Fast-PPP assessment in European and equatorial region near the Solar Cycle maximum

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This poster participates in OSP Outstanding Student Poster Contest

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Introduction

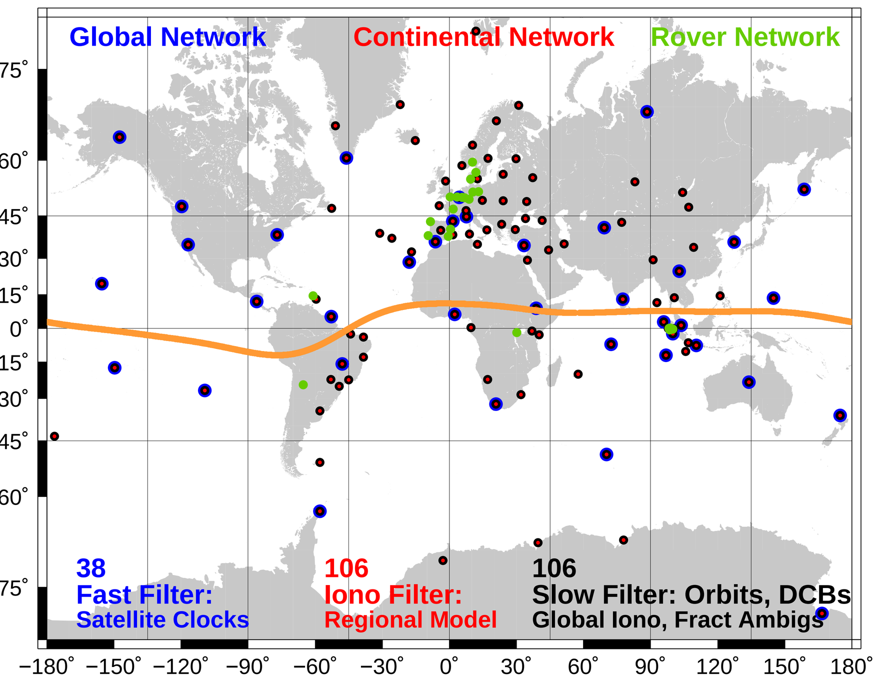
The Fast Precise Point Positioning (Fast-PPP) is a technique to provide quick high-accuracy navigation with ambiguity fixing capability, thanks to an accurate modelling of the ionosphere.

First Wide-Area Real-Time Kinematics (WARTK) feasibility studies [1] enabled differential relative continental navigation using only a few tens of reference stations. The further evolution [3] led to a global PPP service with the added capability of undifferenced ambiguity fixing, and a continental enhancement to shorten convergence based on accurate ionospheric corrections. The technique is protected by several international patents [2] funded by the European Space Agency (ESA).

In this work, Fast-PPP is assessed in single and dual frequency users at a planetary scale for first time, and in near-maximum solar cycle conditions. This includes equatorial latitudes, more challenging than previous results, which were obtained with quieter ionosphere; spatial (Europe mid-latitudes) and temporal (late 2009).

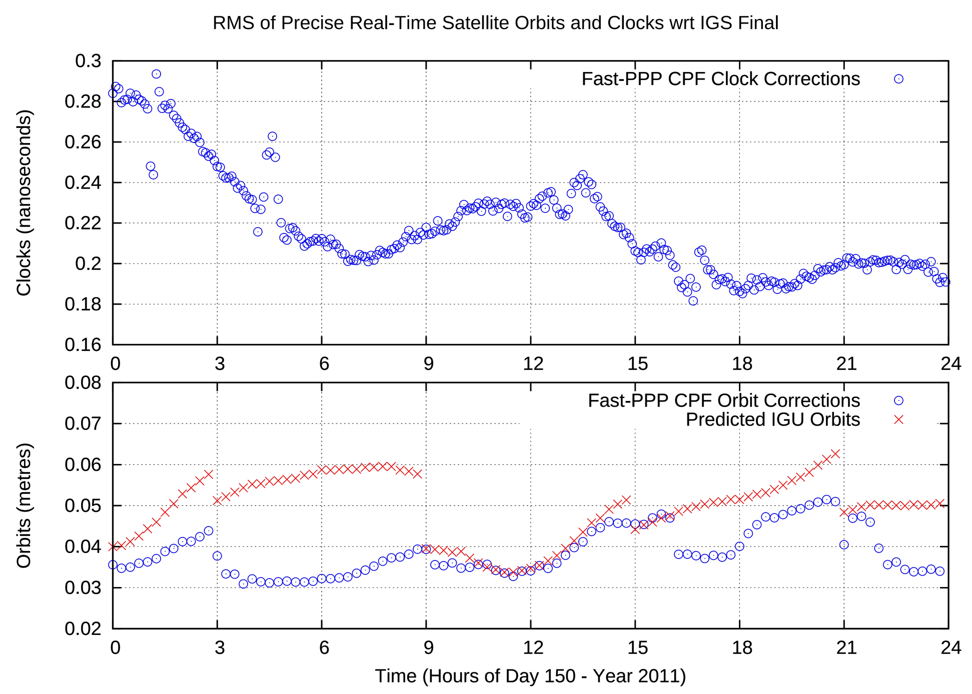
Experiment Description

A world-wide distribution of rovers (green dots) is used to assess the performance of Fast-PPP, with nearest ionospheric references located at more than one order of magnitude greater than typical RTK or Virtual Reference Station (VRS) baselines. Other three networks are used by the Central Processing Facility (CPF) to generate Fast-PPP corrections; orbit and clocks, ionosphere, biases and ambiguities fractional part.



Satellite Orbits and Clocks

The Fast-PPP RMS orbit error is maintained at the level of 3.9 centimetres, while satellite clocks have an accuracy of 0.22 nanoseconds (~ 6 cm). This performance is comparable with International GNSS Service (IGS)-Real Time combined product for the selected day of the scenario is 2.7 centimetres and 0.21 nanoseconds for orbits and clocks.



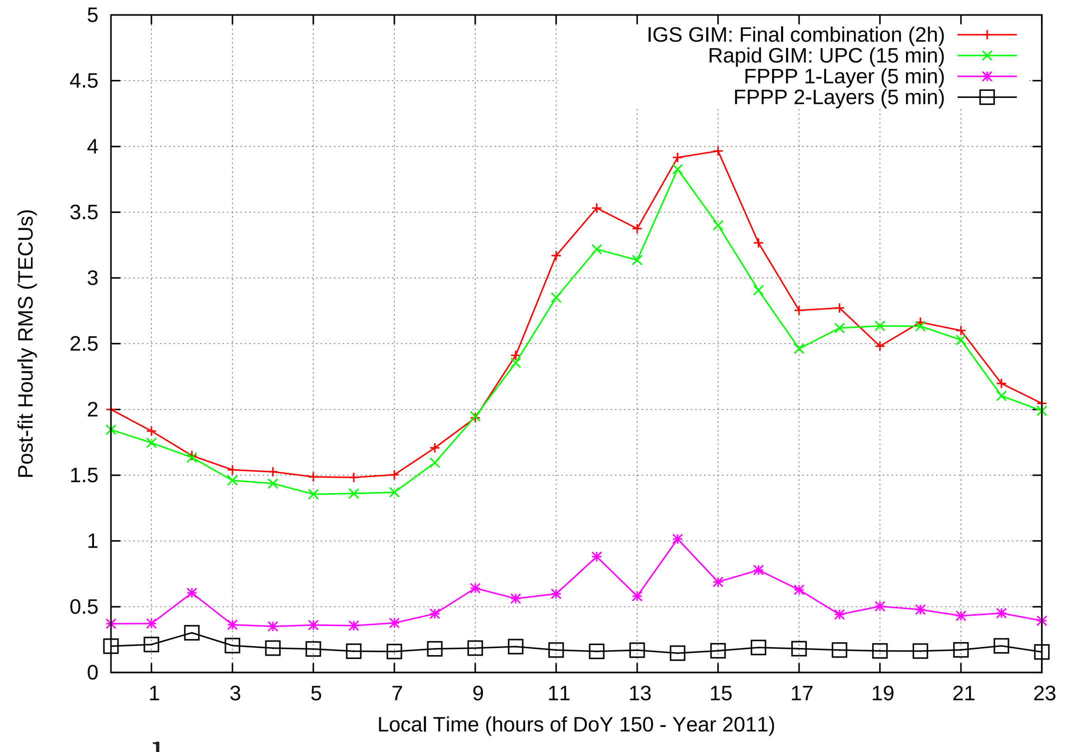
Ionosphere: A metric to assess ionospheric models for GNSS navigation

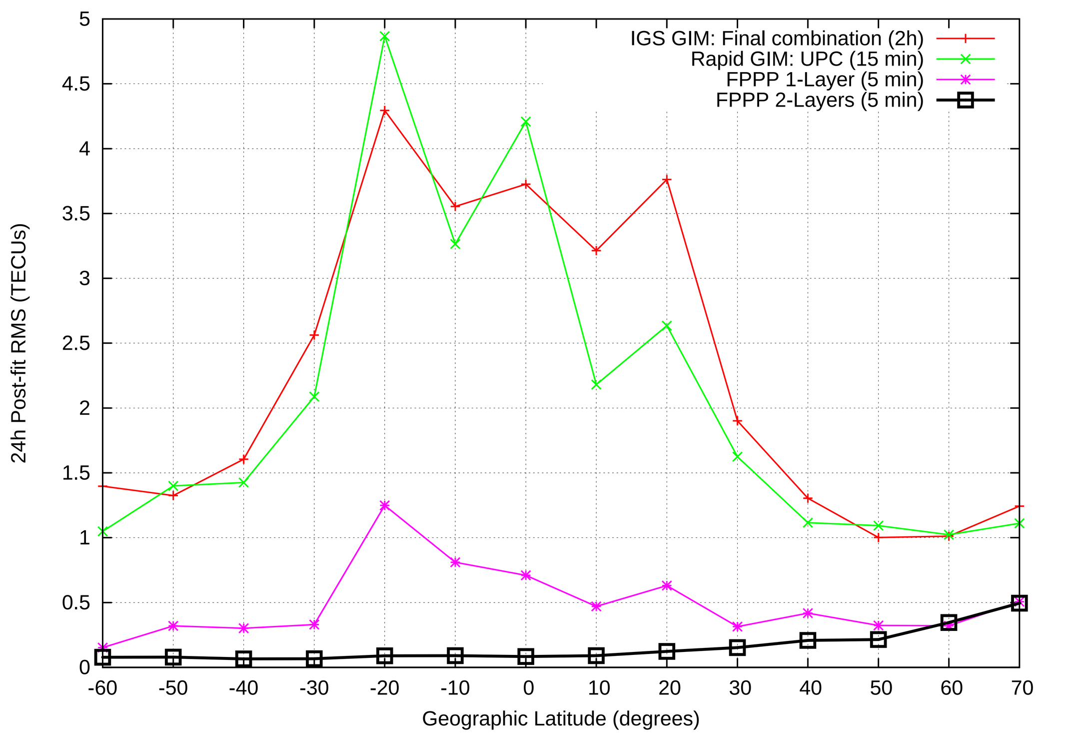
The core of the Fast-PPP is the capability to compute real-time ionospheric corrections with accuracies at the level or better than 1 Total Electron Content Unit (TECU), improving the widely-accepted Global Ionospheric Maps (GIM), which has nominal [4] accuracies of 2-8 TECUs. Fast-PPP large improvement in the modelling accuracy is achieved thanks to:

Unambiguos: Carrier-phase ambiguities are fixed in the same Central Processing Facility (CPF) than geodesy computations (Satellite orbits and clocks).

Unbiased: Satellite DCB are estimated and removed.

Two-layer: Better separation of ionospheric and plasmaspheric delays and its dynamics.



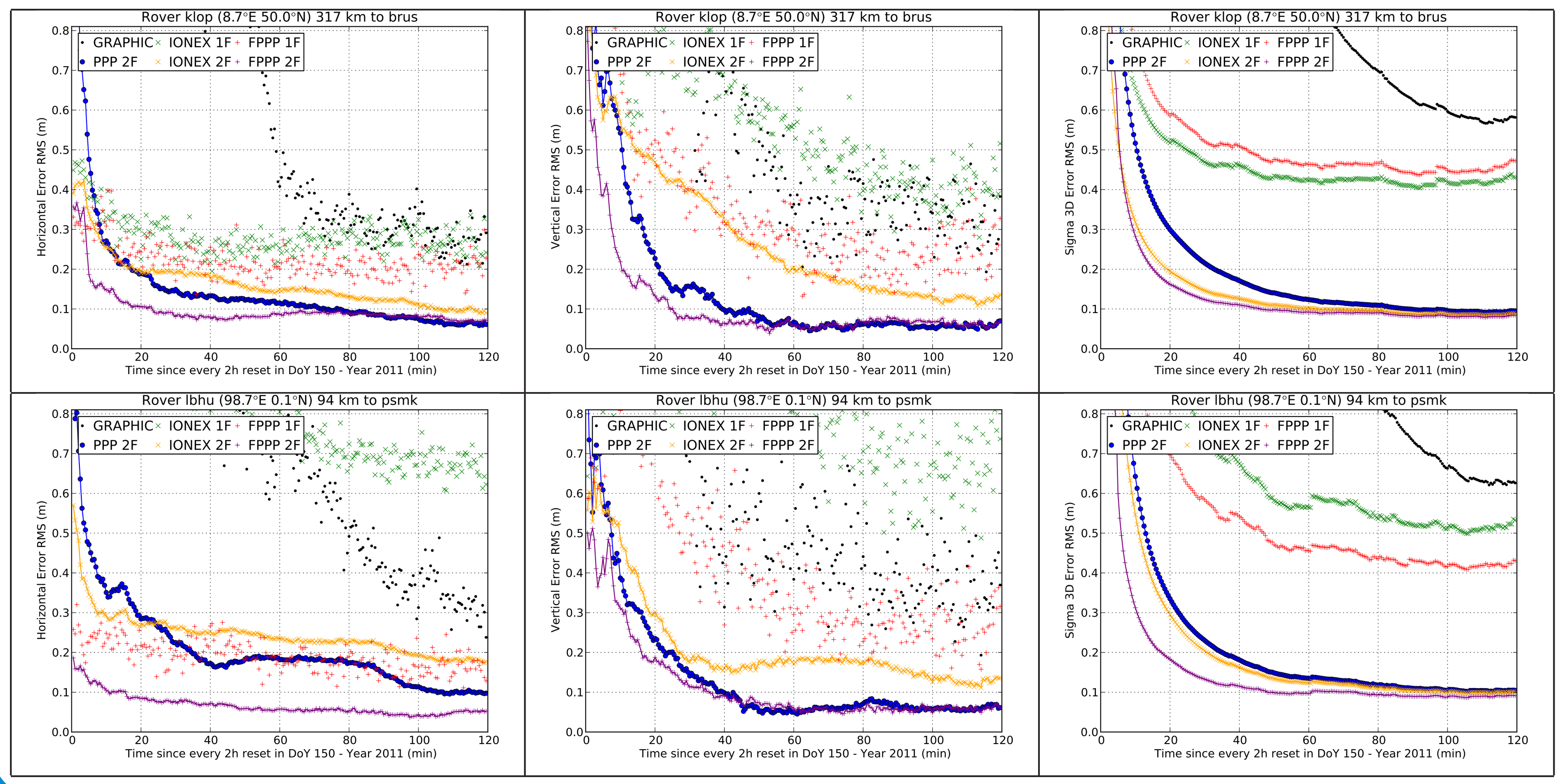


A test to assess any ionospheric model for GNSS navigation is proposed:

1. Computing of Unambiguous and Unbiased (true) STEC from geometry-free combination of carrier phases measurements: $STEC_{true} = L_I - (DCB_{rec} - DCB^{sat}) - B_I^{fix}$
2. RMS of the post-fit residuals of the fit of the difference between the STECs provided by the model under testing and the true STEC ($STEC_{true}$) to a bias per station and per satellite: $STEC_{true} - STEC_{model} = DCB_{rec} - DCB^{sat}$

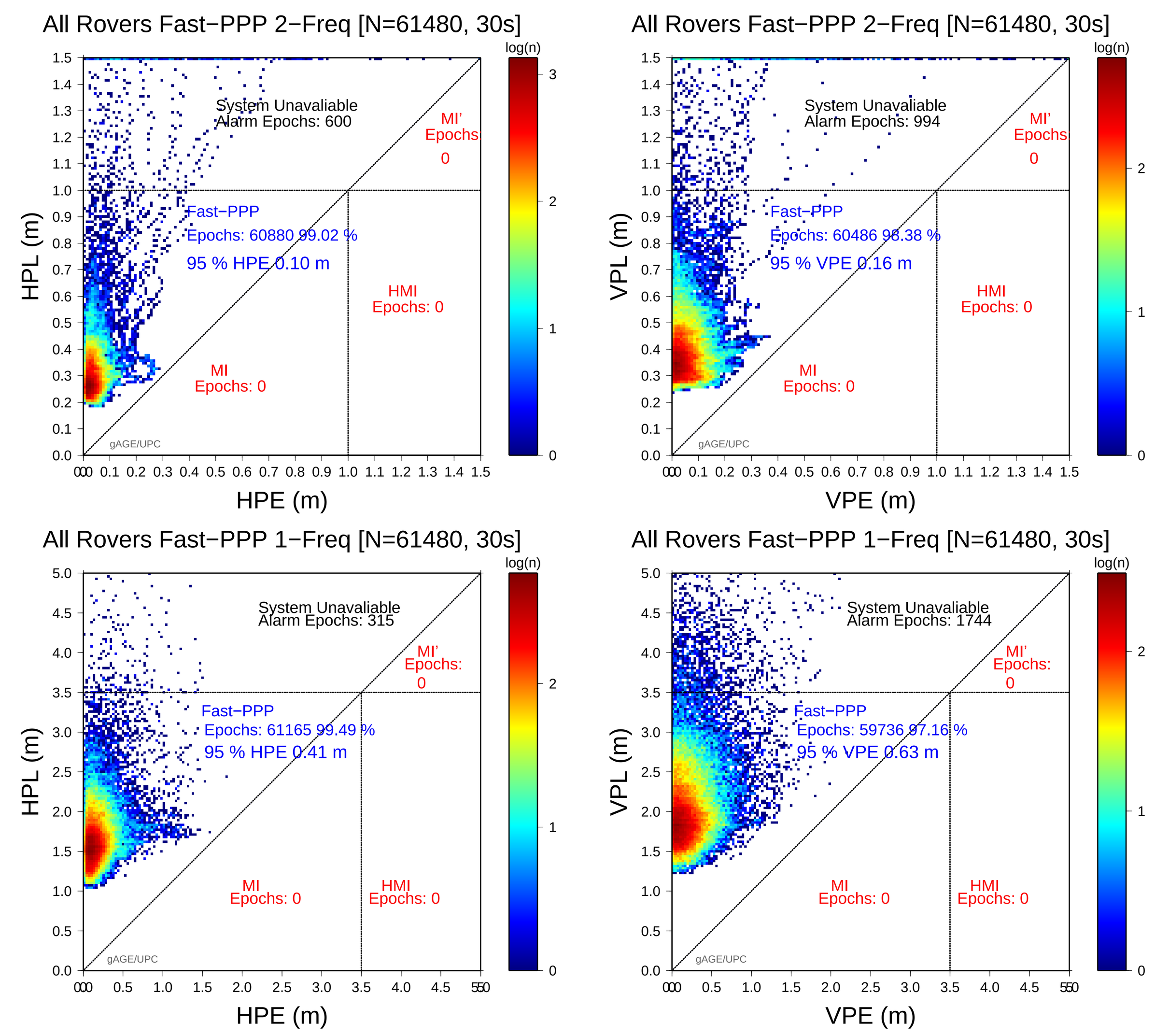
Convergence Assessment

The user state is reset every 2 hours, merging the twelve cold starts on the same plot. Horizontal and Vertical accuracies together with its 3D formal error are plot as a funtion of time. Fast-PPP single and dual frequency positioning are respectively assessed against ionosphere-free strategies; GRAPHIC and classic PPP.



User Domain Protection Levels

A first glance to user domain accuracy and its confidence level is shown by the Stanford plots. The trade-off between formal and actual positioning errors depend on the realism of the corrections sigmas computed by the CPF. Such relation has been carefully studied to obtain safe integrity margins in the world-wide rover network mixing several ionospheric conditions.



Conclusion

Using a world-wide distribution of rovers, the Fast-PPP technique has been assessed from the Central Processing Facility (CPF) corrections to the user domain positioning:

Precise satellite orbits and clocks: are computed with an accuracy at the level to IGS real-time products; few centimetres and few tenths of nanoseconds.

Ionospheric Models are compared: Fast-PPP two-layer, ambiguity-fixed ionospheric real-time determinations better than 1 TECU (16 centimetres in L1) can be used in combination with precise orbits and clocks maintaining their accuracy.

Reduction of convergence time: Dual-Frequency Users enhance from the best part of an hour to 5-10 minutes; in European mid-latitudes and equatorial region.

Accuracy: The improvement of ionospheric modelling is directly translated into the accuracy of single-frequency mass-market users.

Protection levels: Safe margins are achieved thanks to the realism of the Fast-PPP corrections confidence levels computed at the CPF level.

Acknowledgment

The authors acknowledge the use of data from the International GNSS Service, the Sumatran GPS Array (SuGAr) network and the Asia Institute of Technology (AIT).

Funding

This work has been sponsored by the ESA Network Partner Initiative Nr. 220-211 with the industrial partner FUGRO; Technical University of Catalonia grant FPI-UPC Nr. 120-743; Projects GNAVIS from EC-FP7 Grant Nr. 287203 and ANTARTIDA CTM2010-21312 also contribute.

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