Essential Gravimetric Variables – Identification and Initial Assessment

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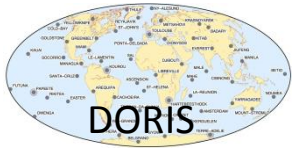
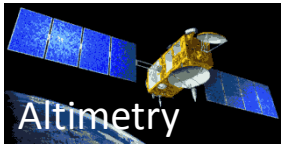
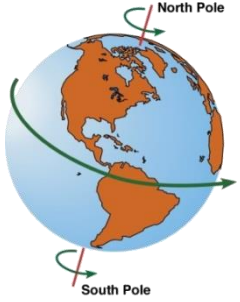


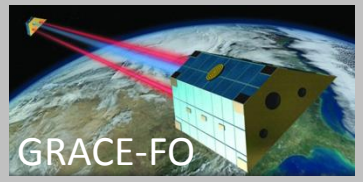
Geometry and Kinematic





Earth Rotation

Reference Systems



Gravity Field

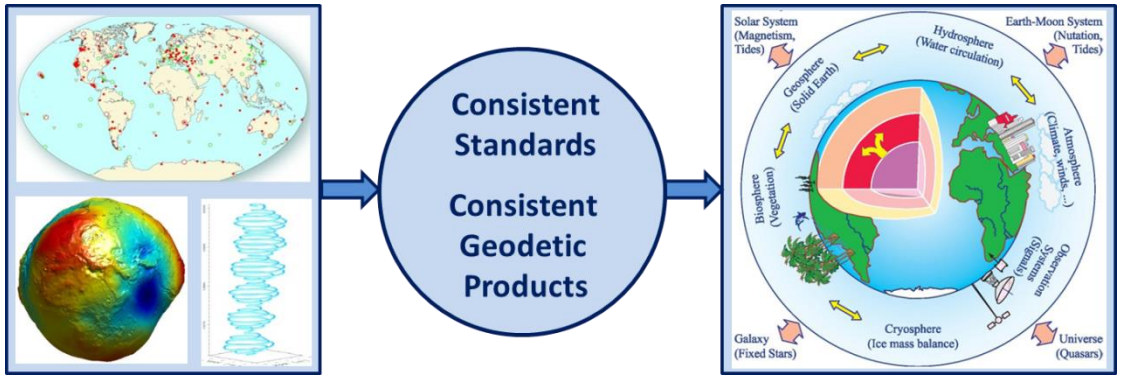
Essential Variables

System	Variables
Global Climate Observing System (GCOS)	**Essential Climate Variables (ECV)** "Physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth' s climate."
Global Ocean Observing System (GOOS)	**Essential Ocean Variables (EOV)**
Group on Earth Observations Biodiversity Observation Network (GEO BON)	**Essential Biodiversity Variables (EBV)**
Global Geodetic Observing System (GGOS)	**Essential Geodetic Variables (EGV)** *"Observed variables that are crucial (essential) to characterizing the geodetic properties of the Earth and that are key to sustainable geodetic observations." (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-Surface	Atmosphere Surface	Atmosphere Upper-air	Atmosph. 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			

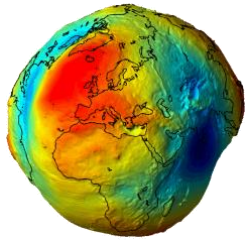
ECV
EOV
ECV & EOV

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 (1st derivative radial)
- Deflections of the Vertical (1st derivatives horizontal)
- Gravity Gradients (2nd derivatives)

Level 2 EGrVs: Geopotential Models
- Global Models (Mean and Time-variable)
- Global Geoid (Mean and Time-variable)
- Regional Geoid (Mean and Time-variable)

Level 3 EGrVs: Application Variables
- Mass Distribution in Earth System
- Mass Transport in Earth System

Contributions to ECV's & EOV'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

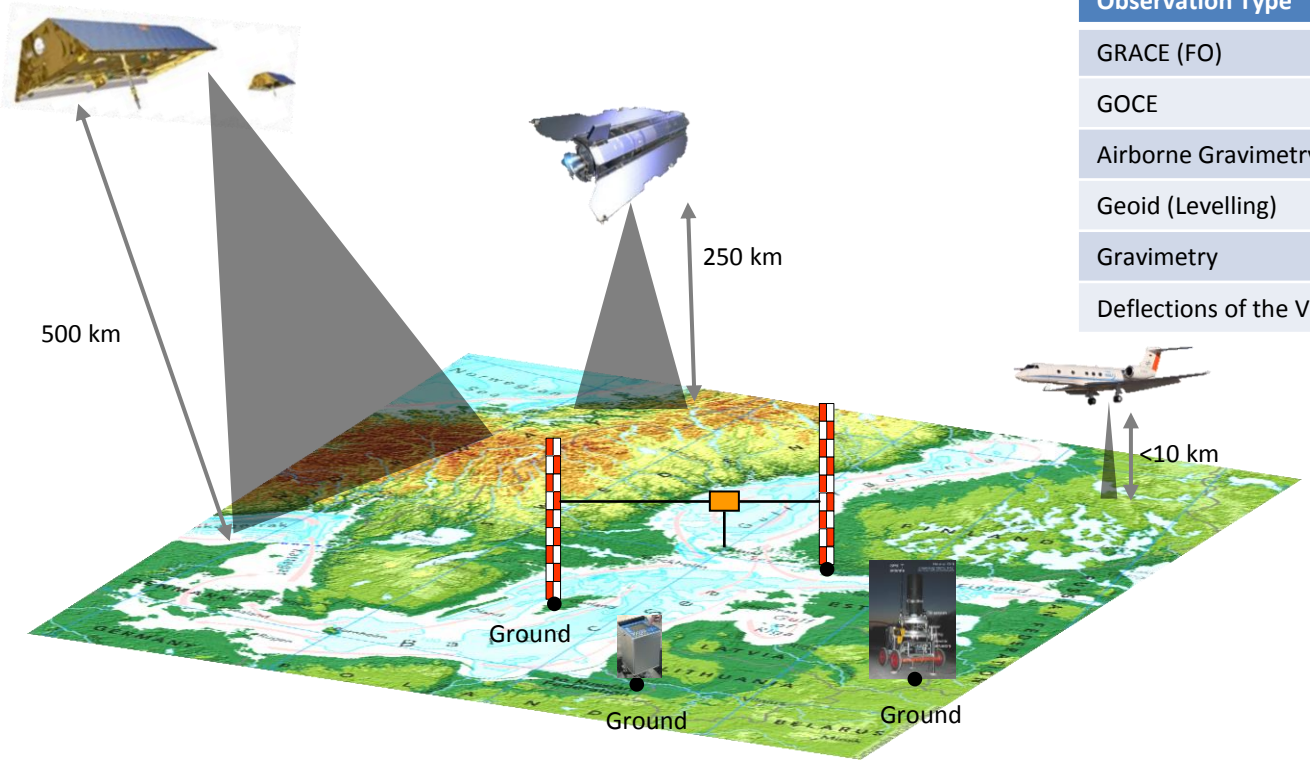
Example: L0 EGrV – Geodetic Standards

IGFS – Central Bureau is implementing a set of standards related to gravity field observations to secure consistency and to promote their use within the geoscientific community (Geoid Metadata Editor (v0.1.3) and Gravity Metadata Editor (v0.2.6)).

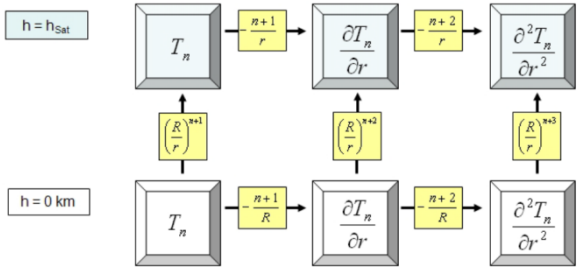
Section	Geoid	Gravity
1. Reference Information	Organisation, Contact, Creation Date	
2. Identification	Reference System, Citation, Description, Status, Point of Contact, Spatial Extent Geographic Bounding Box Coordinates	
3. Distribution	Distributor, Order Process, Constraints	
4. Standard and Conventions	GM, a, f, Tide System, Reference Ellipsoid, Standard Density of the Earth	GM, a, f, normal gravity reference ellipsoid, Tide System, EOP's, Tidal Conventions, Station Coordinates and Corrections
5. Data and Data Quality Information	Data and Data Quality Information; Accuracy, Consistency, Completeness, Data Distribution, Geoid Data, Gravity Data, Position and Height Accuracy	Accuracy, Consistency, Completeness, Data Distribution, Gravity Data, Position and Height Accuracy, Time Period of Content

Example: L1 EGrV - Observations

Ground based, Airborne and Satellite Observations & Integration Area



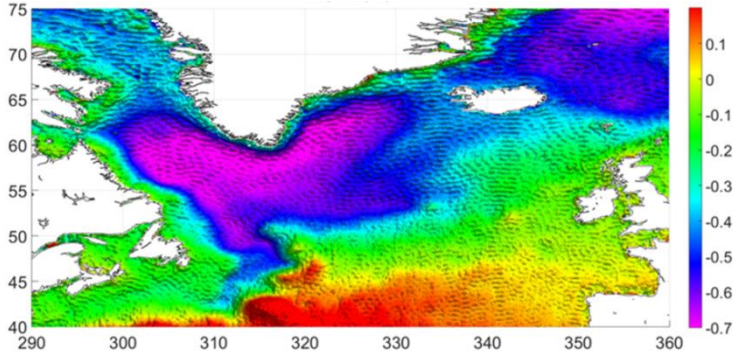
Observation Type	Derivative	Height	Resolution
GRACE (FO)	(1st)	500 km	200 km
GOCE	2nd	250 km	80 km
Airborne Gravimetry	1st	<10 km	2-5 km
Geoid (Levelling)	0	Ground	In-situ
Gravimetry	1st	Ground	In-situ
Deflections of the Vertical	1st	Ground	In-situ



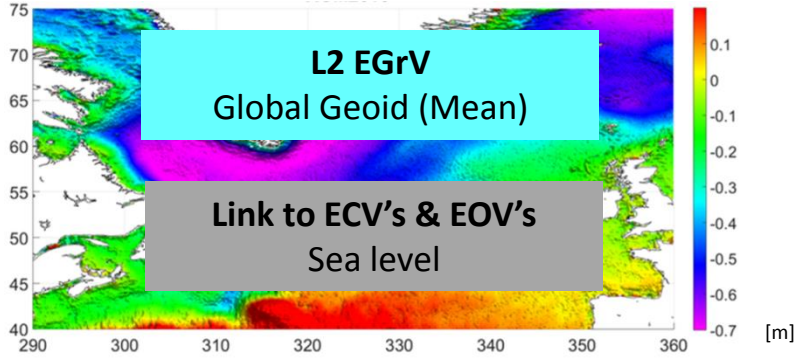
(According to Rummel, van Gelderen, 1995)

Example: L2/L3 EGrV – Ocean Geoid (Mean)

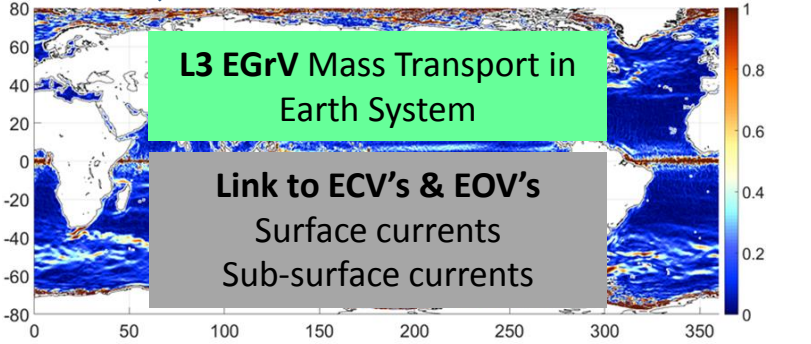
Mean Ocean Geoid as Reference Surface for Ocean Circulation – Geodetic MDT



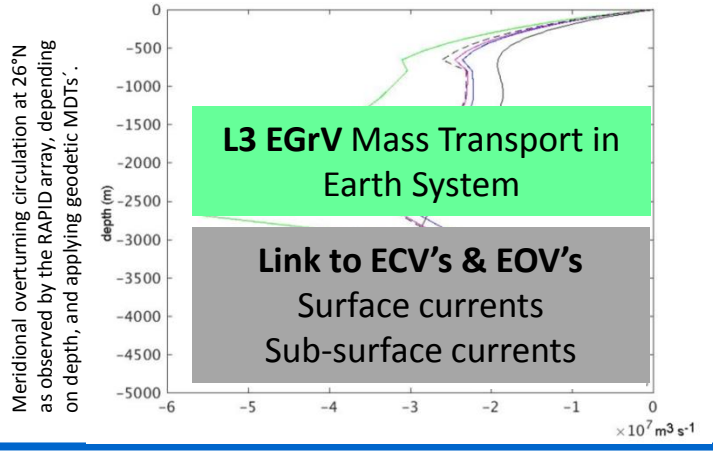
Improved ocean geoid leads to improved MDT



Improved MDT leads to improved geostrophic current velocities

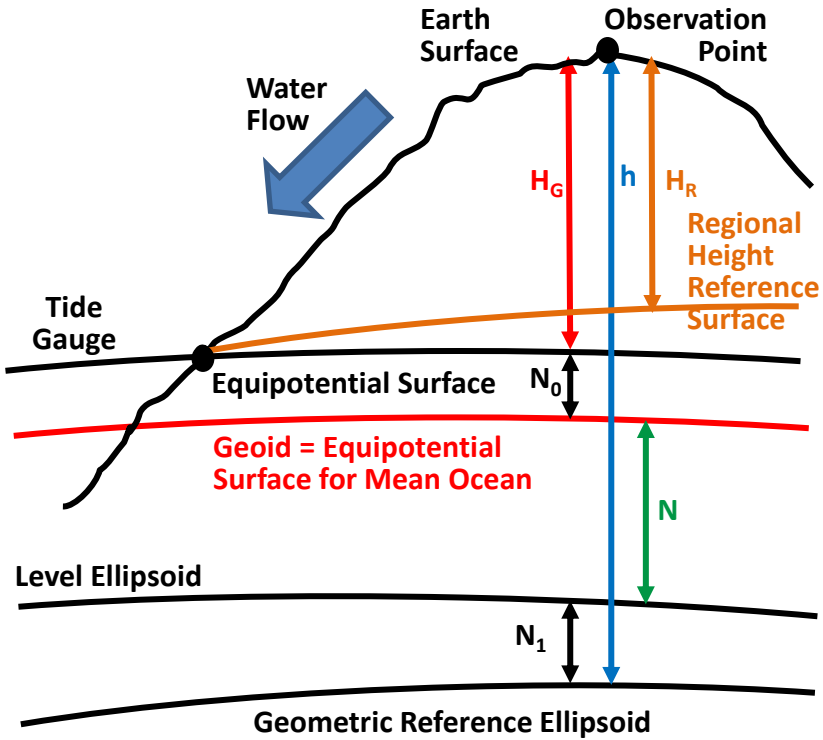


Improved geostrophic current velocities lead to improved transport



Example: L2 EGrV – Regional Geoid (Mean)

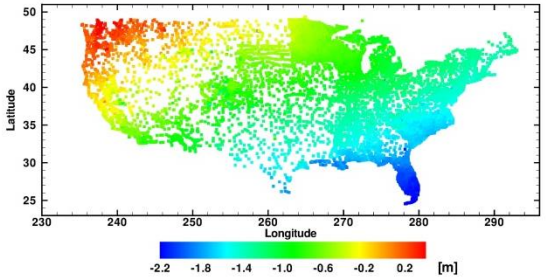
Mean Regional Geoid as Reference Surface for Physical Heights on Land

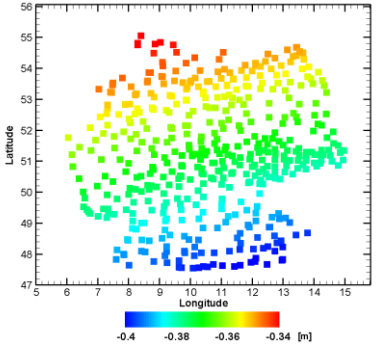


GNSS-Levelling: $H_G = h - N - N_0 - N_1 \approx h - N$

Spirit Levelling: H_R

Ideal Case: $H_G = H_R$

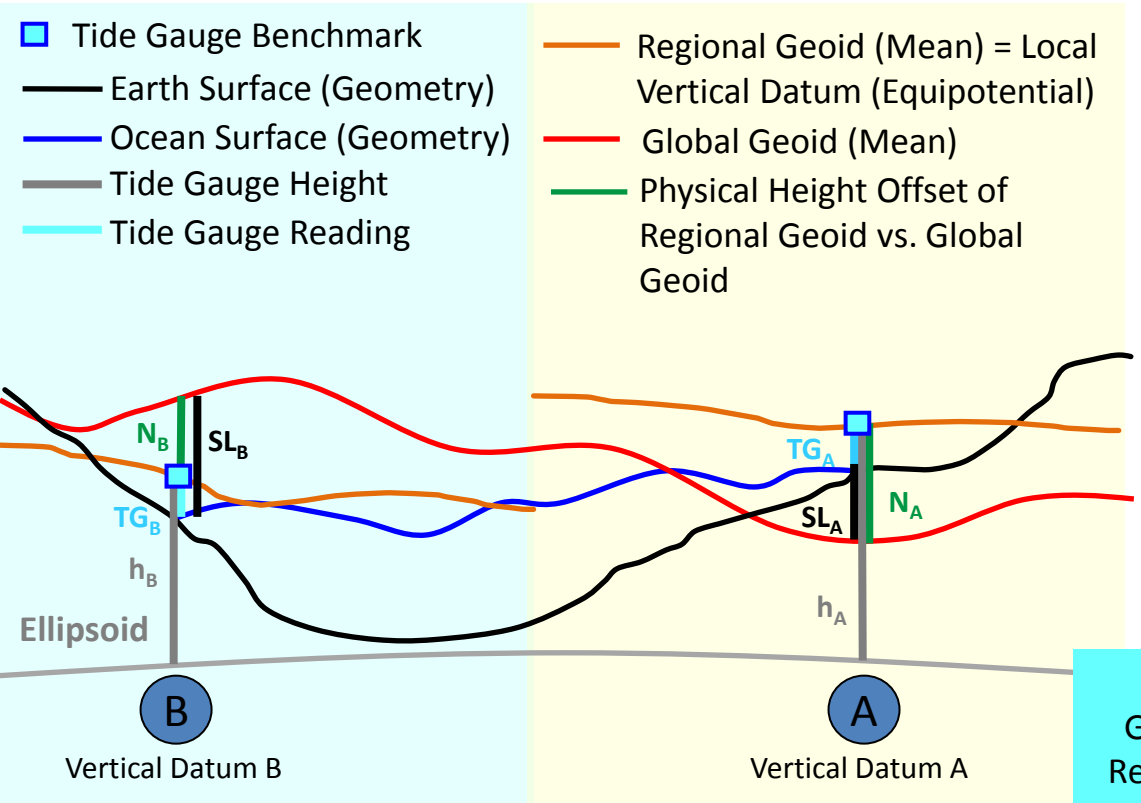




L2 EGrV	**Link to ECV's**
Global Geoid (Mean)	River Discharge
Regional Geoid (Mean)	Lakes
	Sea Level

– Example: L2 EGrV – Global/Regional Geoid (Mean) –

Mean Geoid as Reference Surface for Absolute Sea Level



Sea Level wrt. Local Datum

$SL_A = TG_A$ $\quad SL_B = TG_B$

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

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:

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

L2 EGrV	**Link to ECV's**
Global Geoid (Mean) Regional Geoid (Mean)	Sea Level

EGrVs Requirements

EGrV	Current Resolution, Accuracy	Required Resolution, Accuracy
L0: CoM Gravity Standards (Constants)	? high	1 mm 3-axes high
L1: Land Gravimetry Air & Ship Gravimetry Satellite Gravimetry Geoid (Levelling)	Point Obs., µGal m to km, mGal 100-200km, mGal Point Obs. mm/km, cm/km	Point Obs., µGal m to km, <mGal 100km, <mGal Point Obs., mm/km
L2: Global Models Mean Geoid Global Models TV Geoid Regional Geoid (Mean) Regional Geoid (Time-variable)	8km, cm to dm 200km, 1mo, mm 1-100km, cm to dm -	8km, 1cm 100km, 1d-1mo, 1mm 1km, 1cm ?, 1 cm/decade
L3: Mass Distribution (Satellites) Mass Transport (Satellites)	100km, 50cm EWH 200km, 1mo, $10km^3$(Gt)	100km, 10cm EWH 100km, 1d-1mo, 1Gt

Summary and 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: Geodetic (Gravimetric) Standards
  - Level 1: Gravity Observations of different kind with different integration areas.
  - Level 2: Geopotential Models (regional & global)
  - Level 3: Application Variables (mass distribution and mass transport)
- **Requirements for EGrVs need to be fixed.**