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Thermal Infrared (TIR) Remote Sensing of Volcanic Plumes: An Introduction (?)

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TIR Remote Sensing of Volcanic Plumes

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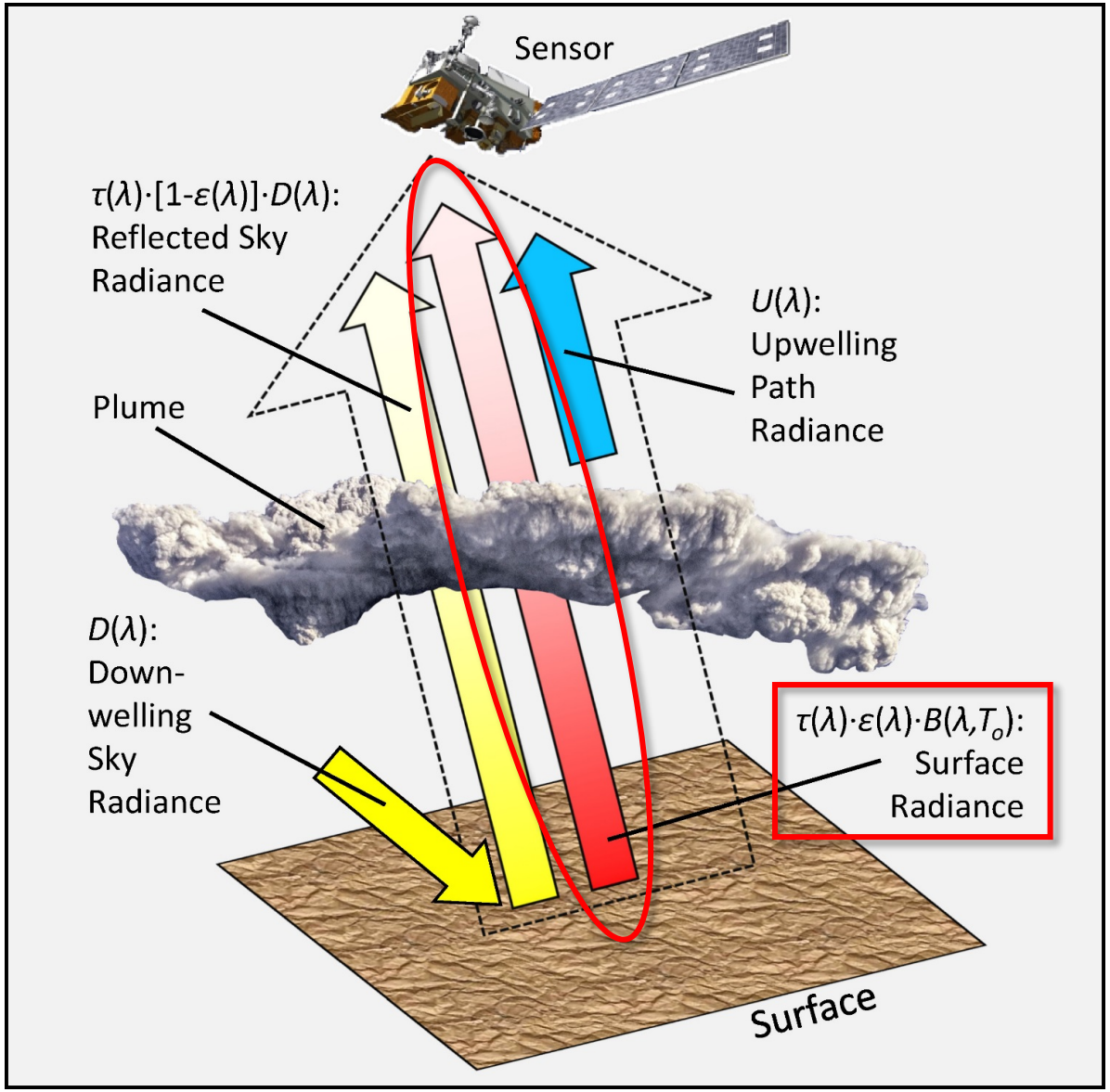
Detect plumes through transmission [$\tau(\lambda)$]:
the attenuation of surface radiance [$\varepsilon(\lambda) \cdot B(\lambda,T_o)$]
passing through the plume enroute to the sensor

$$L(\lambda,T_o) = \{\varepsilon(\lambda)\, B(\lambda,T_o) + [1 - \varepsilon(\lambda)]\, D(\lambda)\}\, \tau(\lambda) + U(\lambda)$$

The observed radiance [$L(\lambda,T_o)$; outlined arrow] includes the surface radiance (red arrow), reflected downwelling sky radiance [$D(\lambda)$, yellow arrow], and upwelling path radiance [$U(\lambda)$, blue arrow]

Reconstruct Observed Radiance:

1) Transmission, sky radiance, and path radiance are estimated through radiative transfer (RT) modeling, cached, and re-used
2) Surface emissivity [$\varepsilon(\lambda)$] available from lab spectra, product archives, or calculated within scene
3) Surface temperature [T_o] estimated from radiance observations



Plume Spectroscopy: Sarychev Peak Volcano

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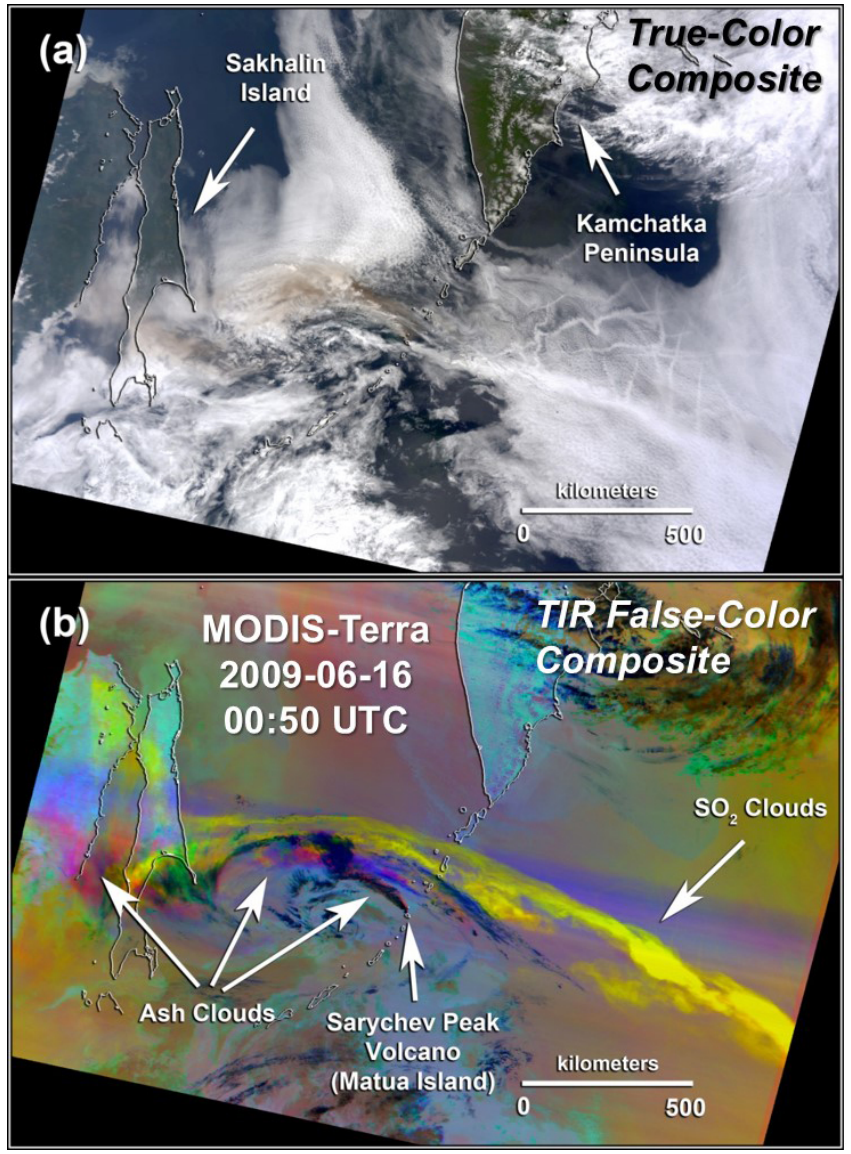
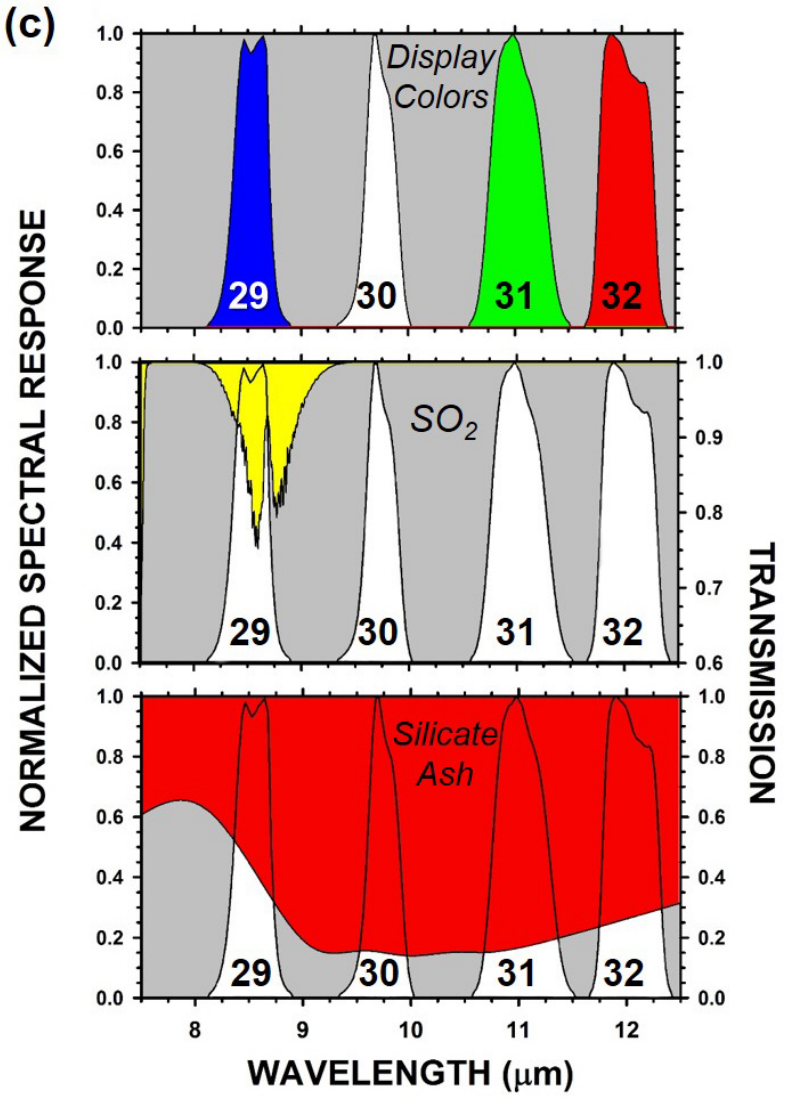
a) MODIS-Terra True-color composite. Volcanic plumes and meteorological clouds have similar appearance at visible wavelengths

b) False-color composite of TIR data from Channels 32, 31, and 29, displayed in red, green, and blue. SO_2 plumes appear yellow, while the display colors of ash plumes range between red and magenta

c) Transmission spectra of SO_2 (middle) and silicate ash (bottom), superimposed on the spectral response of MODIS Channels 29, 30, 31, and 32





Plume Spectroscopy: Calbuco Volcano (Chile)
2015-04-23, 18:35 UTC (Aqua) / 19:12 UTC (SNPP)

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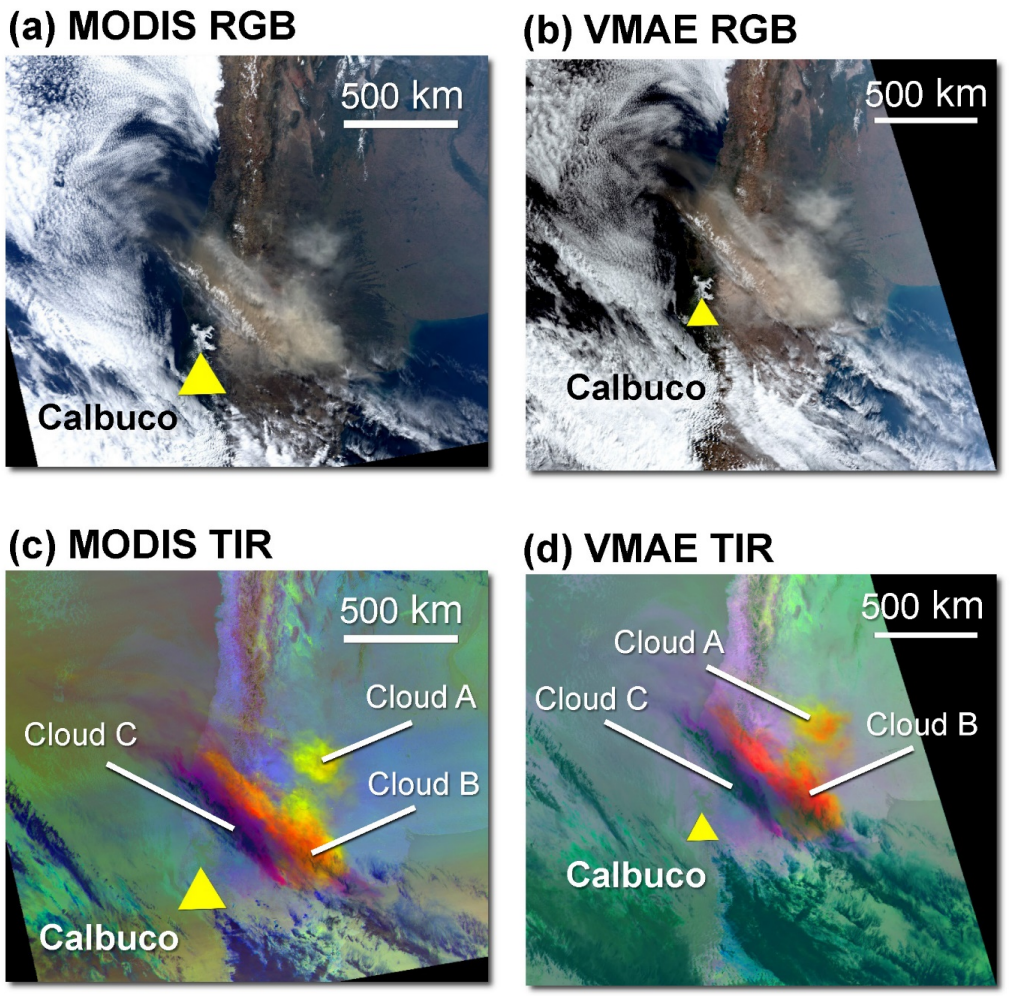

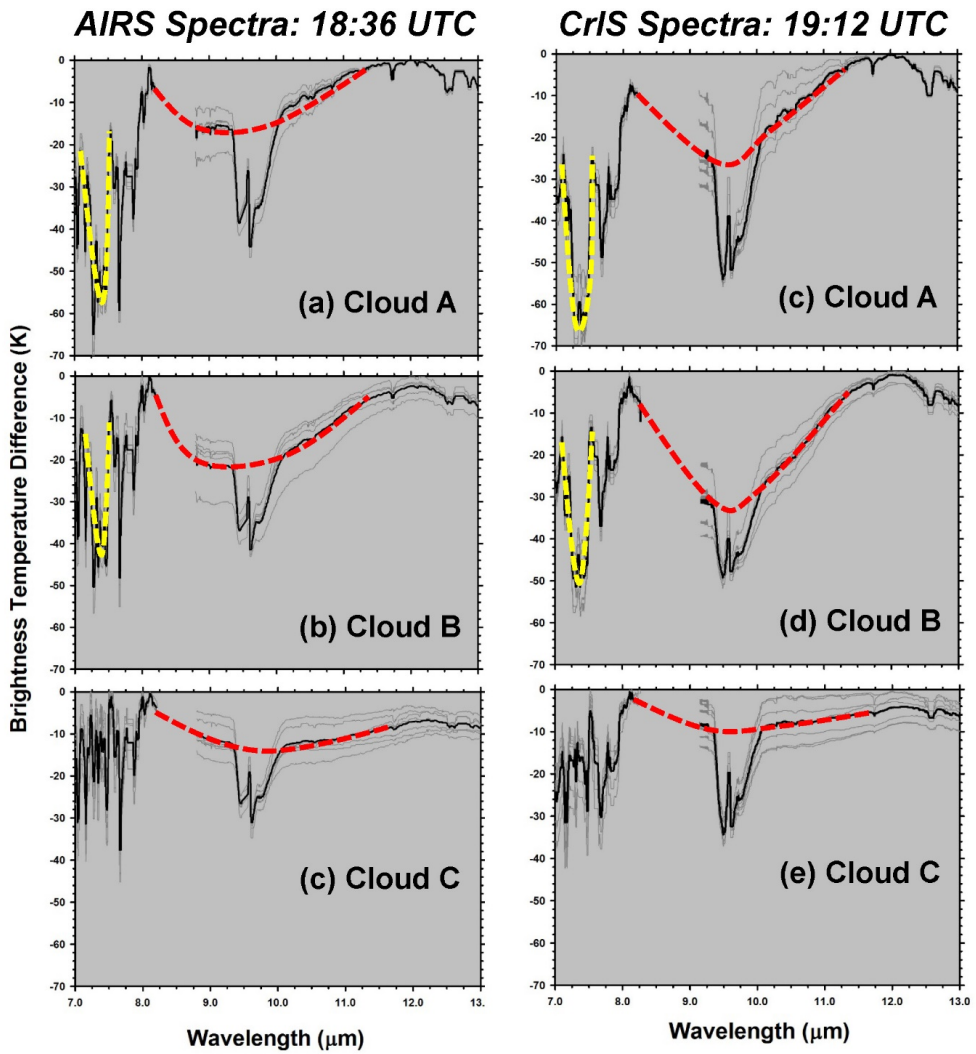

Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER)

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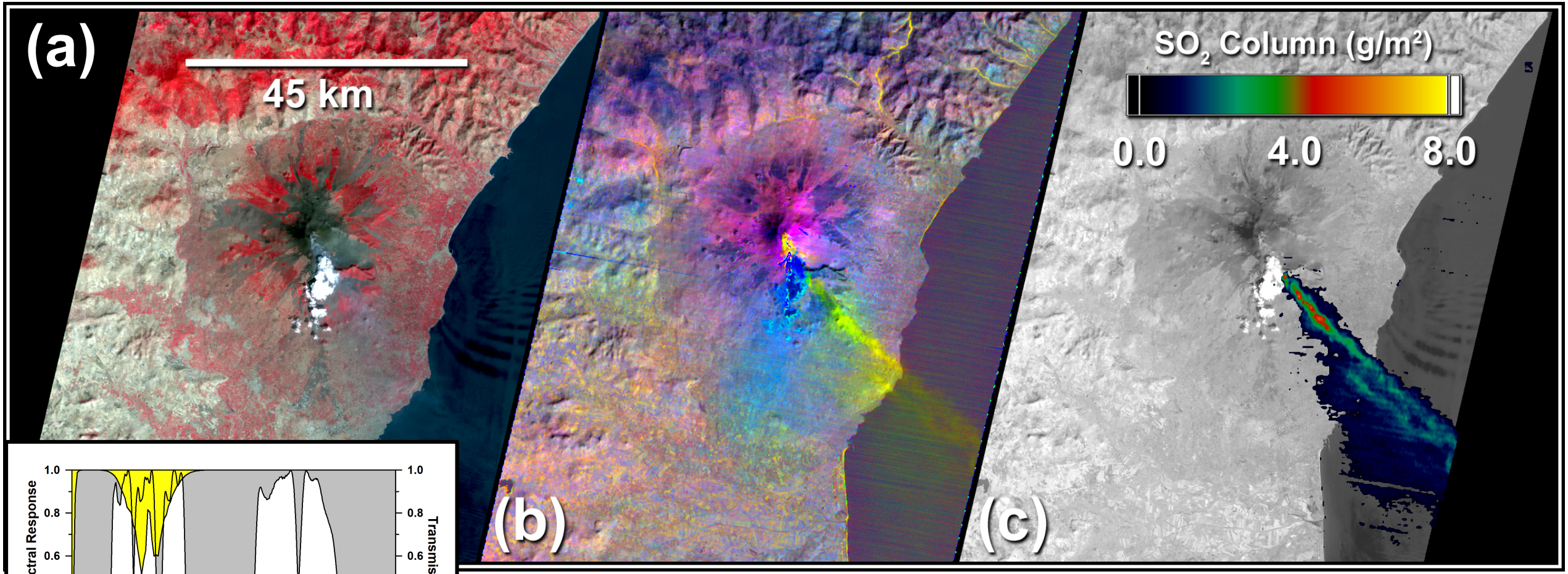

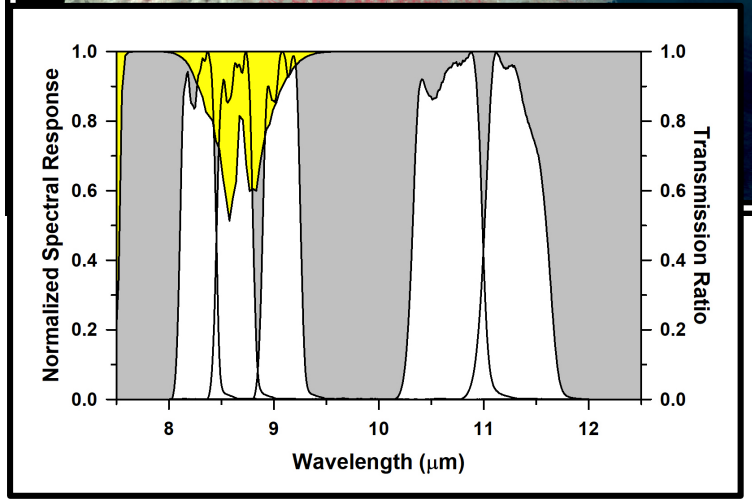

Mount Etna, 2011-07-29, 10:01 UTC
(a) VNIR Composite, (b) TIR Composite,
(c) SO_2 Column Density Map

90 m IFOV,
830 X 700

Moderate-Resolution Imaging Spectrometer (MODIS): 1 km IFOV, 1354 X 2030

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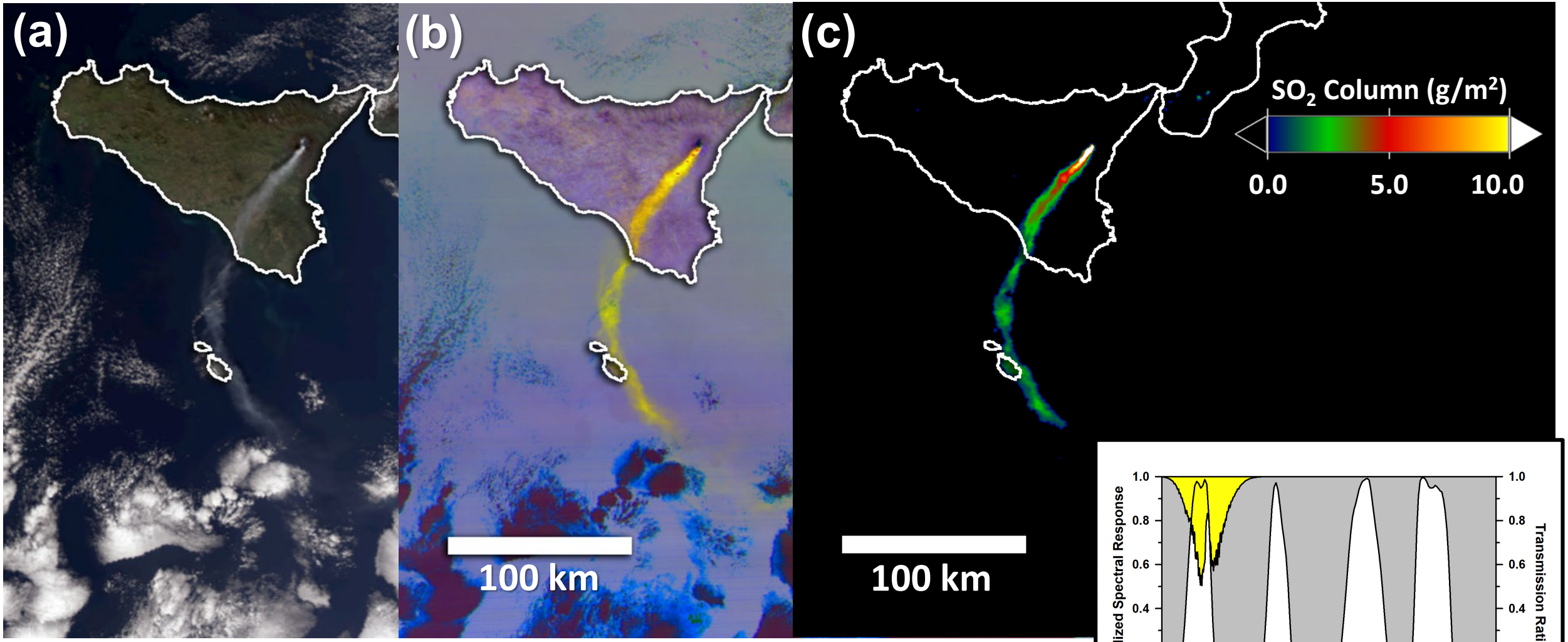

Mount Etna, 2018-12-27, 12:20 UTC

(a) RGB Composite, (b) TIR Composite, (c) SO_2 Column Density Map

Visible Infrared Imaging Radiometer Suite (VIIRS): 750 m IFOV, 3200 X 3232

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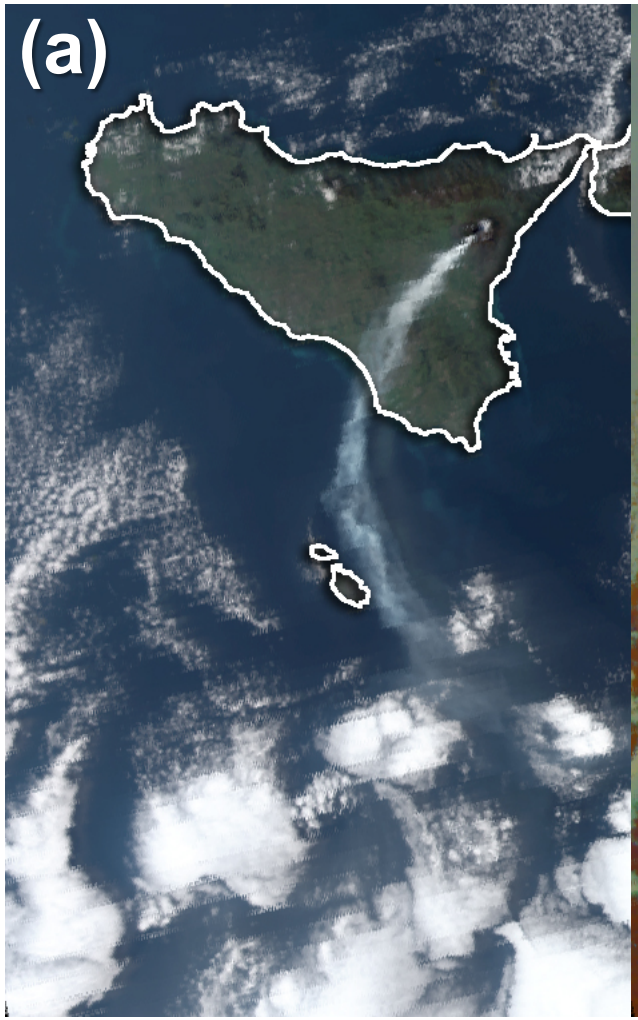

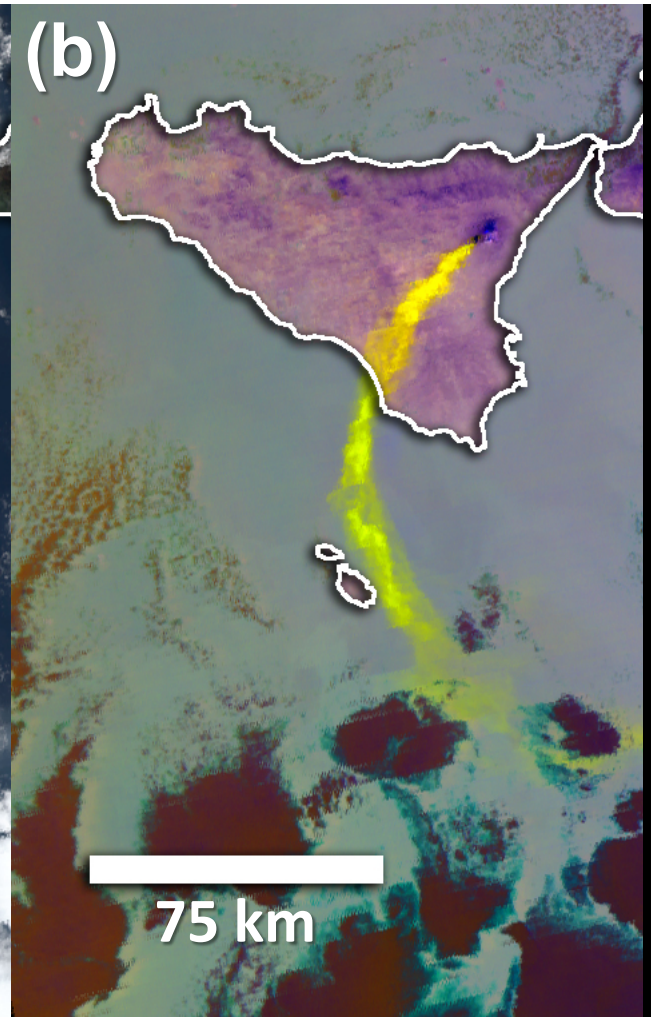

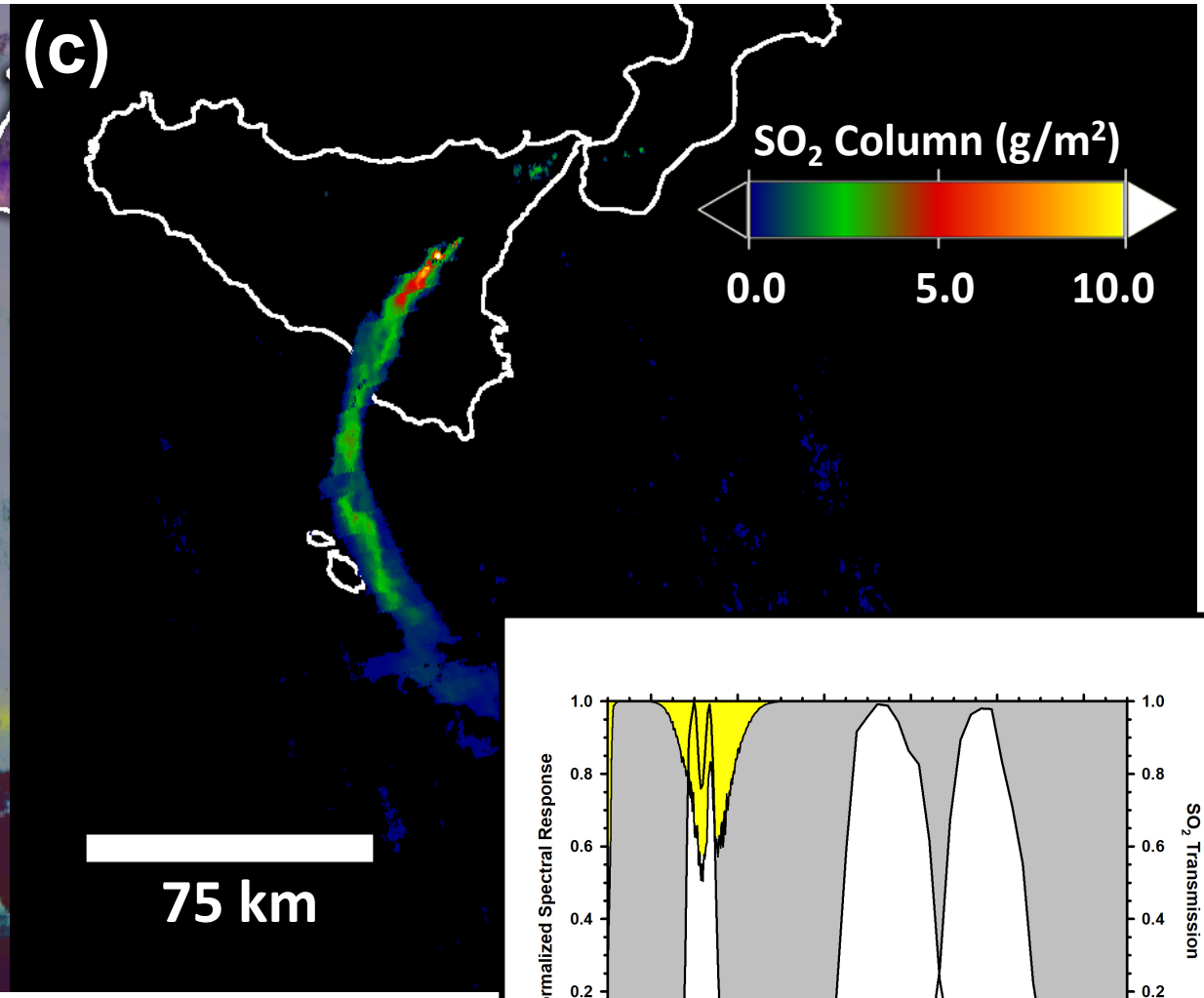

Mount Etna, 2018-12-27, 11:00 UTC

(a) RGB Composite, (b) TIR Composite, (c) SO_2 Column Density Map

TIR Constellation:
1 Descending + 3 Ascending Orbits

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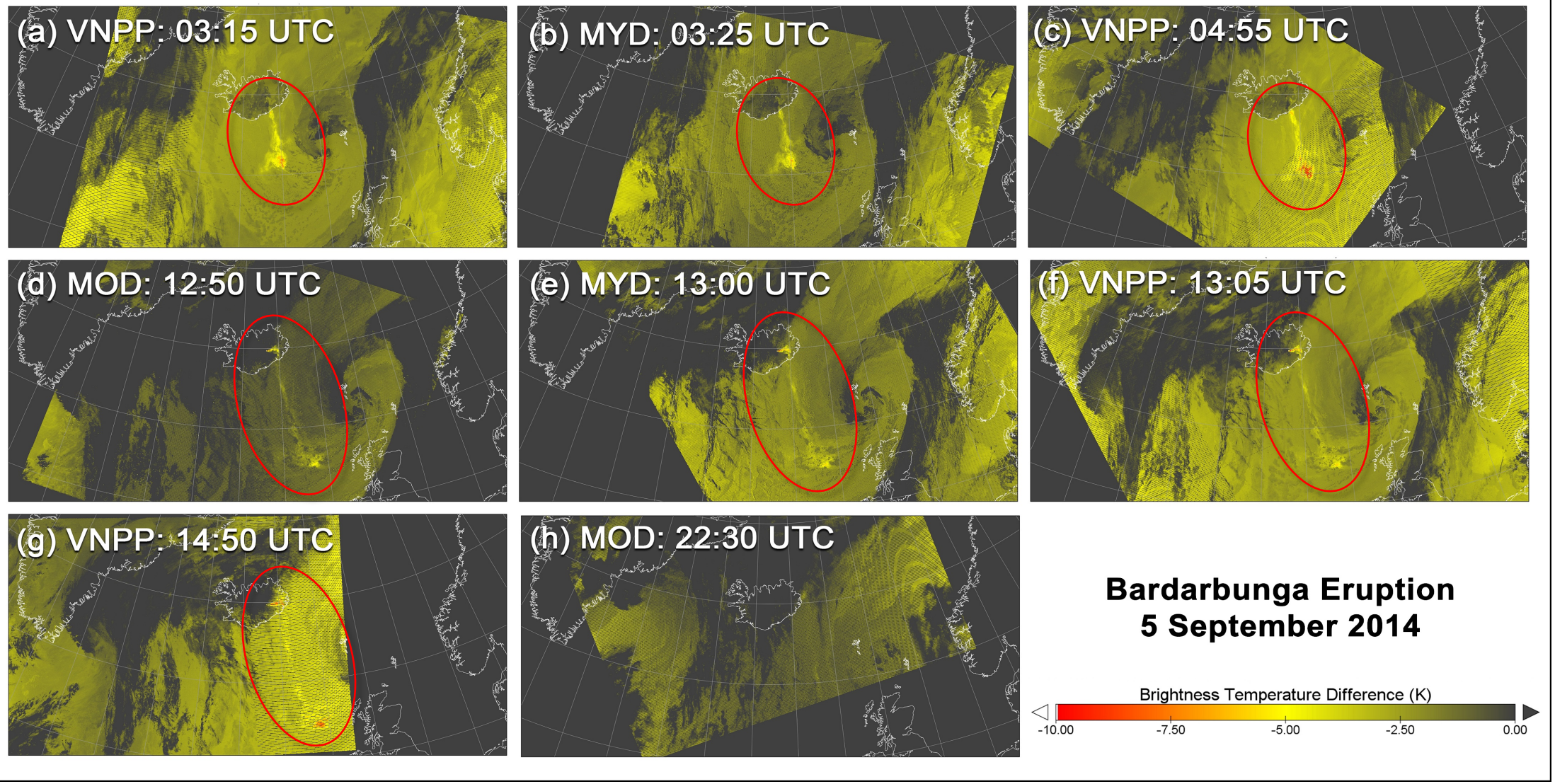
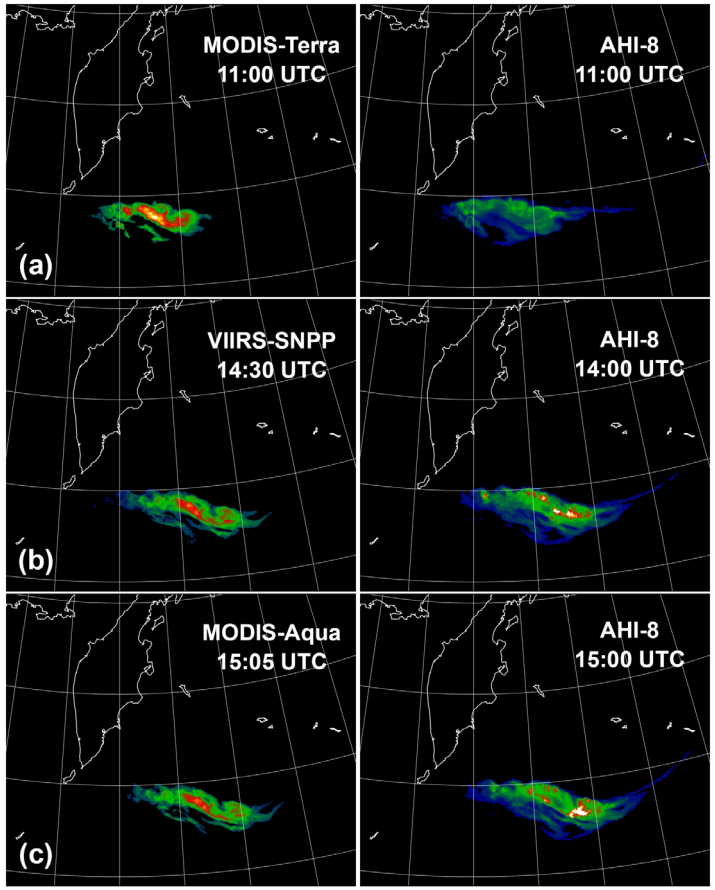


Geostationary Instruments

Spinning Enhanced Visible and Infrared Imager (SEVIRI)
https://www.eumetsat.int/seviri

Advanced Baseline Imager (ABI)
https://www.goes-r.gov/spacesegment/abi.html

Advanced Himawari Imager (AHI)
https://www.data.jma.go.jp/mscweb/en/himawari89/space_segment/spsg_ahi.html



AHI processing courtesy A. Prata

https://search.earthdata.nasa.gov/search

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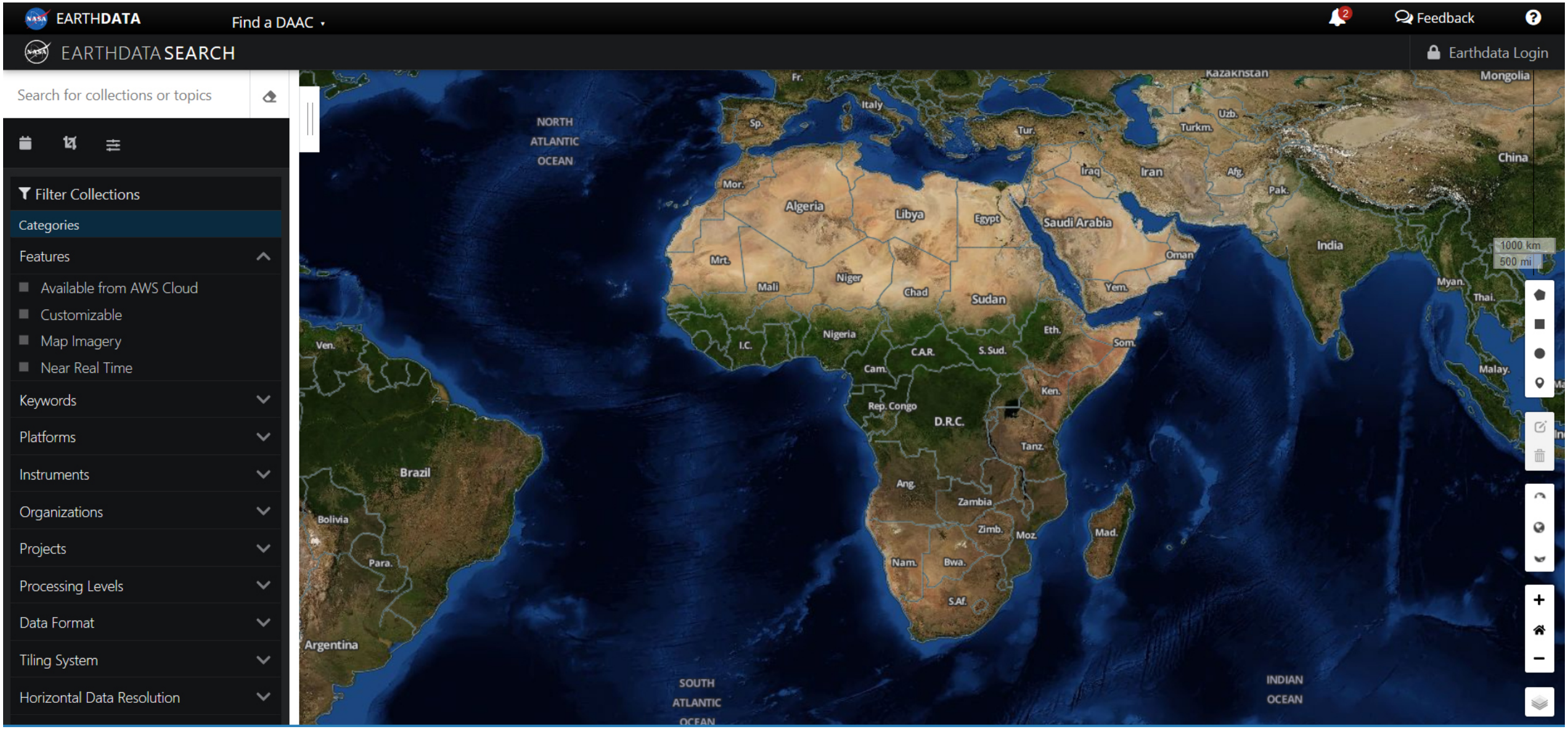

https://ladsweb.modaps.eosdis.nasa.gov/search

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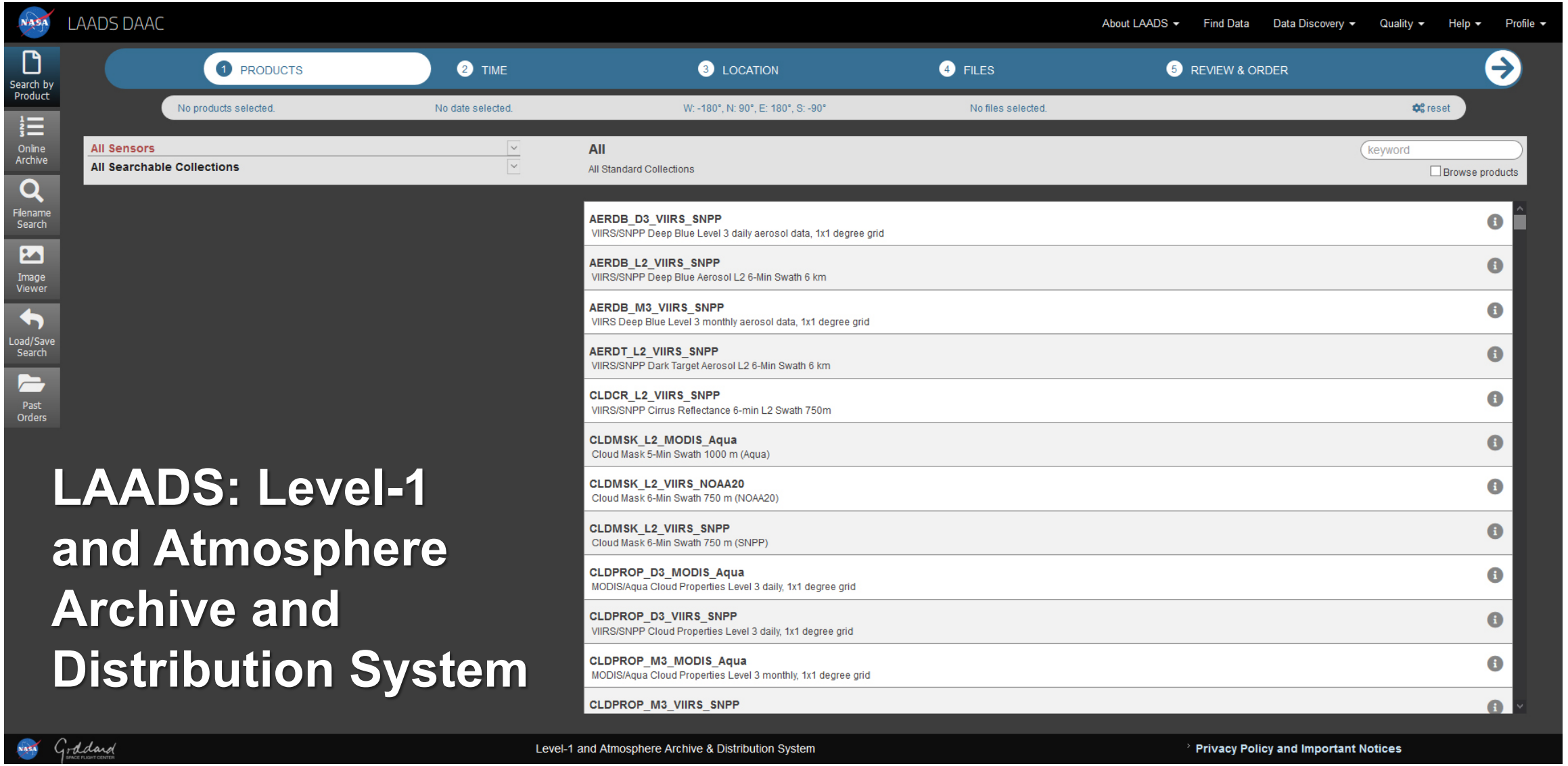

LAADS: Level-1 and Atmosphere Archive and Distribution System

https://ladsweb.modaps.eosdis.nasa.gov/archive/Science Domain/

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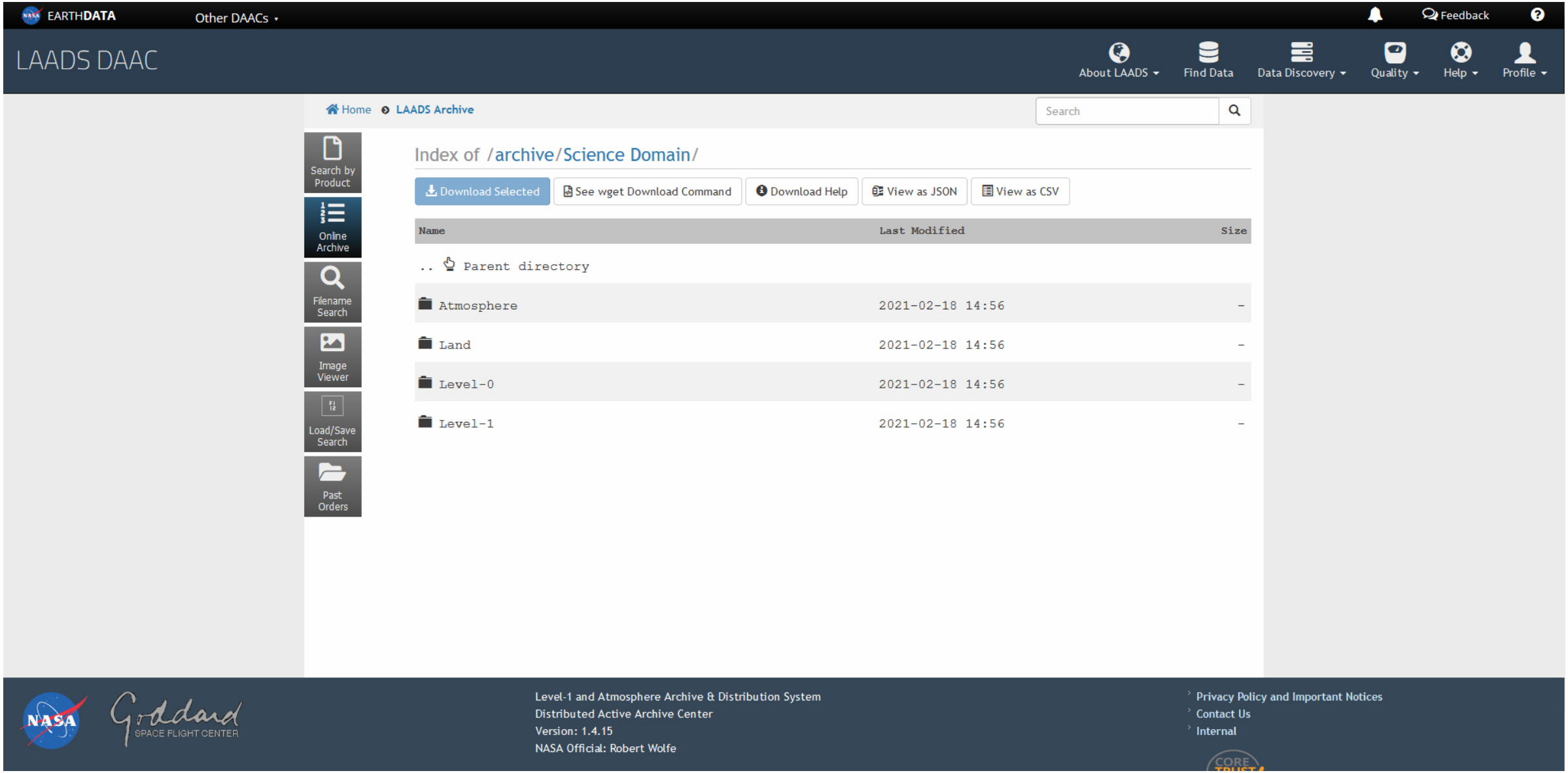

https://lpdaac.usgs.gov/tools/appeears/

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Land Processes (LP) DAAC

- ASTER
- MODIS and VIIRS Land Surface Products
- ECOSTRESS

On-Line Tools:
Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)

https://asterweb.jpl.nasa.gov/

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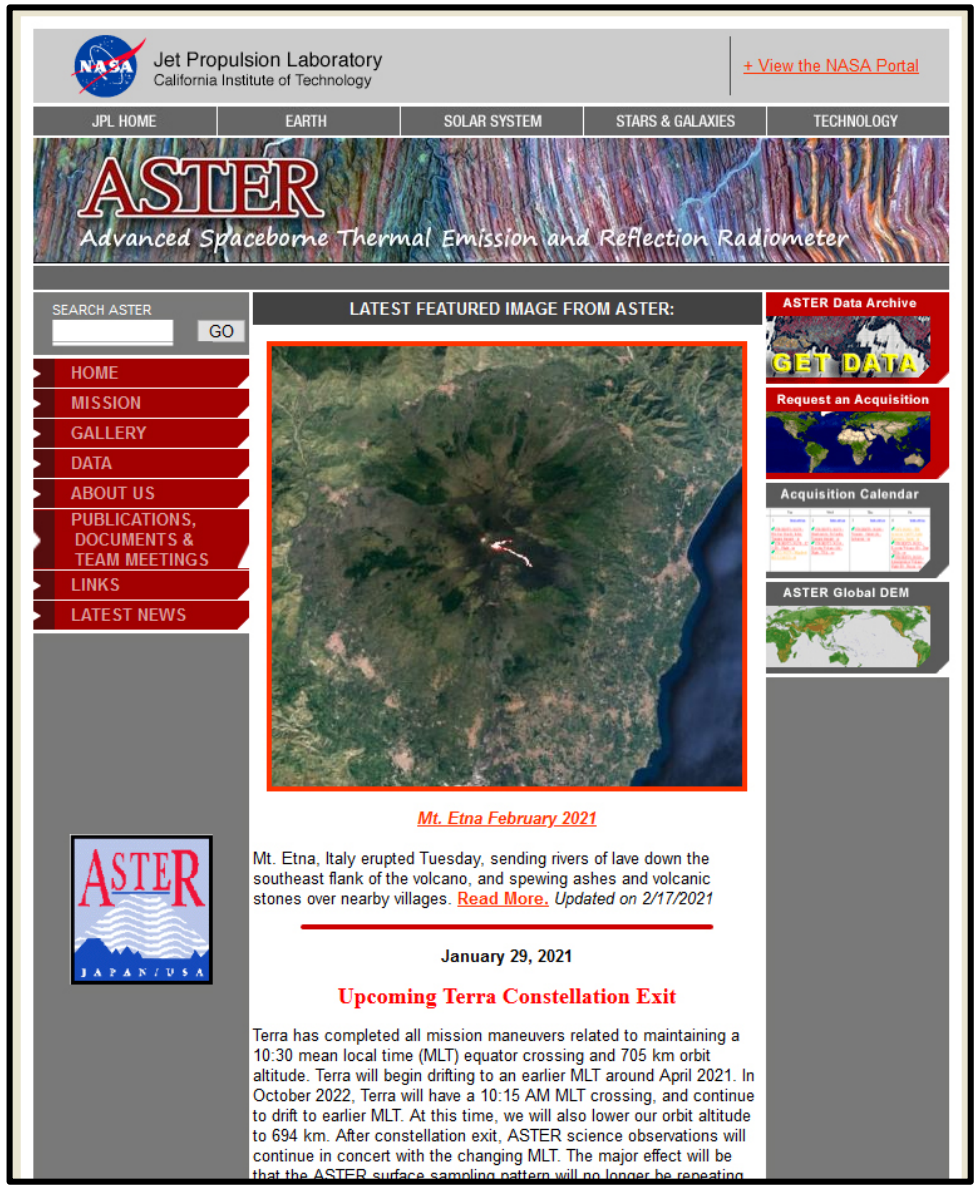

ASTER: On-Demand Observations

- Data Acquired over Specific Targets on Specific Schedules
- Acquisition Calendar Shows Recent and Pending Observations

	- 3 (AESICS) 205511 - Etna (Stromboli, Vulcano) Volcanoes; Italy; Day - @09:58:50 - us					
7 Uplink xAR List - 1 (AESICS) 205509 - Sangay Volcano; Ecuador; Night - @03:45:34 - us	8 Uplink xAR List	9 Uplink xAR List	10 Uplink xAR List - 1 (AESICS) 205510 - Pacaya (Agua, Fuego) Volcanoes; Guatemala; Night - @04:21:05 - us - 4 (AESICS) 205516 - Stromboli (Etna, Vulcano) Volcanoes; Italy; Day - @09:52:31 - us	11 Uplink xAR List - 2 (AESICS) 205514 - Lascar Volcano; Chile; Night - @03:15:01 - us - 4 (AESICS) 205520 - Kliuchevskoi (Bezy,Kizi,Shiv,Tolb,Ushk) Volcanoes; Russia; Day - @00:37:28 - us - 2 (AESICS) 205521 - Popocatepetl Volcano; Mexico; Day - @17:16:33 - us - 2 (URGENT!) 205522 - Flood: Uttarakhand Tapovan Glacial Collapse; India; Day - @05:41:03 - us	12 Uplink xAR List - 4 (URGENT!) 205515 - La Soufriere & Mt.Pelee Volcanoes; St. Vincent; Day - @14:43:46 - us - 2 (AESICS) 205519 - Kliuchevskoi (Bezy, Ushk, Tolb) Volcanoes; Russia; Night - @10:55:46 - us	13 Uplink xAR List - 2 (URGENT!) 205523 - Flood: Uttarakhand Tapovan Glacial Collapse; India; Day - @05:28:52 - us - 2 (AESICS) 205524 - Popocatapetl Volcano; Mexico; Night - @04:53:04 - us
14 Uplink xAR List	15 Uplink xAR List	16 Uplink xAR List	17 Uplink xAR List - 1 (AESICS) 205517 - Pacaya (Agua, Fuego) Volcanoes; Guatemala; Day - @16:40:50 - us - 3 (AESICS) 205518 - Stromboli (Vulcano, Etna) Volcanoes; Italy; Night - @21:02:36 - us - 1 (AESICS) 205527 - Pacaya (Agua, Fuego) Volcanoes; Guatemala; Night - @04:27:02 - us	18 Uplink xAR List (MVR) 9210218 - Inhibit Zone for Drag Make-up Maneuver #126; ; Day - 15:22:51-18:52:51 - jp - 1 (AESICS) 205532 - Nevado del Ruiz Volcano; Columbia; Night - @03:28:39 - us	19 - 2 (AESICS) 205533 - Bezymianny (Kliu, Ushk, Tolb) Volcanoes; Russia; Night - @11:01:38 - us	20 - 5 (AESICS) 205534 - Bezymianny (Kliu,Kizi,Shiv,Tolb,Ushk) Volcanoes; Russia; Day - @00:31:07 - us - 1 (AESICS) 205535 - Reventador Volcano; Ecuador; Day - @15:36:39 - us
21 - 2 (AESICS) 205526 - Lascar Volcano; Chile; Day - @14:47:34 - us	22	23 - 1 (AESICS) 205536 - Sangay Volcano; Ecuador; Night - @03:45:16 - us	24	25 (GC) 205529 - ACTIVATE_RH-12; USA; Day - @15:42:31 - us - 2 (AESICS) 205537 - Sabancaya Volcano; Peru; Night - @03:29:06 - us	26 - 2 (AESICS) 205538 - Sabancaya Volcano; Peru; Day - @15:03:54 - us - 4 (AESICS) 205539 - Etna (Stromboli, Vulcano) Volcanoes; Italy; Day - @09:52:19 - us - 1 (AESICS) 205540 - Pacaya (Agua, Fuego) Volcanoes; Guatemala; Night - @04:20:50 - us	27 - 2 (AESICS) 205541 - Lascar Volcano; Chile; Night - @03:14:40 - us
28						

https://worldview.earthdata.nasa.gov/

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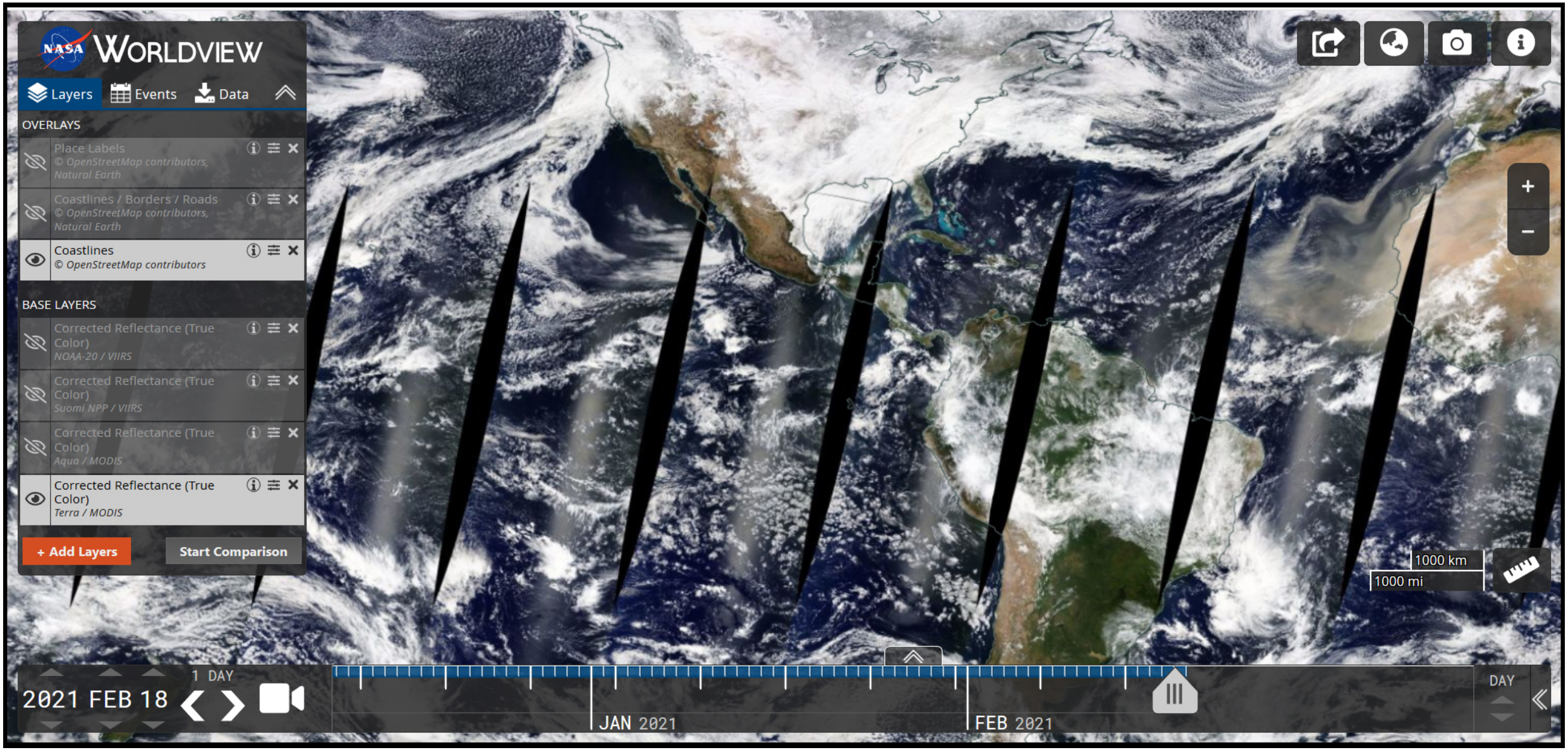

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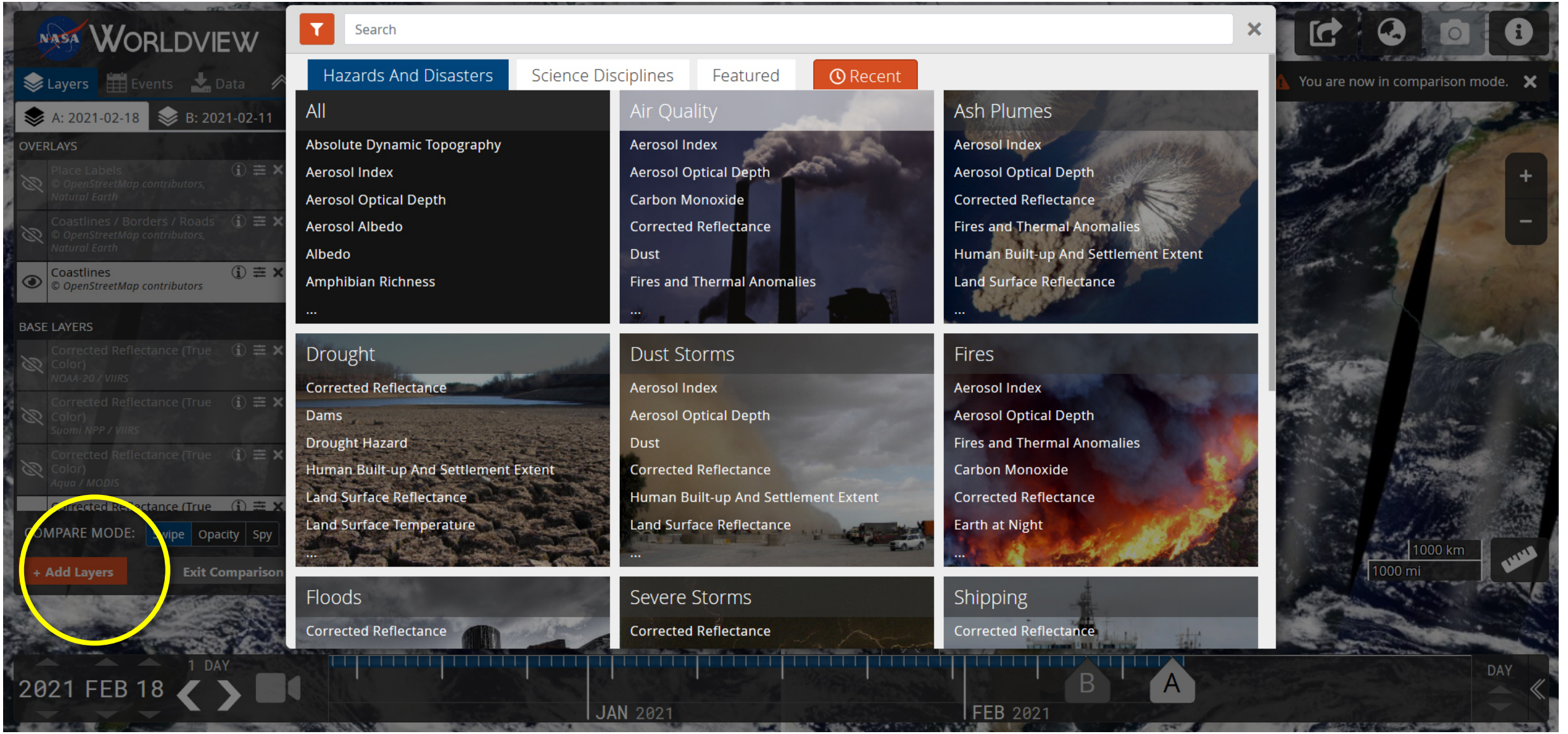

https://airs.jpl.nasa.gov/volcanic_plumes

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AIRS ATMOSPHERIC INFRARED SOUNDER

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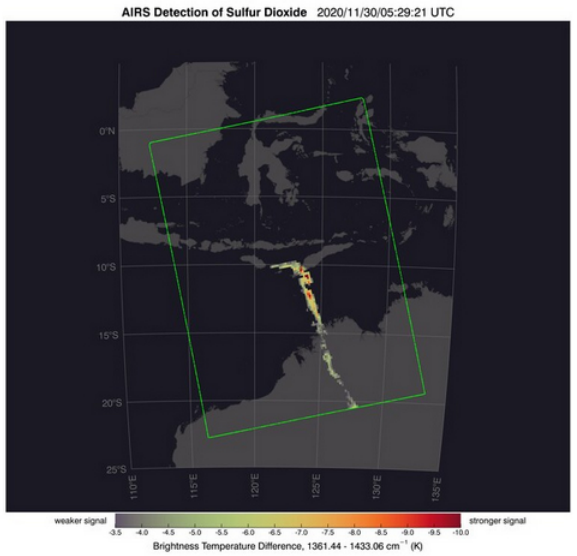
AIRS Rapid Response: Latest Sulfur Dioxide and Dust Detection

Detection Time: 2020/11/30, UTC 05:29:21

Region plotted represents one AIRS data granule.

SO2 DETECTION



About | KMZ | GeoTIFF

Center of Coverage Area

10.0 S, 122.0 E

VIEW AIRS, OMI, OMPS ON NASA WORLDVIEW

SO2 and Dust Detection Archive VIEW

About the AIRS Products

The sulfur dioxide and dust browse products derived from AIRS observations can indicate the possibility of volcanic activity, but more detailed analysis is required to confirm the presence of volcanic clouds or estimate the composition and quantity of materials in the clouds.

More about the products

Get Email Alerts

Sign up to be notified of AIRS SO2 detections.

enter your email

Volcano Resources

- Global SO2 Monitoring (NASA)

Home | Sounding Science | Mission | Data | Applications | Multimedia | Science Meetings

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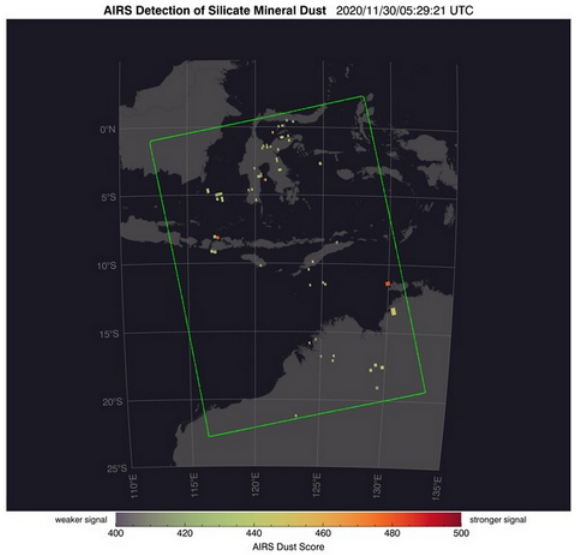
DUST DETECTION



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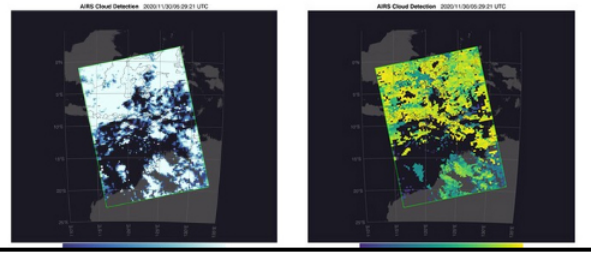
CLOUDS



Volcano Resources

- Global SO2 Monitoring (NASA)
- Volcanic Ash Advisory Center (NOAA/Washington D.C.)
- Volcanic Cloud Monitoring (NOAA/CIMSS)
- Support to Aviation Control Service (ESA)
- Volcanic Activity (Smithsonian)
- U.S. Volcanic Activity (USGS)

Helpful AIRS User Guide Selections

AIRS Level 2 Product User Guide
Provides a description of the AIRS SO2 Flag and Dust Flag along with quality indicators and caveats. See chapter 24, titled "LEVEL 2 PHYSICAL RETRIEVAL SURFCLASS, DUST FLAG, SO2 FLAG AND CLOUD PHASE FLAG".

Product User Guide (PDF)

AIRS Retrieval Channel Sets
Defines the SO2 Flag and Dust Flag tests plus important notes concerning contamination due to volcanic ash and dust. See section 2.12 SO2 Flag (L1B radiances) and Section 2.13 Dust Flag Determination (L1B radiances).

Retrieval Channel Sets (PDF)

Get AIRS Data

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- Standard Data Products

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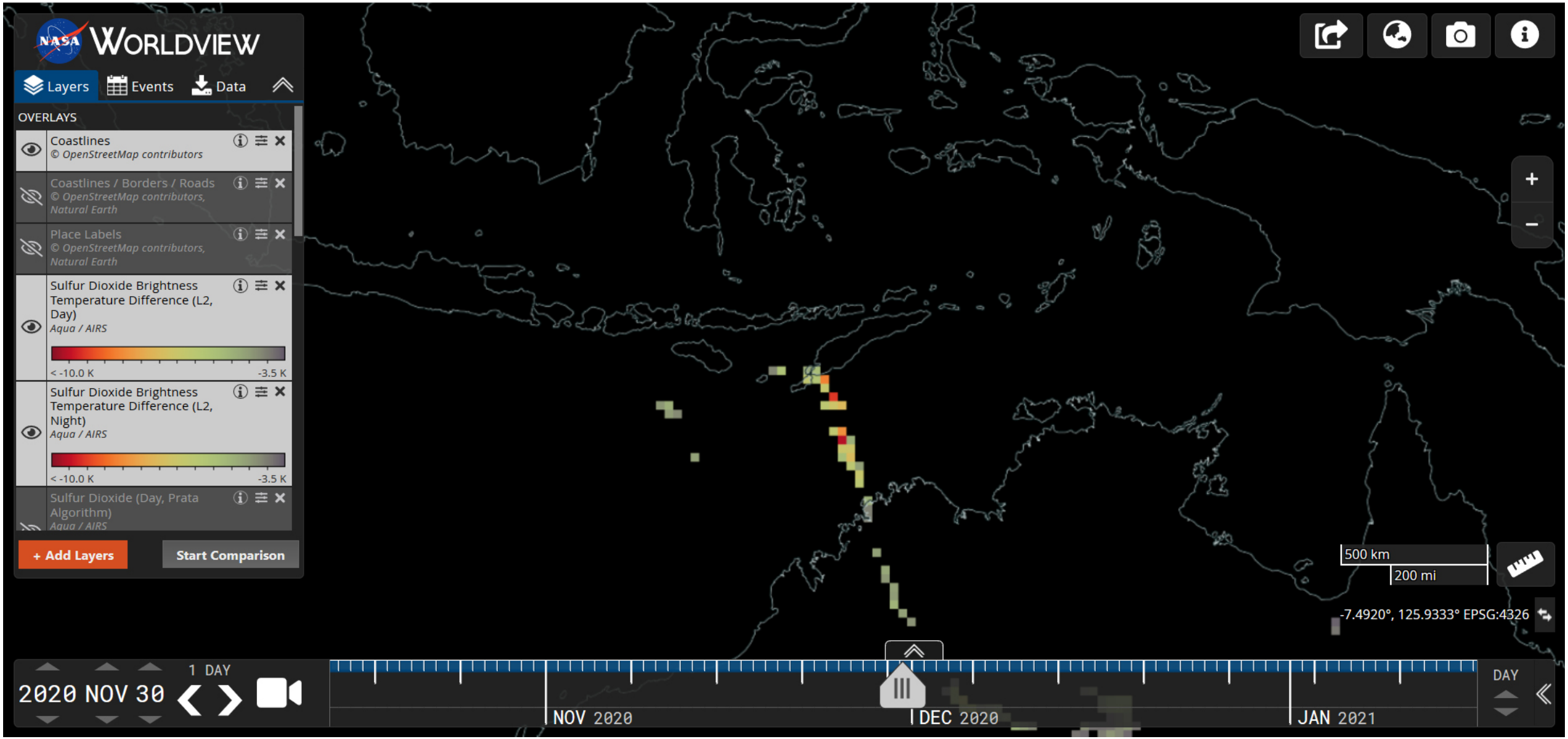

https://maps.disasters.nasa.gov/

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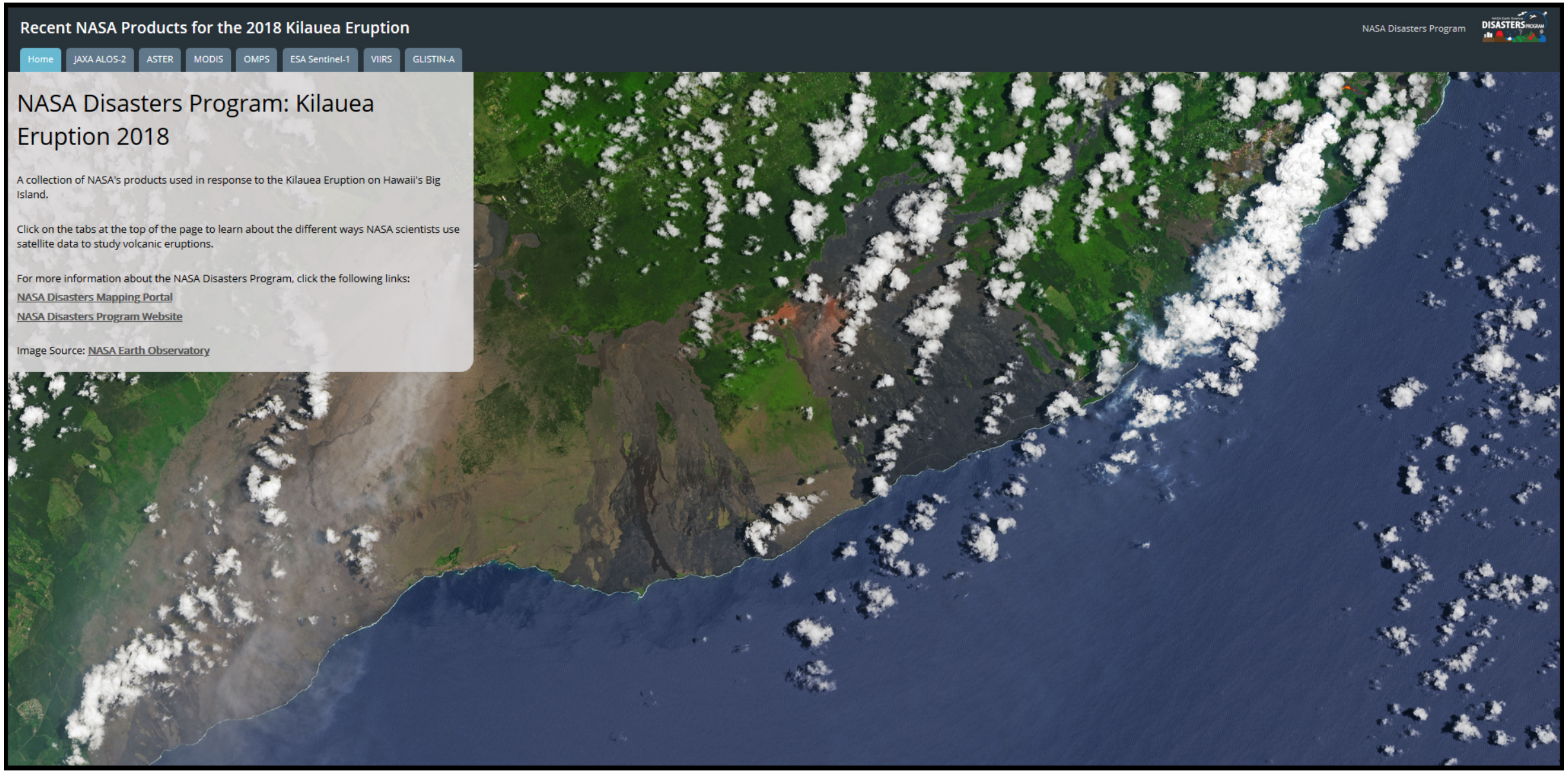

https://maps.disasters.nasa.gov/

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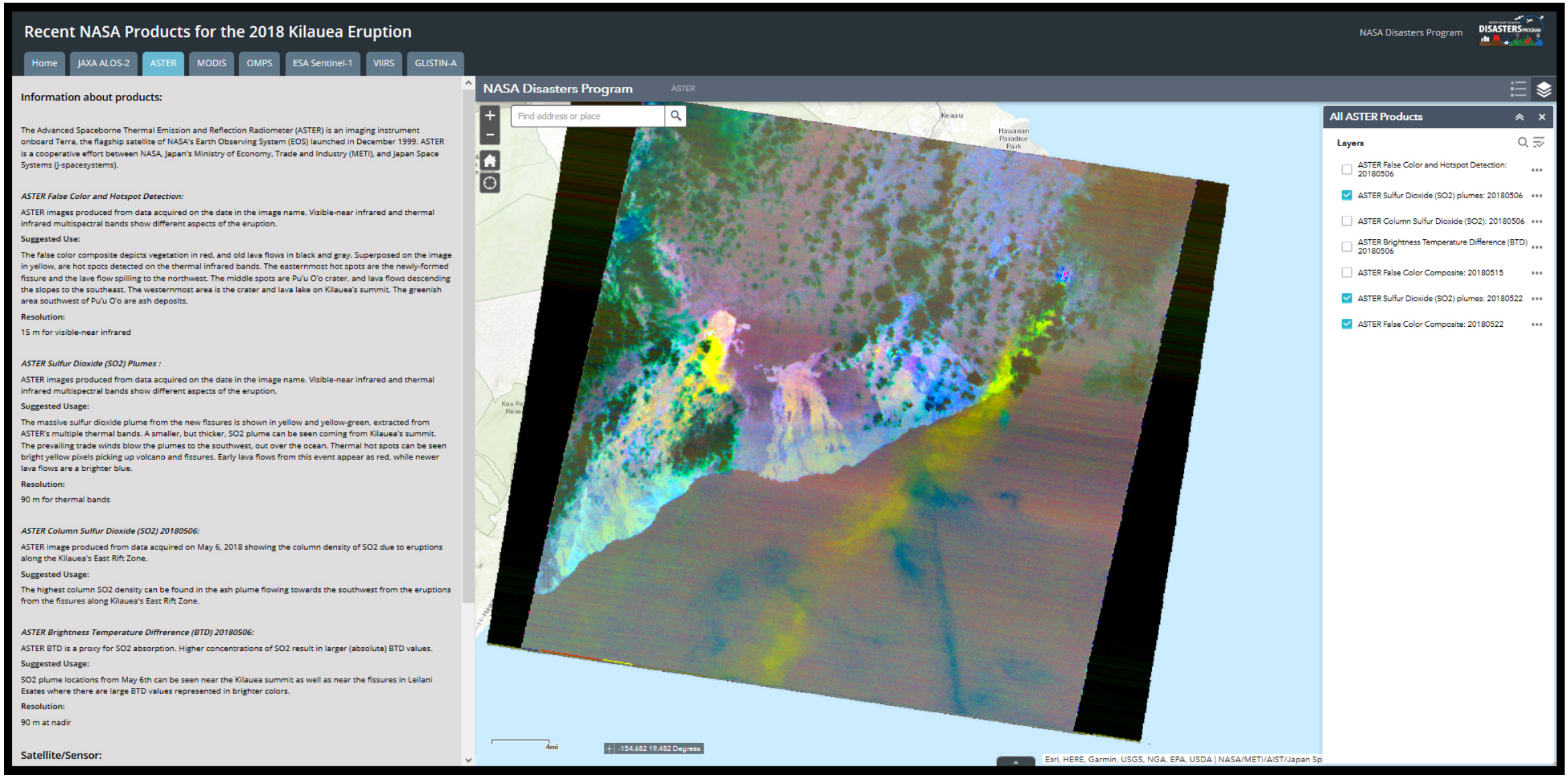

https://maps.disasters.nasa.gov/

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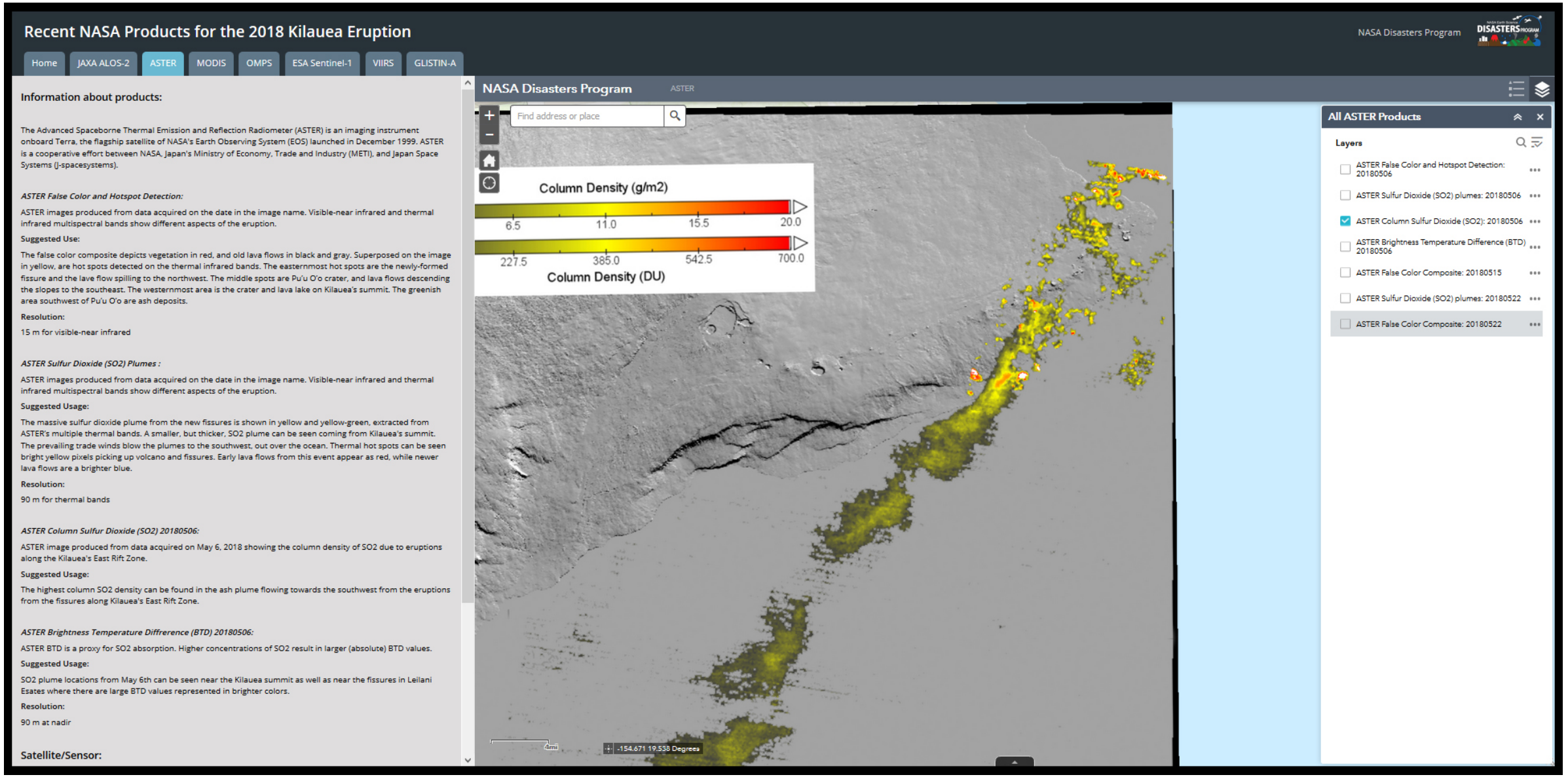

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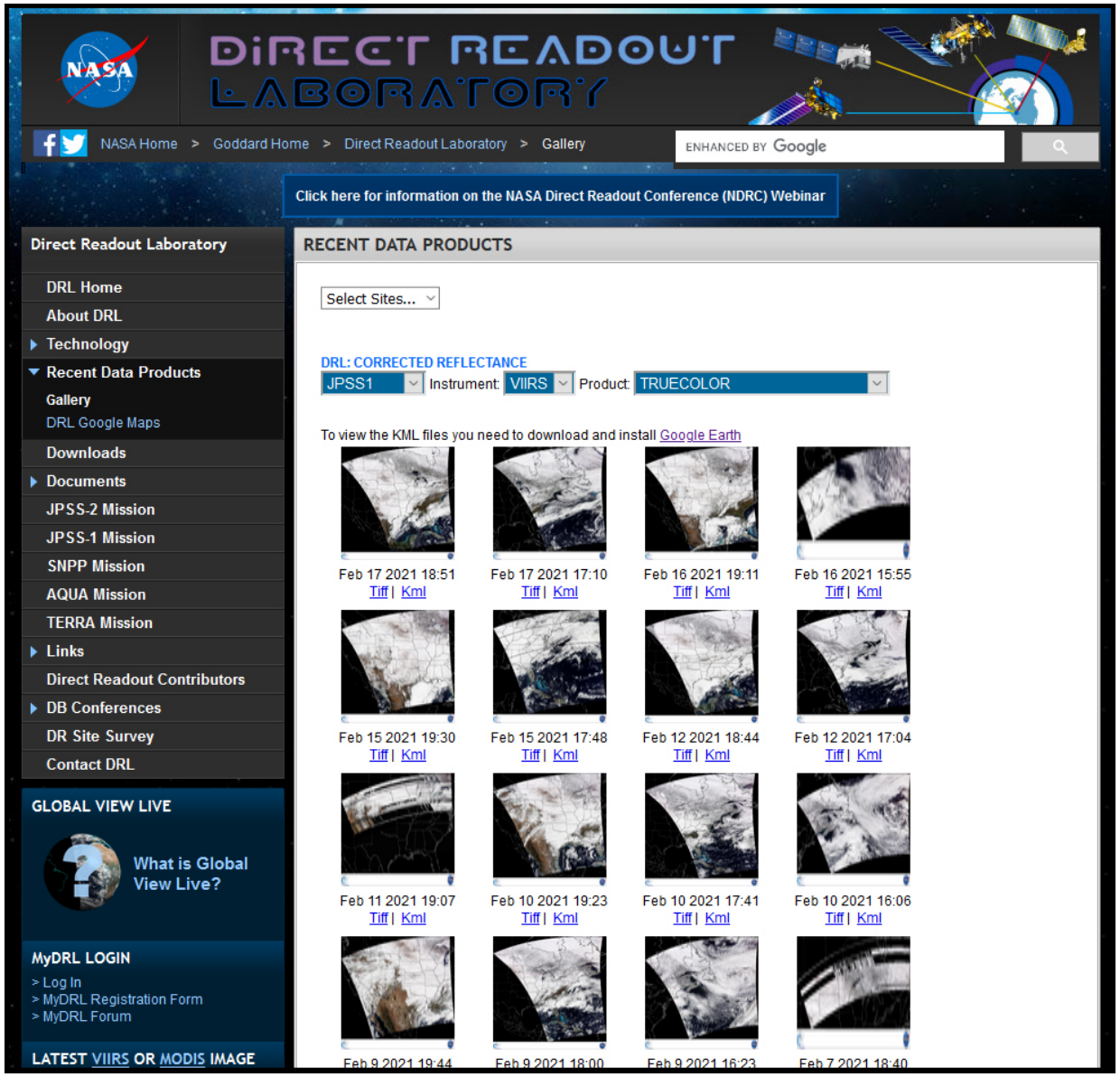

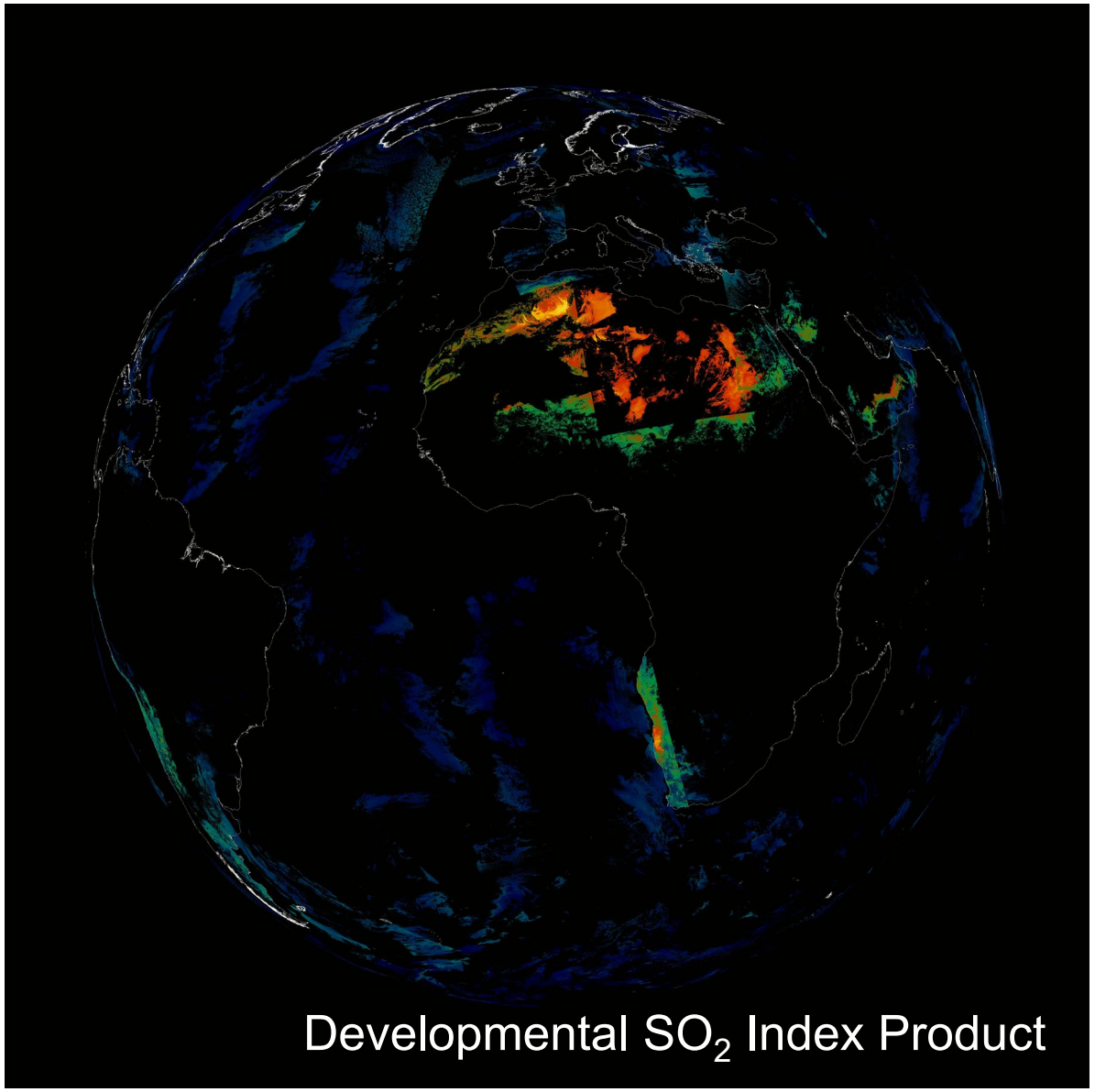

SO_2 Index: Corrections for Emissivity and Water Vapor Absorption

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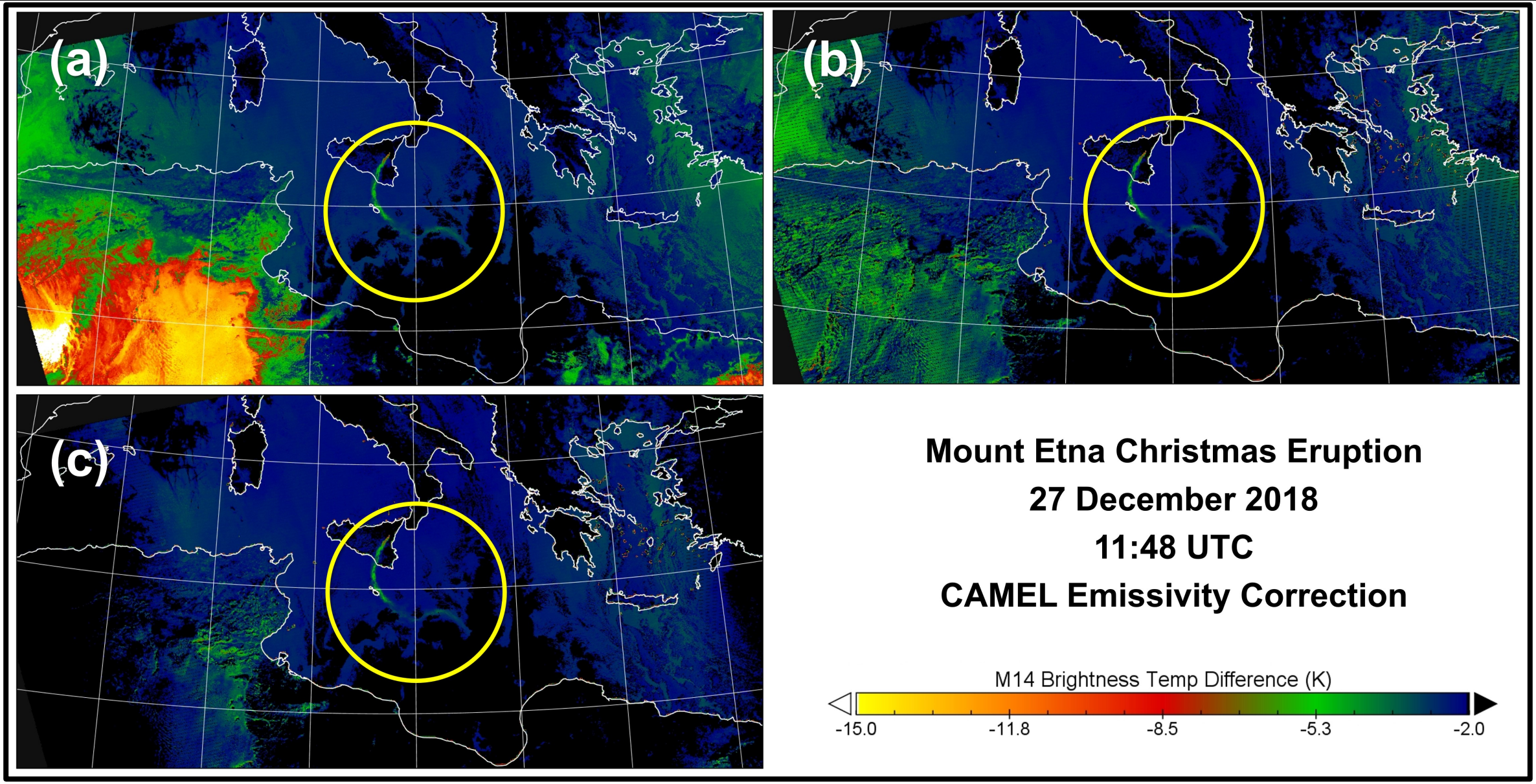

SO_2 Index: Sensitivity to Plume Height and Water Vapor Content Absorption

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Plumes Were Detected in Four Test Cases

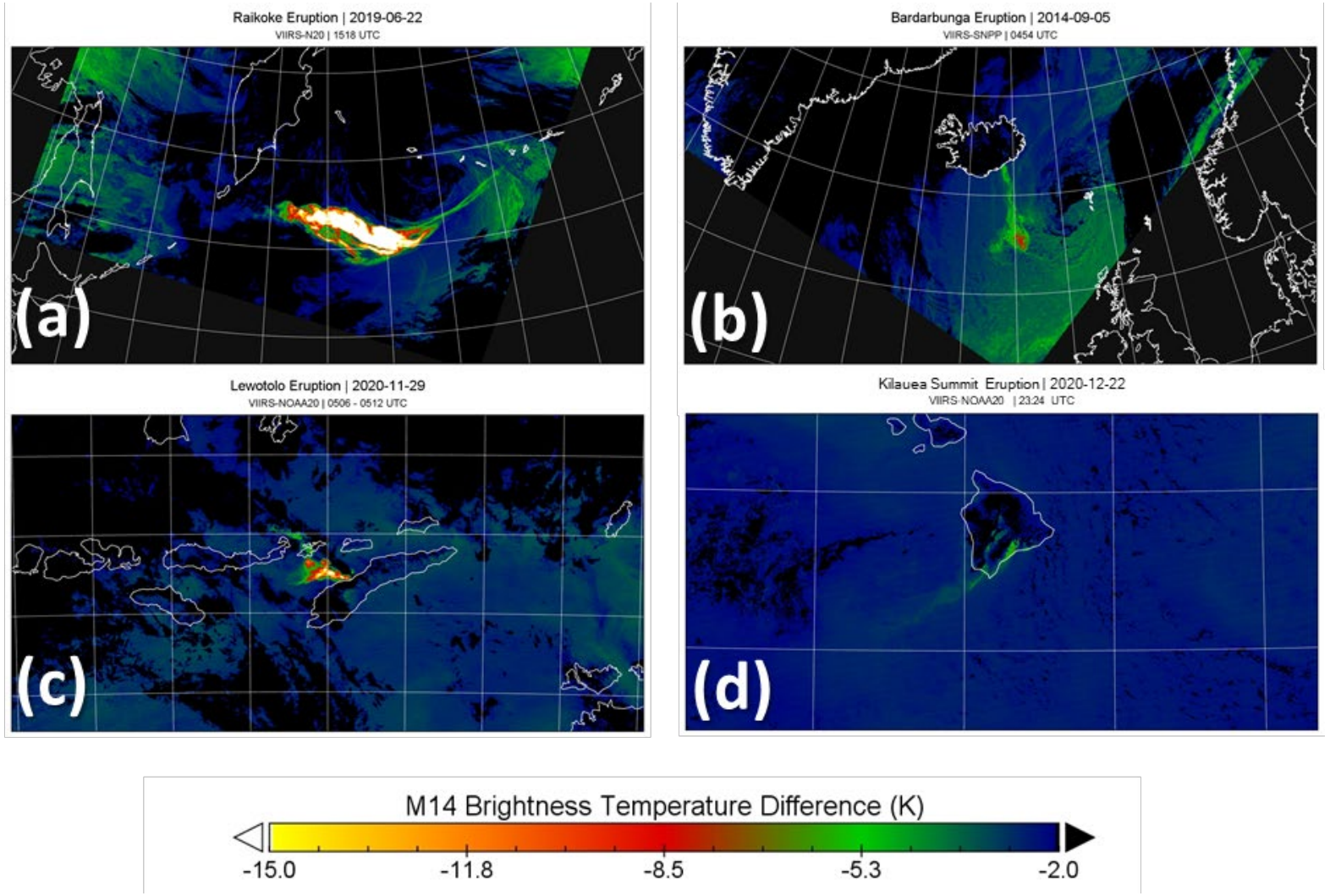
(a) Raikoke: 22 June 2019

(b) Bardarbunga: 5 September 2014

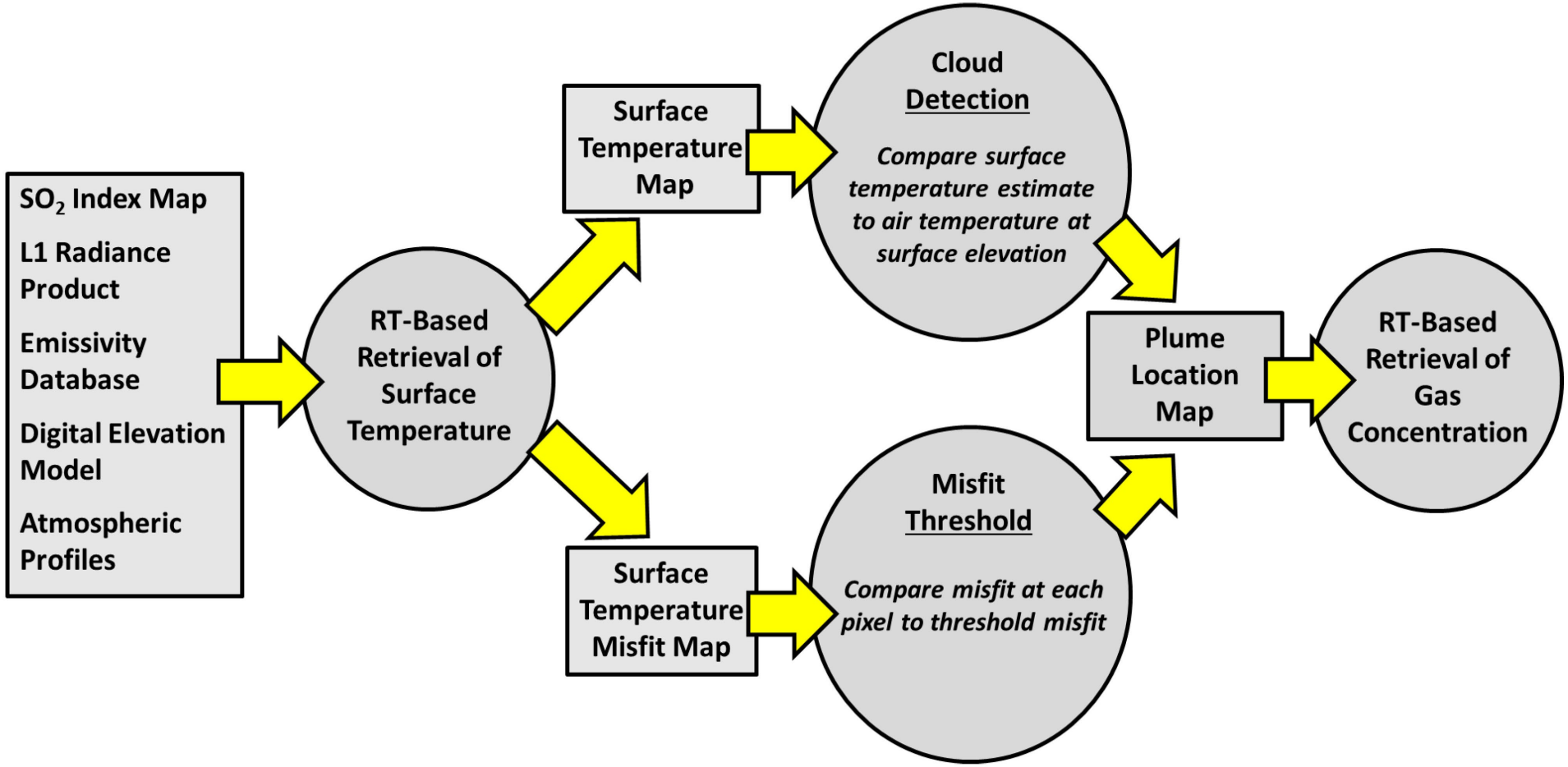
(c) Lewotolok: 29 November 2020

(d) Kilauea: 22 December 2020

Volcano	Latitude	Plume Height (km)	Total Precipitable H_2O (mm)
(a) Raikoke	50° N	10 - 13	22.4
(b) Bardarbunga	62° N	5 - 6	12.6
(c) Lewotolo	9° S	5 - 6	42.9
(d) Kilauea	19° N	~ 2	30.3



Automated Plume Detection and Mapping: Processing Flow



Automated Plume Detection and Mapping: Bardarbunga Volcano (Iceland) 2014-09-05

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a) SO_2 Index: Limits the Surface Temperature Modeling to ~ 20% of Pixels

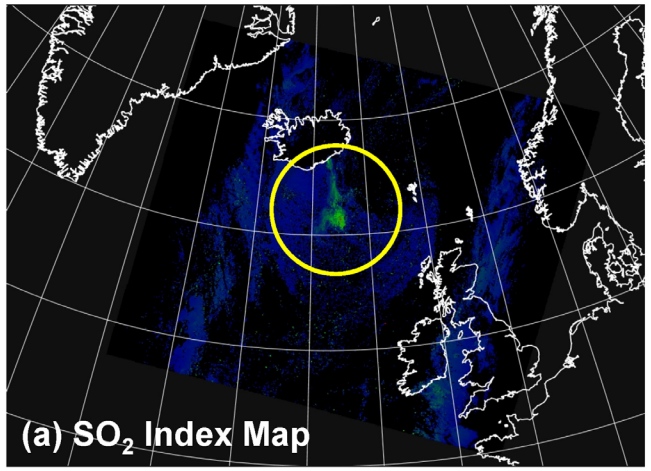
b) No Expression of Plume in Surface Temperature Map

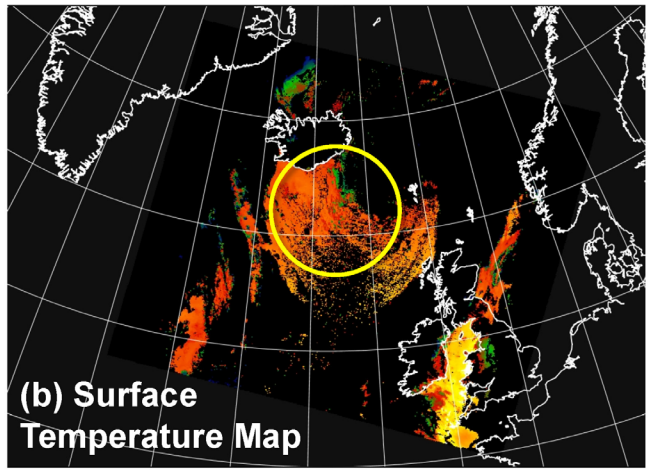
c) Temperature Misfit Map Shows Location of Plume

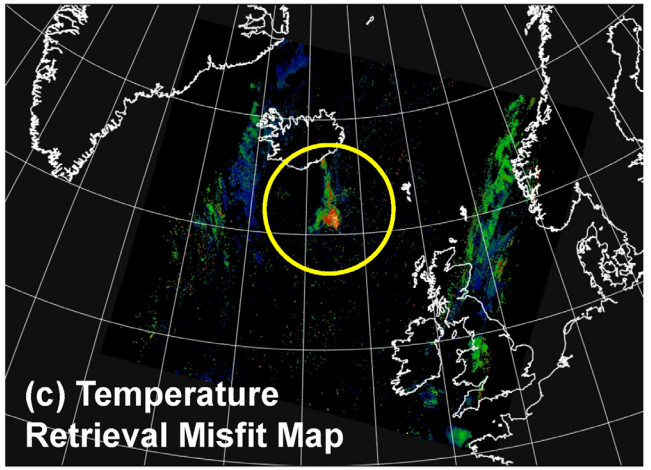
d) Plume Location Map Based on Cloud Detection and Temperature Misfit Combination

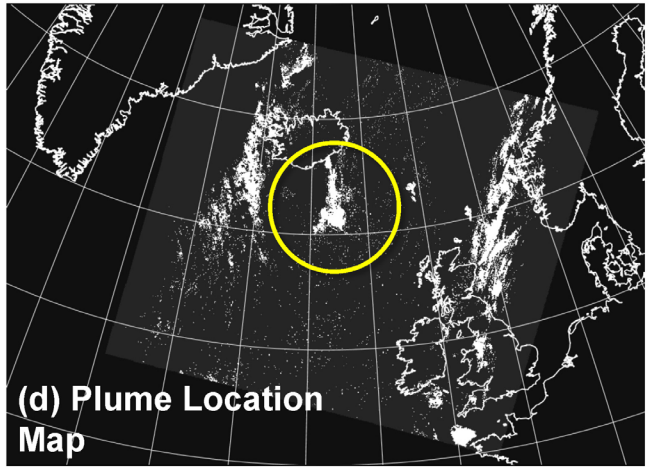
e) SO_2 Estimation Limited to ~7% of Total Pixels

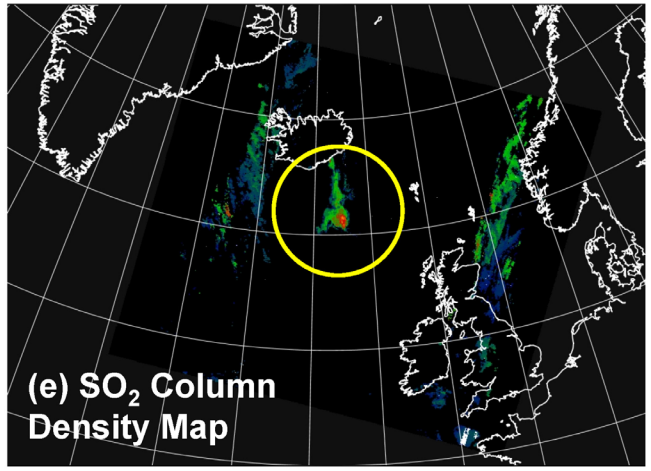
f) No Expression of Plume in Final Misfit Map

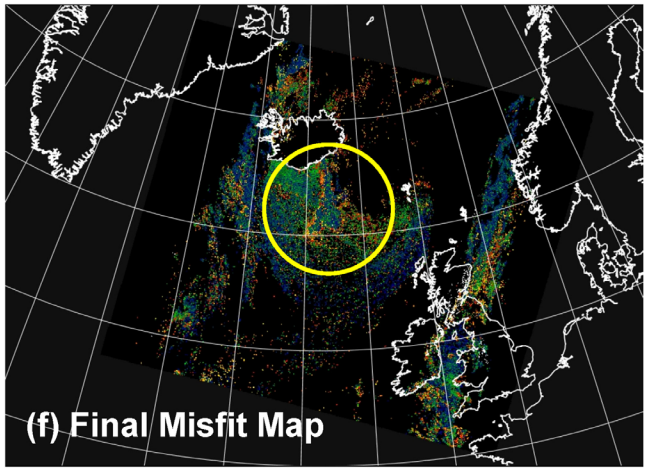










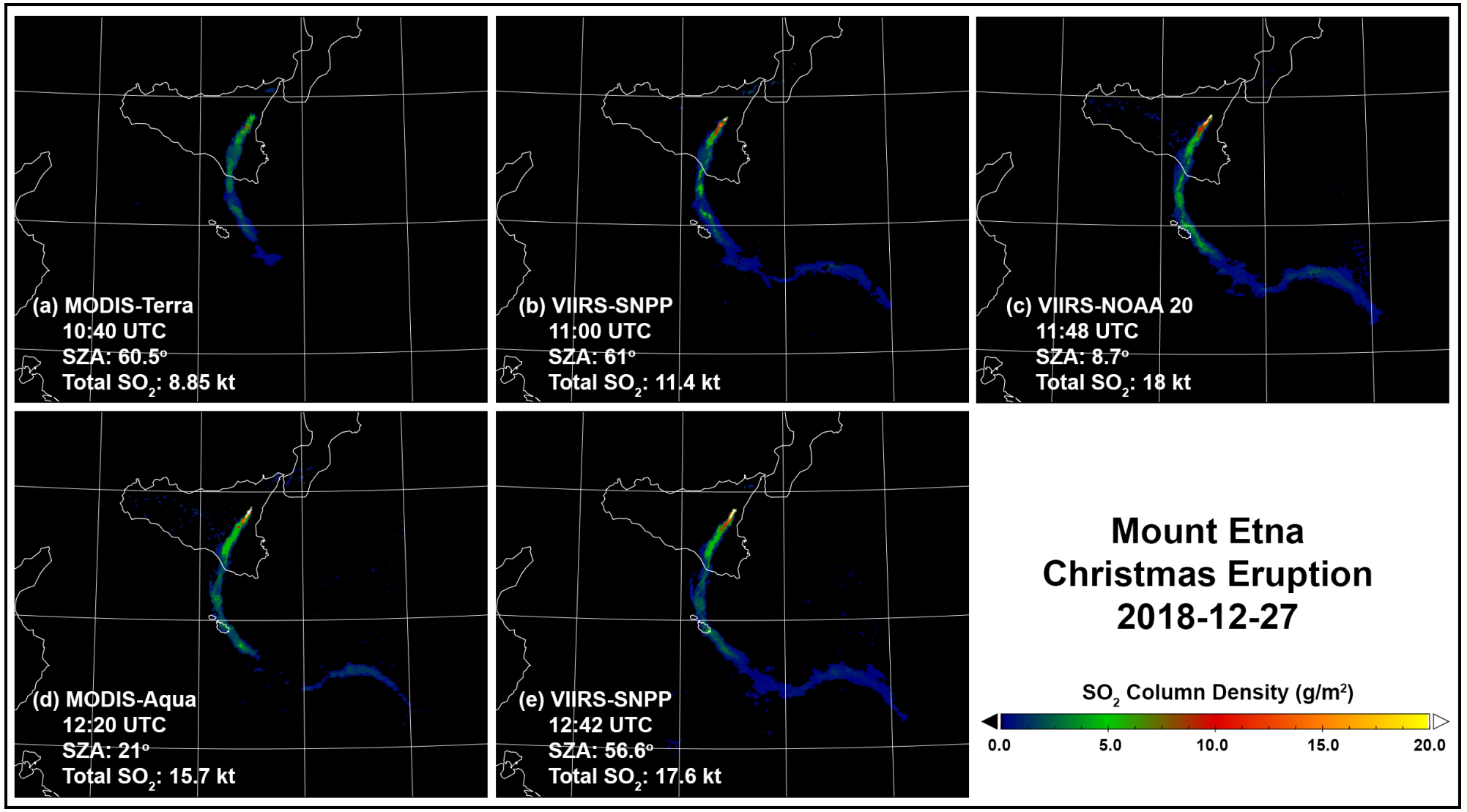


Calibration/Validation: Mt. Etna Example

Jet Propulsion Laboratory
California Institute of Technology

Five Daytime Observations Within Period of ~120 min (average of 36 min between observations)

Validate data products through comparison with field measure-ments and compli-mentary satellite data products (including SEVIRI, IASI, and TROPOMI) provided by Italian National Institute of Geophysics and Volcanology (INGV)



Thanks for Your Attention!