MITIGATION OF VOLCANIC RISK
THE COSMO-SKYMED CONTRIBUTION
P. Sacco, M. G. Daraio, M. L. Battagliere, A. Coletta

COSMO-SkyMed Mission Management Unit
Italian Space Agency (ASI)
COSMO-SkyMed system features

Application domains

COSMO-SkyMed for Volcanoes:
- SRV Pilot Project
- BCK_Vulcani
- SAR4Volcanoes
- Supersites
- DRM Volcano Pilot
- AO ASI/CSA
- Active Volcanoes

Conclusions
SINCE MAY 2011 THE ITALIAN COSMO SkyMed FOUR SAR SATELLITES CONSTELLATION IS FULLY OPERATIONAL
COSMO-SkyMed features

The Largest Italian investment in Space System for Earth Observation

8 JUN. - 2007
COSMO-1

FIRST DUAL USE SYSTEM

5 NOV. - 2010
COSMO-4

NO OTHER 4 SAR SATELLITES CONSTELLATION TODAY ON THE EO OPERATIONAL SCENE
COSMO-SkyMed features

- **SENSOR**: X-BAND SAR (9.6 GHz)
- **BANDWIDTH**: 400 MHz
- **HEIGHT**: 619.6 Km
- **ORBIT**: SSO
- **INCLINATION**: 97.8°
- **ORBITAL PERIOD**

**4 SAR SATELLITES CONSTELLATION**
- Worldwide global coverage
- All weather night/day acquisitions
- Fast response time
- Fast large/long area mapping
- Accurate information frequently updated
- Interferometric revisit (1 day)

FRINGE 2015 WORKSHOP
23–27 March 2015 | ESA–ESRIN | Frascati (Rome), Italy
COSMO-SkyMed features

- **75 Narrow Field**
  - + 375 Wide Field Images per day per satellite
  - 1800 images per day

**MULTI-MODE ACQUISITION CAPABILITY**

**RESPONSE TIME**

- **4 SATELLITES (real cases)**
  - **VERY URGENT**: 6-18 h
  - **CRISIS**: 12-36 h
  - **ROUNTE**: 24-72 h
COSMO-SkyMed features

ASI HEADQUARTERS

Constellation Unique Capabilities

ESA-ESRIN
COSMO-SkyMed features

ESRIN, Frascati, 27 March 2015 (morning - Asc)

SAR4 H4-11
Right
04:54 UTC

SAR3 H4-04
Left
04:12 UTC
COSMO-SkyMed features

ESRIN, Frascati, 27 March 2015 (afternoon - Desc)

SAR2 H4-13
Left
17:53 UTC

SAR3 H4-0A
Left
17:35 UTC

SAR1 H4-0A
Right
17:05 UTC
Application domains

RISK MONITORING AND MANAGEMENT OF EMERGENCIES

OCEAN AND ICE MONITORING

MONITORING AND MANAGEMENT OF COASTALIINES AND INLAND WATERS

MONITORING AND MANAGEMENT OF FORESTRY AND AGRICULTURAL RESOURCES

TECHNICAL CARTOGRAPHY – URBAN PLANNING

SCIENTIFIC APPLICATIONS

SECURITY APPLICATIONS

- FLOODS
- OIL SPILL
- EARTHQUAKES
- HURRICANES
- LANDSLIDES
- VOLCANOES
- SEISMIC RISK
- FIRES
- HUMANITARIAN CRISIS
COSMO-SkyMed for Volcanoes
COSMO-SkyMed for Volcanoes
<table>
<thead>
<tr>
<th>Tipology</th>
<th>Frequency of observation</th>
<th>Number of Sites</th>
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<tbody>
<tr>
<td>Cities</td>
<td>16 days</td>
<td>762</td>
</tr>
<tr>
<td>Extended cities</td>
<td>16 days</td>
<td>150</td>
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<tr>
<td>UNESCO sites</td>
<td>16 days</td>
<td>264</td>
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<tr>
<td><strong>Volcanoes</strong></td>
<td><strong>16 days</strong></td>
<td><strong>163</strong></td>
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<tr>
<td>Infrastructures</td>
<td>16 days</td>
<td>40</td>
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<tr>
<td>Oil &amp; Gas mining</td>
<td>16 days</td>
<td>19</td>
</tr>
<tr>
<td>Subsidence</td>
<td>16 days</td>
<td>20</td>
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30,000 scenes acquired
CEOS/GNLS – Hawai Supersite

http://supersites.earthobservations.org/index.html
Kilauea caldera time series

COSMO-SkyMed Kilauea archive data have dense temporal sampling that improves transient deformation detection and span the March 2011 Kamoamoa fissure eruption.

Analysis by P. Lundgren, JPL
CEOS/GNLS – Iceland Supersite

http://supersites.earthobservations.org/index.html
CEOS/GNLS – Iceland Supersite

Iceland: Volcanic systems and primary target volcanoes for monitoring

CSK 2761
- 26/07/2014
- 01/09/2014
- 10/10/2014
- 22/10/2014

CSK 2762
- 26/06/2014
- 06/09/2014
- 03/10/2014
- 18/11/2014

CSK 2631
- 26/06/2014
- 20/07/2014
- 29/08/2014
- 28/10/2014

CSK 2632
- 26/06/2014
- 03/09/2014
- 12/10/2014
- 13/11/2014
LETTER

Segmented lateral dyke growth in a rifting event at Bárdarbunga volcanic system, Iceland

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Crust at many divergent plate boundaries forms primarily by the injection of vertical sheet-like dykes, some tens of kilometres long1. Previous models of rift events indicate either lateral dyke growth away from a faulting source, with propagation rates decreasing as the dyke lengthens1,2, or magma flowing vertically into dykes from an underlying source23, with the role of topography on the evolution of lateral dykes not clear. Here we show how a recent segmented-dyke intrusion in the Bárðarbunga volcanic system grew laterally for more than 65 km at a variable rate, with topography influencing the direction of propagation. Barriers at the ends of each segment were overcum by the build-up of pressure in the dyke end, then a new segment formed and dyke lengthening temporarily paused. The dyke evolution, which occurred primarily over 14 days, was revealed by propagating seismicity, ground deformation mapped by Global Positioning System (GPS), interferometric analysis of satellite radar images (InSAR), and global positioning (Fig. 1c,d). The rate of extension of the dyke segments varies from an initially radiated direction away from the Bárðarbunga caldera, towards alignment with that expected from regional stress at the distal end. A model minimizing the combined strain and gravitational potential energy explains the propagation path. Dyke spanning and seismicity focused at the most distal segment at any given time, and were simultaneously with magma source definition and show collapse at the Bárðarbunga caldera, accompanied by a series of magnitude M - 3 earthquakes. Dyke growth was slowed down by an effusive fracture eruption near the end of the dyke. Lateral dyke growth with segment barriers breaking by pressure build up in the dyke distal end explains how focused upwelling of magma under central volcanoes is effectively redirected over long distances to create new upper crust at divergent plate boundaries. The formation of dykes is favourable at divergent plate boundaries, because plate movements enrich the crust and reduce the normal stress on potential dyke planes. Rifting events at divergent plate boundaries typically occur in episodes separated by hundreds of years of quiescence. Only a few such episodes have been the most divergent dyke boundary forms mid-ocean ridges. In 1975-78 a rift episode took place at Iceland volcano, system, Iceland, and from 2002 to 2010 in the Afar region of Ethiopia3. Limited geodetic and seismic data have been interpreted in terms of basal flow of magma, with dyke propagation rates of up to 2-3 km per hour initially and then at a declining rate as magma propagates away from a central feeding source4. The propagation of such dykes has been modelled as inflation of magma-filled cracks with uniform excess pressure9. The formation of regional dykes in Iceland has alternatively been attributed to the vertical rise of magma from major magma reservoirs underlying dyke swarms1.

Bárðarbunga is a subglacial basaltic central volcano with a 70 km2 caldera at the northwestern corner of Vatnajökull ice cap in Iceland4 (Fig. 1, Extended Data Fig. 1). It has an associated fissure swarm extending 15 km to the southwest and 55 km to the north-northeast. Activity in the last 1,000 years includes both subglacial eruptions and major effusive fissure eruptions, with 21 erupted fissures in the last 1,100 years5. Timings of the most recent effusive eruptions north of the Vatnajökull ice cap, originating from the Bárðarbunga system, are not well-known, but they are inferred to have produced the Holuhraun lava flow sometime in the period from c. 1294 to 13046. The Holuhraun effusive fissure was reactivated in 2014. In 1996, the Gígjökull subglacial eruption was likely to have been triggered by the Bárðarbunga volcanic system7. Seismic activity at Bárðarbunga has been steadily increasing since 2005, mostly confined to the area northeast of its caldera.

On 16 August 2014 at 03:00 UTC, an intense seismic swarm began at Bárðarbunga. Initial seismic activity occurred in several clusters. One cluster was consistent with the formation of a radial dyke segment aligned in direction N127°E, outward from the Bárðarbunga caldera. Other clusters to the northeast of the caldera may also signify magma movements, or may induce seismicity. GPS observations show simultaneous deflation of the calderas and displacements consistent with widening across the N127°E radial dyke, although deformation due to magma movements in the other clusters may also contribute. The seismic activity then focused on a lineament in a direction N95°E, extending from the southern tip of the initial N127°E dyke segment (Extended Data Fig. 1).

Lateral growth of this dyke is reflected in the migration of seismicity, along segments of variable strike, maximum widening of 1.5 mm measured between stations USHC and E2EB, spread over 25 km apart (Supplementary Information). Displacements of continuous GPS stations indicate the fastest rate of widening at any time in the most distal segment of the dyke throughout its evolution. The rate of dyke propagation varied considerably. A long-abi break in propagation, for 406 days, began on 19 August. Propagation rate exceeded 1 km h -1 on 23 August when a new segment initiated with a 90° left turn and advanced 6 km north-northwest over two short segments. Following this, the dyke took a right turn onto a new lineament, striking N47°E, and then onto a N52°E-striking segment.

The lengthening of the dyke ended on 27 August, around 18 km north of Vatnajökull, and a minor fissure eruption in Holuhraun for about 6 h on 28 August. On 31 August, a new eruption began from the same fissure and is still ongoing at the time of writing. After 4 September the
Amplitude image: 2014/09/06 at 19:37
CEOS/GNLS – Iceland Supersite
CEOS/GNLS – Marmara, Campi Flegrei, Etna Supersites

http://supersites.earthobservations.org/index.html
Joint Announcement of Opportunity: The COSMO-SkyMed/RADARSAT-2 Initiative

Canadian (CSA) and Italian (ASI) Space Agencies joint effort to stimulate the scientific utilization of Earth Observation data acquired by their respective national missions, RADARSAT-2 and COSMO-SkyMed, with an announcement of opportunity seeking for basic and applied research, development of algorithms, methods and applications.

The call is limited to principal investigator from organisations duly established in Canada and Italy only and focuses on the synergistic evaluation of both sensors. Bidders with accepted proposal will have access, free of charge, to ASI and CSA images.

The announcement of opportunity will be opened for a limited two-month period to submit a proposal until November 11th, 2013. The expected evaluation period is 4 to 6 weeks. The proposals will be peer-reviewed by Earth Observation experts chosen by ASI and CSA.

For more information on this initiative, please contact:
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Investigation of dynamic processes of Active Volcanoes, relying on short revisit COSMO-SkyMed InSAR time series

• Kilauea an Mauna Loa volcanoes, Hawaii
• Copahue volcano, Argentina
• Laguna del Maule caldera, Chile
• Afar Rift, Ethiopia
• Sierra Negra, Ecuador

Other volcanoes: Sabancaya (Peru), Vesuvius, Etna, Vulcano (Eolie Islands) and Stromboli
Conclusions

The contribution provided by COSMO-SkyMed mission in the framework of volcanic risk monitoring has been showed, COSMO-SkyMed having proved to be a powerful instrument for space observation aimed at environmental monitoring and territory surveillance. A complete overview of the national and international projects in which COSMO-SkyMed data are exploited for the volcanic risk mitigation has been given. In this context COSMO-SkyMed has already provided its user community with more than 10,000 products and almost 40,000 scenes have been acquired over volcanoes worldwide. Actually, the high frequency of COSMO-SkyMed SAR acquisitions makes it ideal for measuring fast changing ground deformations, allowing scientists to detect volcanoes’ complex dynamics and facilitate identification of precursors to potentially disastrous eruptions.
Thanks for attention!

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