# A Unique Reference Frame: Basis of the Global Geodetic Observing System (GGOS) for Geodynamics and Global Change

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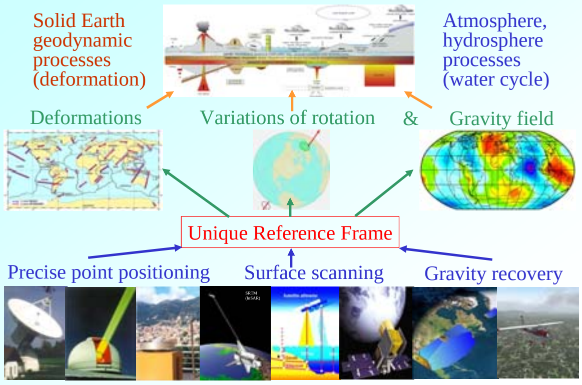
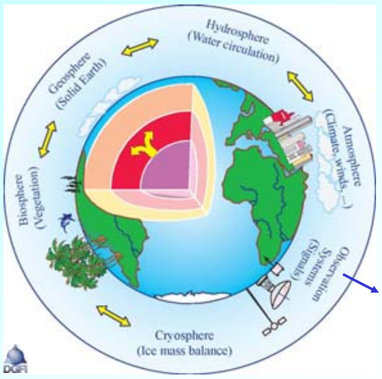
## Global Change and the Geodetic Observing System




## System Earth Elements and Interactions



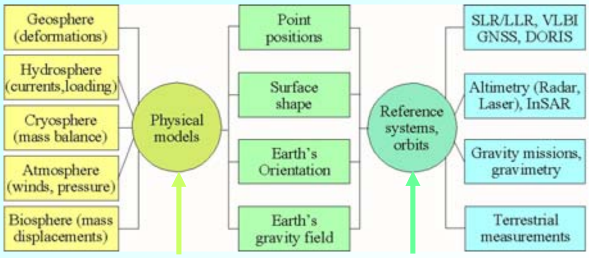

Geodynamics and global change are the processes within and between all elements of the System Earth:

- (solid) Geosphere
- (fluid) Hydrosphere
- (gas) Atmosphere
- (frozen) Cryosphere
- (living) Biosphere

Geodetic observations reflect the effects of the processes‘ signals.



## System Earth Signals and Geodetic Parameters




The signals to be observed are extremely small (sub-millimetre level). Realistic physical models and consistent geodetic reference systems are fundamental requirements for monitoring System Earth processes.

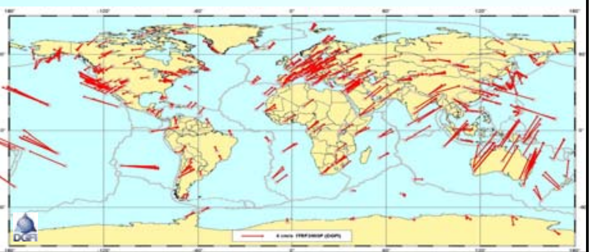


## Realization of Reference Systems by Reference Frames

Reference frames define to which basic parameters geodetic values (positions, velocities, gravity, ...) refer in space and time evolution.

Any change of a status refers to a kinematic reference frame: Nothing is fixed (*panta rei),* a reference motion **must be defined**.

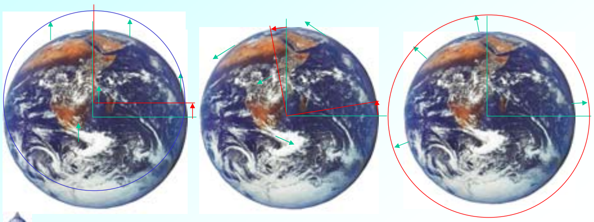
Station velocities are the basis for the description of global change.



## Importance of Time Dependent Reference Frames

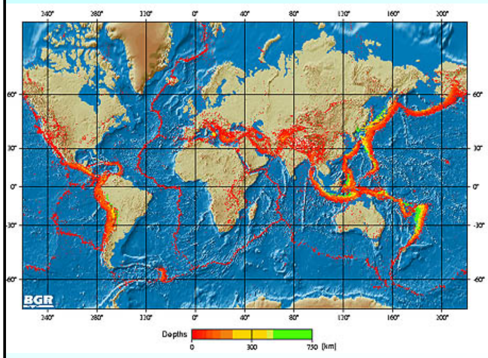
Station velocities in the geometric reference frame (ITRF) provide the reference for the quantification of any change of positions.

They are highly correlated with variations of geodetic datum parameters: origin, orientation, scale of the coordinate systems.



The kinematic reference frame has to be established carefully !

## 1. Monitoring *Solid Earth* Deformation: Earthquake Research




Earthquakes occur mainly in boundary zones of the lithospheric plates, where accumulated stress is released.

**Geometric** observations measure the actual strain.

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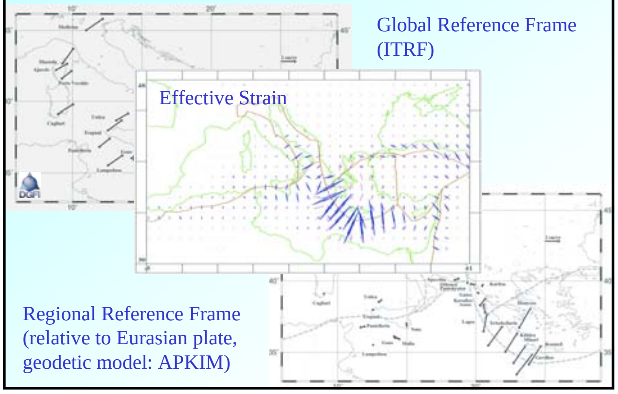
## Example: Mediterranean Orogene

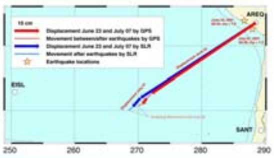
Global Reference Frame (ITRF)




Regional Reference Frame (relative to Eurasian plate, geodetic model: APKIM)

## Monitoring Pre-Seismic and Post-Seismic Strain


Arequipa Earthquake 2001
~ 50 cm horizontal co-seismic displacement on June 23



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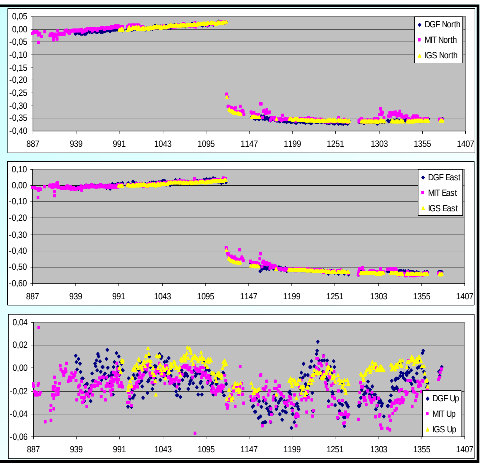
## Precursors in Geodetic Monitoring ?

Co-seismic displacement & non-linear post-seismic movements

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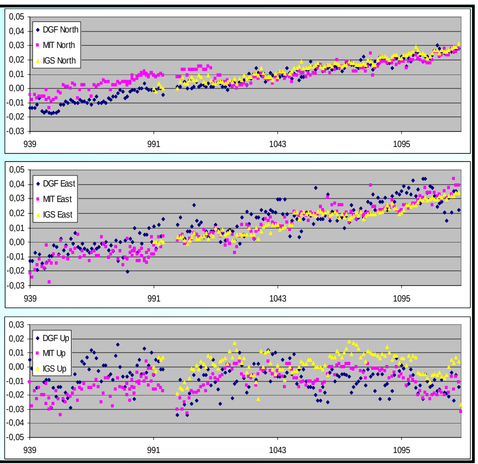
## Precursors in Geodetic Monitoring ?

Non uniform behaviour of time series in little different reference frames

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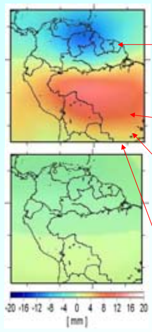
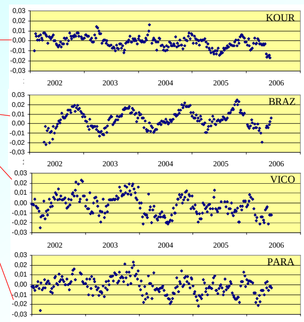
## 2. Monitoring *Solid Earth* Deformation: Hydrology

- Gravimetric observations (GRACE geoid) reflect mass displacements
- Geometric observations (GPS) measure height variations

Geoid
April 2003

Geoid
Sept. 2003



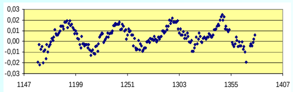



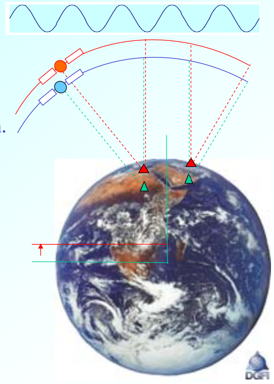
## Effect of the Reference Frame on Satellite Orbits

Satellite orbits are determined in the reference frame in which the tracking stations are given.

Non modelled effects of the reference frame enter into the orbit determination.

If they are periodic, the orbits are periodically distorted, too.



Station position and gravity field variations, if derived from orbits, reflect the orbit errors.

## 3. Monitoring the *Ocean Surface* by Satellite Altimetry

Monitoring sea surface changes by satellite altimetry is based on distance measurements from a **known** orbit.

Orbits are determined from tracking stations with coordinates in the terrestrial **reference frame**.

The accuracy of the orbit and thus of the sea surface depends on the stability and reliability of the **reference frame**.

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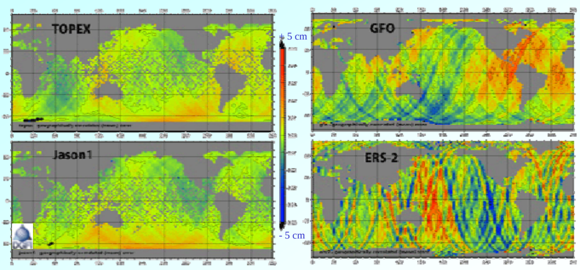
## Effect of Orbit Errors on Sea Surface Estimates




Geographic correlated (mean) errors of TOPEX,Jason1,GFO, and ERS-2 visible only as result of a **multi-mission cross calibration**. If not taken into account these errors propagate sea level estimates.

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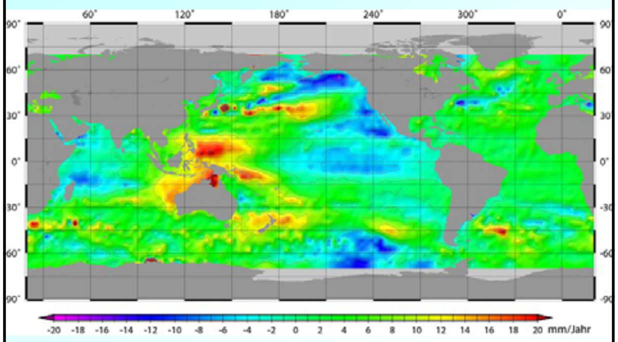
## Secular Sea Surface Change from Satellite Altimetry




How to determine „mean" sea level change ?

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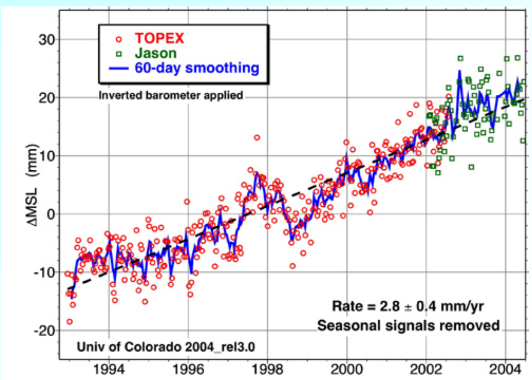
## Mean Sea Level Change from Satellite Altimetry

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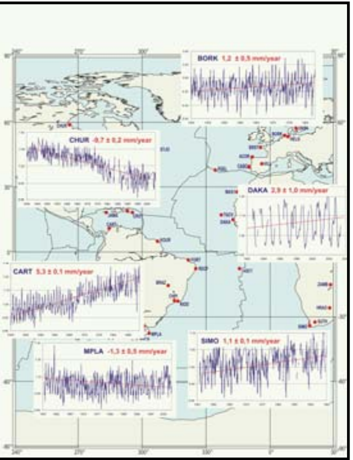
## 4. Monitoring *Sea Level Variations* from Tide Gauges

The traditional way of sea level monitoring is tide gauge registration.

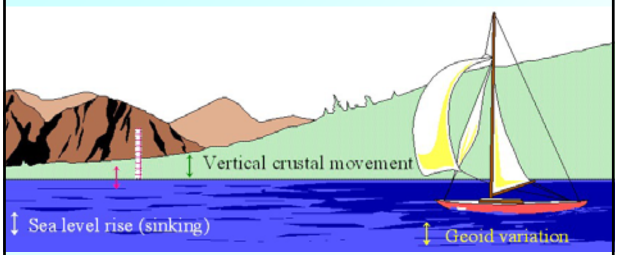
DGFI Network within the IGS TIGA Project (Tide Gauge Monitoring)

## Sea Level Variations from Tide Gauges

Tide gauge registrations show quite different sea level changes, ranging from –9.7 mm/year to +5.3 mm/year in the western Atlantic.



## Causes of Variations in Tide Gauge Records




Consequences: - Monitoring vertical crustal movements by GNSS (change of the **reference frame**)
- Determination of geoid variations by gravity missions

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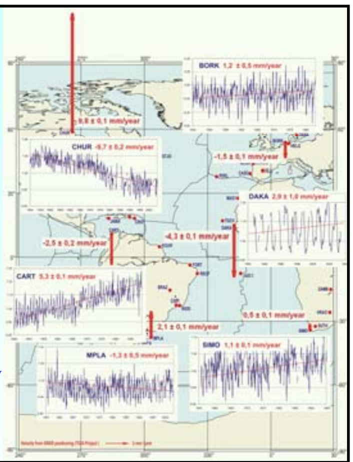
## Sea Level Variations from Tide Gauges

Sea level change is the sum of tide gauge records and vertical crustal movement:

BORK 1.2 – 1.5 = -0.3 mm/a
CHUR -9.7 + 9.8 = 0.1 mm/a
DAKA 2.9 – 4.3 = -1.4 mm/a
CART 5.3 – 2.5 = 2.8 mm/a
SIMO 1.1 + 0.5 = 1.6 mm/a
MPLA -1.3 + 2.1 = 0.8 mm/a

Only the combination of tide gauge records and sat. altimetry provides reliable results.

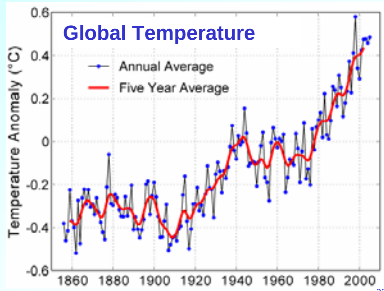


## 5. Monitoring Global Warming of the *Atmosphere*

One of the most discussed effects of Global Change is warming of the atmosphere and the Earth's surface ("greenhouse effect").

There is a dramatic change from 1910 to 1940 and from 1975 to present in global temperature.

Causes for the greenhouse effect are discussed quite controversially.

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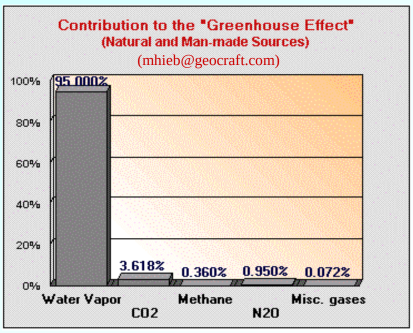
## Contributions to the Greenhouse Effect

95 % are caused by the water vapour of the atmosphere

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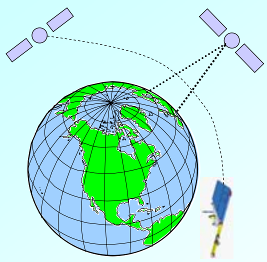
## Geodetic observation of the Water Vapour



1. **Ground-based** GNSS atmosphere sounding: Water vapour estimation from ground networks
2. **Space-based** GNSS atmosphere sounding: Occultation observations between satellites.

http://www.gfz-potsdam.de

**Principle:** To measure the time delay (refractivity) of GNSS signals between **known** ground or satellite positions, respectively.

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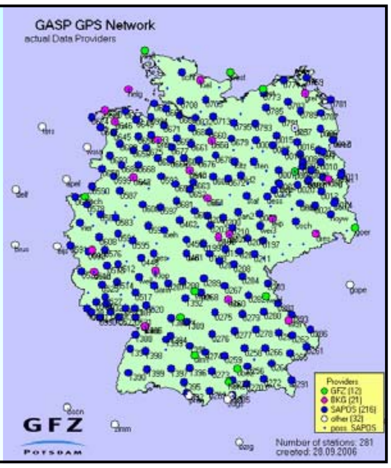
## Atmosphere Sounding

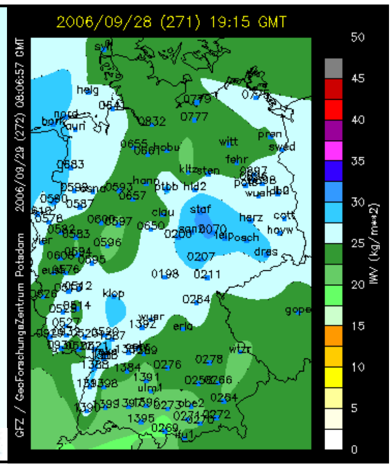
**German Network:**

- Satellite Positioning System (SAPOS)®
- Bundesamt für Kartographie und Geodäsie (BKG)
- GeoForschungs-Zentrum Potsdam (GFZ)
- Neighbouring Countries



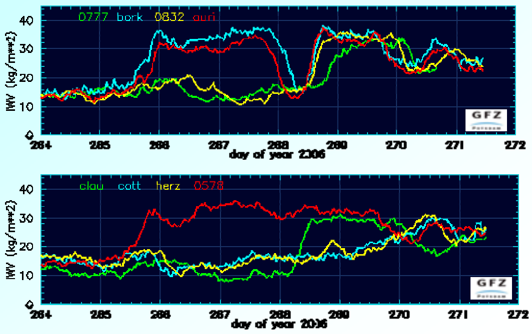

## Atmosphere Sounding

**Hourly near real time integrated water vapour (IWP) estimates (GFZ)**




## Atmosphere Sounding: Stations‘ Time Series

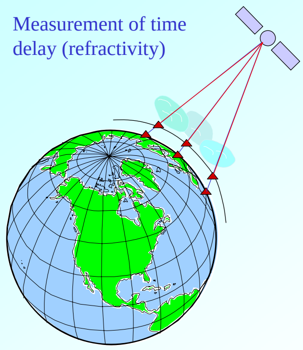
Common trends in time series of IWV may indicate global change






## Atmosphere Sounding: Effects of Reference Frames

Measurement of time delay (refractivity)



Non-modelled motions of reference stations or of the complete frame falsify the measurement of the time delay.

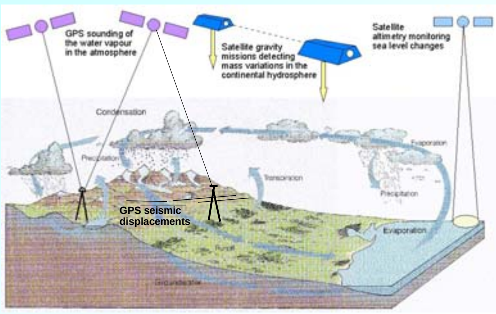
This is problematic, in particular in long-time monitoring (decades).

Reference frames with long-term kinematic stability (over decades) are the fundamental requirement.



## Conclusions

The Geodetic Observing System is capable to monitor geodynamic and global change processes, including the complete water cycle.






## Conclusions (continued)

- In order to detect the very small signals (millimetre in position changes and tenth of milligals in gravity changes) a highly stable and consistent unique reference frame is required.
- The stability of the reference frame has to be guaranteed over long time intervals (decades).
- The realization of such demanding reference frame has to be done by combining all geodetic observations from positioning techniques (SLR, VLBI, GPS, DORIS) and gravity missions (ENVISAT, GFO, JASON, ICESAT, CRYOSAT, GRACE, GOCE, ...) in order to be consistent in geometry and gravity.
- Sophisticated processing and analysis methods have to be applied for the accurate and reliable representation of geodetic results for global change research.


www.astronomie.is4u.de
Thank you !