Global Geodetic Observing System (GGOS) and Climate Change

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Questions

- What is GGOS?
- What is Climate Change?
- What does this have to do with us?

From IPCC 2014 glossary

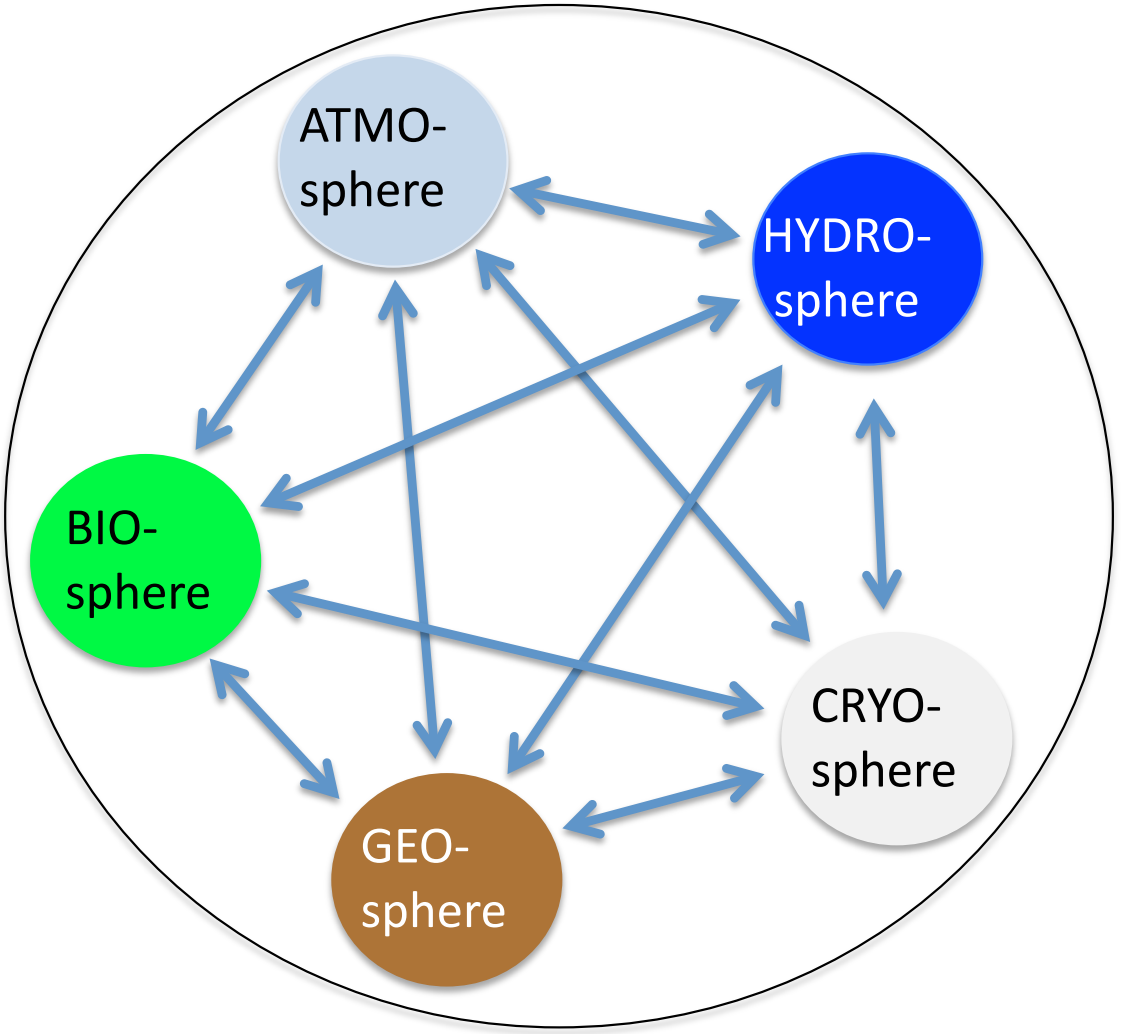
Climate

- "Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system."

Climate system

- "The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land-use change."

System Earth – a climate system

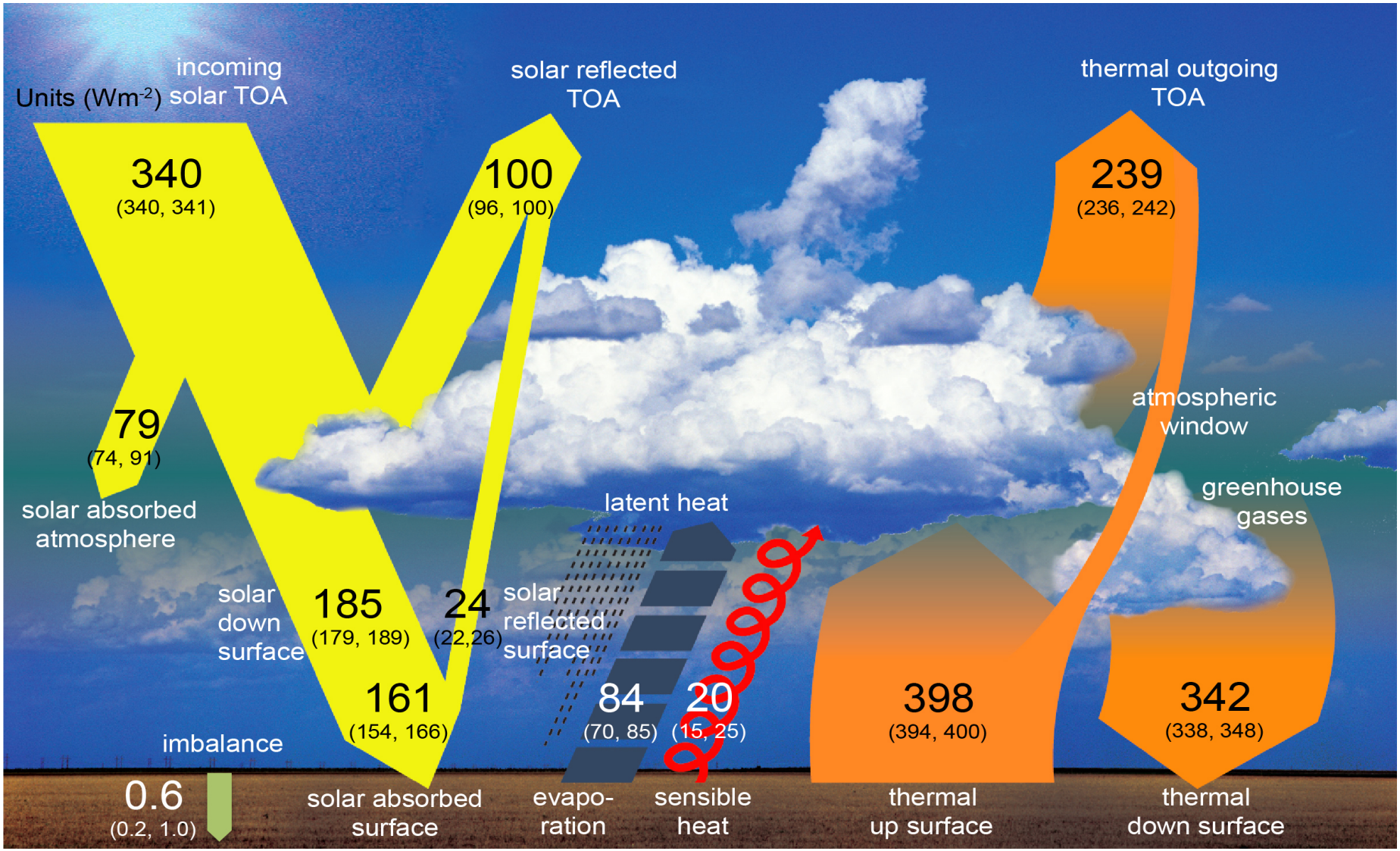


From IPCC 2014 glossary

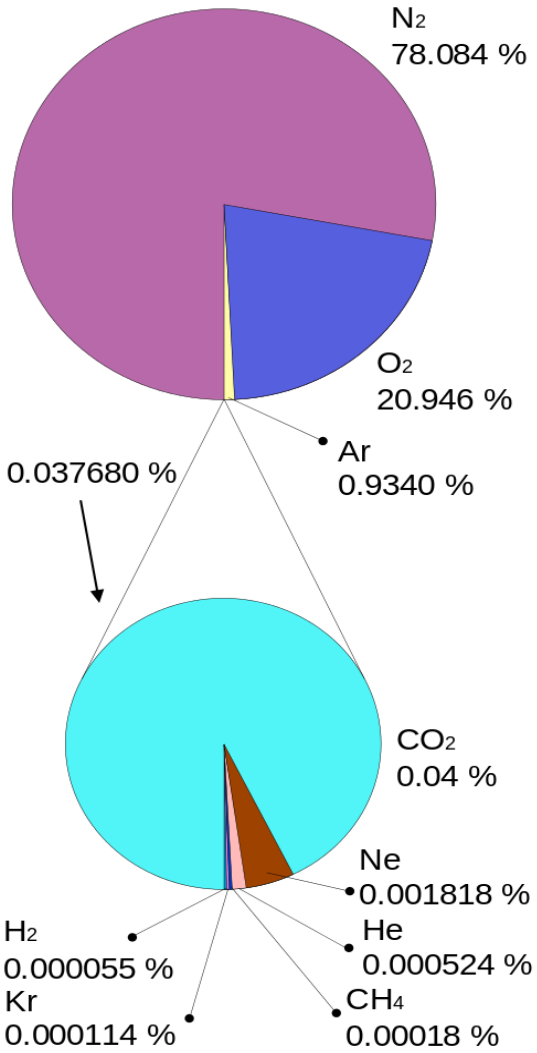
Climate change

- "Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. See also Detection and Attribution."

The Earth's energy balance

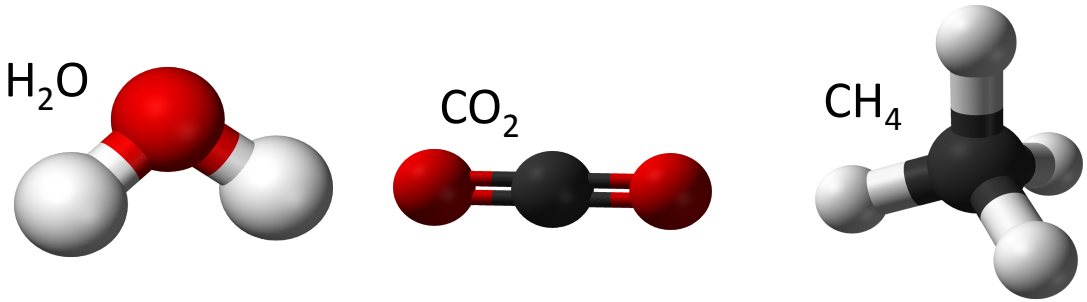


Composition of the atmosphere



The composition of the atmosphere controls to a large extend temperature in the system earth. Via the so-called ”greenhouse gases”

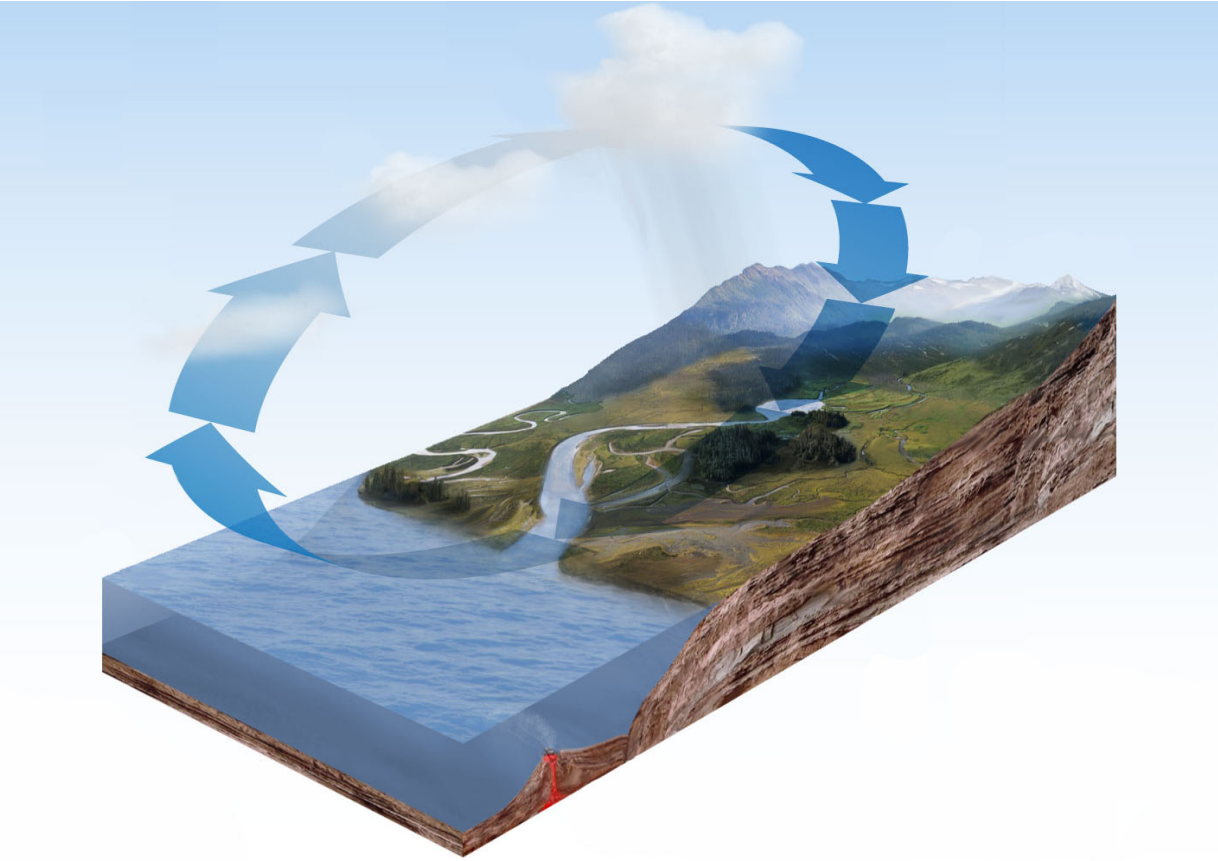
The most important ”Greenhouse gases”



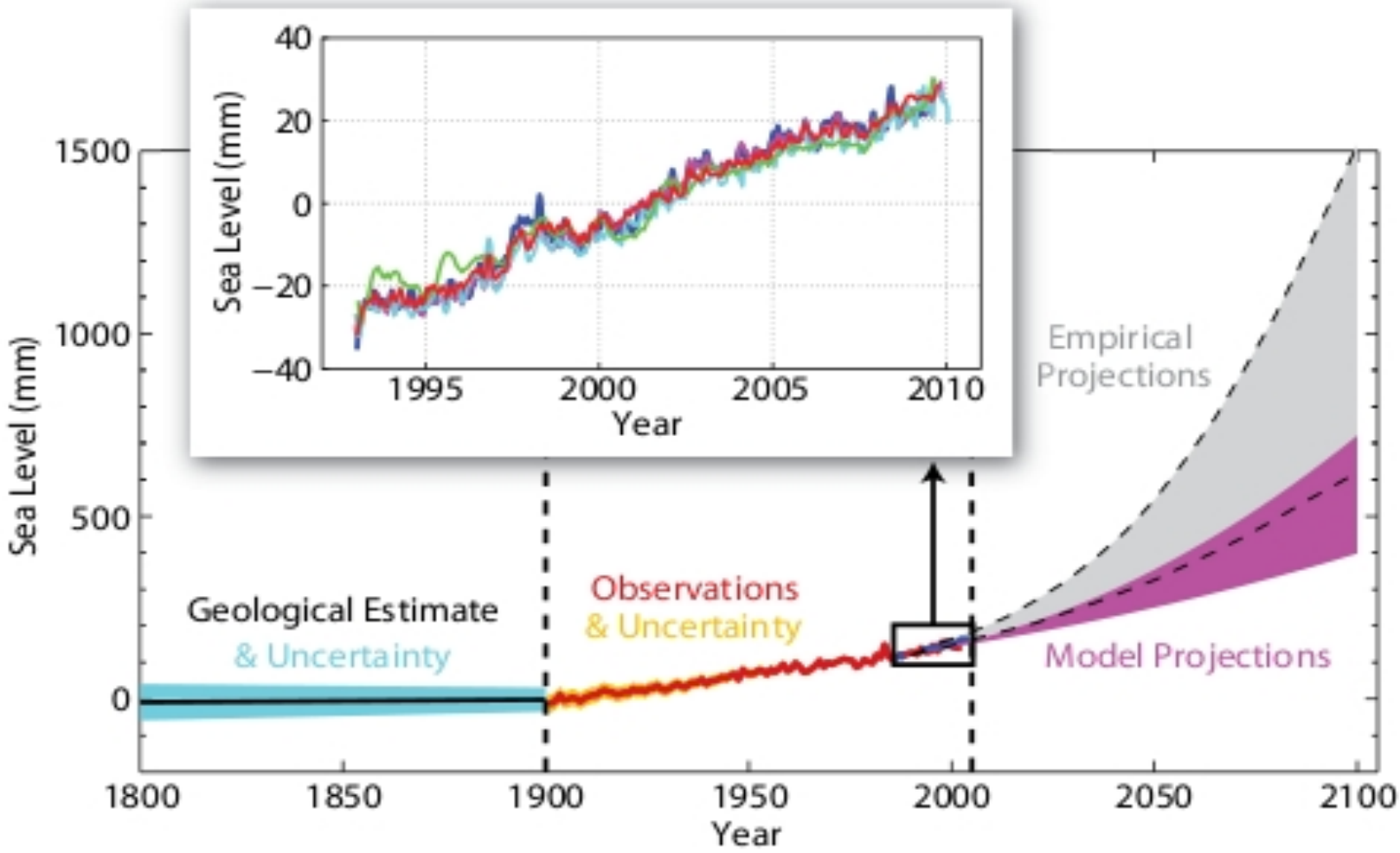
H_2O in the Earth system

– important greenhouse gas
– three physical states
gas – liquid – solid
– states are controlled by temperature and pressure
– circulates in the system Earth
”hydrological cycle”

– essential for life on Earth
– related to sea level



Challenge: Sea level change



Reference: Willis JK, Chambers DP, Kuo C-Y, Shum CK (2010) Global sea level rise: Recent progress and challenges for the decade to come. *Oceanography*, 23(4):26–35, DOI: 10.5670/oceanog.2010.03

Reasons for sea level change

- Size of individual physical contributions to sea level change (IPCC report 2013, Chapter 13):
  - Thermal expansion [+0.16 to +0.26] mm/a
  - Glaciers [+0.08 to +0.21] mm/a
  - Greenland [+0.02 to +0.12] mm/a
  - Antarctica [–0.01 to +0.16] mm/a
  - Land water storage [–0.01 to +0.09] mm/a

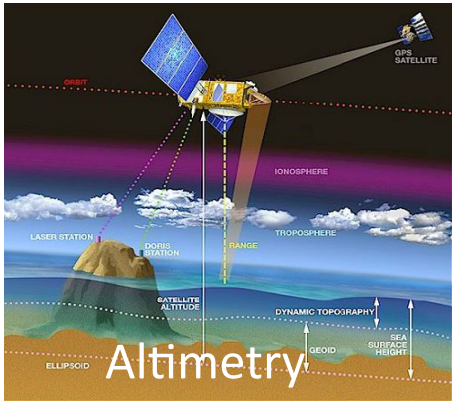
==> We need a very accurate reference frame <==

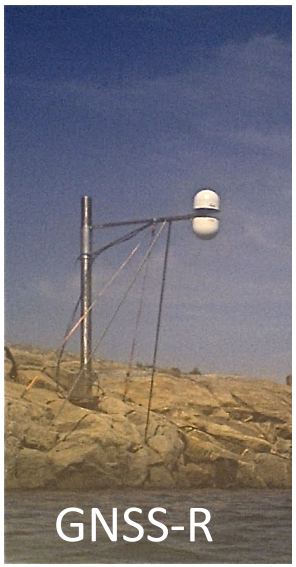
Goal: 0.1 mm/a for origin, 0.01 ppb/a for scale

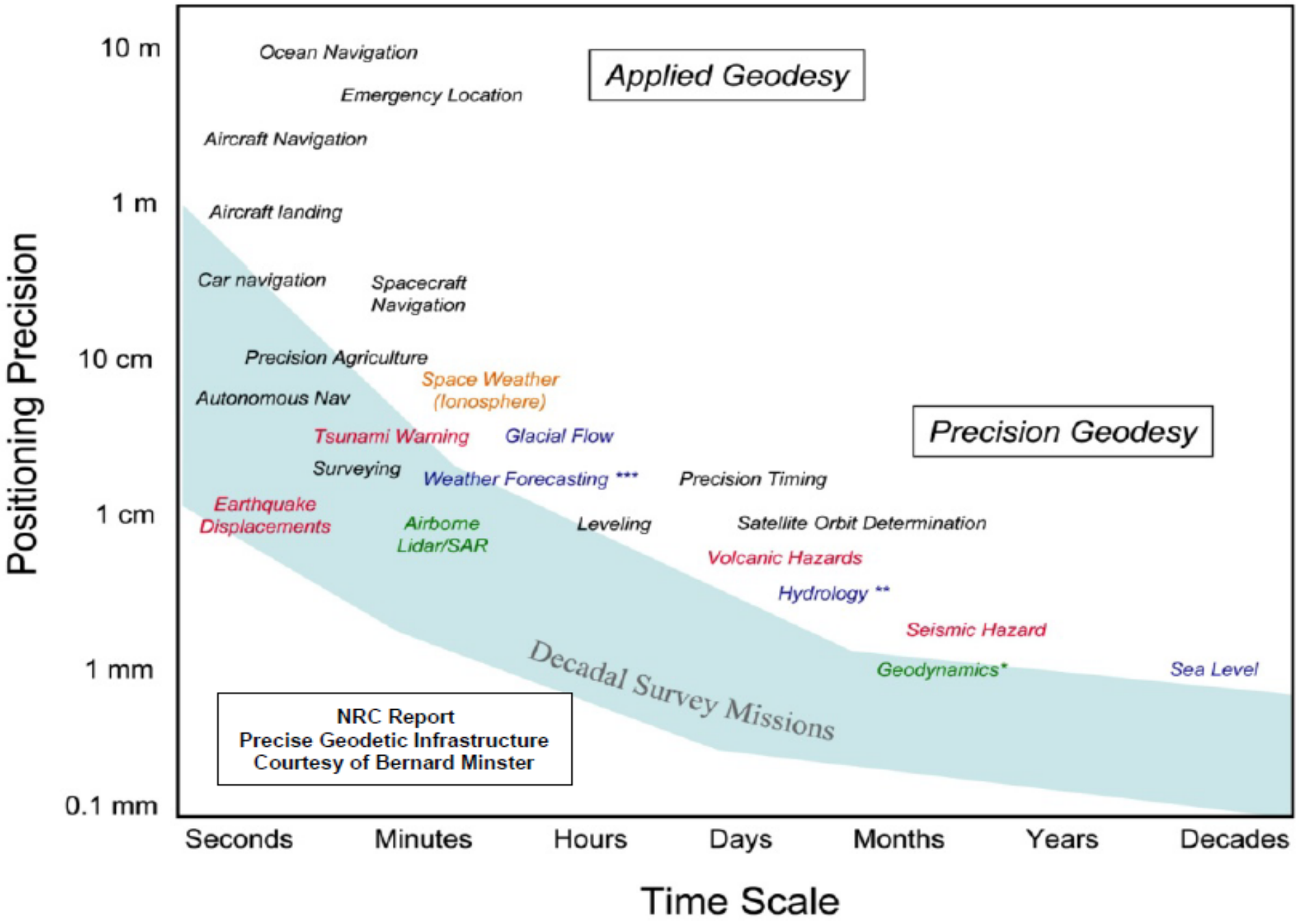
(Not fulfilled by ITRF yet)

Monitoring sea level

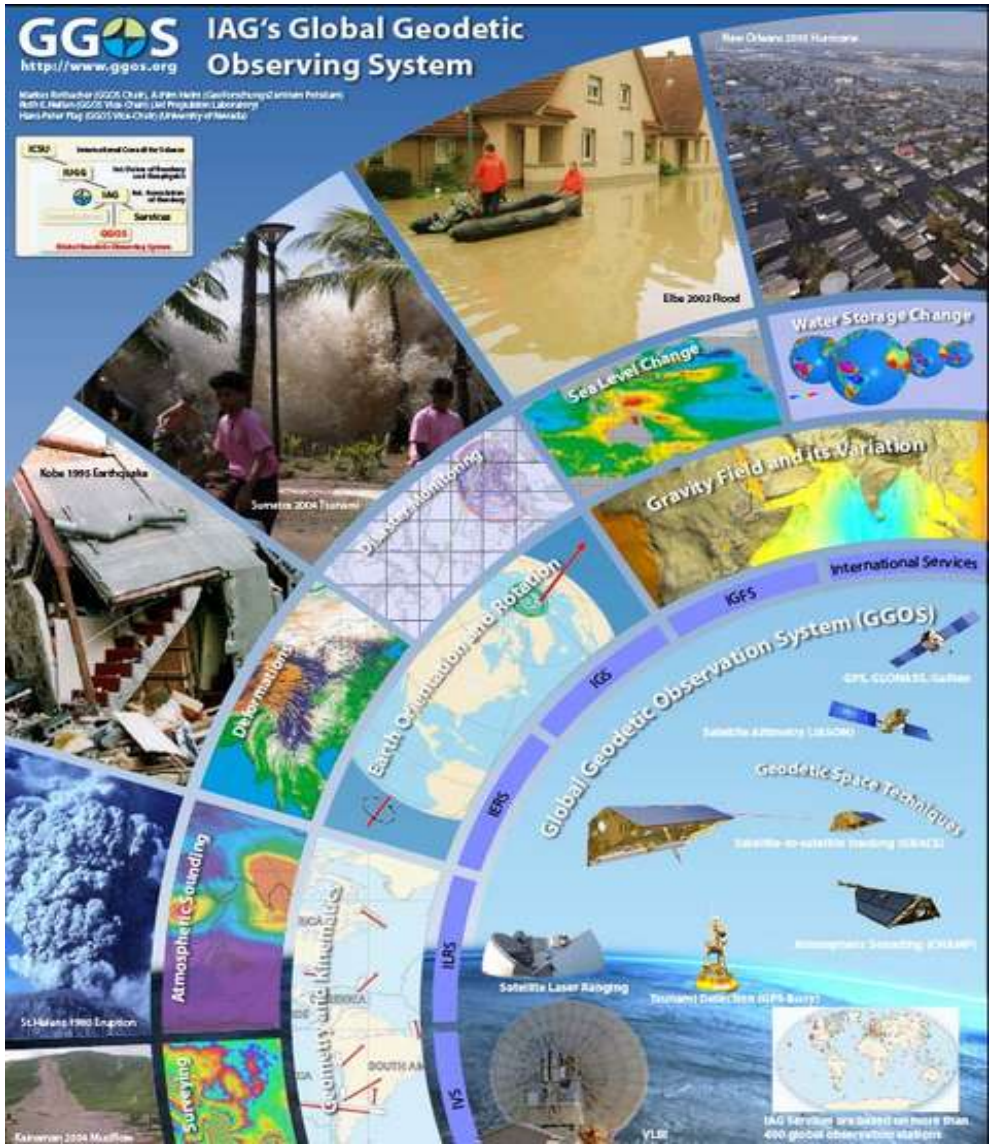
- With traditional tide gauges
  - At the coast
  - Relative w.r.t. the coastal Earth crust
  - (What happens in land uplift areas or tectonic areas?)
- With altimeter satellites
  - Global over open sea
  - Absolute w.r.t. Earth's center of mass
  - (What does this mean for the coast?)
- With GNSS-reflectometry
  - Ground-based at the coast
  - Air-borne and space-borne
  - Relative and absolute sea level
- Crucial: => Different techniques need a common and accurate reference frame






Positioning Precision
10 m
1 m
10 cm
1 cm
1 mm
0.1 mm
Seconds
Minutes
Hours
Days
Months
Years
Decades
Time Scale
Ocean Navigation
Emergency Location
Aircraft Navigation
Aircraft landing
Car navigation
Spacecraft Navigation
Precision Agriculture
Space Weather (Ionosphere)
Autonomous Nav
Tsunami Warning
Glacial Flow
Surveying
Weather Forecasting ***
Precision Timing
Earthquake Displacements
Airborne Lidar/SAR
Leveling
Satellite Orbit Determination
Volcanic Hazards
Hydrology **
Seismic Hazard
Geodynamics*
Sea Level
Applied Geodesy
Precision Geodesy
Decadal Survey Missions
NRC Report
Precise Geodetic Infrastructure
Courtesy of Bernard Minster

GGOS – Global Geodetic Observing System



GGOS aims at:

- Providing reference frames
- Providing observations of the three pillars of geodesy
- Guaranteeing an accurate monitoring of geodetic parameters over long periods
- Integrating different geodetic methods, geophysical models, etc.

⇒Benefit for scientific community and society

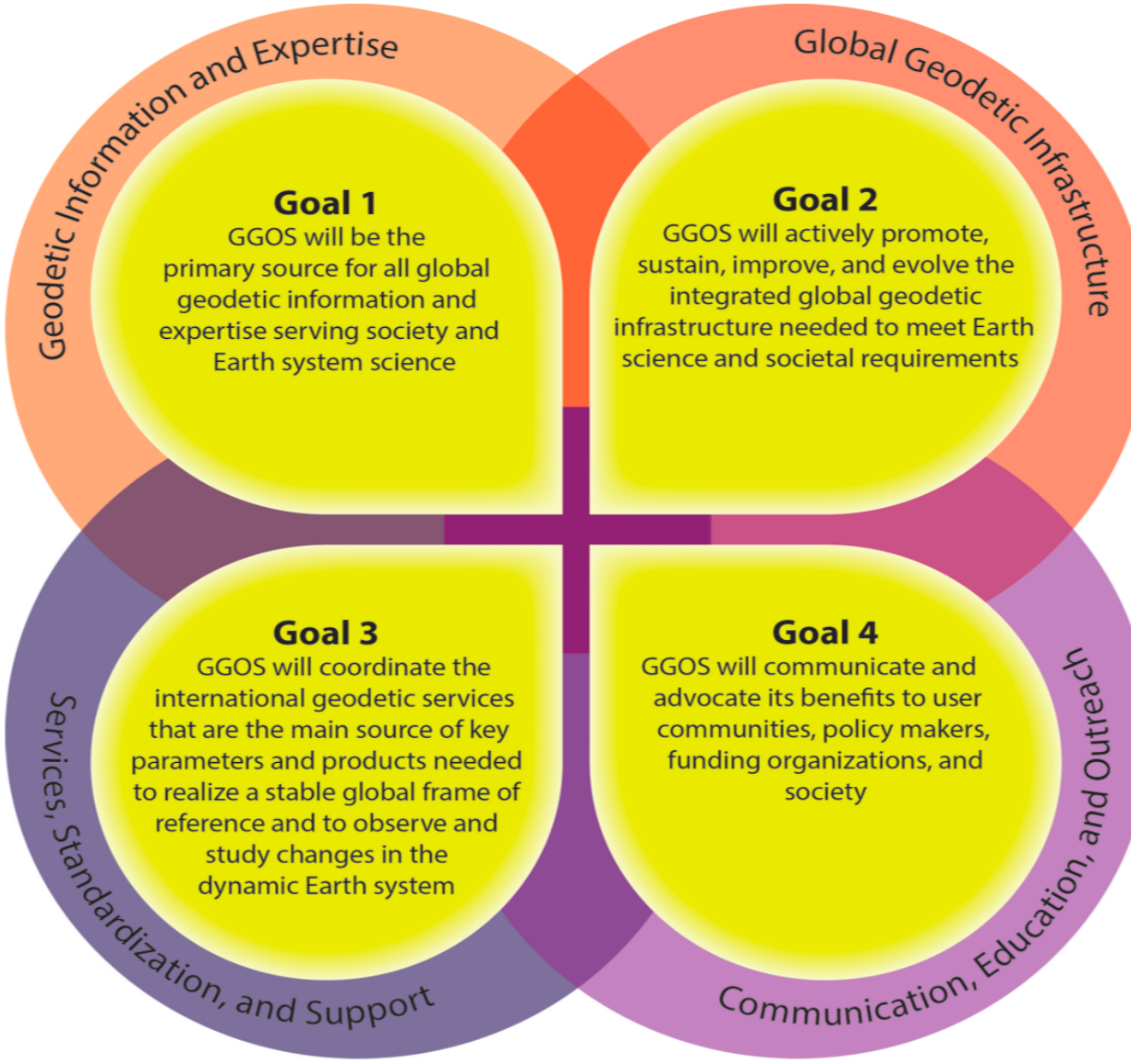
GGOS

- GGOS: interface between the geodetic services and external users such as the Group on Earth Observation (GEO) and United Nations (UN)
- GEO: voluntary partnership of governments and organizations that envisions “a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations and information.”
- GGOS contributes to GEO’s Global Earth Observing System of Systems (GEOSS)

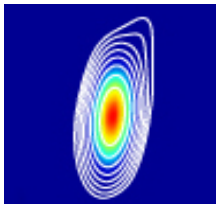
- GGOS works with the IAG components, i.e. the IAG services like IVS (International VLBI Service for Geodesy and Astrometry), IGS (International GNSS Service), ILRS (International Laser Rangingn Service), IDS (International DORIS Service), IERS (International Earth Rotation and Reference Systems Service)
- Focus on the three fundamental geodetic observables and their variations: the Earth's shape, the Earth's gravity field and the Earth's rotational motion
- Observations related to the global hydrological cycle, the dynamics of atmosphere and oceans, and natural hazards and disasters

GGOS strategic plan

- The global observing system of the IAG, the International Association of Geodesy



VLBI – Very Long Baseline Interferometry



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Quasar – point-like radio source at a distance of several billion light years

Moon

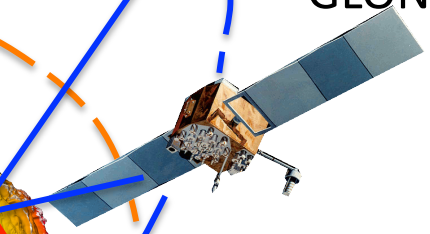
LLR – Lunar Laser Ranging

SLR – Satellite Laser Ranging

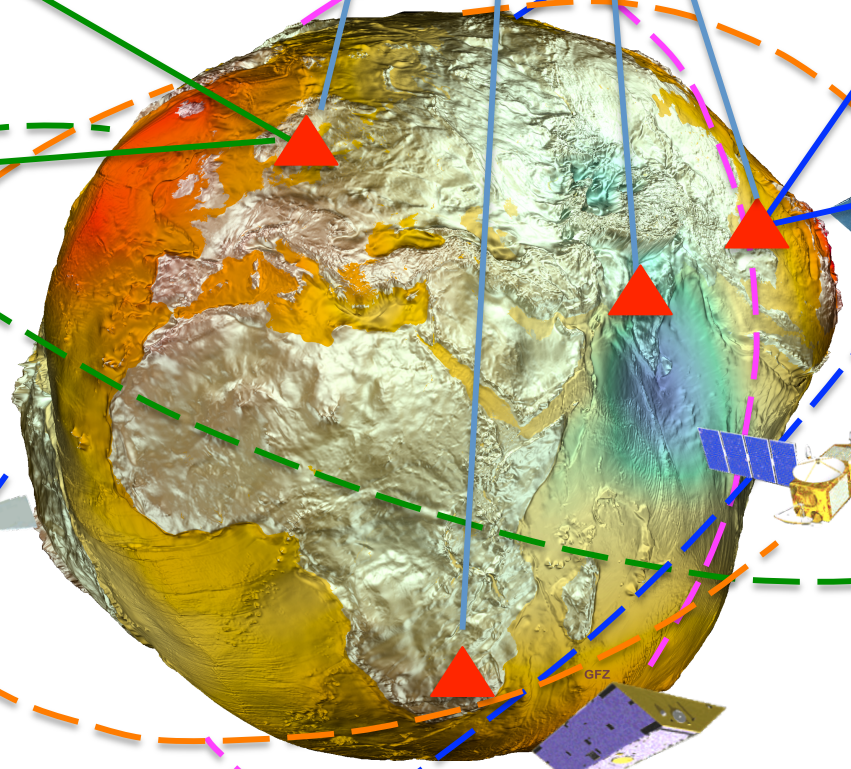
InSAR

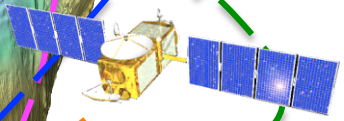
Radar Altimetry

GNSS – Global Navigation Satellite Systems (e.g. GPS, GLONASS, Galileo)



DORIS – Doppler Orbitography and Radiopositioning by Satellite

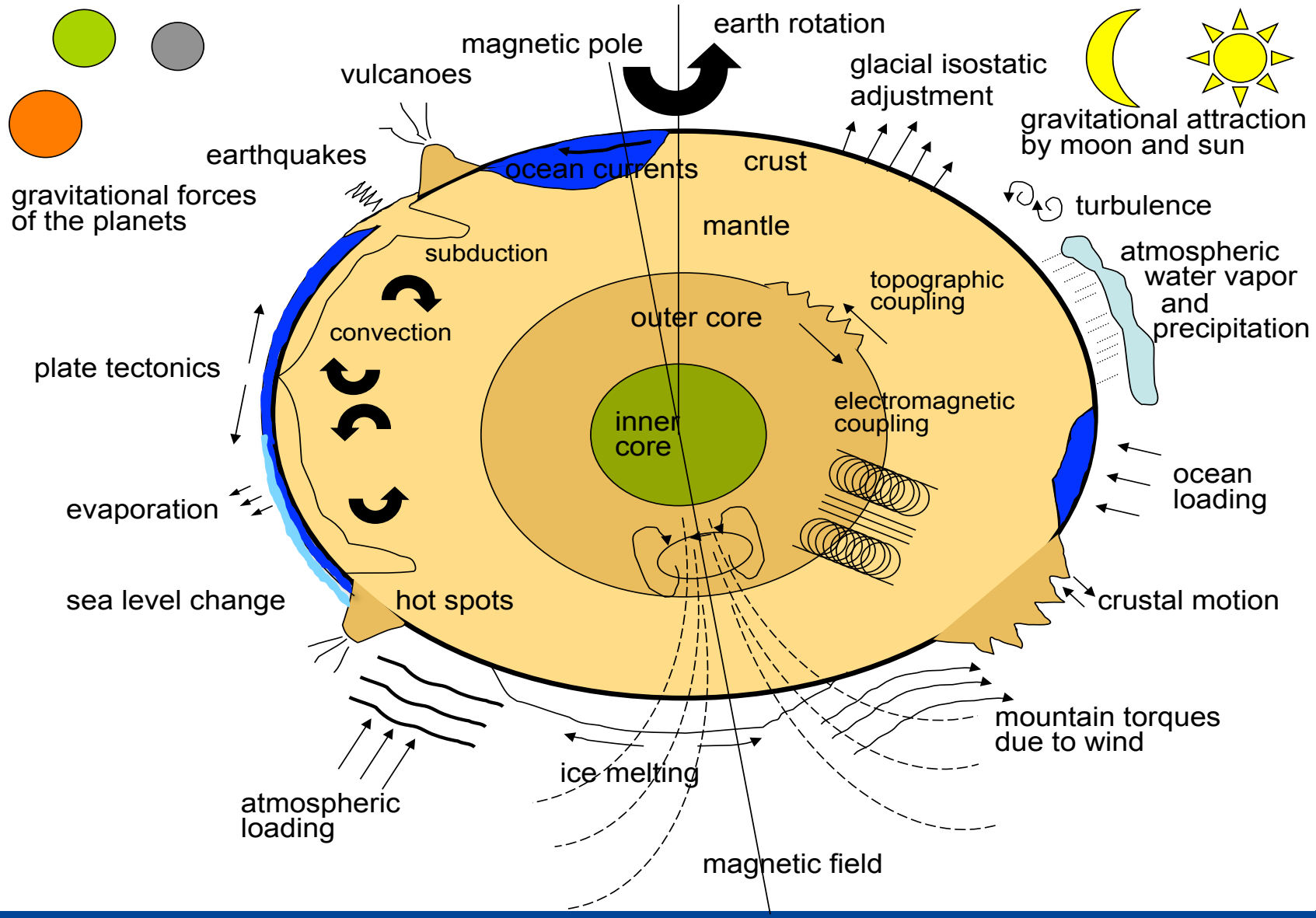




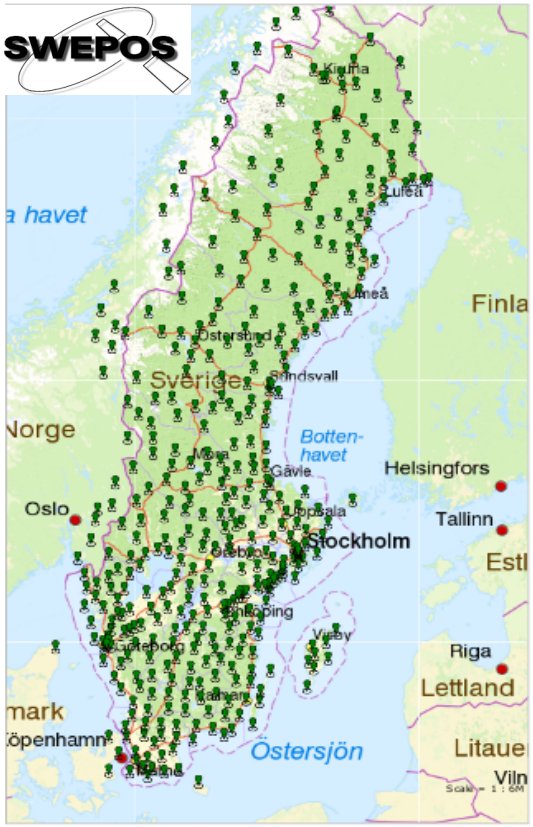
LEO – Low Earth Orbiting Satellite (e.g. gravity, remote sensing, …)

Geodetic fundamental stations (space geodesy + gravity + etc.)

Geodynamical processes

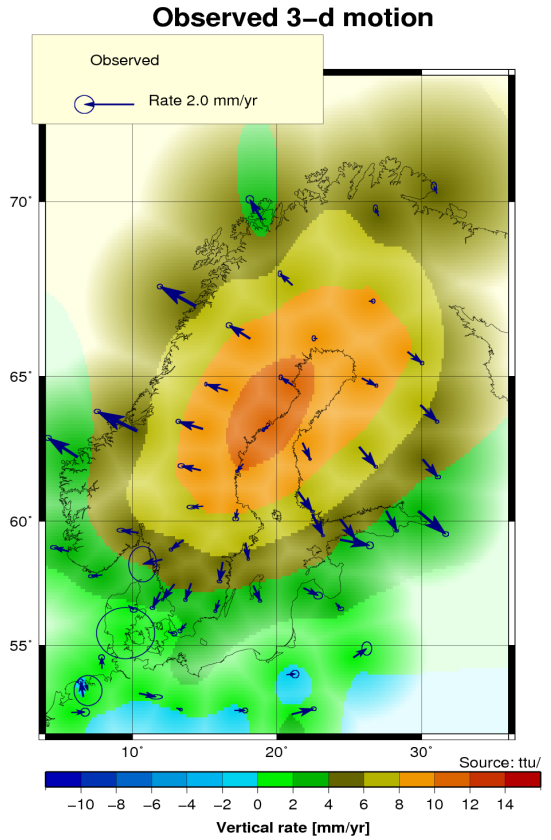


Example: GNSS geodynamics



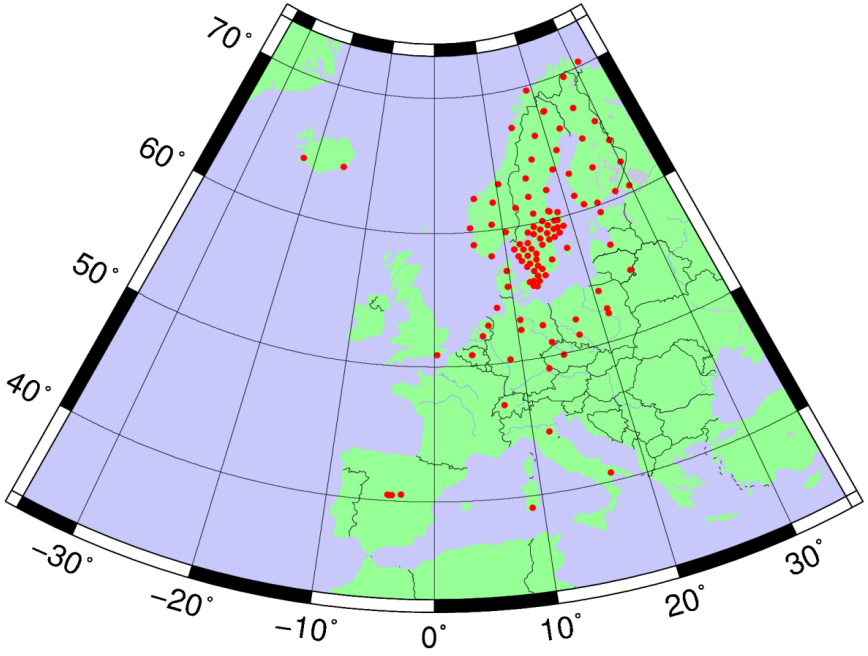
Network of SWEPOS GNSS stations, operated by Lantmäteriet

- Continuous GNSS since 1993
- Start at Onsala
- Geodynamic investigations on glacial isostatic adjustment within the BIFROST-project
- Development of GNSS for meteorology and climatology
- European projects on GNSS input to weather forecast
- Monitoring of ionospheric activity in Fennoscandia, i.e. ”space weather”

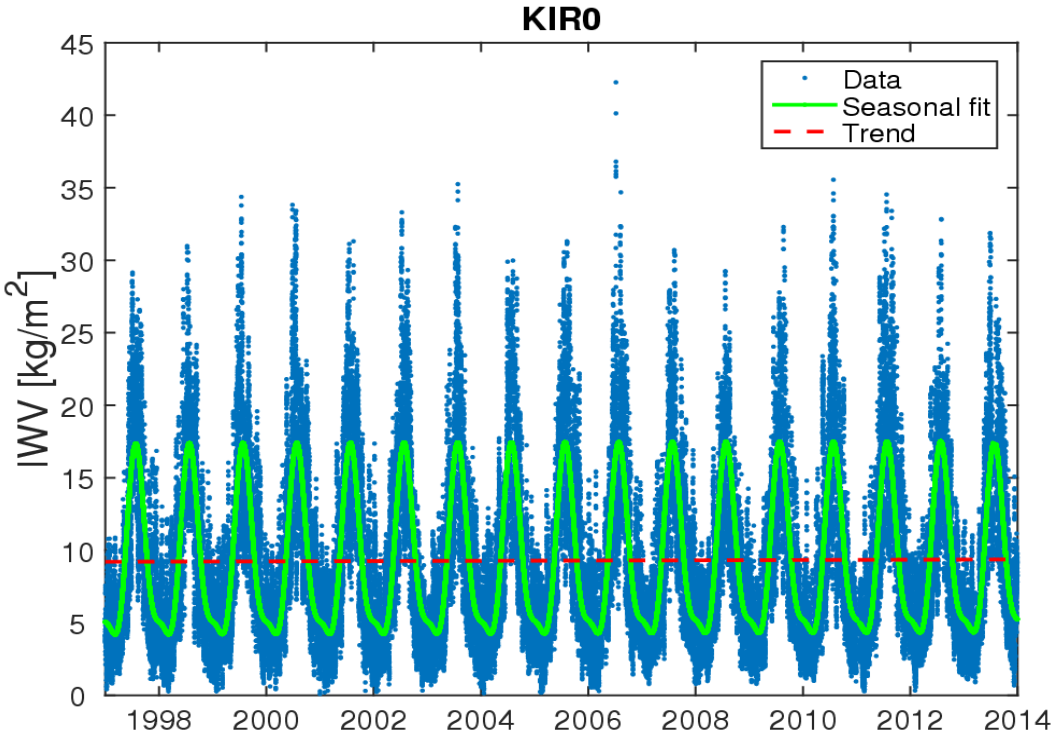


3D station motions derived from 15 years of GNSS observations

Example: GNSS meteorology



Sites used to determine IWV from ground-based GNSS in Europe for 1997-2013



IWV estimates for Kiruna together with the model for a mean, a trend, and a seasonal components

Four crucial techniques for reference frames

- Very Long Baseline Interferometry (VLBI)
- Global Navigation Satellite Systems (GNSS)
- Satellite (and Lunar) Laser Ranging (SLR/LLR)
- Doppler Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)

- => NKG summer school 2016: focus on GNSS


=> Co-location sites allow to integrate different geodetic techniques