SAR interferometry allows DEMs to be produced in equatorial, cloud covered areas For instance, Figure 3 shows an interferogram with an altitude of ambiguity of 17 metres in Ukraine where the elevation variations are within 100 metres: the fringes neighbouring the river beds can be interpreted as elevation contour lines with a precision better than one metre

This ability of SAR interferometry to produce digital elevation models with accuracy in the metre range may especially be useful on fairly flat areas to identify the geographic extent of a potential flooding

Volcanoes

Digital elevation models are used to determine the potential paths of mud or lava flows in the event of a volcanic eruption SAR interferometry can provide such DEMs, especially on volcanoes partially hidden by their plumes or by a cloudy sky. Conventional stereoscopic methods might also be difficult to apply on a ground surface homogeneously covered by lava and therefore generating a poor optical contrast. In contrast, lava appears very coherent for SAR interferometry. as shown in Figure 4 (image of coherence on Mount Etna). Figure 5 shows a fringe pattern of the corresponding interferogram. In the case of an inflation of the volcano, this fringe pattern would be shifted. according to the ground displacement toward the satellite.

In collaboration with the European Space Agency (ESA), C N.E.S. monitors Mount Etna by applying SAR interferometry to all ERS-1 data acquired on the site. This study, once interpreted by geophysicists, will improve our knowledge about the volcano's dynamic behaviour.

3. SAR interferometry limitations

Limitations due to the available sensors

Two civilian spaceborne SAR are currently operating: the European ERS-1 and the Japanese JERS-1, and two more are going to be launched: the European ERS-2 and the Canadian RADARSAT. Those satellites have interferometric capabilities although their missions were not dedicated to SAR interferometry Thus, their operational observation capacities are constrained by the limited Earth coverage and the orbital repetitivity. For instance, ERS-1 SAR data are not recorded on board, which limits the acquisition possibilities to the areas where the satellite is in sight of a ground station. With the 35 day orbital cycle, one could have to wait up to one month to obtain a SAR image over a given site. The interferometric features of a SAR image pair, especially the altitude of ambiguity, cannot be selected before the data acquisition, because the orbital positions cannot be constrained to a better than a metre accuracy Thus, we use the ERS-1 data opportunistically and select the pairs of SAR images which have the desired interferometric features.

Figure 4. Image of interferometric coherence from 2 ERS-1 scenes of the Etna volcano

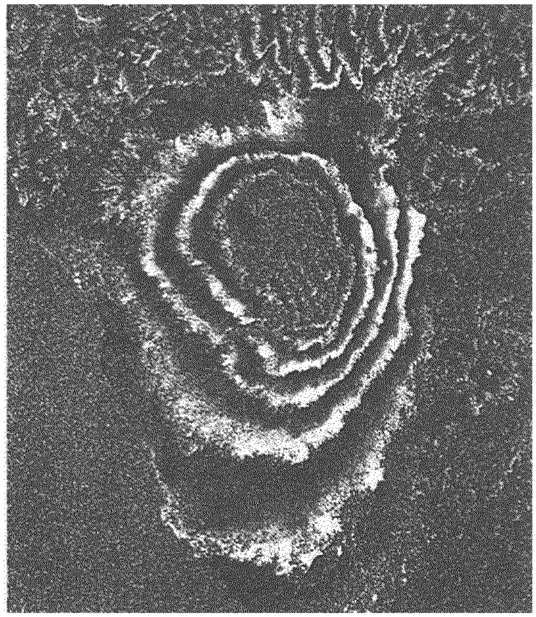

Figure 5 Equivalent topographic fringe pattern to figure 4.

Loss of coherence

The major limitation of SAR interferometry is the loss of coherence due either to the orbital geometry of the acquisitions or to ground surface changes. The phase contribution of the ground target distribution depends on the local incidence angle, which in turn depends on the satellite orbit and on the local topographic slope Any variation of this phase contribution from one image to another generates phase noise on the interferogram, which decreases the coherence according to the amount of variation. Therefore, the two orbital tracks have to be close enough to preserve the coherence, especially on areas with large topographic variations. For instance, with ERS-1, the coherence is usually satisfied if the distance between the tracks is roughly less than 600 metres. This occurs statistically for 25% of the potential interferometric pairs.

A minor geometrical cause of coherence loss is a large gradient of ground displacement, compared to the resolution used to map it. The fringes induced by the displacements will become unreadable if the fringe rate is larger than half a fringe per pixel. For those displacement fields, using the high resolution of the SAR images will help preserve the coherence. Ground surface changes affect directly the phase contribution of the ground target distribution. We assume that the coherence decreases according to the proportion of targets changed in the ground resolution cell. Some changes, such as those due to vegetation, have seasonal or daily variations Other causes of coherence loss may be temporary (ground moisture following rain) or permanent (harvest, building). On the other hand, some regions (deserts, volcanoes) have kept a high coherence over more than one year. Anyway, the loss of coherence is difficult to predict Our experience has to be improved to allow the assessment of coherence loss on a statistical basis.

4. Conclusion

SAR interferometry is already operational with the spaceborne SAR's currently available. Its application domain has still to be explored, but it already includes assessment of major natural hazards such as earthquakes, volcanoes or flooding. SAR interferometry has also potential predictive capabilities (e.g volcano inflation) which have to be demonstrated and could, if confirmed, lead to a dedicated mission.

5. References

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Discussion

Dr. Jones (Met Office) asked if radar interferometry can be used to monitor changes in snow cover, to which the reply was no work had been done, though glacier/ice sheet flow had been measured. Prof. Wadge (NUTIS) and Dr Francis (Open Univ) both asked about availability of data commercially and operationally. There is a problem concerning available, suitable data for interferometry work but eventually the type of commercial product outlined should be widely available Dr. Browitt (BGS) suggested interferometry might be used to track tsunami waves and surface ground waves but Dr. Rossi pointed out that there is still the requirement for pre- and post-event images, which means a large archive of baseline data. Dr Rossi told Dr. Soeters (ITC) that about 16 hours on a 50 megaflop class computer were required to process a 100 x 150 km area.