Status Report on the Seismic Hazards Pilot

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WG Disasters #5
Bonn, Germany
8-10 March, 2016

Outline

- **Seismic Hazards pilot - Status**
- **Results from pilot work to date**
  1. **EO data access for pilot users**
  2. **EO processing**
  3. **Awareness - Promotion of results**
  4. **Observations strategy**
- **Issues and risks identified**

Seismic Hazards pilot - Status

Seismic Hazards pilot - Status

As of today:

- A Collaboration of **ESA, NASA, ASI, CNES, DLR, JAXA**, and other partners: **INGV, NOA, UNAVCO, COMET+, University of Miami, EU Centre, ISTerre/IPGP, BGS** and **CNR IRPI**.
- 20 users: **CNR IREA** shall be fully on-board in the next days.
- The GEP is available since March 2015: supports both EO data access and EO data processing.
- Continued collaboration of pilot group with Sentinel-1 mission Project Manager to optimize coverage of the tectonic mask during ramp up phase.
- Validation of InSAR based velocity measurements is completed over California. Turkey and Japan in progress.
- Major seismic events during this period (2015-2016): Nepal, Greece and Chile.

Seismic Hazards pilot - Objectives

A. **Support the generation of globally self-consistent strain rate estimates and the mapping of active faults at the global scale by providing EO InSAR and optical data and processing capacities to existing initiatives, such as the iGSRM**

[role of EO: wide extent satellite observations]

B. **Support and continue the GSNL**

[role of EO: multiple observations focused on supersites]

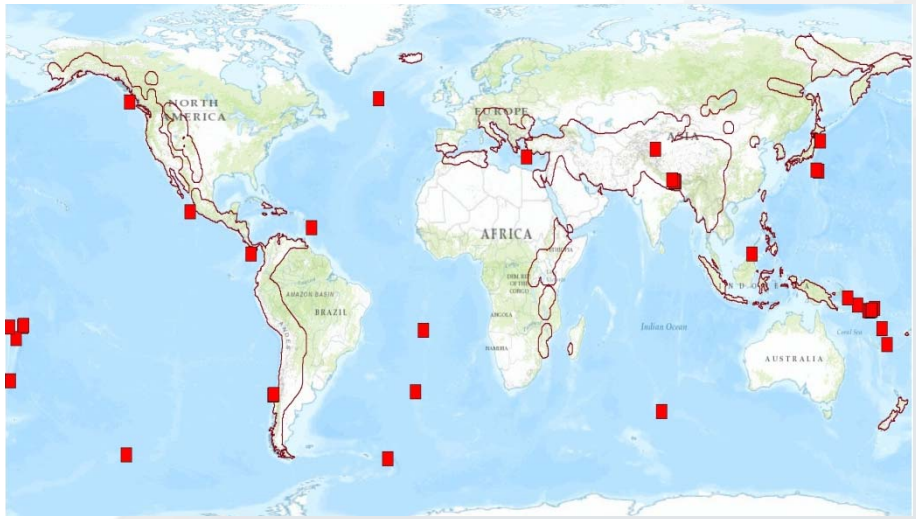
C. **Develop and demonstrate advanced science products for rapid earthquake response.**

[role of EO: observation of earthquakes with M>5.8]

Overview of activities (1)

Objective A:

- **Validation of InSAR based velocity measurements over California is complete (since September 2015).**
- **Regional analysis of Sentinel-1 data in Turkey is on-going.**
- **Next steps:**
  - **Complete Japan validation if a data source can be identified (ex. ALOS-1).**
  - **Complete validation of interseismic strain measurements using TerraSAR-X at the following sites:**
    - **1) North Anatolian Fault**
    - **2) Septentrional Fault in Haiti/D.R.**
    - **3) Chaman Fault in Afghanistan/Pakistan**



Overview of activities (2)

Objective B:

- **The pilot continued to support the Gorkha earthquake Event Supersite.**
- **Gorkha earthquake COSMO-SkyMed data recently made available through the GEP, via a connection with the ASI Data Gateway (only for authorised users who have signed the ASI license form).**
- **No other Event Supersites have been established in the period.**
- **The CEOS has continued to support the active Permanent Supersites, see S. Salvi presentation.**
- **Historical GSNL COSMO-SkyMed data will be accessed through the GEP.**

Objective C:

- **ALOS 2 data obtained through the Seismic pilot for the Gorkha Event Supersite (since JAXA does not support GSNL), ongoing work is focusing on post-seismic deformation (a paper on the earthquake is in review).**
- **Analysis of the Greece earthquake in November 2015.**
- **Analysis of the Chile earthquake in September 2015.**

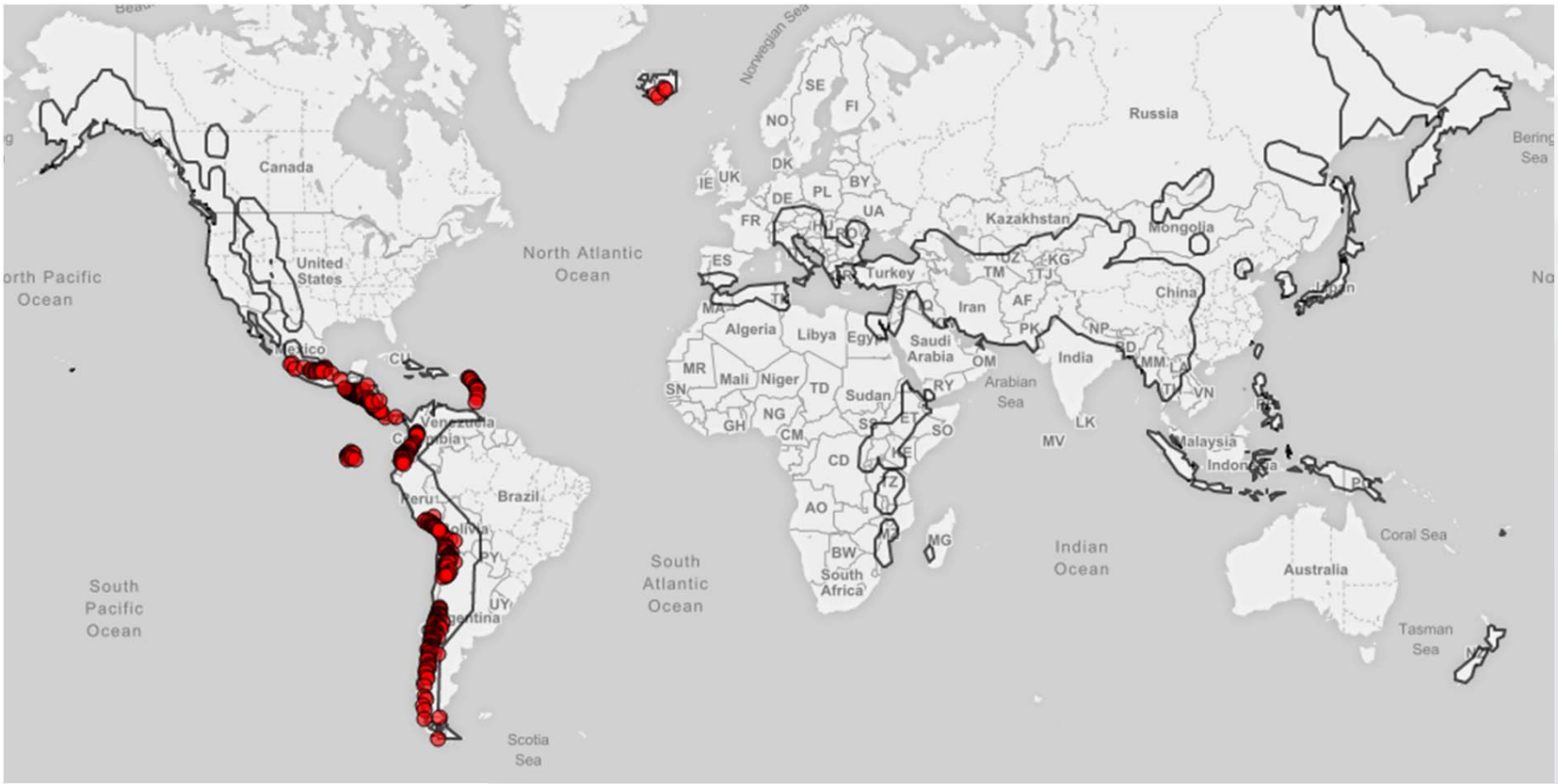
Results from pilot work in the period September 2015- February 2016

1. EO data access for pilot users

CEOS priority areas on GEP

CEOS priority areas masks are available on the GEP GeoBrowser:

- Seismic Pilot
- Volcano Pilot



EO data access for Pilot users

Following the arrangement made by ESA with ASI, DLR and JAXA to support data dissemination through the Geohazards Exploitation Platform (GEP):

-First COSMO-SkyMed data for the Nepal Event Supersite are available for GSNL users (Obj. B) that have signed the ASI license form. All COSMO-SkyMed data for GSNL, Volcano and Seismic pilot shall be accessed through the GEP (ASI: currently updating Hardware).

-TerraSAR-X data are currently catalogued on the platform. Users shall be re-directed to the DLR portal for downloading. Access granted after registration.

-ALOS-2 data for Seismic and Volcano pilot users are available on the GEP.

-For a fair portion of the tectonic mask, dense ESA archive data (ERS, ENVISAT) are available (70+ terabytes) and work is on going to fully cover the area; Copernicus Sentinel-1 data are available through the Scihub https://scihub.esa.int/

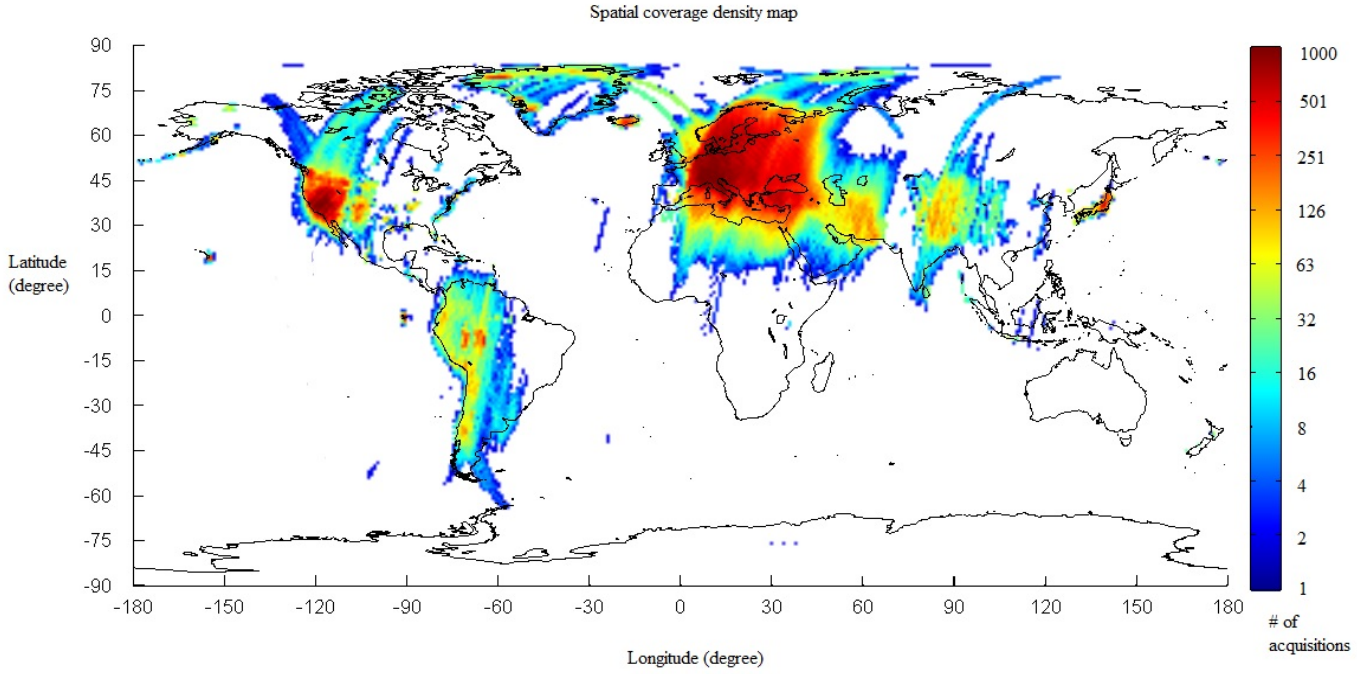
Available ERS, Envisat & Copernicus Sentinel-1A SAR & Sentinel-2 data

Sentinel-1 made available (in raw as well as SLC format) starting with CEOS Pilot targets and with the goal to gradually provide global coverage.
Sentinel-2 are gradually available on the platform since early March.

ERS & Envisat SAR data:

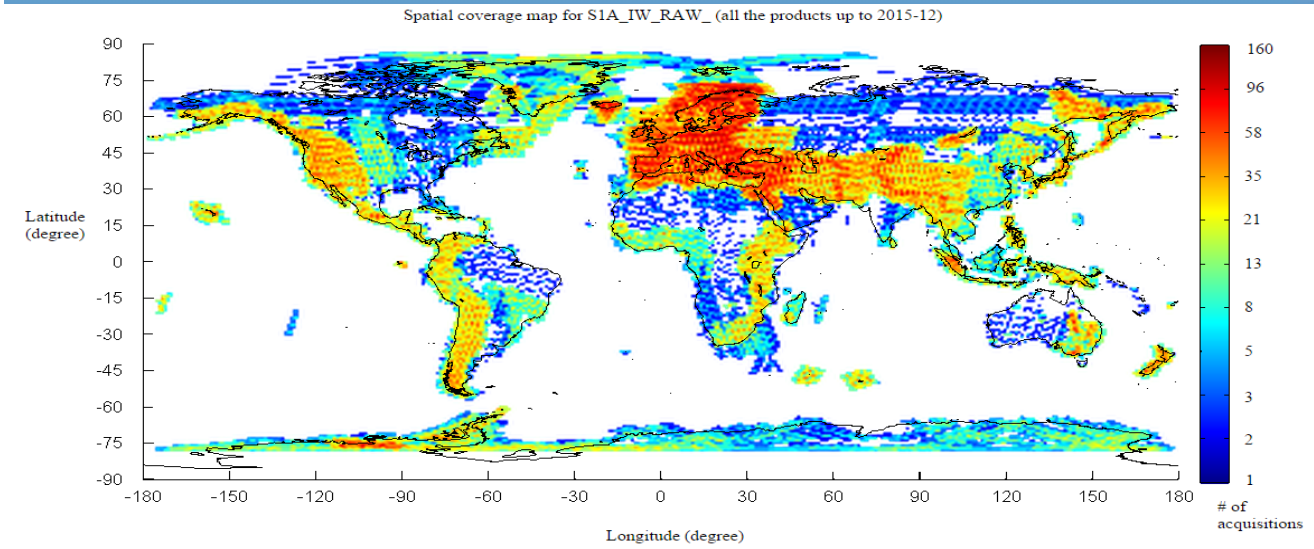
- Current ENVISAT ASAR IM Level-0 Data
- Current ERS SAR IM Level-0 Data

} (70+ terabytes)



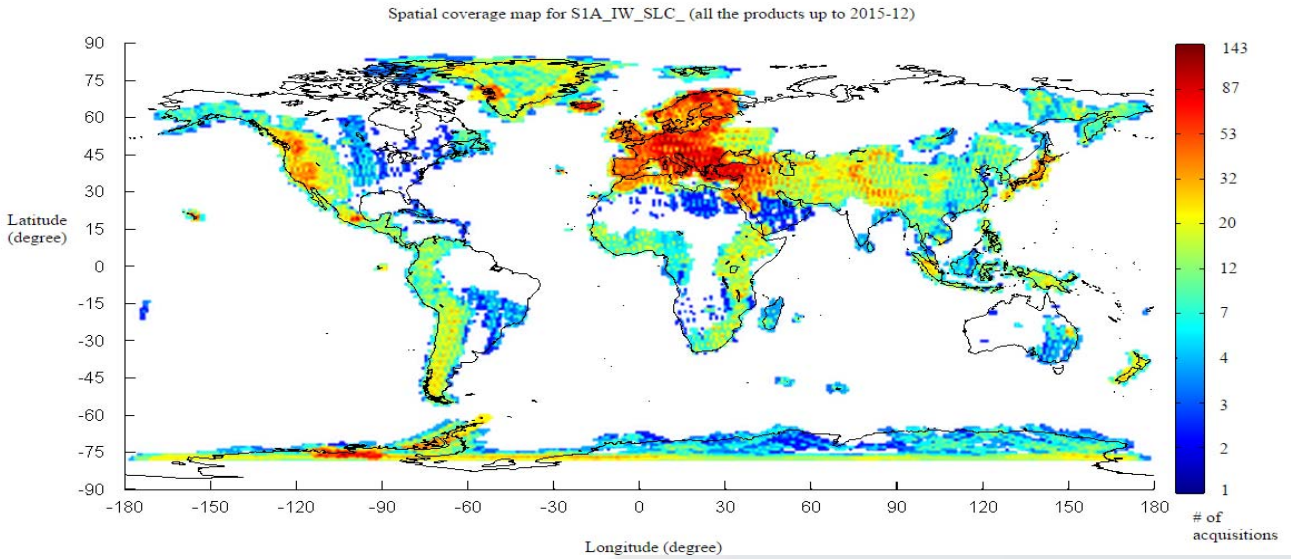
ERS & ENVISAT Level-0 data available as of February ’16.

Available Copernicus Sentinel-1A SAR data



S-1 RAW data available as of December 2015

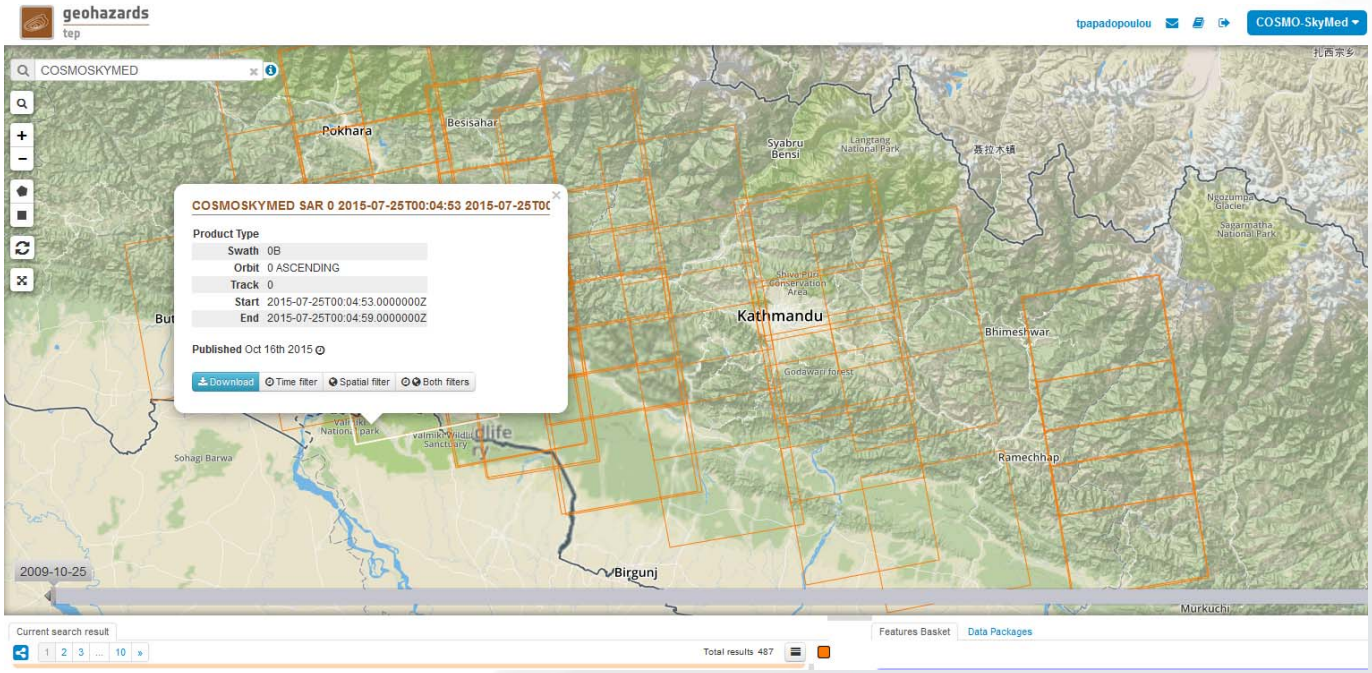
Since November 2015, Sentinel-1 products contain Restituted orbit files.



S-1 SLC data available as of December 2015

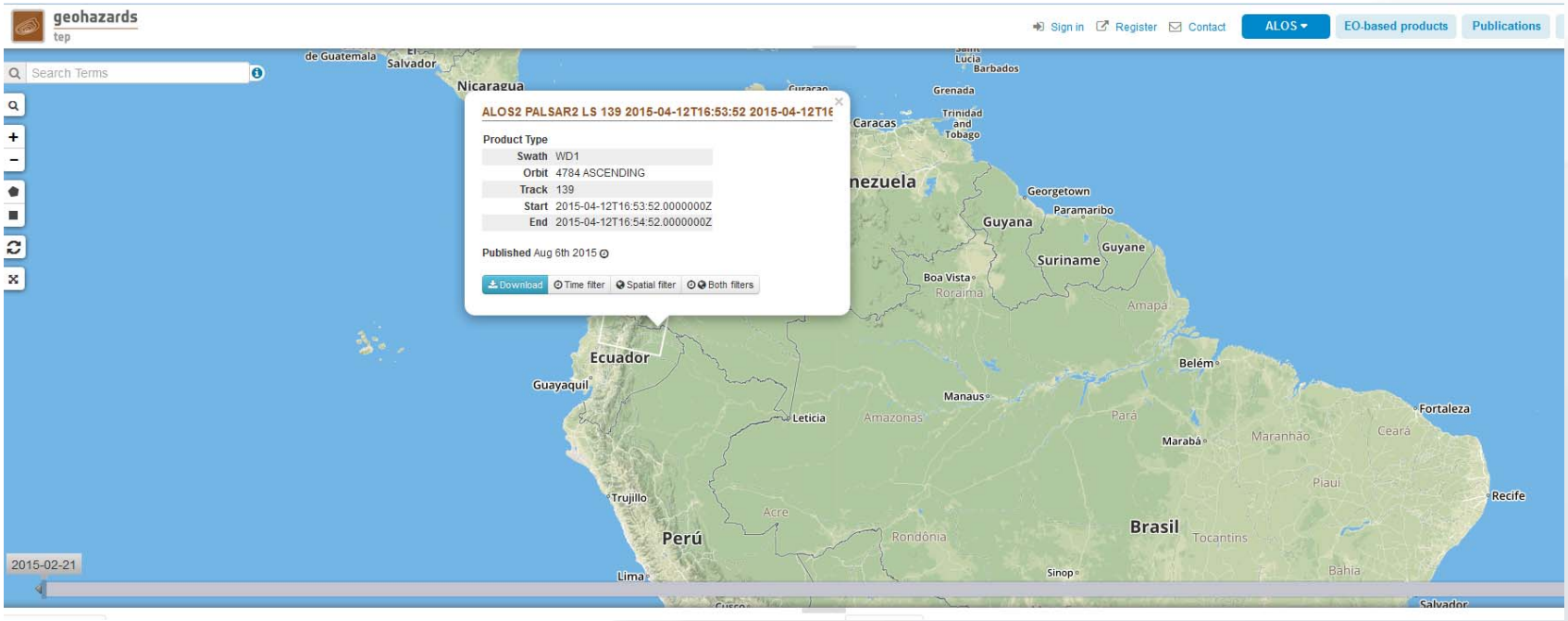
GEP supporting the GSNL

- **COSMO-SkyMed data collections over Nepal available through the GEP (only for authorized users having signed the ASI license form).**



GEP supporting the Volcano pilot

- **ALOS-2 images over Chile and Ecuador volcanoes are available through the GEP. The ALOS-2 collections for the Volcano pilot will reach up to 11 terabytes.**



Yearly Quota 2015

Agency	ASI	CNES Pleiades	CSA	DLR	ESA	JAXA ALOS-2	NASA	USGS Landsat -8
Number of Images	300	50	2	on request	*	100	-	-

*ESA: large dataset through the GEP (ERS & ENVISAT 70+ Tera and Copernicus Sentinel-1 & Sentinel-2 gradually)
DLR (TerraSAR-X): quota shall be provided, if requested
CNES (Spot): no quota provided
Freely available sources: no quota (e.g. USGS L8).

- DLR: Provided 65 images after a request for the Lefkada earthquake. Data acquisitions are on-going.
- JAXA: The 2015 and 2016 quota (200 images) can be ordered until March 2017.

ALOS-2 & Cosmo-SkyMed quota: AOI's defined

Overview of ALOS-2 data (prepared by Erwan Pathier)

Requested images:

- Seismic Pilot-Objective C, Total 27 (up to 37) for the Gorkha Earthquake
- Seismic Pilot-Objective A, Total 67 (can be down to 57 if excluding Taiwan): Turkey (38 products), Nepal interseismic (10 products), Central Andean Subduction (9 products), Taiwan (10 products)

  Total 100 for Y2015

❖ **The data request plan for Y2016 shall be discussed at the meeting.**

Overview of COSMO-SkyMed data (prepared by Barry Parsons)

Areas proposed: China (Haiyuan) and Iran (Shahdad).

2 scenes per area every 16 days would use ~90 scenes out of this allocation.

Further targets on creeping faults can be defined or as agreed in FRINGE it is possible to leave a significant amount of the allocation for earthquake response and postseismic studies.

A provisional order for COSMO-SkyMed was submitted to ASI for coverage over two creeping faults in China (Haiyuan) and Iran (Shahdad).

Total 300 for Y2015

Data requests & access

Objective A

-33 ALOS-2 images (2015 quota) were ordered for Turkey, Andes and Nepal. Soon to be available on GEP.

-Cosmo-SkyMed images over China and Iran were requested (according to the latest update from the users).

-TerraSAR-X request for Obj. A to be forwarded to DLR.

Objective C

Support for the Gorkha earthquake

-25 ALOS-2 post-seismic images are available.

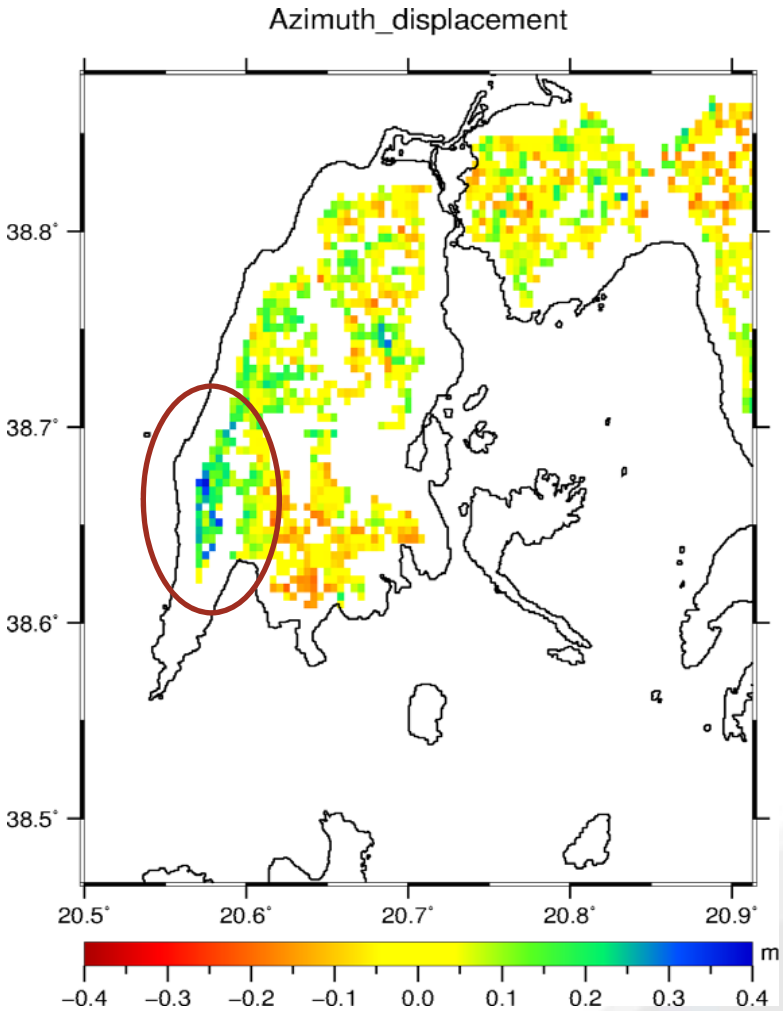
Greece

- 65 TerraSAR-X scenes (strimap) for post-seismic analysis over Lefkada are being acquired starting on 01-12-2015.
- Co-seismic Radarsat-2 data received.
- 60 COSMO-SkyMed stripmap scenes, including co- and post-seismic coverage, have been requested.
- SPOT data request still pending

Results from pilot work in the period September 2015- February 2016

2. EO processing

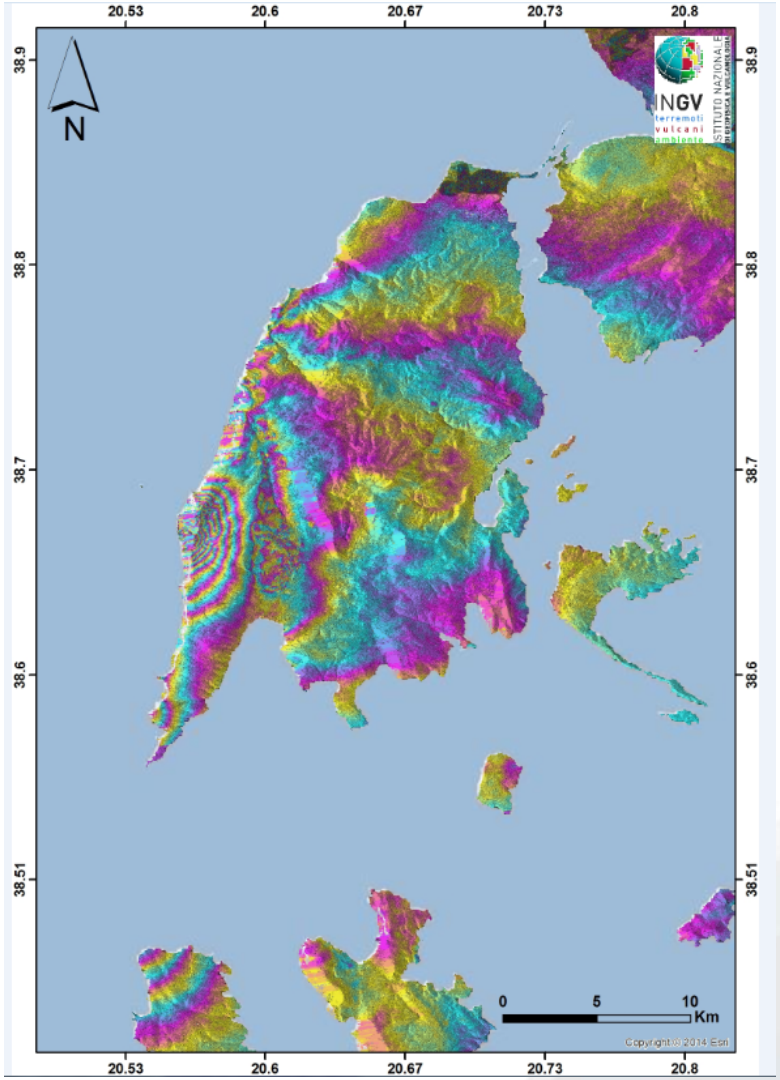
INGV : Azimuth displacement for the 2015 Lefkada earthquake



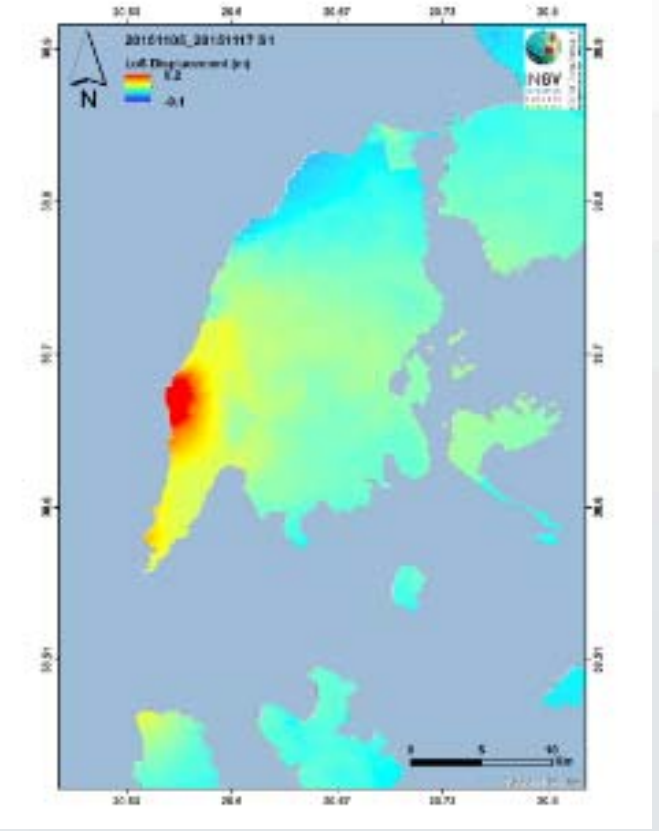
Offset tracking analysis of COSMO-SkyMed stripmap coseismic pair.

20-30 cm southward motion along the western shore of the island.

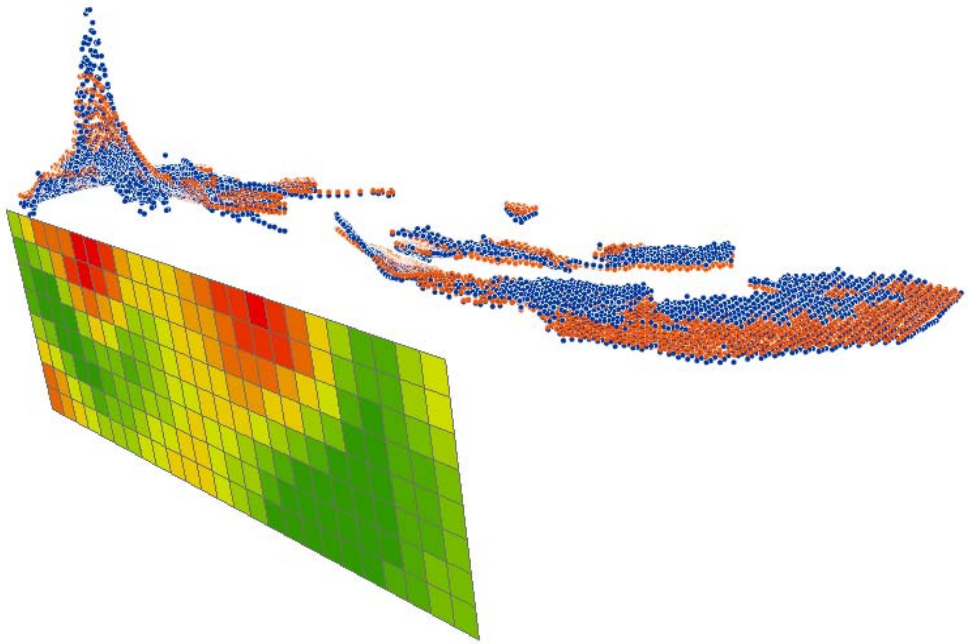
INGV & NOA: Sentinel-1 Displacement



Sentinel-1 ascending data: Interferogram and Displacement



INGV & NOA: Initial fault model for the 2015 Lefkada earthquake



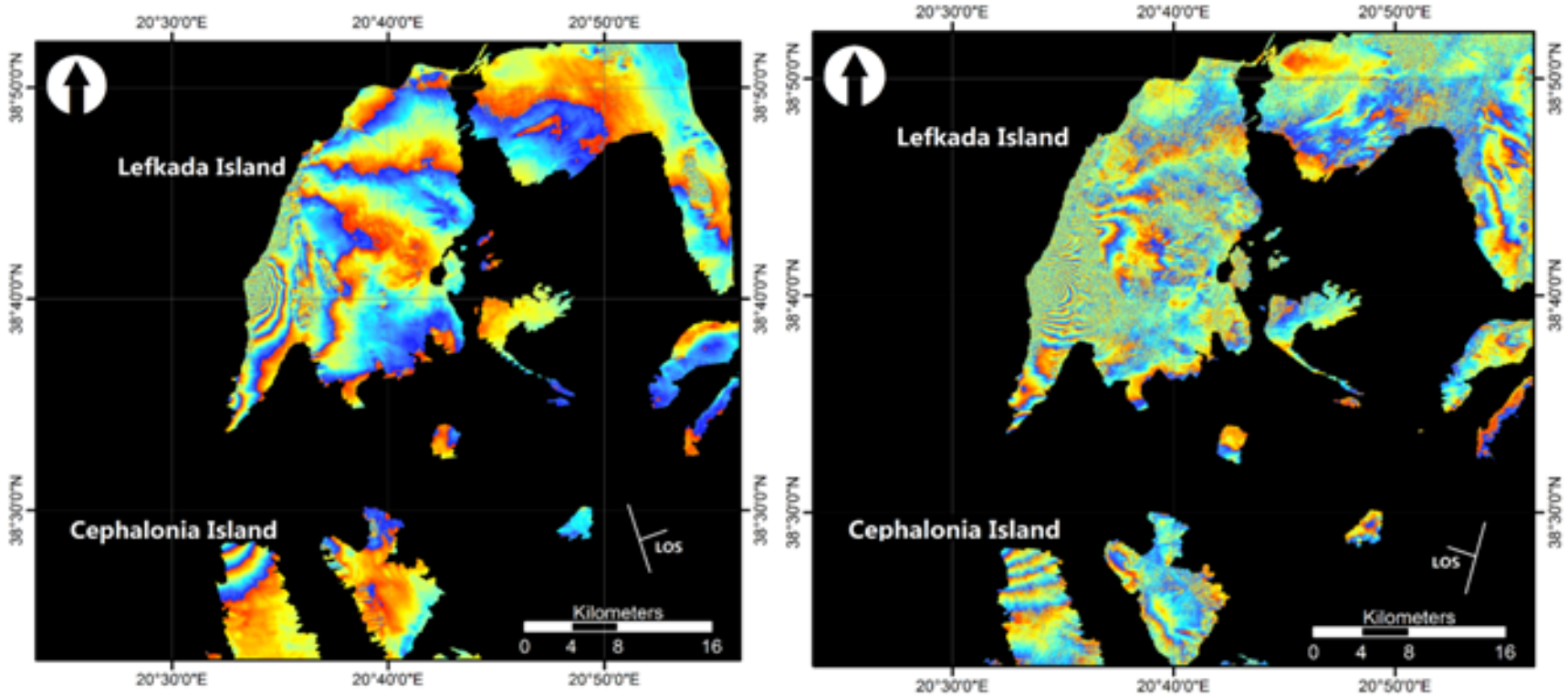
INGV and NOA have inverted COSMO-SkyMed, Radarsat-2, and S-1 data to constrain a source model for the earthquake.

Blue points: observed displacement, red points: modeled displacements.

NOA: Co-seismic deformation in Lefkada (1)

Study of the surface deformation caused by the November 2015 seismic event.

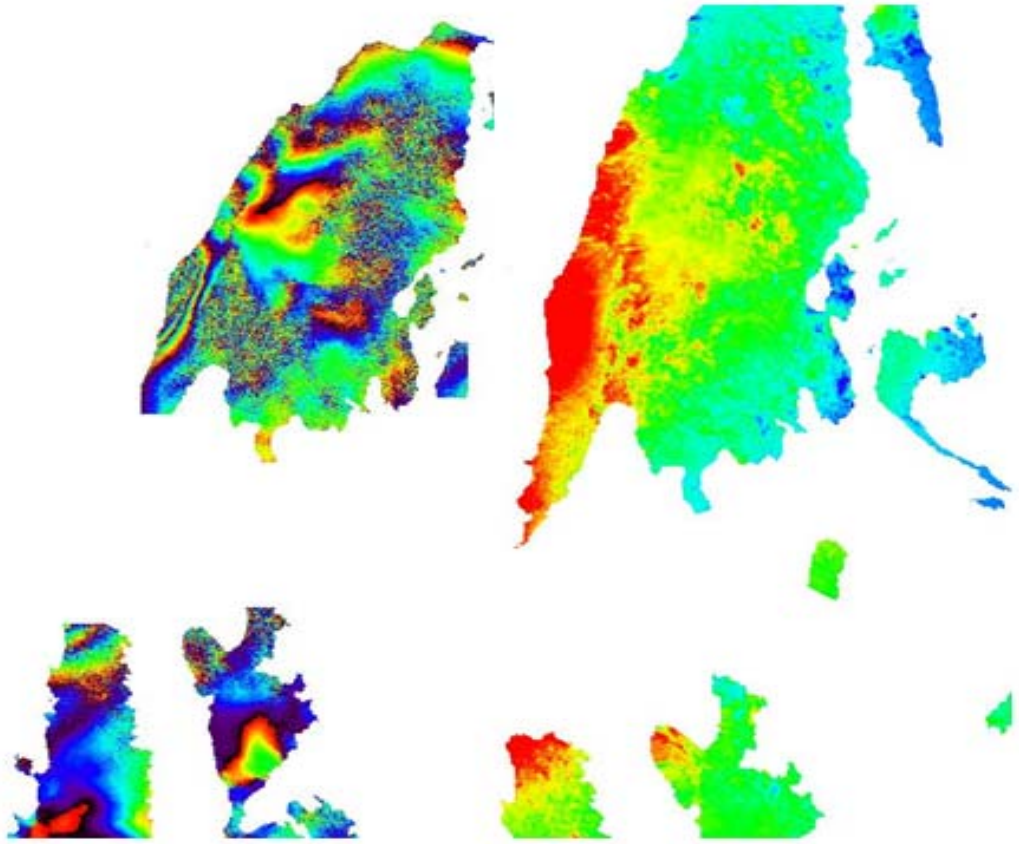
Sentinel-1A differential interferograms of the ascending pair (left) and descending (right)



H. Kontoes, NOA: Sentinel -1 data

NOA: Co-seismic deformation in Lefkada (2)

Study of the surface deformation caused by the November 2015 seismic event.

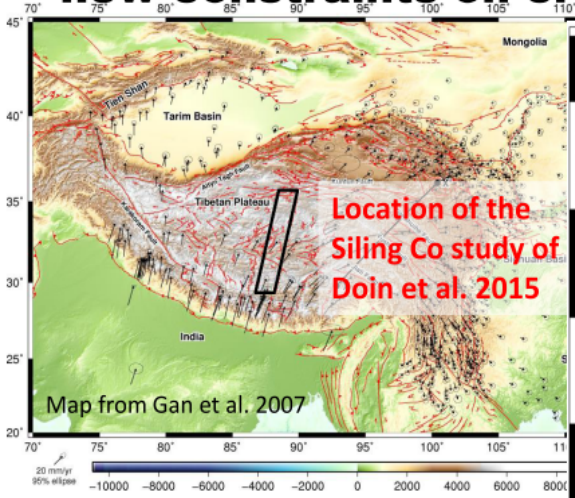


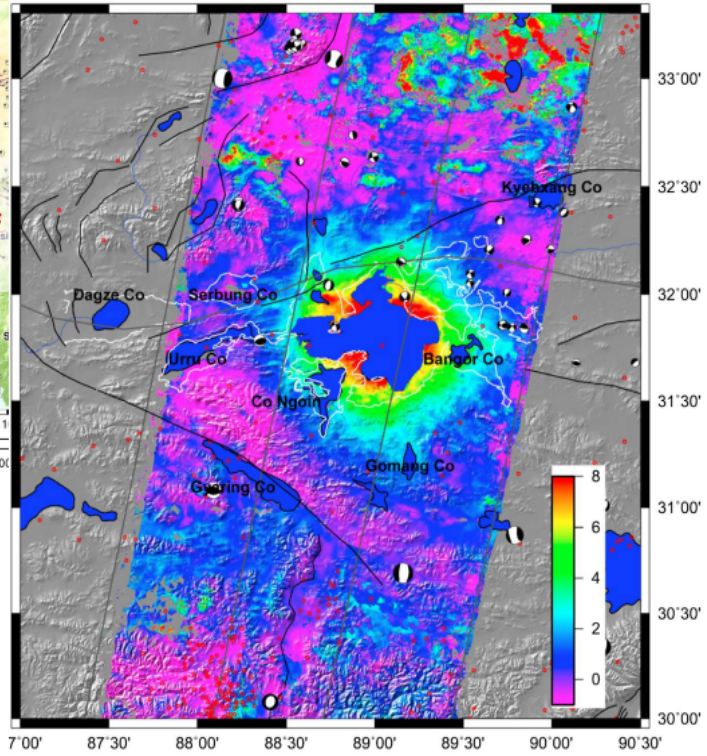
Wrapped (left) and unwrapped (right) preliminary interferograms using Radarsat-2 data for the Lefkada earthquake. Maximum LOS uplift of about 17cm is observed.

H. Kontoes, NOA: Radarsat-2 data

ISTerre: InSAR Deformation measurements using ERS and Envisat

Visco-elastic rebound around Tibetan lake gives new constraints on crust and mantle properties





Right figure shows cumulated ground displacement between 1999 and 2009 related to the loading of the Tibetan Siling Co lake, using data from ERS and ENVISAT satellites.

Modelisation of the time serie analysis favors the existence of a ductile channel in the deep crust above a more rigid mantle and gives new constraints on the rheological properties of the crust and mantle that are critical to the mechanical modeling of solid Earth deformation.

Doin et al, JGR, 2015

ISTerre Institut des Sciences de la Terre

UNIVERSITÉ Grenoble Alpes

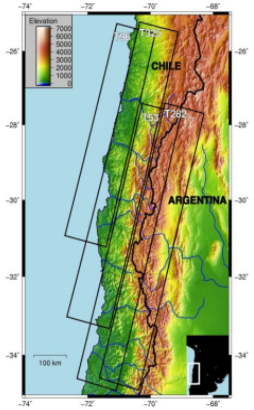
cnrs

ERS and ENVISAT data used
NSBAS chain applied

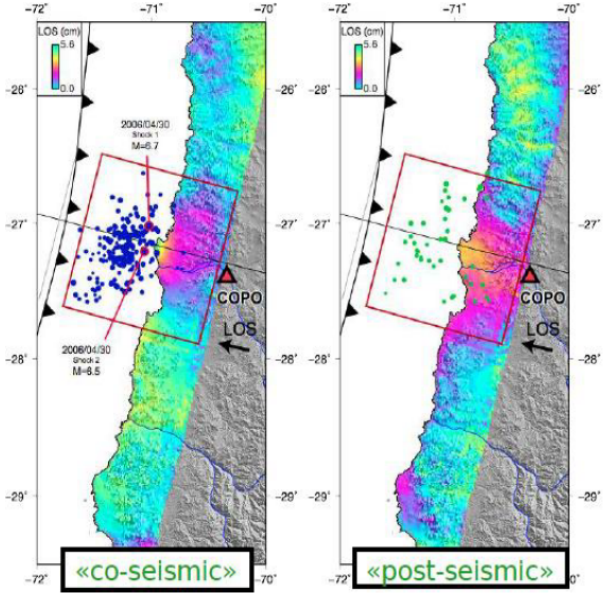
Marie-Pierre Doin, ISTerre

ISTerre: Chile seismic swarms

Earthquake cycle along the Chile subduction zone: quantifying the contribution of seismic swarms



Envisat and ERS data are used to quantify both co- and post-seismic contribution of the 2006 Copiaco Caldera Seismic Swarm



Doin et al, 2014

ISTerre

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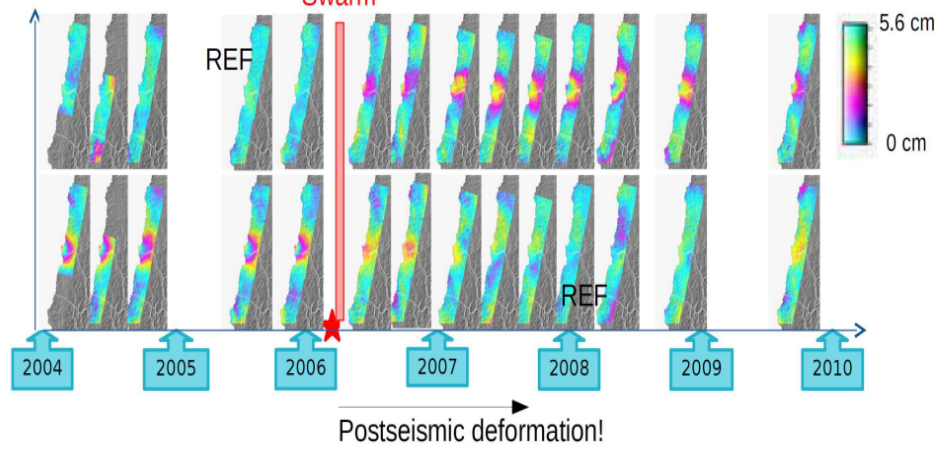
Earthquake cycle along the Chile subduction zone: quantifying the contribution of seismic swarms

Time series analysis on Envisat T96



Detection of step and transient deformation by InSAR time serie analysis.

Co- and post seismic contribution of the Caldera Capiaco and Punitaqui seismic swarms have been isolated from the interseismic signal, which shows more clearly the coupling spatial variations along the subduction zone.

Doin et al, 2014

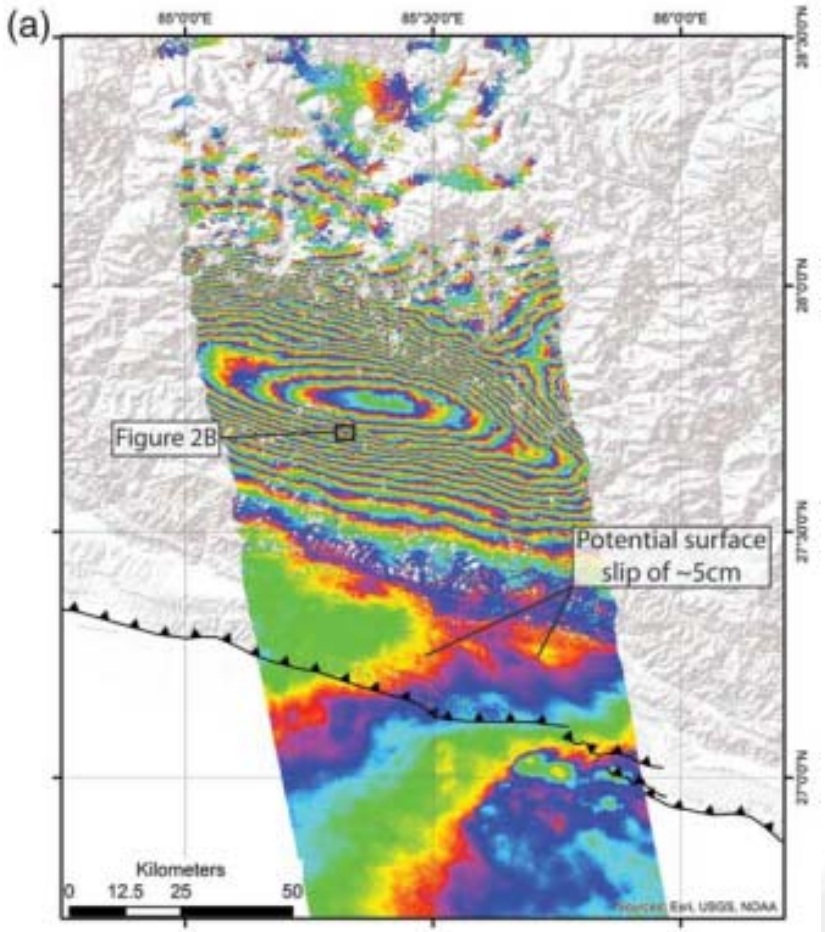
ISTerre

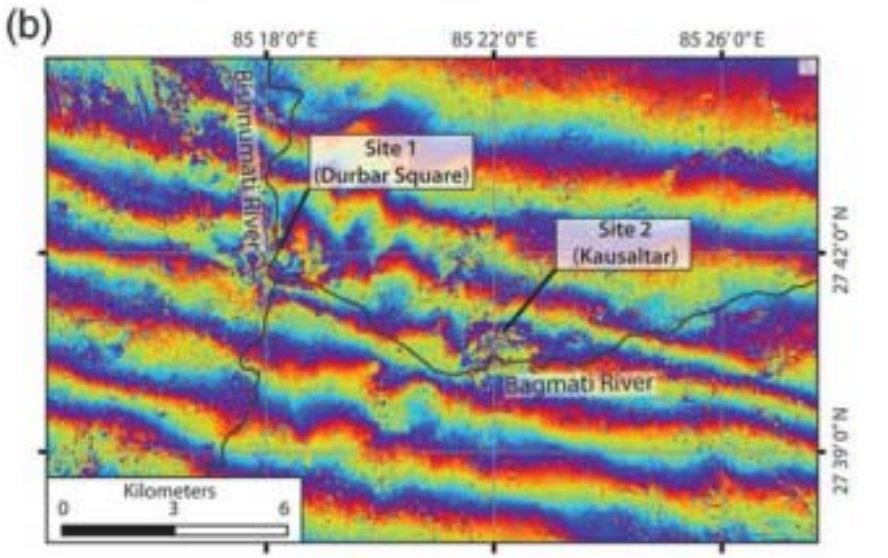
UNIVERSITÉ Grenoble Alpes

cnrs

Marie-Pierre Doin, ISTerre

JPL NASA: ALOS-2 fine-beam interferograms over Kathmandu



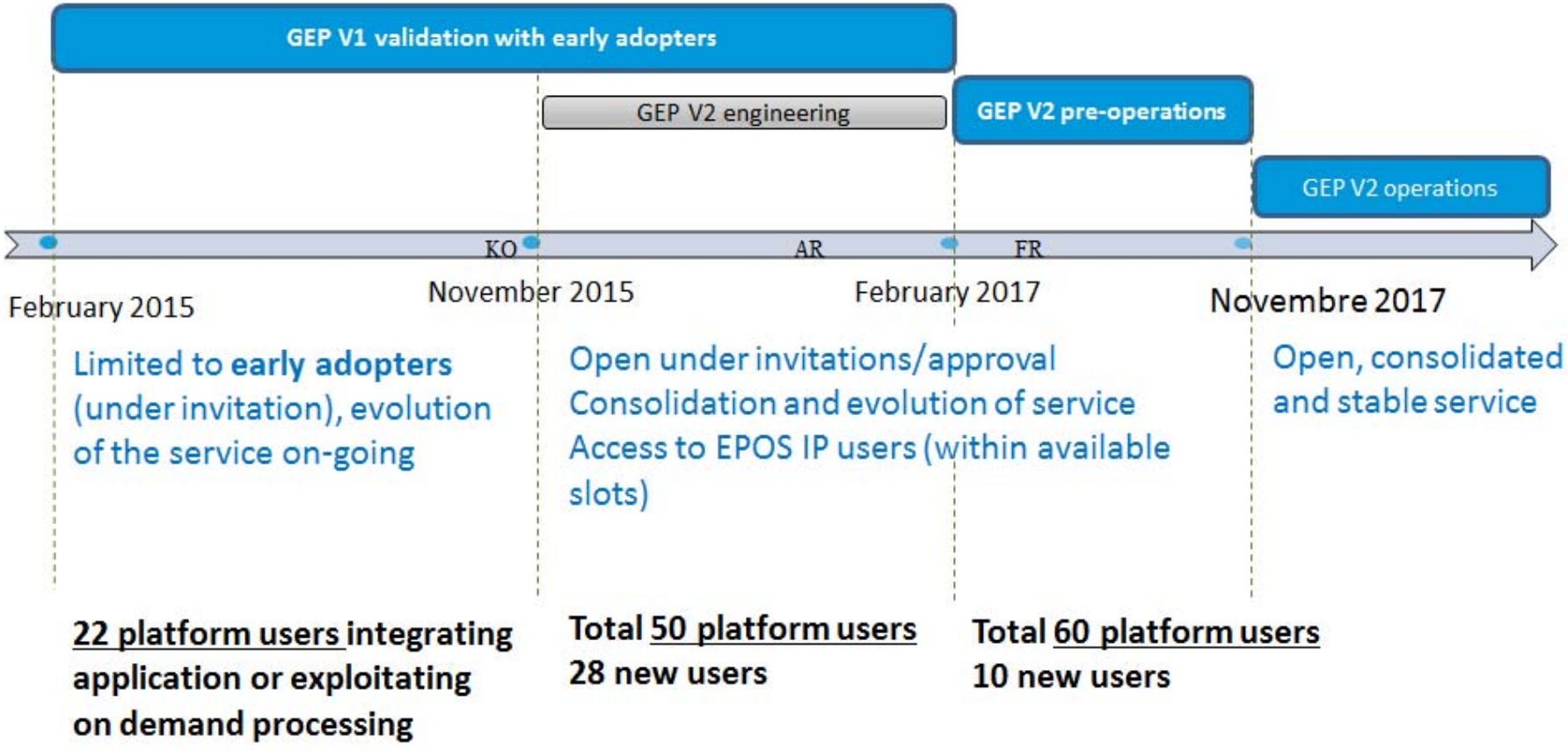


(a) InSAR interferogram of the rupture region constructed from ALOS-2 fine-beam passes on 21 February 2015 and 2 May 2015. Each color fringe depicts 10 cm of displacement (slightly different from original ALOS-2 fringes). (b) Enlarged area of the fine-beam interferogram in Kathmandu showing the disturbance of fringes (each equivalent to 10 cm) that is consistent with a north-trending zone of ground deformation at site 1 and east-trending zone at site 2. The thin black lines show the trace of the Bagmati and Bishnumati rivers.

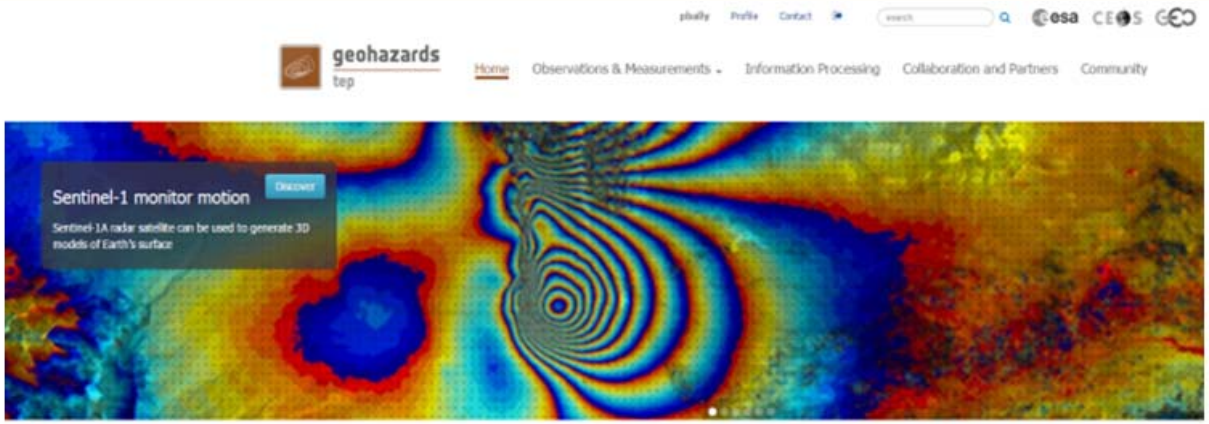
Eric J. Fielding, JPL NASA

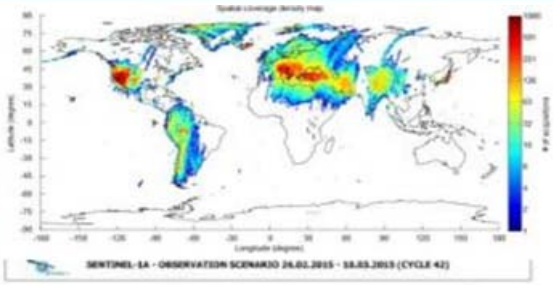
Helping pilot users with on demand cloud processing

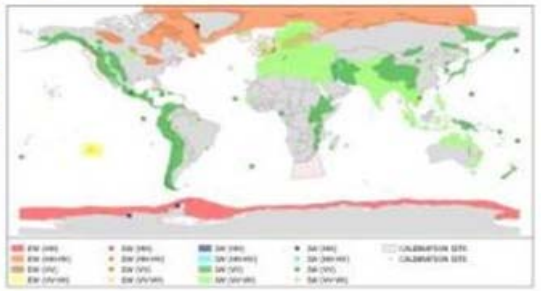
GEP Roadmap


GEP V1 validation with early adopters
GEP V2 engineering
GEP V2 pre-operations
GEP V2 operations
KO
AR
FR
February 2015
November 2015
February 2017
Novembre 2017
Limited to early adopters (under invitation), evolution of the service on-going
Open under invitations/approval
Consolidation and evolution of service
Access to EPOS IP users (within available slots)
Open, consolidated and stable service
22 platform users integrating application or exploitating on demand processing
Total 50 platform users
28 new users
Total 60 platform users
10 new users

GEP: an innovative response







Cloud Dashboard

Geo Browser

Achievements

An Exploitation Platform sourced with **data and processing** relevant to the GeoHazards theme:

- EO data **storage** concerning wide extent tectonic analysis for which large data stacks are needed (typically 1000+ and 5000+ scenes and larger)
- Access to **advanced processing tools** (e.g. InSAR and Optical based)
- A **collaborative** work environment and scientific animation
- 2015: **22 users** on board; end 2017: **60 users**
- One of the *6 Thematic Exploitation Platforms* originated by ESA
- Follows the GPOD, SSEP and TEPQwin precursors

European Space Agency

❖ The GEP KO meeting took place in October 2015.

Examples of *Early Adopters, Validation Phase started in March 2015*

User organisation	Areas
Ecole Normale Supérieure de Paris (France)	Etna, Italy and Corinth Rift, Greece
DLR IMF (Germany)	European tectonic mask
Altamira Information (Spain)	Test sites on landslides and earthquakes
ISTerre / Institut de Physique du Globe de Paris (France)	Subduction zones of Latin America, the NAFZ and Tibet.
INGV Roma (Italy)	Alto Tiberina Fault and Fogo Cape Verde
INGV Roma (Italy)	Marmara, East sector of NAFS
INGV Roma (Italy)	Haiti and West Java
ETH (Switzerland)	Large surface deformations caused by landslides in Bhutan Himalaya
NOA (Greece)	Geohazard sites in Greece
SATIM (Poland)	Silesia & Warsaw (Poland)
Obs. Physique du Globe de Clermont-Ferrand (France)	Piton de la Fournaise in La Réunion, Cordon del Azufre / Lastarria in Chile–Argentina
INGV Catania (Italy)	Etna & Campi Flegrei / Vesuvius
British Geological Survey (UK)	Urban areas of Great Britain
University of Leeds (UK)	Active deformation in the Alpine-Himalayan belt
ESA	Over calibration sites: Rain forest, Germany (DLR targets), Australia Milan, Chicago, Sao Paulo
ESA(Progressive Systems SLR)	Greater Cairo, South Rayan dune field, Middle Egypt province and Aswan province
CNR IREA (Italy)	Tests on Italian volcanoes and Hawaiian and Japanese volcanic and seismic areas
Universita De L' Aquila (Italy)	Abruzzo region: L' Aquila and Teramo for post-seismic ground displacements
University College of London (UK)	UK landslides
ICTP (Italy)	Morocco seismic activity

Volcanoes

Earthquakes

Landslides

PoC for applications: geohazards-tep@esa.int

Processing tasks on the platform from CEOS pilot users

37 processing jobs launched in September

- **36 ISTerre (30 NSBAS, 5 GAMMA, 1 InSAR SBAS)**
- **1 NOA (StaMPS)**

18 processing jobs launched in October

- **5 INGV (InSAR SBAS)**
- **13 ISTerre (11 NSBAS, 2 ROI_PAC)**

18 processing jobs launched in November

- **6 INGV (InSAR SBAS)**
- **3 ISTerre (NSBAS)**
- **4 NOA (StaMPS)**

18 processing jobs launched in December

- **1 ISTerre (NSBAS)**

Next processing activities on (and out of) the platform from CEOS pilot users

NOA: Maria Kaskara performed time series analysis (Persistent Scatterer processing) on SAR data over Istanbul, Turkey (2009-2010).

INGV: Christiano Tolomei processed ENVISAT images over the areas of Iran (Tabriz and Bandar Abbas) and Italy (Gargano Promontory) . ERS multi-frame processing to be launched shortly over Central and South Italy.

ISTerre: activities consisted in processing the ERS over Iran which on GEP is provided as 3 frames (100x100km). ISTerre confirms the usefulness of testing/using the NSBAS installation once logged on the VM via SSH connexion (expert mode), as well as the link to the Geobrowser, allowing to trigger the NSBAS processing as-a-Service from there.

ISTerre future activities include:

- Tibet: launch their own NSBAS work environment from the Cloud dashboard in January to start over their next activities, over East Tibet, with the need to process long tracks and better systematize the "data results" repatriation workflow.
- Turkey: next activities over Turkey will be starting in Spring 2016.

Results from pilot work in the period September 2015- February 2016

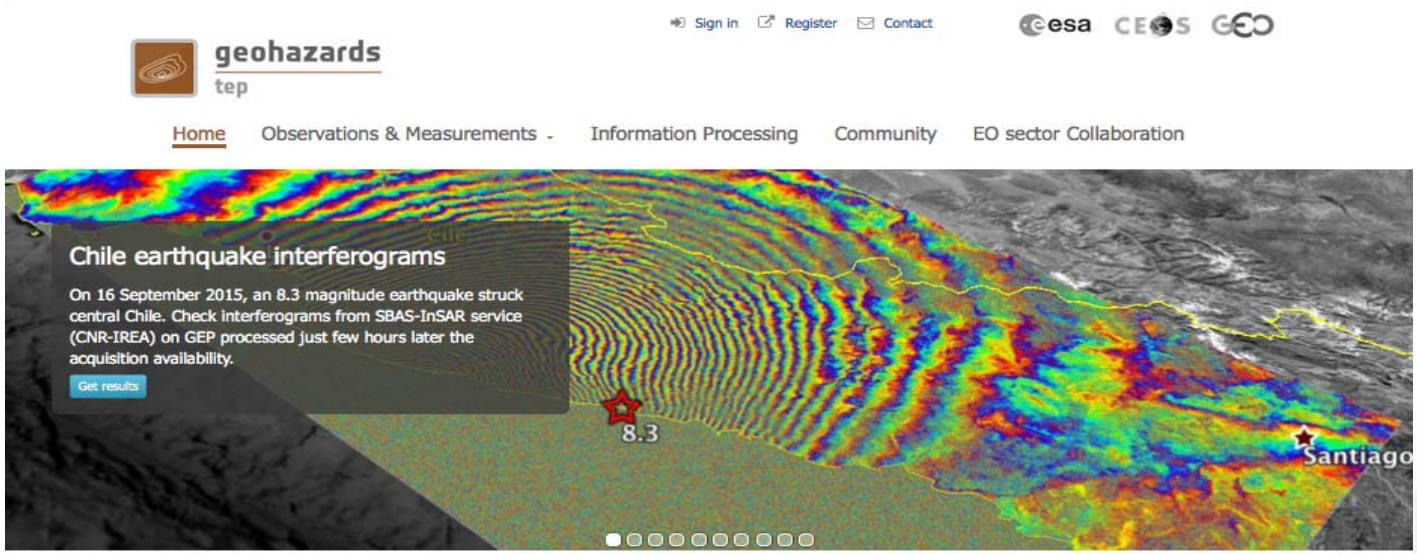
3. Awareness – Promotion of results

Awareness – Promotion of results

CEOS Pilot users can promote their results through:

- **CEOS website (http://ceos.org/)**
- **GSNL portal (http://www.earthobservations.org/gsnl.php)**
- **Geohazards Exploitation Platform (https://geohazards-tep.eo.esa.int/).**

Example of promotion of results on the GEP from CNR IREA

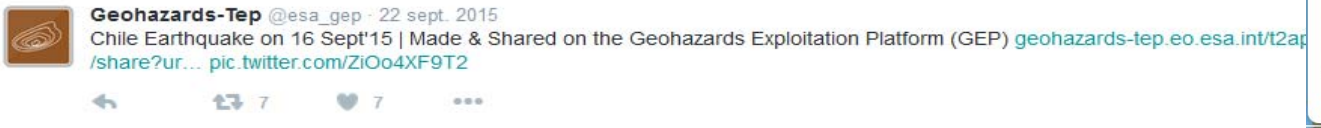


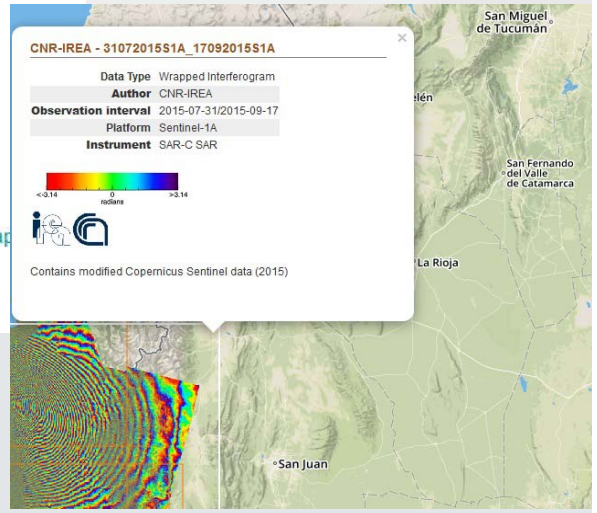
Sentinel-1 interferograms over Chile using the SBAS-InSAR processor.


Background


Geo Browser


Activities





The processing was run on ESA's Grid Processing On Demand (G-POD) where the algorithm is currently integrated. The integration of the SBAS-InSAR service on the GEP is still on-going.

Publications

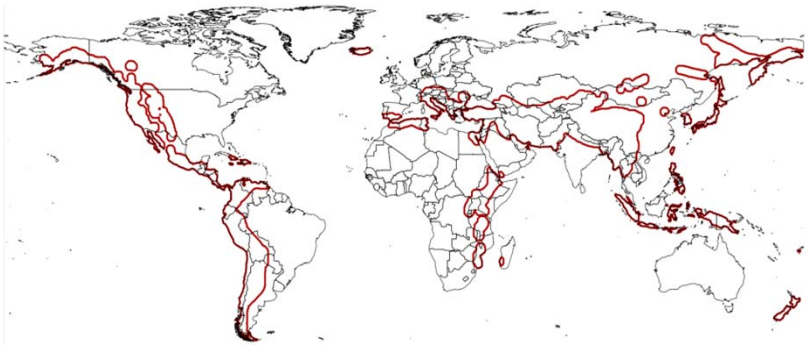
- Grandin et al. (2015), "Rupture process of the Mw=7.9 2015 Gorkha earthquake (Nepal): insights into Himalayan megathrust segmentation" submitted (**IPGP, Obj. C**)
- Doin, M. - P., Twardzik, C., Ducret, G., Lasserre, C., Guillaso, S., & Sun Jianbao. (2015). InSAR measurement of the deformation around Siling Co Lake: Inferences on the lower crust viscosity in central Tibet, *J. Geophys. Res.-Solid Earth*, 120, 5290–5310, doi:10.1002/2014JB011768. (**ISTerre, Obj. A**)
- Papadopoulos et al. (2016), The Mw6,5 earthquake of 17 November 2015 in Lefkada Island and the seismotectonics in the Cephalonia Transform Fault (Ionian Sea, Greece), Geophysical Research Abstracts, Vol. 18, EGU2016-9041-1, 2016 (accepted, **NOA, Obj. C**)
- Melgar D. et al., Slip segmentation and slow rupture to the trench during the 2015, Mw8,3 Illapel, Chile earthquake, doi: 10.1002/2015GL067369 (**JPL, under Obj. C**)
- Angster et al. (2015), Field Reconnaissance after the 25 April 2015 M 7,8 Gorkha Earthquake, Seismological Research Letters, Vol. 8, No. 6 (**JPL, under Obj. C**)

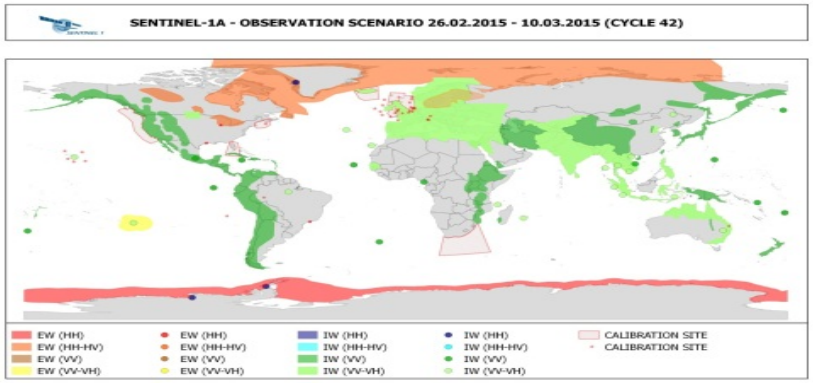
Results from pilot work in the period September 2015- February 2016

4. Observations strategy

Observations strategy

- **Continues exchanges between Seismic Hazards pilot lead and Sentinel-1 mission Project Manager in order to cover the entire tectonic mask.**





- **Study of the examination of the gaps of existing acquisition plans over megacities in areas of high seismic risk: Most sites are at least partially covered by SAR sensor and are:**

  -sites with high repeat coverage using Sentinel-1 and ALOS-2

  -sites with rare coverage using ascending or descending acquisitions from Radarsat-2, TerraSAR X, and COSMO-SkyMed.

https://sites.google.com/a/ingv.it/satellite-monitoring-of-geohazard-prone-megacities---satgeomeg/home

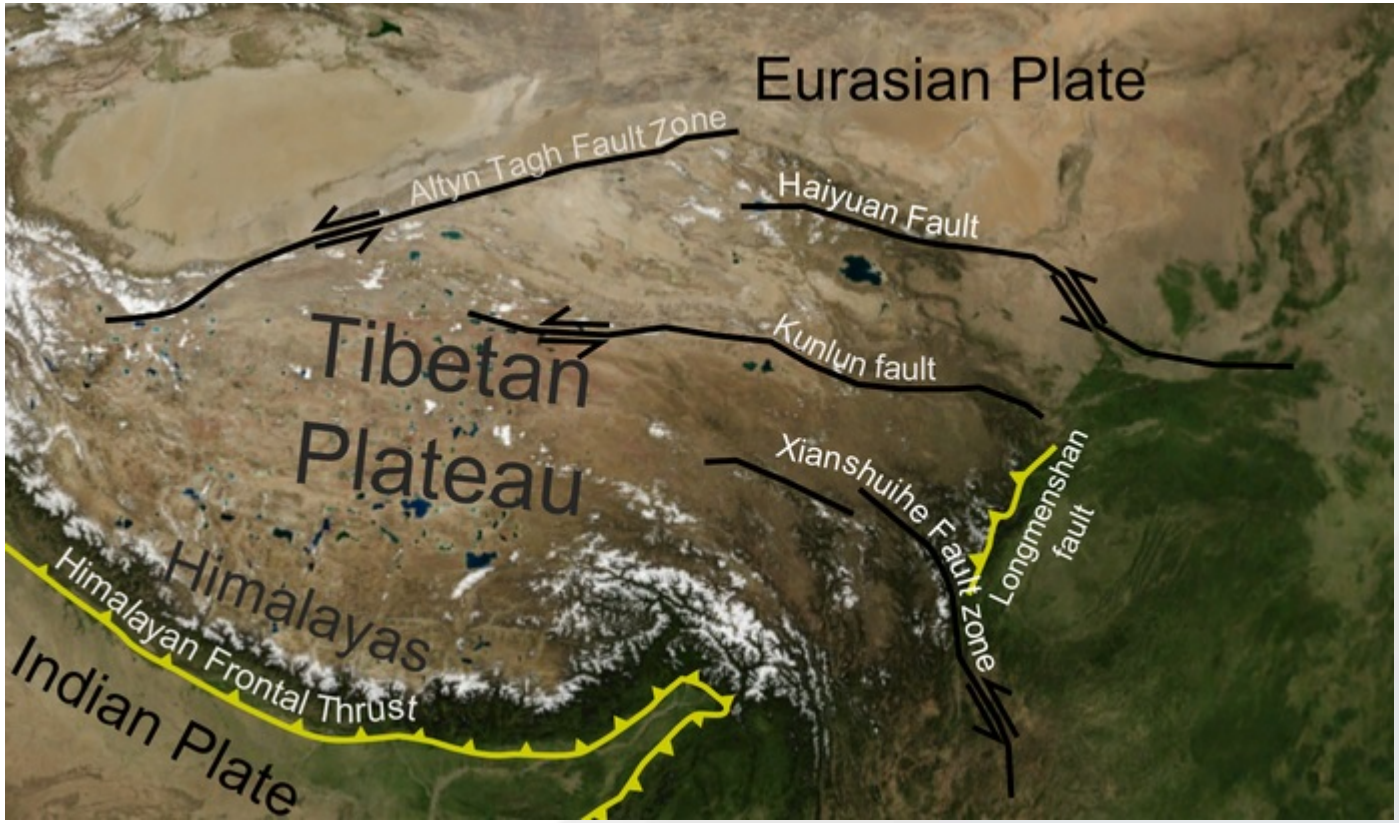
Issues and risks identified

Issues & risks identified

- **Organizing data supply to users has been time-consuming.**
- **User base consists essentially of EO and geophysical science users. End users need a scientific support to take decisions based on pilot results.**
- **Difficult to get detailed user feedback about the value of satellite data and how they exploited products.**
- **Accounting of data accessed can be difficult due to lack of user feedback.**

Thank you!

Haiyuan fault



Current status of GEP

What the Geohazard Exploitation Platform provides:

• a **geobrowser** able to search & map data collections from platform repository and from repositories of CEOS partners contributing data from outside the platform

• Allows using **Cloud appliances** (on demand processing) and have the test data available (as if on an external drive)

• Allows use of a **Developer Sandbox** to develop and integrate new scientific applications and subsequently exploit them against larger sets of data & computing resources

• Allows the users to **consume** via the geobrowser **Web Processing Services** exposed by the user's processing appliance as a Platform as a Service (PaaS) model.

• Exploits third party Web Processing Services such as **G-POD services**.

• Exposes appliances with **SBAS, GAMMA DInSAR, GAMMA L0, GAMMA, ROI-PAC, StaMPS, Doris , GMTSAR, PF-ASAR, Basic SSEP Toolbox, MATLAB and IDL, NEST v5.1, NEST Generic Toolbox, NEST Coreg, NEST InSAR**

• **Processors currently** under integration: **Sentinel-1 Toolbox, DIAPASON, NSBAS, S-1 INSAR QL Processor (DLR), SBAS hybrid, SBAS x S-1, pi-rate**