International Biomass Burning Initiative

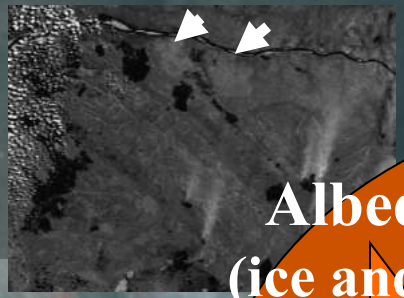
Satellite-based Fire Data and Products: A NASA perspective

Photo courtesy of Brian Stocks

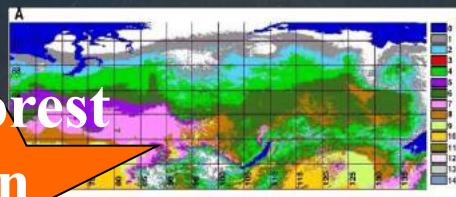
Amber Soja: amber.j.soja@nasa.gov
with slides from:
Louis Giglio and Kelvin Brentzel

Climate and Weather

(temperature, precipitation, clouds, radiation)

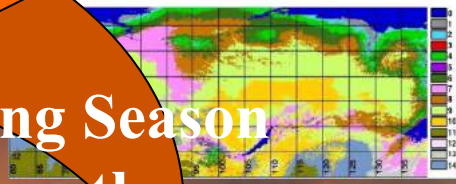


Albedo Change
(ice and forest type)



Species and Forest Composition

Aerosols and Species-specific Emissions



Growing Season Length

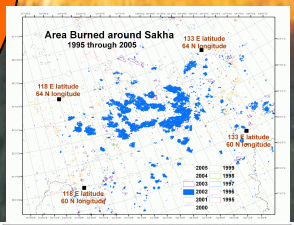
Air Quality

Carbon Balance

Under the control of weather and climate, fire is a driving force of change.

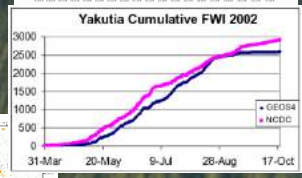
Fire Season Length

Evapo-transpiration



Ignitions from Lightning

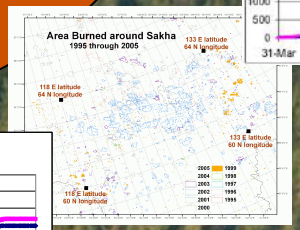
Vegetation Cohort Change



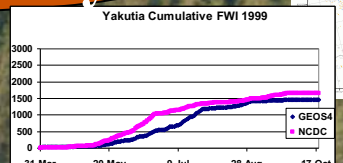
Fuel Moisture

Soil Moisture / Permafrost

Fire Weather Severity



Fire



Human Management

Infestation

Photo: Brian Stocks

NASA Supports Fire Science

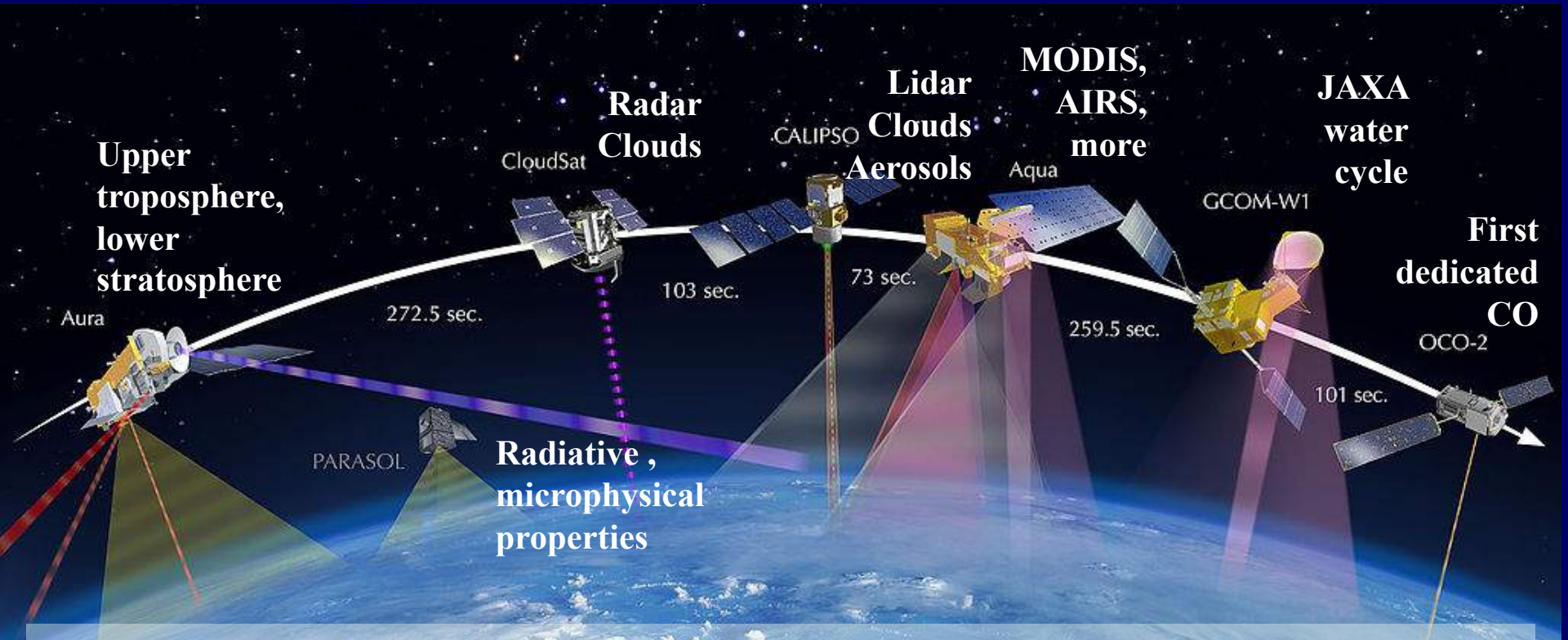
- Science Mission Directorate
- Earth Science Programs
  - Carbon Cycle and Ecosystems (e.g. Carbon Cycle, Land Cover Land Use Change, Terrestrial Ecology, Biodiversity, Climate and Biological Response, HyspIRI, Terra and Aqua, Ocean Biology Biogeochem.)
  - Climate Variability and Change
  - Water and Energy Cycle
  - Tropospheric Chemistry
  - Atmospheric Composition
  - Interdisciplinary Science
  - Weather
  - Applied Sciences

Funding through ROSES

http://nspires.nasaprs.com/external/

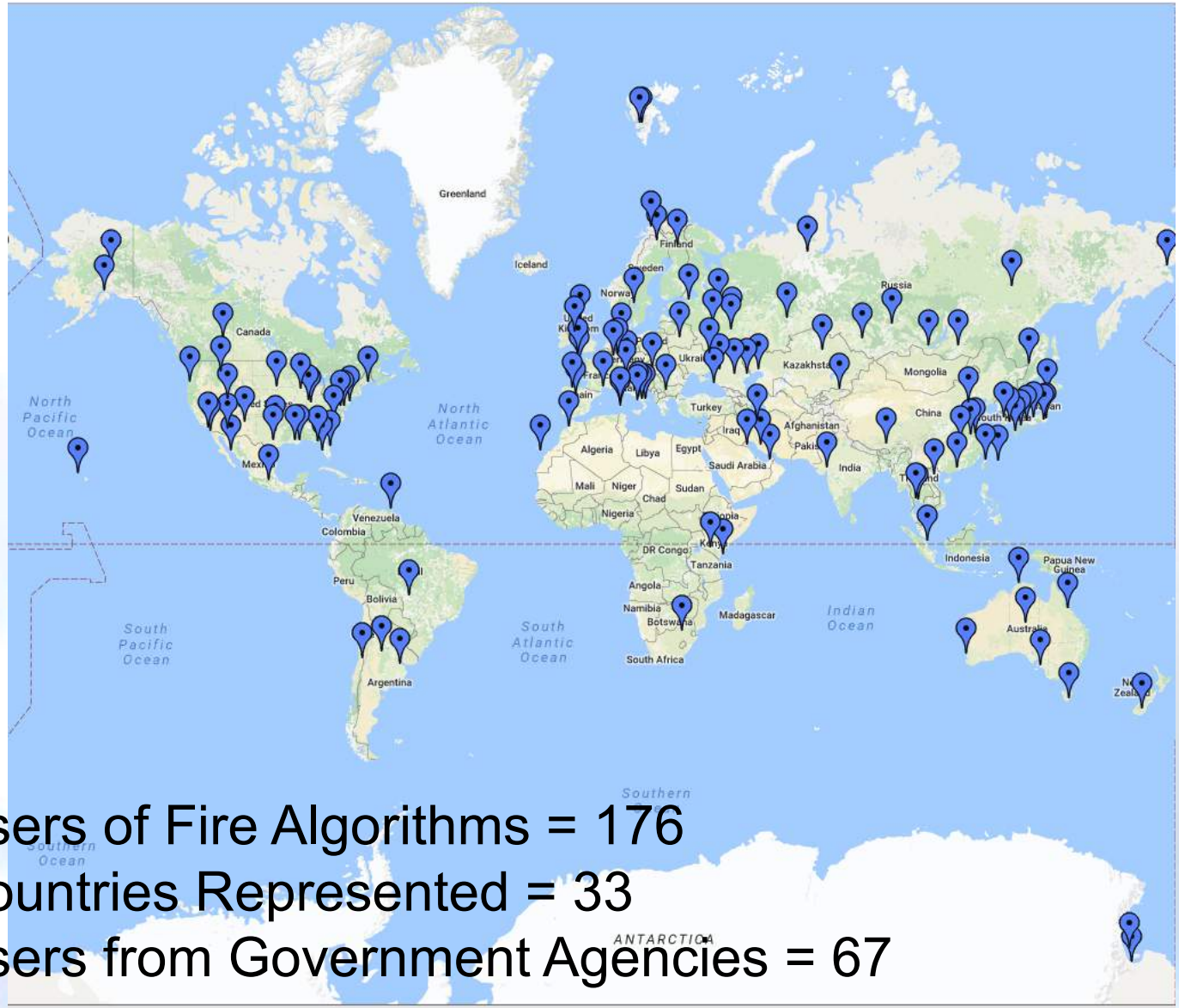

Formulation
Implementation
Primary Ops
Extended Ops
Landsat 9, TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE, TCTE (NOAA)
NISTAR, EPIC (NOAA's DSCOVR)
QuikSCAT
EO-1
Landsat 7 (USGS)
SMAP
Terra
Suomi NPP (NOAA)
Aqua
Landsat 8 (USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2 (NOAA)
OCO-2

NASA A-Train Satellite Constellation



- A-Train formation allows for simultaneous coordinated measurements.
- Data used together to obtain comprehensive information about the atmosphere or processes.
- Combining the information collected simultaneously from several sources provides a more complete understanding.

NASA Real-time Receiving Sites



- Number of Users of Fire Algorithms = 176
- Number of Countries Represented = 33
- Number of Users from Government Agencies = 67

NASA: Discovering the science we didn't know.

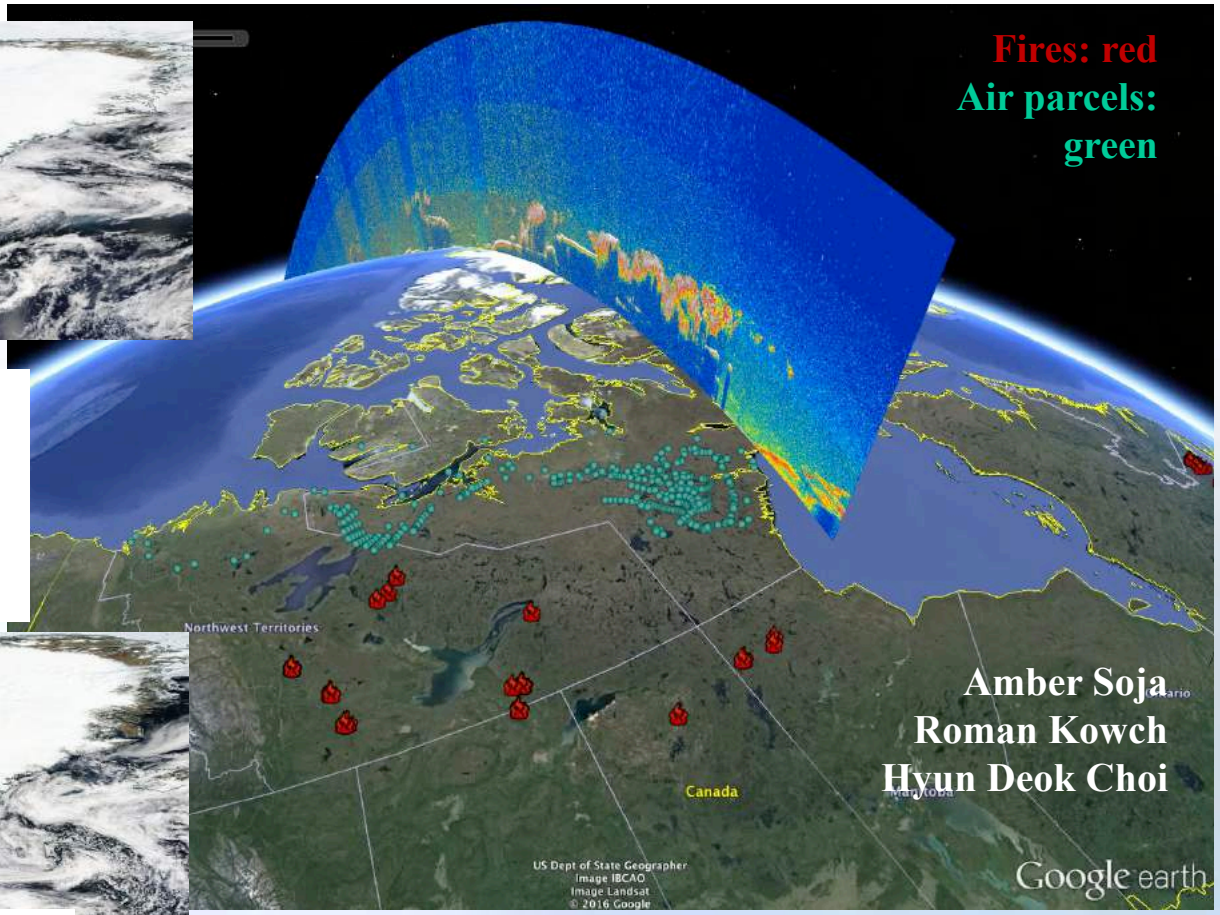
Using the Langley Trajectory Model, MODIS fire detection data, samples taken from pits, and CALIOP space-based lidar data, we can tease apart feedbacks to climate.

July 04th, 2013

WorldView MODIS
Aqua and Terra

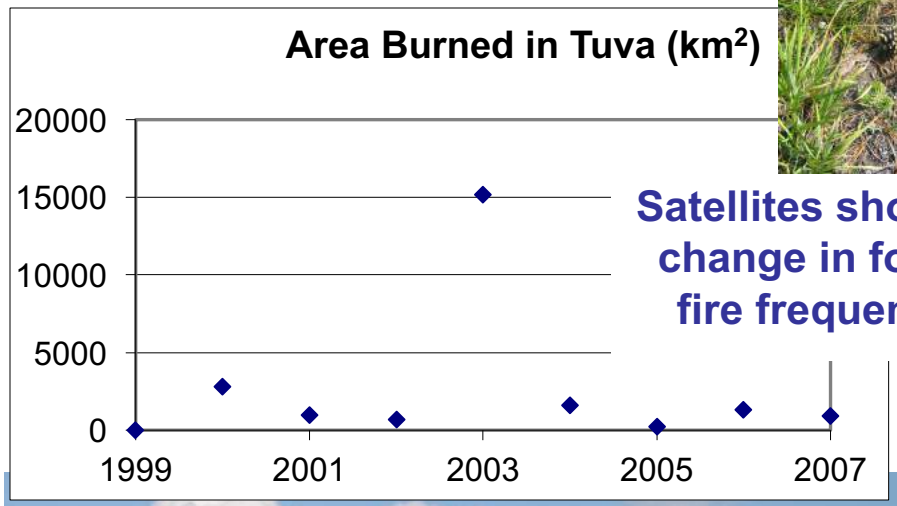
July 28th, 2013

CALIPSO track

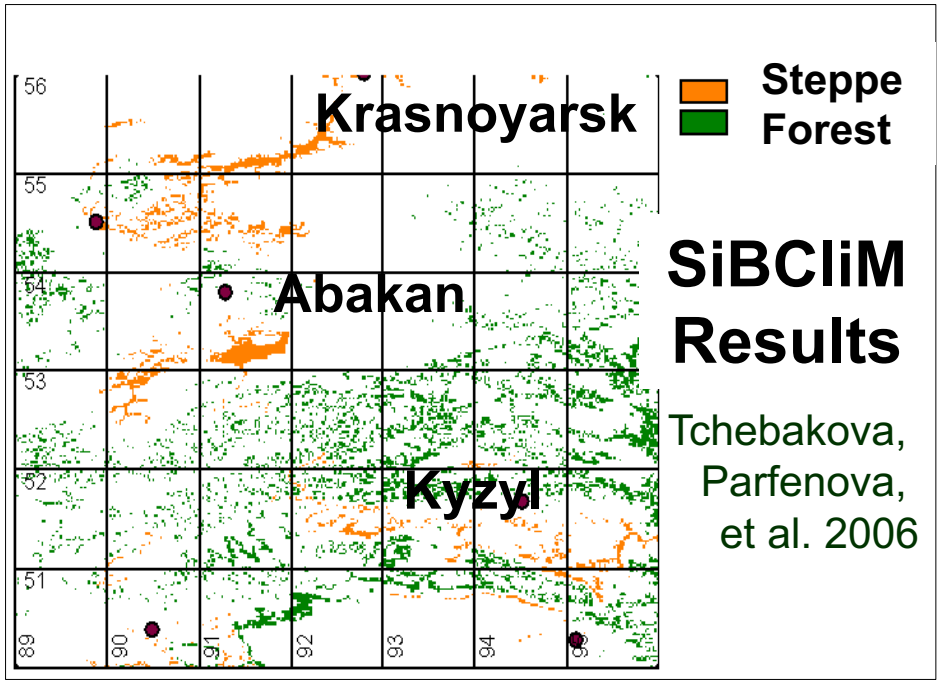


Amber Soja
Roman Kowch
Hyun Deok Choi

IDS: Tyva, Siberia: Locals report forests are disappearing; Models predict this area should exhibit the initial signs of climate change; Field research results - severity of fire increasing and sapling growing conditions hotter and dryer.



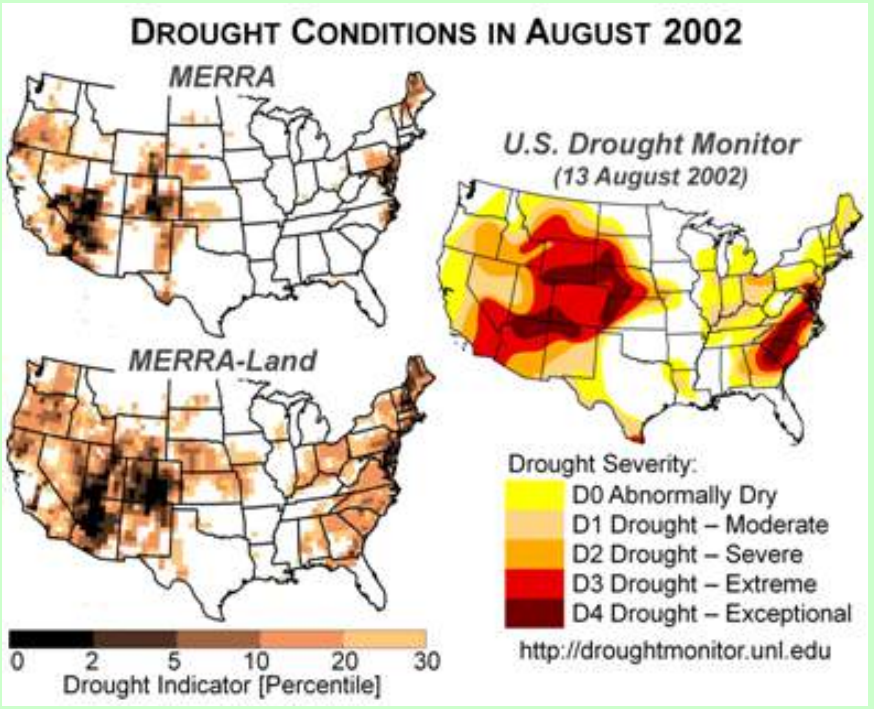
Satellites show no change in forest fire frequency.



NASA model data are freely available

GEOS-5 (Goddard Earth Observing System Data Assimilation System Version 5) data are a long-term data set of satellite-based meteorological and climate data.

MERRA (Modern Era-Retrospective Analysis for Research and Applications) are a reanalysis data set that uses GEOS-5 data and ground-based data to correct the data at a monthly time scale from 1979 through the present.



http://gmao.gsfc.nasa.gov/research/merra/

MODIS (Moderate Resolution Imaging Spectroradiometer)

* Key instrument aboard the Terra (morning overpass) and Aqua (afternoon) satellites.
- Polar orbiter with 36 spectral bands, ranging in wavelength from 0.4 µm to 14.4 µm
- Products

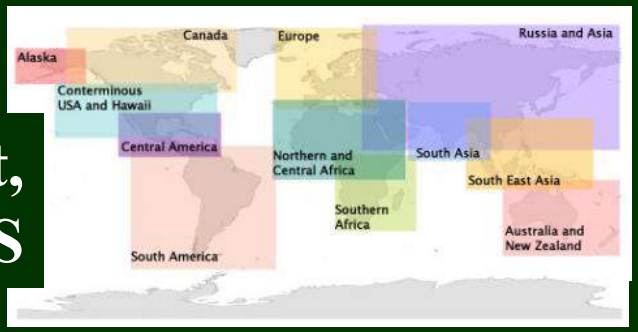
* Atmospheric [~7 (cloud, aerosol, water)]
* Land [~15 (Burned Area, Thermal Anomaly, NDV EVI, GPP, NPP, Temp., reflectance)]
* Cryosphere products [~3 (snow cover, Ice)]
* Ocean products [~9(Sea Surface Temperature, Chlorophyll, Carbon)]

Active Fire

Near Real Time

Worldview

FIRMS: Active Fire - txt, shape, maps, KML, WMS

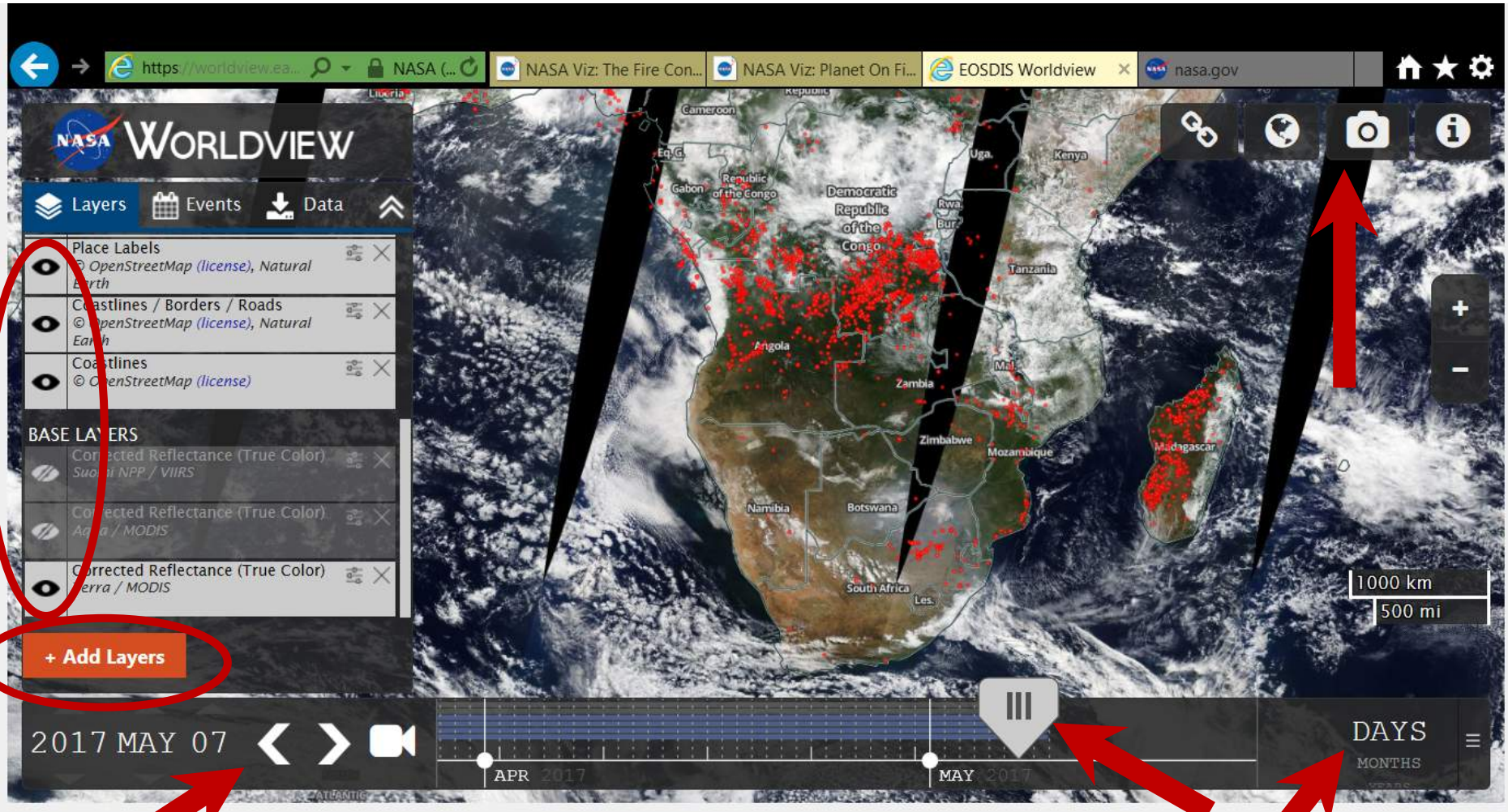


https://earthdata.nasa.gov/earth-observation-data/near-real-time/rapid-response

https://worldview.earthdata.nasa.gov

Visualize NASA fire and other data

NASA Worldview



https://worldview.earthdata.nasa.gov

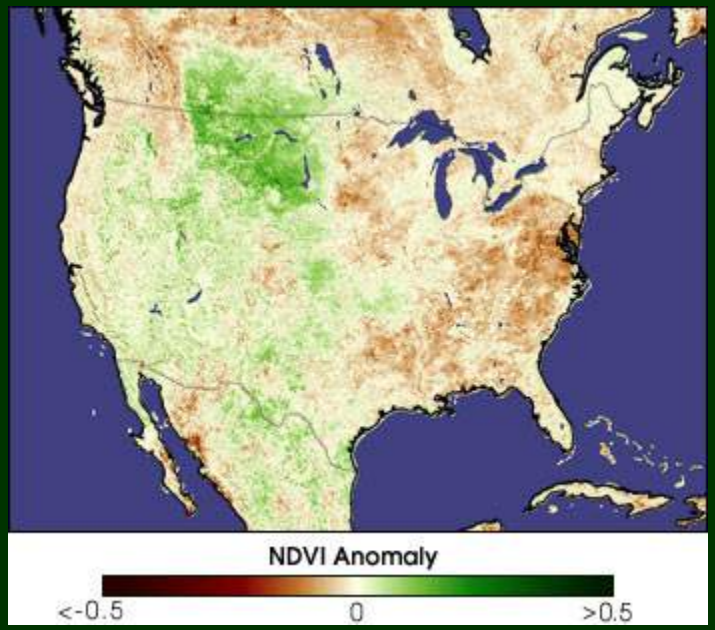
https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms

Vegetation Indices

an indicator that describes greenness - the relative density and health - of vegetation for each pixel in a satellite image

AVHRR NDVI data are available in a consistently processed database from 1982-present at an 8-km re-sampling grid covering the entire planet, and from 1989-present at a 1-km resolution for the conterminous United States

Enhanced Vegetation Index (EVI) – similar to NDVI, corrects for some distortions in the reflected light caused by the particles in the air as well as the ground cover below the vegetation. Doesn't become saturated as easily as NDVI when viewing areas of the Earth with large amounts of chlorophyll.

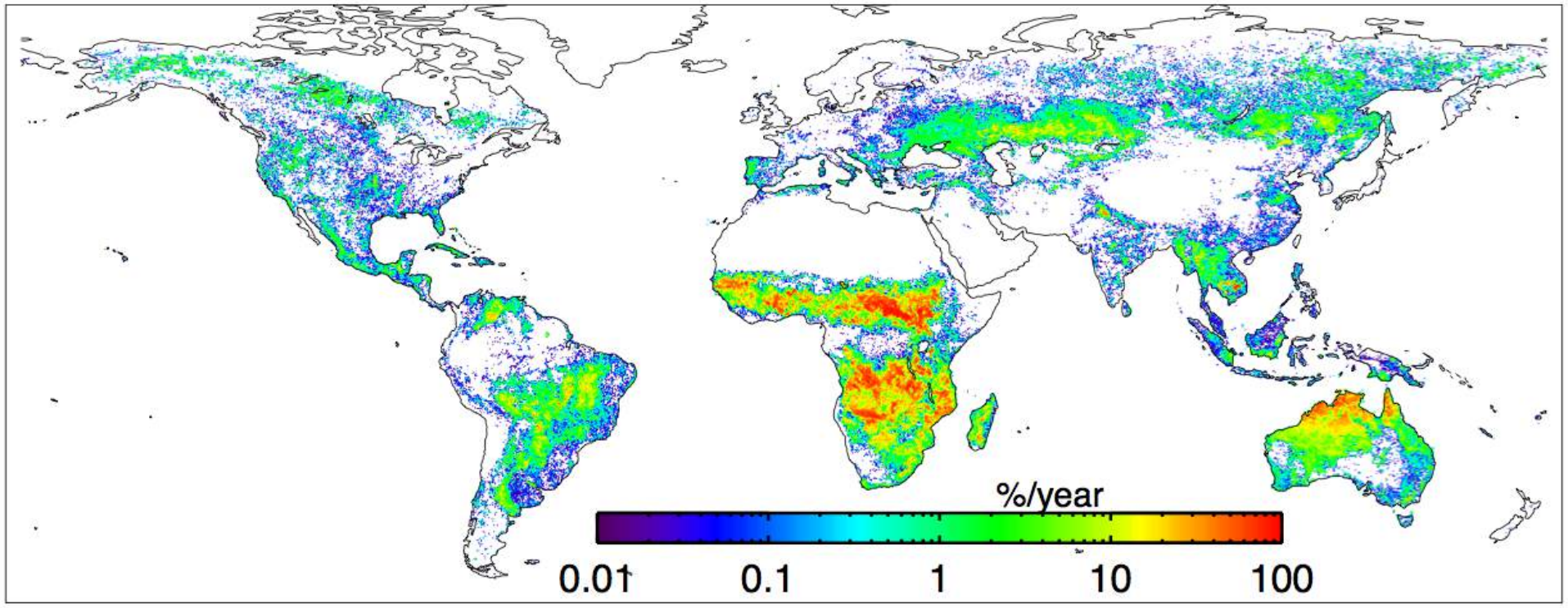


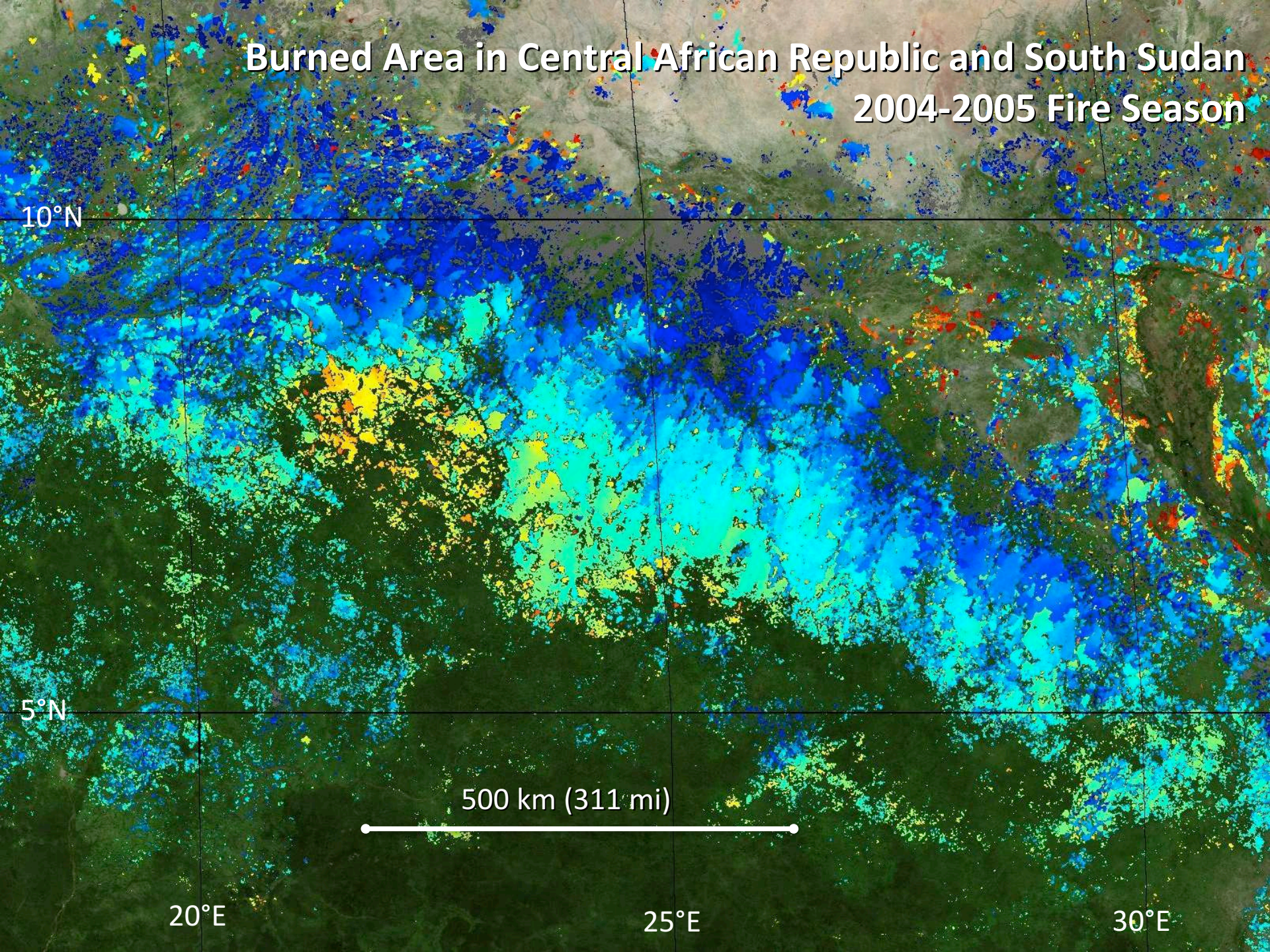
MODIS August 1993

2002-2015 Mean Burned Area

Fraction of a grid cell that burns each year

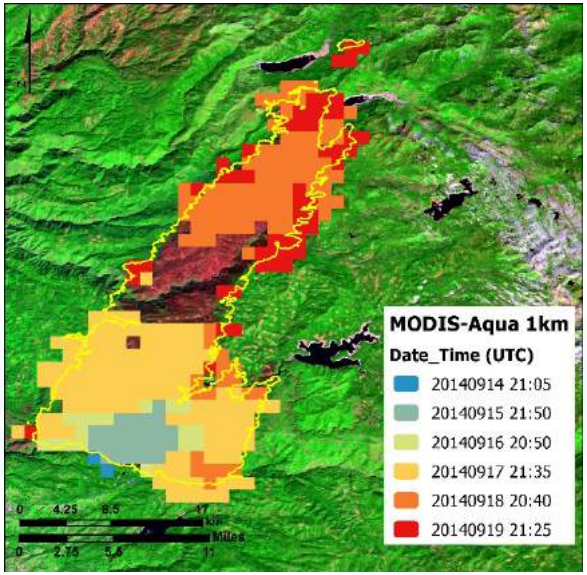
Collection 6 MCD64A1 500 m product

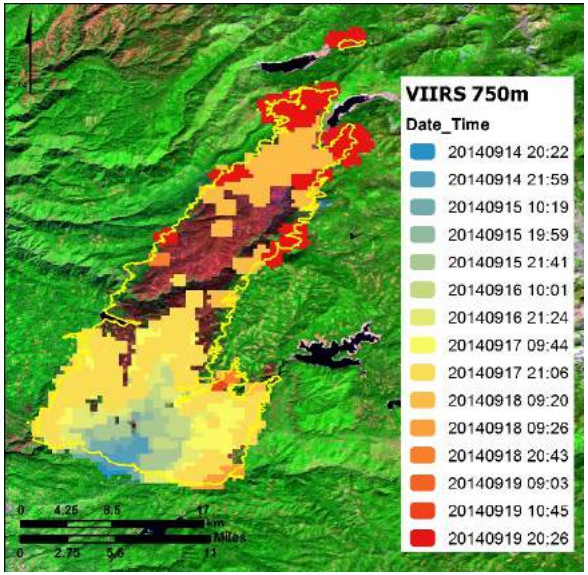


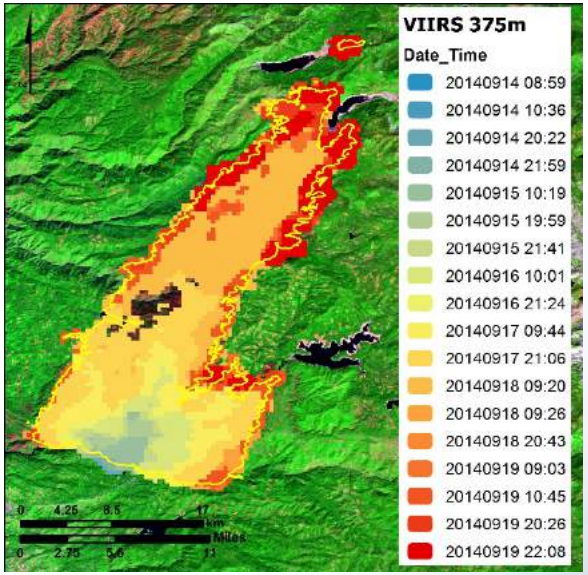

Burned Area in Central African Republic and South Sudan
2004-2005 Fire Season
10°N
5°N
500 km (311 mi)
20°E
25°E
30°E

Aim is to Transition NASA Data, Models, Technologies to Operational Fire Management Support

The VIIRS 375 m active fire detection product enables early detection of small fires and improved mapping of large wildfires.







Wildfire progression: Comparing MODIS & VIIRS 750 & 375m products: Schroeder et al.

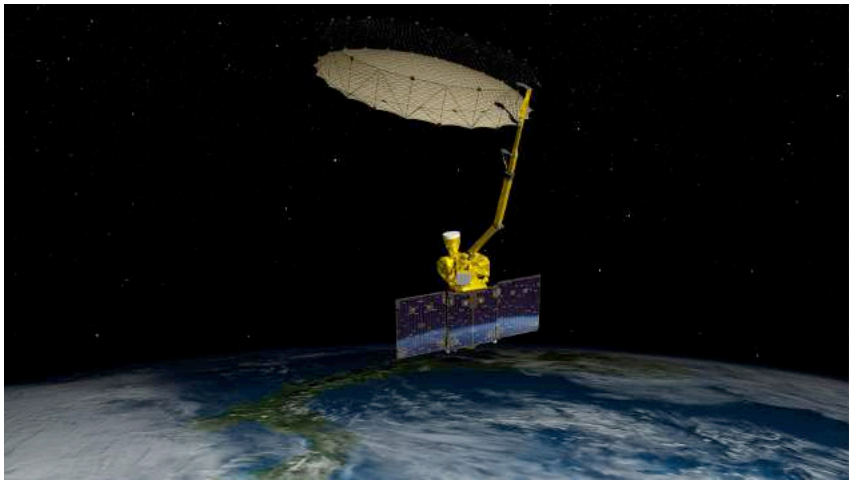
"*These refined data further improve the situational awareness of fire managers and are also ingested into operational modeling, analysis and visualization applications that support fire management decision-making at a landscape scale*." –Brad Quayle, F.S.

VIIRS fire algorithm complements temporally & spatially limited airborne & spaceborne (e.g., NIROPS, Landsat-8 & upcoming Sentinel-2) data to identify remote lightning strikes, support tactical firefighting, evacuation & strategic planning to mitigate ecological & flood impact.

SMAP (Soil Moisture Active Passive) Mission

Launched in January to map global soil moisture and detect whether soils are frozen or thawed

- Near-polar orbit
- 8-day repeat track (*6 am/pm)*
- Global land area 3-day
- Mission life expected ~3 years



SMAP's radar - soil moisture and freeze-thaw measurements
~5.6 miles (9 kilometers) for soil moisture;
~ 1.9 miles (3 kilometers) for freeze-thaw.

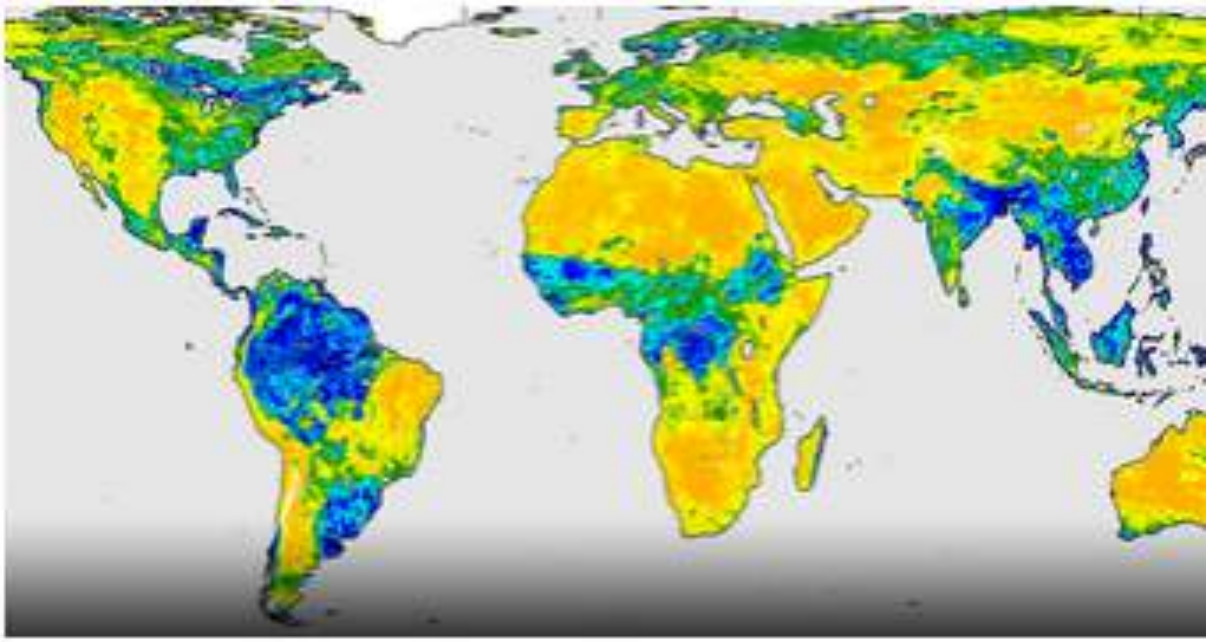
Without radar
~ 25 miles (40 kilometers) for soil moisture and freeze-thaw.

Sensor	Spatial Resolution was expected to be:
Radar (Synthetic Aperture)	10 km Soil Moisture 1-3 km Freeze-Thaw
Radiometer	40 km (IFOV 38km x 49 km)

July 7, 2015
SMAP's radar stopped transmitting

SMAP continues to meet its requirements for soil moisture accuracy and will produce global soil moisture maps every 2 to 3 days.

First-of-their-kind concept, design and measurements



SMAP's radiometer Surface Soil Moisture composite

(3-day Aug. 2015). Dry areas: yellow/orange - Sahara Desert, western Australia, western U.S.

Blue: wet areas; White: snow, ice or frozen ground

Design

The radar enabled high-resolution measurements of up to 1.9 miles, but with lower accuracy for sensing surface soil moisture.

In contrast, the microwave radiometer is more accurate in its measurements, but has lower resolution of about 25 miles.

By combining the active and passive measurements, SMAP was designed to estimate soil moisture at a resolution of about 5.6 miles

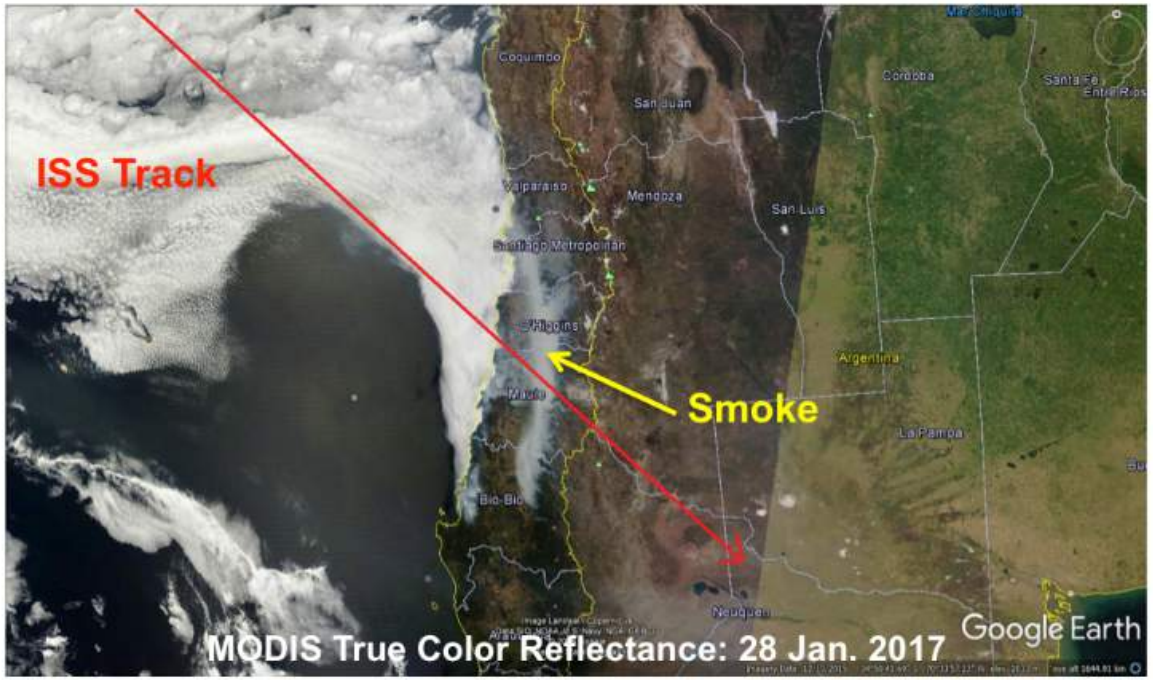
Two instruments are capable of defining fire plume injection heights (if incorrect, transport incorrect as are Air Quality estimates and deposition (i.e. Black Carbon to Arctic).

CALIOP onboard Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) – underway.

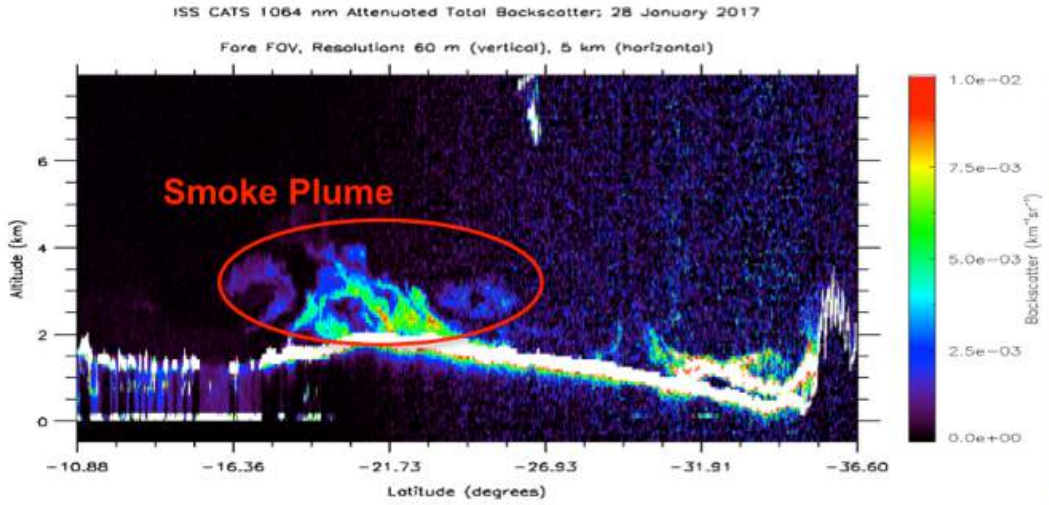
Multi-angle Imaging SpectroRadiometer (MISR) - D. Diner, R. Kahn, J. Logan, et al. - used stereographic heights to derive plume height database (LaRC DAAC).

Chile Wildfires

28 Jan 2017 |



Several wildfires have burned for days over central and southern Chile, killing at least 11 people. The fire and smoke have destroyed thousands of homes and consumed an area 3 times the size of New York City. On 28 Jan. 2017, the smoke plume was observed by MODIS (top left). The ISS passed over the plume (red line) around 11:25 UTC. The CATS backscatter image (bottom left) shows the elevated smoke plume between 2 and 4 km (red circle). The smoke and fire have displaced over 8,000 Chileans from their homes.



http://cats.gsfc.nasa.gov/

CALIPSO

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

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

** smoke plume identification with back trajectories 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;*

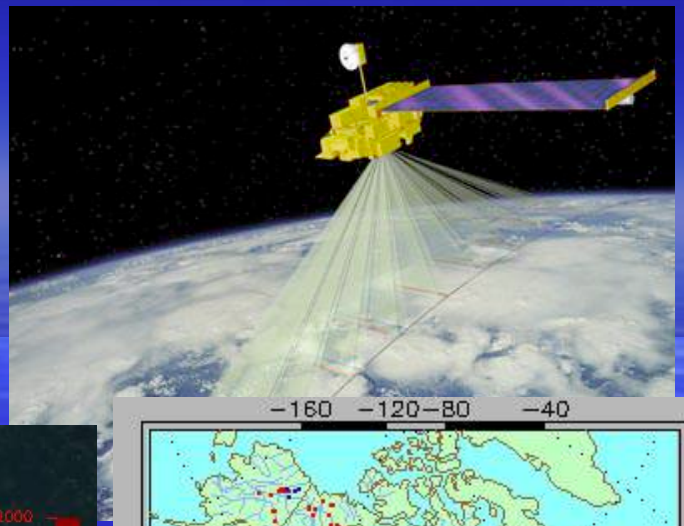
** substantially larger swath width than CALIPSO which results in a greater opportunity to capture smoke plumes [Kahn et al., 2007]; &*

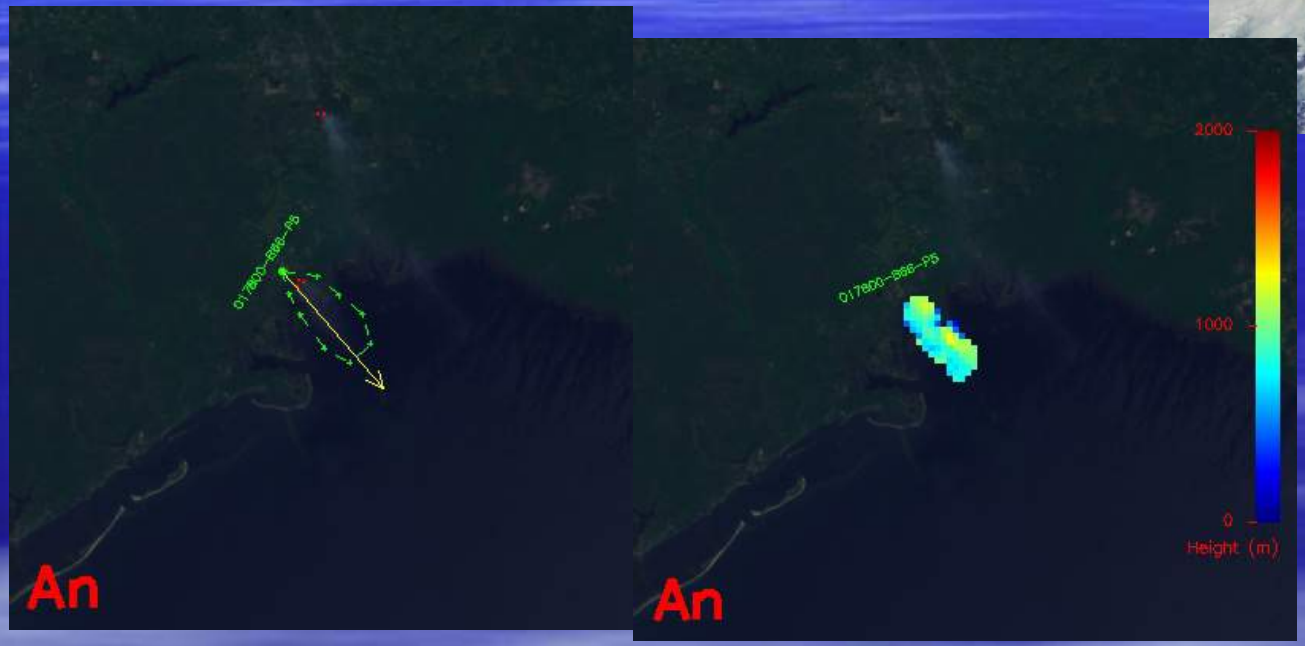
** morning overpasses do not capture the natural temporal fire pattern.*

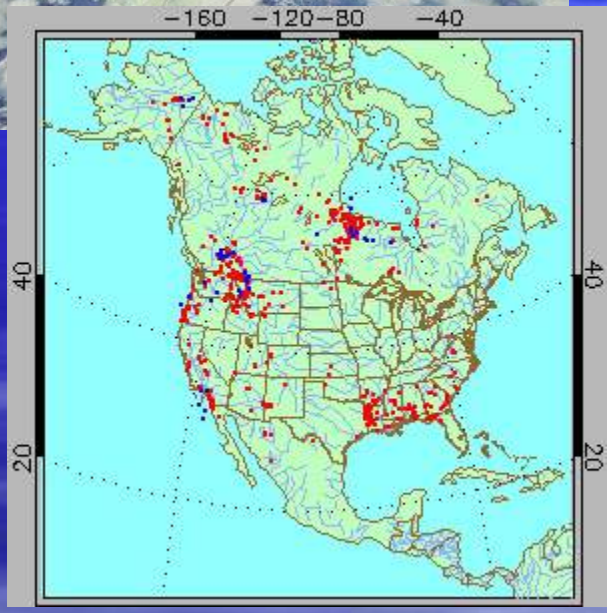
Sensor (spacecraft)	Product	Spatial Resolution	Satellite Overpass	Temporal Availability
MISR (Terra)	AOD, aerosol plume height	1.1 km horizontal x 500 m vertical	10:30 a.m.	~Once every 7 days
CALIOP (CALIPSO)	extinction profile	100 m diameter x 30 m vertical	1:40 p.m.	Once every 16 days

MISR Plume Height Project

MISR
Multi-angle Imaging SpectroRadiometer





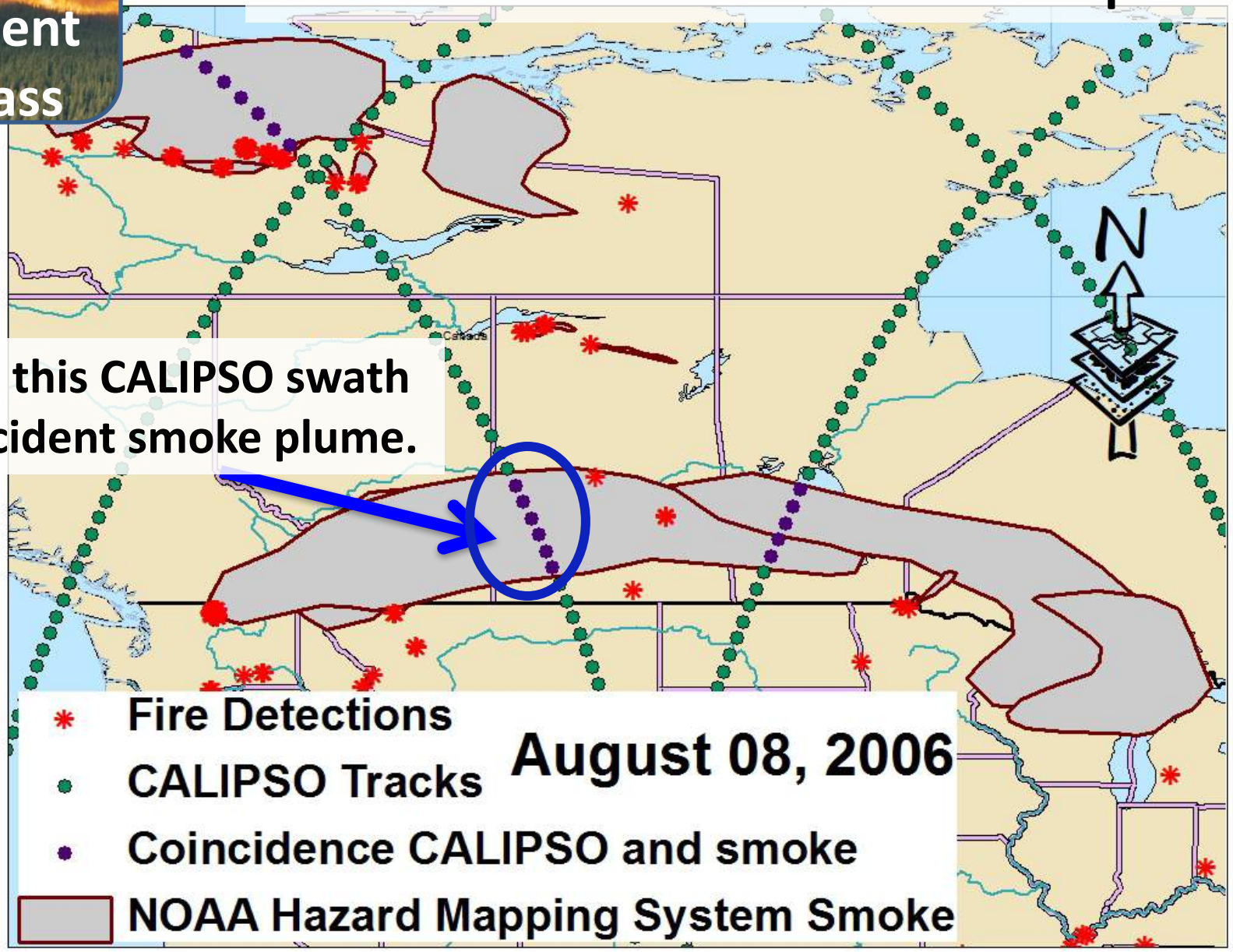


MISR uses cameras pointed in 9 different directions to view the amount of sunlight scattered in different directions.

https://www-misr.jpl.nasa.gov/getData/accessData/MisrMinxPlumes/

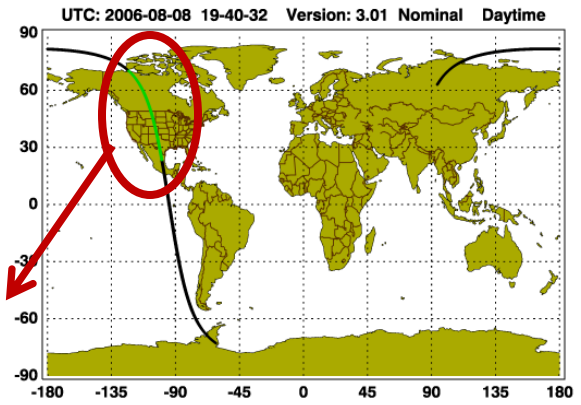
Plume and CALIPSO Coincident Overpass

Coincident NOAA HMS smoke plume, and CALIPSO overpass.



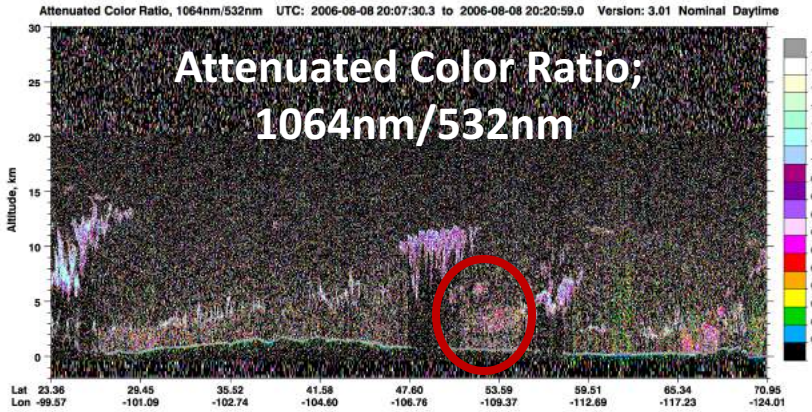
CALIPSO Curtains 08 Aug 2006 (v3)

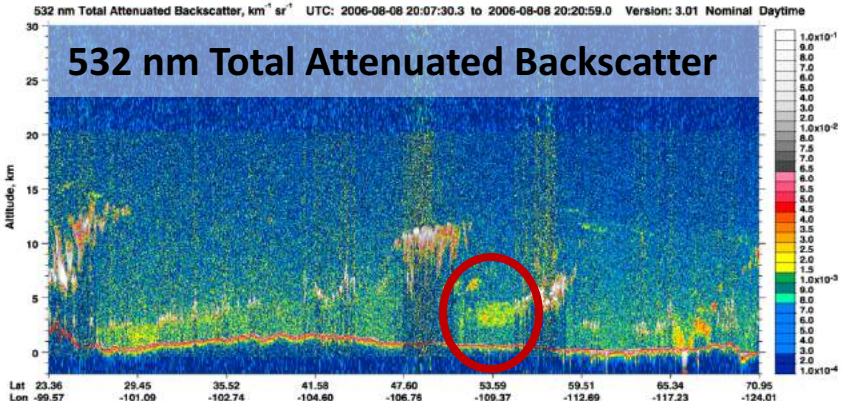
CALIPSO overpass

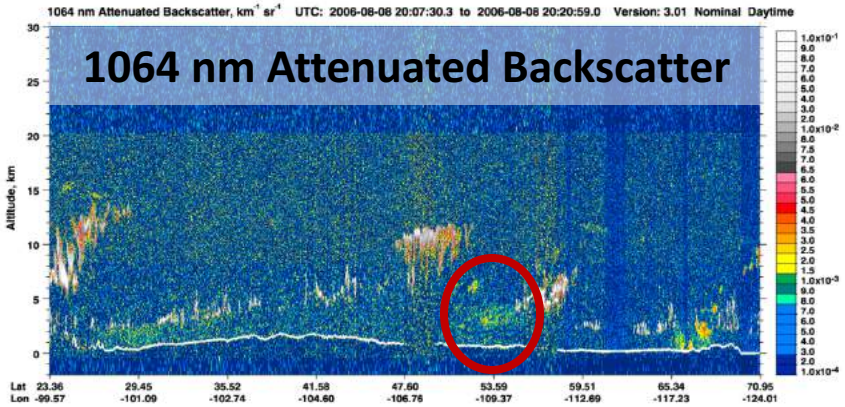


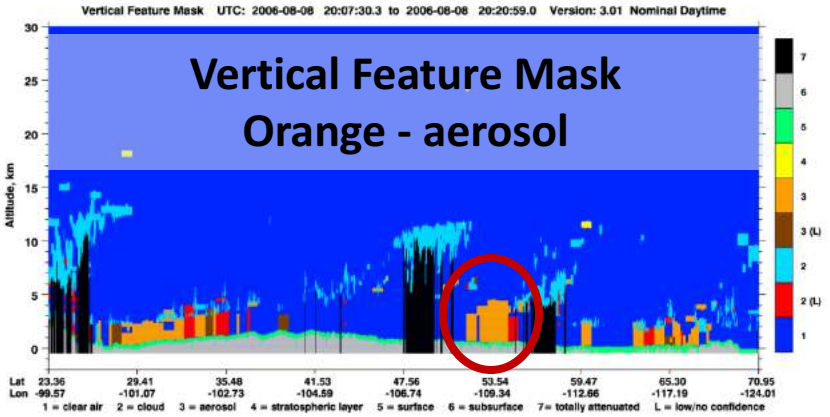
Swath from south to north

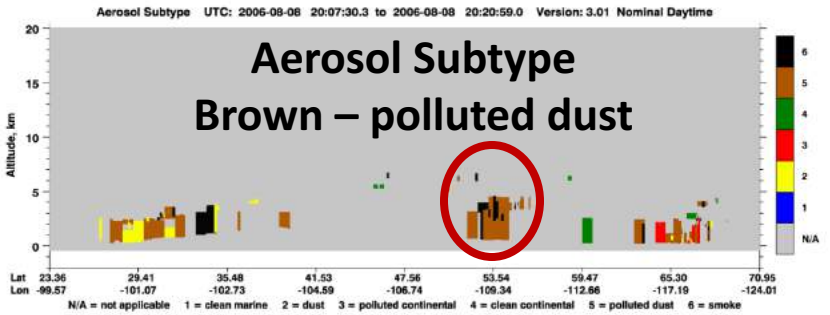
20:07 to 20:20





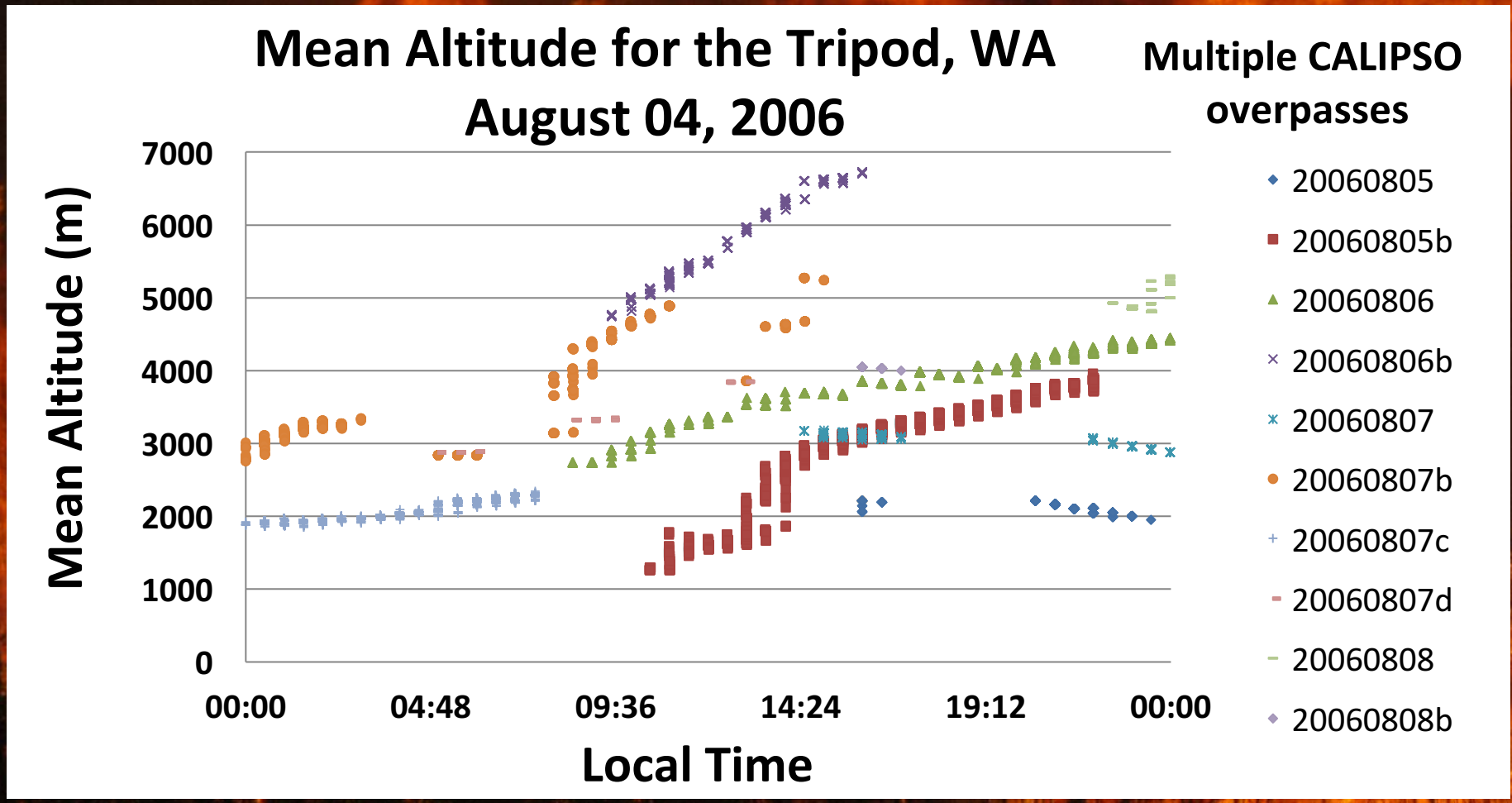






30m Vertical Resolution

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



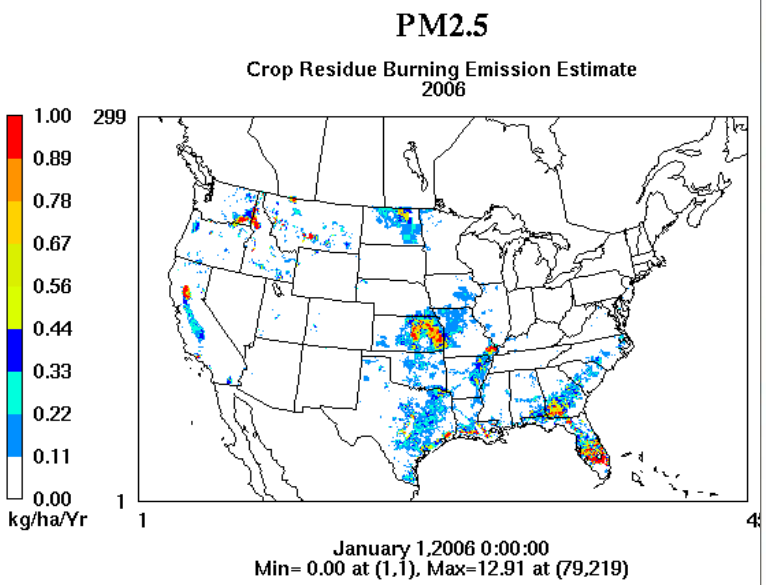
Quantifying Cropland Burning and Related Emissions Using NASA Sensors

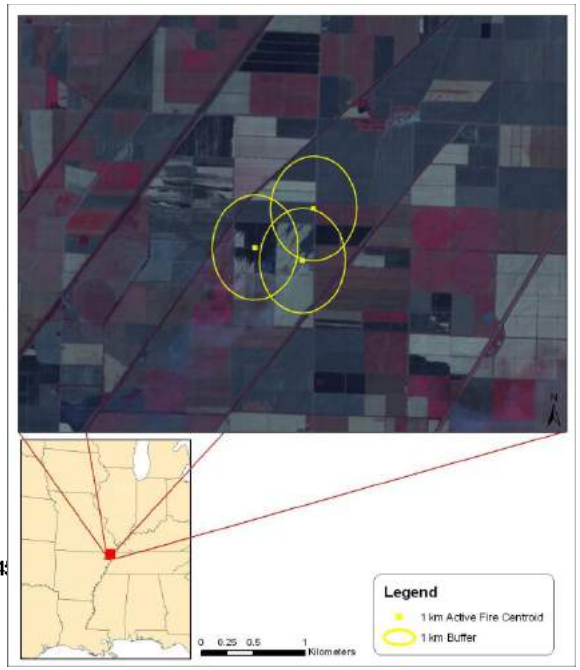
Jessica L. McCarty, PhD

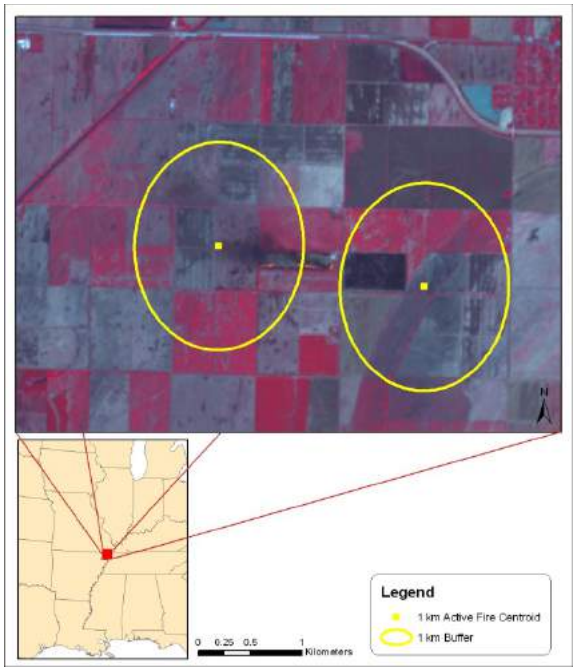
Cropland burning affects local and regional air quality, is a consistent source of emissions, and, as source of GHG /short-lived climate forcers, its impact on climate is not well understood (photo by J. McCarty).

Informing U.S. Emissions Inventories:

- McCarty refined MODIS based cropland burned algorithm to produce county, state, and lat/long specific emission estimates for contiguous U.S. (CONUS) for 25 atmospheric species and 21 crop types (Figure 1).
  - Include as the official source of cropland burning emissions for 2011EPA's National Emissions Inventory.
  - Provided detailed uncertainty analyses upon request from state environmental agencies.
  - NASA Applications contract # NNX12AQ90G; PI: Soja.







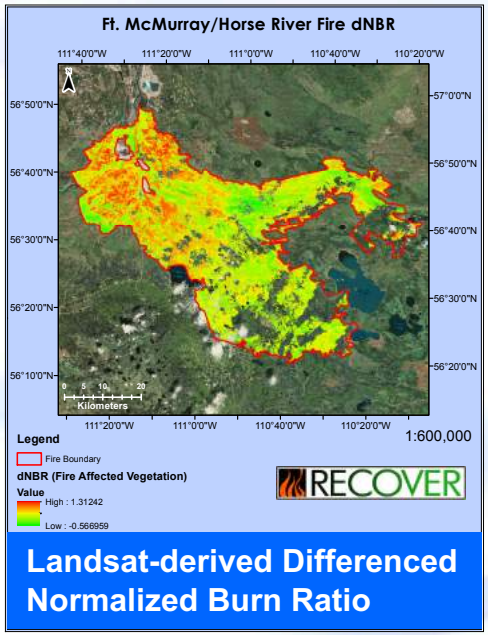
NASA EO Supports Rapid Assessment / Recovery Operations on Ft. McMurray Wildfire

Situation: Ft. McMurray (Horse River) Fire in Alberta burned 1 May to 5 July 2016, and consumed 1.5M acres. **It was the costliest disaster in Canadian history ($3.58B)!**

Approach: Use MODIS and Landsat measurements, coupled with soils and terrain information to model burn severity and create inputs to hydrological forecast models in near-real-time.

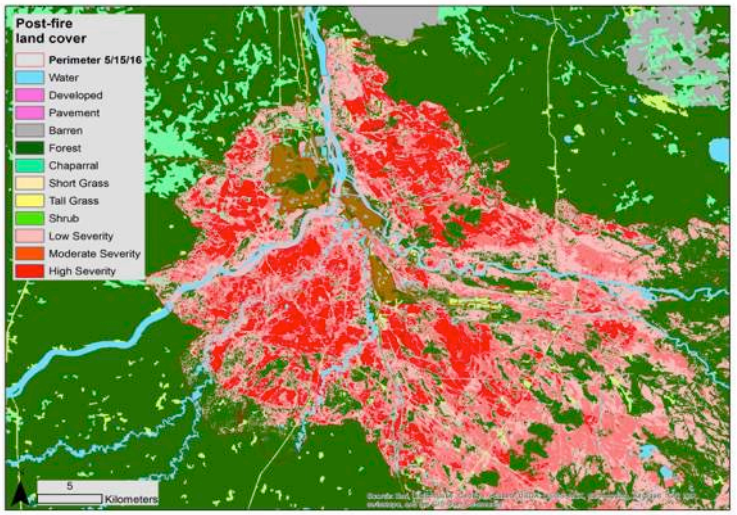
Results / Implications:

- Supported managers with real-time tools to pinpoint active fire, develop post-fire burn severity and model hydrologic processes for rapid remediation remediation actions;
- Helped prioritize watersheds to concentrate post-fire treatment areas and save resources and significant mitigation costs.

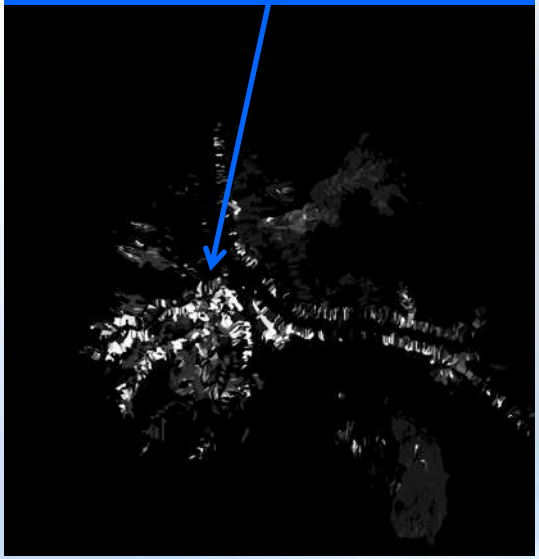


Landsat-derived Differenced Normalized Burn Ratio

Post-fire land cover / burn severity modeled classification



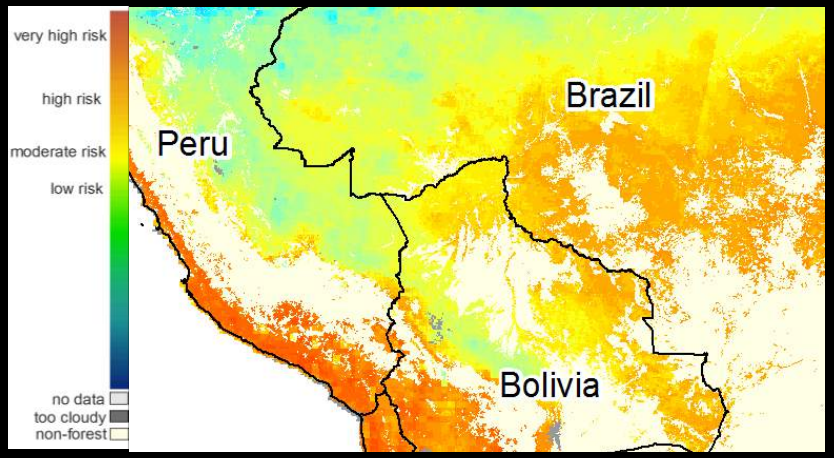
High sediment / runoff predictions



FIRECAST: A Near-Real-Time Monitoring System Improving Forest Management in the Tropics

CONSERVATION INTERNATIONAL

Karyn Tabor and team



FIRECAST uses satellite data to deliver daily email alerts of fire activity and daily forest flammability alerts that are used to warm communities and authorities of dangerous fire conditions.

Targets areas of high biodiversity and specific communities.

Currently the system operates in Brazil, Peru, Madagascar, Indonesia, and Bolivia

Satellites Improve Tropical Forest Management

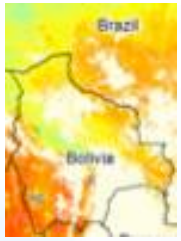
Firecast empowers localities and regional managers with NRT weather and fire information derived from NASA products to enable sustainable landscape management for the protection of biodiversity and ecosystems that provide critical services for human well-being.

FIRECAST is used in Colombia, Indonesia, Peru, Bolivia and Madagascar.

Web map viewer

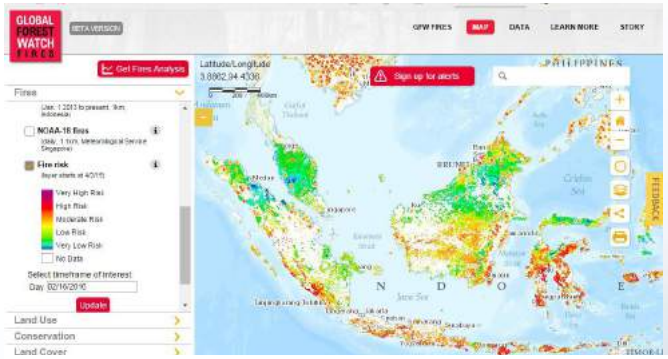
Dashboard: Provides user relevance

Mobile app



Daily fire risk

Fire season severity forecast



Enhanced Fire Risk Assessment: Amazon to Indonesia

New and Unique:

- Mobile Firecast application launched; includes offline map functionality in English, Spanish and French;
- Enhanced Fire Flammability Risk expanded to Indonesia: host Global Forest Watch;
- Partnered with USAID to expand Firecast alerts to Colombia;
- Partnered with Logi Analytics to develop of a new Firecast visualization Dashboard – requested by the data users – puts data in perspective for the decision makers;

Ozone DIAL & Aerosol/Cloud HSRL – DC-8

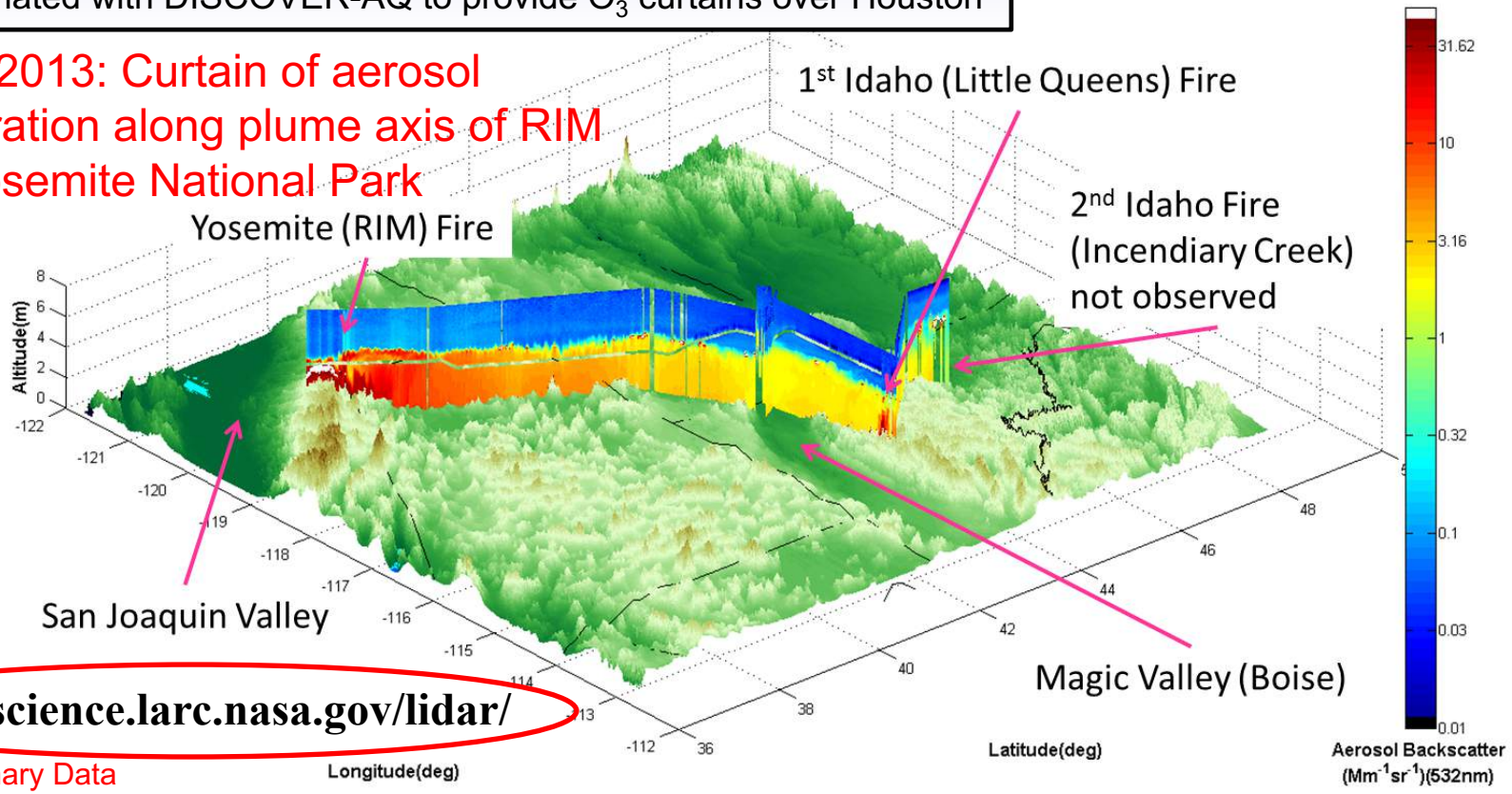
Johnathan Hair - PI NASA LaRC

- ✓ Measured O3 and aerosols profiles on all SEAC4RS flights
- ✓ Provided real-time O_3 & aerosol data for in-flight guidance
- ✓ Provided O3 and aerosol curtains for comparison to CTMs
- ✓ Made UTLS O3 & aerosol measurements for NAM assessments
- ✓ Made HSRL multi-wavelength lidar observations of fire emissions
- ✓ Provided HSRL measurements relevant to CALIOP assessments
- ✓ Provided data for comparison and assessment of remote sensors retrievals on ER-2 (extinction, AOT)
- ✓ Coordinated with DISCOVER-AQ to provide O_3 curtains over Houston

Profile Measurements:

- Ozone Concentrations
- Aerosol Extinction (532nm)
- Layer AOD at 532nm
- Aerosol/Cloud Backscatter (355,532,1064nm)
- Aerosol/Cloud Depolarization (355,532,1064nm)

26 Aug. 2013: Curtain of aerosol concentration along plume axis of RIM fire in Yosemite National Park



http://science.larc.nasa.gov/lidar/

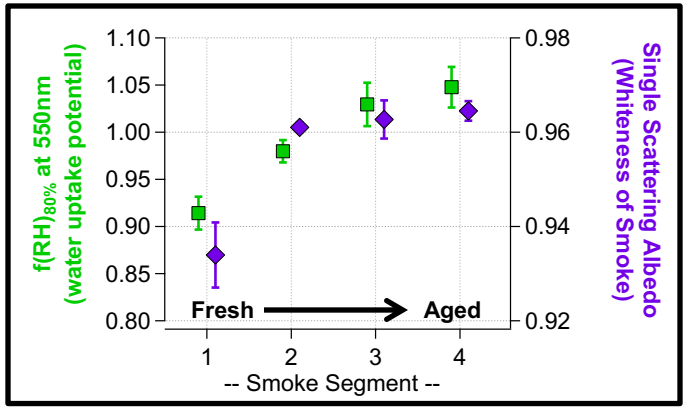
Preliminary Data

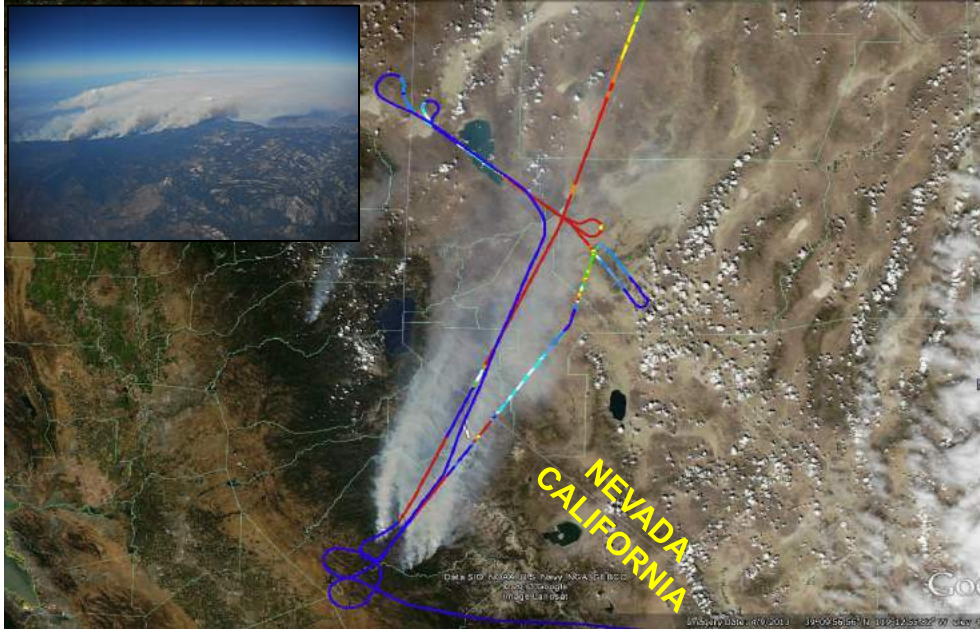
August 2013 Rim Fire (Sierra Nevada, CA)

- Burned for 38 days over 257,314 acres
- Sampled by the NASA DC-8 during the SEAC4RS airborne project
  - Directly at the fire (top)
  - Several days downwind (bottom)

Atmospheric Effects

- Downwind smoke affects ground-level air quality & alters Earth's radiative budget
- Changes in smoke properties were measured as it is transported and ages
  - Aerosols uptake more water (increasing visibility degradation)
  - Albedo of the smoke increases (less absorption of sunlight)





Flight track colored by the smoke concentration (NASA Langley)

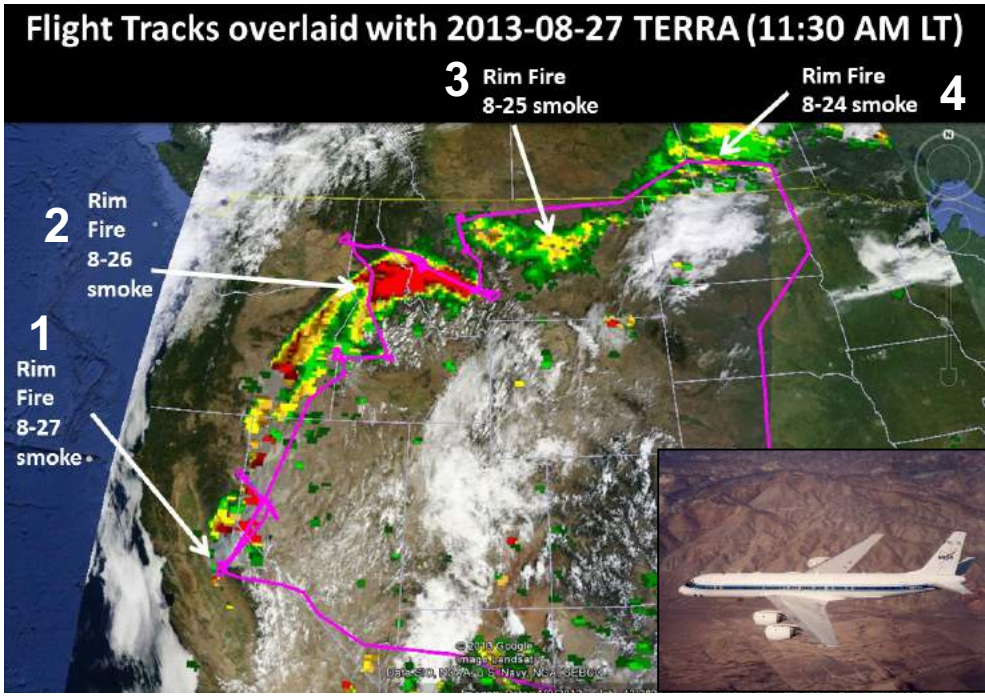
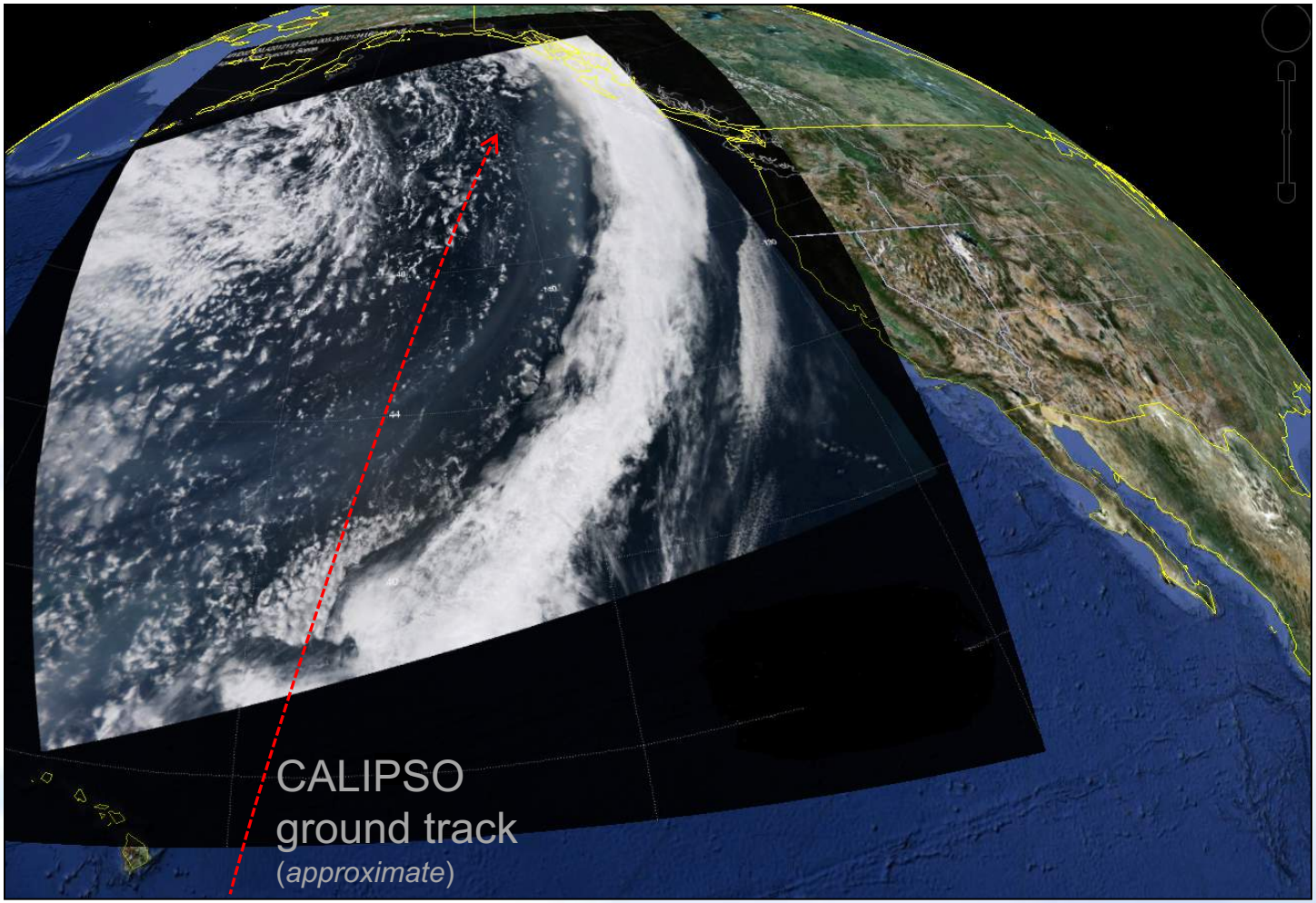


Image courtesy of NASA ESPO

Aerosols Travel Far!

Siberian Fire Smoke

May 12th, 2012



Aerosols Travel Far!

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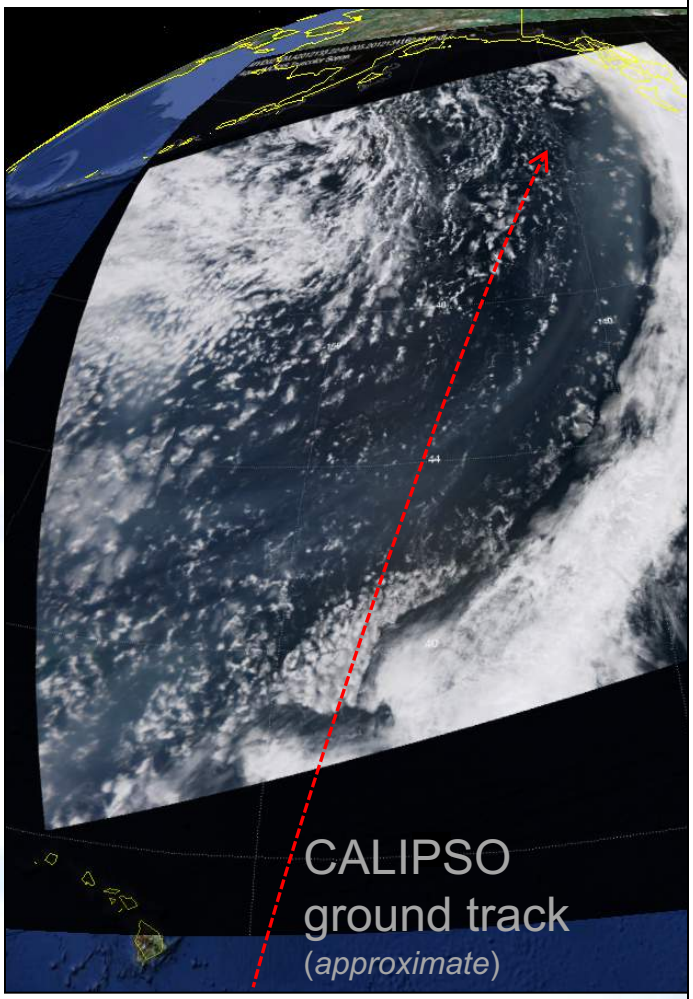
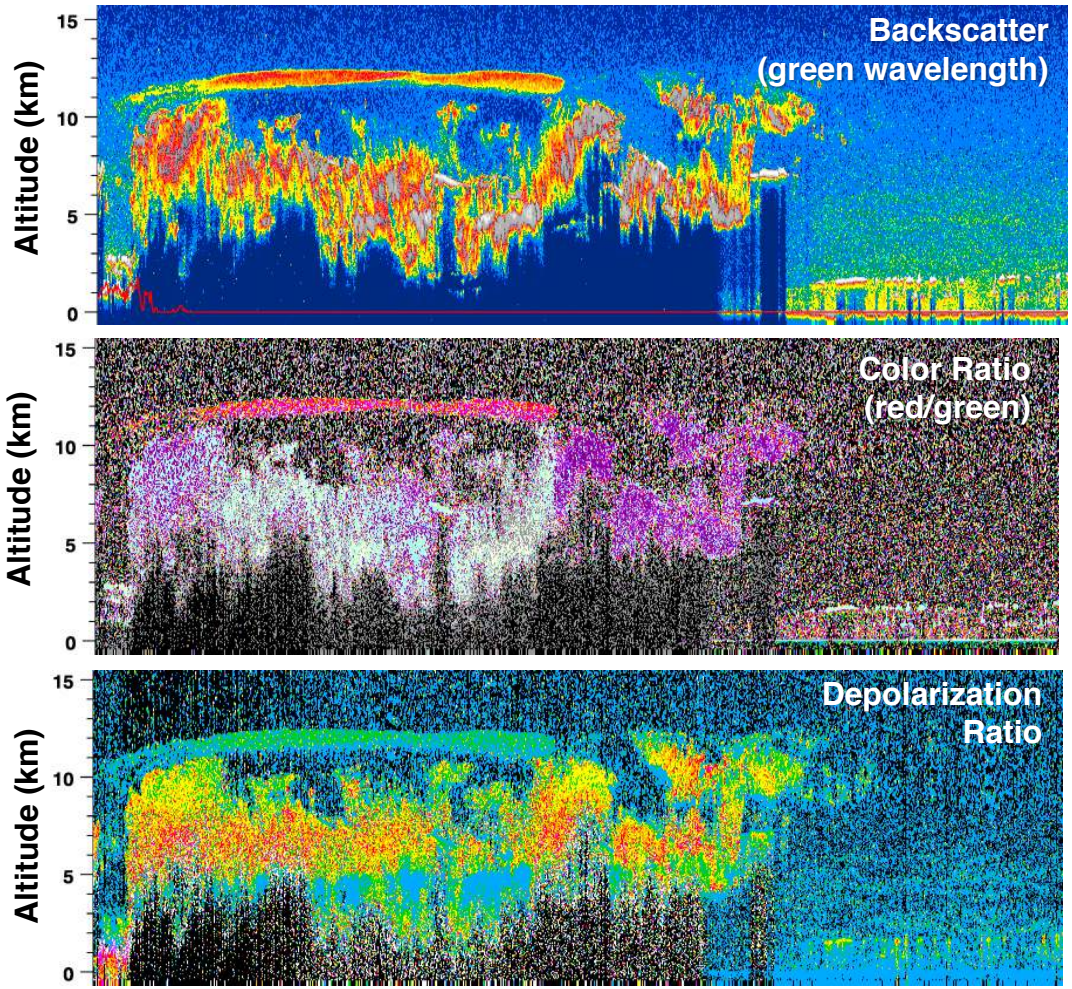
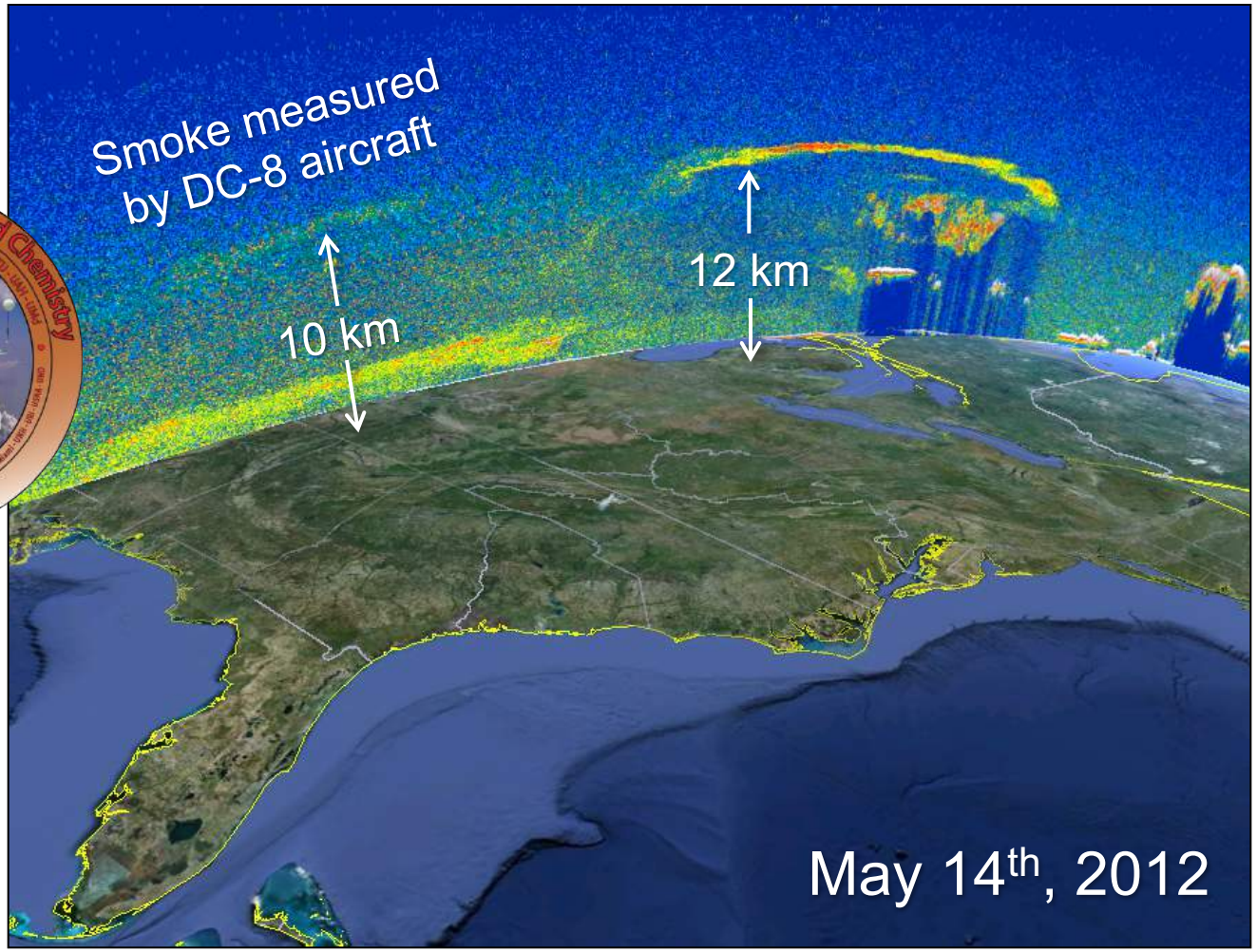




Aerosols Travel Far!
2 days later

Smoke from Siberia over United States



Summary Example of Earth Satellite Data

Sensor (spacecraft)	Product	Spatial Resolution	Satellite Overpass	Temporal Availability
MODIS (Terra and Aqua)	Thermal anomaly (fire detection), area burn, and Aerosol Optical Depth (AOD)	500 m area burned, Fire detection 1 km^2, and AOD 10 x 10 km^2 product	10:30 a.m. 1:30 p.m. 6:30 p.m.	Active fire and AOD 4 times per day (1 day, 1 night overpass per sensor x 2 sensors), 8-day area burned
MISR (Terra)	AOD, aerosol plume height	17.6 x 17.6 km^2	10:30 a.m.	~Once every 7 days
MOPITT (Terra)	Columnar CO (combustion tracer)	22 x 22 km^2	10:30 a.m. 10:30 p.m.	Twice every 3 days
ASTER (Terra)	Level 3 AST14OTH Orthorectified	15 m	10:30 a.m. 6:30 p.m.	Twice per day
AWiFS	Georeferenced visible, NIR, and SWIR data	56 m	variable	Tasked data every ~5 days; orbiting every 14 days
Landsat	L1-L3 L4-L8	Typically 30 m	variable	Every 16 days
AIRS (Aqua)	CH_4, Columnar CO (combustion tracer)	45 km diameter	1:30 a.m 1:30 p.m.	Twice every day
OMI (Aura)	AOD, SSA	13 x 24 km^2	1:45 p.m.	Every day
CALIOP (CALIPSO)	extinction profile, aerosol plume height	100 m diameter x 30 m vertical	1:40 p.m.	Once every 16 days
GOES (east and west)	ABBA instantaneous area	16 km^2	Geostationary Orbit	30 minute data (2 sensors, 15 minute data)

Thank-you for listening!

and a special thanks for conversations with individuals and communities: NASA Applied Sciences programs Wildland Fire and Disasters; FASMEE; FIREX; FIREChem; WE-Can; USDA Forest Service; Environmental Protection Agency; the CALIPSO Science Team; LARGE Team; NOAA HMS team; Wilfrid Schroeder, Brian Stocks, Charles Ichoku, Ralph Kahn, Mark Ruminski, Nancy French, Keith Weber, Christine Wiedinmyer, Bob Yokelson, Karyn Tabor, Mary Ellen Miller and many others.

Questions?

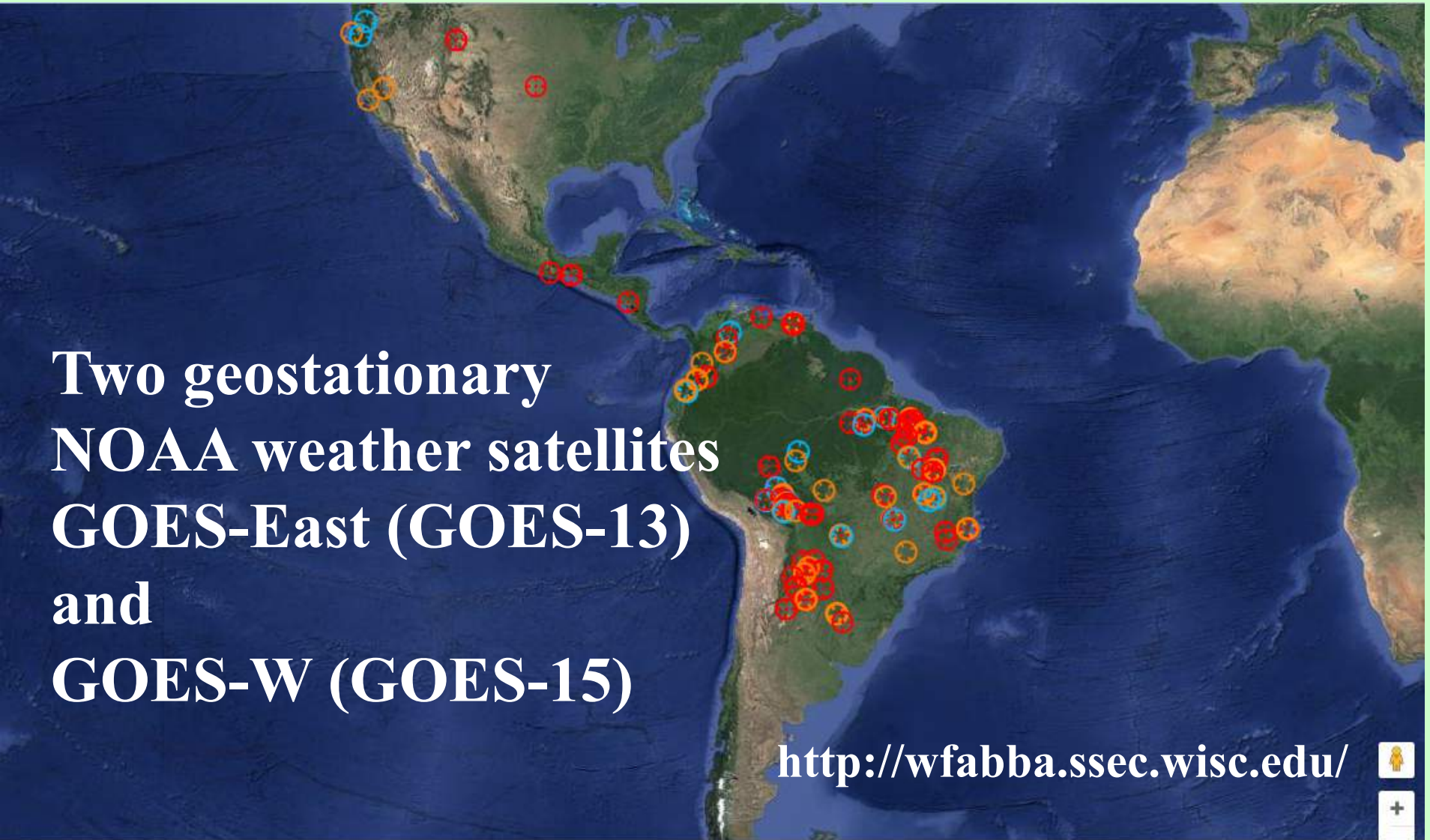
Additionally, there are other Distributed Active Achieve Centers (DAAC)

Oakridge DAAC
http://daac.ornl.gov/

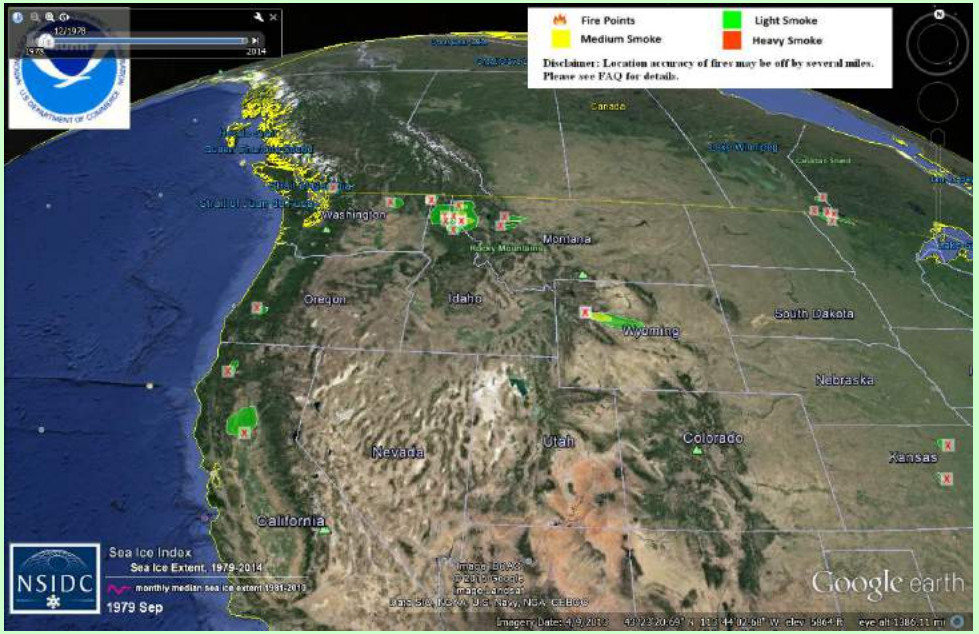
NOAA Comprehensive Large Array-Data Stewardship System (CLASS)
www.class.ngdc.noaa.gov/saa/products/welcome

NASA Goddard Earth Sciences Data and Information Services Center
http://daac.gsfc.nasa.gov/

The Wildfire Automated Biomass Burning Algorithm (WFABBA) processing system uses geostationary satellite data to detect and characterize biomass burning.

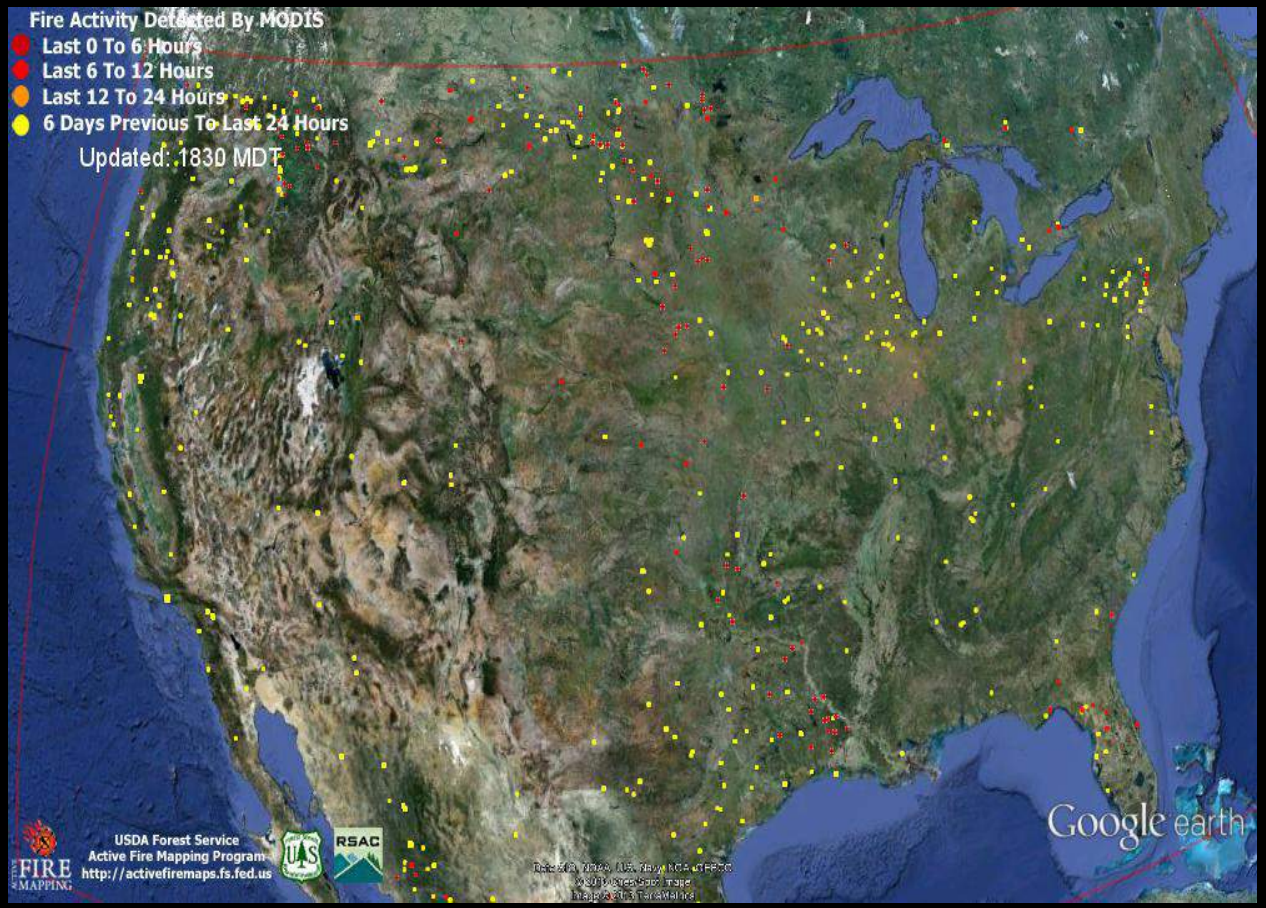


NOAA Hazard Mapping System (HMS) Fire and Smoke Product



Combines information from GOES-ABBA, FIMMA-AVHRR, MODIS and generates unique products

http://www.ssd.noaa.gov/PS/FIRE/hms.html



Remote Sensing Applications Center (RSAC)

Active Fire Mapping (AFM) Program

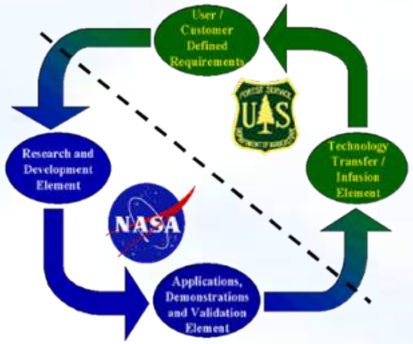
USFS operational use of NASA MODIS and NASA/NOAA VIIRS for wildfire activity in CONUS, Alaska, Hawaii & Canada

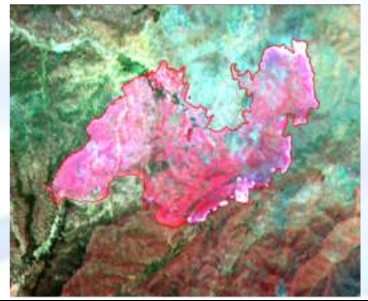
Facilitates decision support for strategic planning and response for U.S. and Canadian fire agencies

http://activefiremaps.fs.fed.us/index.php

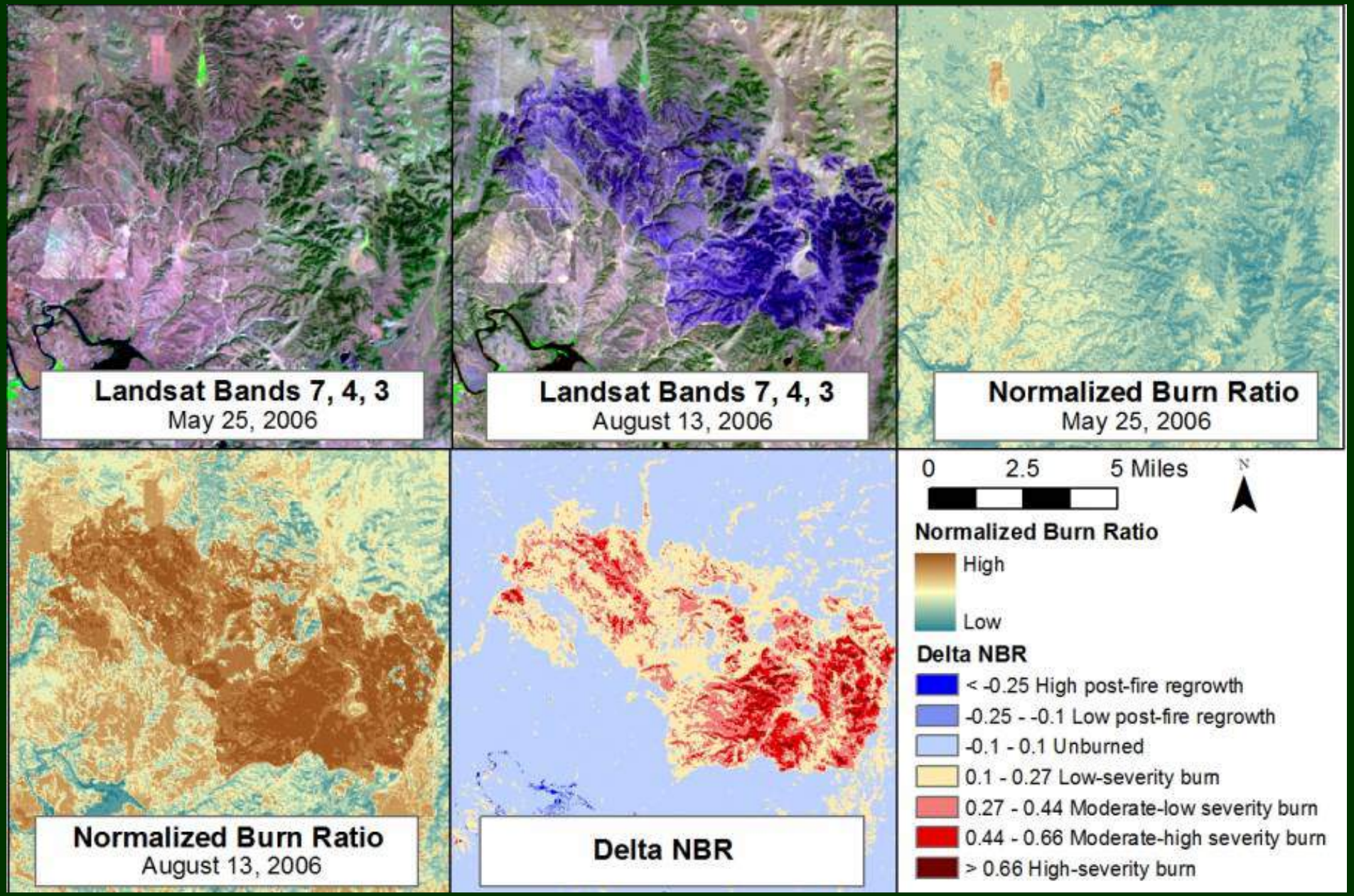
NASA AMS Sensor to USFS Fire Operations

- NASA airborne Autonomous Modular Sensor (AMS) transferred to the USFS National Infrared Operations (NIROPS) and USFS Remote Sensing Applications Center (RSAC) for operations supporting fire and other research / applications needs.
  - » Joint press announcement (NASA and USFS) released on 16 April 2013.
- AMS installed on a USFS Cessna Citation jet (FY2013); Flew a series of missions in support of data collection for partners in USDA Ag Research and the USGS Water Quality.
- AMS has NOT been used in 2013 to support US wildfire events
  - » USFS felt their staff training was too short for adaptation into immediate operations.
- USFS funded $100K to NASA-ARC to support FY13-15 training, sensor calibration, and enhancements, to ready staff for AMS operations in FY2014 (and further support)





http://nirops.fs.fed.us/ams/


Landsat Bands 7, 4, 3
May 25, 2006
Landsat Bands 7, 4, 3
August 13, 2006
Normalized Burn Ratio
May 25, 2006
Normalized Burn Ratio
August 13, 2006
Delta NBR
0
2.5
5 Miles
N
Normalized Burn Ratio
High
Low
Delta NBR
< -0.25 High post-fire regrowth
-0.25 - -0.1 Low post-fire regrowth
-0.1 - 0.1 Unburned
0.1 - 0.27 Low-severity burn
0.27 - 0.44 Moderate-low severity burn
0.44 - 0.66 Moderate-high severity burn
> 0.66 High-severity burn

Satellite Data and Models Inform the Science and Management that then Inform the Data and Science.

Landsat Fire Scar data

MODIS Fire Detection

Bastrop County Fire

Mom and baby black bear

Endangered Canebrake

November 11, 2011
Texas counties with burn bans:
206 of 254