



Exploiting SWPC Products to Aid Positioning and Accuracy

60th CGSIC Meeting, 20-21 Sep 2020

Rob Steenburgh
Space Weather Prediction Center
Boulder, CO
robert.steenburgh@noaa.gov



Outline

GNSS Customer Survey

Model Developments

The Last Mile (actionable products)

Using Today's Products

Acknowledgements:

- Tzu-Wei Fang
- Tim Fuller-Rowell
- Dominic Fuller-Rowell
- George Millward
- Michele Cash



Submitted by
Abt Associates Inc.
6130 Executive Boulevard
Rockville, MD 20852



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March 29, 2019

Summary of User Data Product Requests

The four interviewees identified seven distinct data product requests for the GNSS sector. Requests:

1. **Develop warnings for scintillation, especially in the equatorial zone.**
2. **Improve timing and accuracy for geomagnetic storm forecasts.**



Award Abstract #2028032

SWQU: Forecasting Small-Scale Plasma Structures in Earth's Ionosphere-Thermosphere System

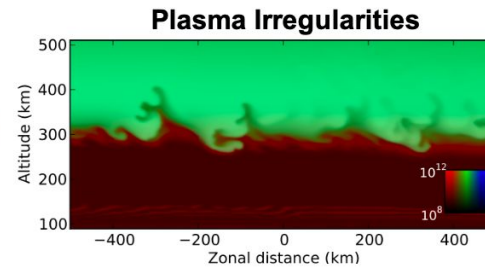
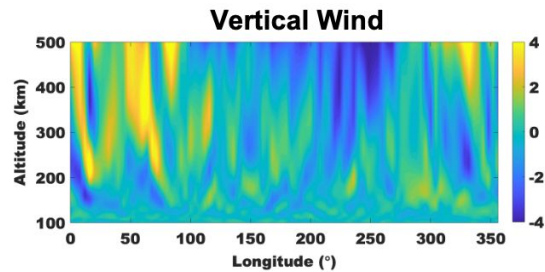
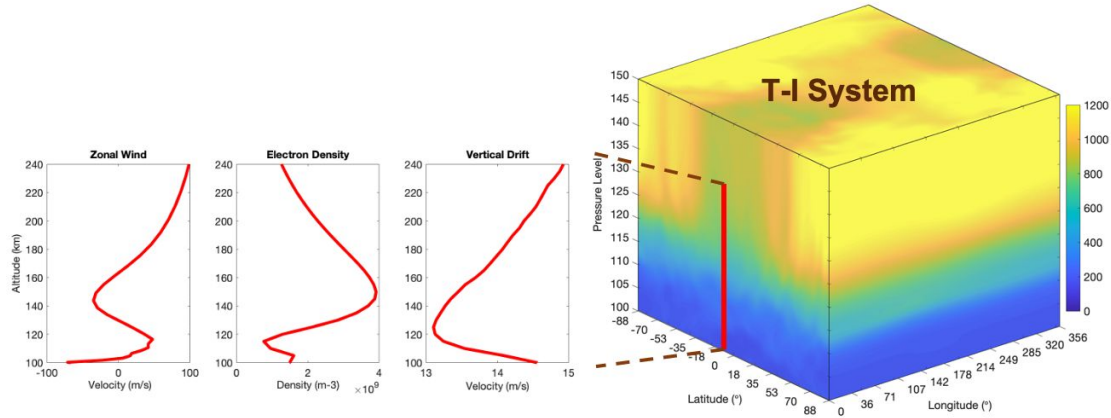
NSF Org:	AGS Div Atmospheric & Geospace Sciences
Initial Amendment Date:	August 28, 2020
Latest Amendment Date:	August 28, 2020
Award Number:	2028032
Award Instrument:	Standard Grant
Program Manager:	Mangala Sharma AGS Div Atmospheric & Geospace Sciences GEO Directorate For Geosciences
Start Date:	September 1, 2020
End Date:	August 31, 2023 (Estimated)
Awarded Amount to Date:	\$2,398,603.00
Investigator(s):	Tzu-Wei Fang tzu-wei.fang@noaa.gov (Principal Investigator) Timothy Fuller-Rowell (Co-Principal Investigator) David Hysell (Co-Principal Investigator) Alireza Doostan (Co-Principal Investigator) Eric Sutton (Co-Principal Investigator)
Sponsor:	University of Colorado at Boulder 3100 Marine Street, Room 481 Boulder, CO 80303-1058 (303)492-6221
NSF Program(s):	AERONOMY, AGS-ATM & Geospace Sciences, Space Weather Research
Program Reference Code(s):	026Z, 1521, 4444, 6897, 7569, 7699, 8092
Program Element Code(s):	1521, 6897, 8089



“Forecasting Small-scale Plasma Structures in the Earth’s Ionosphere-Thermosphere System,” awarded \$2.4M by NSF.

[Tzu-Wei] Fang and her colleagues will model the conditions that lead to disturbances in the ionosphere and use ground- and satellite-based observations to validate the simulated ionosphere-thermosphere conditions. “Our goal is to advance fundamental research underpinning space weather forecasts. Our research will help us better forecast disturbances in the ionosphere and their impact on the satellite signals,” Fang said.

Plasma Irregularities and Scintillation



WAM-IPE Products and Customers



Satellite Navigation and positioning

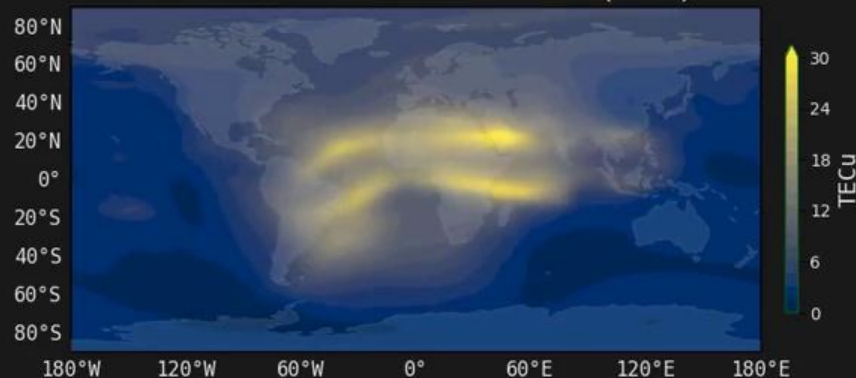
- Global Specification and Forecast of **Total Electron Content (TEC)**
 - Proxy for GPS positioning error
 - Customers: Airlines, Maritime, Surveying and Exploration, Agriculture, Emergency Managers, DOD, FAA, DHS,
- **TEC Gradient**
 - Single frequency GPS/GNSS customers
- **TEC Rate of Change**
 - **Scintillation** (Parametrization of conditions and precursors to scintillation)
 - Dual frequency and precision GPS/GNSS customers

Valid at: Jul 8 2020 13:30 UTC

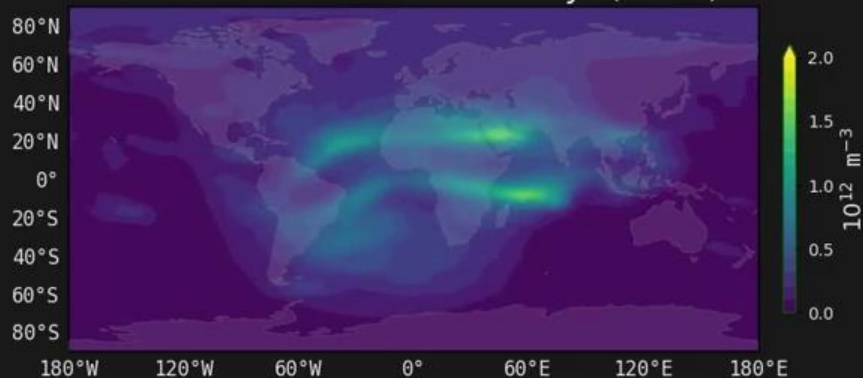
Global Ionosphere

Model: WAM-IPE (wfs) Init: Jul 7 2020 18 UTC

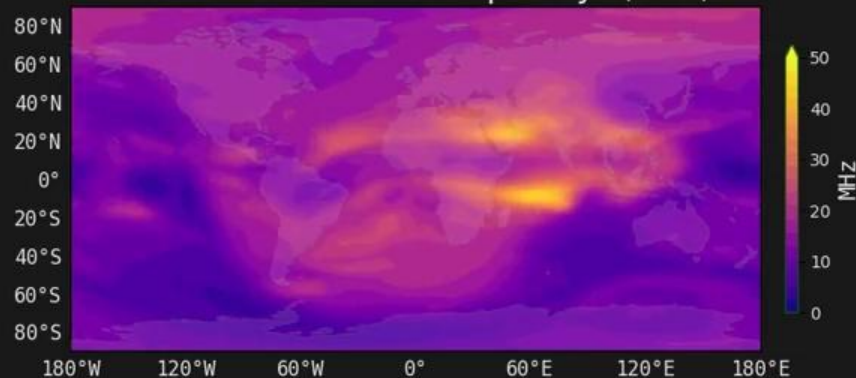
Total Electron Content (TEC)



F2 Peak Electron Density (NmF2)



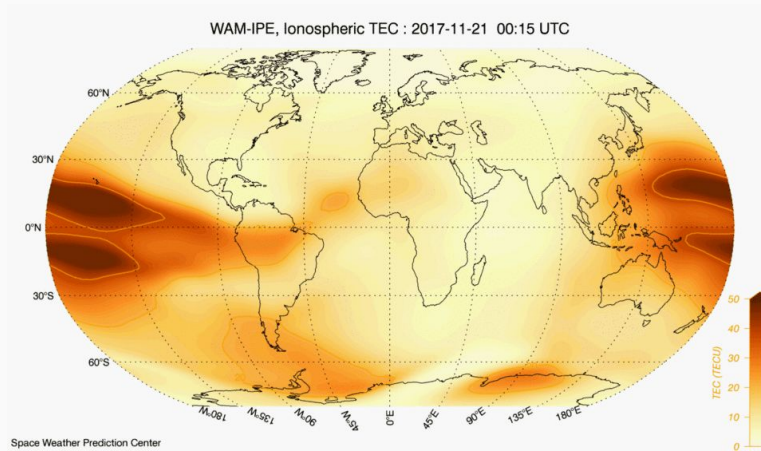
Maximum Usable Frequency (MUF)



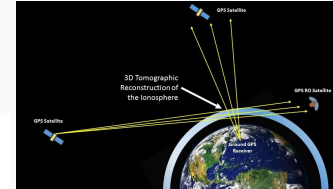
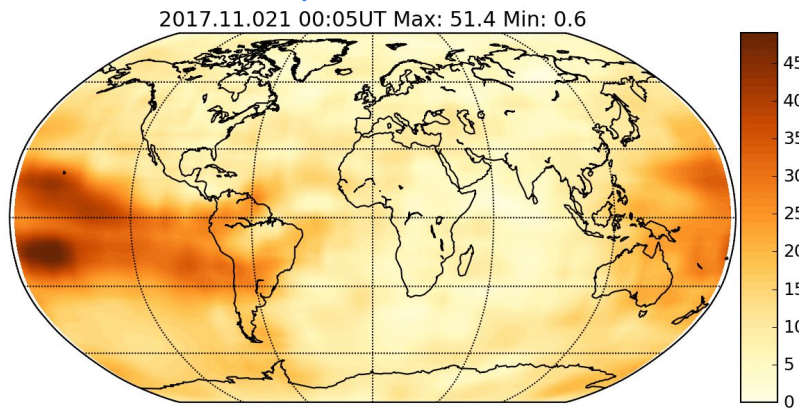
WAM-IPE Products and Forecast Validation

- Initial products: TEC, NmF2, hmF2, and anomalies (departure from 10-day mean)
- Example of animation of global IPE TEC for November 21 2017 (Animation courtesy George Millward)
- WAM-IPE forecasts will be validated against TEC maps from GloTEC, a data assimilation scheme combining ground (GNSS) and space-based (COSMIC RO) data (Courtesy Dominic Fuller-Rowell)

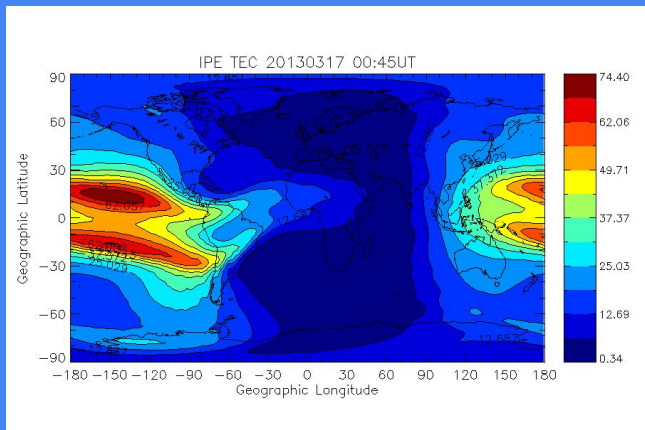
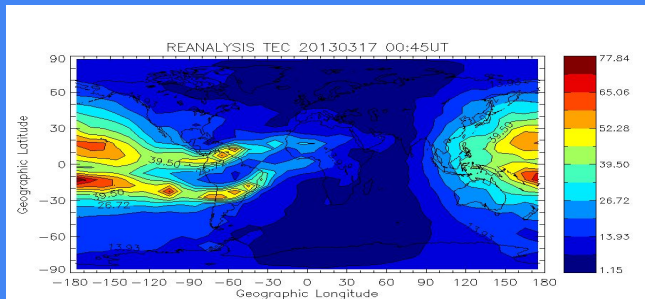
WAM-IPE Forecast of TEC



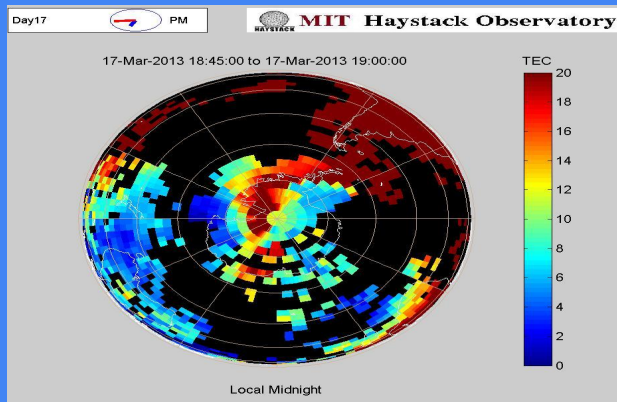
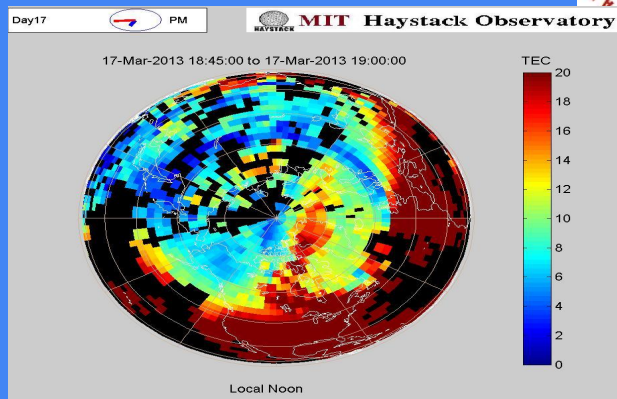
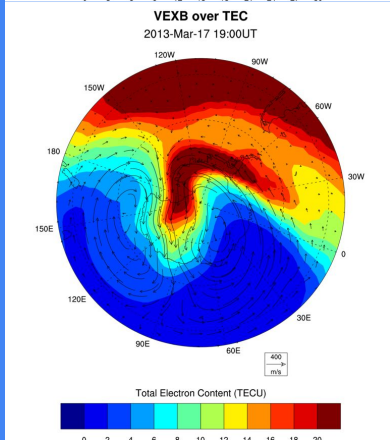
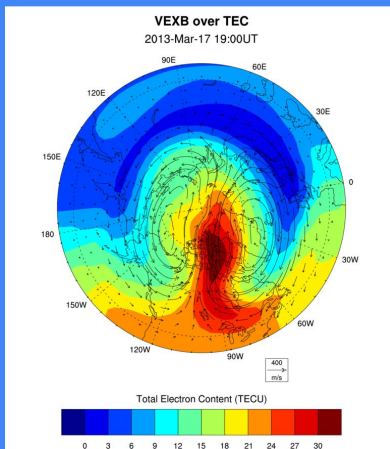
GloTEC Ionospheric Data Assimilation



19UT March 17, 2013 North and South Hemisphere



quiet initial conditions
Re-analysis vs IPE



Anthea Coster
TEC maps MIT



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6130 Executive Boulevard
Rockville, MD 20852



Submitted to
National Oceanic and Atmospheric Administration
Space Weather Prediction Center

March 29, 2019

3. **Develop a product that includes GNSS-specific warnings and nowcast observations.** ...Examples...include scintillation phase and amplitude, geomagnetic storms, and TEC disturbances and gradients.
4. **Develop push alerts** that are specific to users' *geographies*.
5. **Provide tools to translate space weather phenomena to impacts.**
6. **Improve the SWPC website for use by non-experts [simplify]** ...interpretive tools that can relate or lead SWPC customers to the *nature, severity, and timing* of impacts they may experience.
7. **Create a mechanism for users to report GNSS issues**...through software that is already being used.

Using Today's Products



SPACE WEATHER PREDICTION CENTER
 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Tuesday, September 15, 2020 18:00:01 UTC

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SPACE WEATHER CONDITIONS on NOAA Scales

24-Hour Observed Maximums: **R S G** (None None None)

Latest Observed: **R S G** (None None None)

Predicted 2020-09-15 UTC: R1-R2: 1% (1% or greater) 1% **G** (None)

Solar Wind Speed: **380** km/sec Solar Wind Magnetic Fields: Bz 4 nT, Bz 2 nT Noon 10.7cm Radio Flux: **69** stu

GLOBAL POSITIONING SYSTEM (GPS) COMMUNITY DASHBOARD

U.S. TOTAL ELECTRON CONTENT

Approximate L1 Position Error (m) and TECs ($10^{18} \times m^{-2}$)

15-Sep-2020 from 17:30 to 17:45 UT NOAA/SWPC Boulder, CO USA (op.ver: 2.0)

WSA-ENLIL SOLAR WIND PREDICTION

2020-09-20 14:00:00

Source: Weather Prediction Center Run Time: 2020-09-15 14:03 UT Mode: Ambient Image Created: 2020-09-15 15:28 UT

OVATION AURORAL FORECAST

Aurora Forecast

Forecast For: 2020-09-15 18:20:12 2020-09-15 18:20:12 (Typical Range: 5 to 100 km)

SPACE WEATHER OVERVIEW

2020 Sep 13 Sep 14 Sep 15 Sep 16

GOES SOLAR ULTRAVIOLET IMAGER

GOES-16 SUI Composite 195 Angstroms 2020-09-15 17:54:57

SPACE WEATHER PREDICTION CENTER
 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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CURRENT SPACE WEATHER CONDITIONS on NOAA Scales: **R S G** (None None None)

WAM-IPE

WAM-IPE, Ionospheric TEC: 2020-06-22 21:00 UTC

Space Weather Prediction Center **Experimental Test Product : Not For Operational Use**

TEC - TEC Anomaly - IMF2 - IMF2 Anomaly - IMF2 - IMF2 Anomaly

Usage Impacts Details History Data

SPACE WEATHER PREDICTION CENTER
 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Tuesday, September 15, 2020 19:48:52 UTC

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CURRENT SPACE WEATHER CONDITIONS on NOAA Scales: **R S G** (None None None)

NORTH AMERICAN TOTAL ELECTRON CONTENT

NORTH AMERICAN TOTAL ELECTRON CONTENT

Approximate L1 Position Error (m) and TECs ($10^{18} \times m^{-2}$)

15-Sep-2020 from 18:15 to 18:30 UT NOAA/SWPC Boulder, CO USA (op.ver: 2.0)

STANDARD DEVIATION

Total Electron Content Standard Deviation ($10^{18} \times m^{-2}$)

15-Sep-2020 from 18:15 to 18:30 UT NOAA/SWPC Boulder, CO USA (op.ver: 2.0)

ANOMALY

Total Electron Content Difference from 10-day Average ($10^{18} \times m^{-2}$)

15-Sep-2020 from 18:15 to 18:30 UT NOAA/SWPC Boulder, CO USA (op.ver: 2.0)

Questions?

Rob Steenburgh

Space Weather Prediction
Center/Space Weather Forecast Office

Boulder CO

robert.steenburgh@noaa.gov

