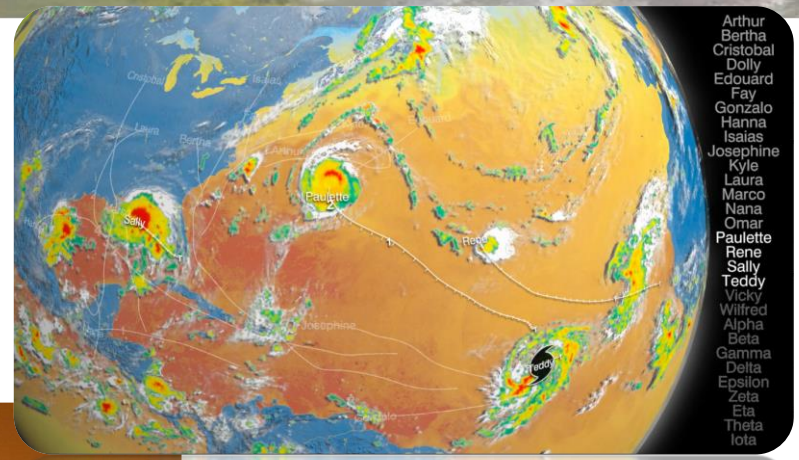
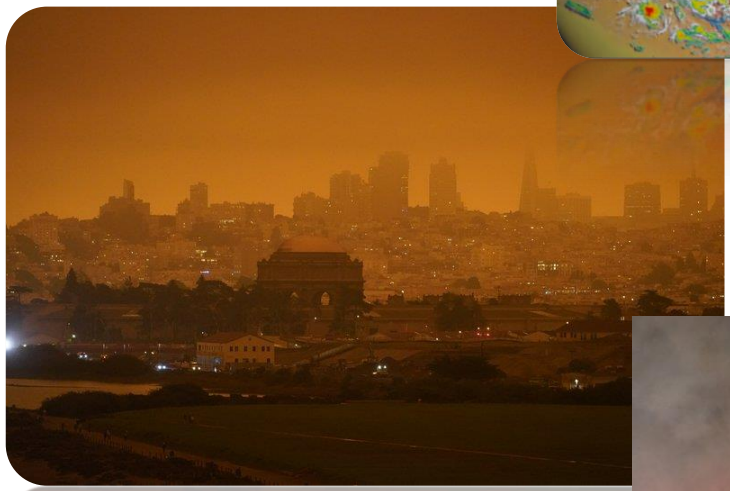
Vertical Science for Societal Benefit

Aerosol Cloud Convection and Precipitation (ACCP) explores the fundamental questions of how interconnections between aerosols, clouds and precipitation impact our atmosphere, air quality, weather, and climate, **addressing real-world challenges to benefit society.**

Amber Soja with the AIT, S Burton, T Thorsen, K Powell, Felix Seidel, P Colarco, E Nowottnick, Xinxin Ye, E Gargulinski, HD Choi, Marta Fenn, R Ferrare, R Kowch, J Tackett, JP Vernier, J Hair, B Holz, D Winker, and M Vaughan

22 billion-dollar weather and climate disasters in 2020





38 million people in the Western US were exposed to unhealthy levels of air pollution from wildfires in 2020

Climate change is exacerbating extremes and stressing our terrestrial and atmospheric environs.

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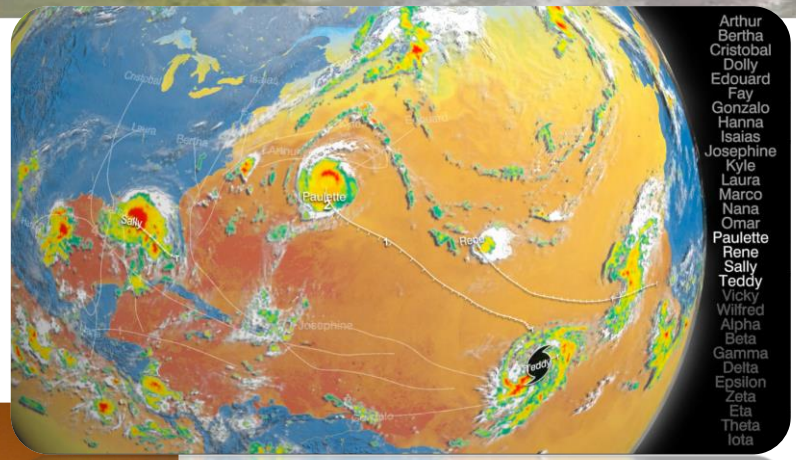
- What orbits and spatial domain?
- What is lidar data?

What's new?

- What are the improvements and advances over what we have right now?

What might these data provide to you?



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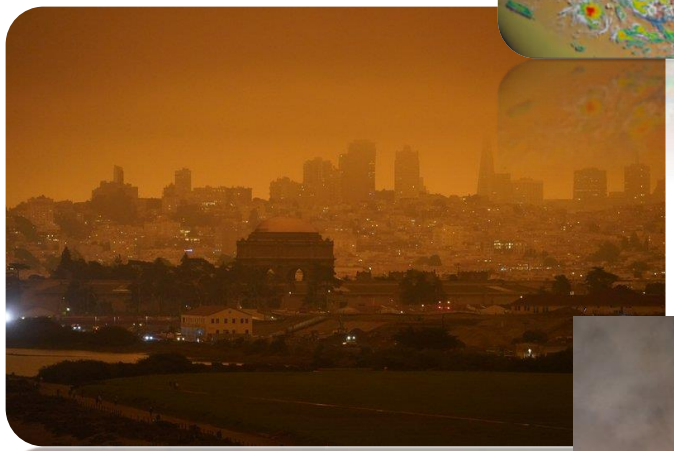

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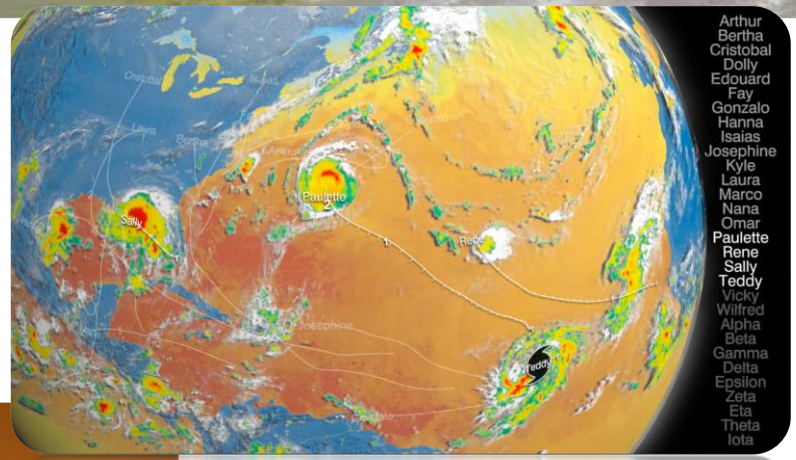

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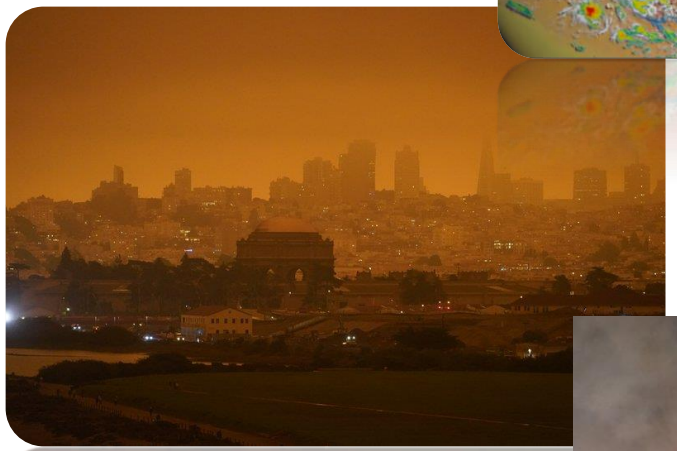

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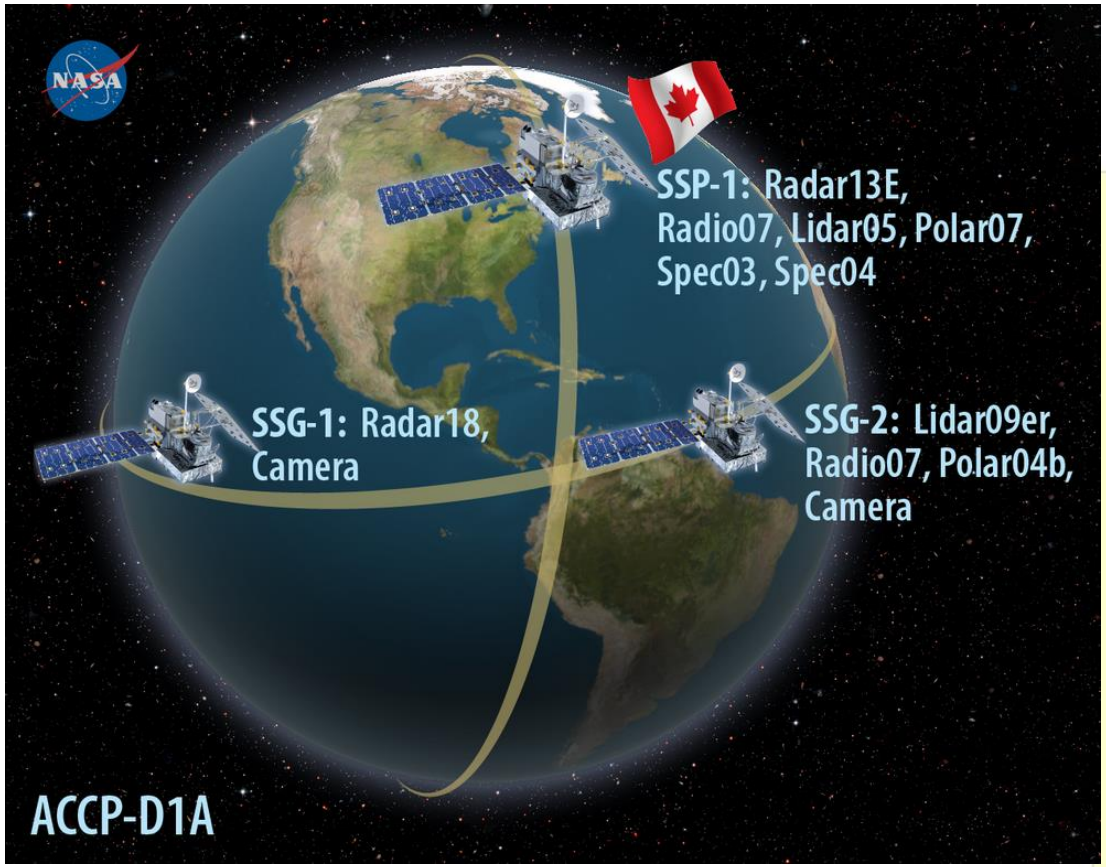
Top Candidate Architectures



Early Science Option - Ku Doppler w/o Swath + 2 WL HSRL + Camera dt

Spacecraft: SSP-1 | SSG-1 | SSG-2

Diurnal | Delta t | Diurnal and Delta t

Architecture: ACCP-P1

All-In International

Spacecraft: SSP-1 | SSP-2

Architecture: ACCP-P2

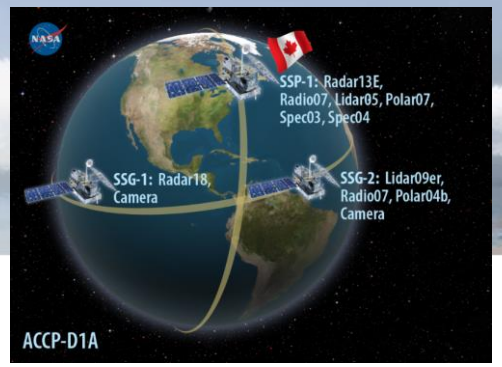
Smaller Swath Radar Option

Spacecraft: SSP-1 | SSP-2

Lidar - 3 wavelength (WL) 355nm, 532nm HSRL, 1064 backscatter (BS)

Lidar: 2 wavelength 532nm HSRL, 1064 backscatter

Top Candidate Architecture



Instrument	Size	Description
SSP-1	**SSP- Polar orbit**	
Radar13E	Medium satellite radar	W band Doppler, Ka band Doppler, 15km swath
Radio07	Small satellite radiometer	118, 183, 240, 310, 380, 660, 880 GHz
Lidar05	Medium satellite lidar	532nm HSRL, 1064nm backscatter
Polar07	Small-medium satellite polarimeter	550km swath, 0.5km resolution
Spec03	Small satellite spectrometer	Long wave infrared
Spec04	Small satellite spectrometer	Short wave infrared

SSG-1	**SSG- Inclined orbit**	
Radar18	Small satellite radar	W band Doppler, Ku band Doppler
Camera	Small satellite camera	Stereo camera visible imaging
SSG-2		
Lidar09er	Small satellite lidar	532nm, 1064nm backscatter
Radio07	Small satellite radiometer	118, 183, 240, 310, 380, 660, 880 GHz
Polar04b	Small satellite polarimeter	1130km swath, 1km resolution
Camera	Small satellite camera	Stereo camera visible imaging

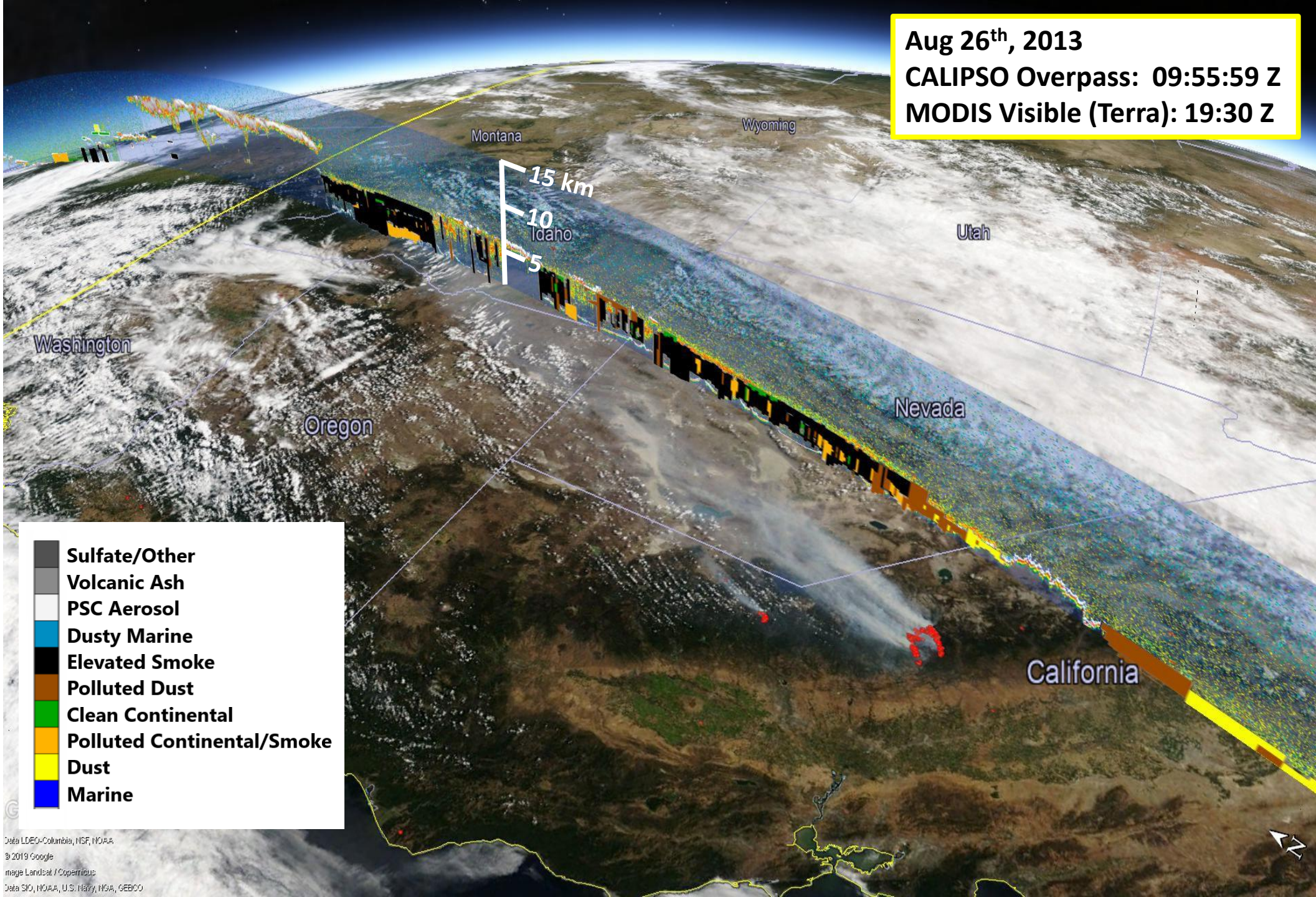
Launch: SSG-1 and SSG-2 will launch as early as 2027-2028, followed by SSP-1

Descope Options: (1) Descope Camera dt (2) Descope Radar18 to Radar12

Rim Fire, CA 2013

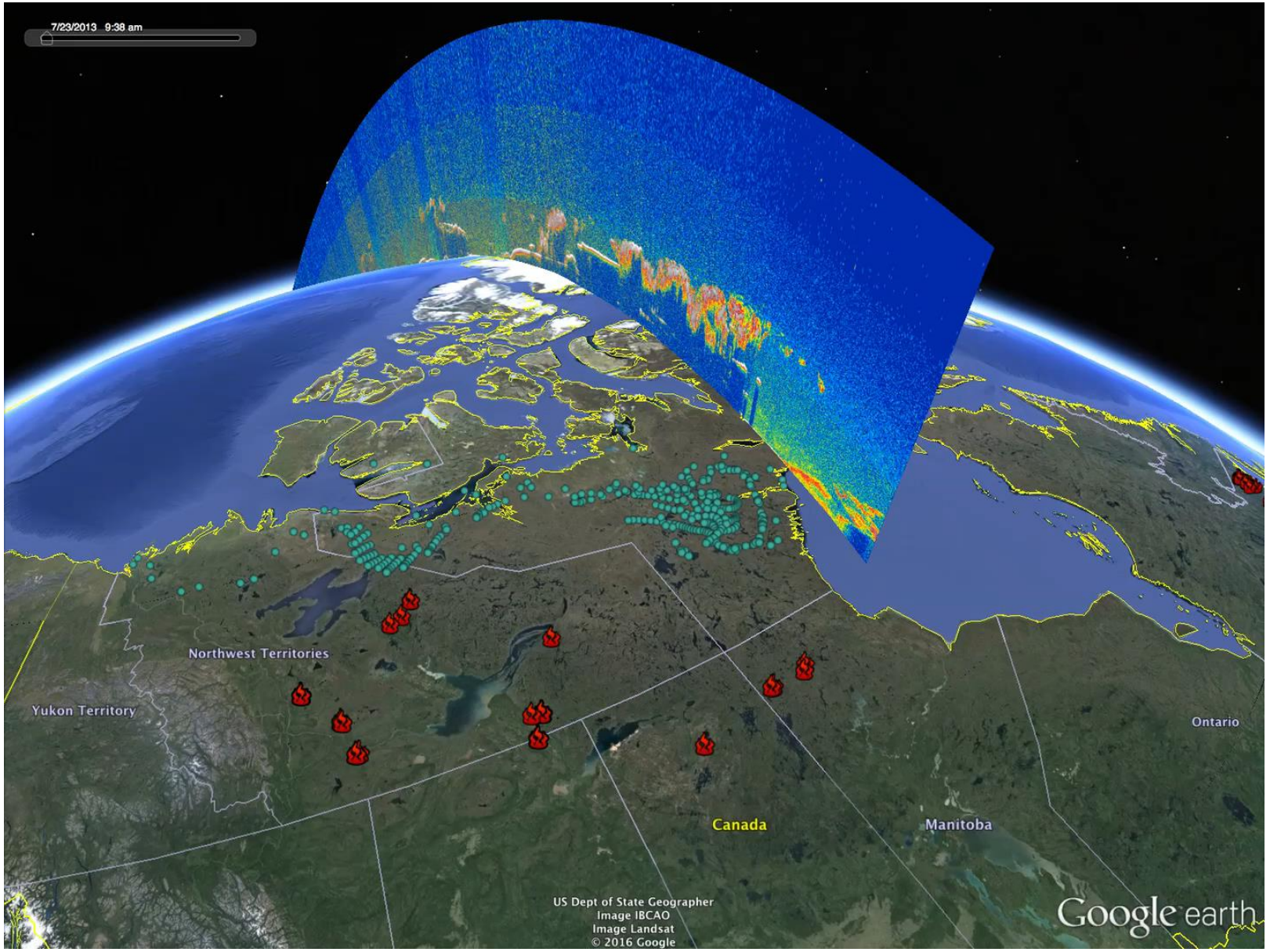
CALIOP detects low-level smoke that extends vertically through the atmosphere and to the surface.

CALIPSO v4 Aerosol Types



CALIPSO vertical swath overlaid on North America MODIS data.
Smoke is in the bottom front of the CALIOP data.

The Langley Trajectory Model shows the smoke-laden air parcels (aqua) being transported from the fires (red), through the CALIOP aerosol data, to the Greenland Ice Sheet, where it is deposited (climate feedback).

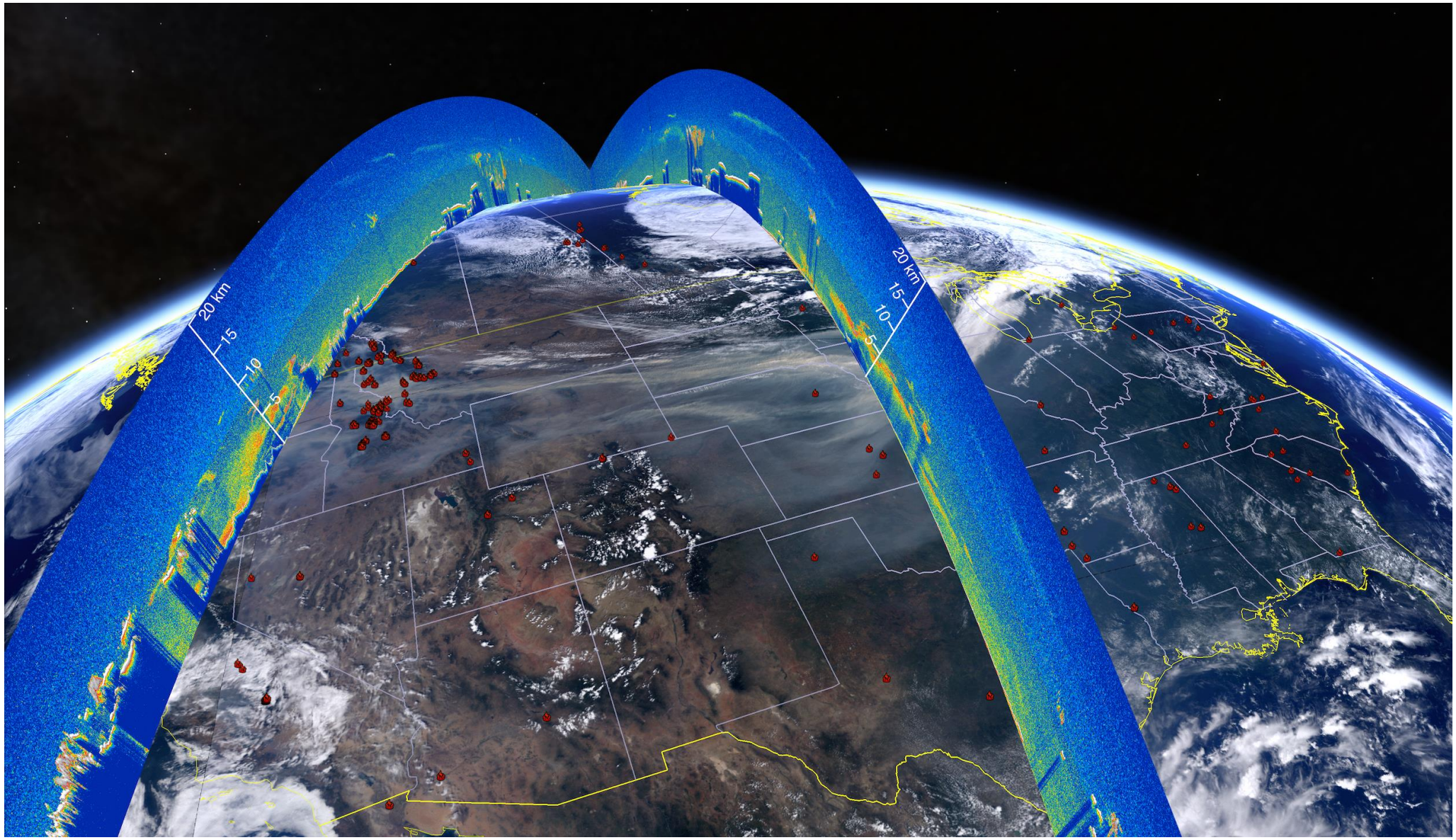


Smoke and volcanic plumes are extensive; related pollution not always localized

Smoke is Expansive

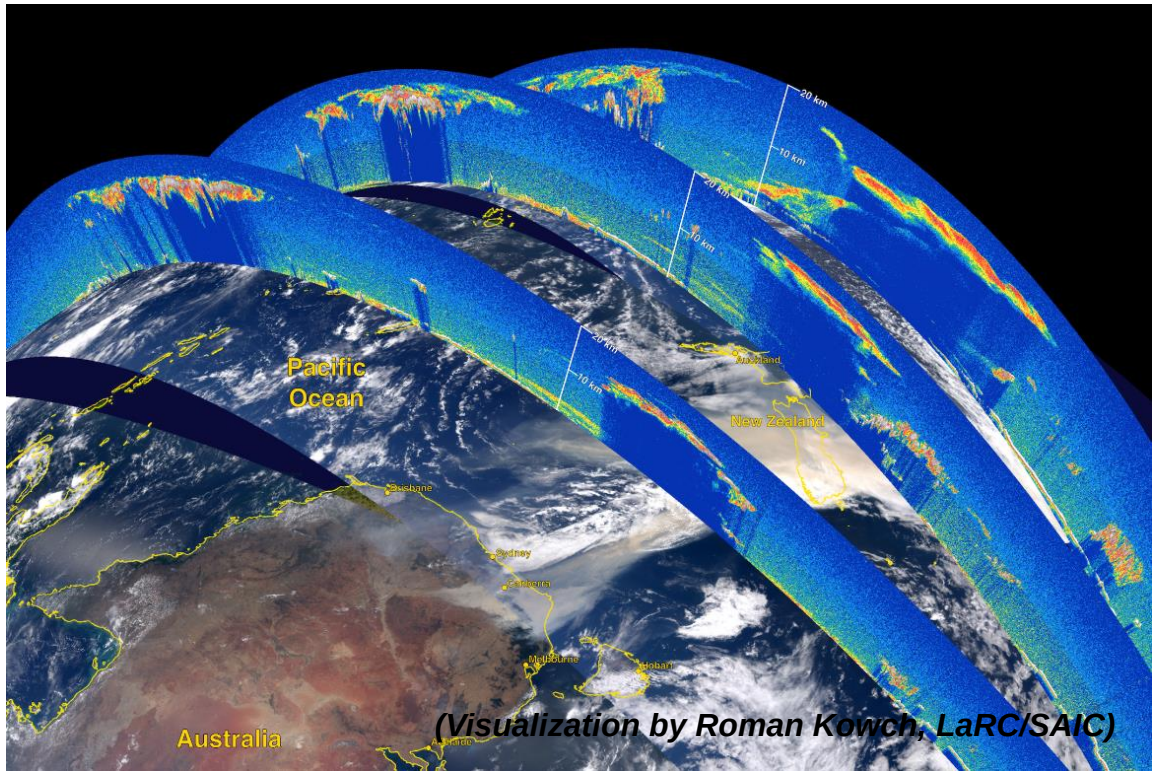
Lidar (CALIOP) does not need to be over a fire to ascertain smoke detrainment height.

Smoke at 4 - 7 km



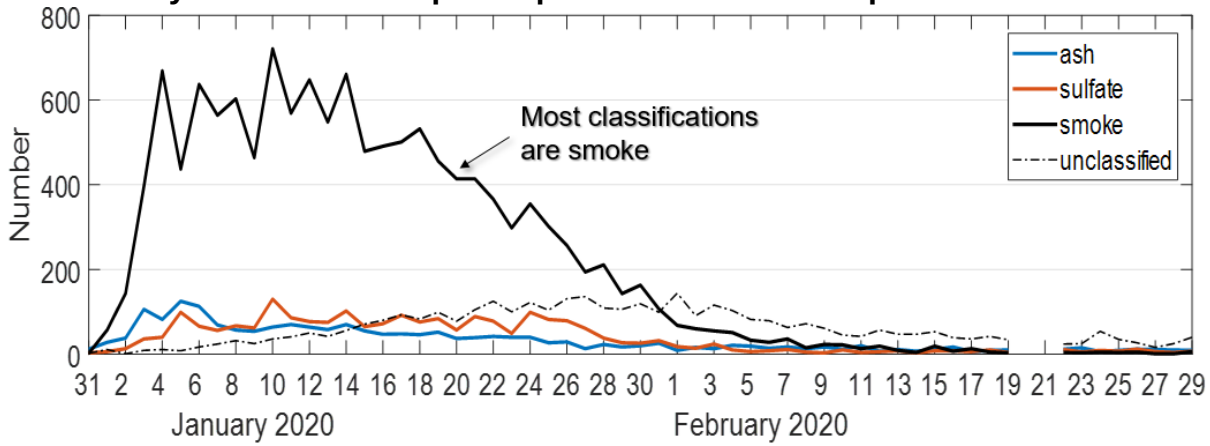
CALIOP overlaid on Terra with active-fire detections September 04, 2017

CALIOP was able to track the Australian smoke plume thousands of kilometers downwind

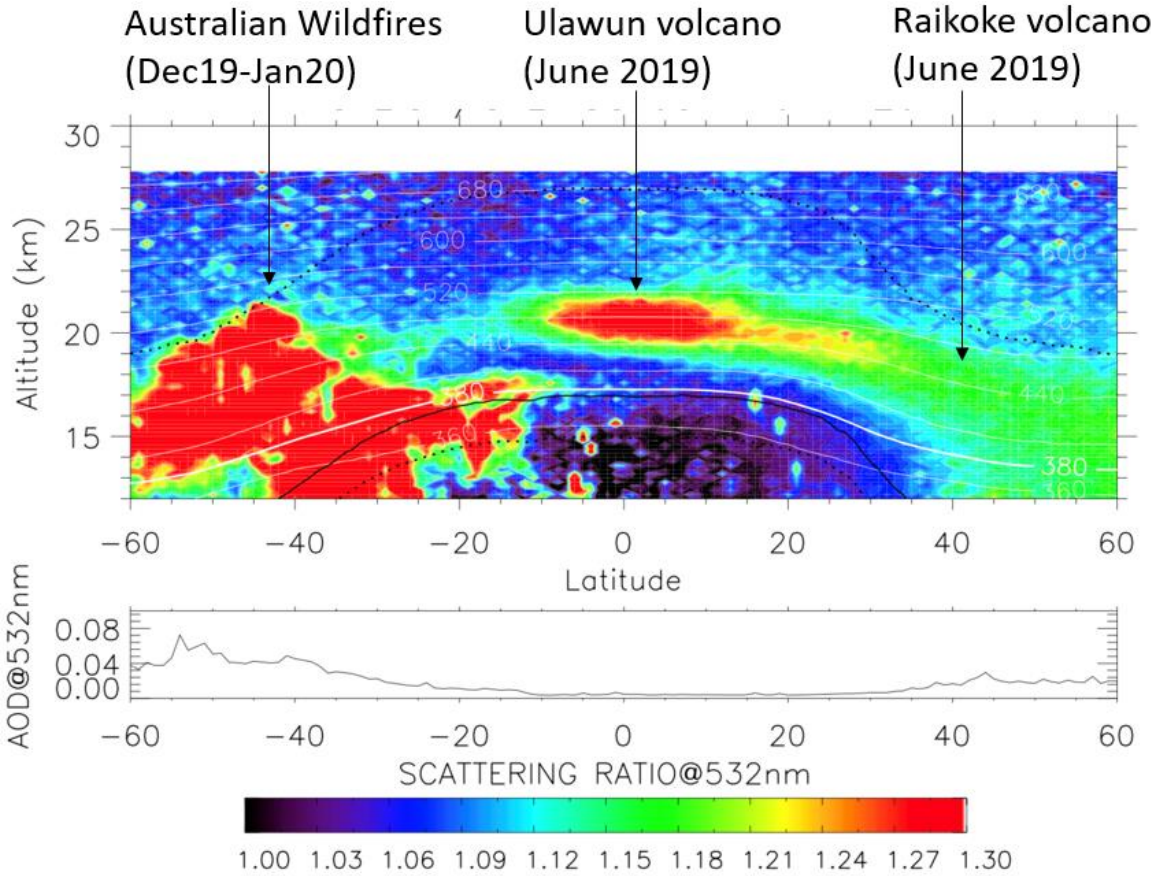


(Visualization by Roman Kowch, LaRC/SAIC)

Daily CALIOP stratospheric plume classifications poleward of 20°S



Averaged CALIOP profiles: 3-12 Jan 2020



(courtesy Jean-Paul Vernier, LaRC/SAIC)

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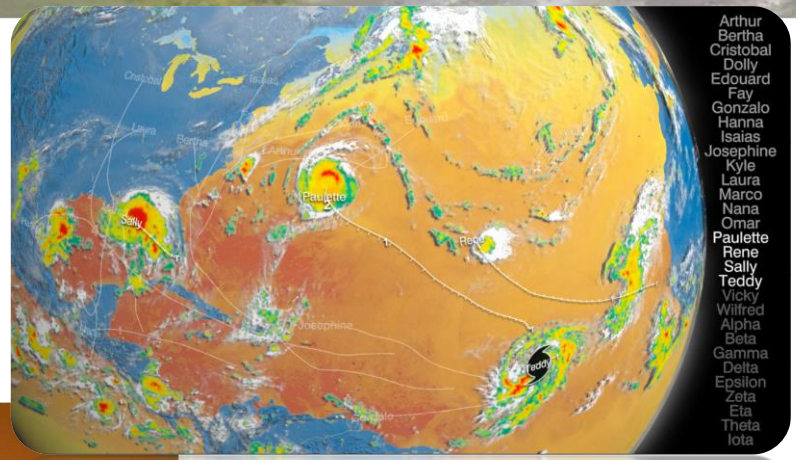

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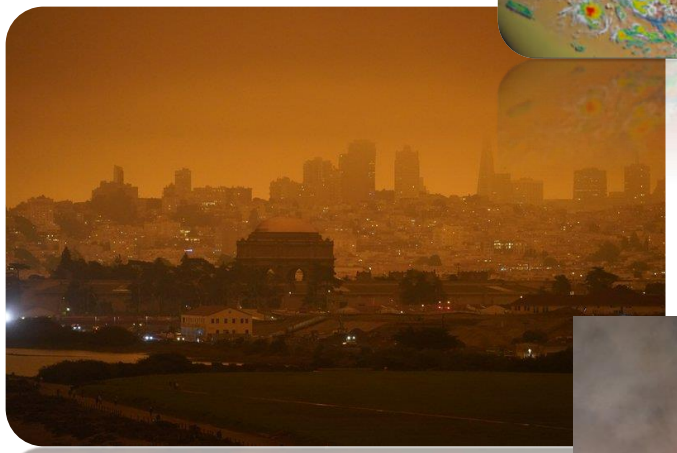

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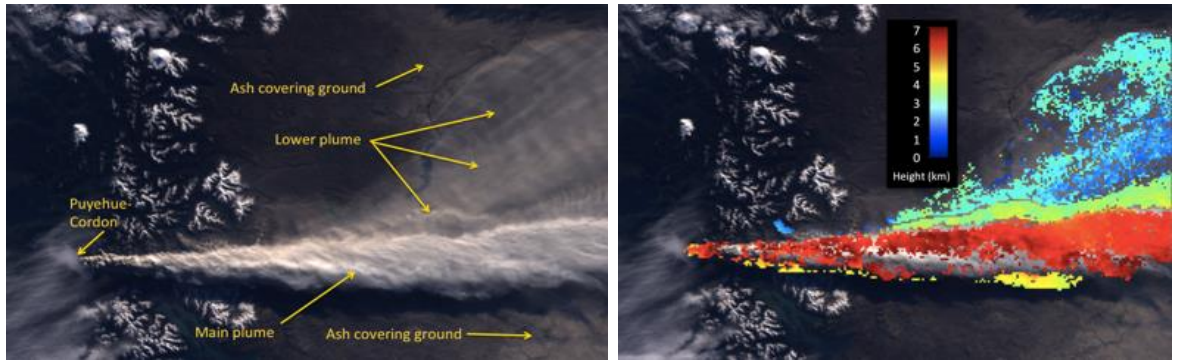
Cameras: Cloud Dynamics Imager (CDI) – MISR Examples

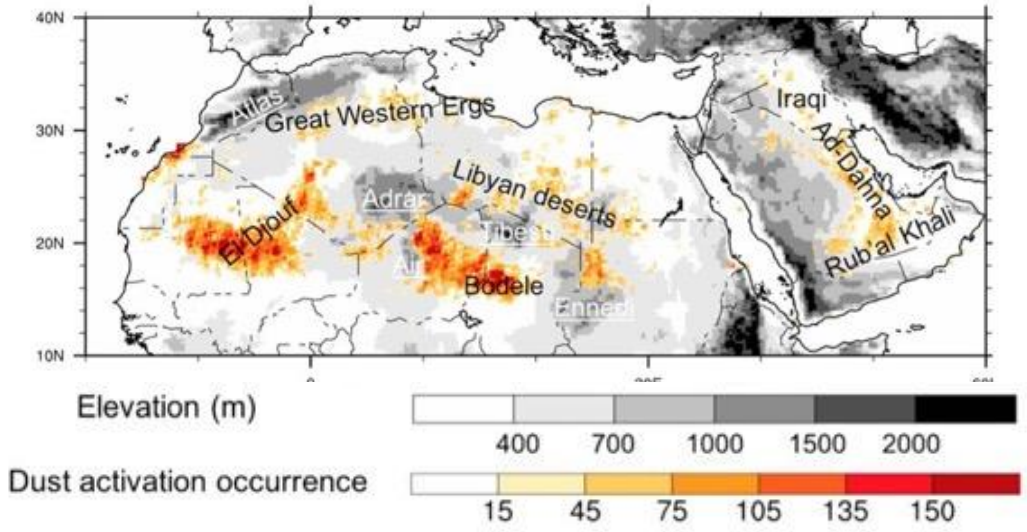


Ash plumes from Puyehue-Cordon volcano in Chile extended above 7 km and disrupted air traffic. (June 2011)

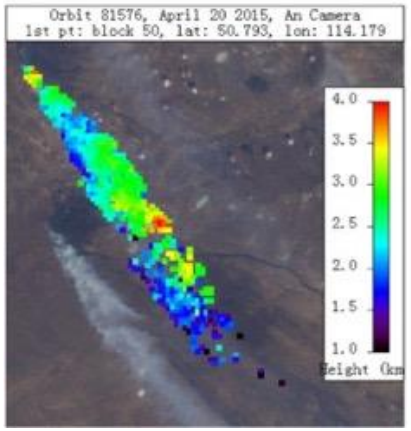
Improvements

- Different times of the day
- Higher spatial resolution (~50m)
- Improved 3D velocity accuracy
- Plume heights with 3D motion
- 2 cameras ~45±15 sec

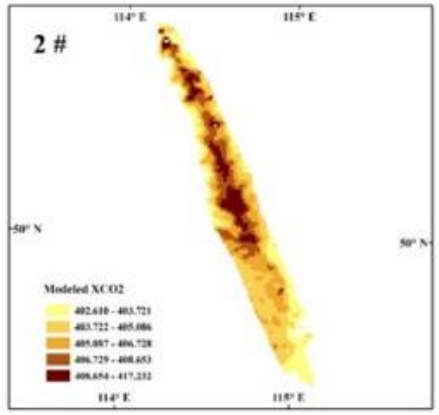
MISR has a well-developed near-field smoke plume database for this morning only overpass. Val Martin et al, 2012



Plume heights and speeds identify dust source regions, and initialize trans-Atlantic trajectory modeling *Yu et al. (2018, 2020)*



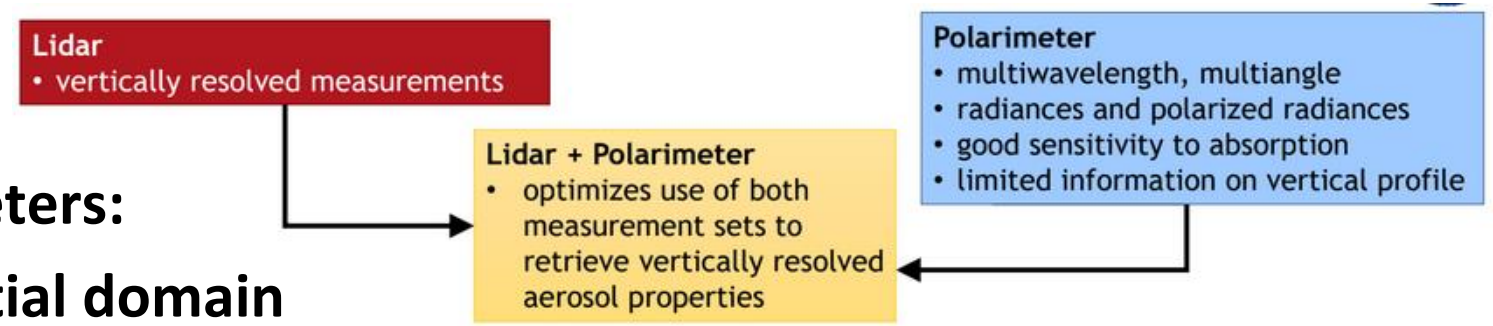
MISR plume heights for two Siberian wildfires



Corresponding CO2 concentrations from MODIS and OCO-2

Fusion of MISR plume heights with MODIS & OCO-2 data enables retrieval of CO2 emissions over Siberian wildfires *(Guo et al., 2019)*.

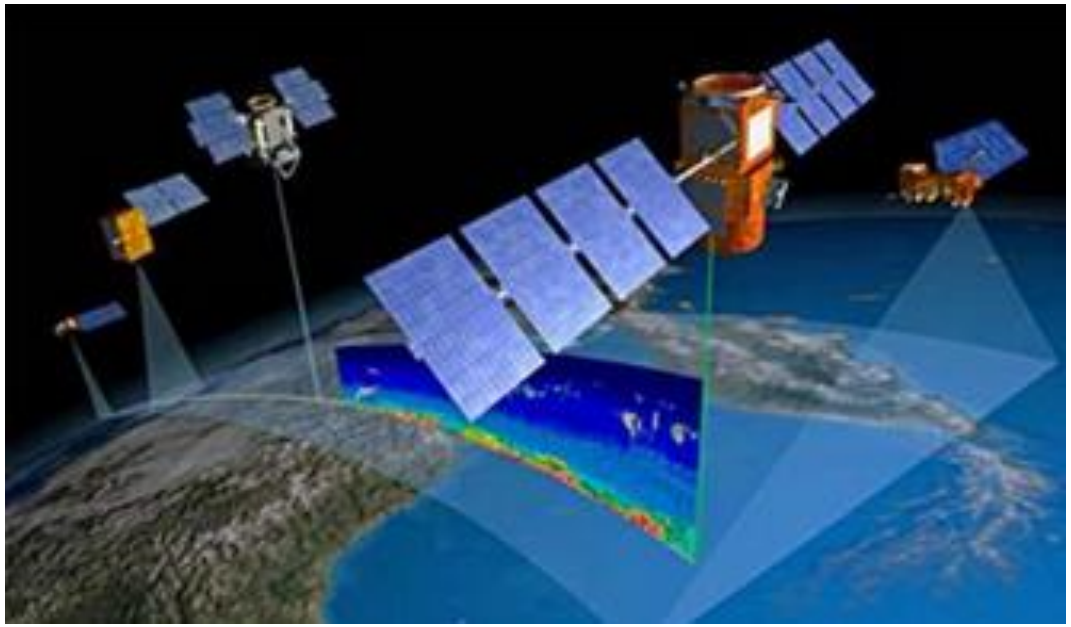
Lidar + Polarimeter Synergy



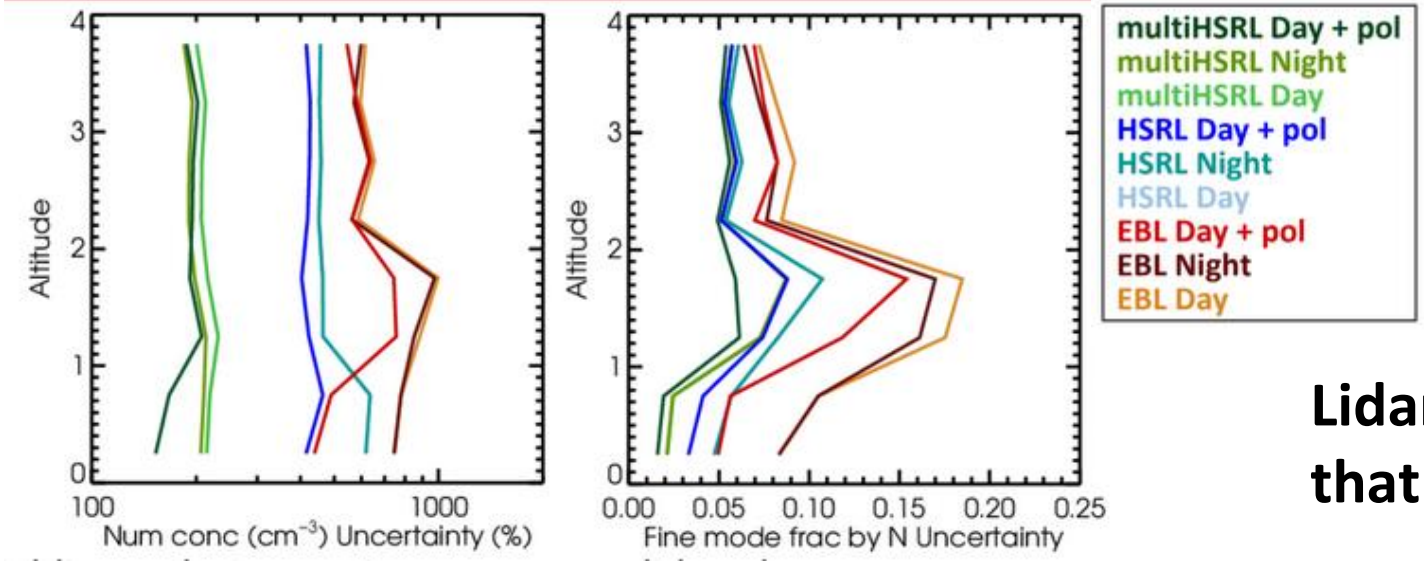
Lidars + Polarimeters:

Enhance the spatial domain of the lidar; and

Improves the uncertainty of the lidars.



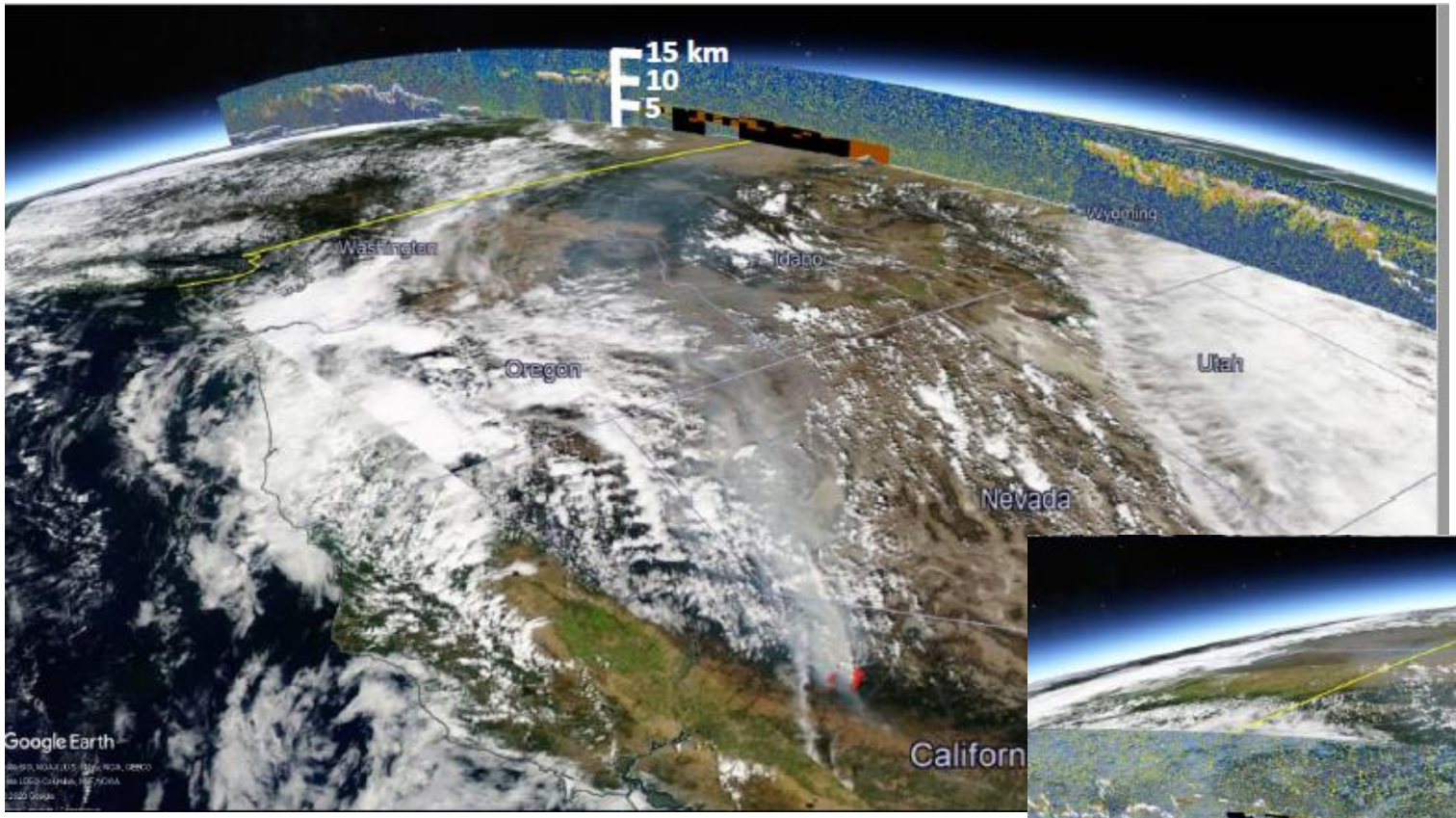
Uncertainty Profiles (Sharon Burton)

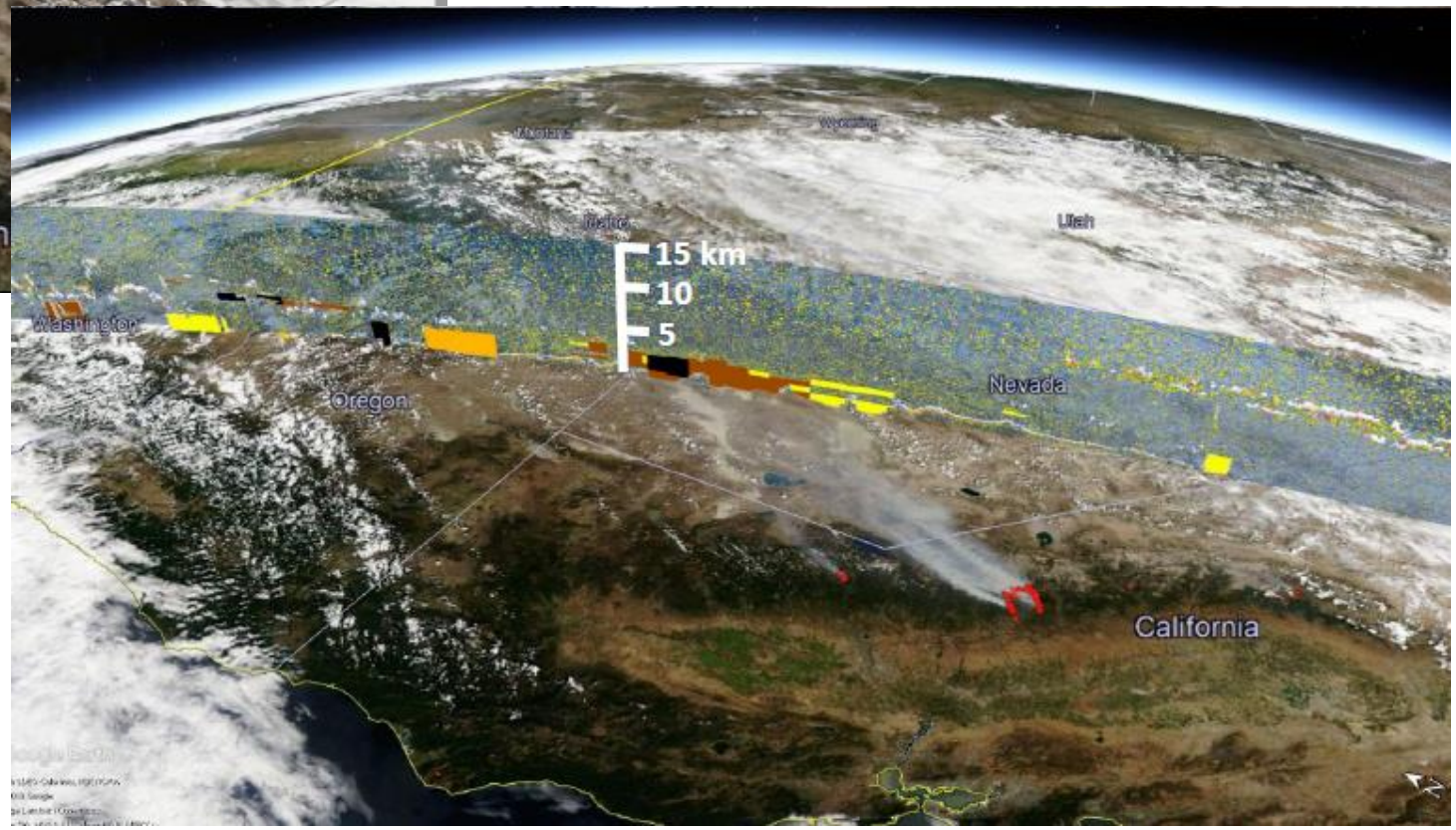


Lidar data provide the vertical aerosol state that is not possible with polarimeters alone.

CALIPSO Elastic Backscatter Lidar

The Lidar Ratio (LR) is a direct HSRL measurement, which will provide for improvements in aerosol type accuracy that was not previously possible.





- Sulfate/Other
- Volcanic Ash
- PSC Aerosol
- Dusty Marine
- Elevated Smoke
- Polluted Dust
- Clean Continental
- Polluted Continental/Smoke
- Dust
- Marine

Rim Fire smoke (big fire)

CALIOP curtains showing species available with CALIOP

Burton et al., 2012; Rodgers et al., 2014

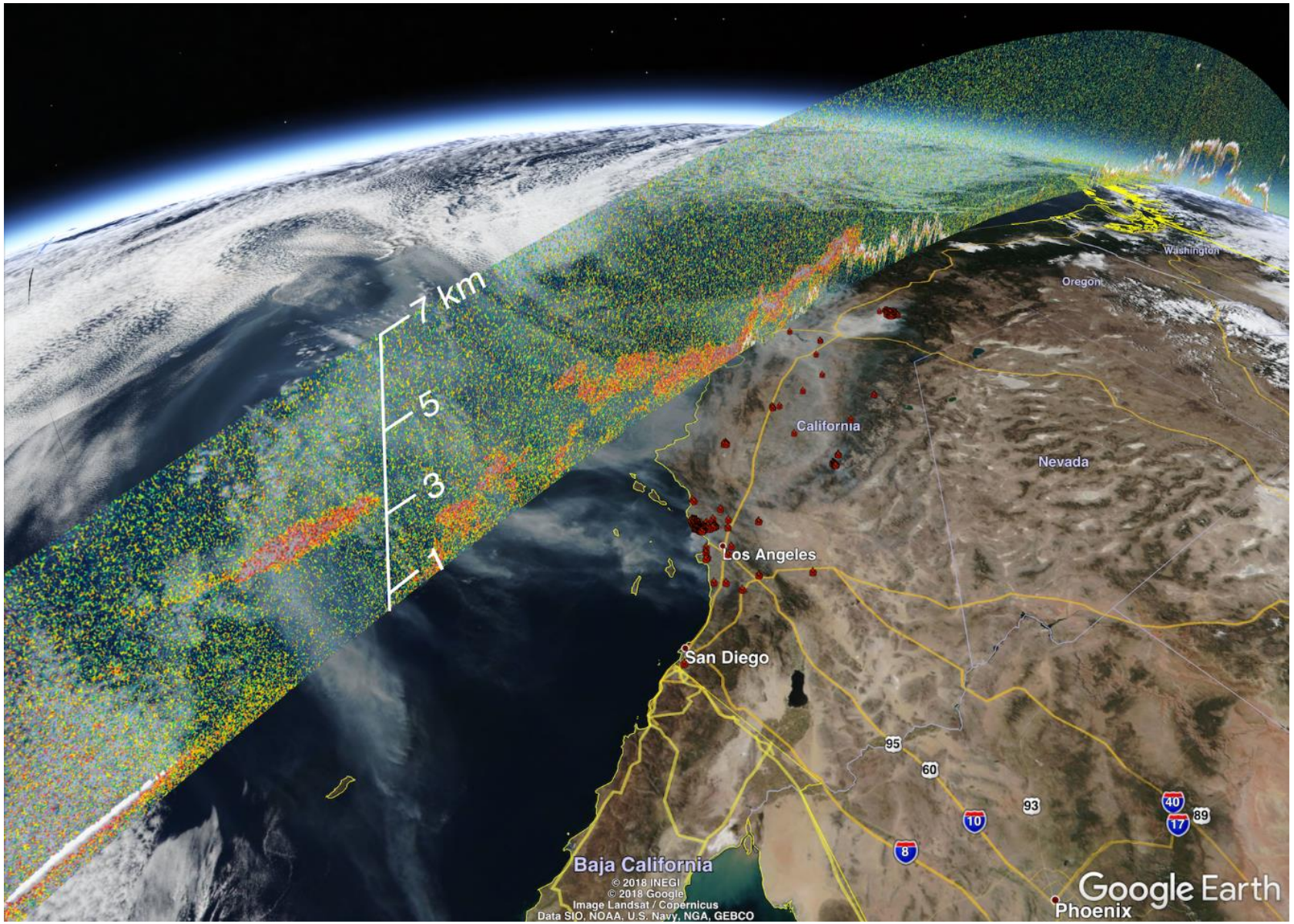
The Lidar Ratio (LR) is a direct HSRL measurement, which will provide for improvements in aerosol type accuracy that was not previously possible.

Camp Fire, CA
November 2018

Smoke is transported west off the coast and then returns.

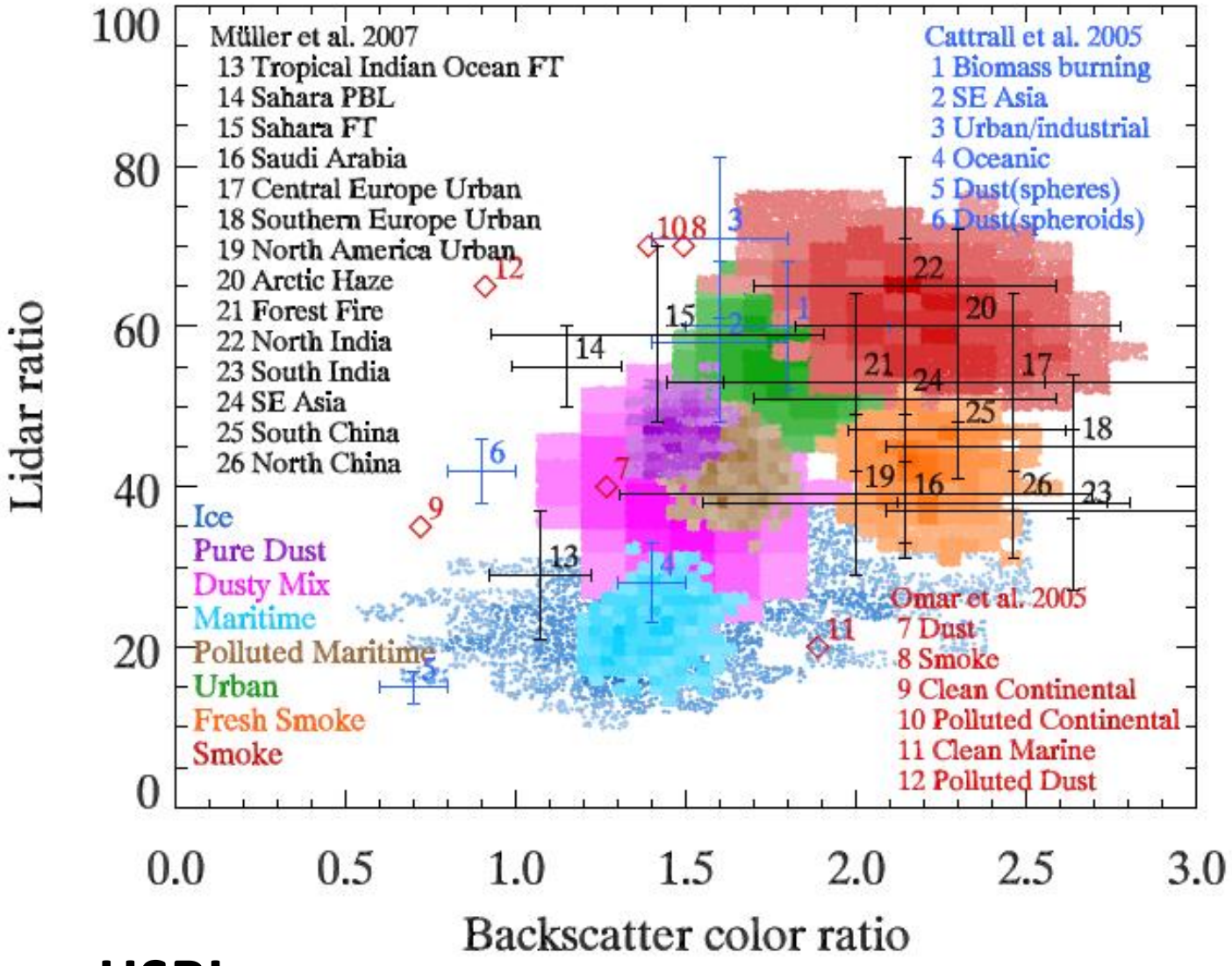
CALIOP data on Google Earth

Problem here is over the ocean, classification is typically marine.



Increased number of Aerosol Types with increased accuracy

High Spectral Resolution Lidar (HSRL) measures the Lidar Ratio enabling accurate Aerosol types, previously not possible.

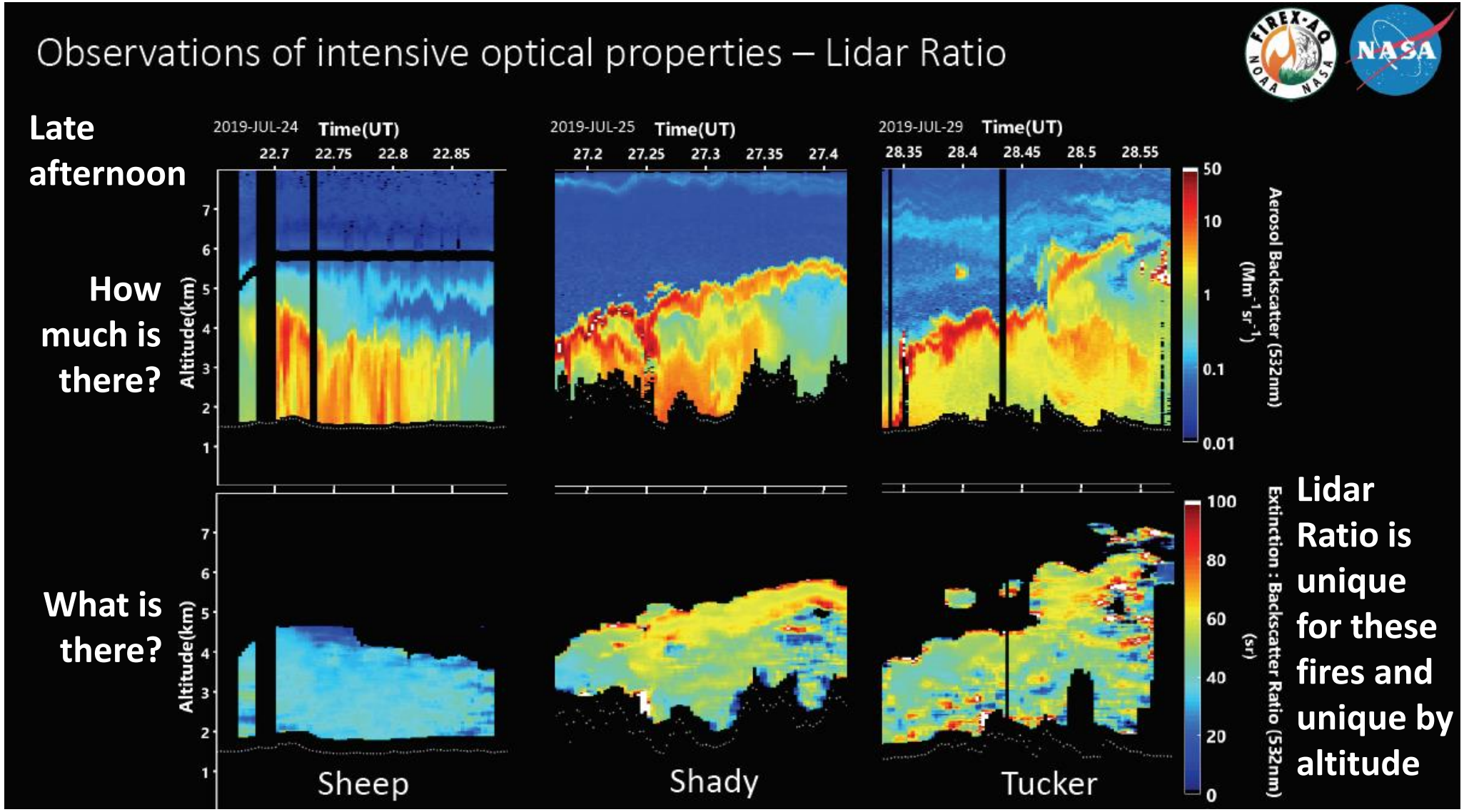


HSRL

Burton et al., 2012; Rodgers et al., 2014

Example: HSRL data showing differences in the optical properties of specific fires

With this clarity, the research and applied value is to question the reasons for these optical property differences (fuel types, amount of fuels, fire weather).



Applications value to emissions inventories and climate model feedbacks

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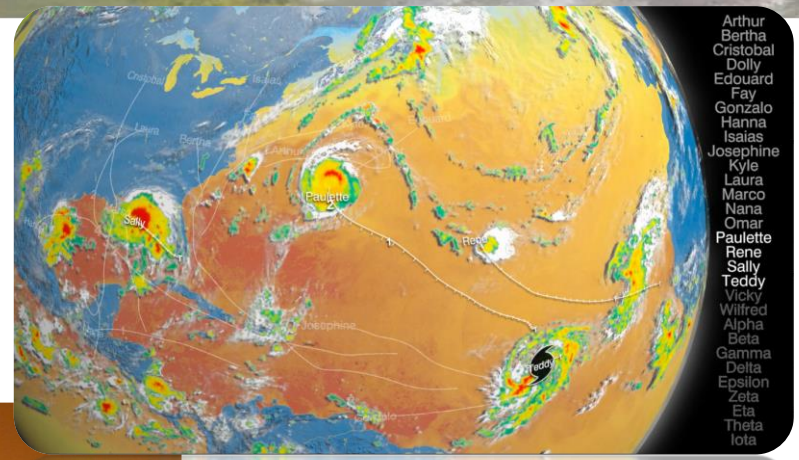

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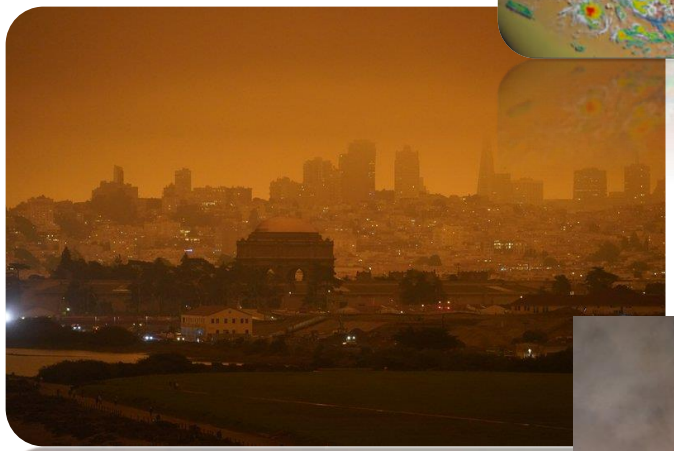

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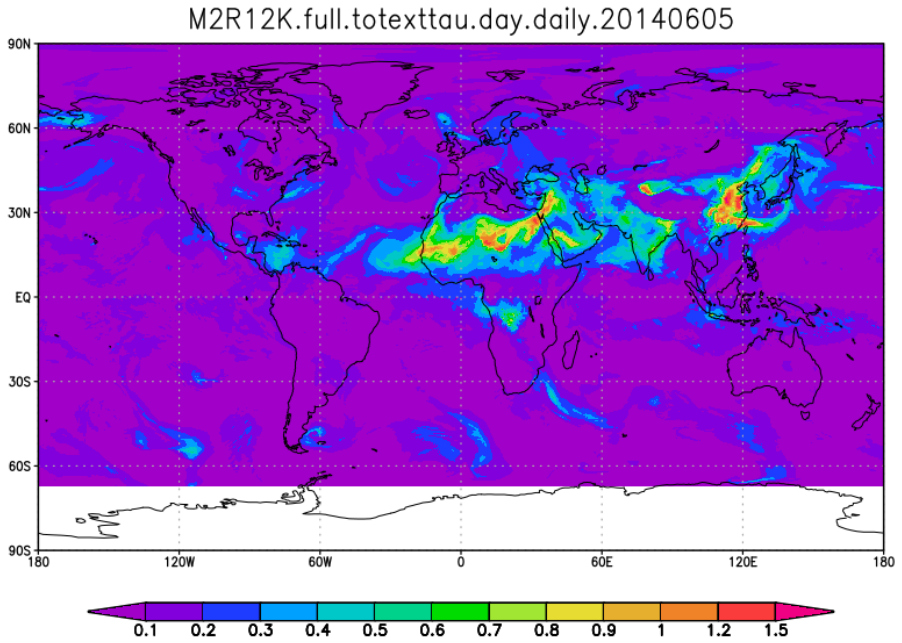
Sample Coverage Daily Average Plots

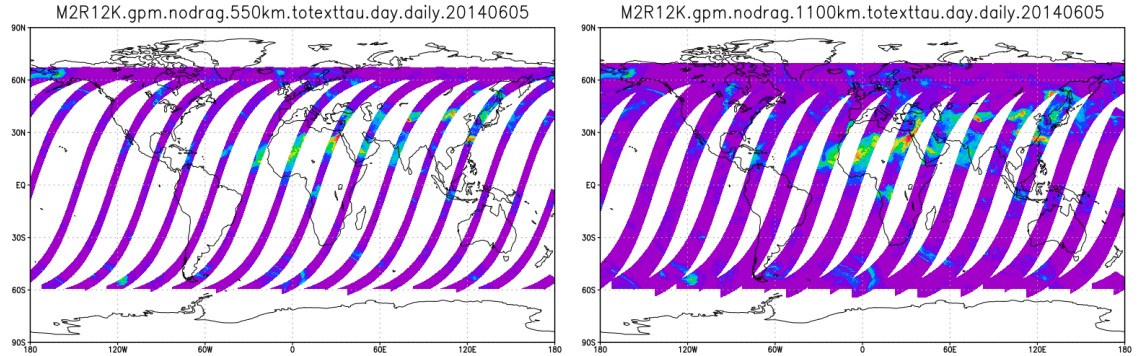


Above: Model data sampled

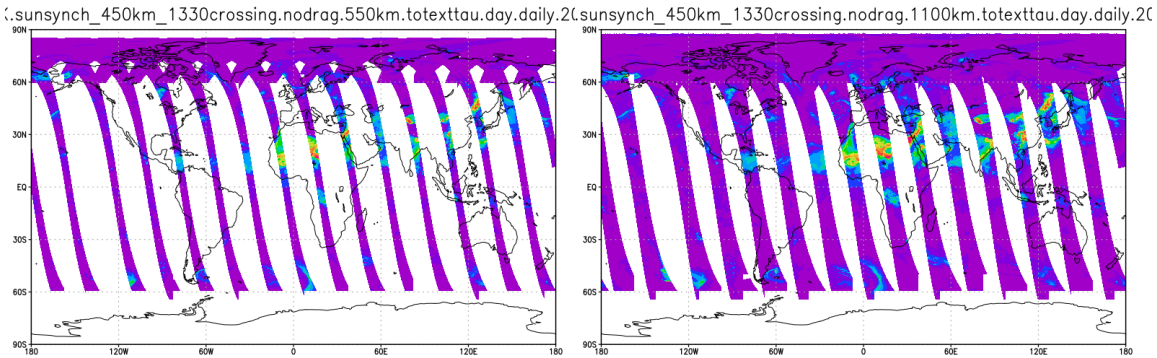
Coverage for Lidar + Polarimeter

Daily averages are computed from hourly output

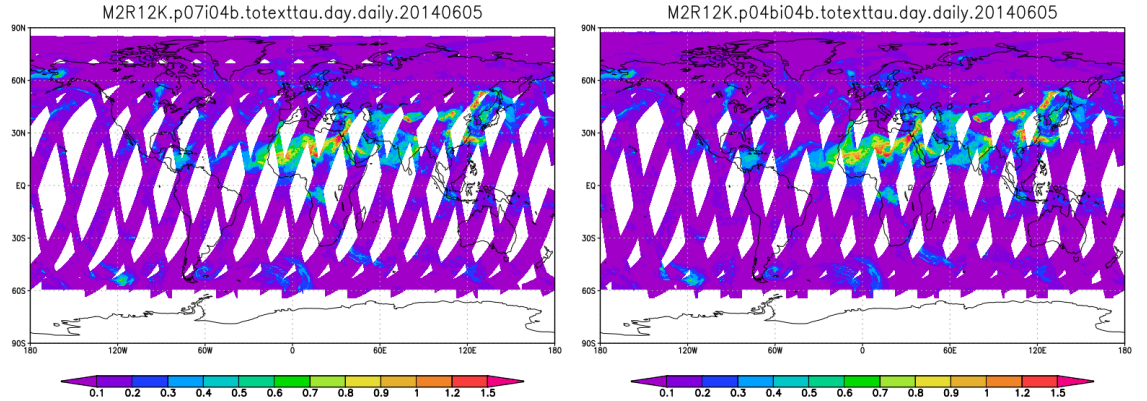
Inclined



Sun-Synch

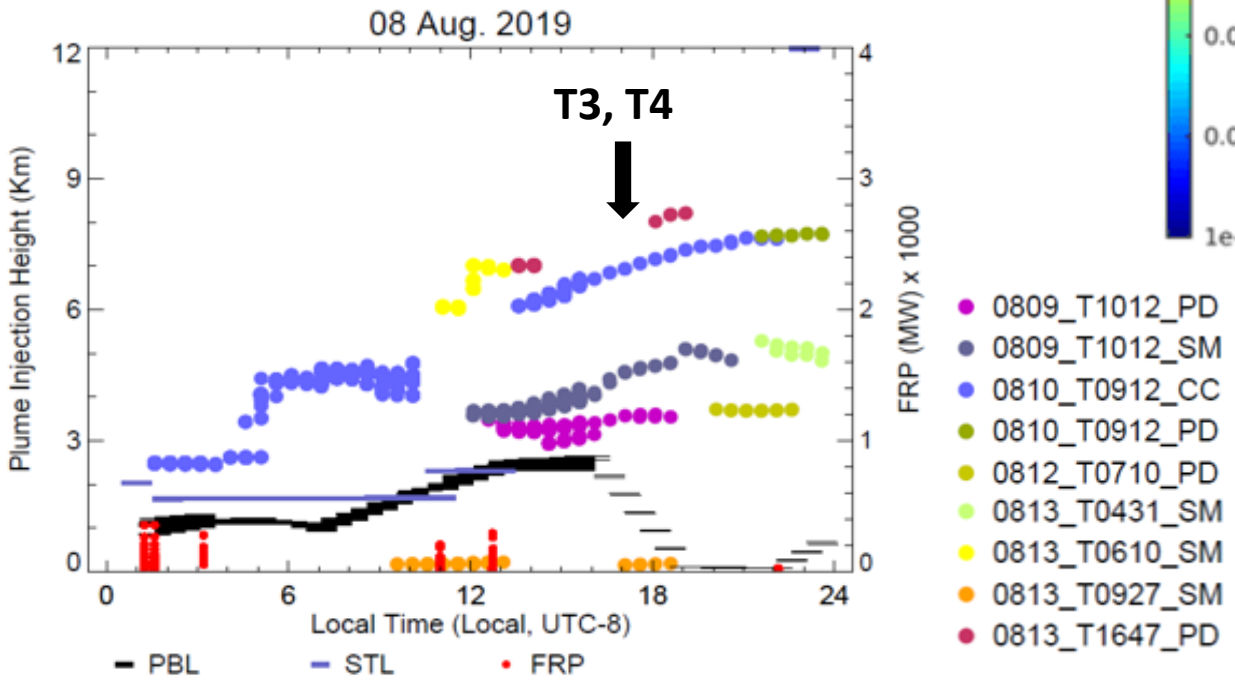


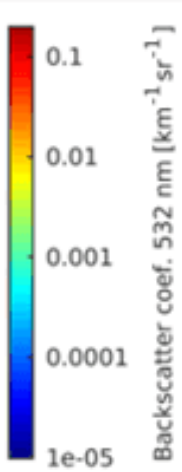
Joint

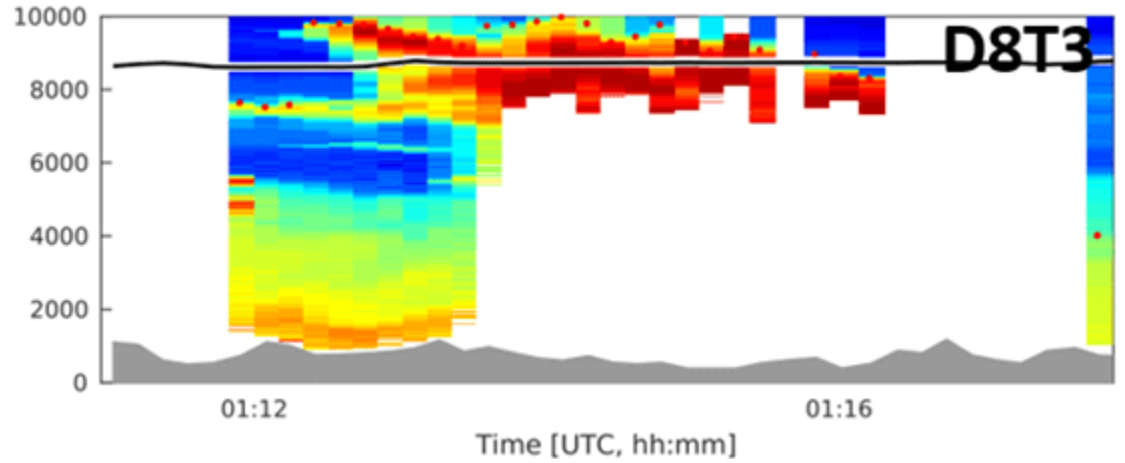


Pete Colarco

Williams Flats Fire CALIOP vs HSRL Backscatter: 08/8/2019

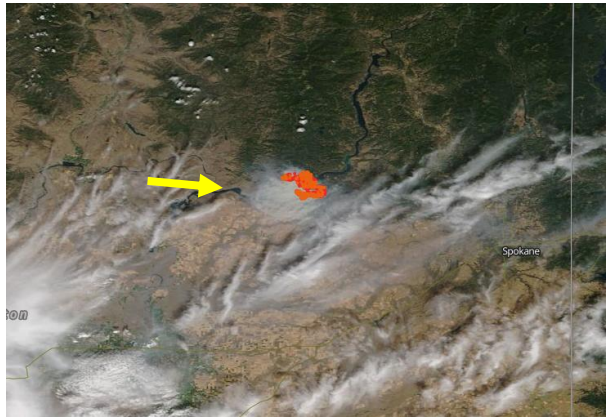




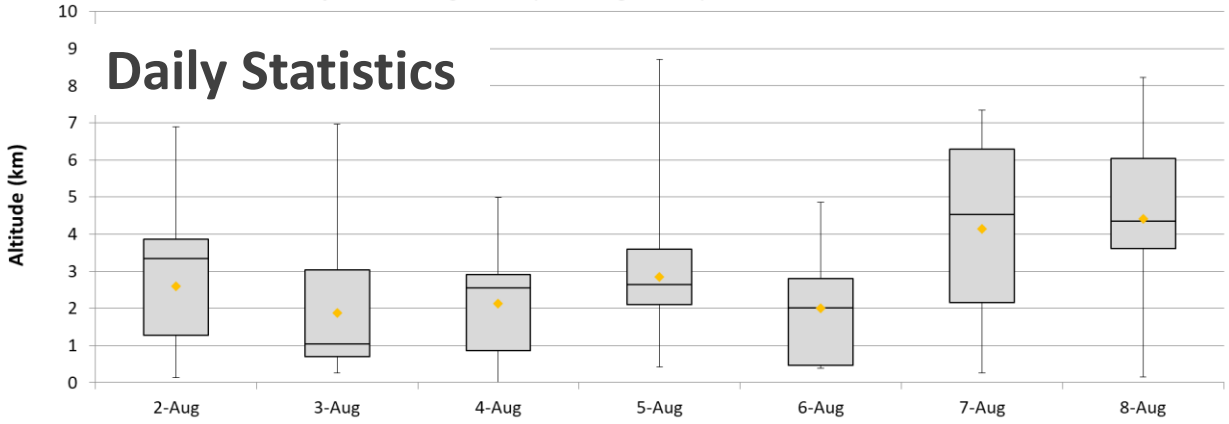


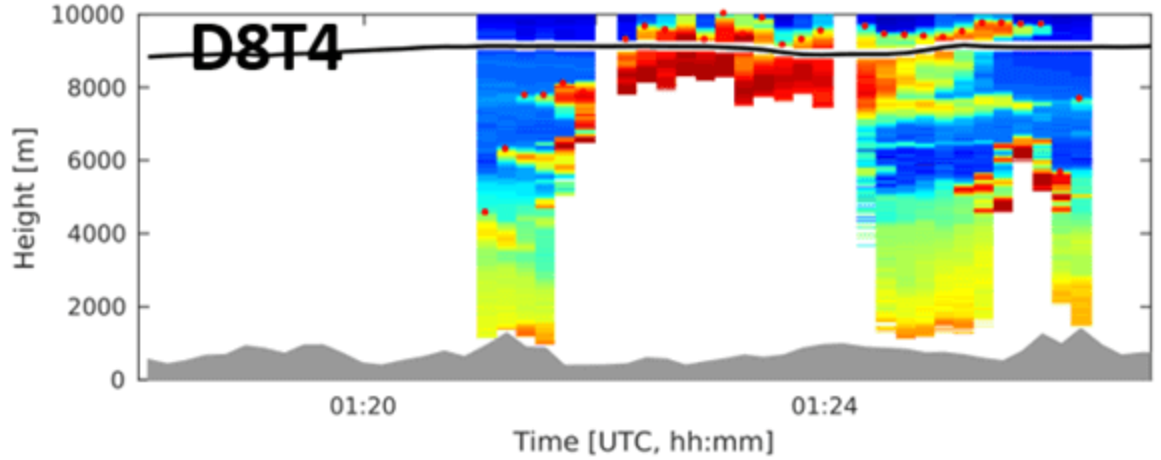
Multiple CALIOP plumes

MODIS: Terra



Plume Injection Height for (above ground) the Williams Flat, WA 2019





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Aerosol, Air Quality, Weather and Cloud Applications: Measurement, potential data products

Processed-based mission

- Processes will be informed and models enhanced
- Cloud and aerosol interactions
- Climate processes

- Fire Weather enhancements
- Identify smoke, dust, and volcanic plumes (ash density)
- Accurate Aerosol Types
- Identification of previously unknown fire regimes (small human prescribed & agriculture)
- Dust, smoke, and volcanic top height and vertical extent
- Cloud and aerosol height, shape, and size
- Boundary and Mixed Layer Heights
- Cloud and aerosol 3D motion (horizontal and vertical)
- Plume top updraft velocities
- Aerosol Optical Depth (per layers)
- Particulate Matter: PM 2.5, PM 1
- Wildfire plume impacts on fire community & air quality
  - Height initialization in plume dispersion models
  - Validation of plume rise models
  - Additional constraints on trace gas emissions and evolution of particle properties from wildfires

Extra Slides

M.-H. Kim et al.: CALIPSO V4 aerosol classification

2018