

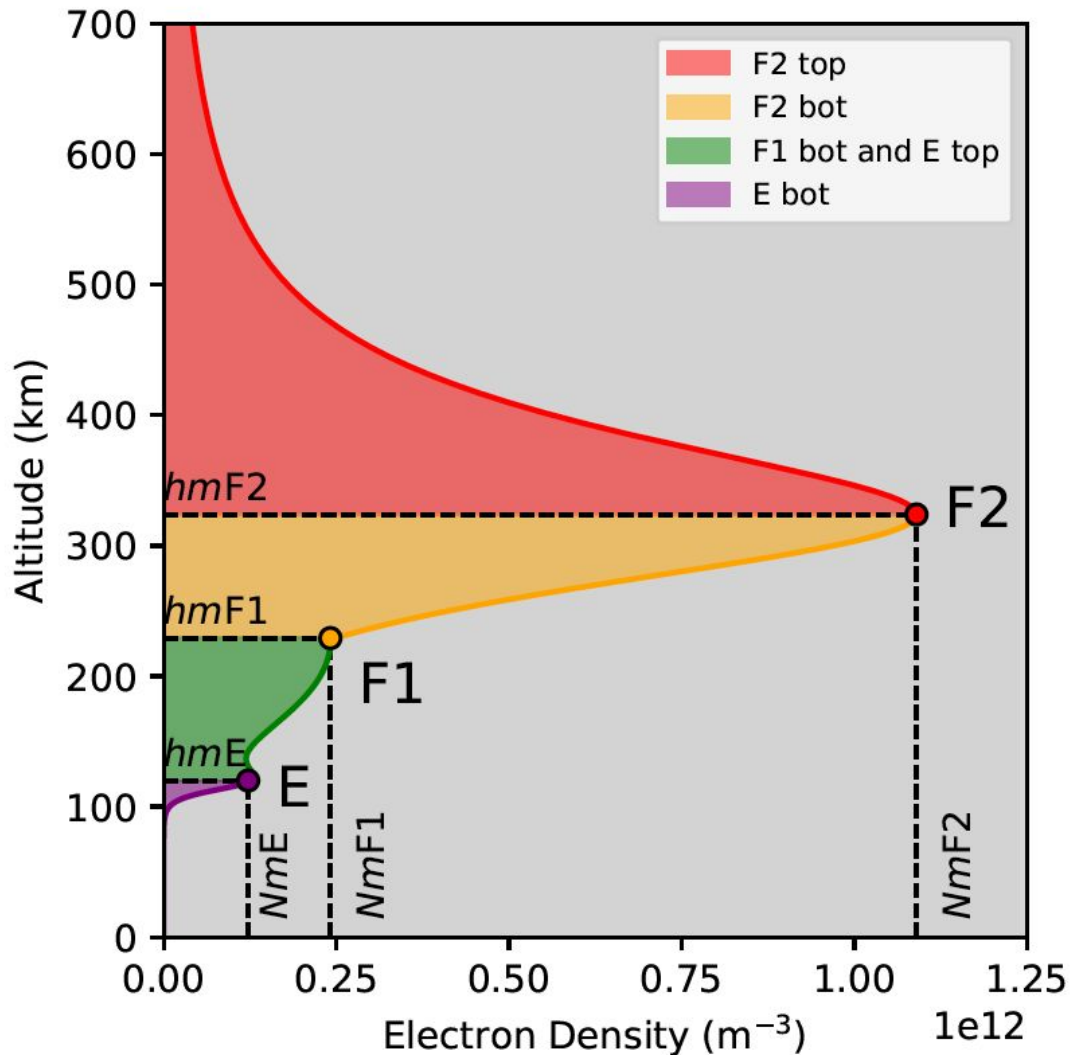


ANCHOR: A New Approach to the Ionospheric Data Assimilation

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Parametrization in ANCHOR



A realistic EDP can be constructed with 12 parameters:

12 anchor points

Fixed at model:

- hmE
- B_{bot}^E
- B_{top}^E

Updated as model:

- $NmF1$
- $hmF1$
- B_{bot}^{F1}

Assimilation:

- $NmF2$
- $hmF2$
- B_{bot}^{F2}
- B_{top}^{F2}
- NmE

- A novel fully Python tool was developed at NRL
- A classical IRI model was re-designed to be suitable for high spatial and temporal resolution grids
- A daily run with irregular grid and 15-min time resolution, requires 6 million executions of FORTRAN IRI
- Same can be done in 3 seconds with PyIRI
- With a special mode it takes only 3 seconds to obtain global ionospheric parameters for the duration of the entire year



Space Weather®

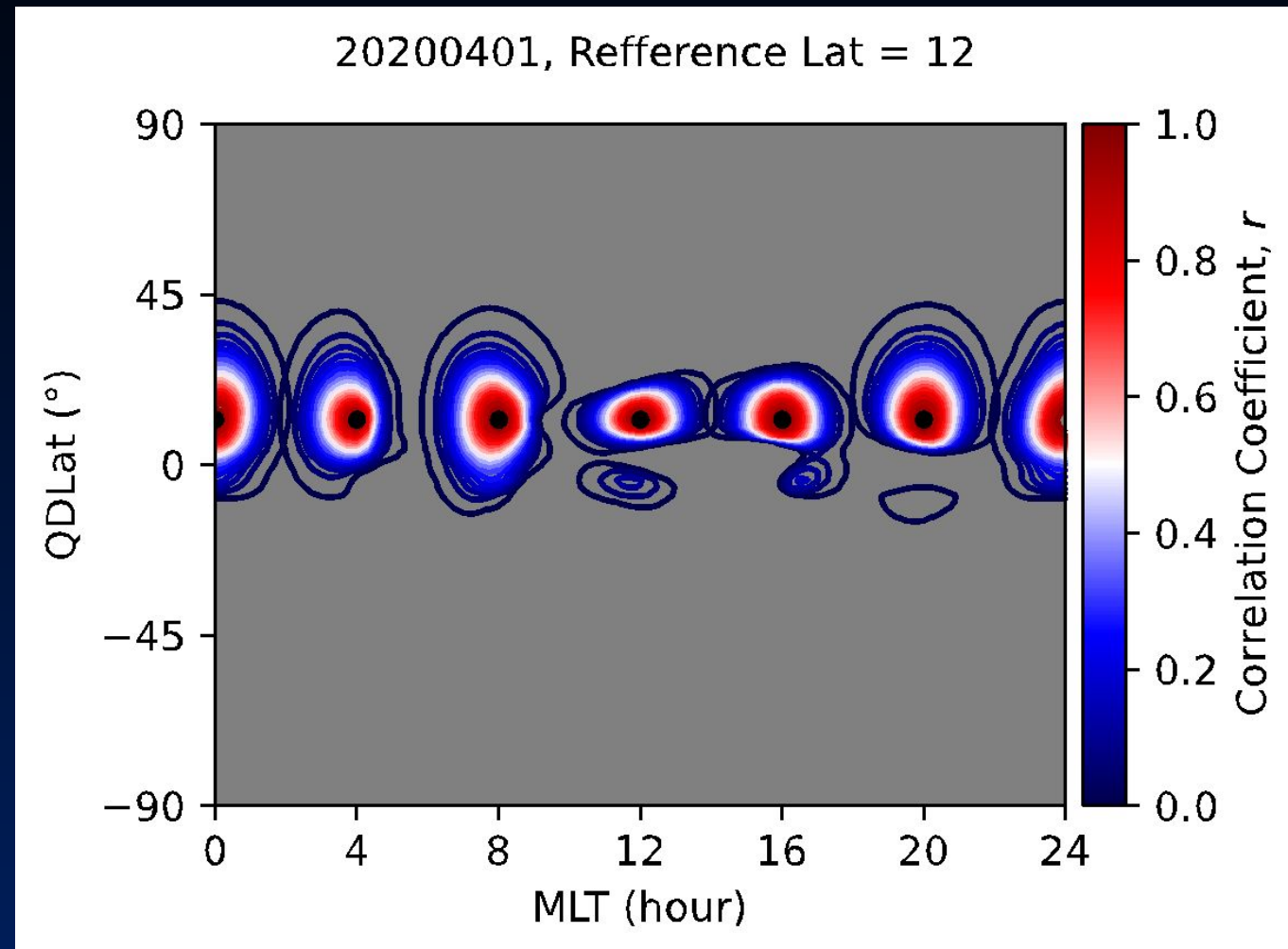
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PyIRI: Whole-Globe Approach to the International Reference Ionosphere Modeling Implemented in Python

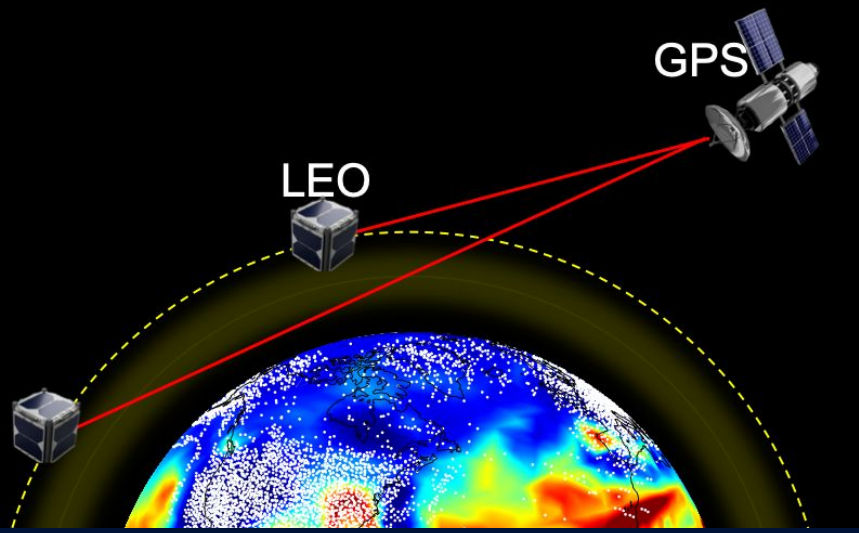
Victoriya V. Forsythe [✉](#), Dieter Bilitza, Angeline G. Burrell, Kenneth F. Dymond, Bruce A. Fritz, Sarah E. McDonald

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- The correlations between deviations of the background from the daily mean are calculated.
- The distribution of the correlations around the reference points reflect the magnetic conjugacy in the equatorial region.
- The correlations are localized to 20 deg of GCD.
- These correlations are used to form the background covariance matrix.



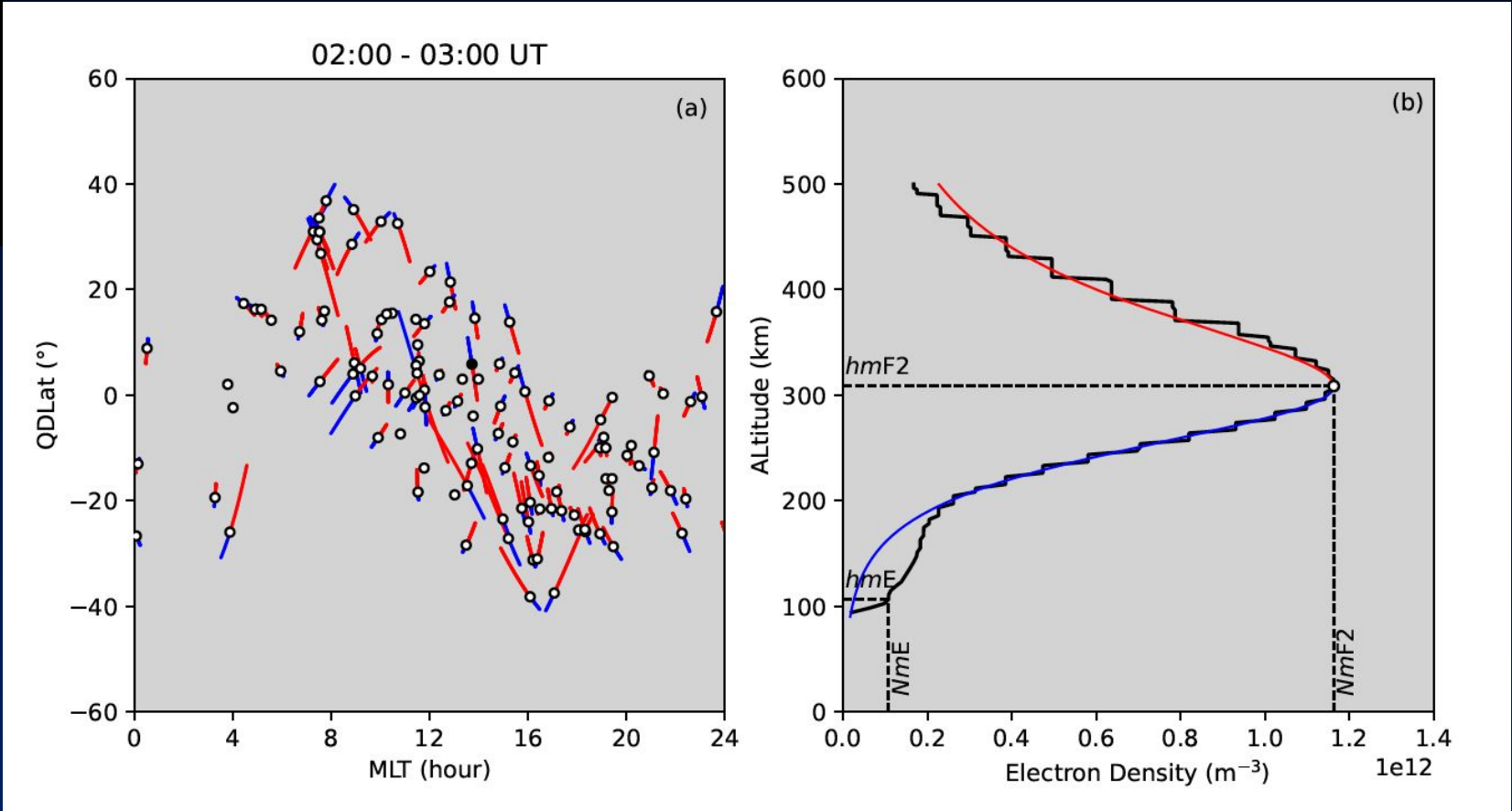
COSMIC-2 Observations \vec{y}



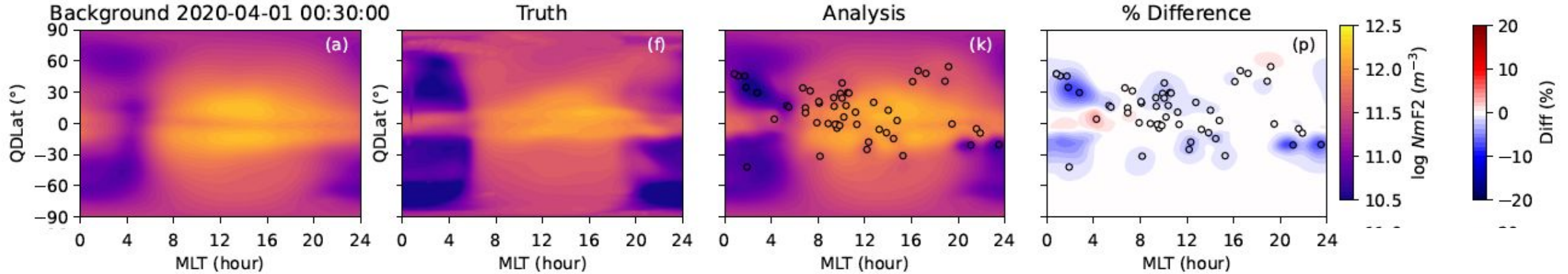
Anchor points are extracted from the data:

- Values and locations are collected for 5 anchor points

- Located at the F2 peak: $NmF2$, $hmF2$, B_{bot}^{F2} , B_{top}^{F2}
- Location of NmE anchor point will be slightly different.



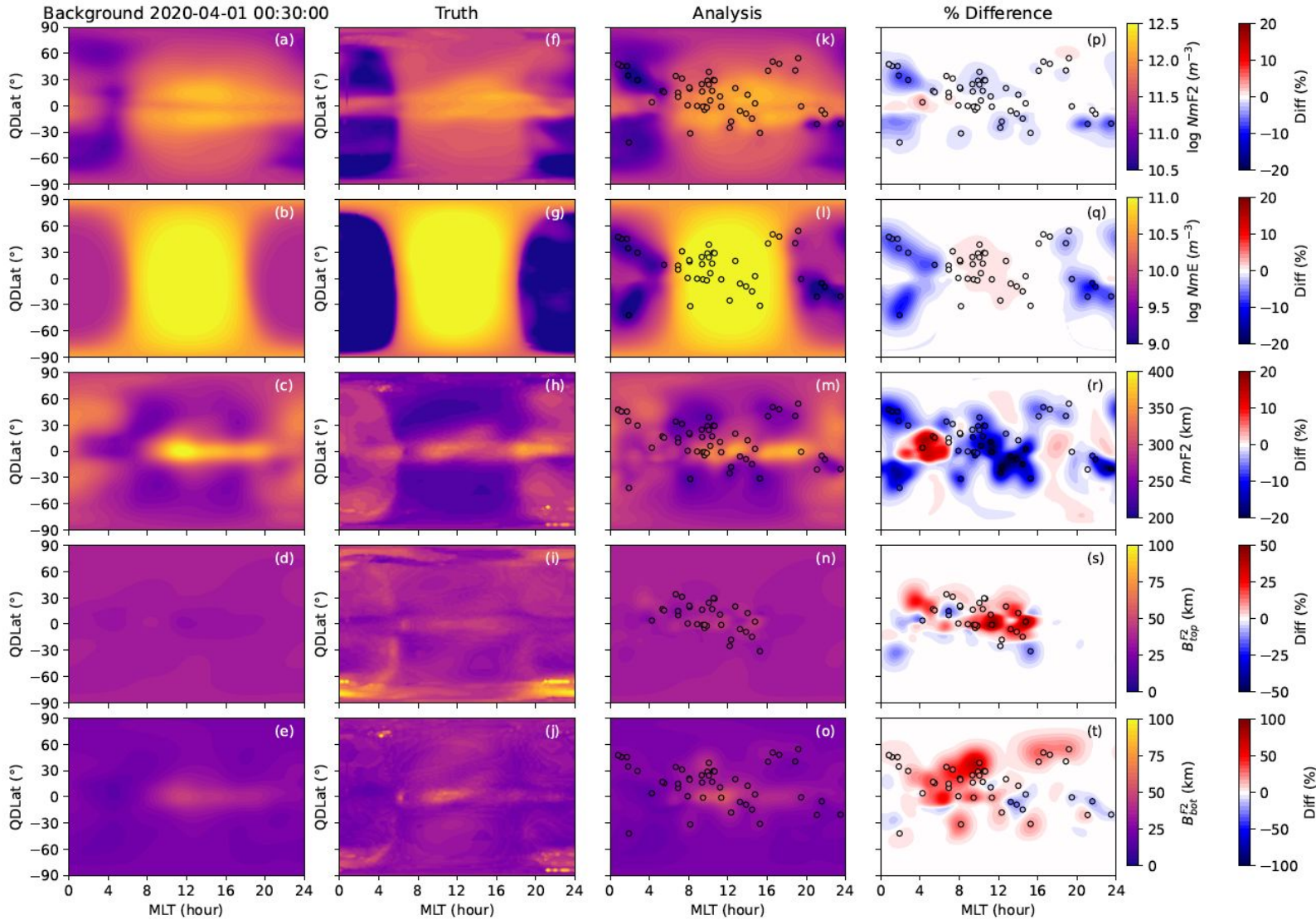
Analysis \vec{x}_a : NmF2 Example



- Anchor points are assimilated into 2-D map of the background parameters as point measurements

$$\vec{x}_a = \vec{x}_b + P_b H^T [H P_b H^T + R]^{-1} [\vec{y}_{data} - H \vec{x}_b]$$

Analysis $\vec{\chi}_a$: All parameters



NmF2

NmE

hmF2

B top

B bot

- Assimilation is performed simultaneously for all parameters
- Parameters are treated as independent

- The RMSEs are reduced for all parameters.
- The vertical structure of the ionosphere is preserved, because of the parametrization
- The DA takes only several minutes for the entire day, which includes data pre-processing, covariance calculation, etc.

ANCHOR: Global Parametrized Ionospheric Data Assimilation

ATMOSPHERIC SCIENCES

GEOPHYSICS

ANCHOR

IONOSPHERE

IONOSPHERIC DATA ASSIMILATION

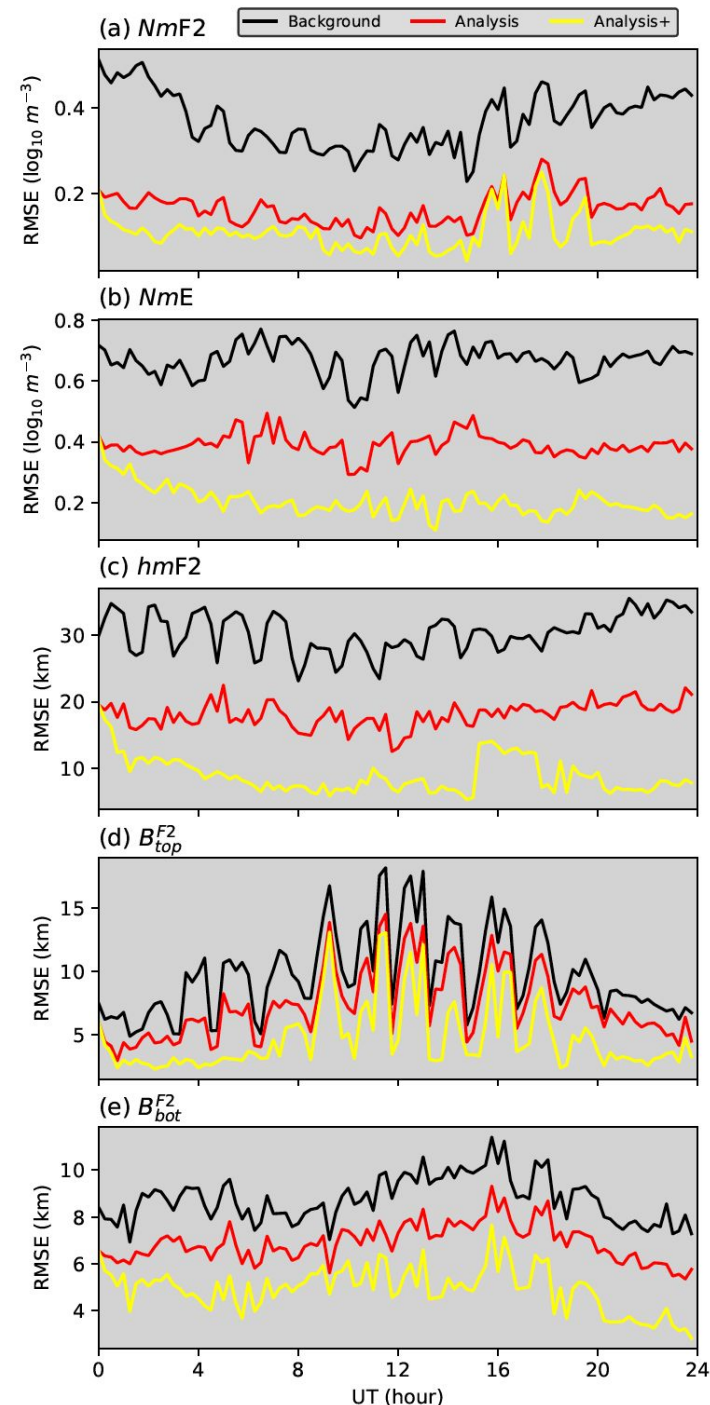
KALMAN FILTER

PARAMETRIZATION

PYIRI



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Meghan Burleigh , Dustin A Hickey , Christopher Metzler, David Derieg Kuhl ,
Daniel Hodyss, Joseph Hughes



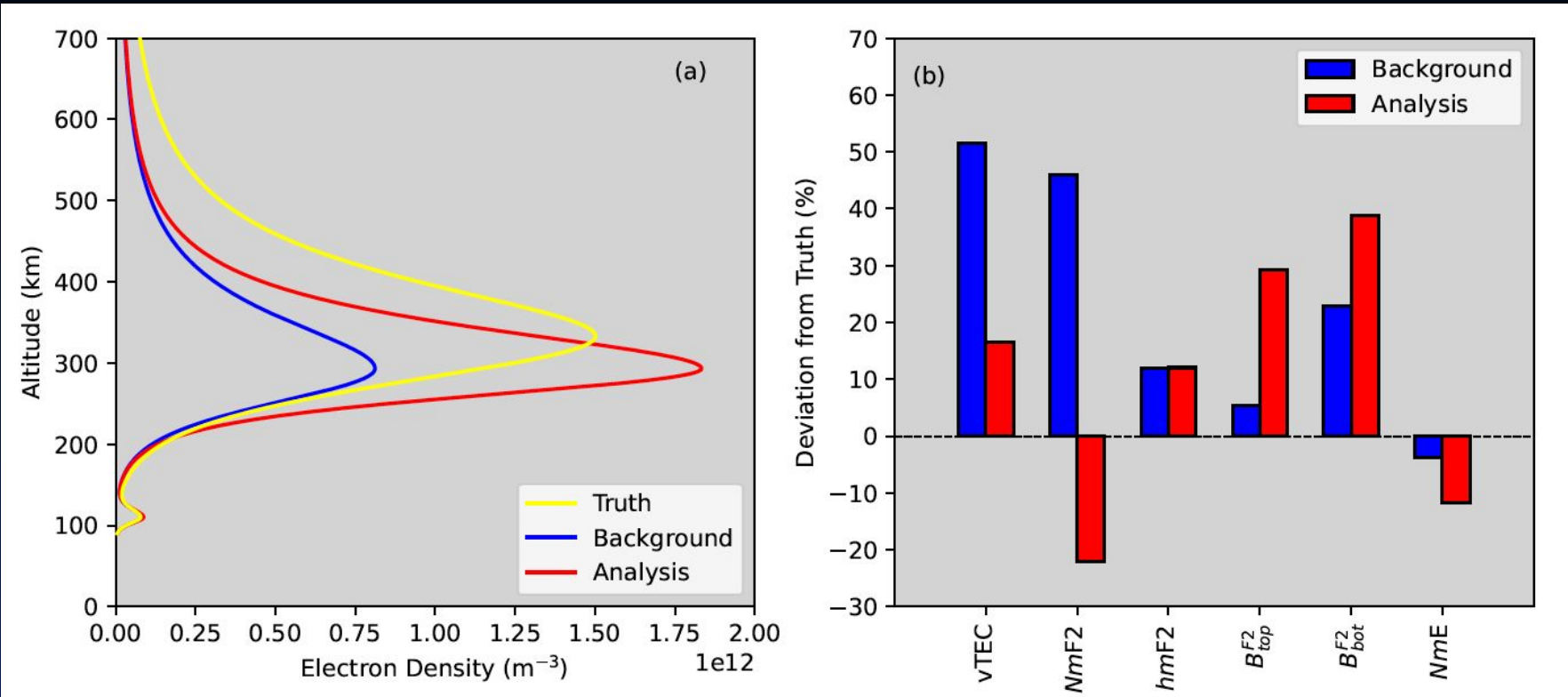
NmF2

NmE

hmF2

B top

B bot

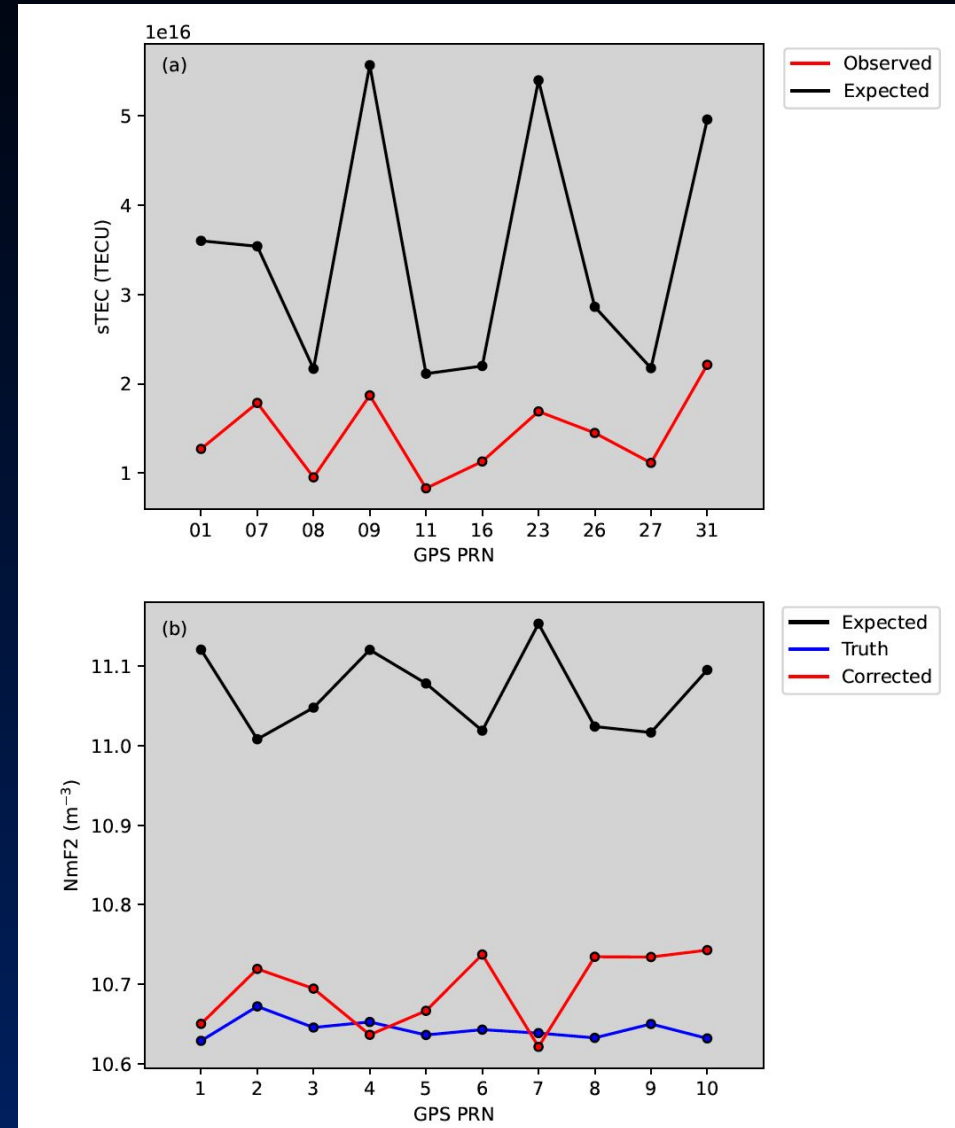


- RO and Ionosonde measurements are local
- sTEC data are integral measurements
- Integral measurements are non-local
- If ingested in a traditional way, it can improve only NmF2
- Other parameters are unchanged (hmF2) or become worse (B_{bot}^{F2} , B_{top}^{F2} , NmE)

- Since ANCHOR corrects other parameters with RO and ionosonde data, we focus only on NmF2
- According to PyIRI formalism:

$$sTEC = \int_{P_r}^{P_t} (F2 + F1 + E) ds$$

- Each layer is expressed as Epstein function
- Only $F2$ is a function of NmF2
- NmF2 correction can be analytically calculated from the observed sTEC
- Obtained NmF2 values are then ingested as point measurements into NmF2 background

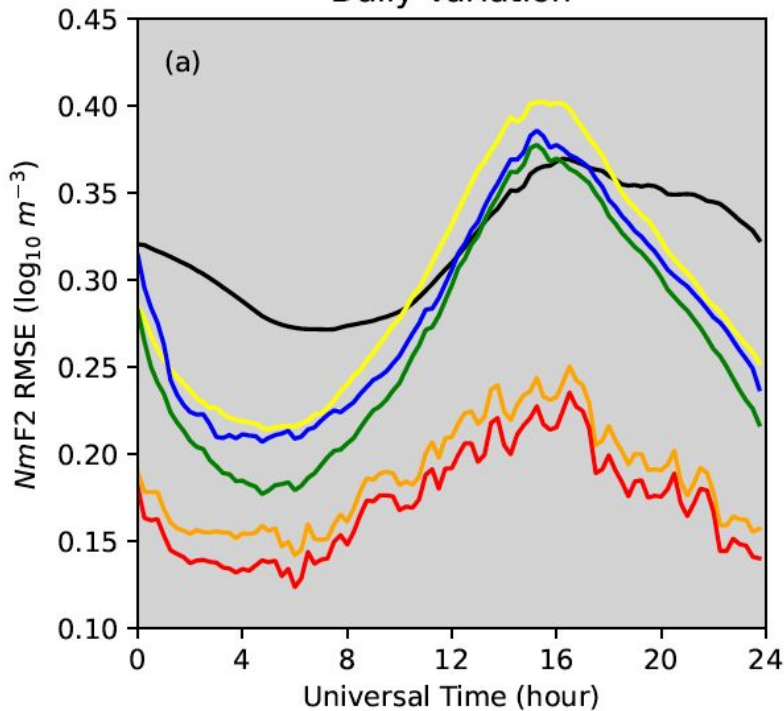


Analysis \vec{x}_a : RMSE Reduction

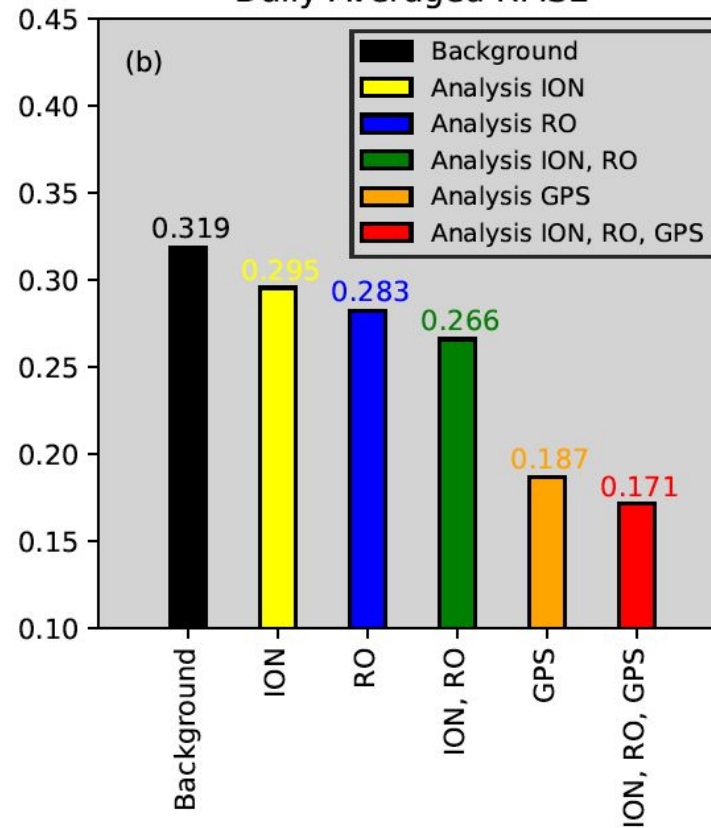


ANCHOR, April 01, 2020

Daily Variation

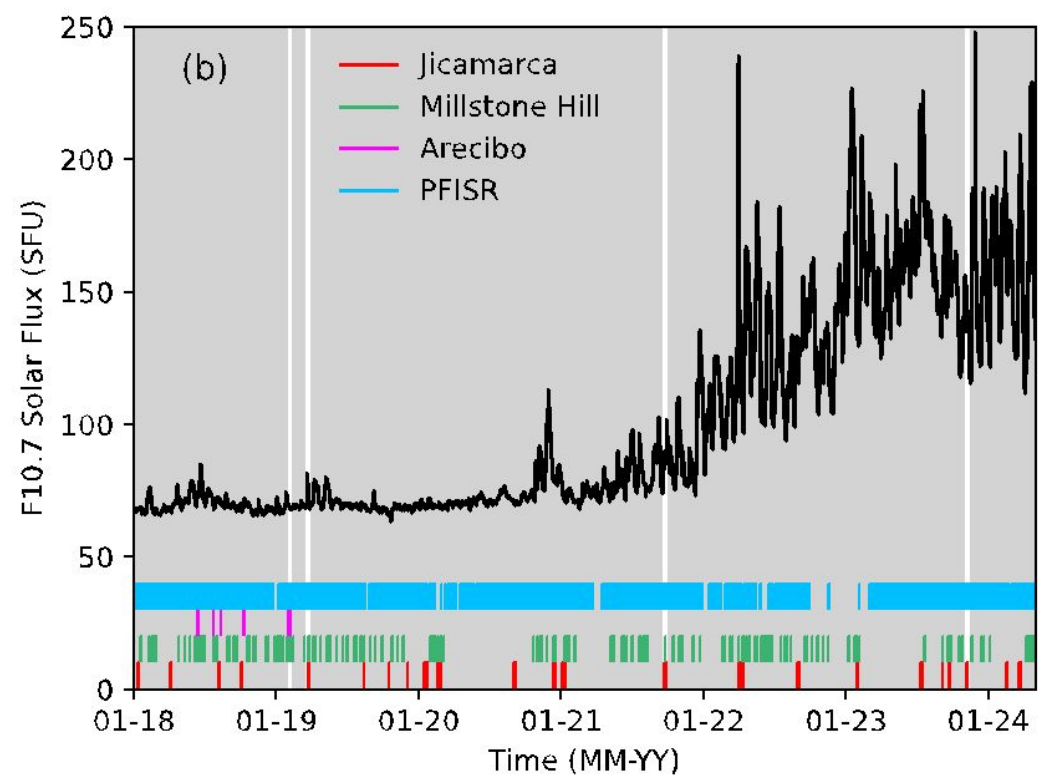
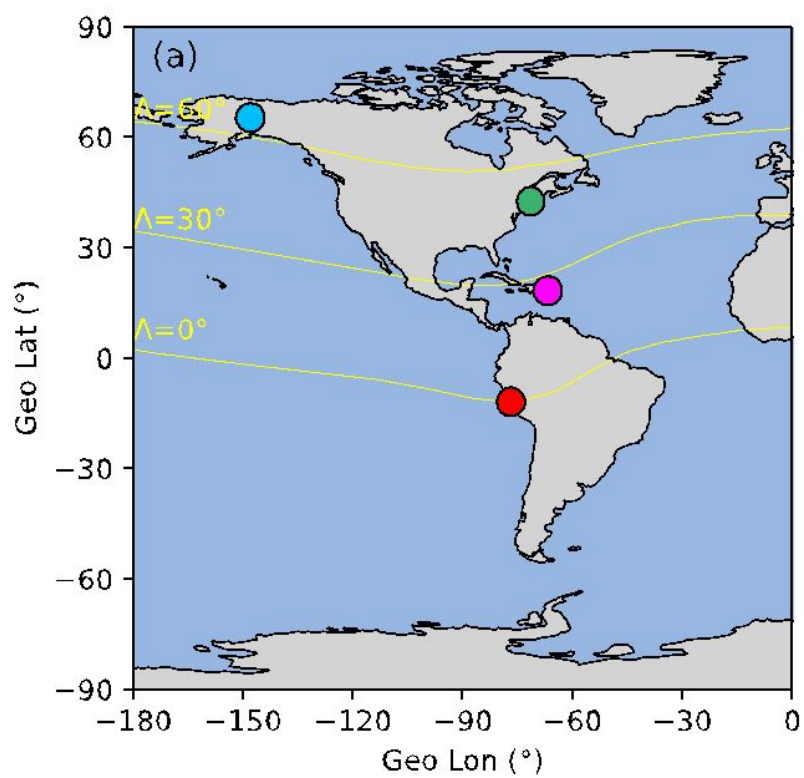


Daily Averaged RMSE



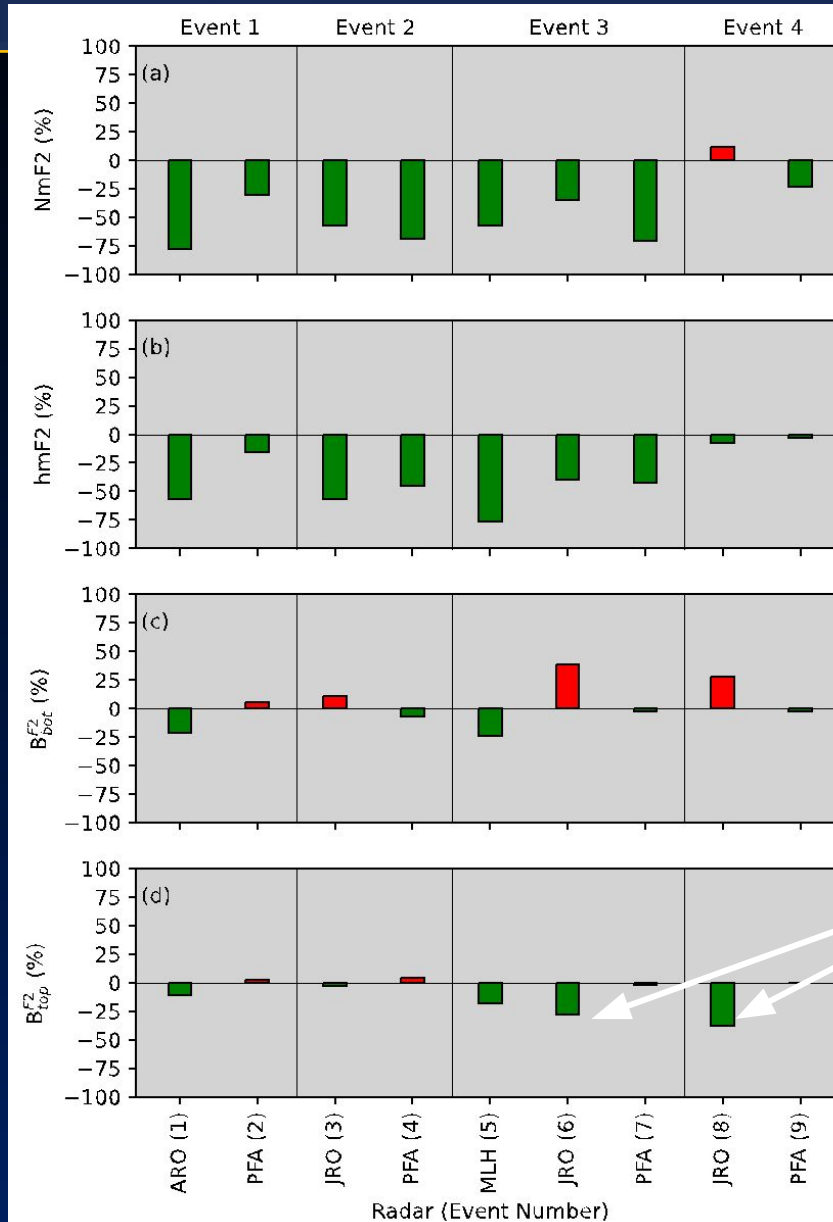
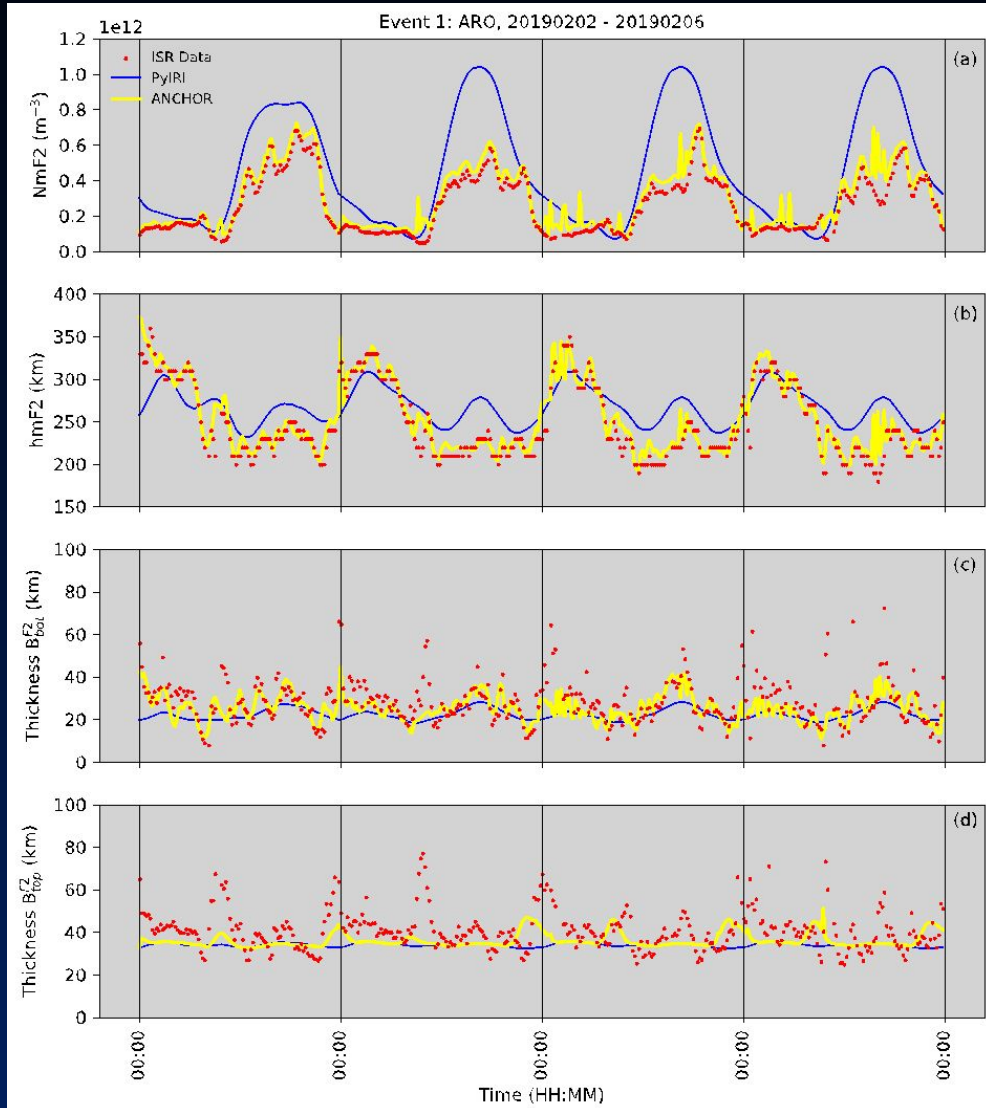
- COSMIC-2 reduces daily RMSE by 11% (blue bar)
- The sTEC data by 41.6% (orange bar), when ingested alone
- by 46.4% (red bar) when ingested together with the ionosonde and RO data.
- This is a significant improvement over ingesting any other of the available data sources separately or in combination.
- The result were submitted for publication to the DoD Journal

Validation with ISR data

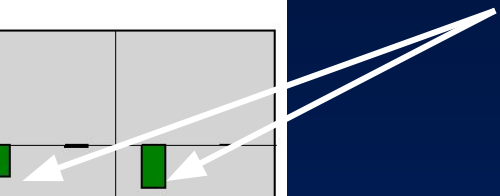


- 4 events (5-day duration) were analyzed

Validation with ISR data



- Up to 75% improvement for NmF_2 and hmF_2
- Some challenges with bottom-side thickness
- COSMIC-2 topside thickness improvement



Tools For The Community



<https://github.com/victoriyaforsthe/PyIRI>



<https://github.com/victoriyaforsthe/PyIRTAM>



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