Localisation précise par moyens spatiaux

Bernese GNSS Software

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The Bernese GNSS Software

The *Bernese GNSS Software* is

- a scientific software package
- for multi-GNSS data analysis
- with highest accuracy requirements
- in regional to global scale networks.

It is developed, maintained and **used** at the Astronomical Institute of the University of Bern since many years.

AIUB

The *Bernese GNSS Software* is online at

http://www.bernese.unibe.ch .

Milestones in the development

Summer 1983 to Autumn 1984: visit of Gerhard Beutler in Canada
start of the first routines for the Bernese GPS Software

21. June 1992: the AIUB/CODE starts the activities as an analysis center of the IGS

1988 to 1995: release of version 3.0 to 3.5 in short intervals

September 1996: version 4.0 with ADDNEQ and BPE is published

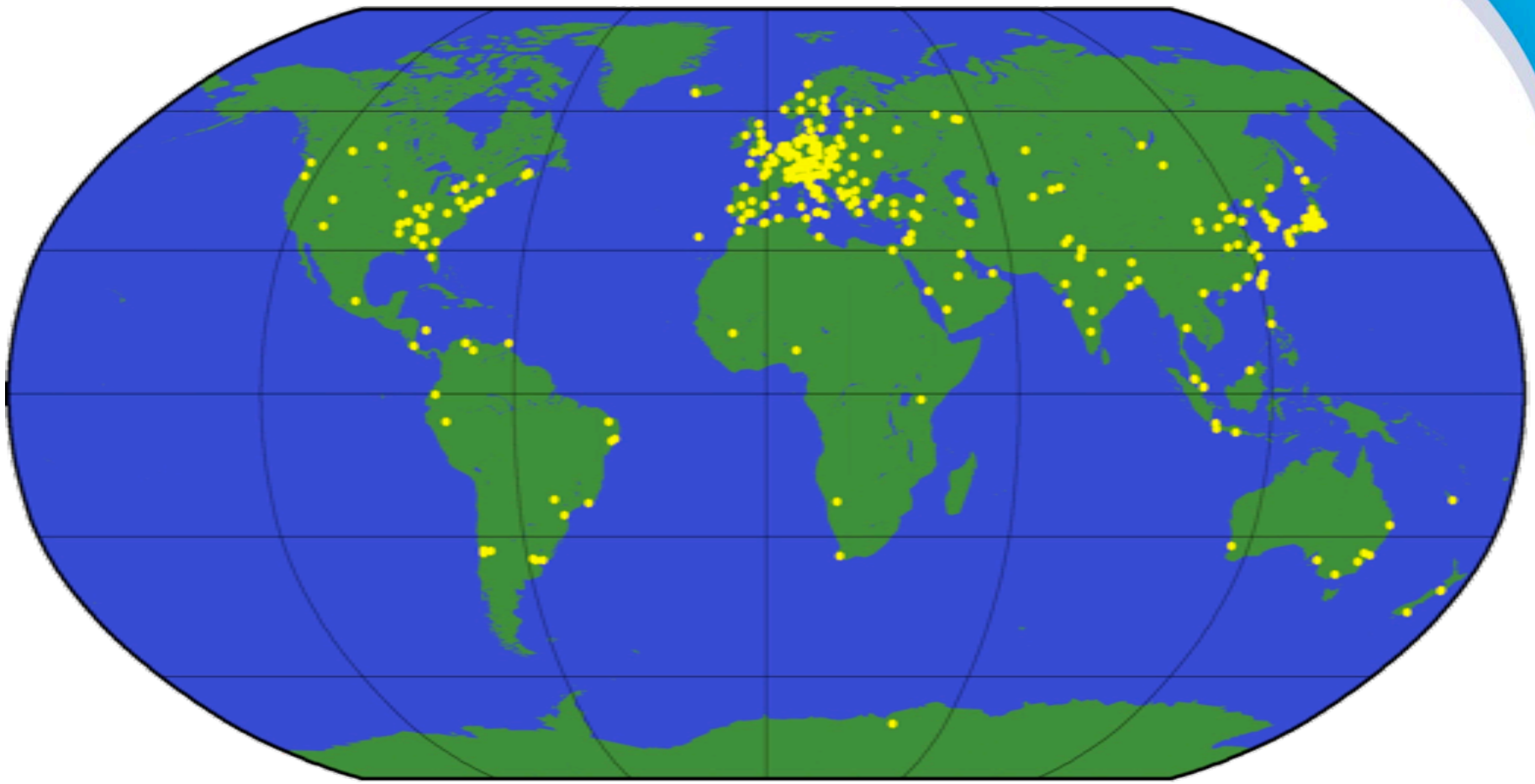
November 1999: version 4.2 contains capabilities for GLONASS processing and comparison of SLR measurements with GNSS orbits

May 2003: start of GPS/GLONASS combined solutions for the IGS

April 2004: version 5.0 with new BPE and GUI based on QT is released

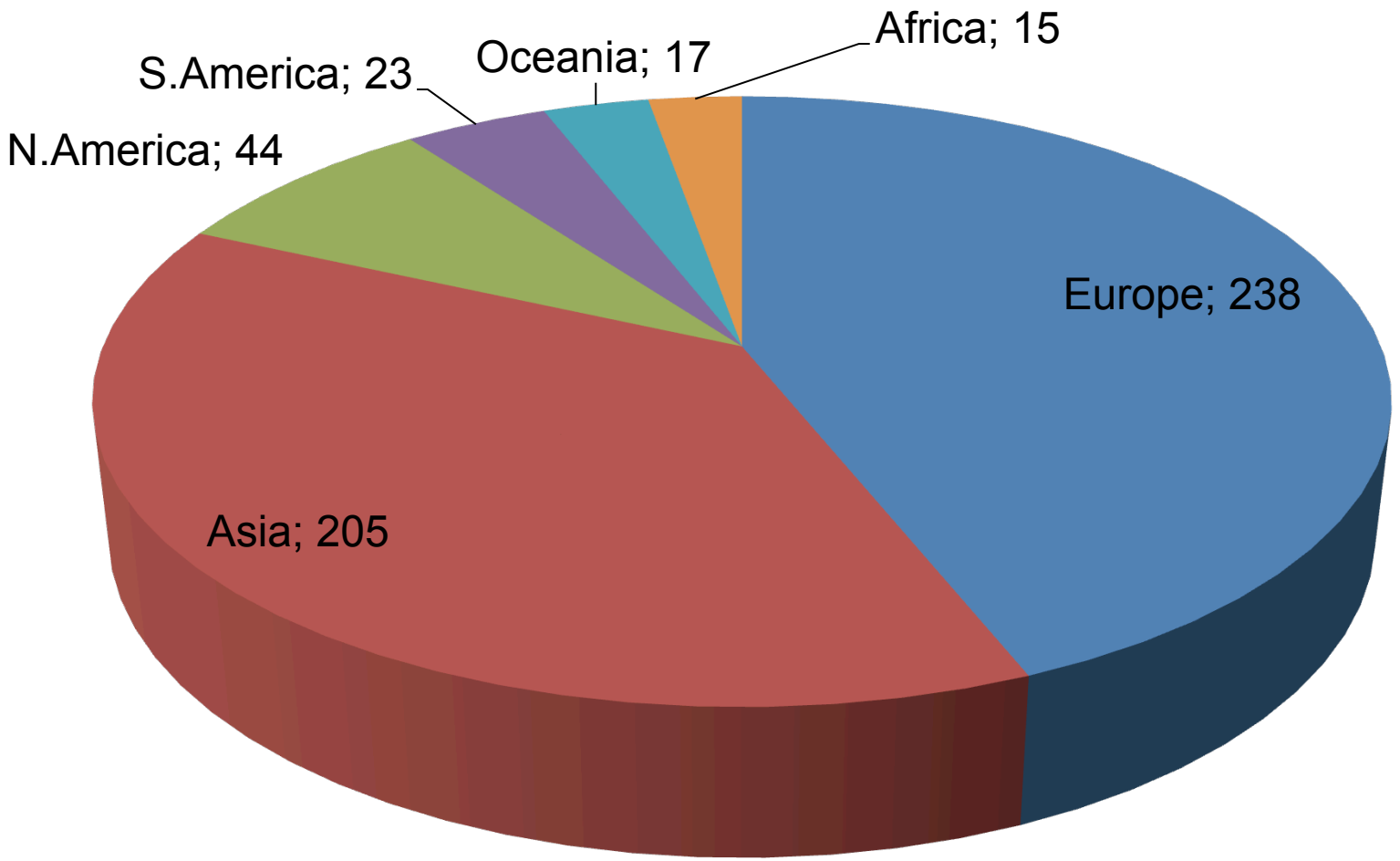
Summer 2012: version 5.2 is prepared for the release

Users of the Bernese GNSS Software



2012 Aug 21 16:11:00 Geographical Distribution of Institutions using the Bernese GPS Software

Users of the Bernese GNSS Software



Total: 542

Bernese GNSS Software, Version 5.2

The Bernese GNSS Software is particularly well suited for:

- rapid processing of small-size single and dual frequency surveys (static as well as kinematic stations — even LEOs),
- automatic processing of permanent networks (BPE),
- processing of data from a large number of receivers,
- combination of different receiver types, taking receiver and satellite antenna phase center variations into account,
- combined processing of GPS and GLONASS observations,
- ambiguity resolution on long baselines (2000 km and longer),
- generation of minimum constraint network solutions,
- ionosphere and troposphere monitoring,
- precise point positioning,
- clock offset estimation and time transfer,
- orbit determination and estimation of Earth orientation parameters.
- . . .

Bernese GNSS Software, Version 5.2

Highlights of the Bernese GNSS Software:

- compliant to the IERS2010 and IGS standards
- ambiguity resolution not only for GPS but also for GLONASS
- estimation of clock corrections from GLONASS data (IFB)
- extensive use of normal equation operations
  (much more efficient for starting each operation on observation level)
- automated analysis of time series (FODITS)
- intensive check of meta-data when importing observation files

Bernese GNSS Software, Version 5.2

Highlights of the Bernese GNSS Software:

- receiver/satellite antenna model estimation
- GLONASS-GPS translation bias to compensate for antenna model deficiency

- State-of-the-art modelling for
  - troposphere modeling: GMF/GPT, VMF1
  - ionosphere modeling: higher order ionosphere correction

- introducing corrections for up to three loading effects from grid files (on observation level with scaling factor)

- handling (estimation) of repositioining events of GPS satellites

Bernese GNSS Software, Version 5.2

The Bernese GNSS Software supports all important international formats:

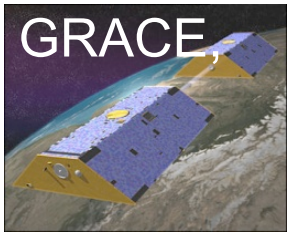
- **RINEX** for observations, navigation messages, meteo data (input)
- **SP3c** for precise orbits (input/output)
- **IGS/IERS** for pole information (input/output)
- **Clock RINEX** for satellite and station clocks (input/output)
- **IONEX** for regional and global ionosphere models (output)
- **SINEX** for solutions and meta–information (input/output)
- **Troposphere SINEX** for troposphere parameter estimates (output)
- **ANTEX** for antenna phase center offsets and variations (input)
- **Vienna Grid Files** coefficients for VMF1 corrections (input)

Bernese GNSS Software, Version 5.2

The Bernese GNSS Software is not only designed for "classical", geodetic, ground-based applications.

- GPS-data from Low Earth Orbiters (LEOs) may be processed.

- Orbits can be computed on a few cm level.
- kinematic as well as a reduced–dynamic orbit determination
- 



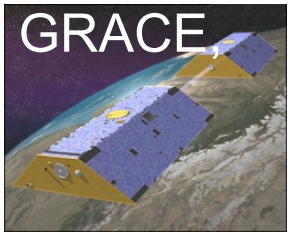
but also MetOp, JASON, SAC–C, . . .
- For the GOCE mission the AIUB is responsible for the Precise Science Orbit.
- Full consistency of the models for the IGS-product generation and their use for LEO orbit determination.

Bernese GNSS Software, developments

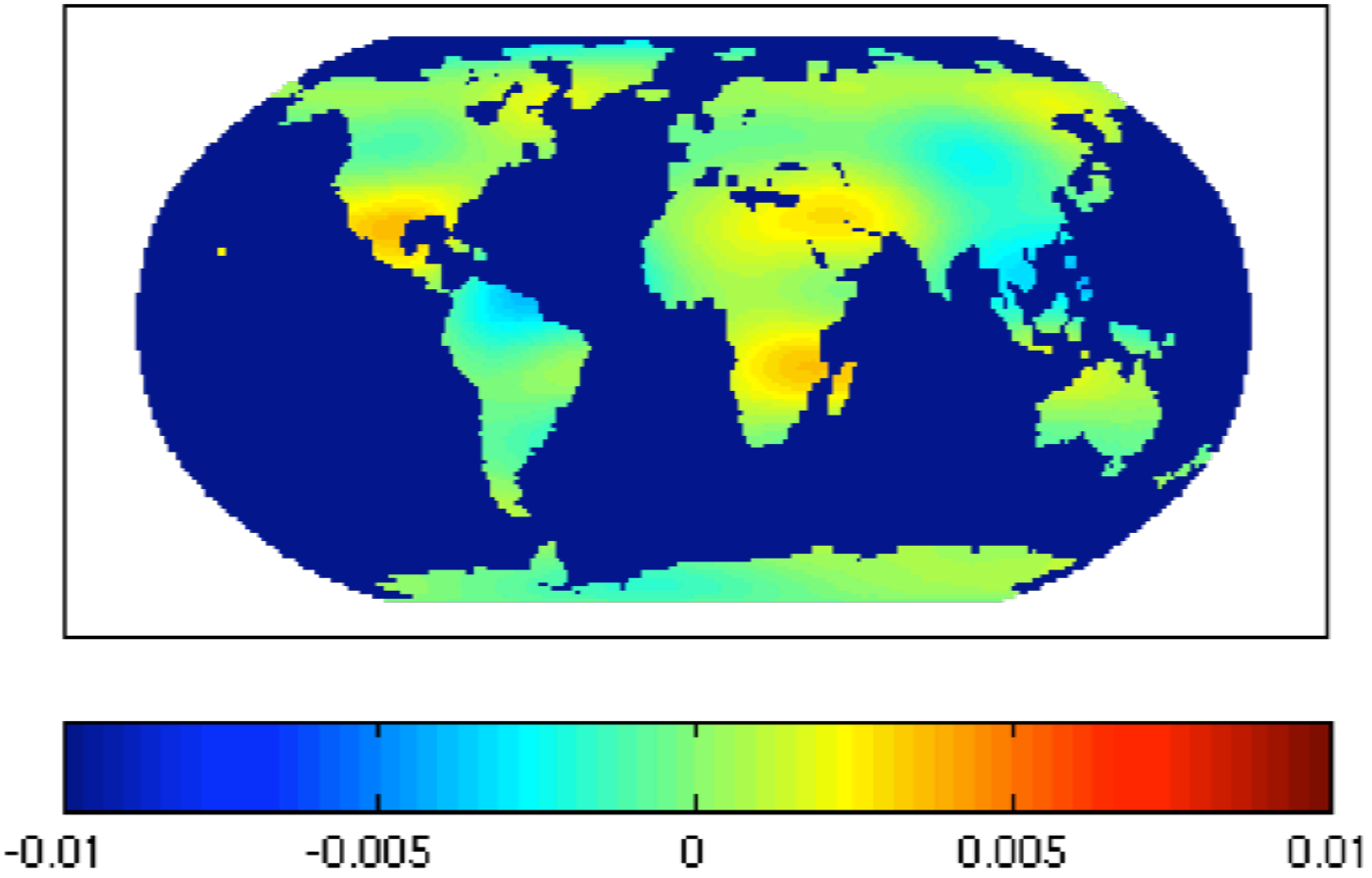
Based on the Bernese GNSS Software a special environment for gravity field determination has been developed.

- full consistency with IGS- and LEO-orbits

- gravity field determination based on kinematic LEO trajectories, K-band (GRACE), and gradiometer (GOCE) measurements.

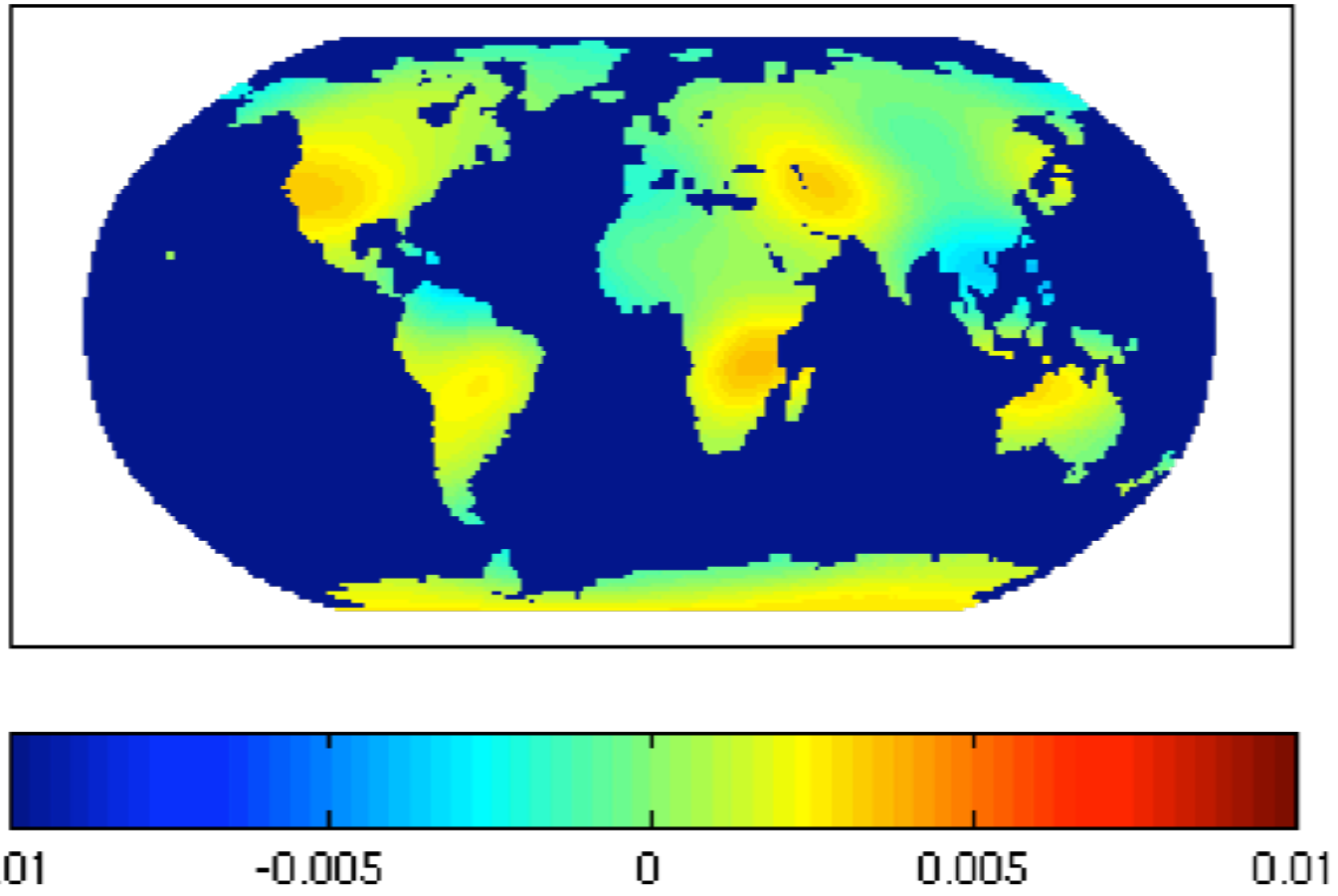


Bernese GNSS Software, developments



Monthly mean geoid heights from CHAMP from years 2002-2009,
Prange : Geodätisch-geophysikalische Arbeiten in der Schweiz, vol. 81

Bernese GNSS Software, developments



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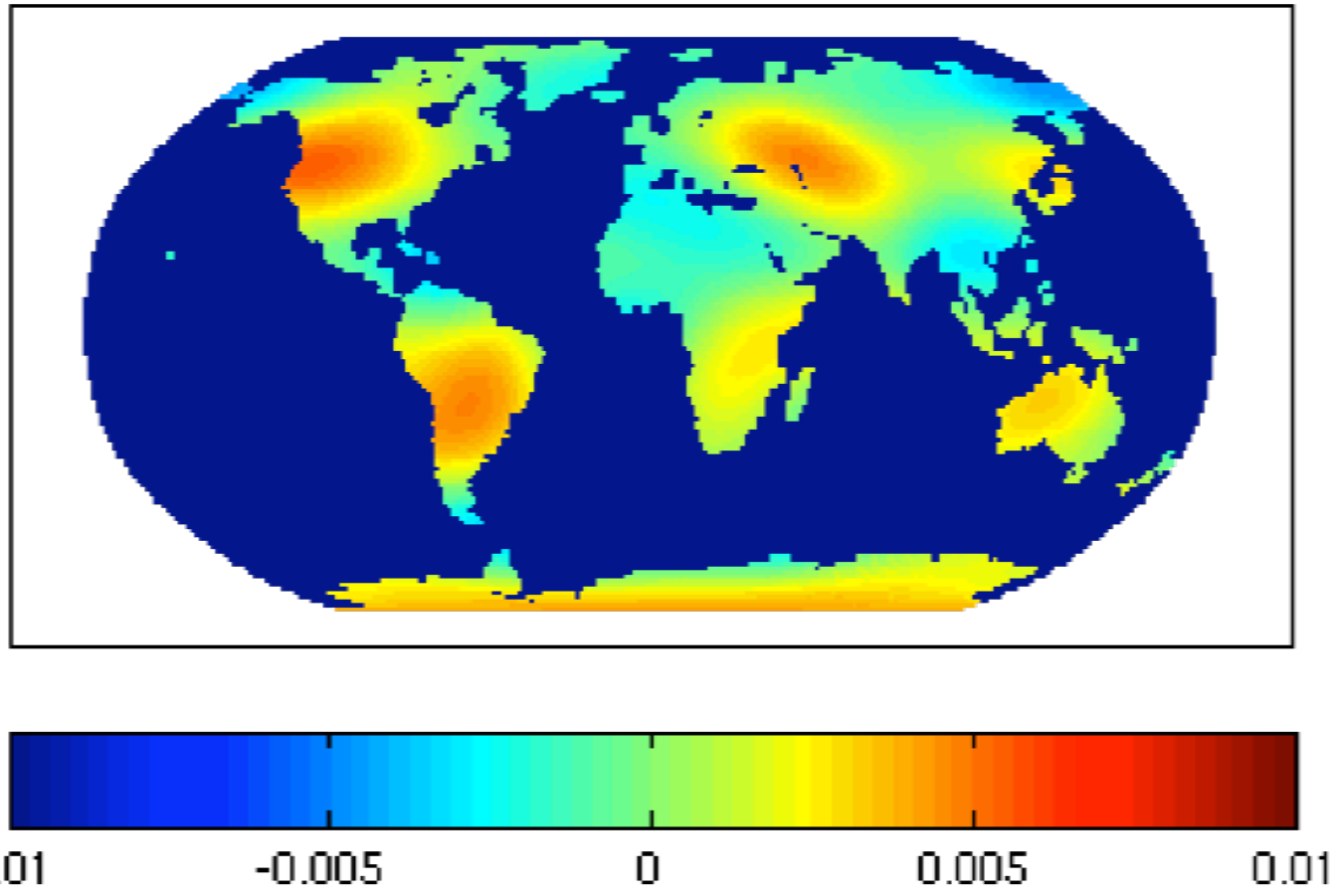
Bernese GNSS Software, developments



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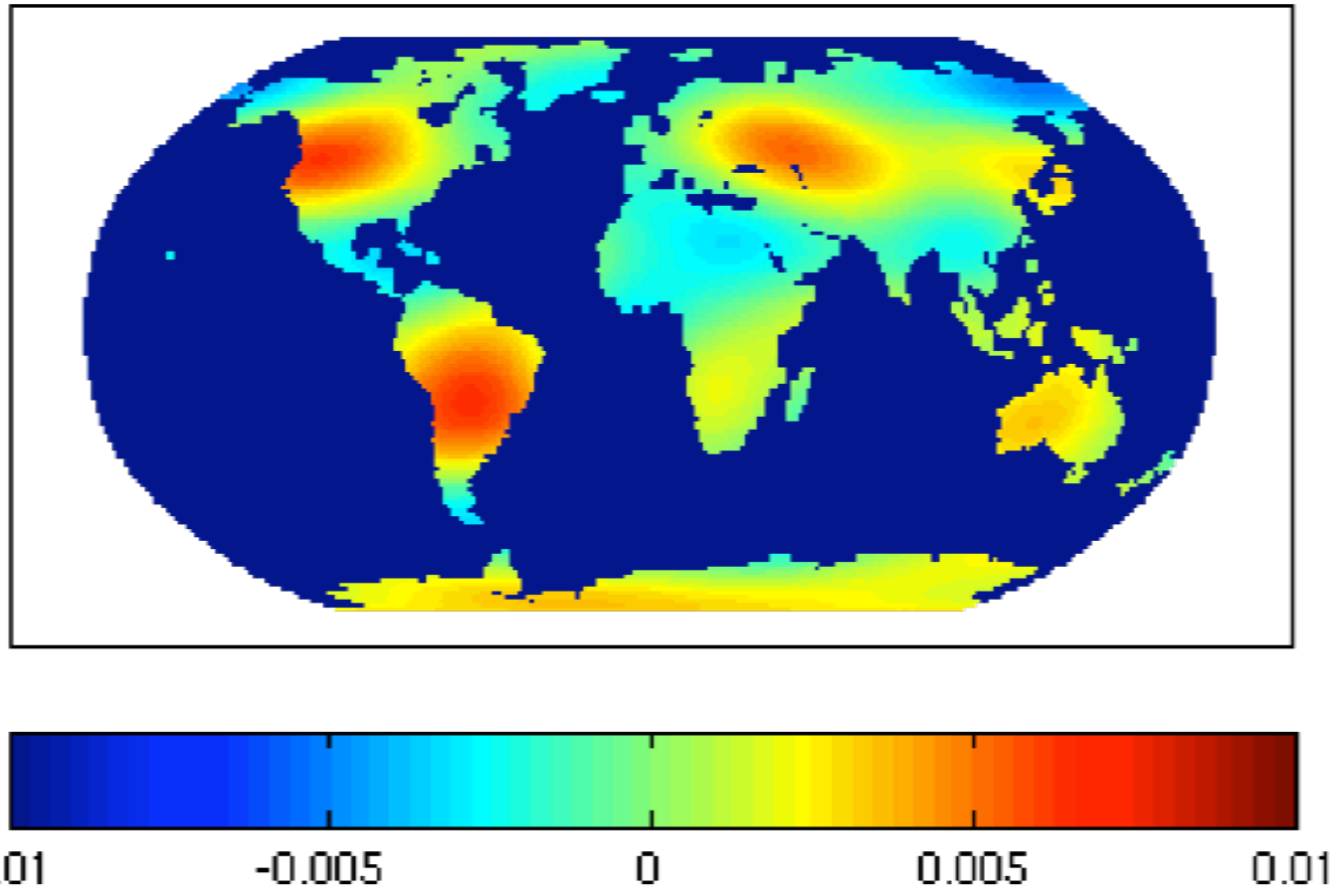

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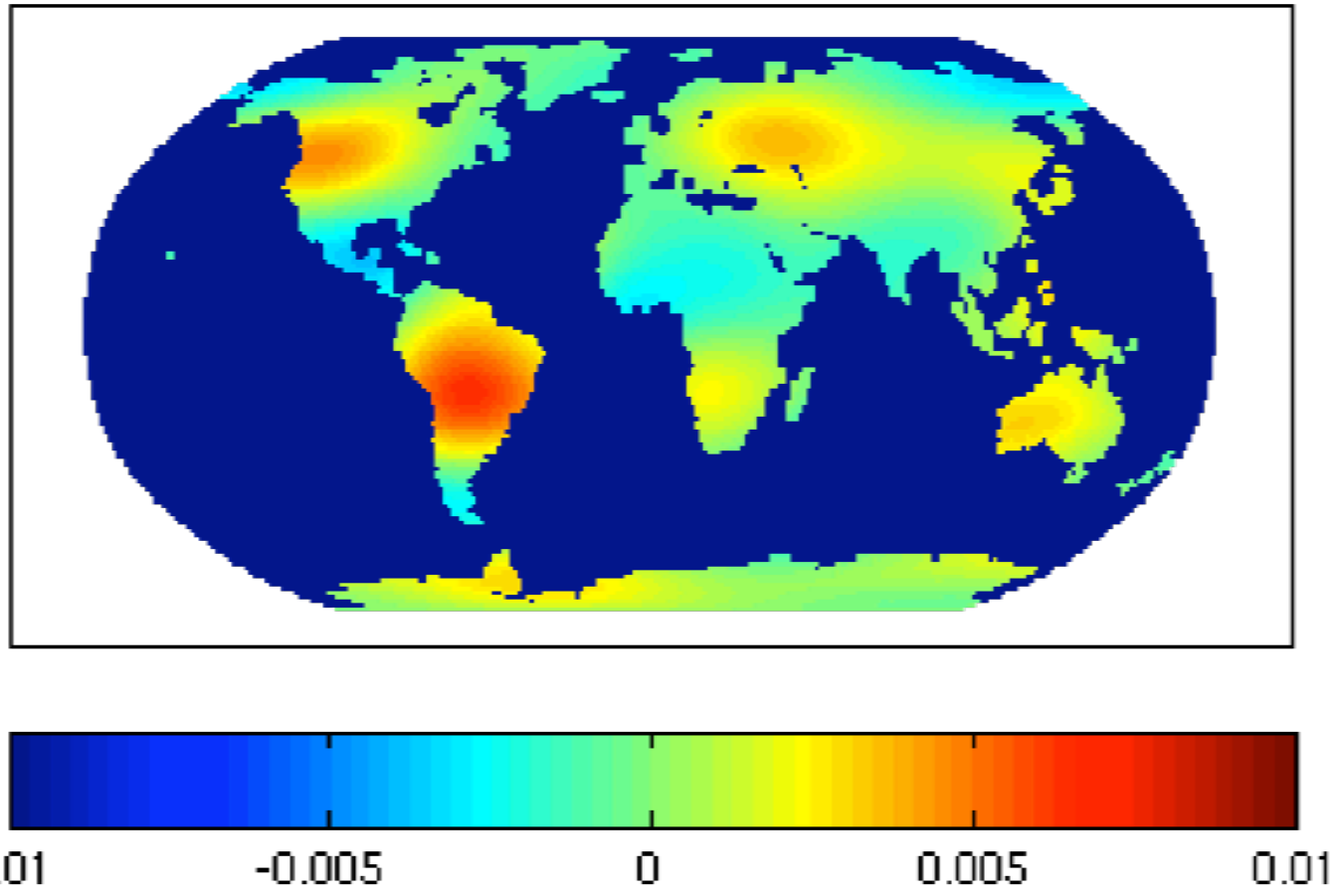

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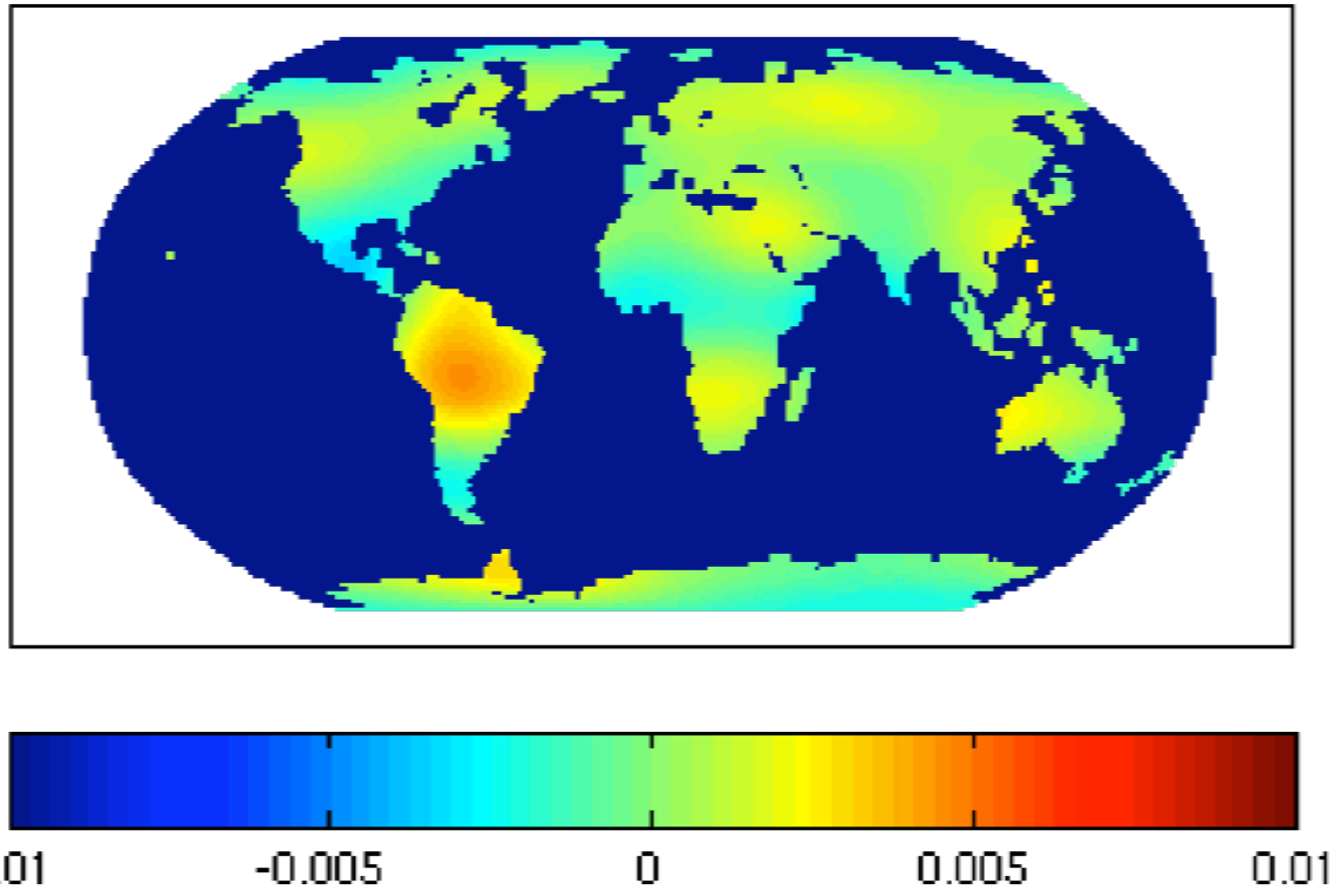

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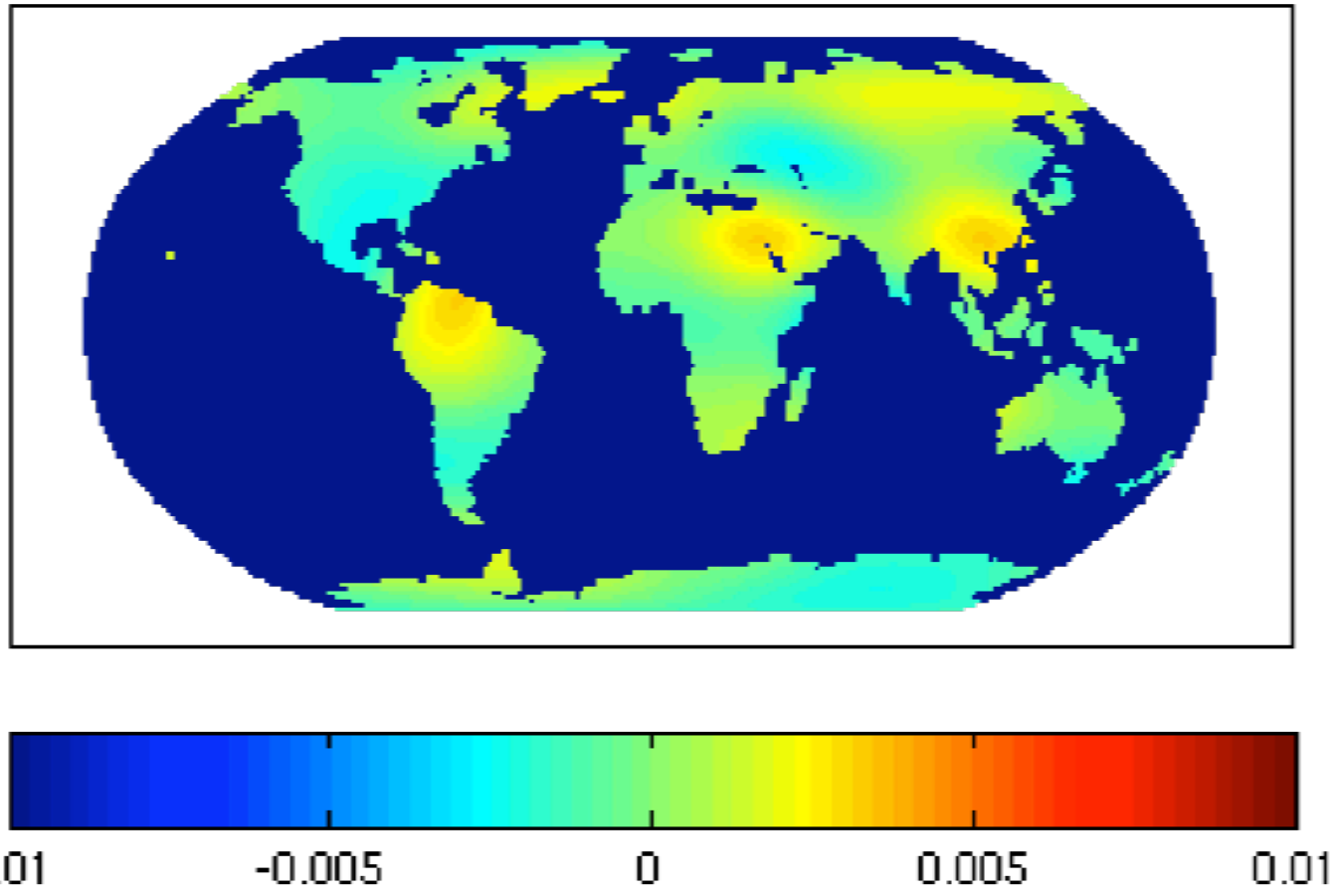

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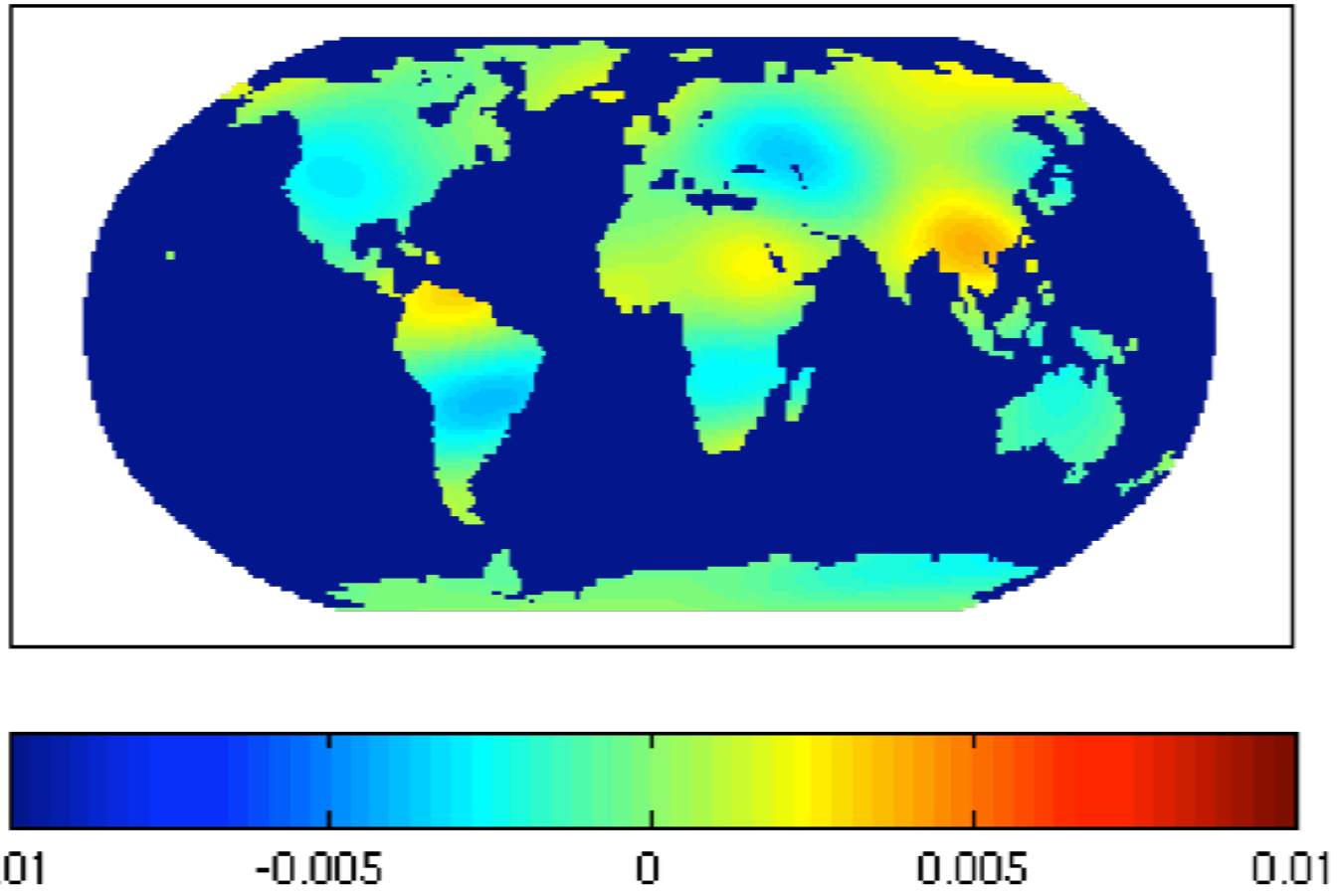

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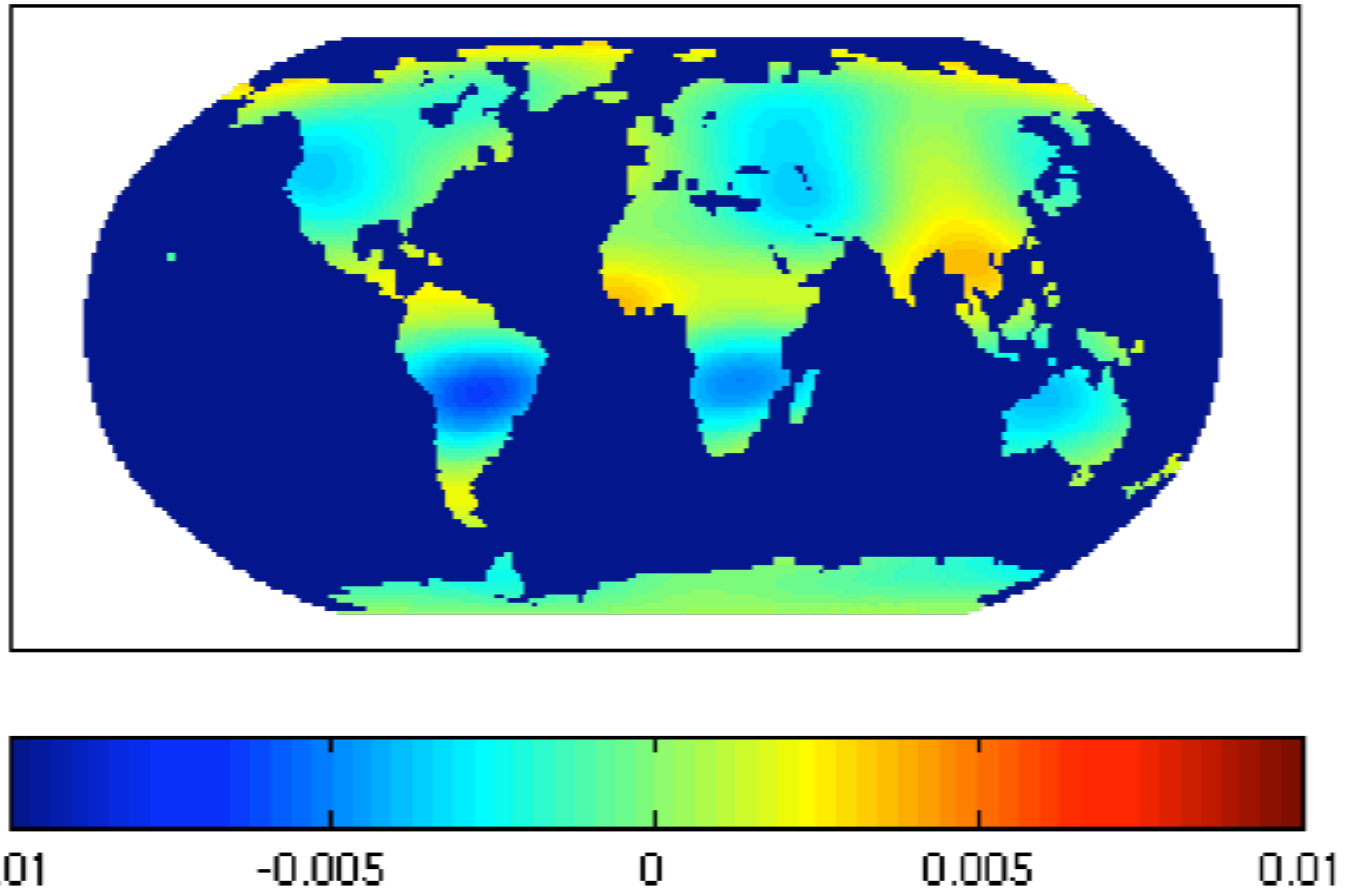

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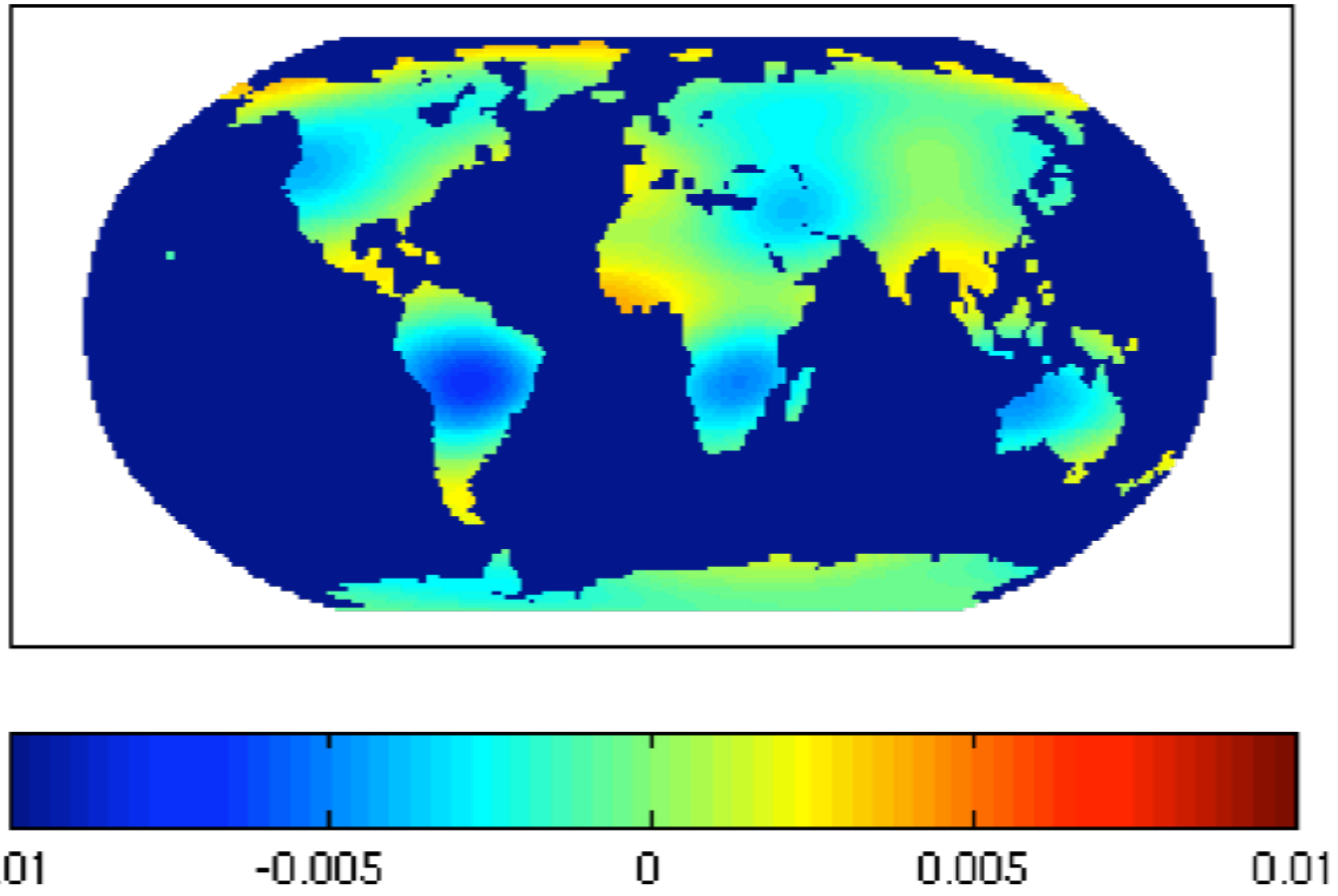
Bernese GNSS Software, developments



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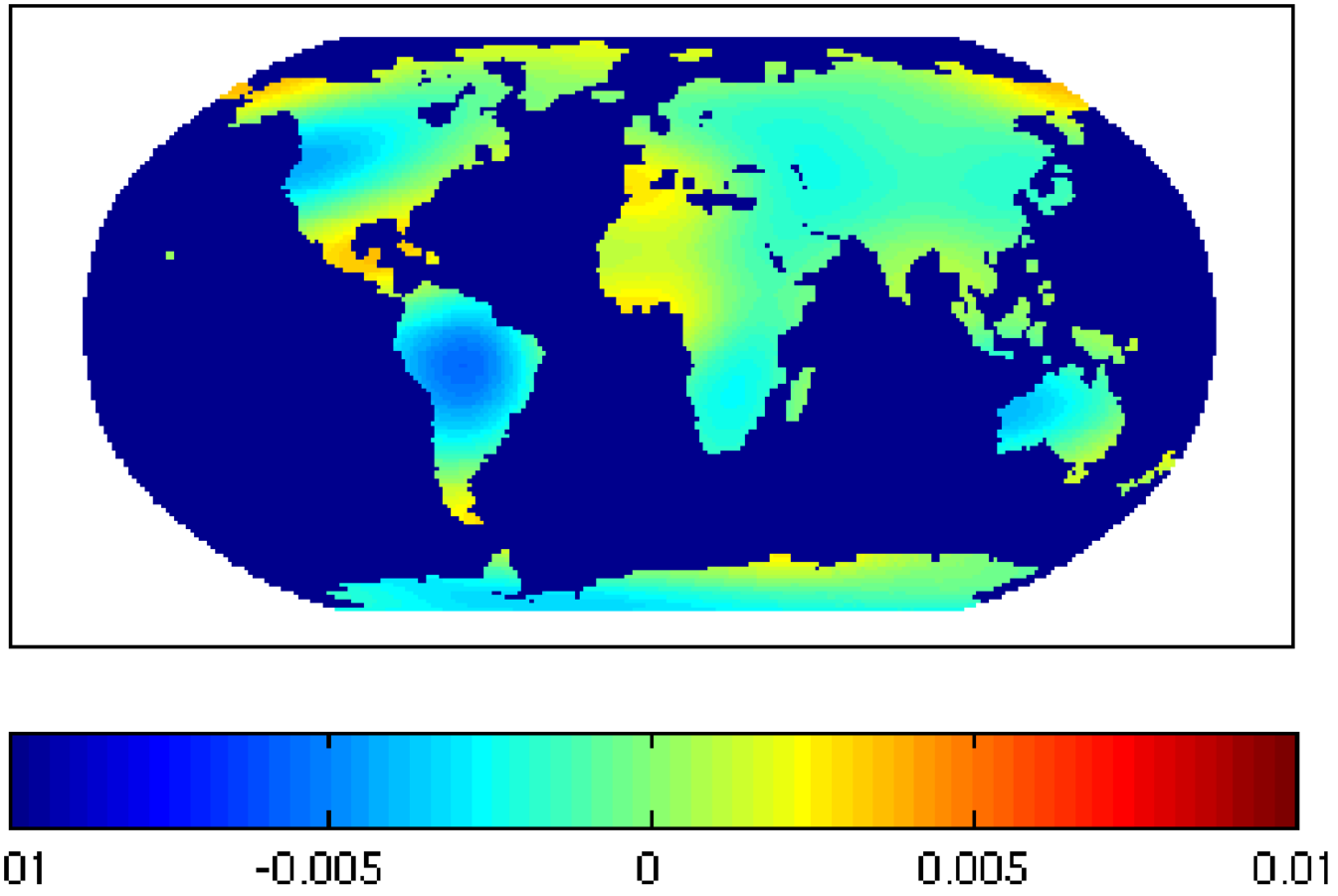

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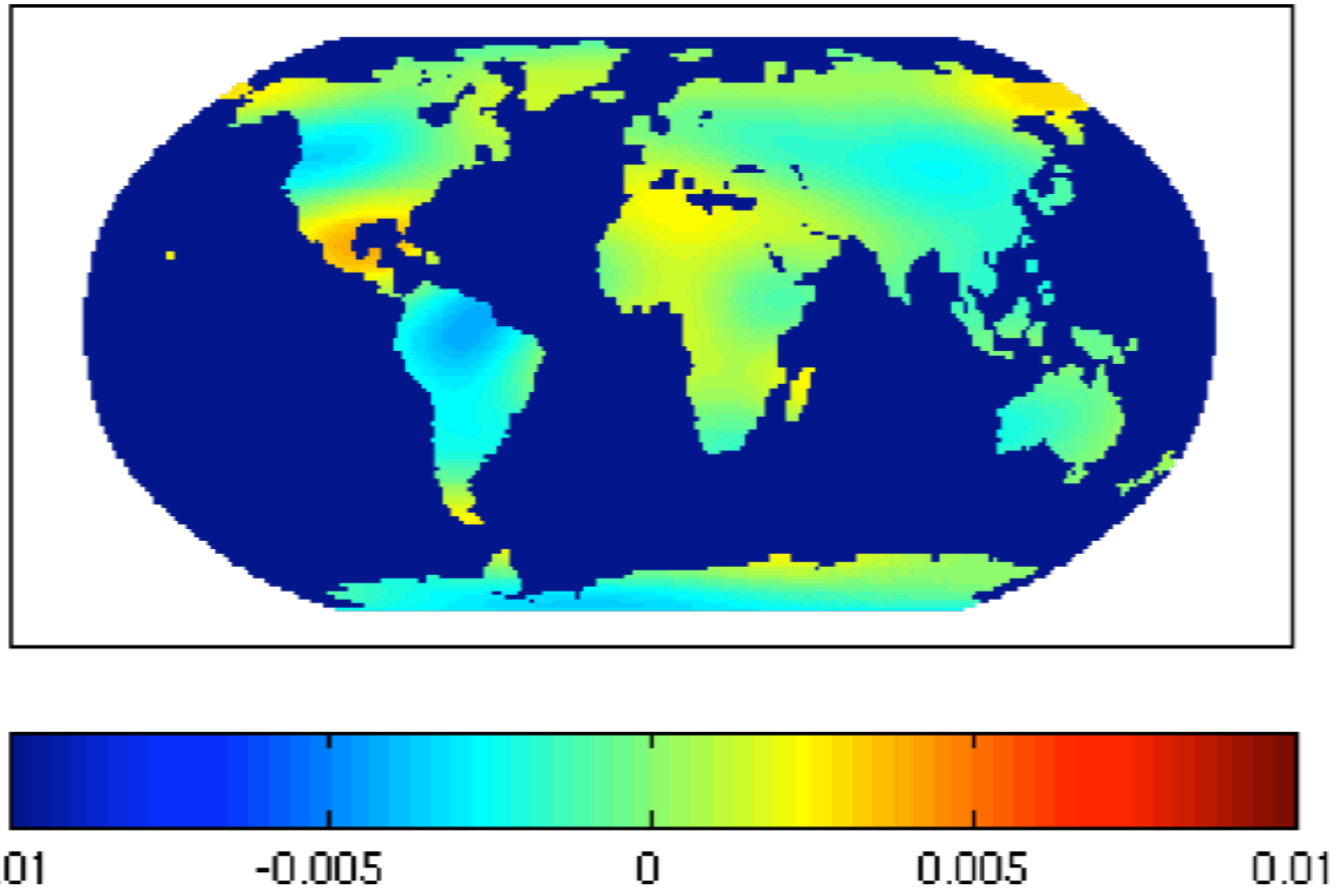

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Bernese GNSS Software, Version 5.2

The Bernese GNSS Software can also process SLR measurements.

- independent validation of estimated orbits for GNSS and LEO satellites

Project with BKG, Frankfurt a. M.:

- extended to process LAGEOS/ETALON satellites
- ILRS analysis center at BKG is using the software for their activities (ILRS-Banchmark test passed in 2010)

- meanwhile further extended to other (lower) geodetic laser satellites

Bernese GNSS Software, Version 5.2

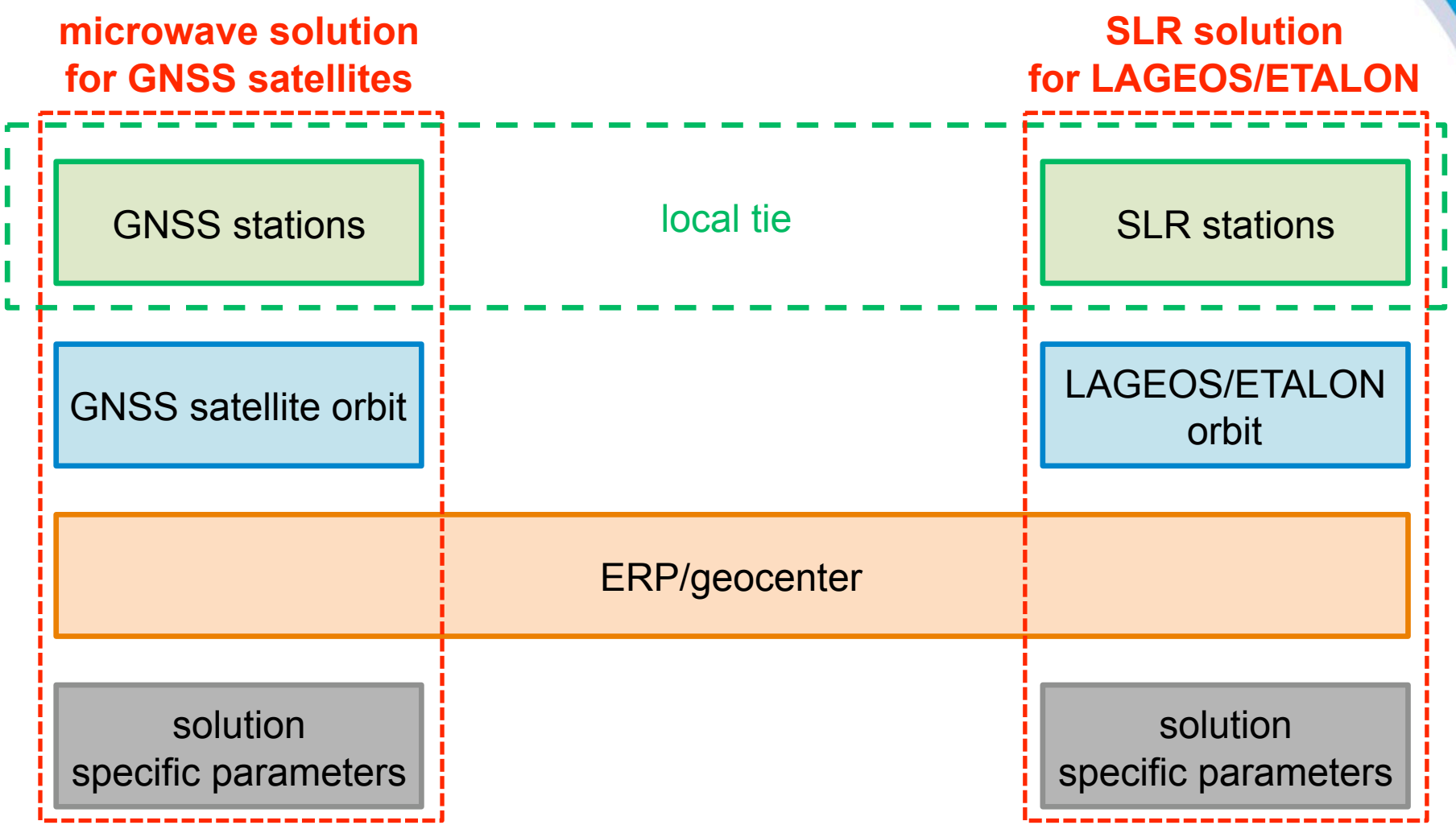
microwave solution for GNSS satellites

- GNSS stations
- GNSS satellite orbit
- ERP/geocenter
- solution specific parameters

SLR solution for LAGEOS/ETALON

- SLR stations
- LAGEOS/ETALON orbit
- ERP/geocenter
- solution specific parameters

Bernese GNSS Software, Version 5.2



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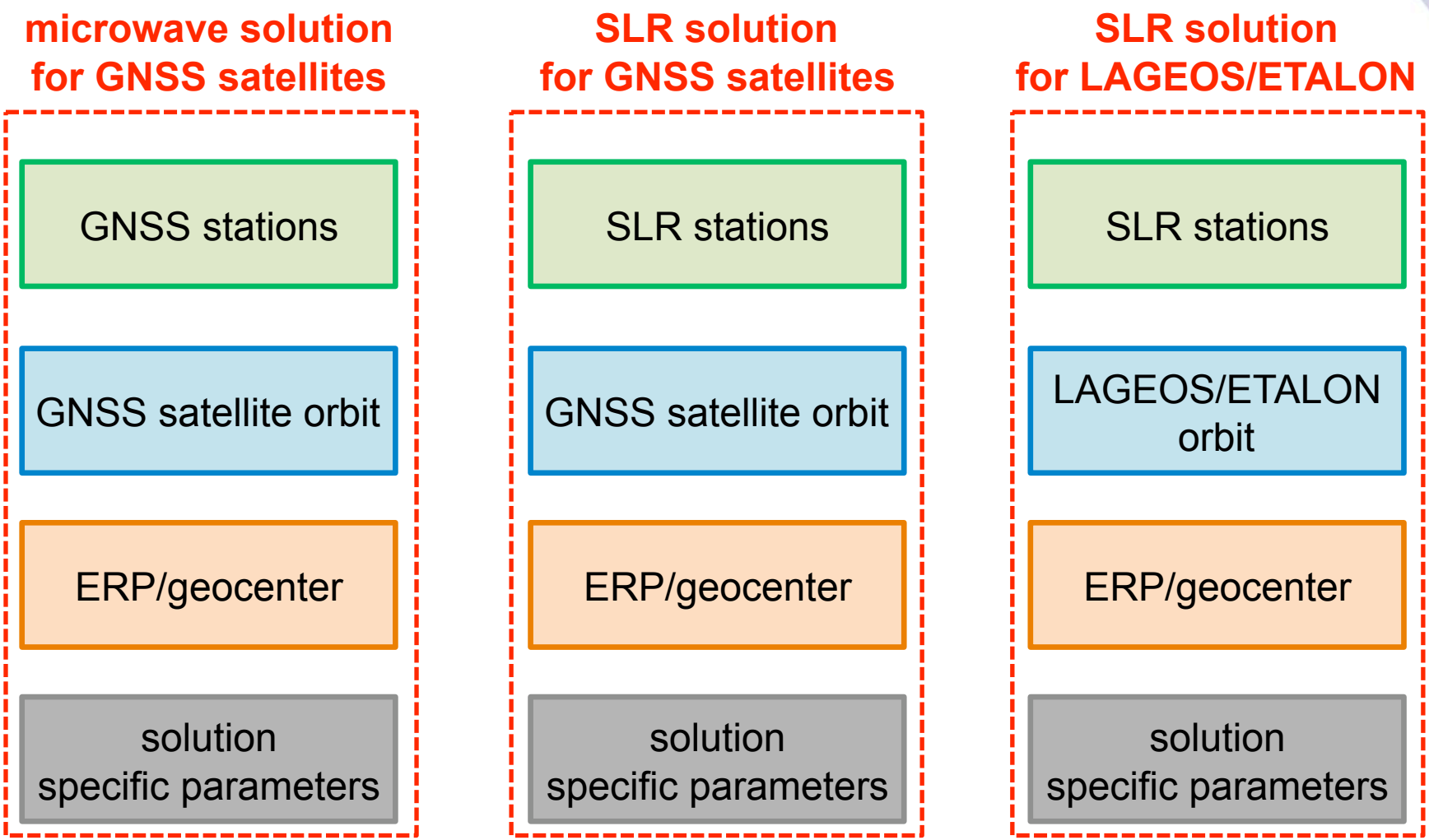

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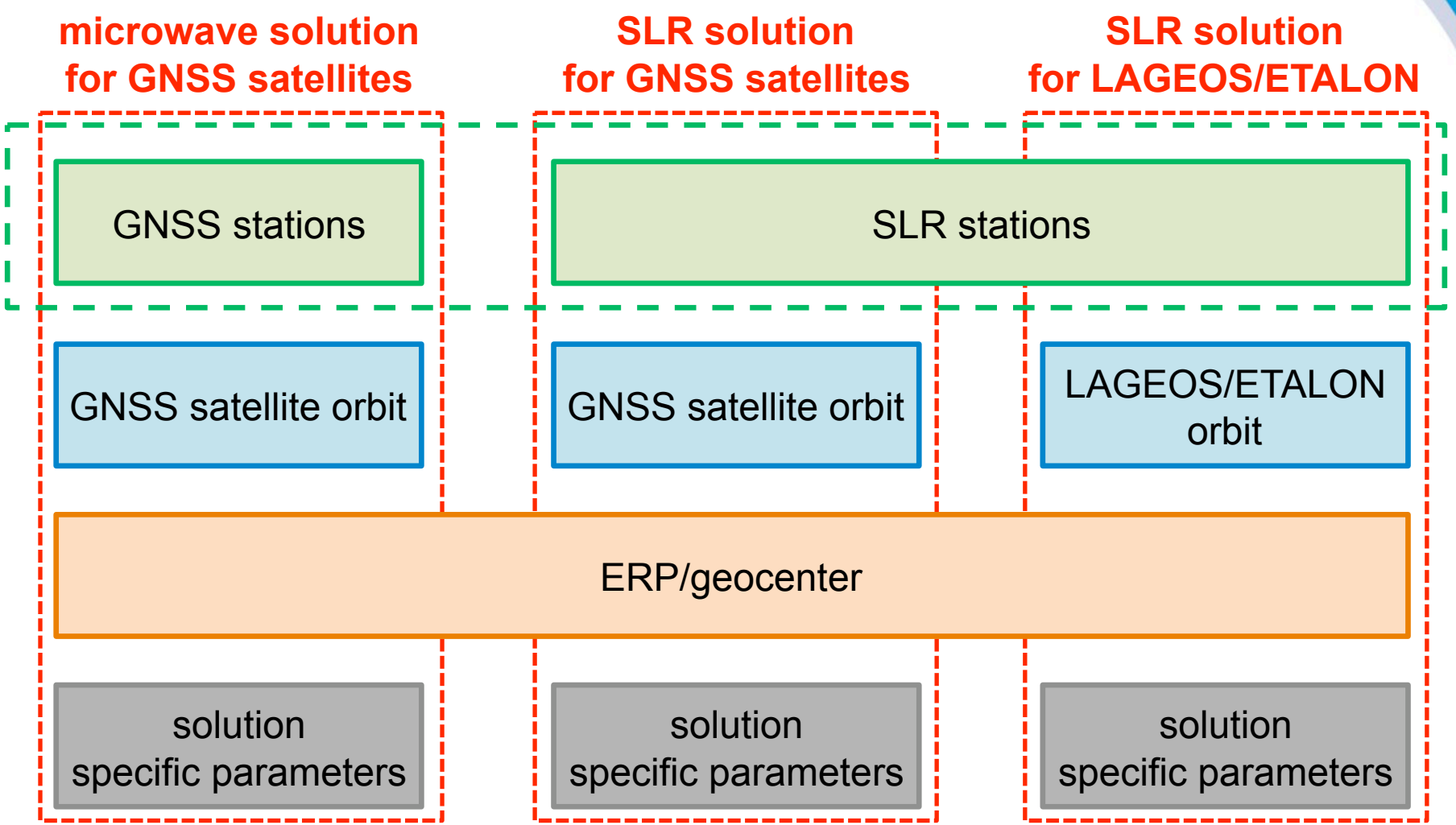

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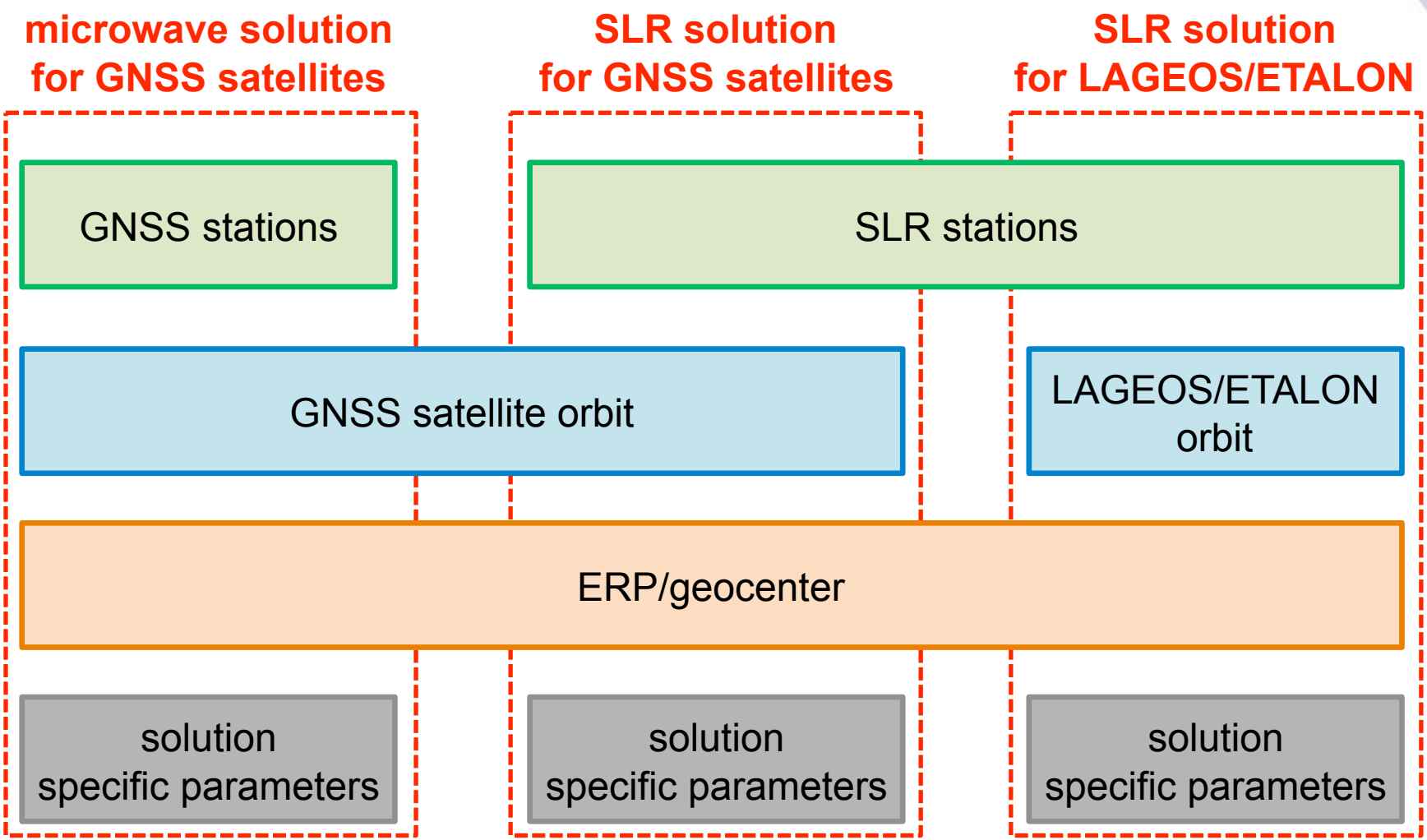


Bernese GNSS Software, Version 5.2

With the Bernese GNSS software we can provide the following three fully consistent solutions:

- microwave GNSS solution
- SLR solution for geodetic SLR satellites
- SLR solution for GNSS satellites

Alternative to local ties are space ties:

- *uncertainty of the knowledge of the local tie is replaced by the problem of the location of the sensors at the satellite.*

Bernese GNSS Software some facts

The software package consists of:

- a QT-based graphical user interface
- a set of fortran (F90) processing programs
- the Bernese Processing Engine (BPE) for automated processing

The software package counts today:

- 108 processing programs and
  1329 subroutines, functions, and modules
- ne[illegible]5,000 lines of source code (including comment lines),
- the GUI/BPE-program with 17500 lines of source code
- 5875 input/output filenames and processing options

supported my an online-help system, a 600 pages user manual, and a one week introductory course in Bern.

PANIC –
Bernese, never again!

Processing examples

The distribution of the software package contains ready-to-use examples:

PPP_BAS.PCF

Standard PPP for coordinate, troposphere, and receiver clock determination based only on GPS data or a combined GPS/ GLONASS solution

PPP_DEMO.PCF

PPP containing several extended processing examples, like pseudo-kinematic, high-rate troposphere, or ionosphere solutions

Processing examples

The distribution of the software package contains ready-to-use examples:

RNX2SNX.PCF

Standard double-difference network solution based only on GPS data or a combined GPS/GLONASS solution with an extended ambiguity resolution scheme

CLKDET.PCF

Zero-difference network solution based only on GPS data or a combined GPS/GLONASS solution providing clock corrections (e.g., w.r.t. an existing coordinate and troposphere solution)

Processing examples

The distribution of the software package contains ready-to-use examples:

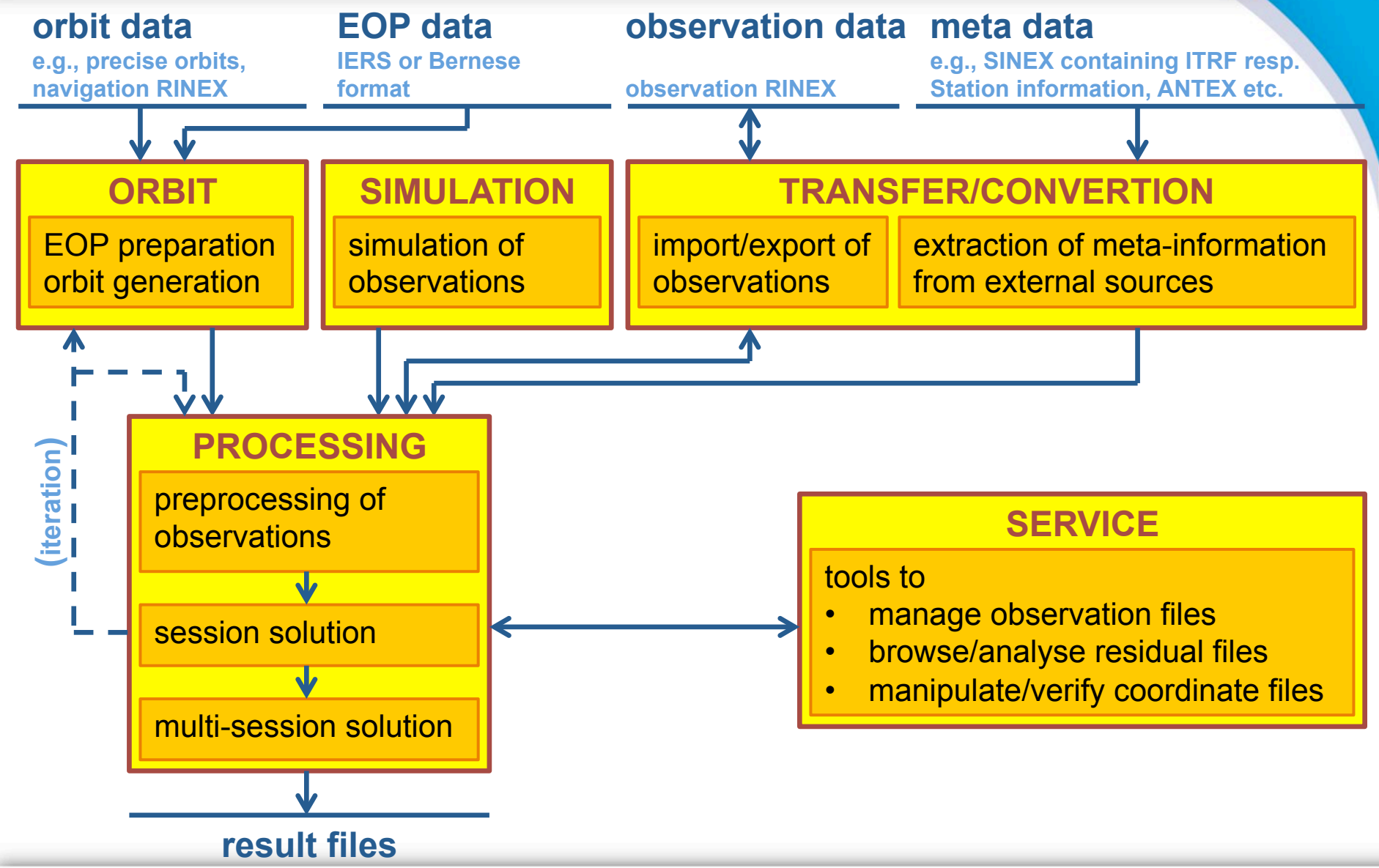
LEOPOD.PCF

Precise Orbit Determination for a Low Earth Orbiting Satellites based on on-board GPS-measurements (e.g., for GRACE)

SLRVAL.PCF

Validation of an existing GNSS or LEO orbit using SLR measurements

Program flow chart



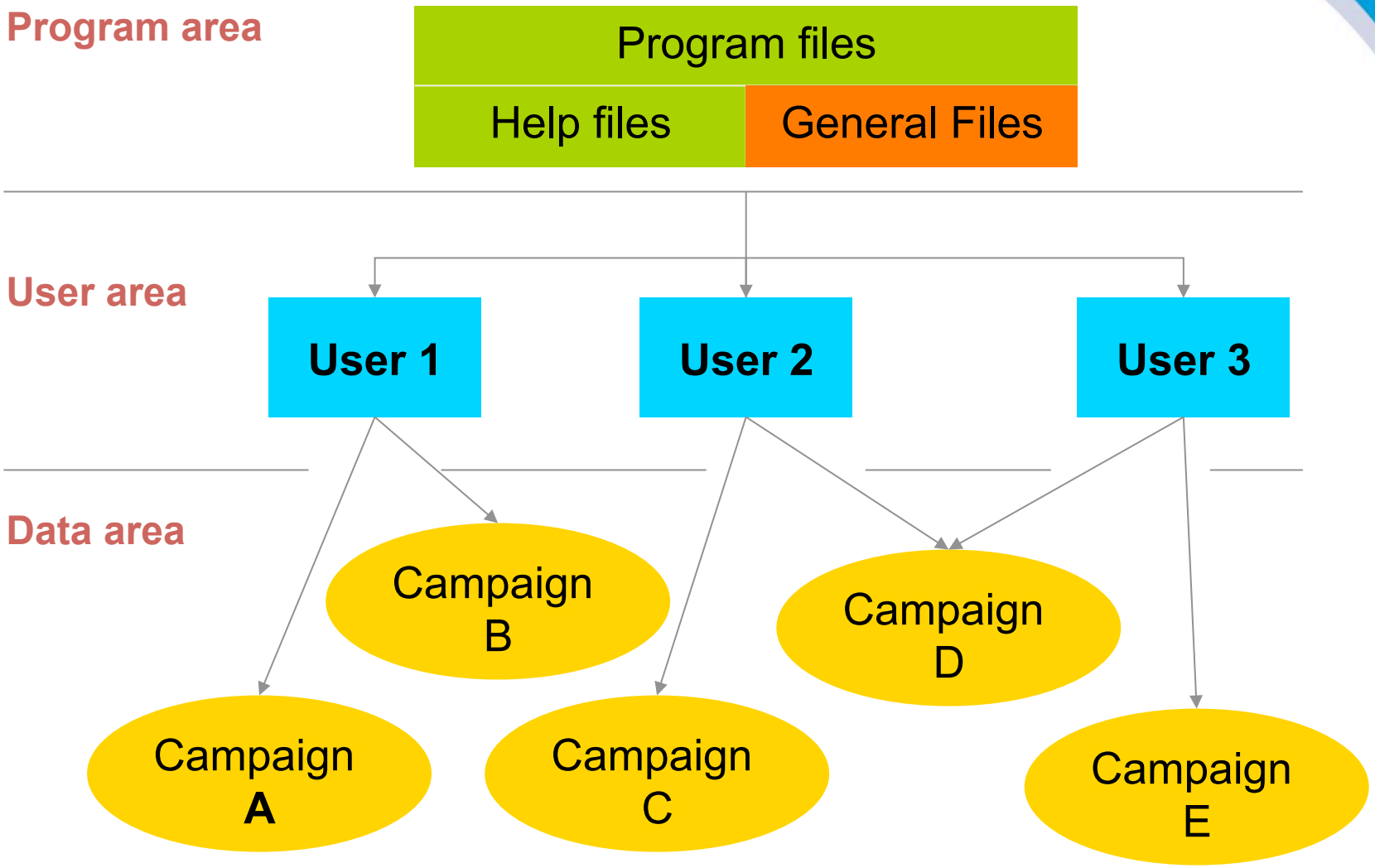
Program structure

- **Transfer Part:**
  Programs for generating files in the Bernese format from RINEX and vice versa. Furthermore, this part also contains a set of tools to cut/concatenate and to manipulate RINEX files.
- **Conversion Part:**
  Programs to extract external information necessary for the processing (e.g., coordinates and velocities from ITRF in SINEX format, ANTEX).
- **Orbit Part:**
  Programs for generation of a source-independent orbit representation (standard orbits), to update orbits, generate orbits in precise orbit format, compare orbits, etc. The Earth orientation related tools are included in this part too.

Program structure

- **Processing Part:**
  Programs for code processing (single station), single/dual frequency code and phase pre-processing, parameter estimation based on GPS and/or GLONASS observations (pgm. GPSEST) and on the superposition of normal equations (pgm. ADDNEQ2).
- **Simulation Part:**
  Program to generate simulated GPS and GLONASS observations (code and/or phase, L1 or L1/L2) based on statistical information (RMS for observations, biases, cycle slips).
- **Service Part:**
  A collection of useful tools to edit/browse/manipulate binary data files, compare coordinate sets, display residuals, etc. A set of programs to convert binary files to ASCII and vice versa belong to the service part, too.

Directory structure



Directory structure

Program area

- contains the program source code, the executable and
- general files used by all programs independent from the processed data

User area

- contains user-specific program configuration files and
- the files needed to run a BPE

Data area

- contains relevant data and related files for processing in project- (campaign)-specific directory structures

Processing steps

	Processing step	Involved programs
1	Data transfer copy data into the campaign area	ftp, cp, perl
2	PPP procedure to complete the list of a priori coordinates/velocities (if necessary)	BPE example PPP_BAS
3	Import observation data into Bernese format	RXOBV3
4	Prepare EOP and orbit information	POLUPD, PRETAB, ORBGEN
5	Data preprocessing: cycle slip detection and correction; outlier rejection	CODSPP, SNGDIF, MAUPRP, GPSEST, RESRMS, SATMRK
6	Make a first network solution (real-valued ambiguities)	GPSEST
7	Resolve ambiguities	GPSEST
8	Create normal equations containing all relavant parameters	GPSEST
9	NEQ-based single- or multi-session solution	ADDNEQ2

Realization of the processing scheme

- This processing scheme is realized in the ready-to-use example: **RNX2SNX.PCF** (full description in **RNX2SNX.README**)

- *PCF stands for Process Control File*
  to be used by a BPE for automated processing.

  The BPE needs to know:
  - what is to do: user scripts
  - there are any dependencies in the order of running the scripts
  - where a script can be started (CPU)

- At the end of the BPE a protocol file summarizes the main results from the run (e.g., **R2S102070.PRC**)

RNX2SNX.PCF

```
# ============================================================================
# RNX2SNX.PCF
# ============================================================================
#
# Purpose:      RINEX-TO-SINEX (RNX2SNX): standard double difference
#               processing for regional networks for static, dual-frequency
#               stations.
#
# ----------------------------------------------------------------------------
#
PID SCRIPT   OPT_DIR  CAMPAIGN CPU      F WAIT FOR....
3** 8******* 8******* 8******* 8******* 1 3** 3** 3** 3** 3** 3** 3** 3** 3**
#
# Copy required files
# -------------------
001 R2S_COP  R2S_GEN           ANY      1
002 ATX2PCV  R2S_GEN           ANY      1 001
003 COOVEL   R2S_GEN           ANY      1 001
004 COOVEL   R2S_GE2           ANY      1 001
005 CRDMERGE R2S_GEN           ANY      1 003 004
011 RNX_COP  R2S_GEN           ANY      1 001
021 OBSMRGAP R2S_GEN           ANY      1 011
022 OBSMRG_P R2S_GEN           ANY      1 021
031 ION_MRG  R2S_GEN           ANY      1 011
099 DUMMY    R2S_GEN           ANY      1 002 005 022 031
#
# Prepare the orbits
# ------------------
101 POLUPDH  R2S_GEN           ANY      1 001
```

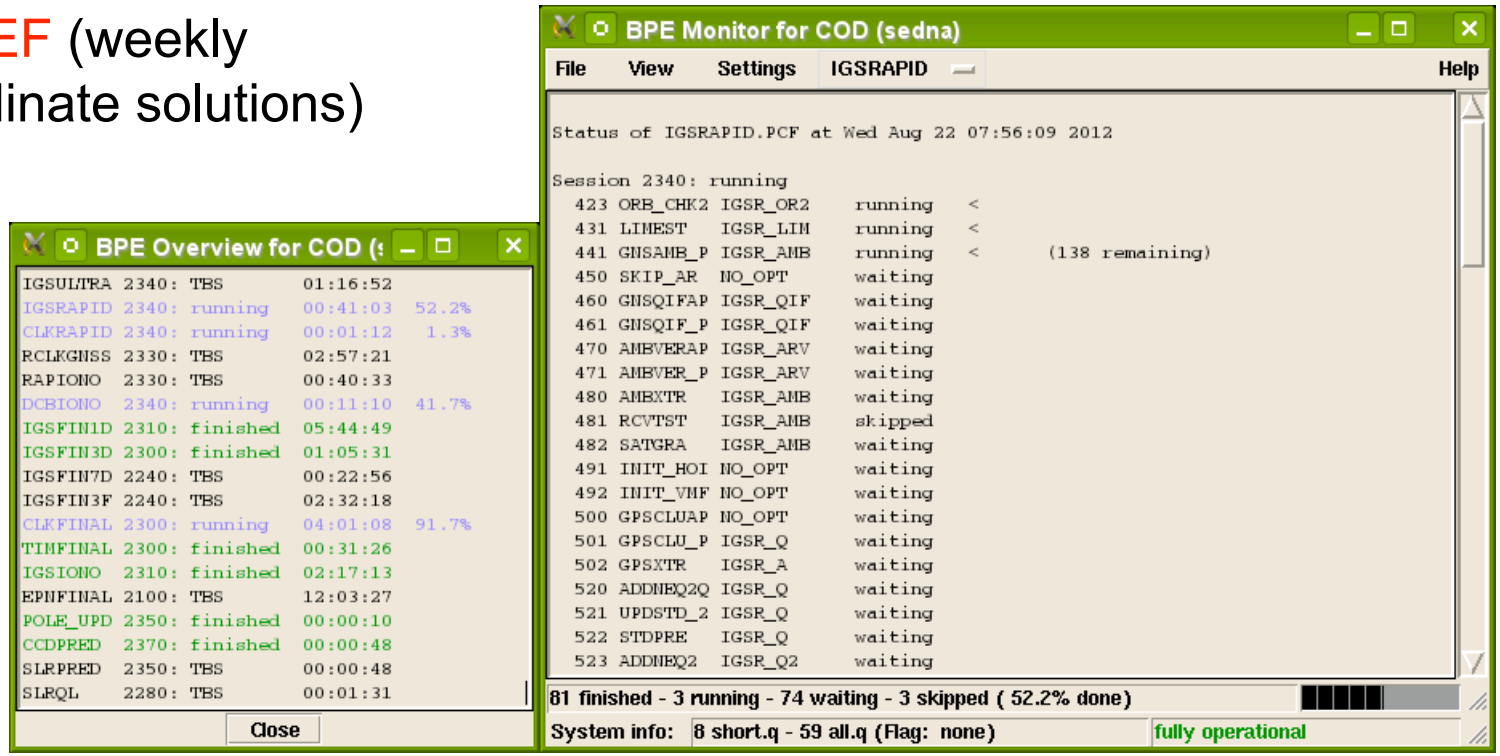
R2S102070.PRC

```
================================================================================
RNX2SNX BPE PROCESSING SUMMARY FOR YEAR-SESSION 10-2070
================================================================================


Summary file generated at 07-Aug-2012 13:59:51 by R2S_SUM

General files:
   Antenna phase center eccentricity file:   PCV.I08
   Satellite information file:               SATELLIT.I08
   Satellite problem file:                   SAT_2010.CRX
   Orbit, ERP and clock products used from:  ${D}/COD

Observation file selection:
   RINEX files copied from:                  ${D}/RINEX/
   Station selection:                        all stations

Reference frame and station related files:
   Station related files used from:          ${D}/REF52/
   External reference frame file series:     IGS08_R.(CRD|VEL)
   Project specific station file series:     EXAMPLE
      Station information file:              STA/EXAMPLE.STA
      RINEX inconsistency file:
      Ocean tidal loading table:             STA/EXAMPLE.BLQ
      Atmosphere tidal loading table:        STA/EXAMPLE.ATL

Other options from PCF:
   Antenna phase center model was not updated.
   Satellite system(s) included:             GPS/GLO
```

IGS processing

Different BPEs are running daily at AIUB for the IGS activities:

- ultra-rapid (several times per day for orbits/EOP)
- rapid (orbits/EOP, clocks, ionosphere products)
- final (orbits/EOP, clocks, ionosphere, weekly coordinate products)
- EUREF (weekly coordinate solutions)



What do we expect in the future?

Today we have 32 GPS and 24 GLONASS satellites.

Modernization programs:

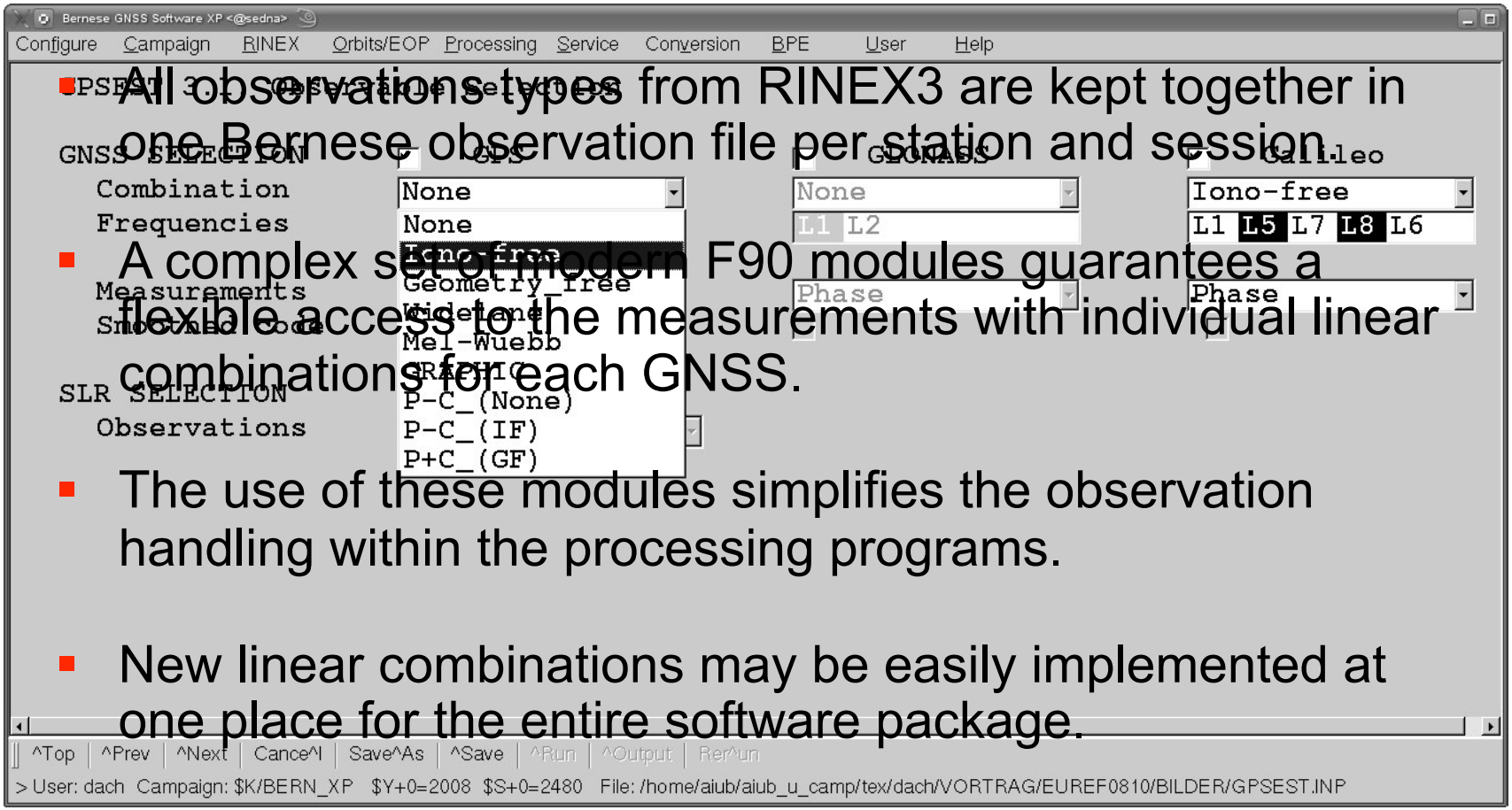
- GPS third frequency
  (first Block IIF since May 2010)
- GLONASS third frequency, FDMA to CDMA
  (first GLONASS-K since Feb. 2011)

New GNSS:

- Galileo a new GNSS with up to five frequencies
  (2011: launch of IOV satellites, 2013: FOC)
- Compass, and other GNSS

Bernese GNSS Software in future

Flexible handling of observation types is necessary:



- All observations types from RINEX3 are kept together in one Bernese observation file per station and session.
- A complex set of modern F90 modules guarantees a flexible access to the measurements with individual linear combinations for each GNSS.
- The use of these modules simplifies the observation handling within the processing programs.
- New linear combinations may be easily implemented at one place for the entire software package.

Bernese GNSS Software in future

New file formats are necessary:

- Bernese observations files
  (may contain all types of observations in one (common) file)
- Bernese residual files
  (considering the new linear combinations)
- Differential code biases
  (many new DCBs have to be expected with the new signal types)
- Receiver information file
  (receiver type: which signal and priority lists for observ. selection)
- Antenna phase center corrections
  (GNSS-dependent receiver antenna PCV information)

Bernese GNSS Software in future

Further developments to get a multi—GNSS software:

- more satellites have to be processed together
  (32 GPS + 30 GLONASS + 36 Galileo ≈100 satellites)
- input/output IDs for each GNSS for all external files
  (e.g., precise orbit file, clock RINEX file, ...)
- GNSS dependent parameter setup
  (e.g., receiver antenna phase center offsets/variations, Earth rotation parameters, ...)
- dynamic memory allocation in the processing programs

Thank you for your attention