Workshop on Satellite-Data-Driven Detection, Tracking and Modeling of Volcanic Hot Spots

FINAL REPORT

5 September 2013

ASMVolc

Advanced Satellite Modelling of Volcanic Hot Spots

1) Summary

Between the 28 and 30 May, 2013, a workshop on Advanced Satellite Modelling of Volcanic Hot Spots was held at the Maison International of the Université Blaise Pascal in Clermont-Ferrand. The title of the workshop was "*Workshop on Satellite-Data-Driven Detection, Tracking and Modelling of Volcanic Hot Spots*", and the final program is given in **Annex 4a**.

The workshop aim was, within the theme of satellite detection and modelling of active lavas, to:

1. Present, review and collate all capabilities in the remote sensing and modelling communities;

2. Through round table discussion, identify key issues that currently need to be addressed;

3. Identify standards and formats, and a platform, to allow products to be handed between each group for comparison, error testing, full probabilistic appraisals and ingestion into crisis response models;

4. Agree on a common data set and carry out a test during which data and products are fed through the chain from remote sensor through modeller to operational responder.

5. To formalise a working group with a common interest in *satellite-data-driven detection, tracking and modelling of volcanic hot spots.*

The working group comprised 48 delegates from France (including Réunion), Italy, UK, Germany, Switzerland, Portugal (Azores) and Iceland. The group, as listed in **Annex 4b**, also included seven delegates from the USA and one from Japan. Thematically, the group comprised four fields:

- Hot Spot Detection and Deliverables (nine delegates);
- Towards Operational Tracking and Dissemination Systems (seven delegates);
- Lava Flow Modelling and Deliverables (seven delegates);
- Crisis Management: Requirements (seven delegates).

Added to this there were the three conveners:

- Andrew Harris (LMV, Université Blaise Pascal);
- Philippe Labazuy (OPGC, Université Blaise Pascal);
- Tom De Groeve (IPSC, European Commission Joint Research Centre).

Plus four masters student representatives from Laboratoire Magmas et Volcans (LMV), and nine LMV staff members.

The group were supportive of the following actions:

1. The establishment of a formal working group, or at the very least a series of follow up meetings, and establishment of an email distribution list to allow up-dates, information sharing and discussion of logistical, scientific and operational issues.

2. The identification of common data sets on which members of the group can run their various algorithms and models to produce a library for demonstration of product types available and comparison.

3. Proposal of a book to IAVCEI special publications in volcanology series collating:
    i. the algorithms, models and response experiences presented at the meeting,
    ii. the results of the group exercise (i.e., the library of item 2), and
    iii. the initial findings and recommendations of the working group.

Currently support for a follow up meeting, likely to be held in Catania during 2014, is being discussed.

2) Description of the scientific content and discussions at the event

The workshop began with an introduction by conveners defining the main objectives of the meeting. These were listed as being to:

(1) Present, review and collate all current capabilities;

(2) Identify key issues that currently need to be addressed;

(3) Agree on standards and formats;

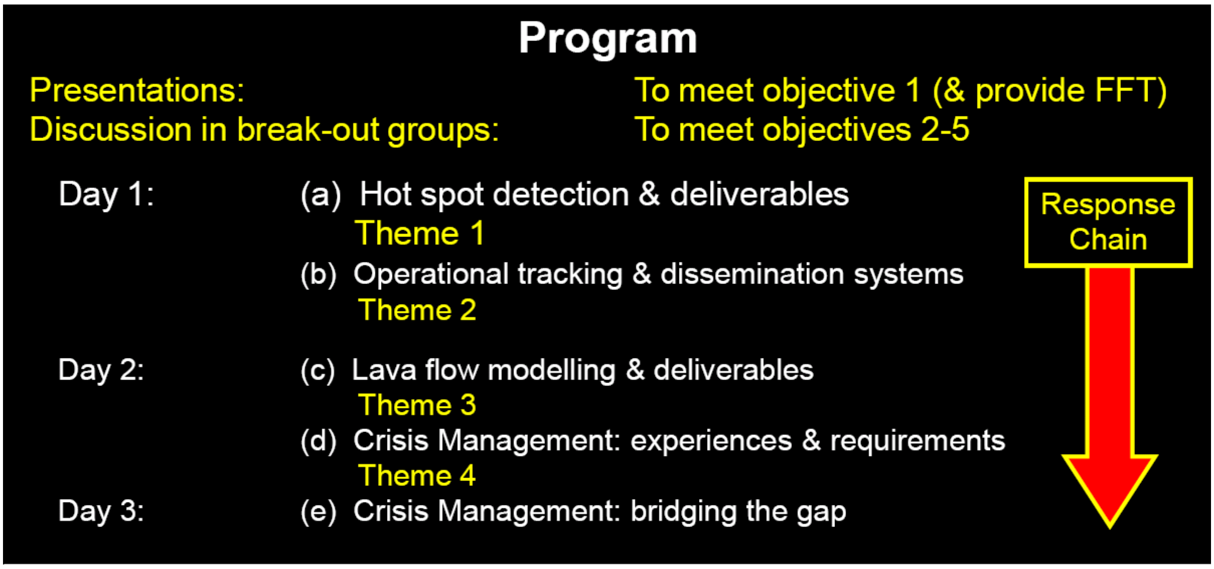
(4) Set up a data sharing hub:
Items 3 and 4 together allow products to be handed between each group and ingestion into crisis response models;

(5) Agree on a common data set and carry out a test:
During the test data and products will be fed through the chain from remote sensor through modeller to operational responder;

(6) To formalise a working group.

The program proceeded as follows, with themes building progressively through the response chain from hot spot detection and tracking (Day 1) through modeling (Day 2) to crisis response (Days 2 and 3). The full program detail is given in **Annex 4a**.

Overview of Workshop Program



FFT = Food for Thought

Day 1 involved presentations on algorithms designed to detect volcanic hot spots and deliver "source term" parameters to the modelers. This first day was split into three parts. Part 1 involved presentation of four well-established and mature algorithms: OKMOK, MODVOLC, RST-VOLC and AVHotRR. Part 2 involved a review of new, cutting-edge approaches, and Part 3 was a review of operational (satellite-data-based) volcanic hot spot tracking systems.

Day 2 was split into two parts. The first part reviewed operational models used for simulations of lava flow emplacement, and the second considered issues regarding use of remote sensing and modelling during eruptive crises, with case studies from Hawaii, Italy, Réunion, Iceland and the Azores. Day 3 involved two presentations from the Research Center of the European Commission and British Geological Survey regarding operational needs for effective and politically-correct response.

At the end of each of days 1 and 2, each theme group would gather for 1-2 hours of discussion, during which issues relating to the theme(s) addressed during the day would be discussed. Discussion points tabled for consideration during each break-out are listed in the program as attached in **Annex 4a**.

The composition of each discussion group was as follows (all participants are listed in **Annex 4b**):

(1) Hot Spot Detection and Deliverables (Reporter: Dehn)

1.	Talfan Barnie	Cambridge University, UK
2.	Diego Coppola	University of Turin, Italy
3.	Jonathan Dehn	AVO, University of Alaska Fairbanks
4.	Fanny Garel	Imperial College London, UK
5.	Yannick Guéhenneux	LMV, Université Blaise Pascal, France
6.	Valerio Lombardo	INGV – Rome, Italy
7.	Nicola Pergola	University of Basilicata, Italy
8.	Robert Wright	University of Hawaii, USA
9.	Klemen Zaksek	University of Hamburg, Germany

(2) Towards Operational Tracking and Dissemination Systems (Reporter: Carn)

1.	Simon Carn	Michigan Technological University, USA
2.	Thibault Catry	Station SEAS-OI, Reunion
3.	Ashley Davies	Jet Propulsion Laboratory (USA)
4.	Gaetana Ganci	INGV-Catania, Italy
5.	Mathieu Gouhier	OPGC, Université Blaise Pascal, France
6.	Andrew Harris	LMV, Université Blaise Pascal, France
7.	Matthew Patrick	USGS - Hawaiian Volcano Observatory, USA

(3) Lava Flow Modelling and Deliverables (Reporter: del Negro)

1.	Noé Bernabeu	University of Grenoble, France
2.	Benoît Cordonnier	ETH Zürich, Switzerland
3.	Eisuke Fujita	Nat. Res. Inst. Earth Sci. & Disas. Prev., Japan
4.	Karim Kelfoun	LMV, Université Blaise Pascal, France
5.	Ciro del Negro	INGV-Catania, Italy
6.	Simone Tarquini	INGV-Pisa, Italy

(4) Crisis Management: Requirements (Reporter: Guðmundsson)

1.	Sonia Calvari	INGV-Catania, Italy
2.	Tom de Groeve	JRC-Ispra, Italy (EC)
3.	Anthony Finizola	University of Reunion, Reunion
4.	Magnús Guðmundsson	University of Iceland, Iceland
5.	James Kauahikaua	USGS - Hawaiian Volcano Observatory, USA
6.	Giovanni Macedonio	INGV – Osservatorio Vesuviano, Italy
7.	José Pacheco	University of the Azores, Portugal
8.	Kay Smith	British Geological Survey, UK

Each group collected minutes for their discussions, which were presented in a feed-back session on the final morning of the workshop. These reports are given **Annex 4c.**

3) Assessment of the results and impact of the event on the future direction of the field

The group agreed to support and pursue five initiatives:

Initiative 1: Formalization of a working group
The group agreed to set up a formal working group entitled "*Advanced Satellite Modeling of Volcanic Hot Spots*" (ASMVolc). An email distribution list has already been set up to allow communication between group members, and liaison over group-wide projects and initiatives (**Annex 4d**). A web-site will be also set up, hosted at OPGC and linked to the MeMoVolc and ESF web-sites, to disseminate information regarding ASMVolc meetings and projects, both within the group, as well as to the wider community and public. Initially, we will upload details regarding the May 2013 workshop (program, abstracts, PDF of presentations, reports, press, etc.).

Initiative 2: Working group book
There was unanimous support for a book that would present the state-of-the-art for satellite-based volcanic hot spot detection, lava flow modeling and simulations, as well as their use for operational monitoring and crisis response. Chapters will comprise write-ups of the presentations given by each delegate, followed by a write up of the reports that review outstanding issues and priorities identified by the working group (a working version of which is attached in **Annex 4c**). A proposal is in preparation for submission to IAVCEI Special Publications, from whom such a proposal has already been encouraged.

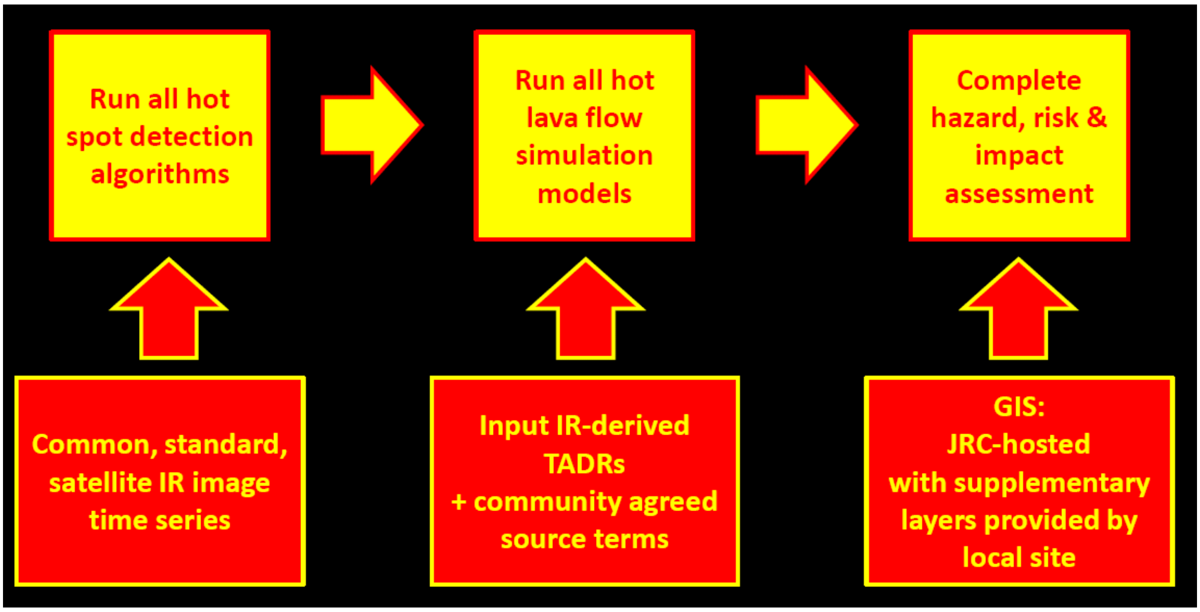
Initiative 3: Complete a hot spot detection algorithm test on a common data set
As part of this initiative, two data sets were mooted for testing of all algorithm and data treatment routines presented by the remote sensing sub-group. Two data sets are good candidates: (i) a set of SEVERI data for a short fountaining event on Etna during 12-13 January 2011, and (ii) a set of MODIS data for a long effusive event with variable effusion rates on Etna during 2008-2009. Both data sets contain many cloud-free (and cloud-contaminated) images, and also have good ground truth data against which algorithm output can be compared. Algorithm output will be compared in terms of number of images, and number/location of pixels on each image, for which hot spots were detected, as well as output parameters such as spectral radiance, lava flow area, heat flux, time-averaged discharge rate and erupted lava volume, as well as errors on these.

Initiative 4: Apply all lava flow simulation models to a common data set
We plan to run all lava flow simulation models over a common DEM and compare output. Two eruptions in the Chain des Puys (France) have been proposed as test cases: those of the Grave Noire (high effusion rate, fountain-fed event) and the Petit Puy du Dome (longer-duration event). Both lava flows are well mapped, and appropriate source term data can be supplied. Both flows also underlie the current urban area of Clermont Ferrand. Results of these tests and comparisons should allow us to address several of the issues raised by the sub-groups, as noted in the working group report (Annex 4c).

Initiative 5: Test the information chain
The results of the hot spot detection algorithms will be fed into each lava flow model. The 12-13 January data will be used for Grave Noire, and Etna 2008-2009 for Petit Puy du Dome. Simulations of inundated area, and the development with time will then be fed into a GIS hosted at the Joint Research Center hosted to assess impacts on Clermont Ferrand and its hinterland.

While the ASMVolc web-site may be a good hub for data pick-up and sharing, the book maybe a good place to present results of these tests and exercises.

Working Group "Information Chain"



Yellow boxes = actions

Red boxes = required input / resource

Arrows = direction of information flow

Follow up

There is general support for a follow up meeting, where results from these initiatives can be presented, and further initiatives and projects discussed. Delegates from the Instituto Nazionale di Geofisica e Vulcanologia in Catania have expressed interest in hosting the next workshop on Etna. This would be an excellent site, as it may allow an on-site, real-time exercise simultaneous with ground-truthing.

Annex 4a: Programme of the meeting

Day I (Tuesday 28 May): Hot Spot Detection, Tracking and Dissemination

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08:30 Welcome, Review of Workshop Objectives and Proposal of Initiatives

Part 1 (Hot Spot Detection and Making the Measurement):

09:00 Jonathan Dehn (AVO – University of Alaska Fairbanks)
20 years of thermal satellite monitoring at the Alaska Volcano Observatory

09:20 Robert Wright (HIGP – University of Hawaii)
MODVOLC: 13 years of autonomous observations of global volcanism

09:40 Nicola Pergola (Istituto Di Metodologie per l'Analisi Ambientale – CNR)
RST-VOLC, an original algorithm for automatic detection and near real-time monitoring of volcanic hotspots from space: main achievements, issues and future perspectives

10:00 Valerio Lombardo (INGV - Rome)
AVHotRR: near real time routine for volcano monitoring using IR satellite data

10:20 Coffee Break

10:40 Diego Coppola (University of Turin)
Hot-spot detection at Stromboli volcano using MODIS: Results from the MIROVA system

11:00 Yannick Guéhenneux (Université Blaise Pascal)
NTI-MSG an adaptation of the Normalized Thermal Index algorithm for the HOTVOLC observing system

11:20 Talfan Barnie (University of Cambridge)
Extracting thermal anomalies from geostationary satellite images using Independent Component Analysis, and modelling their temporal evolution with physically based and empirical kernel convolution models

11:40 Fanny Garel (Imperial College London & Cardiff University)
Interpreting the surface thermal signal of lava flows in terms of dynamics: insights from analogue experiments

12:00 Klemen Zaksek (University of Hamburg)
Constraining the uncertainties of monitoring effusive volcanic activity using Kalman filter

12:20 Lunch

Part 2 (Towards Operational Tracking and Dissemination Systems):

13:20 Gaetana Ganci (INGV - Catania)
HOTSAT: satellite thermal monitoring of volcanic activity

13:40 Mathieu Gouhier (Université Blaise Pascal)
HOTVOLC: Real-time satellite-data-driven system designed for operational monitoring of volcanic eruptions

14:00 Michael Ramsey (University of Pittsburgh)
Synergistic use of satellite hot-spot detection and science: A decadal perspective using ASTER

14:20 Matthew Patrick (USGS - Hawaiian Volcano Observatory)
Operational satellite thermal monitoring of volcanic activity in Hawaii

14:40 Ashley Davies (Jet Propulsion Laboratory – California Institute of Technology)
The NASA Volcano Sensor Web, Advanced Autonomy, and the Remote Sensing of Volcanic Eruptions

15:00 Tea Break

15:20 Simon Carn (Michigan Technological University)
VHub perspective and synergistic use of spaceborne thermal IR and SO_2 measurements

Part 3 (Group discussion for Themes 1 and 2):

15:40 Group breakouts

Key issues:

- What can be provided by the thermal remote sensing community?
- What do we need that is not currently provided?
- What does the modelling and response community need that the thermal remote sensing community can potentially provide?

- How fast can products be delivered following detection?
- Is it fast enough?
- Can we increase the speed of turn around, and if so, how?
- How can we best disseminate the data?

- What are the precision of the measurements, and their reliability?
- How can we improve the measurements?
- Is it possible to monitor at a high temporal frequency the concurrent advance of lava flow and its surface thermal signal?
- What deliverables do we need to provide, and in what format?

- What extra capabilities do we need?
- How can we best integrate the various capabilities that we already have?

17:00 Report Back

Evening: Dinner at Brasserie du Jardin (20:00)

Day II (29 May): Lava Flow Modelling and Operational Response

08:50 Introduction to Day 2

Part 1 (Lava Flow Modelling):

09:00 Ciro Del Negro (INGV - Catania)
Numerical simulations of lava flows using the MAGFLOW physics-based model

09:20 Eisuke Fujita (National Research Institute for Earth science and Disaster prevention)
LavaSIM: its physical base & applicability

09:40 Karim Kelfoun (Université Blaise Pascal)
VolcFlow capabilities and perspectives of development for the simulation of lava flows

10:00 Giovanni Macedonio (INGV - Osservatorio Vesuviano)
Numerical simulation of lava flows based on depth-averaged equations

10:20 Coffee Break

11:40 Simone Tarquini (INGV - Pisa)
Simulating the area covered by lava flows by using the DOWNFLOW code

11:00 Andrew Harris (Université Blaise Pascal)
FLOWGO: An updated version and results of calibration tests on Hawaiian lavas

11:20 Mary Grace Bato (Université Blaise Pascal)
InSAR Volcano Monitoring in Piton de la Fournaise: What have we been doing over the last 3 years?

12:00 Lunch

Part 2 (Application in crisis-mode: experiences and requirements):

13:00 Jim Kauahikaua (USGS - Hawaiian Volcano Observatory)
The Hawaiian Volcano Observatory's approach to forecasting lava flow hazards

13:20 Sonia Calvari (INGV - Catania)
Satellite-derived effusion rates during volcanic crises: the example of Etna

13:40 Magnus Gudmundsson (University of Iceland)
Thermal signals from eruptions in ice-covered volcanoes, experience from Iceland

14:00 Thibault Catry (SEAS-OI, La Reunion)
The SEAS-OI Satellite platform: monitoring and risk assessment on active volcanoes in the Indian ocean using RADAR imagery

14:20 José M. Pacheco (Azores University, Portugal)
Volcano monitoring and risk assessment at the Azores archipelago

14:40 Tea Break

15:00 Benoit Cordonnier (ETH Zurich / UC Berkeley): Benchmarking volcanic mass flow models

Part 3 (Group discussion for Themes 3 and 4):

15:20 Group breakouts

Key issues:

- What can be provided by the modelling community?
- What are the key source terms, input data and relations the models need?
- What can the thermal remote sensing community provide?
- What are the key DEM problems (spatial resolution, coverage, up-dating … …)?
- What are the precision on the model runs, and their reliability and uniqueness?
- How can we improve the models, and what extra capabilities do we need?
- What deliverables do we need to provide, in what format and how can we best disseminate the data?
- How can we best integrate what we already have both across the modelling community, and between the modelling and remote sensing communities?
- Can we design a community-wide (open access) fully-integrated rapid response system?
- Can the modeling community provide thermal outputs comparable to thermal remote-sensing deliverables?
- Can model runs be adjusted/updated using thermal remote-sensing data?

17:00 Report Back

Evening: Cocktails and UNESCO project presentation at:
Salle d'Assemblée du Conseil Géneral du Puy de Dôme

Dinner at Crêperie Le 1513 (20:00)

Day III (30 May): Working Group: Bridging the Gap

08:30 Introduction to Day 3

08:40 Tom de Groeve (Research Center of the European Commission)
Towards a global humanitarian volcano impact alert model integrated in a multi-hazard system

09:00 Kay Smith (British Geological Survey)
Towards a global humanitarian volcano impact alert model integrated in a multi-hazard system

09:20 Group Reports

- What does the operational system need – current status, issues and holes?

10:00 Coffee Break

11:20 Discussion of follow up initiatives

- Identification of validation data sets on which to test the detection algorithms and define standards;
- Identification of a common data set on which to test and compare lava flow simulation models;
- Definitions of test criteria and output standards;
- Collation of global capabilities and generation of a "provider" directory.

- Planning of follow up work, including sharing of validation-test results between detection and modelling groups.
- Proposal for common (IAVCEI- and GDACs-supported) document to implement the results and conclusions reached by the working group:

  Book covering workshop themes and initiatives for Special IAVCEI Publications?

- Proposal for a communal site for communication, dissemination and interaction.
- Proposal for creation of hot spots working group.

12:00 Check out / Transfer

12:30 Tour of La Chaine des Puys

Stop 1: Tour of the lava flows of the Gravenoire and Tiretaine valley

Stop 2: Train to summit of Puy de Dôme, and tour of the summit

Stop 3: Tour of Vulcania (http://www.vulcania.com/), followed by
- Premiere of the film "Volcans Sacrés"
- Dinner at Vulcania

Annex 4b: Full list of speakers and participants

1.	Andrew Harris	LMV, Université Blaise Pascal, France
2.	Philippe Labazuy	OPGC, Université Blaise Pascal, France
3.	Tom De Groeve	European Commission Joint Research Centre, Italy
4.	Talfan Barnie	Cambridge University, UK
5.	Diego Coppola	University of Turin, Italy
6.	Jonathan Dehn	AVO, University of Alaska Fairbanks
7.	Fanny Garel	Imperial College London, UK
8.	Yannick Guéhenneux	LMV, Université Blaise Pascal, France
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11.	Robert Wright	University of Hawaii, USA
12.	Klemen Zaksek	University of Hamburg, Germany
13.	Simon Carn	Michigan Technological University, USA
14.	Thibault Catry	Station SEAS-OI, Reunion
15.	Ashley Davies	Jet Propulsion Laboratory (USA)
16.	Gaetana Ganci	INGV-Catania, Italy
17.	Mathieu Gouhier	OPGC, Université Blaise Pascal, France
18.	Matthew Patrick	USGS - Hawaiian Volcano Observatory, USA
19.	Michael Ramsey	University of Pittsburgh, USA
20.	Noé Bernabeu	University of Grenoble, France
21.	Benoît Cordonnier	ETH Zürich, Switzerland
22.	Eisuke Fujita	Nat. Res. Inst. Earth Sci. & Disas. Prev., Japan
23.	Karim Kelfoun	LMV, Université Blaise Pascal, France
24.	Ciro del Negro	INGV-Catania, Italy
25.	Simone Tarquini	INGV-Pisa, Italy
26.	Sonia Calvari	INGV-Catania, Italy
27.	Anthony Finizola	University of Reunion, Reunion
28.	Magnús Guðmundsson	University of Iceland, Iceland
29.	James Kauahikaua	USGS - Hawaiian Volcano Observatory, USA
30.	Giovanni Macedonio	INGV – Osservatorio Vesuviano, Italy
31.	José Pacheco	University of the Azores, Portugal
32.	Kay Smith	British Geological Survey, UK
33.	Olivier Roche	LMV, Université Blaise Pascal
34.	Jean Battaglia	LMV, Université Blaise Pascal
35.	Mary-Grace Bato	LMV, Université Blaise Pascal, France
36.	Maxime Bombrun (student)	LMV, Université Blaise Pascal, France
37.	Benjamin Latutrie (student)	LMV, Université Blaise Pascal, France
38.	Bénédict Robert (student)	LMV, Université Blaise Pascal, France
39.	Marina Valer (student)	LMV, Université Blaise Pascal, France

Annex 4c: Sub-Group Reports

(Grp. 1) Hot Spot Detection: Conclusions and Recommendations

Satellite-based remote sensing is currently able to provide quite a suite of products. These products, and appropriate product delivery requires:

1. automated detection,
2. product generation in common formats,
3. a move towards adaptive models, rather than use of simple thresholds,
4. open-access data archives loaded with past data, and updated regularly with new data,
5. development of new methods,
6. resolution of daytime/summer issues,
7. quantification of precursors,
8. definition of an acceptable tradeoffs between false alerts and early detection
9. definition of is detection limits (MW vs. GW),
10. an ensemble approach.

Speed of product delivery currently ranges from minutes to hours. Of course, faster is better, but this requires real-time access to a local receiving station. Once the data are in hand, all groups proceeding with web-based dissemination fairly rapidly.

Measurements range widely in accuracy. This led to a call for an ensemble approach. This would involve mixing of different data sets and different models to better constrain activity. That is, the most probably result is that where all models overlap.

In terms of parameter provision, effusion rate is a good and meaningful parameter as a stating point, but would be better if the modelers could constrain the size of the channel, crater, or lava properties to input in two remote sensing conversions, or if these could be derived from simultaneous remote sensing or ancillary data.

Recommendations for, realistic, new directions include better utilization of existing sensors, or existing assets. Some new opportunities are likely in the near future with smaller short-lived sensors, e.g. cubesats.

From the modelers, this theme group needs constraints so that our conversion routines applied to thermal data can provide accurate: lava effusion rates, thermal flux, mass, temperature, area, and volume.

Our biggest concern is up to date DEMs, both for the purposes of lava flow modeling, but also to predict, or help constrain, pixel-mixture models for two component solutions. That is, could the models output provide a theoretical lava flow area and location to put into multiple component pixel mixture models?

New items we could add to our delivery list revolve around including time-average products, to give not just an effusion rate from an image, but a time-averaged discharge rate (averaged over a know and stated period of time), mean output rate and eruption rate. This would allow better characterization of on-going, and past, effusive eruptions.

Using data from different sensors can help better constrain areas and temperatures (SEVIRI and MODIS and ASTER etc.); and interdisciplinary data fusion will aid in our tracking and modeling capabilities. There is a call to create graphics compatible with those from other groups, like seismology and cumulative energy, etc.

Finally, we need to also develop means to determine when an eruption over? This is something we could potentially derive from thermal data in near-real time.

(Grp. 2) Operational Tracking and Dissemination Systems: Conclusions and Recommendations

What can be provided by the thermal remote sensing (TRS) community?

- The basic quantity is emitted spectral radiance received at-sensor. There is relatively low uncertainty on this measurement, and it is comparable between different sensors.
- Other derived products include power (approximation), vent locations, mass flux, effusion rates, etc. However, there is increasing uncertainty propagation, and appropriate calibration, pixel-distortion, atmospheric and emissivity corrections are needed.

What do we need that is not currently provided?

- Error bars on measurements.
- The Kalman filter technique is a good way forward.

What does the modeling and response community need that the TRS community can potentially provide?

- Timeliness.
- Required latency depends on style of activity – delays in product generation of one day may be acceptable for slow moving pahoehoe flow, but for high effusion rate and short (fountain-fed) events (and Mauna Loa) dissemination within minutes-to-hours are needed.
- The type and format of product needed will depend on the end-user (e.g., HVO, civil defense, or public).
- Modeling requirements: several minutes needed for lava flow model runs. These need:
    - to know how many vents + locations, effusion rates for each vent;
    - up-to-date DEM.

How fast can products be delivered following detection?

- Speed of delivery depends on availability of a direct broadcast (DB) station (and DB signal from satellite).
- For events within a DB station mask, product delivery 10-15 minutes after satellite overpass should be possible.
- Outside of a DB station mask, there will likely be several hours delay.
- We also note that most receiving stations are in the northern hemisphere at high latitudes.
- Provision of accurate and checked data (with high spatial resolution and good geolocation) will require a few hours.
- Less accurate data (GOES, SEVIRI) can be provided within minutes, but must be delivery with caution and caveats.
- We need to produce a global map of volcanoes within station masks of DB stations. This will allow us to assess how quickly and accurately vent location and products could be obtained for global volcanoes.

Is it fast enough?

Worst-case scenario: 2002 Nyiragongo eruption
During this eruption rapidly moving, low viscosity lava flows engulfed Goma (DR Congo). Eruptive fissures propagated down slope during the eruption, moving vents closer to the city. Could this eruption have been detected and lava flows forecast in time to evacuate city?

Can we increase the speed on turnaround, and if so, how?

- By installing more direct broadcast (DB) stations and by operating more satellites broadcasting DB data.

- Faster and more reliable internet connections at volcano observatories in developing countries (e.g., DR Congo) are needed for dissemination of data to the most important end-users and stakeholders.

How can we best disseminate the data?

- End-users vary (volcano observatories, civil defense, general public), and we need more dialog between data providers and these end-users to assess needs.
- Volcano observatories use different approaches: HVO only concerned with flow direction (lava shed model) whilst INGV produces detailed lava flow hazard maps based on simulations.
- There are many possible formats and standards for data: shapefiles, text files, JPEGs, KMZ (Google Earth), email alerts, SMS text messages (with web links), smartphone apps, WMS (web mapping service), Open GIS Consortium (OPG) compliance, SensorML … … …

What are the precision of the measurements, and their reliability?

- Geolocation precision is a problem for near real-time data (e.g., MODVOLC), so the most timely data may not provide accurate vent locations, etc.
- There could be significant uncertainty on eruption vent location, and hence lava flow model output.
    - MODVOLC: needs to wait for MOD03 geolocation files (hence 12-20 hours latency).
    - Could activate International Charter to obtain high spatial resolution data (GeoEye, etc.) – but takes 2-3 days to do this.
    - Ground-based observations, seismic data, etc. could provide additional information on vent location at well-monitored volcanoes.

How can we improve the measurements?

We need to trigger high spatial resolution data acquisitions with high temporal resolution sensors.

Is it possible to monitor at a high temporal frequency the concurrent advance of a lava flow and its surface thermal signal?

Cooling rates, surface temperature distributions from satellite data (unrealistic in near-real time)

What deliverables do we need to provide, and in what format?

See above

What extra capabilities do we need?

- More direct broadcast receiving stations (~$100k each) and maintenance.
- Identify regions with poor data acquisition frequency/latency.
- Better internet connections,
- Improved sensors, e.g., HySPIRI – high spectral resolution, high gain settings to avoid saturation. Sensors are actually rarely optimized for volcano measurements.
- How can we best integrate the various capabilities that we already have?
- More workshops.

Primary parameters needed by civil defense at onset of an effusive eruption:

- Which direction will lava flow move?
- How long will the lava flow be (worse-case scenario)?
- How quickly will it attain that length?
- Flow width/thickness of secondary importance, but could be useful e.g., to assess whether lava flow diversion is possible.
- Lava shed model (used by HVO) useful for assessing flow direction.

- Peak effusion rate and vent location critical.
- Empirical relationships between effusion rate and maximum flow length (e.g., Calvari and Pinkerton) useful for worse-case scenarios.

How quickly can this worse-case scenario be revised downward/adjusted as new information becomes available?

- New peak/average effusion rate estimates can be obtained from satellite data.

- Modeling issues:
    1. Temperature – viscosity relationships are poorly defined (for many compositions), and become asymptotic at temperatures of ~600 ºC? Models blow up at this point. INGV lava flow model automatically stops lava flow movement at 600ºC (surface temp?)
    2. Issue of DEM accuracy.
        - What DEM resolution is sufficient?
        - Could models deposit lava on the DEM to 'update' topography in real-time?
        - Stereoscopy using high-spatial resolution visible satellite data for DEM generation.
        - TanDEM-X DEMs expected to be more accurate
    3. Models cannot simulate complex lava flow field evolution – perched lava ponds, levee failure etc.
    4. Need feedback from ground observations.
    5. Data assimilation – lava flow models can be updated with new information (e.g., effusion rates, vent locations) in real time.

(Grp. 3) Lava Flow Modelling: Conclusions and Recommendations

What can be provided by the modeling community?

Several models for lava flow simulations with different characteristics:

a) Deterministic models:

LAVASIM is based on 3dimensional CFD (Fujita)

LAVA2D or SLAG based on depth average equation (Macedonio)

MAGFLOW based on Automata Cellular (Del Negro)

SCIARA based on Automata Cellular (Crisci & Rongo)

FLOWGO 1-D self-adaptive numerical model (Harris)

GPUSPH based on SPH model (Herault and Del Negro)

VOLCFLOW based on the depth average equation (Kelfoun)

b) Probabilistic model

DOWNFLOW based on probabilistic approach (Favalli and Tarquini)

What are the key source terms, input data and relations the models need?

a) Digital Elevation Model (DEM),

b) rheological model (viscosity, yield strength),

c) location of the vent,

d) an estimate of the eruption rate,

e) thermal model (temperature).

What can the thermal remote sensing community provide?

a) power / radiance,

b) temperature distribution,

c) spatio-temporal evolution of the lava flow field,

d) time averaged discharge rates.

What are the key DEM problems (spatial resolution, coverage, up-dating … …)?

a) Updating,

b) spatial resolution,

c) coverage of the eruptive event.

What are the precision on the model runs, and their reliability?

The precision of simulators depends on the resolution of DEM, and maybe also on the resolution of the simulation mesh. Moreover, it is necessary to define some benchmarks for comparing the different models and to evaluate the ability of reproducing the spatio-temporal evolution of lava flow paths. These benchmarks should be based on well-known input parameters, lava emission rate, topography, magma rheology and thermal parameters.

How can we improve the models, and what extra capabilities do we need?

Probably, it is necessary to develop new 3D models to take into account the formation of crust and the consequent formation of tubes and ephemeral vents. Also, analogue experiments in the laboratory are necessary for determining the parameters that control the fluid-solid interaction. Analogue experiments could help constrain the spreading rate of a material with a complex rheology (viscosity, for example, is dependent on composition, temperature, crystals and vesicles). This could help understand how to “approach” the effect of solidification in lava flow simulations with only a yield strength or viscosity parameter. An open question is, should this depend – and if so, how – on temperature, strain rate and velocity? Also, it could help to benchmark the effect of sharp changes in lava emission rate on the spreading of a viscous/Bingham flow.

What deliverables do we need to provide, in what format and how can we best disseminate the data?

The following deliverables can be disseminated via the internet:

a) forecasted lava inundation scenarios,

b) lava flow hazard maps.

How can we best integrate what we already have both across the modeling community, and between the modeling and remote sensing communities?

By sharing of the products of the modeling and remote sensing communities in a common format in an open hub (for example VHUB, WOVODAT)

Can we design a community-wide (open access) fully-integrated rapid response system?

It is necessary to set-up a dedicated project for developing, and using, a Web-GIS platform which the scientific community can access in real-time.

Can the modeling community provide thermal outputs comparable to thermal remote-sensing deliverables?

At the moment, only two models LAVASIM and SPHGPU provide thermal outputs.

Can model runs be adjusted/updated using thermal remote-sensing data?

It should be possible to develop a feedback between models and satellite techniques. For example satellite infrared images can distinguish the active portions of lava flows, and this information could be included in the numerical models for reliable simulations.

(Grp. 4) Crisis Management: Conclusions and Recommendations

You trust what you see

Remote sensing (RS) products are OK, **but** only as part of a bigger picture. Seismicity, local observations, in-situ data and aerial observations are very important to understand the situation. RS products can be very powerful in cases where there is an absence of other data sources, but is not always available (e.g. in the case of fog or clouds).

For local observatories, RS data is complementary. For remote locations, RS data is essential.

You trust what you know

Quantitative measurements, such as lava effusion rates, are very relevant if validated models are in place. At the time of an eruption, no new modeling must be done, but existing models must be implemented. The uncertainties and limitations of models must have been tested and validated beforehand for results to be trusted.

The main driver for using quantitative RS products (and all information in general) is accountability and liability. If the (propagation of) uncertainty of data is unknown, data will not be used during emergencies. Also ownership is important: data and models calculated locally at the observatory tend to be trusted more, mainly because the uncertainties and limitations are well understood.

What is the "magnitude"?

The principle question at the onset of new eruptions is the magnitude of the event.

Hotspots show the occurrence of events, but not the magnitude. Lava effusion rates may be informative in the where case previous modeling has been done and validated to give an idea of accuracy and limitations.

Interesting quantities related to magnitude are: length of fissure.

Plume heights derived from RS are not considered reliable enough.

Timeliness / accuracy

There is a need for fast data. However, interpretation of the data must be done with care. This means that results will be released with longer delays. The high sensitivity of scenarios to small changes in vent location, effusion rates or other parameters, make interpretation and prognosis difficult.

In general, parameters for data delays are: 5 minutes for ash observation, 1 day for lava observations.

Other RS products

RS beyond thermal RS also provides interesting products. These include: radar (for tracking lava, good for cloud penetration) and InSAR (for precursor deformations and post eruption analysis).

Fast access is important. There are mechanisms in the humanitarian / civil protection area including the Charter for Disasters and Copernicus.

Format and standards

It is important to provide both simple products and GIS compliant products. Simple products, including simple images or text files. These are useful for low bandwidth applications and for consultation by non-expert users (including civil protection and humanitarians). GIS products should be georeferenced and preferably OGC compliant.

It is important to standardize on units and quantities reported, e.g. using SI units.

Running different models that calculate the same quantities is a good practice, because it allows an ensemble approach (common in meteorology).

Running different models calculating different, but related quantities is also good practice. It is an analogy to different magnitude estimates for earthquakes (body wave, p waves, etc.). However, the quantity and units must be well described.

Global services

Globally available data services are considered useful, as long as they are restricted to data and/or model products, but don't venture into interpretation, alert levels or advice. This should remain the sole responsibility of local observatories. A service must be inclusive, i.e. open to participation to all, which creates joint ownership and trust.

Emergency communication towards the public was discussed at length, with emphasis on maintaining a "single voice". Only after the civil protection makes their response decision public should (ideally, can) scientists speak publicly.

Scientists should make products that are easy to understand and don't provide misleading information. For instance, never show a single calculation, since it creates a false certainty. Limitations must be clearly explained. Trust must be built before an emergency, but extensive and regular training must be maintained (high staff turnover rates are common in civil protection). Products should avoid jargon.

Scientists should make products that are useful for Civil Protection actors. They are interested in the evolution of an eruption:

- What will happen, when and with which consequences?
- Is it getting worse?
- Is it over?
- Thresholds (when and under which conditions do we execute plan A, B or C?).

Annex 4d: Email distribution list for ASMVolc as of 06 September 2013

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