Sessionen ”Forskarens teori om framtiden”

GEODETISK FORSKNING OCH INFRASTRUKTUR VID CHALMERS OCH ONSALA RYMDOBSERVATORIUM

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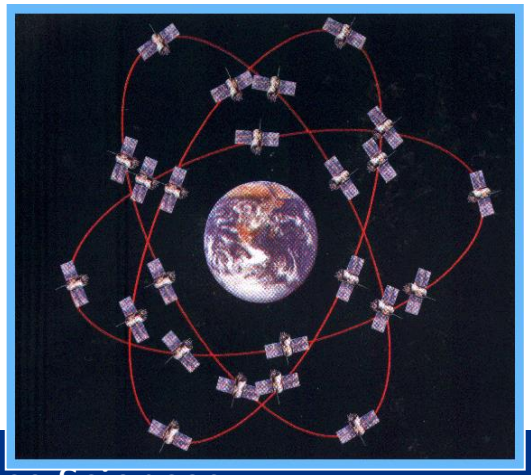
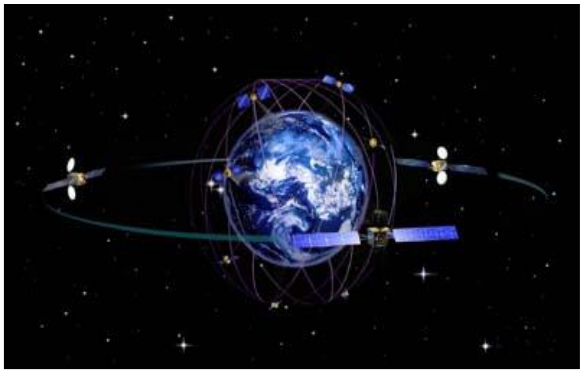
Space Geodetic Challenges for the future

Long term stability of systems and reference frames
Error sources
Robustness
Interoperability

GNSS Real Time Positioning in difficult environments (ej med i detta föredrag)





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."

Från IPCC 2014 ordlista

Enkel översättning

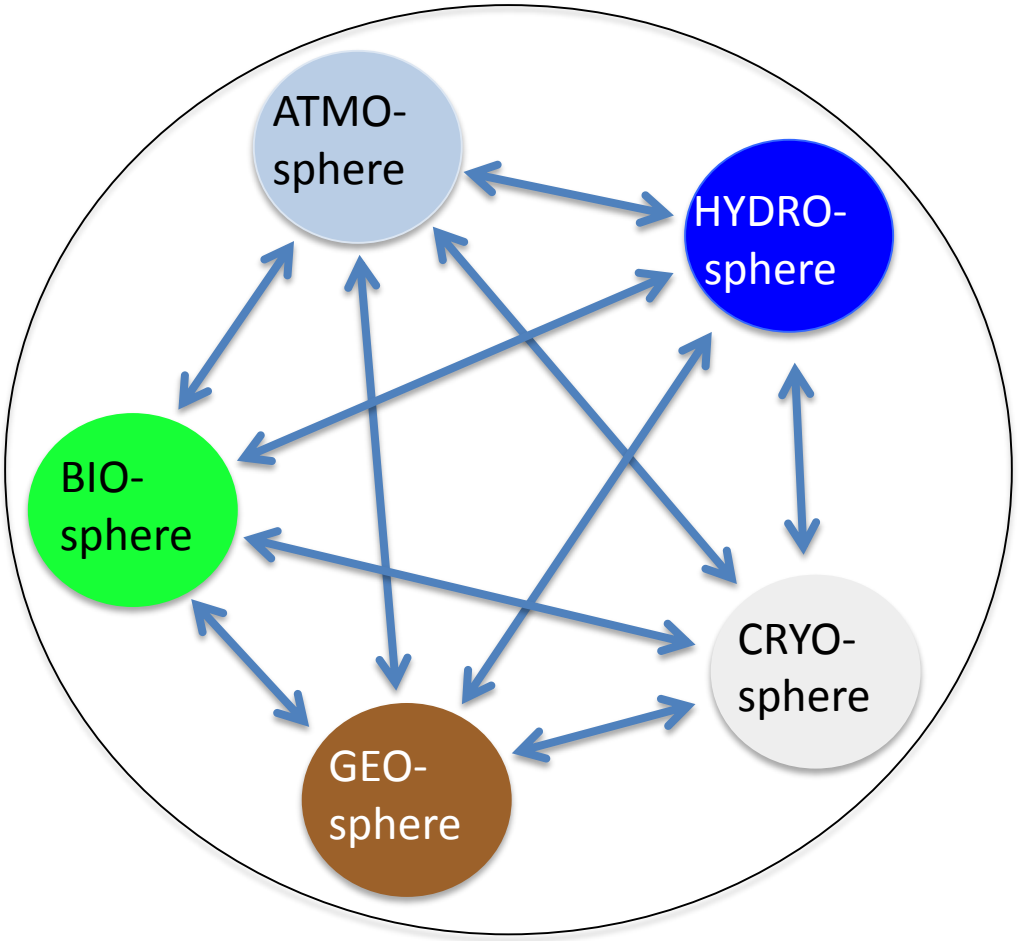
Klimat

- ”I snäv mening brukar klimat definieras som väder i genomsnitt, eller mer strikt, som den statistiska beskrivningen i termer av medelvärde och variation i relevanta parametrar under en tidsperiod som sträcker sig från månader till tusentals eller miljontals år. Den klassiska perioden för medelvärdesbildning av dessa variabler är 30 år enligt definitionen i "World Meteorological Organization". De relevanta parametrarna är oftast variabler såsom temperatur, nederbörd och vind mätta vid jordytan. Klimat är i en vidare bemärkelse tillståndet inklusive en statistisk beskrivning av klimatsystemet.”

Klimatsystem

- “Klimatsystemet är det mycket komplexa system som består av fem huvud-komponenter: atmosfären, hydrosfären, kryosfären, litosfären och biosfären och växelverkan mellan dem. Klimatsystemet utvecklas över tid under inverkan av sin egna interna dynamik och på grund av externa krafter som vulkanutbrott, solens variationer och effekter av människans aktiviteter såsom förändring i sammansättning av atmosfären och förändrad markanvändning.“

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."

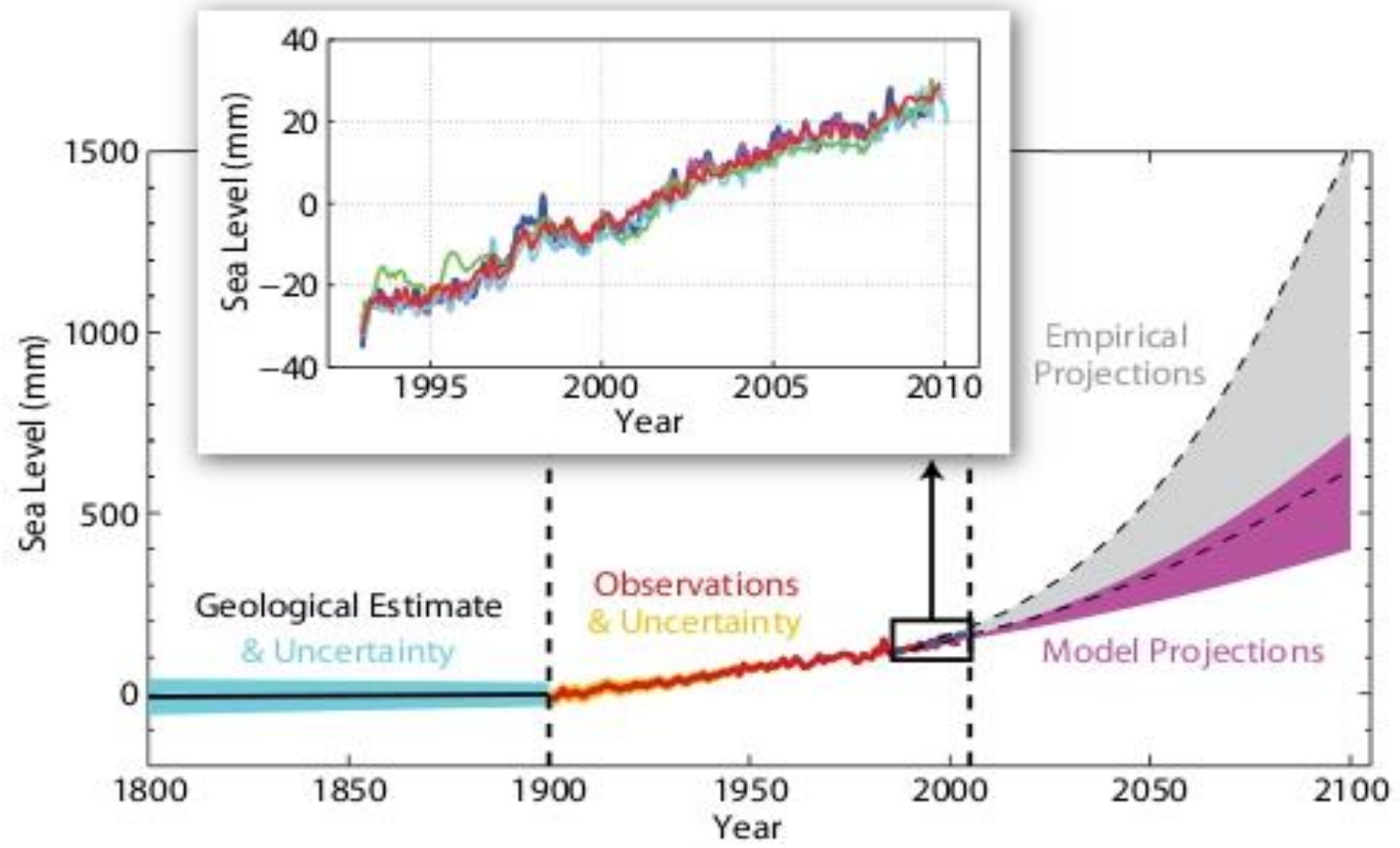
Från IPCC 2014 ordlista

Enkel översättning

Klimatförändring

- “Klimatförändring avser förändring i tillståndet av klimatet som kan identifieras (t ex genom statistiska tester) genom förändringar i medeltalet och/eller variationen av dess egenskaper, och som kvarstår under en längre tid, typiskt årtionden eller längre. Klimatförändring kan bero på naturliga interna processer eller externa krafter såsom förändring i solfläckscykler, vulkanutbrott och bestående förändringar från mänsklig påverkan i sammansättningen hos atmosfären eller i markanvändningen. Notera att ”Framework Convention on Climate Change” (UNFCCC), i sin artikel 1, definierar klimatförändringar som: 'en förändring av klimat vilket hänförs direkt eller indirekt till mänskliga aktiviteter som ändrar sammansättningen av den globala atmosfären och som är utöver naturliga klimatvariationer som observerats under jämförbara tidsperioder’. UNFCCC gör således en skillnad mellan klimatförändringen som beror på mänsklig verksamhet som ändrar atmosfärens sammansättning och variation i klimatet som beror på naturliga orsaker. Se även ’Detection’ och ’Attribution’.”

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/sources for sea level change

- Size of individual physical contributions to sea level change (IPCC AR5 report 2014, Chapter 13):
  - Thermal expansion 1.1 [0.8 to 1.4] mm/a
  - Glaciers 0.76 [0.39 to 1.13] mm/a
  - Glaciers in Greenland 0.10 [0.07 to 0.13] mm/a
  - Greenland Ice Sheet 0.33 [0.25 to 0.41] mm/a
  - Antarctica 0.27 [0.16 to 0.38] mm/a
  - Land water storage 0.38 [0.26 to 0.49] mm/a

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

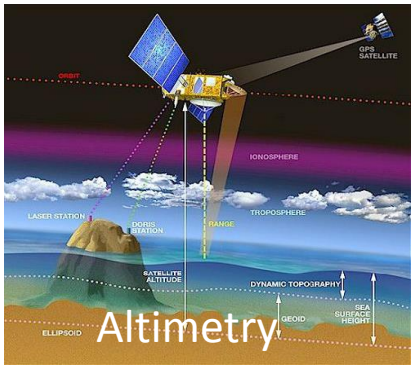
Goal: 0.1 mm/a for origin, 0.01 ppb/a for scale

(Not fulfilled by ITRF yet)

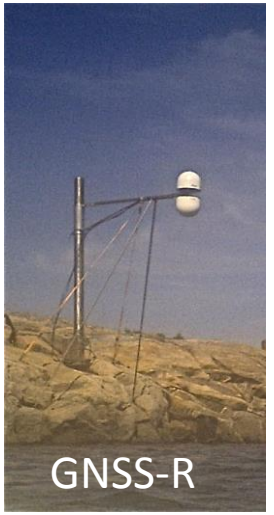
Monitoring sea level

- With traditional tide gauges
  - At the coast
  - Relative w.r.t. the coastal Earth crust
  - (What happens in land uplift areas or tectonic areas?)

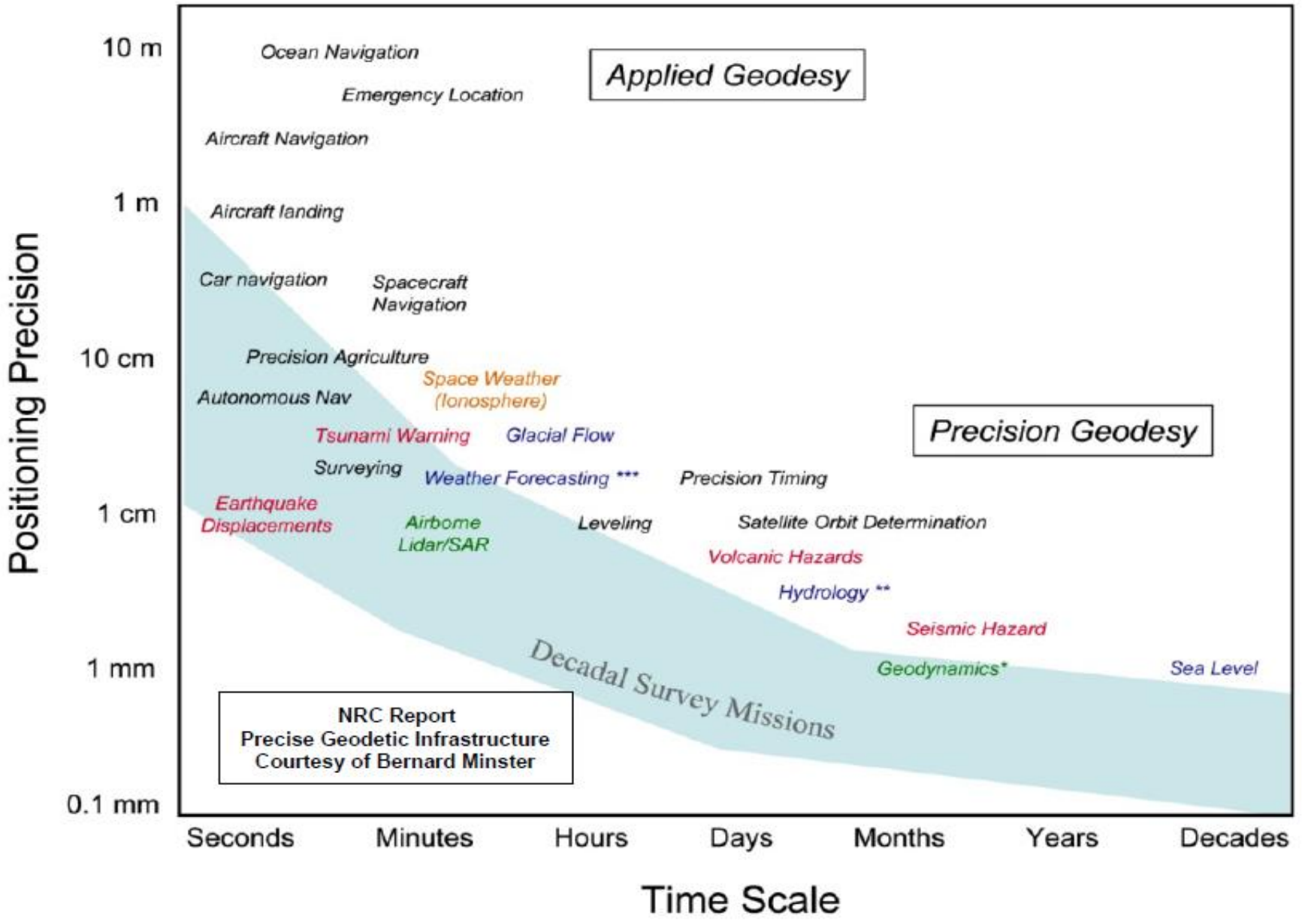
- With altimeter satellites
  - Global over open sea
  - Absolute w.r.t. Earth's center of mass
  - (What does this mean for the coast?)



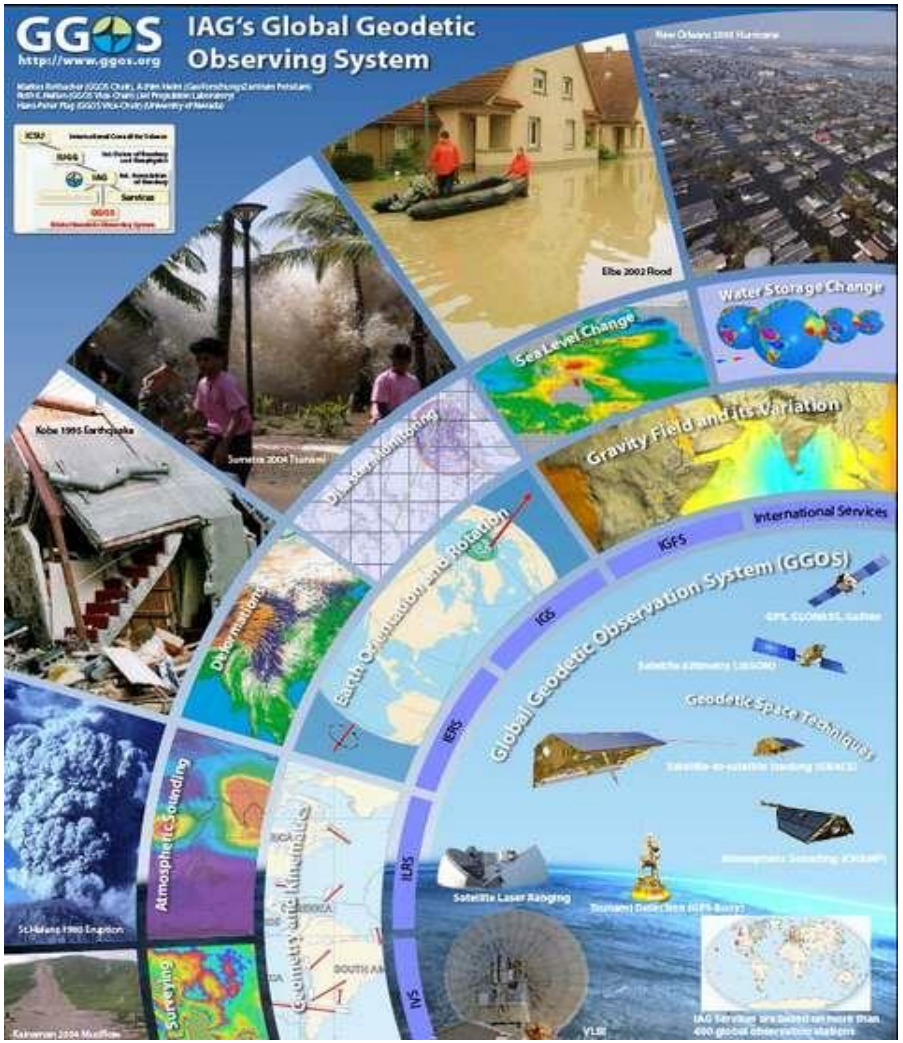
- With GNSS-reflectometry
  - Ground-based at the coast
  - Air-borne and space-borne
  - Relative and absolute sea level



- 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
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
Seconds
Minutes
Hours
Days
Months
Years
Decades
Time Scale

GGOS – Global Geodetic Observing System

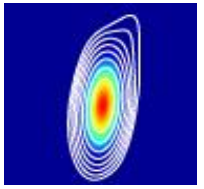


Supported by a UN resolution
(A global geodetic reference frame for sustainable development, 2015-02-25)
GGOS aims at:

- 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

VLBI – Very Long Baseline Interferometry



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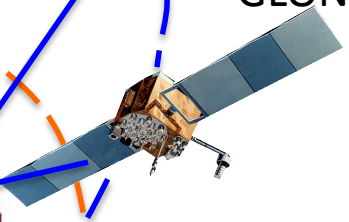
Quasar – point-like radio source at a distance of several billion light years

Moon

LLR – Lunar Laser Ranging

SLR – Satellite Laser Ranging

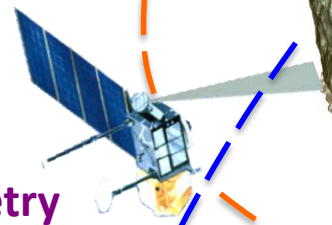
GNSS – Global Navigation Satellite Systems (e.g. GPS, GLONASS, Galileo)

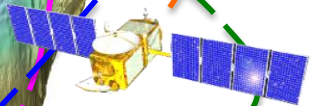


DORIS – Doppler Orbitography and Radiopositioning by Satellite

InSAR

Radar Altimetry

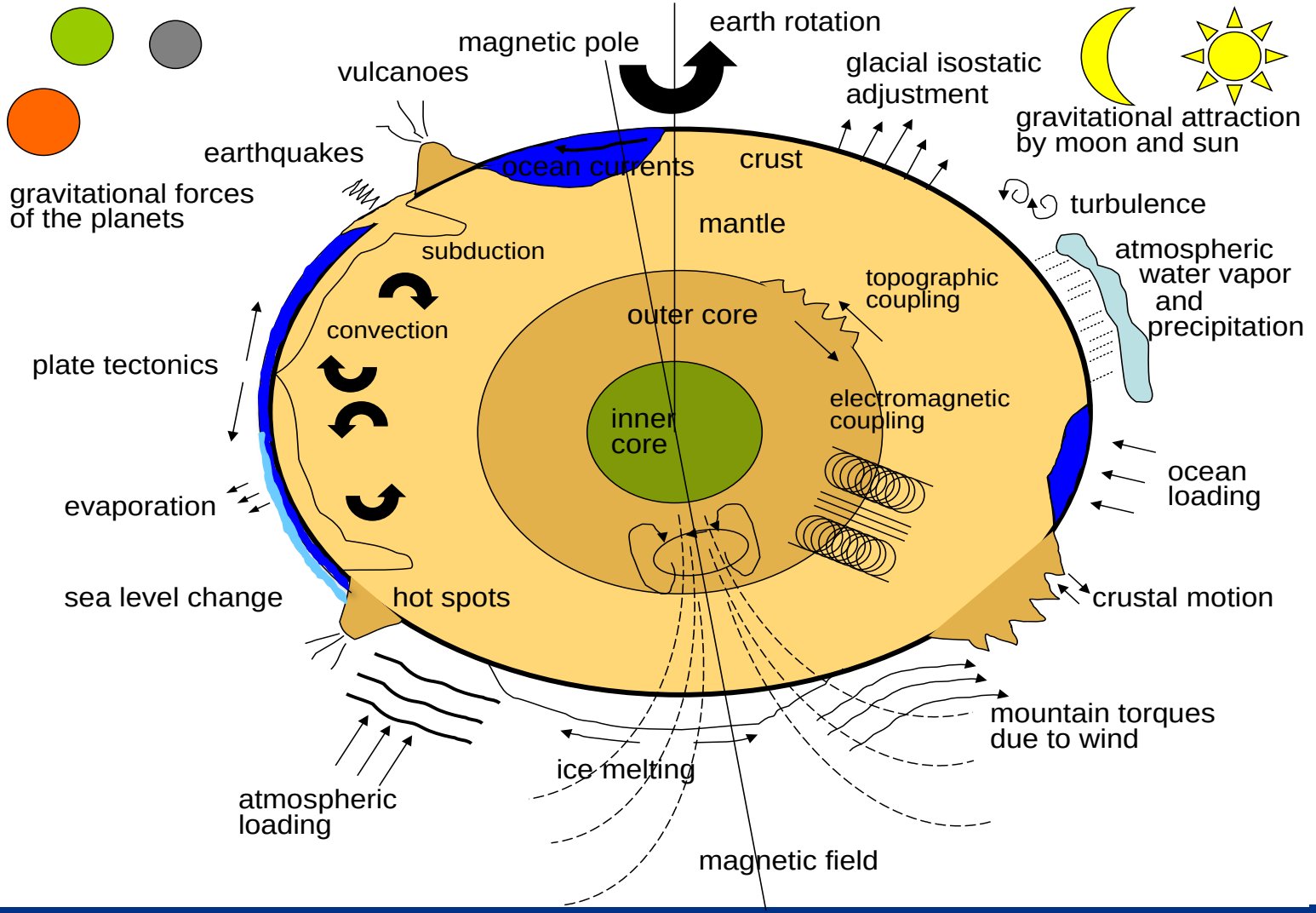




LEO – Low Earth Orbiting Satellite (e.g. gravity, remote sensing, …)

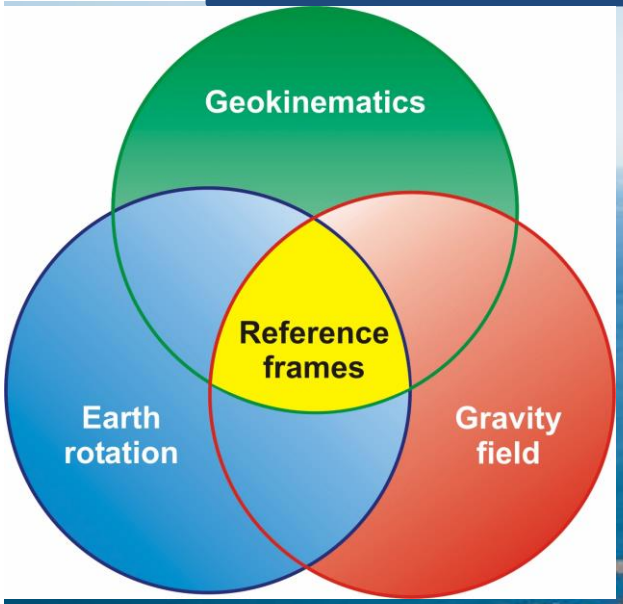
▲ Geodetic fundamental stations (space geodesy + gravity + etc.)

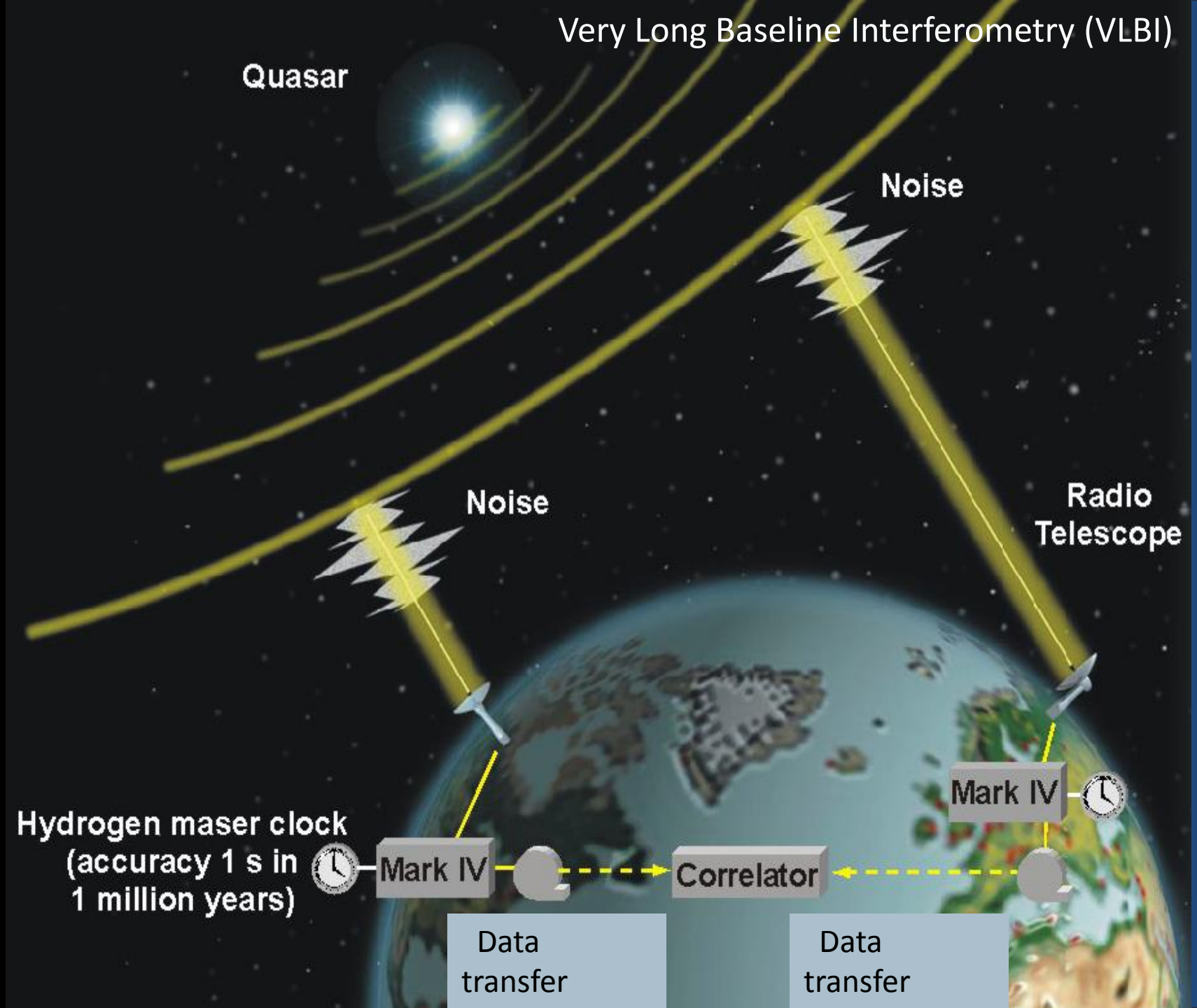
Geodynamical processes



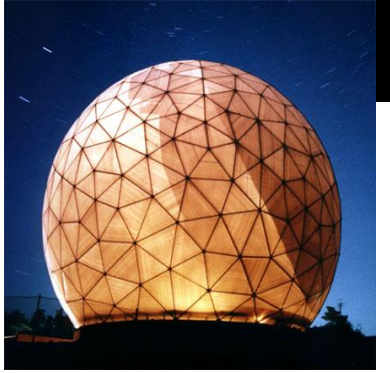
CHALMERS

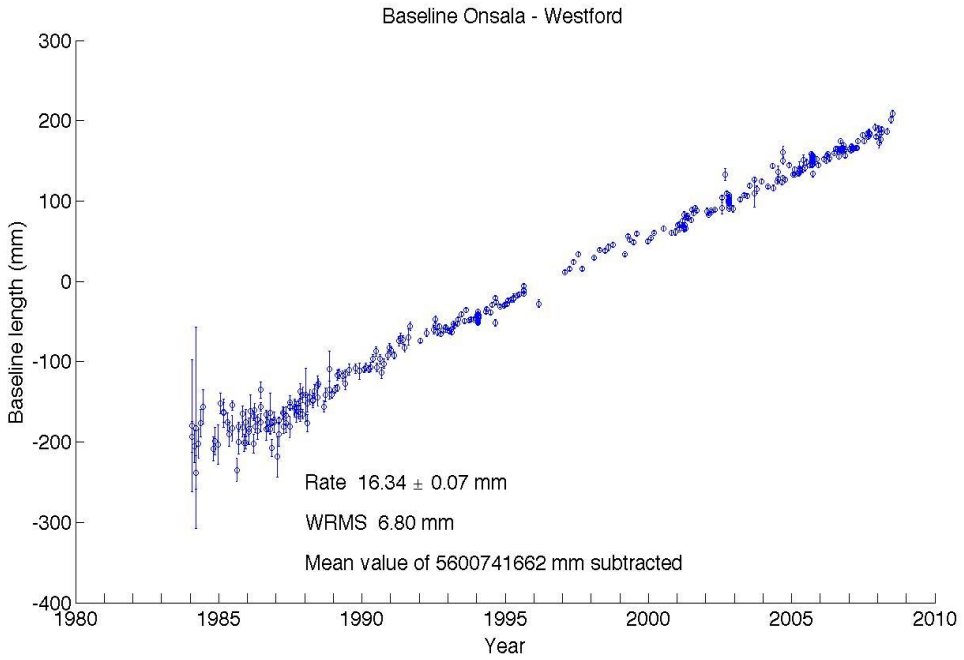
Onsala Space Observatory – a part of the Swedish space geodetic infrastructure



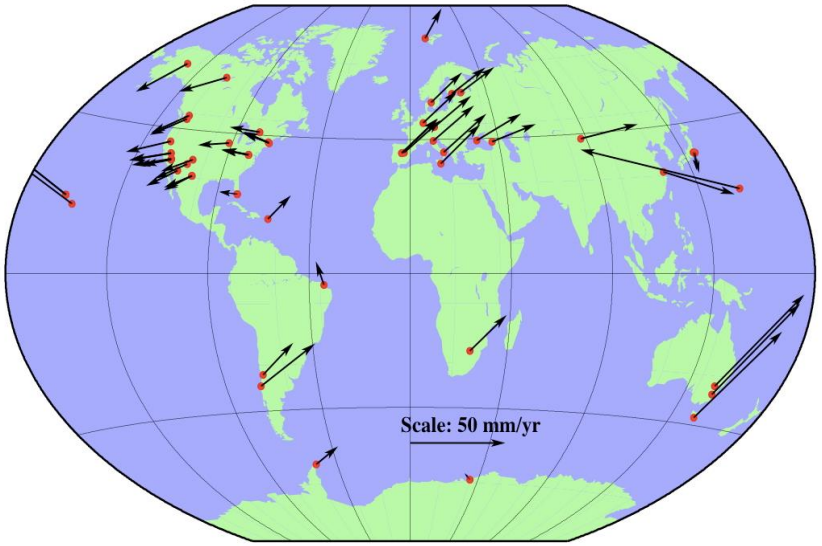

Very Long Baseline Interferometry (VLBI)
Quasar
Noise
Noise
Radio Telescope
Hydrogen maser clock (accuracy 1 s in 1 million years)
Mark IV
Correlator
Mark IV
Data transfer
Data transfer

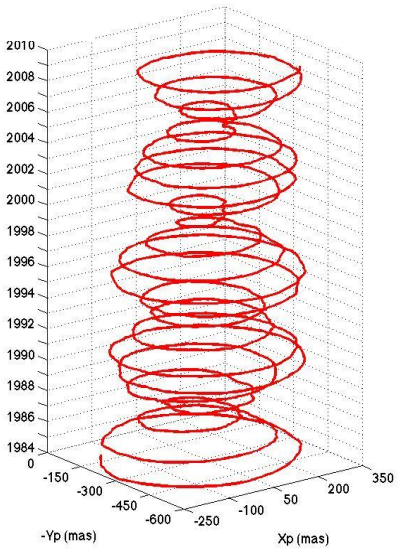
Geodetic VLBI observations (S/X) have been acquired with the 20 m telescope at Onsala since 1980

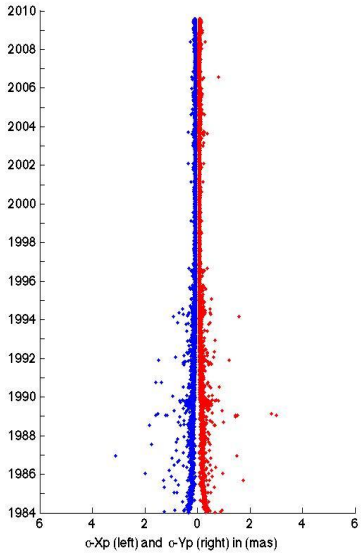




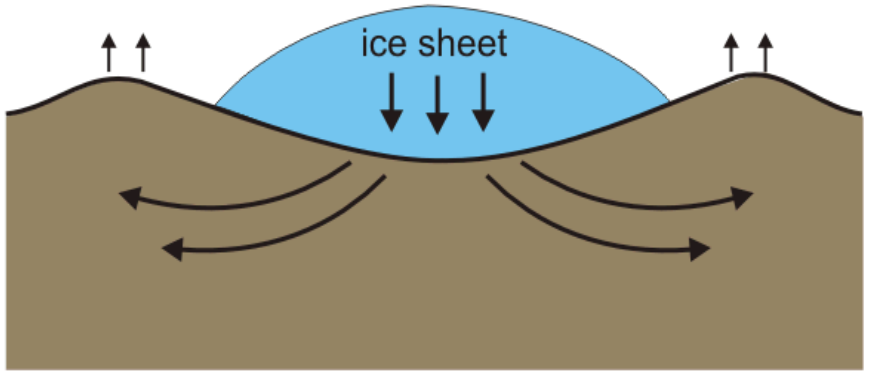
Polar motion: dominated by the annual and the Chandler component

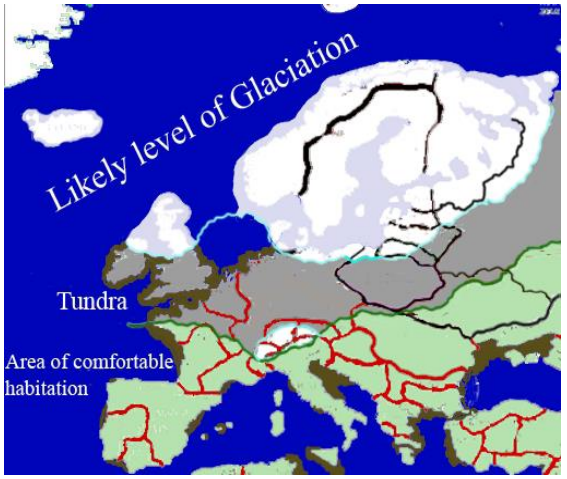


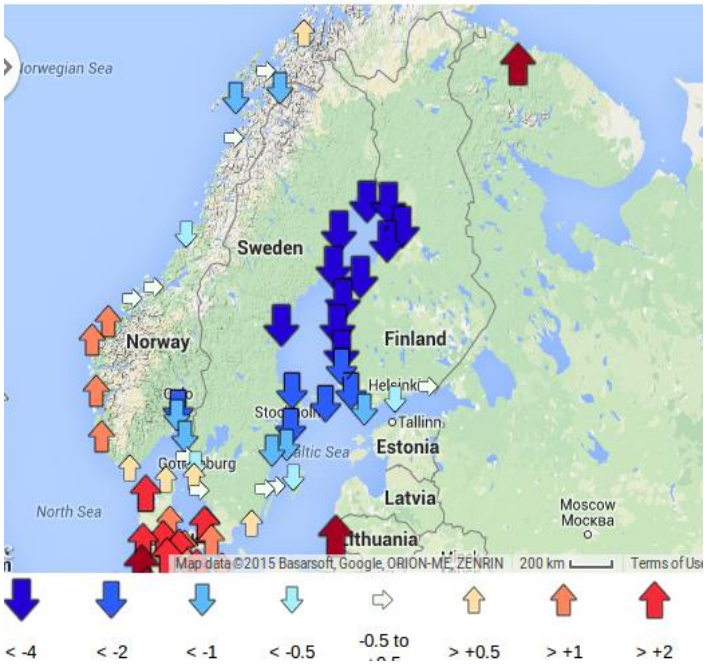




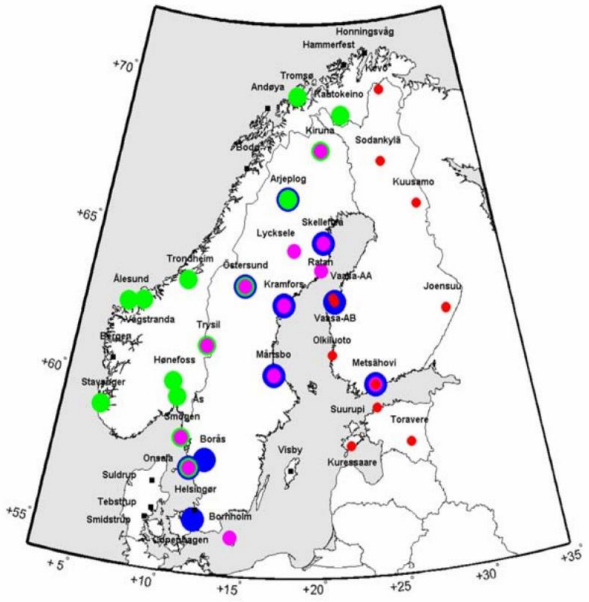
Glacial Isostatic Adjustment (GIA) and observation methods







Tide gauge network, From: http://www.psmsl.org/products/trends/



(b) 2008.

Absolute gravity network, 2008 campaigns from Gitlein (2009)

Mareografer mäter havsnivå

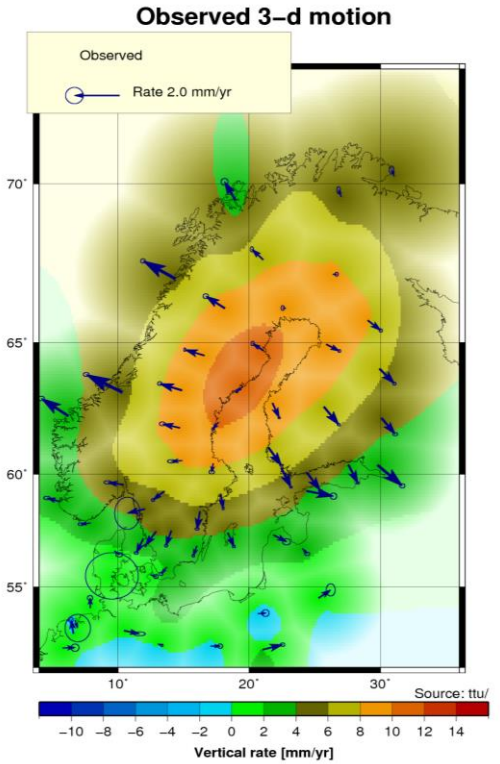
J. Löfgren; P. Widing

The gravimetry house

Example: GNSS geodynamics

Network of SWEPOS GNSS stations, operated by Lantmäteriet

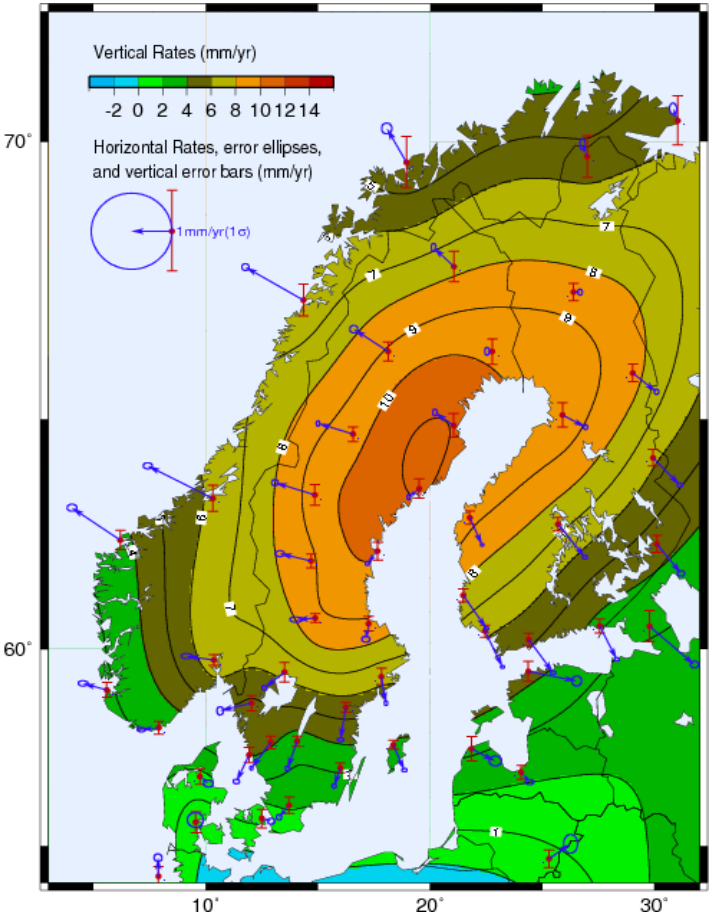
- Continuous GNSS since 1993
- Start at Onsala
- Geodynamic investigations on glacial isostatic adjustment within the BIFROST-project
- Development of GNSS for meteorology and climatology
- European projects on GNSS input to weather forecast
- Monitoring of ionospheric activity in Fennoscandia, i.e.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



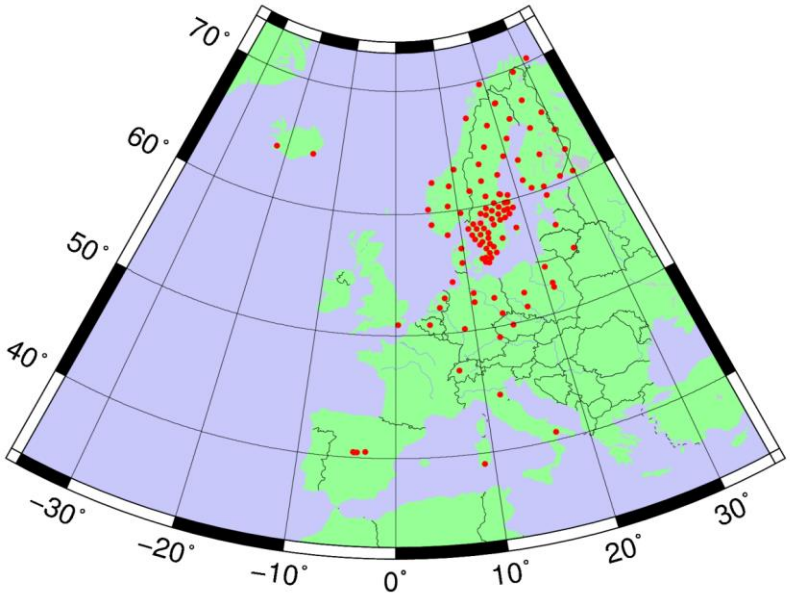
3D station motions derived from 20 years of GNSS observations

BIFROST Core Network – FINNREF, SATREF, SWEPOS

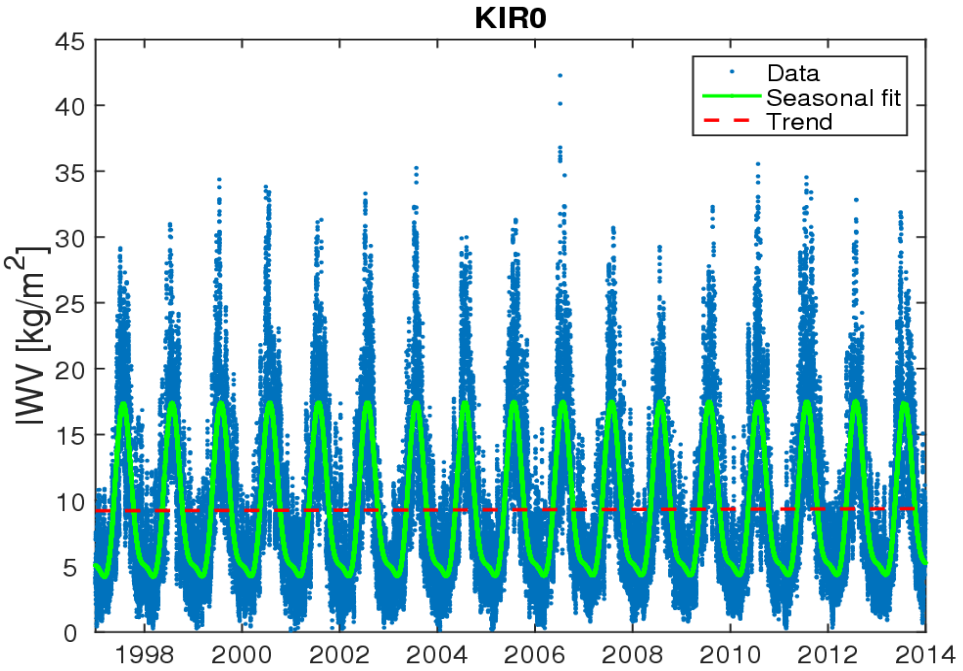
BIFROST
Core Network
1995-2013



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)


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