Past & Present UV/VIS imaging spectrometers for Atm. Composition

1980 1990 2000 2010

TOMS Series — O_3 and SO_2 column only

Single PMT detector

GOME/SCIAMACHY Series — BL Trace Gases: NO_2, SO_2, HCHO…. + GHG

1D SS Array detector

Higher Spatial Res

13km x 24km Aura/OMI 2D CCD — Higher Spatial Res

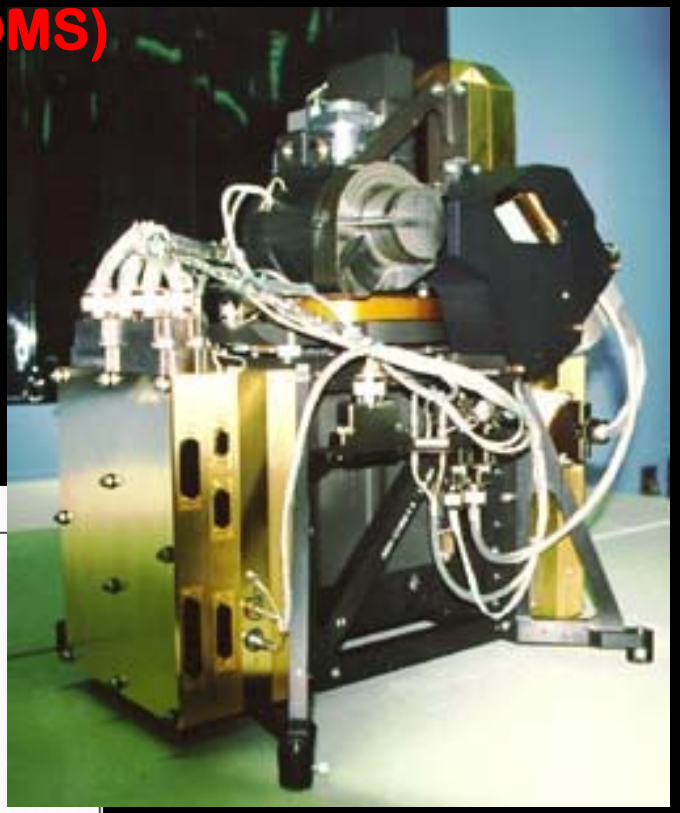
50km x 50km SNPP/OMPS 2D CCD

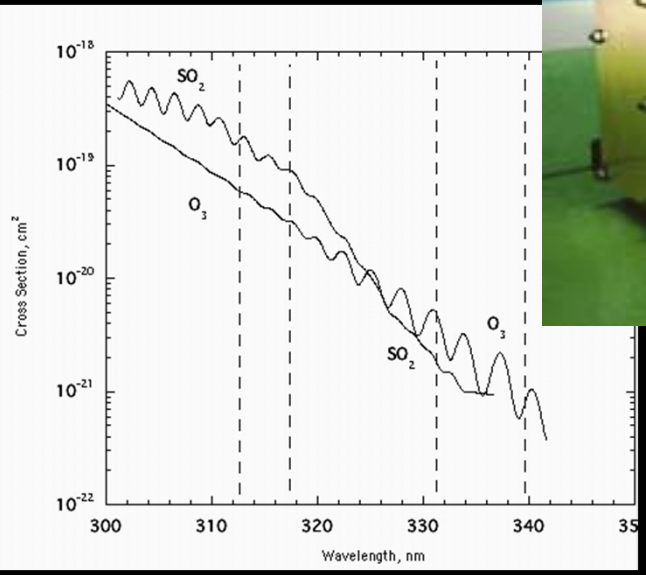
17km x 17km NOAA-20/OMPS 2D CCD

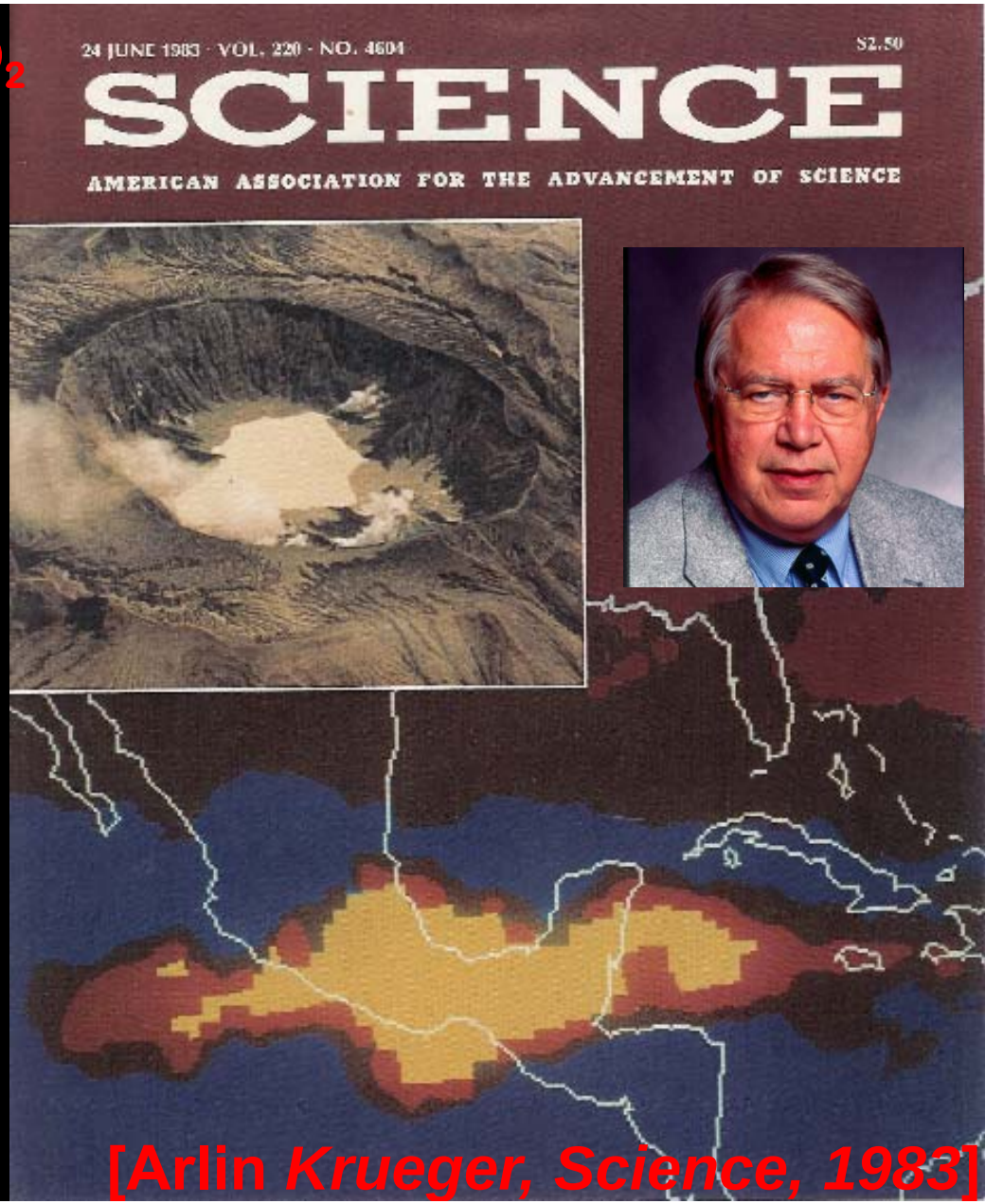
7(5)km x 3.5km Sentinel 5Precursor/ 2D CCD TROPOMI

1980 1990 2000 2010 2017

First detection of April 1982 El Chichon SO_2 cloud with the Total Ozone Mapping Spectrometer (TOMS)



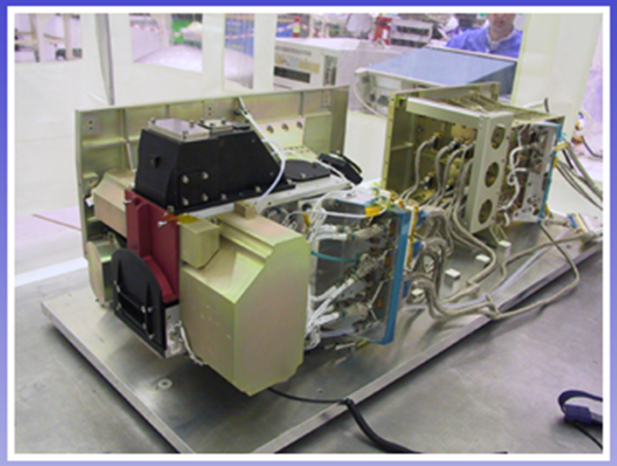


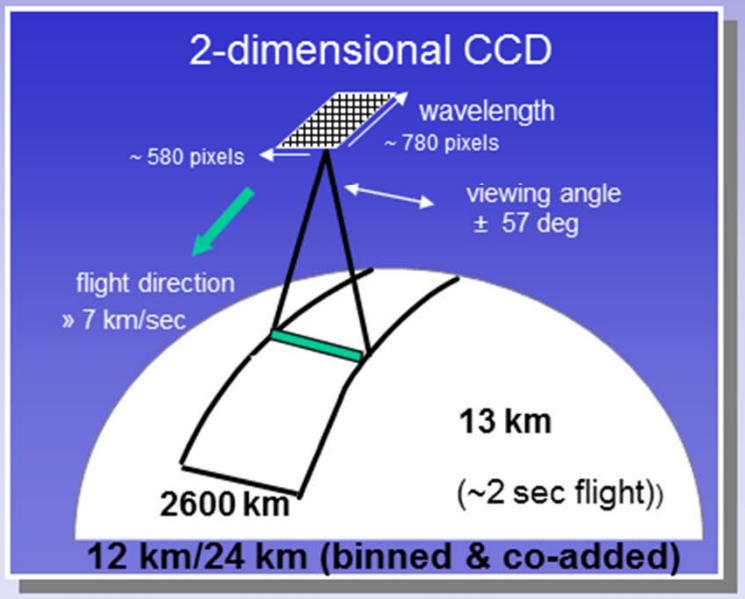


[Arlin *Krueger, Science, 1983*]

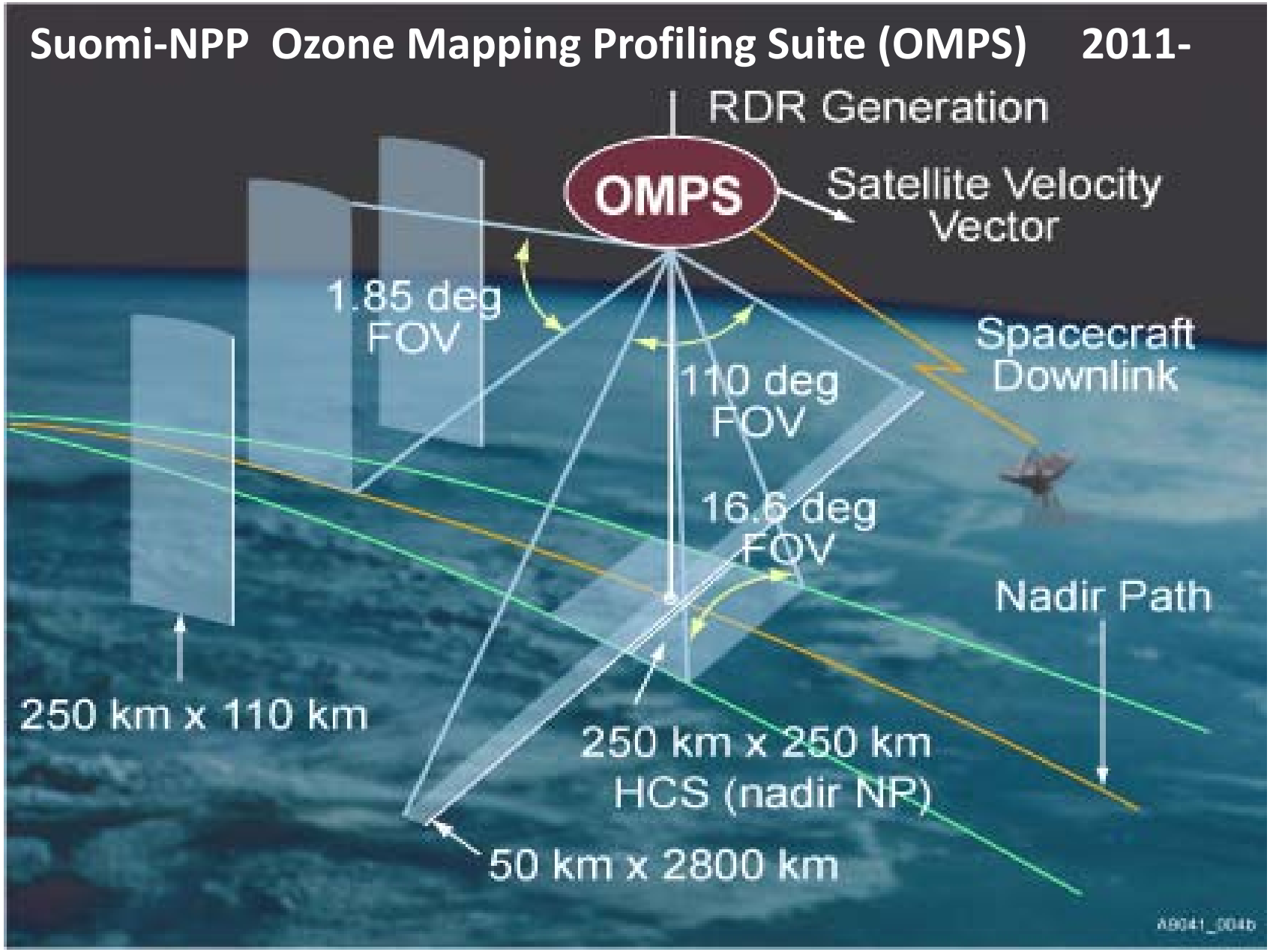
Aura / Ozone Monitoring Instrument (OMI) continues 30+ year O_3 and SO_2 records 2004-

- Joint Dutch-Finnish instrument with Dutch/Finnish.US Science team
  - PI: Pieternel Levelt (KNMI)
- Hyperspectral wide FOV CCD spectrometer
  - 270-500nm
  - 13x24 km nadir footprint (highest resolution)
  - Swath width 2600km (contiguous coverage)
- Launched on NASA EOS Aura platform in 2004
  - http://aura.gsfc.nasa.gov
- Measures total ozone (O_3), O_3 profile, SO_2, NO_2, HCHO, CHO-CHO, aerosols, BrO
- The first sensor to provide daily measurements of anthropogenic pollution from space at high resolution
- ~12+ years of SO_2 and NO_2 measurements of volcanoes and pollution sources: collection 3 and improved data





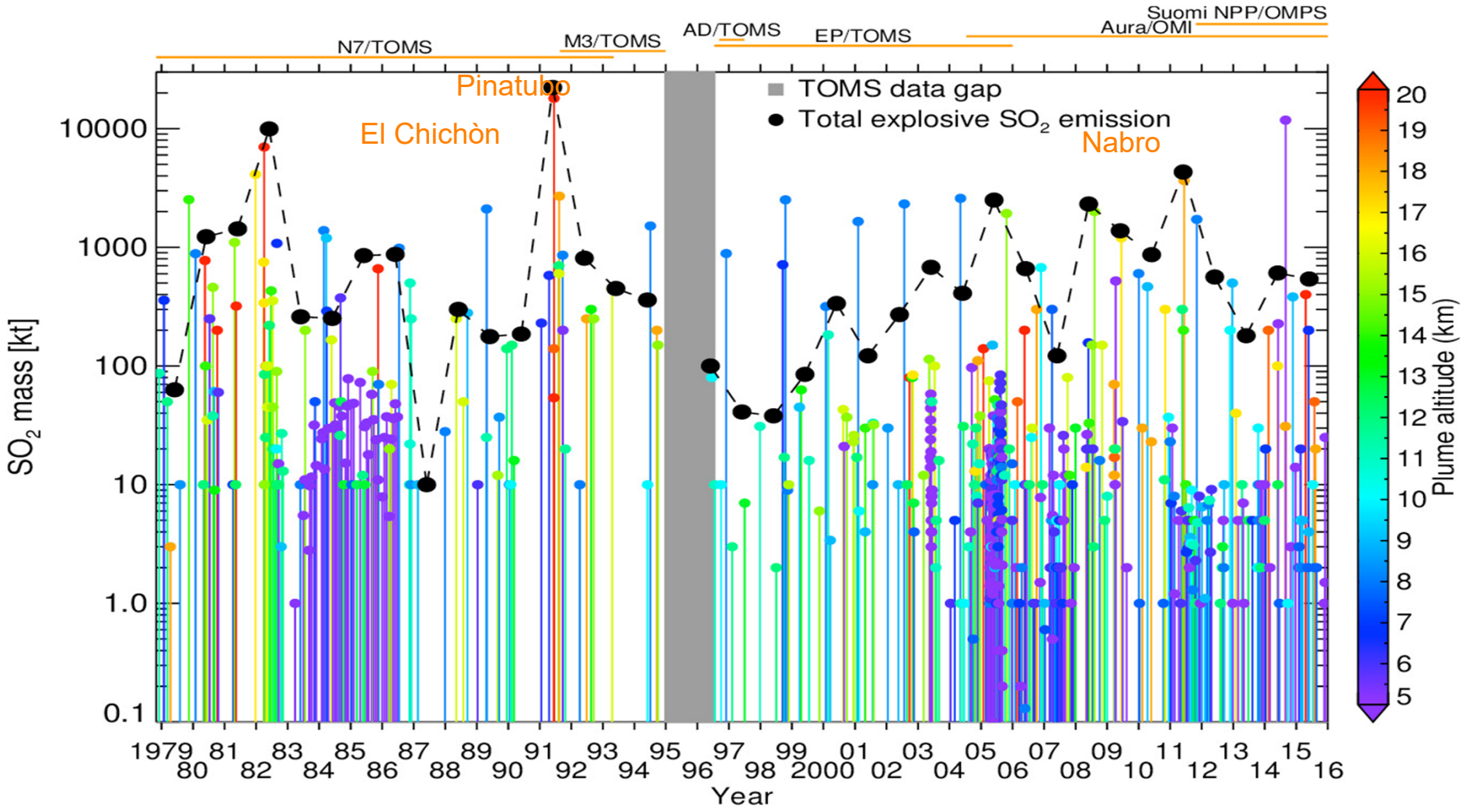
Suomi-NPP Ozone Mapping Profiling Suite (OMPS) 2011-



MSVOLSO2L4: UV multi-satellite volcanic SO_2

https://SO2.gsfc.nasa.gov/MEaSUREs/

[Bluth et al., 1993; Carn et al., 2003, 2015]



National Aeronautics and Space Administration
Goddard Space Flight Center

https://SO2.gsfc.nasa.gov/

Atmospheric Chemistry and Dynamics Laboratory (Code 614)

Global Sulfur Dioxide Monitoring Home Page

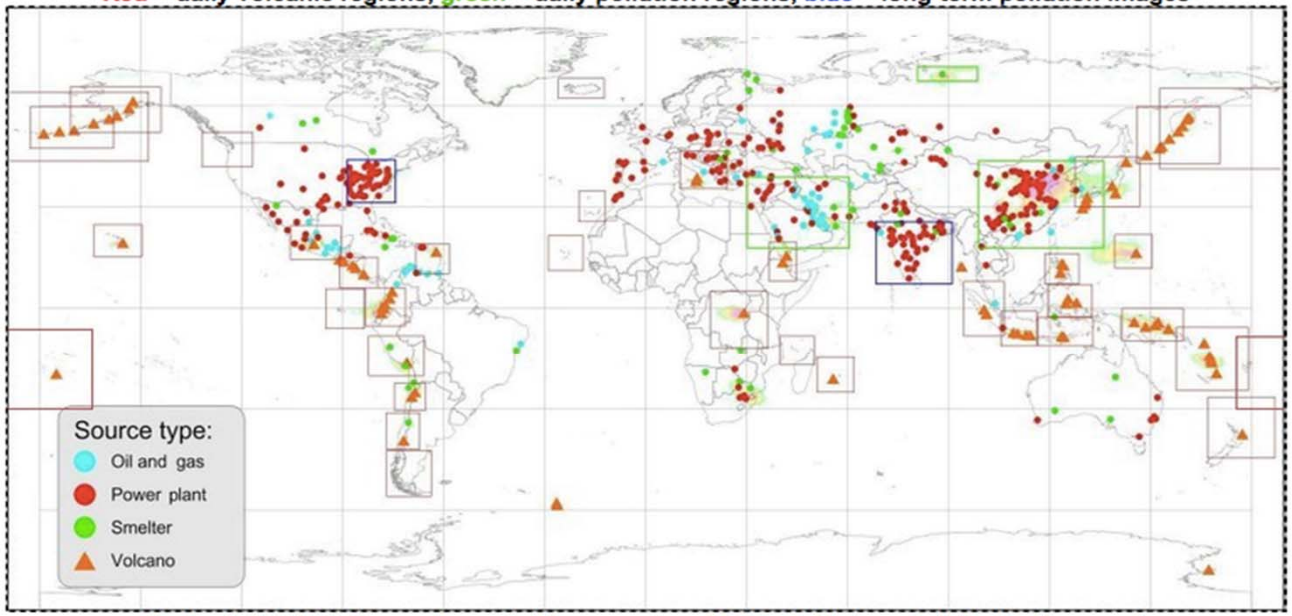
Home | News | Documentation | Publications | Personnel | Links

Latest SO_2 eruption alerts NOAA-NESDIS. SACS_BIRA. IASI-ULB.
SO_2 Near Real-Time Images: NASA(DR). FMI(DR). NASA(NRT). NOAA(NRT). AIRS(NRT). SACS(NRT).

SO_2 climatology from satellite instruments

Latest Daily (OMI/OMPS) Images of SO_2 (click on a highlighted rectangle)

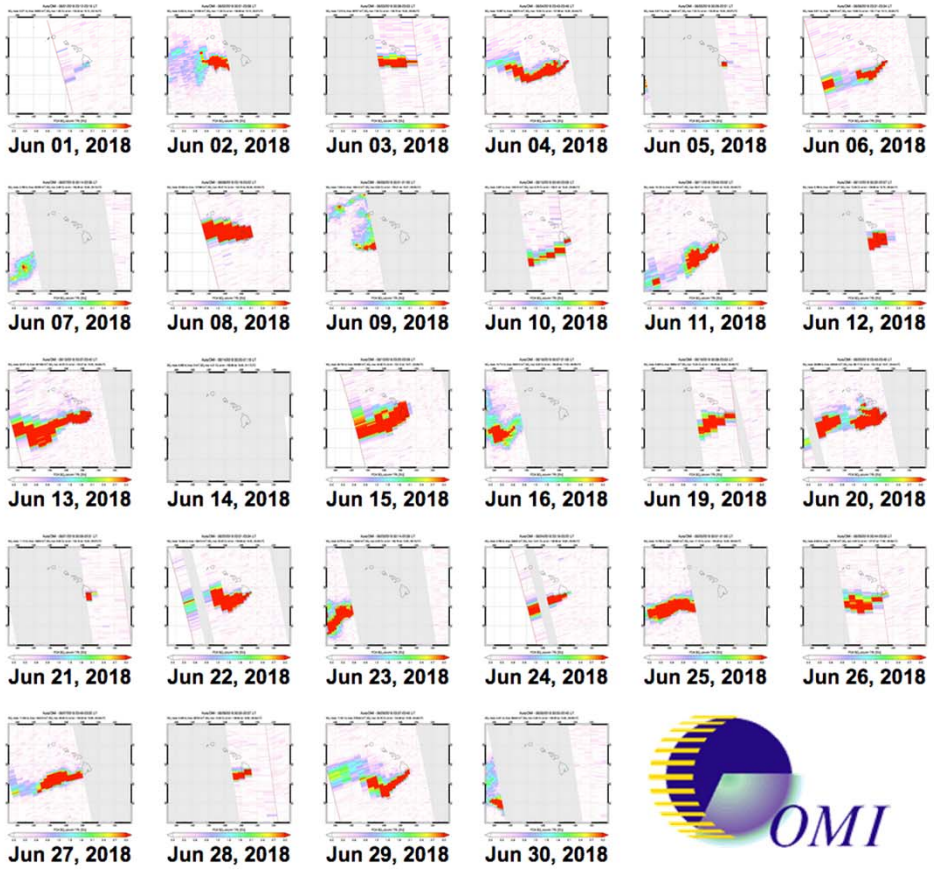
Red = daily volcanic regions, green = daily pollution regions, blue = long-term pollution images



Latest GMAO Experimental forecasts of SO_2 (click outside the boxes)

Hawaii, USA (OMI)

*** BEWARE: data that look like lines (NNW to SSE or NNE to SSW) are probably artifacts ***
*** Missing data are due to OMI row anomaly ***

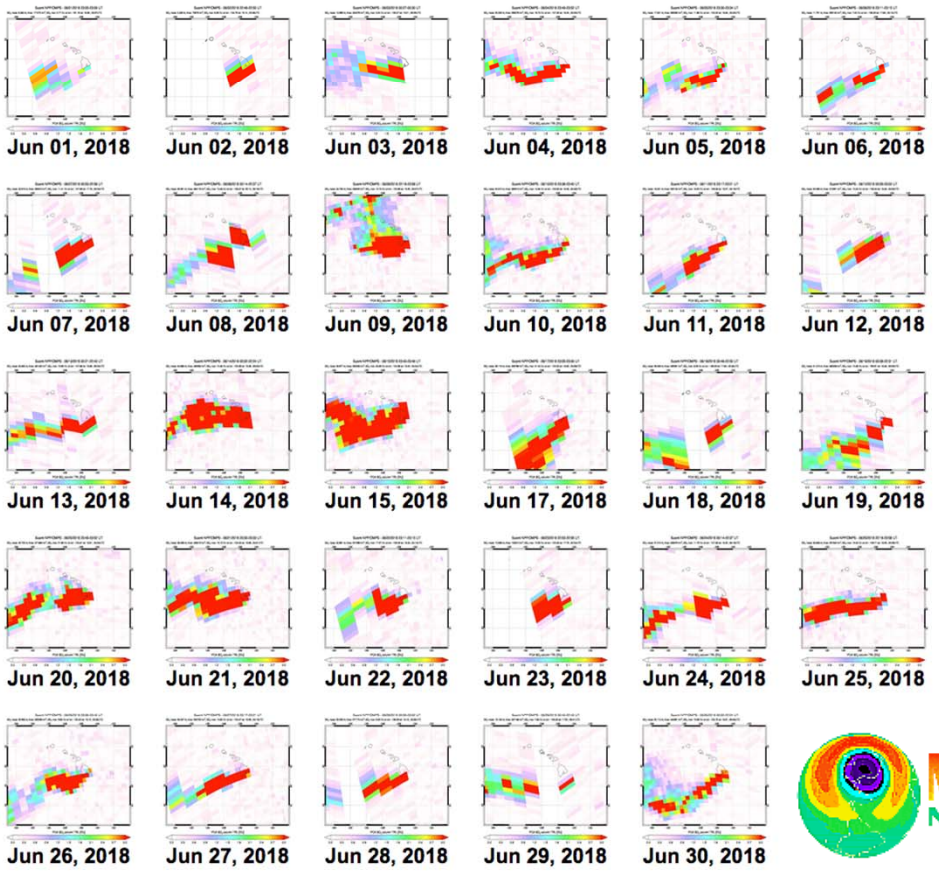


previous month OMPS imgs next month

Time series plot

Hawaii, USA (OMPS)

*** Data used for these OMPS images include non-standard products generated by NASA's Ozone PEATE ***

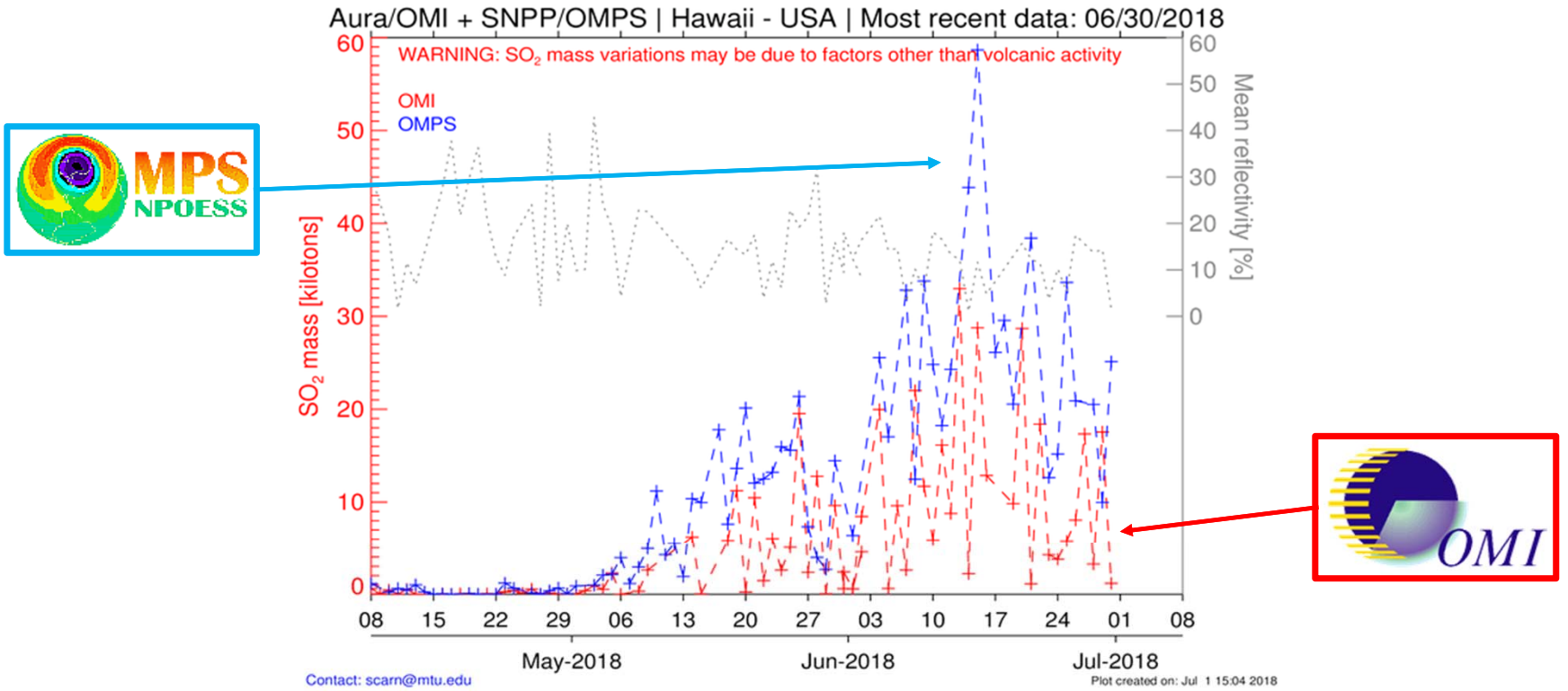


previous month OMI PCA imgs next month

Time series plot

s3_post17.php?yr=18&mo=06&dy=07&bn=hawaii

OMPS data for time series plot

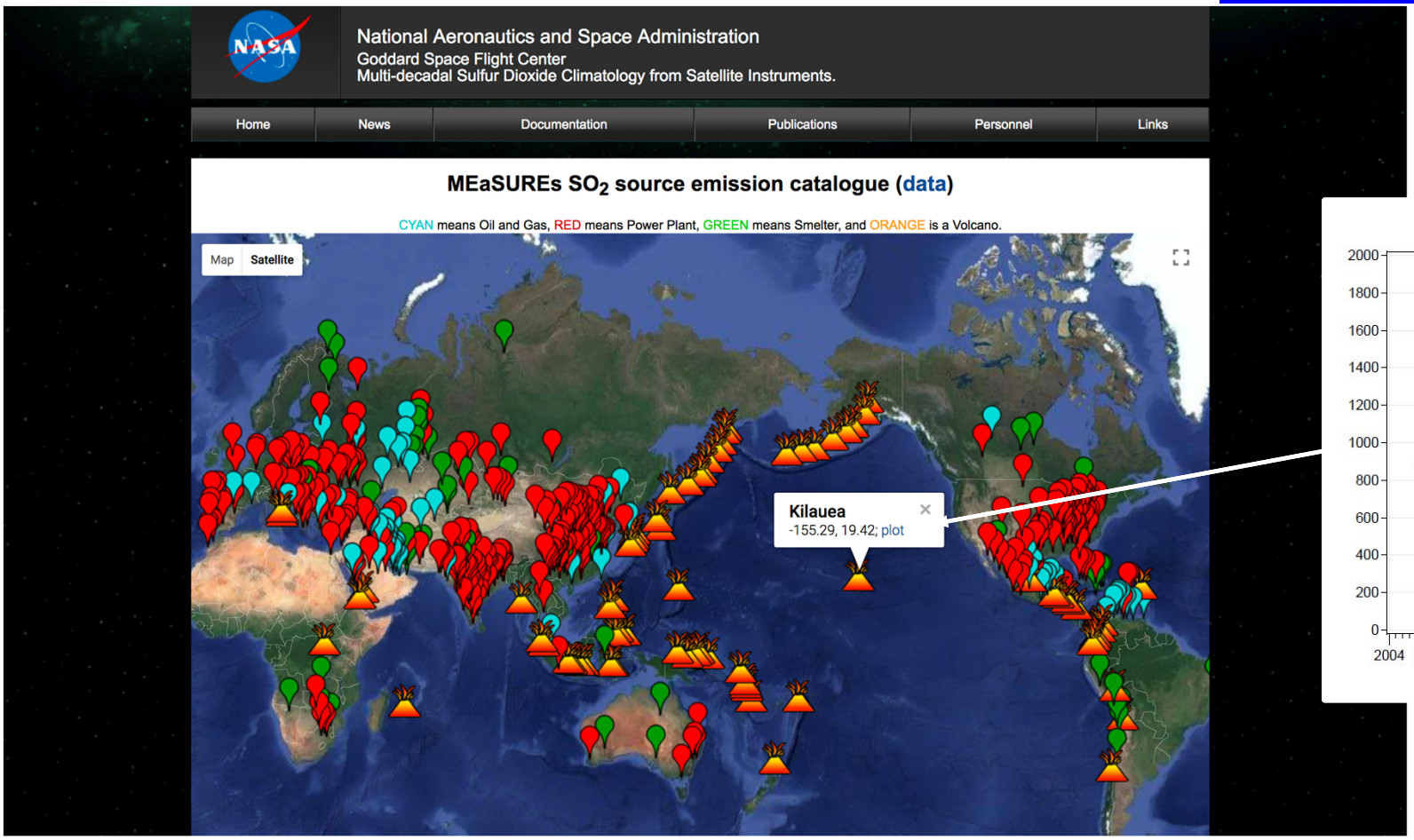

Aura/OMI + SNPP/OMPS | Hawaii - USA | Most recent data: 06/30/2018
WARNING: SO_2 mass variations may be due to factors other than volcanic activity
OMI
OMPS
SO_2 mass [kilotons]
Mean reflectivity [%]
0
10
20
30
40
50
60
08
15
22
29
06
13
20
27
03
10
17
24
01
08
May-2018
Jun-2018
Jul-2018
Contact: scarn@mtu.edu
Plot created on: Jul 1 15:04 2018

Annual SO_2 emissions and plots (2005-2017) for > 500 point sources are posted: MSAQSO2L4

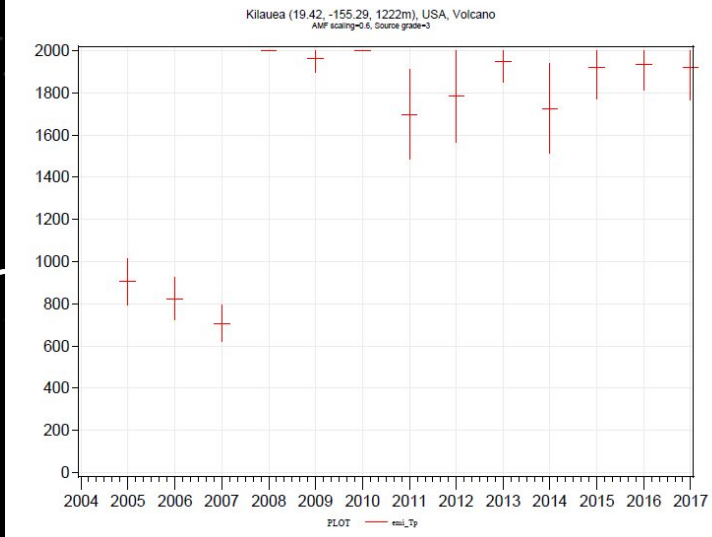
Environment Canada Environnement Canada

https://SO2.gsfc.nasa.gov/MEaSUREs/

https://disc.gsfc.nasa.gov/datasets/MSAQSO2L4_V1/summary

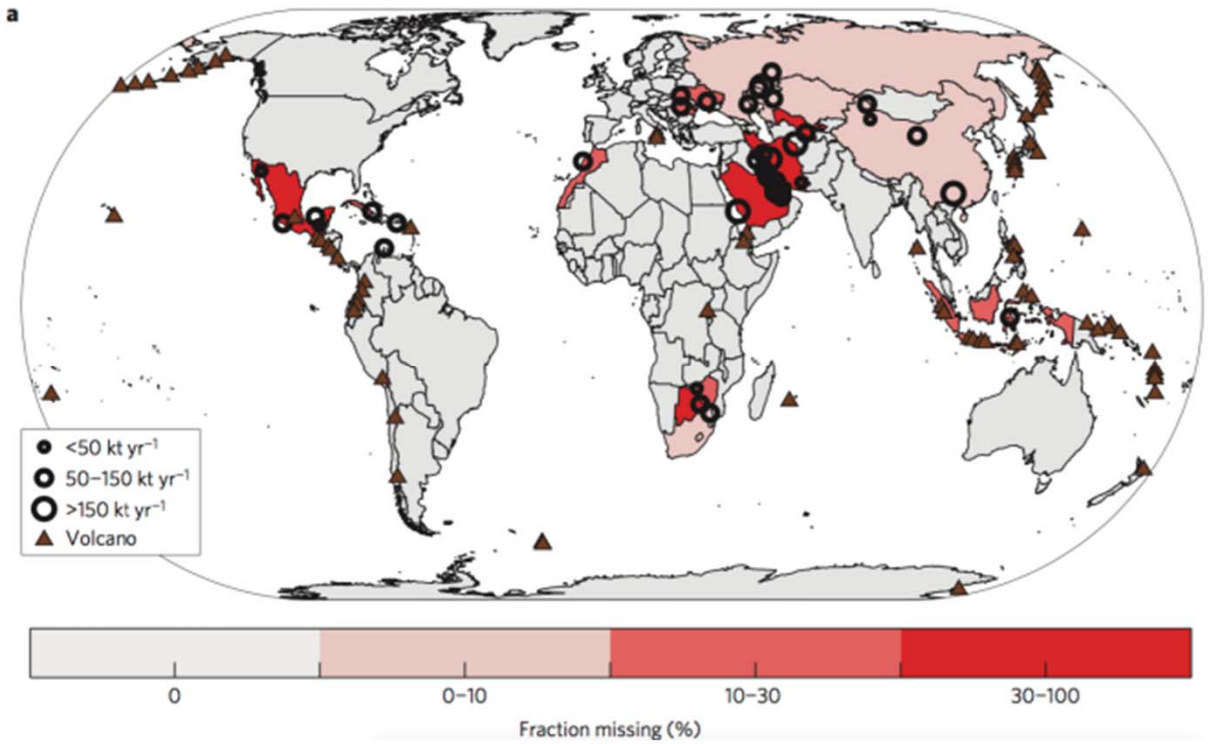


Annual SO_2 emissions: ktons/year



Environment Canada | Environnement Canada

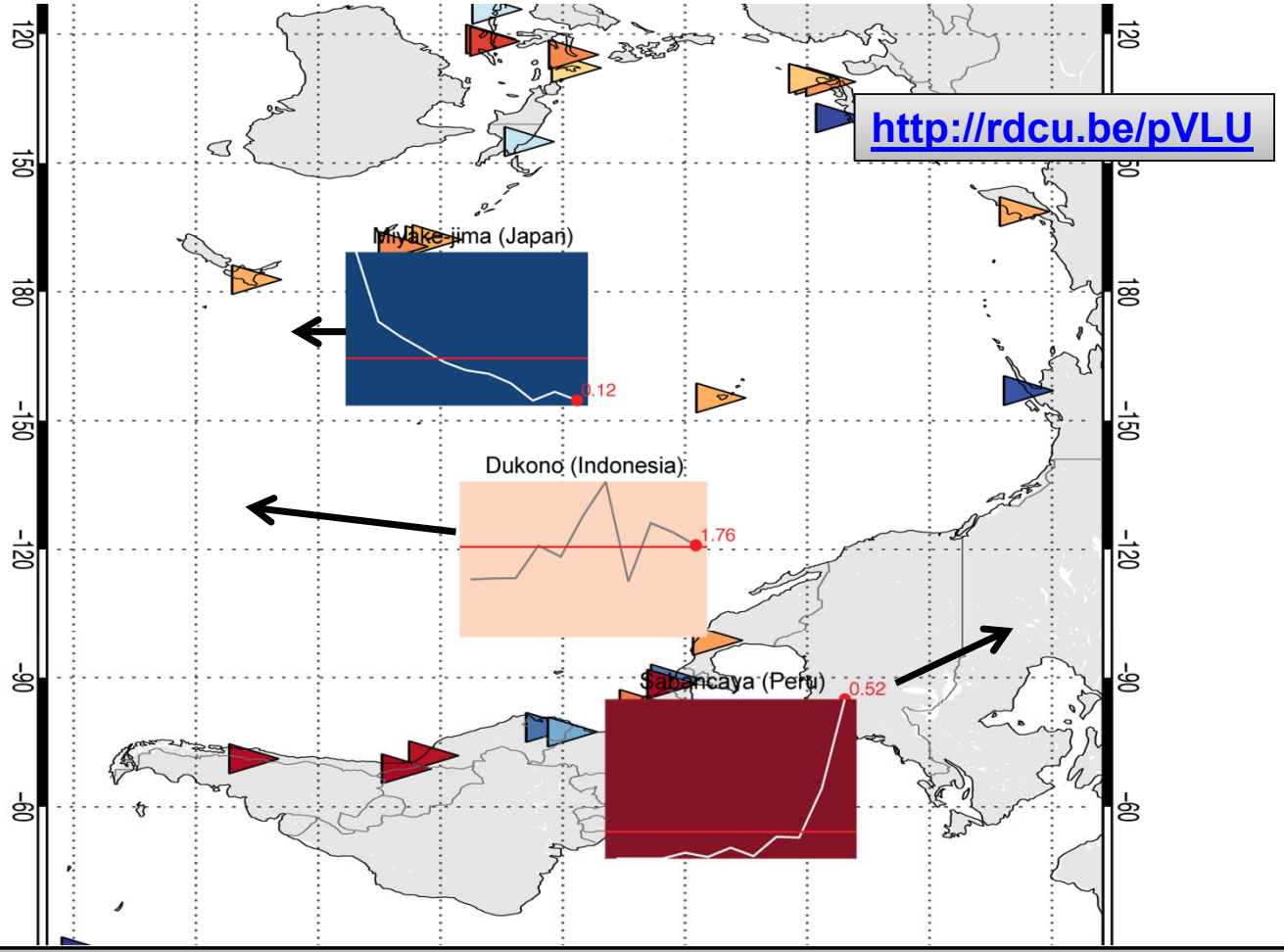
OMI detects "missing" SO_2 sources from traditional "bottom-up" inventories



- An independent "top-down" global SO_2 emission inventory
- Annual emissions quantified for ~500 large sources, ~40 missing or unreported in "bottom-up" inventories, or ~6-12% of the total anthropogenic sources;
- Emissions quantified for 90 volcanoes – large differences between OMI measurements and the Aerocom database.

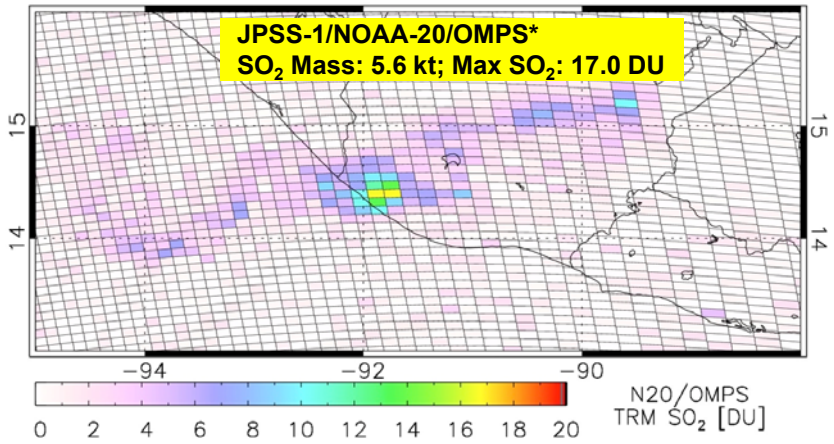
[*McLinden et al.*, NG 2016];

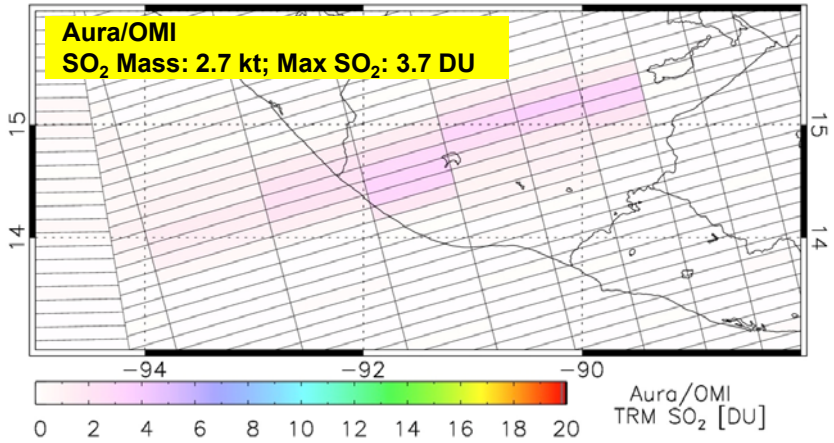
Satellite Data Reveal Global Trends in Volcanic SO_2 Emissions

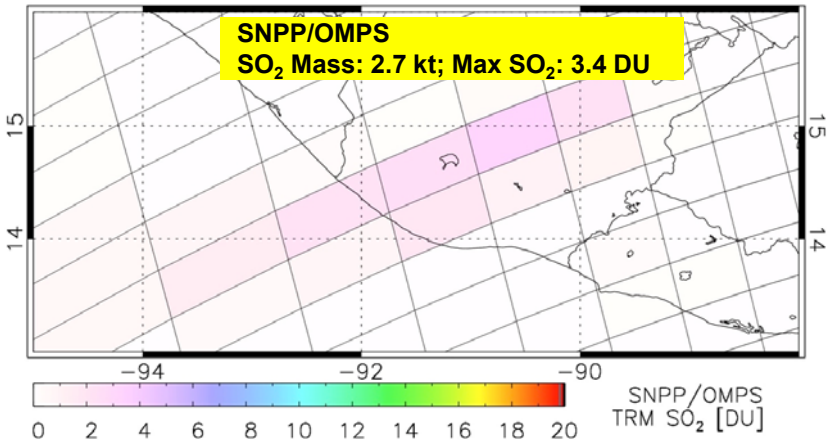


A decade of NASA Aura/OMI volcanic SO_2 measurements (2005-2015) has been used to create the first *global* volcanic emissions inventory, providing new insights into the variability and trends in volcanic degassing. [Carn et al., Sci. Rep. 2017]

Continuing research Aura/OMI with operational Suomi NPP OMPS with NOAA-20/OMPS: 2018 Fuego eruption

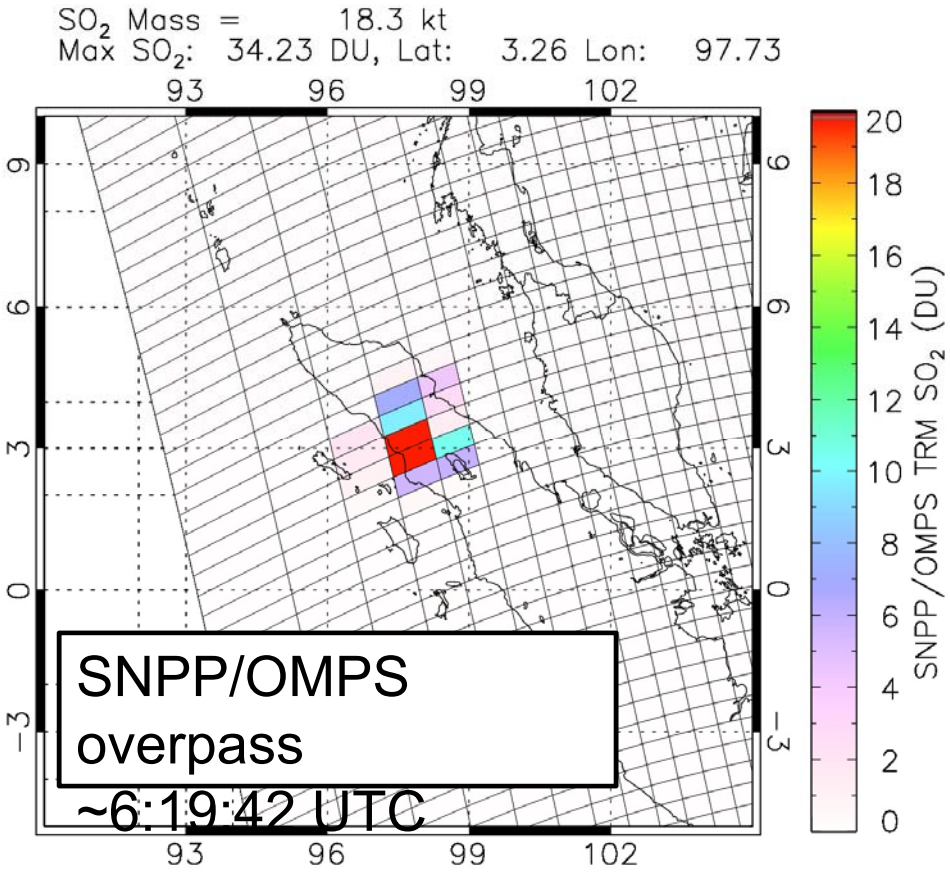


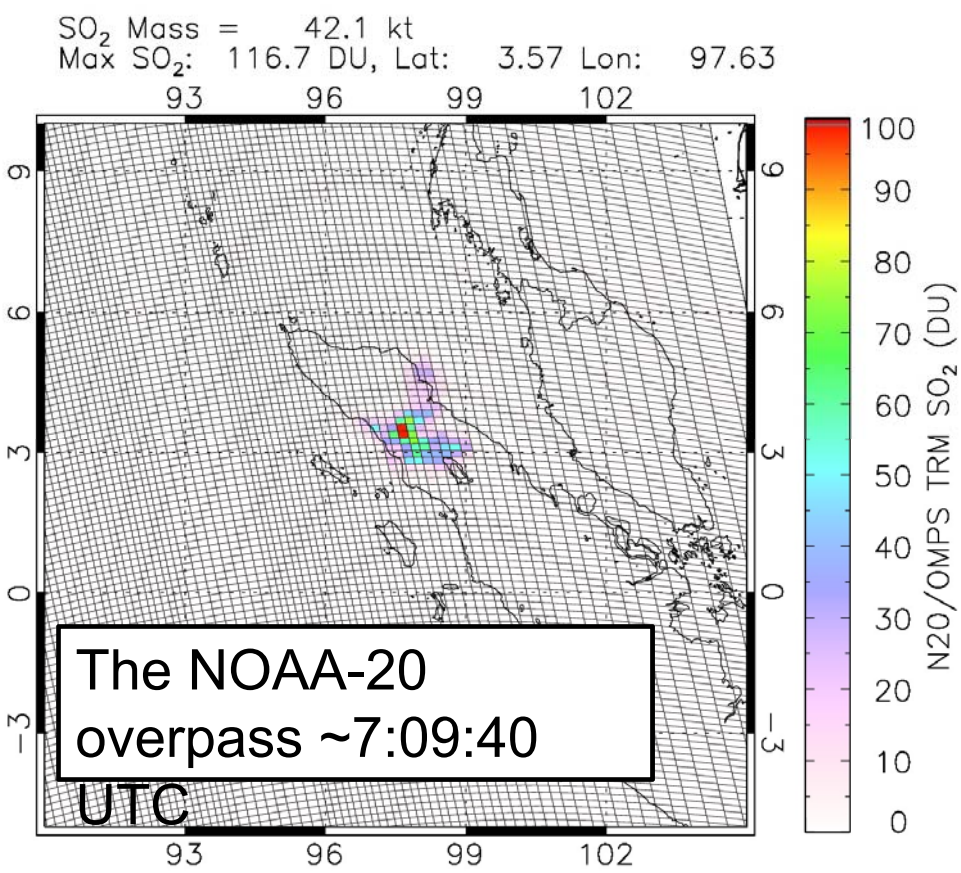




- Maps show SO_2 column amounts in Dobson Units (1 DU = 2.69 × 10^{16} molecules/cm^2) detected by JPSS-1/NOAA-20 (N20)/OMPS, Aura/OMI, and SNPP/OMPS, after the eruption of **Feugo volcano** on Feb. 1, 2018.
- Footprints of the instruments are overlaid on the maps, showing much higher resolution offered by N20/OMPS.
- Such high-resolution measurements reveal greater details and cover a larger portion of the volcanic plume, and yield a higher and likely more accurate (albeit preliminary) estimate of SO_2 injection from the eruption, a key input for climate models.

High resolution SO_2 Retrievals from JPSS-1/NOAA-20 OMPS Reveal Greater Details of Sinabung Volcanic Plume



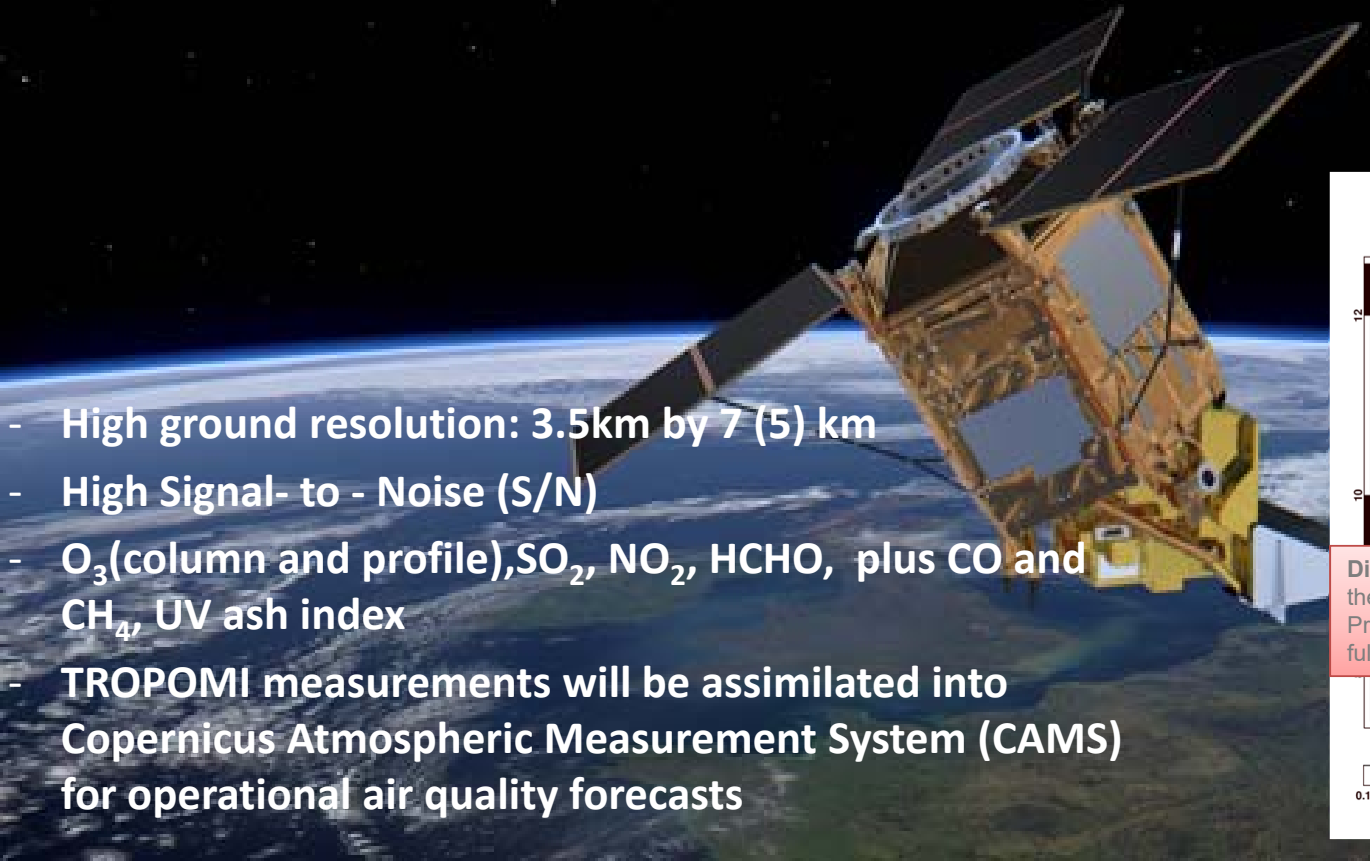


Sinabung volcanic SO_2 cloud measured on February 19 2018

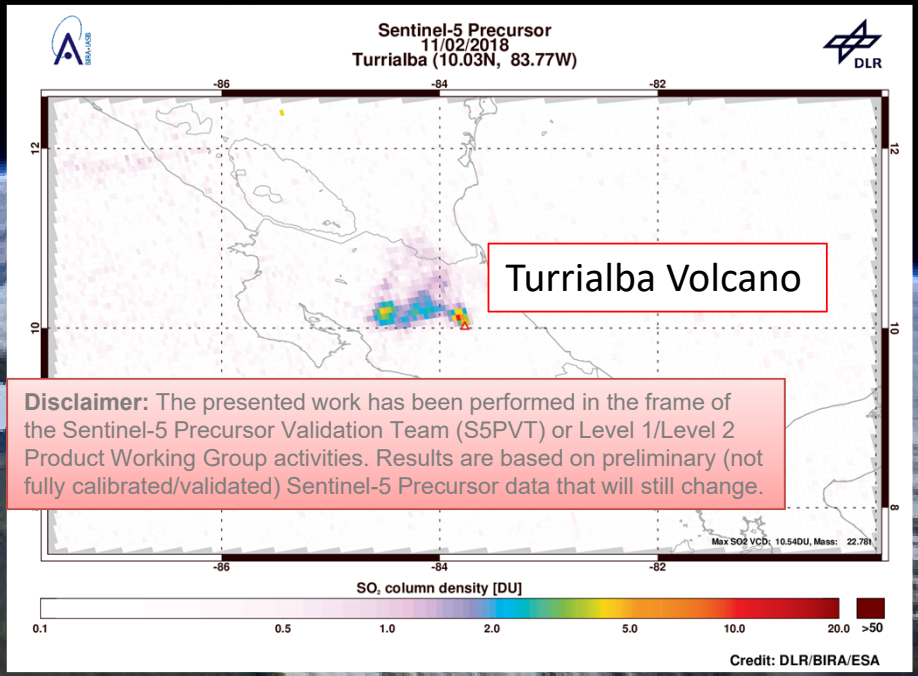
Sentinel 5 Precursor (S5P) / TROPOMI

PI: Pepijn Veefkind (KNMI)
Mission manager: Claus Zehner (ESA/ESRIN)
Data processing : Diego Loyola (DLR)

Sentinel 5 Precursor TROPOspheric Monitor (TROPOMI)
Launched on October 13 2017
Public release in 2018

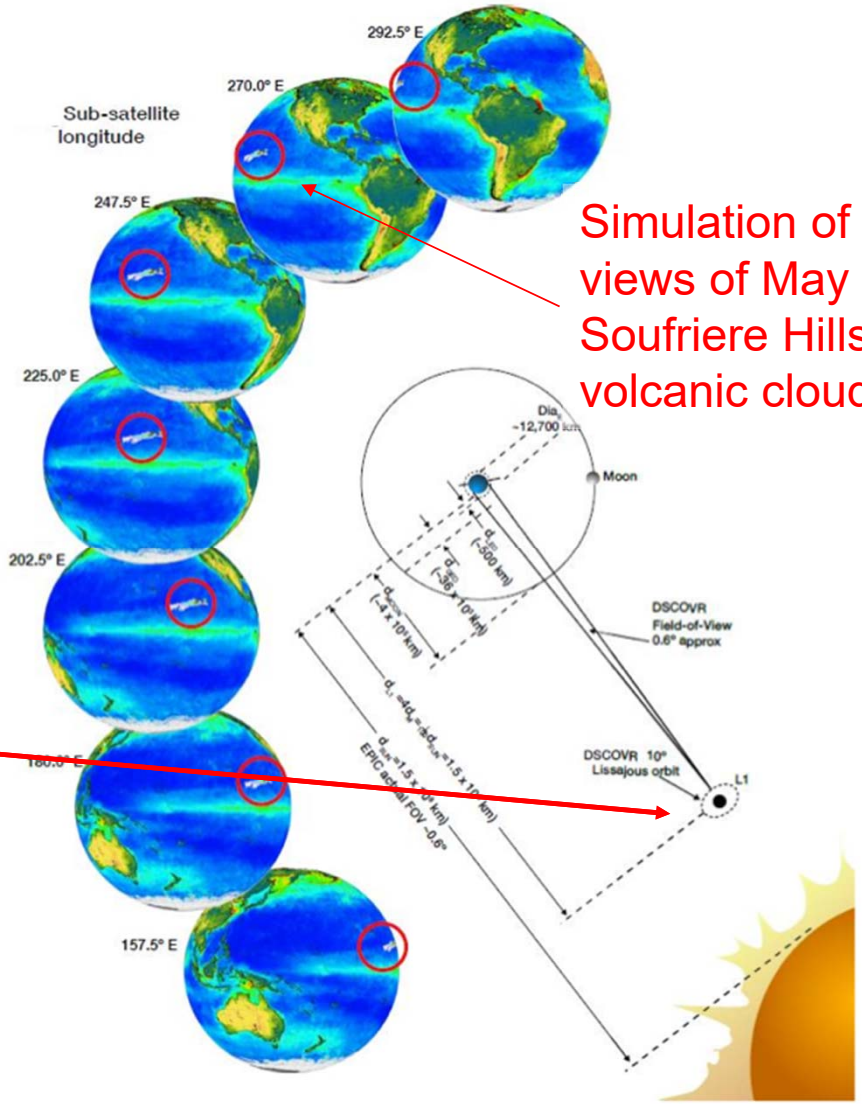


- High ground resolution: 3.5km by 7 (5) km
- High Signal- to - Noise (S/N)
- O_3(column and profile),SO_2, NO_2, HCHO, plus CO and CH_4, UV ash index
- TROPOMI measurements will be assimilated into Copernicus Atmospheric Measurement System (CAMS) for operational air quality forecasts



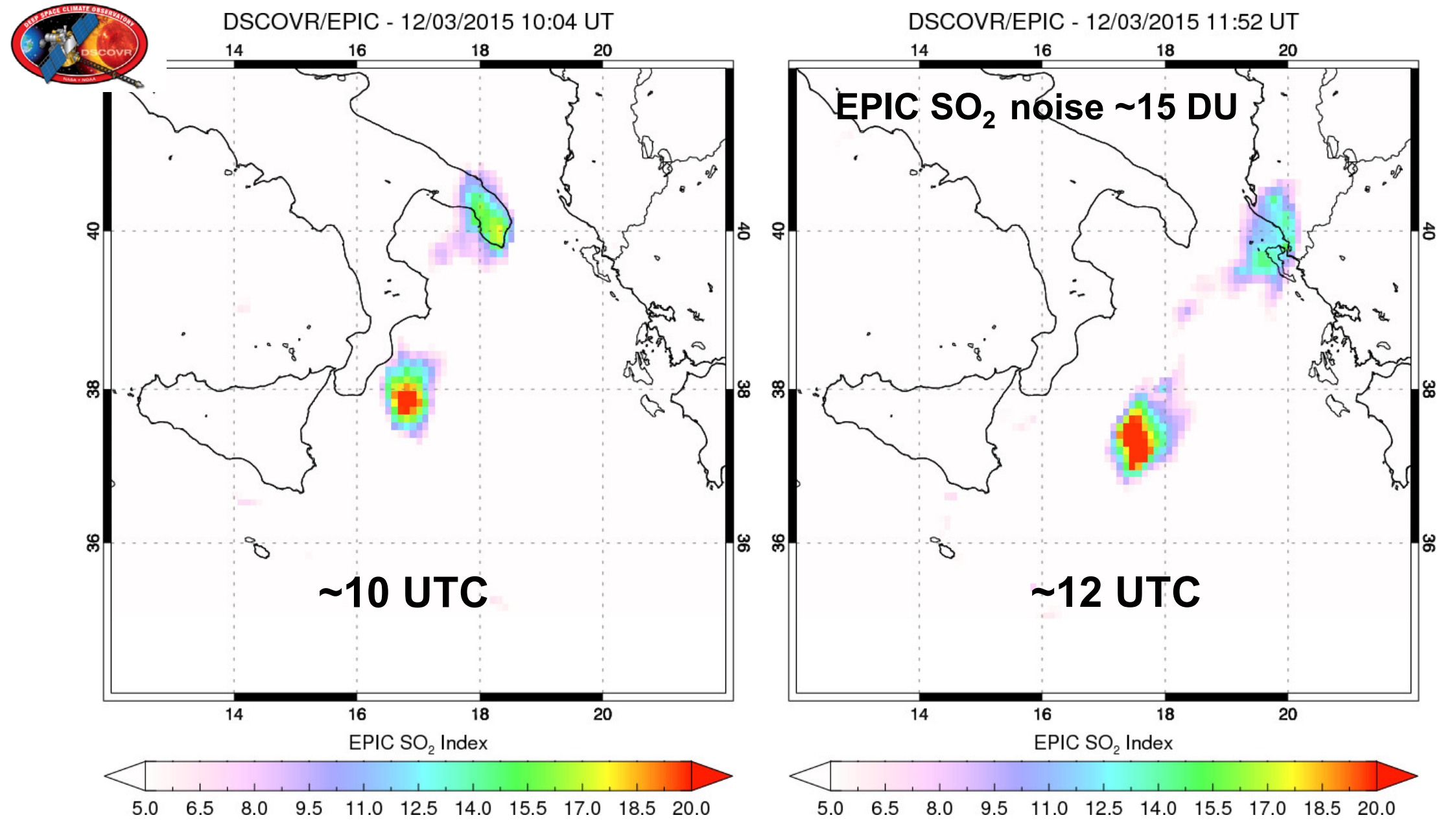
Disclaimer: The presented work has been performed in the frame of the Sentinel-5 Precursor Validation Team (S5PVT) or Level 1/Level 2 Product Working Group activities. Results are based on preliminary (not fully calibrated/validated) Sentinel-5 Precursor data that will still change.

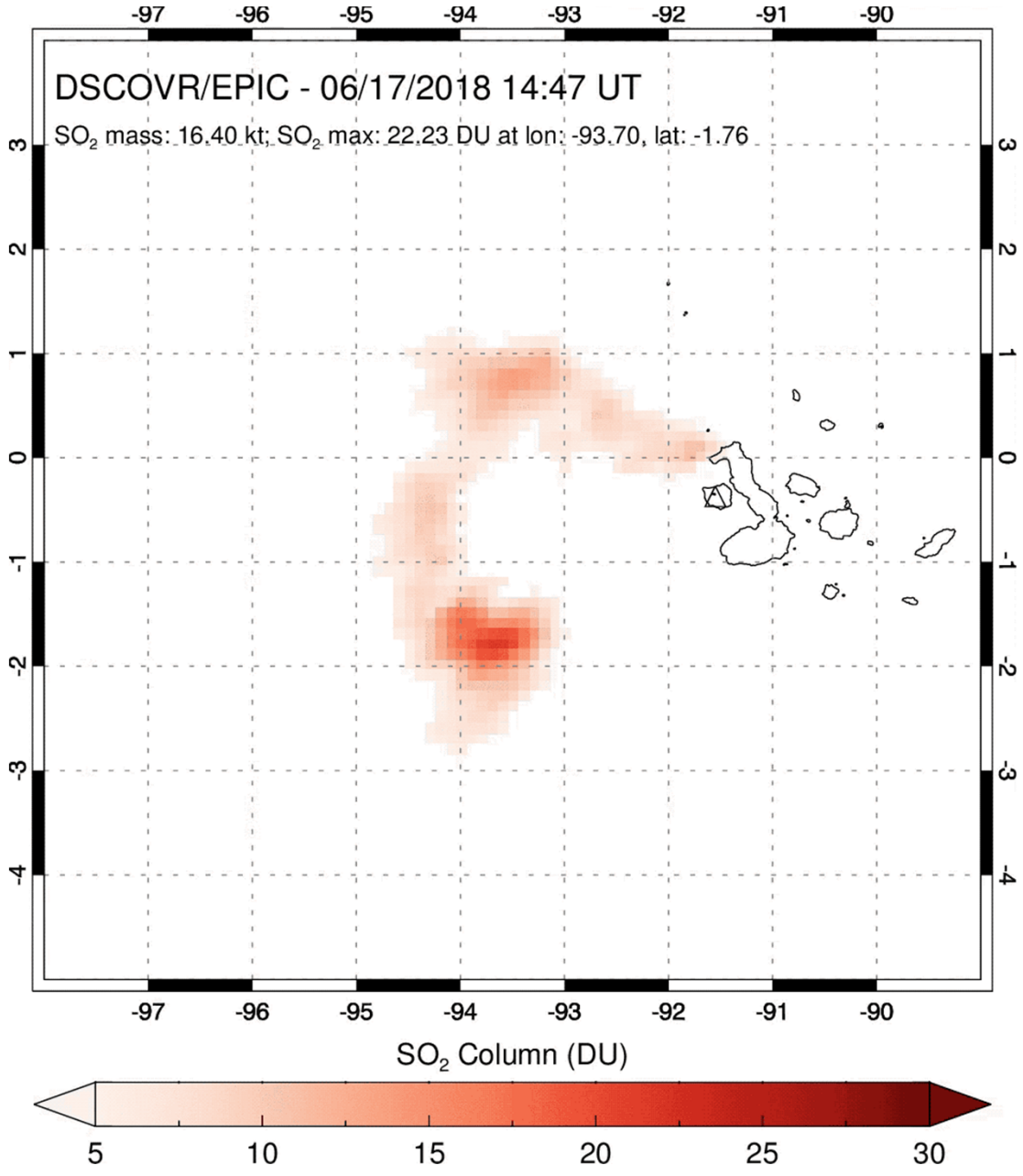
Deep Space Climate Observatory (DSCOVR) at L_1 since 2015-



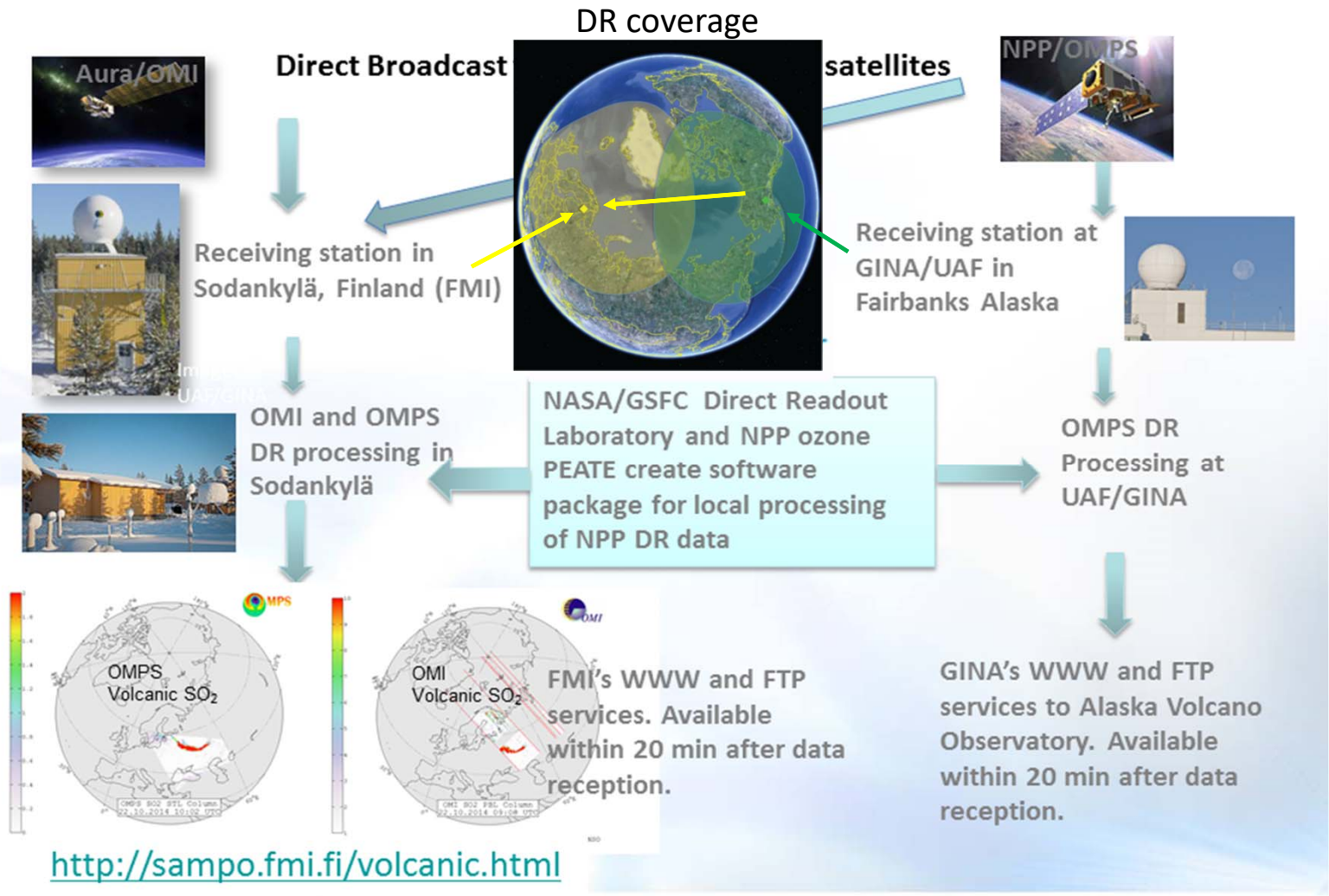
Simulation of EPIC views of May 2006 Soufriere Hills volcanic cloud

- Earth Polychromatic Imaging Camera (EPIC)
  - ~68-100 min temporal resolution
  - Spatial resolution similar to OMI at sub-satellite point (~20 km)
  - Unique vantage point for volcanic SO_2 and ash observations


DSCOVR/EPIC - 12/03/2015 10:04 UT
14
16
18
20
40
38
36
~10 UTC
EPIC SO2 Index
5.0
6.5
8.0
9.5
11.0
12.5
14.0
15.5
17.0
18.5
20.0
DSCOVR/EPIC - 12/03/2015 11:52 UT
EPIC SO2 noise ~15 DU
~12 UTC
EPIC SO2 Index


DSCOVR/EPIC - 06/17/2018 14:47 UT
SO2 mass: 16.40 kt; SO2 max: 22.23 DU at lon: -93.70, lat: -1.76
-97
-96
-95
-94
-93
-92
-91
-90
3
2
1
0
-1
-2
-3
-4
SO2 Column (DU)
5
10
15
20
25
30

NASA ASP Disasters Project: Real-time Volcanic SO_2 data for Aviation alerts



- Aura/OMI (since 2010) and SNPP/OMPS (since 2014) Direct Readout (DR) volcanic SO_2 and ash Index (AI) data have been used by Finnish Meteorological Institute (FMI) Very Fast Delivery Volcanic service
- In addition, NASA-NOAA NPP/OMPS DR data are now received and processed by UAF-GINA in Alaska. DR data used by SACS, USGS/AVO
- In 2018 FMI started posting OMPS DR data from GINA/UAF and provide these to the EUMETCast distribution service