Assessing the increased utility of commercial X-band compared to C-band SAR data for estimating lava flow height: initial stages

Q. Hayes[1,2], K.F. Tiampo[1,2], R. Cassotto[1], B. Corsa[1,3]

[1]Cooperative Institute for Research in Environmental Sciences, [2]Dept of Geological Sciences, University of Colorado Boulder, [3]USGS California Volcano Observatory

Background and Research Goals

The primary goal of this research is to develop a lava height algorithm that will aid hazard agencies in mapping lava flow evolution in near-to-real time. This research will combine Capella commercial X-band and Sentinel-1 A/B C-band synthetic aperture radar (SAR) data, and Maxar and drone-generated optical data to **1)** assess the increased utility of X-band compared to C-band data, **2)** establish the satellite characteristics necessary for accurate measurements of lava height as a volcanic eruption progresses, and **3)** develop a lava height algorithm with freely available code.

Our lava height algorithm builds off the work of Liu et al, 2013 **[1]**, who developed a building height algorithm that calculated layover from X-band radar imagery and a geocoded DEM image, based on the principle that a building's layover length is proportional to its height **[1]**. Layover (L) is calculated by the relationship ($L = H/\tan\theta$), and is proportional to the building height (H) divided by the tangent of the radar incidence angle (θ), as seen below in Figure 1.

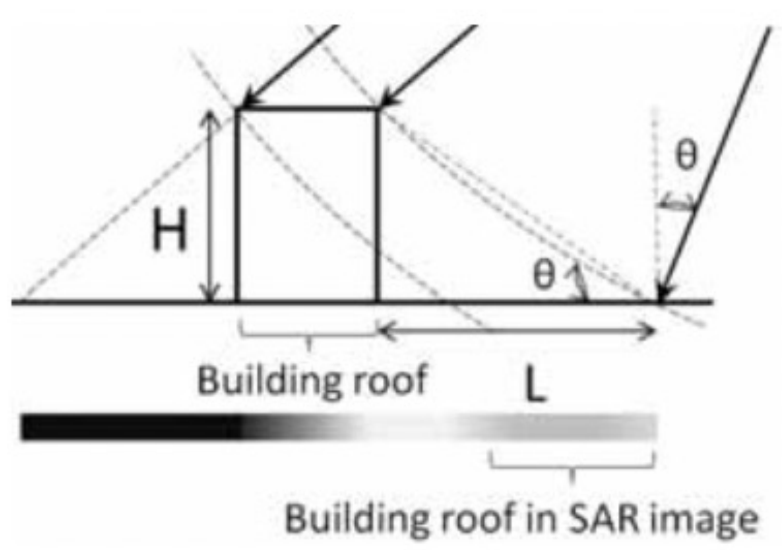

Fig.1: Schematic depicting radar geometry as it flies over a building. H represents building height, L is layover, and theta (θ) is the radar incidence angle. Figure taken from Liu et. al., 2013.

Our research group has modified this algorithm for use with Sentinel-1 C-band data (Cassotto et. al., paper in prep). Under this project, we will further modify the algorithm for use with Capella X-band data and account for varied terrain, rather than the flat urban surfaces in **[1]**. We anticipate that this modified algorithm will yield higher accuracy in identifying lava flow outlines, as Capella has a higher pixel resolution than Sentinel (up to 0,5m in Spot mode, compared to ~5m for Sentinel), as well as a shorter wavelength (~3.1cm compared to Sentinel's ~5.6cm).

Methods and Initial Stages

We begin by processing Sentinel-1 B C-band and Capella X-band radar data for the 2021 volcanic eruption in La Palma, Spain, and comparing initial results. Sentinel-1 imagery utilizes SNAP's radiometric terrain correction, while Capella imagery utilizes GAMMA software. Building outlines generated with machine learning techniques (courtesy of E. Heijkoop) are overlayed on the image, seen in Figures 2, 3, and 5. Eventually we will calculate layover for buildings with the C-band and modified X-band algorithms.

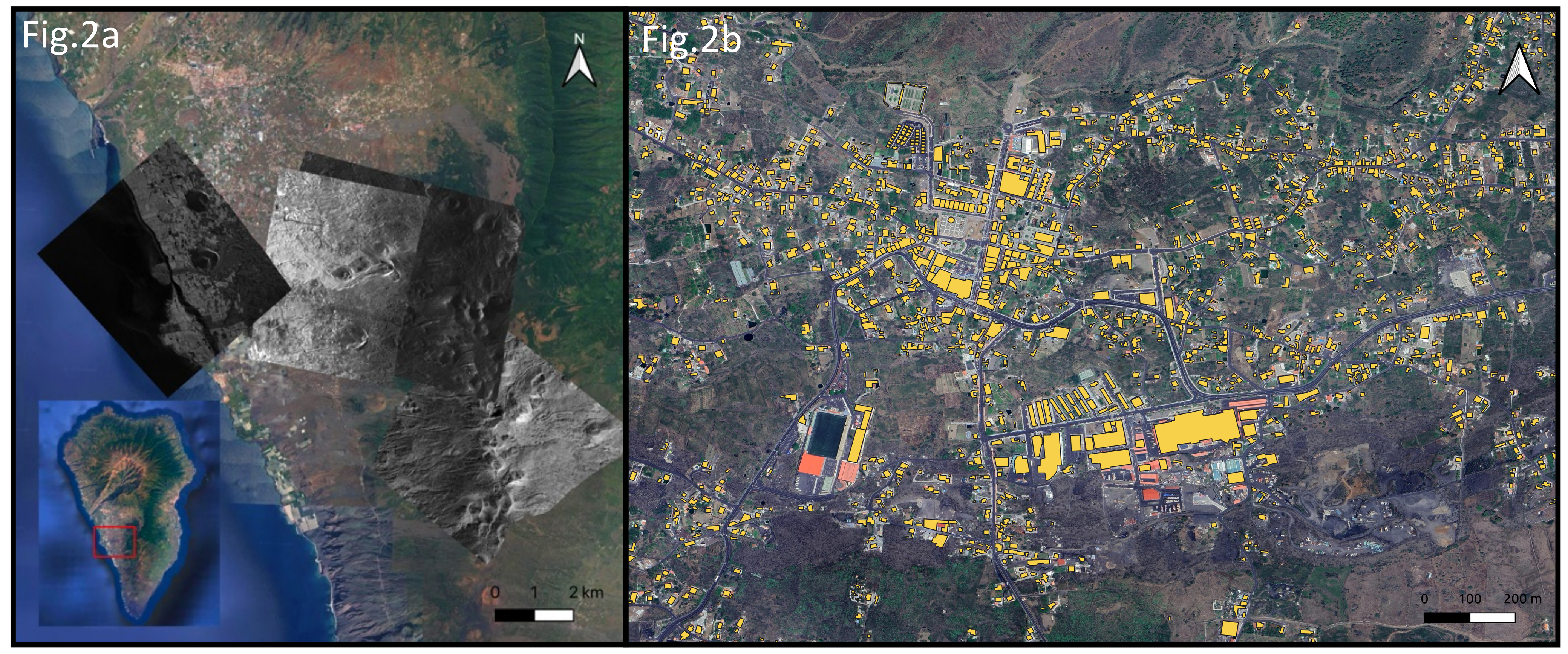

Fig.2: a) La Palma, Canary Islands, Spain, overlain with four of eight freely acquired Capella radar images depicting different stages of the September 2021 volcanic eruption. These images will be used to refine the lava height algorithm. **b)** Sentinel-1 RTC processed image overlain with building outlines (yellow) generated with machine learning techniques for the Tacande de Arriba region, La Palma, Canary Islands.

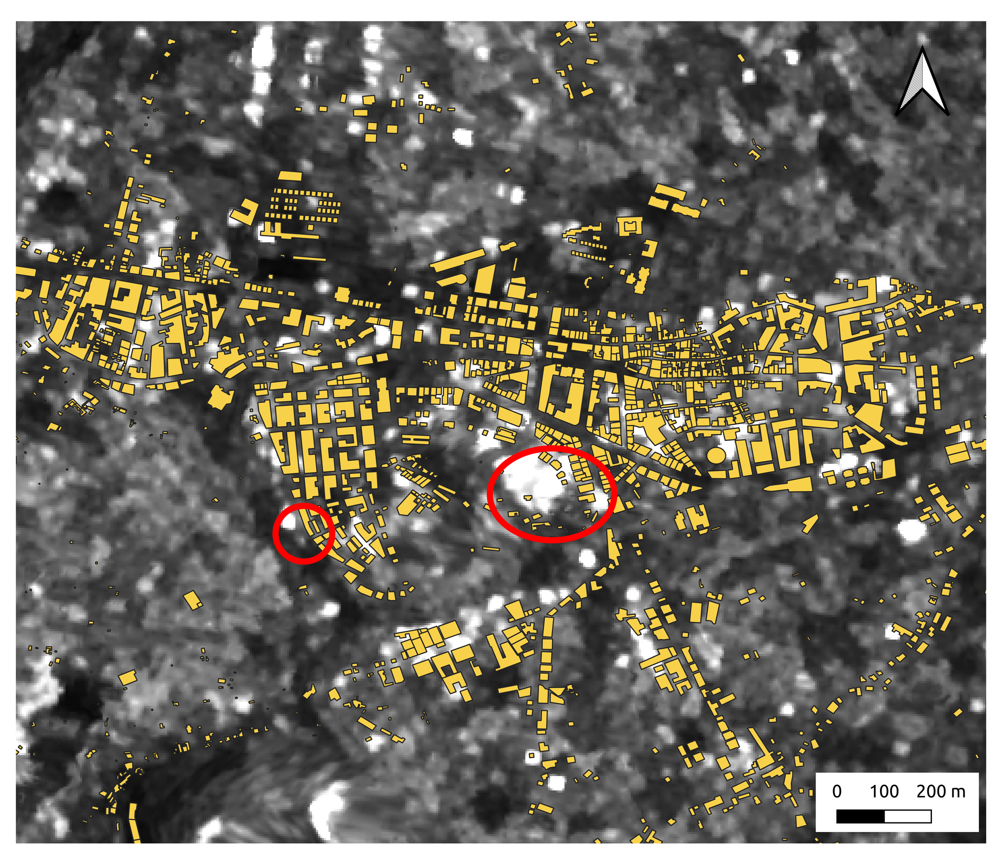

Fig.3) Sentinel-1 imagery overlain with yellow building outlines. Red circles indicated regions with bright returns that do not correlate with building outline layover from the radar.

Fig.4) Google Earth imagery for the same region as Figure 3. Red circles indicate high terrain for the same regions, circled in red. The left red circled area measures ~9 meters in height, while the red circled area measures ~61 meters in height.

Fig.5: a) Sentinel-1 RTC processed La Palma imagery dated 2021-12-21, **b)** Google Earth imagery, **c)** Capella RTC processed imagery dated 2021-10-05. Note the lava flow visible in the top of the image. Each panel is overlain with building outlines in yellow.

Discussion

We are currently testing our methods on La Palma, Canary Islands, which does not replicate the flat, urban surfaces used previously for the C-band building height algorithm. We hypothesize that the steep hillsides seen in Figure 4 are the cause of the bright returns in Figure 3, and are producing false layover (bright spots due to the satellite's ascending geometry and mountainous terrain rather than features of interest) in the Sentinel-1 imagery.

In Figure 5, we see that Capella captures both lava flow outlines and commercial operations where Sentinel-1 does not. We anticipate that Capella will provide better returns than Sentinel for regions such as those in Figure 3 due to its higher resolution and will minimize highly reflective returns compared to Sentinel-1.

Future Work

- Process remaining Capella imagery for La Palma and compare to overlapping Sentinel-1 imagery. Analyze false layover returns.
- Determine satellite geometries that minimize false layover returns due to terrain and provide the best returns for our features of interest (lava flows).
- Modify lava height change algorithm parameters for Capella X-band data instead of Sentinel-1 C-band data. Calculate layover first for buildings, and then modify to calculate lava flow layover.
- Long term goal: Determine number of satellite captures necessary to cover different stages of lava flow for an active eruption so that we may provide timely hazard forecasts and warnings to the general public.

References

- **[1]** Liu, Wen and Yamazaki, F., "Building height detection from high-resolution TerraSAR-X imagery and GIS data," Joint Urban Remote Sensing Event 2013, Sao Paulo, Brazil, 2013, pp. 033-036, doi: 10.1109/JURSE.2013.6550659.

Acknowledgements

This work is made possible through CIRES IRP funding and a student research partnership with Capella Space.