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Earth surface deformation in Germany following the Sumatra Dec 26, 2004 earthquake using 1 Hz GPS data

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Frankfurt am Main, Germany

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Content

- Seismic wave propagation
- Analysis of 1 Hz GPS data
- Results
- Conclusions

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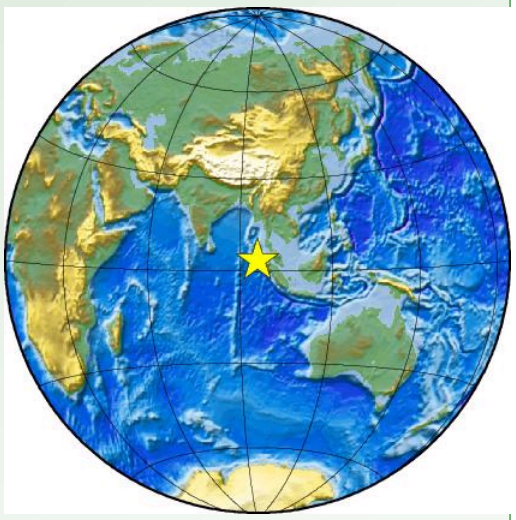
Background

- Sub-oceanic earthquake off the coast (west) of Sumatra on Dec 26, 2004, 7:58:50 Local Time (0.58:50 UTC)
- Epicentre 3.50 ° N / 95.72 ° E, depth ~ 10 km
- Magnitude 9.0 (later reports closer to 9.3)

- Above all: among geodetic analyses and seismological interpretations more than 200000 people died as a result of the Tsunami



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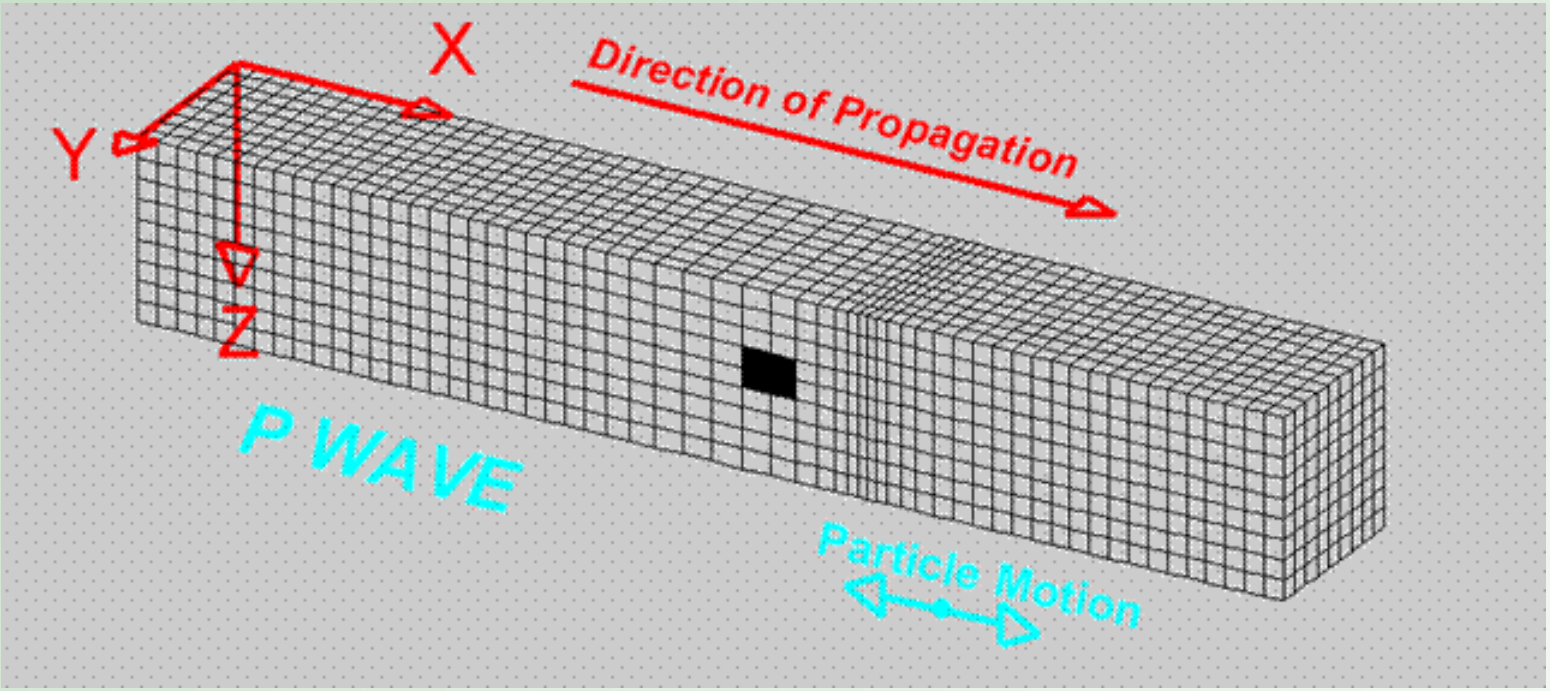
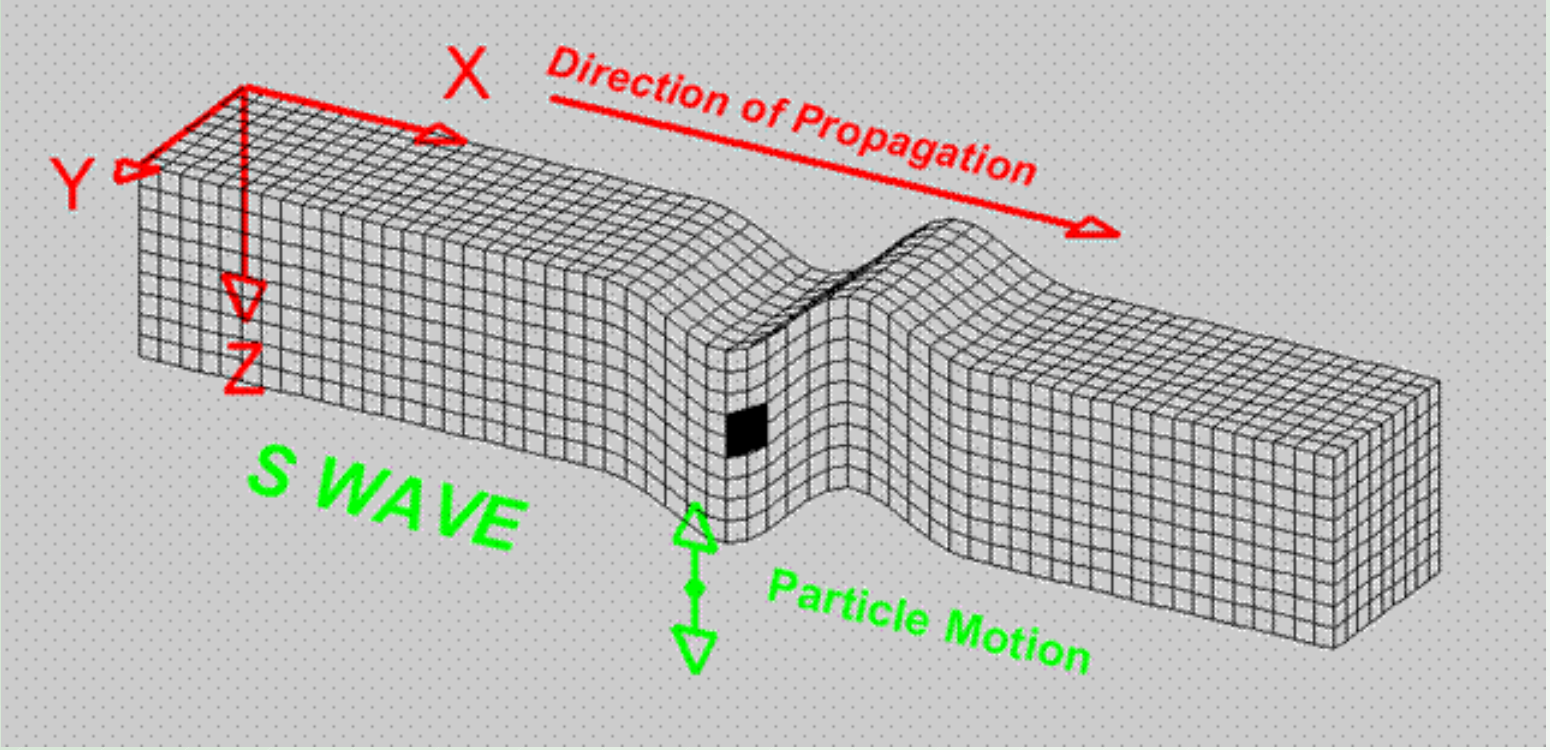
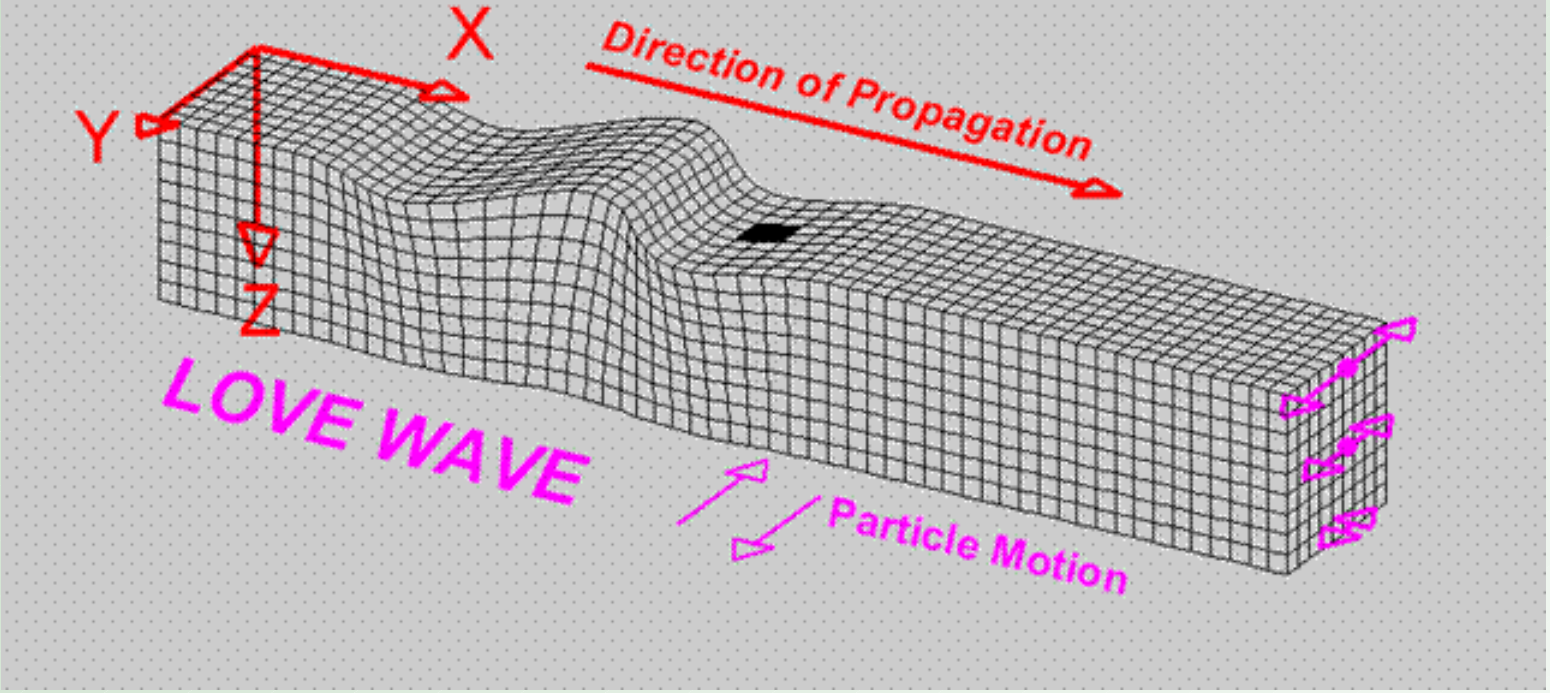
P wave propagation



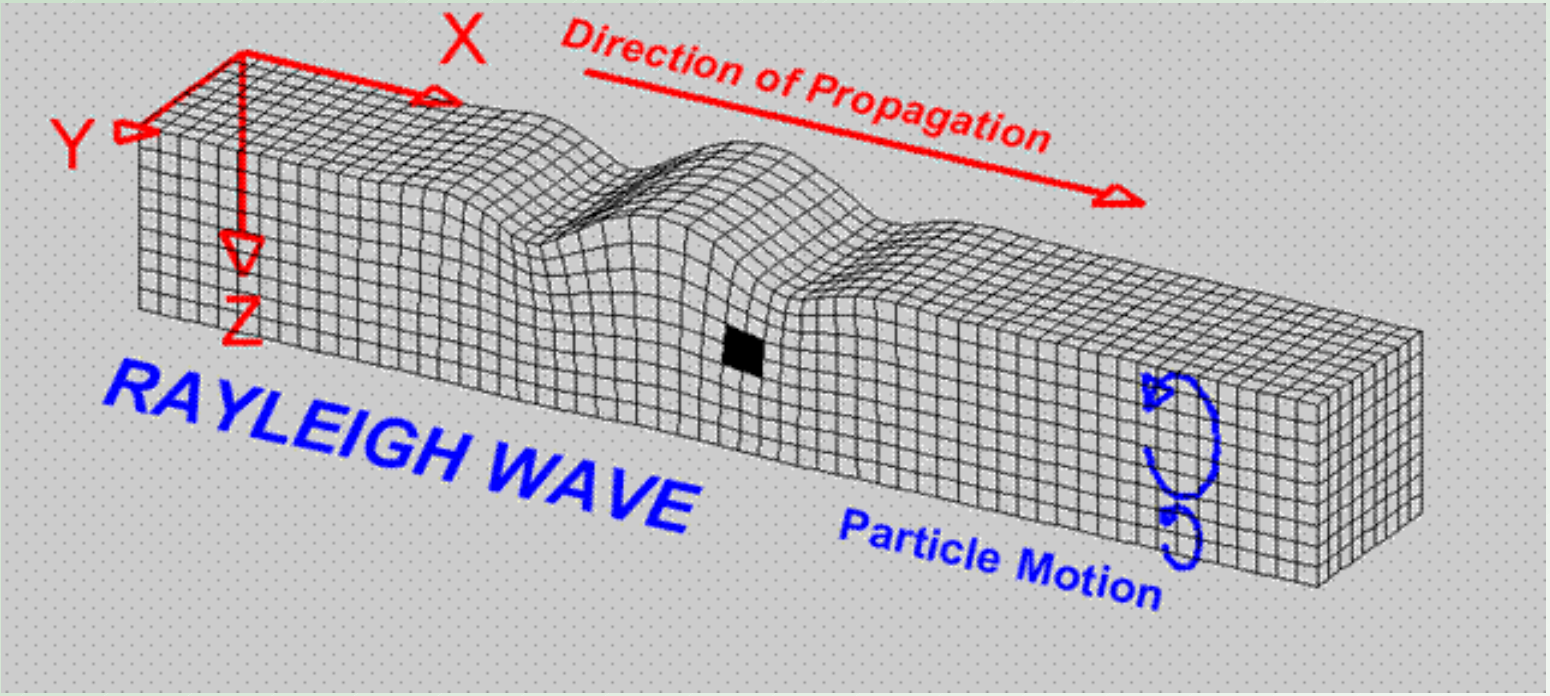
S wave propagation



LOVE wave propagation



RAYLEIGH wave propagation



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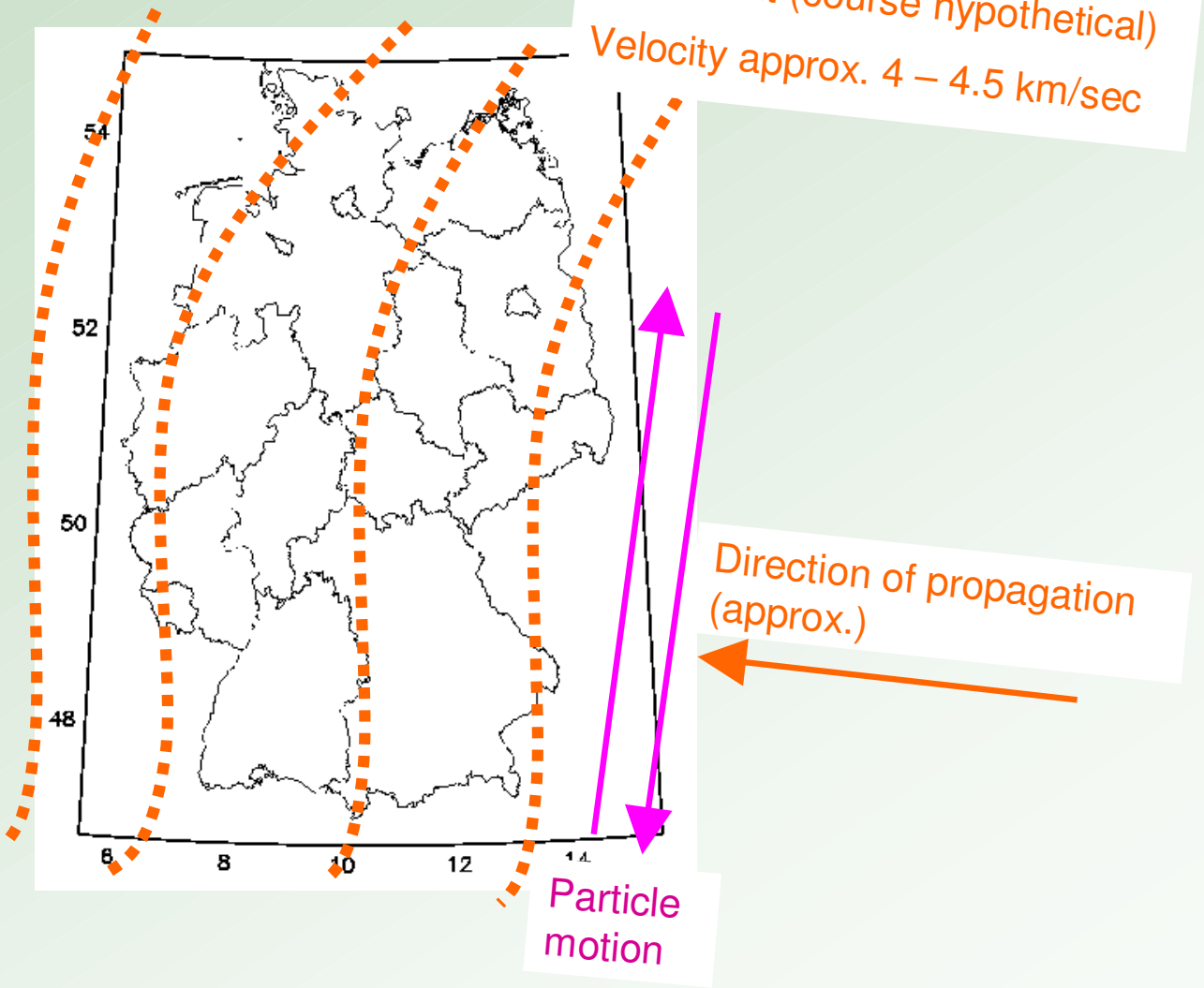
LOVE wave propagation



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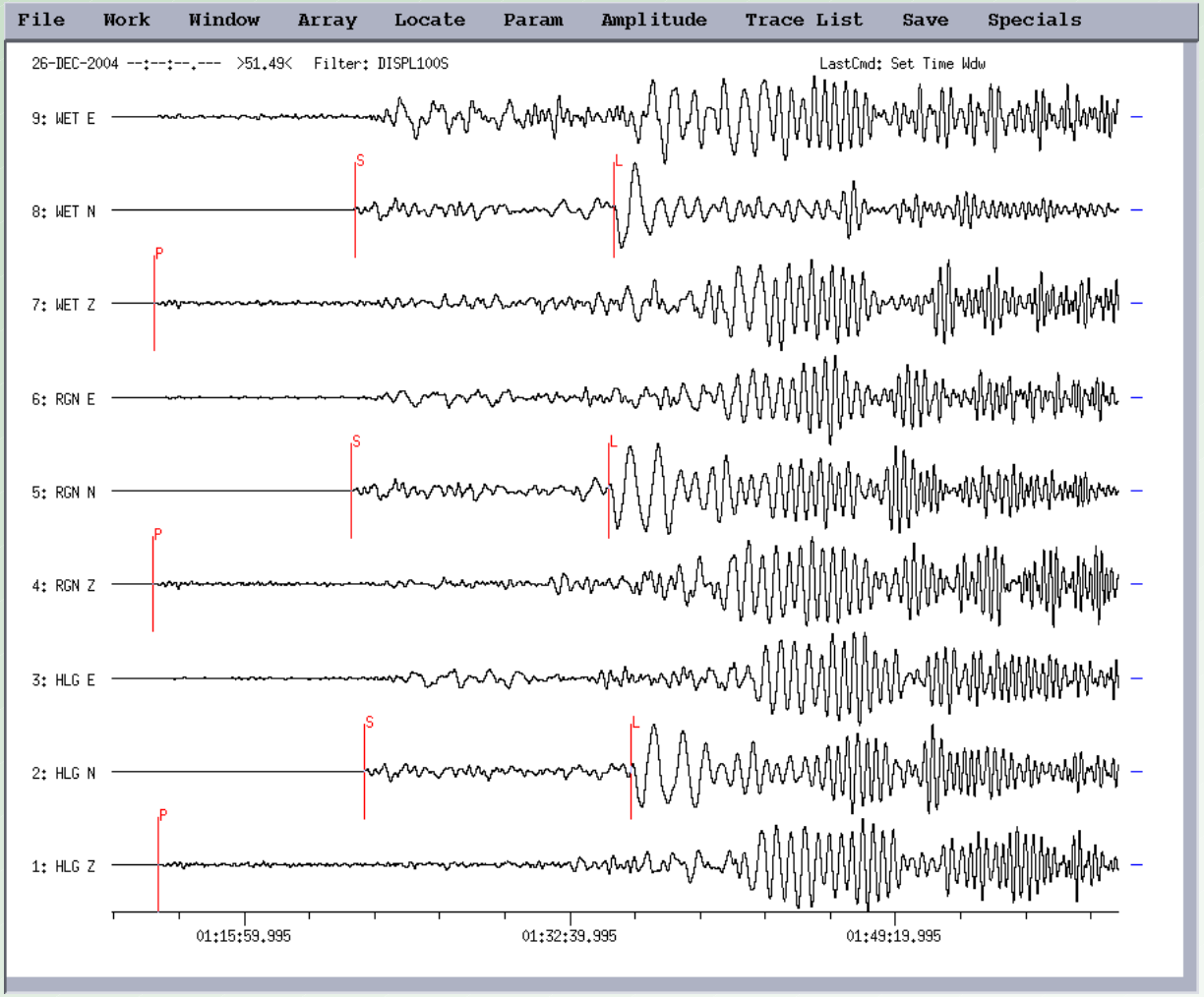
Seismometer results



© Results by K. Klinge (Bundesanstalt für Geowissenschaften und Rohstoffe)

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1 Hz GPS analyses of earthquake-related surface deformation

Event	Date	Magnitude	Distance to analysed sites [km]	Displacements
Denali (Alaska)	Nov 3, 2002	7.9	3900 (Bock et al. 2004)	mm (horiz. comp.)
Tokachi-Oki (Hokkaido)	Sep 25, 2003	8.1	70-240 (Irwan et al. 2004)	dm (all comp.)
San Simeon (California)	Dec 22, 2003	6.5	100 (Ji et al. 2004)	2-4 cm (all comp.)
Parkfield (California)	Sep 28, 2004	6.0	20-50 (K. Larson, 2005)	~ 2 cm (all comp.)
Sumatra-Andaman	Dec 26, 2004	9.3	<3000 (Ohta et al.)	cm
Sumatra-Andaman	Dec 26, 2004	9.3	9000	cm?

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GPS analysis for this study

- Analysis of 1 Hz GPS data covering the area of Germany
- Data of more than 100 permanent sites available according to the kind cooperation with the German Survey Agencies (and GREF stations)
- Bernese Software 5.0
  - „ionosphere free double difference“ observations
  - Ambiguity fixing using QIF method
- Six hours of data (beginning of day)
- Processing of consecutive days shifted by 236 seconds (sidereal day)
- Kinematic option used to output coordinates for every epoch
- Focus on horizontal displacements

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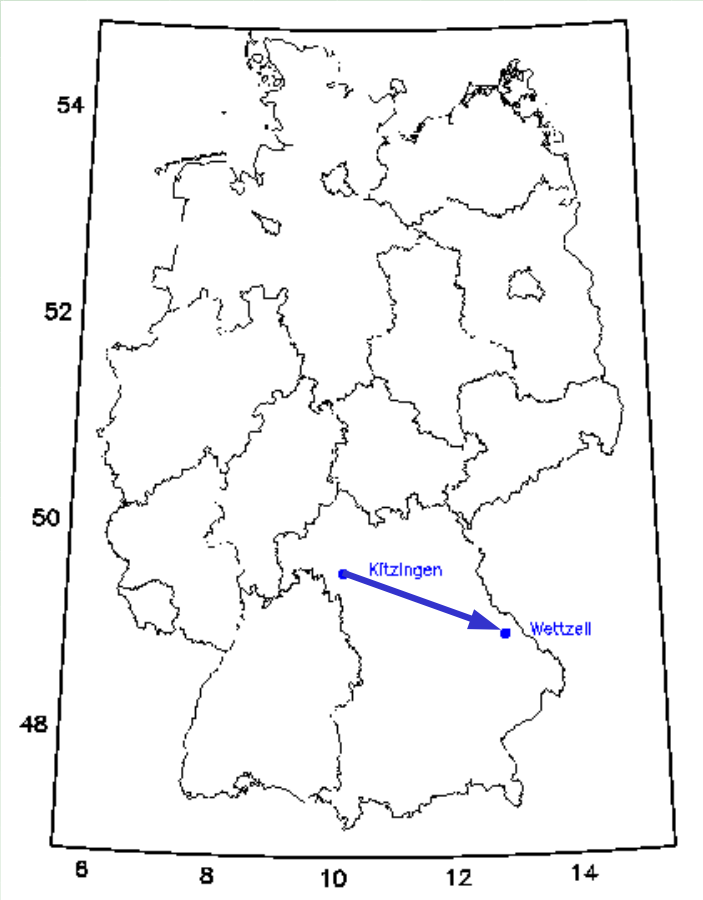
Unfiltered results: Wettzell - Kitzingen (208 km)



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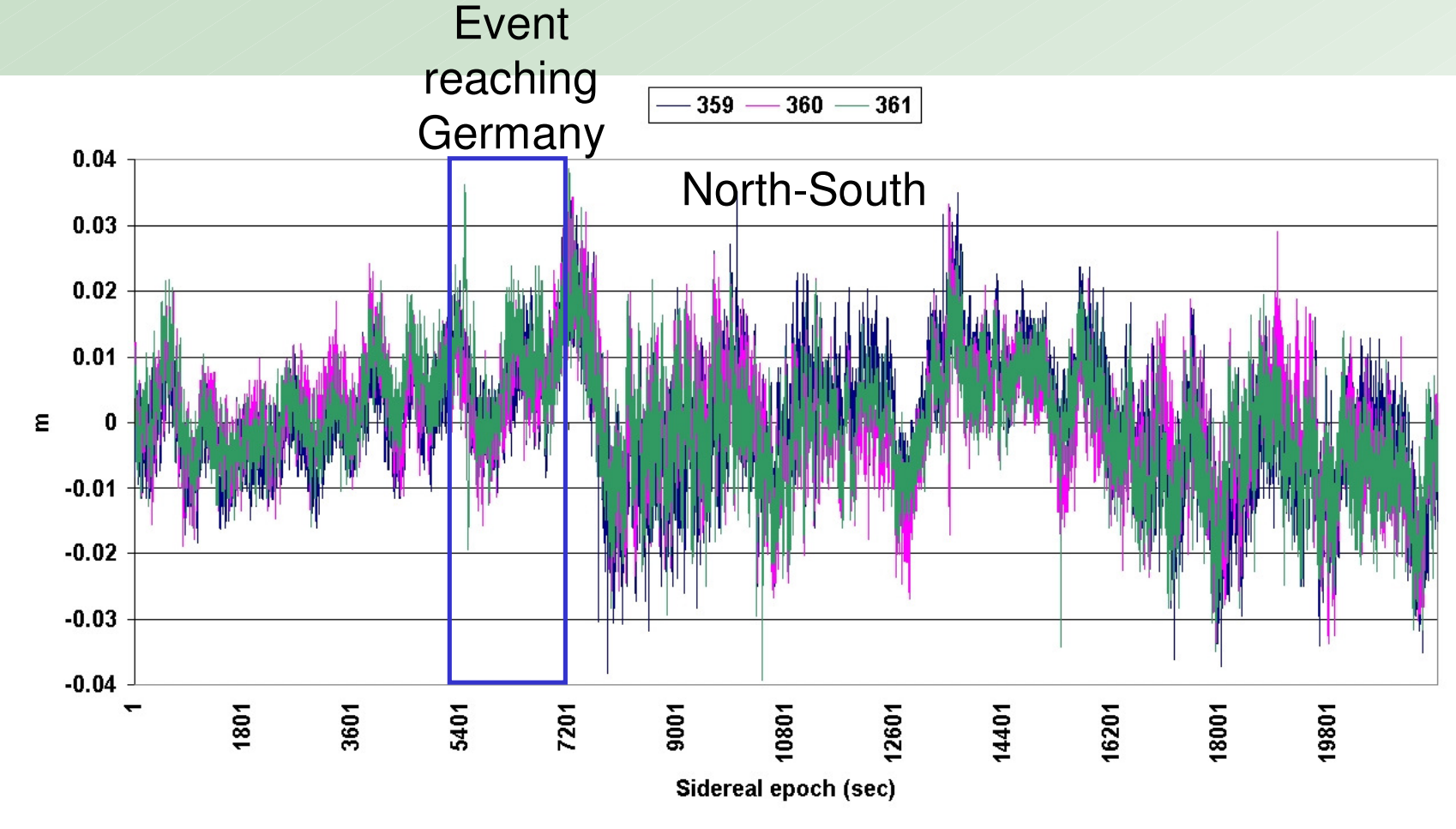

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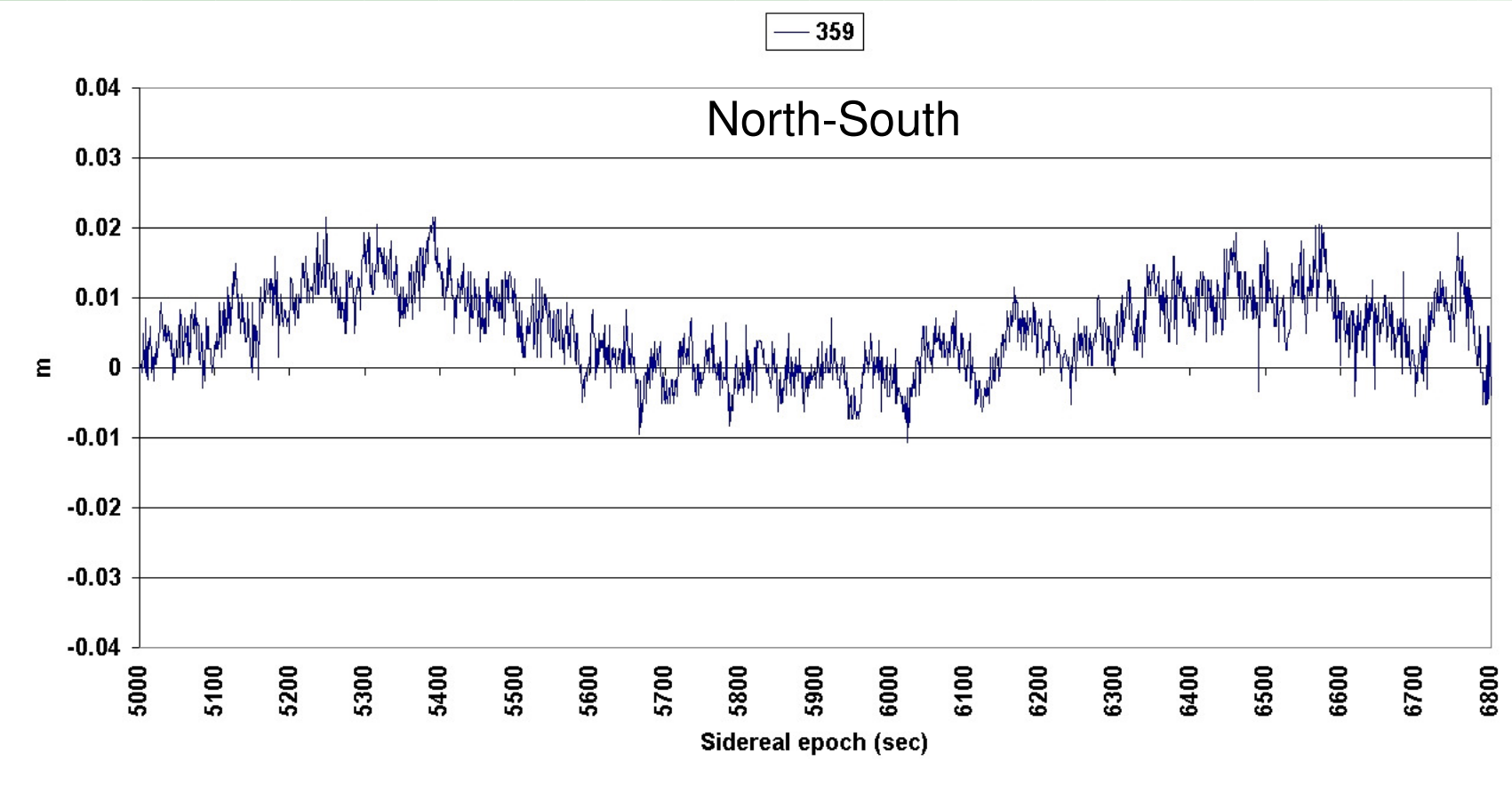

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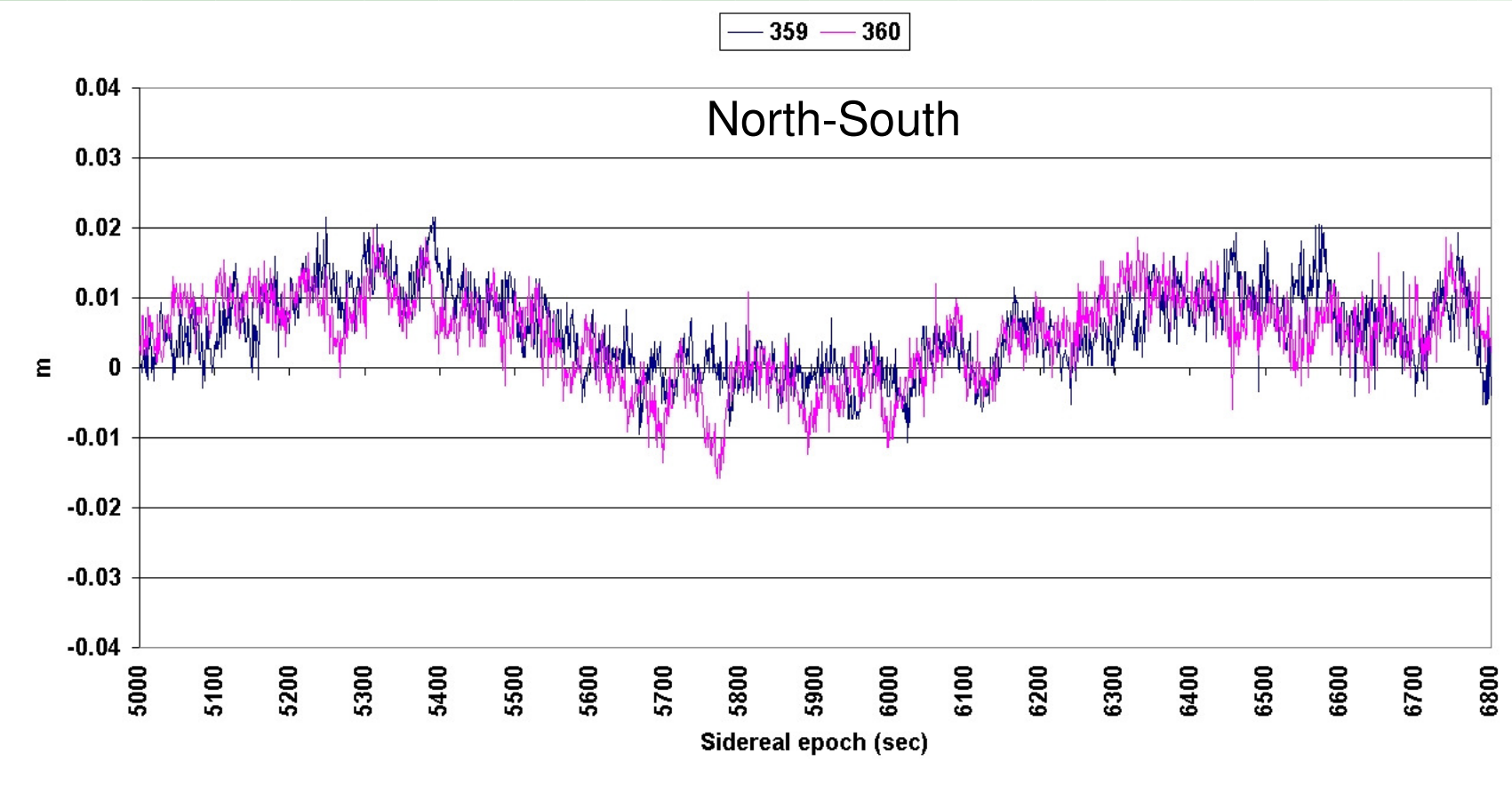

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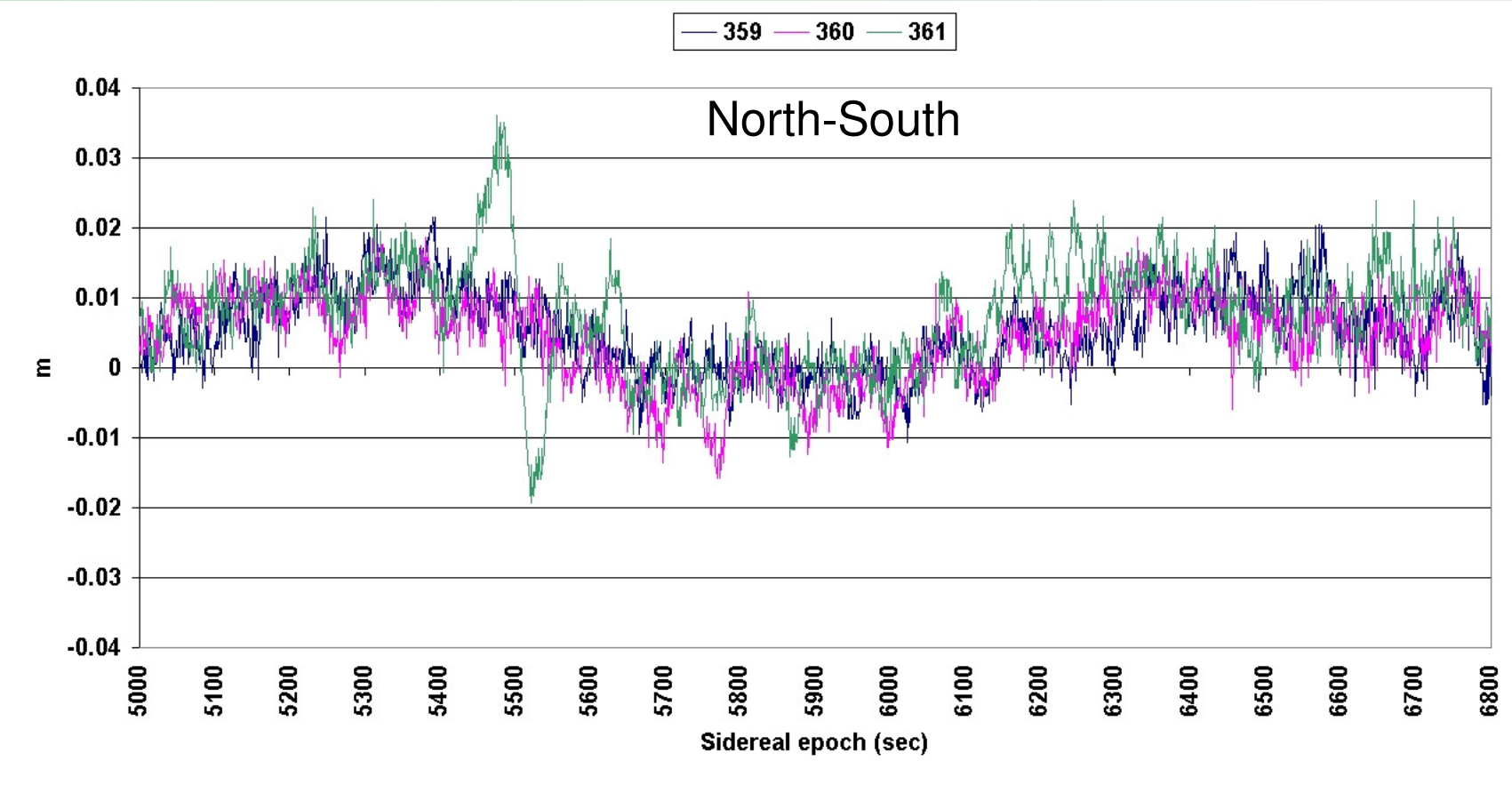

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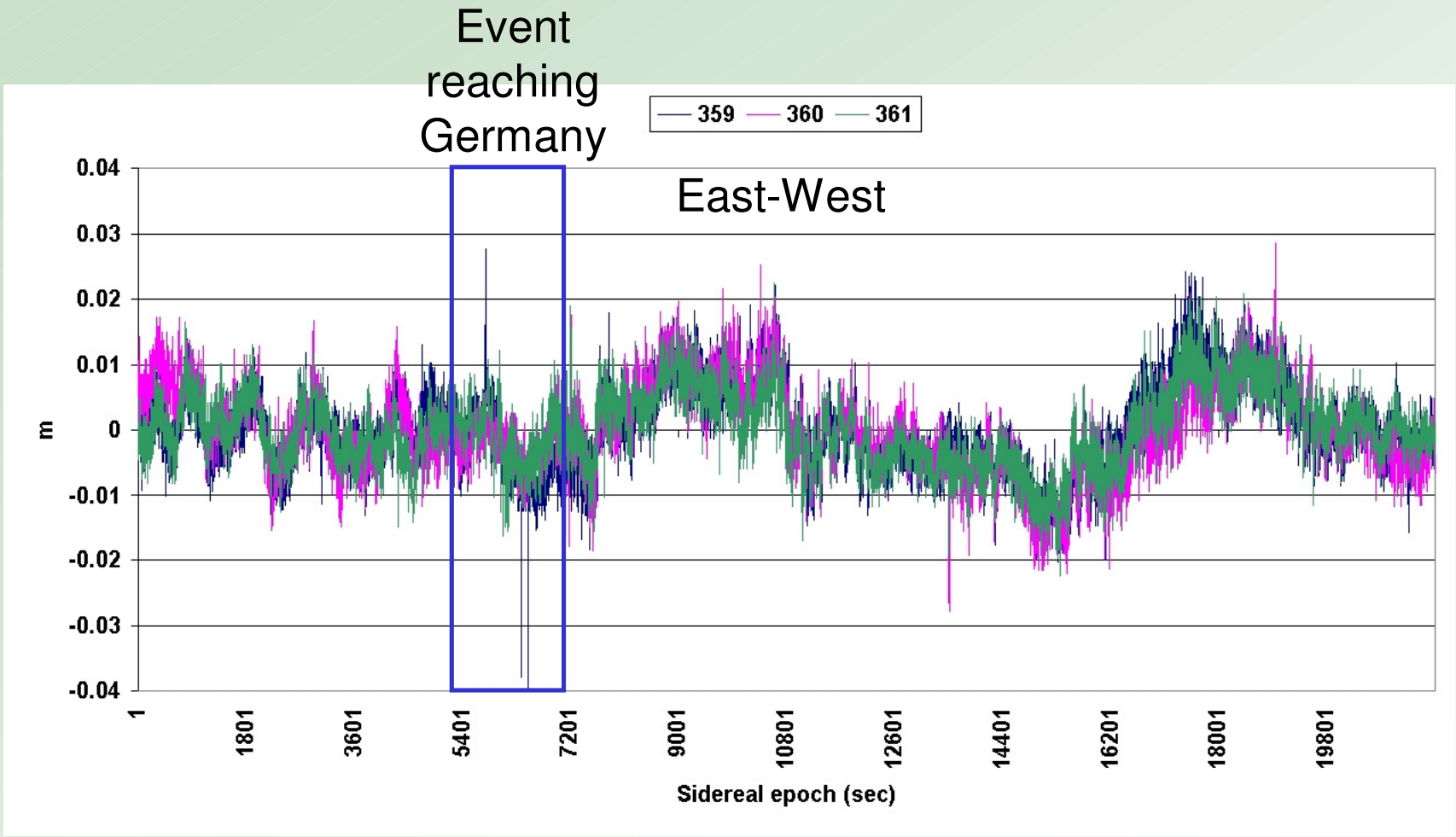

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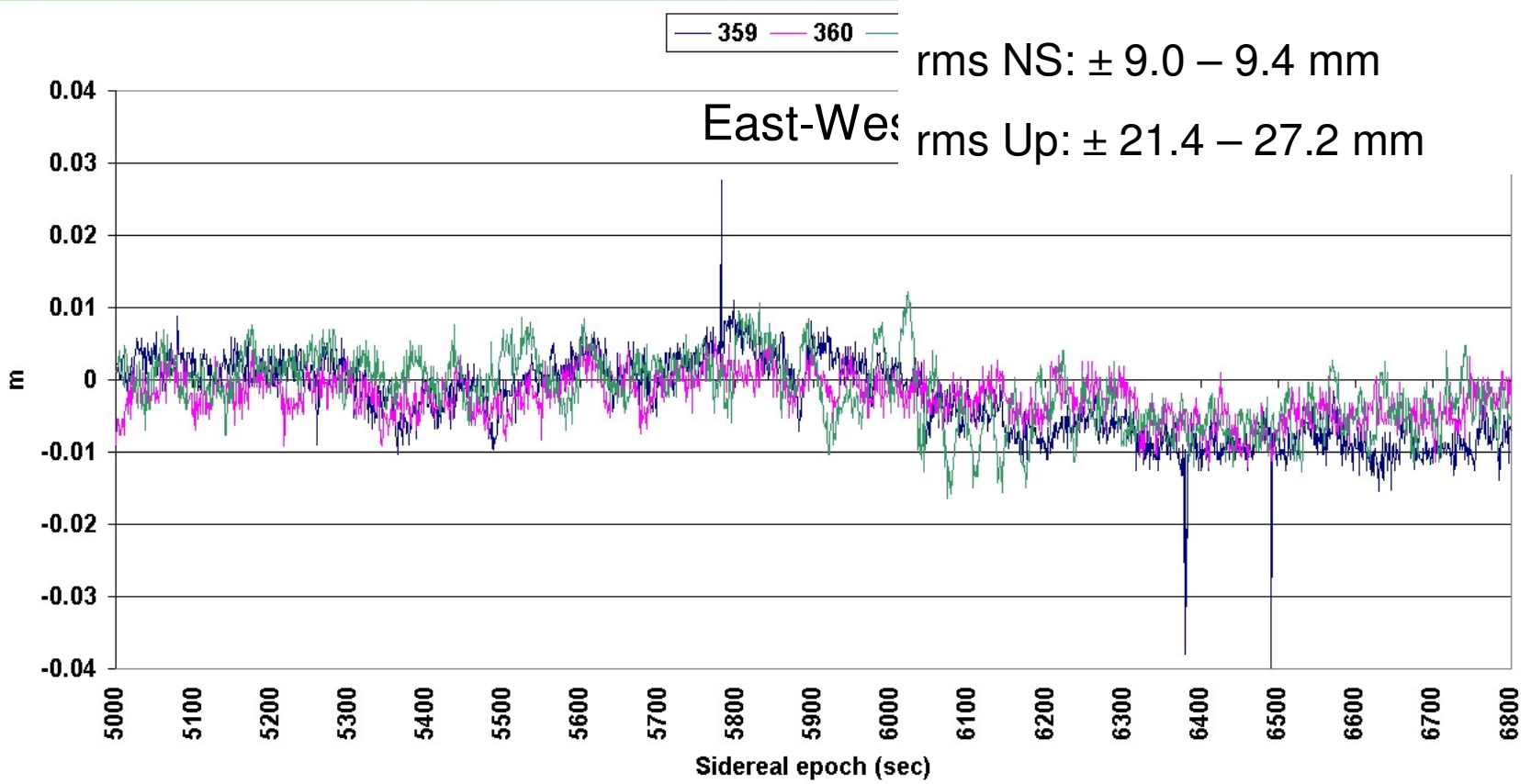
Unfiltered results: Wettzell - Kitzingen (208 km)

rms EW: ± 6.0 – 6.8 mm

rms NS: ± 9.0 – 9.4 mm

rms Up: ± 21.4 – 27.2 mm



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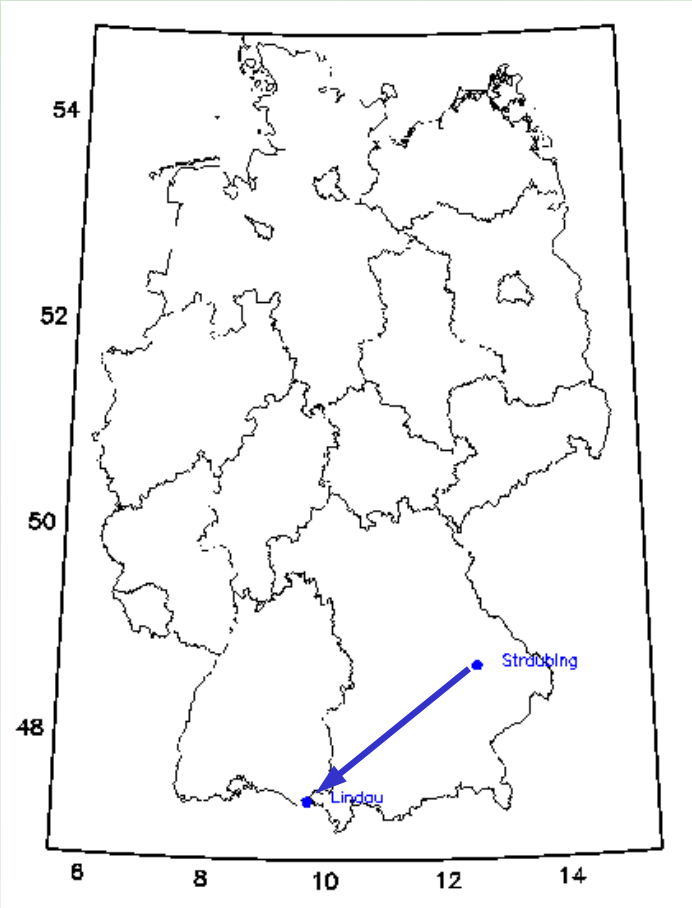
Unfiltered results: Lindau – Straubing (258 km)



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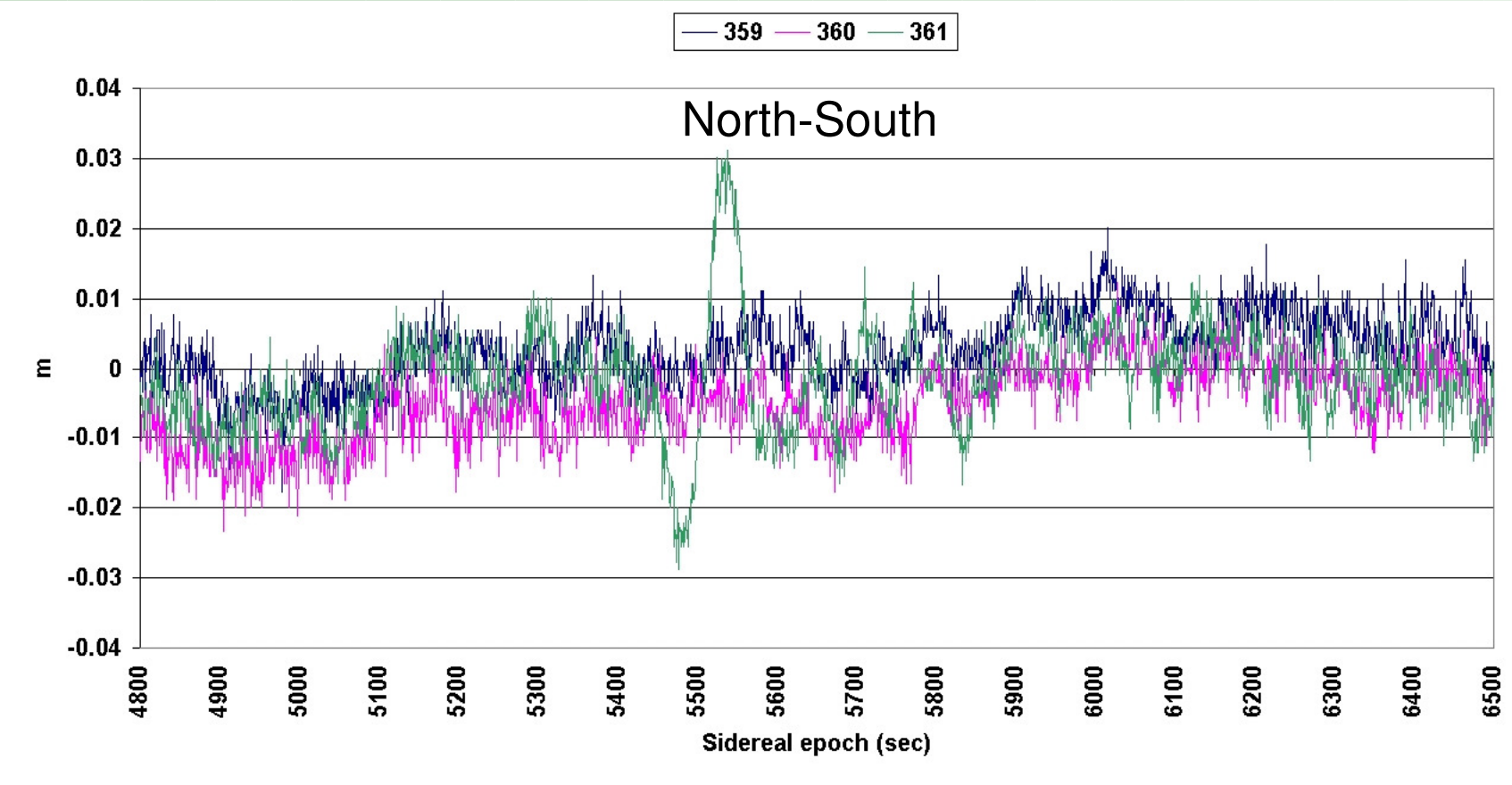

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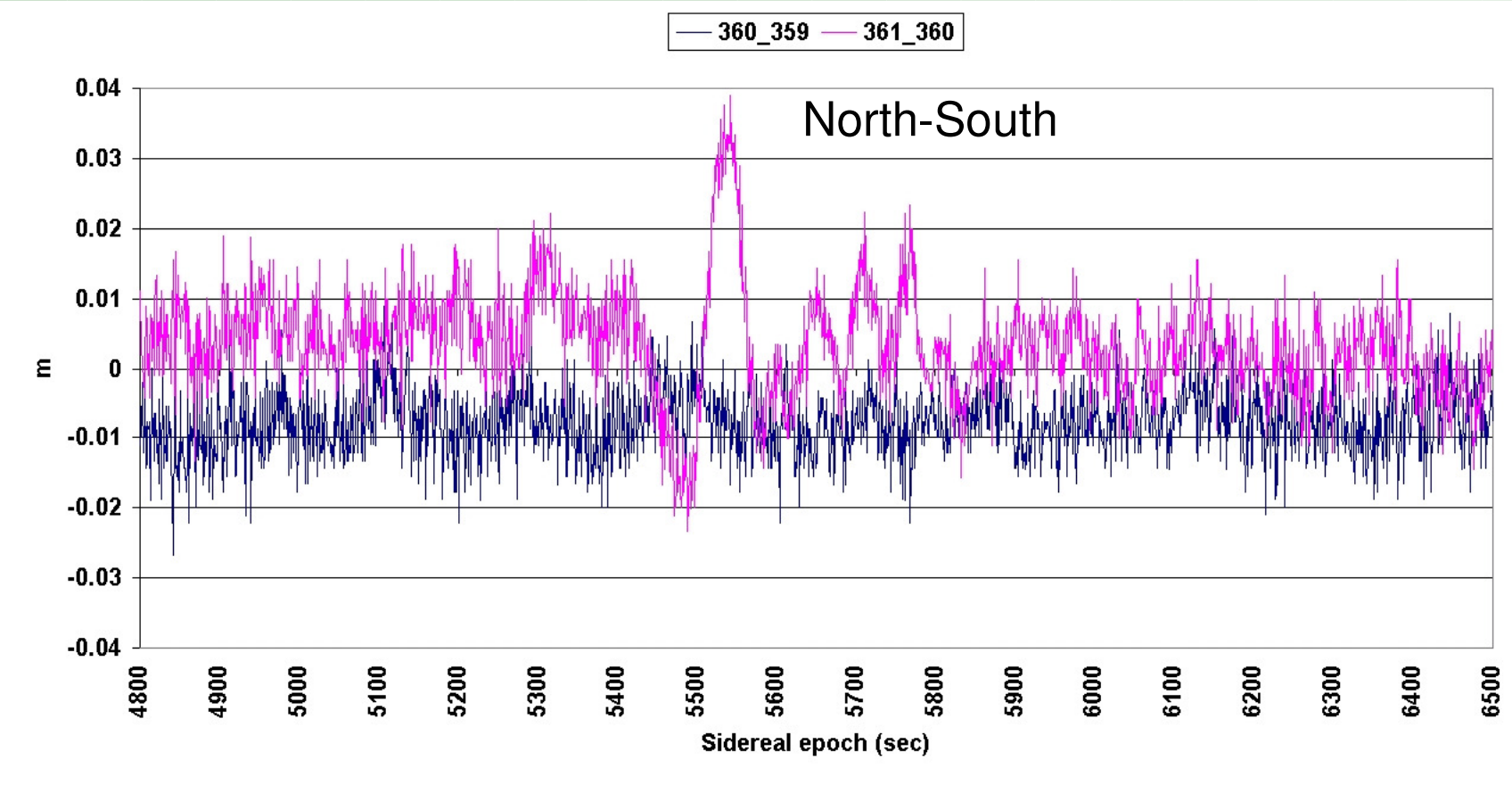

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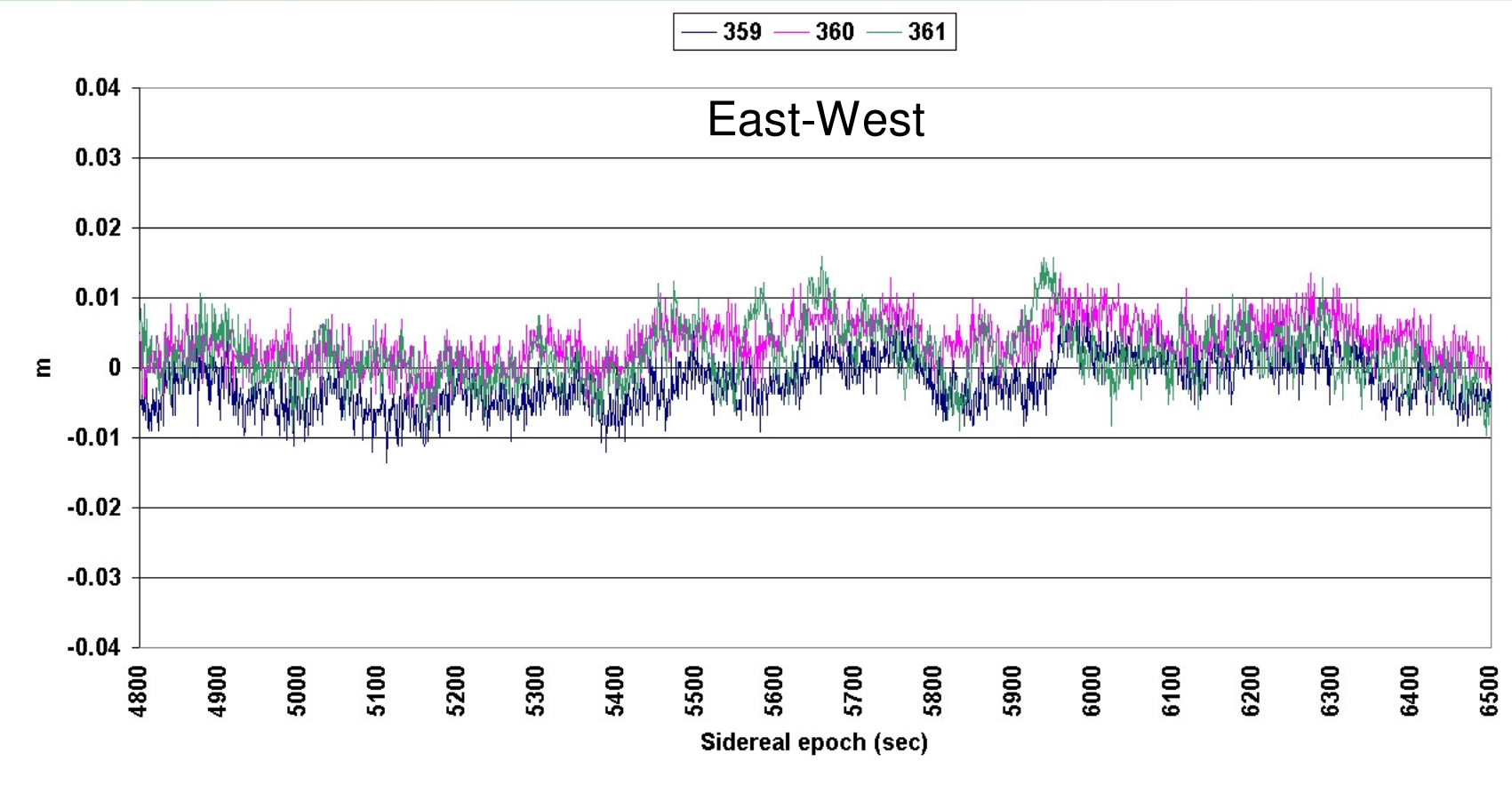

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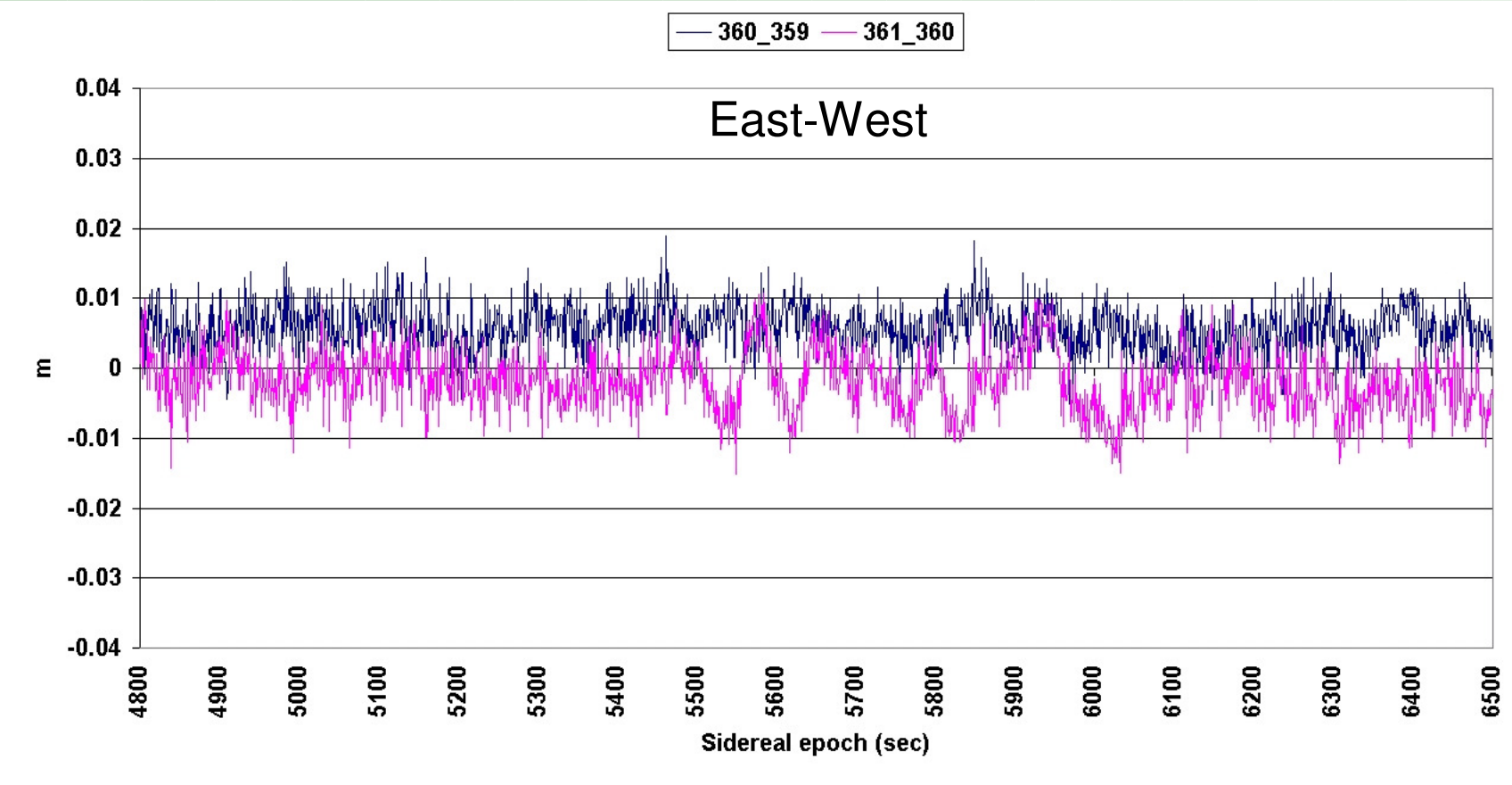

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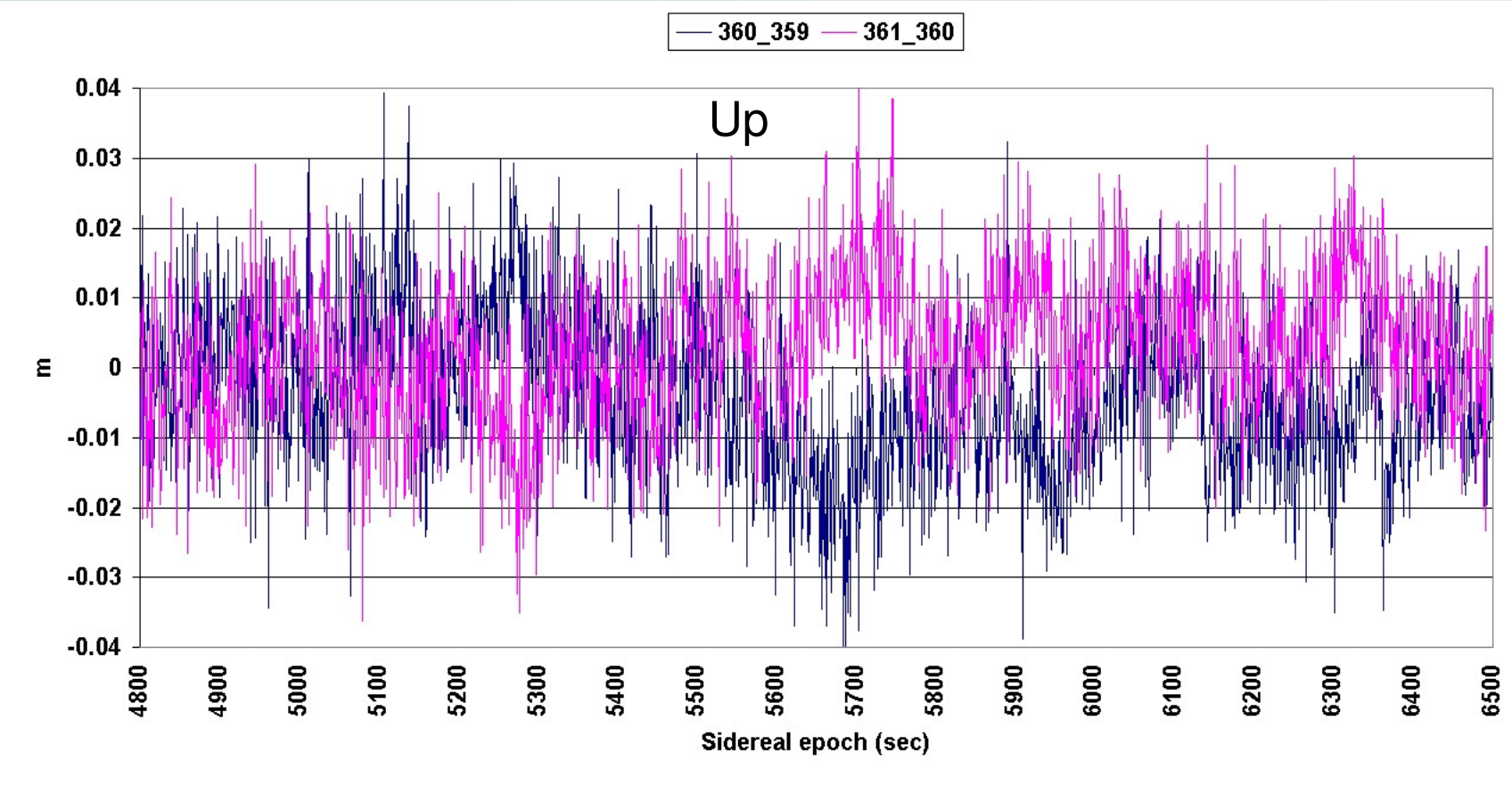

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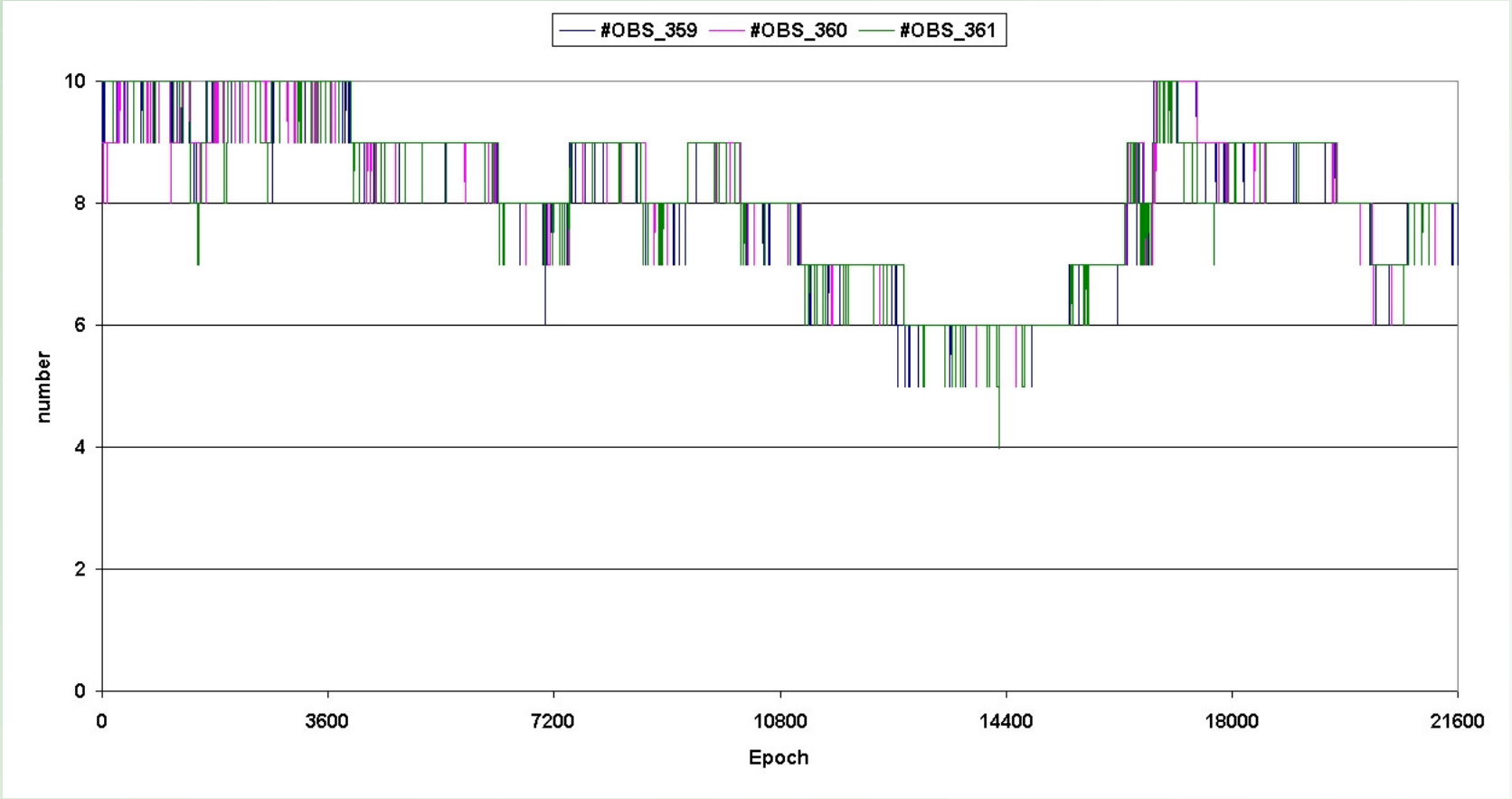
Number of DD observations used in analysis



(baseline Freilassing – Straubing)

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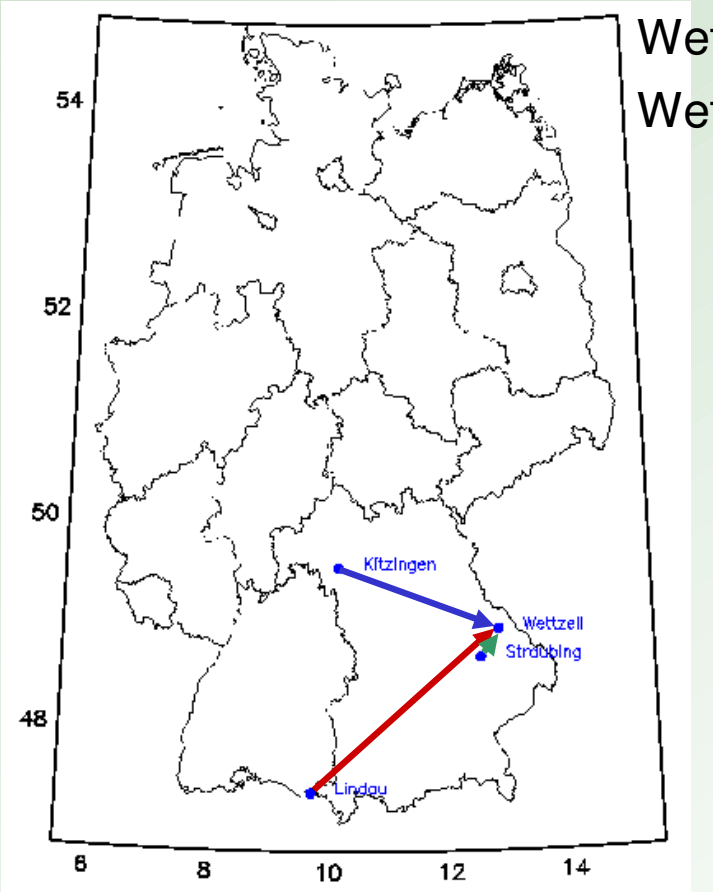
Filtered results: Wettzell

Wettzell - Kitzingen: 208 km
Wettzell - Straubing: 38 km
Wettzell - Lindau: 294 km



Filter means: smoothed by a 5 point moving average and high-pass filtered by a 51 point moving average with MathLab function FILT

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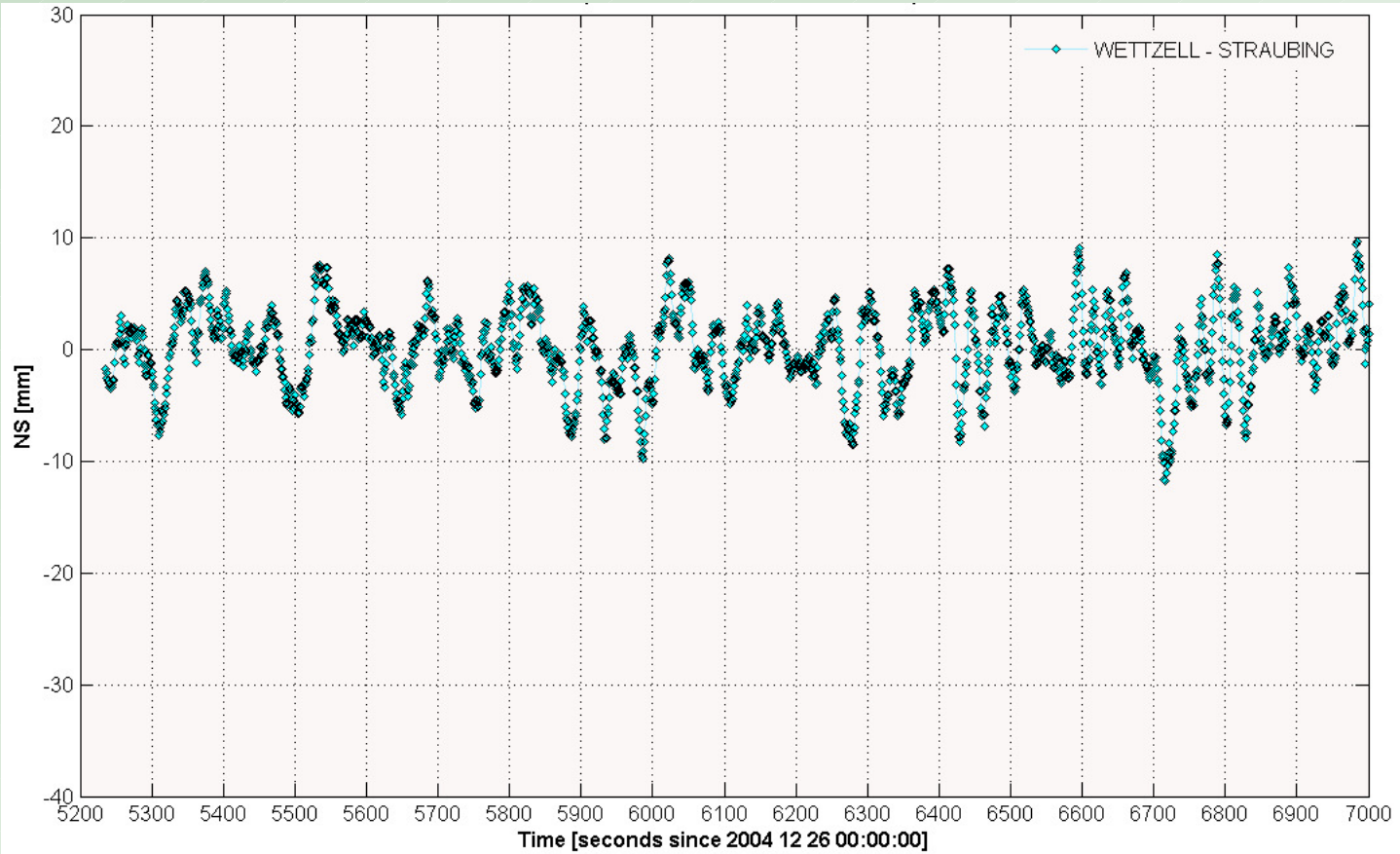
Filtered results: Wettzell



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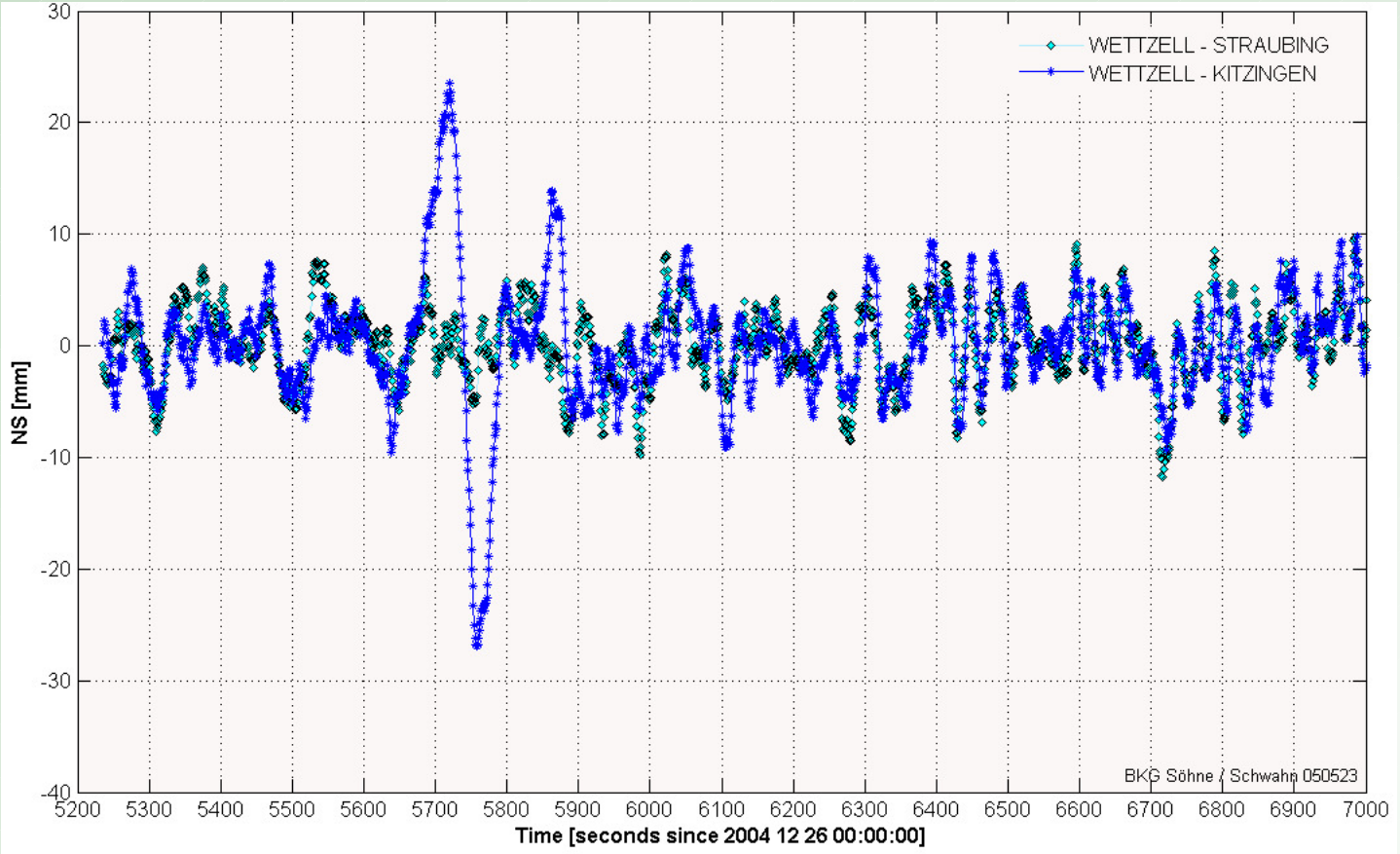

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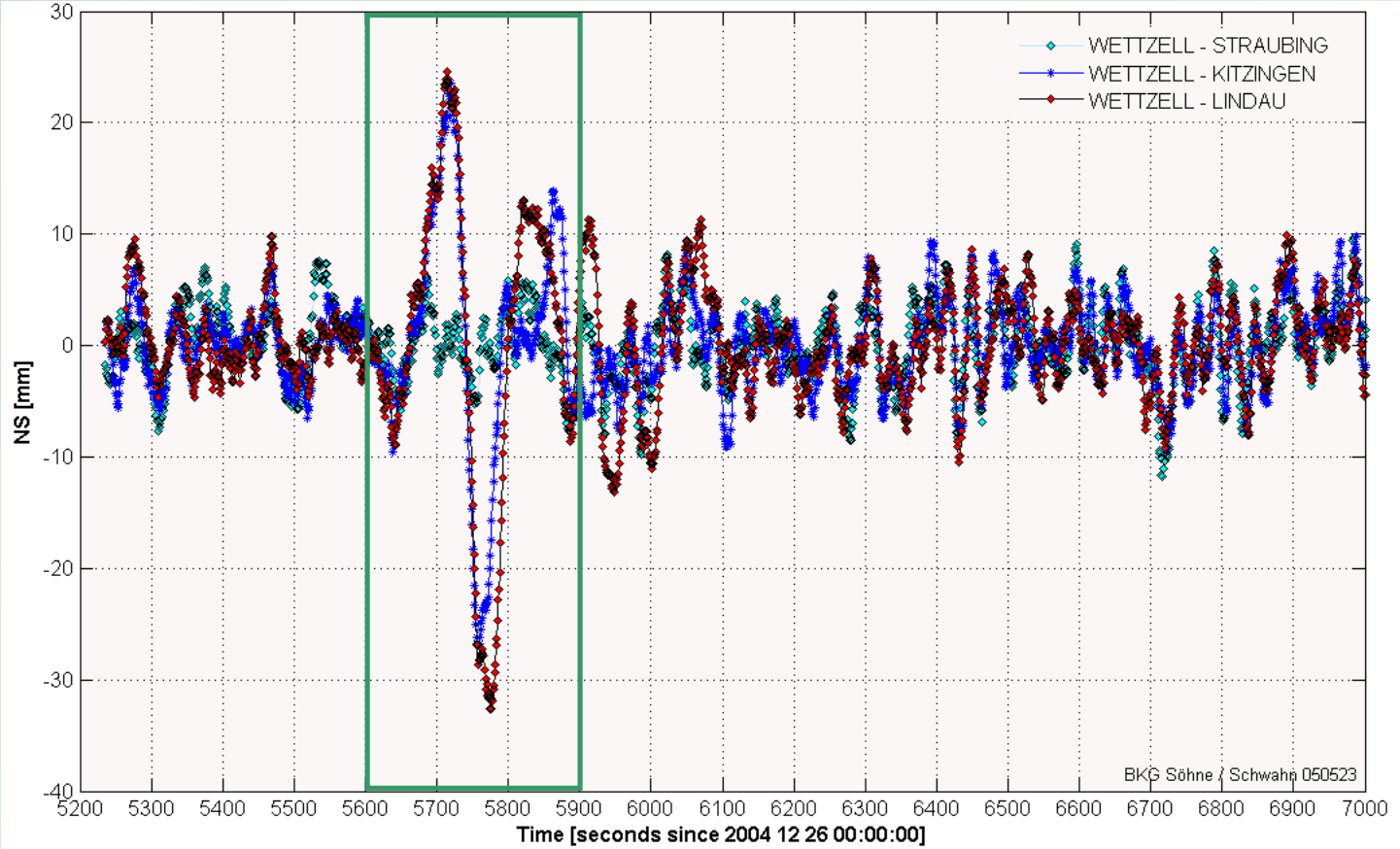

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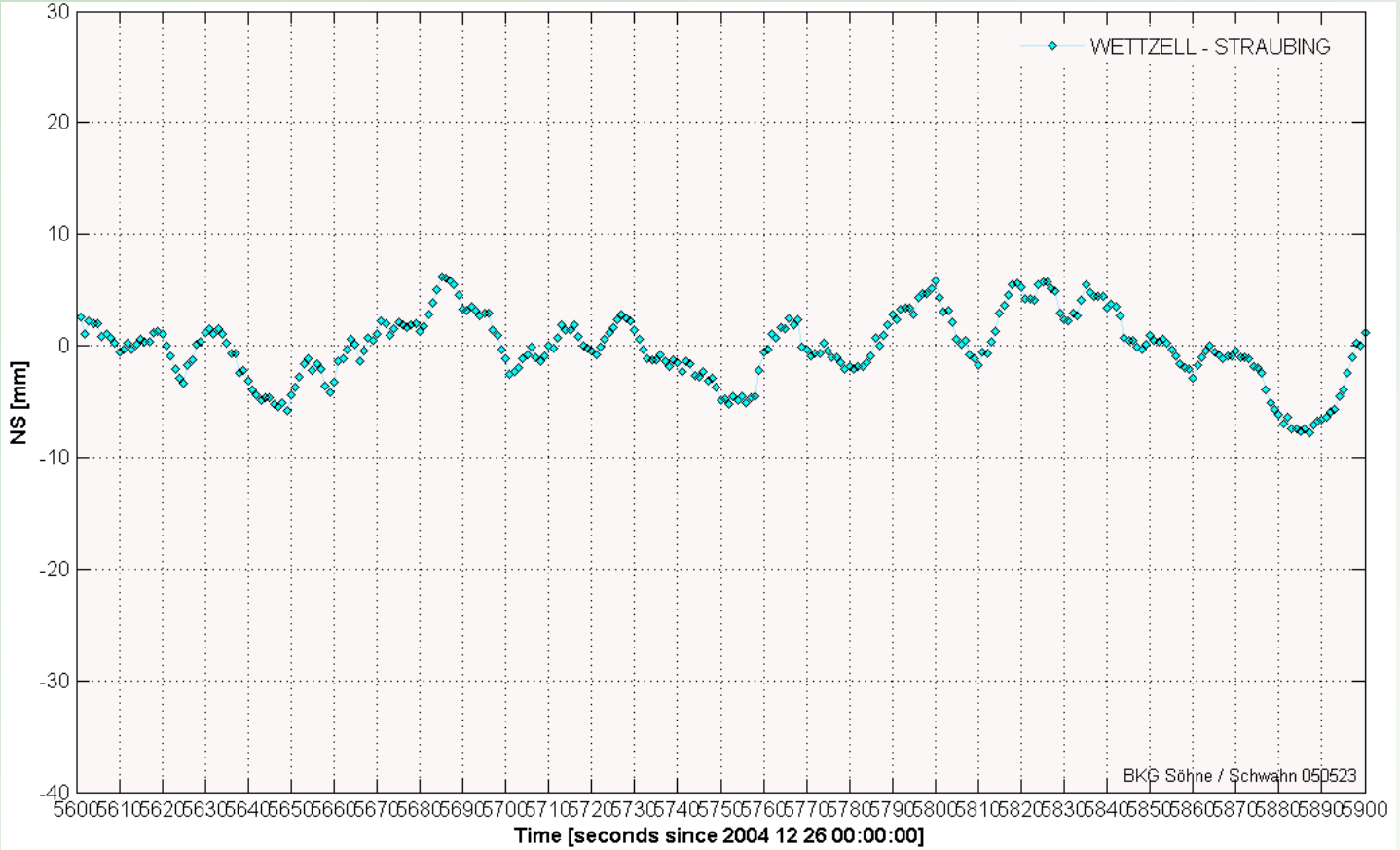

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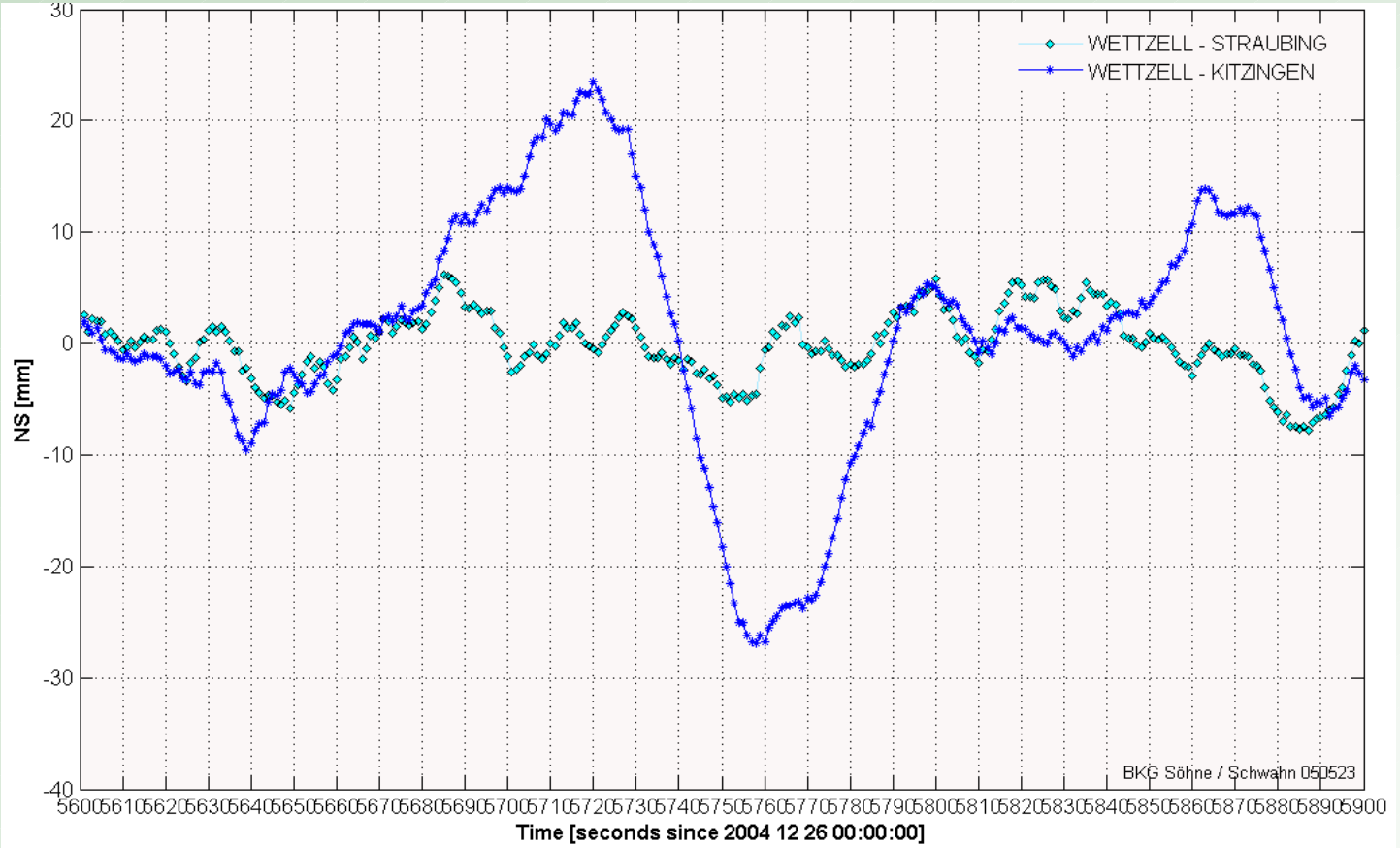

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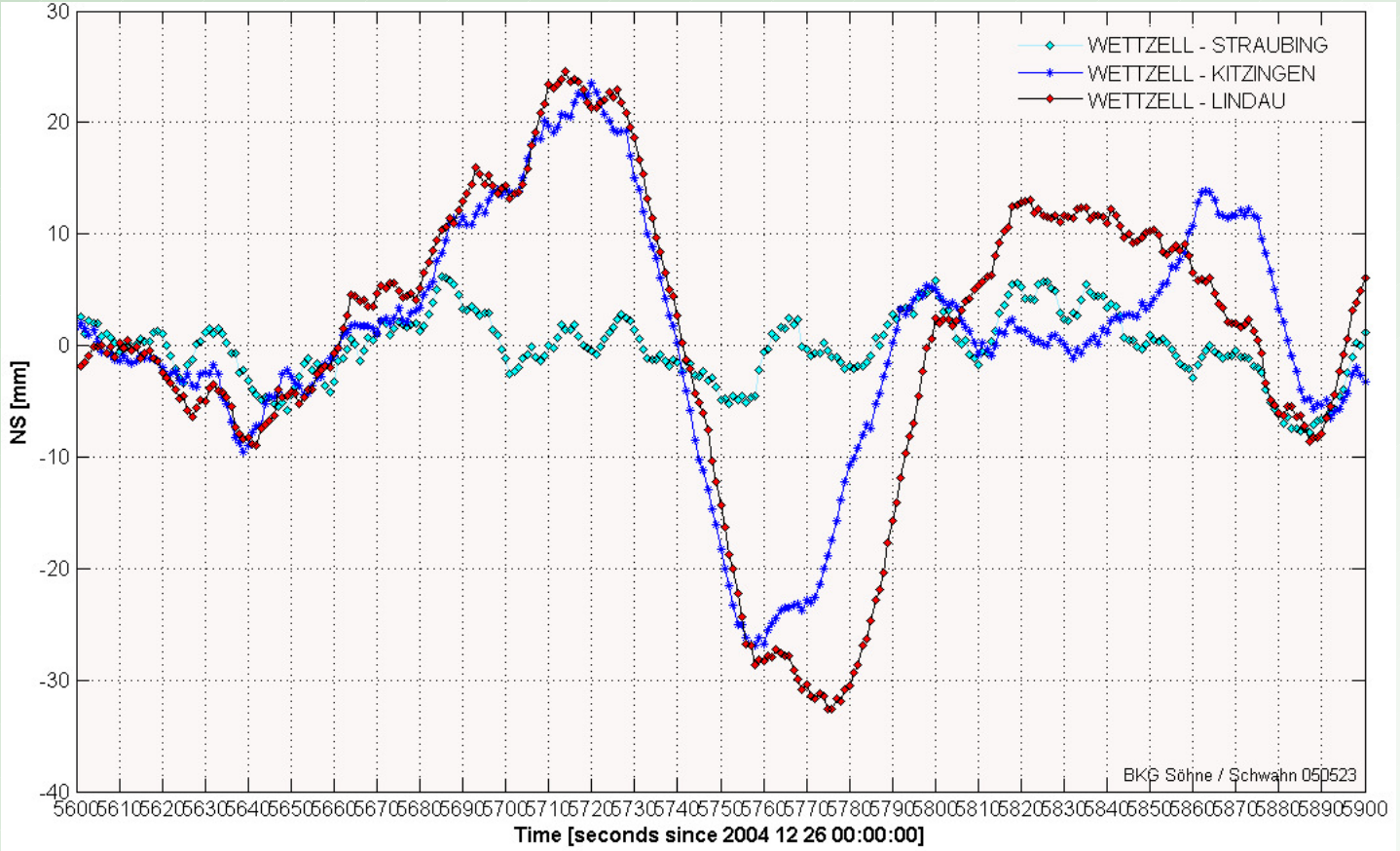

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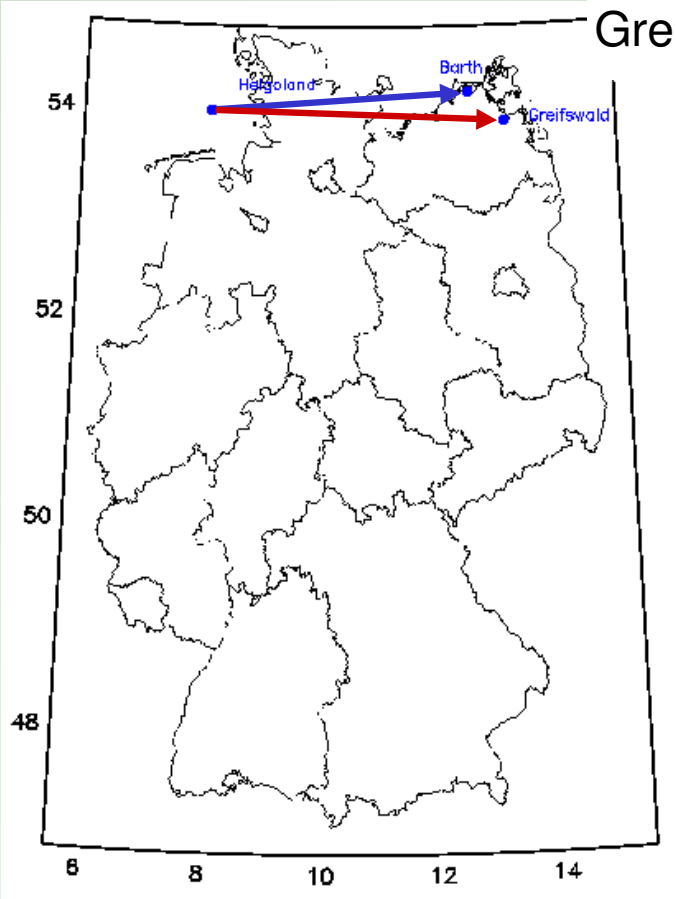
Filtered results: Helgoland

Barth - Helgoland: 315 km

Greifswald - Helgoland: 360 km



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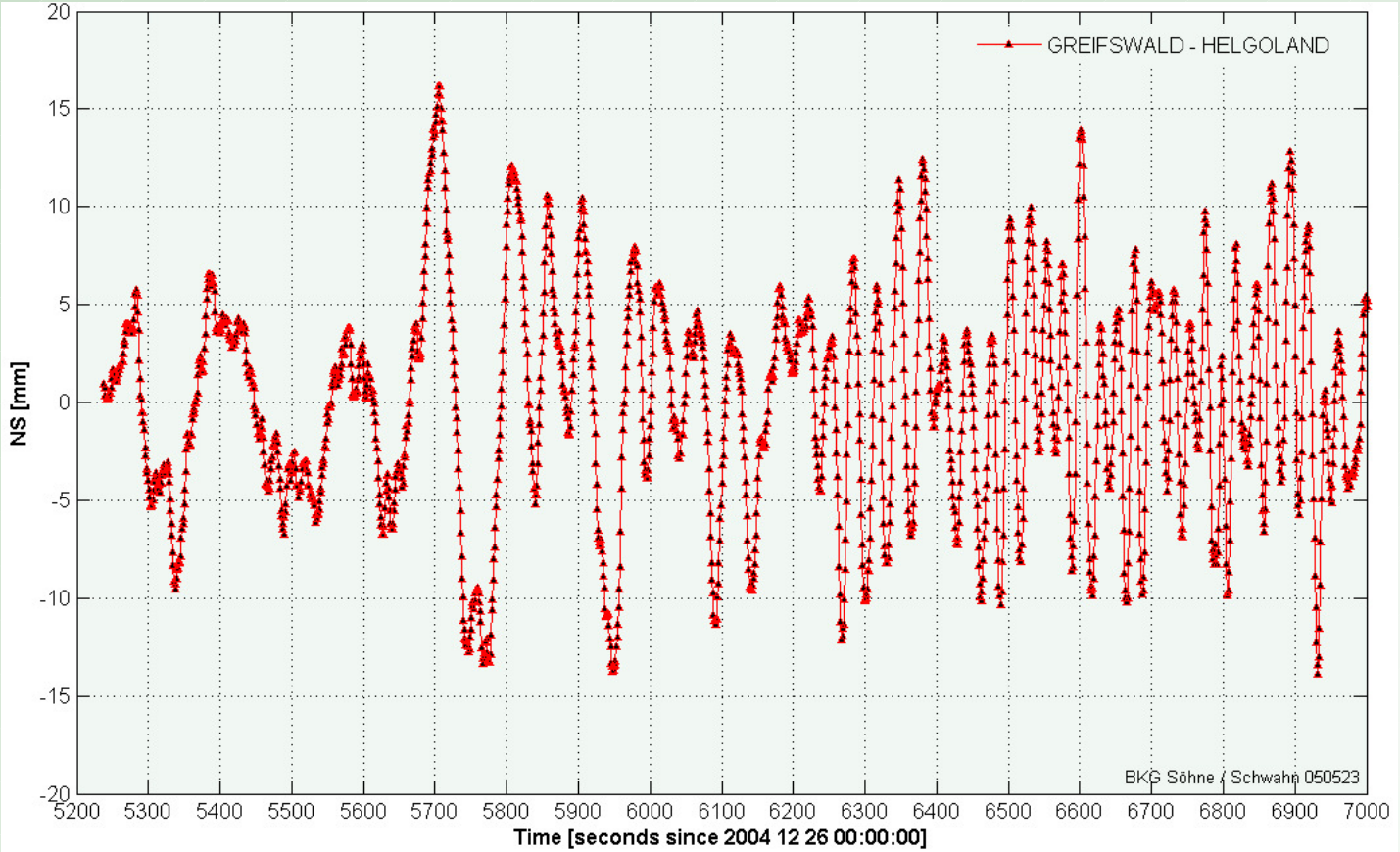
Filtered results: Helgoland



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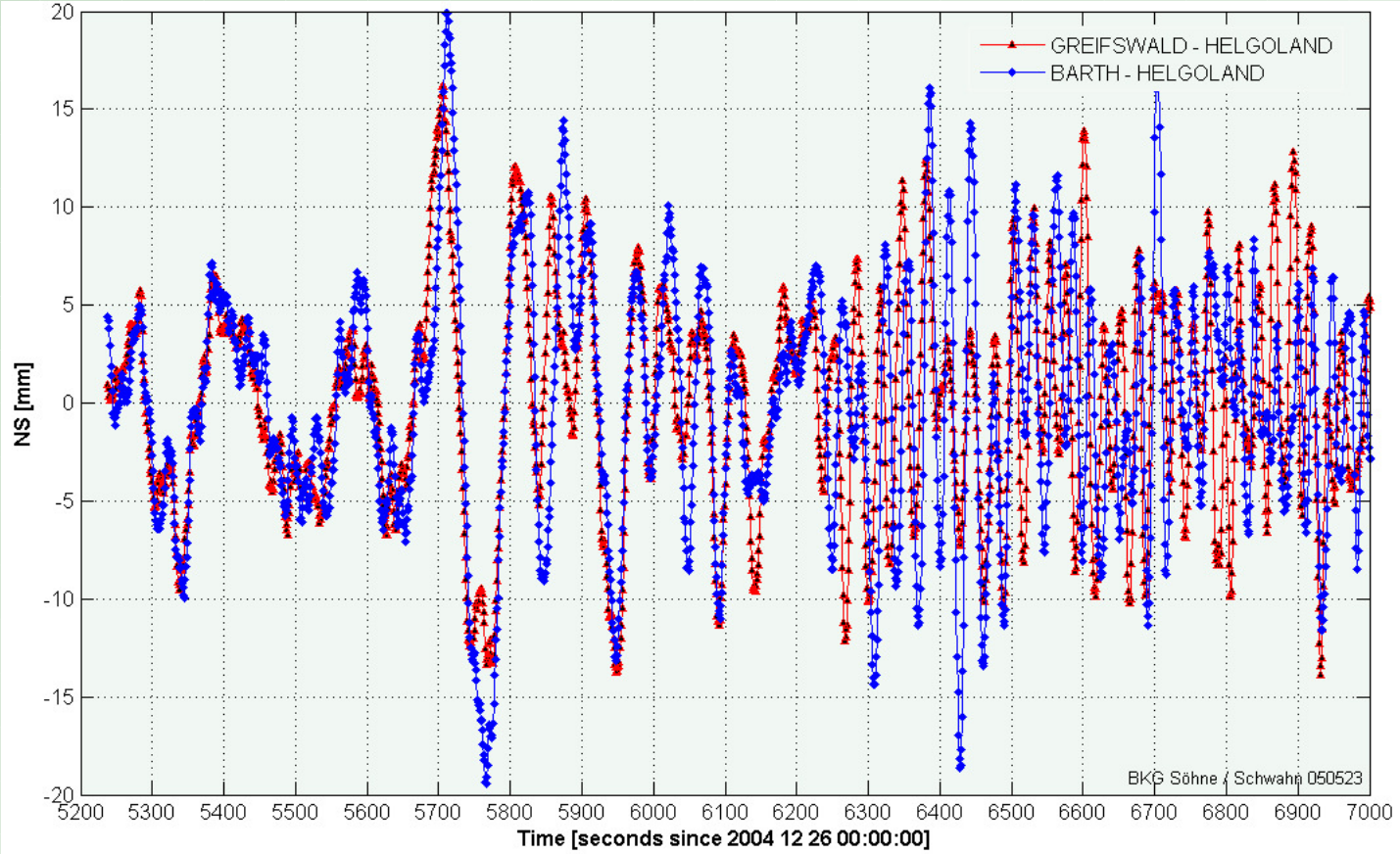

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Conclusions and outlook (1)

- For the 2004 Sumatra earthquake in a distance of 9000 km from the epicentre 1 Hz GPS positioning time series with baseline length in the range of 100 ... 500 km were able to monitor Earth surface deformation
- At the time of LOVE wave passage in the area of Germany horizontal displacements in North-South-direction up to 2.5 ... 3 cm within one minute occurred during 01:35 ... 01:37 GMT (Dec 26, 2004)
- Precision of relative positioning during this event seems to be nearly independent from the baseline length in the range of 50 ... 500
- High-rate GPS time series cover a larger band of periods than seismometers – slow deformations can be monitored

Conclusions and outlook (2)

- Comparison of GPS seismograms with observations of other sensors, e.g. seismometer, superconducting gravimeter, strainmeter, ring laser, to be done
- Storage of 1 Hz data of selected stations of GPS permanent networks for future event investigations desirable
- Improved analysis techniques ((modified) sidereal filtering, spatial filtering) are able to monitor earthquakes with magnitudes below 7 – applicable in regions with low seismicity
- This investigation is a first step towards a continuous (near) real-time processing of high-rate GPS time series; transport via Ntrip provides a worldwide possibility to monitor remote sites and their displacements, e.g. EPN sites in Iceland