Efficient Raw Data Processing For Multi-GNSS And Multi-Frequency

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Outline

- Current Status
- Undifferenced & Uncombined Data Processing
- Carrier-Range Concept for Computational Efficiency
- Result
- Conclusion

GNSS current status

More Stations

- IGS networks (about 460)
- US-CORS (over 1900);
- GEONET (over 1300)
- China CORS (over 1000)

More GNSS systems

- *GPS; GLONASS*
- *Beidou (5 GEO; 5 IGSO; 4 MEO);*
- *GALILEO (4)*

More Frequency (The third frequency)

- GPS (L1, L2, L5);
- Beidou (B1, B2, B3);
- GALILEO (E1, E5, E5a, E5b, E6);

Current processing strategy

- *D/U Differenced*
- *LC combination (Ionosphere-free)*

Challenges

- Integrated processing is expected to give more accurate and reliable products
- Multi-GNSS service requires consistent products
  - ✓ Inter-system biases
  - ✓ Inter-frequency biases
- Which ionosphere-free combinations should be used
- More information from measurements
  - ✓ Ionosphere
  - ✓ DCB

➔ Undifferenced, uncombined data processing (raw data processing)

Raw data processing

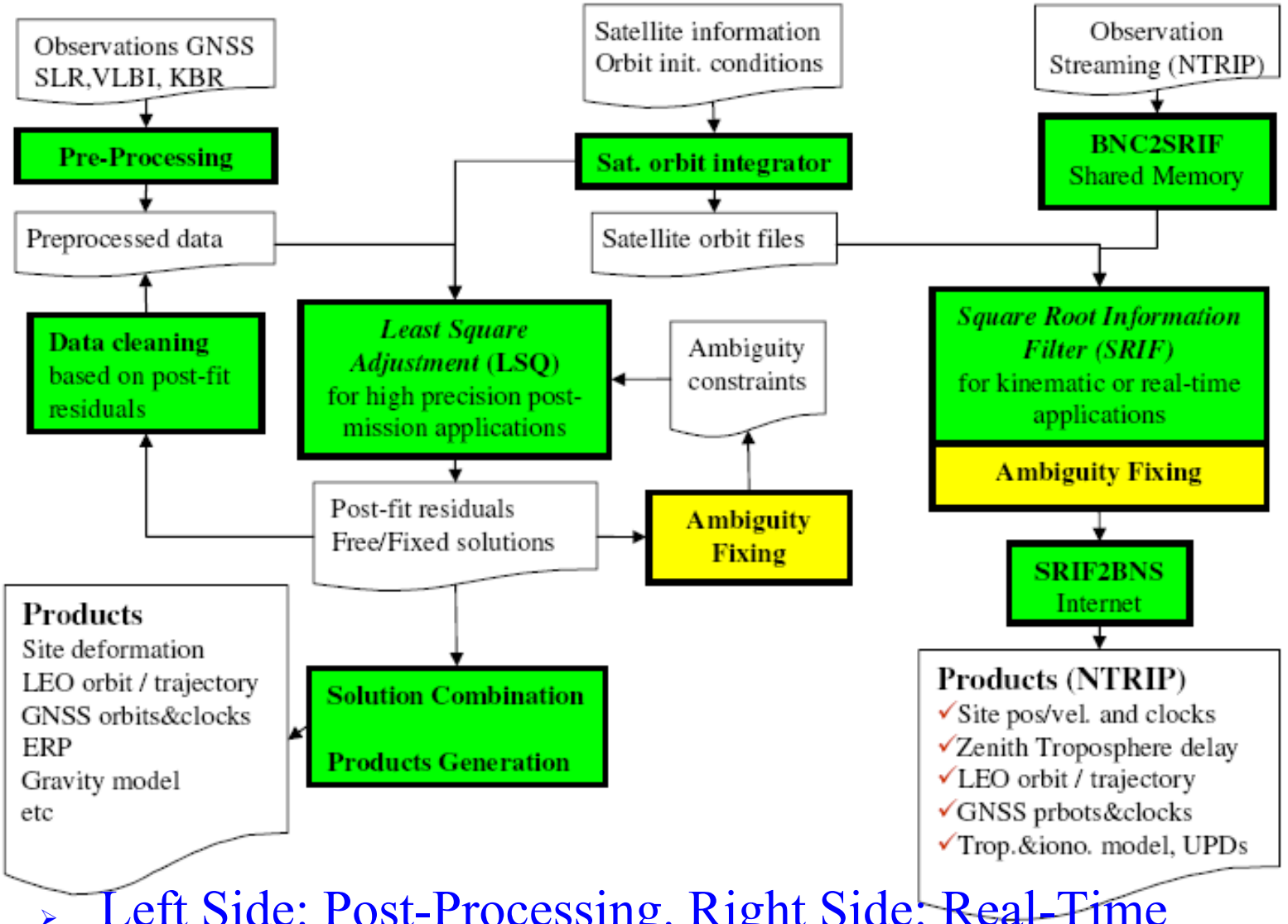
- Observation Equation (**Schönemann et al., 2013**)

$$L_i = \rho + B_{sys} + dt_R - dt^S + T + a_i I + \lambda_i(\delta b_{1R} - \delta b^{1S}) + \lambda_i N_i + \Delta\rho_{Li}$$

$$P_i = \rho + B_{sys} + dt_R - dt^S + T - a_i I + DCB_{Ri} - DCB_{Si} + \Delta\rho_{Pi}$$

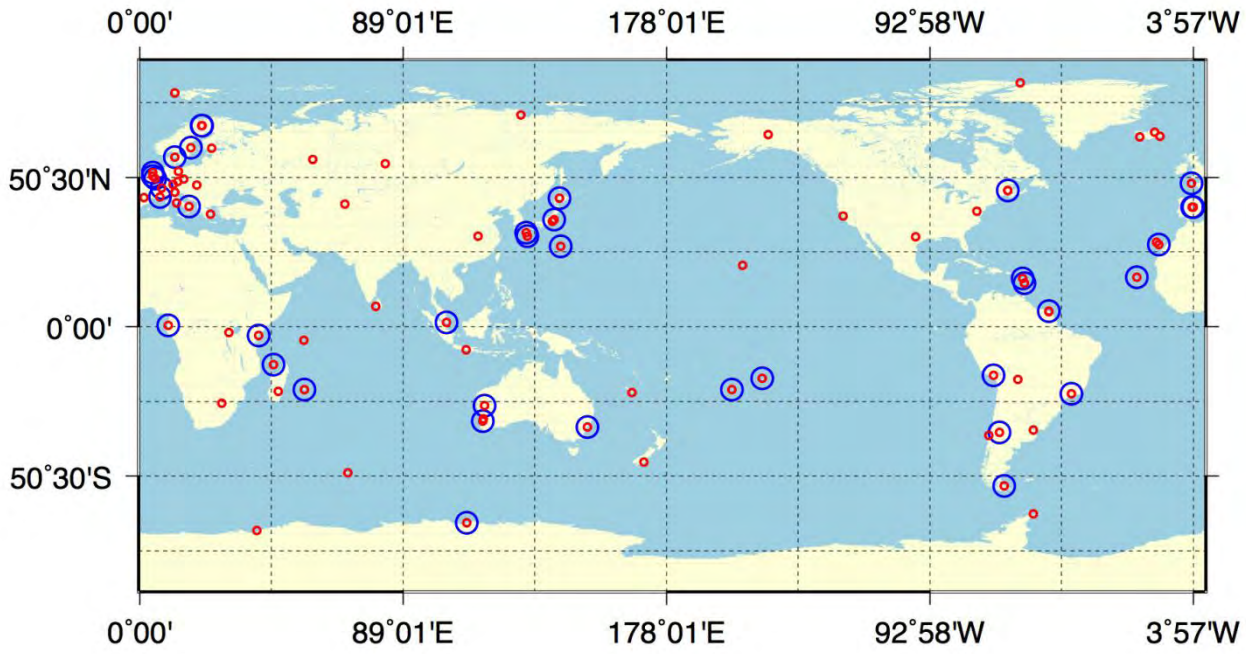
- Ionosphere delay (every receiver-satellite pair)
- Inter-system/Inter-frequency Bias (sum zero condition)
- DCB (sum zero condition)

PANDA Software



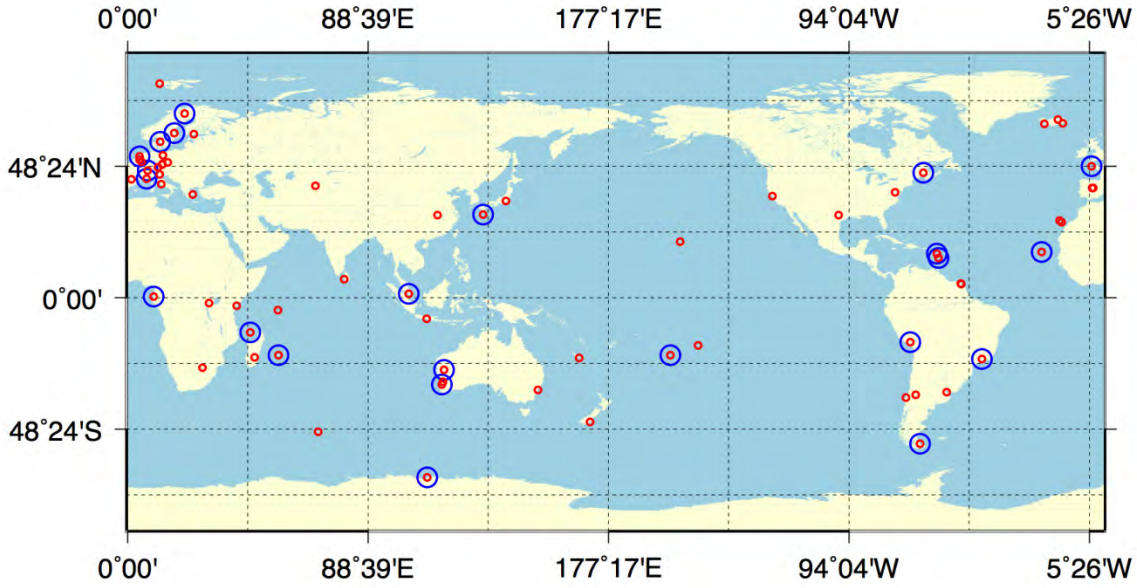
- Left Side: Post-Processing. Right Side: Real-Time

Experimental Network



- 91 GPS stations (Red)
- 39 Beidou stations (Blue)
- Data from day 127 ~145, 2014

Stations With Third Frequency



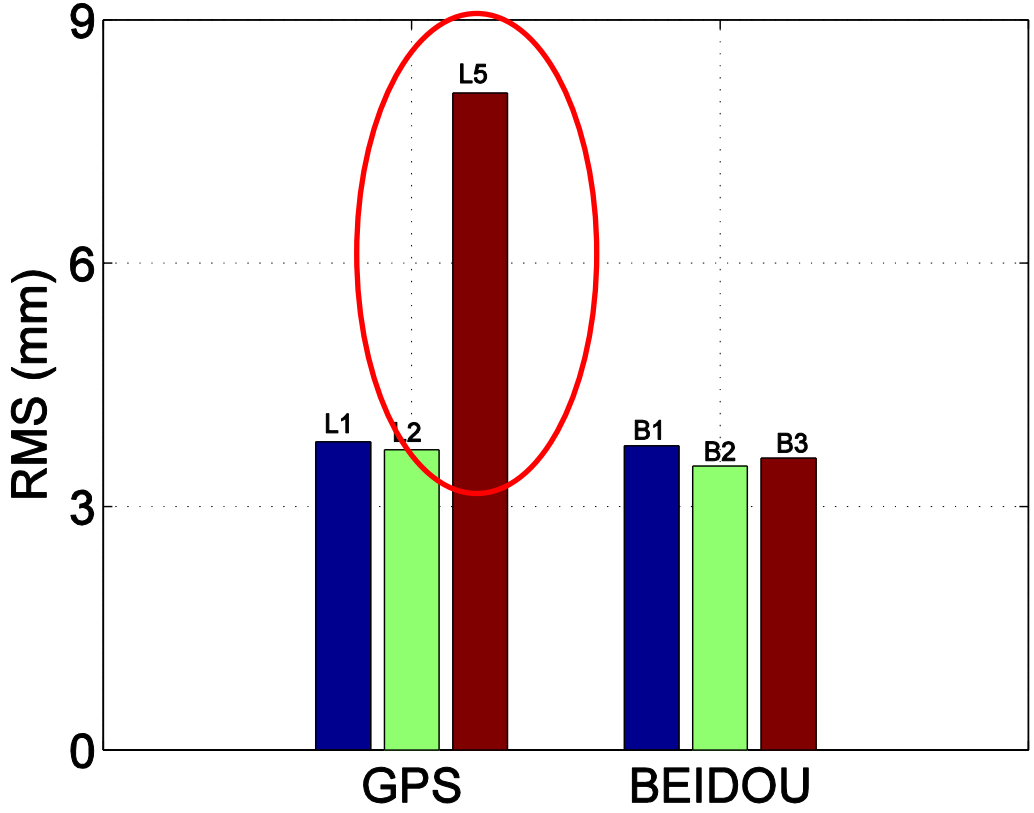
stations with data of three frequencies

GPS (BLOCK IIF):
G01 G24 G25 G27
G30

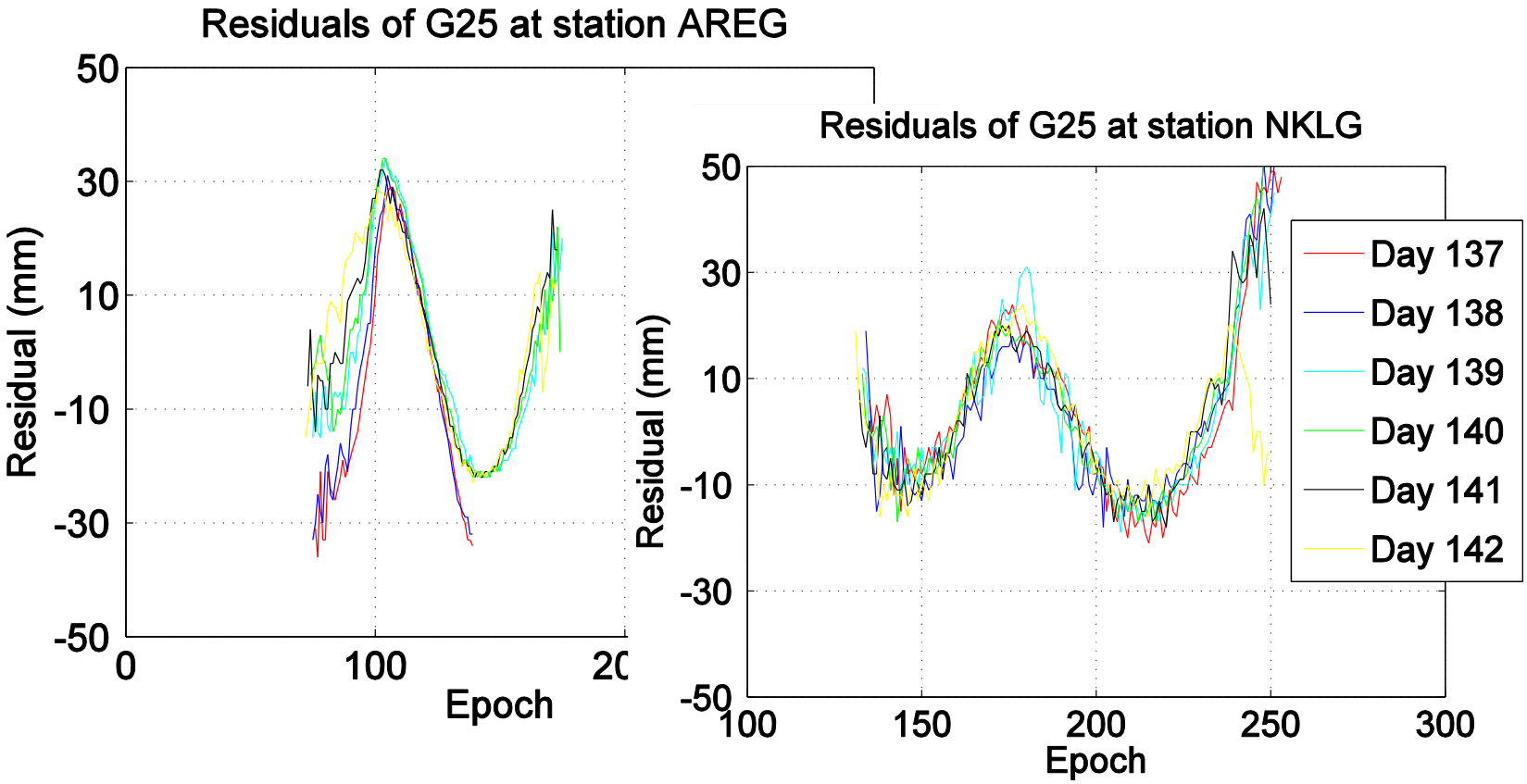
Beidou:
B1 B2 B3

- 77 GPS stations (Red)
- 23 Beidou stations (Blue)

RMS of residuals



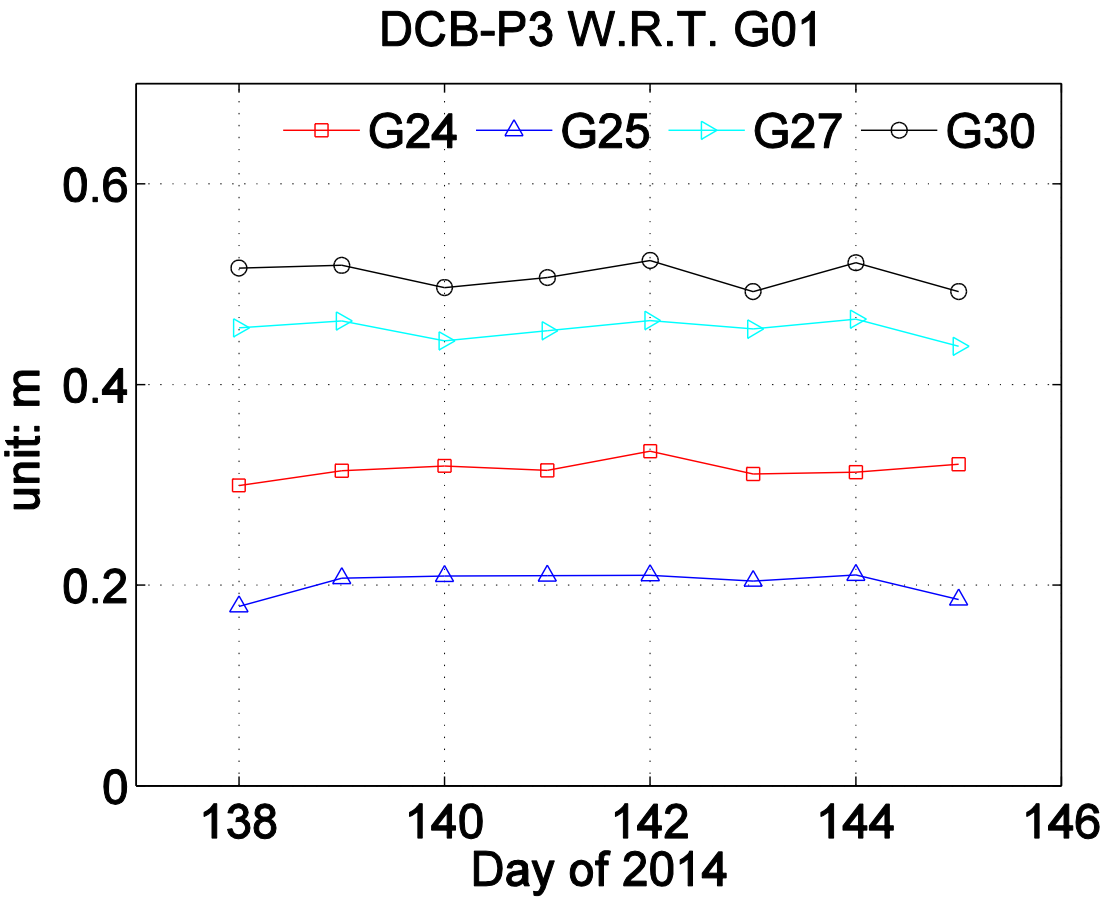
Residuals of the third frequency



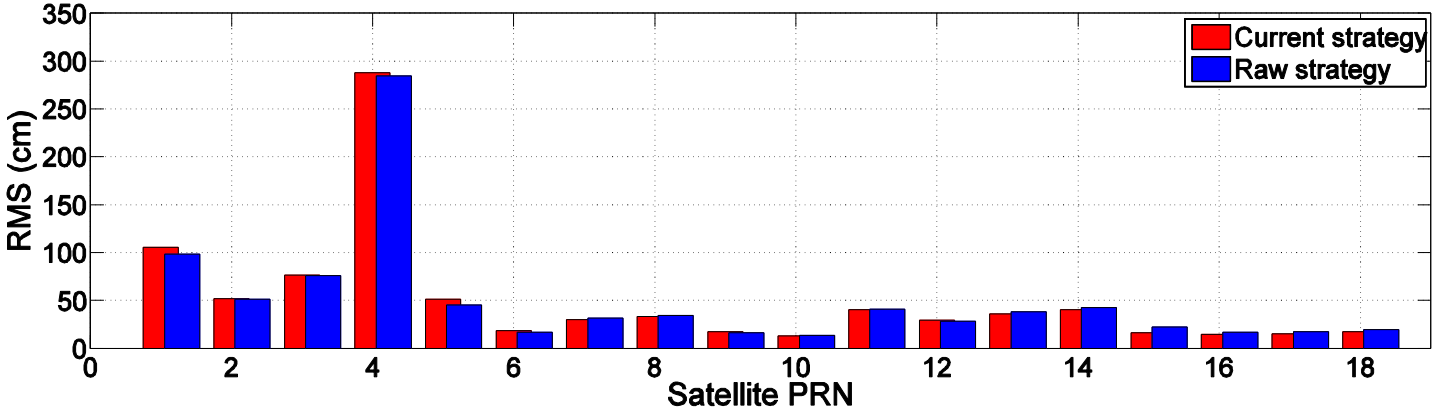
- Residuals behave similarly for each day.
- No clear relationship with antenna PCO

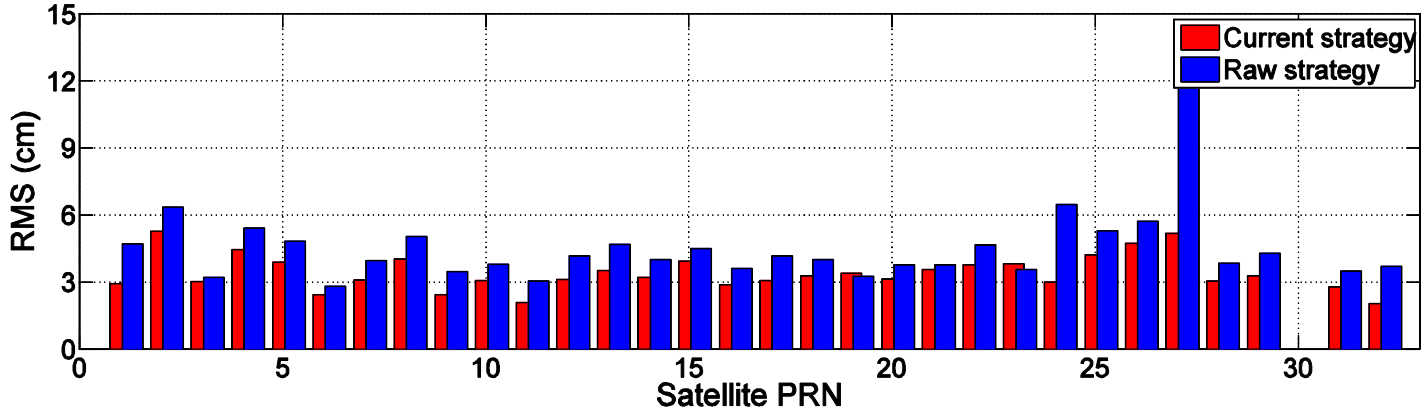
DCB of the third frequency

- DCB-C1\P1\P2 were fixed;
- DCB-P3 is estimated and which is stable;



RMS of Overlapping Orbits





Efficient strategy

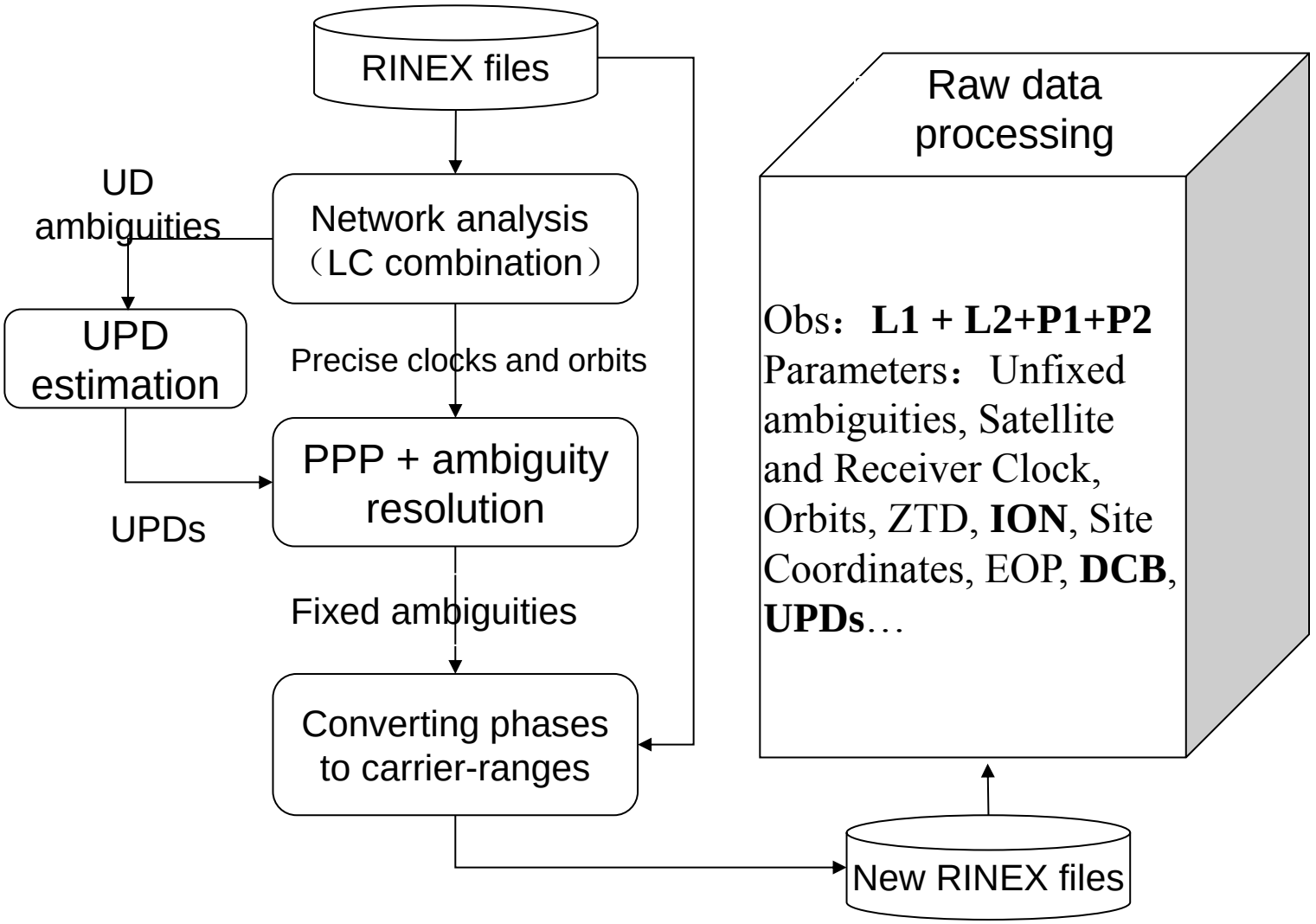
- The realization works but time-consuming

- PPP ambiguities-resolution + Carrier-range concept (Blewitt et al., 2010).

$$L_i - \lambda_i N_i = \rho + B_{sys} + dt_R - dt^S + T + a_i I + \lambda_i(\delta b_{1R} - \delta b^{1S}) + \Delta\rho_{Li}$$

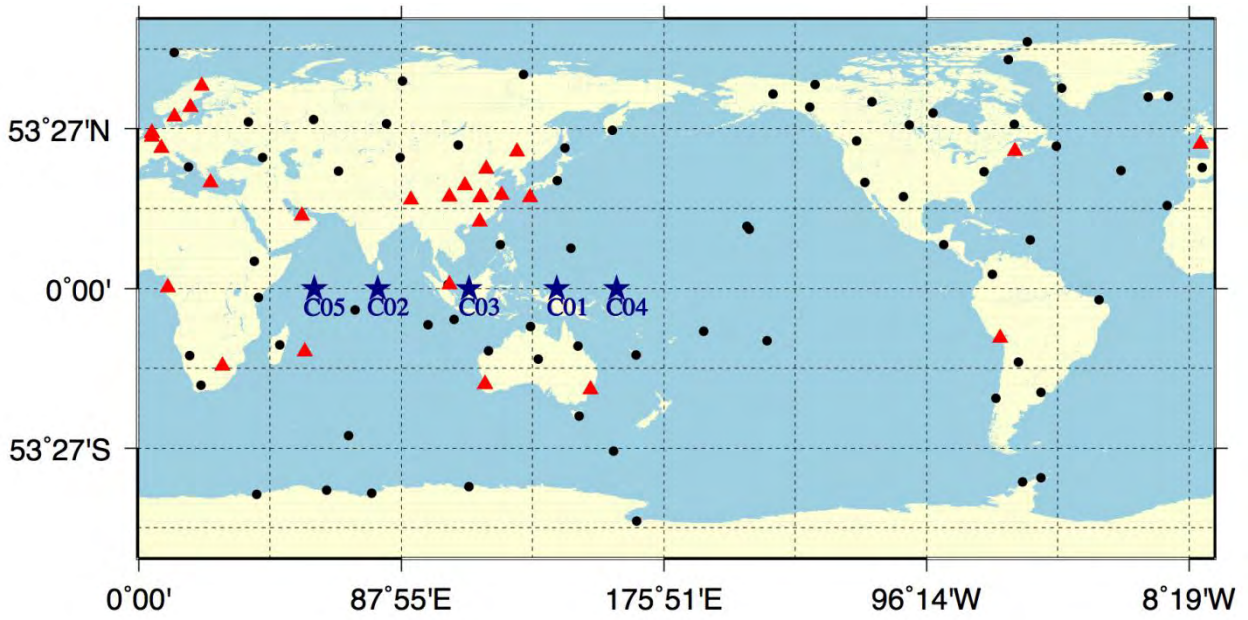
$$P_i = \rho + B_{sys} + dt_R - dt^S + T - a_i I + DCB_{Ri} - DCB_{Si} + \Delta\rho_{Pi}$$

Overview of the Efficient strategy



Experiments

- Carrier-phases + code-ranges
- Carrier-ranges + code-ranges
- Carrier-phases + code-ranges + Ionosphere constraints
- Carrier-ranges + code-ranges + Ionosphere constraints

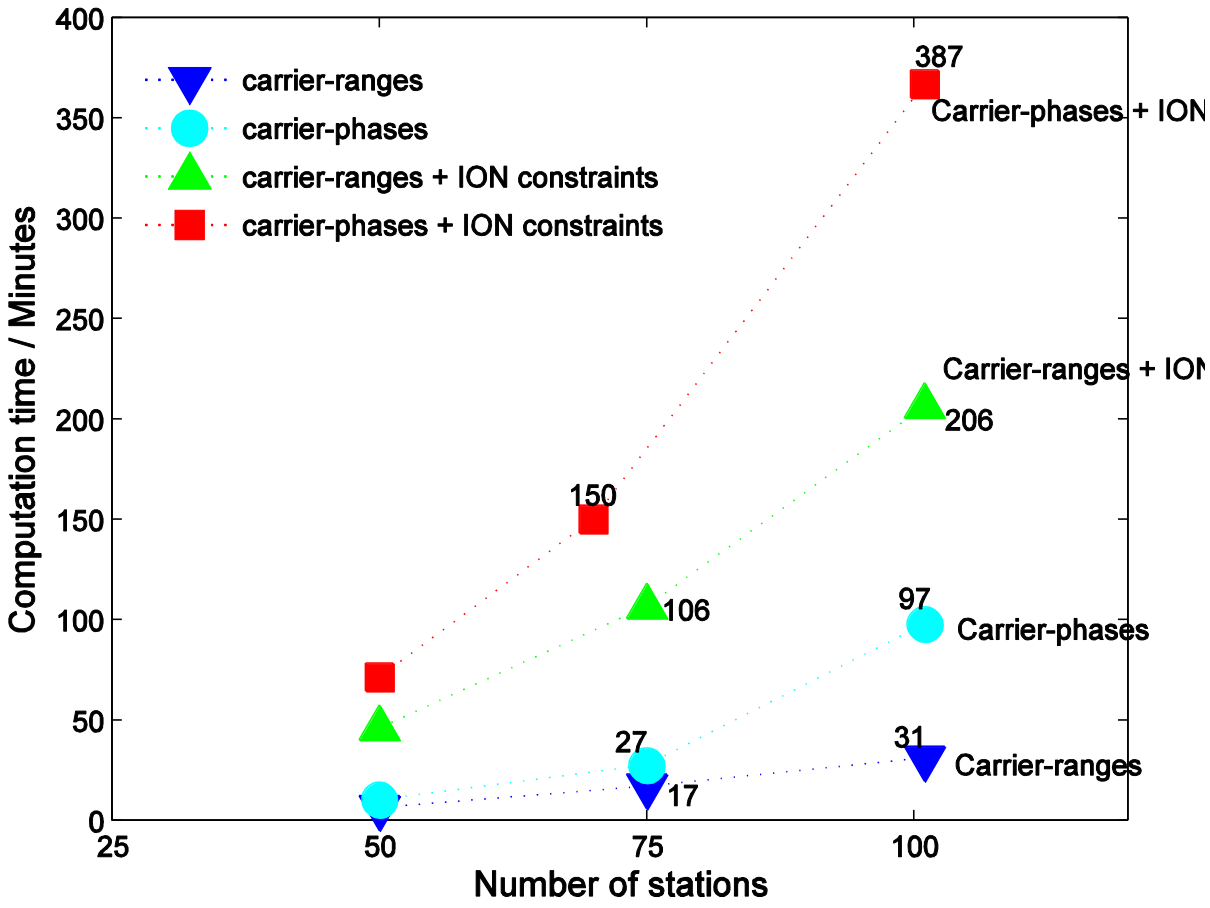


78 GPS stations (blue dots)

29 GPS + Beidou (red triangles)

Day 160 ~187, 2013

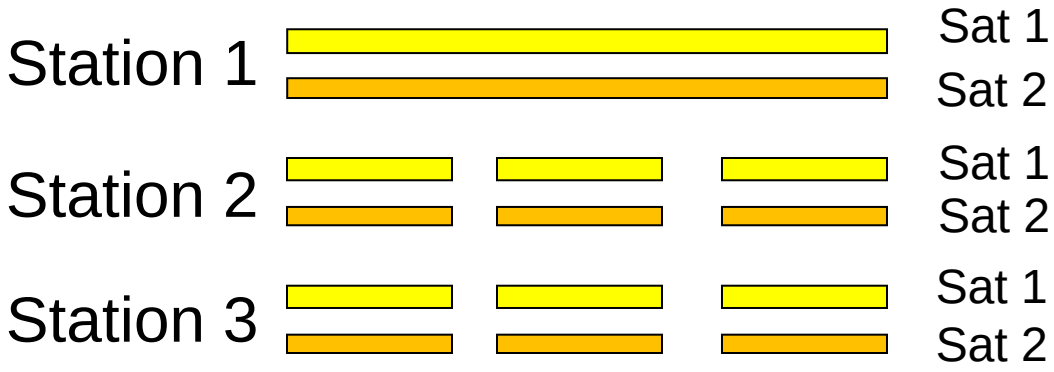
Efficiency



- Carrier-range improves the efficiency greatly
- Applying constraints on iono. parameters restricts the improvement.

Advantage (Data continuity)

- Fixing DD ambiguities

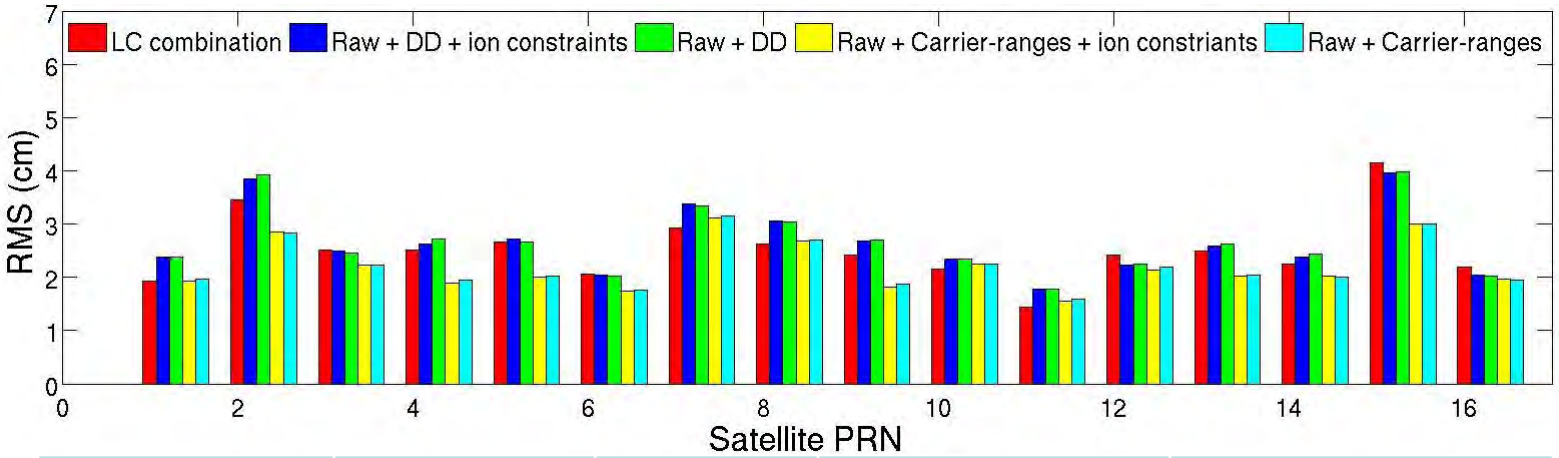


14 UD amb (total)
6 DD amb (fixed)
8 freedom

- If data are connected (cycle slips are repaired).

6 UD amb (total)
2 DD amb (fixed)
4 freedom

Orbits (GPS)



LC Combination	*Raw + DD + ION*	*Raw + DD*	*Raw+ Carrier range + Ion*	*Raw + Carrier ranges*
2.6 cm	2.7 cm	2.7 cm	2.3 cm	2.3 cm

- Carrier-range reduce overlapping rms from 2.6 cm to 2.3 cm
- Ionospheric constraint should be investigated for further improvement.

Conclusion

- Raw data processing strategy is a unified data processing for multi-GNSS and multi-frequency, and which is realized in PANDA software.
- It seems there is a repeatable single between the GPS third frequency and the first two frequencies.
- PPP ambiguities resolution and carrier-range concept are combined to speed up the raw data-processing, which could also improve the data continuity.

Thanks