

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 eruption characteristics influence their environmental impact. **Satellite monitoring** provides **global observations** even for **remote volcanoes**.

Changes in volcanic emissions correspond to **variations in the magma plumbing system**. By tracking emissions we aim to help understand the processes occurring at depth.

Incorporated instruments and data products

Satellite-based remote sensing data was collected from **multiple NASA polar orbiting instruments** with **significant data records** (14-19 years).

MISR (Multi-angle Imaging SpectroRadiometer):

Plume height, extent, and **dispersion** characteristics
Plume particle **microphysical properties**

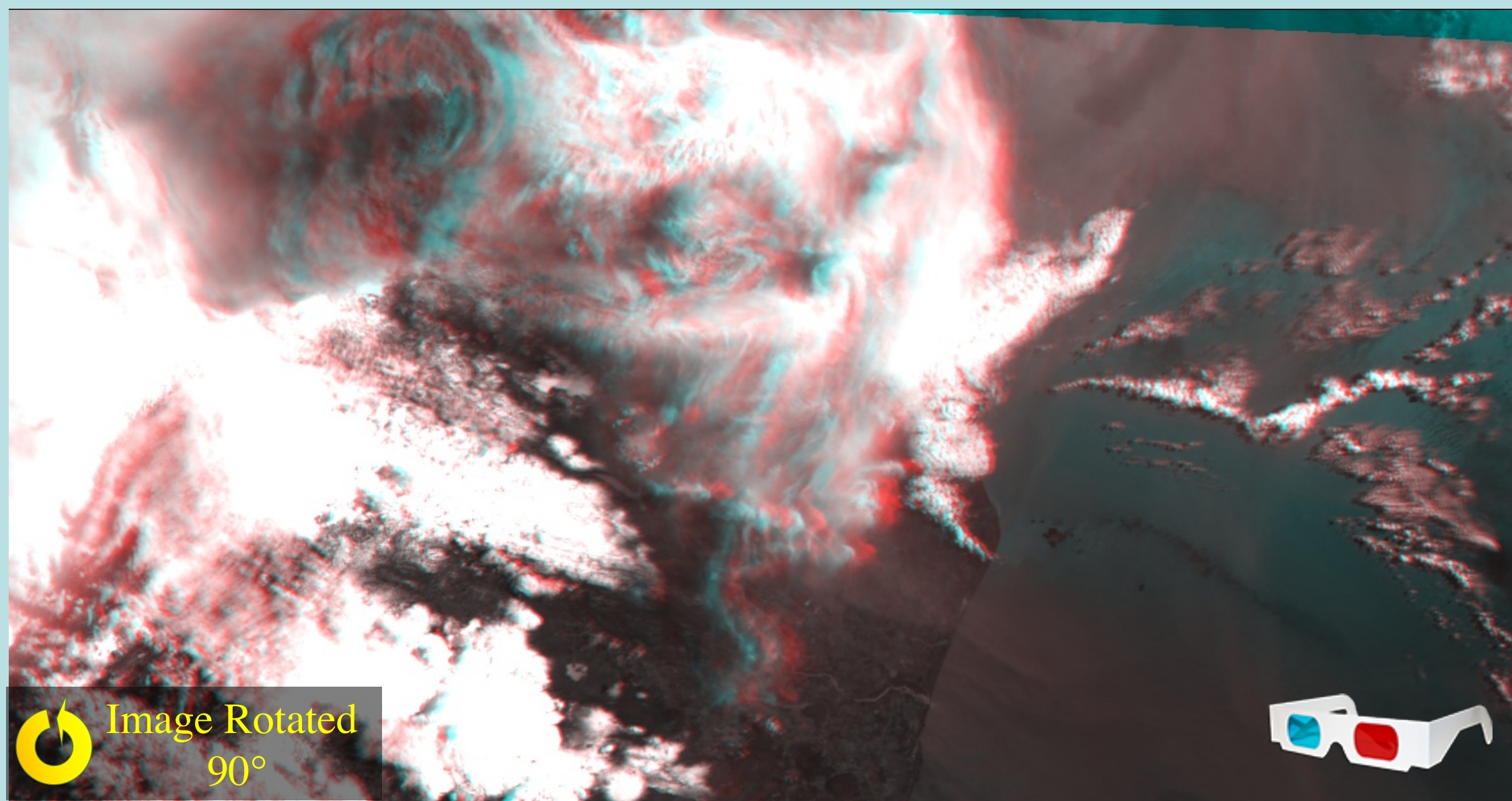
MODIS (MODERate resolution Imaging Spectroradiometer):

Visual assessment of **regional setting** and **plume tracking**
Thermal anomaly presence, extent & intensity

OMI (Ozone Monitoring Instrument):

Present and extent of **sulfur dioxide (SO_2)** emissions.

Grímsvötn 2011



Stereo anaglyph of volcanic plume at Grímsvötn May 22, 2011.
To view in 3D, please use glasses provided

Multi-layer plume imaged by MISR: height retrievals indicate three distinct layers with **varying particle properties in each layer**. The **dispersion of particles in early plume ejection** can be inferred from the observations of the Grímsvötn plume (Fig. 1).

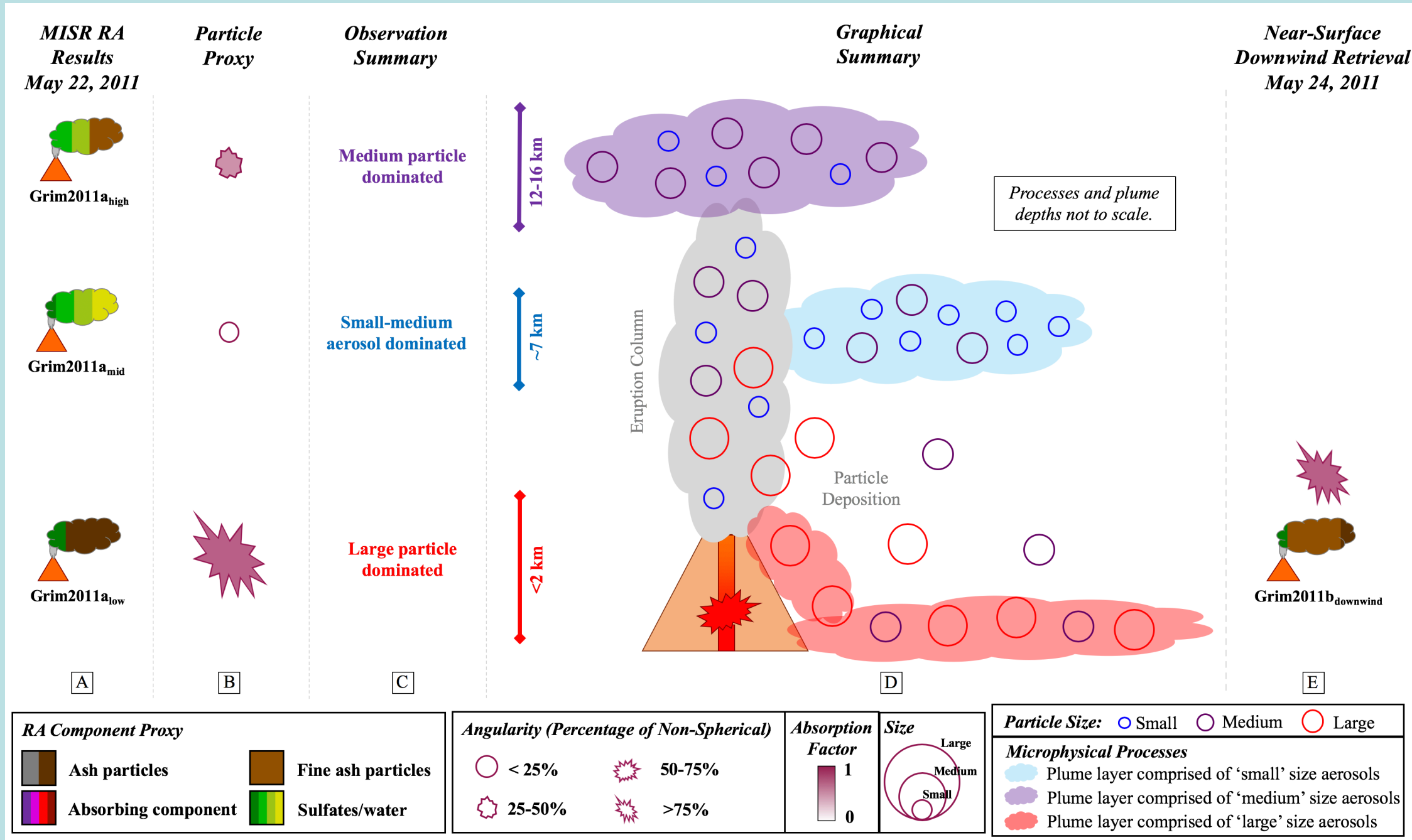


Figure 1 – Plume particle properties in multiple layers of the May 22, 2011 Grímsvötn eruption. Variations in particle types are highlighted in the graphical summary.

Subsequent observations of the **near surface plume** (2 days after emission) qualitatively indicate an **overall decrease in particle size**, consistent with the **gravitational deposition of the largest particles** from the plumes as transportation occurs.

Aggregated Satellite Data and Volcanological Interpretation

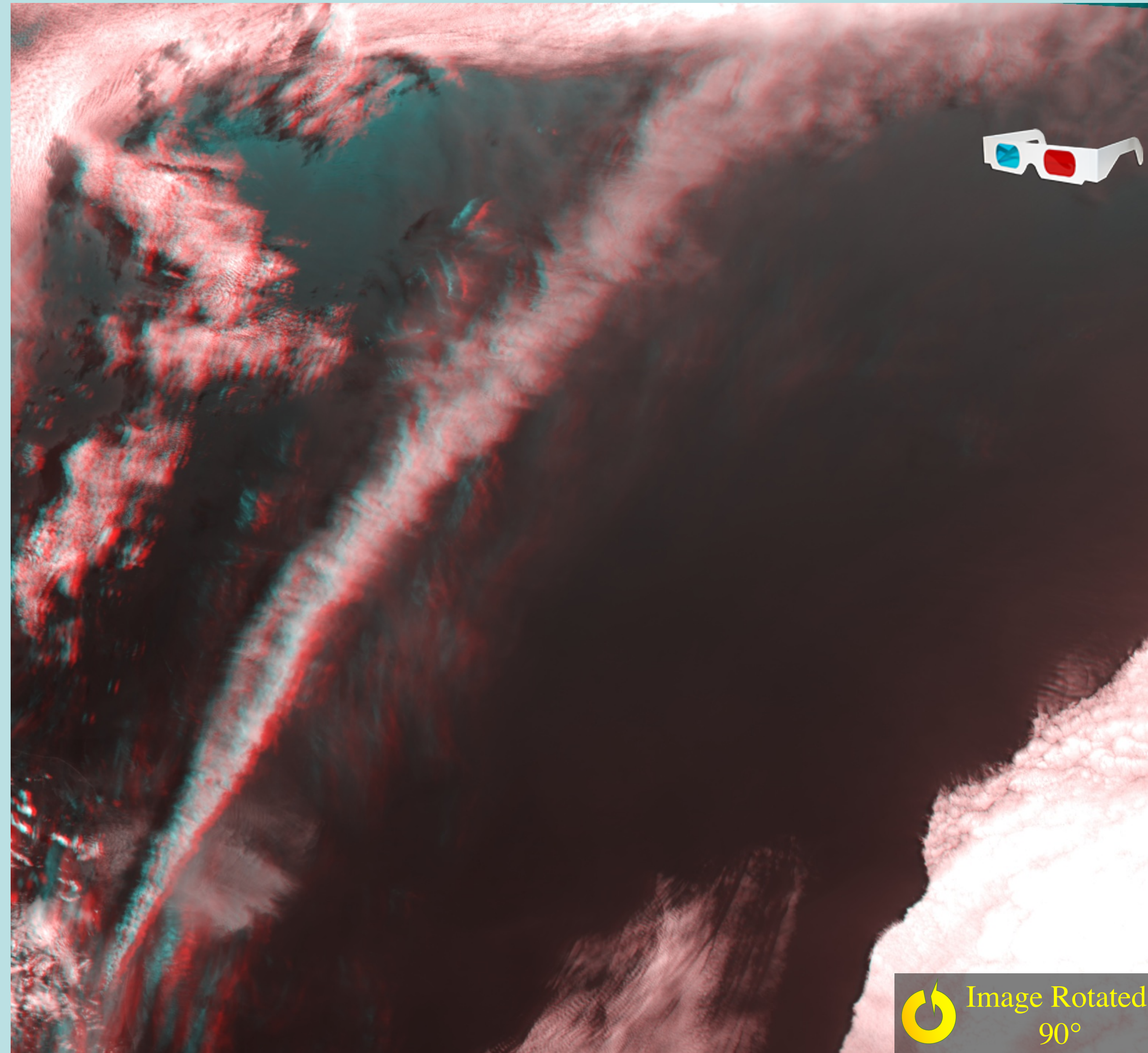
Combined remote sensing data: plume height (Fig. 2C; 3C), particle properties (Fig. 2B, 3B), lava flow intensity (Fig. 2C, 3C) and SO_2 emissions (Fig. 2C, 3C).

Investigation of individual eruption phases makes it possible to **interpret volcanological dynamics** (Fig. 2D, 3D), including:

Volcanic **eruption escalation**; **waning explosivity**; and **shifts in the volatile content** of upwelling magma.

Eyjafjallajökull 2010

Ash-rich eruption: **variable** plume ejection height, particle properties, gaseous emissions and thermal output resulting from **shifting eruption dynamics between phases**.



Stereo anaglyph of volcanic plume at Eyjafjallajökull May 7, 2010.
To view in 3D, please use glasses provided

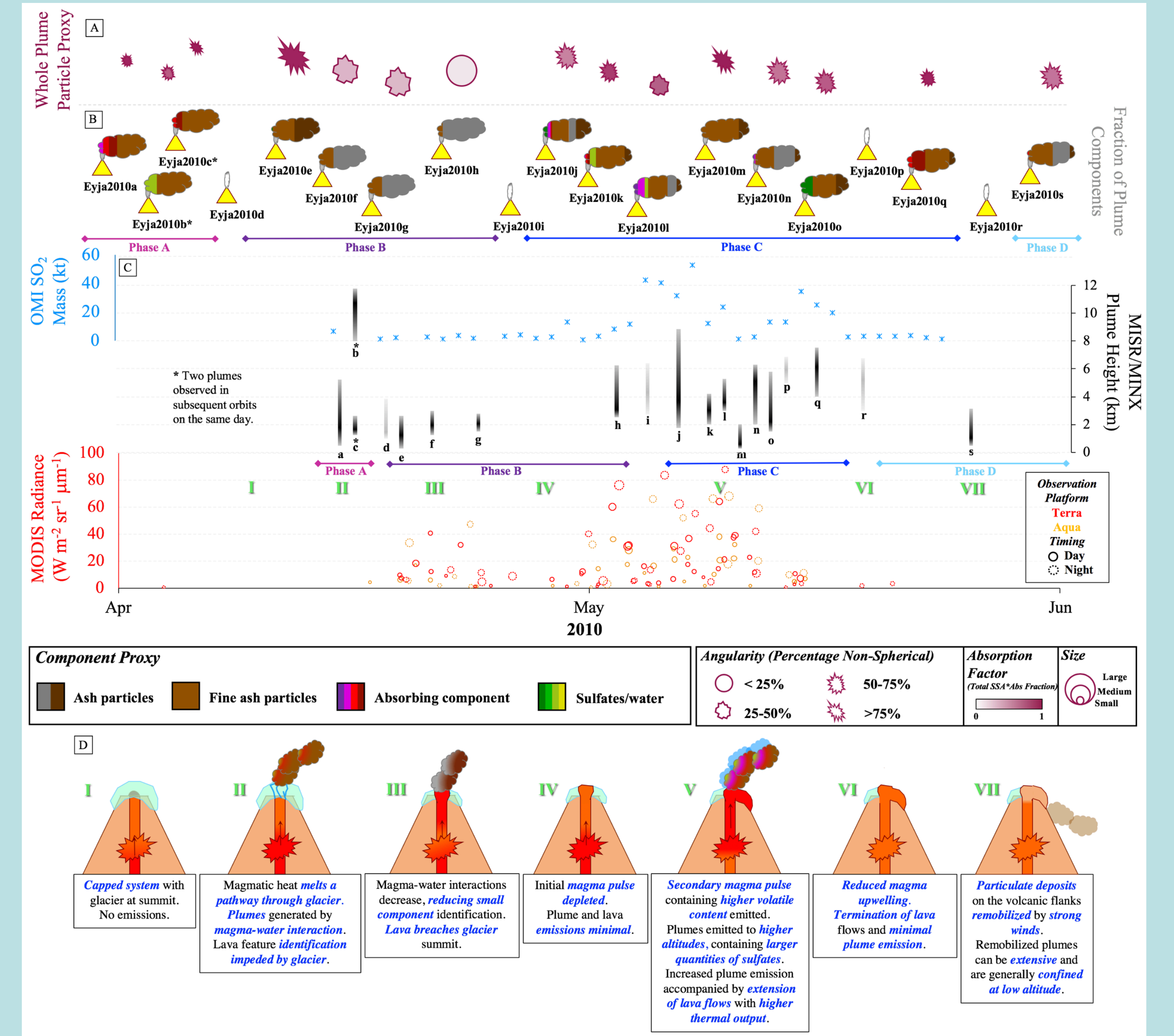
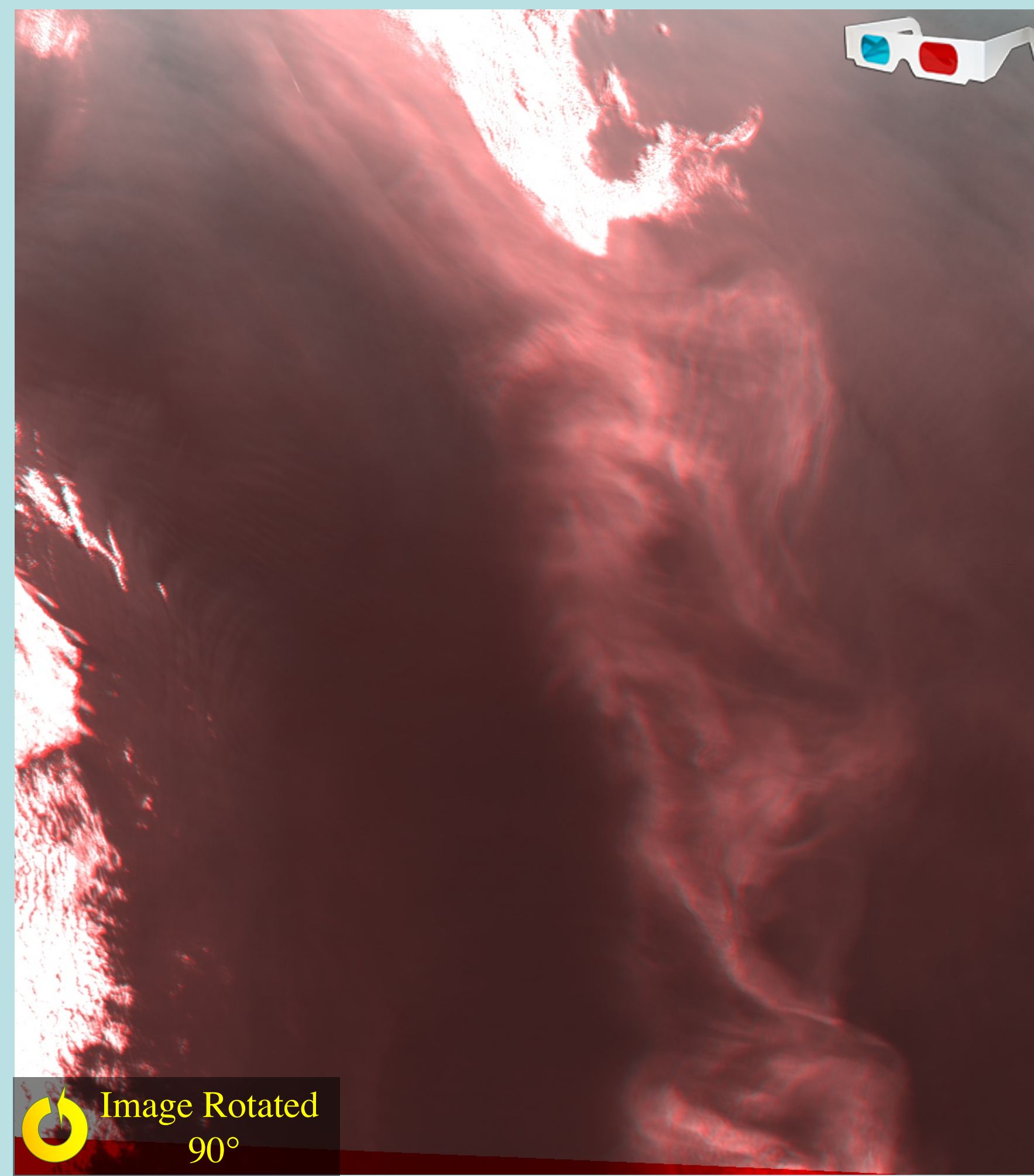


Figure 2 –Satellite remote sensing signals and geological interpretations of Eyjafjallajökull 2010
Left Panels (top to bottom): A) Derived MISR whole plume particle size, B) MISR particle-types, C) Retrieved OMI SO_2 , MISR plume heights and MODIS thermal anomalies.
D) Inferred volcanic activity based on satellite signals.

Holuhraun 2014-2015

Sulfate-rich eruption: **decreasing** plume ejection height, gaseous emissions and thermal output resulting from **slow waning of eruption as magma source depleted**. Sulfate plumes **consistently** contain **small, spherical, non-absorbing components**



Stereo anaglyph of volcanic plume at Holuhraun Sep 11, 2014.
To view in 3D, please use glasses provided

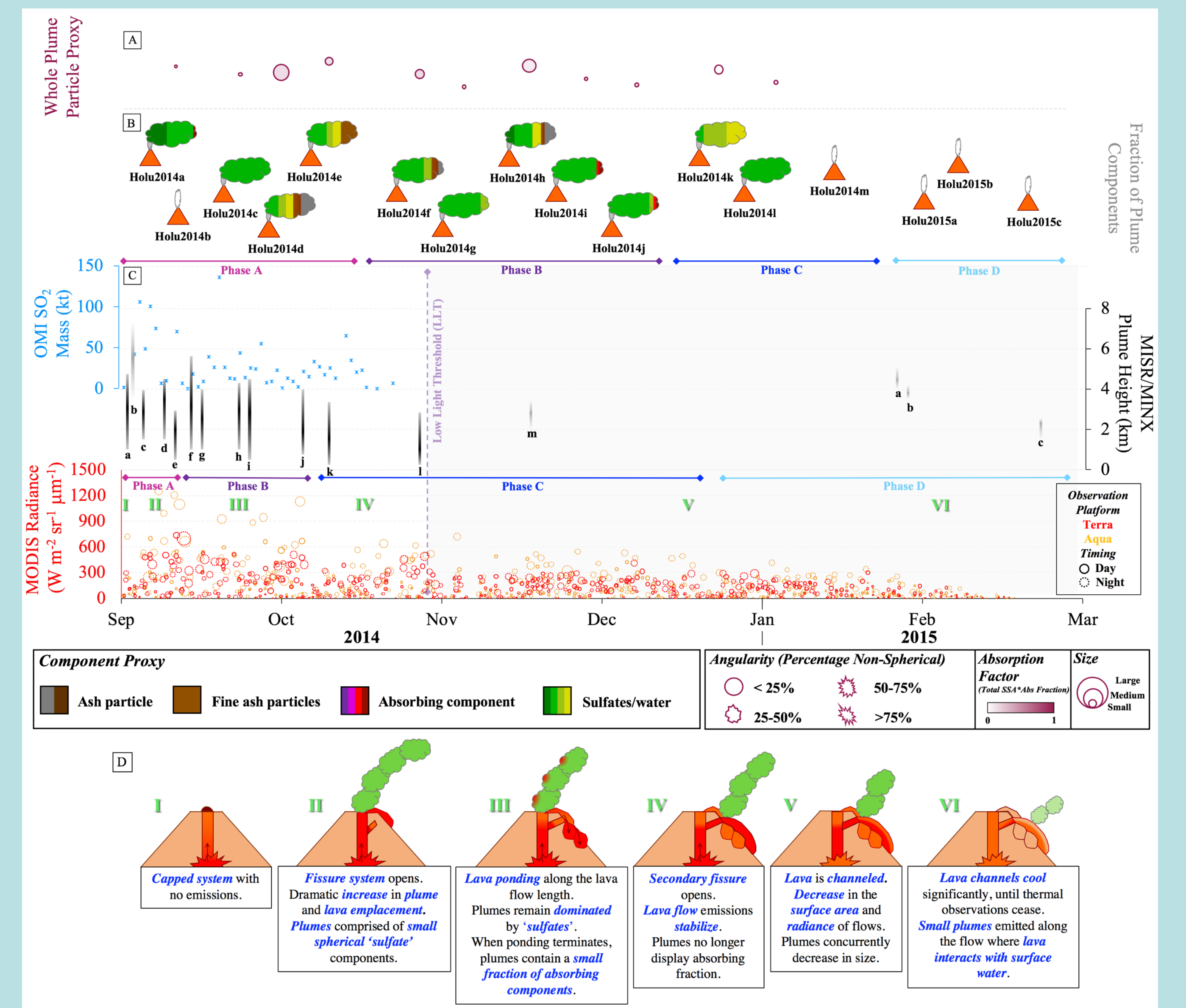


Figure 3 –Satellite remote sensing signals and geological interpretations of Holuhraun 2014-2015
Left Panels (top to bottom): A) Derived MISR whole plume particle size, B) MISR particle-types, C) Retrieved OMI SO_2 , MISR plume heights and MODIS thermal anomalies.
D) Inferred volcanic activity based on satellite signals.

Conclusion

Remote sensing observations of Icelandic eruptions broadly distinguish different types of volcanic emissions (e.g. ash-rich, sulfate-rich)

Variations in derived particle proxies, in ash-rich plumes, correlate to changes in eruptive processes and magma composition.

Evidence of downwind aerosol formation, sulfur hydration and wet deposition identified during Icelandic plume transport.

References

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