UPC-IonSAT activities on precise GNSS positioning

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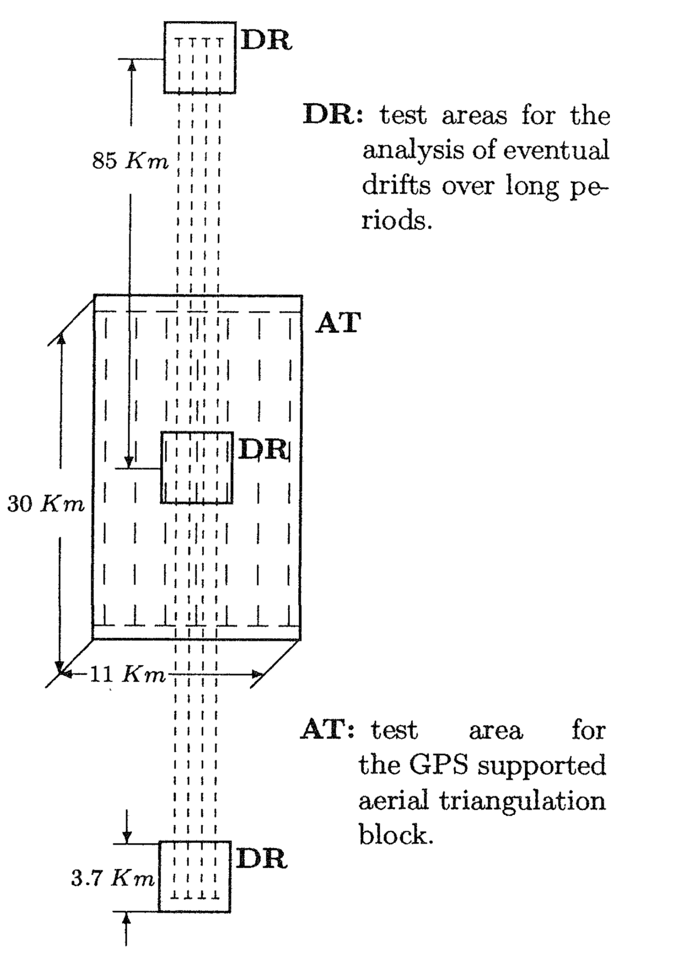
IGS Workshop 2014, June 23-27, Pasadena, California, USA

Abstract

Several past and recent activities on precise GNSS positioning, in which members of the UPC-IonSAT research group have been directly involved, are summarized in this work (in cronological order): (1) GPS-supported air-based cartography, (2) sea-level GPS precise determination, (3) Wide Area Real Time Kinematic and Fast Precise Point Positioning, and (4) realistic ionospheric higher order mitigation strategies for precise GNSS products.

Figure 1: Left: Test areas as of the original Urgell test plan. **Right:** Partenavia airplane used.



(1) GPS-supported air-based cartography

The very first precise GNSS activities involving UPC-IonSAT researchers, at such a time at the Cartographic Institute of Catalonia (ICC), were performed at the beginning of the nineties: an aerial triangulation photogrammetric experiment (Urgell test) helped to confirm the feasibility of the GPS-supported air-based cartography, by replacing control ground points by the GPS-georeferencing of the camera projection center (*Colomina et al. 1992*, see Figure 1).

(2) Sea-level GPS precise determination

Later on, we showed the advantages of a non-fiducial global network processing, to increase the GPS sea-level positioning accuracy (*Rius et al. 1995*, see Figure 2).

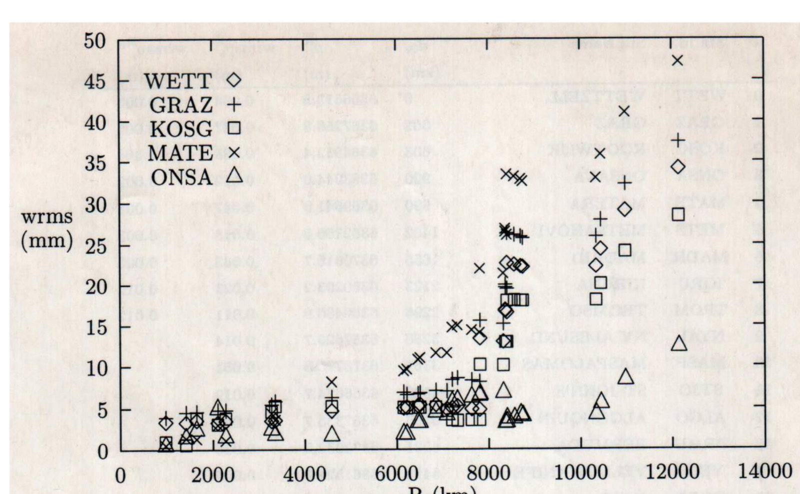


Figure 2: The wrms of the radial coordinate of the indicated sites are plotted vs. the radius R of subnetwork centered on Wettzell used in the analysis.

(3) Wide Area Real Time Kinematic (WARTK) and Fast Precise Point Positioning (FPPP)

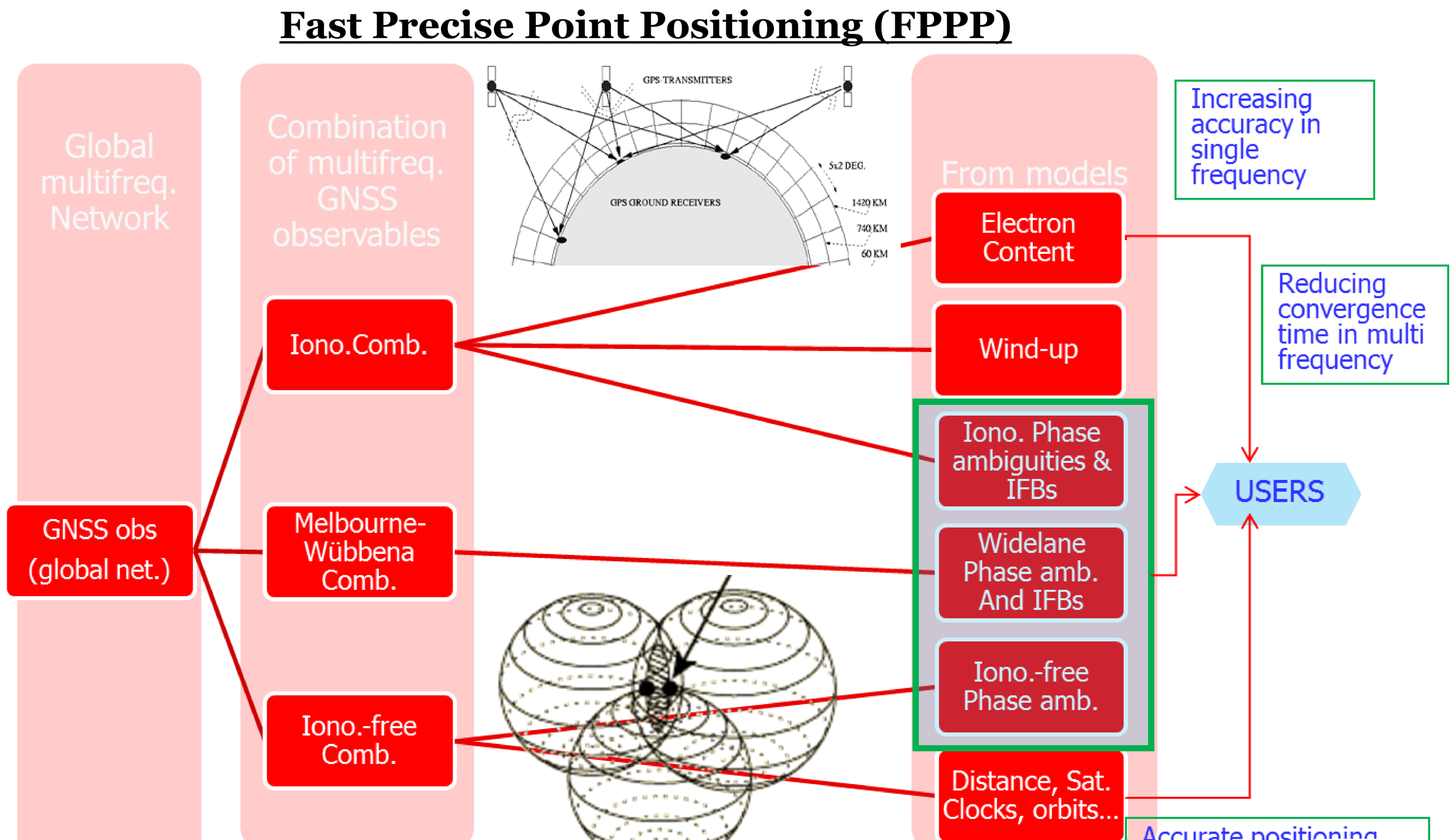


Figure 3: Top-left: Layout of the geodetic-ionospheric hybrid approaches (such as Wide Area RTK and Fast PPP) to improve the performance of precise GNSS navigation.

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(3) Wide Area Real Time Kinematic (WARTK) and Fast Precise Point Positioning (FPPP) –Cont.--

Other activities closer in time, exploited the synergies produced by the simultaneous processing of geodetic and ionospheric models in regional, continental and global GNSS networks: the so called Wide Area Real Time Kinematic (WARTK, see *Hernández-Pajares et al. 2000*) and the Fast Precise Point Positioning (FPPP see *Juan et al. 2012*). Such techniques are the differential and non-differential (absolute) implementations of the same main concept (see Figure 3): firstly, the GNSS data driven ionospheric model is improved thanks to the simultaneous processing of the geometric and ionospheric (tomographic-voxel) models, connected by the common unknowns such as the carrier phase ambiguities of the dual-frequency signals. And secondly, the user positioning is improved thanks to receiving (typically in real-time) an accurate estimate of the ionospheric delay for each satellite in view. If this information, taken as an additional datum, is accurate enough (i.e. better than 0.25 TECUs for GPS L1, L2 observations), it accelerates and increase the precise GNSS RT-positioning, at 10-cm error level (we showed the feasibility of this technique for rover distances to the nearest reference GNSS site of up to 400 kilometers, at mid lat. and any Solar-cycle condition).

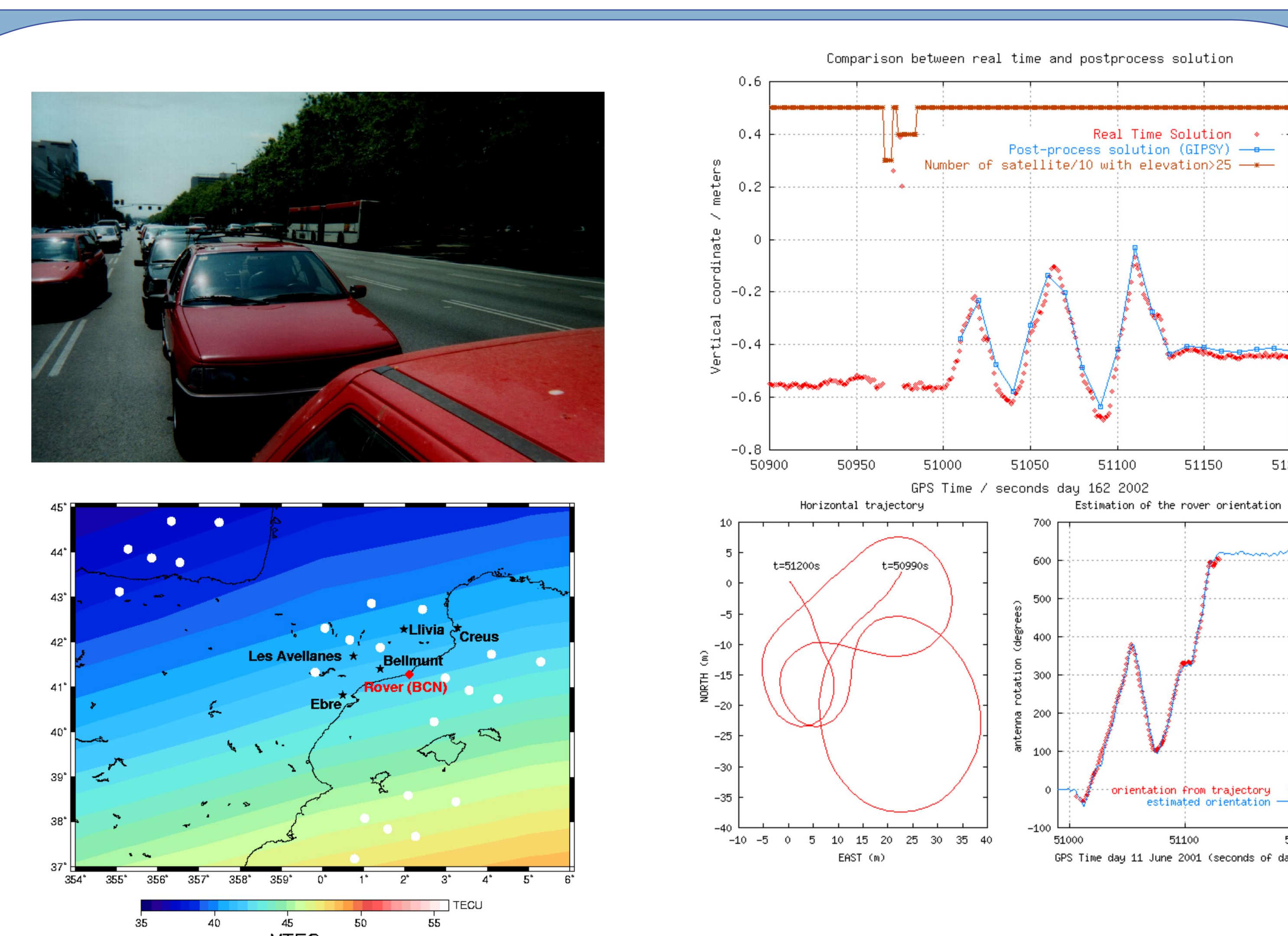

Figure 4: Top-left: View of the car bringing the two GPS antennas used in the UNBAR01 experiment, to demonstrate the feasibility of Wide Area Real Time Kinematics (WARTK) and the antenna attitude determination with a single antenna.**Top-right:** WARTK radial coordinate (red) and post-processed reference solution (blue). **Bottom-left:** Permanent network of GPS reference receiver (black dots), placed at more than 100 km from the rover (red). The ionospheric pierce points for 4 satellites in view are represented overimposed to the VTEC in a certain time during UNBAR01 experiment. **Bottom-right:** Plots showing the horizontal movement of the roving receiver, during a part of the UNBAR01 experiment (left). At the right hand plot, the corresponding wind-up estimation (blue) compared with the value derived from the trajectory (red) are shown.

(4) Realistic ionospheric higher order mitigation strategies for precise GNSS products

Recently UPC-IonSAT has leaded an ESA-funded study (IONO-DeCo), in close collaboration with the Royal Observatory of Belgium (ROB), on the GNSS higher order ionospheric effects (second order, third order, geometric bending and STEC-difference bending) on satellite orbits and clocks, receiver positions and clocks, vertical tropospheric non-hydrostatic delay and geocenter offset), when a global processing is performed, and their final impact on a PPP user (*Hernández-Pajares et al. 2014*). In this way the previous work *Hernández-Pajares et al. (2007)* done only for second order term and GNSS networks has been extended. Among other conclusions, it has been shown that realistic ionospheric higher order mitigation strategies, which can be applied in real situations, reduce the missmodelling in GNSS precise processing very significantly (below 4 mm level), in particular when applying the main ones: second ionospheric order and STEC-difference bending terms .

Conclusions

- The main research activities of IonSAT members (since 1989 to 2014) related with precise GNSS positioning have been summarized.
- Among the first activities related with kinematic GPS technique to support aerial cartography and precise sea levelling, the most recent and active ones have been summarized in more detail:
  - The combination of precise ionospheric and geodetic modelling in a hybrid approach to increase the coverage of precise RTK positioning (from few tens to few hundreds of kilometers from the nearest GNSS reference site) and to accelerate the convergence to precise positioning (from the best part of one hour to the best part of few minutes), also for the undiff. technique: the Fast PPP.
  - The caracterization of the effects and mitigation errors of proposed practical techniques for the four main higher order ionospheric effects on precise GNSS processing.

Acknowledgments

Most of these works have been possible thanks to the existence of the International GNSS Service, and thanks to the continuous confidence of the European Space Agency, with 17 competitive projects granted to UPC-IonSAT members since 1998. The authors of this poster are very grateful to the colleagues of different research groups (within CSIC, ESA, IC, ICGC/ICC, IdG, NASA, ROB, UPC among others) leading or collaborating in the summarized works on precise GNSS positioning during the last 25 years: Nicolas Bergeot, Oscar Colombo, Ismael Colomina, Pedro Coutinho, Pascale Defraigne, Shaojun Feng, Martí Jofre, J.Miguel Juan, Ana M. Madrigal, Washington Ochieng, Raül Orús, Roberto Prieto-Cerdeira, Pere Ramos, Antonio Rius, Jaron Samson, Jaume Sanz, Julià Talaya, Assumpció Termens, and Michael Tossaint, among others.

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