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PROCESSING GROUND AND COSMIC GPS MEASUREMENTS FOR NEAR-REAL TIME IONOSPHERIC DATA ASSIMILATION USING USC/JPL GAIM

Attila Komjathy[*], Philip Stephens[*], Brian Wilson[*], Vardan Akopian[*], Byron Iijima[*], Xiaoqing Pi[*] and Anthony J. Mannucci[*]

[*] Jet Propulsion Laboratory California Institute of Technology M/S 238-600
4800 Oak Grove Drive, Pasadena CA 91109

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1 INTRODUCTION

The University of Southern California (USC) and the Jet Propulsion Laboratory (JPL) have jointly developed the Global Assimilative Ionospheric Model (GAIM) to monitor space weather, study storm effects, and provide ionospheric calibration for space weather applications. JPL/USC GAIM is a physics-based 3D data assimilation model that uses both 4DVAR and Kalman filter techniques to solve for the ion and electron density state and key drivers such as equatorial electrodynamics, neutral winds, and production terms.

Ionospheric remote sensing is in a rapid growth phase, driven by an abundance of ground and space-based GPS receivers, new UV remote sensing satellites, and the advent of data assimilation techniques for space weather. The joint U.S./Taiwan Constellation Observing Systemfor Meteorology, Ionosphere and Climate (COSMIC; http://cosmicio.cosmic.ucar.edu/cdaac/index.html), a constellation of six satellites, nominally provides up to 3000 ionospheric occultations per day. COSMIC now provides an unprecedented global coverage of GPS occultation measurements (between 1400 and 2400 good soundings per day as of January 2010). Calibrated measurements of ionospheric delay (total electron content or TEC) suitable for input into assimilation models are currently made available in near real-time (NRT) from the COSMIC with a latency of 30 to 120 minutes. Similarly, NRT TEC data are available from two worldwide NRT networks of ground GPS receivers (~75 5-minute sites and ~125 hourly sites, operated by JPL and others). The combined ground and space-based GPS datasets provide a new opportunity to more accurately specify the 3-dimensional ionospheric density with a time lag of only 15 to 120 minutes. With the addition of the vertically-resolved occultation data, the retrieved profile shapes are expected to represent the hour-to-hour ionospheric "weather" much more accurately. We have now begun integrating COSMIC-derived TEC measurements with real-time ground-based GPS TEC data and assimilating these data into models such as the JPL/USC GAIM so that real-time three-dimensional global electron density structures and ionospheric drivers can be estimated [e.g., Mandrake et al, 2005]

2 GROUND-GPS DATA PROCESSING

We have improved our ground and COSMIC data processing capabilities. The new software we developed is a monolithic code written in python, glued with some of the GIPSY ninja data editing capabilities along with the RINEX reader library written in C/C++. The new code executes quickly and efficiently making it ideal to use for front-end processing of real-time GPS measurements. The fundamental difference between old and new processing scheme is that in the new approach we use the GPS multipath linear combination to level the phase observables using the pseudorange data. The old code used elevation angle weighting approach for the leveling. We validated our new TEC leveling and data-editing algorithm extensively. Figure 1 shows our old and new processed TEC observations agreeing well at the sub-TECU level. It is clear that in the case of the ground-GPS data processing the elevation angle weighting works adequately as well.

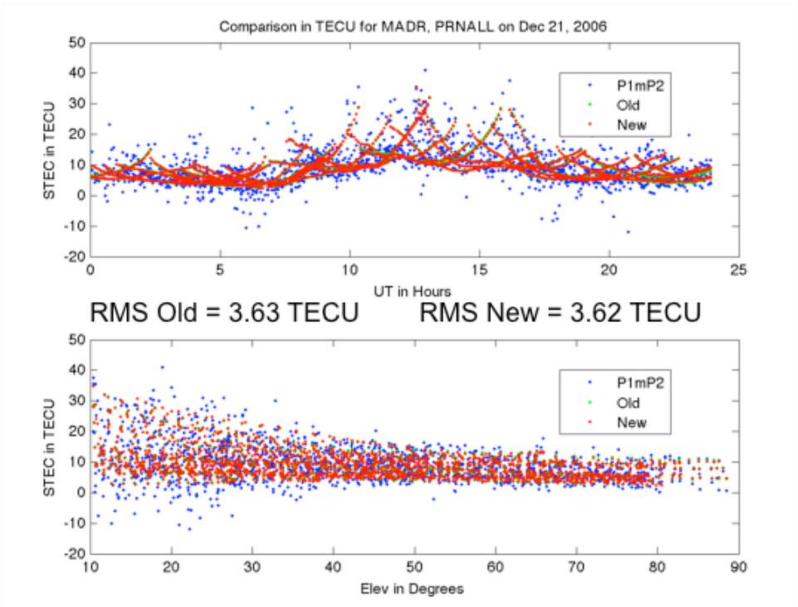

Figure 1: Comparison of old and new ground-GPS data processing for station MADR.

3 SPACE-BORNE GPS DATA PROCESSING

We also validated our new processing scheme using COSMIC data sets. We selected the data set of December 21, 2006 because of our prior experience and published results for that day [Komjathy et al, 2010]. In Figure 2, we show large multipath signatures using PRN38 for CSM4. Old and new processing results indicate 4-5 TECU level differences due to significant multipath on the code ionospheric observables. Frequent phase-breaks make the leveling process more challenging as it is shown in Figure 2.

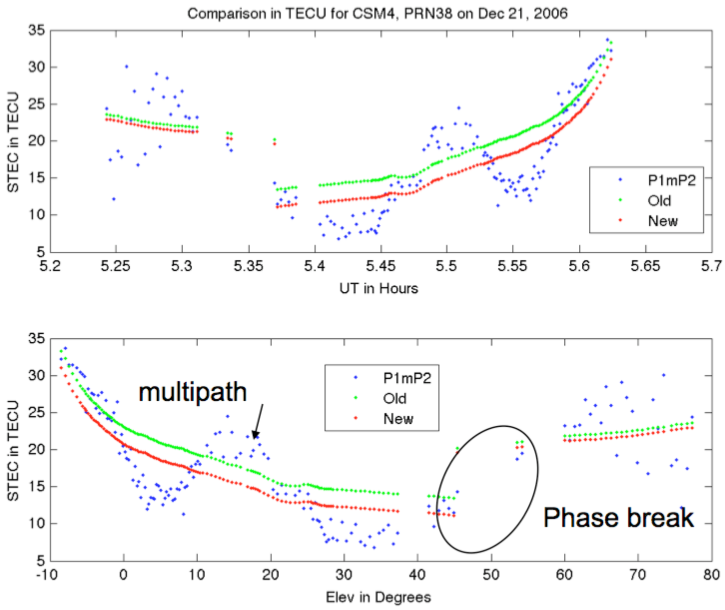

Figure 2: Leveling night-time data with phase-break and multipath show poorer agreement.

We have looked at all six COSMIC satellites using all available GPS occultation measurements. We found significant improvement in leveling the phase data using the new code over the old elevation angle-based leveling. In Figure 3, on the left we show the differences of the two algorithms with the biases removed code ionospheric observables. The differences are at the 10-15 TECU level. On the right, we show histograms of the differences. The RMS of the differences indicates that the multipath combination based leveling resulted in significant improvement in the quality of the leveling. We found an average of about 10 percent RMS improvement over the old algorithm using the COSMIC satellites.

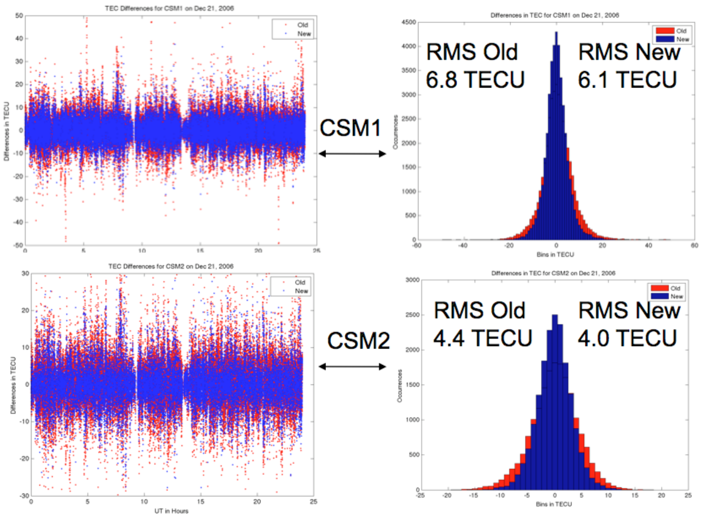

Figure 3: All CSM1 and CSM2 residuals and histograms for Dec 21, 2006.

4 REAL-TIME SYSTEM

We currently have GAIM running with real-time ground TEC measurements. We update GAIM states every 15 minutes using 5-minute ground GPS data. In Figure 4, we show the schematic for the 2-hours updates from COSMIC data propagated to a 15-minute thread for maximizing data usage.

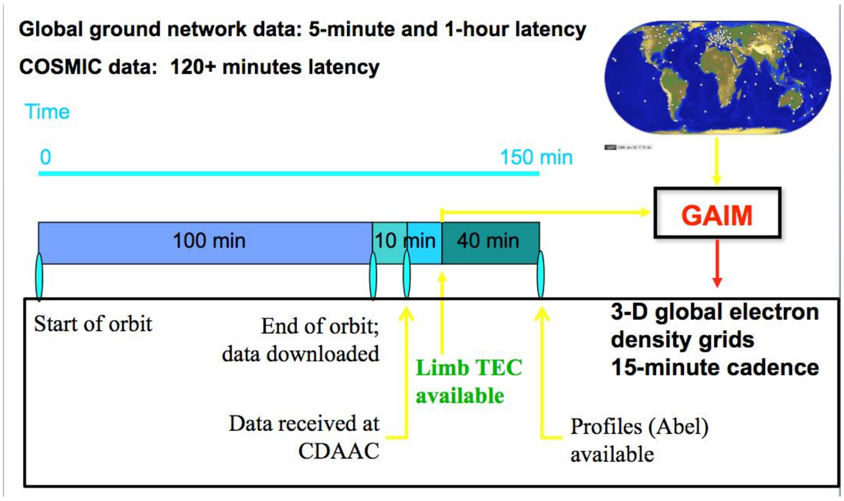

Figure 4: Schematic of the real-time system.

5 CONCLUSIONS

We extensively validated our front-end GPS data processing tools. We found that the new algorithm resulted in significant improvement over the old processing scheme using COSMIC data sets. We now have GAIM running operationally assimilating ground GPS data. A routine COSMIC data assimilation is currently under development.

ACKNOWLEDGEMENT

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