The U.S. Interagency Volcanic Hazards Sciences and Services Coordination Group

John J. Murray
Associate Program Manager,
Atmospheric and Hydrological Disasters

Applied Sciences Program
Earth Science Division
Science Mission Directorate
NASA
Washington, DC USA

John.j.murray@nasa.gov

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Interagency Volcanic Hazards Sciences and Services Coordination Group Terms Of Reference

- The group provides interagency expertise on volcanic ash science and services, including, but not limited to, impact to aviation and will be co-chaired by members from each participating agency.
- This working group has no explicit policy making function.
- The objective of this working group is to facilitate collaboration and exchange of information on volcanic ash to ultimately improve the quality of hazard information for each agency's stakeholders and mitigate the impacts of volcanic ash.
- Current topics for collaboration and information sharing:
  1. NASA/DOD/FAA/USGS/Industry Vehicle Integrated Propulsion Research (VIPR)
  2. NOAA Automated Volcanic Ash Detection System
  3. Increasing NASA Calipso Near-real time data availability and use
  4. NASA/NOAA/USGS Suomi NPP Applications Transition to Operations
  5. Rapid response proposals for volcanic ash

Interagency Volcanic Hazards Sciences and Services Coordination Group
Participating Organizations

Interagency Volcanic Hazards Science/Services Coordination Group (IVHSCG)		
Group Participants	**Organization**	**Group Role**
Cecilia Miner cecilia.miner@noaa.gov	NOAA, Aviation Services Branch NWS Volcanic Ash Program Manager	Co-Chair
Charles Mandeville cmandeville@usgs.gov	USGS, Program Coordinator Volcano Hazards Program	Co-Chair
John Murray john.j.murray@nasa.gov	Associate Program Manager for Disasters NASA Applied Sciences Program	Co-Chair
Charles Holliday charles.holliday@us.af.mil	AFWA 16WS/WXE) Chief, METSAT Applications	
Barbara Stunder barbara.stunder@noaa.gov	NOAA OAR ARL	
Jeff Osiensky jeffrey.osiensky@noaa.gov	NOAA NWS Alaska Region Volcanic Ash Program Manager	
Grace Swanson grace.swanson@noaa.gov	NOAA NESDIS Satellite Analysis Branch Washington Volcanic Ash Advisory Center (VAAC) Manager	
Don Moore donald.moore@noaa.gov	NOAA NWS Alaska Aviation Weather Unit Anchorage Volcanic Ash Advisory Center Manager	
Marianne Guffanti guffanti@usgs.gov	USGS Reston, volcanological rep to ICAO and USGS Ash Hazards Project Chief	
Jamie Kibler jamie.kibler@noaa.gov	Washington VAAC Operations Manager	
Larry Mastin lgmastin@usgs.gov	USGS David A. Johnston Cascades Volcano Observatory	
Tom Murray tlmurray@usgs.gov	USGS Director, Volcano Science Center	
Tina Neal tneal@usgs.gov	USGS Alaska Volcano Observatory	
Mike Pavolonis michael.pavolonis@noaa.gov	NOAA NESDIS	
Dave Schneider djschneider@usgs.gov	USGS Research Geophysicist Alaska Volcano Observatory	
Matt Strahan matt.strahan@noaa.gov	NOAA NWS/NCEP International Operations Chief	
Renee Tatusko renee.l.tatusko@noaa.gov	NOAA NWS International Activities Office	
Bruce Entwistle bruce.entwistle@noaa.gov	NOAA NWS/NCEP Science and Operations Officer	Interested Party
Clinton Wallace clinton.wallace@noaa.gov	NOAA NWS/NCEP Deputy Director, Aviation Weather Center	Interested Party

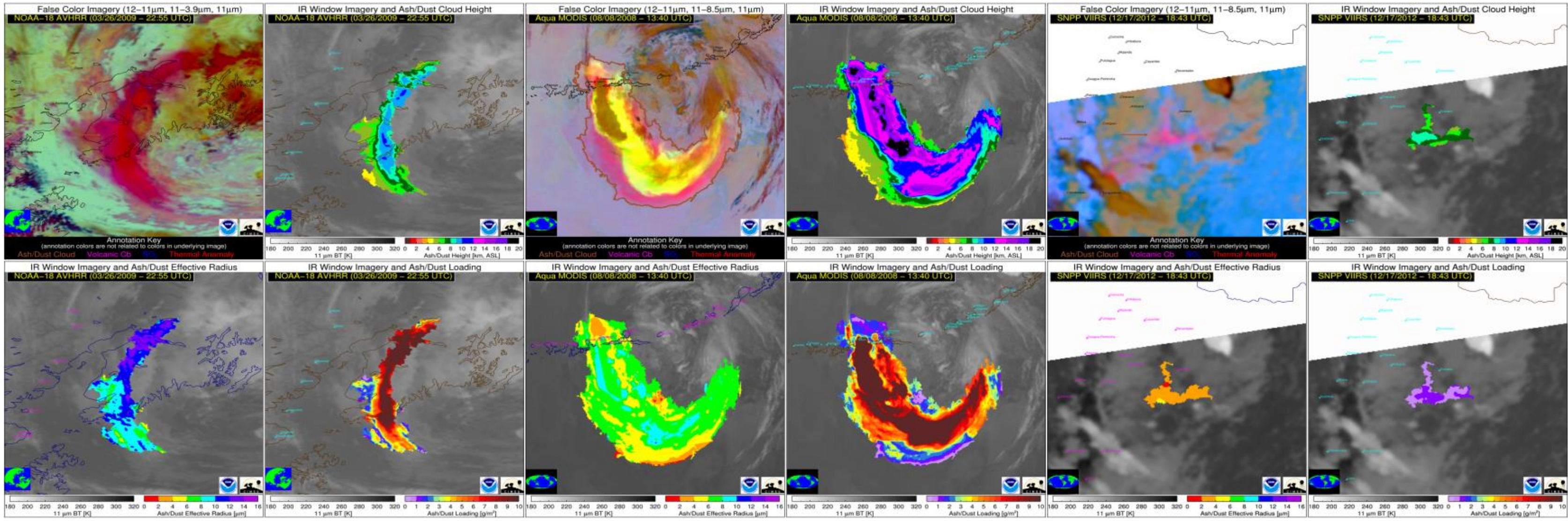
Aircraft Engine Ingestion Testing

The NASA Vehicle Integrated Propulsion Research (VIPR) Project is the first effort that may provide insight as to modern jet aircraft engine and related system impact thresholds for time and volume integrated exposure to diffuse volcanic ash clouds that my be encountered in operation airspace systems operations. Partners: NASA, DOD, USGS, FAA, Industry.

Making Full Use of the Space-based Observing System for Volcanic Cloud Monitoring

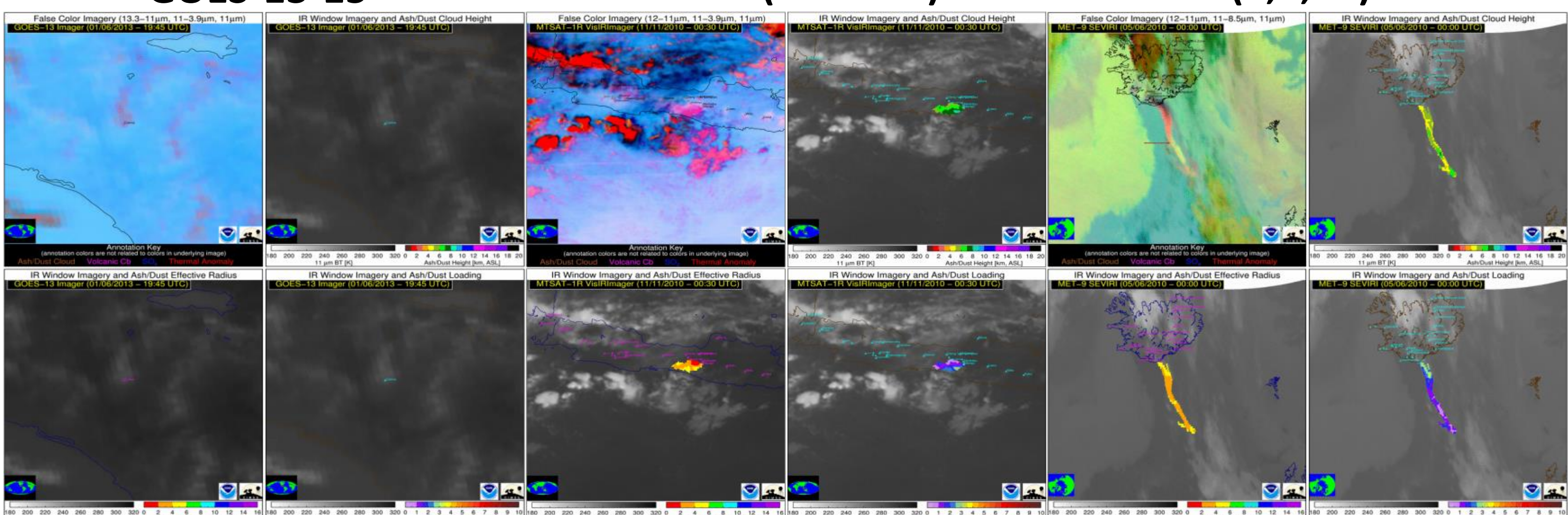
LEO

NOAA and MetOp AVHRR | Terra and Aqua MODIS | SNPP-VIIRS



GEO

GOES-13-15 | MTSAT-(1r and 2) | Met-(8,9,10) SEVIRI



NOAA Automated Volcanic Ash Detection and Characterization System

From: Mike Pavolonis NOAA Federal
Subject: **NOAA/CIMSS Volcanic Cloud Alert**
Date: May 30, 2014 6:08:15 AM CDT
To: Mike Pavolonis NOAA Federal

@**********VOLCANIC ALERTS**********
STARTING DATE/TIME OF IMAGE: 2014-05-30 10:32:00 [UTC]
PRIMARY INSTRUMENT: MTSAT-2 Vis/IR_Imager
WMO SPACECRAFT ID: 172
LOCATION/ORBIT: GEO
L1 FILE: mtsat02_1_2014_150_1032.area.gz
VOLCANO DATABASE: /data/common//VOLCAT_DATA/alerts/V
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

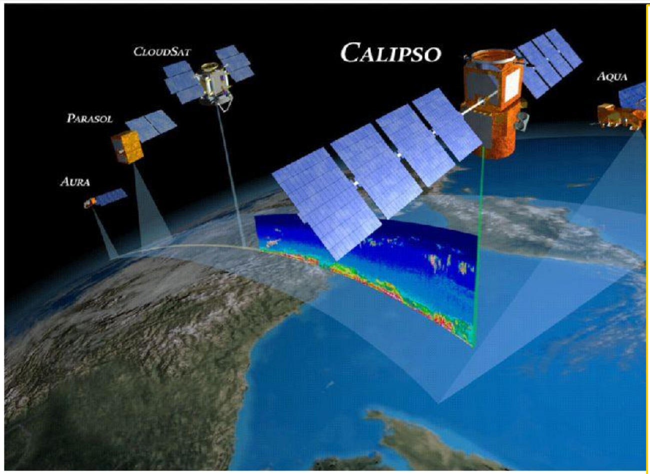
REPORT WITH IMAGES:
http://volcano.ssec.wisc.edu/alert/report/14318

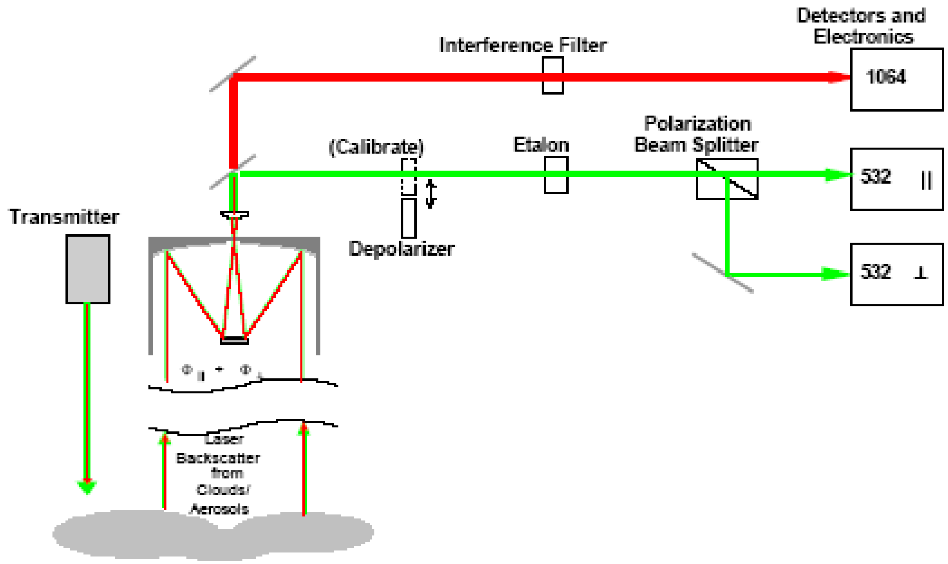
POSSIBLE VOLCANIC ASH CLOUD FOUND
Alert Status: New Alert Object
Latitude of Radiative Center: -8.421 [degrees]
Longitude of Radiative Center: 119.678 [degrees]
Mean Viewing Angle: 31.21 [degrees]
Mean Solar Zenith Angle: 100.73 [degrees]
Nearby Volcanoes (meeting alert criteria):
Sano, Wai(49.71 km)
Sangeang Api(71.71 km)
Poco Leok(93.32 km)
Ranakah(94.86 km)
Inielika(147.81 km)
Cloud Object Probability: 99.99957 [%]
Median Probability of Object Pixels: 92.45512 [%]
Percent Unambiguous Pixels: 12.30223 [%]
Maximum Height [AMSL]: 10.2 [km] (33355.06 [ft])
90th Percentile Height [AMSL]: 9.6 [km] (31600.68 [ft])
Mean Tropopause Height [AMSL]: 16.5 [km] (54080.38 [ft])
Total Mass: .004477 [Tg]
Median Effective Particle Radius: 5.74 [um]
Total Area: 1281.51 [km^2]

Geographic Regions of Nearby Volcanoes: Lesser Sunda Is
VAAC Regions of Nearby Volcanoes: Darwin
FIR Regions of Nearby Volcanoes: Unknown

Earth Science Missions in Operation

Caliop - The CALIPSO lidar





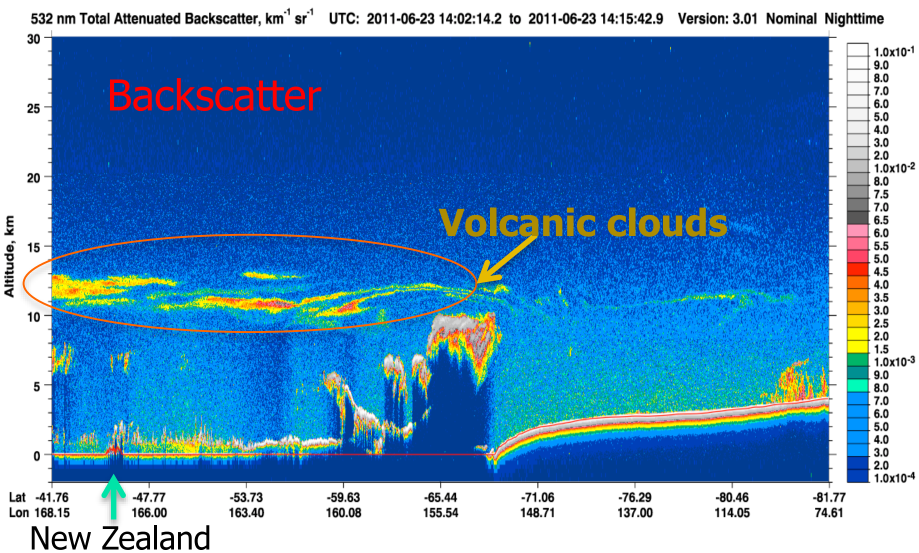
- Operating since 2006
- Polar Orbit
- Equatorial Crossing-time at 0130 and 1330 LET
- Repeat cycle of 16 days

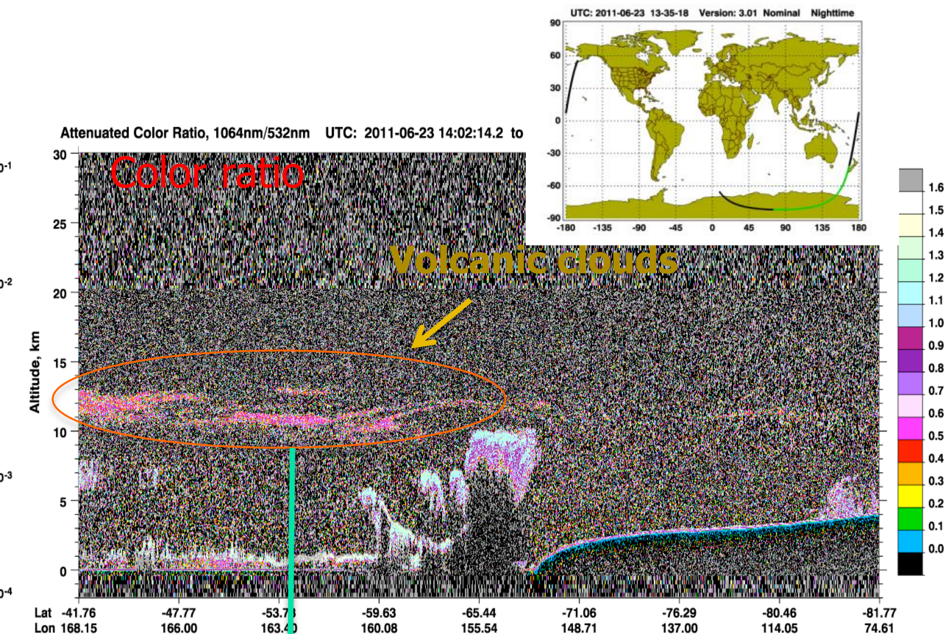
- Total Backscatter at 532 nm (density)
- Depolarization at 532 nm (geometry)
- Color Ratio (1064/532) (composition, size)

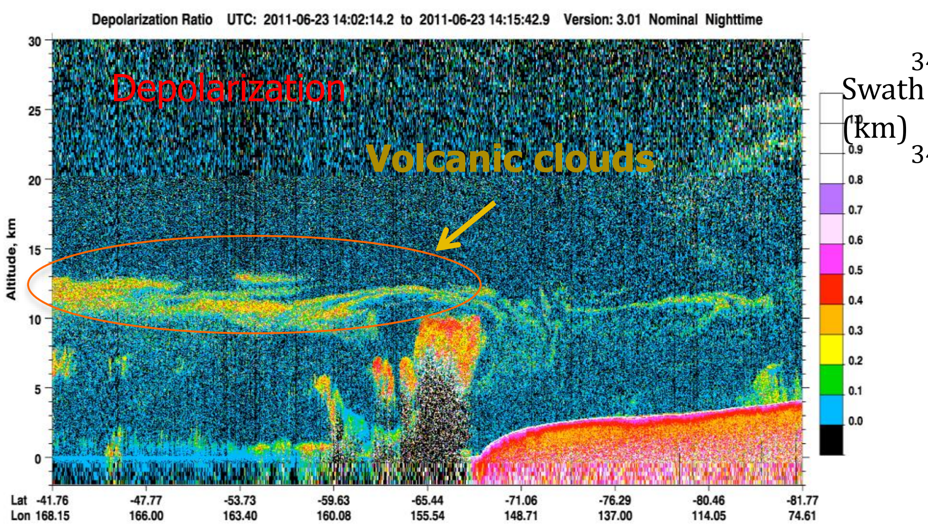
- High vertical resolution (60 m) of backscatter profiles
- Optical parameters provide unique capability to detect volcanic ash and its vertical structure

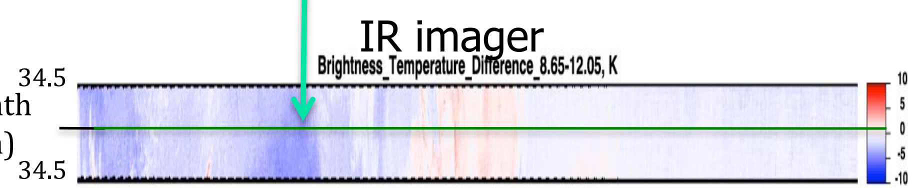
Langley Research Center

Calipso Data for Volcanic Ash



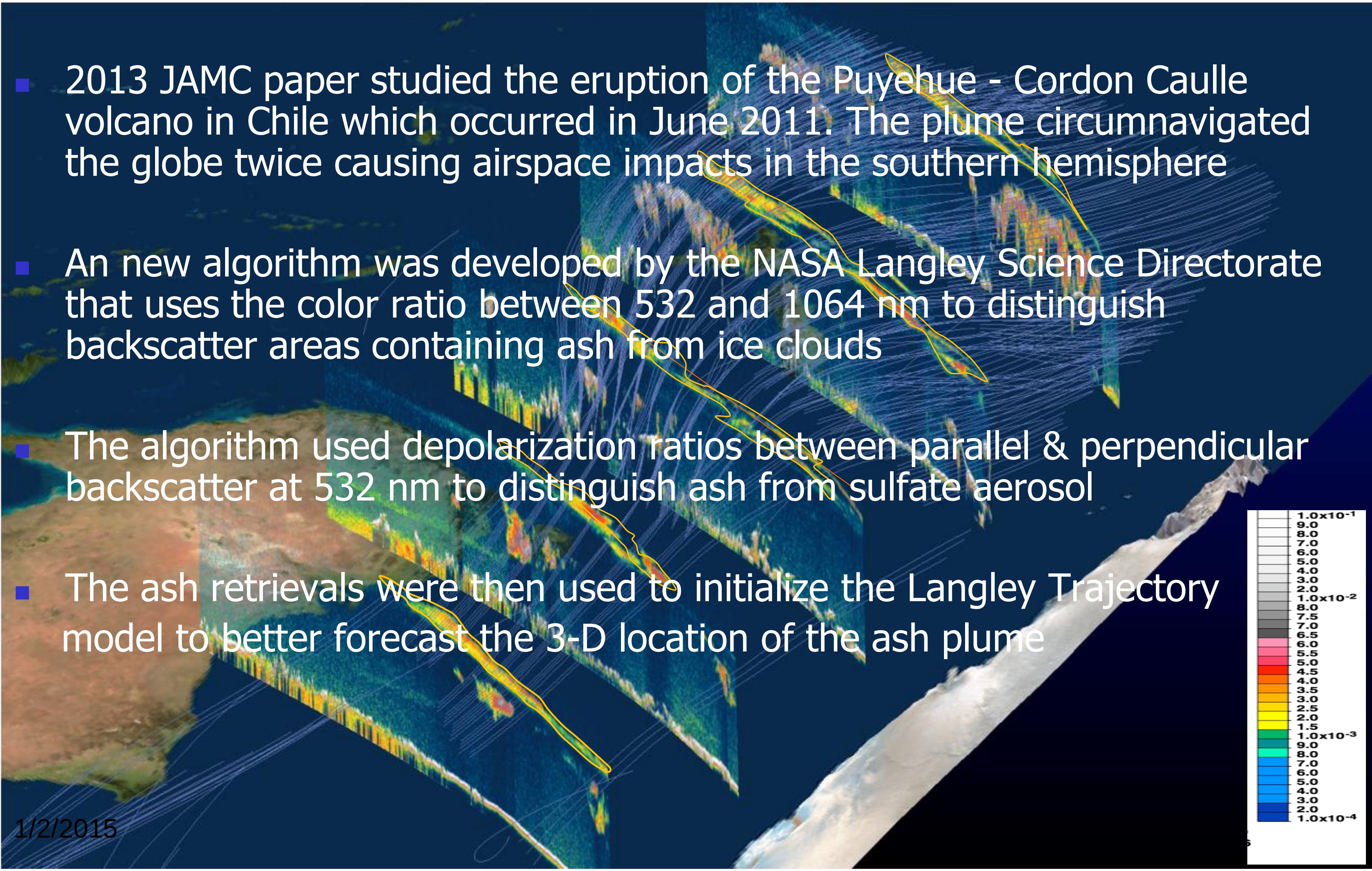






- Multi laminar layers with low color ratio (0.5) and high depolarization (0.3-0.4)
- Negative BT from IIR on board CALIPSO

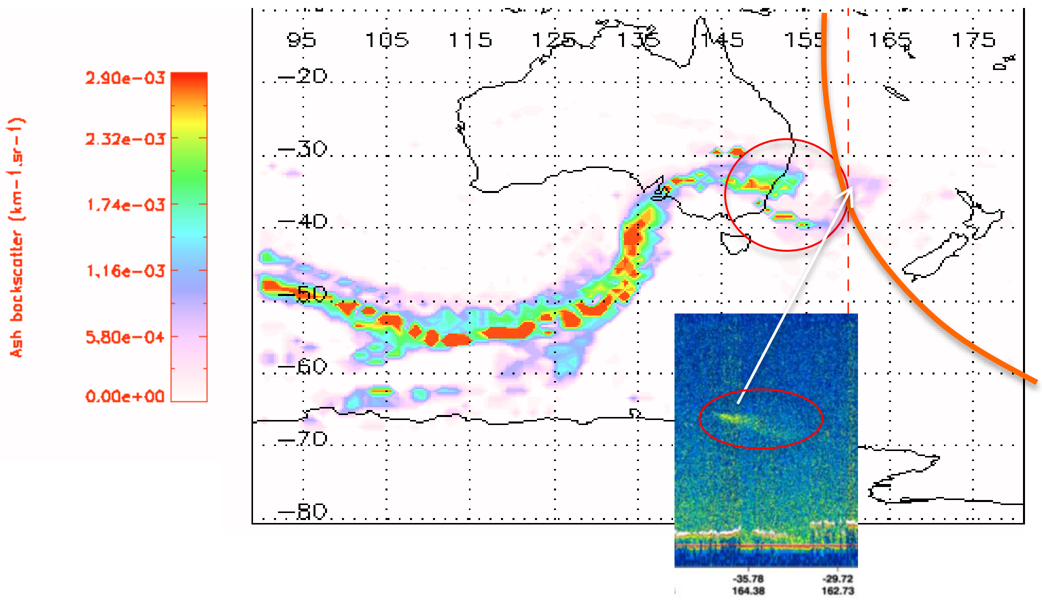
Caliop Applications for Volcanic Ash



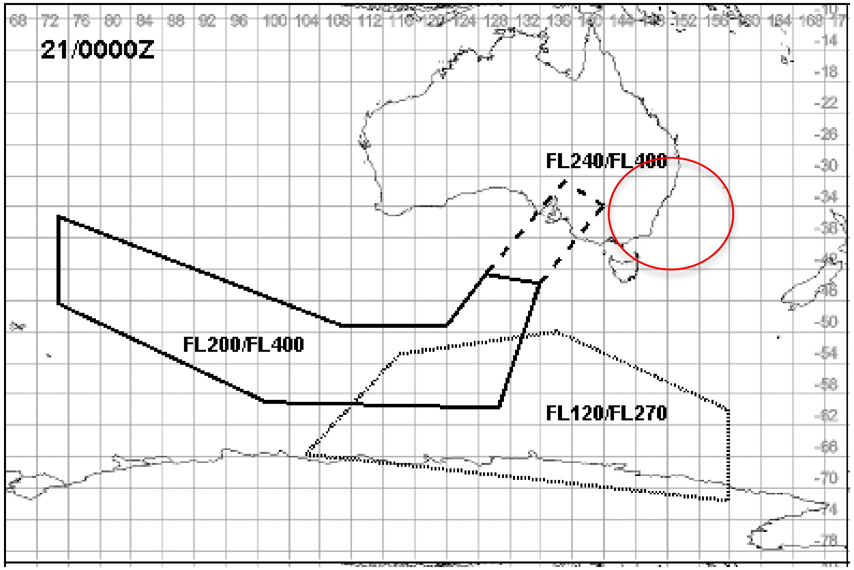
- 2013 JAMC paper studied the eruption of the Puyehue - Cordon Caulle volcano in Chile which occurred in June 2011. The plume circumnavigated the globe twice causing airspace impacts in the southern hemisphere
- An new algorithm was developed by the NASA Langley Science Directorate that uses the color ratio between 532 and 1064 nm to distinguish backscatter areas containing ash from ice clouds
- The algorithm used depolarization ratios between parallel & perpendicular backscatter at 532 nm to distinguish ash from sulfate aerosol
- The ash retrievals were then used to initialize the Langley Trajectory model to better forecast the 3-D location of the ash plume

Adding value to GEO Imager Data

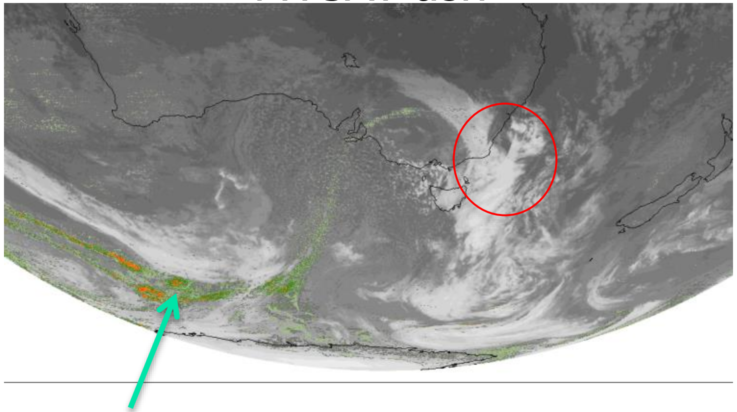
CALIPSO-trajectory mapping



Volcanic Ash Advisory from Darwin VAAC



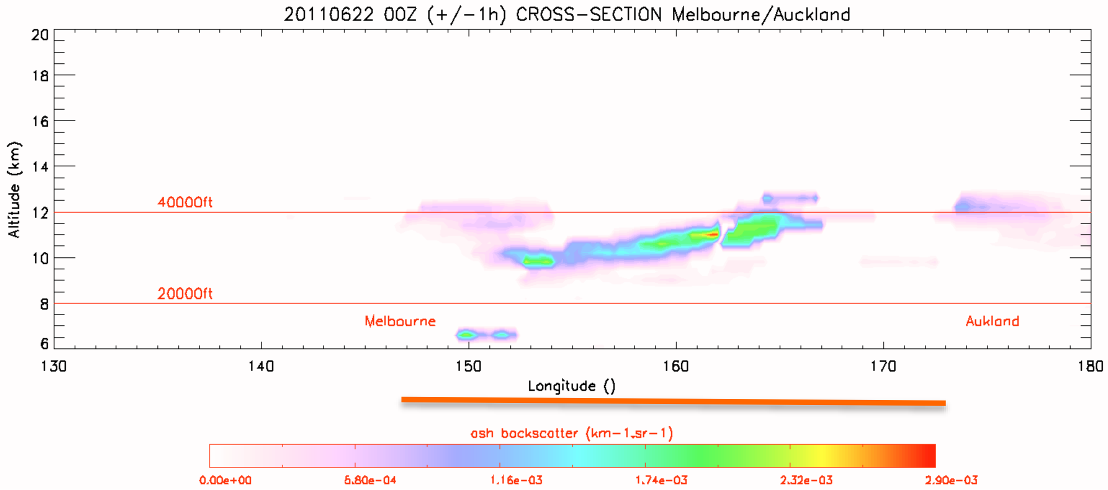
MTSAT ash

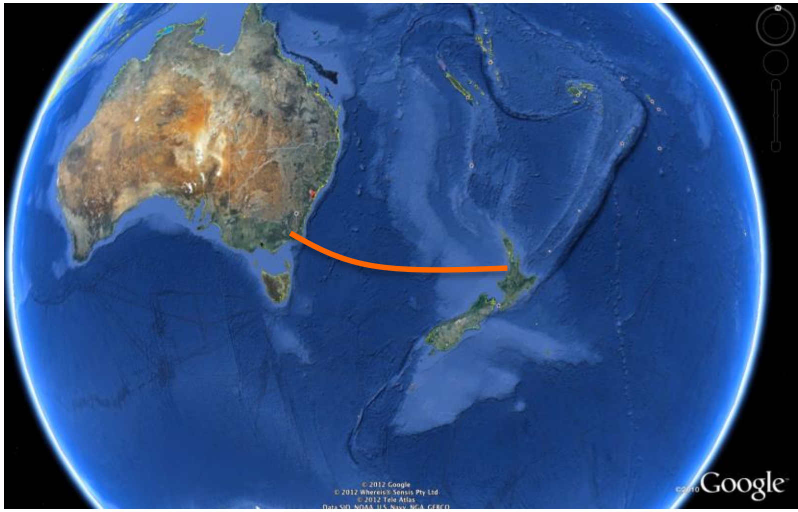


Visible Volcanic ash cloud

- Ash cloud masked by ash in MTSAT data over SE Australia (Sydney)
- Ash Advisory misses area over Tasman Sea
- CALIPSO-trajectory map captured the head of the plume on time (as validated by a subsequent independent daytime overpass)

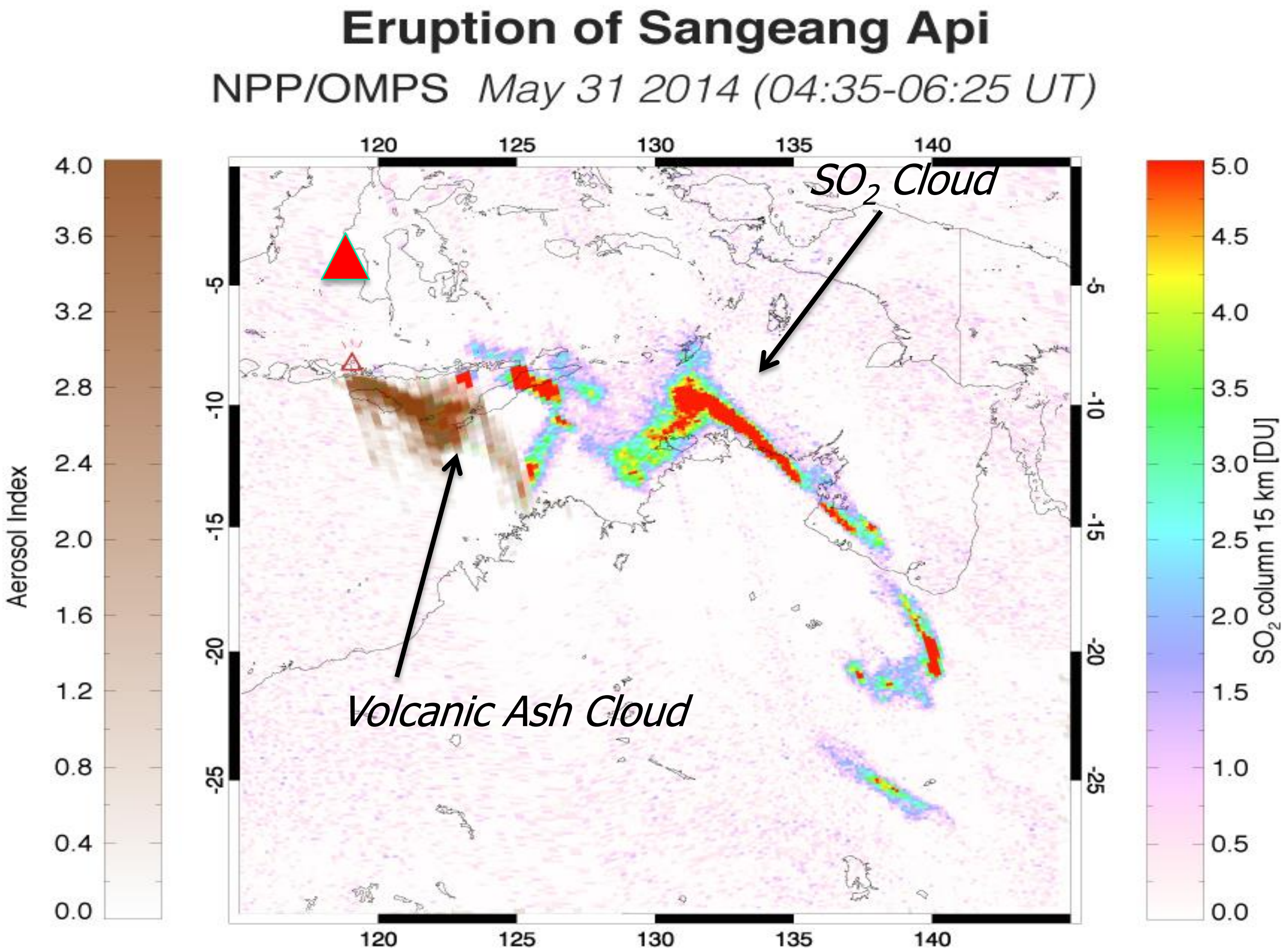
Cross-sections along flight tracks : Potential new tool for the VAACs





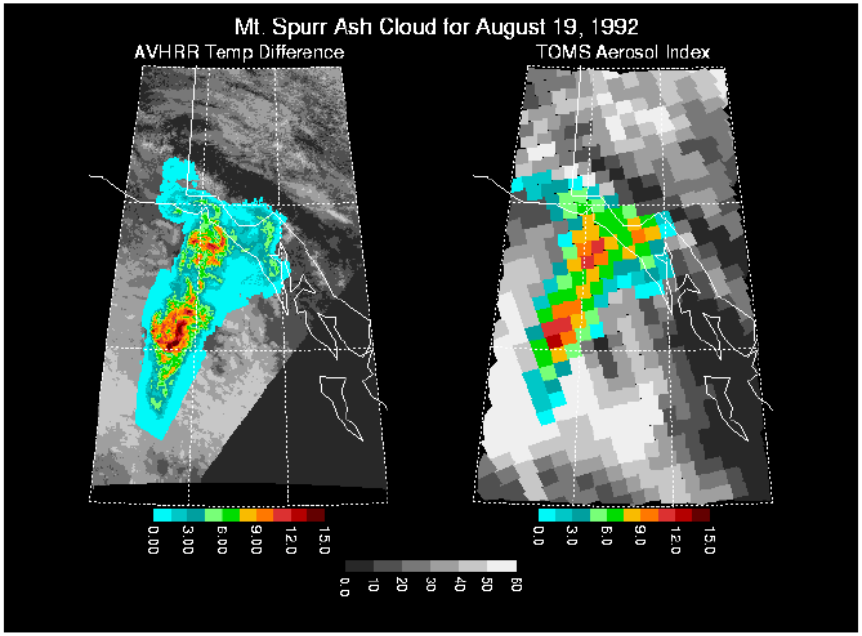
- These trajectory-mapped, ash backscatter maps and cross-sections present a potentially important new tool to improve navigation under diffuse volcanic ash conditions and to optimize flight planning and ash avoidance.

SNPP/OMPS NRT SO_2 & Ash Index



Imager and UV Sun-photometer Complementarity

- IR ash detection:
  - Plume must be transparent
  - Water hides ash
  - Plume temperature contrast with underlying surface
  - Low concentration not detectable
- Fresh ash clouds:
  - Dense, must wait until sheared to thin layer
  - Full of water, ice



IR: T11-T12

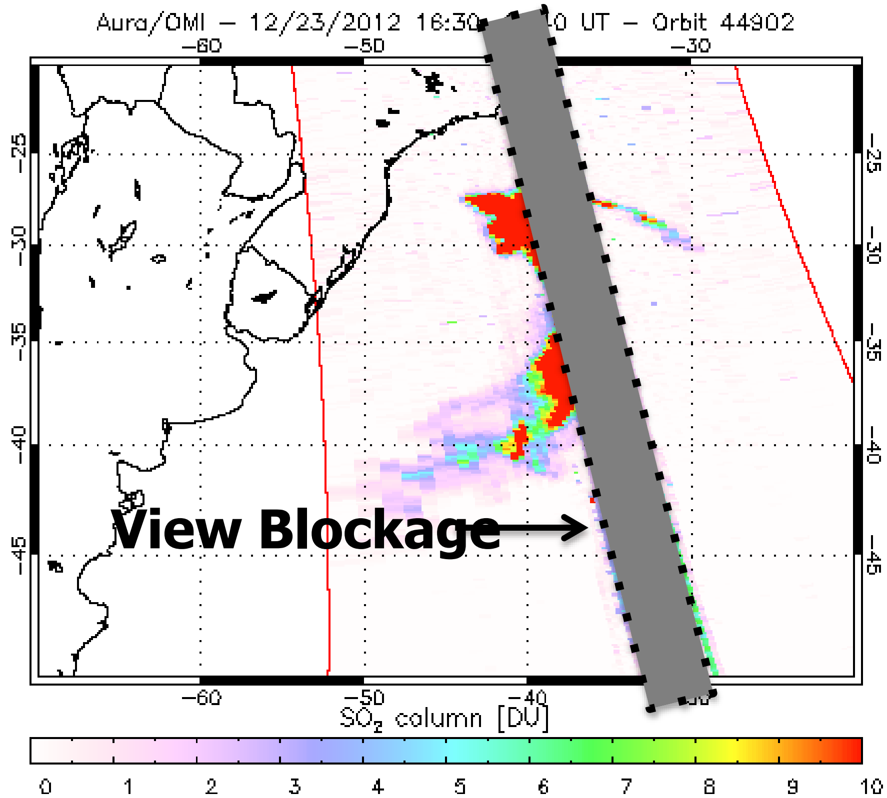
UV ash: AI

- UV ash (AI) detection:
  - Scattering by ash differs from Rayleigh scattering
  - Sunlight necessary
  - Low concentrations are detectable

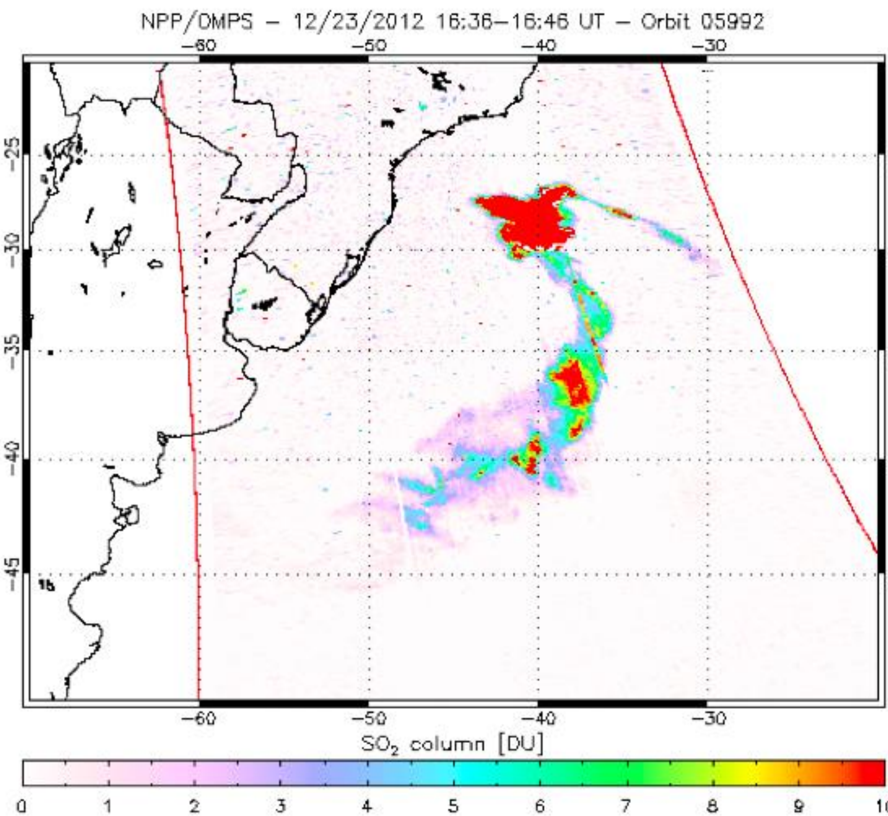
Fresh ash clouds:
  - Detected upon eruption
  - Independent of water content
  - Not detectable at night

Transitioning from Research to Operations

Aura/OMI NRT SO_2



SNPP/OMPS NRT SO_2



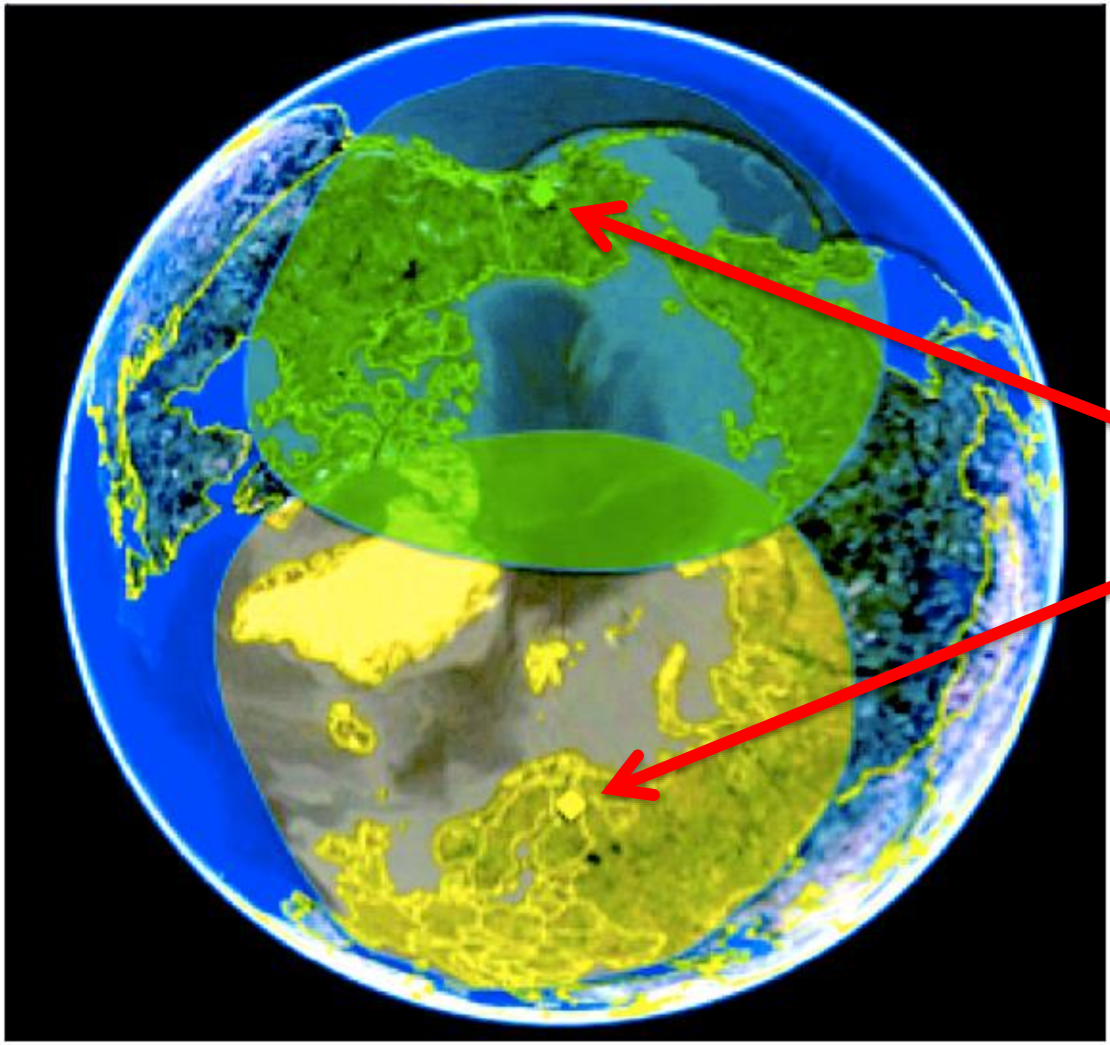
OMI and OMPS are very similar instruments.

Disadvantages: Courser ground resolution

Advantages: No data gap. Operational.

Direct Readout of SNPP

North Pole Coverage using Direct Readout Processing



North pole region generally obscured from geostationary satellite

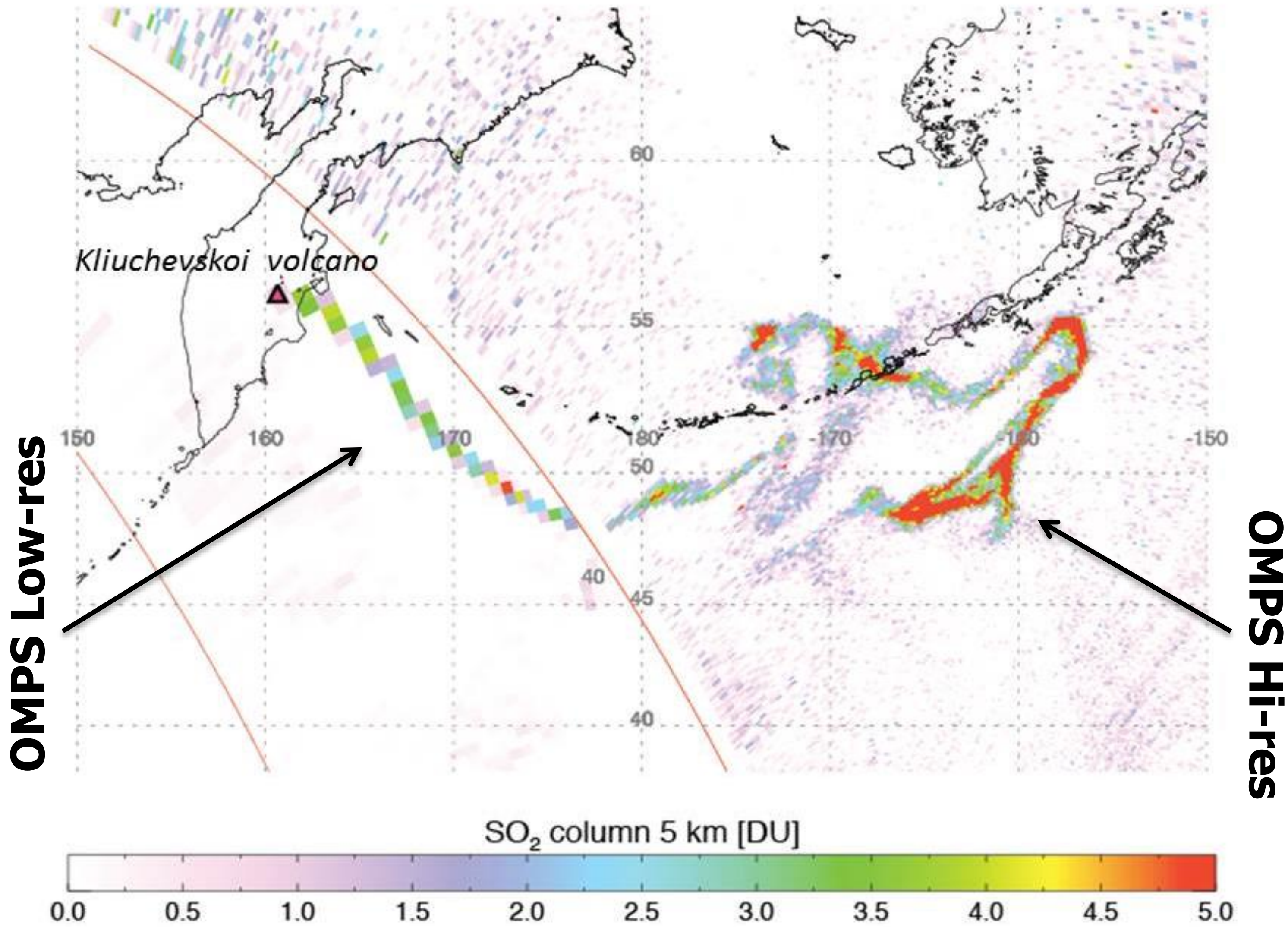
(Fairbanks, Alaska. USA)

Ground Receiving Stations

(Sodankylä, Finland)

North Pole View

OMPS: *Hi-res vs. Low-res Data*



SO_2 map from October 19th 2013

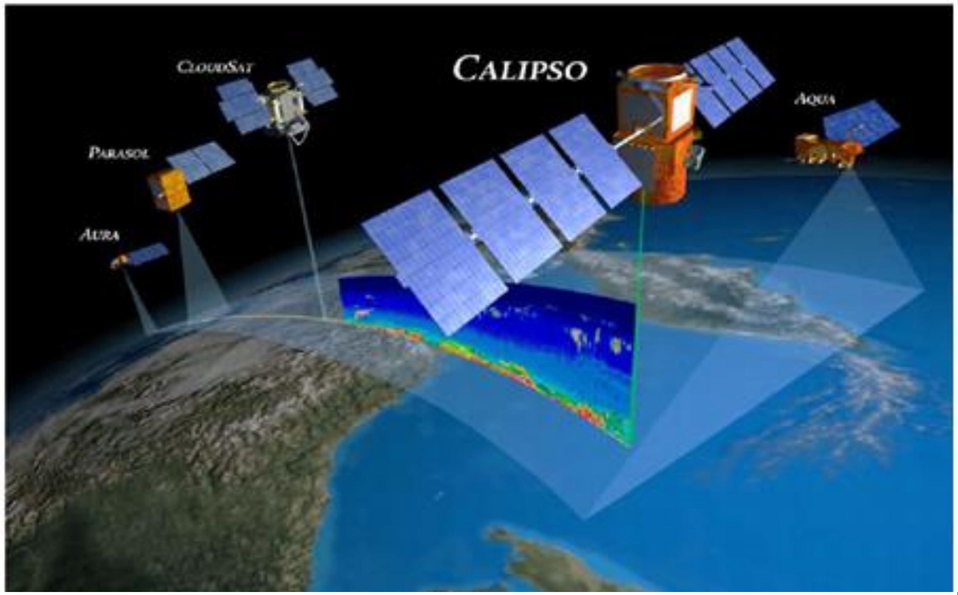
Obtaining More accurate and frequent ash concentration measurements to initialize dispersion models

Highly accurate ash plume trajectory forecasts are currently possible.

Accurate quantitative dispersion forecasts are much more difficult since there are infrequently sufficient concentration measurements needed to adequately initialize and sustain the model forecast.

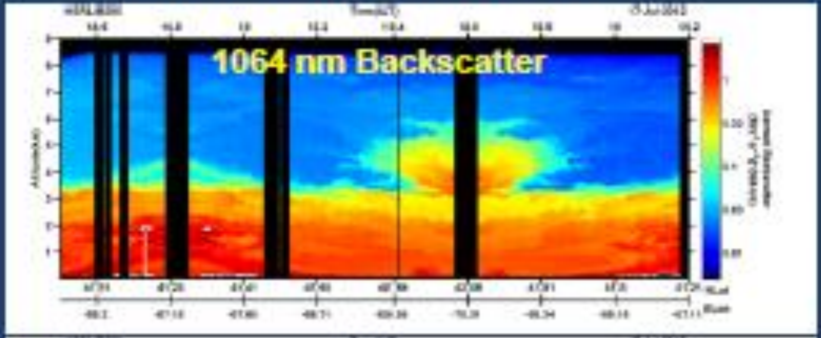
How can we obtain them?

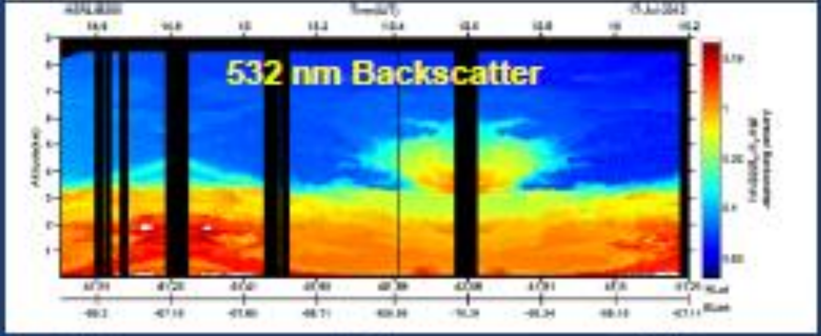
Sources of mass loading information to calibrate satellite retrievals of ash concentration.

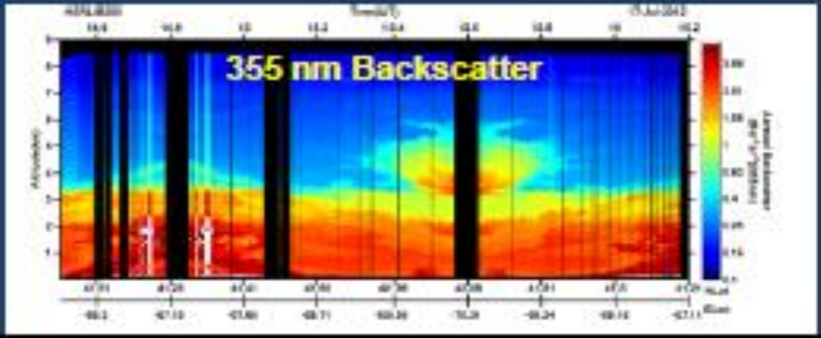


LaRC Airborne HSRL-2: World's First Airborne Multi-wavelength HSRL

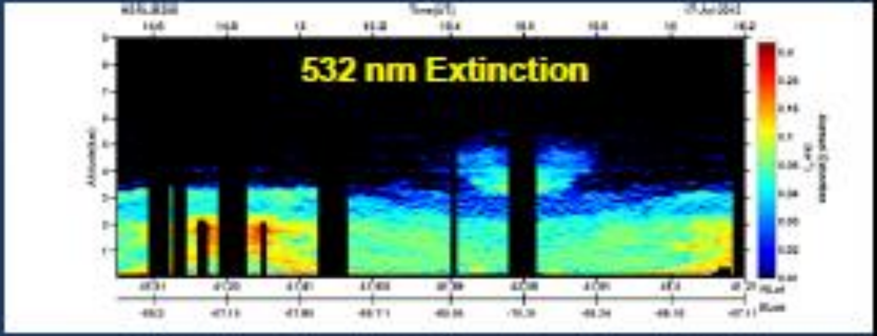
07/17/2012 TCAP flight on B200 aircraft

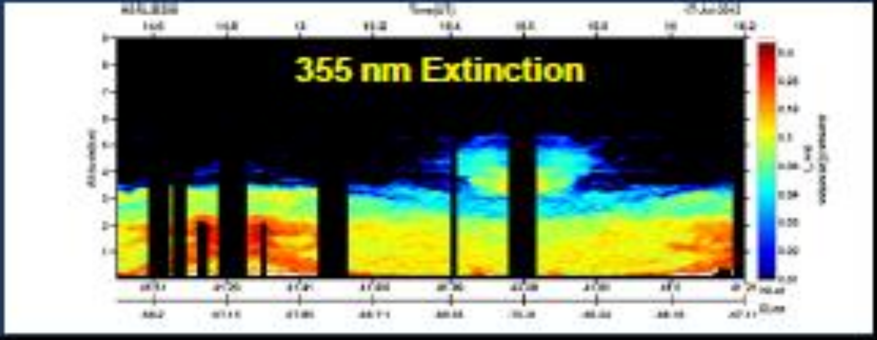






- High Spectral Resolution Lidar (HSRL) provides independent retrievals of aerosol extinction and backscatter
  - HSRL-2 Capabilities
    - Backscatter at 355, 532, and 1064 nm
    - Extinction at 355 and 532 nm (HSRL)
    - Depolarization at 355, 532, 1064 nm





From HSRL-2 to ACE

- **Inversion with regularization of HSRL-2 Data**

Aerosol Backscatter at 355, 532 and 1064 nm

+

Extinction at 355 and 532nm

↓

- **Aerosol Microphysical Properties :**
- Effective radius
- Index of refraction
- Scattering and absorption coefficients
- Single scattering albedo
- Concentration:
  1. Number
  2. Surface
  3. Volume

- **ACE* – Aerosol/Cloud/Ecosystem Mission Recommended Payload**
- HSRL-2 Lidar for measurement of aerosol heights, cloud top heights, and aerosol properties
- Radar measurements of microphysics structure for cloud and precipitation
- Polarimeter for measuring aerosol optical properties and aerosol types
- Ocean color spectrometer for measuring ocean leaving light which contains information on biological components
- **Enhanced Science Payload**
- Infrared radiometer imager for cloud measurements
- High frequency microwave radiometer for cloud ice measurements
- Low frequency microwave radiometer for precipitation and water measurements
- Microwave temperature and humidity sounder

*ACE is a tier 2 decadal survey mission. NASA is currently preparing For the next decadal survey beginning with workshops in 2015.


Marco Fulle - www.stromboli.net

Questions?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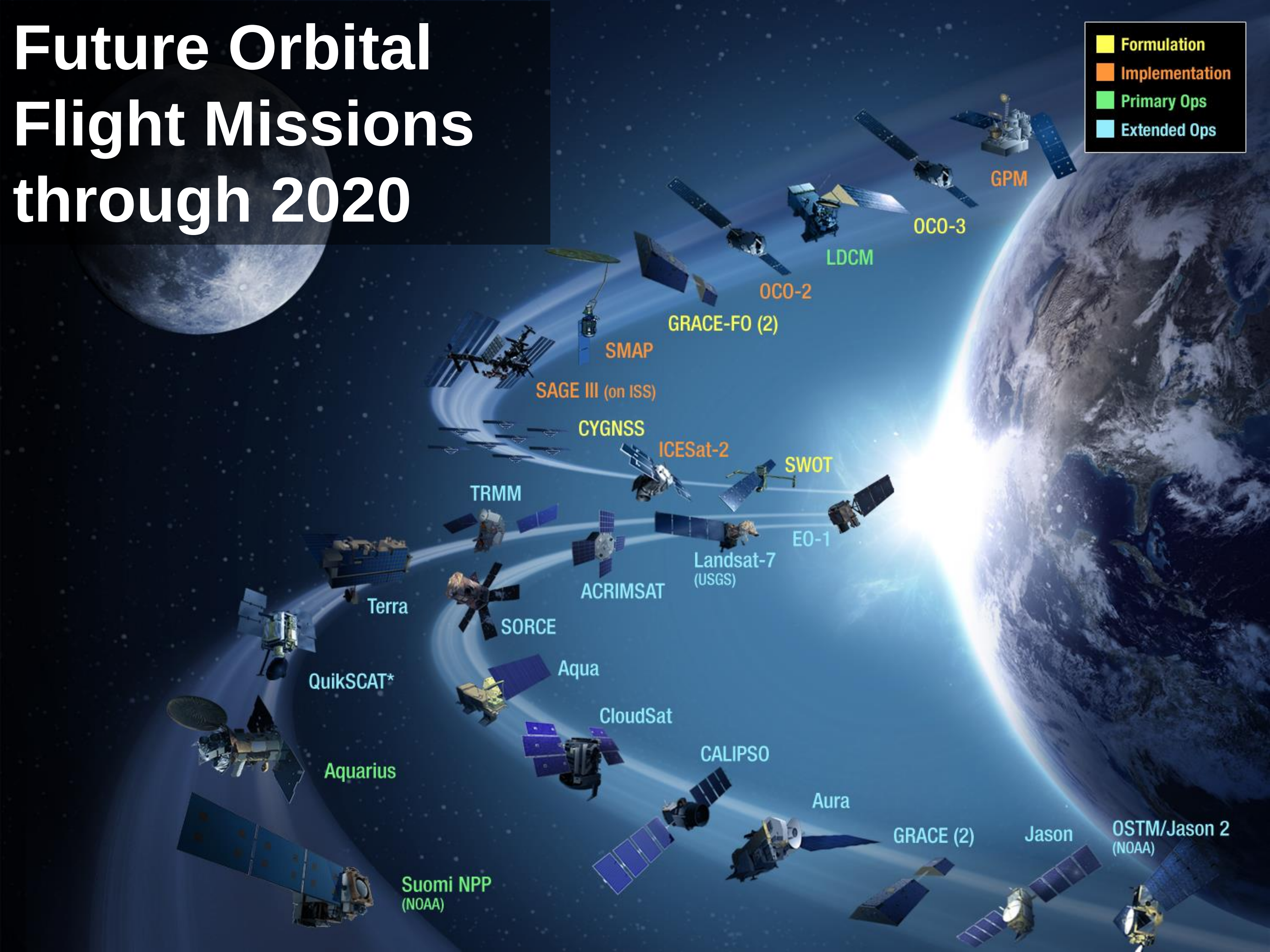
Back-up slides

Future Orbital Flight Missions through 2020



ESD/Applied Sciences Program

Discovering and demonstrating innovative and practical uses of Earth observations in organizations' policy, business, and management decisions.

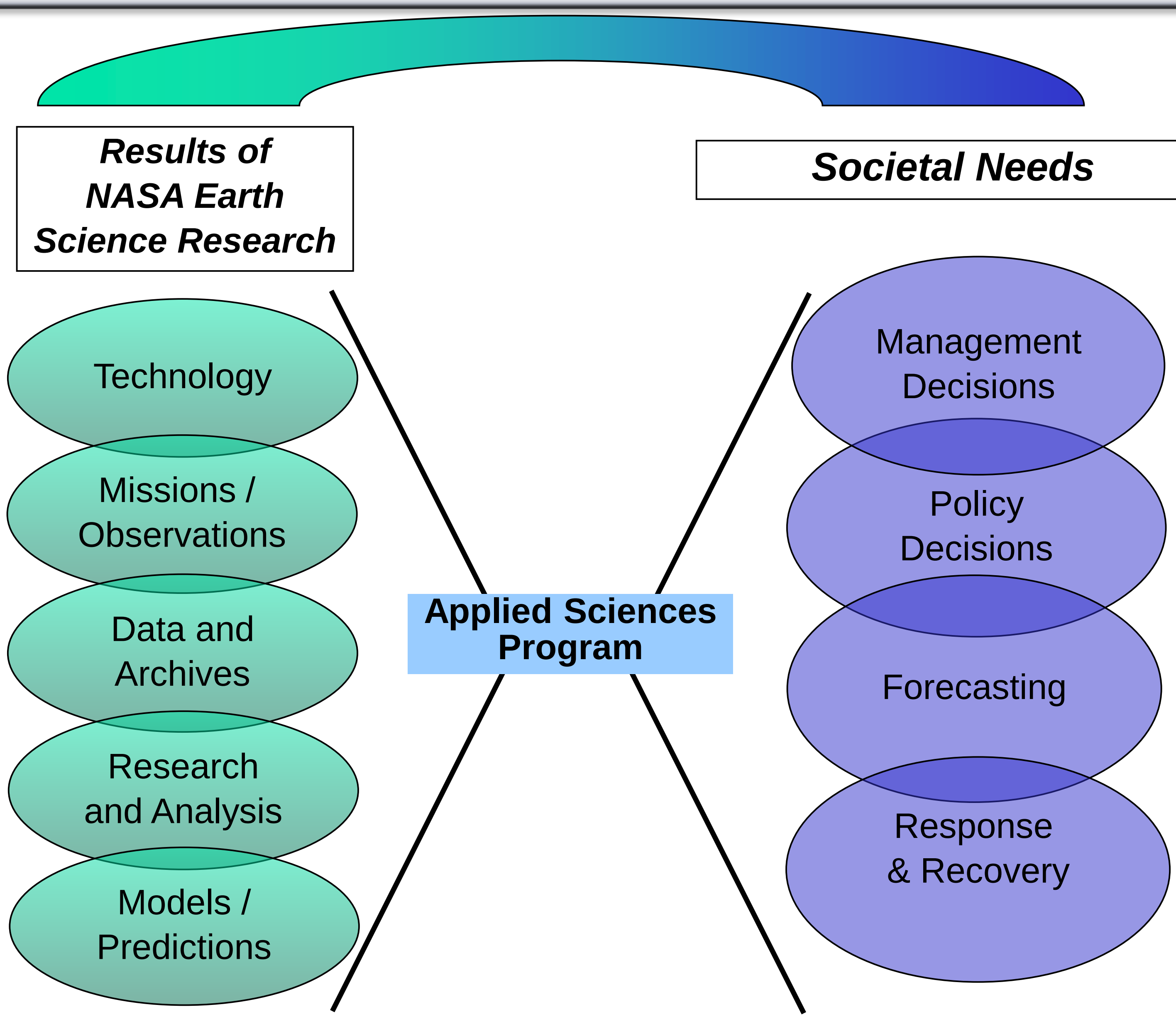
http://AppliedSciences.NASA.gov

Applications
Prove-out, develop, and transition applications ideas for sustained uses of Earth obs. in decision making.

Capacity Building
Build skills and capabilities in US and developing countries to access Earth observations to benefit society.

Mission Planning
Identify applications early in mission lifecycle and integrate end-user needs in mission design and development.

NASA Applied Sciences Architecture



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Applications Areas

Emphasis in 4 Applications Areas

Health & Air Quality

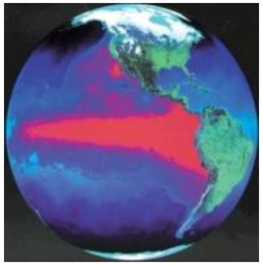
Water Resources

Disasters

Ecological Forecasting

Support opportunities in 5 additional areas

Agriculture



Climate

Weather

Energy

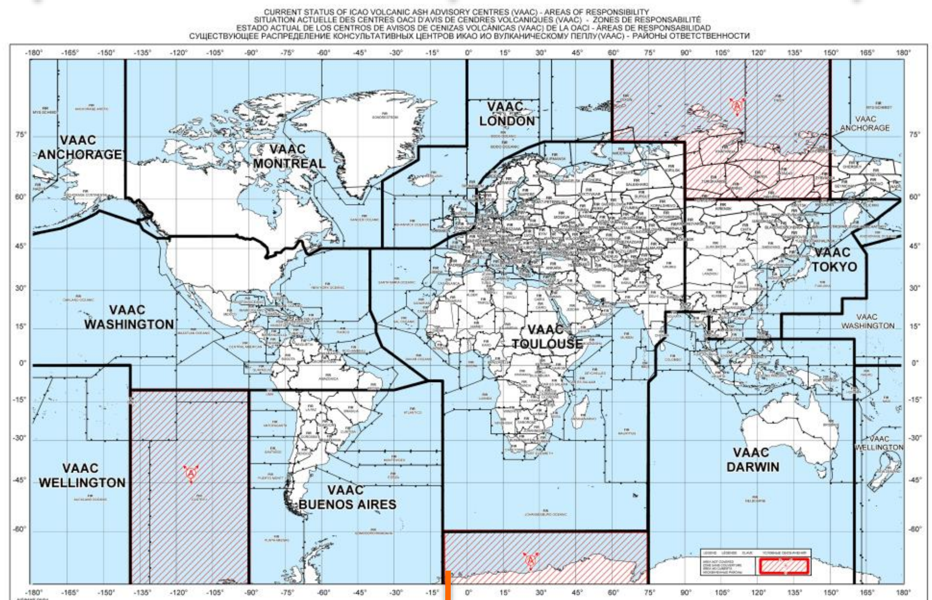
Oceans

Volcanic Ash and Aviation

Dispersion Models

Pilot reports

Satellite obs



Ash Advisory

Aviation industry

- 9 worldwide VAACs to monitor volcanic ash
- multiple sources of information (dispersion models, pilot reports, satellites) to prepare ash advisory
- Information used by for aviation industry (flight cancellation, re-routing)

Finding an Optimal Solution for Volcanic Ash

- All sensors for ash detection and characterization provide important, unique information, but none are a panacea.
- Imager data can be obscured by clouds or multiple layers of ash and/or clouds, so it may not detect the entire extent of the ash plume.
- UV Photometers can detect associated SO2 plumes but only during daylight.
- Satellite lidar is not a detection tool but sees through clouds to provide excellent height, layering and composition data, and calibrated multiple swaths can render very accurate 3-D dispersion model forecasts if sufficient concentration data exist.
- Dispersion models initialized with accurate concentration measurements are the best means of depicting plume boundaries, but currently they lack sufficient observations of aerosol concentration to forecast the 3D/geographic distribution of ash concentration needed for reliable ATM.
- Forward looking and in situ airborne systems provide excellent concentration measurements for tactical maneuvering but due to limited coverage, their greater value may also lie in their ability to initialize dispersion models.
- The optimal solution may be to obtain and integrate all available ash concentration measurements to initialize dispersion models well enough to produce an accurate 3D analysis and forecast of the entire plume.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The Optimal Solution for Volcanic Ash

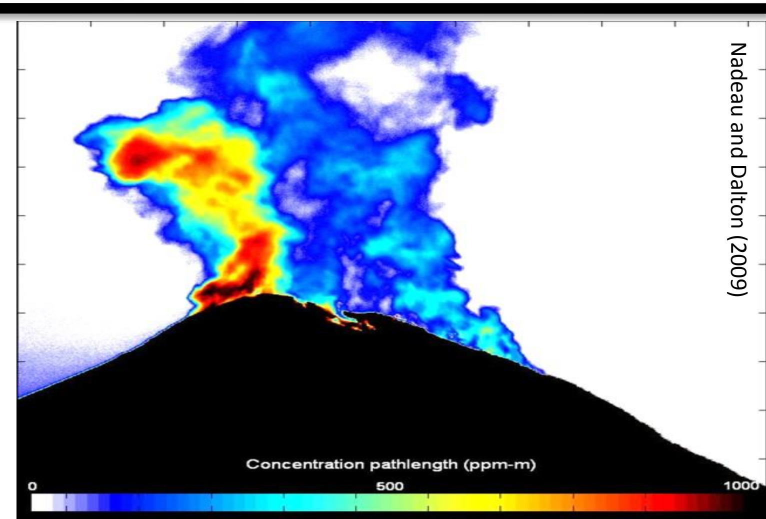
- All sensors for ash detection and characterization provide important, unique information, but they have significant shortcomings when used alone.
- Imager data can be obscured by clouds or multiple layers of ash and/or clouds, so it may not detect the entire extent of the ash plume.
- UV Photometers can detect associated SO2 plumes but only during daylight.
- Satellite lidar is not a detection tool but sees through clouds to provide excellent height, layering and composition data, and calibrated multiple swaths can render very accurate dispersion model forecasts.
- Dispersion models initialized with a variety of accurate concentration measurements are the best means of depicting plume boundaries, but currently they lack sufficient observations of aerosol concentration to forecast the 3D geographic concentration distribution of ash needed for reliable ATM.
- Forward looking and in situ airborne systems provide excellent concentration measurements for tactical maneuvering but due to limited coverage, their true value lies in their ability to initialize dispersion models.
- The optimal solution is to integrate all concentration measurements to initialize dispersion models well enough to produce an accurate 3D analysis and forecast of the entire plume.

Volcanic Cloud Types

1). Ash dominated volcanic plumes – Semi-transparent clouds dominated by volcanic ash. Lightning is usually not present in these clouds.

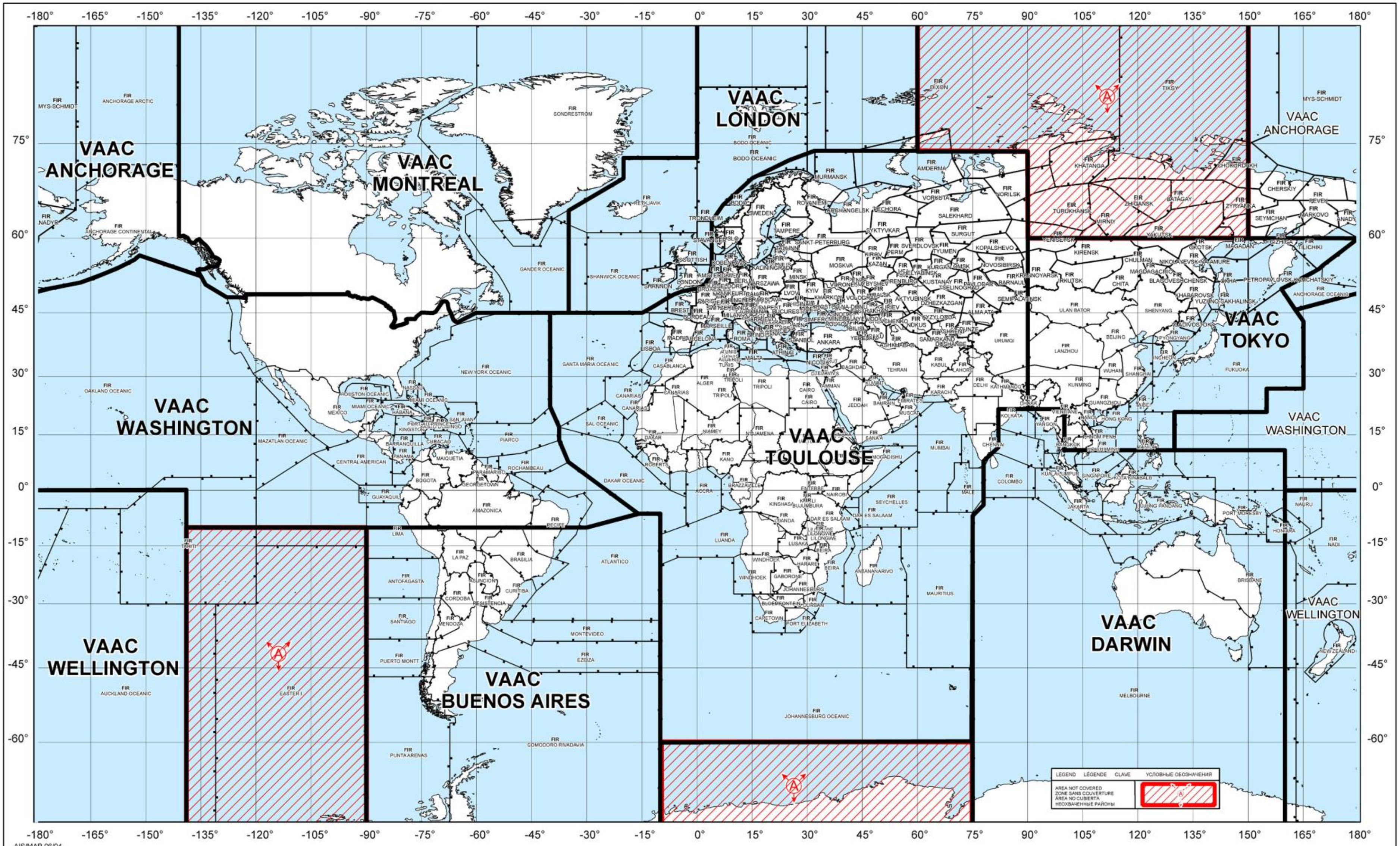
2). Ice topped umbrella clouds – These clouds are mostly observed during a major eruption. A spectral based volcanic ash signal is usually initially absent because the ash is encased in ice and/or the cloud is opaque. Lightning is often present in these clouds.

3). SO_2 clouds – Sulfur dioxide clouds (SO_2 gas is invisible to the eye) that may or may not contain volcanic ash. Some eruptions produce large amounts of SO_2 and very little ash and vice-versa.



Nadeau and Dalton (2009)

CURRENT STATUS OF ICAO VOLCANIC ASH ADVISORY CENTRES (VAAC) - AREAS OF RESPONSIBILITY
SITUATION ACTUELLE DES CENTRES OACI D'AVIS DE CENDRES VOLCANIQUES (VAAC) - ZONES DE RESPONSABILITÉ
ESTADO ACTUAL DE LOS CENTROS DE AVISOS DE CENIZAS VOLCÁNICAS (VAAC) DE LA OACI - ÁREAS DE RESPONSABILIDAD
СУЩЕСТВУЮЩЕЕ РАСПРЕДЕЛЕНИЕ КОНСУЛЬТАТИВНЫХ ЦЕНТРОВ ИКАО ИО ВУЛКАНИЧЕСКОМУ ПЕПЛУ(VAAC) - РАЙОНЫ ОТВЕТСТВЕННОСТИ



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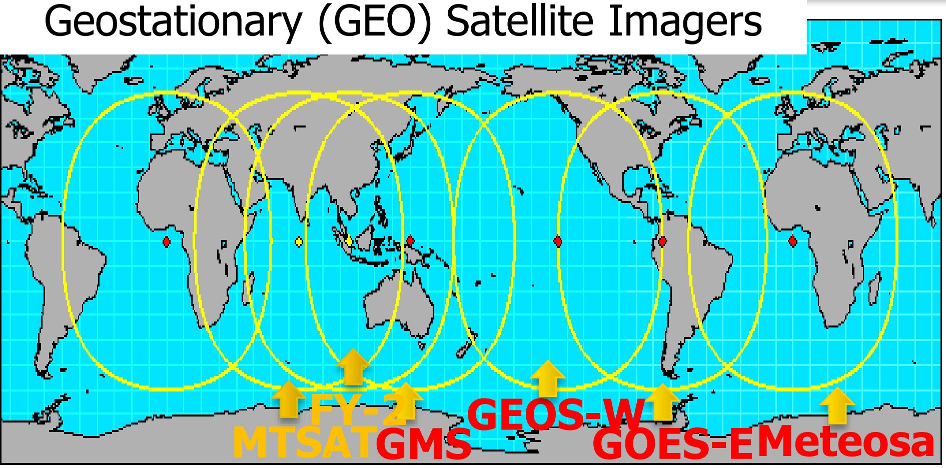
GEO Vs LEO Observations

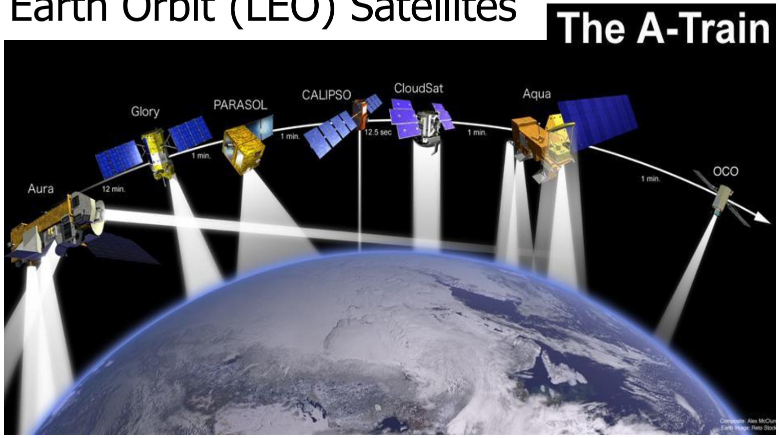
Geostationary (GEO) Satellite Imagers



- Imagers from GEO with different spectral capabilities
- Visible/NIR/IR spectral coverage (1-xkm horizontal resolution)
- Temporal resolution (15min-1h)
- **"Split-window" for ash detection** (Ellrod2004)

GEO Imagers are the best detection and tracking tool for thick volcanic ash clouds
Ice and water clouds can cover or obscure ash
Very limited information on ash cloud layering, not sensitive to diffuse ash cloud

Low Earth Orbit (LEO) Satellites



- VIS/NIR/IR Imaging radiometer AVHRR/MODIS (250m-1km horizontal resolution) **volcanic ash**
- Infrared Hyperspectral sounders (AIRS/IASI) volcanic **SO2 and volcanic ash**
- UV/Vis sounder (GOME-2/OMI) **aerosol index and SO2**

- Detection of volcanic ash and SO2 (UV or IR)
- Better sensitivity to thin volcanic clouds than GEO
-Combination of several instruments to have collocated SO2/ash information (A-train)

Excepting Lidar, most satellites have limited vertical resolution and are not sensitive to diffuse ash

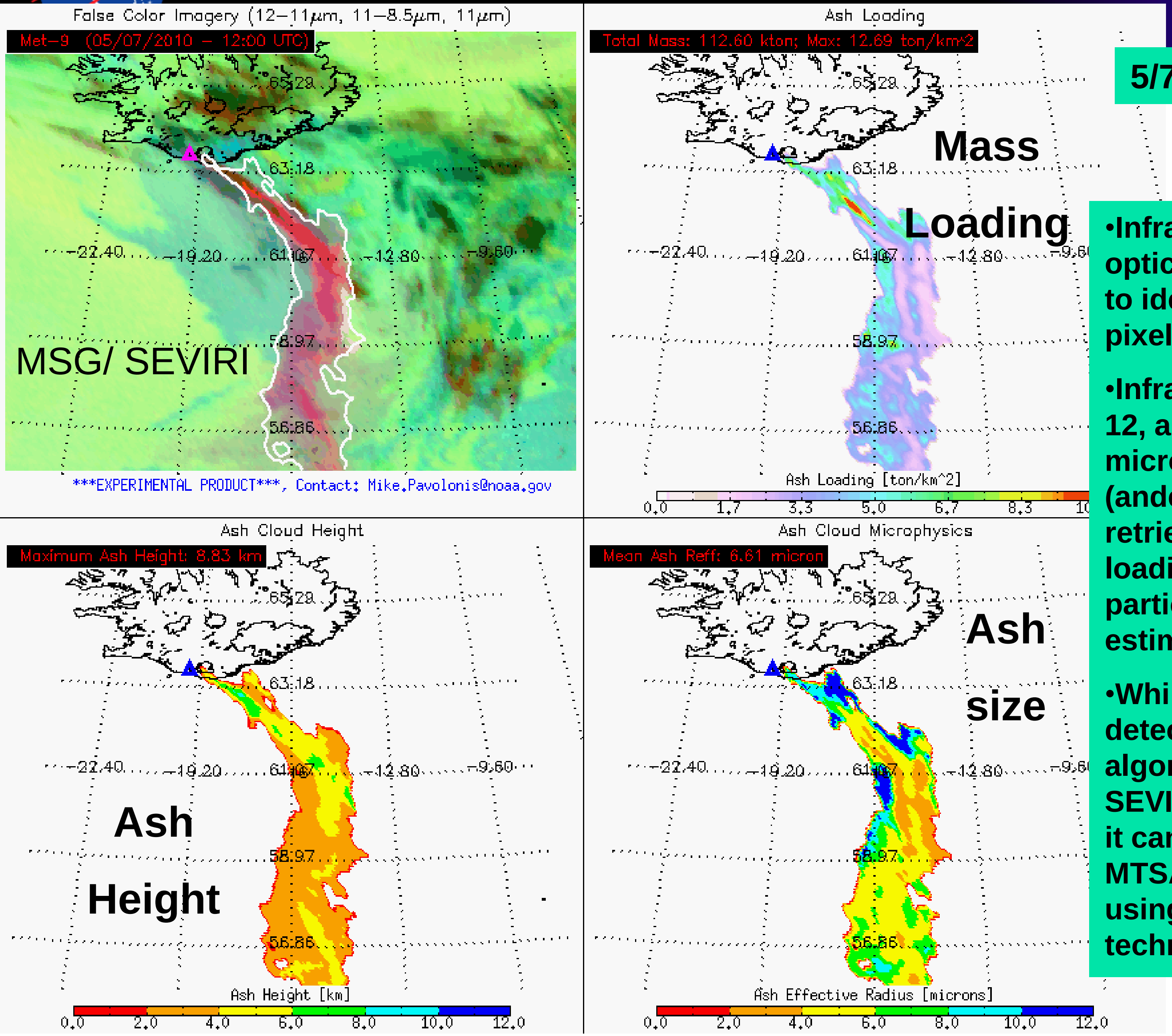
Satellite Imagers' Primary Limitations

- Volcanic ash must be the highest cloud layer
- The products will be degraded if L1 sensor data is degraded
- The ash cloud properties, and to a lesser extent, the ash detection results, will be more accurate if determined from a more advanced sensor (methods are being explored to address this issue) New GOES-R project with USGS to integrate additional satellite and non-satellite data sources (hyperspectral IR, lightning, infrasound, seismic, etc…)
- The selection criteria applied to cloud objects generally works well, but is still being refined
- Low level ash plumes that have a very similar temperature as the surface or warmer than the surface will often be missed by the ash detection algorithm at the present time



Langley Research Center

Advanced IR data for volcanic clouds



5/7/2010, 12:00 UTC

- **Infrared effective absorption optical depth ratios are used to identify volcanic ash pixels (Pavolonis, 2010).**
- **Infrared measurements (11, 12, and 13.3 μm) and microphysical models of ash (andesite) are used to retrieve ash height, mass loading, and effective particle radius in an optimal estimation framework.**
- **While this volcanic ash detection and retrieval algorithm works best on SEVIRI, MODIS and GOES-R, it can be applied to GOES, MTSAT, FY2C, and AVHRR using a bi-spectral technique.**

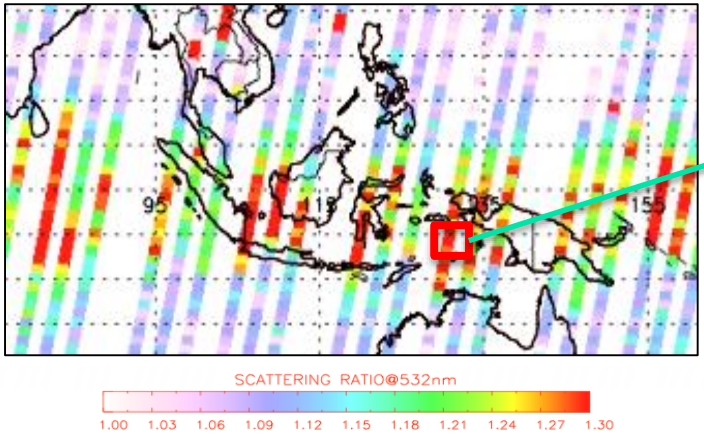
KlAsh deployment after Mt Kelud eruption

(Left). Medium balloon launch with sondes to measure aerosol backscatter . (Right) Preparation of the Optical Particle Counter flight under a large balloon.

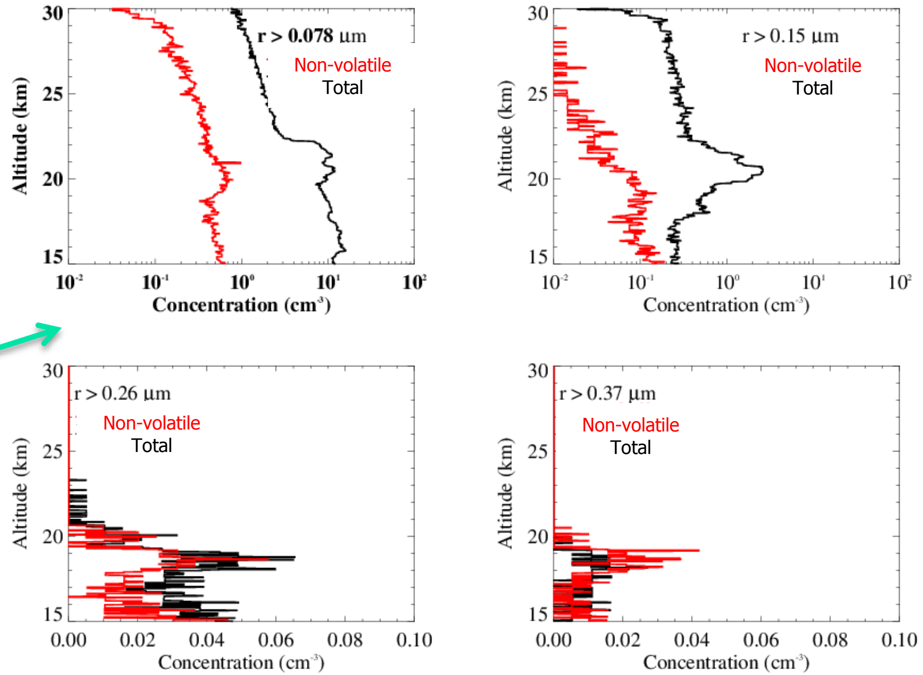
KlAsh campaign

10-day balloon field experiment in Darwin (Australia) May, 2014 to sample volcanic aerosol from the Mt Kelud eruption. *Rapid Response*, with critical support from NASA HQ (Considine, Kaye), CALIPSO (Trepte), SAGE (Thomason), Australian BOM (Atkinson), CASA.

Accumulated CALIPSO observations (14-24 May 2014)



Optical Particle Counter, May 20th

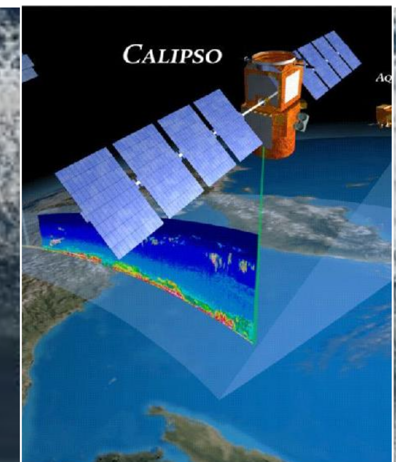


- 3 months after the Mt Kelud eruption, the KlAsh campaign has revealed the persistence of volcanic ash in the lower stratosphere. Current models do not account for the climate impact of volcanic ash.

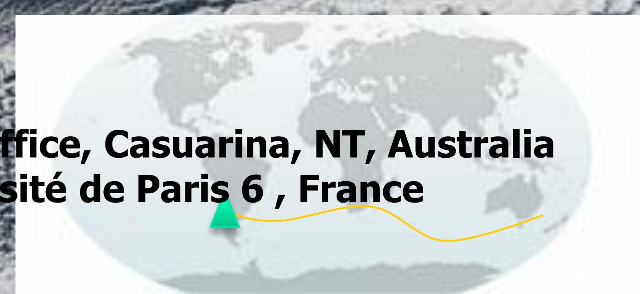
September 2013 AMS JAMC Article: An advanced system to monitor the 3D structure of diffuse volcanic

A case study after the Puyehue-Cordon Caulle eruption in June 2011 by:

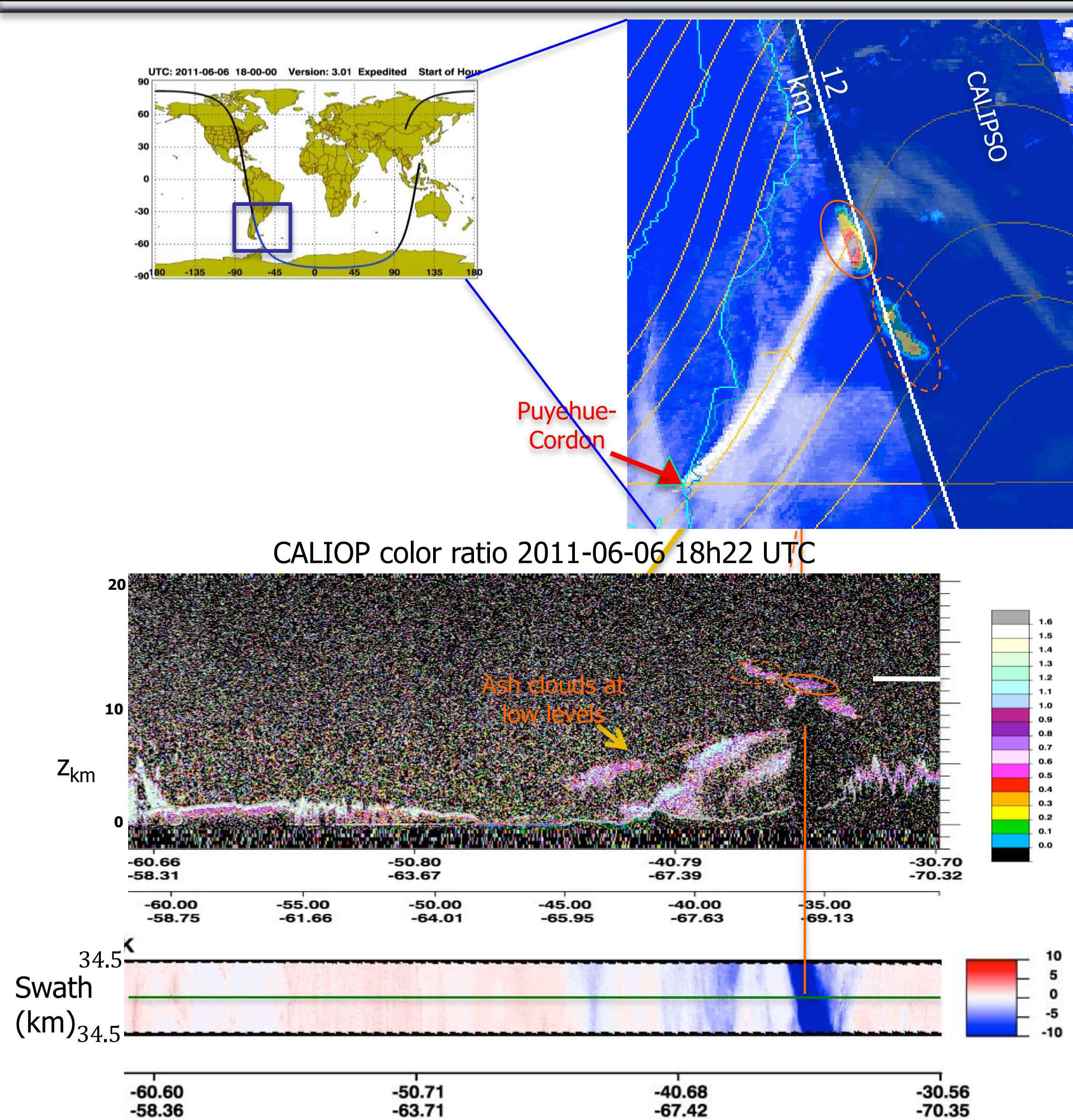
J.-P. Vernier[1,2], T. D. Fairlie[2], J. J. Murray[2], C. Trepte[2] , A. Tupper[3] , D. Winker[2], J. Pelon[4], A. Garnier[1,2,4], J. Jumelet[4], M. Pavolonis[5]



1- Science Systems and Applications, Inc., Hampton, USA
2- NASA Langley Research Center, Hampton, USA
3- Australian Bureau of Meteorology, Northern Territory Regional Office, Casuarina, NT, Australia
4- LATMOS, CNRS-INSU, Université de Versailles St Quentin, Université de Paris 6 , France
5- NOAA/NESDIS, Madison, Wisconsin, USA

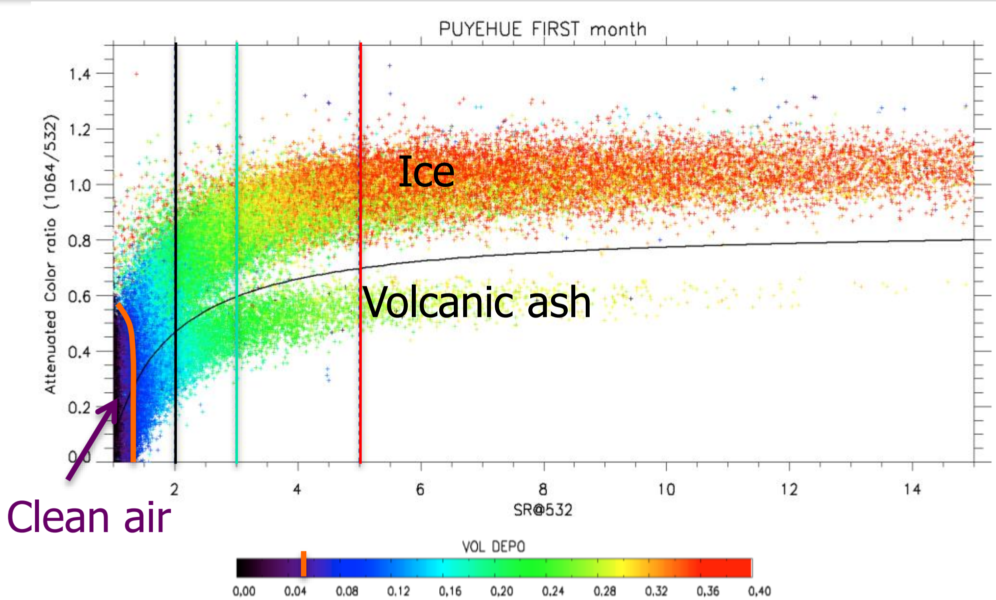


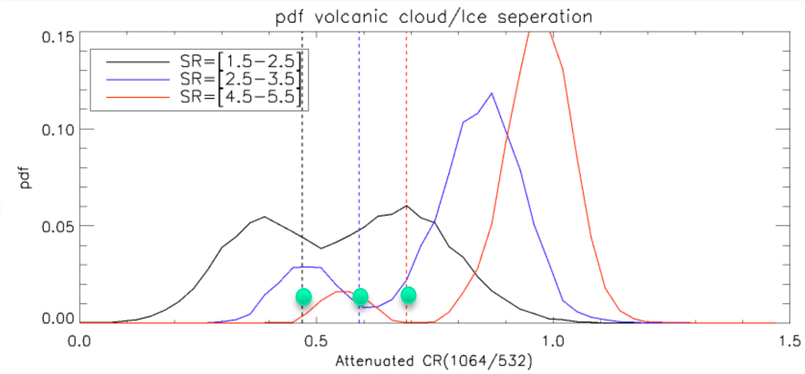
Cordon plume sampled by CALIPSO just after the erruption



- Recent volcanic plume sampled by CALIPSO after the eruption
- Strong negative BT signature (-20K) on the IIR
- Low color ratio (0.5-0.6) from CALIOP compared to ice (~1)
  Consistent with small ash particles emitted by Cordon

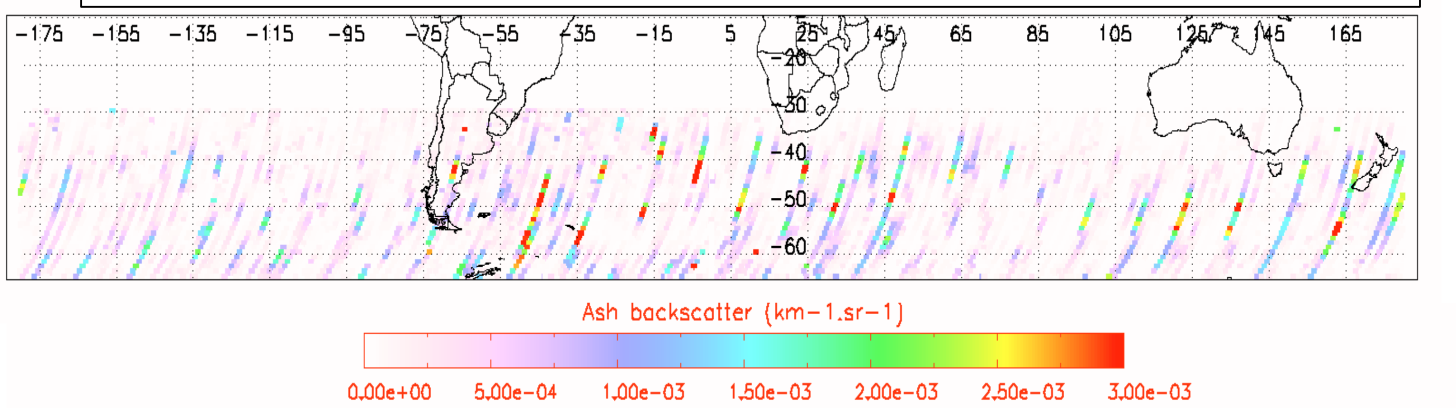
Detection method





- Volcanic ash detection based on color ratio
- Ash backscatter derived from Total Backscatter (Ansmann et al., 2011) using depolarization

Cumulative CALIPSO backscatter (8-13 km) for June 2011



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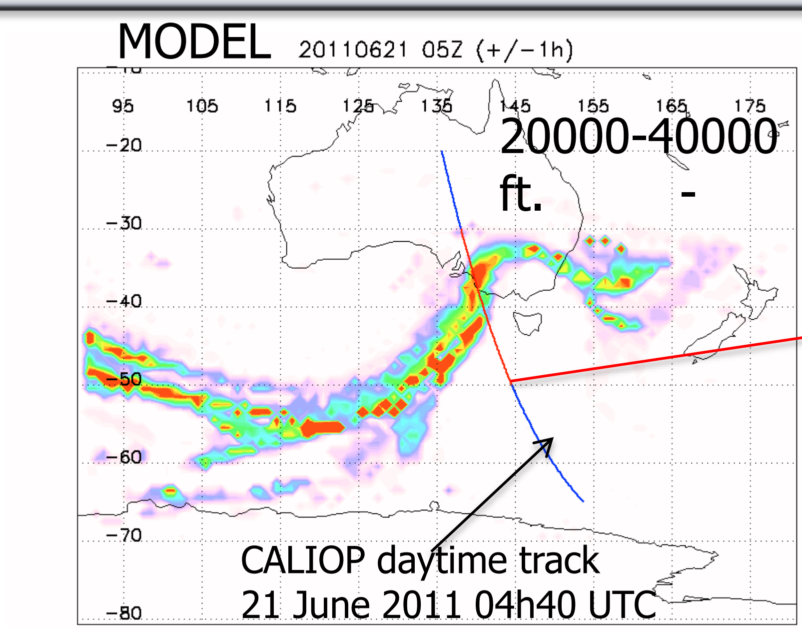
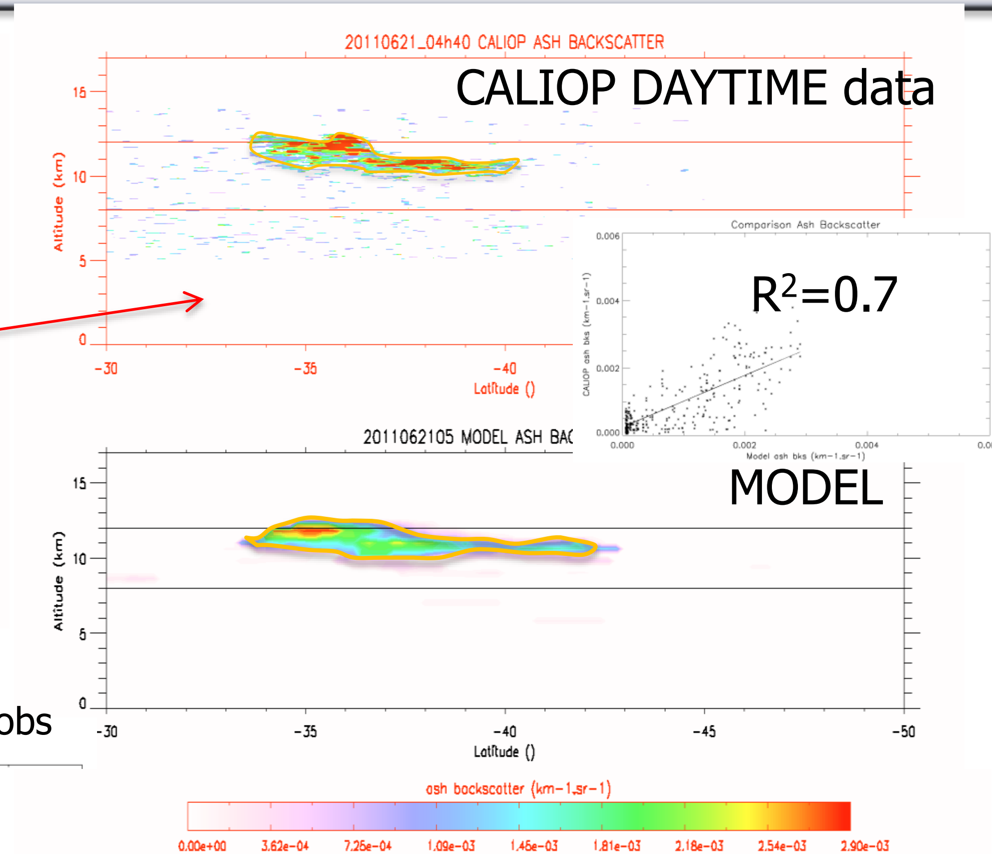
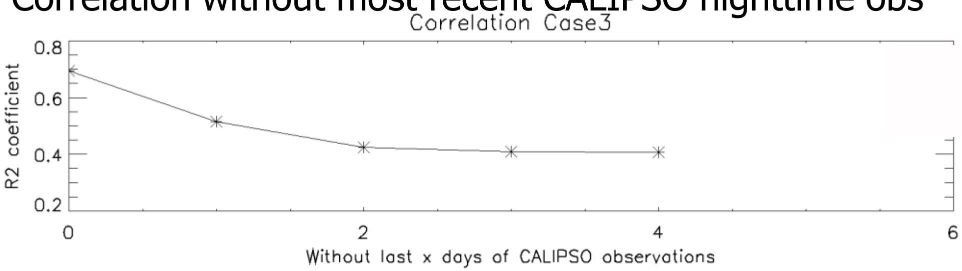
Validation with independent CALIPSO daytime data





Correlation without most recent CALIPSO nighttime obs

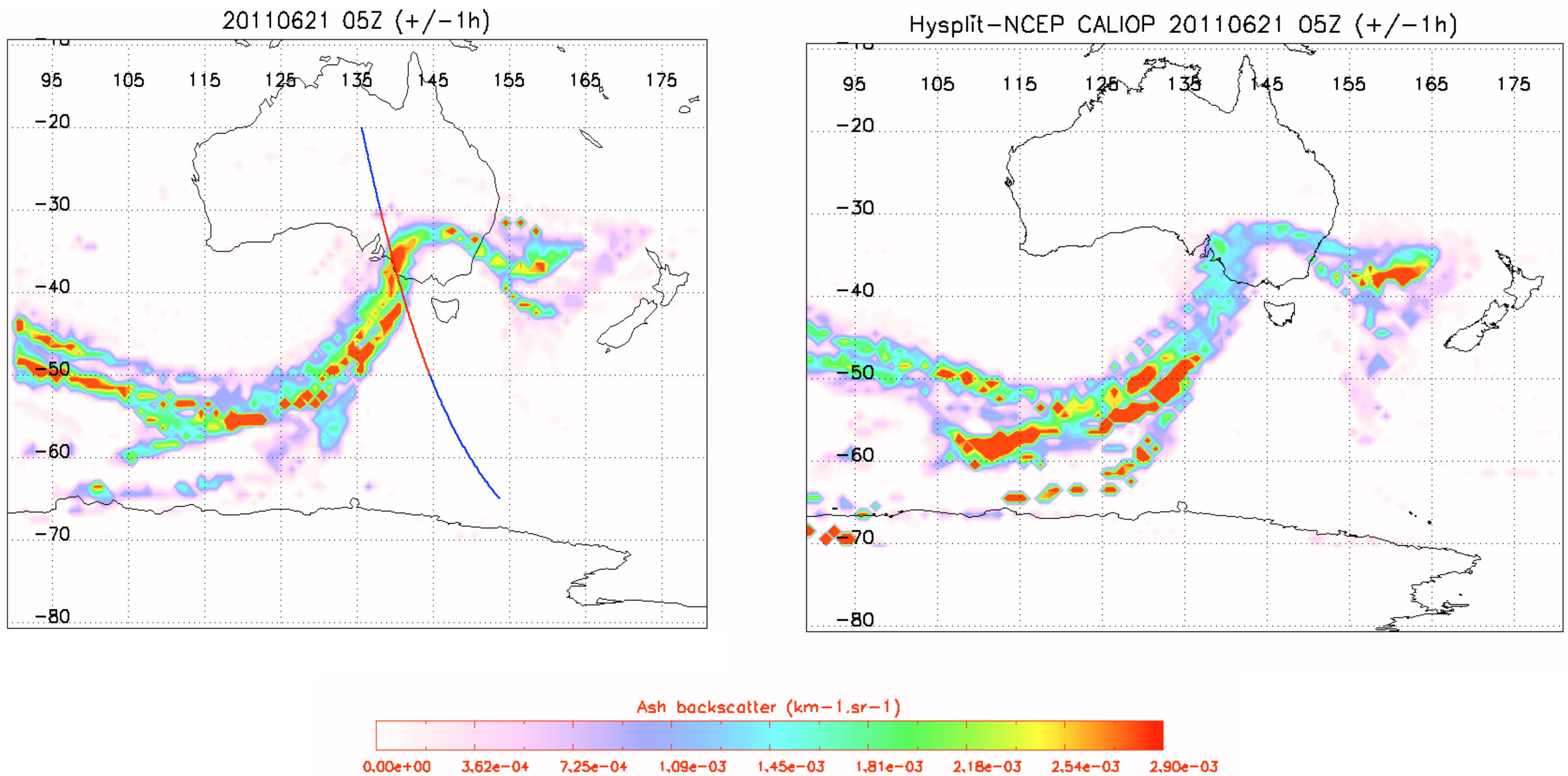


- Plume vertical structure and location very well reproduced by the model
- Input of most recent observations (nighttime) have positive impact on the analysis
- CALIPSO near-real time data can be obtained within 24 h and be used for operational purposes

Transition to NOAA Operations

GEOS-5 NASA Langley Trajectory Model

NOAA NCEP HYSPLIT



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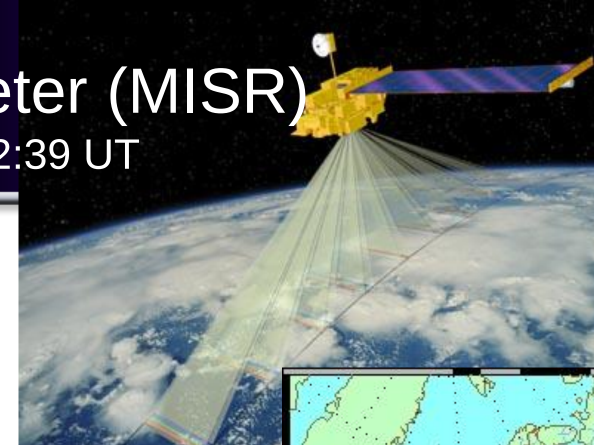
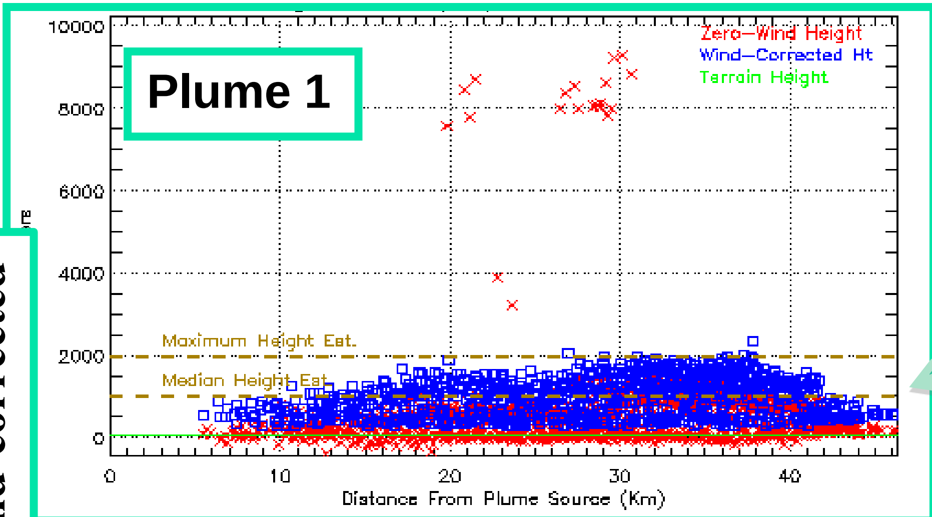
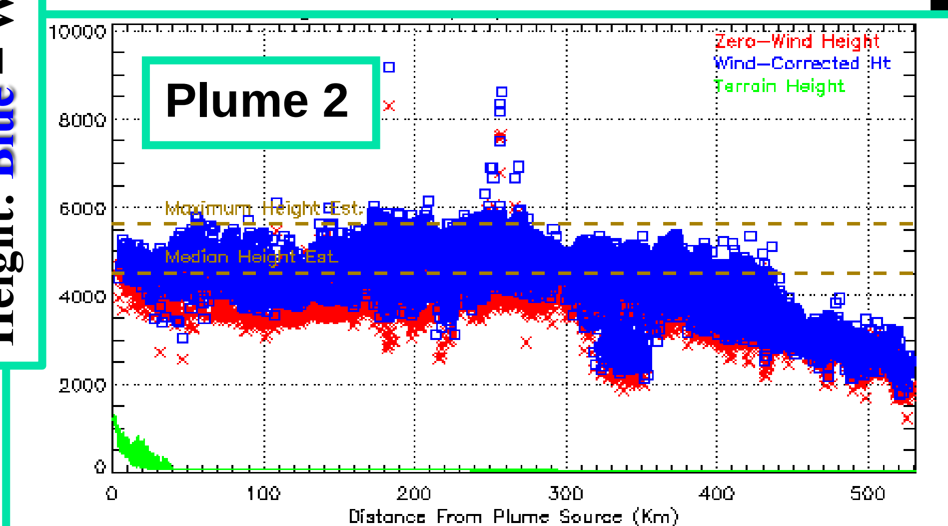
Multi-angle Imaging SpectroRadiometer (MISR)

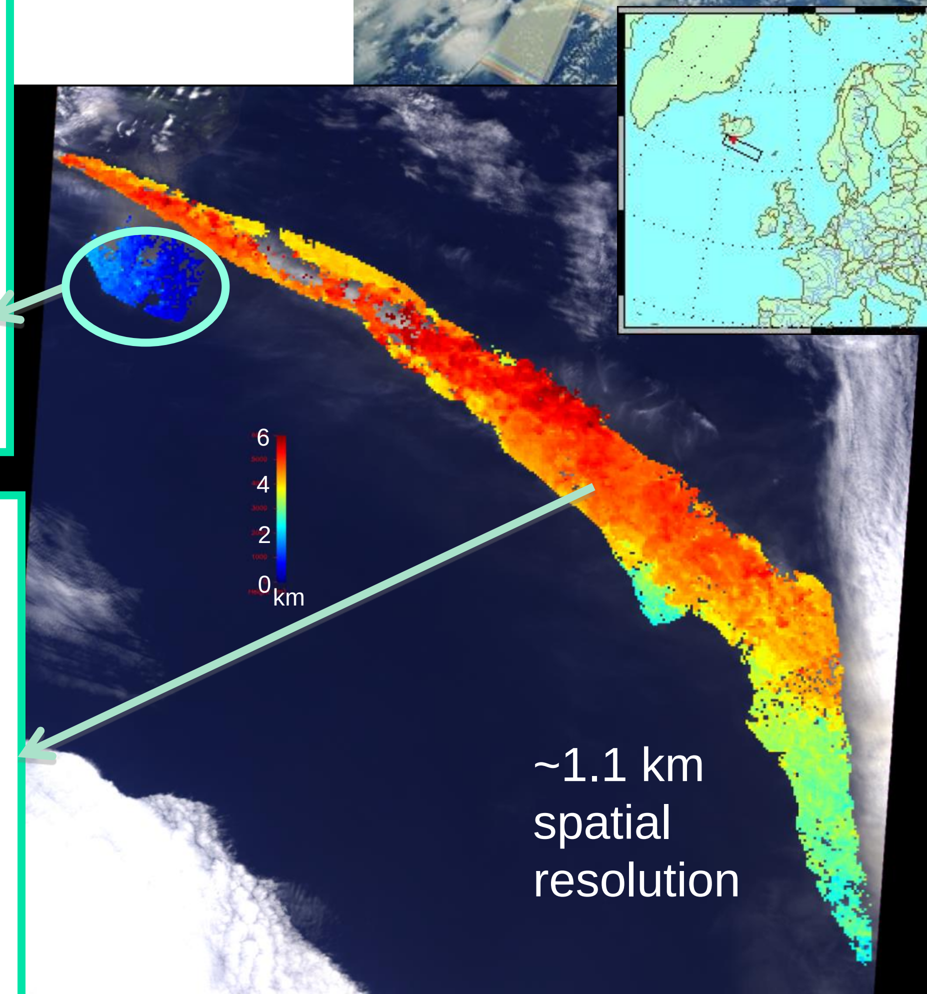
Stereo-Derived plume heights on May 7 at 12:39 UT



Height: Blue = Wind-corrected







R. Kahn, D. Nelson, and the MISR Team, NASA JPL and GSFC