

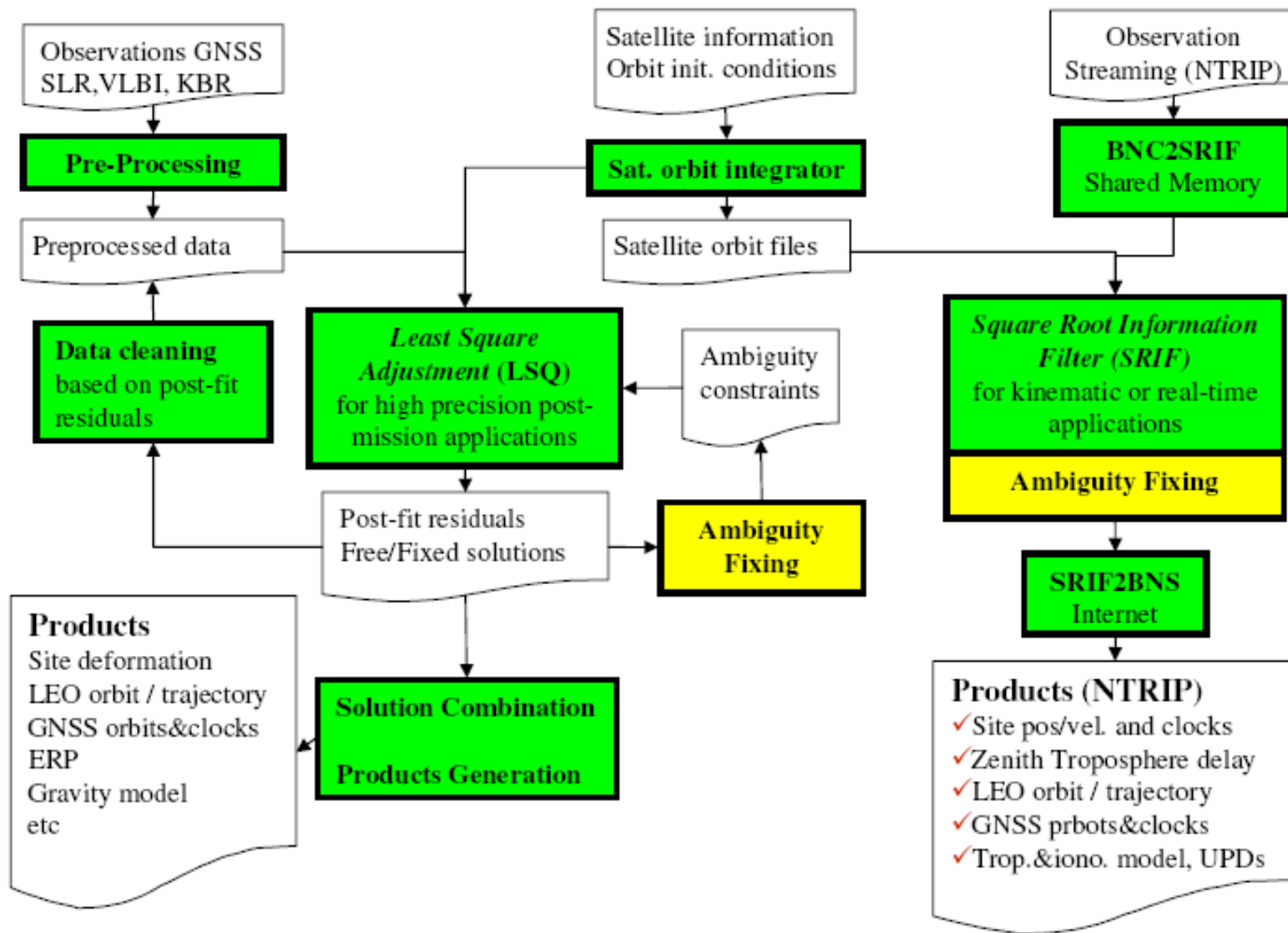
# Development of the GFZ Real-Time Precise Point Positioning Service

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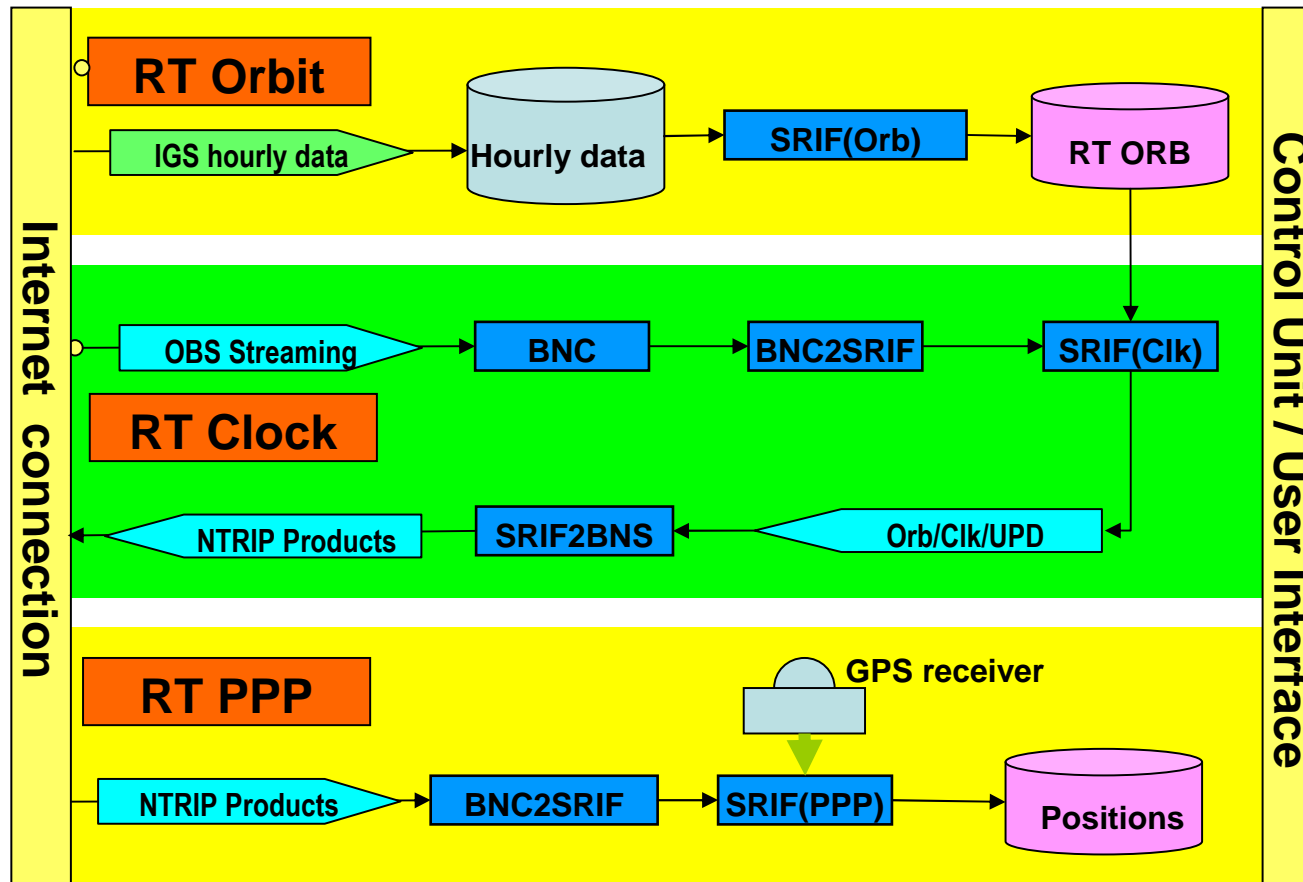
- EPOS-RT Software
- EPOS-RT For PPP Service
- Integer Ambiguity Fixing
- Data Gap Connection
- Regional Augmentation
  - For Instantaneous Ambiguity Fixing
  - To Replace NRTK

- **Since Sept. 2007**
- **Already Available**
  - GPS/GLONASS Clock Estimation
  - GPS/LEO Orbit Determination (Cui et al, EGU2011, Presentation)
  - Regional Augmentation/NRTK (Li et al, EGU2011, Poster)
  - Real Time ZTD (Bender et al, EGU2011, Presentation)
  - Embeddable User Software
- **Further Coming**
  - GALILEO/COMPASS (GEOs)
  - (Near) Real-time Ionosphere Model



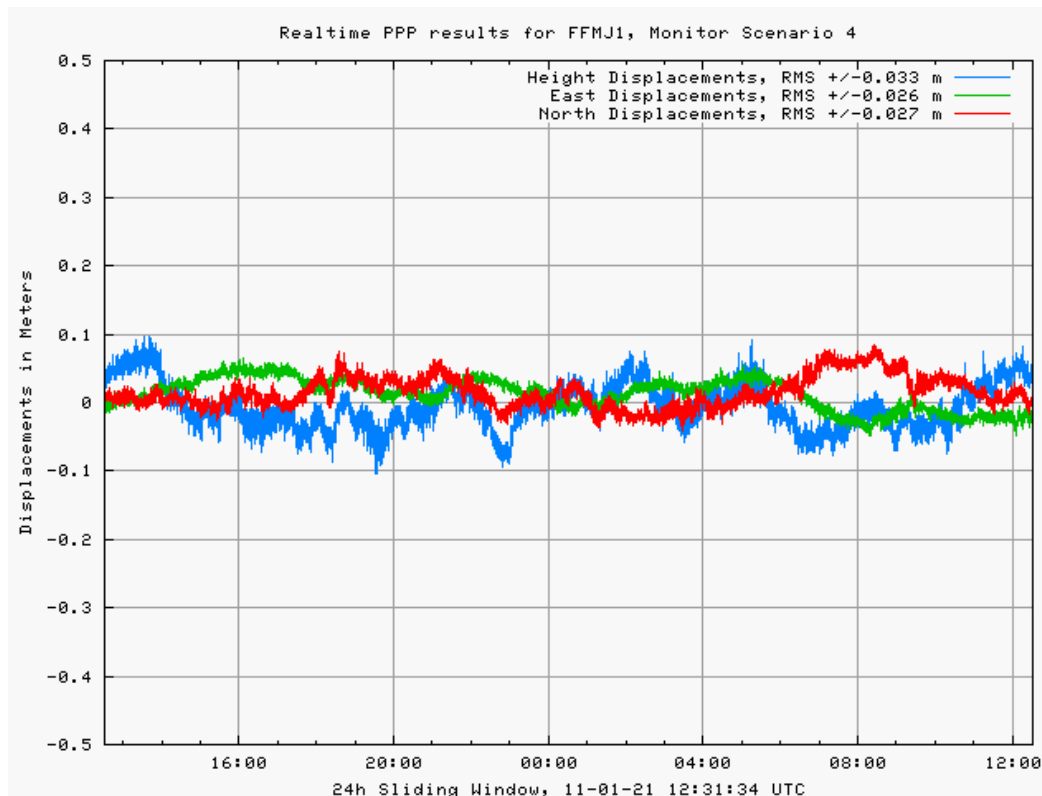
- Left Side: Post-Processing. Right Side: Real-Time

## GFZ IGS Real-Time Analysis Center



IGS RT PPP Online Validation:

<http://igs.bkg.bund.de/ntrip/ppp>



## ➤ Uncalibrated Phase Delay (UPD)

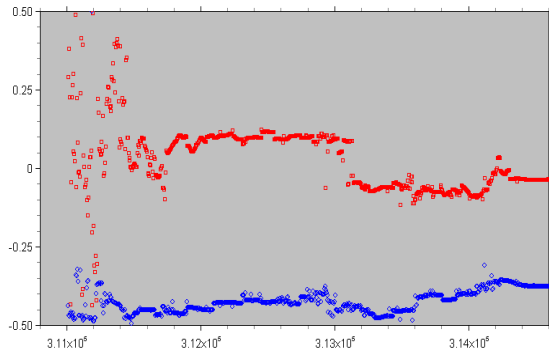
- Temporary Change Into Clocks
- Constant Part Into Ambiguities

$$b_{mk}^i = n_{mk}^i + \Delta\phi_m^i - \Delta\phi_{mk}$$

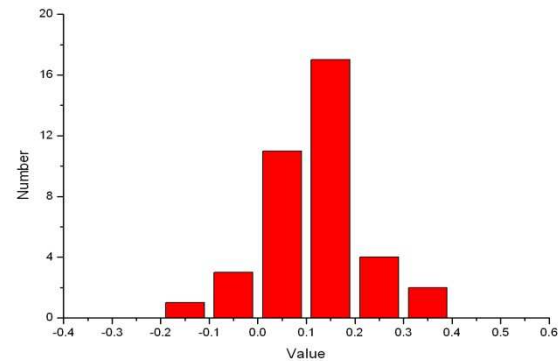
## ➤ UPD or IC

- Enforce  $b_{mk}^i = n_{mk}^i$  In Clock Estimation → IC
- Retrieve Fractional Part From  $b_{mk}^i$  → UPD

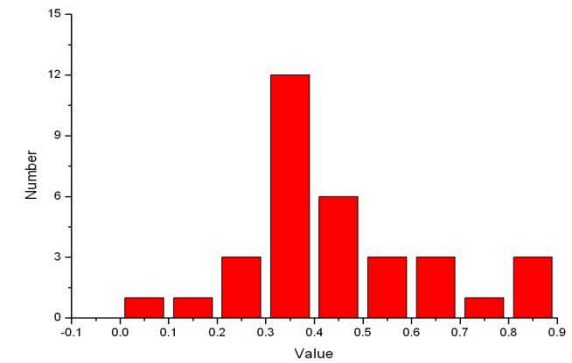
**Geng et al 2010 JoG**



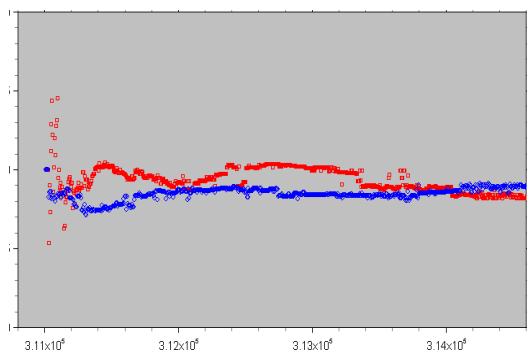
PRN20 Real-Time UPD



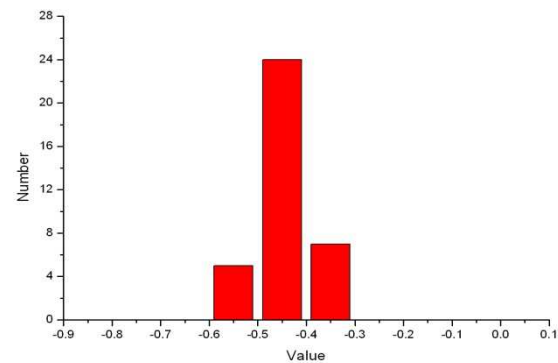
Wide-lane UPD Distribution



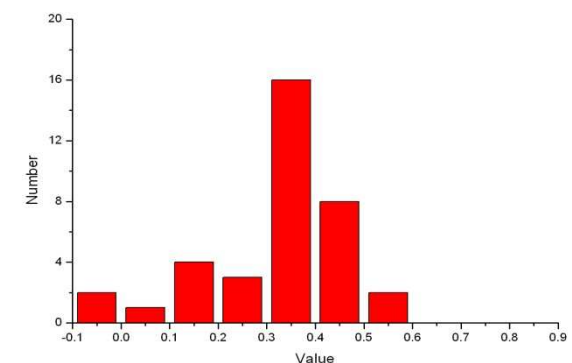
Narrow-lane UPD distribution



PRN32 Real-Time UPD



Wide-lane UPD Distribution



Narrow-lane UPD distribution

Wide-lane: 20-30 minutes

Narrow-lane: larger scatters



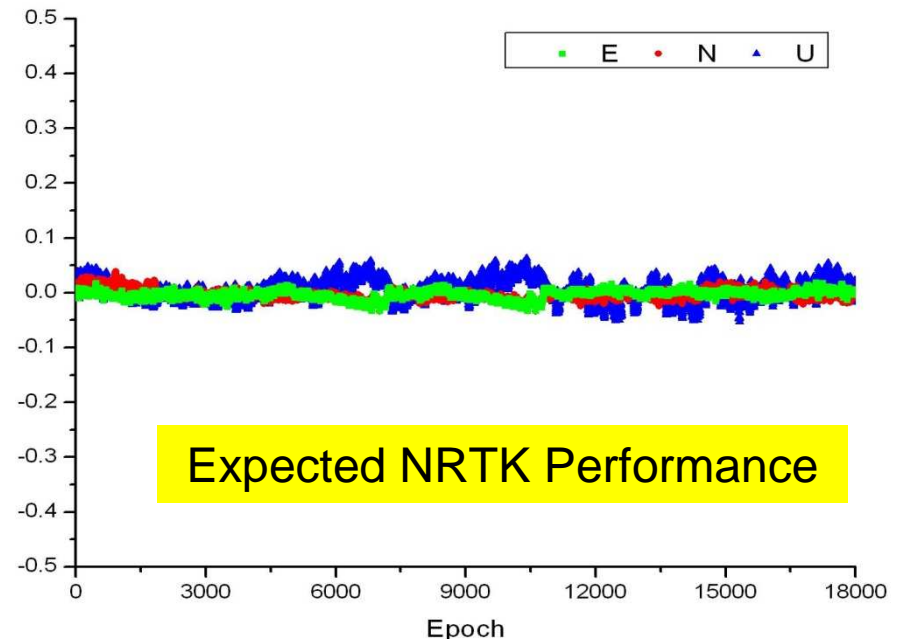
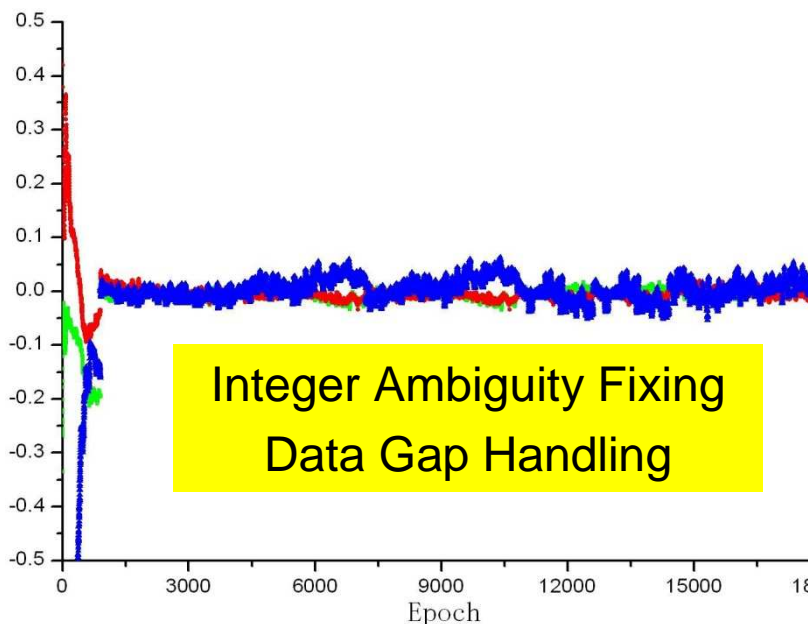
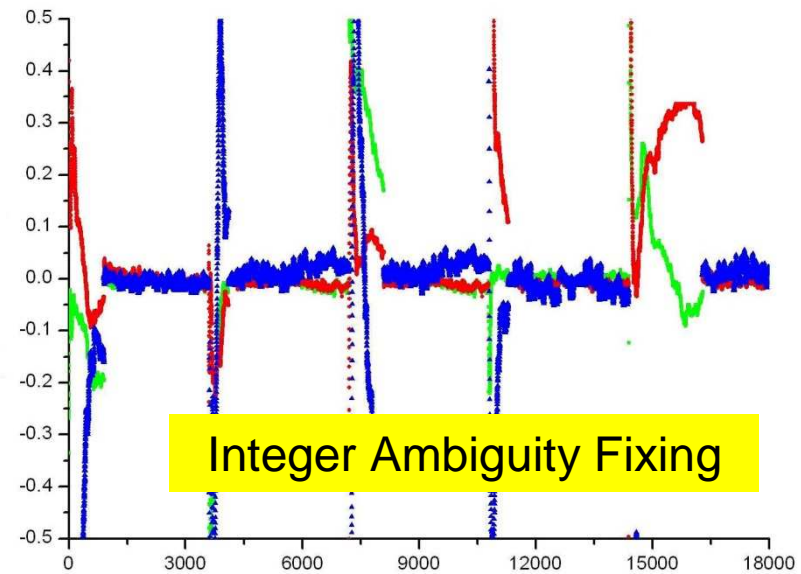
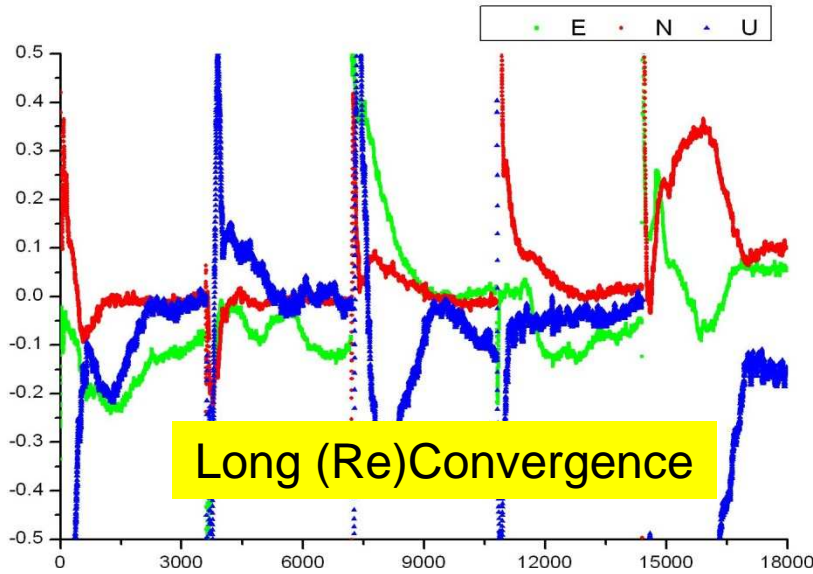
- Lost Tracking to Most Satellites
- Temporal Stability of Atmosphere Delays
- Instantaneous Cycle Slip Repairing

Presentation by Zhang and Li

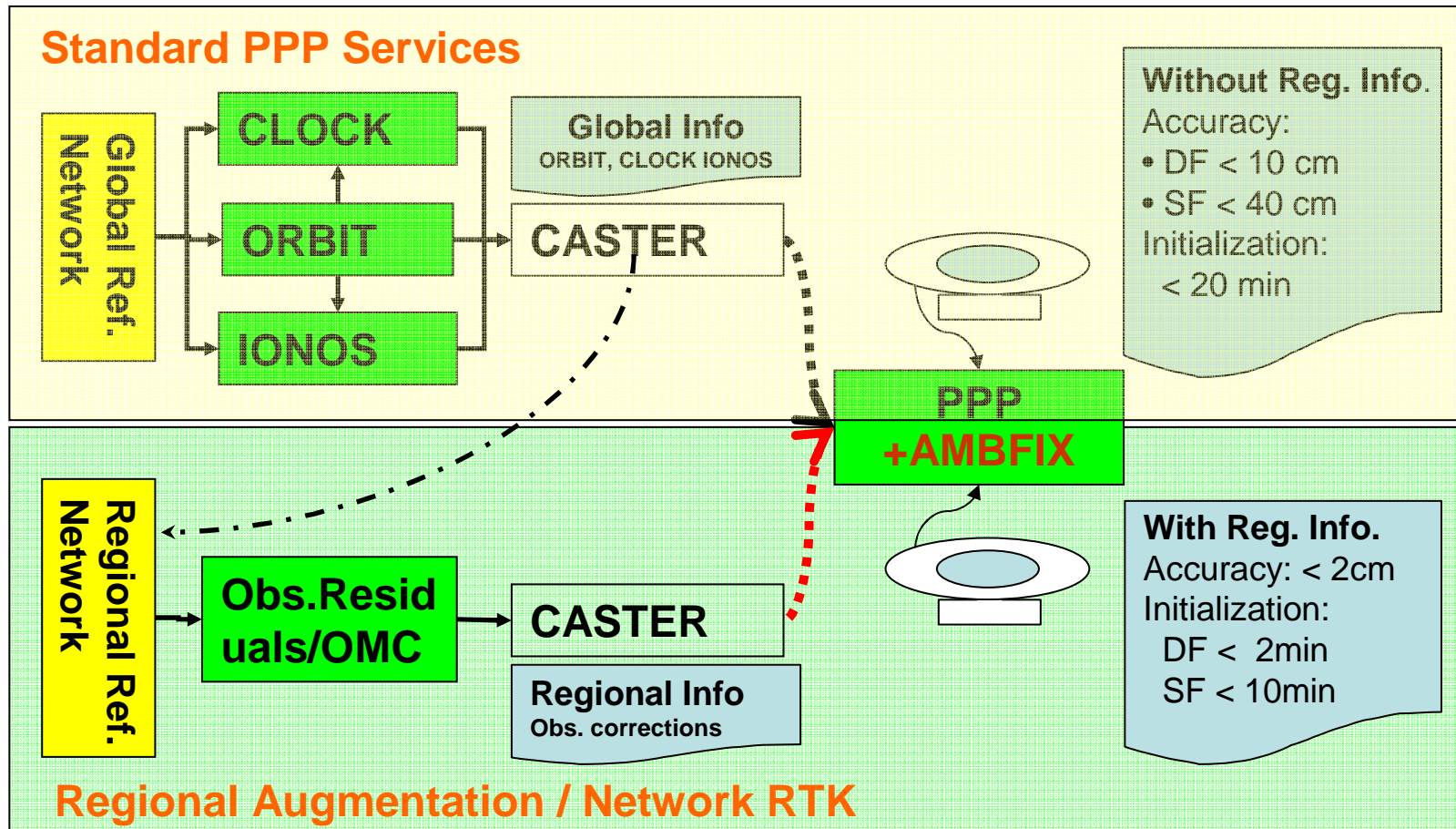
Paper by Geng et. al, JoG

Paper by Li and Zhang, GPS solution.

# Impact Summary



# Augmentation of PPP Service



**Undifferenced “True” OMC Including All Remaining Biases**

## ➤ OMC of Station k to Satellite i

$$\begin{aligned}
 omc_k^i &= L_k^i - \tilde{\rho}_k^i & \delta S_k^i & \text{Orbit Bias} \\
 &= \delta S_k^i - \delta t^i + \delta t_k + \delta I_k^i & f_k & \text{UPD Receiver} \\
 &+ \delta T_k^i + n_k^i + f_k - f^i & f^i & \text{UPD Satellite}
 \end{aligned}$$

## ➤ Unambiguous OMC (Ambiguity Known)

$$\begin{aligned}
 l_k^i &= omc_k^i - n_k^i \\
 &= \delta S_k^i - \delta t^i + \delta t_k + \delta I_k^i + \delta T_k^i + f_k - f^i
 \end{aligned}$$

## ➤ Interpolated User Correction

Interpolated Correction	User Obs. Equ.	Cor. Obs. Equ.
$\bar{l}_u^i = \sum_{k=1}^3 \alpha_k (\delta S_k^i + \delta I_k^i + \delta T_k^i)$ $+ \sum_{k=1}^3 \alpha_k (\delta t_k + \delta f_k)$ $- \delta t^i - \delta f^i$ <p>With <math>\alpha_1 + \alpha_2 + \alpha_3 = 1</math></p>	$l_u^i = \delta S_u^i + \delta I_u^i + \delta T_u^i$ $+ \delta t_u + \delta f_u$ $- \delta t^i - \delta f^i + n_u^i$ $+ u_u^i \delta x_u$	$\approx 0$ $= \text{Contant}$ $= n_u^i$ $= u_u^i \delta x_u$

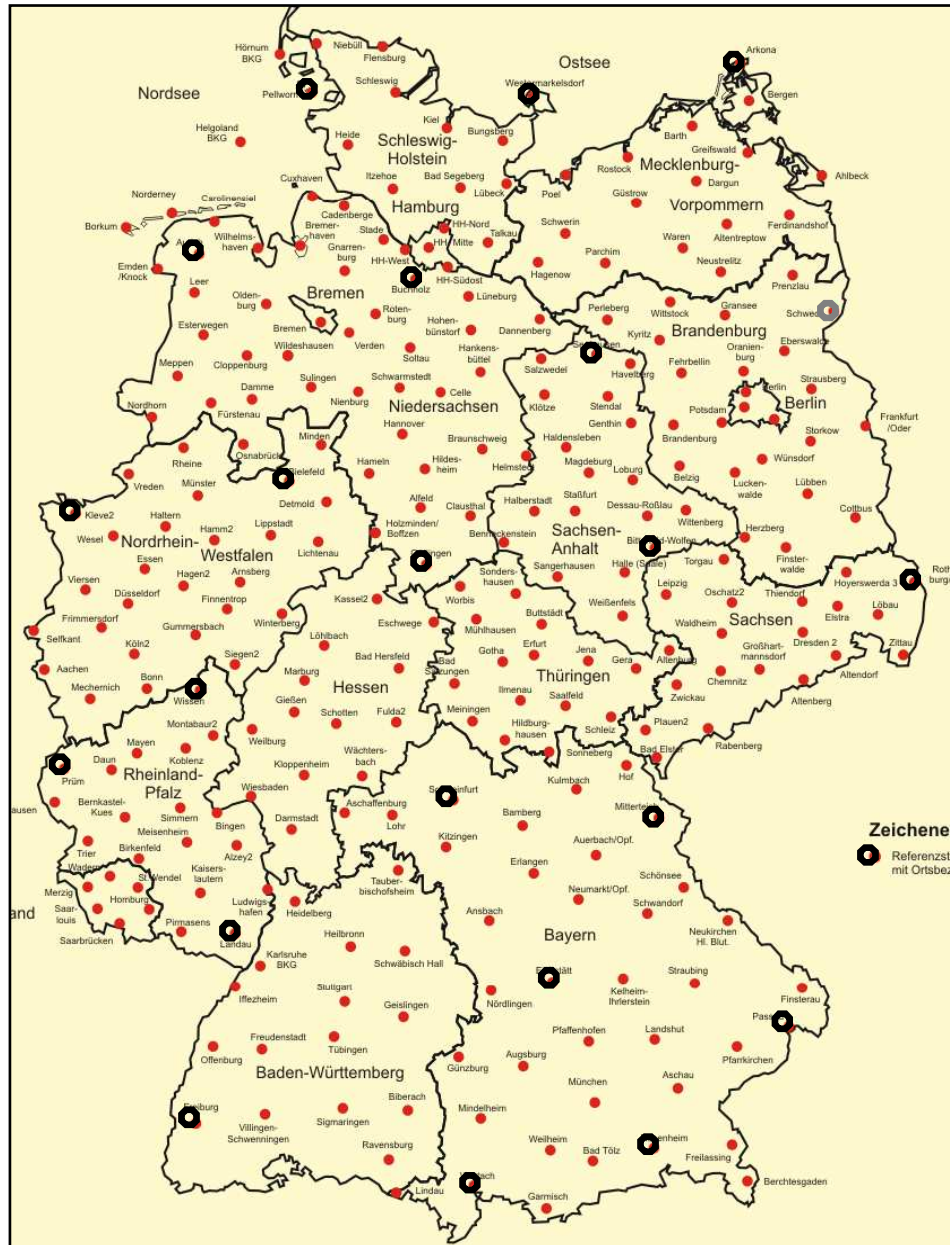
- **Corrected Obs. Equ == PPP With Integer SD-Ambiguities**
- **How To Get The Integer UD-Ambiguities For L1&L2 ?**

“Consistent” Int. UD Amb. Instead of Their True  
Consistent == “Int. DD Amb. Constrained”

## **Two Ways (Ambiguity Mapping):**

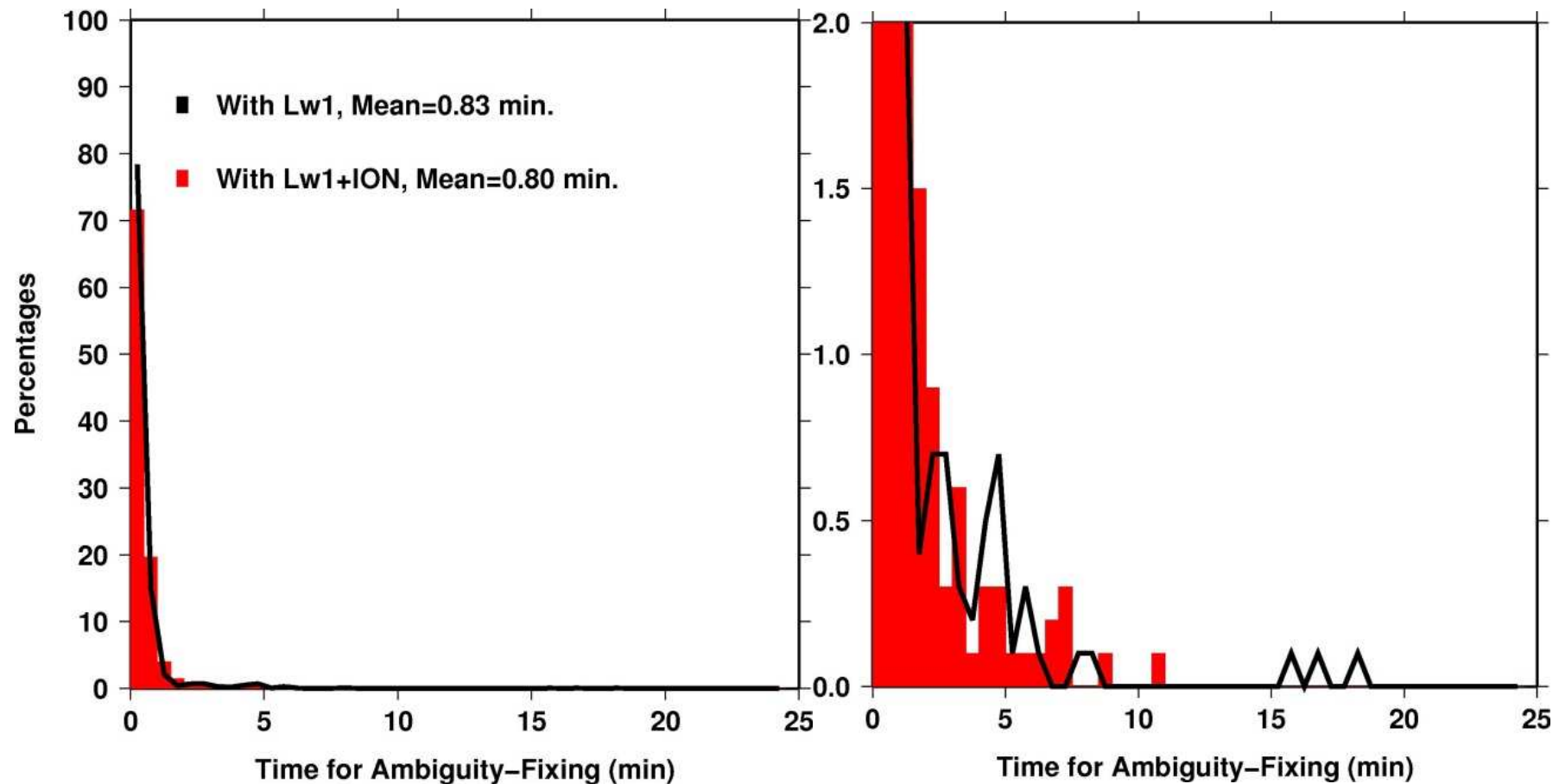
- Without Precise Sat. Clocks --- New NRTK  
(Based On Fixed DD-ambiguities)
- With Precise Sat. Clocks--- PPP Augmentation,  
(Based On Fixed UD/SD-ambiguities)





- **DATA** (Map: [www.sapos.de](http://www.sapos.de))
  - SAPOS Data of 290 stations
  - Various receiver types
  - 30 seconds sampling rate
- **Reference Network**
  - Selected 22 reference stations
  - Inter-station distance 184 km
  - Others are user stations
- **Software**
  - EPOS-RT

# Results: Fixing Time (Lw+L1)

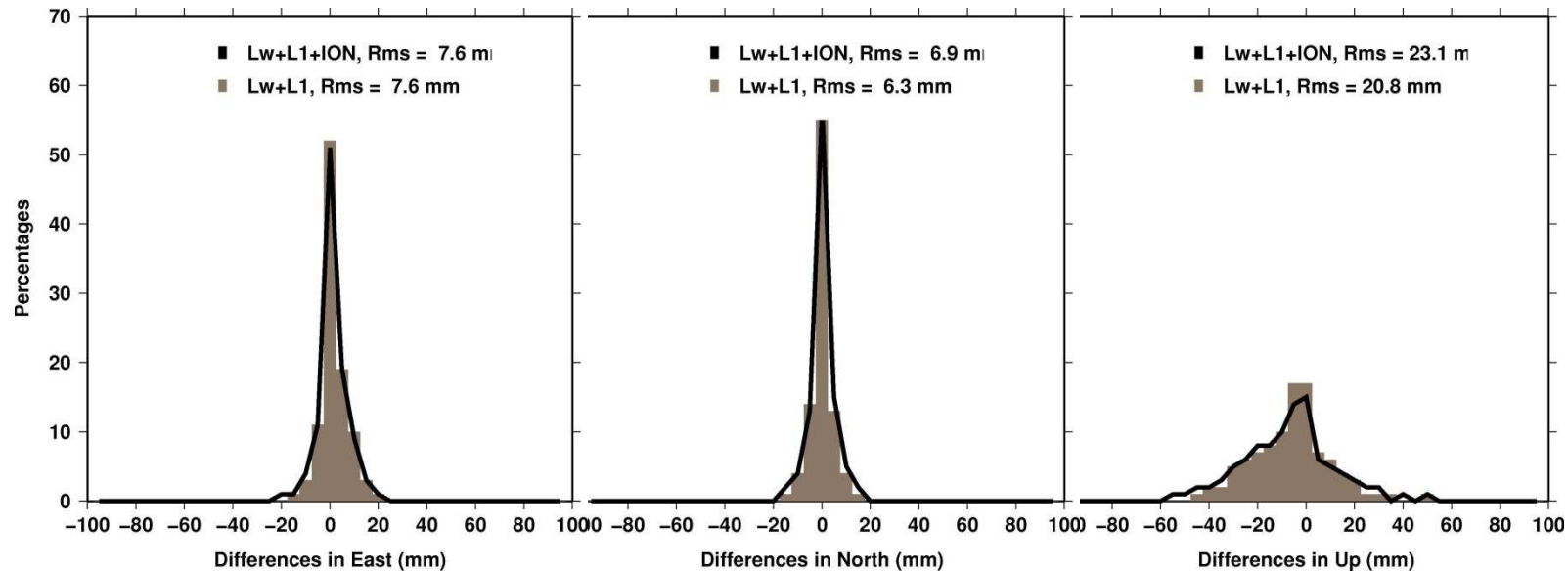


- Lw+L1 can be fixed with 1 epoch data, On average 1.6 epochs, half of Lw (3 epochs)
- LW+L1+ION.PAR can furthermore reduce the fixing time but slightly. Improvement found for cases where long fixing time needed.



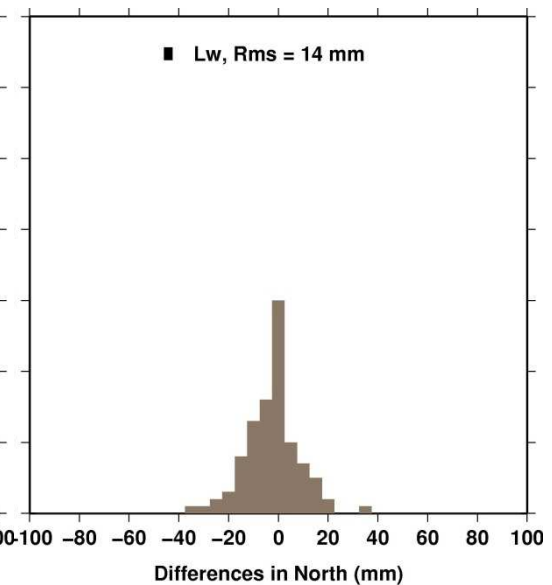
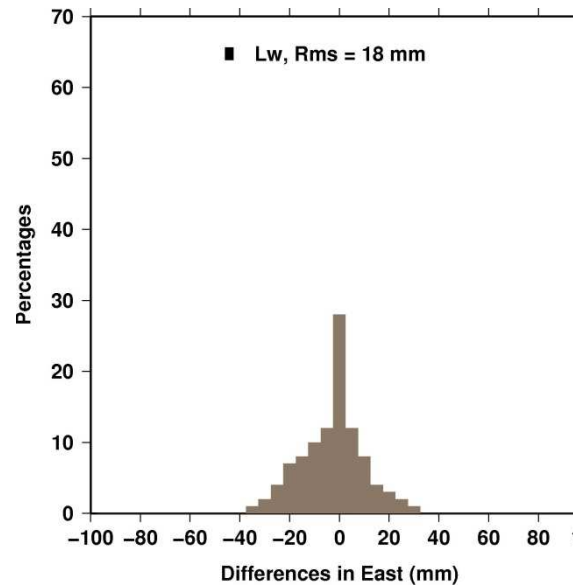
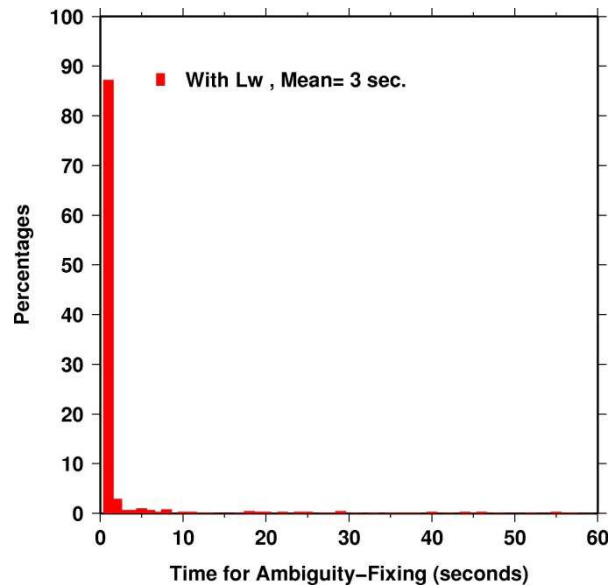
# Results: Position Accuracy

Accuracy of the Positions at the first fixed epoch  
Using Lw+L1

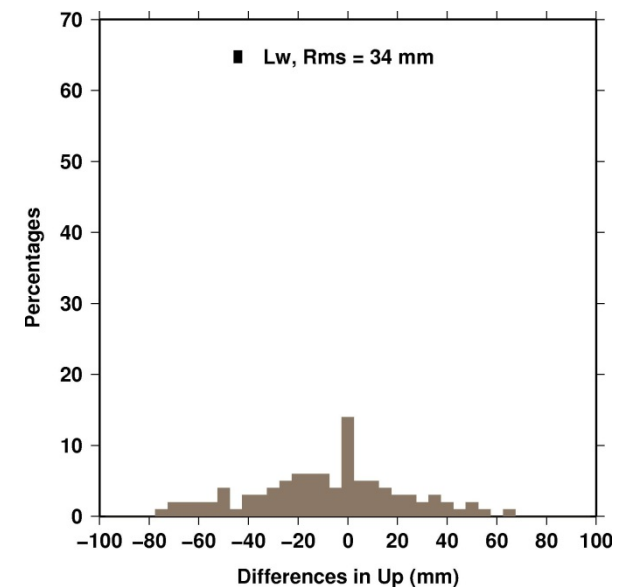


- Lw+L1 8, 6 and 21 mm in ENU, the same as L1 7, 6, and 20 mm
- Lw+L1+ION, slightly worse than Lw+L1, but fixing is improved





- Every Minute Reset Filter
- 90% Fixed With 1 Epoch, On average 3 s
- Lw, 18, 14 and 34 mm ENU
- Lw+L1 in development



## ***Performance Of The Augmented PPP Service***

- Without Regional Augmentation**
  - Open Ocean, ...
  - 5-10 cm, after 30 min., 3-5 cm after Ambiguity-Fixing (15 min)
- With Regional Augmentation**
  - Developed Cities, ...
  - 1-2 cm, within 1-2 min. depends on ...