Interpreting time series of radiance from volcanic eruptions

Talfan Barnie*, Clive Oppenheimer
Department of Geography, Cambridge University, UK
*tdb29@cam.ac.uk
1. Location

Eruption

Nabro 2011
Zubair group 2012

Erota Ale 2010

Gab’ho 2005 (Ayelew et al, 2007)
Manda Hararo 2007
Manda Hararo 2009
(Ferguson et al, 2010)

Manda Hararo 2007
(Marchese et al, 2009)

Alu –DalaFilla
2008 (Pagli et al, in review)
2. SEVIRI instrument

In geostationary orbit—each pixel images the same area with the same look angle in successive images.

Images acquired in 12 bands every 15 minutes, with ~3km pixel spacing at nadir.

Afar / Red sea region


R: 1.6 um, G: 0.8 um, B: 0.6 um
3. The large fissure eruptions

Days

Radiance at 1.6 um

Dalla Filla
November 2008

Manda Hararo
June 2009

Manda Hararo
August 2007

Manda Hararo
May 2010
3. The large fissure eruptions

Dalla Filla
November 2008

Manda Hararo
August 2007

Manda Hararo
June 2009

Manda Hararo
May 2010

Wadge, 1981

Fig. 1. Variation of effusion rate with time for a hypothetical basaltic eruption. The eruption rate, calculated by dividing the total volume of material by the duration of the eruption, is also shown.
4. Jebel al Tair
4. Jebel al Tair
5. Ertu Ale overflow

R: 1.6 um, G: 0.8 um, B: 0.6 um
5. Erta Ale overflow

Top graph:
Red curve: radiance from Erta Ale pixel
Blue curve: radiance from background pixel
Yellow curve: difference (excess thermal radiation from Erta Ale)
Grey tint shows cloud contamination (ignore these parts)
Red tint shows presence of thermal anomaly

Bottom graph:
Earthquakes in region from EMSC plotted as radial distance from Erta Ale against time, color indicates depth, size indicates magnitude.

1st thermal anomaly period
2nd thermal anomaly period
Djibouti swarm
5. Erta Ale overflow
Red series – Erta Ale pixel
Blue series – background pixel (cold basalts nearby)
Green series – difference (thermal anomaly)
Observations spaced every 15 minutes

Lava lake is in view shadow

Julian days
Red series – Erta Ale pixel
Blue series – background pixel (cold basalts nearby)
Green series – difference (thermal anomaly)
Observations spaced every 15 minutes

Overflow onto pit floor is visible

Julian days
Red series – Erta Ale pixel
Blue series – background pixel (cold basalts nearby)
Green series – difference (thermal anomaly)
Observations spaced every 15 minutes

Overflows raise pit floor as lake level rises
Lots of overflows, superimposed on background lava activity

Some overflows, background lava activity continues

No overflows, but background lava lake activity continues

Thermal signal of lake activity fades away. Looks like lake level has sunk below SEVIRI line of sight, as MODIS, which gets a better view angle, is still registering thermal anomalies.
Lots of overflows

Some overflows, superimposed on background lava lake activity

No overflows, but background lava lake activity continues

Lava lake comes in to view

Thermal signal of lake activity fades away. Looks like lake level has sunk below SEVIRI line of sight, as MODIS, which gets a better view angle, is still registering thermal anomalies.
Lots of overflows

Some overflows, superimposed on background lava lake activity

No overflows, but background lava lake activity continues

Thermal signal of lake activity fades away. Looks like lake level has sunk below SEVIRI line of sight, as MODIS, which gets a better view angle, is still registering thermal anomalies.
Lots of overflows. Some overflows, superimposed on background lava lake activity. No overflows, but background lava lake activity continues. Thermal signal of lake activity fades away. Looks like lake level has sunk below SEVIRI line of sight, as MODIS, which gets a better view angle, is still registering thermal anomalies.
Lots of overflows

Some overflows, superimposed on background lava lake activity

No overflows, but background lava lake activity continues

Thermal signal of lake activity fades away. Looks like lake level has sunk below SEVIRI line of sight, as MODIS, which gets a better view angle, is still registering thermal anomalies.
Lots of overflows, superimposed on background lava lake activity

Some overflows, background lava lake activity continues

No overflows, but background lava lake activity continues

Thermal signal of lake activity fades away. Looks like lake level has sunk below SEVIRI line of sight, as MODIS, which gets a better view angle, is still registering thermal anomalies.
5. Erta Ale overflow

Sequence of events appears to be as follows:

1) A period of lake level rise
2) Hiatus in lake rise or lake fall, preceding;
3) Seismic swarm in Gulf of Aden
4) Second period of lake level rise
5) Period of stable high lake level
6) Fall in lake level

```
<table>
<thead>
<tr>
<th>Time</th>
<th>Lake Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st anomaly</td>
<td>GoA event</td>
</tr>
<tr>
<td>2nd anomaly</td>
<td></td>
</tr>
</tbody>
</table>

- 1st anomaly
- GoA event
- 2nd anomaly
```
Bands at 1.6, 3.9 and 10.8/12.0 um facilitate detection of eruptive activity at a range of different scales, from ~30m diameter lava lake to km long basaltic fissures – one band will be free from saturation

High repeat rate captures short term variations in radiance from the waxing and waning of large fissure eruptions to individual hour long lava lake overflows, and allows them to be correlated with seismic events and terrestrial observations
Acknowledgments:

Ethiopian Geophysical Observatory
Addis Ababa University
Ethiopian air force