Electronic Supplement 9

Fixed threshold algorithms used for volcano hot spot detection

In Chapter 5, MODVOLC is given as an example of a fixed threshold algorithm applied to the detection of volcanic hot spots. However, at least three other fixed threshold algorithms have been applied to volcano thermal anomaly detection in thermal infrared satellite data. These are detailed here.

Harris *et al*. (2002)

Harris *et al*. (2002) presented a probabilistic fixed threshold algorithm. It applied four tests to an image with the aim of assigning a percent probability to each pixel for the likelihood that it contained a hot spot. Designed to run with GOES data containing volcanic hot spots, the tests were as follows:

Test 1 *Brightness (cloud and reflection) test*
The pixel reflection in the VIS (V) was compared to a reflection threshold (V_{thresh}) to determine the probability that a pixel was cloud covered. Bright pixels (i.e., pixels for which $V > V_{thresh}$) were given a negative weighting depending on the magnitude of the difference between V and V_{thresh}. Dark pixels (i.e., pixels for which $V < V_{thresh}$) were given a positive weighting depending on the magnitude of the difference between V and V_{thresh}.

Test 2 *Thermal difference test*
The MIR radiance corrected for reflection (R_{MIR}) was compared with the mean MIR radiance for a 25 × 25 pixel area centered on the target pixel (R_{mean}). If R_{MIR} was greater than R_{mean}, then the pixel was given positive weighting dependent on the magnitude of the difference between R_{MIR} and R_{mean}. Pixels for which R_{MIR} was less than R_{mean} were given negative weightings.

Test 3 *Thermal anomaly test*
The MIR radiance (corrected for reflection) minus the TIR radiance (R_{TIR}, so that $\Delta R = R_{MIR} - R_{TIR}$) was compared with a ΔR threshold (ΔR_{thresh}) which corresponded to a ΔT equivalent of 10 °C. If ΔR was greater than ΔR_{thresh}, then the pixel

was given positive weighting dependent on the magnitude of the difference between ΔR and ΔR_{thresh}. Pixels for which ΔR was less than ΔR_{thresh} were given negative weightings.

Test 4 *Cold (cloud) test*

The TIR radiance (R_{TIR}) was compared with a TIR radiance threshold (R_{thresh}), equivalent to a pixel brightness temperature of –23 °C. If R_{TIR} was greater than R_{thresh}, then the pixel was given a positive weighting dependent on the magnitude of the difference between R_{TIR} and R_{thresh}. Pixels for which R_{TIR} was less than R_{thresh} were given negative weightings.

For each case, the test results were scaled between 0 and 1, where negative values are mapped to the range 0.0 to 0.5 (i.e., 0–50 % probability) and positive values are mapped to the range 0.51 to 1.0 (i.e., 51–100 % probability). This gave four probability scores (one for each test) which were multiplied together to give an overall probability that the pixel contained a hot spot. Pixels exceeding a threshold probability were flagged 'hot' and, if falling within a region of interest centered on a potentially active area, used to trip an automated email notice linking the user to the image from which the notice was generated.

Kaneko *et al.* (2002)

Designed to run on direct-reception AVHRR data (received at a ground station in Tokyo) for Japanese volcanoes, the algorithm of Kaneko *et al.* (2002) executed four steps:

Step 1: Extract a 100 × 100 pixel sub-image centered on the target volcano.
Step 2: Flag any pixel within the mask with a TIR brightness temperature less than –13.5 ° C as cloud covered.
Step 3: Select all pixels with $\Delta T < 1$ °C, and calculate the mean (M) and standard deviation (σ) for these pixels.
Step 4: Flag any pixel with a $\Delta T > M + 3\sigma$ as thermally anomalous.

Therefore the algorithm used a fixed threshold taken from each image to test a pixel for the presence of a hot spot. It thus applied a case-specific fixed threshold.

Webley *et al.* (2008)

Like the algorithm of Kaneko *et al.* (2002), the detection algorithm of Webley *et al.* (2008) used mean and standard deviations in ΔT (ΔT_{mean} and $\sigma_{\Delta T}$) for AVHRR sub-images centered on the volcano of interest to define an image-specific ΔT fixed threshold that assigned a pixel anomalous status if:

$$\Delta T \text{ for the current pixel } > \Delta T_{mean} \text{ for the subimage } + 2\,\sigma_{\Delta T}$$

ΔT_{mean} and $\sigma_{\Delta T}$ being the mean and standard deviation of ΔT defined for the sub-image.

References

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