



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

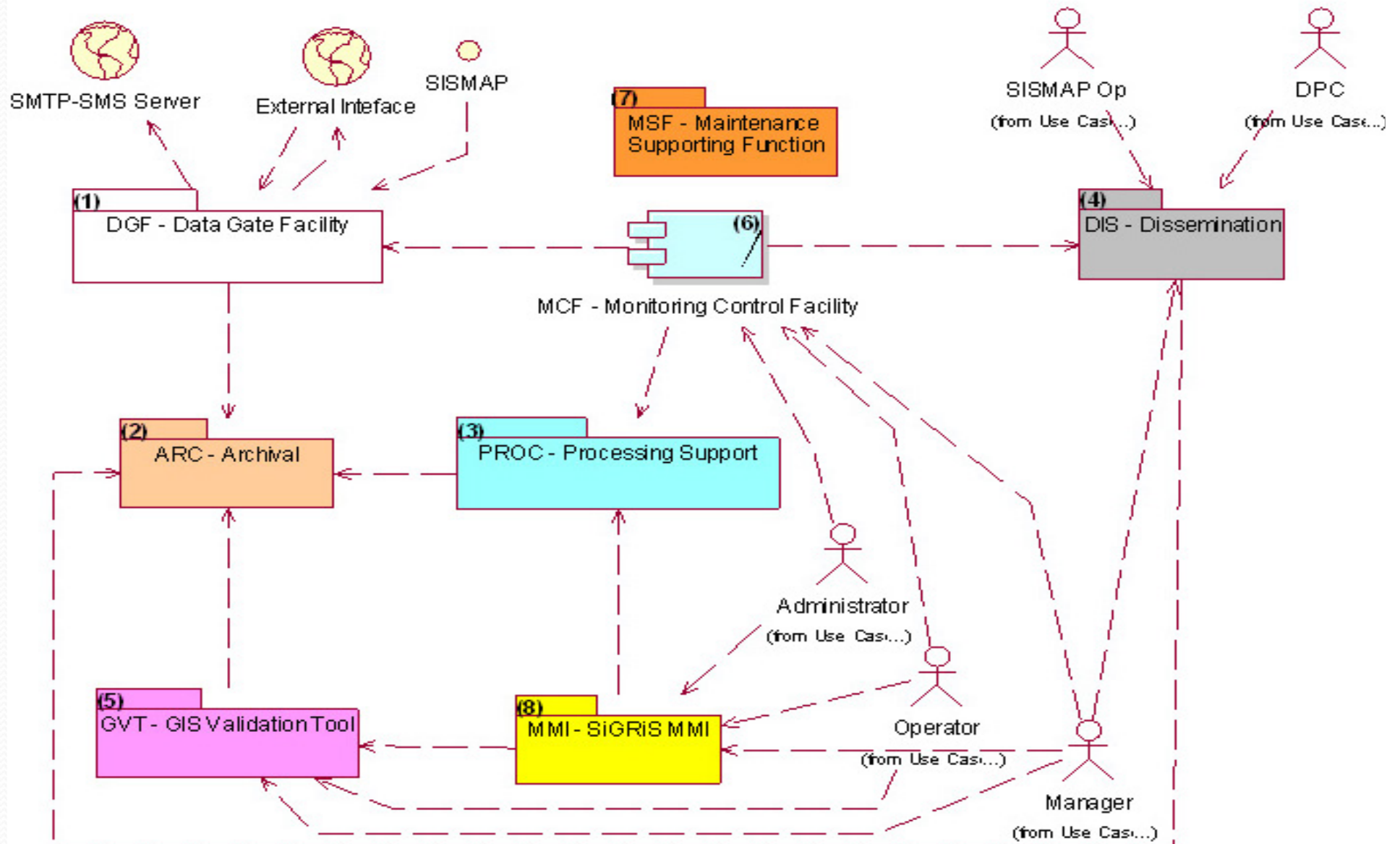


Requirements for the Crisis products

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

The screenshot displays the ArcMap interface with a seismic source map of large earthquakes. The map shows a central area with a color-coded grid (green to red) and several yellow circles representing seismic sources. A dialog box titled "Find best fitting fault plane: details" is open, showing a table of fault lines and hypocenters. The table has columns for X, Y, and Z coordinates. The selected row (highlighted in blue) has the following values: X=373,300.423596, Y=4,678,581.357487, Z=230.000000. The dialog also includes an "Output type" section with radio buttons for "Raster layer" (selected) and "Feature layer".

	X	Y	Z
▶	370,480.663131	4,681,111.911751	223.000000
	371,709.789488	4,678,002.945084	212.000000
	367,299.394914	4,681,545.721053	124.000000
	374,312.645302	4,678,581.357487	221.000000
	373,734.232898	4,675,761.597022	240.000000
	377,349.310418	4,675,183.184619	167.000000
	373,300.423596	4,678,581.357487	230.000000

Output type:
 Raster layer Feature layer

OK Cancel



GIS-embedded modelling codes

The screenshot displays the SIGRIS GIS interface. The main window title is "SIGRIS [Phase Pre seismic event (Pre-Crisis phase)] Logged user: su". The menu bar includes File, Edit, View, Bookmarks, Insert, Selection, Tools, Window, and Help. The toolbar contains various GIS tools and a scale of 1:196,951,769. The ArcToolbox is open, showing a hierarchy: Pre-seismic products, Co-seismic products, and Post-seismic products. The "Levenberg-Merquardt Inversion" option is highlighted in the "Post-seismic products" sub-menu. A world map is visible in the background.

Two dialog boxes are overlaid on the interface:

- PR-7:lm_inversion**: A dialog box with tabs for "Observed Data", "Modelling Source", and "Inversion Parameters". The "Add" button is highlighted.
- id1**: A dialog box for model configuration. The "MODELS" list contains "okada". The "Source Name" is set to "::*". The "Lenght" is 5000.0, "width" is 200.0, "Depth" is 1000.0, "Strike angle" is 0.0, "Dip angle" is 0.0, "Fault east" is 700000.0, "Fault north" is 4210000.0, "rake angle" is -80.0, "slip" is 0.0, "Opening" is 0.0, "lame_mu" is 3.0e+11, and "lame_lambda" is 3.0e+11.



SIGRIS is alerted by the INGV 24h monitoring service





Alerts automatically sent in RT to SM

SisMap - the Real Time Earthquake Viewer - By F.Doumaz, S.Vinci & L.Badiati (INGV) 2002-2010

File Strumenti Visualizza Configurazioni Connessione Help

SISMAP FULL

Event ID 2212948840 - Data 28/06/2010 - Ora 02:44:53.60 - Distretto Valle del Crati

Ora GMT : 14:57:23 Ora Locale : 16:57:23

Monitoraggio di \\\Kyoto\DD\SEVMS65\2010\06\28\ attivo

Mappe Sismicità Mini GIS Sequenze Visualizza Eventi Output Piano Quotale Registr. Continua

Kyoto Lunedì 28 giugno 2010 Tokyo

T. Loca	Ora GMT	Distretto	MI	NumStaz
XX 01:50		MAR- DI- SICILIA	1.3	4
01 01:52		GRAN-SASSO	NA	5
03 01:52		AQUILANO	0.8	9
XX 01:52		AQUILANO	0.8	10
WW 01:52		GRAN-SASSO	0.7	7
01 01:57		PIANURA-PADANA-EMILIANA	NA	3
XX 01:57		PIANURA-PADANA-EMILIANA	1.9	3
01 02:05		MONTI-REATINI	NA	4
XX 02:05		MONTI-REATINI	1.5	4
01 02:33		METAURO	NA	4
XX 02:33		METAURO	NA	4
01 02:44		VALLE-DEL-CRATI	NA	12
03 02:44		VALLE-DEL-CRATI	2.5	31
XX 02:44		VALLE-DEL-CRATI	2.5	40
WW 02:44		VALLE-DEL-CRATI	2.5	15
01 02:45		GOLFO-DI-S-EUFEMIA	NA	12
XX 02:45		GOLFO-DI-S-EUFEMIA	2.5	12
01 02:45		I. S. S. I. A.	NA	9

28 giu - Kyoto: 176 eventi di cui 18 WW e 67 XX

Visualizza dettagli Riocalizza con Sispick! Evento su Mappa Evento in Agenda Pagina Web Prot. Civile

Distretto Valle del Crati

Dati dell'evento selezionato

Tipo Loca: WW Mostra Eventi EarthWorm

Profondità: 10.0 km Err. 0.00 km

Lat./Long: 39.465 16.292 Err. 1.66 km

Data: 2010/06/28 Ora Locale

Ora GMT: 02:44:53.60 MI: 2.5 0.20

Num. Stazioni: 15 Gap 137° Ms: XXX n/a

Qualità Loca: AC BUONA Mv: XXX n/a

Nazione: ITALIA Località più vicine

Regione: CALABRIA

Provincia: Cosenza

Num	Nome	Peso	Dist. in km	Cod. Rete	Rete
1	PIPA	75	5	IV	Italian Seismic Network
2	MMNI	100	5	IV	Italian Seismic Network
3	SERS	25	6	IV	Italian Seismic Network
4	ORI	30	7	IV	Italian Seismic Network
5	GRI	32	7	IV	Italian Seismic Network
6	CLIC	68	7	MN	MedNet Mediterranean Very Bro
7	SCHR	70	8	IV	Italian Seismic Network
8	SIRI	90	9	IV	Italian Seismic Network

ID: 2212948840
Data UTC: 2010/06/28 02:44:53.60
Profondità in km: 10
Magnitudo: 2.5
Località: Valle del Crati

Lon: 14.027 Lat: 39.565 Scala 1:3,500,000

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 ($24,9^\circ$ - $28,4^\circ$)

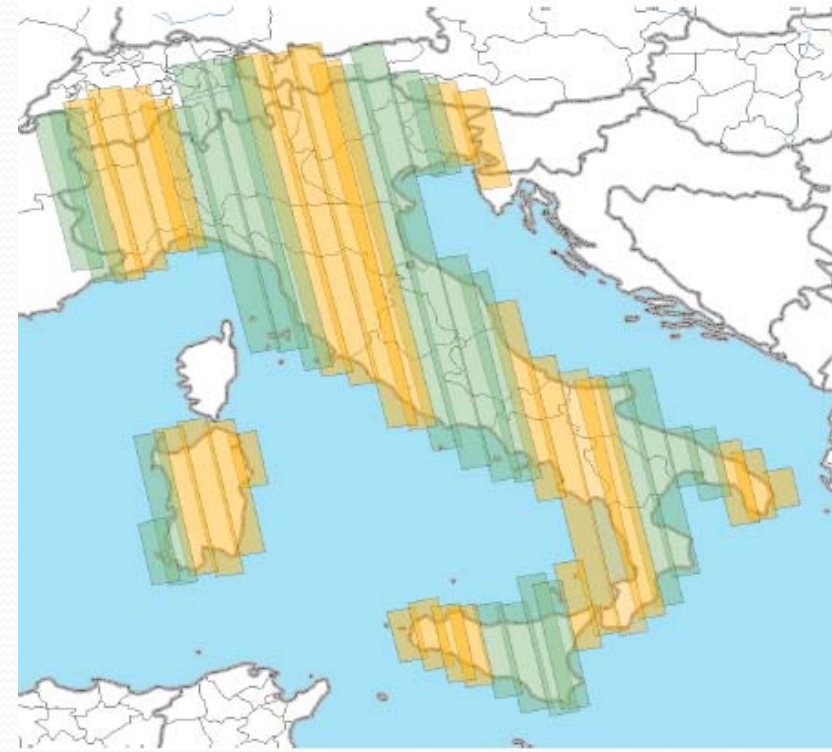
Beam H4-3 ($27,7^\circ$ - $31,0^\circ$)

Beam H4-4 ($30,7^\circ$ - $33,8^\circ$)

Beam H4-5 ($32,4^\circ$ - $35,5^\circ$)



The Maptaly 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

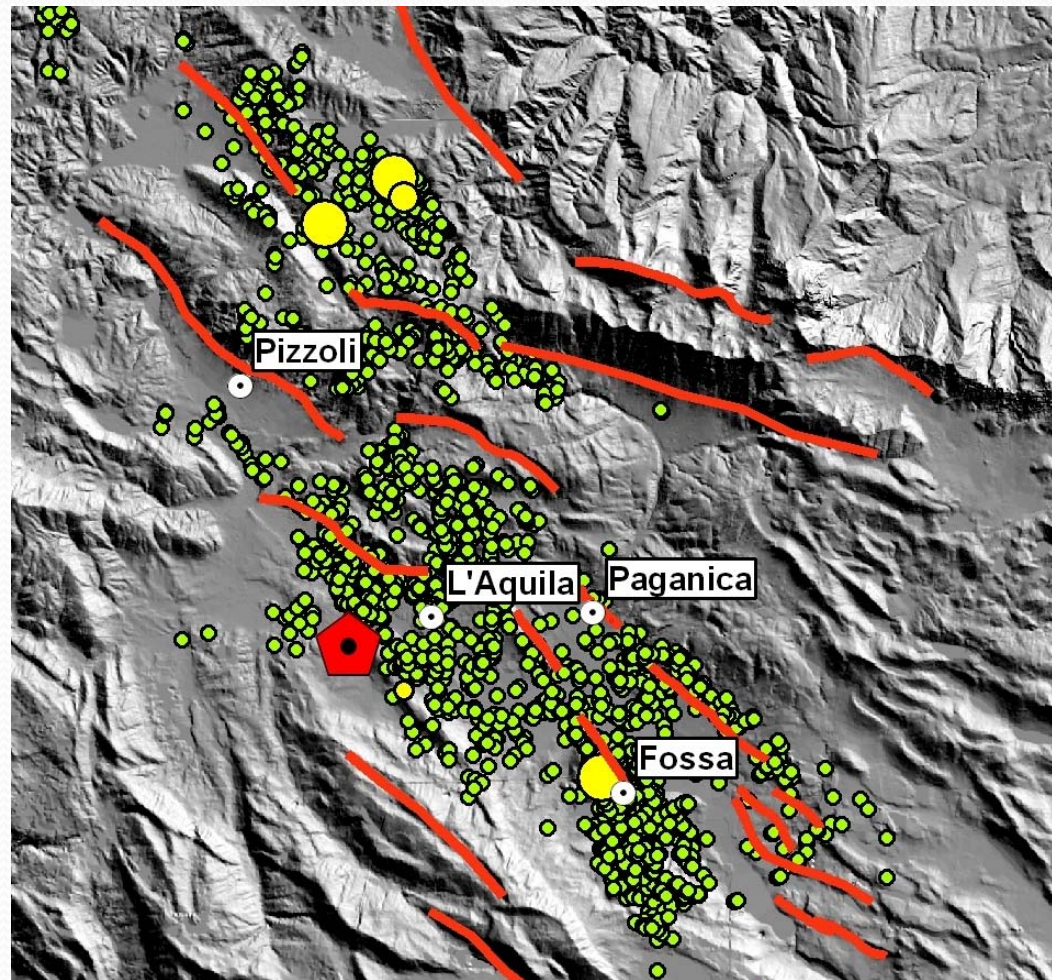


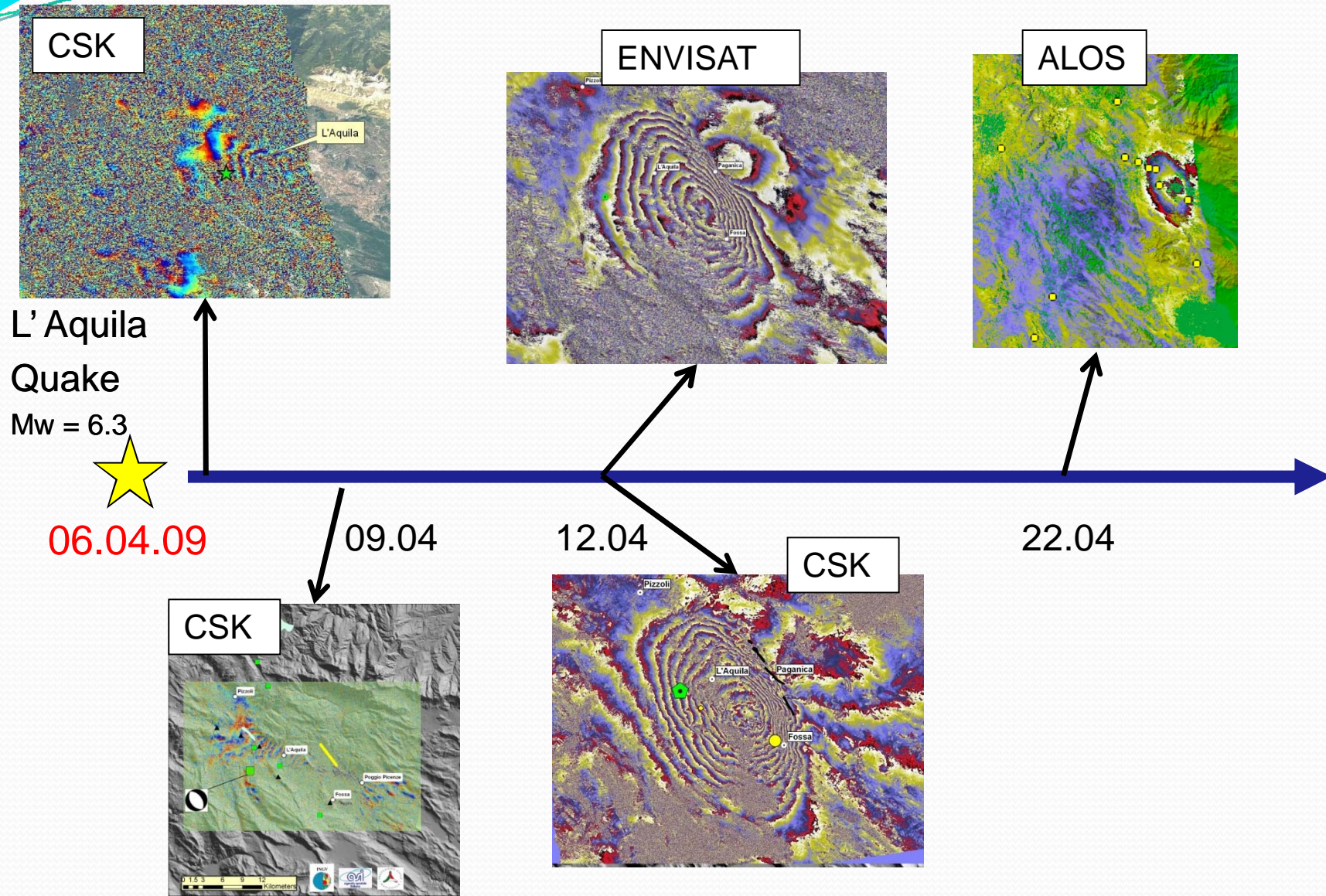
Examples of SIGRIS Crisis products:

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



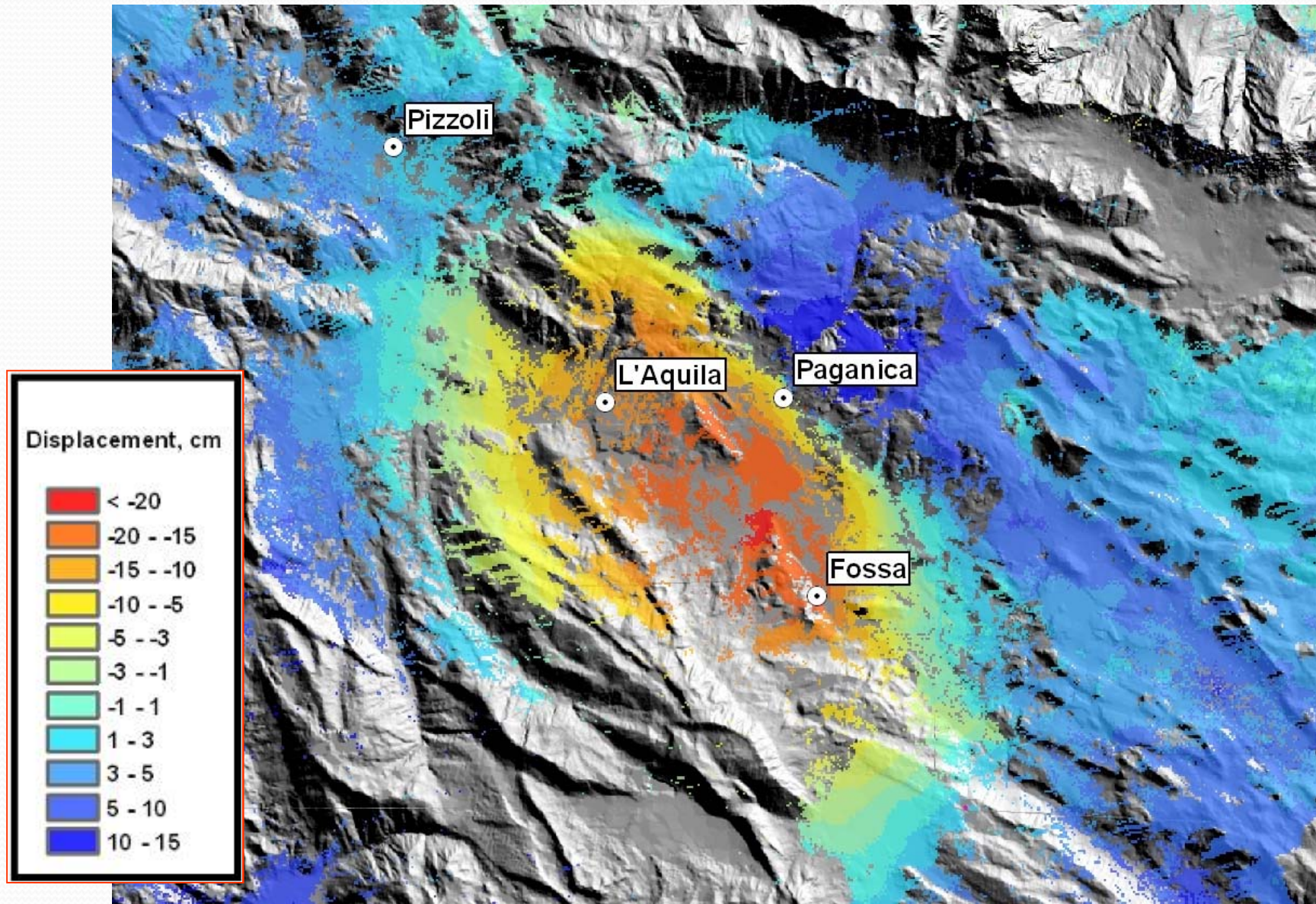
The Mw= 6.3 2009 L'Aquila Earthquake, Central Italy





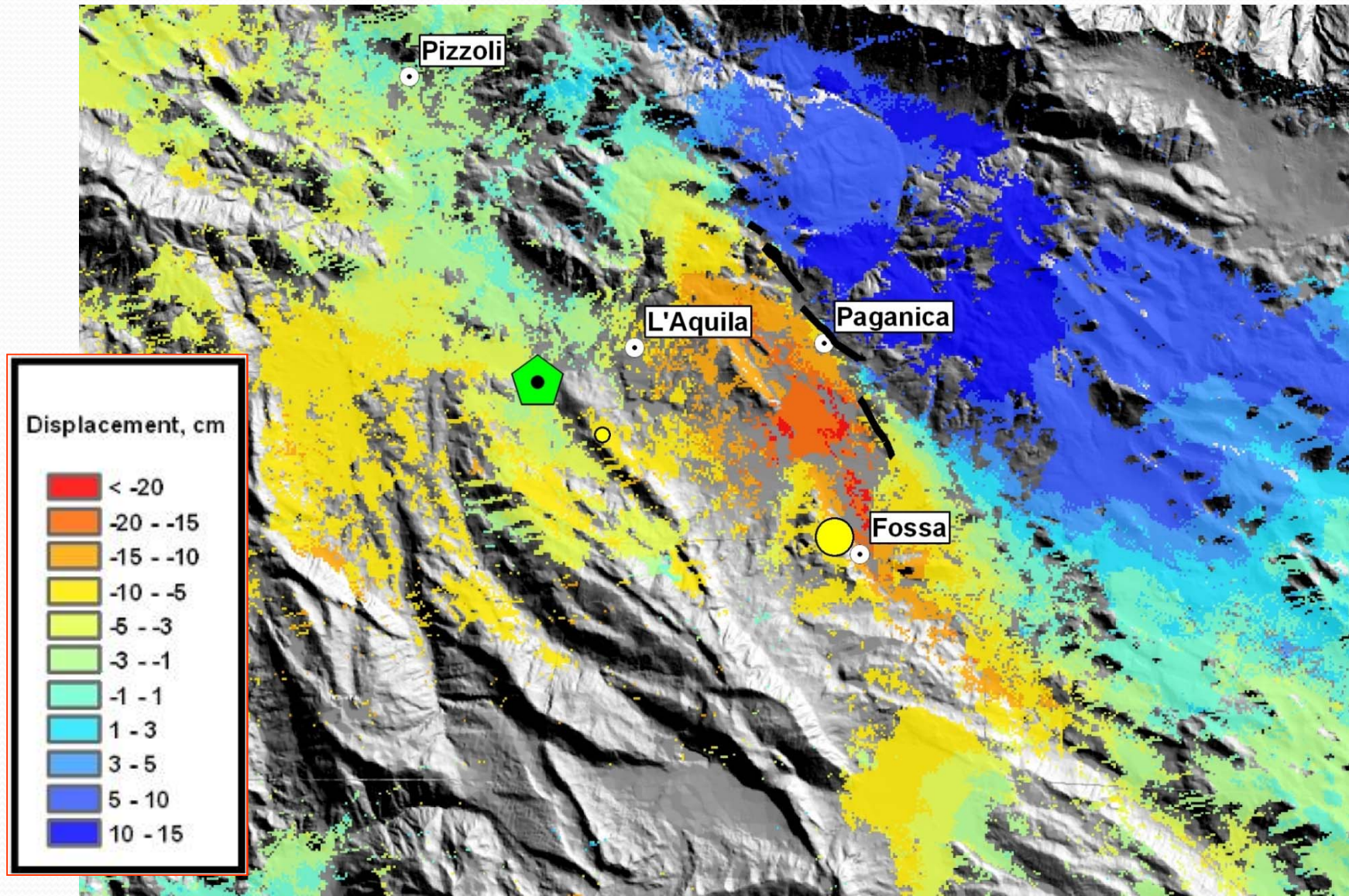


Up ground displacements





East ground displacements

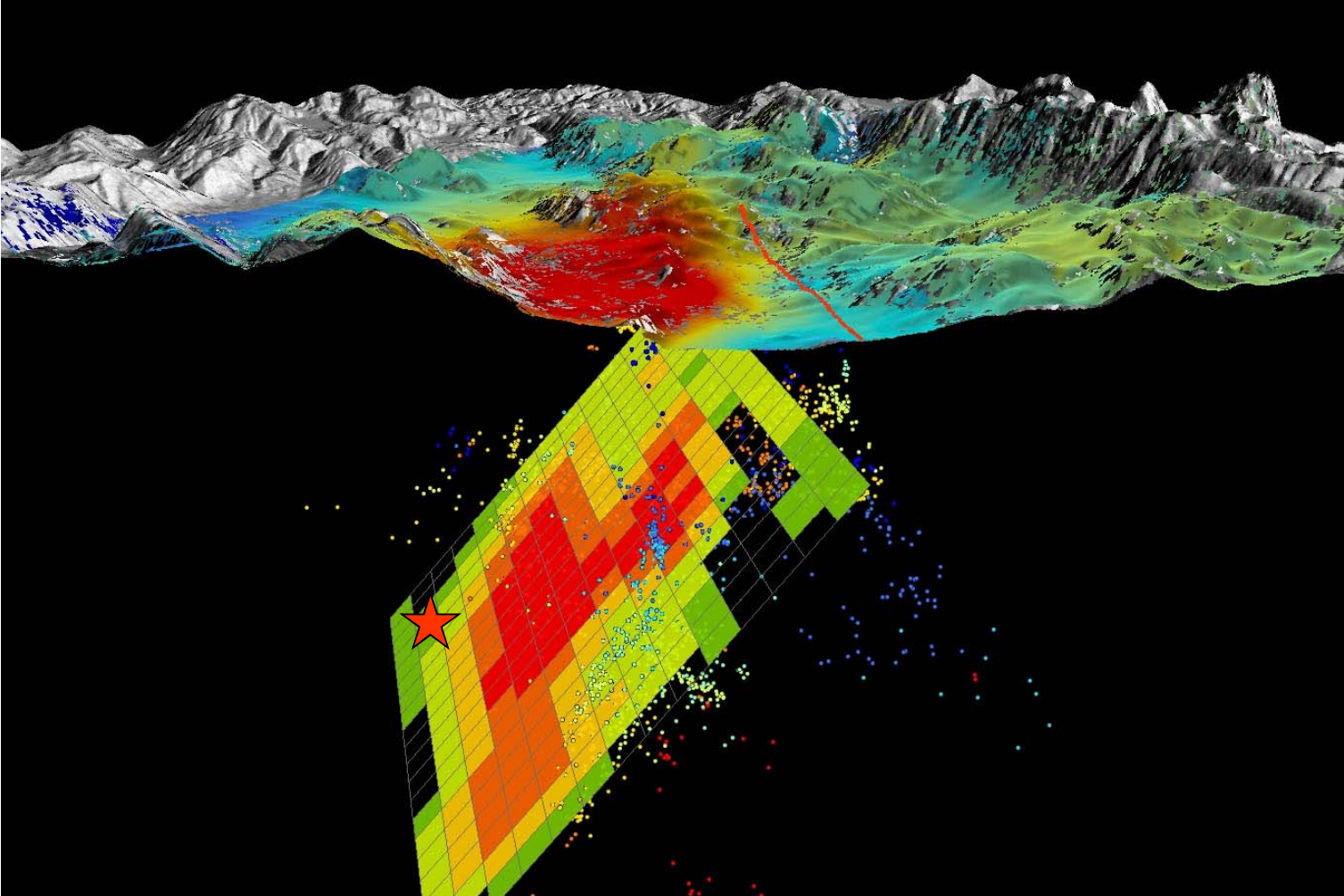




Validated source model

Validated with
seismological
and geological
data.

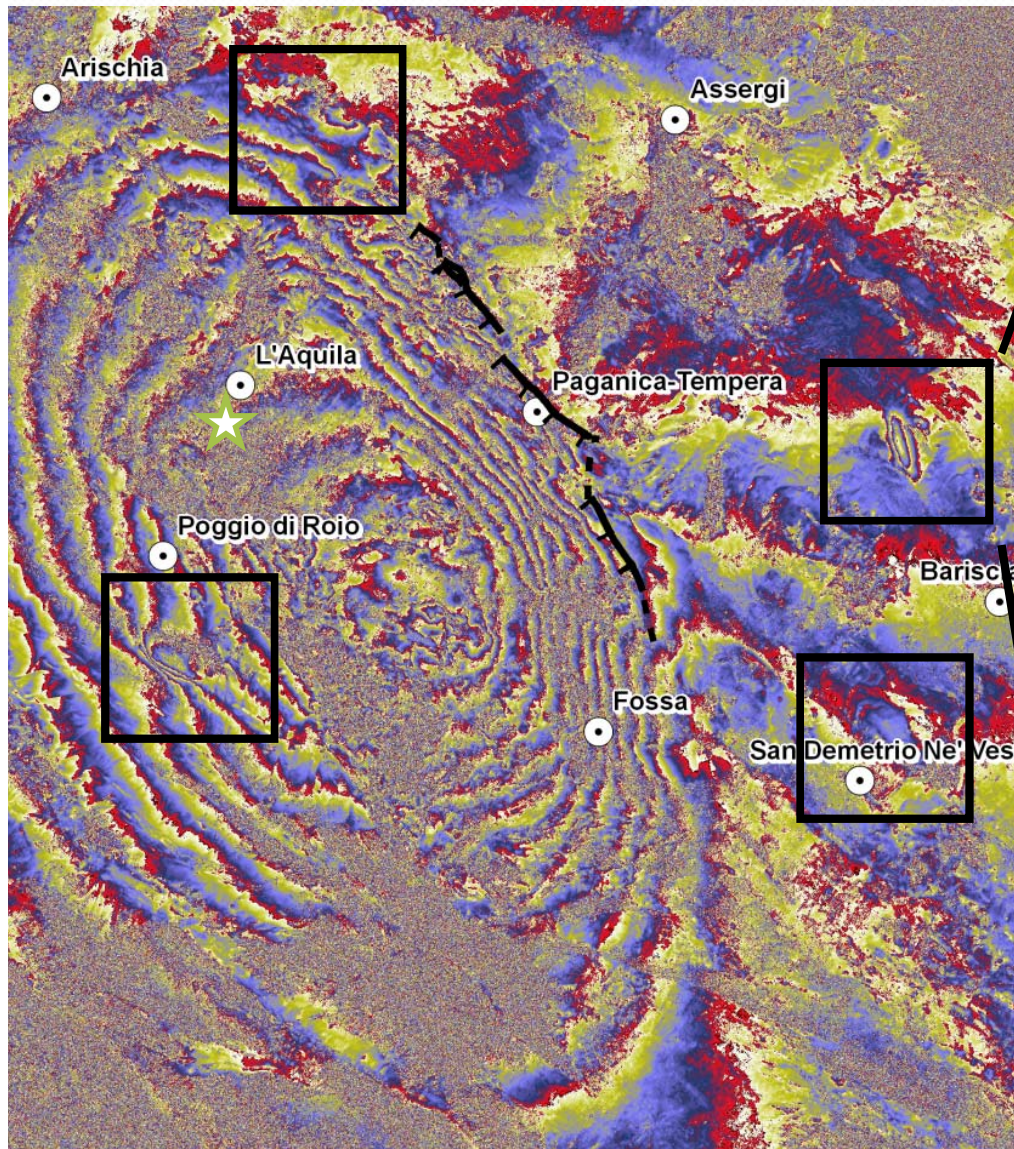
Atzori et al, 2009
GRL



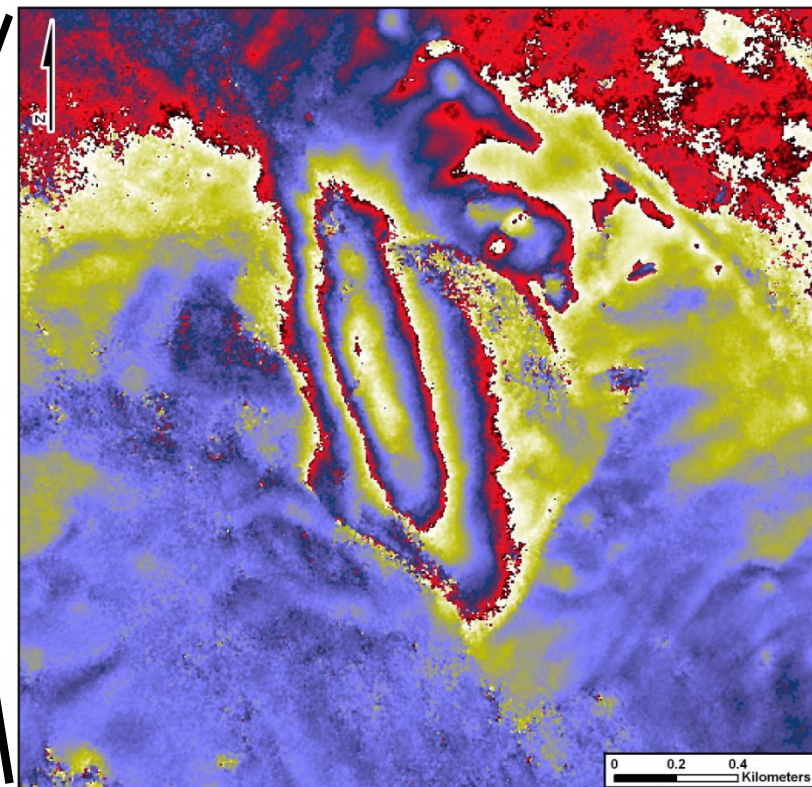
Strike (°)	Dip (°)	Rake (°)	Length (km)	Width (km)	Slip (cm)	Top depth (km)
133C	47°	-103°	20	14	Max 91	1



Map of local earthquake effects



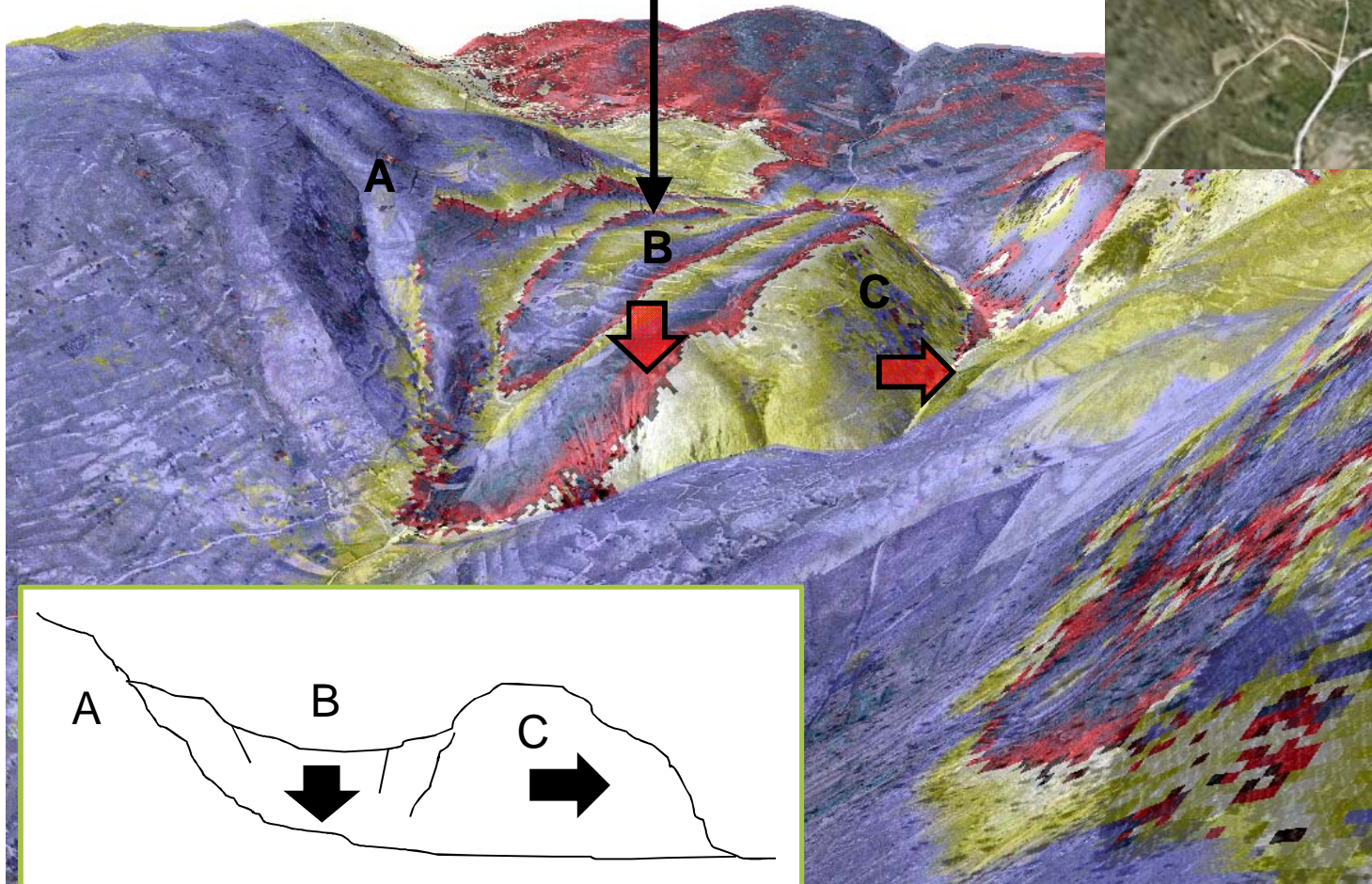
COSMO-SkyMed high resolution





Triggered gravitational deformation

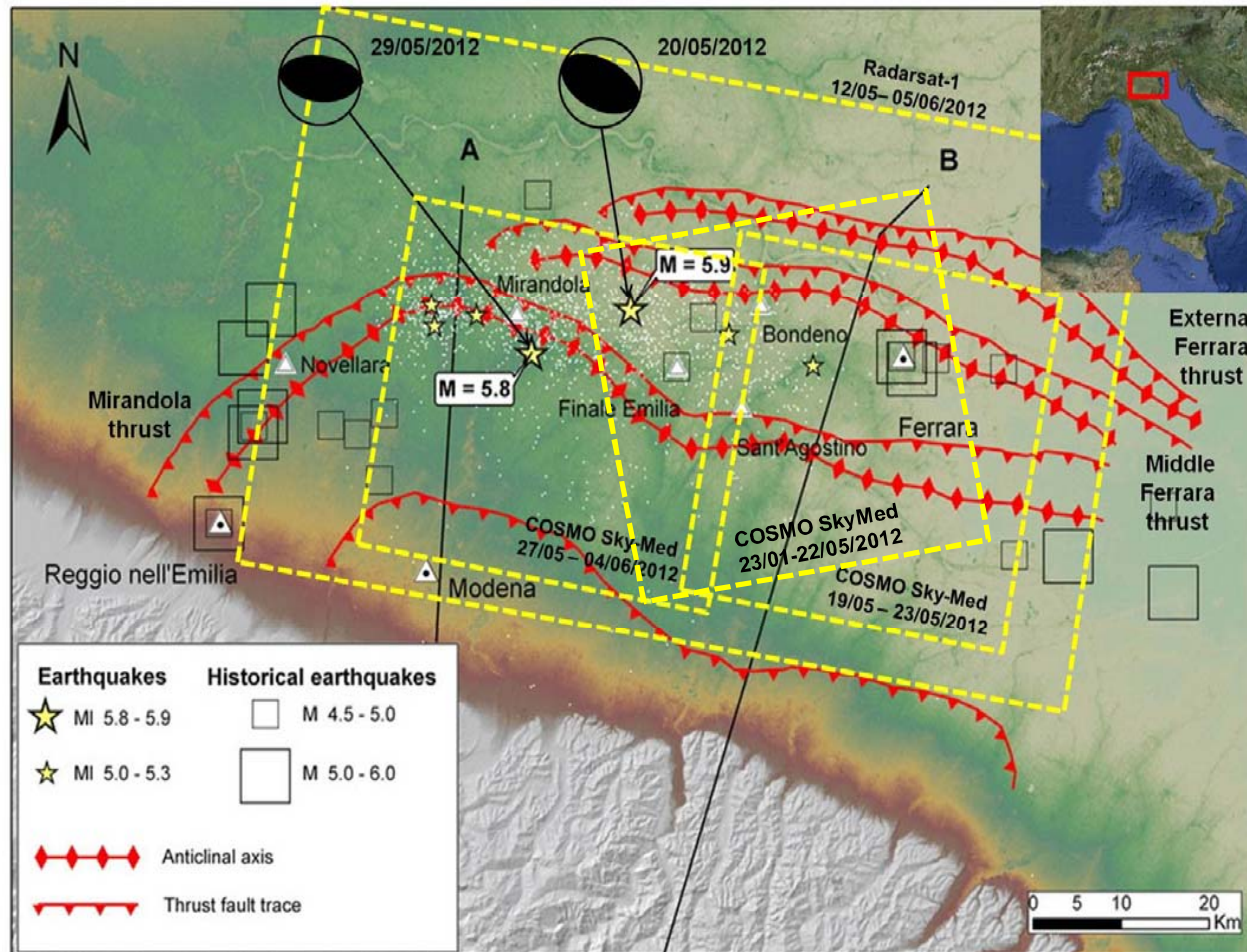
Major trench zone



Moro et al, 2010
Geology



The 2012 Emilia sequence (Mw 5.9)



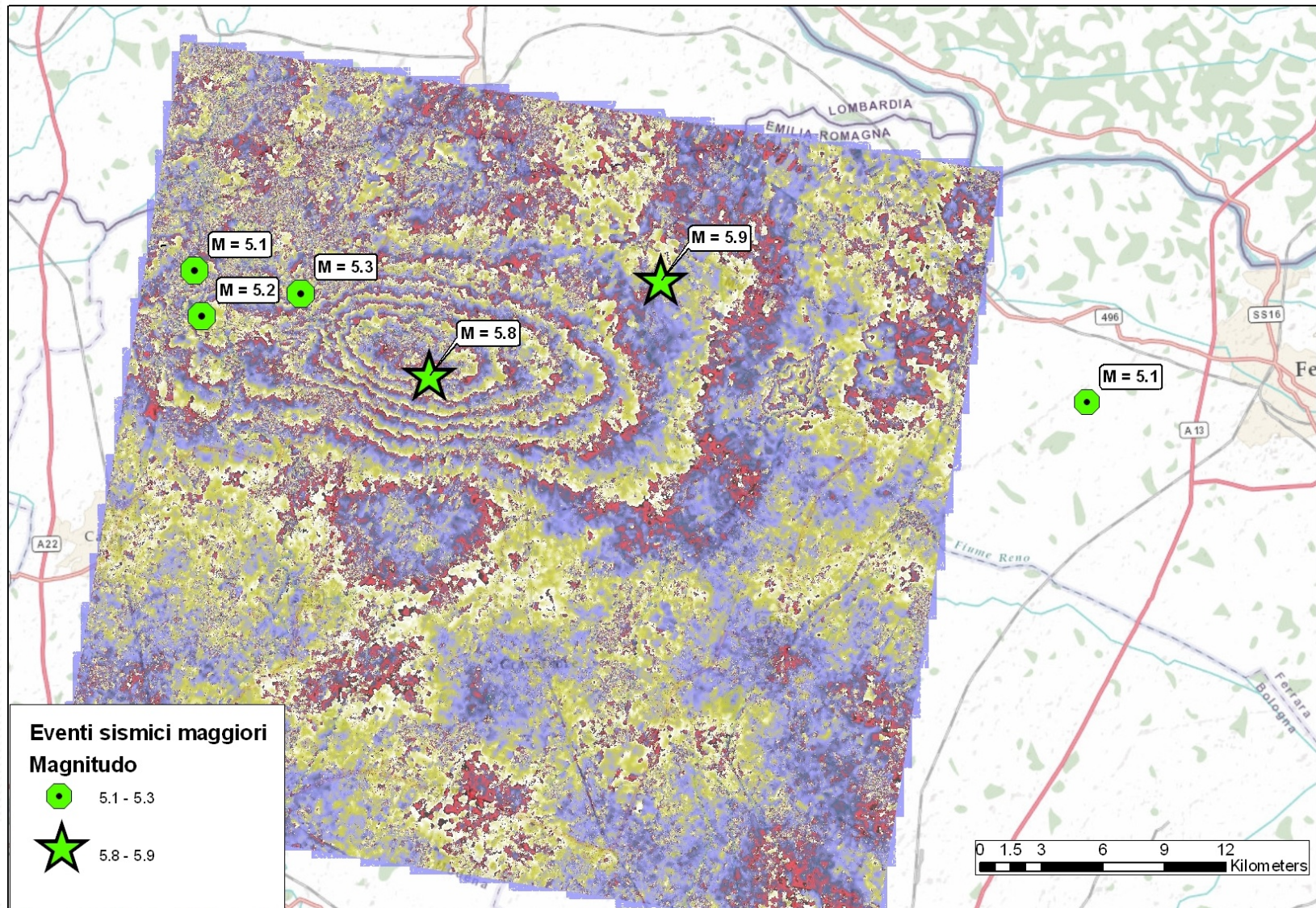
Few pre-event CSK images: “holes” in the MapItaly archive

Pezzo et al, 2013, SRL



The 2012 Emilia sequence (large aftershock Mw 5.8)

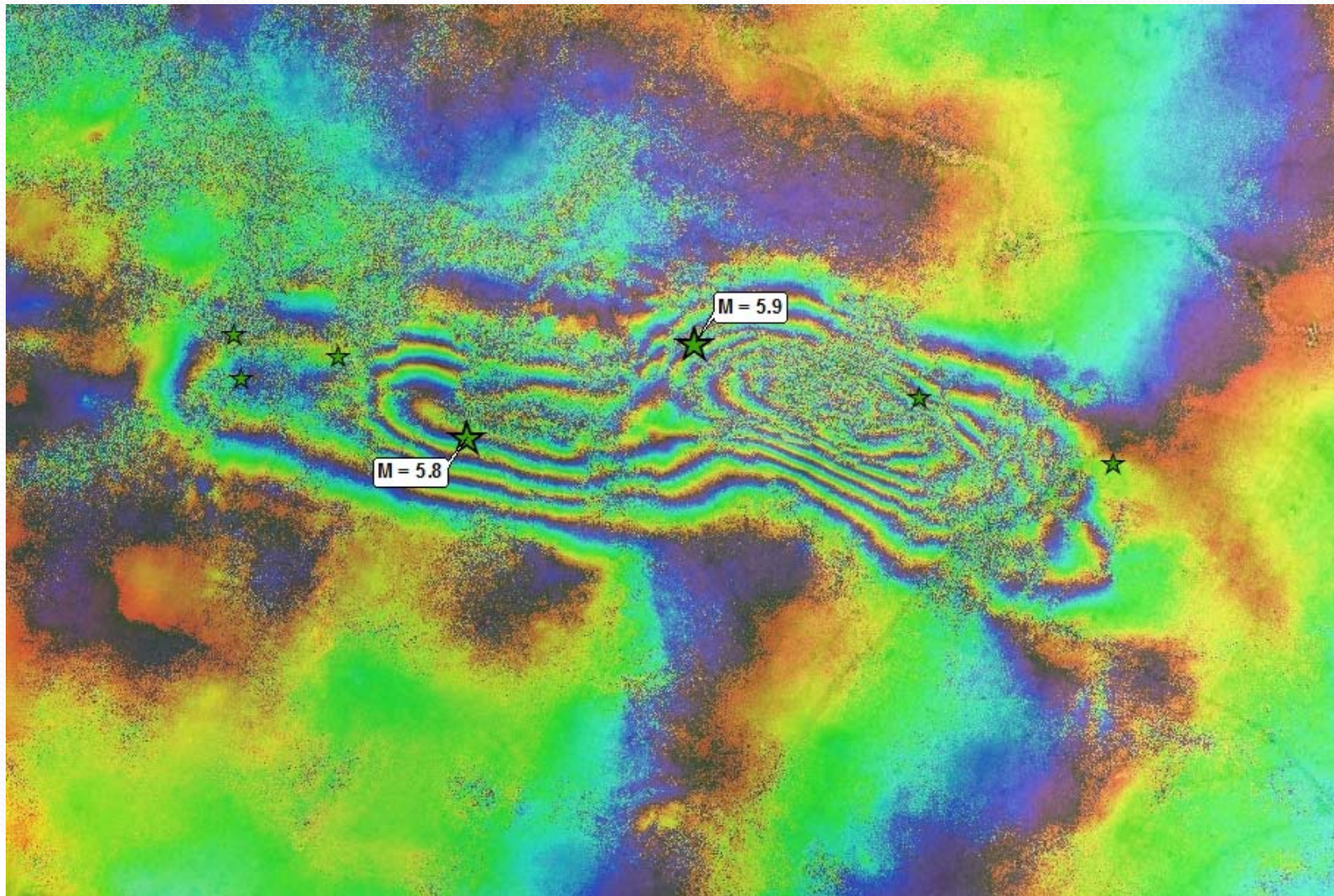
COSMO-SkyMed interferogram





The 2012 Emilia sequence (the largest events)

Radarsat interferogram





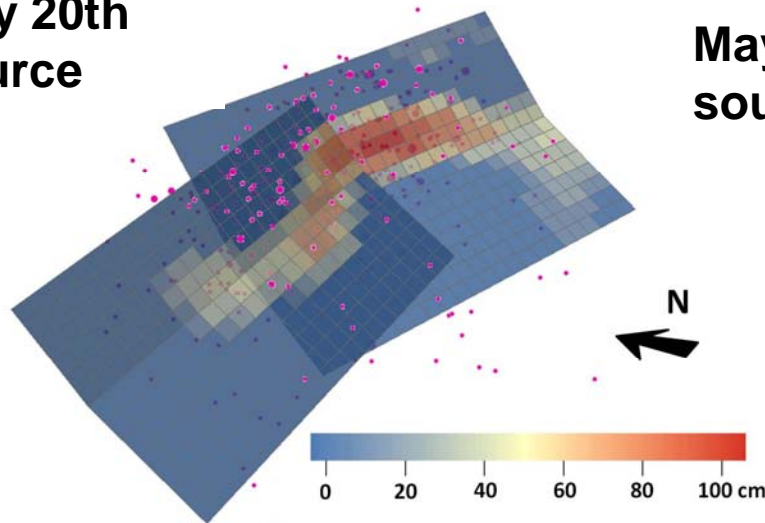
The 2012 Emilia source model

Source parameters

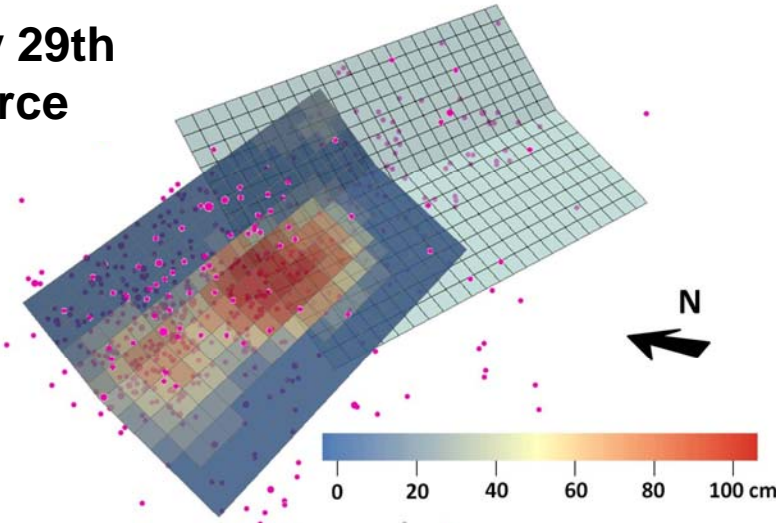
Pezzo et al, 2012 - SRL

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

May 20th source



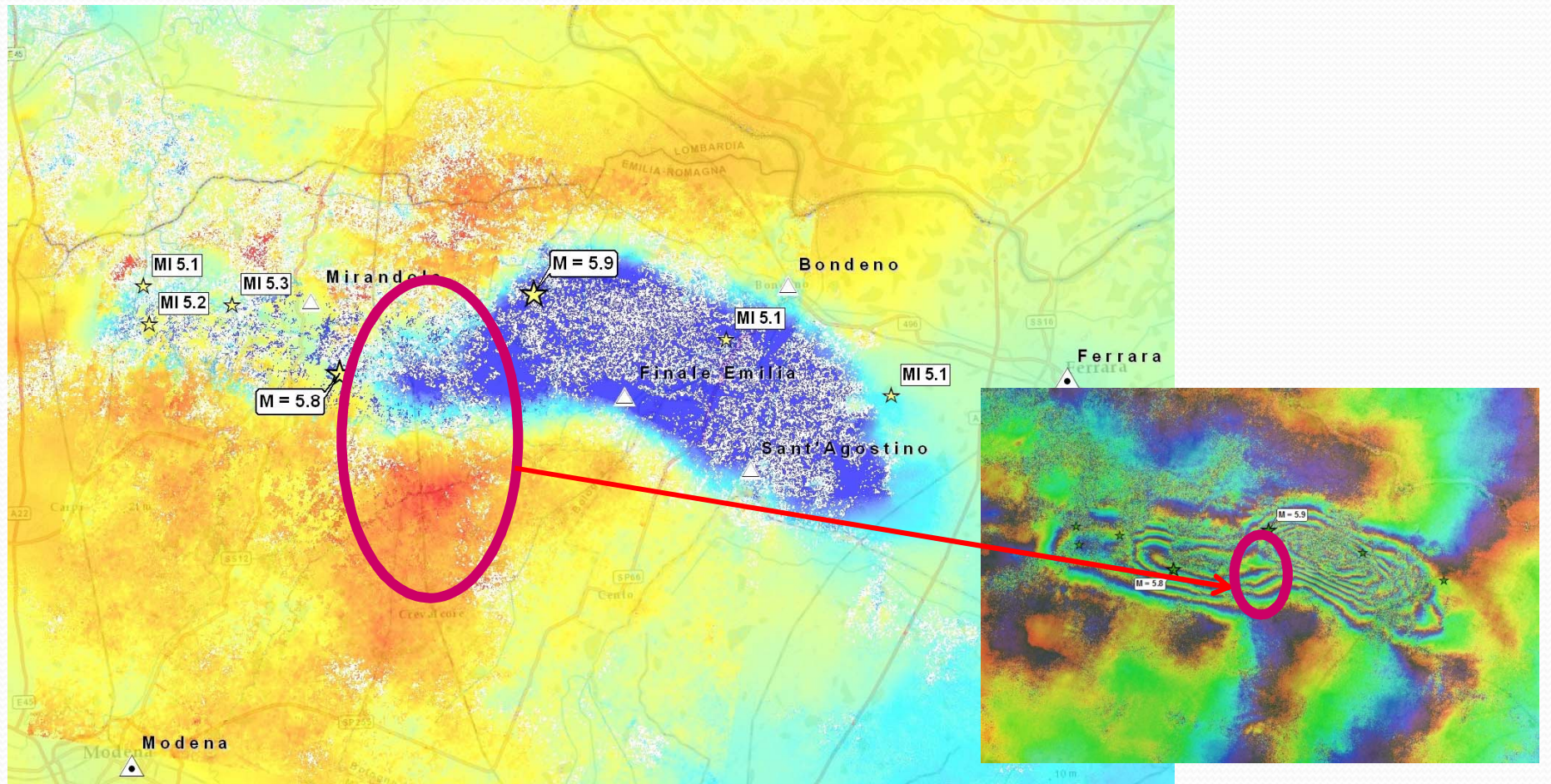
May 29th source





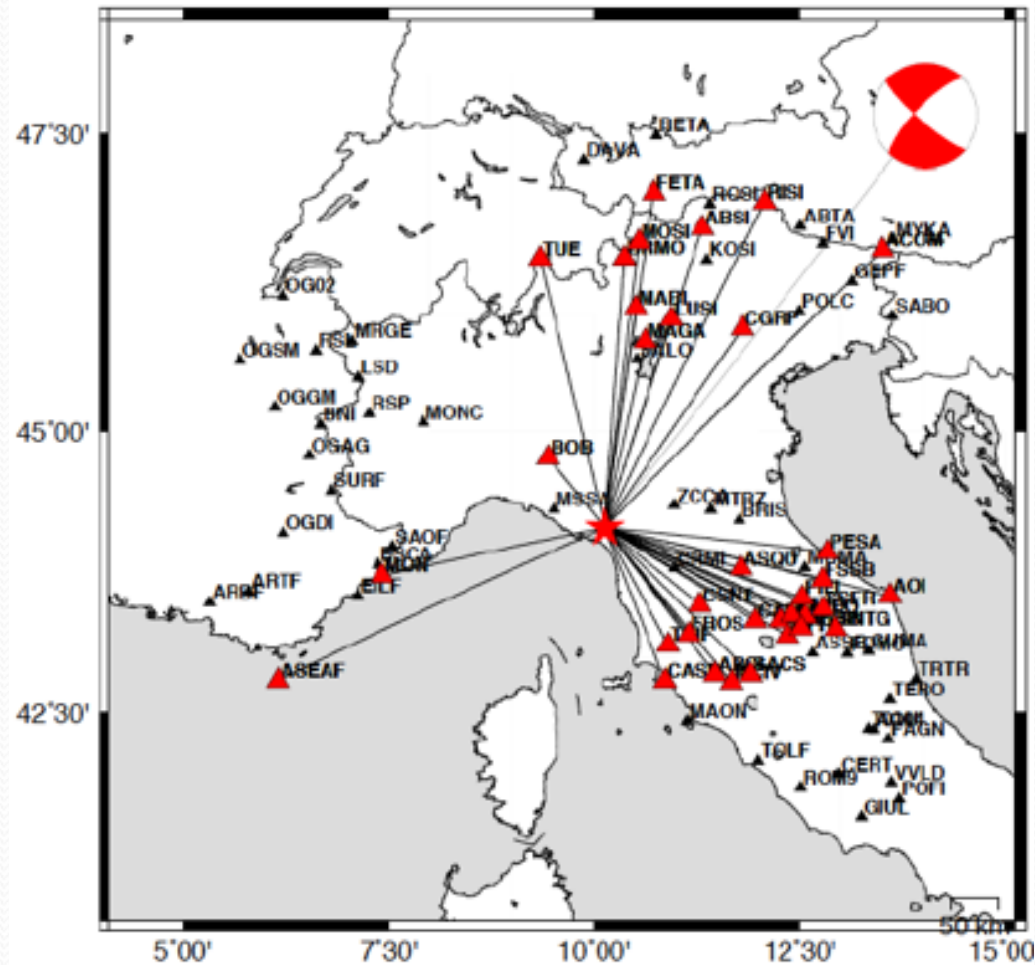
A slow slip event ?

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.





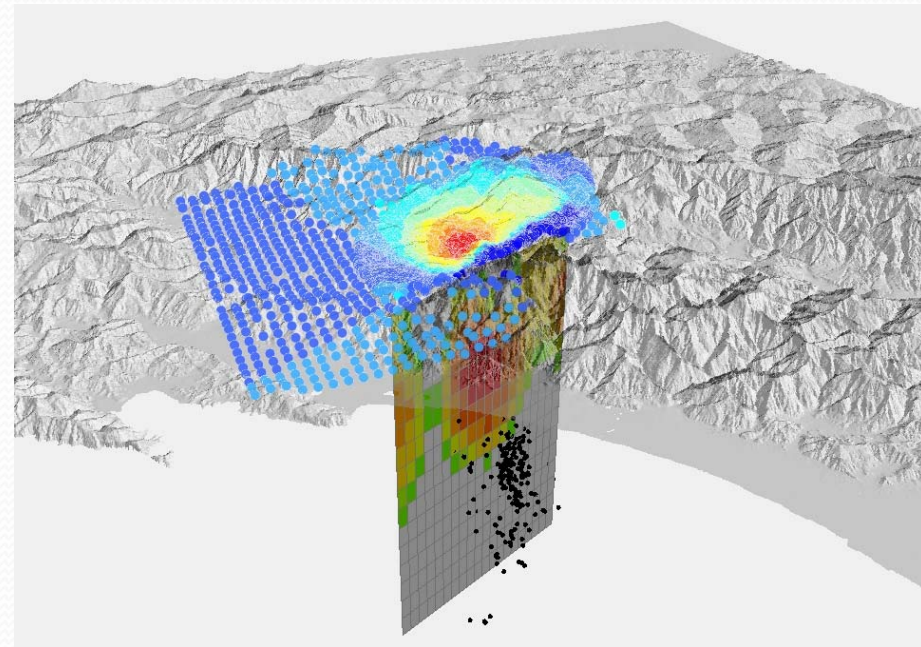
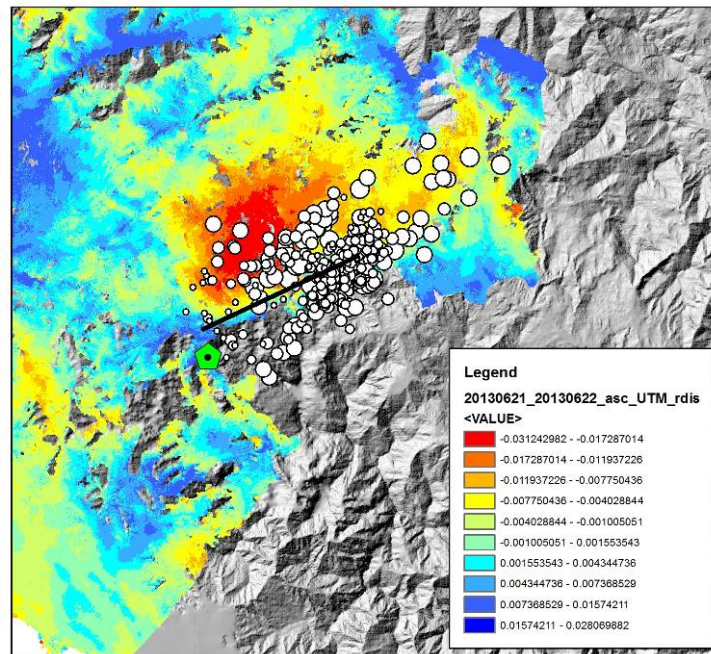
The June, 21st 2013 Lunigiana event (Mw 5.4)





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.