The International Beacon Satellite Symposium *BSS2010*
P. Doherty, M. Hernández-Pajares, J.M. Juan, J. Sanz and A. Aragon-Angel (Eds)
Campus Nord UPC, Barcelona, 2010

HIGH RESOLUTION IONOSPHERIC IMAGING USING A DENSE REGIONAL NETWORK OF GPS RECEIVERS

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Key words: Ionospheric Imaging, Tomography, Software Receivers.

Summary: The ability to accurately image few kilometer structures from a dense array of GPS receivers is investigated.

1 A LOW COST, SPACE-WEATHER GPS SOFTWARE RECEIVER

Over the last two years Cornell University and ASTRA have collaborated on a joint research and development program to produce a low-cost, robust, reliable and accurate space-weather software-based GPS receiver. The new "Connected Autonomous Space Environment Sensor" (CASES) will be a low-cost sensor that will deliver near real-time space-weather data. Some of the characteristics of CASES include

1. A dual-frequency GPS receiver (L1 and L2C) with robust dual-frequency tracking performance
2. Stand-alone capability
3. Complete software upgradability
4. Small footprint. Cases will have a size of ~ paperback book
5. Low cost: It is anticipated that, in production, CASES will be < $2,500 per receiver in production
6. Measure TEC at a few 0.01 TECU precision at a cadence of up to 100 Hz
7. Measure, for up to 12 satellites in view, C/N_0 and phase at 50 Hz on both L1 and L2C
8. Calculate the scintillation severity indicators S_4, τ_0, and σ_ϕ at a cadence that is user defined

9. Able to track through scintillation with { S_4, τ_0, C/N_0} combinations as severe as {0.8, 0.8 seconds, 43 dB-Hz (nominal)} (i.e., commensurate with vigorous post-sunset equatorial scintillation) with a mean time between cycle slips greater than 240 seconds and with a mean time between frequency-unlock greater than 1 hour

Cases is anticipated to be in production and available in late 2010. With the development of a low cost, space-weather optimized GPS receiver, the possibility of deploying dense arrays of GPS receivers to do space-weather science becomes truly cost-effective for the first time. As such, the scientific question naturally arises: How much, and what kind of new science capability does such a dense network of sensors provide. This presentation provides initial results from a simulation study designed to answer that question.

2 HIGH RESOLUTION REGIONAL IONOSPHERIC IMAGING

A dense network of CASES receivers leads to the concept of using the GPS TEC data to do high-resolution regional imaging of the ionosphere. By high-resolution it is meant primarily horizontal high-resolutions, with horizontal scales on the order of 1-10 kilometers. Since GPS TEC data is somewhat limited in its capabilities to recover vertical structure, the resolution vertically remains the same as for traditional global ionospheric imaging methods ~20-40 kilometers in the F-region of the ionosphere.

In order investigate the capabilities of a dense network of GPS receivers; spatial structures with large spatial gradients over small horizontal scales are simulated on top of a background smooth ionosphere. For this study three different types of structures are simulated:

1. Storm Enhanced Density (SED) structures, which have very sharp horizontal gradients along the boundaries of the plumes. The SED structures are allowed to move with realistic *ExB* Velocities.
2. Polar patches, which have sharp horizontal gradients on all edges. Again, the patches are transported under *ExB* Velocities.
3. Equatorial plumes, which have longitudinal scales of 50-100 kilometers, and very sharp longitudinal gradients. The plumes drift west to east with realistic equatorial drift speeds.

For all of these structures, a dense network of GPS receivers is laid down, and GPS TEC data is simulated over a several hour period.

For each of the above simulations, the data is ingested into the "Ionospheric Data Assimilation Four-Dimensional" (IDA4D) algorithm[1], which produces a three-dimensional time evolving reconstruction of the structure over the time period of interest. For this study, IDA4D was modified to run on a regional high-resolution ionospheric grid.

3 ANTICIPATED RESULTS

Comparisons will be made between the true simulated ionospheric structures and those reproduced from IDA4D. How well IDA4D reconstructs the time-evolving structures will be investigated as a function of the number of receivers in the dense array, the overall size and extent of the array, the spatial resolution of the array, spatial resolution of the ionospheric grid used by IDA4D, the simulated data error covariances, and the error covariances of the background model used by IDA4D.

The figures of merit that will determine how well IDA4D reconstructed the simulated truth will include overall statistical accuracy, capability of recovering the overall shape of the structure, capability of recovering the gradients along the boundaries of the structure, and capability of recovering the velocity with which the structure is moving.

CONCLUSIONS

This presentation investigates the capabilities of dense arrays of GPS receivers to provide new scientific results in terms of imaging the ionosphere. A state-of-the-are ionospheric data assimilation algorithm is used to ingest simulated data from the dense GPS array. The results of the ionospheric assimilation are compared against the “truth” simulation for a number of different data-algorithm configurations.

REFERENCES

[1] Bust, G.S, T.W. Garner, and T. L. Gaussiran II, Ionospheric Data Assimilation Three Dimensional (IDA3D): A Global, Multi-Sensor, Electron Density Specification Algorithm, J. Geophys. Research, 109, A11312, doi:10.1029/2003JA010234, 2004.