





Multi-constellation GNSS TEC and Scintillation Measurements

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Presentation Outline

- 1. Background & Motivation
- 2. Software Algorithms
- 3. Preliminary Results
- 4. Summary

<u>What</u> are we doing here?

- Use multi-constellation Global Navigation Satellite System (GNSS) receivers to determine Total Electron Content (TEC) for GPS, GLONASS, Galileo, and Beidou constellations
- Find conjunction points on ionosphere between GNSS and Super Dual Auroral Radar Network (SuperDARN) Blackstone Radar and then conduct statistical analysis

<u>Why</u> are we doing these?

- Higher-accuracy TEC monitoring system using the growing GNSS
- Inspired by the work in Reference [1], to investigate if the ionospheric irregularity regions detected by SuperDARN Blackstone Radar are correlated with the scintillation level of GNSS signals at mid-latitude

[1] A. Eltrass, W. A. Scales, et al. (2016), Investigation of the role of plasma wave cascading processes in the formation of midlatitude irregularities utilizing GPS and radar observations, Radio Sci., 51, 836–851

• TEC

Integration of electron density along the line of sight between 2 points

• Ionospheric Irregularities

Small-scale regions in the ionosphere with irregular plasma density

• Scintillation

Phase and/or amplitude fluctuations of GNSS signals

• SuperDARN

A global network of high frequency (HF) coherent scatter radars designed mainly for studying plasma convection in the auroral ionosphere ^[1]

• S4

Standard deviation of measured GNSS signal amplitude over a period of time

• Sigma Phi

Standard deviation of measured GNSS signal <u>phase</u> over a period of time

[1] Greenwald et al. 1995

Global Navigation Satellite System (GNSS) Coverage Comparison



• <u>Ranging Errors, Pseudorange (P), Carrier Phase (CP)</u>



Ionospheric Remote Sensing for <u>TEC</u> and <u>Scintillation</u>



Multi-constellation GNSS TEC and Scintillation Measurements

Multi-frequency multi-constellation GNSS receiver

Novatel OEM628



Novatel GPStation-6



- Track GPS, GLONASS, Galileo and BeiDou for up to 120 channels
- Maximum data logging rate 100 Hz
- Our TEC software has been developed to process the GNSS raw data

- Track GPS, GLONASS and Galileo for up to 120 channels
- Maximum data logging rate 50 Hz
- Generate 1-Hz raw pseudorange TEC measurements and smoothed carrier phase TEC in 15 seconds interval
- Generate S4 and Sigma Phi every 60 seconds

Flow Diagram of TEC Data Processing



Ground-based GNSS TEC Measurements

TEC Results Benchmarking



7-day Ground-based GNSS Measurements



Ionospheric Irregularity Remote Sensing Demonstration



Examples of Ground-based Scintillation Measurements





Ground-based Amplitude Scintillation Measurements Example



Multi-constellation GNSS TEC and Scintillation Measurements

Ground-based Phase Scintillation Measurements Example



Multi-constellation GNSS TEC and Scintillation Measurements

Two Storm Days Results

		(24-hr Max Kp = 5) ((24-hr Max Kp = 4)
S4 index		Feb 1 2017	Feb 2 2017
GPS	Daily total number of data	14836	14882
	Mean value	0.0778	0.0774
	Total number of in-conjunction data	144	27
	Mean value	0.1061	0.0975
Glonass	Daily total number of data	16716	16725
	Mean value	0.1048	0.1041
	Total number of in-conjunction data	402	155
	Mean value	0.1201	0.1301
Galileo	Daily total number of data	16072	16734
	Mean value	0.0614	0.0643
	Total number of in-conjunction data	292	88
	Mean value	0.0909	0.0829

• On each day, the S4 mean values of in-conjunction IPPs are always higher than the average S4 values

Conclusions and Future Work

- The software for multi-constellation TEC measurements and model evaluation has been developed and validated by comparing with other benchmark TEC software. It is being used for ground-based TEC monitoring.
- Mid-Latitude ionospheric irregularities detected by SuperDarn Blackstone HF radar is correlated with the scintillation indices of Multi-constellation GNSS signals from two case studies. Long term data need to be processed to validate such correlation
- In the near future, more data (e.g. TEC cycle slips or gradients) need to be processed and used to produce statistical results







Thank you!

Any question? 🕲

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