The Global Geodetic Observing System (GGOS) and how it relates to IGOS Geohazards

(International Association of Geodesy, IAG)

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Contributions

- GGOS Steering Group and WG members (G. Beutler, B. Engen, R. Forsberg, C. Ma, R. Neilan, M. Pearlman, C. Reigber, B. Richter, M. Rotacher, S. Zerbini, and others)
- Nevada Geodetic Laboratory (G. Blewitt, C. Kreemer)
- Nevada Bureau for Mines and Geology (J. Price, J. Bell)
- Literature, WWW (many colleagues)

Overview

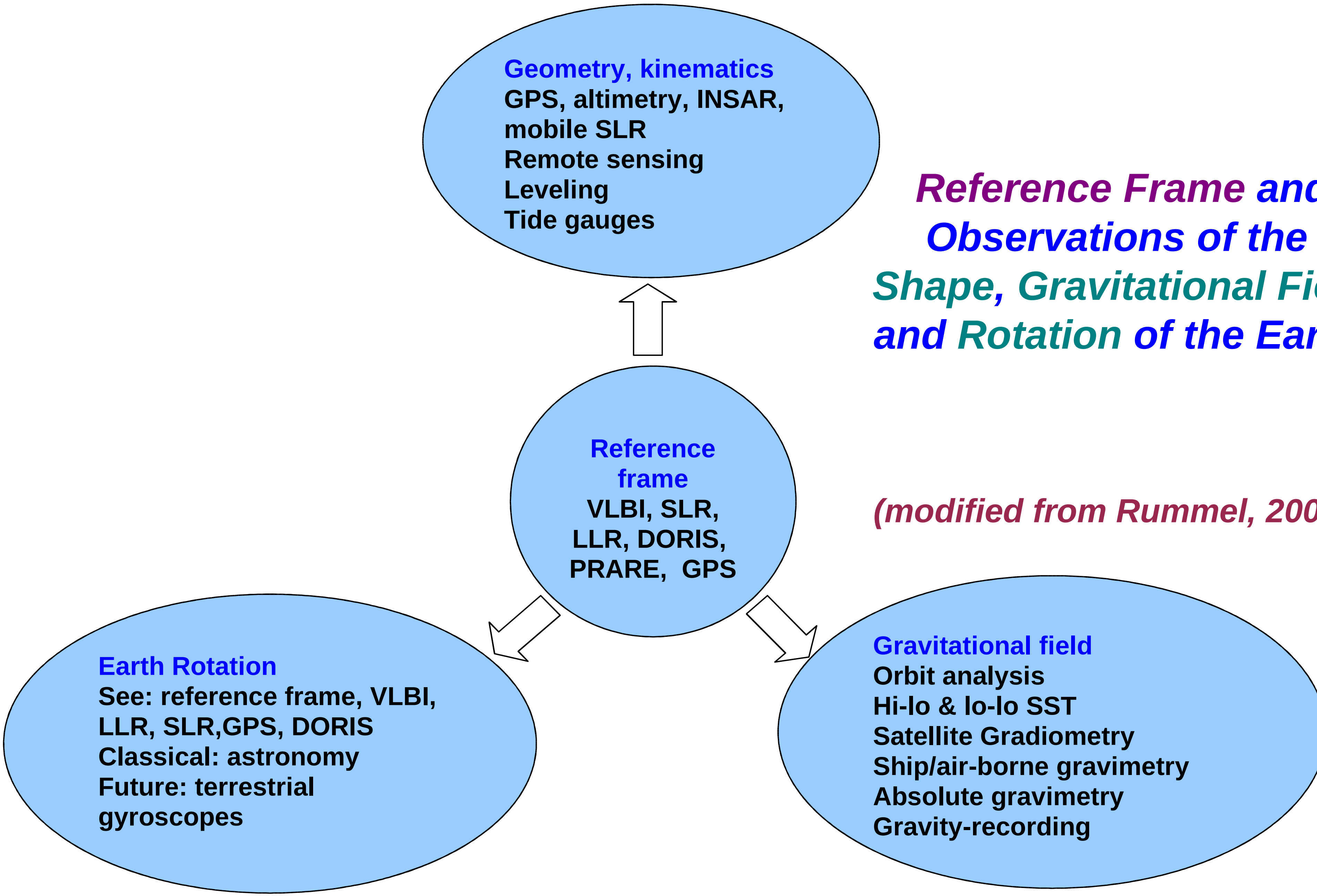
- Geodesy's Contribution to Earth System Monitoring
- The Vision of GGOS
- The Global and Regional IAG Networks
- The Implementation of GGOS
- Examples of Geohazards Related Applications and Results
- GGOS and IGOS-P Geohazards
- Preliminary conclusions

Geodesy's Contribution to Earth System Monitoring

The geodetic quantities

- Changes in the shape of the Earth (geometry):
  - displacements
  - kinematics
  - strain
- Changes in the gravity field of the Earth:
  - local gravity
  - geoid
  - gravity field
- Changes in the Earth rotation:
  - polar motion
  - length of day

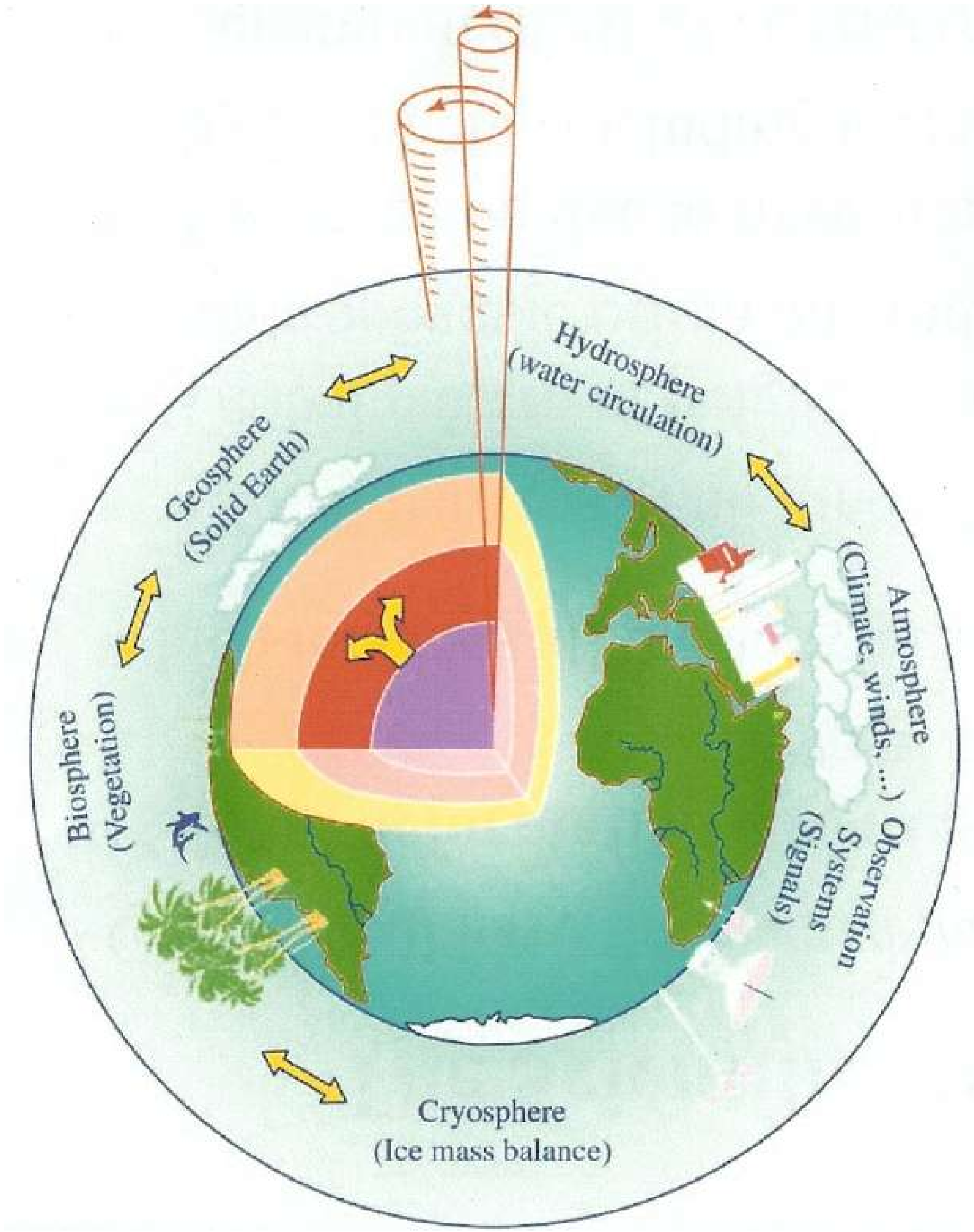
Geodesy's Contribution to Earth System Monitoring



Reference Frame and Observations of the Shape, Gravitational Field and Rotation of the Earth

(modified from Rummel, 2000)

Geodesy's Contribution to Earth System Monitoring

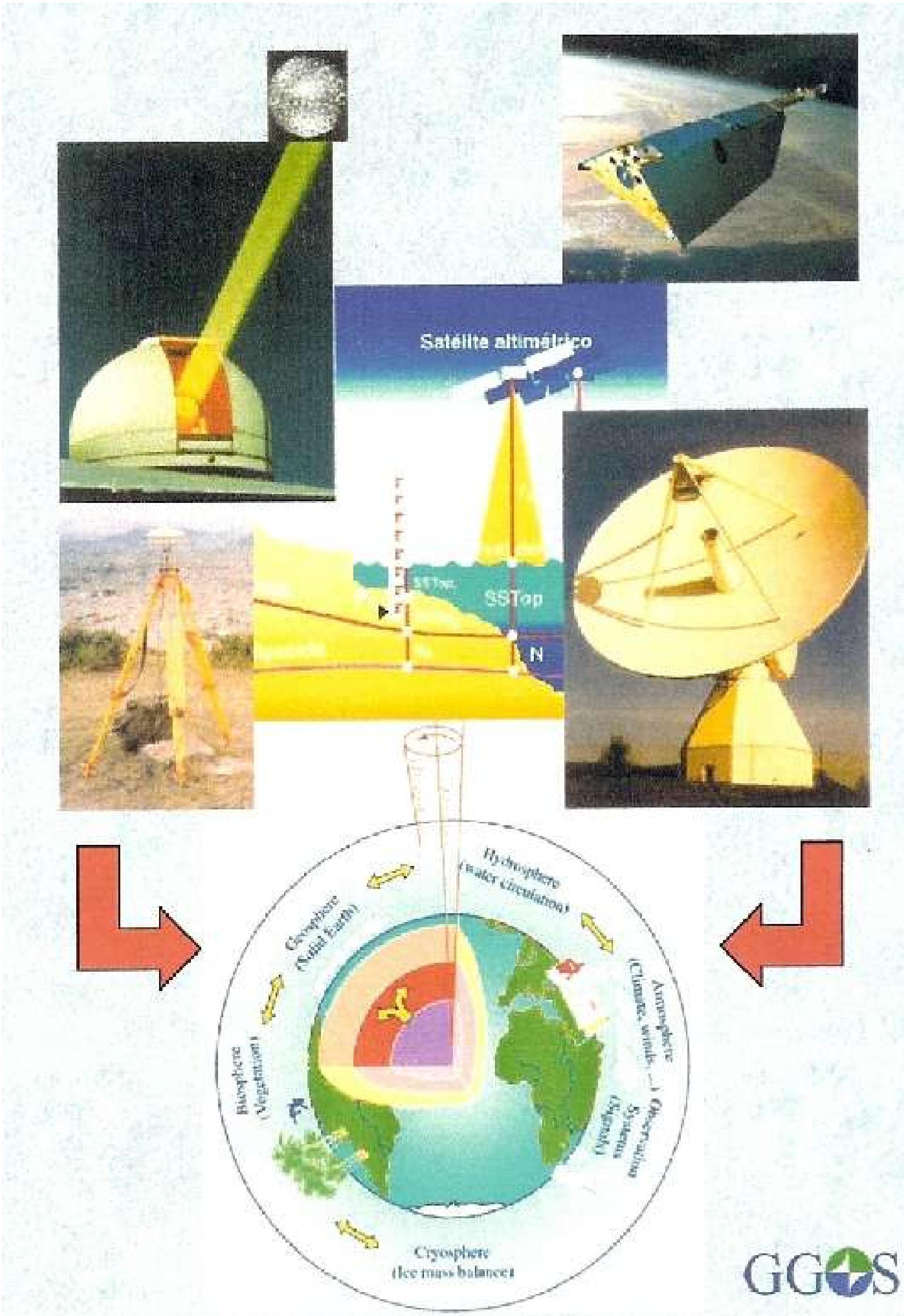


Geodesy's contribution to Geosciences

Geodesy provides information on mass transport and dynamics of the Earth system:

- Deformation of the solid Earth, (geometry and kinematics)
- Mass transport in the Earth system (gravity field, Earth rotation,
- Atmosphere-Ocean dynamics (Earth rotation)
- Global water cycle (gravity field, satellite altimetry, atmospheric sounding)

The Vision of GGOS

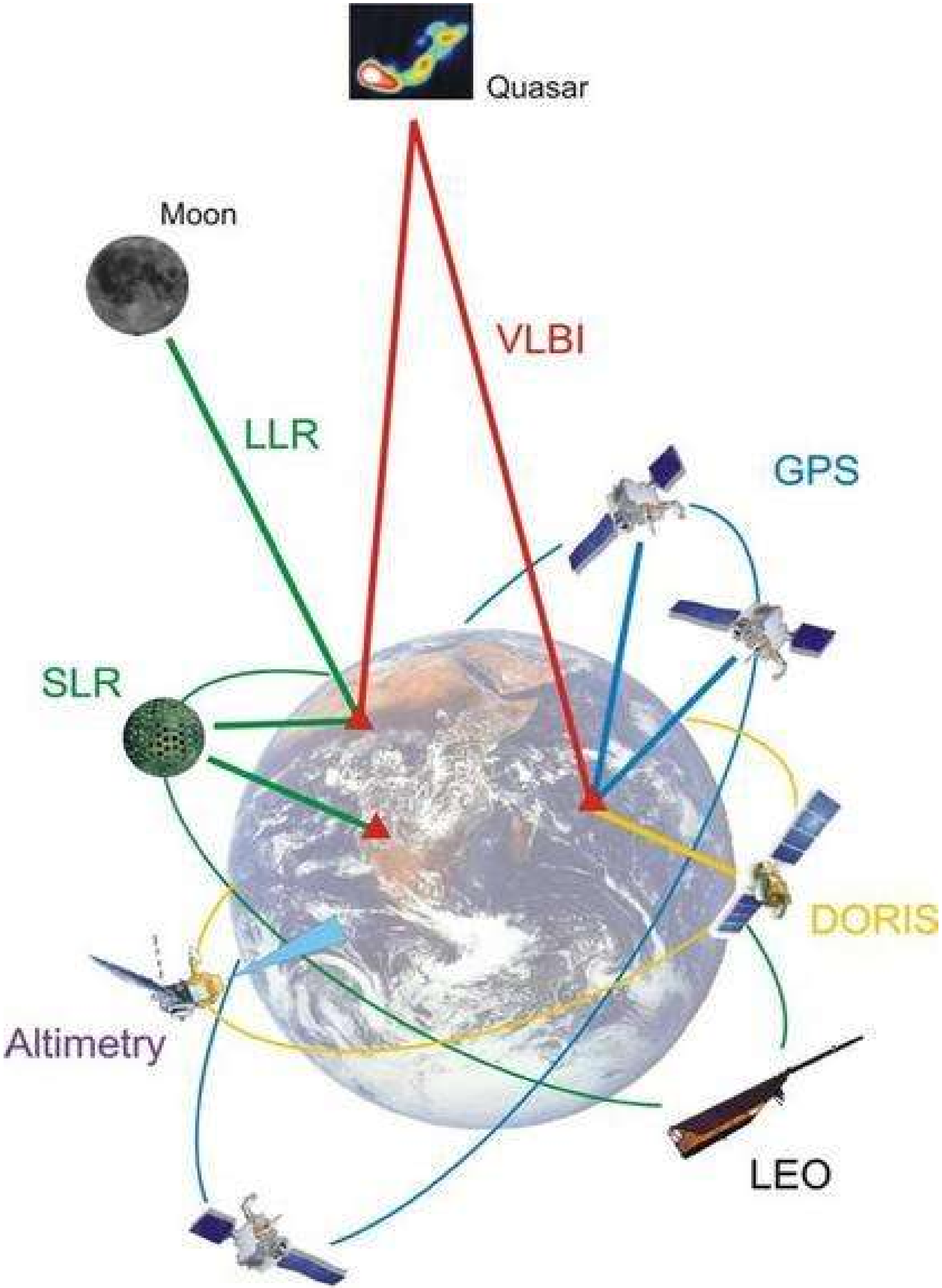


- GGOS integrates different geodetic and space-geodetic and their ground-based networks, different approaches, and different models into a consistent observing system in order to achieve higher accuracy, long-term stability, and better accessibility to products and information.

- GGOS aims at a better understanding of geodetic, geodynamic and global change processes

- GGOS provides a utility for Earth system research and monitoring

The Vision of GGOS



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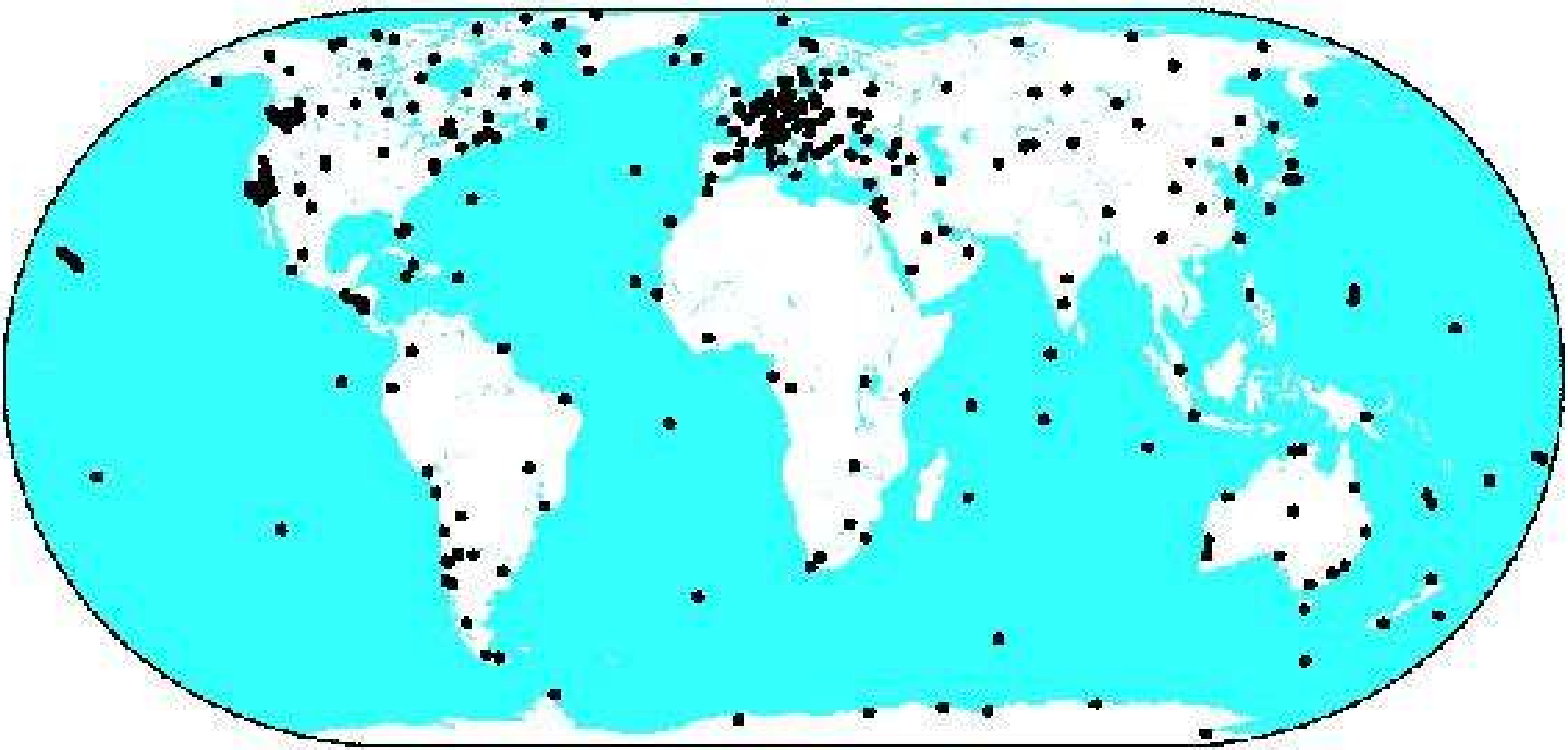
The global and regional IAG networks

- International Earth Rotation and Reference Systems Service (IERS)
  - International Terrestrial Reference System (ITRS) and Frame (ITRF)
- International VLBI Service (IVS): Quasars as sources ==>
  - Earth rotation
- International Laser Ranging Service (ILRS): laser ranging to satellites ==>
  - geocenter
  - scale
- International GNSS Service(IGS): Global Navigation Satellite Systems (GPS, GLONASS, Galileo) ==>
  - satellite orbits and clocks
  - highly accurate access to reference frame
- International DORIS Service
- International Gravity Field Service (IGFS)
- Global Geodynamic Project
- International Satellite Altimetry Service (IAS, In preparation)
- International InSAR Service (under discussion)

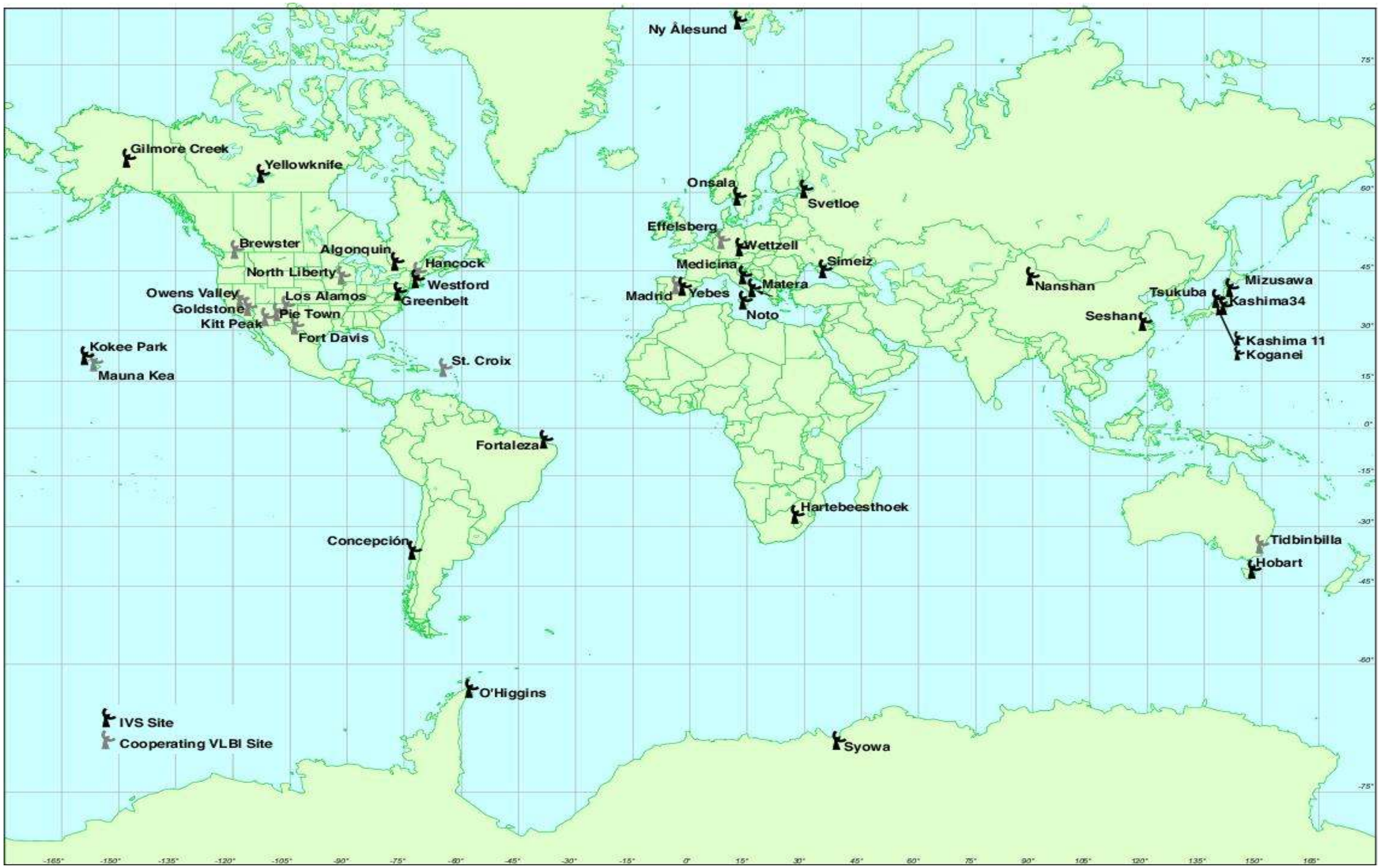
The global and regional IAG networks



The IGS Network

- More than 300 stations
- Main Products: Station time series, satellite oribits and clocks, geocenter, ERP, ionosphere, troposphere

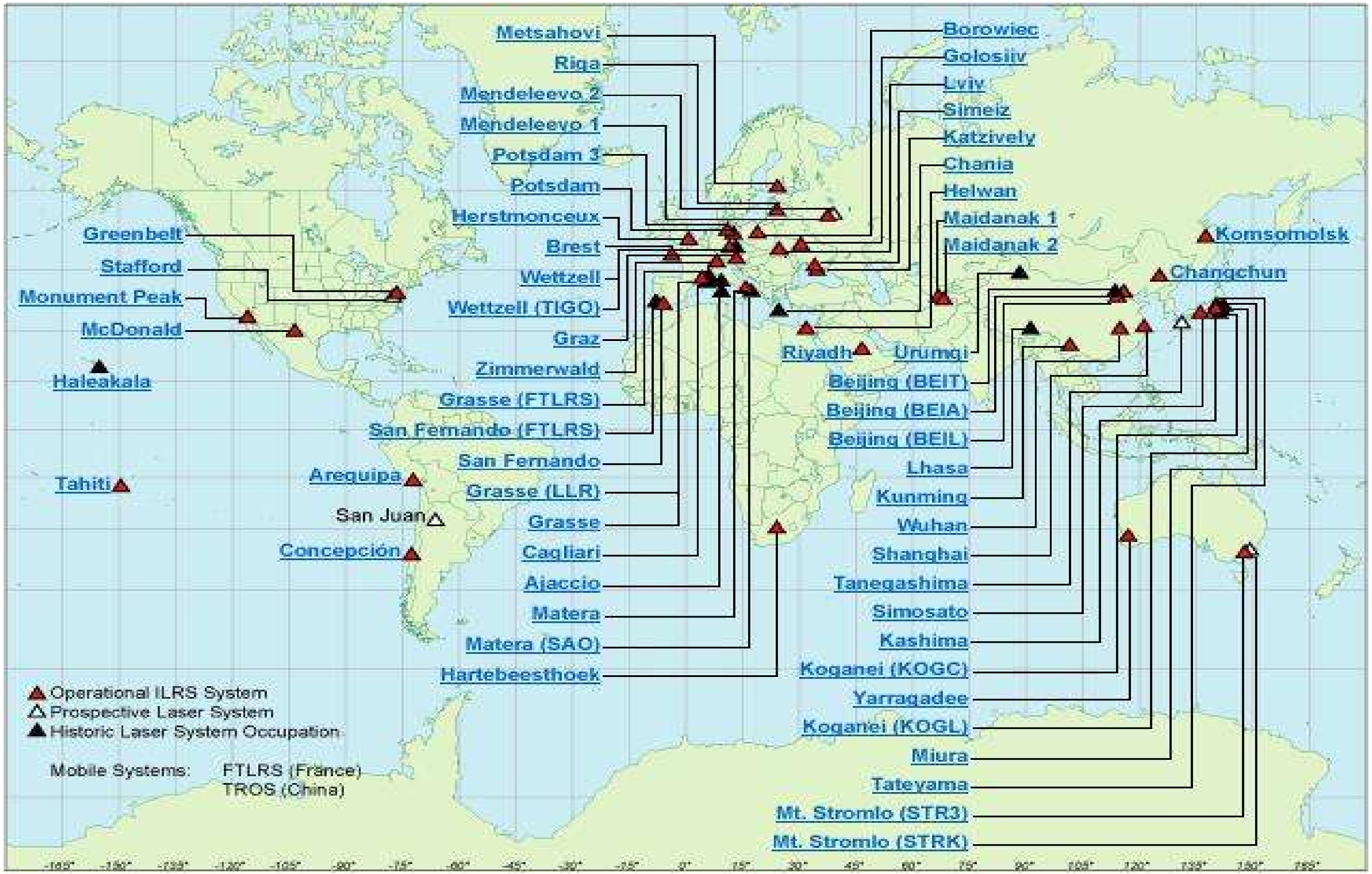
The global and regional IAG networks



The IVS Network

- Some 30 stations
- Main Products: long-term stable ERP, station time series

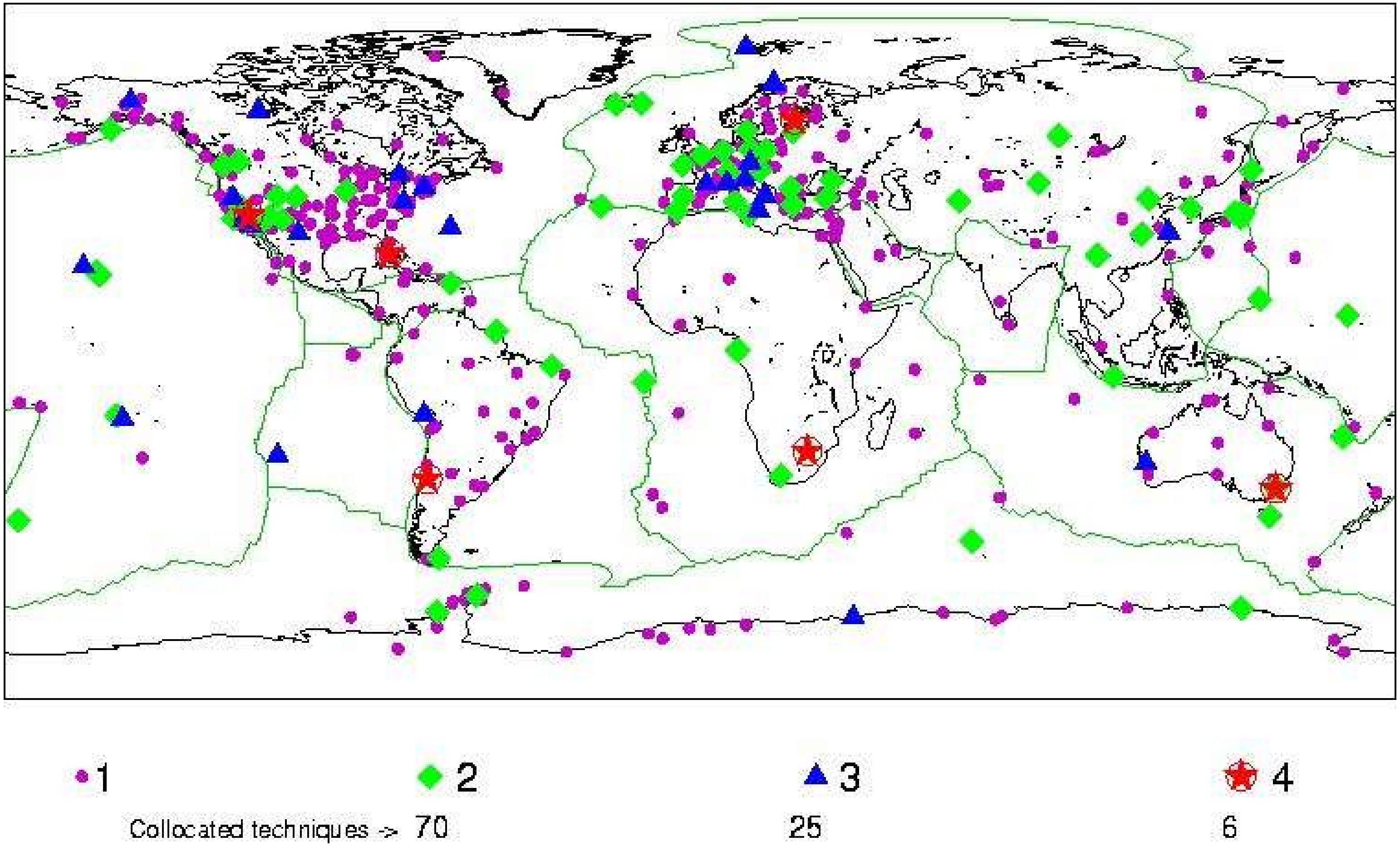
The global and regional IAG networks



The ILRS Network

- Some 30 stations
- Main Products: Geocenter, scale, tracking of satellites, station time series

The global and regional IAG networks

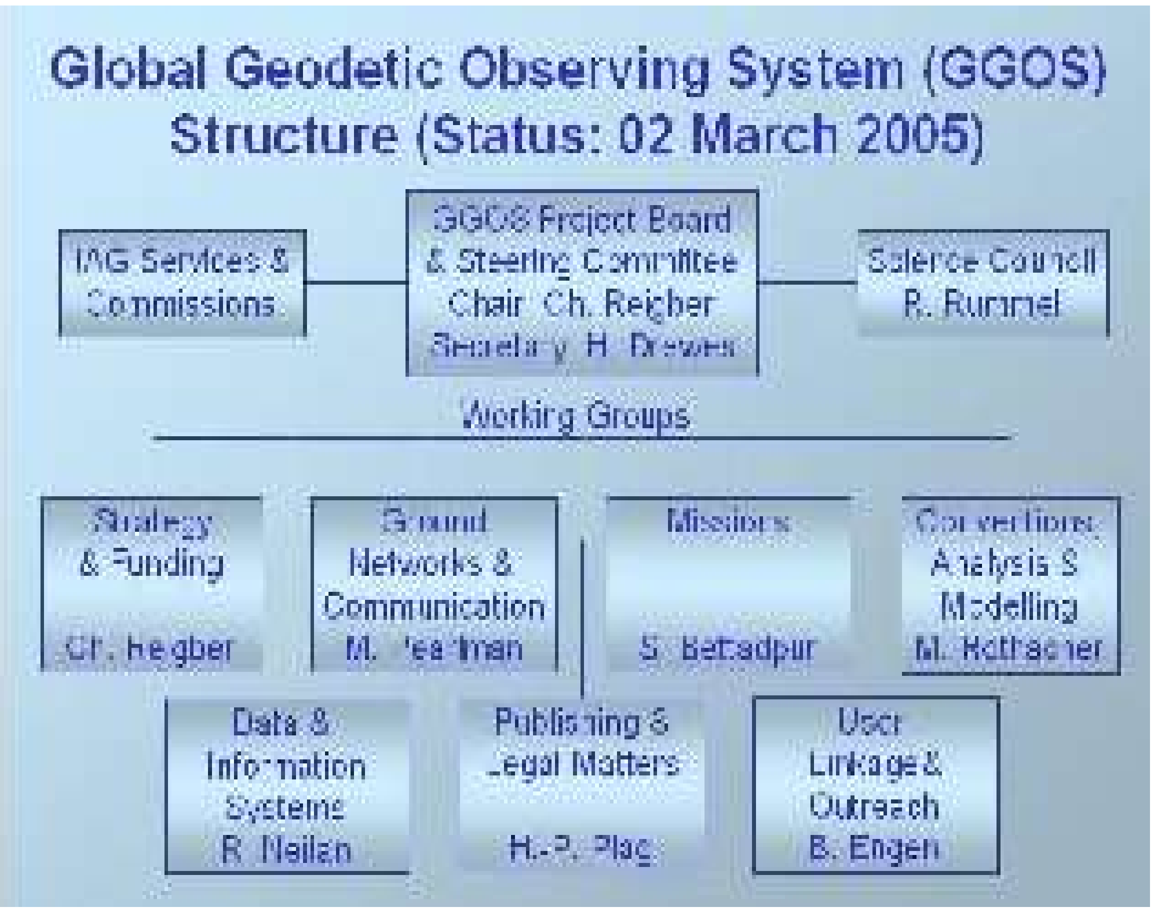


The ITRF Network

- About 430 stations
- Main Products: ITRF point coordinates and velocities


IAG's Global Geodetic Observing System (GGOS)
IAG Services
GGOS Project Board and Steering Committee
Science Council
Working Groups
Copyright, Data Access Policy, Publishing, Certification
Data and Info Systems
Infrastructure: Networks, Communication
User Linkage: Science, Industry, Authorities, Outreach
ICSU
IUGG
IAG
Services
GGOS
Products
Atmospheric Sounding (CHAMP)
Satellite-to-satellite tracking (GRACE)
Satellite Altimetry
Geometry and Kinematics
Earth Orientation and Rotation
Gravity Field and its Variability
Positions and Velocities
Sea Level Changes
Hydrological Cycle
Specific Humidity
Geohazards
Ice Mass Balance
GGOS
http://www.ggos.org
IAG services are based on more than 400 global observation stations.

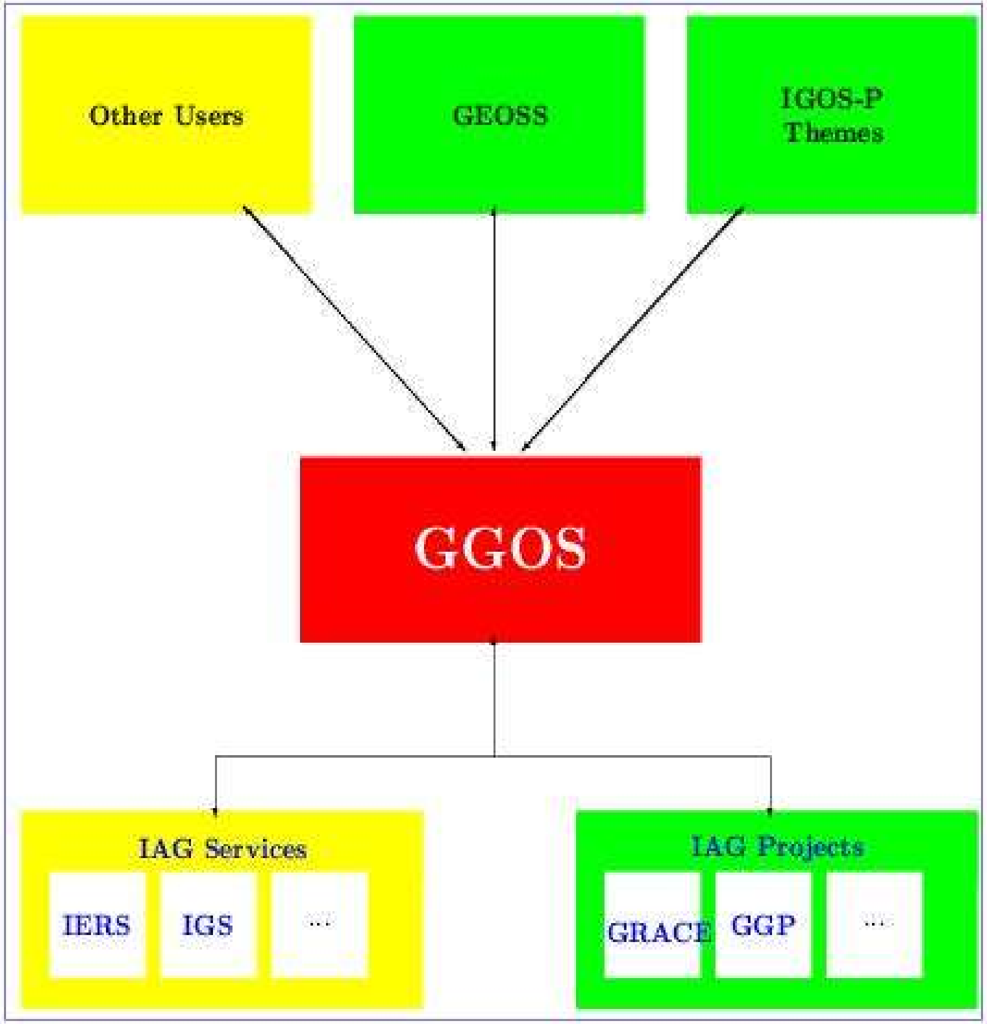
The Implementation of GGOS



Geodesy's contribution to Geosciences

- Established at IUGG 2003 as project
- Several Steering Group and WG meetings since spring 2004
- 1st Workshop on 1-2 March 2005, Potsdam, Germany
- UN affiliation and IGOS-P membership application in progress
- IAG Executive Meeting in August 2005, Cairns, Australia, expected to establish GGOS as permanent system

The Implementation of GGOS



GGOS Role in Earth Observation

Externally:

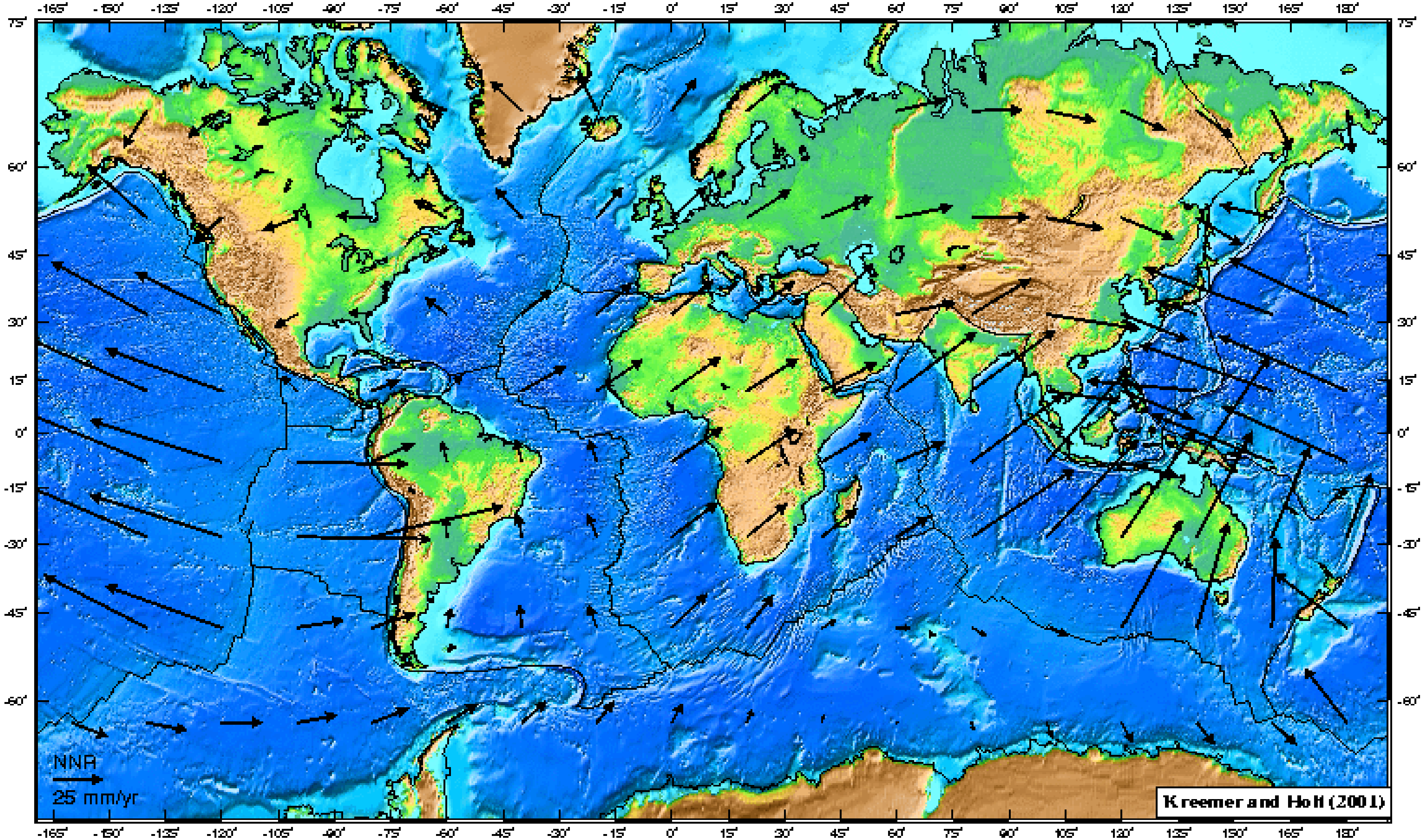
- GGOS will be the unique interface for external users
- GGOS will ensure that the interface is fully interoperable with other systems contributing to GEOSS
- GGOS will contribute to IGOS-P Themes

Internally:

- GGOS will facilitate fully consistent data processing, quality control, and modelling
- GGOS will advocate standardization of products

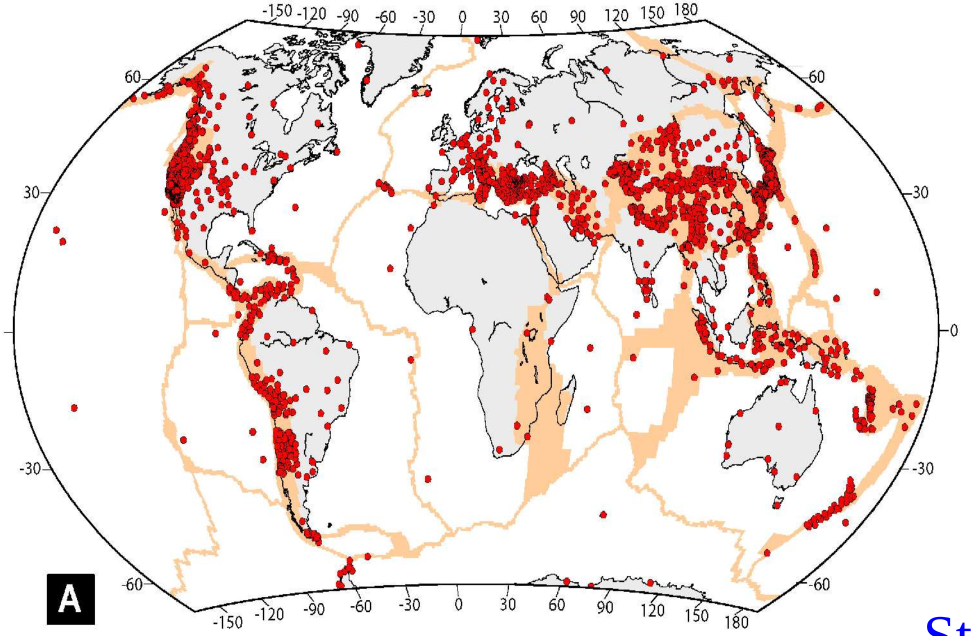
Examples of Geohazards related Applications and Results

Global Model of Horizontal Plate Velocities: Mainly from GPS

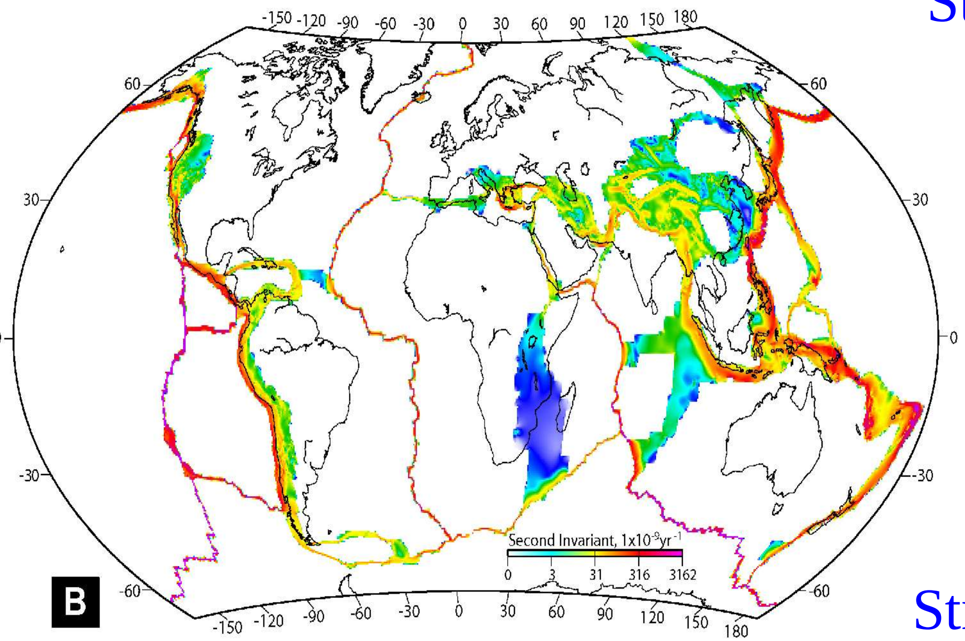


Examples of Geohazards related Applications and Results

Global maps of strain rates



Stations

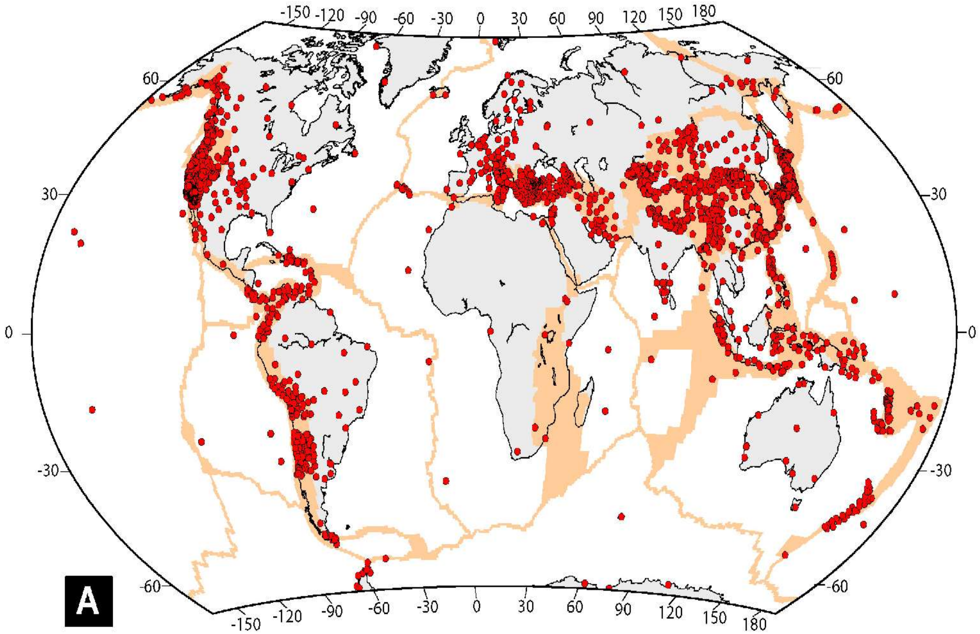


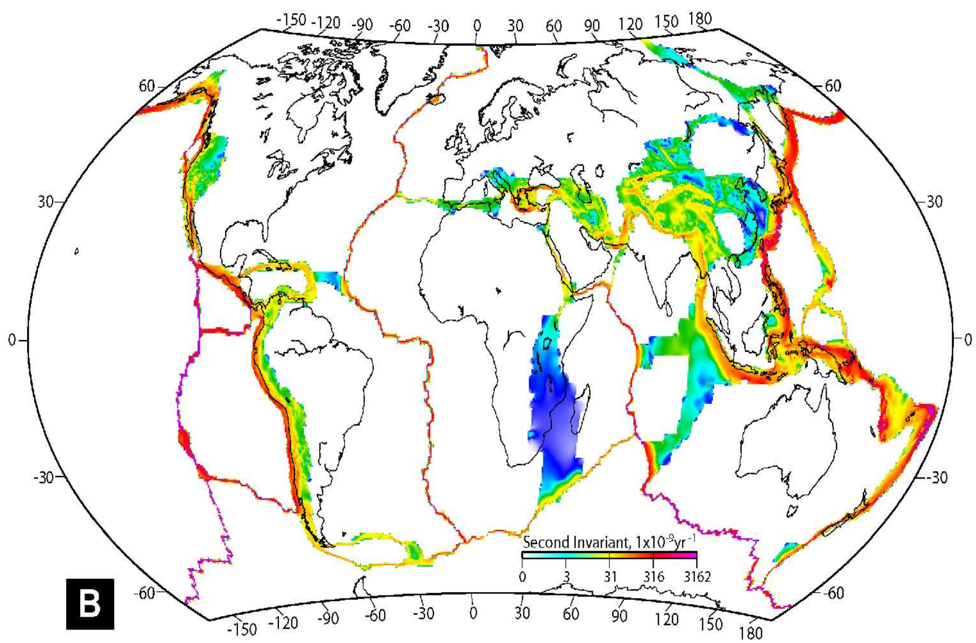
Strain rates

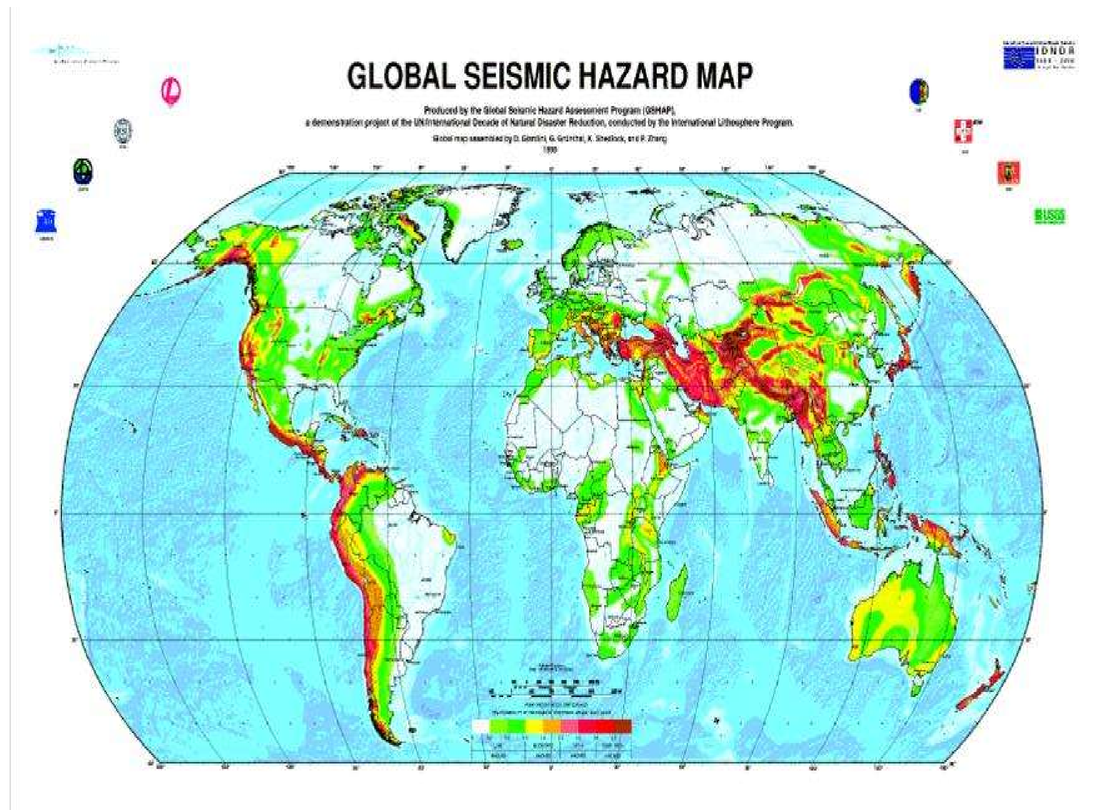
Kreemer et al. 2003

Examples of Geohazards related Applications and Results

Global maps of strain rates



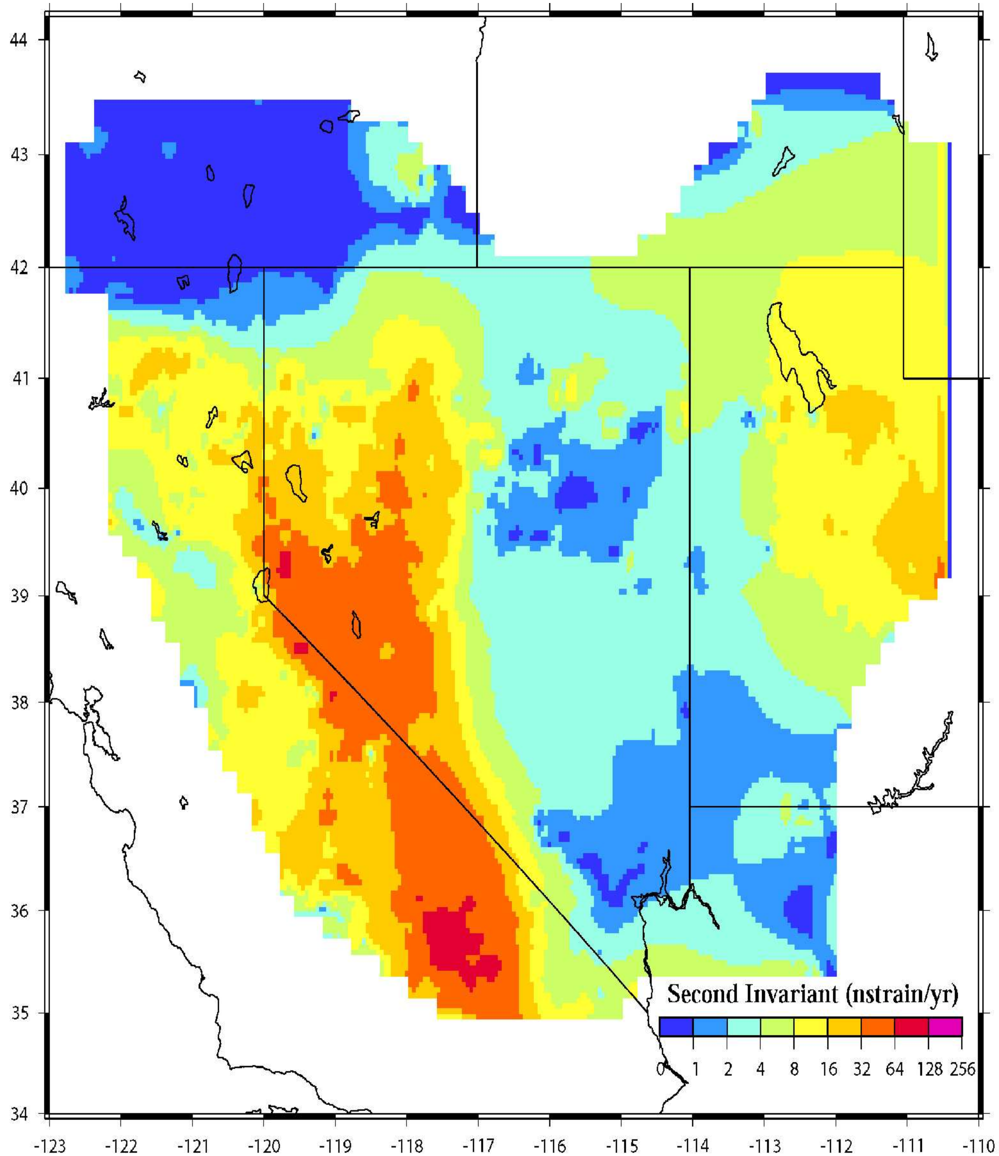




Kreemer et al. 2003

Examples of Gehazards related Applications and Results

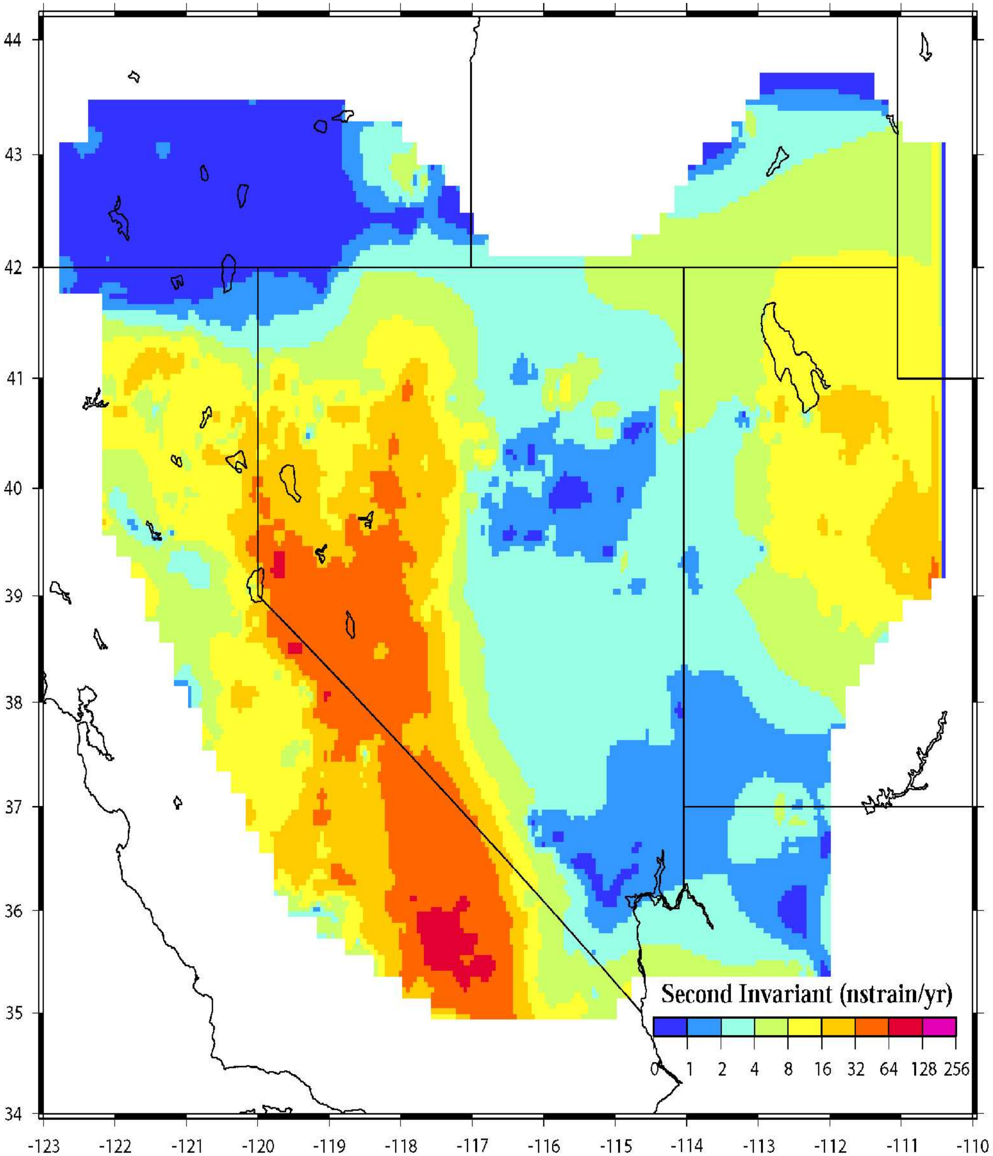
Local maps of strain rates

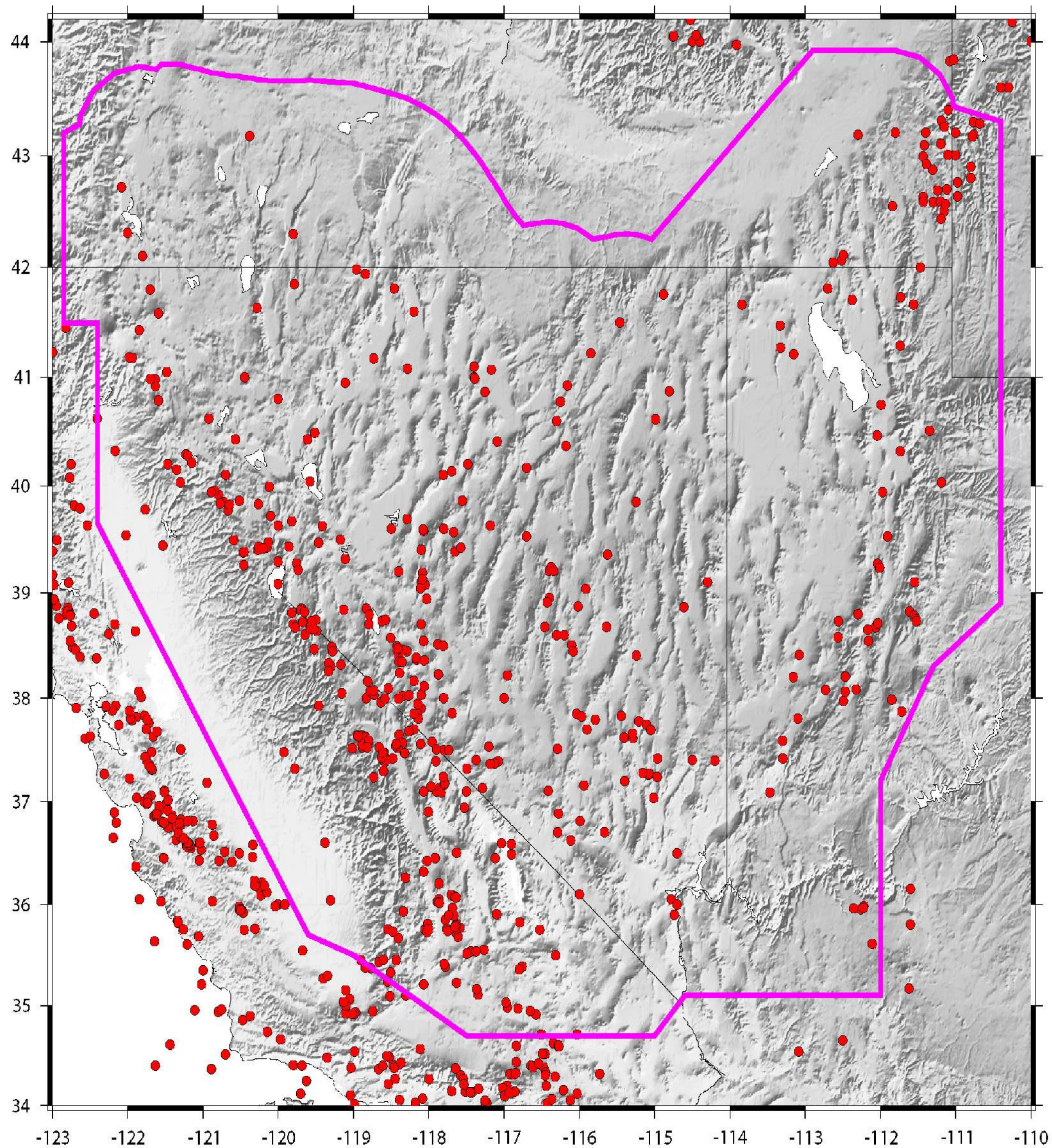


Kreemer, 2005

Examples of Geohazards related Applications and Results

Local maps of strain rates





Kreemer, 2005

Examples of Geohazards related Applications and Results

Largest earthquakes since 1900:

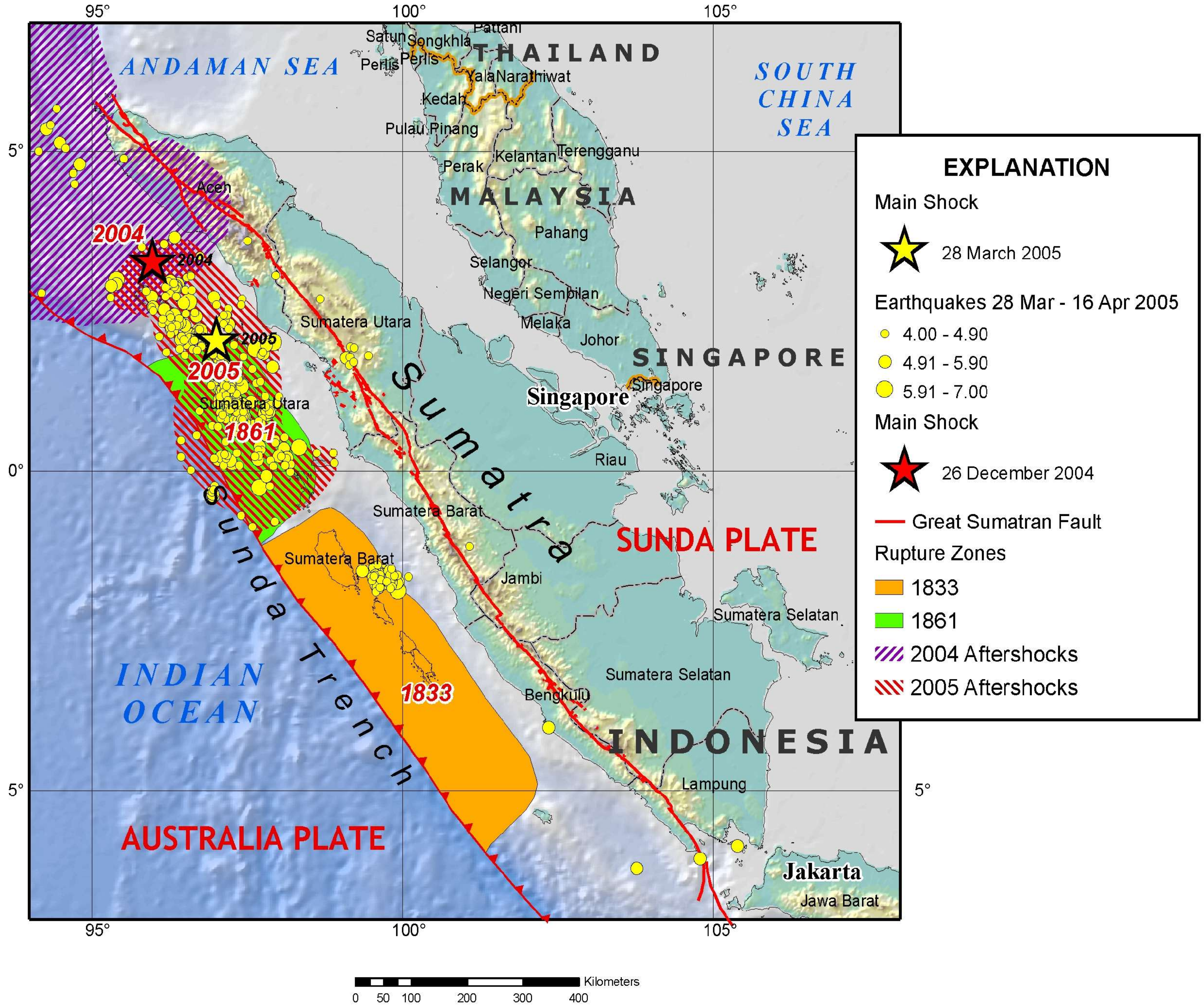
Mag.	Year	Location
9.0	1952	Kamchatka
9.1	1957	Andreanof Islands, Alaska
9.5	1960	Chile
9.2	1964	Prince William Sound, Alaska
9.0	2004	Sumatra

The December 26, 2004 Sumatra earthquake is the largest event ever observed by space-geodetic techniques:

Unique opportunity to test models, observations and analysis methods, study new phenomena, new discoveries

USGS
science for a changing world

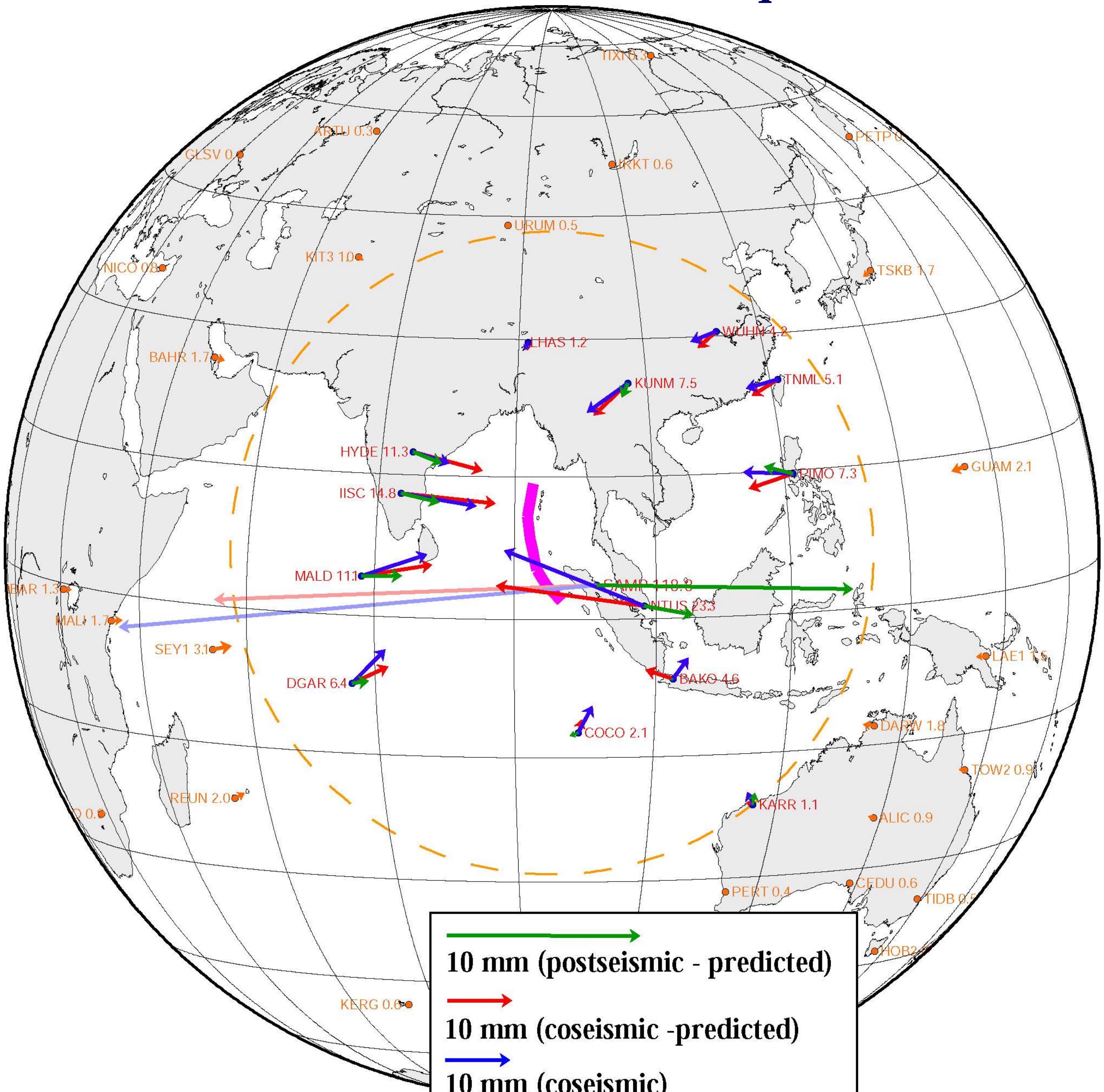
Northern Sumatra Earthquake of 28 March 2005



18 April 2005 @ 1000 MDT

Examples of Geohazards related Applications and Results

Co- and post-seismic displacements for the December 26, 2004 Sumatra Earthquake



GPS Analysis

- GIPSY-OASIS II
- 39 stations < 7600 km
- 14 stations < 4000 km
- 2000/1/1 to 2005/4/9

Co-seismic displacement

- for stations < 4000 km
- detrended time series
- step: 32 days before and after

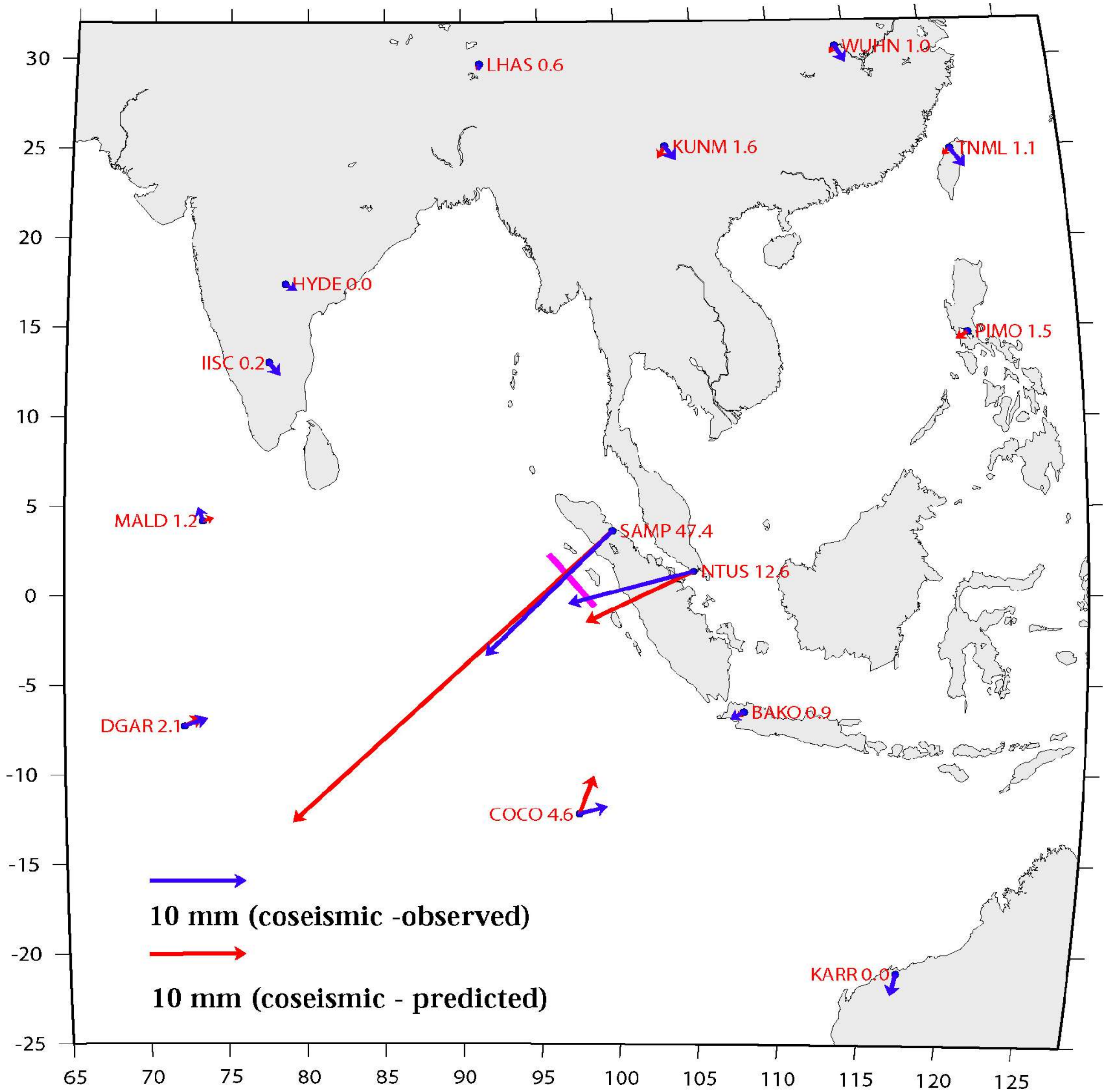
Results show

- GPS (blue)
- Co-seismic Model (red)
- Post-seismic model (green)
- Good agreement for Mw = 9.15 and increase of shear modulus with depth

Blewitt et al., 2005

Examples of Goehazards related Applications and Results

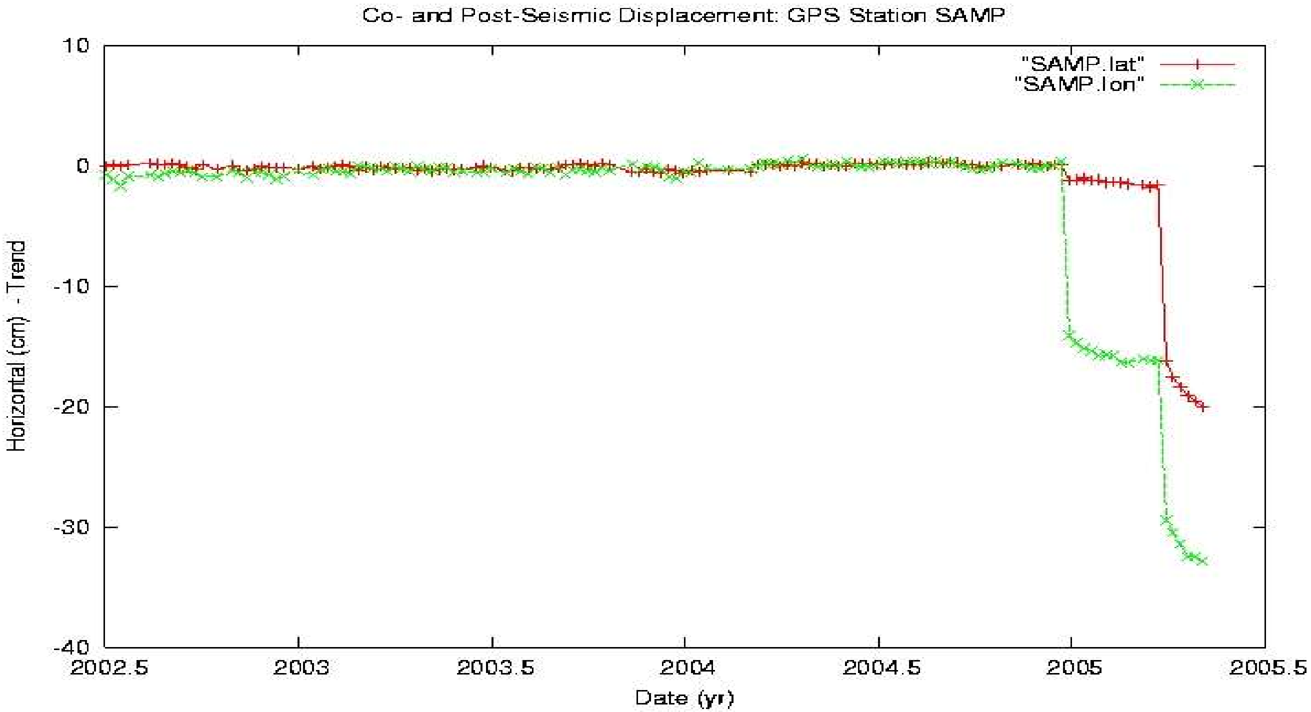
Co- and post-seismic displacements for the March 28, 2005 Earthquake

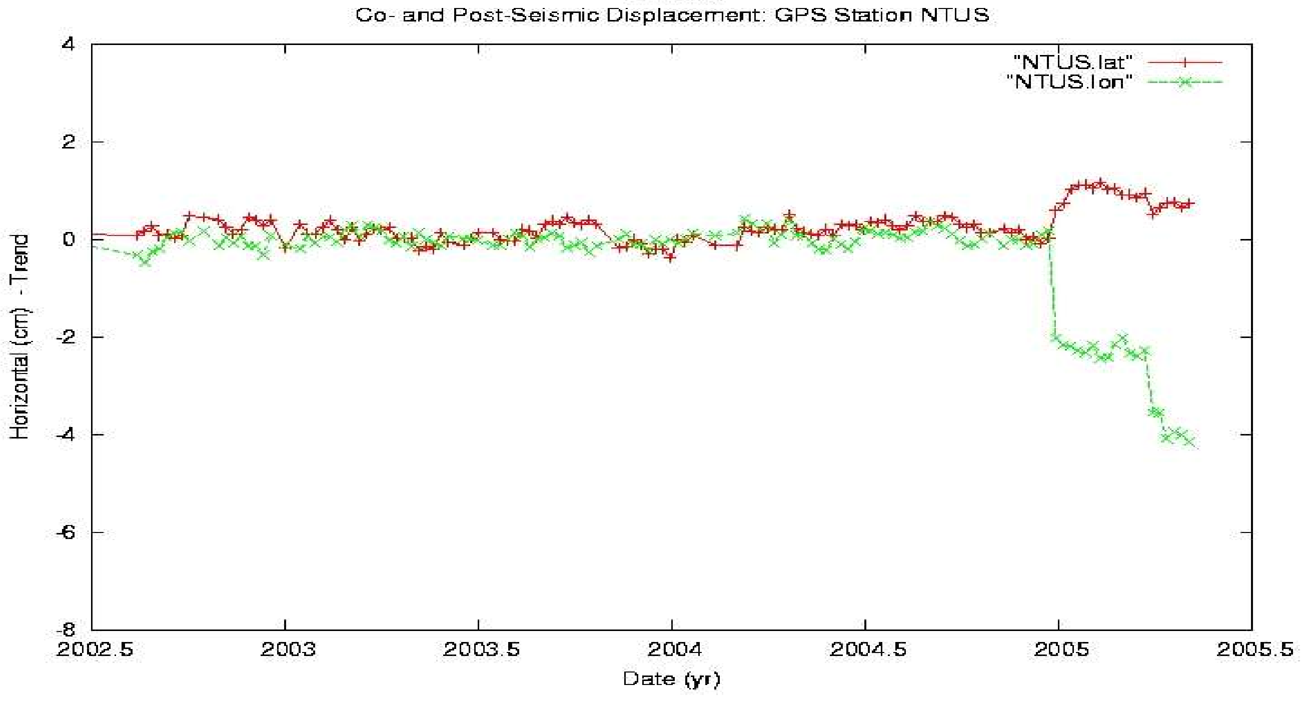


- **Co-seismic displacement**
  - only 5 days following event included ≤ April 2
  - 20 cm at SAMP (300 km)
- **Co-Seismic model**
  - 450 km x 220 km
  - uniform 3.7-m slip
  - Mw = 8.7
  - good agreement with GPS

Blewitt et al., 2005

Examples of Geohazards related Applications and Results





Observed co- and post-seismic displacements

Distance to epicenter:

SAMP: ~ 300 km

NTUS: ~ 900 km

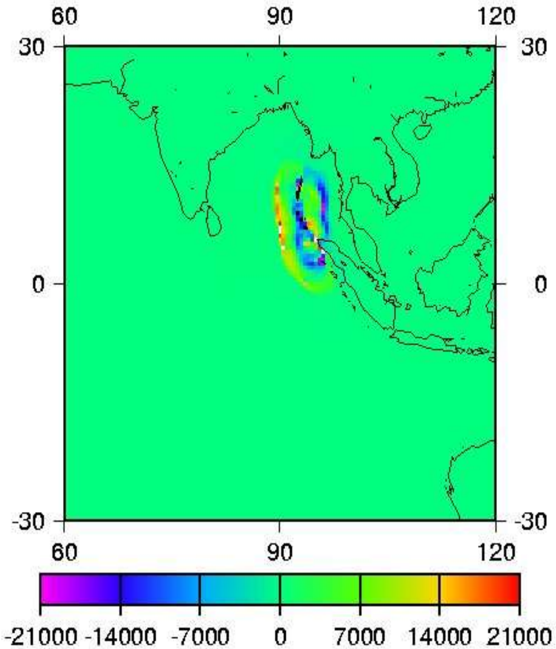
Blewitt et al., 2005

Examples of Geohazards related Applications and Results

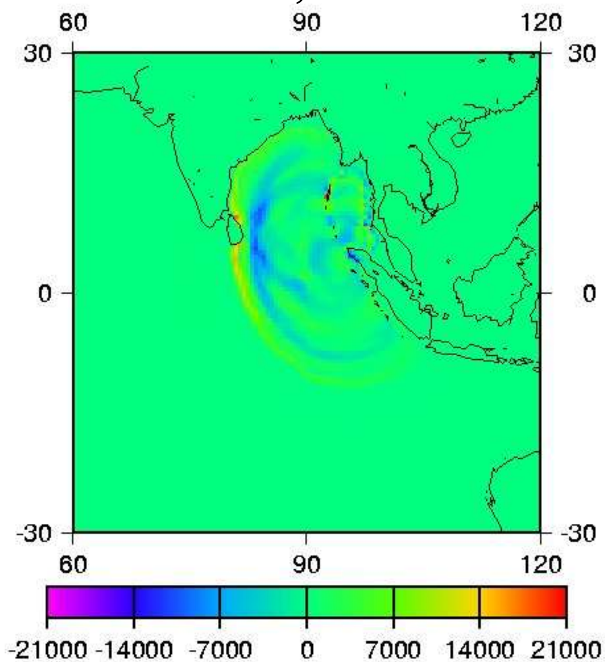
Tsunami Loading: Bottom Pressure

(data from V. Titov, NOAA Tsunami Research Program)

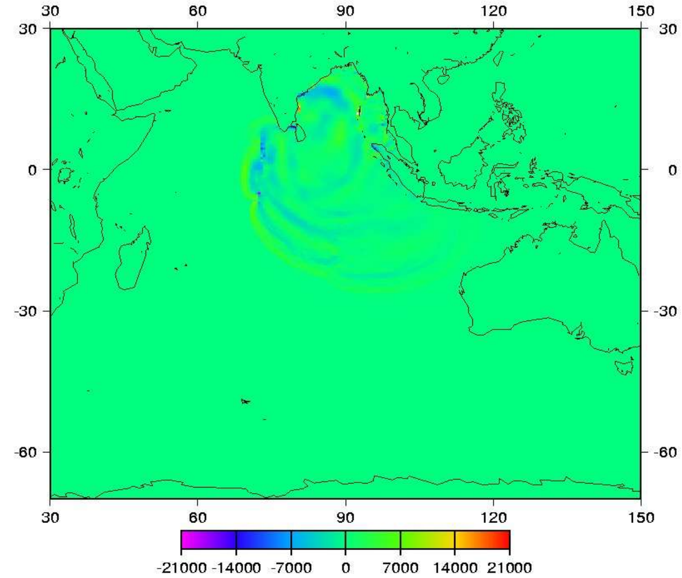
Dec 26, 1:30 am



Dec 26, 3:00 am



Dec 26, 5:00 am



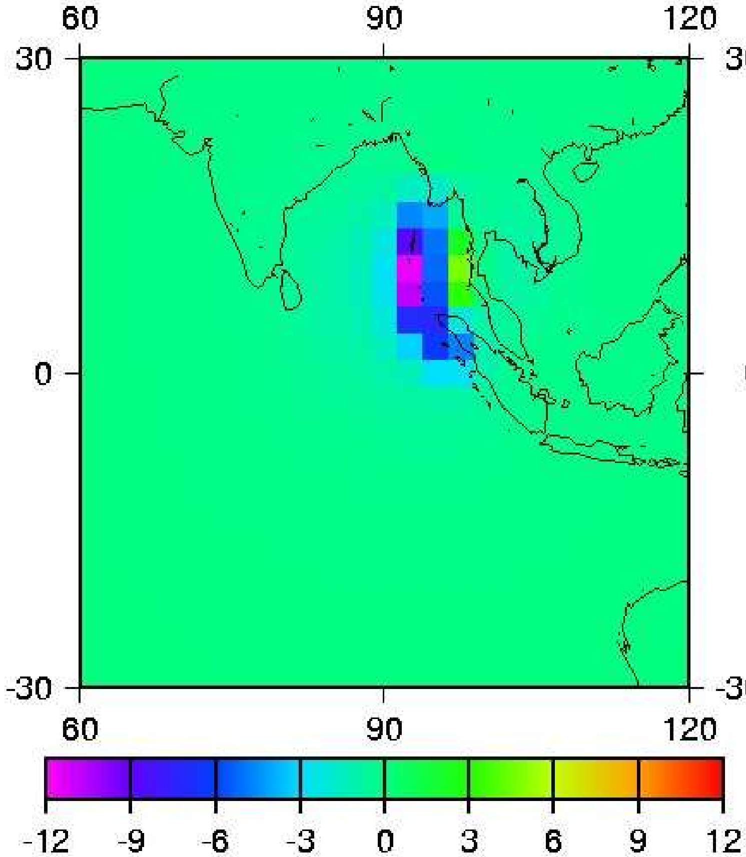
Barotropic propagation

- pressure is fully transmitted to the ocean floor (similar to ocean tides)
- barotropic waves deform the Earth's surface
- also force polar motion (more than the earthquake?)
- tsunami is part of the earthquake and not merely a consequence of it

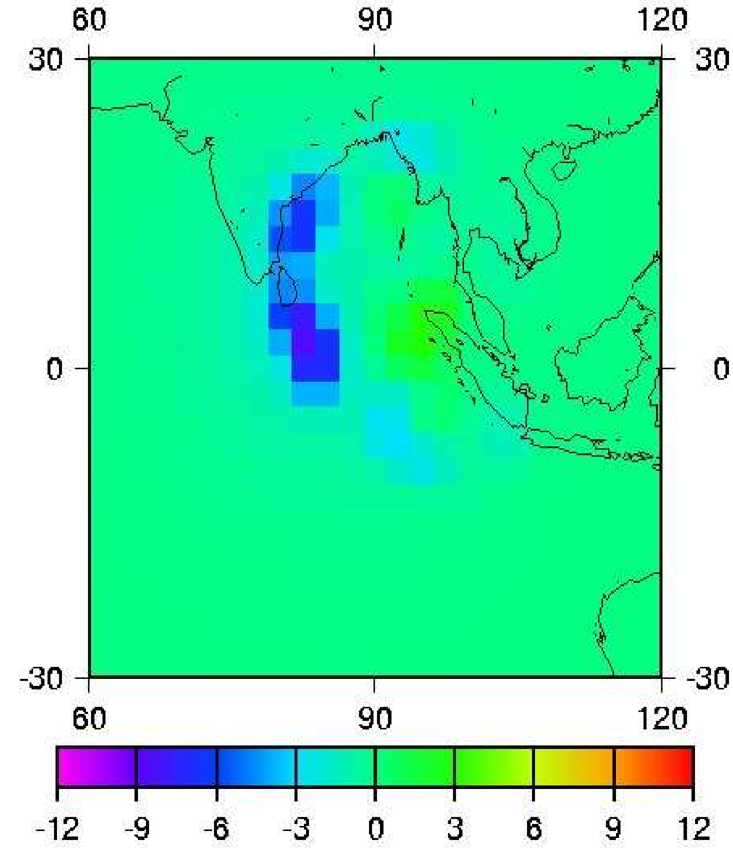
Examples of Geohazards related Applications and Results

Tsunami Loading: Earth Deformation

Dec 26, 1:30 am



Dec 26, 3:00 am

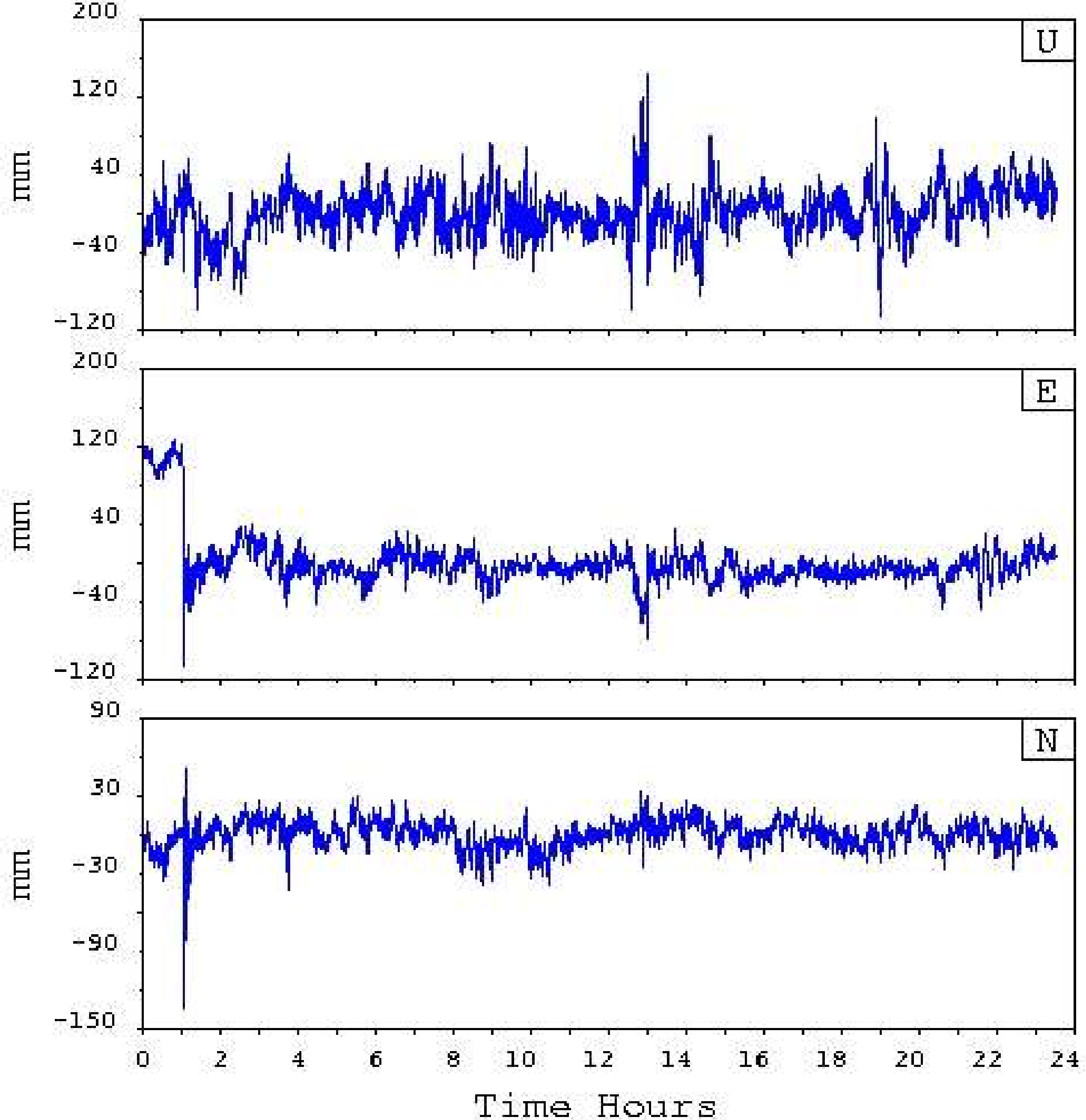


UNR Model:

- Convolution of bottom pressure with Green's function for PREM
- >10 mm level vertical displacements
- Detectable by GPS? In real-time, in advance of wave arrival?

Plag et al., 2005

Examples of Geohazards related Applications and Results



High-resolution GPS

Station SAMP
Distance to epicenter:
~ 300 km
Day: 26 Dec 2004
30 seconds sampling rate

Blewitt et al., 2005

Examples of Goehazards related Applications and Results

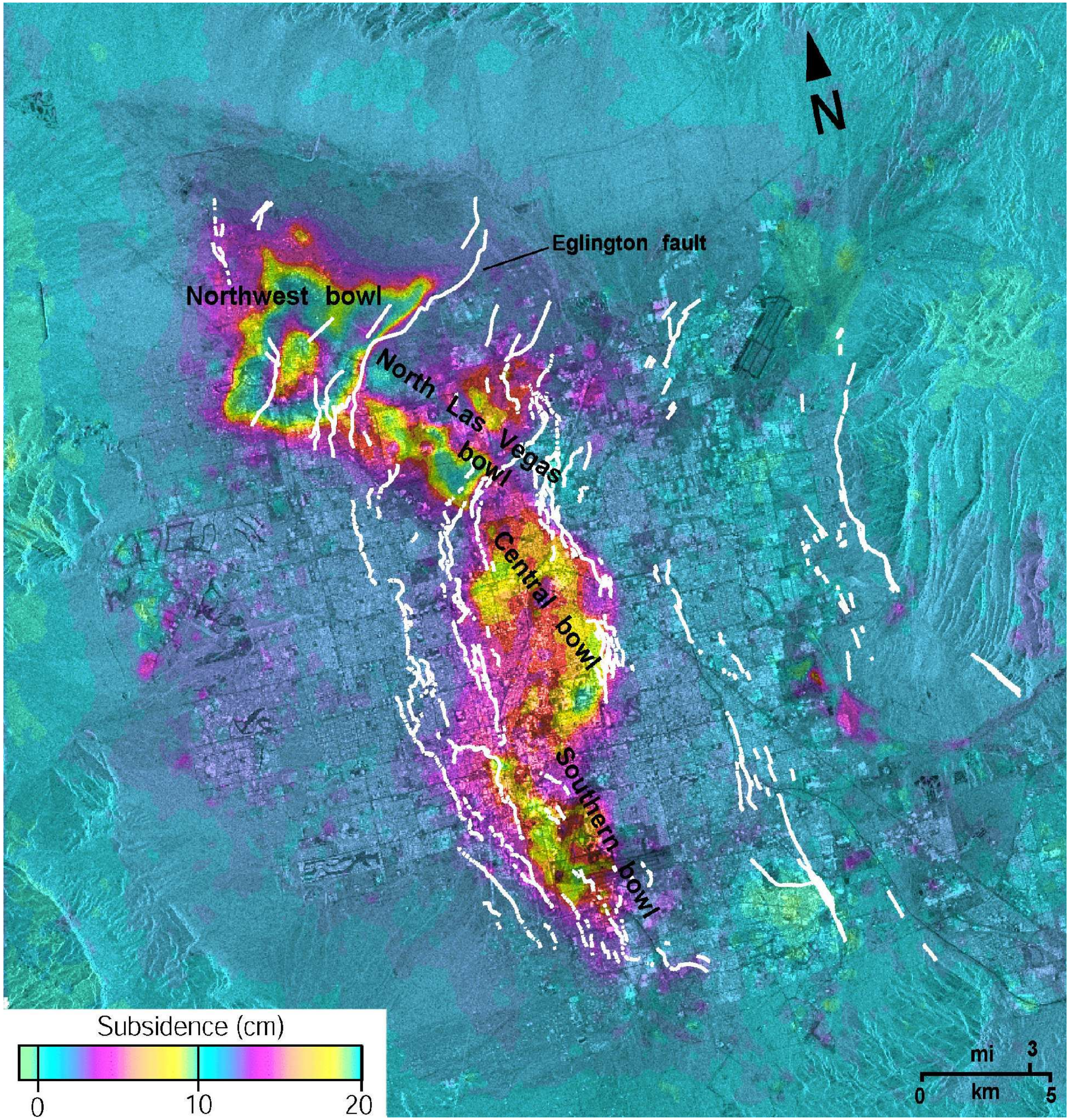
Man-made Subsidence

Upper Left: Mining, Northern Nevada

All others: groundwater extraction, Southern Nevada

(Court. J. Bell)

Examples of Geohazards related Applications and Results



Man-made Subsidence

Groundwater extraction, Las Vegas, Nevada

<u>Subsidence 1992-1997</u>

Four subsidence bowls

Aquifer system response strongly controlled by faults

Faults are subsidence barriers

Subsidence rate is decreasing

Amelung et al., 1999

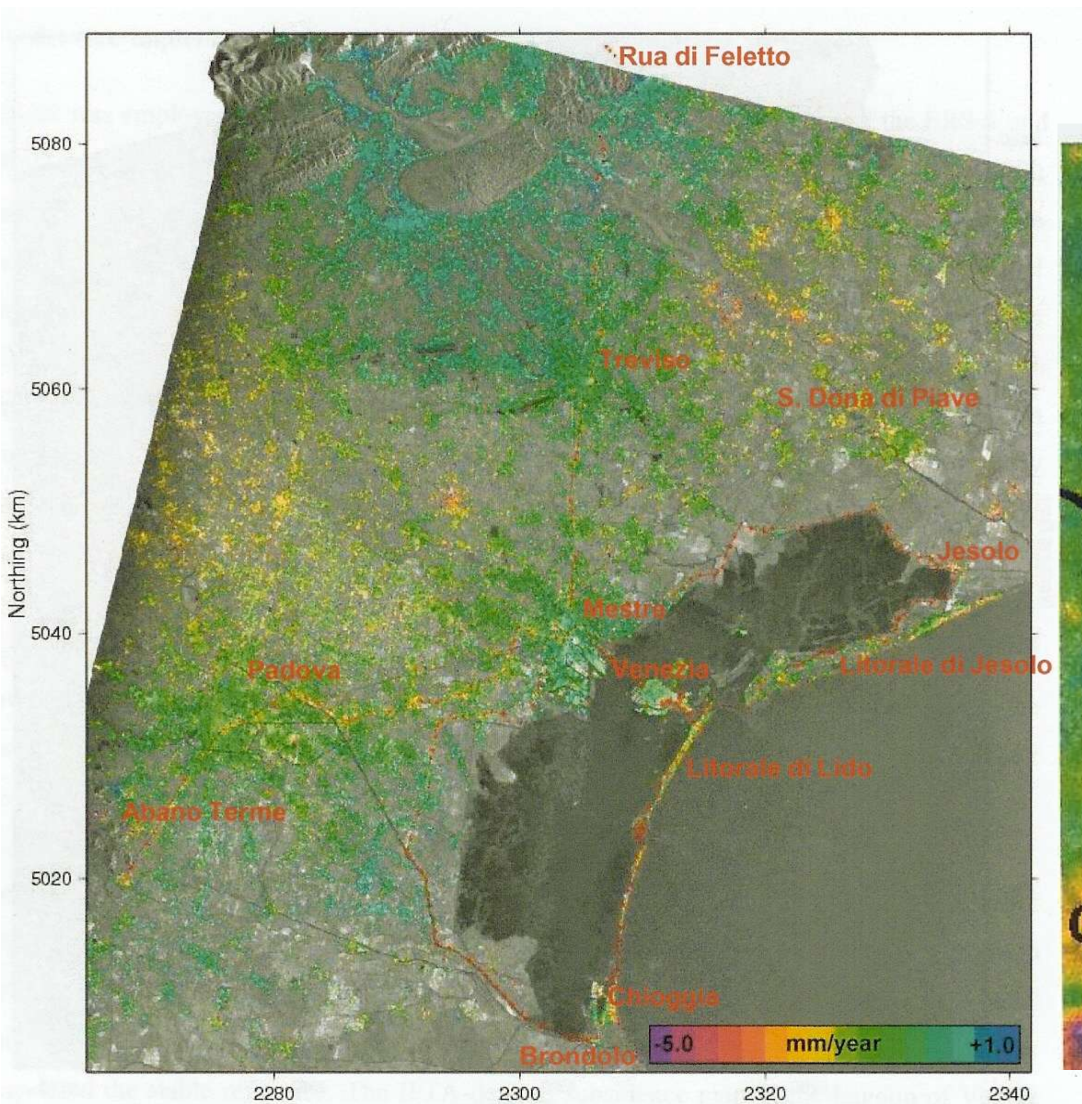
Examples of Geohazards related Applications and Results

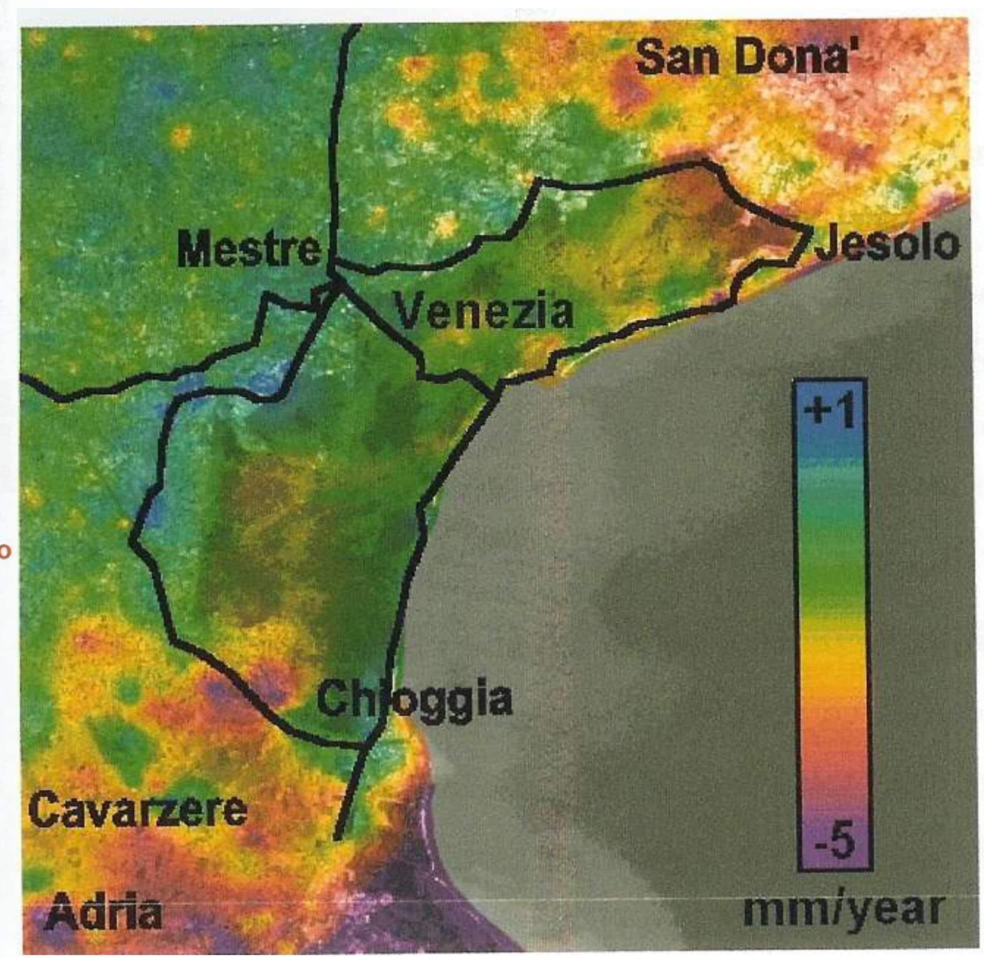
Coastal Subsidence

Natural and anthropogenic processes,

Venice, Italy

Strozzi et al., 2003





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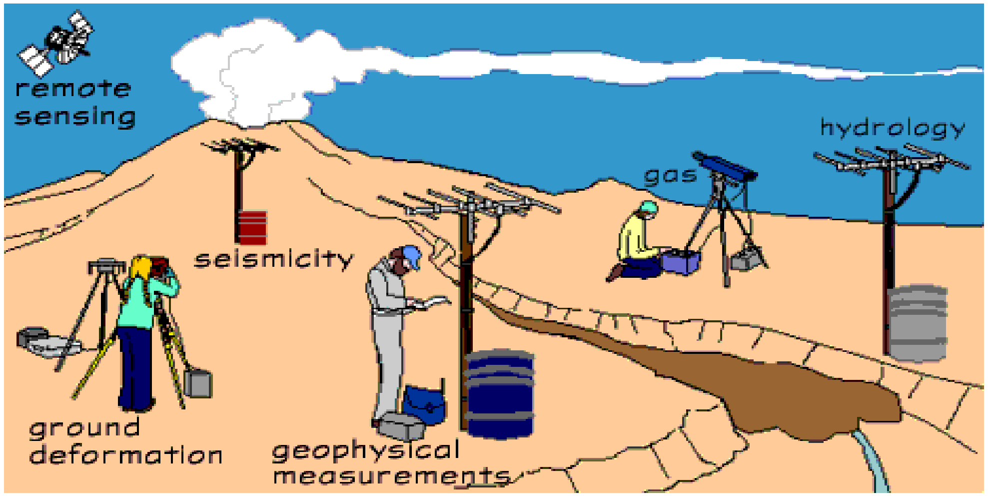
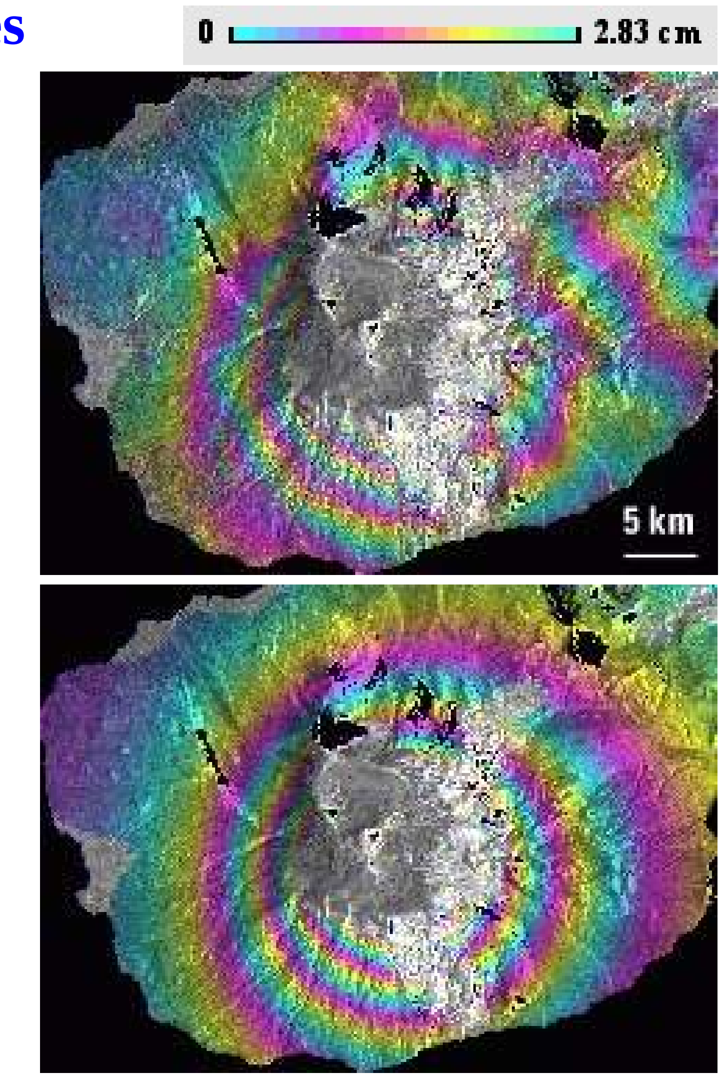
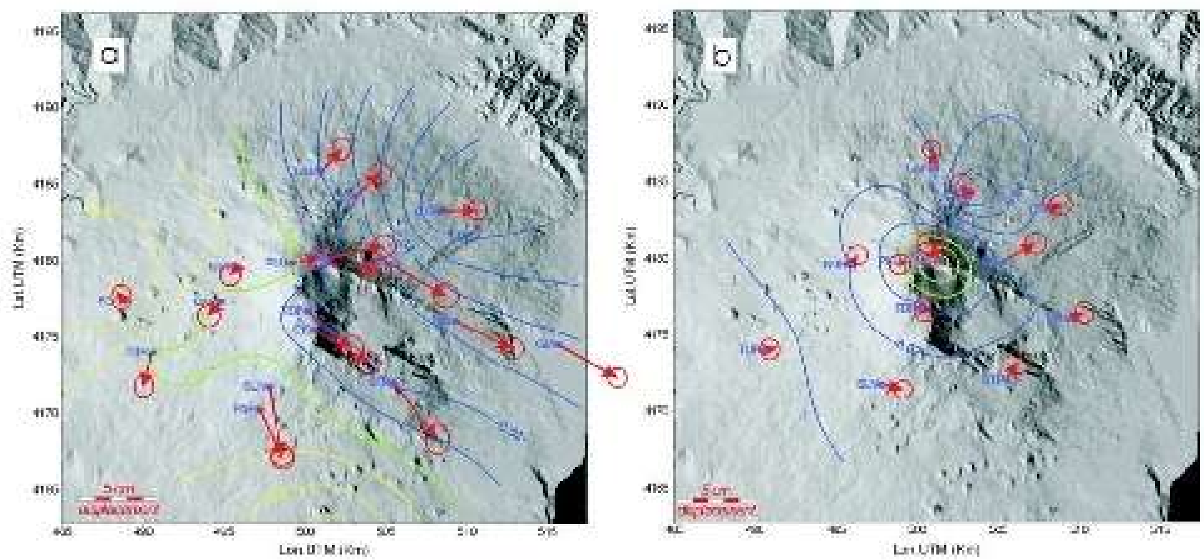


Monitoring surface displacements: Volcanoes



Westdahl Peak volcano, Alaska, 1993-1998

http://volcanoes.usgs.gov

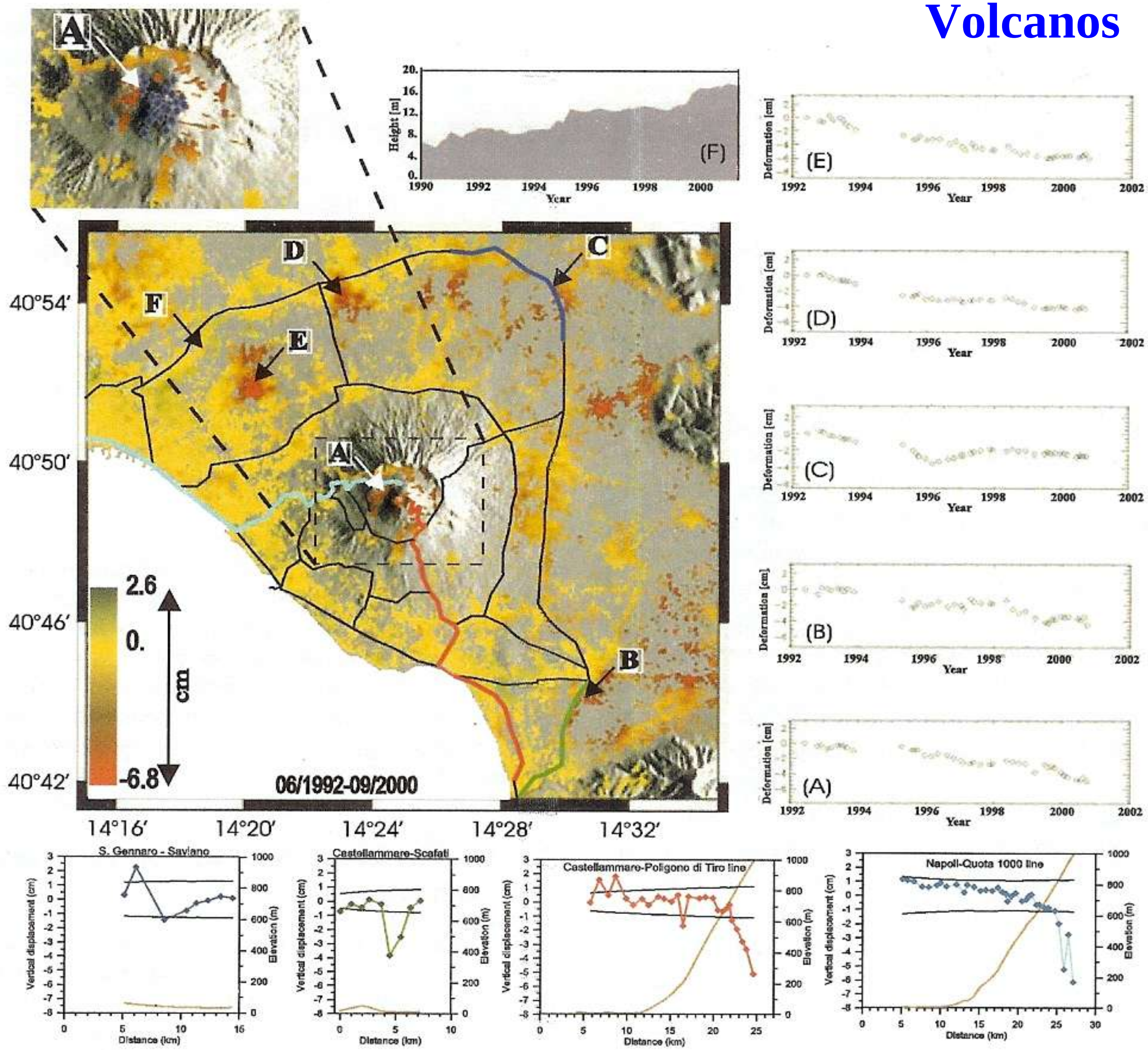


Mount Etna volcano, Italy, 1994 - 1995

Bonforte and Puglisi, 2003

Examples of Geohazards related Applications and Results

Monitoring Surface displacements: Volcanos



Vesuvius volcano, Italy
Lanari et al., 2002

GGOS and IGOS-P Geohazards

GGOS Contribution to a “Solid Earth Observing System” (SEOS)

Products:

- International Terrestrial Reference Frame (ITRF)
- Global and regional kinematics: velocities, strain rates
- Regional gravity field variations
- Local gravity observations (absolute, superconducting)

Services and activities:

- Access to ITRF *ad hoc* in near-real time based on GNSS
- Standardization of processing, models, products, alerts, ...
- Coordination of local and regional geodetic networks
- Facilitate steps towards an International InSAR Service (IISS)
- Integration with other techniques
- Interoperability
- Integration into global warning systems (Alert systems)

Preliminary Conclusions

GGOS:

- Geodetic techniques are indispensible for a solid earth observation system
- GGOS operates global networks for monitoring displacements, gravity variations and Earth's rotation variations
- GGOS provides the backbone for Earth observations: ITRF
- GGOS provides observations related to the dynamics of the Earths for research

GGOS and IGOS-P:

- Local and regional networks are needed, spatial and temporal flexibility, some on demand and on short notice
- GGOS can contribute to coordination (together with IGOS-P) of observations and products