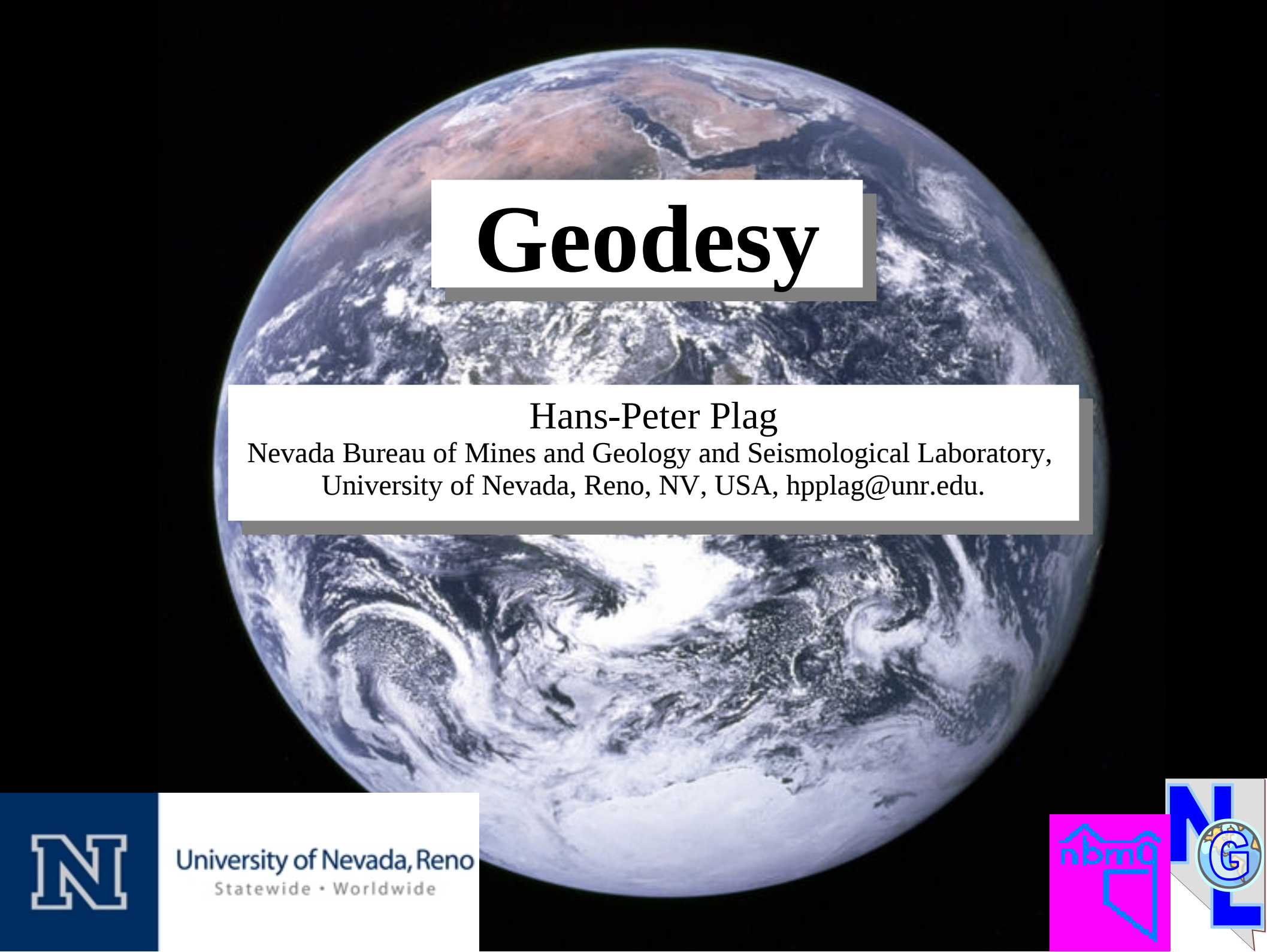
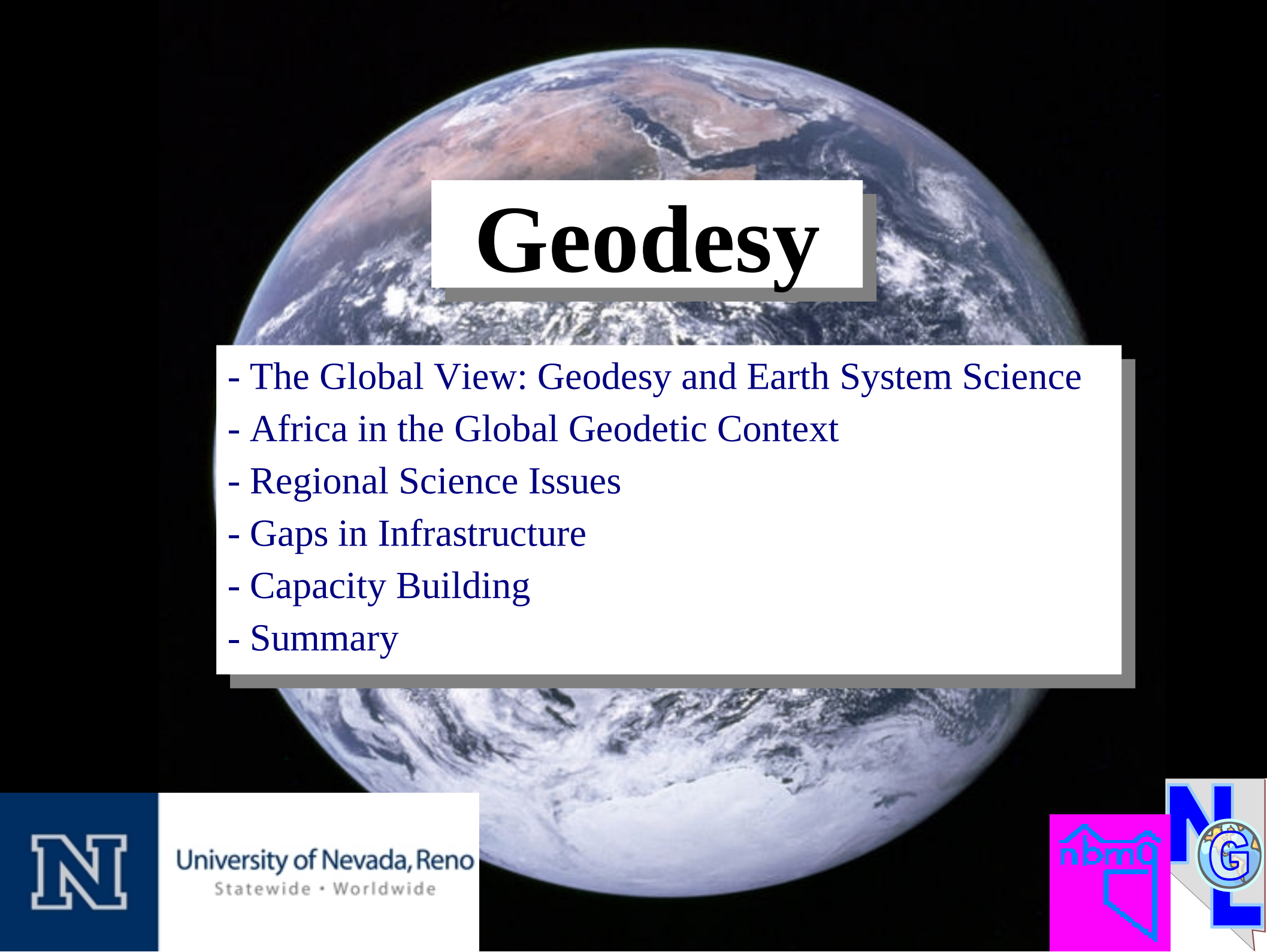


# Geodesy

Hans-Peter Plag
Nevada Bureau of Mines and Geology and Seismological Laboratory,
University of Nevada, Reno, NV, USA, hpplag@unr.edu.

University of Nevada, Reno
Statewide • Worldwide

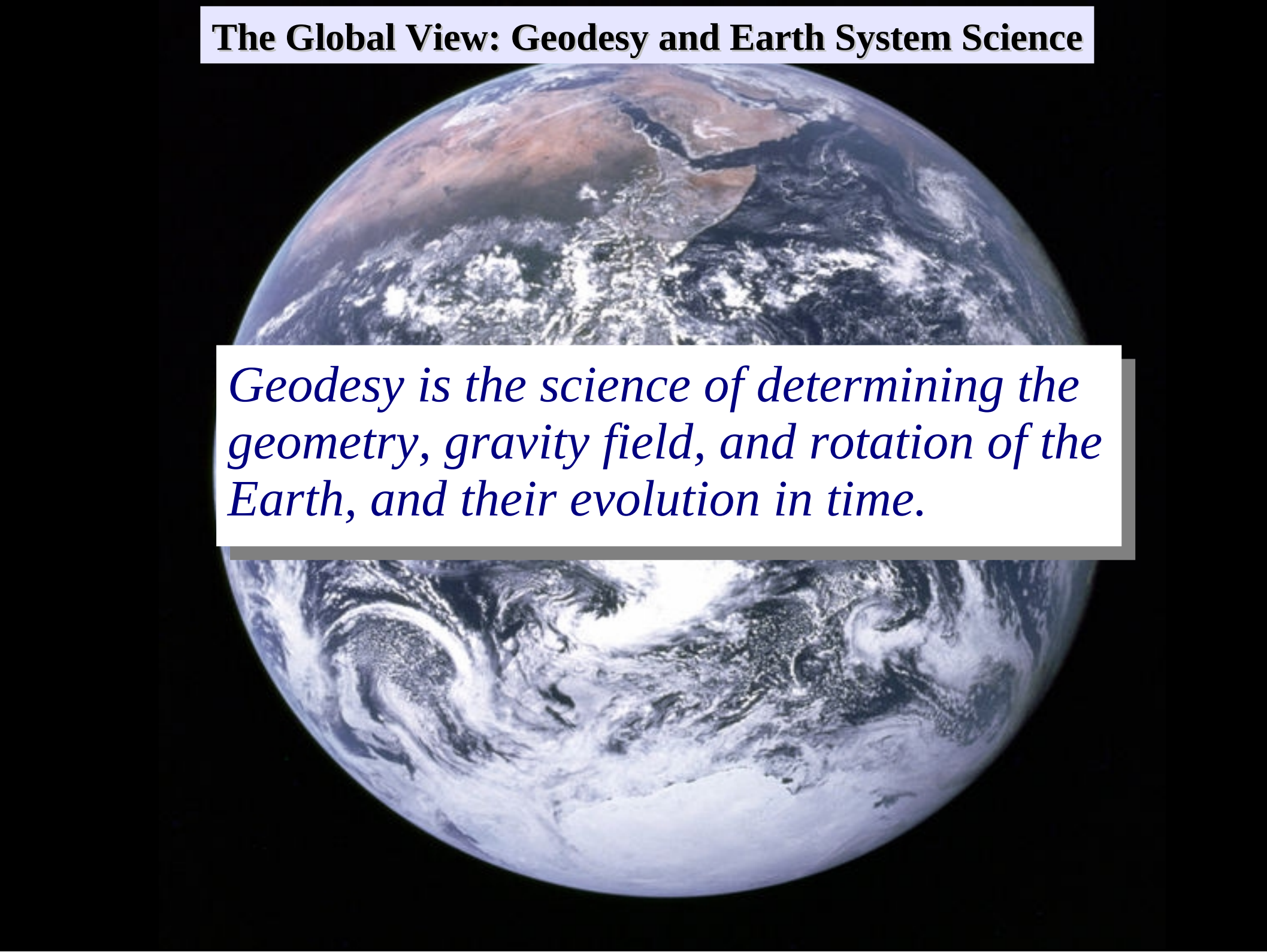


# Geodesy

- The Global View: Geodesy and Earth System Science
- Africa in the Global Geodetic Context
- Regional Science Issues
- Gaps in Infrastructure
- Capacity Building
- Summary

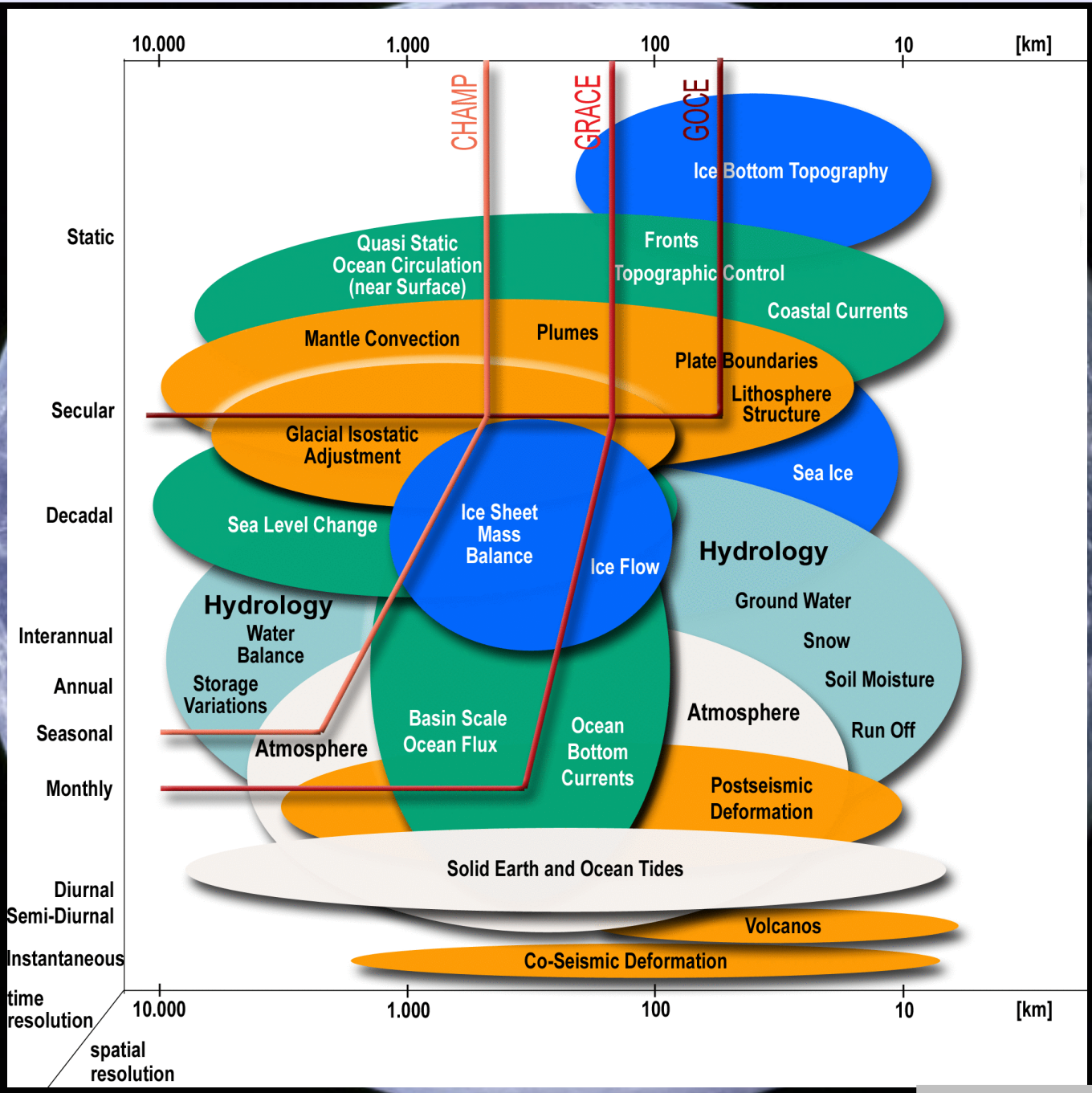
University of Nevada, Reno
Statewide • Worldwide

# The Global View: Geodesy and Earth System Science



*Geodesy is the science of determining the geometry, gravity field, and rotation of the Earth, and their evolution in time.*

# The Global View: Geodesy and Earth System Science




*Ilk et al., 2005*

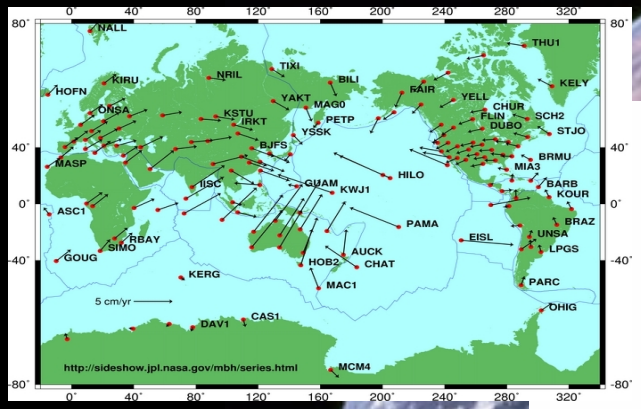
# The Global View: Geodesy and Earth System Science

*Science questions relevant to geodesy:*

**Convection**: *nature of anomalies in seismic velocities*;
**Plate tectonics**: *location of and processes at plate boundaries*;
**Ice sheets/glaciers**: *ice load history, including present-day changes*;
**Sea level**: *quantification of different contributions*;
**Rheology**: *linear versus non-linear; transient versus steady-state; lateral heterogeneities*;
**Core-mantle dynamics**: *processes at core-mantle boundary*;
**Hydrological cycle**: *better quantification of fluxes; groundwater movements; land water storage*;
**Solid Earth response to loading**: *load history (continental water storage, ice loads, non-tidal ocean loading)*;
**Rotational dynamics**: *coupling of angular and linear momentum; free modes of ocean*;
**Tides**: *validation of ocean tidal models*;
**Earthquakes**: *strain/stress accumulation and earthquakes; physical processes*;
**Earth structure**: *structure and composition of the deep Earth and mantle dynamics*;

*According to Rummel et al., 2009*

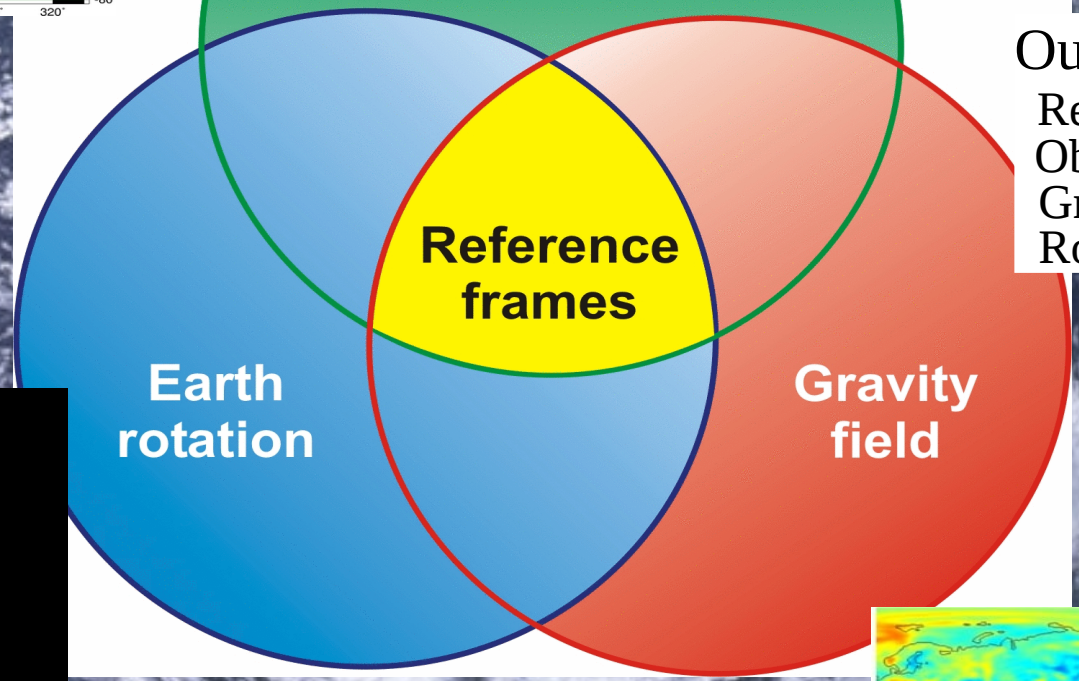
# The Global View: Geodesy and Earth System Science




The 'three pillars of geodesy':

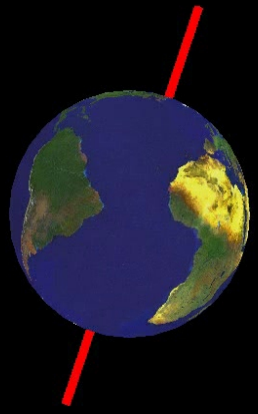
- Earth's Shape (Geokinematics)
- Earth's Gravity Field
- Earth Rotation

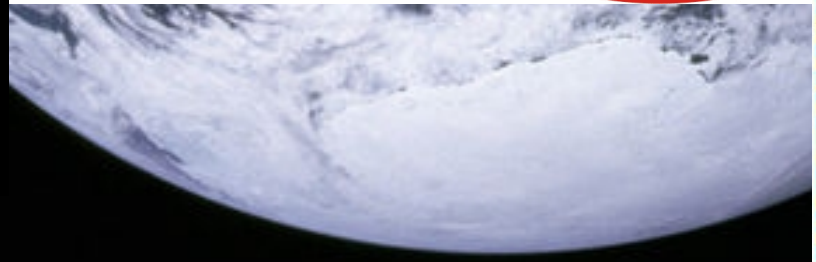
(Fourth pillar:
- remote sensing of the atmosphere)

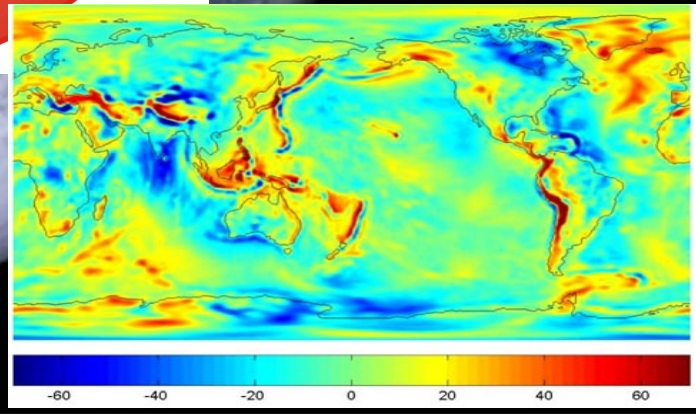



Output:

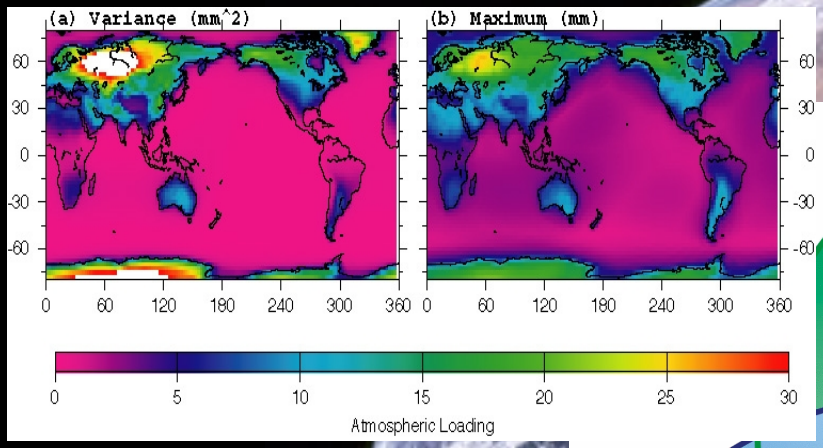
Reference Frame
Observations of the Shape, Gravitational Field and Rotation of the Earth







# The Global View: Geodesy and Earth System Science

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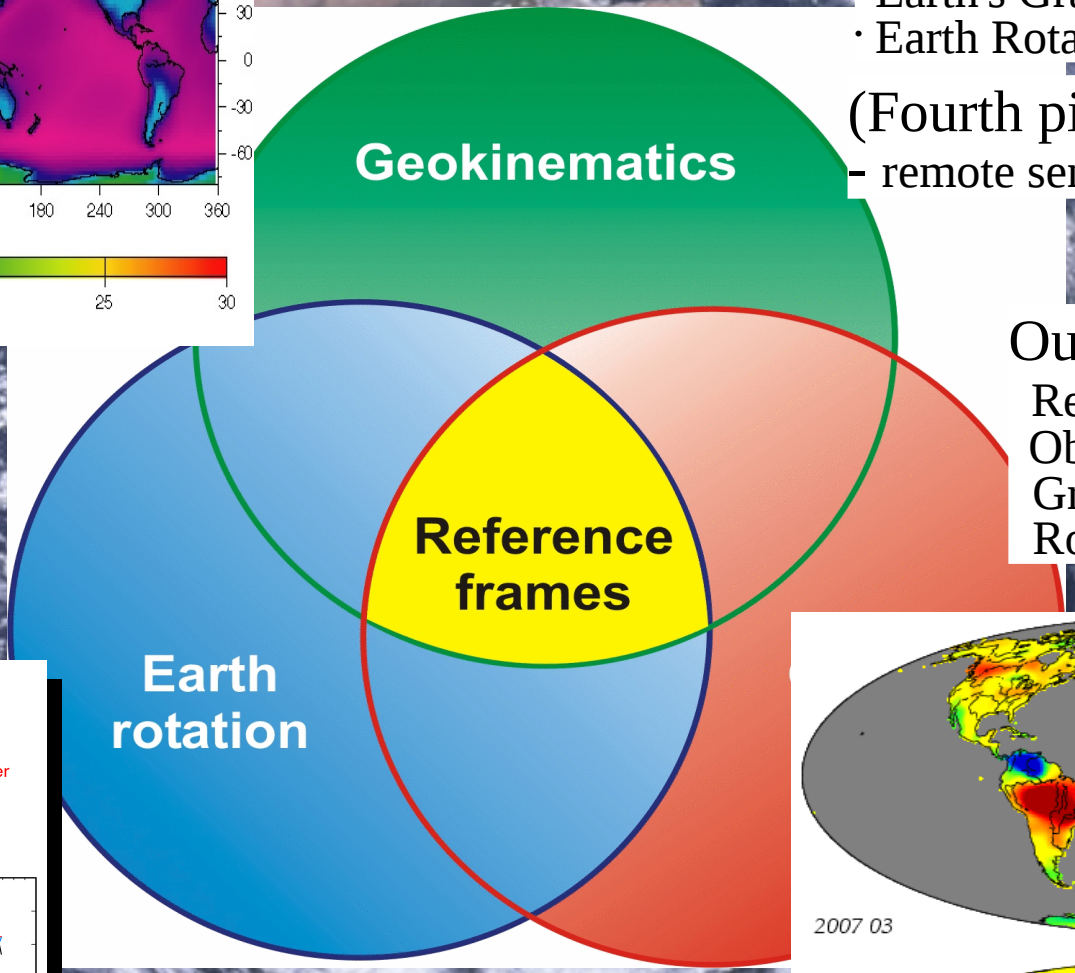


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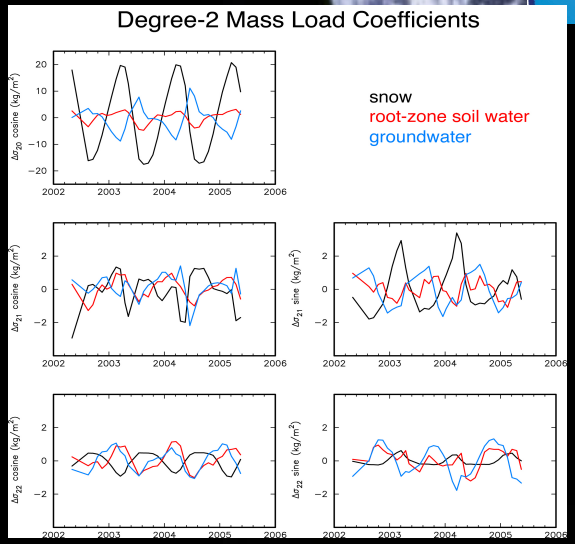
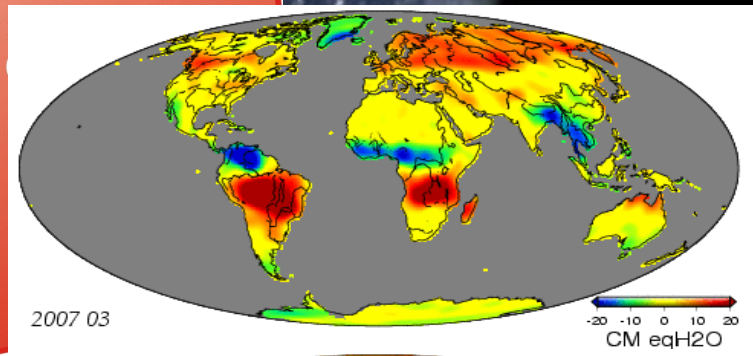
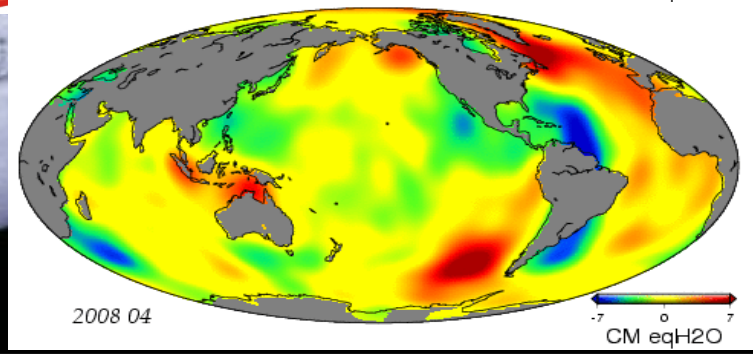
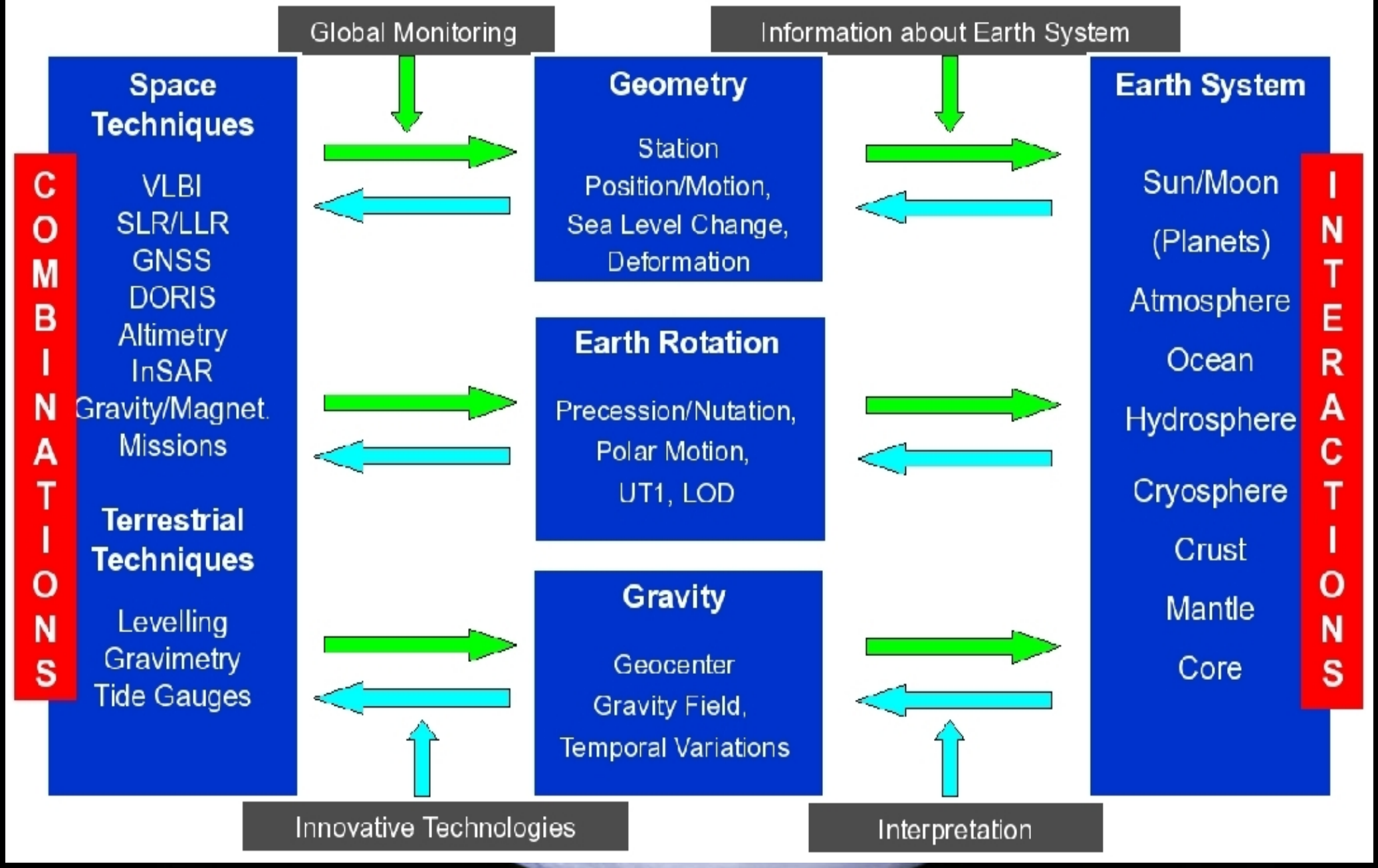


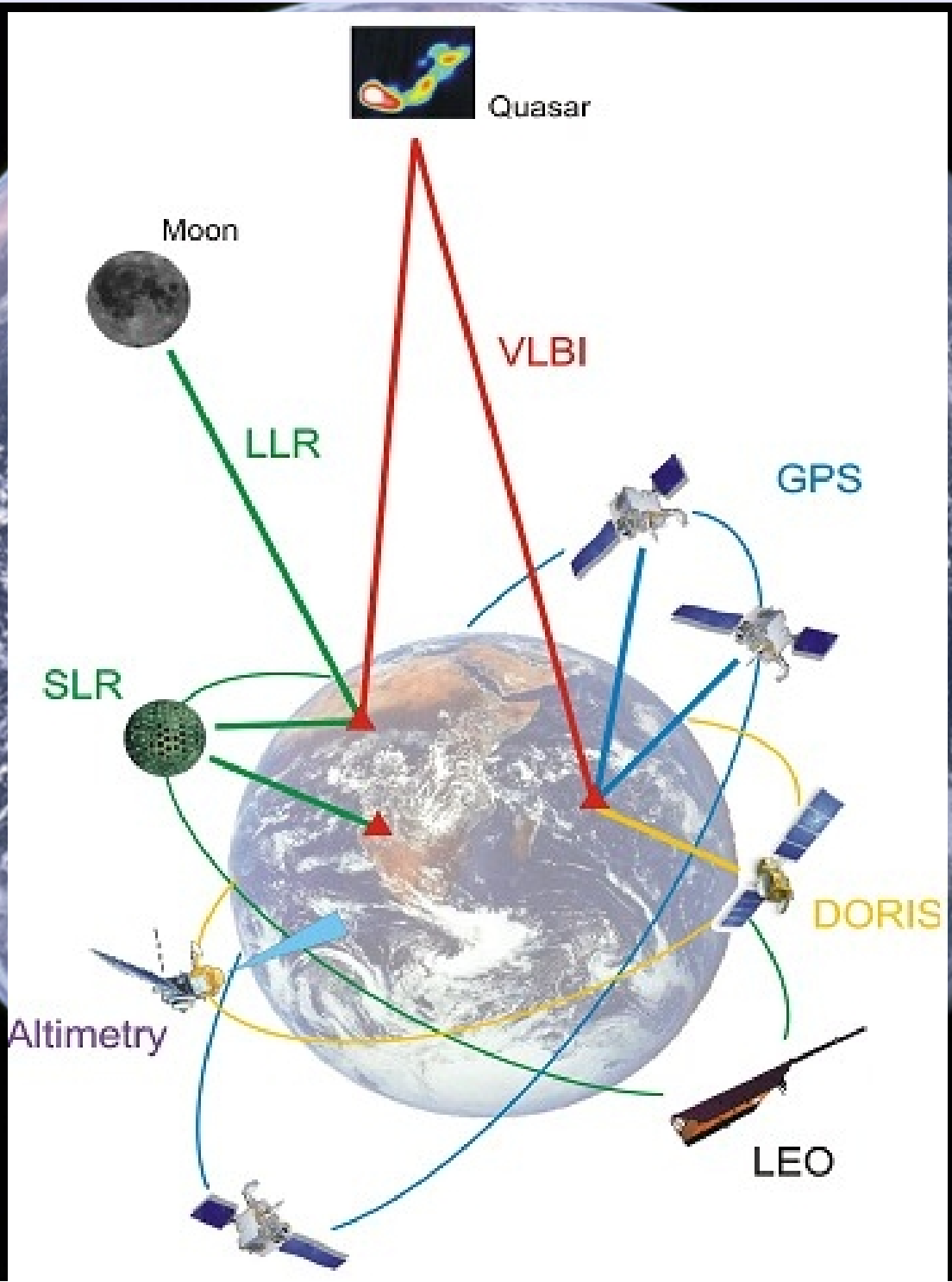



# The Global View: Geodesy and Earth System Science



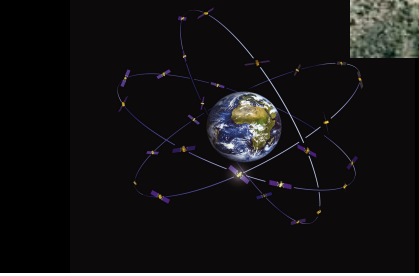

*Rummel et al., 2009*

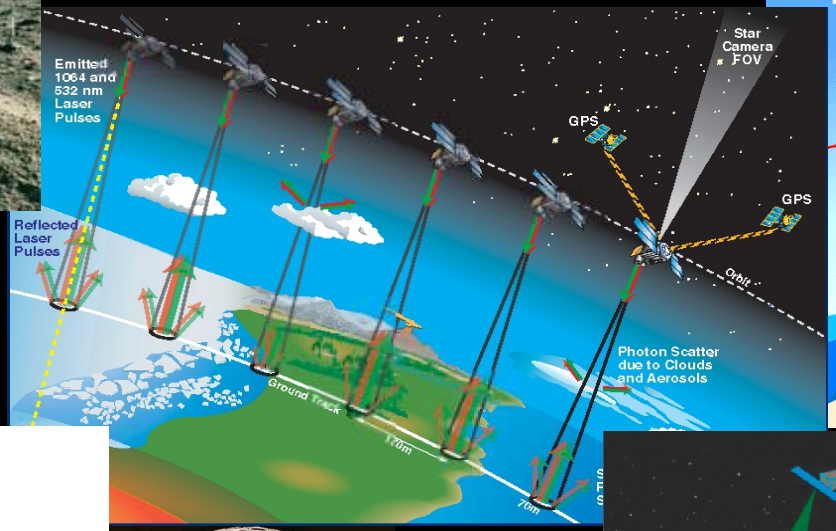
# The Global View: Geodesy and Earth System Science

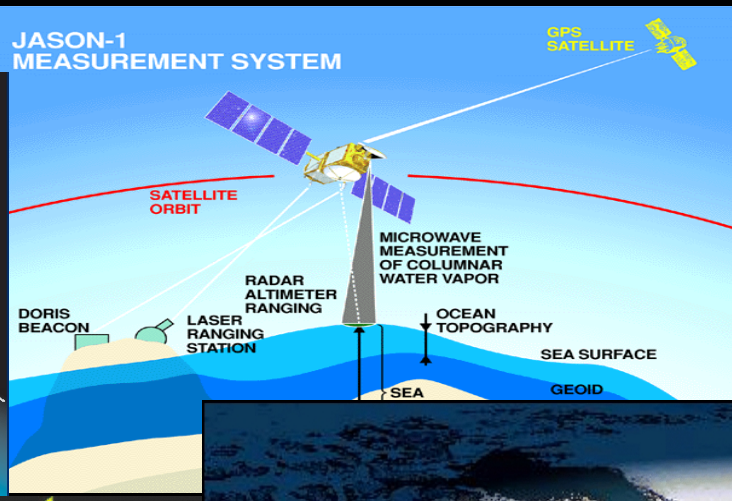


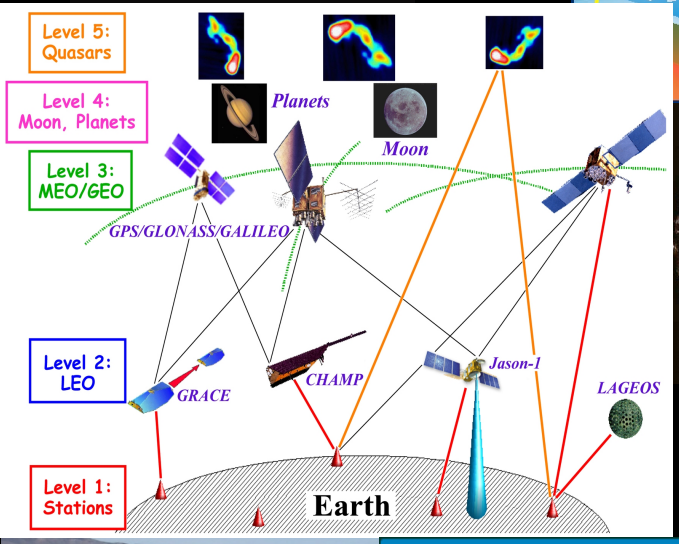
# The Global View: Geodesy and Earth System Science

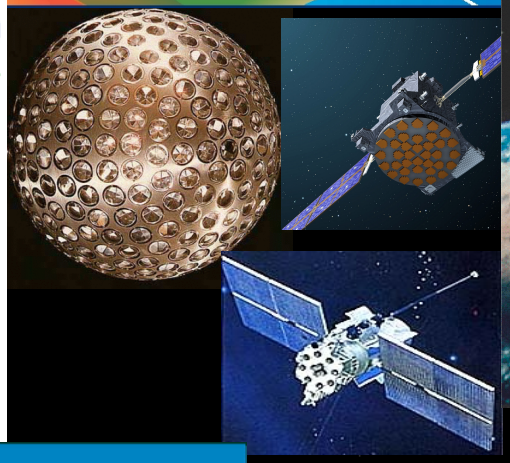
IAG GGOS

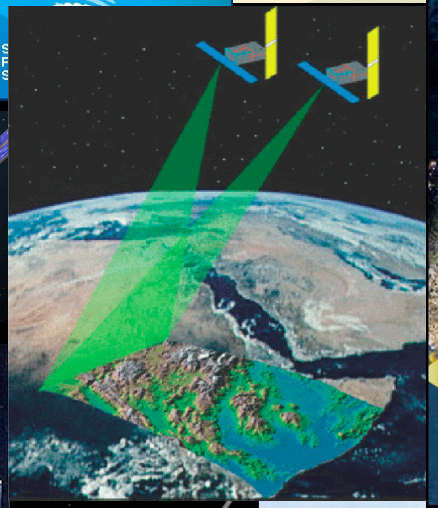


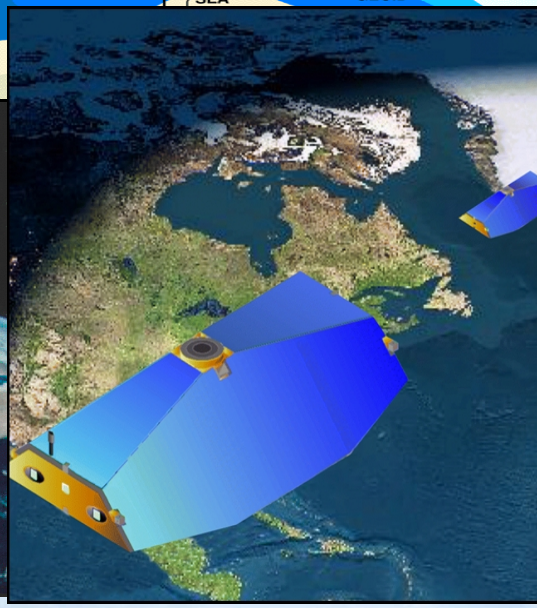


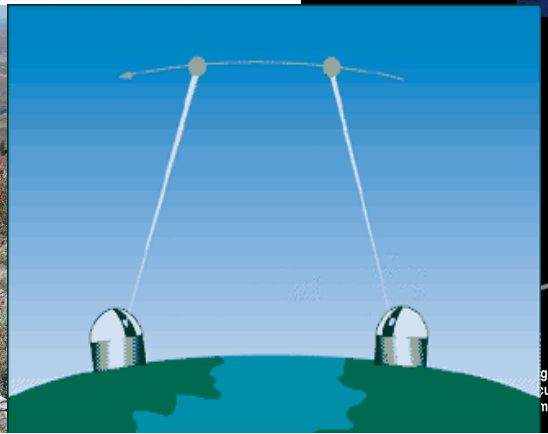



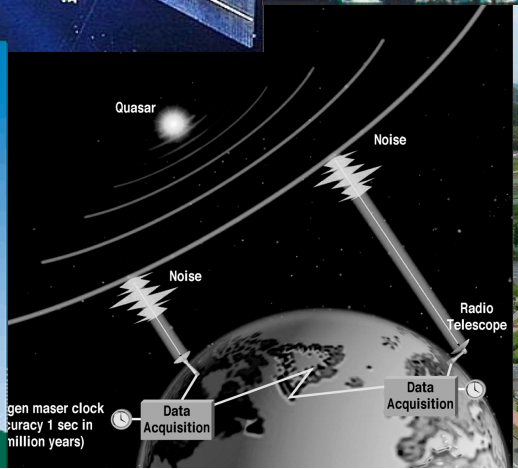



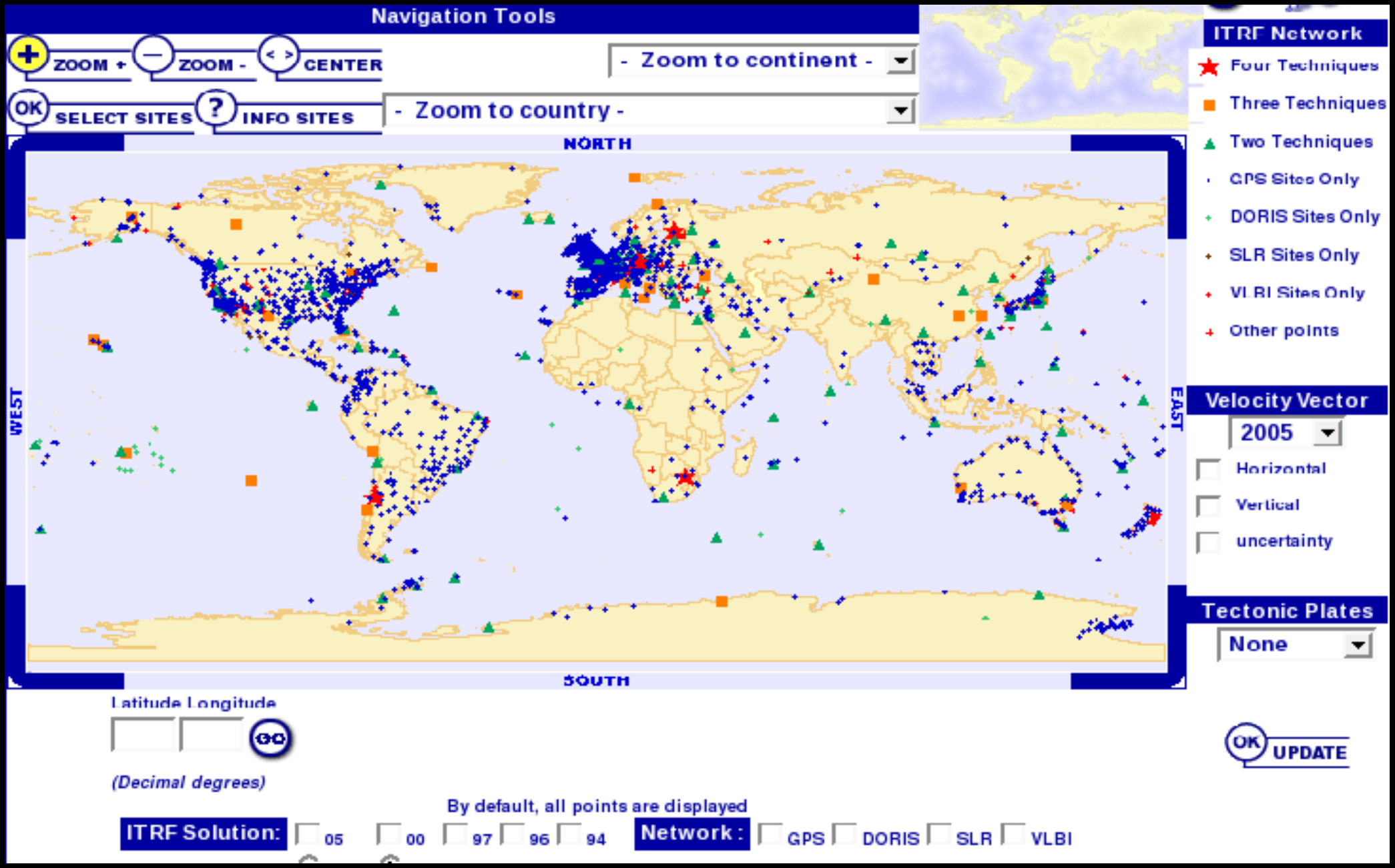






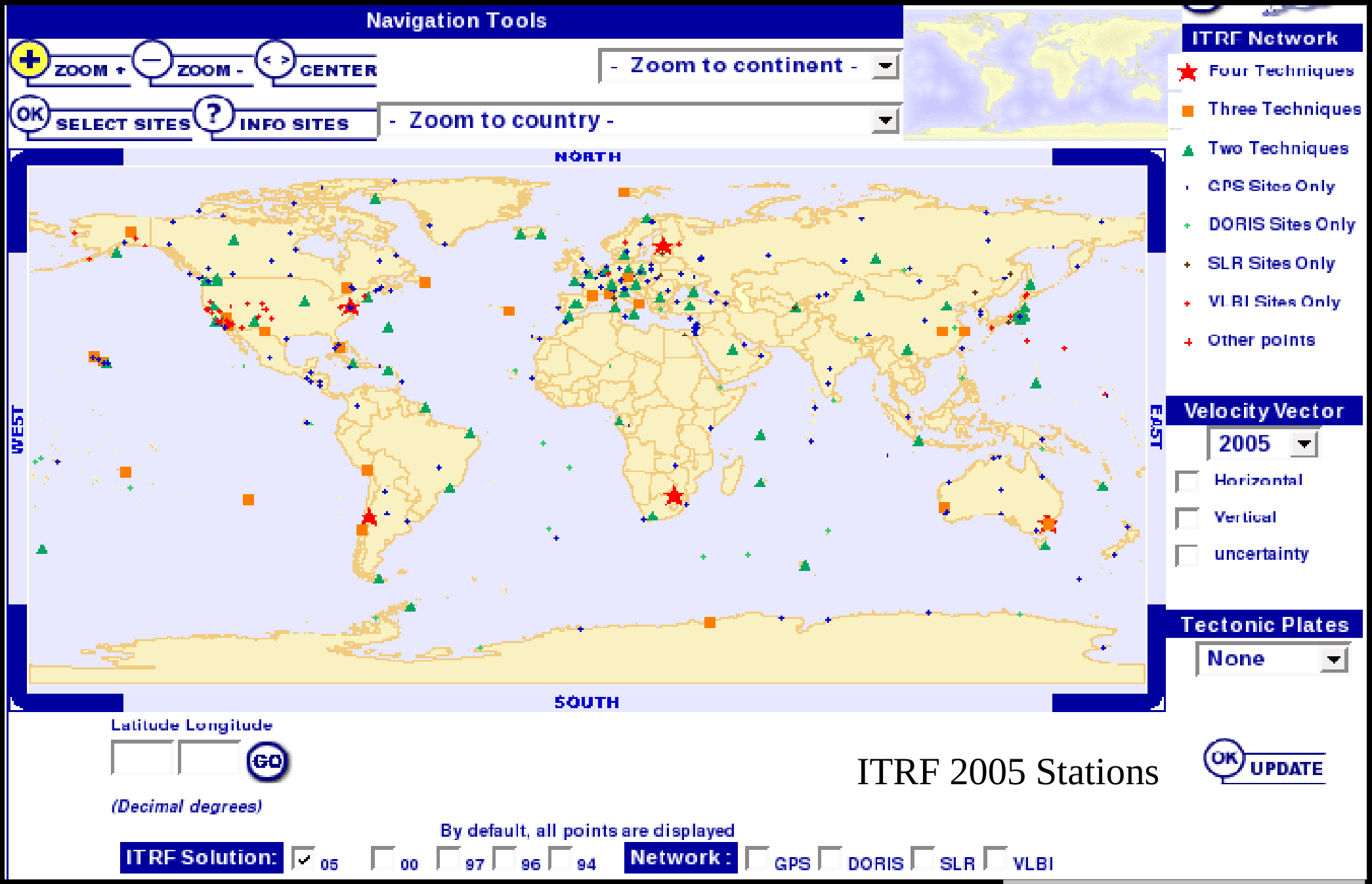



# Africa in the Global Geodetic Context



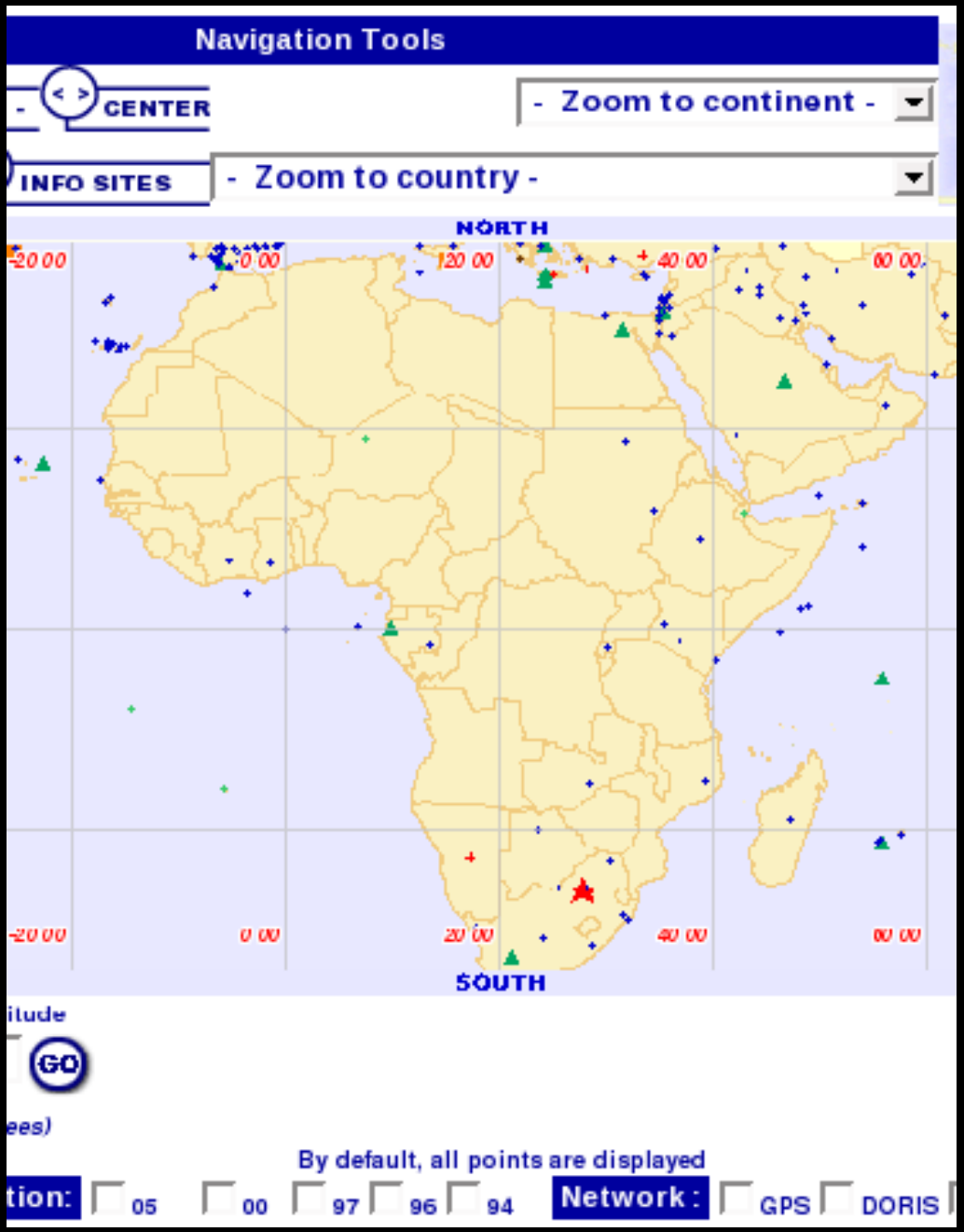

http://itrf.ign.fr/GIS/

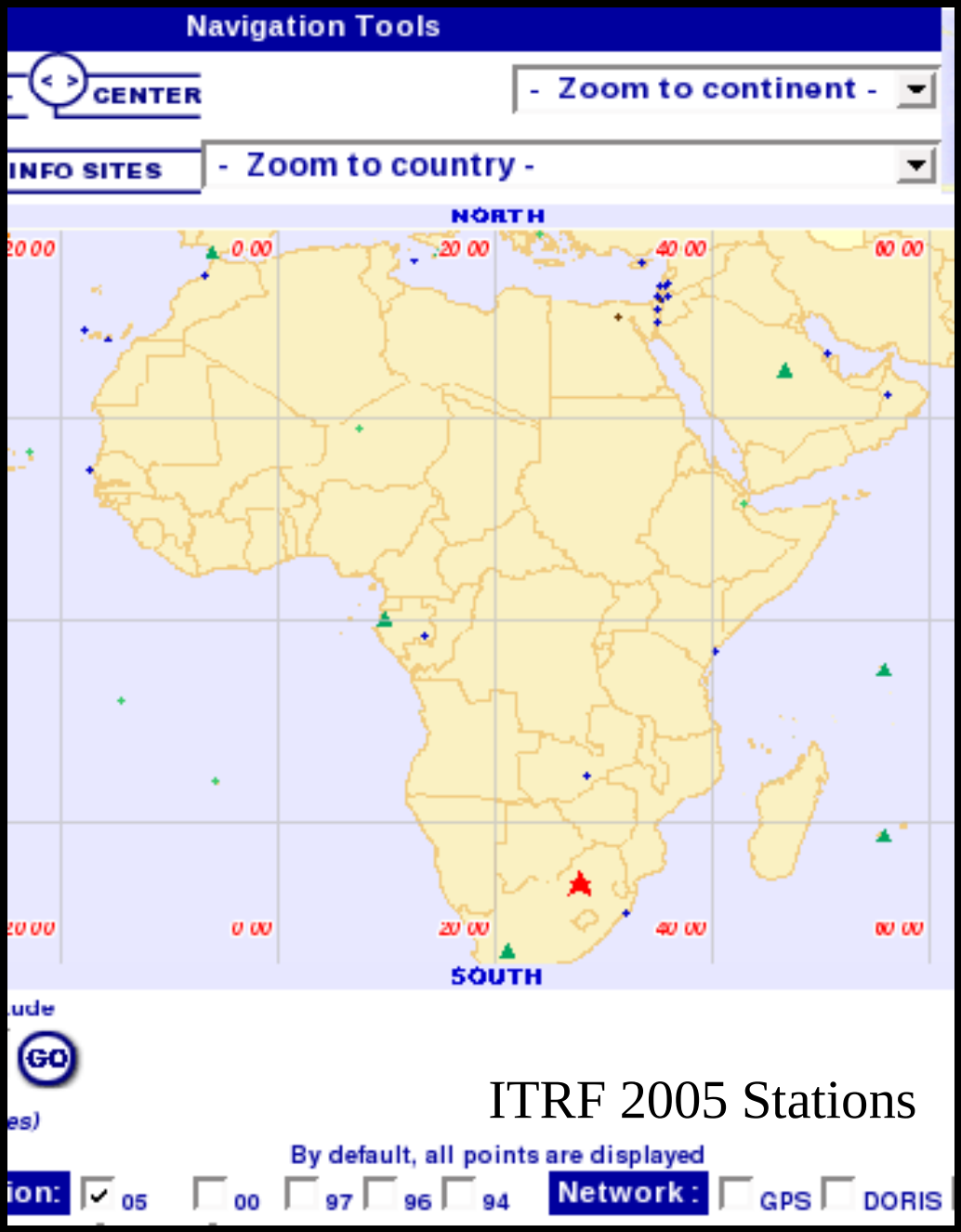
# Africa in the Global Geodetic Context




*http://itrf.ign.fr/GIS/*

# Africa in the Global Geodetic Context

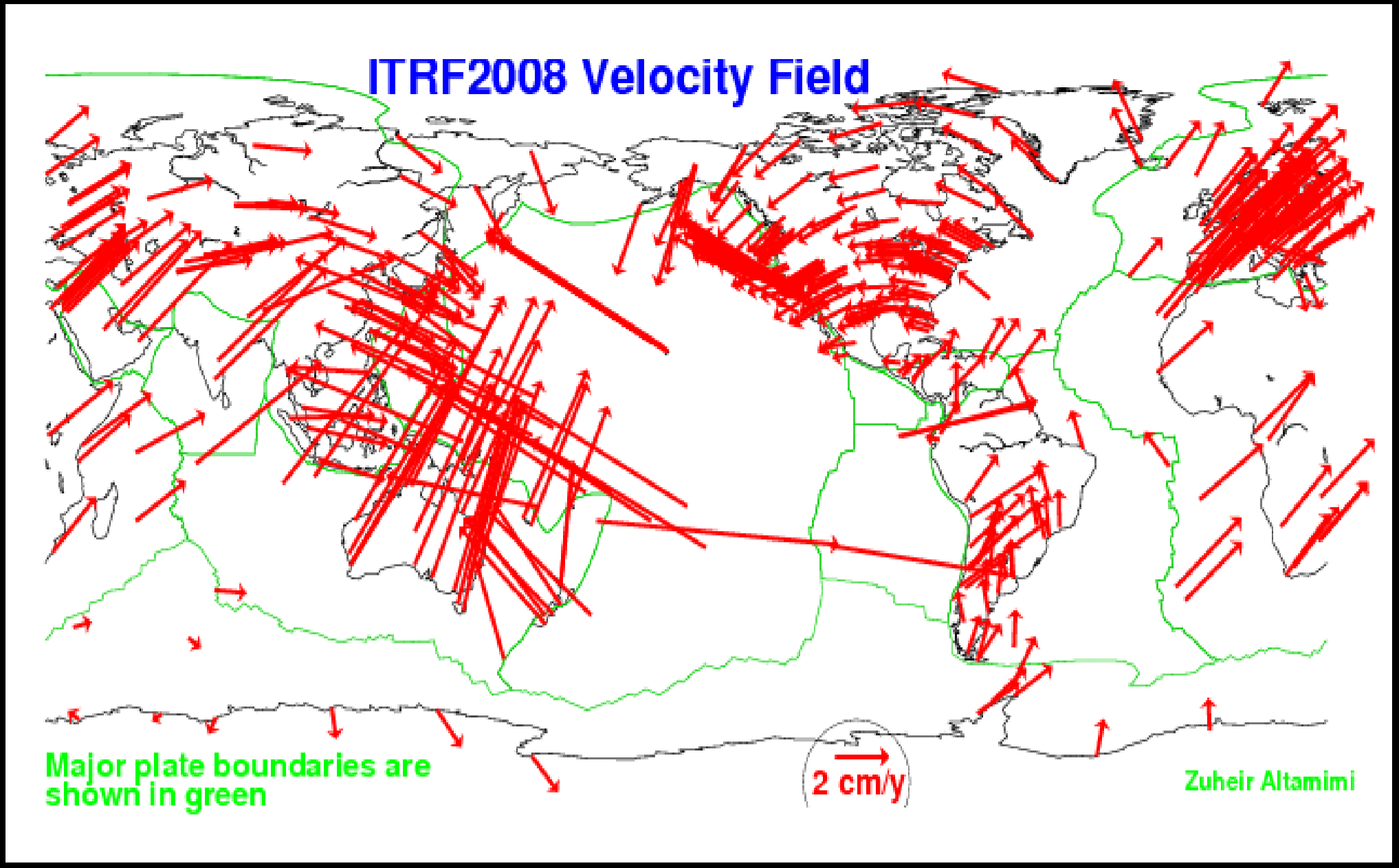



ITRF 2005 Stations

*http://itrf.ign.fr/GIS/*

# Africa in the Global Geodetic Context

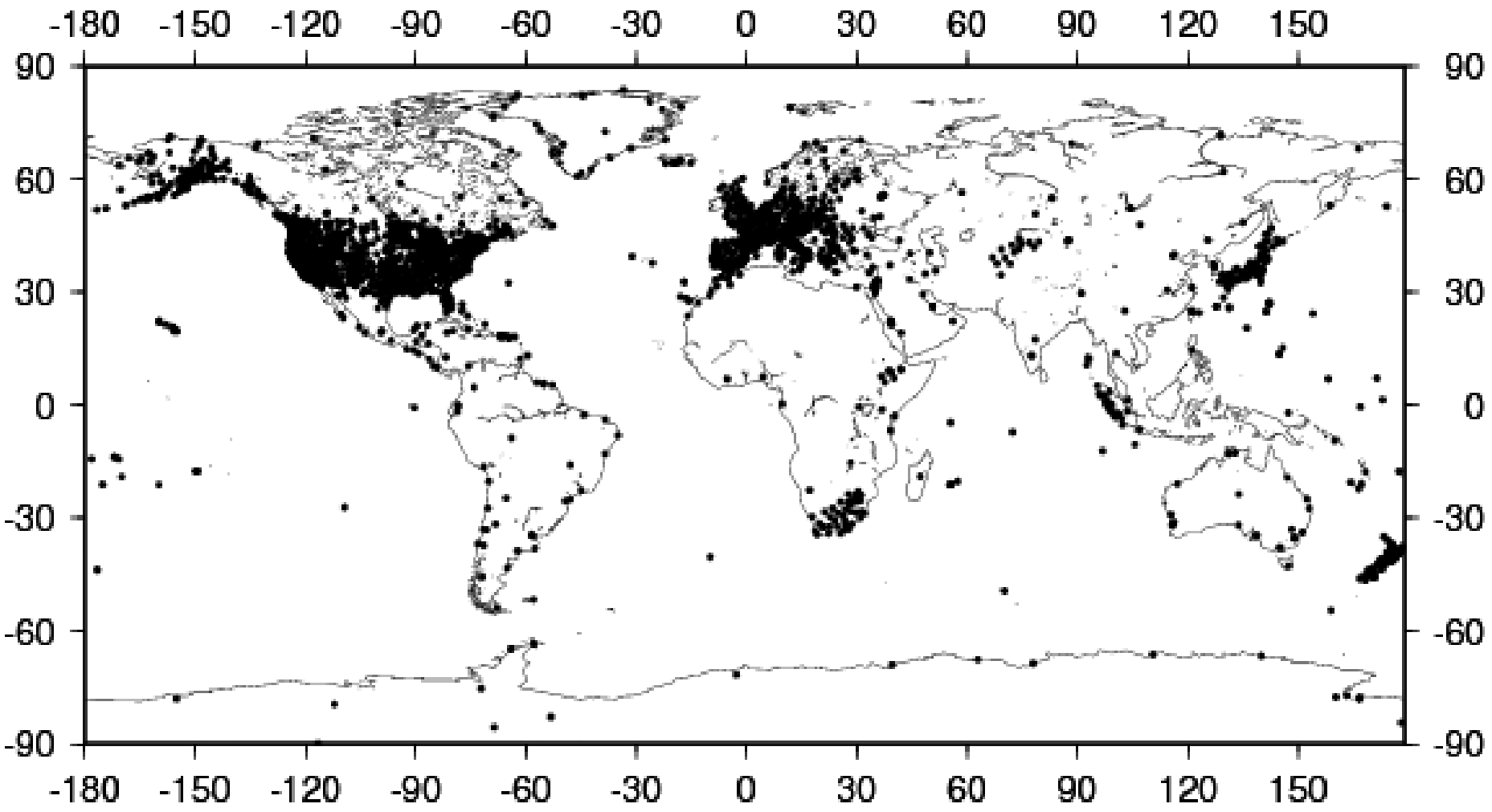



http://itrf.ign.fr/GIS/

# Africa in the Global Geodetic Context

*~4,000 publicly available GPS stations*

*Blewitt and Kreemer, 2008*

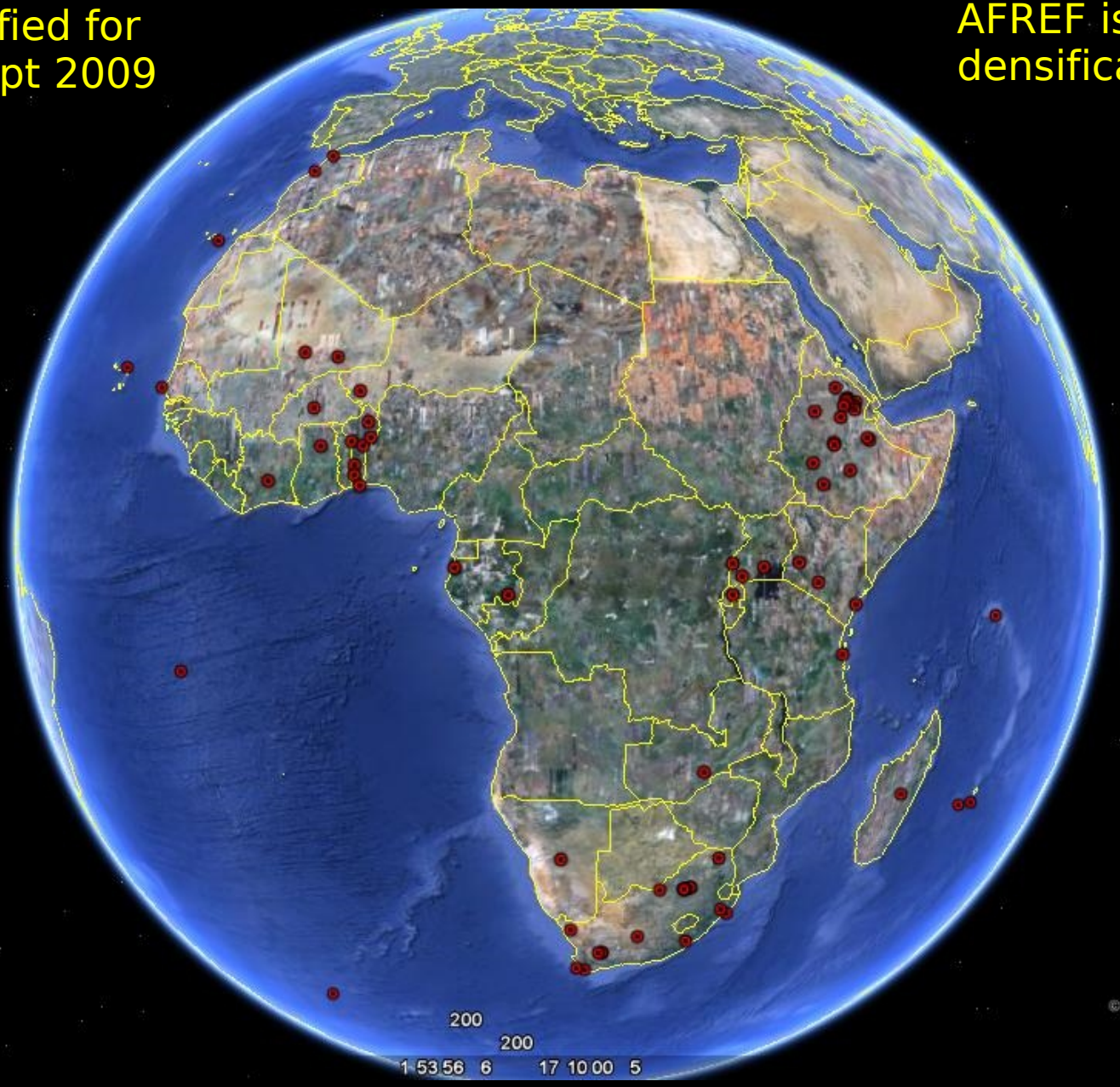



*Issue: GPS/GNSS provides access to the geodetic reference frame*

# Africa in the Global Geodetic Context

Stations Identified for AFREF ODC Sept 2009

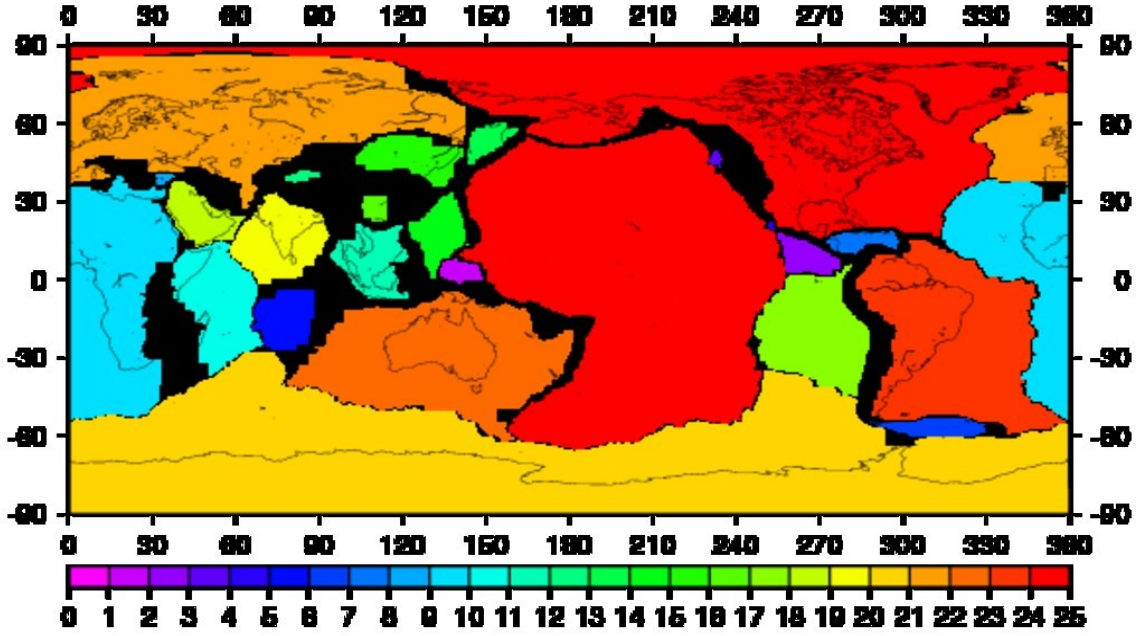
AFREF is regional densification of ITRF




Issue: High accuracy reference frame prerequisite for many scientific studies.

*Wonnacott, 2009*

# Regional Science Issues



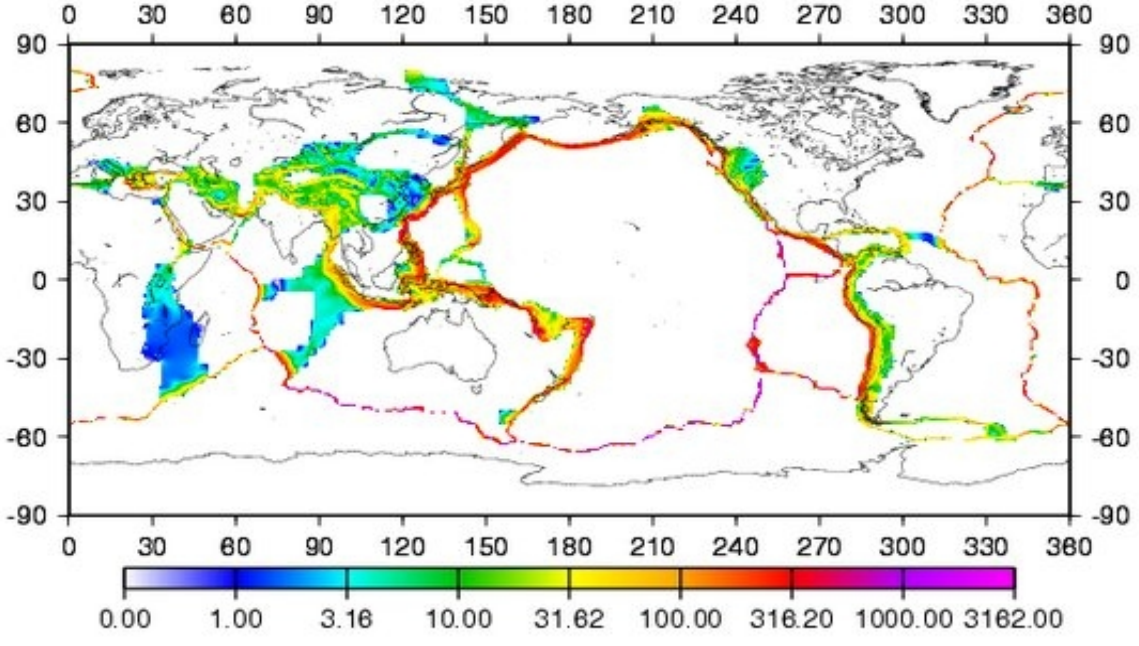



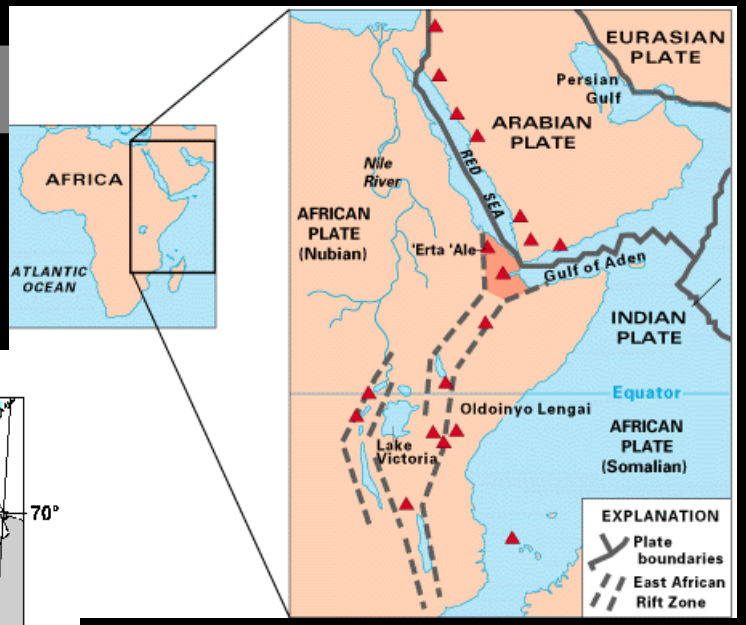

Plate boundaries: location, kinematics, and processes

Challenge: Determination of surface velocity field and strain field with high spatial resolution

*From Rummel et al., 2009*
*Based on Kreemer et al., 2003 and unpublished work*

# Regional Science Issues

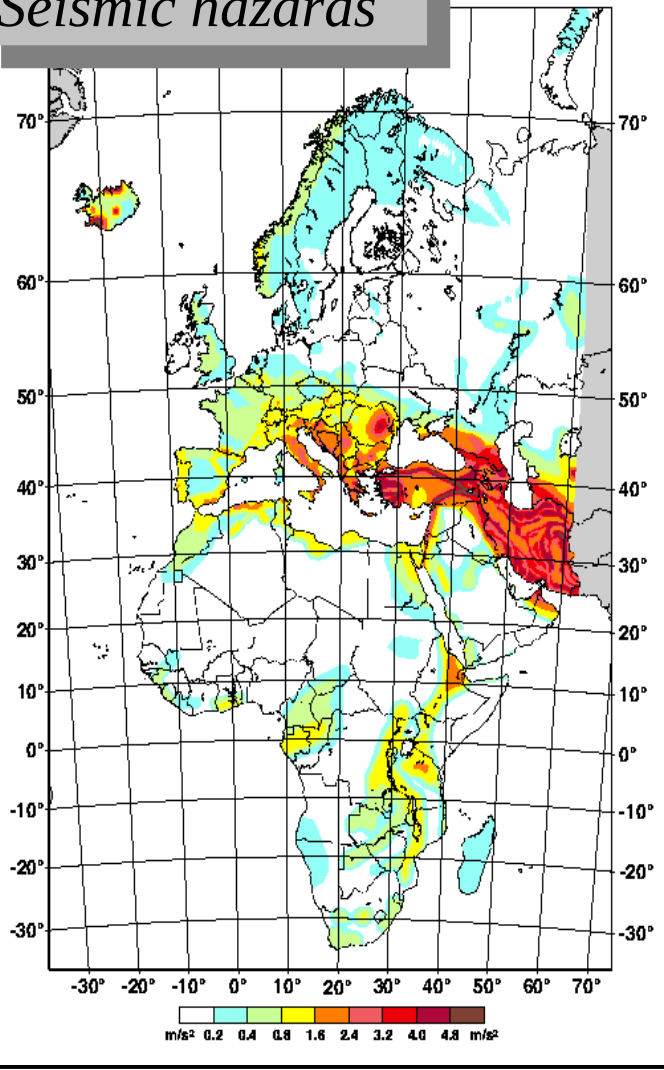
*USGS*

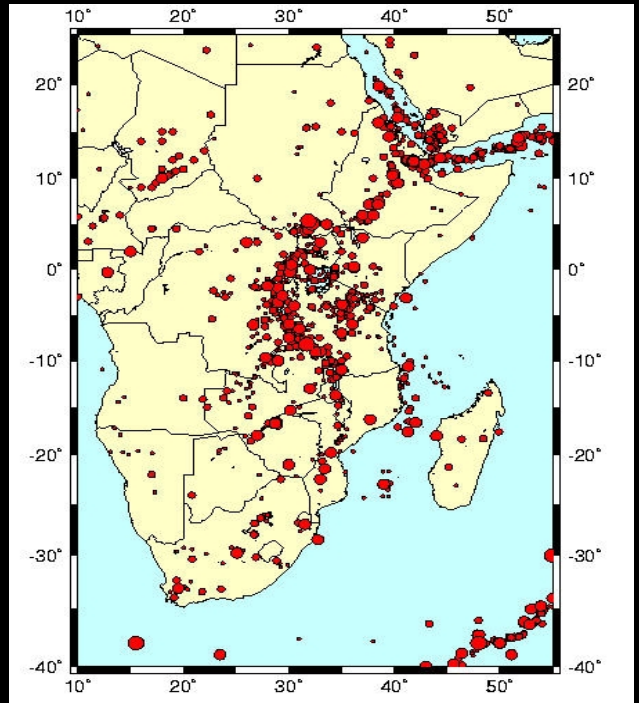



## Plate boundaries: location, kinematics, and processes

Goals:
- Understanding generation of earthquakes;
- spatial distribution of strain rates;
- temporal variations of strain rates;
- mantle

*Seismic hazards*



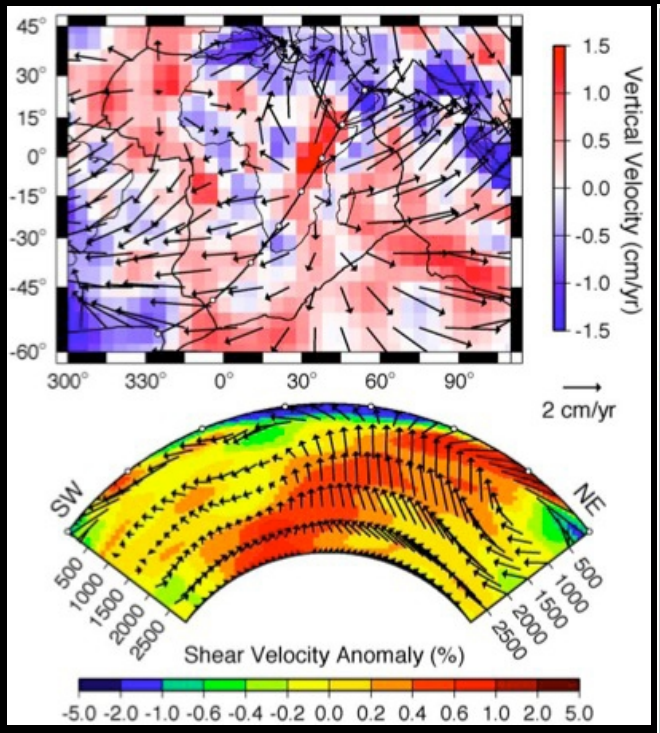




Challenge: Determination of surface velocity field and strain field with high spatial resolution

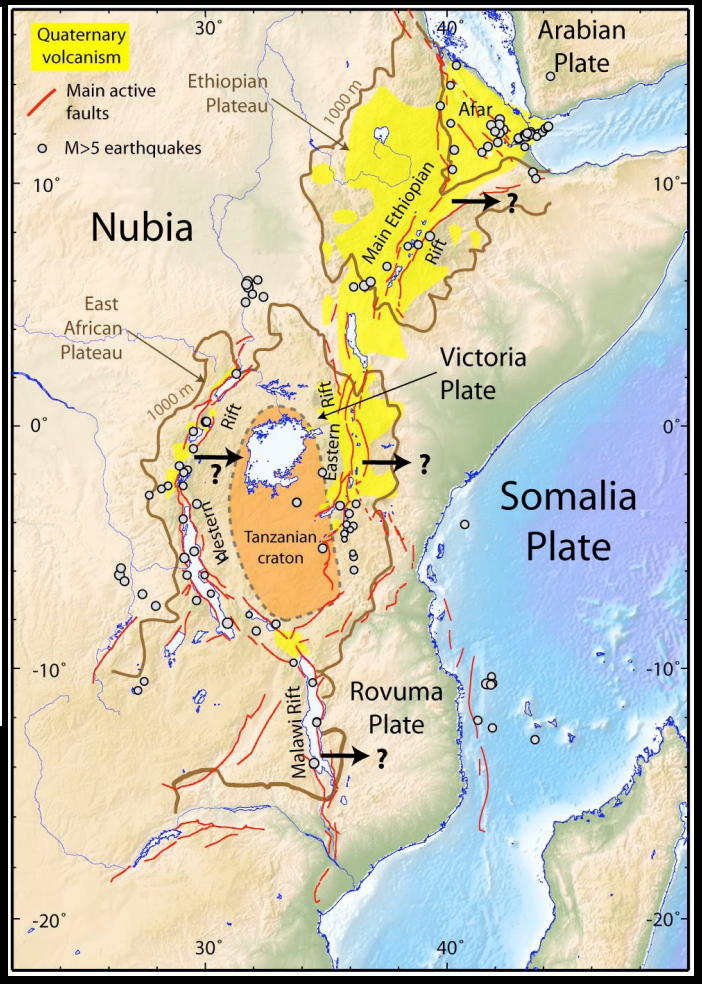
*Earthquakes*

*GSHM Project*

# Regional Science Issues




*Behn et al., 2004; Ritsema et al., 1999*




## Plate boundaries: location, kinematics, and processes

Goals:
- Understanding generation of earthquakes;
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- temporal variations of strain rates;
- mantle dynamics

Challenge: Determination of surface velocity field and strain field with high spatial resolution

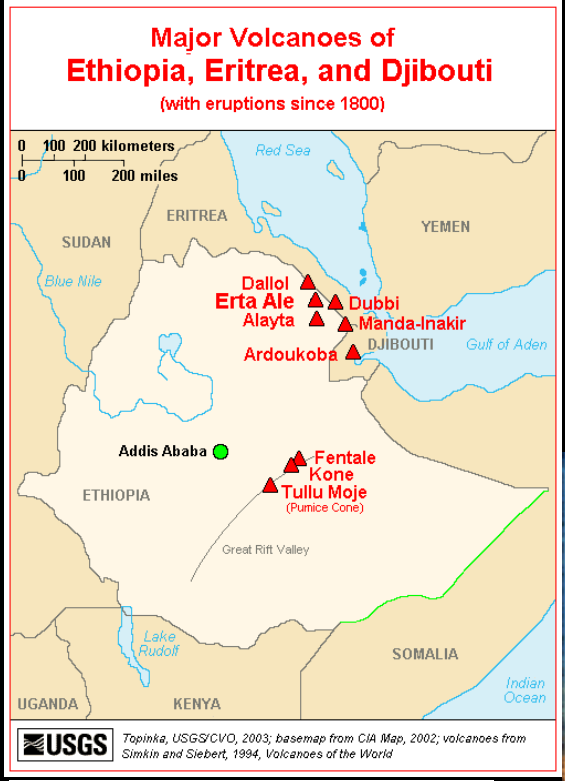
# Regional Science Issues


## Volcanoes

Goals:
- Understanding dynamics;
- Monitoring;
- Early Warning.

Challenge:
- long-term stable reference frame
- local geodetic networks
- InSAR capacity

# Regional Science Issues

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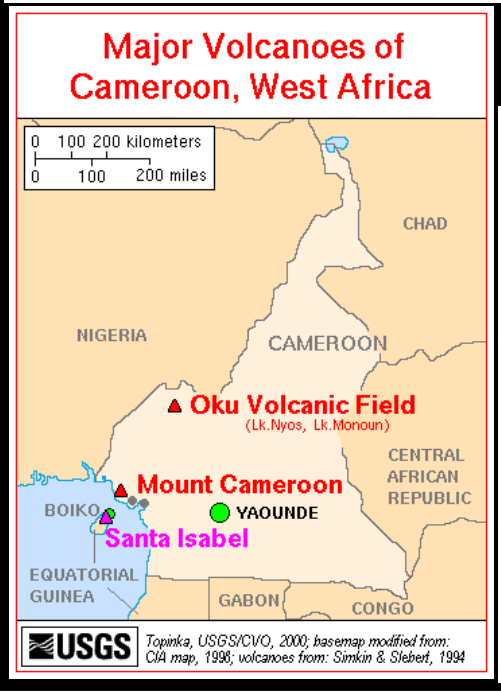
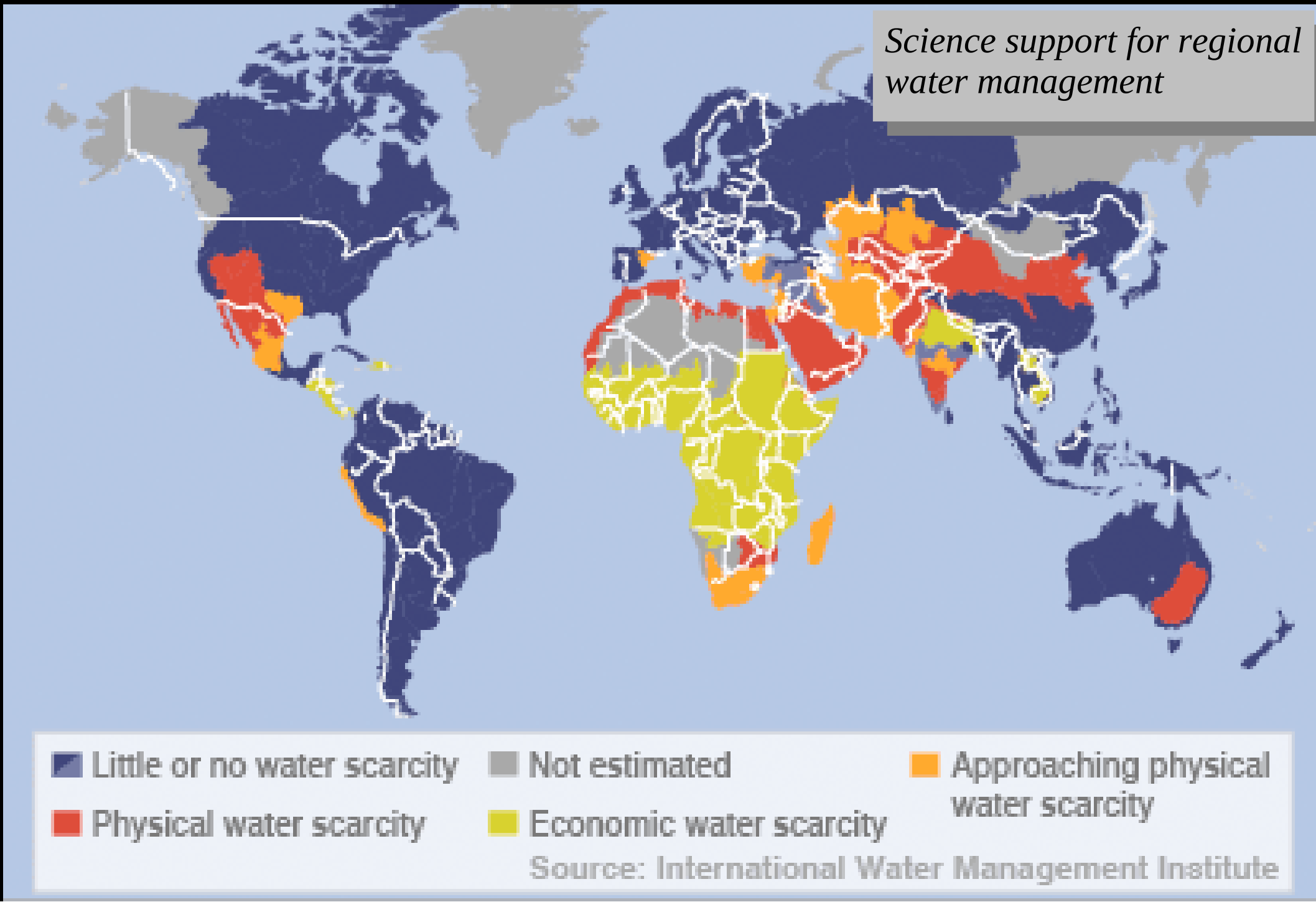
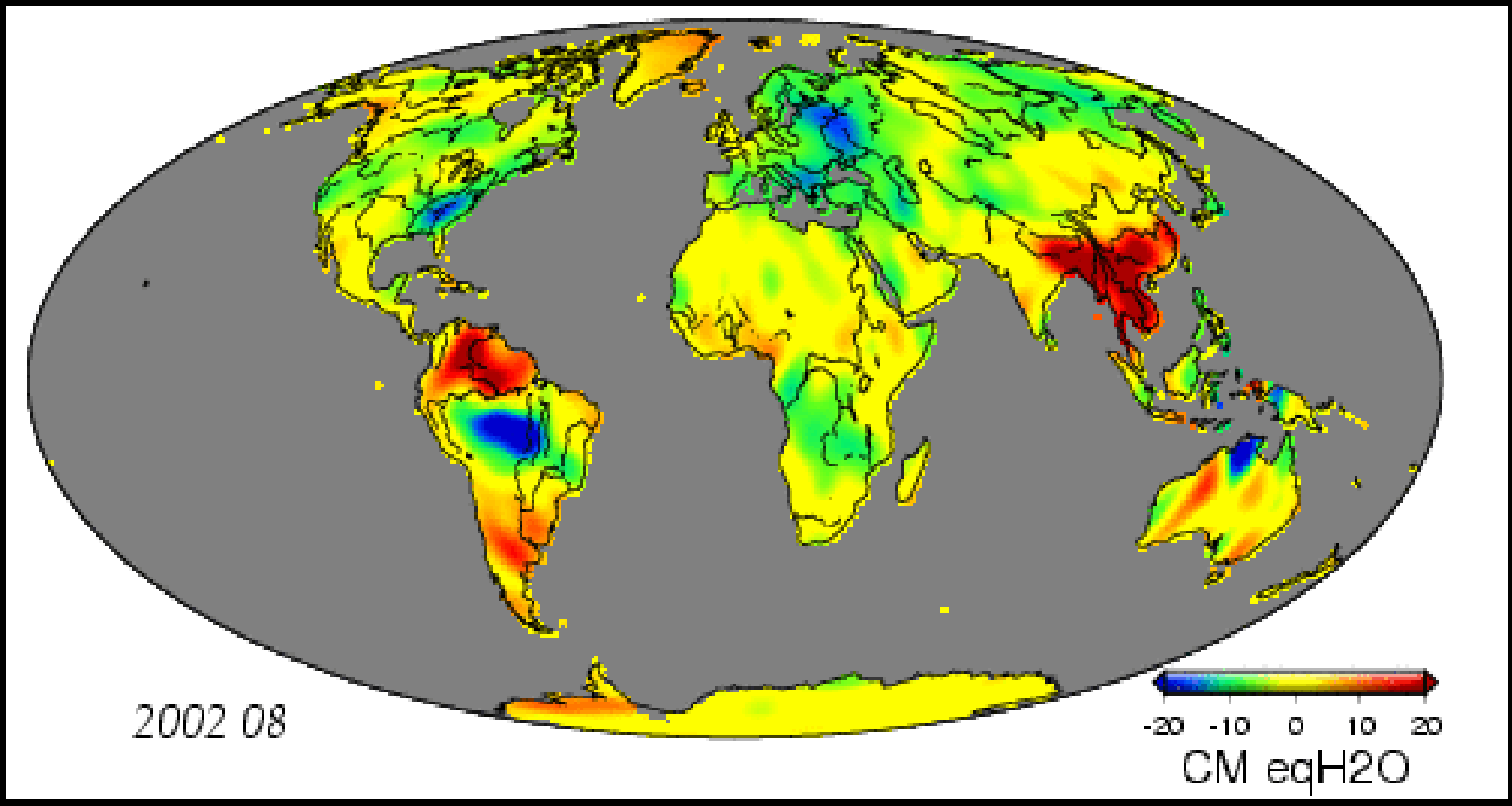



# Regional Science Issues



# Regional Science Issues

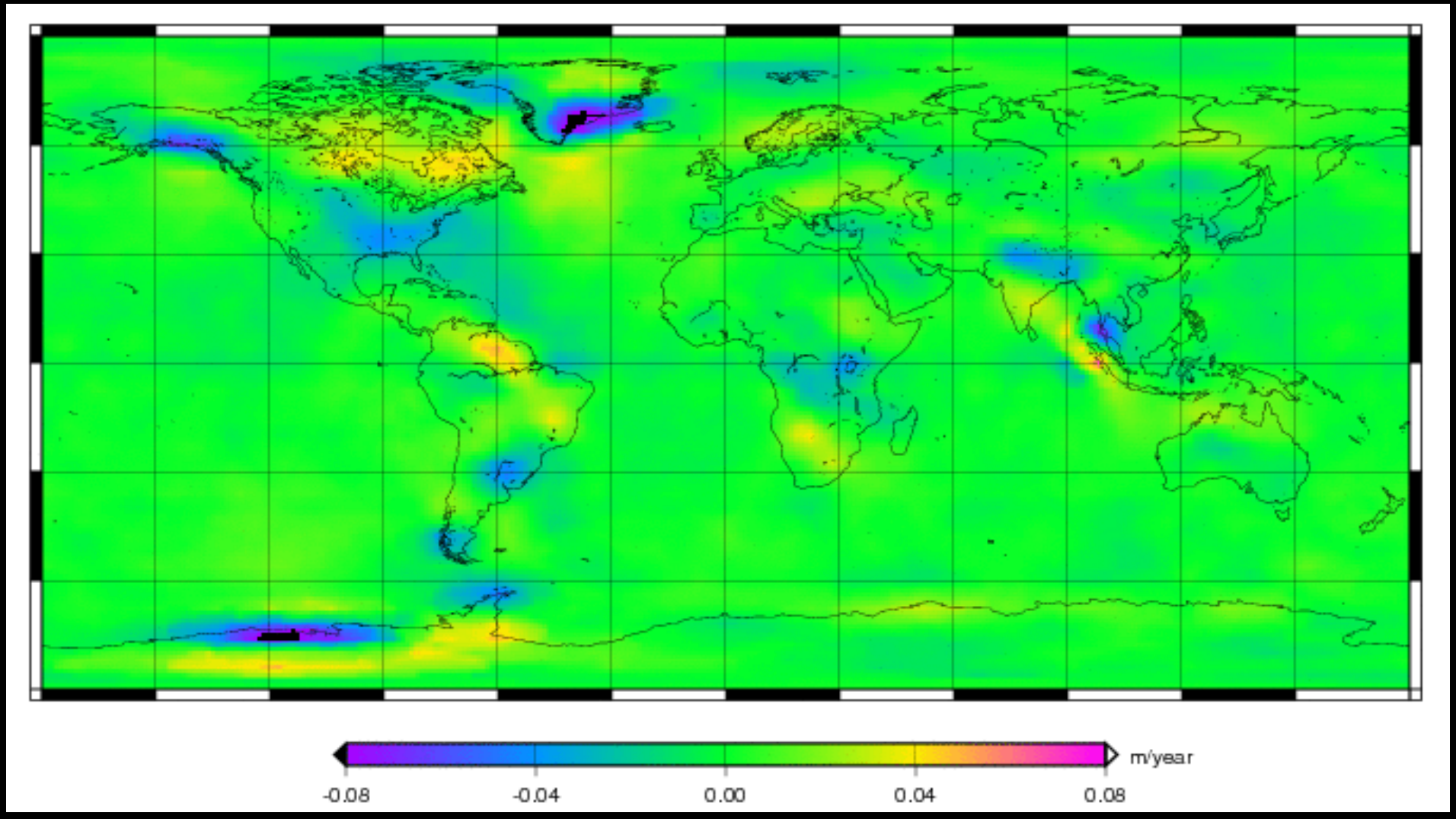



*http://grace.jpl.nasa.gov/information/*

*Satellite Gravity Missions (GRACE)*

# Regional Science Issues

## Hydrology:
## Secular trends in Land Water storage

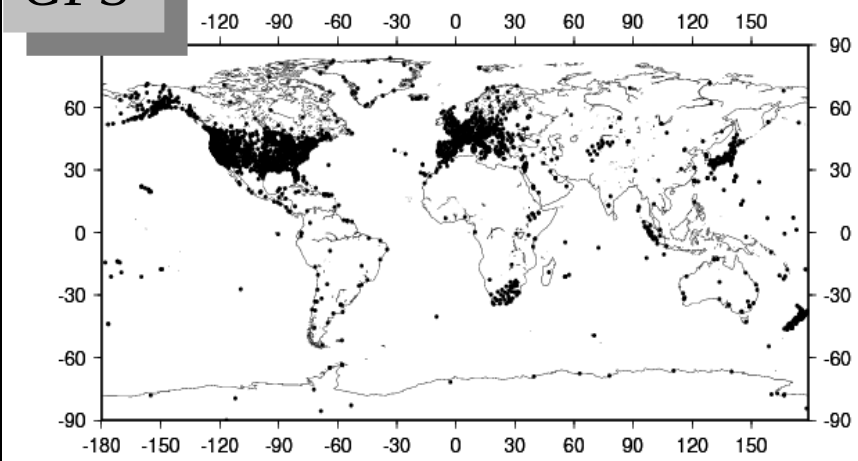



JPL MASCON, secular trends 2003-2007, Watkins, 2008

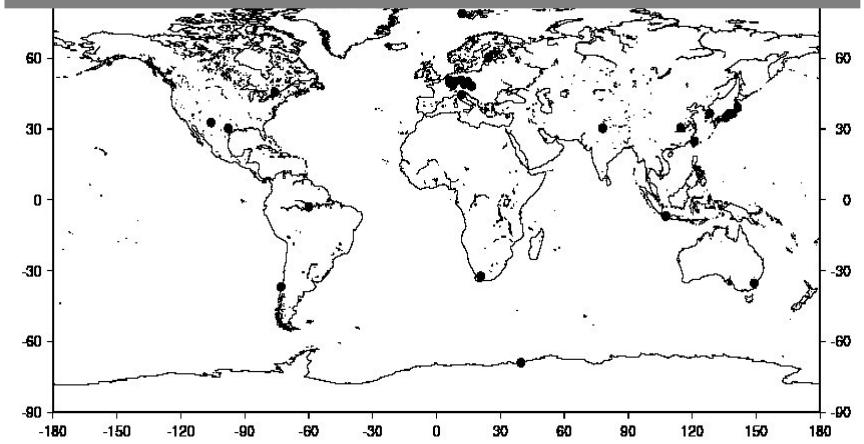
# Regional Science Issues

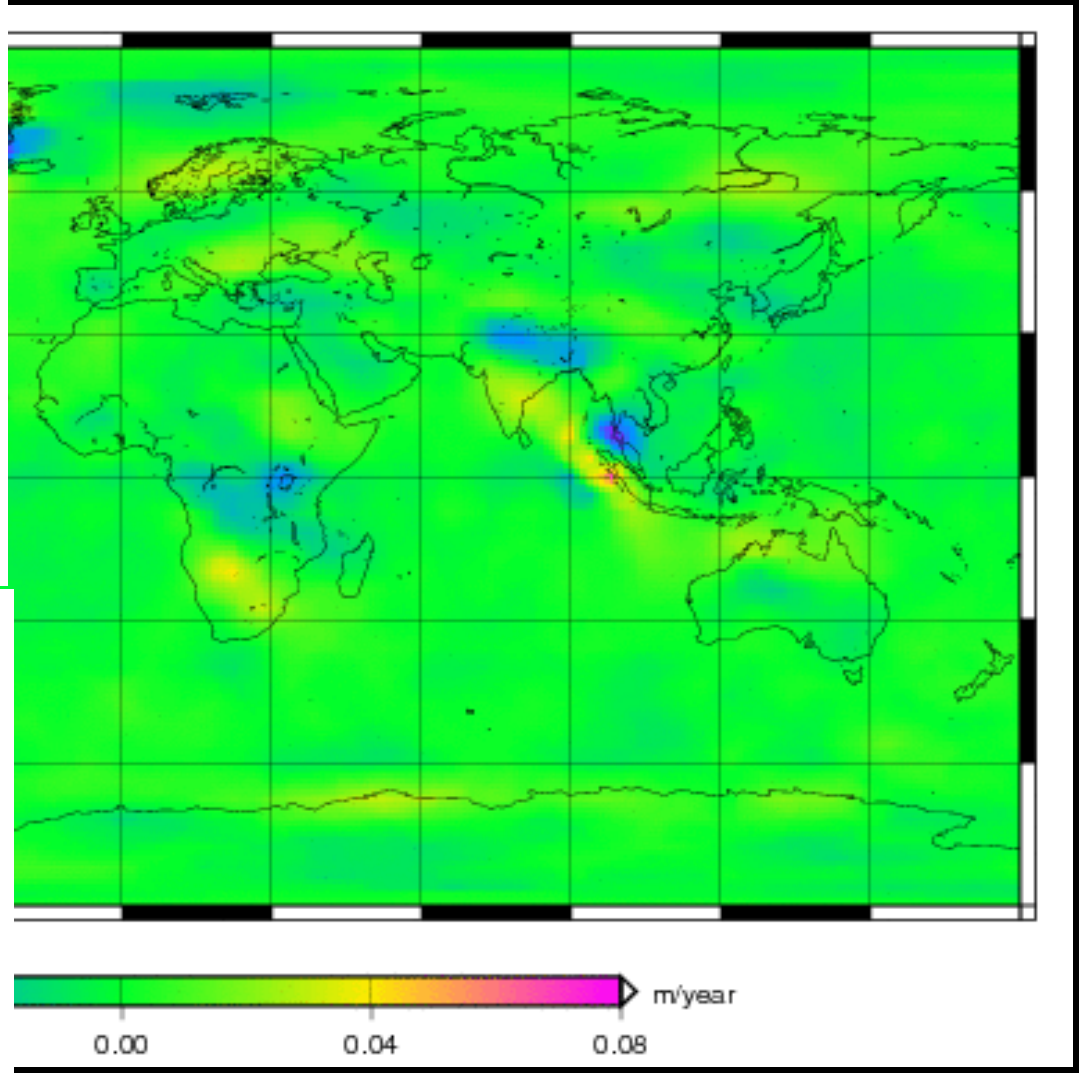
## Hydrology:
## Secular trends in Land Water storage

*GPS*



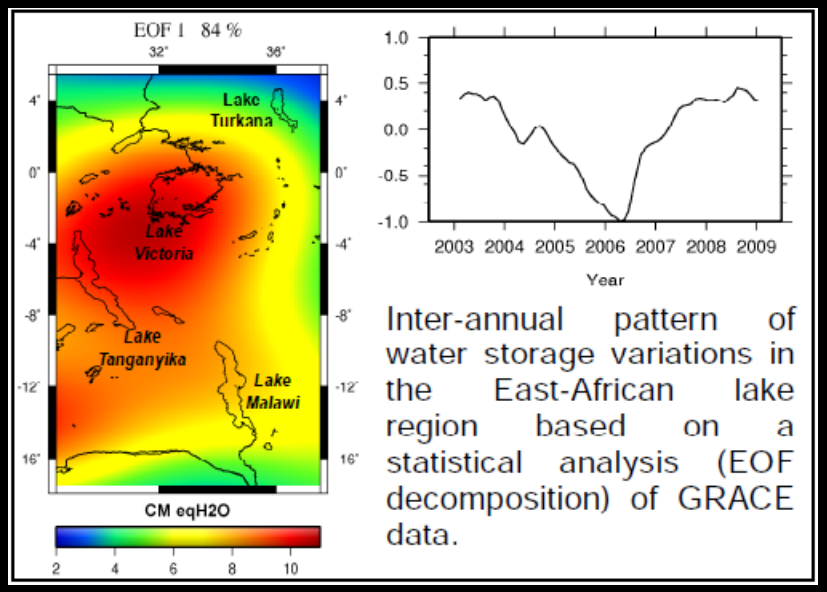

*Superconducting Gravimeters (GGP)*




)3-2007, Watkins, 2008

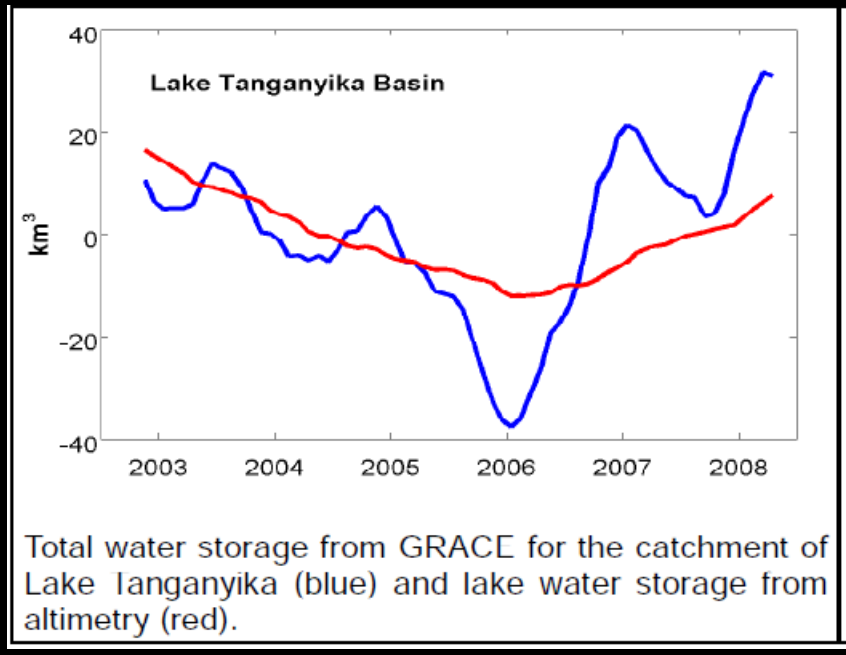
# Regional Science Issues



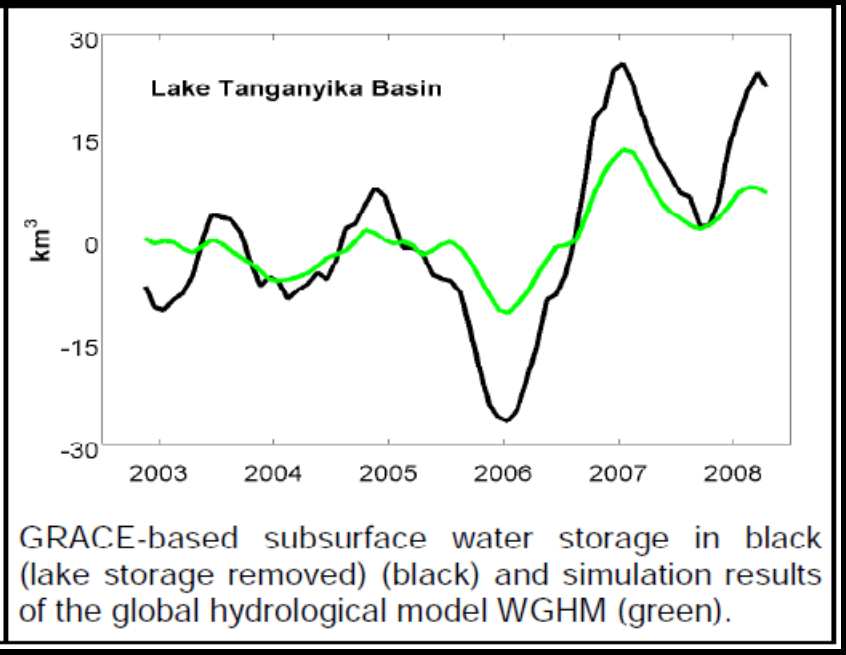

Inter-annual pattern of water storage variations in the East-African lake region based on a statistical analysis (EOF decomposition) of GRACE data.

## Hydrology: Seasonal and interannual changes in land-water storage

Issue: Increased spatial and temporal resolution through combination of satellite gravity, surfaces displacements, and in situ gravity



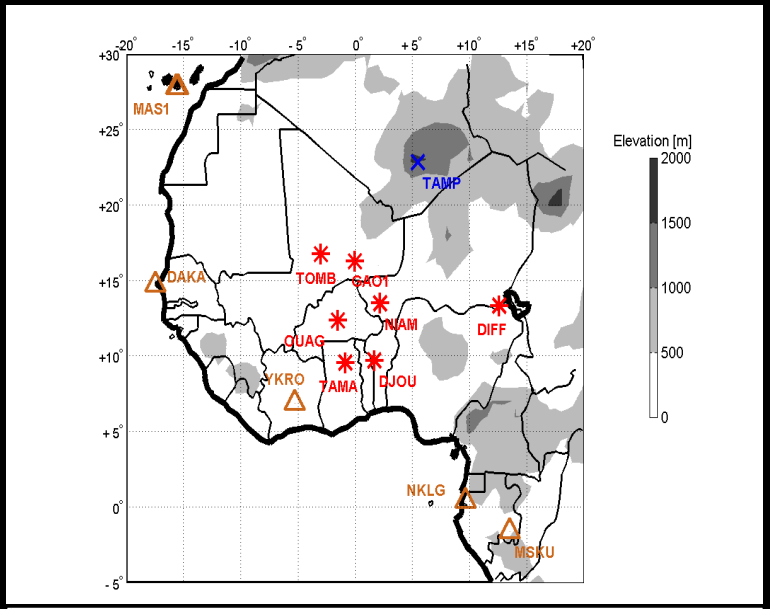

Total water storage from GRACE for the catchment of Lake Tanganyika (blue) and lake water storage from altimetry (red).

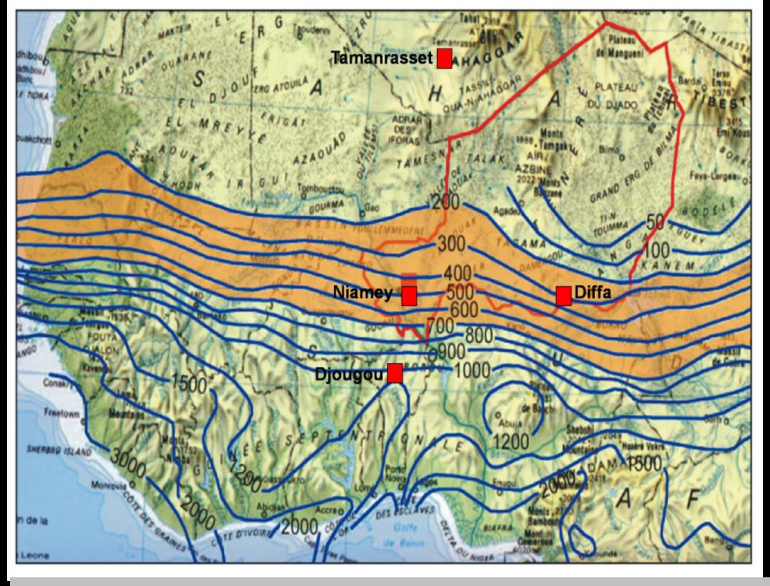



GRACE-based subsurface water storage in black (lake storage removed) (black) and simulation results of the global hydrological model WGHM (green).

*Becker et al., 2009*

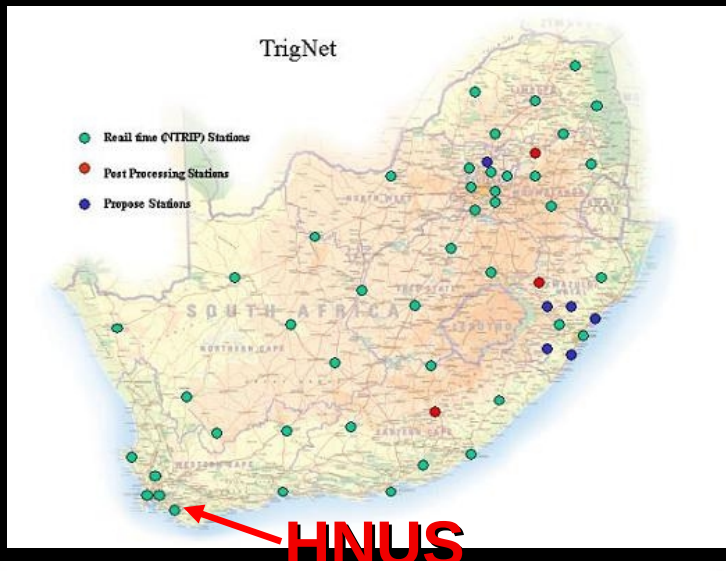
# Regional Science Issues

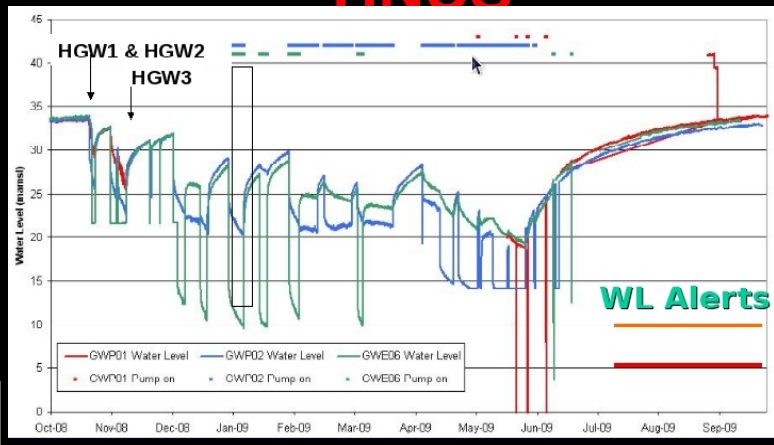



## Hydrology: Groundwater storage and water management

Issue: determination of hydrological parameters; assimilation in models

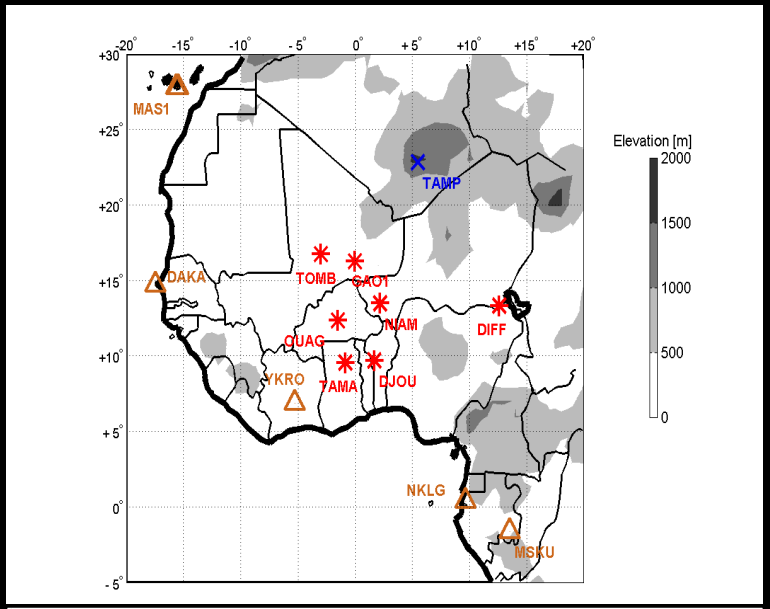



*GHYRAF Project; Hinderer et al., 2009*

*Hermanus Project; Hartnady et al., 2009*

# Regional Science Issues

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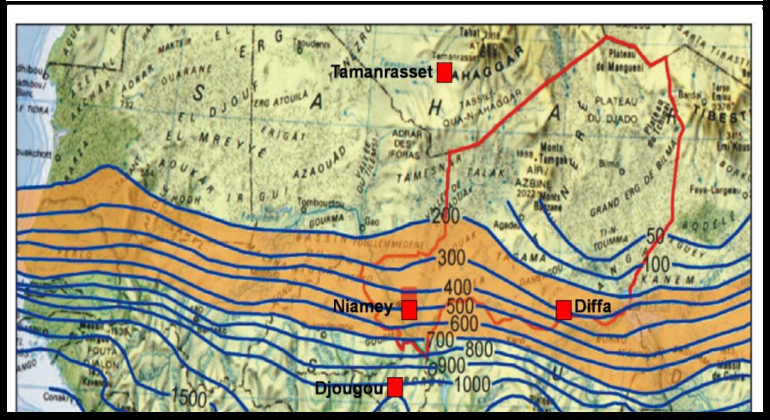
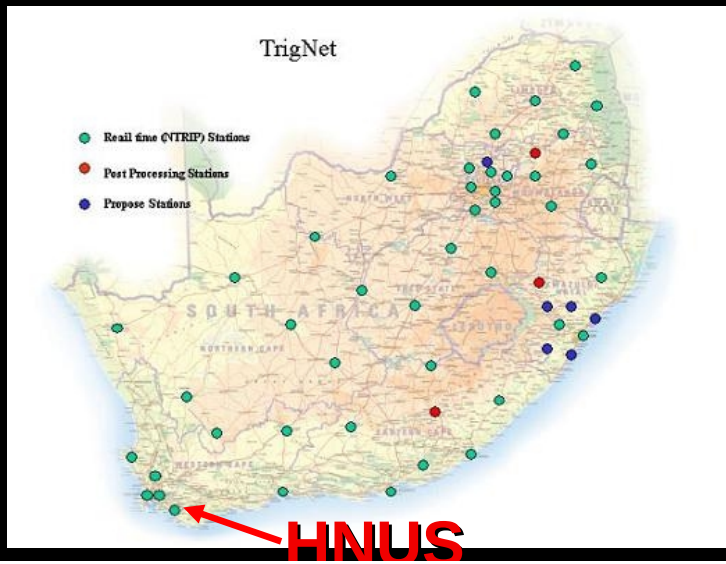


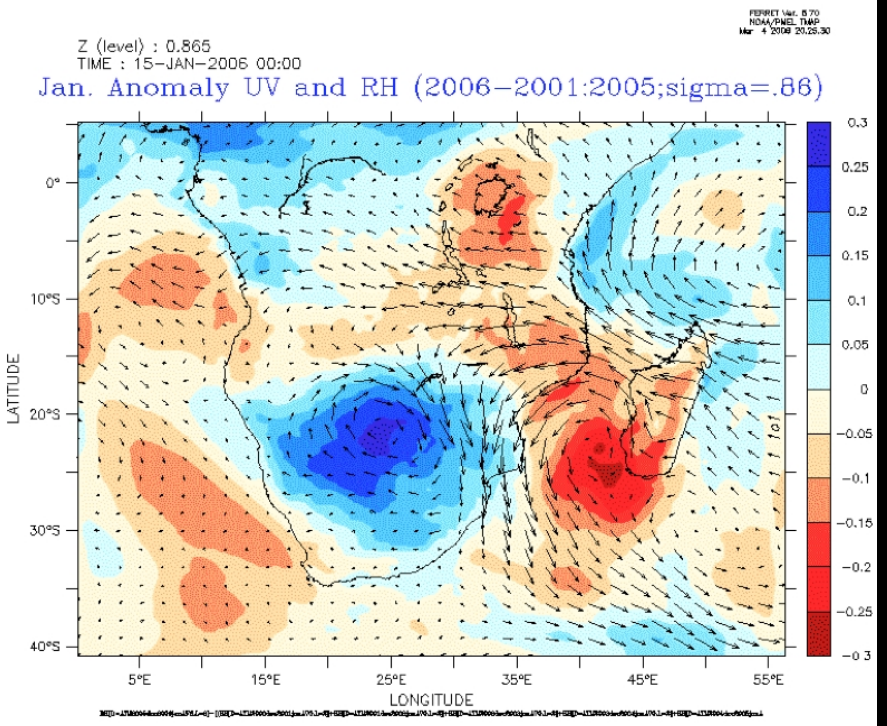

# Regional Science Issues

## Atmospheric Water Vapor; examples:

- numerical weather forecasting (extremes);
- climate change monitoring;
- drought and dry spells are linked with meningitis outbreaks

## Challenges:

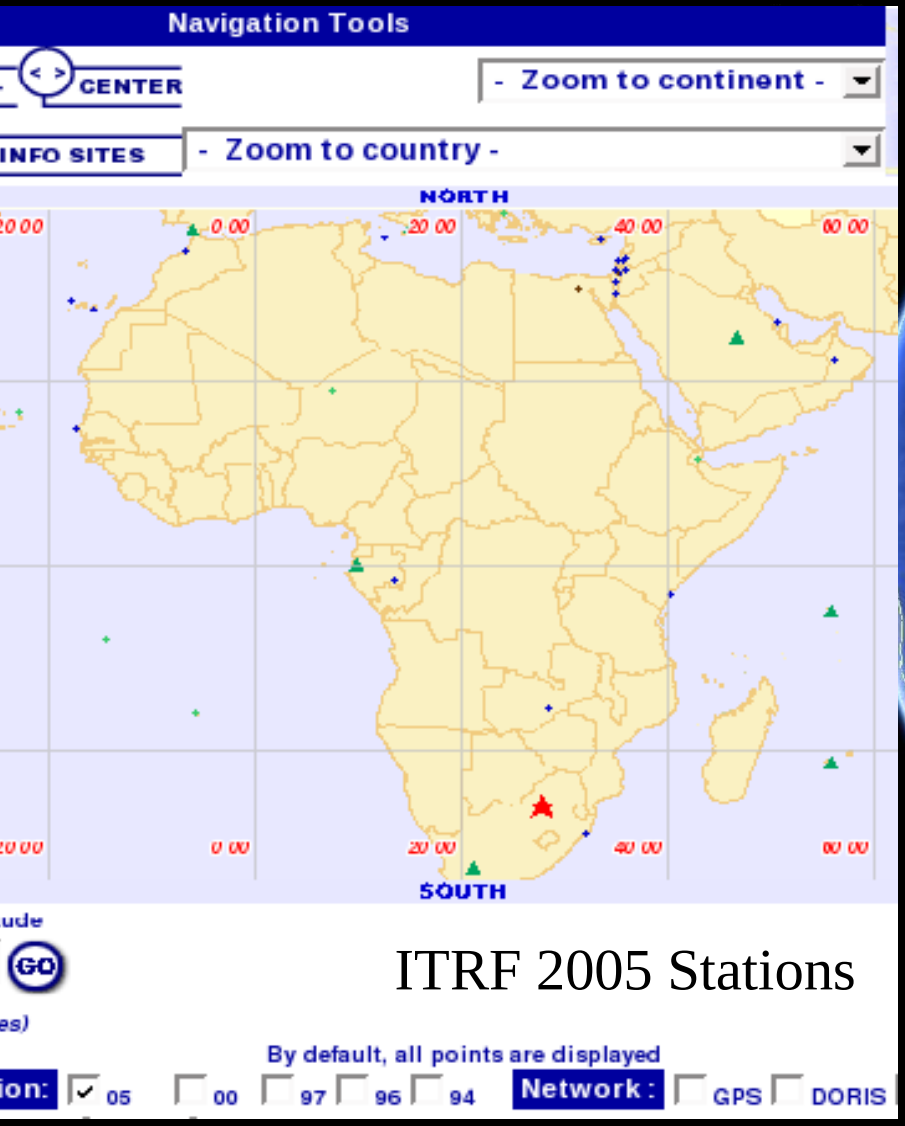
- high spatial resolution;
- low latency;
- long-term stability (climate)



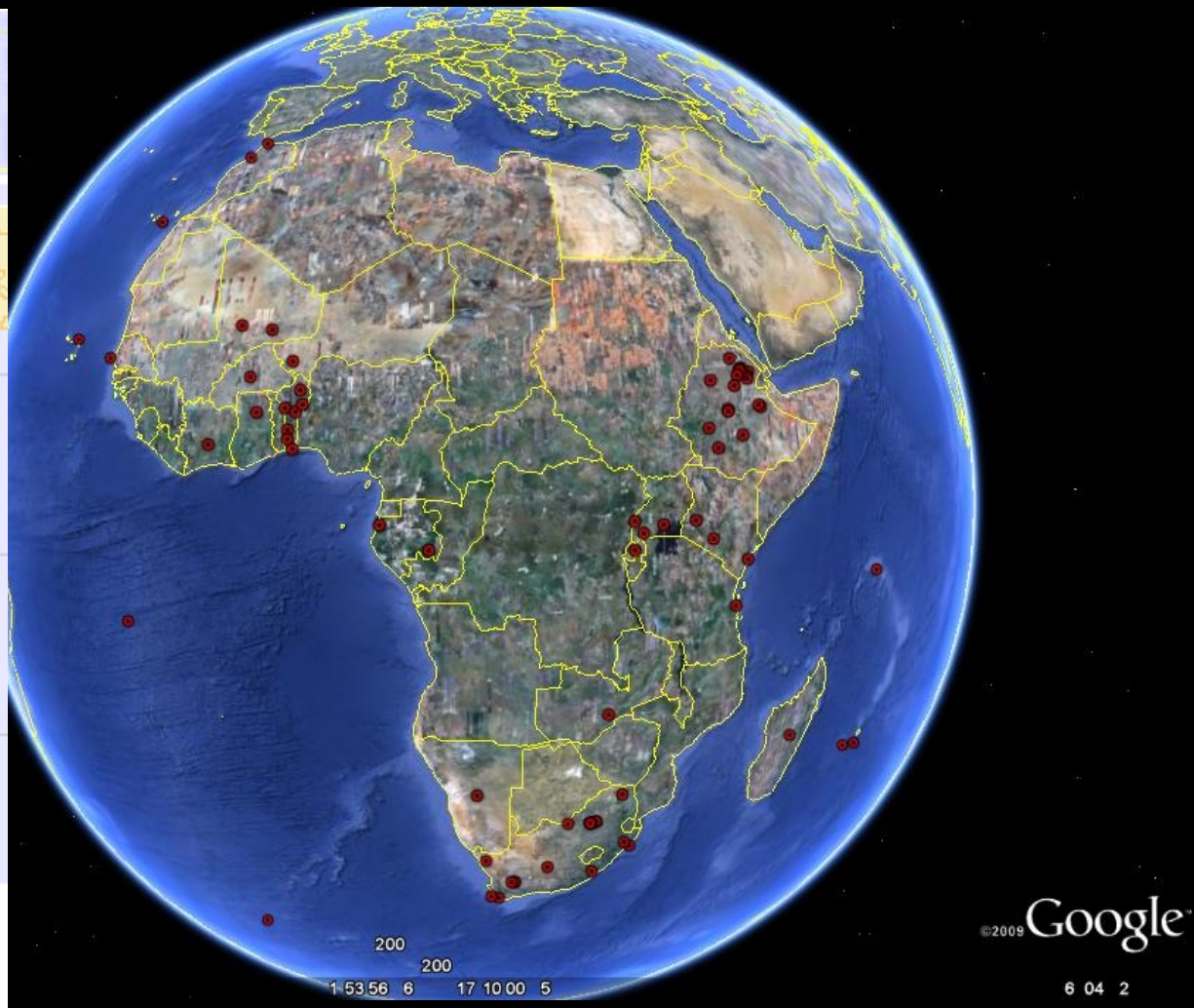

Left: annihilated wildlife in Tanzania during the 2005 record drought.
Right: Prediction of drought conditions based on vertically integrated relative humidity. Although the model results appear to be qualitatively realistic, one cannot confirm the model results because the upper air coverage is too sparse over the region.

*From Calais, 2009*

# Gaps in Infrastructure



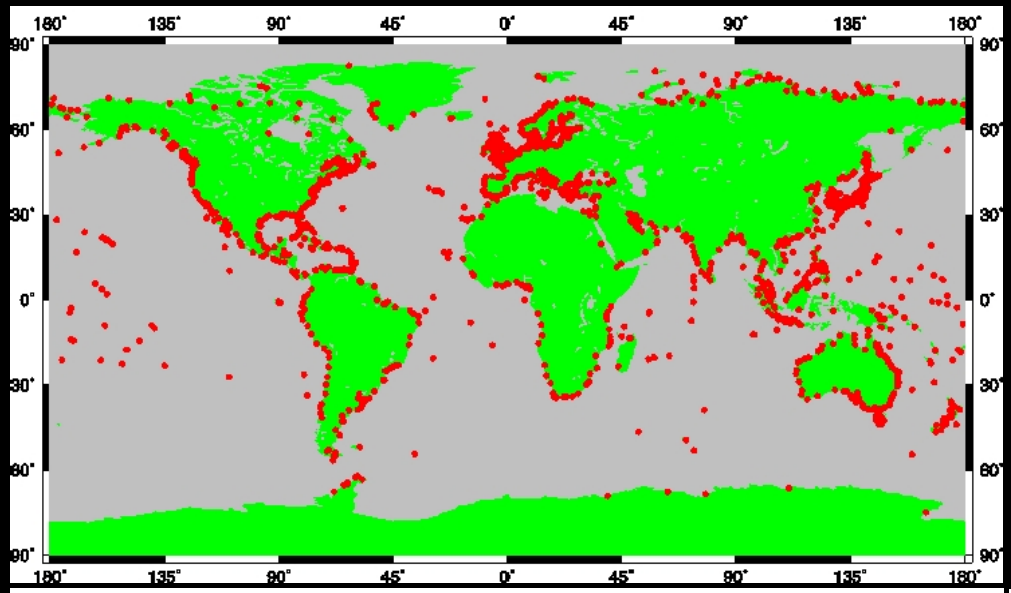

ITRF 2005 Stations

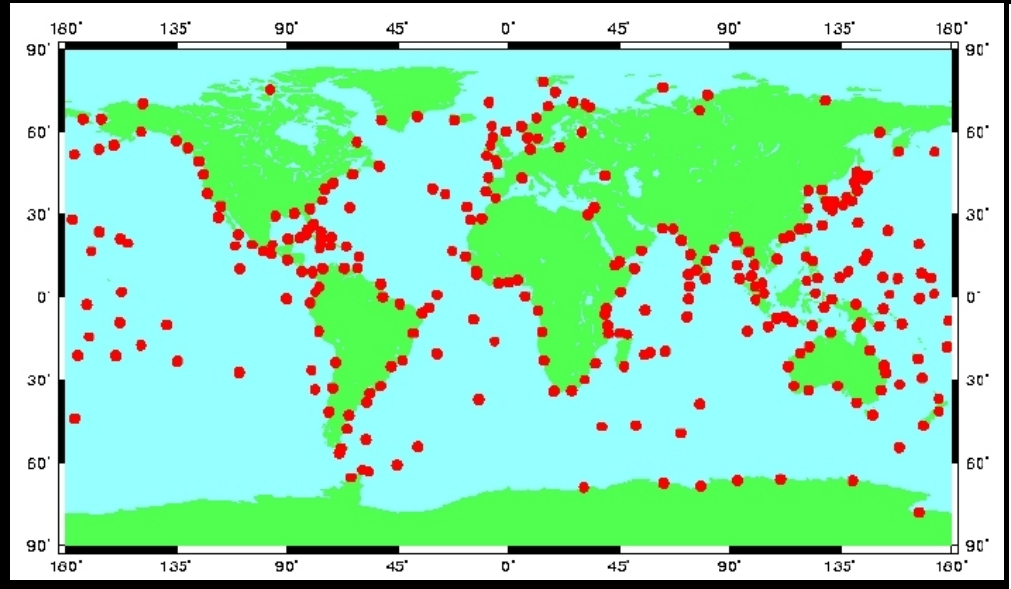



Issue: Many science applications depend on access to long-term stable, accurate reference frame.

Challenge: Increase number of ITRF stations; co-location of techniques;
Increase number of GNSS stations providing access to reference frame (AFREF)

# Gaps in Infrastructure

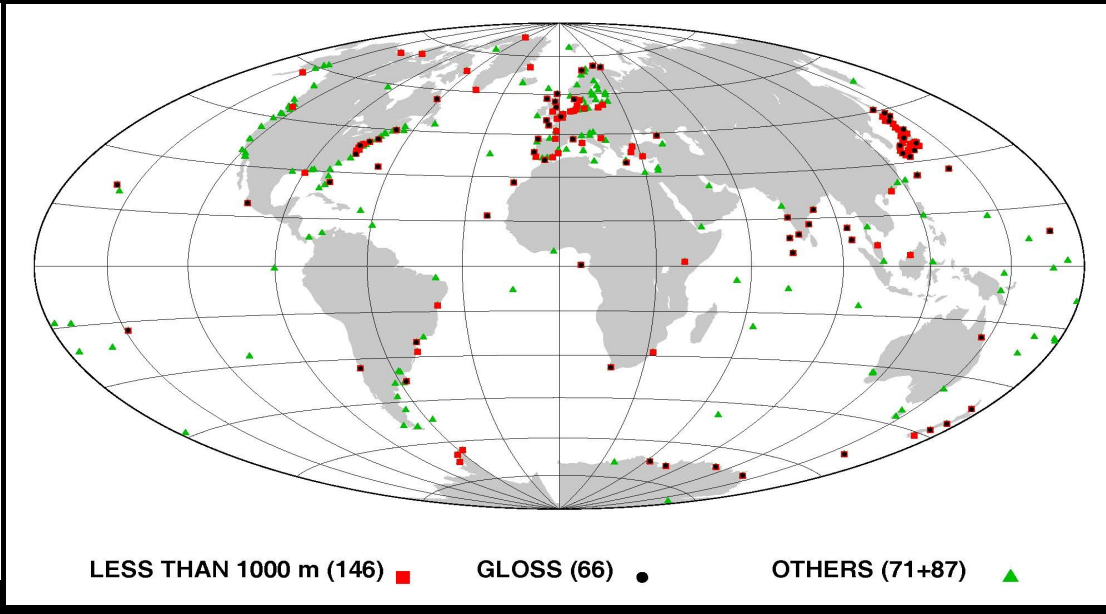



*PSMSL, 2009*

**Tide Gauges and GPS:**

- *Low density of tide gauges with long records*
- *Extremely few tide gauges co-located with GPS*




*Woeppelmann et al., 2007*

# Capacity Building

## (Some) Challenges

- *Broad involvement of African scientists in international projects;*
- *Interdisciplinary approach to capacity building;*
- *Community building;*
- *Capacity retention (emphasized at the GEO Coastal Zone CoP Workshop, Cotonou, Benin, Feb. 2010)*

## Role of AFREF:

- *New GPS stations: Basis for training of students using regional/local data;*
- *Support for/participation in training courses;*
- *Interdisciplinary approach to geodesy capacity building.*

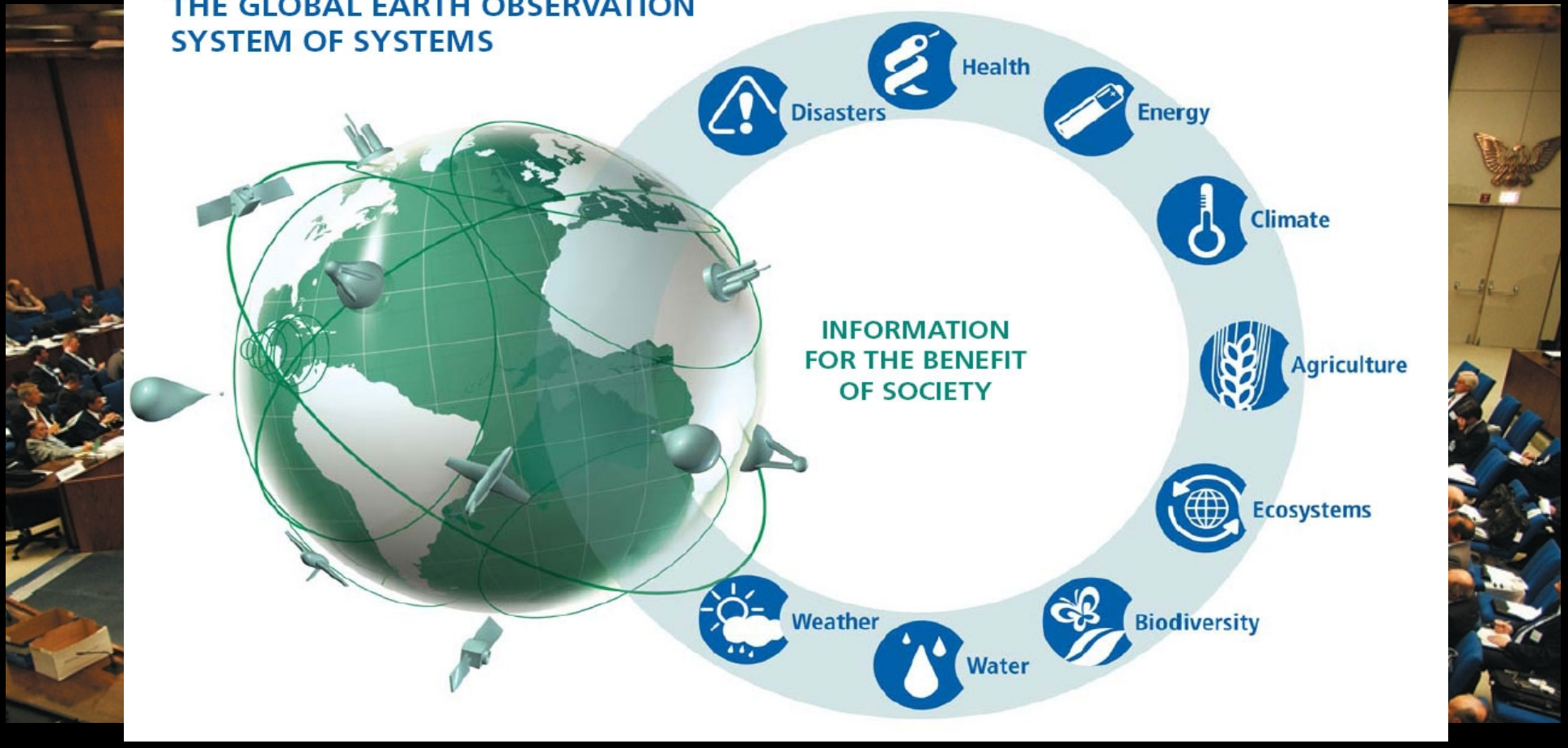
# GEO, the Group on Earth Observations

## An Intergovernmental group with 80 Members and 57 Participating Organizations

# Capacity Building

## GEO, the Group on Earth Observations

### An Intergovernmental group with 80 Members and 57 Participating Organizations



# GEO, the Group on Earth Observations

## An Intergovernmental group with 80 Members and 57 Participating Organizations

THE GLOBAL EARTH OBSERVATION

**Group on Earth Observations (GEO)**

- *Strong focus on Africa in the Societal Benefit Areas "Water" and "Health"*
- *Geodetic infrastructure and capacity important for utilizing the societal benefits of Earth observations*
- *GEO has focus on capacity building*
- *Call for Proposals: included Water SBA, many proposals from Africa.*

***Challenges**:*

- *capacity retention*
- *closing the gap between science/earth observations and governance/policy making*

# Conclusions/Summary

- *Geodesy serves many other sciences; infrastructure for multi-applications*
- *Geodesy is inherently global*
- *Reference frame:*
    - *Global perspective: more reference stations are needed in Africa; co-location is a key issue*
    - *Regional reference frame (AFREF) crucial for many science applications*
    - *Dense network of CGPS/CGNSS stations for access to reference frame*

*Some science issues/science-related challenges:*

- *Tectonics: secular velocity field, secular strain rates, transients (GNSS, InSAR)*
- *Geohazards: earthquake generation, early warning, risk management cycle*
- *Hydrology: groundwater variations; land water storage (GRACE, GNSS, InSAR, in situ gravimetery)*
- *Sea Level: Co-location of tide gauges and GPS*
- *Atmospheric water vapour: numerical weather forecast; droughts and dry spells, health applications (meningitis, malaria, ...); climate change - very demanding*