Ingestion of Radio Occultation Data For Ionospheric Data Assimilation

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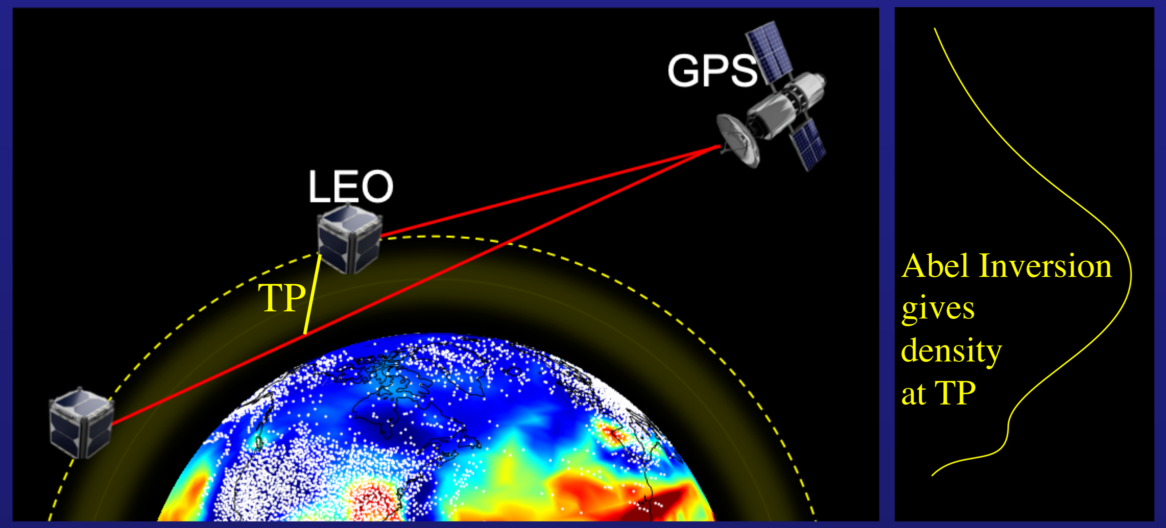
Abstract:

Radio Occultation (RO) data is one of the most important data sources for many Ionospheric Data Assimilation schemes. For example, COSMIC-2 RO data has dense coverage of the low- and mid-latitude regions of the ionosphere. It is usually believed that it is better to ingest raw data into data assimilation scheme and to minimize data pre-processing, therefore, schemes like IDA4D ingest slant total electron content (sTEC) RO data. This study demonstrates that better results can be achieved by performing Abel inversion to invert electron density along tangent points and then ingesting these point density measurements into data assimilation. A 2-D experiment with real RO geometry was performed to directly compare these two methods of data ingestion. The ingestion of Abel inverted point density is able to better retrieve the hmF2 parameter and the structure of the bottom side of the profile in comparison to the direct ingestion of sTEC data, especially when the hmF2 of the truth is below the hmF2 of the background or when the horizontal gradient is present.

Introduction:



Kalman Filter:

$$\vec{x}_a = \vec{x}_f + K(\vec{y} - \tilde{H}\,\vec{x}_f)$$

$\vec{x}_a \equiv$ analysis
$\vec{x}_f \equiv$ forecast
$K \equiv$ Kalman gain
$\vec{y} \equiv$ data
$\tilde{H}\,\vec{x}_f \equiv$ model data

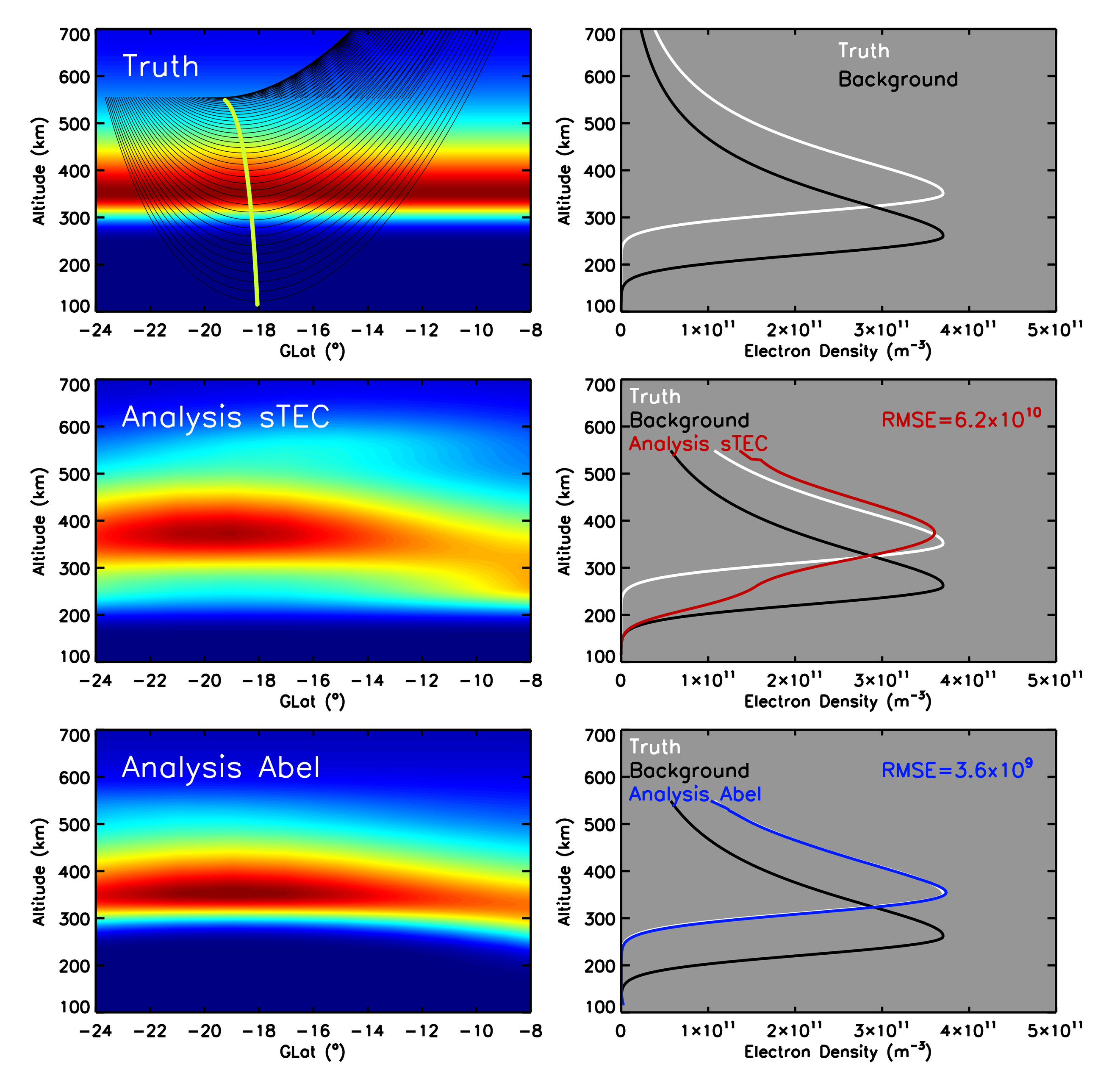
Focus Question:

What is better to ingest for accurate ionospheric bottom side nowcast?

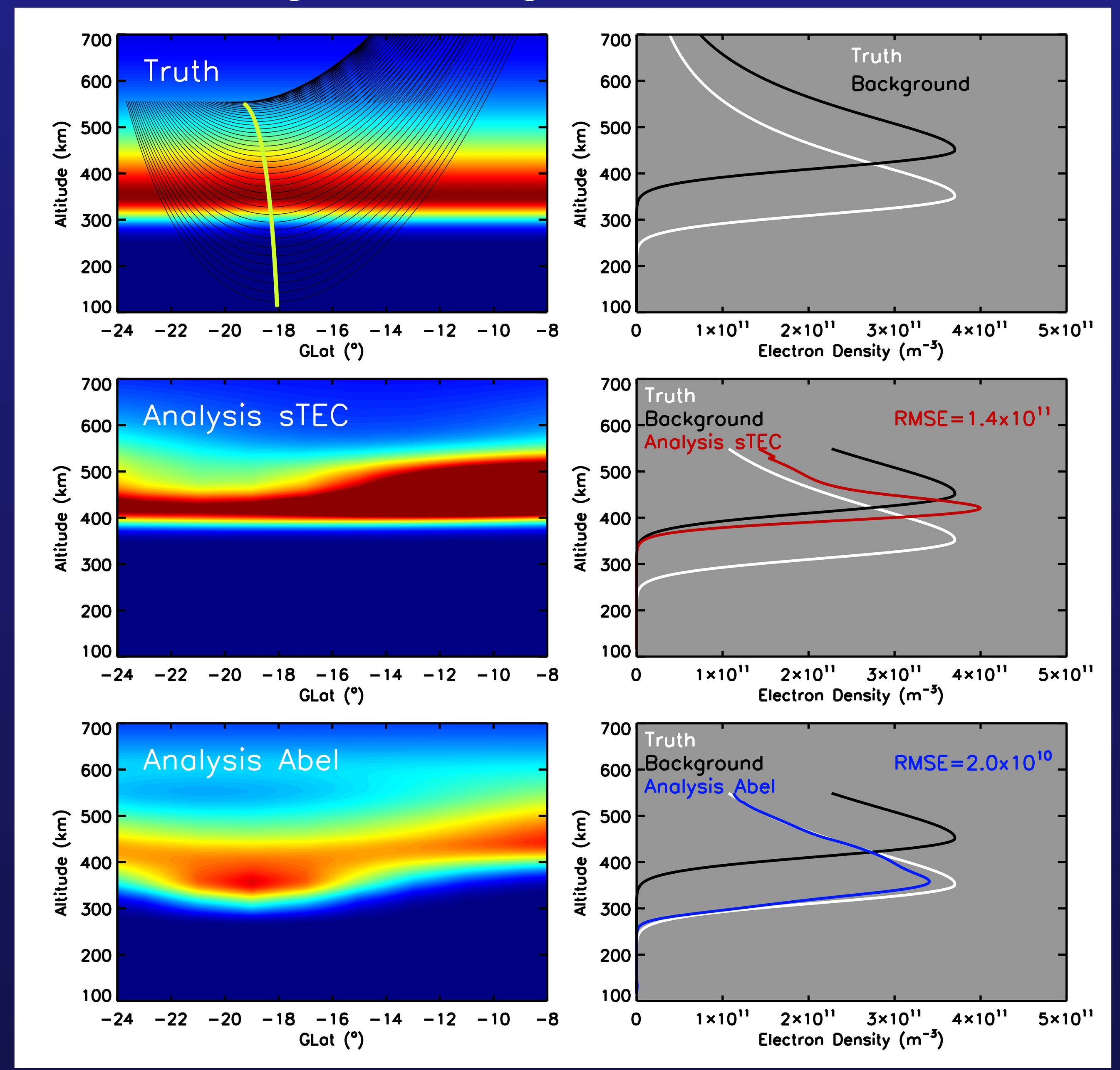
$\vec{y} \equiv$ sTEC RO data or
$\vec{y} \equiv$ Density at TP after Abel Inversion

hmF2 Experiment:

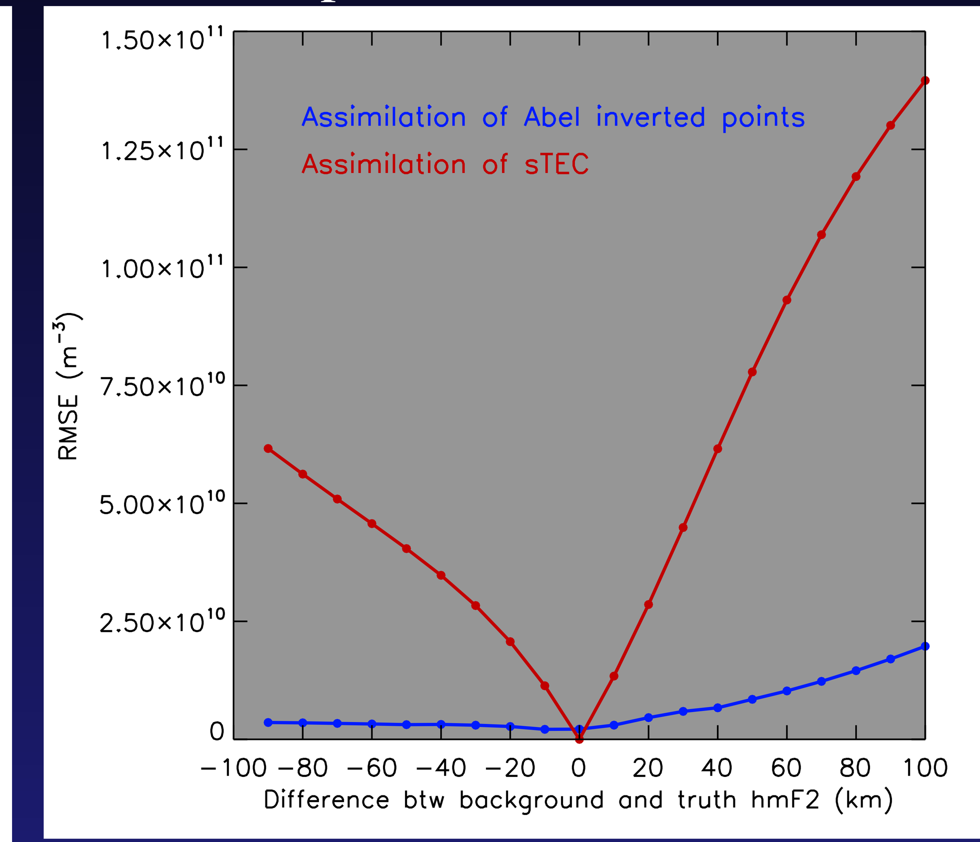
hmF2 of background is lower than the truth:



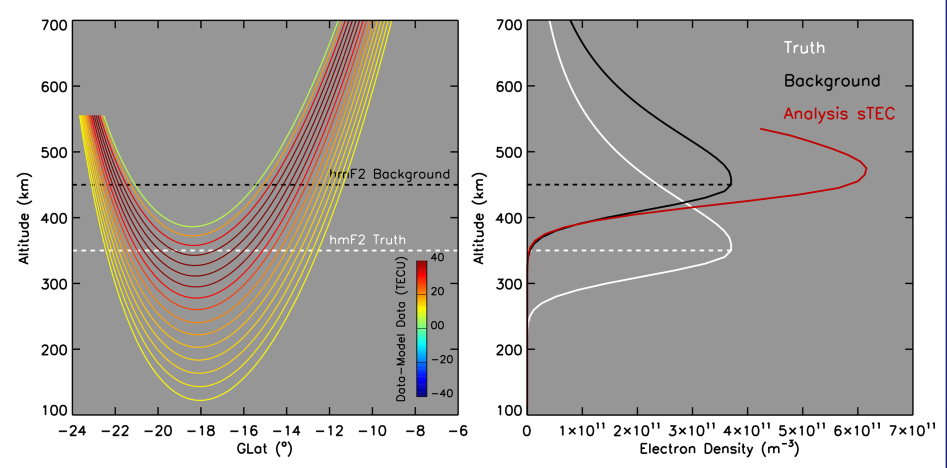
hmF2 of background is higher than the truth:

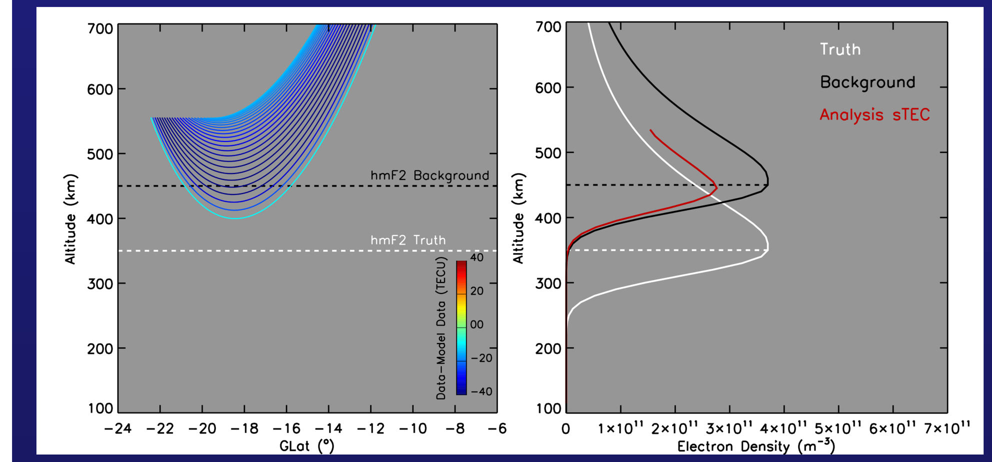


RMSE comparison:



Data and model data difference $\vec{y} - \tilde{H}\,\vec{x}_f$:

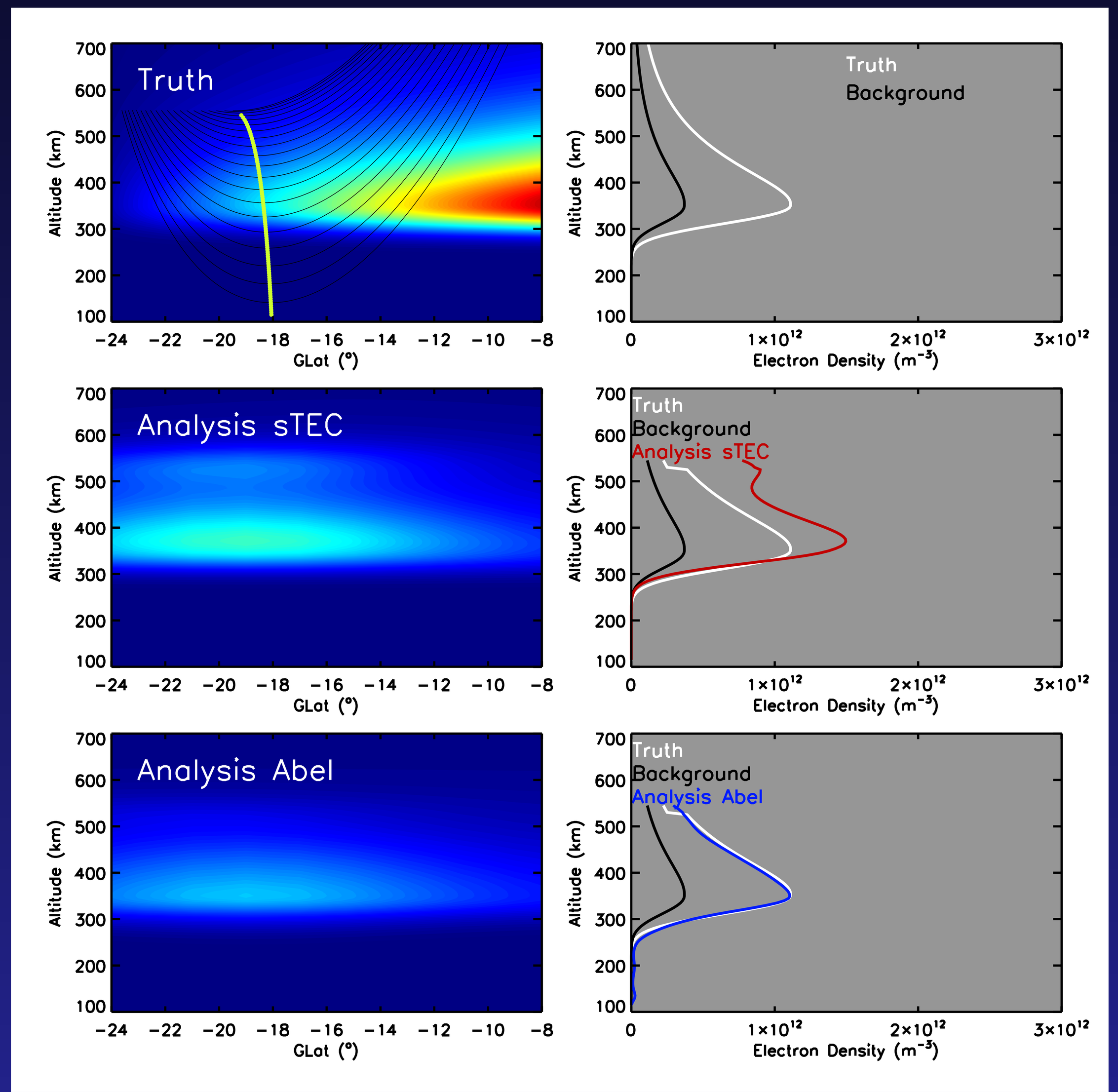




The difference between the measured sTEC and model data sTEC is positive (negative) for the lower (higher) rays, which increase (decrease) the peak of the profile from the background, but does not change the height, causing the thinning of the layer.

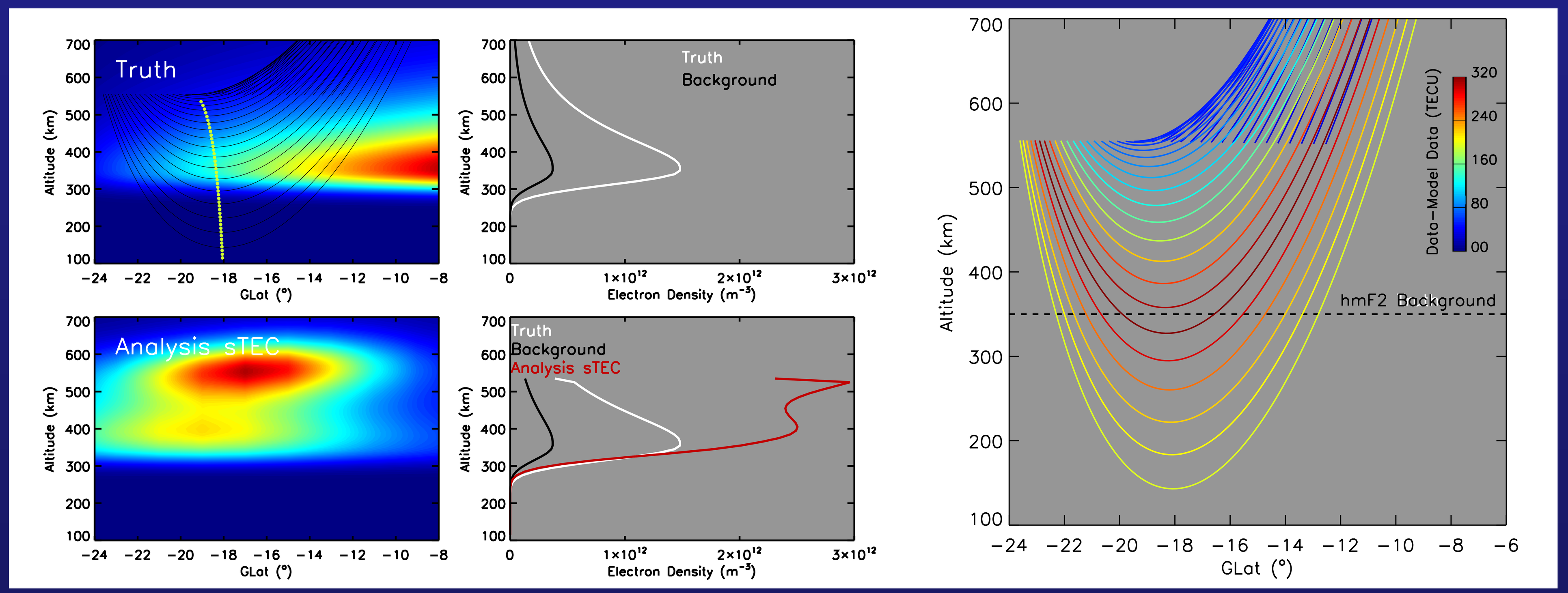
Gradient Experiment:

Truth has density gradient, but the background does not.
Assimilation of rays with negative elevation only:



When the horizontal density gradient is present, but is not present in the background, the ingestion of sTEC can create an artificial F3 layer. This happens even when the rays with positive elevation angles are excluded. This happens because $\vec{y} - \tilde{H}\,\vec{x}_f$ is large due to the gradient at high rays.
The result is even worse when all the rays are assimilated.

Assimilation of sTEC from all of the rays with reduced resolution:



Conclusion:

- The ingestion of Abel inverted density points into Ionospheric Data Assimilation outperforms the assimilation of sTEC along RO rays.
- sTEC ingestion method struggles to retrieve the bottom side of the profile especially when hmF2 of the background is lower than the truth.
- When the horizontal gradients are present the appearance of artificial F3 layer in the analysis is possible.

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