Towards operational Zero-Difference GNSS Processing at Center for Orbit Determination in Europe (CODE)

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CODE provides continuous GNSS products

AIUB

Schweizerische Eidgenossenschaft
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CODE provides continuous GNSS products

- Official **IGS Analysis Center** contributing to the International GNSS Service
- AIUB develops and maintains the **Bernese GNSS Software**
- Continuous global GNSS product generation since **1992**
- Current operational processing based on **Double-Difference (DD)** approach

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Motivation to consider Zero-Difference processing

Aspect	Double-Difference (DD)	Zero-Difference (ZD)
Observation model	Differenced between stations and satellites	Undifferenced observations
Parameter elimination	Receiver/satellite clocks only implicitly	Receiver/satellite clocks explicitly available
Mathematical equivalence	Equivalent results achievable for the same data selection	Equivalent results achievable for the same data selection
Network topology	Baseline structure	Flexible, any network geometry
LEO satellite integration	Complex	Straightforward

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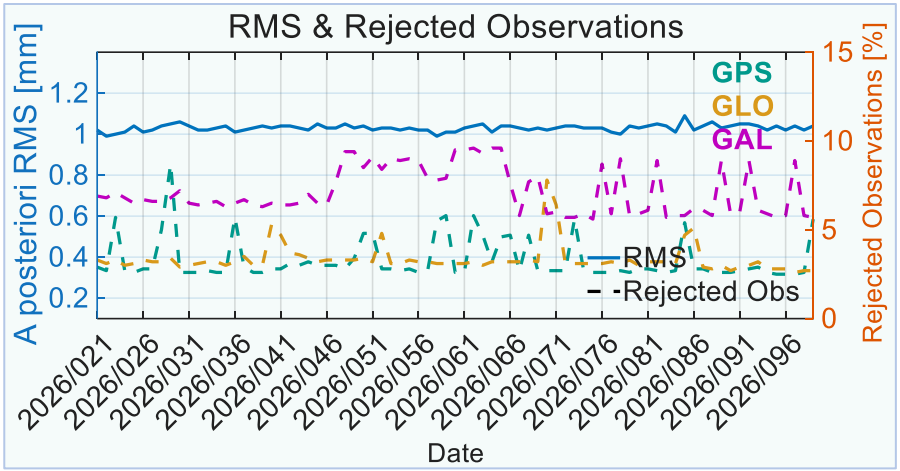
ZD processing evaluation

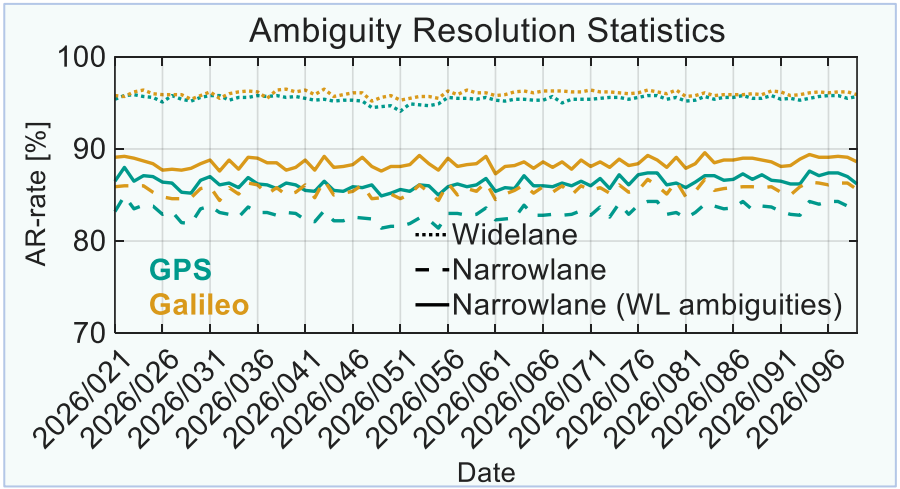
Test period: ~75 days
1-Day solutions
Identical ground station network

Quality indicators:

- A posteriori RMS
- Rejected observations
- Ambiguity fixing rates

The high stability of these indicators over the full test period confirms the **robustness of the ZD processing chain**.





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ZD solution agrees with CODE DD products

Helmert transformation to IGc20

Stable transformation parameters confirm no systematic frame offset between ZD and DD solutions

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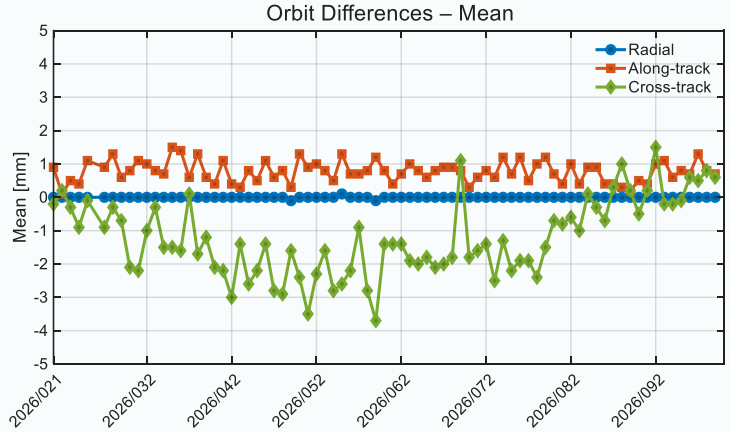
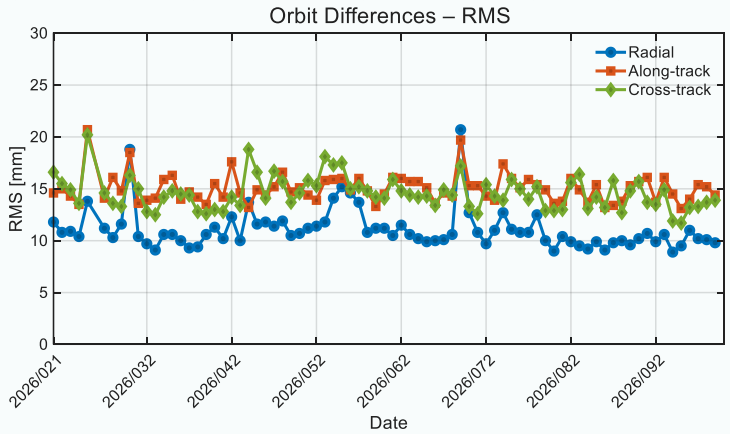
ZD solution agrees with CODE DD products

- **Mean differences:** within ±5 mm for all three orbit components (Radial, Along-track, Cross-track)
- **RMS differences:** typically, 10–15 mm





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Results confirm ZD processing quality

Evaluation over the test period yields key conclusions:

Stable time series

High ambiguity fixing rates

The results show that the ZD-based GNSS processing represents a promising foundation for **next generation GNSS solutions** at CODE.

Good agreement with CODE DD products

Global products feasible

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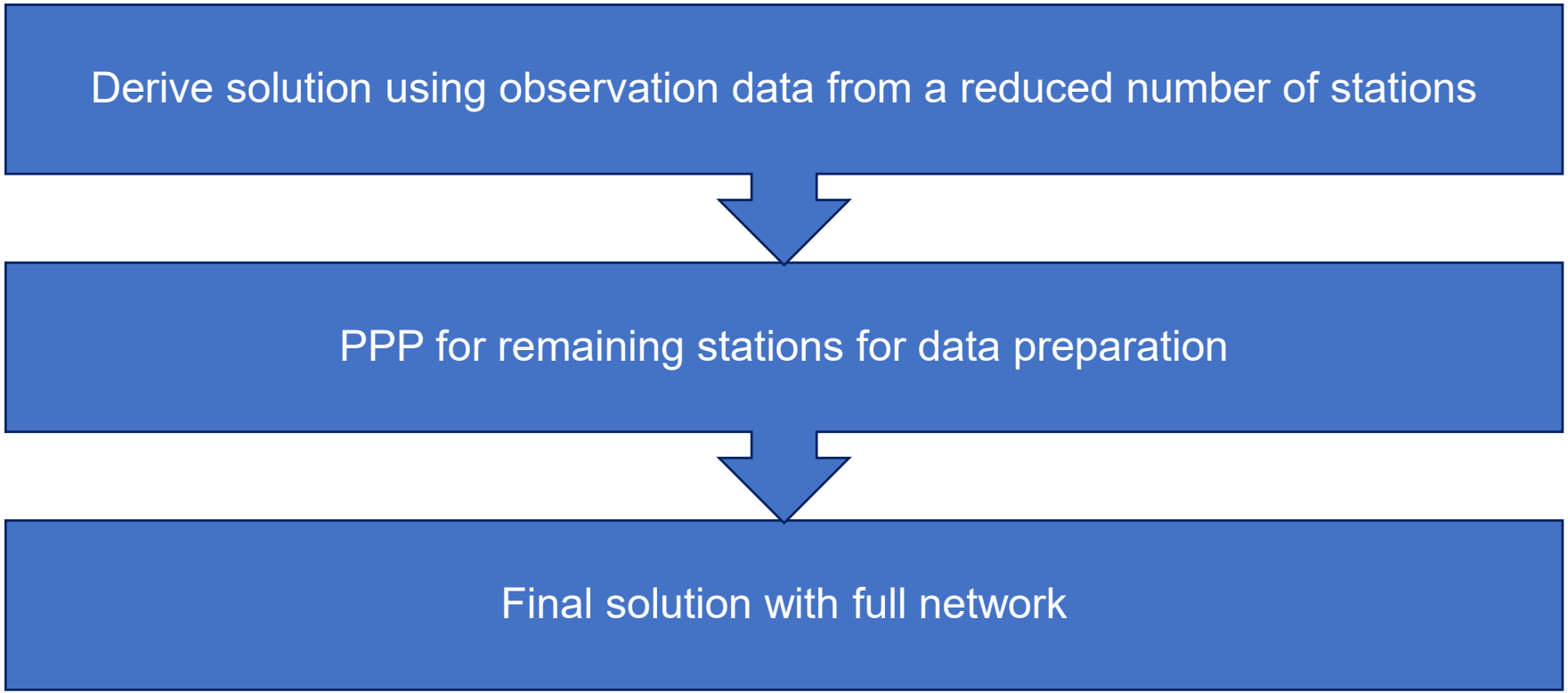
Processing chain



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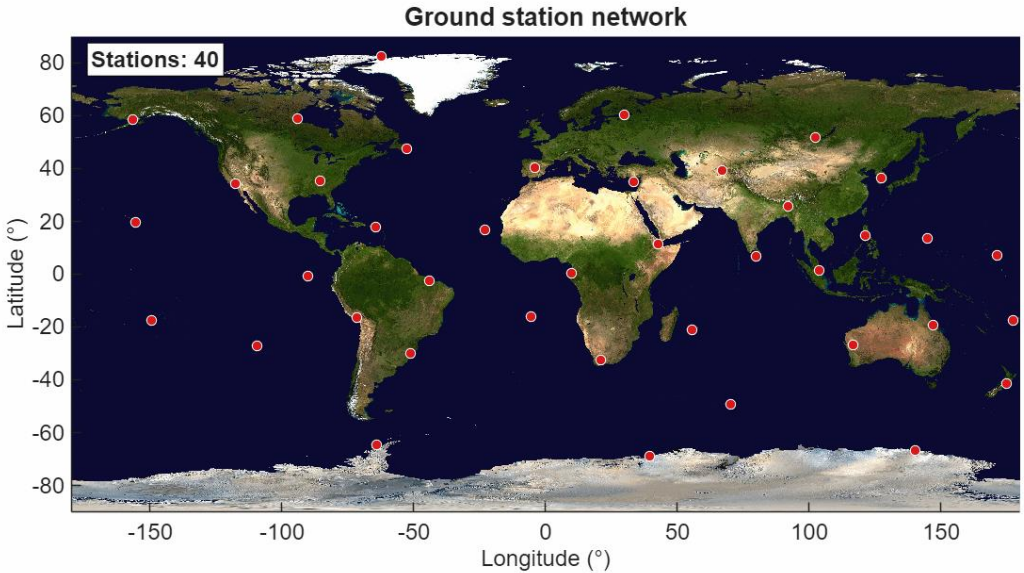
Reduced ground station network

- ZD strategy allows for flexible number of ground stations
- Reduce computational effort



Station Distribution:

- Homogeneous global distribution
- Preference for multi-GNSS stations

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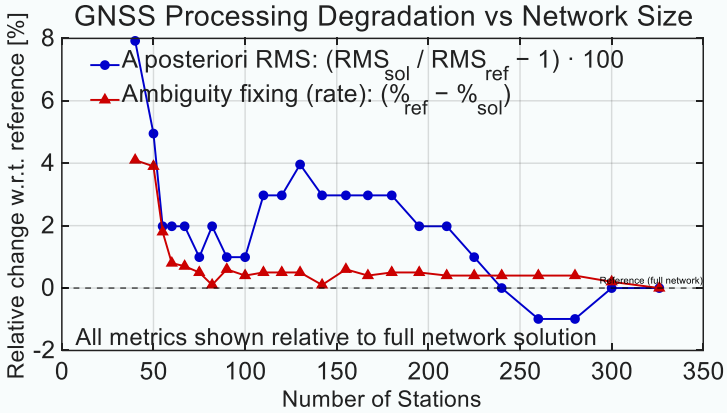
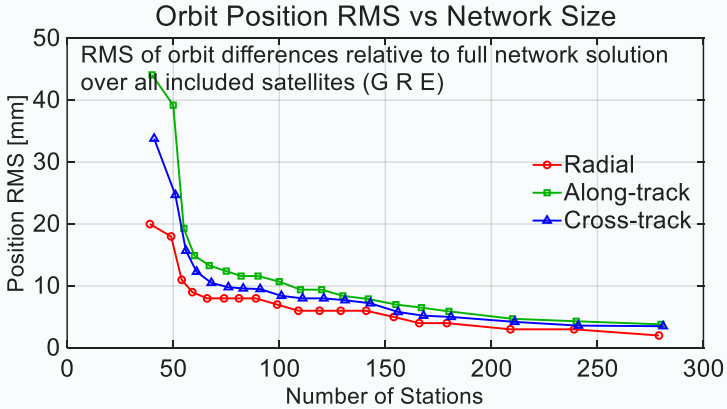
Orbit and coordinate quality

Orbit Position RMS

Station Coordinate Degradation

Processing statistics





The **elbow point** in all metrics consistently appears near **60 stations**, establishing this as the practical minimum for operationally acceptable ZD solutions.

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ZD processing is operationally feasible at CODE

Summary of findings

1. ZD-chain is **under development**
2. First results show **good agreement** with CODE DD products
3. Processing chain is being tuned using a **small network** for initial step

Next steps:

- Evaluation of long-term time series after each processing step
- Integration of LEO observations

Thank you for your attention

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Backup slides:

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The ZD processing chain follows CODE's proven DD strategy

1 **Preprocessing**

Code and phase screening, cycle-slip detection

2 **Station-wise NEQ Generation**

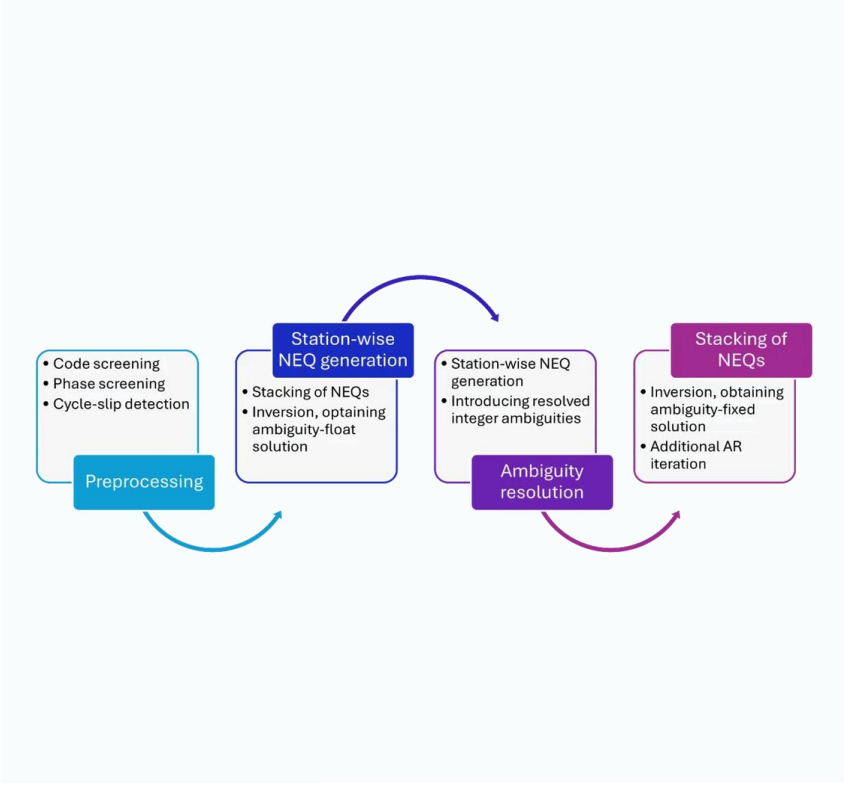
Stacking of normal equations, inversion to obtain the ambiguity-float solution

3 **Ambiguity Resolution**

Station-wise NEQ generation with resolved integer ambiguities introduced via a globally applied clustering strategy

4 **Final NEQ Stacking**

Inversion to obtain the ambiguity-fixed solution, followed by an additional AR iteration for consistency



The pipeline is **fully parallelized** at the station level, enabling efficient processing of large global networks. Ambiguity resolution uses a **between-satellite clustering strategy** based on preliminary orbit and clock information.

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