Review of current and planned activities of the International Space Weather Activity Team on Ionospheric Indices and Scales (ISWAT G2B-04)

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Outline

- Status, objectives
- Activities
- Achievements
- Plan of future activities
- Summary/conclusions

ISWAT - G2B-04 on Ionospheric perturbation indices and scales (https://iswat-cospar.org/G2B-04)

- Status
  - The team is part of the International Space Weather Action Team (ISWAT) established via COSPAR.
  - Currently, 59 team members from 18 countries are officially registered.
  - Online meetings are organized quarterly to discuss selected topics and coordinated activities.

- Objectives
  - Being aware of the **high potential of ionospheric indices to characterize the perturbation degree** of the ionosphere, the team will contribute to **identify/develop indices and scales** which are well suited to **estimate the impact of ionospheric perturbations** on ground and space-based radio systems
  - Encourage **scientific research** in the context of overall space weather processes
  - **Review of ionosphere activity indices** and related scales
  - Encourage **comparative studies and test runs** of different types of ionospheric indices and scales
  - Intensification of the **dialog with customers** and gathering of feedback from customers to find optimal solutions both for space weather services as well as for customers
  - **Recommendations** for using selected indices and scales on international level.
  - Address data **standardization**, preservation and access

Ionospheric indices – current situation

- As discussed at the COSPAR Assemblies in Pasadena and Sydney, there is a need to complete the internationally widely used NOAA space weather scales for trans-ionospheric radio wave propagation.
- As experienced with geomagnetic and solar activity indices, proxies that describe the perturbation degree of the ionosphere can essentially support various applications, e.g. in navigation and positioning.
- In the same way, ionospheric indices will help to better understand ionospheric perturbation processes and can provide important information to mitigate space weather impact on applications.
- Being aware that numerous index approaches and related scales already exist, different indices must be compared with respect to customer requirements considering their strengths and weaknesses.

List of ionospheric perturbation indices considered in Europe
Borries et al., 2020, Advances in Space Research

Index	Name
AATR	Along Arc TEC Rate
Dfu/ Dfl	DfoF2-upper and Dfl: DfoF2-lower
DIXSG, DIXSGp	Disturbance Ionosphere Index – Spatial Gradient
GEC/ dGEC	Global Electron Content (Rate)
IBI	Ionospheric Bubble Index
IG12	12-month-running mean of the ionospheric IG index
R12eff	DIAS Effective Sunspot Number
ROTI	Rate of Change of TEC Index
S4/ Sigma_Phi	Scintillation indices
SIDX, GIX	Sudden Ionospheric Disturbance IndeX, Gradient Ionosphere IndeX
SOLERA, SOLERA-drift	SOLar Euv flux RAte GNSS proxy
SISTED	Sunlit Ionosphere Sudden TEC Enhancement Detector
SRMTID/SSMTID	Single Receiver Medium Scale Travelling Ionospheric Disturbance Index and Single Satellite Medium Scale Travelling Ionospheric Disturbance index
W-index	Ionospheric Weather W index

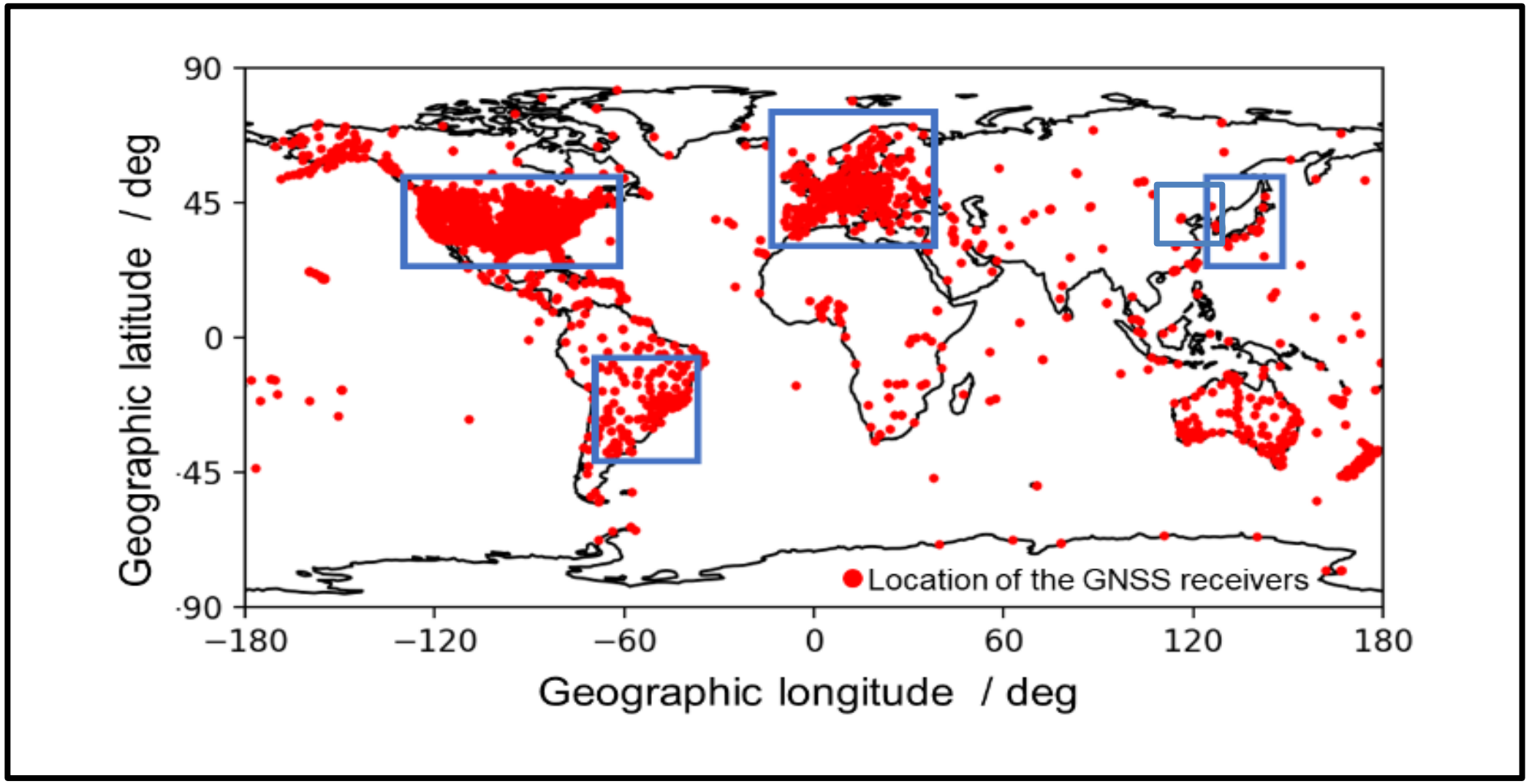
ISWAT G2B-04 - Activities

- Regularly organized **online meetings** enable intensive discussion on selected topics concerning ionospheric indices and scales, their development and use.
- Initiation of a **Coordinated Ionospheric Study on Scales and Indices (CISSI)** to enable a comparison of different index approaches based on identical data sets. International collaboration to identify specific strengths and weaknesses of indices for different applications is essential.
- To review the **specification of current indices and scales** for different applications, the team **elaborates compact fact sheets for numerous indices** currently used. The initiative intends to provide a quick orientation for young scientists and customers.

ISWAT G2B-04 - Achievements

- **Definition of CISSI areas and time intervals** usable for coordinated studies.
- **Establishment of repositories** to access GNSS and vertical sounding data for two selected periods.
- The present CISSI activity focuses on **two periods from16-19 March 2015 (St. Patrick storm) and from 22-25 May 2015 (quiet reference).** Predefined regions cover Europe, North- and South-America and Asia. The current **data sets stored and hosted by data centers and research institutions in different countries** contain ground based GNSS and vertical sounding data. This and further campaigns shall help to develop and/or consolidate ionospheric space weather scales used in space weather services.

View of selected geographical regions for the CISSI campaign 2022



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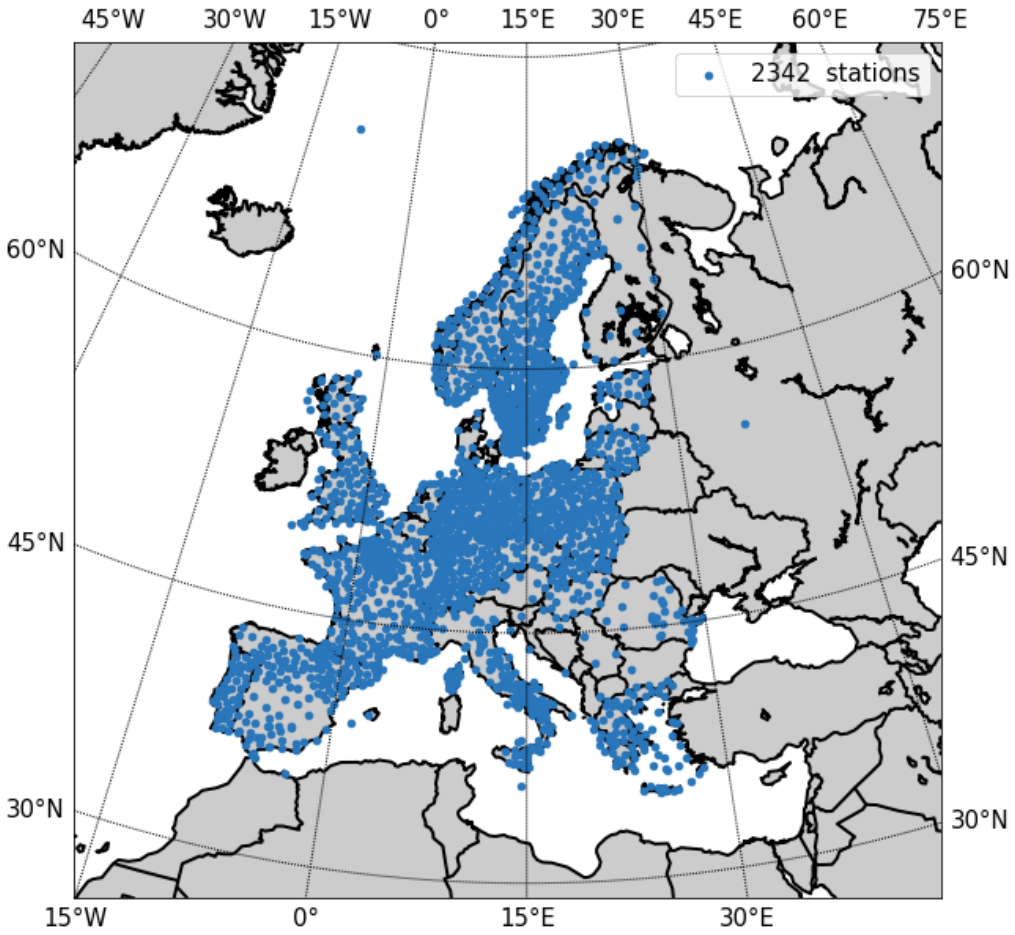
  - First contributions at the URSI-RASC Meeting by Cahuasquí/Jakowski/Hoque on preliminary results
  - 2 presentations at this COSPAR 2022 assembly in Athens comparing different indices over Europe

European data set



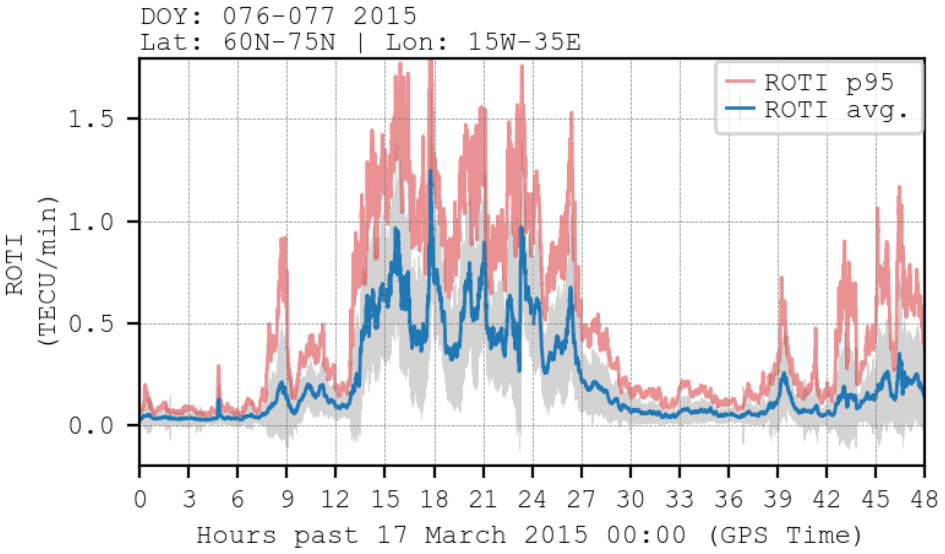
European GNSS data for CISSI are provided via DLR supported by

Grzegorz Nykiel / Gdansk University

- Two CISSI periods of time in 2015:
  C1-1: St. Patrick storm (March): DoY 075-078
  C1-2: Low activity period (May): DoY 142-145
- 30 European data networks
- GNSS data with a 30-second resolution
- Data from up to 2342 ground-based receivers per day

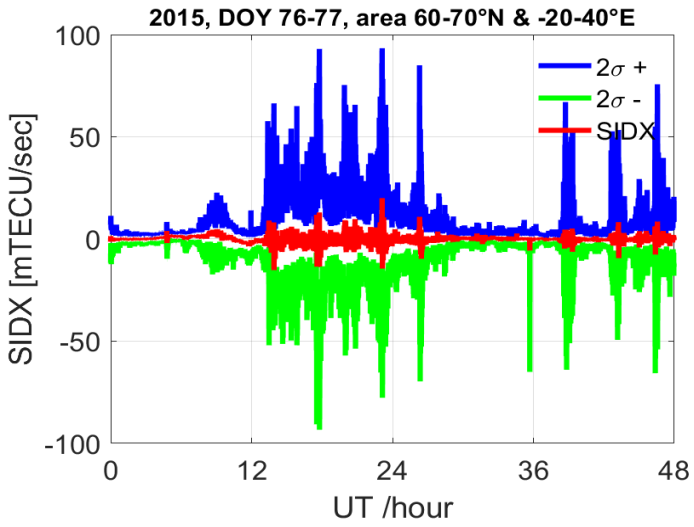
Preliminary CISSI results at high latitudes over Europe

Rate Of TEC Index (ROTI)

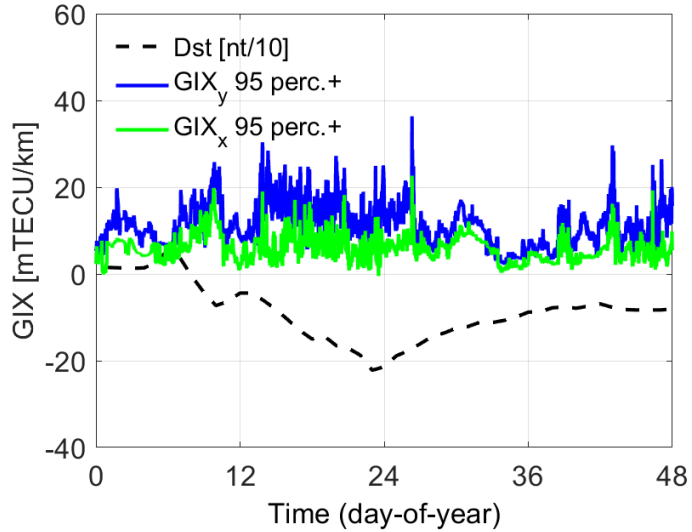


Plot kindly provided by Grzegorz Nykiel / Gdasnsk University

Sudden Ionospheric Disturbance indeX (SIDX)



Gradient Ionospheric indeX (GIX)



Plots kindly provided by Juan Andrés Cahuasquí, Institute for Solar-Terrestrial Physics /DLR,
See talk by Cahuasqui et al. on „Regional characterization of ionospheric perturbation degree with GIX and SIDX“

Comparison of different indices allow estimating specific characteristics of different indices.

Here: ROTI has closer similarities with variations of SIDX than with horizontal gradients of TEC (GIX) at high latitudes.

Elaboration of fact sheets for ionospheric indices

- 2 page fact sheets for ionospheric indices have been presented and discussed.
- We plan to collect fact sheets to get a systematic **overview of ionospheric indices currently in use** for scientific as well as for commercial applications
- Fact sheets considered so far:
  - ROTI (Knut Stanley Jacobson, Pierre Cilliers)
  - GIX (Norbert Jakowski, Mohammed Mainul Hoque)
  - FIF-based adapted Sigma Phi (Luca Spogli et al.)

  planned for upcoming meetings:
  - S4 (Yannick Beniguel)
  - SIDX (Norbert Jakowski, Mohammed Mainul Hoque)
- Because a **review of fact sheets can help young scientists and customers** to understand quickly index related basic science and application potential, respectively, such a review should be worth to be published, e.g. in ASR (cf. Borries et al., 2020, ASR for Indices used in Europe).

Future Work

- Enhanced comparative analysis of different indices based on studies utilizing an identical CISSI data base.
- Exploration of equivalent indices based on satellite in-situ and radio occultation observations.
- Combination of ground and space-based observations to maximize global coverage.
- Identification of specific advantages and drawbacks of different indices focusing both on basic research and practical applications. These efforts are supported by the compilation of fact sheets for all available indices, suggested and discussed by the team members.
- Definition of Ionospheric Scale(s) applicable for a wide spectrum of applications in space-based radio systems in close collaboration with customers e.g. in precise positioning and safety of life navigation.
- Recommendation of a few indices covering a broad spectrum of spatial and temporal scales of the ionosphere for standardization.

To be part of the team, please join ISWAT G2B-04 via https://iswat-cospar.org/G2B-04.

Summary and conclusions

- Activities of **ISWAT G2B-04 team** have a high potential to **contribute for completing internationally well accepted space weather scales** by identifying/developing indices and scales for trans-ionospheric radio wave propagation.

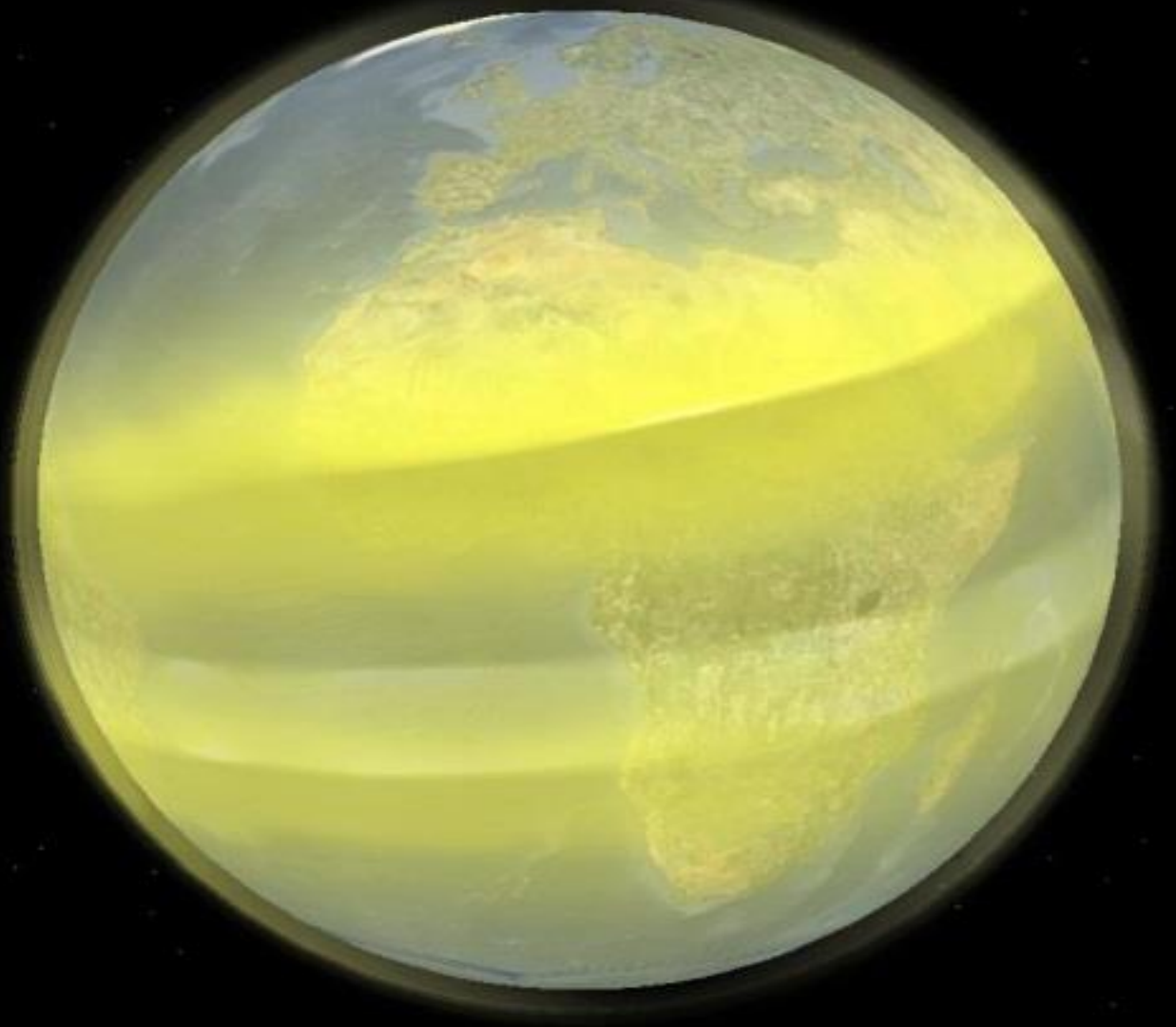
- Activities currently focus on **comparative studies of different index approaches** to identify optimal solutions for space weather services and customers

- Development of Ionospheric scales trans-ionospheric radio wave propagation requires **broad international discussion and collaboration** also in future, e.g.

  Topic should be addressed in the **Space Weather Roadmap** initiated by COSPAR
  Continuation of the discussion at **subsequent meetings such as COSPAR 2024**
  Next meeting: International Workshop on GNSS Ionosphere (IWGI)
  held at DLR Neustrelitz, Sept. 25-28, 2022

Ionosphere from space

Electron density
July 23, 2011
14:00 UT



Thank you for your attention!