Real-time Precise Point Positioning with Ambiguity Resolution for Geosciences

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Contents

- Precise Point Positioning (PPP)
- PPP Ambiguity Resolution & Convergence in Real Time
- Real-Time PPP in Europe
  - Satellite Clock Estimation
  - Positioning Accuracy Improvement
  - Rapid re-convergence
- Case study: L'Aquila Earthquake
  - Data
  - Station Displacement
- Conclusions

Precise Point Positioning (PPP)

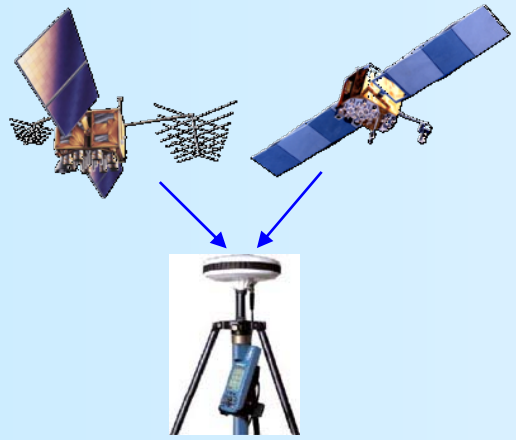
- Precise positioning at only a single station when precise satellite orbits and clocks are provided
  - Absolute positioning based on only a sparse network
  - Homogeneous positioning accuracy in wide area or even on a global scale

- Current applications
  - Crustal deformation monitoring
  - Meteorology
  - Orbit determination of low Earth orbiters (LEOs)
  - Offshore surveying

Positioning accuracy

- Normally decimetre level provided by real-time PPP crucially due to real-valued ambiguities kept in final solutions

- The integer property of an ambiguity at a single station is destroyed by the uncalibrated hardware delays which are removed by double differencing in relative positioning techniques



- Between-satellite difference removes common errors in receivers

- However, between-receiver difference is not feasible in PPP

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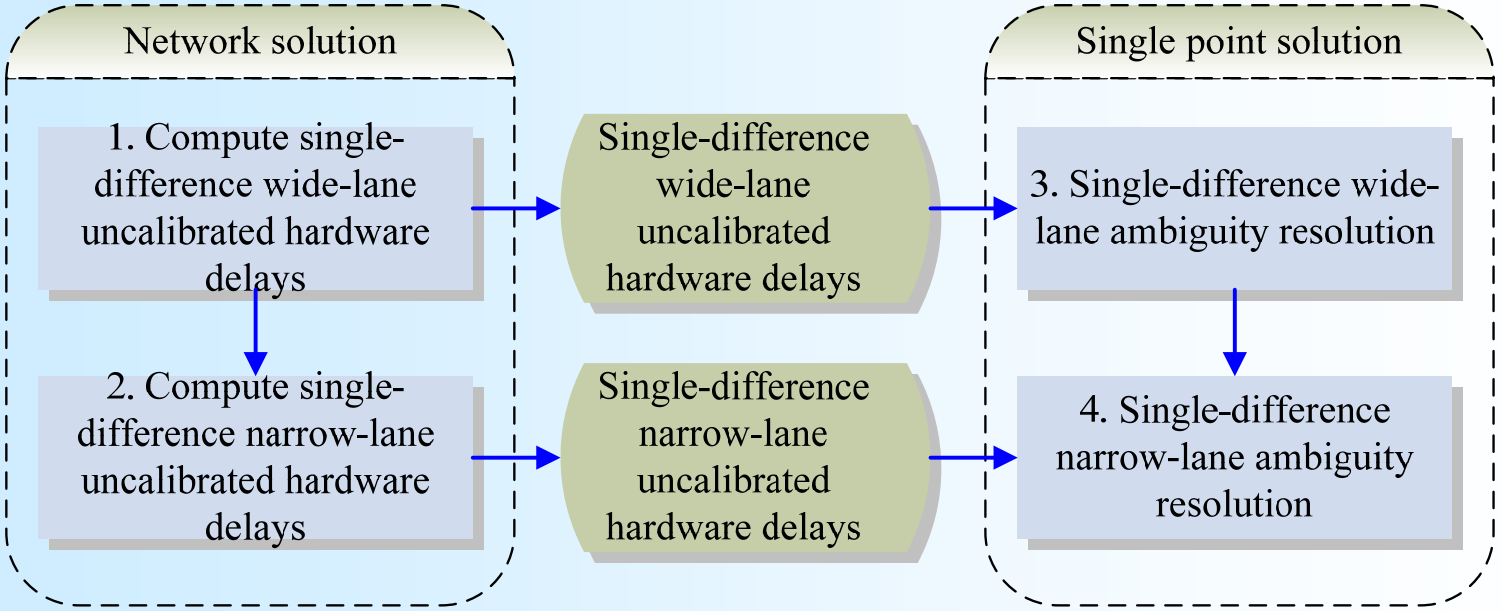
Ambiguity resolution in PPP

- Determine between-satellite uncalibrated hardware delays using a network of base stations
- Uncalibrated hardware delays are then provided for single stations to recover the integer property of ambiguities



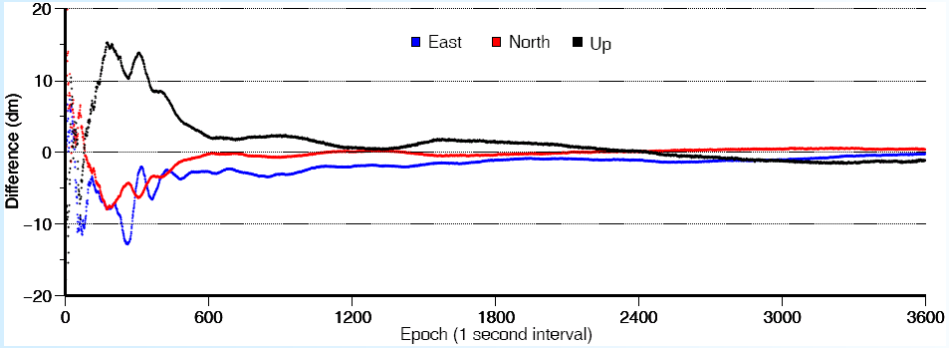
Published positioning accuracy improvement after PPP ambiguity resolution

- Ge et al., 2007: 30% in East using daily data
- Geng et al., 2009: mm level in horizontal plane using only hourly data; improvement of over 80% in East, over 60% in North and over 40% in Up
- Laurichesse et al., 2007; Collins et al., 2008; Mervart et al., 2008 …
- Possible and potential applications of real-time PPP with ambiguity resolution in Geoscience

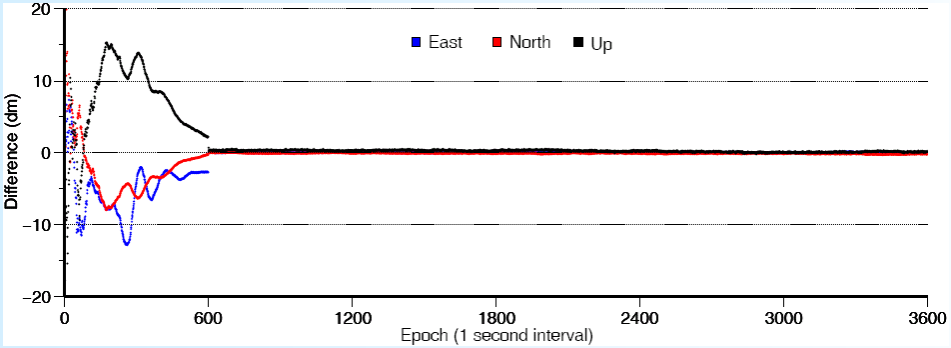
A prototype design of real-time PPP with ambiguity resolution in Geoscience

PPP convergence

- Slow convergence up to tens of minutes to dm level positioning accuracy



- To date, slow convergence up to tens of minutes to first fixed solution in PPP



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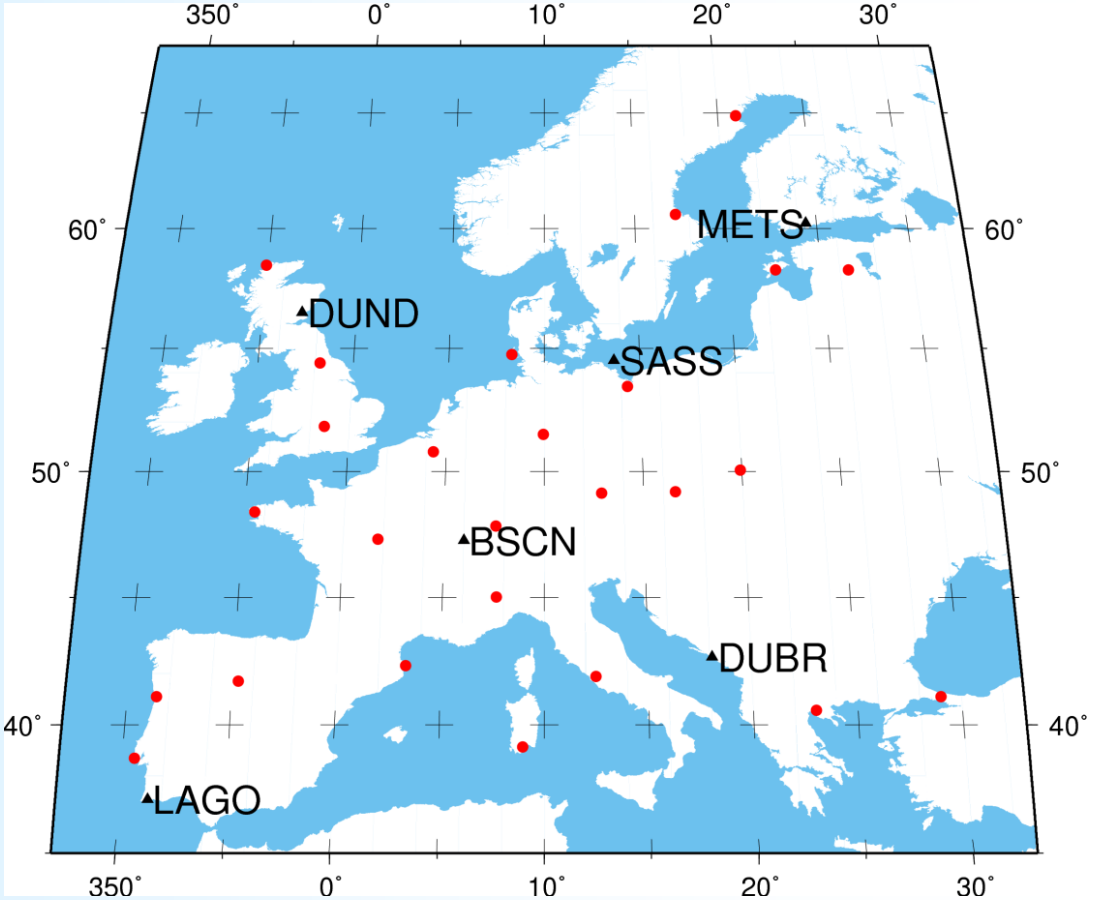
Real-time PPP with ambiguity resolution in Europe

- 1-Hz real-time data from EUREF-IP project on Day 188 in 2008
- 25 reference stations are selected with inter-station distances larger than 200 km
- IGU predicted satellite orbits and Earth rotation parameters



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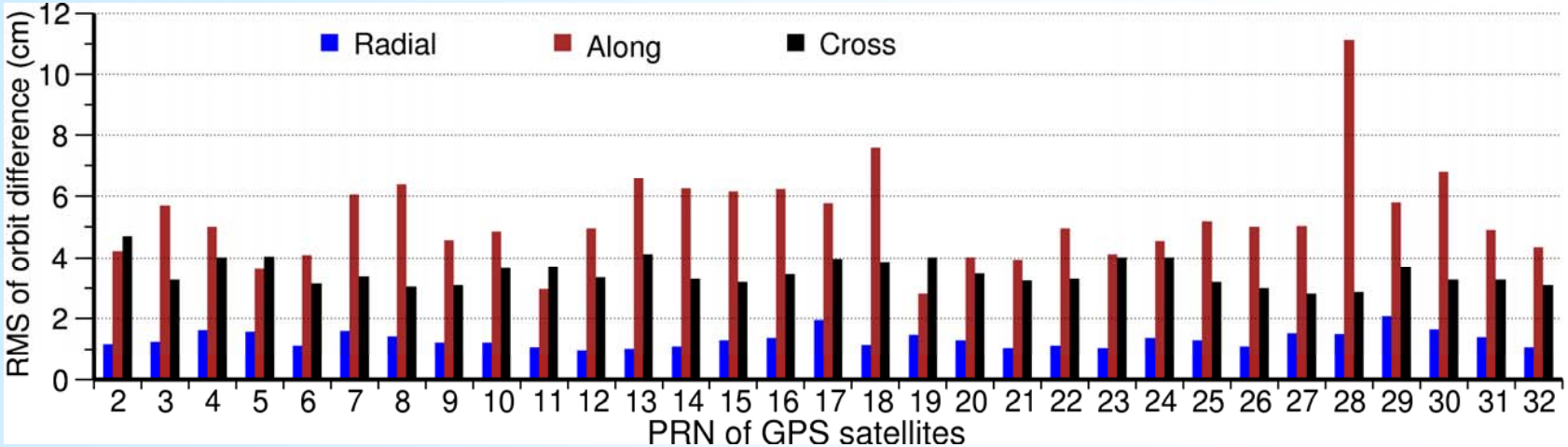
Satellite orbit and clock accuracy

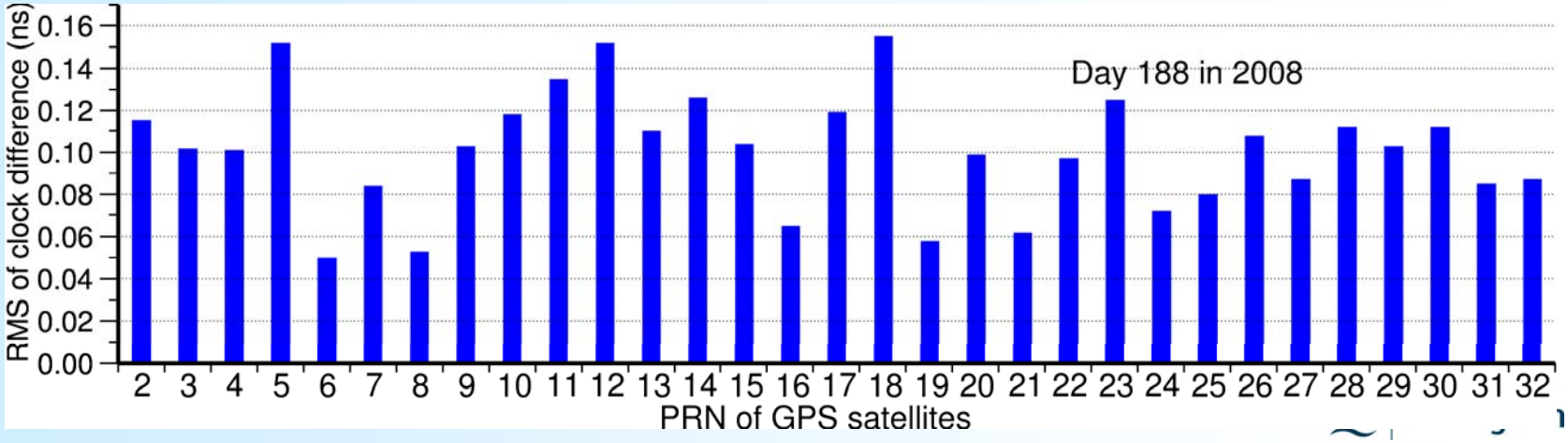
Orbit

Radial
< 2 cm

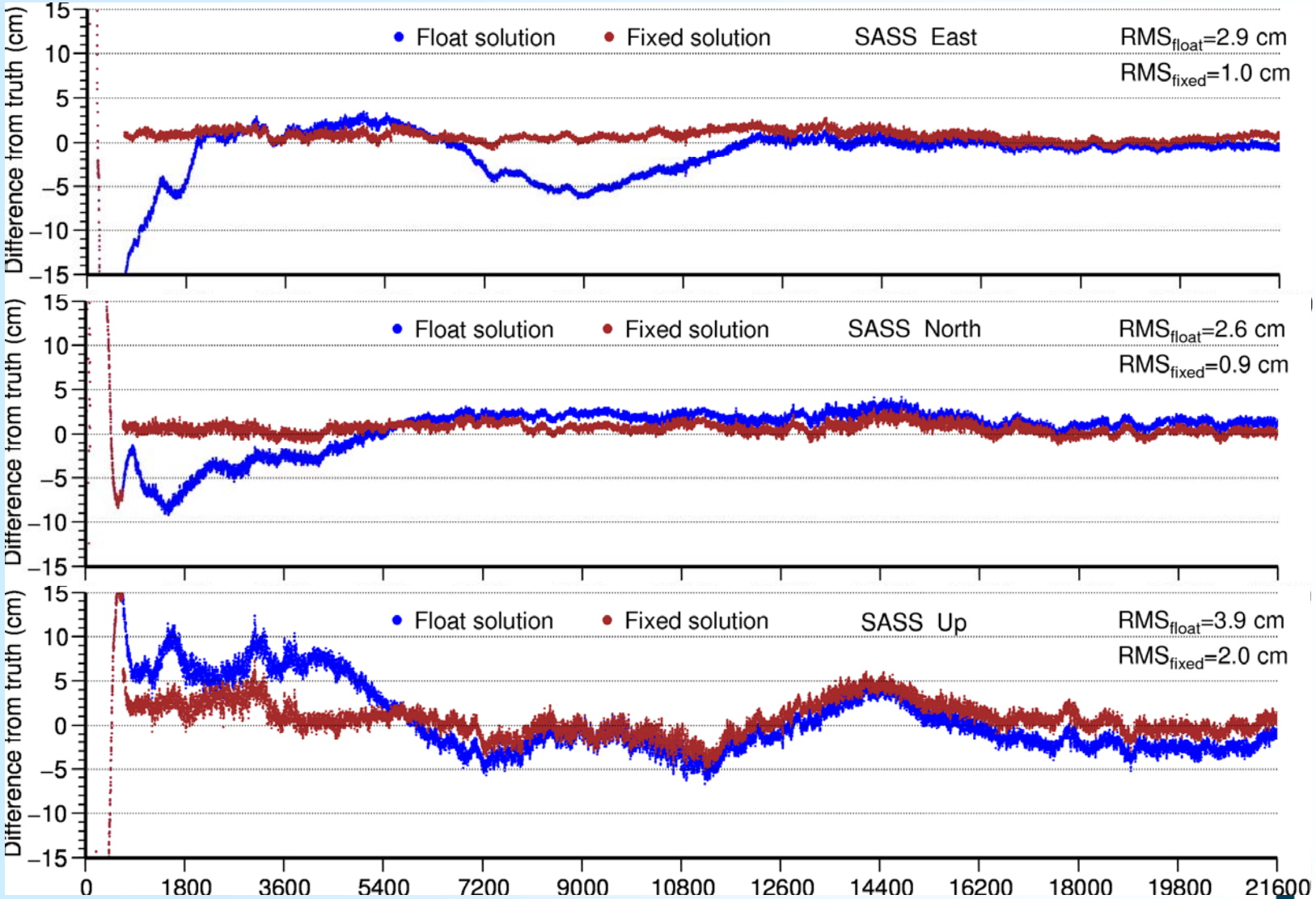


Clock

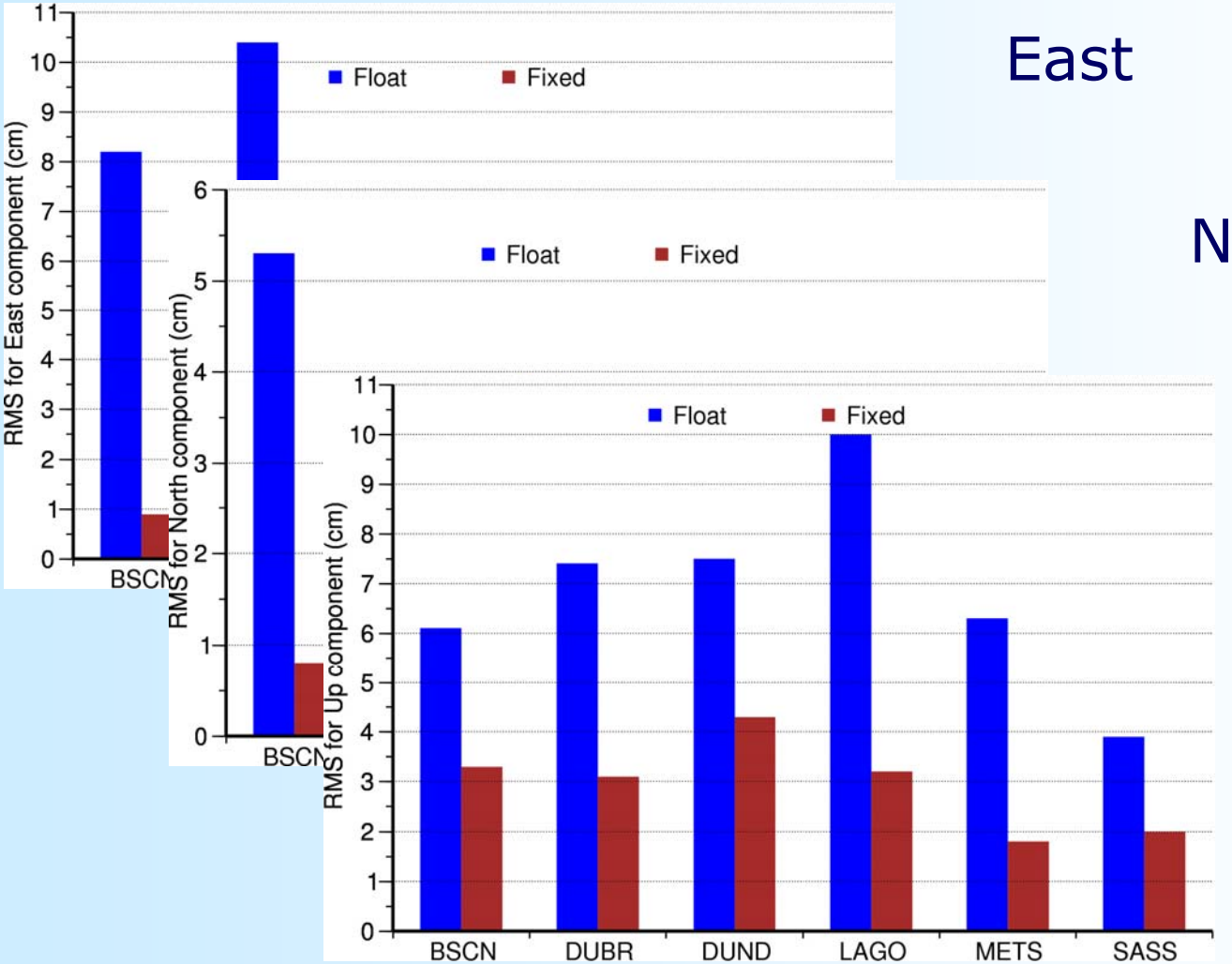
Mean ≈
0.10 ns



Kinematic positioning accuracy



Positioning accuracy improvement



East

North

Up

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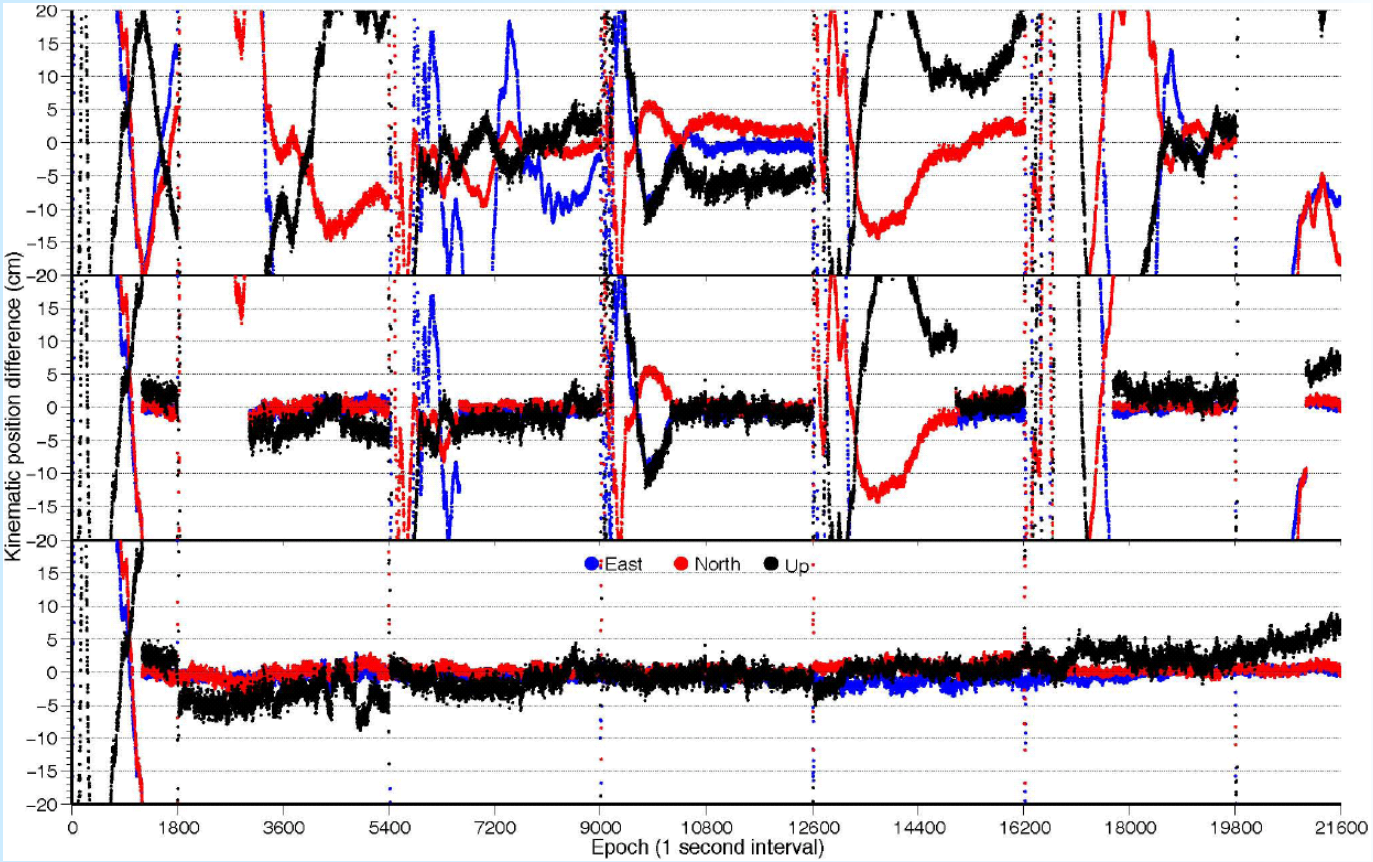
Rapid re-convergence

- Information generated in previous fixed solutions can be used to speed up re-convergence



Float solution

Fixed solution

Float solution with rapid re-convergence

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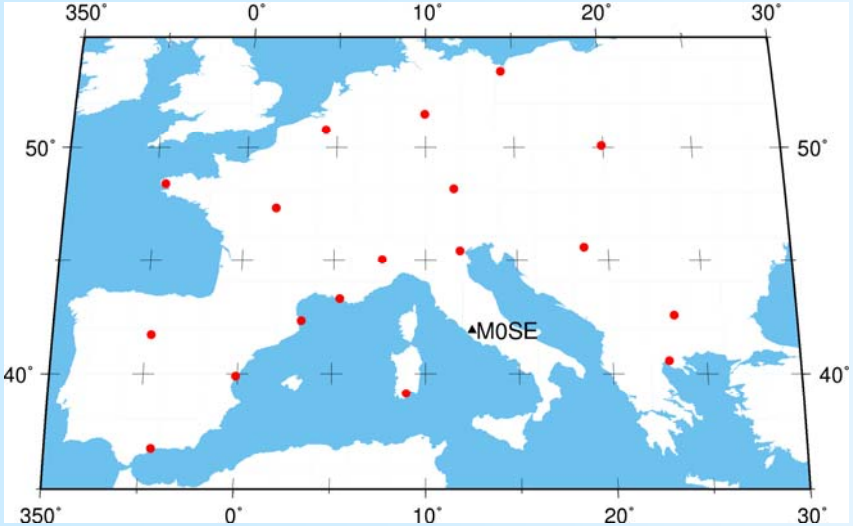
L'Aquila Earthquake on April 6 (Day 096)

Earthquake details (from USGS)	
Magnitude	6.3
Date-time	Monday, April 06, 2009 at 01:32:39 UTC
Location	42.334° N, 13.334° E
Depth	8.8 km (5.5 miles)
Region	Central Italy
Distances	75 km (45 miles) W of Pescara, Italy 85 km (55 miles) NE of Rome, Italy 115 km (75 miles) SE of Perugia, Italy 145 km (90 miles) S of Ancona, Italy

Highrate Data

- 18 1-Hz base stations from EUREF-IP project
- M0SE: 1-Hz station in ROME near the epicentre (~85 km)
- IGU predicted satellite orbits and Earth rotation parameters



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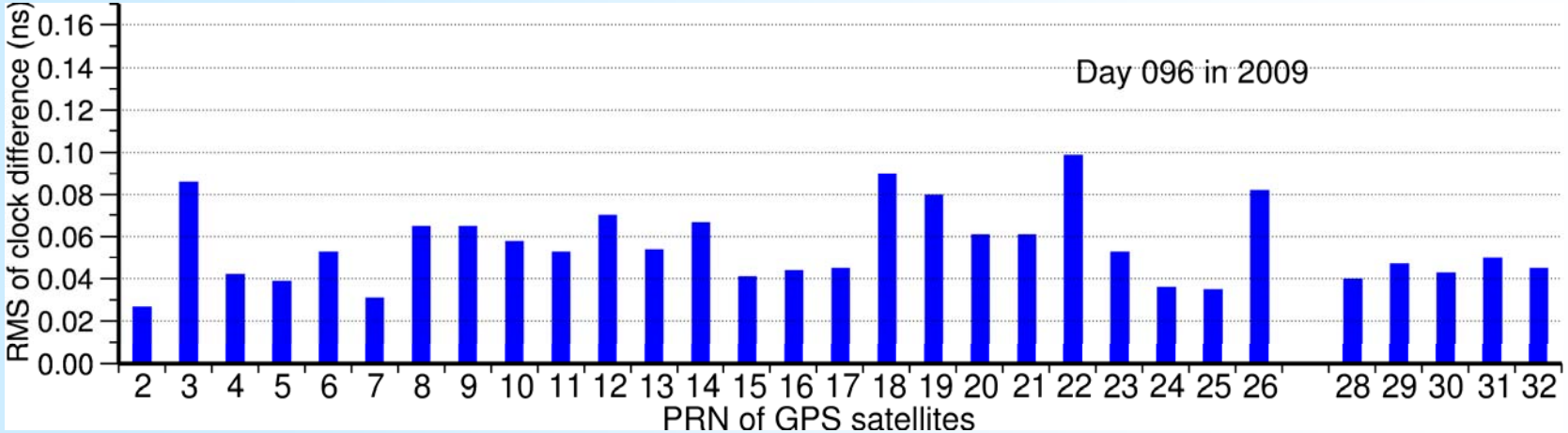
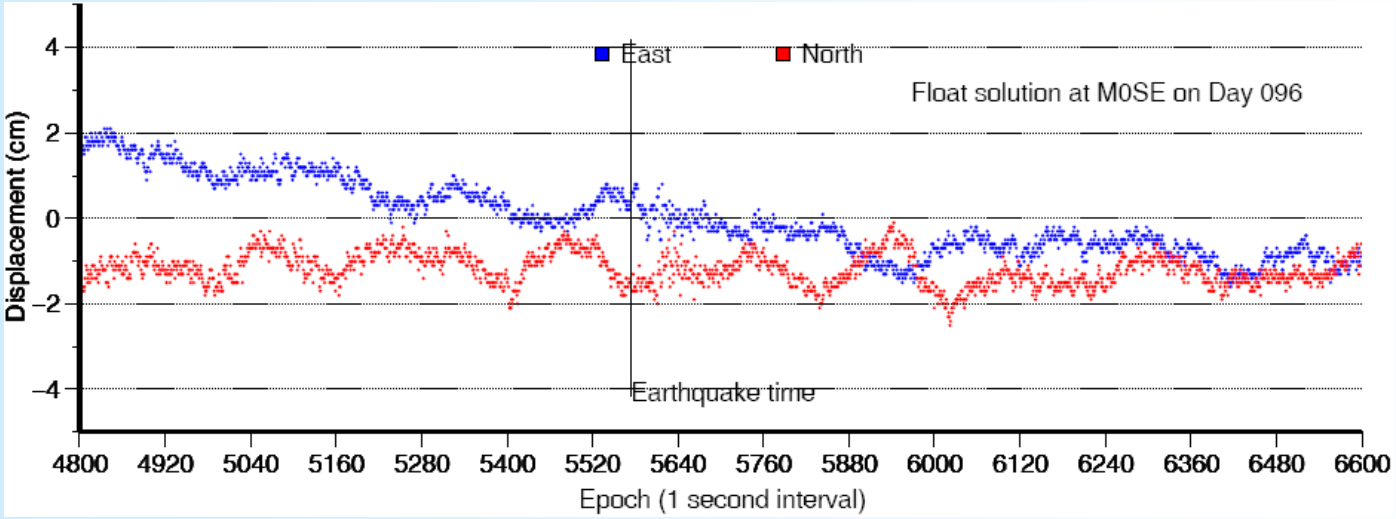
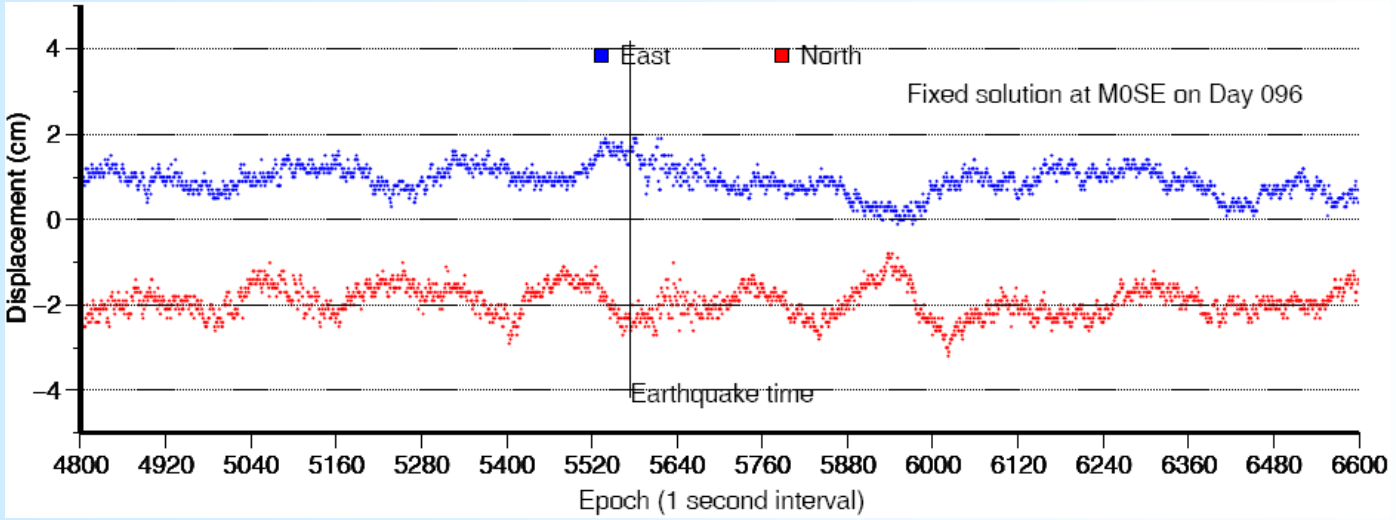
Satellite clock accuracy



Mean: 0.06 ns

Comparison between float & fixed solutions





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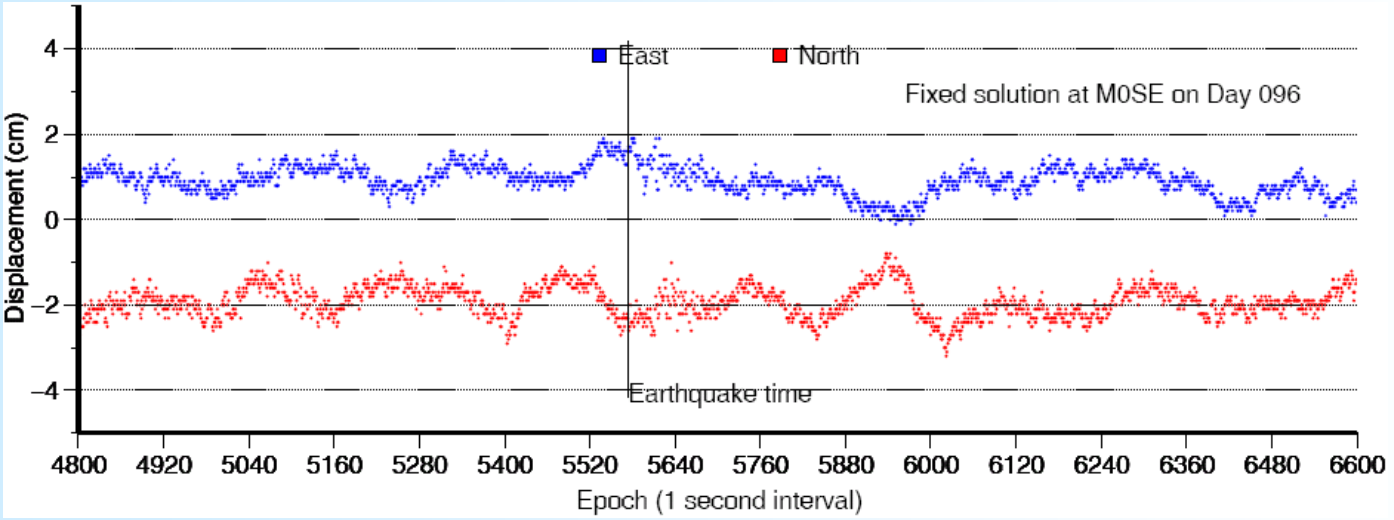
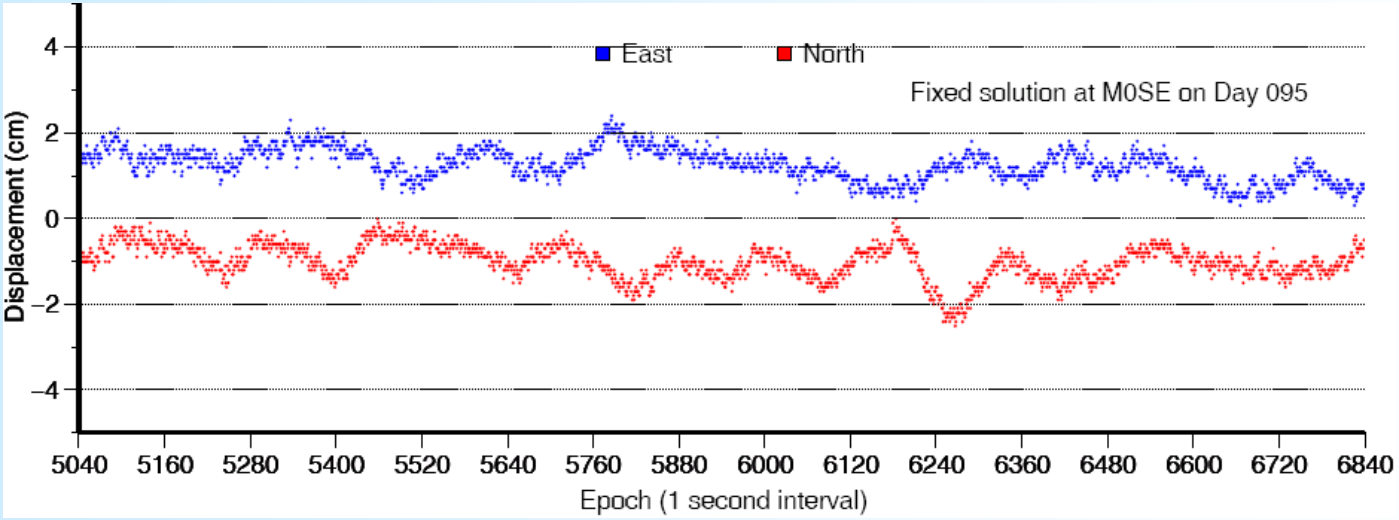
Sidereal filtering





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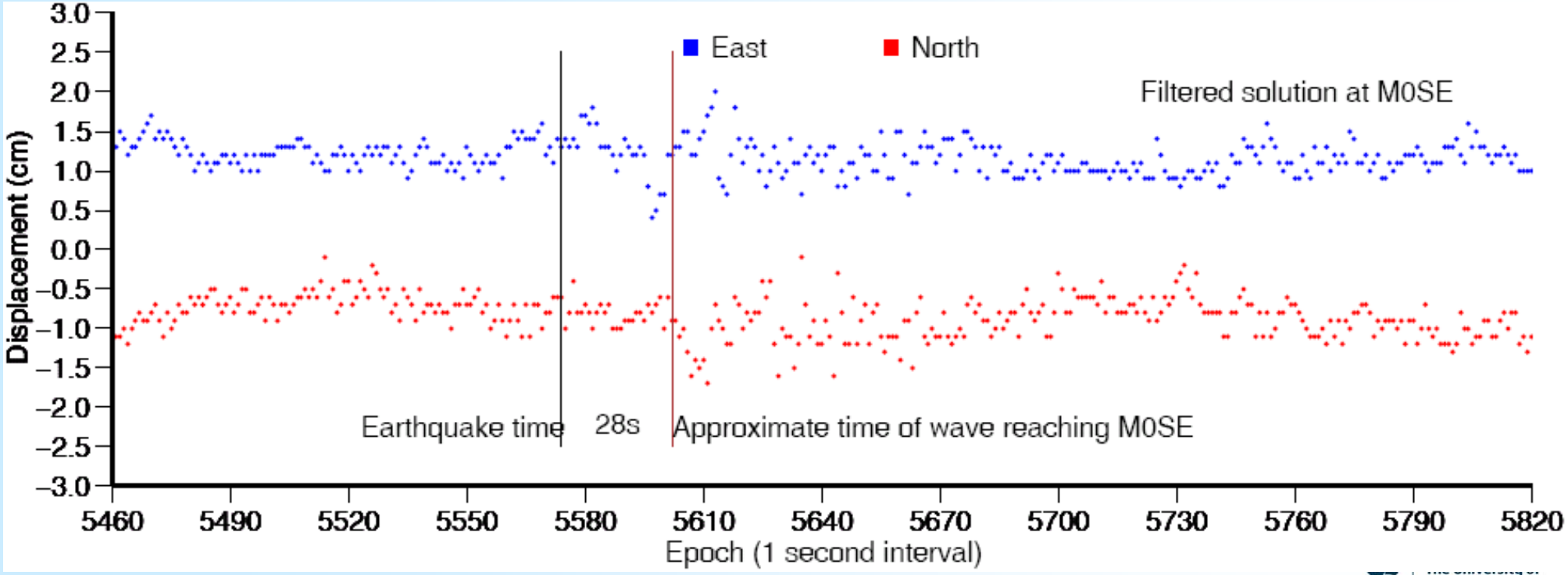
Displacement at M0SE

- Time window: 1h31m ~ 1h37m
- Presumed seismic wave speed: 3.0 km/s



Conclusions

- Integer ambiguity resolution contributes significantly to improving the positioning accuracy in real-time PPP
- Rapid re-convergence is possible and may be useful in future applications
- A design of the prototype of real-time PPP system for crustal deformation can be built
- Real-time PPP with ambiguity resolution possibly determines the displacement caused by the Earthquake in L'Aquila

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Thank you for your attention!

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