Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

Definition of Essential Geodetic Variables (EGVs)

Contribution of Geodesy to Earth Observation

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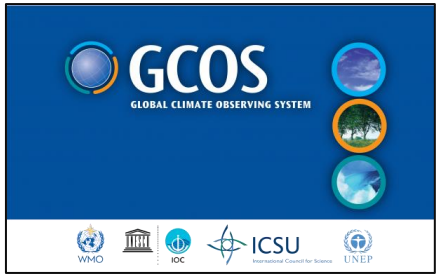
Introduction – Why to define Essential Variables?

Essential Variables: Variables that are capable of describing and monitoring the climate (ECVs), the oceans (EOVs) and **geodetic properties of the Earth (EGVs)** in a systematic and sustainable way.

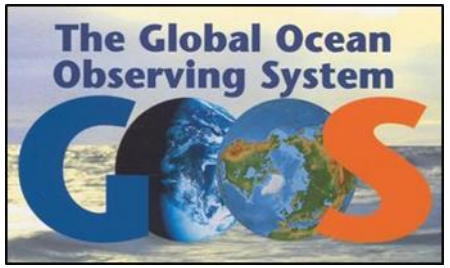
- Encourage **scientists and observing systems** to put more emphasis to these variables.
- Stimulate engagement of **national and international organizations** and **funding agencies to support provision of these variables**.
- Help decision makers to commit the **support of systematic and sustained Earth observation with satellites and Earth-based systems**.
- Support **UN-GGCE** (United Nations Global Geodetic Centre of Excellence), and **GEO Societal Benefit Areas (SBAs)** as well as **UN Sustainable Development Goals (SDGs)**.

Introduction – Who defines Essential Variables?

- First Essential Variables have been defined by the Global Climate Observing System (**GCOS**) in 2011: **55 Essential Climate Variables (ECVs)** have been defined so far.



- Global Ocean Observing System (**GOOS**) follows in 2014: **31 Essential Ocean Variables (EOVs)** have been defined so far.

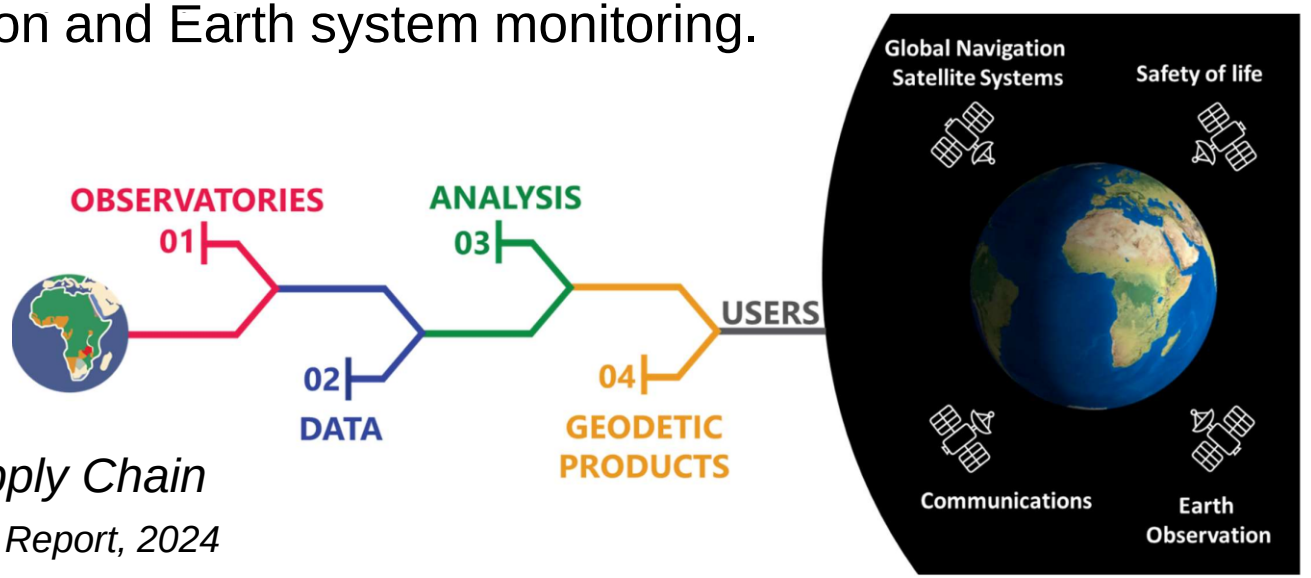


- Global Geodetic Observing System (**GGOS**) is working on the **definition of Essential Geodetic Variables (EGVs)** as **Contribution of Geodesy to Earth Observation**.

- Under the GGOS Bureau of Products and Standards **(BPS)** the **Committee on Essential Geodetic Variables** has been established (Chair since 2023: Thomas Gruber following Richard Gross).

Why to define Essential Geodetic Variables?

- **Geodesy provides a large number of products** that are essential for Earth observation and for many tasks of modern society (e.g. positioning, navigation, timing, engineering, land and resource management, and many other geospatial applications).
- So far, however, **these products suffer from a lack of visibility** for the global society and in some cases, they are also not easy to understand for non-experts.
- **Geodesy as a discipline is also not well known to the public** and therefore, there is a need to better promote these geodetic products.
- EGVs are designed to ensure the sustainability of the **Global Geodetic Supply Chain** for product generation and Earth system monitoring.



Global Geodesy Supply Chain

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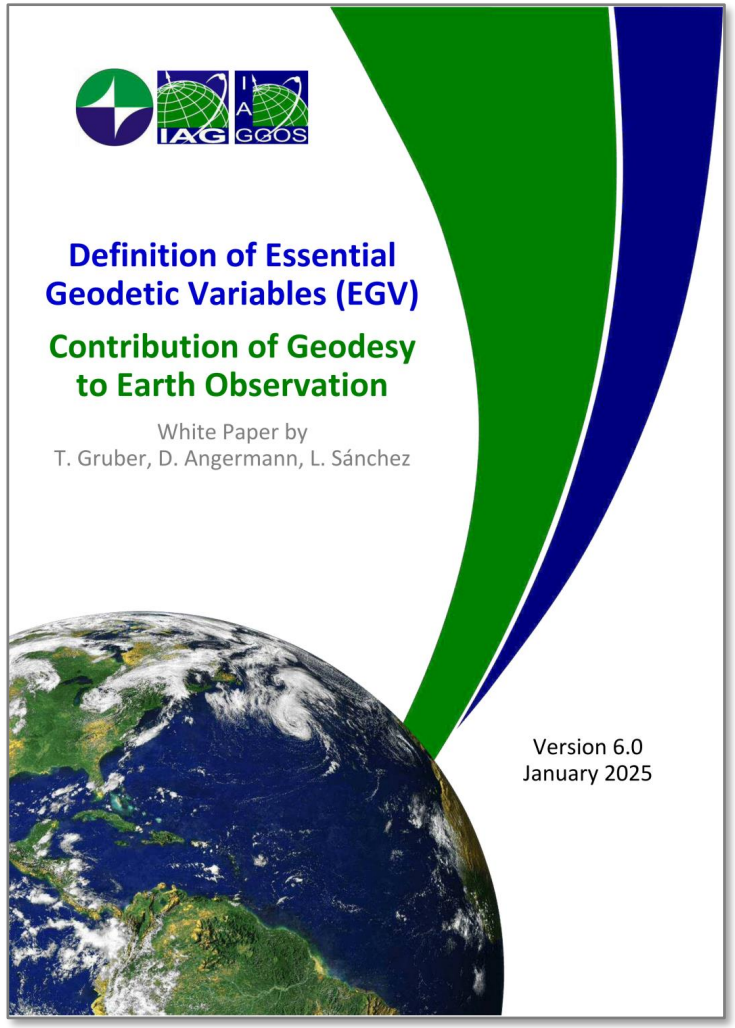
White Paper – Definition of Essential Geodetic Variables



Imprint

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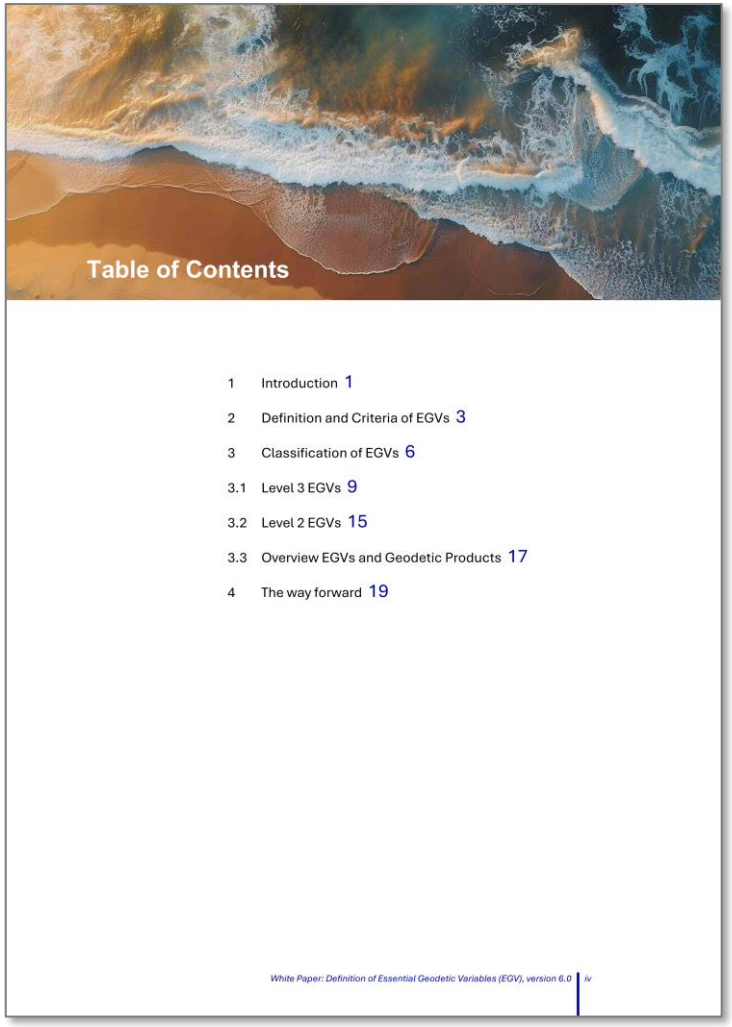
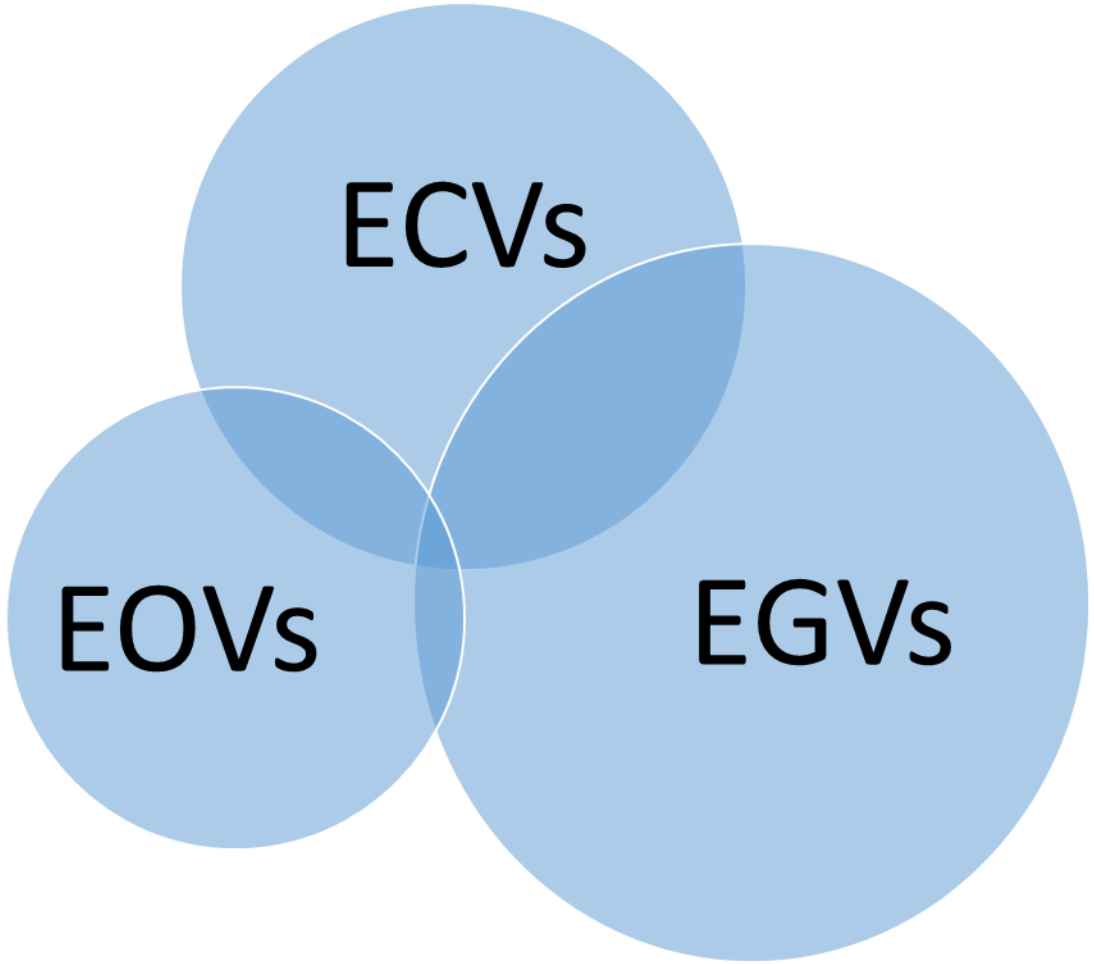


Classification and Criteria of Essential Variables (ECVs, EOVs, EGVs)



Classification:

ECVs: Atmosphere
Land
Ocean

EOVs: Physical
Biogeochemical
Biological/ecosystems

EGVs: Global
Land
Ocean

Criteria (for all EVs):

- Relevance
- Feasibility
- Cost effectiveness

Additionally for EGVs:

- Sustainability
- Consistency

Levels of EGVs:

- Level 0: Calibrated instrument data
- Level 1: Earth observation data based on agreed standards
- Level 2: Products determined from a combination of data
- Level 3: High-level accumulated products

List of proposed EGVs

18 EGVs in total

- Level 3: 14
- Level 2: 4

Domain

- Global: 6
- Land/Ocean: 3
- Land: 5
- Ocean: 4

Subdomain

- Geometric: 7
- Physical: 6
- Geometric/Physical: 5

EGVs and GCOS/GOOS

- 8 EGVs linked to ECVs
- 3 EGVs linked to EOVs

EGV	Level	Domain	Subdomain	ECV*	EOV**
Earth Orientation Parameters	L3	Global	Geometric		
Global Reference Frames	L3	Global	Geometric/Physical		
Global Earth Gravity Field	L3	Global	Physical		
Regional Reference Frames	L3	Land/ Ocean***	Geometric/Physical		
Regional Gravity Field Model	L3	Land/ Ocean***	Physical		
Land Geometry	L3	Land	Geometric		
Sea Surface	L3	Ocean	Geometric	X	X
Sea Level	L3	Ocean	Physical	X	X
Sea Ice	L3	Ocean	Geometric	X	X
Ice Sheets	L3	Land	Geometric/Physical	X	
Glaciers	L3	Land	Geometric/Physical	X	
Inland Water Level	L3	Land	Geometric/Physical	X	
Terrestrial Water Storage	L3	Land	Physical	X	
Atmosphere	L3	Global	Physical	X	
Satellite Orbits	L2	Global	Geometric		
Station Positions and Variations	L2	Global	Geometric		
Sea Water Level Records	L2	Ocean	Geometric		
Land and Marine Gravity Data	L2	Land/ Ocean***	Physical		

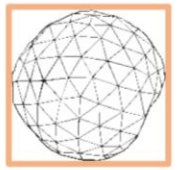
** Essential Geodetic Variables common to Essential Climate Variables*
*** Essential Geodetic Variables common to Essential Ocean Variables*
**** For regional applications at land and ocean*

Description of Essential Geodetic Variables

	**Earth Orientation Parameters**
Domain	Global
Subdomain	Geometric
Scientific Area	Change of the orientation of the Earth with respect to a global reference frame (celestial pole offsets, UT1, LOD, polar motion).
EGV Stewards	
Products	▪ Celestial Pole Offset (CPO): *Differences with respect to the conventional celestial pole position defined by precession and nutation models with respect to the CRF*. ▪ Universal Time (UT1): *Computed from a measure of the Earth's angle with respect to the CRF, called the Earth Rotation Angle*. ▪ Length of Day (LOD): *Time series of LOD variations*. ▪ Polar Motion (PM): *Time series of pole coordinates relative to the TRF and rates of PM*.

	**Global Reference Frames**
Domain	Global
Subdomain	Geometric/Physical
Scientific Area	Geometric reference frames for the determination of the positions of astronomical objects in the celestial system and of points on or above the Earth surface in the terrestrial system. Physical reference frames for determining the gravity acceleration and the equipotential surface as a height reference.
EGV Stewards	
Products	▪ Celestial Reference Frame (CRF): *Catalog of precise equatorial coordinates of extragalactic radio sources*. ▪ Terrestrial Reference Frame (TRF): *Concrete points (markers) attached to the solid Earth crust with precisely determined coordinates (mean 3D positions of the stations and their motions)*. ▪ Gravity Reference Frame (GRF): *Absolute gravity measurements traceable to the International System of Units (SI) that contain conventional temporal gravity corrections*. ▪ Height Reference Frame (HRF): *Reference stations homogeneously distributed over the world and with known geopotential numbers or height values with respect to a global common reference surface.*

Description of Essential Geodetic Variables

	**Global Earth Gravity Field**
Domain	Global
Subdomain	Physical
Scientific Area	Global Earth gravity field in the spectral and spatial domains including derived quantities with respect to a reference (ellipsoidal) gravity field.
EGV Stewards	
Products	▪ Global Gravity Field Models and its variation (GGM): *Spherical or ellipsoidal harmonic series of gravity potential either as mean or as a temporal series (low degree harmonics from satellite-only combined models).* ▪ Topographic Gravity Field Models (TGFM): *Spherical or ellipsoidal harmonic series of gravity potential originated by the attraction of the Earth's topographic masses.* ▪ Gravity Field Quantities (GFQ): *Calculated gravity functionals on grids or selected points either with reference to an ellipsoidal reference field (height anomaly, geoid, gravity disturbance, gravity anomaly, deflections of the vertical, equivalent water height) or as full signal (gravitation, gravitational potential, gravity, gravity potential, normal gravity, normal potential, gravity gradient).*

	**Regional Reference Frames**
Domain	Land/Ocean
Subdomain	Geometric/Physical
Scientific Area	Regional densification of global reference frames to improve the station distribution and provide access to the global TRF, GRF and HRF at regional/national scales. A regional height system is not necessarily a regional densification of the HRF, as the reference surface of most of the existing physical height systems is linked to the mean sea level determined at a tide gauge and consequently to the regional geoid model (RGM). The link between the regional height systems and the global HRF is provided by vertical datum parameters (VDP).
EGV Stewards	
Products	▪ Regional Terrestrial Reference Frame (RTRF)*: Concrete points (markers) attached to the solid Earth crust with precisely determined coordinates (mean 3D positions of the stations and their motions) for regional networks.*
	▪ Regional Gravity Reference Frame (RGRF)*: Absolute gravity measurements traceable to the SI that contain conventional temporal gravity corrections.* ▪ Regional Height Reference Frame (RHRF)*: Reference stations regionally distributed with known geopotential numbers or height values with respect to the global HRF reference surface.* ▪ Vertical Datum Parameter (VDP)*: Connection of the regional height system to the global height reference frame (HRF).*

Geodetic Products associated to the EGVs

Acronym	Definition	Acronym	Definition
AGM	Absolute Gravity Measurements	MRWL	Mean Regional Water Level
CPO	Celestial Pole Offset	MSL	(Global) Mean Sea Level
CRF	Celestial Reference Frame	MSS	Mean Sea Surface
DEM	Digital Elevation Model	PKM	Plate Kinematic Model
DOT	Dynamic Ocean Topography	PM	Polar Motion
DTM	Digital Terrain Model	RGFQ	Regional Gravity Field Quantities
EOT	Empirical Ocean Tide Model	RGM	Regional Geoid Model
ESD	Earth Surface Deformation	RGRF	Regional Gravity Reference Frame
ESO	Earth Observation Satellite Orbits	RHRF	Regional Height Reference Frame
GFQ	Gravity Field Quantities	RMSL	Relative Mean Sea Level
GFV	Glacier Flow Velocities	RSLC	Relative Sea Level Change
GGM	Global Gravity Field Model	RTRF	Regional Terrestrial Reference Frame
GIM	Global Ionosphere Maps	RWLC	Regional Water Level Change
GIT	Glacier Ice Thickness	SES	Sea State
GMC	Glacier Mass Change	SIE	Sea Ice Extension
GRF	Gravity Reference Frame	SIV	Sea Ice Volume
GSC	GNSS Satellite Clocks	SLA	Sea Level Anomaly
GSO	GNSS Satellite Orbits	SLC	(Global) Sea Level Change
HRF	Height Reference Frame	SLWR	Sea Level Water Records
IMC	Ice Mass Change	SPTS	Station Position Time Series
IST	Ice Sheet Thickness	TDM	Thermosphere Density Model
IWV	Integrated Water Vapor	TGFM	Topographic Gravity Field Model
LGM	Land Gravity Measurements	TGM	Time Series Gravity Measurements
LOD	Length of Day	TRF	Terrestrial Reference Frame
MDT	Mean Dynamic Topography	TWSA	Terrestrial Water Storage Anomaly
MGC	Mean Geostrophic Currents	UT1	Universal Time
MGM	Marine Gravity Measurements	VDP	Vertical Datum Parameter

EGV: Global Reference Frames

- **CRF** Celestial Reference Frame
- **GRF** Gravity Reference Frame
- **HRF** Height Reference Frame
- **TRF** Terrestrial Reference Frame

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UN-Resolution 2015 (A/RES/69/266)
Global Geodetic Reference Frame for Sustainable Development

IAG IAG GGOS

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EGV: Earth Orientation Parameters

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

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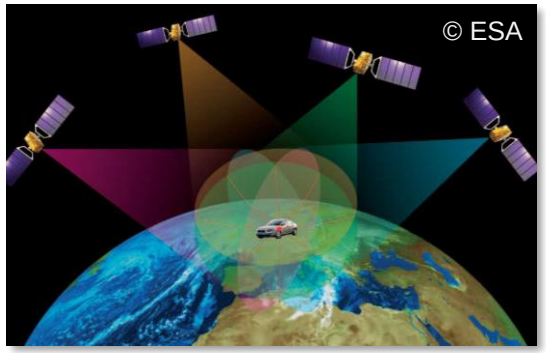

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EGV: Earth Orientation Parameters

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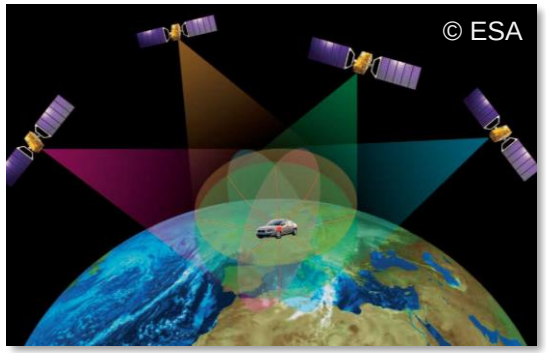
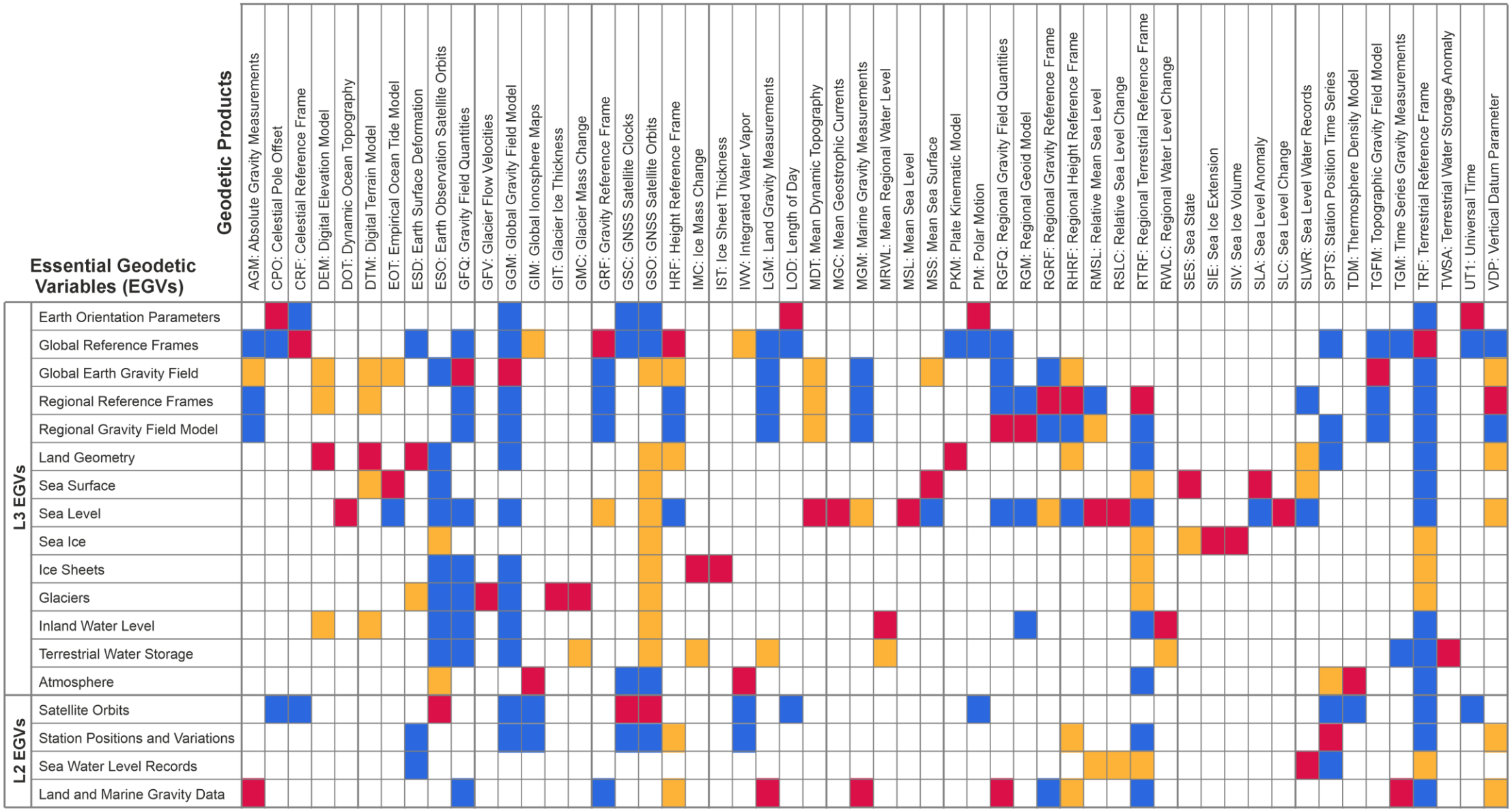


EGV: Regional Reference Frames

- **RGRF** Reg. Gravity Reference Frame
- **RHRF** Reg. Height Reference Frame
- **RTRF** Reg. Terrestrial Reference Frame
- **VDP** Vertical Datum Parameter

Contribution of Geodetic Products to the EGVs



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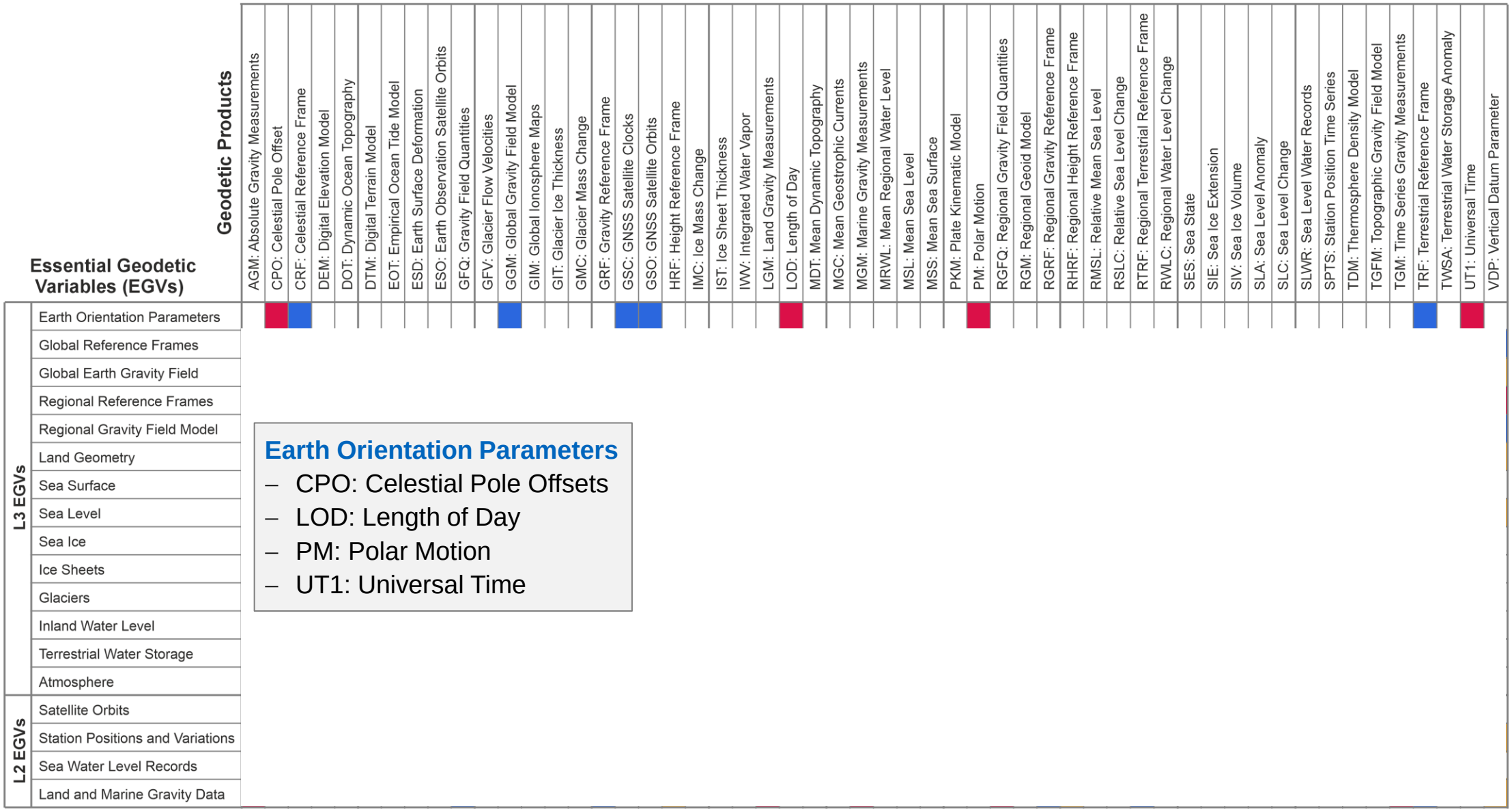


Earth Orientation Parameters

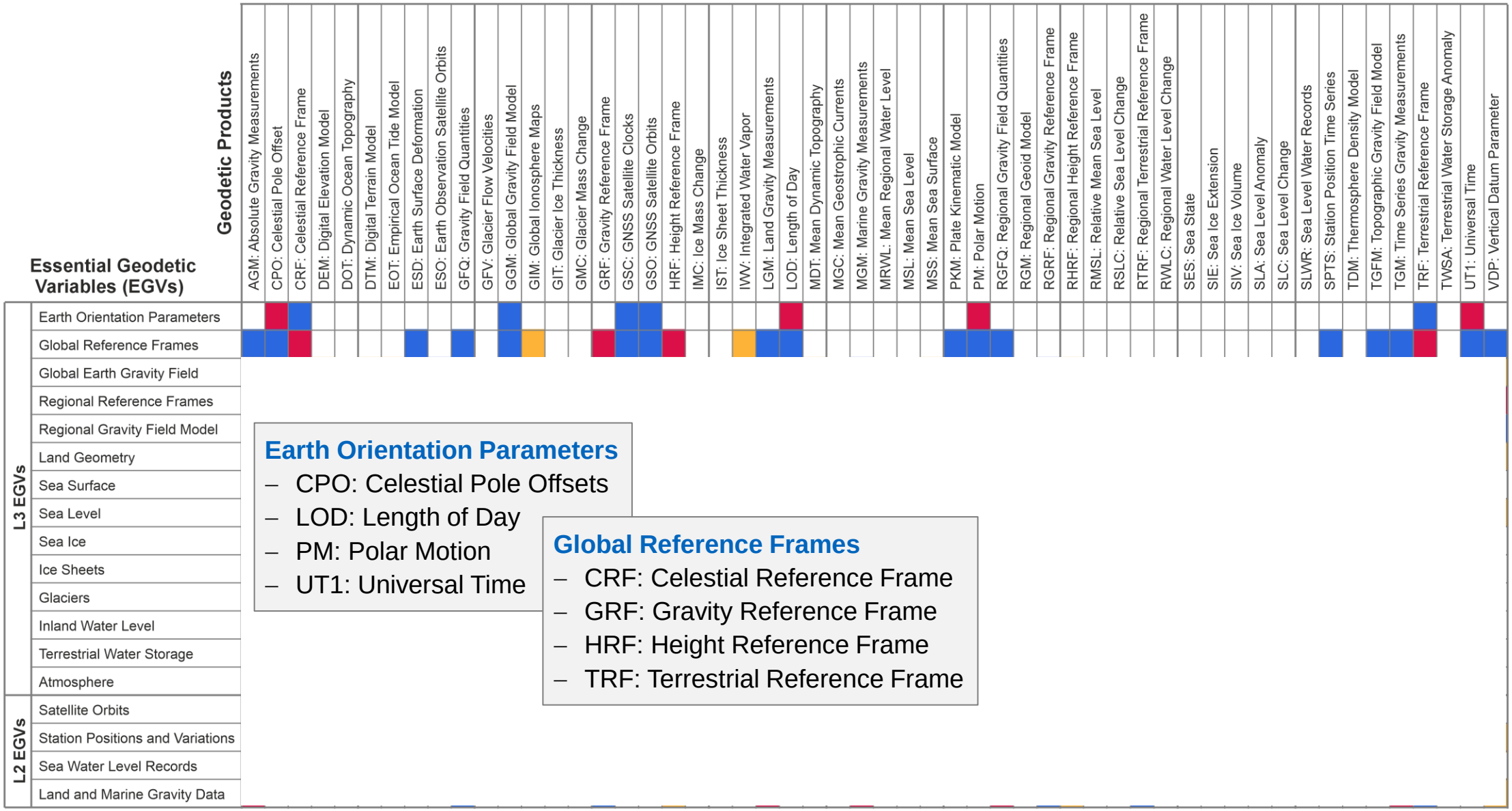
- CPO: Celestial Pole Offsets
- LOD: Length of Day
- PM: Polar Motion
- UT1: Universal Time

Primary geodetic products directly related to the EGV

Geodetic products that provide important information to the EGV

Geodetic products indirectly linked to the EGV

Contribution of Geodetic Products to the EGVs



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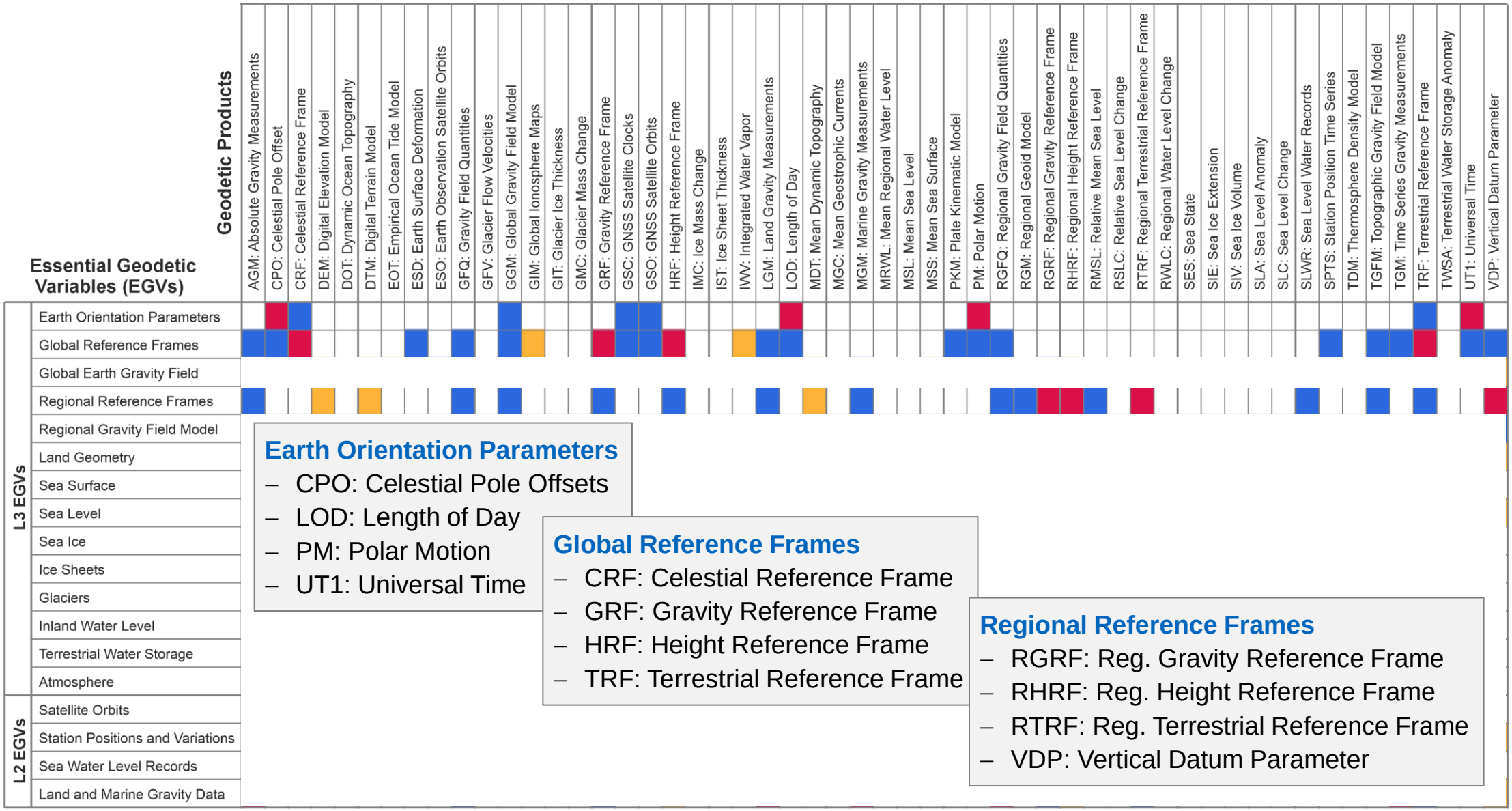

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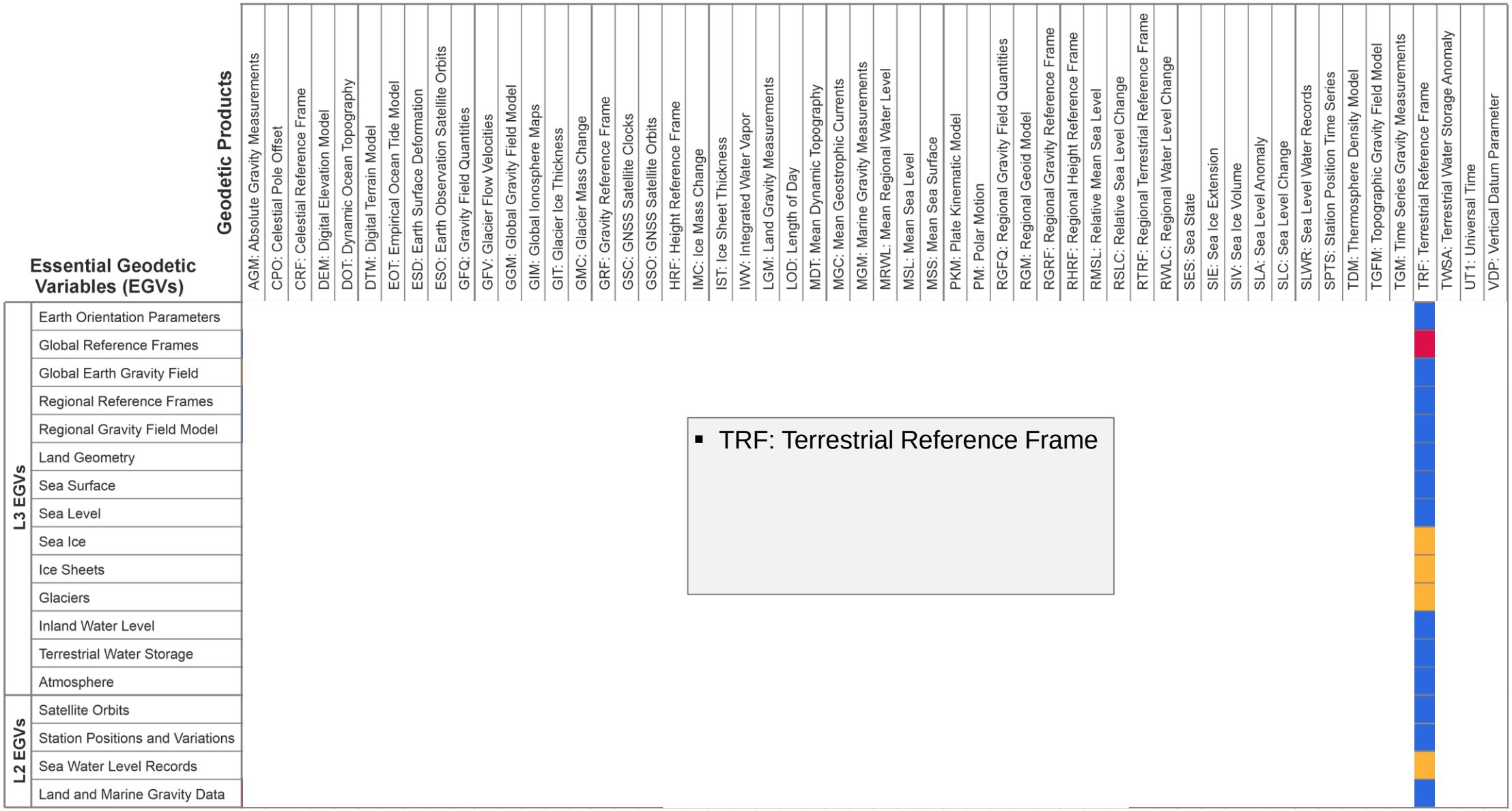

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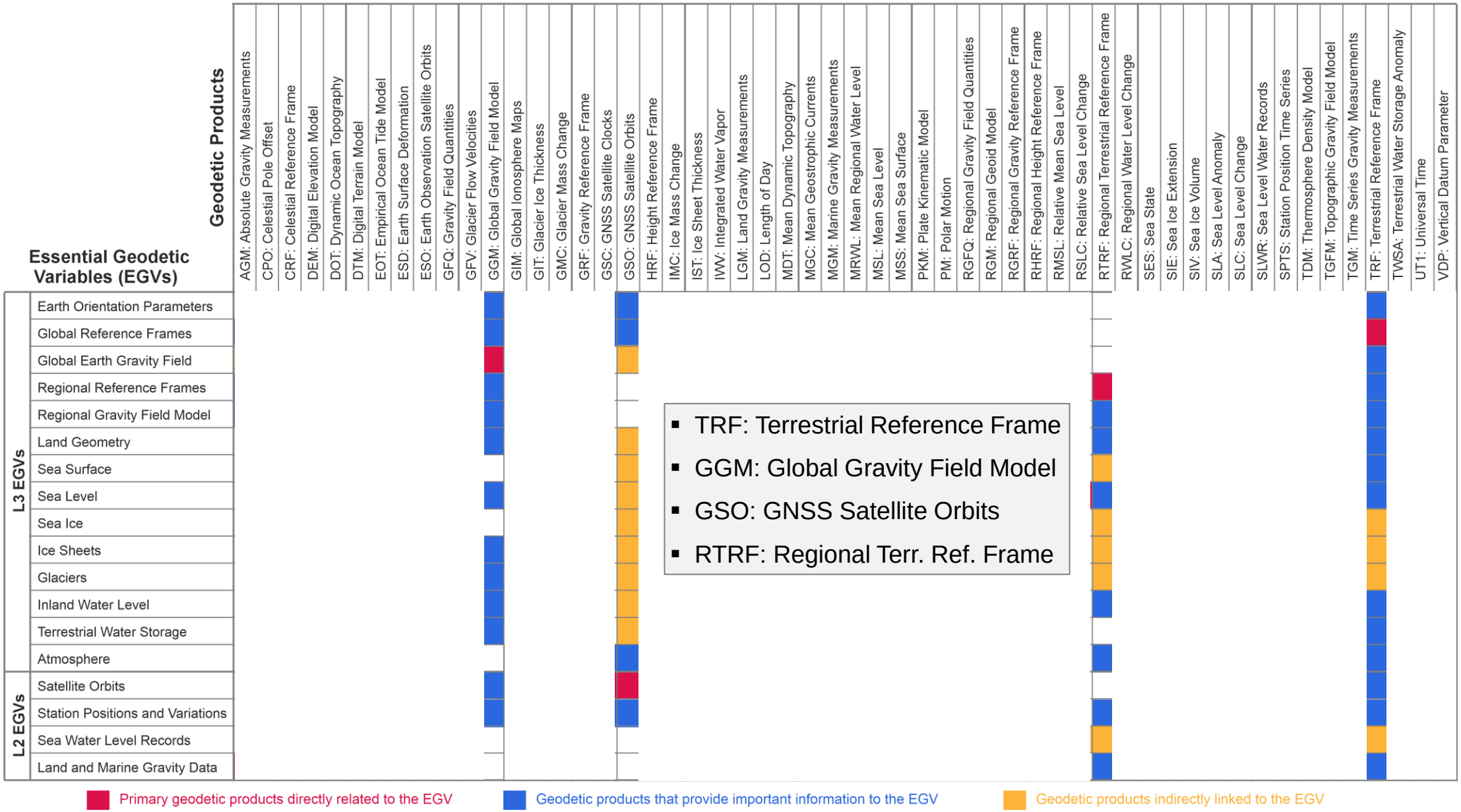

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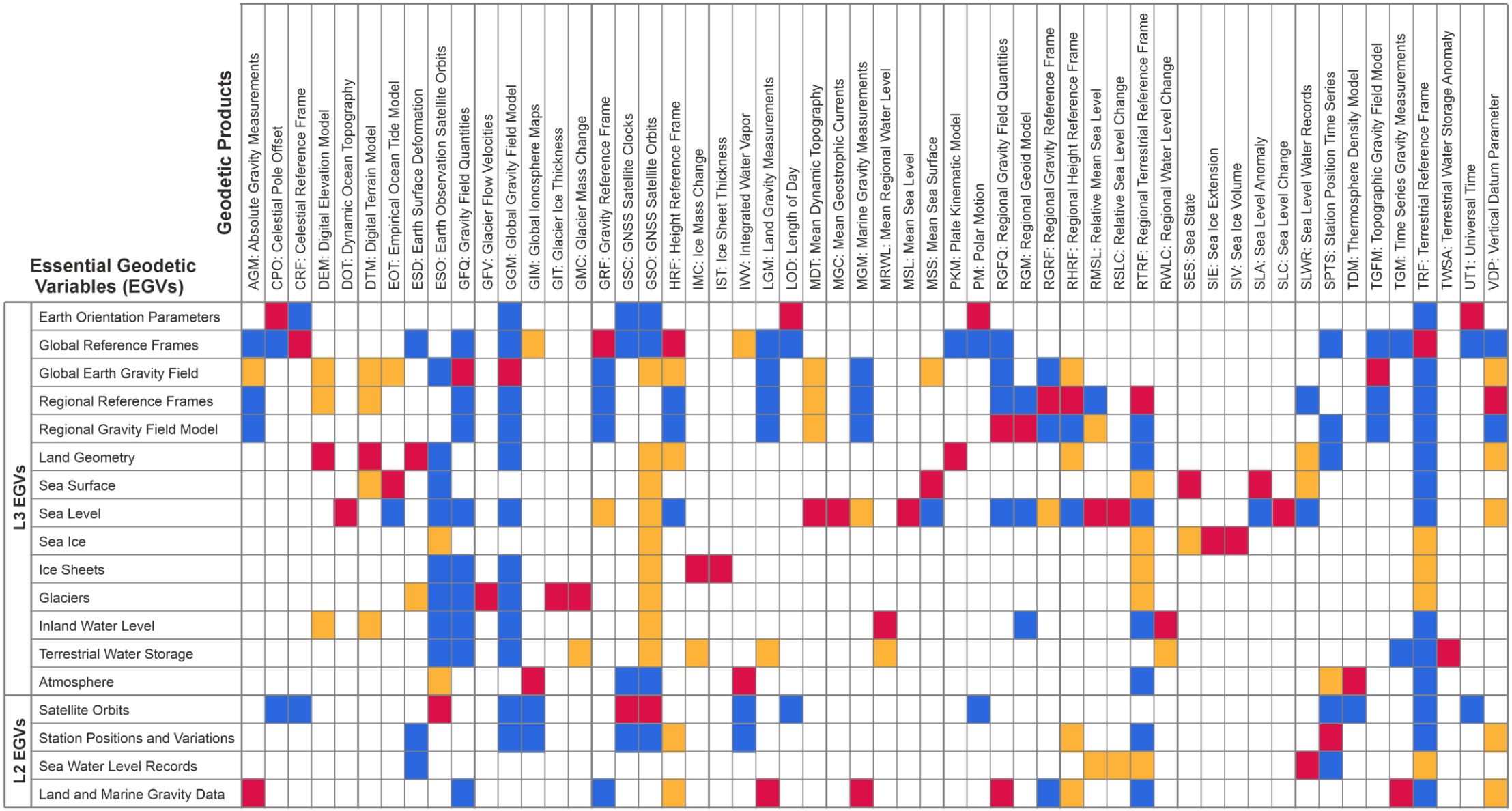
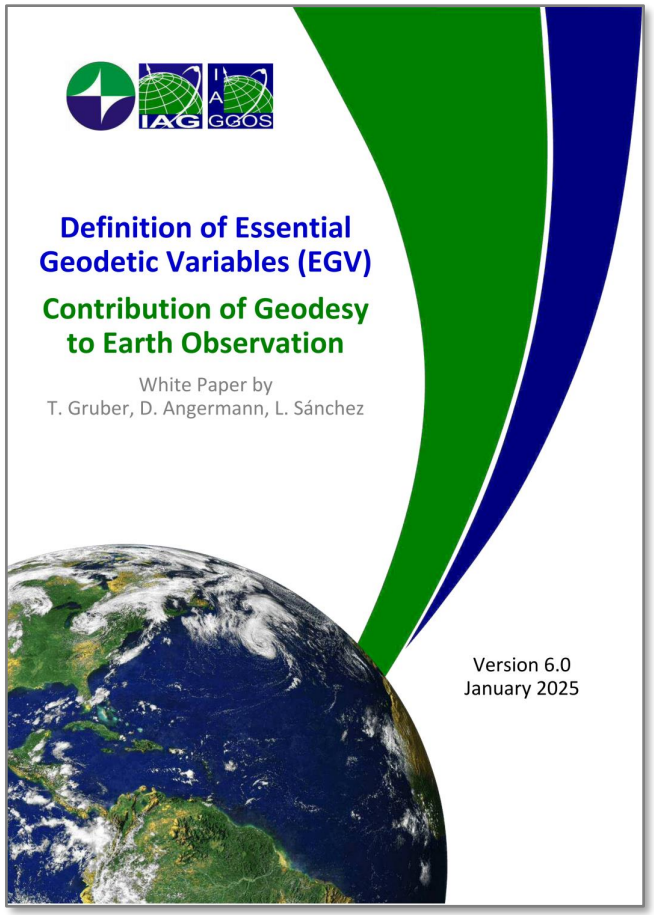
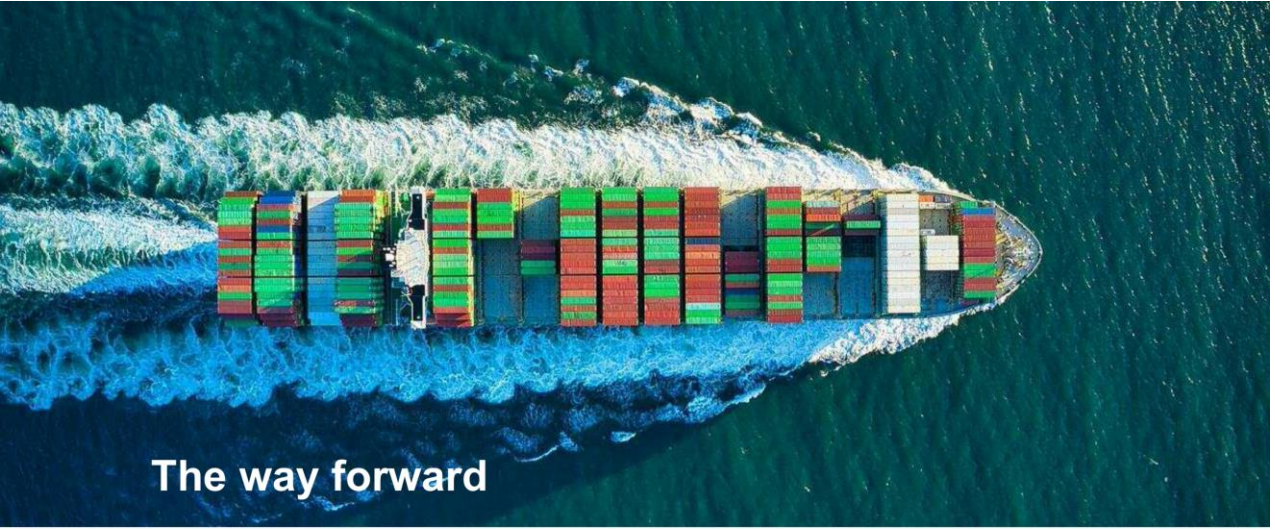


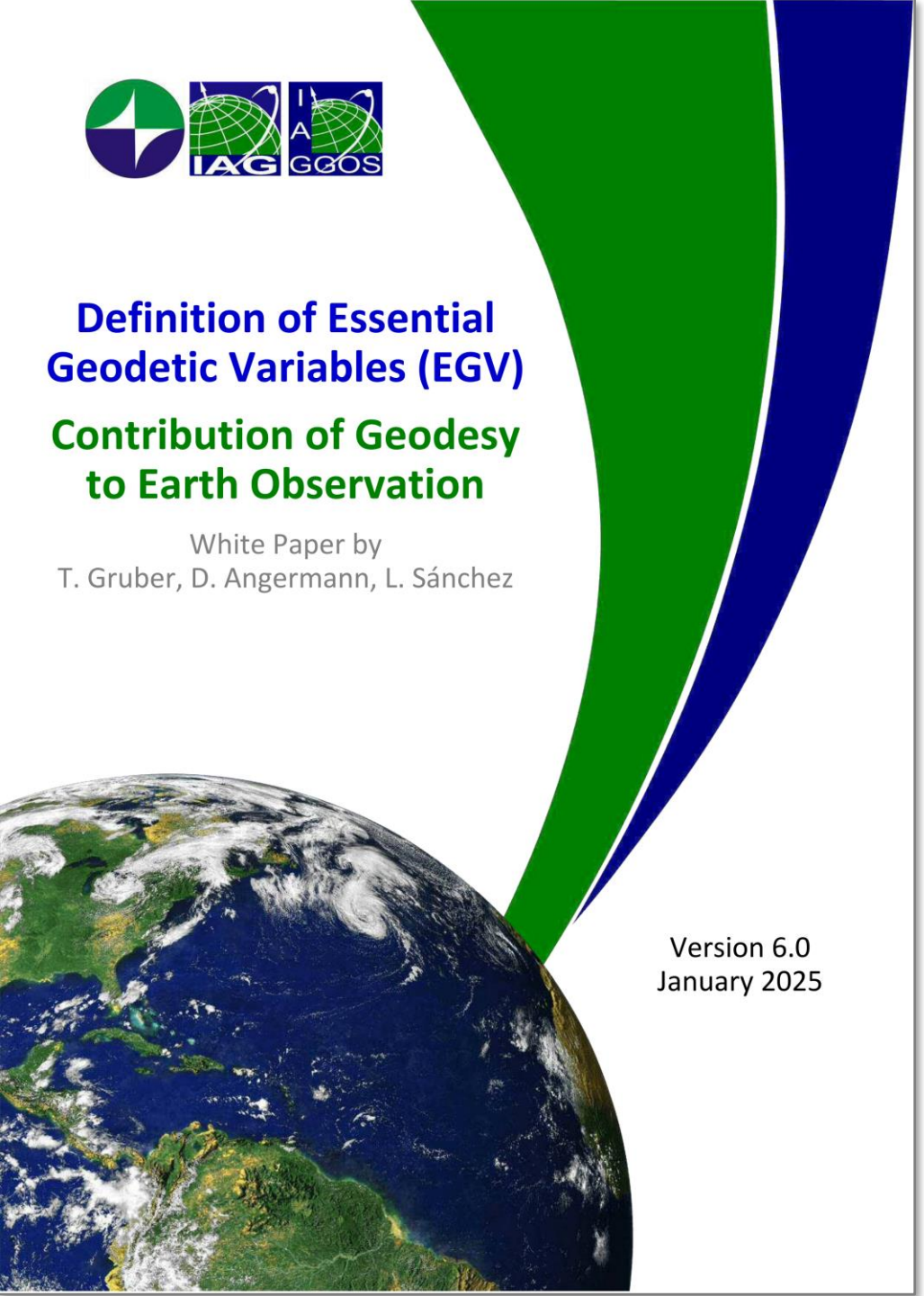
Status on the definition of Essential Geodetic Variables

- In January 2025, the **White Paper "Definition of EGVs"** has been published at zenodo: *https://doi.org/10.5281/zenodo.14619439*.
- The document has been reviewed by the GGOS Science Panel and GGOS Governing Board members (valuable comments and suggestions received, feedback incorporated).
- Early this year, the revised document has been sent to the IAG Executive Committee members and the UN-GGCE team.
- Feedback from several IAG EC members and UN-GGCE team received (Nick and Liubov reviewed the document and provided valuable comments and suggestions).
- The revision of the document is under way.





- A broader public review will be initiated, taking into account relevant stakeholders and the global geodetic community to achieve a general consensus on the EGV definition.
- Defining specific requirements to be met by the geodetic products to support the assessment of the EGVs; identification of stewards for the EGVs.
- Work with other IAG components and relevant stakeholders, including the UN-GGCE, to define requirements and promote EGVs; fact sheets and policy briefs for EGVs.
- Interact with GEO and the other Earth observing systems (GCOS, GOOS).



Thank you

Your feedback is greatly appreciated

Please feel free to contact me if you have any comments and/or suggestions

You can also send your feedback to the GGOS Coordinating Office (co@ggos.org)

Detlef Angermann - detlef.angermann@tum.de