TOPOGRAPHIC AND THERMAL MAPPING OF VOLCANIC TERRAIN USING THE AVTIS GROUND BASED 94GHZ DUAL-MODE RADAR/RADIOMETRIC IMAGER

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1. INTRODUCTION

The AVTIS remote sensing instrument is a custom built millimeter wave sensor that has been developed as a practical field tool for remote sensing of volcanic terrain at active lava domes. The portable instrument combines active and passive millimeter wave measurements to record 3D topography and thermal data in almost all weather conditions from a ground-based survey point. AVTIS has been used to make measurements on four campaigns at Soufrière Hills Volcano, Montserrat and once at Arenal Volcano in Costa Rica. The scientific results derived from those measurements are reported elsewhere [1] – [4]. Here we describe how the instrument is deployed in the field, the quality of the primary ranging and radiometric measurements and the post-processing techniques used to derive the geophysical products of the terrain surface, surface temperature and reflectivity.

2. SYSTEM DESCRIPTION AND CAPABILITY

The AVTIS system is typically operated by two people and can be readily transported by car or helicopter to a suitable surveying site (Fig.1.). AVTIS consists of a single, gimbal-mounted, 0.3 m diameter Cassegrain antenna feeding the main sensor head which combines a heterodyne radiometer with a homodyne, frequency modulated continuous wave (FMCW) radar using a multiplied 7GHz PMYTO as a single 94GHz source for the radar transmitter and the local oscillator for the radiometer [5]. Active and passive modes are selected by attenuating the transmit path in radiometric mode, switching between the appropriate intermediate frequency channels and choosing either FMCW source modulation (for radar) and no modulation (for radiometer). The instrument head and gimbal are battery powered and controlled by laptop computer. Radar topography and radiometry imagery are gathered by rastering the antenna across the scene of interest. Data acquisition and storage is semi-automated with sequential scans stacked for repeat scans of the same scene. Although basic display of data are available to the user in real time, data calibration, terrain reconstruction and alignment to the GPS grid is generally post processed offline. AVTIS has a range resolution of 0.85m with a maximum radar range of approximately 7km. The thermal sensitivity of radiometric measurements is <5K, which is sufficient for lava dome imaging.

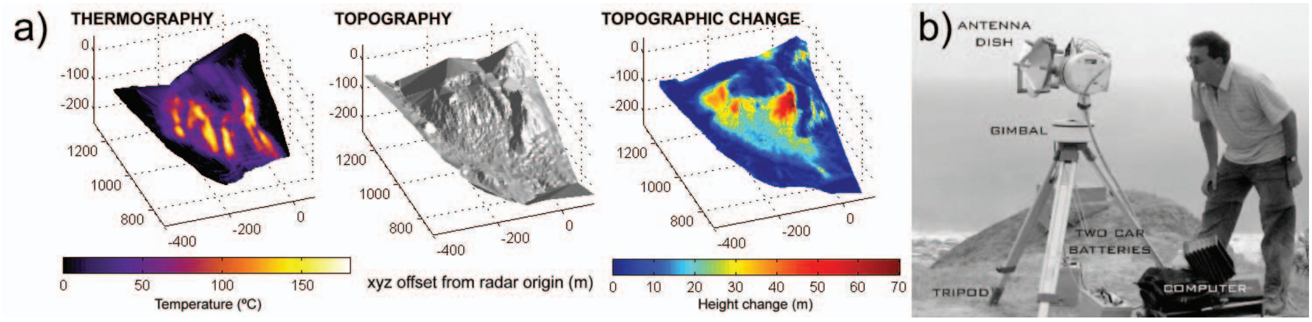

Fig 1. a) MMW remote sensing capability: AVTIS provides detailed 3D topography and thermal imagery from a single, portable instrument, regardless of viewing conditions. These data show lava dome growth recorded over ten days at the Soufrière Hills Volcano, Montserrat, in November 2005 .b) Instrument set up for use in the field

3. DATA CAPTURE AND ANALYSIS

The process for generating a georeferenced Digital Elevation Map (DEM) has been developed over the last five years from a time consuming manual analysis of the raw data that would take many months to produce accurate results, to a semi autonomous state which can provide a DEM a few minutes after data acquisition. Each raw AVTIS radar dataset consists of a rastered set of FMCW spectra with a single measurement sweep taken for each line-of-sight. This volumetric set of range vs reflected power spectra is then corrected for fall-off in range and gain in the receiver amplification chain. In addition, since the incident radar beam on the target scene topography can extend over many tens of metres (especially for oblique surfaces) and can be dominated by a strongly reflecting facet (eg. a large perpendicular boulder) the spectra are filtered against range to provide a measurement of radar reflectivity for the bulk topography. For longer ranges (>3km) averaging of successive scans can be required to increase signal-to-noise. Topography is then extracted from this processed spectra volume by locating a single range at the point of maximum reflectivity for each line-of-sight. The resulting set of data points is then thresholded against reflected power to discard lines of sight with no discernible return; these occur at the edges of ridges etc.

Registration of the data to a GPS frame of reference requires AVTIS to scan several artificial retroreflectors placed at locations measured by GPS, which records their angular position in the radar frame of reference. The retroreflectors are also used for periodic calibration of the radar range measurement. Combining these vectors with the GPS position of the instrument then provides the translation and rotation transforms to reference the radar topography geographically. Iterative minimization of each DEM to known static topography is also used as a final check on the absolute position of the radar derived topography within a georeferenced grid system.

Radiometric scanning uses a two stage calibration process with short term gain fluctuations in the receiver calibrated against an internal noise source for each line of sight in a raster. Absolute temperature calibration is achieved by reference to the thermal temperature gradient of the atmosphere. Co-locating the thermal data with the radar data is then trivial since the measurements share the same antenna.

4. NOTES

This paper is intended as a summary of a journal publication now in preparation for IEEE TGARS. In addition, the AVTIS instrument is currently being upgraded to operate as a fully autonomous instrument for round the clock monitoring of the lava dome at the Soufrière Hills Volcano, Montserrat in 2010. We plan to report on progress with the new setup at IGARSS 2010.

5. REFERENCES

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