# AIRS Applications Overview: Volcano, Influenza, Drought & More

**Sharon Ray**
**AIRS Applications Development Lead**
Jet Propulsion Laboratory, California Institute of Technology
October 2017

**Joao Teixeira, Tom Pagano, Eric Fetzer, Bjorn Lambrigtsen**
**Ed Olsen, Steve Licata, Luke Chen, Paulo Penteado, Jeff Hall**
**Vince Realmuto, Stephanie Granger, Ali Behrangi, Alireza Farahmand, Heidar Thrastarson**

© 2017 California Institute of Technology. Government sponsorship acknowledged.

# AIRS Applications Catalog - *FLUID!*

## DROUGHT

USDM

## AVIATION

Volcanic SO2 Detection in VAAC

Volcanic SO2 Loading in VAAC (Prata)

Volcanic Ash/Dust Loading in VAAC (Prata)

JPL Volcano Rapid Response - *improved detection and products*

Cold Air Aloft

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

# *Drought Application*

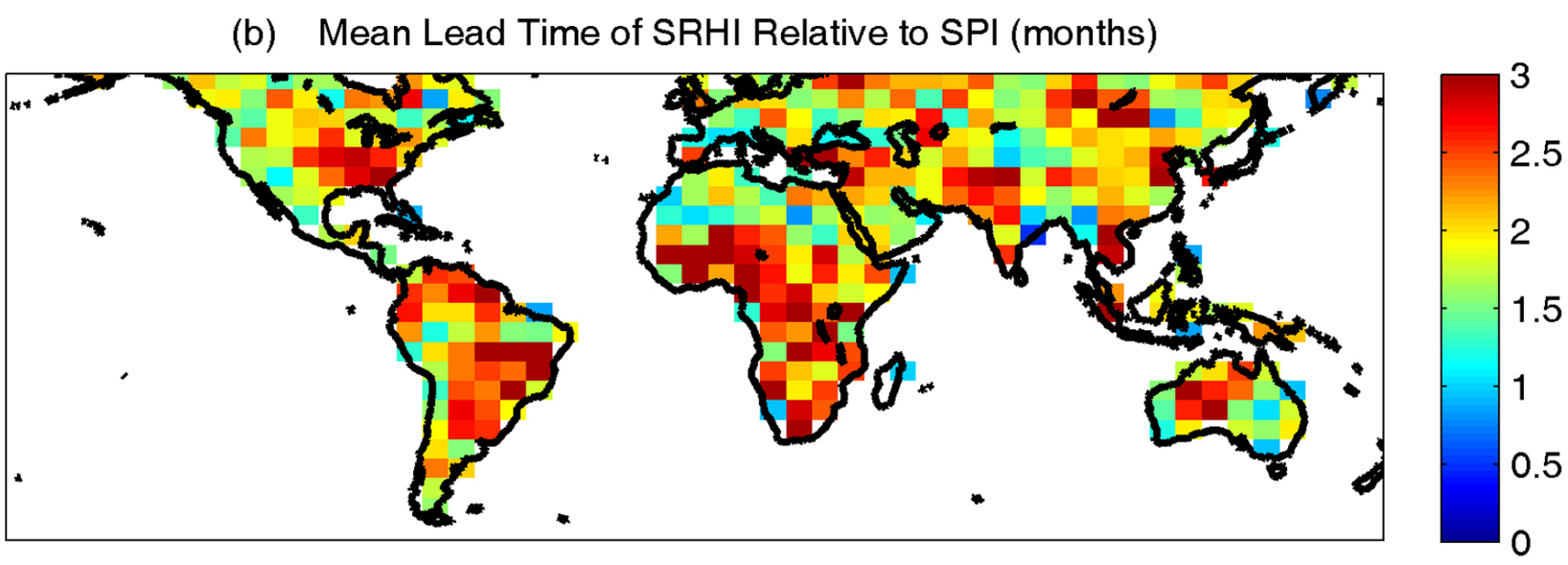
# AIRS & the U.S. Drought Monitor

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

## Drought Onset Detection

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

**Meteorological drought**
when dry weather patterns dominate an area

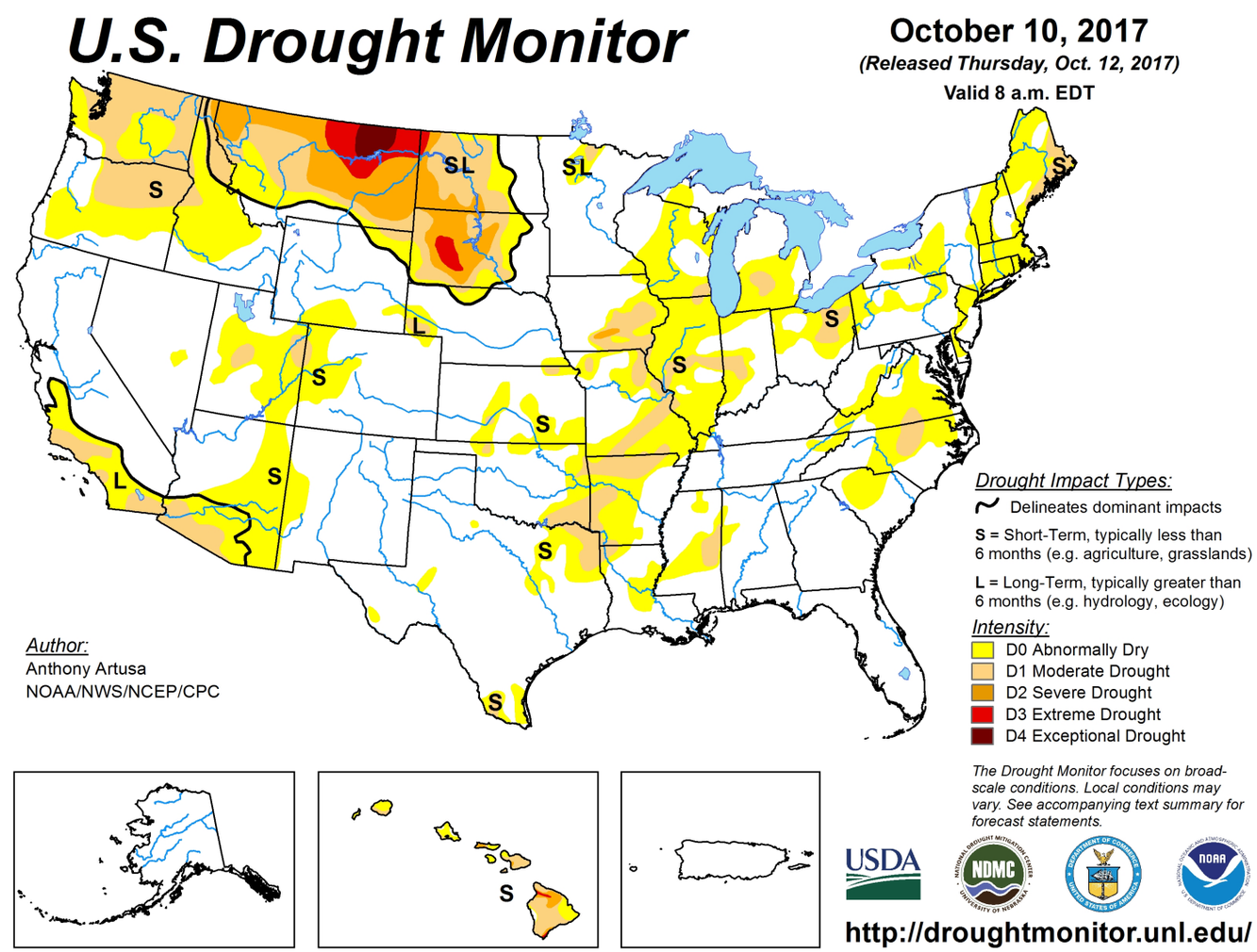



*Credit: A. Farahmand, JPL*

# U.S. Drought Monitor *est. 1999*

## Weekly map of drought conditions, produced jointly by NOAA, US Dept Ag, National Drought Mitigation Center at Univ. of Nebraska-Lincoln

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




**U.S. policymakers use USDM in discussions of drought and allocating drought relief**

**USDA makes drought declarations nearly automatic for a county shown in severe drought on USDM for eight consecutive weeks**

**July 2017**

## AIRS Vapor Pressure Deficit, Relative Humidity, Surface Air Temperature *are 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

## Next Steps

- Determine if AIRS drought products have utility in National Drought Mitigation Center QuickDRI product
- NDMC – Serve AIRS drought products?
- Transfer operational production to NOAA?

## *Fire Application*

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

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

Santa Rosa, California 10/9/17

# There are no operational fire assessments that use NASA satellite information to help predict fire risk

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

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

**Proposal: JPL Research and Technology Development (R&TD) Program**

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

**Can AIRS VPD-fire** and the **relationship between VPD, drought & fire** (at monthly to daily timescales) **contribute to determination of fire-risk?**

# Gallery: Firefighters battle wind-driven brush fire in Ventura

Firefighters responded to a fast-moving brush fire along the hills north of Ventura on Tuesday afternoon. CONTRIBUTED/VENTURA COUNTY FIRE DEPARTMENT

# *Health Applications*

# AIRS & Influenza/Vector-Borne Disease

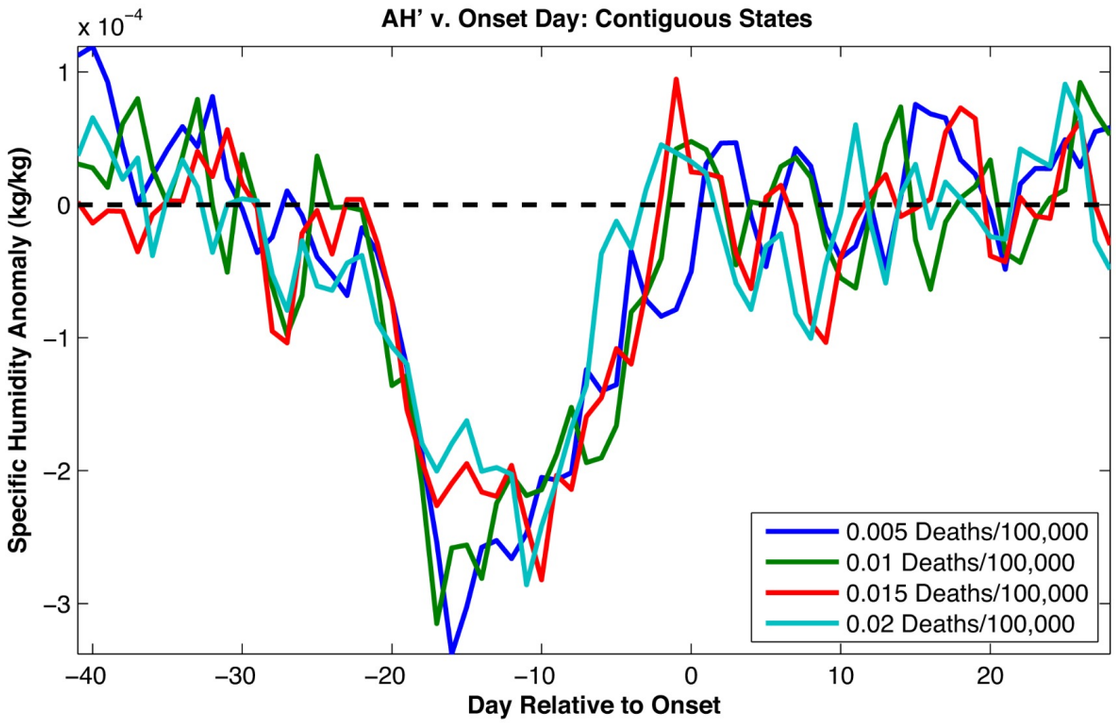
*H. Thrastarson / J. Teixeira (JPL)*

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

## Influenza

- **Studies show humidity conditions as a leading explanation for seasonal behavior of flu outbreaks in temperate regions** (Shaman et al., 2010 & Shaman & Karspeck, 2012)

- **Increased wintertime flu-related mortality in US associated with anomalously low absolute humidity levels that precedes outbreaks.**




Credit: Jeffry Shaman et al

## Influenza…

- **At JPL** – Quasi-operational numerical prediction system based on SIRS model for flu outbreaks
- **Results support hypothesis** – Local humidity a significant driver
- **Data** –
  - Humidity – AIRS near-surface humidity + NCEP forecast
  - Flu – CDC: weekly reports of # people with flu from lab & doctor visits; Google Flu Trends: based on # searches for flu, for validation only, historical data only
- **Paper in development** – includes production and processing of hindcasts and validation results

**SIRS Model**
based on # of people that cycle through 3 modes:
**Susceptible > Infectious > Recovered/Immune > Susceptible**

# Vector-Borne Disease: Zika/Dengue

- Determine which environmental variables are most important in Zika outbreaks.

# *Health/Air Quality Application*

# Temperature Inversion

*Intern M. Worden / Mentors: S. Ray, E.Olsen, E. Fetzer, B. Lambrigtsen, S. Wong (JPL)*

## Inversions over cities result in lower air quality by trapping pollutants within the boundary layer

**Inversion strength**
difference between maximum temperature in the inversion and the minimum temperature

**Inversion thickness**
altitude at which lapse rate resumes the decrease with altitude (the top of the boundary layer)

## Help characterize AIRS' skill in determining temperature inversions off coast of California (AOI for SCAQMD)

- Inversion strength, height
- Compare to radiosonde data

### Summary

- AIRS has skill detecting inversion strength around and off California coast
- Data shows inversion strength increases from ocean to land
- Did not find skill in AIRS-based inversion height

### Next Steps

- SCAQMD - interest in AIRS and TI?

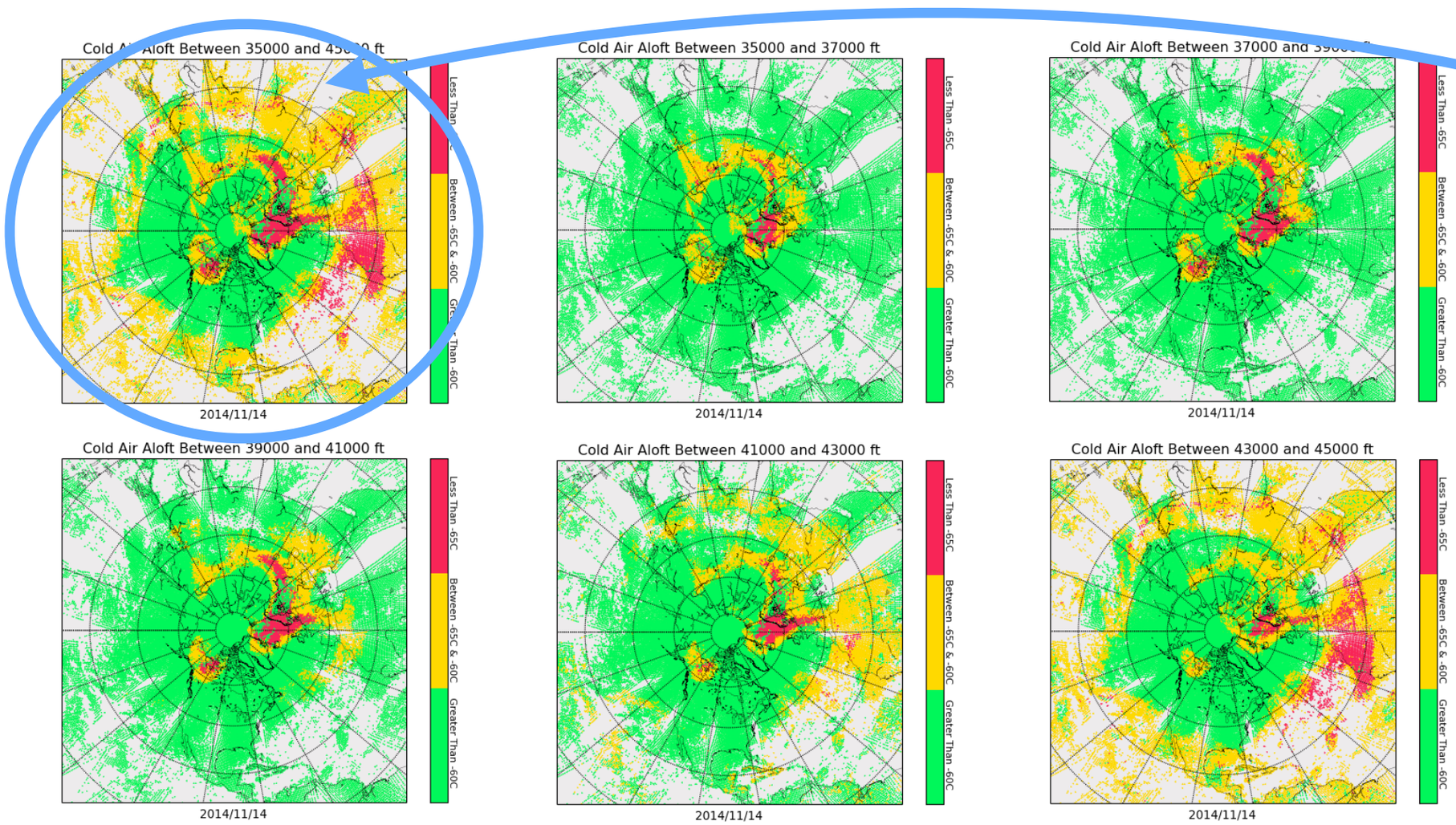
# *Aviation Application*

# Cold Air Aloft

*Intern M. Worden / Mentors: S. Ray, E.Olsen, E. Fetzer, B. Lambrigtsen (JPL) – C. Barnet (STC), B. Zavodsky (SPoRT)*

**CAA: Cold temperatures at or below -65 °C that occur at aircraft cruising altitudes are a safety hazard for the commercial aviation industry, can cause fuel to gel**

- **Intern Matthew Worden** (Freshman/Sophomore, UC Berkeley/Physics)
- **Limited temperature data at polar altitudes and over ocean > AIRS NRT could locate regions of cold air**




**Plot regions of cold air in cruise zone (35-45k feet)**

**If regions of cold air found in cruise zone, then plot cold air in 2000-foot slices to isolate it vertically**

**Can show altitudes that are safe to fly**

Red–Danger: T < -65 C
Yellow–Warning: T between -65 and -60 C
Green–Safe: T > -65 C

## Next Steps

- B. Zavodsky (SPoRT)– Forecasters familiar with NUCAPS; discuss with E. Berndt (SPoRT)
- C. Barnet (STC) – Lori Borg paper on Validation of AIRS V6 with NUCAPS
- Create operational images of CAA, post on AIRS site, can use for discussion with forecasters

## *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)*

Mt. Agung, Bali, Indonesia
September 26, 2017

**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 plumes and clouds made by several European groups

## *SO2 Detection: Support to Aviation Control Service (SACS)*

- Initiated by ESA, **supports Toulouse & London VAACs** provides NRT SO2 & volcanic ash from UV-vis (OMI, GOME-2A, GOME-2B, OMPS) and InfraRed (AIRS, IASI-A, IASI-B)
- Uses AIRS SO2 BT DIFF = (1361.44 cm-1) - (1433.06 cm-1)

## *SO2/Ash Loading – Prata/Bernardo retrieval method ————————*

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

- ESA funded, also supports VAACs

***Challenge***

- No standard data products for volcanic ash and volcanic gas (principally SO2) – *has led to ad hoc approaches and systems, lack of data product coordination between VAACs*
- But mature techniques from research community can be implemented for operational use
- No internationally agreed-upon satellite-based volcanic product standards
- No protocol in place for safe limits when planes encounter airborne volcanic substances
- **Part of solution = provide quantitative satellite information and some means for validation**
- **Another important factor: timeliness.** Most danger to jet aircraft occurs within 3 hours of a volcanic eruption; night
- http://savaa.nilu.no/

### Nicarnica

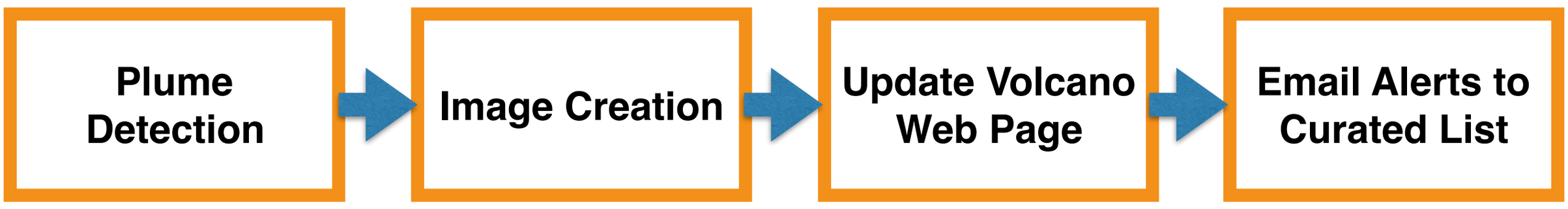
– spin-off of NILU; private company providing airborne natural hazard info to aviation
https://nicarnicaaviation.com/calbuco-eruption-april-2015/

# 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 – AUTOMATED***



# About the plume detection algorithm

- **SO2 is the driver for plume detection, dust used in secondary way**

- **Plume event declared upon threshold exceedance of one of these:**
  1. *High # of SO2-only events*
  2. *Lower # of SO2+Dust events (combined allows for lower threshold limit)*
  3. *Extremely high # of Dust-only events (not likely, threshold set very high)*

- **High dust counts alone will not trigger a plume alert, causes too many false positives**

- **We can't yet differentiate between volcanic and non-volcanic dust sources without also checking for presence of SO2**

# AIRS volcanic plume detection algorithm

**Incoming L1B Data Granule**

- Available within 1-1.5 hours of satellite overpass
- Contain 90 x 135 AIRS radiance footprints (cross track x along track)
- Footprints 14 km diameter at nadir

**Divide granule into subregions**

- 6x9 subregions
- Subregion = 225 footprint (250 km x 250 km at nadir)
- Maximizes sensitivity to spatially localized volcanic plume
- Minimizes false alarms due to widely scattered random hits

**Test every AIRS footprint in subregion**

## For each AIRS footprint:

**Determine if footprint over ocean or land**

Allows for future tuning of dust test

**SO2-Only Test**

Compare SO2 channel to non-SO2 channel. If SO2 brightness temperature difference exceeds threshold, increment SO2-Only counter

**If SO2 Detected, then test for Dust in same footprint**

If Dust Score > 380, increment SO2+Dust counter

**Dust-Only Test**

If Dust Flag indicates potential for dust AND Dust Score > 380, increment Dust-Only counter

**Check all the subregion counter tallies: SO2-Only, SO2+Dust, Dust-Only**

If any threshold exceeded, subregion has plume event

Dust-Only counter tally threshold set extremely high, only trips for very large events. SO2+Dust counter tally threshold is set lower than S2-Only and Dust-Only.

**If any subregion has plume event, granule is flagged, plume event characterized, trigger is set**

Create images, update web page, send email notification to community

Any subregion with plume event causes trigger to set. Code tests all subregions (even though it only takes one subregion to set the trigger) to allow for future fine-tuning of algorithm.

# 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

*Available in JPG, KMZ, GeoTIFF*

**Volcano imagery to be added to suite of AIRS products produced by NASA LANCE NRT**

viewable in NASA Worldview
archived in perpetuity on NASA GIBS

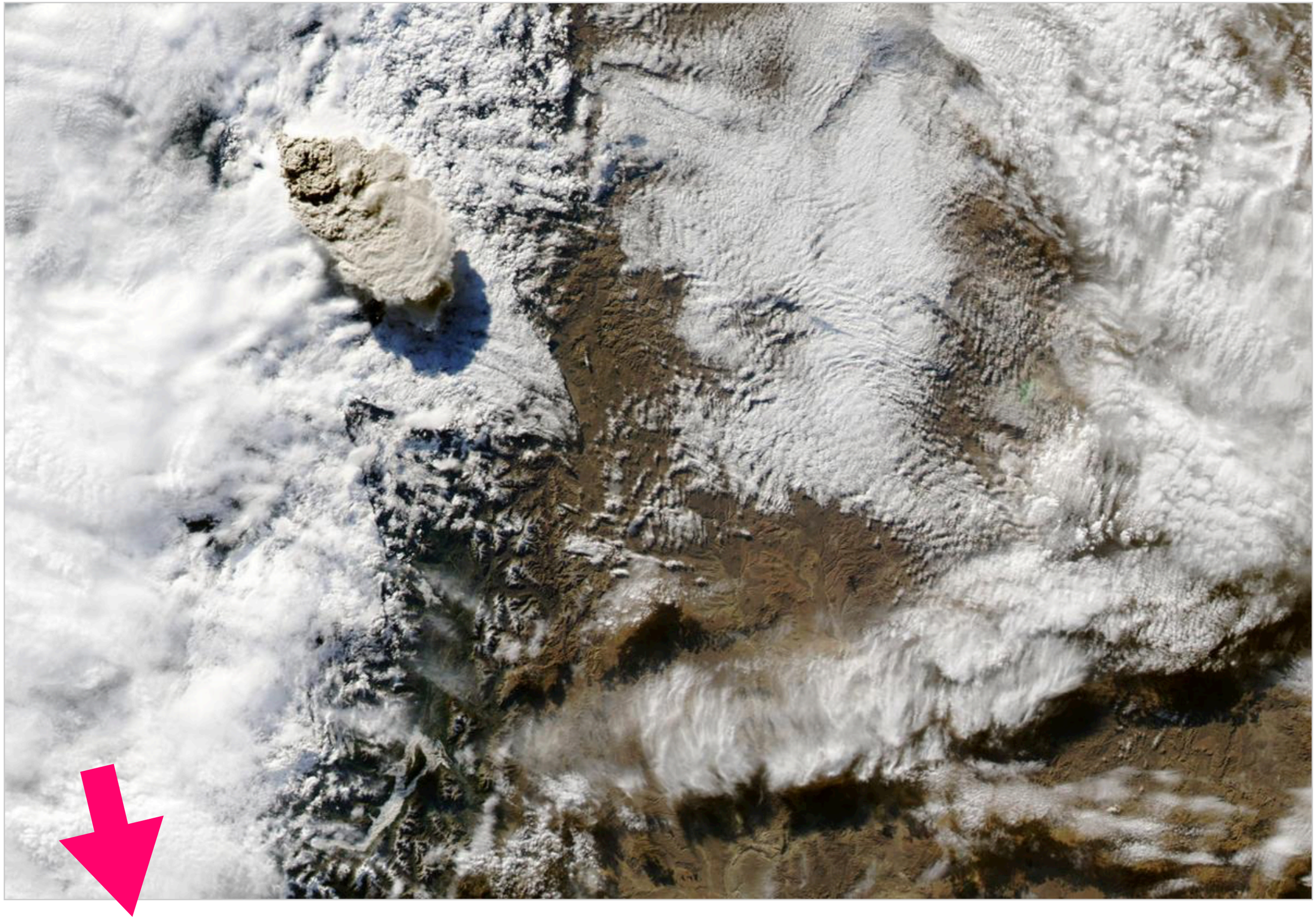
# Puyehue Volcano, Chile June 2011

**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

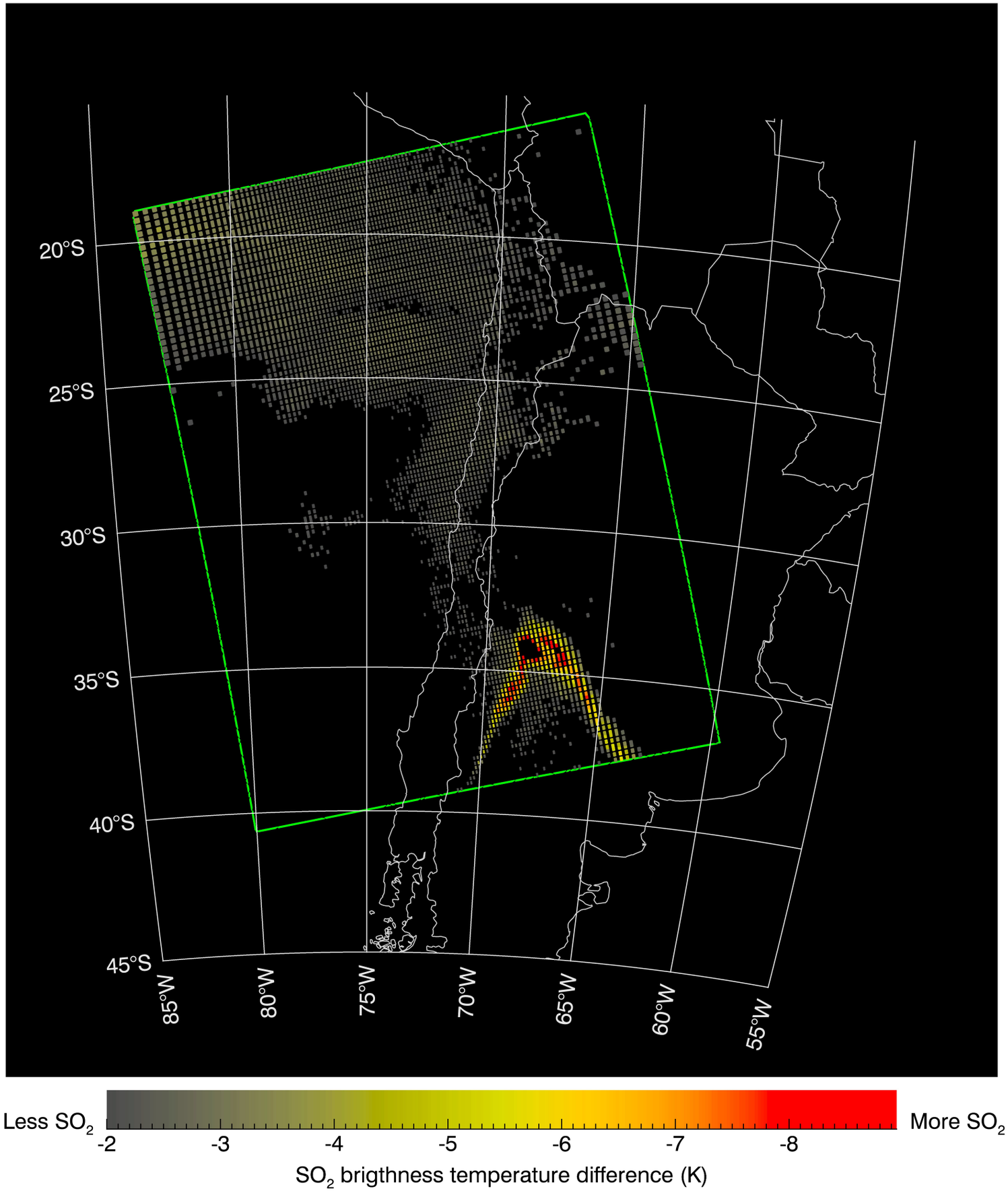
theatlantic.com



3. NASA Aqua satellite image of the eruption of Puyehue volcano, seen from low Earth orbit on June 4, 2011. #

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

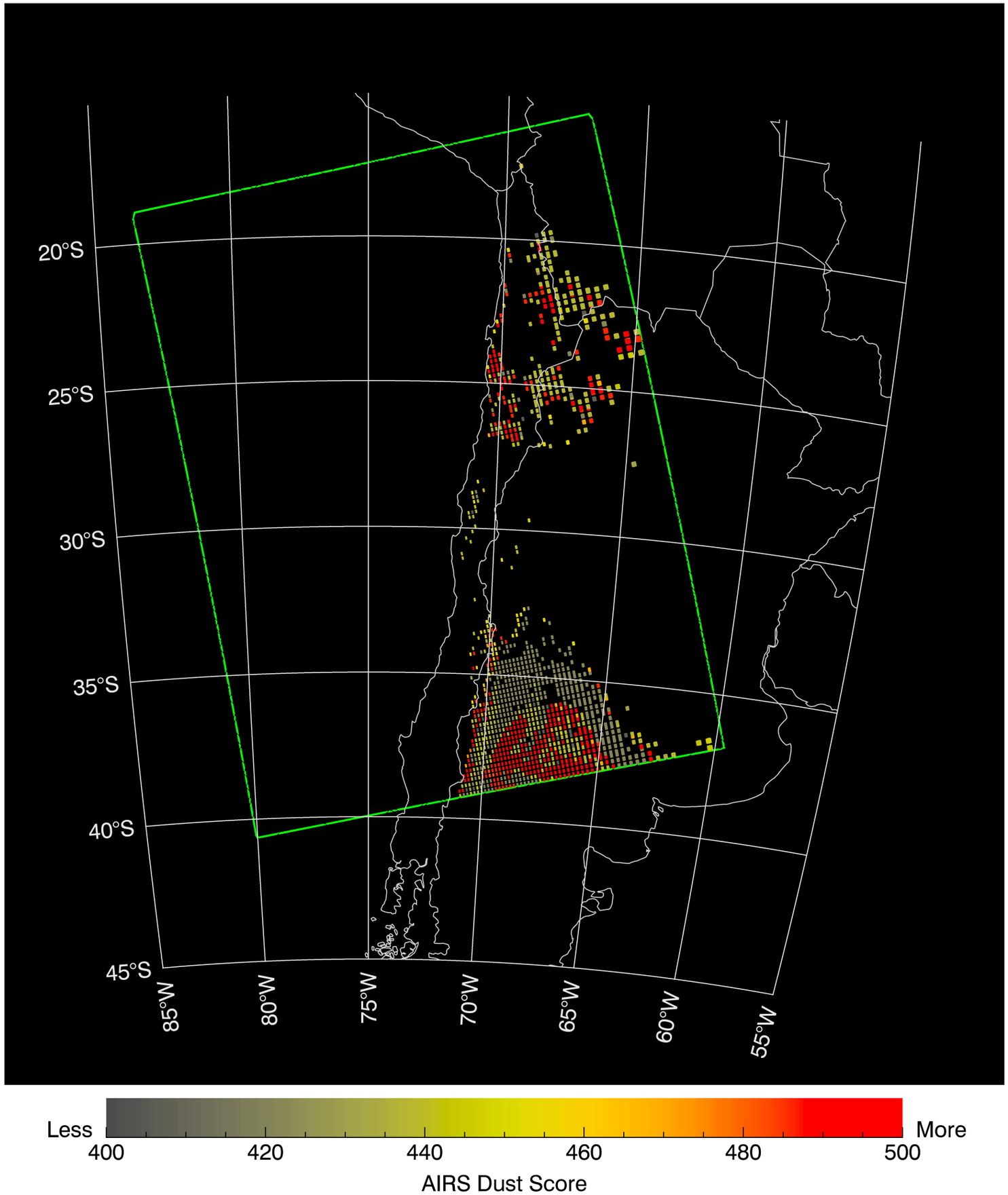
AIRS detection of $SO_2$ 2011.06.06.187




**June 6**

**SO2 BT DIFF**

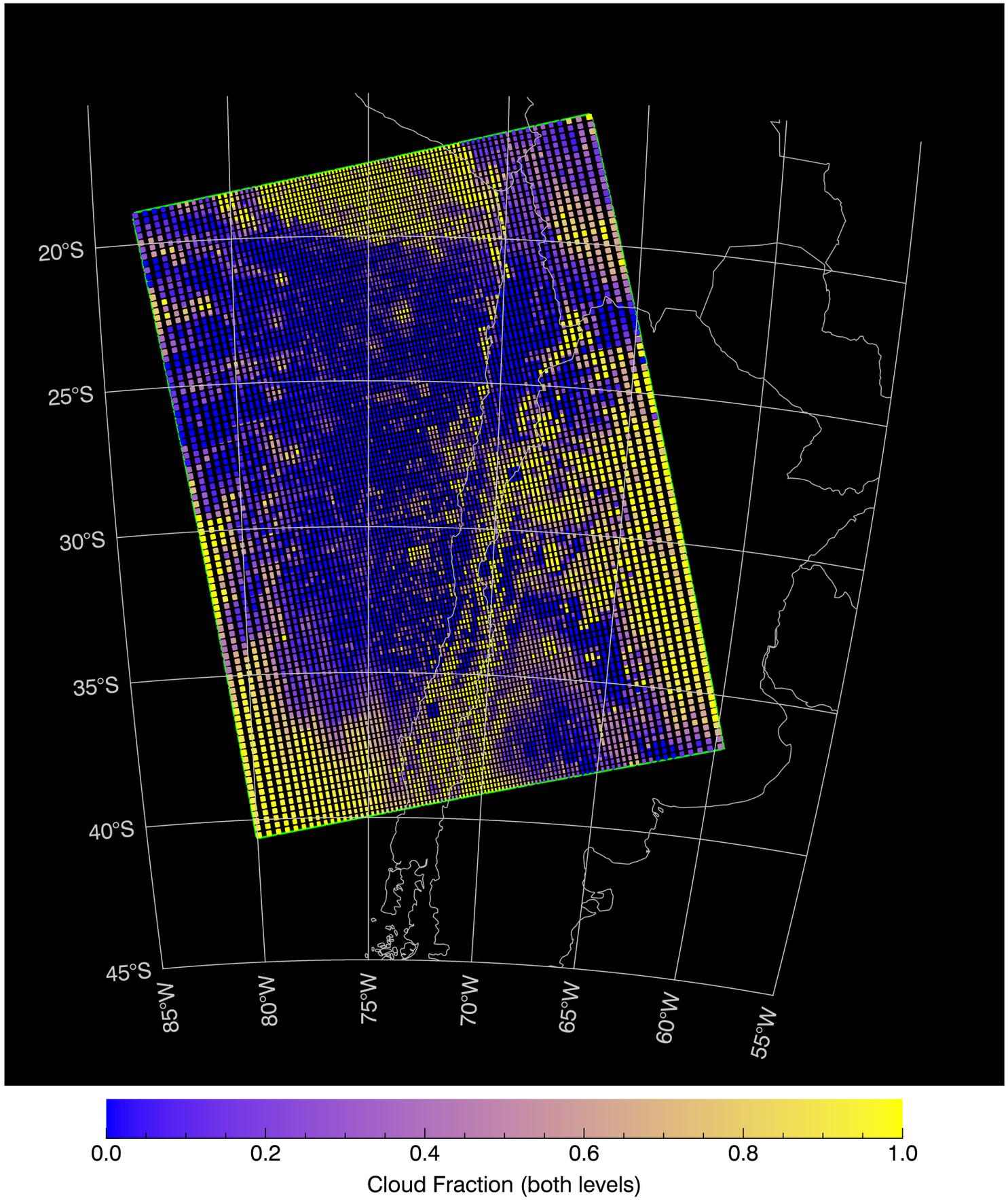
AIRS Detection of Dust 2011.06.06.187




**June 6**

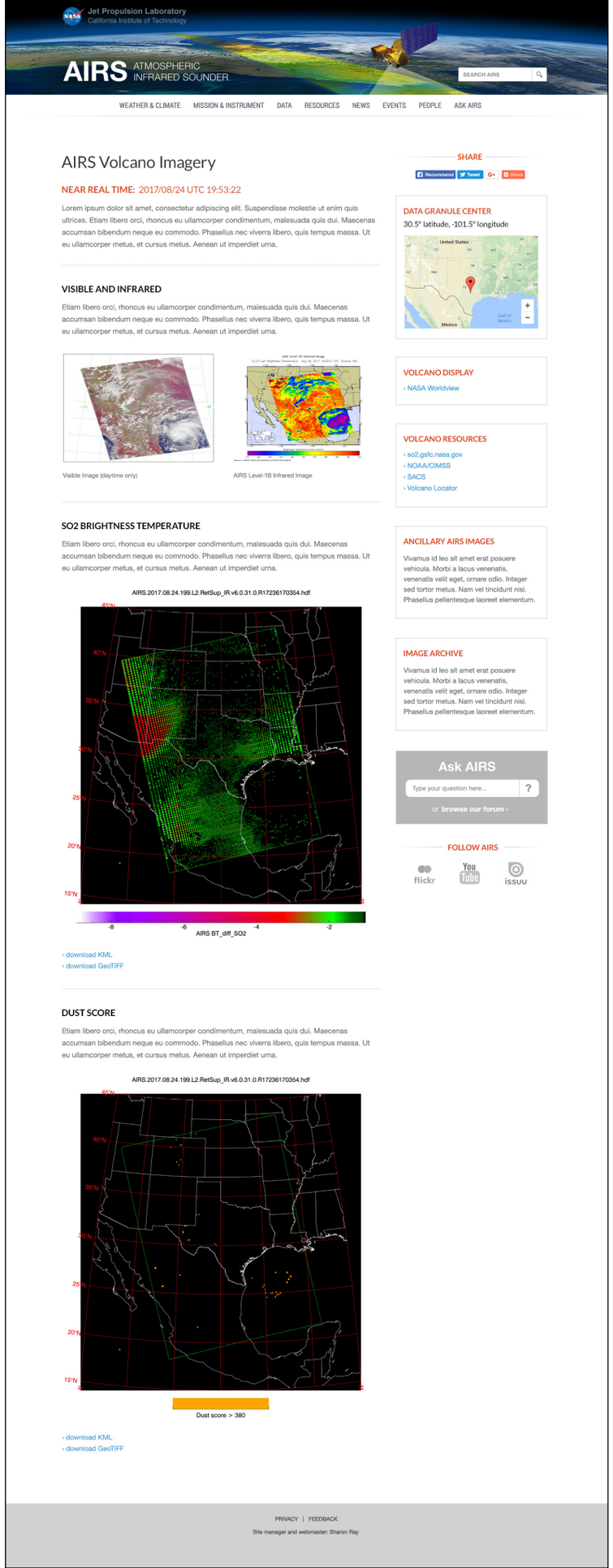
**Dust Score**

AIRS cloud detection 2011.06.06.187




**June 6**

**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) + Volcano Finder

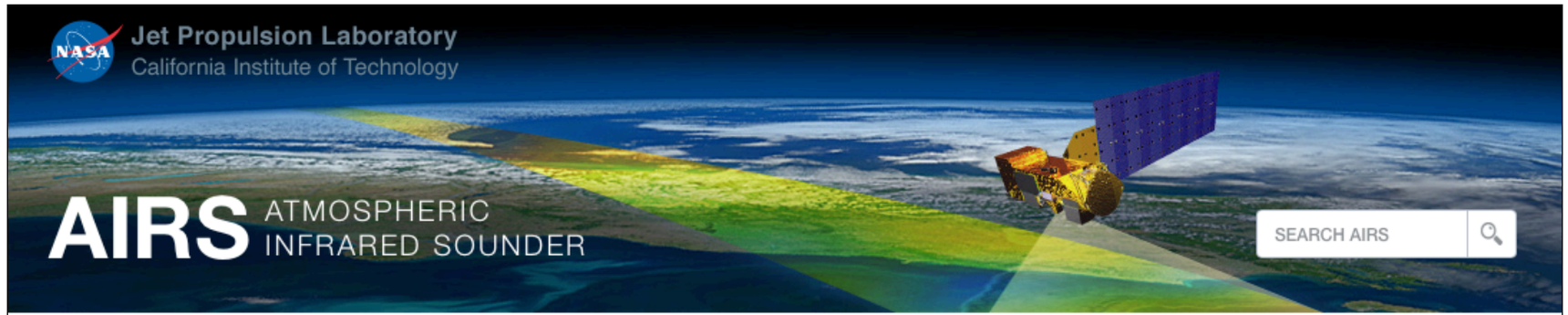
Links to ancillary products: *SO2 Loading, Ash/ Dust Loading, Cloud Product(s), Media Product*

Custom link to NASA Worldview, shows AIRS volcano product layers

Link to AIRS User Guide

Links to other volcano resources

Link to AIRS volcano image archive






## AIRS Volcanic Plume Rapid Response Products

# Image Archive

### 2017/10/15, UTC 19:11:22, 192

-31.5 latitude, -78.0 longitude

### 2017/10/15, UTC 14:29:22, 145

20.5 latitude, -18.5 longitude

### 2017/10/15, UTC 10:05:22, 101

39.5 latitude, -119.5 longitude

### 2017/10/15, UTC 03:47:22, 38

-23.5 latitude, -38.0 longitude

### 2017/10/14, UTC 18:29:22, 185

-27.5 latitude, -69.0 longitude

### 2017/10/08, UTC 09:59:22, 100

38.5 latitude, -118.5 longitude

### 2017/10/06, UTC 12:59:22, 130

30.5 latitude, 2.5 longitude

SHARE

Recommend Tweet G+ Share

Ask AIRS

Type your question here... ?

or browse our faq ›

FOLLOW AIRS

flickr YouTube issuu

# Launching the AIRS Volcano Web Page

Soft launch of the web page

Phase 1: SO2 & Dust Score

Phase 2: SO2, & Ash Loading; Cloud

Solicit reviews from colleagues

SO2.nasa.gov

Earth Observatory

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.**

# Disaster Response - Volcano

**JPL Disaster Response (M. Glasscoe), coordinates with HQ Disasters**
**Disaster Level - Tier 0, Tier 1 etc**
***Agung Volcano currently in play***
**Telecon Participants – JPL, NASA, USGS-AVO (Rick Wessels) - includes INSAR/GPS - ground deformation**

1. **Event status - what's the situation, what are you seeing?**
2. **What products do you have?**
3. **Who are the end users?**
4. **Has anyone asked you for a product?**

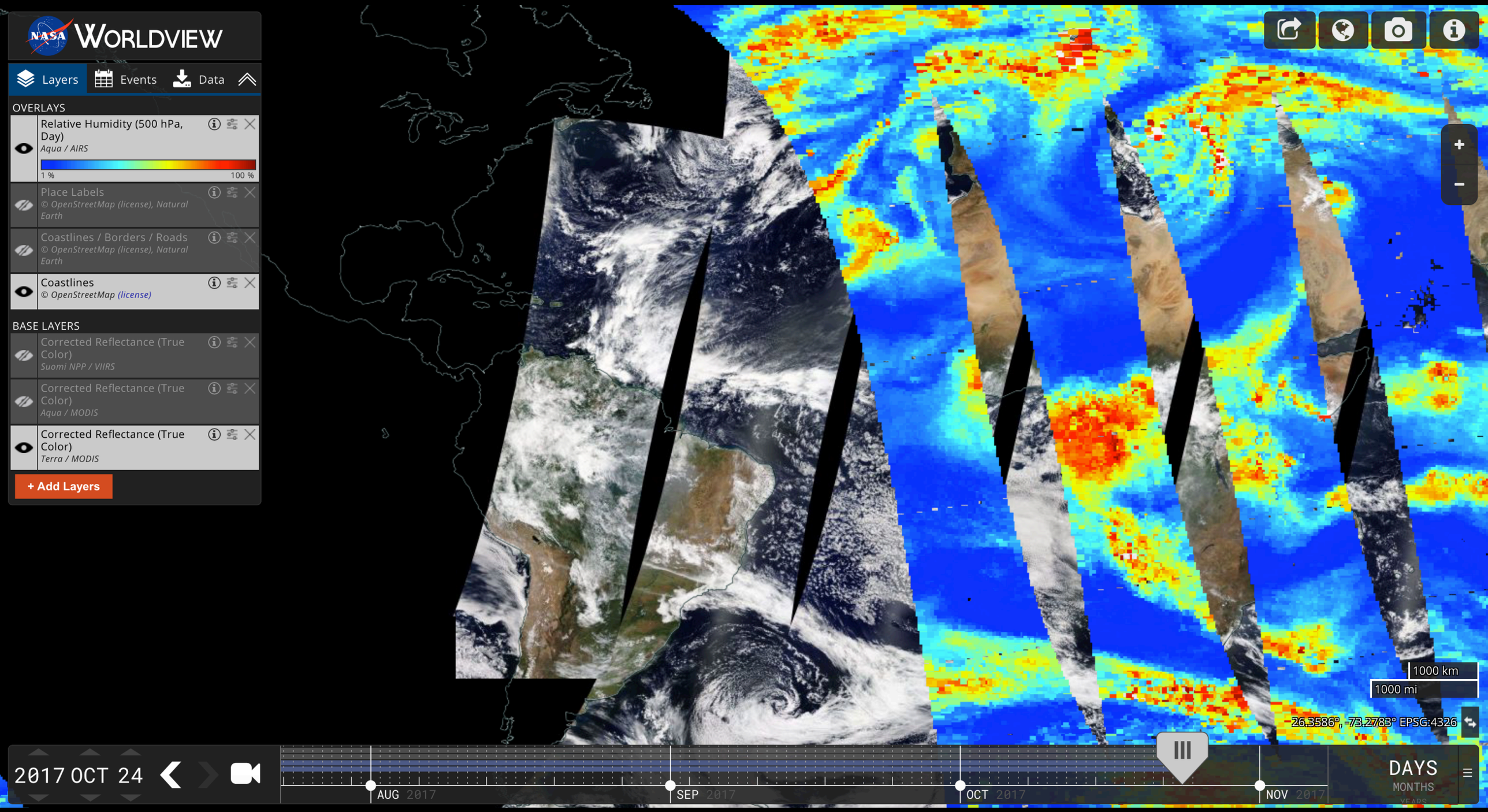
***SO2 products* - USGS says "as long as your NASA products are online we train people how to access them in their country, lots of people use NASA products, …"**

**David S Green**
**Program Manager, Disasters**
**NASA Applied Sciences Program**

***- who are potential Event leads and alternates***
***- who are the key agencies in country***
***- in region***
***- contacts at dos/OES/ dos/ofda***
***- contacts at USGS , vdap …***
***- contacts at UN agencies, WB, Red Cross,***
***- contacts at CEOS, Copernicus***
***- routine product inventory***
***- potential event specific products***

# AIRS L2 Imagery in NASA LANCE NRT, GIBS Archive > NASA Worldview

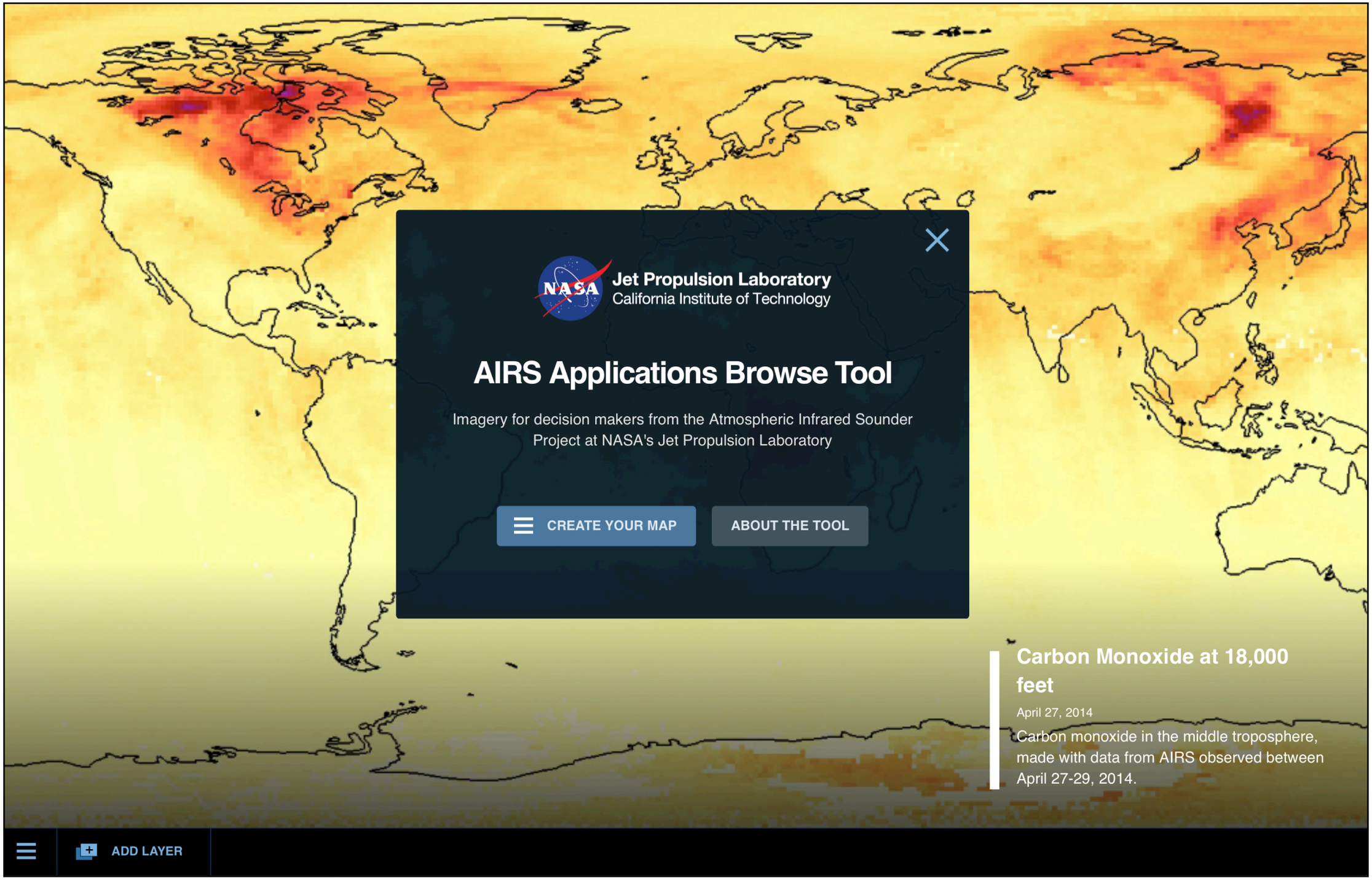
| Currently in LANCE | Modifications | Status |
|---|---|---|
| CO Total Column<br>Dust Score<br>Precip Estimate<br>SO2 Load (Prata algorithm)<br>RH 400, 500, 600, 700, 850 hPa<br>T 400, 500, 600, 700, 850 hPa | NEW Surface Air Temp<br>NEW Surface Skin Temp<br>NEW Surface Relative Humidity<br>NEW Carbon Monoxide 500 hPa<br>NEW Methane 400 hPa<br>.....<br>REVISED COLORBAR Temperature 500<br>REVISED COLORBAR Temperature 700<br>REVISED COLORBAR Temperature 850<br>.....<br>REVISED COLORBAR Relative Humidity 500<br>REVISED COLORBAR Relative Humidity 700<br>REVISED COLORBAR Relative Humidity 850<br>.....<br>REMOVE Relative Humidity 400, 600<br>REMOVE Temperature 400, 600<br>REMOVE Carbon Monoxide total column<br>.....<br>NO CHANGE Prata SO2 Loading<br>.....<br>COMING SOON – REVISED COLORBAR for Precip Estimate<br>COMING SOON – REVISED COLORBAR for Dust Score<br>COMING SOON – NEW SO2 BT DIFF<br>COMING SOON – NEW SO2 Load<br>COMING SOON – NEW Ash + Dust Load<br>COMING SOON – NEW Cloud Fraction + SO2 (TBD)<br>COMING SOON – NEW Add Absolute Humidity<br>COMING SOON – NEW H20MMR Total Column<br>COMING SOON – NEW H20MMR 500<br>COMING SOON – NEW H20MMR 700<br>COMING SOON – NEW H20MMR 850 | • New AIRS visualization algorithm delivery *in progress* (LANCE NRT first, then likely Non-NRT DAAC)<br>• Colorbar delivered to GIBS for most of the new and revised images<br>• Visualization specs determined for most products<br>• LANCE updates will occur shortly |


WORLDVIEW
Layers
Events
Data
OVERLAYS
Relative Humidity (500 hPa, Day)
Aqua / AIRS
1 %
100 %
Place Labels
© OpenStreetMap (license), Natural Earth
Coastlines / Borders / Roads
© OpenStreetMap (license), Natural Earth
Coastlines
© OpenStreetMap (license)
BASE LAYERS
Corrected Reflectance (True Color)
Suomi NPP / VIIRS
Corrected Reflectance (True Color)
Aqua / MODIS
Corrected Reflectance (True Color)
Terra / MODIS
+ Add Layers
1000 km
1000 mi
26.3586°, -73.2783° EPSG:4326
2017 OCT 24
AUG 2017
SEP 2017
OCT 2017
NOV 2017
DAYS
MONTHS

# AIRS Browse Tool – waiting in the wings

## Showcase AIRS Imagery, can include other missions

## Can show internal only imagery in development



# New Visualization in progress – *GRAVITY WAVES*

***Paper – "Multisensor profiling of a concentric gravity wave event propagating from the troposphere to the ionosphere"***

*Irfan Azeem (ASTRA LLC), Jia Yue (Hampton Univ), Lars Hoffmann (Julich), Steven D. Miller (CIRA), William C. Straka III (CIMSS), Geoff Crowley (ASTRA LLC)*

- GWs are an important driver of the upper atmospheric circulation
- Near-simultaneous obs of GW event in stratosphere, mesosphere, and ionosphere over south central United States, tracked from convective source in troposphere to the ionosphere where it appears as a traveling ionospheric disturbance (TID)
- AIRS, Suomi NPP/VIIRS, and GPS TEC data
- Multi-sensor obs of TIDs and GWs can provide a unique perspective on ionosphere-atmosphere coupling

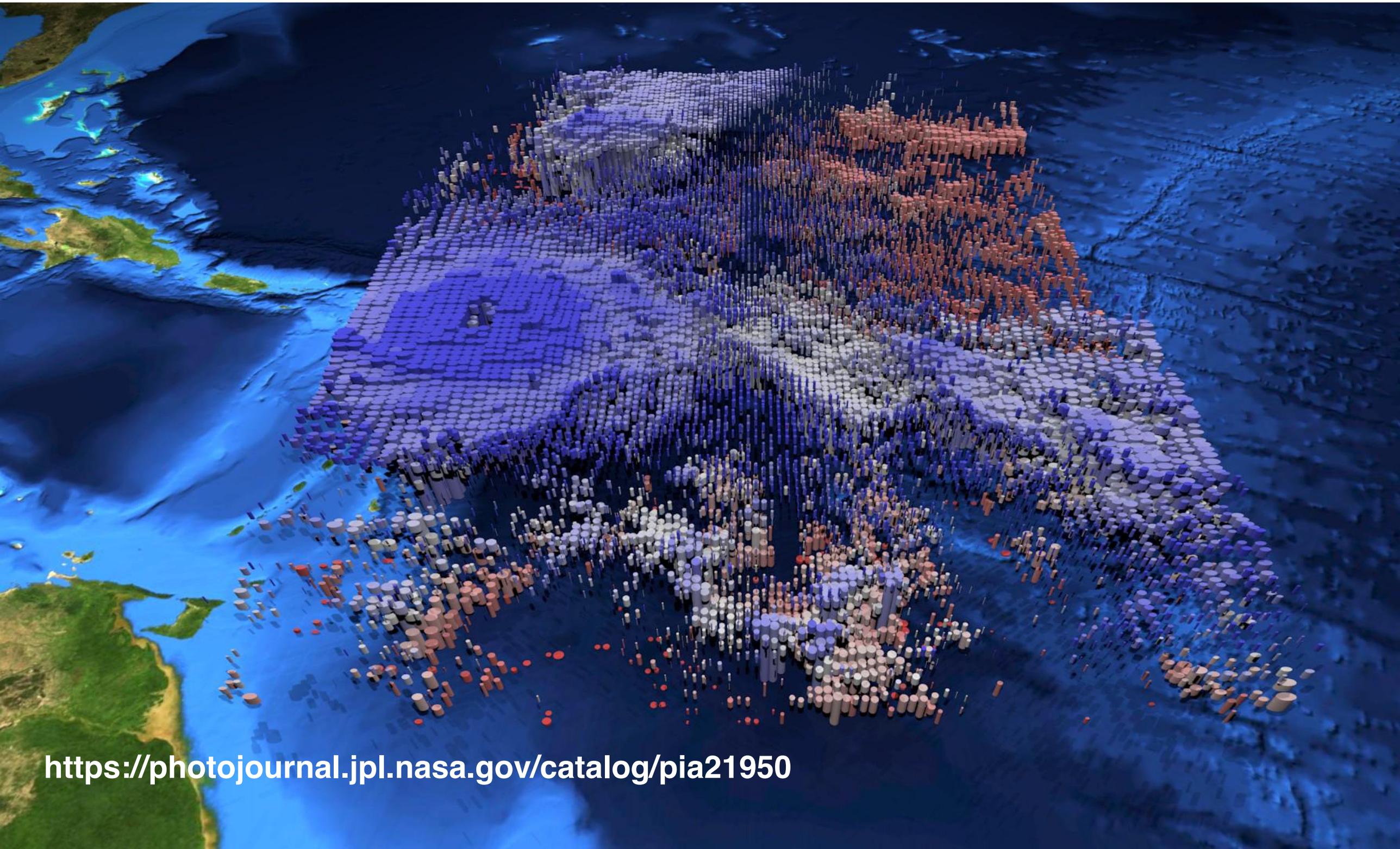
- AIRS gravity wave visualization in progress @ Goddard SVS
- Lori Perkins (SVS) working with Yue, Azeem
- Focus areas:
  - Tornado – Moore, Oklahoma in May 2013
  - SpaceX launch – Jan 17, 2016
- Possible debut at AGU

# 3D AIRS Visualization

## *Hurricane Irma, 9/5/17*

Evan Manning, JPL

- **Cylinders** = volume of cloud detected by AIRS
- **Oval cylinder size** = proportion of clouds filling view area
- **Largest ovals** about 30 miles (45 kilometers) across
- **Height of cylinders** = cloud thickness (thickest clouds reach surface)
- **Colors** = cloud top temperatures
- 15x vertical exaggeration

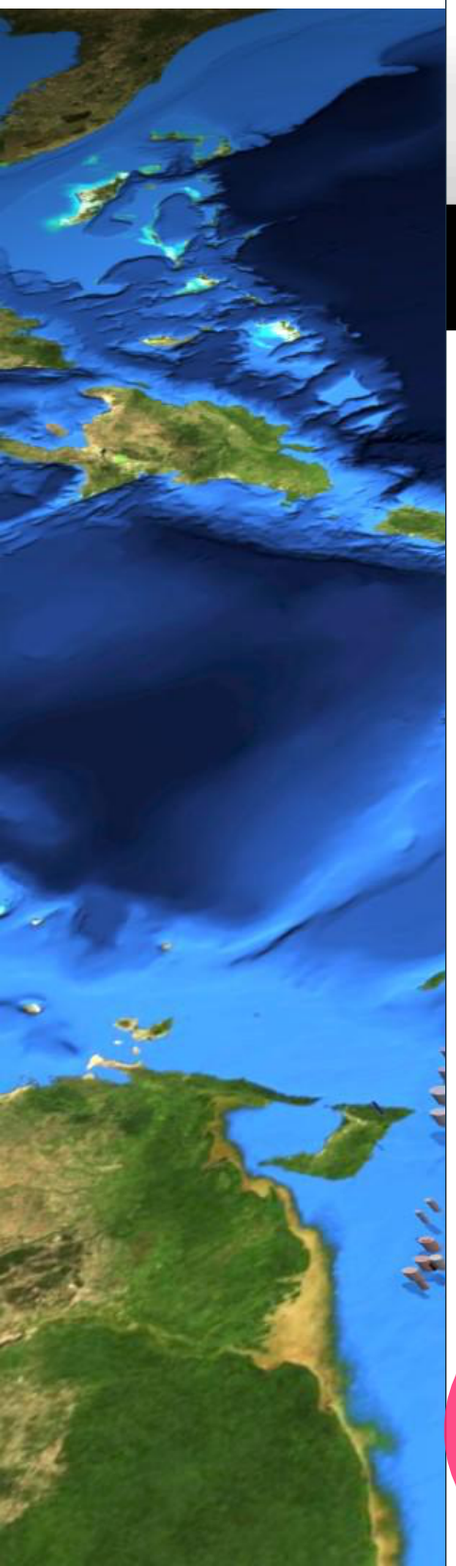


# 3D AIRS Visualization

## *Hurricane Irma, 9/5/17*

Evan Manning, JPL

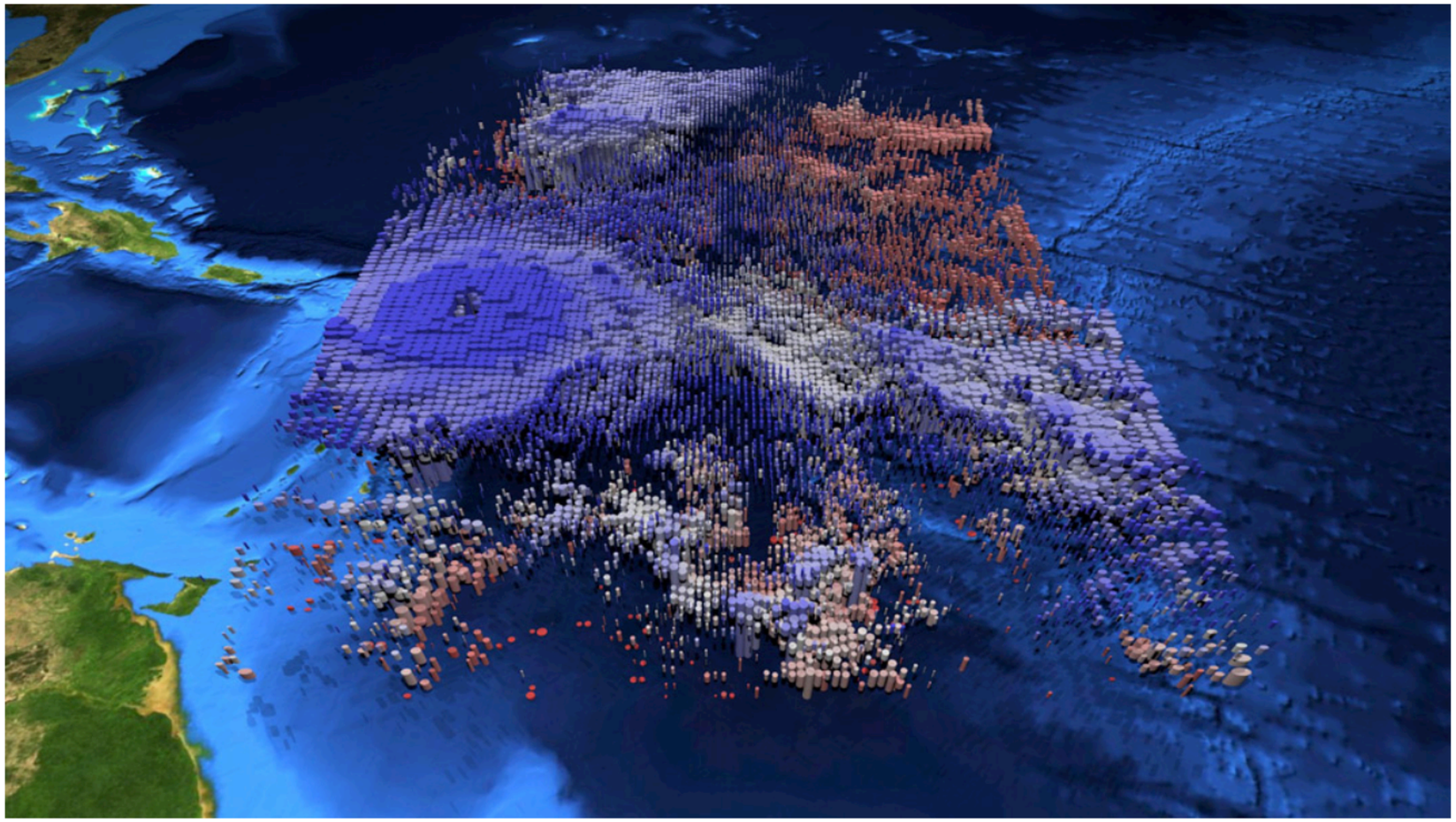
- **Cylinders** = volume of cloud detected by AIRS
- **Oval cylinder size** = proportion of clouds filling view area
- **Largest ovals** about 30 miles (45 kilometers) across
- **Height of cylinders** = cloud thickness (thickest clouds reach surface)
- **Colors** = cloud top temperatures
- 15x vertical exaggeration



SPACE IMAGES

Enter search text | Search | Advanced Search | Browse by C

72 images found

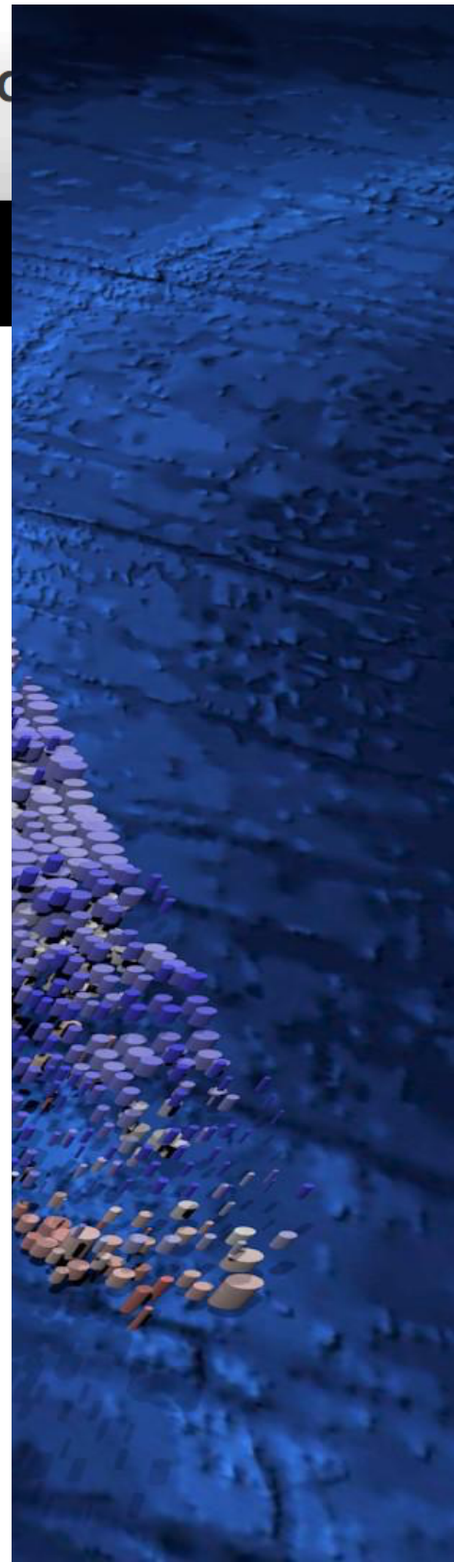


Add to album: | About this image: DETAILS | Download: | Share image:

Hurricane Irma's Cloud Structure as Seen by NASA's AIRS

Views: 917

The large-scale structure of clouds in and around Hurricane Irma is seen in this image created with data AIRS instrument on NASA's Aqua satellite. The clouds are typical of tropical areas both nearby and away from tropical



# Possibly explore more 3D with AIRS

- **Hurricane 3D visualization shows cloud top temperature, but could show cloud thermodynamic phase, cloud particle size, etc**

*B. Kahn – "Sometimes the visualization...resonates not only for its scientific merit but for other, more nebulous reasons...the most well-liked comment on the NASA main page complimented NASA's innovative approaches at visualization."*

# Looking ahead...

## Application focus areas

Drought
Influenza / Dengue / Zika (Health)
Volcano (Aviation, Disaster)
Wildfire (Fire Weather, Air Quality)
Temperature Inversion (Air Quality)
Carbon Monoxide (Air Quality)
Ammonia (Air Quality)
Cold Air Aloft (Aviation)
Deep Convective Clouds (Aviation)
NUCAPS / AWIPS

## Imagery

LANCE/GIBS/Worldview
Anomaly products for GIBS/Worldview
CrIS/IASI image products
3D visualization development
SVS Visualization
GIS

## Web Site / User Guides

Upgrade to better serve community, attract new users
New pages: Applications, CO2, Calibration, Science Overview, FAQ, more
Webify User Guides