Fuel2Fire, Enhancing Wildland Fire Emissions Estimates: The devil is in the detail and defined by the purpose of the emission estimates

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See **Emily Gargulinski** next ***Global Carbon Consumption for Wildland Fire***

Fuel2Fire, Enhancing Wildland Fire Emissions Estimates

Our thinking is from the ground perspective, but with a focus on how we can bring the reality of fuels and emissions on the ground to larger-scale models and inventories using satellite data.

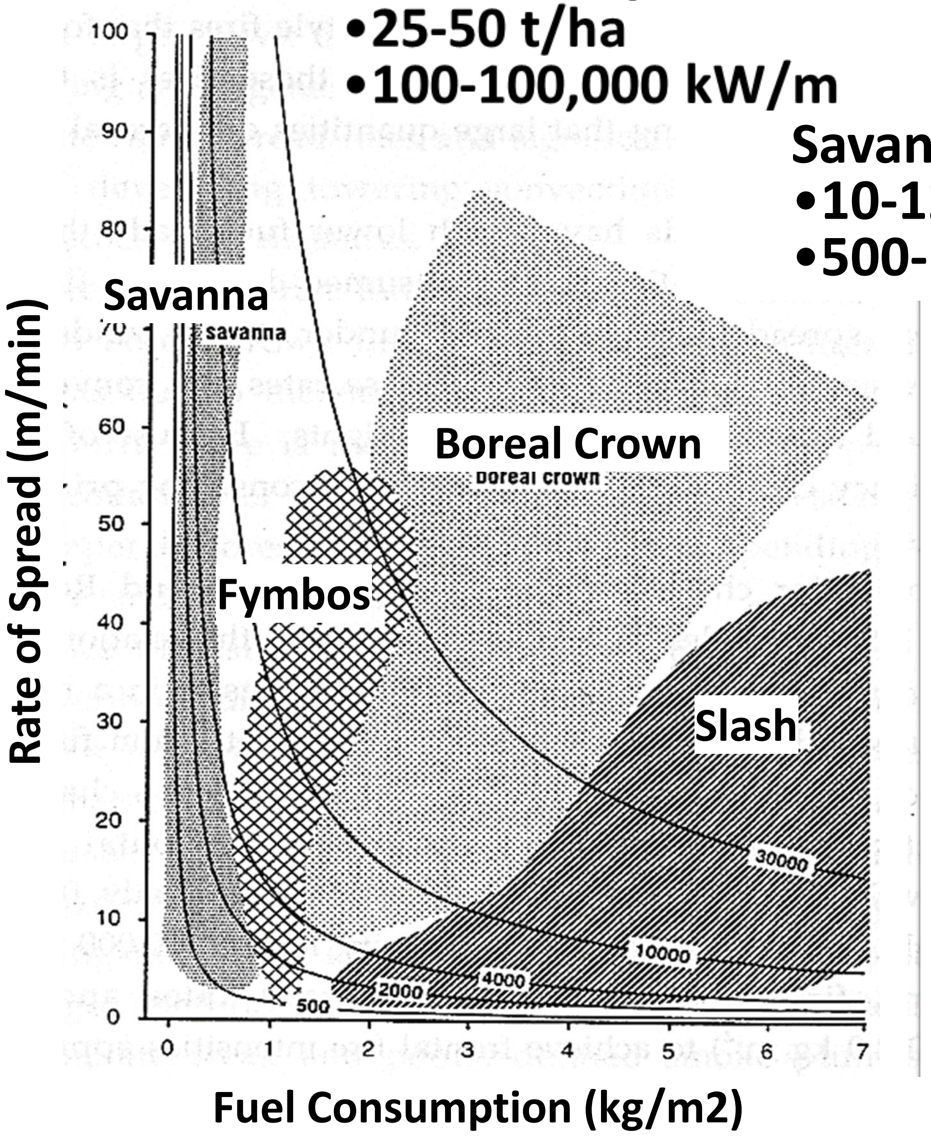
Focus of this talk: Investigate the parameters used to estimate wildland fire emissions to enhance these estimates.

1)	Fuel estimates (ground to satellite) for CONUS;	5
2)	GOES-derived diurnal fire cycle;	4
3)	Emissions comparisons;	1
4)	Validation using 2019 Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) data;	2
5)	Global fuel estimates (ground to satellite);	1
6)	Quantifying small fires from space.	3

Fuel Characteristics- Fire Intensity- Energy Release- Emissions

Boreal/Temperate Forest Fire:
- 25-50 t/ha
- 100-100,000 kW/m

Savanna Fire:
- 10-12 t/ha
- 500-10,000 kW/m



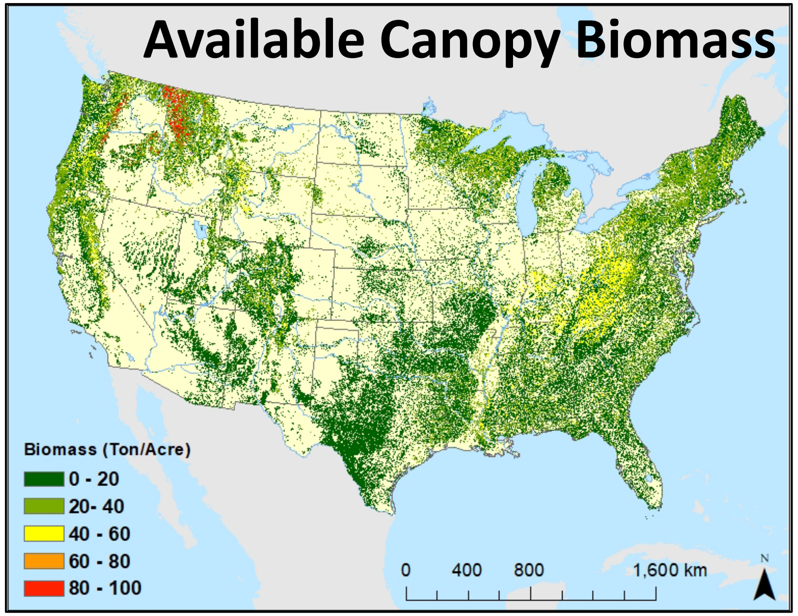
Driving force: Fire Weather & Available Fuel

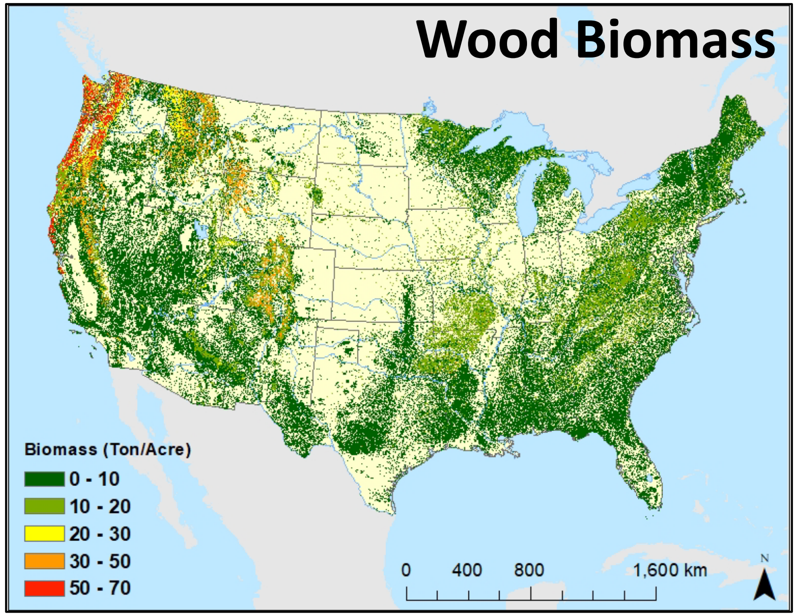
Fueled from below: Biomass – Fuel - Carbon

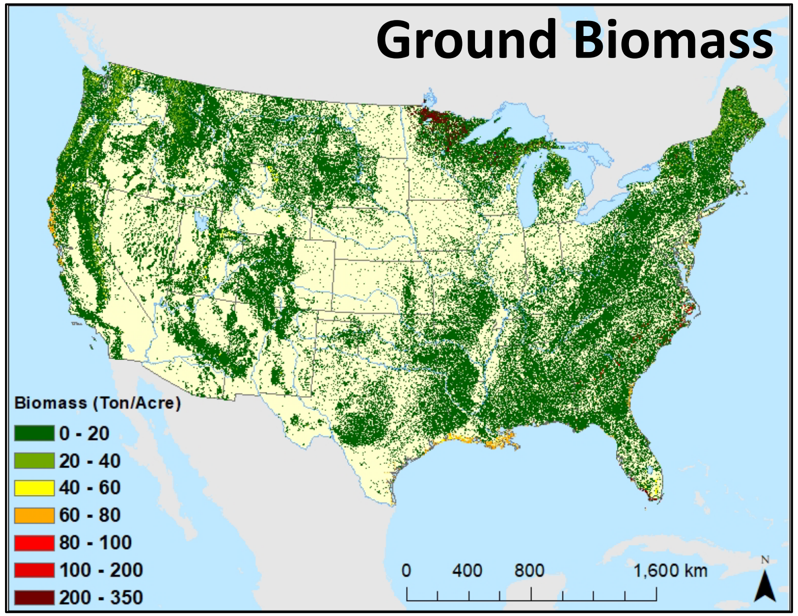
1

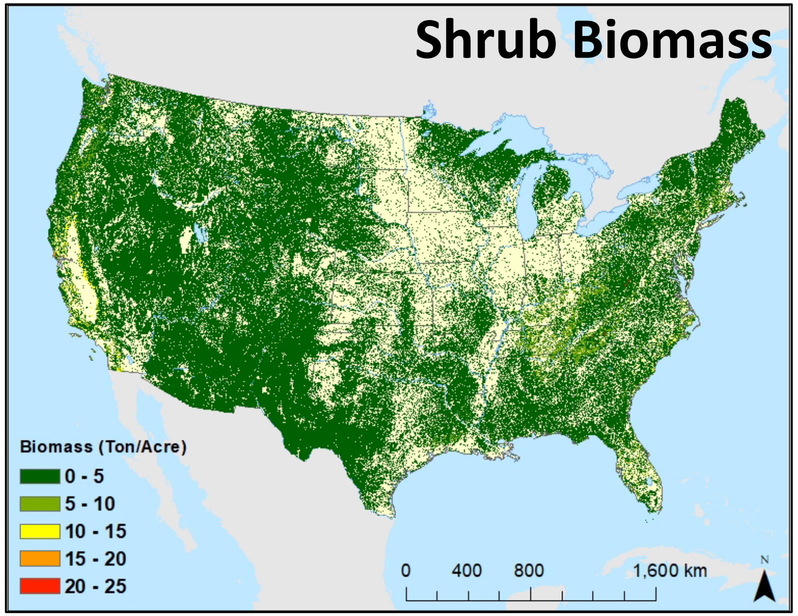
CONUS Fuel Characteristic Classification System (FCCS) Fuelbeds- 30 m

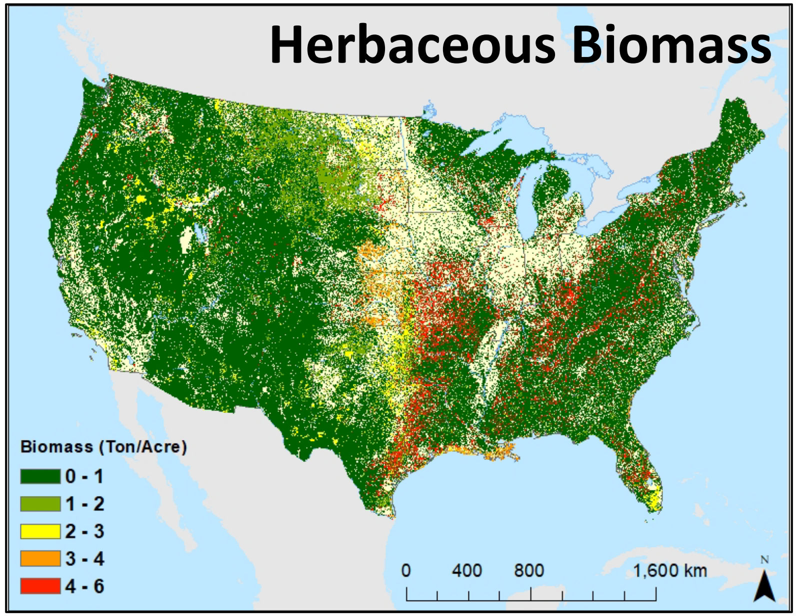
Over 250 Fuels!











Fuel Decision Table: Allocation of New:Residual

1

Percentage of Fuel Burned in each Fire Weather Category New (N) burned area / previously burned Residual (R) area					
Variable	**Extreme N/R**	**Very High N/R**	**High N/R**	**Moderate N/R**	**Low N/R**
Canopy_avai_load	90 / 5	80 / 5	60 / 5	10 / 0	0 / 0
Shrub_tpa_biomass	100 / 0	80 / 5	60 / 5	40 / 5	20 / 5
Herb_tpa_biomass	100 / 0	80 / 5	60 / 5	40 / 5	20 / 5
Wood_tpa_biomass	20 / 40	10 / 20	10 / 20	10 / 10	10 / 5
LLM_tpa_biomass	100 / 0	80 / 5	60 / 5	40 / 5	20 / 5
Ground_tpa_fuel	20 / 40	10 / 20	10 / 20	10 / 10	10 / 5

Total available fuel loading of canopy fuels, including tree crowns, C2 and C3 snags, and ladder fuels.

Does not include tree boles or C1 snag wood.

Total aboveground shrub and herbaceous biomass

Total combustible wood, including downed wood, rotten and lightered stumps, and piled wood.

Litter, lichen and moss biomass

Ground fuels including duff, basal accumulations and squirrel middens

Soja et al., 2004
Pierce et al., 2007
Petrenko et al., 2012

Fuel Decision Table: Flaming to Smoldering

1

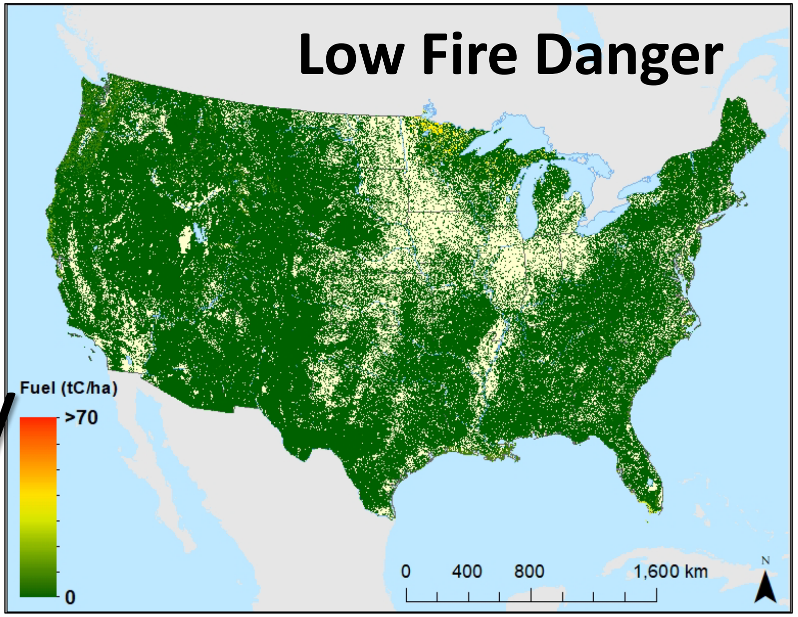
Of the FCCS fuel burned in the 'New' burned area and the 'Residual' previously burned area, these carbon fuels are partitioned by flaming and smoldering components, also in accordance with fire weather.

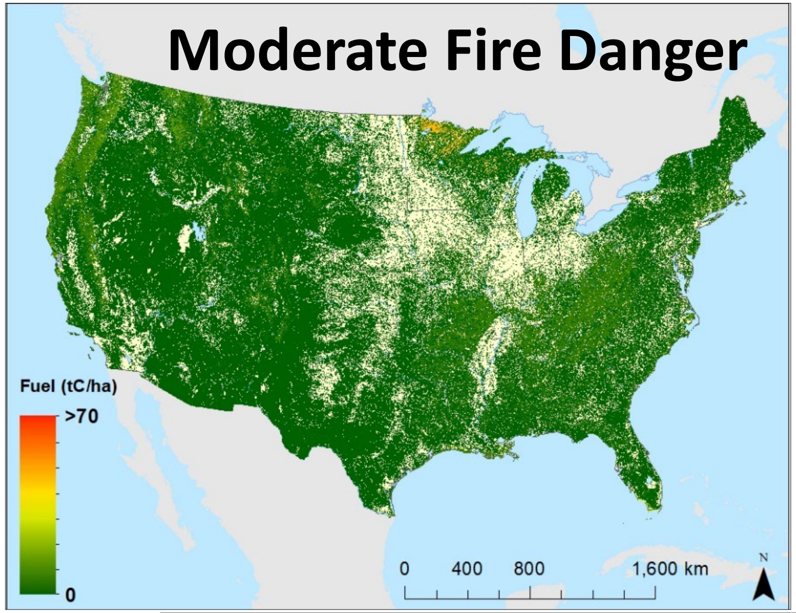
	Percentage of flaming/smoldering in each fire weather category				
	New (N) / Residual (R)				
	Extreme N / R	Very High N / R	High N / R	Moderate N / R	Low N / R
Flaming	90 / 20	80 / 5	70 / 5	60 / 0	50 / 0
Smoldering	10 / 80	20 / 95	30 / 95	40 / 100	50 / 100

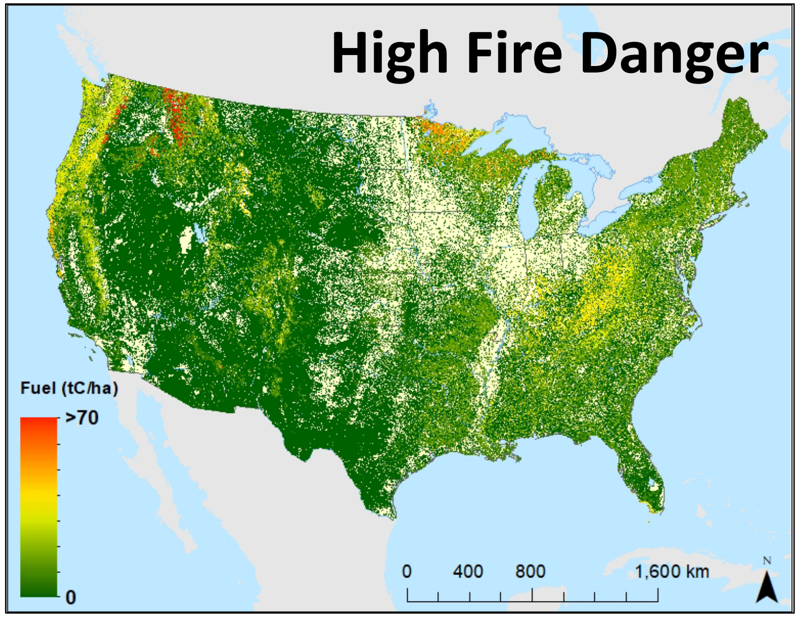
Fuel Available: One 1-km (30m) value/weather

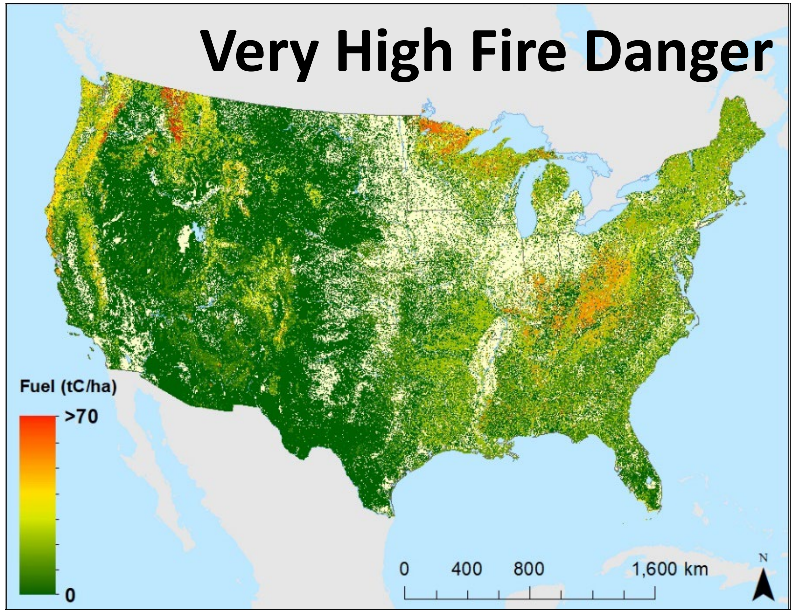
1

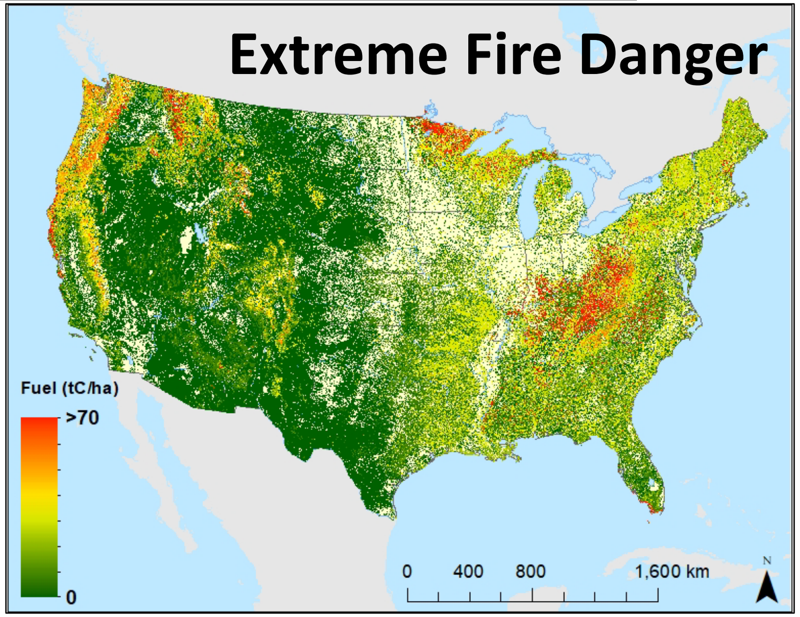
FCCS-based Fuel, per Fire-weather-based Fire Danger (severity of potential fire or Fire Radiative Power/ Energy, FRP/FRE?)





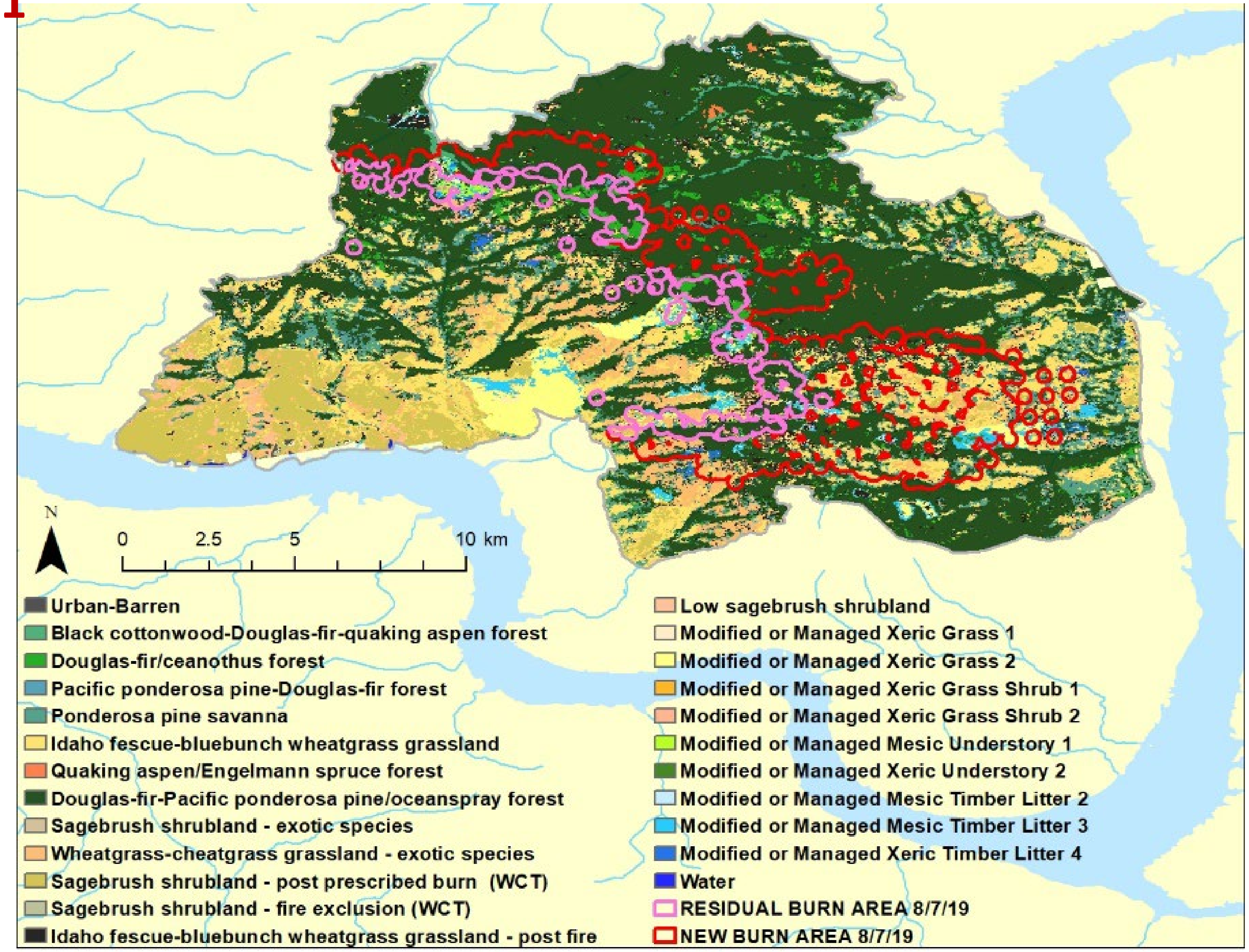






Fueled from below: FCCS Fuels and burned area

1



<u>Diversity of Ecosystems</u>

Williams Flats fire

August 7th 2019

FCCS 30 m fuels

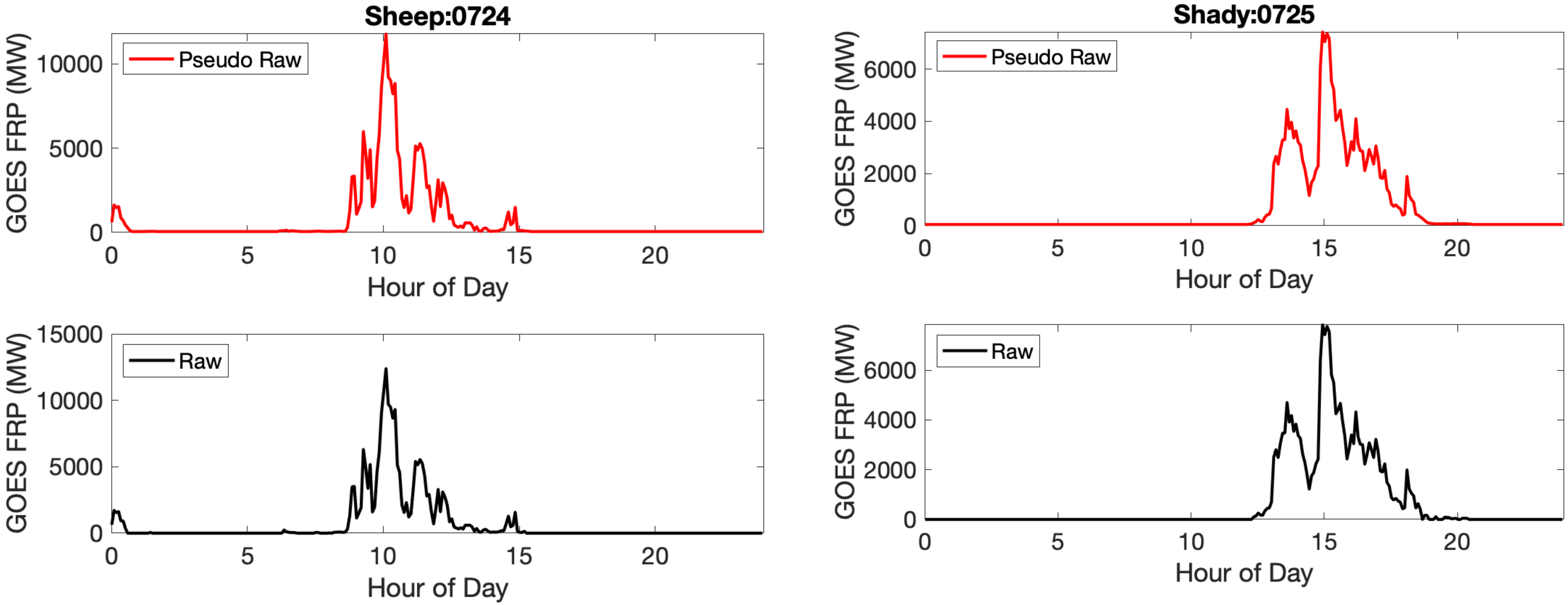
Burned area outlines

VIIRS 375m buffered area

New burned area
in red and
Residual or
previously burned areas
in pink-purple

Connecting Terrestrial and Atmospheric Systems: Value Added and Analyses of FIREX-AQ Data to Enhance Air Quality Modeling

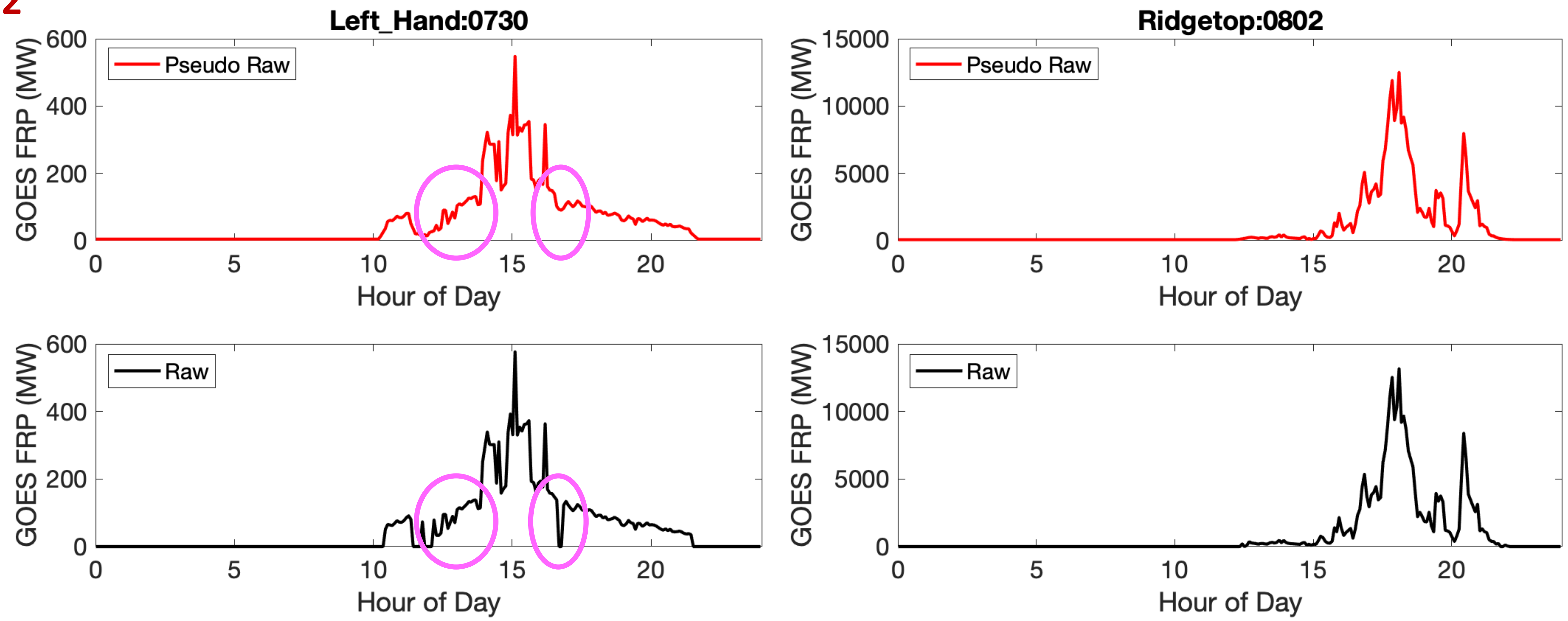
2



*** Note - the different times of day that fires in these two distinct ecosystem types, Sheep (shrubland) and Shady (understory), peak.**

Connecting Terrestrial and Atmospheric Systems: Value Added and Analyses of FIREX-AQ Data to Enhance Air Quality Modeling

2



*** Note - Unique diurnal patterns, with smoothed transitions.**

Connecting Terrestrial and Atmospheric Systems: Value Added and Analyses of FIREX-AQ Data to Enhance Air Quality Modeling

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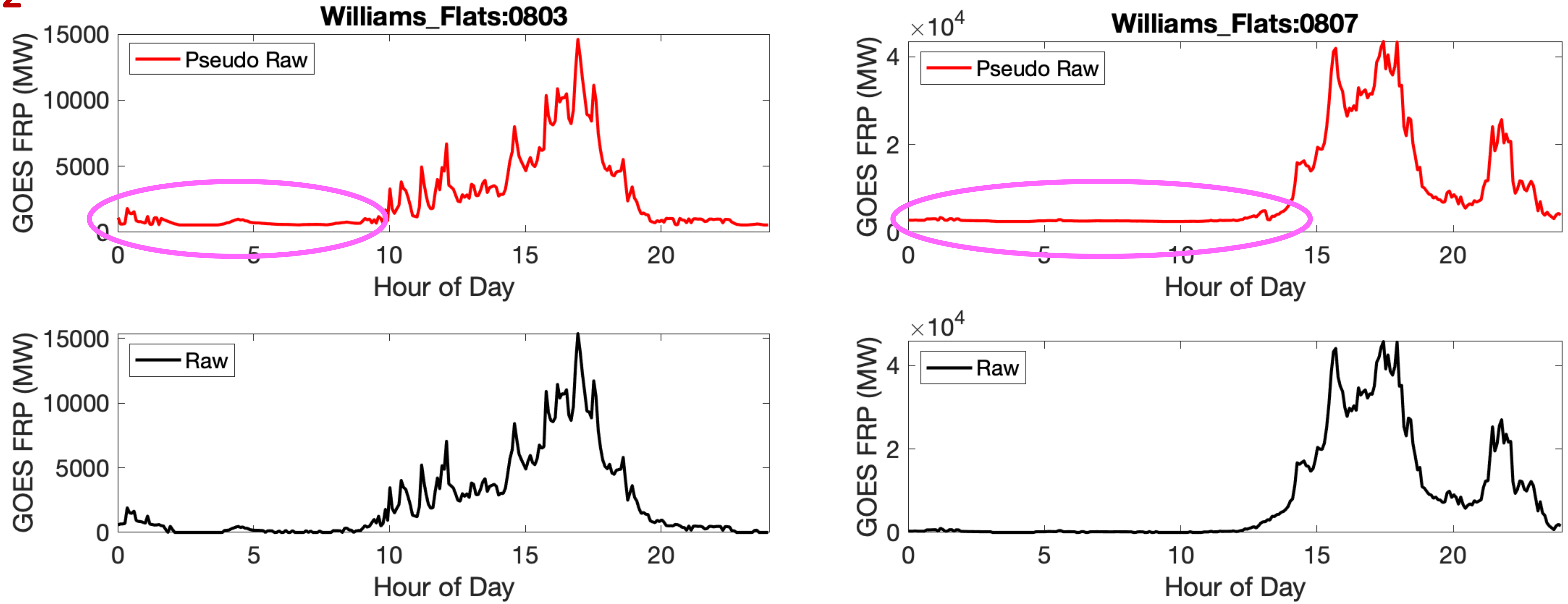
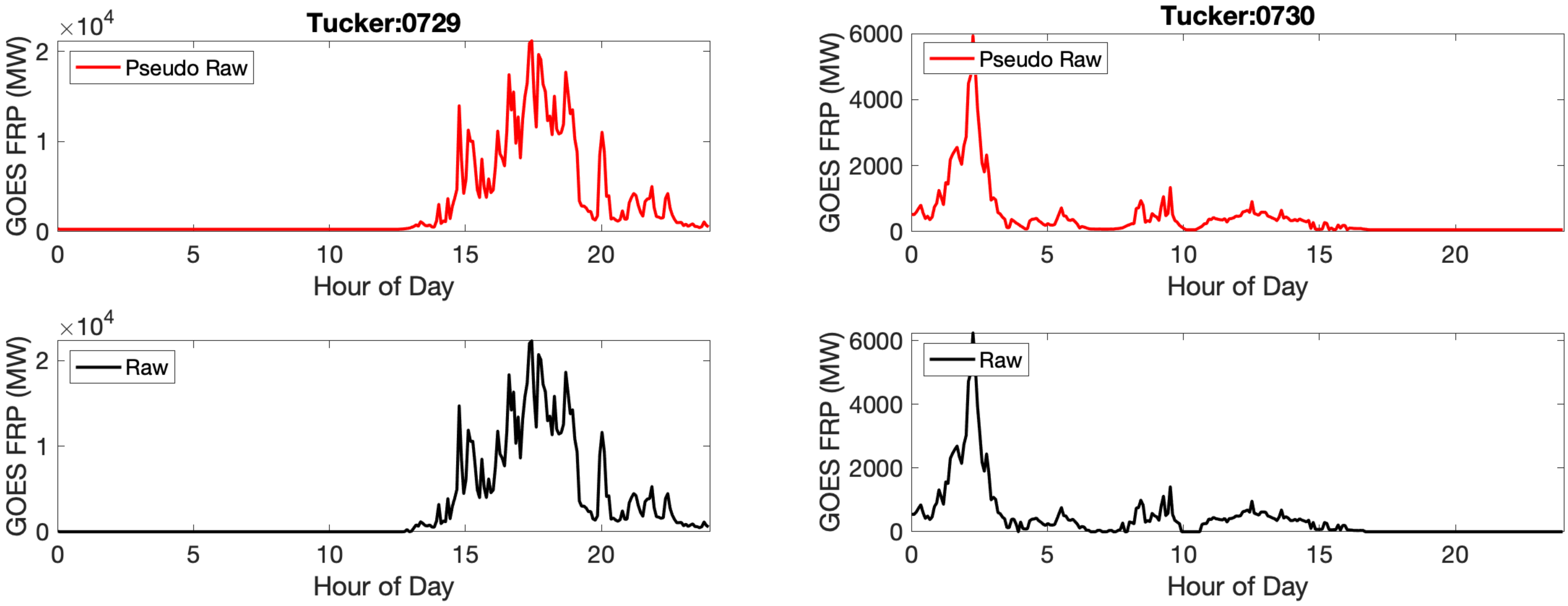


*** Note - Unique diurnal patterns of the same fire burning in unique ecosystem (3rd primarily grassland; 7th primarily forest) on different days. Here the nighttime smoldering is more evident in our smoothed transition.**

Connecting Terrestrial and Atmospheric Systems: Value Added and Analyses of FIREX-AQ Data to Enhance Air Quality Modeling

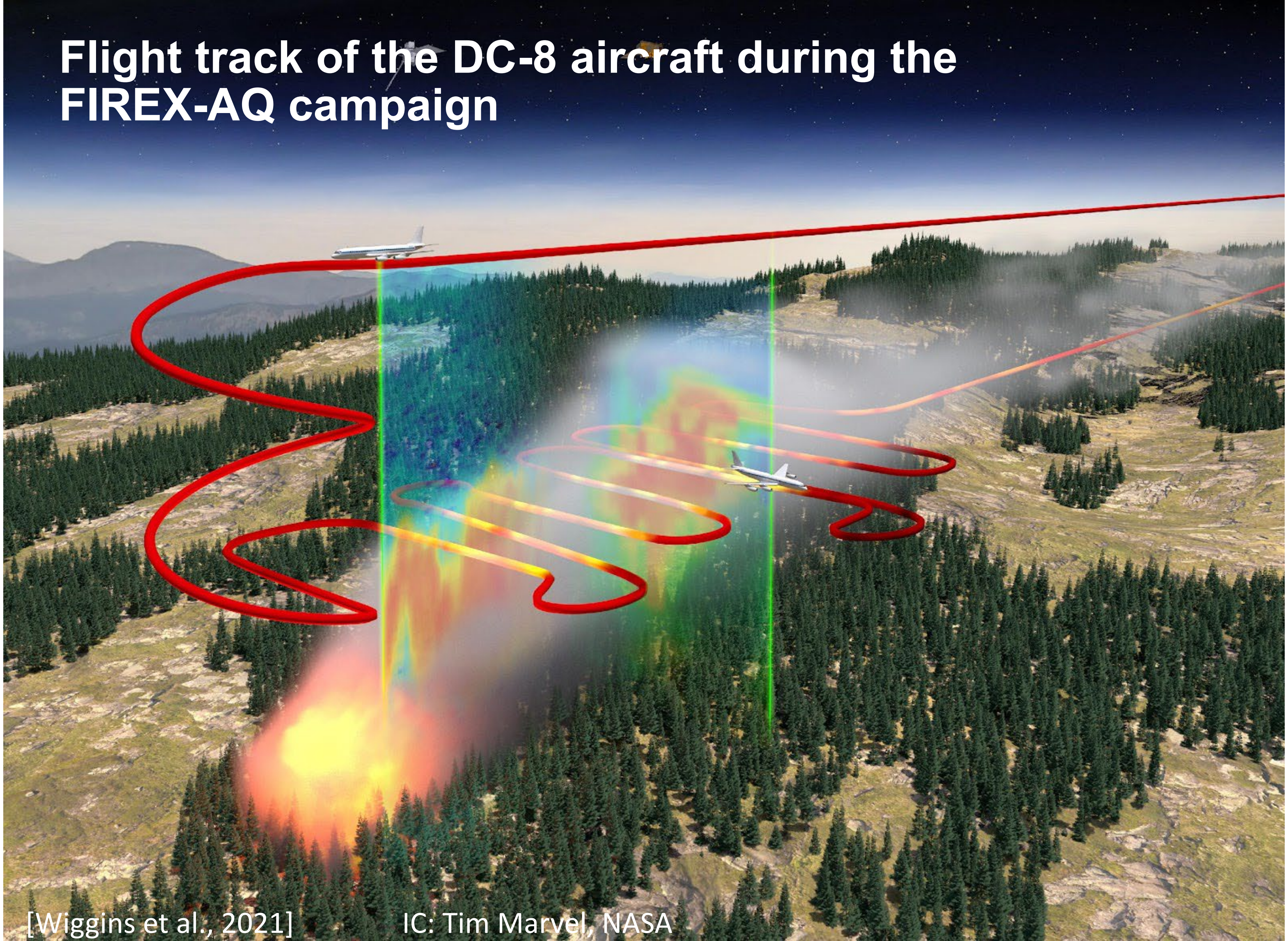
2



*** Note - Unique diurnal patterns, with smoothed transitions. Same fire different days and the nighttime burning in strong on the 30th.**

4

Flight track of the DC-8 aircraft during the FIREX-AQ campaign



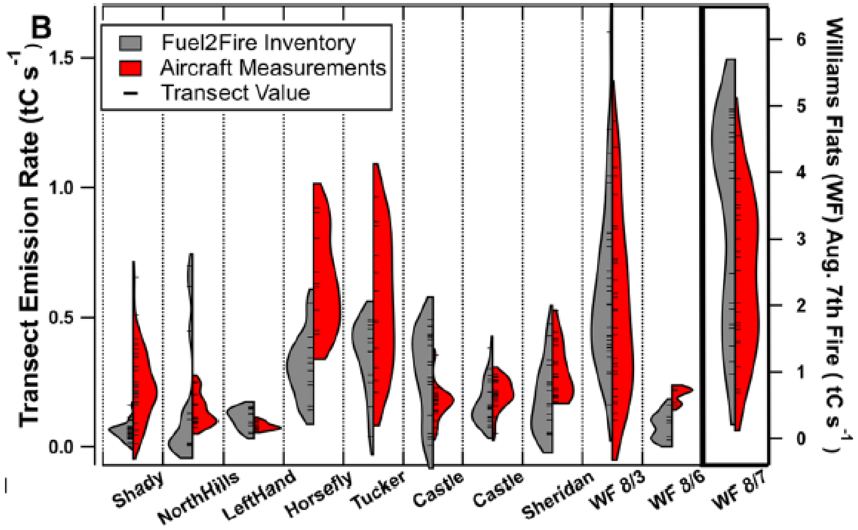
[Wiggins et al., 2021] IC: Tim Marvel, NASA

Biomass Burning Emission Model Comparisons to FIREX-AQ Data

Fuel2Fire emissions compared with in-situ aircraft data and modeled data

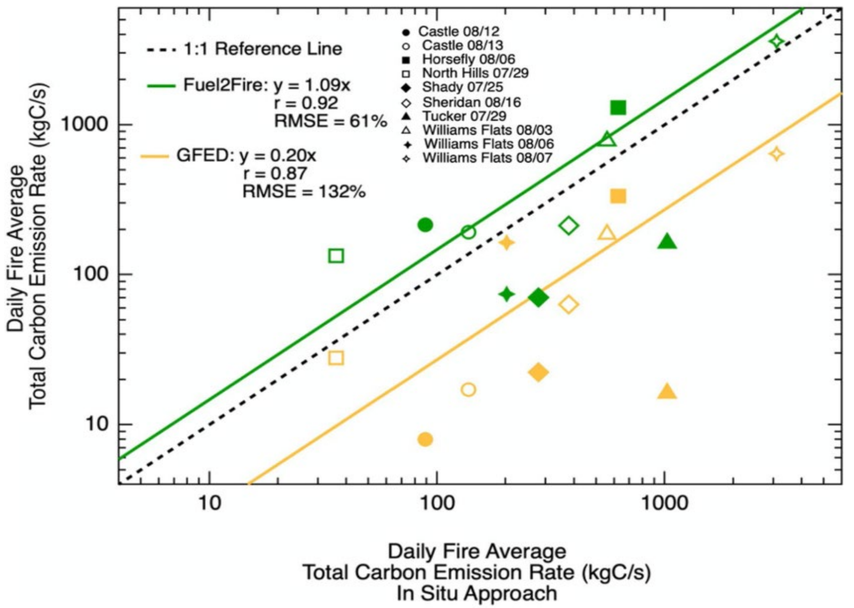
4

* Two distinct methodologies comparing every fire flown to Fuel2Fire data



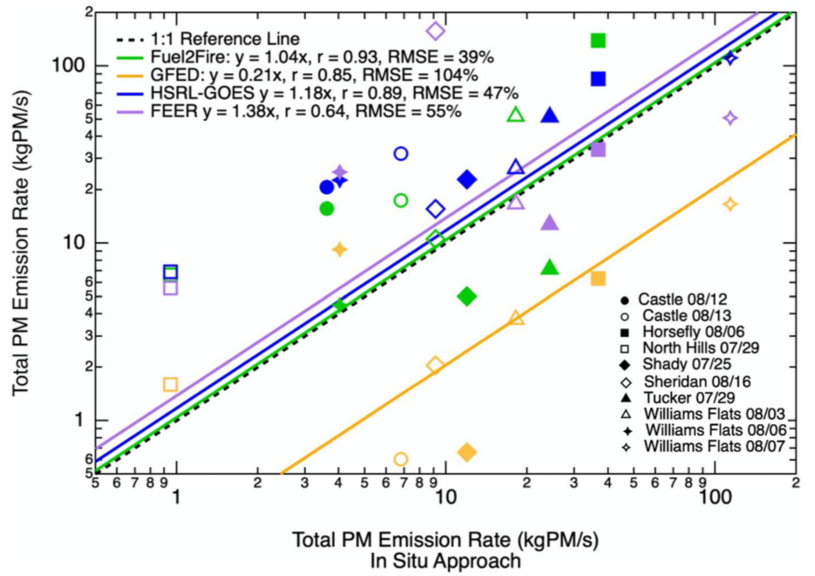
Aircraft in-situ to Fuel2fire

Stockwell et al, 2022



Aircraft in-situ, Fuel2fire, GFED

Wiggins et al, 2021



Aircraft in-situ, Fuel2fire, GFED, HSRL-GOES FEER

Wiggins et al, 2021

Fuel2fire total carbon emissions comparisons with FIREX-AQ in-situ aircraft data.

Sources: Wiggins et al., GRL 2020; Wiggins et al., JGR 2021; Stockwell et al., 2022

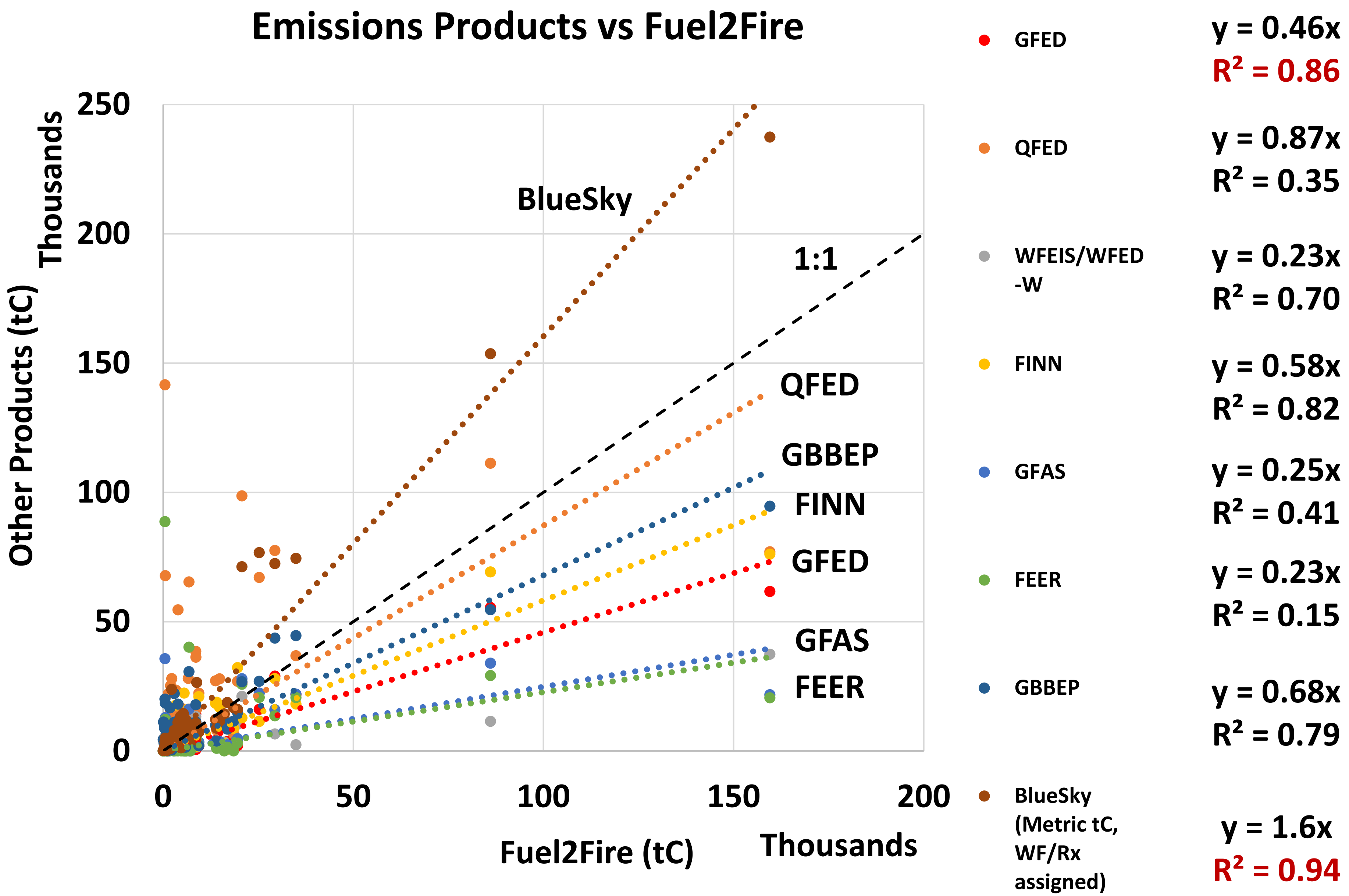
Emissions Model Comparison

3

With 1 exception Fuel2fire generally the largest estimate

Highest correlation BlueSky $R^2 = 0.94$ (~60% > Fuel2Fire, where most fuels burned)

GFED $R^2 = 0.86$
~54% < Fuel2Fire
Indicated by regression coefficients



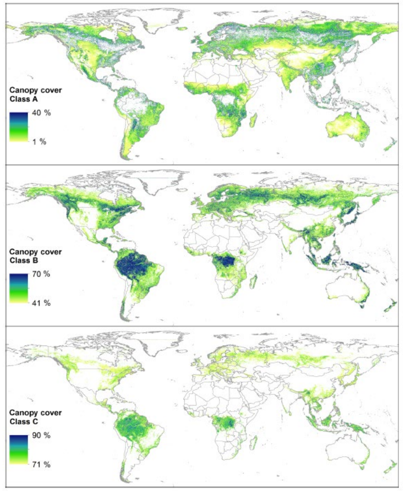
Global Carbon Consumption Database

M. Lucrecia Pettinari and
Emilio Chuvieco, 2016

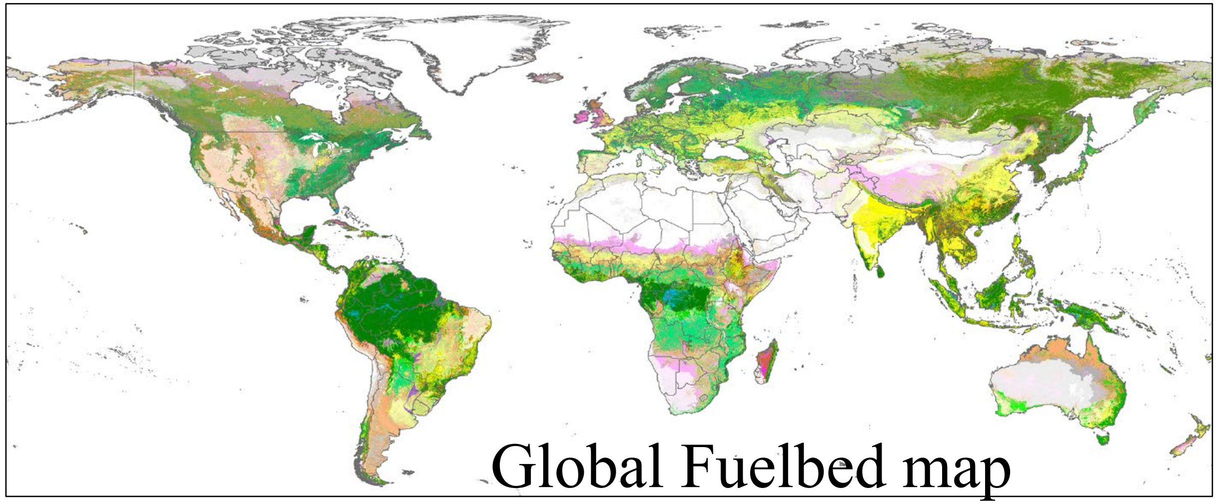
5

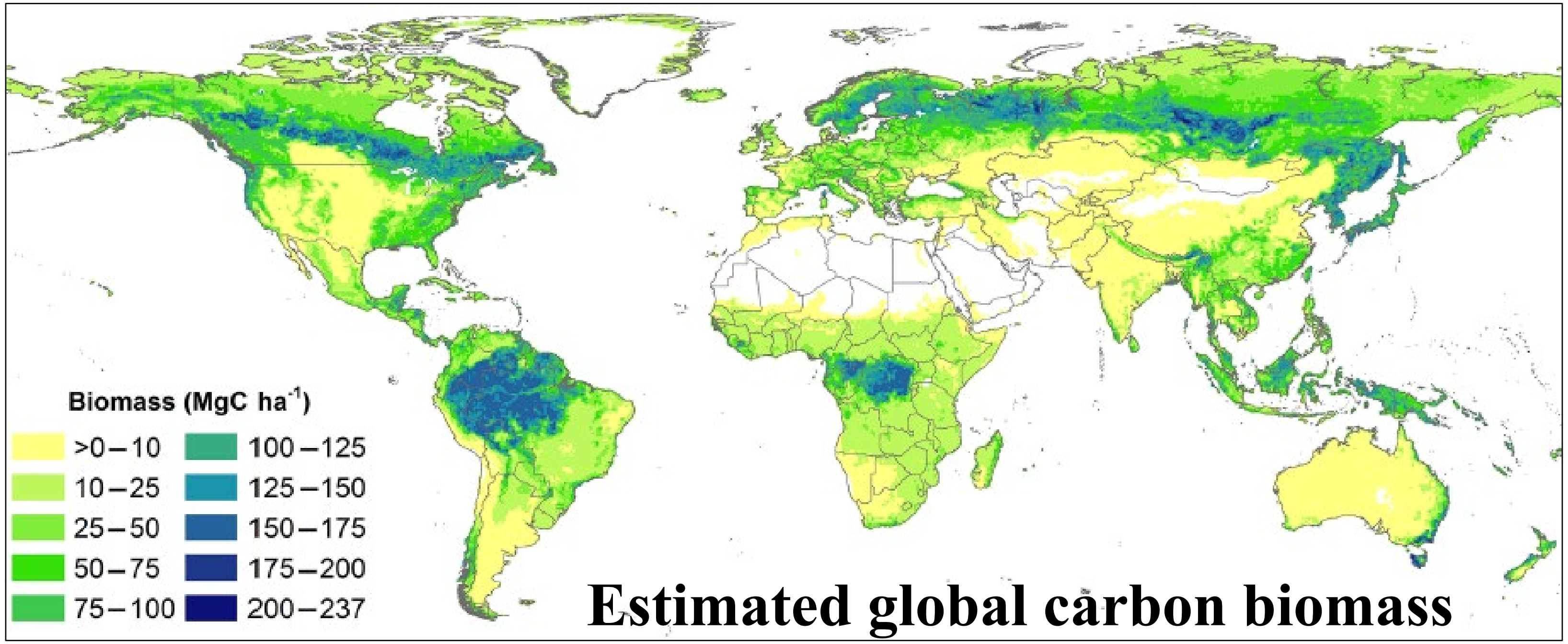
Developed using

- **Global fuel map standardized with Fuel Characteristic Classification System (FCCS) biomass parameters**
  - **Includes: Canopy, Woody, Herb, Shrub, Litter, Lichen, Duff, etc**
- **~300m resolution**
- **274 main fuelbeds**



MODIS Vegetation Continuous Field (VCF)





Pettinari, M. L. & Chuvieco, E.: Generation of a global fuel data set using the Fuel Characteristic Classification System, Biogeosciences, 13, 2061–2076, https://doi.org/10.5194/bg-13-2061-2016, 2016.

6

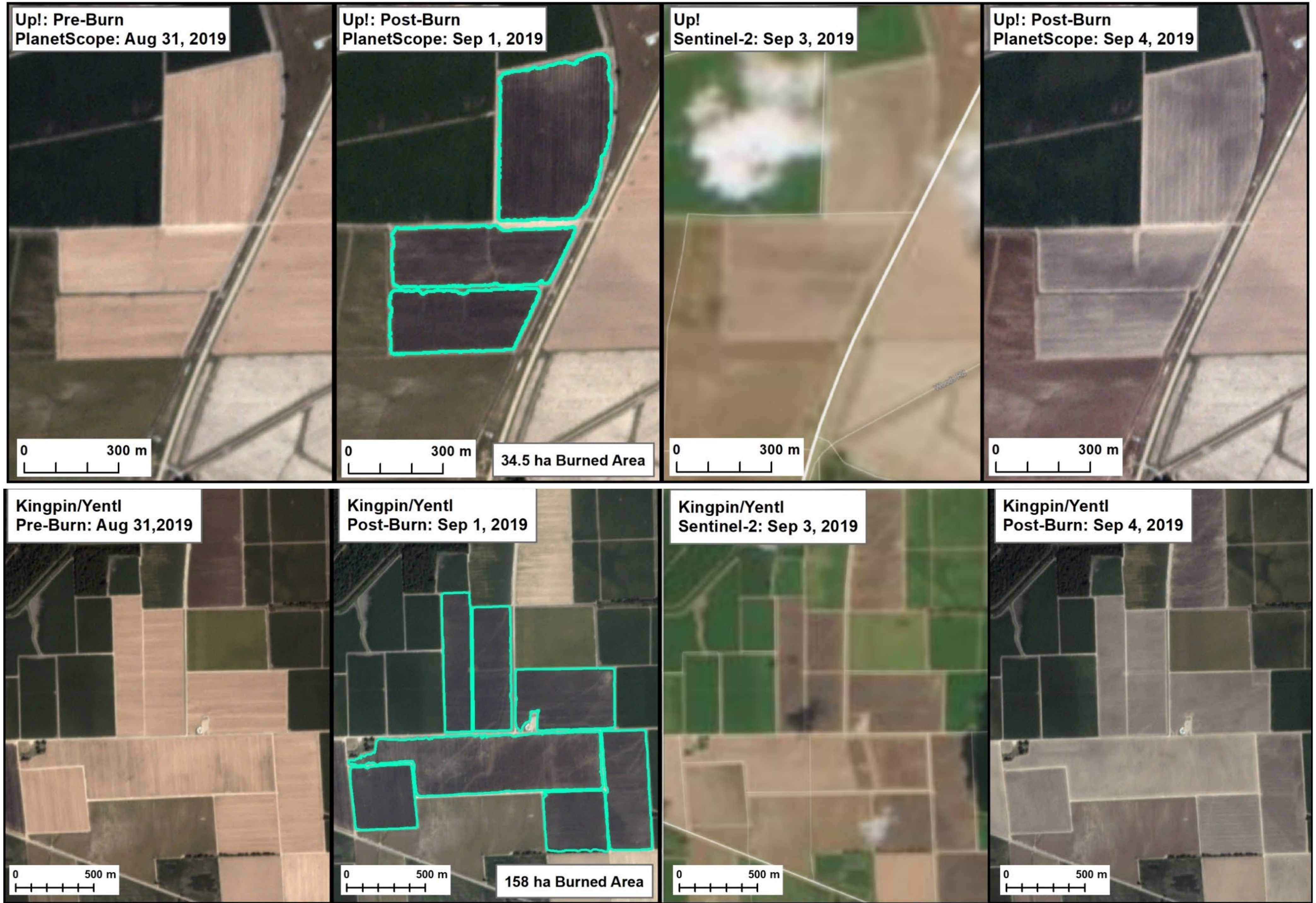
Digitizing Small Burned Area

Challenges in agricultural lands are:

Burn scars recover quickly

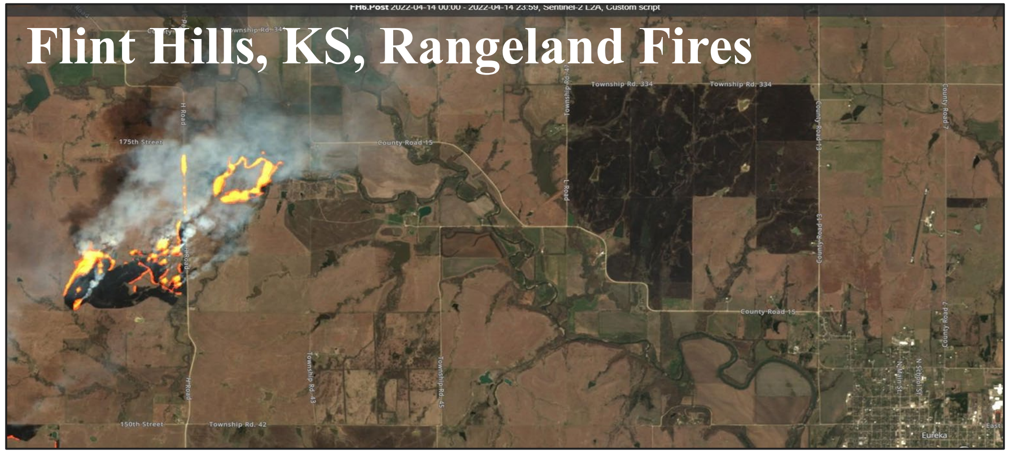
Polar orbiting satellites are not overhead 2 times/day (MODIS, VIIRS)

Geostationary satellites have a lower 2-km resolution



Flints Hills grasslands and Everglades crops

6



A lack of complete fire emissions inventories hinders the ability of federal, state and local health and Air Quality managers and regulators to monitor, evaluate, track, and statistically analyze fire and smoke impacts.

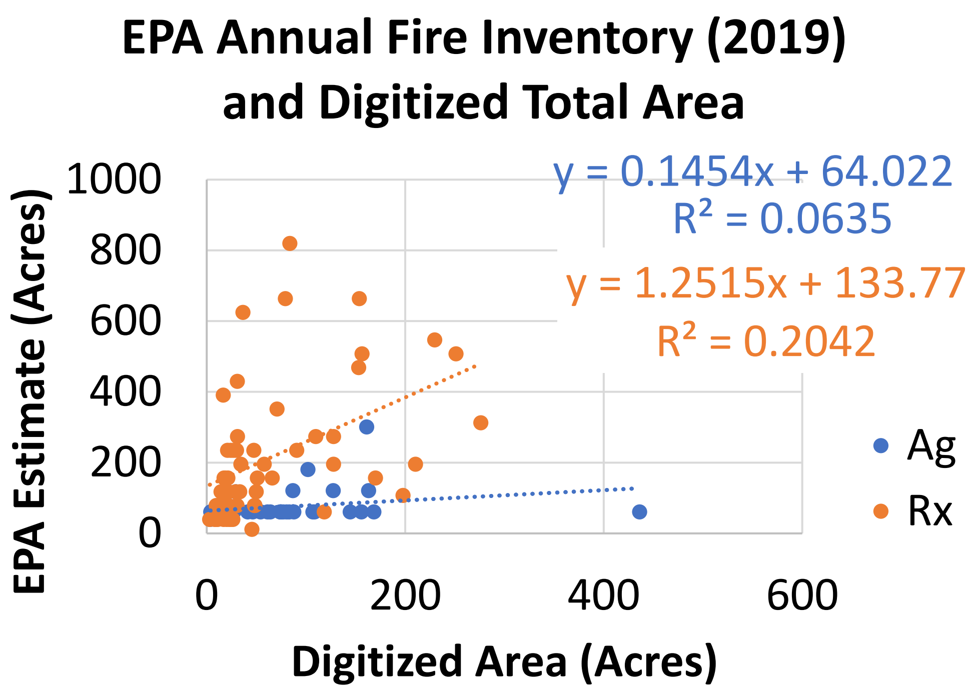
Performance of Satellite products

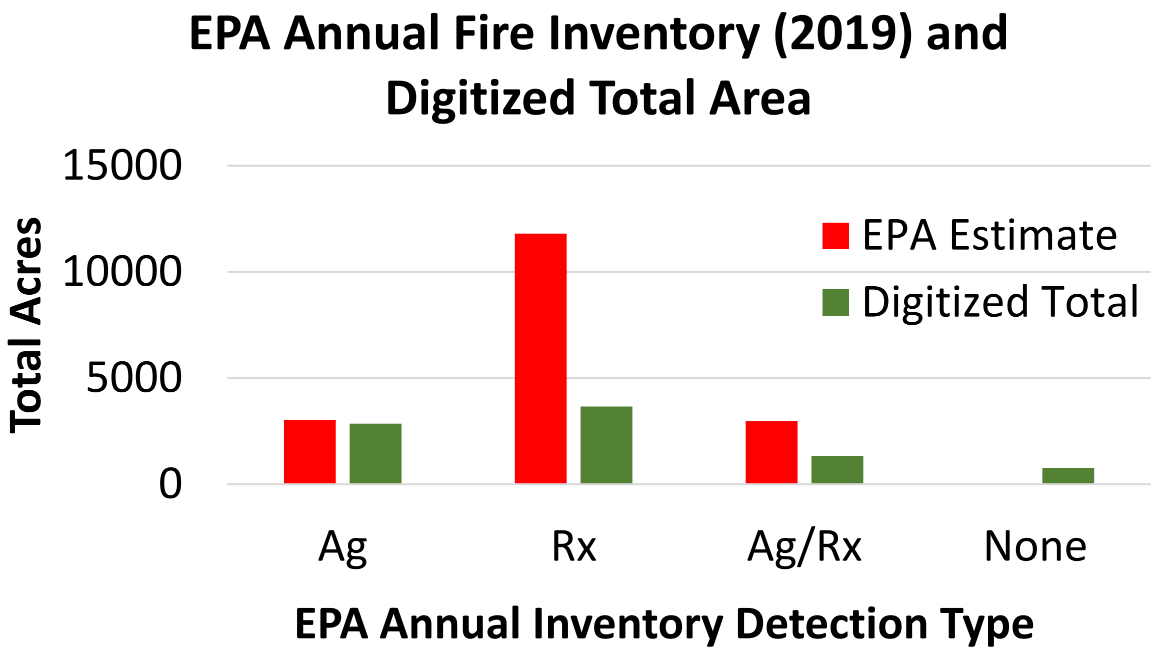
Fire Detection Products		
Satellite	**Flint Hills, KS Captured**	**Everglades Agriculture Area, FL Captured**
MODIS Aqua	8%	4%
MODIS Terra	20%	16%
VIIRS Suomi	35%	10%
VIIRS NOAA20	33%	13%
All satellites	**47%**	**30%**

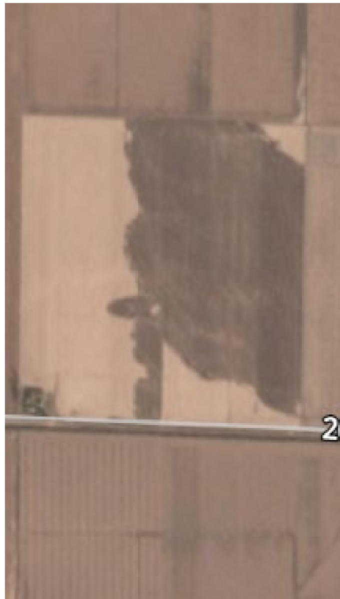
MODIS Burned Area Product			
Region	Intersection (Agreement)	Commission (Overestimate)	Omission (Missed)
Flint Hills, KS & OK	**65%**	8%	27%
Everglades Agriculture Area, FL	24%	23%	**53%**

Comparisons of Burned Area in Iowa croplands (ditches, prescribed, agriculture burning)

6







Agricultural Fields

Conclusions:

Each base dataset can be used to enhance any existing model, moving more closely to a land-based reality, because we now have the data and computer capacity.

- Fuel can be used with fire weather or Fire Radiative Power/Energy
- Diurnal cycles can be applied by fire by day
- Small fires can be calibrated by land cover type and regions

Fuel2Fire, Enhancing Wildland Fire Emissions Estimates:
The devil is in the detail and defined by the purpose of the emission estimates

Fuel2Fire, Enhancing Wildland Fire Emissions Estimates

Focus: Investigate the parameters used to estimate wildland fire emissions to enhance these estimates.

1) **Fuel estimates (ground to satellite) for CONUS;**
2) **GOES-derived diurnal fire cycle;**
3) **Validation using 2019 Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) data;**
4) **Emissions comparisons;**
5) **Global fuel estimates (ground to satellite);**

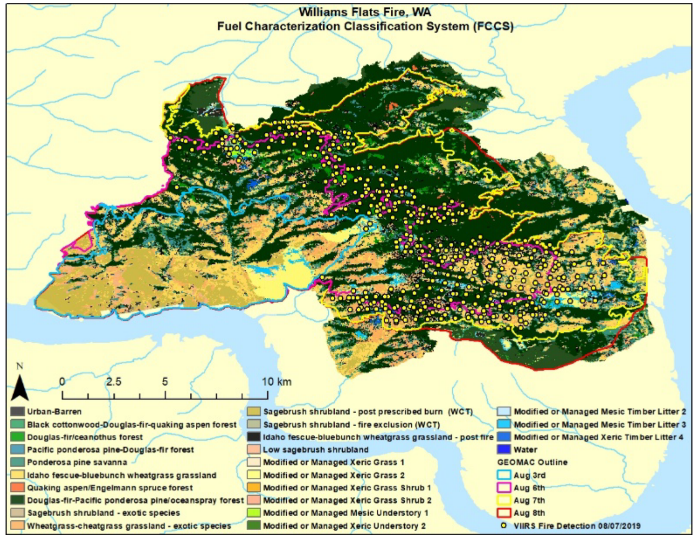
    Emily Gargulinski *Global Carbon Consumption for Wildland Fire*

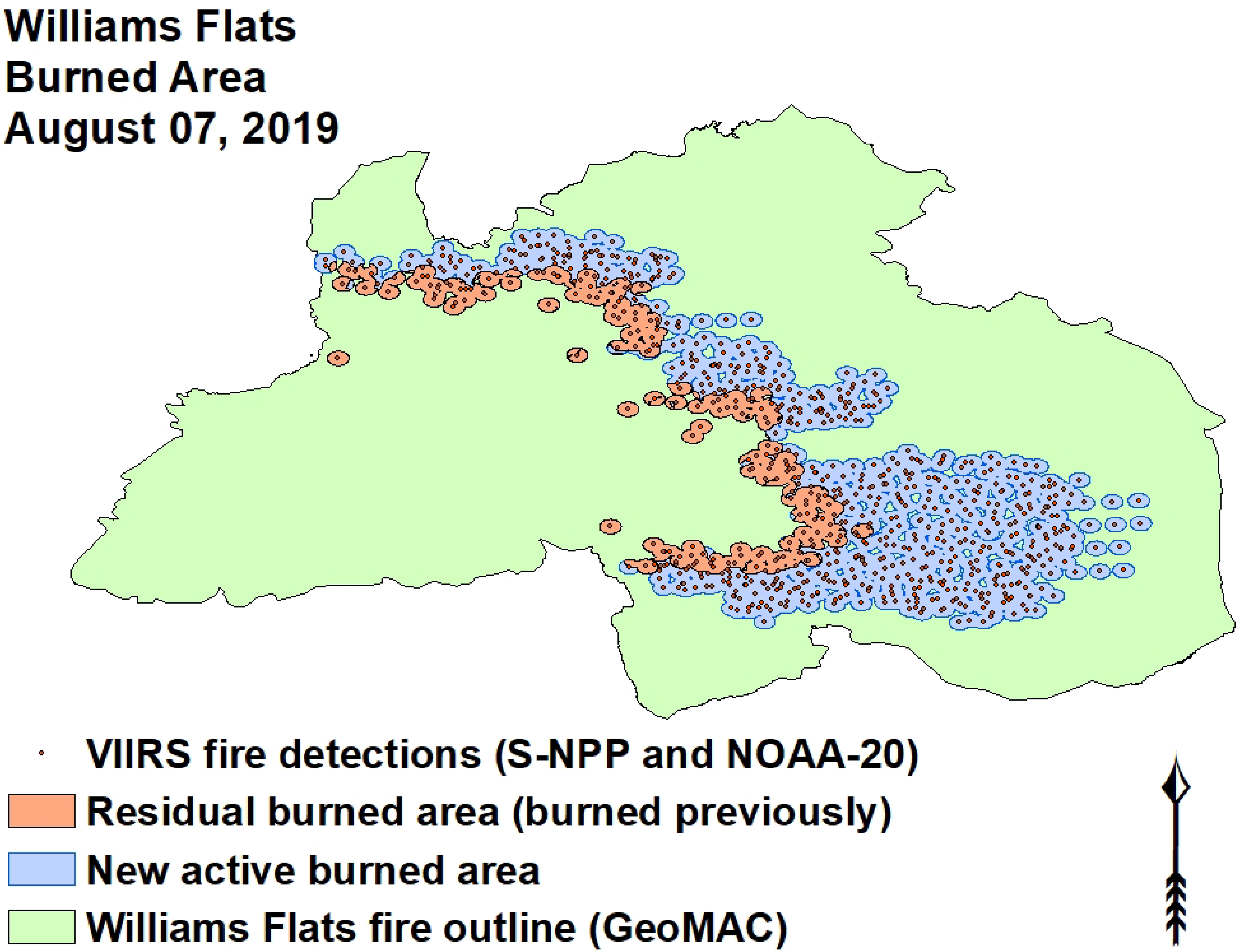
6) **Quantifying small fires from space;**

Extra Slides

Extra Slides Follow

Fueled from below: New/Residual burned area



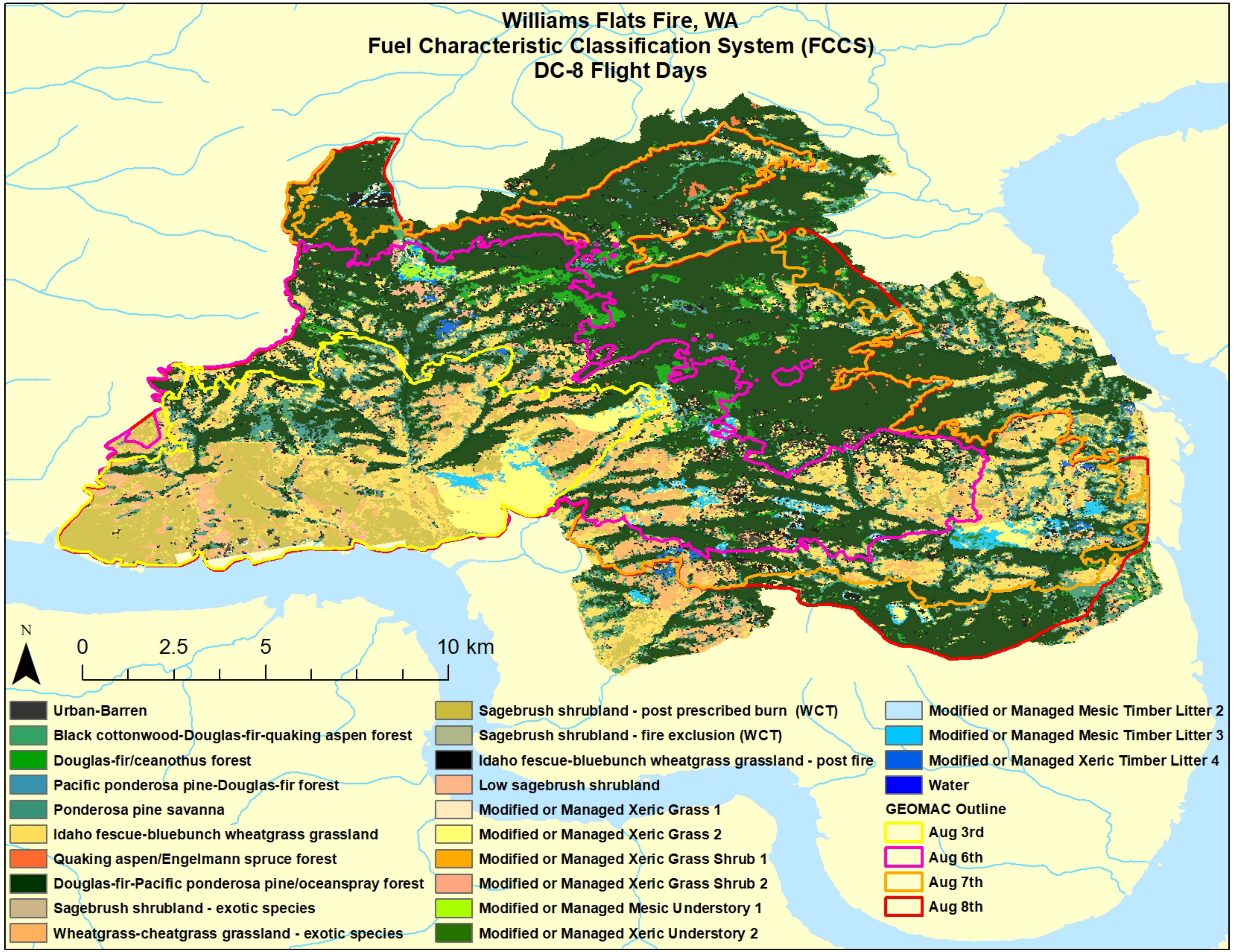


- Active fire buffered to 375m diameter and overlaid.
- Previously burned –Residual (coral)
- New active fire (blue)
- Overlap removed

Fueled from below: FCCS– Ecosystems to Carbon

Williams Flats fire
WA, 2019

The **Fuel Characteristic Classification System (FCCS)** is a tool that enables land managers, regulators, and scientists to create and catalog fuelbeds and to classify those fuelbeds for their capacity to support fire and consume fuels. (Ottmar et al., 2007)

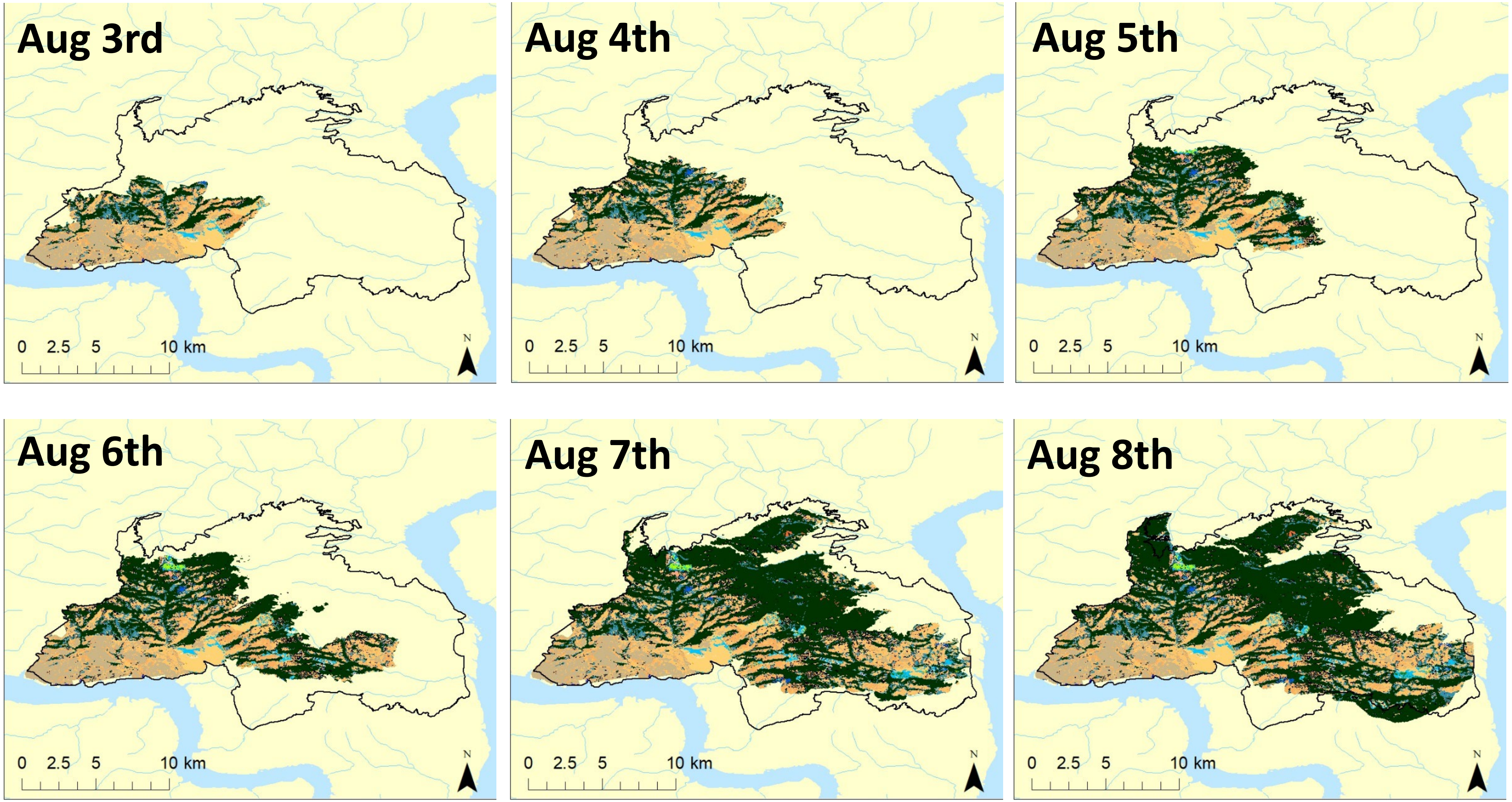


Fueled from below: Fuels burned

Williams Flats Fire

GeoMAC Outlines

FCCS-derived Fuels



Connecting Terrestrial and Atmospheric Systems: Value Added and Analyses of FIREX-AQ Data to Enhance Air Quality Modeling

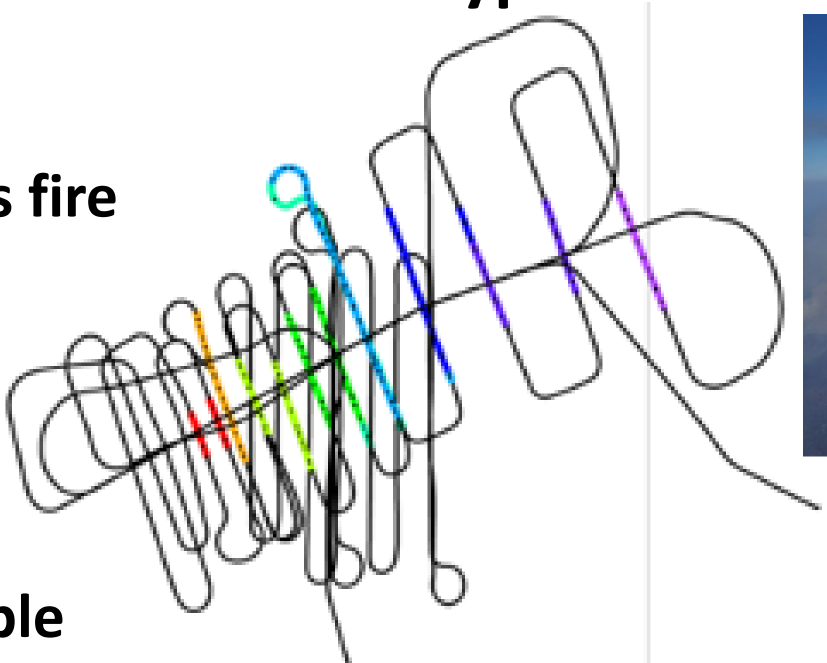
- **119 Distinct smoke events sampled**
- **22 Western fire-smoke events with many transects (Boise, ID)**
  - **DC-8 platform only**
- **97 Eastern smoke events (Salina, KS)**
- **70 Unique minor fuel types**

Major Fuel Type, per day, per largest fire area burned	
1	Forest
2	Savanna
3	Shrubland
4	Grassland
5	Cropland
6	Pile
7	Slash
8	Understory
9	Urban/Barren

Williams Flats fire

August 3rd 2019

Typical DC-8 transect sample



Williams Flats: Aug 7th
Emily Gargulinski

Methods for Emissions

Daily Fire Emissions Methodology

$$C_t = A \times B \times F_c \times C_b$$

[Seiler and Crutzen, 1980]

A = Area Burned (VIIRS/MODIS)

B = Biomass Density (FCCS)

F_c = 0.5 (Assumed biomass carbon)

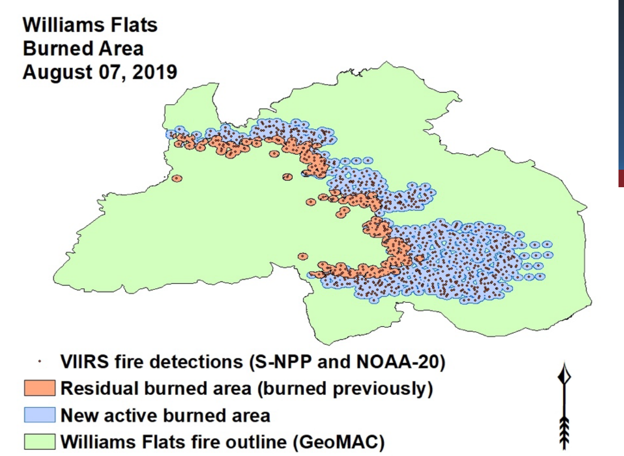
C_b = Fraction of biomass consumed (Weather)

-Diurnal Cycle Derived from 5-min GOES FRP Observations

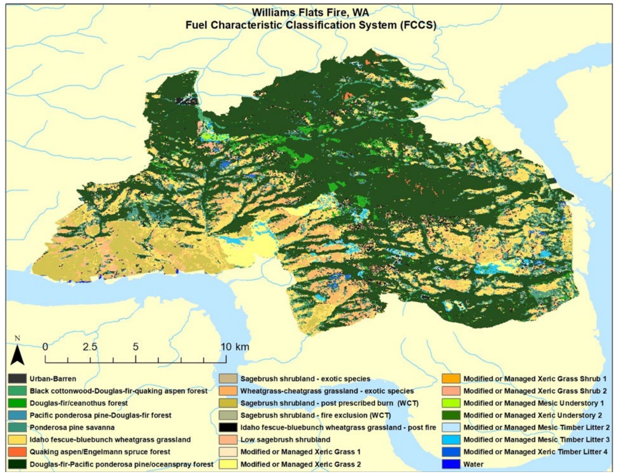
-Output 1-sec ICARTT Emissions

[Soja et al., 2004; Pierce et al., 2007; Pierce et al., 2009; Wiedinmyer et al., 2011]

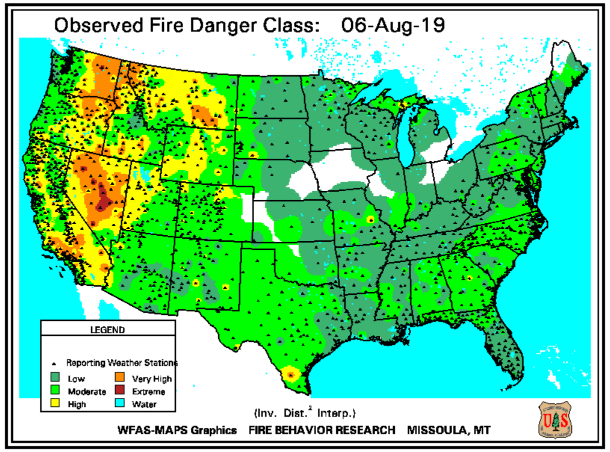
A



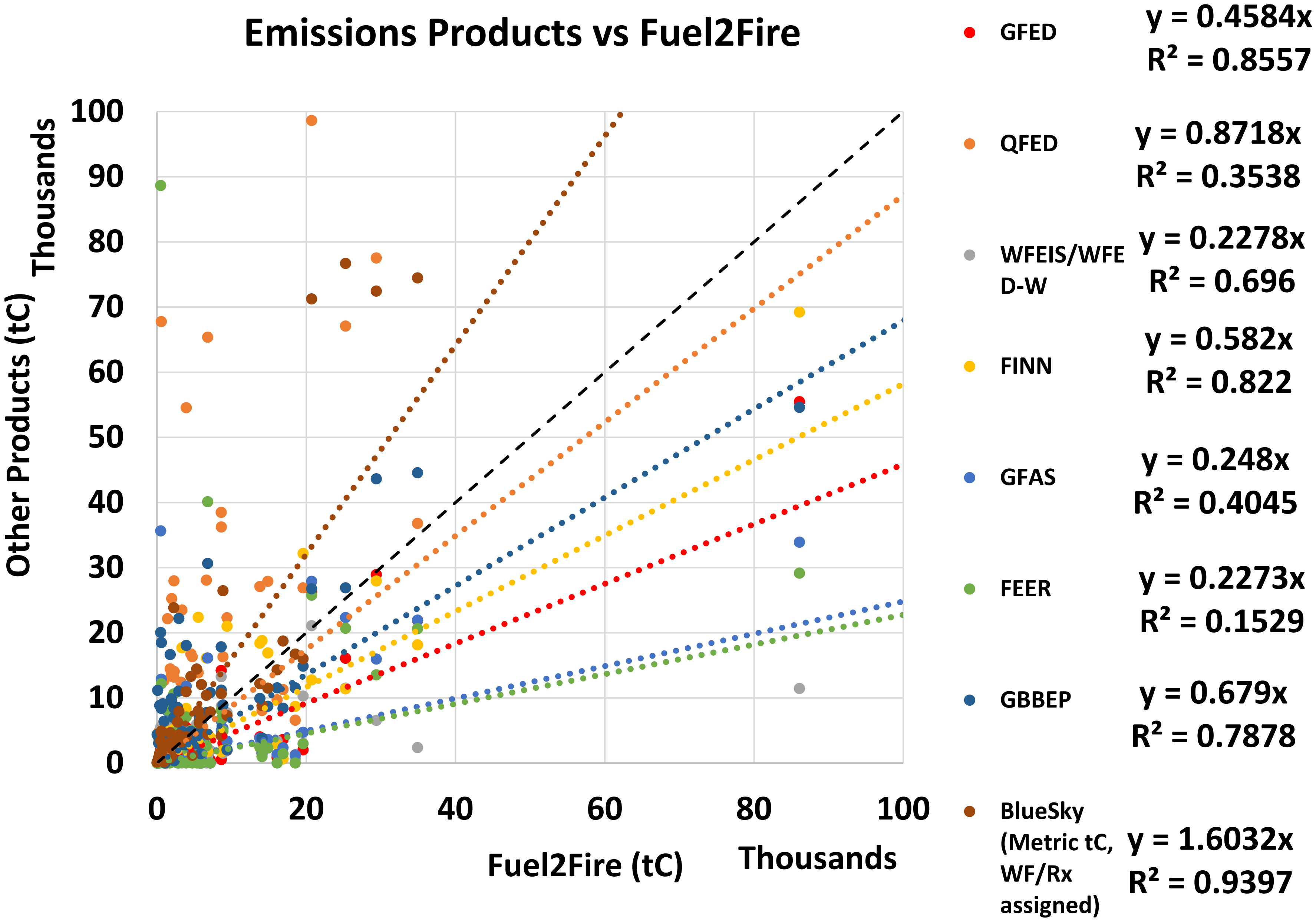
B



C_b



Emissions Comparison: Zoom In



BlueSky: Wildfire vs Prescribed model