Stereoscopic estimation of volcanic ash cloud-top height from two geostationary satellites

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APHORISM ADVANCED PROCEDURES FOR VOLCANIC AND SEISMIC MONITORING

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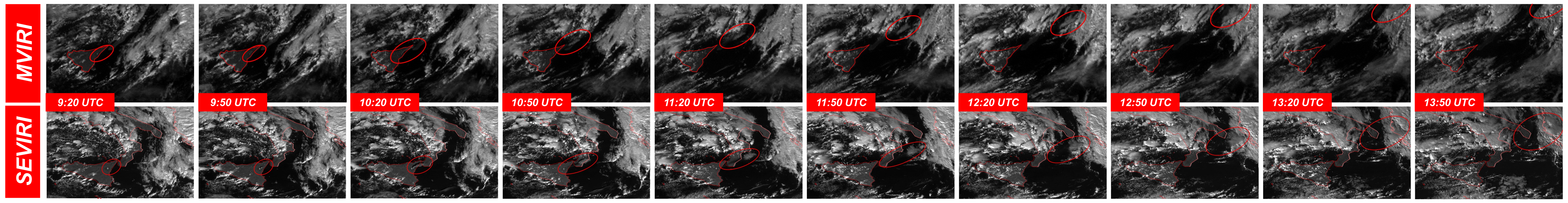


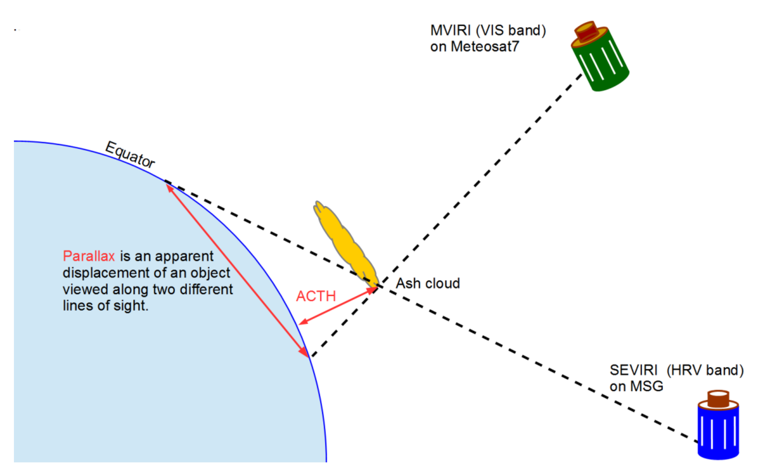
Please refer to **poster # 2**, Corradini et al., for the 23.11.2011 Etna eruption description and for the comparison of this result with ACTH estimates based on different space- and ground- based measurements.

Photogrammetric methods can be used to improve **volcanic ash cloud top height (ACTH)** estimates.

We propose a novel application of a method based on the parallax between data acquired from two geostationary instruments.

A combination of MSG SEVIRI (HRV band; 1000 m nadir spatial and 5 min temporal resolution) and METEOSAT7 MVIRI (VIS band, 2500 m nadir spatial and 30 min temporal resolution) images has been used to estimate the ACTH for a Mt. Etna, Sicily, Italy, eruption occurred on November 23, 2013. The estimated ACTH is of ~8 km.

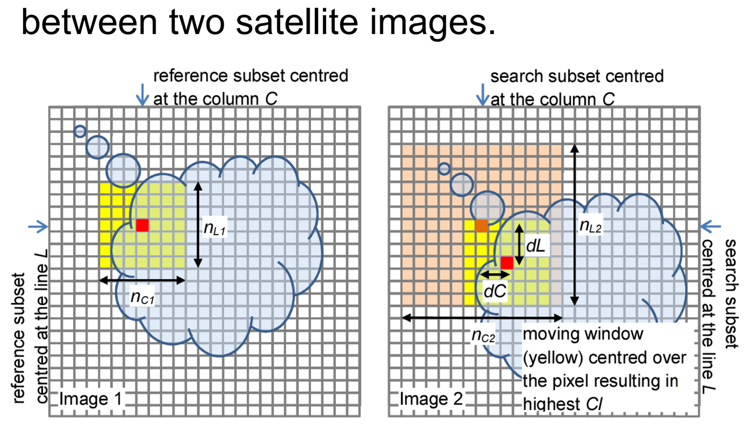
The parallax method



The scheme of observations as seen by an observer above the North pole; the lines of sight from two satellites cross in one point. Its coordinates are easy to determine in the Cartesian geocentric coordinates system. Conversion to geodetic coordinates gives us ACTH.

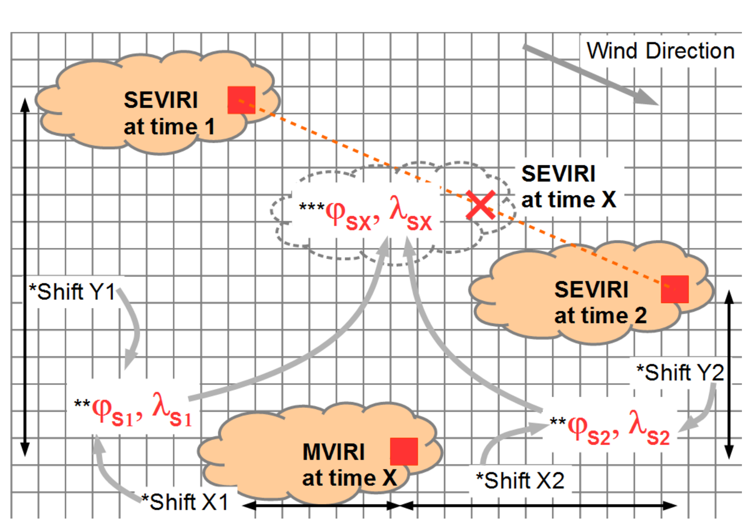
ACTH estimation consists of three main steps:

- Projection of MVIRI data on the SEVIRI spatial grid
- Automatic image matching to identify point pairs between two satellite images.

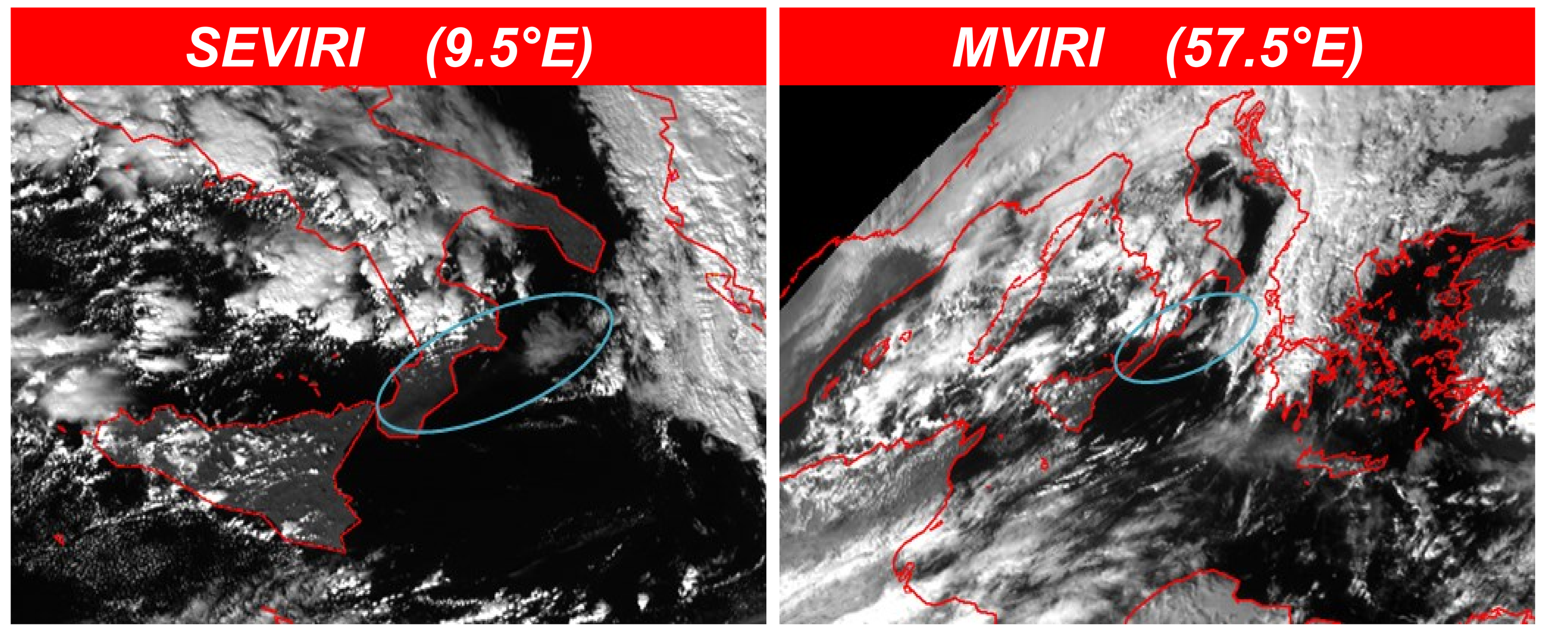


Schema of area-based image matching

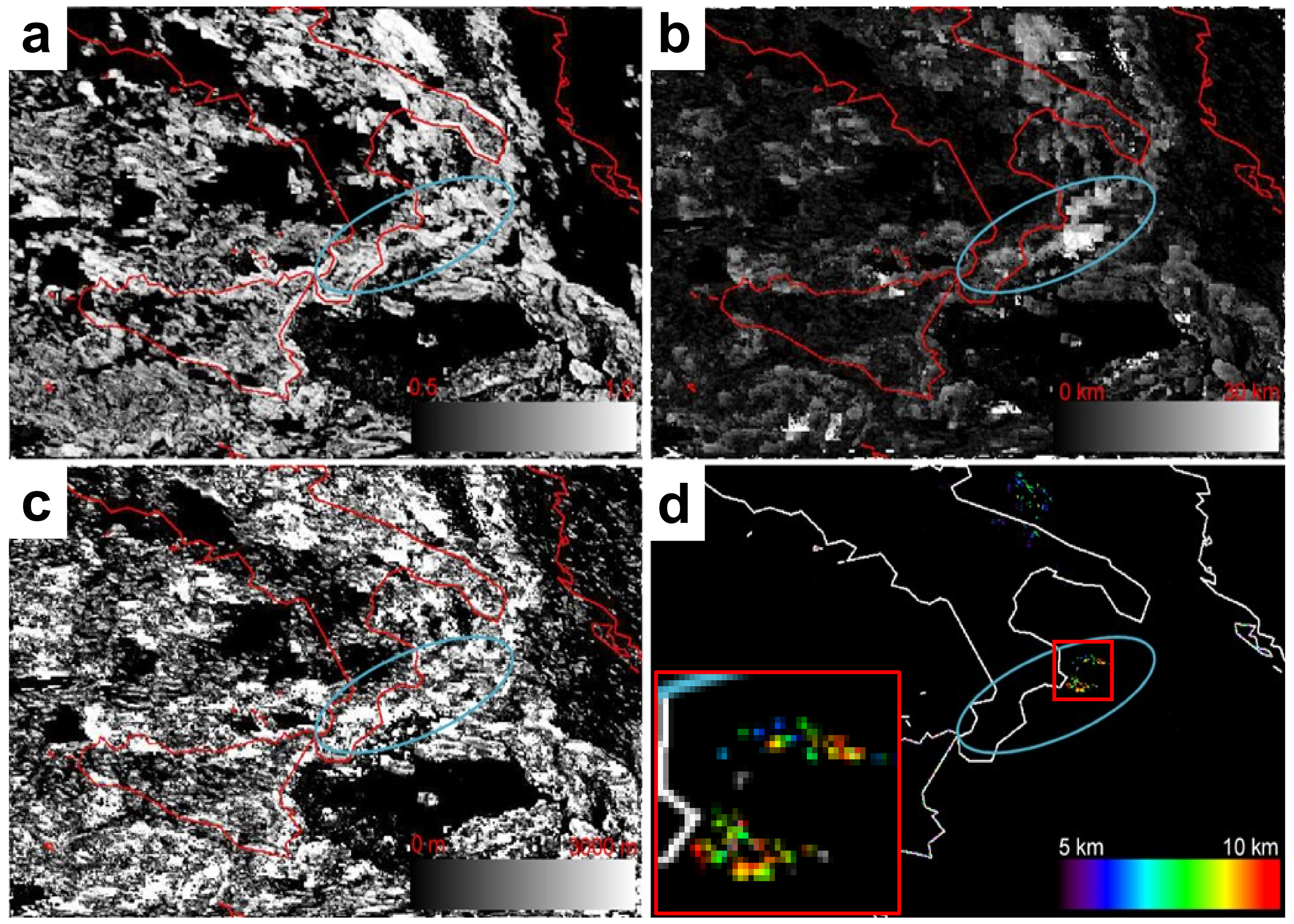
- Generation of lines of sight connecting observed points of both satellites; the intersection points of SEVIRI and MVIRI lines of sight are then used to estimate ACTH.



The procedure of determining the position of a cloud in SEVIRI image at the time of MVIRI retrieval. * Shifts in column and line direction are estimated twice by automatic image matching between MVIRI (retrieved at time X) and SEVIRI (retrieved at times 1 and 2). ** Estimated geographic cloud's positions are observed by SEVIRI at times 1 and 2. *** Interpolated geographic position of the plume as SEVIRI would observe it at times X corresponding to MVIRI retrieval



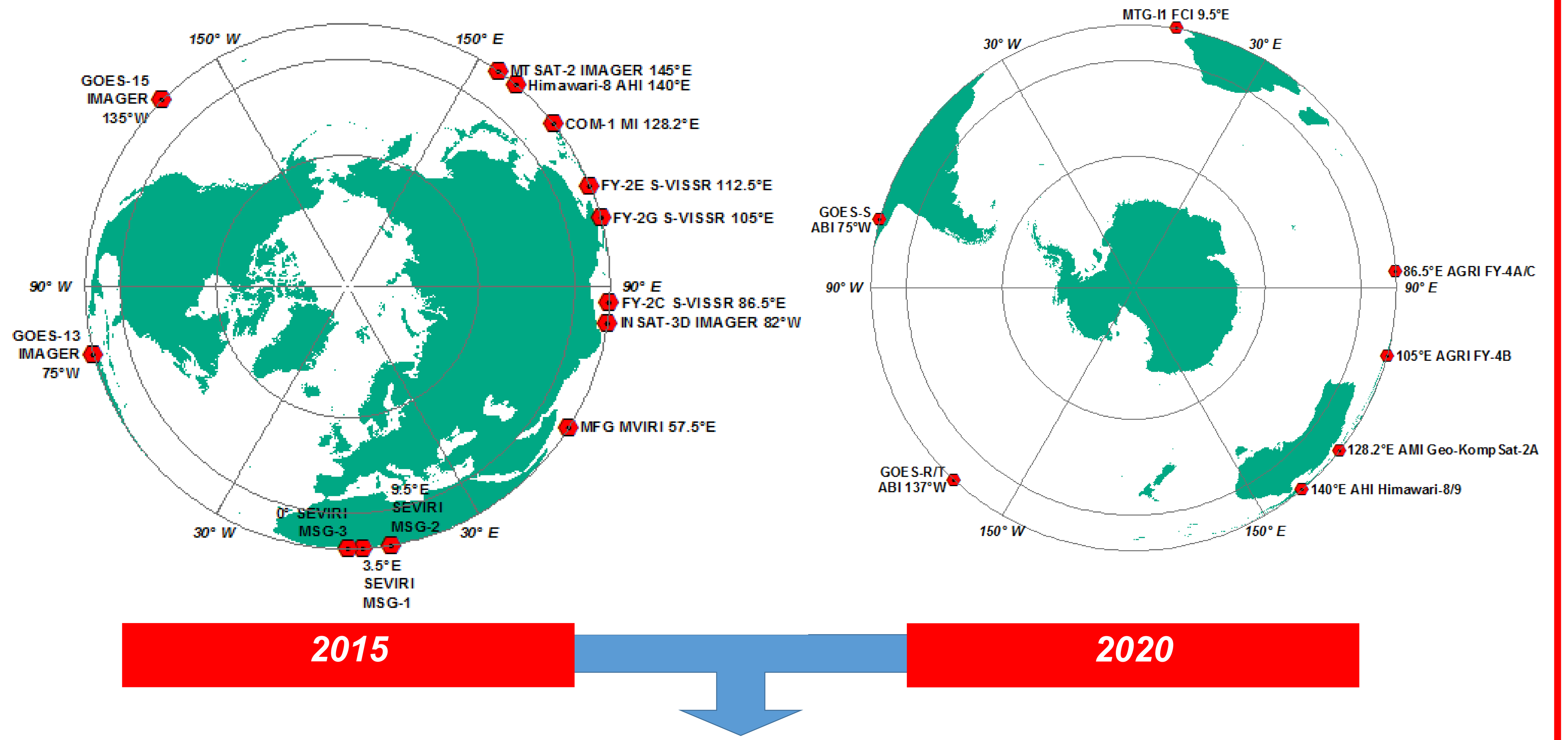
The Etna 23.11.2013 eruption viewed in the images collected around 11:49 UTC from SEVIRI (9.5°E) on the left and MVIRI (57.5°E) on the right. The cloud of volcanic origin is marked by a blue ellipse.



(a) Correlation, (b) parallax, (c) distance between intersection lines, (d) final height based on the following quality control: appropriate spectral value, small distance between the intersection lines, AHCT > 3000 m (Etna is 3300 m). The Inset in the lower left corner is a zoomed region to the area of the volcanic cloud.

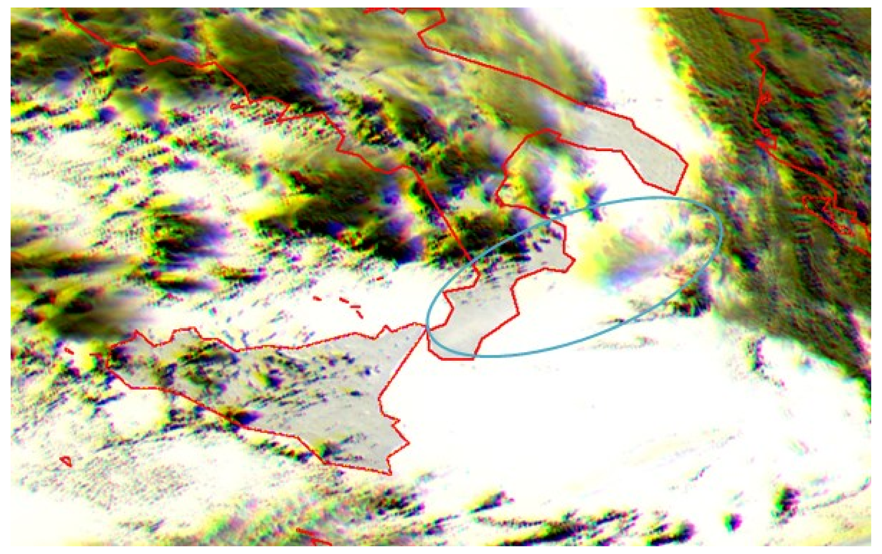
Multi-purpose VIS/IR imagery from GEO satellites	
Definition	This capability consists of medium-resolution multi-channel radiometers operating in the VIS and IR parts of the spectrum, in geostationary orbit.
Reference Observing Strategy	• six sectors, 60 degrees wide along the equator (centres: 0°, 60°E, 120°E, 180°E, 120°W, 60°W); • at least one "SEVIRI-class" instrument in each sector, and one backup, as similar as possible.

based on WMO OSCAR website http://www.wmo-sat.info/oscar/observingmissions/view/2



The GEO observational capability will rapidly grow allowing for the GEO parallax-based ACTH estimation:

- ✓ **Optimal viewing geometry**
- ✓ **Continuous global coverage**
- ✓ **Increasingly better spatial/spectral resolution, and repetition cycle of GEO VIS/IR data acquisition**



Colour composite *qualitative* visualisation of the situation as seen by the two sensors at about 11:49 UTC. This figure highlights in yellow a visual representation of the parallax between MVIRI and SEVIRI, and in turquoise the effect of the wind between the two SEVIRI images. The volcanic cloud is marked by a blue ellipse.

Overview of satellite methods for cloud top height retrieval

Methodology	Pros / Cons
Lidar and radar	+ very high vertical resolution and accuracy – too long revisit time (16 days) and only nadir observations from currently operational instruments (lidar CALIOP, radar CPR)
Radio occultation	+ high resolution in lower troposphere – globally available only about 2000 times per day
Backward trajectories modelling	+ possible estimate even for clouds drifted away from the source – requires wind field data for a large area and reliable trajectory model (e.g. turbulence not easy to handle); homogenous wind field results in high uncertainty of the source height
Brightness temperature	+ easy to apply, possible with instruments having a short revisit time – requires atmospheric profile and emissivity of the cloud; assumption of thermal equilibrium; problems around tropopause
O_2 A-band absorption	+ high accuracy – requires high spectral resolution data (not available on many satellites, long revisit time); good performance only over dark surface; requires radiative transfer modelling; daytime only
CO_2 absorption	+ good performance also by semi-transparent clouds – accurate only in the high levels of troposphere; problems around tropopause
Shadow length	+ easy to apply; requires no additional data – possible only during daytime; retrieves the height of the cloud horizontal edge and not its top
Stereoscopy	+ high accuracy; requires no additional data; based on geometry → no problems in the case of ash reaching the stratosphere – requires simultaneous data from two different viewpoints
Optimal estimation	+ include error estimate - require atmospheric profiles, ash optical properties and radiative transfer

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