

Linking Ground, Airborne, and Satellite Measurements of Fire Power

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Northern &
Rocky Mountain
Research
Stations

Linking Ground, Airborne, and Satellite Measurements

Opportunity

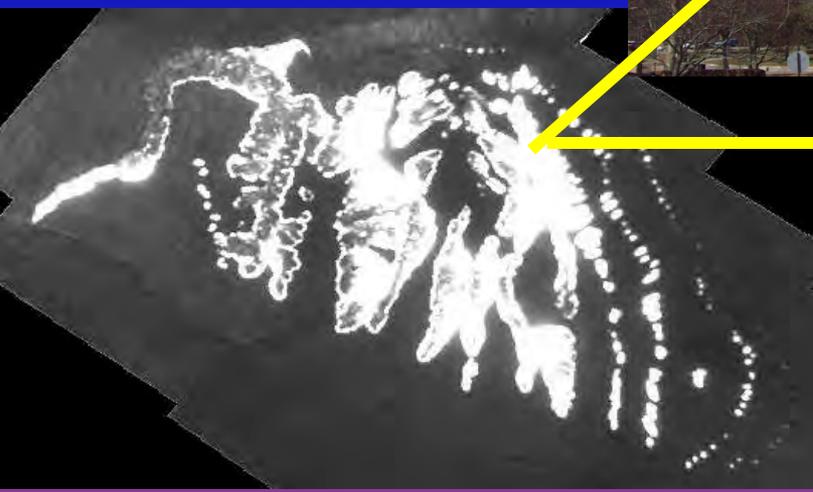
FIRE RADIATION - is a direct manifestation of combustion used as a worm hole into the universe of fire behavior and effects

MERITS - physical measurement @ high resolution and large extent

Smoke emission & dispersion



Ecological effects (e.g., tree mortality)



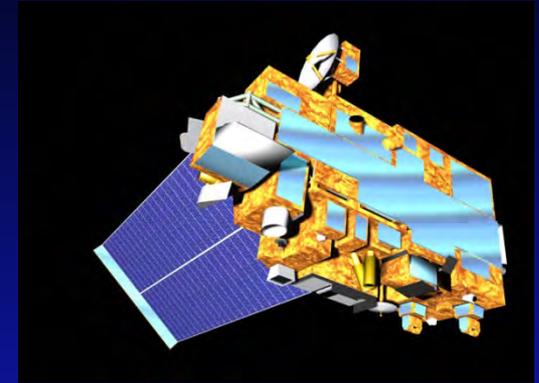
Fire heat budget and propagation



Linking Ground, Airborne, and Satellite Measurements

Opportunity

Growing number and quality of airborne platforms & sensors that can help quantify radiation



Satellites



Manned Flights



Unmanned Aerial Systems (UAS)

See Tom Zajkowski & Greg Walker's talks

Challenges

NEEDED ADVANCE IN RADIATION METROLOGY:

- development of sensors & analysis methods
- Measurement validation
- Understanding of fire heat budget to enable use

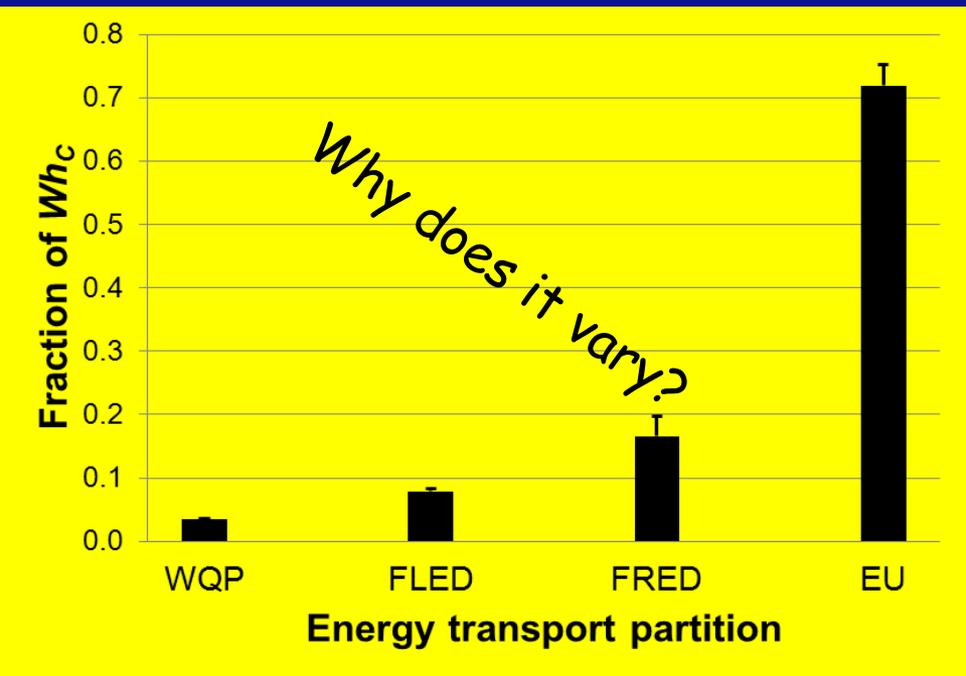
Linking Ground, Airborne, and Satellite Measurements

Challenges

MUST CONSTRAIN THE FIRE HEAT BUDGET
to use radiation measurements

$$Wh_c(1 - \phi) = WQ_p + FLED + FRED + FCED + E_s \quad (\text{Integrated form})$$

Heat source Inefficiency Pre-heating Latent Radiative Convective Soil



$$E_U = FCED + E_s + Wh_c\phi$$

Unknown components Convective Soil heating Inefficiency

Convective
~50% of Wh_c ?

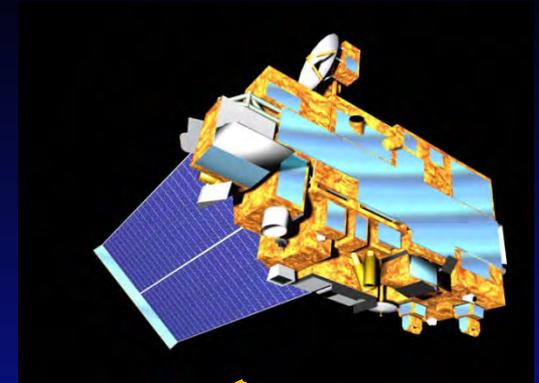
Fire radiation is #2 dissipation mode

From: Kremens et al. 2012

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Solution

Airborne & satellite radiation measurements validated with ground-based measurements of radiation & the rest of the fire heat budget

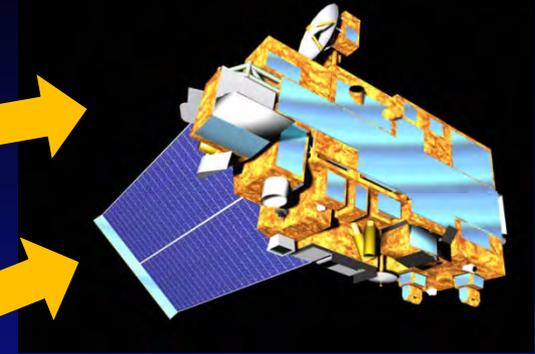


GROUND:

- Radiation
- Convection
- Soil heat.
- Comb. eff.
- Fuel cons.
- Etc.

Linking Ground, Airborne, and Satellite Measurements

Solution Hierarchical calibration



GROUND:

- Radiation
- Convection
- Soil heat.
- Comb. eff.
- Fuel cons.
- Etc.



This talk:

Linking Ground, Airborne, and Satellite Measurements of Fire Power - Initial Results

Outline

1. Rx-CADRE measurements on burn S5
 - ❑ Satellite retrieval
 - ❑ Radiometers & UAS estimate
 - ❑ Boom-mounted FLIR estimate
2. Henry Coe fire (Wilfrid Schroeder, Craig Clements et al.)

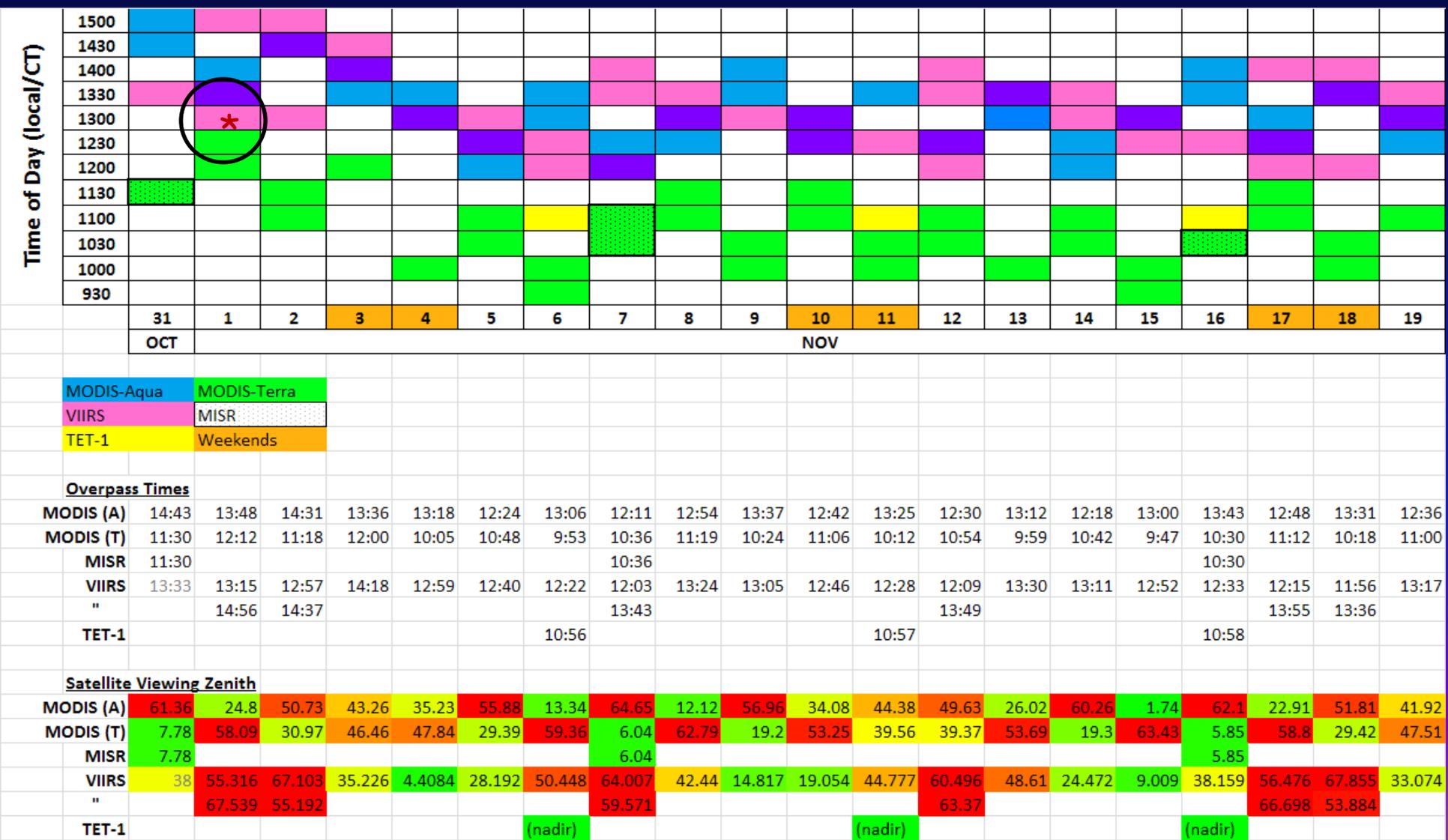
Linking Ground, Airborne, and Satellite Measurements

Rx-CADRE - S5 unit (100 x 200 m grass)



Linking Ground, Airborne, and Satellite Measurements

Satellite retrieval



Linking Ground, Airborne, and Satellite Measurements

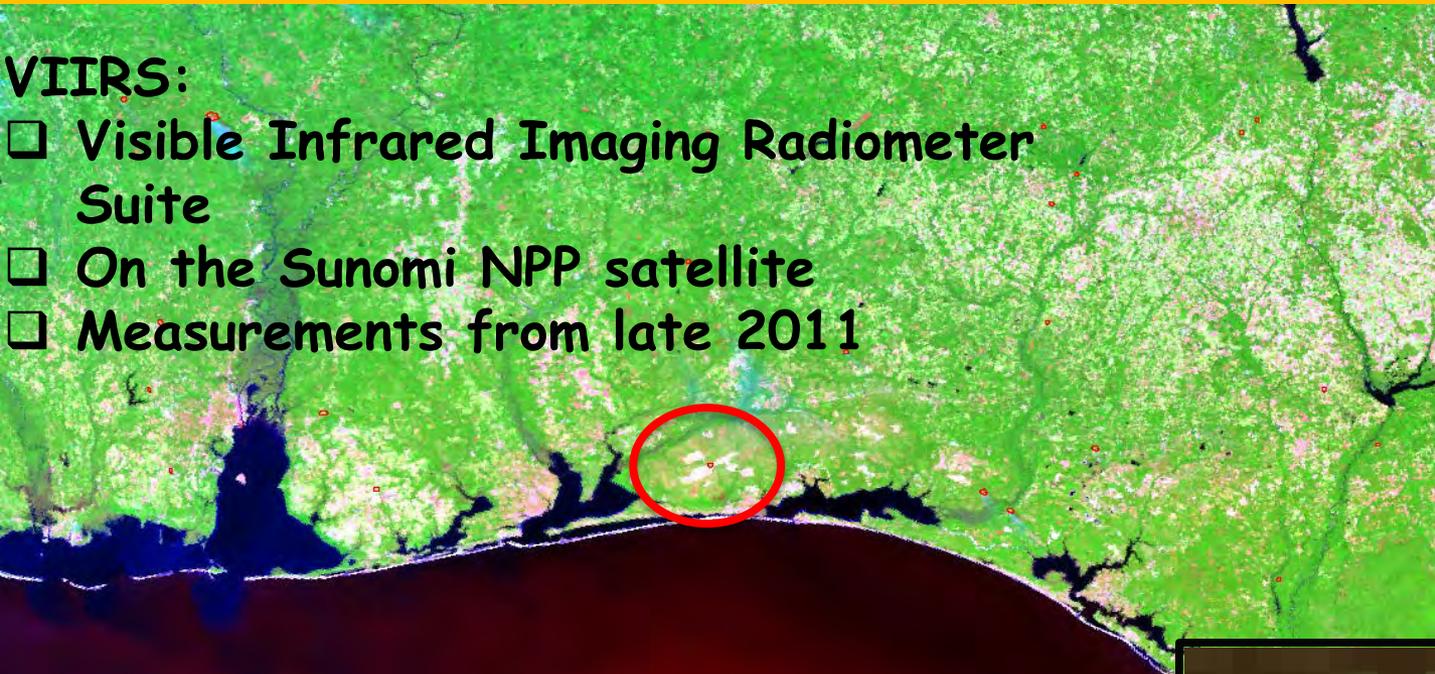
Satellite retrieval - S5

VIIRS:

- ❑ Visible Infrared Imaging Radiometer Suite
- ❑ On the Sunomi NPP satellite
- ❑ Measurements from late 2011

VIIRS 375m
1 November 2012
18:15:58 UTC

S5 unit
4.2<>5.5 MW



Linking Ground, Airborne, and Satellite Measurements

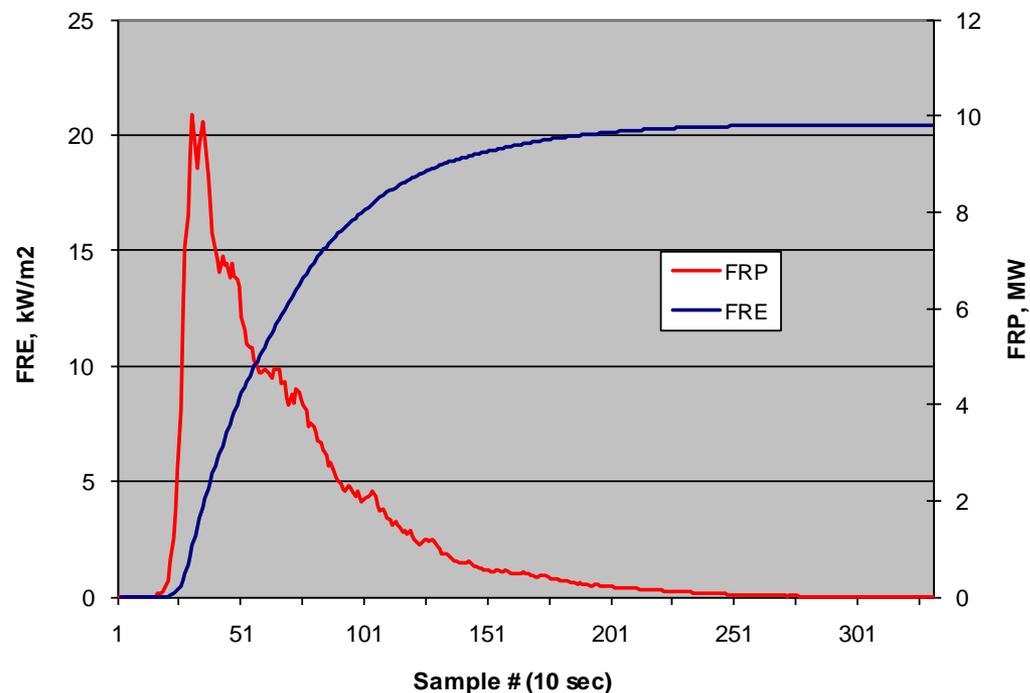
UAS-based estimate

Surface-leaving radiative flux density (kW/m^2)
estimated from dual-band radiometers (LWIR and MWIR)



See Kremens et al. 2010
for analysis methods

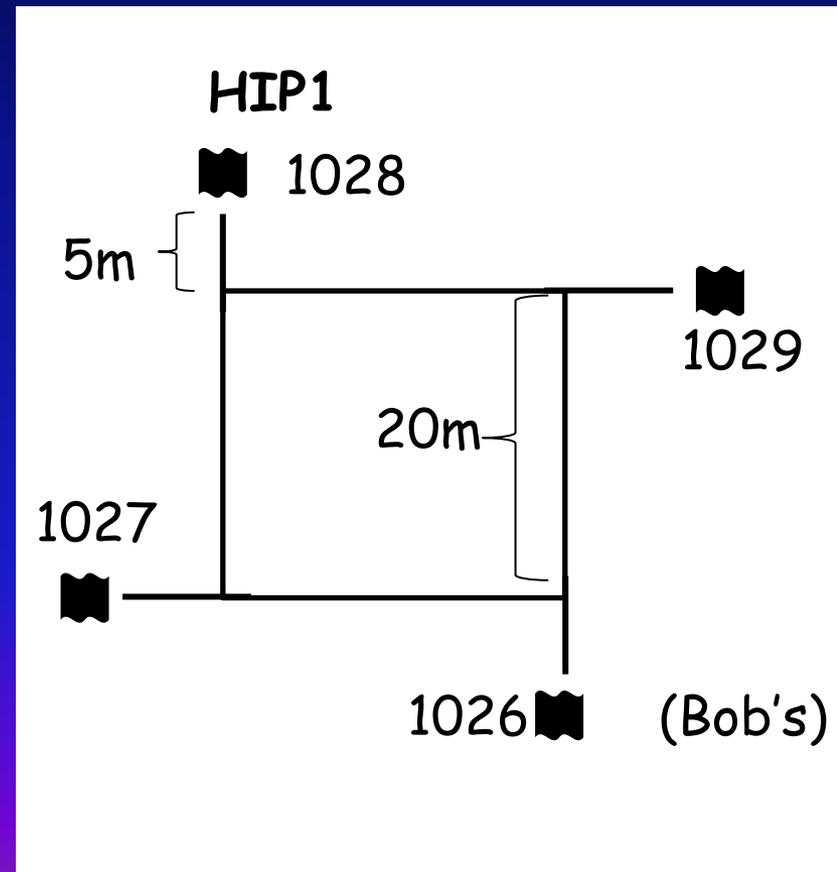
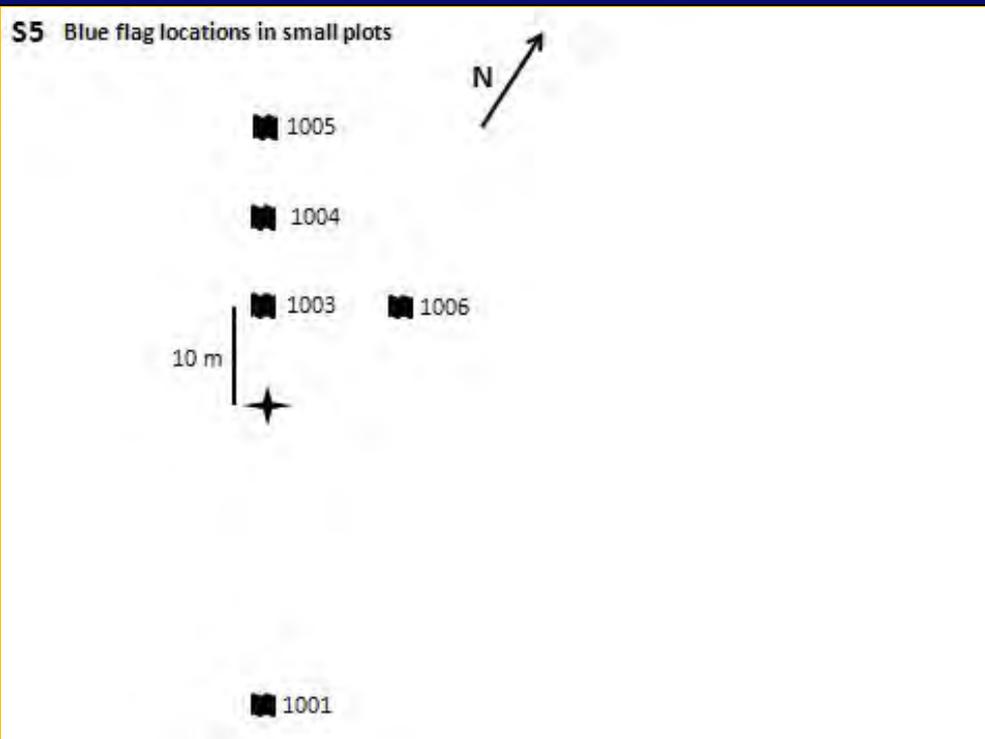
VFEF12 FRP and FRE and vs. Time



Linking Ground, Airborne, and Satellite Measurements

UAS-based estimate

Surface-leaving radiative flux density (kW/m^2)
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Linking Ground, Airborne, and Satellite Measurements

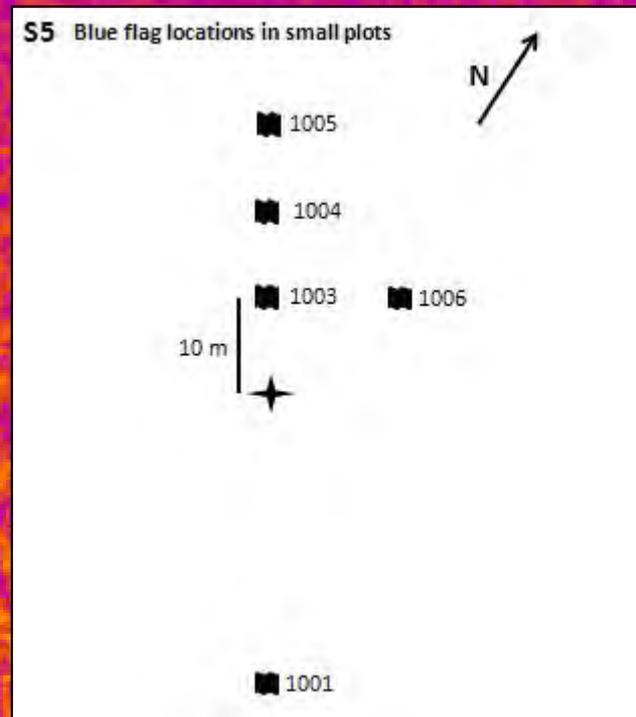
UAS-based estimate



"Hot Target" Locations:

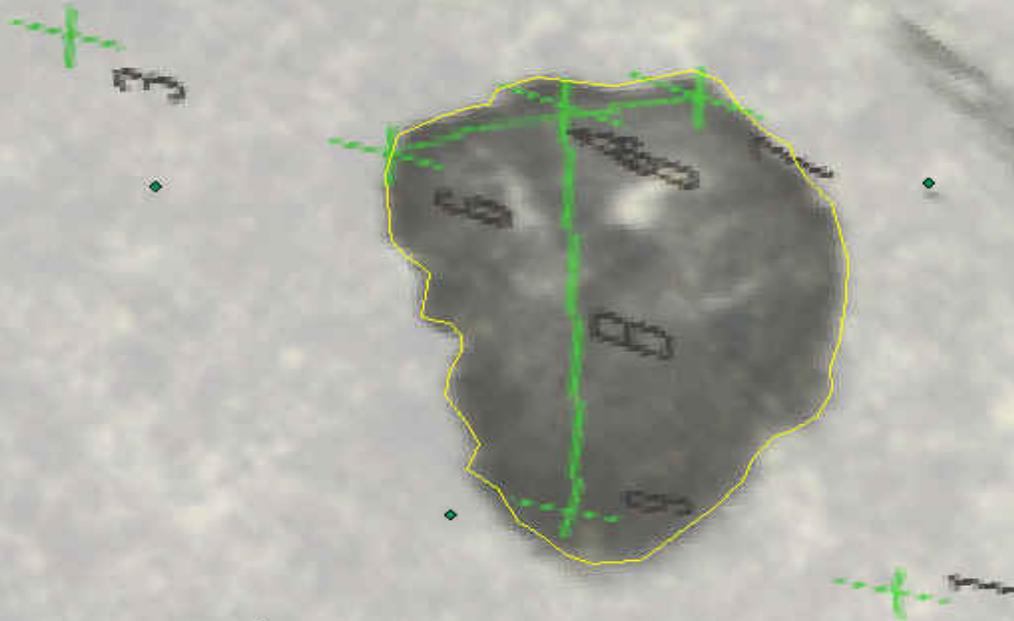
- Surveyed pre-fire
- Coffee cans with charcoal
- For ortho-geo-rectification

NW corner



Linking Ground, Airborne, and Satellite Measurements

UAS-based estimate



S5 Unit

1 November 2012

18:15:58 UTC (satellite overpass time)

Average FRFD from radiometer 4.26 kW/m²

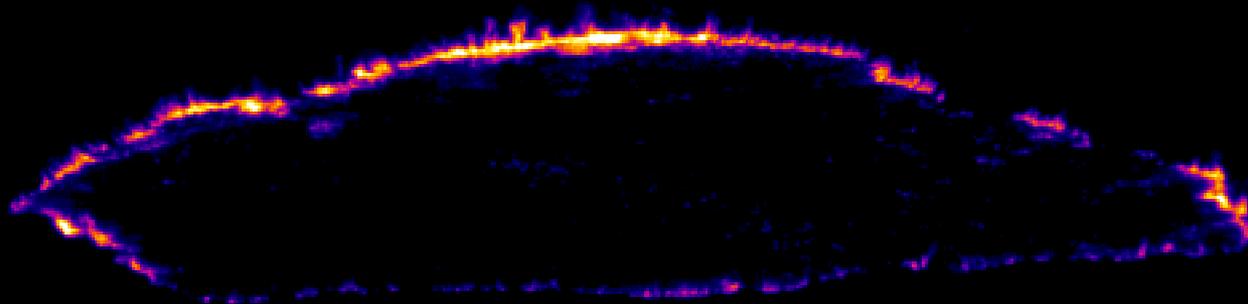
Fire area (UAS) 5210 m²

Power (Average FRFD in MW x Fire Area) 22.2 MW

Linking Ground, Airborne, and Satellite Measurements

523.0°C

Boom-mounted FLIR estimate (~100 ft)



1 November 2013

18:15:58 UTC (satellite overpass time)

Total power from FLIR

0.3 MW

<200.0°C

Linking Ground, Airborne, and Satellite Measurements

Satellite vs UAS/radiometer vs FLIR

UAS/radiometer*	22.2	MW	"Fire area" too large (mismatch with ground- radiometer threshold)
Satellite retrieval	4.2<>5.5	MW	
Boom-mounted FLIR*	0.3	MW	Obscuration?

*Not fair, work in progress!

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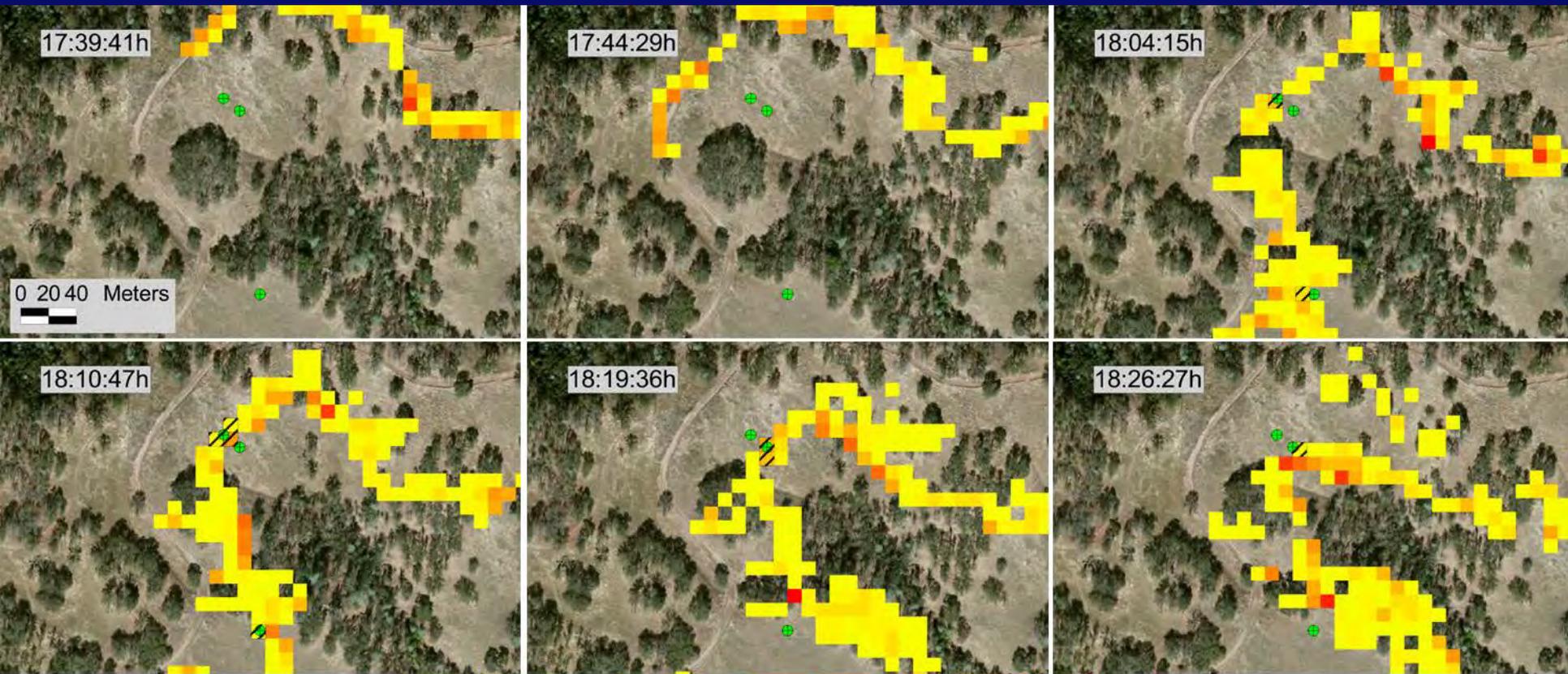
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Results: Radiant Heat Flux

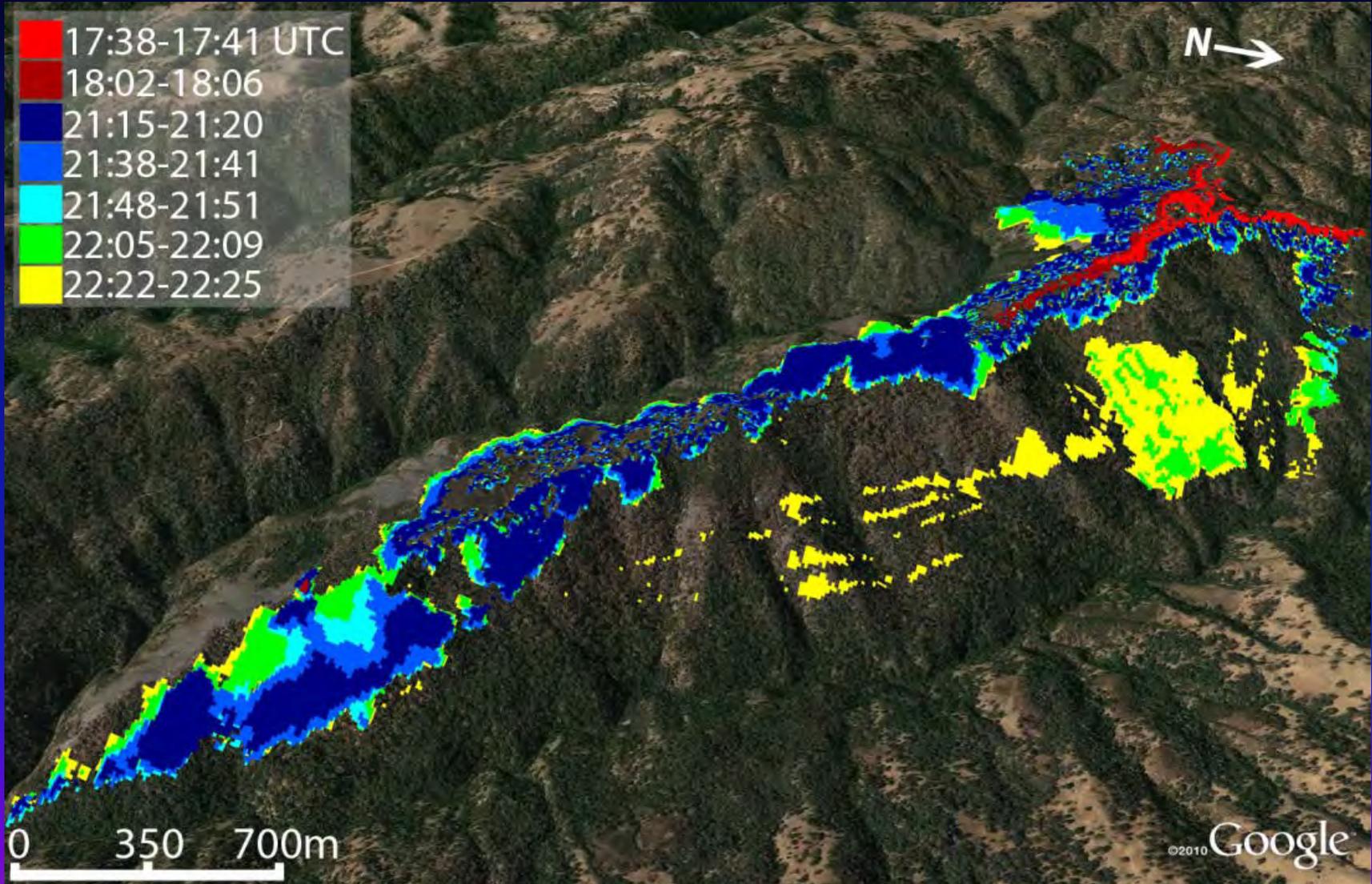
Ground
(radiometers)



Airborne
(NASA/AMS)



Airborne Fire Mapping (18 Oct 2011)

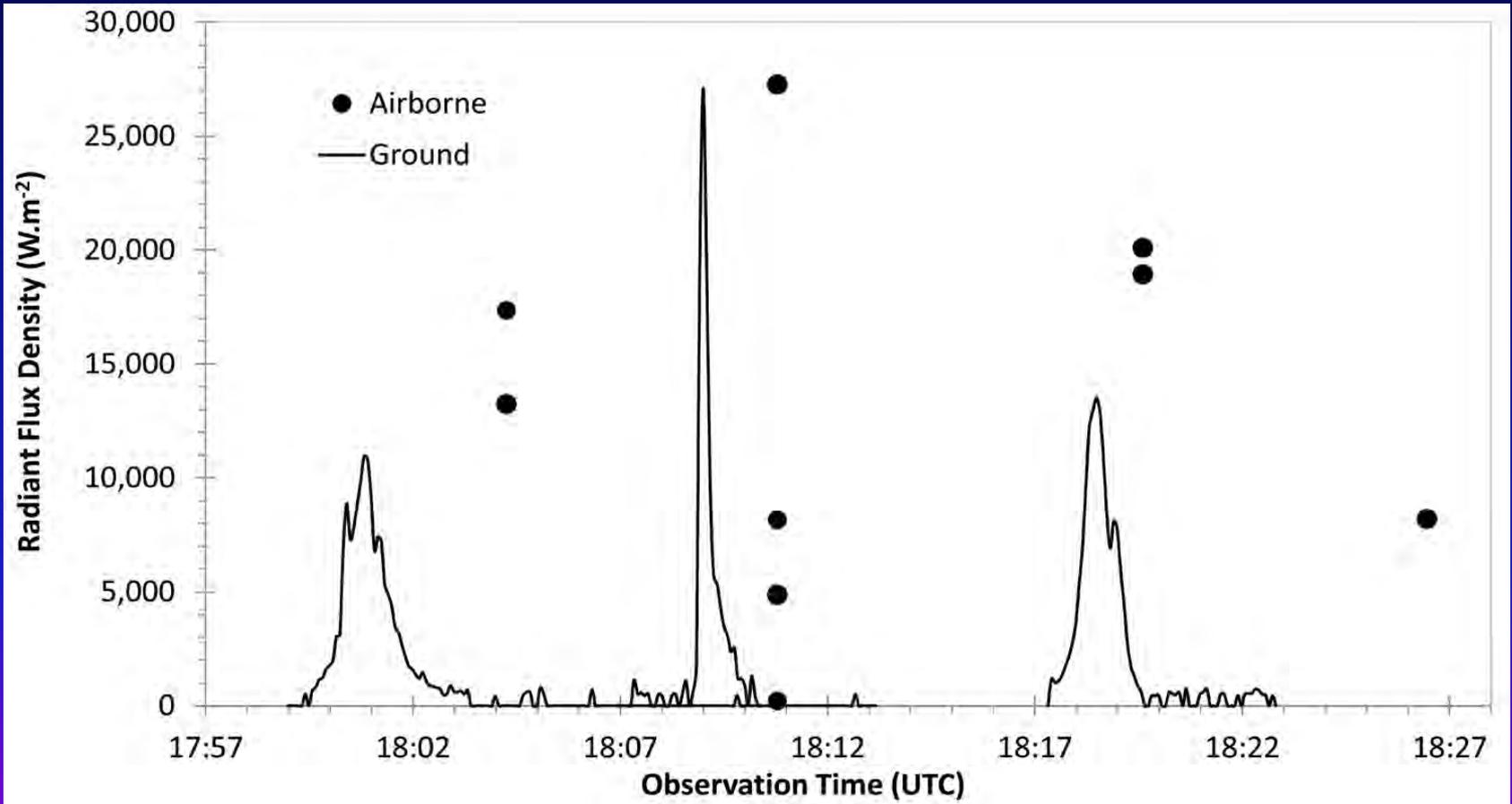


Results: Radiant Heat Flux

Ground
(radiometers)



Airborne
(NASA/AMS)

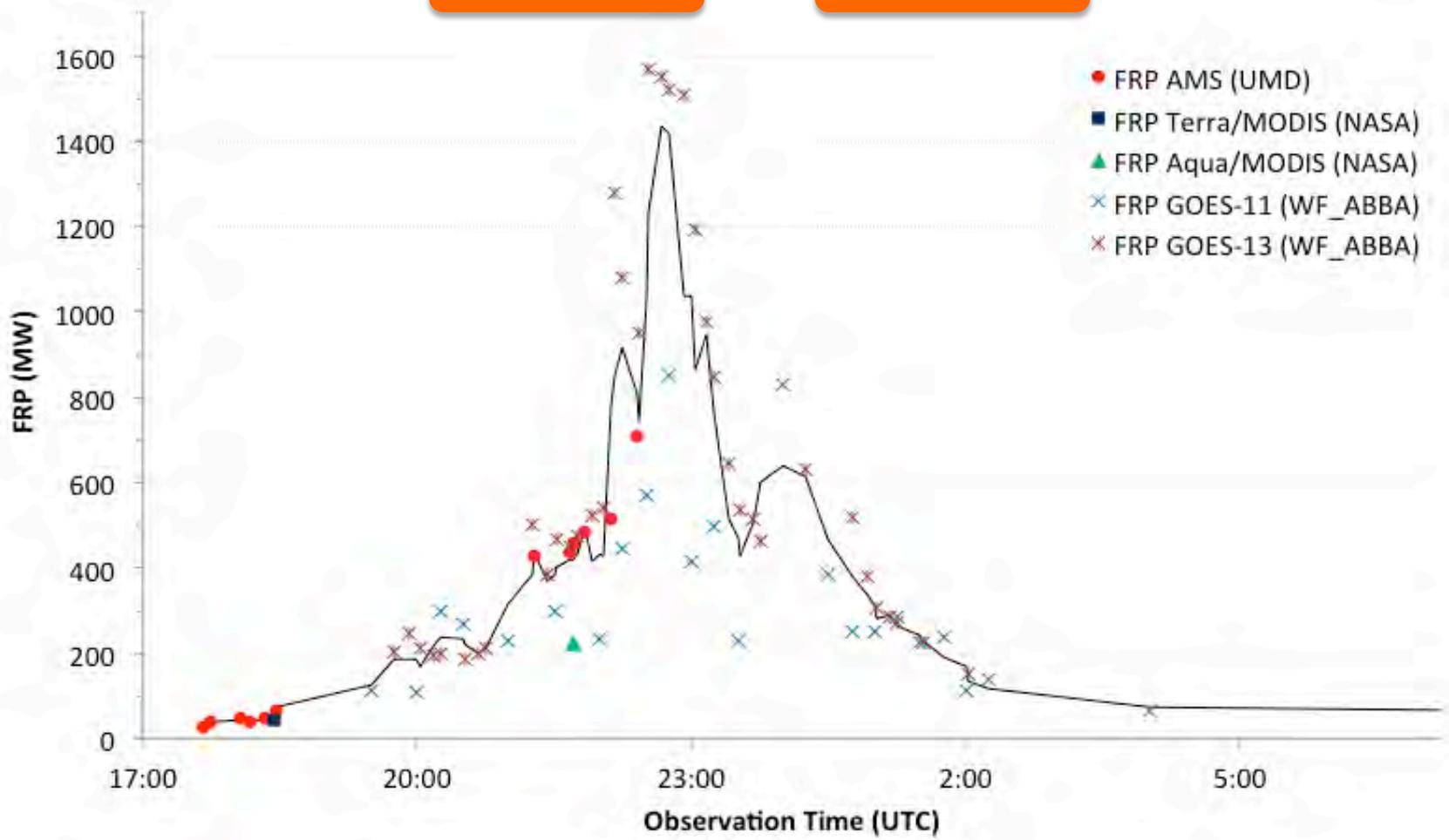


Minutes

Airborne
(NASA/AMS)



Spaceborne
(MODIS&GOES)



Hours

Linking Ground, Airborne, and Satellite Measurements

Radiation measurements overview

Satellite retrievals	S5, L2F (VIIRS) MODIS - at least one large unit
Manned aircraft - WASP system	L2F, L1G, and L2G
Dual-band radiometers @ 20 ft	All small plots (distributed) All HIPS on large burns
UAS measurements	2-3 platforms/sensors - all burns

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Acknowledgements

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Rocky Mountain
Research
Stations

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David Peterson - U. Nebraska

(Other lesser supporters)