

# GROOPS: The Open-source Software from TU Graz

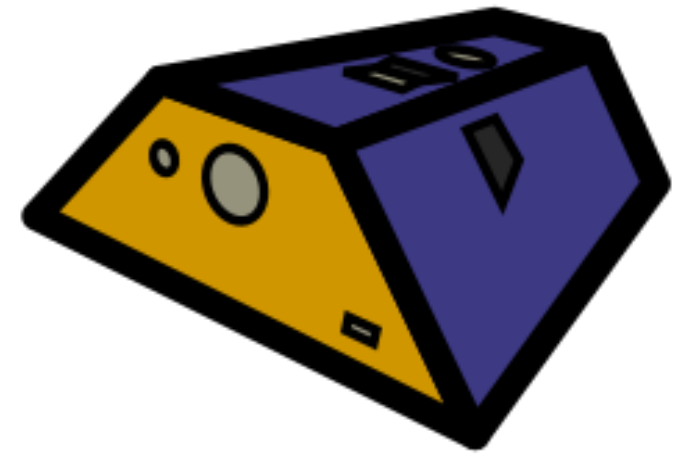


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## Introduction

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>

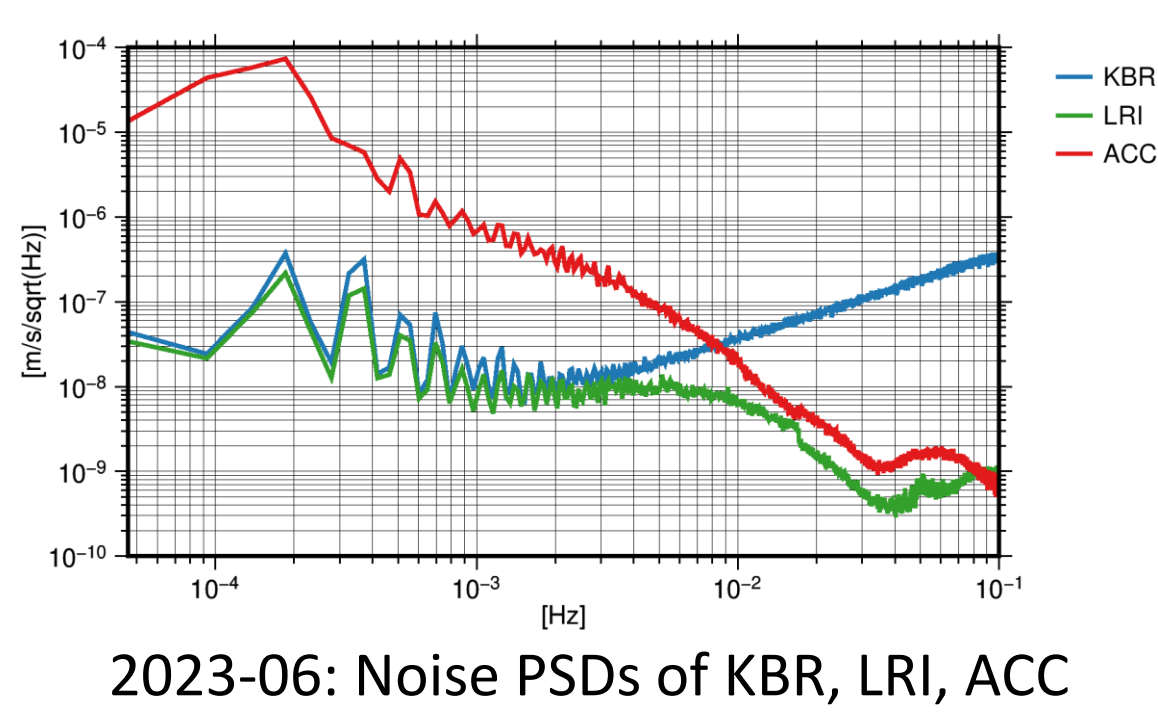


GROOPS

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

## GRACE processing: ITSG-Grace2018

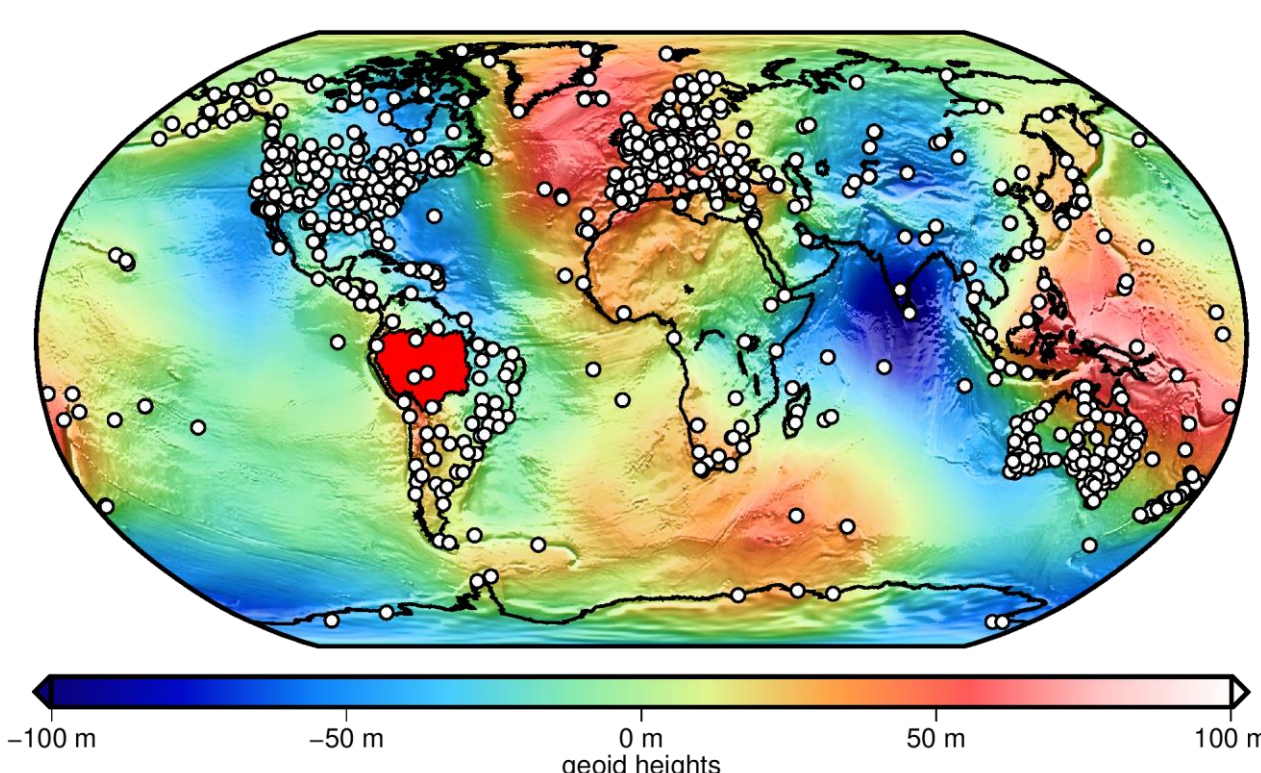
- Complete Level-1b to Level-2 processing
- Alternative accelerometer transplant product
- Kinematic orbits from GPS
- Integration of satellite orbits, variational equations
- Observation equations for orbits, KBR, LRI
- Sophisticated noise modelling:
  - Estimation of Power Spectral Densities (PSD) via Variance Component Estimation (VCE)
  - Subdaily errors in background models
- Daily Kalman filtered solutions



2023-06: Noise PSDs of KBR, LRI, ACC

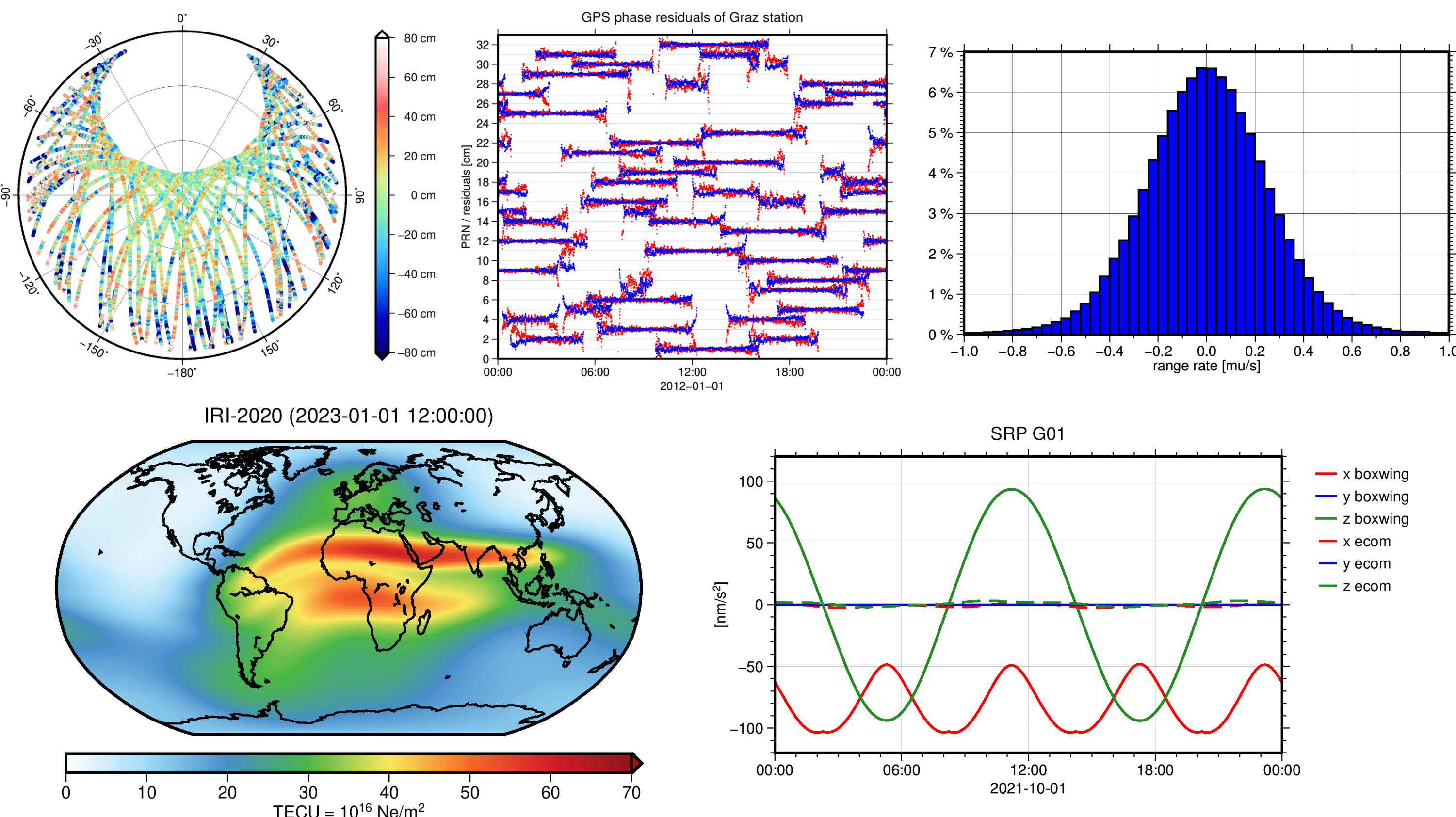
## Terrestrial water storage

- Analysis/synthesis of spherical harmonics
- Gridding: Geographical, Reuter,
- Filtering: Gaussian, DDK, ...
- Conversion to TWS, Loading deformation, Geoid heights, Gravity anomalies, ...
- GIA correction
- Area mean of river basins
- Temporal analysis:
  - Trend, seasonal, polynomial, splines, wavelets, ...

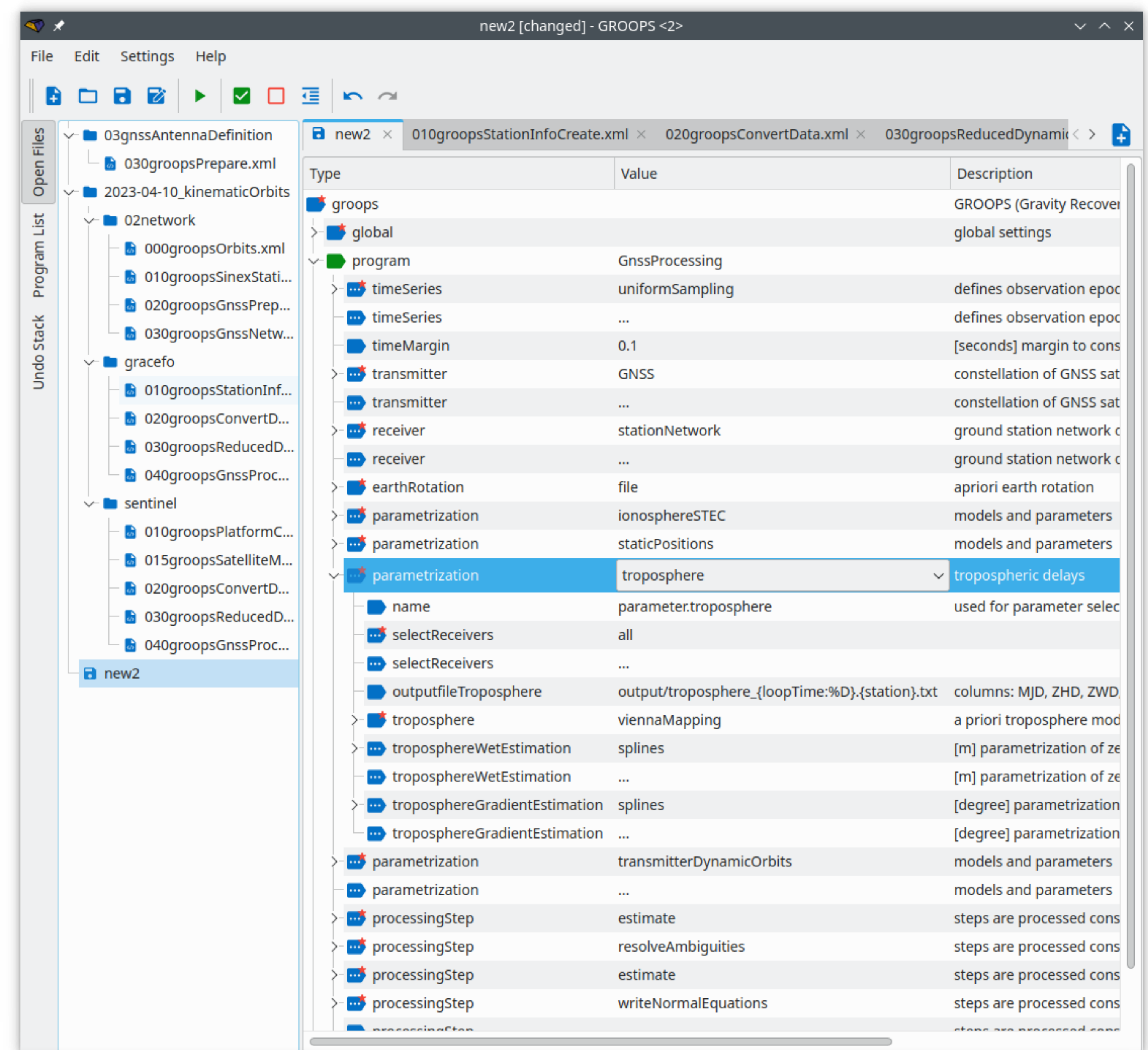


## Data analysis and visualization

- 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
- Global GNSS network processing
  - Contribution to ITRF2020
- 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 and cookbooks <https://groops-devs.github.io/groops/html/index.html>
- YouTube tutorials <https://www.youtube.com/@groopsdevelopers8754>
- Discussion board <https://github.com/groops-devs/groops/discussions>

## Acknowledgments

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## References

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 [2] Kvas, A., Behzadpour, S., Ellmer, M., Klinger, B., Strasser, S., Zehentner, N., Mayer-Gürr, T. (2019). ITSG-Grace2018: Overview and evaluation of a new GRACE-only gravity field time series. *Journal of Geophysical Research: Solid Earth*, <https://doi.org/10.1029/2019JB017415>

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 [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)

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