









The Aurora: Natural Plasma Laboratory and Space Weather Hazard

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Publications

Semeter, J., Mrak, S., Hirsch, M., Swoboda, J., Akbari, H., Starr, G., Pankratius, V. GPS signal corruption by the discrete Aurora: Precise measurements from the Mahali experiment. *Geophys. Res. Lett.*, *44*, 9539?9546. https://doi.org/10.1002/2017GL073570, 2017.

Mrak, S., Semeter, J., Hirsch, M., Starr, G., Hampton, D., Varney, R. H., ? Pankratius, V. (2018). Field?aligned GPS scintillation: Multisensor data fusion. *Journal of Geophysical Research: Space Physics*, *123*, 974?992. https://doi.org/10.1002/2017JA024557

Pankratius, V., F. Lind, A. Coster, P. Erickson, and J. Semeter, Mobile Crowd Sensing in Space Weather Monitoring: The Mahali Project, *IEEE Communications Magazine, special issue on Mobile Crowd Sensing*, vol 52 issue 8, pp., 22-28, August 2014.

For background on GNSS in CEDAR science:

Anthea Coster tutorial: <u>http://cedarweb.vsp.ucar.edu/on-line_video/2011/2011_GEM-CEDAR_Student_Tutorial_Coster.mp4</u> (video) <u>http://cedarweb.vsp.ucar.edu/wiki/images/5/53/2011_Coster_Student_tutorial_gps.pdf</u> (slides)

Jonathan Makela tutorial: <u>http://cedarweb.vsp.ucar.edu/wiki/images/2/24/Makela Tutorial.pdf</u> (slides only)

Note: For 20 years of CEDAR tutorials (most with video!),

http://cedarweb.vsp.ucar.edu/wiki/index.php/Workshop:CEDAR_Videos



GPS as lonospheric Diagnostic

Cm



GPS Nominal Constellation 24 Satellites in 6 Orbital Planes 4 Satellites in each Plane 20,200 km Altitudes, 55 Degree Inclination

Code propagates at group velocity. 1 bit of information is about 300m long. Absolute delay determined by correlation at the receiver, but there is inherent meter-level range uncertainty. Carrier propagates at phase velocity. 1 cycle is about 20 cm. Sample to sample variation in phase provides precise information about change in phase speed along signal path, but has inherent 2π ambiguity.



Subtle effects of a solar eclipse



2017-08-21 18:58:30



Mrak et al GRL 2018

GPS scintillation by substorm auroras





The NSF Mahali Experiment



https://mahali.mit.edu

Pankratius et al., IEEE Comm. Mag., 2016, Semeter et al., GRL 2017, Mrak et al JGRA 20197









All Sky Camera: 2015-10-07 06:18:35.520 UT GNSS: 10/07/2015 06:18:24 - 06:18:35 UT



4000



All Sky Camera: 2015-10-07 06:18:48.006 UT GNSS: 10/07/2015 06:18:37 - 06:18:48 UT

- 4000 - 3500 - 3000

- 2500

- 2000

All Sky Scale

1000



All Sky Camera: 2015-10-07 06:19:00.520 UT GNSS: 10/07/2015 06:18:49 - 06:19:00 UT

- 4000 - 3500 - 3000

- 2500

- 2000

All Sky Scale

1000



All Sky Camera: 2015-10-07 06:19:13.020 UT GNSS: 10/07/2015 06:19:02 - 06:19:13 UT



- 4000 - 3500 - 3000

- 2500

- 2000

All Sky Scale

1000











All Sky Camera: 2015-10-07 06:19:38.020 UT GNSS: 10/07/2015 06:19:27 - 06:19:38 UT



All Sky Camera: 2015-10-07 06:19:50.520 UT GNSS: 10/07/2015 06:19:39 - 06:19:50 UT



- 4000 - 3500



All Sky Camera: 2015-10-07 06:19:50.520 UT GNSS: 10/07/2015 06:19:39 - 06:19:50 UT







All Sky Camera: 2015-10-07 06:20:03.020 UT GNSS: 10/07/2015 06:19:52 - 06:20:03 UT





All Sky Camera: 2015-10-07 06:20:15.535 UT GNSS: 10/07/2015 06:20:04 - 06:20:15 UT



All Sky Camera: 2015-10-07 06:20:28.082 UT GNSS: 10/07/2015 06:20:17 - 06:20:28 UT



- 4000 - 3500 - 3000

- 2500

- 2000

- 1500 - All Sky Scale

1000









All Sky Camera: 2015-10-07 06:20:40.612 UT GNSS: 10/07/2015 06:20:29 - 06:20:40 UT



4000











West Geographic Longitude

Strong E-region phase scintillation observed only along the trailing edge of the westward traveling surge





Evidence for bursty flows exceeding 3 km/s (150 mV/m)

with components normal and tangential to auroral density gradient.

BUT, fields and flows within the surge are unresolved by current capabilities.



Summary and Future

- "Field of view" is small for GNSS (order kilometer). Spatial sampling limited by density of receivers (hence, money, processing power).
- GNSS techniques are highly synergistic with incoherent scatter radar (see, Semeter et al., Rad. Sci., 2015)
 - GNSS measured integrated density from satellite to ground.
 - ISR measures integrated density over some volume.
 - Can be treated as synergistic projections of the same parameter.
- We are currently exploring data fusion using measurements from inexpensive single-frequency sensors e.g., in your mobile phone!