Impacts of Small-Scale Structures on Observation System Simulation Experiments for HF Propagation

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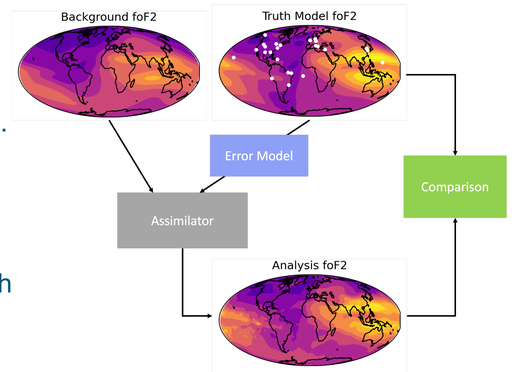
WHAT'S AN OSSE?

An OSSE (Observation System Simulation Experiment) is a numerical experiment that can predict the performance of ionospheric specification. It has 3 steps:

1. Simulate measurements from a truth model
2. Assimilate these measurements and update a background model to make an 'analysis'
3. Compare the analysis and background to the truth model

Iterate on steps 1-3 with configurations of the observation system to find the configuration that best meets the operational need at minimum cost.

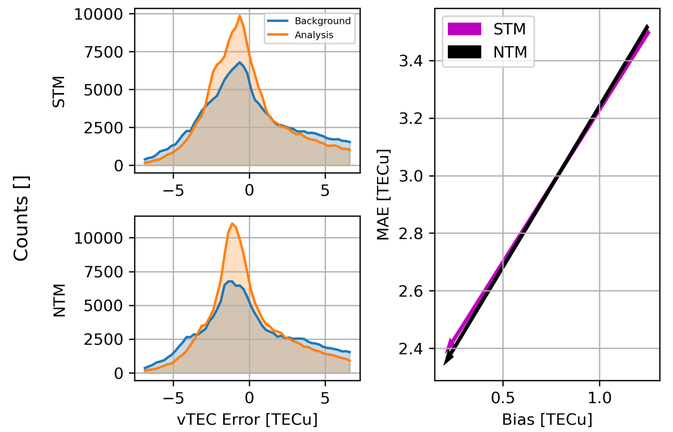


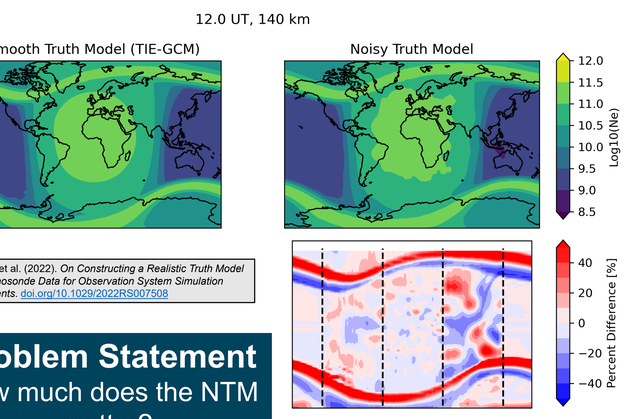
In Prep: Joe Hughes et al., *A Verification and Validation of the Observation System Simulation Experiment Tool for Ionospheric Electron Density Specification*

IMPACT ON VTEC

We compute the vTEC for all models. We then subtract both the background and analysis from the truth to make errors. We do this for both the STM and NTM.

Left panels show distributions of errors, right panel shows arrows which point from the background to the analysis in Bias and MAE. The STM and NTM predict almost identical results for vTEC improvement





Hughes, et al. (2022). *On Constructing a Realistic Truth Model Using Ionosonde Data for Observation System Simulation Experiments*. doi.org/10.1029/2022RS007508

Problem Statement
How much does the NTM matter?

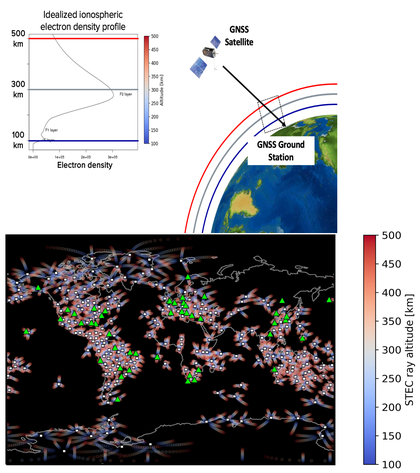
WHAT'S THE NOISY TRUTH MODEL?

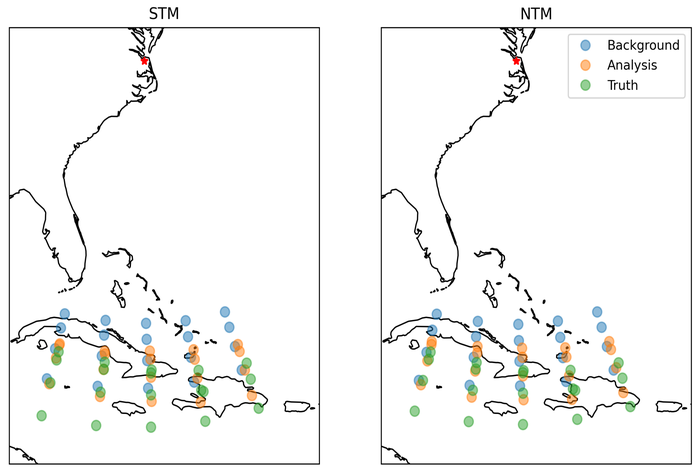
Many physics-based truth models do not represent the small-scale and short period scales of the real ionosphere. To solve this problem, we created the noisy truth model (NTM) by adding structured noise to TIE-GCM. The structured noise is informed by 2 years of ionosonde data and has consistent vertical, horizontal, and temporal structure.

EXPERIMENT

We performed two OSSEs where the only difference was the truth model. In the NTM run, we used the noisy truth model. In the STM we used the Smooth Truth Model (TIE-GCM) without noise. We wanted to see how much more optimistic the STM OSSE was than the NTM OSSE.

For both OSSEs, we use the Modern Modular Model for Space Data Assimilation (M3SDA) in a EKF mode. We used data from 48 ground ionosondes and 262 ground TEC stations.





A NEW METRIC

HF propagation is a more sensitive and often a more relevant metric. We propagate the same ray (azimuth, elevation, frequency) through the background, analysis, and truth and compare the landing locations

Landing locations shown for STM and NTM in figure. Note that the analysis (orange) is closer to the truth than the background. Our question is whether the STM is more optimistic than the NTM.

IMPACT ON HF METRIC

The STM OSSE is more optimistic than the NTM. The background errors are about 10-15% lower for the STM. The improvement is up to 60% higher for the STM depending on which metric you use.

HIGHLIGHTS

1. OSSEs are a powerful tool to design and test sensor systems before they are built
2. The NTM was created to increase OSSE accuracy
3. OSSES performed with NTM and STM were nearly identical for vTEC, but OSSEs with the STM are 10-60% more optimistic than OSSEs with the NTM.