The South Sarigan submarine volcanic eruption, May 2010: an example of International Monitoring System waveform data synergy

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- The South Sarigan submarine eruption
- International Monitoring System data recordings
- Hydroacoustic signals and modelling
- Infrasound signals and modelling
- Preliminary interpretation
South Sarigan

- Eruption of submarine volcano, ~11km south of Sarigan island in late May 2010
- Located on the Marianas arc, in the west Pacific ocean
- 2003 bathymetric survey placed summit at ~300m below sea level
- A day after visual sightings (discoloured water, possible floating debris) an ash and steam plume was generated that rose to >10km altitude
- The International Monitoring System recorded signals on sensors of all three waveform technologies:
  - Hydroacoustic
  - Infrasound
  - Seismic
Relevance to S&T conference

- ‘The Earth as a complex system’
  - Natural events that generate signals
  - Hazard Identification
  - Understanding the natural environment
  - Improve signal interpretation
  - Mitigation of natural hazards
  - Added value of SHI observations in source characterization
Recorded Signals

Seismic:
REB entries include teleseismic recordings

Infrasound:
IS39 1584km from volcano

Hydroacoustic:
H11N 2257km from volcano
Hydroacoustic signals

- Signals recorded clearly on H11N (Wake Island Hydrophone station)
- Climactic events also recorded on H02 (Qn Charlotte Islands, Canada, T-phase station)

- H11 signals consist of a period of event clusters for 2 days prior to climactic event
  - As volcanic crisis progresses:
    - Increasing acoustic power output
    - Decreasing repose time between clusters (i.e., accelerating activity rates)

- On 29th May 2010, clusters merge: large discrete events and tremor observed
Hydroacoustic activity clusters

Accelerating occurrence of clusters  |  Discrete events + tremor

05/27  05/28  05/29  05/30

Time (UT), 27-29/05/10

0  10  20  30  40  50

Freq. [Hz]

22:45  23:00

Time (UT) 2011/05/28


Time (UT) 2011/05/29

Hydroacoustic Waveform Similarity

- Clusters of hydroacoustic events are comprised of many small discrete events
- These exhibit a high degree of waveform similarity
  - Quantified using the linear cross-correlation coefficient
- Find three main ‘families’ of event:
  - Fam 1. (2621 events)
  - Fam 2. (476 events)
  - Fam 3. (145 events)
- Overlaying the families show that they have similar waveform morphology
  - Higher-frequency onset
  - Low-frequency, ringing coda
- Can we identify waveform structure associated with source and/or propagation?
Hydroacoustic Waveform Similarity

- Family 1 (Dominant waveform group)
- Matrix plot shows subtle changes over time, predominantly in event onset.
- Ringing coda shows little variation over time
- Occurrence of waveforms associated with these families reduces significantly on 29th May 2010, as climactic phase begins.
- Which characteristics are related to the source, and which are related to propagation?
Hydroacoustic Modelling

- Normal-mode modelling indicates bathymetric blocking is the reason for lower amplitude signals at H11S compared to H11N
Infrasound Signals

- Infrasound associated with the eruption recorded at IS39 (Palau)
  - 1584km from eruption location
  - Signals only recorded during climactic phase

- Infrasound signals suggest that there was a significant subaerial plume (or jet) from at least 2010/05/29 05:00UT

- The increase in signal bandwidth and pressure amplitude over time suggests the acoustic generation mechanism increased in power until ~12:00UT

Coloured regions indicate sections of detected signal – black periods are noise
Infrasound Propagation Modelling

- 1D effective sound speed profiles exhibit weak stratospheric and mesospheric ducts
- Ray-tracing only predicts thermospheric arrivals
- Parabolic Equation modelling of wavefield suggests some energy returned from stratosphere and mesosphere
- Care needed with interpretation, as effective velocity profiles are in reality range-dependent
Signal association

- Association of signals requires accurate propagation velocity models
- For South Sarigan example:
  - Seismic
  - Hydroacoustic
  - Infrasound

  Large uncertainties in propagation are assumed to be reason for non-alignment with seismic and hydroacoustic signals. Current propagation models predictions are too slow; celerity of 0.31km/s required for alignment.
Interpretation (preliminary)

Cluster of small explosive events (analogous to strombolian or vulcanian explosions?)

Plume contained under sea surface

Acceleration and increased intensity of activity over time

Continuous output at vent (resulting in hydroacoustic tremor)
Breaching of plume at sea surface (resulting in infrasound signals)

Climactic explosions
Future Plans

- Engage with volcanological community, to help with our volcanological interpretations

- Study signals in context of other volcanic eruptions (especially infrasound signals – are there any characteristics that are unusual compared to subaerial eruptions?)

- Location studies – identify an optimal method for combining the location and origin time constraints from all three waveform technologies

- Publish results – so that volcanological monitoring community are made aware of the potential benefits of the IMS data for civilian applications
Conclusions

- South Sarigan submarine eruption in May 2010 was recorded on hydroacoustic, infrasound and seismic sensors of the IMS. The data provides a rare glimpse of the activity preceding a submarine eruption which subsequently breached the sea surface.

- Cyclic activity at submarine volcano observed using IMS hydroacoustic data.

- Onset time of sea surface breach by volcanic plume/jet constrained using IMS infrasound data.

- The IMS is global: therefore, an excellent platform for developing monitoring and interpretation tools for future submarine and subaerial volcanic eruptions.

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