# The SIGRIS operational system

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# The SIGRIS project

An ASI-funded project (2.7 M€) to demonstrate the potential of satellite imagery (focus on COSMO-SkyMed) for the operational monitoring of the Earthquake Cycle and the management of the Seismic Risk.

# Specific tasks

Generate state-of-the-art scientific products for operational use by the Civil Protection Service to support two Seismic Risk Management phases:

1. Knowledge & Prevention, i.e. support to the Seismic Hazard assessment

2. Crisis, i.e. support to the Emergency management

# The SIGRIS User

Pre-operational demonstration at the Italian scale.

Only one User: the **National Civil Protection Service**

Scientific demonstration for the global scale.

Products generated and published as scientific results (no reference User).

# Two operation modes

1. **Normal Routine Operations**: products to support Seismic Hazard Assessment are generated through long-term activities (Inter-seismic monitoring)

2. **Crisis Operations**: the generation of NRT co-seismic and post-seismic products is activated for EQs > M5-5.5. Incremental product versions are normally provided for a few months.

# User needs for the Crisis management

*User needs (in NRT):*

- Plan and safely execute search and rescue operations
- Define the area to evacuate
- Find the best locations for emergency shelters
- Estimate probability of large aftershocks
- Assess increments of induced risks (landslides, sinkhole collapse, flooding, etc.)

SiGRiS

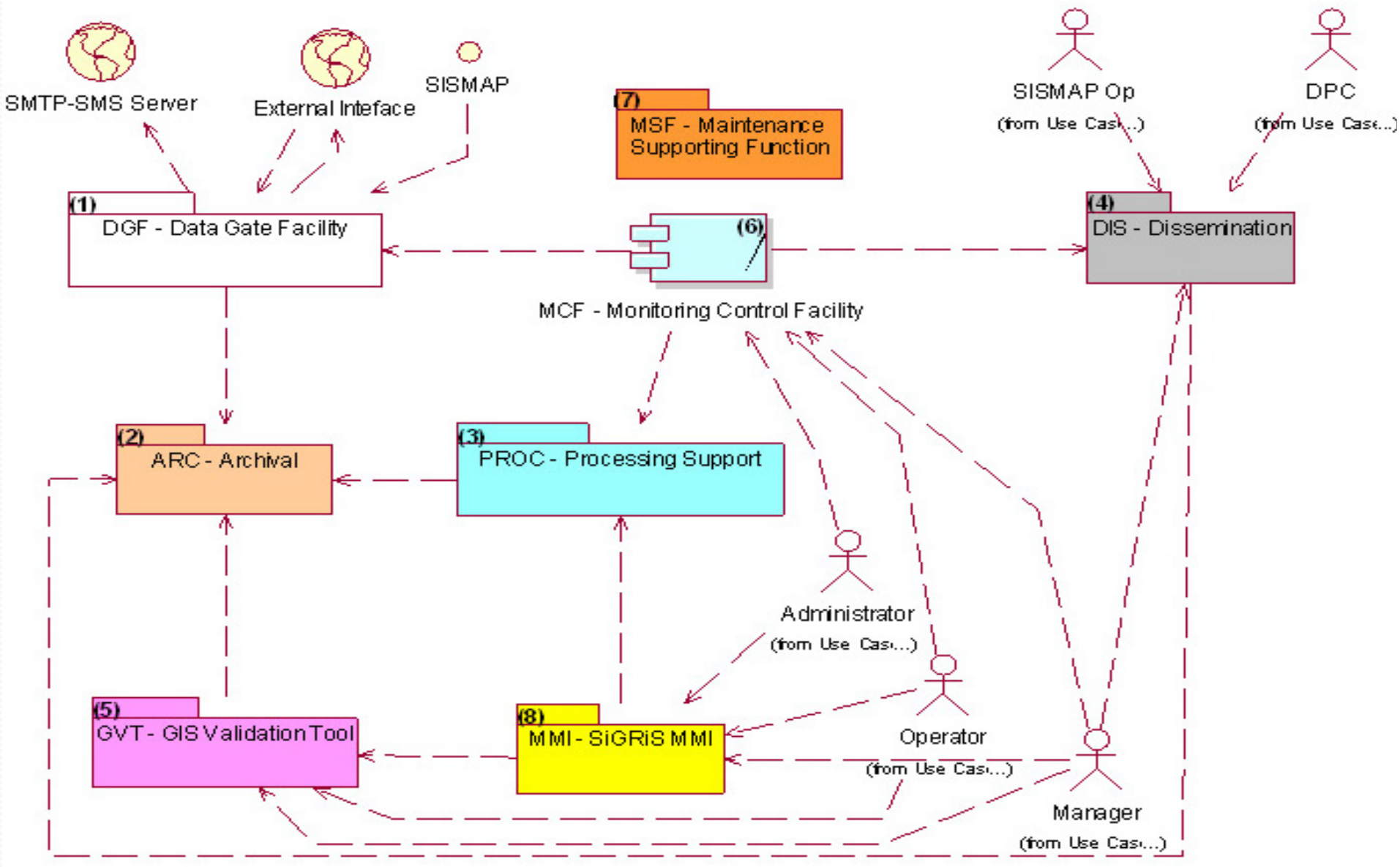
*Products (in NRT):*

- Maps of co-seismic deformation
- Seismic source models
- Stress transfer estimates on nearby faults
- Damage maps
- Post-seismic deformation monitoring
- Maps of local earthquake effects

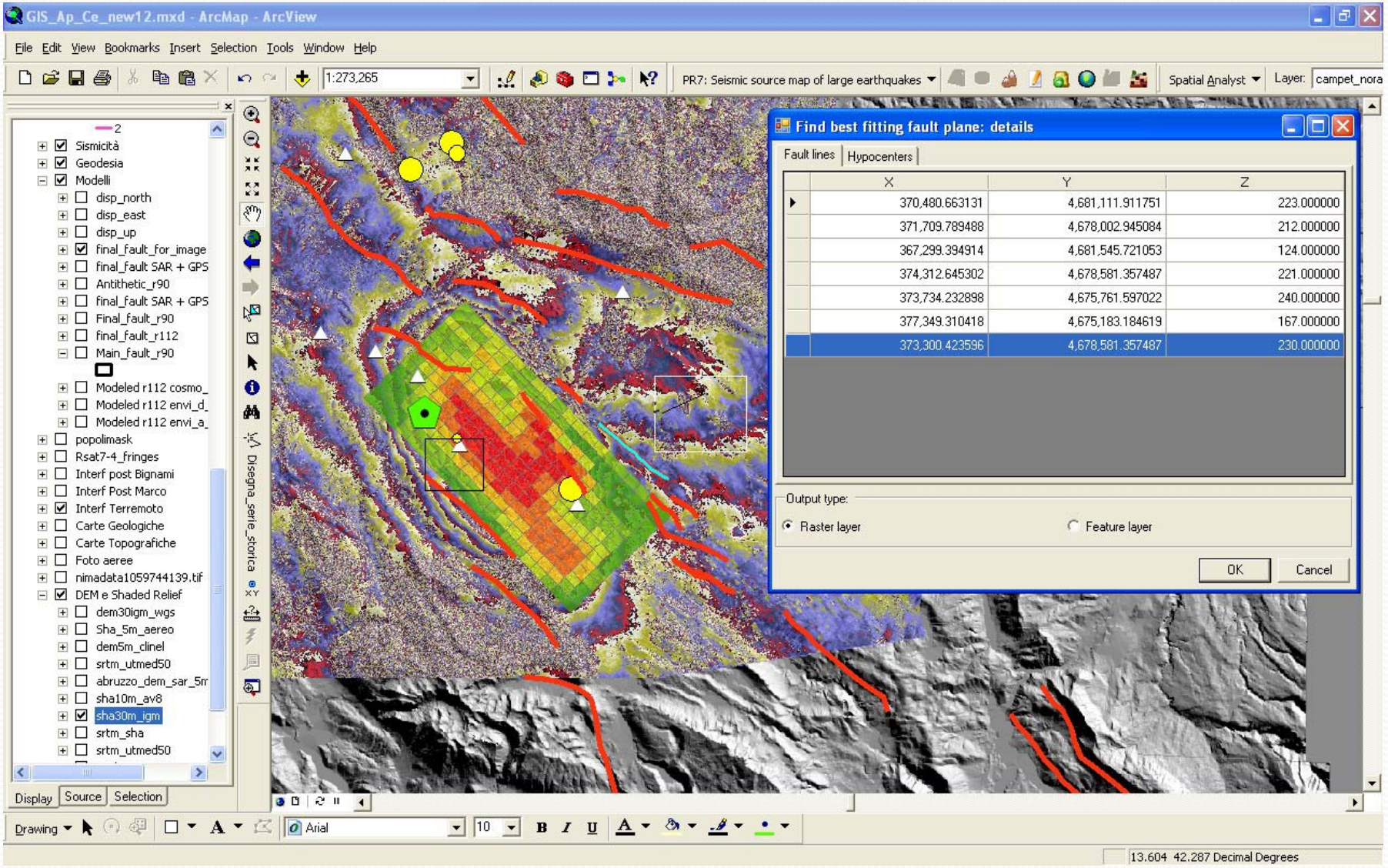
# Requirements for the Crisis products

1. Timeliness (NRT)
2. Established precision/accuracy
3. Cross-validation of results
4. Standardization
5. Synthetic reporting
6. GIS formats
7. Full logging of operator activities

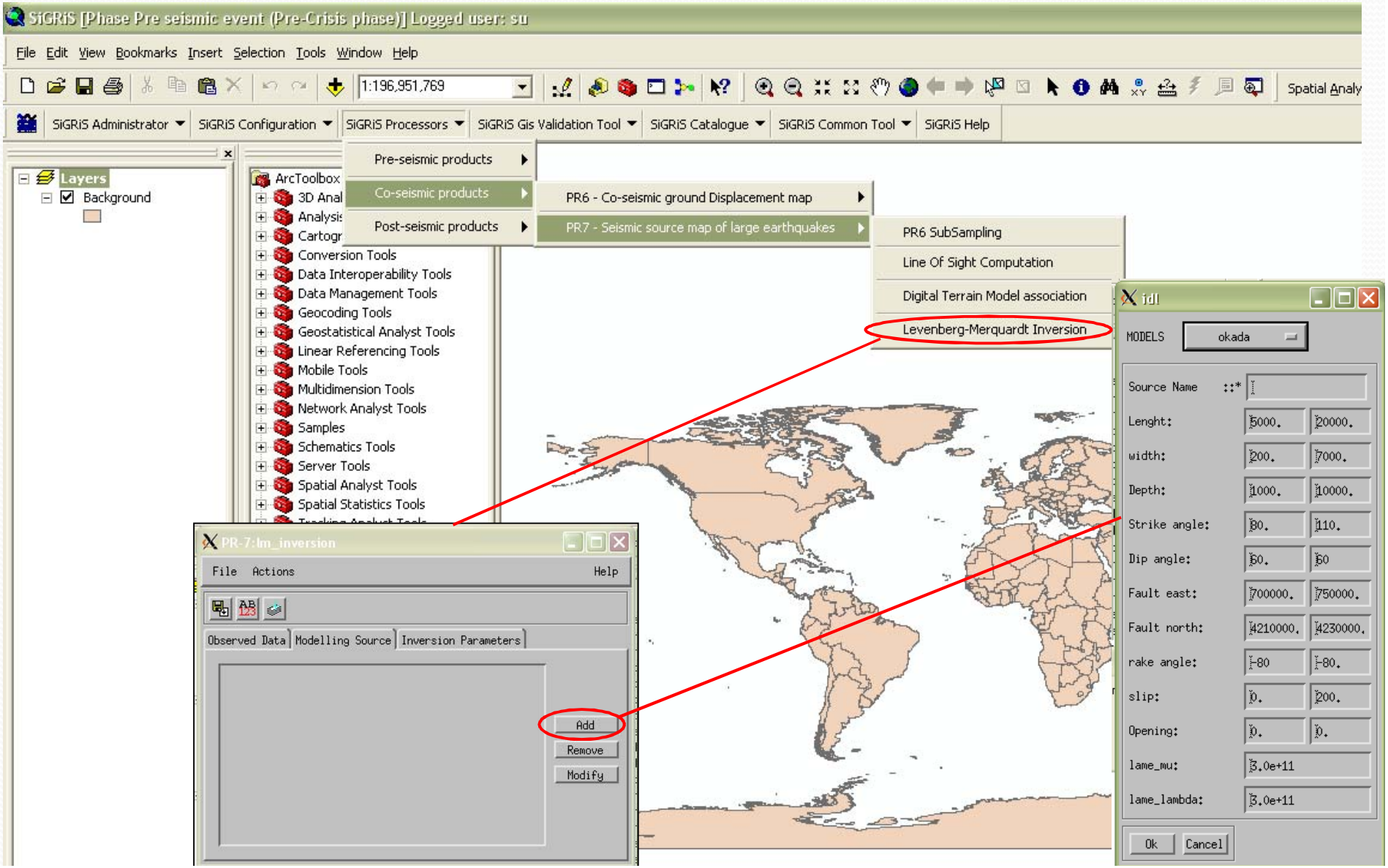
# The SiGRiS architecture (high level)



# GIS-based operator interface

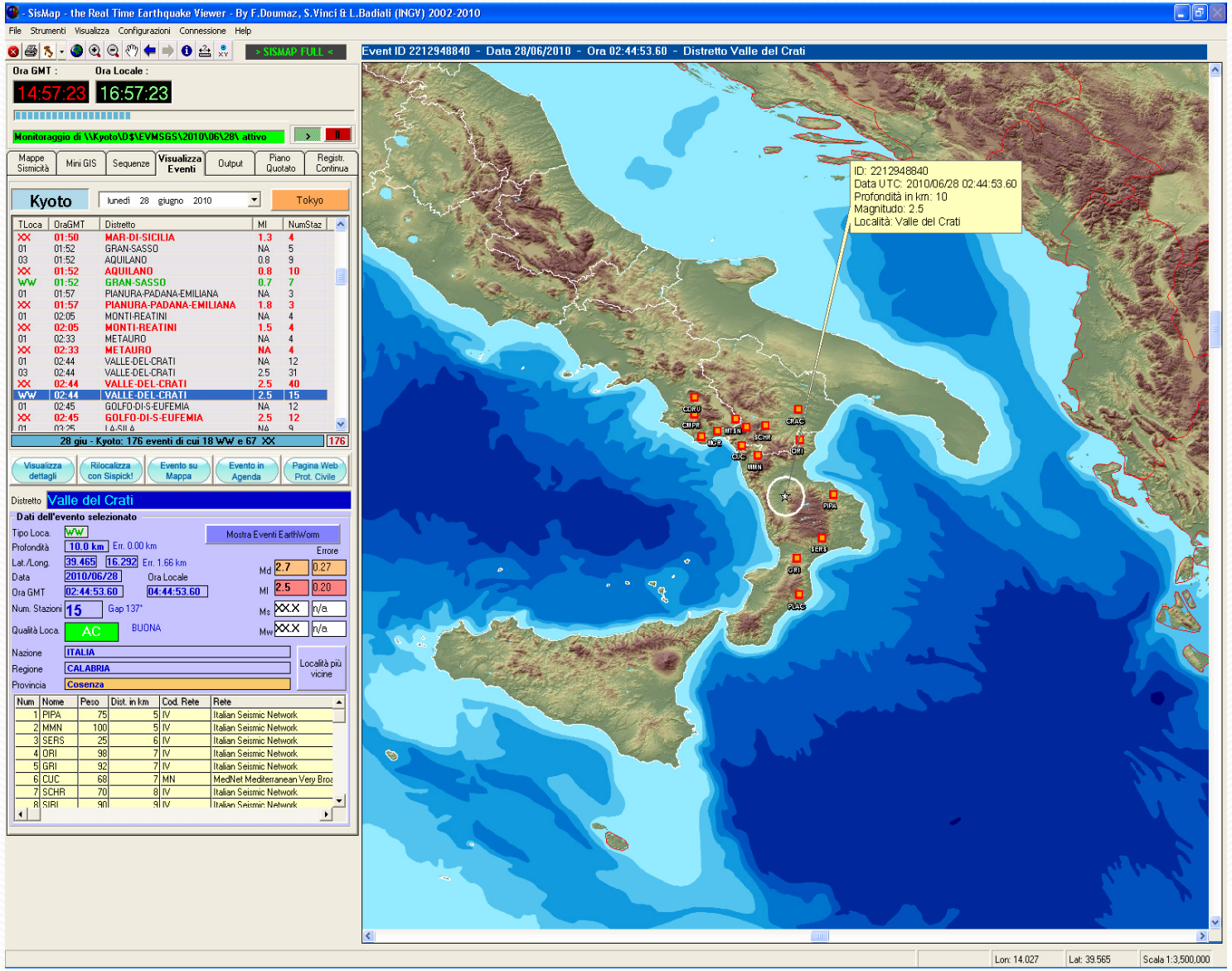


# GIS-embedded modelling codes



# SIGRIS is alerted by the INGV 24h monitoring service

# Alerts automatically sent in RT to SM




**EMAIL and SMS for events:**
**M>5 in Italy**
**M>6 elsewhere**

# SIGRIS activation by SM

The Scientific Manager evaluates the earthquake, and:

- for foreign earthquakes, decides whether to activate the SIGRIS system.
- for Italian earthquakes, the SM activates SIGRIS at once.

In case of activation, the CSK archive is examined and the best post-seismic acquisition modes matching pre-event data, are selected. Then the SM sends detailed acquisition requests to the Civil Protection Focal Point.

CP then activates ASI for satellite tasking. If the state of emergency is officially declared, CSK is put into priority mode.

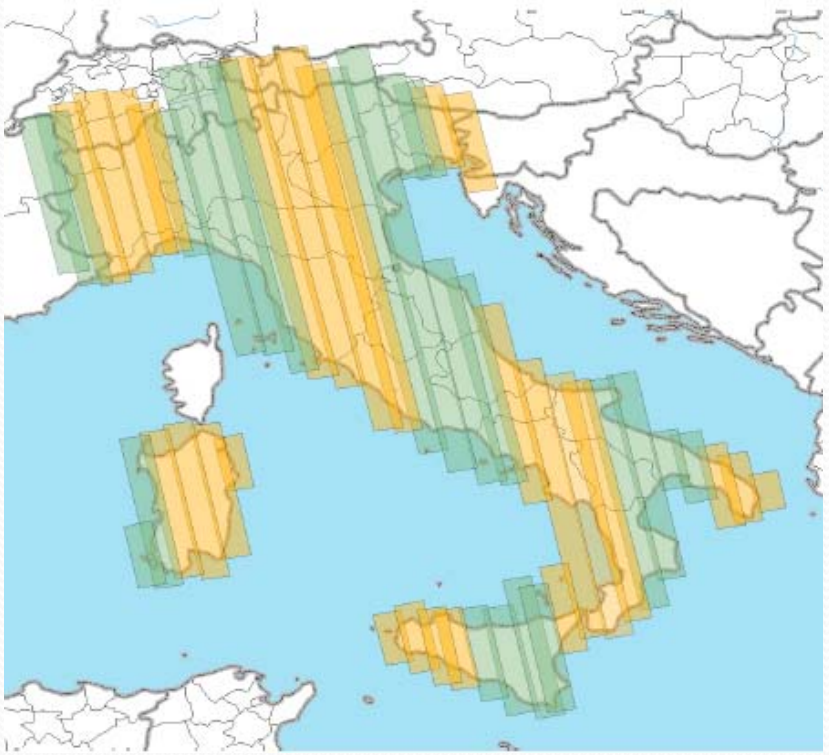
# The MapItaly archive

Through the Italian Civil Protection, the scientific institutions have set the requirements for the Italian routine acquisition planning.

The MapItaly interferometric plan consists of 48 ascending and 47 descending tracks, acquired every 16 days (nominally) in stripmap mode (HH), with pre-fixed incidence angles:

Beam H4-1 (24,9° - 28,4°)
Beam H4-3 (27,7° - 31,0°)
Beam H4-4 (30,7° - 33,8°)
Beam H4-5 (32,4° - 35,5°)

# The MapItaly plan

# SIGRIS: present status

The system is now used operationally for Emergency management during italian earthquakes.

For foreign earthquakes activities are carried out only if funded by ASI/INGV projects. At present we have funding and availability of satellite capacity for one more year.

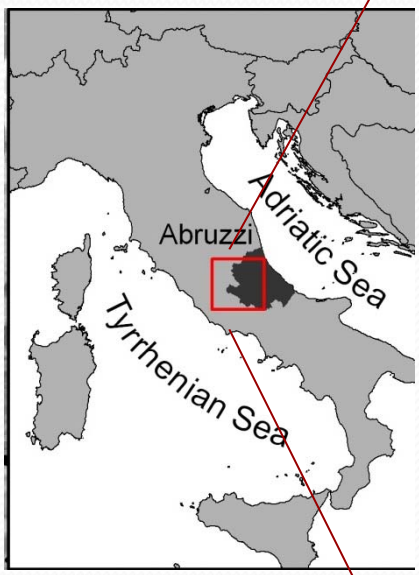
# SIGRIS Crisis activations

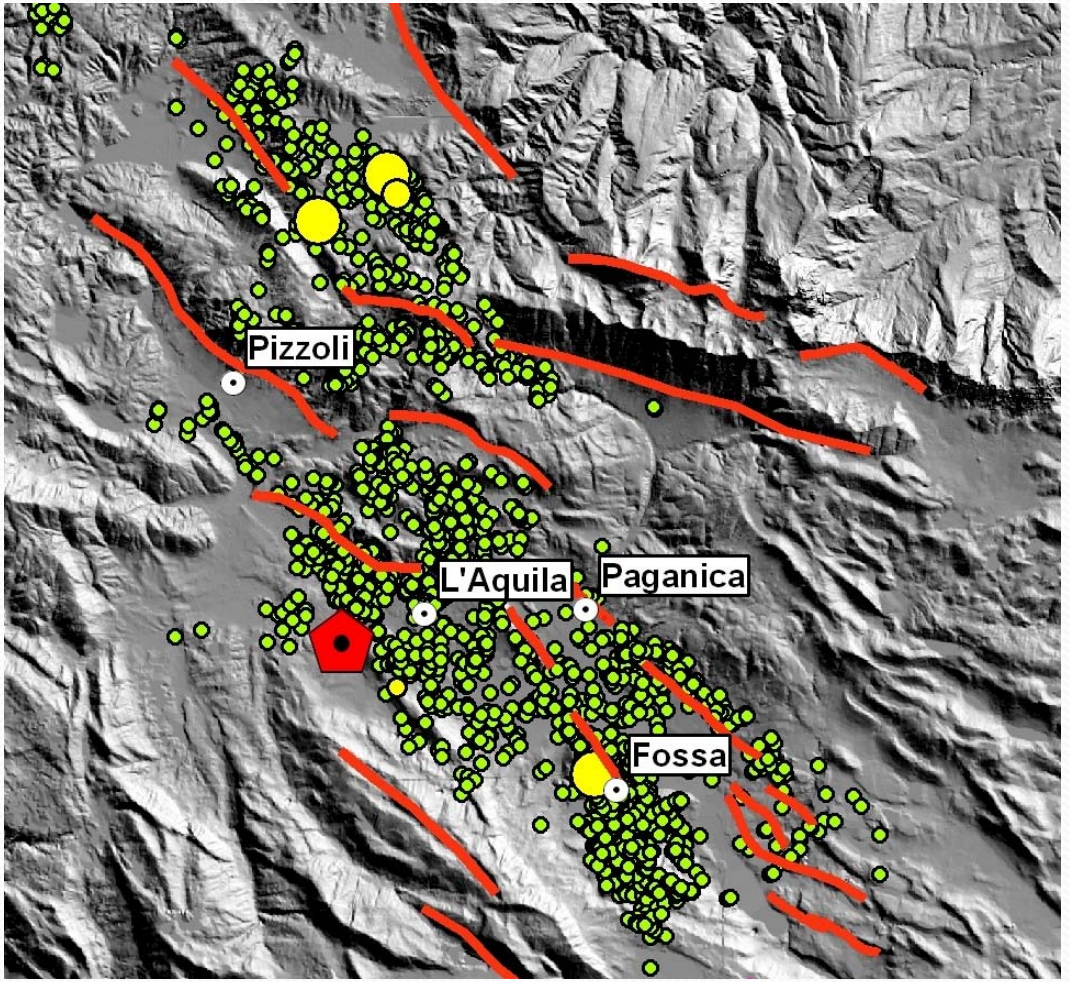
| | | |
|---|---|---|
| 1. | Pakistan, October 2008 – | Mw=6.4 |
| 2. | L'Aquila, Italy, April 2009 – | Mw=6.3 |
| 3. | Haiti, January 2010 – | Mw=7.0 |
| 4. | Yushu, China, April 2010 – | Mw=6.9 |
| 5. | Darfield, New Zealand, September 2010 – | Mw=7.1 |
| 6. | Hosseinabad, Iran, December 2010 - | Mw=6.5 |
| 7. | Tohoku, March 2011 – | Mw=9.0 |
| 8. | Christchurch, NZ, February 2011 – | Mw=6.3 |
| 9. | Christchurch, NZ, June 2011 – | Mw=6.3 |
| 10. | Van, Turkey, October 2011 – | Mw=7.1 |
| 11. | Emilia, Italy, May 2012 – | Mw=5.9 |
| 12. | Pollino, Italy, October 2012 – | Mw=5.4 |
| 13. | Lunigiana, Italy, June 2013 – | Mw=5.4 |

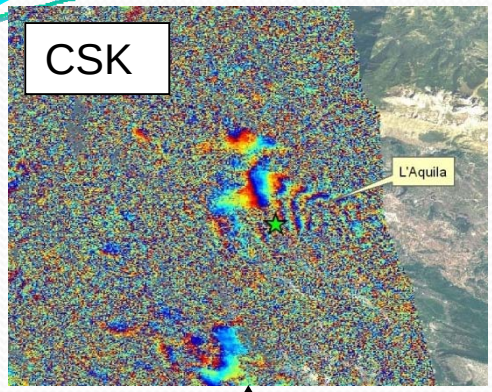
# Examples of SIGRIS Crisis products:

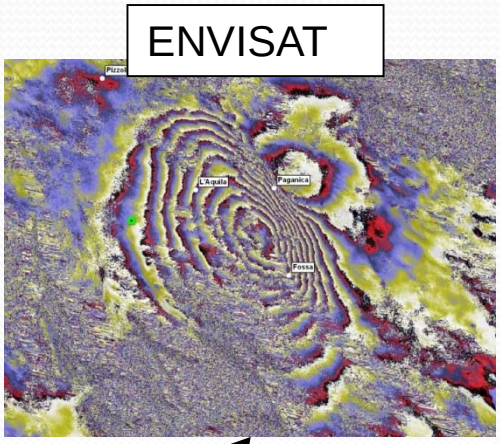
1. L'Aquila sequence, Italy
2. Emilia sequence, Italy
3. Most recent: the Lunigiana event, Italy

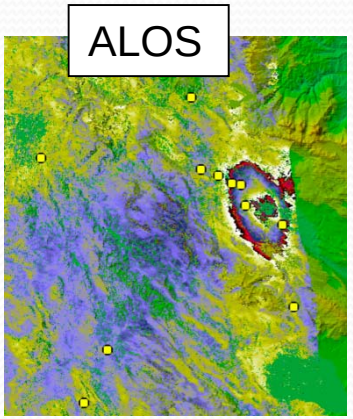
# The Mw= 6.3 2009
# L'Aquila Earthquake, Central Italy





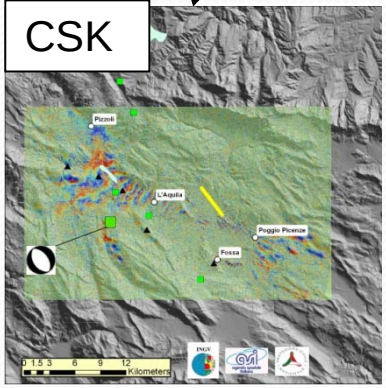

L' Aquila Quake
Mw = 6.3

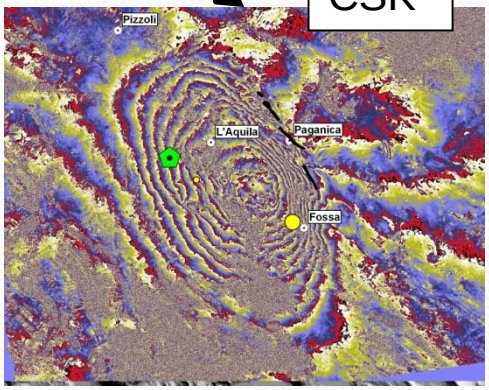
06.04.09

09.04

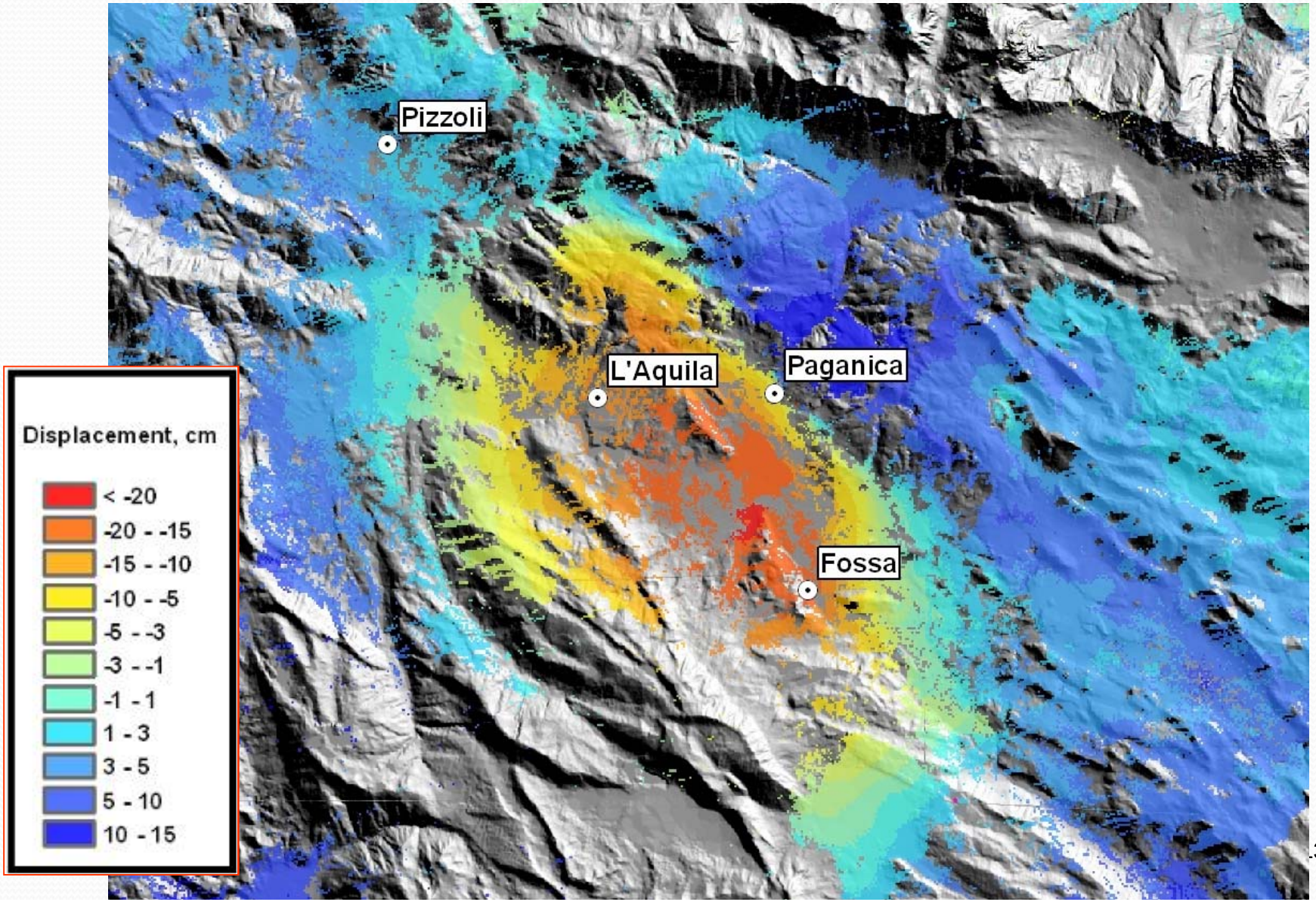
12.04

22.04

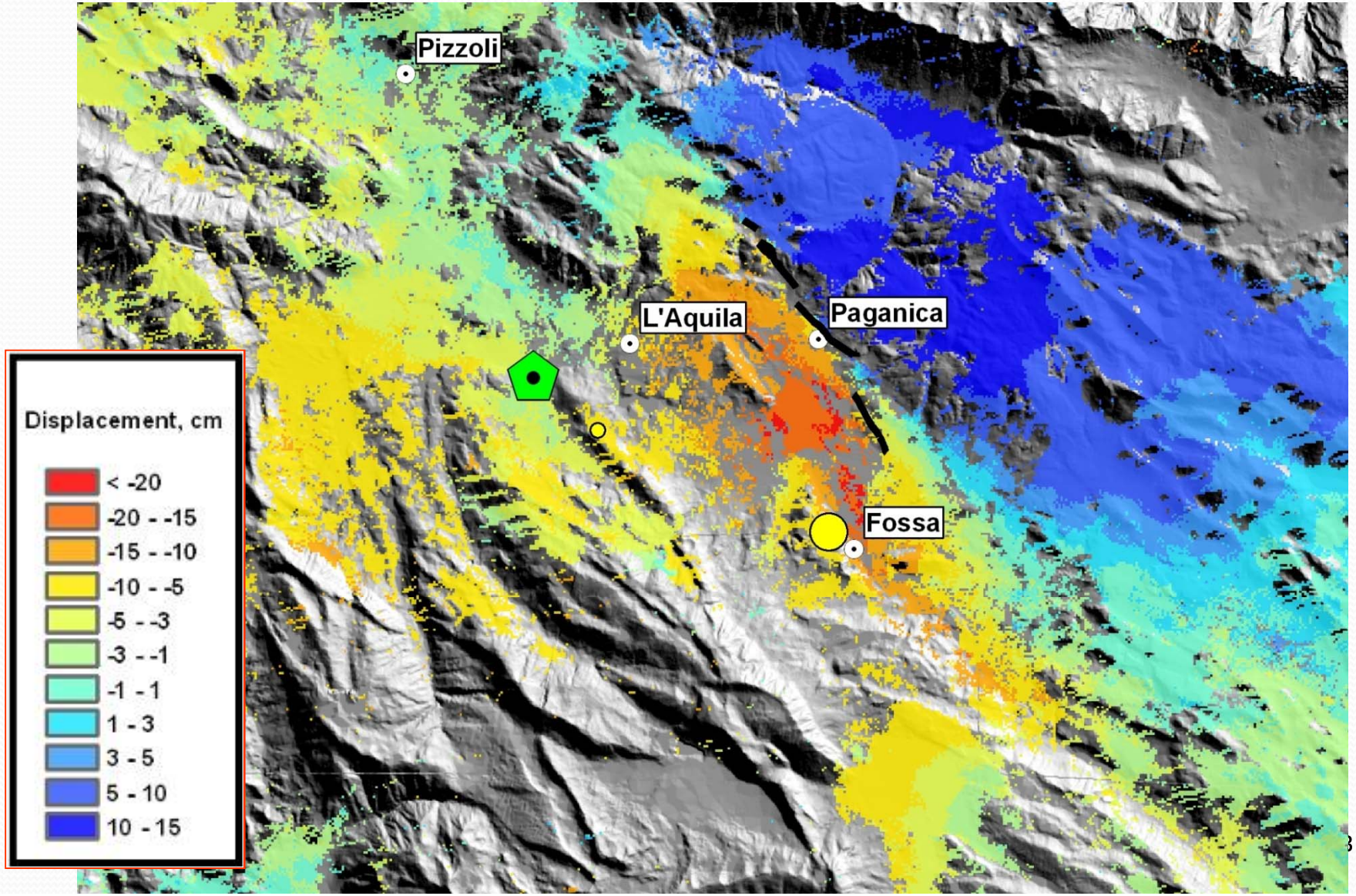


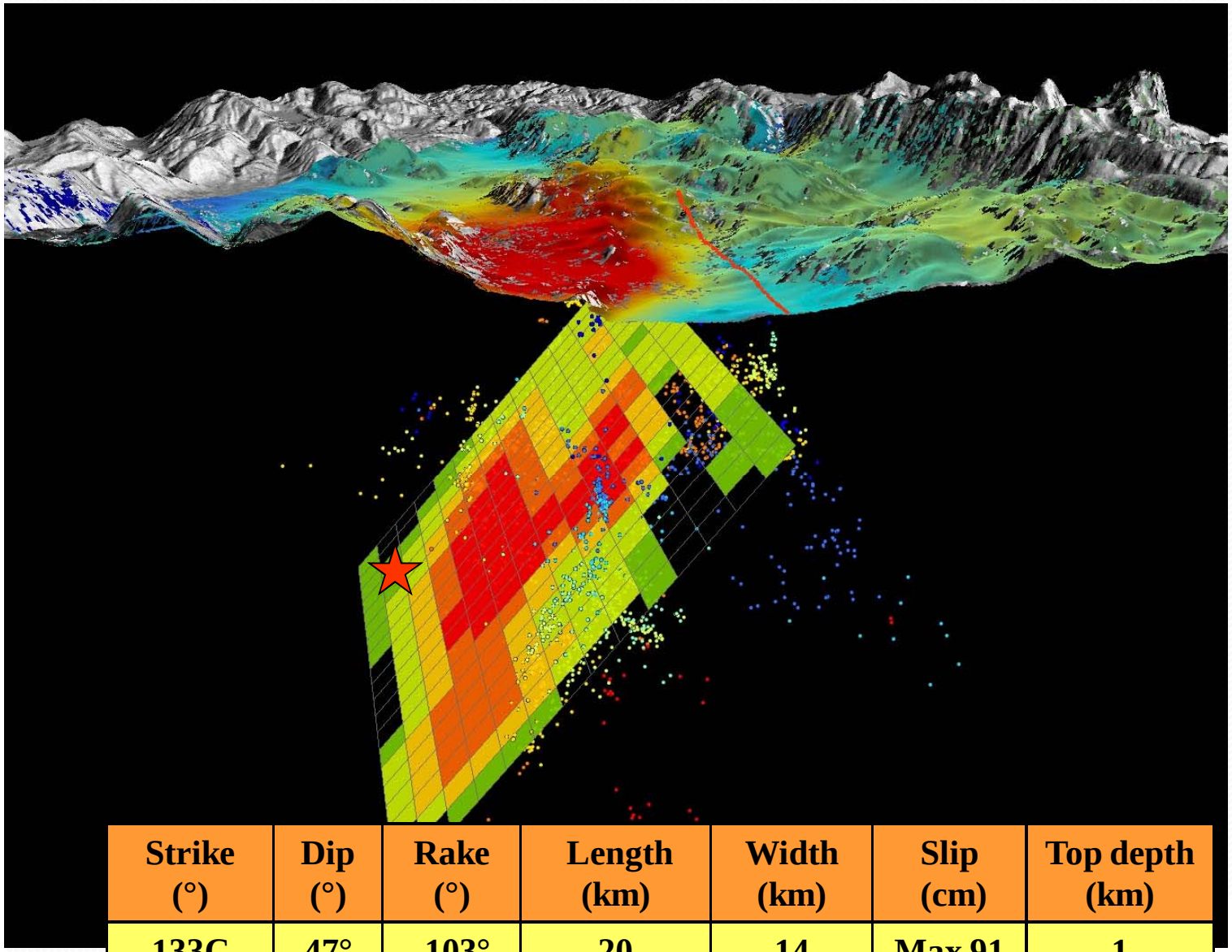
# Up ground displacements



# East ground displacements



# Validated source model

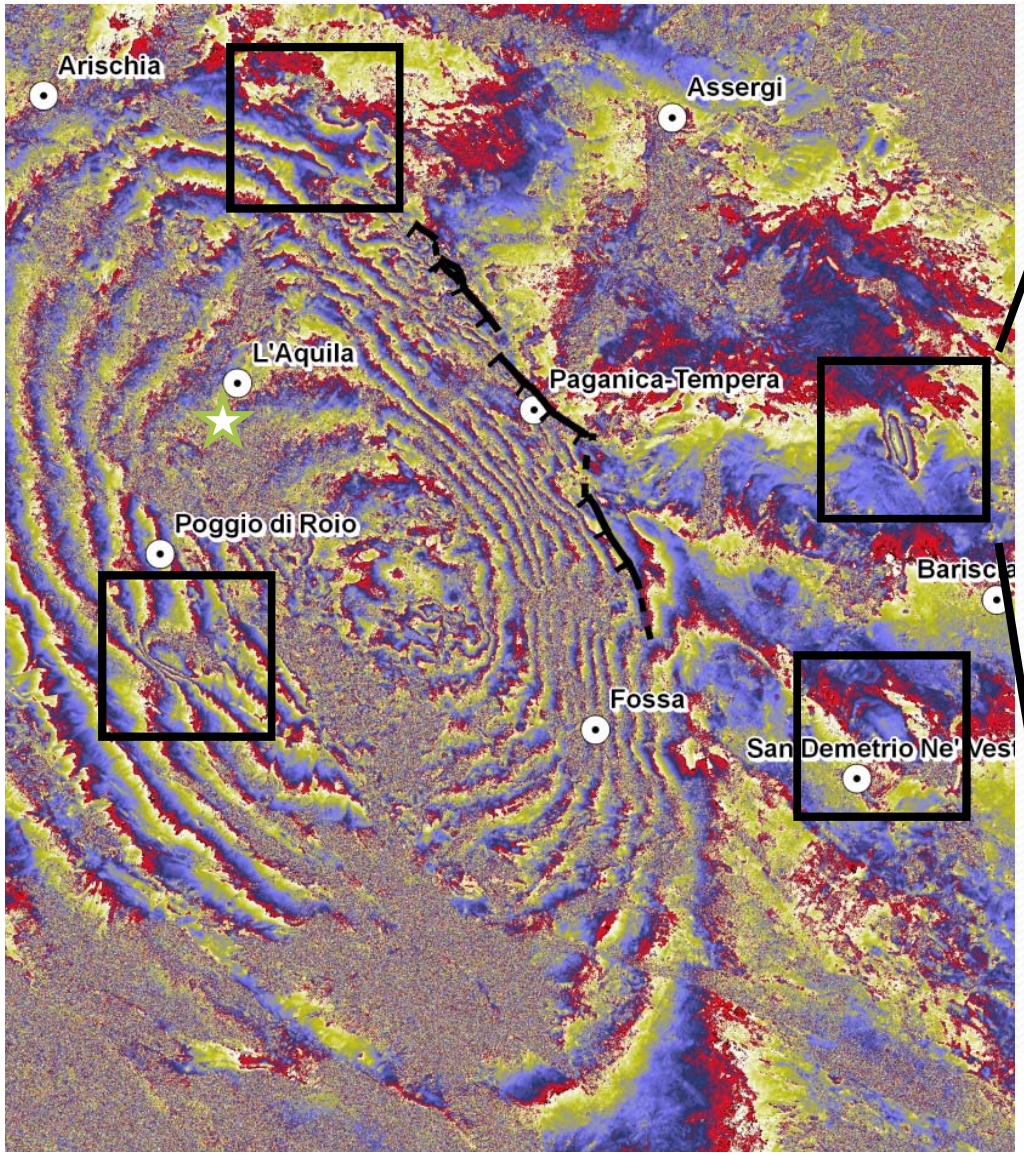


Validated with seismological and geological data.

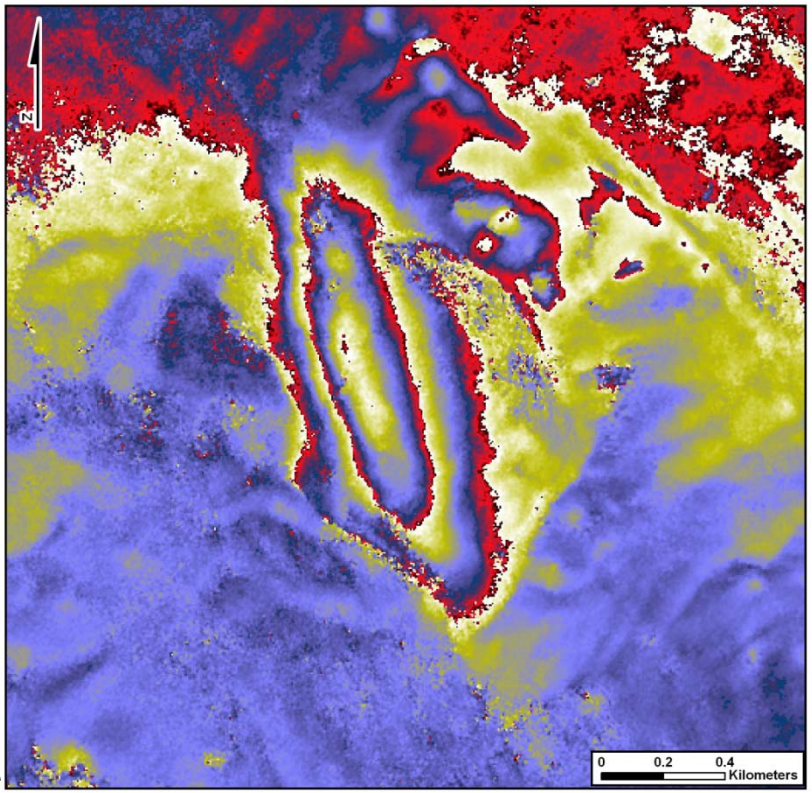
Atzori et al, 2009 GRL

| Strike (°) | Dip (°) | Rake (°) | Length (km) | Width (km) | Slip (cm) | Top depth (km) |
|---|---|---|---|---|---|---|
| 133C | 47° | -103° | 20 | 14 | Max 91 | 1 |

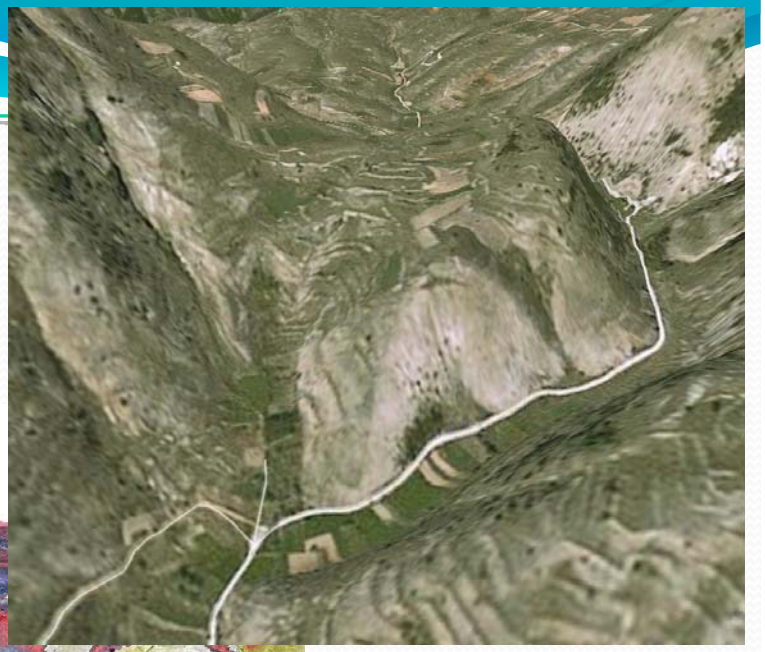
# Map of local earthquake effects

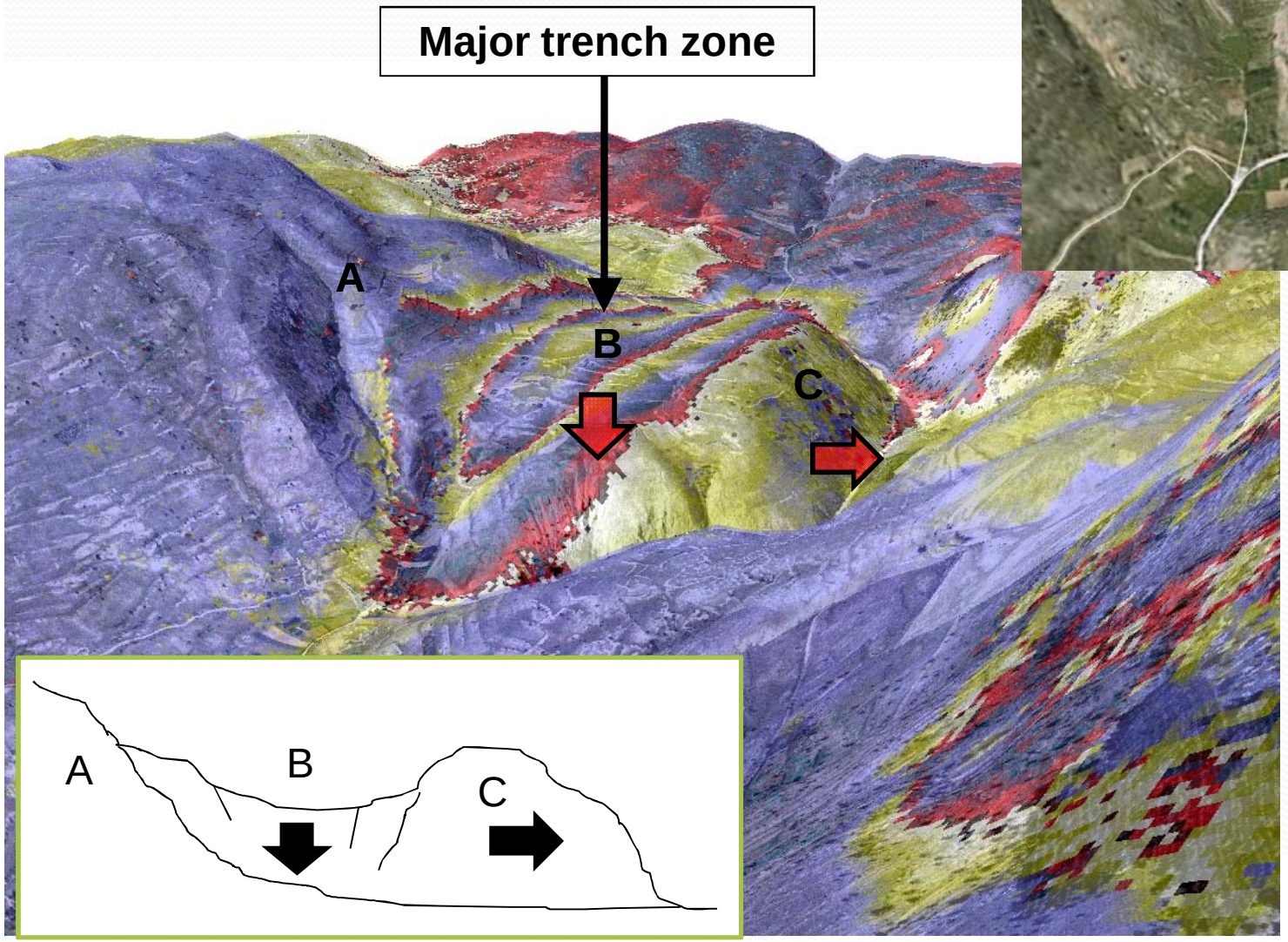



**COSMO-SkyMed high resolution**



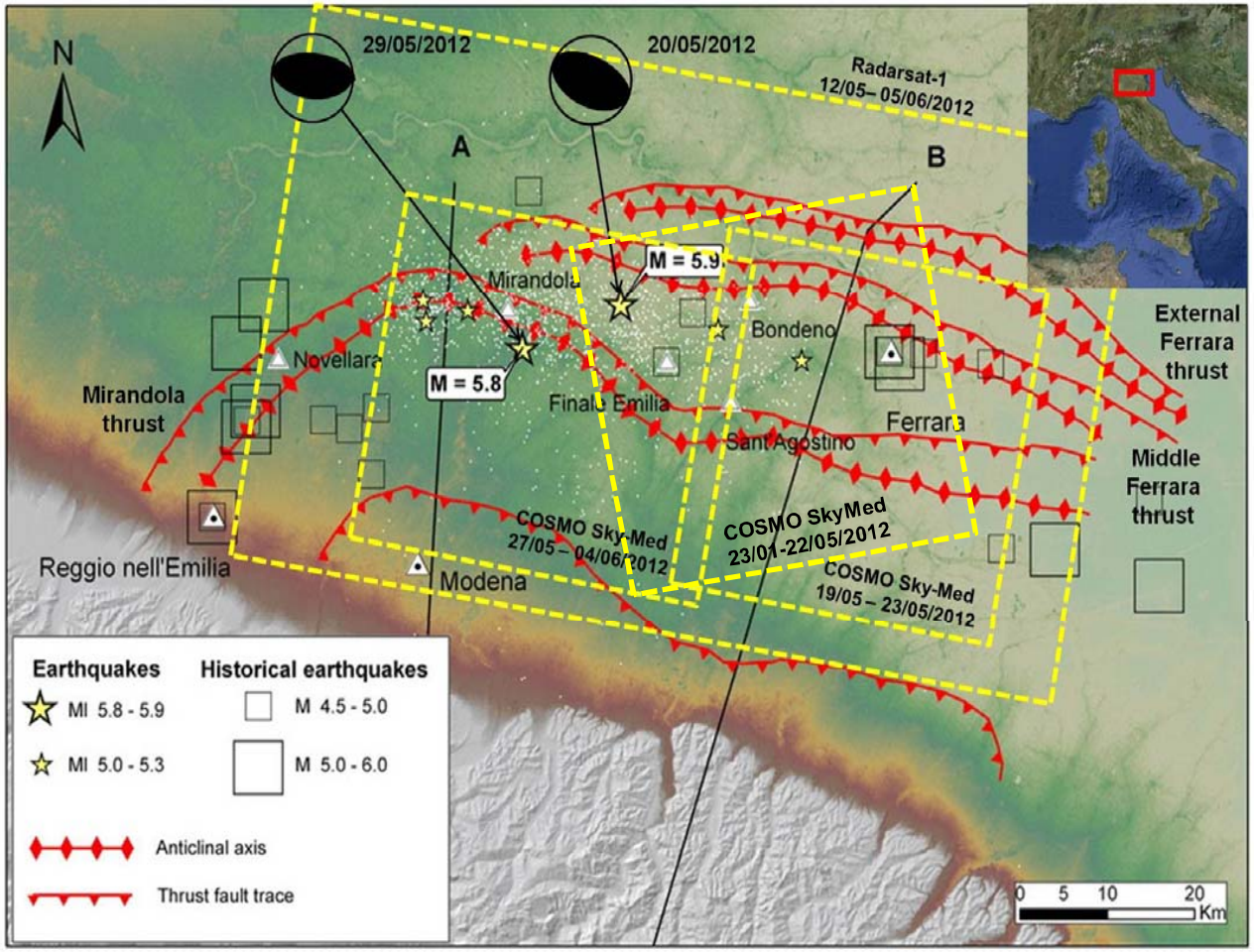
# Triggered gravitational deformation






Moro et al, 2010
Geology

# The 2012 Emilia sequence (Mw 5.9)

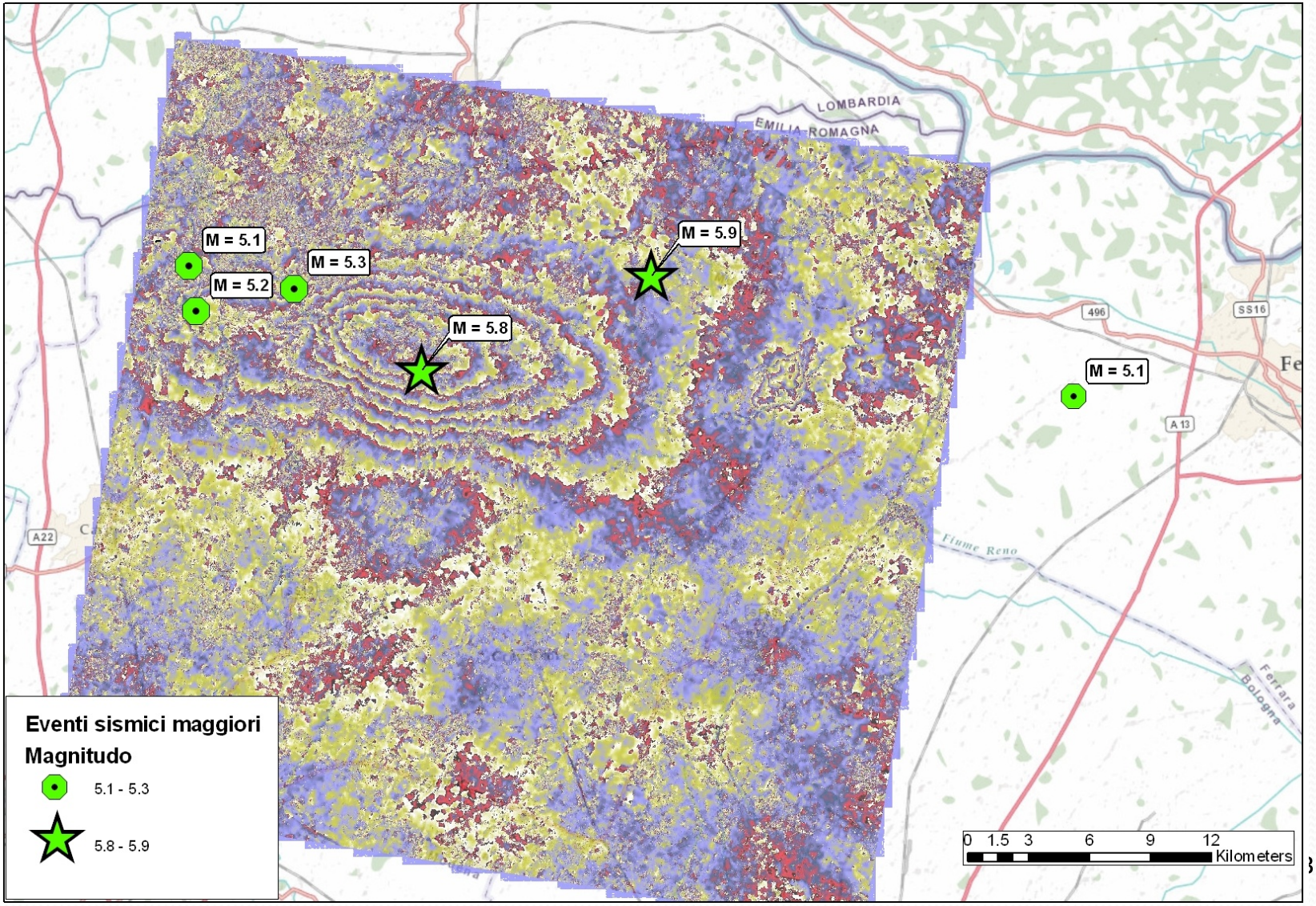



Few pre-event CSK images: “holes” in the MapItaly archive

Pezzo et al, 2013, SRL

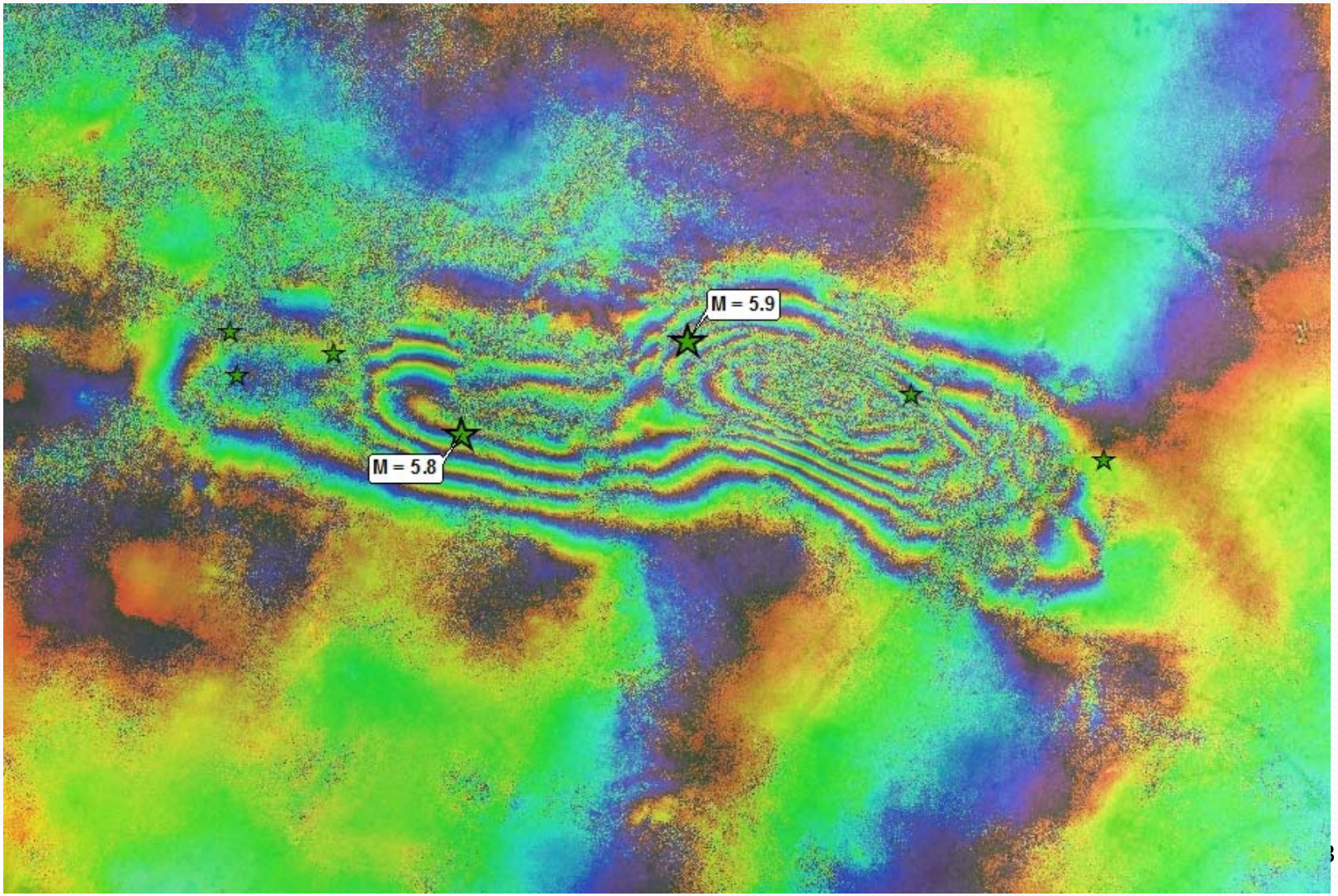
# The 2012 Emilia sequence (large aftershock Mw 5.8)

## COSMO-SkyMed interferogram



# The 2012 Emilia sequence (the largest events)

## Radarsat interferogram



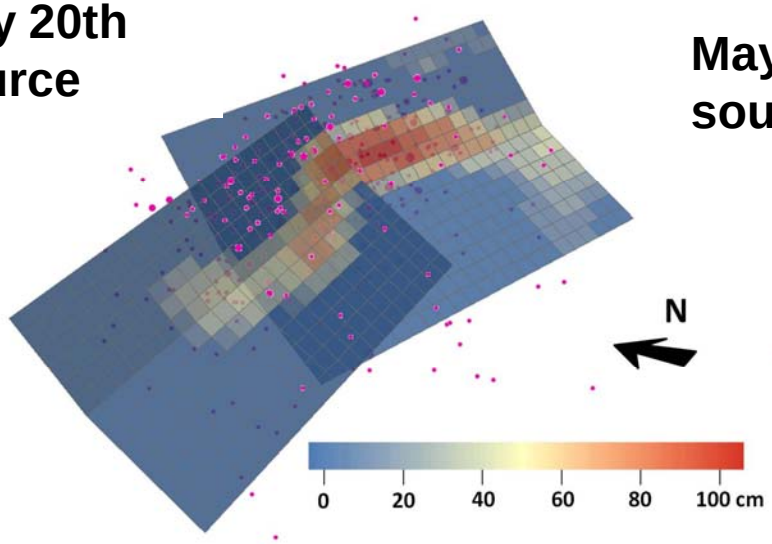
# The 2012 Emilia source model

## Source parameters

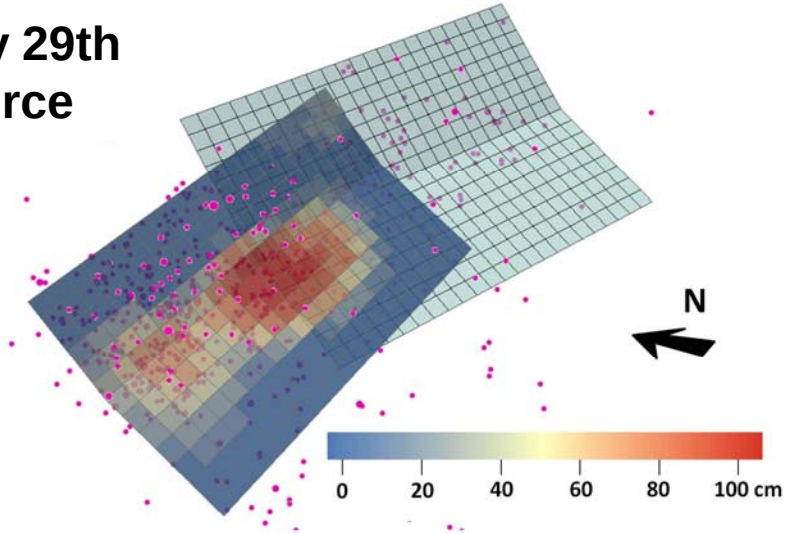
Pezzo et al, 2012 - SRL

| Sources | | Length [km] | Width [km] | Top depth [km] | Strike [deg] | Dip [deg] | Rake [deg] | Maximum slip [cm] |
|---|---|---|---|---|---|---|---|---|
| May 20th source (middle Ferrara thrust) | Upper | 34 | 11 | 1 | 114 | 40 | 90 | 120 |
| | Lower | | 12 | 22.5 | | 20 | | |
| May 29th source (frontal Mirandola thrust) | Upper | 32 | 7.5 | 1 | 95 | 45 | 85 | 54 |
| | Lower | | 10 | 12 | | 30 | | |

May 20th source



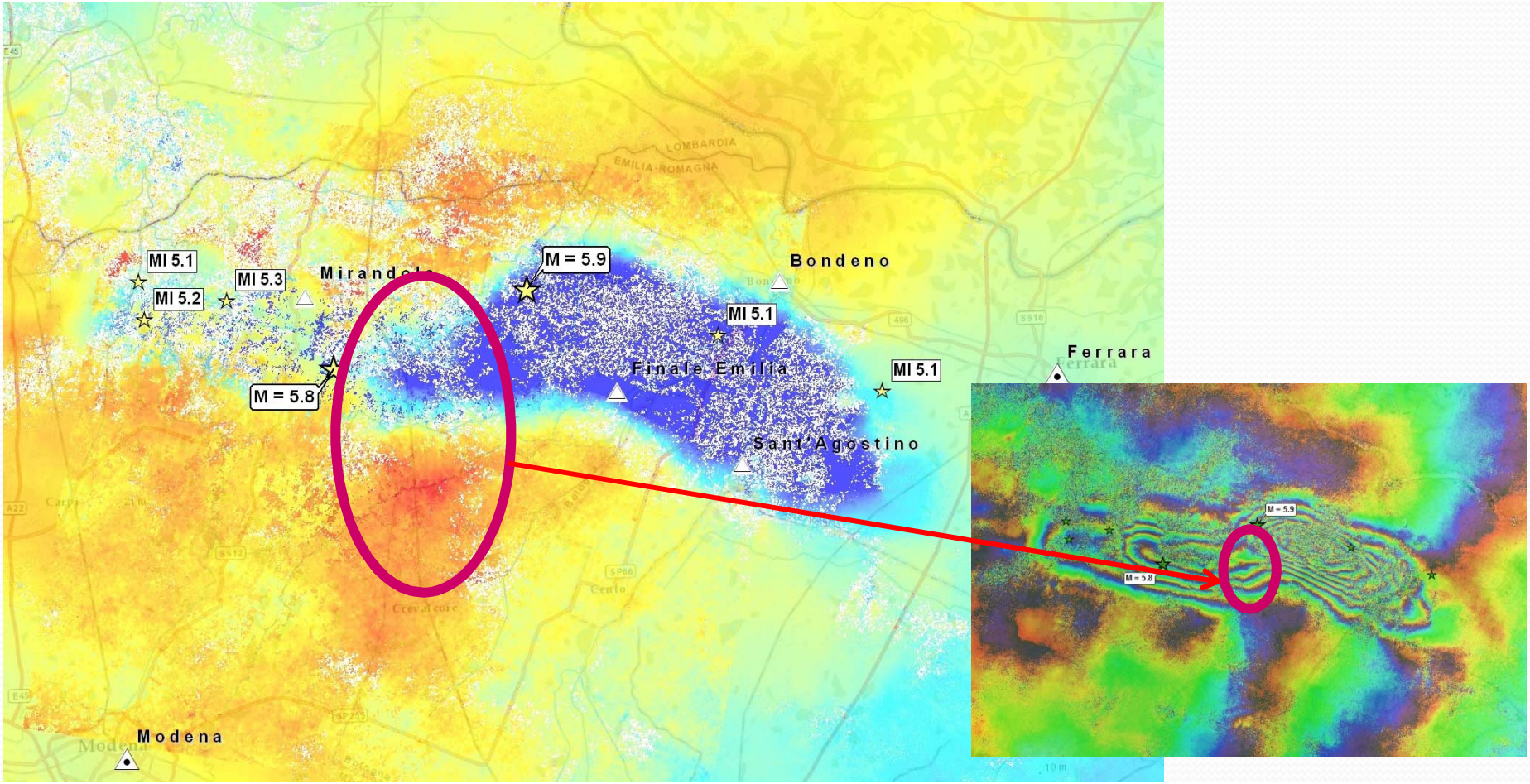

May 29th source



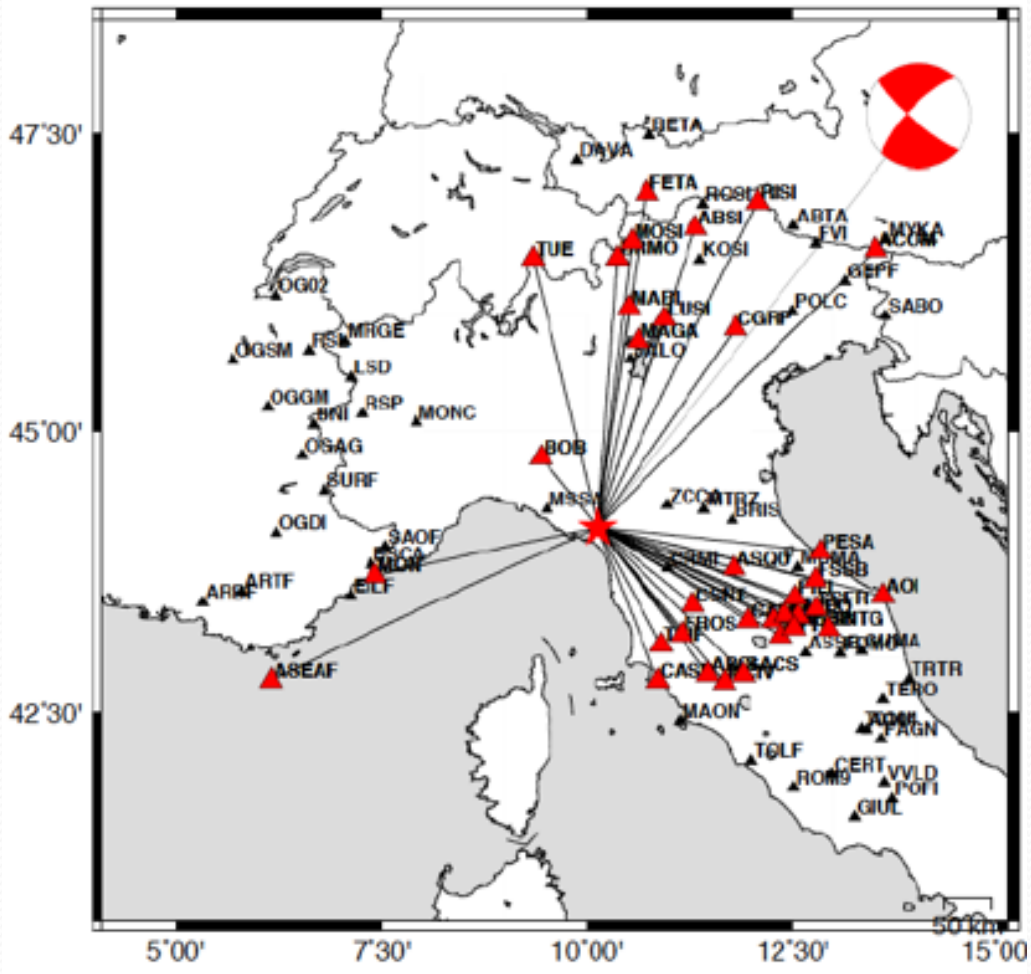
# A slow slip event ?

We detected a clear thrust-like deformation pattern not associated with aftershocks, located between the epicenters of the two largest shocks.

It occurred in the interval between the two main shocks.

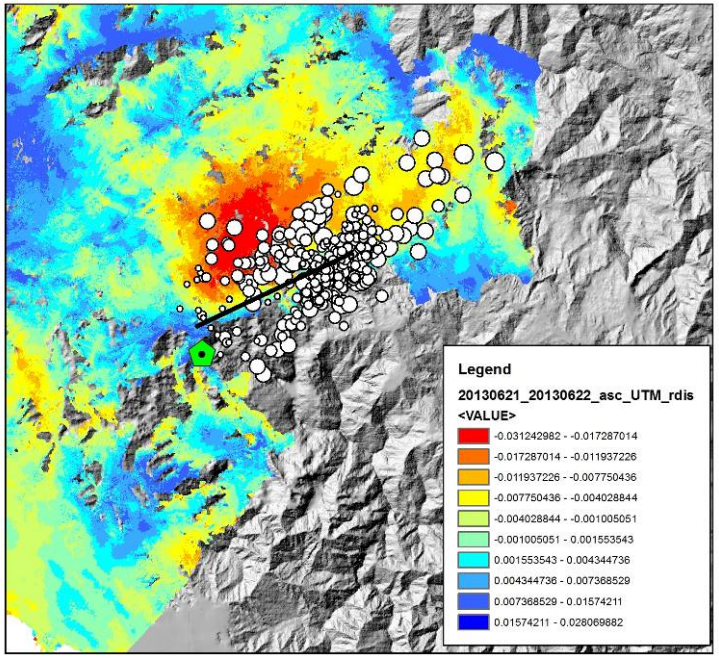


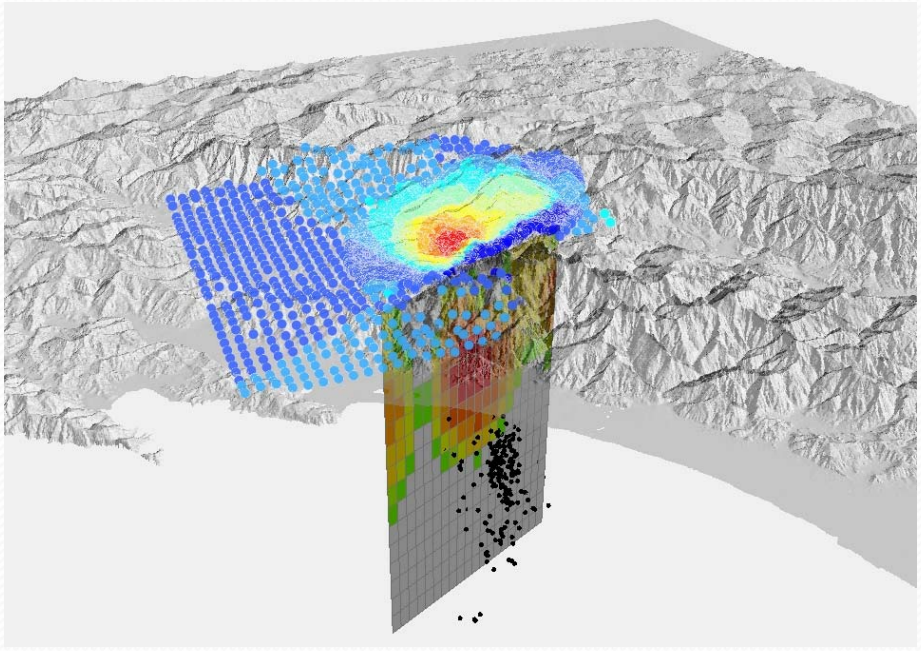
# The June, 21st 2013 Lunigiana event (Mw 5.4)



# The June, 21st 2013 Lunigiana event (Mw 5.4)

Very vegetated area, good coherence only on temporal baseline of **1 day**!



| L, m | W, m | D, m | Strike, ° | Dip, ° | Rake, ° | Slip, cm | RMS, cm |
|---|---|---|---|---|---|---|---|
| 17000 | 7000 | 1000 | 245 | 90 | -170 | 38 | 0.7 |

# Conclusions

The SIGRIS system demonstrated that it is now possible to integrate optical and SAR satellite data into information products needed to support seismic risk management.

The COSMO-SkyMed constellation in principle can provide high resolution data, with good sensitivity to deformation and frequent observation rates, all extremely important for crisis management.

Unfortunately COSMO-SkyMed does not always guarantee constant data acquisition, mainly due to conflicts arising from its dual and commercial uses.

We expect that the Sentinel-1 data will overcome this important limitation and provide the basis for operational services in this and other applications.