HyspIRI Airborne Science: Combining Multi-Sensor Remote Sensing with In-Situ Sampling and Dispersion Modeling to Study the Impact of Volcanic Sulfur Dioxide Emissions on Air Quality in Hawaii

Vincent J. Realmuto
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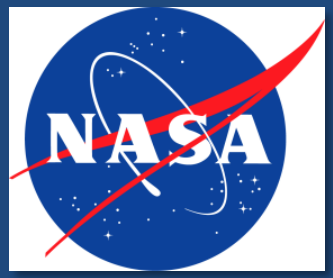
California Institute of Technology



2017 HyspIRI Science Workshop

Government sponsorship acknowledged.

Contributors

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Lacey Holland	University of Hawaii – Manoa
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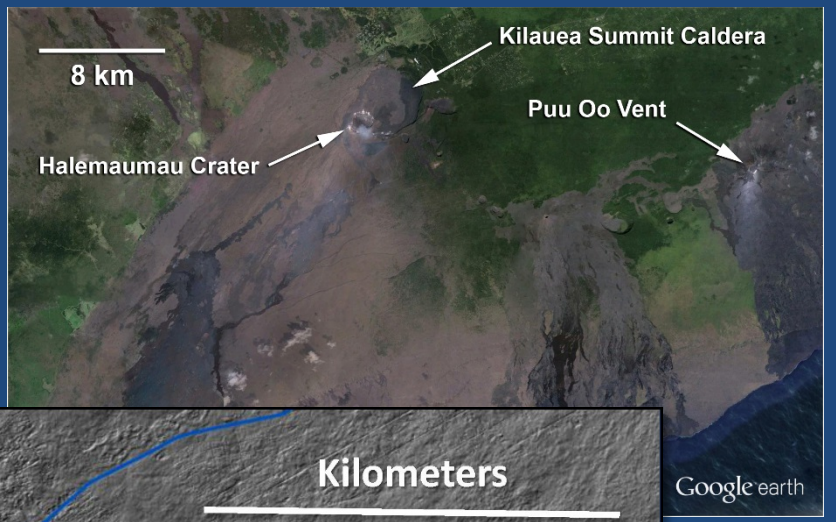
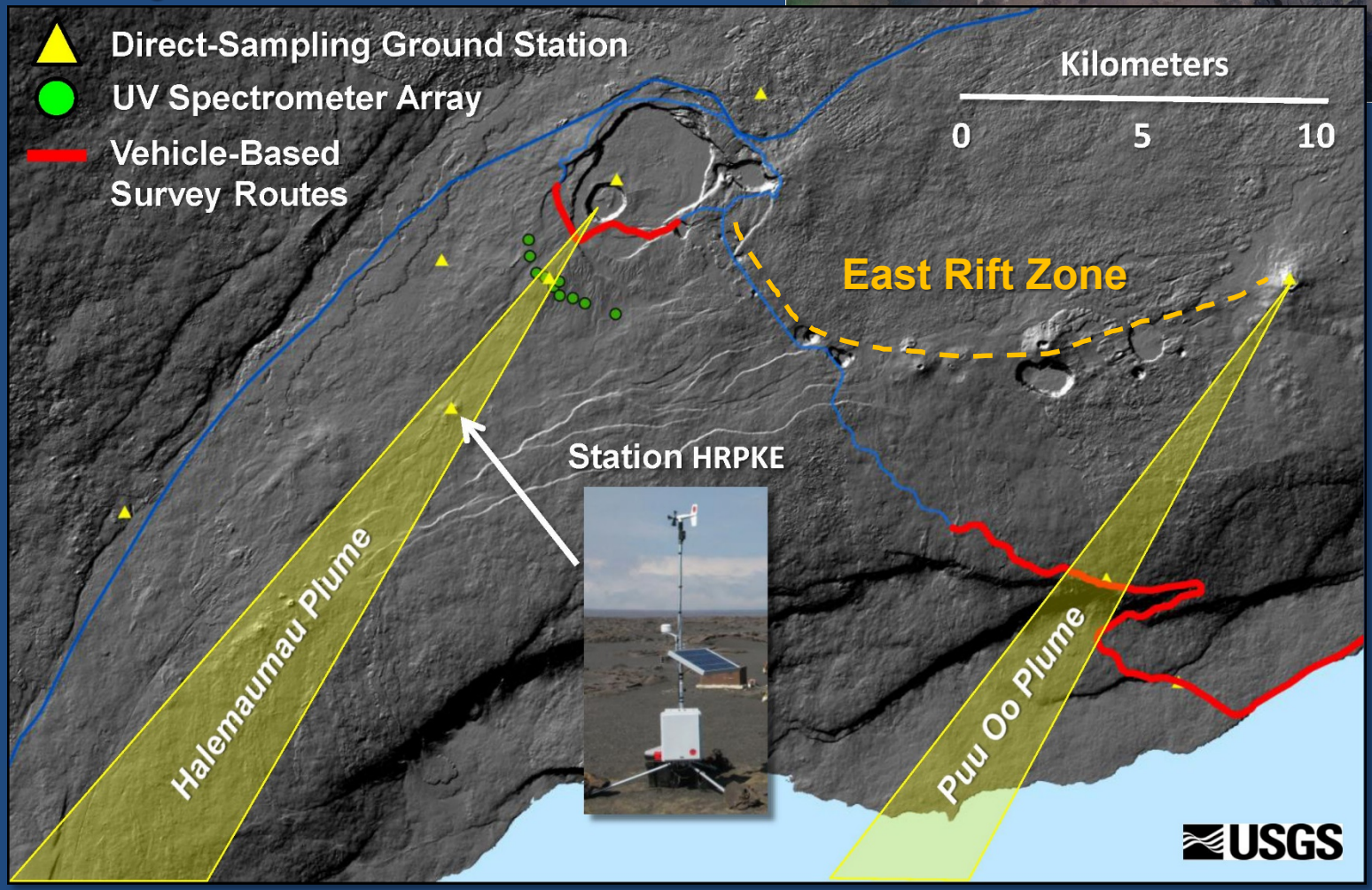
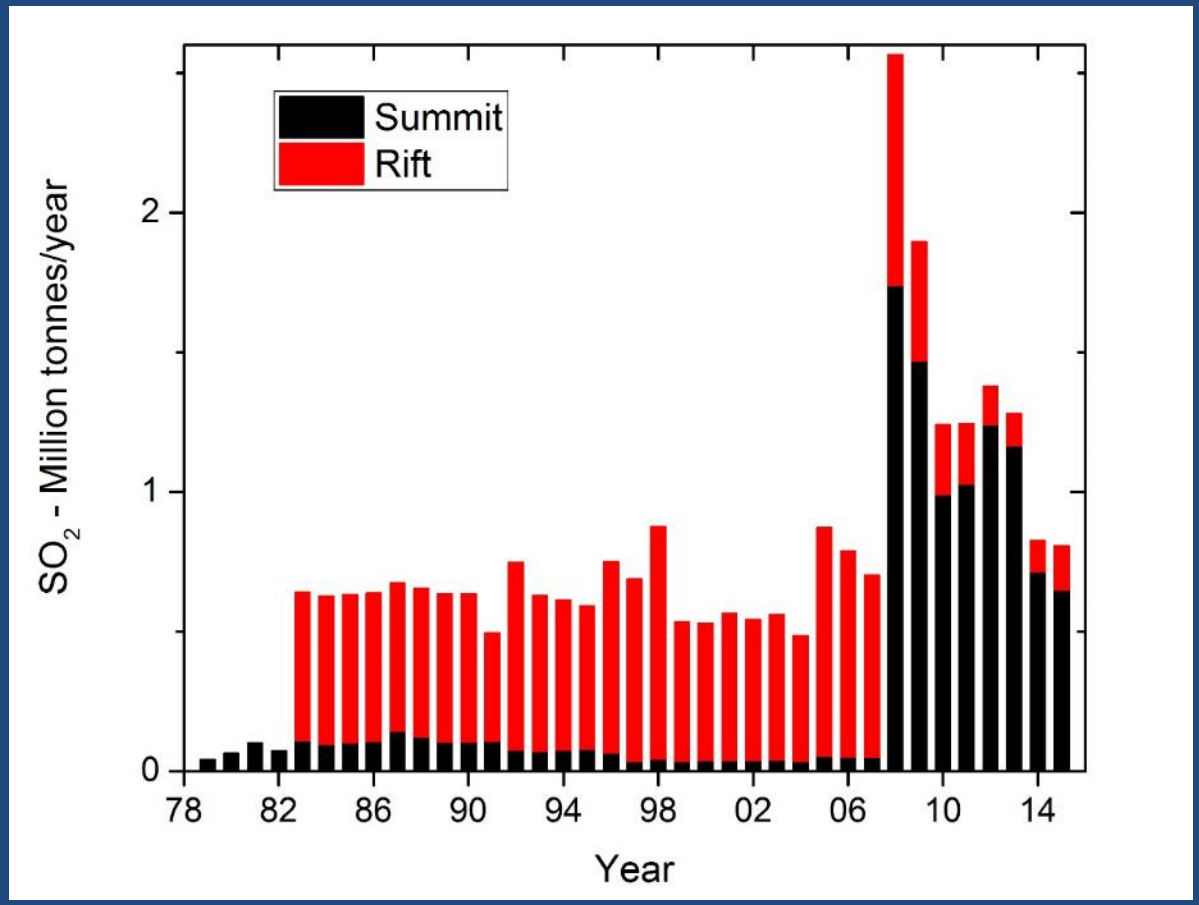
USGS-Hawaii Volcano Observatory Gas Geochemistry Network

- Comprehensive Network of Direct-Sampling Ground Stations, UV Spectrometer Array, and Vehicle-Based Spectrometer Surveys
- SO_2 Emission Measurements Used to Initialize the Univ. Hawaii Vog Model





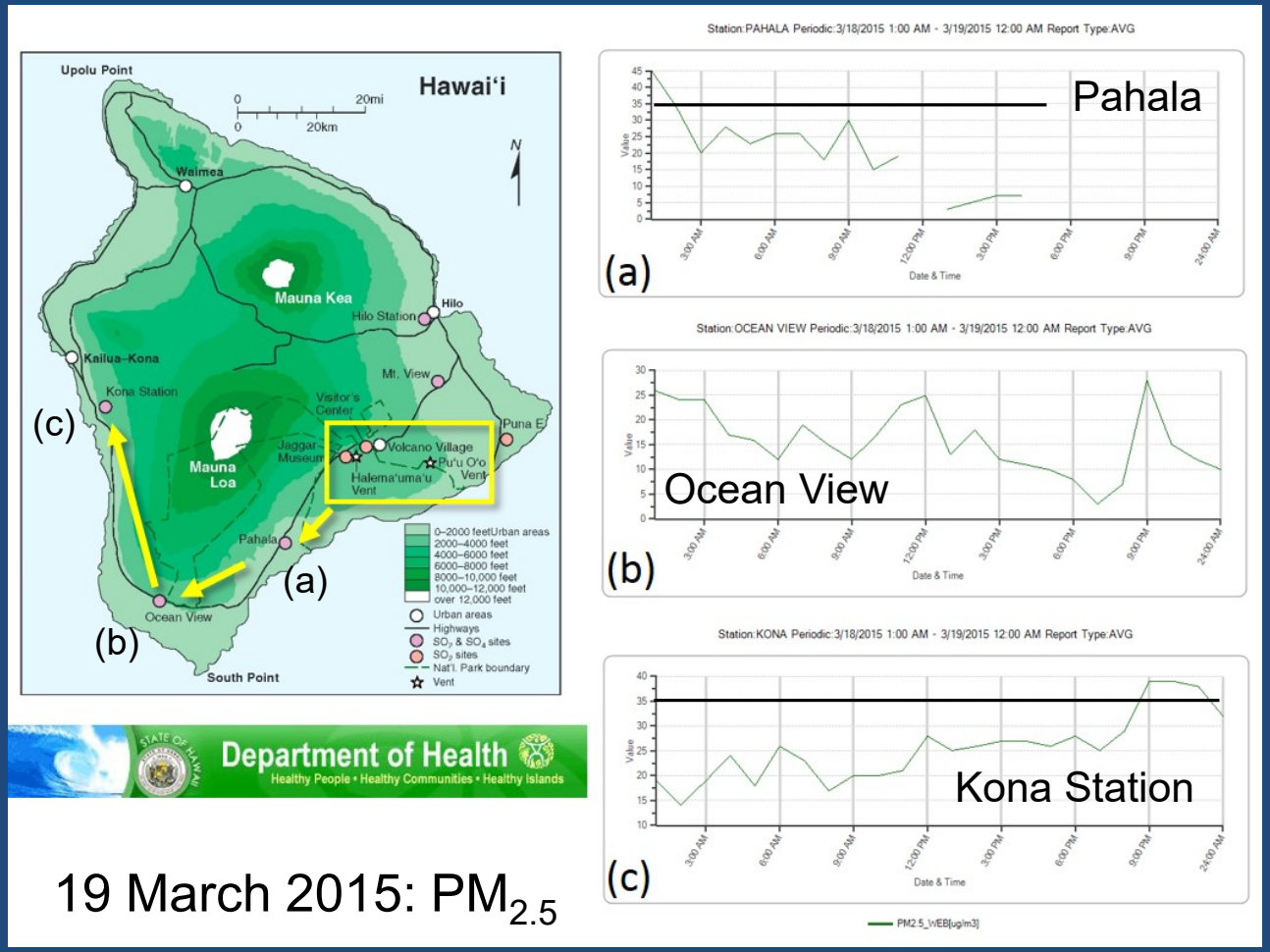
Kīlauea Annual SO_2 Emissions: Summit vs. East Rift Degassing



USGS
science for a changing world

Hawaii Department of Health (DOH) Network of Air Quality Stations

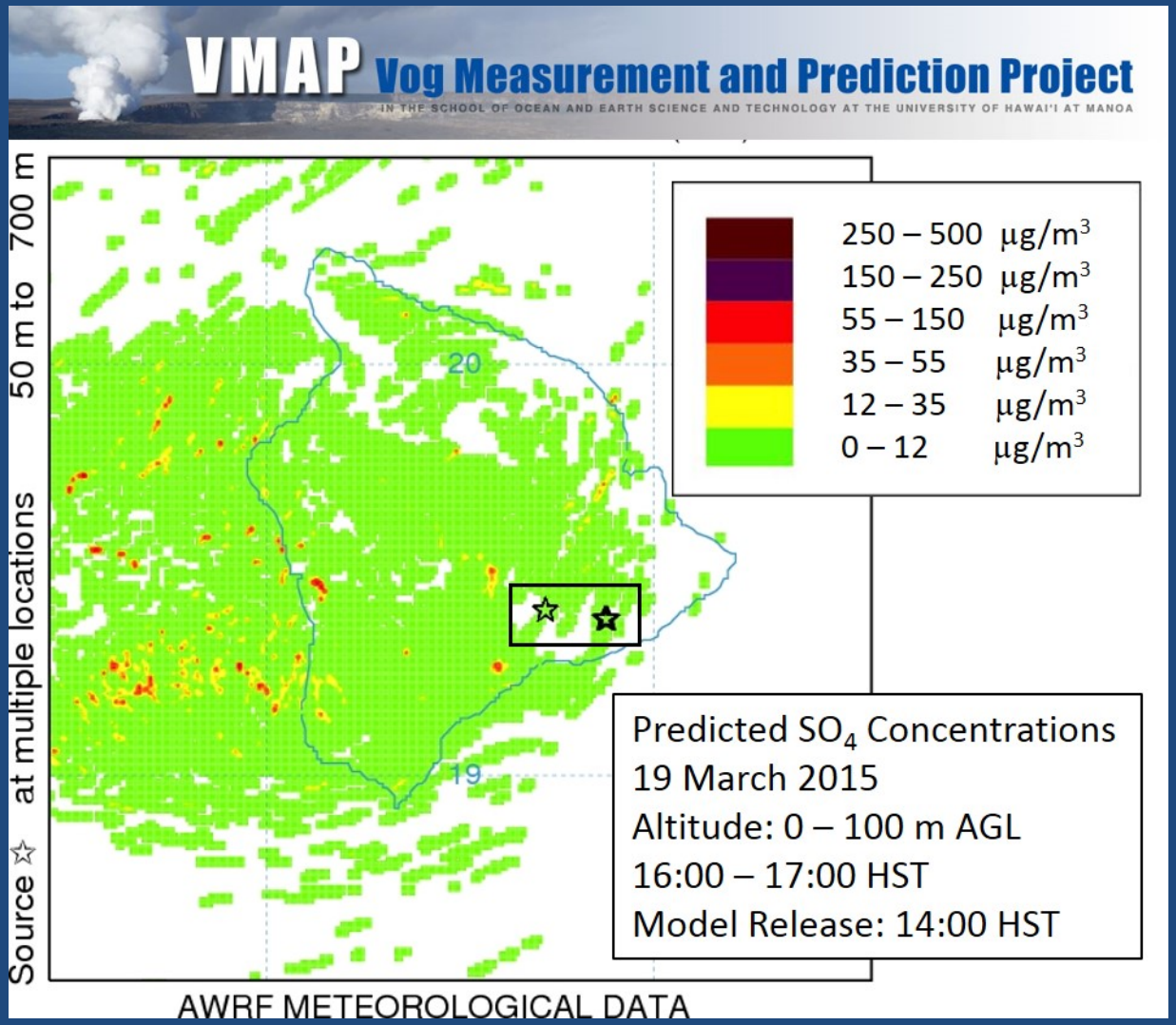
- Minimize public exposure to $PM_{2.5}$
- Hourly spikes at Pahala and Kona Station exceed the 24-hr Standard of 35 $\mu g/m^3$
- Kona Station exceeded Annual Standard of 12 $\mu g/m^3$ in 2011 and 2012 (200 "Flagged" days in 2012)



19 March 2015: $PM_{2.5}$

UH VMAP Project: Hourly Forecasts of $PM_{2.5}$

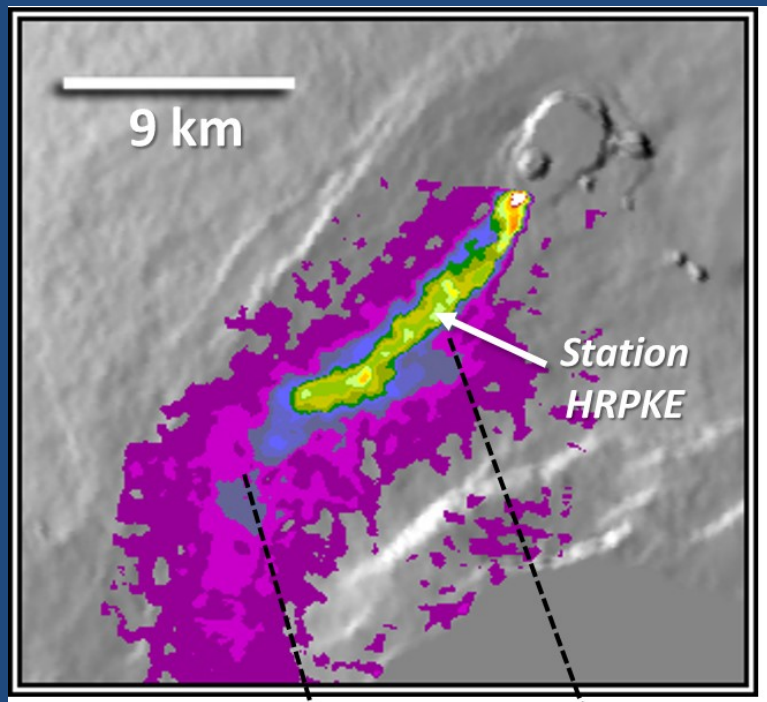
- Initialized by HVO measurements of SO_2 emission rate
- Prediction skill (training) via comparison with DOH stations
- Fine resolution of model domain (1 km grid spacing) + sparse DOH network = most of the forecast field cannot be validated



Plume Tracker Analysis of ASTER TIR Data

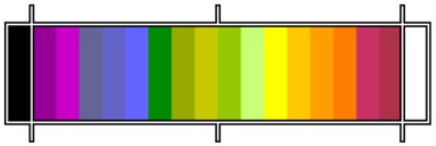
SO_2 retrievals at fine spatial resolution (90 m) provide important input parameters for vog model

- 2-D maps of SO_2 source is superior to line source model
- Longitudinal profiles record the chemical evolution of plume - constrain SO_2 loss rates
- Spatial resolution of MODIS (1 km) and VIIRS (750 m) TIR data are finer than Vog Model grid spacing (1 km)

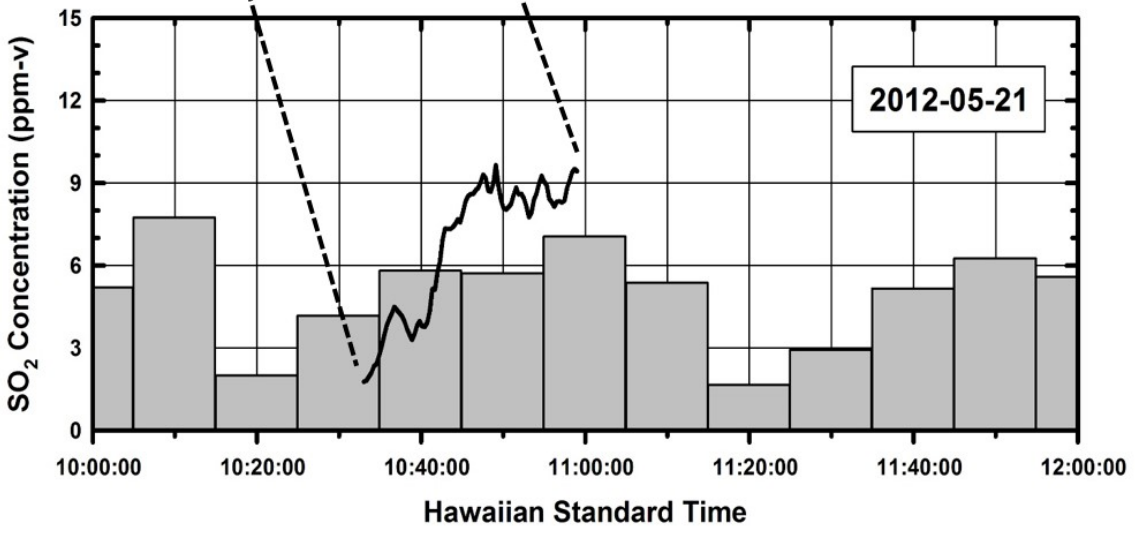


2012-05-21
10:59 HST

SO_2 Concentration



ppm-v



HyspIRI Preparatory Science Airborne Campaign

MODIS/ASTER Airborne Simulator (MASTER) TIR Observations to Map SO_2 Emissions at Summit of Kilauea

AVIRIS VSWIR Observations to Map Changes in Optical Depth Related to SO_4 Aerosols

Input Data products into the UH VMAP Vog Model and Evaluate Impact on Forecasting Skill

Photo Courtesy of Stu Broce

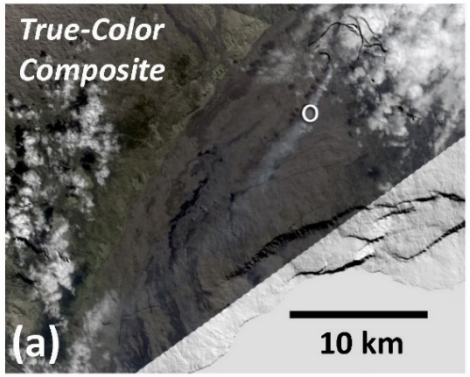
Brightness Temperature Difference (BTD) Time Series

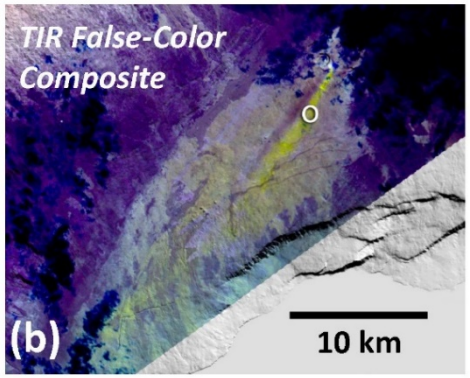
(a) True-Color composite of visible (RGB) data. MASTER data from 2017-02-21, collected between 20:18 - 20:29 UTC.

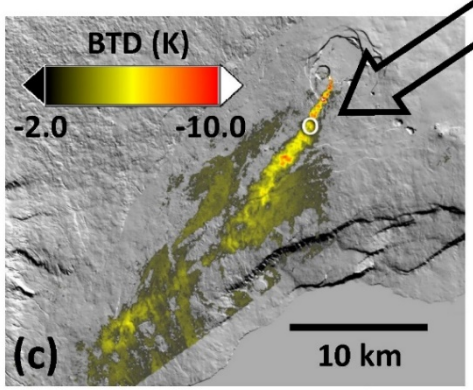
(b) False-Color composite of TIR data. SO_2 plume appears in yellow.

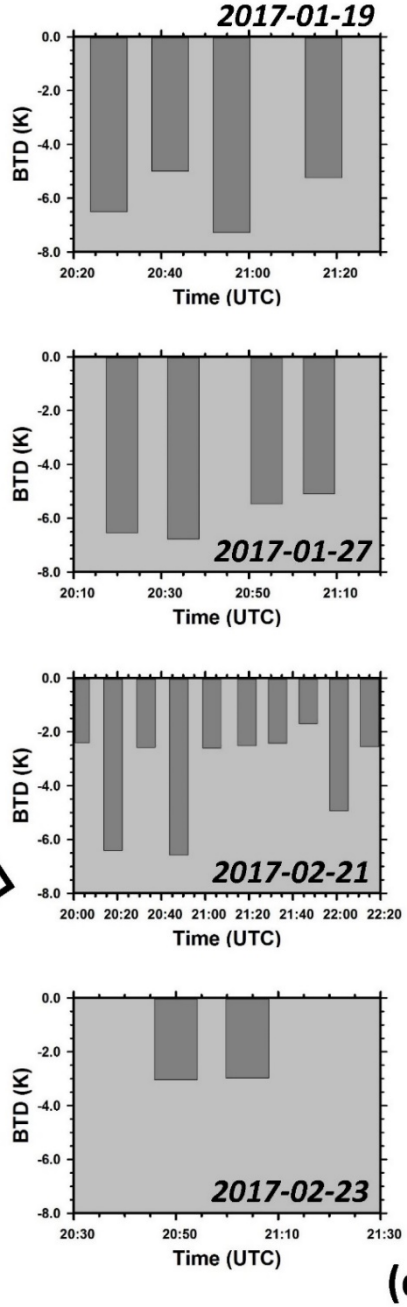
(c) Brightness Temperature Difference (BTD), calculated as difference between the BT in Channel 43 (8.7 μm) and the maximum BT over all of the MASTER TIR channels.

(d) BTD Values between 2017-01-19 and 2017-02-23, corresponding to the sample location marked by the white circle in Panels a – c. The decrease in (absolute) BTD for this location suggests a decrease in the concentration of SO_2 in the plume over this time interval.

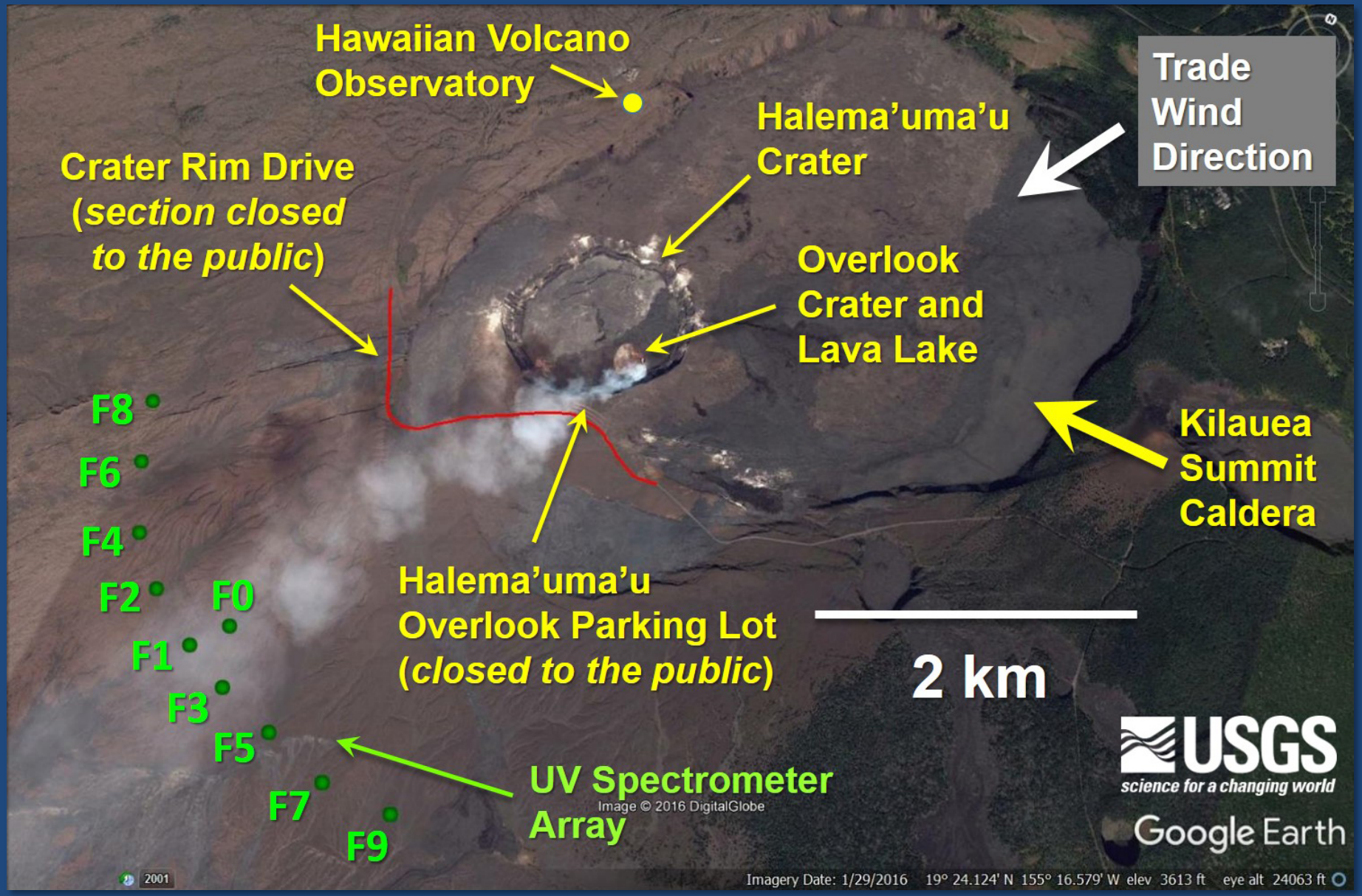








Kilauea Summit: Location Map



Field Measurements

FLYSPEC Station 7: UV Measurement of SO_2 Column (ppm·m) and Emission Rates (mt/day)

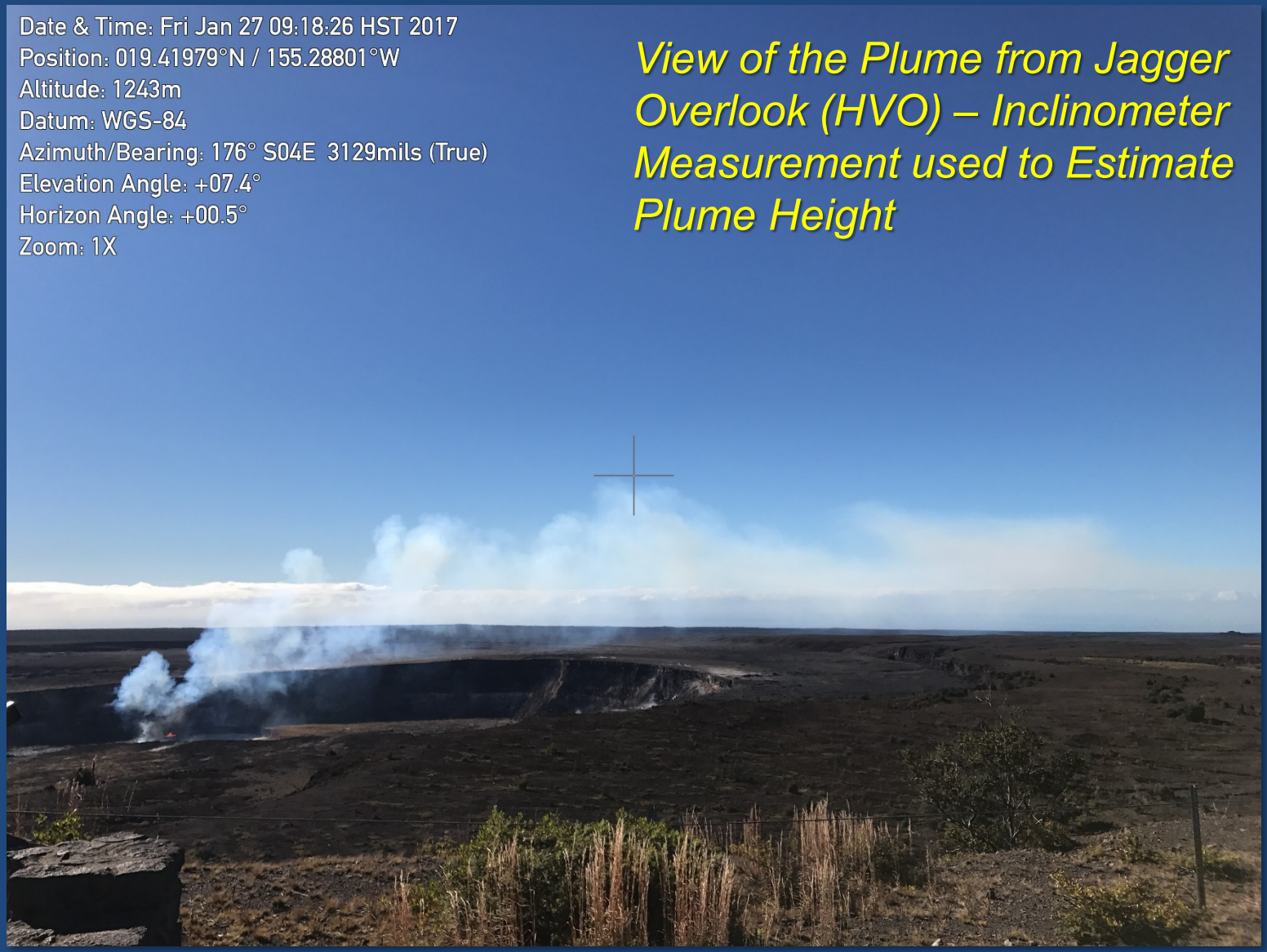
Portable FLYSPEC: UV Measurement of SO_2 Column (ppm·m)

MicroTOPS: V-SWIR Measurement of Aerosol Optical Depth (AOD)

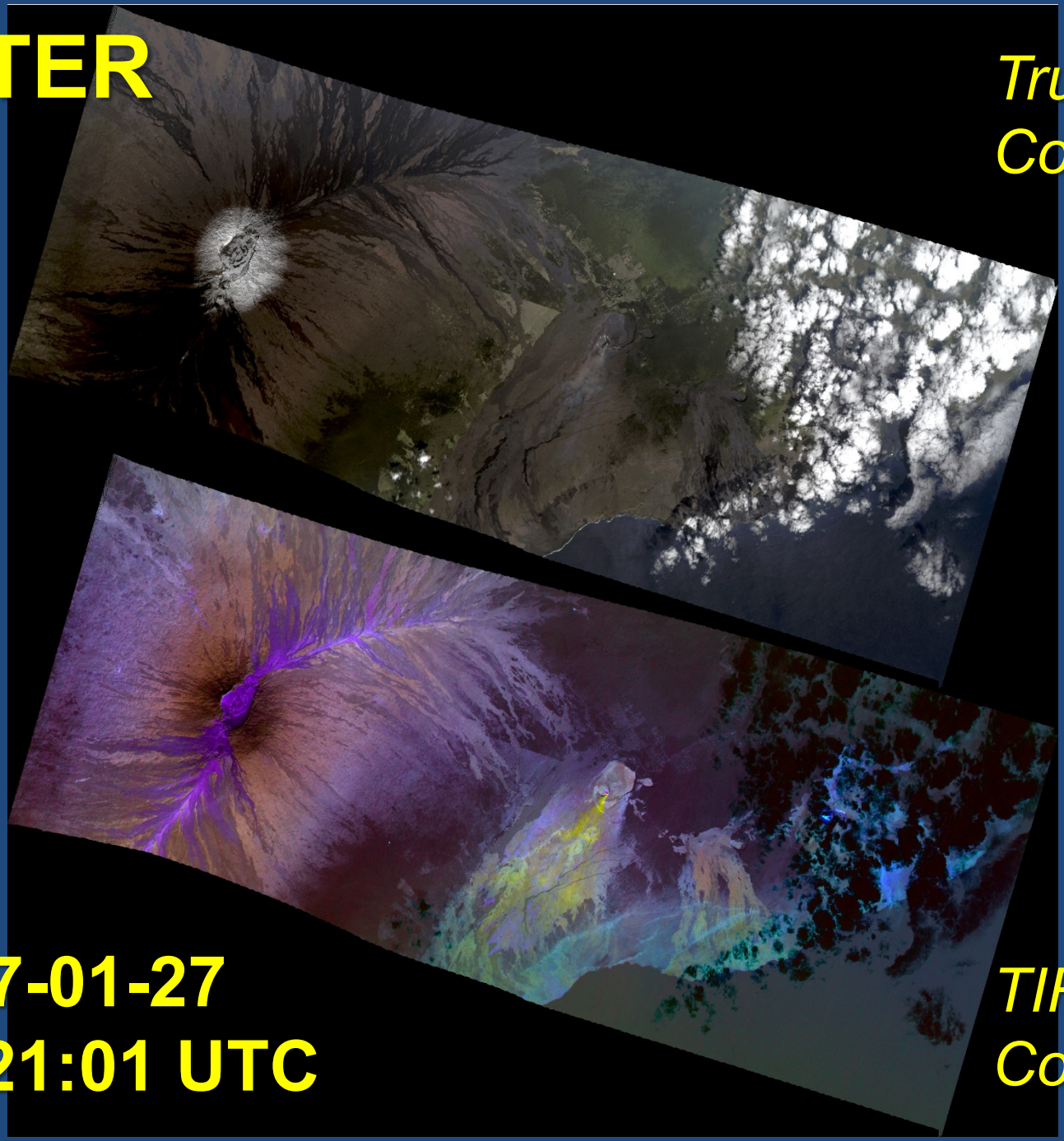
Field Measurements

Radiosonde-based profiles of atmospheric temperature, pressure, and humidity, plus wind direction and wind speed: Courtesy of ASTER Project

Golden Day: 2017-01-27

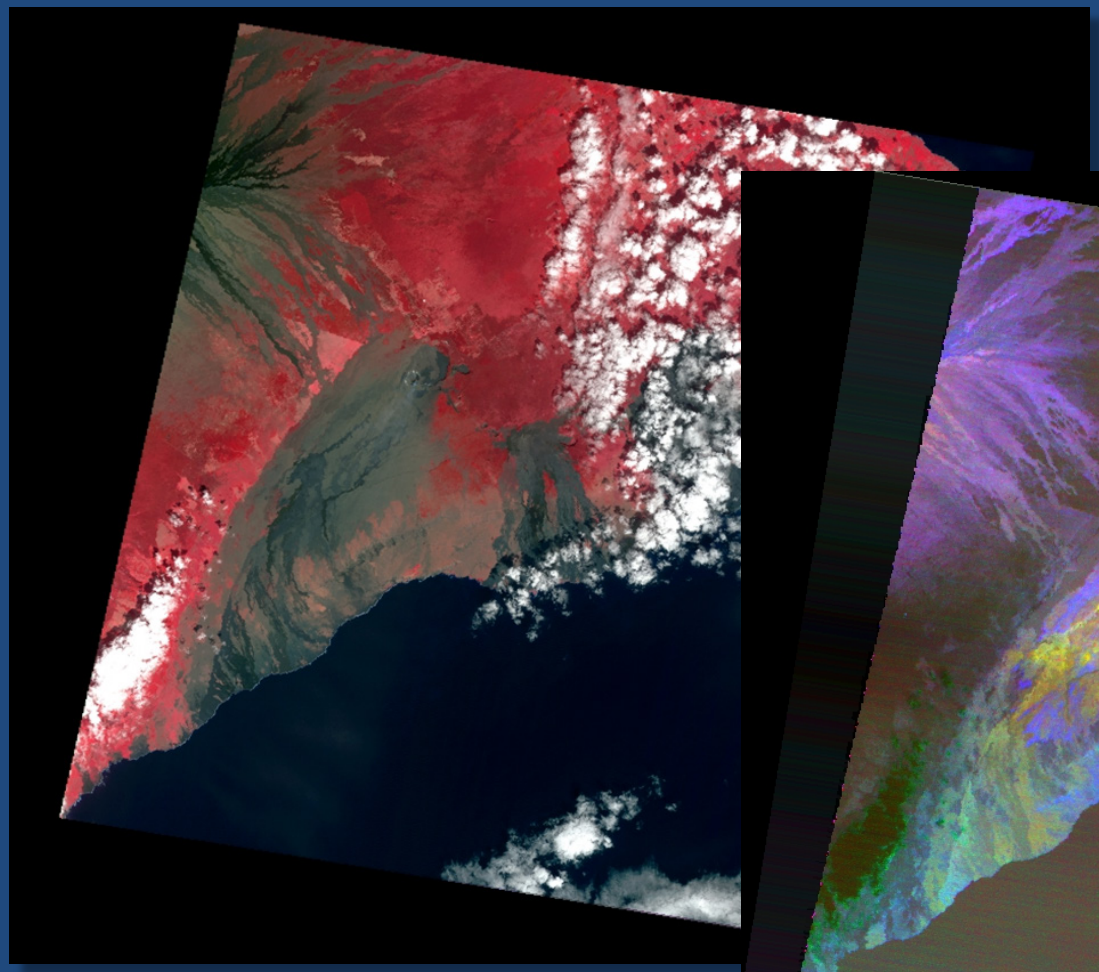


View of the Plume from Jagger Overlook (HVO) – Inclinometer Measurement used to Estimate Plume Height

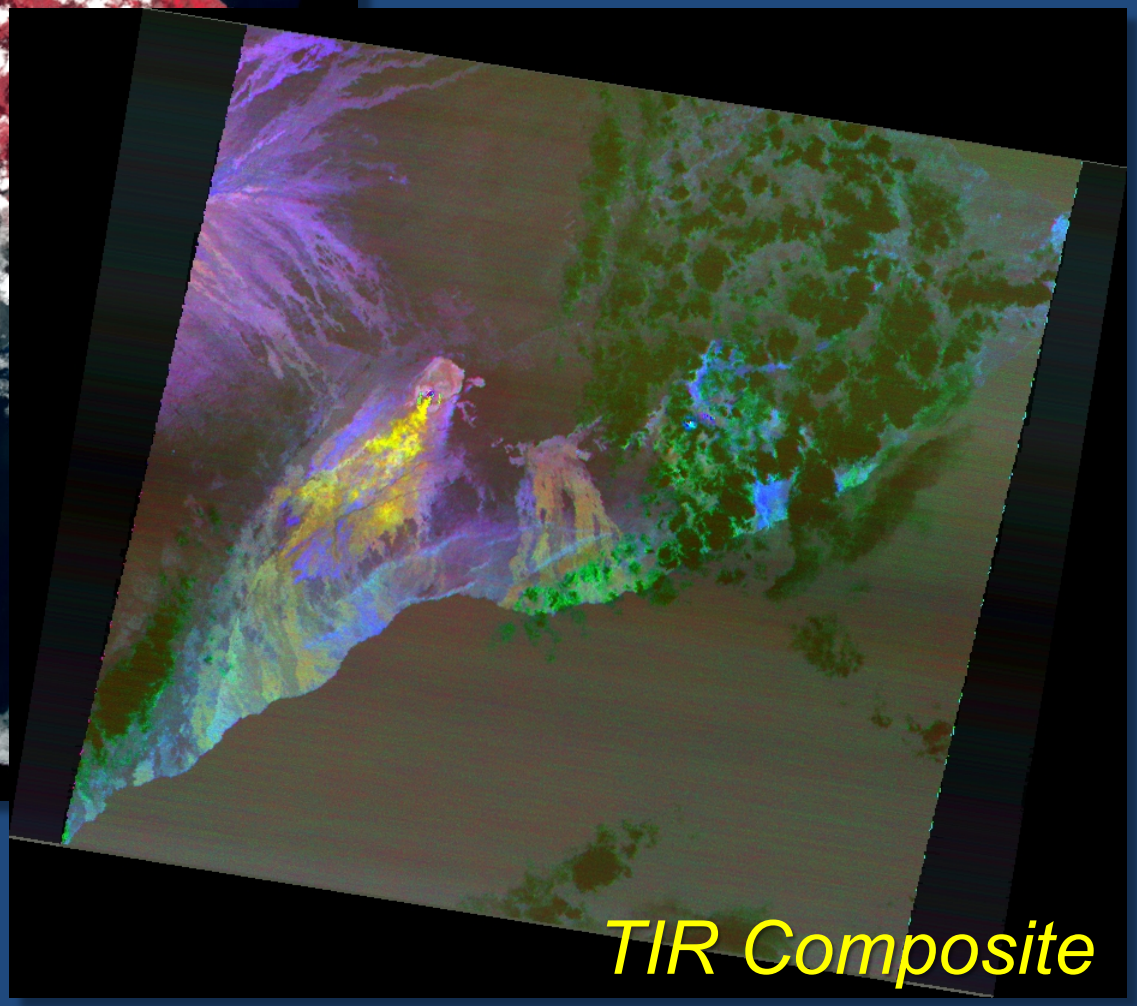

MASTER
True-Color
Composite
2017-01-27
20:54-21:01 UTC
TIR
Composite

ASTER

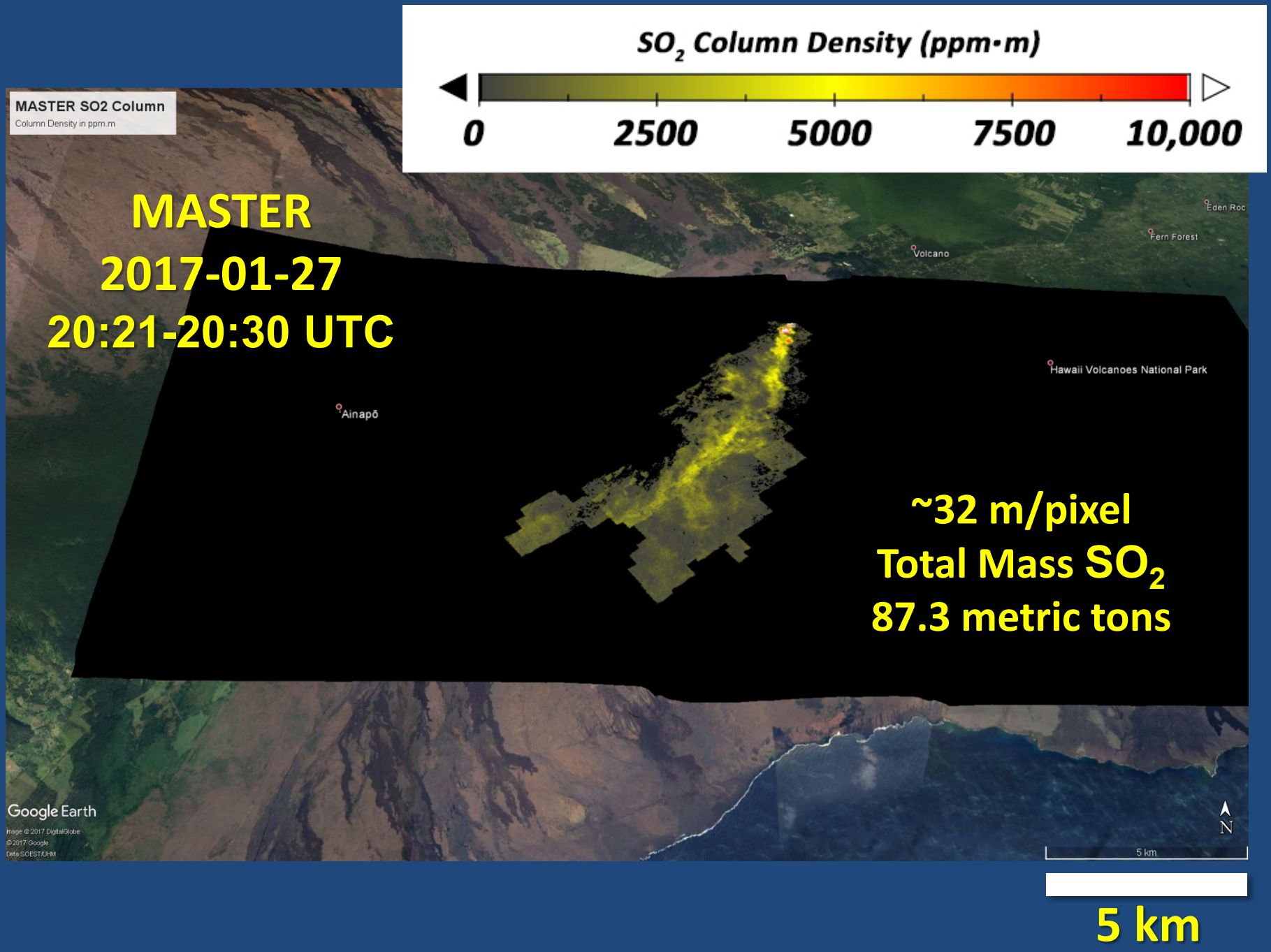
2017-01-27
20:59 UTC

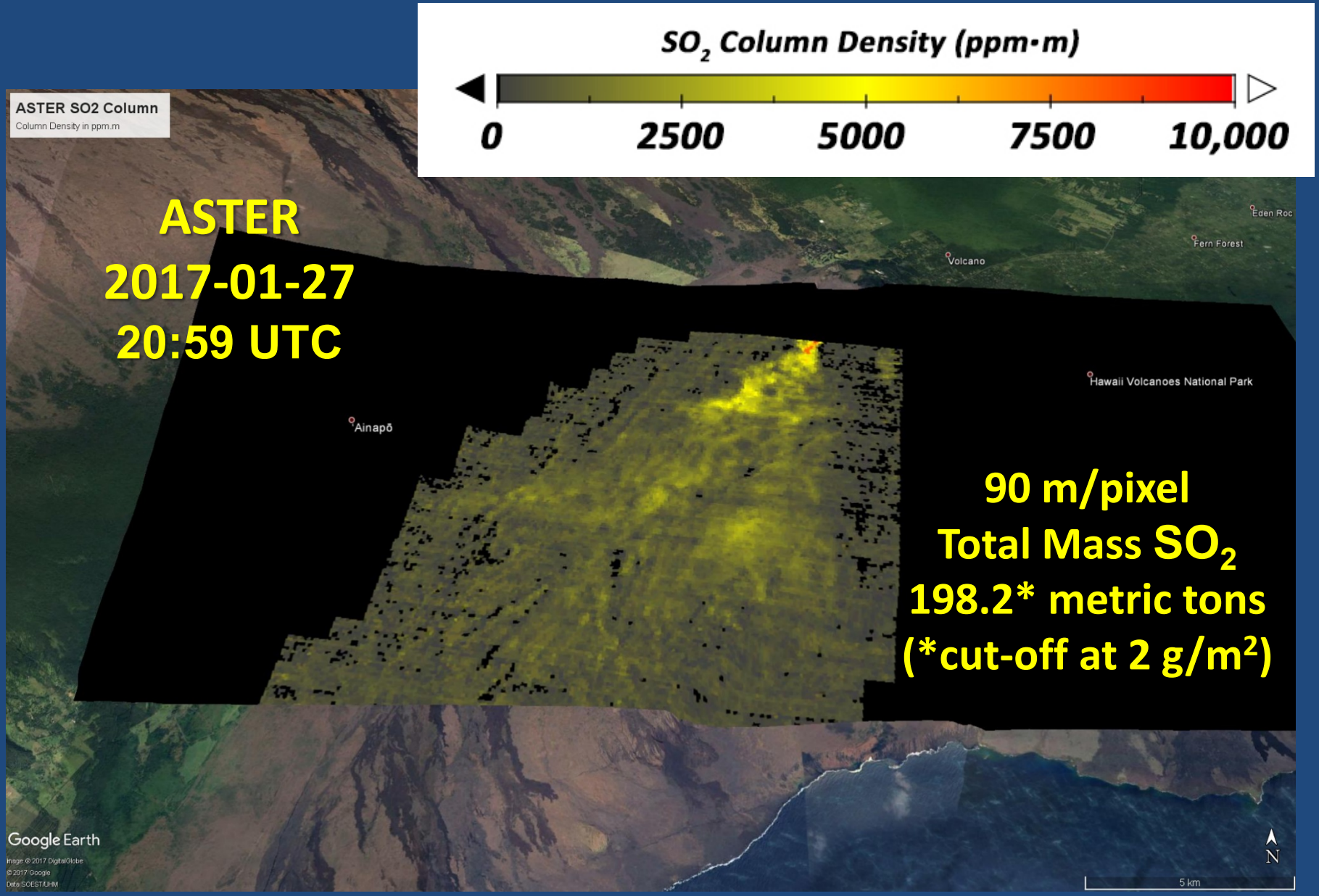


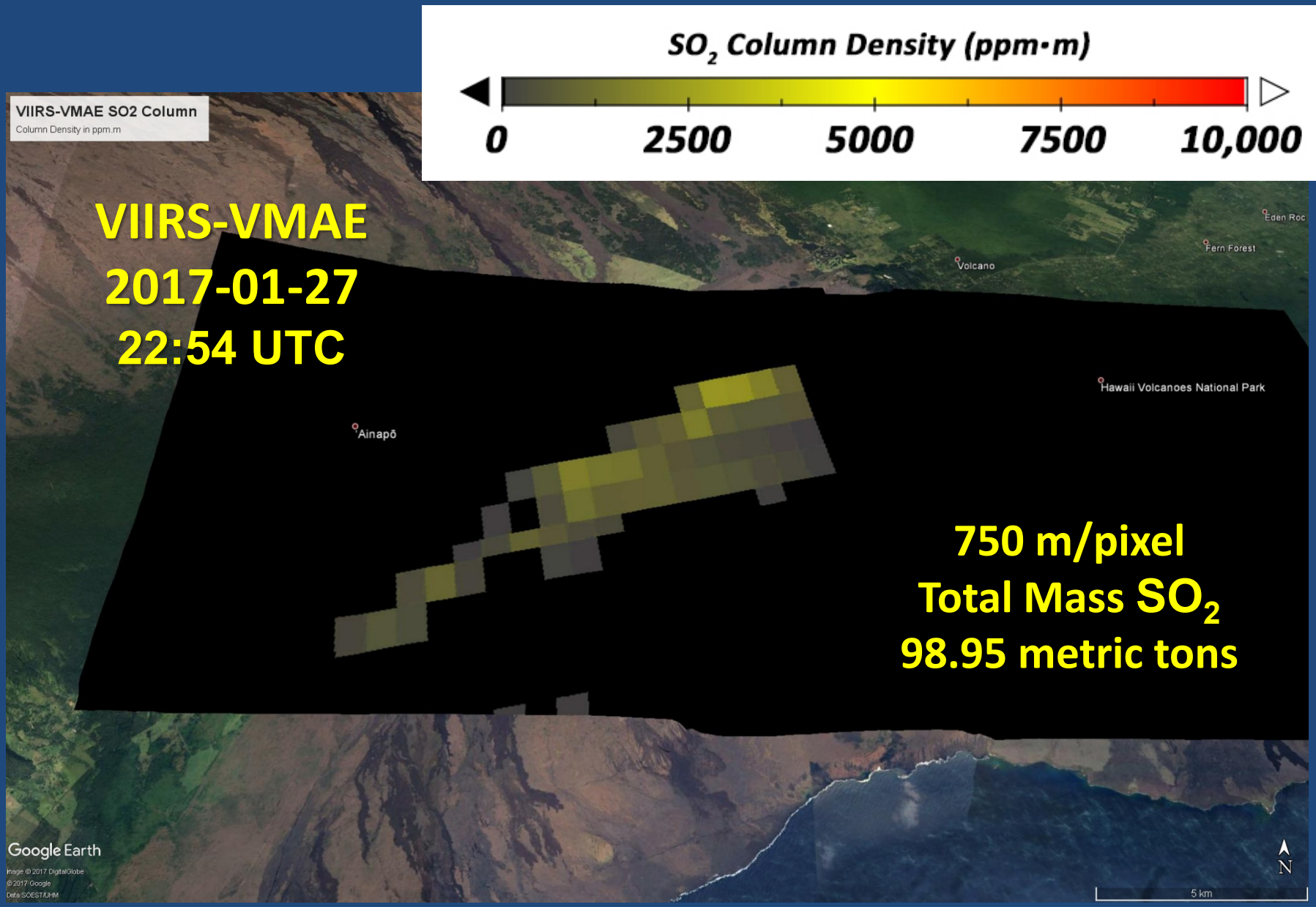
VNIR Composite



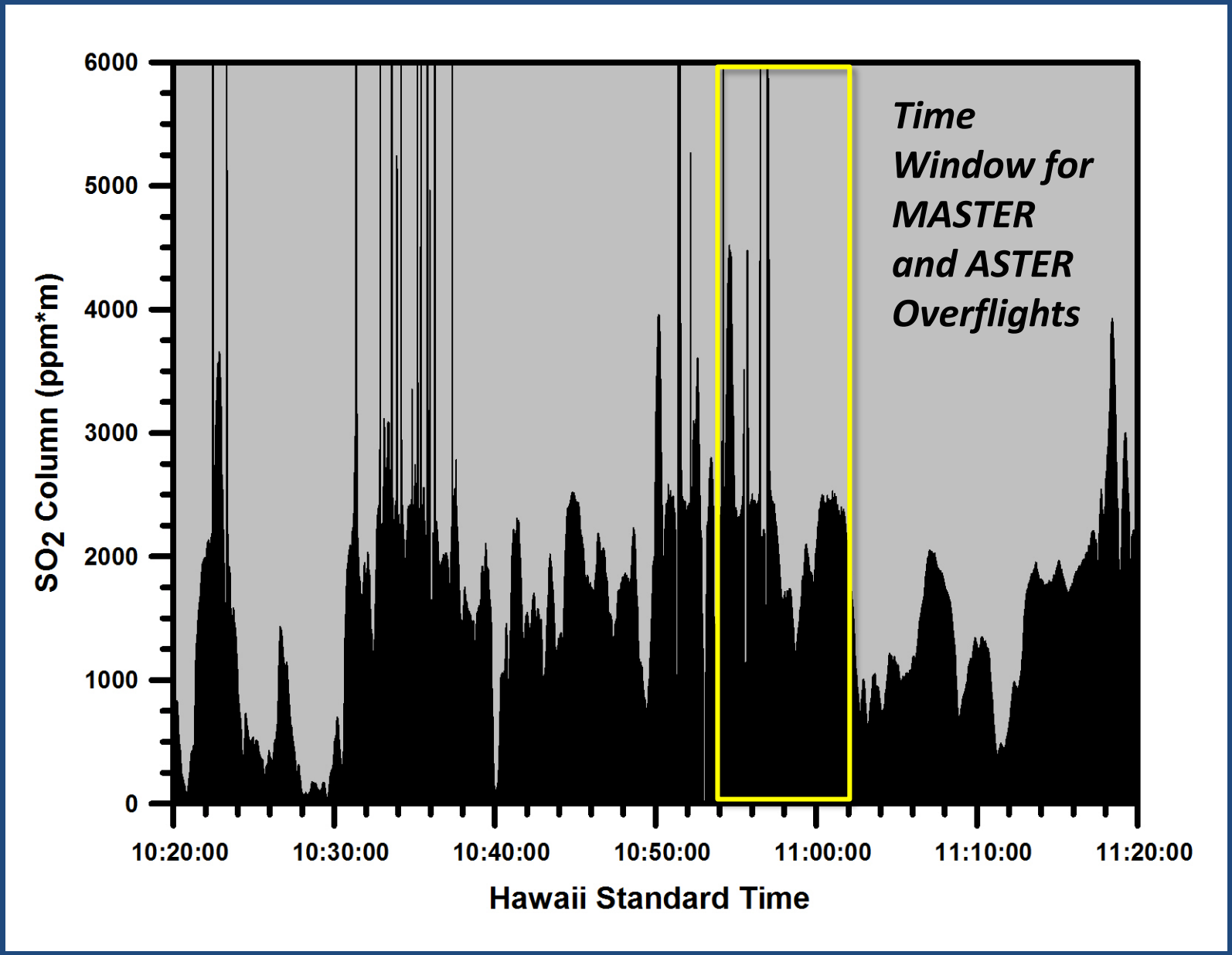
TIR Composite


SO_2 Column Density (ppm·m)
0
2500
5000
7500
10,000
MASTER SO2 Column
Column Density in ppm.m
MASTER
2017-01-27
20:21-20:30 UTC
Eden Roc
Fern Forest
Volcano
Hawaii Volcanoes National Park
Ainapō
~32 m/pixel
Total Mass SO_2
87.3 metric tons
Google Earth
Image © 2017 DigitalGlobe
© 2017 Google
Data SOEST/UHM
N
5 km
5 km


SO_2 Column Density (ppm·m)
0
2500
5000
7500
10,000
ASTER SO2 Column
Column Density in ppm.m
ASTER
2017-01-27
20:59 UTC
Eden Roc
Fern Forest
Volcano
Hawaii Volcanoes National Park
Ainapō
90 m/pixel
Total Mass SO_2
198.2* metric tons
(*cut-off at 2 g/m²)
Google Earth
Image © 2017 DigitalGlobe
© 2017 Google
Data SOEST/UHM
N
5 km
5 km

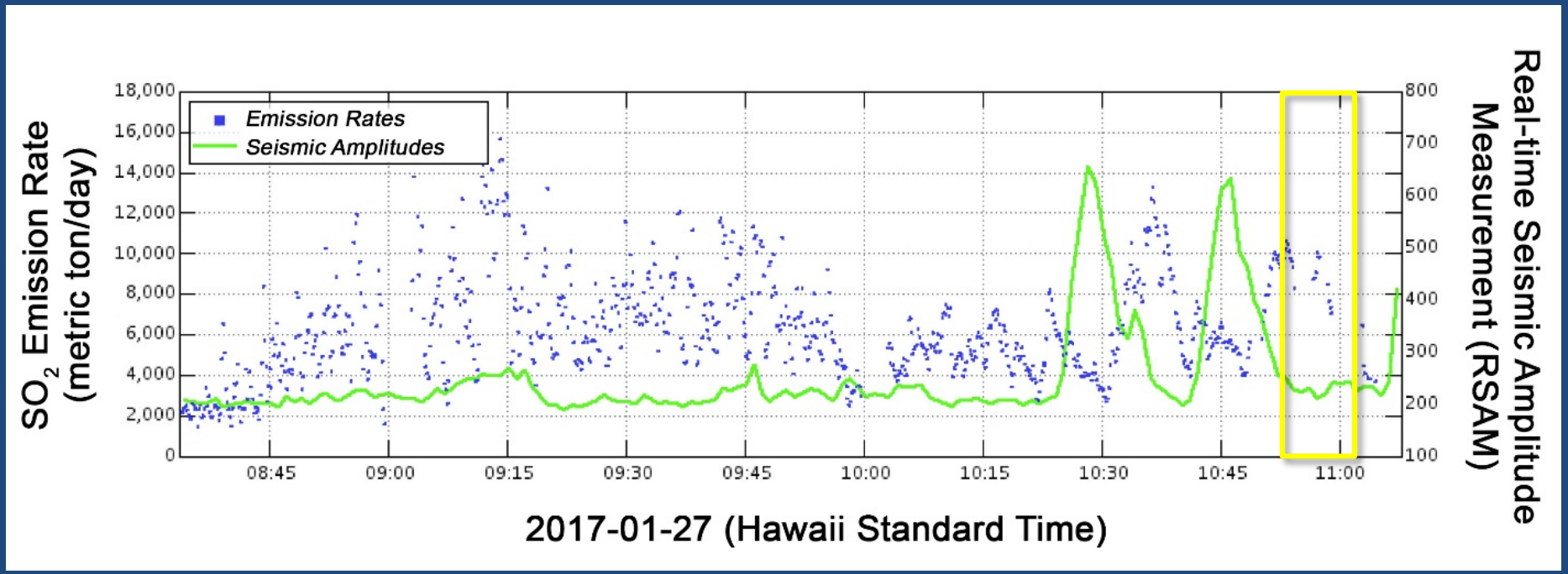

SO_2 Column Density (ppm·m)
0
2500
5000
7500
10,000
VIIRS-VMAE SO2 Column
Column Density in ppm.m
VIIRS-VMAE
2017-01-27
22:54 UTC
Eden Roc
Fern Forest
Volcano
Hawaii Volcanoes National Park
Ainapō
750 m/pixel
Total Mass SO_2
98.95 metric tons
Google Earth
Image © 2017 DigitalGlobe
© 2017 Google
Data SOEST/UHM
N
5 km
5 km

Portable FLYSPEC Data Record



FLYSPEC Array Emission Rates

- Better to compare TIR-based retrievals to SO_2 column records at individual FLYSPEC stations
- Complex wind fields in summit caldera can result in high variations in emission rates and poor correlation between rates and RSAM



Data Courtesy of Tamar Elias, USGS-HVO

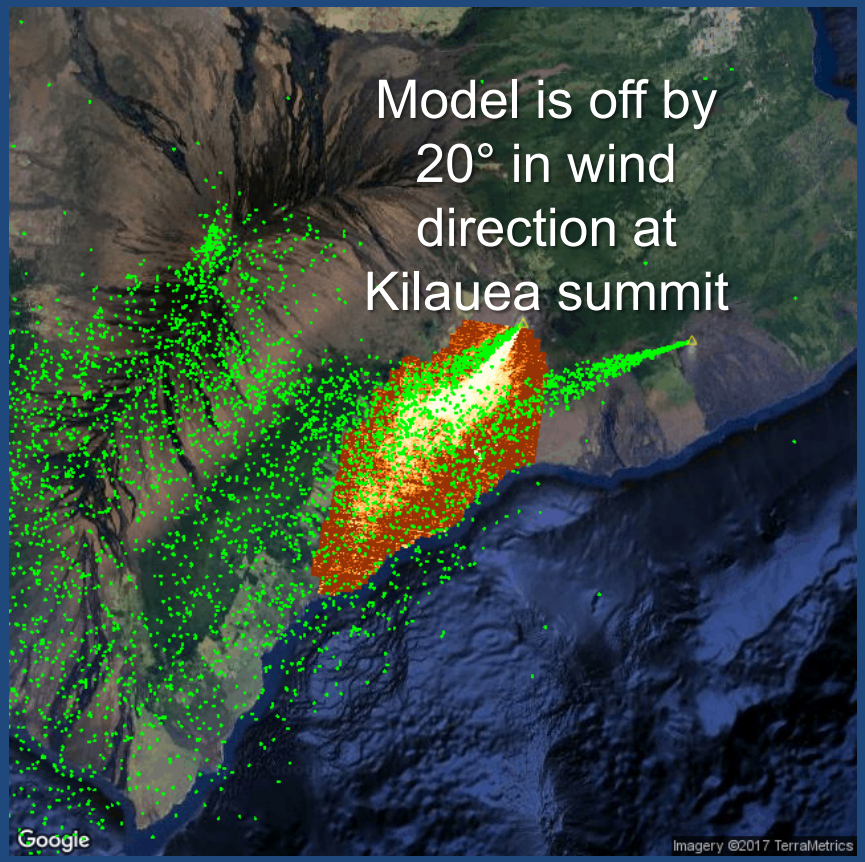
VMAP Integration

- HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) generates forecasts
- North American Mesoscale (NAM) model as meteorological model that drives HYSPLIT
  - 2 km resolution, 40 vertical levels, Hawai'i domain
- Two days to "spin-up" HYSPLIT particles
- Test Case: ASTER SO_2 Map from 2012-04-19
- ***Current (2017) emission rates used as proxy for 2012 rate***

Modeling Courtesy of Lacey Holland, UH-M

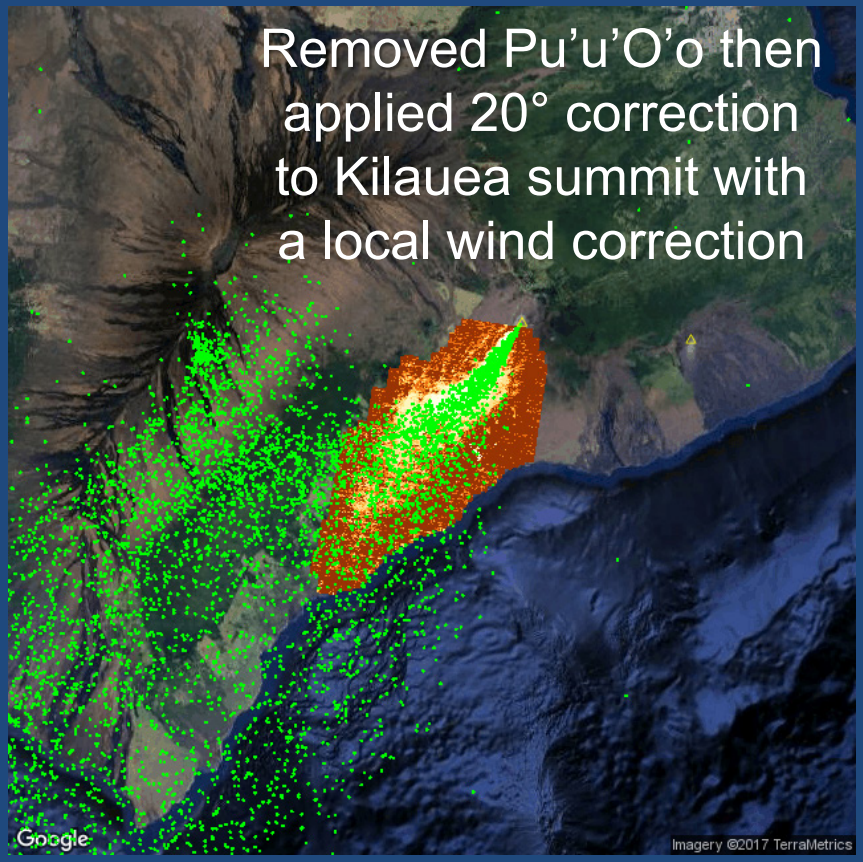
Can we improve summit plume location?

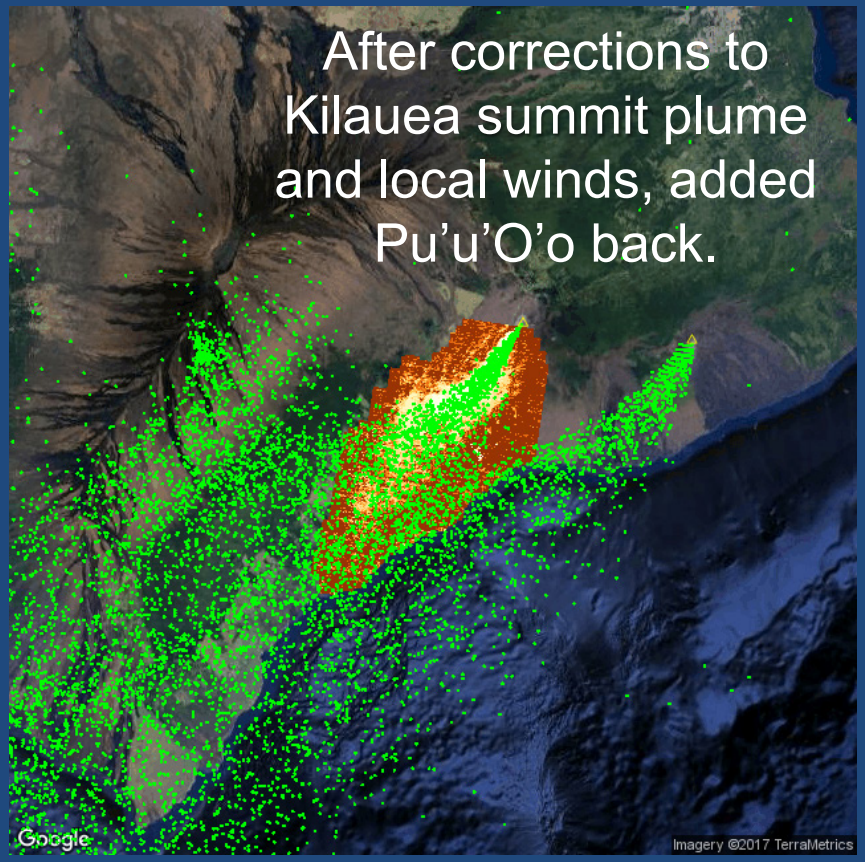
SO_2 plume detected by ASTER at Kilauea summit caldera at 2012-04-19 @ 2000 UTC



SO_2 plume at Kilauea summit caldera from ASTER with HYSPLIT initialization for 2012-04-20 @ 00 UTC

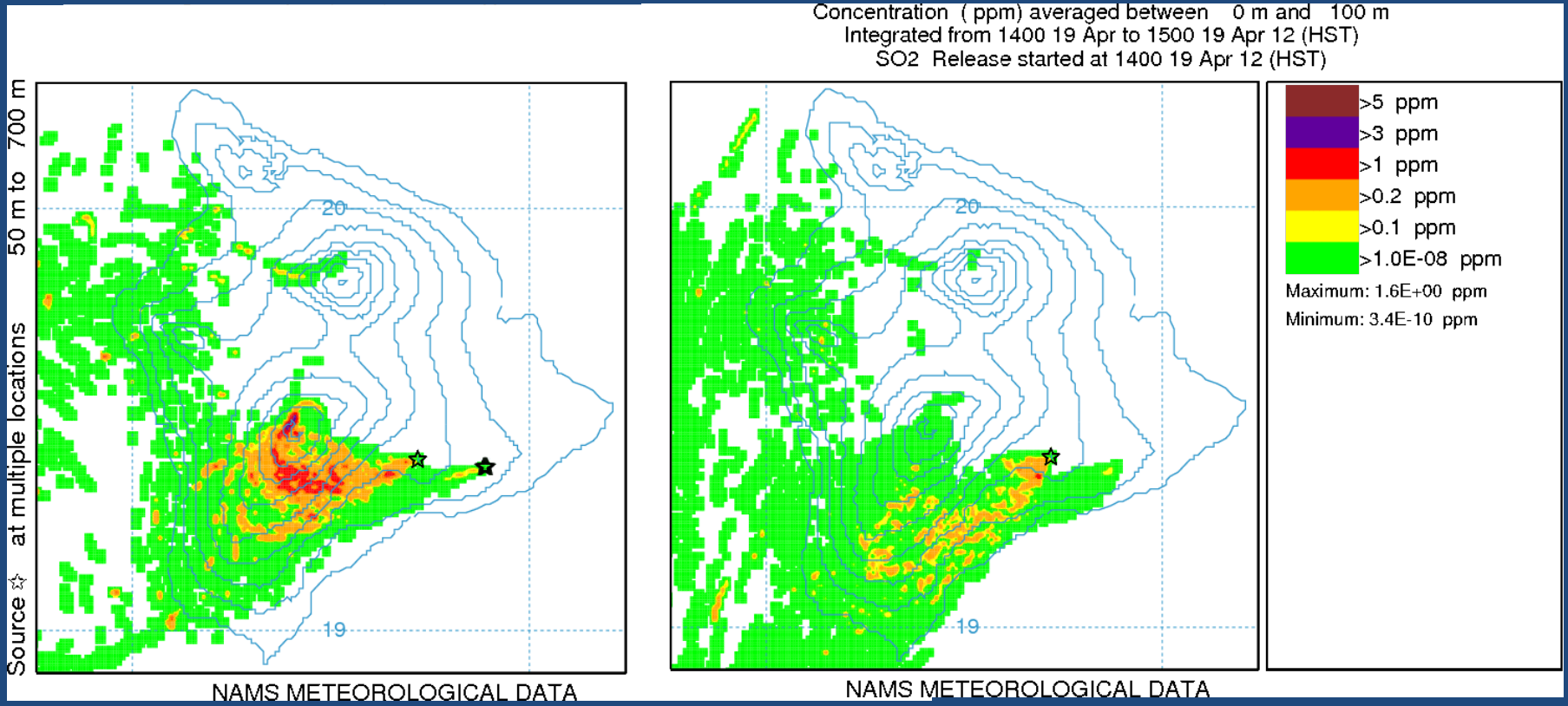
Can we improve summit plume location?





SO_2 plume at Kilauea summit caldera with 20° rotation plume correction in initialization for 2012-04-20 00 UTC

Impact on SO_2 concentrations on the Island of Hawai'i

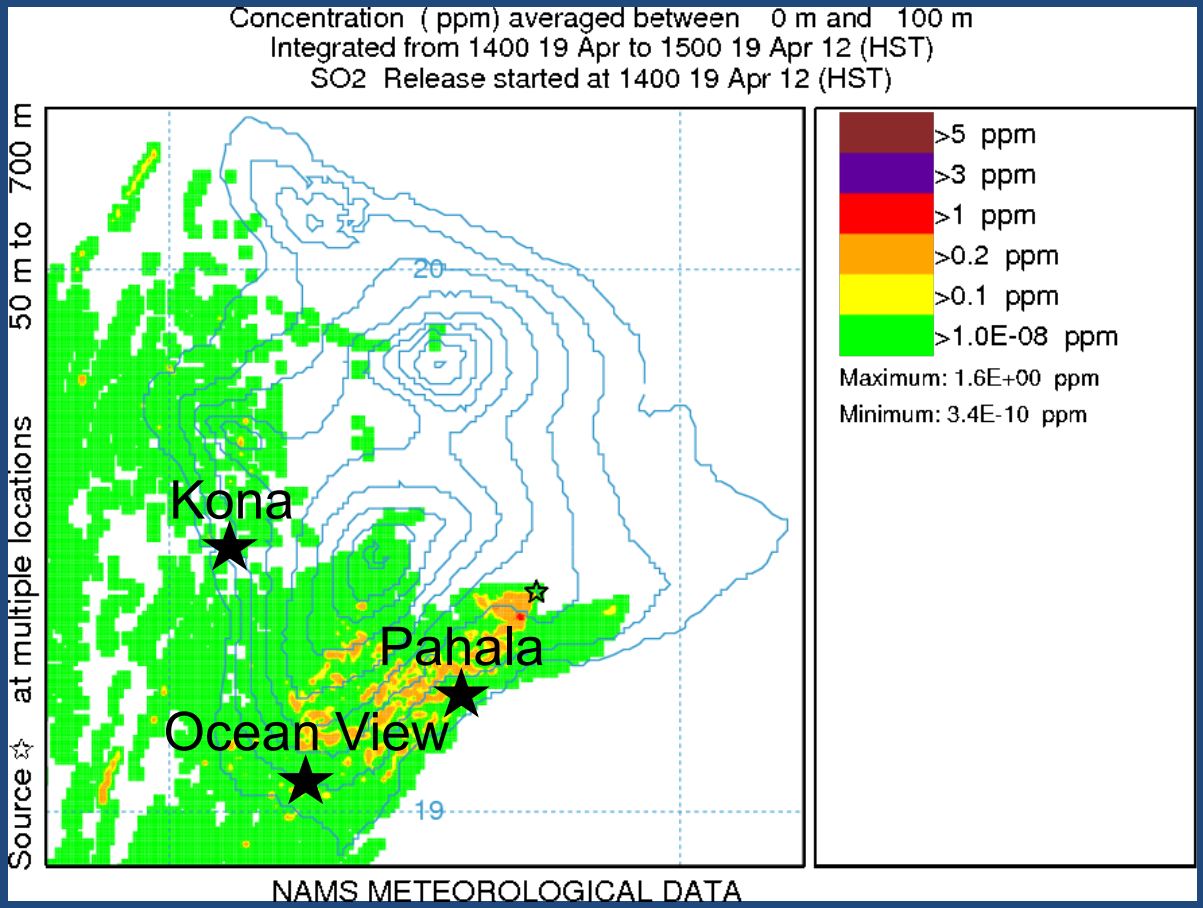


Control run (before plume correction) 1 h forecast

Plume adjusted based on SO_2 detected, local wind field adjusted, 1 h forecast

Comparison with Air Quality Stations: How do the forecasts verify over 24 h?

Kona: RMS error reduced from 0.025 to 0.010 (ppm SO_2)



Ocean View: RMS error reduced from 0.40 to 0.30 (ppm SO2)

Pahala: RMS error unchanged (0.055 ppm SO_2)

Thank You for
Your Attention.