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***The Bernese GPS Software***  
**for the analysis of**  
**GNSS, SLR and VLBI data**  
**and for the**  
**SINEX/NEQ combination**

Daniela Thaller <sup>1)</sup>, Rolf Dach <sup>1)</sup>, Ralf Schmid <sup>2)</sup>,  
Urs Hugentobler <sup>2)</sup>, Maria Mareyen <sup>3)</sup>, Bernd Richter <sup>3)</sup>

*(1) Astronomical Institute, University of Bern, Switzerland*

*(2) Technische Universität München, Germany*

*(3) Bundesamt für Kartographie und Geodäsie, Frankfurt/Main, Germany*

# Overview

## 1. Analysis of **observation data**

- a) GNSS
- b) SLR
- c) VLBI

## 2. Combined **GNSS+SLR** analysis using **satellite co-locations**

## 3. **Combination** using normal equations (intra- and inter-technique)

# Analysis of GNSS data

Combined **GPS+GLONASS** analysis is possible with the *Bernese GPS Software (BSW)*

## Global analysis:

- CODE: IGS analysis center
- Final, rapid and ultra-rapid products
- Operational GPS+GLONASS contribution since May 2003

## Regional analysis:

- EUREF / SIRGAS contributions by most analysis centers

Extension to **multi-system** GNSS analysis:

- Different systems (GPS, GLONASS, Galileo, ...)
- Different/individual observation types per GNSS

# Analysis of SLR data

**SLR residual analysis** w.r.t. given orbits / EOPs / station coordinates

→ Contribution of AIUB to ILRS as associated analysis center:  
SLR residuals w.r.t. GNSS orbits

Extension of the BSW to a **full SLR analysis** software package:

→ SLR observations to geodetic satellites (mainly Lageos, Etalon)  
→ Estimation of SLR-specific parameters (orbits, range biases)  
→ ILRS modeling and data handling issues are implemented

**Intention:** ILRS contribution of BKG generated with BSW

**Status:** ILRS Benchmark solutions submitted  
→ validation process ongoing

# Analysis of VLBI data

Extension of the BSW to a **VLBI analysis** software package

**Simplified VLBI analysis** for limited set of VLBI sessions possible:

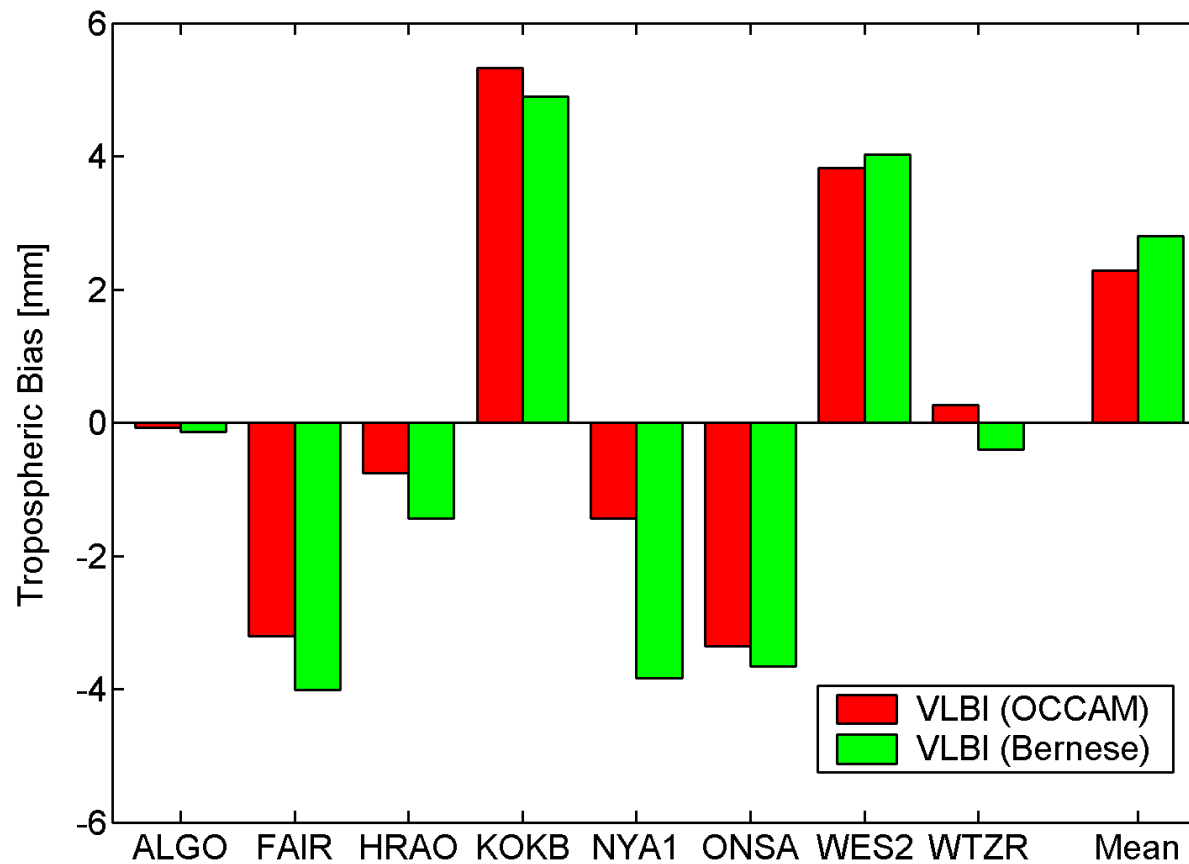
- Low degree of automation
- Simple clock model
- VLBI-specific effects like telescope deformations not yet implemented
- Starting from NGS Card Format

Extensions needed to become a **full VLBI analysis** software package:

- Estimation of VLBI-specific parameters (e.g., quasar coordinates)
- Improvement of a priori models and parameterization (e.g., clocks, telescope deformation)
- Automation for analysing the entire history of VLBI sessions

# Analysis of VLBI data

Comparison of VLBI-derived troposphere zenith delays with GPS-derived estimates:



⇒ Remaining differences are not due to deficiencies in the software but due to unmodeled effects (e.g. uncalibrated radomes)

# Combined GNSS+SLR analysis

**Idea:** Use satellite co-locations for connecting GNSS and SLR

→ GNSS observations: GPS, GLONASS, (Galileo)

→ SLR observations to GNSS satellites: 2/1 GPS, 3 GLONASS, ???

## 1. Common parameters:

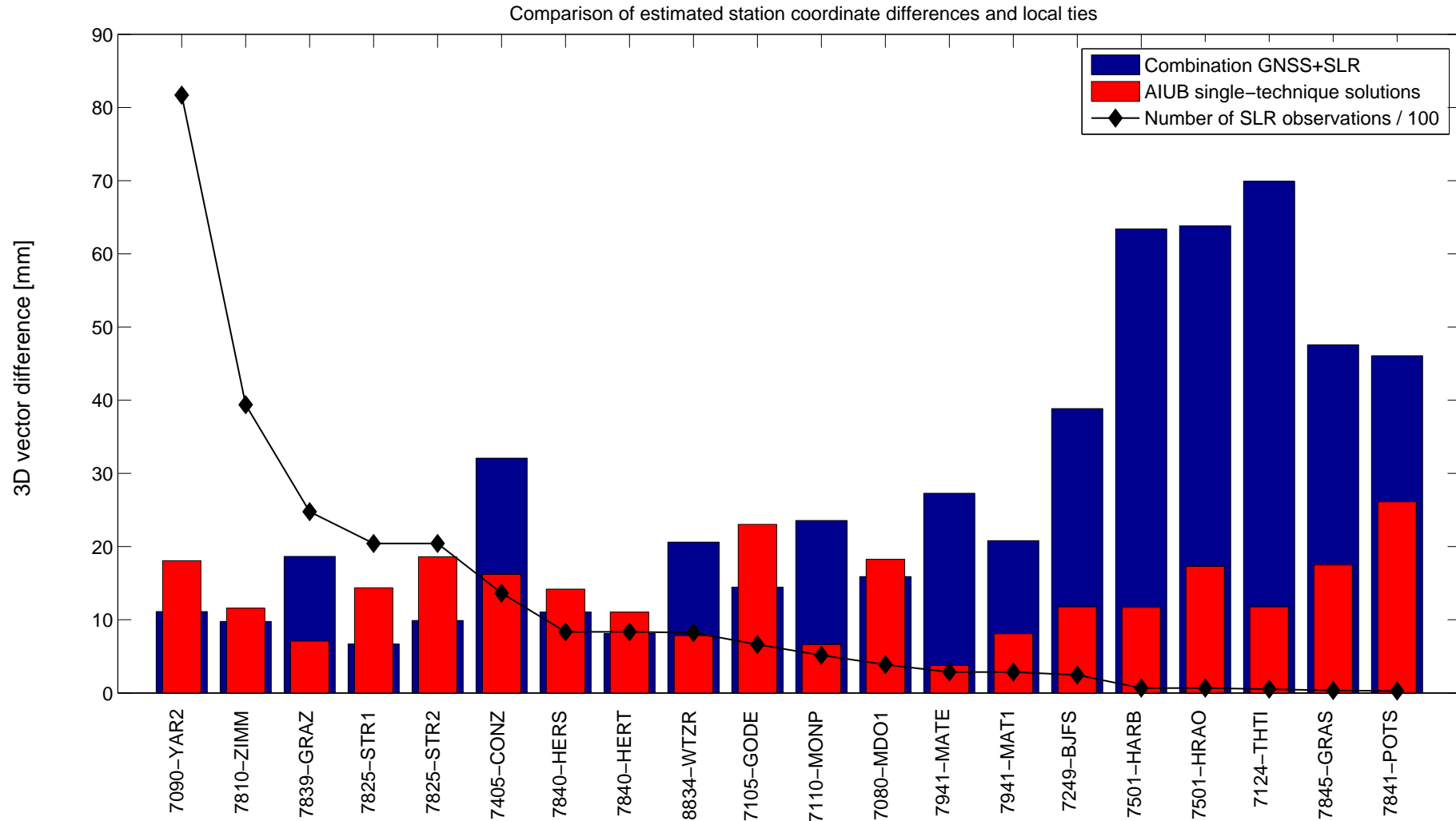
- *EOP*
- *Geocenter*
- *Station coordinates*
- *Satellite orbit parameters (dynamical)*

Already done for combination  
at NEQ level

## 2. Needed for connection:

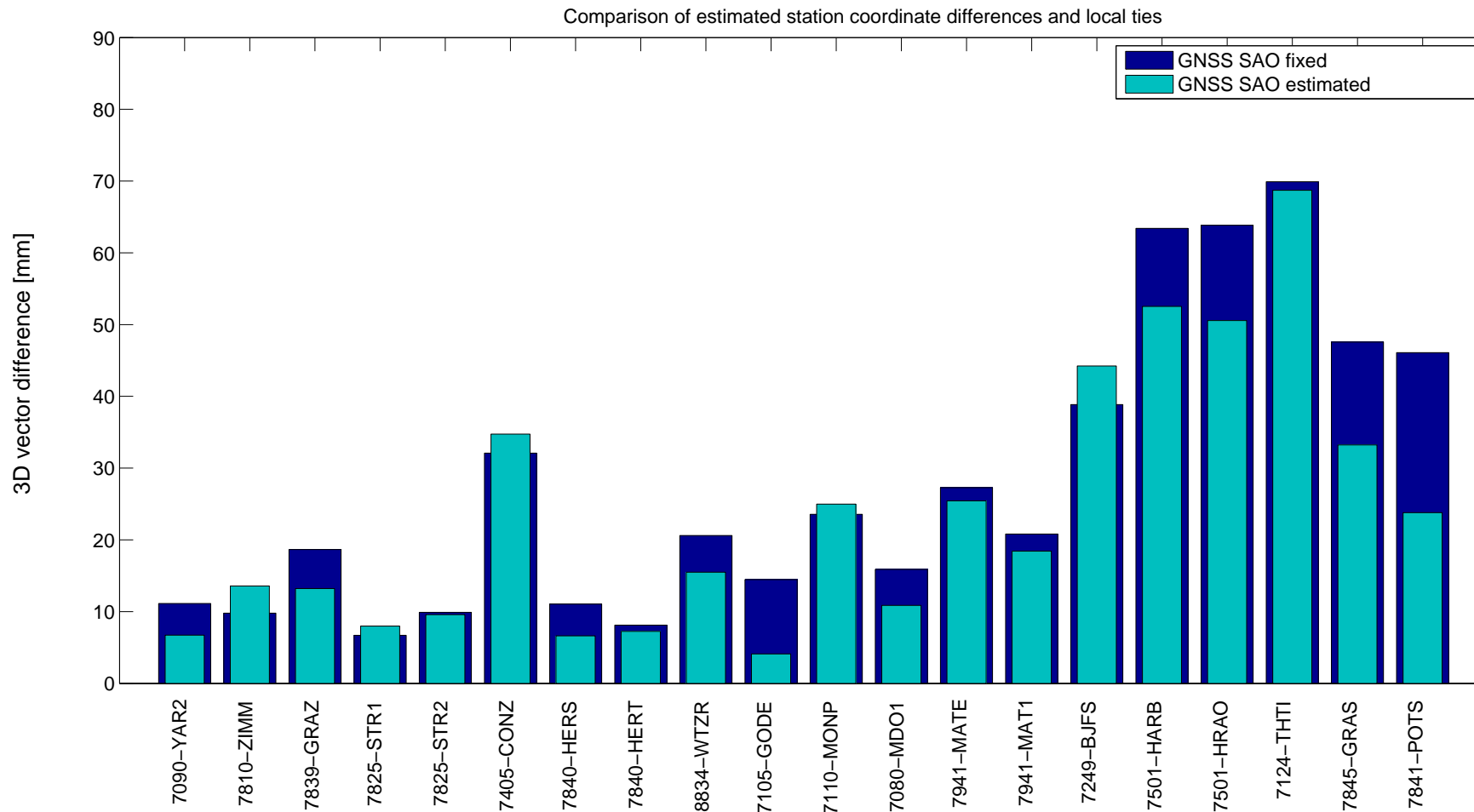
- Stations: **Local ties**
- Satellite CoM: **Vectors to** microwave antenna and to laser retro-reflectors

# Combined GNSS+SLR analysis: Advantages



→ Connection of techniques either *on ground (LT)* or *in space (orbits)*

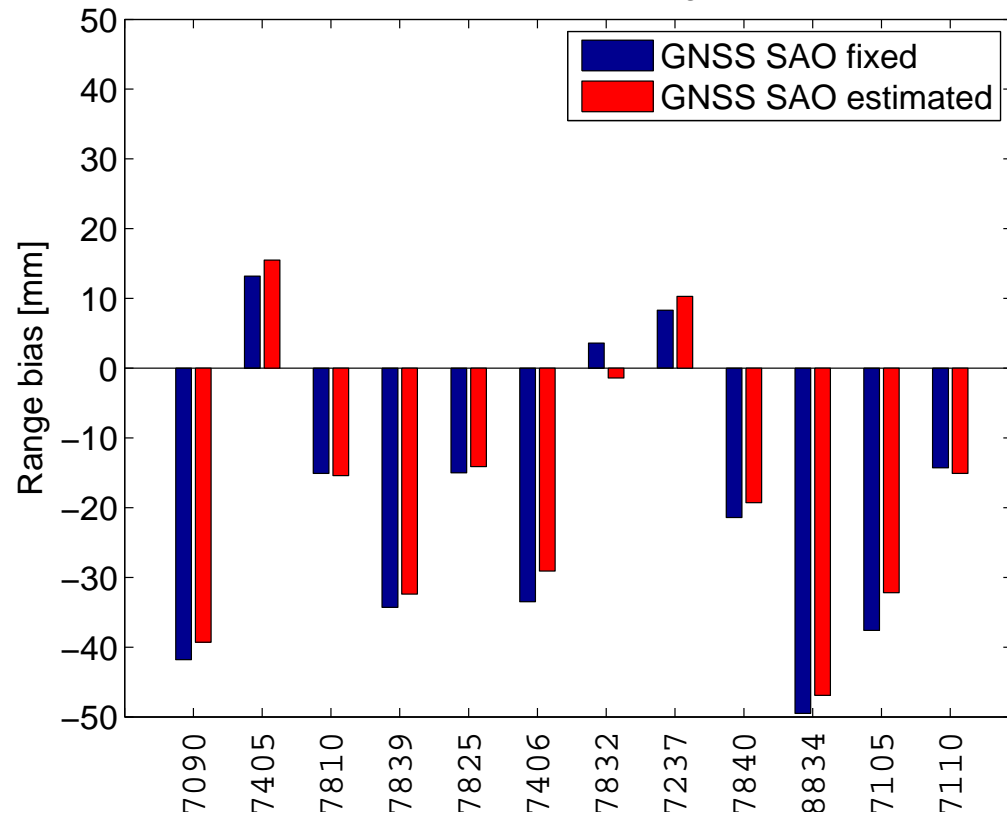
# Combined GNSS+SLR analysis: Advantages



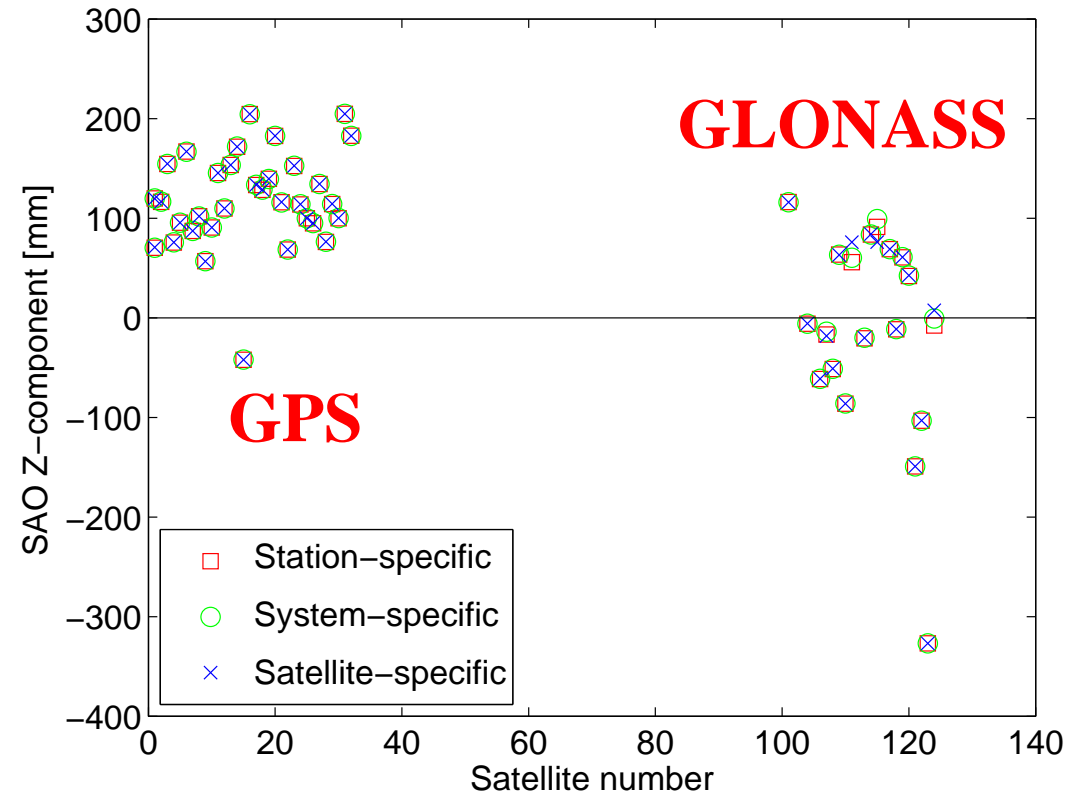
- Allows transfer of **scale** information from SLR into GNSS network
- Estimation of **SLR range biases (RGB)** together with **GNSS satellite antenna offsets (SAO)** is possible

# Combined GNSS+SLR analysis: Advantages

Station-specific SLR range biases



SAO corrections for different RGB estimation



- Allows transfer of **scale** information from SLR into GNSS network
- Estimation of **SLR range biases (RGB)** together with **GNSS satellite antenna offsets (SAO)** is possible
- Estimation of **SAO** consistently for GPS and GLONASS, and consistently with SLR scale

# Combined GNSS+VLBI analysis

## Common parameters:

- EOP
- Troposphere
- Station coordinates

## Advantages:

- **Full EOP information** from VLBI transferred to GNSS (polar motion, UT/LOD, nutation)
- Stabilization of coordinates by **common troposphere estimates**

- Benefit already shown for combination at *NEQ level*
- Not yet done for combination at the *observation level*

# Combination using NEQs

General strategy in BSW concerning **constraints**:

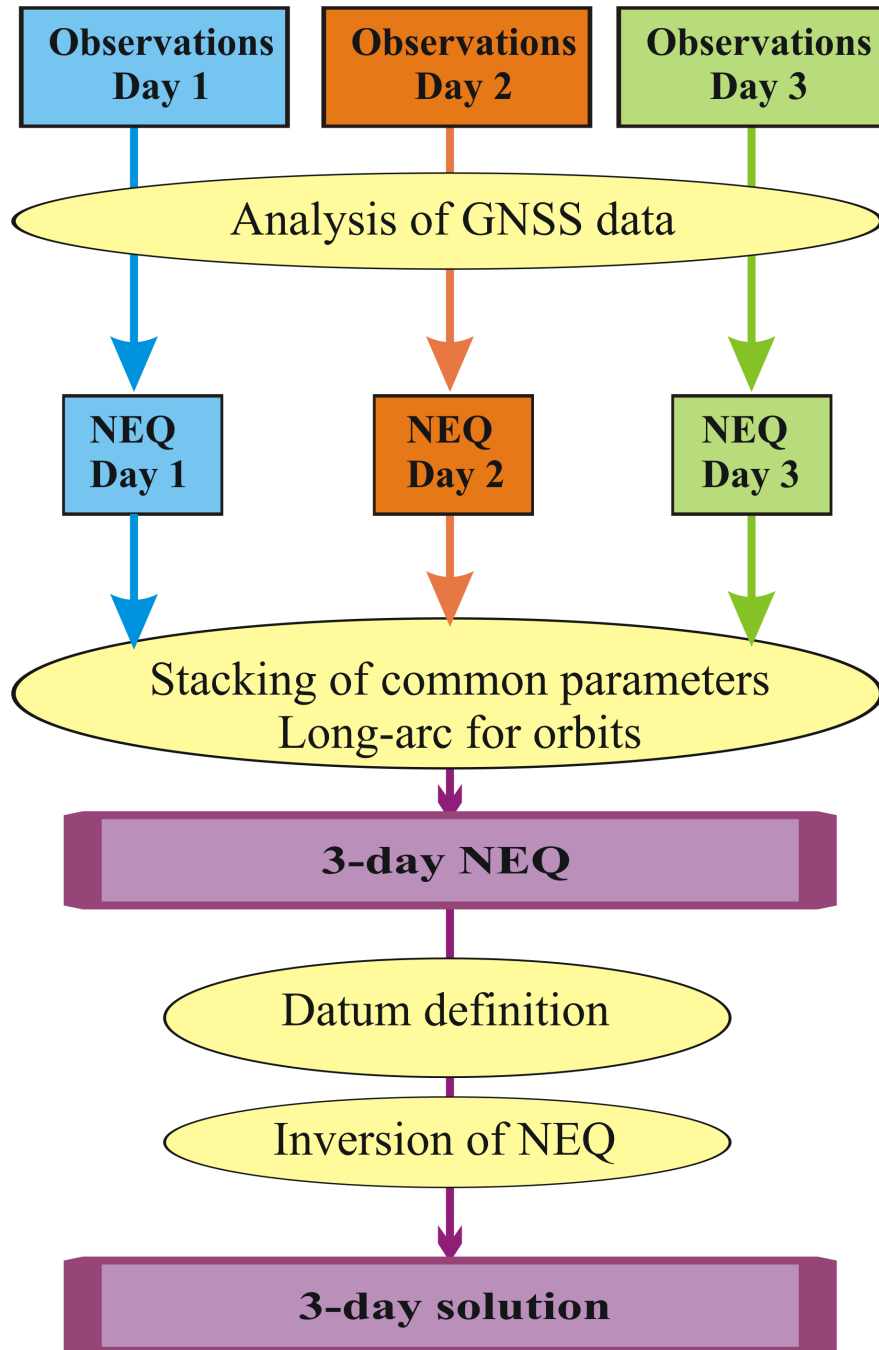
- **NO** constraints when storing individual NEQs
- Application of constraints only if
  - a) pre-eliminating parameters
  - b) generating a solution (before inversion of NEQ)

⇒ **Full flexibility** for computation of combined solutions

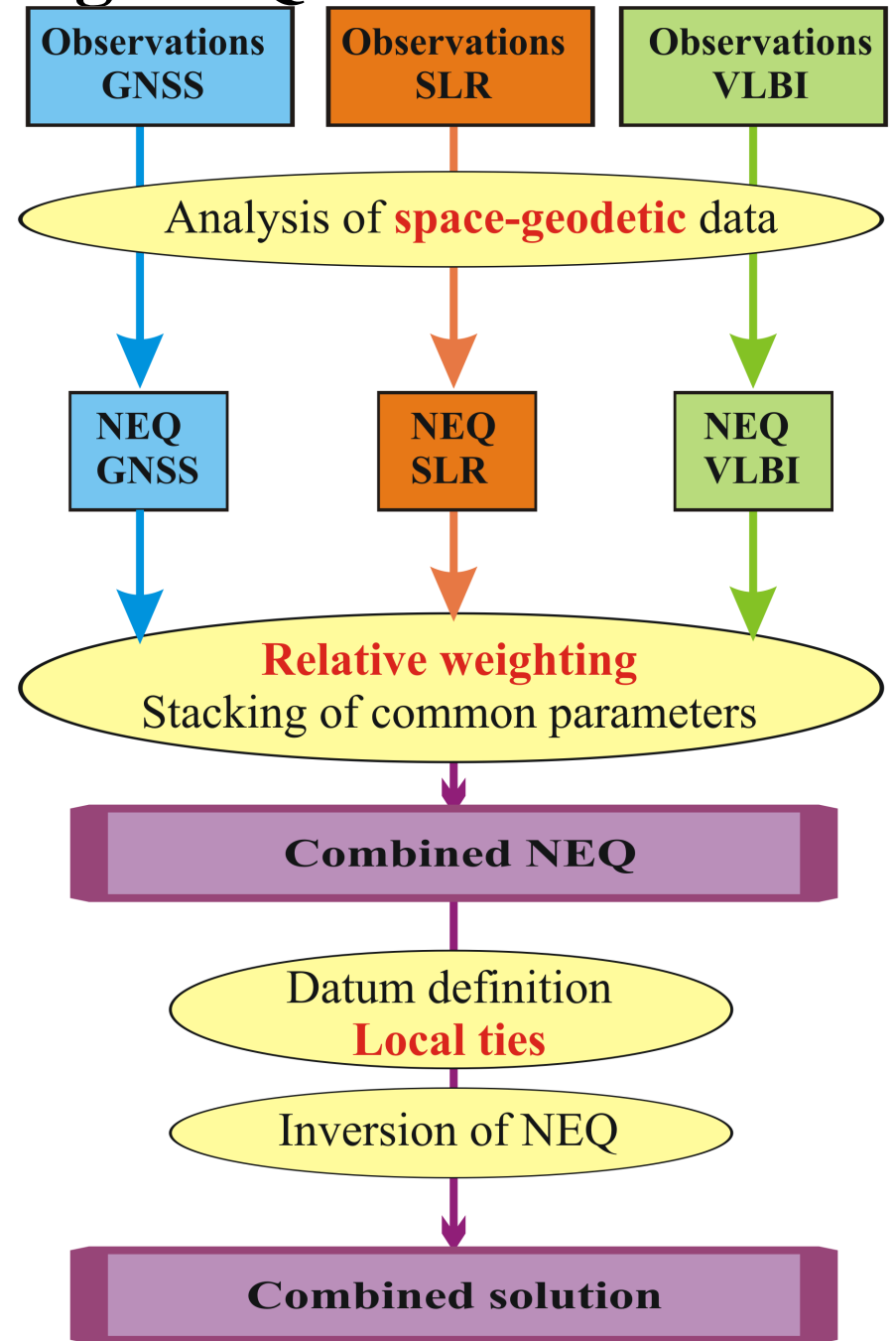
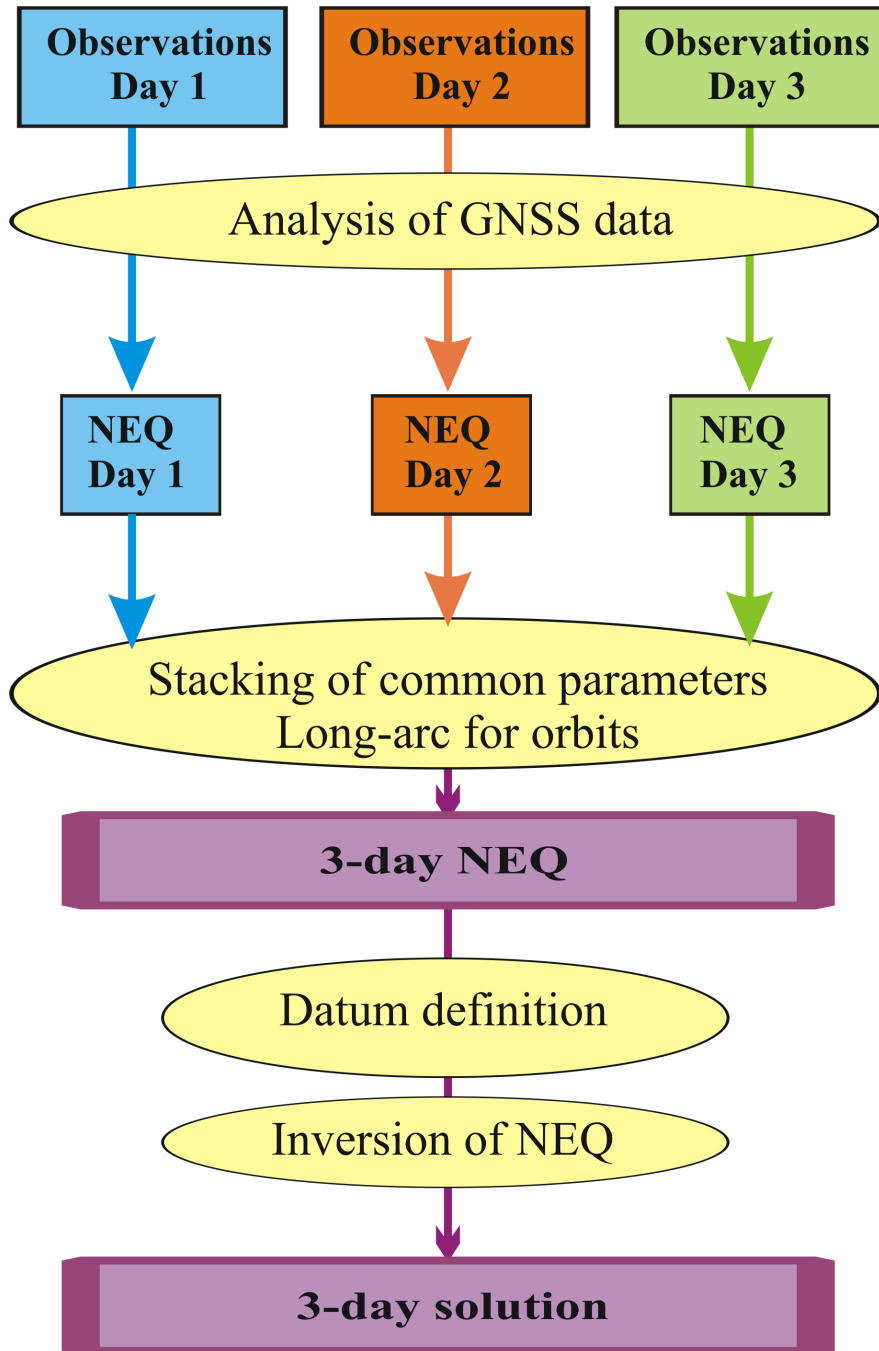
**3 equivalent applications** within BSW:

- GNSS 1-day analysis ⇒ GNSS  $n$ -day solution (e.g. 3-day)
- Separate GNSS/SLR/VLBI analysis ⇒ Combined solution
- SINEX input ⇒ Combined solution

# Combination using NEQs



# Combination using NEQs



# Combination using NEQs

