AIRS Applications Overview: Volcano, Influenza, Drought & More

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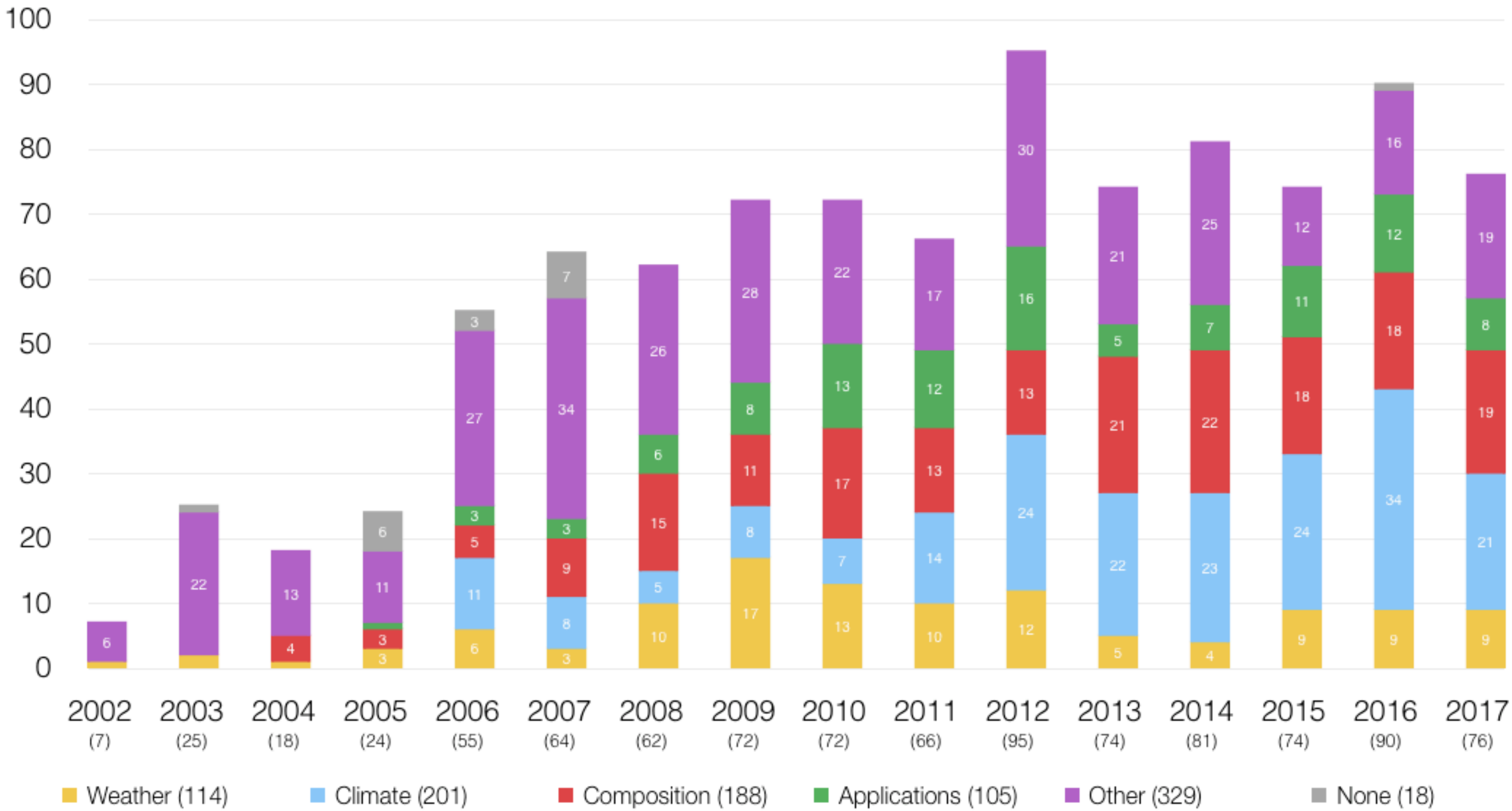
AIRS Peer Reviewed Publications

January 2002 to January 2018



AIRS Applications Catalog *– FLUID!*

DROUGHT

USDM

AVIATION

- Volcanic SO2 Detection in VAAC
- Volcanic SO2 Loading in VAAC (Prata)
- Volcanic Ash/Dust Loading in VAAC & EU SACS (Prata)
- JPL Volcano Rapid Response - improved detection and products
- Deep Convective Clouds

FIRE

- Fire Danger Assessment System
- Indonesia Fires Seasonal Threshold

HEALTH

- Influenza
- Zika
- Dengue Fever

AIR QUALITY

- Temperature Inversions
- Air pollution CO tracer
- Ozone intrusion from stratosphere into troposphere in NAWIPS

The Decision-Making Pipeline

- Path that starts at data and ends with decision-maker
- The task: Identify the steps in between

Why determine the pipeline?

- **Identify where your product will have relevancy and who might be interested in it.** *Discuss product concept with this group, get feedback/guidance*
- **Can ask people in the know about decision-maker needs.** *DM needs may be less rigorous than what we assume*
- **Can determine if we're going to step on toes.** *See conduits to the appropriate organizations*

Benefits

Save time and money

Make a better product

Cultivate partners, advocates

Improve chance of successful outcome

Example: Multiple Volcano Decision Pipelines*

	Data Source	Operational Services	Decision Makers	
U.S.	USGS Volcano Observatories	National Weather Service Anchorage and Washington DC VAACs	FAA Department of Homeland Security VDAP	
U.S.	*USGS* *UK Met Office* *other data suppliers*	USAF Air Weather Service	DOD Agencies	
U.K.	*Data suppliers*	UK Met Office London VAAC	CAA & NATS	Airline SRAs
Int'l	ICAO & WMO			

**Note:*
These pipelines are used to understand the pathway to decision-makers. AIRS products are not currently in these pipelines.

Detail: U.S. Volcanic Emissions Decision Pipeline

Data Source →	Operational Services →	Decision Makers
USGS Volcano Observatories	National Weather Service Anchorage and Washington DC VAACs	FAA Department of Homeland Security Volcanic Disaster Assistance Program

VOs

- 5 observatories monitor/report on eruptive behavior
- Develop research models of ash dispersion and ashfall
- Sends reports to the NWS

NOAA NWS

- Run operational ash dispersion models
- Formal guidance about what to do comes from the NWS
- NWS gets *its* guidance and information from the USGS

NOAA Volcanic Ash Advisory Centers

- Only deal with ash—they report the extent and movement of ash
- The National Weather Service is really the VAAC

FAA

Looks at NWS products and makes aviation-related decisions

Department of Homeland Security

Decides on whether there should be an evacuation

VDAP

- USGS + Office of Foreign Disaster Assistance partnership, developed/funds VDAP
- Developing countries contact US State Dept which contacts VDAP
- Responds to select volcanic crises worldwide, works to reduce fatalities, economic loss
- Works through USAID, USGS scientists rapidly respond with consultation, forecasting, remote sensing data, monitoring equipment
- Between crises VDAP works with international partners to build/improve volcano monitoring systems; conducts joint activities to reduce volcanic risk and improve understanding of volcanic hazards
- Jewel in the crown of the USGS

AIRS products here

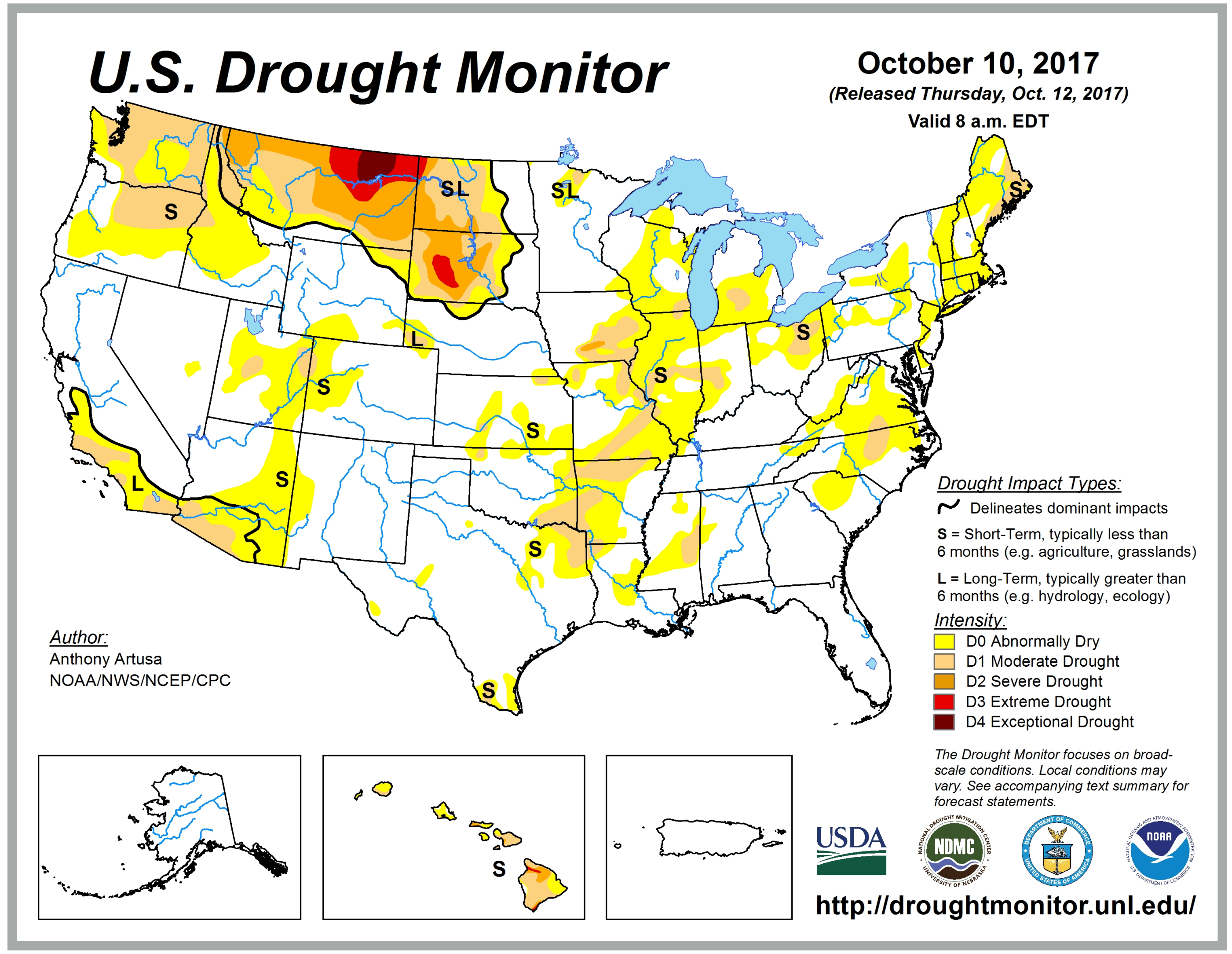
AIRS & the U.S. Drought Monitor

S. Granger / A. Behrangi / A. Farahmand (JPL)

USDM = weekly map of drought conditions, produced jointly

1. **NOAA**
2. **US Dept Ag**
3. **National Drought Mitigation Center at Univ. of Nebraska**

- Climatic/hydrologic/soil measurements + reports
- ~350 U.S. contributors, 11 climatologists take turns as lead
- Not strictly quantitative, use author judgment to reconcile differences between sources

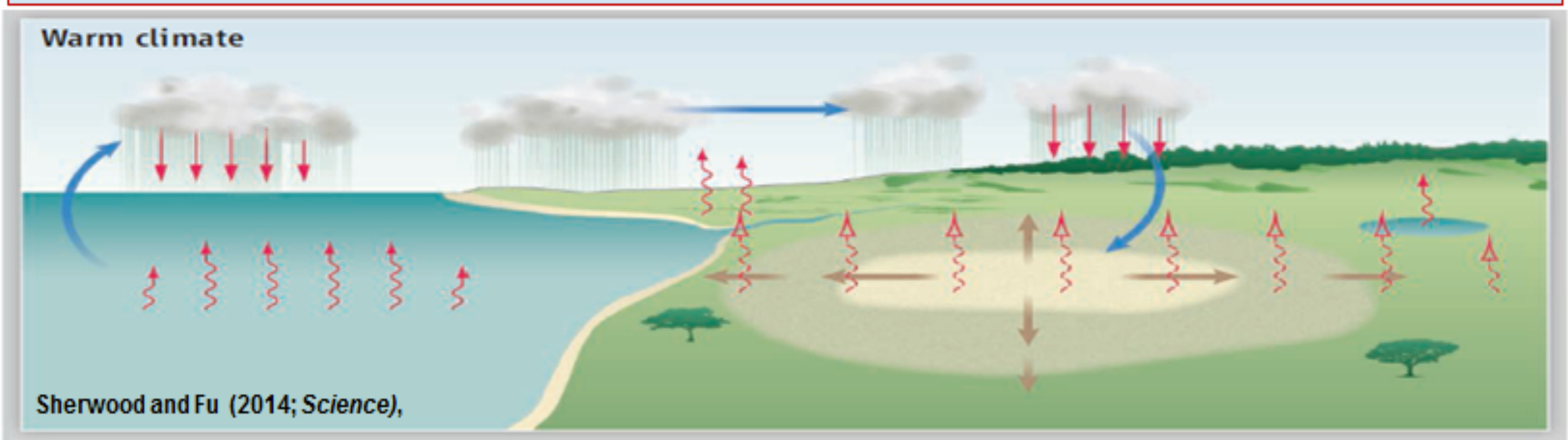


Impact of USDM

- U.S. policymakers use USDM in discussions of drought and allocation of drought relief
- USDA makes drought declarations nearly automatic for a county shown in severe drought on USDM for 8 consecutive weeks

Why use AIRS data?

The key factor in drying over land is that land surfaces (and the air just above them) warm, on average, about 50% more than ocean surfaces (M. M. Joshi *et al.* 2008).



This suggests that Vapor Pressure Deficit ($e_s - e$) will increase over land

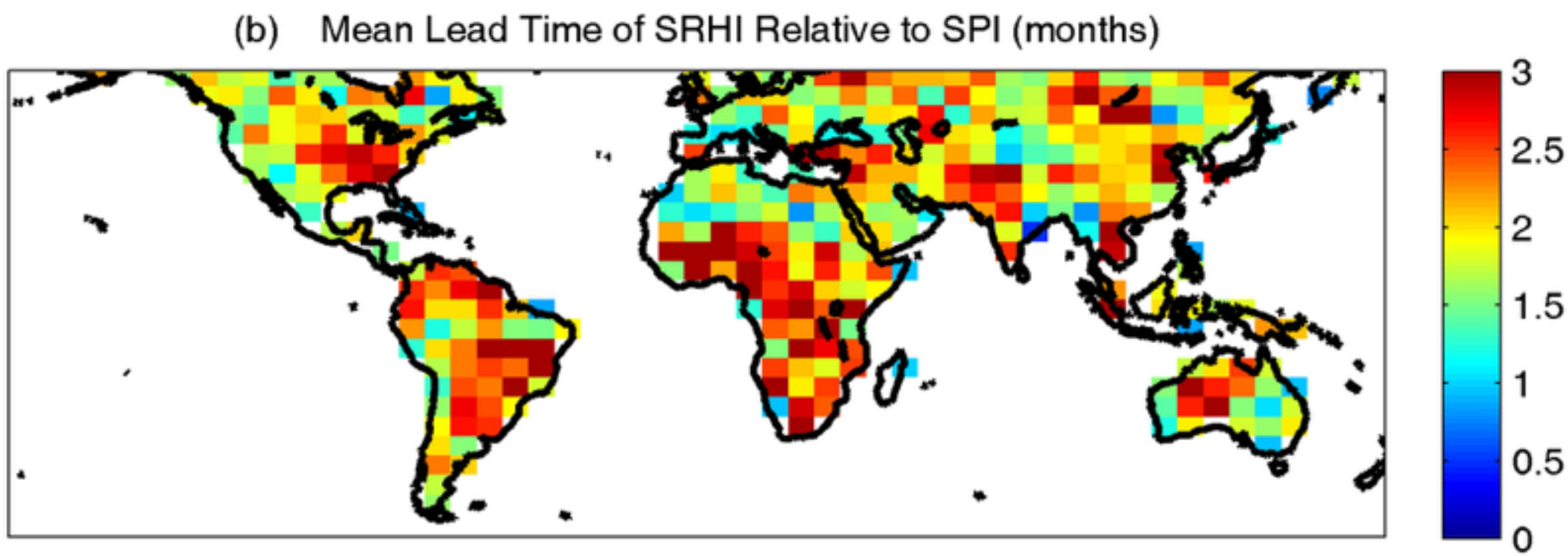
VPD = the tendency of the atmosphere to wick soil from the ground

Credit: A. Behrangi, JPL

Drought Onset Detection

- AIRS-derived standardized vapor pressure deficit (Behrangi et al. 2016) and standardized relative humidity index (Farahmand et al. 2015) can show early detection lead times of up to two months ahead of SPI
- AIRS valuable for the monitoring & early detection of meteorological drought

Meteorological drought when dry weather patterns dominate an area



Credit: A. Farahmand, JPL

Since July 2017, AIRS…

Vapor Pressure Deficit
Relative Humidity
Surface Air Temperature

Now included in the generation of the U.S. Drought Monitor

Probationary period 6-12 months –
If utility proven, will be used in generation of USDM going forward

Fire Application

AIRS & the JPL Fire Danger Assessment System: Using satellite observations to map global wildfire risk

JT Reager / Ali Behrangi / Natasha Stavros (JPL)
James Randerson (UCI)

Ventura, California 12/4/17
Credit: Sharon Ray

Currently —

No operational fire assessments use NASA satellite information to help predict fire risk

Recent research shows satellite-based climate and hydrology data sets may give a statistically significant advantage in fire prediction skill.

Simultaneous existence of multiple water cycle satellite missions (SMAP, AIRS, GRACE/GRACE-FO) **creates the opportunity for major advancement in operational fire-risk assessment**

?

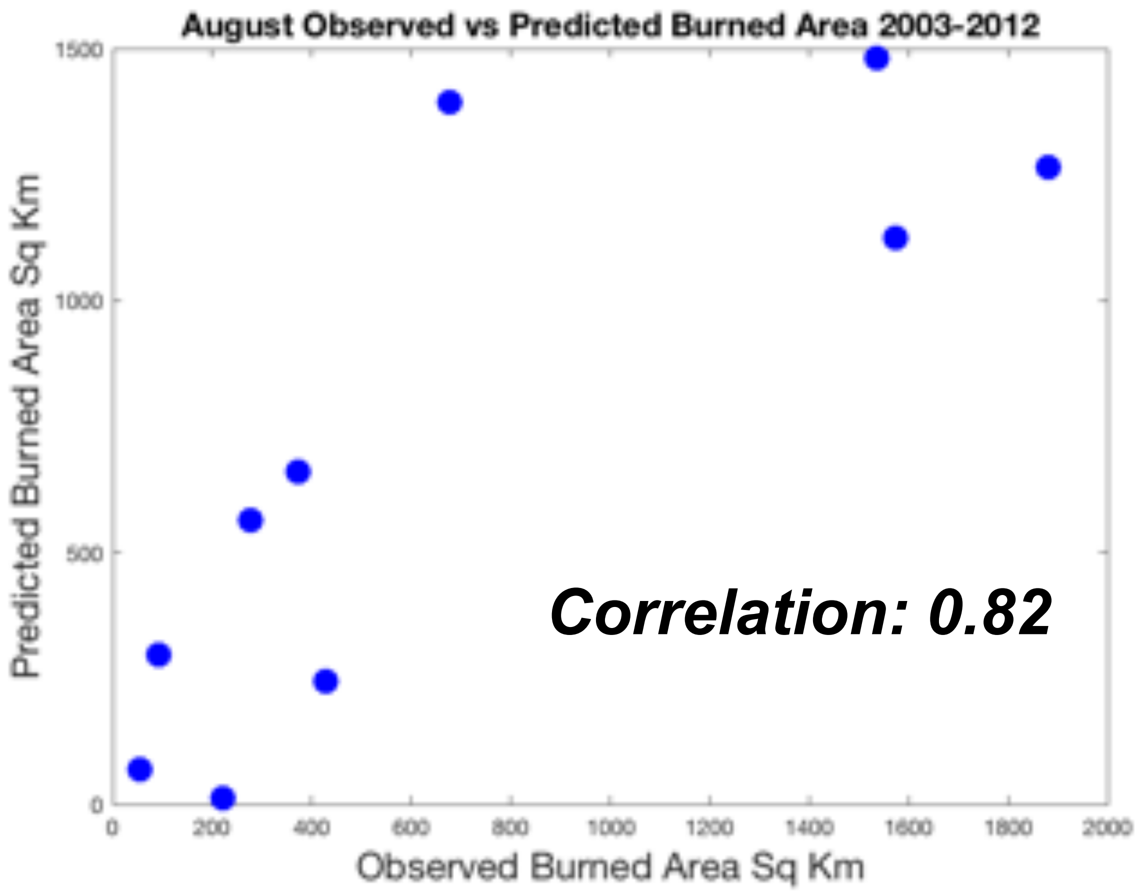
Can AIRS VPD and the relationship between VPD, drought & fire contribute to determination of fire-risk?

Fire Danger Assessment System:

1) Build formal relationship between JPL and operational fire science community
2) Use recent research advancements & NASA data to create global fire-potential data product
3) Make product publicly available
4) Use guidance/input of operational fire experts

Northern Rockies
(two-month lead prediction)

August observed vs predicted fire burned area 2003-2012



Credit: A. Behrangi, JPL

Health Applications

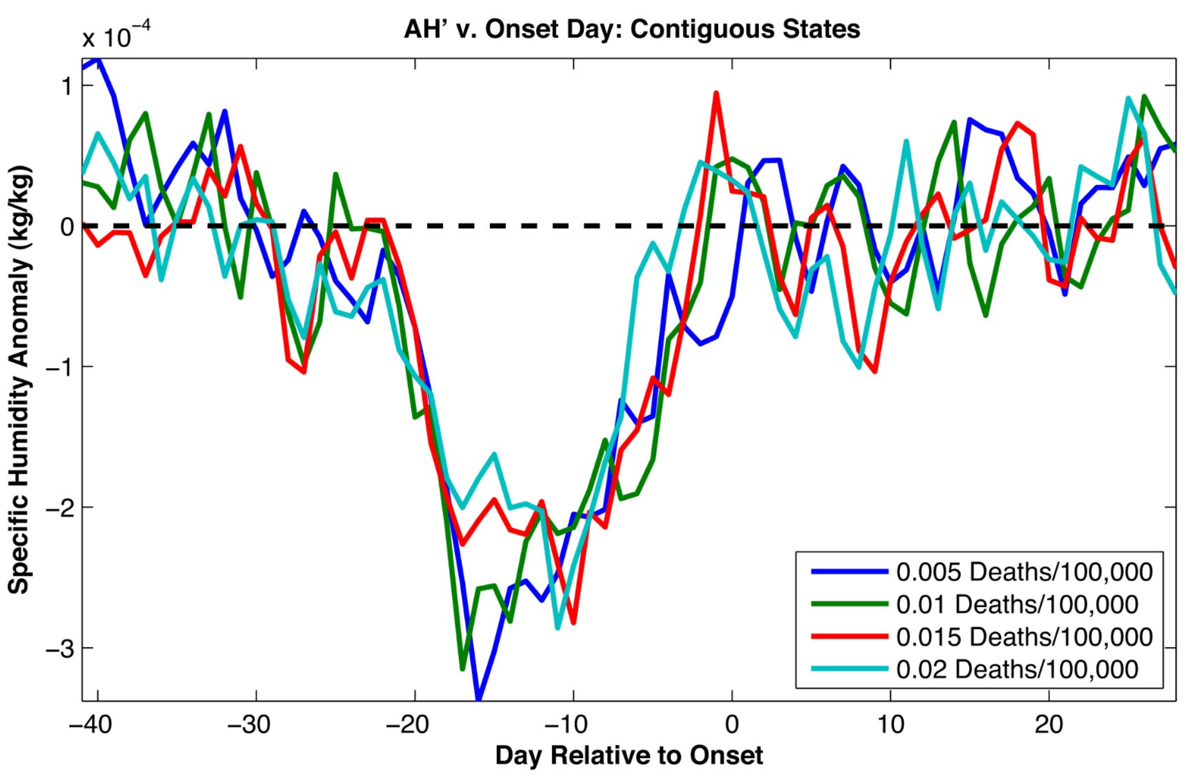
AIRS & Influenza/Vector-Borne Disease

H. Thrastarson / J. Teixeira (JPL)

Creating a system for outbreak risk assessment that will be useful in public health efforts

Flu & Environment

- Flu incidence generally peaks in winter (temperate regions) but specific timing, magnitude, duration of local outbreaks is variable and not well-explained
- Studies point to humidity as a leading driver for seasonal flu outbreaks in temperate regions (Shaman et al., 2010; Shaman & Karspeck, 2012)
- Potential mechanisms: Carrier droplet size, human defense (mucous membranes), virus survival times
- Increased wintertime flu-related mortality in US associated with anomalously low absolute humidity levels that precede outbreak



Credit: Jeffry Shaman (Columbia Univ) et al

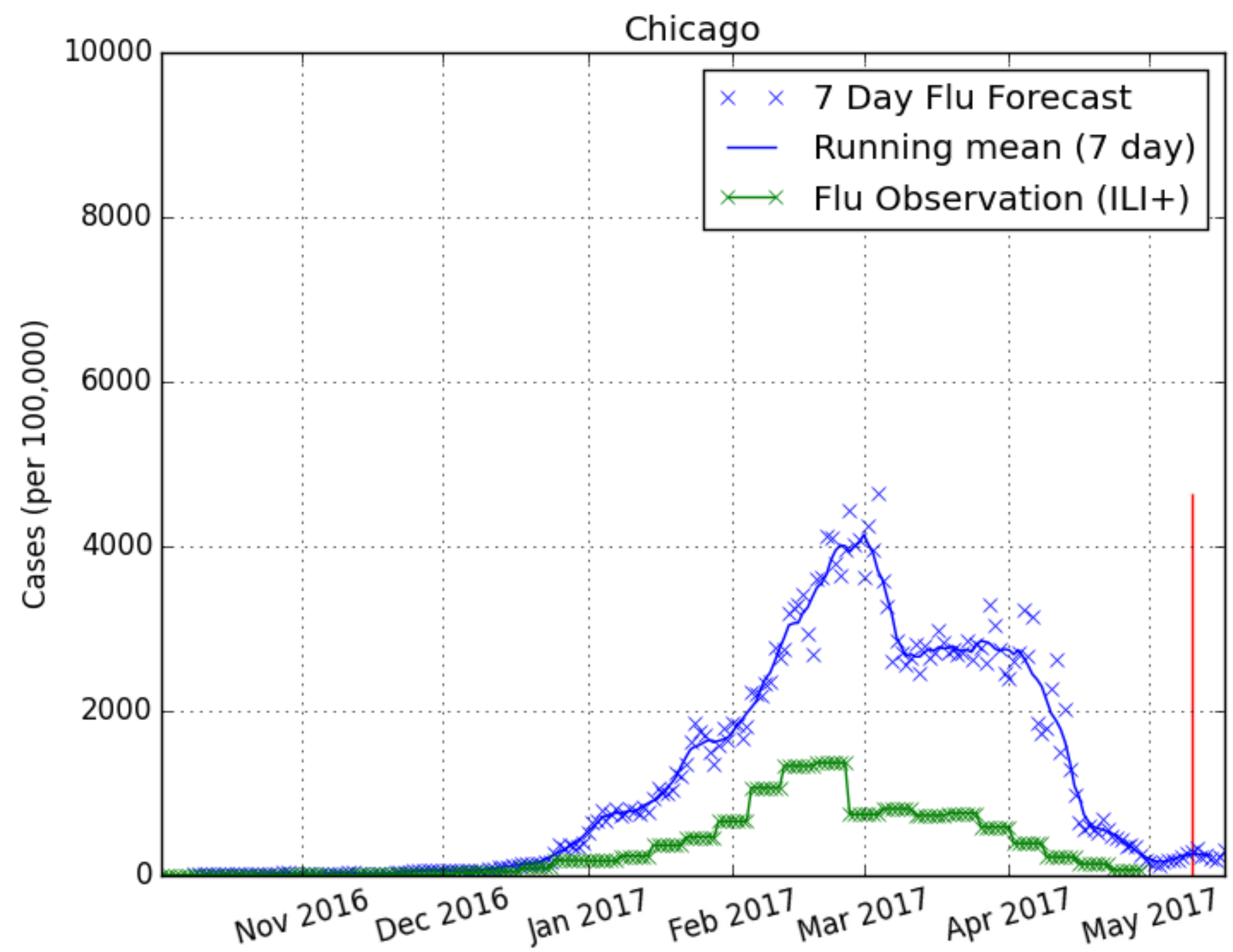
AIRS & Influenza

- Using AIRS data to explore humidity hypothesis + the role of temperature
- *Model At JPL*: Humidity-driven, quasi-operational numerical prediction system based on SIRS model for flu outbreaks; Numerically solves ODEs for # of susceptible/infected people in population; Effective infection rate modulated by humidity
- *Humidity Data*: Most recent values of AIRS near-surface humidity + NCEP humidity predictions ingested into model
- *"Observational" Data*: CDC weekly reports from labs/doctor visits of # people with flu; Google Flu Trends (based on # searches for flu) historical data only, used only for validation
- Ensembles of forecasts run with different model parameter values drawn from distributions reflecting limited constraints
- Retrospective simulations also performed using AIRS data for US cities/states/regions as well as South African provinces

SIRS Model

# of people that cycle through 3 modes:
Susceptible > Infectious > Recovered (Immune) > Susceptible

- System running quasi-operationally for several US cities
- Timing, relative behavior of flu outbreaks captured fairly well
- Determining number of affected people more challenging
- **Results support hypothesis:** ***Local humidity a significant driver***



Credit: Heidar Thrastarson, JPL

Applying the model to vector-borne disease: **Dengue Fever**

Exploring the application of AIRS climate data to the prediction of dengue fever incidence to develop an improved prediction model

- Dengue Fever most common mosquito-borne virus in the world
- Aedes aegypti mosquito (same as Zika, Chikungunya and Yellow Fever) ***strongly affected by environmental conditions***
- **Temperature**: mosquito development and reproduction, frequency of feeding, virus incubation period and geographical range of the vector (tropics and sub-tropics)
- **Precipitation:** breeding sites and stimulates egg hatching
- **Humidity**: substantial factor affecting favorable conditions for the vector

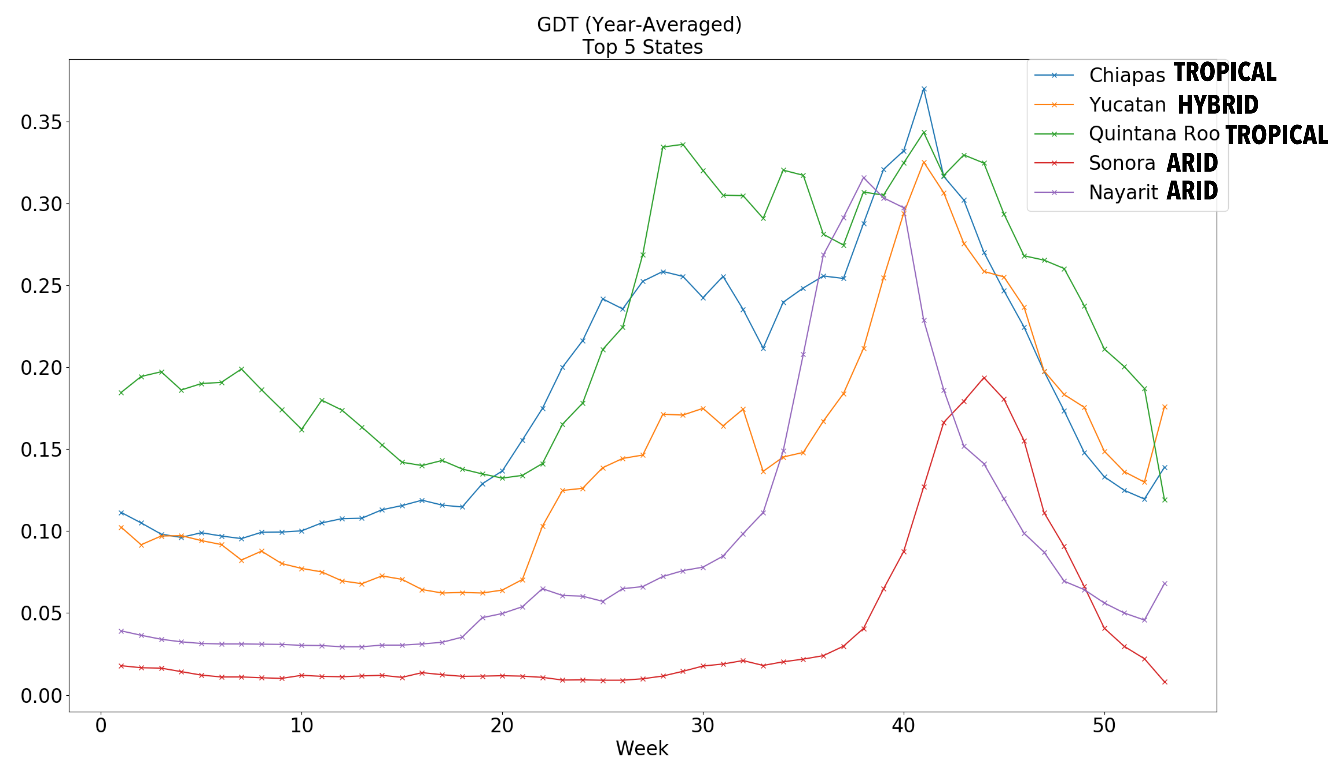
Case Study

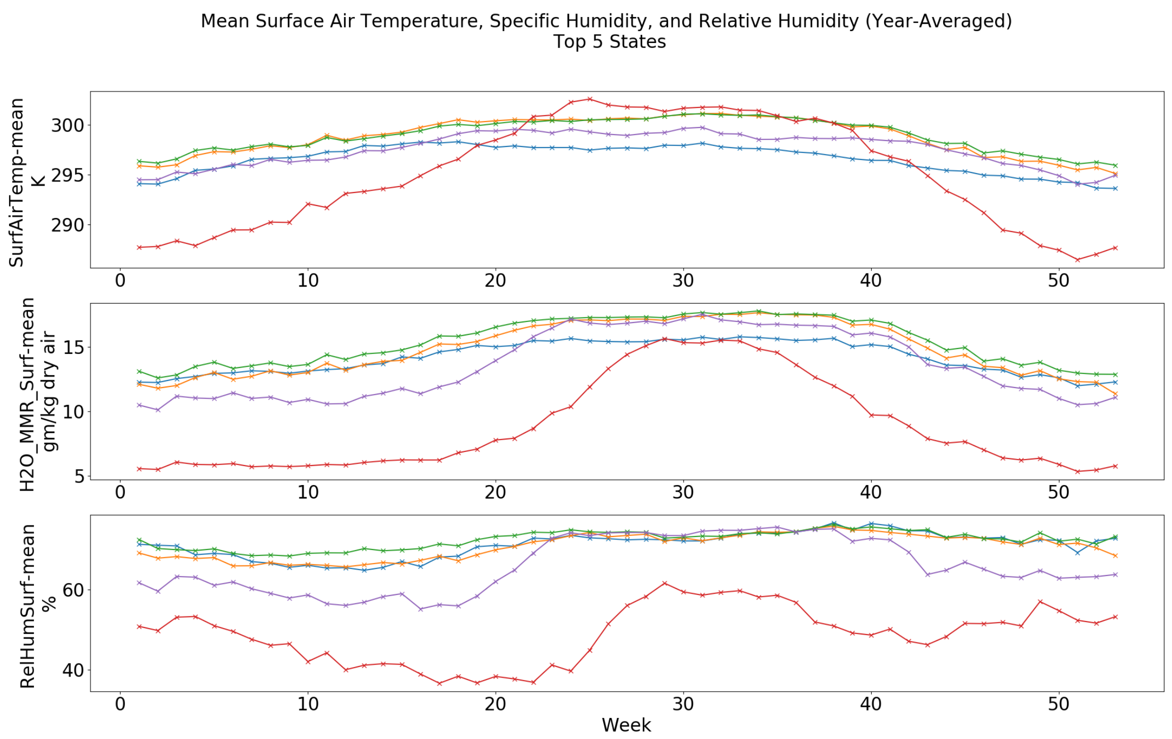
- Focused on dengue fever in Mexico, 2003-2015
- Significant dengue incidence in varied climate conditions
- AIRS surface air temperature, specific humidity, relative humidity
- Weekly Google Dengue Trends data – available at state level, gives estimate of disease activity
- Examined trends, patterns and time lags, regression models of varying complexity

Preliminary Results:
Climate-related regional differences

More tropical
- More extended and elevated dengue seasons
- In correlation with extended and elevated temperatures and humidity
- Shorter time lags in the climate-dengue relationship

More arid
- Dengue peaks more sharply and only once
- In correlation with steeper rises and falls in temperature and humidity
- Longer time lags in the climate-dengue relationship





Sonora vs Chiapas & Quintana: Distinct climates, distinct dengue behaviors

Credit: Heidar Thrastarson, JPL

Aviation Application

Volcanic Plume Detection Rapid Response

S. Ray / V. Realmuto / E. Olsen / S. Licata / L. Chen / E. Fetzer / B. Lambrigtsen / P. Penteado / J. Hall (JPL)

Full Report – 2017 Earth Science Senior Review Subcommittee

The importance and utility of AIRS/AMSU was widely noted. Data are of significant importance to FAA and the aviation community (sulfur dioxide, volcanic plumes). AIRS data are utilized in volcanic ash detection for the NOAA Rapid Update Cycle Rapid Refresh Model.

AIRS-based maps of volcanic SO2/ash already in use by European groups

Support to Aviation Control Service (SACS)

- Initiated by ESA, supports Toulouse & London VAACs
- Provides NRT SO2 & volcanic ash

SAVAA Project (Support to Aviation for Volcanic Ash Avoidance) – NILU (Norwegian Institute for Air Research)

- ESA funded, also supports VAACs
- SO2/Ash loading, Prata/Bernardo retrieval

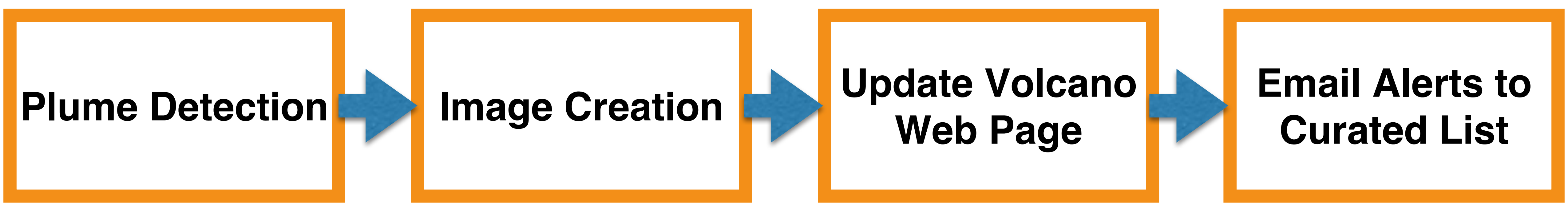
Nicarnica

- spin-off of NILU
- Private company providing airborne natural hazard info to aviation

AIRS automated rapid response system *in development at JPL*

Low-Cost Strategy
Re-purpose SO2 BT DIFF and Dust Score as low-latency (rapid) response products for volcanic plume detection and SO2/ash loading

Rapid Response System Components – FULLY AUTOMATED



About the plume detection algorithm

- **SO_2 main driver, dust used in secondary way**

- **Scan every incoming L1B data granule**

- **Plume event declared on threshold exceedance of:**
  - High # of SO_2-only counts
  - Lower # of SO_2+Dust counts (combined allows for lower threshold limit)
  - Extremely high # of Dust-only counts (not likely, threshold set high)

- **Dust count threshold alone — too many false positives**
  We can't yet differentiate between volcanic & non-volcanic dust sources without also checking for presence of SO_2

AIRS Volcanic Plume Imagery

Evidence of Activity

SO2 BT DIFF, Dust Score

Loading

SO2, Ash & Dust (S. DeSouza-Machado)

Cloud Obstruction

Total Cloud Fraction + SO2 Overlay, VIS, IR

Imagery available in JPG, KMZ, GeoTIFF

Volcano imagery to be produced by NASA LANCE NRT (viewable in NASA Worldview, archived in perpetuity on NASA GIBS)

Puyehue Volcano, Chile June 2011

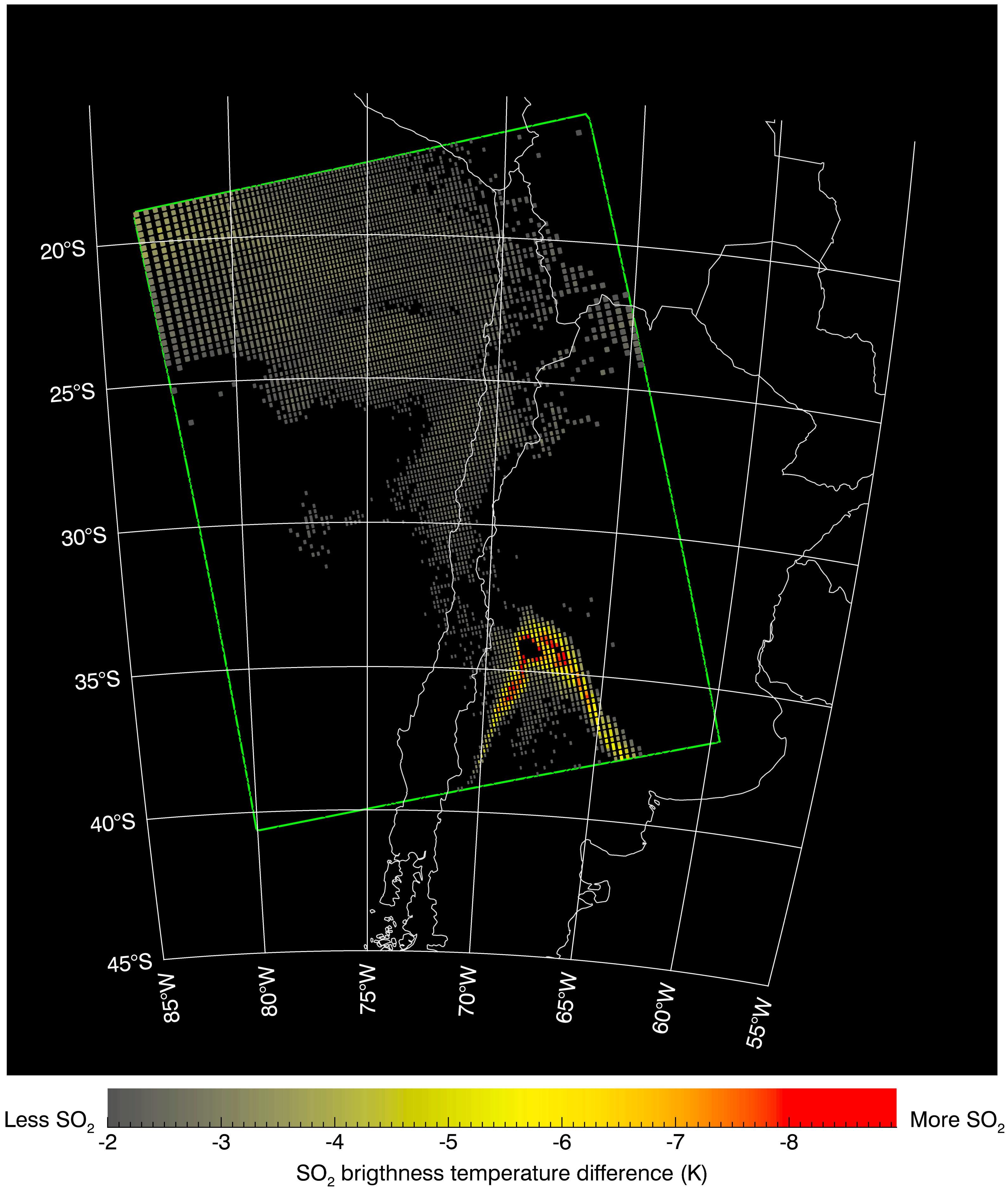
Dormant 50 years
Ash higher than 6 miles up
Region put under alert – 230 earthquakes/hour prior to eruption

The Atlantic

Photos taken June 5, 2011

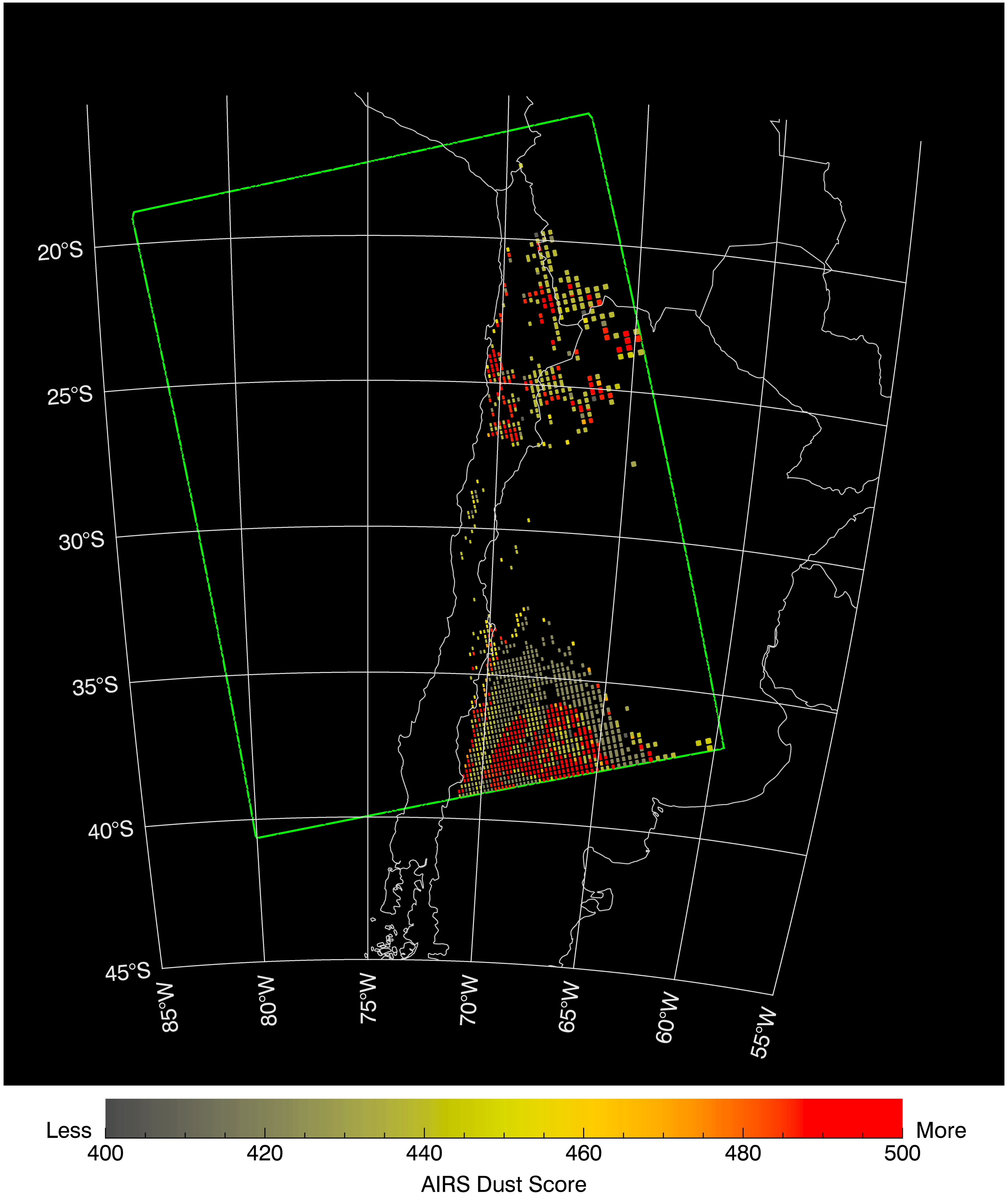
Santiago
San Luis
Rancagua
San Rafael
Argentina
Santa Rosa
Concepción
Chillán
Los Ángeles
Temuco
Neuquen
Ba
Pucón
Valdivia
San Martín
de los Andes
Osorno
San Carlos
de Bariloche
Las Grutas
Viedma
Puerto Montt
Ancud
El Bolsón
Isla Grande
de Chiloé
Esquel
Puerto Madryn
Quellón
Trelew
Playa Union

AIRS detection of SO_2 2011.06.06.187



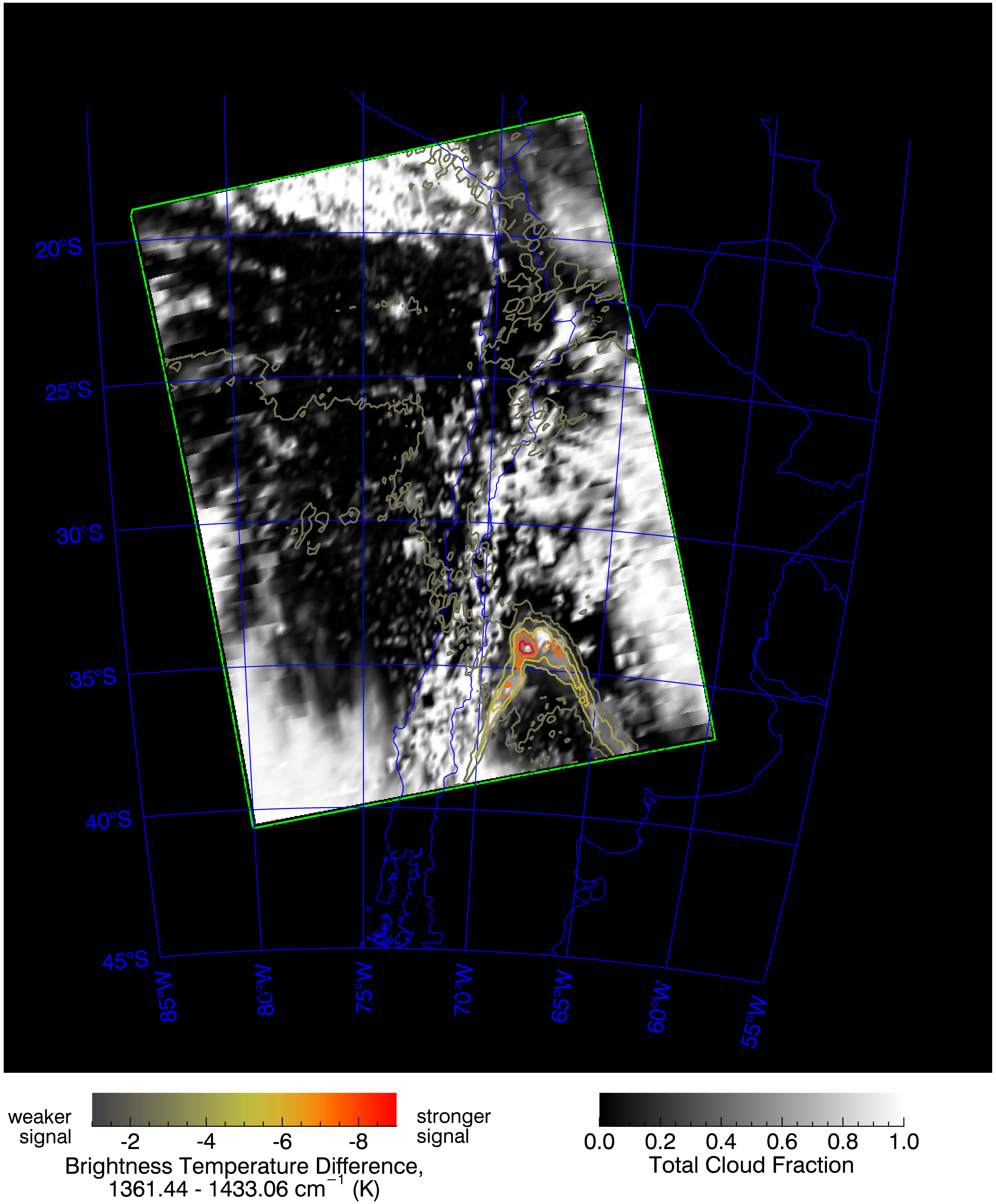
SO2 BT DIFF

AIRS Detection of Dust 2011.06.06.187

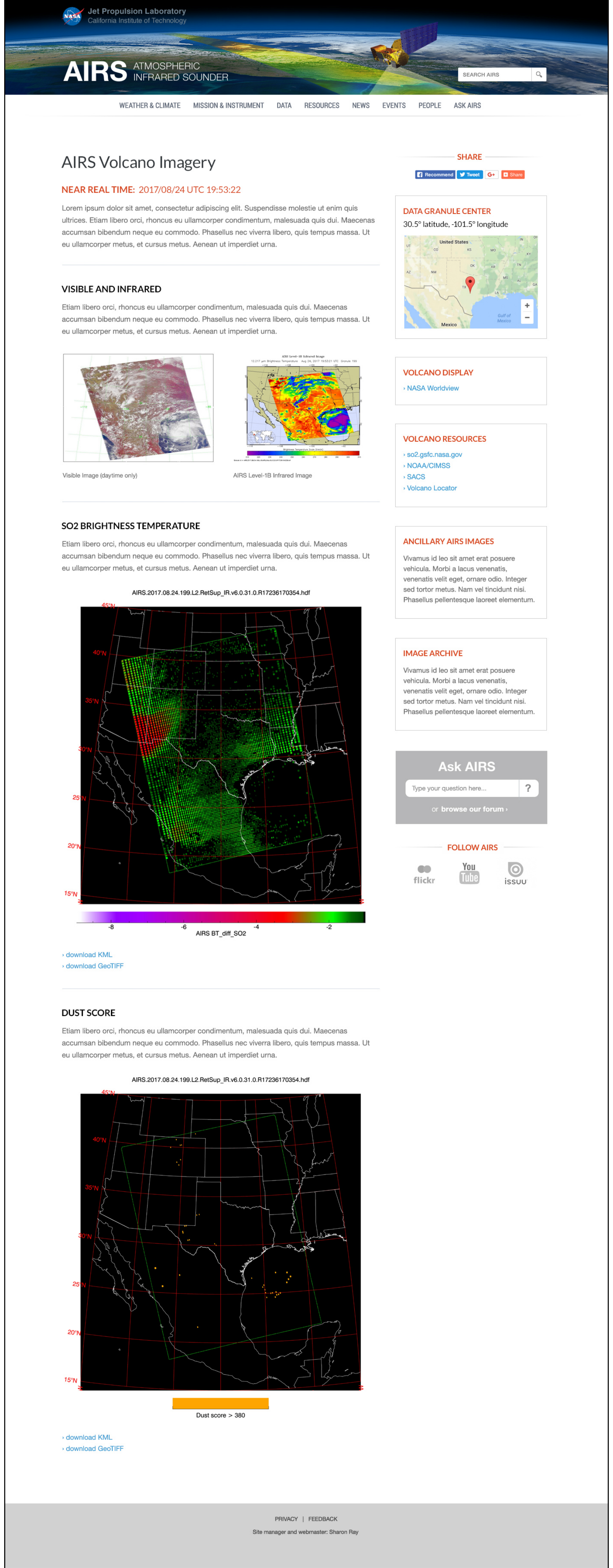


Dust Score

AIRS Detection of Sulfur Dioxide 2011/06/06/18:41:24 UTC



SO2 BT DIFF + Total Cloud Fraction



AIRS Volcanic Plume Detection

Rapid Response Web Page

About AIRS Volcano Rapid Response Imagery

Event time stamp

Image descriptions

“Lay of the Land” images: Vis, IR

Headline images: SO2, Dust Score

Where on Earth locator (center of granule)

Links to ancillary products: SO2 Loading, Ash/Dust Loading, Cloud Product(s), Media Product

Custom link to NASA Worldview, shows AIRS volcano product layers

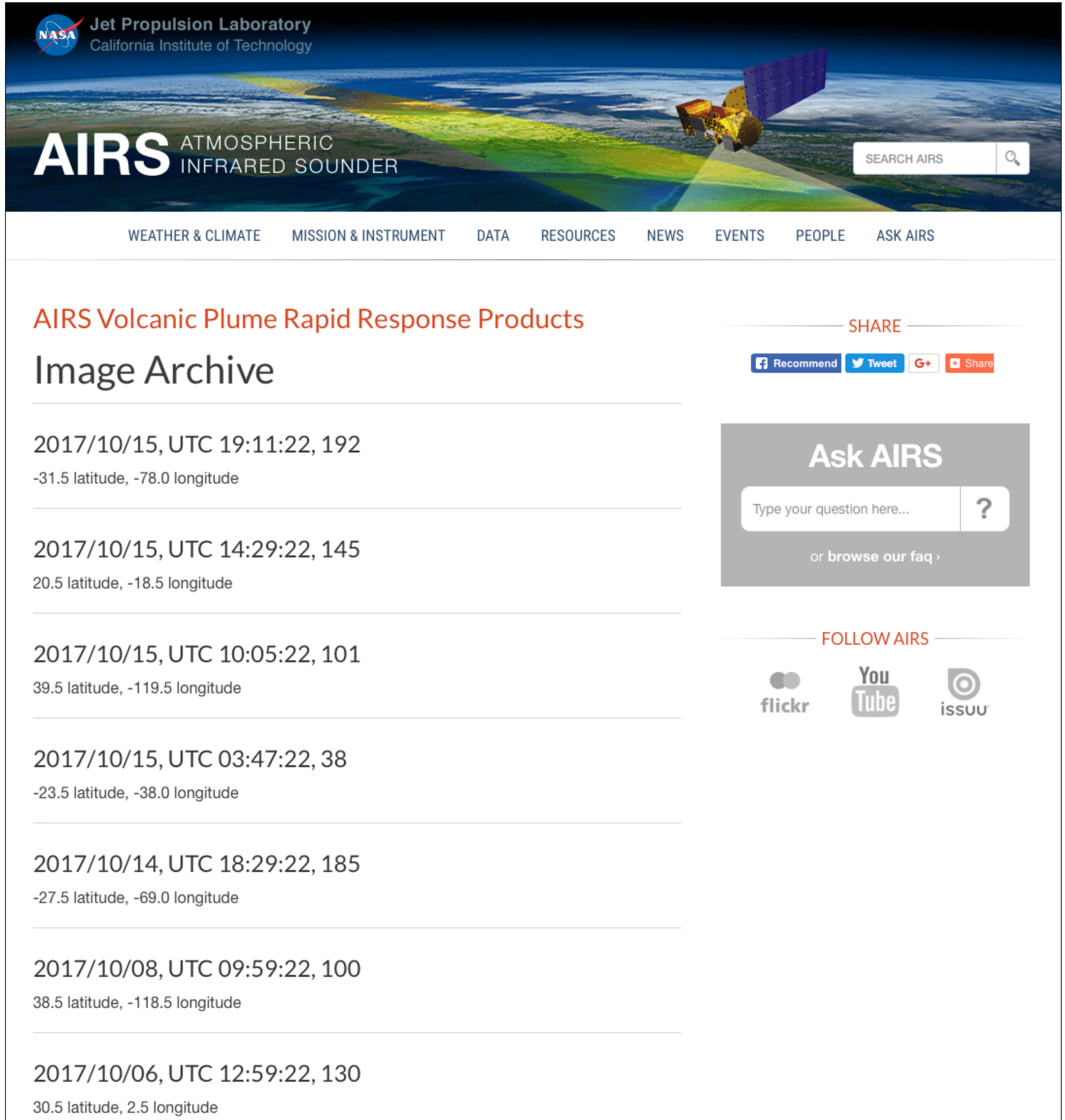
Link to AIRS User Guide relevant sections

Links to other volcano resources

Link to AIRS volcano image archive

AIRS Volcano Archive

- Local 3 month rolling archive
- NASA GIBS permanent archive



Launching the AIRS Volcano Web Page

Soft launch web page

Solicit colleague reviews

Link from SO2.nasa.gov

Earth Observatory feature

Announce to Volcano Clouds list

NASA Applied Sciences, NOAA/NESDIS Hazards

NASA Worldview “Themes” page

Rapid response framework developed for volcano can be re-purposed to work with ANY AIRS data product

Looking ahead…

Application focus areas, continue development and new areas for consideration

Drought

Influenza / Dengue / Zika (Health)

Volcano (Aviation, Disaster)

Wildfire (Fire Weather, Air Quality)

Temperature Inversion (Air Quality)

Carbon Monoxide (Air Quality)

Ammonia (Air Quality)

Deep Convective Clouds (Aviation)

NUCAPS / AWIPS