Planet Ocean Geodesy for Sea level & Climate

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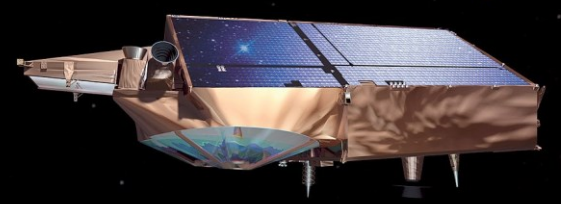
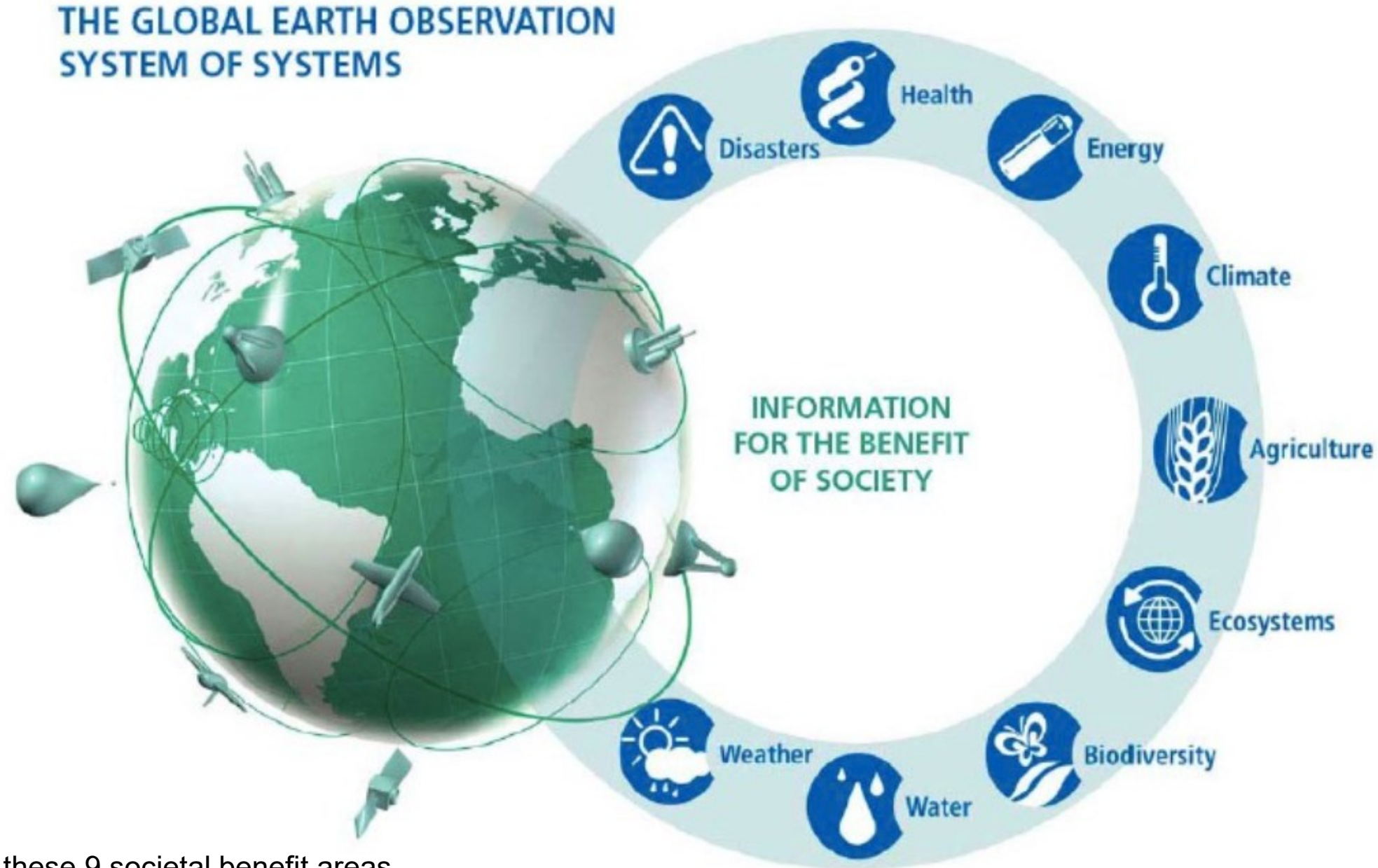
Carsten Bjerre Ludwigsen (DTU)
Steve Nerem (U. Colorado at Boulder)
Stine K. Rose (DTU)

DTU Space
National Space Institute

DTU Technical University of Denmark





GEOSS addresses these 9 societal benefit areas.

GGOS

GGOS contributes the geodetic component of GEOSS.

It provides:

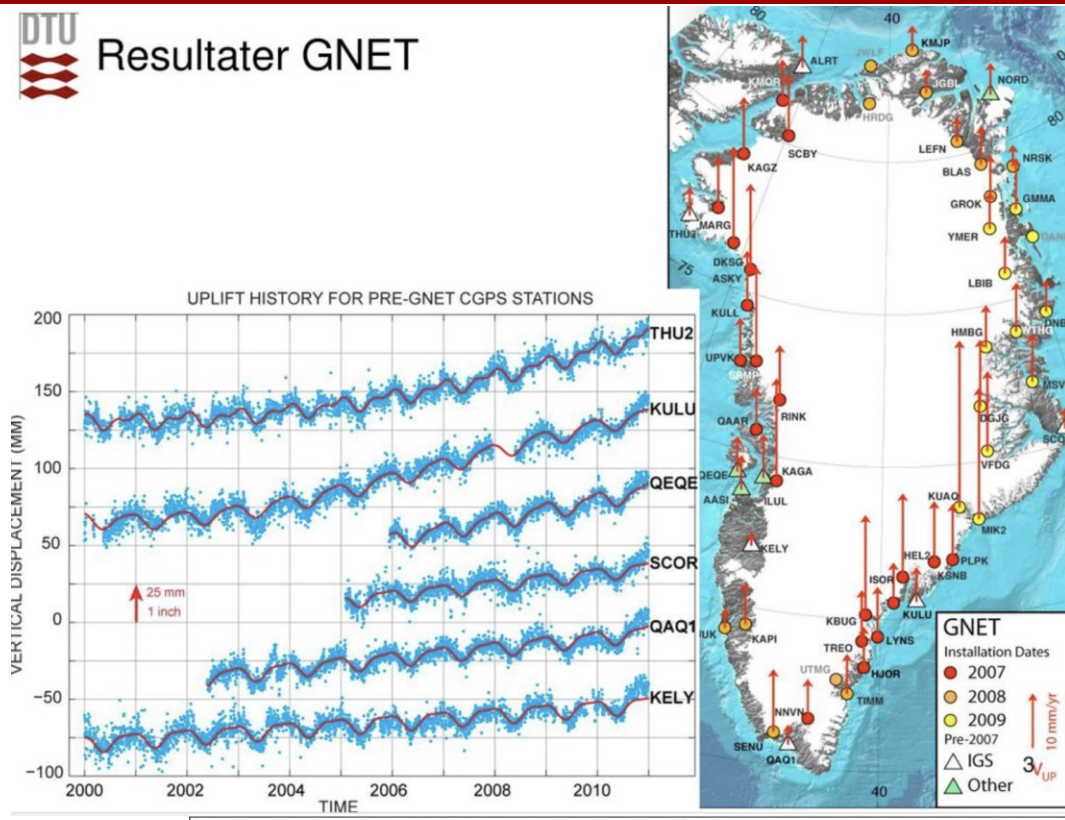
The **reference frames** required for all location-dependent observations and thus contributes to the foundation of most Earth observations, and

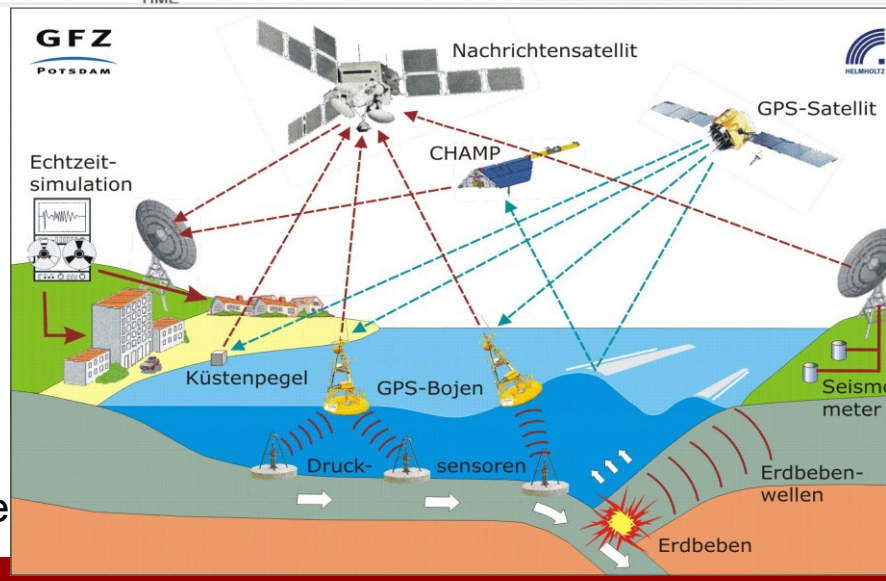
The **measurement** of the **time-variable geometrical shape**, **gravity field**, and **rotation of the Earth**, and thus contributes to the **Earth observation database**.

Monitoring long-term changes to geometrical shape (e.g., sea level, climate & plate motions) requires:

VERY high stability of the observation system & continuous observations.

Everything move





Sea-Level rise is a societal threat (long-term)

Low-lying coastal zone is home to 680 million people

For every cm of sea level rise 3 million extra people at flooding risk + retreat of 20.000 km2 land globally

IPCC predictions for 2100 show 0.43 - 0.84 meter increase of sea level

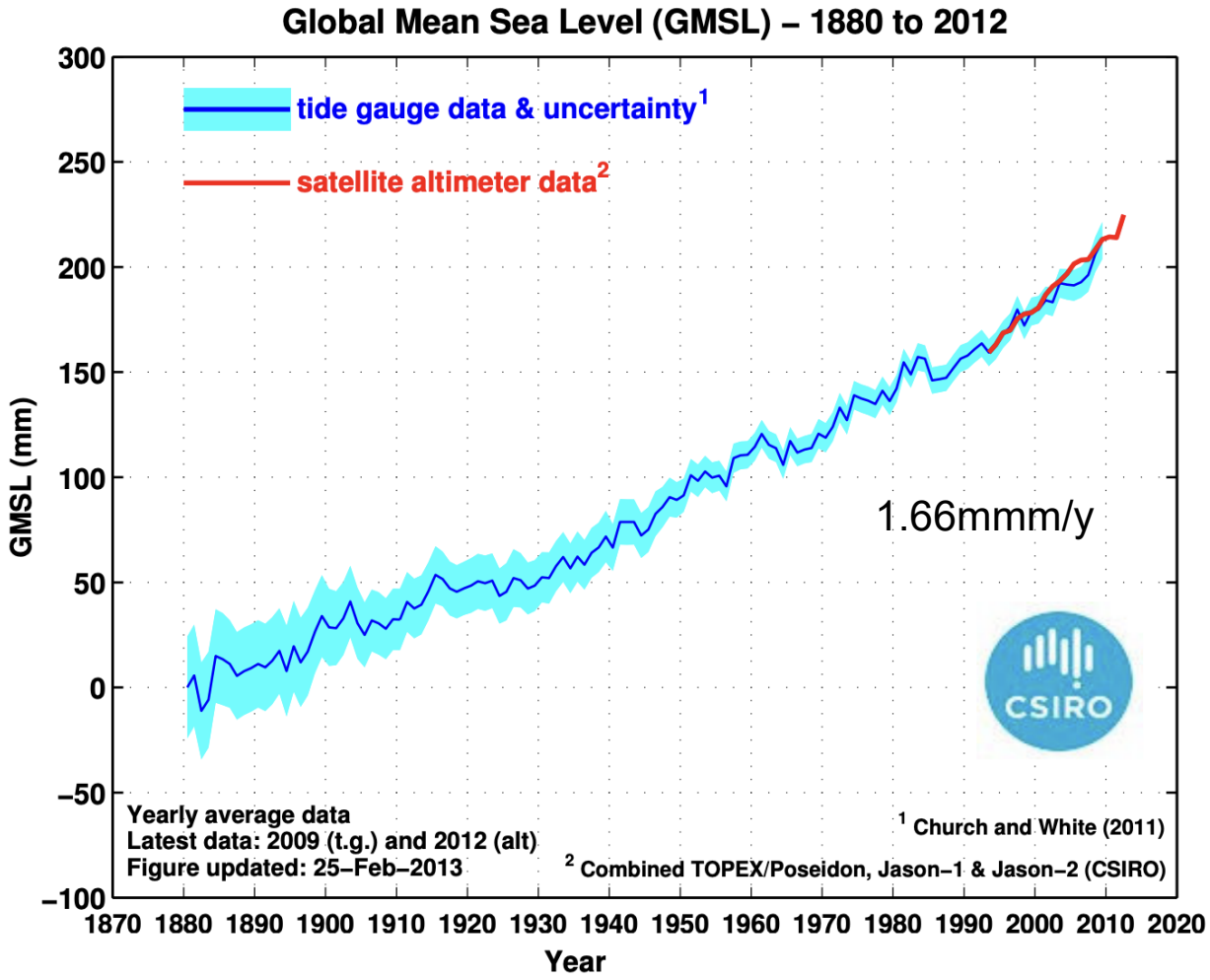
Sea level monitoring using Tide Gauges

Tide gauges monitor Relative Sea level

Can be affected by Local hydraulics, tectonics, GIA, etc

Importance: Records for up to 150 years

Permanent Service for Mean Sea level (IAG)



Satellite altimetry measures sea level for > 30 years

Measures:

Absolute Sea level (ASL)

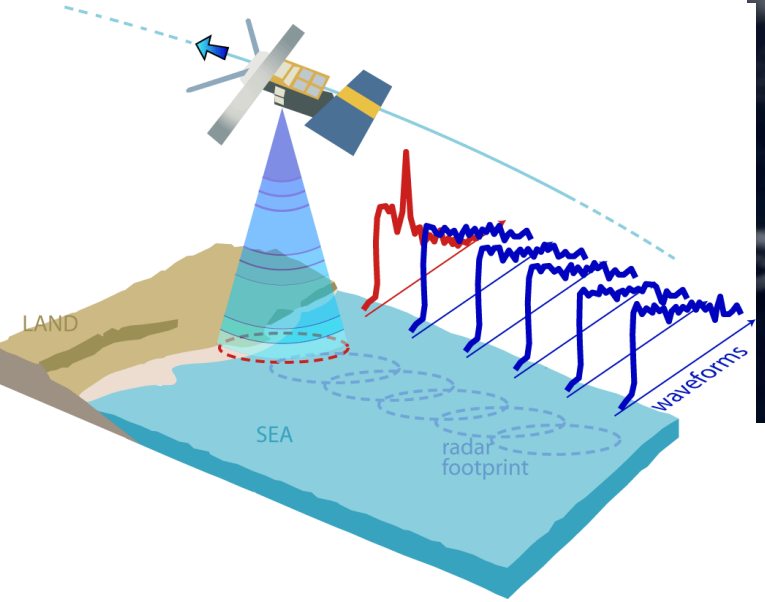
Or Geocentric Sea Level

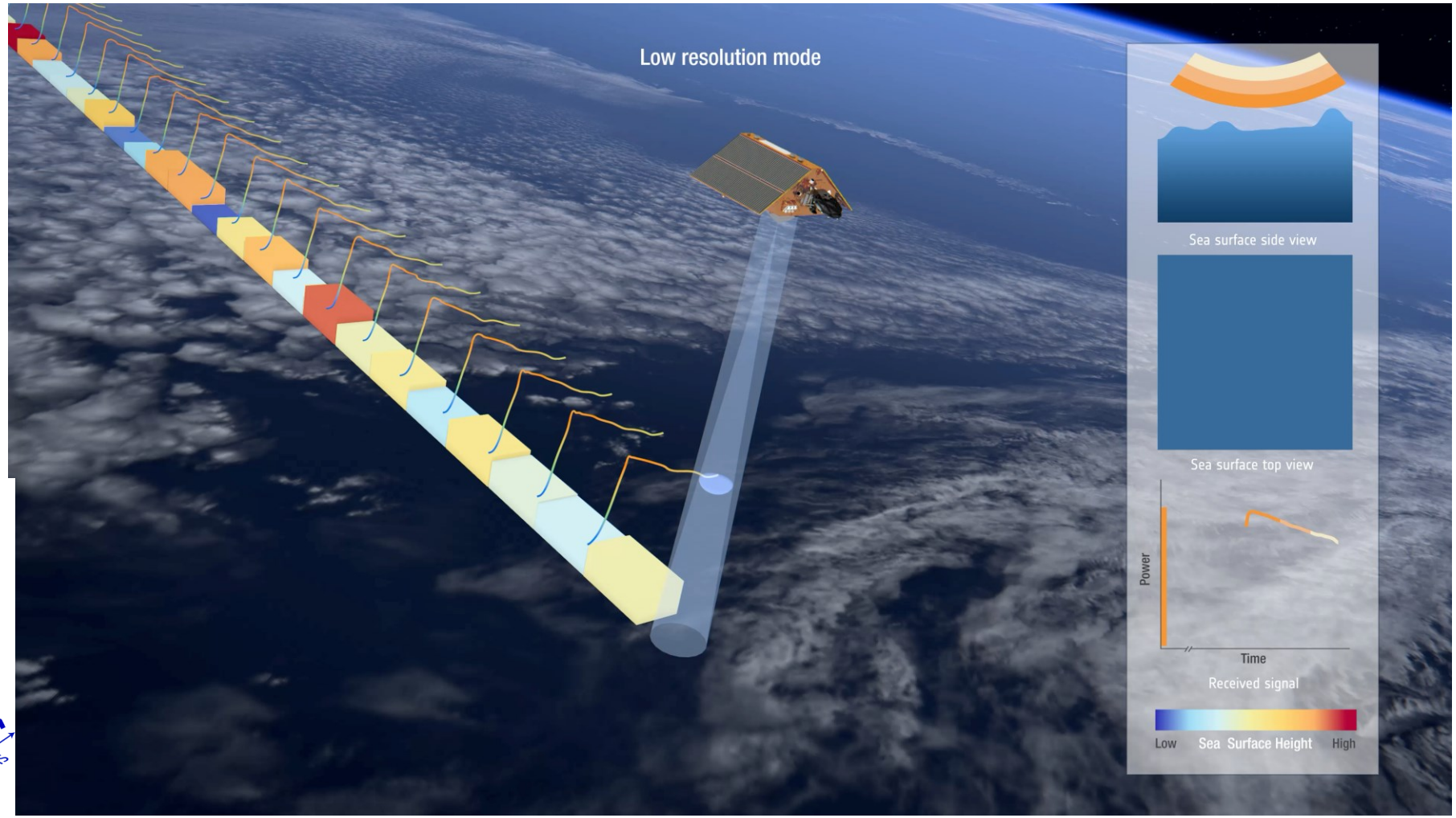
GLOBALLY

Essential Climate Variable

Range precision = 1 cm

mm stability over decades



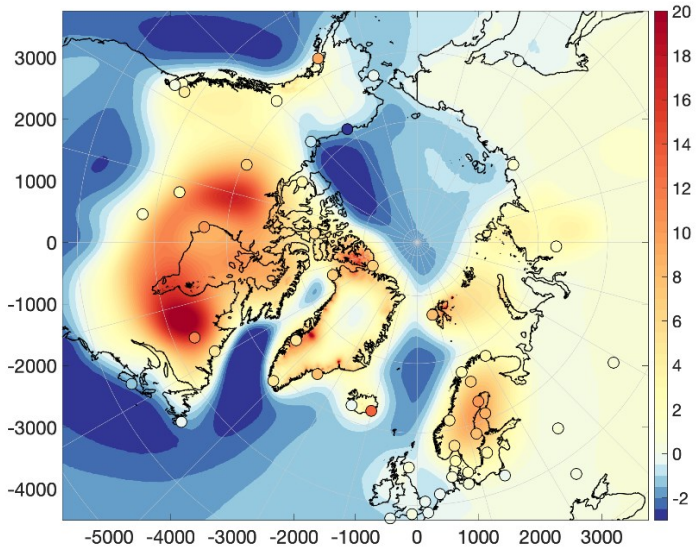


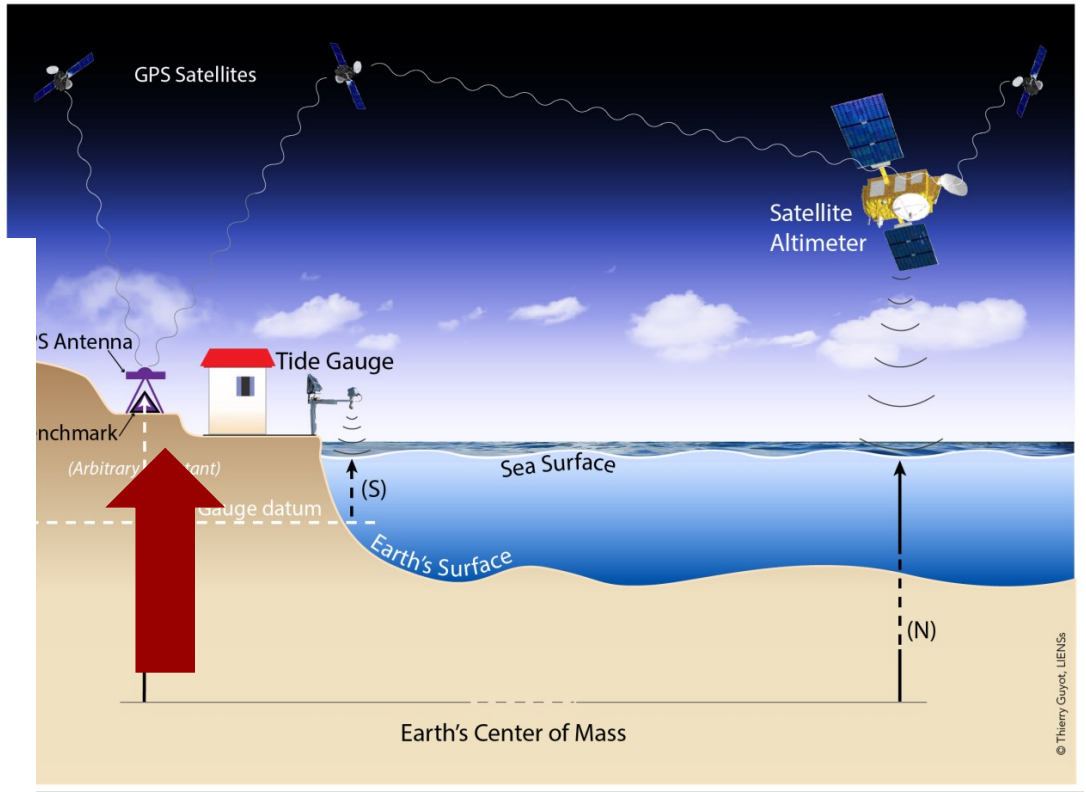
Absolute vs Relative Sea level changes:

Altimetry (**absolute SL**) = Tide-Gauge (**relative SL**) + **VLM** (GNSS)

Correct for

Vertical Land Movement using model



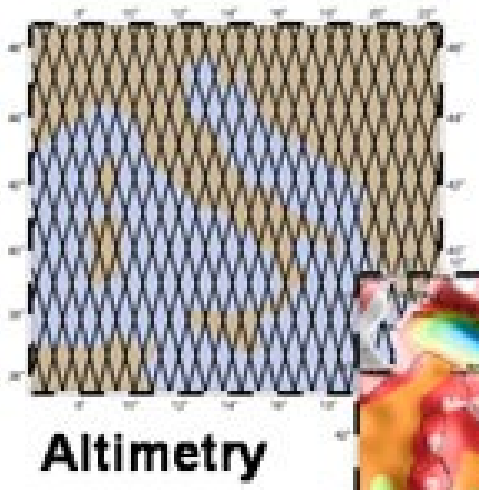


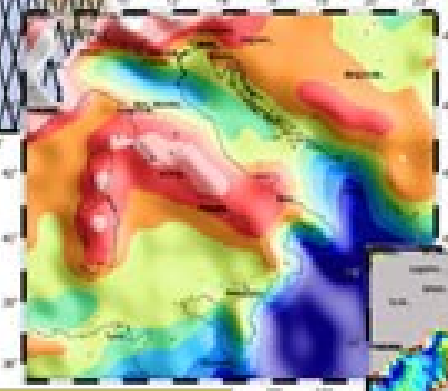
Global Isostatic Adjustment is "Linear"

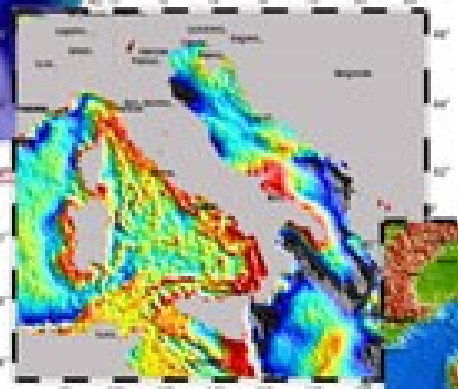
But applicable to Tide Gauge data.

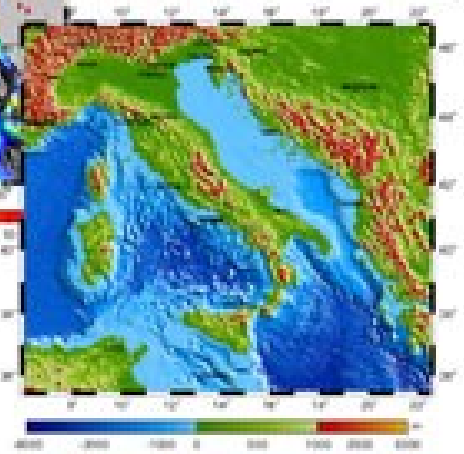
Only at **coastal locations** with GNSS/Tide Gauge combination.

MSS, Gravity &Bathymetry from Satellite Altimetry

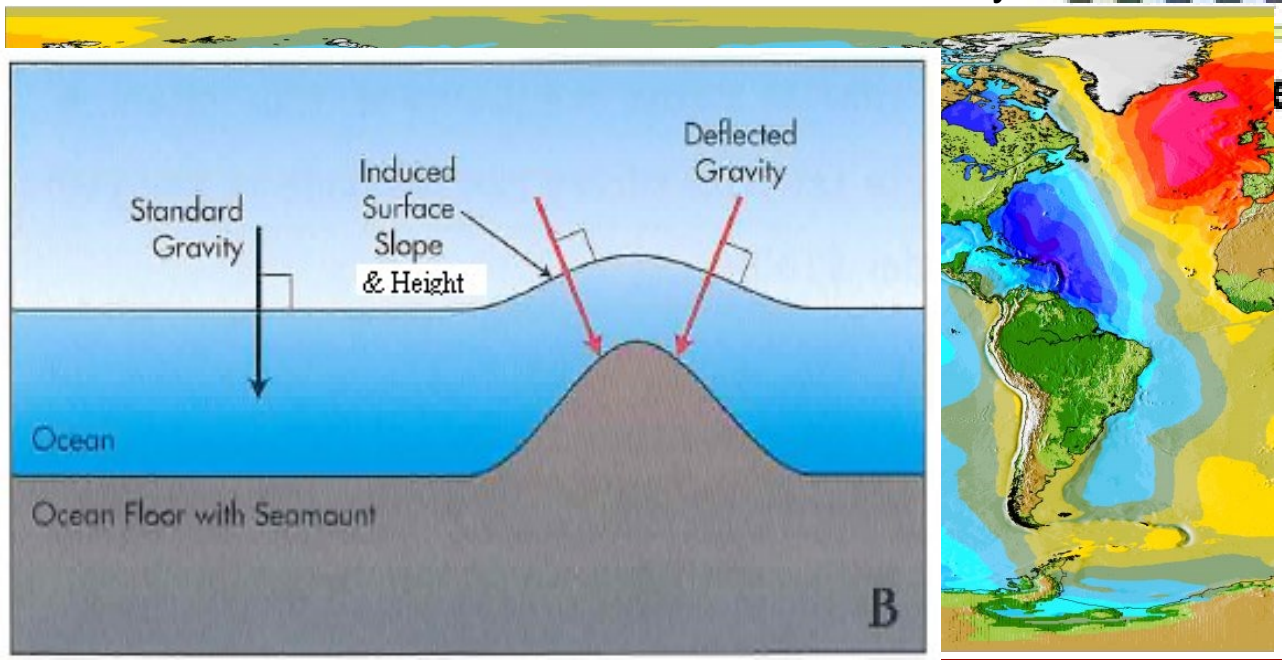








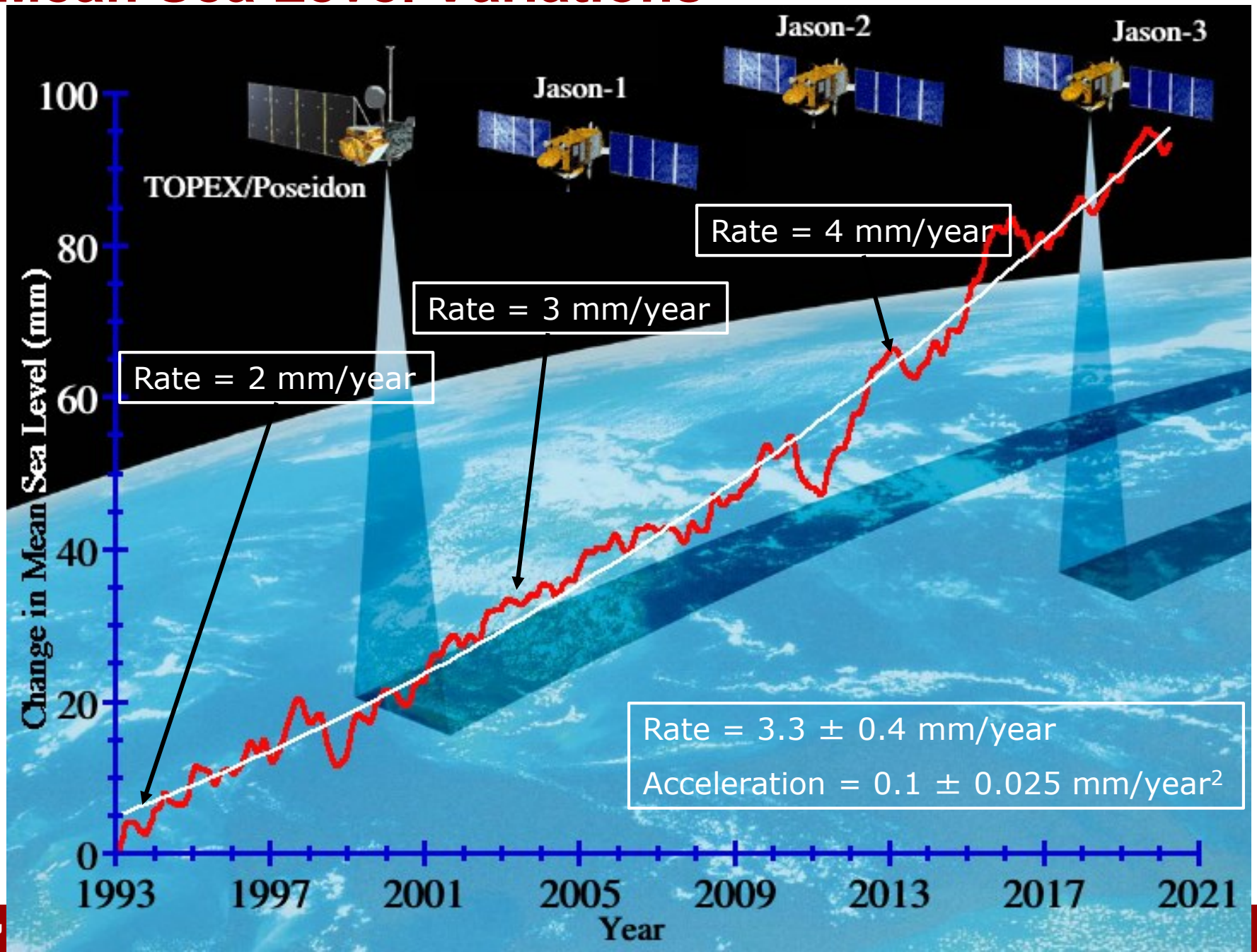
DTU21MSS is vertical offshore ref frame for altimetry



eoid

Gravity anomalies

Global Mean Sea Level Variations



Spatial sea level change

Sea level determins our Vertical Datums.

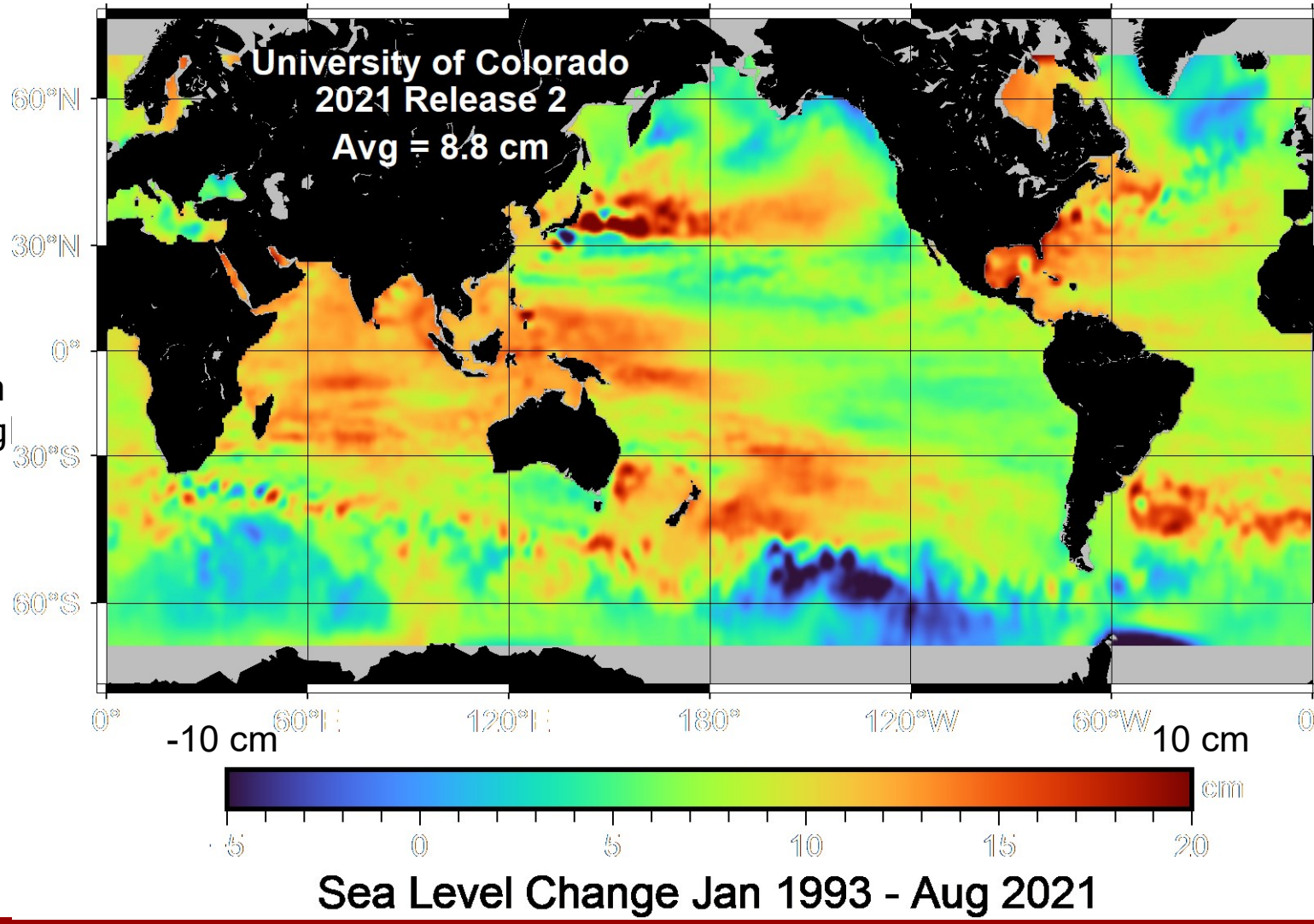
MSS is the Vertical reference for SL Anomalies

MSS (DTU/CLS) are averaged over 20 years (1993-2012) The MSS becomes increasingly "**outdated**" with time

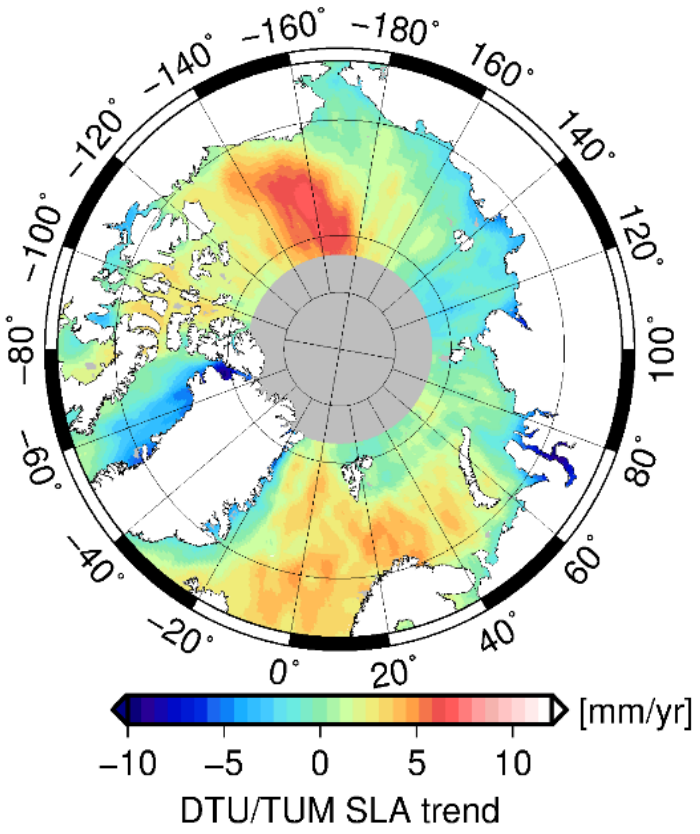
Danish DVR90 vertical Datums is fitted to sea level around 1990 DVR90 becomes increasing "outdated" with time.

Fortunately, GIA counteract this locally

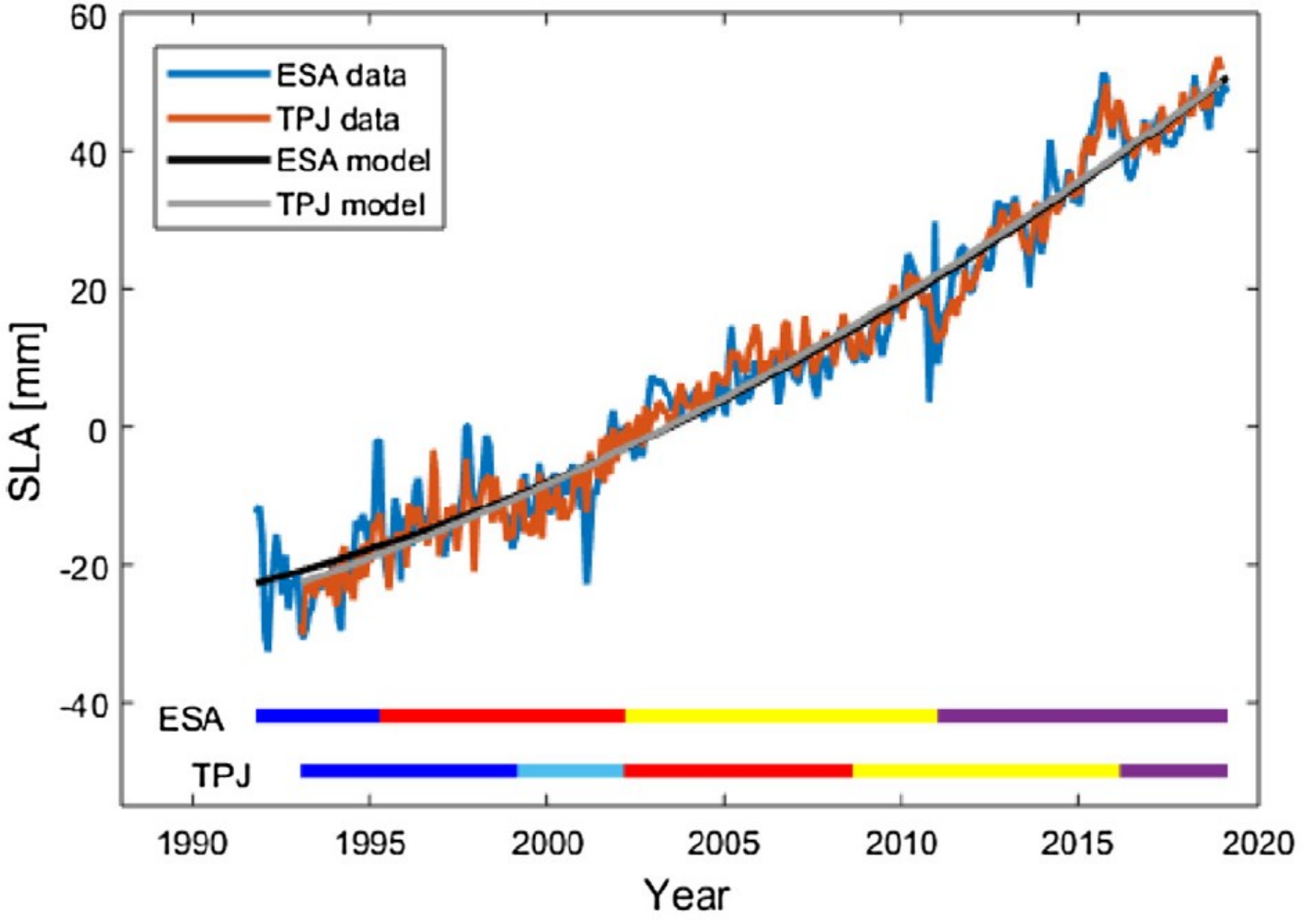
Critical for computing sea level and flooding thresholds/exceedance etc.



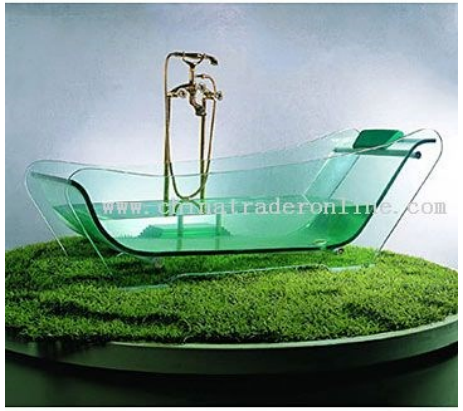
Independent satellite data confirms GMSL change



Rose, Andersen, Passaro (2019)
Veng and Andersen (2019)



Confirming sea level changes: Sea level budget closure



Altimetry (various satellites 1993-now)

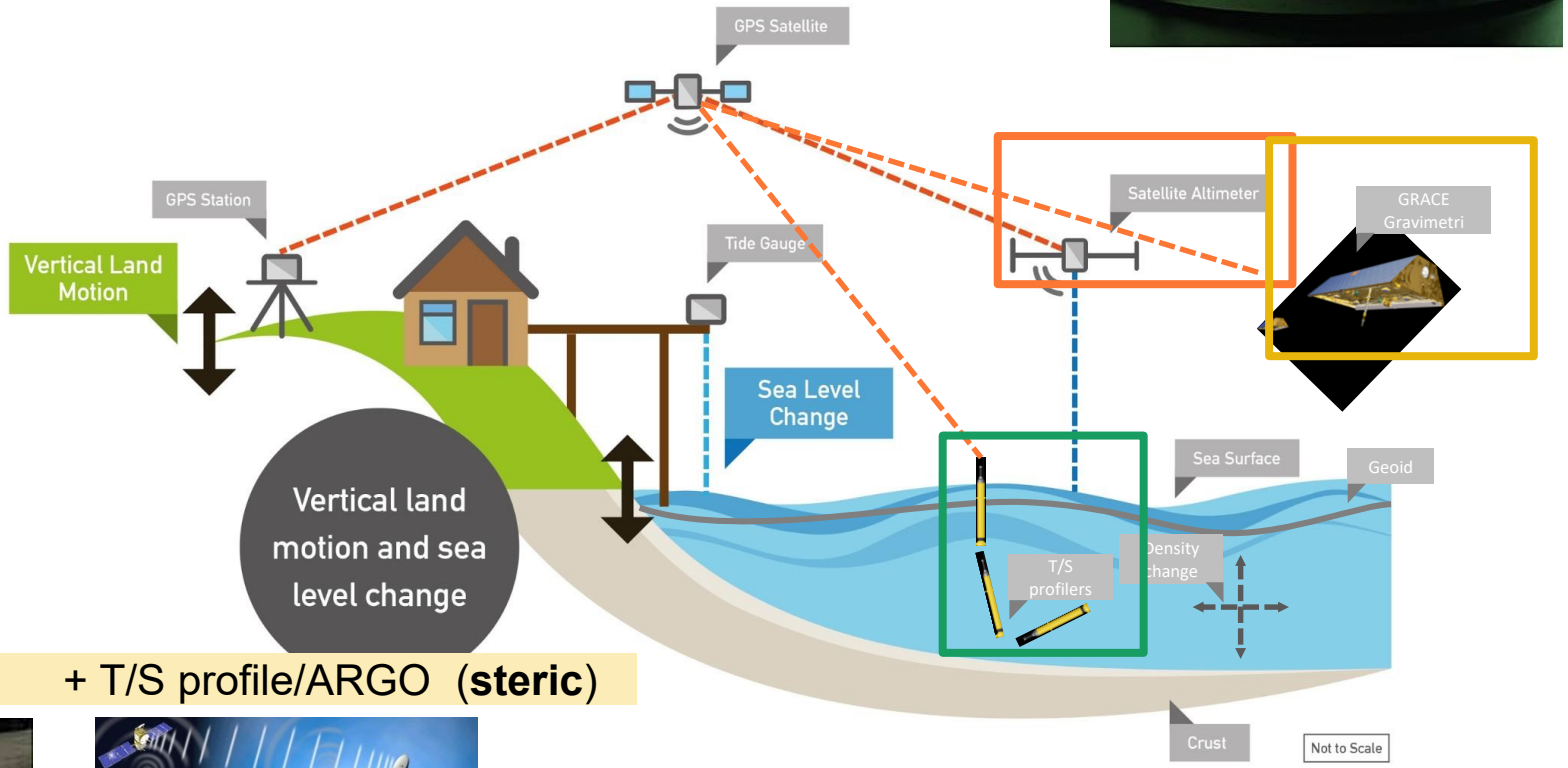
Sea surface height: **absolute sea level** (ASL) w.r.t. a geocentric reference.

GRACE (2002-2017) and GRACE-FollowOn (2018-now)

Gravemetri: observes **mass changes** on the earth (both land and ocean), which alters the geoid.

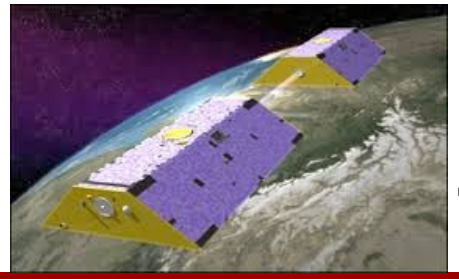
T/S profilers (since 1950's, ARGO 2001-now)

In-situ temperature and salinity measurements can be converted to changes in density changes, called **steric sea level**.



Altimetry (**absolute SL**) = GRACE (**mass**) + T/S profile/ARGO (**steric**)

=



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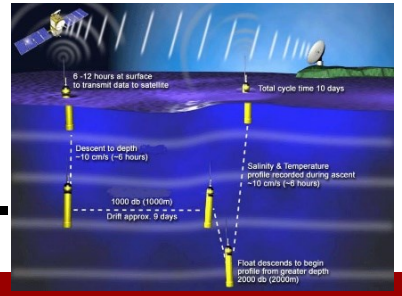
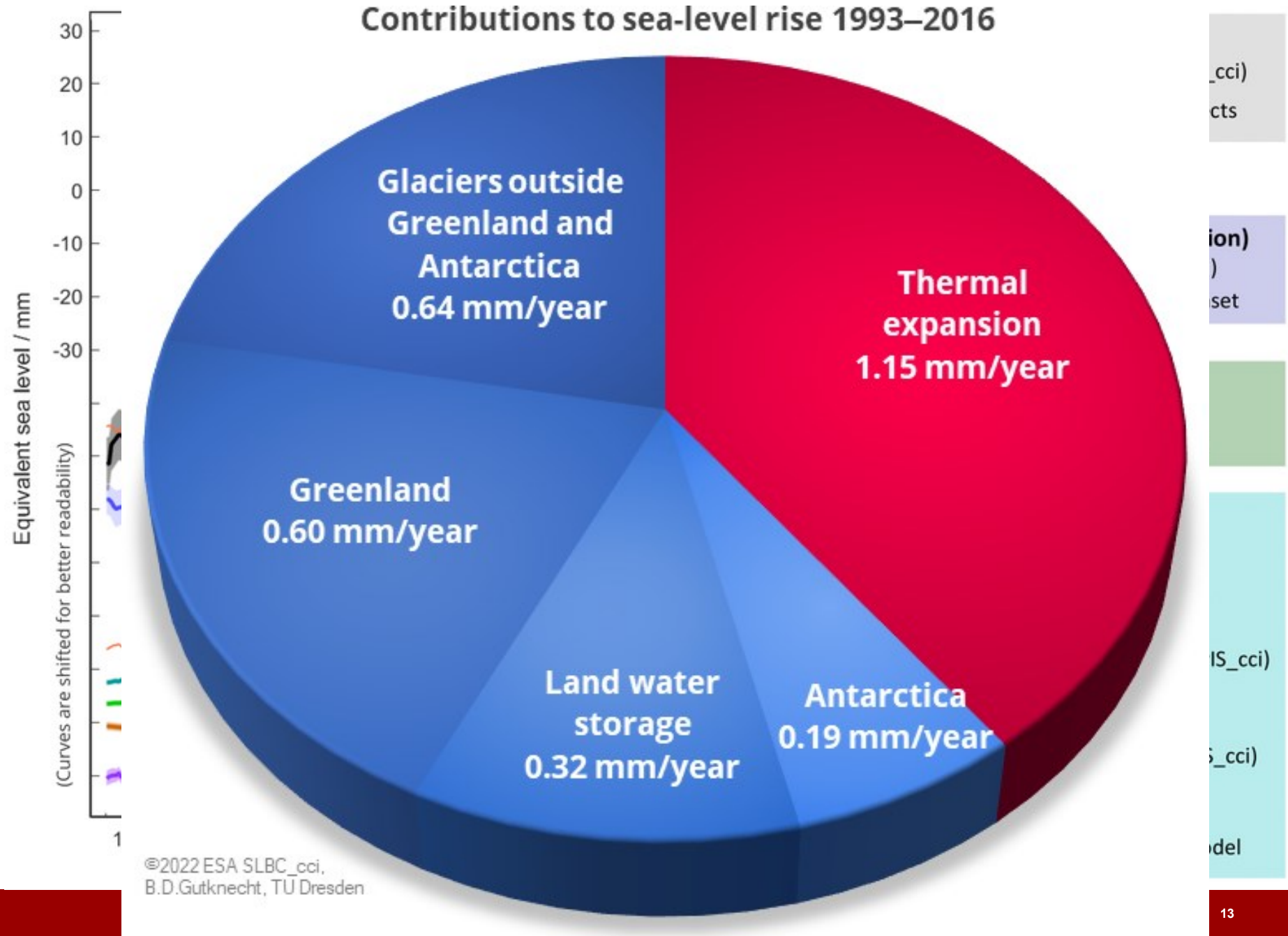


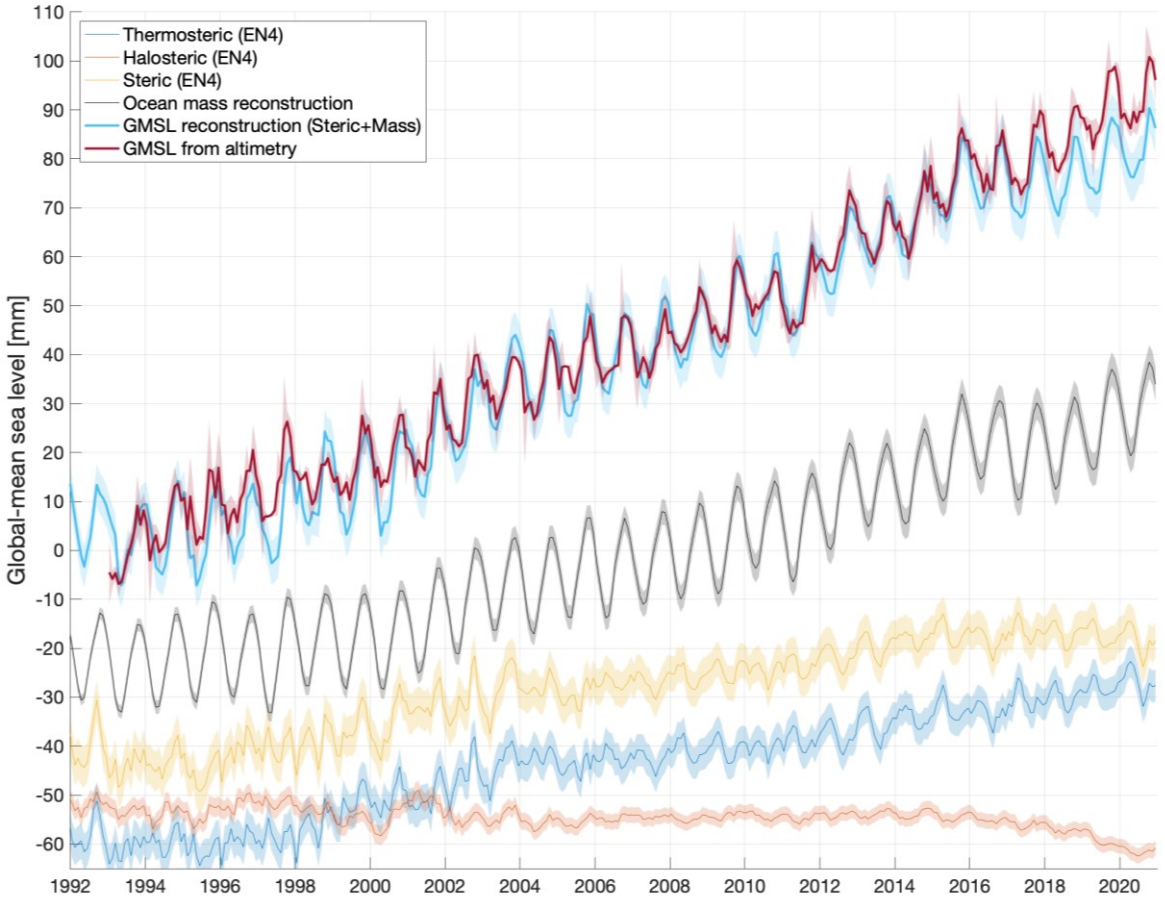
+ **TWS+VLM + …..**

Sea level budget closure



Horwart, Andersen &18 others, 2022

Non-closure during 2016-2021



Altimetry GMSL

Reconstructed GMSL (steric + mass)

mass reconstruction
(land and ice)

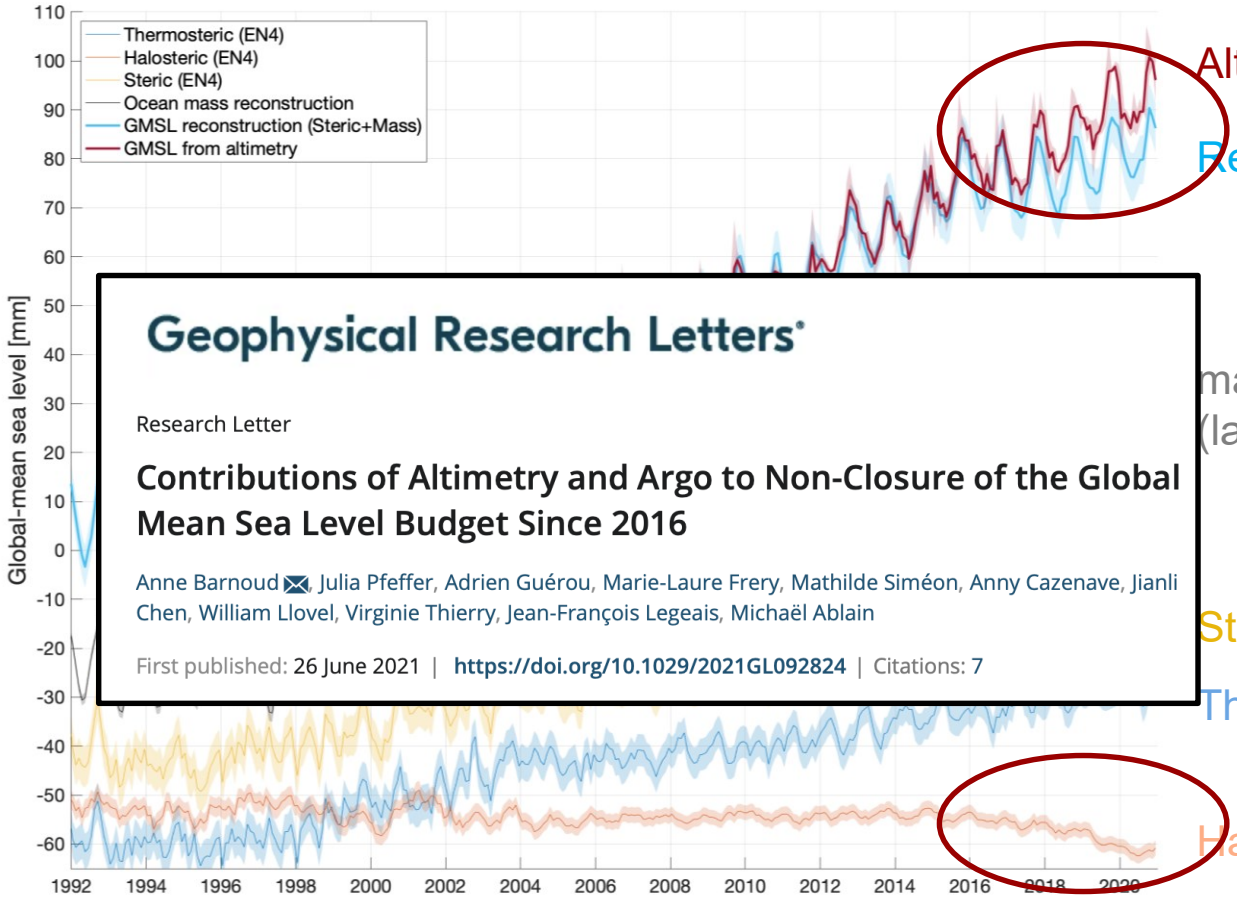
Steric sea level

Thermosteric sea level

Halosteric sea level

Ludwigsen, Andersen and Rose (2022)

Non-closure during 2016-2021



Geophysical Research Letters

Research Letter

Contributions of Altimetry and Argo to Non-Closure of the Global Mean Sea Level Budget Since 2016

Anne Barnoud, Julia Pfeffer, Adrien Guérou, Marie-Laure Frery, Mathilde Siméon, Anny Cazenave, Jianli Chen, William Llovel, Virginie Thierry, Jean-François Legeais, Michaël Ablain

First published: 26 June 2021 | https://doi.org/10.1029/2021GL092824 | Citations: 7

Altimetry GMSL

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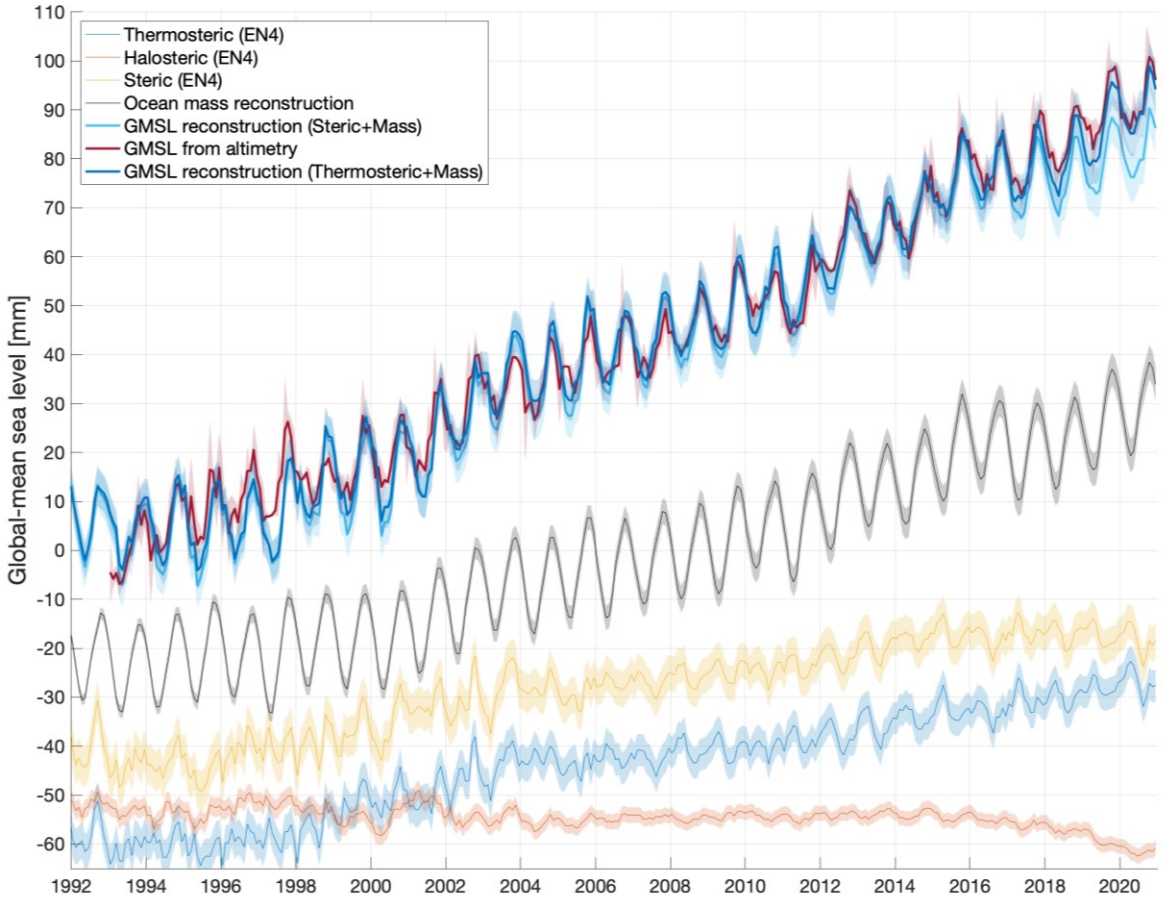

Altimetry GMSL

Reconstructed GMSL (thermosteric + mas

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What causes mis-closure:

Altimetry: Jason-2 -> Jason-3

GRACE: GRACE -> GFO

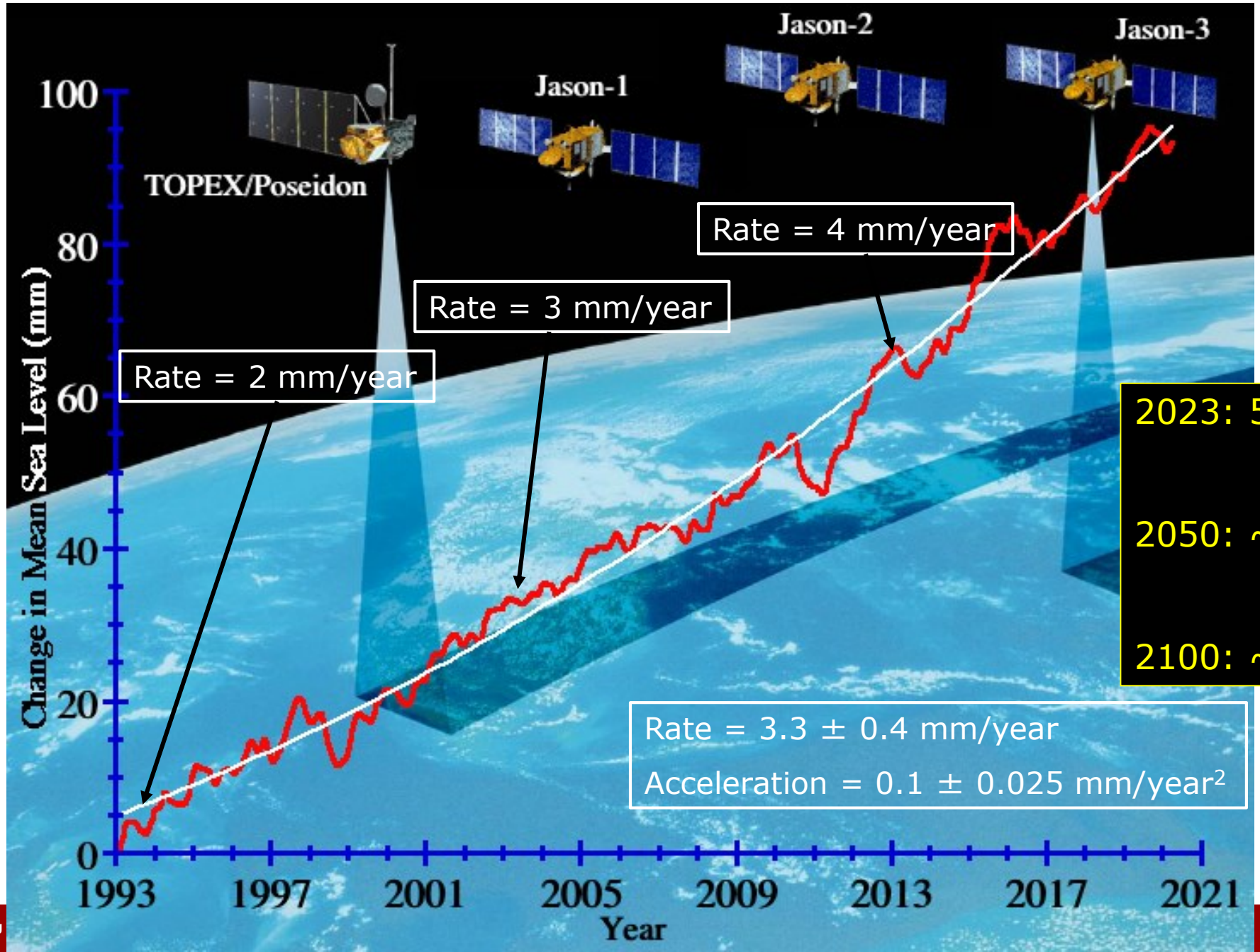
ARGO (conductivity)?

Something different?

…… TWS, Permafrost etc)

Importance of stability of reference and observing systems over decades

The Acceleration in Global Mean Sea Level



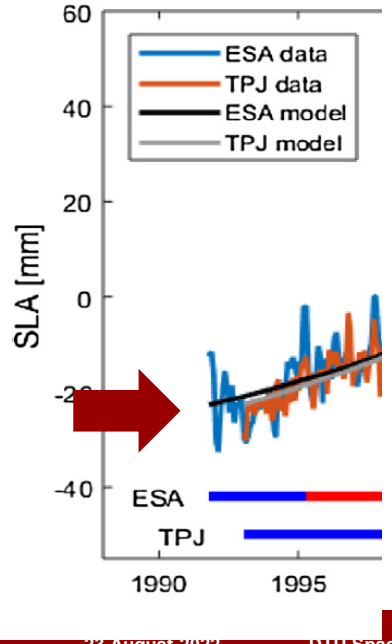
2023: 5 mm/year

2050: ~8 mm/year?

2100: ~14 mm/year?

What is causing the acceleration of GMSL?

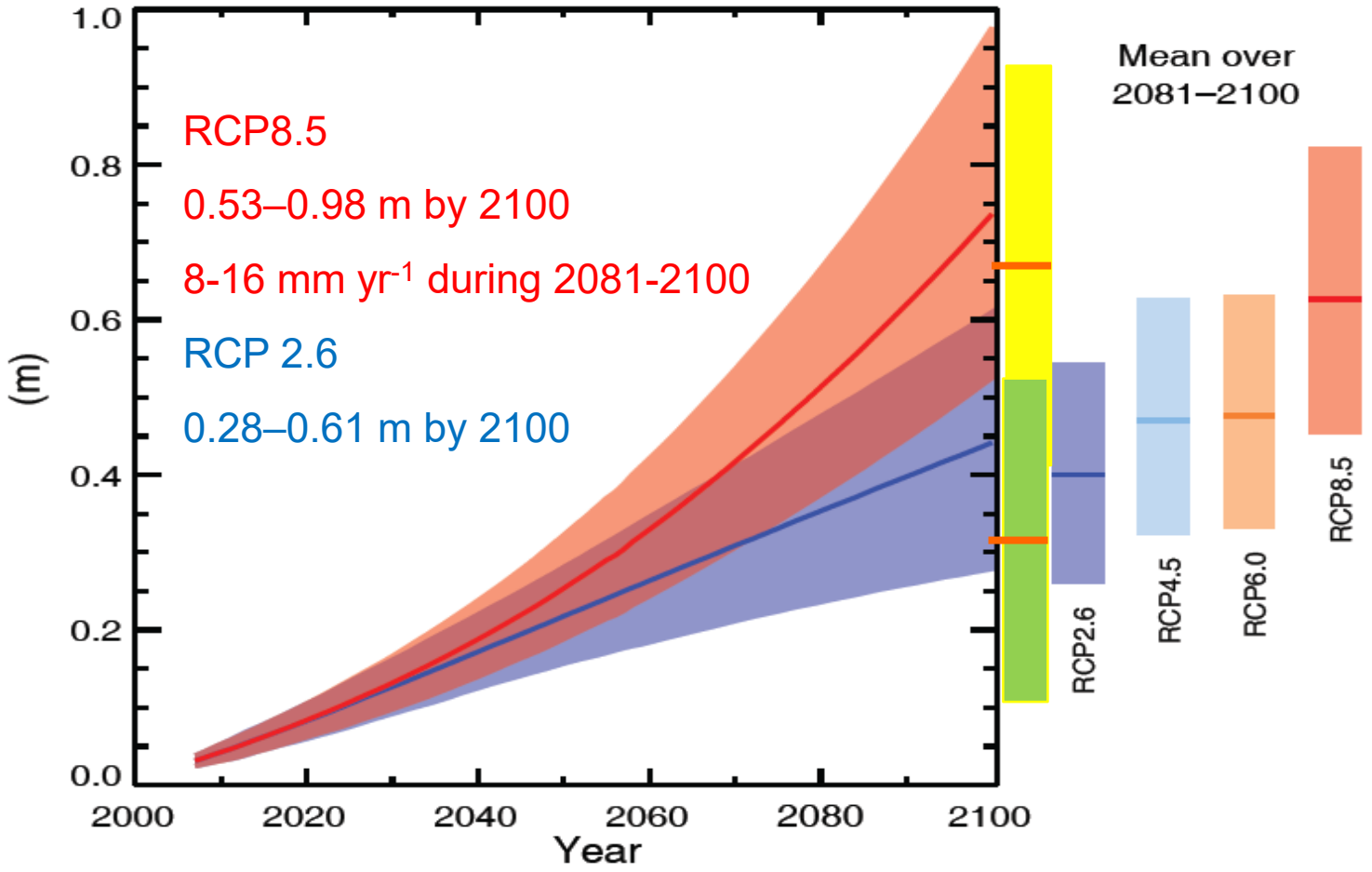
1991 Eruption.



Component	Time Period	Acceleration (mm/yr^2)	Reference
Greenland	1992.0-2020.0	0.027	Mankoff et al. 2021
Antarctica	1992.0-2017.4	0.028	IMBIE2
Mountain Glaciers & Small Ice Caps	2000.0-2020.0	0.013	Hugonnet et al. 2021
Thermosteric	2005.0-2021.0	0.038	Argo/NOAA
Pinatubo Eruption	1993.0-2021.0	0.020	Fasullo et al., 2016
ENSO Effects	1993.0-2021.5	- 0.036	Hamlington et al., 2020
Sum of Components		0.090	
Altimeter Observed	1993.0-2021.5	0.099	

Future GMSL rise

Projections of 21st-century GMSLR under Different RCPs from the IPCC 5th Assessment Report

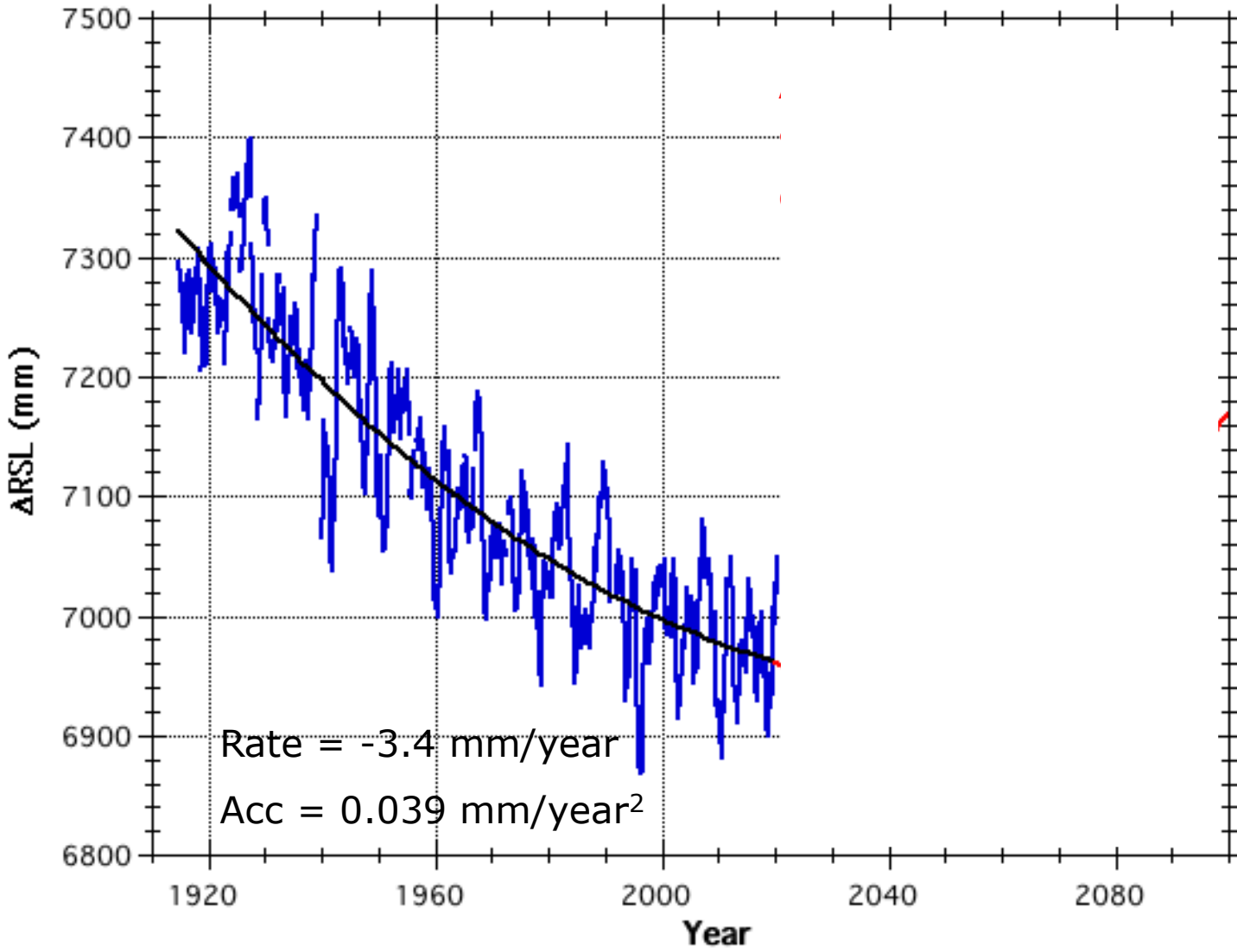


Sea Level projections for Scandinavia

Local projection onto 2150

NKG Venue

Oslo Relative Sea level




THANK YOU!


TIRSDAG
03 JANUAR 2012
NOTE:
Drawing maps will
be easier in the future
WWW.WULFFMORGENTHALER.DK