

**United Nations Workshop on
the International Space Weather Initiative:
The Way Forward**
Vienna, Austria, 26 – 30 June, 2023



An open-access massive data set for research on geomagnetic field effects on GPS/GNSS ionospheric delay

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- Content
- Introduction & motivation
- Method and material
- Research results
- Discussion
- Recommendations

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- Introduction & motivation
- Challenges for GNSS researchers:
 - Need for experimental data in GNSS research
 - Lack of large-scale experimental data collected in real scenarios of GNSS utilisation
 - Diversity of experimental data formats and sources
- The presented research aims at the framework development for data aggregation, collation, and formatting
- **Hypothesis: TEC determined by predictors of geomagnetic activity (B_x , B_y , B_z , Dst)**

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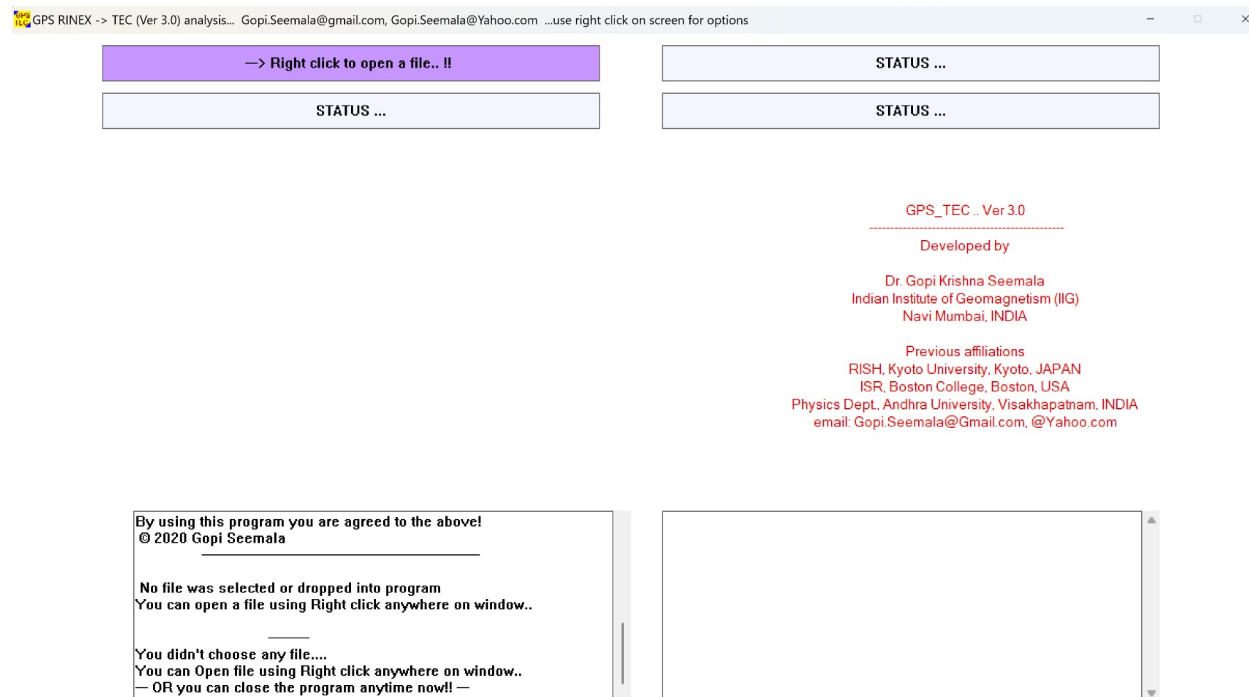
- Method
- Generalised programmable framework for data aggregation, collation, formatting, and descriptive statistical analysis
- GNSS scenarios determined by structured data sets from internet-based archives (International GNSS Service, IGS), and contextual descriptions (here: geomagnetic conditions, Dst index, from International Service of Geomagnetic Indices, ISGI)
- Outcome: a large-scale data set of dual-frequency GPS-based TEC estimates and geomagnetic predictors observations at a selected IGS reference station throughout the year in consideration

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- Method
- IGS GPS pseudoranges post-processed with GPS TEC software (Dr Gopi Seemala)



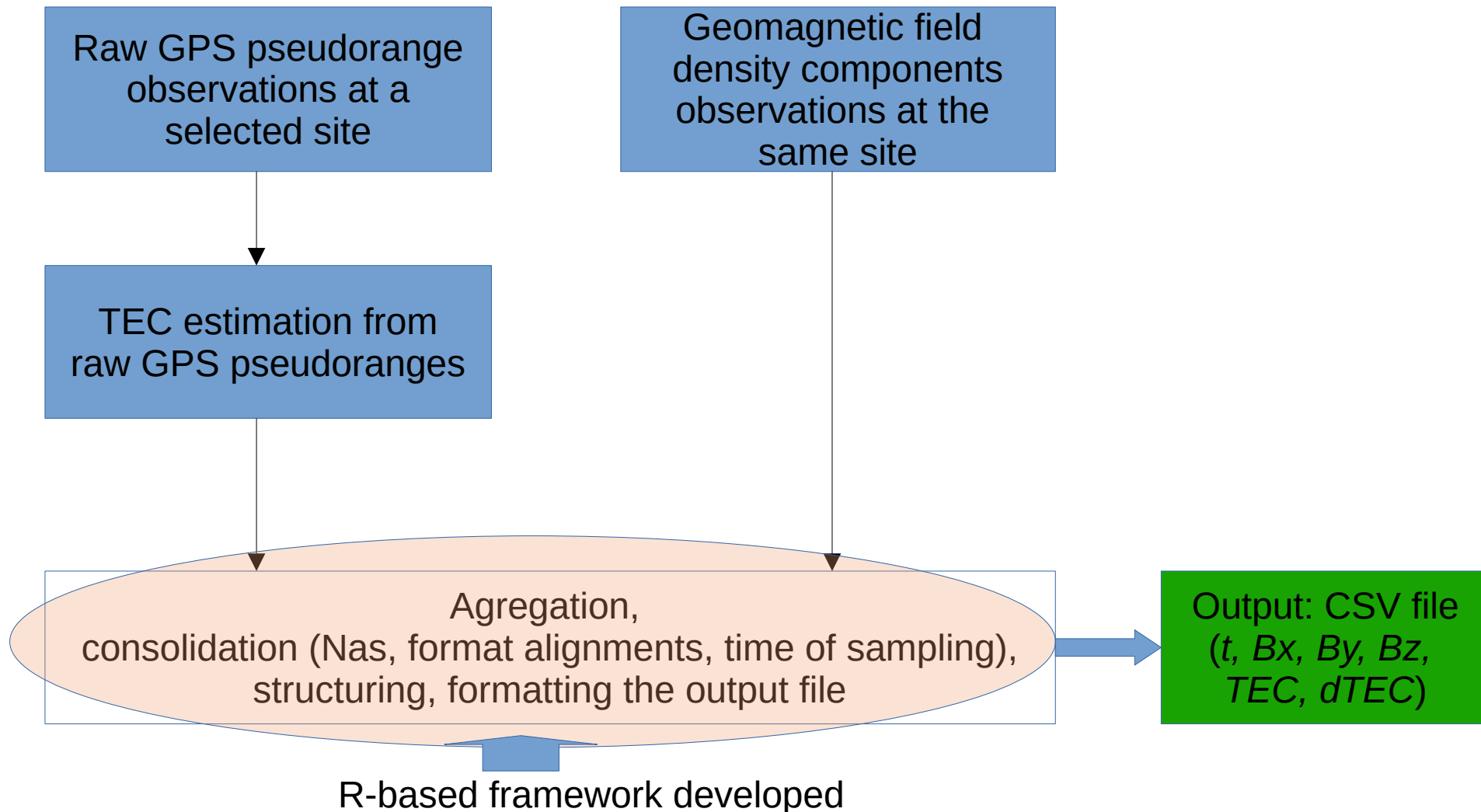
- Post-processing result in the CSV file structure:
time, Bx, By, Bz, GPS-based TEC estimate, dTEC

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- Method

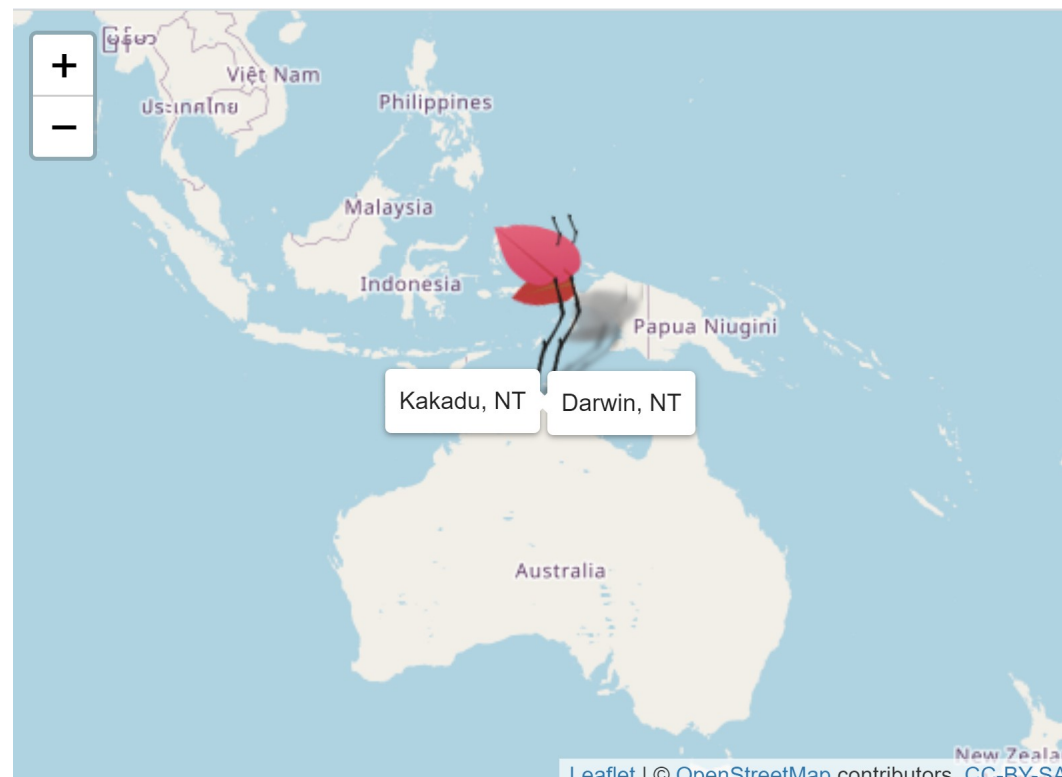
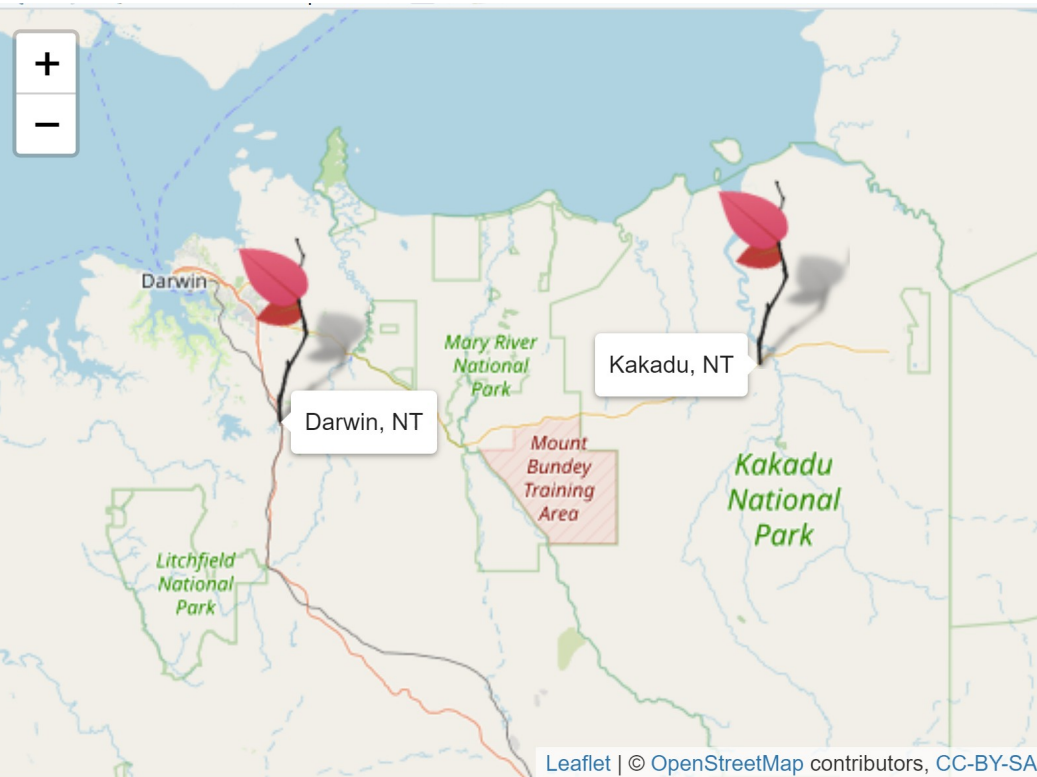


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- Material
- Case of the IGS Darwin, NT, Australia reference station (sub-equatorial region)



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- Research results
- Darwin 2014 hourly data set
- 522 297 hourly observations
- Data set openly available to everyone

DOY	hr	min	sec	TEC
Min. : 1	Min. : 0.00	Min. : 0.00	Min. : 0	Min. : 1.00
1st Qu.: 92	1st Qu.: 6.00	1st Qu.: 15.00	1st Qu.: 0	1st Qu.: 7.26
Median : 183	Median : 12.00	Median : 30.00	Median : 0	Median : 19.62
Mean : 183	Mean : 11.54	Mean : 29.56	Mean : 0	Mean : 40.00
3rd Qu.: 274	3rd Qu.: 18.00	3rd Qu.: 45.00	3rd Qu.: 0	3rd Qu.: 34.23
Max. : 365	Max. : 23.00	Max. : 59.00	Max. : 0	Max. : 1288.00

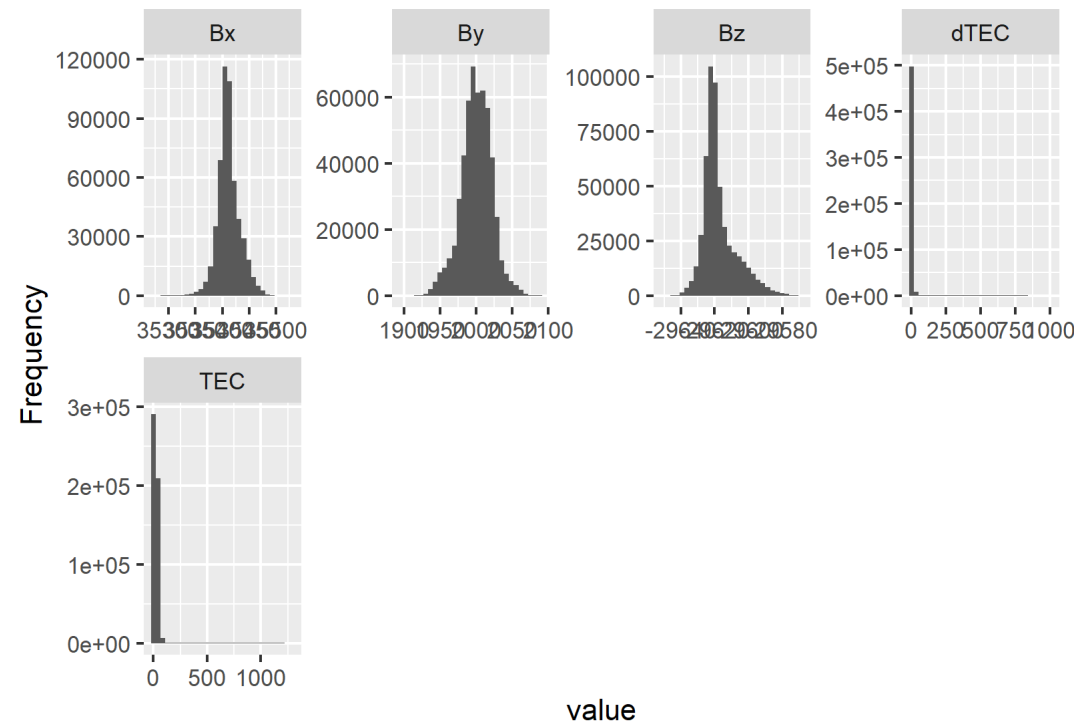
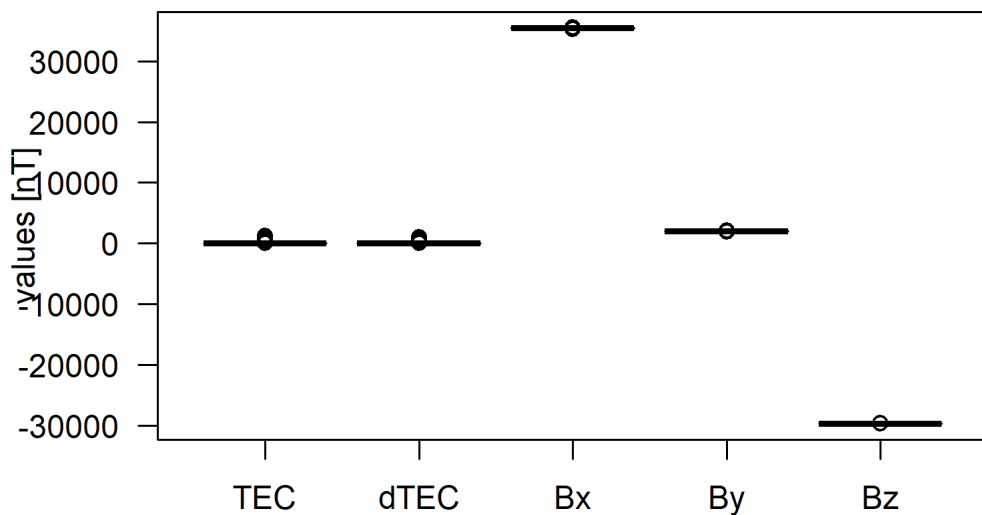
dTEC	Bx	By	Bz
Min. : 0.01	Min. : 35268	Min. : 1900	Min. : -29651
1st Qu.: 1.66	1st Qu.: 35400	1st Qu.: 1988	1st Qu.: -29623
Median : 3.13	Median : 35410	Median : 2001	Median : -29620
Mean : 15.88	Mean : 35412	Mean : 2001	Mean : -29617
3rd Qu.: 6.49	3rd Qu.: 35423	3rd Qu.: 2015	3rd Qu.: -29613
Max. : 997.00	Max. : 35527	Max. : 2092	Max. : -29570

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- Research results
- Framework developed in the R environment for statistical computing

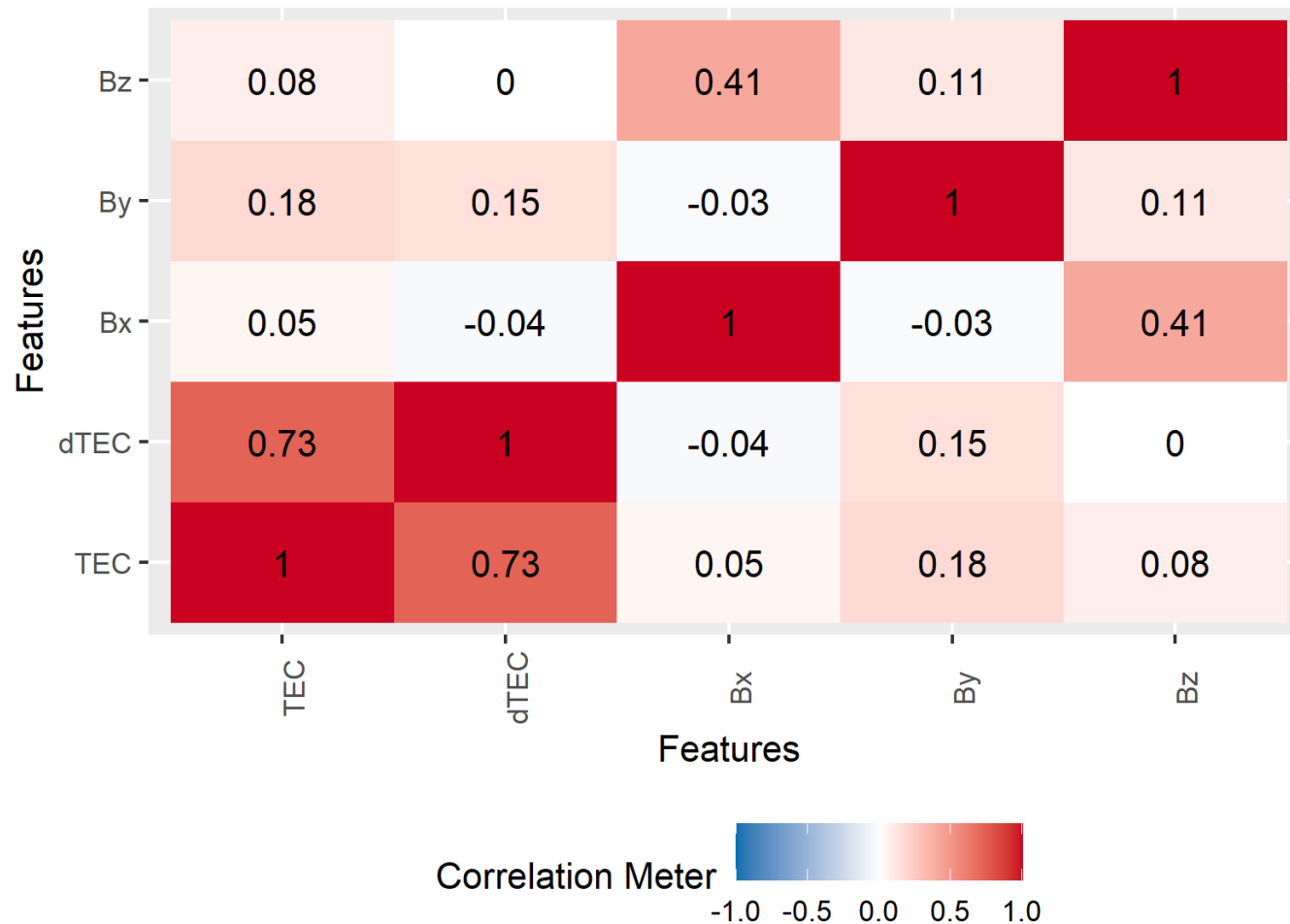


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- Research results



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- Discussion
- A method is presented and its deployment is demonstrated to create a massive data set of GPS/GNSS TEC data for further research in GNSS resilience
- Proposed principle utilises openly available GNSS raw pseudorange measurements, as well as geomagnetic observations
- Framework for data aggregation, collation, and formatting developed in the R environment for statistical computing

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- **Recommendations**
- **1. Facilitate international co-operation on systematic collection of dual-frequency GNSS pseudorange observations.**
- **2. Encourage collection of SW positioning environment data in the near proximity of GNSS pseudoranges collecting reference station.**
- **3. Facilitate international SW and GNSS data formats and structures standardisation activities.**
- **4. Educate researchers on utilisation of SW and GNSS observations databases, as well as implementation of widely accepted programming frameworks for statistical analysis and modelling, such as R.**

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In appreciation of your attention!

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