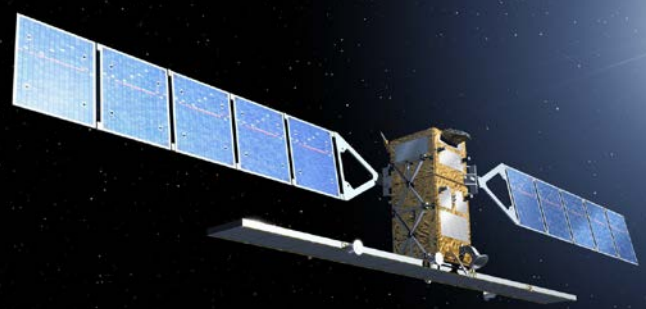
# Why the Sentinel-1 is a game changer for monitoring our restless planet: early results from INSARAP-B

Tim Wright, Andy Hooper, **Pablo J. González**, Richard Walters (COMET, University of Leeds, UK);
Yngvar Larsen (Norut, Tromsø, Norway);
Petar Marinkovic (PPO.labs, the Netherlands);
John Elliott (COMET, University of Oxford, UK)

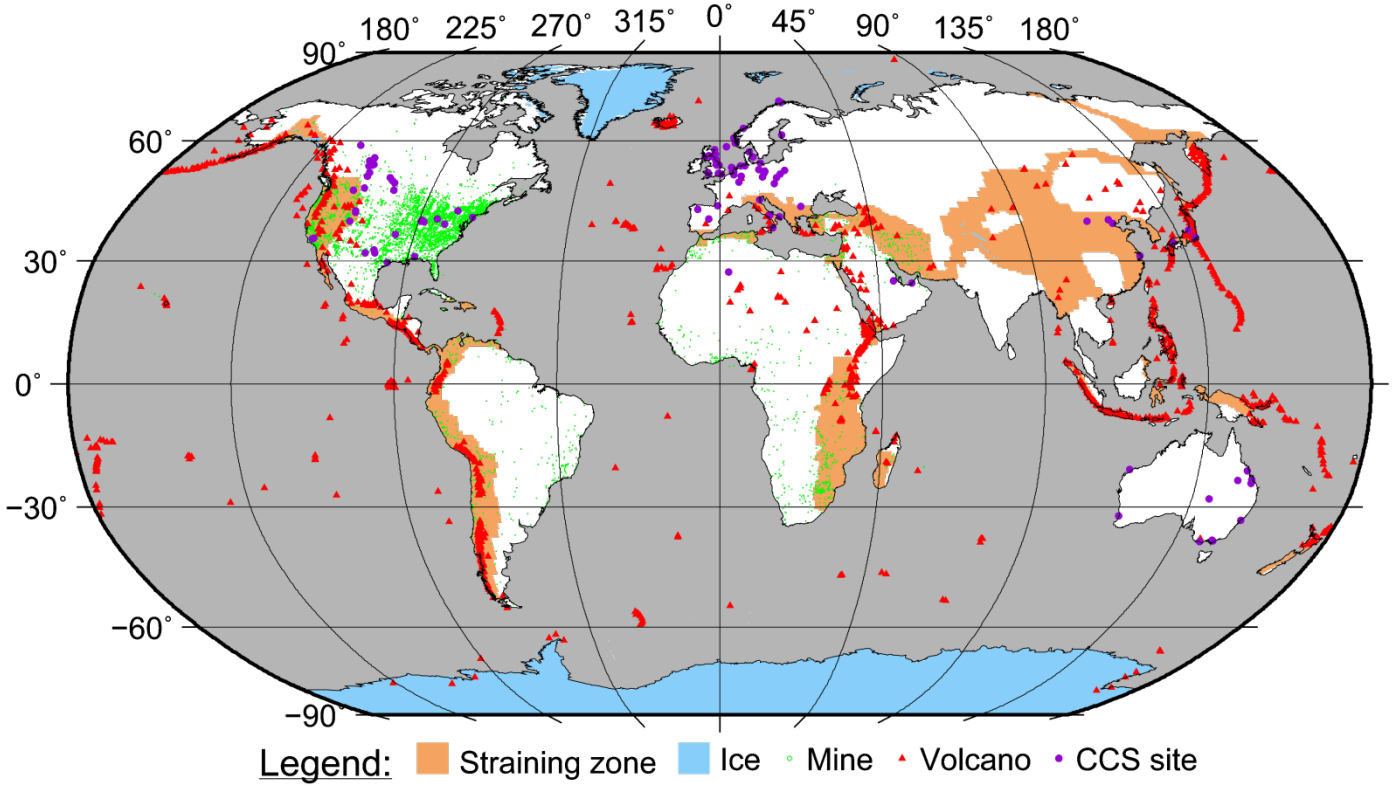
# Summary / Outline



| Sentinel-1 | Other SAR mission archives |
|---|---|
| 1. Systematic acquisitions for tectonics and volcanoes: “InSAR everywhere all the time” | Haphazard acquisitions (multiple modes, no unified strategy) |
| 2. TOPS: 250 km x 1000+ km: Continental scale InSAR | Small areas imaged, usually less than 100 km swaths. |
| 3. Small perpendicular baselines, acquisitions every 6/12/24 days, ascending and descending -> high coherence | Typically large perpendicular baselines and long gaps between acquisitions -> poor coherence |
| 4. 20 year operational program, designed for InSAR | Stand-alone missions not designed for InSAR |
| 5. Free, full and open data policy, enables mass processing. | Restricted data access, often commercial pricing |

# 1. “InSAR everywhere, all the time”

(NASA Solid Earth Science Working Group Report, 2002, NASA InSAR Workshop Report, 2004)



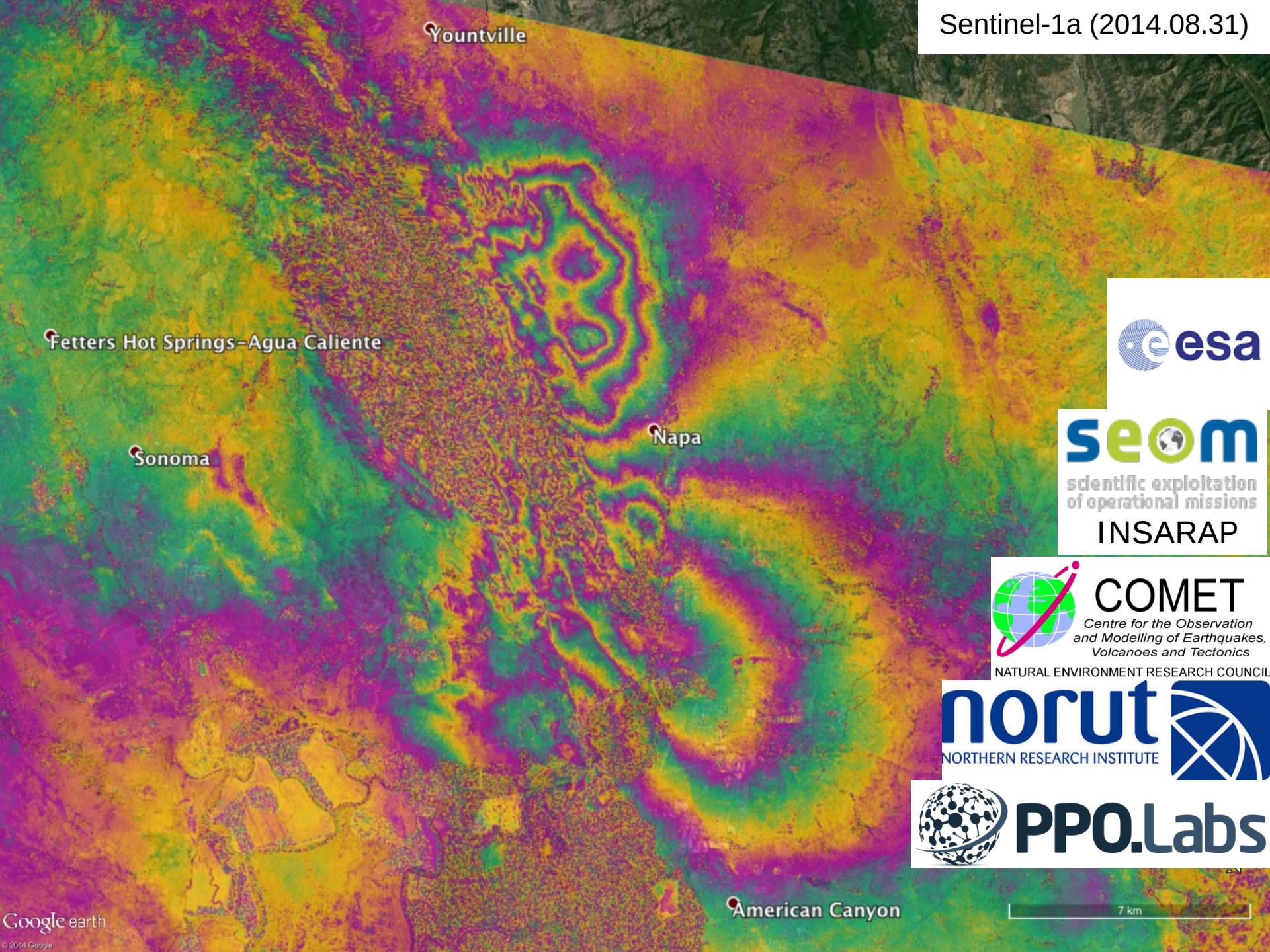

We can’t give short-term predictions for which faults will fail in earthquakes, and many volcanoes erupt without warning.

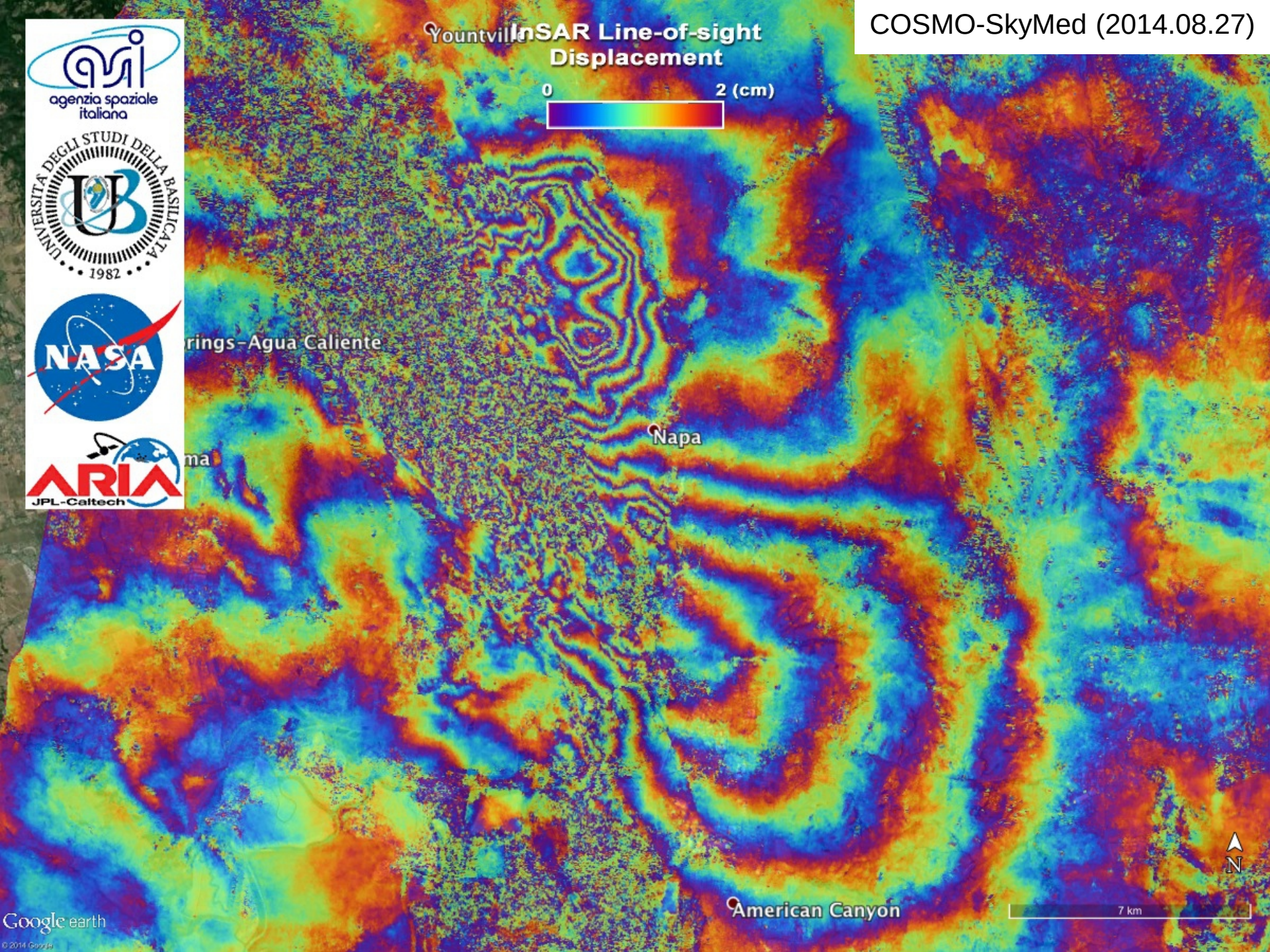
# 1. “InSAR everywhere, all the time”

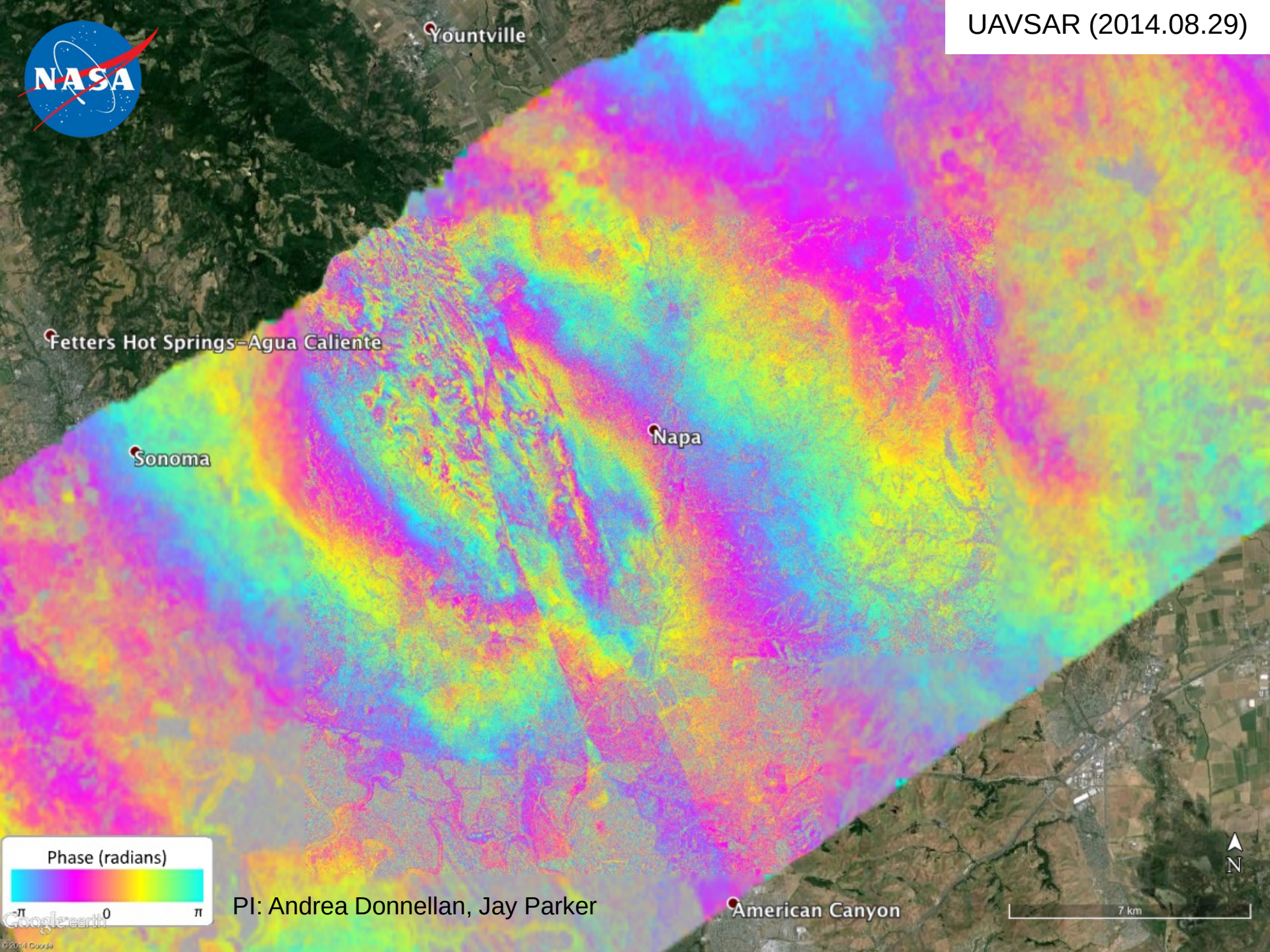
(NASA Solid Earth Science Working Group Report, 2002, NASA InSAR Workshop Report, 2004)


# 24 August 2014 South Napa Earthquake

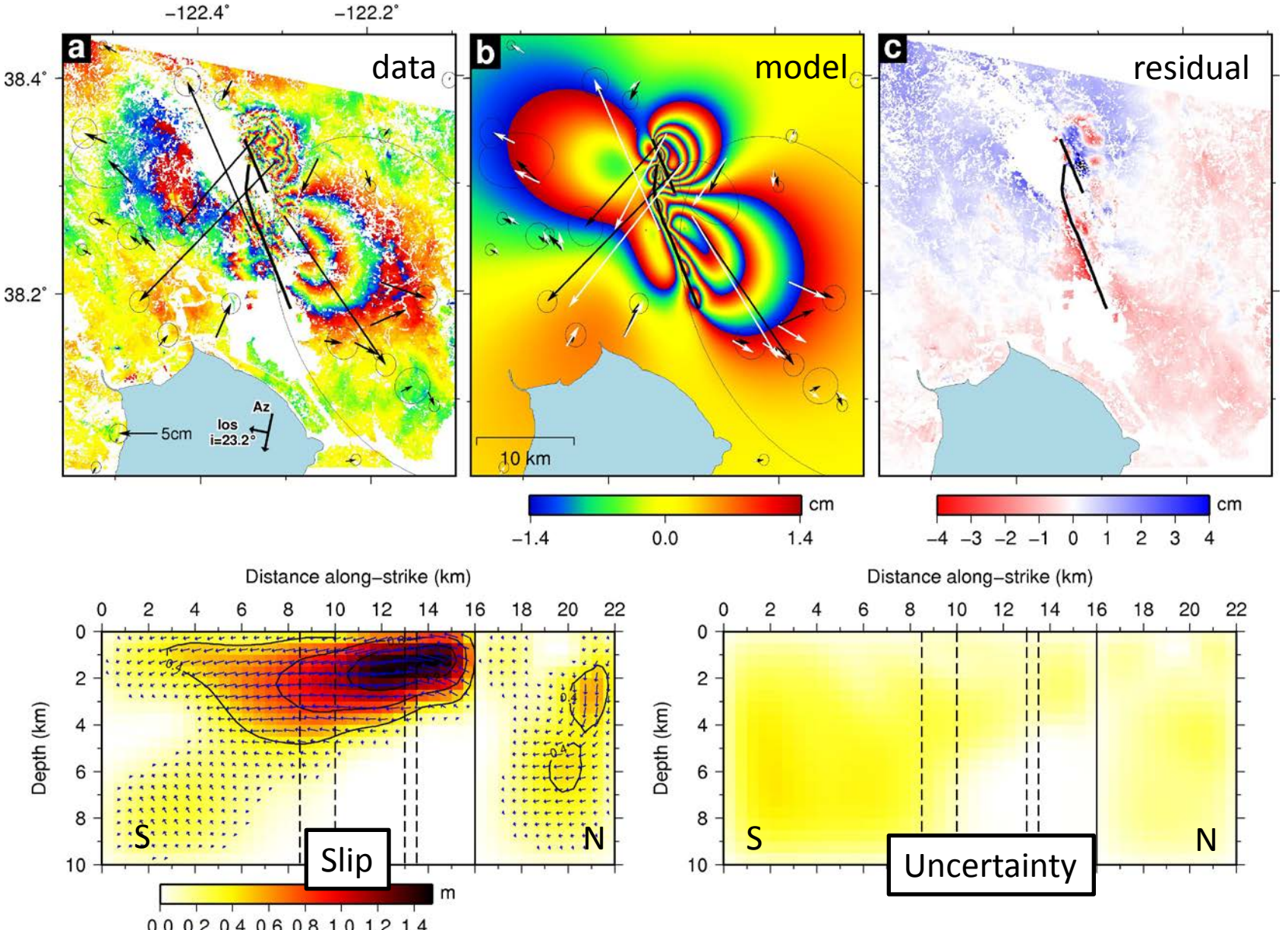
- Largest earthquake in California in 20 years.
- 1 death, ~160 injuries
- $1 Billion costs to wine industry
- Pre-earthquake Stripmap image acquired by Sentinel-1A on 7 August (the day it reached nominal orbit)
- Post-earthquake image on 31 August, scheduled by special request.


Sentinel-1a (2014.08.31)
Yountville
Fetters Hot Springs-Agua Caliente
Napa
Sonoma
American Canyon
7 km
Google earth
esa
seom
scientific exploitation of operational missions
INSARAP
COMET
Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics
NATURAL ENVIRONMENT RESEARCH COUNCIL
norut
NORTHERN RESEARCH INSTITUTE
PPO.Labs


COSMO-SkyMed (2014.08.27)
InSAR Line-of-sight Displacement
0
2 (cm)
Yountville
rings-Agua Caliente
Napa
American Canyon
N
7 km
Google earth
agenzia spaziale italiana
UNIVERSITÀ DEGLI STUDI DELLA BASILICATA
1982
NASA
ARIA
JPL-Caltech


UAVSAR (2014.08.29)
Yountville
Fetters Hot Springs-Agua Caliente
Sonoma
Napa
American Canyon
Phase (radians)
-π
0
π
N
7 km
PI: Andrea Donnellan, Jay Parker

# Source model from InSAR and GPS

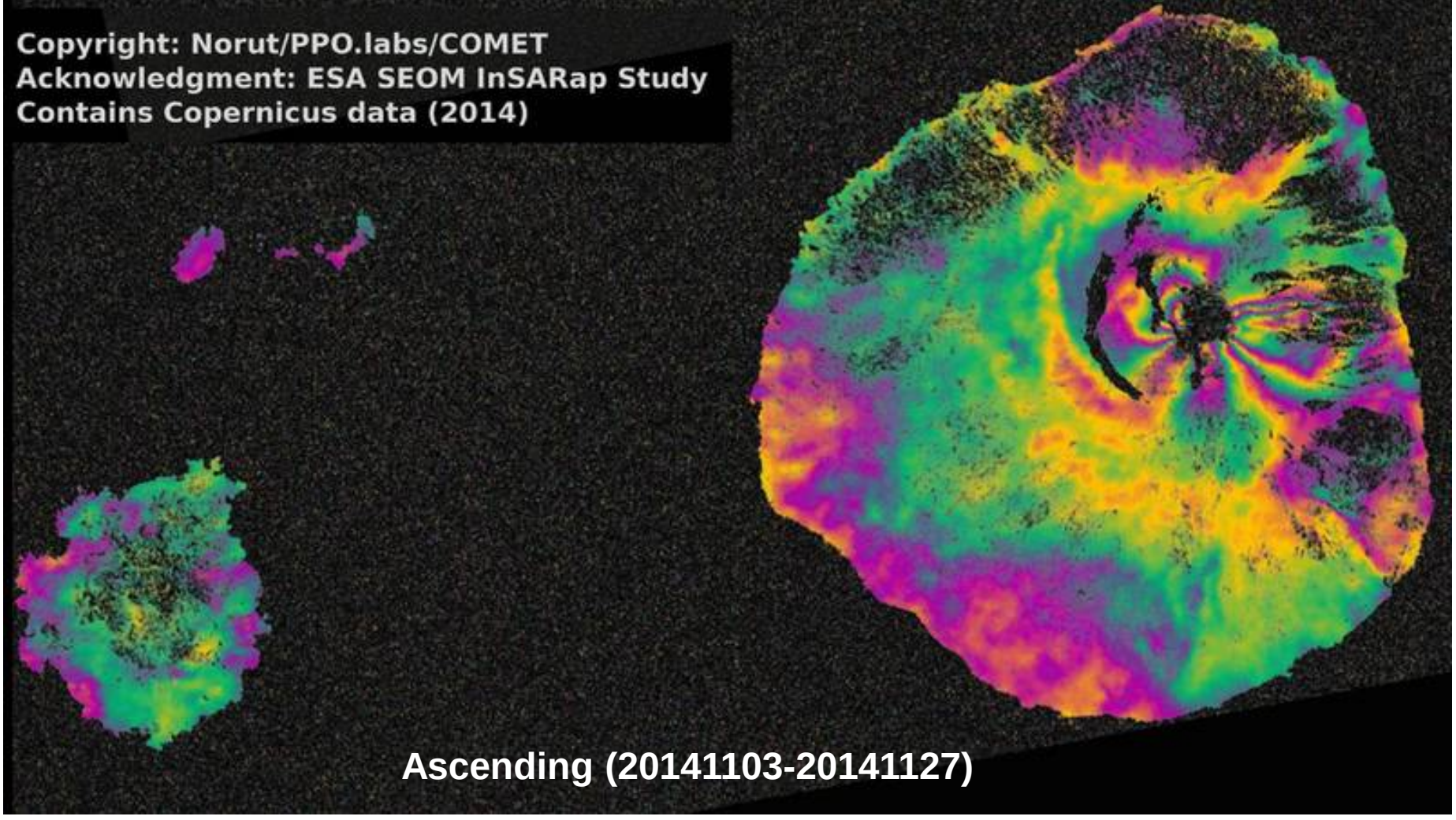


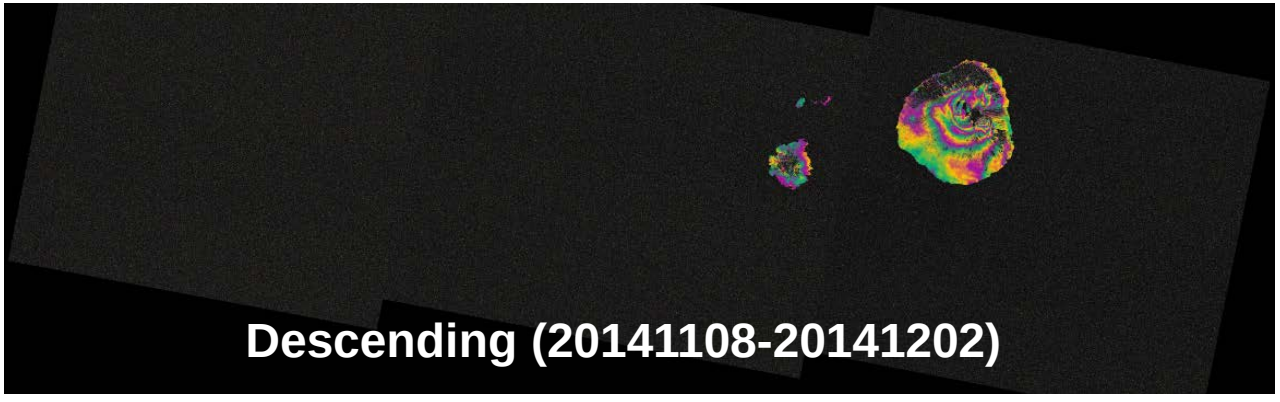
# 2014 Pico do Fogo eruption (Ilha do Fogo, Cabo Verde)


wikicommons

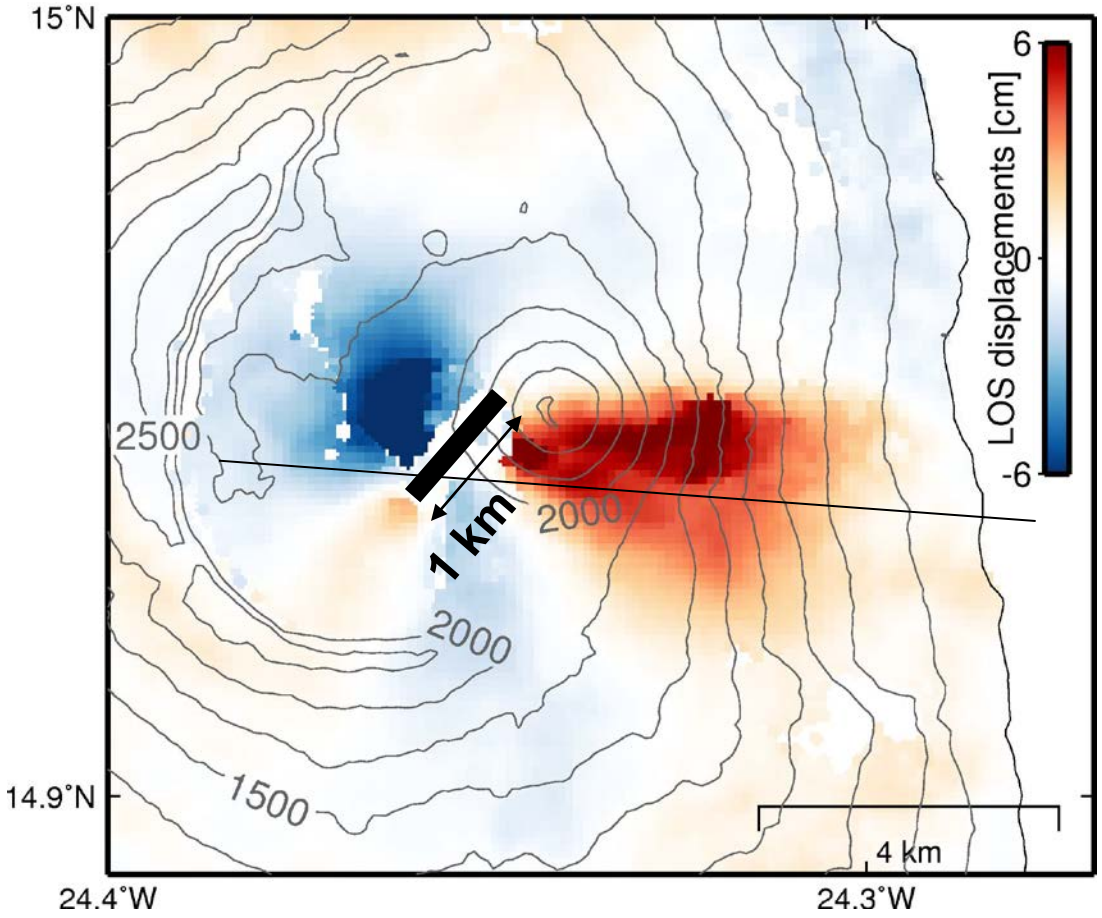
# 23 Nov 2014 Pico do Fogo Eruption

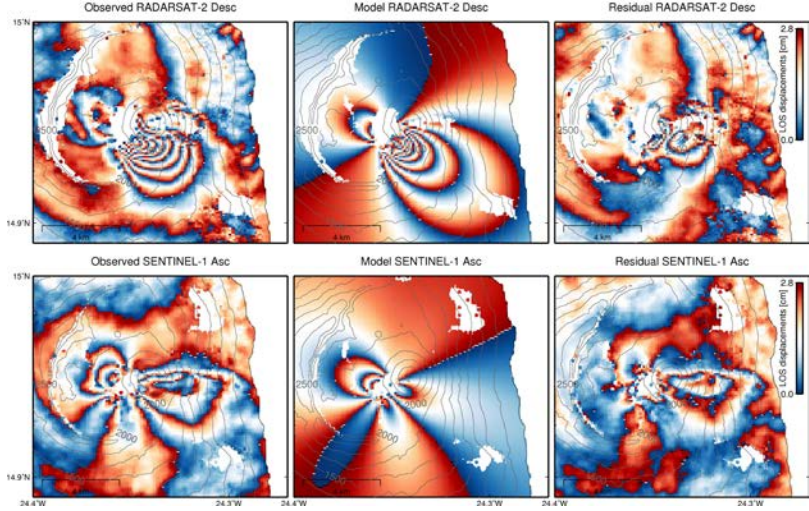
- 1st eruption in 20 yrs (1995)
- Flights to S. America diverted
- ~1500 evacuated people
- Damages not yet evaluated
- Up to today, two towns completely destroyed

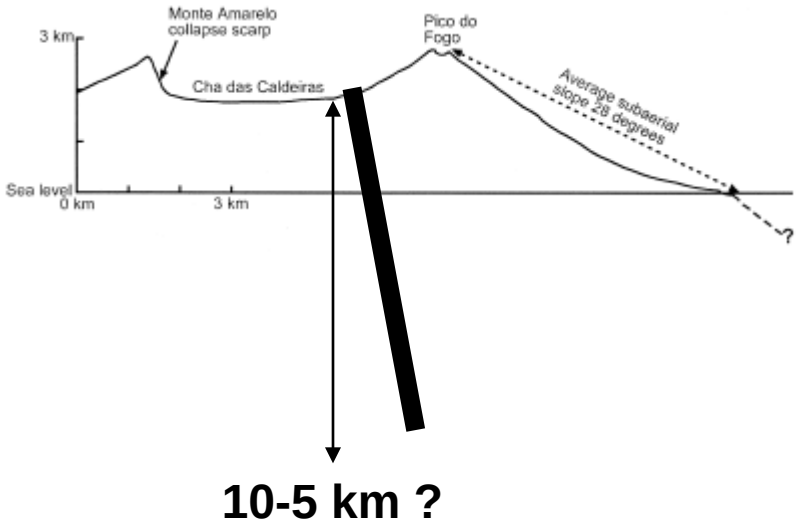


Copyright: Norut/PPO.labs/COMET
Acknowledgment: ESA SEOM InSARap Study
Contains Copernicus data (2014)
Ascending (20141103-20141127)


Descending (20141108-20141202)

# Preferred Model



# Eruption isn't over and Sentinel-1 data continues providing critical information

Office Outlook Web Access | Type here to search | This Folder | Address Book | Options | Log Off

Mail
Calendar
Contacts

Deleted Items (18)
Drafts [2]
Inbox
Junk E-Mail
Sent Items

Click to view all folders

Manage Folders...

Reply | Reply to All | Forward | Move | Delete | Close

**Fogo -- mapping of lava front advance with InSAR?**

Sandra Heleno [sandra.heleno@ist.utl.pt]

You replied on 09/12/2014 22:18.

**Sent:** 09 December 2014 16:35
**To:** Pablo Jose Gonzalez Mendez
**Cc:** Joao Fonseca [jfonseca@tecnico.ulisboa.pt]; Vittorio.Bosi@protezionecivile.it; Giuseppe Cornaglia [giuseppe.cornaglia@prociv.pt]; ana.p.falcao@tecnico.ulisboa.pt; anafonseca@lnec.pt; Bruno Faria [brunofaria@sapo.cv]

Dear Pablo,

Cloud cover is precluding efficient mapping of the lava front advance inside
the caldera by the Copernicus emergency service.
The situation is very critical, since authorities need information to decide
on evacuation measures.
Would your group at Leeds be able to help with InSAR, using decorrelation?

Thanks a lot for your support.

Kind regards,
Sandra

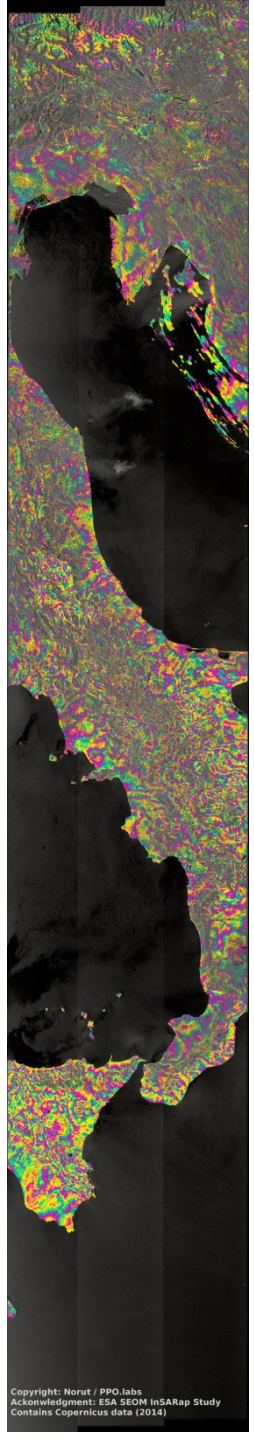
-----Original Message-----
From: Sandra Heleno [mailto:sandra.heleno@ist.utl.pt]
Sent: terça-feira, 9 de Dezembro de 2014 14:54
To: 'Pablo Jose Gonzalez Mendez'
Subject: Video taken last sunday in Fogo

Hi again Pablo,

Just to give you some info on the situation in Fogo.
Things are getting really rough. All (2, totaling 700 people) villages
inside the caldera were destroyed.
Local authorities are now concerned with the population outside the caldera.

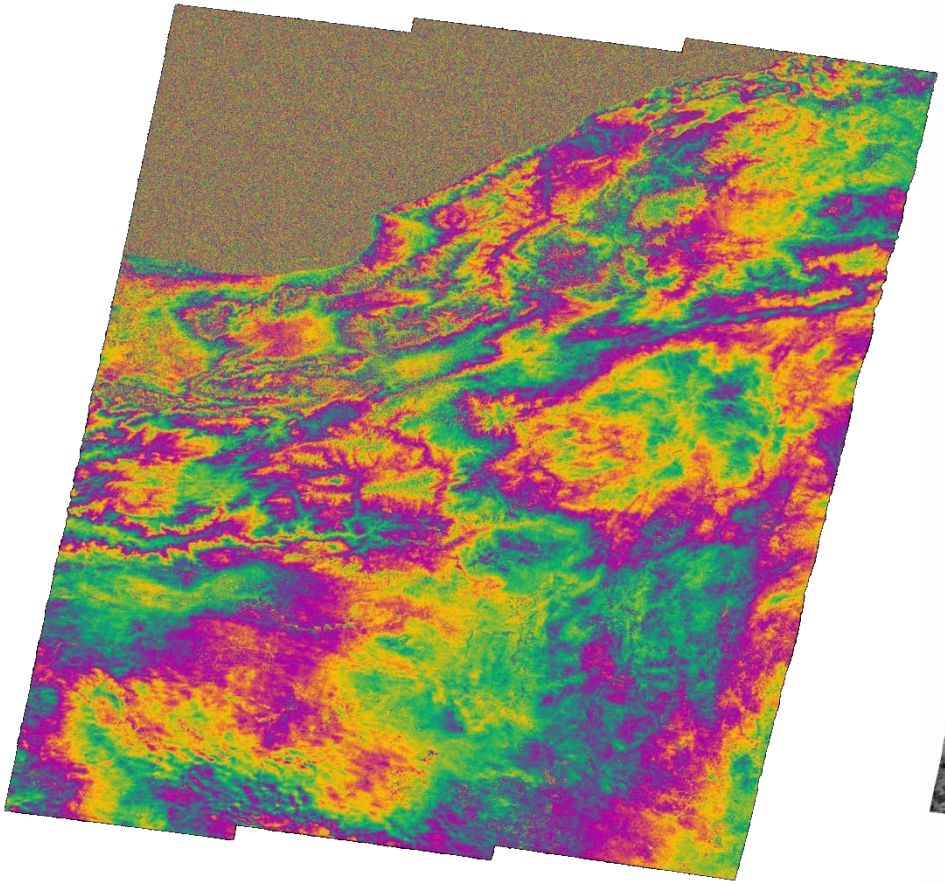
Dec. 8th *former* Bangaeira

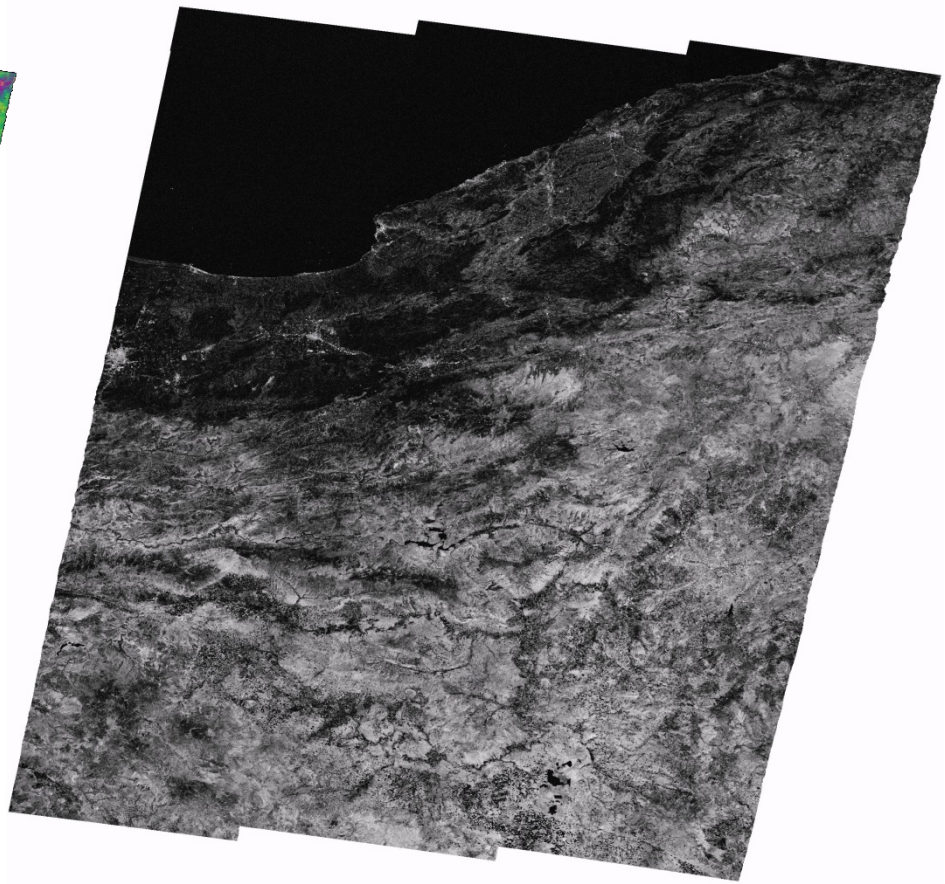
# 2. Continental Scale InSAR



# 3. Short revisit and Small perpendicular baselines -> Excellent Coherence

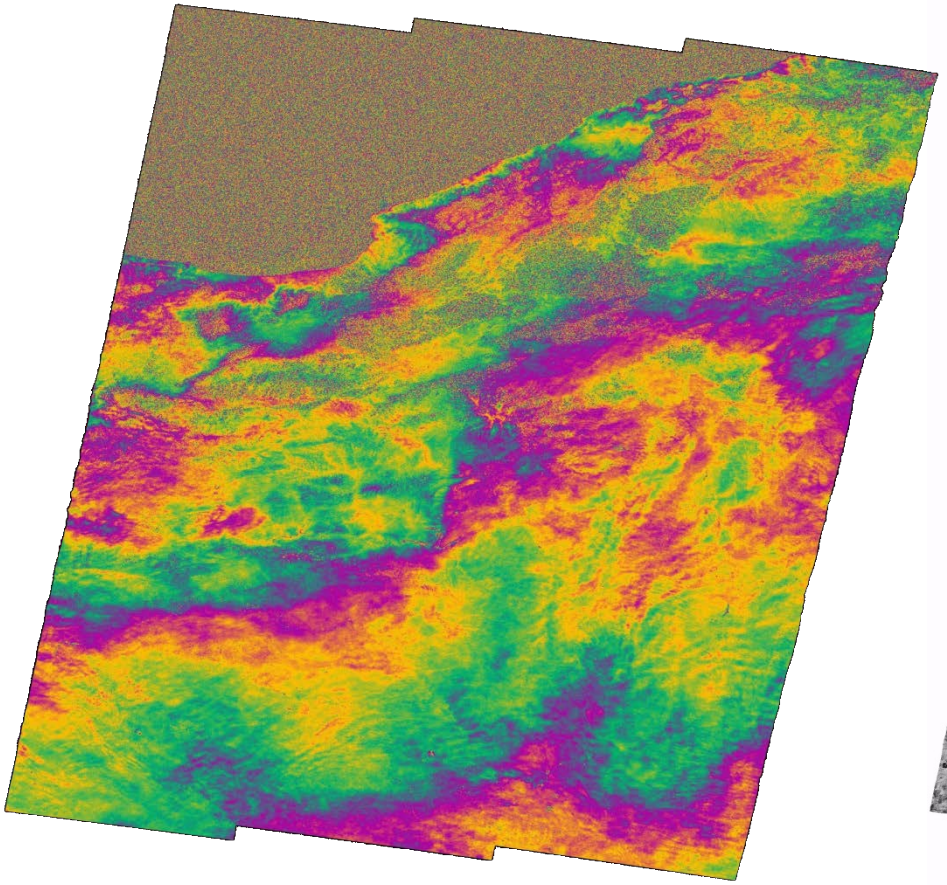
Creeping section of the North Anatolian Fault, 12-days

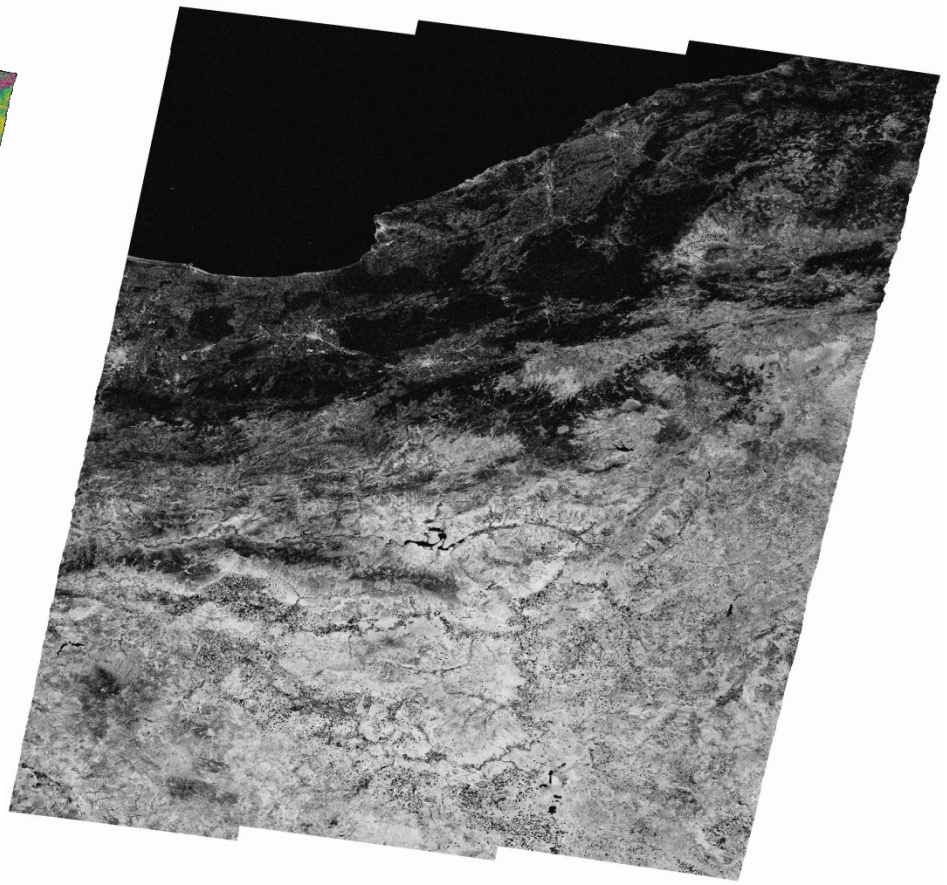




# 3. Short revisit and Small perpendicular baselines -> Excellent Coherence

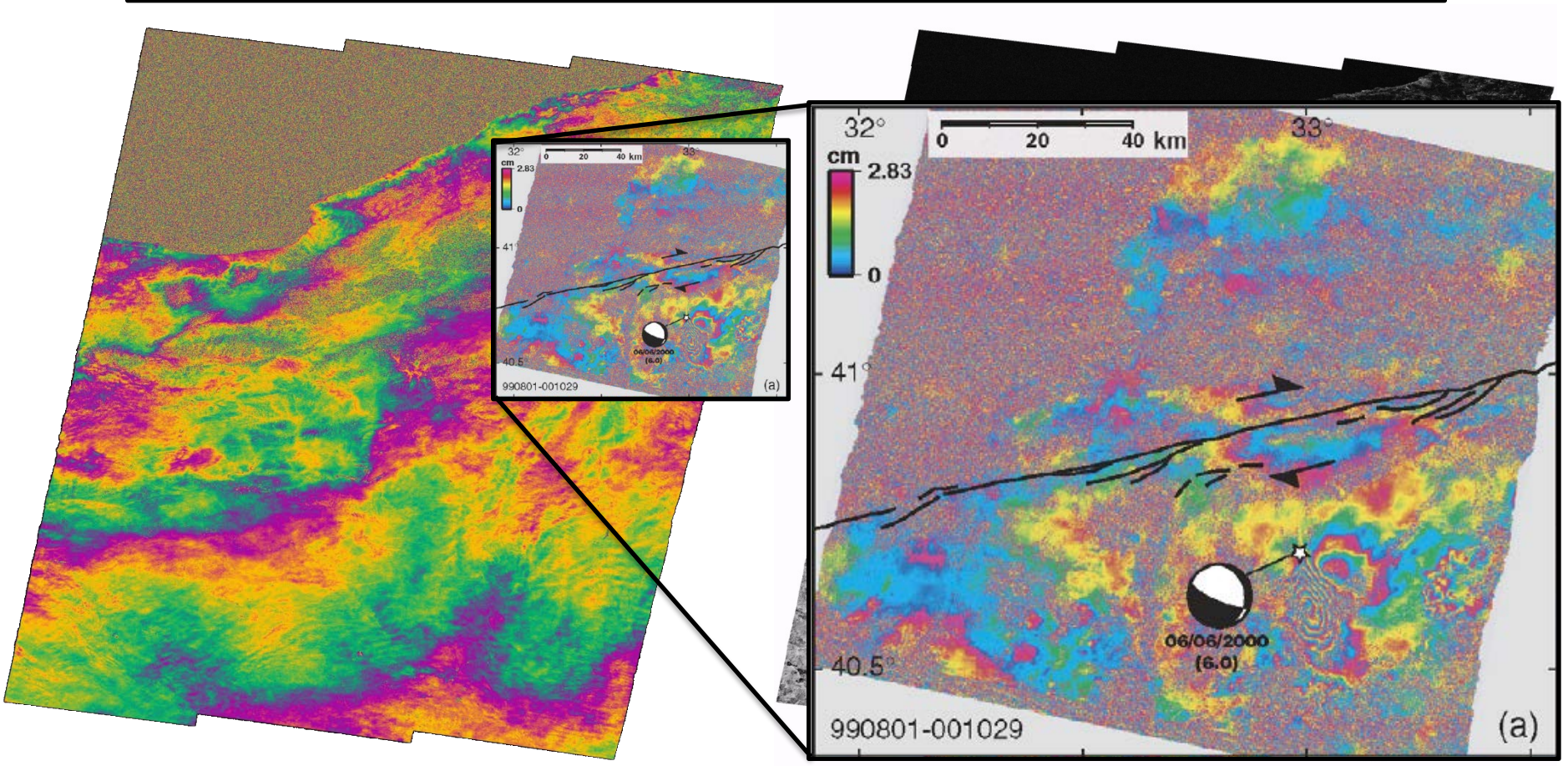
Creeping section of the North Anatolian Fault, 24-days





# 3. Short revisit and Small perpendicular baselines -> Excellent Coherence

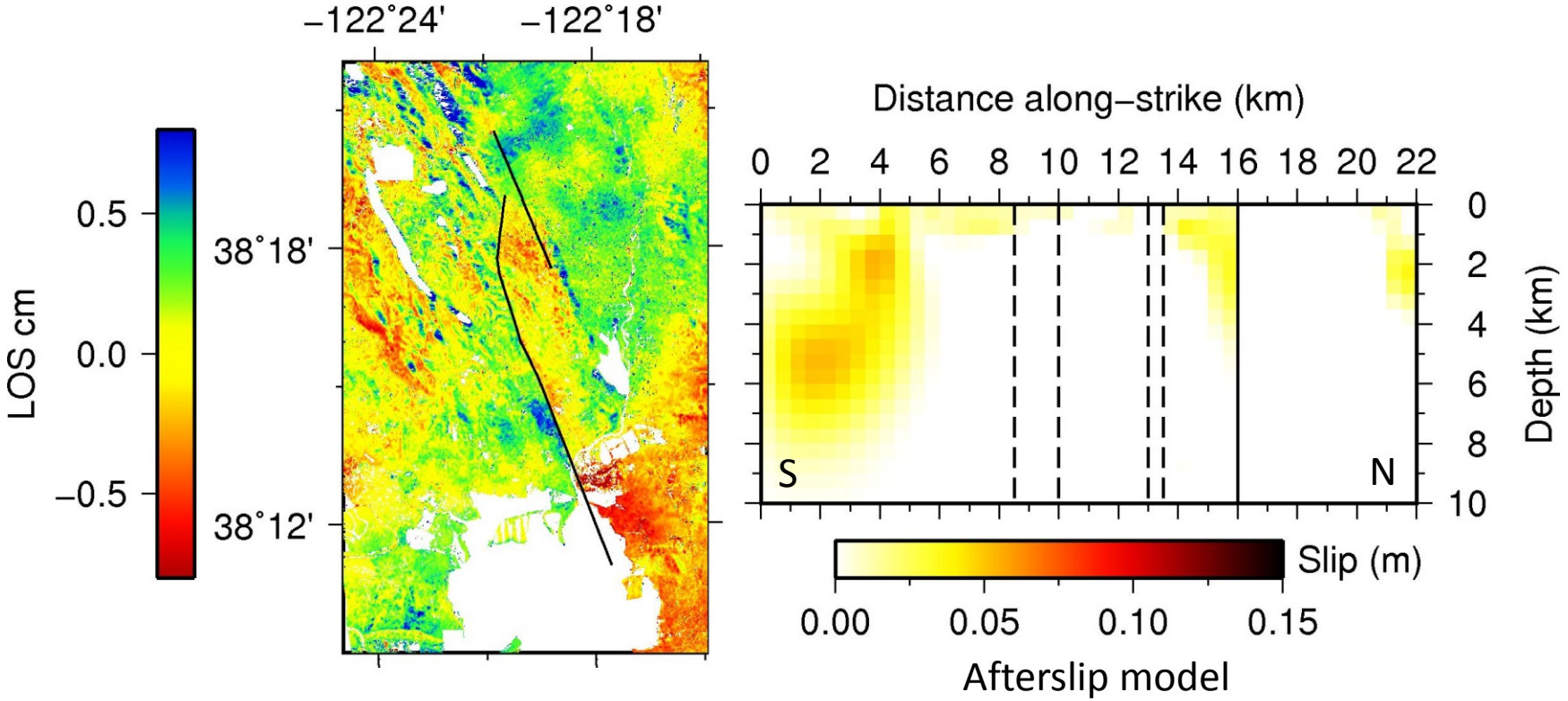
Creeping section of the North Anatolian Fault, 24-days




Typical ERS coherence (Cakir et al., 2005)

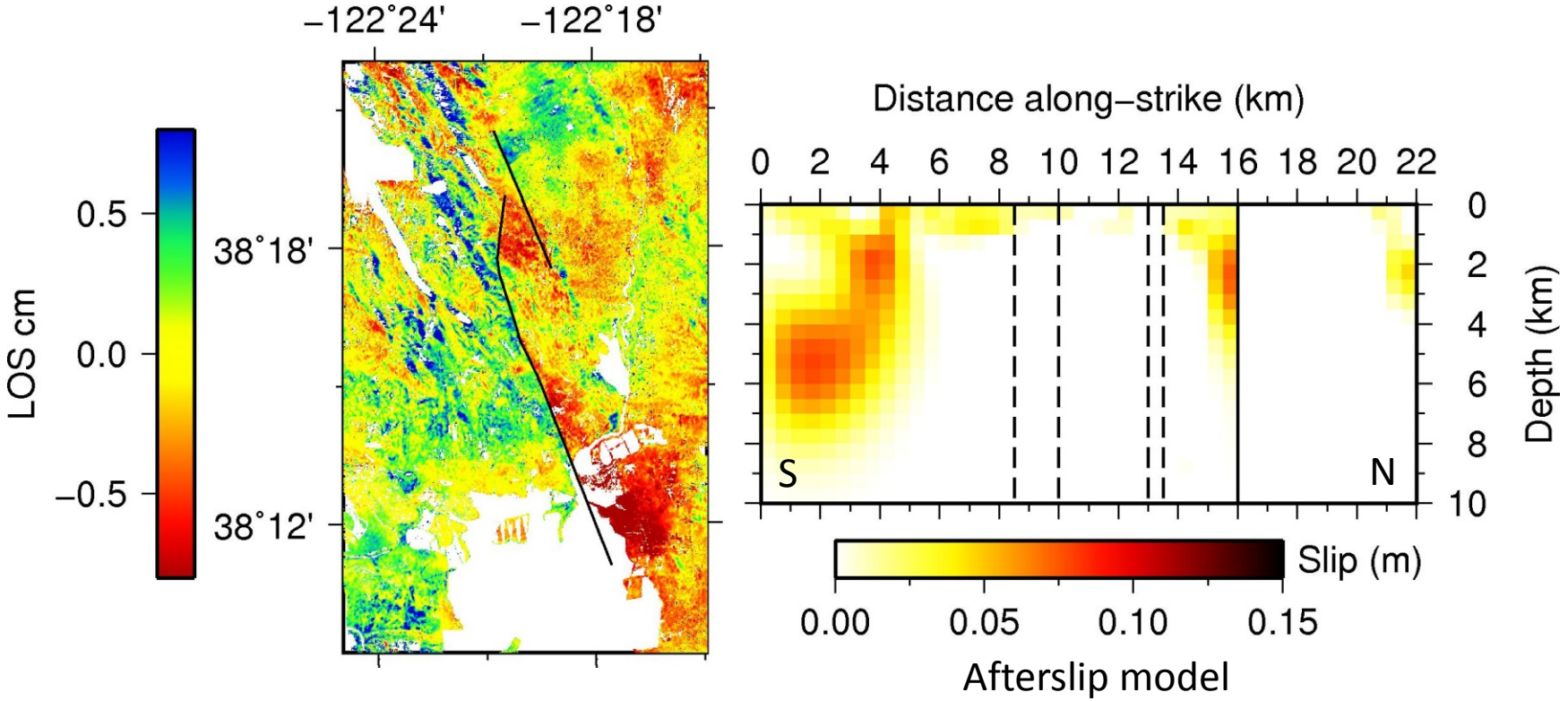
# 3. Short revisit -> rapid phenomena

Napa Postseismic deformation: 31 August – 12 September 2014



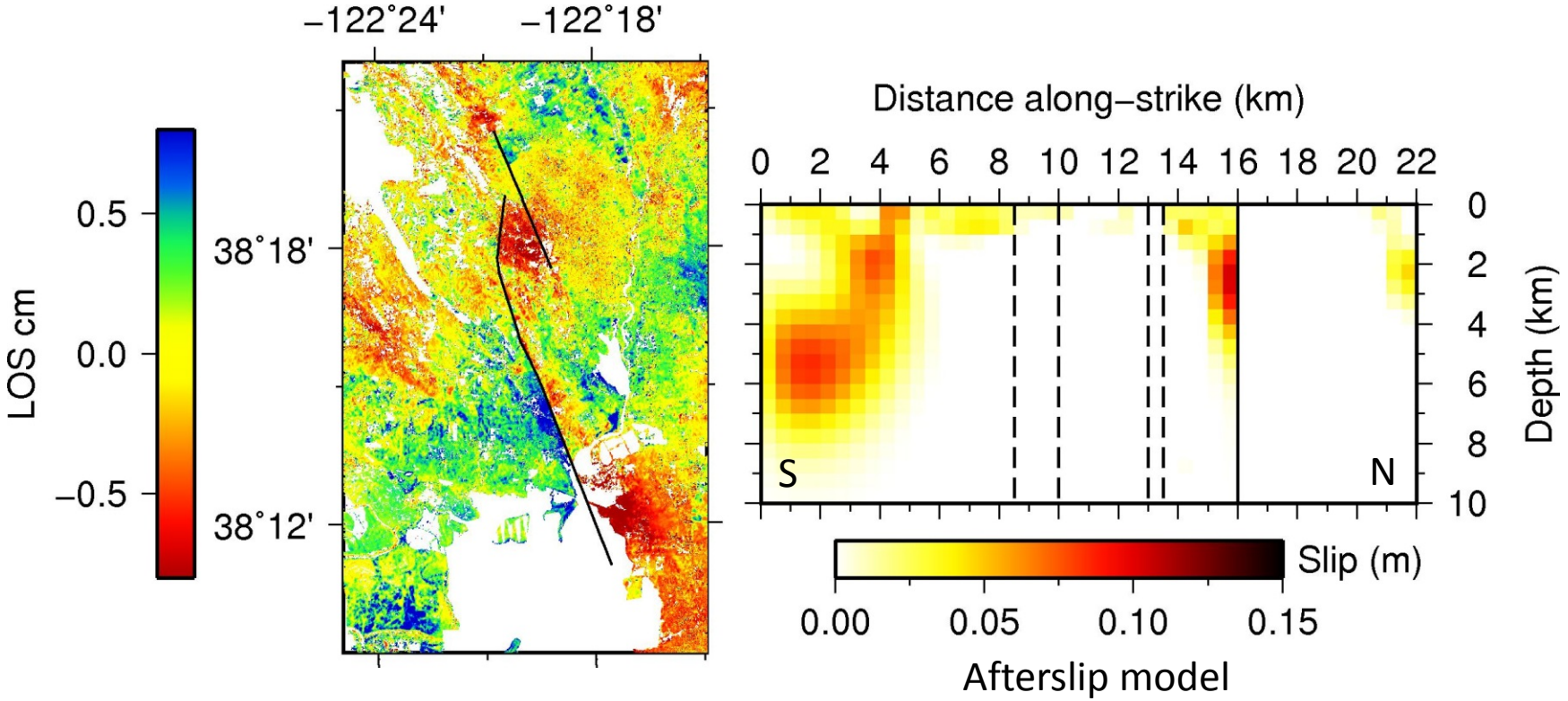
# 3. Short revisit -> rapid phenomena

Napa Postseismic deformation: 31 August – 24 September 2014



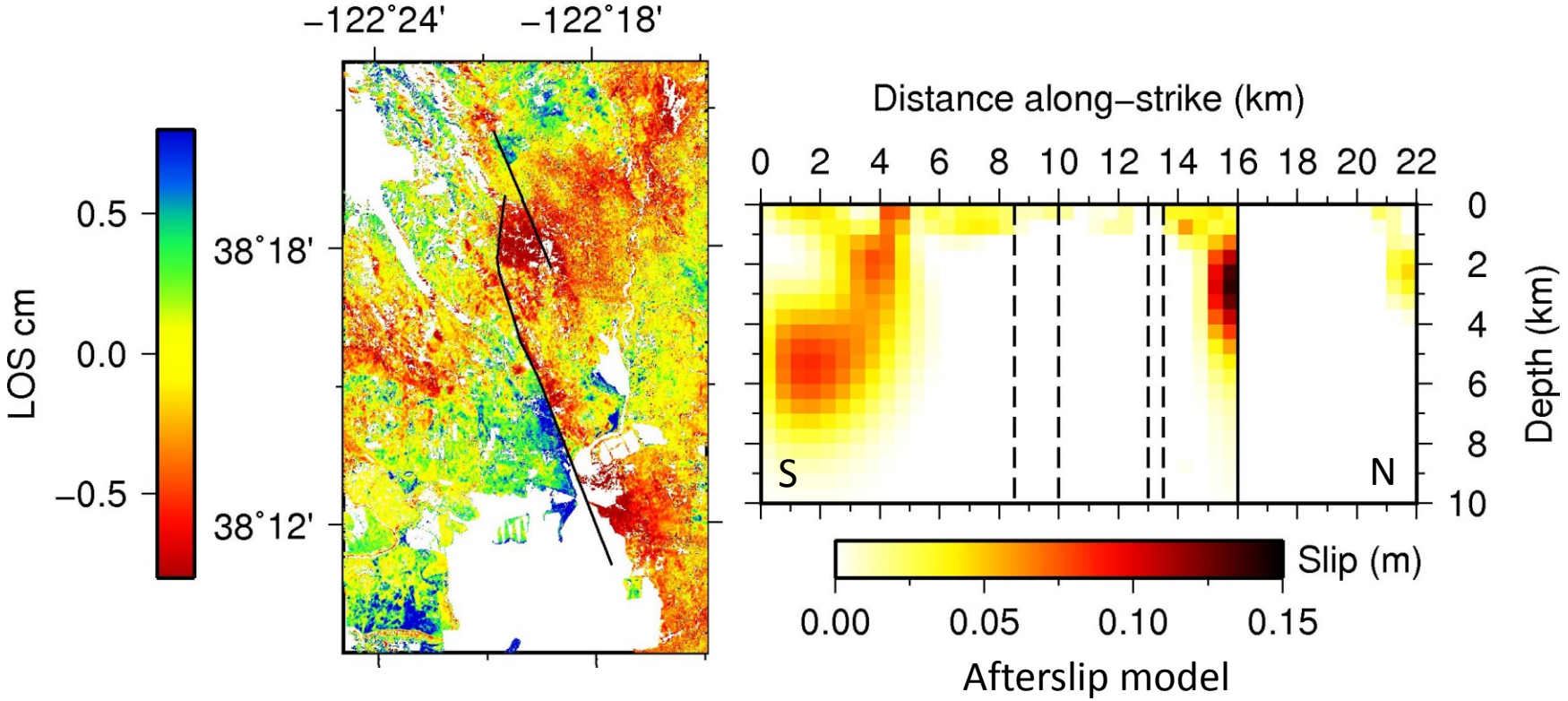
# 3. Short revisit -> rapid phenomena

Napa Postseismic deformation: 31 August – 6 October 2014



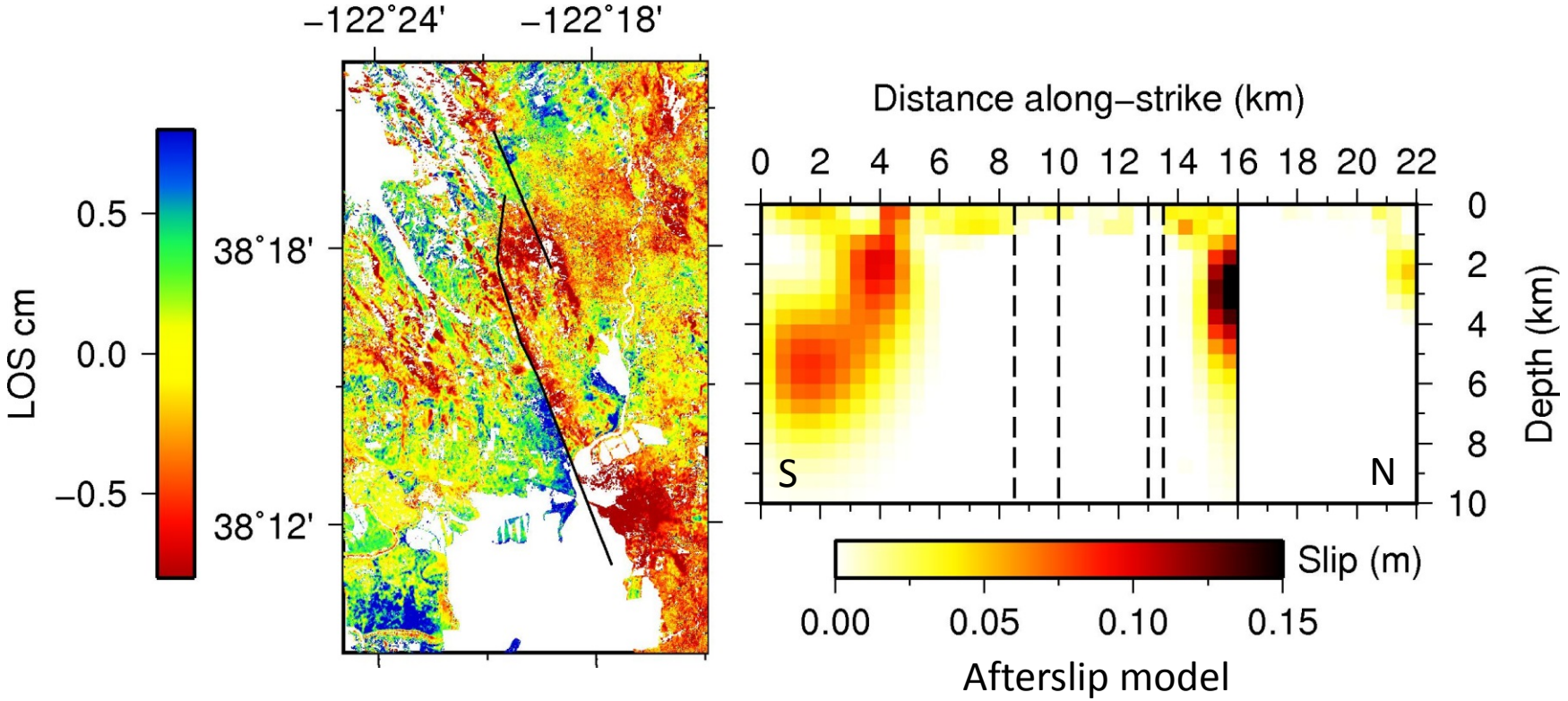
# 3. Short revisit -> rapid phenomena

Napa Postseismic deformation: 31 August – 18 October 2014

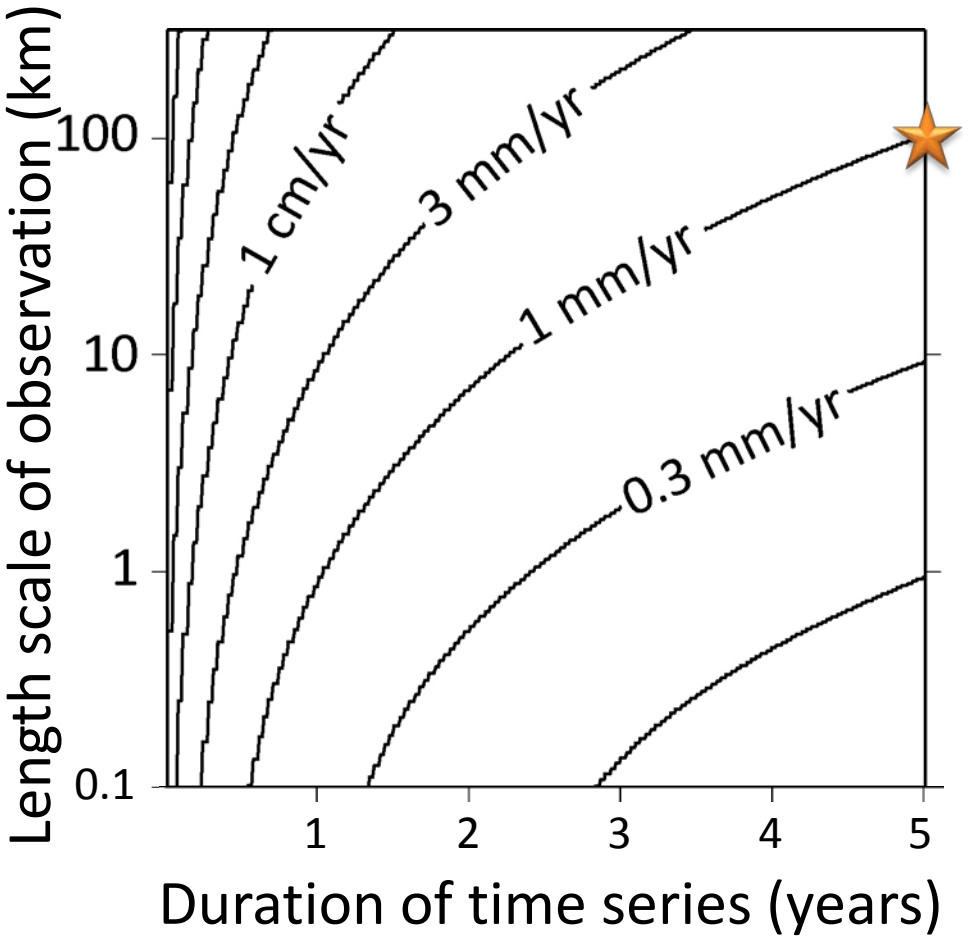


# 3. Short revisit -> rapid phenomena

Napa Postseismic deformation: 31 August – 30 October 2014

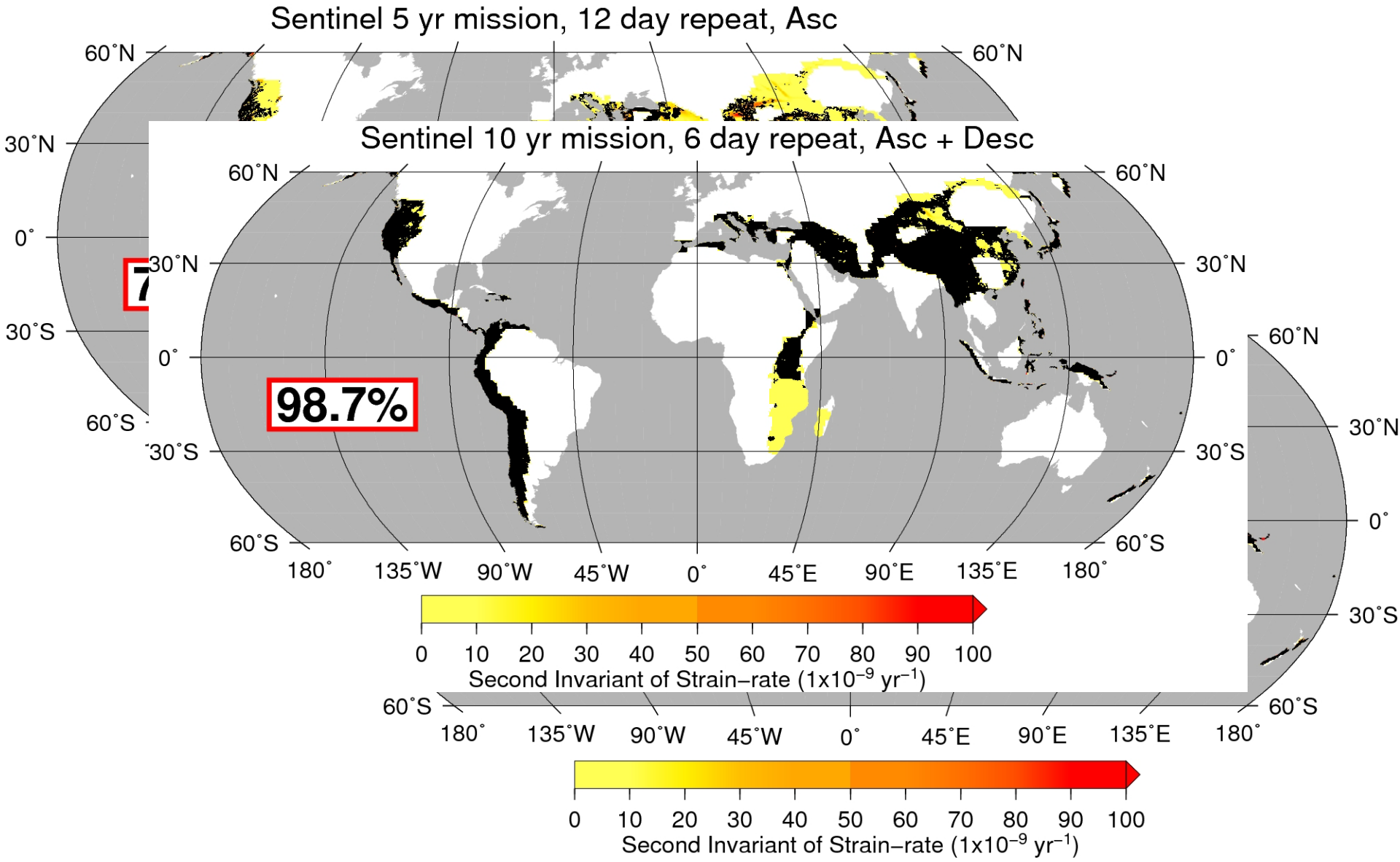


# 4. 20-year operational program




1 mm/yr rates over 100 km can be achieved with 5 years of acquisitions (12 day revisit)

# Ability of Sentinel-1 to map tectonic strain above target threshold (1 mm/yr over 100 km)

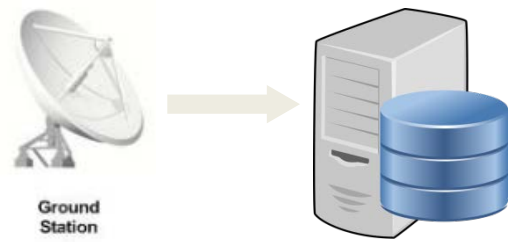


# 5. “Free, full and open” data policy
# ⇒ Mass Processing

***UK-PAF***

CATAPULT Satellite Applications

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL



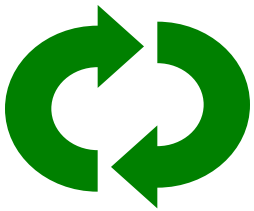

***Sentinel-1 SAR processor***

***Sentinel-1 archive***
***mainly for Copernicus core services***

***Farnborough***

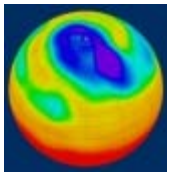
***1-month Sentinel-1 rolling archive***

***SLCs***



***storage facility (and future public services)***

CEMS
An ISIC Facility



***CEDA***

***processing facility***


***LiCS processing facility***

***Harwell***

# Conclusions

- The Sentinel-1 constellation will be transformative for Tectonic and Volcanic Geodesy.
- Early results are very encouraging.
- Once data access issues are fully resolved, we look forward to two decades of incredible science from this mission.

# Validation with Radarsat-2

Ascending

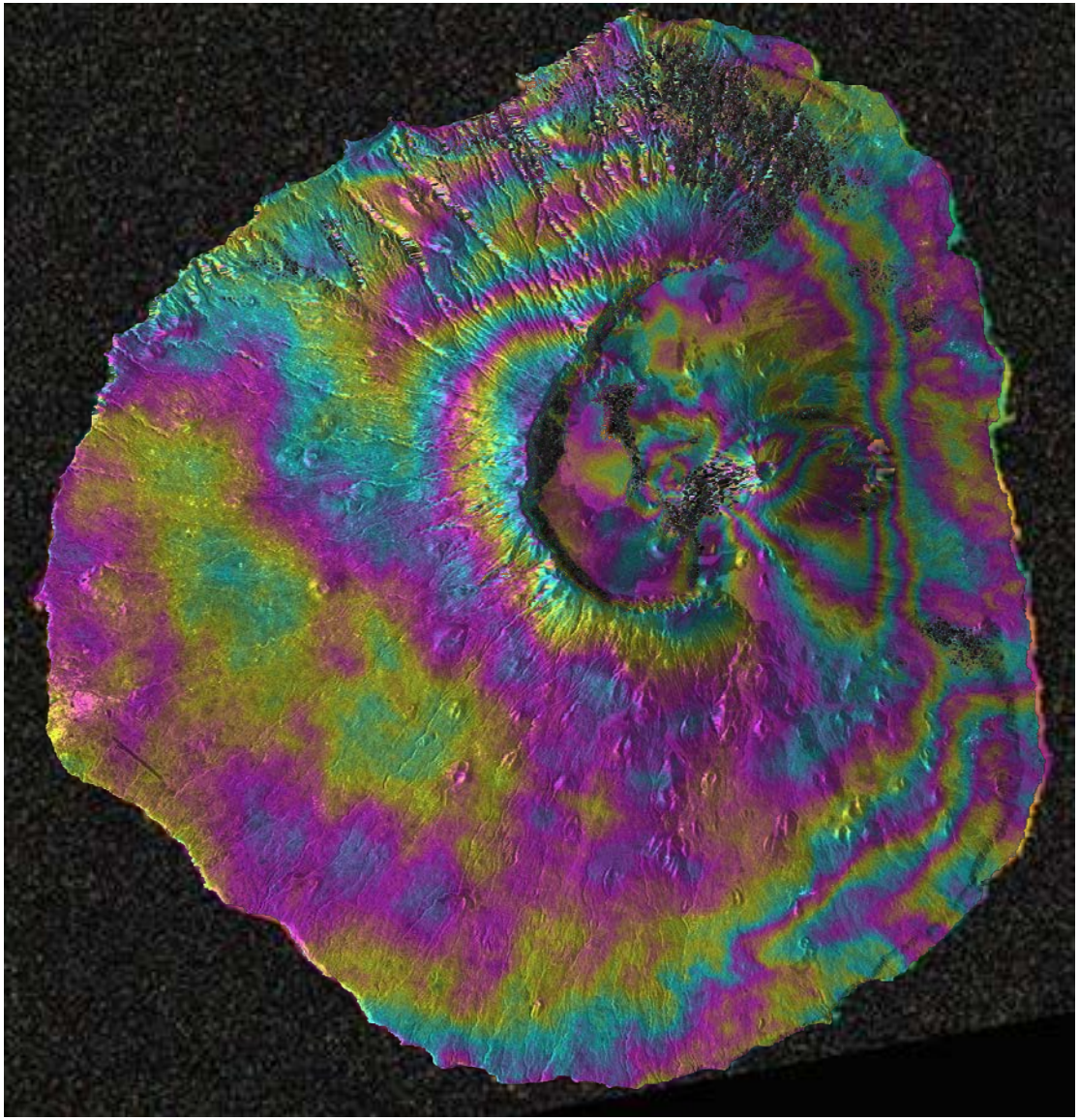
Inc_S1=42

Inc_R2=37

Fine mode

R2 (12/11-06/12)

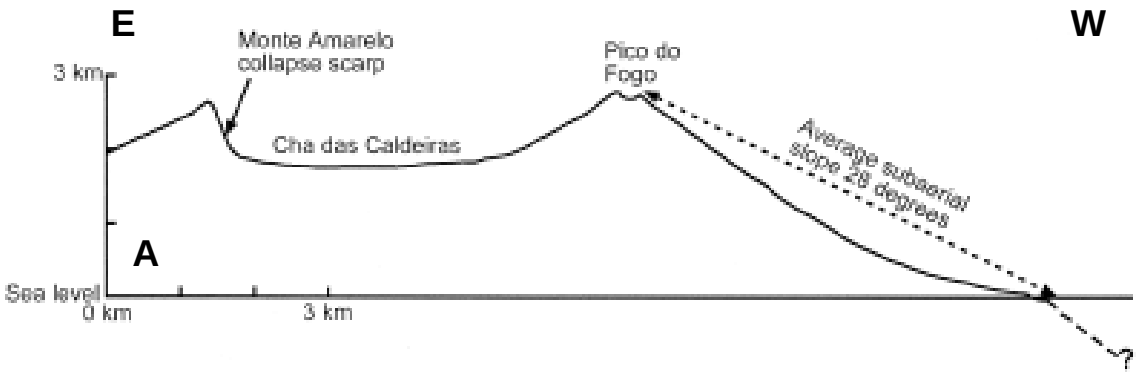
S1 (03/11-27/11)

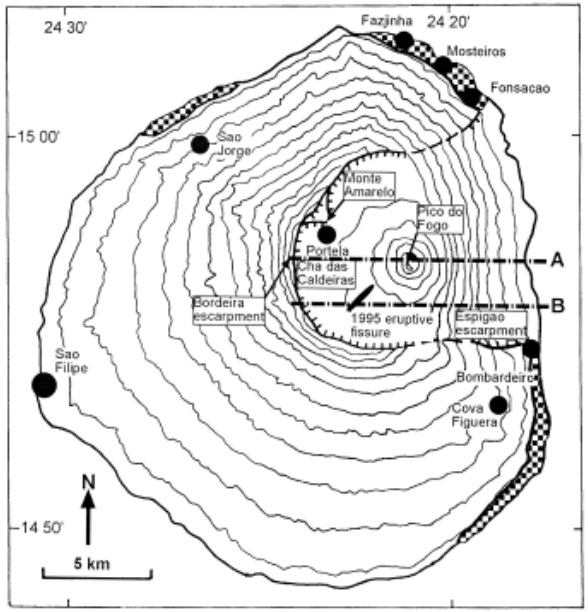


# Volcano with very steep topo

Local researchers' concerns on unexpected evolution

Sentinel-1 data helped to answer critical questions


Day et al., (1999)