Spectral Image Enhancement and Analysis of the 2022 Mauna Loa Eruption

REMS5001 – Fundamentals of Remote Sensing and Digital Imagery

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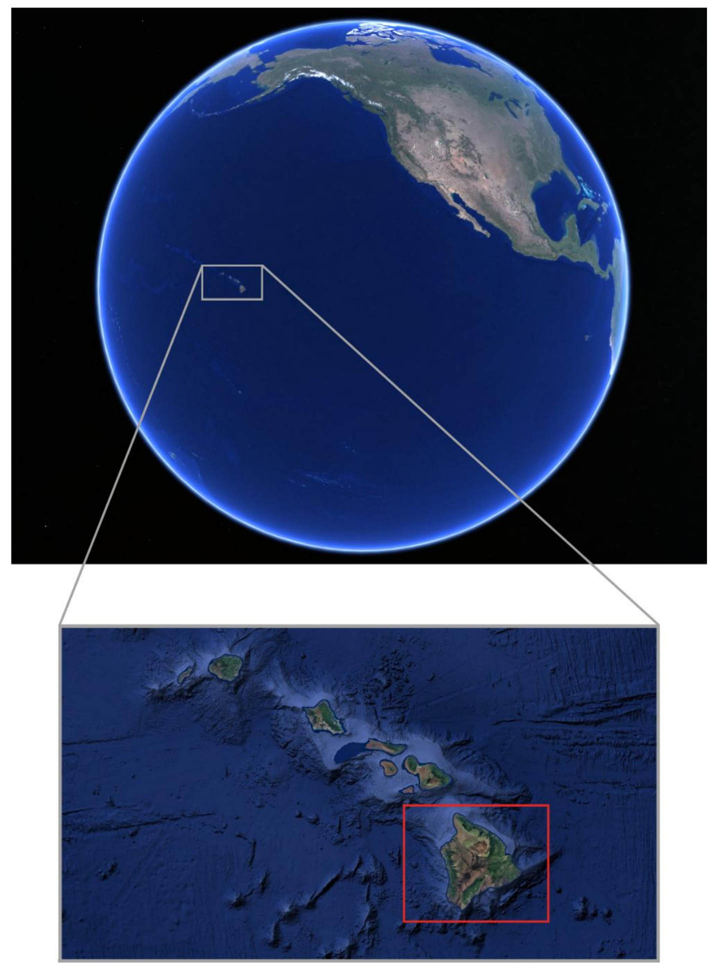

Figure 1.1: Map showing all the Hawaiian Islands

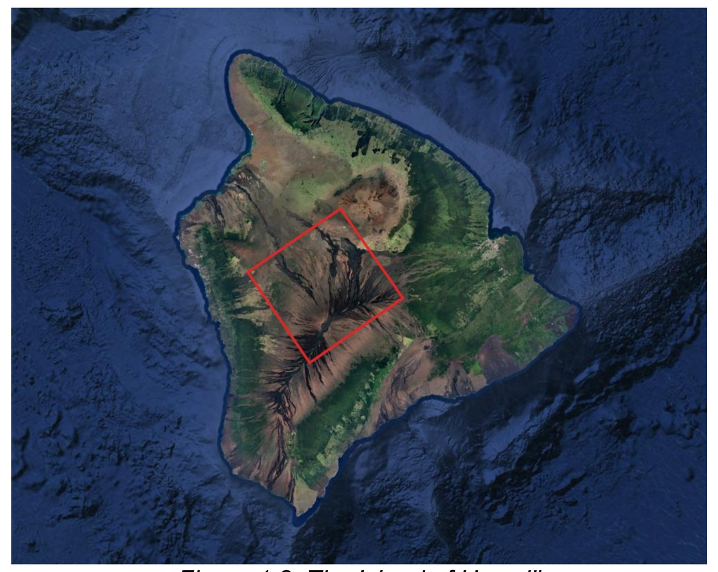

Figure 1.2: The Island of Hawai'i

STUDY AREA

Mauna Loa, located on The Island of Hawai'i (also known as "The Big Island"), is the largest active volcano on Earth in both mass and volume. Its broad shield structure and significant elevation make it a defining feature of the island's landscape. This study focuses on the summit region and the Northeast Rift Zone, where recent eruptive activity began and where the primary lava flow traveled roughly 16 kilometers downslope.

LOCATION AND PROJECT BACKGROUND

Mauna Loa's November 27th 2022 eruption produced large and fast-moving basaltic lava flows visible across the island, marking its first eruption in nearly four decades. The event provided a rare opportunity to analyze the occurrence using satellite imagery and accurately delineate the lava extent. The low-viscosity of basalt allowed the lava to travel long distances, reaching 24 kilometers from the caldera over the span of two weeks. This project aims to assess the primary flow by improving its visualization with standard enhancements and by further highlighting low-visibility features such as the caldera, outer margins and secondary flow paths with a custom enhancement.

DATA SOURCE

The Landsat 9 image (Path 063, Row 046) was downloaded from the USGS website, filtered for captures between November 27 and December 13, 2022, with a maximum cloud cover of 25%. Some nearby clouds were present to the Northeast, Southeast and Southwest. To maximize coverage of Mauna Loa, the image was rotated −60 degrees to fit between clouds, extending the study area to 34 × 36 kilometers. This image is a Level-1 Terrain Corrected (L1TP) product, projected in UTM (Zone 5) with the WGS 84 datum.

HYPERSPECTRAL PLOT FOR BAND SELECTION

The spectral plot selections included two types of volcanic soil and several sections of the lava flow categorized by their proximity to the flow core. Not all plots were used in the analysis; the most relevant ones are listed below:

- **Outer Margin**
- **Inner Margin**
- **Flow Core**
- **Secondary Flow**
- **Caldera**

ID	Name	Color	Show
2	Moderate Volcantic Soil		✓
3	Flow Toe		✓
4	Outer Margin		✓
5	Inner Margin		✓
6	Flow Core		✓
7	Secondary Flow		✓
8	Caldera		✓

Figure 2.1: Hyperspectral Plot Legend

As shown in Figure 2.2, the flow core becomes visible in the red band (4), while the remaining plots exhibit similar spectral signatures up to the near-infrared band (5). Greater distinctions appear in the shortwave infrared bands; SWIR1 (6) and SWIR2 (7). Based on these observations, this study used bands SWIR2, SWIR1, and NIR (bands 7, 6, 5).

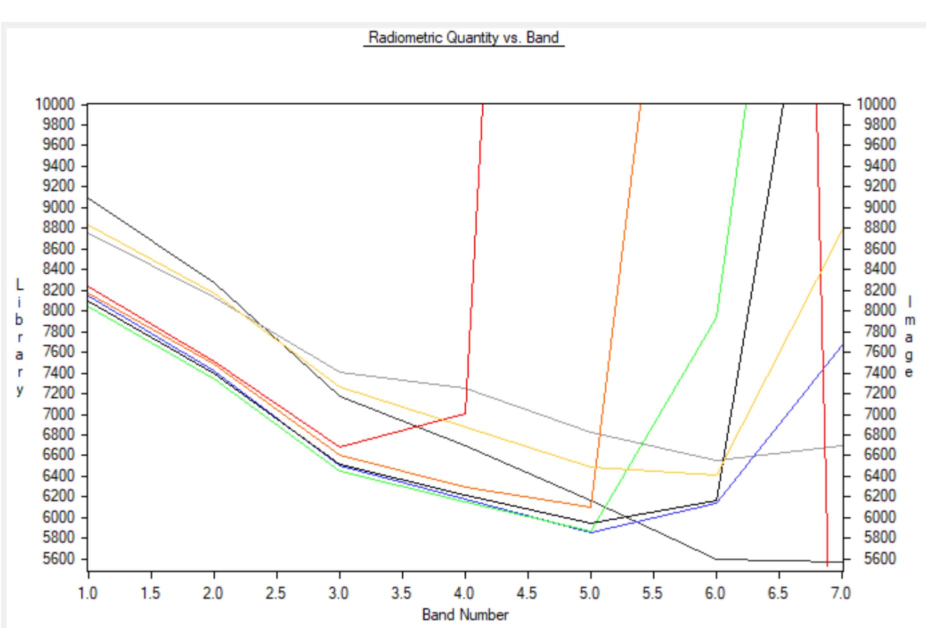

Figure 2.2: Hyperspectral Plot Legend

Figure 4.1: Unenhanced Landsat 9 image

CUSTOM ENHANCEMENT

Two separate *Bitmaps* were created to produce the custom enhancement—one for the inner caldera and another for surrounding soil. Red DN values were increased with the caldera mask to emphasize red- and orange-toned pixels, with similar effects occurring in the secondary flow and outer margin. In the soil mask, green DN values were reduced to shift those areas toward cyan-blue. The enhancement was applied using the following sequence of functions:

A manually drawn Root function was applied to the red channel within the caldera mask, using two standard deviations to capture a slightly broader range of red DN values. The mask was created with high precision to avoid including dark gray pixels, which could be mistaken for soil areas. Manually shaping the curve allowed lower DN pixels to be intentionally brightened, enhancing visibility within the caldera beyond what a standard root function would achieve.

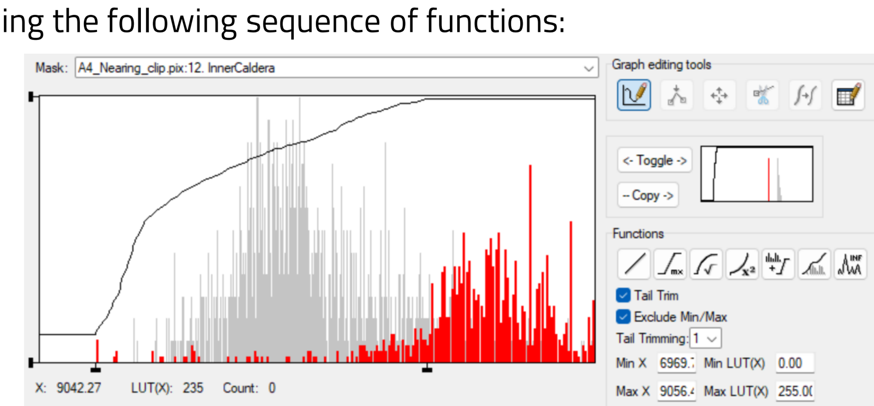

Figure 3.1: Manually drawn Root Function on the InnerCaldera mask

A manually drawn function was applied to the green channel within the soil mask. This suppressed darker green values, and when combines with the enhanced blue channel, shifted the soil toward cyan-blue tones. This adjustment sharply outlined both the main and secondary flows, while also making heat plumes and steam signatures more apparent.

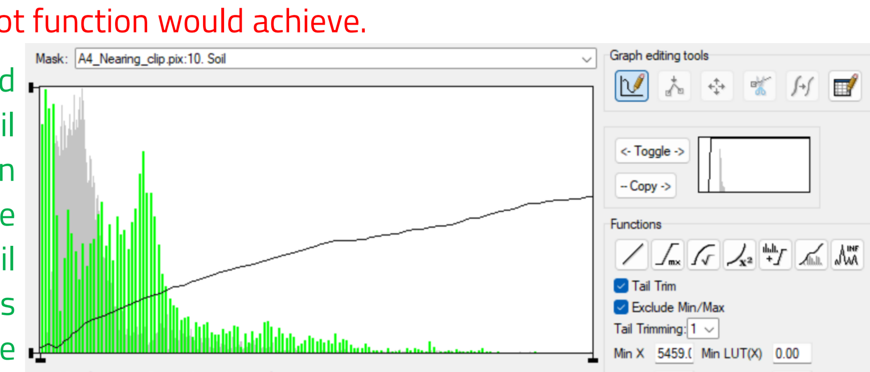

Figure 3.2: Lowering green values with the Soil mask

A Root function was applied to the full blue channel (no mask), boosting the blue DN values across the image. This increase in blue, combined with relative reductions in green, reinforced cyan-blue tones in the soil and enhanced overall contrast.

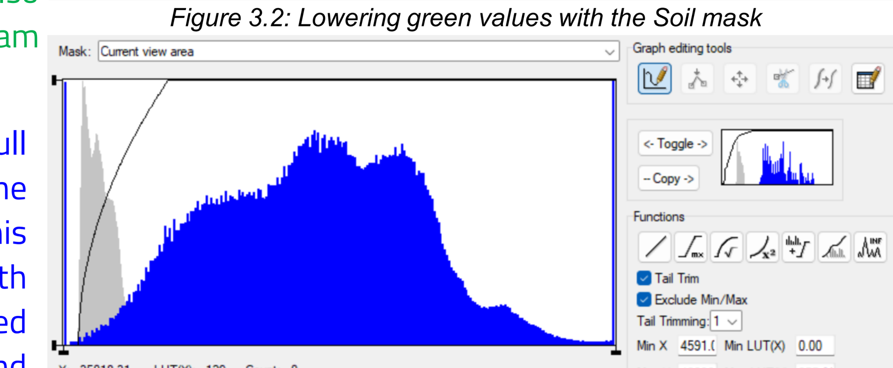

Figure 3.3: Standard Root Function for the blue channel (no mask)

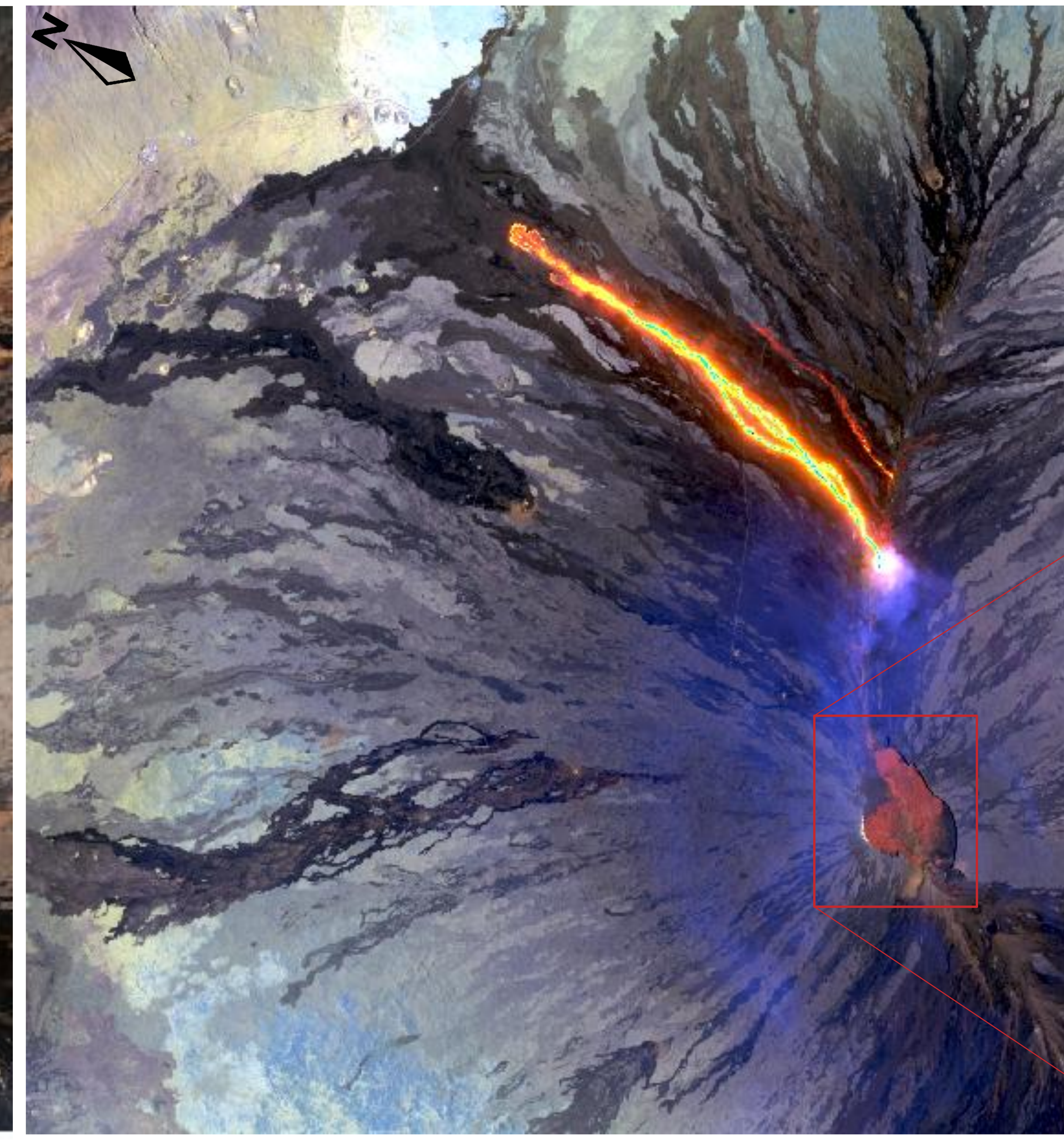

Figure 4.2: Standard enhancement comprised of SWIR2, SWIR1 and NIR composite (7,6,5) and Root Function

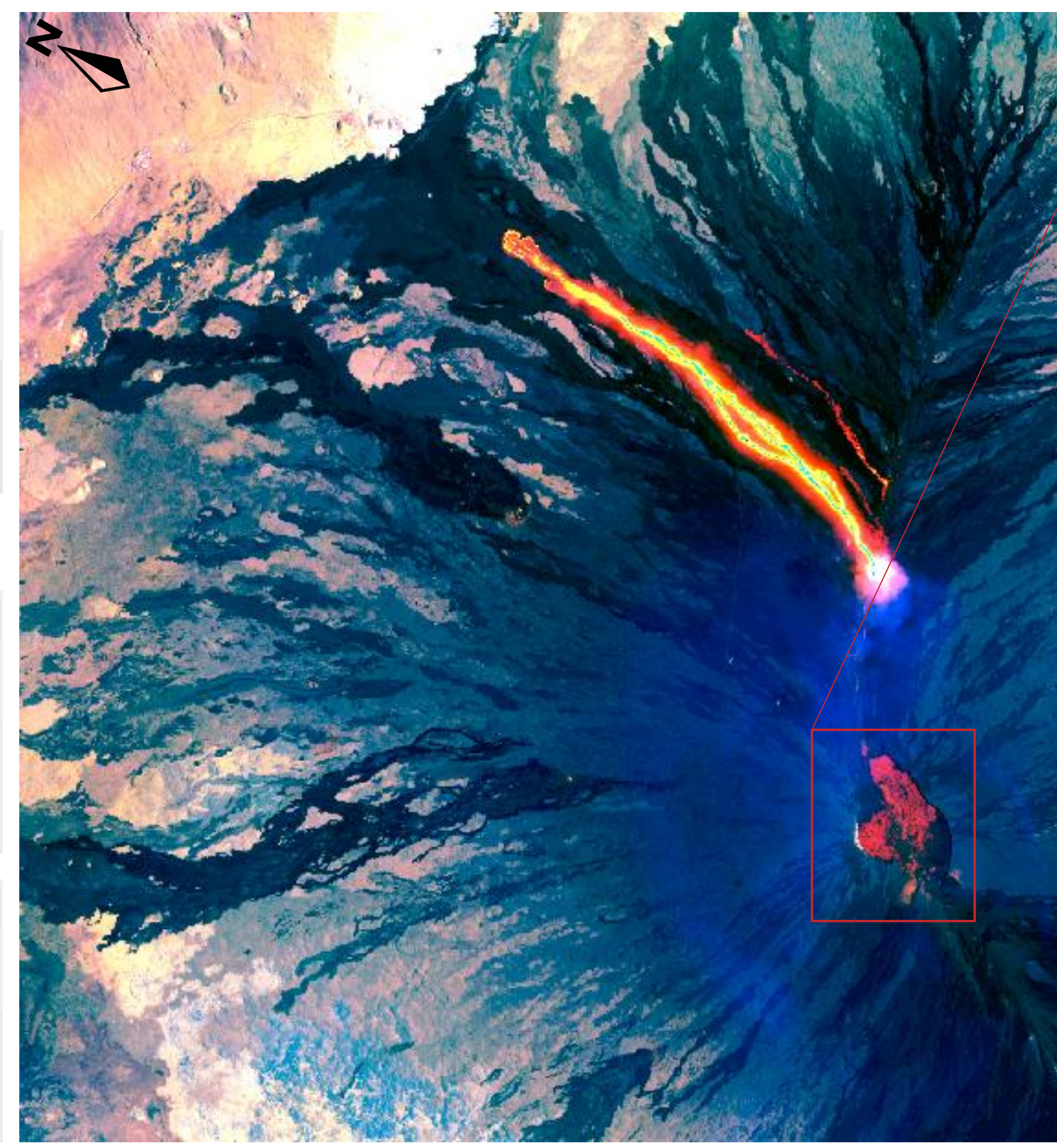

Figure 4.3: Custom enhancement achieved with a Bitmap covering the Inner Calera to increase red values

STANDARD ENHANCEMENT

The SWIR2, SWIR1, and NIR bands were selected for their effectiveness in visualizing active lava flows. The SWIR bands capture thermal energy from molten and recently cooled lava, providing strong contrast to distinguish lava from surrounding terrain, while also penetrating volcanic haze to preserve surface details. The NIR band reduces smoke effects and improves contrast between lava, cooled margins, and surrounding soils. A Root Function was applied to enhance lower DN values, particularly brightening the caldera and thick volcanic soil, whose previously dark DN values were expanded across the histogram, producing a clearer and more detailed representation of these features. This combination of bands and enhancement allows for better visualization of the study area.

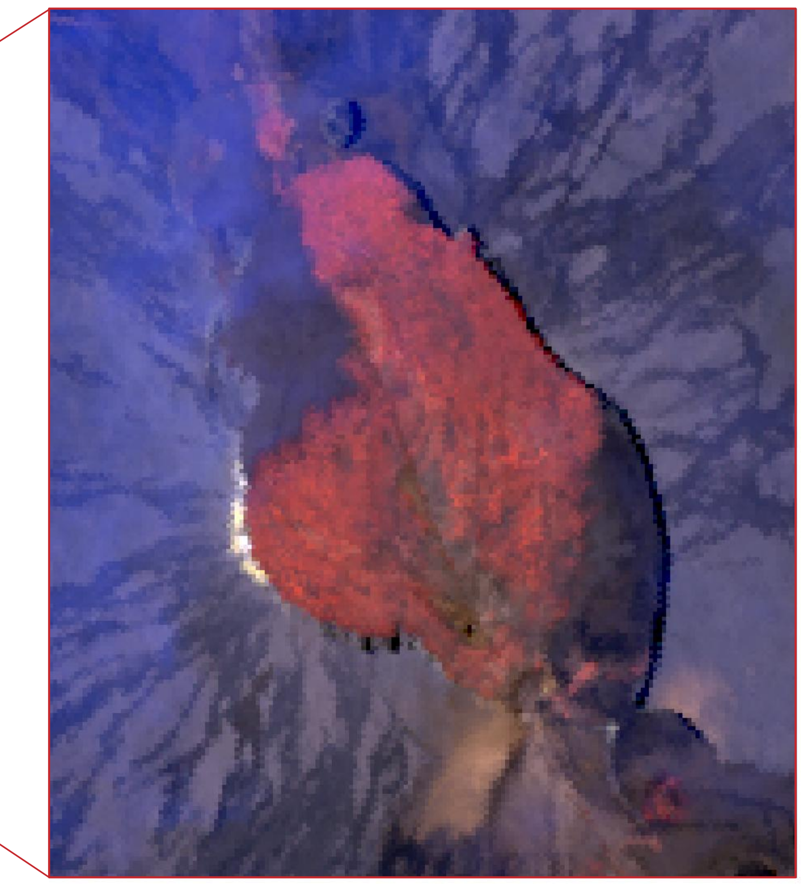

Figure 5.1: Caldera close-up; standard enhancement

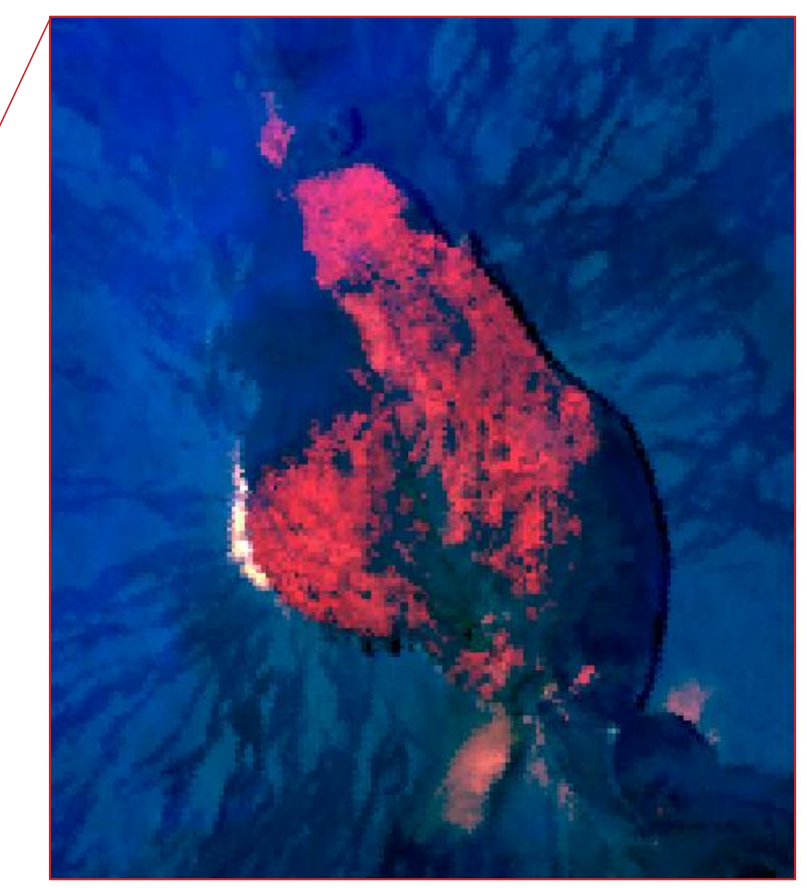

Figure 5.2: Caldera close-up; custom enhancement

CONCLUSION

The final image exhibits a complementary-style color scheme, with reduced greens remaining in the soil, brightened red values in the lava, and cyan-blue tone in the immediate neighbouring landscape. This enhances the distinction between red-orange lava and cooler-colored soil, demonstrating how controlled color manipulation can more clearly separate contrasting terrain across the study area.