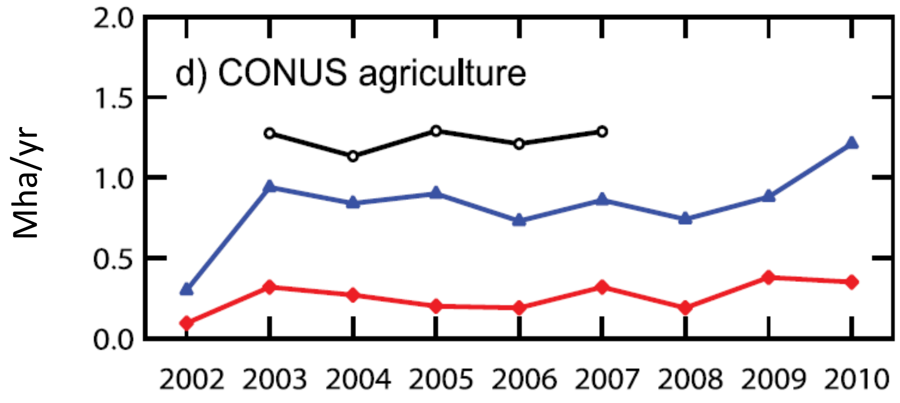


$\alpha\gamma = 1.5 \times 0.23 = 0.345$ km^2
-or- 34.5 ha

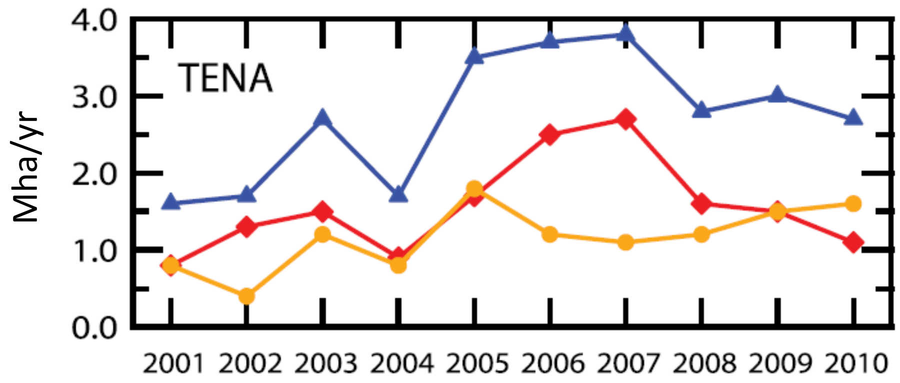


Red = area burned detected by burn scars
Orange = estimated area burned by small fires

Annual area burned by small fires is estimated at 43%, but less in July (24%) / August (28%) and more in September (48%)



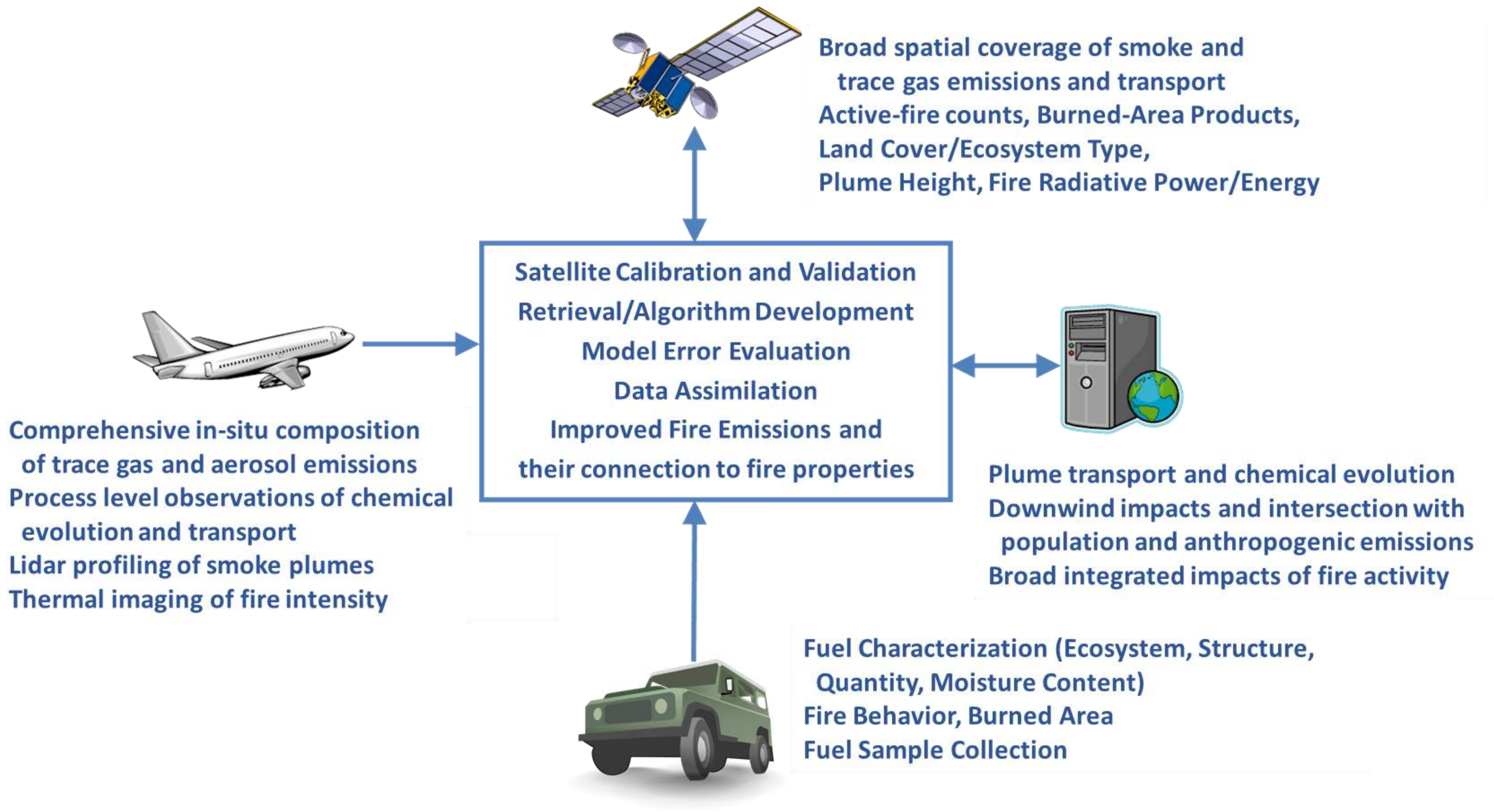
Regional observations (black)
MODIS + Small fires (blue)
MODIS burned area (red)



MODIS burned area (red)
Small Fires (orange)
Total (blue)

Randerson et al. 2012

FIREChem seeks to inform integrated observing strategies.



FIREChem Needs

1) Help with airspace coordination, especially for fires under active control. Obtaining permission, developing a plan for aircraft separation, etc.

2) Connection to ground conditions. Gathering information on what was burning, fuel loading, duration, etc.

3) Prediction of small fire activity. Are there organized plans for burning? When are fires expected to start? Where are conditions conducive to burning? Can GOES provide guidance or updates on burning progress?

4) Advice on selection of fires to target. Which fire is likely to yield more information. Is it in an area that is well characterized? Is it likely to persist?