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Detection and Characterization of Traveling Ionospheric Disturbances (TIDs) with GPS and HF sensors

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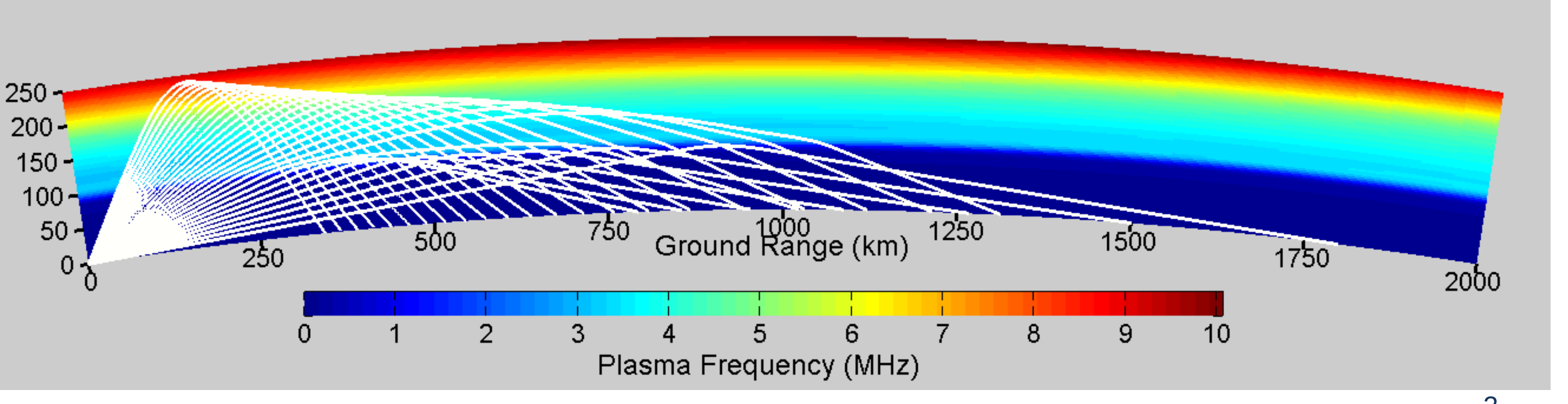
Outline

- Introduction and Motivation
- Technical Approach
- Preliminary results
- Summary



Motivation

- Disturbances in the ionosphere can often be the limiting factor in the performance of high frequency (HF) systems
- Current techniques to detect, characterize and correct for such disturbances using sensors and models are inadequate
- The goal of this effort is to detect and characterize disturbances with GPS sensors for comparison with effects on HF propagation
- The results will help us better understand the nature of traveling ionospheric disturbances and improve our ability to interpret their signatures on specific sensors

Technical Approach

1. Monitor high frequency (HF) propagation channels using available broadcasts on appropriate paths
2. Collect and correlate GPS total electron content (TEC) data to detect and characterize TID spectrum and dynamics
3. Determine suitability of GPS observations for meaningful prediction of HF propagation effects

Implementation

A. Use the VIPIR ionosonde at Wallops Island, VA as the primary HF receiver capable of measuring angle-of-arrival

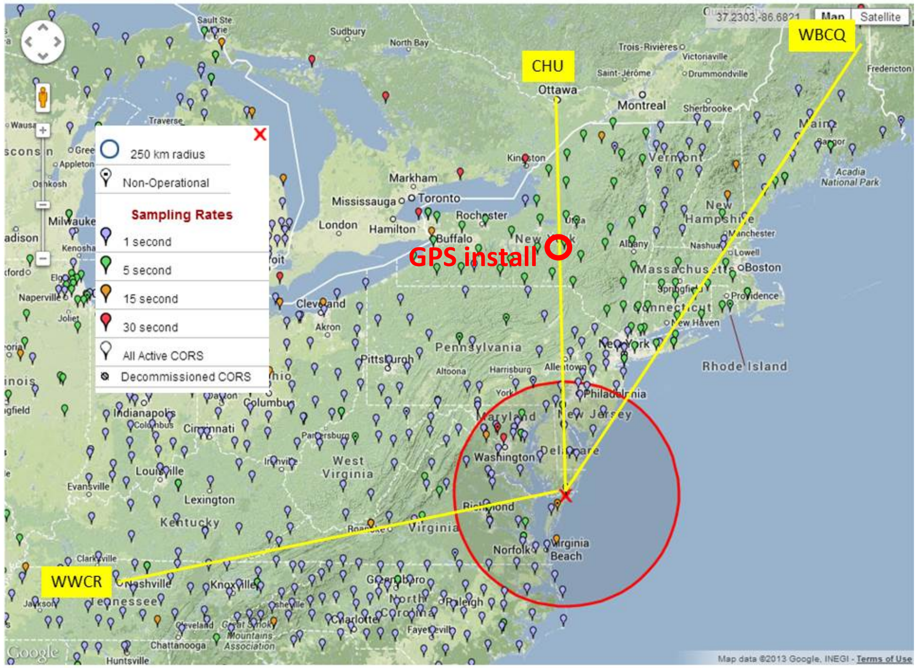
B. Use CORS and other available GPS receivers to measure TEC signatures along the HF raypaths

C. Install a compact (baseline < ~10 km) three GPS rx array to test performance for TID characterization

Aspects of Link Selection

The three proposed links each offer unique measurement opportunities

- WBCQ (Maine): longest path (1200 km) mid-point over MA/NH supports compact GPS array analysis
- CHU (Ottawa): Geographic N-S propagation path; Canada time reference: No frequency offset or drift in transmitter
- WWCR (Nashville): Predominantly E-W path ideal for dusk/dawn gradients; variety of frequencies used ensures available signal

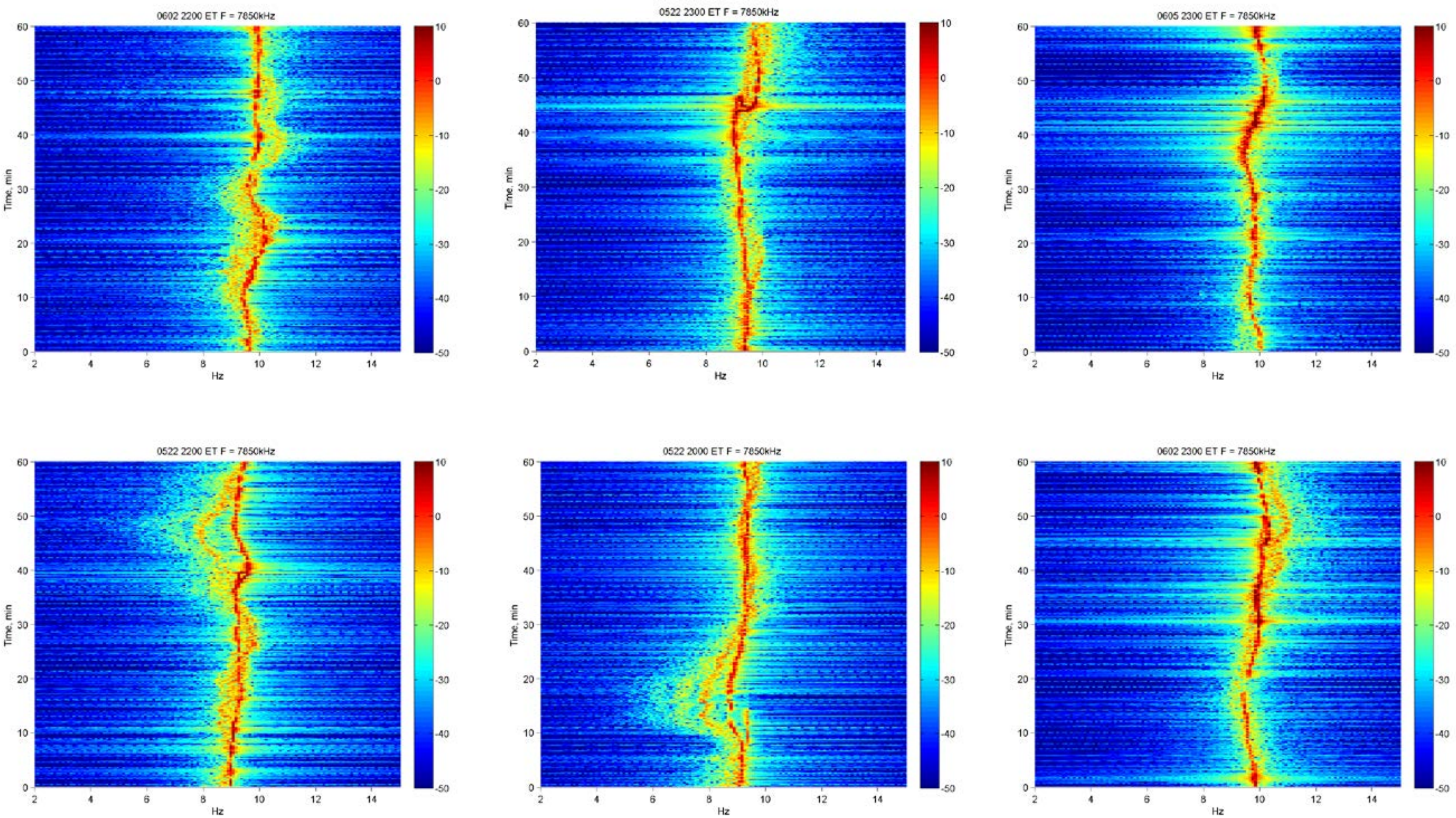


We are monitoring all three sites simultaneously for Doppler information

Preliminary Data Analysis Summary

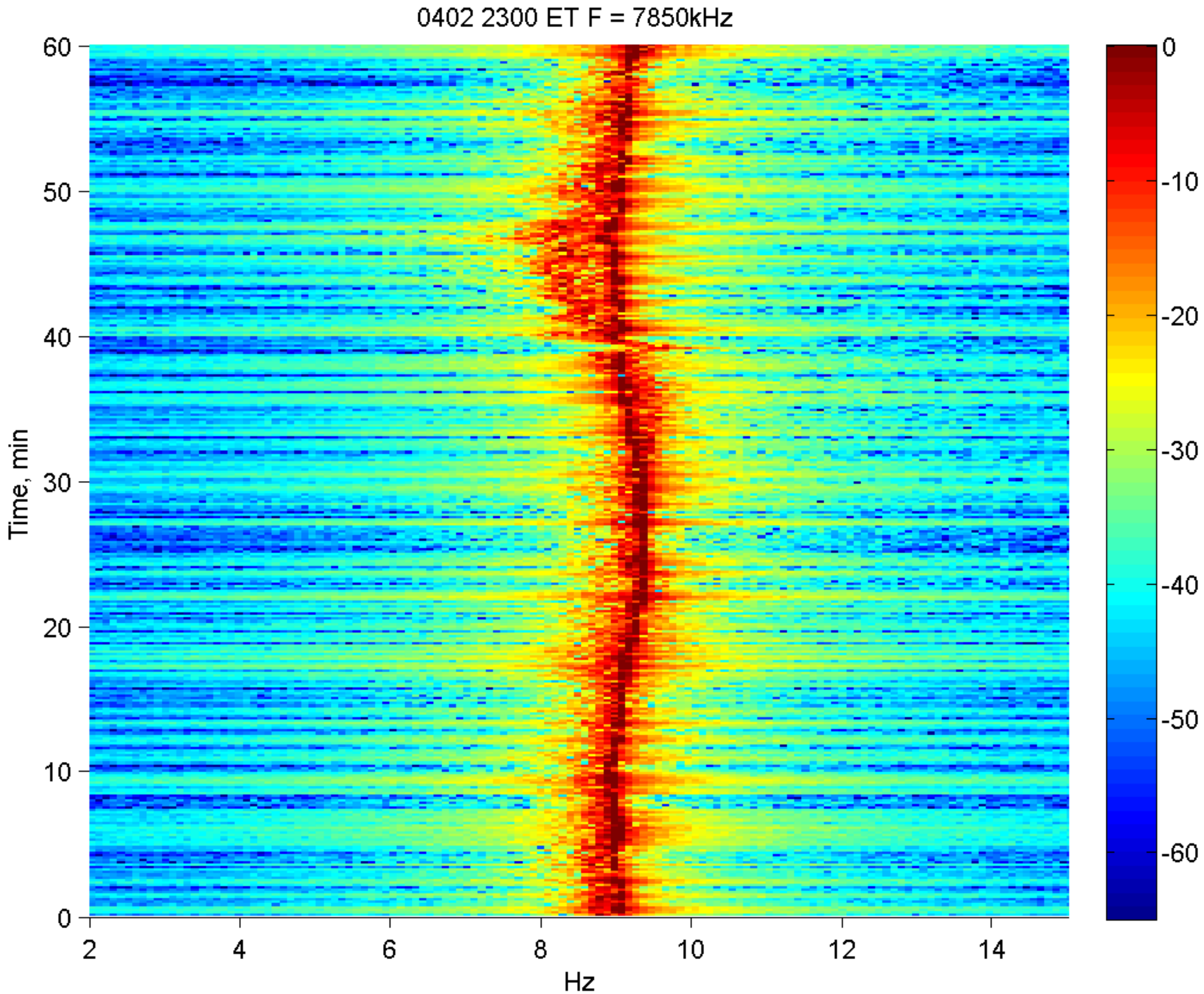
- HF and GPS common data collection window with all sensors spans 28 Aug - 16 September; 11 December to present…
- Both GPS and HF sensors show numerous perturbations; a few cases have been examined for qualitative correlation
- Quantitative correlations just getting underway
- It appears data will support planned studies, but it is not possible to predict outcome at this stage in the research

TID Signatures in HF Doppler



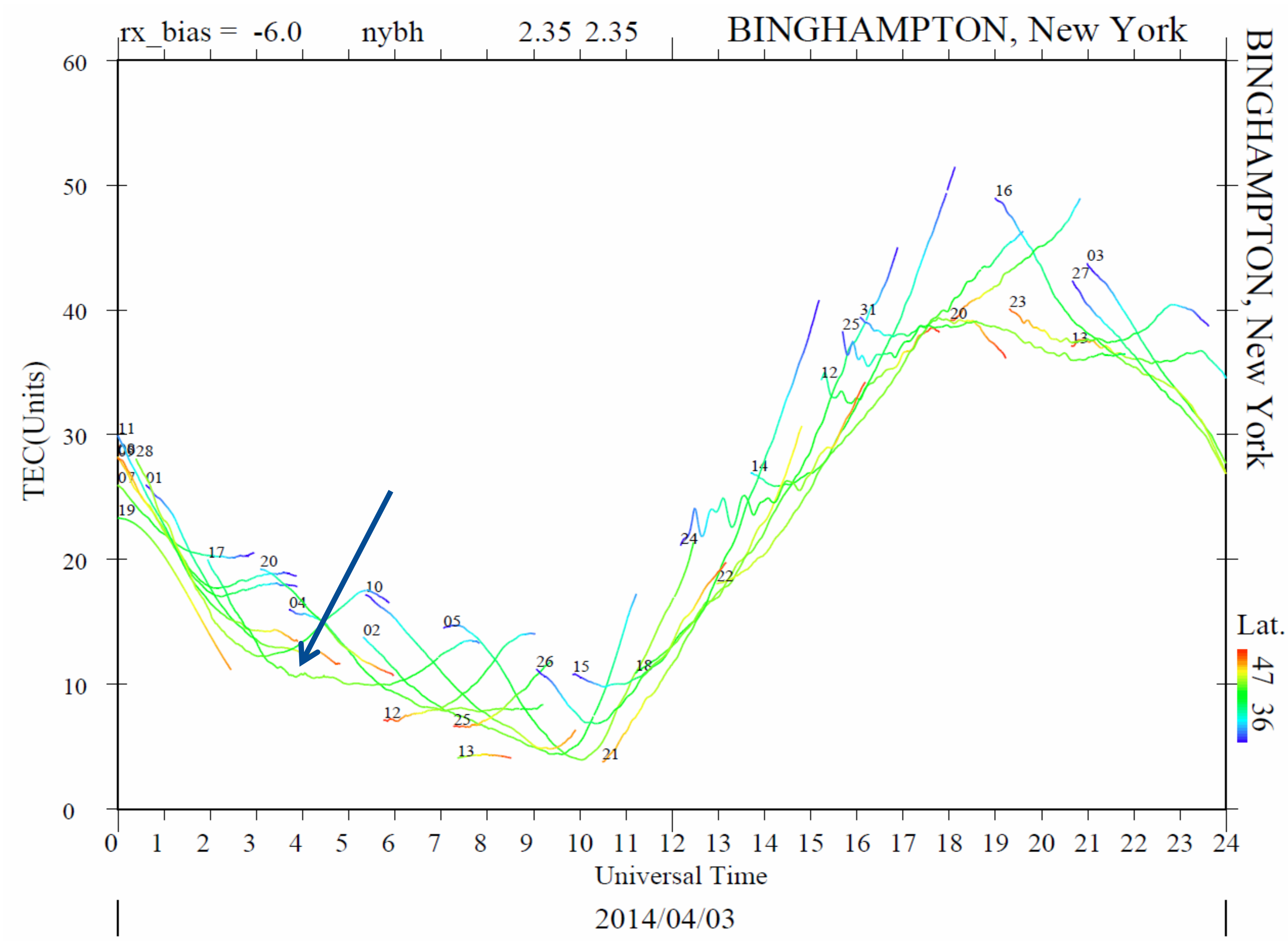
Collected on a variety of frequencies at different times and different raypaths over just a few days

Preliminary Analysis Case Study:
02 April 2300-0000 EDT WFF-CHU

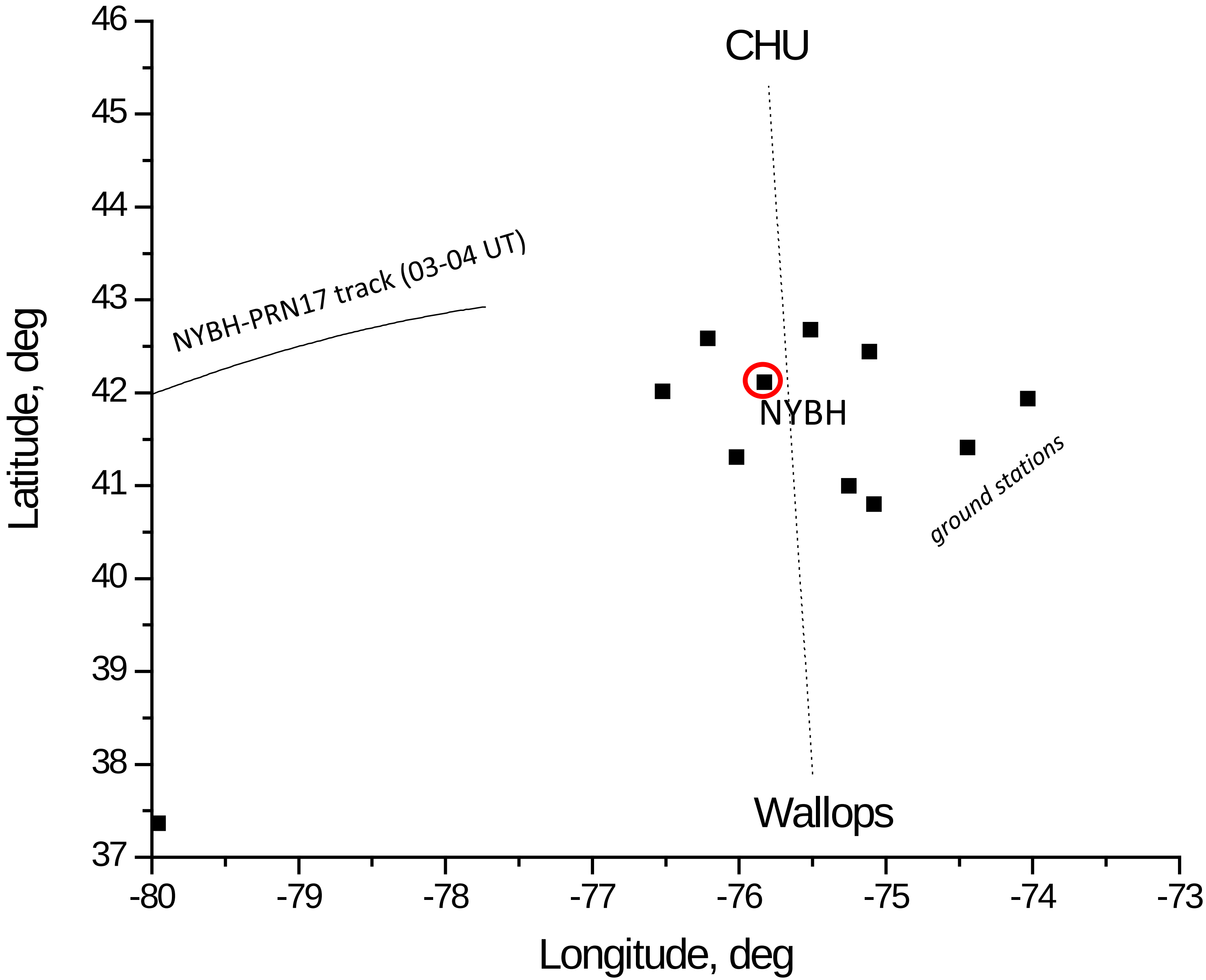


- TID structure observed with ~45 min period

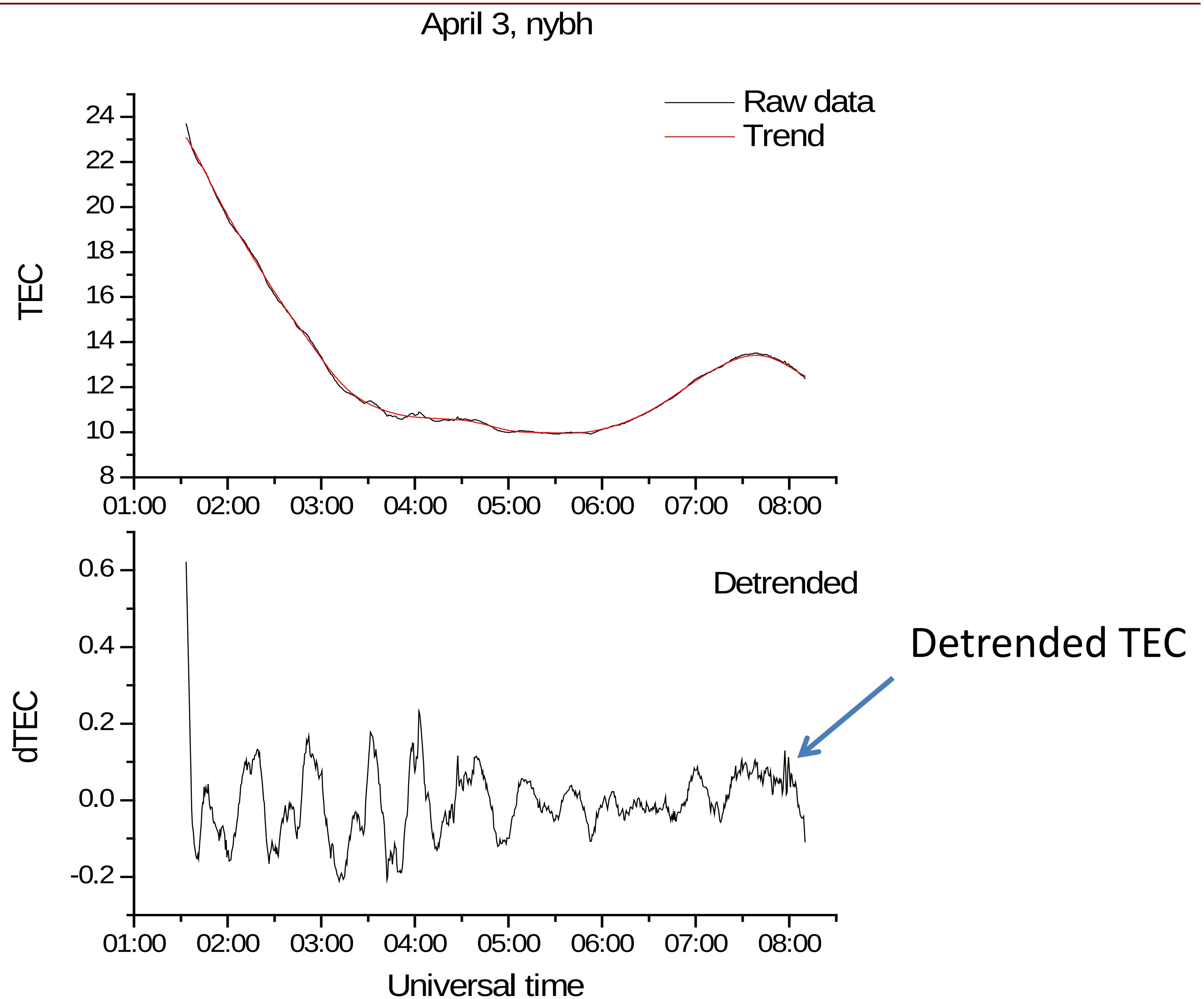
Fluctuations Observed on PRN 17



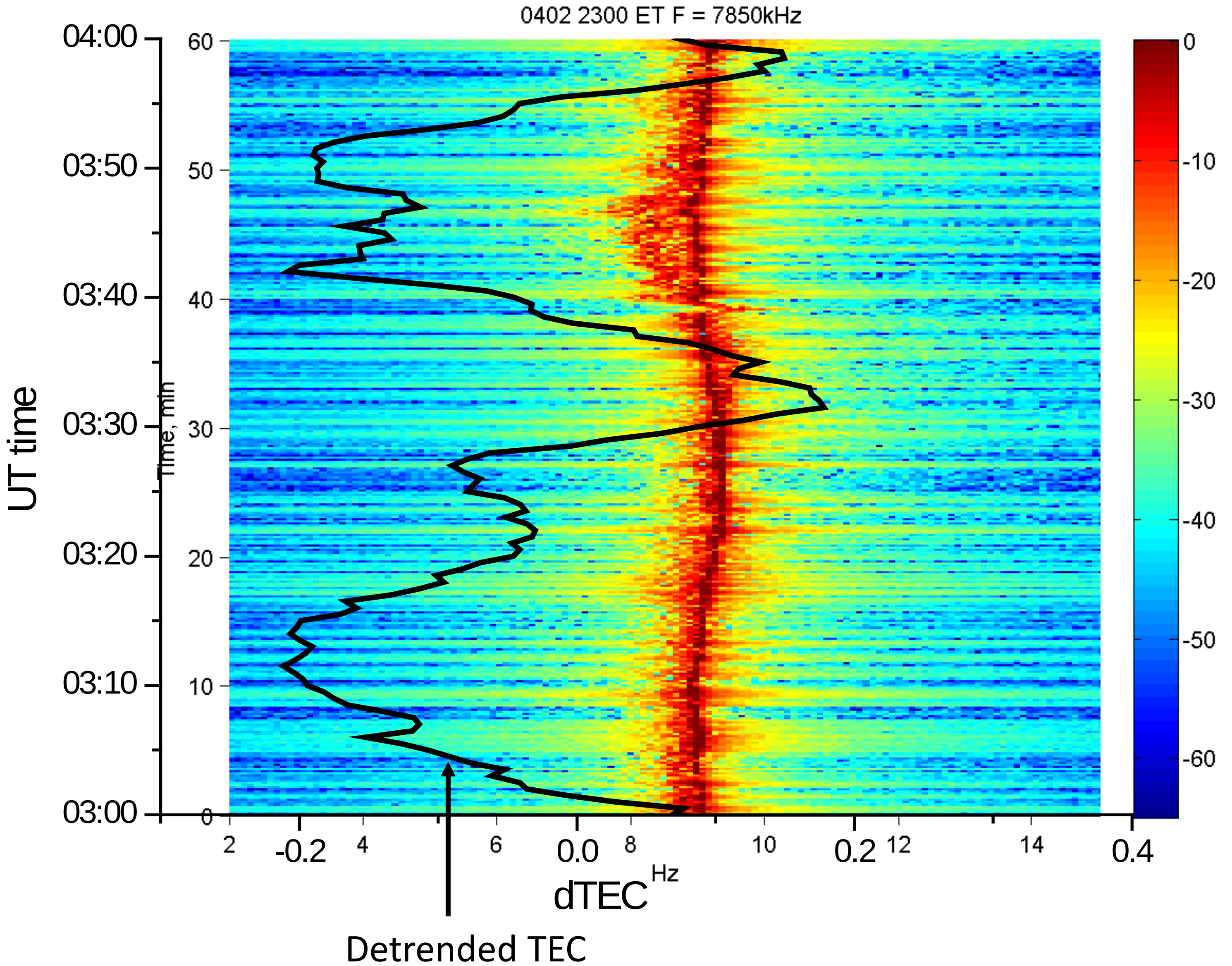
Binghamton, NY Station is Nearest to Wallops-CHU Mid-Point



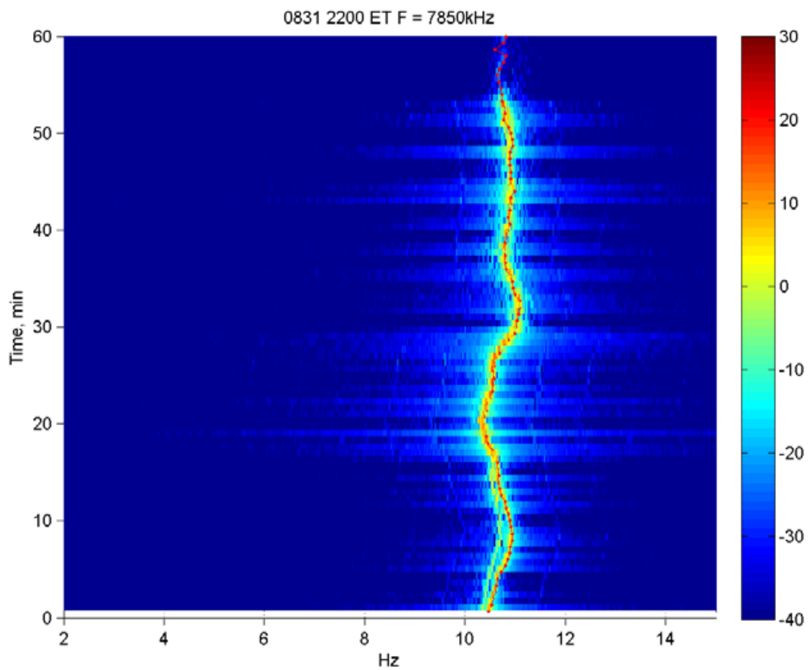
TEC Fluctuations: Examining the Details

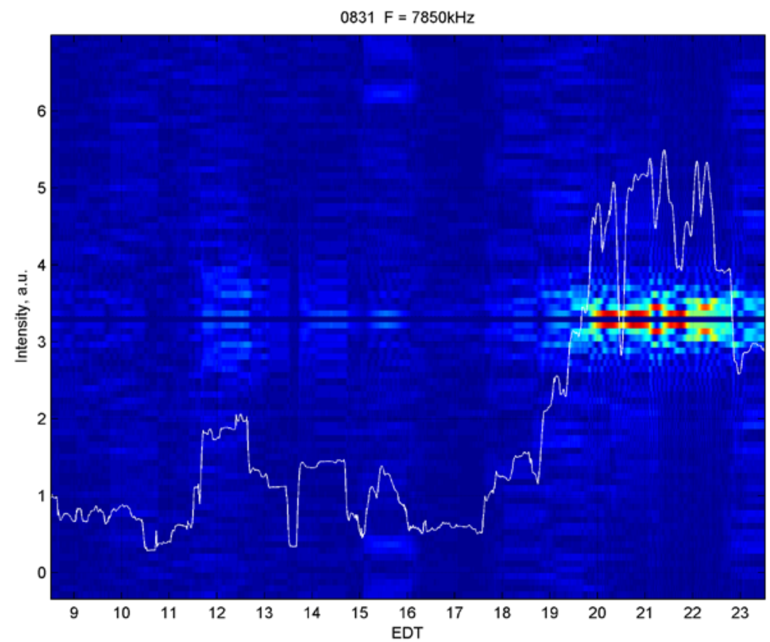


HF Doppler and GPS TEC Correlation



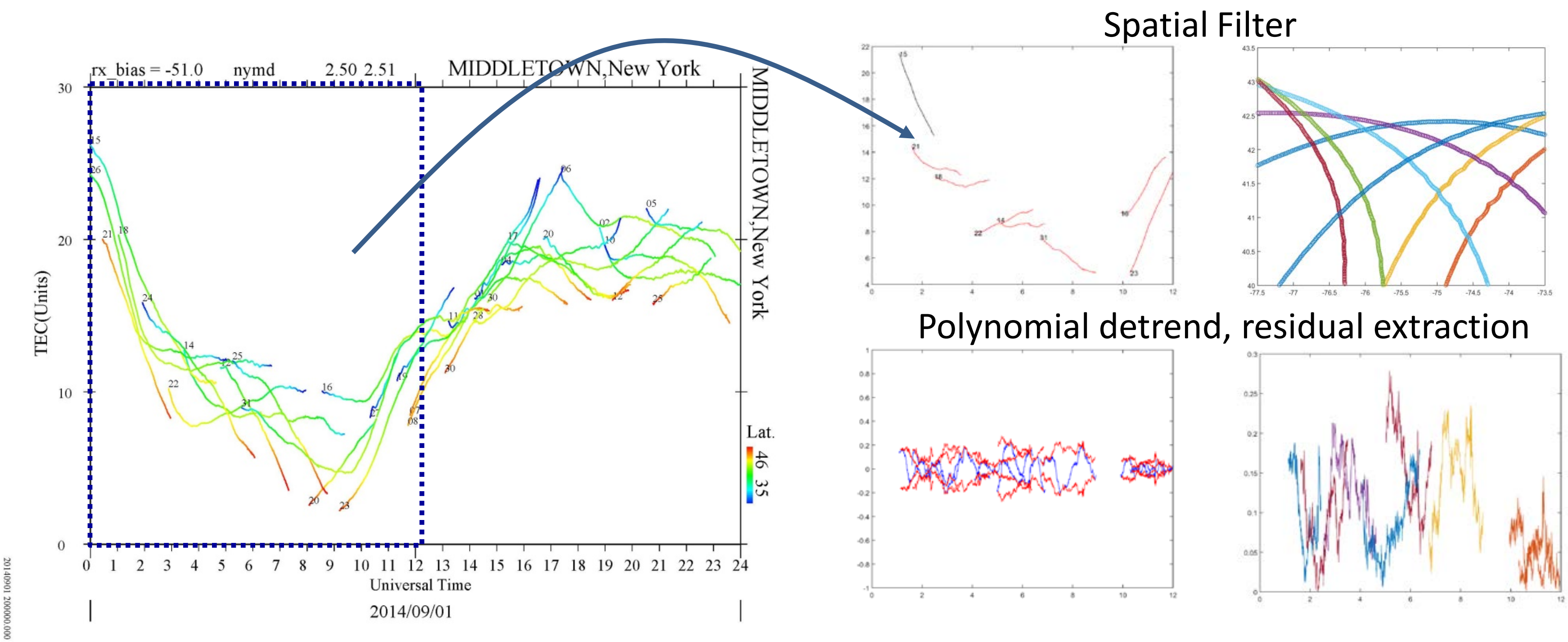
HF Link TID Detection Processing





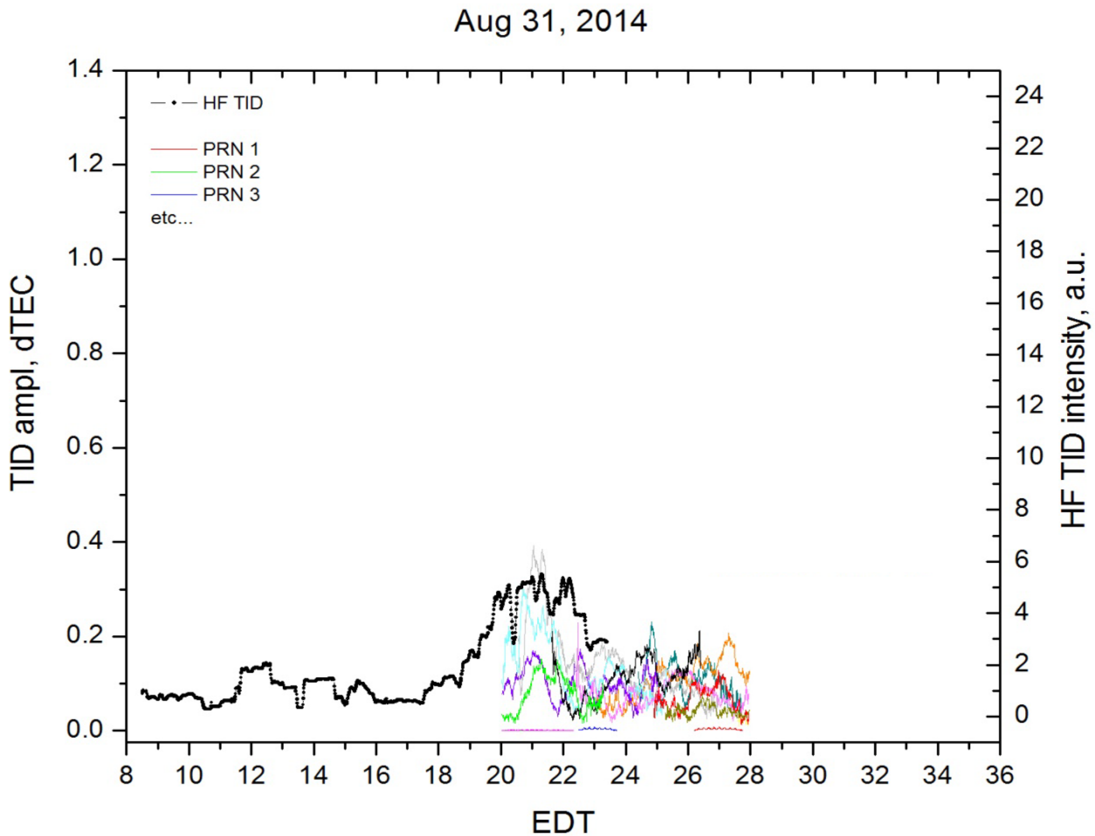
- Track principal frequency in a given HF channel
- Extract Doppler variations and take real FFT to detect TID “power”
- Automated processing applied to reduce all HF data
- Reduction of GPS data performed separately

GPS Data Processing



- GPS processing has more free parameters (space and time)
- Detrending process introduces artifacts; optimum approach still under consideration
- Spatial filtering to limit responses to region near HF mid-points may not be appropriate
- Signatures are geometry-dependent

Combine HF and GPS Results



- Good, but not perfect, correlation in cases examined thus far
- GPS signatures may be strongly dependent on observing geometry
- More analysis needed to quantify and understand correlations

Activity on September 12, 2014

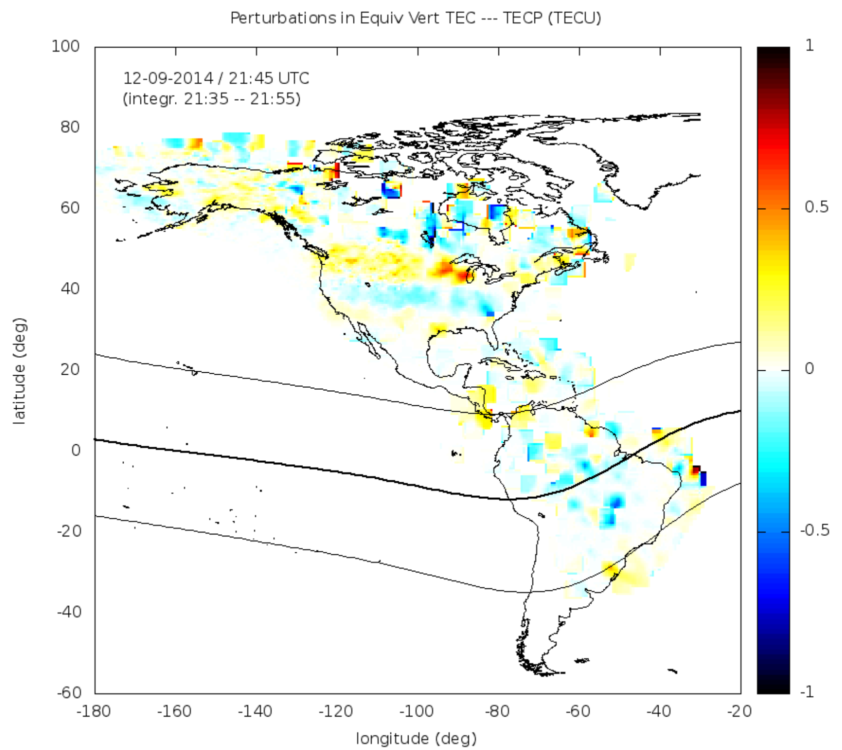
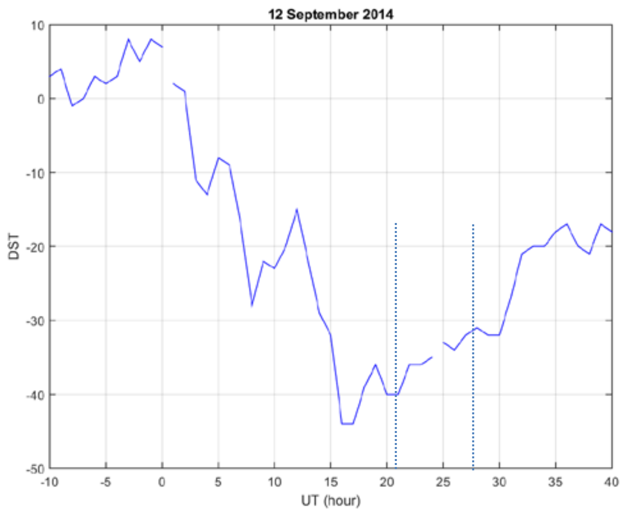
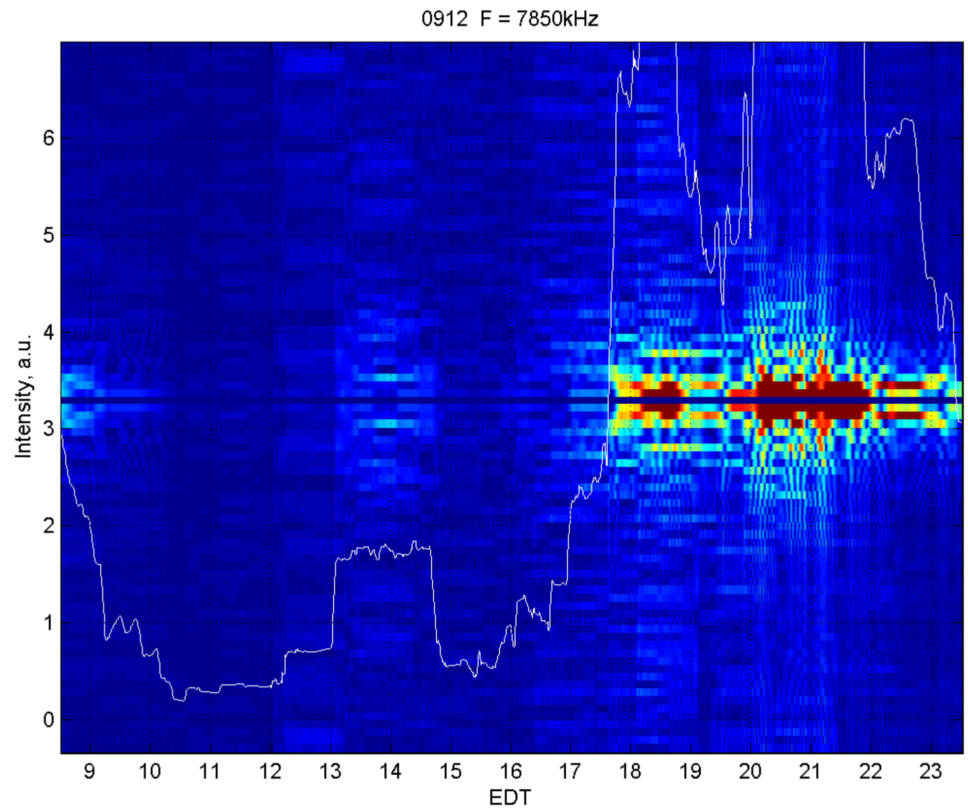


Image courtesy of R. Predipta

- Minor storm activity on 12 September resulted in significant large and medium scale TID generation observed by GPS
- Signatures were also observed on HF links

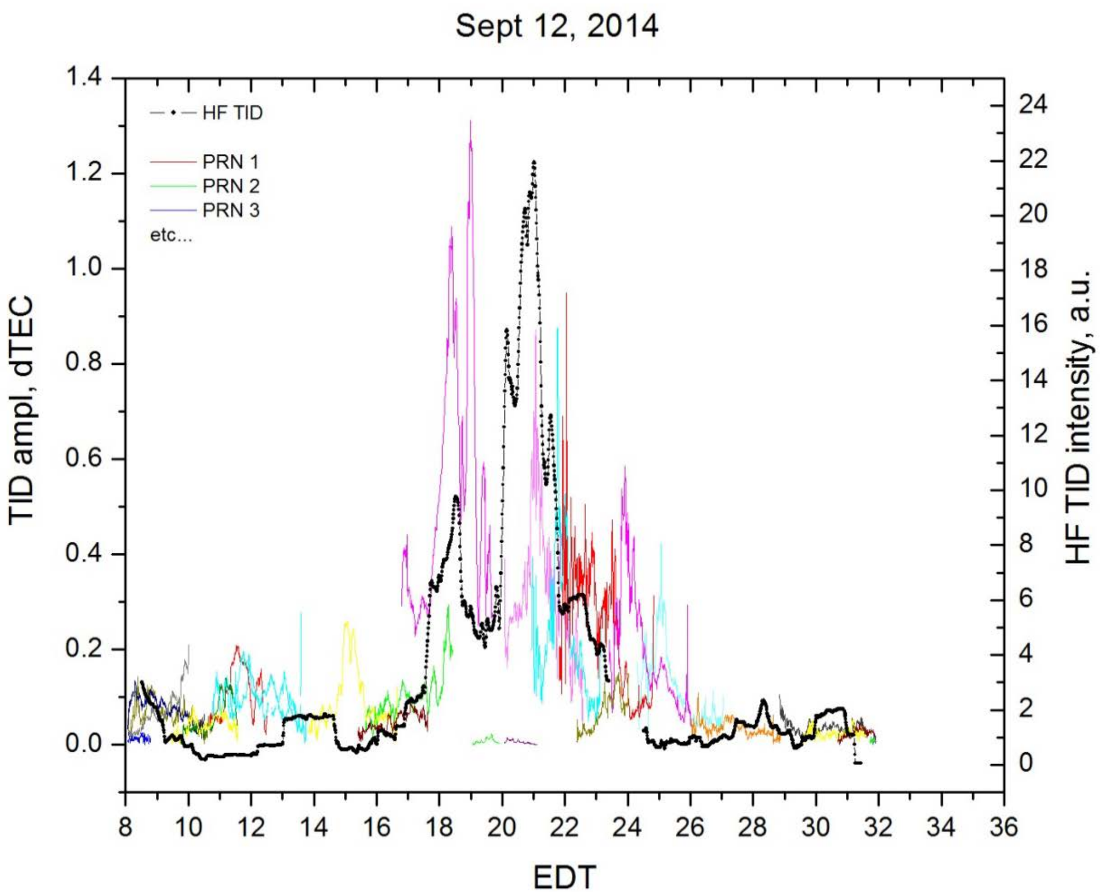
12 September HF TIDs





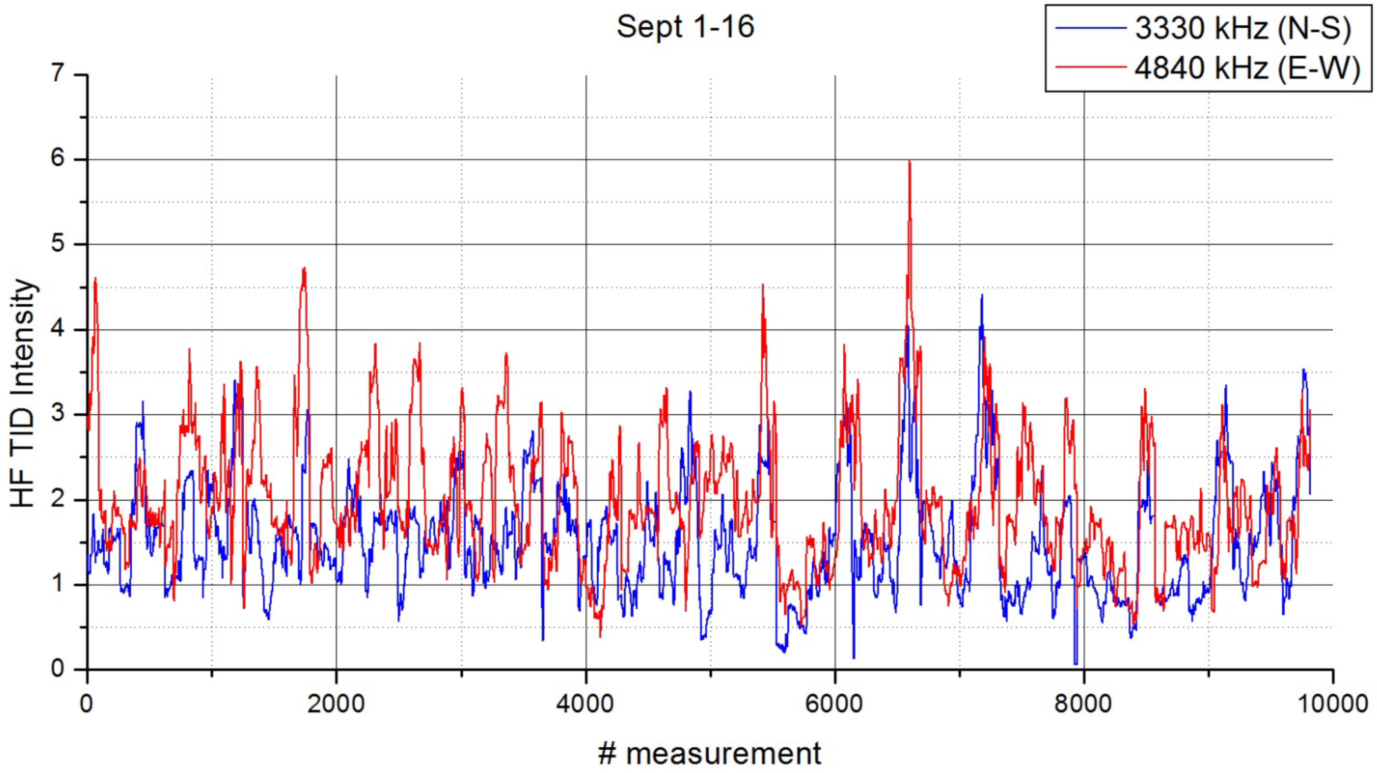
- TIDs show a fairly abrupt "turn-on" on 12 Sep, during recovery from negative DST excursion
- These are the strongest TID events observed through the period 28 Aug-16 Sep

HF and GPS Data Comparison



- Ratio of responses on GPS and HF varies significantly
- Note large GPS signature at 19:00 corresponds to relatively modest signature on HF; conversely, at 21:00 HF response exceeds GPS

Higher Frequencies More Effective for TID Detection (i.e., more susceptible)



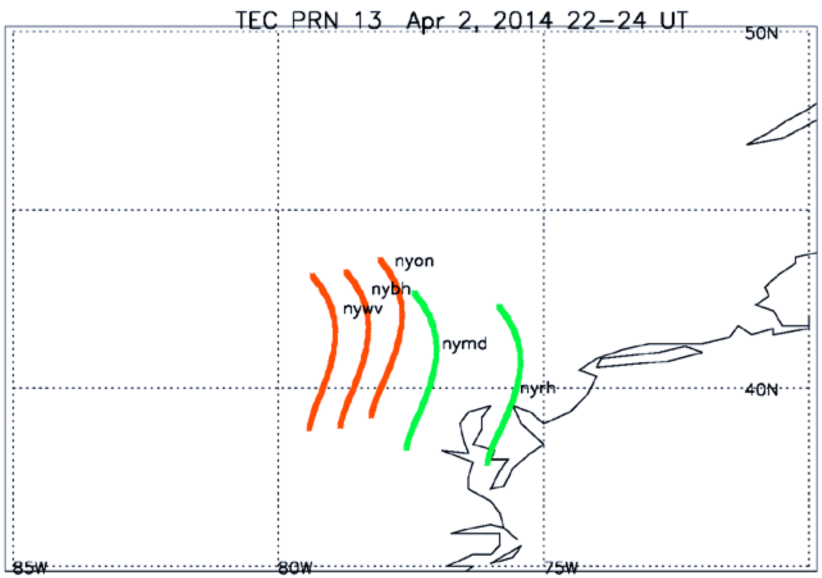
- Higher frequencies show improved sensitivity to TID signatures
- Penetration into the medium increases as frequency increases
- These are not simply bottomside disturbances

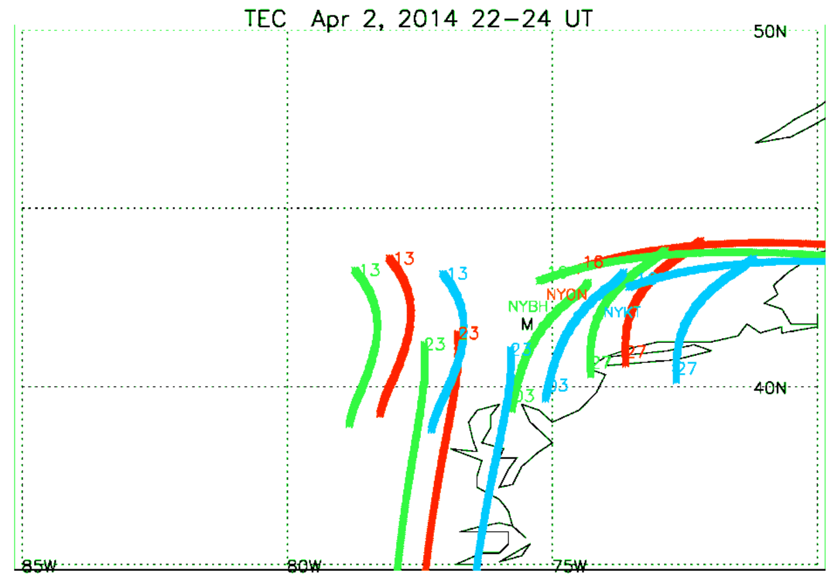
Summary

- Numerous cases for analysis of GPS TEC and HF signatures; lots of activity detected; dynamic environments observed
- Activity in September highest in the post-sunset to midnight period in both GPS and HF
- Preliminary comparisons show high qualitative comparison between observations on HF and GPS, but magnitudes of responses vary significantly
- Signatures on both systems depend on observing geometry; understanding this aspect of the observations will be critical to extracting TID parameters from data
- Multi-constellation GNSS observations should improve sensitivity further and provide additional information on TID characteristics
- Data collection to continue through summer 2015; “optimum” GPS algorithm development still ongoing

Back-Up

The Observing Capabilities of GPS Networks





- A single link observed from different stations can dial in a desired position
- All visible links from a few sites expand coverage significantly
- It is usually possible to find a few links along the raypath, though they may not come from the nearest station

24/7 Schedule