A first release of νSolve

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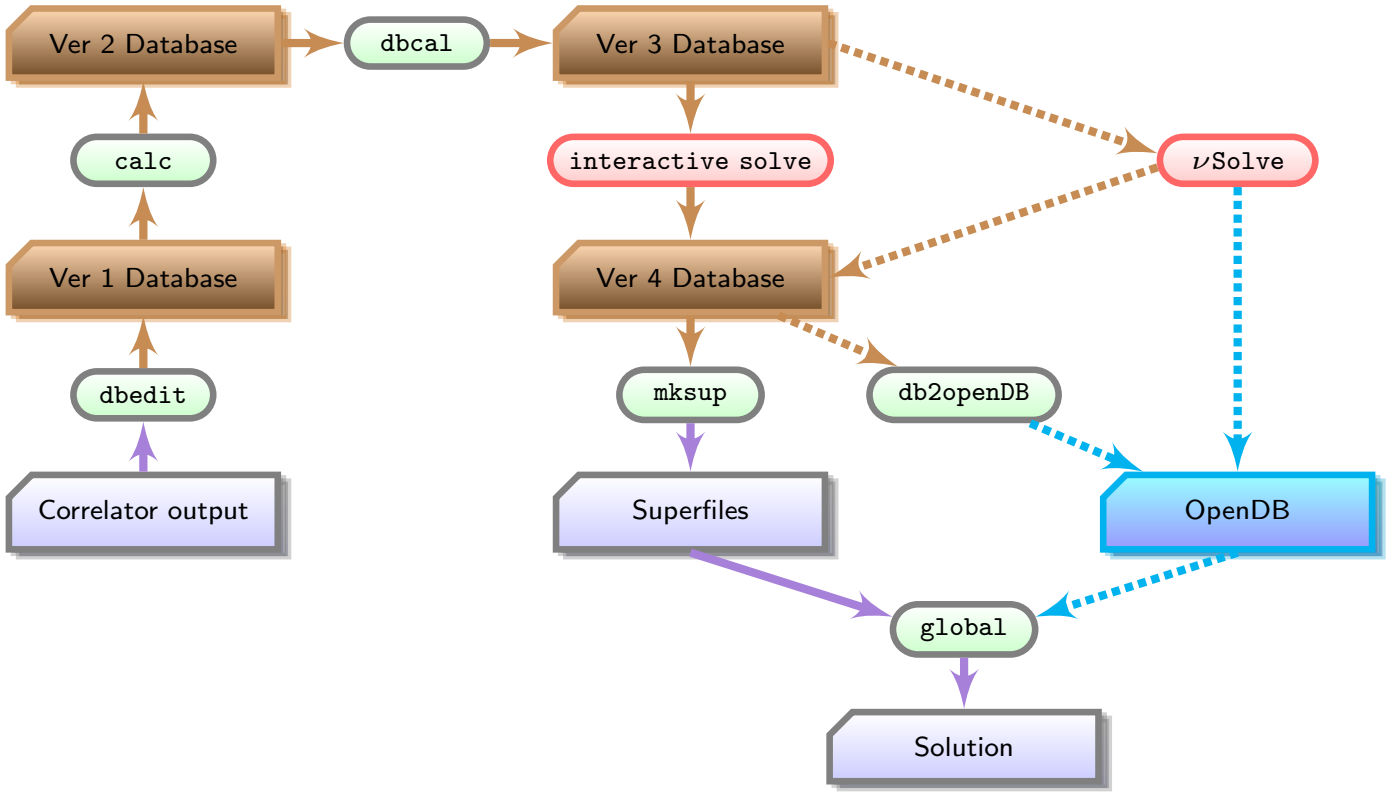
VLBI data analysis software

- New generation VLBI data analysis software
  - Increase in number of observations.
  - VLBI2010 introduce new observables.
- History of development
  - The IVS Working Group on VLBI data structures (IVS WG4) was established in 2007.
  - In August of 2009 the VLBI group at the NASA GSFC started the development of new VLBI data analysis software.
  - A design of system architecture was presented at the IVS General Meeting at Hobart (Tasmania) in 2010.
  - We demonstrated a prototype version of **νSolve** at the 20^{th} EVGA Meeting in Bonn, 2011.
- **νSolve** and VLBI data flow
  - **νSolve** is designed to replace most sensitive and user time consuming part of CALC/SOLVE system, interactive SOLVE.
  - It produces **Version 4** databases: edited, ambiguity resolved and with ionospheric corrections.
- In this presentation we will cover the current status of the software development process.

Geodetic VLBI data flow



Software development environment

The software is designed to (but not limited) work under Linux/GNU operation system.

It is written in **C++ programing language**.

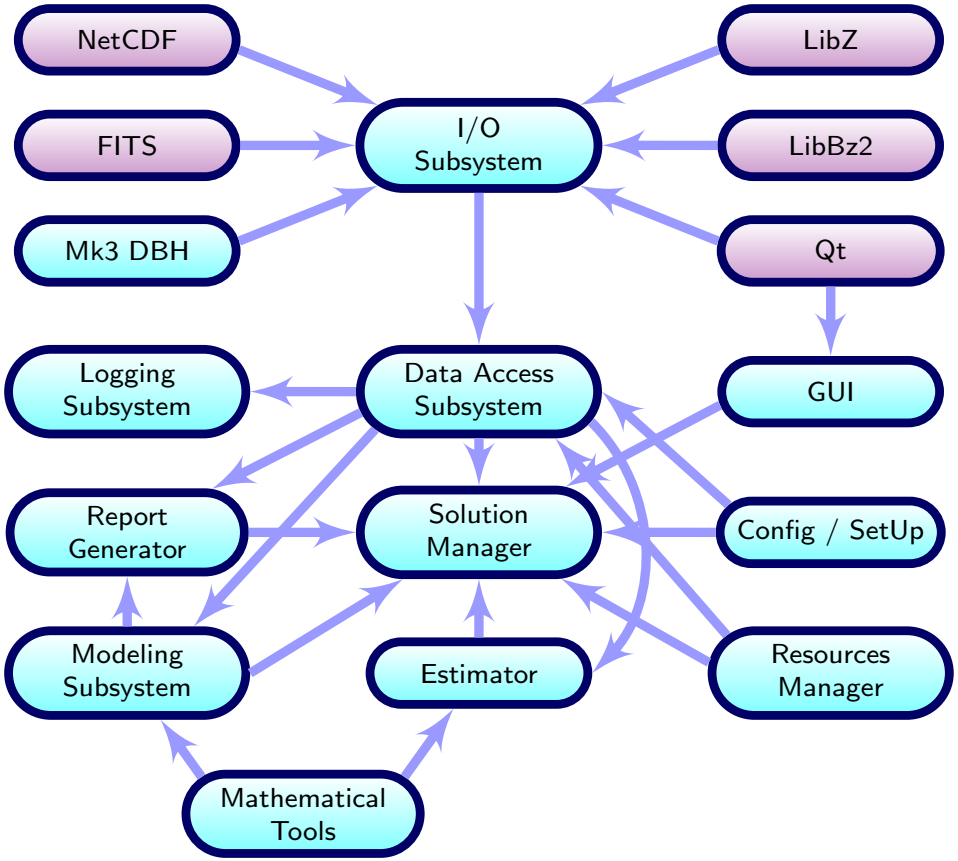
We distribute the software code and use **GNU Build System** to make it portable.

It uses the **Qt** library for high level data abstraction and system **libc**, **libm** for low level system functions.

Currently, it consists of two parts:

- **Space Geodesy Library**, where all algorithms are implemented (90% of source code);
- an executable **νSolve** – a driver that calls the library and organizes work with an end-user (10% of source code).

Modular structure of the software



System Decomposition

To keep our system stable and flexible we designed it modular.

Module is a logical block of code that is loosely tied with other parts of the software.

Each arrow on the diagram represents a **dependency** or, in other words, provides information (types, function calls, constants).

Only main **dependencies** are shown on the diagram.

General features

Current functionality

The software is able:

- Read/Write files in Mk3 DBH format;
- Display various information that were stored in the files;
- Process a single VLBI session and save results;
- Estimate various parameters;
- Detect and process clock breaks;
- Resolve ambiguity;
- Perform ionospheric correction;
- Calibrate weights of observations;
- Eliminate outliers;

General features

Current functionality

The software is able:

- The software is able to read and write data in Mk3 DBH format.
- It can also use new OpenDB format.
- There is no limitations on number of stations, sources or observations.
- It can work either through CALC/SOLVE catalog subsystem or in a standalone mode.
- Process of VLBI data analysis can be automated,

General features

Data processing

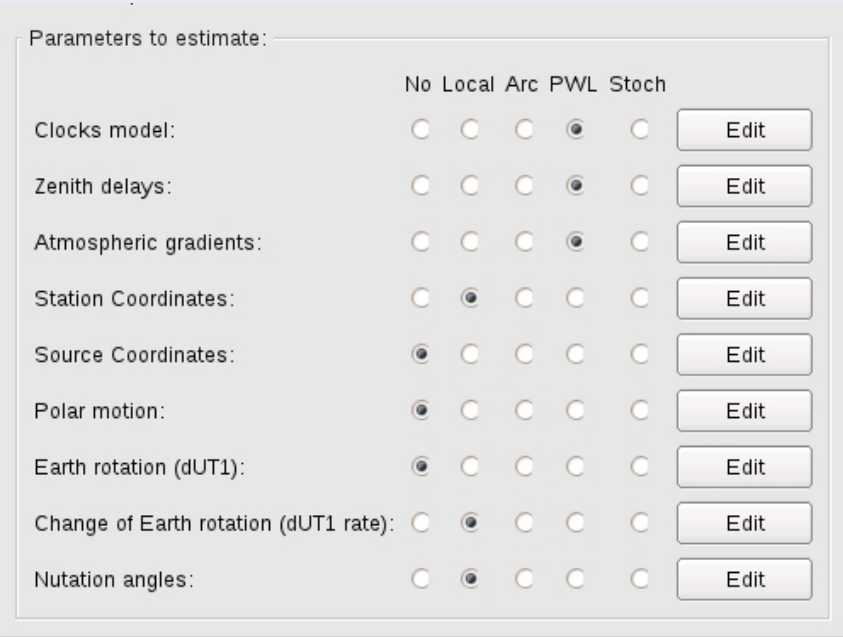
- Single session mode:
  - **νSolve** is designed to analyze a single session, performs necessary calibrations and data editing.
  - Later it will evolve in powerful session editor that allows us to fix all known anomalies of the VLBI observation.
- Multiple session mode:
  - A separate executable (driver) will be developed to perform data analysis of multiple sessions of VLBI observations.

Estimator

Estimated parameters

We can estimate:

- Clock parameters;
- Zenith delays and theirs gradients;
- Stations positions;
- Sources coordinates;
- Polar motion;
- Earth rotation and its rate;
- Angles of nutation.



Estimated parameters

Estimator

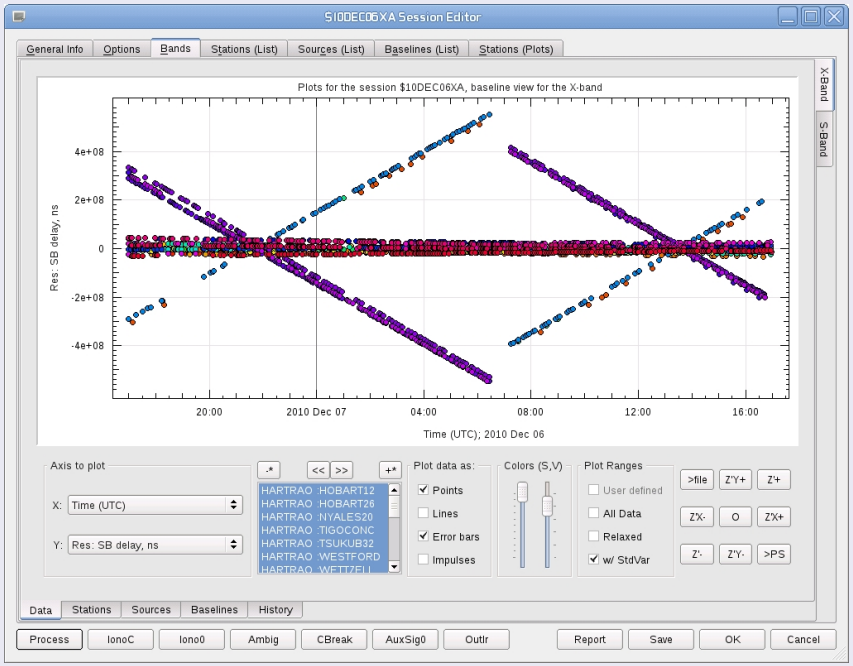
Types of parameters

- The estimated parameters can be modeled as:
  - Local parameter – an unbiased parameter determined for whole session
  - Arc parameter – an unbiased parameter estimated for specified by user interval (e.g., 1 hour)
  - Piecewise linear function, coefficients of continuous linear function are estimated from data, an interval between nodes is specified by user
  - Stochastic parameters
- There is no limitations on length of arcs or step between nodes of piecewise linear functions.

Clock break correction

Clock break processing

- To compensate a clock break, ν**Solve** adds a step-wise linear function to the station clocks.
- There are session wide and band dependent clock break models.
- Clock breaks can be detected and corrected in automatic, semi-automatic and manual mode.

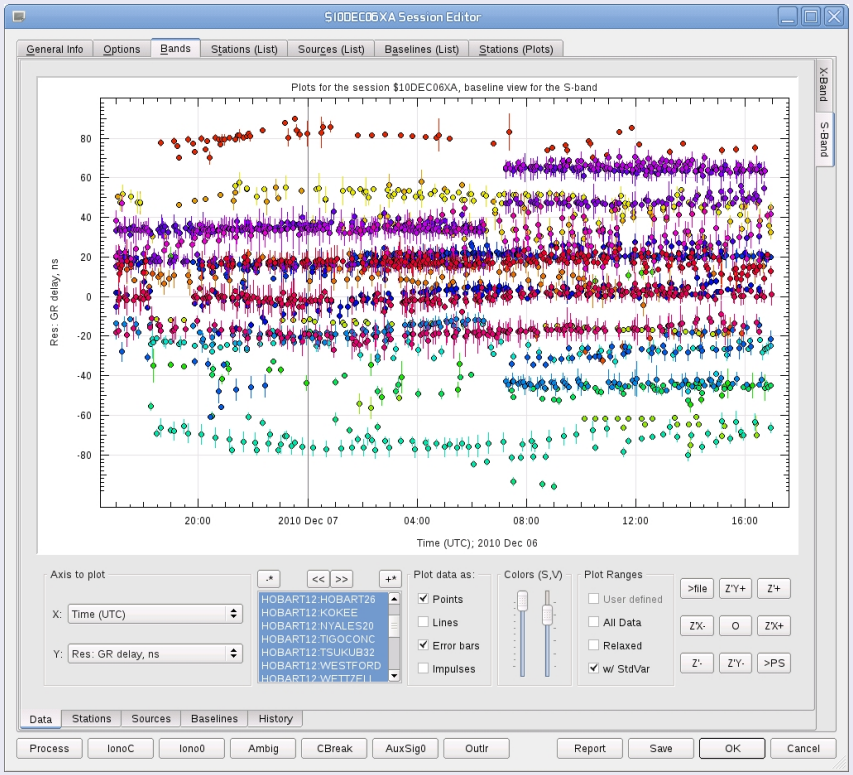


Example of a 1 second clock break

Ambiguities

Ambiguity resolution

- Ambiguity resolution is done using ideas implemented in CALC/SOLVE.
- There is no assumption about ambiguity spacing. **νSolve** can process sessions with mixed ambiguity spacing.
- In addition, there is ability to adjust multipliers of ambiguity manually.

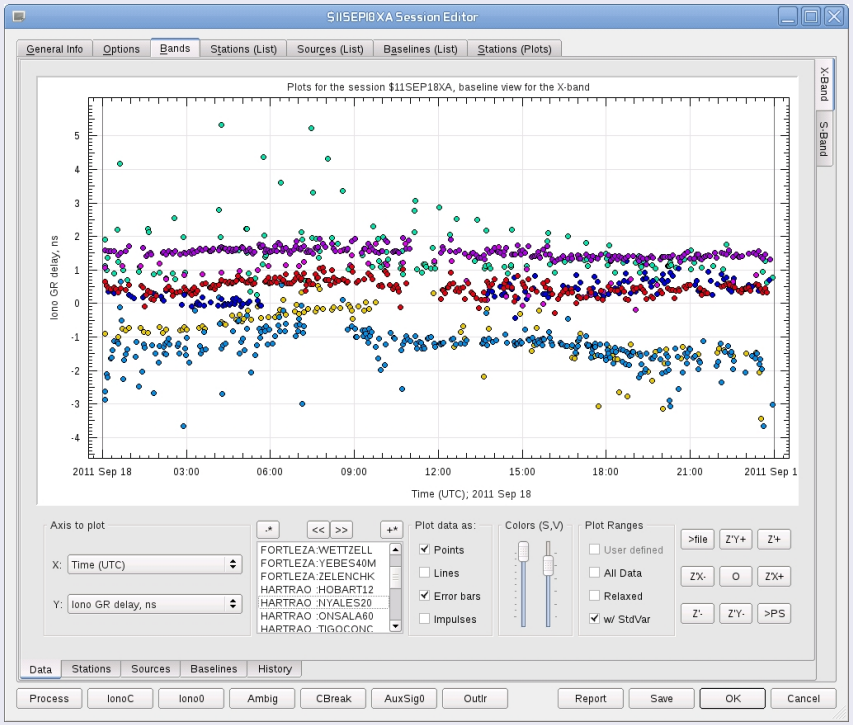


Group delay residuals with unresolved ambiguities

Ionosphere

Ionospheric correction

- From dual band observations the group delay, phase rate and phase delay ionospheric corrections are evaluated.
- Ionospheric corrections are performed after clock breaks and ambiguity resolutions were processed.

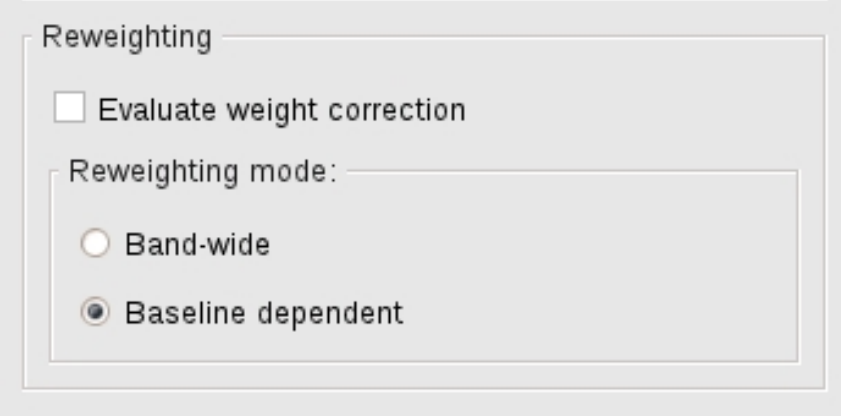


Impact of ionospheric effect on group delay residuals

Reweighting

Observations weights calibration

- Weight calibration is performed to keep normalized χ^2 equal to unit.
- Two modes of reweighting:
  - Session wide;
  - Baseline dependent.
- Reweighting is performed in conjunction with outlier elimination.

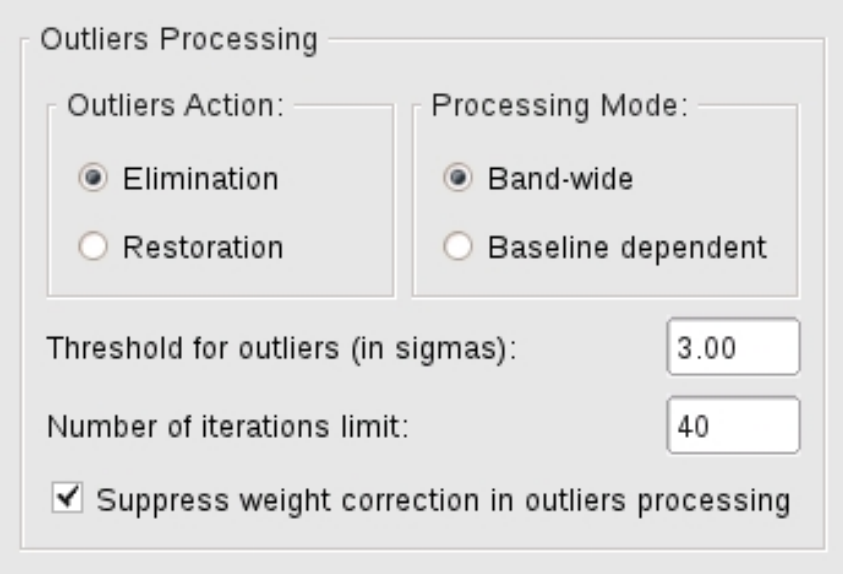


Reweighting control GUI

Outliers

Outliers processing

- Outlier is an observation which absolute value of normalized residual is greater than user specified threshold.
- Two modes of outliers processing:
  - Session wide;
  - Baseline dependent.
- Excluded observations can be included back in restoration action.
- Outlier elimination is performed in conjunction with reweighting.



Outliers processing control GUI

Data processing

VLBI data processing

- Read observations
- Obtain single band delay solution
- Check for clock breaks
- Resolve ambiguities in both bands

- Check for clock breaks
- Evaluate ionosphere corrections
- Add to estimated parameters zenith delays and station positions
- Manually remove big outliers

- Switch estimated parameters (clocks and zenith delays) to PWL functions
- Manually remove large outliers
- Add to estimated parameters UT1 rate and angles of nutation
- Calibrate weights of observations
- Eliminate outliers
- Iterate reweighting/outlier processing
- Save results

First public release

A first public release will be in the forthcoming release of CALC/SOLVE system.

Following functions need to be implemented before the public release:

- Add ability to use external a priori information, **νSolve** uses data from databases only;
- Add additional models, **νSolve** applies models that were calculated by CALC (except tropospheric effects).

After public release we expect users feedback to improve the software.

Thank you for attention!