Integrating Remote Sensing and Meteorological Technologies to Improve Fire Weather Research

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Acknowledgements

Dr. Jun Wang, University of Nebraska (Lincoln)
Dr. Charles Ichoku, NASA Goddard Space Flight Center
Dr. Lorraine Remer, NASA Goddard Space Flight Center

ECSA Junior Faculty Forum: 7/14/2010

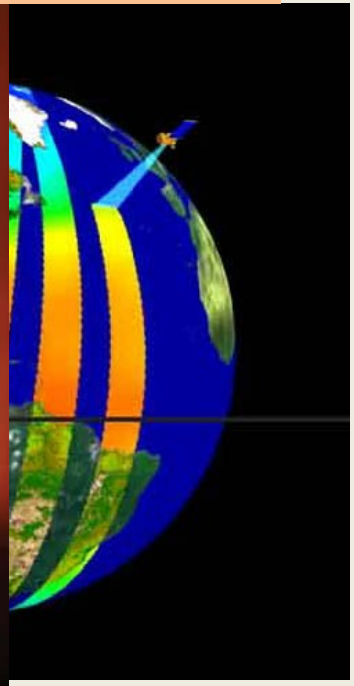
About Me...

Ph.D. student at the University of Nebraska (Lincoln)

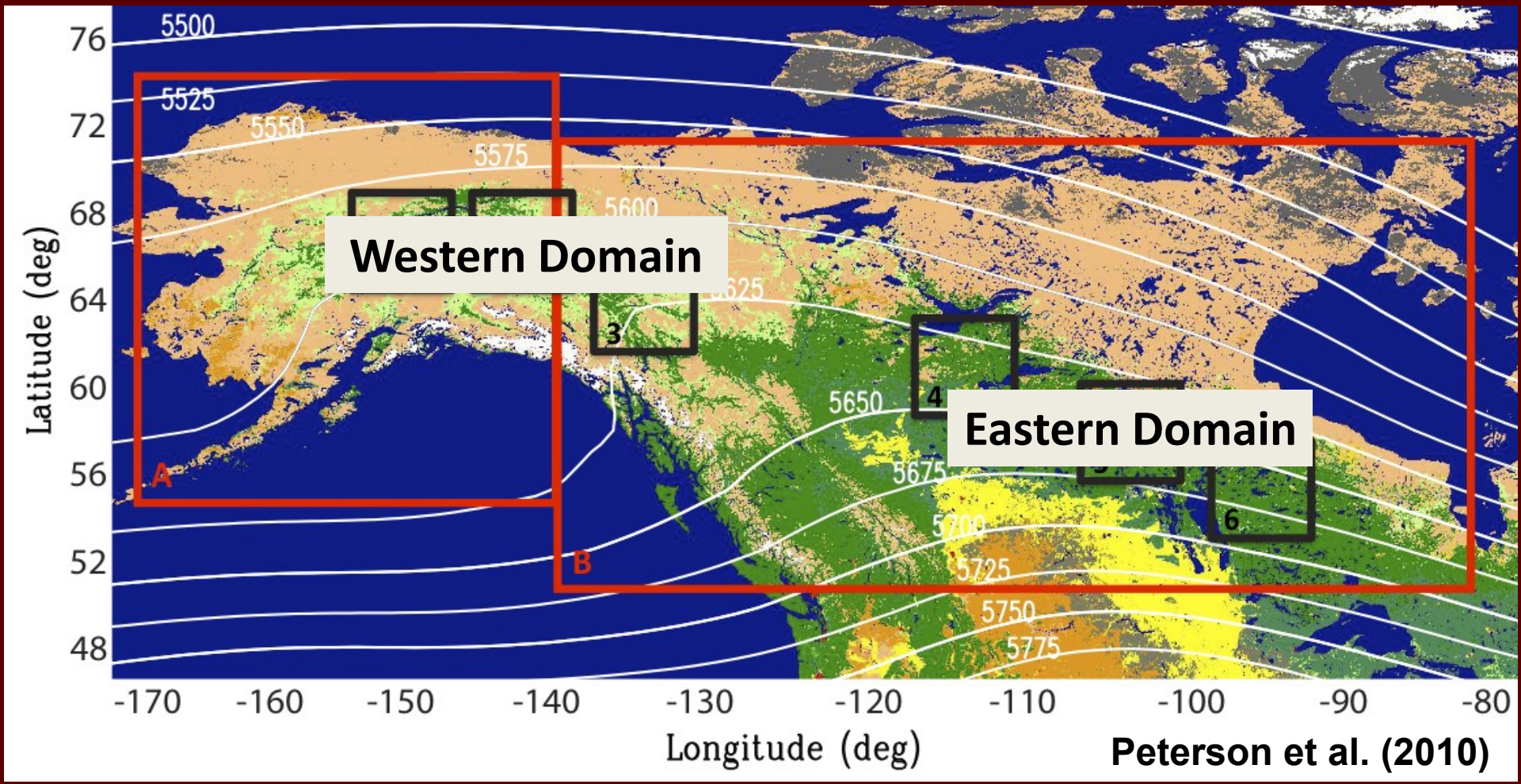
- Adviser: Dr. Jun Wang

Research Interests

Meteorology **Remote Sensing**



Meteorological Focus

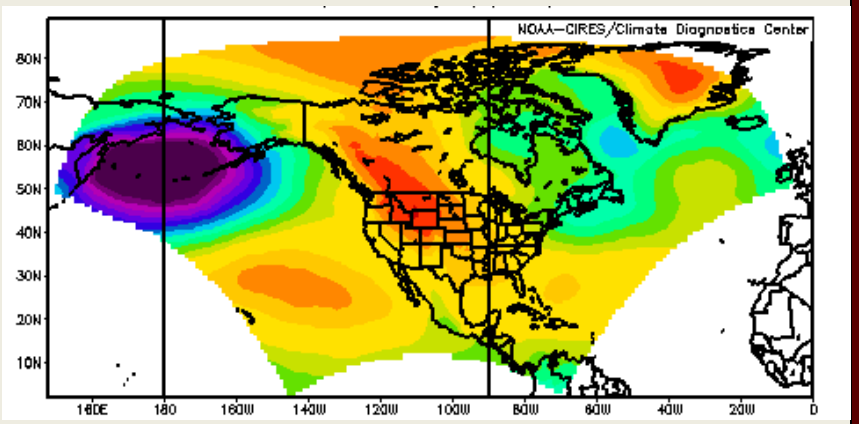


Peterson et al. (2010)

Data Integration

North American Regional Reanalysis (NARR)

- 32 km version of the NCEP 1993 operational ETA model and ETA data assimilation system (EDAS)
- Monthly and 3-hourly data



Years of data: 2000 – 2006

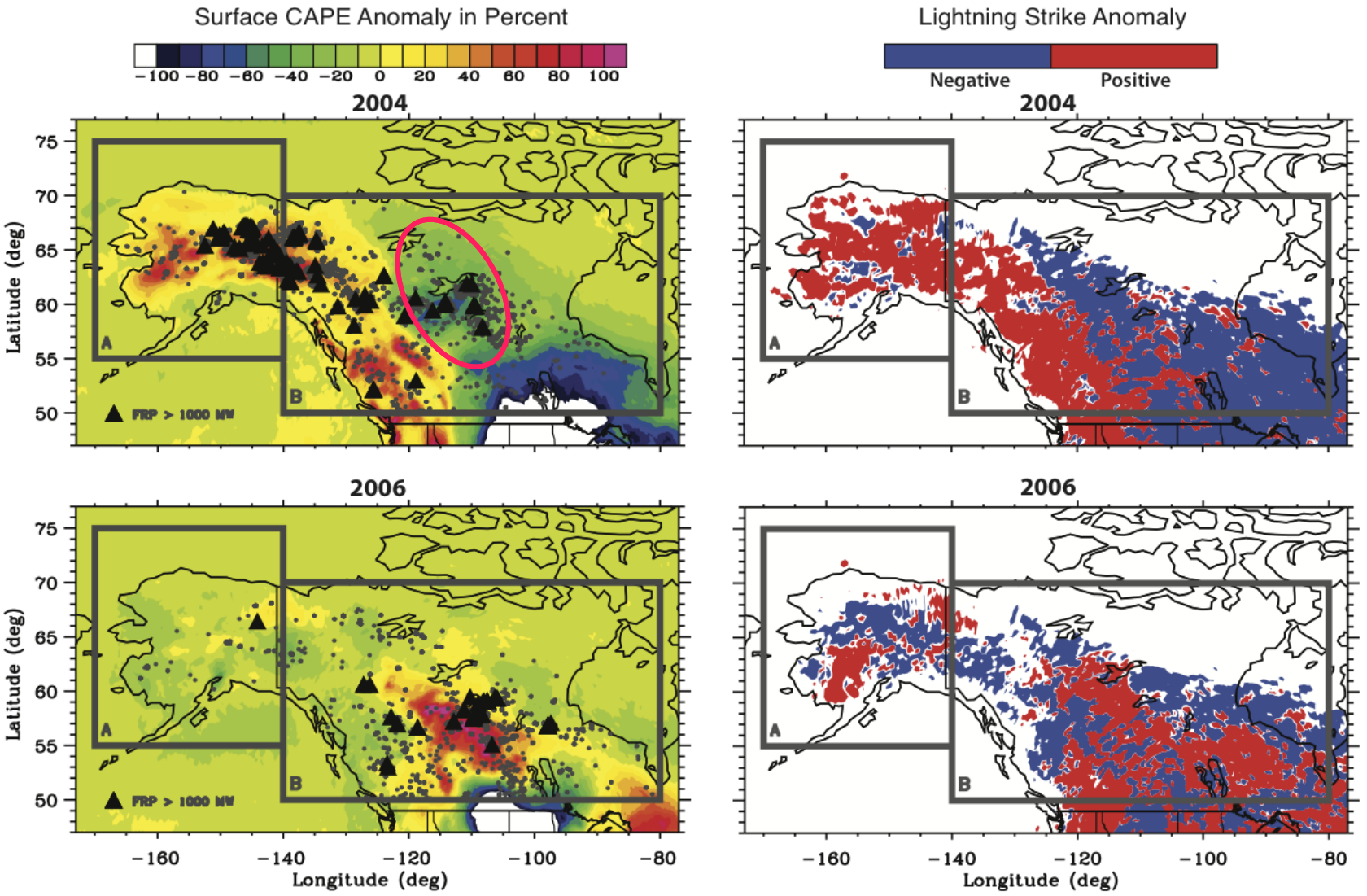
Lightning Strike Data:

- Environment Canada:
  Canada Lightning Detection Network (CLDN)
- Bureau of Land Management:
  Alaska Lightning Detection Network (ALDN)

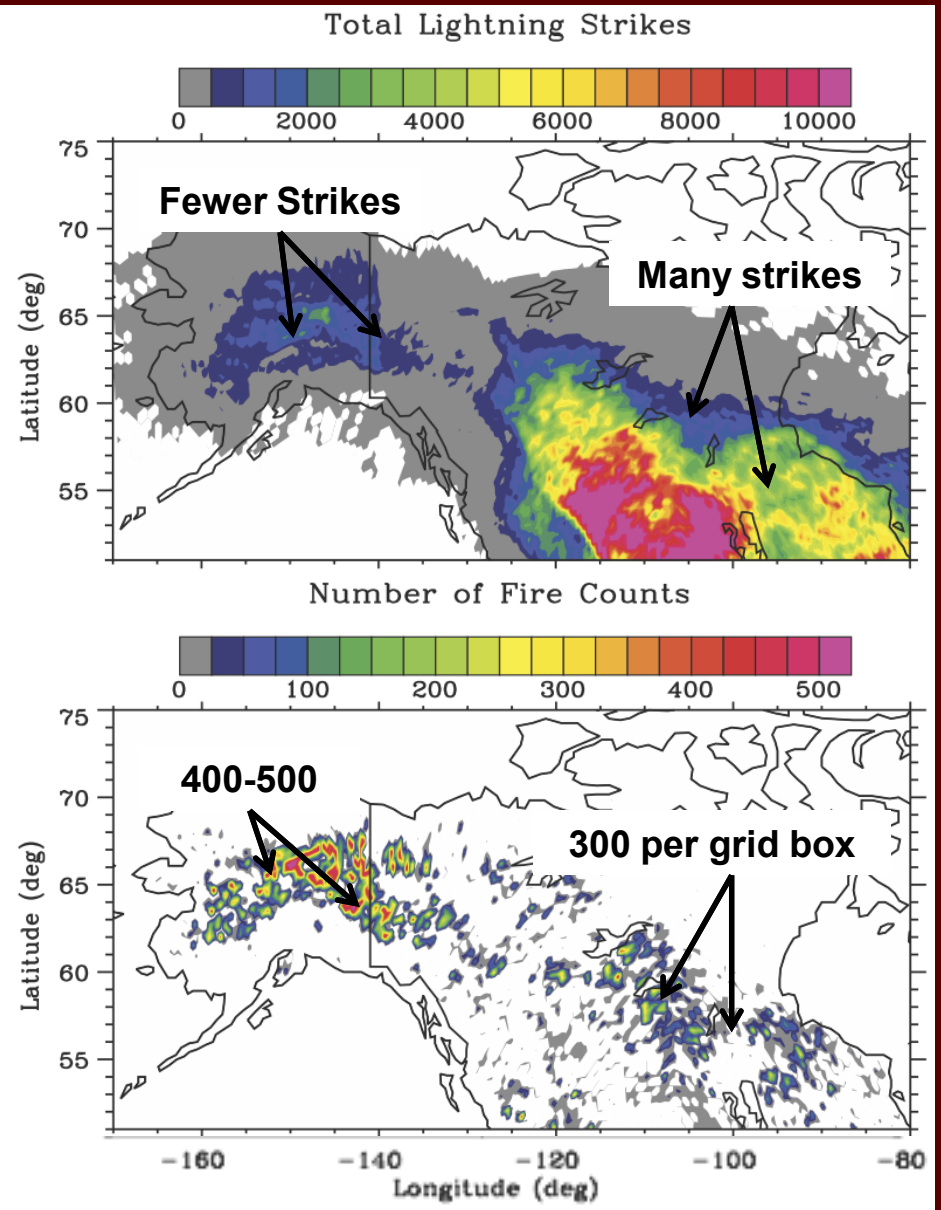
Satellite Fire Data (MODIS):

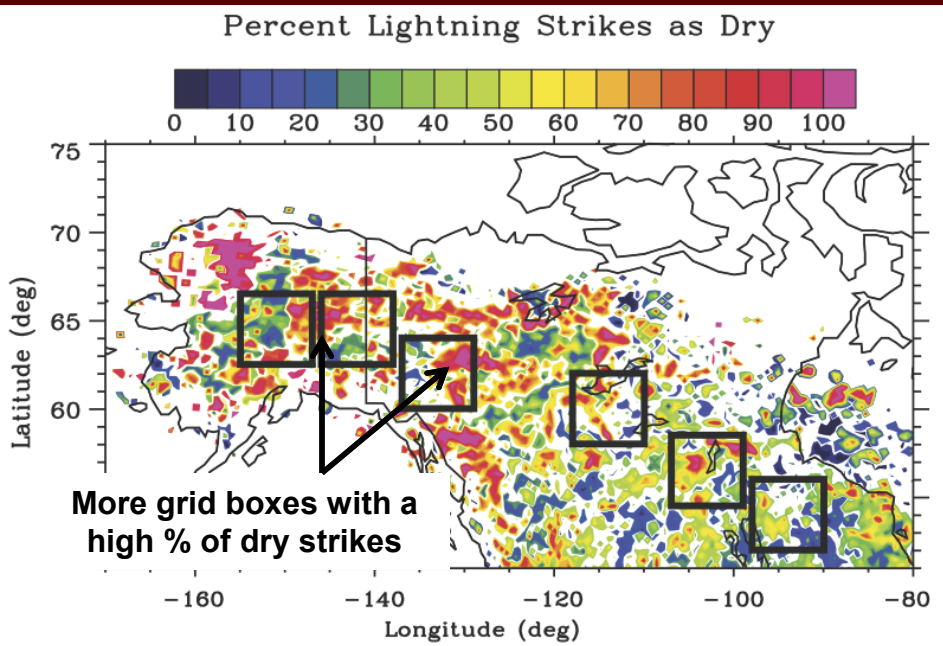
- Day overpass fire counts and fire radiative power (FRP) as used in Ichoku et al. (2008)

Impact of CAPE and Lightning on Fire Activity

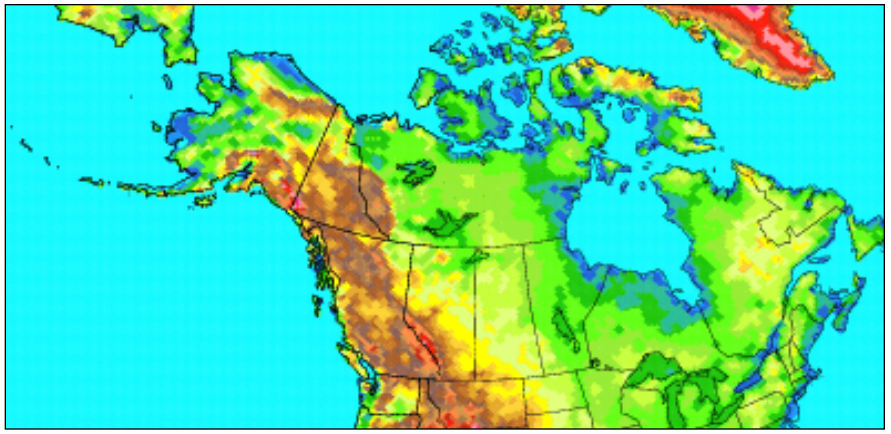


Fine-Scale Observations: 2000 – 2006

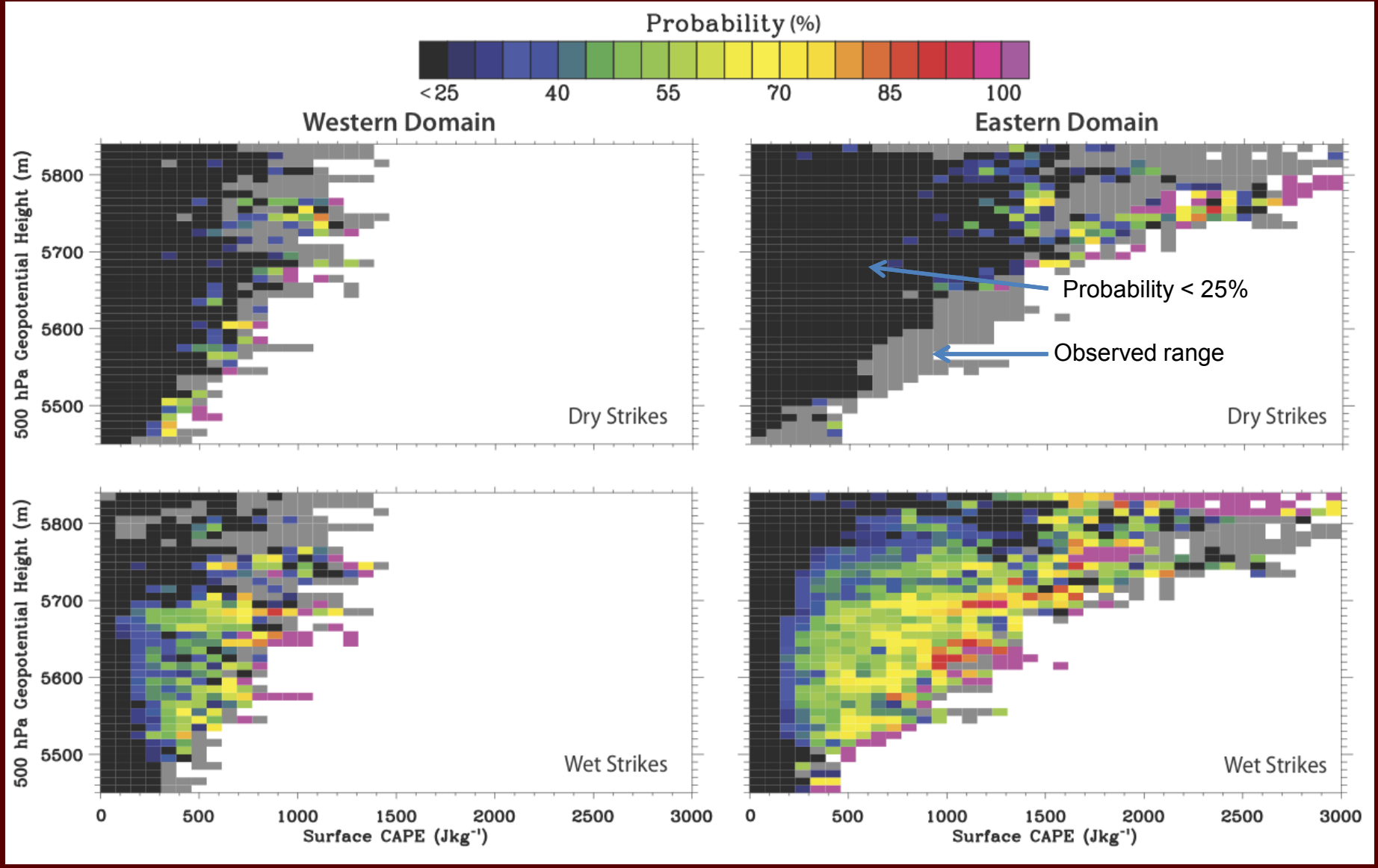




North American Topographic Map

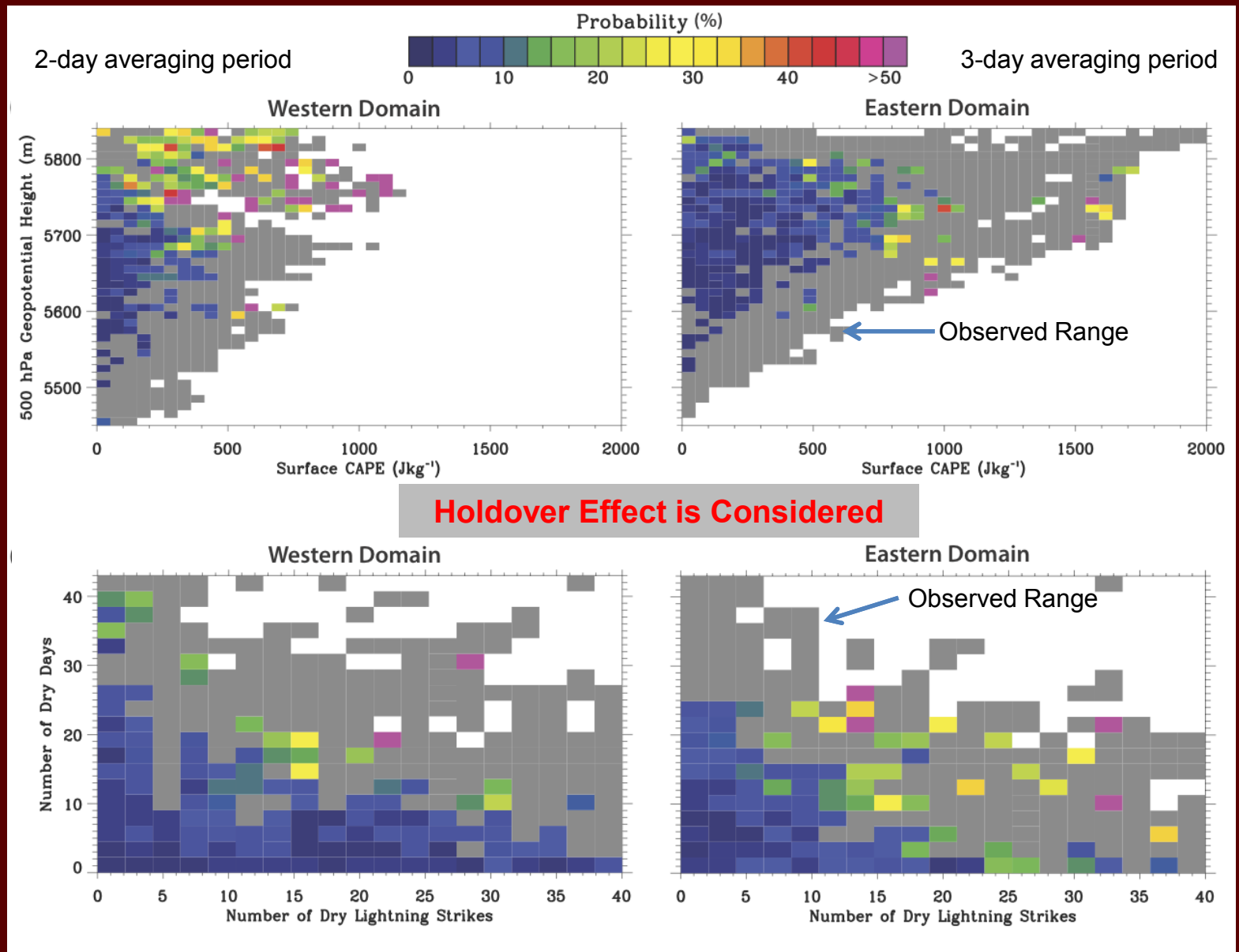


Under what conditions do dry and wet lightning occur?

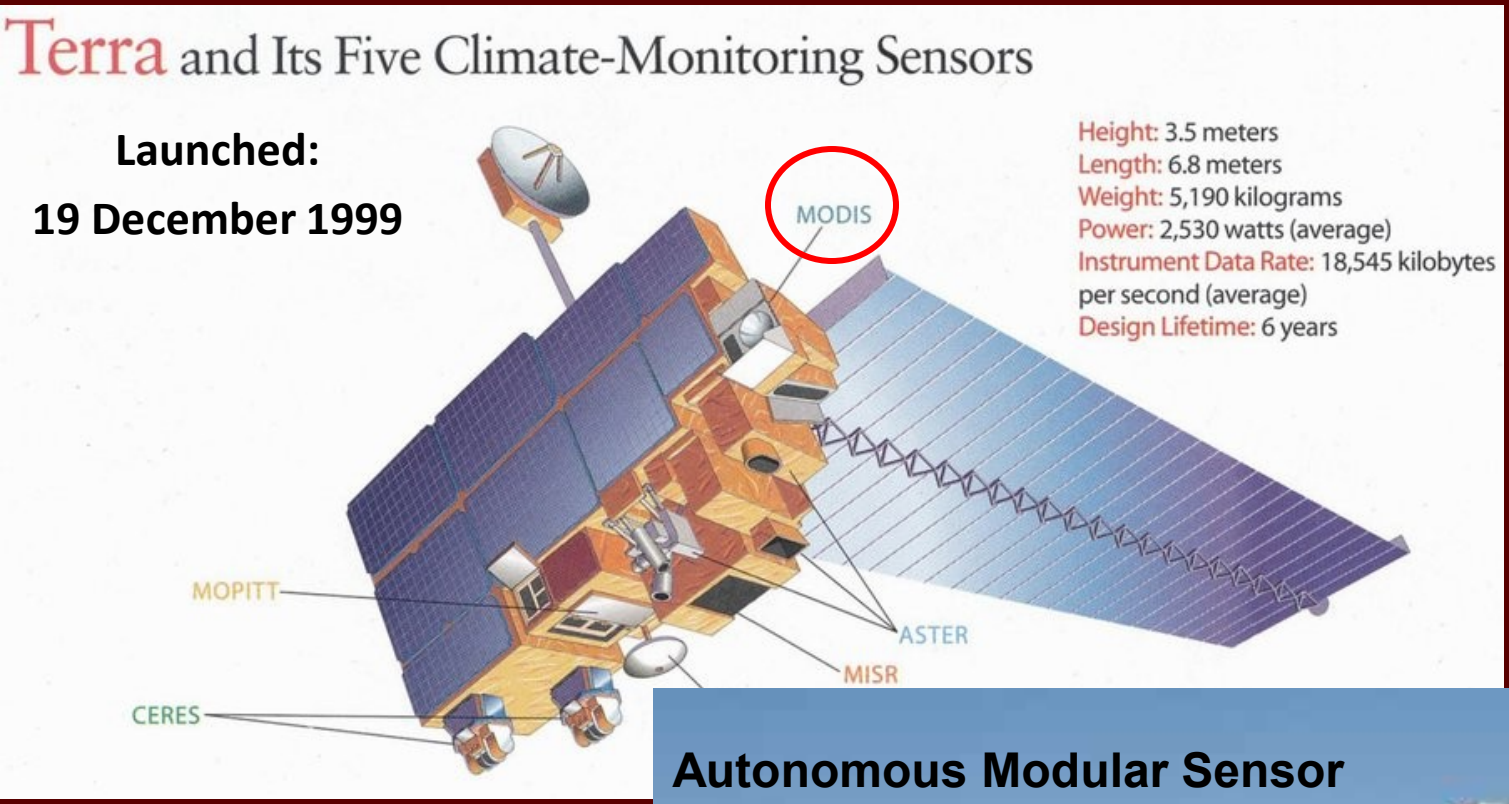


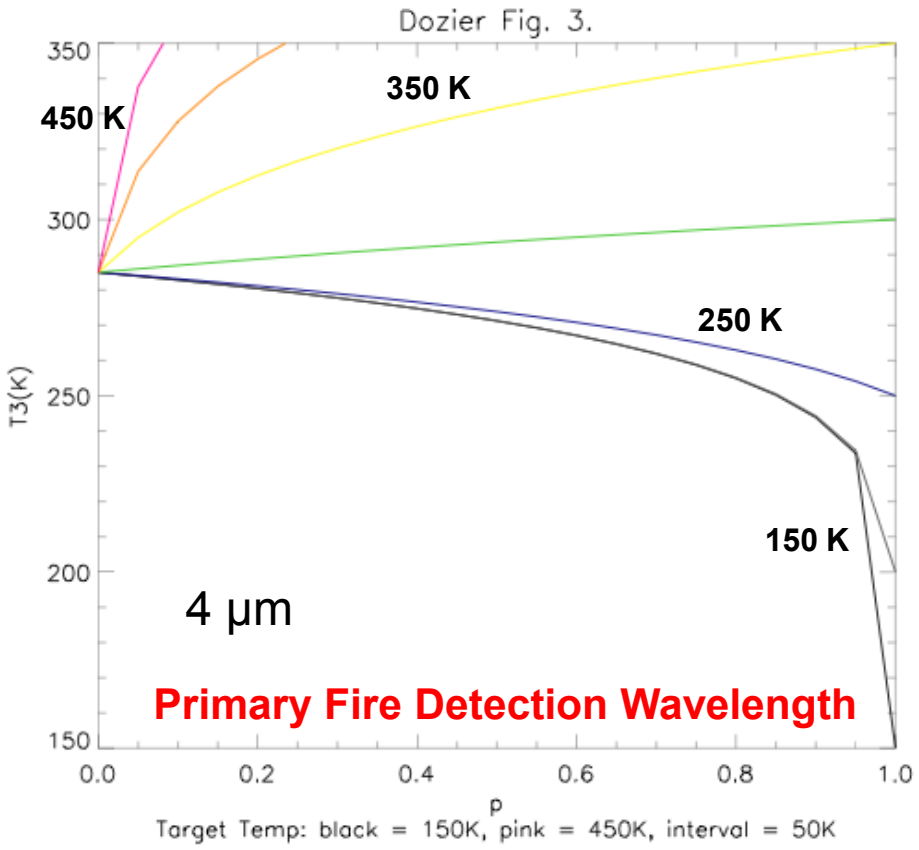
Under what conditions do dry strikes ignite fires?

Joint Probability ("hits and misses" analysis)



Remote Sensing Focus

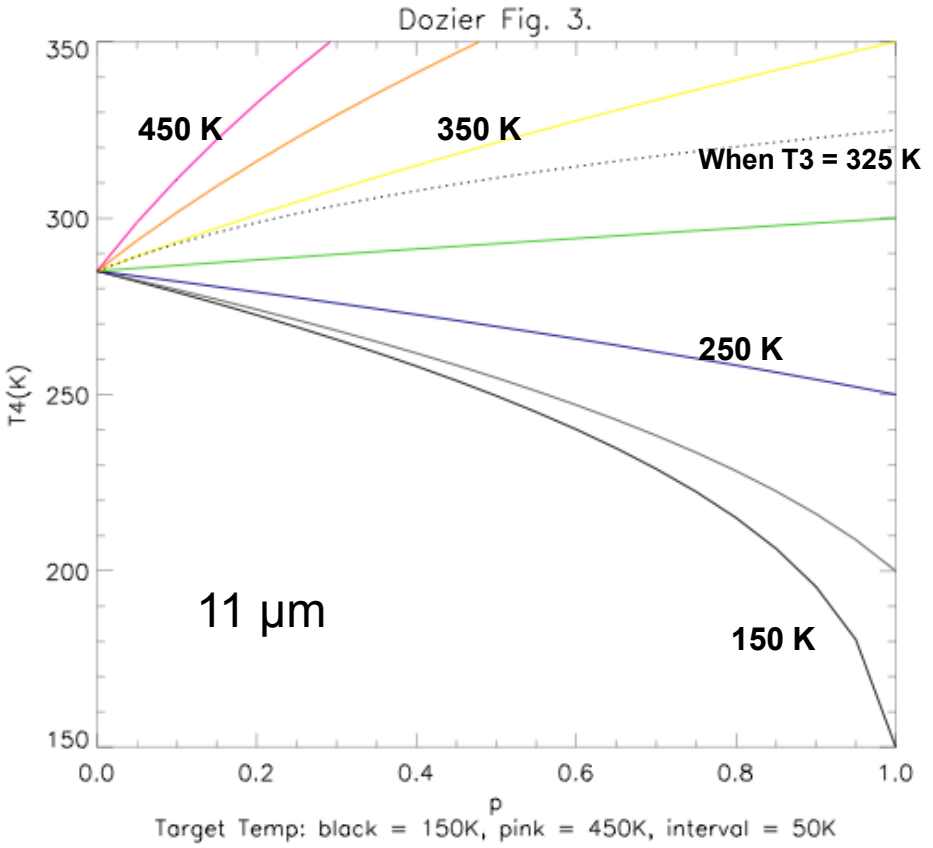




Dozier, 1981 (early study)

Varying the fire (target) temp...

Background temp = 285 K



4 and 11 μm (IR) channels

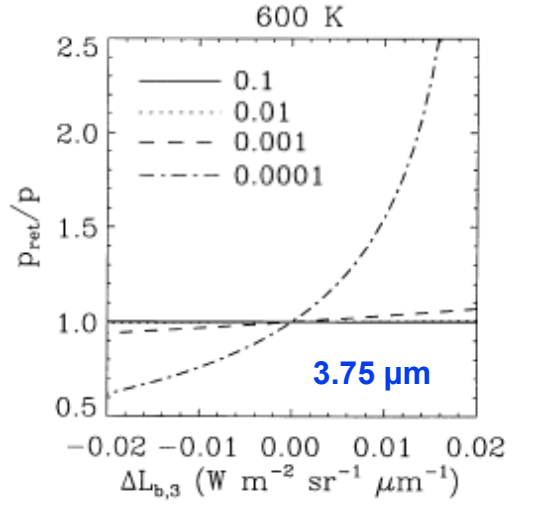
$$L_4(T) = P\,L_4(T_f) + (1\text{-}P)\;L_4(T_b)$$
$$L_{11}(T) = P\,L_{11}(T_f) + (1\text{-}P)\,L_{11}(T_b)$$

L: IR Planck function
P: fire area fraction

Background and Motivation

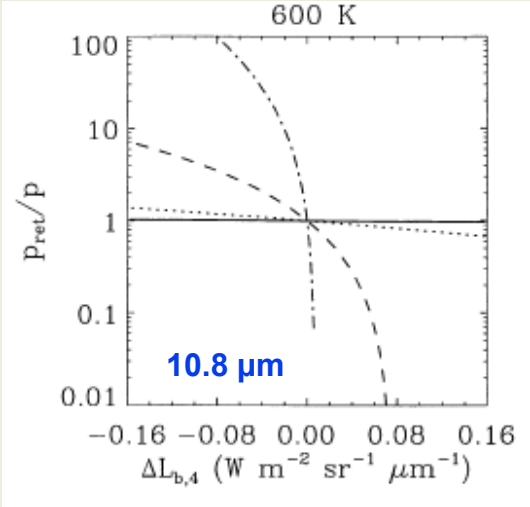
Post Dozier Era

- Giglio and Kendall (2000) tested the method for various fire area fractions
- Sensitivity analysis
- The smallest detectable fire area fraction for MODIS is > ~0.003

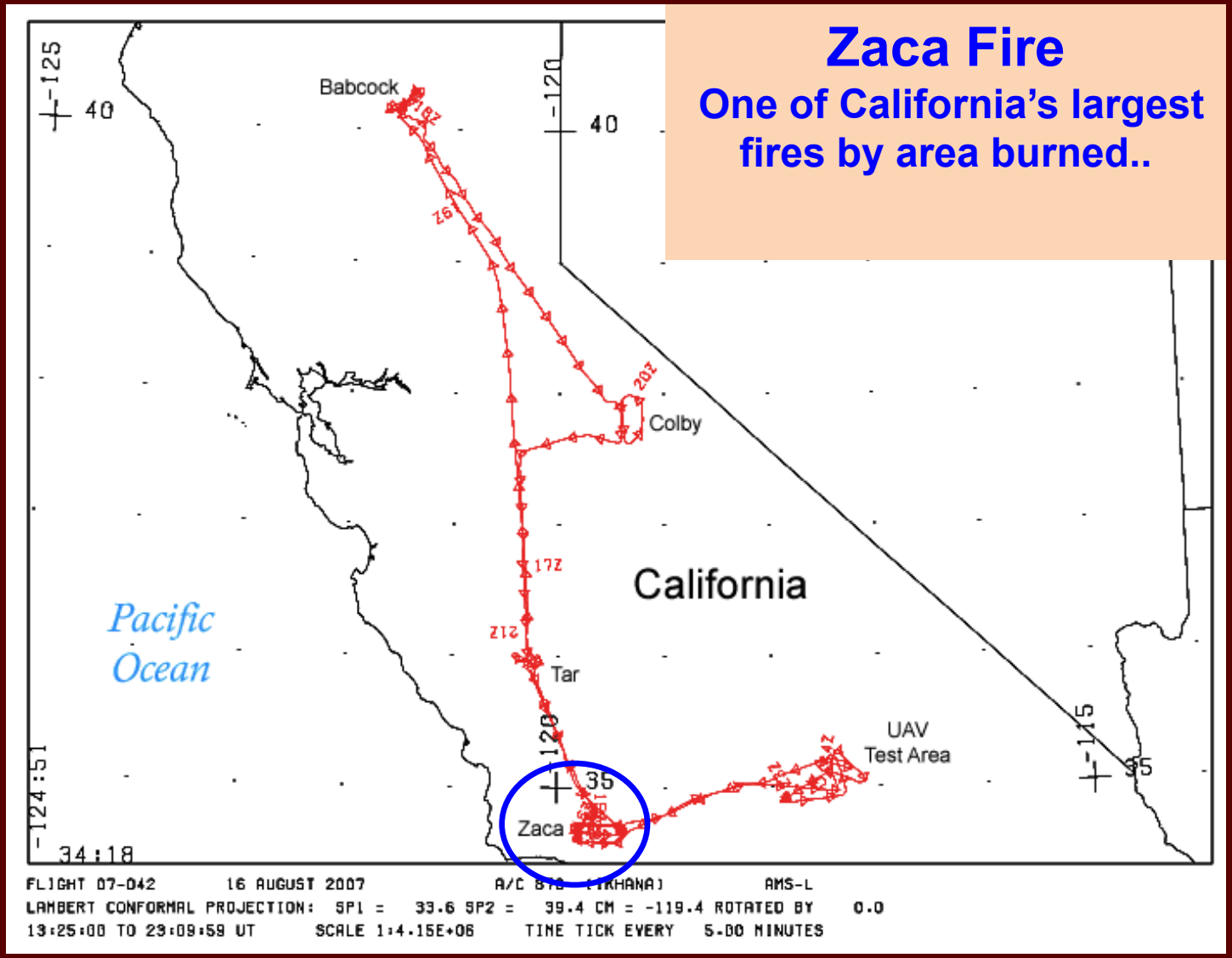


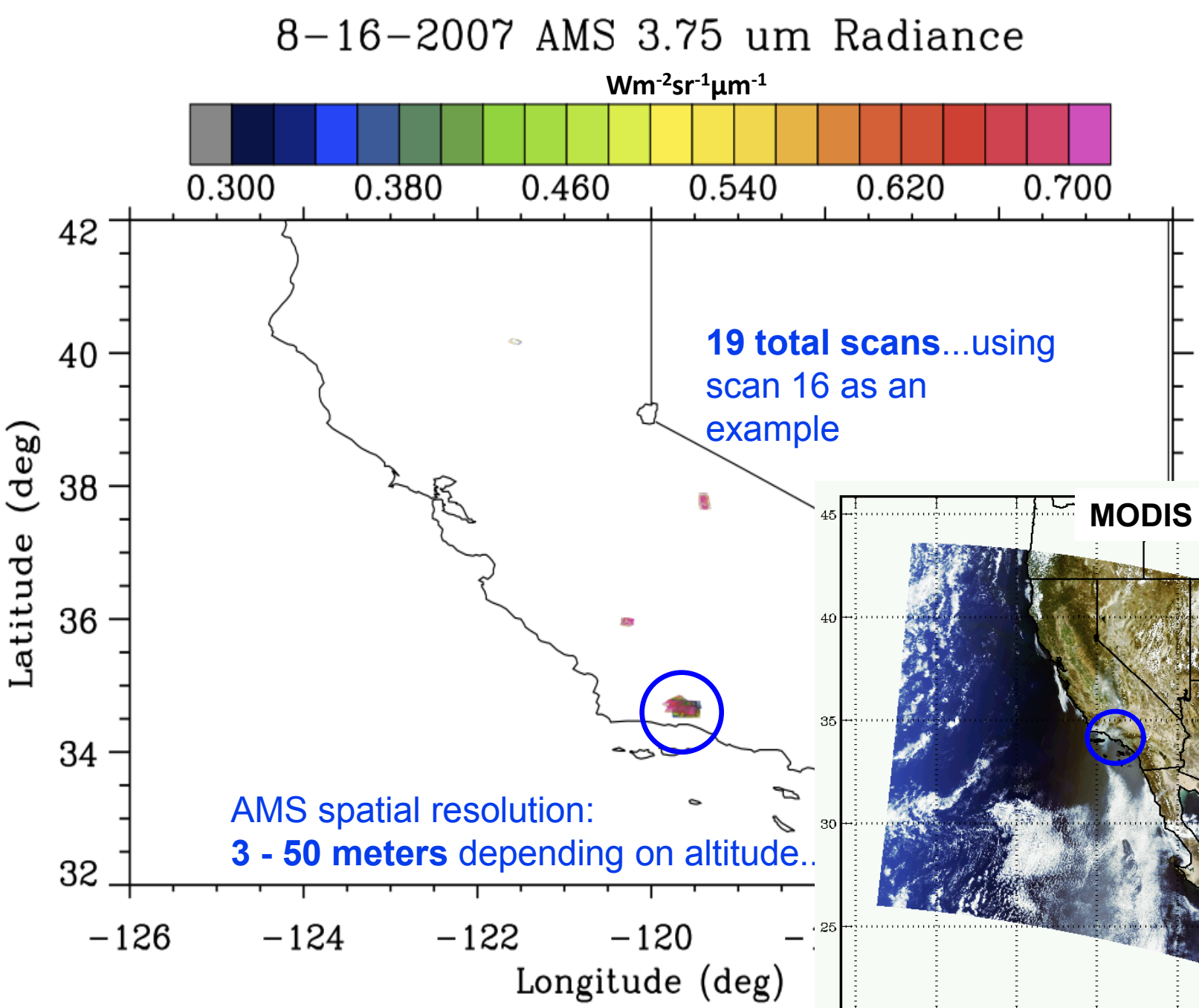
Motivation

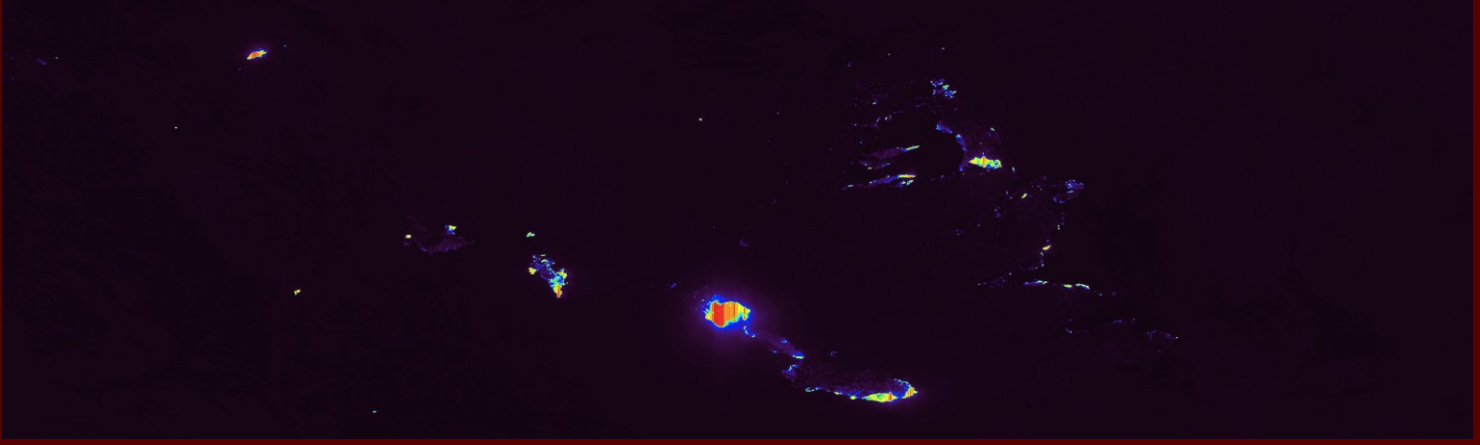
- Improved fire radiative power (FRP) data...
- Currently, MODIS FRP is normalized by the pixel area, **not fire area**
  - Statistically, how accurate is the method (at the sub-pixel level)?
  - Validation using AMS data



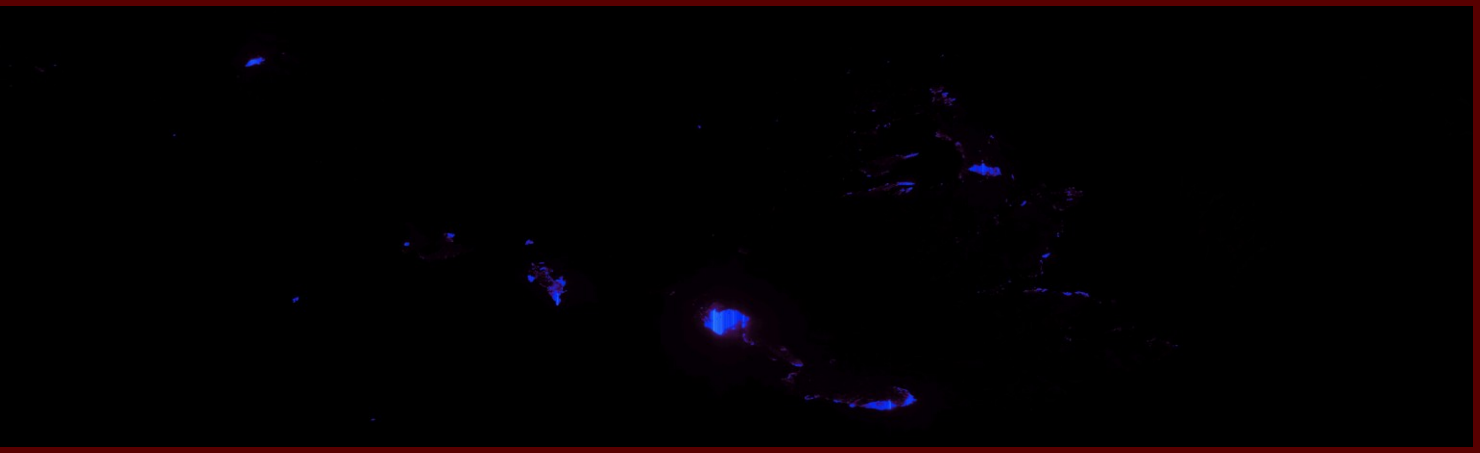
UAV (AMS) Flight Path: 8/16/2007




8–16–2007 AMS 3.75 um Radiance
Wm-2sr-1µm-1
0.300
0.380
0.460
0.540
0.620
0.700
42
40
38
36
34
32
Latitude (deg)
–126
–124
–122
–120
Longitude (deg)
19 total scans...using scan 16 as an example
AMS spatial resolution:
3 - 50 meters depending on altitude..
MODIS True Color
45
40
35
30
25



3.75 µm

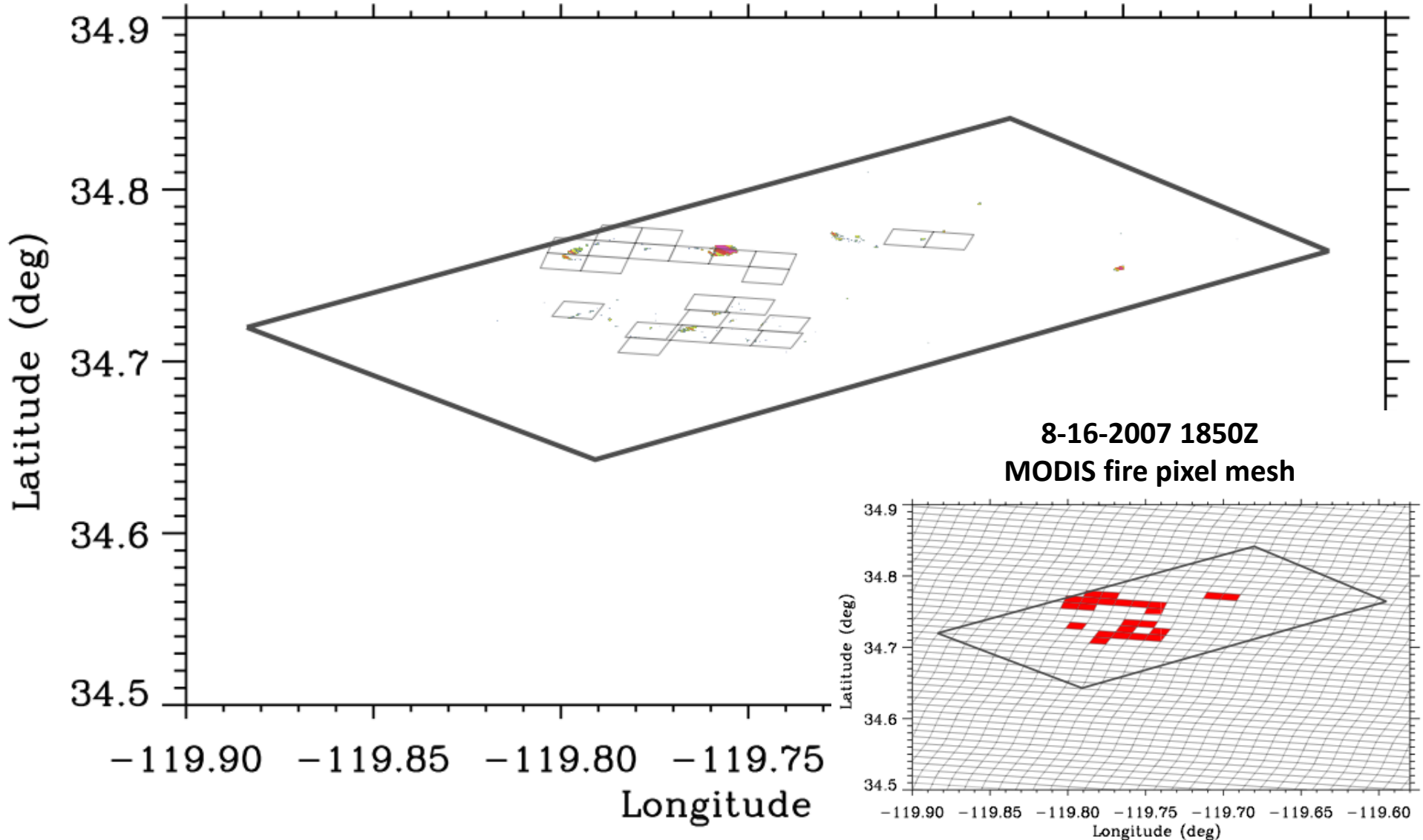


10.19 µm

VIS

8-16-2007 2133Z AMS (hot spots) and MODIS fire pixels

Shading indicates fire hot spots: 3.75 µm Brightness Temp. > 500 K



8-16-2007 1850Z
MODIS fire pixel mesh

LOOKUP TABLE
SBDART Radiative Transfer Model
- Account for atmospheric effects
- Vary the potential geometries
- Vary the surface temp. (bottom of atmosphere)

⇩

MODIS INPUTS
- Geolocation data
- Level 1B radiances
- Fire product background temps.

⇩

SOLVE DOZIER EQUATIONS

⇩

OUTPUTS
- **Fire area fraction**
- **Actual (surface) fire temp.**

⇩

COMPARE OUTPUT WITH AMS
- Check for MODIS false alarms
- Investigate background temp. choices

Performing the Retrieval

Applications for the algorithm output

- Estimates of fire (hot spot) size
- Improved emissions estimates

Meteorological...

- Impacts on fire radiative power (FRP)
- Tool for fire weather forecasting
- Fire index?

4 and 11 μm (IR) channels

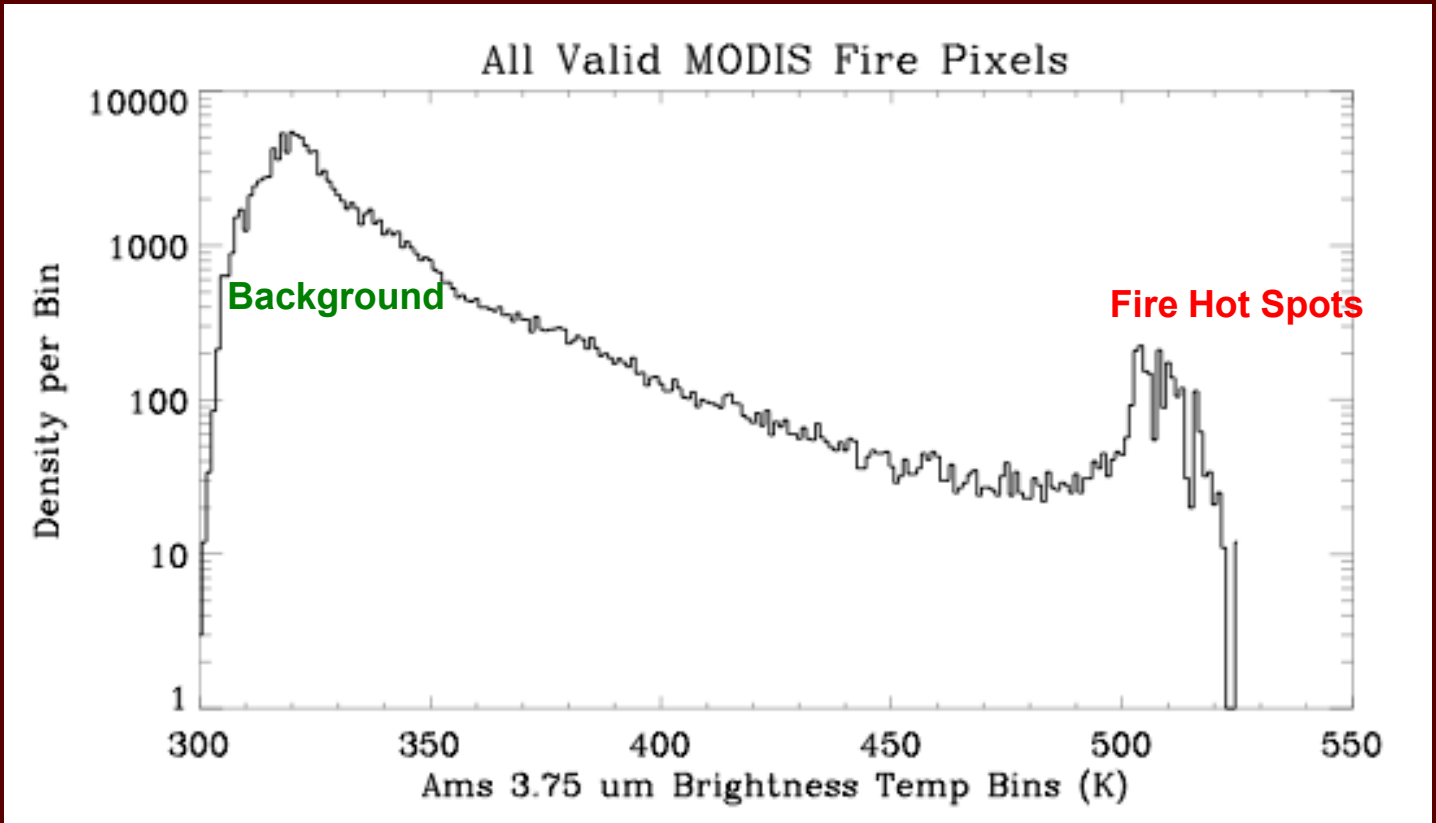
$$L_4(T) = P\,L_4(T_f) + (1-P)\,L_4(T_b)$$
$$L_{11}(T) = P\,L_{11}(T_f) + (1-P)\,L_{11}(T_b)$$

L: IR Planck function
P: fire area fraction

Validation Via AMS

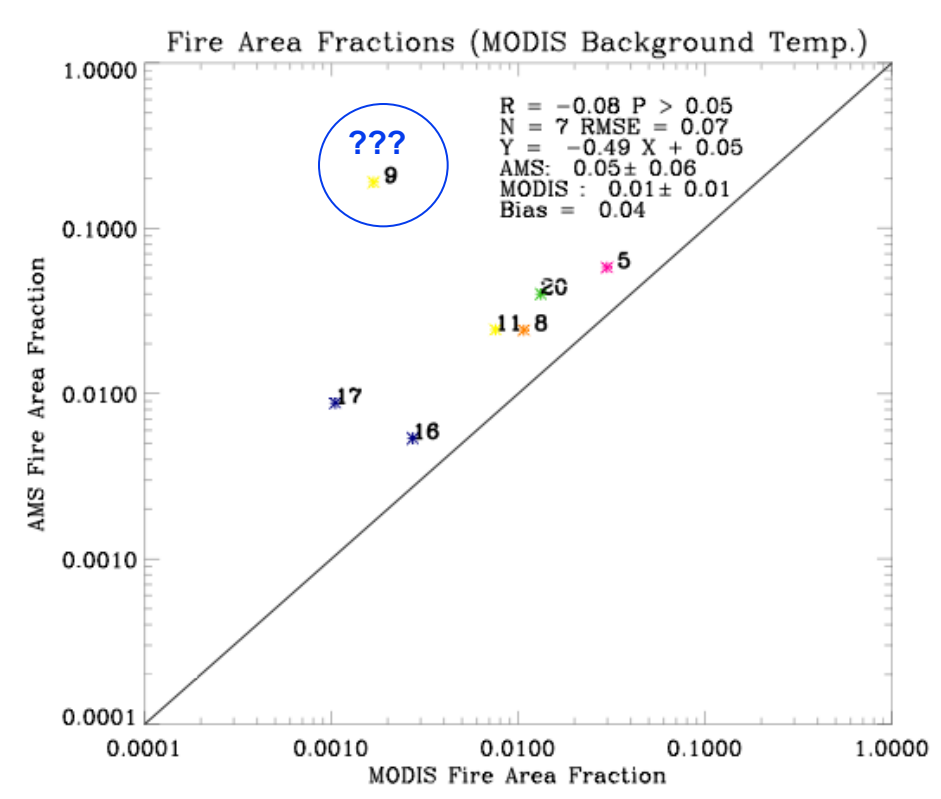
AMS fire (hot spot) threshold:
Brightness temperature at 3.75 μm (band 11) > 500 K

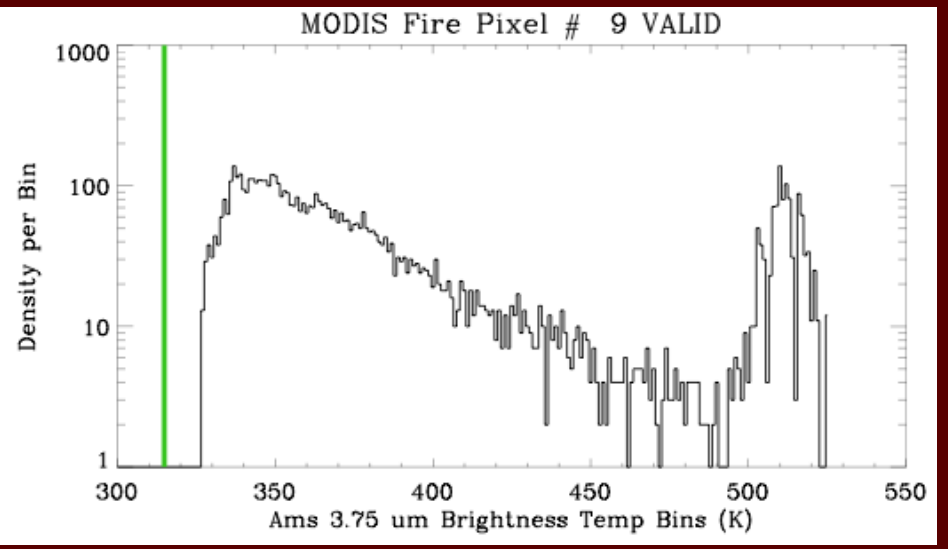
AMS background temperature:
Automated process for each MODIS footprint...

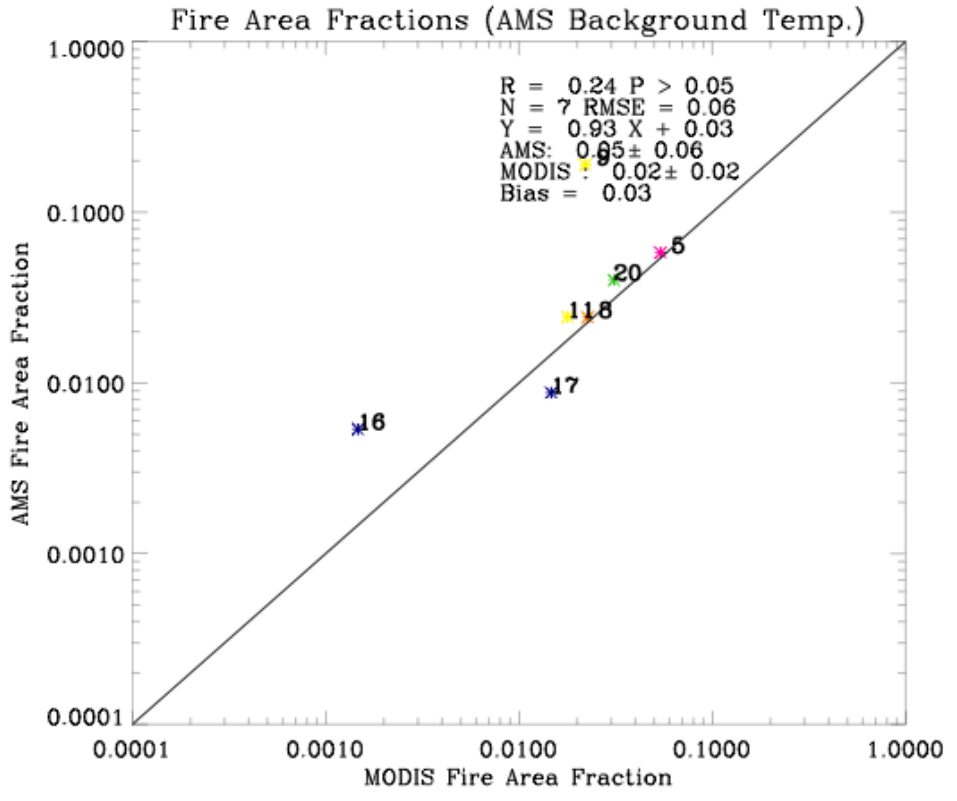


Preliminary Results

23 MODIS fire pixels
5 false alarms
7-8 with a fraction > 0.003







THANK YOU!

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Special Thanks

NASA Earth and Space Science Fellowship
NASA Earth Science New Investigator Program (Jun Wang)
NASA Graduate Student Summer Program
Environment Canada
Bureau of Land Management (Alaska)

Holdover Fires (Lag Effect)

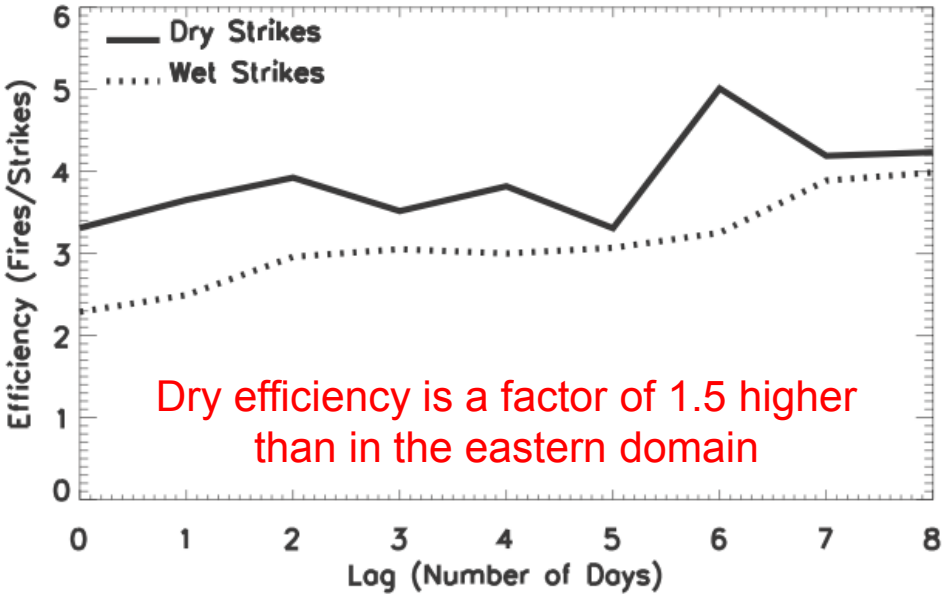
- Fire may smolder for several days before it's observed...
- When was the fire actually started?

Lightning Efficiency

 # fires/# lightning strikes

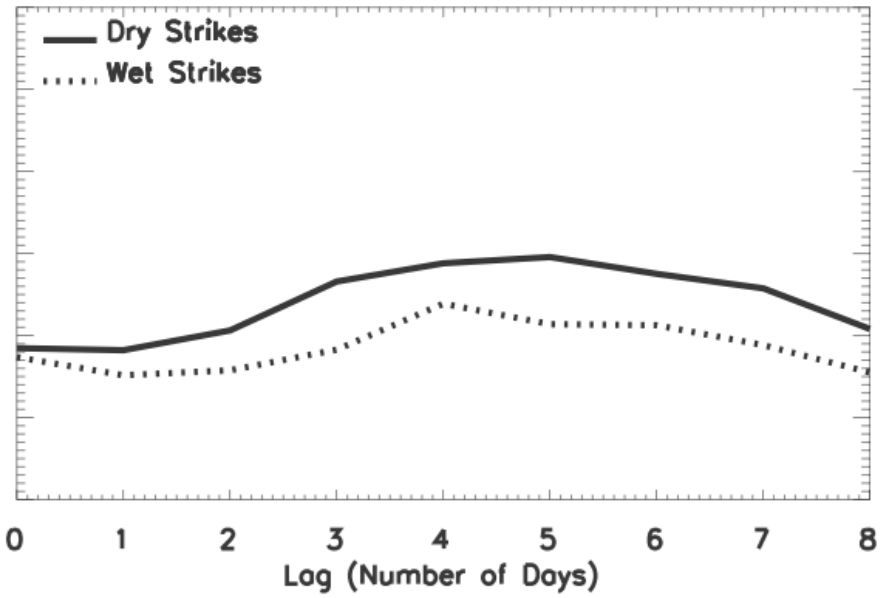
- Dry strike efficiency > wet efficiency
  - There is a wet strike influence...

Western Domain



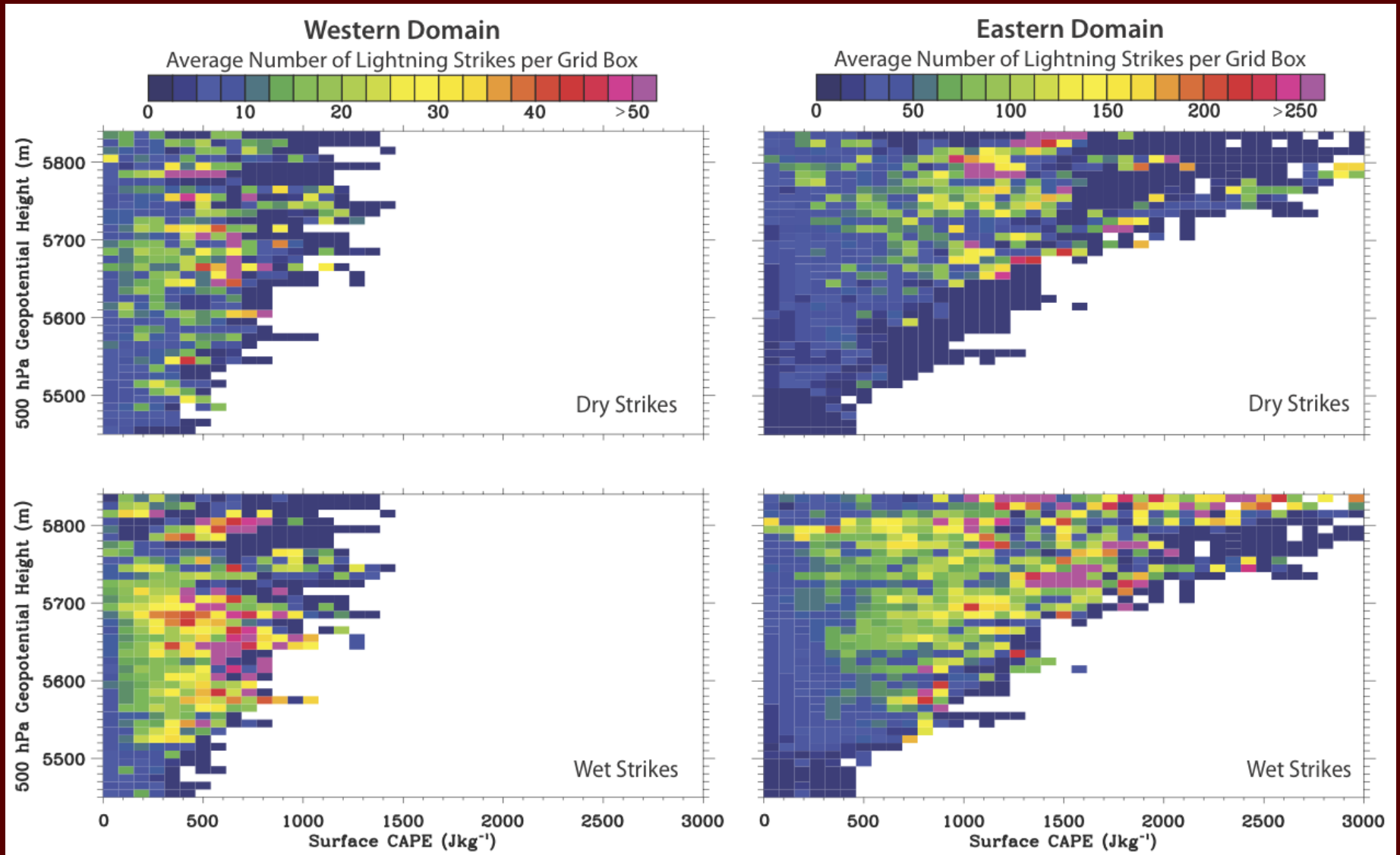
Dry efficiency is a factor of 1.5 higher than in the eastern domain

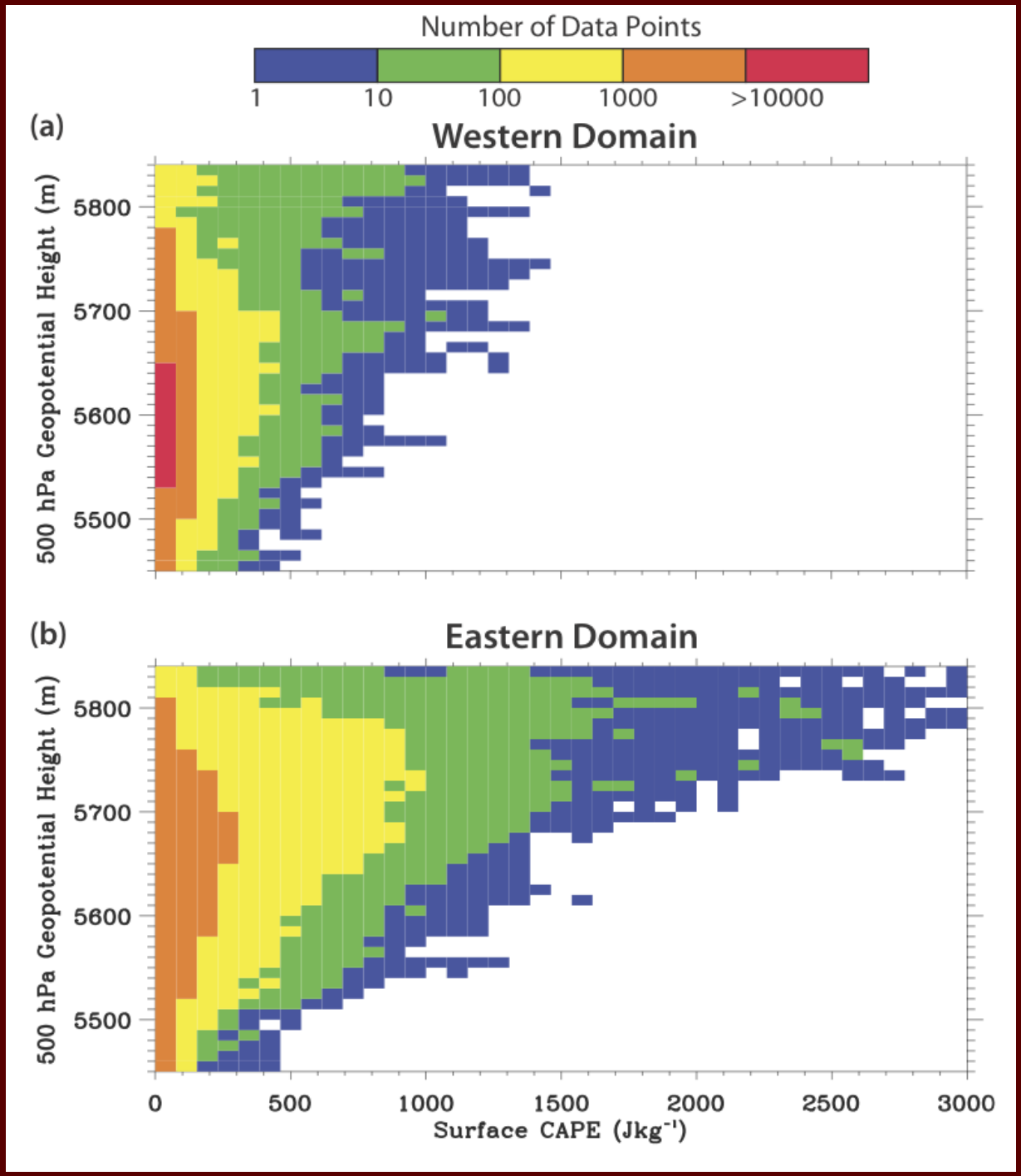
Eastern Domain



The scenarios for each fire event can be infinite.
An averaging period of 2-3 days appears to be statistically optimal.

Under what conditions do dry and wet lightning occur?




Number of Data Points
1
10
100
1000
>10000
(a)
Western Domain
500 hPa Geopotential Height (m)
5800
5700
5600
5500
(b)
Eastern Domain
500 hPa Geopotential Height (m)
5800
5700
5600
5500
0
500
1000
1500
2000
2500
3000
Surface CAPE (Jkg⁻¹)

East and West Contrast

Correlation: lightning data and fire counts

Western Domain

Interannual data:

Fire counts: 10-34000

Max dry strikes: 23000

- **Positive relationship with lightning (all temporal windows)**
- **Limited large-scale variability**

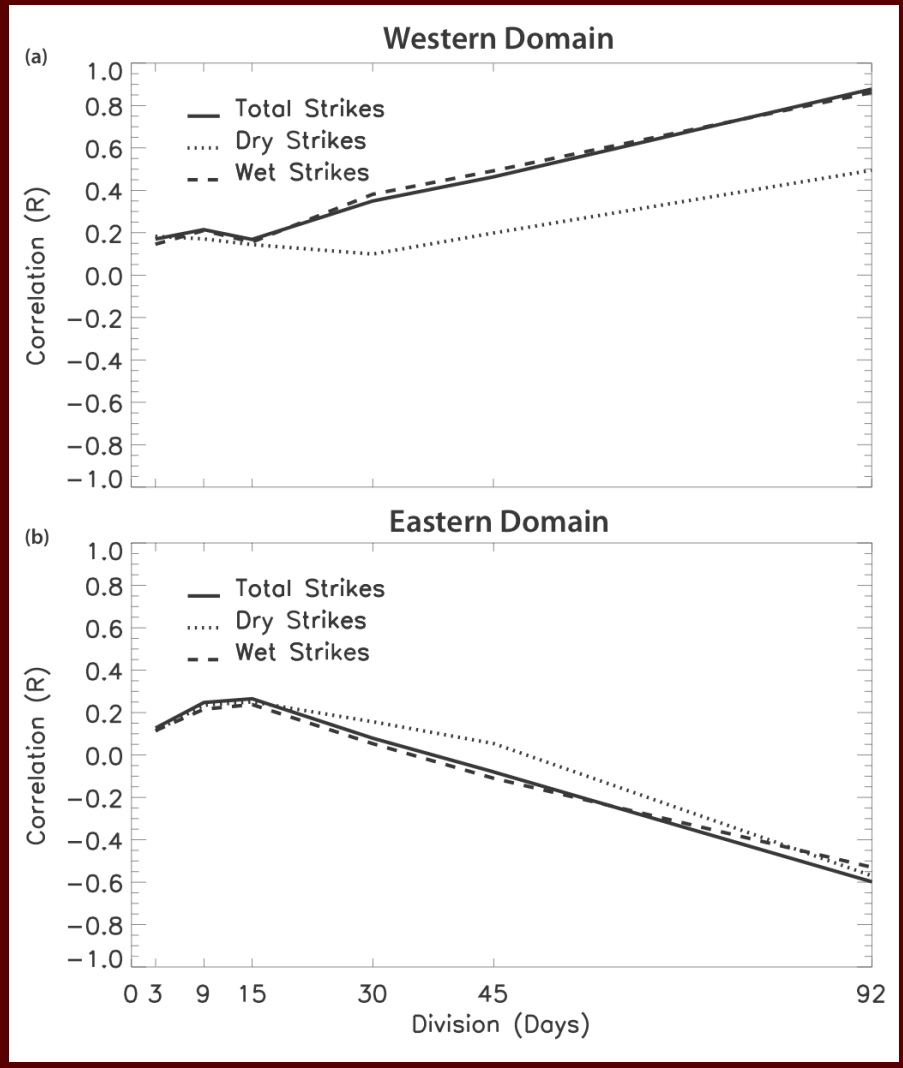
Eastern Domain

Interannual data:

Fire counts: 5-5100

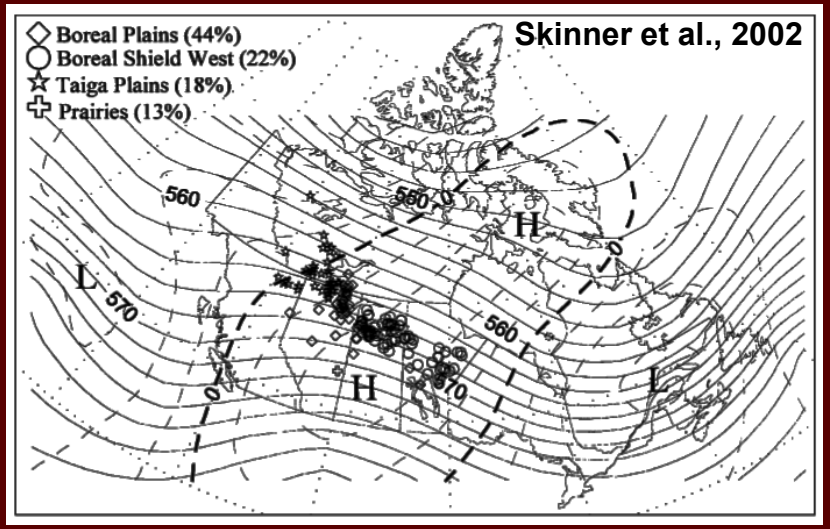
Max dry strikes: 100000

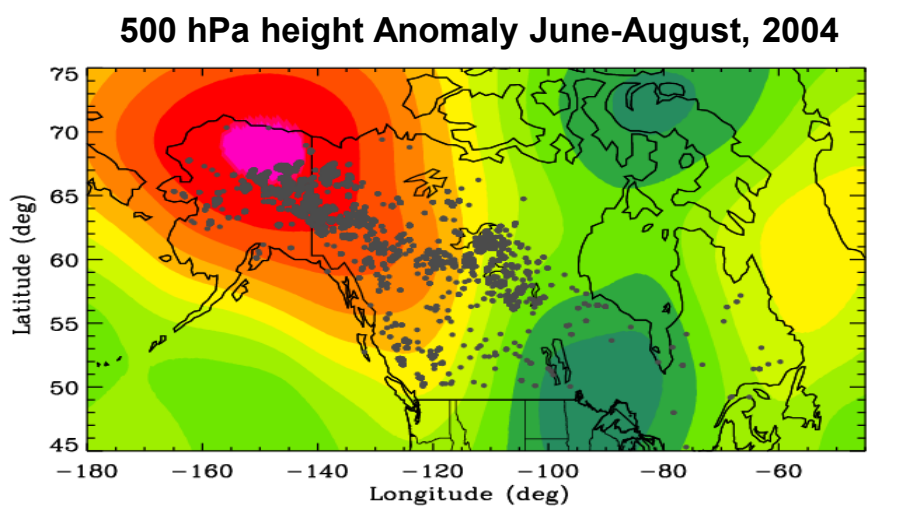
- **Negative relationship with lightning (after 10-15 days)**
- **Transient environment**

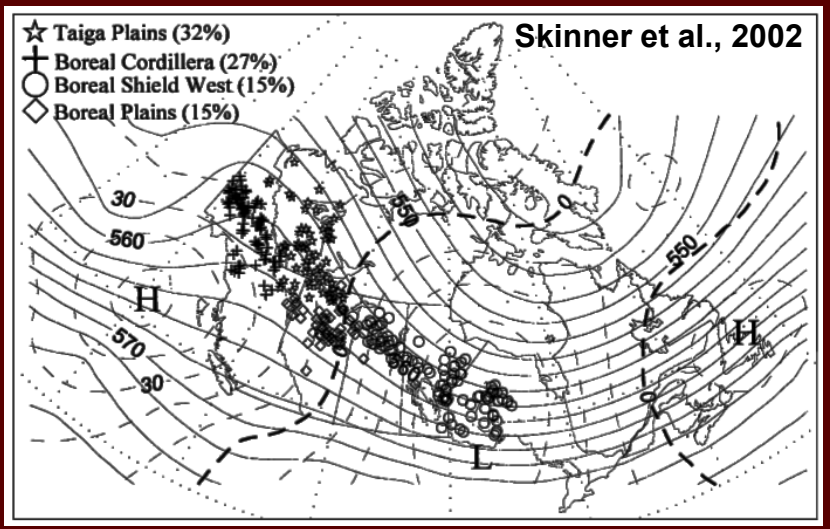


Synoptic Pattern (500 hPa)

- Positive height anomalies linked to enhanced fire activity... (Skinner et al., 1999; 2002)
- Persistence of 10 days... (Fauria and Johnson, 2006)

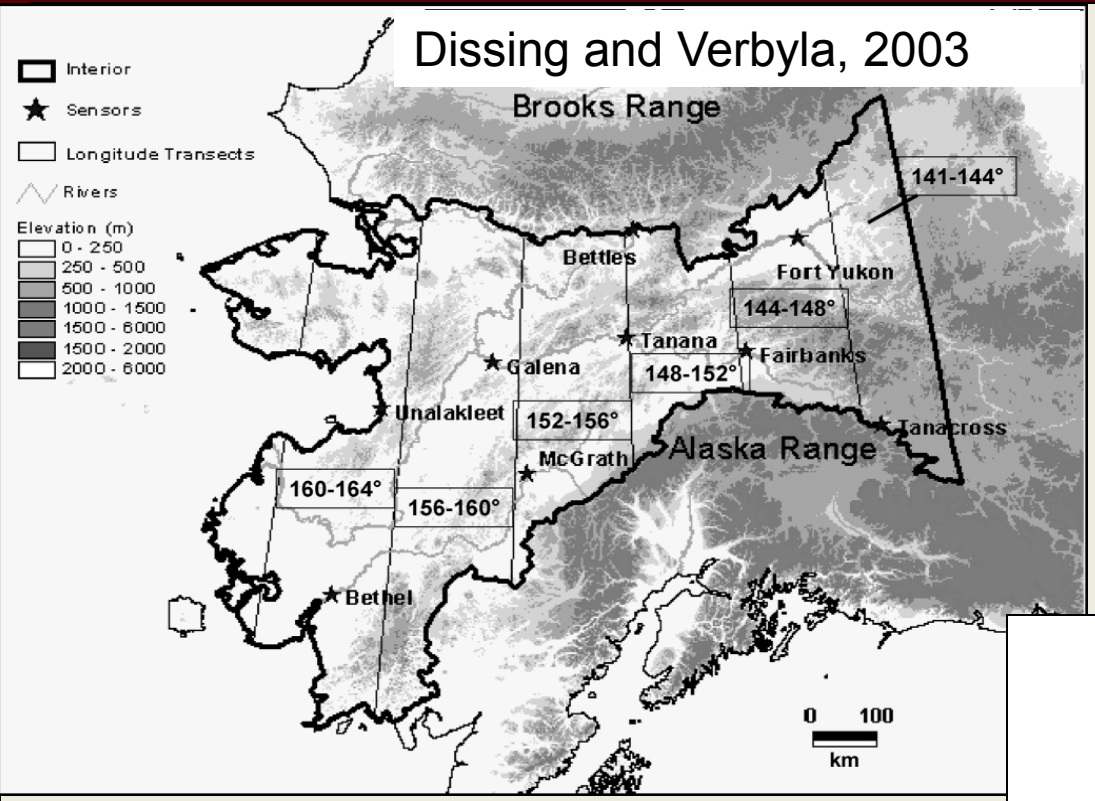






Lightning Detection

Spatial Coverage

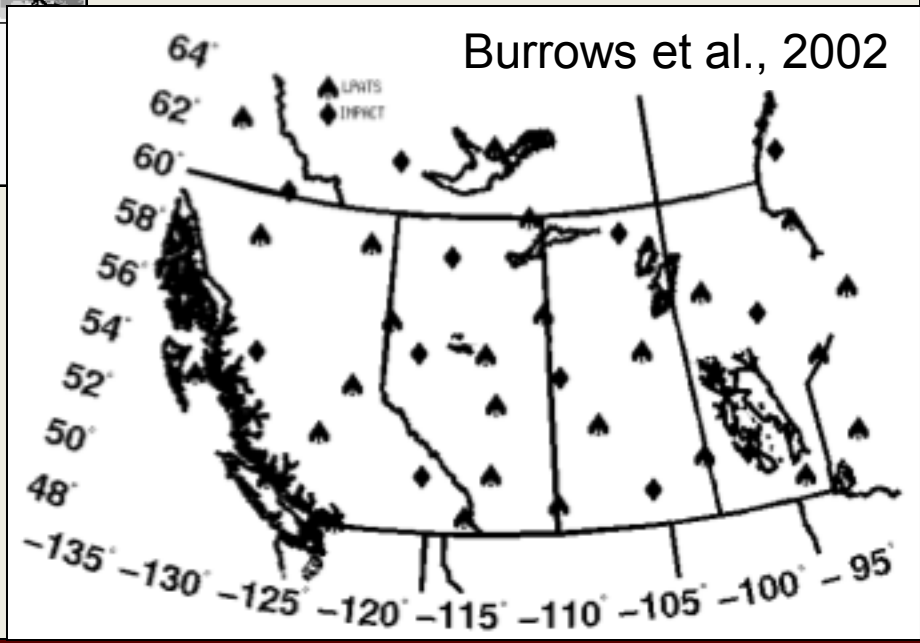


CLDN

- ~34 sensors in the study region
- Detection efficiency: 80-90 %
- Positional Accuracy: 500 meters

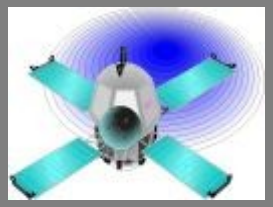
ALDN

- 9 sensors in the study region
- Detection efficiency: 80 %
- Positional Accuracy: 1000 meters



Terra MODIS

Fire Detection: 4 and 11 µm



Detects fire pixels up to 500 K

Account for cloud cover, sun glint, water reflectance, etc.

1. Absolute Detection

$T_4 > 360$ K or $T_4 - T_{11} > 25$ K

Confirm Fire Pixel

$T_4 < 310$ K or $T_4 - T_{11} < 10$ K

Pixel Disqualified

2. Relative Detection

Compare potential fire pixels with background pixels...

Potential Fire Pixels (T_f)

$T_4 > 325$ K day

$T_4 > 310$ K night

and

$T_4 - T_{11} > 20$ K day

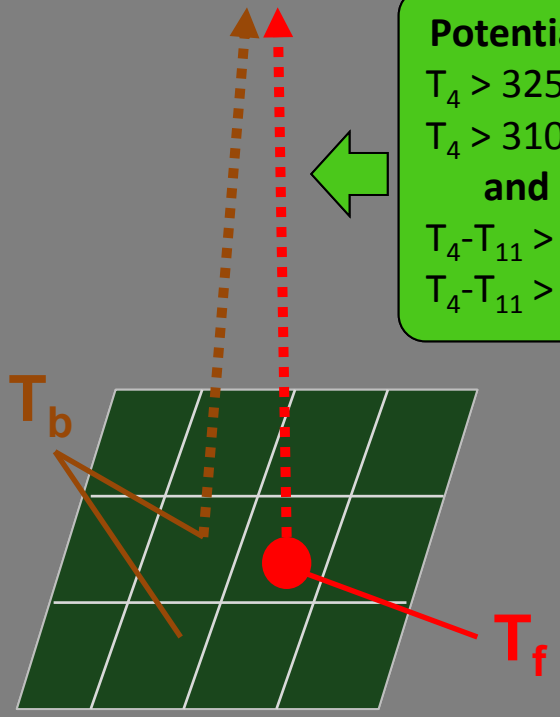
$T_4 - T_{11} > 10$ K night

Compute background pixel mean and standard deviation for T_4, T_{11}, and $T_4 - T_{11}$

Additional Testing

Pixel Disqualified

Confirm Fire Pixel



Max detectable fire area: 100 m^2

Probability of detection: 80-100%

Giglio et al., 2003