

Nadir and limb UV-visible satellite observations of volcanic clouds

**Simon Carn¹, Matt DeLand², Nick Gorkavyi²,
Eric Hughes³ and Nick Krotkov⁴**

- 1. Michigan Technological University, Houghton, MI*
- 2. Science Systems and Applications, Inc., Lanham, MD 20706, USA*
- 3. University of Maryland, College Park, MD, USA*
- 4. Code 614, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA*

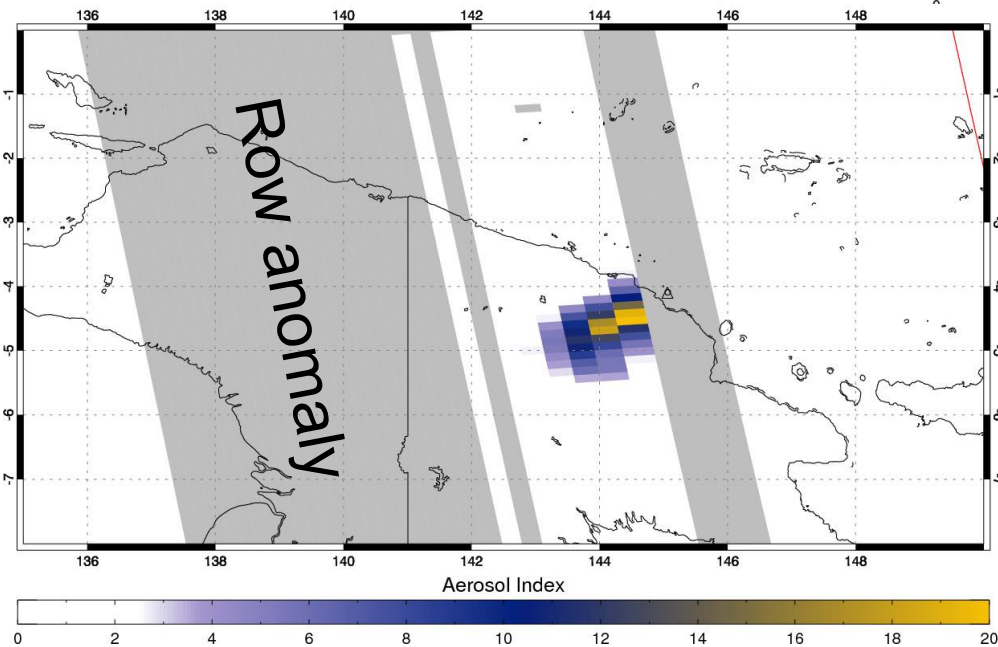
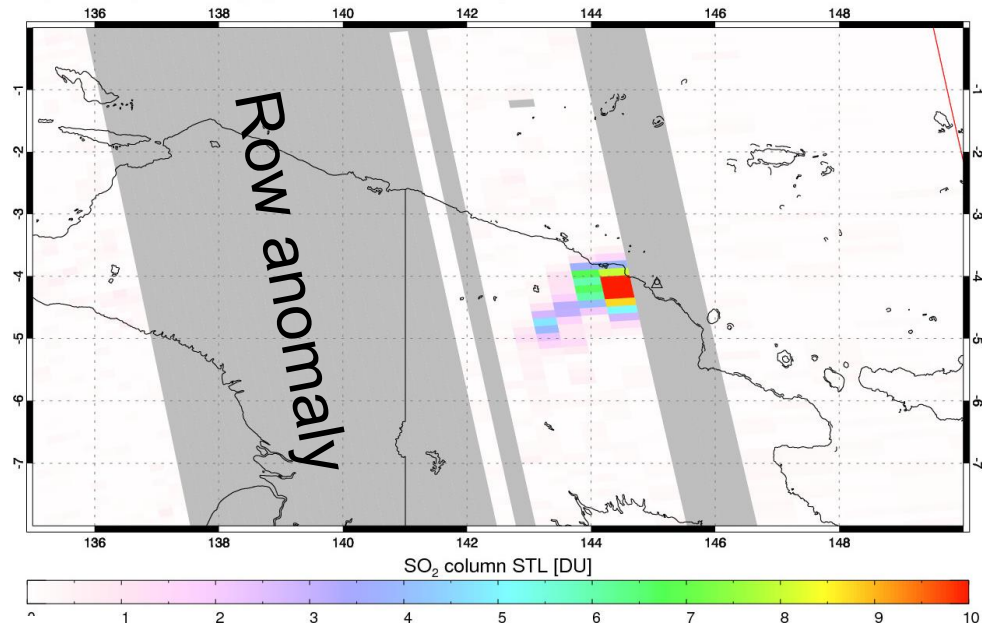
UV satellite instruments currently in orbit

Instrument	Satellite(s)	Overpass	Nadir footprint area (km²)	Data coverage
<i>Polar orbiters (LEO)</i>				
Ozone Monitoring Instrument (OMI)	Aura	1:45 pm	312 (13 × 24)	Sep 2004 - present
Global Ozone Monitoring Experiment-2 (GOME-2)	MetOp-A/B	9:30 am	3200 (40x80)	Oct 2006 - present
Ozone Mapper and Profiler Suite (OMPS)	Suomi NPP	1:30 pm	Standard: 2500 (50 × 50) Zoom: 100 (10 × 10)	Apr 2012 - present
<i>L₁ Lagrange Point</i>				
Earth Polychromatic Imaging Camera (EPIC)	DSCOVR	Full disk every ~90 mins	576 (24 × 24)	From late 2015

(Geostationary UV sensors planned for later this decade)

Current OMI measurements

- OMI measurements of Manam (PNG) eruption on July 31, 2015
- OMI spatial coverage since 2008 affected by row anomaly data gap – global coverage achieved every 2 days
- Good data in useable parts of swath

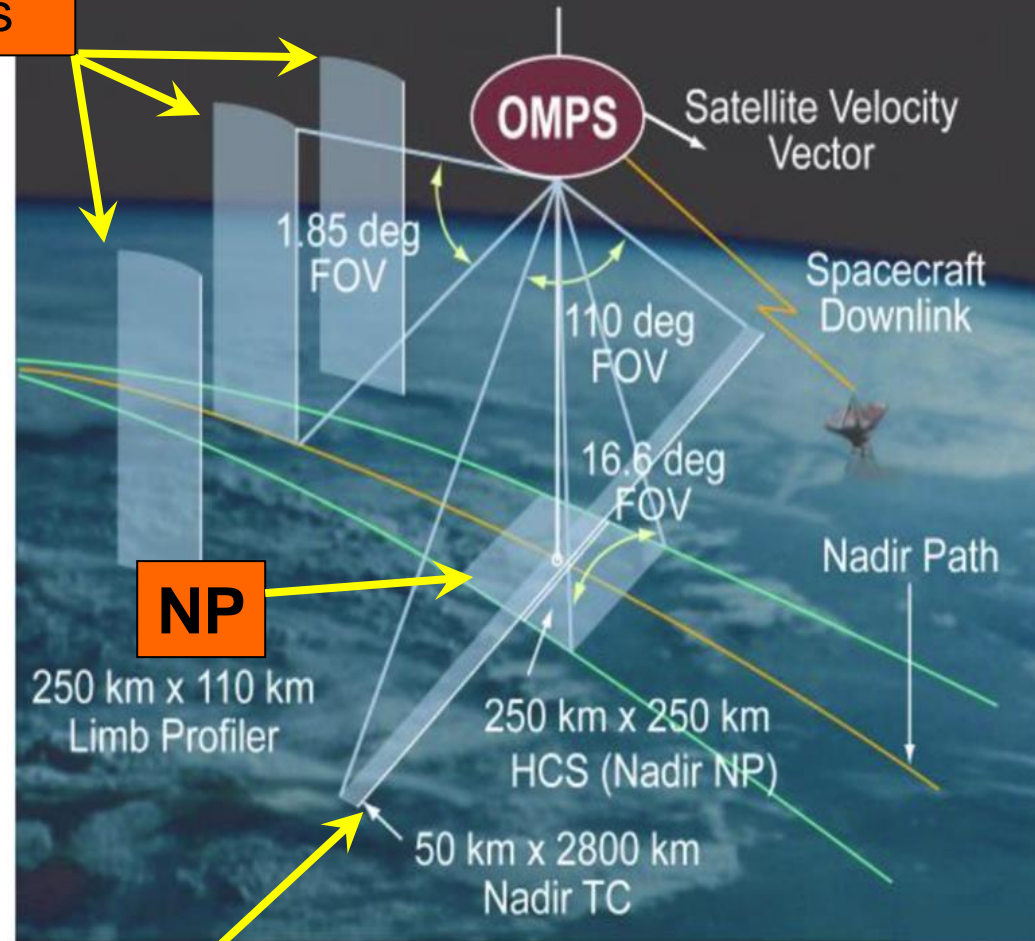


- UV satellite products:
- SO₂ column amount
 - Sensitive to tropospheric and stratospheric SO₂
- UV Aerosol Index (UVAI)
 - Semi-quantitative indication of ash presence
 - Sensitive to any UV-absorbing aerosol (ash, smoke, dust)

Suomi-NPP/OMPS Sensors

Limb Profiler (LP): Aerosol and Ozone profiles

- 3 OMPS instruments
 - Nadir Mapper (NM; \approx OMI)
 - Nadir Profiler (NP)
 - Limb Profiler (LP)
- 13:30 LT ascending node
- OMPS LP:
 - Looks aft, following nadir view by ~ 7 minutes
 - 3 vertical slits with 250 km spacing
 - Spectral range: 290-1000 nm
 - ~ 2 km vertical resolution; surface to ~ 105 km altitude



NP

OMPS-NM spatial zoom mode: 10x10 km

Nadir Mapper (NM):
swath similar to OMI

Launched October 2011

Aura (2004-)

OMI - SO₂, NO₂, BrO
TES - SO₂
MLS - strat. SO₂, HCl

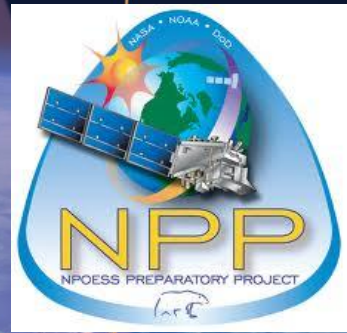
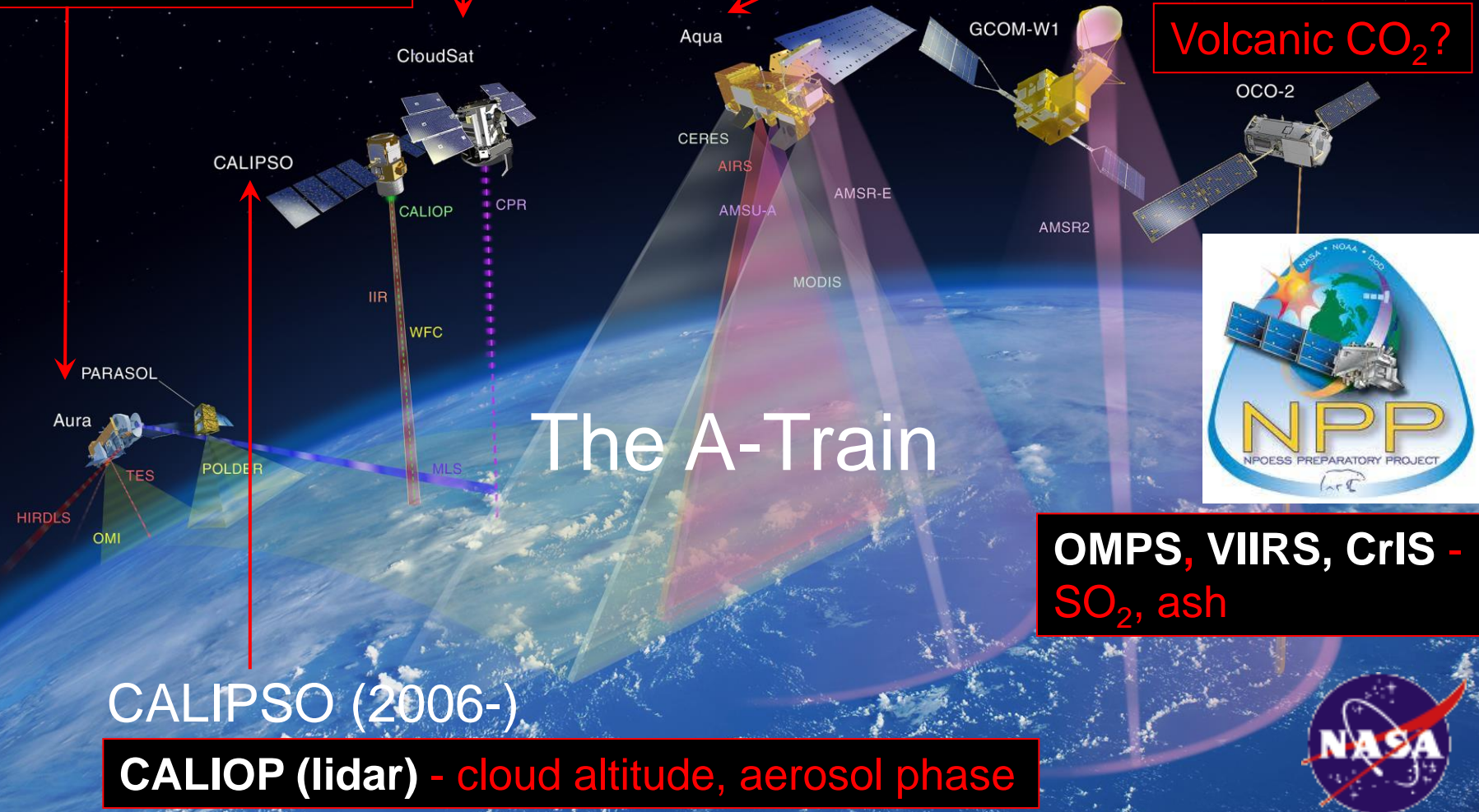
CloudSat (2006-)

CPR (radar) –
precipitation,
hydrometeors

Aqua (2002-)

MODIS - SO₂, ash, sulfate
AIRS - UTLS SO₂, ash

Volcanic CO₂?



CALIPSO (2006-)

CALIOP (lidar) - cloud altitude, aerosol phase

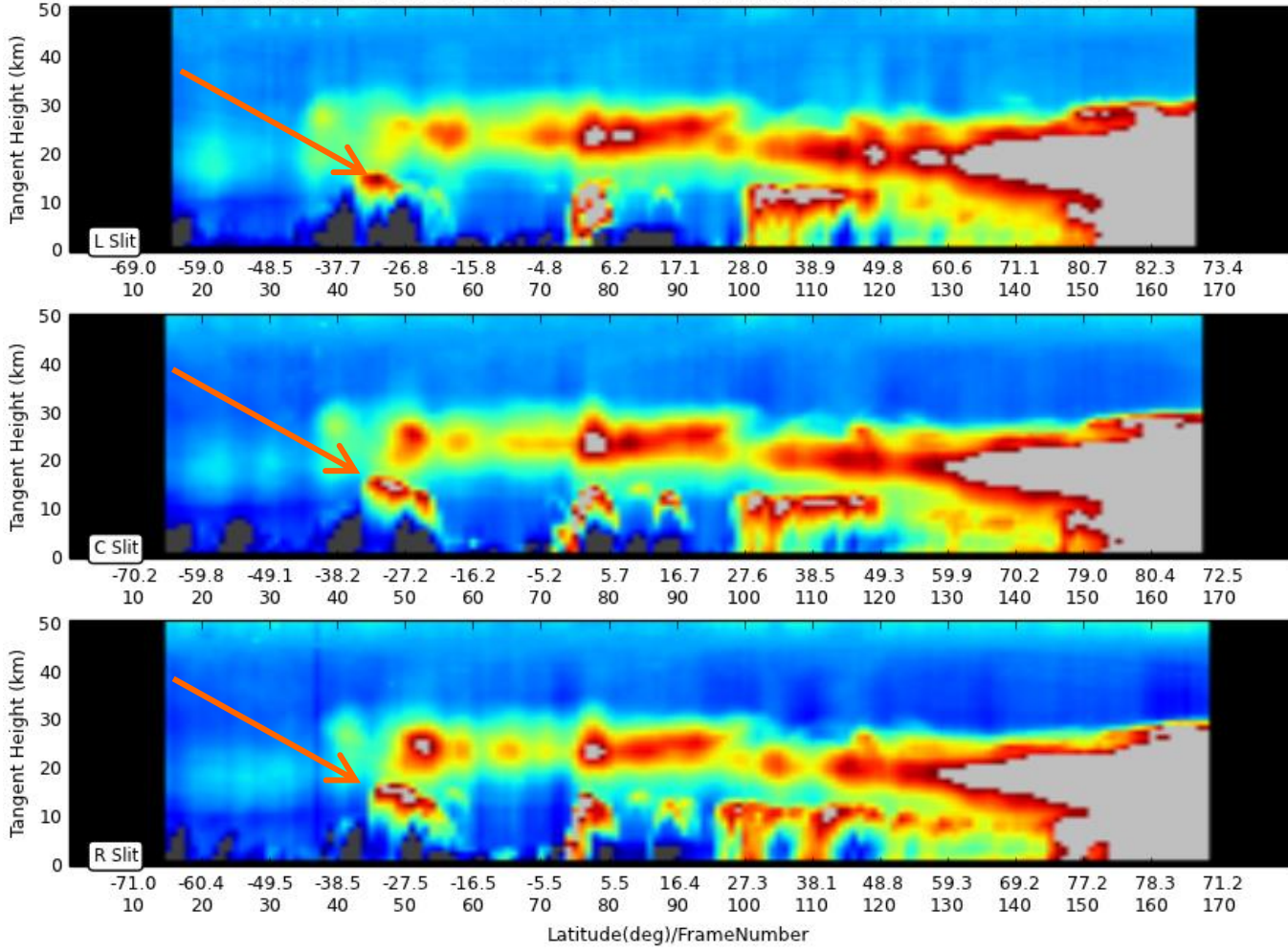
OMPS, VIIRS, CrIS -
SO₂, ash



OMPS-LP Aerosol Scattering Index (ASI)

Calbuco (Chile) plume on April 26, 2013

ASI at 674nm (unitless) for Orbit 18107 (STB version 0.8)
 StartTime: Sun 2015-04-26T14:42 EndTime: Sun 2015-04-26T16:24



Aerosol Scattering Index (ASI)

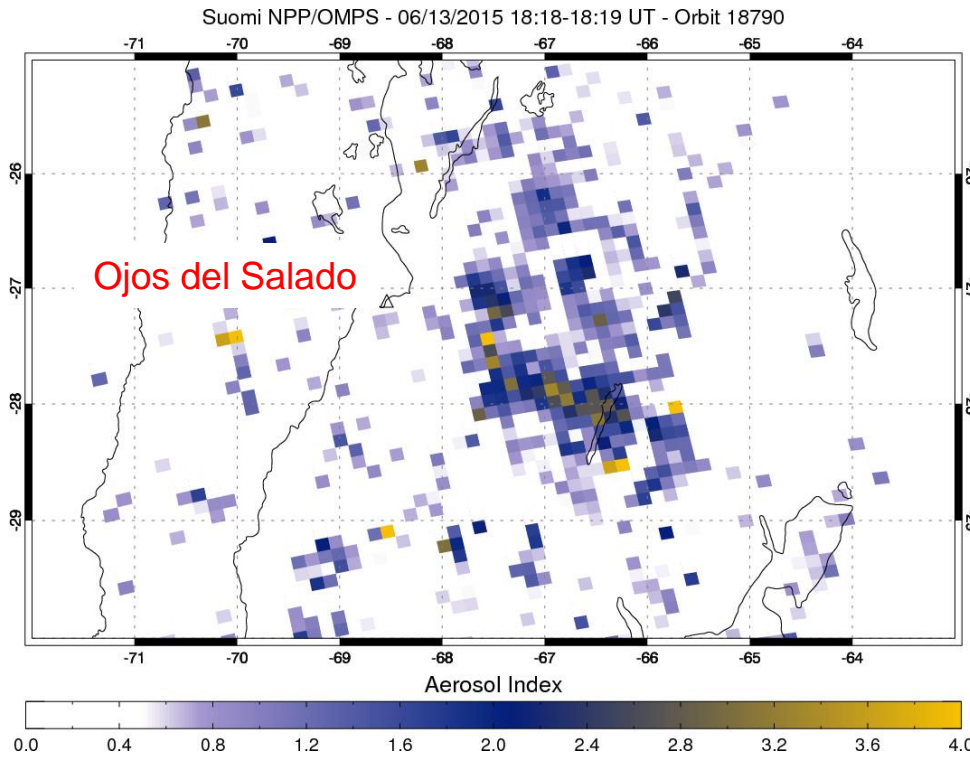
$$ASI = \ln \left(\frac{I_0}{I_R} \right)$$

I_0 = observed radiance
 I_R = modeled Rayleigh radiance

ASI is not a retrieval,
 but a semi-quantitative
 Indication of
 aerosol/cloud presence

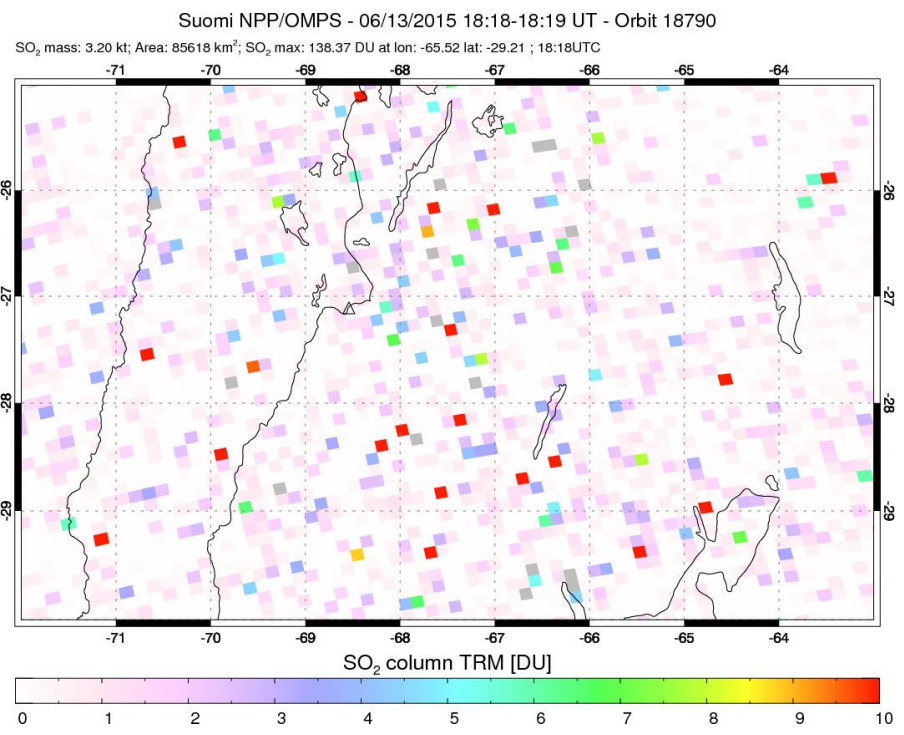
Scattering angle
 effects important

OMPS (zoom): Ojos del Salado 'plume' – June 13, 2015



- OMPS-NM zoom mode observations of Ojos del Salado 'plume' on June 13, 2015
- No global OMPS-LP data during OMPS-NM zoom mode operation (bandwidth)

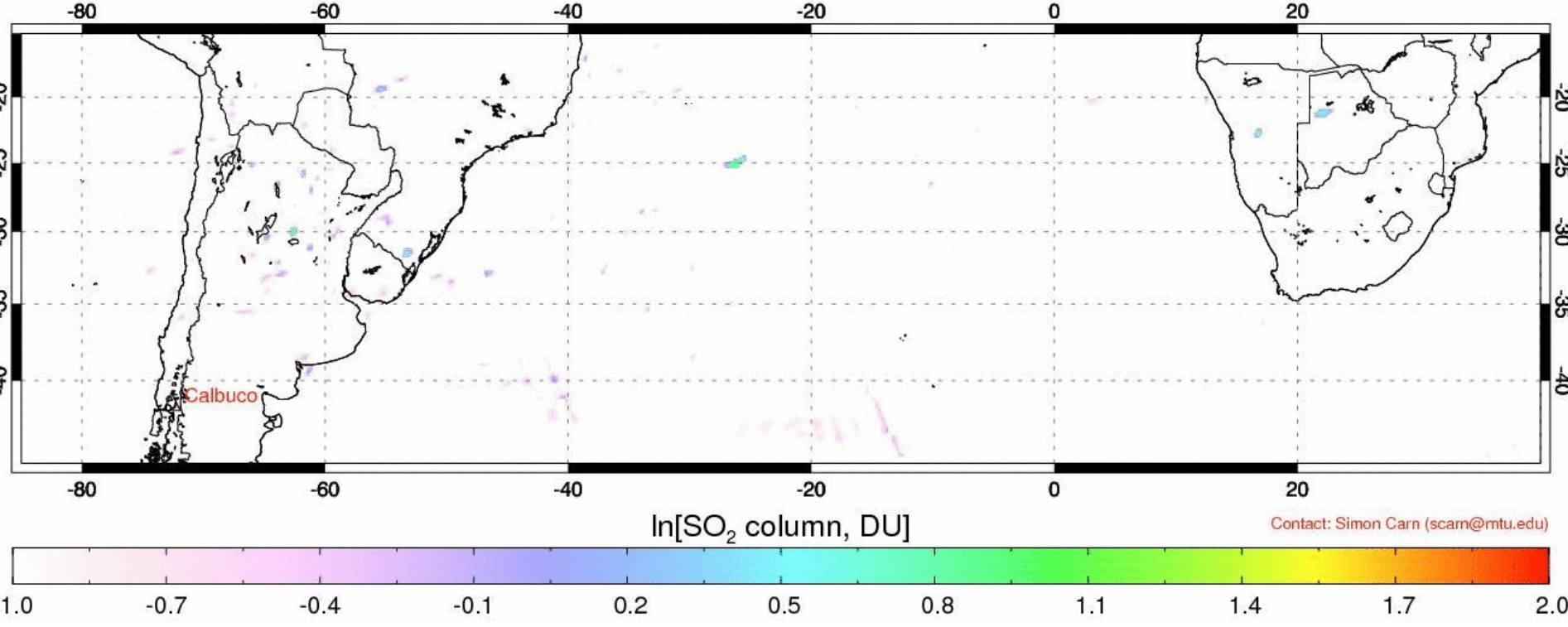
- Clear OMPS UVAI signal
- No coincident OMI UVAI anomaly (spatial resolution effect?)
- No OMPS or OMI SO₂ signal
- Volcanic eruption source unlikely



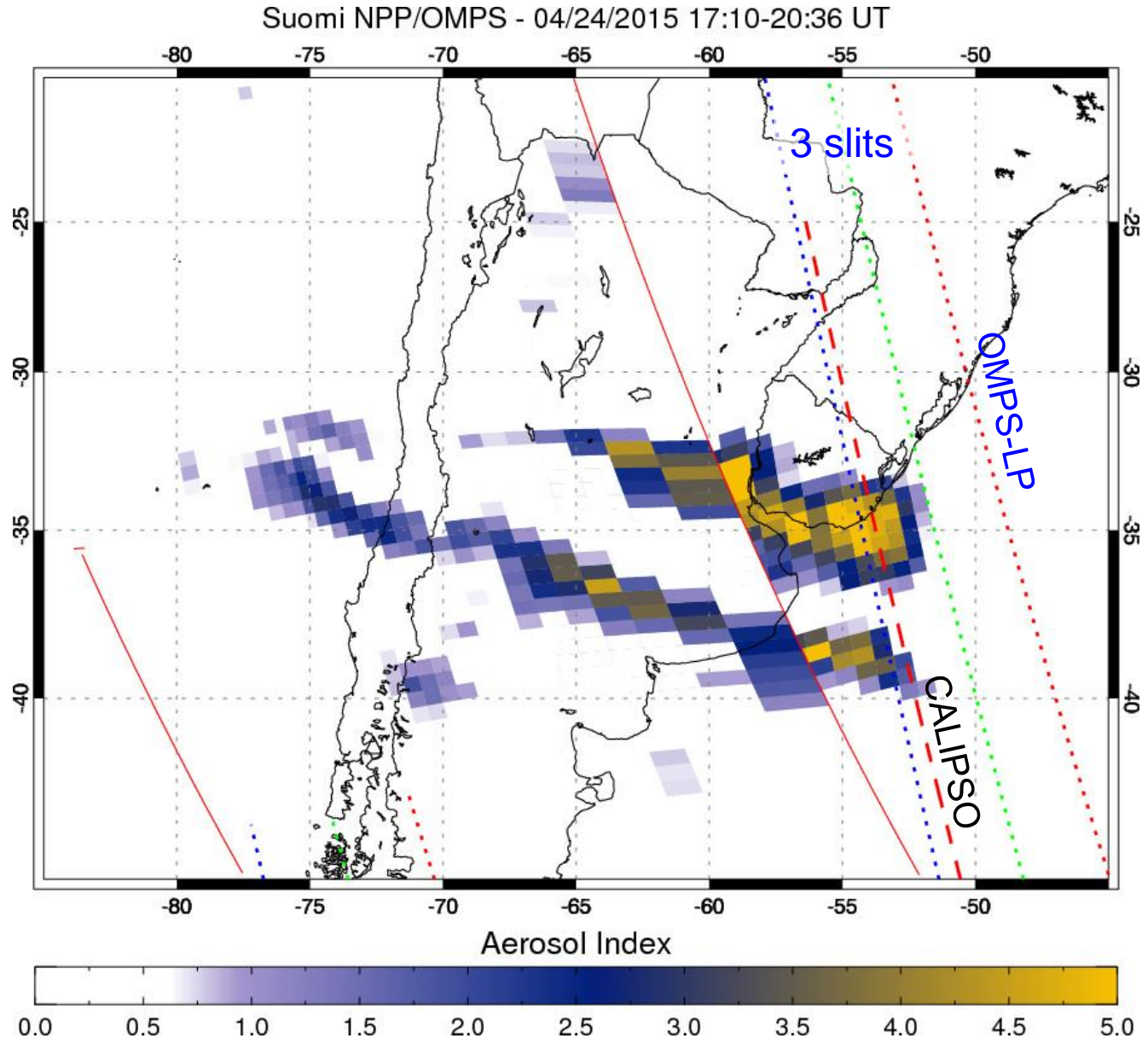
OMPS-NM SO₂ – Calbuco (Chile), Apr 22 – May 20, 2015

Suomi NPP/OMPS - 04/22/2015 11:03-19:38 UT

SO₂ mass: 0.482 kt; Area: 27770 km²; SO₂ max: 3.68 DU at lon: -26.24 lat: -25.10 ; 16:12UTC



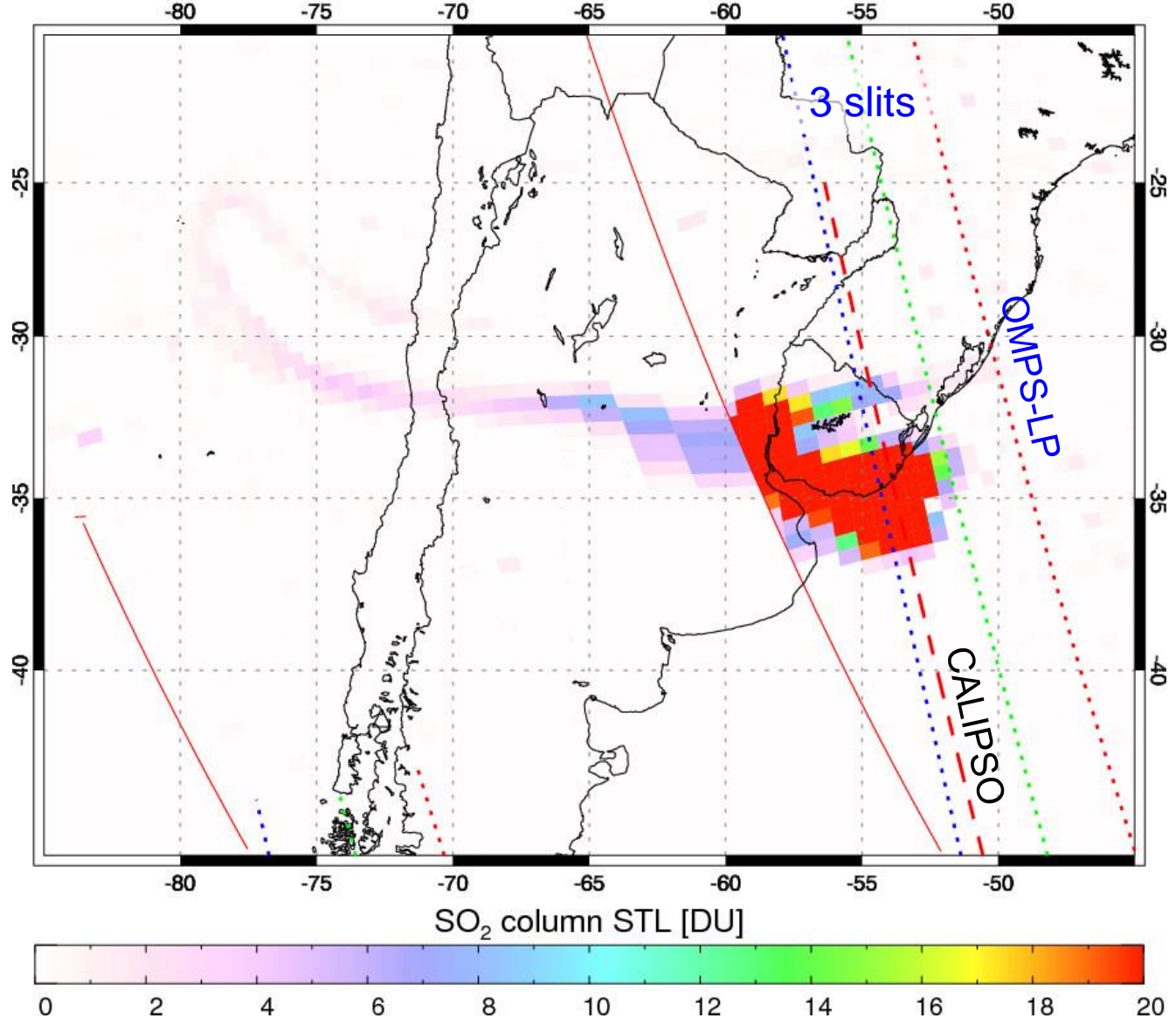
OMPS-NM UVAI – Calbuco (Chile), April 24, 2015



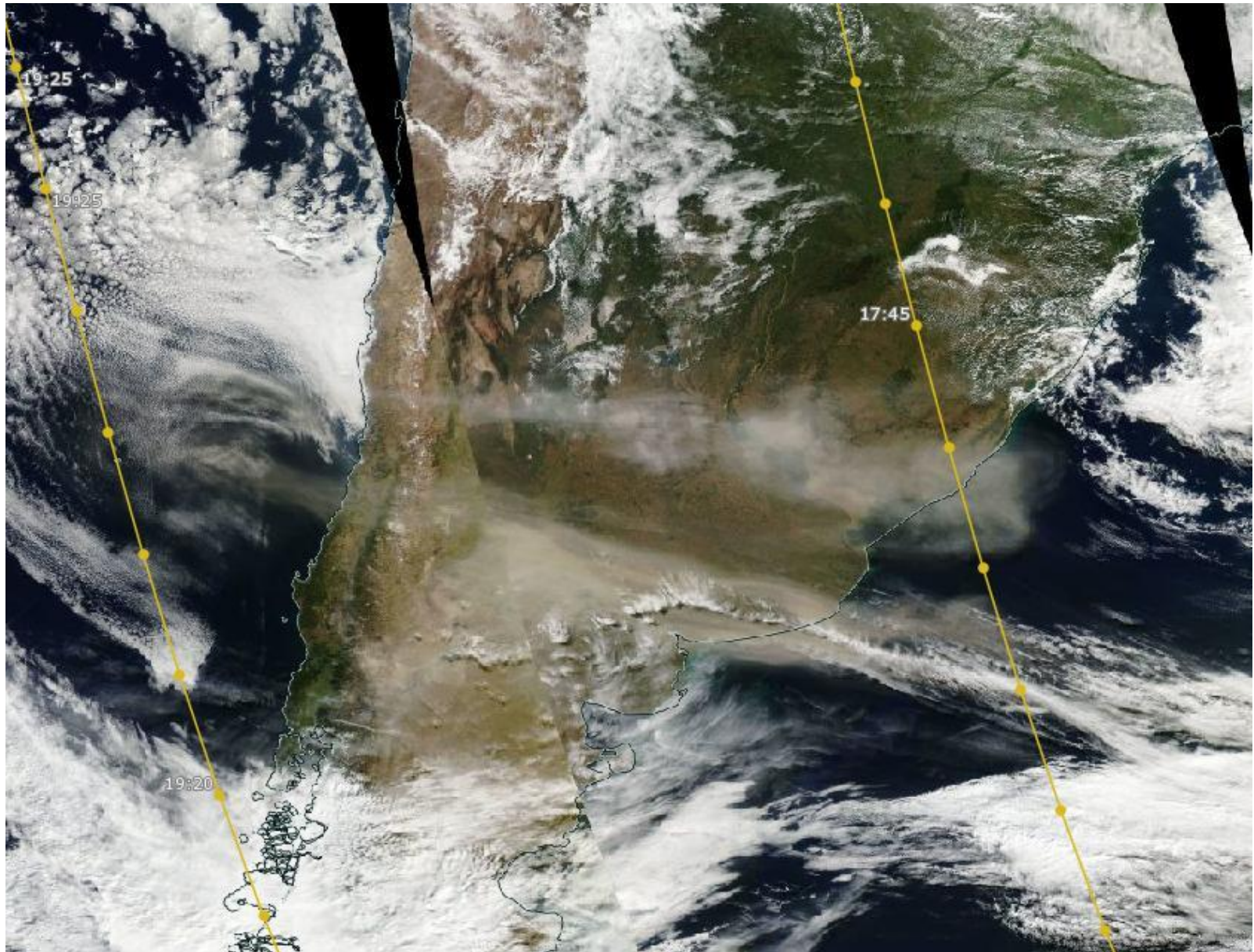
OMPS-NM SO₂ – Calbuco (Chile), April 24, 2015

Suomi NPP/OMPS - 04/24/2015 17:10-20:36 UT

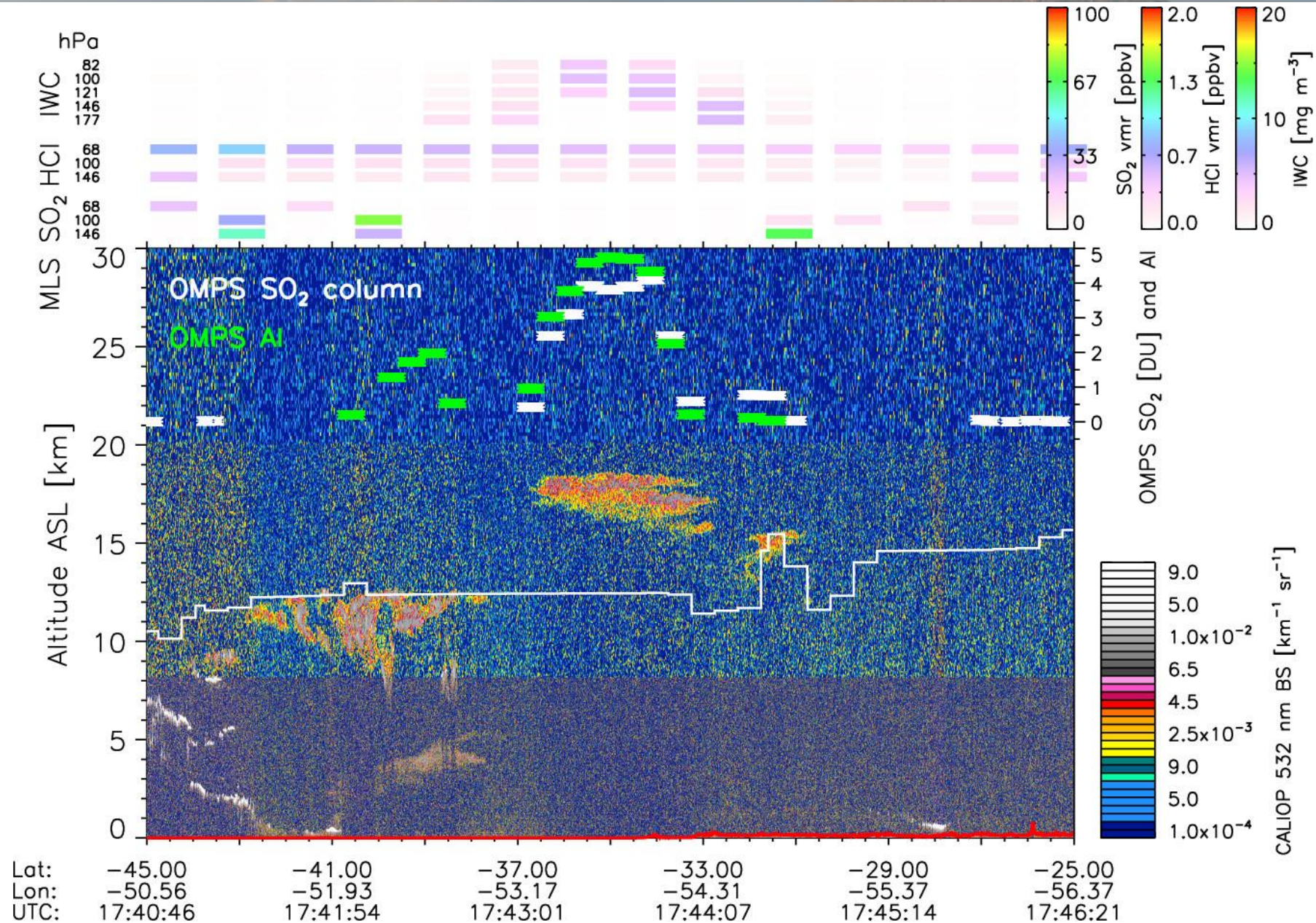
SO₂ mass: 279.64 kt; Area: 1856179 km²; SO₂ max: 50.35 DU at lon: -59.97 lat: -33.25 ; 17:14UTC



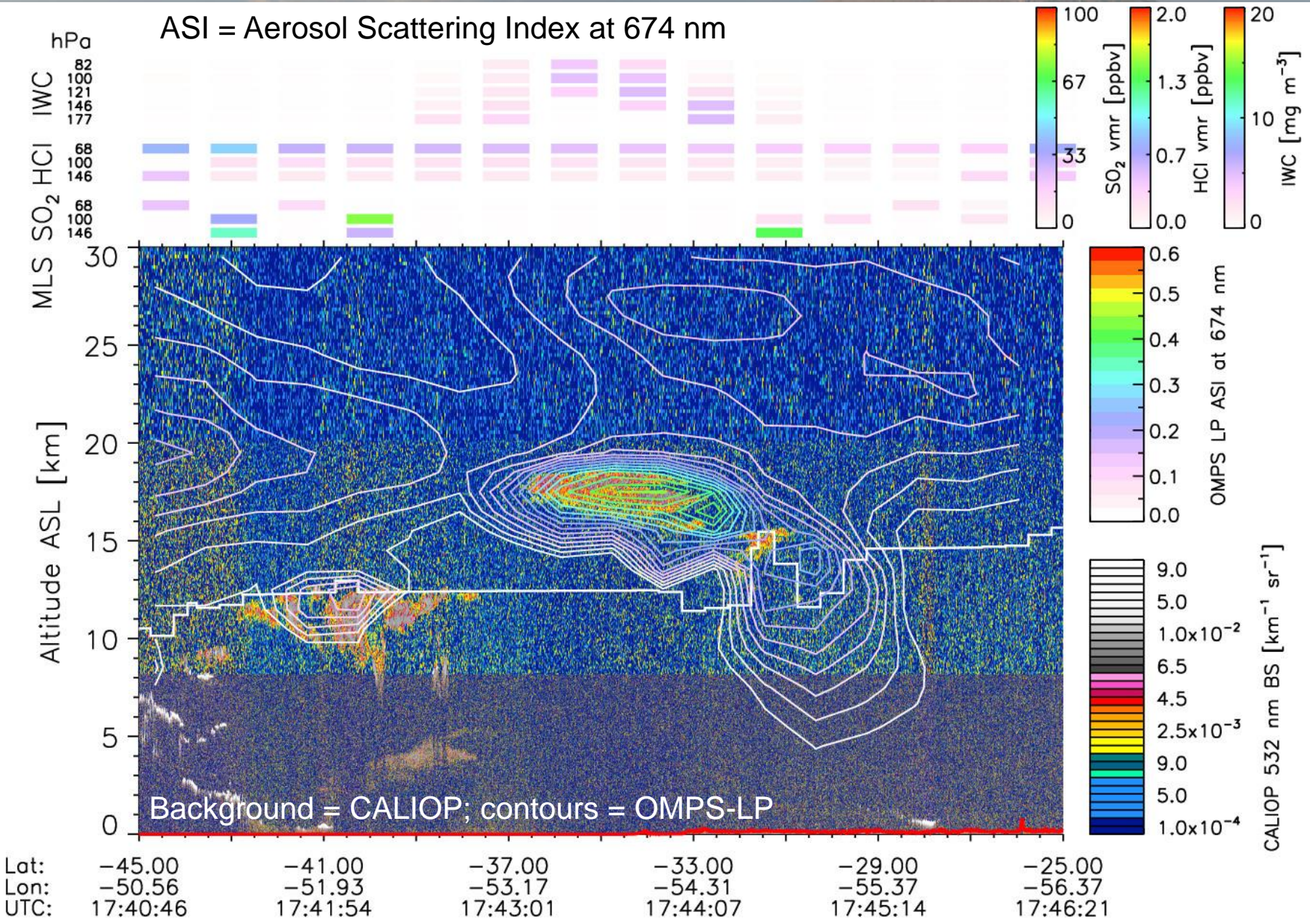
Aqua/MODIS showing Calbuco ash – April 24, 2015



CALIPSO + OMPS-NM – Calbuco (Chile), April 24, 2015



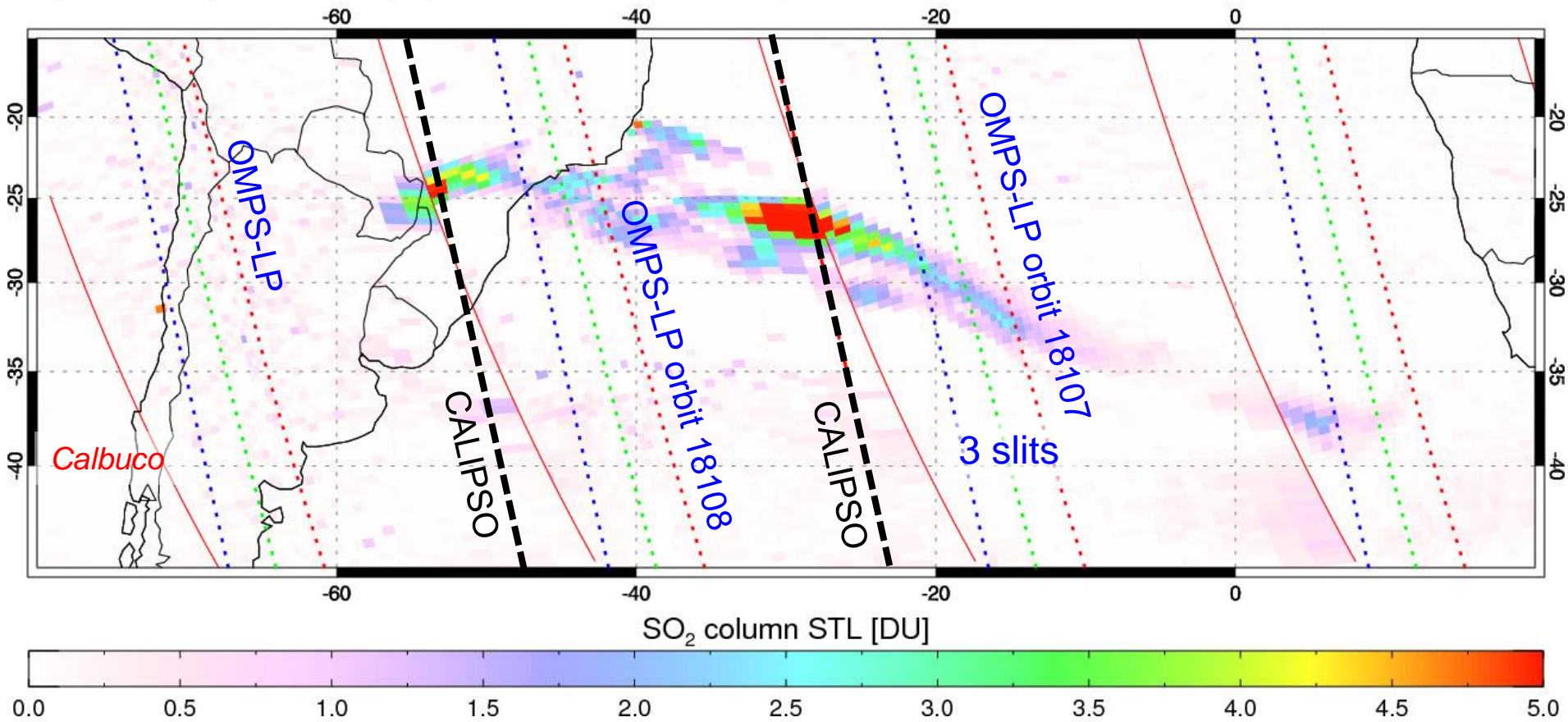
CALIPSO + OMPS-LP – Calbuco (Chile), April 24, 2015



OMPS-NM SO₂ – Calbuco (Chile), April 26, 2015

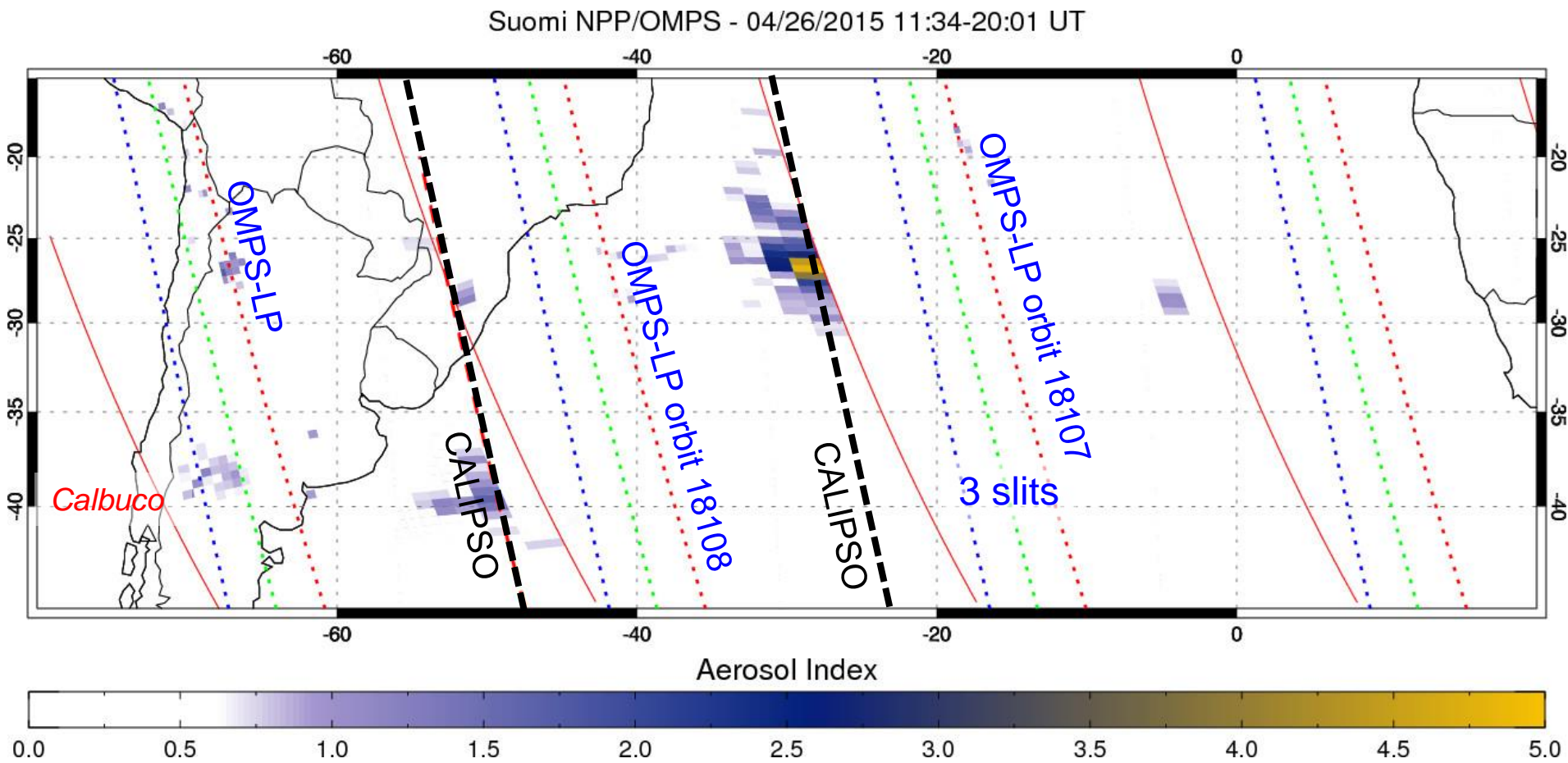
Suomi NPP/OMPS - 04/26/2015 11:34-20:01 UT

SO₂ mass: 127.70 kt; Area: 5666621 km²; SO₂ max: 8.67 DU at lon: -28.69 lat: -26.81 ; 16:37UTC



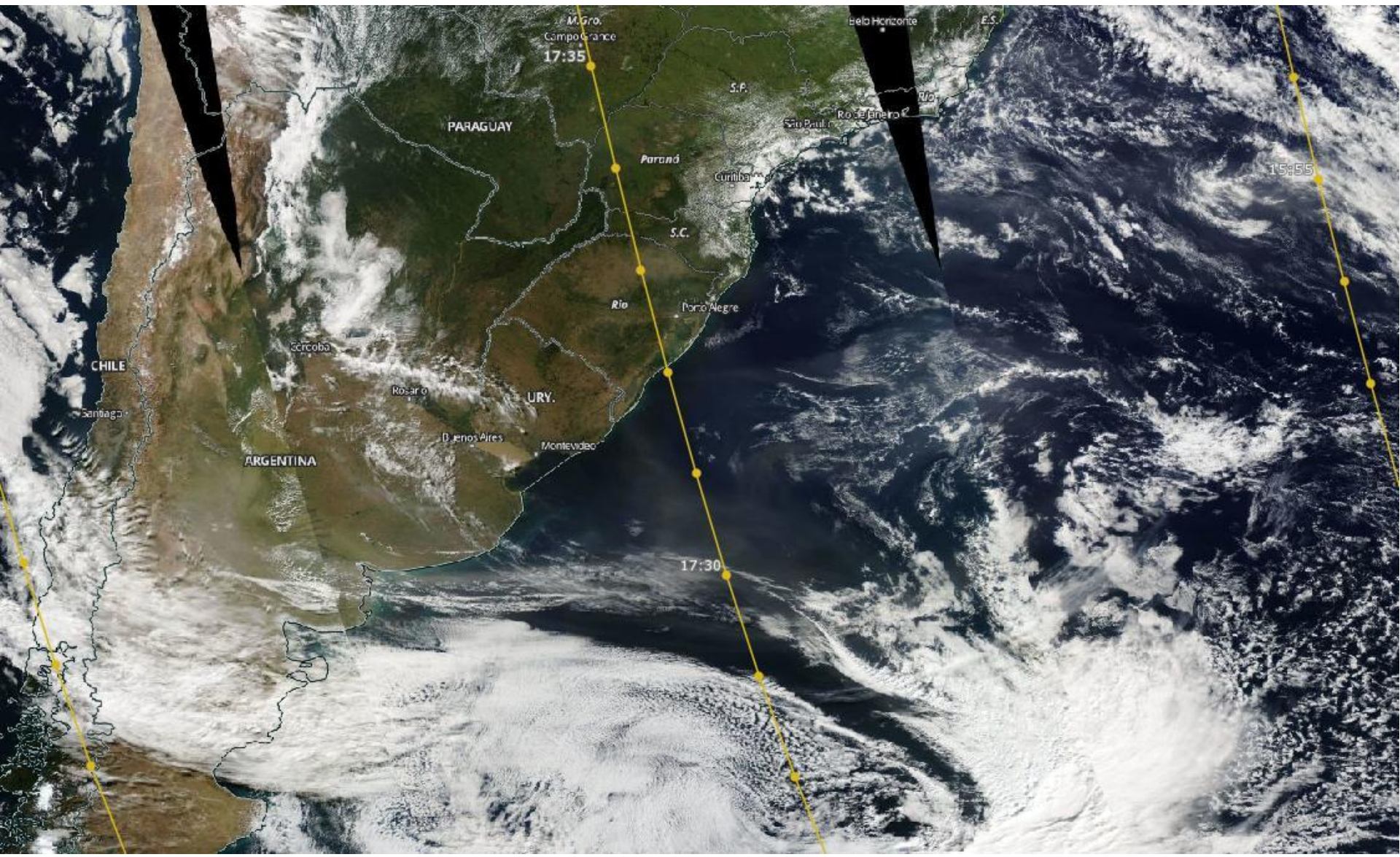
OMPS-LP slits and CALIPSO tracks

OMPS-NM UVAI – Calbuco (Chile), April 26, 2015

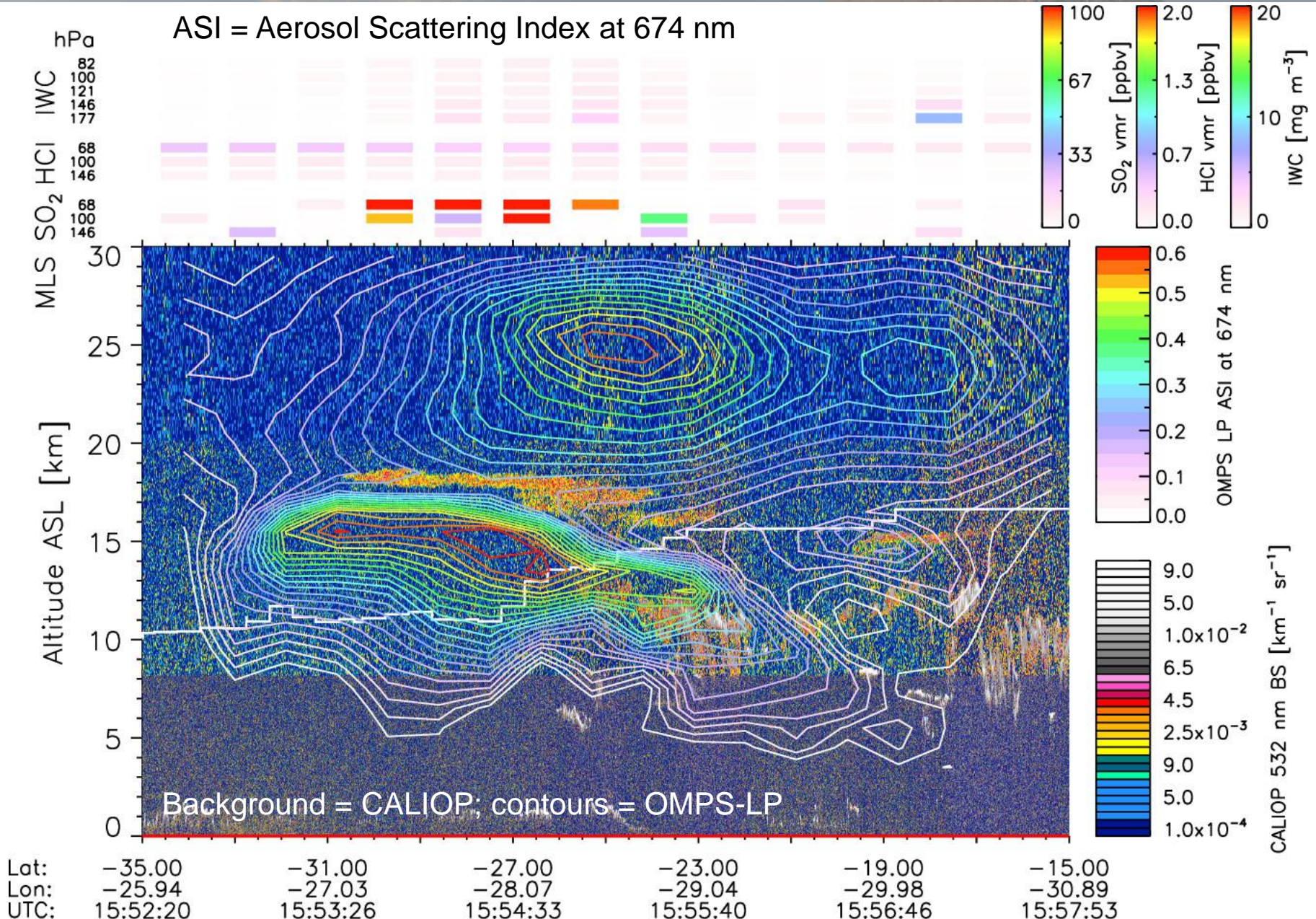


OMPS-LP slits and CALIPSO tracks

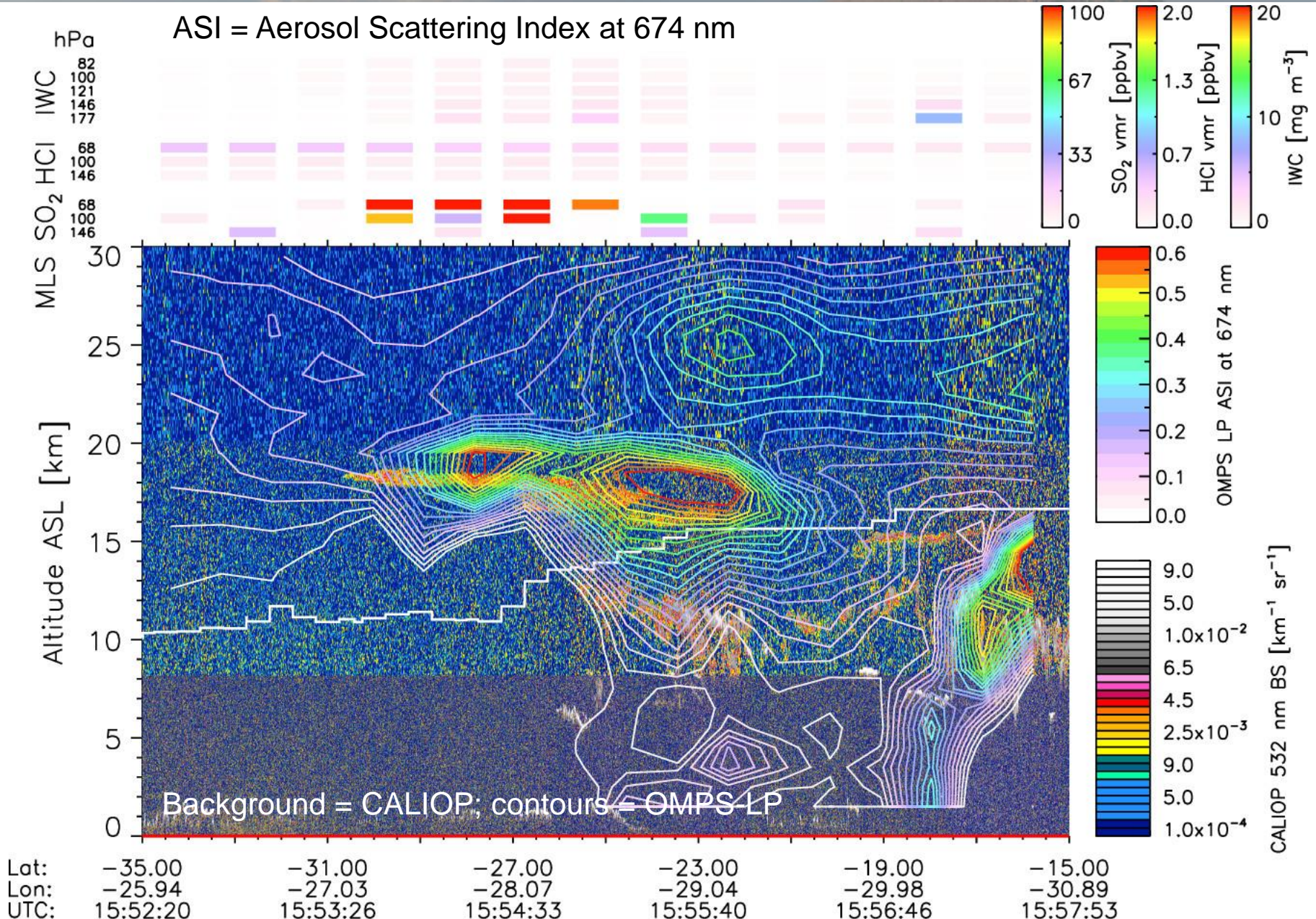
Aqua/MODIS showing Calbuco ash – April 26, 2015



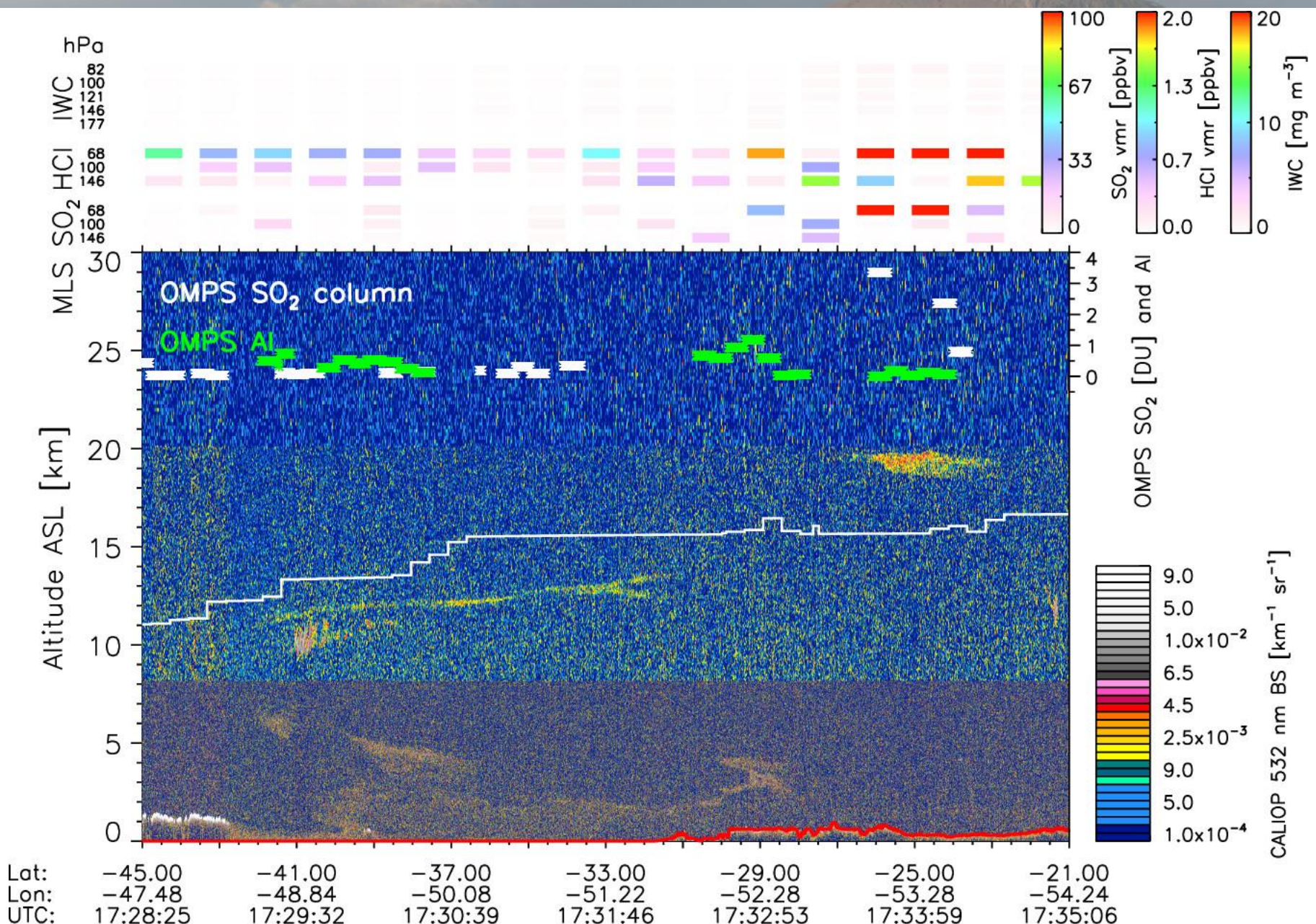
CALIOP backscatter and OMPS-LP ASI (to east)



CALIOP backscatter and OMPS-LP ASI (to west)



CALIOP backscatter and OMPS-NM



OMPS Direct Broadcast data for the North Atlantic

SAMPO Satellite Measurements from Polar Orbit
- Instantly delivered Direct Readout products

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Volcanic products

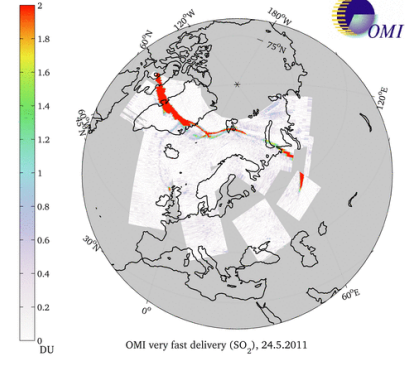
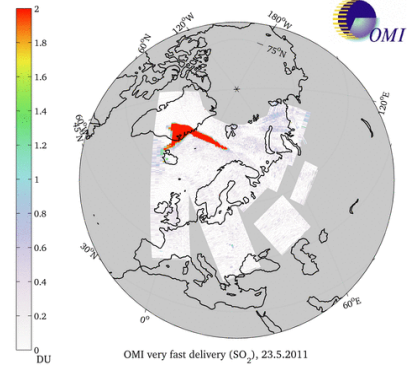
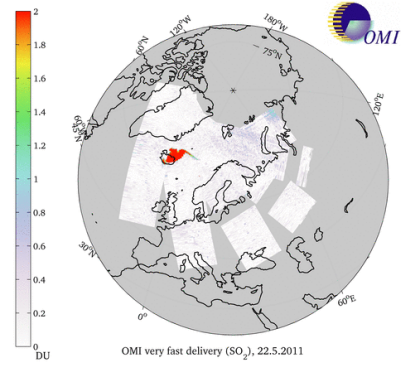
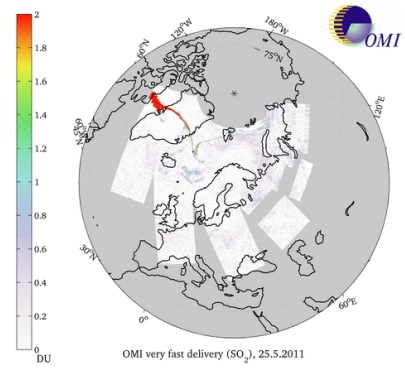
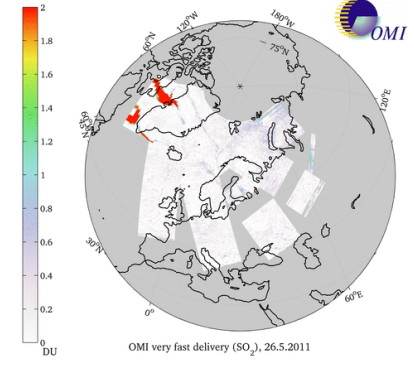
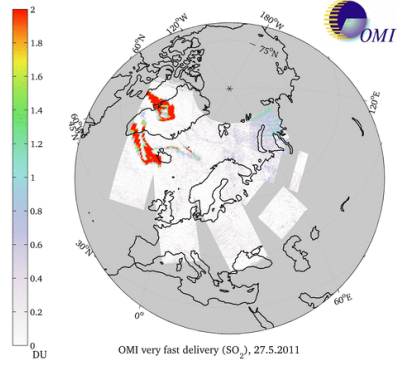
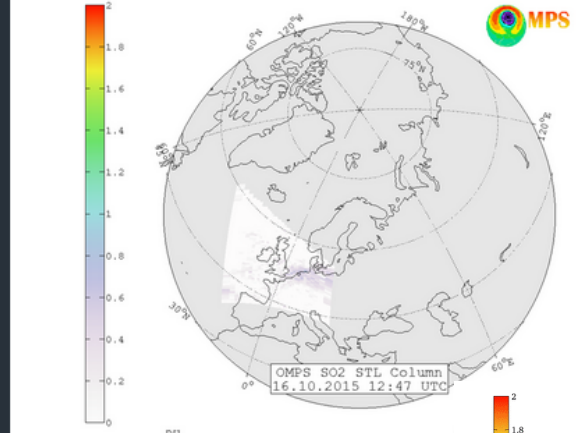


- [Image search](#)
- [Volcanic products](#)
- [Ozone products](#)
- [Highlights](#)



OMPS			OMI		
SO2	AI	CF	SO2	AI	CF
SO21	AI1	CF1	SO21	AI1	CF1
SO22	AI2	CF2	SO22	AI2	CF2
SO23	AI3	CF3	SO23	AI3	CF3
SO24	AI4	CF4	SO24	AI4	CF4
SO25	AI5	CF5	SO25	AI5	CF5
SO26	AI6	CF6	SO26	AI6	CF6
SO27	AI7	CF7	SO27	AI7	CF7
SO28	AI8	CF8	SO28	AI8	CF8
SO29	AI9	CF9	SO29	AI9	CF9
SO210	AI10	CF10	SO210	AI10	CF10

AI = Aerosol Index
CF = Cloud Fraction



Finnish Meteorological Institute (FMI)
<http://sampo.fmi.fi/volcanic.html>

OMPS Direct Broadcast data for the North Pacific

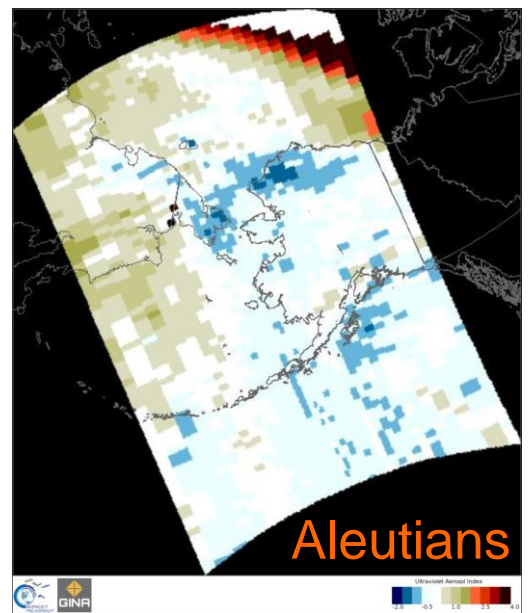
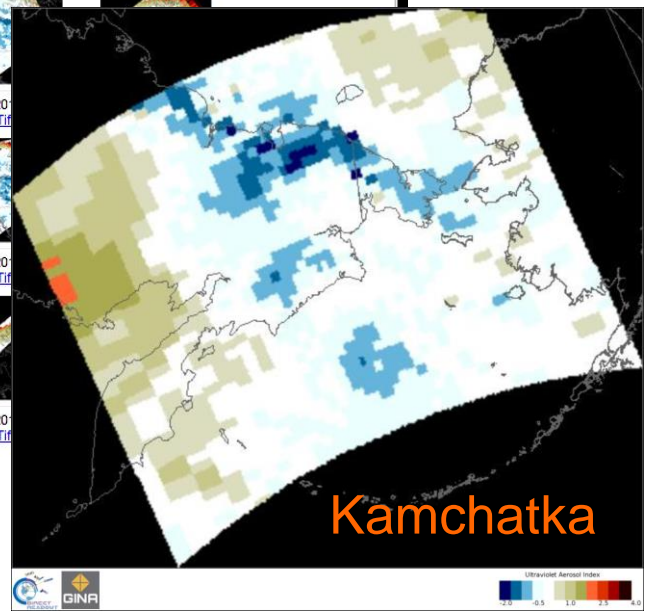
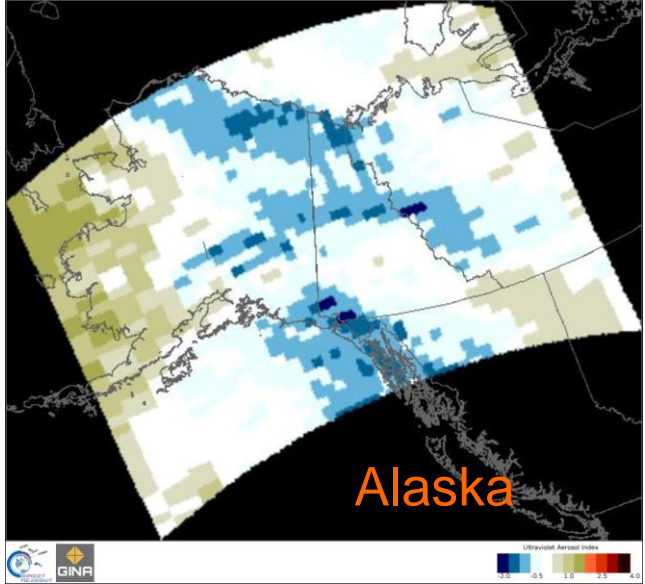
The screenshot shows the NASA Direct Readout Laboratory interface. At the top, there is a navigation bar with the NASA logo and the text "DIRECT READOUT LABORATORY". Below this, there are links for "NASA Home", "Goddard Home", "Direct Readout Laboratory", and "Gallery". A search bar is also present. A prominent yellow banner reads "Register now for the NASA Direct Readout Conference (NDRC-9) · Rabat, Morocco · March 8 - 11, 2016".

The main content area is titled "RECENT DATA PRODUCTS". It features a "Select Sites..." dropdown menu. Below this, there are filters for "GINA: UV AEROSOL INDEX", "SUOMI NPP", "Instrument: OMPS", and "Product: UVAEROSOL". A link to "Google Earth" is provided for viewing the KML files.

A grid of 12 satellite data product thumbnails is displayed, each with a timestamp and a "Tiff" download link. The timestamps range from Oct 12 2015 21:38 to Oct 16 2015 18:01. The thumbnails show a curved view of the Earth's surface with color-coded data representing the UV Aerosol Index.

On the left side of the page, there is a sidebar menu with the following sections:

- Direct Readout Laboratory
 - DRL Home
 - About DRL
 - Technology
 - Recent Data Products
 - Gallery
 - Global View Today
 - DRL Google Maps
 - Downloads
 - Documents
 - SNPP Mission
 - AQUA Mission
 - TERRA Mission
 - Links
 - Direct Readout Contributors
 - DB Conferences
 - DR Site Survey
 - Contact DRL
 - MyDRL LOGIN
 - > Log In
 - > MyDRL Registration Form
 - > MyDRL Forum
 - GLOBAL VIEW TODAY
 -

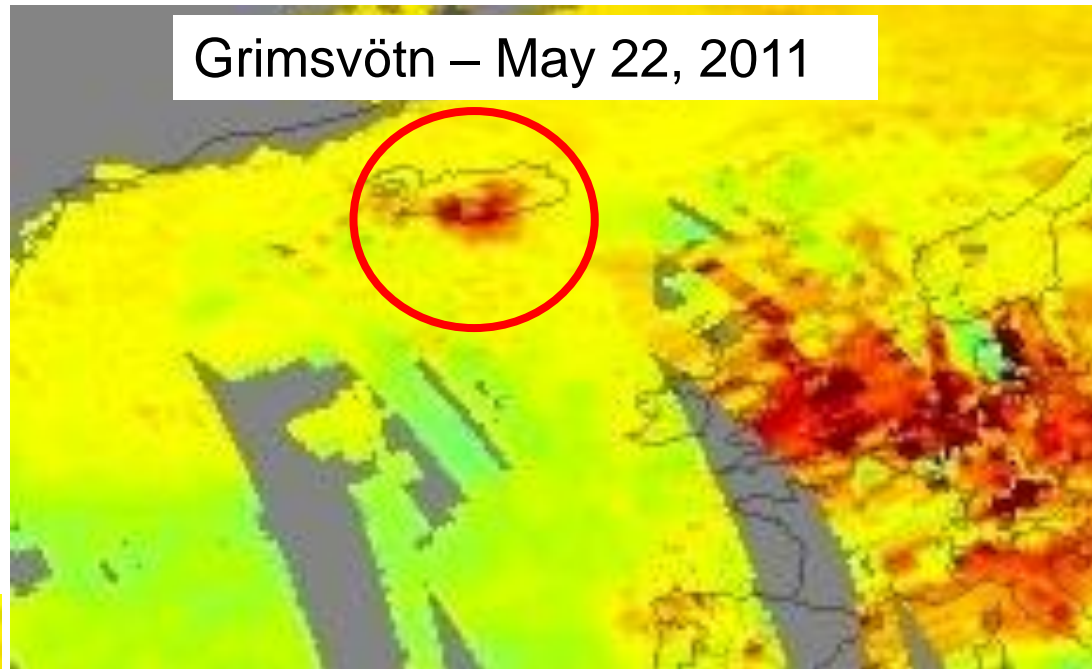


Geographic Information Network of Alaska (GINA)

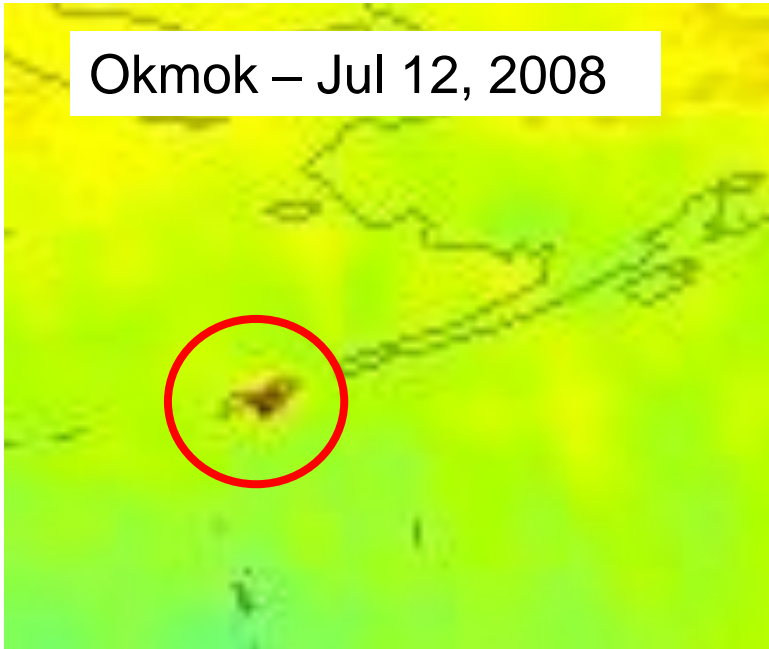
<http://directreadout.sci.gsfc.nasa.gov/?id=dspContent&cid=159>

Detection of NO₂ in volcanic eruption plumes

- OMI detected NO₂ in 2011 Grimsvötn and 2008 Okmok volcanic clouds
- NO₂ known to be generated by lightning in thunderstorms
- Signal of plume electrification at overpass time
- Indicates air (N₂) entrainment



Okmok – Jul 12, 2008

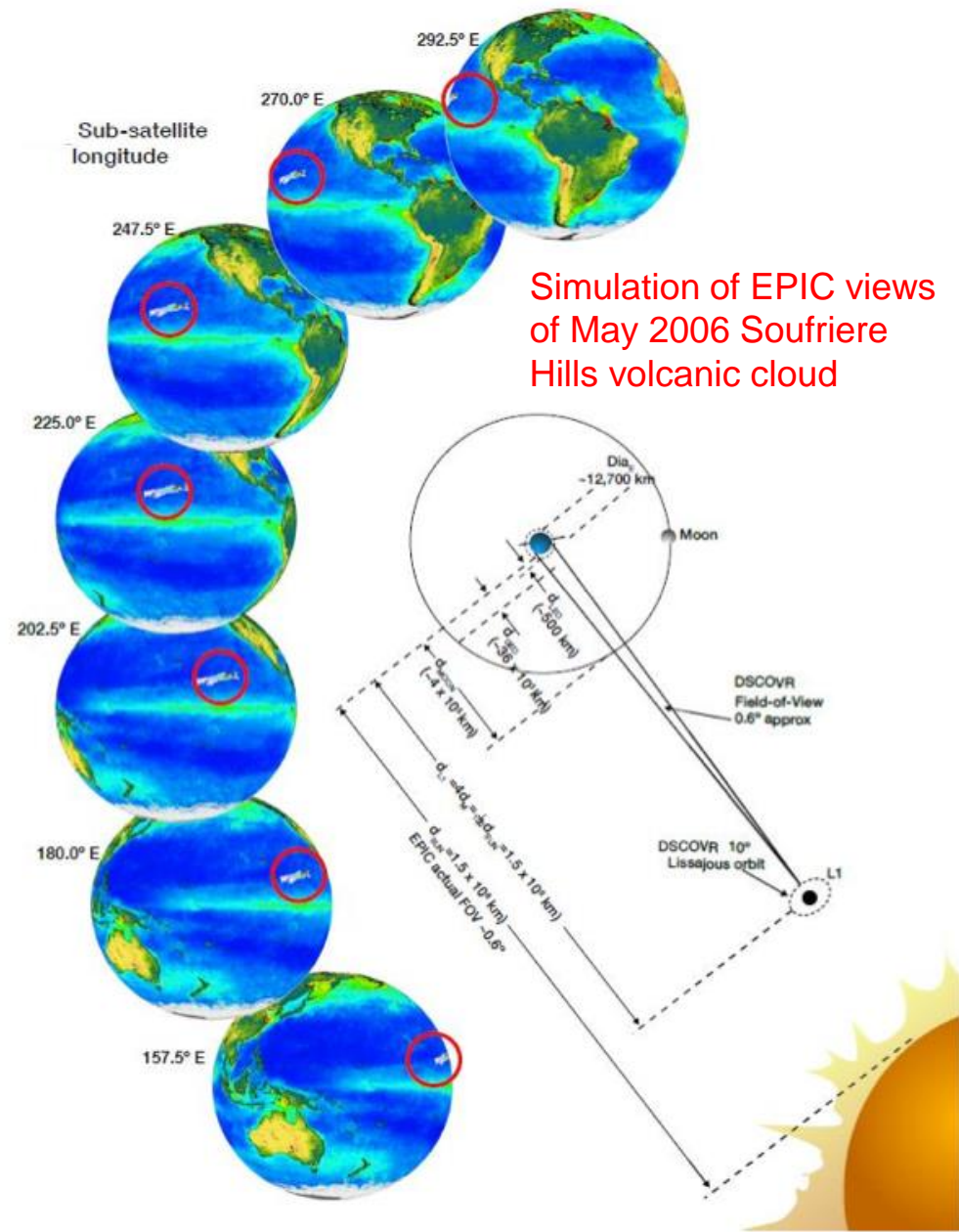


- Both the Grimsvötn and Okmok eruptions featured distinct vertical separation of gas (SO₂) and ash
- Plan to analyze NO₂ data for other explosive eruptions and coincident WWLLN lightning detections

Deep Space Climate Observatory (DSCOVR) at L₁



- Earth Polychromatic Imaging Camera (EPIC)
 - ~90 min temporal resolution
 - Spatial resolution similar to OMI at sub-satellite point
 - SO₂, UVAI and volcanic ash retrievals planned



Summary

- OMI still providing high quality data outside data gaps
- OMPS-NM zoom mode (Saturdays) provides increased sensitivity to volcanic ash and SO₂
 - Ojos del Salado resuspended ash plume detected in UVAI; no SO₂
 - Future OMPS instruments on JPSS may be 100% zoom mode
- OMPS-LP: useful new tool for analysis of volcanic plumes
 - Additional plume altitude information between CALIOP overpasses
 - Aerosol type information?
 - Aerosol scattering signal in LP profiles even in young plumes
- Lightning-generated NO₂ detected in some eruption plumes
 - Additional technique for eruption detection
 - Indicative of strong convection and plume electrification at satellite overpass time
- DSCOVER/EPIC soon to be operational at L₁
 - Volcanic SO₂ and UVAI data with ~90-minute temporal resolution

Ash spectral refractive indices in the UV-visible

