Swarm 15th Data Quality Workshop & 1st NanoMagSat Symposium

Swarm L2 Ionospheric Indices NeGIX and TEGIX: Overview, Developments, and Challenges Towards FAST Implementation

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Context

Two new gradient indices have recently been added to the family of **operational (OPER)** Swarm products, now accessible via the **Swarm Data Access**:

NeGIX
Electron Density Gradient Ionospheric indeX

- ✓Derived from **in-situ Langmuir Probe** measurements from Swarm satellites A and C.
- ✓Estimates horizontal gradients of electron density over **scales of 30–200 km**.

TEGIX
Total Electron Content Gradient Ionospheric indeX

- ✓**Based on GNSS** Precise Orbit Determination **(POD)** measurements from Swarm satellites A and C.
- ✓Provides horizontal gradients of total electron content (TEC) over **scales of 30–200 km**.

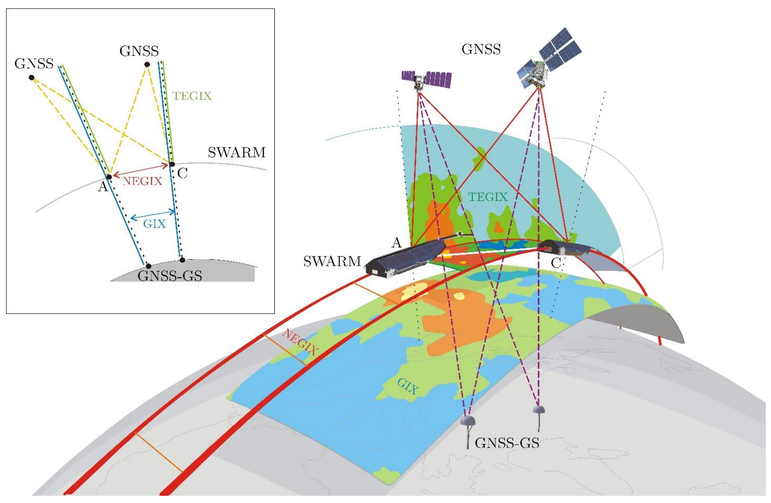


Figure 1. Scheme of the spatial configuration and definition of NeGIX and TEGIX

Novelty

- ✓Both indices exploit the near-polar, parallel orbits of Swarm **satellites A and C**.
- ✓Data from the two spacecraft are combined with a **latitudinal resolution of 0.5°**, increasing robustness and statistical reliability.
- ✓Unlike existing Swarm indices, NeGIX and TEGIX provide gradient **information in both meridional (South–North) and zonal (West–East) directions**.

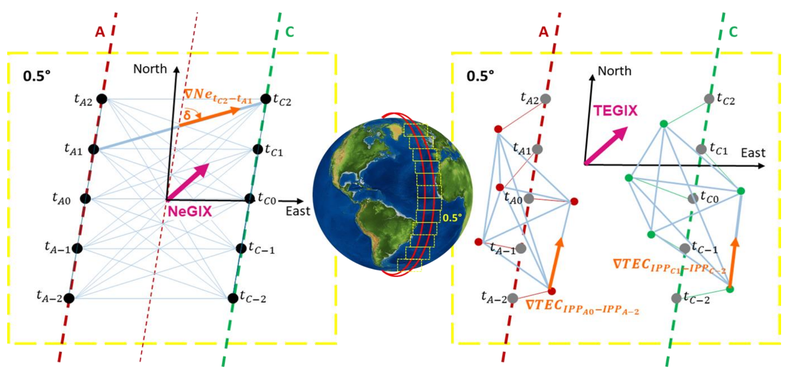


Figure 2. Scheme of data combination used by NeGIX and TEGIX

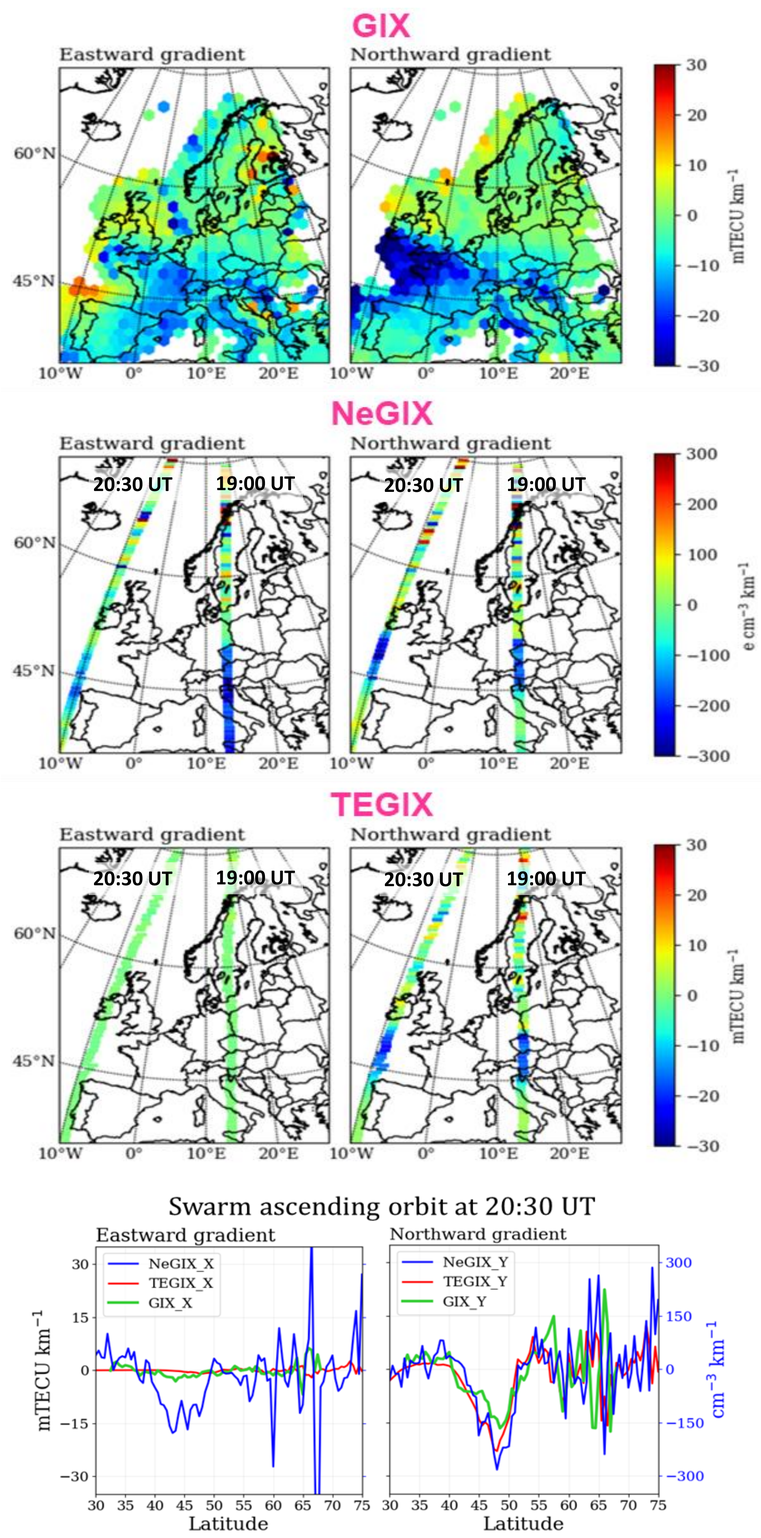
Applications & Potential

NeGIX and TEGIX open new opportunities for ionospheric research, operational monitoring, and space-weather applications, especially during geomagnetically disturbed conditions.

Domain	How NeGIX & TEGIX Contribute
Space-weather impact on critical systems	✓ Post-event monitoring of severe **spatial gradients** and **TEC fluctuations** affecting trans-ionospheric signals. ✓ Post-processing investigation of effects on **Safety-of-Life applications** and augmentation systems (e.g., **EGNOS**).
Geomagnetic storm dynamics	✓ Provide **zonal & meridional gradients** to track **ionospheric fronts** and **traveling disturbances** during storm events.
Solar terminator effects	✓ Distinguish between **zonal vs meridional gradients** to analyze variability at twilight and its impact on **radio-wave propagation**.
Scintillation & plasma bubbles	✓ Detect **ionization patch borders** linked to scintillation. ✓ Characterize **plasma bubble morphology** and associated sharp gradients.
Modeling & forecasting	✓ Contribute to **empirical & numerical ionospheric models** using >11 years of Swarm data. ✓ Low-latency potential via **FAST data dissemination.**

NeGIX & TEGIX during perturbed geomagnetic conditions

St. Patrick's Day storm – March 17, 2015



Perturbed Summer Months (May-July) of 2024

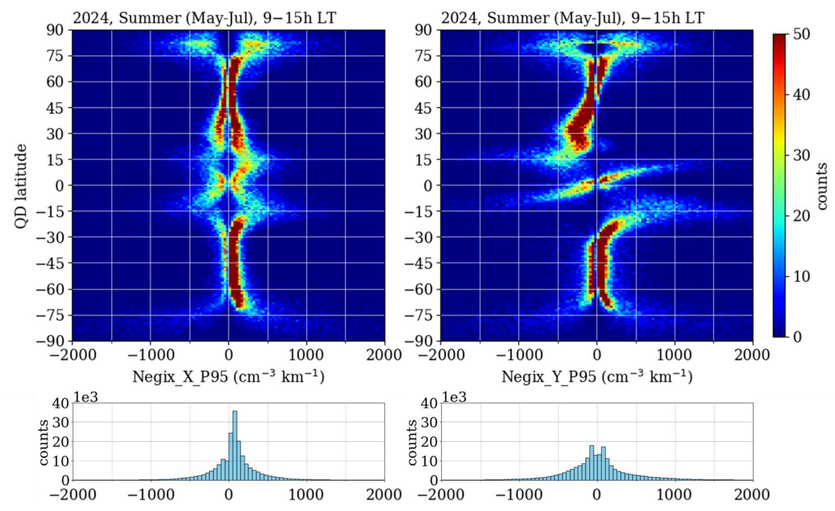


Figure 3. NeGIX zonal and meridional components as a function of **Quasi-Dipole latitude** for a large dataset covering the diurnal hours (9 – 15 LT) of the Northern summer months of 2024.

- ✓ NeGIX and TEGIX have been **validated under both quiet and disturbed geomagnetic conditions** (case studies + large datasets).
- ✓ **Strong agreement with ground-based GIX**, the reference index for defining NeGIX & TEGIX.
- ✓ **Combined use of NeGIX, TEGIX, and GIX** → insights into **altitude dependencies** and extended coverage over oceans & remote regions.
- ✓ **Strong correlation with Swarm IPIR gradients**, particularly in the meridional component.

Figure 4. Comparison of the performance of NeGIX, TEGIX, and GIX, during the severe St. Patrick's Day storm on March 17, 2015, over Europe.

Data Dissemination

- ✓ **Easy to compute** – results in few minutes.
- ✓ Public Level 2 OPER products (TIX_TMS_2F & NIX_TMS_2F) available **via Swarm Data Access / DLR-IMPC.**
- ✓ **4–5 day latency.**
- ✓ Time resolution ca. **8 seconds.**

Scan me to access references, data, and more from the NEW data!

Challenges Towards FAST Implementation

- ✓ **FAST latency ca. 12h** → still too slow for real-time forecasting.
- ✓ **Orbital limits:** only 2 passes/day per longitude; full local-time coverage ca. 4 months → short-lived features can be missed.
- ✓ **Dual-satellite dependence:** needs simultaneous data from Swarm A & C; separate FAST products complicate usage.
- ✓ Next step: **new automated approach of data processing** with IMPC, DTU, Swarm Data Access & VIRES.