CALIPSO-CLOUDSAT

TEN-YEAR PROGRESS ASSESSMENT AND PATH FORWARD

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PARIS OCEANOGRAPHIC INSTITUTE

The Importance of CALIOP Data to Biomass Burning and Smoke Plume Injection Height

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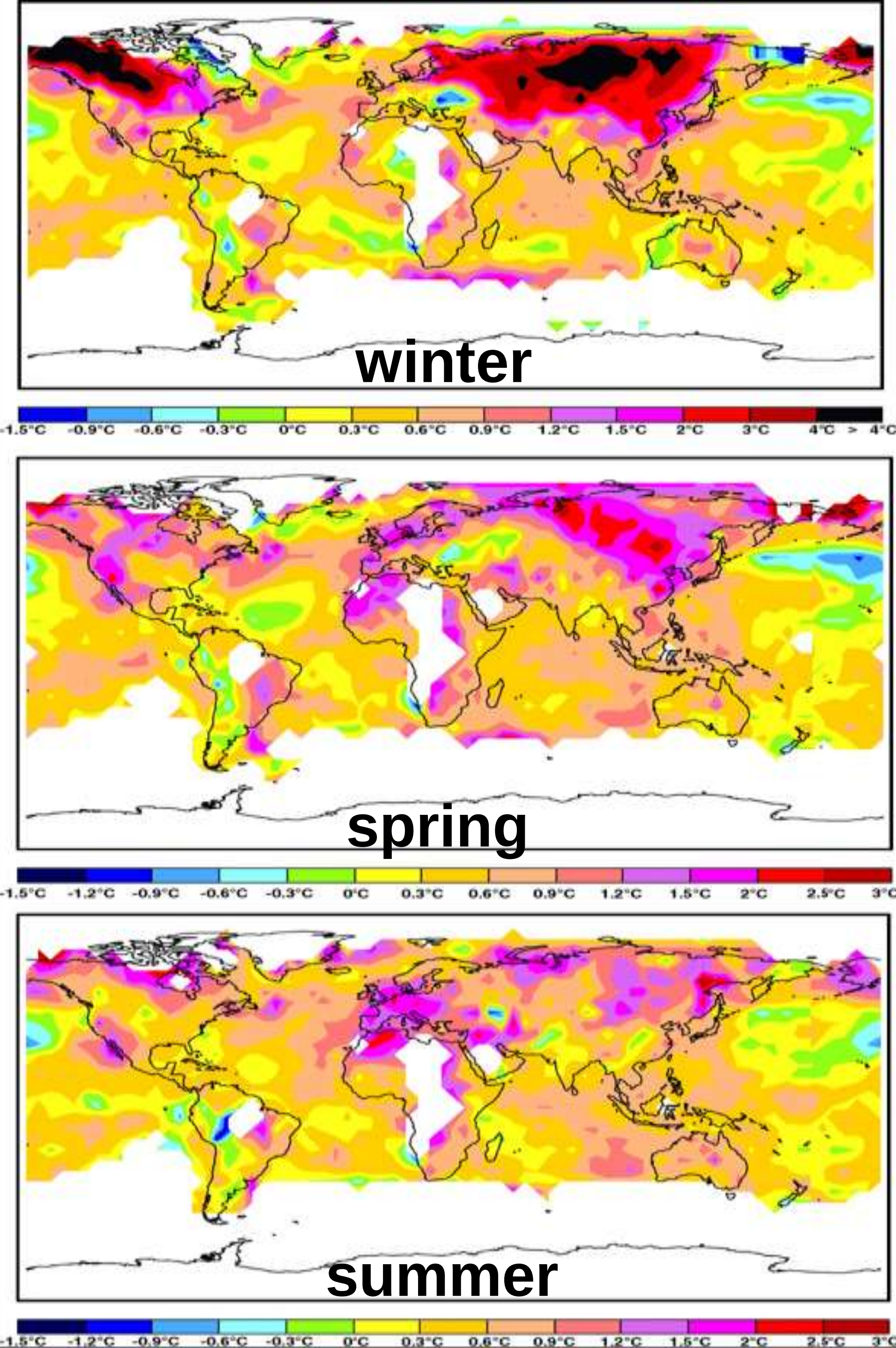
Photo courtesy of Brian Stocks

Outline:

- Brief introduction to the driving forces of fire and smoke plume injection height
- Examples of the value and success of CALIPSO
  - General transport
  - Plume injection height and the application of that information
  - General science questions
- Highlights
- Looking forward



Mean seasonal temperature change.

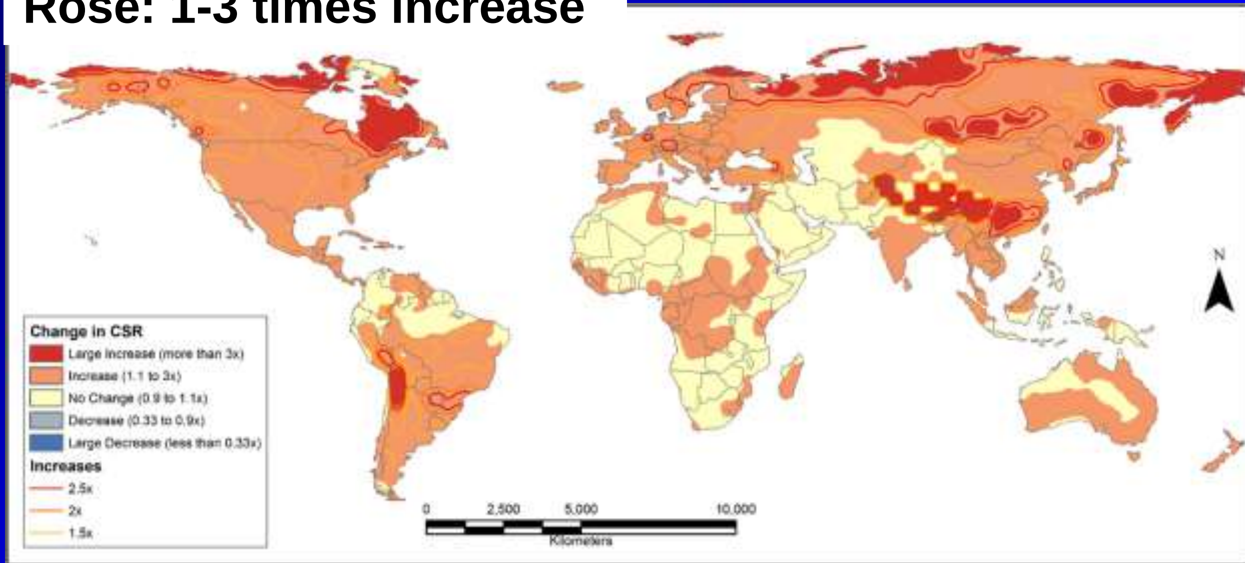
**Temperatures are increasing, particularly in the Northern Hemisphere winter and spring,
which leads to
longer growing seasons, increased potential evapotranspiration and extreme fire weather.**

It is time to get fire feedbacks integrated.

[Groisman et al., 2007; Jones and Moberg, 2003, updated]

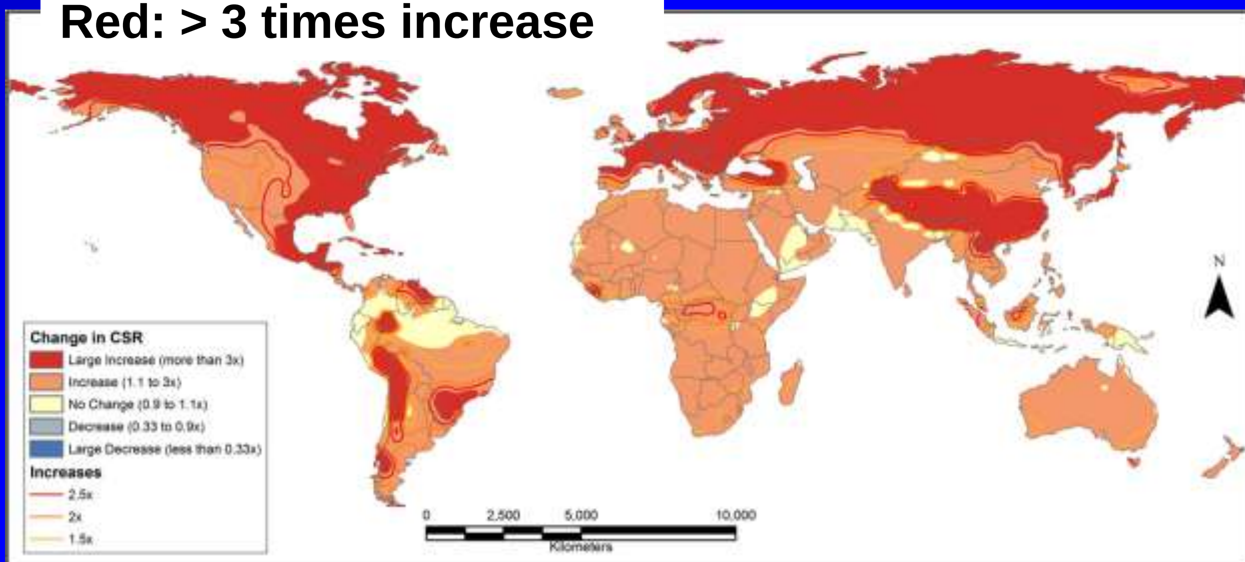
Predicted Cumulative Fire Severity Rating

Rose: 1-3 times increase



Anomalies for 2041–2050, relative to 1971–2000 base period.

Red: > 3 times increase

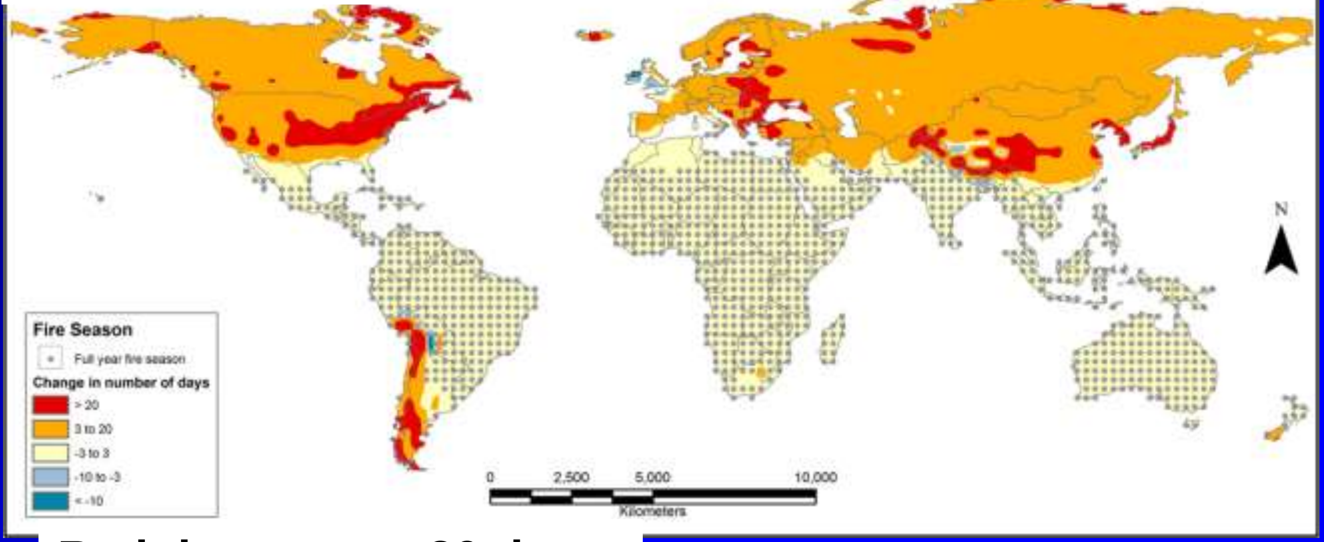


Anomalies for 2091–2100, relative to 1971–2000 base period.

Flannigan et al., 2013 Modeled based on French IPSL-CM4 A2 scenario

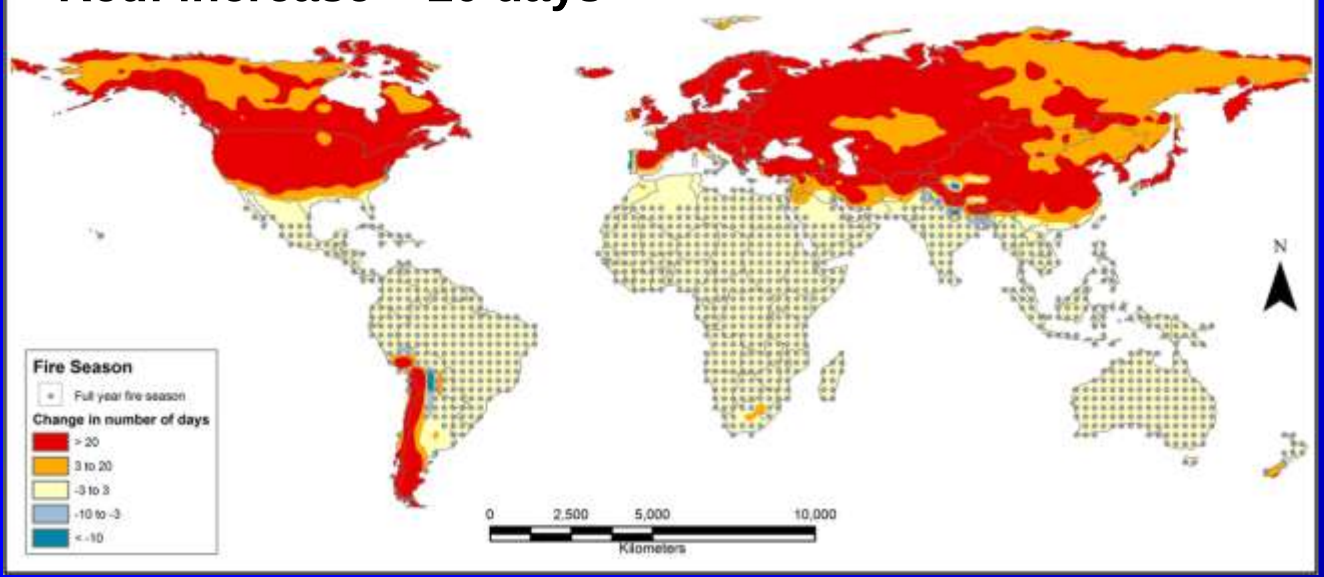
Predicted Fire Season Length

Yellow: increase of 3-20 days



Anomaly for 2041–2050, relative to 1971–2000 base period.

Red: increase > 20 days



Anomaly for 2091–2100 relative to 1971–2000 base period.

Flannigan et al., 2013 Modeled based on Hadley CM3 B1 scenario

If we don’t get injection height correct, the transport of pollutants will be incorrectly modeled and tracked.

Climate Feedbacks

* Smoke alters the Earth’s radiation balance and feeds back to climate systems [e.g., patterns of precipitation (cloud condensation nuclei), change in Earths reflectance - albedo (vegetation change, clouds, black carbon on snow and ice].

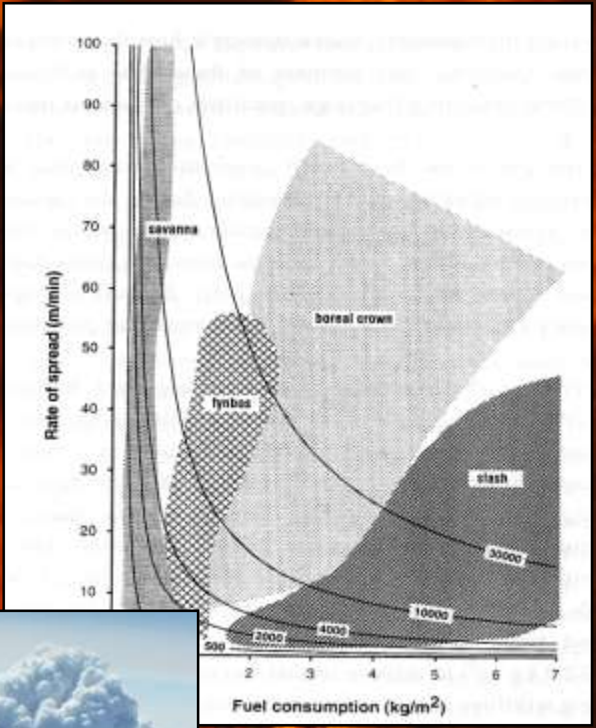
Air Quality

* A mis-informed public (air quality reports), which could adversely affect human health;

* In the U.S., inability to quickly and accurately assess the Exceptional Events Rule (72 FR 13560, March 22, 2007).

Fire Intensity-Energy Release-Plume Height

- Combine rate of spread/fuel consumption/heat of combustion to determine fire intensity (I=HWR) = resistance to control
- Savanna Fires:
  - 10-12 t/ha
  - 500-10,000 kW/m
  - Lower convection columns
- Boreal/Temperate Forest Fires:
  - 25-50 t/ha
  - 100-100,000 kW/m
  - > fuel consumption & intensity
  - Towering convection columns reaching UTLS



A typical high-intensity boreal crown fire convection column viewed from an altitude of ~10 km *(photo courtesy Mr. Todo, JAL)*

Driving force:

Fire Weather and Fuel

Fire Regimes Vary Widely: Fuel & conditions; time of day

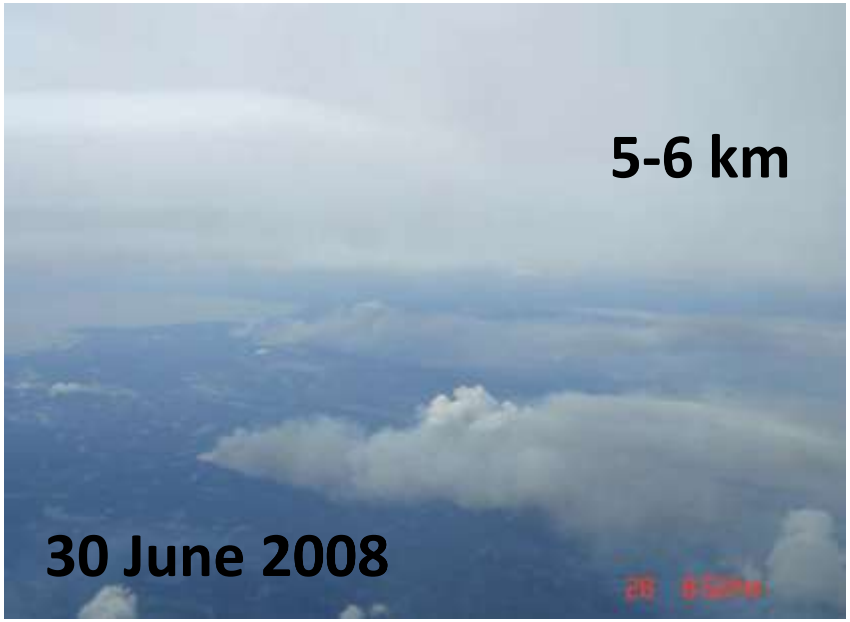
What burns and how dry are the fuels does matter.

** Peak late afternoon when the fuels are most available:

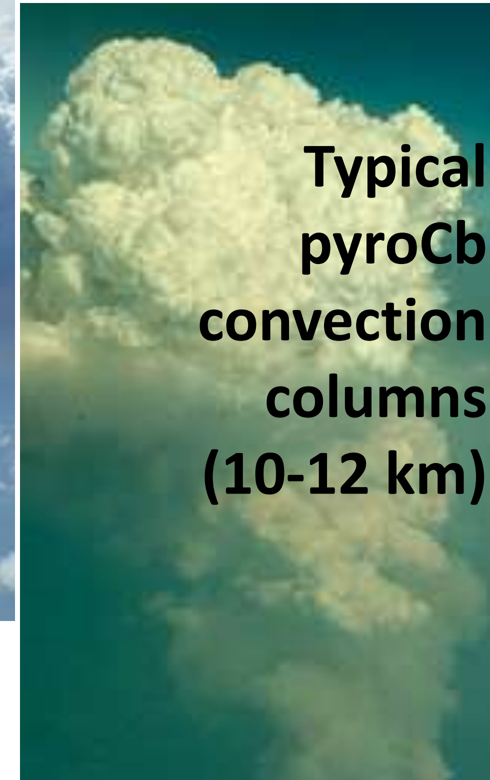
Hot, Dry,
Low
Relative
Humidity

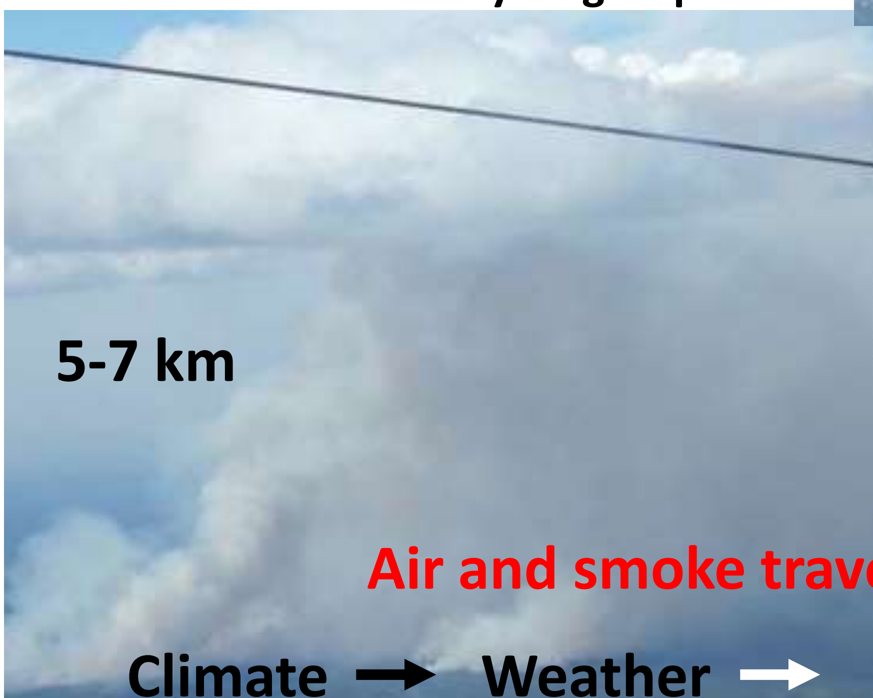
Fires
lay down
at night

Photos:
Stocks and
Soja



ARCTAS: Photos courtesy P3 group





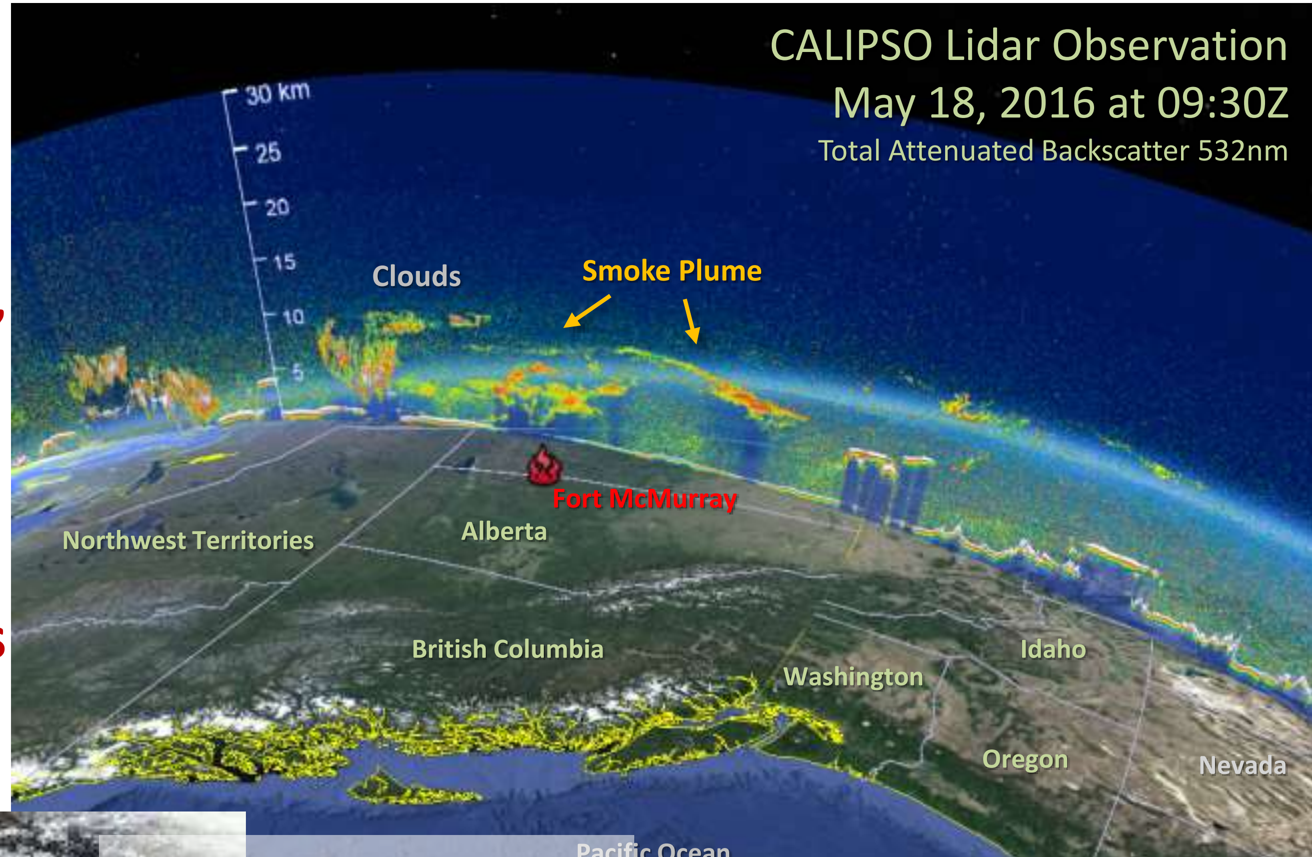
Air and smoke travel faster at higher altitudes

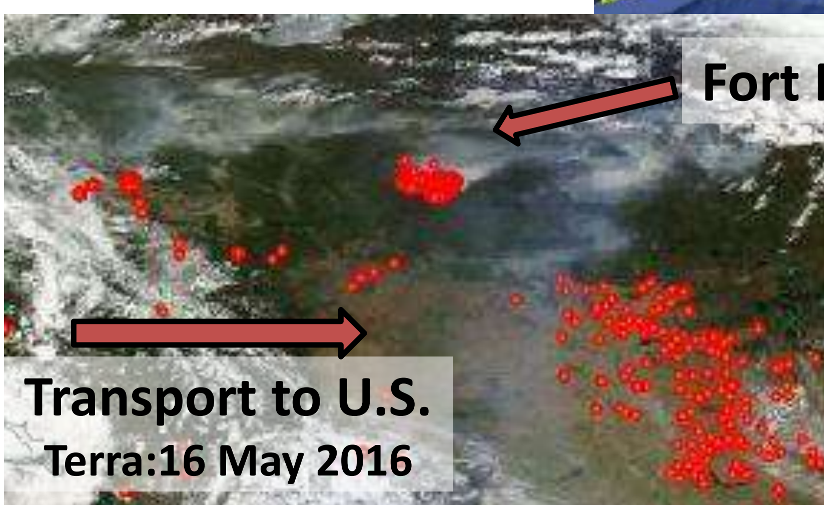
Climate → Weather → Available Fuel → Injection height

CALIPSO Value: Fort McMurray fire, still burning in Alberta CAN

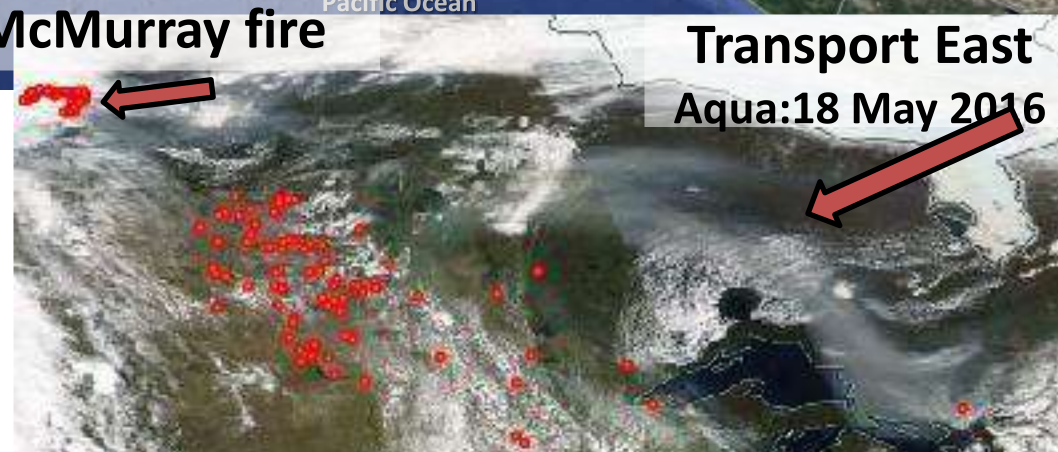
Numerous CALIOP images have traced smoke aerosol trails, distant from the fires, south to the U.S. and east to Europe, then across Siberia.

ONLY with lidar is this verification possible.





Fort McMurray fire



CALIPSO value: Fort McMurray fire, still burning in Alberta CAN

Started May 01 2016; Update June 6, 70% contained - expected to burn to fall; 581,696 ha burned (984 km perimeter); 2400 homes; 2804 fire fighters now, still extreme burning



Quickly found over a dozen CALIOP images from the pyroCb forum – a global group that analyzes all large fires using CALIOP and other data.

2016 (to 05 May) 5 pyroCb documented; 68 in 2015; 64 in 2014

Photo credits: Canadian Press; Global News

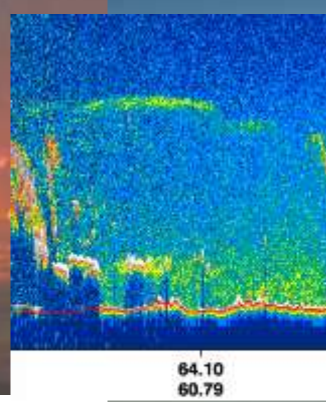


Photo credits: Klaus Siever


History: Plume height modeling

Based on the pioneering work of G.A. Briggs [1969; 1971] and verified with limited field data [Clements et al., 2007].

We have an increasing number of ground-based lidar and aircraft verification measures.

There are currently 2 satellites that can provide the statistics necessary to understand and verify plume height.

I. *MISR - Multi-angle Imaging SpectroRadiometer*

II. *CALIPSO - Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation*

CALIPSO

** Increased capability of detecting optically thin smoke layers at a finer vertical resolution;*

** Able to identify plume heights from extensive smoke fields;*

** Paired with back trajectories, smoke plume identification are temporally random, representing the entire temporal range of fire plumes.*

MISR

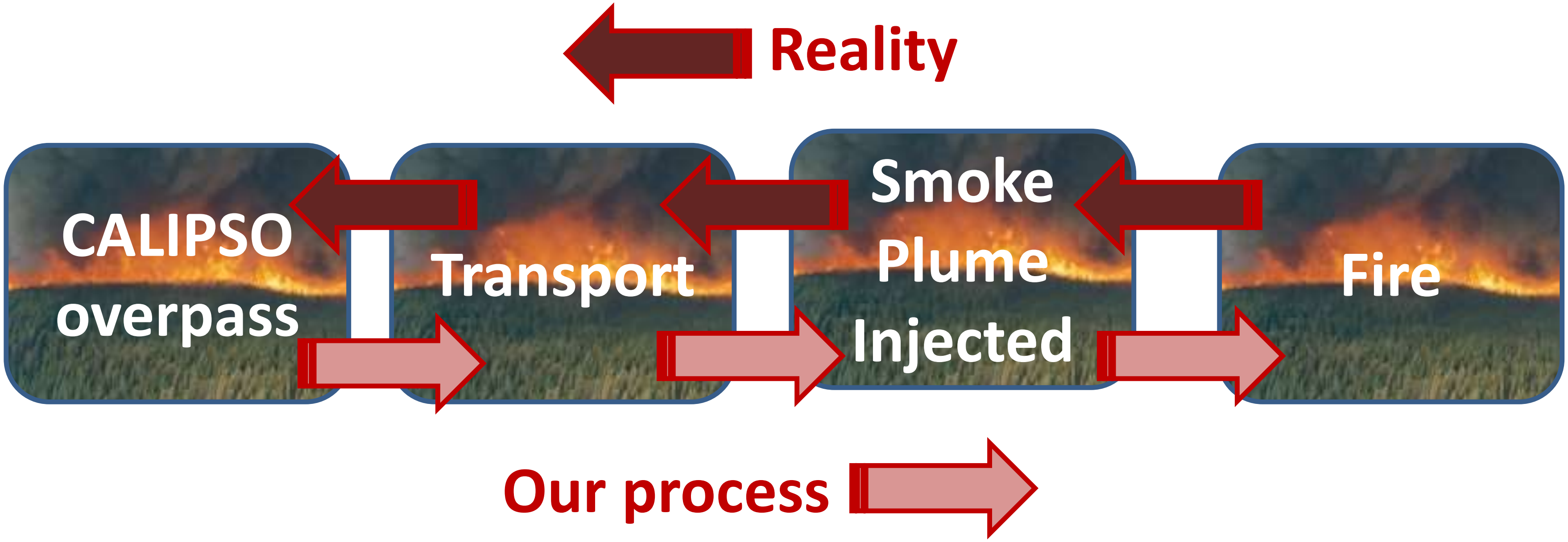
** needs abrupt well-defined columns - relies on multi-view angles to estimate the stereo height of distinct features;*

** substantially larger swath width than CALIPSO which results in a greater opportunity to capture smoke plumes [Kahn et al., 2007]; &*

** morning overpasses do not capture the natural temporal fire pattern.*

Sensor (spacecraft)	Product	Spatial Resolution	Satellite Overpass	Temporal Availability
MISR (Terra)	AOD, aerosol plume height	1.1 km horizontal x 500 m vertical	10:30 a.m.	~ Once every 7 days
CALIOP (CALIPSO)	extinction profile	100 m diameter x 30 m vertical	1:40 p.m.	Once every 16 days

Methodology

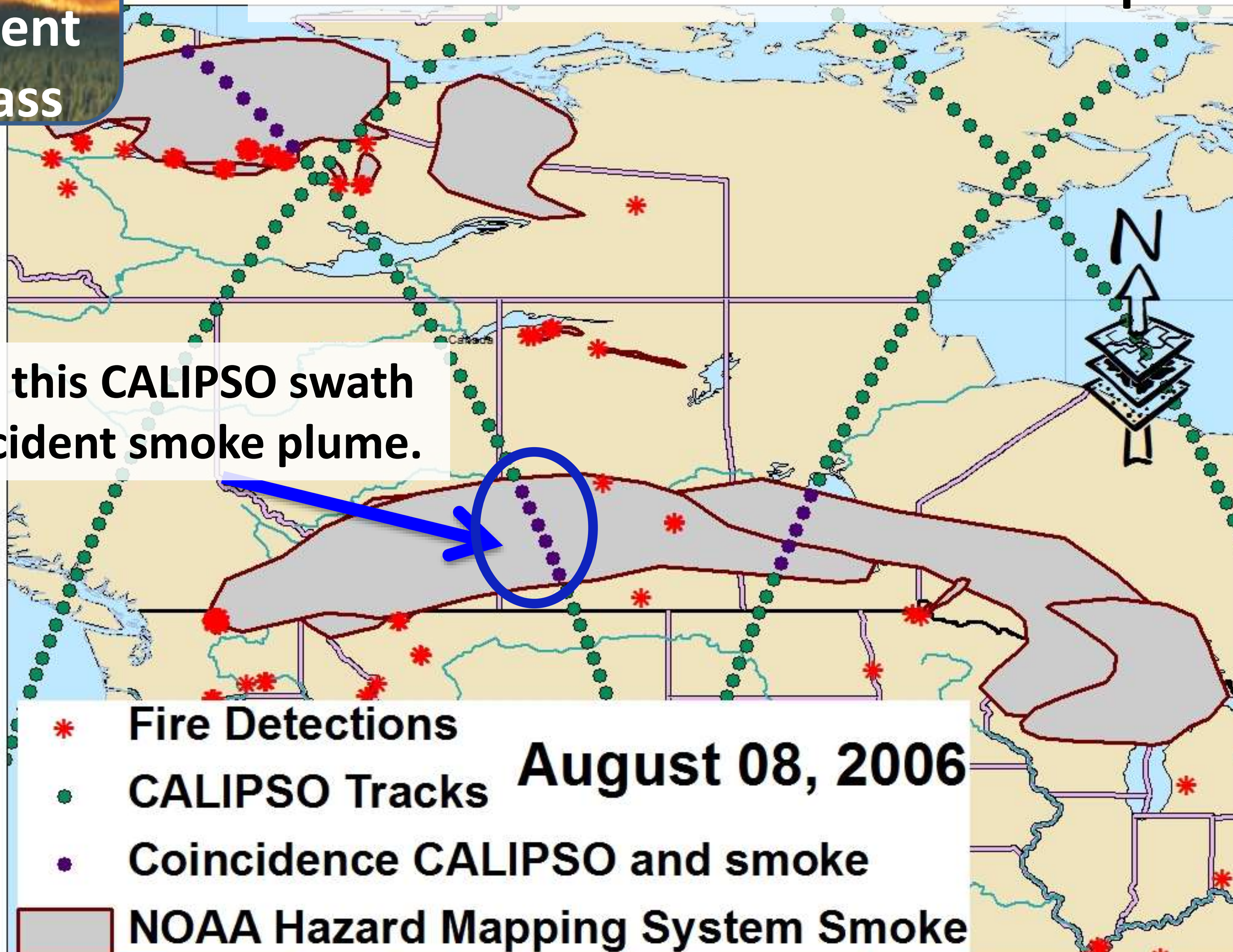


- Coincidence in CALIPSO tracks & NOAA Hazard Mapping System (HMS) smoke plume data;
- LaRC trajectory model (backwards);
- Coincidence with MODIS fire detection.

All in 3-dimensional space and time

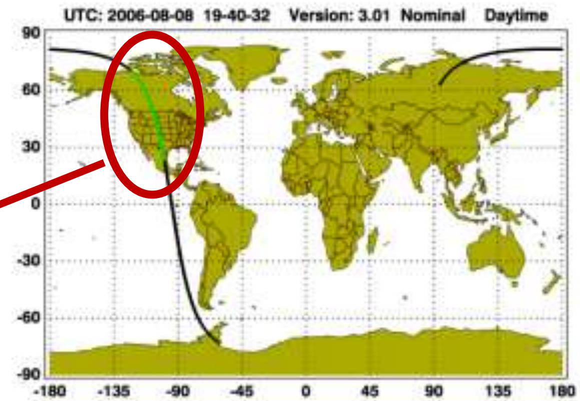
Plume and CALIPSO Coincident Overpass

Coincident NOAA HMS smoke plume, and CALIPSO overpass.

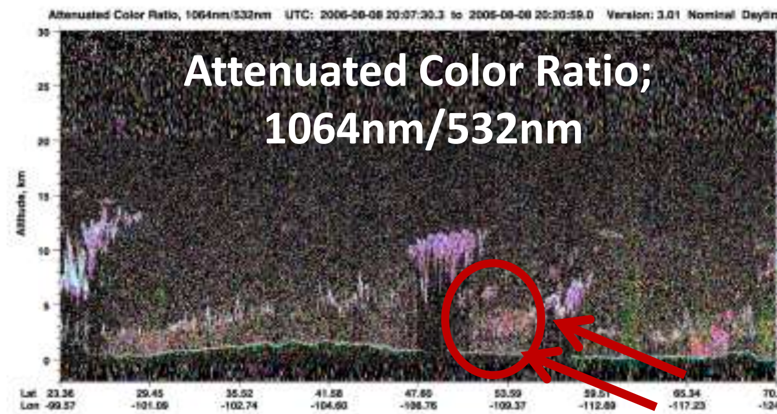


Focus on this CALIPSO swath and coincident smoke plume.

CALIPSO Curtains 08 Aug 2006 (v3)

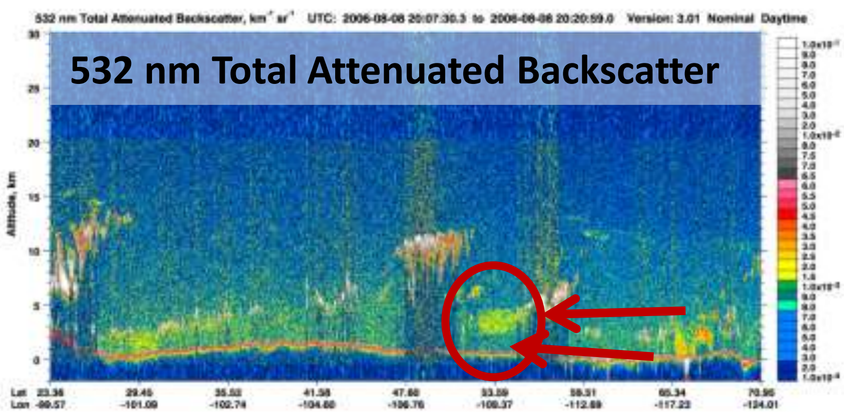


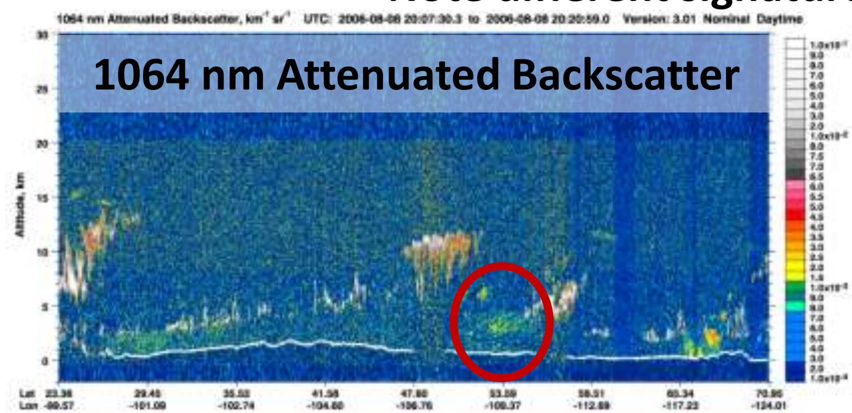
Swath from south to north

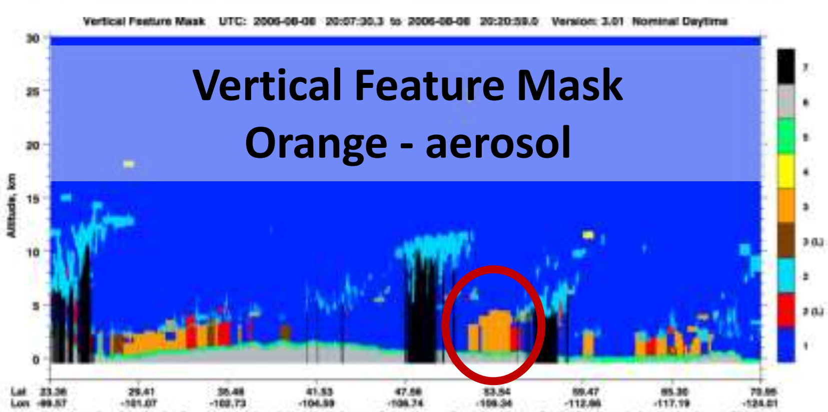


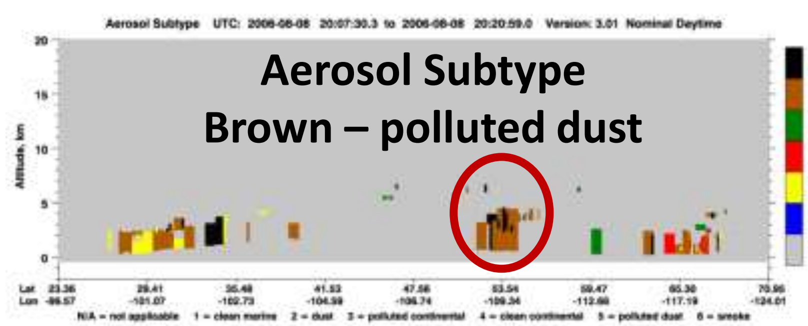
Note different signature

20:07 to 20:20

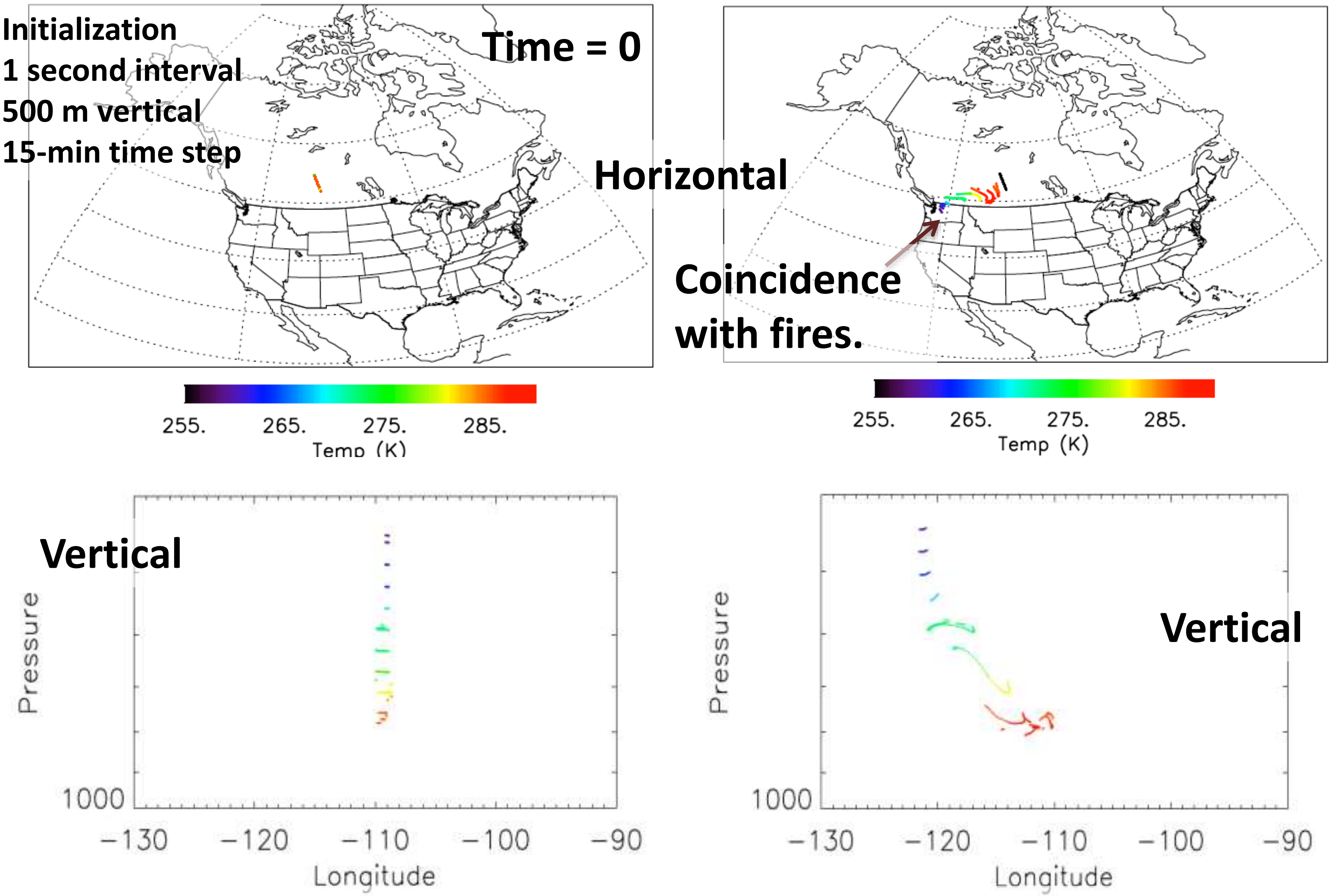








Langley Trajectory Model (LaTM)

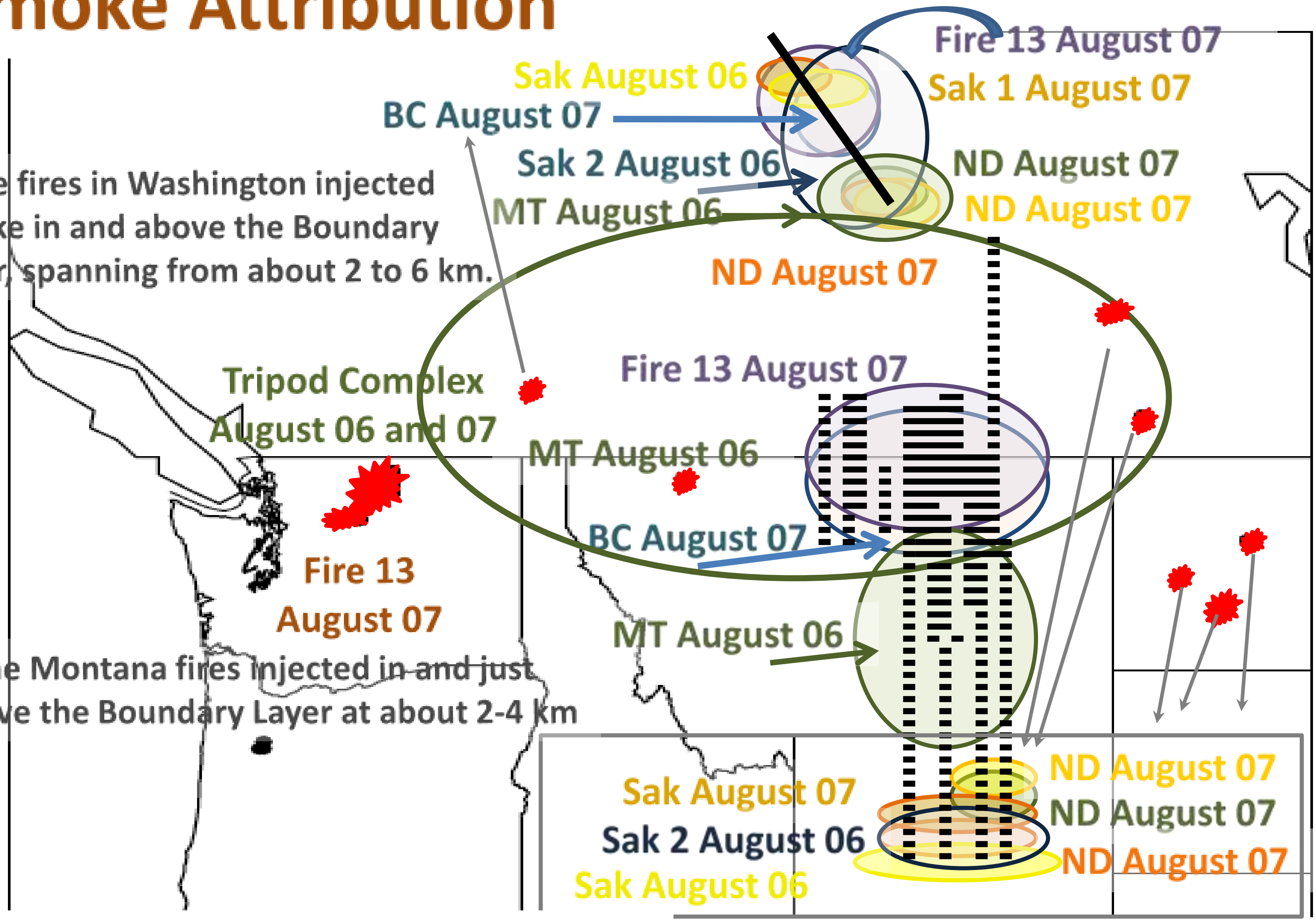


Extracted smoke segment along CALIOP & transport path.

Smoke Attribution

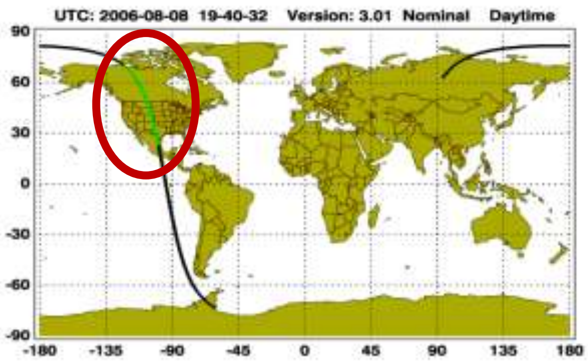
* The fires in Washington injected smoke in and above the Boundary Layer, spanning from about 2 to 6 km.

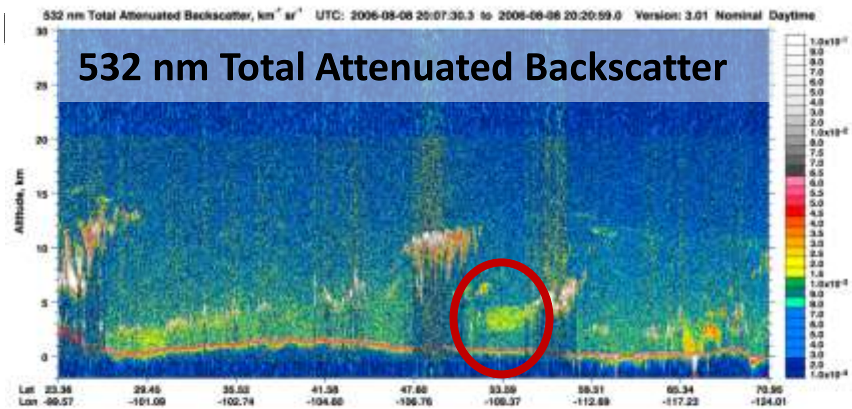
* The Montana fires injected in and just above the Boundary Layer at about 2-4 km

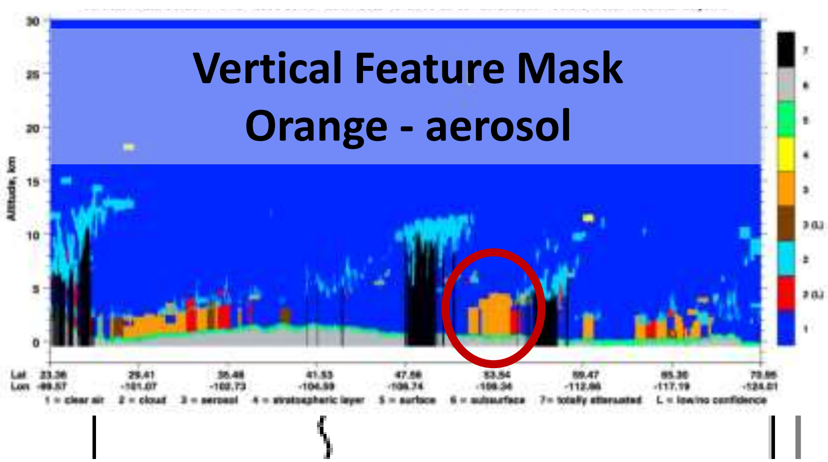


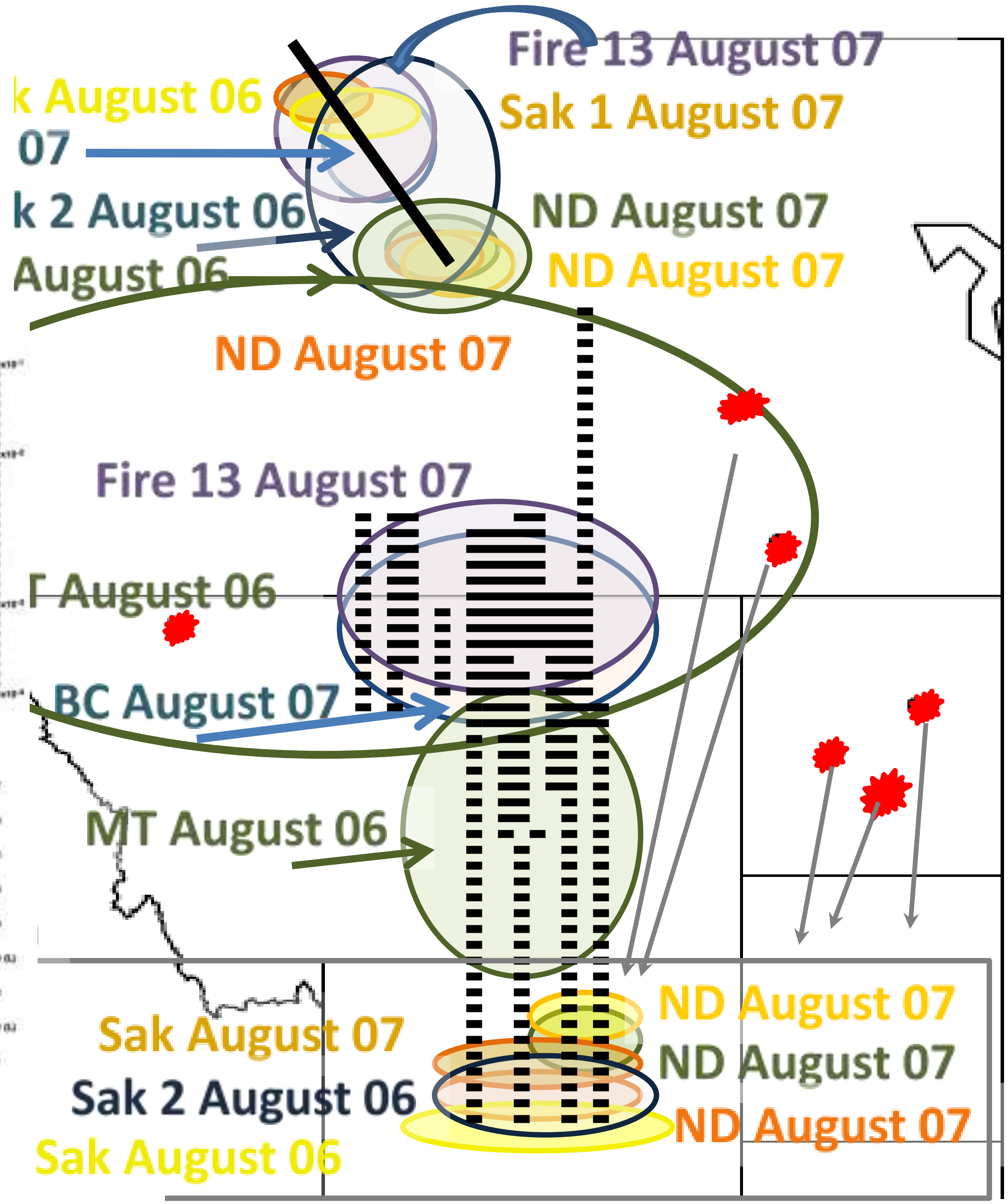
CALIOP Vertical Signal
August 08 2006

* All Saskatchewan and North Dakota fires injected in the Boundary Layer at around 1 km





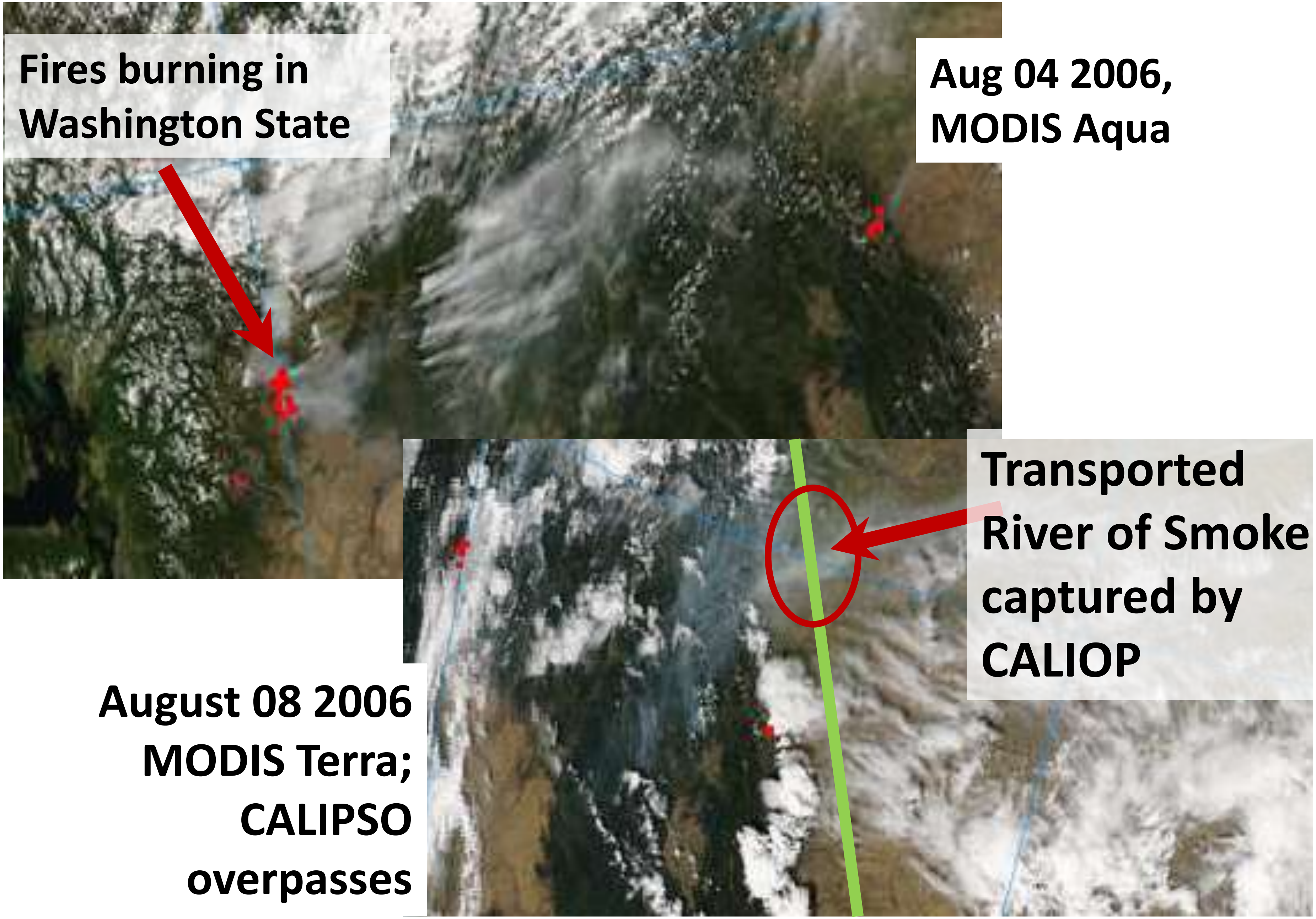




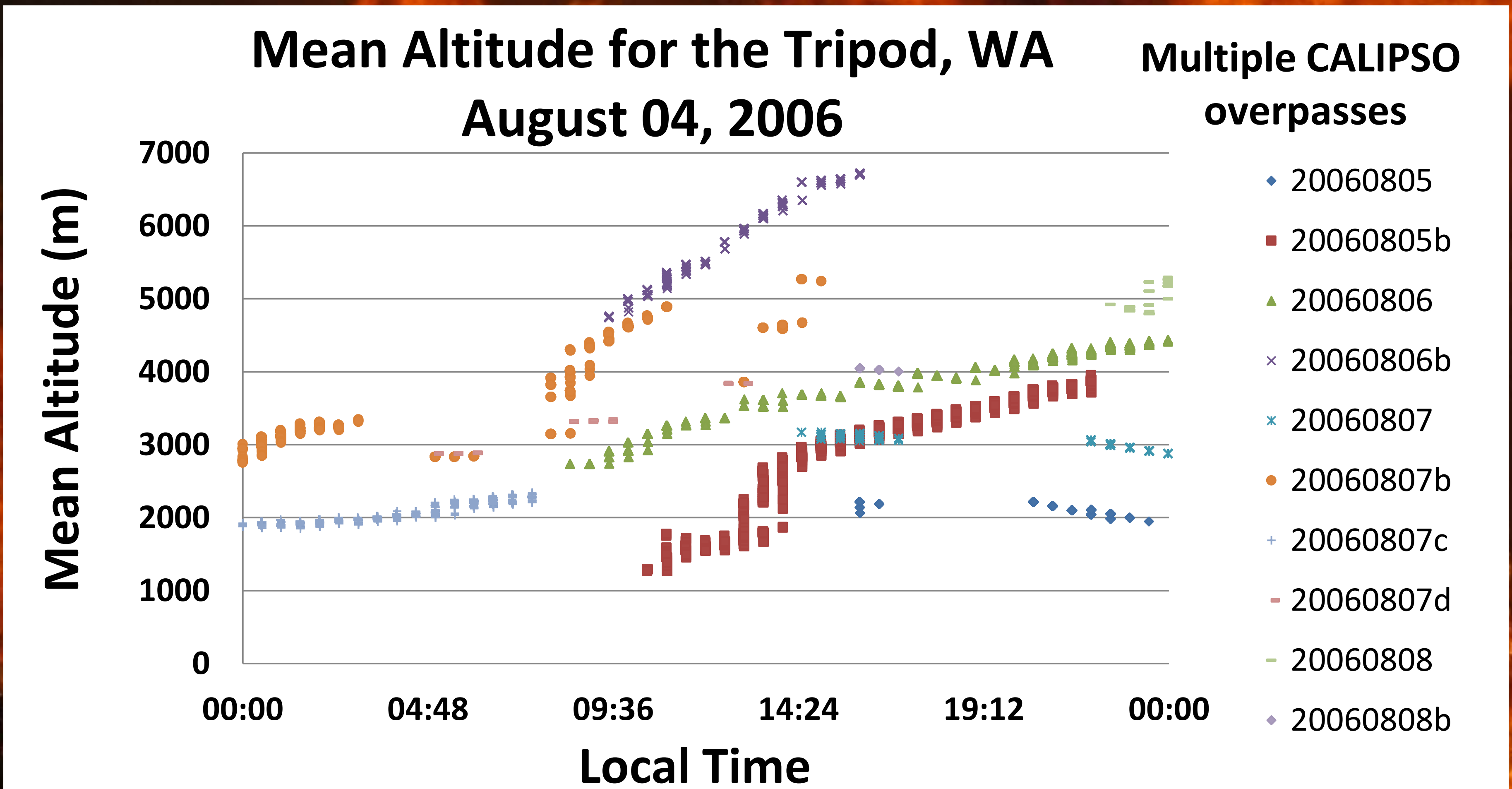
* All Saskatchewan and North Dakota fires injected in the Boundary Layer at around 1 km

CALIOP Vertical Signal
August 08 2006

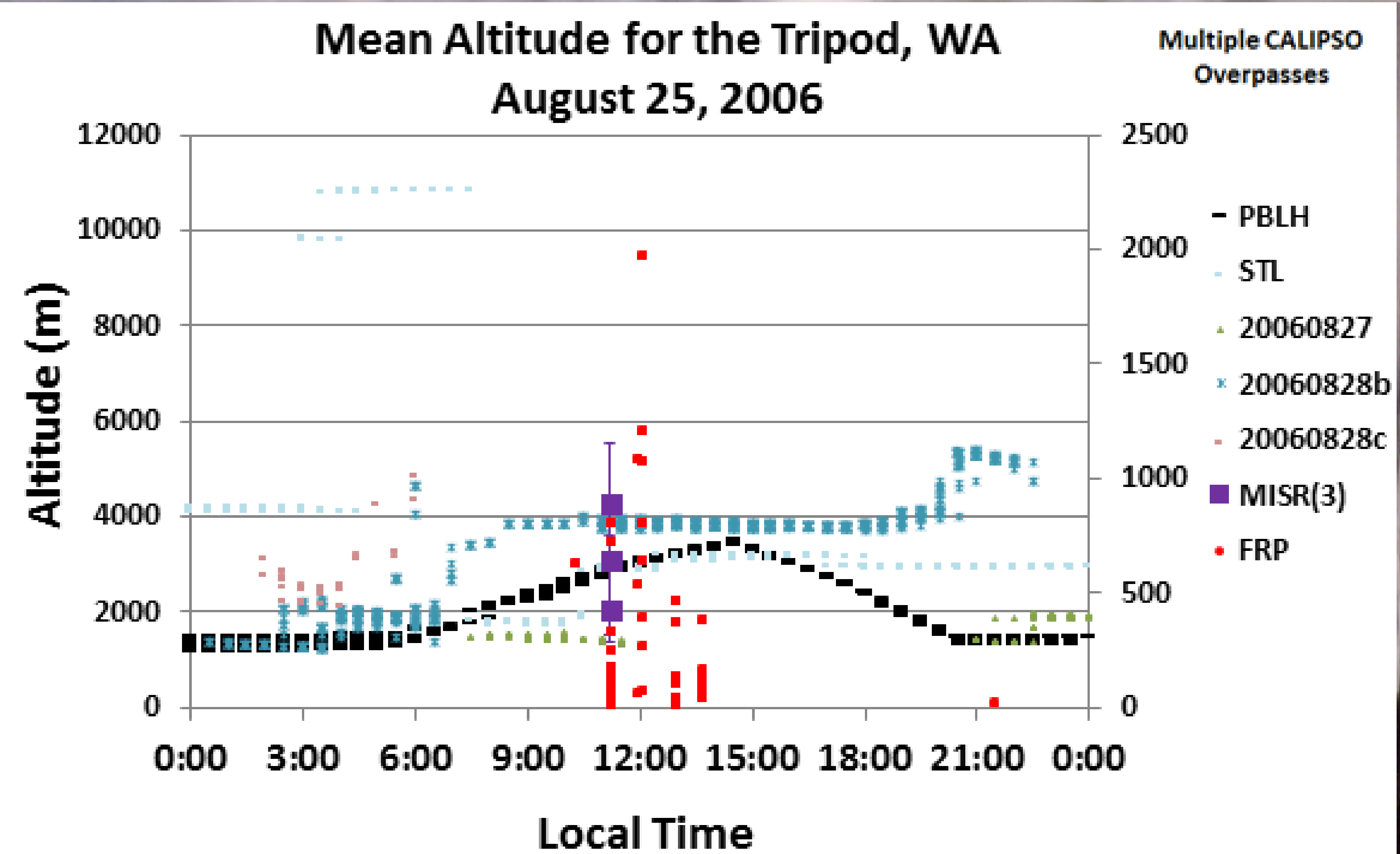
A River of Smoke



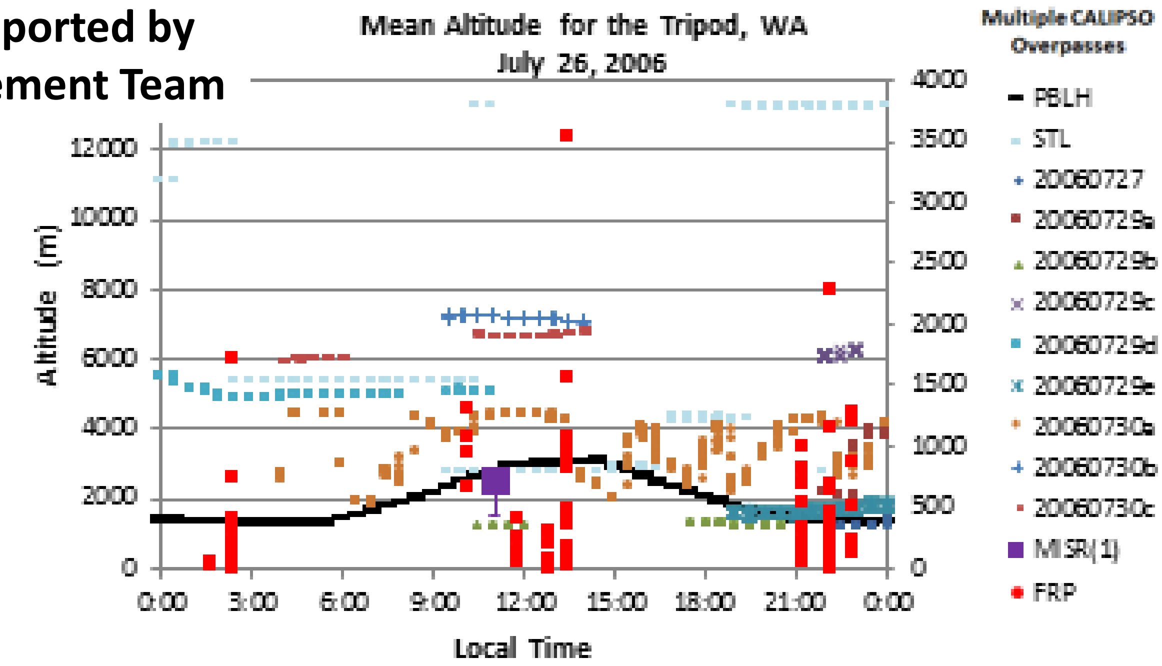
Using multiple CALIPSO overpasses (w/ LaTM), the evolution of a smoke plume can be defined. This is unique and a new application.



Mean Altitude of the Tripod Fire: CALIOP and MISR data compare well



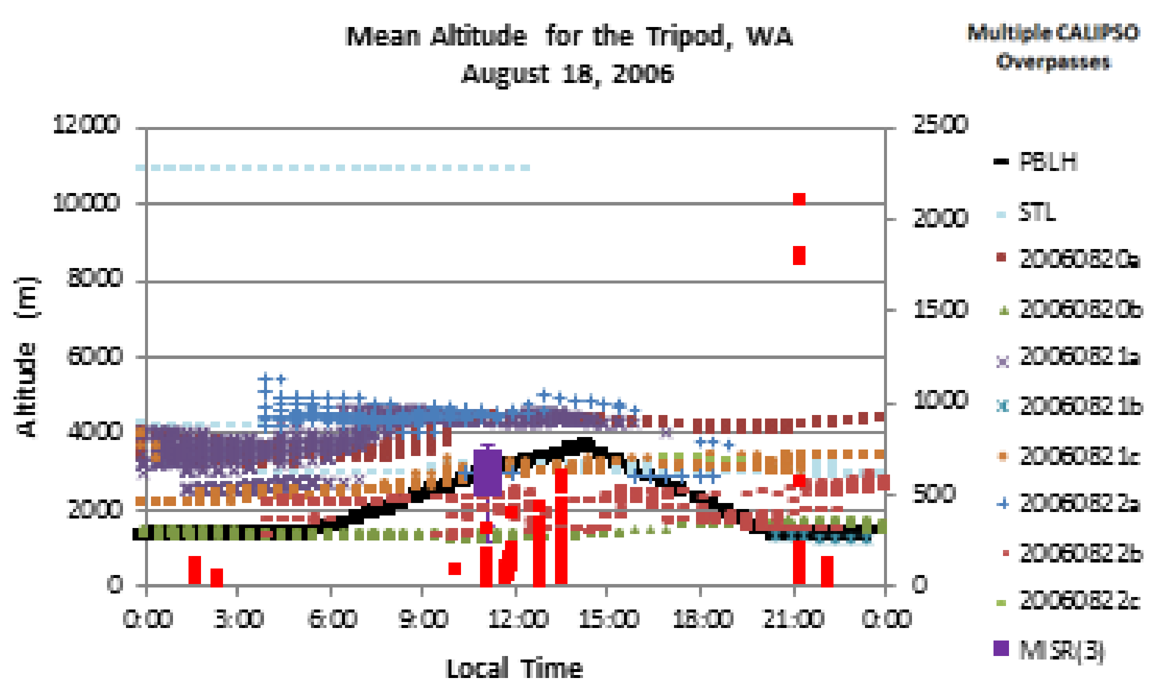
6700 – 7600 m reported by Incident Management Team



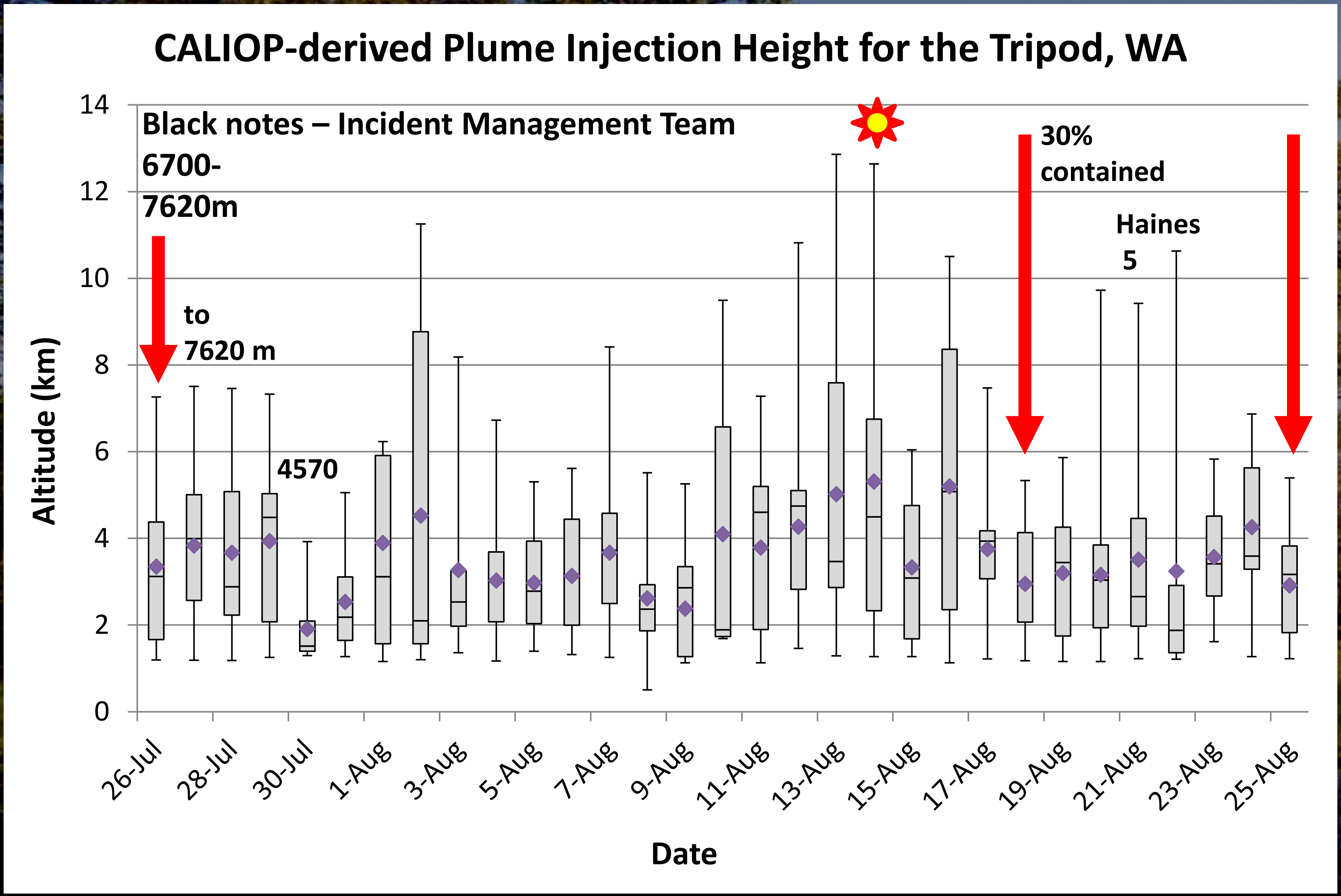
CALIOP data are used to define the daily smoke plume evolution of the Tripod Complex from July 26th through August 29th 2006.

MISR data capture morning overpasses for 3 days in this range.

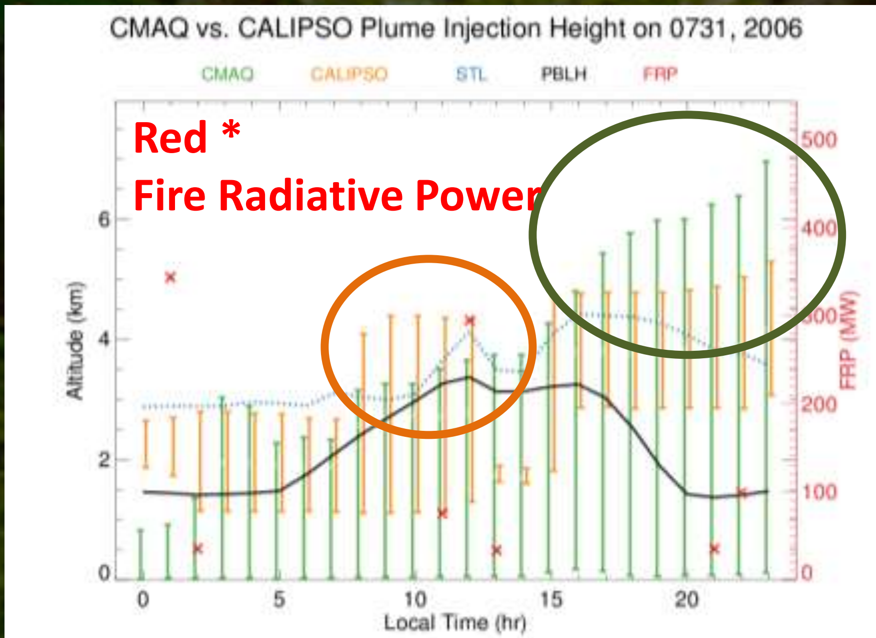
MISR low biased for all large plumes.

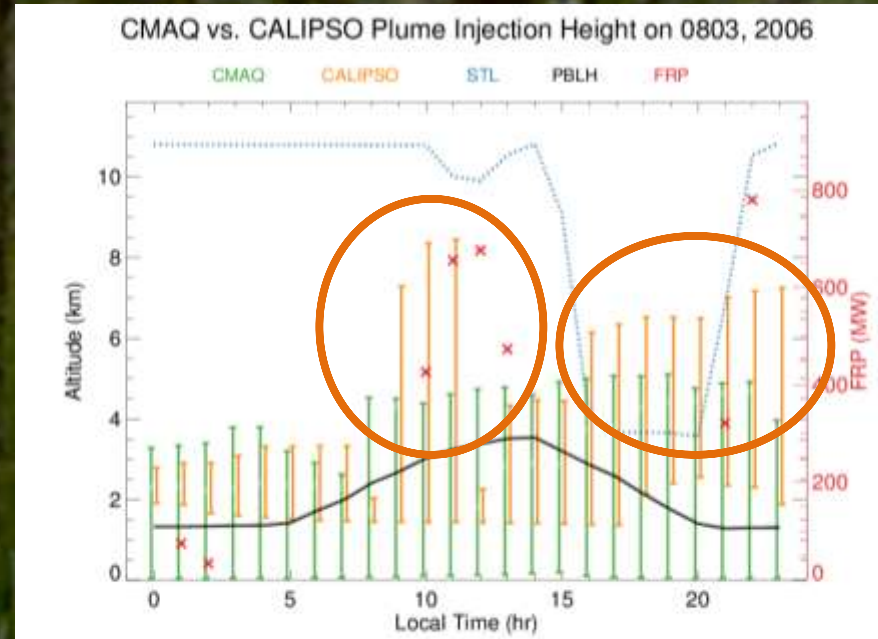


Daily Smoke Plume Injection: Tripod Complex 2006
Daily statistics (minimum, mean, median and maximum)
Three coincident MISR days



Comparing CALIOP and CMAQ modeled Injection Height

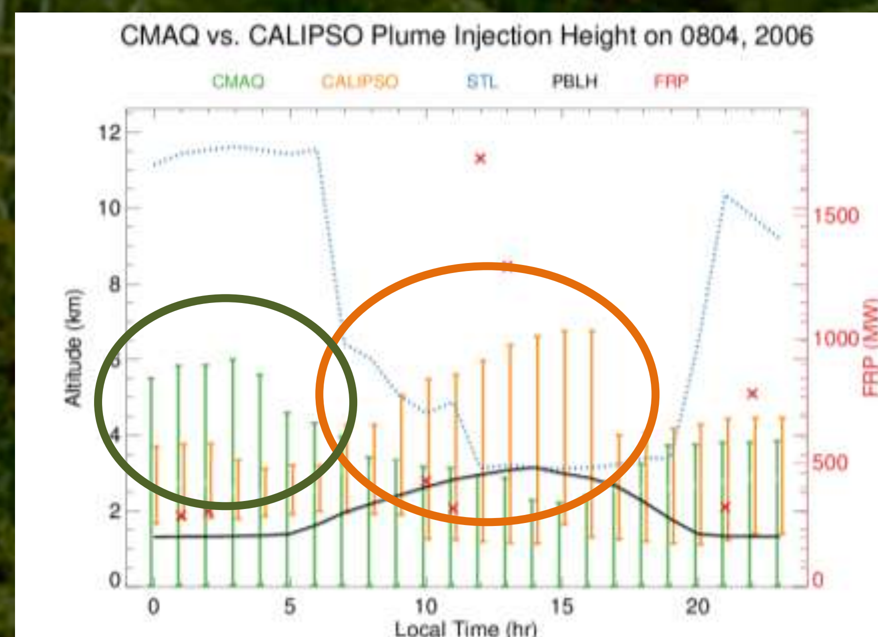




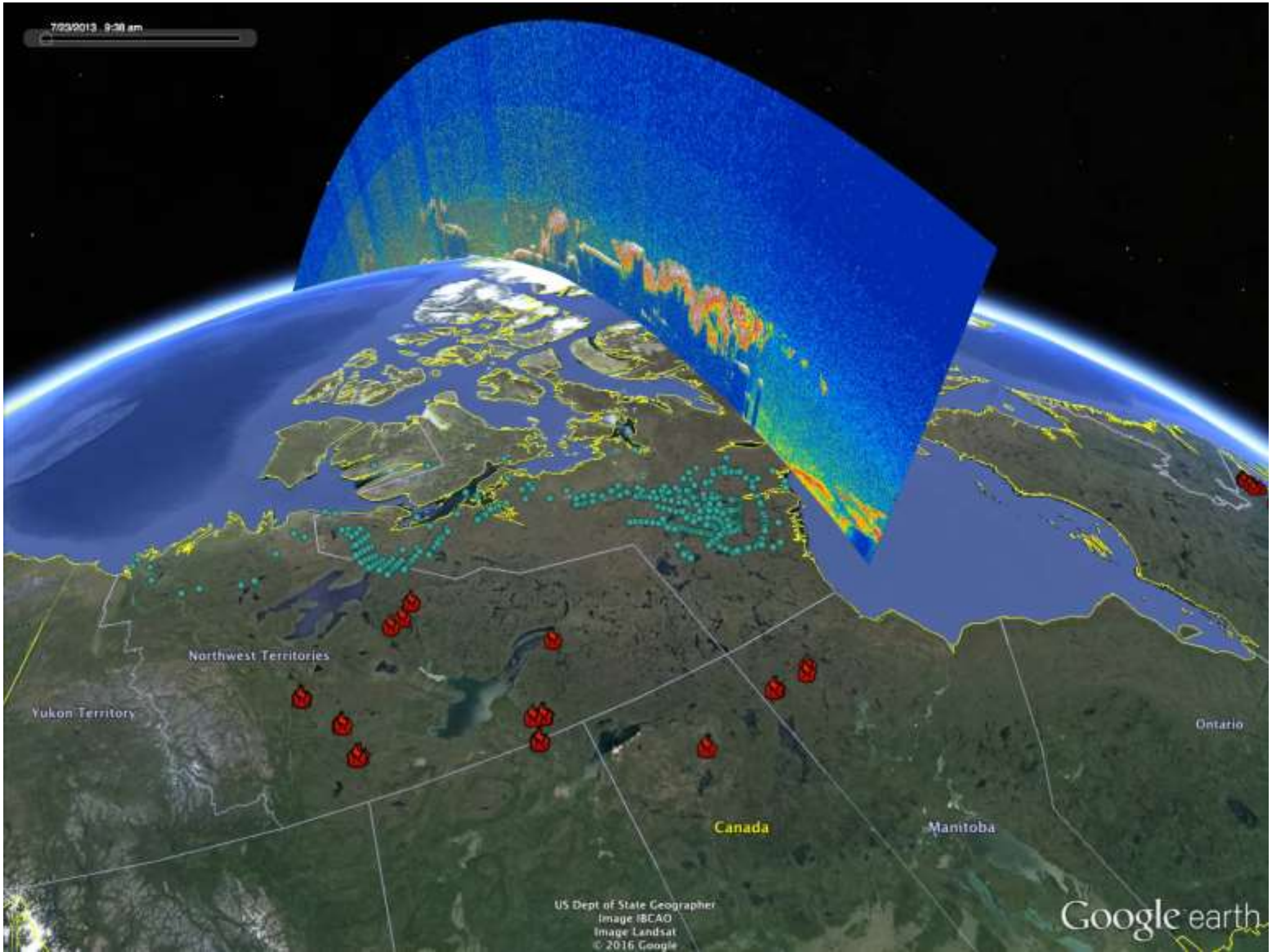
Comparing CMAQ and CALIOP: Initial Analysis

CMAQ tends to underestimate when the fires are burning the hottest (FRP) and;

CMAQ tends to overestimate late and early when the FRP is lowest.



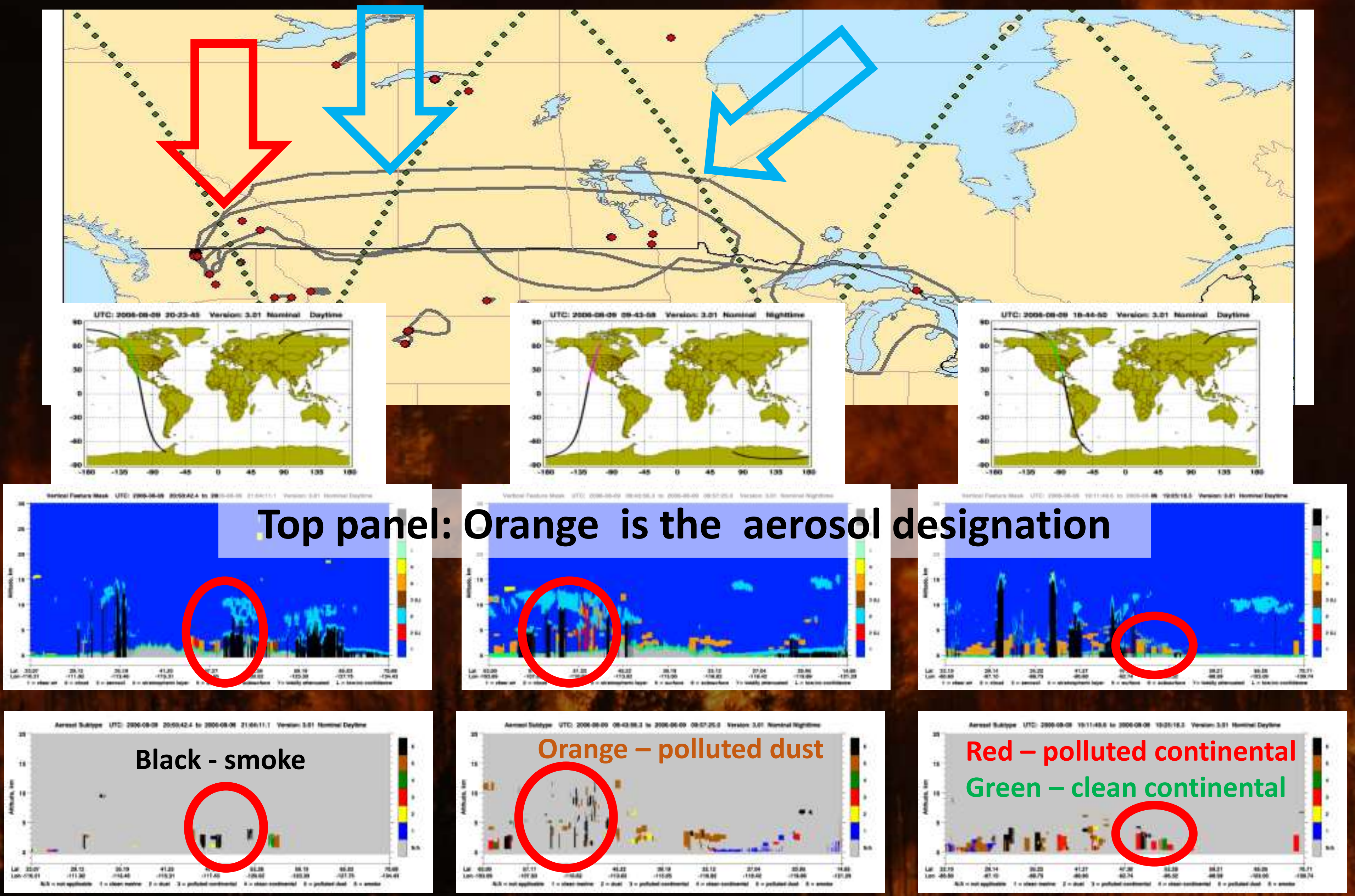
Discovering the science we didn't know. **Using the LaTM, FD, samples taken from pits, and CALIOP data, we can tease apart feedbacks to climate. Specifically, preliminary analysis shows, it is not the amount of fire that burns that is directly related to deposition, rather a complicated pattern of fire, smoke transport, storms and snowfall.**



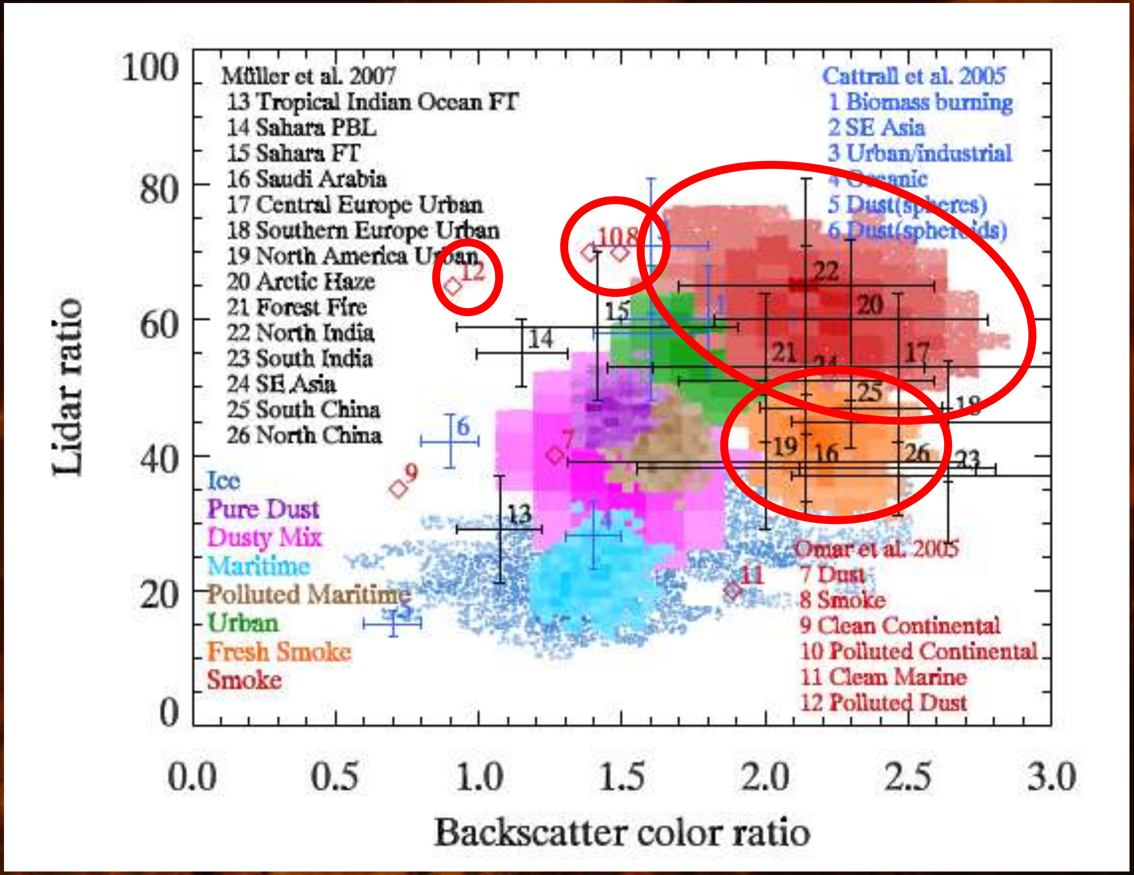
Highlights: Value of CALIOP space-based lidar.

- CALIPSO data provide a spatially & temporally random view of fire plume data, one not limited to particular fire types or time of day.
- CALIOP data have been used to confirm pyroCb and to show pyro-cumulous are not as random as had been previously thought.
- CALIOP data are used to trace widespread global smoke transport.
- CALIOP data have been used to tease apart scientific concepts about which we had not thought (e.g., Ice sheet aerosol distribution).
- One CALIOP swath can be representative of a complicated 3-D temporal and spatial story that incorporates several days, several fire events and a range of fire types from agricultural to large wildfires.
- CALIOP data can define the evolution of smoke over a day, which is an unprecedented process and result.
- CALIOP data can be used to verify many application processes that define plume injection height for air quality, chemical transport models and feedbacks to climate change.

Looking Forward: Potential improvement



Looking Forward



Burton et al., 2012

CALIOP on CALIPSO holds tremendous and unique value to both science and the application of these data, highlighting the need for continued and enhanced space-based lidar.

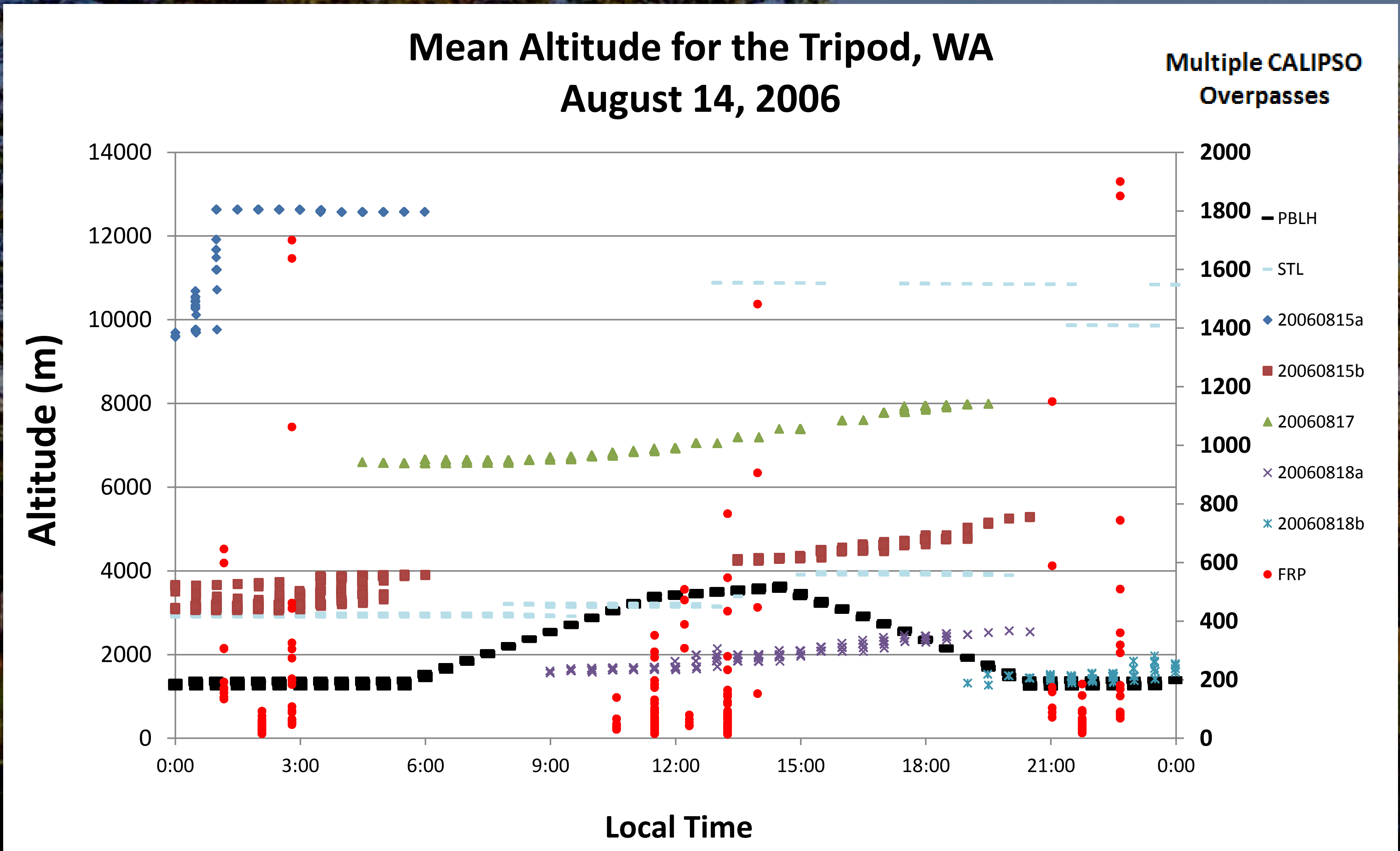
Merci beaucoup!
Thank-you for listening!

and thanks for conversations with individuals and communities: the CALIPSO Science Team, USDA Forest Service, Environmental Protection Agency, ARCTAS/ARCPAC science teams, LARGE Team, NOAA HMS team, Brian Stocks, Louis Giglio, Charles Ichoku, Ralph Kahn, Mark Ruminski and many others.

Questions?

And a special thanks to NASA CALIPSO for this invitation and the opportunity to attend this workshop and the 10-year celebration!

High Fire Radiative Power and coincident smoke injection



This plume can be attributed to 9 separate fires, burning on different days (12 fire-event-days):

Washington - large fire

August 6th (~ 3400 m);

August 7th (mean 3300 m, range 1900 – 6300 m);

Washington - medium-sized fire

August 7th (range 2200 – 4400 m)

British Columbia

August 7th about 3400 m

Montana fires – 2 of them

August 6th – mean 1980 m

Saskatchewan (2 fires)

August 6th and 7th ~ 1000 m

North Dakota (2 fires) August 7th ~ 2000 m

Each CALIOP air parcel is associated with the following related parameters:

<u>Fire</u>
Number of active Fire Detections (MODIS Terra and Aqua)
Fire Radiative Power

<u>Land</u>
IGBP vegetation 1km MODIS
Elevation
Available fuel

<u>Langley Trajectory Model (LaTM)</u>
Air parcel counts, mean range

<u>Meteorological</u>
Relative Humidity (2m, 10m)
Temperature (2m, 10m)
Wind speed and direction
Precipitation
Fire weather
Time of day
Planetary Boundary Layer
Stable Layer

<u>Location</u>
Latitude/longitude
fire location and plume
Fire name