Methods and Outcomes for Recent Evaluations of Commercial Radio Occultation Total Electron Content

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OVERVIEW

A radio occultation (RO) satellite can measure the total electron content (TEC) along the path to a GNSS satellite. TEC measurements are critical for scientific and operational applications in the Earth's ionosphere. Commercial RO providers are now providing TEC measurements that supplement those of COSMIC-2. Orion Space Solutions has evaluated several commercial RO datasets on behalf of US government agencies.

What we look at when evaluating commercial RO TEC data

Ease of Use	Quality	Accuracy
• Data access • Data format • Accuracy and completeness of metadata • Customer support	• Number of occultations • Presence of data gaps • Occurrence of cycle slips • Amount of noise	• **Compare TEC measurements to COSMIC-2** • **Compare electron densities (from Abel inversion) to ionosondes**, ISRs, etc.

Coverage	Impact

• **Coverage across elevation angle and altitude**
• Visualizations of coverage in time and space
  • "Fan" plots
• Quantitative measures of coverage in time and space
  • Grid coverage across local time, latitude, and altitude
	• Observing System Experiment (OSE): Data assimilation without and with commercial RO data, comparison to independent measurements
	• **Observing System Simulation Experiment (OSSE):** assimilate *synthetic* data to estimate impact at all times and locations

Orion's commercial RO evaluation efforts

2018-2019: US Air Force Commercial Satellite Data (**CSD**) program
- Spire and GeoOptics
- Ionosphere and lower atmosphere

2019-2022: US Air Force Commercial Weather Data Pilot (**CWDP**) program
- PlanetiQ
- Ionosphere and lower atmosphere

2023-present: NASA CSDA New Vendor Onramp Evaluation (**CNVOE**) program
- GeoOptics
- Ionosphere only

This poster:

1 Highlights from CWDP (**PlanetiQ** evaluation)
- Impact assessment procedure
- OSSE results for global foF2 specification

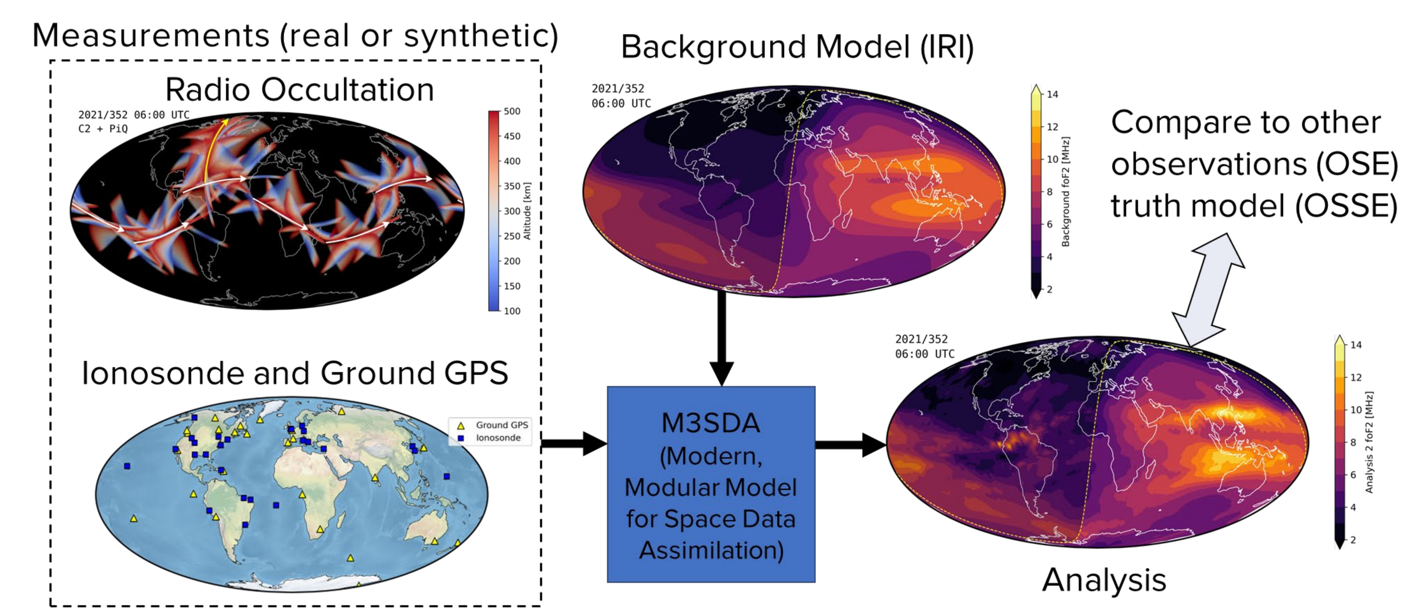
2 Methods used for CNVOE (**GeoOptics** evaluation)
- Elevation angle coverage
- Absolute and relative TEC validations
- Revisit rate and coverage improvement

1 HIGHLIGHTS FROM CWDP (PLANETIQ EVALUATION)

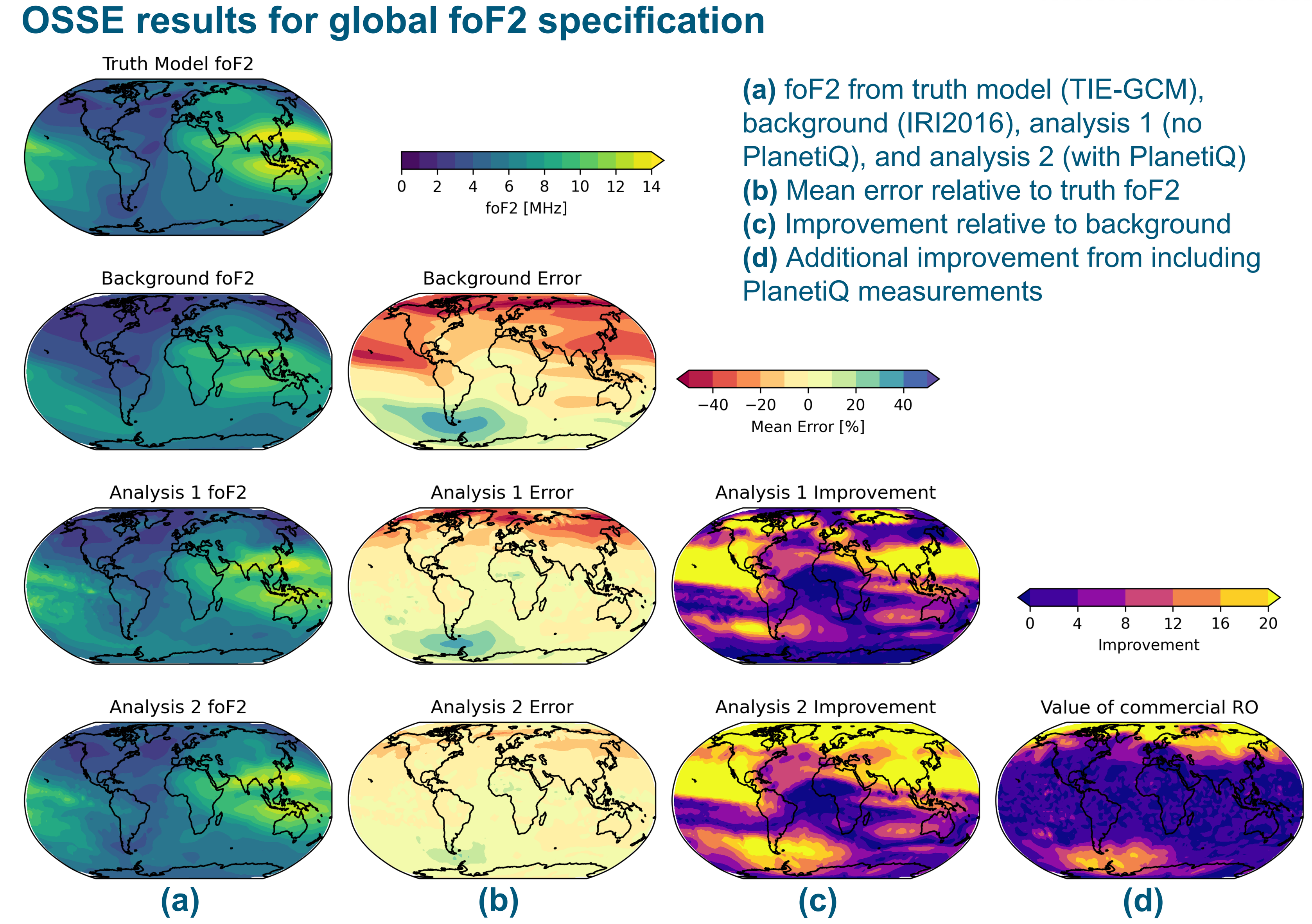
Impact assessment procedure: perform data assimilation without and with the PlanetiQ data to see additional impact of assimilating their data.

Observing System Experiment (OSE)
- Use real data to specify the real ionosphere
- Compare to independent observations

Observing System *Simulation* Experiment (OSSE)
- Use synthetic data that are simulated from a known "truth"
- Since we know "truth", we can assess impact everywhere



OSSE results for global foF2 specification



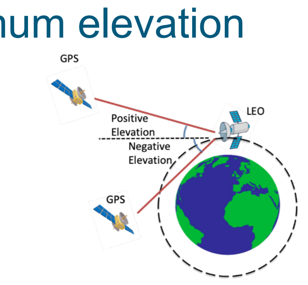
(a) foF2 from truth model (TIE-GCM), background (IRI2016), analysis 1 (no PlanetiQ), and analysis 2 (with PlanetiQ)
(b) Mean error relative to truth foF2
(c) Improvement relative to background
(d) Additional improvement from including PlanetiQ measurements

An OSSE can investigate improvements without validation data. An example case for foF2 prediction is shown here. OSSEs and OSEs are complimentary: they fill in each other's gaps.

Results:
- PlanetiQ data has good elevation coverage, but not as good as COSMIC-2.
- PlanetiQ has high quality data, which is very close in quality to COSMIC-2.
- There is good agreement between PlanetiQ and COSMIC-2 median overhead TEC values.
- PlanetiQ provides almost 61,000 profiles from its single satellite in contrast to COSMIC-2's six. It also has excellent agreement with the ionosonde data, but not quite as good as COSMIC-2's.
- Assimilating PlanetiQ data improves the ionospheric specification, with a larger impact at high latitudes.

2 METHODS USED FOR CNVOE (GEOOPTICS EVALUATION)

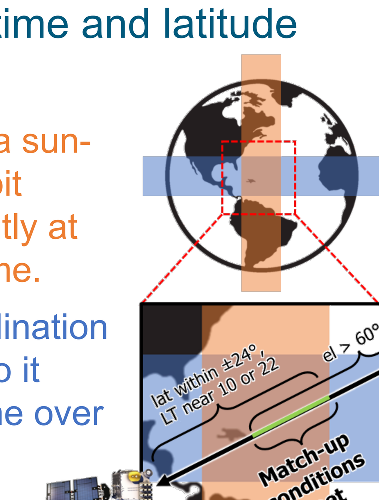
Elevation angle coverage (likelihood of occultation data):
In an ideal situation, all data would have a very low minimum elevation angle and a maximum elevation angle that was at least as large as the absolute value of the minimum elevation angle.



Absolute TEC validation:
We compared averaged overhead TEC from each occultation with COSMIC-2 when they are in a common local time and latitude region.

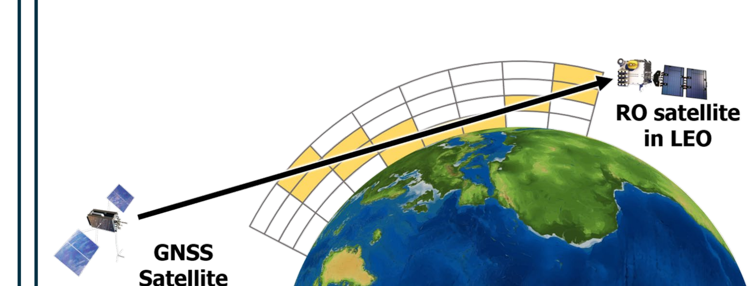
GeoOptics is in a sun-synchronous orbit which is constantly at 10 or 22 local time.

COSMIC-2's inclination is 24 degrees, so it spends all its time over the tropics.



Relative TEC validation:
We Abel inverted the TEC data to yield electron density profiles (EDPs) and compared these to ionosonde data. Differences between the ionosonde and RO electron densities will be more indicative of relative TEC accuracy when the tangent point (lowest altitude point on the raypath) is close to the ionosonde. We also compared foF2 and hmF2 with ionosondes for COSMIC-2 and GeoOptics.

Percent revisit rate and spatial coverage ("day in the life"):
We split the ionosphere into voxels and kept track of when a unique raypath passes through each voxel. The grid is global 2.5° × 2.5° lat/lon, 10 km altitude (100 to 1000 km), and 10- minute timestep.



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