

Essential Geodetic Variables: Status and the way forward

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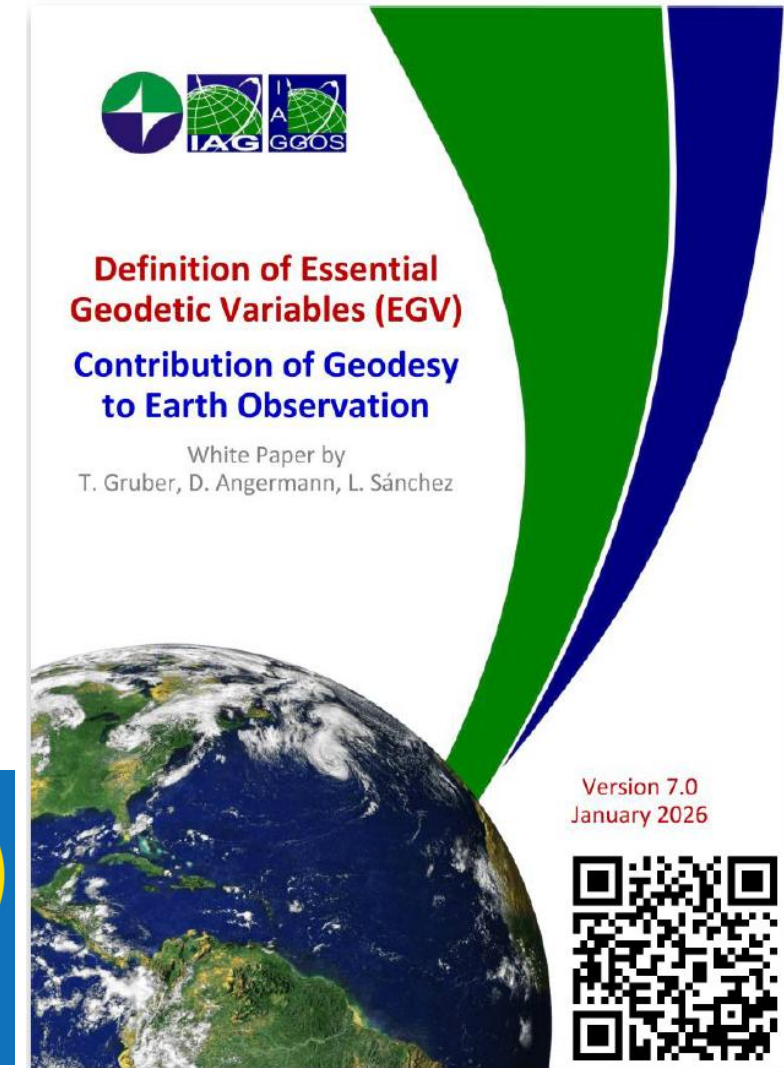
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Essential Variables in Environmental and Social Sciences



- Encourage scientists and observing systems to **prioritise these variables**
- Mobilise national and international organisations and funders to **support their provision**
- Enable **cross-disciplinary** data assimilation and interpretation
- Provide **accountable scientific knowledge** for evidence-based policymaking
- Facilitate **interoperability** between science and policy processes.



United Nations
Framework Convention on
Climate Change

SUSTAINABLE
DEVELOPMENT
GOALS



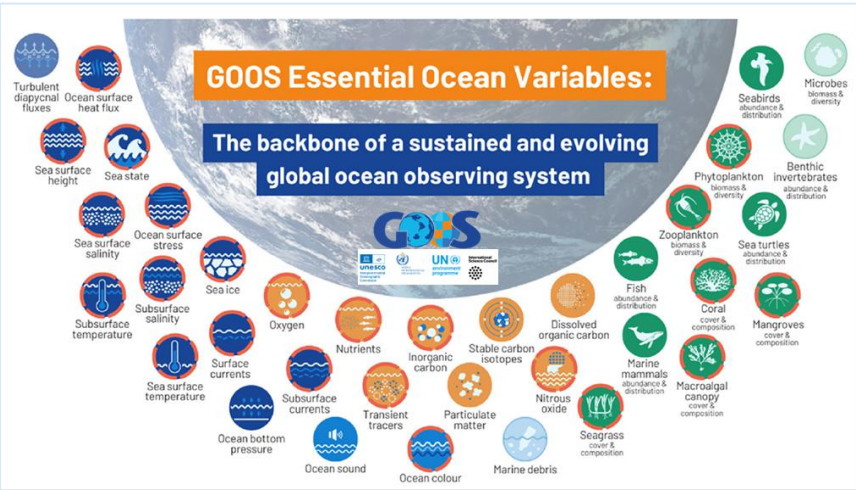
- Scientific organisations and observing systems to improve the monitoring of the Earth system.
- Space agencies to define priorities for spatial programmes and data provision.
- Policy makers and frameworks to report on global environmental pacts.
- Sustainability evaluators to track the UN Sustainable Development Goals.

Examples of existing Essential Variables frameworks



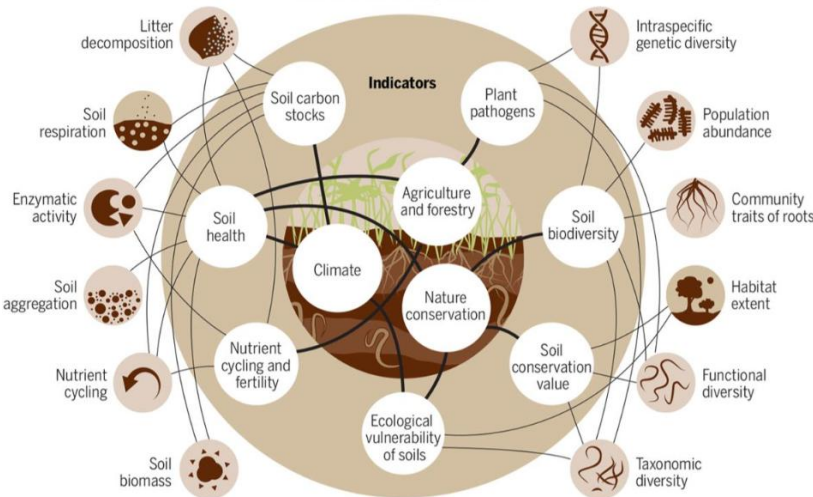
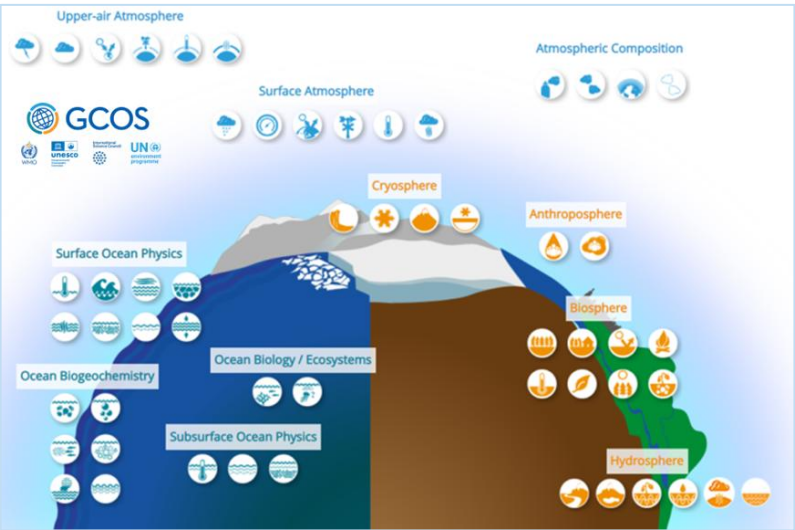
Essential Ocean Variables (EOV) by GCOS

Martín Míguez, et al. 2026,
<https://doi.org/10.3389/fmars.2026.1737002>



Essential Climate Variables (ECV) by GCOS

<https://gcos.wmo.int/site/global-climate-observing-system-gcos/essential-climate-variables>



Essential Biodiversity Variables (EBV) by EuropaBON

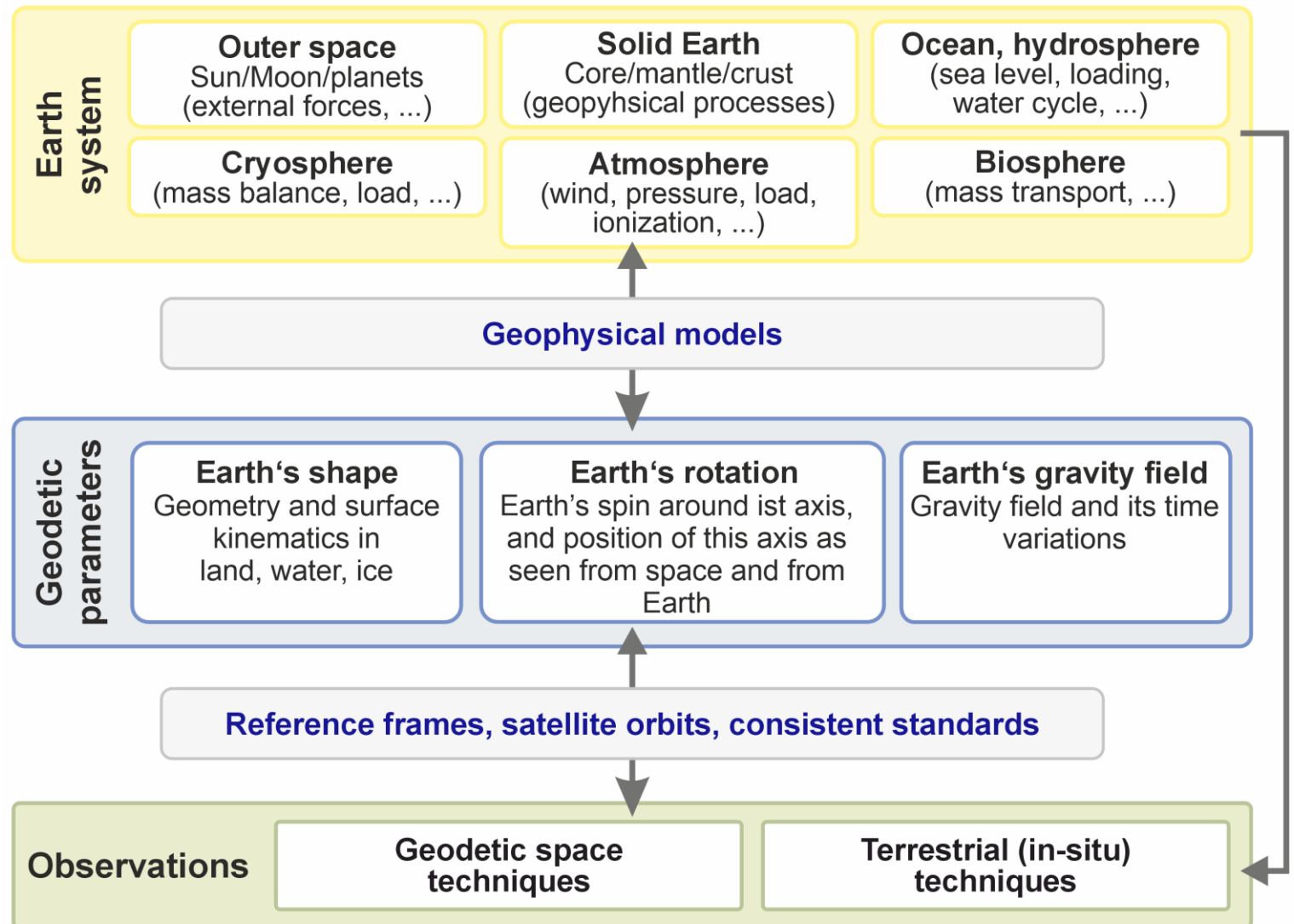
(Europa Biodiversity Observation Network)
Calderon Sanou, 2024,
<https://doi.org/10.3897/arphapreprints.e128926>

Primary EWVs	Supplemental EWVs
Precipitation	Surface Meteorology
Evaporation	Surface and Atmospheric Radiation Budgets
Evapotranspiration	Clouds
Snow	Aerosols
Soil Moisture	Land Cover
Soil Temperature	Vegetation
Groundwater	Land Use
Runoff/Streamflow/river discharge	Elevation/Topography
Lakes/reservoir levels and aquifer volumetric change, terrestrial water storage	
Water use/demand	Geological Stratypfication
Water Quality	

Essential Water Variables (EWV) by GEOGLOWS
<https://www.geoglows.org/>

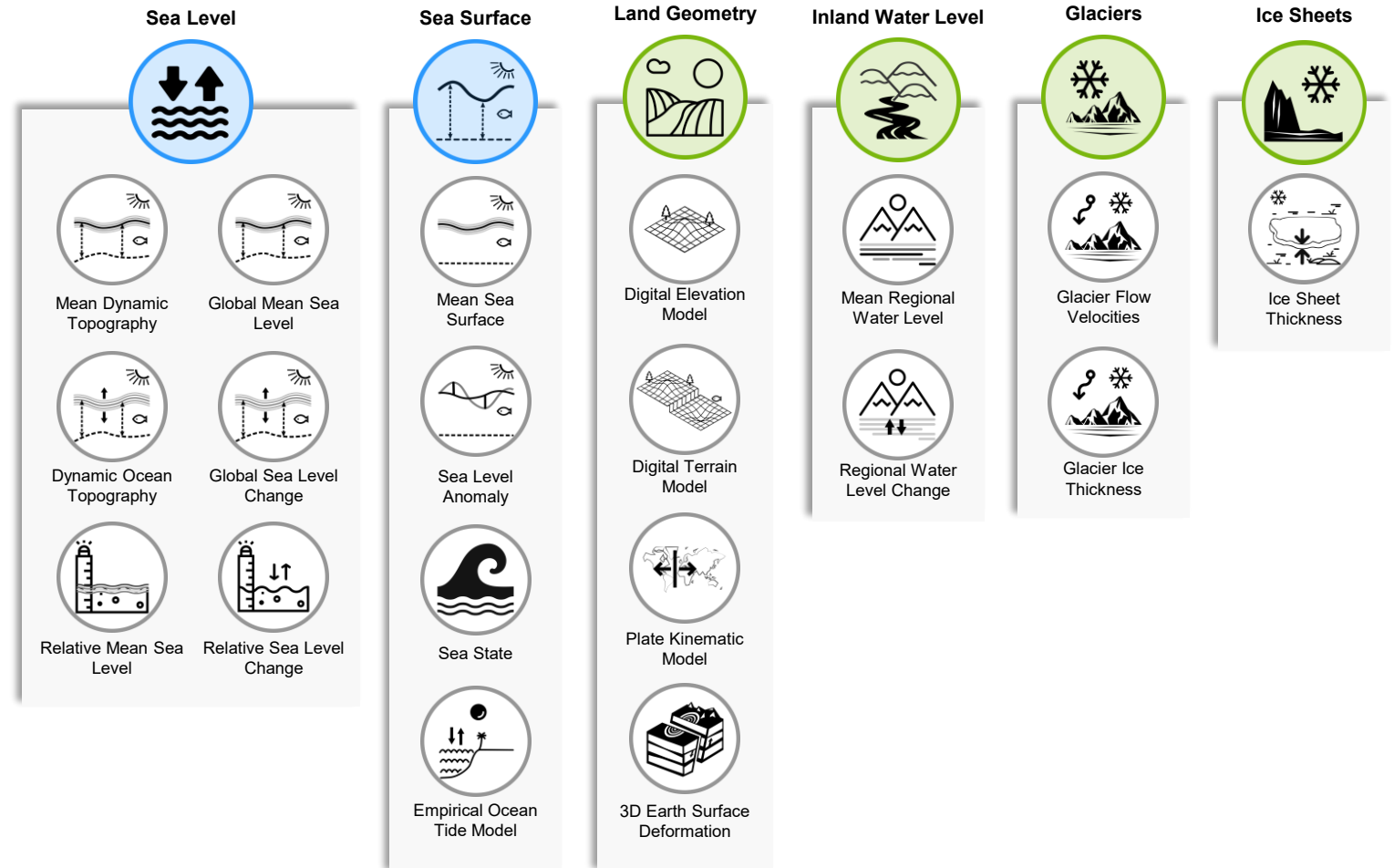
Definition of Essential Geodetic Variables (EGVs)

- Essential variables are parameters that, if changed, directly alters the fundamental behaviour or outcome of a system.
- Geodesy determines the shape, rotation and gravity field of the Earth as functions of time and space.
- Essential Geodetic Variables: Minimum set of parameters needed to observe, model, and understand the Earth's shape, rotation, and gravity field as functions of time and space.



Essential Variables in Geodesy: Earth's shape

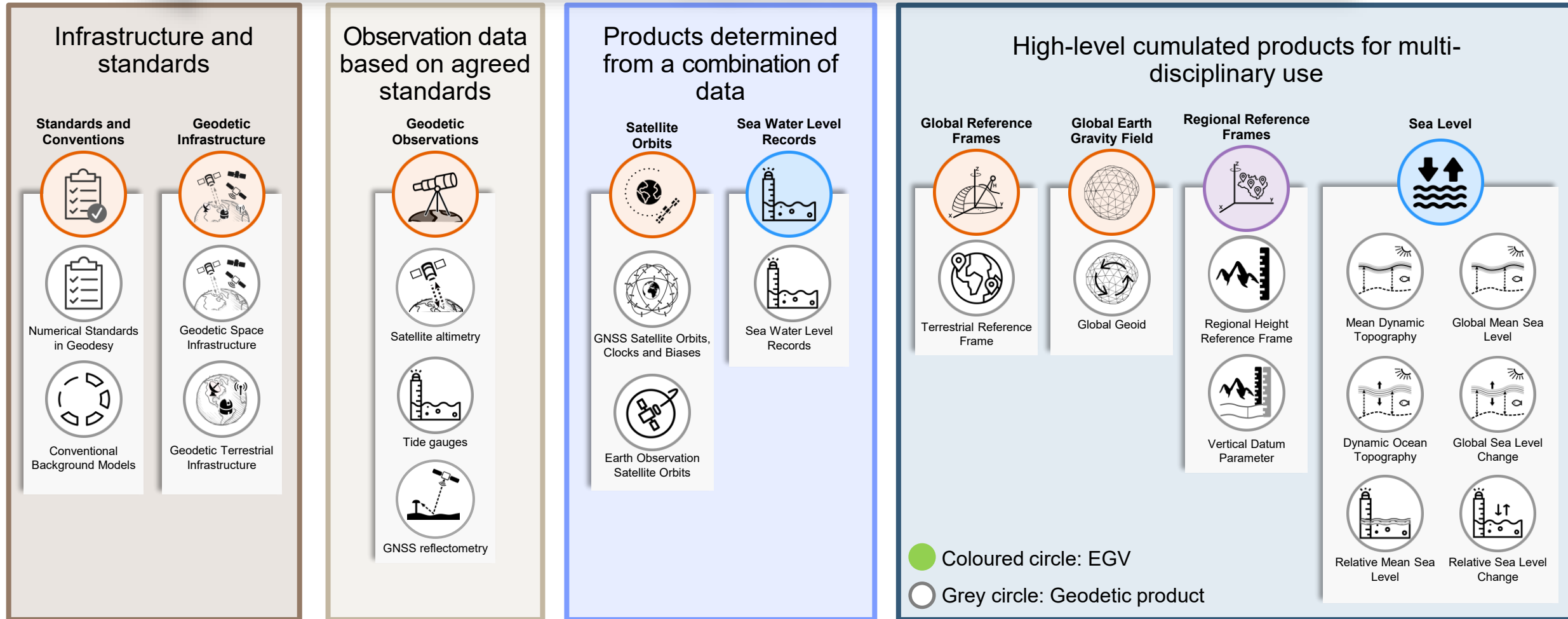
Surface kinematics in land, water and ice



 Coloured circle: EGV
 Grey circle: Geodetic product

Essential Variables in Geodesy: Sea Level

Dependence



Complexity

Criteria and classification of EGVs

21 EGVs, based on **59 geodetic products**

Criteria: relevance, feasibility, cost effectiveness, **sustainability, consistency and interoperability**

Domains: **Global**, **Land**, **Ocean**, **Land/Ocean (coasts)**

Infrastructure and standards



Geodetic Infrastructure



Standards and Conventions

Observation data based on agreed standards



Geodetic Observations

Products determined from a combination of data



Station Positions and Variations



Satellite Orbits



Land and Marine Gravity Data



Sea Water Level Records

High-level cumulated products for multi-disciplinary use



Earth Orientation Parameters



Atmosphere Parameters



Land Geometry



Ice Sheets



Sea Surface



Global Ref. Frames



Regional Ref. Frames



Inland Water Level



Glaciers



Sea Level



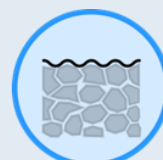
Global Earth Gravity Field



Reg. Gravity Field Model



Terrestrial Water Storage



Sea Ice

EGVs vs geodetic products



		Essential Geodetic Variables (EGVs)		Geodetic Products	
Basis	L3 EGVs	L2 EGVs	L1		AGD: Absolute Gravity Data
					CBM: Conventional Background Models
					CPO: Celestial Pole Offset
					CRF: Celestial Reference Frame
					DEM: Digital Elevation Model
					DOT: Dynamic Ocean Topography
					DTM: Digital Terrain Model
					EOT: Empirical Ocean Tide Model
					ESD: Earth Surface Deformation
					ESO: Earth Observation Satellite Orbits
					GFQ: Gravity Field Quantities
					GFV: Glacier Flow Velocities
					GGM: Global Gravity Field Models
					GGO: Geodetic Geometric Observations
					GIM: Global Ionosphere Maps
					GIT: Glacier Ice Thickness
					GMC: Glacier Mass Change
					GOCB: GNSS Satellite Orbits, Clocks, Biases
					GPO: Geodetic Physical Observations
Basis	L2 EGVs	L1			GRF: Gravity Reference Frame
					GSI: Geodetic Space Infrastructure
					GTI: Geodetic Terrestrial Infrastructure
					HRF: Height Reference Frame
					IMC: Ice Mass Change
					IST: Ice Sheet Thickness
					IWW: Integrated Water Vapor
					LGD: Land Gravity Data
					LOD: Length of Day
					MDT: Mean Dynamic Topography
					MGC: Mean Geostrophic Currents
					MGD: Marine Gravity Data
					MRWL: Mean Regional Water Level
					MSL: (Global) Mean Sea Level
					MSS: Mean Sea Surface
					NSG: Numerical Standards in Geodesy
					PKM: Plate Kinematic Model
					PM: Polar Motion
					RGFQ: Regional Gravity Field Quantities
					RGM: Regional Geoid Model
Basis	L1				RGRF: Regional Gravity Reference Frame
					RHRF: Regional Height Reference Frame
					RMSL: Relative Mean Sea Level
					RSLC: Relative Sea Level Change
					RTRF: Regional Terrestrial Reference Frame
					RWLC: Regional Water Level Change
					SES: Sea State
					SIE: Sea Ice Extension
					SIV: Sea Ice Volume
					SLA: Sea Level Anomaly
					SLC: (Global) Sea Level Change
					SPTS: Station Position Time Series
					SWLR: Sea Water Level Records
					TDM: Thermosphere Density Model
					TGD: Time Series Gravity Data
					TGM: Topographic Gravity Field Model
					TRF: Terrestrial Reference Frame
					TWSA: Terrestrial Water Storage Anomaly
					UT1: Universal Time
					VDP: Vertical Datum Parameter

Primary geodetic products directly related to the EGV

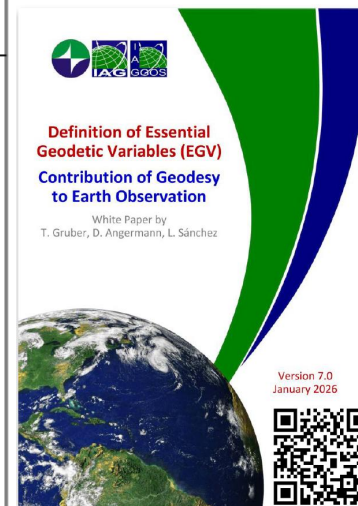
Geodetic products that provide important information to the EGV

Geodetic products indirectly linked to the EGV

Characterisation of EGVs

- ✓ Name
- ✓ Domain
- ✓ Subdomain
- ✓ Scientific area / Description
- ! Stewards / Data sources
- ✓ Products
- ! Requirements
- ✓ Relevance

	Inland Water Level
Domain	Land
Subdomain	Geometric/Physical
Scientific Area	Water levels of inland lakes and rivers for estimating water mass variations and water runoff into the oceans.
EGV Stewards	tbd
Products	▪ Mean Regional Water Level (MRWL): <i>Mean water level of inland lakes and rivers.</i> ▪ Regional Water Level Change (RWLC): <i>Time series of water levels of inland lakes and rivers.</i>
Relevance	Monitoring inland water levels (in lakes, rivers, reservoirs, and wetlands) is essential for environmental sustainability, disaster preparedness, and resource management. Geodesy provides time series of inland water levels from satellite altimetry and optical remote sensing imagery that combined with in-situ measurements improve hydrological models. These models are the basis to understand the impact of climate change on the hydrological cycle, to plan freshwater consumption and recharge, to manage dams and hydropower plants, to forecast risks associated with floods or droughts, and to inform local and regional policies on water management and environmental conservation.



Ongoing activities

- **Characterisation of geodetic products:** Description in terms of **uncertainty, spatial and temporal resolution, timeliness, reliability, data sources.**
- **Identification of EGVs' stewards:** Who will take responsibility for safeguarding the long-term integrity, functionality, and resilience of the EGVs.
- **Implementation of the GGOS Portal:** One-stop shop for the geodetic data and products supporting the EGVs.
- **Preparation of outreach material on the EGVs:** Easy to understand descriptions for non-geodesists.



Role of Data Stewards



Collaborating with business and technical teams.



Tracing the source of problems and recommending corrections.



Reviewing reports or dashboards to identify errors

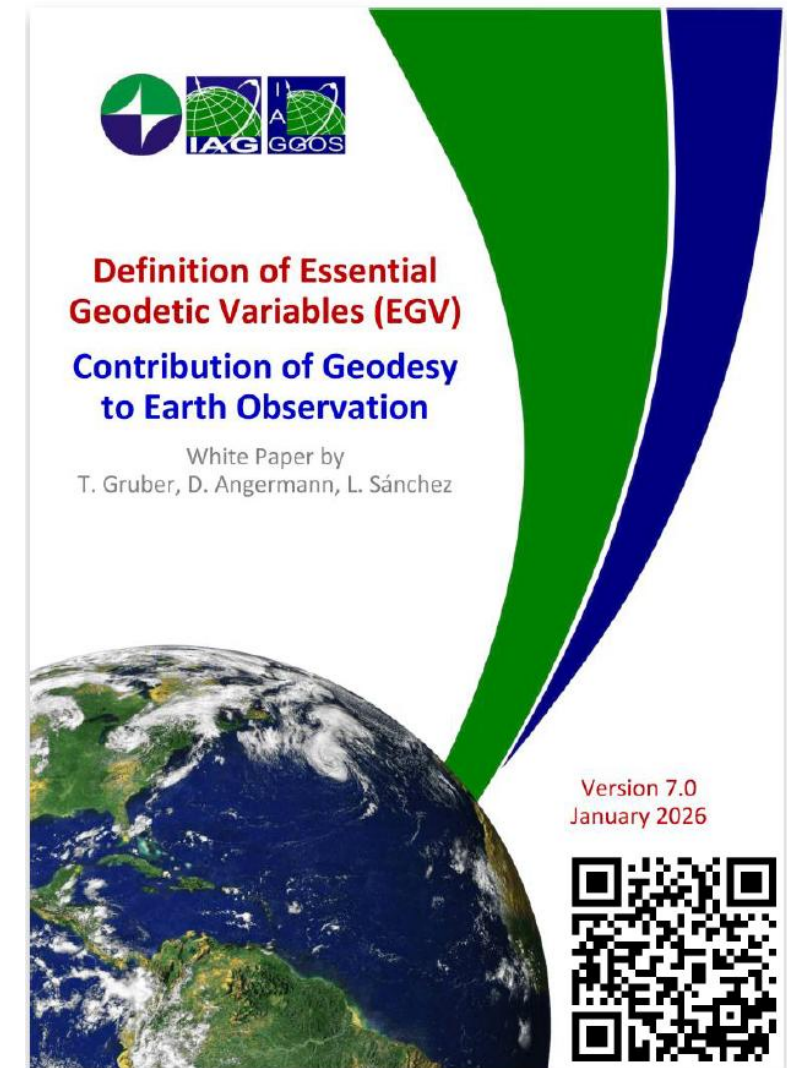


Documenting data definitions and standards



Closing remarks

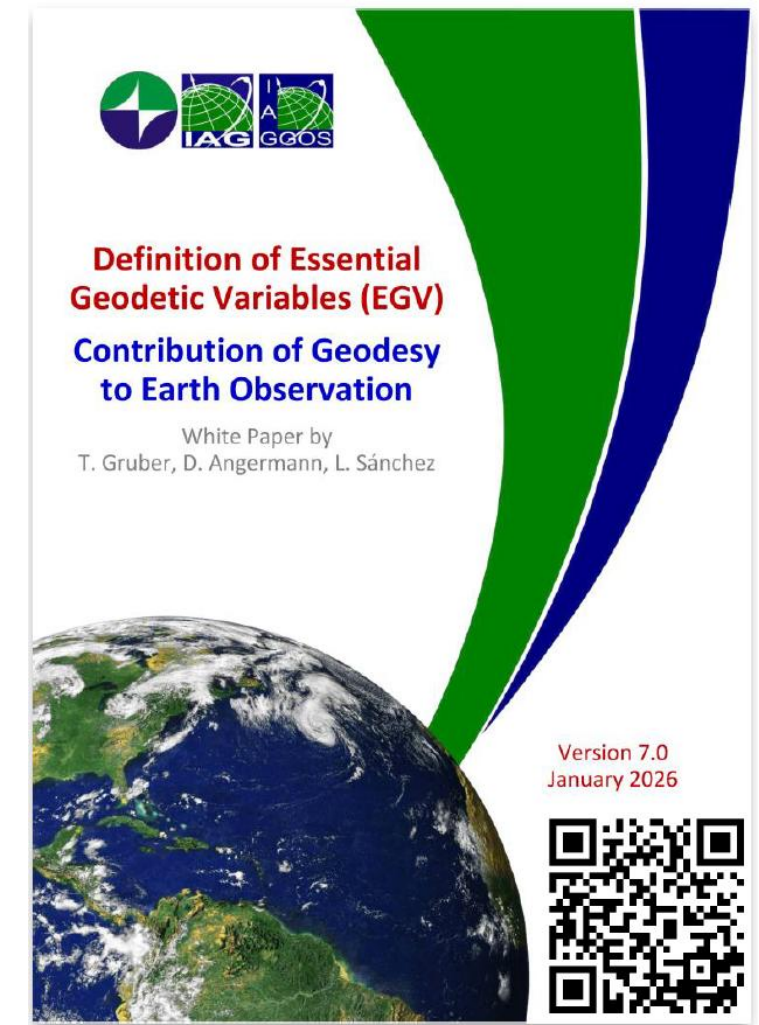
- EGV concept already reviewed by
 - GGOS Science Panel
 - GGOS Governing Board
 - IAG Executive Committee
 - UN Global Geodetic Centre of Excellence (UN-GGC)
- EGVs are a central component of
 - the GGOS Strategic Plan
 - the UN-GGCE 1st Joint Development Plan for Global Geodesy
- EGVs usability:
 - **Internal**: to set up requirements on geodetic observations, data and products.
 - **External**: to promote the importance of geodesy to funding organisations, policy makers, etc.
- Progress depends on **teamwork, cooperation, and a willingness to commitment.**



Back up

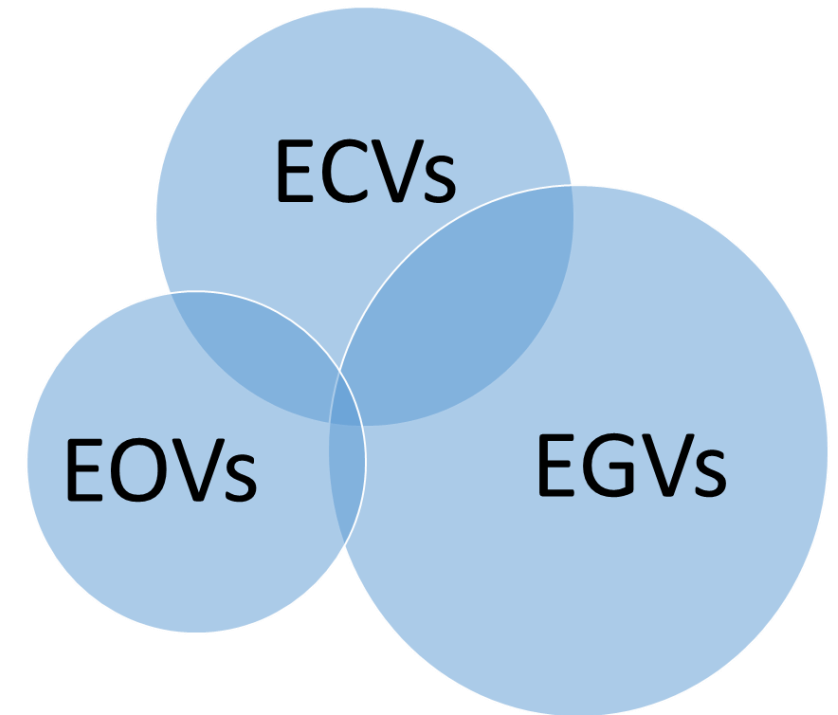
Milestones and Status of the EGV Definition

- **2018**: Establishment of the Committee on EGVs within the Bureau of Standards and Products (BPS) of the Global Geodetic Observing Systems (GGOS).
- **2018-2023**: Conceptional developments: criteria, EGV levels, presentations at IUGG/IAG Symposia, GGOS Days, ...
- **2024**: Release of initial White Paper “Definition of EGVs”: Review by GGOS Science Panel and GGOS Governing Board.
- **2025**: Revision and publication of the White Paper “Definition of EGVs” version 6.0 (<https://doi.org/10.5281/zenodo.14619439>).
- Review by IAG Executive Committee and UN-GGCE members.
- Second revision (editorial update, inclusion of Basis and Level 1 variables, addition of “Relevance” descriptions for EGVs).
- **Jan 2026**: Publication of the White Paper “Definition of EGVs” version 7.0 (<https://zenodo.org/records/18313946>).
- Future reviews if needed.

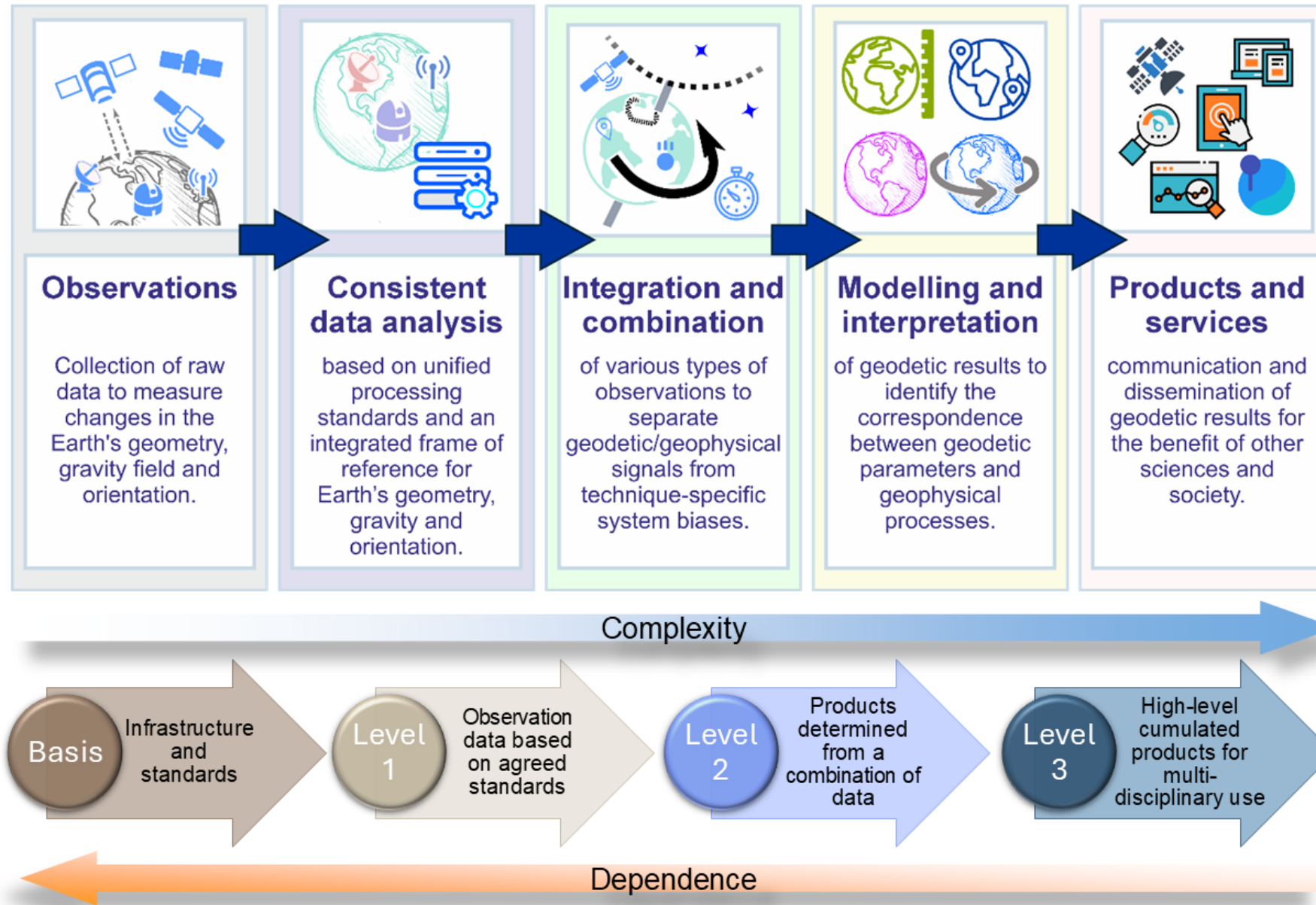


Criteria to become an EGV

- **Relevance effectiveness (ECV, EOV, EGV)**: The variable is critical for characterising the properties of the Earth system and its temporal changes.
- **Feasibility effectiveness (ECV, EOV, EGV)**: Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
- **Cost effectiveness (ECV, EOV, EGV)**: Generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology.
- **Sustainability (EGV)**: The variable shall be made available over decades and the tools for observing it shall be sustainable.
- **Consistency and interoperability (EGV)**: The variables shall be consistent in terms of reference systems and standards/conventions so that they can be easily combined or used together.



EGVs and the workflows of geodesy for Earth system monitoring



EGV Classification according to domain and subdomain



		Subdomain								
		Geometric			Physical		Geometric/Physical			
Domain	Global									
		Earth Orientation Parameters (L3)	Satellite Orbits (L2)	Station Positions and Variations (L2)	Global Earth Gravity Field (L3)	Atmosphere Parameters (L3)	Global Reference Frames (L3)	Geodetic Observations (L1)	Standards and Conventions (Basis)	Geodetic Infrastructure (Basis)
	Land									
		Land Geometry (L3)			Terrestrial Water Storage (L3)		Ice Sheets (L3)	Glaciers (L3)	Inland Water Level (L3)	
	Ocean									
		Sea Surface (L3)	Sea Ice (L3)	Sea Water Level Records (L2)	Sea Level (L3)					
	Land/ Ocean									
					Regional Gravity Field Model (L3)	Land and Marine Gravity Data (L2)	Regional Reference Frames (L3)			

- The goal of defining EGVs is to increase **awareness of geodesy by describing and communicating geodetic products**.
- Current EGV catalogue is based on an inventory of
 - operational products by the **IAG Services**,
 - operational products from other sources,
 - non-operational products from short-term research studies.
- The EGVs serve as the **main classification framework** for geodetic products.
- **As few EGVs as possible, but flexible (as many products as available)**.
- The **EGV catalogue is not static** – it is a living document that will evolve with technological/methodological advances and be updated as new products emerge.



Characterisation of geodetic products



Description of the **quality of the geodetic products** supporting the EGVs

- Uncertainty
- Spatial resolution
- Temporal resolution
- Timeliness
- Reliability
- Data sources

Phase 1: Inventory of current values

Phase 2: Target requirements for an improved Earth system monitoring

Example: GNSS satellite orbits, Clock and Biases

EGV Satellite Orbits						
Product: GNSS Satellite Orbits, Clocks and Biases (GOCB)						
Definition:						
- Orbits: Ephemerides of GNSS satellites. - Clocks: Clock solution for GNSS satellites. - Code and phase biases: Solutions for systematic errors between GNSS observations at the same or different frequencies.						
Sub-product	Uncertainty	Spatial resolution	Time resolution	Timeliness	IAG Service / Data sources	Notes
GPS satellite orbits broadcast	20 cm	N/A	2 h	Real time	IGS and data sources therein	Orbit SISRE RMS https://doi.org/10.1007/s10291-024-01793-6
IGS GPS ultra-rapid (predicted half) orbits	5 cm	N/A	15 min	Real time	IGS and data sources therein	Orbit uncertainty corresponds to 1D mean RMS values over the three XYZ geocentric components. IGS accuracy limits, except for predicted orbits, are based on comparisons with independent laser ranging results and discontinuities between consecutive days. The precision is better.
IGS GPS ultra-rapid (observed half) orbits	3 cm	N/A	15 min	3 to 9 hours	IGS and data sources therein	
IGS GPS rapid orbits	2.5 cm	N/A	15 min	17 to 41 hours	IGS and data sources therein	
IGS GPS final orbits	2.5 cm	N/A	15 min	12 to 19 days	IGS and data sources therein	
IGS GLONASS final orbits	3 cm	N/A	15 min	12 to 19 days	IGS and data sources therein	
Galileo final orbits (???0MGXFIN)	2-3 cm ?		5 min			