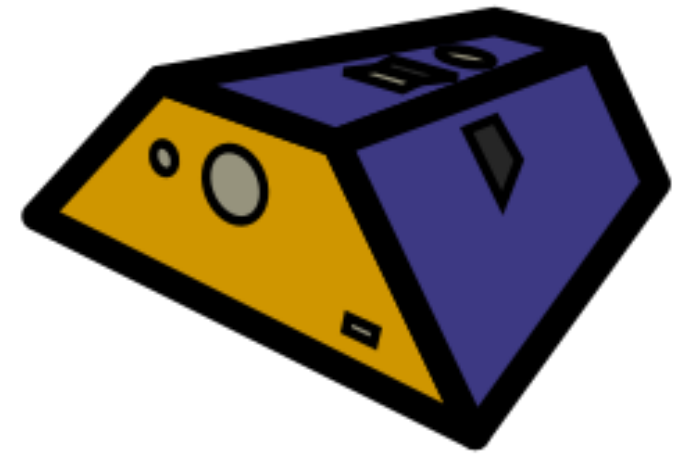


Introduction

GROOPS: The Gravity Recovery Object Oriented Programming System

- Source code is available on GitHub under open-source license GPL-3.0:
<https://github.com/groops-devs/groops>

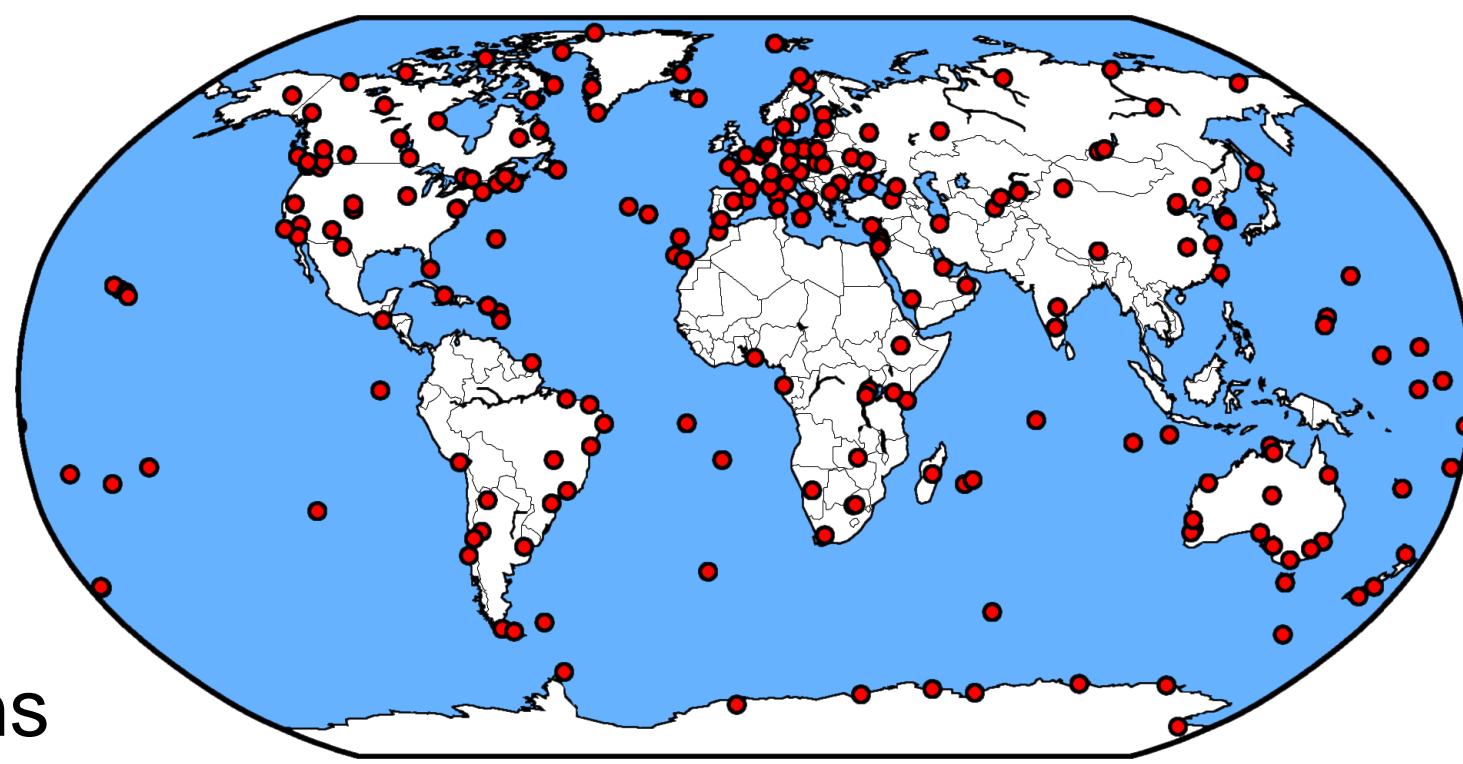


GROOPS

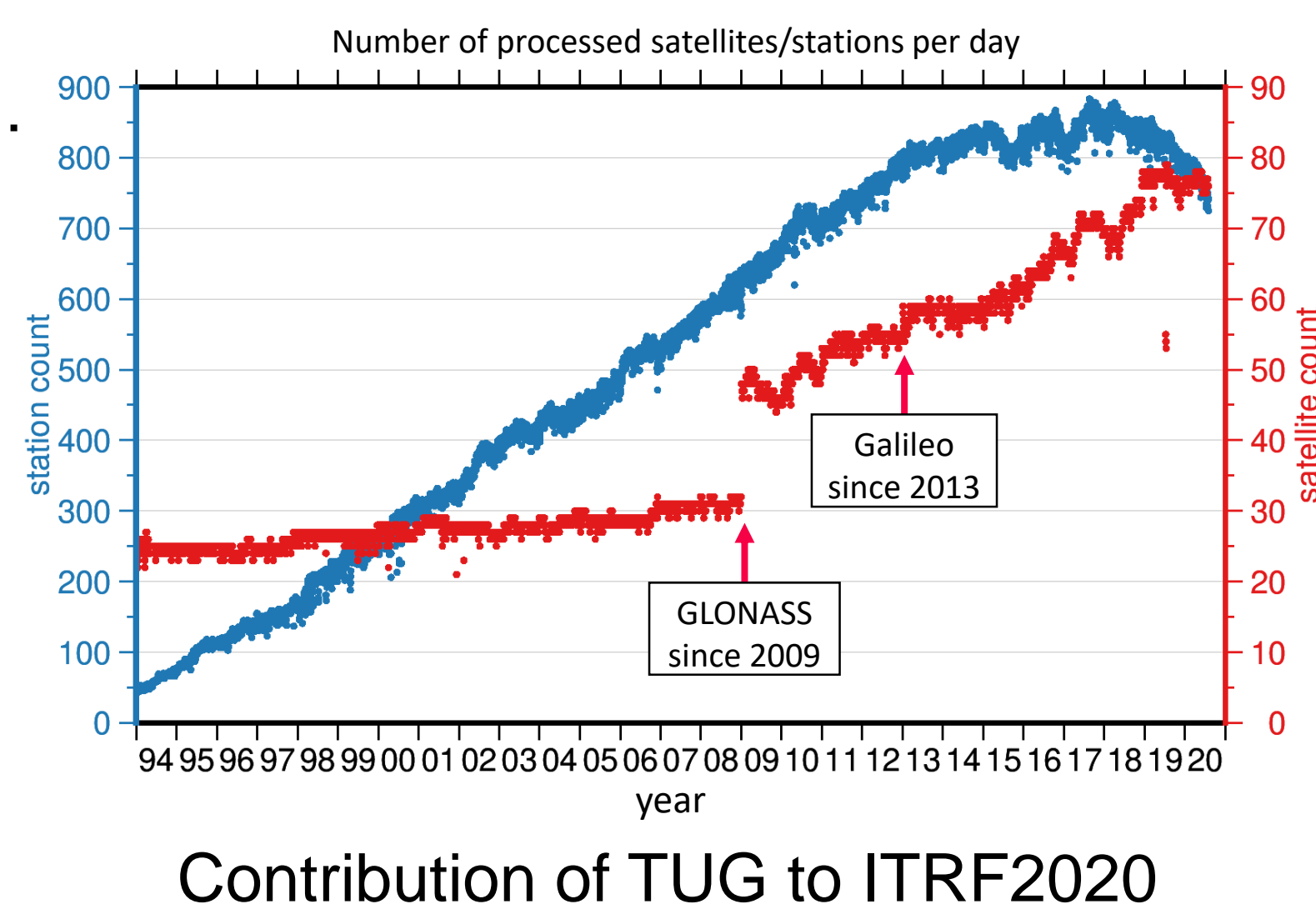
- > 300 programs
- ~200,000 lines of C++ code
- Parallelization using Message Passing Interface (MPI)
- Using fast BLAS/LAPACK for matrix algebra
- Linux, Windows, (Mac)

Global GNSS network processing

- Global network processing and PPP with the raw observation approach
 - All signals can be used: Code & Phases at all frequencies
 - GPS, Galileo, GLONASS, BeiDou
 - Ambiguity resolution with MLAMBDA

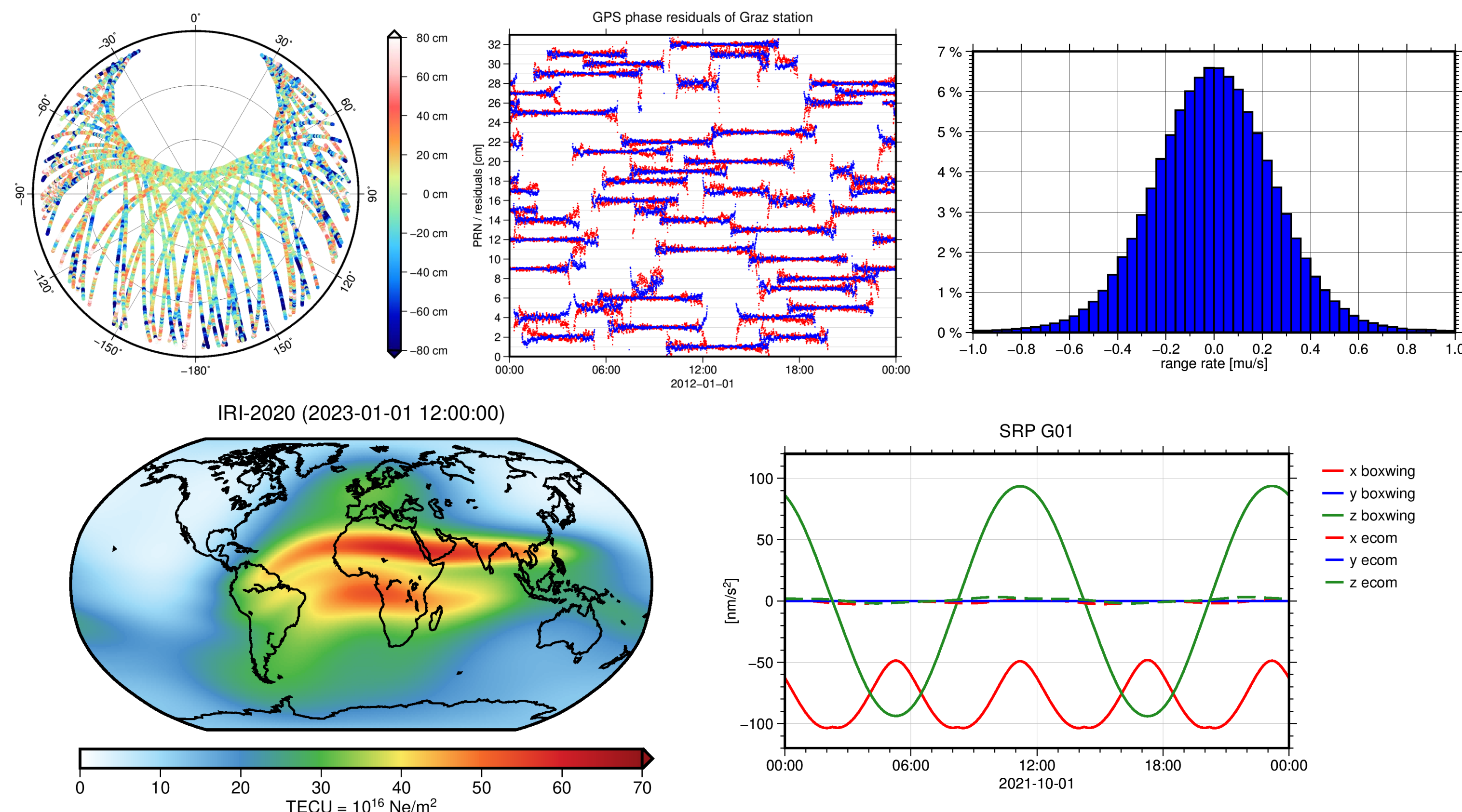


- Least squares adjustment with flexible parametrization:
 - Station coordinates
 - with possible NNR, NNT, NNS constrains
 - Dynamic satellite orbits
 - Boxwing model
 - Stochastic pulses, ECOM, ECOM2, ...
 - Kinematic LEO orbits
 - Earth Orientation Parameters (EOP)
 - Troposphere: VMF3, GPT, ...
 - Ionosphere: global maps, VTEC
 - Clocks (with stochastic modelling)
 - Code biases (pseudo-absolute)
 - Phase biases, ambiguities
 - Temporal changing bias (e.g. GPS L5)
 - Antenna Center Offsets & Variations
 - Receivers & transmitters

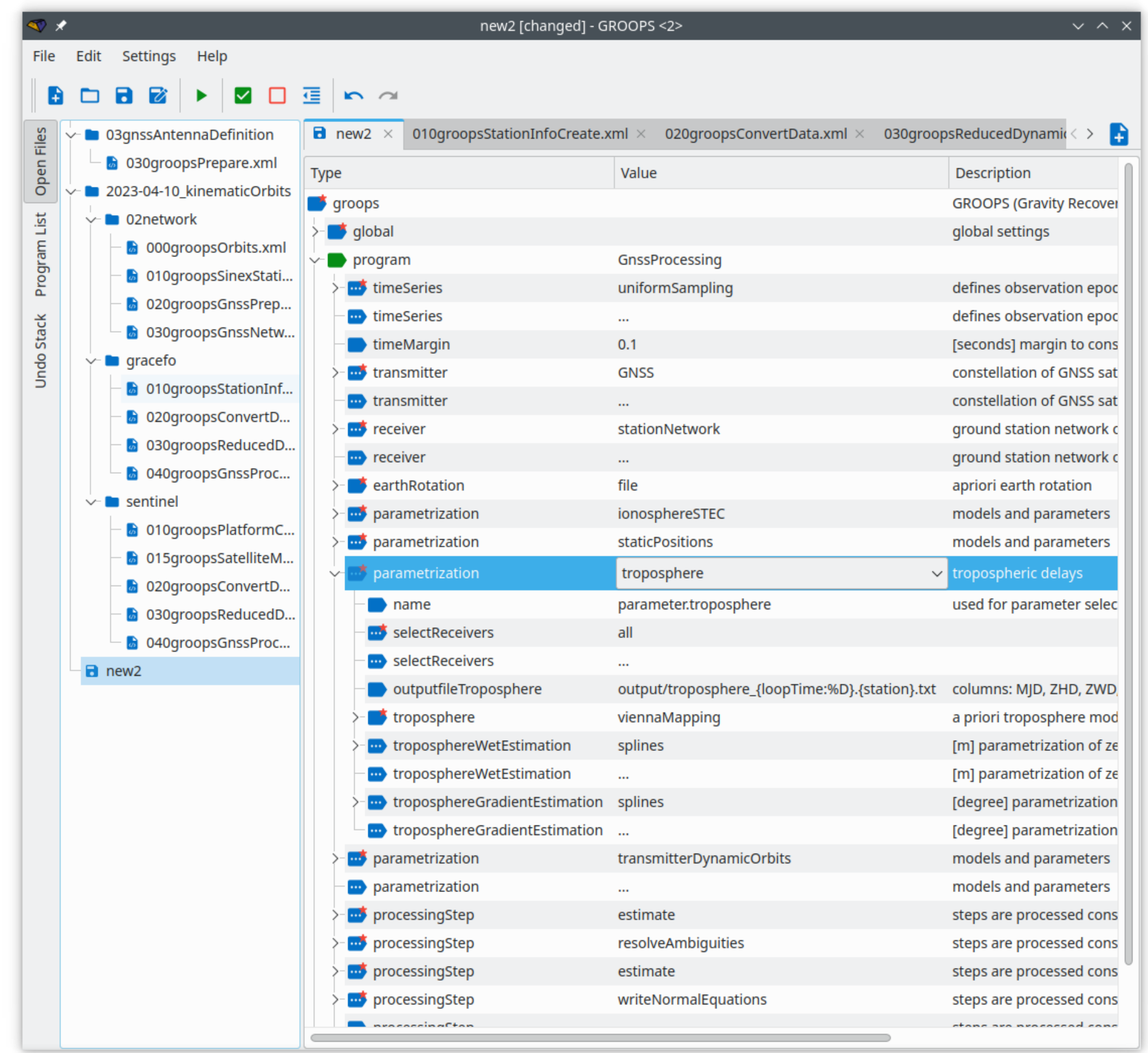


Data analysis and visualization

- Large number of data modification and analysis tools:
 - synchronization, outlier removal, filtering, sorting, ...
 - RMS, median, correlation, power spectral density, wavelets, ...
- Handling of normal equations:
 - parameter elimination, combination, Variance Component Estimation (VCE), ...
- Plotting using GMT: maps, sky views, graphs, ...



Graphical User Interface (GUI)



Scripting

Smooth transition of first „clicking“ the configuration towards automated jobs

- Frequently used settings can be defined as variables
- Mathematical expressions in all numeric input fields

```
removalCriteria abs(data0-data0median) > 3*1.4826*data0mad
```

- Loops/conditions for programs and config elements

```
inputfile [loop] [condition] gnssReceiver_{loopTime:%D}.(station).dat.gz
  loop timeSeries
  condition fileExist
```

- Date/time formatting, regular expressions

```
station {{trinxFile}/(#{4}).*AL$1} first 4 characters in lower case
```

- Passing variables in a console command

```
> groops -g timeStart=date2mjd(2024,7,2) --log logfile config.xml
```

Further applications

- Gravity field recovery
 - ITSG-Grace2018
 - GOCO06s
- Kinematic/reduced dynamic LEO orbits
 - CHAMP, GRACE, GOCE, Jason, MetOp, Sentinel, TerraSAR-X, ...
- Satellite Laser Ranging (SLR)
- Regional geoid determination: DACH, AlpGeoid
- Ocean tides for orbit determination
- Space weather: thermospheric densities

Products available: <https://ifg.tugraz.at/downloads>

Documentation

- Documentation <https://groops-devs.github.io/groops/html/index.html> and cookbooks
- YouTube tutorials <https://www.youtube.com/@groopsdevelopers8754>
- Discussion board <https://github.com/groops-devs/groops/discussions>

Acknowledgments

Financial support by the Austrian Research Promotion Agency (FFG) in the framework of the Austrian Space Application Program (ASAP 19, Project Geo Frame, 53749641).



References

[1] Mayer-Gürr, T., Behzadpour, S., Eicker, A., Ellmer, M., Koch, B., Krauss, S., Pock, C., Rieser, D., Strasser, S., Süsser-Rechberger, B., Zehentner, N., Kvas, A. (2021). GROOPS: A software toolkit for gravity field recovery and GNSS processing. *Computers & Geosciences*, [10.1016/j.cageo.2021.104864](https://doi.org/10.1016/j.cageo.2021.104864)
 [2] Strasser, S. (2022). Reprocessing Multiple GNSS Constellations and a Global Station Network from 1994 to 2020 with the Raw Observation Approach. Doctoral Thesis. [10.3217/978-3-85125-885-1](https://doi.org/10.3217/978-3-85125-885-1)

[3] Süsser-Rechberger, B., Krauss, K., Strasser, S., Mayer-Gürr, T. (2022). Improved precise kinematic LEO orbits based on the raw observation approach. *Advances in Space Research*, DOI: [10.1016/j.asr.2022.03.014](https://doi.org/10.1016/j.asr.2022.03.014).
 [4] Kvas, A., Brockmann, J. M., Krauss, S., Schubert, T., Gruber, T., Meyer, U., Mayer-Gürr, T., Schuh, W.-D., Jäggi, A., and Pail, R. (2021). GOCO06s – a satellite-only global gravity field model, *Earth Syst. Sci. Data*, DOI: [10.5194/essd-13-99-2021](https://doi.org/10.5194/essd-13-99-2021)

Contact

Torsten Mayer-Gürr
✉ mayer-guerr@tugraz.at

