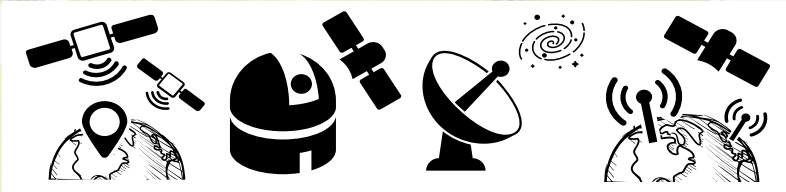
GEODESY FOR A RESILIENT AFRICA

0- A short overview of the four space-geodetic techniques (GNSS, SLR/LLR, VLBI, DORIS)



Karine Le Bail

(Chalmers University of Technology, Onsala Space Observatory, Sweden)

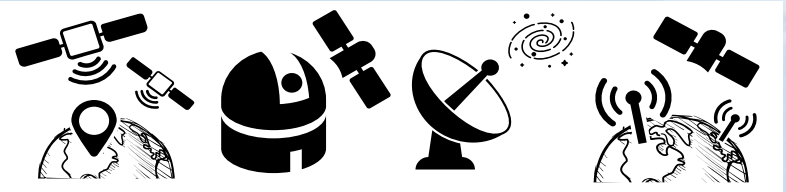
June 16, 2026

DORIS special session

IDS

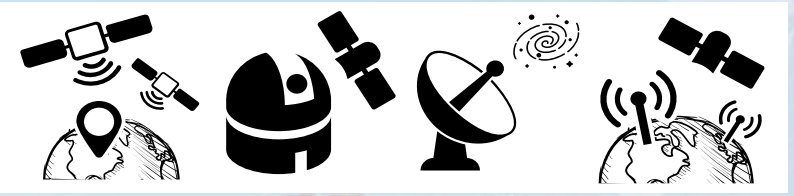
DORIS

What we will cover



- Short introduction to the lecturer and to the participants
- What is space geodesy?
- The four space-geodetic techniques
- Why are these measurements important for this school?
- Time for questions

Who am I?



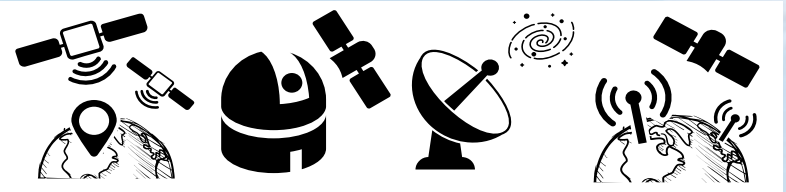
- Background in **Mathematics**, **Astronomy**, and **Space Geodesy**
- 2000: MSc. **VLBI**, celestial reference frame
- 2000-2004: PhD. **DORIS**, implementation and station positions
- 2005-2009: Postdoctoral researcher. Assistant to IDS analysis coordinator and DORIS contribution to ITRF2008
- 2010-2020: VLBI, scientist in technique development
- 2020-now: Associate Professor. VLBI, DORIS
- 2021-2024: Member-at-large, **IDS Governing Board**
- 2023-2027: IDS representative to the **GGOS** Governing Board
- **IERS** associate member and **IAU** member

IDS

IVS

GGOS Global Geodetic Observing System

Who am I?



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VLBI = Very Long Baseline Interferometry

DORIS = Doppler Orbitography and Radiopositioning Integrated by Sa[illegible]

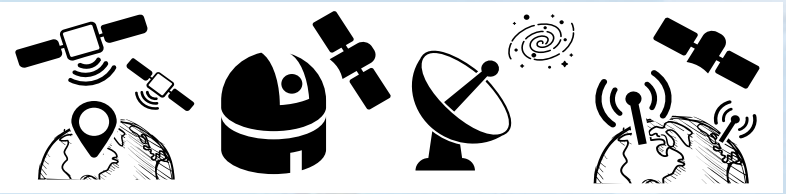
IDS = International DORIS Service

IDS

IVS

GGOS Global Geodetic Observing System

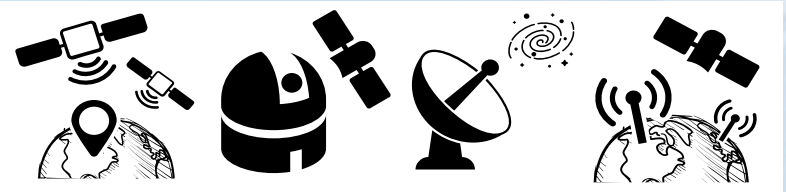
Who are you?



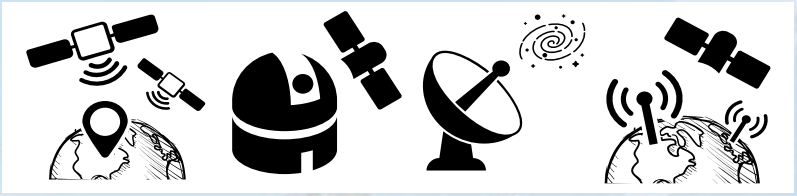
Introduce yourself!

- Your name
- Where you are from (university / institution, place)
- Why you are interested in this summer school

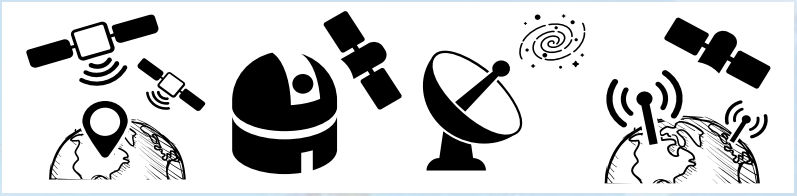
What do you know about space geodesy?



- Raise your hand or write an answer in the chat

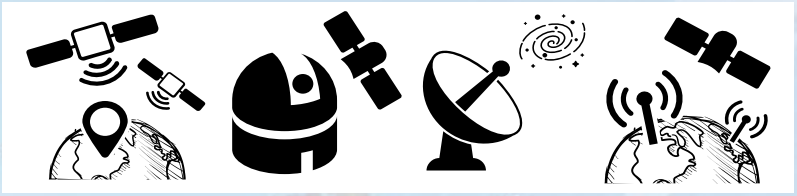


Space geodesy definition

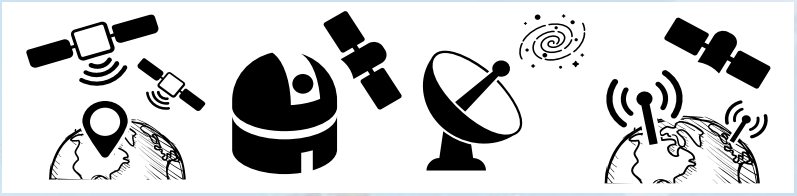


GEODESY

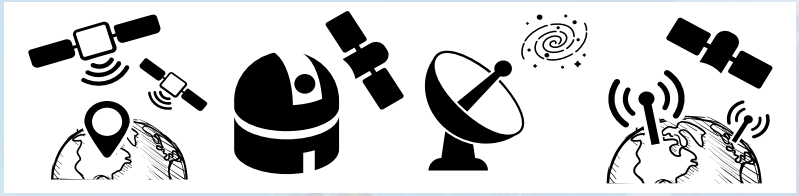
https://youtu.be/_Cj1vgmXr5M?si=RAhaBLccDk4gfwtM



GEODESY



GEO *DESY*



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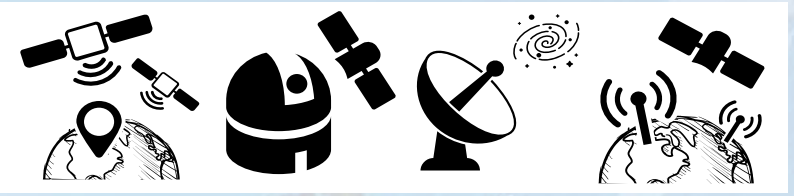

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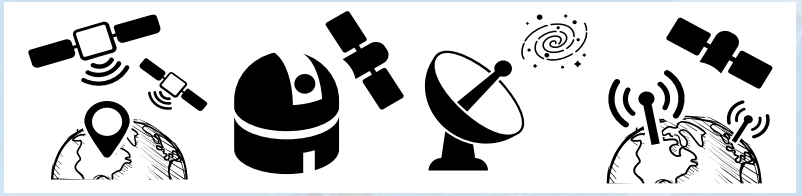
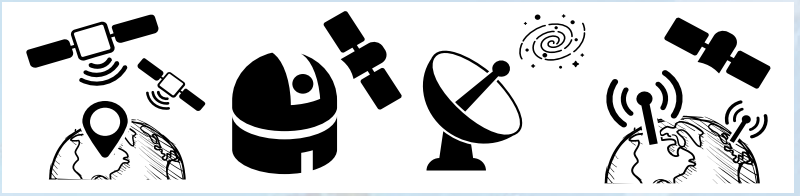




Accurately measuring and understanding

Branch of mathematics

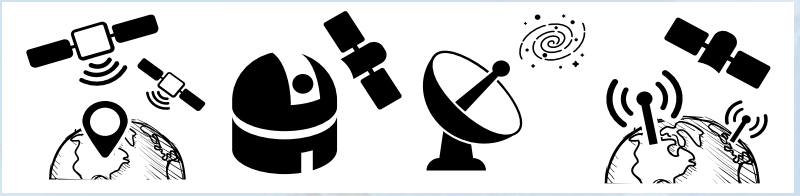
GEODESY

Earth’s figure (geometric shape and size)

Gravity field

Science

Orientation in space



Accurately measuring and understanding

Branch of mathematics

SPACE GEODESY

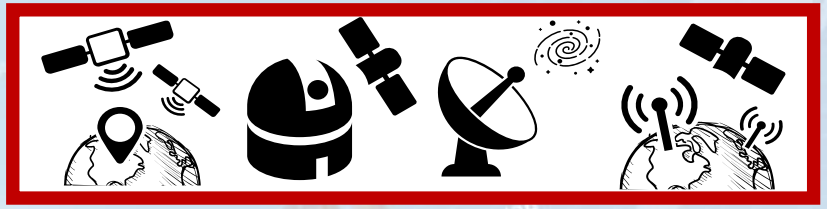
Measurement techniques linked to space

Earth’s figure (geometric shape and size)

Gravity field

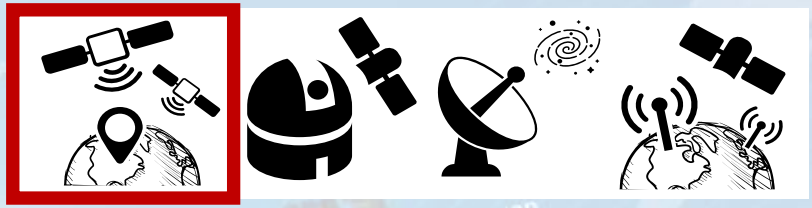
Science

Orientation in space



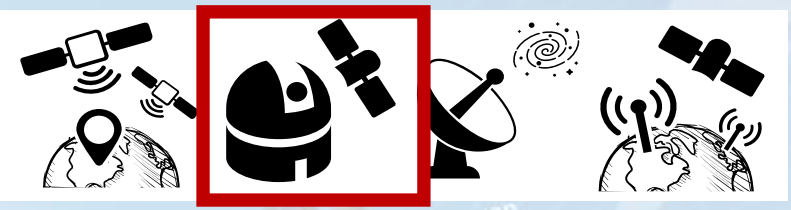
Space-geodetic techniques

Global Navigation Satellite Systems (GNSS)

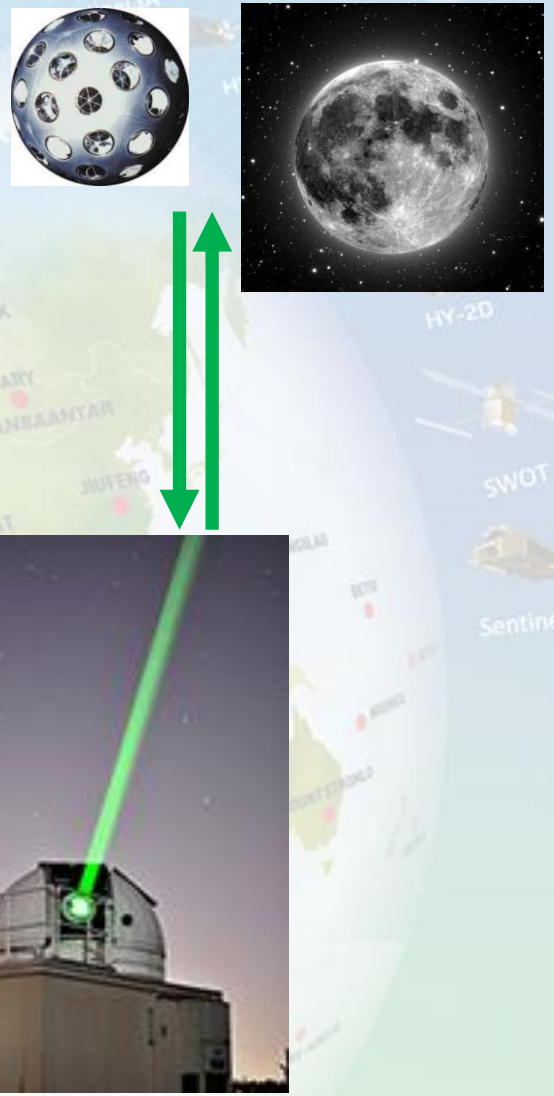


- **How It Works:** Determines position by measuring signals transmitted from multiple satellites to ground receivers.
- **Measurement Type:** Precise satellite-to-receiver ranges derived from code and carrier-phase observations.
- **Applications:** Reference frame realization, crustal deformation monitoring, sea-level studies, atmospheric sensing, and navigation.
- **Strengths:** Global coverage, continuous observations, high precision, and a dense worldwide network of stations.

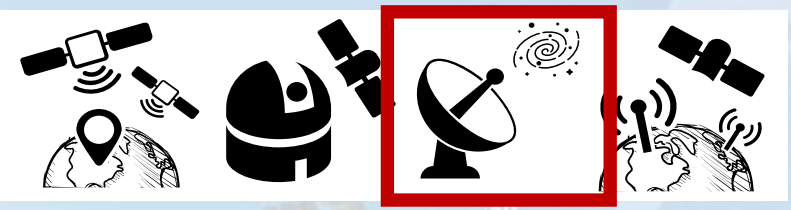
Satellite and Lunar Laser Ranging (SLR/LLR)



- **How It Works:** Ground stations transmit laser pulses to satellites equipped with retroreflectors and measure the round-trip travel time.
- **Measurement Type:** Precise distance between a ground station and a satellite.
- **Applications:** Reference frame realization, Earth gravity field studies, satellite orbit determination, and sea-level monitoring.
- **Strengths:** Direct geometric measurement, millimeter-level accuracy, and essential for defining the geocenter and scale of the terrestrial reference frame.

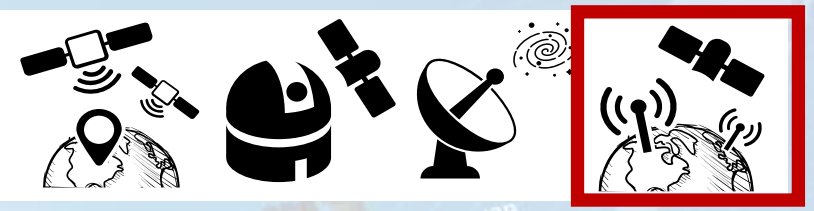


Very Long Baseline Interferometry (VLBI)

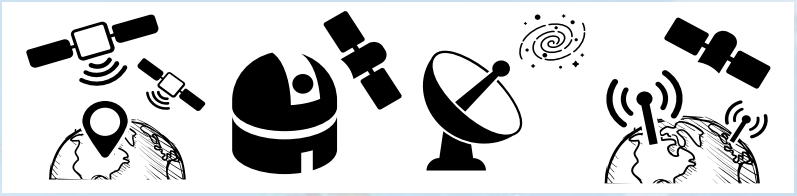


- **How It Works:** Radio telescopes around the world simultaneously observe signals from distant quasars.
- **Measurement Type:** Time difference in signal arrival between pairs of radio telescopes.
- **Applications:** Celestial and terrestrial reference frames, Earth orientation monitoring, plate tectonics, and geodynamics.
- **Strengths:** Unique link between the Earth and the celestial reference frame, highly accurate Earth rotation measurements, and global-scale precision.

Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)

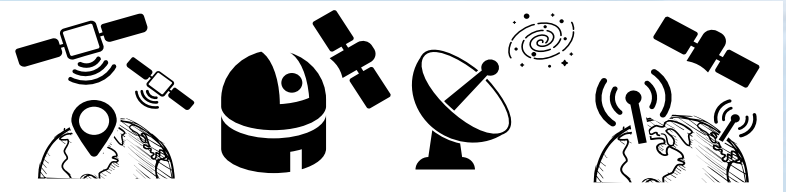


- **How It Works:** Satellites receive radio signals from a global network of ground beacons and measure the Doppler shift of the signals.
- **Measurement Type:** Doppler frequency shifts between ground beacons and satellites.
- **Applications:** Precise satellite orbit determination, terrestrial reference frame realization, sea-level monitoring, and geodynamics.
- **Strengths:** Homogeneous global network, excellent orbit determination capability, and strong contribution to long-term Earth observation and reference frames.

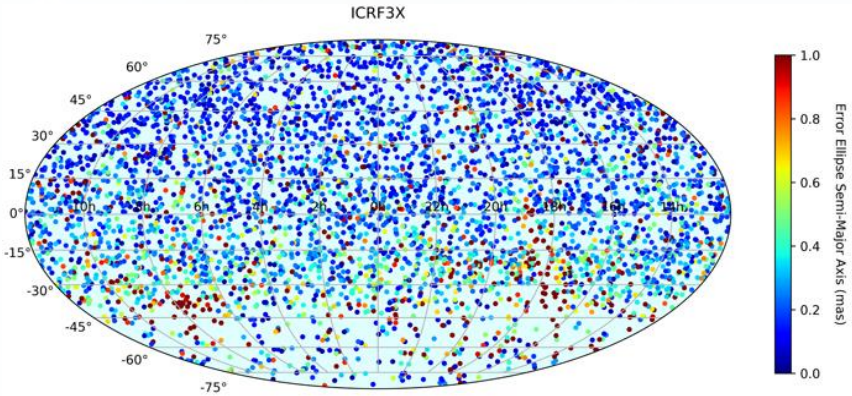


Combining observations to realize reference frames

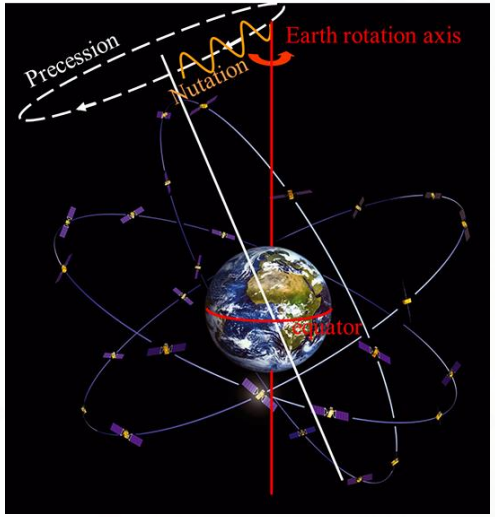
Reference frames



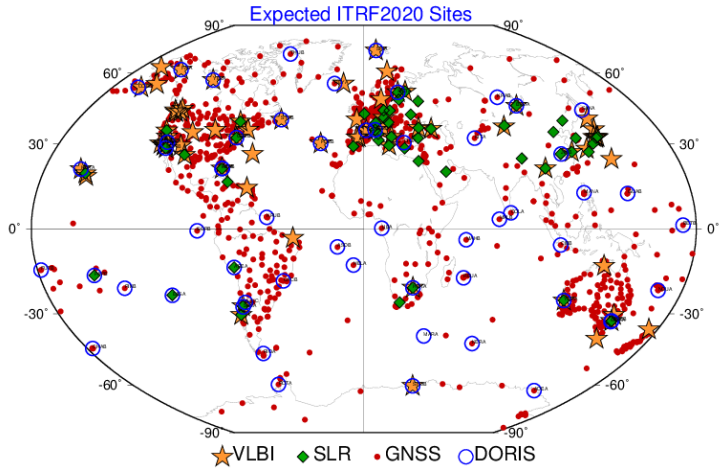
International Celestial Reference Frame (ICRF)
Set of (Right Ascension, Declination) coordinates: positions of IVS radiosources in the sky



Credit: IERS ICRS Center



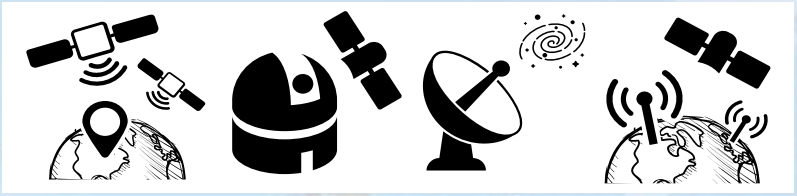
International Terrestrial Reference Frame (ITRF)
Set of (X,Y,Z) coordinates: positions of space geodetic stations on the surface of the Earth

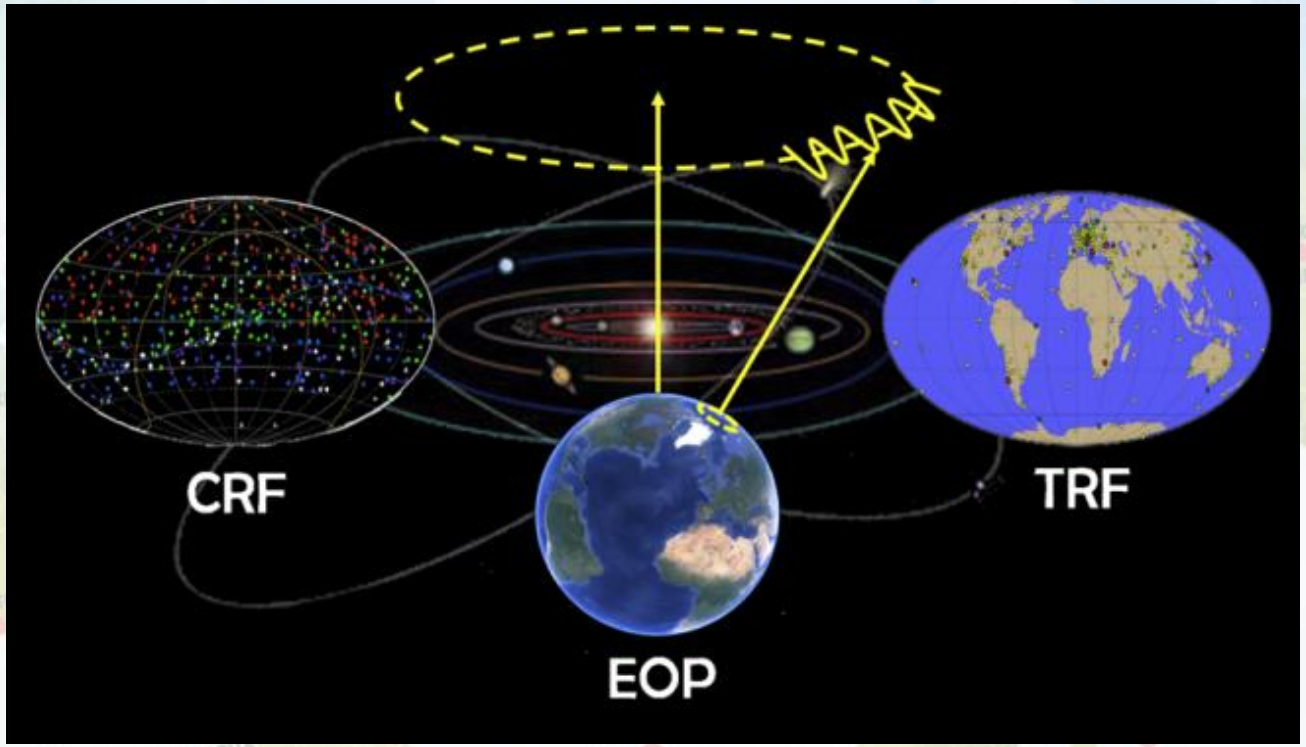


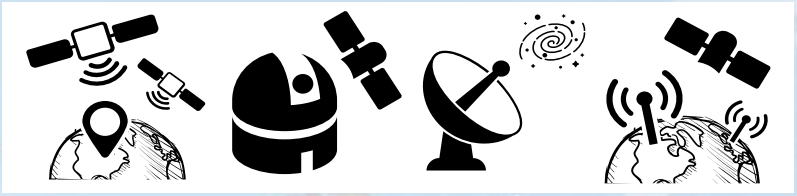
Credit: Altamimi et al., G2 2021

Earth Orientation Parameters (EOP)
Precession-nutation, polar motion, d(UT1-UTC)
Credit: https://eos.org/ adapted from J. Huart, European Space Agency

Reference frames

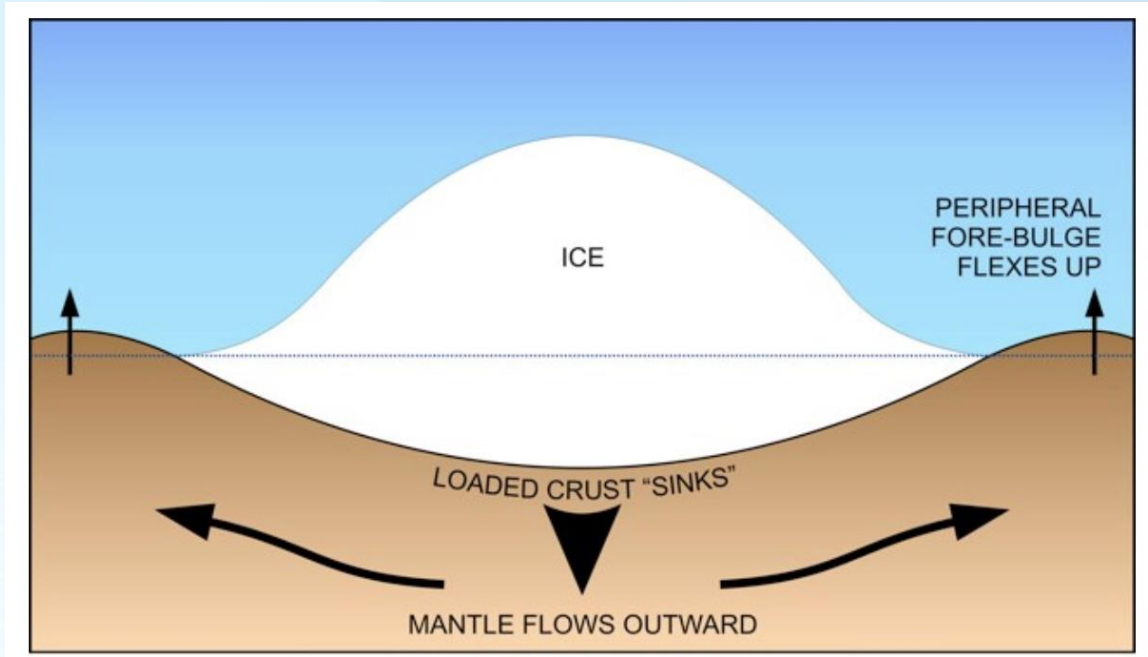


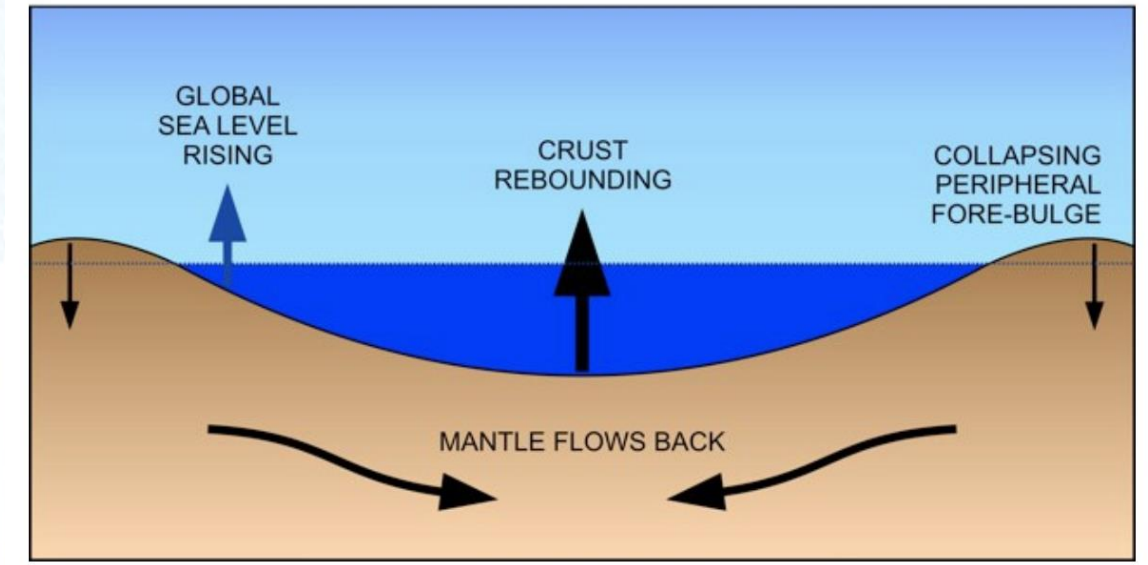


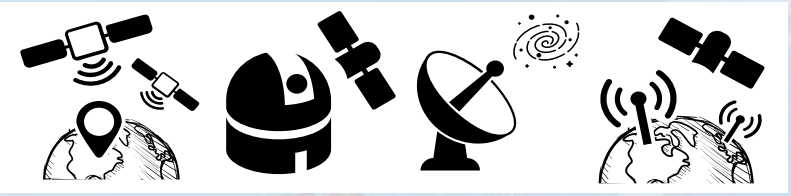


How can space geodesy help us understand the Earth and climate change?

Present-day ice mass loss







The general process of Glacial Isostatic Adjustment (GIA)

Top: heavy ice loads Earth's surface.
Bottom: once the ice is removed, some areas rebound, while others collapse.
(UNAVCO, 2020)

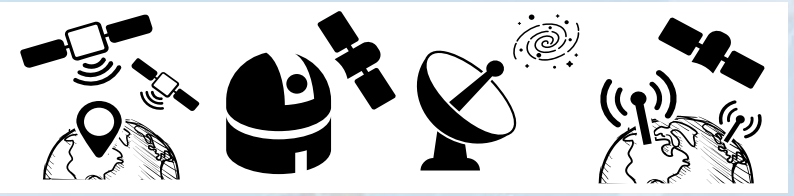
A visit to Ny-Ålesund, Svalbard

Credit: R. Haas

Credit: R. Haas

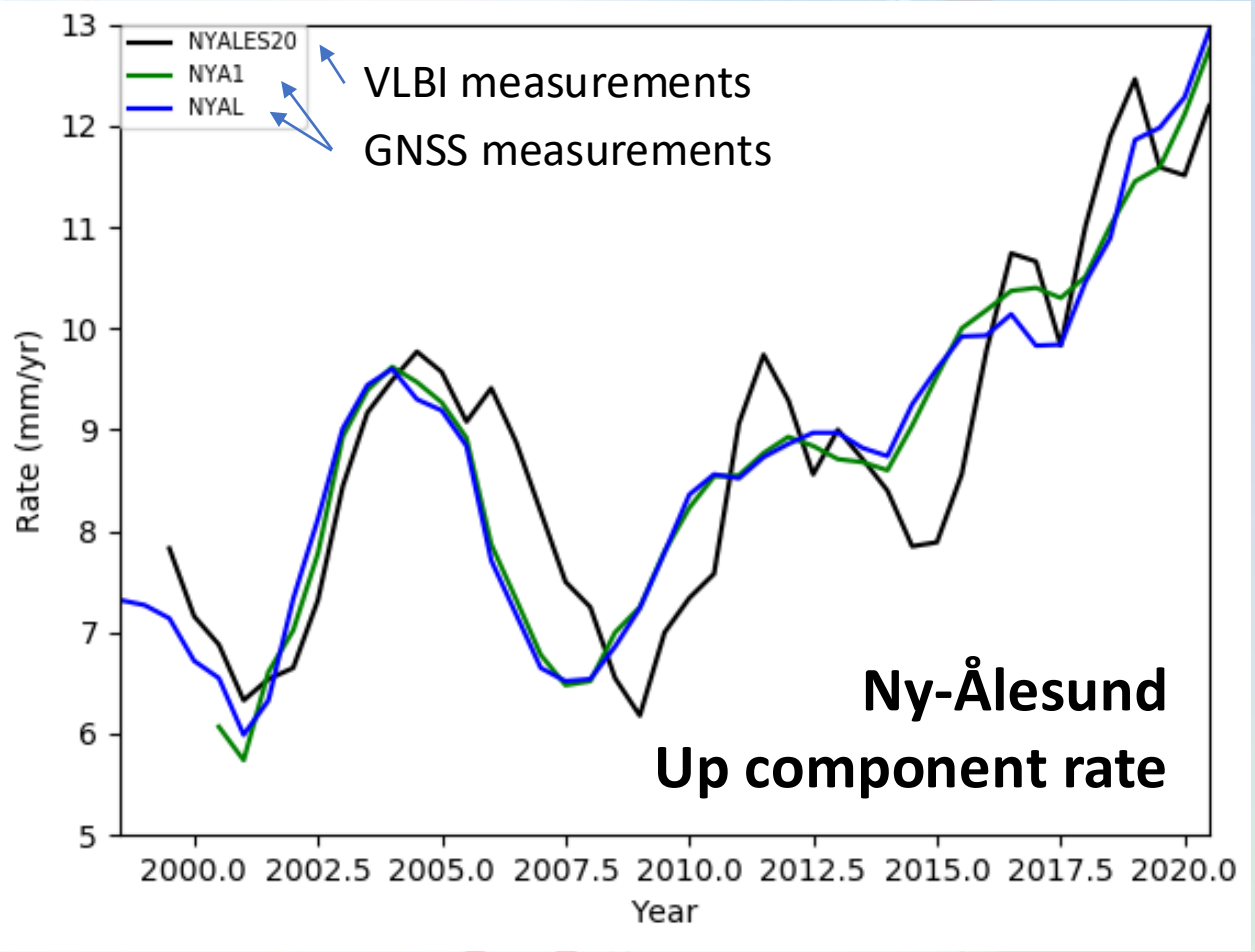
Credit: Wikipedia

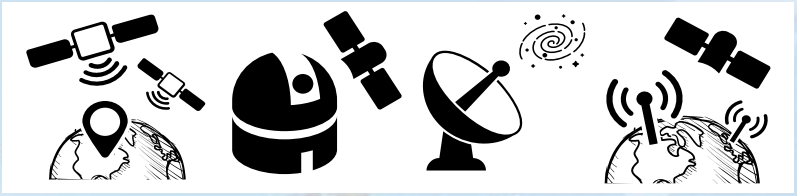
Measuring an effect of glacial changes



Time-varying uplift in Svalbard

Credit: H. Kierulf (see Kierulf et al., 2021 + 2022)

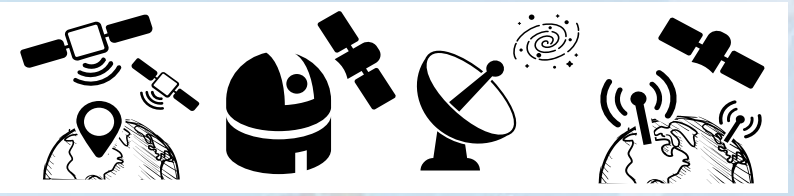


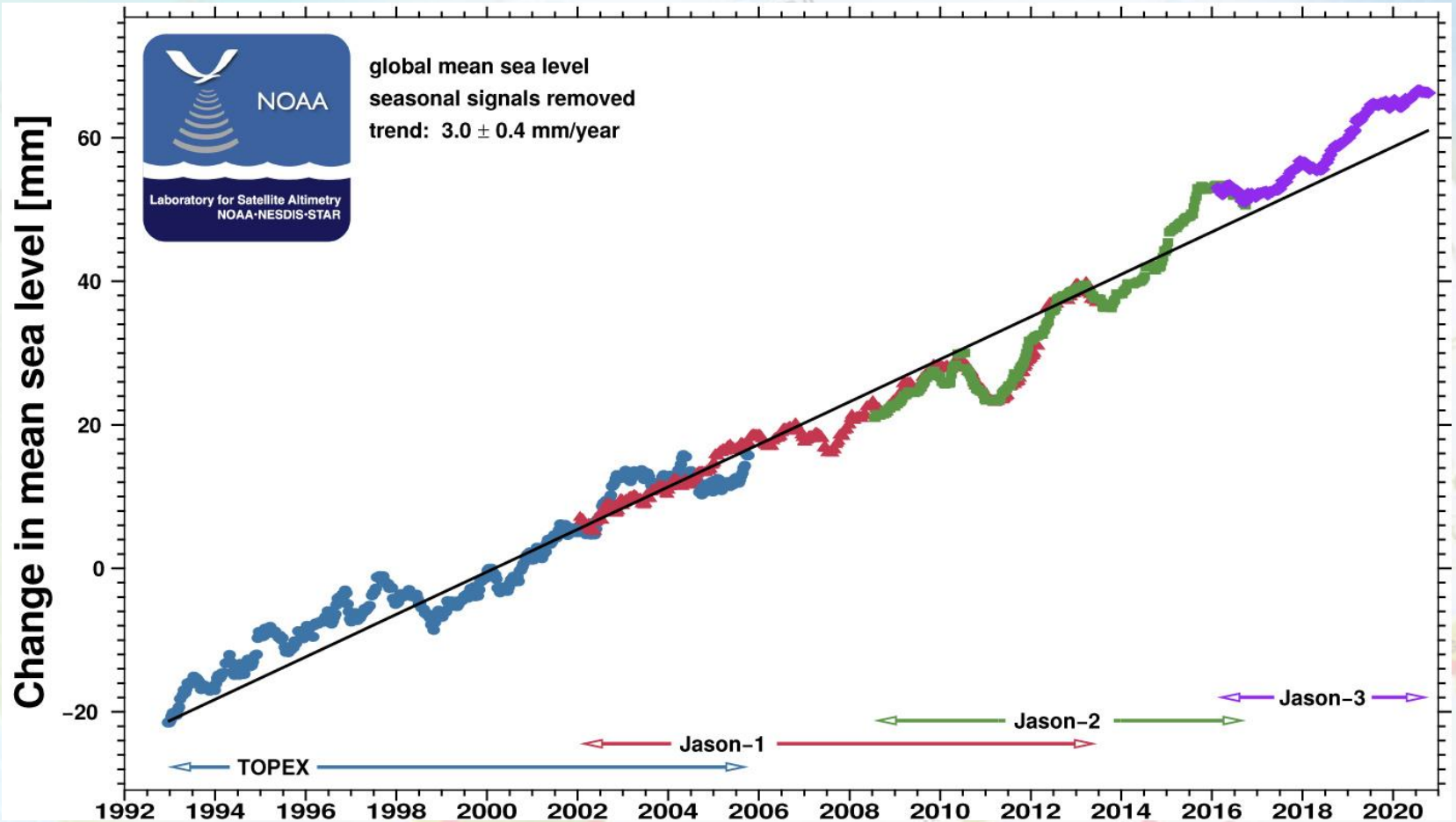


How can space geodesy help us understand the Earth and climate change?

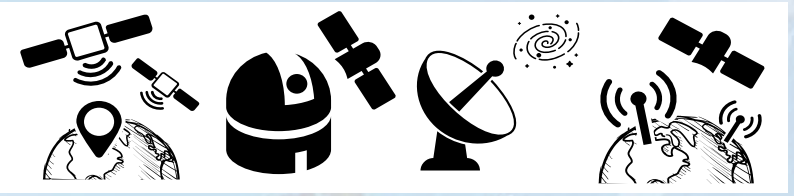
Mean sea level

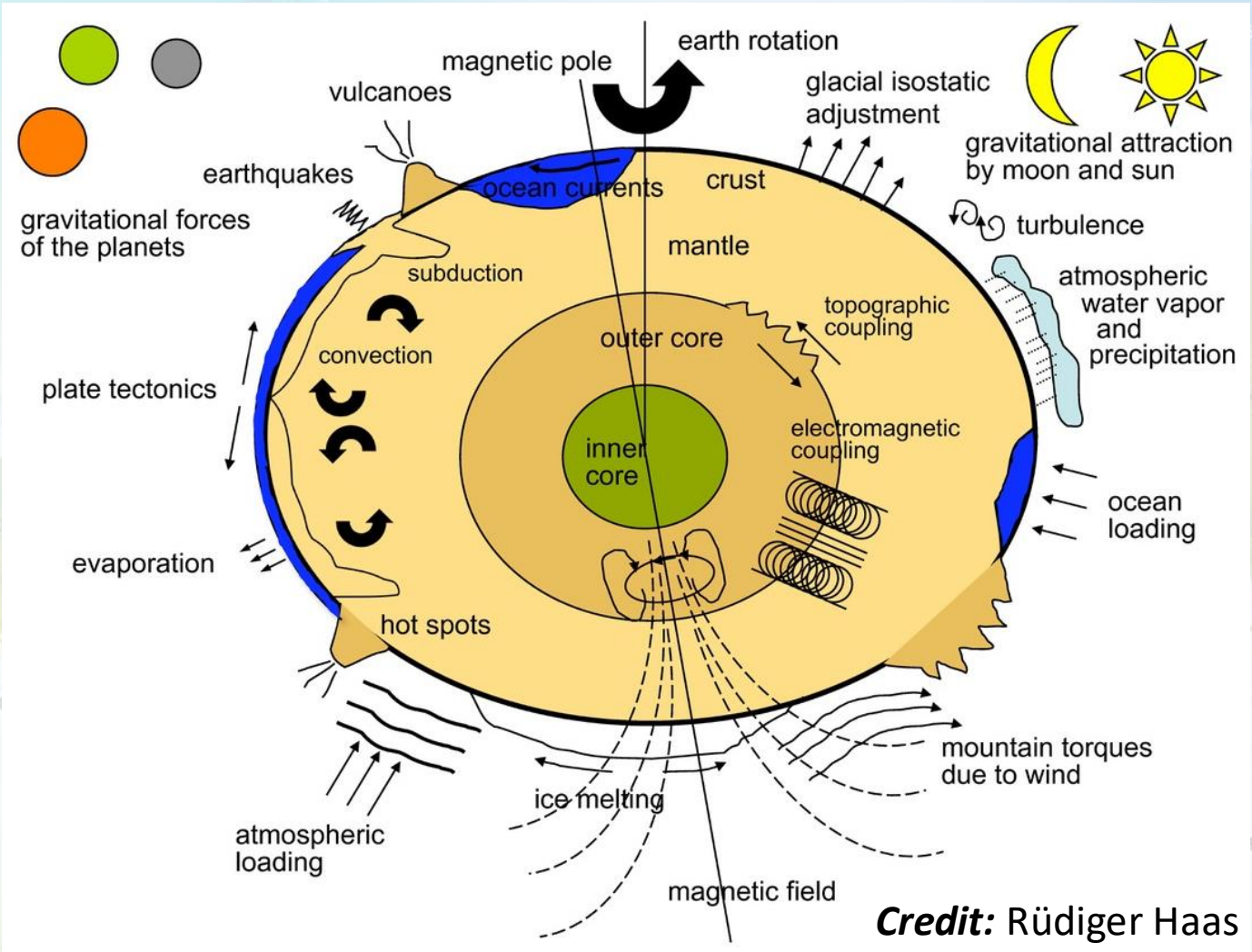
DORIS as a tool to measure Global Mean Sea Level





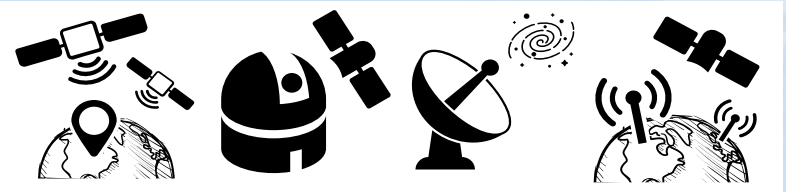
Earth processes





Credit: Rüdiger Haas

Key points



- Space geodesy allows us to measure the Earth with millimeter precision.
- GNSS, SLR, VLBI, and DORIS provide complementary observations that together define our global reference frames.
- Reference frames are essential for positioning, navigation, Earth observation, and scientific research.
- Space-geodetic observations reveal ongoing changes in ice sheets, sea level, and the solid Earth.
- Long-term geodetic measurements are crucial for understanding climate change and its impacts.
- International cooperation and global observing networks make these measurements possible.

Have a great summer school!

Contact me:
karine.lebail@chalmers.se

More information on geodesy:
https://geodesy.science/about-geodesy/