Federal Office of Metrology and Surveying

Landesamt für Digitalisierung, Breitband und Vermessung

GGOS/IERS Unified Analysis Workshop 2026
Munich, Germany, 5 – 6 March 2026

https://geodesy.science/events/munich2026/

Program

February 2026

Venue

The Unified Analysis Workshop 2026 (UAW2026) will be hosted at the *Landesamt für Digitalisierung, Breitband und Vermessung* (LDBV) (www.ldbv.bayern.de/) located at

Alexandrastraße 4, 80538 Munich.

Open hours: 08:00 – 18:00

The conference venue is in a very central location, about a 10-minute walk from Munich's central square (Marienplatz). It is also possible to reach it by metro (U-Bahn, U4 and U5 to Lehel station) or tram (Line 16 to Lehel station). It is best to reach the venue by public transport because traffic is usually very heavy, and parking fees can be expensive. See the latest ticket fare information at https://www.mvv-muenchen.de/en/tickets-and-fares/tickets-daytickets/index.html.

Format

In general, each session will be open with an (or some) introductory presentation(s). The discussions will be conducted in a panel format. Solicited colleagues will act as panellists, developing the discussion with the session conveners. Other audience members are also invited to participate in the discussion. To support preparation for the discussions, the following sections of this document include pre-meeting reading material for each session. It is expected that the discussions will result in some recommendations or agreements. These will be presented at the UAW2026 closing session by the conveners of each session and their implementation will be monitored in future.

Schedule Overview

Time slots	Thursday, 5th March 2026	Friday, 6th March 2026
08:30 – 09:00	Registration	Challenges and opportunities in analysing Genesis data, **page 15**
09:00 – 09:30	Opening	
09:30 – 10:00	Open session (1), **page 4**	
10:00 – 10:30	Coffee break	Coffee break [group photo]
10:30 – 12:00	IERS Conventions update, **page 6**	Resilience of IAG Scientific Services, **page 18**
12:00 – 13:00	Lunch	Lunch
13:00 – 14:30	What do we need from the next generation of geophysical models, and their future use in geodetic data analysis and reference frame?, **page 11**	Availability of geodetic products for the Essential Geodetic Variables, **page 20**
14:30 – 15:00	Coffee break	Coffee break
15:00 – 16:00	Challenges in the new ITRF operational updates, **page 14**	Open session (2), **page 37**
16:00 – 16:30		Wrap up, Closing

Science team

Laura Sánchez | *Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), TUM School of Engineering and Design, Technische Universität München*, Germany

Robert Heinkelmann | *GFZ Helmholtz Centre for Geosciences*, Germany

Zuheir Altamimi | *IGN-IPGP*, France

Hanane Ait-Lakbir | *CNRS - Geosciences Environnement Toulouse*, France

Detlef Angermann | *Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), TUM School of Engineering and Design, Technische Universität München*, Germany

Christian Bizouard | *LTE, Observatoire de Paris, Sorbonne Université, Université PSL, Université de Lille, LNE,CNRS*, France

Johannes Böhm | *TU Wien, Vienna University of Technology*, Austria

Jean-Paul Boy | *EOST/ITES*, France

Sharyl Byram | *United States Naval Observatory*, United States

Cornelia Eschelbach | *Frankfurt University of Applied Sciences* , Germany

Jeff Freymueller | *Michigan State University*, United States

Susanne Glaser | *University of Bonn*, Germany

Richard Gross | *International Association of Geodesy*, United States

Thomas Gruber | *Institute of Astronomical and Physical Geodesy (IAPG), Technische Universität München*, Germany

Thomas Herring | *Massachusetts Institute of Technology*, United States

Urs Hugentobler | *Satellite Geodesy, TUM School of Engineering and Design, Technische Universität München*, Germany

Hansjörg Kutterer | *Karlsruhe Institute of Technology (KIT)*, Germany

Torsten Mayer-Guerr | TU Graz, Austria

Benedikt Soja | ETH Zürich , Switzerland

Nick Stamatakos | *United States Naval Observatory*, United States

Local Organizing Committee

Mathis Bloßfeld | *Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), TUM School of Engineering and Design, Technische Universität München*, Germany

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Participants

See page 40.

Open Session | Topic A: Resolution on Modelling Gravity-Induced Deformations of the Radio Telescope Receiving Unit

Convener Cornelia Eschelbach (Chair of the Working Group Metrology of Space Geodetic Infrastructure)

Program Thursday 5th March 2026 | 09:30 – 10:00
09:30 – 09:40 Introductory presentation by Cornelia Eschelbach
09:40 – 10:00 Discussion

Concept Note

High-quality geodetic products obtained from Very Long Baseline Interferometry (VLBI) depend on virtually unbiased observations. Since the late 1980s it has been known that the receiving unit of VLBI radio telescopes is deformed by gravity, and numerous studies confirm this behaviour. As gravity-induced deformations constitute systematic errors, these errors must be corrected to ensure almost unbiased results. The key question at hand is not whether the receiving unit deforms, but how large the deformations are.

The commonly used correction model derived by Clark & Thomsen (1988) assumes a holistic deformation of the receiving unit and considers only main deformation patterns. However, recent studies show that these assumptions are unfounded, and the model proposed by Clark & Thomsen (1988) is only a first-order model. Thus, an adapted and more suitable modelling strategy is required, which considers all deformations caused by gravity.

Based on recent investigations, the joint working group: Metrology of Space Geodetic Infrastructure recommends:

1) Modelling the main-reflector deformations not only via focal-length changes but also by more comprehensive approaches such as Zernike polynomials.
2) Including displacements and tilts of the sub-reflector or prime focus feed horn, instead of modelling solely an axial shift along the principal axis.
3) Using a pointing-direction dependent delay model, which considers both the primary and the secondary axis angle, rather than relying exclusively on elevation-dependent expression.

Objective

Representatives of the IVS (International VLBI Service for Geodesy and Astrometry) and members of the Working Group Metrology of Space Geodetic Infrastructure are invited to discuss the feasibility and challenges of implementing the recommendations in the near future.

Further reading

Presentation at REFAG 2026: Eschelbach, C., Lösler, M., McCallum, L., Zhou, A., Greiwe, A.: *Deformation Modelling of the receiving unit of a VLBI radio telescope. In Session: Development and prospects for optimal geodetic ground-based infrastructure*.

Lösler, M., Eschelbach, C., Greiwe, A., Zhou, B., McCallum, L.: *Innovative approach for modelling gravity-induced signal path variations of VLBI radio telescopes*. Earth, Planets and Space, 77(1), 9, 2025. https://doi.org/10.1186/s40623-024-02110-8

Wang, J, Lou, Z.,· Jiang, Y., Sun, Z., Yu, L., Zhong, W., Jiang, Y., Zhao, R. Fu, L., Ye, Q. Shi, S., Liu, Q., Zuo, Y.: *The measurement and modeling of gravitational deformation for large radio telescope based on wavefront perturbation method*. Experimental Astronomy, 56:779–792, 2023. https://doi.org/10.1007/s10686-023-09917-5

Lösler, M., Eschelbach, C., Greiwe, A., Brechtken, R., Plötz, C., Kronschnabl, G., Neidhardt, A.: *Ray Tracing-Based Delay Model for Compensating Gravitational Deformations of VLBI Radio Telescopes*. Journal of Geodetic Science, 12(1), S. 165-184, 2022. https://doi.org/10.1515/jogs-2022-0141

Salas, P., Marganian, P., Brandt, J., Shelton, J., Sharp, N., Jensen, L., et al.: *Evaluating a strategy for measuring deformations of the primary reflector of the Green Bank telescope using a terrestrial laser scanner*. Advanced Control for Applications, 4(1), 1–16, 2022. https://doi.org/10.1002/adc2.99

Session: IERS Conventions update

Conveners

Sharyl Byram (Chair IERS Conventions)
Nick Stamatakos (Chair IERS Rapid Service/Prediction Centre)
Christian Bizouard (Chair IERS Earth Orientation Product Centre)

Program

Thursday, 5th March 2026, 10:30 – 12:00

10:30 – 10:45	Introductory presentation: Status of the IERS Convention update by Sharyl Byram
10:45 – 12:00	Discussion

Panellists

Nick Stamatakos (editor for chapters 1&5)
Detlef Angermann (expert for chapter 1)
Robert Heinkelmann (expert for chapter 2)
Jean Souchay (editor for chapter 3)
Patrick Charlot (editor for chapter 3)
Frank Lemoine (editor for chapter 4)
Zuheir Altimimi (expert for chapter 4)
Jose Ferrandiz (editor for chapter 5)
John Ries (editor for chapter 6)
Srinivas Bettadpur (editor for chapter 6)
Jean-Paul Boy (expert for chapter 7)
Sigrid Böhm (editor for chapter 8)
Johannes Böhm (editor for chapter 9)
Maria Davis (software editor for all chapters)
Maria Karbon (expert for Earth Rotation)
Alberto Escapa (expert for Earth Rotation)
Mathis Blossfled (expert for SLR)
Rudiger Haas (expert for VLBI)
Rolf Dach (expert for GNSS)
Guilhem Moreaux (expert for DORIS)
Xavier Collilieux (expert for ITRF)
Kyriakos Balidakis (expert for Atmosphere)

Objective

Panellists are invited to participate in the discussion and provide advice, primarily on their corresponding chapters/topics and, if desired, on the other chapters/topics. The main objectives are to review for consistency and impact, and to finalise the content in v2.0.0 through general discussion.

Further reading

Current and archived versions can be found at: https://iers-conventions.obspm.fr/.

Conventions Format Changes

The intent is for the chapters to follow a “handbook” or “cookbook” style, which will contain the basic information about the chapter models and implementation as well as recommendations by technique, so the IERS Conventions are accessible to all levels of users—especially beginners. For anyone who would like to dive deeper into the chapter topics, additional information such as detailed theory, equation derivations, associated data, or in-depth explanations can be provided in the supplementary material or cited as references within the chapters.

The guidelines for this style, including an example chapter, were sent to the contributors in 2019 when the rewrite effort started. For reference, the IERS Conventions document has grown in length over the editions from an average of 6 pages/chapter for the 1989 Conventions to an average of 15 pages/chapter for the 2010 Conventions (normalized to number of chapters in 2010 Conventions). Significant increases or decreases in the proposed number of pages for a chapter will be noted in the following sections discussing each chapter's content updates.

Chapter Content Changes from 2010 IERS Conventions

The following chapter content changes are current as of December 2025. The IERS Conventions Centre and the conventions contributors are actively working on updating the chapters' format and content; as a result, please recognize that by March 2026 at the UAW, some of the following information may have changed and additional chapter updates will have been made which are not included in the below sections. The most current updates will be presented at this UAW session.

As a reminder, the following content changes have not been published by IERS and are what has been proposed by the convention contributors. This session at the UAW will be our opportunity to finalize the content.

Chapter 1: General definitions and numerical standards

(*Updates in progress. Conventions Centre awaiting draft*)

Changes to some numerical values in the following tables are being proposed but have not been submitted:

1) IERS numerical standards table.
2) Parameters of the Geodetic Reference System GRS80.

Several updates to the values in the Chapter 1 tables have been proposed and are being reviewed by the chapter contributors. See REFAG2026/UAW2026 poster: *Review of IERS Conventions Chapter 1 for Numerical Standards and IERS Conventional Values*. Authors: Dr. Dennis McCarthy, Dr. Detlef Angermann, Nick Stamatakos.

The strongest criteria for adoption are IAU, IAG, or IUGG resolutions; however, there are other lesser criteria, such as working groups sanctioned by IUGG, which are also considered. Some of the proposed updates impact various IERS components and other organizations (such as the IAU); chapter contributors are gathering more information regarding potential impacts.

Final decisions on many updates will be made by the end of the UAW. Some components or other organizations that may still use older values will be noted in Appendices or via Table identifiers (captions in tables) but specifics of how to note differences are TBD.

Chapter 2: General relativistic models for space-time coordinates and equations of motion (*previously Chapter 10*)

The proposed length has increased from 8 pages in 2010 Conventions to 40 pages and includes additional topics. Figure 1 shows the timescales and transformations between timescales submitted for Chapter 2, while Figure 2 shows what is included in the 2010 Conventions. These figures illustrate the additional timescales and transformations proposed.

Submitted updates not covered in the 2010 Conventions include:

1) Terrestrial timescales and transformations including TAI, UTC, and UT1.

2) GNSS timescales and transformations.
3) Lunar timescales and transformations (*should these be included? There are no other chapters with specific lunar information*).
4) Equations of motion for solar system bodies including Newtonian force component, Post-Newtonian force component, Einstien-Infled-Hoffman (EIH) component, and Lense-Thirring (LT) component (*should these be included?*).

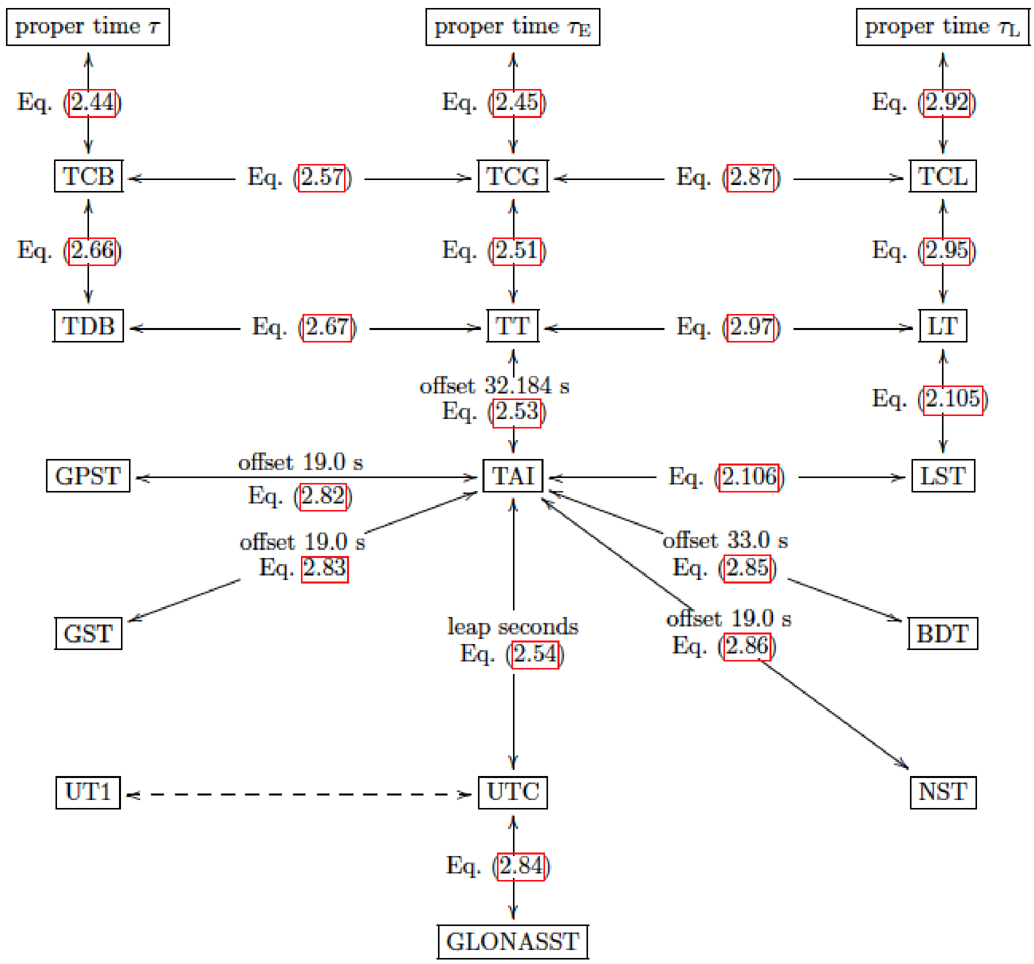

Figure 1: The proposed Chapter 2 included timescales and transformations (links to equations not in this document)

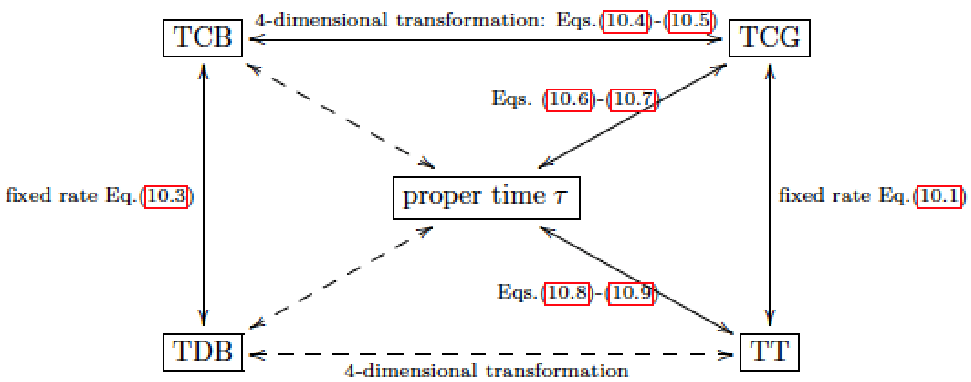

Figure 2: The 2010 IERS Conventions Chapter 10 included timescales and transformations (links to equations not in this document)

Chapter 3: Celestial reference system and frame (*previously Chapters 2&3*)

(*Updates in progress. Conventions Centre awaiting draft but believe major update will be usage of ICRF3 and adding a radio realization section*).

Chapter 4: Terrestrial reference systems and frames

Note that the last complete chapter update was in April 2019 but is still referred to as the 2010 Conventions in this document.

Submitted chapter updates include:

1) ITRF2020 usage and corresponding transformation parameters to the previously used ITRF2014 in the 2010 Conventions.
2) Rank deficiency in space geodesy TRF solutions moved to Appendix.
3) History of the ITRF products moved to Appendix.
4) Other ITRS realizations included in Appendix.
5) IERS network included in Appendix.

Chapter 5: Transformation between the International Terrestrial Reference System and the Geocentric Celestial Reference System

Note that the last chapter update was in August 2012 but is still referred to as the 2010 Conventions in this document. The proposed length of Chapter 5 has decreased from 33 pages in 2010 to 16 pages.

Free Core Nutation (FCN) models are being evaluated by chapter contributors. A FCN model was included in the 2010 Conventions, but not 1996 conventions. *Is a FCN model needed in IERS Conventions document? Or should the model(s) be provided in the supplementary material/appendix?*

The FCN models that are being evaluated will be discussed at the UAW.

Chapter 6: Geopotential

Proposed updates to Tables 6.3, 6.5c 6.6, 6.7 provided by John Ries; these updates were submitted as proposed changes to the IERS Conventions Centre and are under evaluation.

(*Further updates in progress. Conventions Centre awaiting draft*).

Chapter 7: Displacement of reference points

(**Conventions Centre actively seeking an editor**).

Chapter 8: Tidal variations in the Earth's rotation

(*Updates in progress. Conventions Centre awaiting draft*)

Note that the last chapter update was in February 2018 but is still referred to as the 2010 Conventions in this document.

Updates to values, including new values in the following tables:

1) Coefficients of sin(argument) and cos(argument) of diurnal variations in pole coordinates xp and yp caused by ocean tide.
2) Coefficients of sin(argument) and cos(argument) of diurnal and semidiurnal variations in UT1 and LOD caused by ocean tides.

Chapter 9: Models for atmospheric propagation delays

Updates that have been submitted are:

1) Discussion of alternate laser ranging mapping functions.
2) Section on the asymmetry of the troposphere.
3) Addition of appendix with deduction of the relative contribution of second, third and fourth order ionospheric terms.

Chapter 10: General relativistic models for propagation (*previously Chapter 11*)

The proposed length of Chapter 10 has increased from 7 pages in 2010 Conventions to 23 pages.

Submitted updates not covered in the 2010 Conventions include:

1) General form of geometric delay.
2) Atmospheric delay (*is this covered in chapter 9?*).
3) Baseline-based delay in the Geocentric Coordinates.
4) Antenna-based time delay.
5) Ranging techniques discussion expanded to include ranging to non-Earth orbiting spacecraft and solar system planets (*should these be included?*).

Session: What do we need from the next generation of geophysical models, and their future use in geodetic data analysis and reference frames?

Conveners

Jeff Freymueller (Chair Working Group "Impact of geophysical models on reference frames")
Jean-Paul Boy (Chair IERS Global Geophysical Fluids Centre)
Torsten Mayer-Guerr (Theoretical Geodesy and Satellite Geodesy, TU Graz)

Program

Thursday, 5th March 2026, 13:00 – 14:30

13:00 – 13:30 Introductory presentations

- Observed modes of variability by Jeff Freymueller
- Everything is a model that assimilates observations by Torsten Mayer-Guerr
- What is done/removed for gravity field, displacement, Earth rotation, orbit determination by Jean-Paul Boy

13:30 – 14:30 Discussion

Panellists

Henryk Dobslaw (IERS Global Geophysical Fluids Centre, Special Bureau for the Oceans)
Karen Simon (Working Group "Impact of geophysical models on reference frames")
Rebekka Steffen (President IAG Commission 3 "Earth Rotation and Geodynamics")
Anna Klos (Working Group "Hydrologic signature in geodetic observations")
Manuela Seitz (Chair ITRS Combination Centre DGFI-TUM)
Bejamin Männel (Chair IGS Analysis Centre at GFZ)

Concept note

Geophysical loading signals are a substantial source of variability in geodetic position time series. Considerable work has been done in comparing higher-frequency variations (days to seasonal) in models and observations, but hydrologic signals extend over multi-year timescales as well, including trend changes. While very long-term trends, including for example trends induced by GIA, are captured in the estimated station velocities, changes in the trends must be approximated by estimating multiple consecutive velocities for a station. Because such changes, caused e.g. by today's ice melt, shifts in the hydrological regime, or groundwater extraction, often occur regionally or across wider areas, multiple stations can be affected by the segmentation of the time series. This, in turn, limits the long-term stability of the reference frame. Furthermore, given that inter-annual variations in loading deformation can be observed in many parts of the world, some of what we have thought of as "stable, long-term" velocities are likely partly due to loading deformation and thus fundamentally time-dependent. A recent study of trend changes found that uplift rates across South Africa are likely caused by hydrologic mass variation – if the hydrologic systems are perturbed in the future, then we can expect those uplift rates to change.

Seasonal hydrologic variations, which have been better studied, also must be handled with care in geodetic analyses. For example, there are significant differences at seasonal timescales between different hydrological models. In addition, if a purely linear/piecewise linear model of coordinate evolution has been adopted, real seasonal motions may be aliased into other parameters. For example, Cheng (2024) demonstrated that when a linear model of SLR station motions is assumed, seasonal loading deformation can be aliased into what appear to be time-dependent range biases. Traditional reference frame models have also used a piecewise linear model for coordinate evolution, and the ITRF, DTRF, and JTRF model approaches all handle non-secular motions in different ways.

Because hydrological mass transport in particular is subject to continual change, we need to disentangle the hydrologic signals from other signals, including their contribution to the (apparent) long-term trends. This is a great opportunity for close integration of at least two of the "three pillars of geodesy", gravity field and positioning. From the perspective of gravity field, determination of the underlying mass changes is usually viewed as an estimation problem, while from the perspective of positioning it is often viewed as a calibration problem, that is, something for which we hope to remove its effects using models. The changing mass distribution underlies both gravity and positioning investigations, and may be productively viewed as a multi-observable data assimilation problem. We can view the quantities we want to know, such as station coordinates, observed gravity changes, or the independent measures of changes of mass distribution as a function of time, as modeled quantities that depend on underlying variables (mass distribution). We learn information about the underlying variables through the assimilation of data, with changes in the underlying variables being propagated into changes in observables through appropriate physical models.

In the positioning problem, there are additional challenges for reference frame realization, because the positions we estimate (and would ingest into an assimilation framework) are directly influenced by how we define our reference frame. Any re-envisioning of the reference frame definition will require careful definitions (for example, should we define load-free vs mean load as the "zero variation"?). Empirically, seasonal and shorter-term variations can be represented by periodic models (or by time series), but accounting for interannual and longer-term mass variations is much more challenging because it can impact the datum definitions. Specifically, if a given signal causes both a long-term trend and changes in that trend, can we (and should we?) remove the changes in trend without removing the long-term trend as well? Removing the entire loading signal might change the datum definition of the frame, but removing only the variations from the trend presumes that we somehow know what the "true" long-term trend is (and over what time period do we define that?). There are comparable issues in the gravity field problem, notably in certain very low degree harmonics, and all definitions must be consistent across the disciplines.

At present, non-tidal atmospheric and ocean loading models appear to account reasonably well for some of the observed coordinate variations. However, the present generation of hydrological loading models have more limitations. Key challenges include accurately accounting for mass variations in the cryosphere and linking these with terrestrial water storage models, accurately accounting for groundwater variations, and properly fusing the information from GRACE and from land surface process models. There are missing or over-simplified components or physics in most hydrological models (ground and also surface waters). Modeling of river discharge might be significantly improved with SWOT for example.

Objective: To discuss the strengths and weaknesses of the current models and identify what we should be doing differently if we truly understood/knew the changes in mass distribution.

Points of Discussion

1) What are the limitations of the present models and what needs to be done to better quantify global mass redistribution and its impacts?
2) Can we identify inconsistencies in our present models and practices?

3) We think that it is likely that the velocities of stations that are included in the reference datum constraints include some component of hydrologic or cryospheric loading deformation, so that a complete removal of these deformation signals would likely change the datum constraints. How can we deal with this?
4) If we had sufficiently accurate (time series) models become available to describe all components of global mass redistribution, on all timescales including multi-decadal trends, how can the datum (origin and scale) of the reference frame be realized in accordance with its definition, and how would we handle ongoing (future) time series updates?
5) Are we certain that the present definition is not biased as a result of some hydrologic or cryospheric deformation?

Pre-Meeting Reading

This paper presents an updated geocenter time series, and shows how the current SLR practice causes surface loading to be aliased into the range bias parameters:

Cheng, M. (2024). *An Updated Estimate of Geocenter Variation from Analysis of SLR Data*. Remote Sens. 2024, 16(7), 1189; https://www.mdpi.com/2072-4292/16/7/1189

This paper shows how loading deformation and the reference frame alignment strategy interact:

Bogusz, J., Rebischung, P., Klos, A. (2025). *Impact of alignment strategy to the reference frame on the 3D annual station motions from different GNSS solutions*. J Geod, 99(12), 1-11. https://link.springer.com/article/10.1007/s00190-025-02009-6

A nice case study of the time-depending ice melting in Svalbard and its impacts:

Kierulf, H. P., Kohler, J., Boy, J. P., Geyman, E. C., Mémin, A., Omang, O. C., ... Steffen, R. (2022). *Time-varying uplift in Svalbard—an effect of glacial changes*. Geophys J Int, 231(3), 1518-1534. https://academic.oup.com/gji/article/231/3/1518/6634243

Kern, L., Krásná, H., Nothnagel, A., Böhm, J. (2025). *Terrestrial reference frame scale drift anomalies in VLBI and the contribution of Ny-Ålesund radio telescopes*. Earth, Planets and Space, 77(1), 40. https://link.springer.com/article/10.1186/s40623-025-02159-z

Similar, focused at least in part on Greenland issues:

Métivier, L., Altamimi, Z., Rouby, H. (2020). *Past and present ITRF solutions from geophysical perspectives*. Advances in space research, 65(12), 2711-2722. https://www.sciencedirect.com/science/article/pii/S0273117720302039?via%3Dihub

Mémin, A., Boy, J. P., Santamaria-Gomez, A. (2020). *Correcting GPS measurements for non-tidal loading*. GPS Solutions, 24(2), 45. https://link.springer.com/article/10.1007/s10291-020-0959-3

Additional useful papers

Klos, A., Dobslaw, H., Dill, R. et al., (2021). *Identifying the sensitivity of GPS to non-tidal loadings at various time resolutions: examining vertical displacements from continental Eurasia*. GPS. Solut., 25, 89. https://doi.org/10.1007/s10291-021-01135-w

Männel, B., Dobslaw, H., Dill, R. et al. (2019).*Correcting surface loading at the observation level: impact on global GNSS and VLBI station networks*. J. Geod., 93, 2003–2017. https://doi.org/10.1007/s00190-019-01298-y

Session: Challenges in the new ITRF operational updates

Conveners

Robert Heinkelmann (IERS Analysis Coordinator)
Zuheir Altamimi (ITRS Combination Centre IGN)
Christian Bizouard (Chair IERS Earth Orientation Product Centre)
Thomas Herring (IGS Analysis Coordinator)

Program

Thursday, 5th March 2026, 15:00 – 16:30

15:00 – 15:45 Introductory presentations (Moderator Robert Heinkelmann)

1a - ITRS Center (IGN)	5' Zuheir Altamimi
1b – ITRS Center (JPL)	5' Zuheir Altamimi
1c – ITRS Center (DGFI-TUM)	5' Manuela Seitz
2a - EOP Center (OPA)	5' Christian Bizouard
2b - EOP Center (USNO)	5' Sharyl Byram/Nick Stamatakos
3a - IDS Analysis Representative	5' Petr Štěpánek
3b - IGS Analysis Representative	5' Thomas Herring
3c - ILRS Analysis Representative	5' Mathis Blossfeld
3d - IVS Analysis Representative	5' Benedikt Soja/Alexander Kehm

15:45 – 16:30 Discussion

Panellists

Zuheir Altamimi (ITRS Combination Centre IGN)
Manuela Seitz (ITRS Combination Centre DGFI-TUM)
Christian Bizouard (IERS Earth Orientation Product Centre)
Sharyl Byram, Nick Stamatakos (IERS Conventions)
Petr Štěpánek, Guilhem Moreaux (IDS Representatives)
Thomas Herring, Rolf Dach (IGS Representatives)
Mathis Blossfeld, Frank Lemoine (ILRS Representatives)
Benedikt Soja, Rudiger Haas (IVS Representatives)

Topics of discussion

The objective of this session is to define an appropriate and timely practice for updating IERS products, particularly the Terrestrial Reference Frame solutions and the Earth Orientation Parameters (EOP) time series. Given the annual TRF updates, it is essential to ensure consistency between TRF-dependent products. Based on this, the following issues should be clarified/agreed:

1) How long does it take (min – max) the component (IAG Geometric Service, ITRS Combination Centre, EOP Combination Centre) to produce/adopt updates, such as ITRF2020-u2023, or the corresponding EOP series updates?
2) What are the requirements for your component to do the update, i.e. what step(s) do you need in advance? e.g. C04 series update need to get the EOP that are determined consistently together with the TRF-update. Are there other dependencies?
3) What is the current procedure when updating; for instance, waiting for all Analysis Centres in order to do the update at once or should a deadline be introduced?
4) Another aspect would be to sketch the optimal update procedure or individual important features from your point of view.
5) Furthermore, each Technique Service might have individual issues with product consistency. Please sketch your consistency concerns, if any.

Session: Challenges and opportunities in analysing Genesis data

Conveners Johannes Böhm (Chair Working Group "Genesis")
Urs Hugentobler (President IAG Commission 1 "Reference Frames")
Susanne Glaser (Working Group "Genesis")
Hanane Ait-Lakbir (Working Group "Genesis")

Program Friday, 6th March 2026, 08:30 – 10:00

09:00 – 09:10	Joint pilot projects for the analysis of Genesis observations by Johannes Böhm
09:10 – 09:20	Orbit combination at normal equation level by Urs Hugentobler
09:20 – 10:00	Discussion

Panellists: Jean-Christophe Berton (European Space Agency)
Zuheir Altamimi (ITRS Combination Centre IGN)
Florian Seitz (ITRS Combination Centre DGFT-TUM)
Arnaud Pollet (Working Group "Genesis")
Alexandre Couhert (Working Group "Genesis")

Concept Note

Genesis is a satellite mission of the European Space Agency (ESA) to be launched in 2028 to a polar orbit at an altitude of 6000 kilometres and an inclination of 95 degrees. The mission is dedicated to the improvement of the terrestrial reference frame by utilising a space tie connecting antennas of the Global Navigation Satellite Systems (GNSS) and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), a Satellite Laser Ranging (SLR) retroreflector, and a dedicated VLBI (Very Long Base Interferometry) transmitter onboard the satellite. Of utmost importance is the calibration of those instruments with respect to the centre of mass of the satellite with millimetre-accuracy.

There will be a variety of links between the space geodetic techniques and the Genesis satellite (see Table 1). Genesis will be directly connected by observations to VLBI, SLR, and DORIS stations at the Earth surface and to GNSS satellites on the other hand. Thus, all space geodetic techniques will be able to contribute to the orbit determination of Genesis, including VLBI for the first time. At the same time, VLBI is the only technique to directly access the celestial reference frame and all Earth orientation parameters. Furthermore, all techniques will be sensitive to the centre of mass of the Earth and – apart from SLR – linked to the same clock realised with an ultra-stable oscillator on the satellite. However, this aspect only holds for VLBI if Pseudo-Random Noise (PRN) signals are emitted by the VLBI transmitter. Interestingly, DORIS and VLBI to Genesis observations will be subject to the same atmospheric delays at co-located stations, which can be exploited in dedicated investigations.

It is evident that the common orbit is the centrepiece of the Genesis mission and key for the improvement of the terrestrial reference frame. Most recently in their presentation at the workshop of the IAG JWG 1.1.1 on Genesis (with GGOS and IERS) in Frankfurt/Main on November 20-21, 2025, Hugentobler and Bloßfeld presented orbit combination strategies with a focus on the combination at the normal equation level. Specifically, they are proposing a 3-step approach:

- Convert state vector parameters into tabular orbit positions by transforming the normal equation.
- Stack the normal equations, considering the orbit positions as parameters.
- Convert the normal equation back to orbit state vectors referring to a selected force model.

Table 1 (modified from Böhm et al., 2026). Links between Genesis and space geodetic techniques along with sensitivities. [a] VLBI will have direct access to the satellite clock if Pseudo-Random Noise (PRN) signals are sent by the VLBI transmitter. [b] SLR has about the same atmosphere paths between ground station and Genesis for co-located stations, however, the delays are different as SLR is using optical frequencies.

	VLBI	GNSS	SLR	DORIS
Genesis to ground	+		+	+
Genesis to satellite		+		
EOP/CRF	+			
Genesis orbit	+	+	+	+
Earth centre of mass	+	+	+	+
Same satellite clock	+[a]	+		+
Same atmosphere paths	+		+[b]	+

Orbit combination at the normal equation level has the advantage, that different software packages and analysis centres using different space geodetic techniques can contribute to the orbit determination. In any case, the Solution Independent Exchange Format (SINEX) must be extended to allow for orbit combination at the normal equation level. Of course, combination at the observation level across all techniques with one software package is a good and legitimate goal as well. However, there should still be ways to combine the results with those from other software packages.

In any case it is very important for the scientific community to be ready for Genesis in 2028. There are various activities by research groups and national co-operations (e.g., GENESIS-D, GENESIS-F) aiming at the exploitation of real data (Schreiner et. al., 2023) and the investigations with simulated observations (Pollet et al., 2023). Also, to test various scenarios and applications, JWG 1.1.1 (IAG/GGOS/IERS) on Genesis together with ESA WG1 has initiated a pilot project to investigate various strategies for the implementation. Basis are 7-day orbits of Genesis, Sentinel 6, and LAGEOS 1. For those scenarios, precise orbits will be generated together with real and simulated observations. Of course, there are still some questions and levels of uncertainty. For example, simulated observations can be as precise as possible, but they could also contain error sources, such as troposphere delays or clock errors. These uncertainties must be kept in mind when using the data.

Table 2. Overview of data sets of pilot project initiated by IAG JWG 1.1.1 on Genesis (with GGOS and IERS) and ESA WG1. While the Genesis orbit will be fully simulated, there are real observations for Sentinel 6 (GNSS, SLR, DORIS) and LAGEOS 1 (SLR).

7-day orbit	VLBI	GNSS	SLR	DORIS
Genesis	simulated	simulated	simulated	simulated
Sentinel 6	simulated	real	real	real
LAGEOS	simulated	simulated	real	simulated

The data from this pilot project can be used for various investigations:

– Test the concept of orbit combination at the normal equation level. Since the simulated observations are not “perfect”, one cannot expect that the orbit combination will be of utmost precision, but the concept can be tested and validated.

- With simulated observations generated by group A and the same observations used by group B, it will be possible to detect inconsistencies between and errors in the software packages.
- Station coordinates can be derived from the simulated observations to the satellites from the different space geodetic techniques. Are there biases in the station coordinate estimates from the different techniques?

Questions and points of discussion

- Is the orbit combination at the normal equation level the most promising approach? What else has to be considered with this approach? Are analysis centres willing to provide SINEX files for orbit combination?
- What can be done to make the best out of the pilot project? How should the observations be simulated? What can be or has been investigated with already existing real data, and what should be investigated with simulated data? How to make use of existing VLBI observations of GNSS satellites? What specific VLBI to GNSS observing campaigns would be most beneficial?
- What changes are necessary to the analysis software to enable the simultaneous estimation of orbital parameters and a common set of geodetic parameters from GNSS, VLBI, SLR and DORIS? For example, UTC versus GPS time tags. What additional tools are needed (e.g., for orbit comparisons)?
- Are the existing IERS conventions sufficient for Genesis data analysis, or are updates necessary?
- Which formats need to be adapted or newly developed (e.g. for exchange of non-gravitational accelerations)?
- How should the different technique-dependent systematic effects (e.g. antenna phase centre variations, antenna/reflector offsets, VLBI transmitter delays, SLR centre-of-mass offsets, DORIS beacon offsets and GNSS inter-frequency biases) be parametrised in the analysis of Genesis data?
- What comparison campaigns between analysis centres, software packages, techniques have to be envisaged and developed?
- What methodologies should be used or developed to allow for in-orbit calibrations?
- What coordinated multi-technique observation strategies (e.g. simultaneous VLBI and SLR observations) are feasible and beneficial for the mission?
- What is the status of the different IAG services in the preparation of the Genesis mission? What processing chains at individual analysis centres have to be modified, what information exchange is required between the Services? What are current limitations? Will there be daily or weekly sessions by the techniques?
- VLBI observations to satellite are rather new. Are we ready?

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Böhm, J., Wolf., H., Hugentobler, U., *Genesis and tasks for the scientific community*, Proceedings of the IAG Scientific Assembly, Rimini 2025, submitted (2026).

Pollet, A., Coulot, D., Biancale, R. et al, *GRGS numerical simulations for a GRASP-like mission*, Journal of Geodesy, 97, 45, 2023. https://doi.org/10.1007/s00190-023-01730-4

Schreiner, P., König, R., Neumayer, K., Reinhold, A., *On precise orbit determination based on DORIS, GPS and SLR using Sentinel-3A/B and -6A and subsequent reference frame determination based on DORIS-only*, Advances in Space Research, 72, 1, 2023. https://doi.org/10.1016/j.asr.2023.04.002

Session: Resilience of IAG Scientific Services

Conveners Richard Gross (President of the International Association of Geodesy)
Hansjörg Kutterer (Chair of GGOS D-A-CH)

Program Friday, 6th March 2026, 10:30 – 12:00

10:30 – 11:15 Panel Resilient Scientific Data Infrastructures in Geodesy – State, Constraints, and Threats
10:30 – 10:40 Introductory presentation by Hansjörg Kutterer
10:40 – 11:15 Discussion

11:15 – 12:00 Panel Improving the Resilience of IAG's Products
11:15 – 11:25 Introductory presentation by Richard Gross
11:25 – 12:00 Discussion

Panellists

Resilient Scientific Data Infrastructures in Geodesy – State, Constraints, and Threats

Allison Craddock (UN Global Geodetic Centre of Excellence, Germany)
Martin Lidberg (Chair of EUREF, GGOS-BNO Deputy Director)
Daniela Thaller (Director of the IERS Central Bureau)
Kirsten Elger (Chair of the GGOS Committee on DOIs)
Taylor A. Yates (IGS ACC Representative)
Martin Sehnal (Director of the GGOS Coordinating Office)

Improving the Resilience of IAG's Products

Robert Heinkelmann (IERS Analysis Coordinator)
Tom Herring (IGS Analysis Coordinator)
Frank Lemoine (ILRS Science Coordinator)
Benedikt Soja (IVS Analysis Coordinator)
Petr Štěpánek (IDS Analysis Coordinator)
Riccardo Barzaghi (IGFS Chair)

Concept Note

The International Association of Geodesy (IAG) is a scientific organization that has been serving scientists since 1862. The data and products provided by the IAG Scientific Services have been used to gain greater understanding of the geodetic properties of the Earth including its shape, gravity, and rotation and how they change in space and time. The IAG's data and products have also been widely used by other geoscientific disciplines such as seismology, vulcanology, and tectonophysics to further our understanding of the earthquake cycle, volcanic eruptions, and plate tectonic motions. Besides the scientific applications of the IAG's data and products, they are also being increasingly used by society for positioning and navigation services.

GNSS (Global Navigation Satellite Systems) receivers can be incorporated into cell phones, vehicles, drones, airplanes, and satellites to aid in positioning and navigating those platforms. Commercial companies are operating private networks of GNSS stations to serve the needs of their customers in areas such as farming, mining, and forestry. And surveying techniques are increasingly relying on GNSS for land administration, construction, and monitoring the deformation of structures such as dams. Underlying many of these societal applications of GNSS is a reference frame within which the position of the platform, GNSS station, or survey marker is given. Oftentimes, the reference frame used for this is based on the International Terrestrial

Reference Frame (ITRF) that is determined and maintained by the International Earth Rotation and Reference Systems Service (IERS).

The growth of the reliance of society on the IAG's data and products means that the IAG is no longer serving just scientists but is now also serving society in its needs for geodetic information. This places additional requirements on the IAG's data and products. While scientists are largely concerned with the accuracy and timeliness of the IAG's data and products, many societal applications are more concerned with their continuous and unrestricted availability and their proven reliability. Meeting the needs of society for geodetic information therefore means making the data and products provided by the IAG's Scientific Services as well as the underlying, fundamental observation and data infrastructures more resilient. In addition to the robustness of the established workflows, this also refers to reliable authoritative and institutional commitment in terms of human and material resources.

The geometric Services of the IAG, namely the International GNSS Service (IGS), International VLBI Service (IVS), International Laser Ranging Service (ILRS), and International Doris Service (IDS), already have a number of individual Analysis Centres that provide data and products determined by that individual Analysis Centre. These Services are therefore reasonably resilient in that regard. However, most of these Services, including the IERS, have only one Combination Centre or Analysis Centre Coordinator that takes the data and products from the individual Analysis Centres and combines them. This represents a single source of failure for the combined products. Making the combined products resilient to failure means having additional Combination Centres or Analysis Centre Coordinators that provide consistent combined products from redundant processing chains and IT infrastructures.

The gravity field-related Services play a central role as data repositories. For instance, BGI (Bureau Gravimétrique International) stores, curates and provides gravity values collected by various organisations; ISG (International Service for the Geoid) and ICGEM (International Centre for Global Earth Models) store, curates and provide regional or global gravity field models; IDEMS (International Digital Elevation Model Service) collects and makes available digital terrain models from various sources; and IGETS (International Geodynamics and Earth Tide Service) supports the monitoring of temporal variations in the Earth's gravity field by analysing long-term records from ground gravimeters, tiltmeters, strainmeters, and other geodynamic sensors. Despite their long history of operation and strong connections with data providers and users around the world, their repositories typically depend on a single institution. There is little redundancy or backup centres, which makes their long-term stability vulnerable.

Based on the above, this session will be a forum for exploring the ways and means within the IAG and its Services

- To identify data repositories at risk and evaluate datasets that may no longer be available, either now or in the future.
- To develop strategies to preserve geodetic observations, products, and research results, for example by encouraging the establishment of data repositories located on different continents.
- To discuss ways of improving the availability of geodetic data and products to the research community and to society in general.
- To identify the main challenges relating to storage capacity and personnel resources for the indexing, curation or disciplinary aggregation of data, as well as legal assessment processes and integrating data into cross-regional or worldwide structures.
- To evaluate the suitability of using cloud environments as geodetic data repositories.
- To discuss how the combined products from the IAG's Geometric Services, including the IERS, can be made more resilient.

Session: Availability of geodetic products for the Essential Geodetic Variables

Conveners
Laura Sánchez (President of GGOS)
Detlef Angermann (Director of the GGOS Bureau of Products and Standards)
Thomas Gruber (Chair of the GGOS Committee "Definition of Essential Geodetic Variables")

Program
Friday, 6th March 2026, 13:00 – 14:30
13:00 – 13:15 Introductory presentation by Laura Sánchez
13:15 – 14:30 Discussion

Panellists
Peter Teunissen (Vice-President of the IAG)
Adrian Jäggi (Chair of the IERS Directing Board)
Alexandre Couhert (Working Group "Genesis")
Peter Steigenberger (IGS Multi-GNSS Pilot Project)
Michael Hart-Davis (Ocean Surface Topography Science Team)
Jeff Freymueller (Working Group "Impact of geophysical models on reference frames")

Concept Note

The Global Geodetic Observing System (GGOS) is the response of the international geodetic community, organised under the International Association of Geodesy (IAG), to the need to continuously monitor the Earth system. GGOS was established with the vision of using geodetic data and products to serve science and society beyond the traditional task of measuring and mapping the Earth's surface. The basic principle is to move from the provision of usual geodetic products (station coordinates, geoid, Earth orientation parameters, satellite orbits) to a level of consistent modelling and interpretation of Earth system processes and interactions that ensure an integrated observing system rather than a collection of individual technique-specific products. A current strategic goal of GGOS is the implementation of a catalogue of Essential Geodetic Variables (EGVs) to highlight the contribution of geodesy to Earth system monitoring (Sánchez et al., 2024). Essential Variables (EVs) are specific measurements, observations or parameters that are critical for understanding, monitoring and predicting changes in complex systems such as the Earth's climate, environment or socio-economic conditions (GEO 2020). These variables are selected on the basis of their significant impact on these systems, their ability to provide actionable information, and their usefulness in supporting scientific research, decision-making and policy development.

The Global Climate Observing System (GCOS) was the first community to introduce the concept of EVs, namely the Essential Climate Variables (ECVs), which have been widely adopted in science and policy (Bojinski et al. 2014). Subsequently, the Global Ocean Observing System (GOOS) defined a set of Essential Ocean Variables (EOVs) aligned with the ECVs (Fischer and Grimes 2012). Following the same arrangement of GCOS and GOOS, which defined the ECVs and EOV, respectively, GGOS is working on the definition of the essential geodetic variables. Gruber et al. (2026) describes in detail the concept of defining and classifying EGVs. This concept has been reviewed and endorsed by the GGOS Science Panel, the GGOS Governing Board, the IAG Executive Committee and the members of the UN-GGCE (UN Global Geodetic Centre of Excellence). Indeed, the definition of EGVs is one of the main activities of the First Joint Development Plan for Global

Geodesy (UN-GGCE 2025). The EGVs are based on the following considerations (see Gruber et al. 2026 for more details):

1) In the context of EVs, “essential” means something that is absolutely necessary, indispensable, or fundamental to the core of a concept. A variable is considered essential if it significantly enhances the reliability and accuracy of desired outcomes. It may also be deemed essential if it provides critical insights relevant to a specific objective, even if it is not directly measurable or related to a physical/mathematical characteristic. Thus, the concept of “variable” does not adhere to the same definition as in physics or mathematics, but rather to the principle of being fit for purpose.

2) The “essentiality” of a variable may vary according to the needs of different communities or audiences, such as those in the scientific or policy-making communities. Any variable may be considered essential by someone or for the achievement of a particular goal, making the definition of essential variables inherently subjective.

3) An “essential geodetic variable” is an observation or parameter that critically contributes to the characterisation of the geometric and physical shape of the Earth and to its orientation in space. As changes to these characteristics are inherently related to changes occurring within and between the Earth's components (the geosphere, atmosphere, hydrosphere, cryosphere and biosphere), some essential geodetic variables are necessarily linked to understand the dynamics of the Earth system in all its components and their interplay.

4) Different levels of EGVs are defined, mainly representing the level of detail or complexity of a variable. Following the conventions usually applied to Earth observation satellite data, the lowest level represents the observed data (i.e. measurements), while the highest level is defined by combined products providing relevant geodetic and Earth system parameters. This classification is coherent with the process of modelling changes in the Earth system from geodetic measurements (Fig. 1).

5) The EGVs are characterised by geodetic products. The products represent measurable parameters, processed/value-added datasets, quantities and models as well as the infrastructure and the standards needed as foundation for the EGVs. As the observations (measurements) are the primary input for the determination of the products defining the EGVs, and as these products shall be processed based on agreed standards and conventions to ensure consistency and interoperability, the geodetic observing infrastructure as well as the geodetic standards and conventions are considered as the basis level for the EGVs (Fig. 1).

6) The EGVs are defined on the basis of
   - Relevance: It is critical for characterising the geometric and physical properties of the Earth and its temporal changes.
   - Feasibility: Observing or deriving the variable on a global scale is technically feasible using proven and scientifically understood methods.
   - Cost effectiveness: Generating and archiving data about the variable is affordable, mainly relying on coordinated observing systems using proven technology, taking advantage of historical datasets (when possible).
   - Sustainability: The variable shall be made available over decades and the tools for observing it shall be sustainable.
   - Consistency and interoperability: The variables shall be consistent in terms of reference systems and standards/conventions, so that they can be easily combined or used together and are interoperable.

7) Some EGVs are common to ECVs and EOVs. The definition of these EGVs and the associated products does not fully match with the definition of ECVs and EOVs. The reason for this is that the concept of the EGV definition focuses primarily on the available geodetic data and products. Thus, the geodetic products considered in the EGVs provide additional information for the essential variables defined by GCOS and GOOS.

8) The present concept considers 21 EGVs based on 59 geodetic products. The EGVs are classified into the domains global (for the whole Earth), land, ocean and land/ocean (i.e. coastal areas). The sub-domain indicates whether the EGV relates to the geometry or the physics (gravity field and atmosphere) of the Earth. For each EGV, a set of supporting products has been identified (see Table 1) . Current efforts concentrate on characterising the geodetic products associated with the EGVs.

9) All available geodetic products should be considered, not only those produced by the IAG Services, but also those generated by space and national agencies, research institutes, universities, etc. The inventory of products supporting the EGVs should be available on the GGOS Portal. This Portal is configured to describe geodetic data products through detailed metadata while the datasets remain physically located in their original data centres.

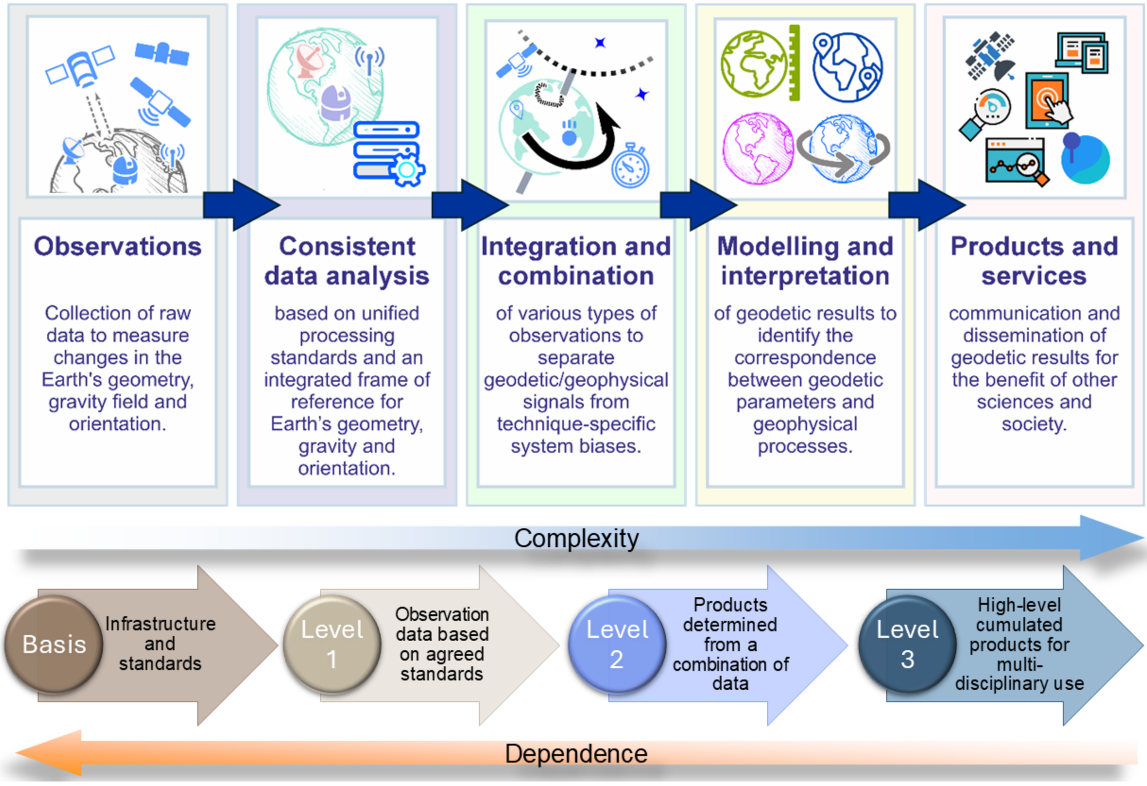

Fig. 1 From geodetic measurements to Earth system modelling: The classification of the essential geodetic variables in different levels (lower panel) is coherent with the process of modelling changes in the Earth system from geodetic measurements (upper panel). Following levers are considered: Basis: Geodetic observing infrastructure and standards/conventions required to produce higher level EGVs; Level 1: Data collected by satellites, airborne or ground-based infrastructure annotated with geo-location and epoch. They are based on agreed standards and conventions; Level 2: Products determined from a combination of various Earth observation data sets describing specific parameters of the Earth system in the space and time domains; Level 3: High-level accumulated products describing the geometric and physical shape of the Earth or its orientation in space as well as further parameters of the Earth system, after

performing a significant data processing and/or data combination. These variables are application-oriented and shall be directly applicable to multidisciplinary Earth system monitoring.

Objective

This session aims to gather recommendations on how to characterise the geodetic products required for quantifying and monitoring the EGVs. The following premises should be discussed:

1) The general characterisation of the products should be given by (see Tables 2 and 3 as examples):
   - **Uncertainty**: expressed in terms of standard deviation (unless stated otherwise).
   - **Spatial Resolution**: horizontal and vertical (if needed).
   - **Temporal resolution** (or frequency): the frequency of the product e.g. hourly, daily, annual, etc.
   - **Timeliness**: The time expectation for accessibility and availability of the product.
   - **IAG Service / Data sources**
   - Are any additional characteristics necessary?
2) The characterisation of the products should be developed in three phases:
   - **Phase 1**: Inventory of current characteristics (see previous item): Description of the present status according to available observations, analysis strategies, frequency and latency of production and current practices.
   - **Phase 2**: Possible improvements over the next 10 years: How will the characteristics change (improve) over the next 10 years according to new technologies and improved analysis methods in implementation?
   - **Phase 3**: Target requirements: The resolution, frequency and accuracy necessary to monitor specific Earth system signals that demand significant improvements of current technologies and methods. This characterisation should be linked to the update of the GGOS 2020 book (Plag and Pearlman, 2009).
3) In the characterisation of the Essential Climate Variables by GCOS (WMO 2022), following criteria are considered (see Tables 4 and 5 as examples):
   - **Goal (G)**: An ideal requirement above which further improvements are not necessary.
   - **Breakthrough (B)**: An intermediate level between threshold and goal which, if achieved, would result in a significant improvement for the targeted application. The breakthrough value may also indicate the level at which specified uses within climate monitoring become possible. It may be appropriate to have different breakthrough values for different uses.
   - **Threshold (T)**: The minimum requirement to be met to ensure that data are useful.

   These criteria are application-driven, i.e. they represent the requirements for monitoring specific Earth system signals, regardless of current limitations in the observing system. Should these criteria be also applied for the Essential Geodetic Variables?
4) The current catalogue of EGVs is primarily based on products generated by IAG Services and expanded to include products and datasets from other sources (space and national agencies, research institutes, universities, etc.). Given that Essential Variables are intended to encourage national and international organisations to support the provision of these variables, shall potential geodetic products be considered that are not available

yet? This could provide a basis for space, national and international agencies to further discuss potential new projects and activities on these topics, in a similar way to that done for the ECVs. See, for example, the ESA Climate Change Initiative (CCI) programme. (https://climate.esa.int/en/projects/).

5) A main requirement of the EGVs is that they are sustainable. They should be provided on a long-term basis, and their reliability and consistency should be ensured. In this context, stewards must be identified who will take responsibility for safeguarding the long-term integrity, functionality, and resilience of the EGVs. These stewards should act on behalf of broader stakeholders to ensure responsible management, transparency, and continuous improvement. How should the stewards for the EGVs be identified?

Further pre-meeting reading material

Gruber T., Angermann D., Sánchez L. (2026), *Definition of Essential Geodetic Variables (EGV): Contribution of Geodesy to Earth Observation, White Paper, Version 7.0*, Global Geodetic Observing System (GGOS), https://doi.org/10.5281/zenodo.18313946.

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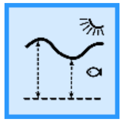
WMO (2022), *The 2022 GCOS ECVs Requirements*, World Meteorological Organization, 244 pp.

Table 1: Essential Geodetic Variables and supporting products (Gruber et al. 2026)

EGV		Level	Domain	Subdomain	Products
	Earth Orientation Parameters	L3	Global	Geometric	– Celestial Pole Offset (CPO) – Universal Time (UT1) – Length of Day (LOD) – Polar Motion (PM)
	Global Reference Frames	L3	Global	Geometric/ Physical	– Celestial Reference Frame (CRF) – Terrestrial Reference Frame (TRF) – Gravity Reference Frame (GRF) – Height Reference Frame (HRF)
	Global Earth Gravity Field	L3	Global	Physical	– Global Gravity Field Models (GGM) – Topographic Gravity Field Models (TGFM) – Gravity Field Quantities (GFQ)
	Regional Reference Frames	L3	Land/ Ocean[1]	Geometric/ Physical	– Regional Terrestrial Reference Frame (RTRF) – Regional Gravity Reference Frame (RGRF) – Regional Height Reference Frame (RHRF) – Vertical Datum Parameter (VDP)
	Regional Gravity Field Model	L3	Land/ Ocean[1]	Physical	– Regional Geoid Model (RGM) – Regional Gravity Field Quantities (RGFQ)
	Land Geometry	L3	Land	Geometric	– Digital Elevation Model (DEM) – Digital Terrain Model (DTM) – Plate Kinematic Model (PKM) – Earth Surface Deformation (ESD)
	Sea Surface	L3	Ocean	Geometric	– Mean Sea Surface (MSS) – Sea Level Anomaly (SLA) – Sea State (SES) – Empirical Ocean Tide Model (EOT)

Sea Level	L3	Ocean	Physical	– Global Mean Sea Level / Mean Dynamic Topography (MSL/MDT) – Mean Geostrophic Currents (MGC) – Global Sea Level Change / Dynamic Ocean Topography (SLC/DOT) – Relative Mean Sea Level (RMSL) – Relative Sea Level Change (RSLC)
Sea Ice	L3	Ocean	Geometric	– Sea Ice Extension (SIE) – Sea Ice Volume (SIV)
Ice Sheets	L3	Land	Geometric/ Physical	– Ice Mass Change (IMC) – Ice Sheet Thickness (IST)
Glaciers	L3	Land	Geometric/ Physical	– Glacier Mass Change (GMC) – Glacier Ice Thickness (GIT) – Glacier Flow Velocities (GFV)
Inland Water Level	L3	Land	Geometric/ Physical	– Mean Regional Water Level (MRWL) – Regional Water Level Change (RWLC)
Terrestrial Water Storage	L3	Land	Physical	– Terrestrial Water Storage Anomaly (TWSA)
Atmosphere Parameters	L3	Global	Physical	– Integrated Water Vapor (IWV) – Global Ionosphere Maps (GIM) – Thermosphere Density Model (TDM)
Satellite Orbits	L2	Global	Geometric	– GNSS Satellite Orbits, Clocks and Biases (GOCB) – Earth Observation Satellite Orbits (ESO)

 Station Positions and Variations	L2	Global	Geometric	– Station Position Time Series (SPTS)
 Sea Water Level Records	L2	Ocean	Geometric	– Sea Water Level Records (SWLR)
 Land and Marine Gravity Data	L2	Land/ Ocean[(1)]	Physical	– Land Gravity Data (LGD) – Marine Gravity Data (MGD) – Absolute Gravity Data (AGD) – Time Series Gravity Data (TGD)
 Geodetic Observations	L1	Global	Geometric/ Physical	– Geodetic Geometric Observations (GGO) – Geodetic Physical Observations (GPO)
 Geodetic Standards and Conventions	Basis	Global	Geometric/ Physical	– Numerical Standards in Geodesy (NSG) – Conventional Background Models (CBM)
 Geodetic Infrastructure	Basis	Global	Geometric/ Physical	– Geodetic Space Infrastructure (GSI) – Geodetic Terrestrial Infrastructure (GTI)

(1) For regional applications at land and ocean.

Table 2: Proposal for the characterisation of EGVs, example EGV Satellite Orbits (source International GNSS Service – IGS, with additions by Peter Steigenberger)

<table>
<tr><td colspan="7">EGV Satellite Orbits</td></tr>
<tr><td colspan="7">Product: GNSS Satellite Orbits, Clocks and Biases (GOCB)</td></tr>
<tr><td colspan="7">Definition:
- Orbits: Ephemerides of GNSS satellites.
- Clocks: Clock solution for GNSS satellites.
- Code and phase biases: Solutions for systematic errors between GNSS observations at the same or different frequencies.</td></tr>
<tr><td>Sub-product</td><td>Uncertainty</td><td>Spatial resolution</td><td>Time resolution</td><td>Timeliness</td><td>IAG Service / Data sources</td><td>Notes</td></tr>
<tr><td>GPS satellite orbits broadcast</td><td>20 cm</td><td>N/A</td><td>2 h</td><td>Real time</td><td>IGS and data sources therein</td><td>Orbit SISRE RMS https://doi.org/10.1007/s10291-024-01793-6</td></tr>
<tr><td>IGS GPS ultra-rapid (predicted half) orbits</td><td>5 cm</td><td>N/A</td><td>15 min</td><td>Real time</td><td>IGS and data sources therein</td><td rowspan="4">Orbit uncertainty corresponds to 1D mean RMS values over the three XYZ geocentric components. IGS accuracy limits, except for predicted orbits, are based on comparisons with independent laser ranging results and discontinuities between consecutive days. The precision is better.</td></tr>
<tr><td>IGS GPS ultra-rapid (observed half) orbits</td><td>3 cm</td><td>N/A</td><td>15 min</td><td>3 to 9 hours</td><td>IGS and data sources therein</td></tr>
<tr><td>IGS GPS rapid orbits</td><td>2.5 cm</td><td>N/A</td><td>15 min</td><td>17 to 41 hours</td><td>IGS and data sources therein</td></tr>
<tr><td>IGS GPS final orbits</td><td>2.5 cm</td><td>N/A</td><td>15 min</td><td>12 to 19 days</td><td>IGS and data sources therein</td></tr>
<tr><td>IGS GLONASS final orbits</td><td>3 cm</td><td>N/A</td><td>15 min</td><td>12 to 19 days</td><td>IGS and data sources therein</td><td></td></tr>
<tr><td>Galileo final orbits (???0MGXFIN)</td><td>2-3 cm ?</td><td></td><td>5 min</td><td></td><td></td><td></td></tr>
</table>

BeiDou-3 MEO final orbits (???0MGXFIN)	4-8 cm		5 min			https://doi.org/10.1016/j.asr.2022.08.058
BeiDou-3 IGSO final orbits (???0MGXFIN)	10-20 cm		5 min			https://doi.org/10.1016/j.asr.2022.08.058
BeiDou-3 GEO final orbits (IGSO)	60 cm		5 min			https://doi.org/10.1016/j.asr.2022.08.058
GPS satellite clocks broadcast	5 ns RMS 2.5 ns SDev	N/A	2 h	Real time	IGS and data sources therein	
GPS ultra-rapid (predicted half) clocks (IGS0OPSULT)	3 ns RMS 1.5 ns SDev	N/A	15 min	Real time	IGS and data sources therein	The accuracy (neglecting any contributions from internal instrumental delays, which must be calibrated separately) of all clocks is expressed relative to the IGS timescale, which is linearly aligned to GPS time in one-day segments. The standard deviation (SDev) values are computed by removing a separate bias for each satellite and station clock, whereas this is not done for the RMS values.
GPS ultra-rapid (observed half) clocks (IGS0OPSULT)	150 ps RMS 50 ps SDev	N/A	15 min	3 to 9 hours	IGS and data sources therein	
GPS rapid clocks (IGS0OPSRAP)	75 ps RMS 25 ps SDev	N/A	5 min	17 to 41 hours	IGS and data sources therein	
GPS final clocks (IGS0OPSFIN)	75 ps RMS 20 ps SDev	N/A	30 s	12 to 19 days	IGS and data sources therein	
GLONASS ???						
GALILEO???						
BDS???						
Code biases	?	N/A	Daily	2 - 3 days 3 months	IGS and data sources therein	Analysed signals GPS: C1C, C1W, C2L/S/X, C2W, C5Q/X

						GLO: C1C, C1P, C2C, C2P GAL: C1C/X, C5Q/X, C7Q/X, C8Q/X, C6C BDS: C2I, C6I, C7I
Phase biases			Daily			Typically GPS: L1C/W, L2C/W GAL: L1C/X, L5Q/X BDS: L1P/X, L5P/X

Table 3: Proposal for the characterisation of EGVs, example EGV Global Earth Gravity Field (source International Center for Global Gravity Field Models – ICGEM, with additions by Thomas Gruber)

EGV Global Earth Gravity Field						
Product: Global Gravity Field Models (GGM)						
Definition: Spherical or ellipsoidal harmonic series of gravity potential either as mean or as a temporal series						
Sub-product	**Uncertainty**	**Spatial resolution**	**Time resolution**	**Timeliness**	**IAG Service / Data sources**	**Notes**
Satellite-only static models	1.5 cm in terms of geoid height up to d/o 200	Degree from 8 to 300	N/A	N/A	ICGEM and sources therein	
Combined static models (satellite-only + surface gravity)	2 cm to 40 cm in terms of geoid height	Degree from 300 to 720	N/A	N/A	ICGEM and sources therein	Uncertainty depends on the coverage of the surface gravity data included in the model
High-resolution models (satellite-only + surface gravity + topography)	2 cm to 40 cm in terms of geoid height	Degree from 720 to 5540	N/A	N/A	ICGEM and sources therein	Uncertainty depends on the coverage of the surface gravity data included in the model and on the topography mass density values considered for the topography gravity signals.
Time series (temporal) models	1 mm in terms of geoid height up to d/o 60	Degree 60, 96, 120	Monthly	Three months	ICGEM and sources therein	

...						
EGV Global Earth Gravity Field						
Product: Topographic Gravity Field Models (TGFM)						
Definition: Spherical or ellipsoidal harmonic series of gravity potential originated by the attraction of the Earth's topographic masses.						
Sub-product	**Uncertainty**	**Spatial resolution**	**Time resolution**	**Timeliness**	**IAG Service / Data sources**	**Notes**
Topographic gravity field models	1 cm geoid height up to d/o 5400 or higher	Degrees: 1800, 2190, 3660, 5480, 7300	N/A	N/A	ICGEM and sources therein	Uncertainty depends on the digital elevation model describing the shape of Earth's topography and assumptions of the mass density inside the topography.
EGV Global Earth Gravity Field						
Product: Gravity Field Quantities (GFQ)						
Definition: 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).						
Sub-product	**Uncertainty**	**Spatial resolution**	**Time resolution**	**Timeliness**	**IAG Service / Data sources**	**Notes**
Gravity field quantities	Depends on the primary GGM	Depends on the primary GGM	Depends on the primary GGM	Depends on the primary GGM	ICGEM and sources therein	

Table 4: Requirements for the Essential Climate Variables (ECVs), example Terrestrial Water Storage Anomaly (taken from WMO 2022, p. 204)

Name	**Terrestrial Water Storage Anomaly**				
Definition	TWS is the total amount of water stored in all continental storage compartments (ice caps, glaciers, snow cover, soil moisture, groundwater, surface water bodies, water in biomass). The change of TWS over time balances the budget of the water fluxes precipitation, evapotranspiration and runoff, i.e., it closes the continental water balance.				
Unit	km^3 or mm water equivalent ($kg\ m^{-2}$)				
Note	Measuring TWS is possible by satellite and terrestrial gravimetry in relative terms only, not in absolute values. Thus, TWS is given as the deviation relative to a long-term mean				
Item needed[(1)]	**Unit**	**Metric**	**Value**[(2)]		**Notes**
Horizontal resolution	km		G	1	Resolve the topography- and land cover-driven patterns of landscape-scale water storage dynamic.
			B	10	Many climate and Earth system models are moving to a grid size of 10 km or finer. Often a relevant local to regional water management scale.
			T	200	Comprehensive continental-scale patterns of water storage change.
Vertical resolution			G		N/A, as total water storage represents an integrative value in the vertical, overall storage compartments and depths.
			B		
			T		
Temporal resolution	day		G	1	To resolve water storage changes caused by heavy precipitation events and occurring during flood events.
			B		
			T	30	To resolve major seasonal, intra- and inter-annual dynamics as well as long-term trends of water storage.
Timeliness	day		G	1	Required latency for warning for and managing of extreme events, in particular floods.
			B		

			T	60-90	Current latency of GRACE-FO based TWS product.
Required measurement uncertainty (2-sigma)	mm		G	1	Order of magnitude required to resolve TWS effect of daily evapotranspiration.
			B		
			T	20	Order of magnitude to resolve monthly TWS variations.
Stability	mm y^{-1}		G	<1	Stability needed to detect subtle long-term TWS trends caused by global change and anthropogenic impacts on the water cycle.
			B		
			T	<5	Stability needed to resolve major long-term TWS changes, e.g., related to melting ice sheets, groundwater depletion.
Standards and references	Pail, R., Bingham, R., Braitenberg, C., et al. (2015): *Science and User Needs for Observing Global Mass Transport to Understand Global Change and to Benefit Society*. Surveys in Geophysics 36, 743-772. Güntner, A., Reich, M., Mikolaj, M., et al. (2017): *Landscape-scale water balance monitoring with an iGrav superconducting gravimeter in a field enclosure*. Hydrology and Earth System Sciences, 21(6), 3167-3182, doi: 10.5194/hess-21-3167-2017. Jäggi, A., Weigelt, M., Flechtner, F., et al. (2019): *European Gravity Service for Improved Emergency Management (EGSIEM) - from concept to implementation*. Geophysical Journal International, 218(3), 1572-1590, doi: 10.1093/gji/ggz238. Peter, H., Meyer, U., Lasser, M., Jäggi, A. (2022): *COST-G gravity field models for precise orbit determination of Low Earth Orbiting Satellites*. Advances in Space Research, 69(12), 4155-4168, doi: 10.1016/j.asr.2022.04.005.				

(1) The requirements are expressed in terms of five criteria: (a) Spatial Resolution - horizontal and vertical (if needed). (b) Temporal resolution (or frequency) – the frequency of observations e.g. hourly, daily or annual. (c) Measurement Uncertainty – the parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand (GUM). It includes all contributions to the uncertainty, expressed in units of 2 standard deviations, unless stated otherwise. (d) Stability – The change in bias over time. Stability is quoted per decade. € Timeliness - The time expectation for accessibility and availability of data.

(2) For each of the requirements, a goal, breakthrough and threshold value are presented. These are defined as: Goal (G): an ideal requirement above which further improvements are not necessary. Breakthrough (B): an intermediate level between threshold and goal which, if achieved, would result in a significant improvement for the targeted application. The breakthrough value may also indicate the level at which specified uses within climate monitoring become possible. It may be appropriate to have different breakthrough values for different uses. Threshold (T): the minimum requirement to be met to ensure that data are useful.

Table 5: Requirements for the Essential Climate Variables (ECVs), example Global Mean Sea Level (taken from WMO 2022, p. 117)

Name	**Global Mean Sea Level**				
Definition	The height of the ocean surface relative to a [global] reference geoid.				
Unit	m				
Note	Estimates of the global mean sea level are obtained by averaging individual sea surface heights over the global ocean during a given period.				
Item needed[1]	**Unit**	**Metric**	**Value**[2]		**Notes**
Horizontal resolution	km		G	10	
			B		
			T	100	
Vertical resolution			G	-	N/A
			B	-	
			T	-	
Temporal resolution	day		G	1	
			B		
			T	30	
Timeliness	day		G	1	
			B		
			T	365	
Required measurement uncertainty (2-sigma)	mm		G		
			B		
			T	2-4	Values for the global mean. The uncertainty over a global mesh is = 10 mm

Stability	mm yr^{-1}		G	<0.03	Target to be considered for the detection of permafrost melting. From the WCRP grand challenge on sea level and coastal impacts the required stability in GMSL is <0.03 mm/year (over a decade, 90%Cl) to detect permafrost thawing.
			B	<0.1	Target to be considered for the estimation of deep ocean warming and Earth energy imbalance is 0.1 mm/year (over a decade, 90% Cl).
			T	<0.3	Adapted for sea level impact detection (detection of a change in the rate of rise of the global mean sea level). From the WCRP grand challenge on sea level and coastal impacts the required stability in GMSL <0.3 mm/year (global mean, 90% Cl) for the detection attribution of sea level rise.
Standards and references	The uncertainty budget of the global mean sea level derived from satellite altimetry strongly relies on the precise orbit determination of the platform, the instrumental, geophysical and environmental altimeter corrections used to derive the sea level anomalies. Meyssignac, B., Boyer, T., Zhao, Z.,et al. (2019). *Measuring global ocean heat content to estimate the Earth energy imbalance*. Frontiers in Marine Science, 6, p.432. Cazenave, A., Hamlington, B., Horwath, et al. (2019). *Observational requirements for long-term monitoring of the global mean sea level and its components over the altimetry era*. Frontiers in Marine Science, p.582.				

(1) The requirements are expressed in terms of five criteria: (a) Spatial Resolution - horizontal and vertical (if needed). (b) Temporal resolution (or frequency) – the frequency of observations e.g. hourly, daily or annual. (c) Measurement Uncertainty – the parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand (GUM). It includes all contributions to the uncertainty, expressed in units of 2 standard deviations, unless stated otherwise. (d) Stability – The change in bias over time. Stability is quoted per decade. € Timeliness - The time expectation for accessibility and availability of data.

(2) For each of the requirements, a goal, breakthrough and threshold value are presented. These are defined as: Goal (G): an ideal requirement above which further improvements are not necessary. Breakthrough (B): an intermediate level between threshold and goal which, if achieved, would result in a significant improvement for the targeted application. The breakthrough value may also indicate the level at which specified uses within climate monitoring become possible. It may be appropriate to have different breakthrough values for different uses. Threshold (T): the minimum requirement to be met to ensure that data are useful.

Open Session | Topic B: Correlations in atmospheric parameter estimation

Convener Benedikt Soja (IVS Analysis Coordinator, Chair GGOS-FA IA4G)

Program 6th March 2026, 15:00 – 15:30
15:00 – 15:10 Introductory presentation by Benedikt Soja
15:10 – 15:30 Discussion

Concept Note

Geodetic parameter estimation often relies on Least Squares Adjustment (LSA) with diagonal covariance matrices, implicitly assuming that subsequent observations are independent. Sequential estimators like Kalman filters or constraints in LSA can account for temporal links, yet they usually depend on average atmospheric conditions rather than using site-specific stochastic parameters. These simplifications neglect the physical reality of Kolmogorov turbulence, the spatial correlations between co-located stations, and the coupling between atmospheric delays, station heights, and clock offsets. This concerns all techniques and is still not thoroughly handled, typically resulting in very optimistic uncertainties and potentially in sub-par estimates.

This session furthermore serves to explore the feasibility of a multi-technique combination of tropospheric parameters with the goal of establishing a new operational IERS product. Beyond the stochastic modeling, many other aspects must be discussed to make such a product a reality, including standardized data formats, optimal parameterizations, inter-technique biases, and the latencies required to serve both the geodetic and meteorological communities.

Objective: This session aims to discuss the rigorous treatment of correlations in atmospheric parameter estimation and simulations, and the path toward establishing a new operational IERS product for the troposphere.

Representatives from all IAG Services are invited to share their thoughts on the matter.

Further pre-meeting reading material

Treuhaft, R. N., & Lanyi, G. E. (1987). *The effect of the dynamic wet troposphere on radio interferometric measurements*. Radio Science, 22(2), 251–265. https://doi.org/10.1029/rs022i002p00251

Schön, S., & Brunner, F. K. (2008). *A proposal for modelling physical correlations of GPS phase observations*. Journal of Geodesy, 82(10), 601–612. https://doi.org/10.1007/s00190-008-0211-3

Soja, B., Nilsson, T., Karbon, M., Zus, F., Dick, G., Deng, Z., ... Schuh, H. (2015). Tropospheric delay determination by Kalman filtering VLBI data. Earth, Planets, and Space, 67(1). https://doi.org/10.1186/s40623-015-0293-0

Halsig, S. (2018). *Atmospheric refraction and turbulence in VLBI data analysis*. Doctoral dissertation, Rheinische Friedrich-Wilhelms-Universität Bonn]. Bonn, Germany.

Kitpracha, C., Nilsson, T., Heinkelmann, R., Balidakis, K., Modiri, S., & Schuh, H. (2022). *The impact of estimating common tropospheric parameters for co-located VLBI radio telescopes on geodetic parameters during CONT17*. Advances in Space Research, 69(9), 3227–3235. https://doi.org/10.1016/j.asr.2022.02.013

Schartner, M. (2025). *Deriving a global troposphere model for space geodetic simulations based on an ML ensemble featuring uncertainty quantification*. Journal of Geodesy, 99(9). https://doi.org/10.1007/s00190-025-01996-w

Open Session | Topic C: Increased automation in geodetic data analysis

Convener Benedikt Soja (IVS Analysis Coordinator, Chair GGOS-FA IA4G)

Program 6th March 2026, 15:30 – 16:00
15:30 – 15:40 Introductory presentation by Benedikt Soja
15:40 – 16:00 Discussion

Concept Note

Increased automation in geodetic data analysis is essential to facilitate operational workflows, reduce product latencies, and minimize the risk of human error. As the volume of space geodetic data continues to grow, automated processes become a critical component for increasing the resilience of geodetic products and enabling smaller research groups with limited human resources to contribute effectively. While certain tasks, such as routine GNSS processing and analysis of VLBI Intensive sessions, are already largely automated, other areas like the analysis of 24-hour VLBI sessions remain significantly more challenging. Furthermore, massive efforts like IGS reprocessing campaigns (e.g., repro3) highlight the heavy workload placed on Analysis Centers, which makes it difficult to maintain a consistently reprocessed time series, causing existing products to become increasingly outdated. The need for automation extends to other geodetic problems, such as identifying station position discontinuities in terrestrial reference frame determination or anomaly detection in early-warning applications.

This session explores the current state of automation in geodetic data analysis and aims to identify specific areas where these processes can be extended. By promoting a cross-technique discussion on shared themes like automated data selection, quality checks and error mitigation, we seek to establish pathways for transforming geodetic workflows into more autonomous and resilient systems. Considering also that the geodetic community is now entering a new era of tools based on Artificial Intelligence, we will discuss how these methods could facilitate automation beyond traditional algorithmic approaches.

Objective: This session aims to discuss current and future automation in geodetic data analysis, with an overall goal of improving the reliability and timeliness of geodetic products.

Representatives from all IAG Services are invited to share their experiences and thoughts on the matter.

Further pre-meeting reading material

Schuh, H., & Schwegmann, W. (2000). A vision towards automated real-time VLBI. Physics and Chemistry of the Earth Part A Solid Earth and Geodesy, 25(12), 813–817. https://doi.org/10.1016/S1464-1895(01)00012-6

Schartner, M., Plötz, C. & Soja, B. Automated VLBI scheduling using AI-based parameter optimization. J Geod 95, 58 (2021). https://doi.org/10.1007/s00190-021-01512-w

Soja, B., Schartner, M., & Kłopotek, G. (2021). ETHZ VLBI Analysis Center Biennial Report 2019/2020. In K. M. Armstrong, D. Behrend, & K. D. Baver (Eds.), International VLBI Service for

Geodesy and Astrometry 2021+2022 Biennial Report (pp. 205–209). NASA. https://ethz.ch/content/dam/ethz/special-interest/baug/igp/space-dam/documents/acethz.pdf

Crocetti, L., Schartner, M., & Soja, B. (2021). Discontinuity Detection in GNSS Station Coordinate Time Series Using Machine Learning. Remote Sensing, 13(19), Article 19. https://doi.org/10.3390/rs13193906

Chen, X., Ge, M., Zuo, X., & Schuh, H. (2024). An effective automatic processing engine for improving the multi-GNSS constellation precise orbit prediction. GPS Solutions, 28(2). https://doi.org/10.1007/s10291-024-01618-6

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