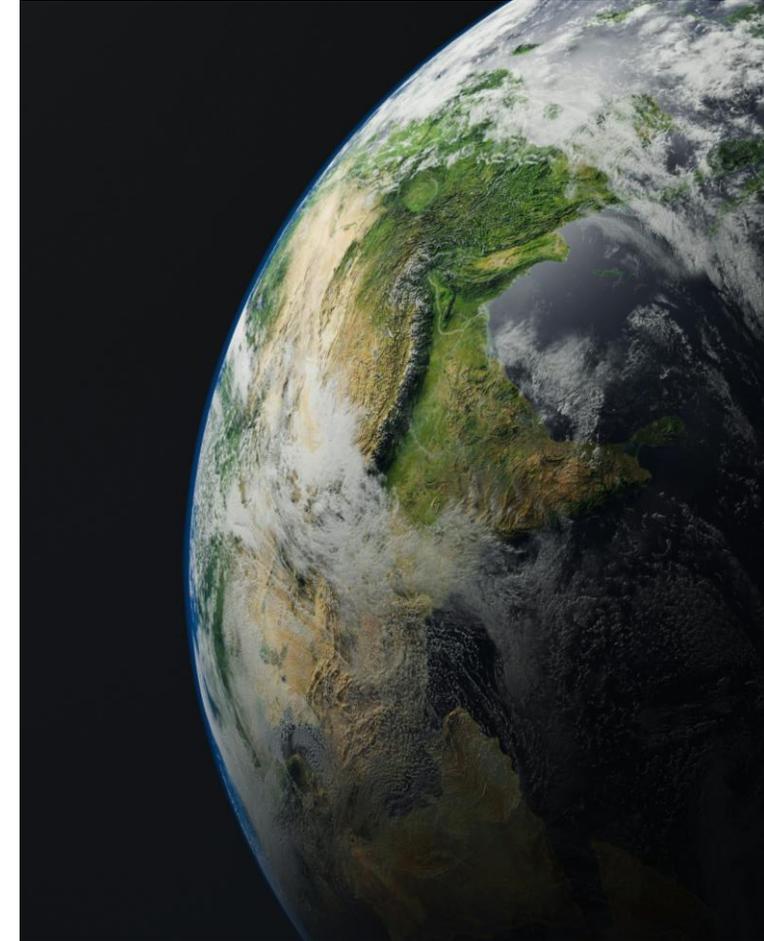
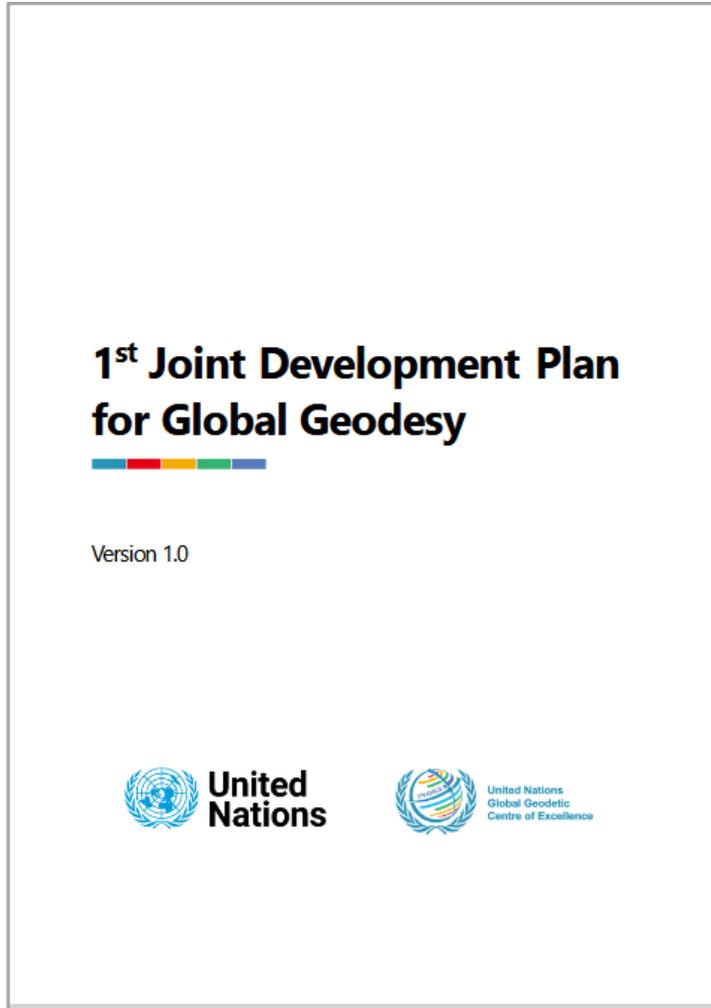


Essential Geodetic Variables

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- ¹ Director of the GGOS Bureau of Products and Standards (BPS)
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- ² Chair of the GGOS Committee “Definition of Essential Geodetic Variables“
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- ⁴ Virtual Seconded to the United Nations Global Geodetic Centre of Excellence (UN-GGCE)





Objective 2.3 – Decision-makers are convinced of the importance of a robust supply chain

Proposed Activities of partners

- 64. Define the Essential Geodetic Variables (EGV) and describe the importance of them to policy makers.
- 65. Advocate for additional resourcing to be provided to Member States for the global geodesy supply chain.

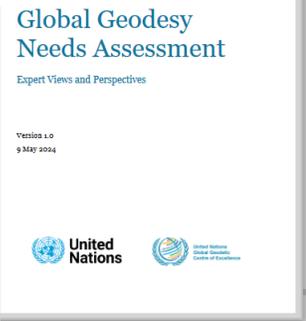
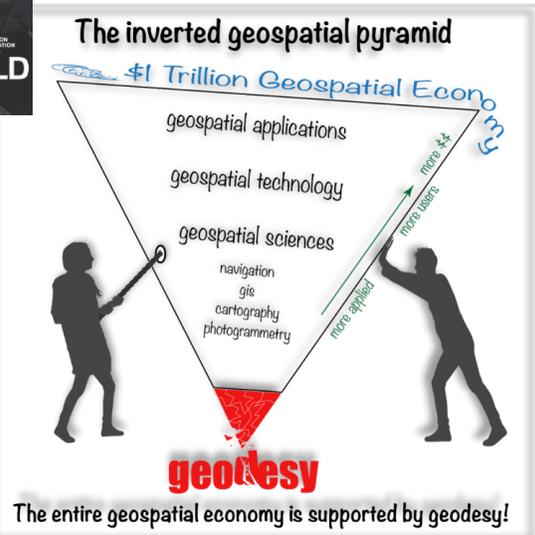
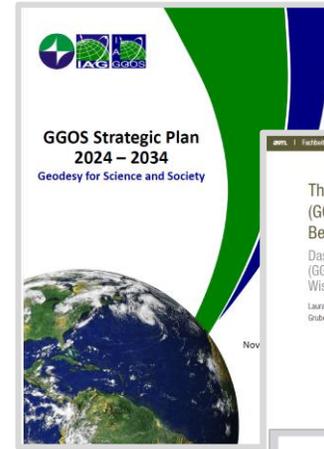
Timeline and Committed Parties: Objective 2.3

	Q4 2024	2025 (Q1-Q2)	2025 (Q3-Q4)	2026	Beyond 2026
63		• UN-GGCE	• UN-GGCE	• UN-GGCE	• UN-GGCE
64	• IAG	• IAG	• IAG		
65		• IAG	• IAG	• IAG	• IAG

Motivation: Raising awareness of Geodesy



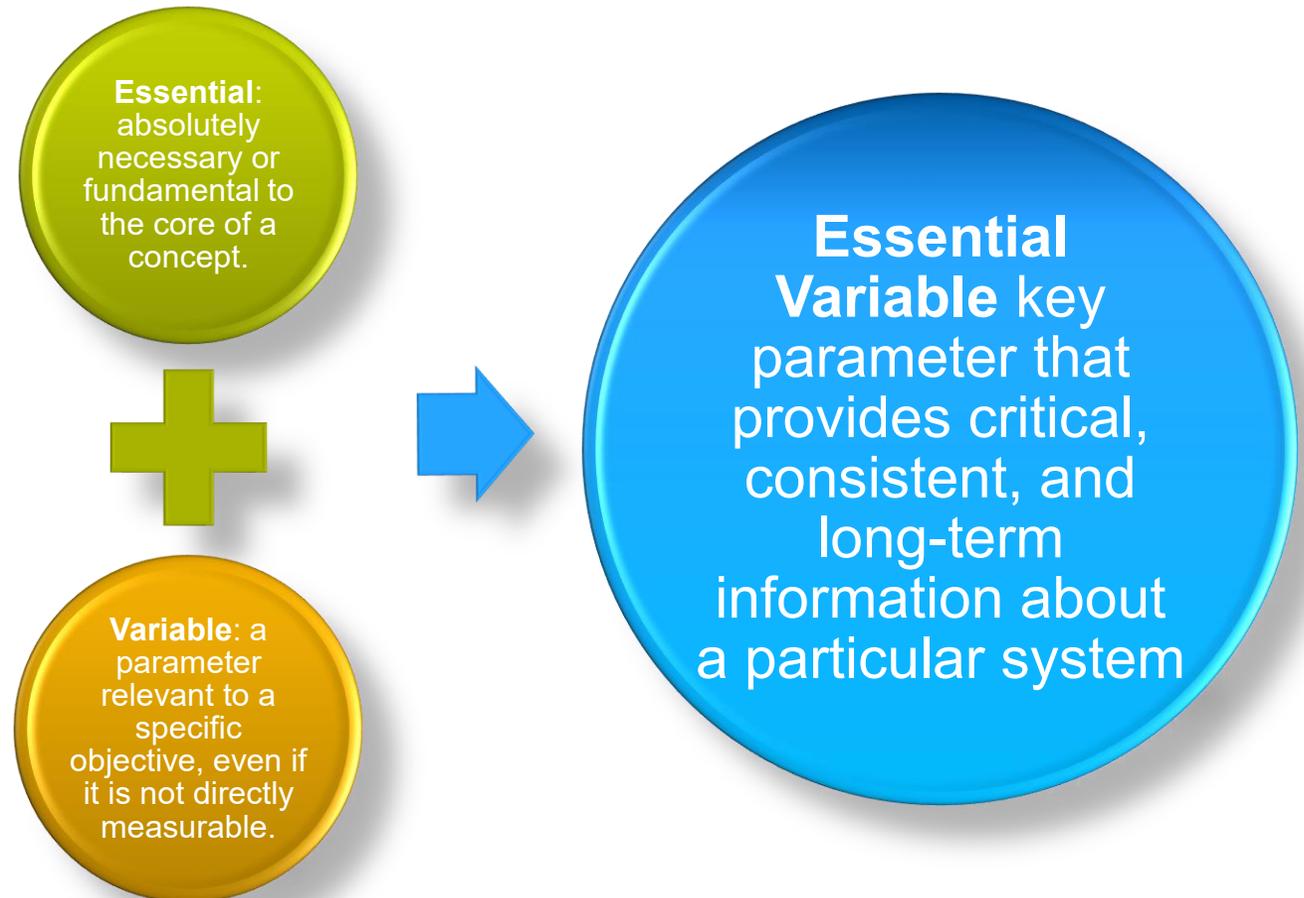
- Uneven global coverage, ageing infrastructure, **insufficient funding**
- **Declining workforce** and **limited new talent**
- Geodetic products on a **best-effort basis** (no guaranteed long-term operations)
- Challenging **transition from research to operational services**
- Limited translation of geodetic information into **actionable insights for decision-makers and the public**
- **Low visibility** in policy, international initiatives, and other scientific domains



Essential Variables (EVs): A powerful tool to raise awareness globally and across disciplines



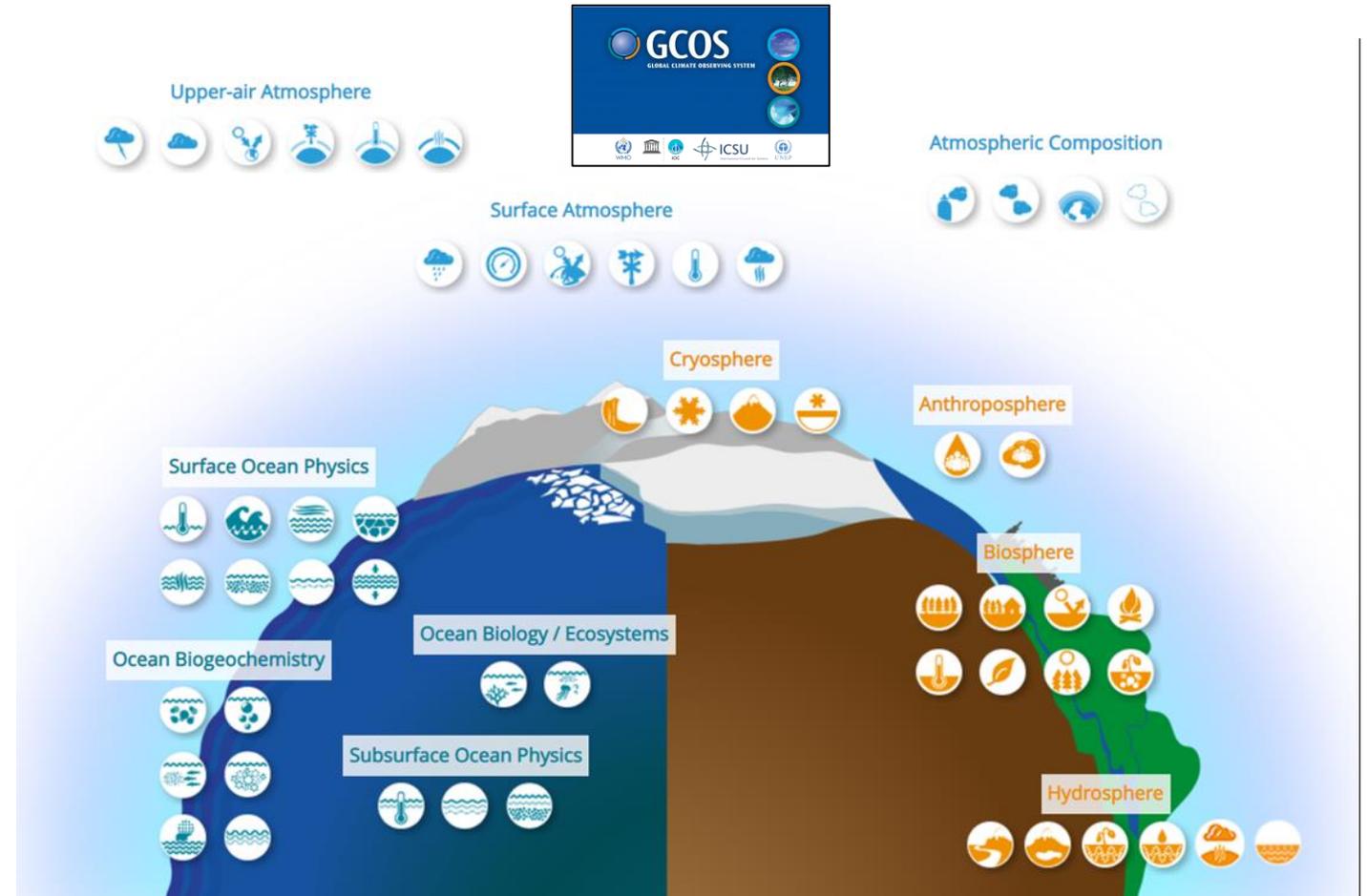
- **Encourage** scientists and observing systems to place **more emphasis** on these variables.
- **Stimulate** the **commitment** of national and internat. organisations and funding agencies to support the provision of these variables.
- **Enable** **cross-disciplinary data assimilation and interpretation**.
- **Facilitate interoperability** between science and evidence-based policy.



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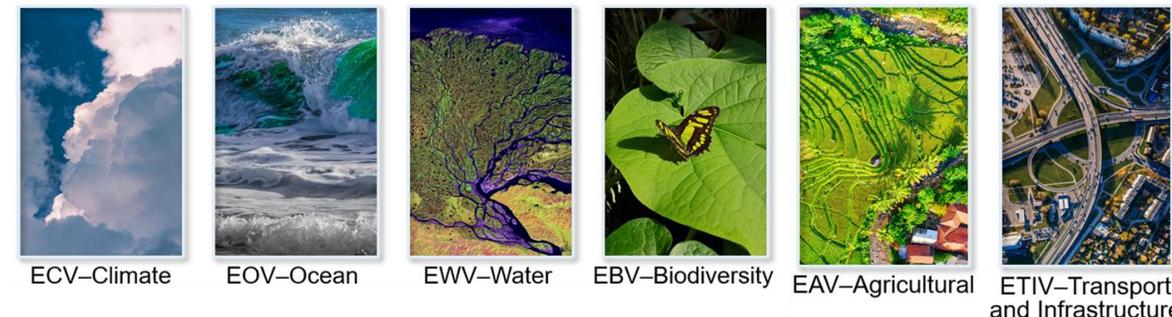
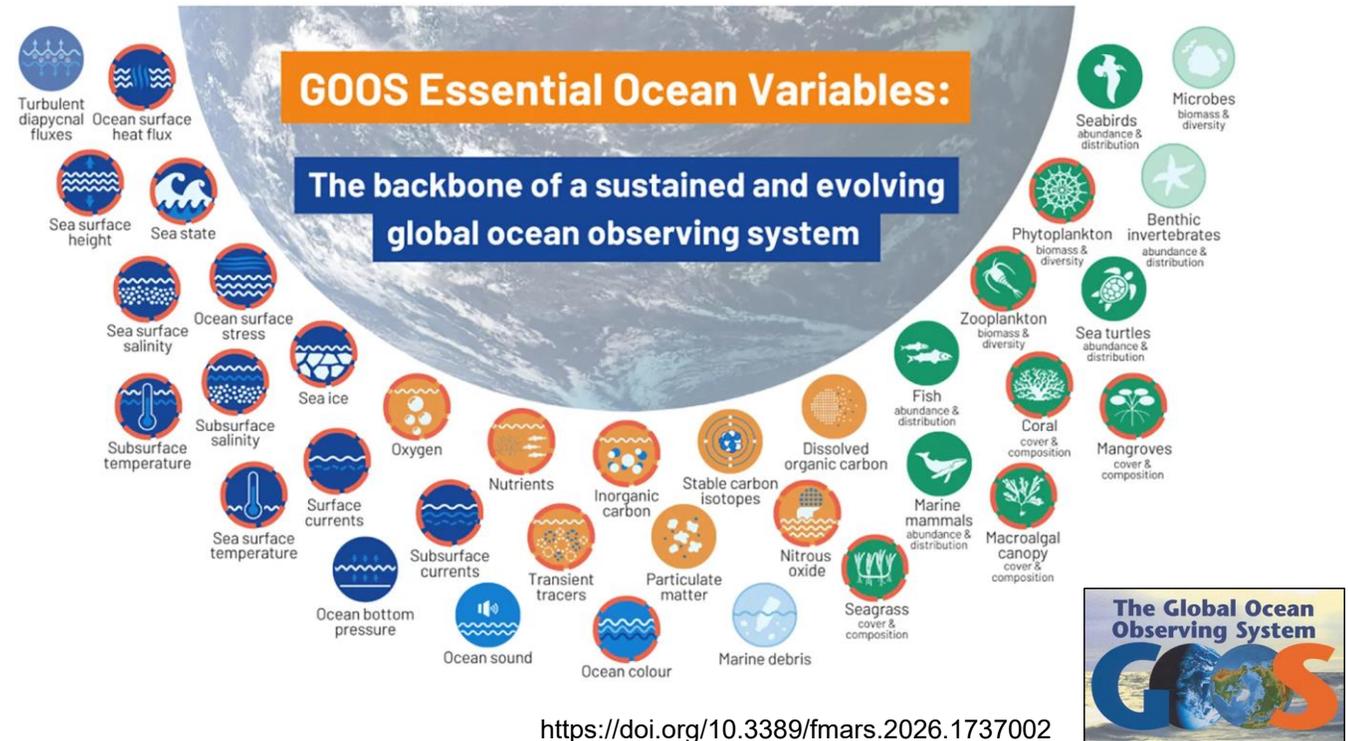


<https://gcos.wmo.int/site/global-climate-observing-system-gcos/essential-climate-variables>

Essential Variables (EVs): A powerful tool to raise awareness globally and across disciplines



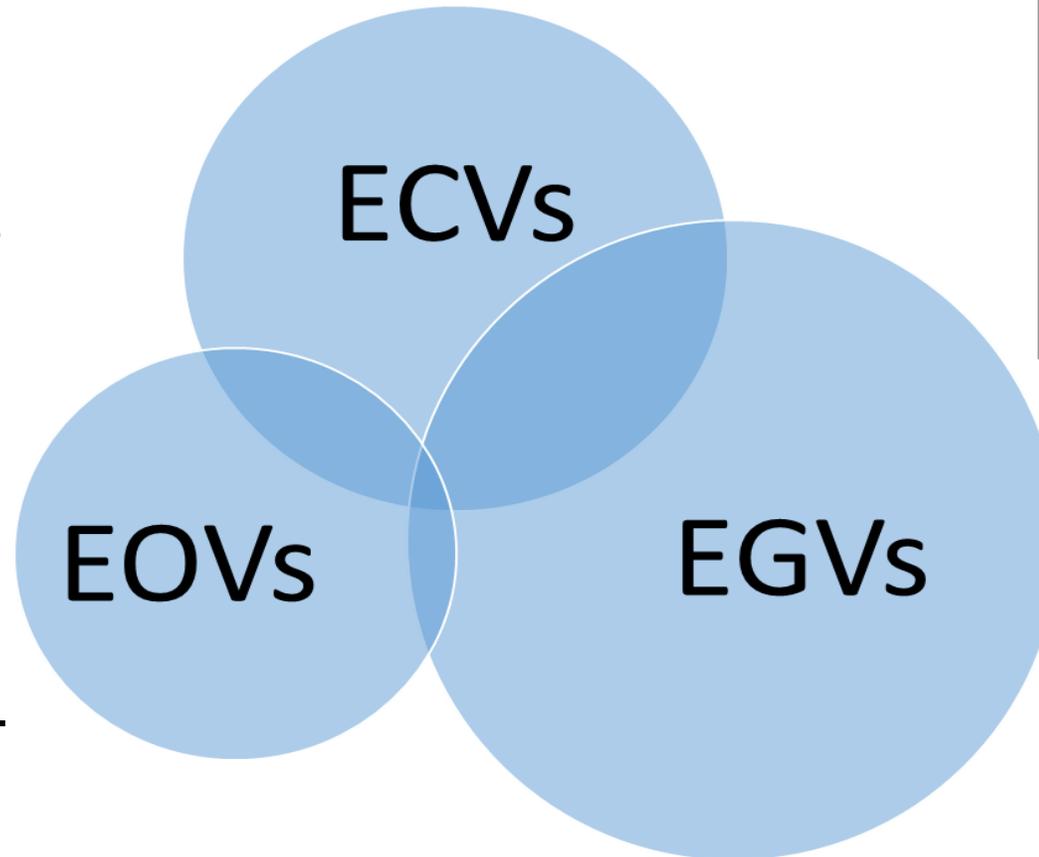
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Essential Variables (EVs): A powerful tool to raise awareness globally and across disciplines



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Criteria for all EVs:

- Relevance
- Feasibility
- Cost effectiveness

Additionally for EGVs:

- Sustainability
- Consistency and interoperability

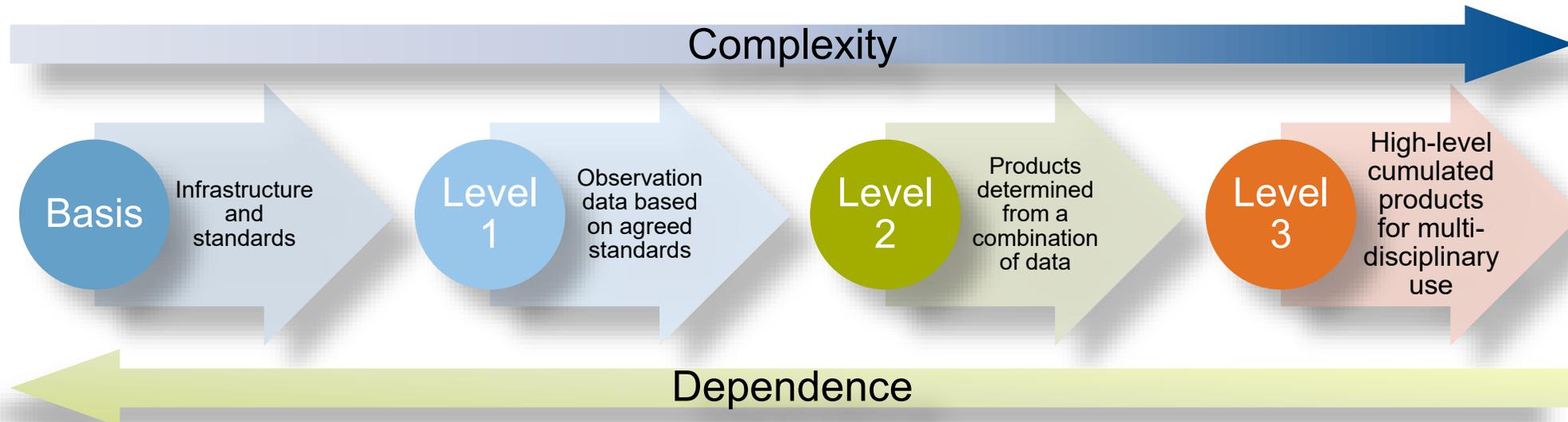
Workflows of Geodesy and EGV Levels



From geodetic observations to Earth system modelling



Essential Geodetic Variables Levels



Characterization of EGVs (in total 21 EGVs proposed)



		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)

EGVs
 Level 3: 14
 Level 2: 4
 Level 1: 1
 Basis: 2

Domain
 Global: 9
 Land: 5
 Ocean: 4
 Land/Ocean: 3

Subdomain
 Geometric: 7
 Physical: 6
 Geometric/Physical: 8

EGVs and ECVs/EOVs
 EGV = ECV 8
 EGV = EOVS 2

EGVs and associated Geodetic Products



Basis



Geodetic Standards & Conventions

- Numerical Geod. Standards (NSG)
- Conventional Background Models (CBM)



Geodetic Infrastructure

- Geodetic Space Infrastructure (GSI)
- Geodetic Terrestrial Infrastructure (GTI)

Level 2



Satellite Orbits

- GNSS Satellite Orbits, Clocks and Biases (GOCB)
- Earth Observation Satellite Orbits (ESO)



Station Positions and Variations

- Station Position Time Series (SPTS)



Sea Water Level Records

- Sea Water Level Records (SWLR)



Land & Marine Gravity Data

- Land Gravity Data (LGD)
- Marine Gravity Data (MGD)
- Absolute Gravity Data (AGD)
- Time Series Gravity Data (TGD)

Level 3



Earth Orientation Parameters

- Celestial Pole Offset (CPO)
- Universal Time (UT1)
- Length of Day (LOD)
- Polar Motion (PM)



Global Earth Gravity Field

- Global Gravity Field Models and its Variation (GGM)
- Topo. Gravity Field Models (TGF)
- Gravity Field Quantities (GFQ)



Atmosphere Parameters

- Integrated Water Vapor (IWV)
- Global Ionosphere Maps (GIM)
- Thermosphere Density Model (TDM)



Global Reference Frames

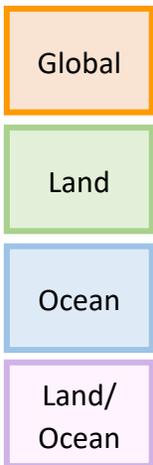
- Celestial Reference Frame (CRF)
- Terrestrial Reference Frame (TRF)
- Gravity Reference Frame (GRF)
- Height Reference Frame (HRF)

Level 1



Geodetic Observations

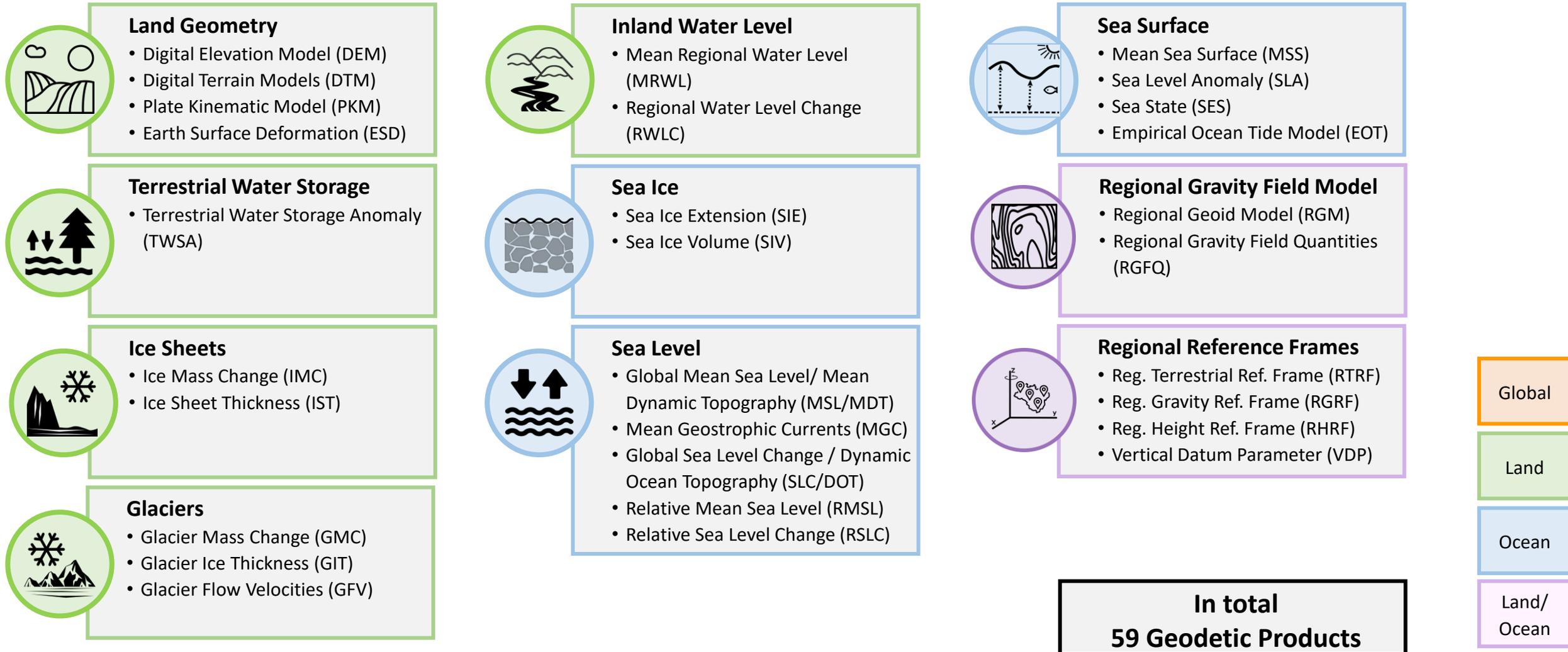
- Geodetic Geometric Observations (GGO)
- Geodetic Physical Observations (GPO)



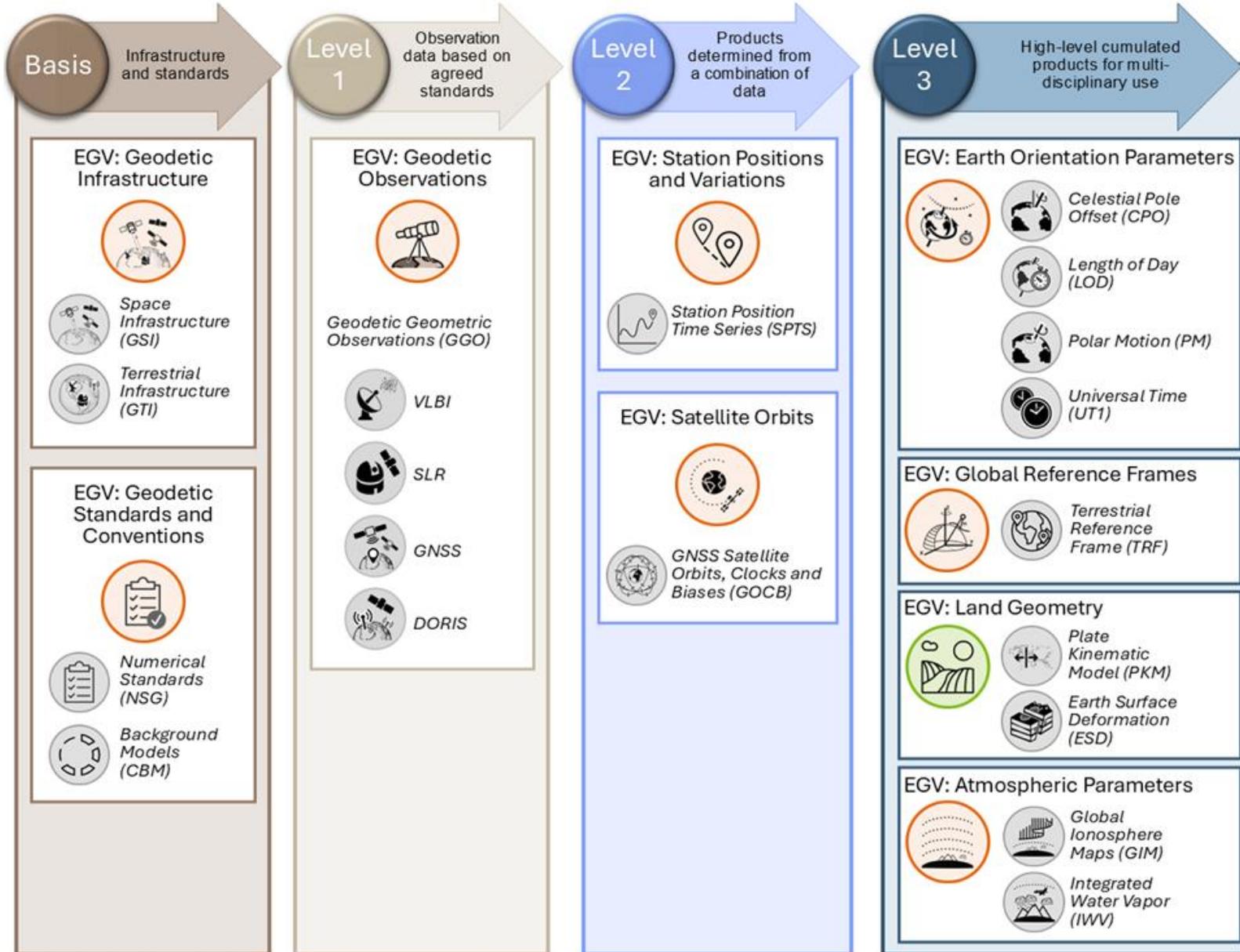
EGVs and associated Geodetic Products



Level 3



Example: ITRF and EOP generation



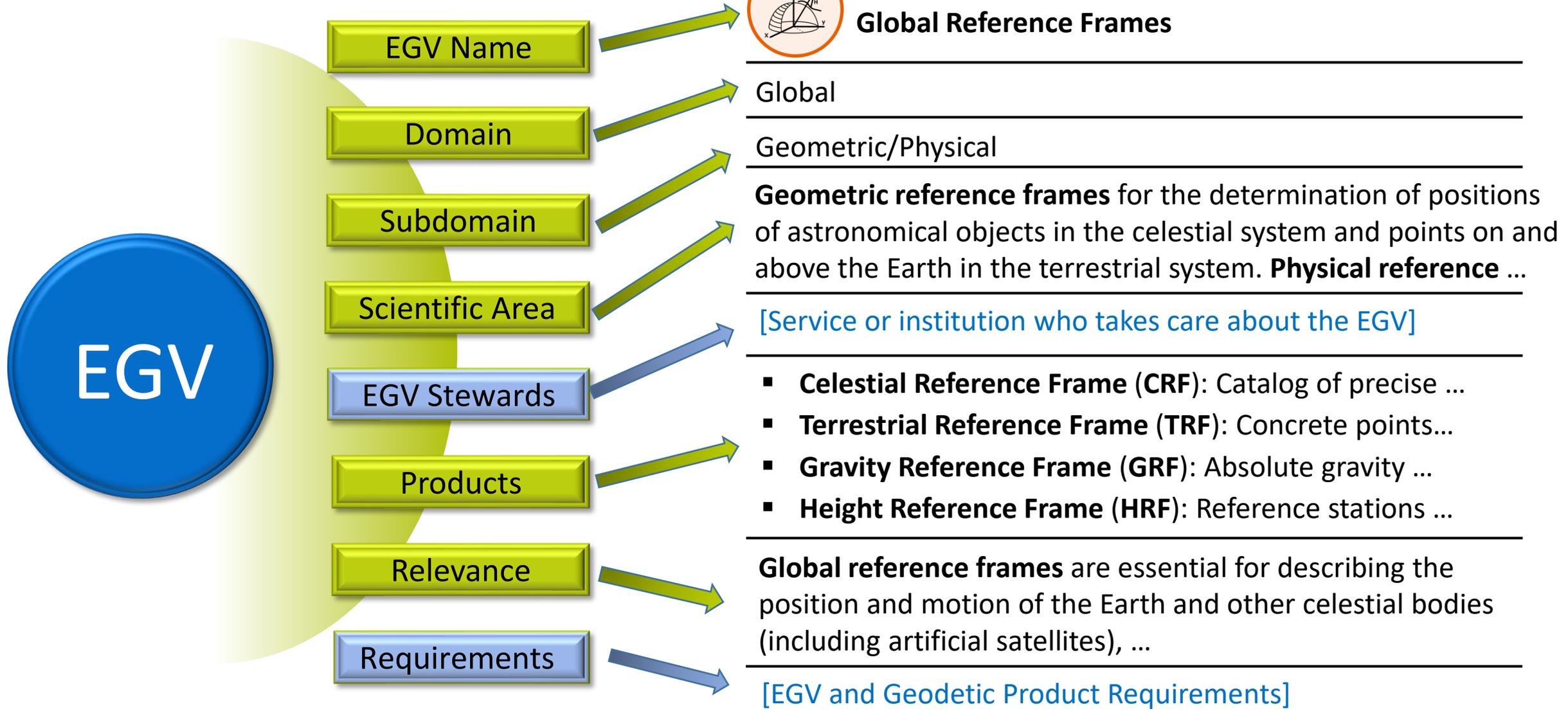
Colored circles represent EGVs

- global domain

- land domain

Grey circles represent products

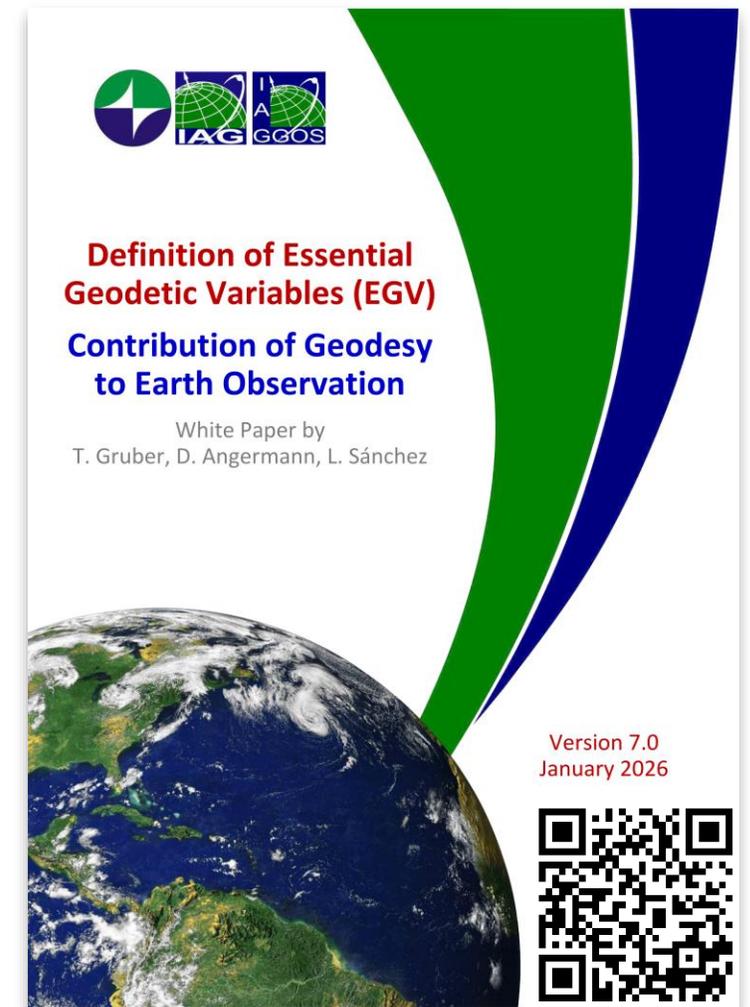
Description of EGVs



Milestones and Status of the EGV Definition



- 2018: Establishment of the Committee on EGVs within BPS.
- 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.
- Final 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>).



The way forward



- 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.
- Defining, adopting and maintaining the EGVs requires a **coordinated framework** across global, regional and national geodetic stakeholders.
- Progress depends on **teamwork, cooperation**, and a **willingness to compromise**.
- Next steps:
 - **Characterize geodetic products** (uncertainty, spatial and temporal resolution, timeliness, IAG Service / data sources, ...)
 - **Define product requirements ...**
 - **Identify Stewards for the EGVs** (IAG Service or responsible institution)
- GGOS/IERS Unified Analysis Workshop, 5-6 March 2026, Munich, Germany:
Session “*Availability of geodetic products for the Essential Geodetic Variables*”.

Characterization of geodetic products (in practice)



Example: Characterization of GNSS Satellite Orbits (Source: International GNSS Service – IGS)

EGV Satellite Orbits						
Product: GNSS Satellite Orbits, Clocks and Biases (GOCB)						
Definition:						
<ul style="list-style-type: none"> - 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			

Proposed criteria:

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

Towards the definition of requirements



- **Phase 1:** Inventory of current characteristics (accuracy, resolution, ...) for geodetic products, so that users know how reliable the products are (equivalent to **Threshold** for ECVs)
- **Phase 2:** Possible improvements over the next 10 years due to technological improvements (equivalent to **Breakthrough** in the ECVs)
- **Phase 3:** Target (ideal) requirements that are necessary to monitor specific Earth system signals (equivalent to **Goal** in the ECVs).

Example: Requirements for ECV Terrestrial Water Storage (Source: Global Climate Observing System)

- The requirements for the ECV consider three different statuses (**user oriented, independent of the available data**):
 - Goal (G): An **ideal requirement** above which further improvements are not necessary.
 - Breakthrough (B): An **intermediate level** between threshold and goal which, if achieved, would result in a significant improvement for the targeted application.
 - Threshold (T): The **minimum requirement** to be met to ensure that data are useful.

Name	Terrestrial Water Storage Anomaly				
Item needed ⁽¹⁾	Unit	Metric	Value ⁽²⁾		Notes
Horizontal resolution	km		G	1	Resolve the topography- and land cover-driven patterns of landscape-scale water storage dynamic.
			B	10	Many climate and Earth system models are moving to a grid size of 10 km or finer. Often a relevant local to regional water management scale.
			T	200	Comprehensive continental-scale patterns of water storage change.

(1) The requirements are expressed in terms of five criteria: (a) Spatial Resolution - horizontal and vertical (if needed), (b) Temporal resolution, (c) Measurement Uncertainty, (d) Stability, (e) Timeliness.
 (2) For each of the requirements, a goal, breakthrough and threshold value are presented.

Long-term sustainability of the EGVs



- A main requirement of the EGVs is that they are sustainable.
- EGVs should be provided on a long-term basis, and their reliability and consistency should be ensured.
- In this context, stewards must be identified who will take responsibility for safeguarding the long-term integrity, functionality, and resilience of the EGVs.
- EGV Stewards might be IAG Services or external providers (e.g., space agencies or other institutions).
- Requirements need to be defined.

EGV Name

Domain

Subdomain

Scientific Area

EGV Stewards

Products

Relevance

Requirements

Essential Geodetic Variables

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Thank you for your attention!

