Current capabilities and limitations of satellite monitoring and modeling forecasting of volcanic clouds: and example of Eyjafjallajökull eruption (pronounced EYE-a-fyat-la-jo-kotl)

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90s: Volcanic ash (UV and IR) and SO$_2$ (UV)

- Thermal IR split window technique (BTD= T11 - T12 < 0 ) technique was developed to retrieve ash mass loading and particle sizes and applied to NOAA AVHRR satellites
- Pattern recognition techniques were applied Geostationary GOES data

- UV SO$_2$ and aerosol index AI retrievals were pioneered at NASA Goddard using the Total Ozone Mapping Spectrometer (TOMS)
- Geostationary VolCam was selected as a backup ESSP mission behind CloudSat and CALIPSO (not flown)
2010: NASA EOS assets for volcanic clouds studies

OMI - SO$_2$, aerosols, BrO
TES - SO$_2$, HCl
MLS - strat. SO$_2$, HCl

MISR (Terra) - ash height and opt.prop
MODIS (Terra, Aqua) - SO$_2$, ash, sulfate
AIRS - UTLS SO$_2$, aerosols, SO$_2$ profile?

CALIPSO - cloud height, aerosol type

The A-Train
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 the 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.  

Mike Pavolonis
4/19/2010, 13:00 UTC

Terra MODIS image at 12:50 UTC.

MISR-Derived Ash Plume Aerosol Amount & Properties
• This application of NASA data was vision of Arlin Krueger
• Iceland and North Europe sectors added at 1:00 PM April 15
Eyjafjallajokull volcano, May 5

http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/iceland.html

SO₂

OMI SO₂
OMI Reflectivity

http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/iceland.html

OMI Field-of-View blockage

OMI Reflectivity

Latest Data:

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GeoTiff, NetCDF, McIDAS and JPEG formats:

[ SO2 ] | [ AI ]

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Eyjafjallajökull volcano, May 6

Aerosol Index (ash)

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[ SO2 ]  [ AI ]

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5/7/2010, 12:00 UTC

MISR Stereo-Derived Ash Plume Heights
Parcel Modeling: volcanic source

- Goddard Kinematic Trajectory Model [Mark Schoeberl]
- Clusters of parcels emitted at volcano location
- Injections from 1.5 - 10 km on April 14
- Injections from 1.5 - 2.5 km on April 15
- Colors indicate parcel altitude

KTM simulation courtesy of Gary Morris, Valparaiso University
Parcel Modeling: height estimation

- PUFF model drives clusters of parcels with NOAA GFS winds
- Plume base height of 2 km better matches trailing Western edge
- Plume base height of 9 km better matches leading Eastern edge
- Conclusion: Early eruption at 8-10 km, followed by low altitude ash emissions

OMI AI
PUFF MODEL

April 15

2 km

9 km

Puff Simulation courtesy of Eric Hughes, ESSIC/NOAA
Model Initialization

- Mass concentration
- Spatial extent
- Plume injection height
- Particle size distribution
- Composition (e.g. ash vs. sulfate)
- Meteorology

MISR visible image (courtesy of NASA Earth Observatory Web Site)
Ash modeling with GEOS 5 Goddard Earth Observing System global climate model and data assimilation system.

- Ash uses a dust-like particle size distribution
- SO$_2$ and Ash emissions are:
  - “10” on April 14
  - “1” on subsequent days
- Injection height:
  - 1.5 - 10 km on April 14
  - 1.5 - 5 km on subsequent days

simulation courtesy of Peter Colarko
Simulated ash not in OMI observations. Wrong injection height?
April 16

Coincidence of narrow ash band. Obscured by clouds in MODIS, but clearly evident in OMI AI.
Road Forward

• Models need ingesting satellite data “operationally” in real time

• *Refine ash module in models*

• Measure ash samples for refractive index (UV to IR), size and shape distributions

• Use backward trajectories to estimate heights of volcanic clouds and develop satellite techniques for direct ash/SO2 height measurements

• *Realtime: would need short turnaround of satellite obs of height, location, and amount of material*

- Sodankylä satellite downlink station receives OMI Direct Broadcast data
- Fast processing: 15 min. for O$_3$ and UV products
- High latitude site: ~3-5 orbits/day

Action Items:
- Add SO$_2$ and AI to distribution
- Push for release of software to process data at other sites

http://omivfd.fmi.fi