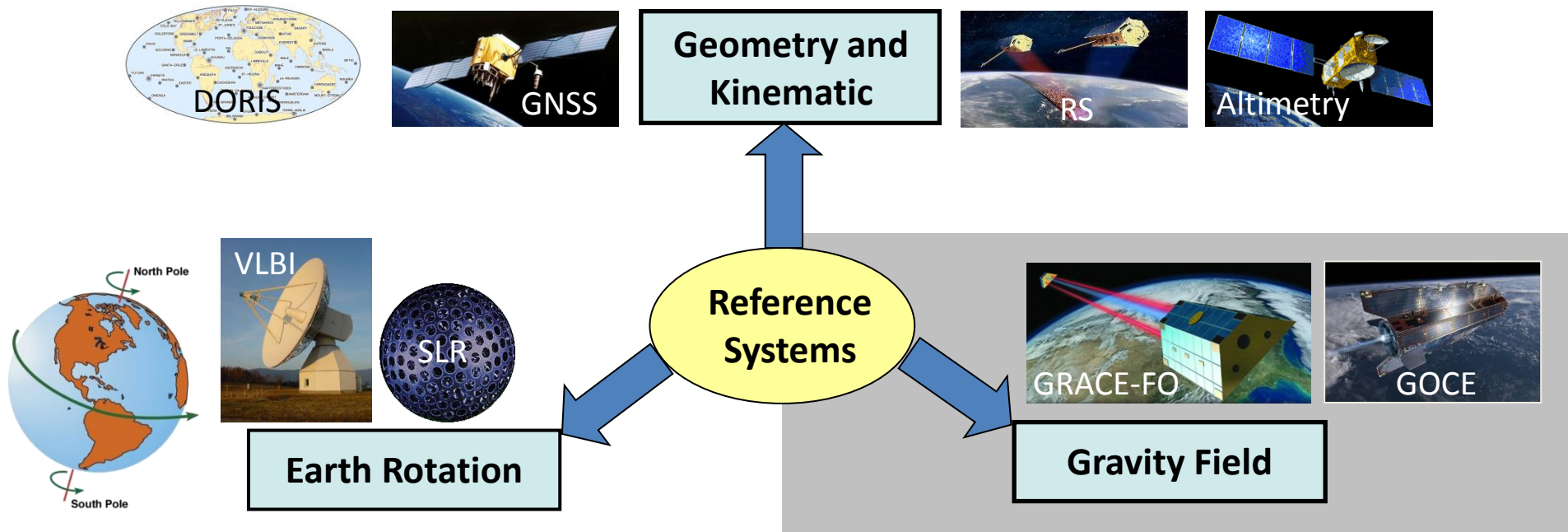


# Essential Gravimetric Variables – Identification and Initial Assessment

Thomas Gruber & Roland Pail

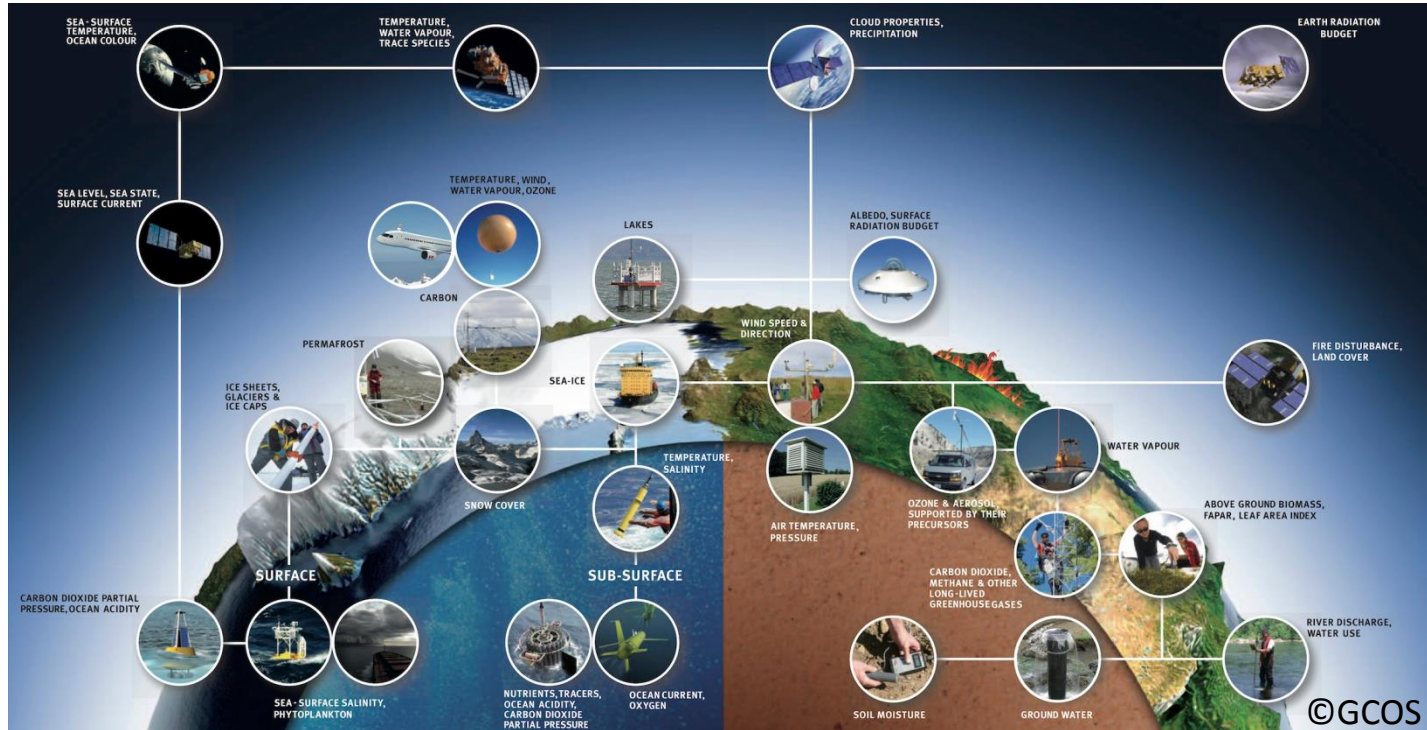
Institute of Astronomical and Physical Geodesy, Technical University of Munich, Germany



# Essential Variables

## Global Climate Observing System (GCOS) → Essential Climate Variables (ECV)

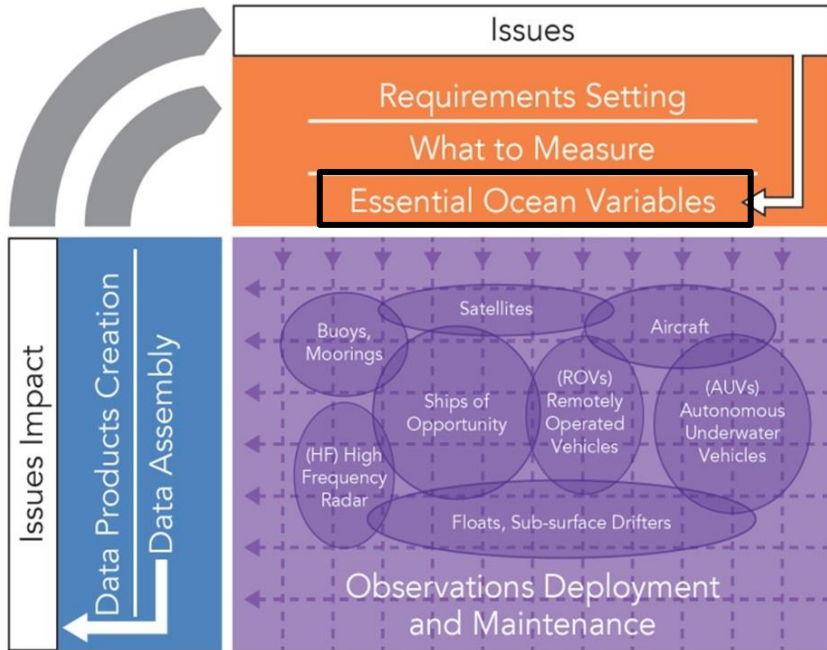
*“An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth’s climate.”*



# Essential Variables

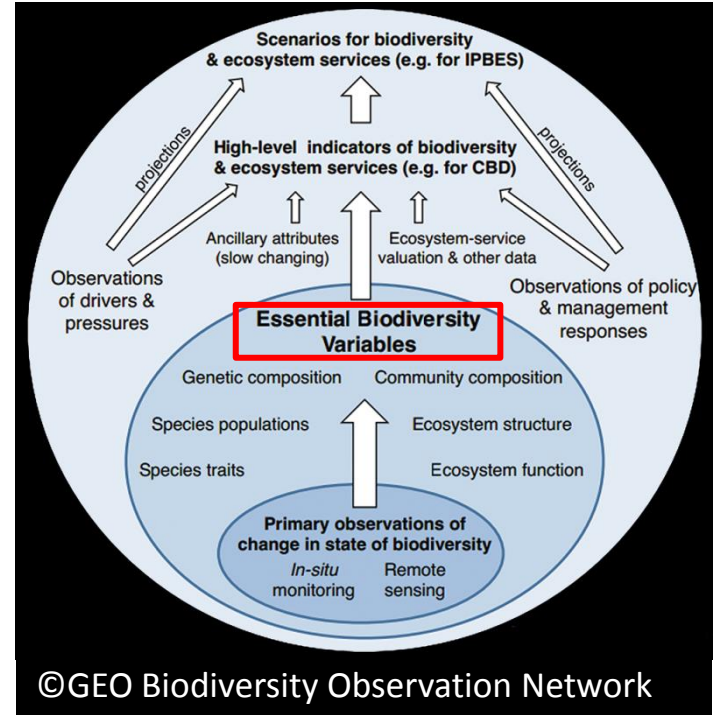
Global Ocean Observing System (GOOS) →  
Essential **Ocean** Variables (**EOV**)

Framework for Ocean Observing Process Diagram



©GOOS

Group on Earth Observations Biodiversity  
Observation Network (GEO BON) → Essential  
**Biodiversity** Variables (**EBV**).

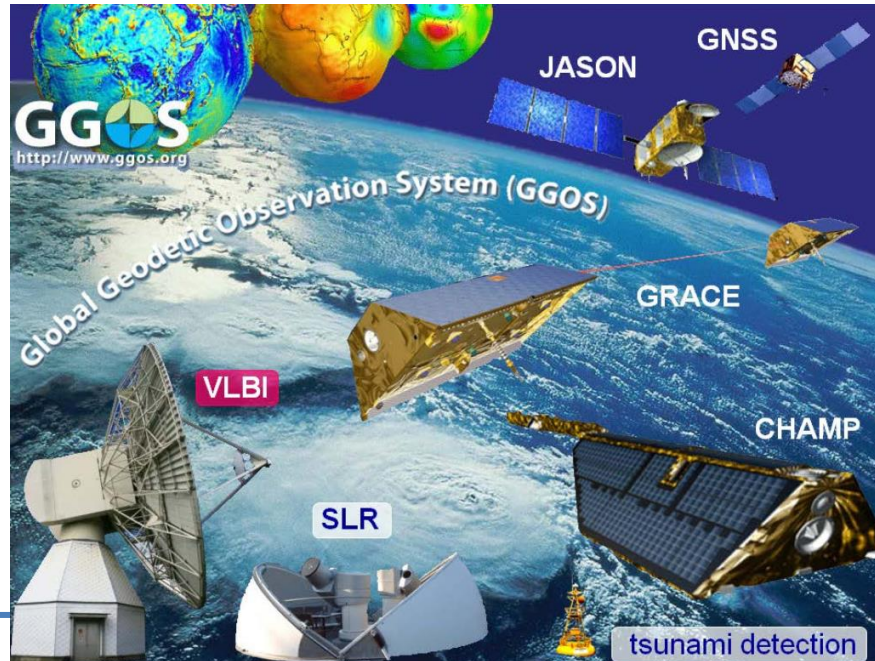


©GEO Biodiversity Observation Network

# Essential Geodetic Variables

Global Geodetic Observing System (GGOS) → Essential **Geodetic Variables (EGV)**

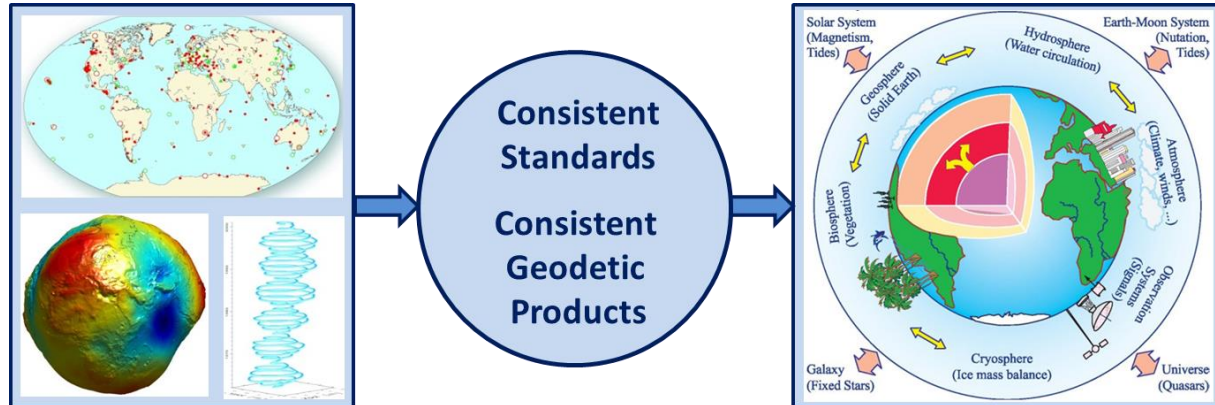
*“EGVs are observed variables that are crucial (essential) to characterizing the geodetic properties of the Earth and that are key to sustainable geodetic observations. Examples of EGVs might be the **positions** of reference objects, **Earth orientation** parameters, ground- and space-based **gravity measurements**, etc.” (R. Gross)*



# GGOS Bureau of Products and Standards (BPS)

The BPS supports GGOS in its key goal to obtain consistent products describing the geometry, rotation and gravity field of the Earth.

- Homogenization of IAG standards and products;
- Keep track of the adopted geodetic standards and conventions across IAG components,
- Integration of geometric and gravimetric parameters and to develop new geodetic products, needed for Earth sciences and society.
- Coordinate the Committee on “Essential Geodetic Variables (EGVs)” whose task is apart from others the definition of “Essential Gravimetric Variables (EGrVs)”



after Drewes (2007),  
IAG Symposia 130

# Links between Essential Variables and EGrVs

Land	Ocean Surface	Ocean Sub-Surfae	Atmosphere Surface	Atmosphere Upper-air	Atmosphere Composition
River discharge	Temperature	Temperature	Temperature	Temperature	
Water use	Salinity	Salinity	Wind speed & dir.	Wind speed & dir.	
Ground water	Sea level		Water vapour	Water vapour	
Lakes	Sea state		Pressure		
Soil moisture	Sea ice		Precipitation	Lightning	
Snow cover	Surface Current	Sub-surface current	Surface radiation	Earth radiation	
Glaciers & ice caps	Ocean colour			Cloud properties	Cloud properties
Ice sheets	Carbon dioxide	Carbon dioxide			Carbon dioxide
Permafrost	Ocean acidity	Ocean acidity			
Land cover	Phytoplankton				
FAPAR	Stress	Oxygen			Methane
Leaf area index	Heat flux	Nutrients			Ozone
Biomass		Tracers			Aerosols properties
Soil carbon		Nitrous oxide			Greenhouse gas
Fire disturbance		Carbon isotopes			Precursors
Albedo		Organic carbon			

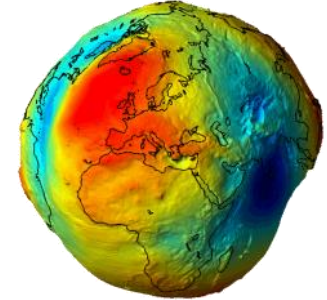
ECV  
EOV  
ECV & EOV

[Link to EGrV](#)

EOV's for Biology & Ecosystems and EBV's not connected to EGV's

# Essential Gravimetric Variables (EGrVs)

## Geodetic Product Levels = EGrV Levels



### Level 0 EGrVs: Geodetic Standards

- Reference Frames: e.g. Center of Mass
- Gravity Standards

### Level 1 EGrVs: Observations

- Gravity Potential (Geoid)
- Gravity Acceleration (1<sup>st</sup> derivative radial)
- Deflections of the Vertical (1<sup>st</sup> derivatives horizontal)
- Gravity Gradients (2<sup>nd</sup> derivatives)

### Level 2 EGrVs: Geopotential Models

- Global Models (Mean and Time-variable)
- Global Geoid (Mean)
- Regional Geoid (Mean)

### Level 3 EGrVs: Application Variables

- Mass Distribution in Earth System
- Mass Transport in Earth System

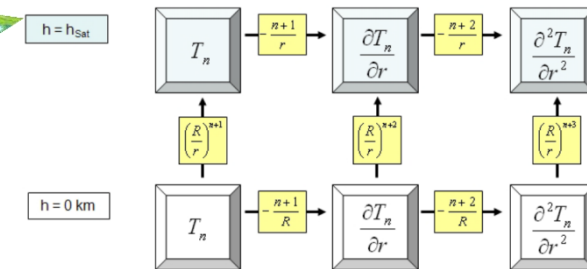
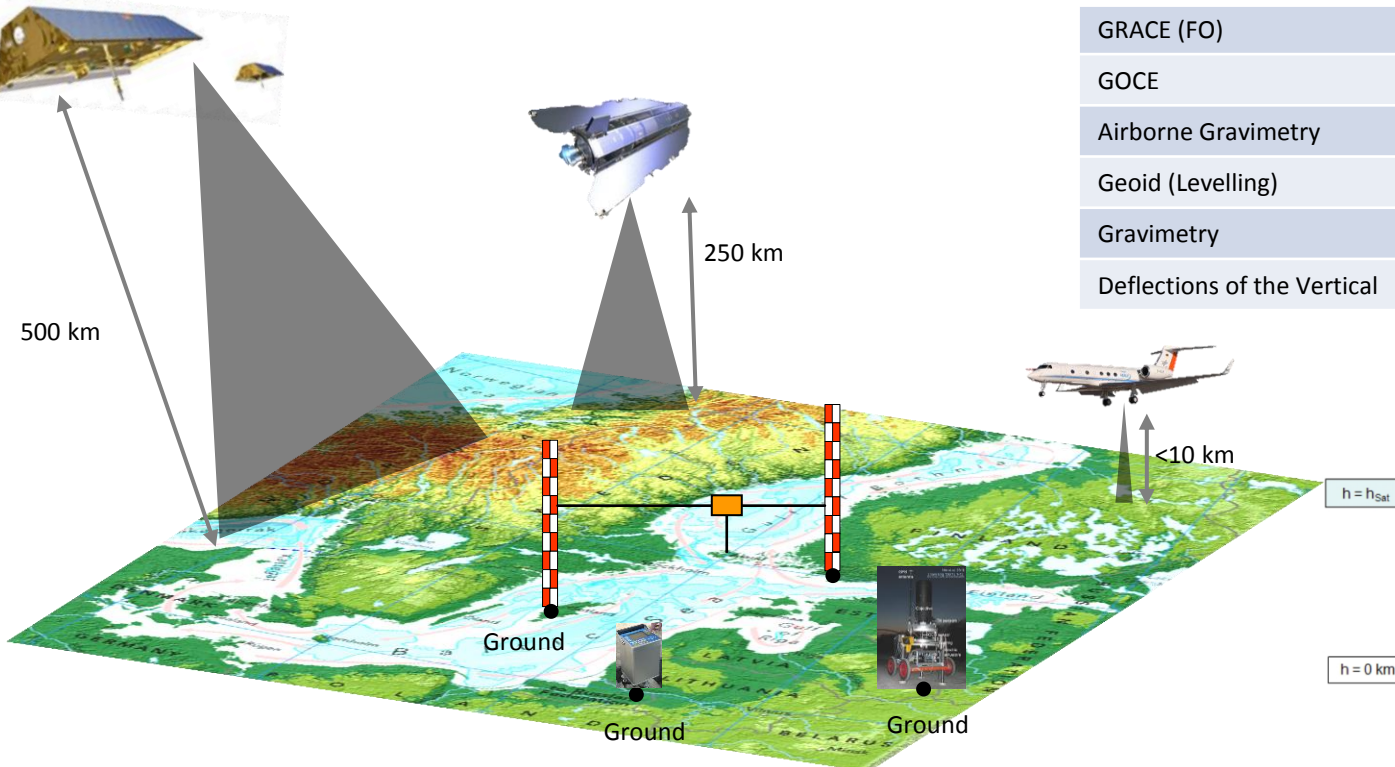
### Contributions to ECV's & EOVS's

River discharge	Water use	Ground water
Lakes	Soil moisture	Snow cover
Glaciers	Ice caps	Ice sheets
Permafrost	Sea level	Surface currents
Sub-surface currents		Pressure

# Example Level 1 EGrV - Observations

## Ground based, Airborne and Satellite Observations & Integration Area

Observation Type	Derivative	Height	Resolution
GRACE (FO)	1 <sup>st</sup>	500 km	200 km
GOCE	2 <sup>nd</sup>	250 km	80 km
Airborne Gravimetry	1 <sup>st</sup>	<10 km	2-5 km
Geoid (Levelling)	0	Ground	In-situ
Gravimetry	1 <sup>st</sup>	Ground	In-situ
Deflections of the Vertical	1 <sup>st</sup>	Ground	In-situ

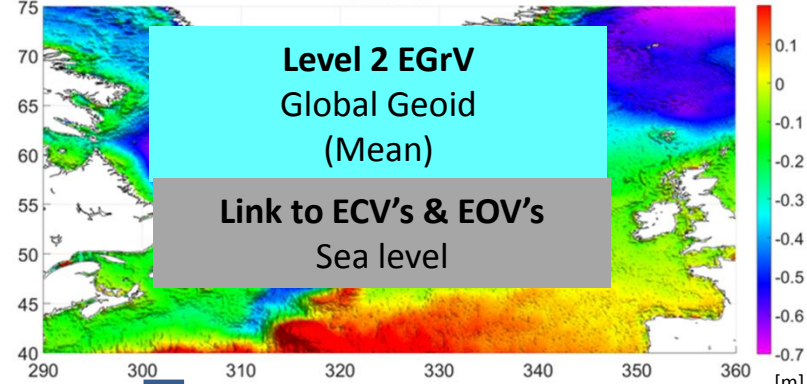
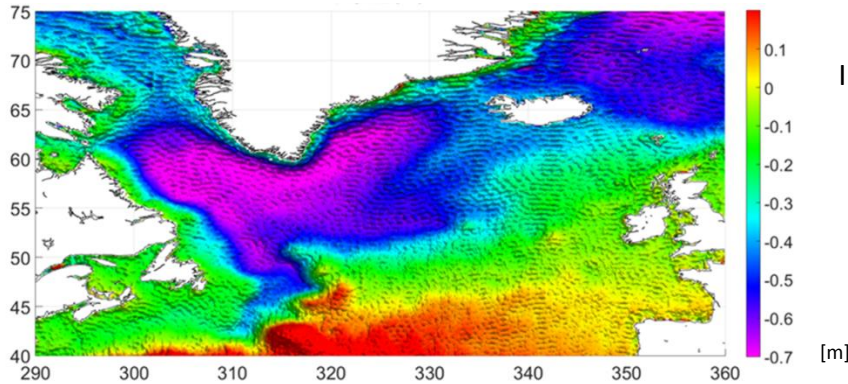


(According to Rummel, van Gelderen, 1995)



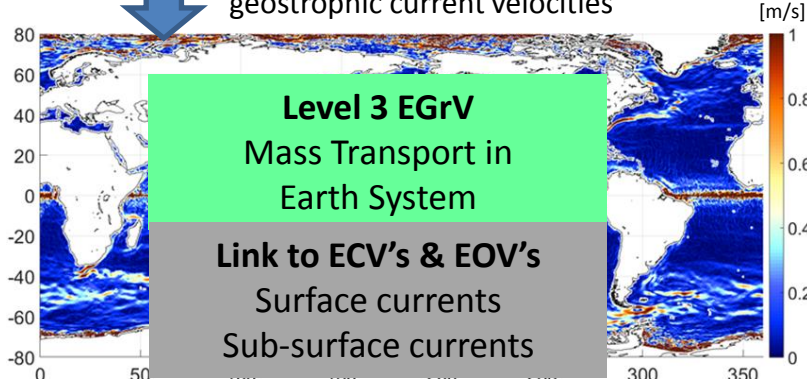
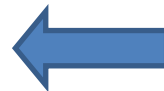
# Example Level 2 EGrV – Global Geoid (Mean)

## Mean Ocean Geoid as Reference Surface for Ocean Circulation – Geodetic MDT

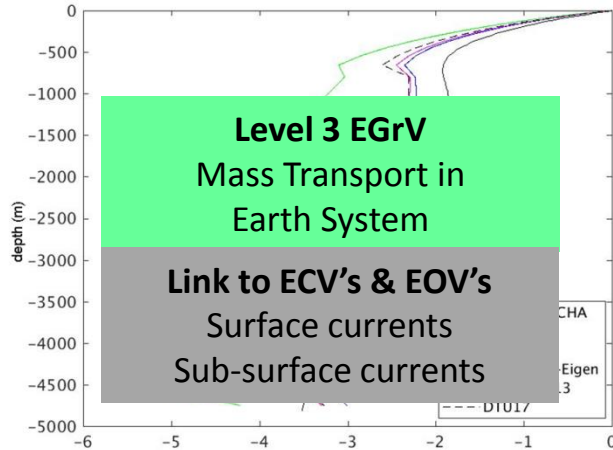


Improved MDT leads to improved geostrophic current velocities

Improved geostrophic current velocities lead to improved transport

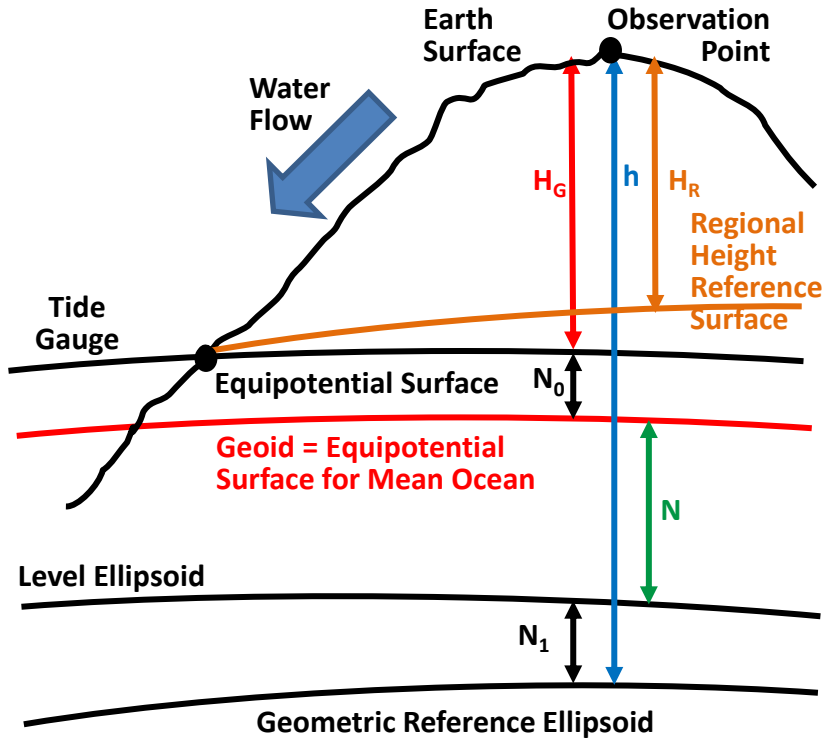


Meridional overturning circulation at 26°N as observed by the RAPID array, depending on depth, and applying geodetic MDTs.



# Example Level 2 EGrV – Global & Regional Geoid (Mean)

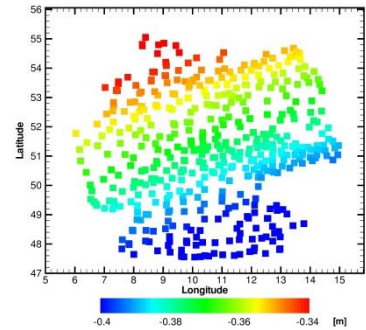
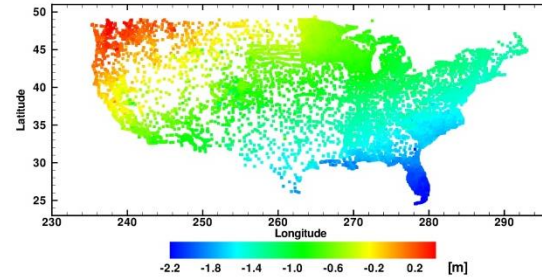
## Mean Geoid as Reference Surface for Physical Heights on Land



GNSS-Levelling:  $H_G = h - N - N_0 - N_1 \approx h - N$

Spirit Levelling:  $H_R$

Ideal Case:  $H_G = H_R$

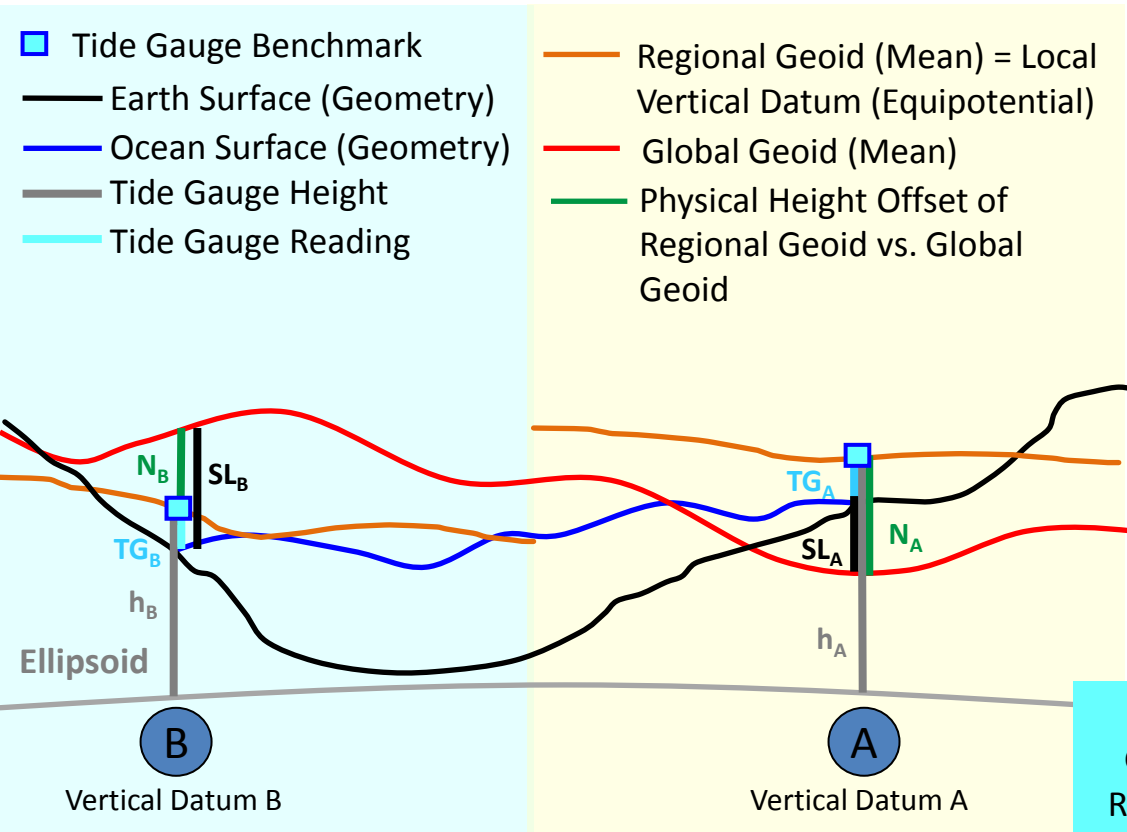


Level 2 EGrV  
Global Geoid (Mean)  
Regional Geoid (Mean)

Link to ECV's  
River Discharge  
Lakes  
Sea Level

# Example Level 2 EGrV – Global & Regional Geoid (Mean)

## Mean Geoid as Reference Surface for Absolute Sea Level



### Sea Level wrt. Local Datum

$$SL_A = TG_A$$

$$SL_B = TG_B$$

$$\Delta SL_{AB} \neq TG_A - TG_B$$

### Absolute Sea Level wrt. Global Geoid

$$SL_A = TG_A + N_A$$

$$SL_B = TG_B + N_B$$

$$\Delta SL_{AB} = SL_A - SL_B = TG_A - TG_B + (N_A - N_B)$$

### In Case of Vertical Land Motion:

$$\Delta SL_{AB} = TG_A - TG_B + (N_A - N_B) + (h_A - h_B)$$



**Level 2 EGrV**  
 Global Geoid (Mean)  
 Regional Geoid (Mean)

Link to ECV's  
 Sea Level

# Summary & Conclusions

- ECVs and EOVs well defined
- EGVs for Geometry, Earth Orientation and Gravimetry → Essential Gravimetric Variables (EGrVs).
- Different Levels of EGrVs are proposed:
  - Level 0: Gravimetric Standards
  - Level 1: Gravity Observations (terrestrial, airborne, satellite-borne) of different kind (derivative of gravity potential) and with different integration areas.
  - Level 2: Geopotential Models (regional & global)
  - Level 3: Application Variables (mass distribution and mass transport after separation of contributing components)
- EGrVs contribute to a number of EGVs and EOVs.
- Discussion and refinement of proposal within EGV committee is needed.