COMET Event Response

Area of Interest: Fentale Volcano, Ethiopia
Date Covered: 14 January - 16 February 2025
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Purpose/Caveats: This event response report was produced to assist situational awareness and rapid response efforts. It represents best endeavours at the time of issue. Analysis and interpretation of the data is preliminary, which may not reflect the most up-to-date or complete information due to the evolving situation.

Data Used:

- InSAR images collected by the European Sentinel-1 satellite and processed using the COMET LICSAR system (https://comet.nerc.ac.uk/comet-lics-portal/)
- InSAR and SAR backscatter images acquired by the COSMO-SkyMed (CSK) and COSMO-SkyMed 2nd generation (CSG) satellites, provided through the CEOS GVEWERS programme and processed at the University of Bristol using GAMMA.
- Digital Surface Model (DSM) based on the DSM-OPT webservice developed and performed by FormaTerre, Solid Earth component of the Data Terra Research Infrasctructure. Pléiades images were provided under the CIEST² (CNES-FormaTerre) initiative (image Pléiades ©CNES2025, distribution AIRBUS DS). This dataset is licenced under CC BY-NC 4.0.
- USGS Earthquake Catalogue (https://earthquake.usgs.gov/earthquakes/search/)

Plain language summary:

Despite the continued decreasing rate of dyke opening between Fentale and Dofen volcanoes, there has been elevated levels of activity at Fentale. Since 14 January 2025, temperature hotspots and white plumes (steam) have been observed within Fentale crater. Starting from 19 January, satellites have also detected emissions of large volumes of methane. Retrospective analysis of InSAR measurements at a higher spatial resolution reveals localised shallow subsidence within the crater during the same period. On 14 February UTC 20:28, USGS reported a M 6.0 earthquake with a focal mechanism typically associated with ring faulting which may indicate the start of a caldera collapse phase. SAR backscatter images and satellite optical imagery show that this was accompanied large magnitude displacements within the crater.

Recent Activity:

Localised activity within the caldera of Fentale – Methane Emissions

Large methane plumes have been detected at Fentale using TROPOMI since 19 January. GHGSat reported substantial emissions of methane from within Fentale caldera with rates of 58 tonnes/hr detected on 31 January (GHGSat, 7 Feb). Consequently, we reassessed the previously reported thermal anomalies and plumes that have been observed within Fentale caldera from infrared (VIIRS MIROVA detections) and optical (Sentinel-2 and Planet) satellite imagery since 14 January (refer to Event Response Report 1.5 and 1.6). As of 15 February, thermal anomalies and plumes continue to be present.

Reprocessed CSK interferograms spanning 15-23 January with a higher resolution DSM show localised deformation (predominantly subsidence) within the crater, where line-of-sight (LOS) displacement away from the satellite is ~ 31 cm (Fig 1). This is an update of the original interferograms (Event Response Report 1.5) that were processed at a lower resolution which meant that the deformation that occurred over a smaller spatial scale within the crater could not be resolved. The overlapping deformation patterns, with broader subsidence across more than 15 km and localised intra-crater subsidence over ~ 2 km, suggests there are likely to be multiple deformation sources (Fig 1). The localised subsidence suggests that methane-rich gases were stored in the shallow subsurface at least temporarily prior to emission.

CSK SAR images show an increase in backscatter northeast to the localised subsidence that could be related to increase in moisture content in the ground (Fig 1). The location of backscatter changes correlates with where plumes are observed. Degradation of vegetation and hydrothermal alteration within the caldera are also visible since mid-January.

M 6.0 earthquake on 14 February 2025

USGS reported nine M 4.2-4.8 earthquakes from 3-12 February. On 14 February UTC 20:28, a M 6.0 earthquake was reported, with a vertical-P compensated-linear-vector-dipole (CLVD) focal mechanism that cannot be explained by shear along planar faults associated with pure double-couple forces. In volcanic settings, CLVD earthquakes have been attributed to dip slip motion along curved ring faults (Shuler et al., 2013). For example, this was previously documented at Bárdarbunga volcano, Iceland in 1996 and during the 2014-2015 caldera collapse (Nettles and Ekström, 1998; Gudmundsson et al., 2016), and during the co-diking caldera ring faulting at Ambrym volcano, Vanuatu, in 2018 (Shreve et al., 2019).

Preliminary investigation of Sentinel-1 and CSG InSAR images available at the time of writing spanning the M 6.0 earthquake do not show conclusive evidence of ring faulting within Fentale caldera. However, normal sense slip occurred along a ~ 4 km fault located about 5 km east of the centre of the crater (Fig 2a).

Within the caldera, SAR range offsets show motion of up to ~ 30 m away from the satellites which could be representative of slumping (Fig 2b). Concurrently, in the same area, Planet imagery shows up to ~ 15 m of horizontal displacement toward the west (Fig

3). These large displacements could represent a local collapse of material due to volume loss at shallow depth.

Deformation along the eastern wall of the caldera is visible in satellite optical imagery from Sentinel-2 and Planet after 14 February, and is likely associated with the M 6.0 earthquake (Planet timelapse). Changes in ground backscatter properties observed in CSG SAR backscatter images are suggestive of formation of cracks or fractures, and a possible rockfall (Fig 4).

Continued slowdown in dyke opening

The latest 12-day ascending and descending Sentinel-1 interferograms continue to show a decrease in deformation rate associated with dyke opening, evidenced by the reduced number of fringes within consecutive 12-day intervals (Fig 5). There is > 8 cm of LOS displacement from 3-15 February, which is a decrease from > 20 cm from 22 January – 3 February, and > 65 cm from 10-22 January.

Forward Look:

As of 16 February, plumes and thermal anomalies within the caldera of Fentale continue to be visible in satellite imagery. There has been no further > M 4 earthquakes reported by the USGS at the time of writing. The M 6.0 earthquake on 14 February, together with observations of slumping and subsidence within the caldera, may represent the beginning stages of a caldera collapse phase.

We will continue to monitor surface deformation with the upcoming Sentinel-1 and COSMO-SkyMed images. This, in combination with other data, observations and models, will provide evidence on which the potential evolution of the event can be considered. A scientific committee comprising scientists from Addis Ababa University (IGSSA and School of Earth Science), the Geological Institute of Ethiopia and other relevant institutions is monitoring the events and keeping the Ethiopian Disaster Risk Management Commission (EDRMC) and the public continuously informed. The government has reminded citizens to follow precautionary messages given by professionals.

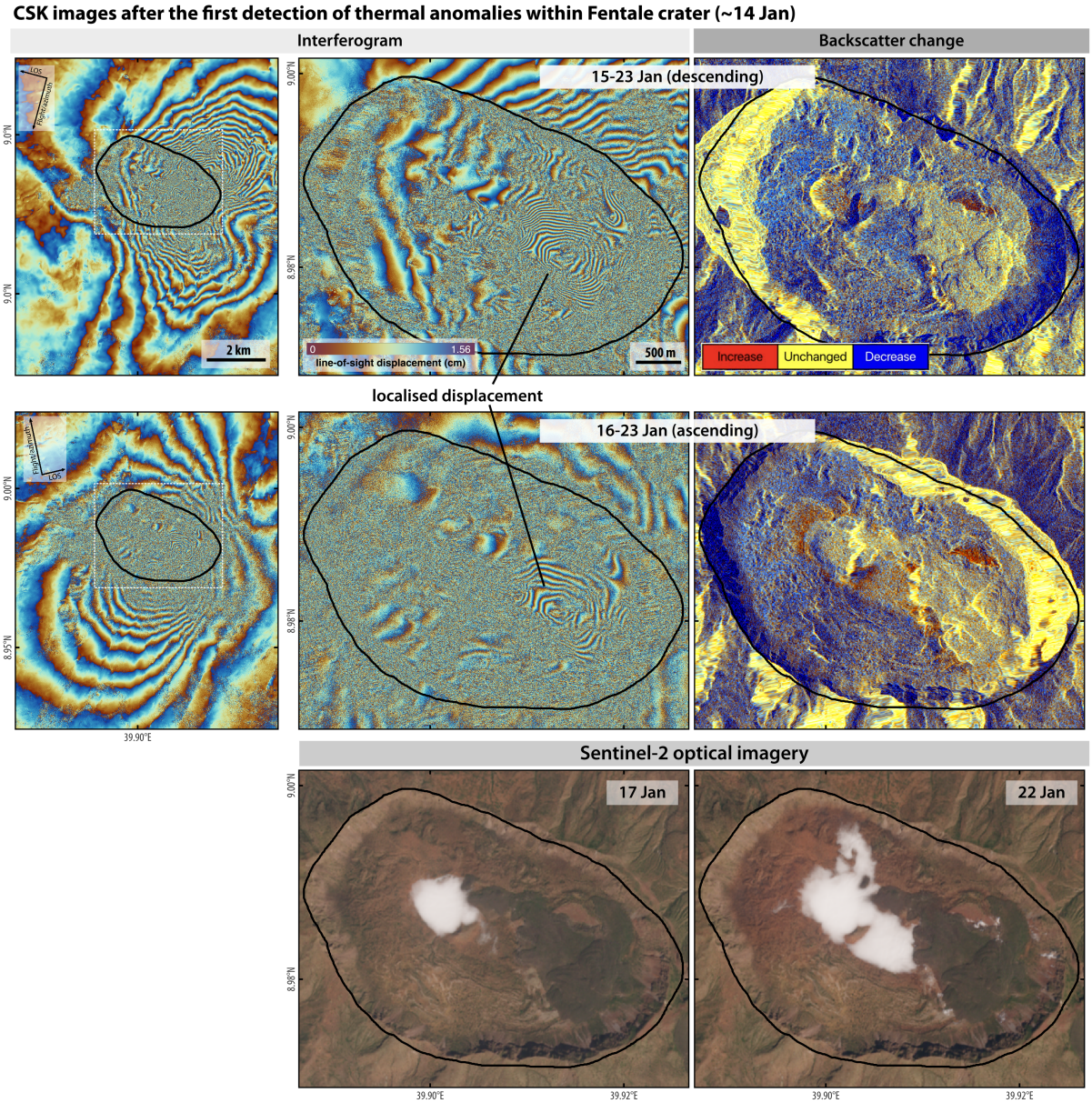

Fig 1. CSK interferograms showing localised deformation within Fentale crater, shortly after the first detections of thermal anomalies from VIIRS (MIROVA) on 14 January and plumes from optical imagery (Sentinel-2 and Planet). There is approximately 31 cm of LOS displacement away from the satellite from 15-23 January (descending acquisitions), and 14 cm from 16-23 January (ascending). Changes in backscatter during the same time periods could be related to increased moisture content in the ground. Plumes are visible in the true colour Sentinel-2 optical imagery on 17 and 22 January.

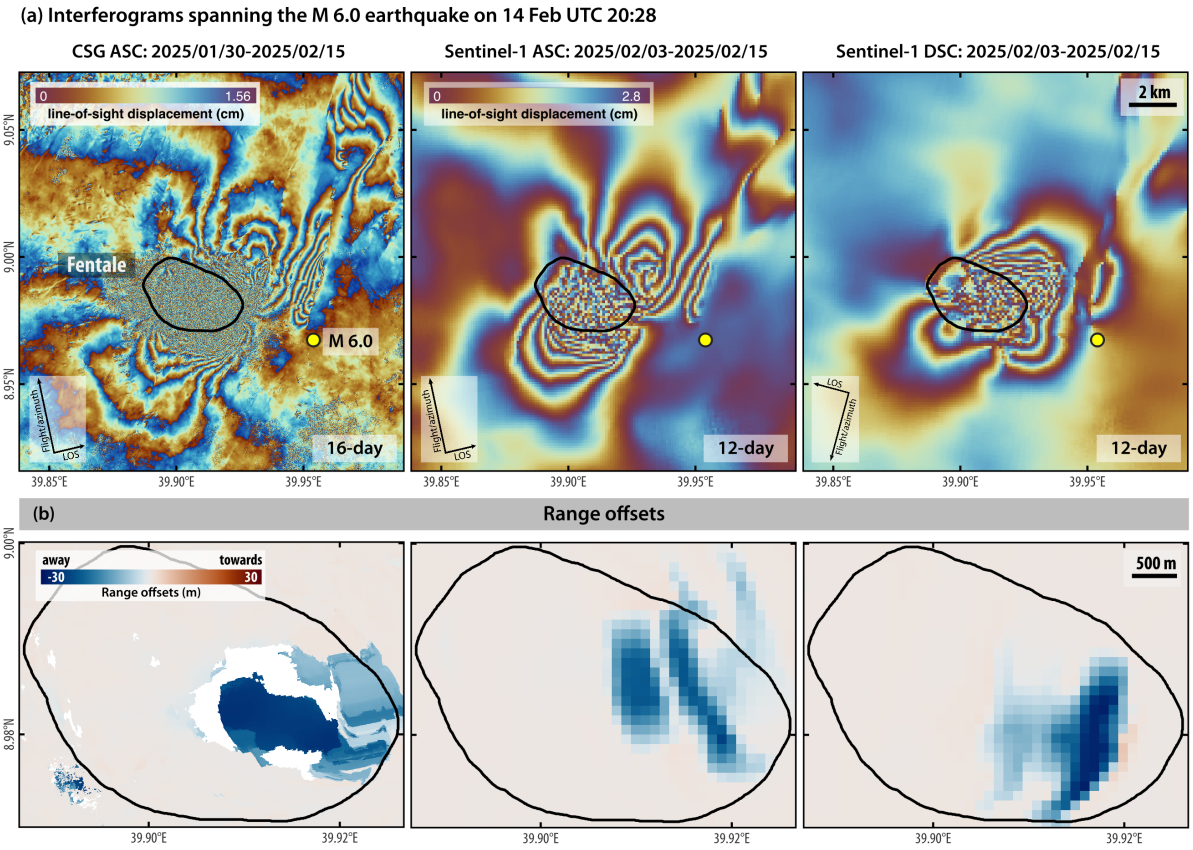

Fig 2. (a) 16-day ascending CSG and 12-day Sentinel-1 images centred on Fentale caldera, spanning the predominantly non-double-couple (vertical CLVD) M 6.0 earthquake recorded on 14 February, UTC 20:28. Normal faulting is observed just north of the epicenter of the M 6.0 located by USGS. (b) Range offsets show motion away (blue) from the satellite of ~ 30 m. Areas with low SNR are masked in the CSG offsets.

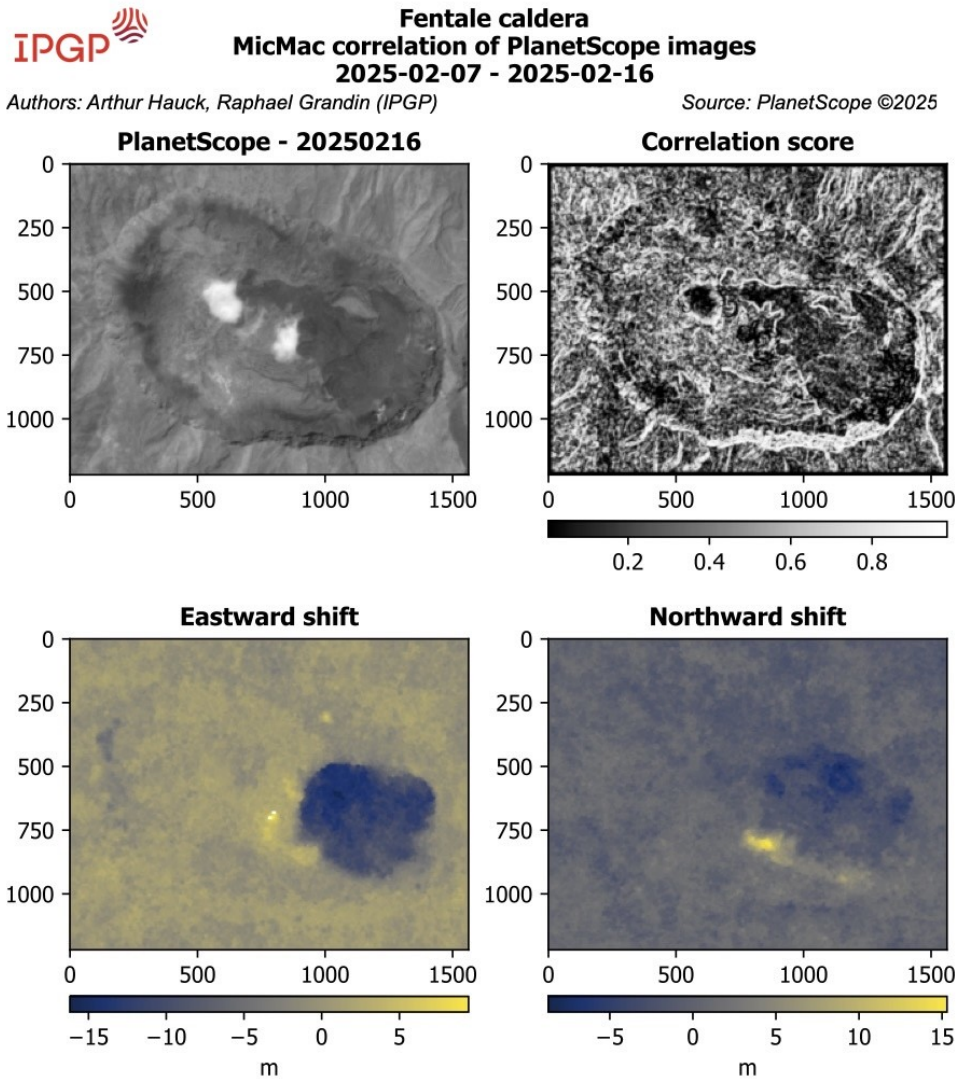

Fig 3. Horizontal surface displacement from correlation of PlanetScope images acquired on 7 February 2025 and 16 February 2025 (pixel size: 3 m). The upper-left panel shows a panchromatic image acquired on 16 February 2025, showing at least two sites of steam emission. The upper-right panel is the correlation score. In the lower-left panel, negative values (in blue) indicate motion toward the west. In the lower-right panel, negative values (in blue) indicate motion toward the south.

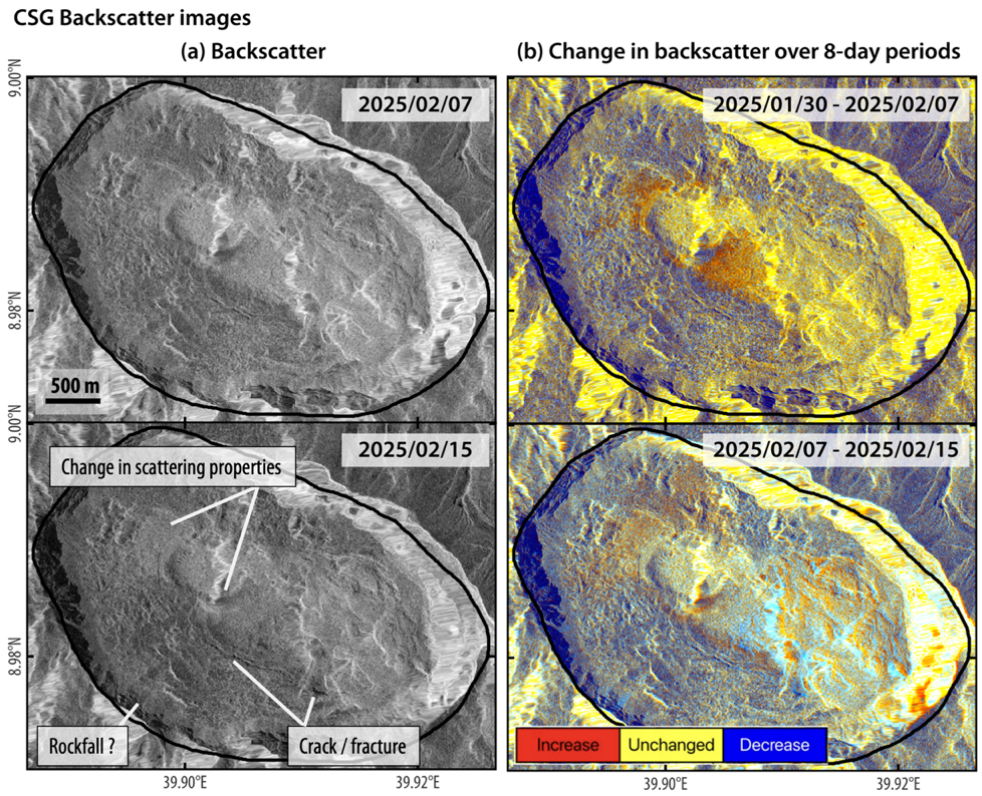

Fig 4. CSG backscatter data to show changes in ground scattering properties. (a) Comparing individual backscatter images on 7 and 15 February reveals changes that might be related to possible rockfall and formation of cracks. (b) RGB images of change in backscatter over consecutive 8-day periods.

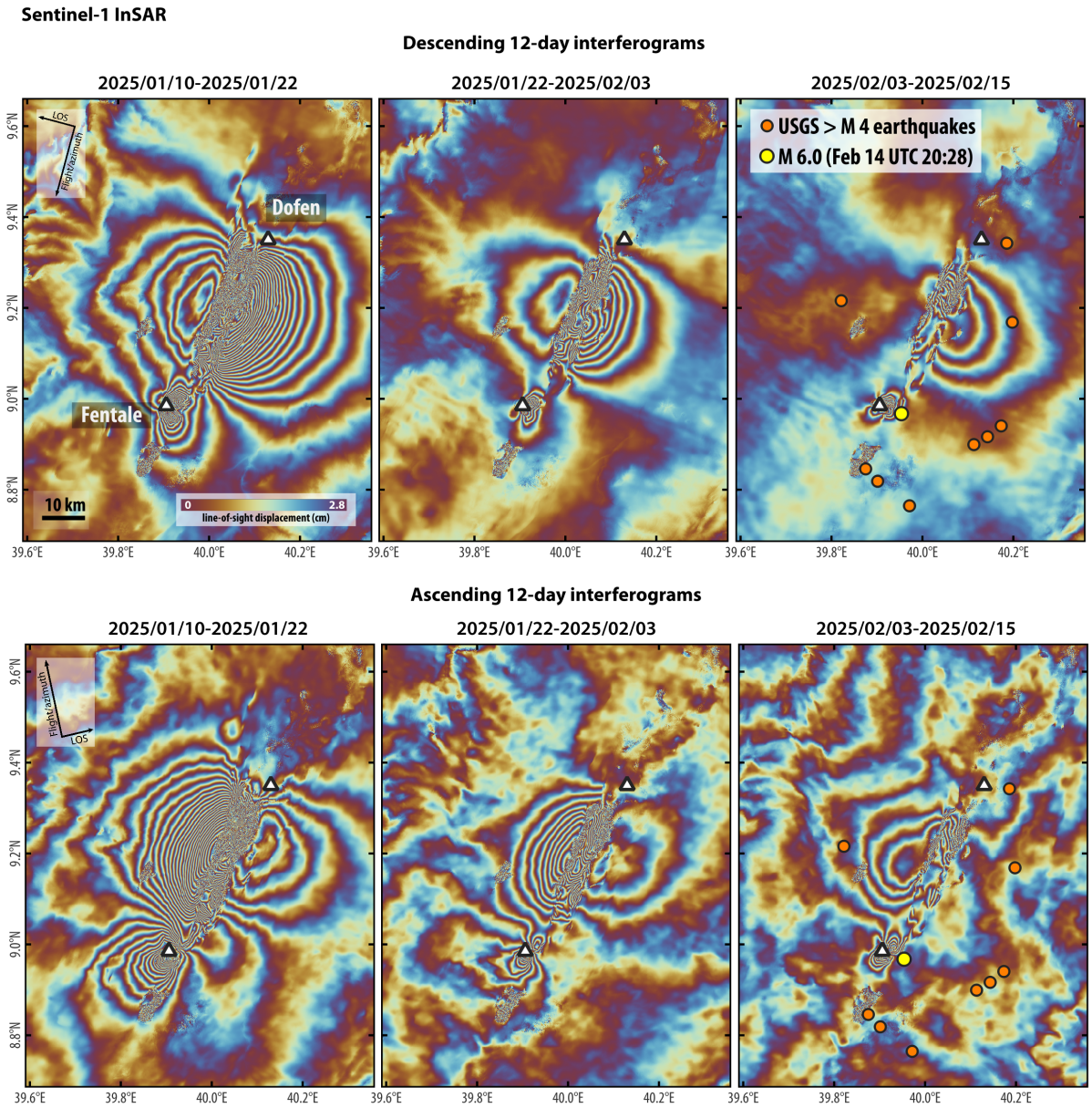

Fig 5. 12-day consecutive descending and ascending Sentinel-1 interferograms up to 15 February, showing continued slowdown in deformation related with dyke opening and subsidence at Fentale. Earthquakes larger than magnitude 4 that occurred from 3-15 February reported by USGS are also plotted on the most recent interferograms.

References

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