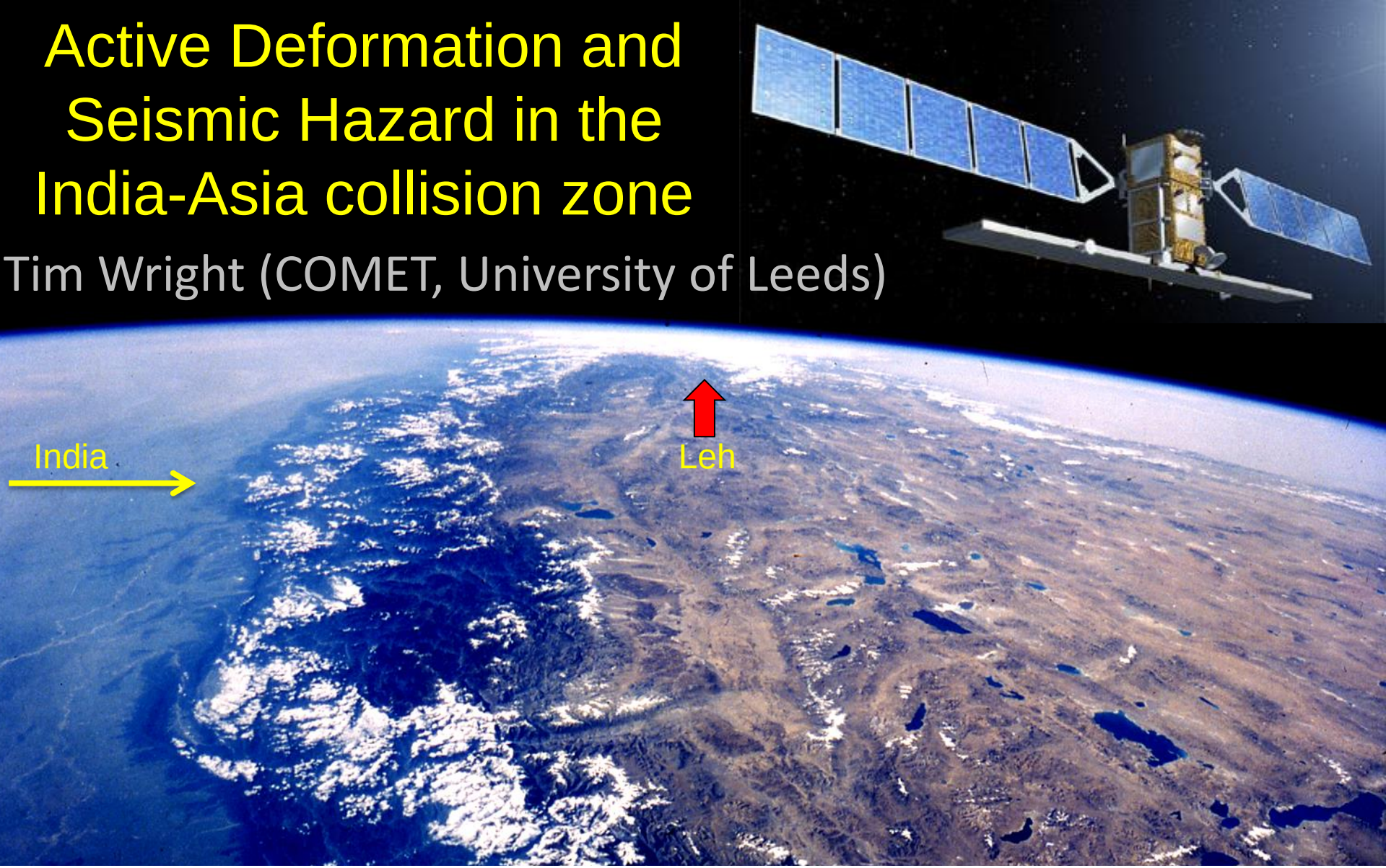
Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)



NERC SCIENCE OF THE ENVIRONMENT

Earthquakes without Frontiers

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS

Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)

Thanks to…

1. Geological Society and IERT for the invitation
2. Collaborators: Richard Walters (Leeds, UK), Hua Wang (Guangdong University of Technology, China), Barry Parsons, John Elliott (Oxford, UK)

NERC SCIENCE OF THE ENVIRONMENT

Earthquakes without Frontiers

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS

Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)

Outline

1. Seismicity in the India-Asia collision zone
2. Seismic Hazard Maps
3. Using Satellite Geodesy to measure tectonic strain
4. Using strain for seismic hazard assessment

NERC SCIENCE OF THE ENVIRONMENT

Earthquakes without Frontiers

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS

Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)

Key Points

1. Seismic Hazard is widely distributed, and small(er) earthquakes can be more deadly
2. Past seismicity is an imperfect guide to future seismicity
3. Satellite Geodesy provides a complementary tool for estimating seismic hazard

NERC SCIENCE OF THE ENVIRONMENT

Earthquakes without Frontiers

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS

Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)

1.Seismicity in the India-Asia collision zone

NERC SCIENCE OF THE ENVIRONMENT

Earthquakes without Frontiers EwF

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS

Potential for Large Earthquakes on the Himalayan Front

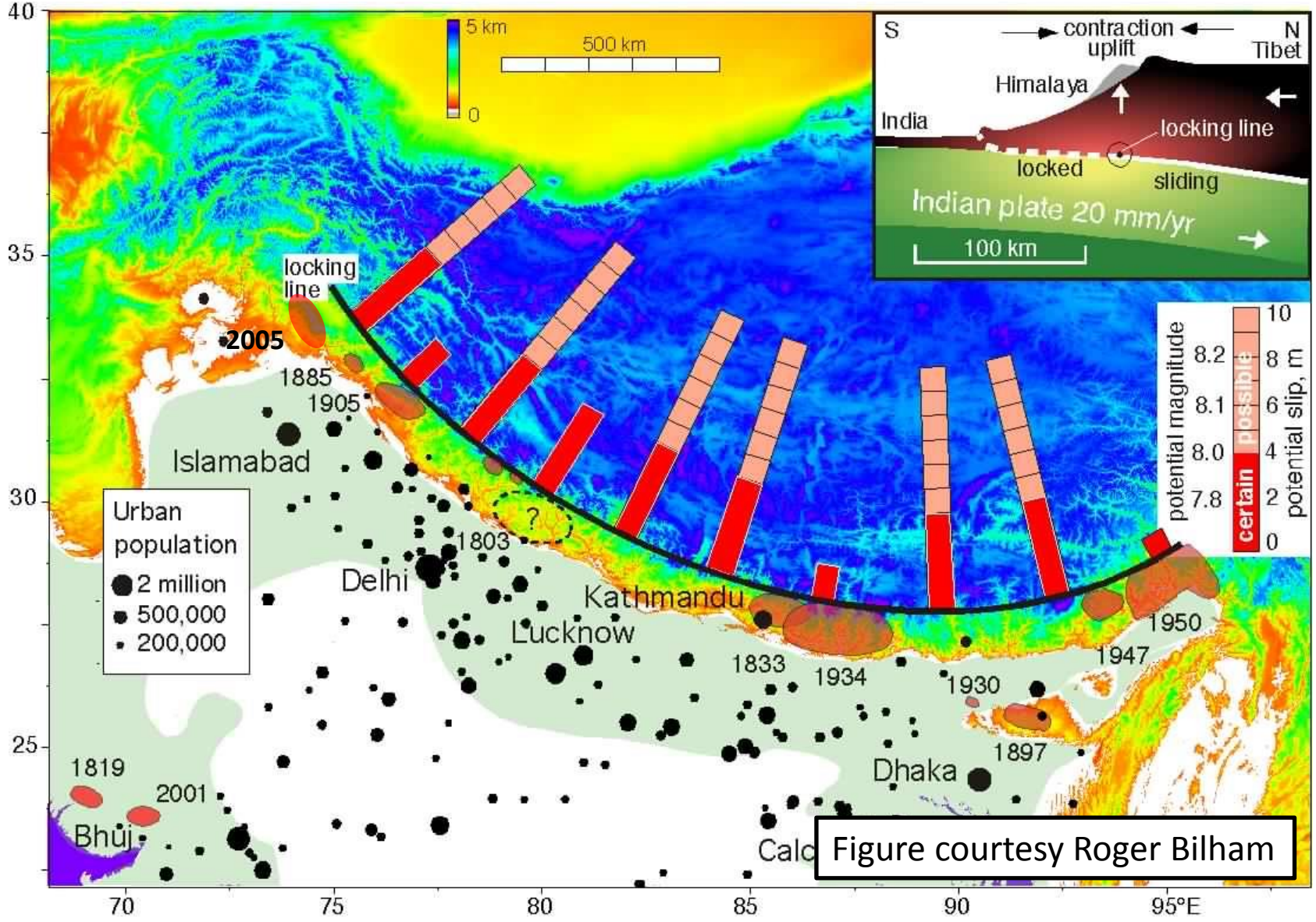
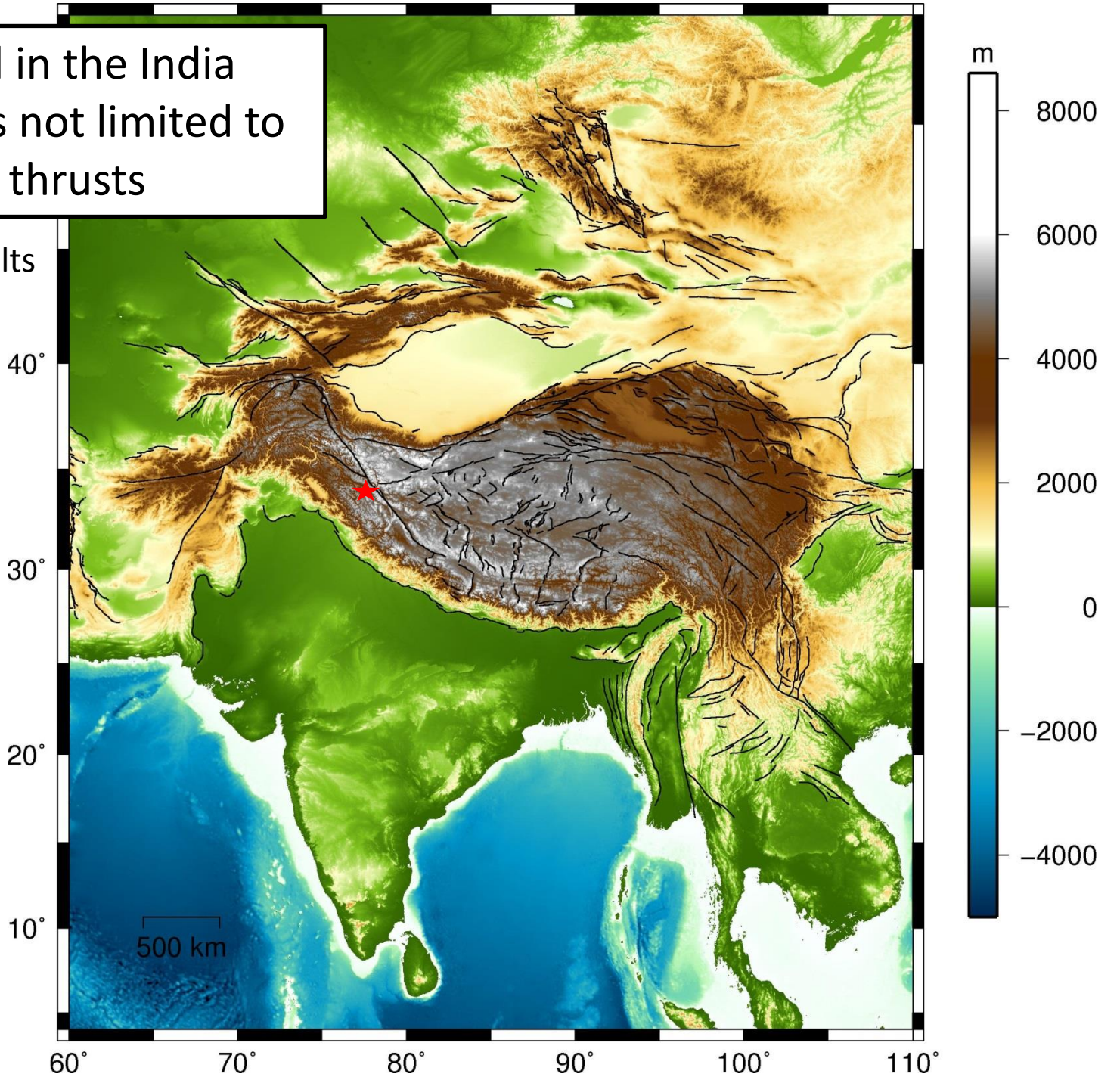


Figure courtesy Roger Bilham

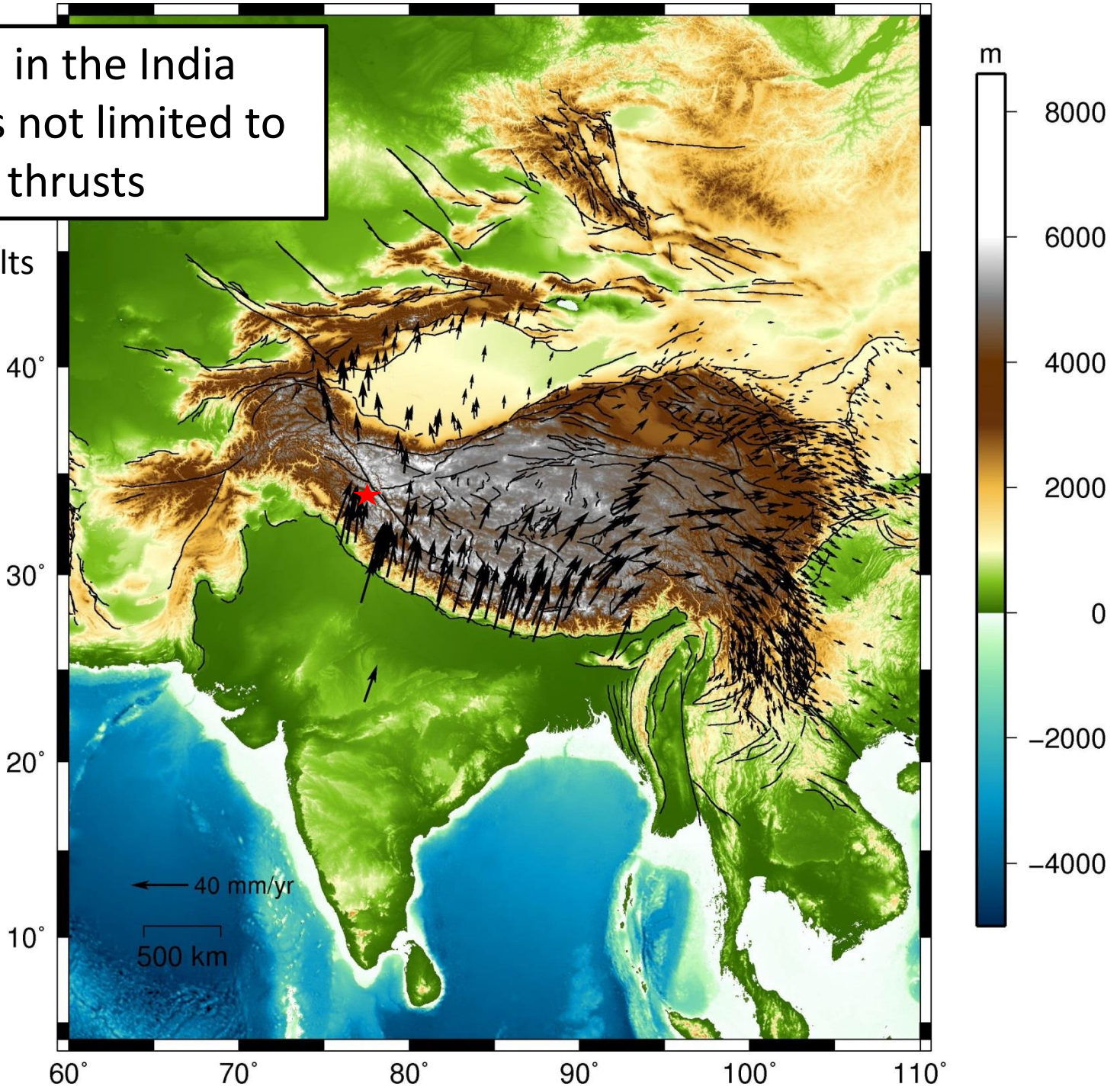
Seismic hazard in the India Asia collision is not limited to the Himalayan thrusts

1. Topography + Faults



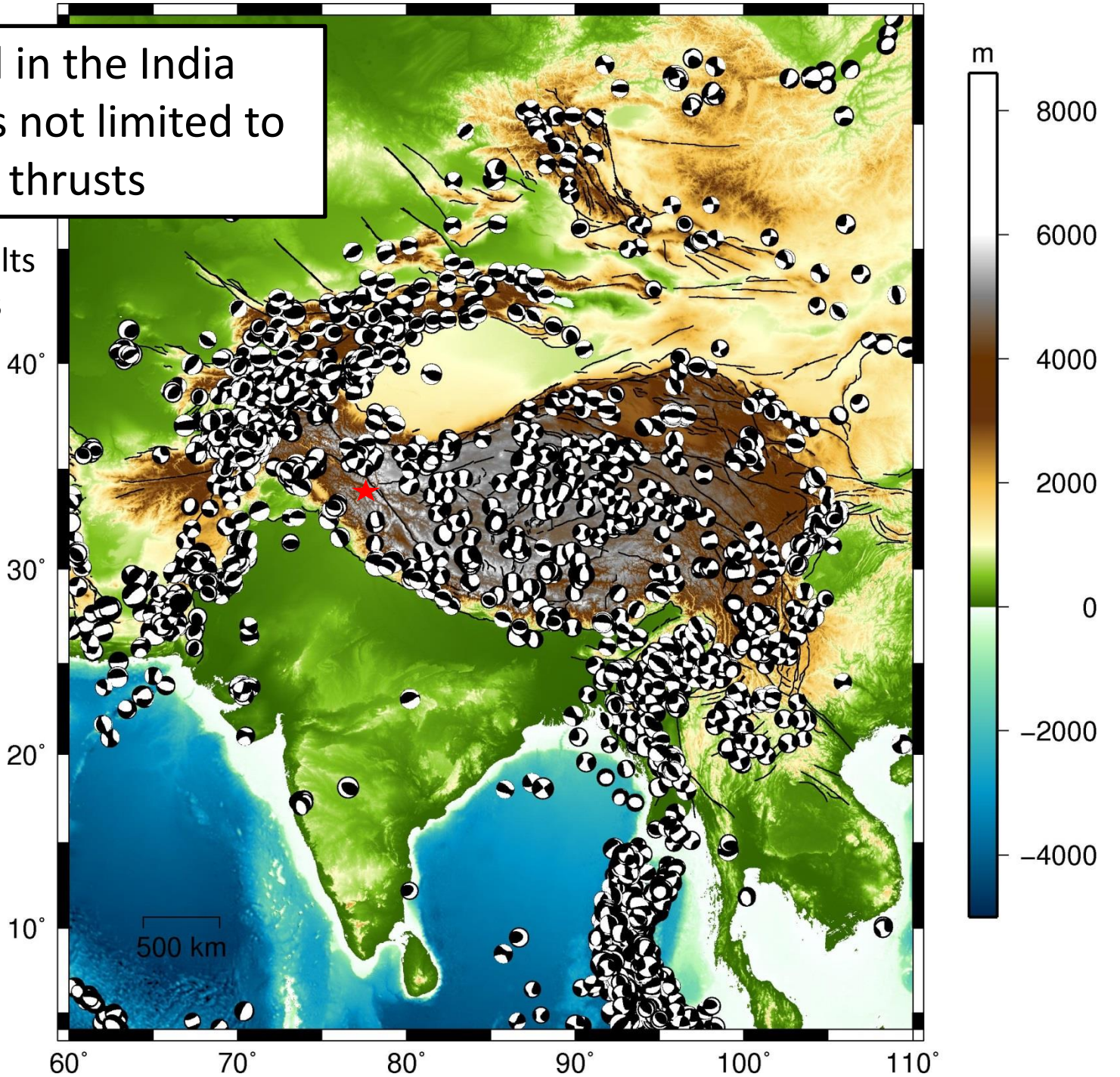
Seismic hazard in the India Asia collision is not limited to the Himalayan thrusts

2. Topography + Faults + GPS velocities (Gan et al., 2007)



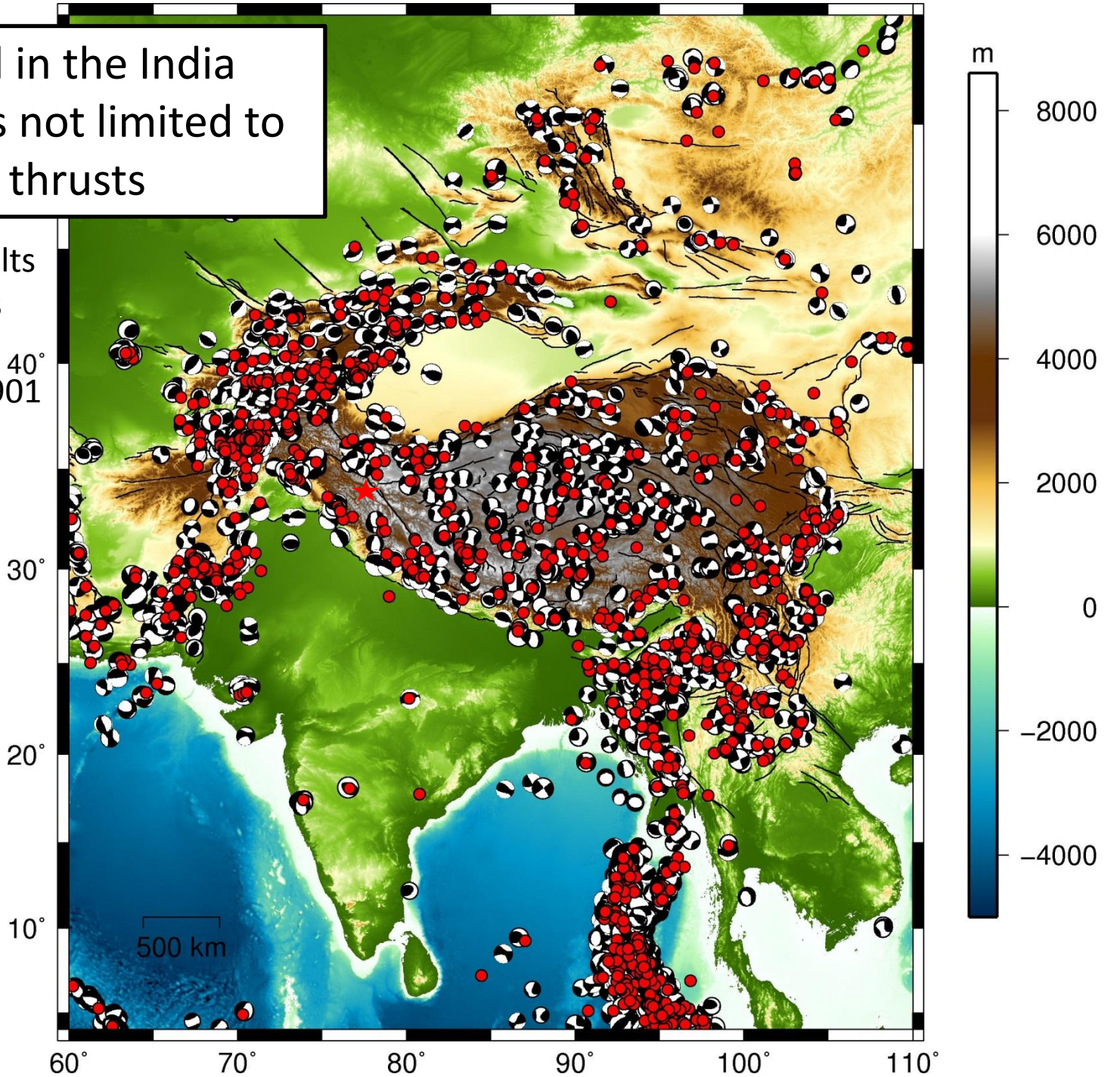
Seismic hazard in the India Asia collision is not limited to the Himalayan thrusts

3. Topography + Faults + Large Earthquakes since 1976



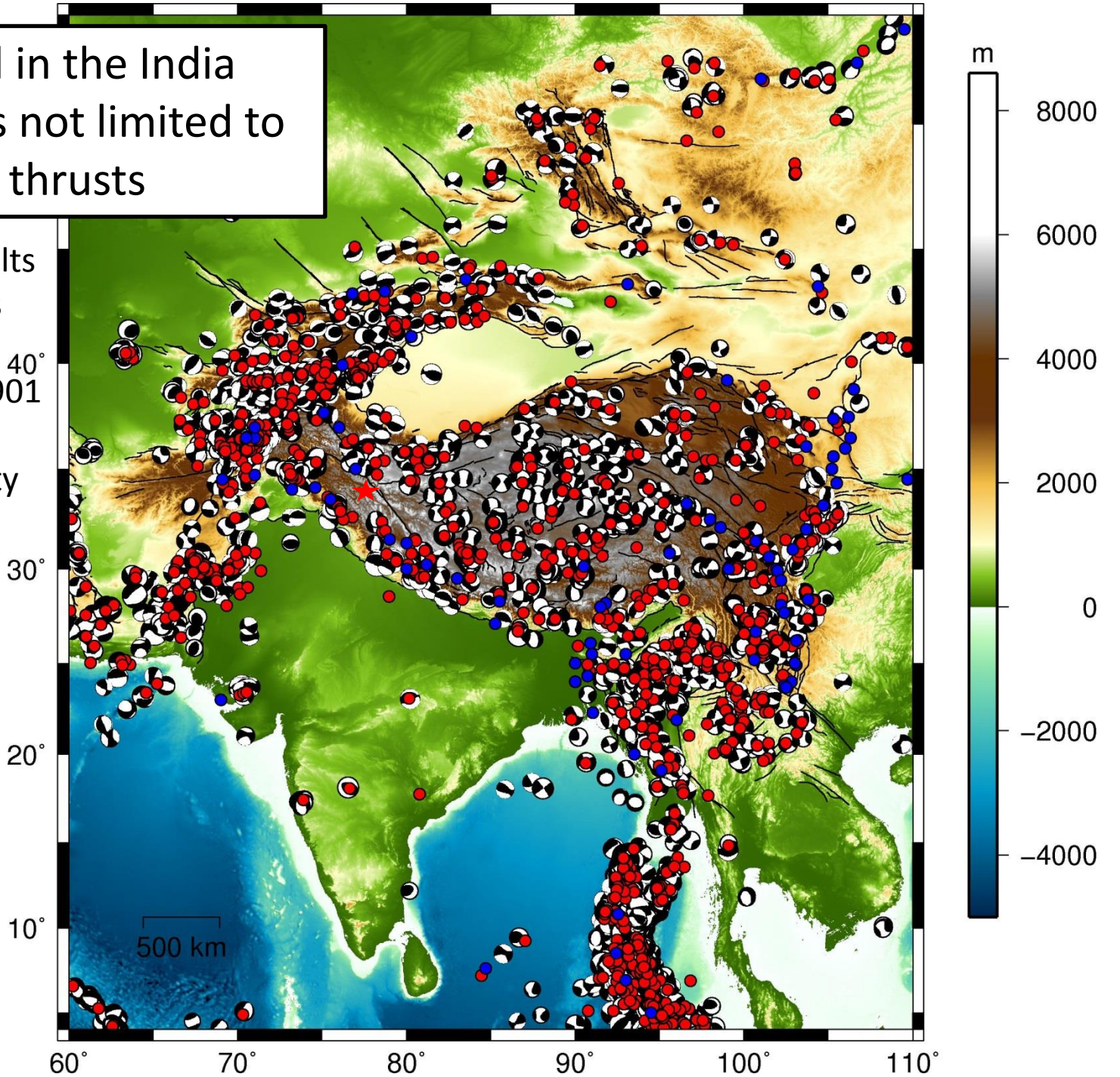
Seismic hazard in the India Asia collision is not limited to the Himalayan thrusts

4. Topography + Faults + Large Earthquakes since 1976 + seismicity since 1901 (red)

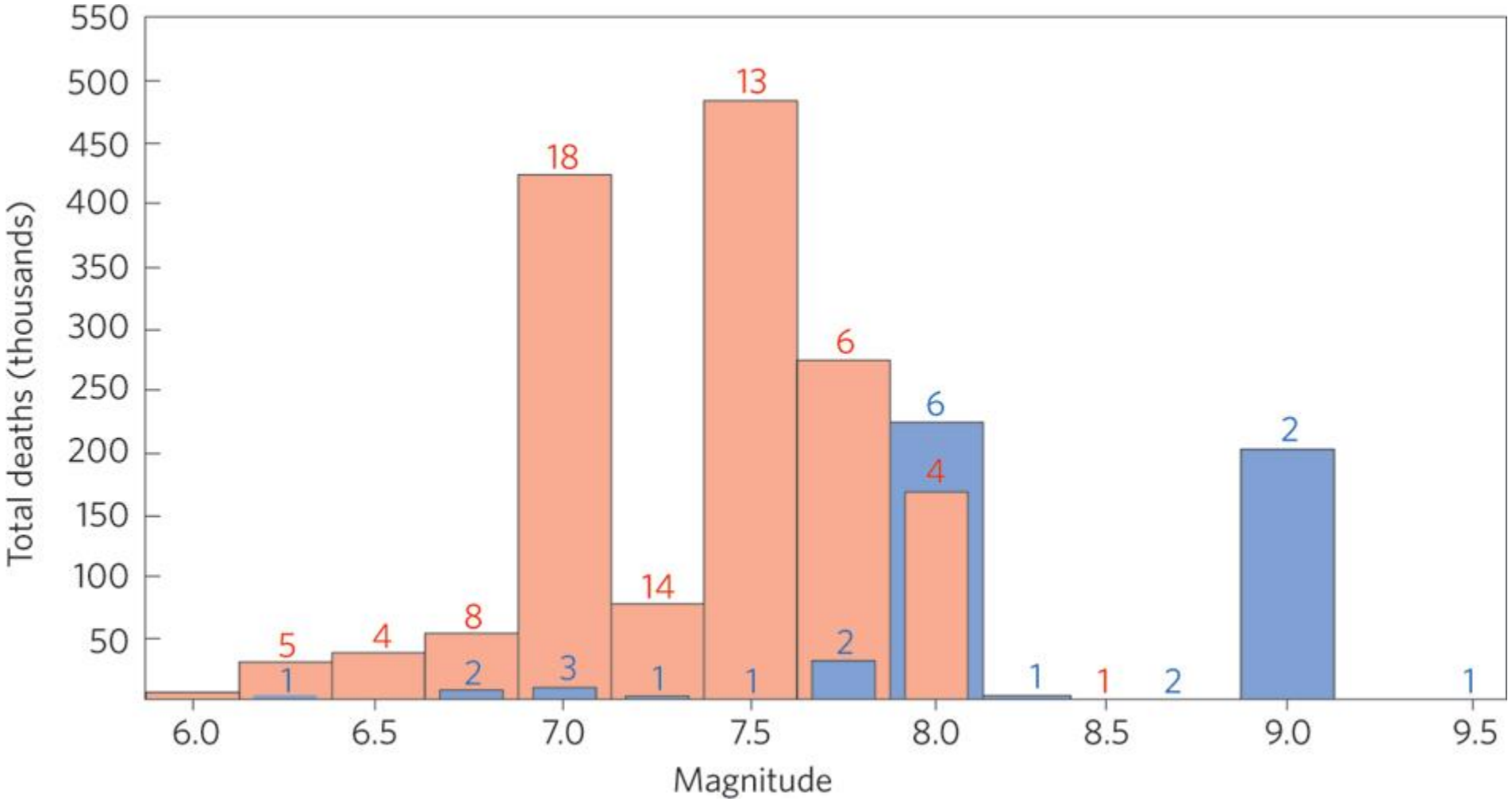


Seismic hazard in the India Asia collision is not limited to the Himalayan thrusts

5. Topography + Faults + Large Earthquakes since 1976
+ seismicity since 1901 (red)
+ historical seismicity (blue)



M7-7.5 Earthquakes are most deadly



Earthquake deaths in last 100 years, from England and Jackson, 2011

Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)

2. Seismic Hazard Maps

NERC SCIENCE OF THE ENVIRONMENT

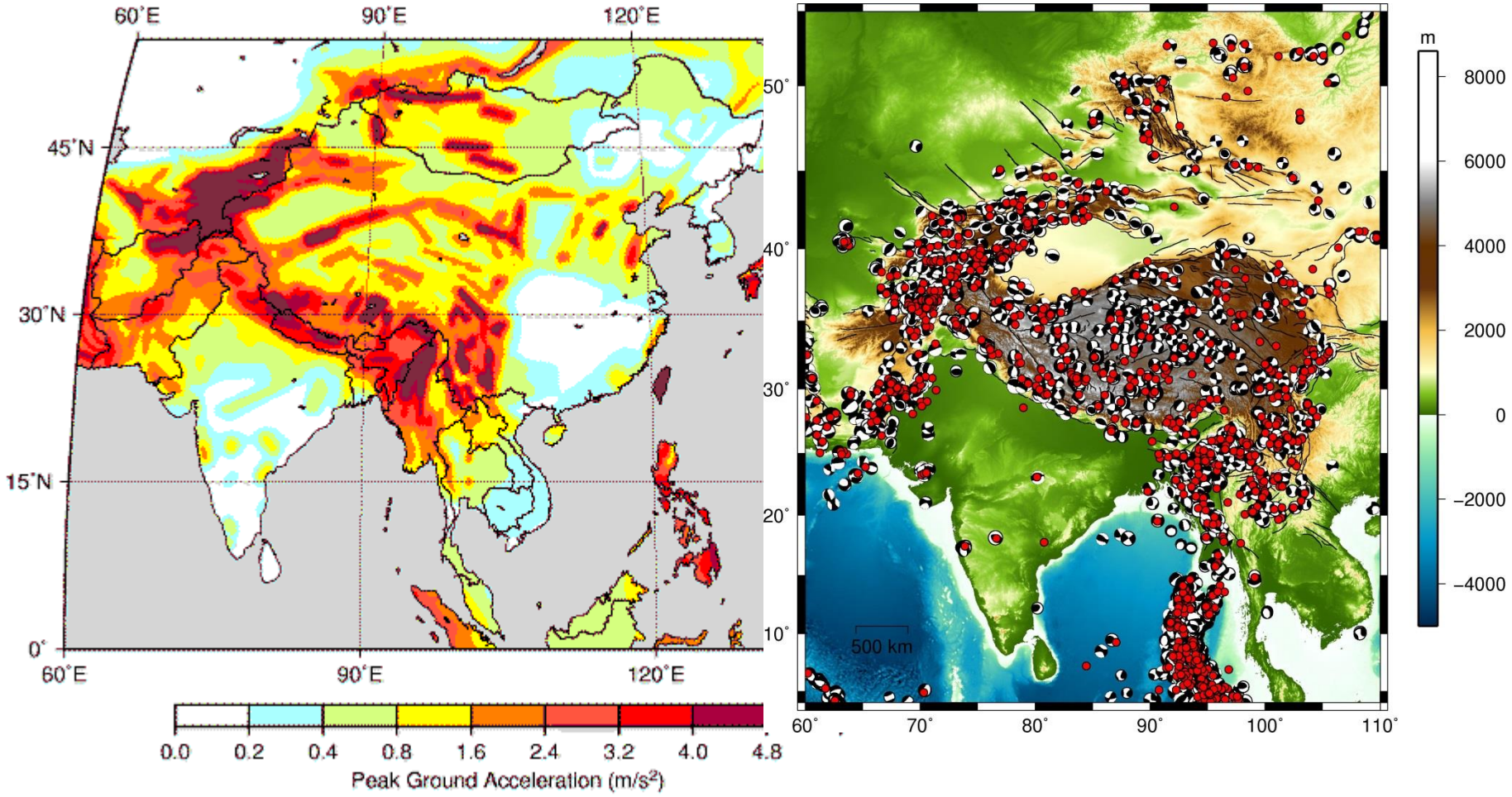
Earthquakes without Frontiers EwF

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

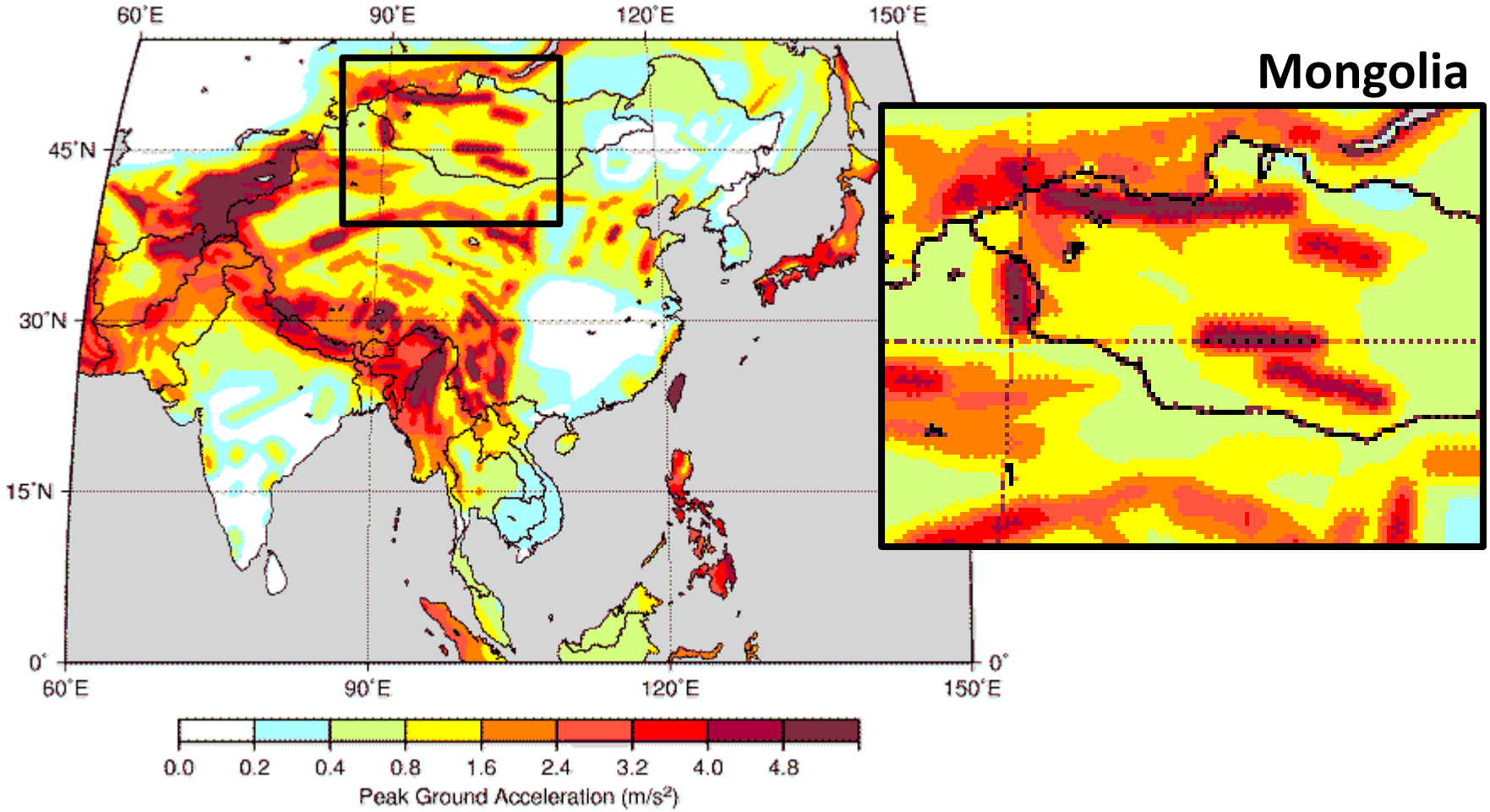
UNIVERSITY OF LEEDS

Seismic Hazard in India-Asia Collision



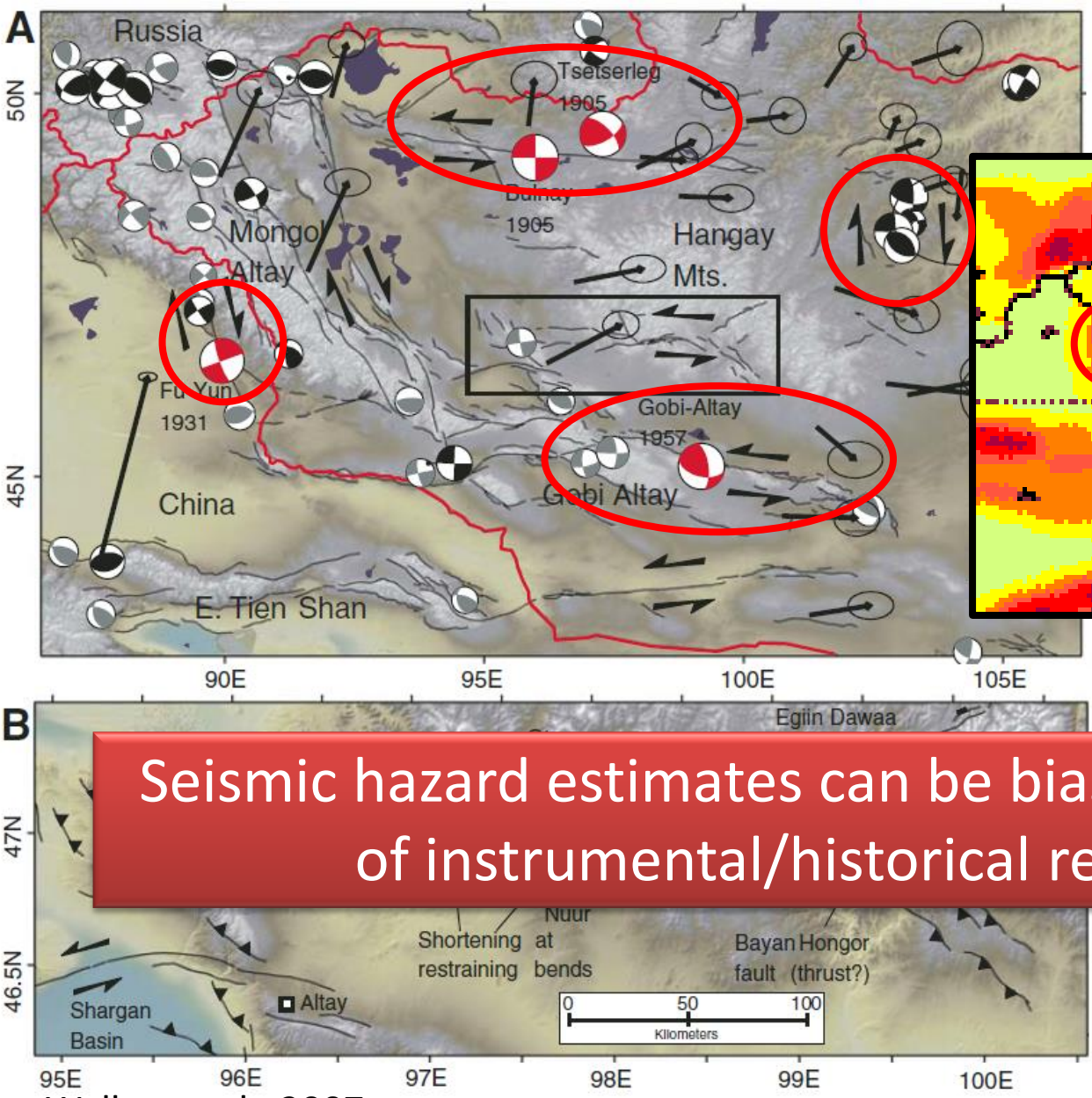
Global Seismic Hazard Assessment Program Hazard Map (1999)

Seismic Hazard in India-Asia Collision

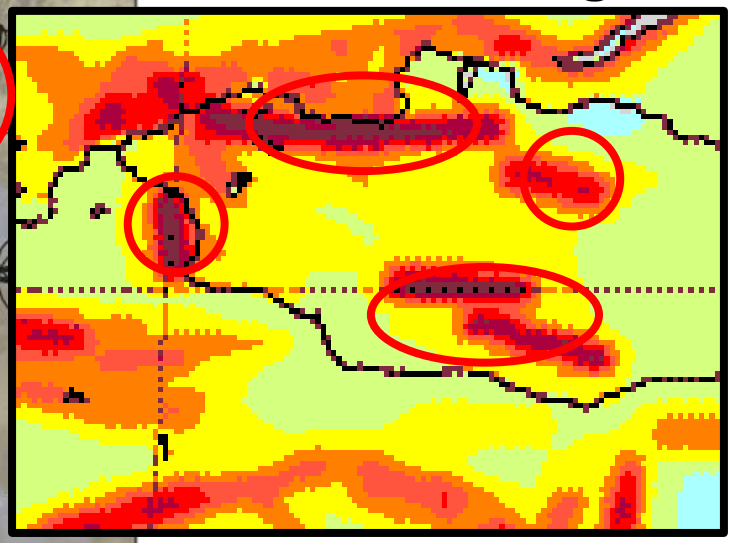


Global Seismic Hazard Assessment Program Hazard Map (1999)

Seismic Hazard in India-Asia Collision



Mongolia



Seismic hazard estimates can be biased by brevity of instrumental/historical records

Walker et al., 2007

Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)

3. Using Satellite Geodesy to measure tectonic strain

NERC SCIENCE OF THE ENVIRONMENT

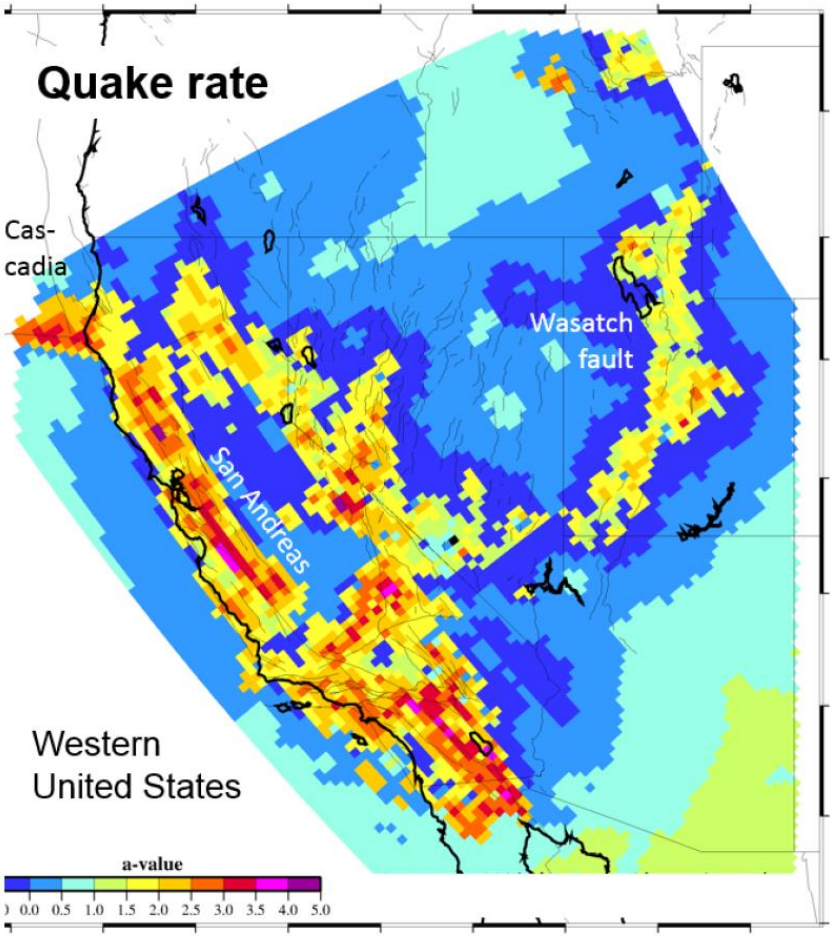
Earthquakes without Frontiers

COMET

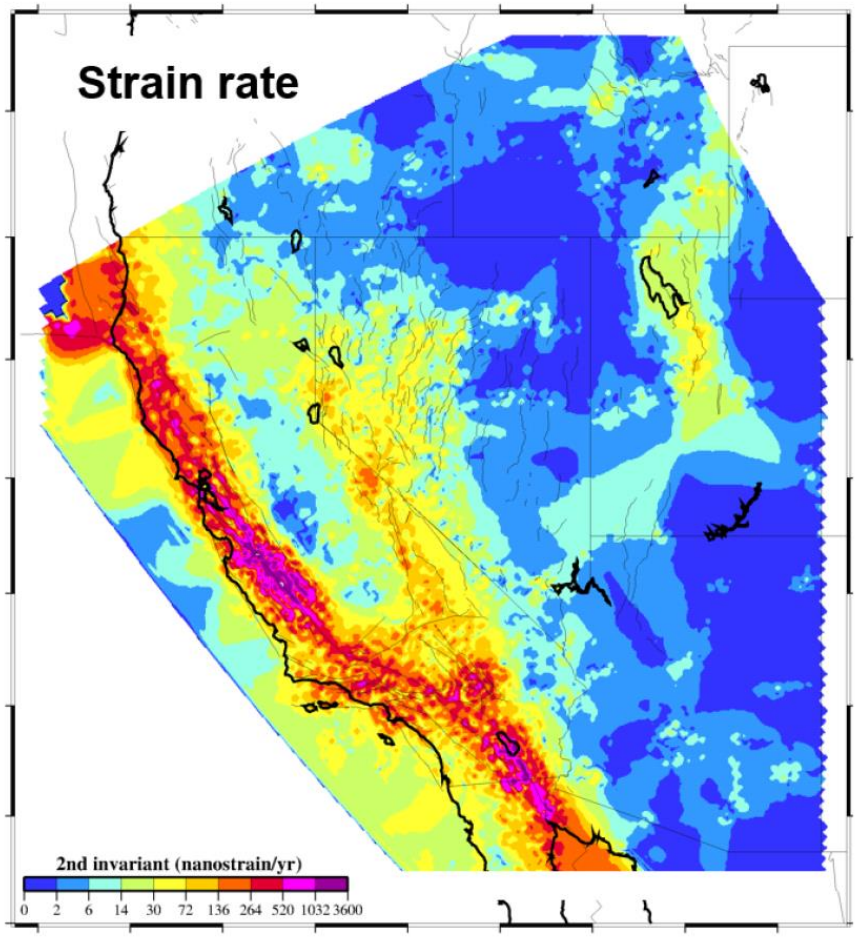
@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS

Does present-day strain tell us anything about seismic hazard?



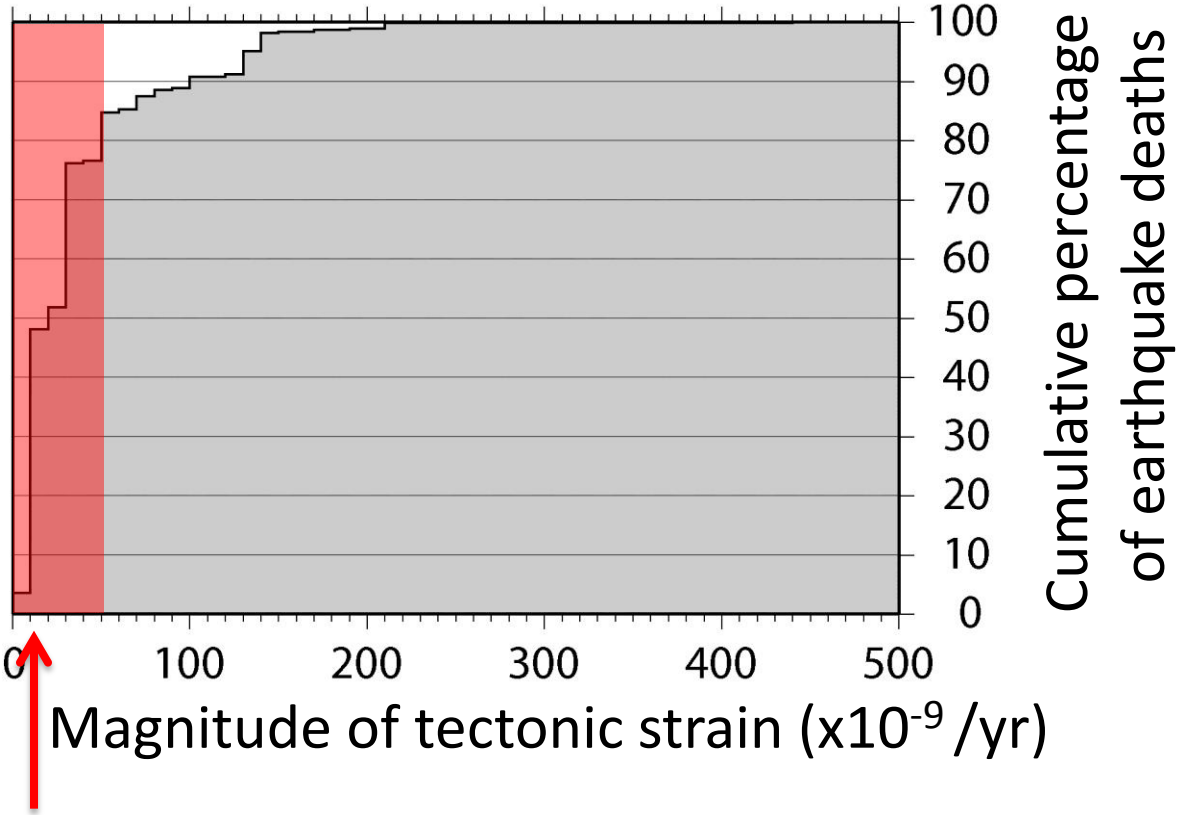
Gutenberg-Richter a-value from declustered ANSS catalog (Arnaud Mignan, ETH Zurich)



2000-2011 GPS velocities used by Kreemer et al for the GEM Strain Rate Model

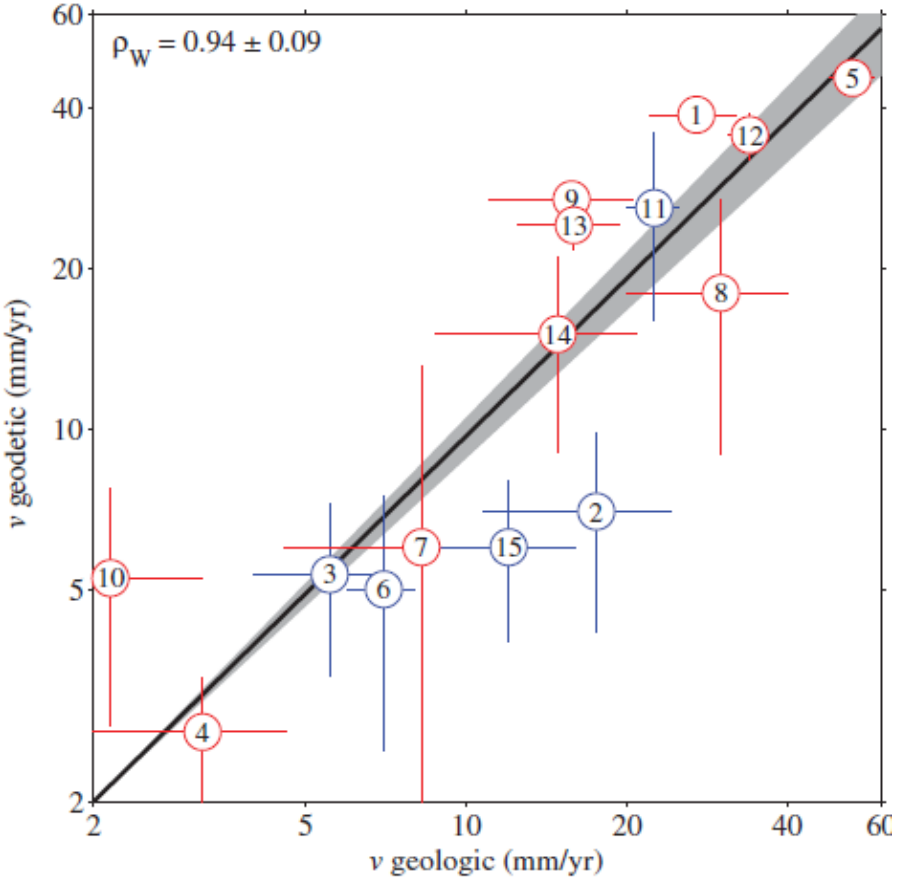
Figure from Corné Kreemer/Ross Stein/GEM

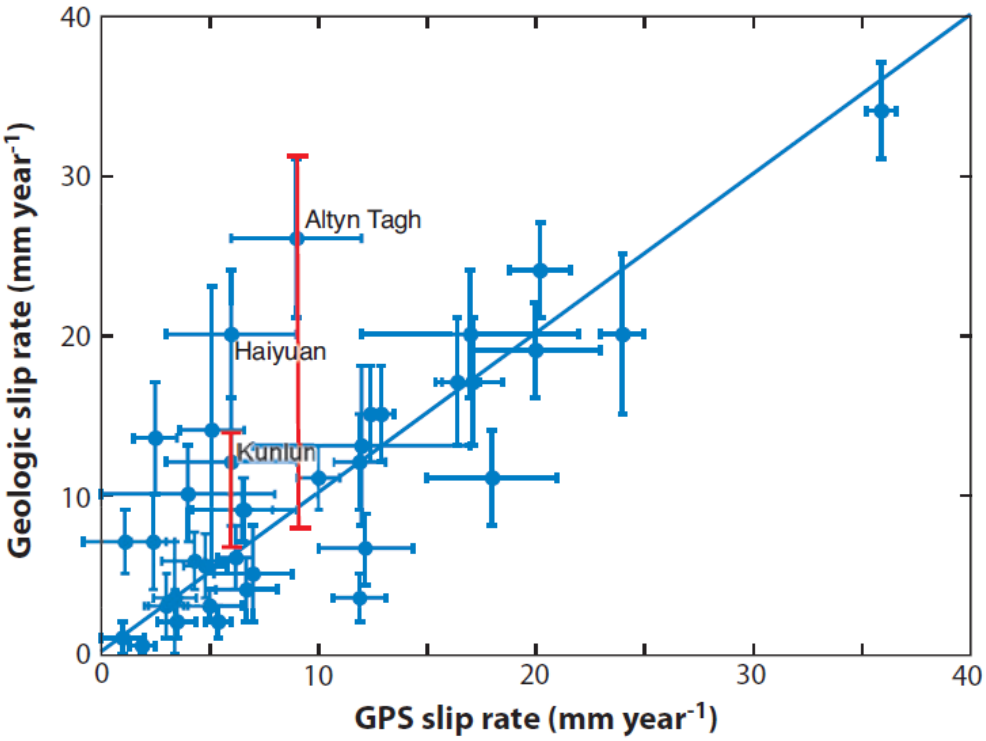
Does present-day strain tell us anything about seismic hazard?



- 96% of all earthquake deaths are in regions with strain rates greater than 1mm/yr over 100 km (10^{-8}/yr)
- 77% of fatalities occur where deformation rates are ≤ 5 mm/yr over 100 km.

Does present-day strain tell us anything about seismic hazard?

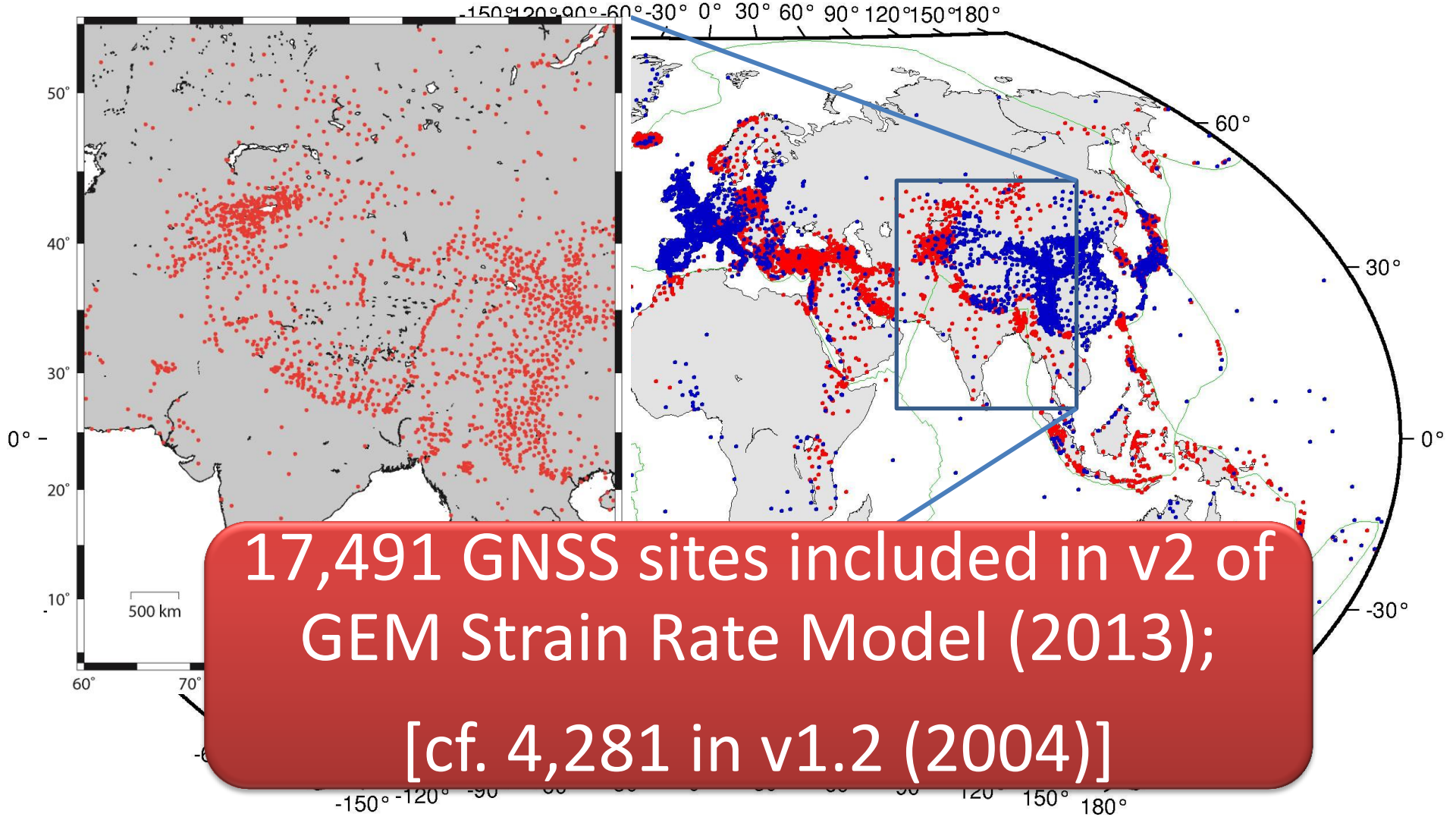




Geodetic vs Geologic slip rates for major faults
(left: Meade et al., 2013; right: Thatcher 2009)

Installing GPS sites

Global GPS in GEM Strain Rate Model

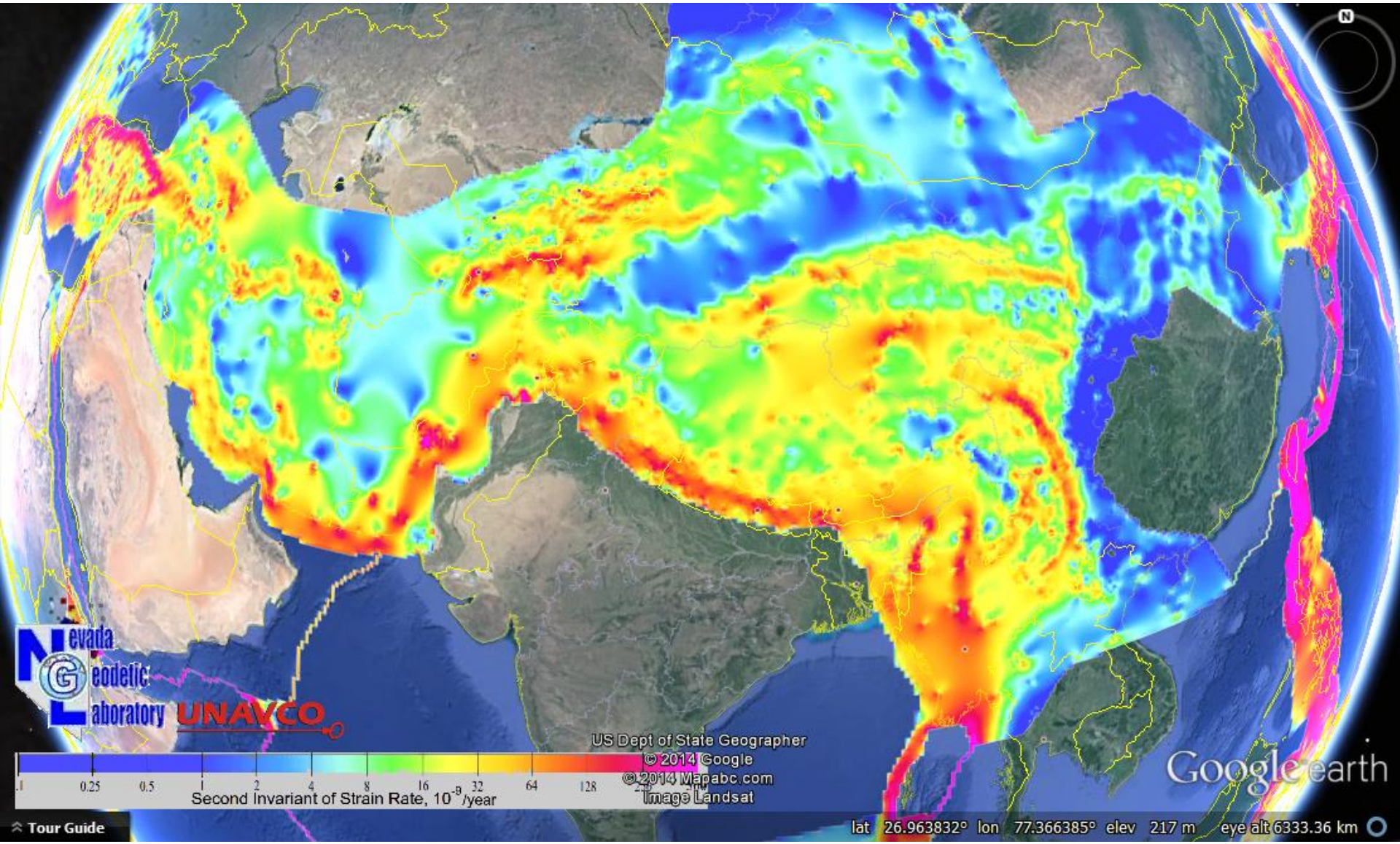


17,491 GNSS sites included in v2 of GEM Strain Rate Model (2013);

[cf. 4,281 in v1.2 (2004)]

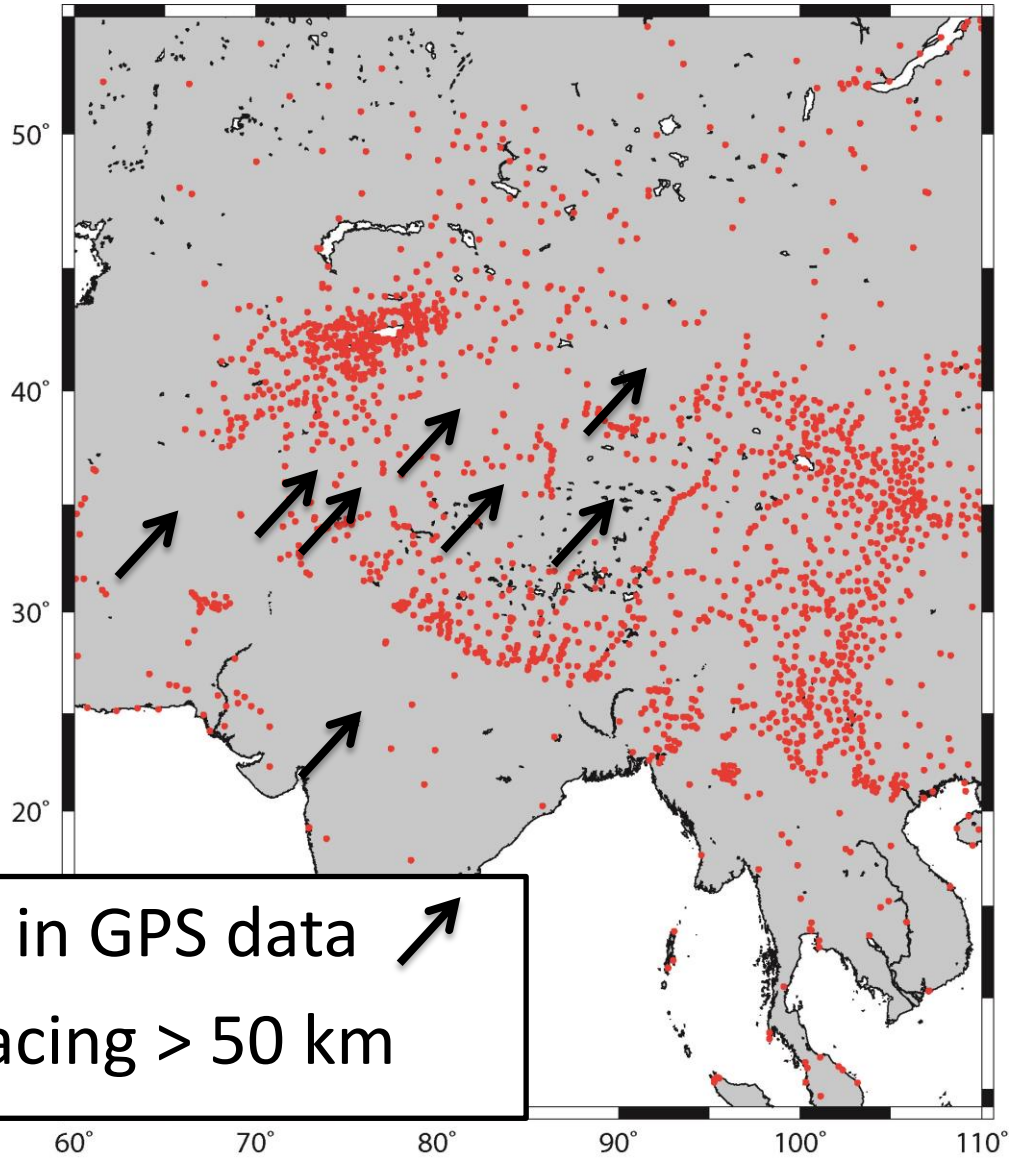
Data from University of Reno: GSRM, Corné Kreemer

Strain rate calculated from GPS



Data from http://gsrm2.unavco.org

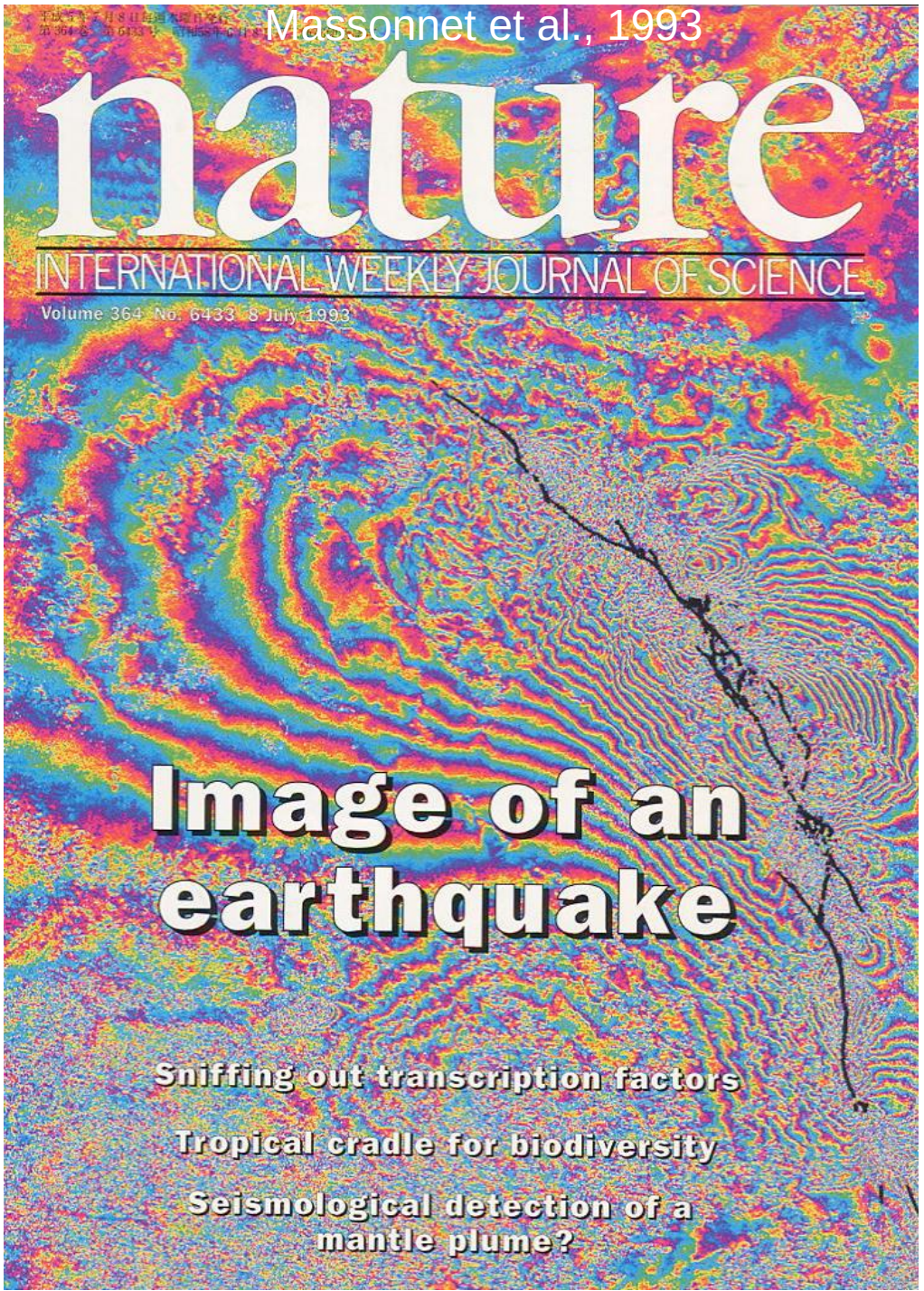
Gaps in GPS coverage?



- Large gaps in GPS data ↗
- Station spacing > 50 km

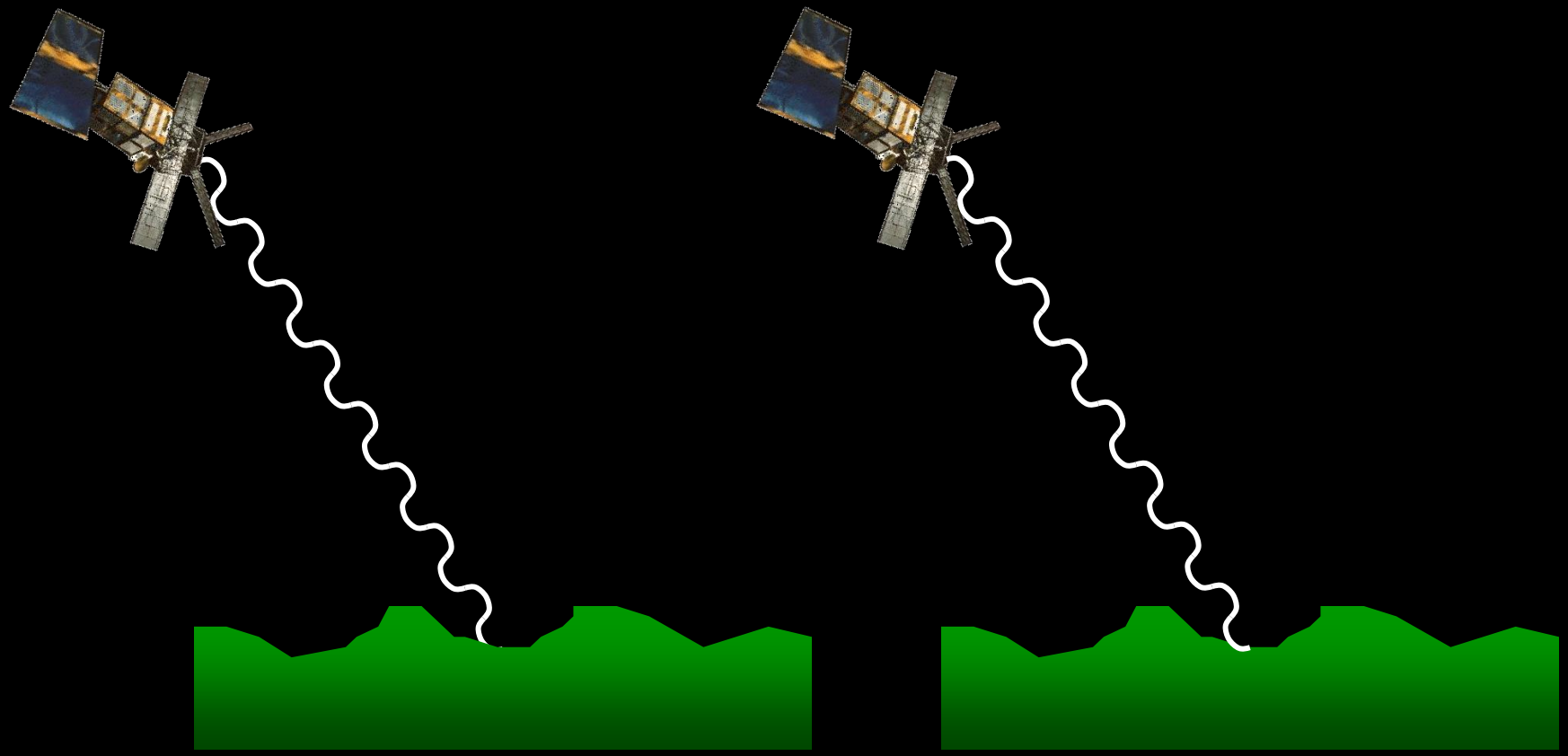
Data from University of Reno: GSRM, Corné Kreemer

Massonnet et al., 1993



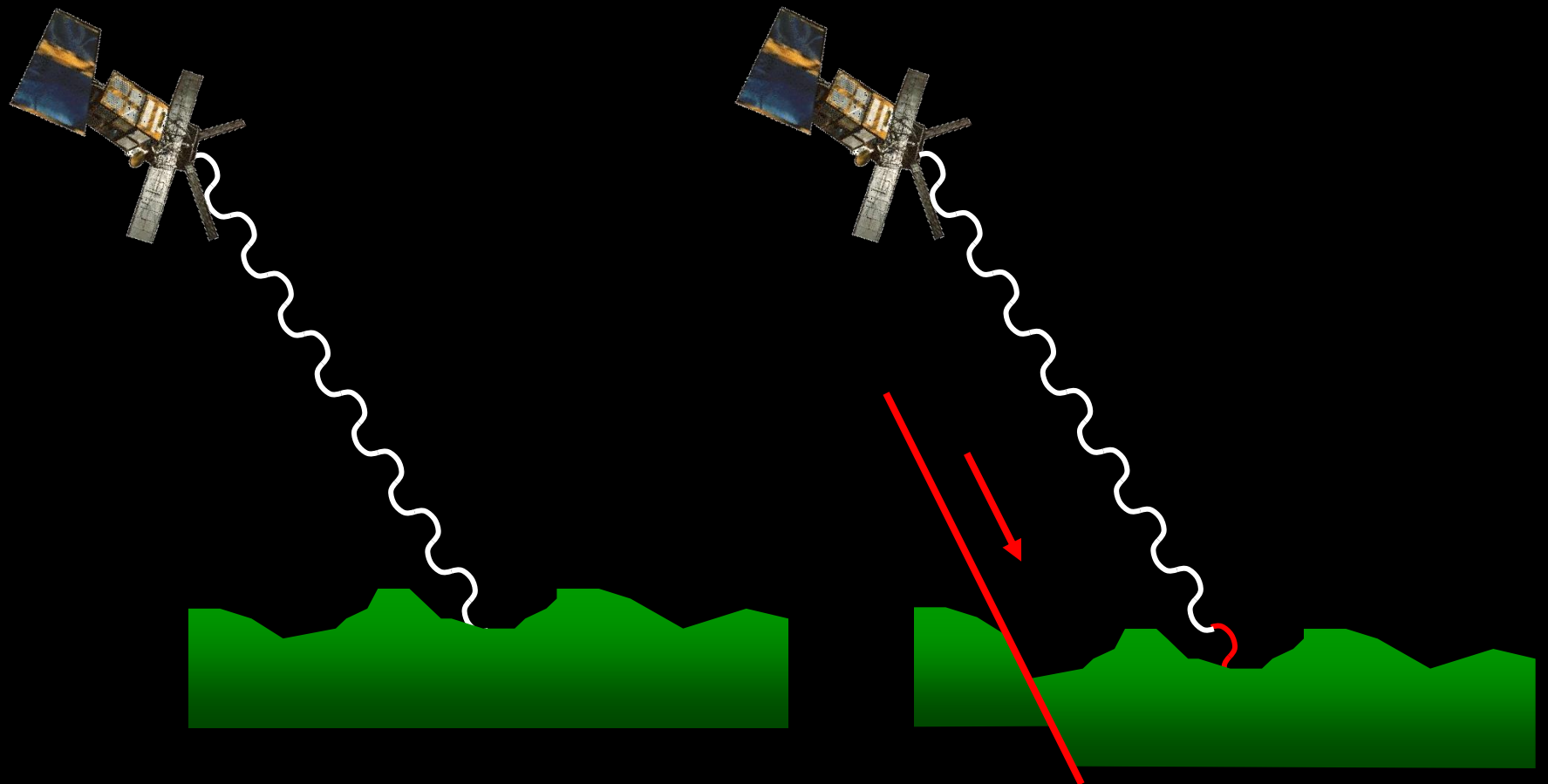
InSAR – how it works

- Phase is a function of distance from satellite to ground (range)

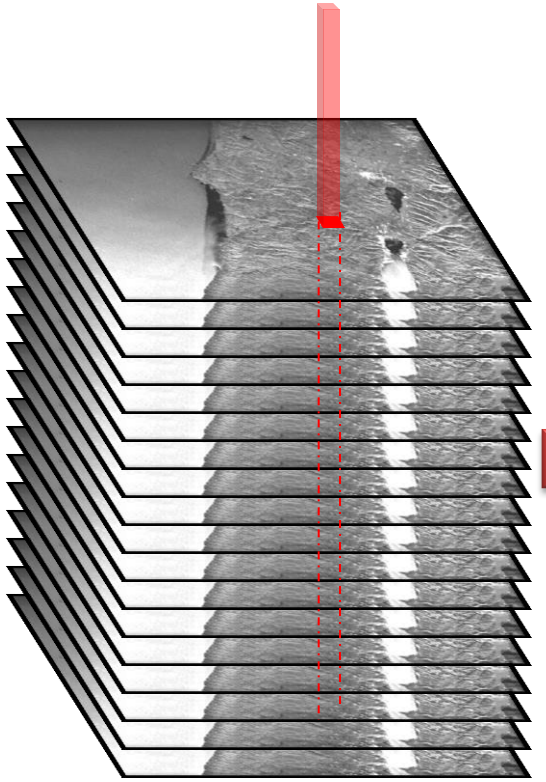


InSAR – how it works

- Phase is a function of distance from satellite to ground (range)



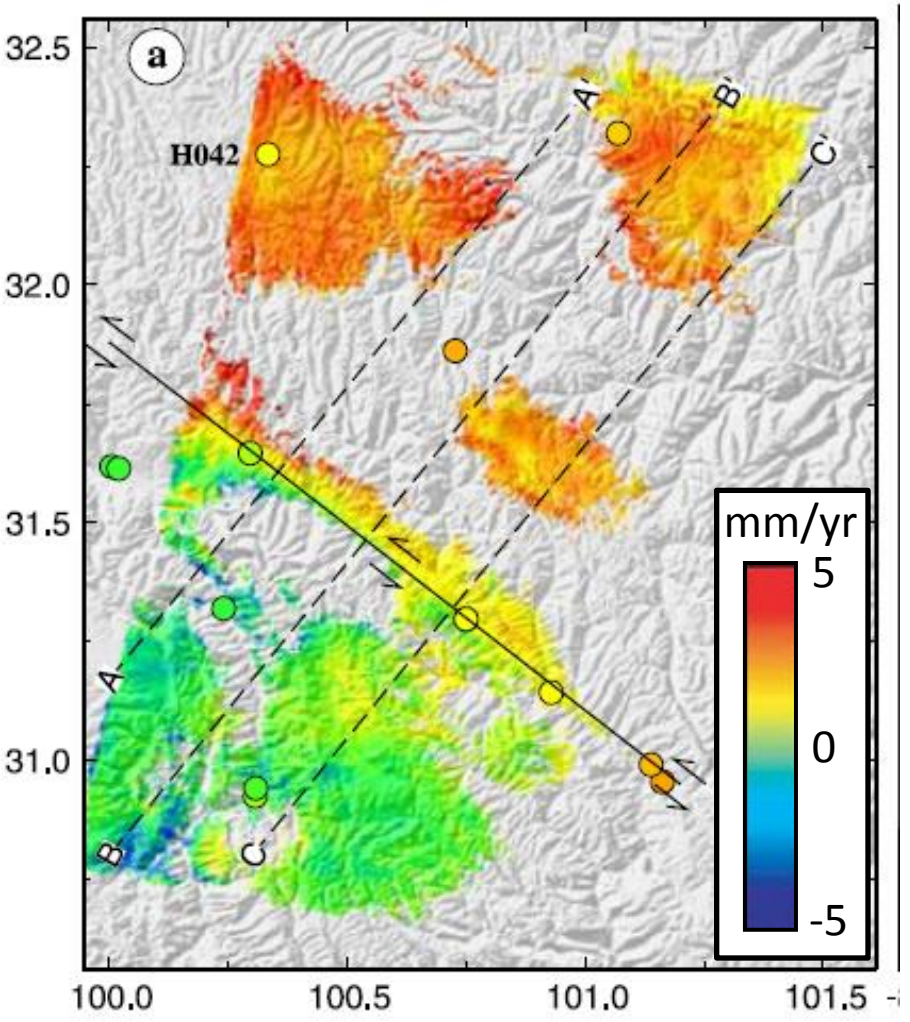
Achieving 1 mm/yr accuracy



Accurate Orbital Models

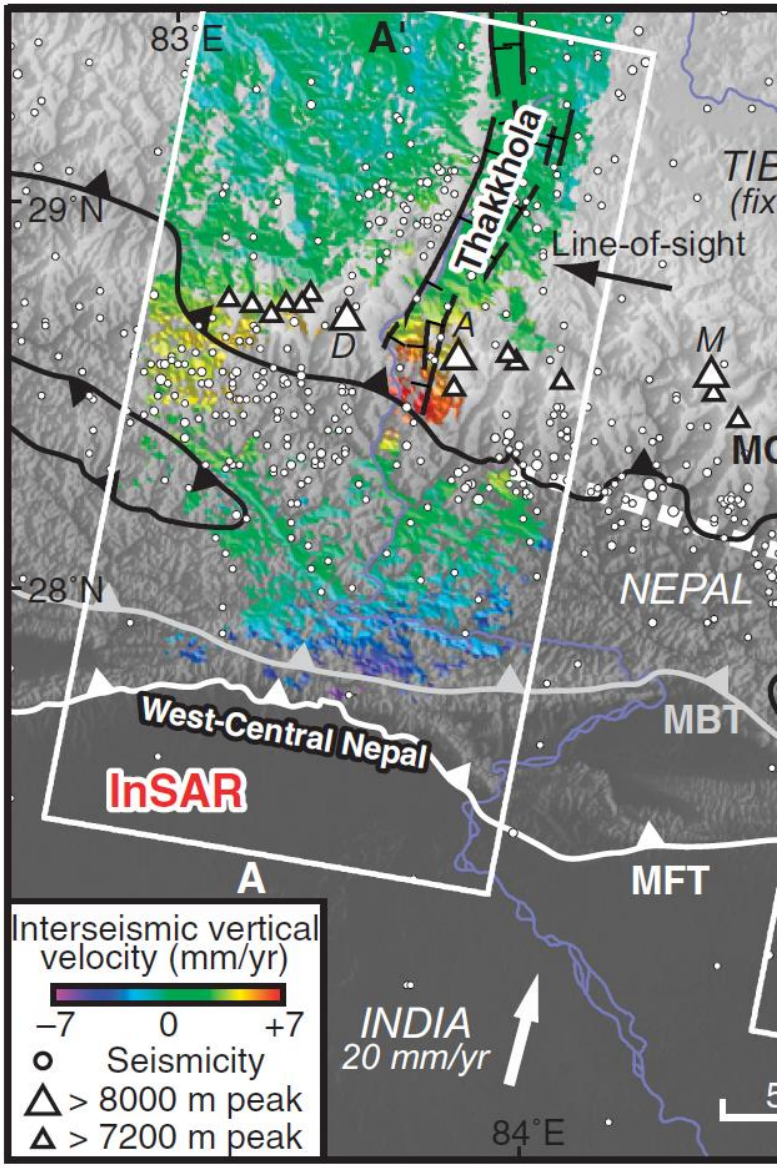
Atmospheric Corrections

Xianshuihe Fault

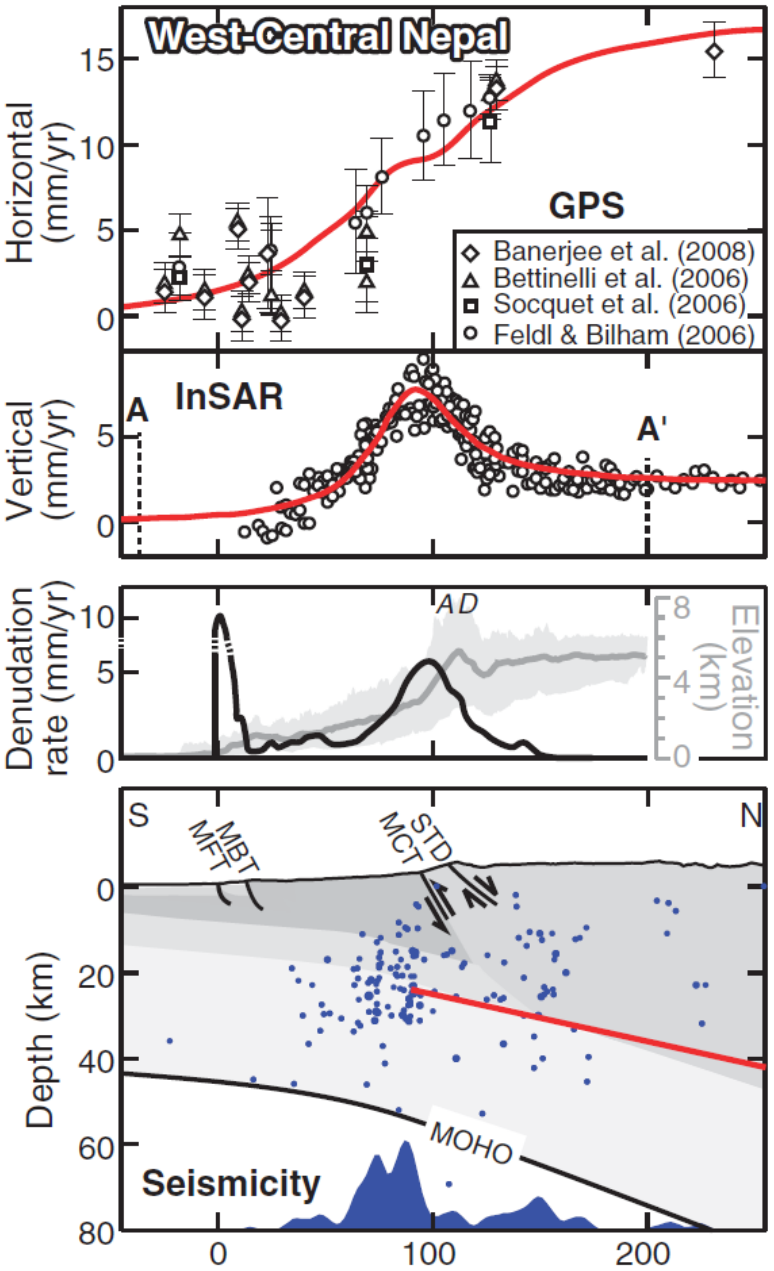


Wang, Wright et al, 2008

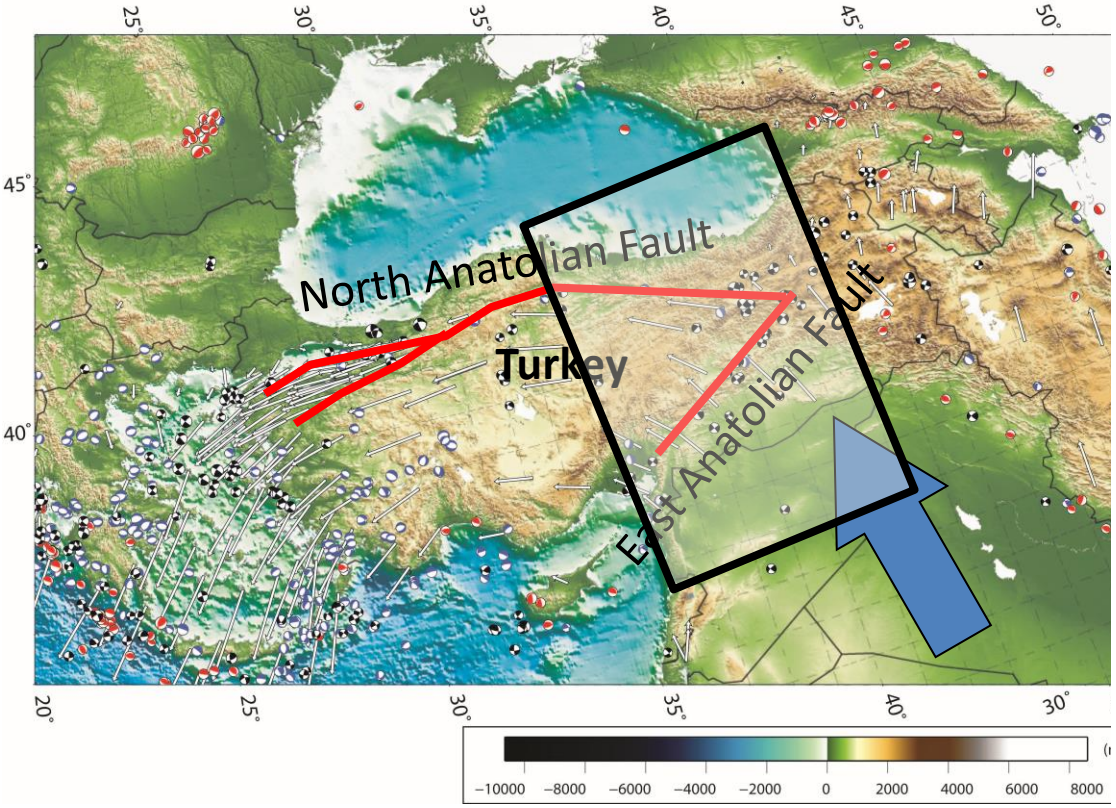
Uplift in Nepal

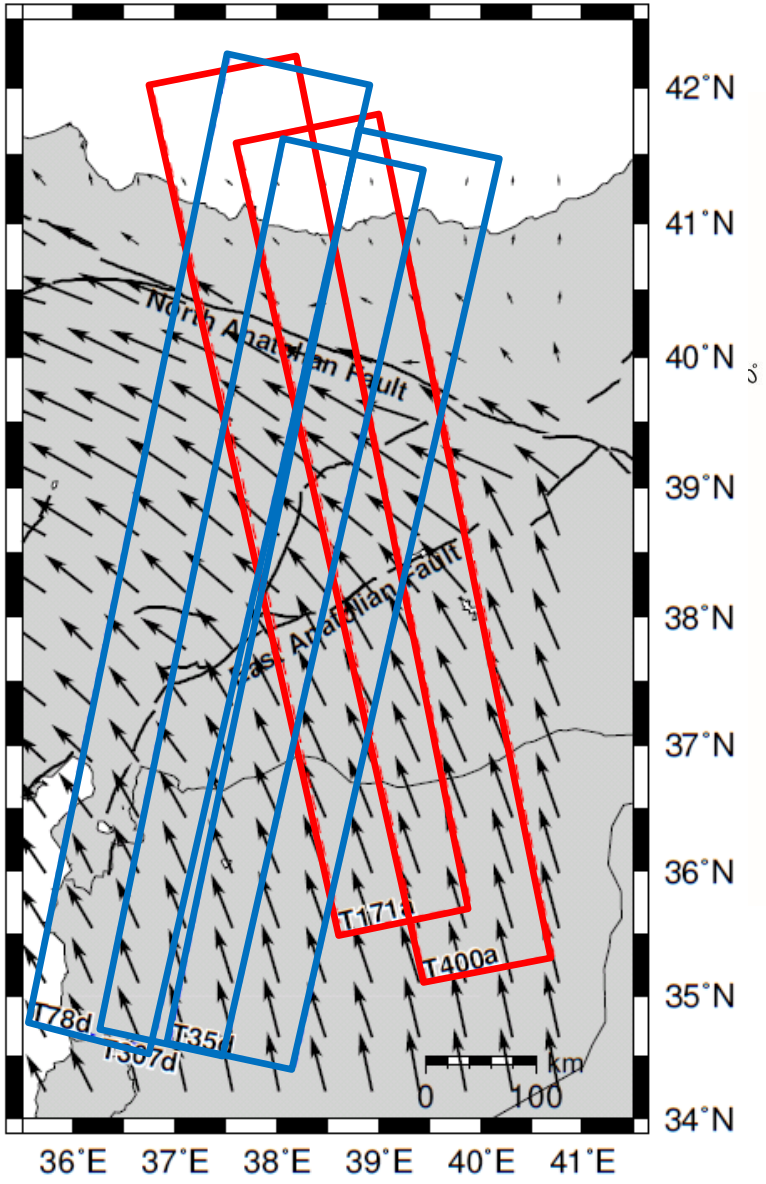


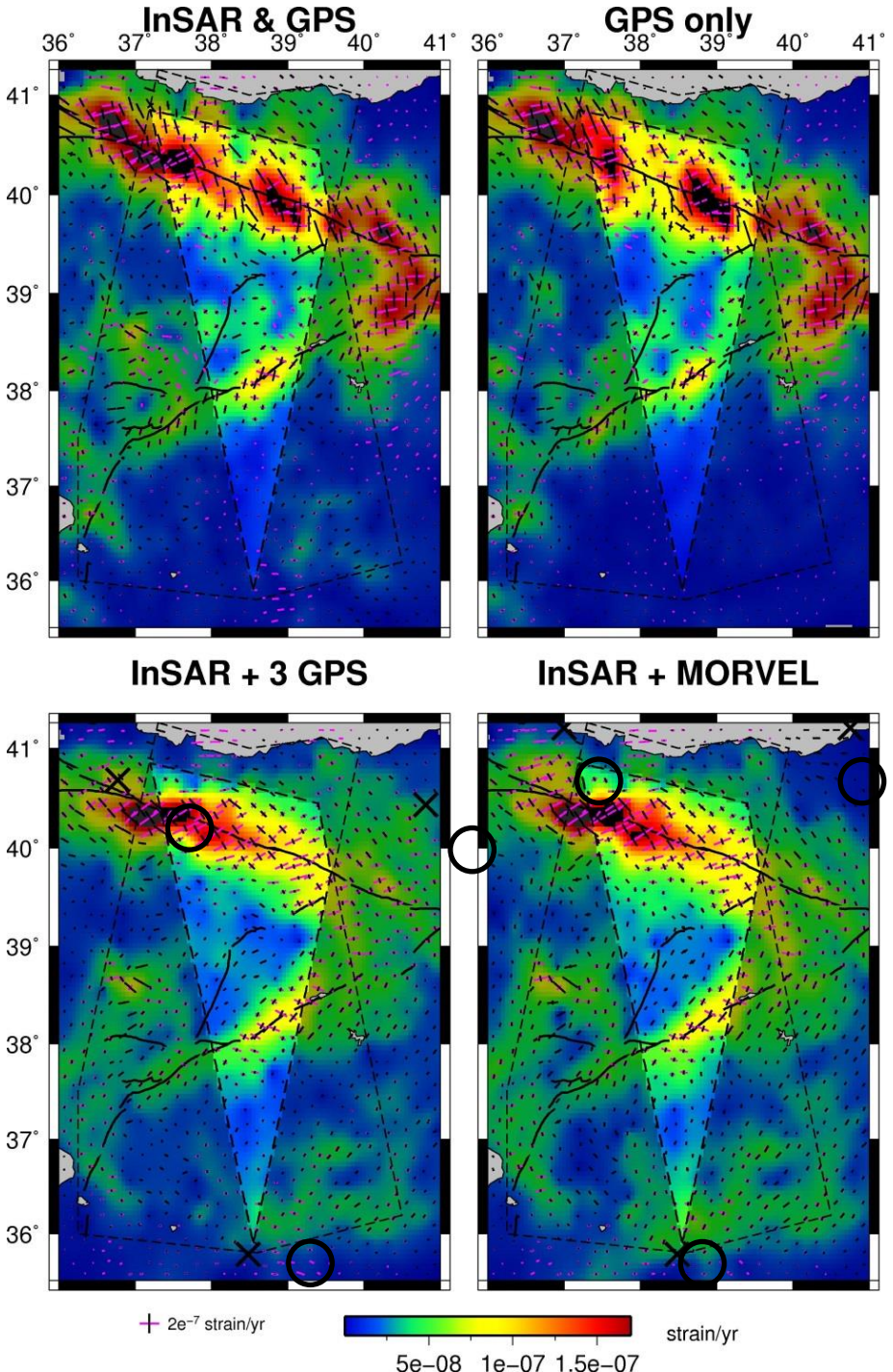
Grandin et al., 2012



Strain mapping in E. Turkey



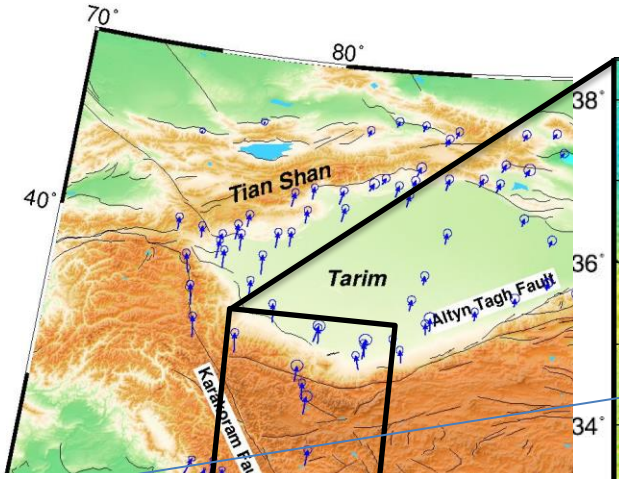


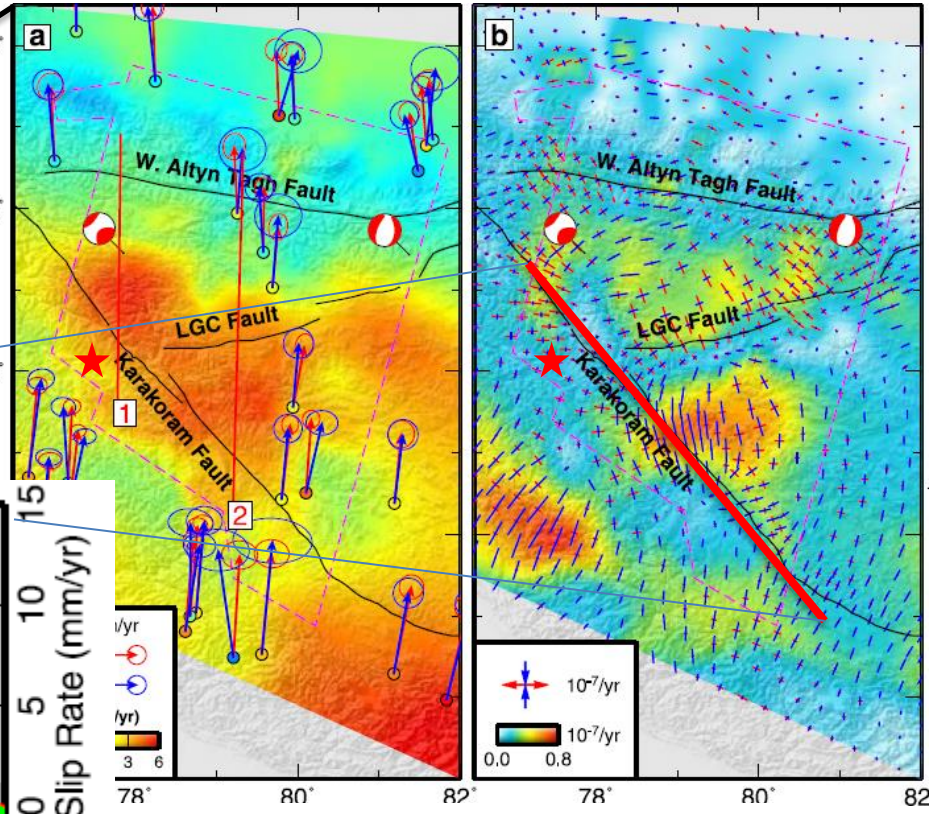


Mapping tectonic strain with InSAR

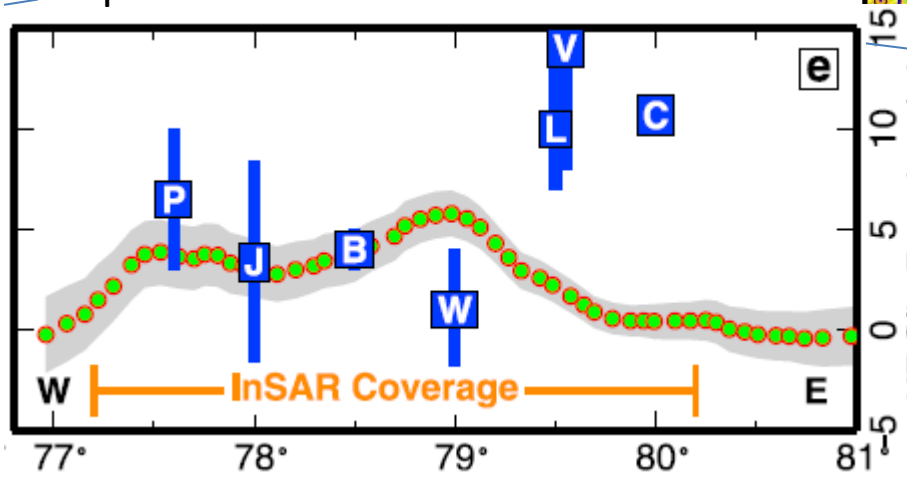
Walters et al. (JGR 2014)
Methods: Wang and Wright (GRL 2012)

Western Tibet



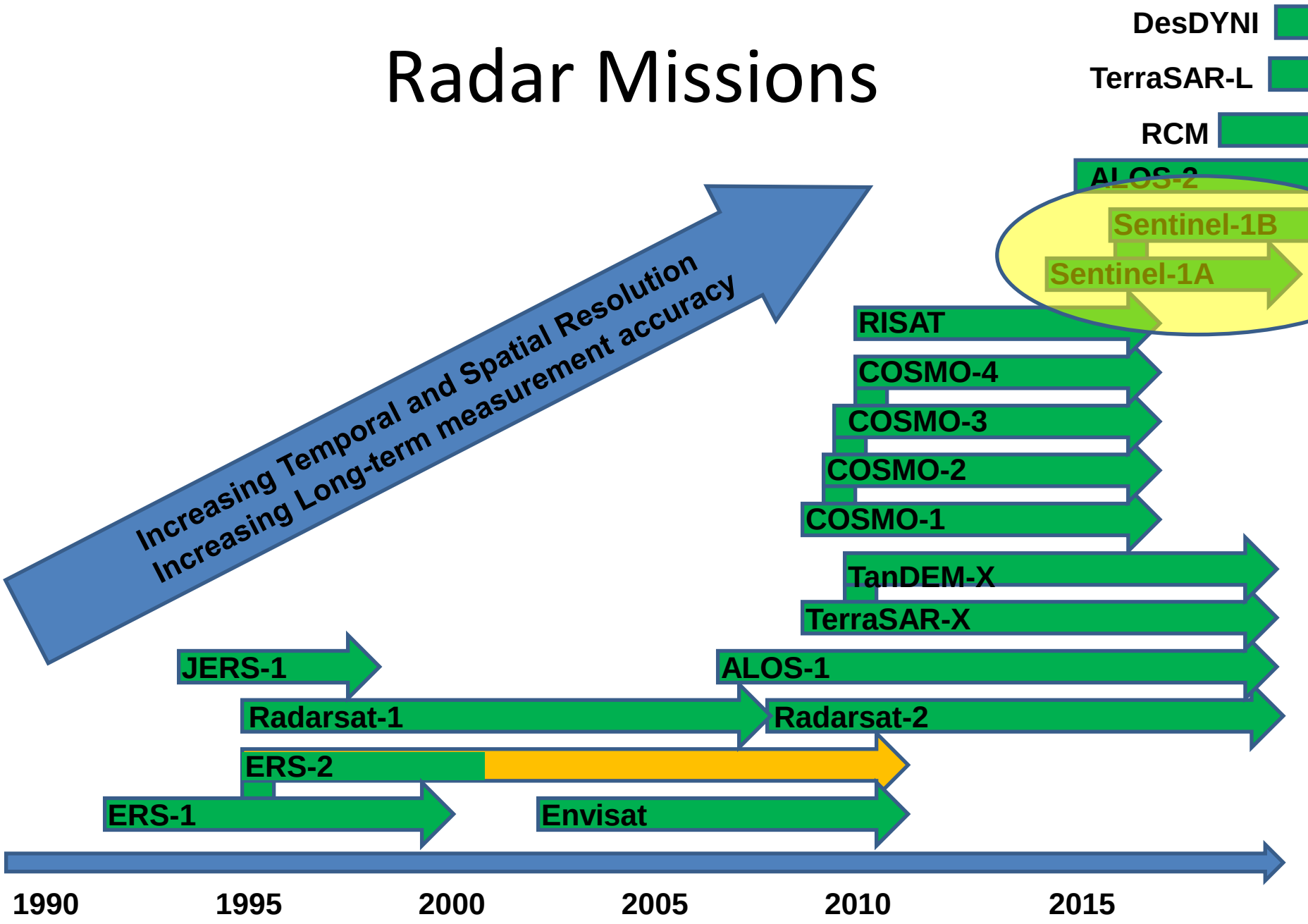


Slip rate of the Karakoram Fault

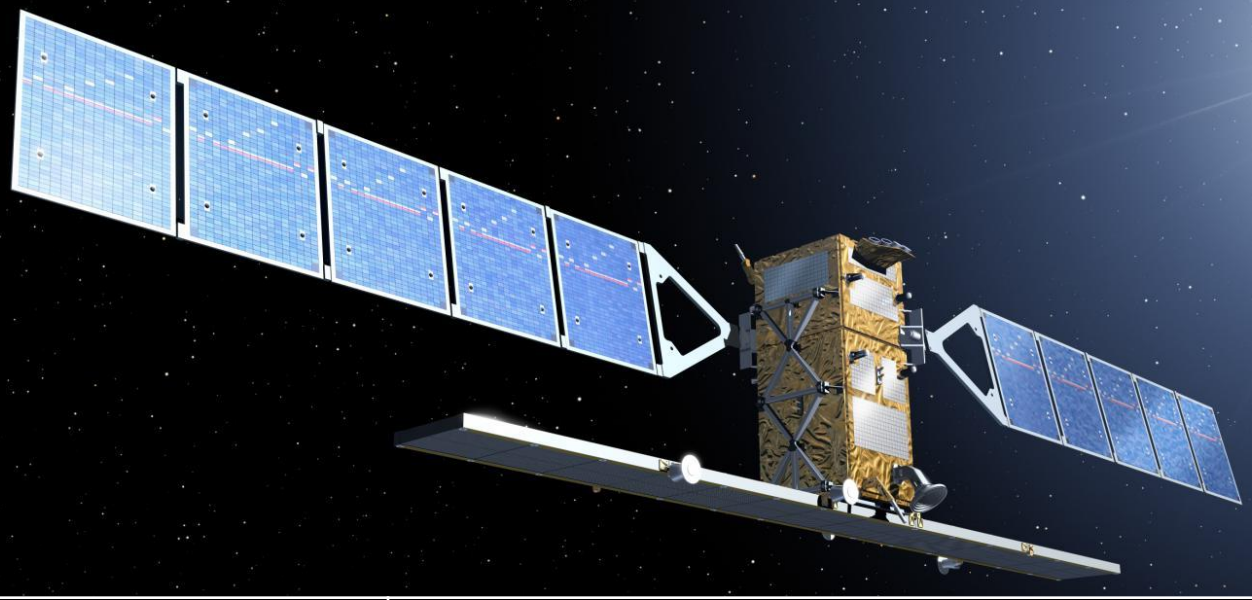


ang & Wright, *GRL* 2012

Radar Missions

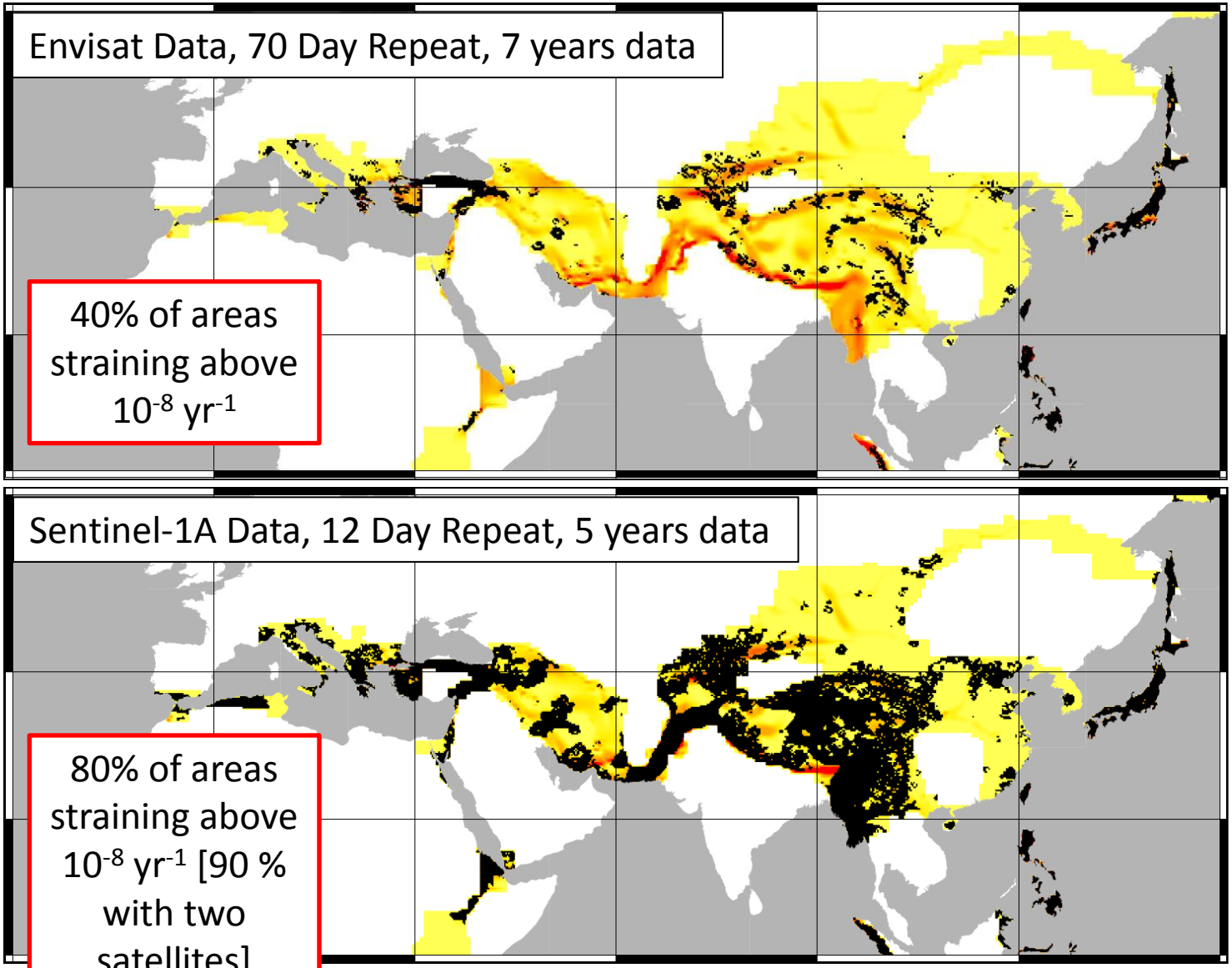


Sentinel-1 Constellation



Envisat	Sentinel-1
Stand-alone mission not specifically designed for InSAR	20 year operational program, designed for InSAR
Haphazard acquisition strategy (multiple modes)	Systematic acquisitions over deformation belts
Archive typically has ~30 images over 7 years	12 day revisit → 30 images per satellite per year
Loss of signal due to long time gaps or large orbital separations	6 day revisit (with two satellites), small orbital separation

How much better than existing missions?



Wright et al., Fringe 2011

Active Deformation and Seismic Hazard in the India-Asia collision zone

Tim Wright (COMET, University of Leeds)

4. Using strain for seismic hazard assessment

NERC SCIENCE OF THE ENVIRONMENT

Earthquakes without Frontiers

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS

Geodesy is not the only tool, but it complements other methods

The Global Earthquake Model

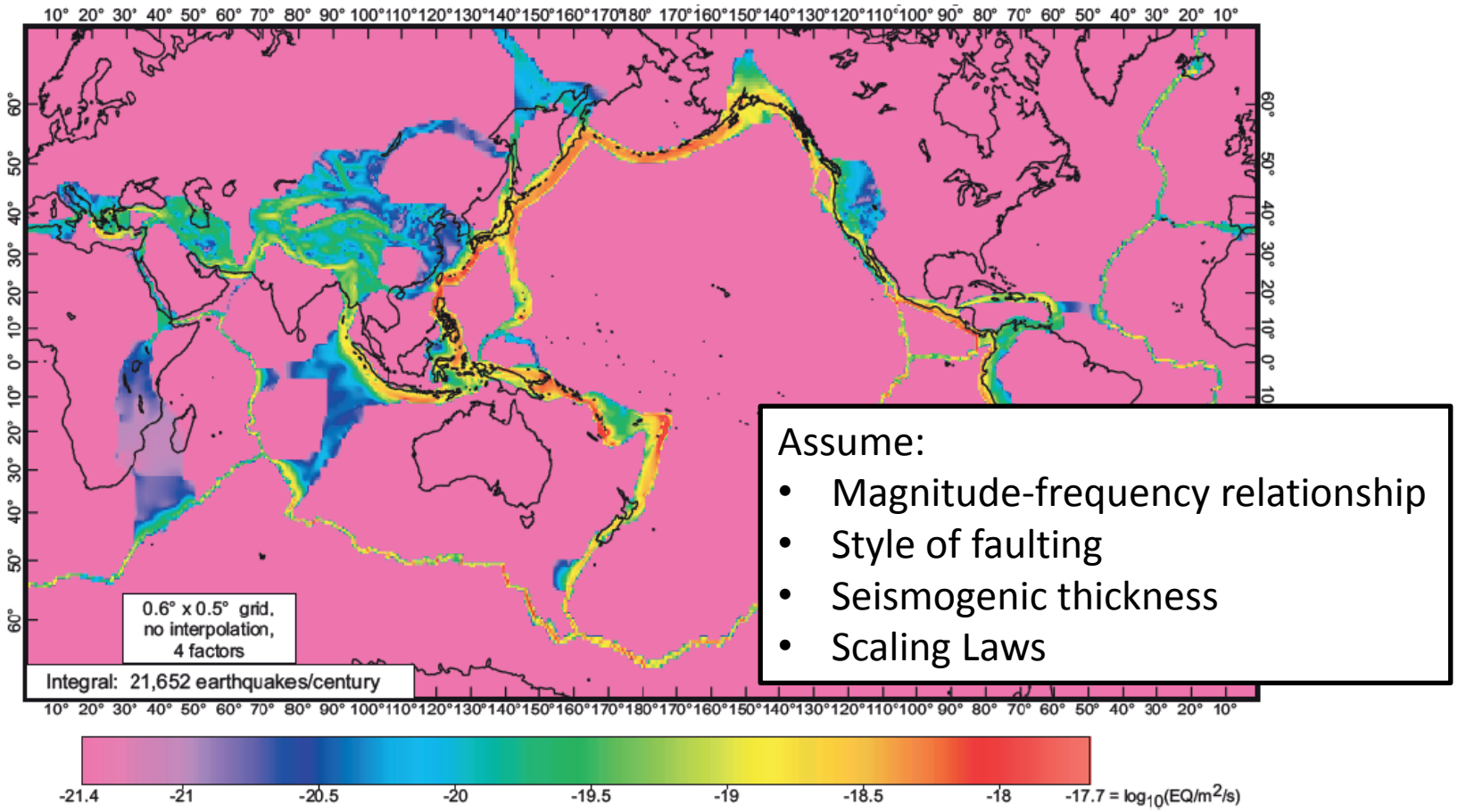
Seismic Hazard

- Instrumental Seismicity
- Historical Seismicity
- **Geodetic Strain Rate**
- Active Faults Database
- Ground Motion Prediction Equations

Risk

http://globalquakemodel.org

Q. How to turn strain into hazard maps?



Assume:

- Magnitude-frequency relationship
- Style of faulting
- Seismogenic thickness
- Scaling Laws

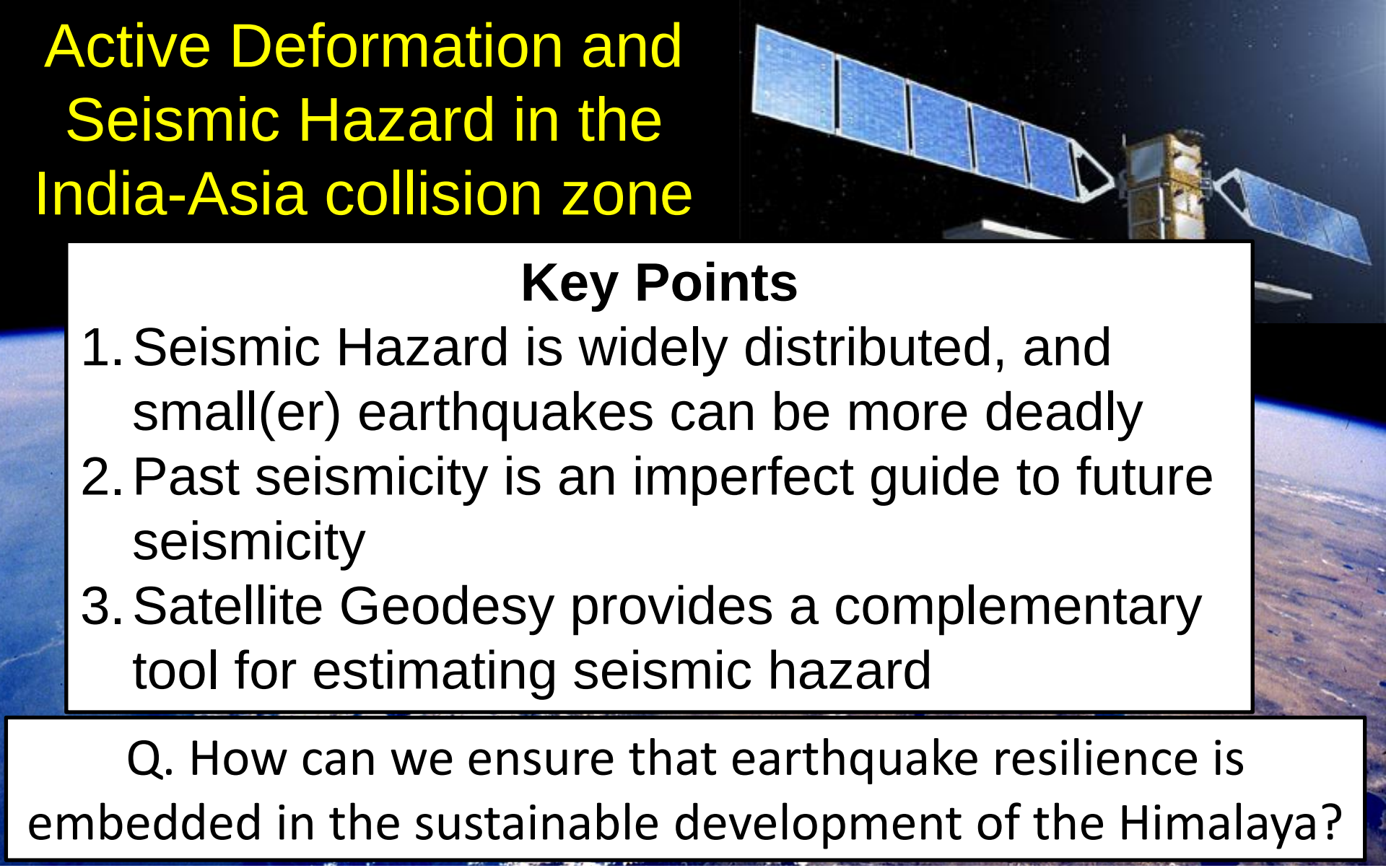
Number of earthquakes forecast with M > 5.66, from **Bird et al., 2010**.
Green = 1 earthquake per century in a 100 x 100 km area .
[Crude because strain data is low resolution]

Q. How can we ensure that earthquake resilience is embedded in the sustainable development of the Himalaya?

Q. How can we ensure that earthquake resilience is embedded in the sustainable development of the Himalaya?

26th December 2003, Bam (Iran) M_w 6.6

Active Deformation and Seismic Hazard in the India-Asia collision zone



Key Points

1. Seismic Hazard is widely distributed, and small(er) earthquakes can be more deadly
2. Past seismicity is an imperfect guide to future seismicity
3. Satellite Geodesy provides a complementary tool for estimating seismic hazard

Q. How can we ensure that earthquake resilience is embedded in the sustainable development of the Himalaya?

NERC SCIENCE OF THE ENVIRONMENT

Earthquakes without Frontiers

COMET

@NERC_COMET
@timwright_leeds
@EwFProject

UNIVERSITY OF LEEDS