Use of Satellite Radar Observations for Earthquake Response and Risk Assessment

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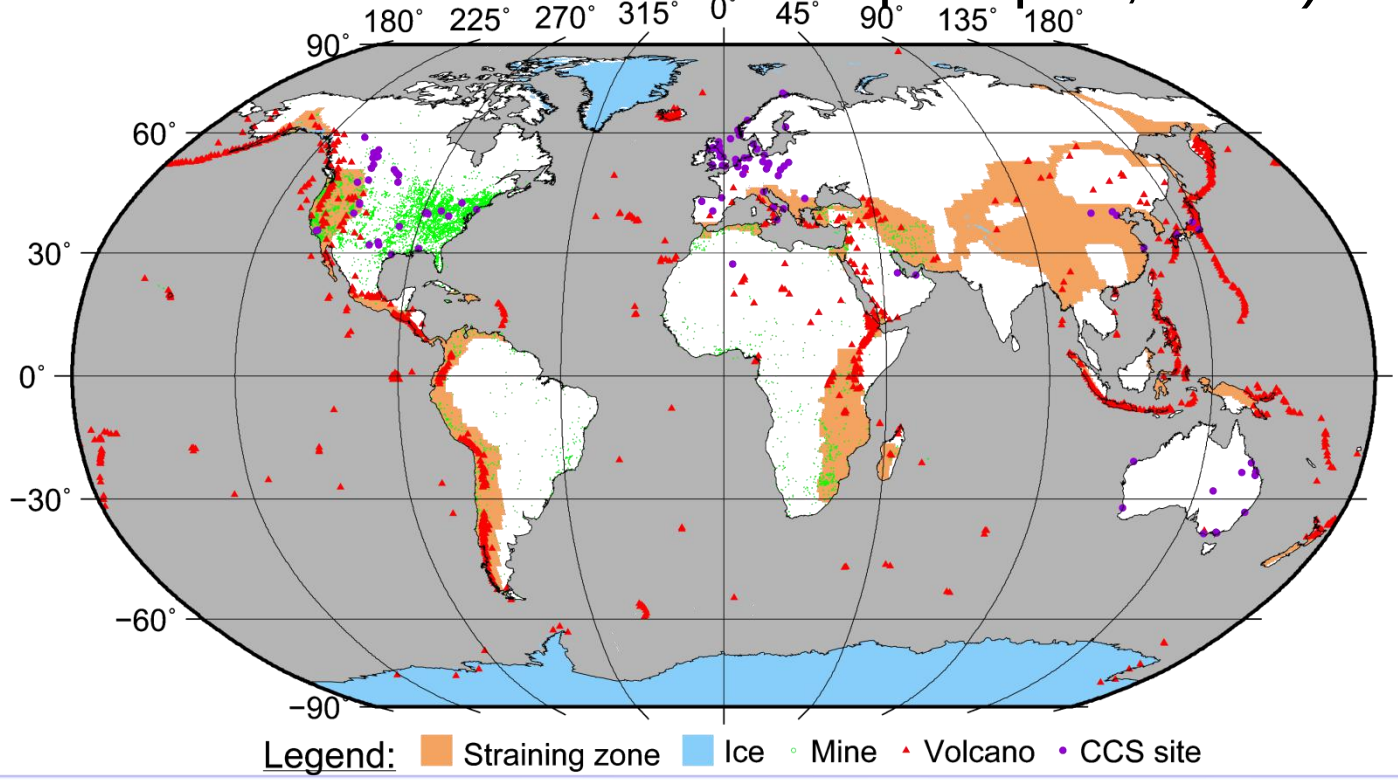
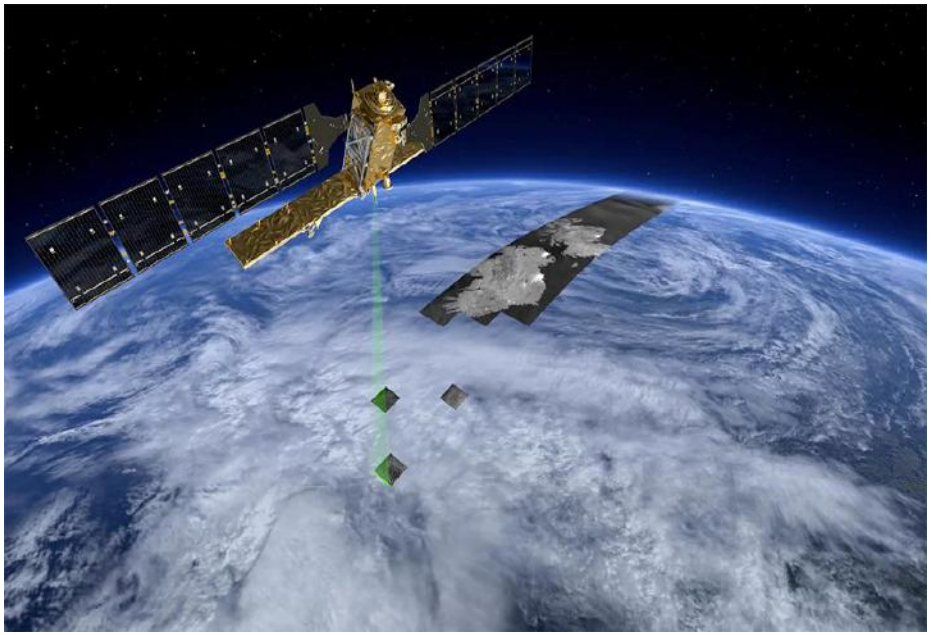
"InSAR everywhere, all the time"

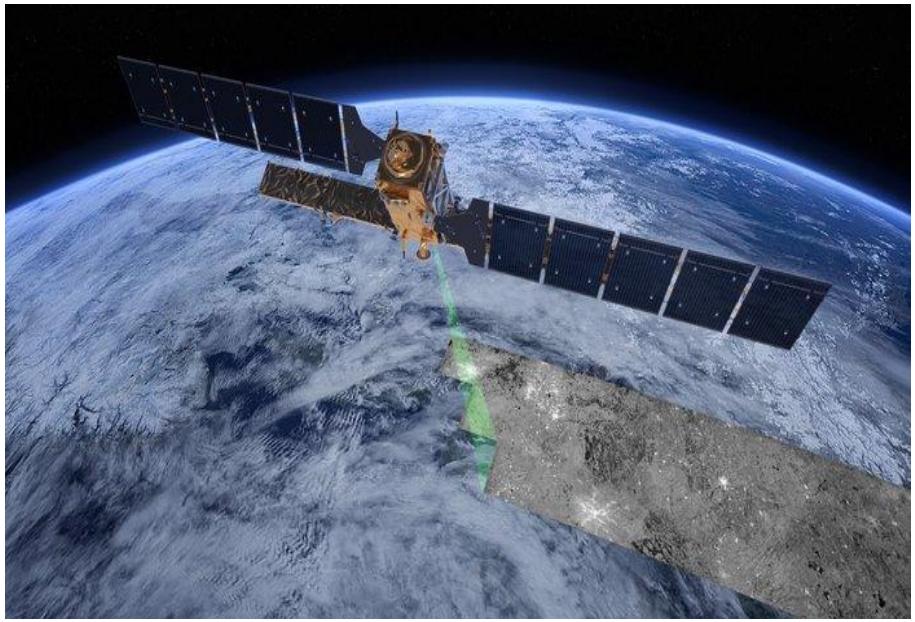
(NASA Solid Earth Science Working Group Report, 2002, NASA InSAR Workshop Report, 2004)



We can't give short-term predictions for which faults will fail in earthquakes.

ESA's C-band Sentinel-1





Sentinel-1A

Launch date: 3 April 2014

Repeat cycle: 12 days

Sentinel-1B

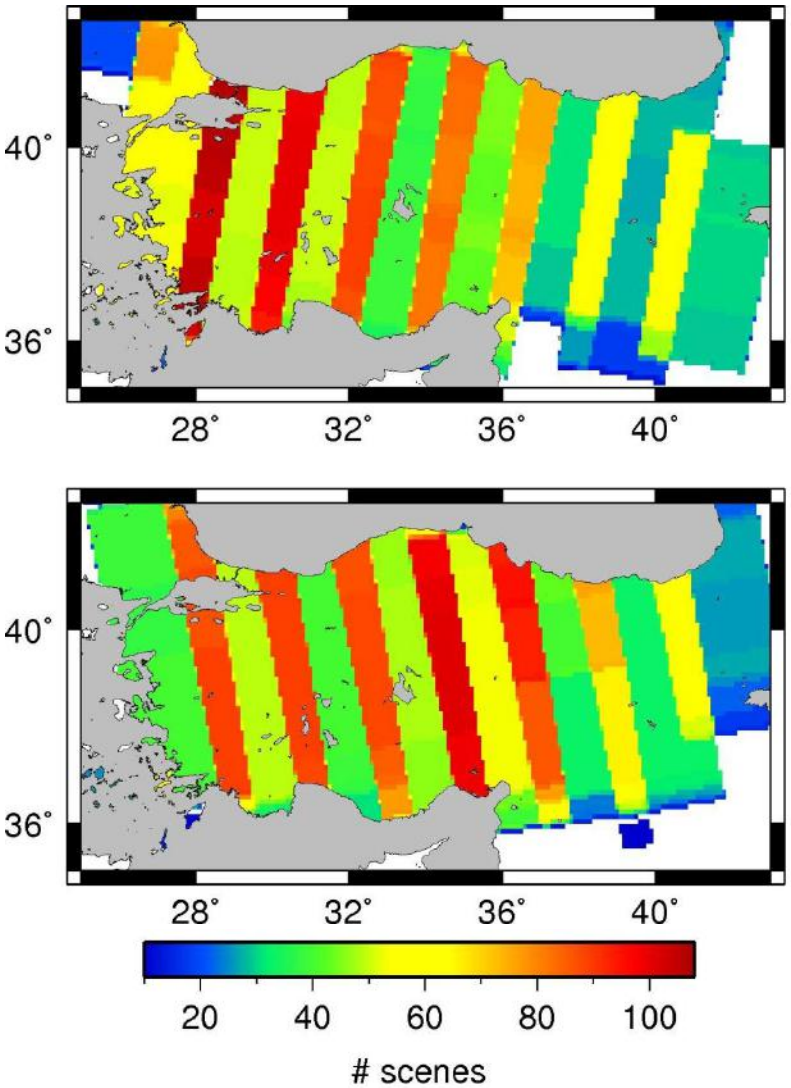
Launch date: 25 April 2016

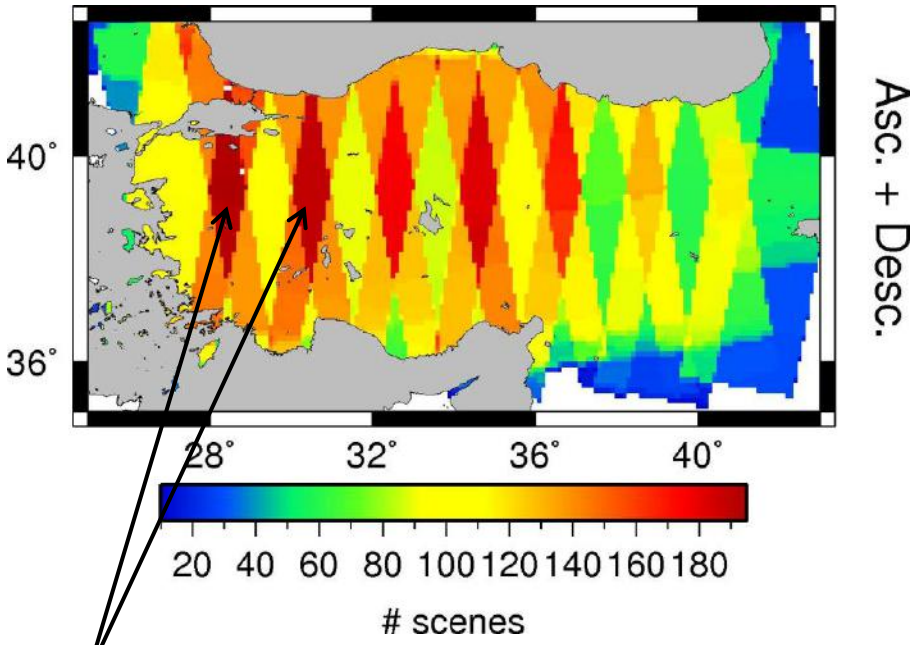
Repeat cycle: 12 days

Sentinel-1 is a Game Changer!

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, swath widths usually less than 100 km.
3. Small perpendicular baselines, acquisitions every 6/12/24 days, ascending and descending -> high coherence	Often large perpendicular baselines and long gaps between acquisitions -> poor coherence
4. 20 year operational program, designed for InSAR	Stand-alone missions, often not designed for InSAR
5. Free, full and open data policy, enables mass processing.	Restricted data access, often commercial pricing

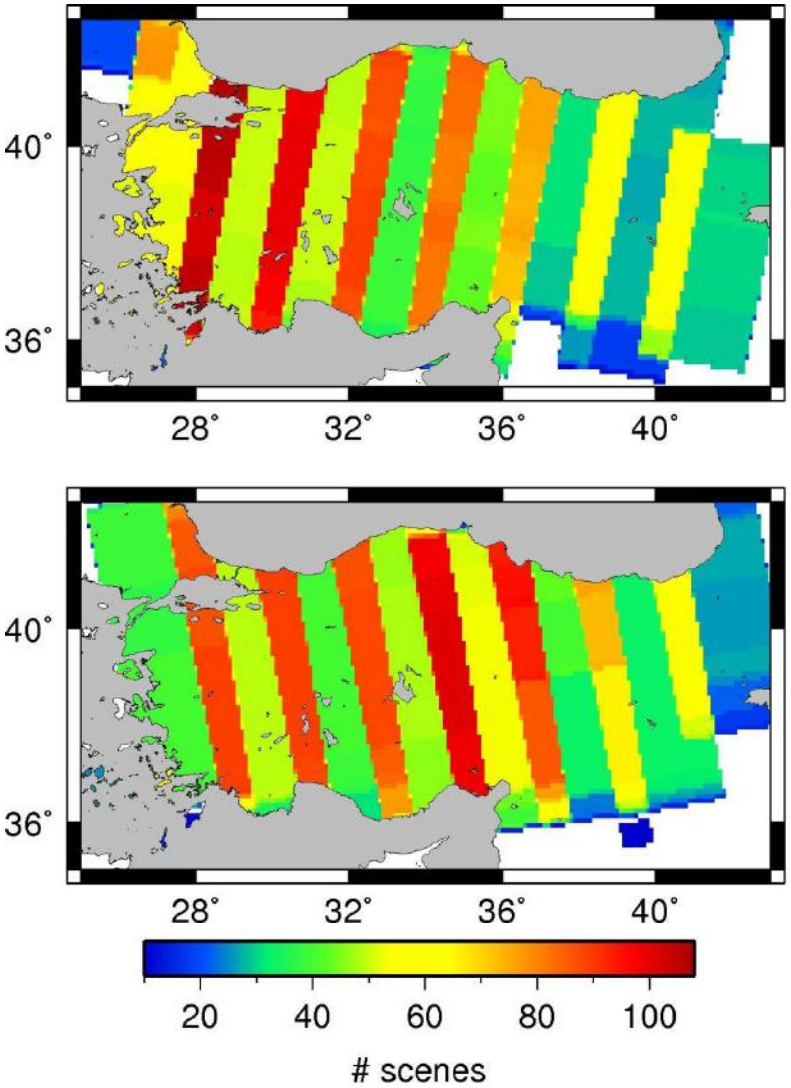
Data coverage for Turkey: Sentinel-1A only

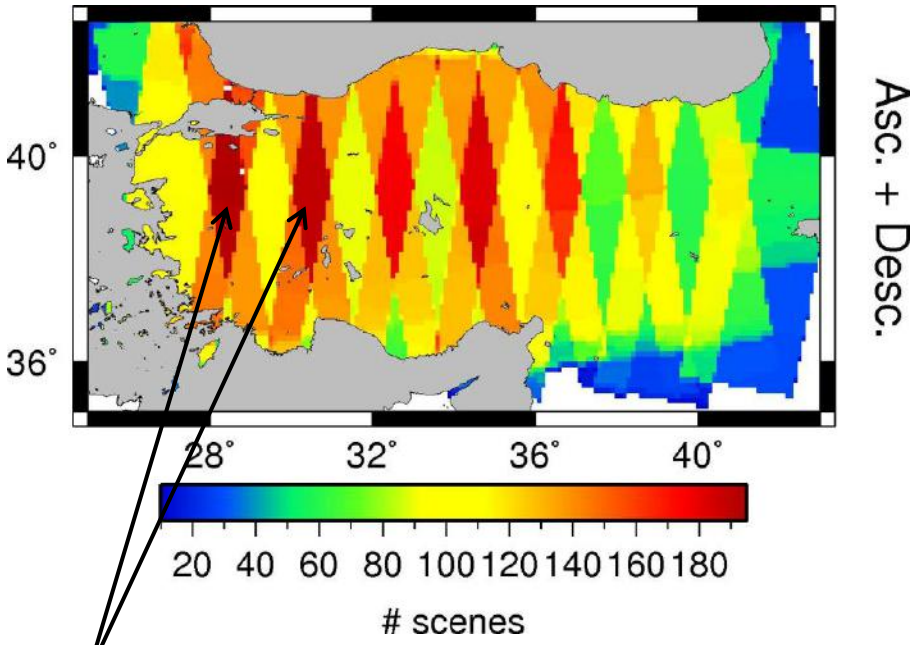




4 acquisitions per orbit (12 days) for these diamond-shaped regions = 2 Asc + 2 Desc

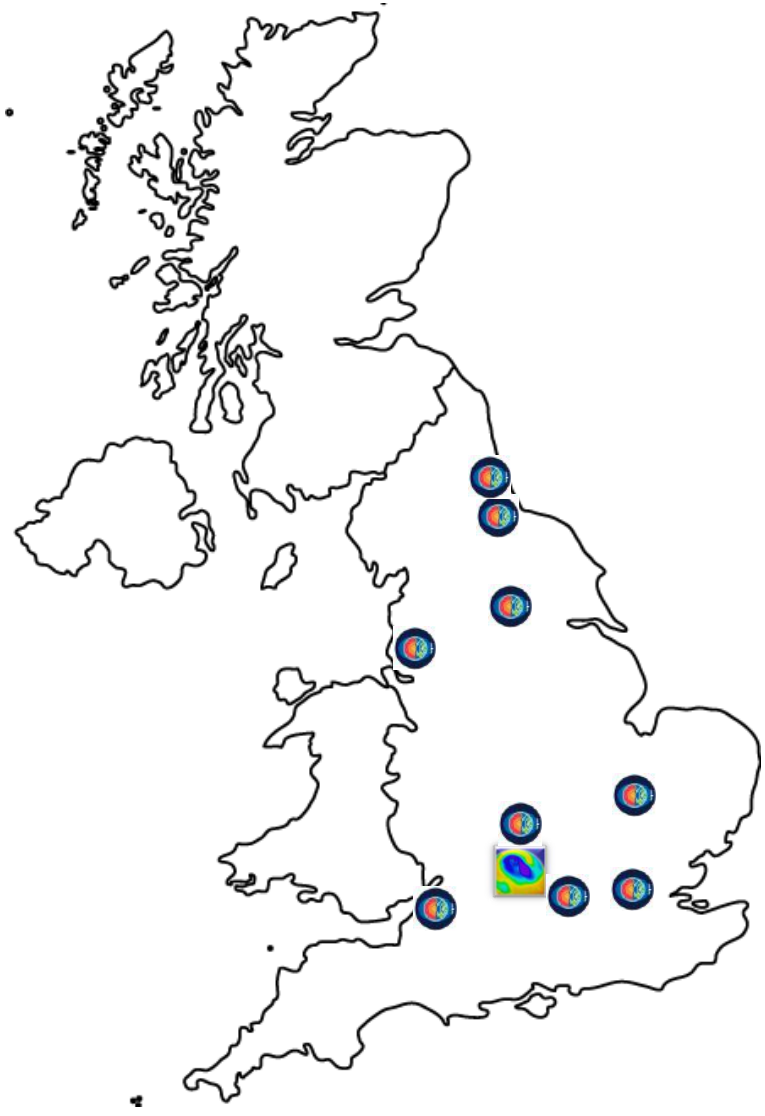
Data coverage for Turkey: Sentinel-1A + Sentinel-1B





8 acquisitions per orbit (12 days) for these diamond-shaped regions = 4 Asc + 4 Desc

COMET-CEMS processing facility



Command and monitoring

COMET

storage facility

(and future public services)

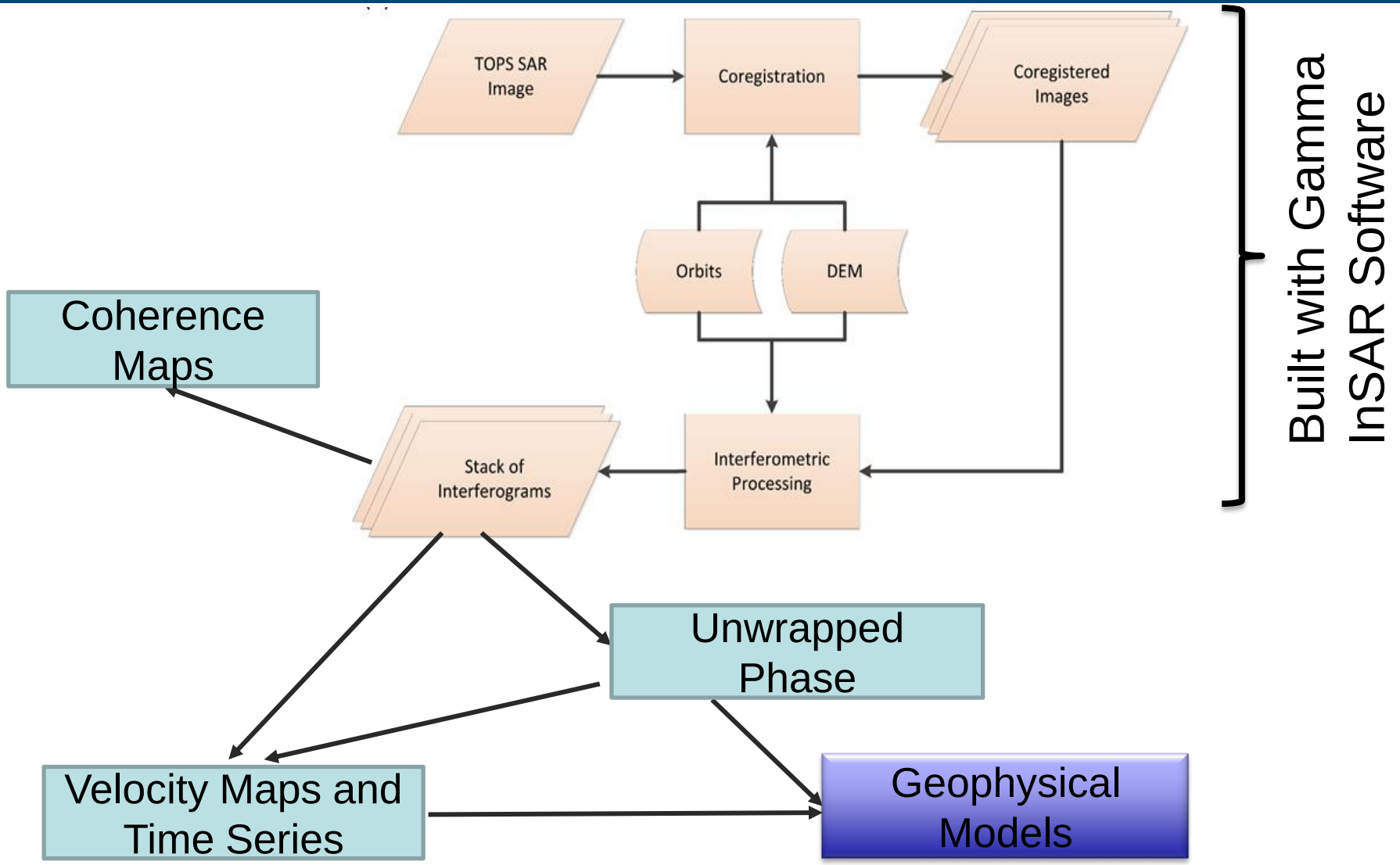
CEDA

CEMS

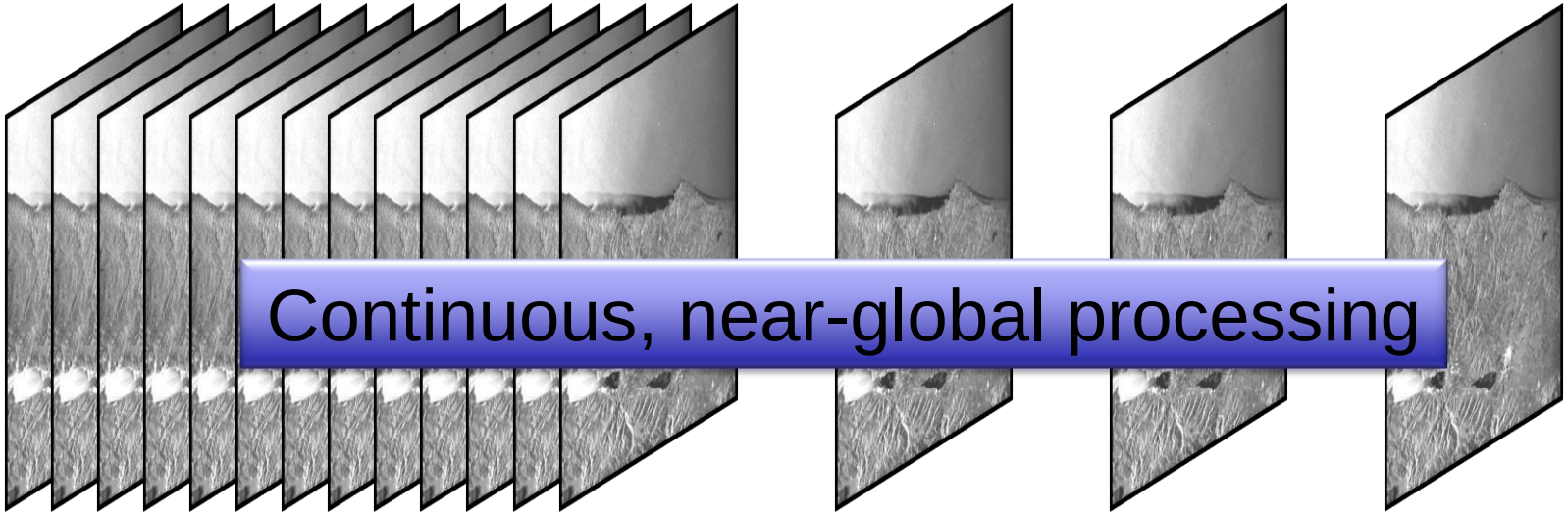
Climate, Environment & Monitoring from Space

processing facility

COMET InSAR Automatic Processing Chain (LiCSAR)



COMET InSAR Processing Chain (Time Series)



Continuous, near-global processing

T=0 ~1 yr +12 days +24 days +36 days

Orbit Models (real time + precise)

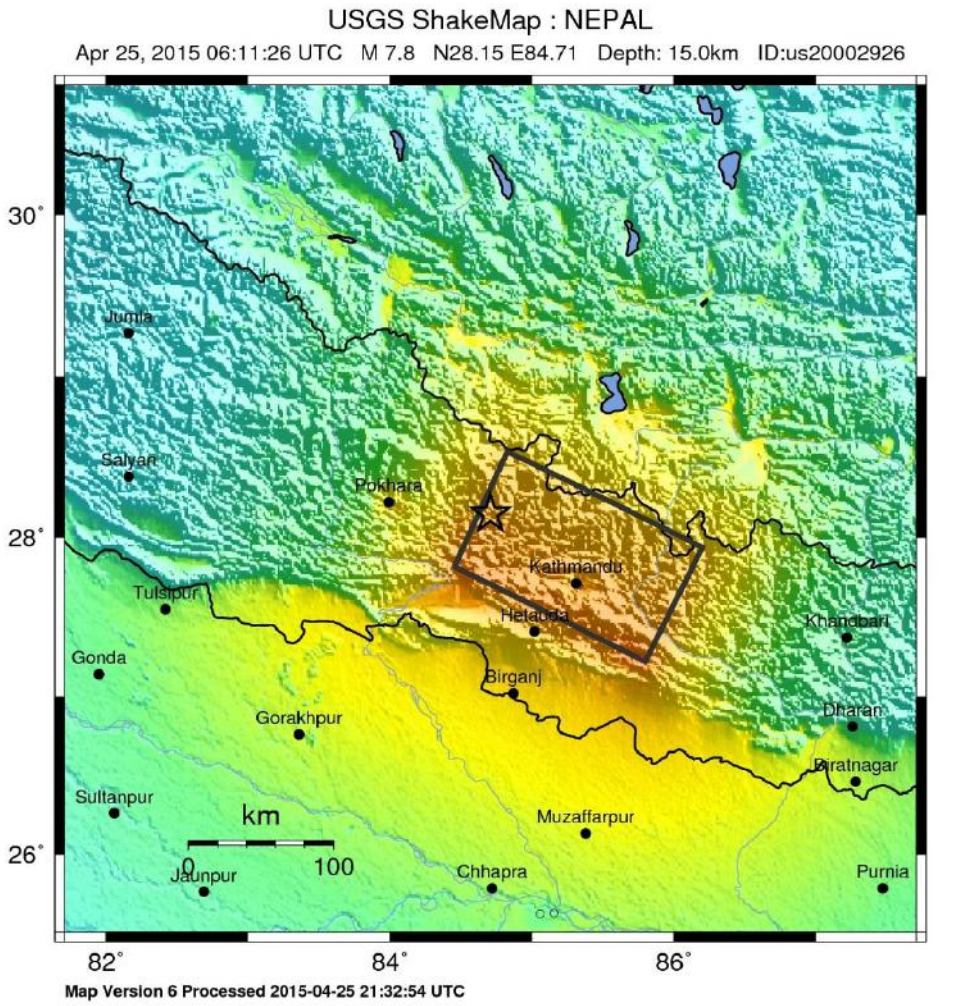
Atmospheric Models (real time + HR ECMWF)

Initial time series
Initial linear rates

Updated time series
Updated linear rates

The 2015 Ghorka (Nepal) earthquake: CCTV footage of Dabali

Initial location & magnitude comes rapidly from seismology…



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

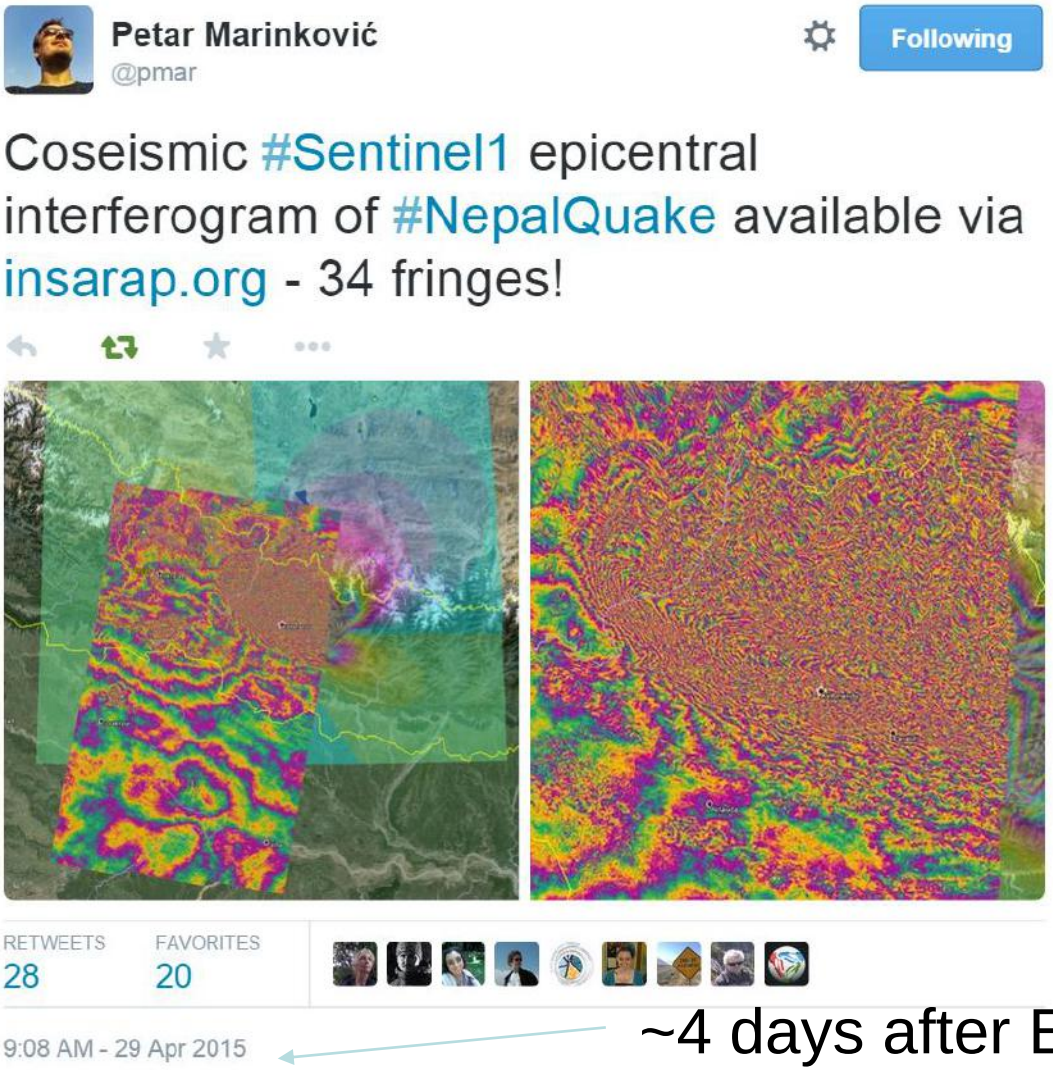
Scale based upon Worden et al. (2012)

v1 EQ + 19 minutes
v2 EQ + 52 minutes
v3 EQ + 83 minutes
v4 EQ + 2 hours
v5 EQ + 4 hours
v6 EQ + 15 hours

Ground shaking map

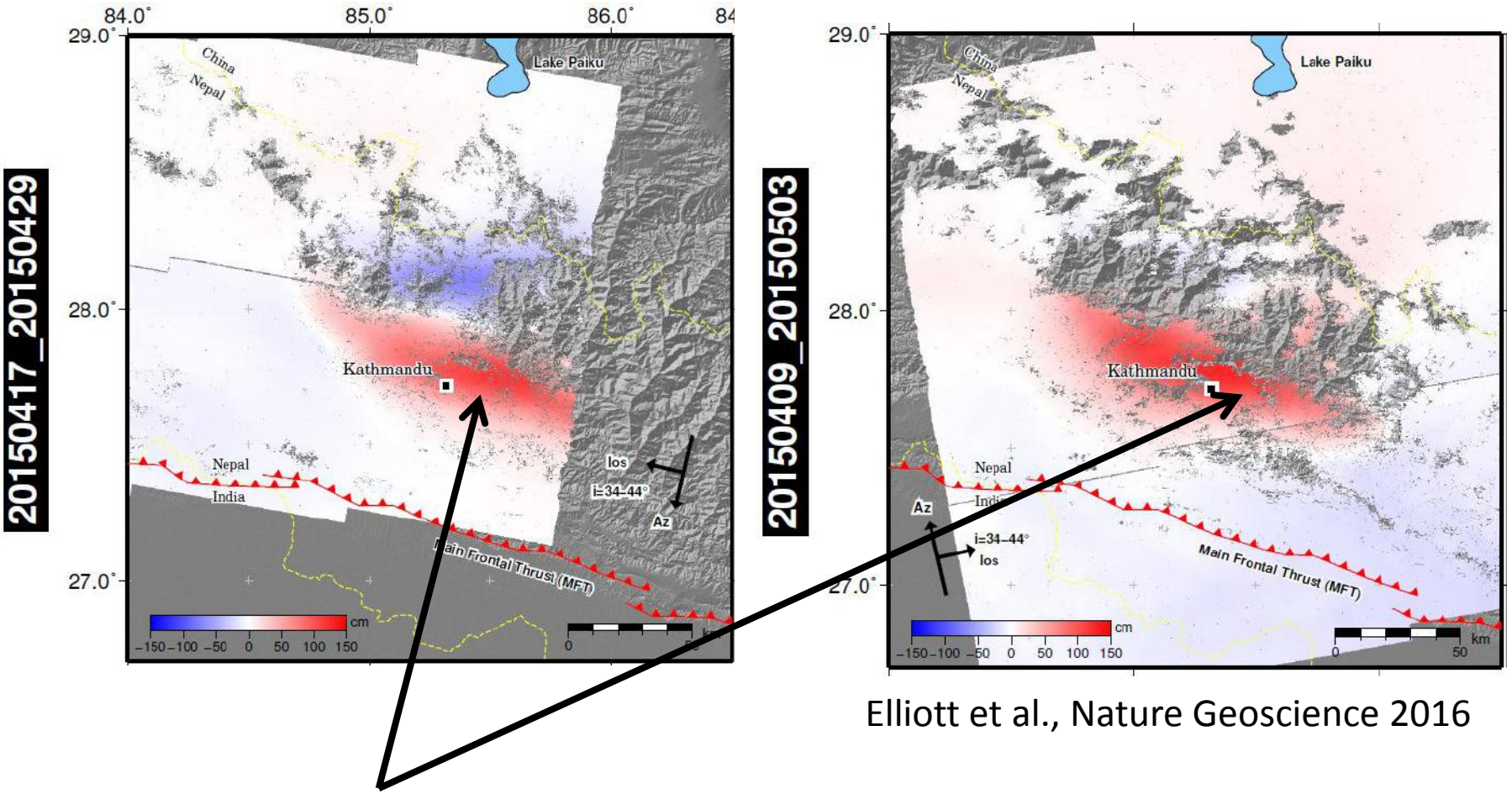
Thanks to Richard Briggs, Gavin Hayes, Bill Barnhard, USGS

The 2015 Ghorka (Nepal) earthquake: First Sentinel-1A Interferograms



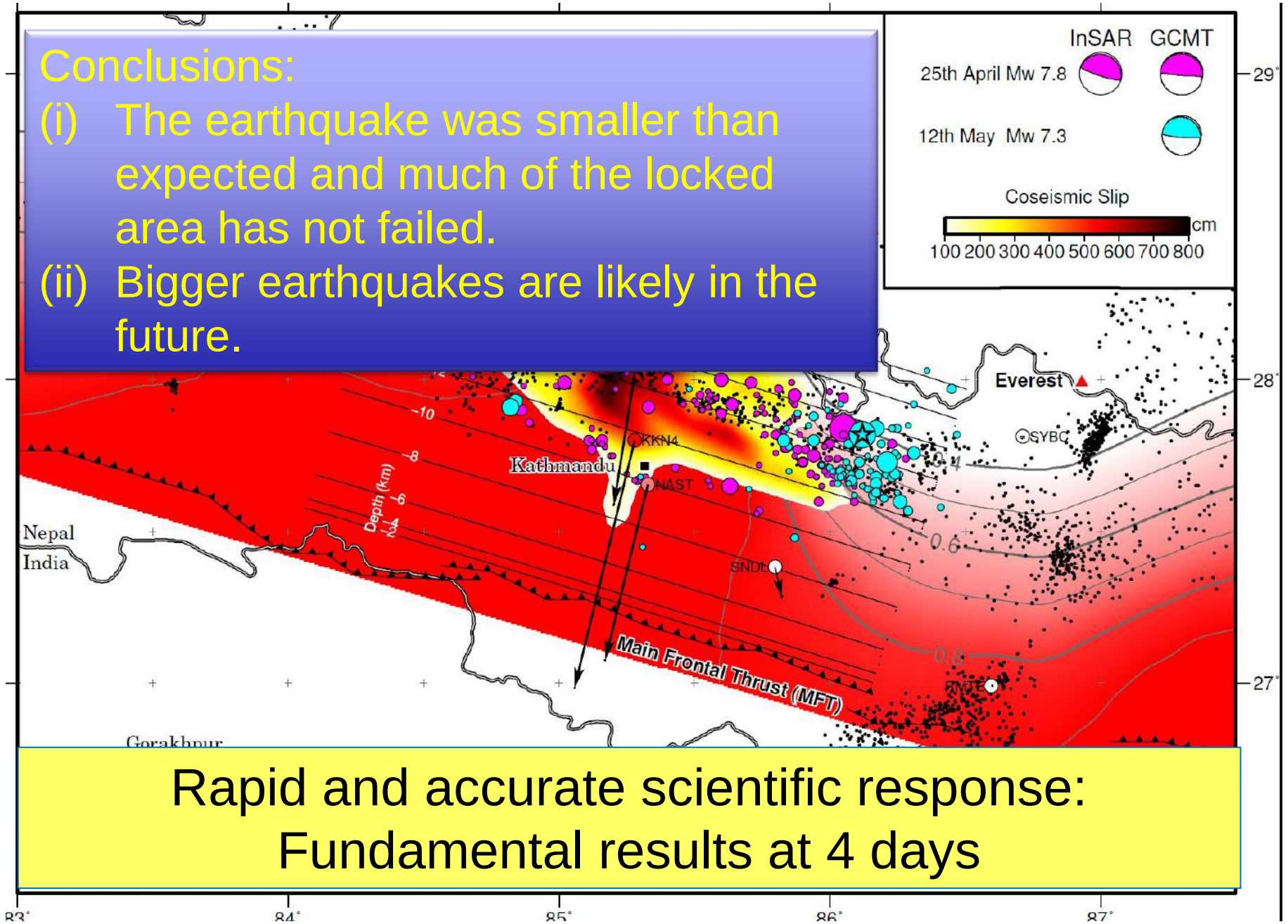
~4 days after EQ

The 2015 Ghorka (Nepal) earthquake: Sentinel-1A coseismic interferograms



Elliott et al., Nature Geoscience 2016

Area around Kathmandu moved towards satellite by over 1 m



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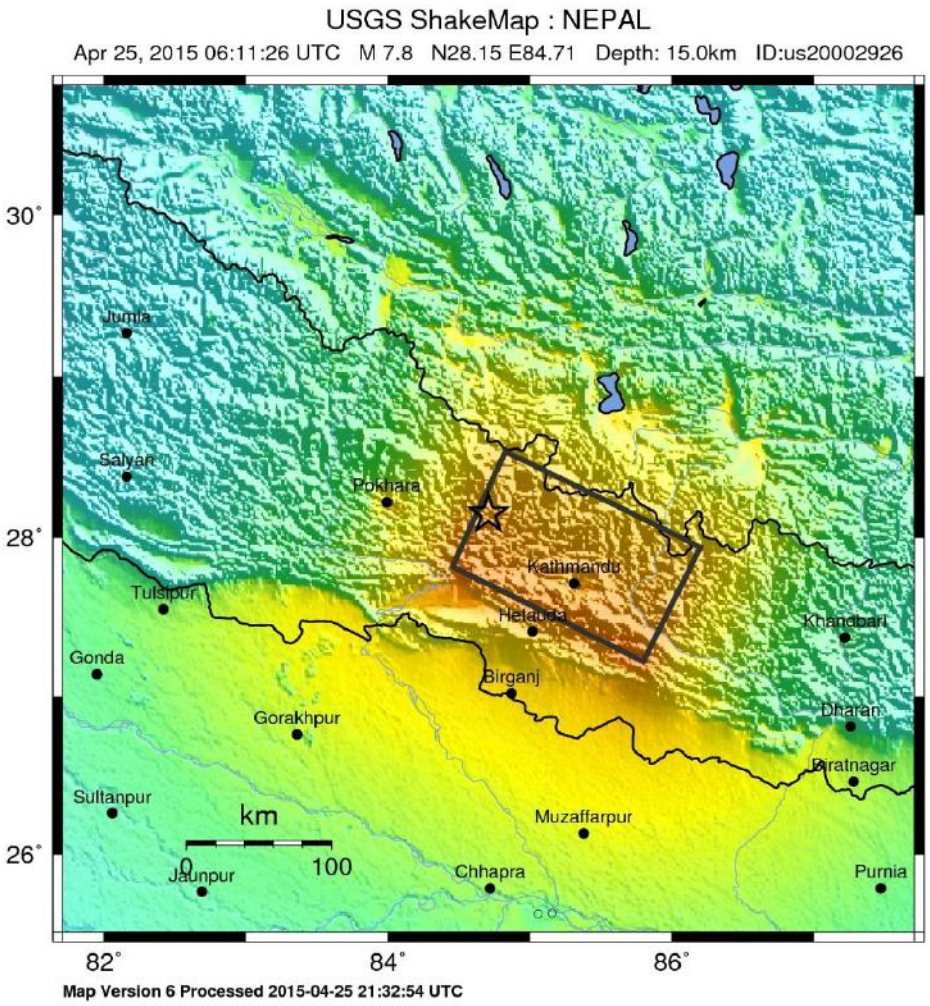

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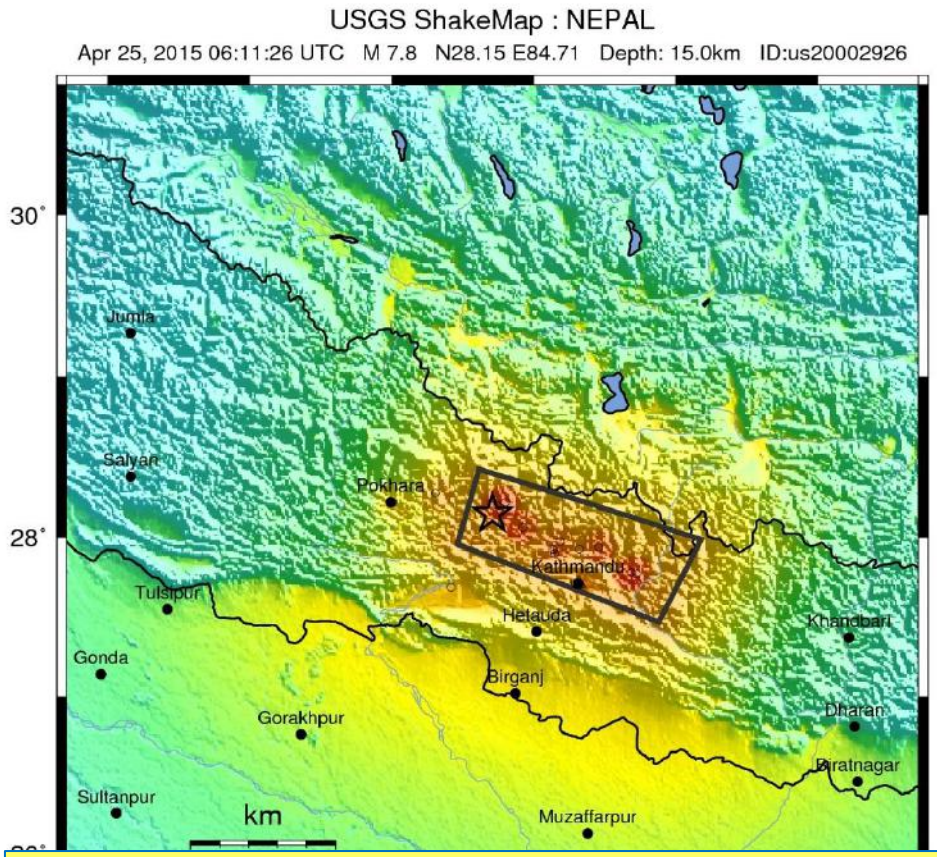


Initial location & magnitude comes rapidly from seismology…

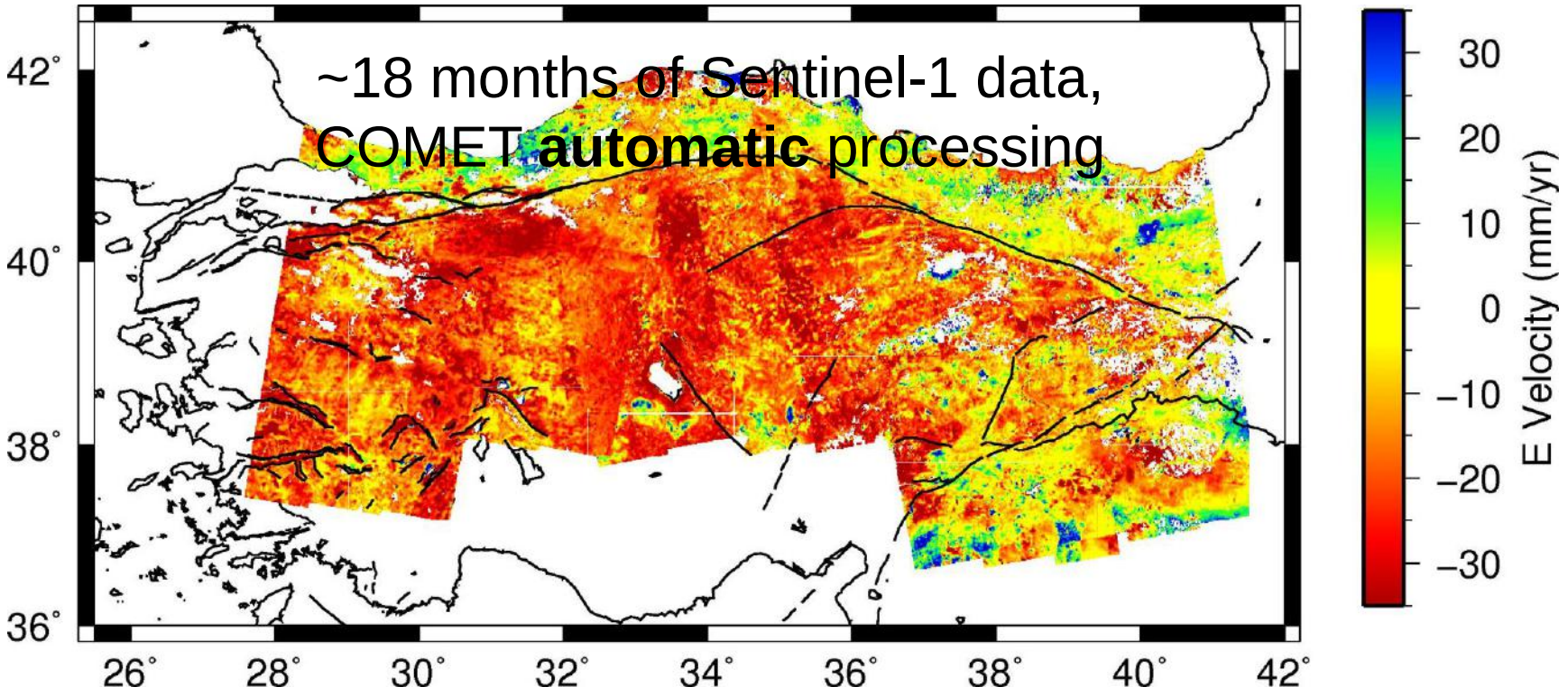
v1 EQ + 19 minutes
v2 EQ + 52 minutes
v3 EQ + 83 minutes
v4 EQ + 2 hours
v5 EQ + 4 hours
v6 EQ + 15 hours
v7 EQ + 10 days

Ground shaking map

(i) Incorporating satellite deformation data changes the predictions of ground shaking.
(ii) Sentinel-1 can provide the results that allow this to be done routinely.

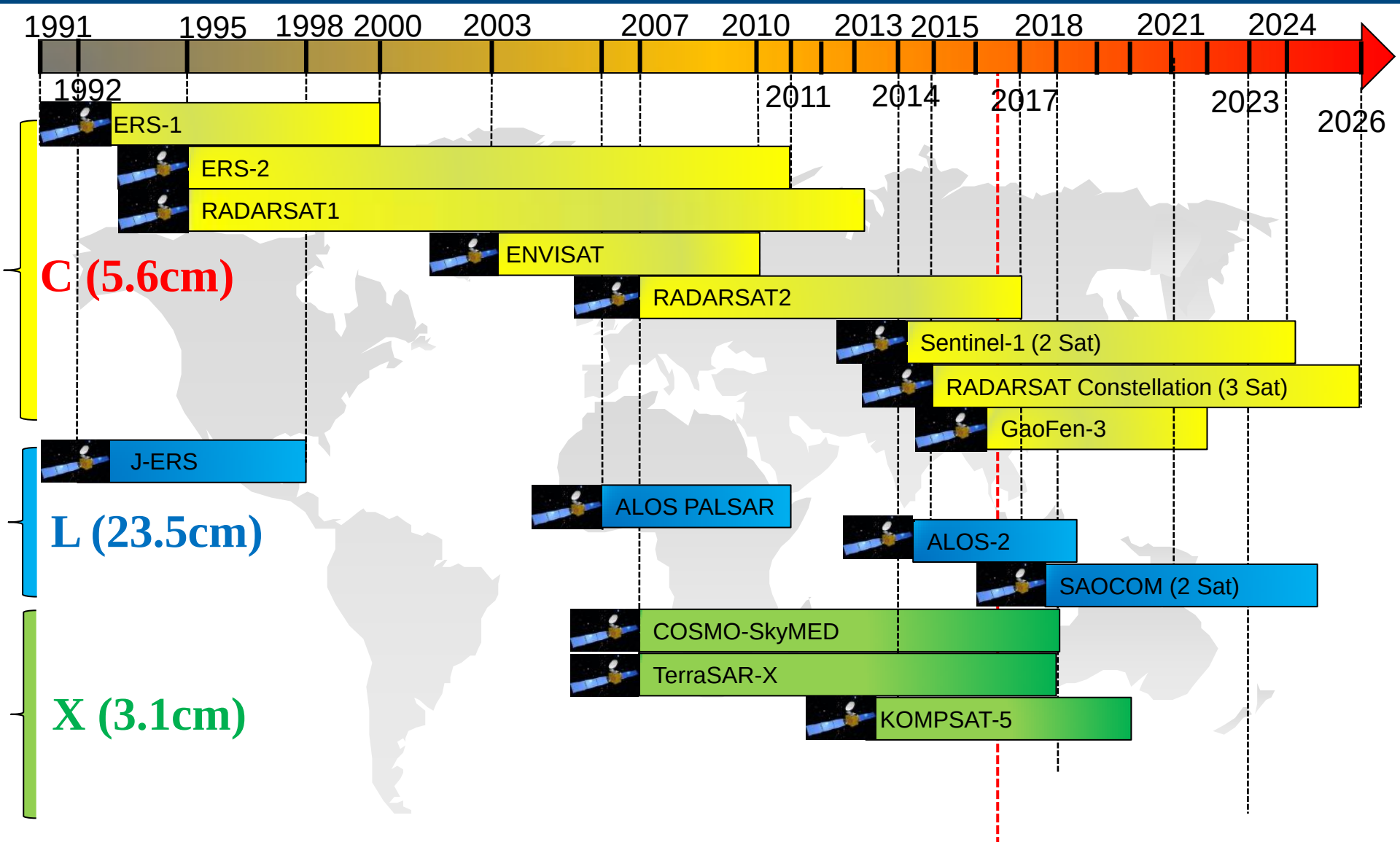
Disaster Preparedness: The North Anatolian Fault

- 1 PhD 1997-2000 (Wright): 2 ERS Frames / 100 km of fault / ~20,000 km^2
- 1 PhD 2009-2012 (Walters): 5 Envisat Tracks / 200km of fault / ~250,000 km^2
- 1 PhD 2012-2016 (Hussain): 23 Envisat Tracks / entire fault / ~750,000 km^2



Richard Walters, Durham COMET

Satellite Radar (SAR) Missions



Conclusions

- Sentinel-1 is a game changer – Thanks ESA/Copernicus
- The overall repeat cycle of the current SAR missions (S1, TSX, CSK, ALOS-2 and RadarSAR-2) is 1.6 days, which makes disaster risk responses and assessment possible
- Automatic processing for wide regions can lead to major advances in responding to large earthquakes and preparing for future hazards

Newcastle University

Disaster Management Cycle