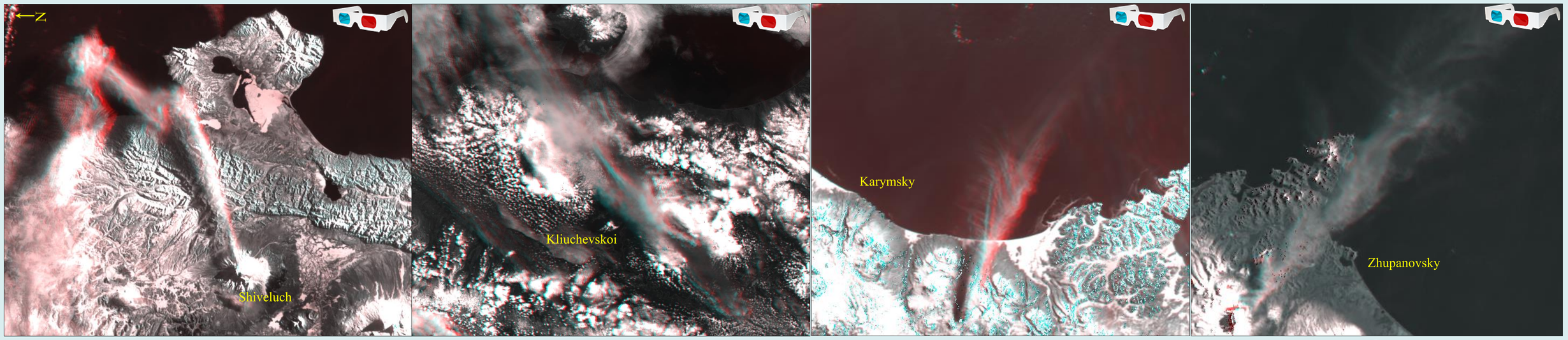
Volcanology from Space:
Interpreting volcanic processes using space-borne remote sensing imagery

Verity J. B. Flower[1,2] and Ralph Kahn[1]

[1]NASA Goddard Space Flight Center, [2]Universities Space Research Association

NASA POSTDOCTORAL PROGRAM
Administered by USRA



3D Volcanic Plumes

Stereo anaglyphs *of volcanic plumes in Kamchatka.* ***To view in 3D, please use glasses provided.***

A) Shiveluch, November 23, 2014; B) Kliuchevskoi, June 29, 2007; C) Karymsky, February 27 2015; and D) Zhupanovsky, November 9, 2014. Note: North is to the left in each anaglyph.

3D Volcanic Plumes

Motivation

Volcanoes represent a ***significant source of airborne particles*** that can produce local, regional and global effects, impacting Earth systems and human health. Individual plume characteristics can further influence their environmental impact. ***Satellite monitoring*** provides ***global observations*** even for ***remote volcanoes***.

Multi-Sensor Theory

Changes in volcanic emissions correspond to ***variations in the magma plumbing system***. By tracking emissions (Fig. 1) we aim to help understand the processes occurring at depth. Satellite-based remote sensing data was collected from ***multiple NASA polar orbiting instruments*** with ***significant data records*** (13-18 years).

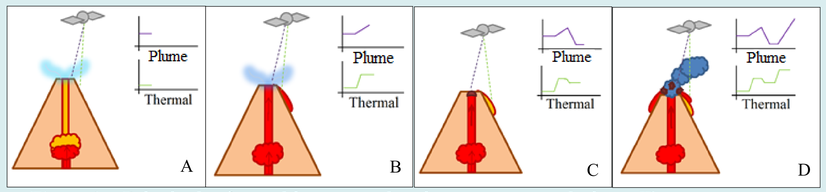


Figure 1 – ***Principals of a multi-sensor volcanic assessment technique****. The remote sensing signals co-vary as volcanic activity evolves causing shifts in emissions.*
Insets: Illustrative MISR plume elevation and MODIS surface thermal anomaly

Incorporated instruments and data products

MISR (Multi-angle Imaging SpectroRadiometer):
- ***Plume height*** (Fig. 2), ***extent***, and ***dispersion*** characteristics
- Plume particle ***microphysical properties***

MODIS (MODerate Imaging Spectroradiometer):
- Visual assessment of ***regional setting*** and ***plume tracking***
- ***Thermal anomalies*** presence, extent & intensity

OMI/OMPS (Ozone Monitoring Instrument/Ozone Mapping and Profiling Suite):
- Present and extent of ***sulfur dioxide (SO_2)*** emissions

Acknowledgements

V.JB. Flower's research was supported by the NASA Postdoctoral Program at the NASA Goddard Space Flight Center, administered by Universities Space Research Association under contract with NASA. The work of R. Kahn is supported in part by NASA's Climate and Radiation Research and Analysis Program under H. Maring, NASA's Atmospheric Composition Program under R. Eckman, and the NASA Earth Observing System's MISR project

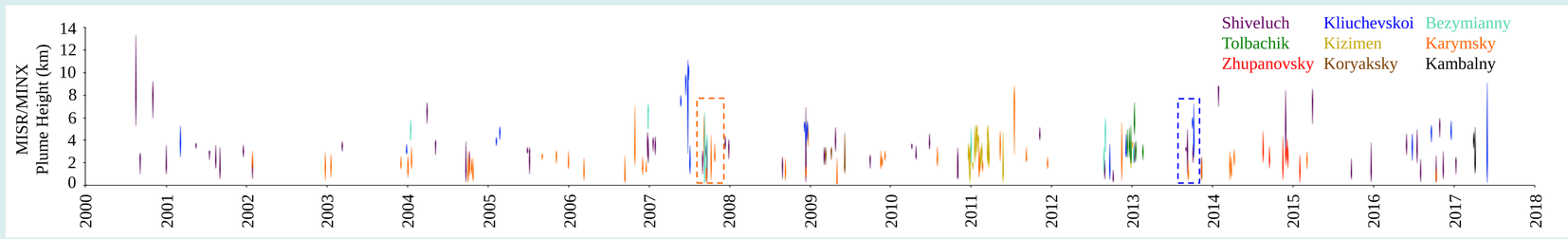


Figure 2 – ***Timeline of plume heights*** *identified in Kamchatka (2000-2018). Plumes are* ***segregated by volcano*** *of origin (different colors).*
Retrievals represent the min and max altitude of each plume, with the altitude of the most frequently retrieved 1.1 km pixel elevation in the plume corresponding to the greatest color saturation.

Aggregated Satellite Data and Volcanological Interpretation

Combining remote sensing data sets: *plume height* (Fig. 2; 3), *particle properties* (Fig. 3), *lava flow* intensity and extent (Fig. 3) and SO_2 emissions (Fig. 3B).
Investigation of individual eruption phases makes it possible to ***interpret volcanological dynamics*** (Fig. 3), including:
Volcanic ***eruption escalation***; ***waning explosivity***; and ***shifts in the volatile content*** of upwelling magma.

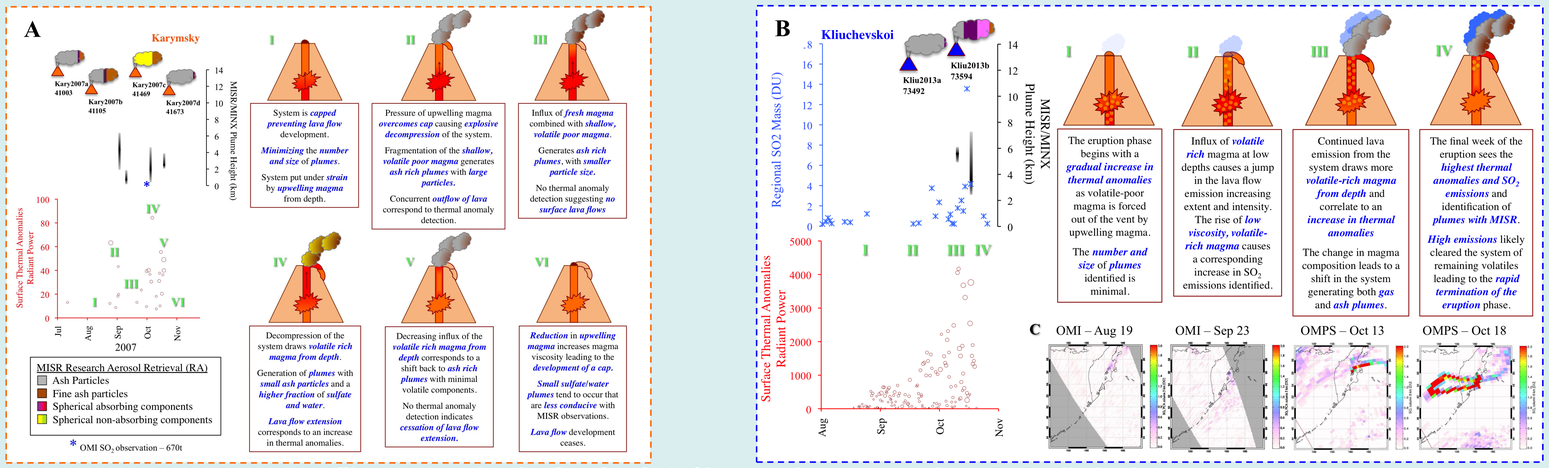


*Figure 3 –****Satellite remote sensing signals*** *and* ***geological interpretations (A) Karymsky 2007; (B) Kliuchevskoi 2013****.*
Left Panels (top to bottom): Retrieved MISR ***particle-types,*** *MISR* ***plume heights, OMI SO_2*** *(4B only),* ***and*** *MODIS* ***thermal anomalies***

References

Flower, V.J.B., & R.A. Kahn. (2017). *Assessing the altitude and dispersion of volcanic plumes using MISR multi-angle imaging: Sixteen years of volcanic activity in the Kamchatka Peninsula, Russia. J. Volc. Geotherm. Res. 337*, 1–15. doi:10.1016/j.jvolgeores.2017.03.010
Flower, V. J. B. & R.A Kahn. (2018) Karymsky volcano eruptive plume properties based on MISR multi-angle imagery and the volcanological implications, Atmos. Chem. Phys., 18, 3903-3918, https://doi.org/10.5194/acp-18-3903-2018.

The work detailed here will be submitted for review to Remote Sensing of Environment: **Flower, V.J.B.**, & R.A. Kahn. Regional volcanology of Kamchatka based on satellite remote sensing imagery.