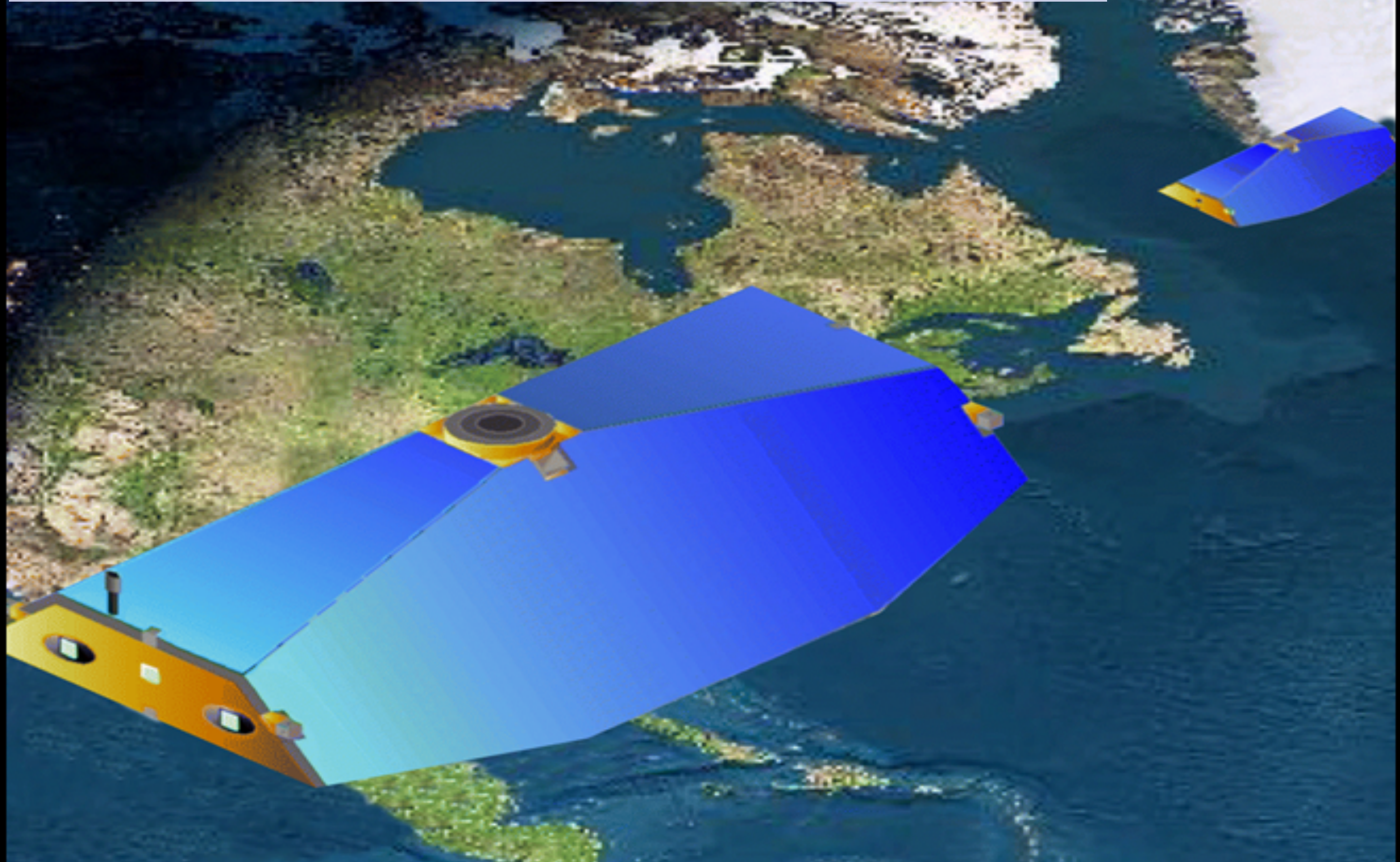
Supporting Water Management at River Basin Scale with Hydrogeodesy

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

Hydrogeodesy: GRACE +

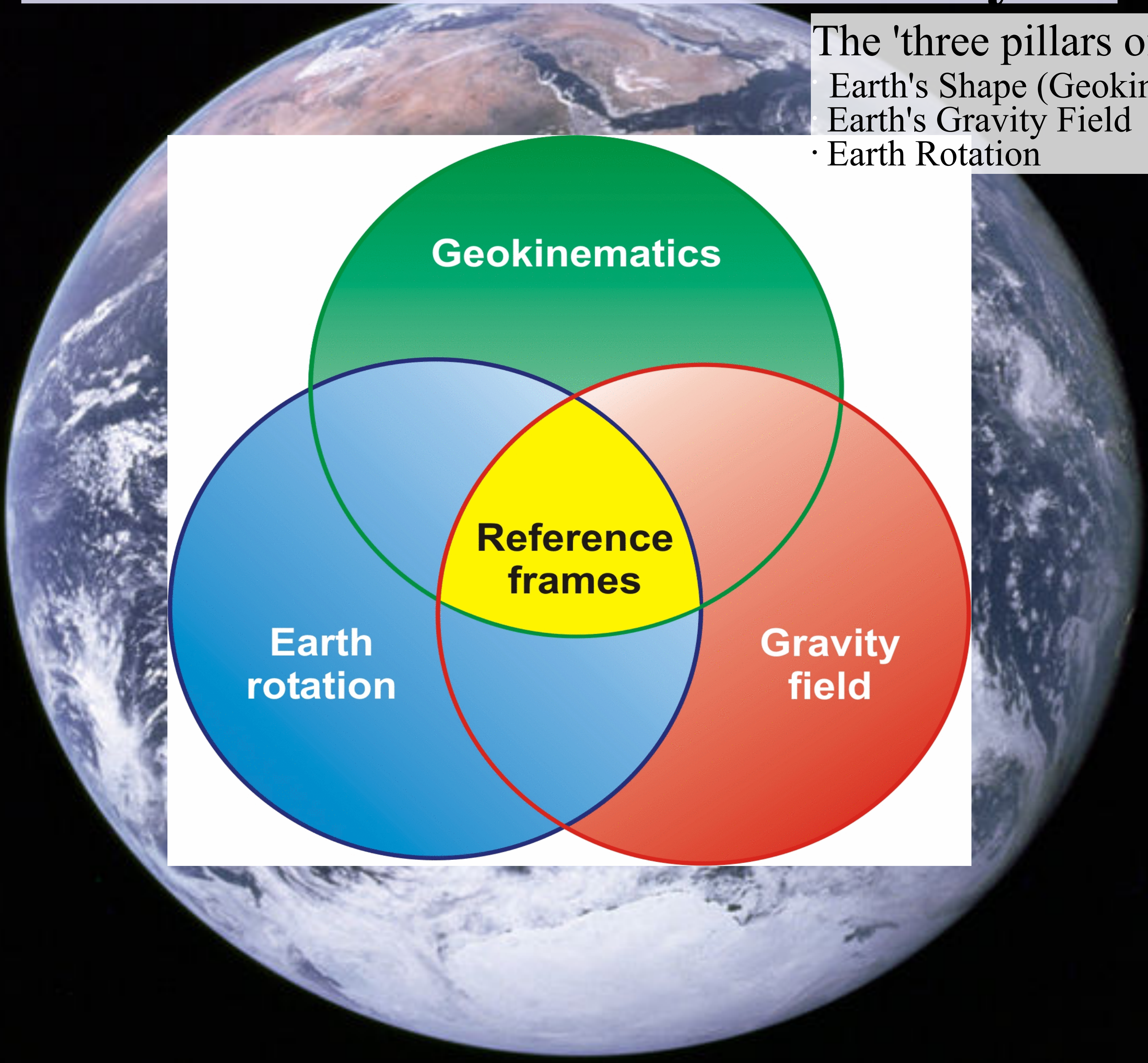
GRACE: Gravity Recovery And Climate Experiment



The Three Pillars of Geodesy

The Three Pillars of Geodesy

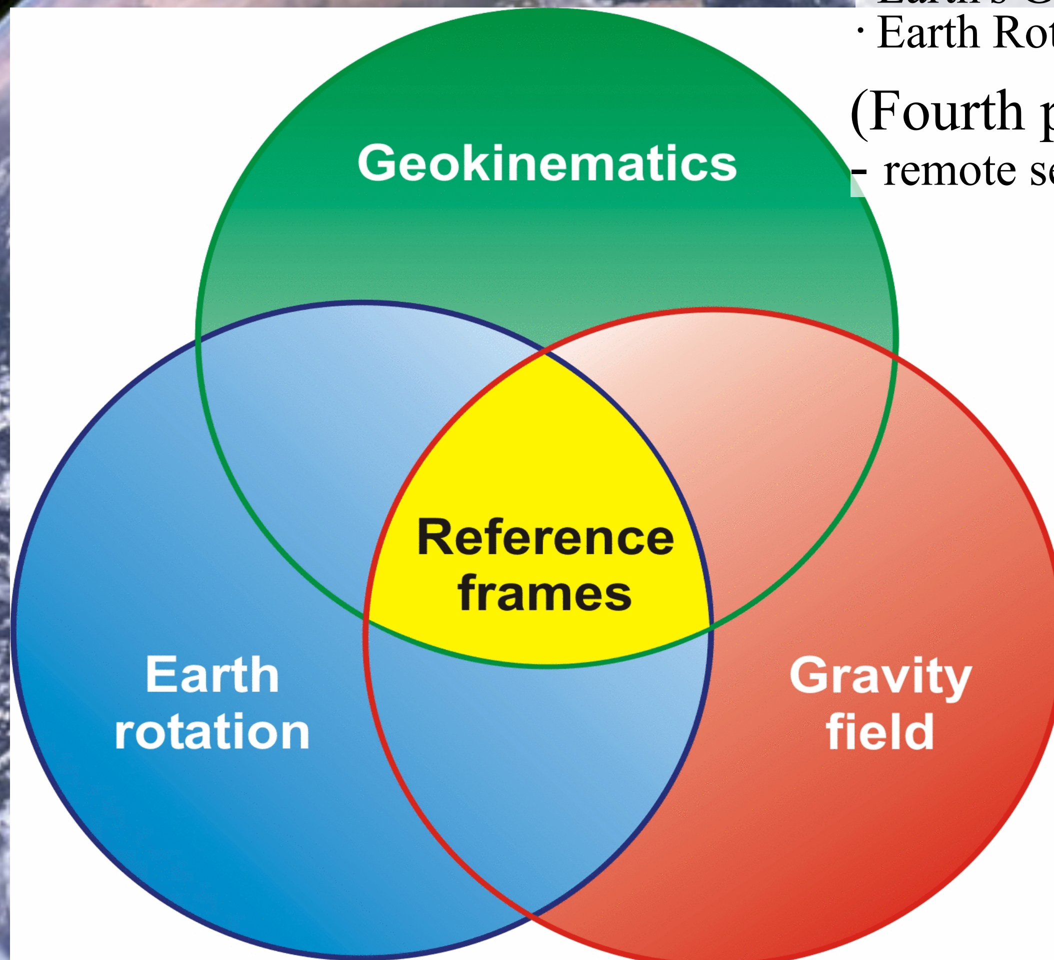
The 'three pillars of geodesy':
- Earth's Shape (Geokinematics)
- Earth's Gravity Field
- Earth Rotation



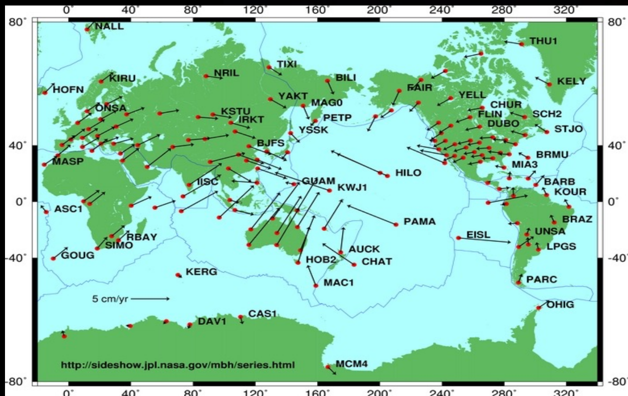
The Three Pillars of Geodesy

The 'three pillars of geodesy':
- Earth's Shape (Geokinematics)
- Earth's Gravity Field
- Earth Rotation

(Fourth pillar:
- remote sensing of the atmosphere)

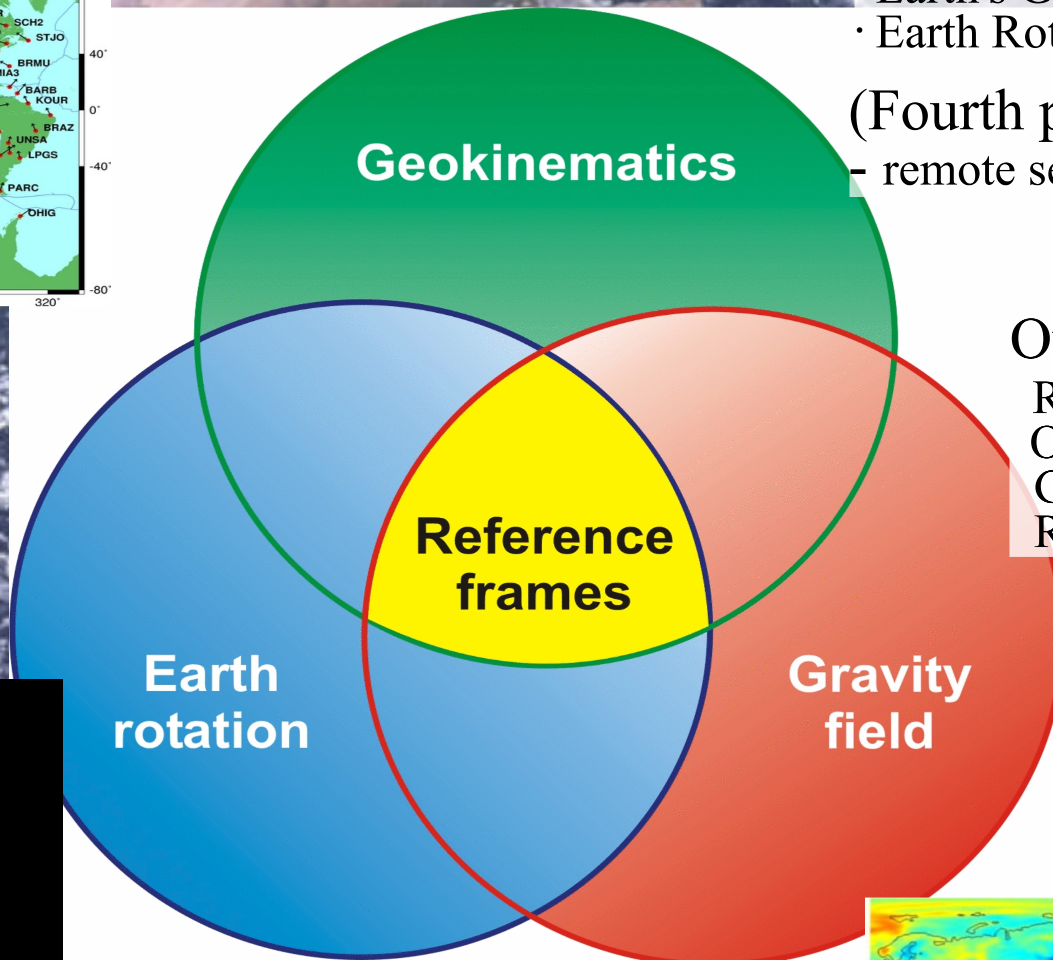


The Three Pillars of Geodesy

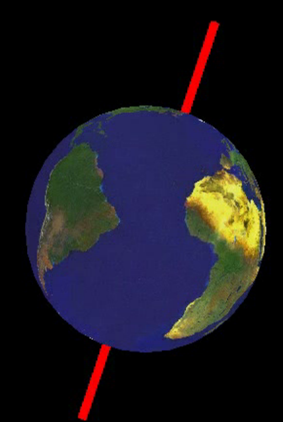


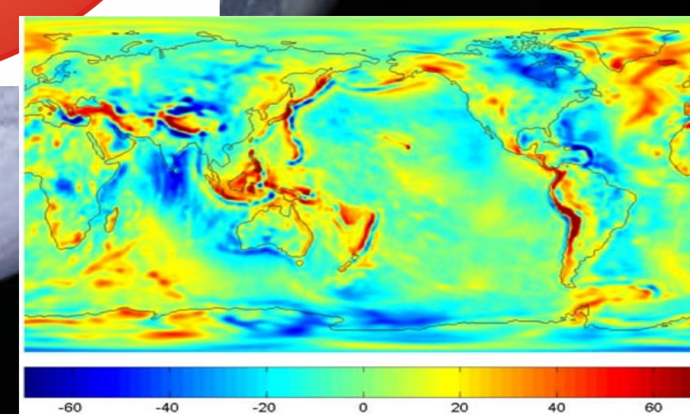
The 'three pillars of geodesy':
- Earth's Shape (Geokinematics)
- Earth's Gravity Field
- Earth Rotation

(Fourth pillar:
- remote sensing of the atmosphere)

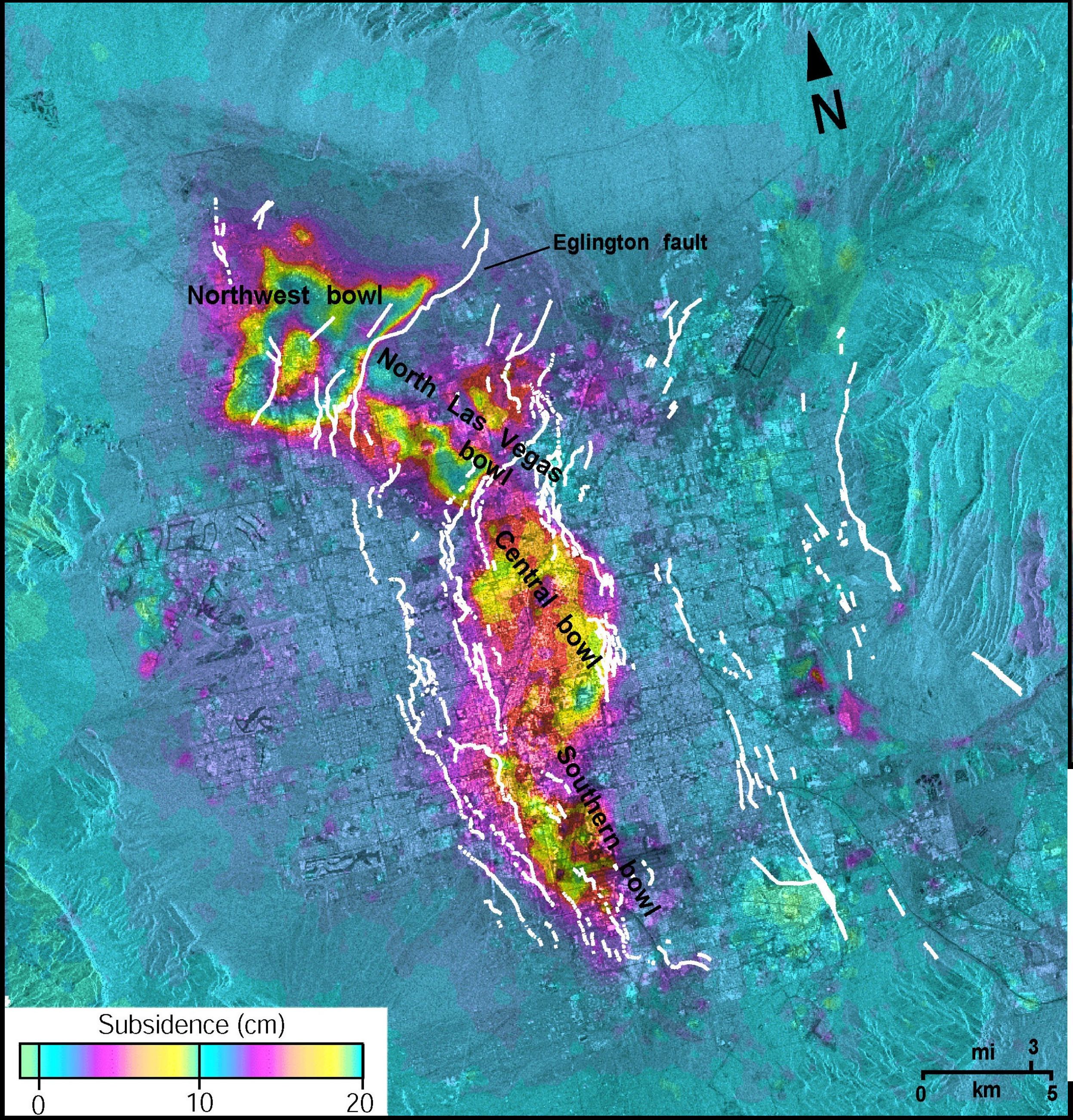


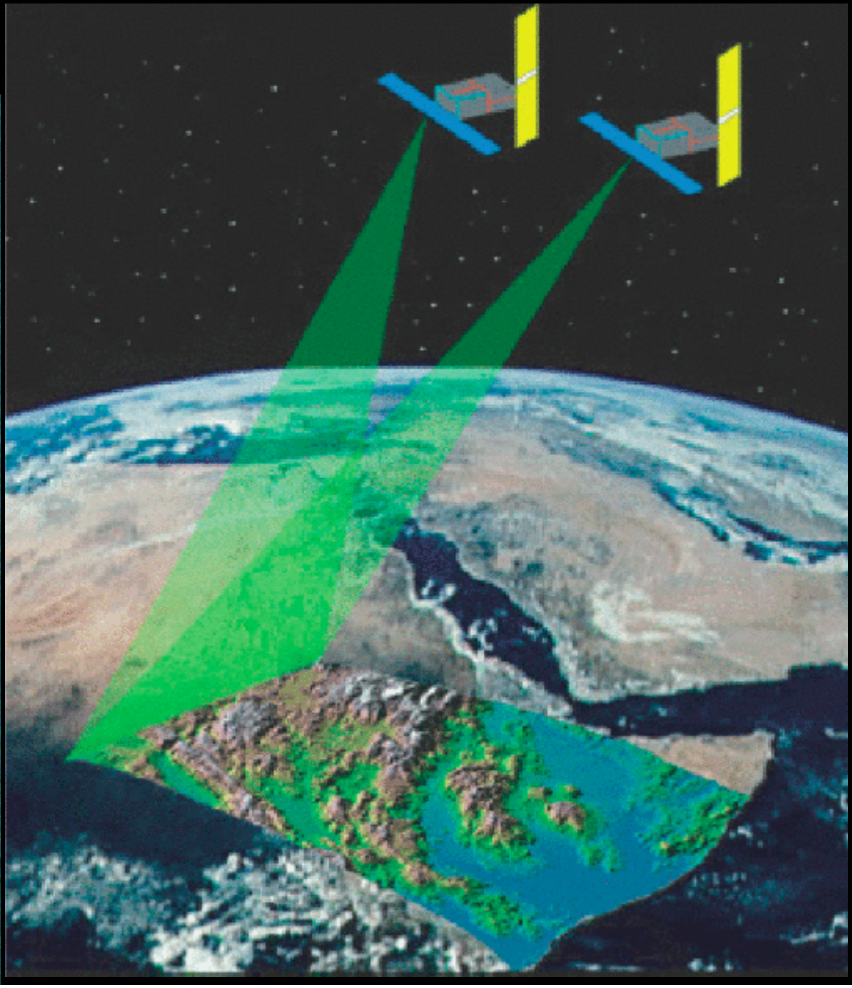
Output:
Reference Frame
Observations of the Shape, Gravitational Field and Rotation of the Earth





InSAR-Determined Surface Displacements





<u>Subsidence 1992-1997</u>

Four subsidence bowls

Aquifer system response strongly controlled by faults

Faults are subsidence barriers

Amelung et al., 1999

GRACE Measurement Principle

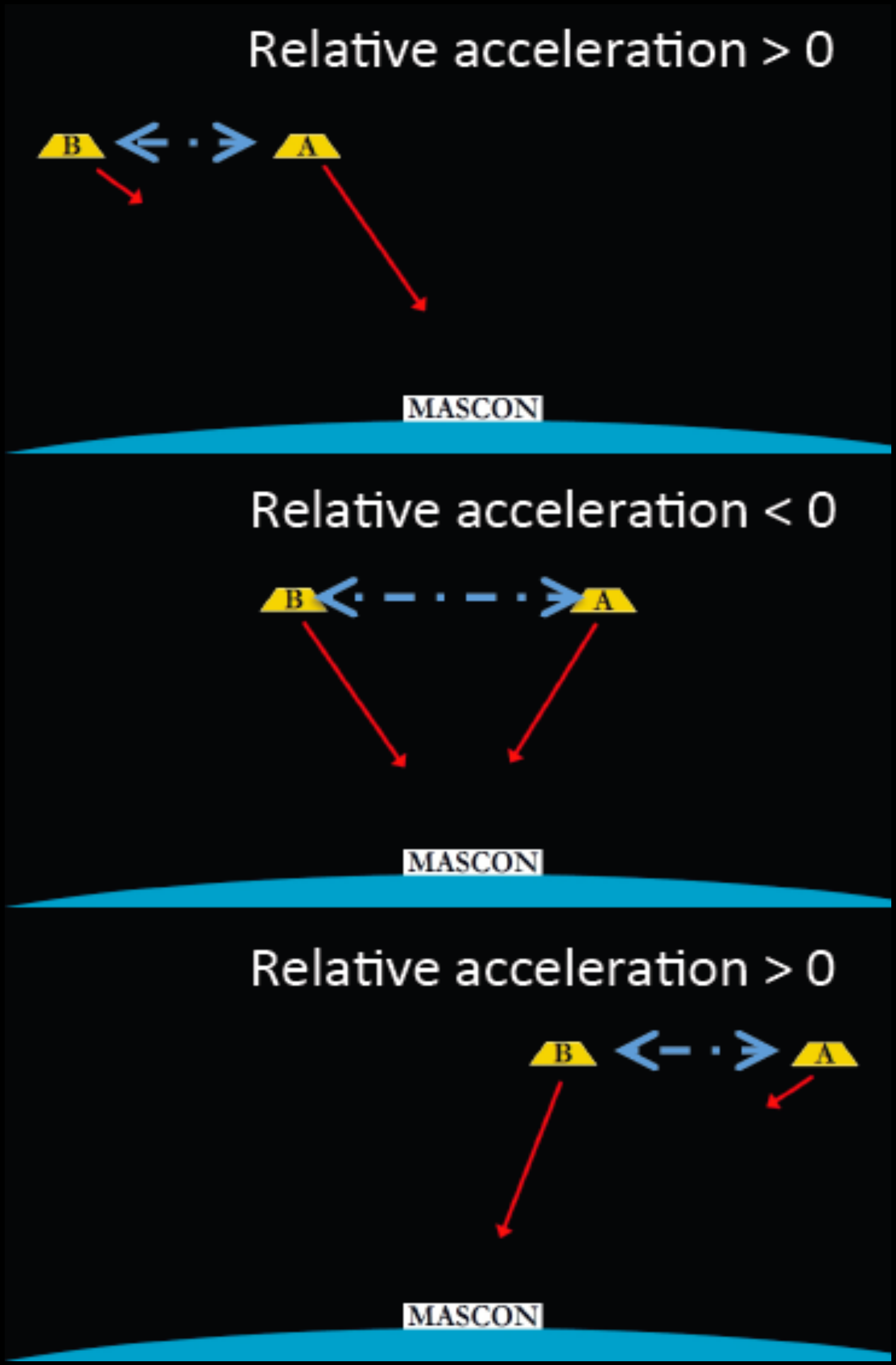
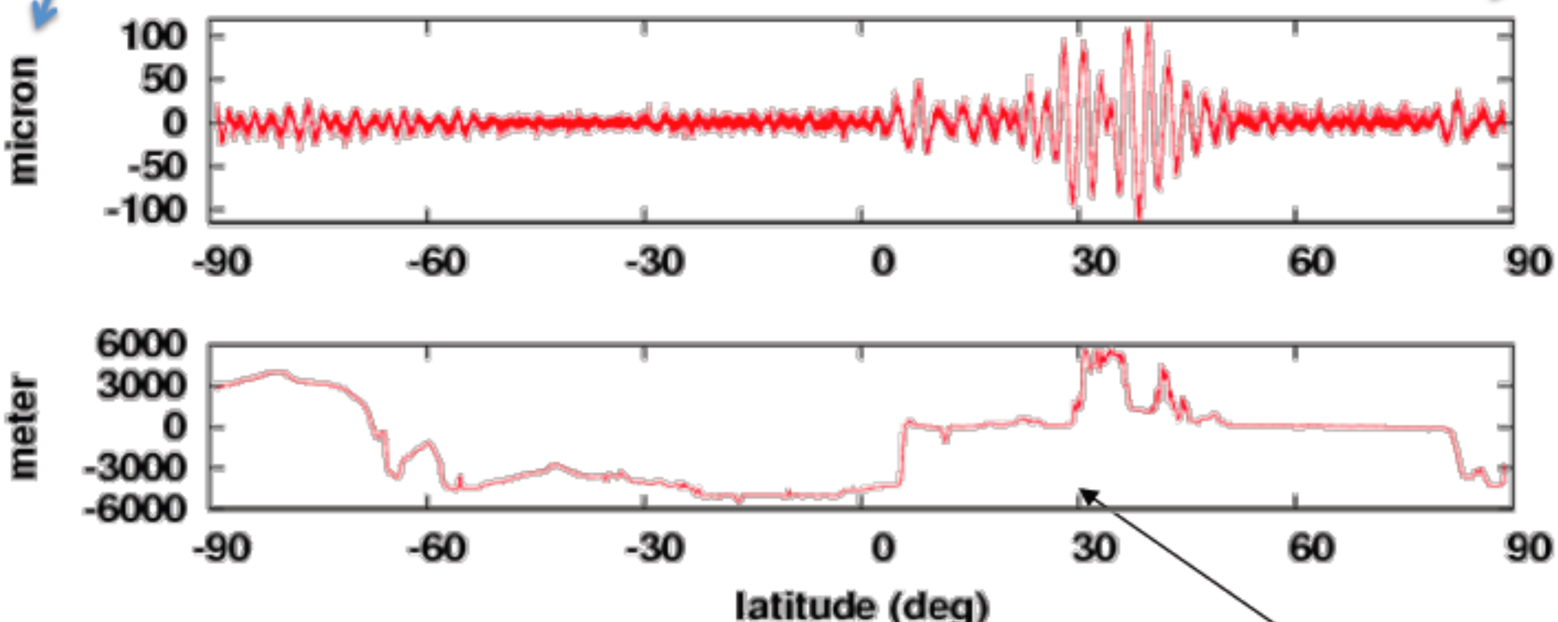


Figure by Brian Killett, JPL, USA

GRACE Measurement Principle

Note: the thickness of a human hair is ~50 micron!

Half-orbit from South to North Pole:



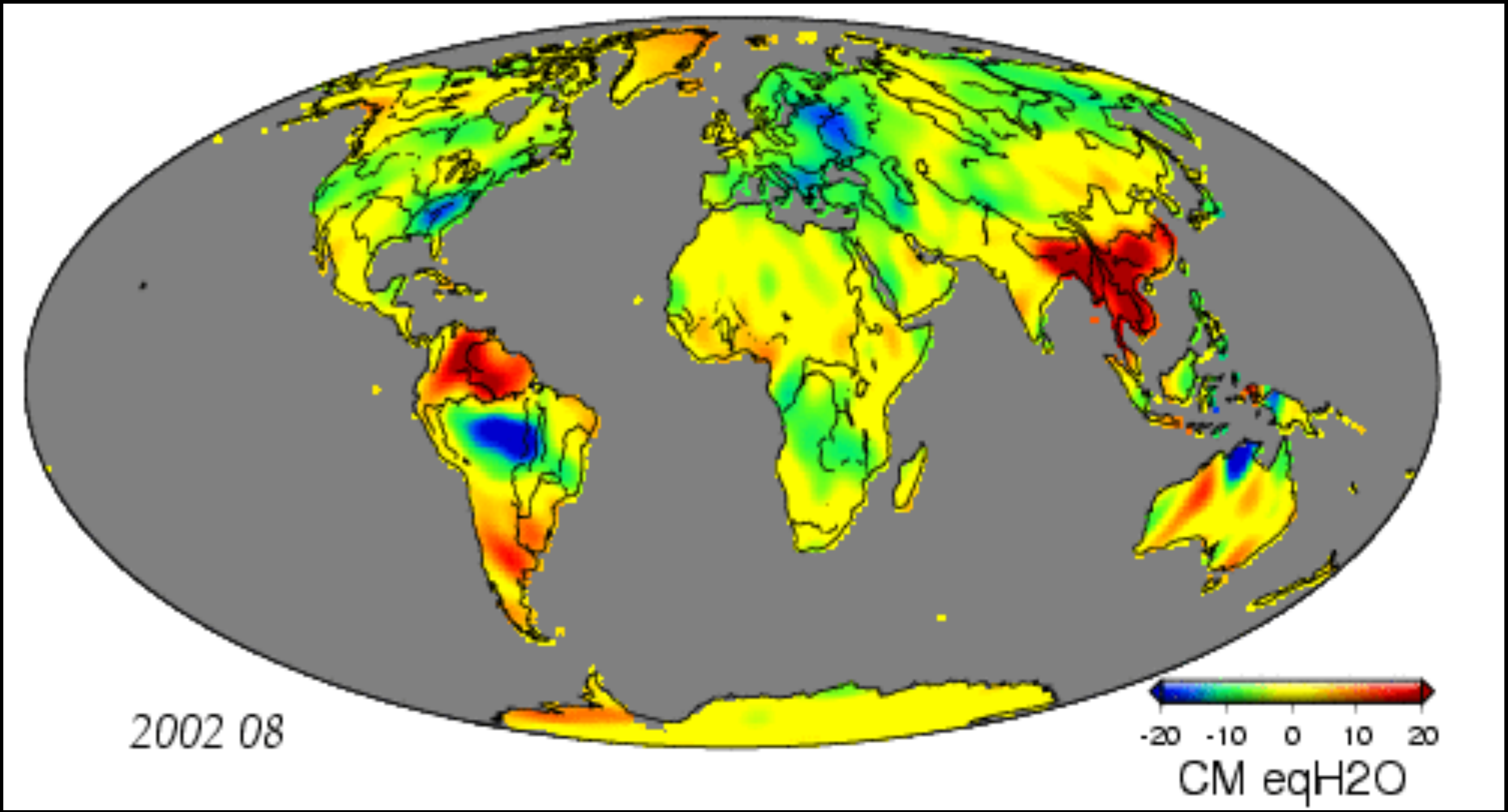
Distance variations between satellites Related to gravity

Topography Along Groundtrack

Himalayas

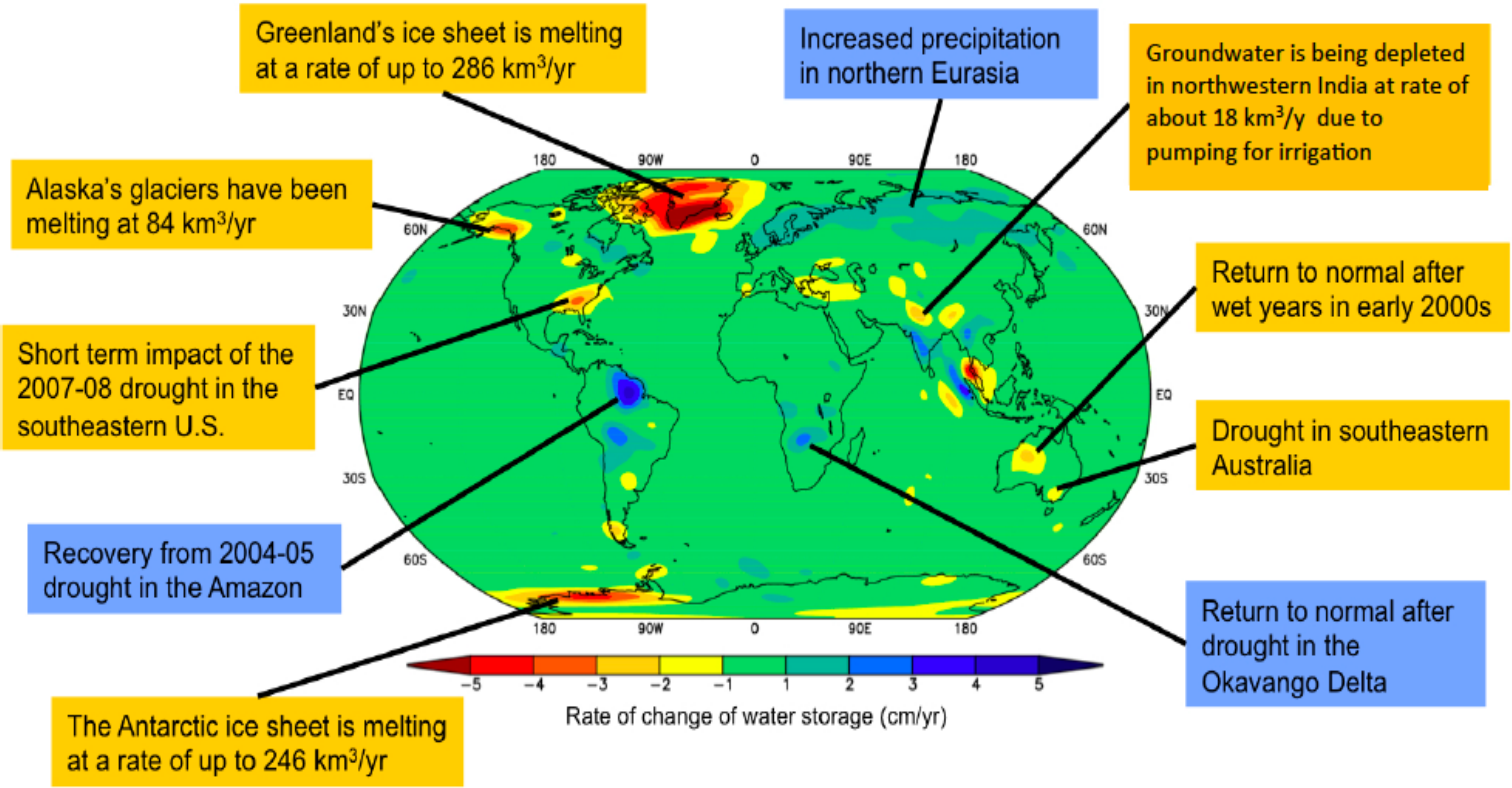
Gross et al., 2012

GRACE: Monthly Gravity Variations (2003-2008)



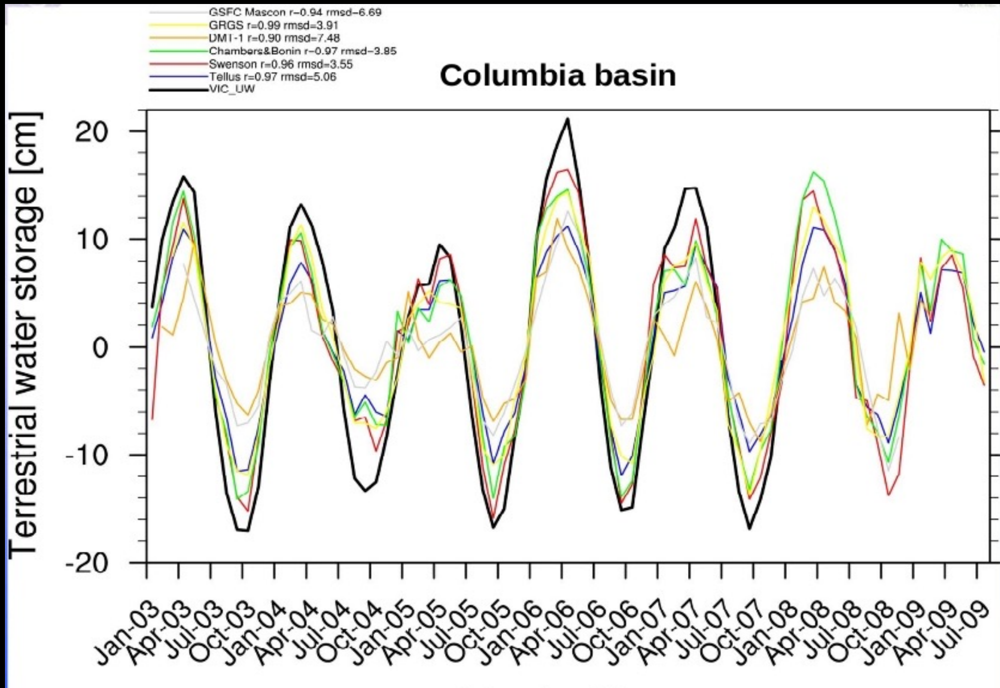
http://grace.jpl.nasa.gov/information/

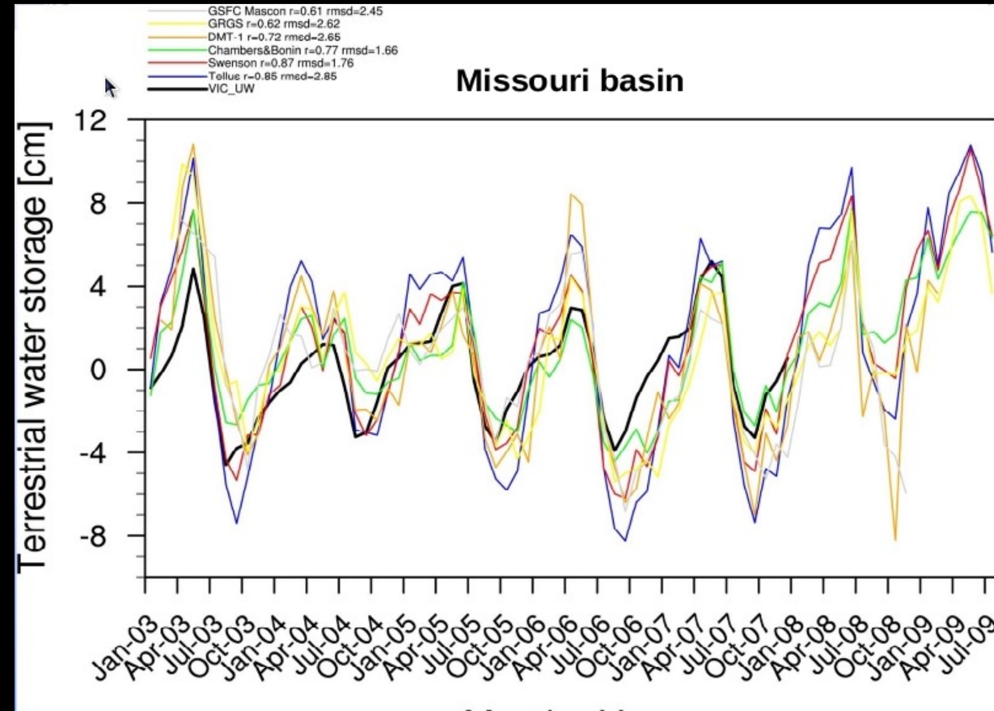
GRACE Secular Trends (2002-2010)

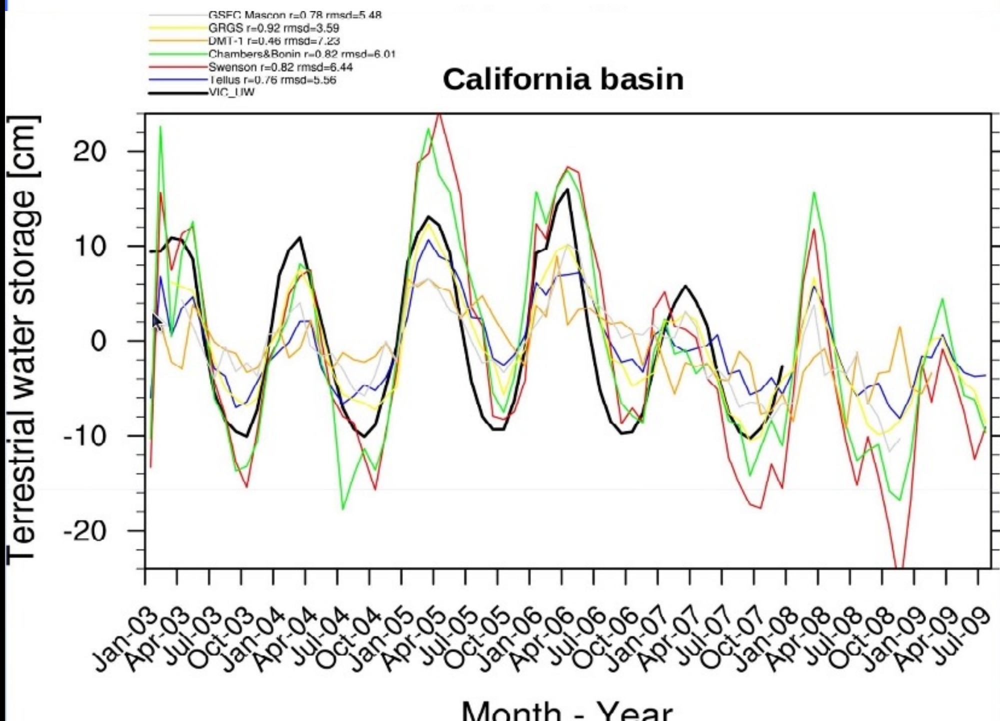


Gross et al., 2012

GRACE Hydrology Products Versus University of Washington Hydrology Data





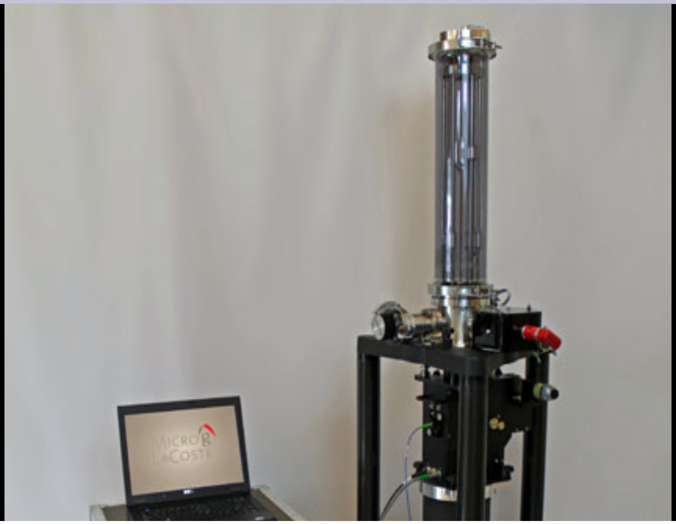


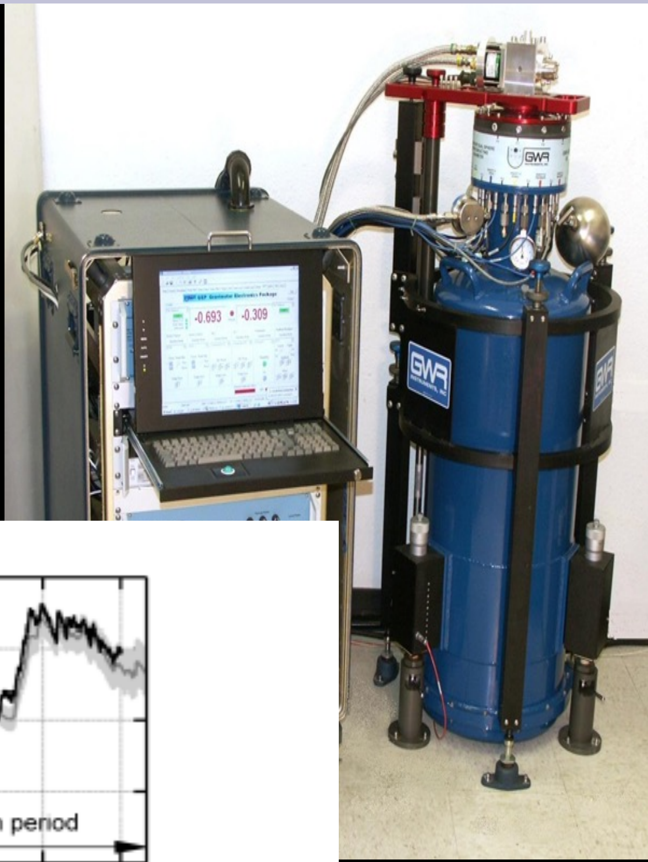
UW - GRACE	California		Columbia		Missouri	
	R	*RMS*	*R*	*RMS*	*R*	*RMS*
UW - Tellus	0.76	5.56	0.97	5.06	0.85	2.85
UW - Swenson	0.82	6.44	0.96	***3.55***	***0.87***	1.76
UW - DMT-1	0.46	7.23	0.90	7.48	0.72	2.65
UW - GSFC Mascon	0.78	5.48	0.94	6.69	0.61	2.45
UW - Chambers&Bonin	0.82	6.01	0.97	3.85	0.77	***1.66***
UW - GRGS	***0.92***	***3.59***	***0.99***	3.91	0.62	2.62

Rodell et al., 2010

Absolute and Relative Gravimetry (in situ)

Absolute and Relative Gravimetry (in situ)





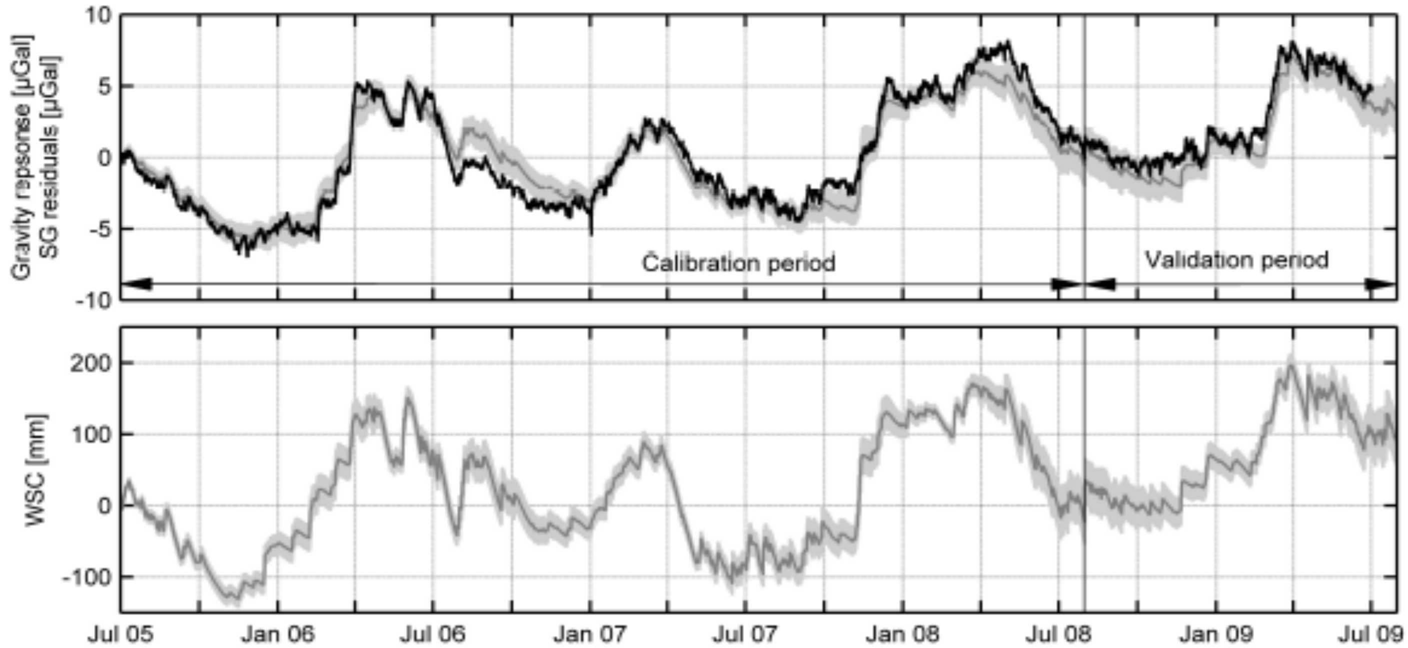
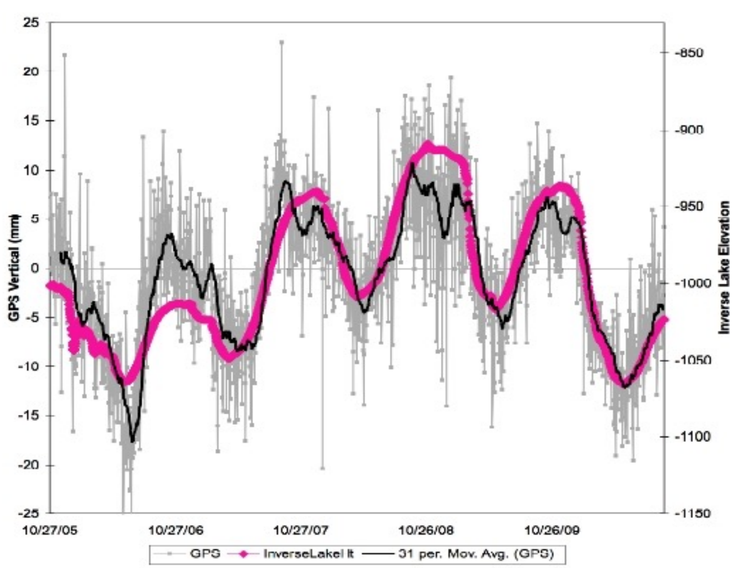


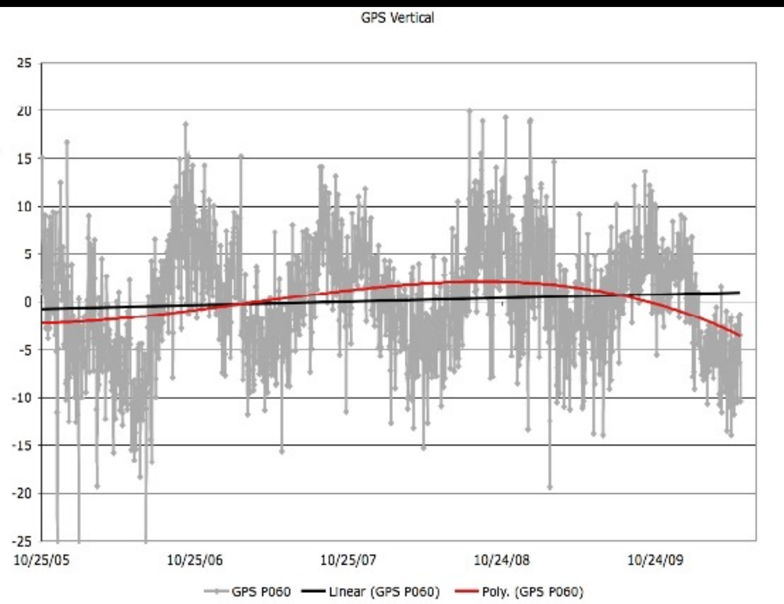
Fig. 7. SG residuals (black line) and modelled gravity response (grey band) (top). Modelled water storage change (bottom). The model was calibrated against the SG residuals for the period of 1 July 2005 to 30 July 2008.

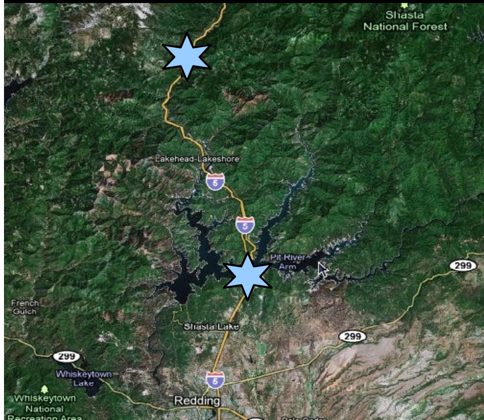
Creutzfeldt et al., 2010

GPS-Determined Surface Displacements

P349: Close to Lake Shasta, California:
affected by lake loading
P060: Further away from Lake Shasta:
Not affected by lake loading; but effects of subsurface loading

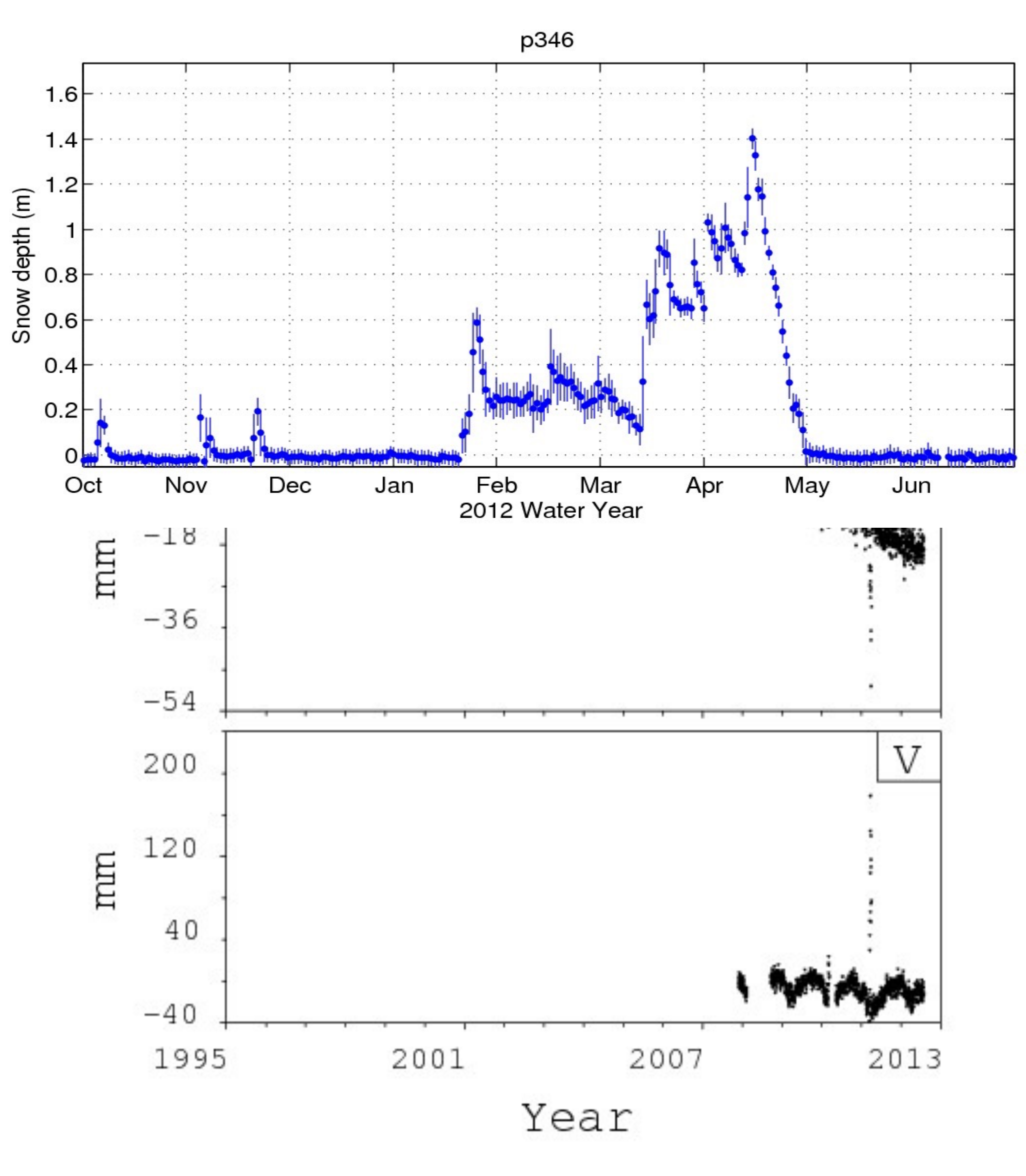


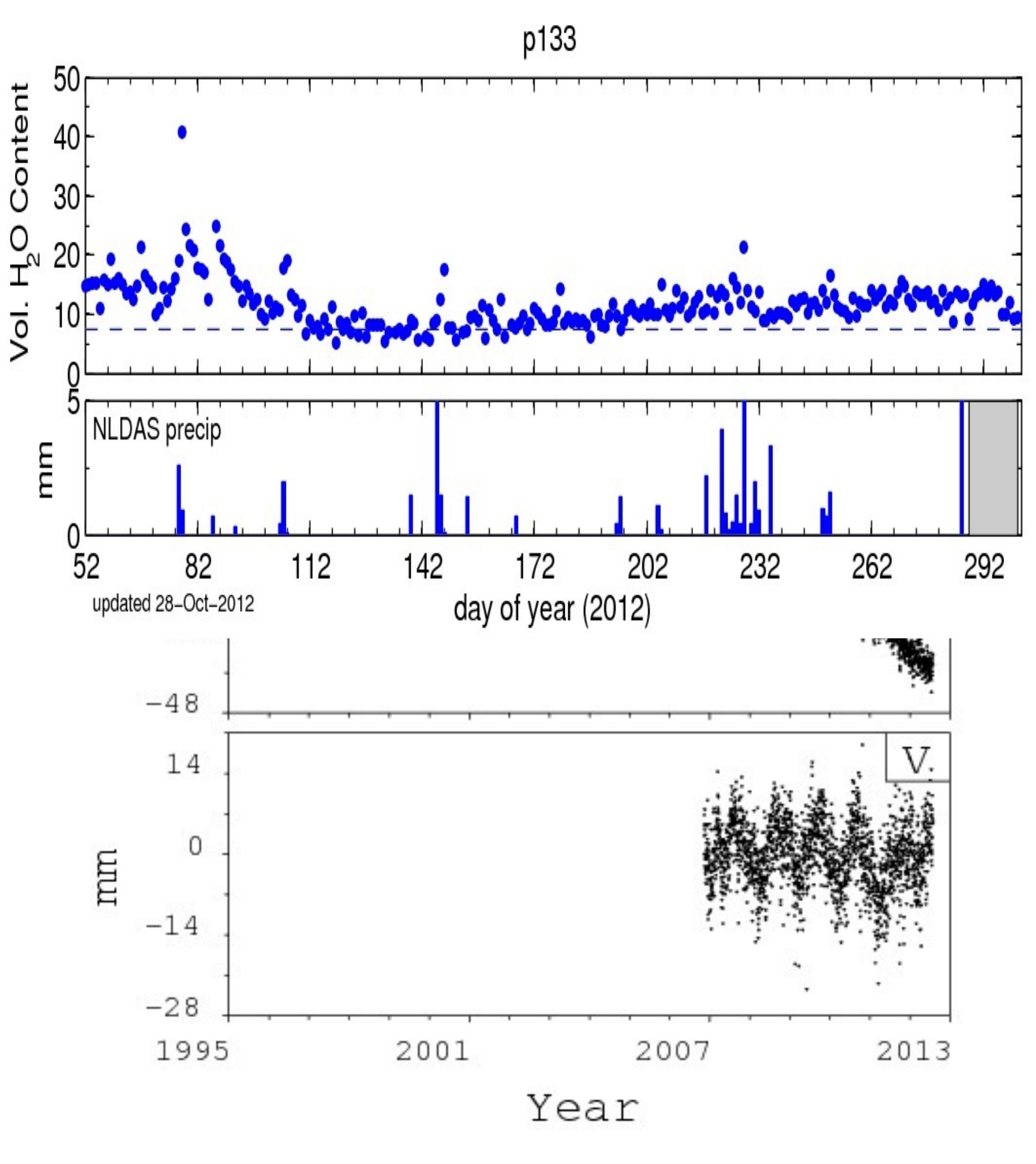




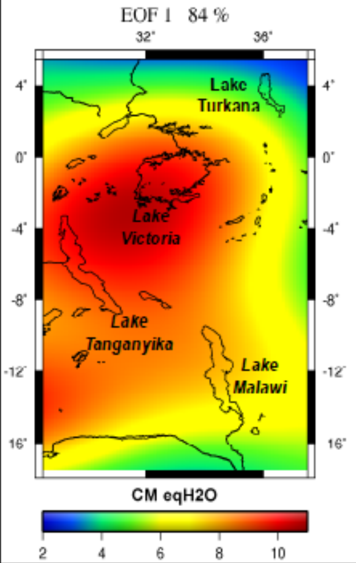
GPS Multipath: Snow Depth and Soil Moisture

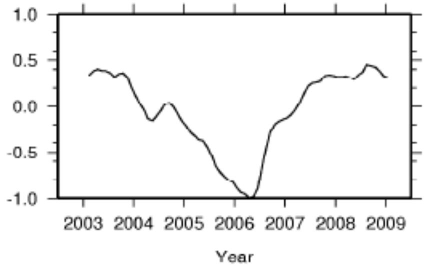
P346: California, Sierra Nevada, alpine area, 2039.4 m
P133: Nevada, open shrubland, 1782 m





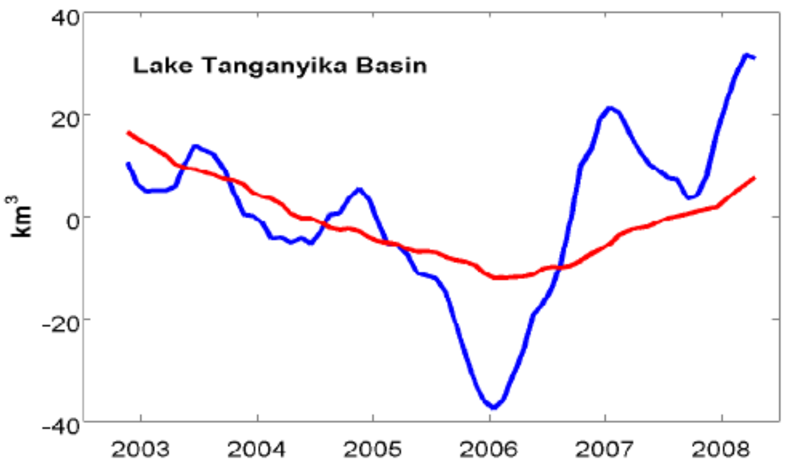
Combination of Techniques: GRACE and Satellite Altimetry



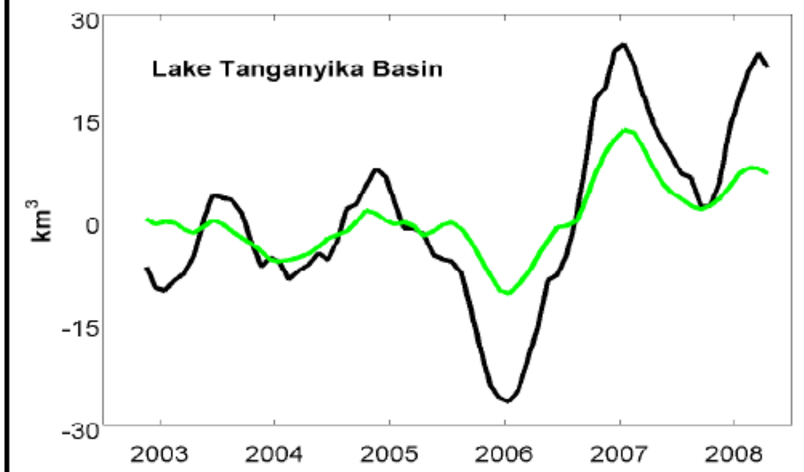


Inter-annual pattern of water storage variations in the East-African lake region based on a statistical analysis (EOF decomposition) of GRACE data.

Hydrology:
Seasonal and interannual changes in land-water storage



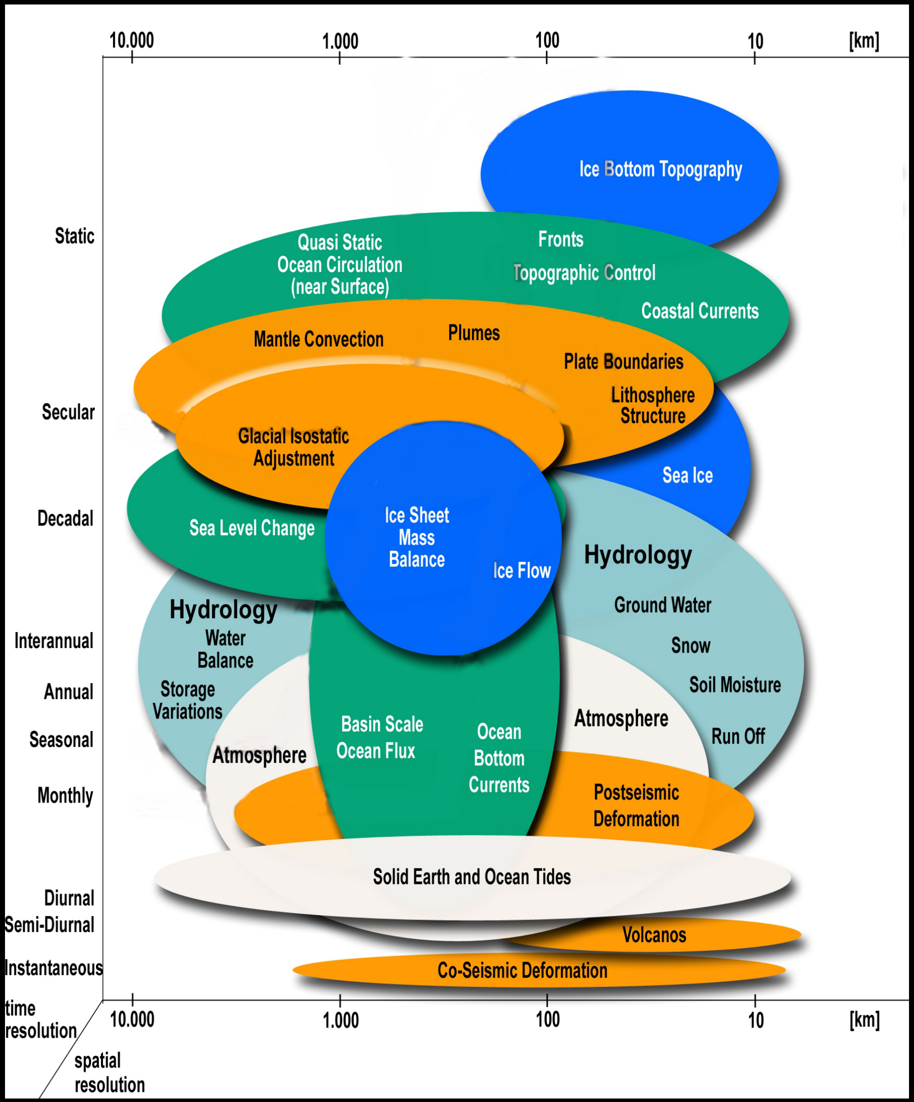
Total water storage from GRACE for the catchment of Lake Tanganyika (blue) and lake water storage from altimetry (red).



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

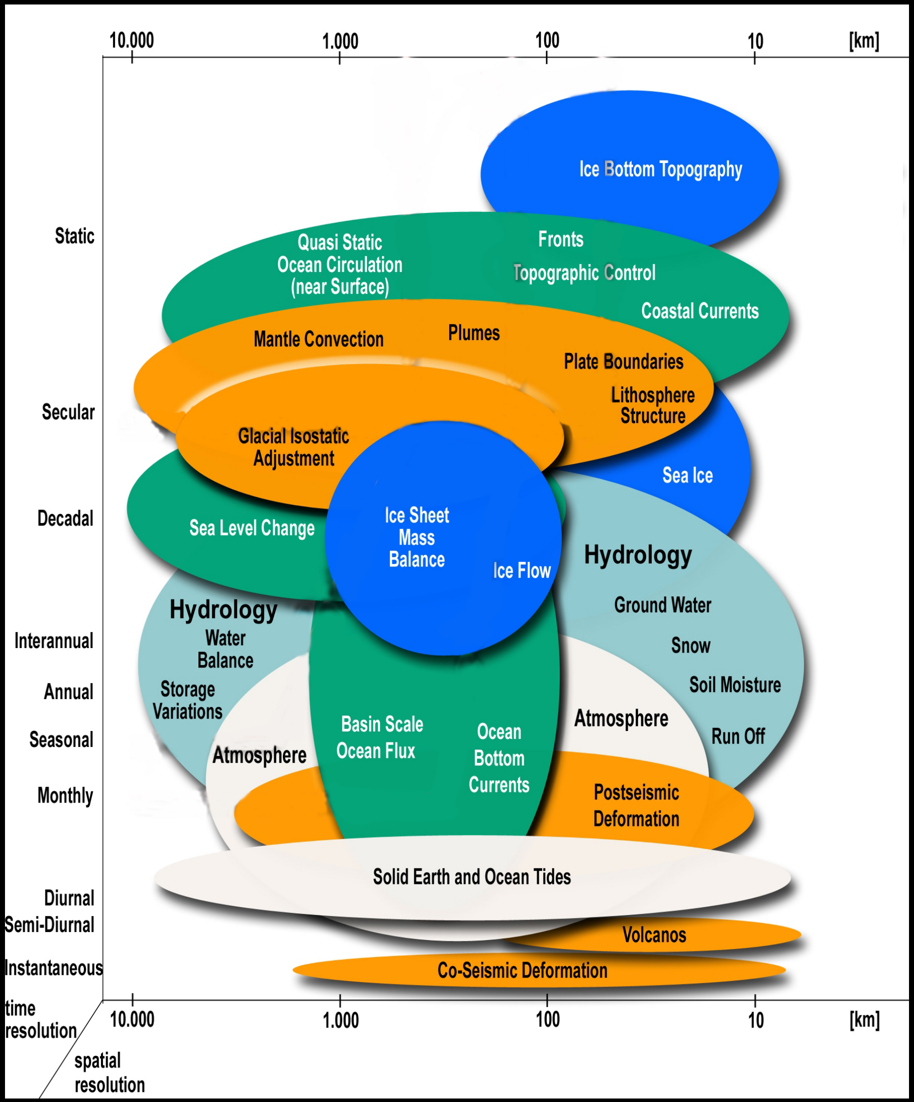
Application



Geodetic observation techniques capture signals of many processes overlapping in spatial and temporal scales.

Modified from Ilk et al. (2005).

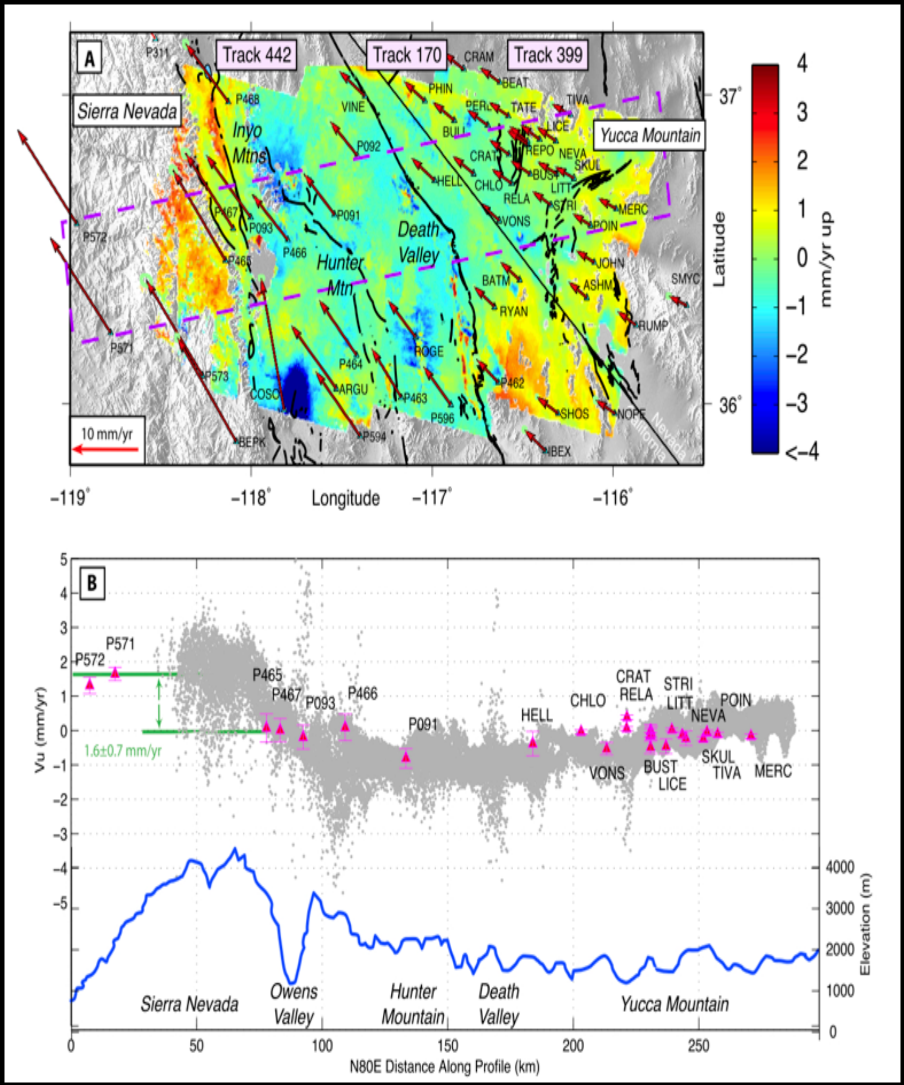
Application



Geodetic observation techniques capture signals of many processes overlapping in spatial and temporal scales.

Modified from Ilk et al. (2005).

CASE STUDY: SIERRA NEVADA UPLIFT



Hammond et al, 2012: *Present-day uplift of Sierra Nevada: 1 to 2 mm/yr*

What are the forcing processes?

Hydrogeodesy Summary

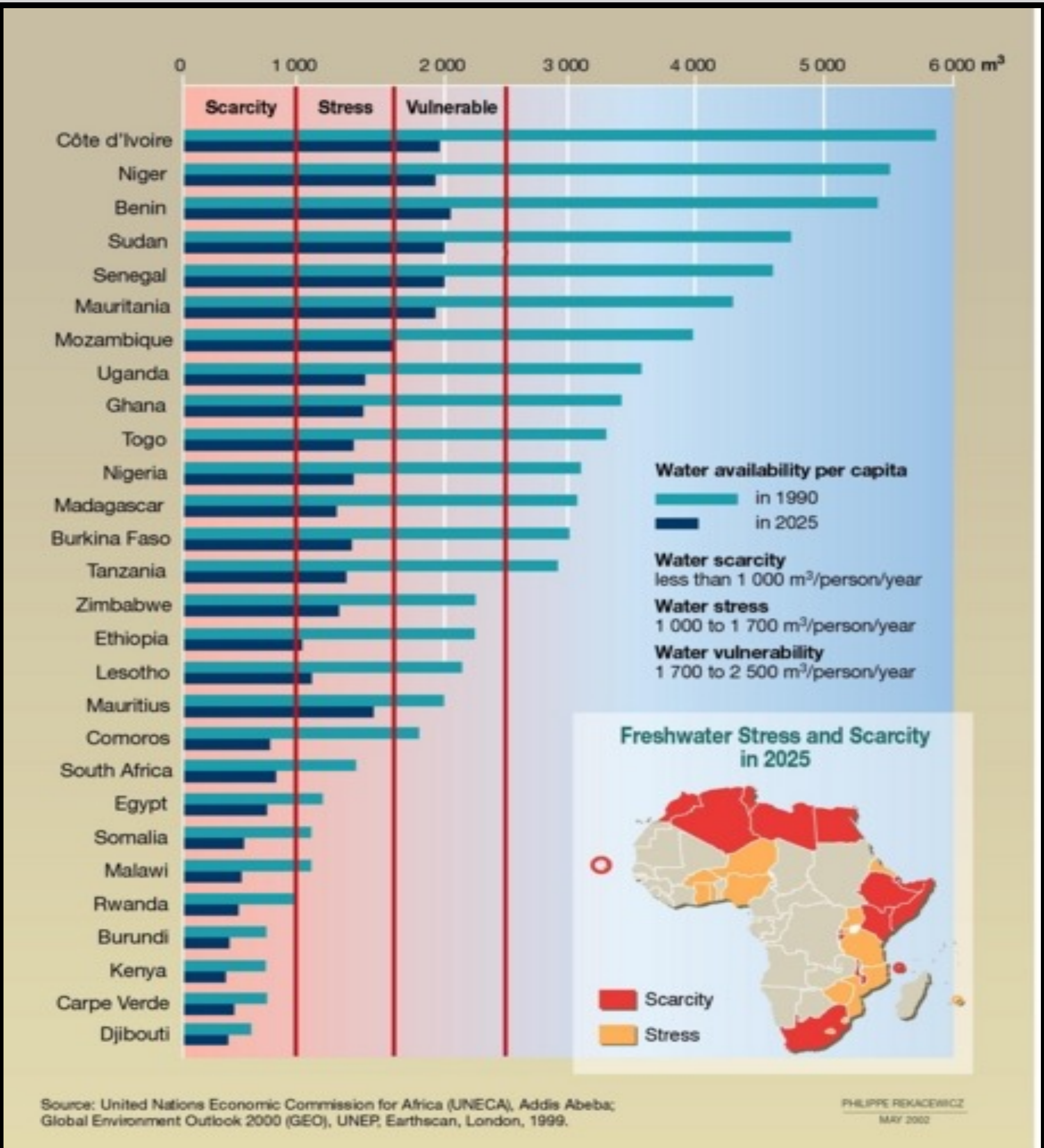
Time-variability in the “three pillars of geodesy” is observed with a portfolio of geodetic techniques:

- point-geodetic methods,
- surface imaging techniques for land, ice and ocean surfaces,
- (emerging reflectometry),
- in situ and space-borne gravity sensors.

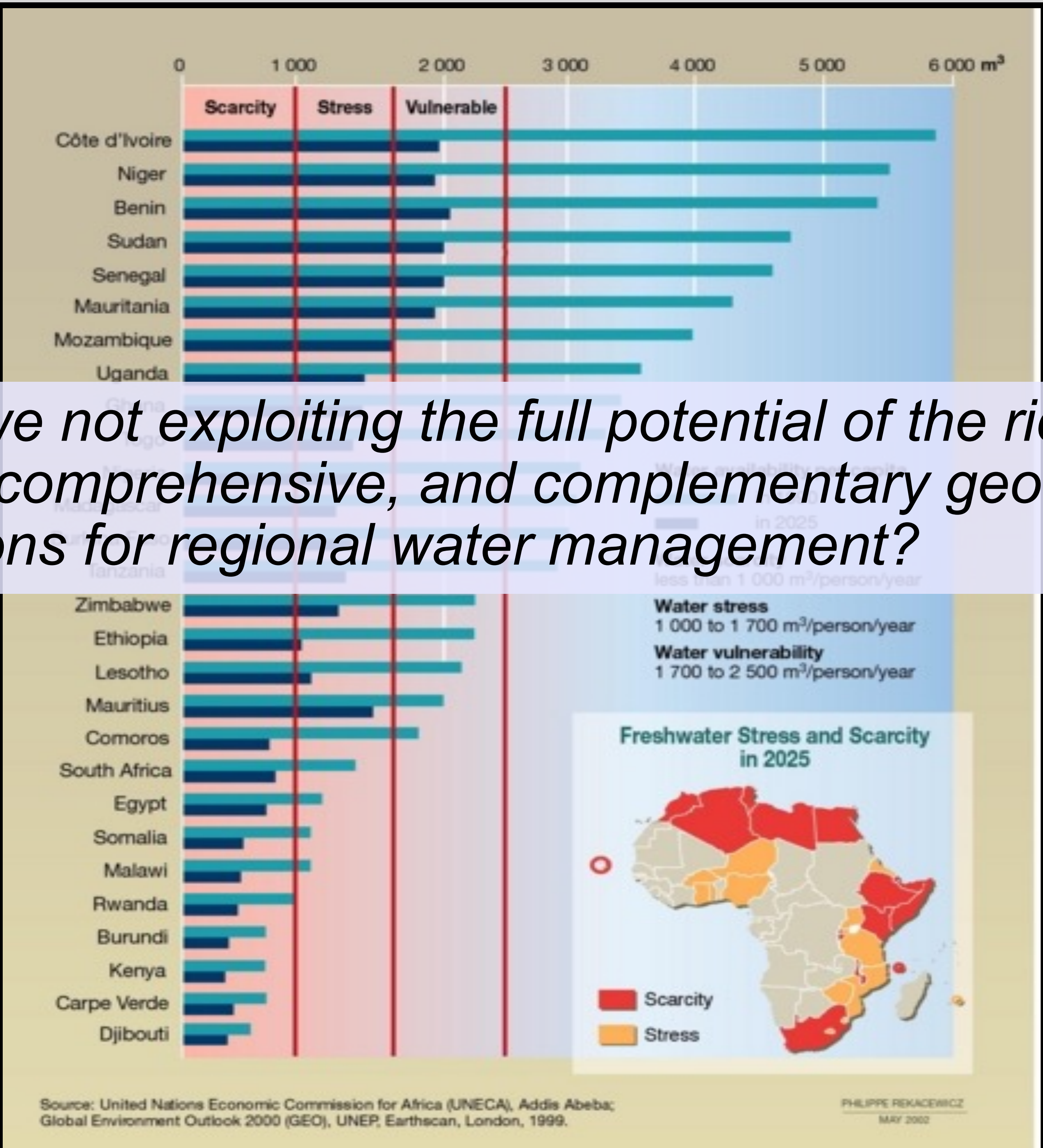
All techniques capture signals of the same, unique Earth system but have different sensitivities in terms of spatial and temporal scales.

Many physical processes in the Earth system impact geodetic observations on wide and overlapping ranges of spatial and temporal scales.

Societal Benefits



Societal Benefits



Why are we not exploiting the full potential of the rich, accurate, comprehensive, and complementary geodetic observations for regional water management?

Obstacles

The (rapidly improving) accuracy of the geodetic observations increasingly requires an interdisciplinary integrated Earth system approach to the analysis of the observations.

Challenge to (small) research groups:
- integrated use of multiple geodetic techniques
- wide range of expertise in system modeling

The fundamental link between the different observations – the Earth system producing the signals - is not yet widely explored in geodesy.

Even within one of the pillars, focus is often on one aspect of the Earth system (a tectonic process, atmospheric loading, ocean loading, hydrological loading, ...)

Tools and products easy-to-use for water managers are not available: No science-decisionmaking interface

TOWARDS A WORKBENCH FOR GEODESY

A comprehensive geodesy workbench would:
• serve the broad geodetic community
• support the integration of the three pillars of geodesy.

The workbench could be developed following the example of other community-based modeling frameworks:
• Community Surface Dynamics Modeling System (CSDMS),
• Global Earthquake Model (GEM),
• emerging community ice model systems (Lipscomb et al., 2009).

Workbench would constitute a cyber infrastructure:
•globally available with global participation
•building the tools, ensuring appropriate standardization and interoperability.

TOWARDS A WORKBENCH FOR GEODESY

Components and Benefits of a community-built, web-based (virtual) workbench for geodesy include:

Components:
- data archive(s) for observations in the three pillars;
- data analysis tools (software);
- data analysis results (time series, grids, ...);
- integrated modeling software;
- model predictions.

Benefits:
- standardization, interoperability, data assimilation;
- joint analyses in an interdisciplinary context;
- support local and regional studies, access to expertise;
- framework for community products;
- global availability (capacity building);
- significant impact on education.