



# Definition of Essential Geodetic Earth Observation Variables with Emphasis to the Earth Gravity Field

Authors: Thomas Gruber<sup>(1)</sup>, Detlef Angermann<sup>(2)</sup>, Laura Sánchez<sup>(2)</sup>

<sup>(1)</sup> Institute of Astronomical and Physical Geodesy (IAPG), Technical University of Munich

<sup>(2)</sup> Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), Technical University of Munich



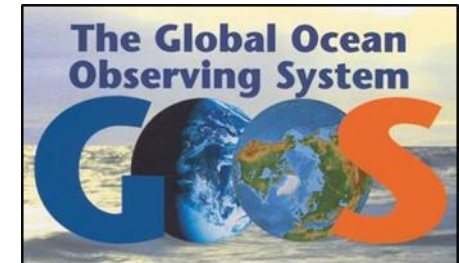
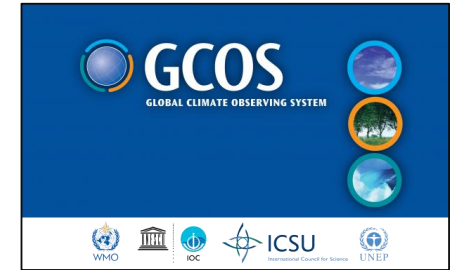
# Introduction - Why to define Essential Variables?

**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 **GEO Societal Benefit Areas (SBAs)** and **UN Sustainable Development Goals (SDGs)** including the **UN-GGCE** (United Nations Global Geodetic Centre of Excellence).

# 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)**.
- 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).



# Introduction - Development and Current Status

- **2017 GGOS Days:** Initial gap analysis (R. Gross).
- **2018 GGOS Days:** Committee on EGVs established and definition of tasks. Initial thoughts presented.
- **2019 IUGG:** Talks about EGV requirements, EGVs for Earth geometry and gravity field.
- **2022 GGOS Days:** Target audience and first list of EGVs.
- **2023 IUGG:** Status & Plans; Identification of a basic set of EGVs; Definition of criteria, levels and requirements of EGVs.
- **2024 White Paper:** “Definition of Essential Geodetic Earth Observation Variables”. Review by GGOS Science Panel completed. Next revision under preparation.

# White Paper - Naming of Essential Variables

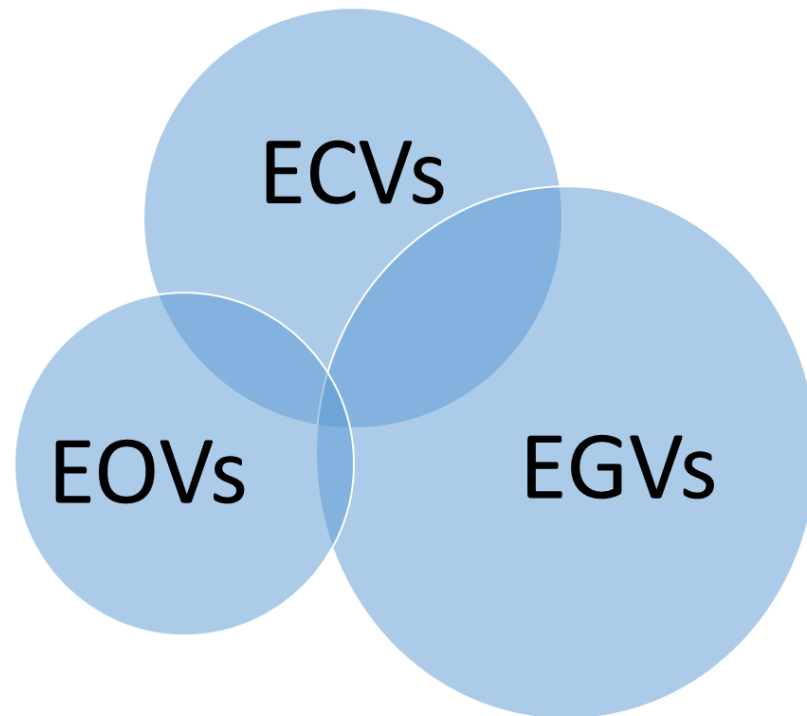
Why calling them "**Essential Geodetic Variables (EGV): Contribution of Geodesy to Earth Observation**"?

- **Geodesy observes the Earth as a whole**, from the interior to the surface including the atmosphere, with regional refinements and provides a **large number of products**.
- 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
- In order to **clearly state that such geodetic variables observe the Earth** this name is proposed.

# White Paper - Classification, Criteria and Levels of EGVs

## Classification

EGVs may overlap with ECVs or EOVs



- **ECVs:** Atmosphere, Land, Ocean
- **EOVs:** Physical, Biogeochemical, Biological/ecosystems

Options for EGVs following GGOS Products:

- **Geodetic Fields:** Geometry, Gravity, Earth Rotation, Reference Frames, Positioning & Applications
- **Earth System Components:** Solid Earth, Oceans, Cryosphere, Hydrosphere, Atmosphere

**Proposed classification for EGVs:**

**Global**, Land, Ocean

# White Paper - Classification, Criteria and Levels of EGVs

## Criteria to become an EGV

- **Relevance effectiveness (ECV, EO, EGV):** The **variable is critical** for characterizing the properties of the Earth system and its temporal changes.
- **Feasibility effectiveness (ECV, EO, EGV):** Observing or deriving the variable on a global scale is **technically feasible** using proven, scientifically understood methods.
- **Cost effectiveness (ECV, EO, 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 (EGV):** The variables shall be **consistent in terms of reference systems and standards/conventions** so that they can be easily combined or used together.

# White Paper - Classification, Criteria and Levels of EGVs

## EGVs Level Definition (as it is commonly used in EO satellite missions)

- **Level 0: Calibrated instrument data** collected by satellites, airborne or ground-based campaigns annotated with geo-location and epoch.
- **Level 1: Earth observation data sets based on agreed standards and conventions** with geophysical corrections **as geo-located time series**.
- **Level 2: Products determined from a combination of various Earth observation data sets** describing specific parameters of the Earth system in space and time domain.
- **Level 3: Accumulated products describing the geometrical and physical shape of the Earth** or its orientation in space. These variables are application-oriented.

Currently **EGVs are defined at level 3 and partially at level 2** for variables that are relevant to a large user community.



# White Paper - Proposed EGVs

| EGV                                 | Level | Domain     | Subdomain          |
|-------------------------------------|-------|------------|--------------------|
| <b>Global Reference Frames</b>      | L3    | Global     | Geometric/Physical |
| Land Geometry                       | L3    | Land       | Geometric          |
| Sea Surface                         | L3    | Ocean      | Geometric          |
| <b>Sea Level</b>                    | L3    | Ocean      | Physical           |
| Sea Ice                             | L3    | Ocean      | Geometric          |
| <b>Ice Sheets</b>                   | L3    | Land       | Geometric/Physical |
| <b>Glaciers</b>                     | L3    | Land       | Geometric/Physical |
| <b>Global Earth Gravity Field</b>   | L3    | Global     | Physical           |
| <b>Terrestrial Water Storage</b>    | L3    | Land       | Physical           |
| <b>Inland Water Level</b>           | L3    | Land       | Geometric/Physical |
| Earth Orientation Parameters        | L3    | Global     | Geometric          |
| Neutral Atmosphere and Ionosphere   | L3    | Global     | Physical           |
| Station Positions and Variations    | L2    | Land       | Geometric          |
| Tide Gauge Records                  | L2    | Ocean      | Geometric          |
| <b>Land and Marine Gravity Data</b> | L2    | Land/Ocean | Physical           |
| <b>Regional Gravity Field Model</b> | L2    | Land/Ocean | Physical           |
| <b>Regional Reference Frames</b>    | L2    | Land/Ocean | Physical           |
| Satellite Orbits                    | L2    | Global     | Geometric          |

## 18 EGVs in total

- Level 3: 12
- Level 2: 6

## Domain

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

## Subdomain

- Geometric
- Physical = Gravity Field related

53 Geodetic Products in total being part of EGVs

ECV linked to Earth Gravity Field

# White Paper - Geodetic Products for EGVs

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

- **53 Geodetic Products in total being part of EGVs.**
- **24 out of 53 Geodetic Products are linked to observations or models of the Earth gravity field.**
- **12 out of 24 gravity field related products are primary gravity field observations or models.**

Primary Gravity Field Geodetic Product

Link to Gravity Field Geodetic Product

# White Paper - Examples Primary Gravity Field EGV Description

| 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.<br><b>Physical reference frames for determining the gravity acceleration and the equipotential surface as a height reference.</b>   |
| EGV Stewards            |  |
| Products                | <ul style="list-style-type: none"> <li>▪ Celestial Reference Frame (CRF): Catalog of precise equatorial coordinates of extragalactic radio sources.</li> <li>▪ 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).</li> <li>▪ Gravity Reference Frame (GRF): Absolute gravity measurements traceable to the SI that contain conventional temporal gravity corrections.</li> <li>▪ 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.</li> </ul> |

| Global Earth Gravity Field |   |
|----------------------------|---|
| Domain                     | Global  |
| Subdomain                  | Physical  |
| Scientific Area            | <b>Global Earth gravity field in the spectral and spatial domains including derived quantities with respect to a reference (ellipsoidal) gravity field.</b>   |
| EGV Stewards               |   |
| Products                   | <ul style="list-style-type: none"> <li>▪ <b>Global Gravity Field Models and its variation (GGM): Spherical or ellipsoidal harmonic series of gravity potential either as mean or as a temporal series.</b></li> <li>▪ <b>Topographic Gravity Field Models (TGFM): Spherical or ellipsoidal harmonic series of gravity potential originated by the attraction of the Earth's topographic masses.</b></li> <li>▪ <b>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).</b></li> </ul> |

# White Paper - Examples Linked Gravity Field EGV Description

## Sea Level

|                 |  |
|-----------------|--|
| Domain          | Ocean  |
| Subdomain       | Physical   |
| Scientific Area | <b>Height of ocean surface with respect to the geoid</b> , which is defined as the global equipotential surface of the Earth's gravity field that is most closely approximated by the global MSS, or with respect to the local equipotential surface at the height reference station of a regional height reference system.  |
| EGV Stewards    |  |
| Products        | <ul style="list-style-type: none"> <li>▪ <b>Mean Sea Level / Mean Dynamic Topography (MSL/MDT):</b> <i>Geo-located deviation of MSS with respect to the geoid.</i></li> <li>▪ <b>Mean Geostrophic Currents (MGC):</b> <i>Geostrophic currents derived from MSL/MDT.</i></li> <li>▪ <b>Sea Level Change / Dynamic Ocean Topography (SLC/DOT):</b> <i>Time series of geo-located deviations of the instantaneous sea surface height from the geoid.</i></li> <li>▪ <b>Regional Mean Sea Level (RMSL):</b> <i>Geo-located deviation of MSS with respect to local equipotential surface defined by a regional height reference system.</i></li> <li>▪ <b>Regional Sea Level Change (RSLC):</b> <i>Time series of geo-located deviations of the instantaneous sea surface height from the local equipotential surface defined by a regional height reference system.</i></li> </ul> |

## Glaciers

|                 |  |
|-----------------|--|
| Domain          | Land   |
| Subdomain       | Geometric/Physical   |
| Scientific Area | <b>Temporal changes of the volume and mass of glaciers.</b>  |
| EGV Stewards    |  |
| Products        | <ul style="list-style-type: none"> <li>▪ <b>Glacier Mass Change (GMC):</b> <i>Temporal gravity changes from satellite gravimetry missions caused by ice mass change and transport for glaciers (physical method).</i></li> <li>▪ <b>Glacier Ice Thickness (GIT):</b> <i>Temporal changes of the thickness of glaciers from radar and laser altimeters (geometric method).</i></li> <li>▪ <b>Glacier Flow Velocities (GFV):</b> <i>Ice volume changes by glacier flow velocities from interferometric SAR and net snow accumulation from atmospheric models.</i></li> </ul> |

# White Paper - Selected Geodetic Products Contributing to an EGV

| Products | Global Reference Frames | Land Geometry | Sea Surface | Sea Level | Sea Ice | Ice Sheets | Glaciers | Global Earth Gravity Field | Terrestrial Water Storage | Inland Water Level | Earth Orient. Param. | Neutral Atmosph. and Ionosph. | Station Positions and Variations | Tide Gauge Records | Land and Marine Gravity Data | Regional Gravity Field Model | Regional Reference Frames | Satellite Orbits |
|----------|-------------------------|---------------|-------------|-----------|---------|------------|----------|----------------------------|---------------------------|--------------------|----------------------|-------------------------------|----------------------------------|--------------------|------------------------------|------------------------------|---------------------------|------------------|
| EGV      | L3                      | L3            | L3          | L3        | L3      | L3         | L3       | L3                         | L3                        | L3                 | L3                   | L3                            | L2                               | L2                 | L2                           | L2                           | L2                        | L2               |
| ECV      |                         |               | X           | X         | X       | X          | X        |                            | X                         | X                  |                      | X                             |                                  |                    |                              |                              |                           |                  |
| EOV      |                         |               | X           | X         | X       |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| Domain   | Global                  | Land          | Ocean       | Ocean     | Ocean   | Land       | Land     | Global                     | Land                      | Land               | Global               | Global                        | Land                             | Ocean              | Land/Ocean                   | Land/Ocean                   | Land/Ocean                | Global           |
| GRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| HRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TGFM     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GFQ      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MSL      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MDT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MGC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SLC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| DOT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RMSL     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RSLC     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GMC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |

## EGV Global Reference Frames

- Gravity Reference Frame (GRF)
- Height Reference Frame (HRF)

## EGV Glaciers

- Glacier Mass Change (GMC)

## EGV Global Earth Gravity Field

- Global Gravity Field Models and its variation (GGM)
- Topographic Gravity Field Models (TGFM)
- Gravity Field Quantities (GFQ)

## EGV Sea Level

- Mean Sea Level / Mean Dynamic Topography (MSL/MDT)
- Mean Geostrophic Currents (MGC)
- Sea Level Change / Dynamic Ocean Topography (SLC/DOT)
- Regional Mean Sea Level (RMSL):
- Regional Sea Level Change (RSLC)

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| Products | Global Reference Frames | Land Geometry | Sea Surface | Sea Level | Sea Ice | Ice Sheets | Glaciers | Global Earth Gravity Field | Terrestrial Water Storage | Inland Water Level | Earth Orient. Param. | Neutral Atmosph. and Ionosph. | Station Positions and Variations | Tide Gauge Records | Land and Marine Gravity Data | Regional Gravity Field Model | Regional Reference Frames | Satellite Orbits |
|----------|-------------------------|---------------|-------------|-----------|---------|------------|----------|----------------------------|---------------------------|--------------------|----------------------|-------------------------------|----------------------------------|--------------------|------------------------------|------------------------------|---------------------------|------------------|
| EGV      | L3                      | L3            | L3          | L3        | L3      | L3         | L3       | L3                         | L3                        | L3                 | L3                   | L3                            | L2                               | L2                 | L2                           | L2                           | L2                        | L2               |
| ECV      |                         |               | X           | X         | X       | X          | X        |                            | X                         | X                  |                      | X                             |                                  |                    |                              |                              |                           |                  |
| EOV      |                         |               | X           | X         | X       |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| Domain   | Global                  | Land          | Ocean       | Ocean     | Ocean   | Land       | Land     | Global                     | Land                      | Land               | Global               | Global                        | Land                             | Ocean              | Land/Ocean                   | Land/Ocean                   | Land/Ocean                | Global           |
| GRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| HRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TGFM     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GFQ      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MSL      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MDT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MGC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SLC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| DOT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RMSL     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RSLC     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GMC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |

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Primary Geodetic Product directly related to EGV

Geodetic Products providing important information to EGV

Geodetic Products indirectly linked to EGV



# White Paper - Selected Geodetic Products Contributing to an EGV

| Products | Global Reference Frames | Land Geometry | Sea Surface | Sea Level | Sea Ice | Ice Sheets | Glaciers | Global Earth Gravity Field | Terrestrial Water Storage | Inland Water Level | Earth Orient. Param. | Neutral Atmosph. and Ionosph. | Station Positions and Variations | Tide Gauge Records | Land and Marine Gravity Data | Regional Gravity Field Model | Regional Reference Frames | Satellite Orbits |
|----------|-------------------------|---------------|-------------|-----------|---------|------------|----------|----------------------------|---------------------------|--------------------|----------------------|-------------------------------|----------------------------------|--------------------|------------------------------|------------------------------|---------------------------|------------------|
| EGV      | L3                      | L3            | L3          | L3        | L3      | L3         | L3       | L3                         | L3                        | L3                 | L3                   | L3                            | L2                               | L2                 | L2                           | L2                           | L2                        | L2               |
| ECV      |                         |               | X           | X         | X       | X          | X        |                            | X                         | X                  |                      | X                             |                                  |                    |                              |                              |                           |                  |
| EOV      |                         |               | X           | X         | X       |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| Domain   | Global                  | Land          | Ocean       | Ocean     | Ocean   | Land       | Land     | Global                     | Land                      | Land               | Global               | Global                        | Land                             | Ocean              | Land/Ocean                   | Land/Ocean                   | Land/Ocean                | Global           |
| GRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| HRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TGFM     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GFQ      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MSL      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MDT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MGC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SLC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| DOT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RMSL     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RSLC     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GMC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |

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- Regional Sea Level Change (RSLC)

# White Paper - Selected Geodetic Products Contributing to an EGV

| Products | Global Reference Frames | Land Geometry | Sea Surface | Sea Level | Sea Ice | Ice Sheets | Glaciers | Global Earth Gravity Field | Terrestrial Water Storage | Inland Water Level | Earth Orient. Param. | Neutral Atmosph. and Ionosph. | Station Positions and Variations | Tide Gauge Records | Land and Marine Gravity Data | Regional Gravity Field Model | Regional Reference Frames | Satellite Orbits |
|----------|-------------------------|---------------|-------------|-----------|---------|------------|----------|----------------------------|---------------------------|--------------------|----------------------|-------------------------------|----------------------------------|--------------------|------------------------------|------------------------------|---------------------------|------------------|
| EGV      | L3                      | L3            | L3          | L3        | L3      | L3         | L3       | L3                         | L3                        | L3                 | L3                   | L3                            | L2                               | L2                 | L2                           | L2                           | L2                        | L2               |
| ECV      |                         |               | X           | X         | X       | X          | X        |                            | X                         | X                  |                      | X                             |                                  |                    |                              |                              |                           |                  |
| EOV      |                         |               | X           | X         | X       |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| Domain   | Global                  | Land          | Ocean       | Ocean     | Ocean   | Land       | Land     | Global                     | Land                      | Land               | Global               | Global                        | Land                             | Ocean              | Land/Ocean                   | Land/Ocean                   | Land/Ocean                | Global           |
| GRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| HRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TGFM     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GFQ      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MSL      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MDT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MGC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SLC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| DOT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RMSL     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RSLC     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GMC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |

## EGV Global Reference Frames

- Gravity Reference Frame (GRF)
- Height Reference Frame (HRF)

## EGV Glaciers

- Glacier Mass Change (GMC)

## EGV Global Earth Gravity Field

- Global Gravity Field Models and its variation (GGM)
- Topographic Gravity Field Models (TGFM)
- Gravity Field Quantities (GFQ)

## EGV Sea Level

- Mean Sea Level / Mean Dynamic Topography (MSL/MDT)
- Mean Geostrophic Currents (MGC)
- Sea Level Change / Dynamic Ocean Topography (SLC/DOT)
- Regional Mean Sea Level (RMSL):
- Regional Sea Level Change (RSLC)



Primary Geodetic Product directly related to EGV

Geodetic Products providing important information to EGV

Geodetic Products indirectly linked to EGV





# White Paper - Overview Geodetic Products Contributing to an EGV

Primary Geodetic Product directly related to EGV

Geodetic Products providing important information to EGV

Geodetic Products indirectly linked to EGV

| Products | Global Reference Frames | Land Geometry | Sea Surface | Sea Level | Sea Ice | Ice Sheets | Glaciers | Global Earth Gravity Field | Terrestrial Water Storage | Inland Water Level | Earth Orient. Param. | Neutral Atmosph. and Ionosph. | Station Positions and Variations | Tide Gauge Records | Land and Marine Gravity Data | Regional Gravity Field Model | Regional Reference Frames | Satellite Orbits |
|----------|-------------------------|---------------|-------------|-----------|---------|------------|----------|----------------------------|---------------------------|--------------------|----------------------|-------------------------------|----------------------------------|--------------------|------------------------------|------------------------------|---------------------------|------------------|
| EGV      | L3                      | L3            | L3          | L3        | L3      | L3         | L3       | L3                         | L3                        | L3                 | L3                   | L3                            | L2                               | L2                 | L2                           | L2                           | L2                        | L2               |
| ECV      |                         |               | X           | X         | X       | X          | X        |                            | X                         | X                  |                      | X                             |                                  |                    |                              |                              |                           |                  |
| EOV      |                         |               | X           | X         | X       |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| Domain   | Global                  | Land          | Ocean       | Ocean     | Ocean   | Land       | Land     | Global                     | Land                      | Land               | Global               | Global                        | Land                             | Ocean              | Land/Ocean                   | Land/Ocean                   | Land/Ocean                | Global           |
| AGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| CPO      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| CRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| DEM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| DOT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| DTM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| EOT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| ESD      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| ESO      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GFO      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GFV      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GIM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GIT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GMC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GSC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| GSO      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| HRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| IMC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| IST      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| LGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| LOD      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MDT      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MGC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MRLW     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MSL      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| MSS      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| PKM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| PM       |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RGRF     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RHRF     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RMSL     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RSLC     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RTRF     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| RWLC     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SES      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SIE      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SIV      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SLA      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SLC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| SPTS     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TDM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TGFM     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TGM      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TGR      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TRF      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| TWSA     |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| UT1      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| VDP      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |
| WVC      |                         |               |             |           |         |            |          |                            |                           |                    |                      |                               |                                  |                    |                              |                              |                           |                  |

# White Paper - Requirements for EGVs

- After fixing the list of EGVs requirements for the Geodetic Products need to be specified.
- Requirements shall be specified such that the Geodetic Product will contribute to the EGV. This includes accuracy, temporal and spatial resolution, latency, needed observation systems, product provider, etc. (see example below)

| EGV                                 | Product | Accuracy   | Temporal resolution                             | Spatial Resolution | Observations              | Service/ Provider                                  |
|-------------------------------------|---------|--|---|--------------------|---------------------------|--|
| <b>Global or Land/Ocean</b>         |         |  |   |                    |                           |  |
| <b>Global Reference Frames</b>      | CRF     | 25 $\mu$ s, stability<br>3 $\mu$ s/yr  | Decades long-term?                              | Not specified      | VLBI                      | IERS /<br>ICRS Centre                              |
|                                     | GRF     |  |   |                    |                           |  |
|                                     | HRF     |  |   |                    |                           |  |
|                                     | TRF     | Origin: 1 mm,<br>stability 0.1 mm/yr<br>Scale: 0.1 ppb,<br>stability 0.01 ppb/yr | Decades long-term?                              | Not specified      | VLBI, SLR, GNSS,<br>DORIS | IERS /<br>ITRS Centre                              |
| <b>Earth Orientation Parameters</b> | CPO     |  | 1 hour, latency<br>weekly to near real-<br>time | Not specified      | VLBI                      | IERS EOP Centre /<br>Rapid Service<br>Pred. Centre |
|                                     | LOD     |  |   |                    | VLBI, SLR, GNSS,<br>DORIS |  |
|                                     | PM      | 30 $\mu$ s   |   |                    | VLBI, SLR, GNSS,<br>DORIS |  |
|                                     | UT1     | 2 $\mu$ s  |   |                    | VLBI                      |  |

# Summary and Conclusions

- Proposed name: "Essential Geodetic Variables (EGV): Contribution of Geodesy to Earth Observation". Improve visibility to non-geodetic communities.
- A set of 18 EGVs has been defined partially overlapping with ECVs and EOVs.
- Currently only Level 3 and some Level 2 EGVs are considered as these have major impact for interdisciplinary users.
- So far 53 Geodetic Products have been identified contributing to an EGV.
- EGV Descriptions have been prepared and links between EGVs and Geodetic Products were identified.
- Requirements for Geodetic Products need to be defined after general concept has been reviewed and confirmed by GGOS and IAG bodies (GGOS Days 2024 as next milestone).

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