DISPEC

Scientific exploitation of space Data for improved Ionospheric SPECification

Revised electron density reconstruction model and derived High-Level Data Products

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Revised electron density reconstruction model

Outline

- Motivation
- Methodology
- Accuracy and uncertainty of the method
- Demonstrated value
- Proposed High-Level Data Products
- Conclusions and Outlook

Motivation

Improving Electron Density Reconstruction for Reliable Performance Under Disturbed Conditions

- The DISPEC developments build on the **TaD (TSM-assisted Digisonde)** model.
- TaD is validated with **CHAMP RO**, **IMAGE RPI**, **ISIS topside sounders**, and **Malvern ISR**.
- Typical TaD error: **~5 TECU**; during disturbed conditions: **>10 TECU**.
- Errors increase for locations **>1000 km** from Digisondes.

Main limitations of the TaD legacy approach:

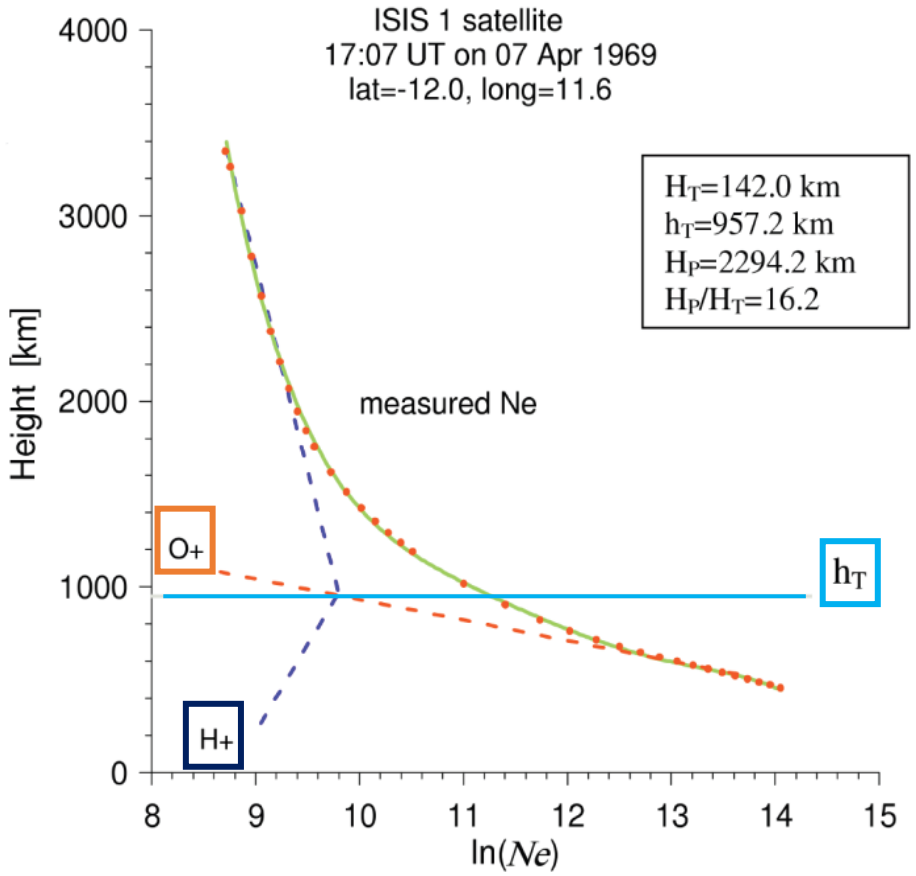
- **Autoscaling inaccuracies** in ionosonde parameters.
- **Simplified bottomside Ne representation**.

DISPEC introduces **new methodologies** for a **more accurate and robust Ne reconstruction**, especially under disturbed conditions.

Methodology: TaD inputs and assumptions

TaD Model Basis (starting point for DISPEC developments)

- Peak Height specification: foF2 and hmF2 extracted from ionograms
- Topside specification:
  - O^+ topside region: a-Chapman approximation
  - H^+ plasmasphere region: exponential approximation
- scale heights H_T , H_P and the transition height h_T, O^+/H^+ , derived from extensive ISIS 1-2 and Alouette datasets (1962 – 1979)



Methodology: the HyNT approach

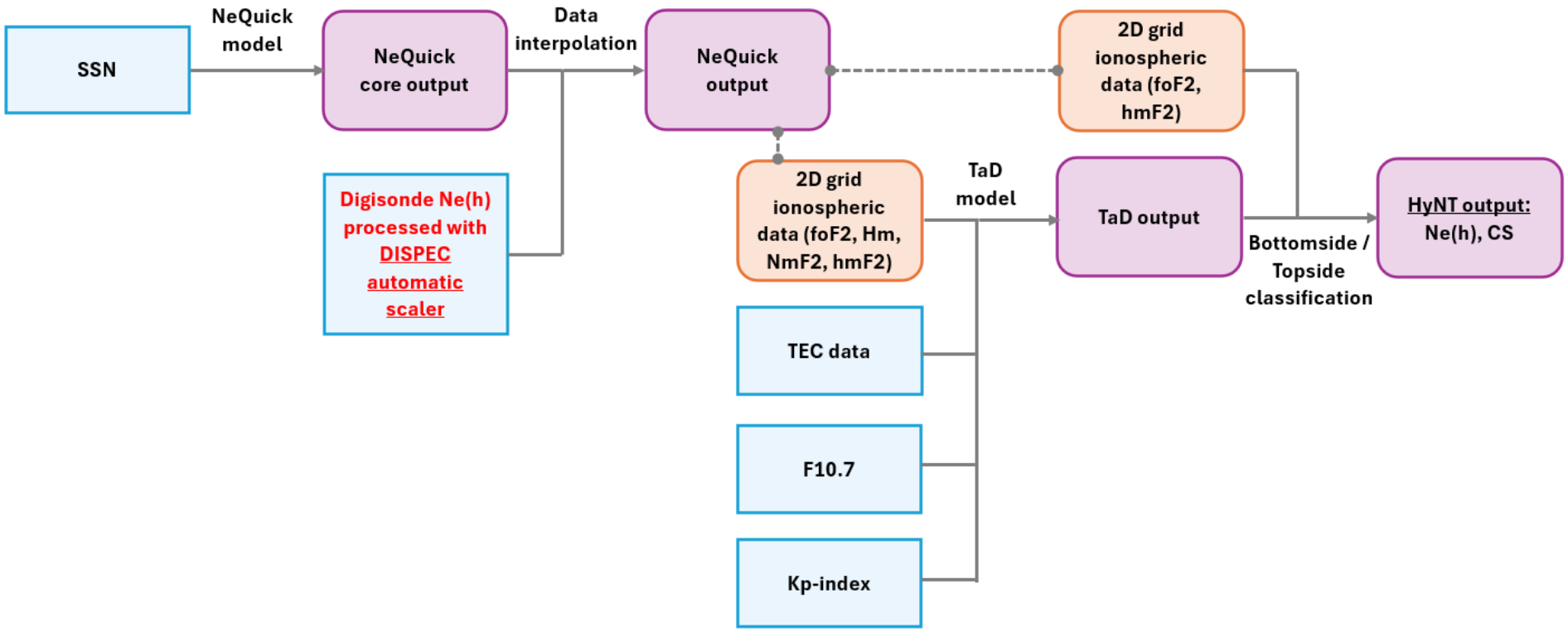
HyNT: NeQuick – TaD (HyNT) Model

Bottomside:

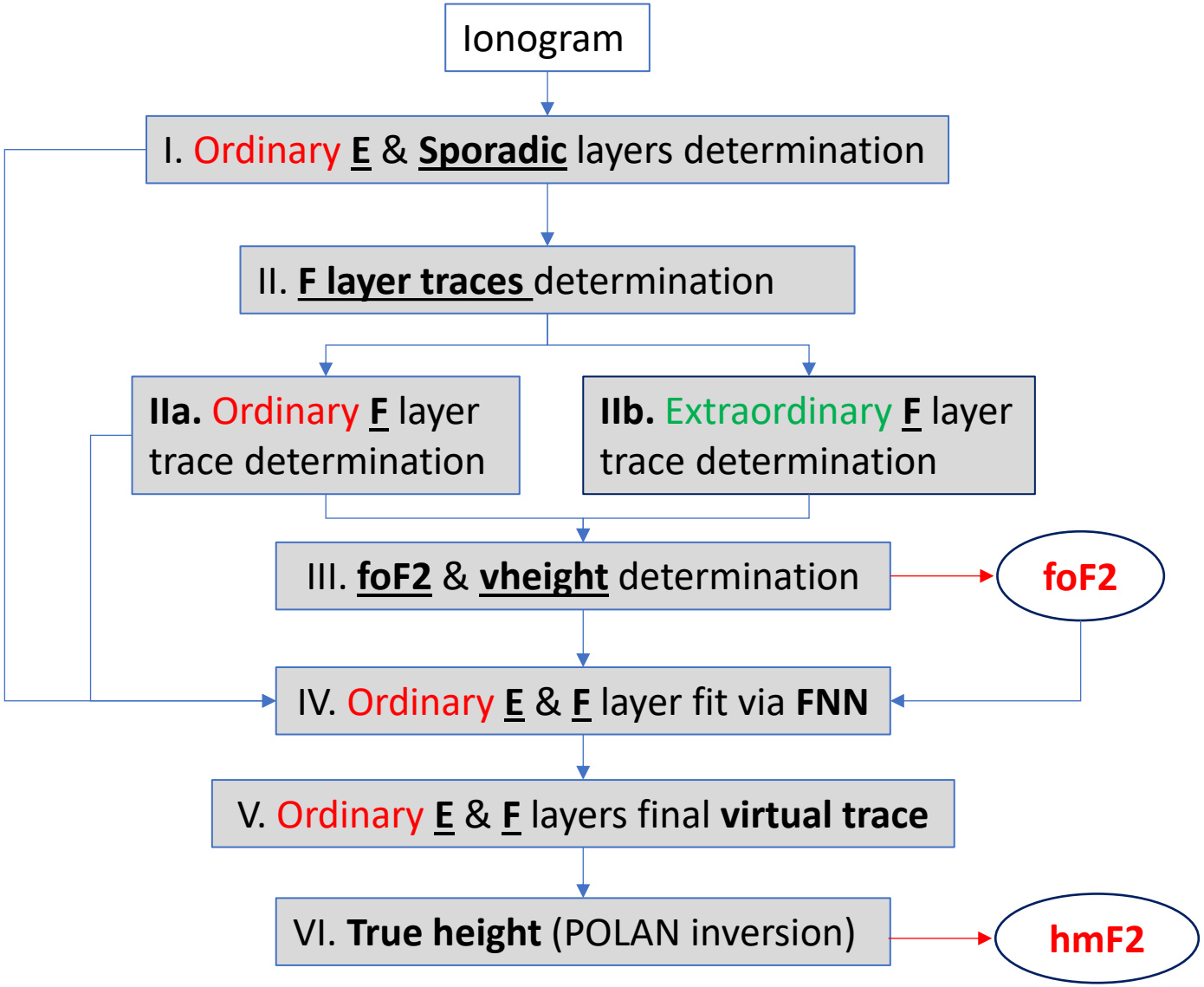
- NeQuick as background model
- Ingested Digisonde Ne Profiles processed with DISPEC scaler

Topside:

- TaD reconstruction driven by foF2, Hm, hmF2, GNSS-TEC



Methodology: DISPEC Automatic Scaler



Outputs

- foF2, hmF2
- Clean traces
- Confidence metrics

Methodology: Confidence Metrics

DISPEC scaler assigns a confidence score by detecting:

Spread F

Sporadic E layer

Multiple Reflections

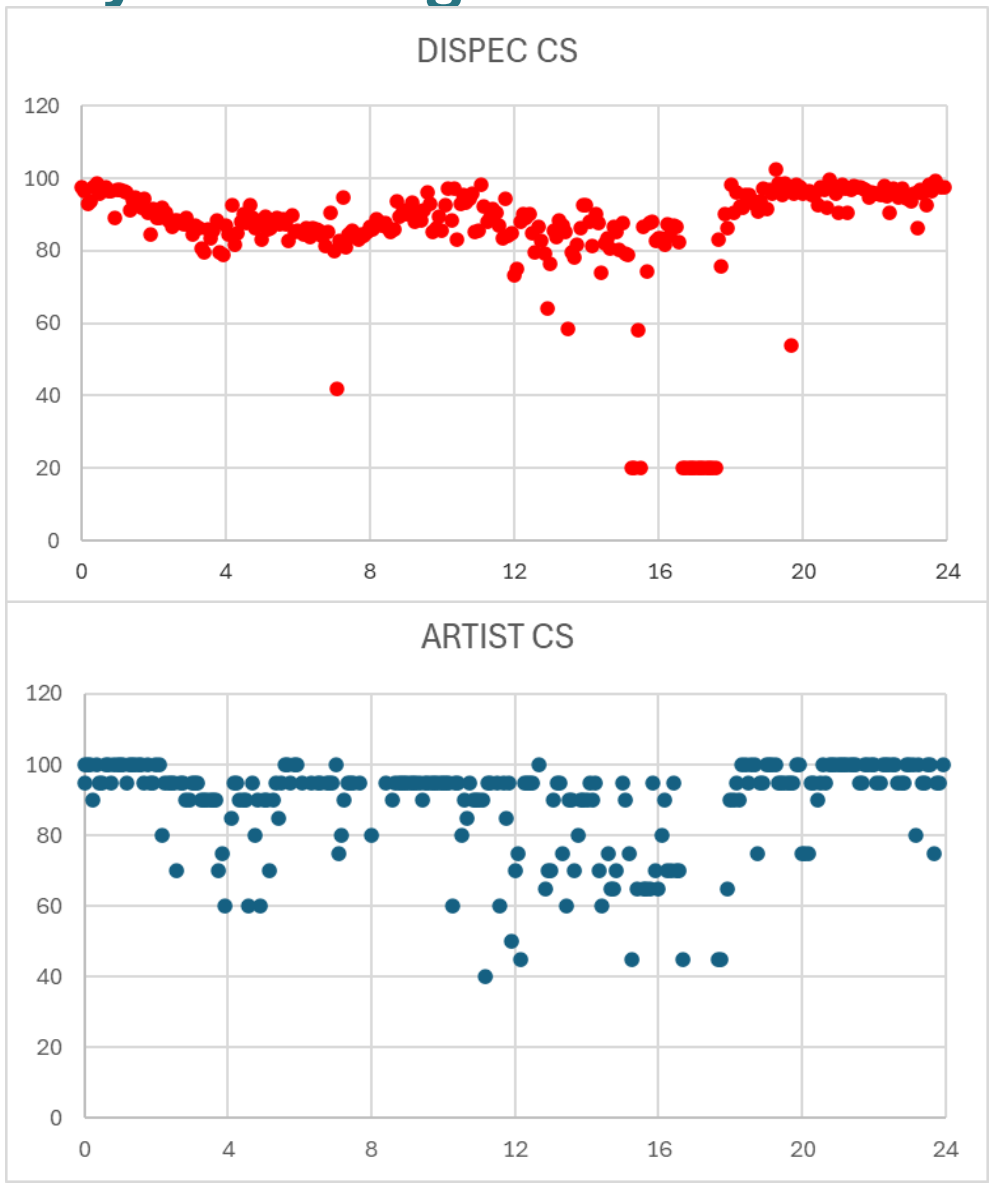
foF2 and fxF2 mismatch

O/X cusp not unique

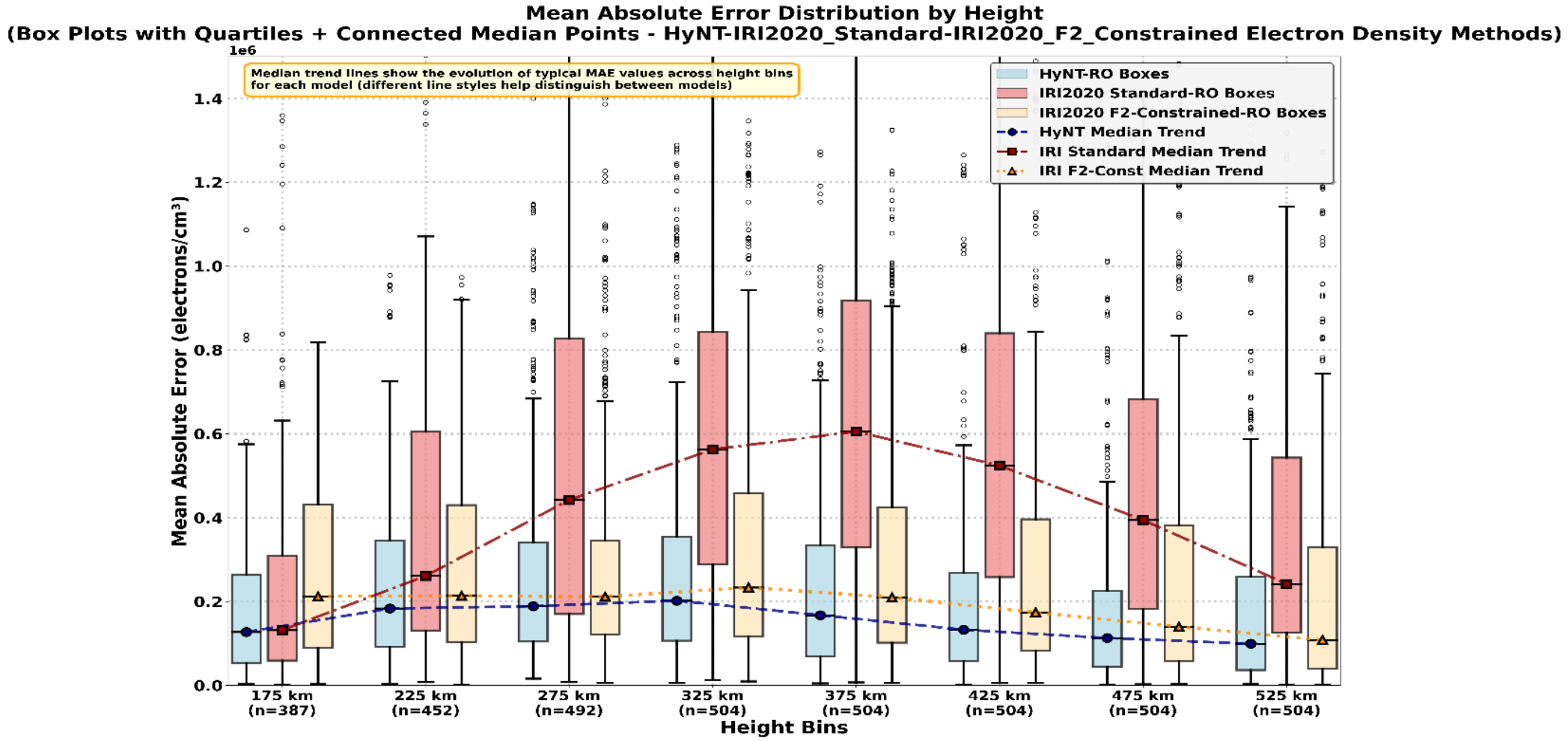
Interference

Satellite traces

Noise (individual points) and interferences (vertical clusters)



Methodology: Validation of HyNT vs IRI and COSMIC RO



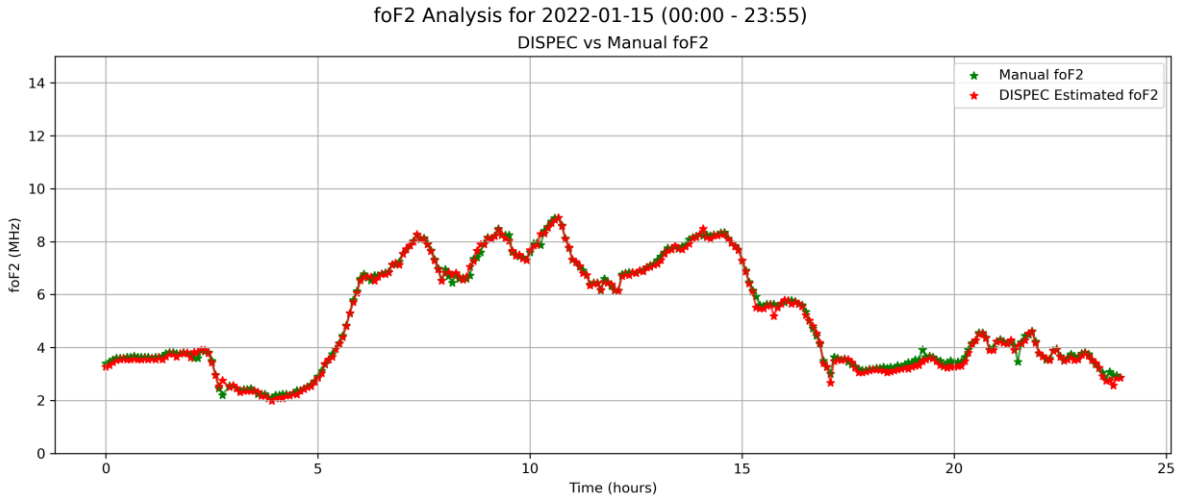
HyNT vs COSMIC-RO and IRI profiles (Time period: 2023 – 2025)

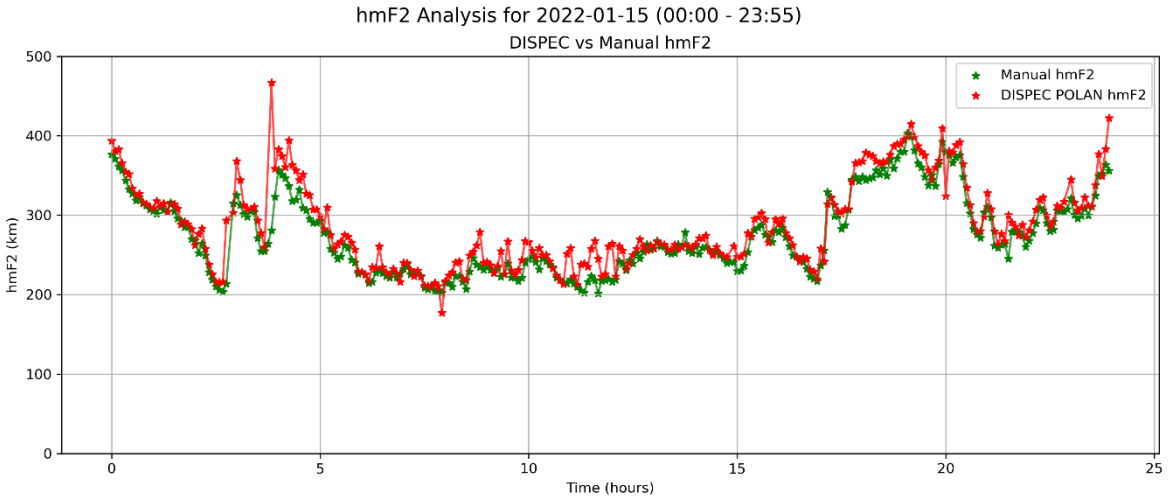
Accuracy and Uncertainty

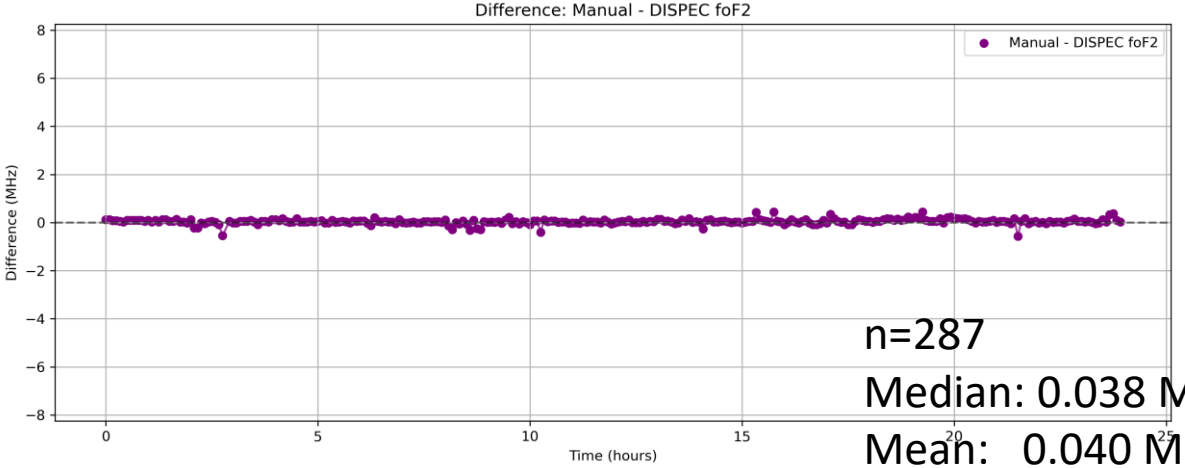
Sensitivity analysis: 1. The input data accuracy

Athens Digisonde AT138

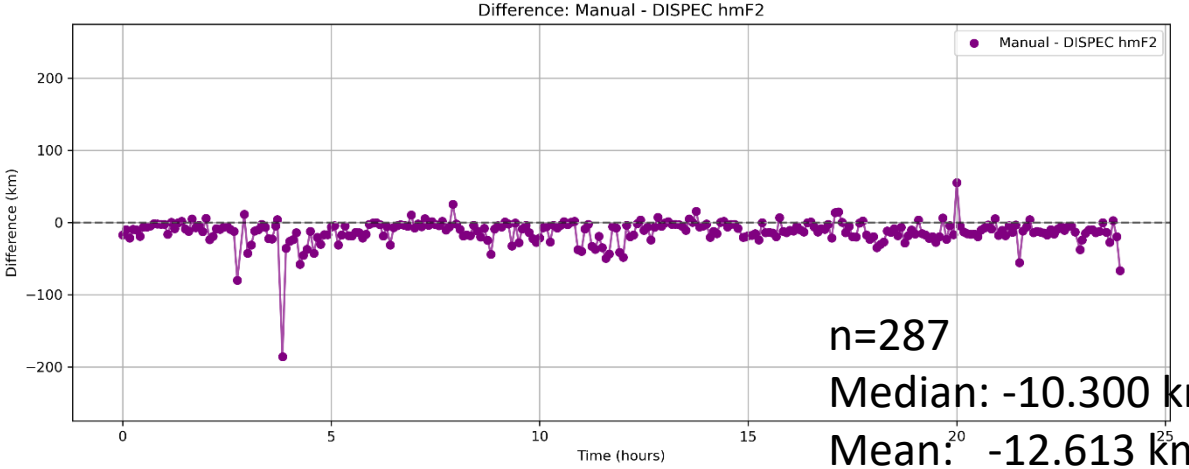
DISPEC vs Manual scaling







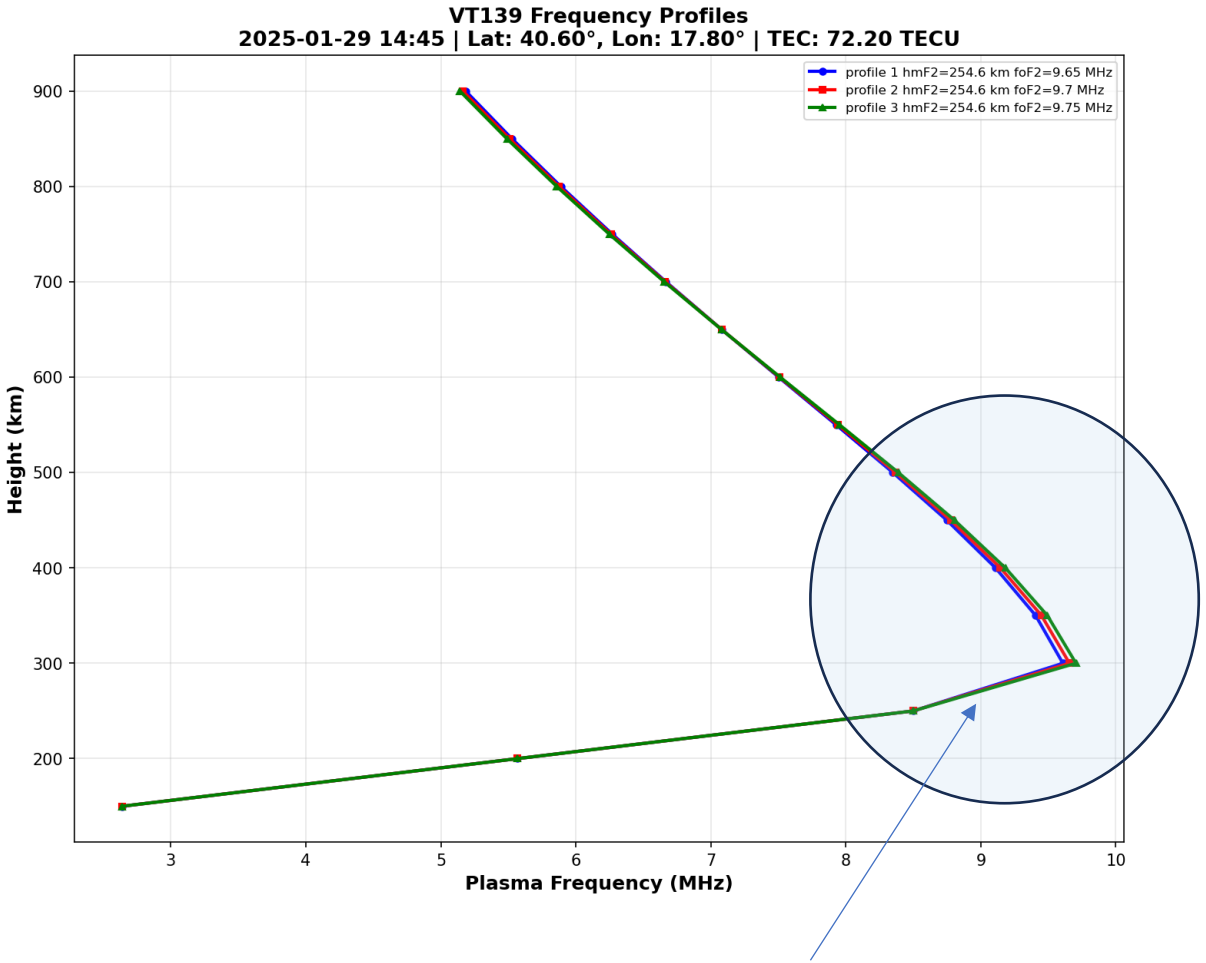
n=287
Median: 0.038 MHz
Mean: 0.040 MHz
Std: 0.110 MHz

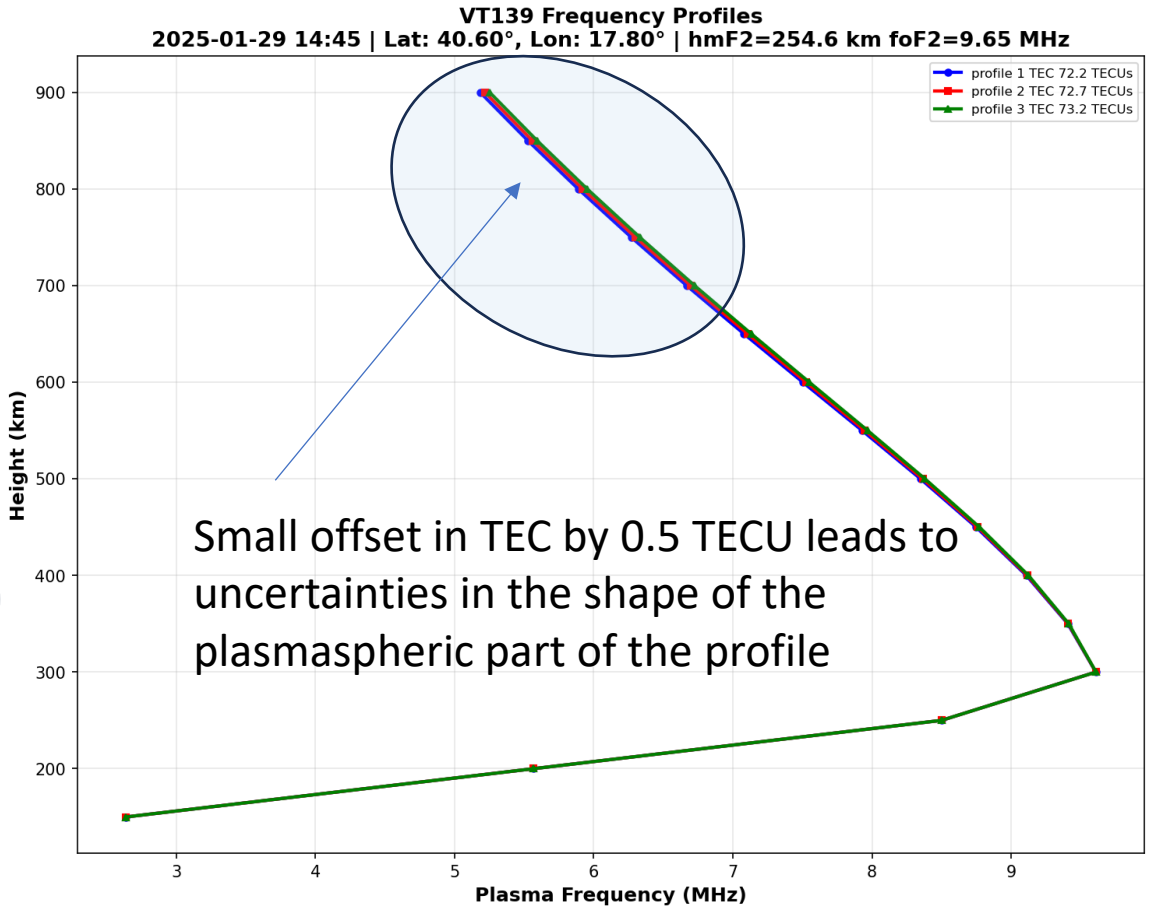


n=287
Median: -10.300 km
Mean: -12.613 km
Std: 17.231 km

Accuracy and Uncertainty

Sensitivity analysis: 2. Error propagation





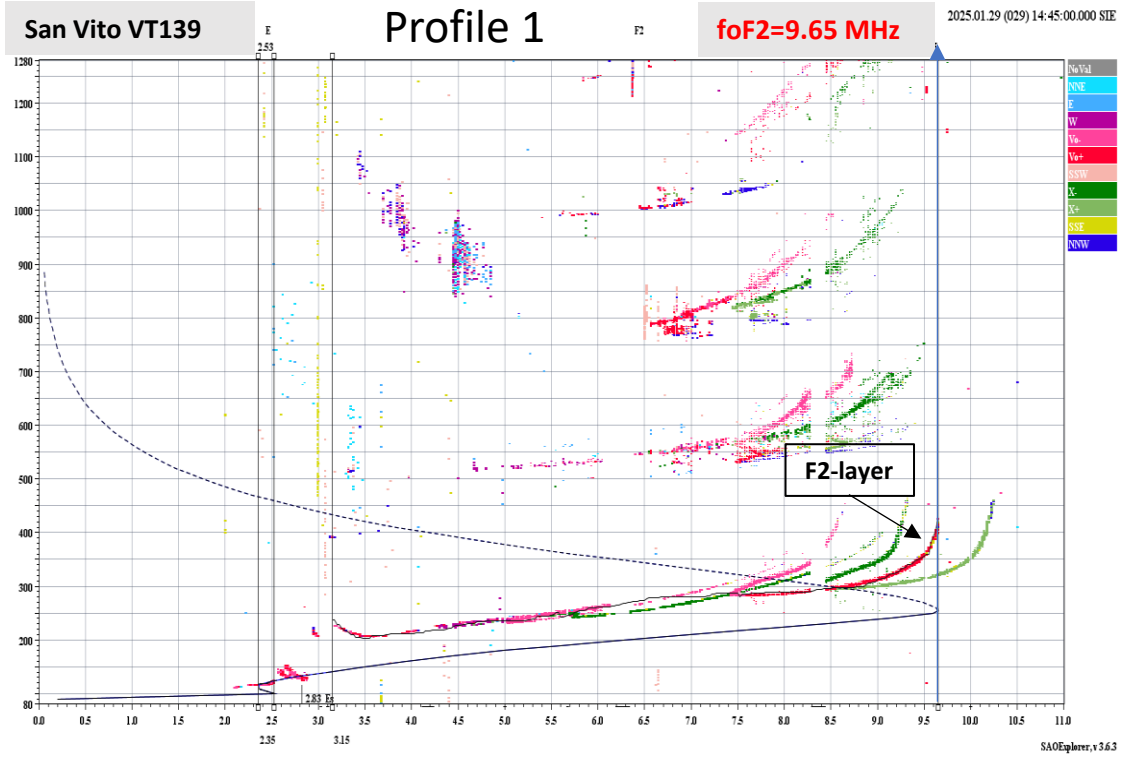
Small offset in foF2 by 0.05 MHz leads to uncertainties in the F-layer shape (bottomside + topside)

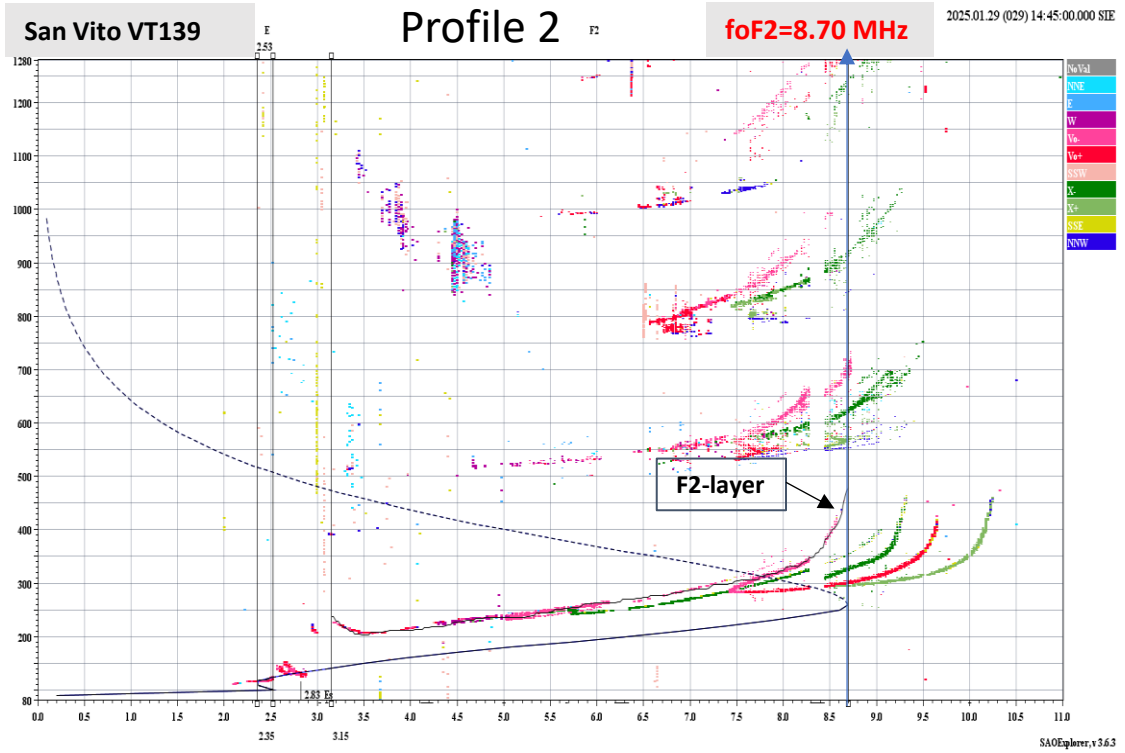
Demonstrated value: MSTID Case

Impact of Autoscaling Ambiguity on HF Propagation

San Vito Digisonde Ionogram (14:45 UT)

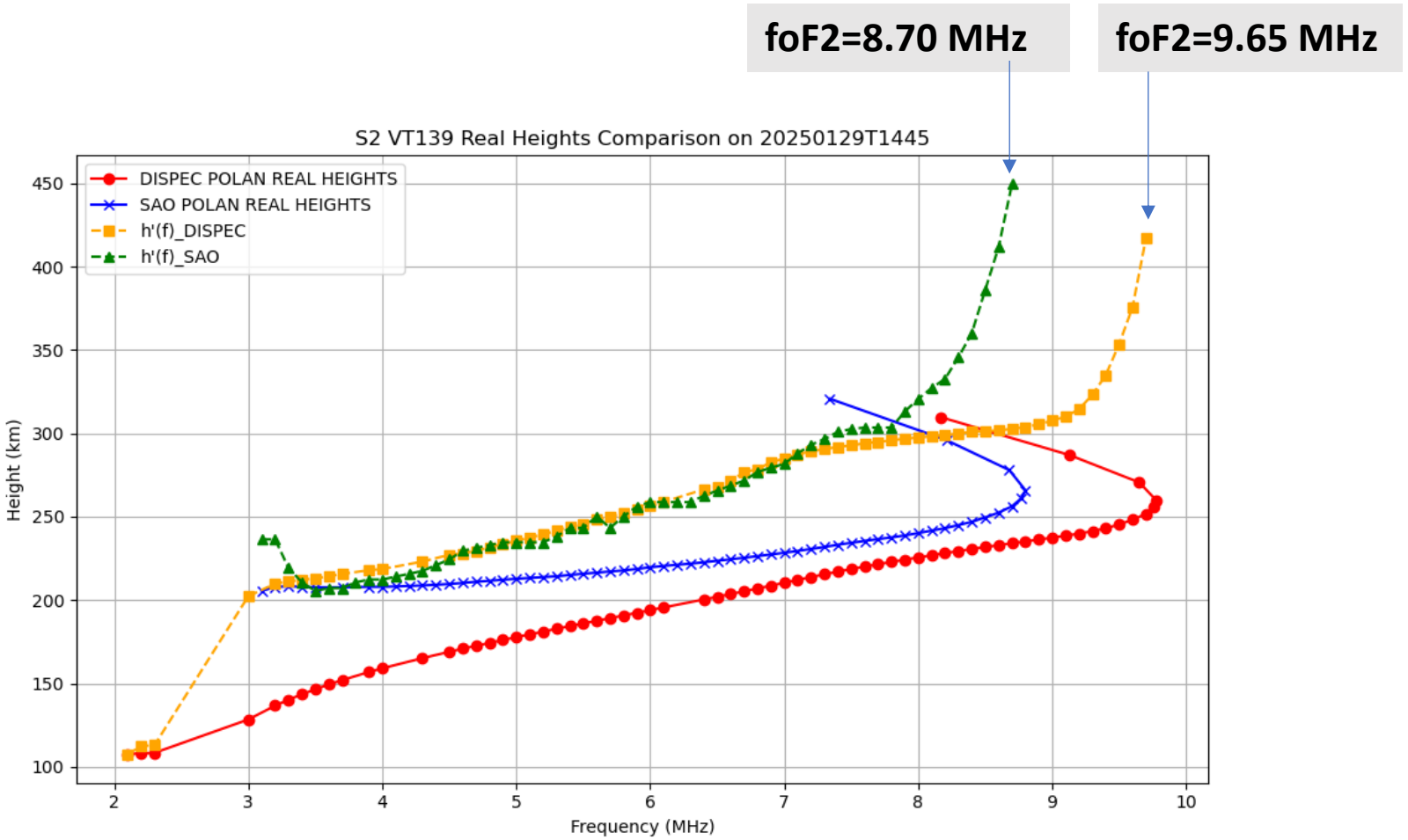
- Possible foF2 solutions: foF2=8.70MHz or foF2=9.65MHz
- Estimated uncertainty: ±1MHz





MSTID Case: POLAN Inversion Comparison

Two POLAN-derived profiles reflect ~1MHz foF2 difference
Strong sensitivity to MSTID conditions at the reflection point



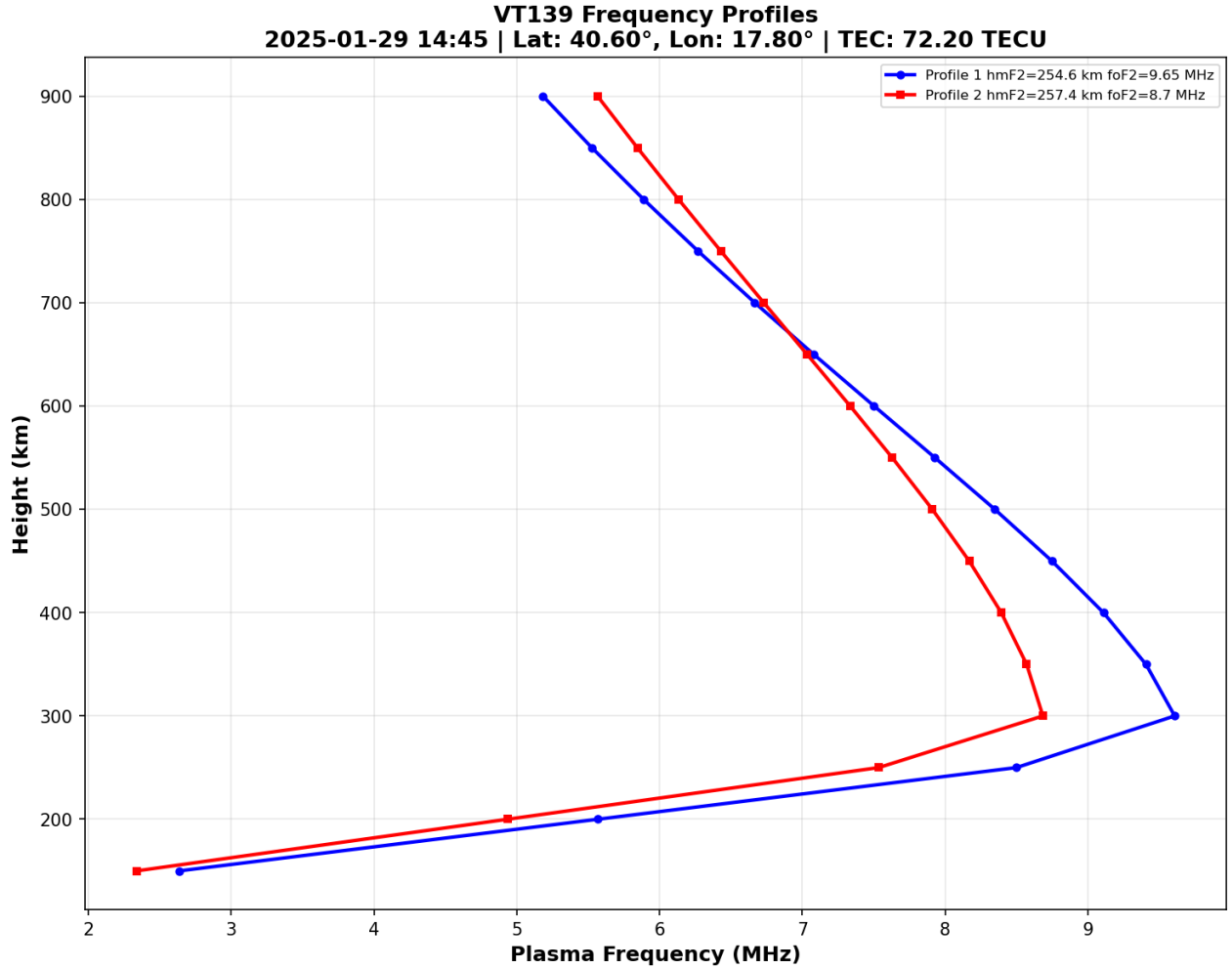
MSTID Case: HyNT Profile Sensitivity

Impact on HF Propagation Parameters

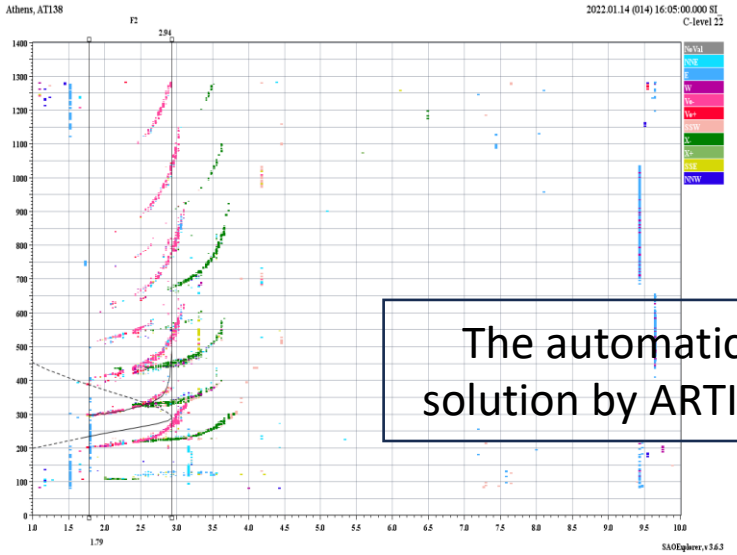
MUF_1=36 MHz → MUF_2=40 MHz
FOT_1=31 MHz → FOT_2=34 MHz

A ~1 MHz foF2 shift creates large operational consequences.

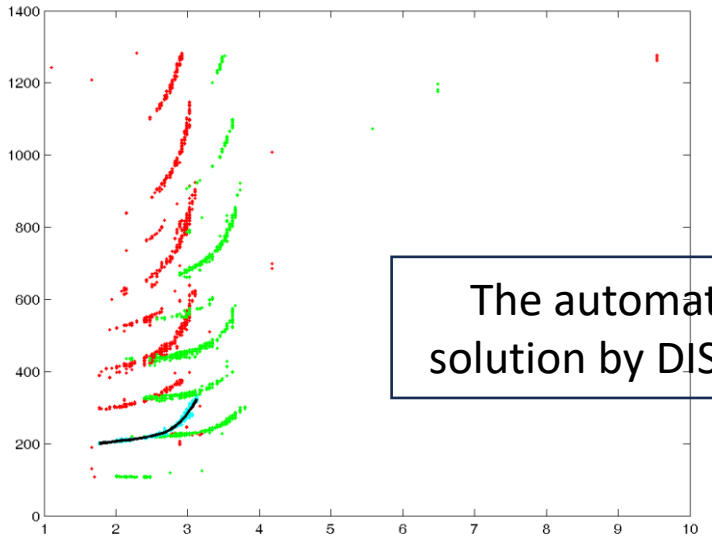
HyNT reduces sensitivity by providing consistent, confidence-weighted inputs.



Demonstrated value: multiple reflection case



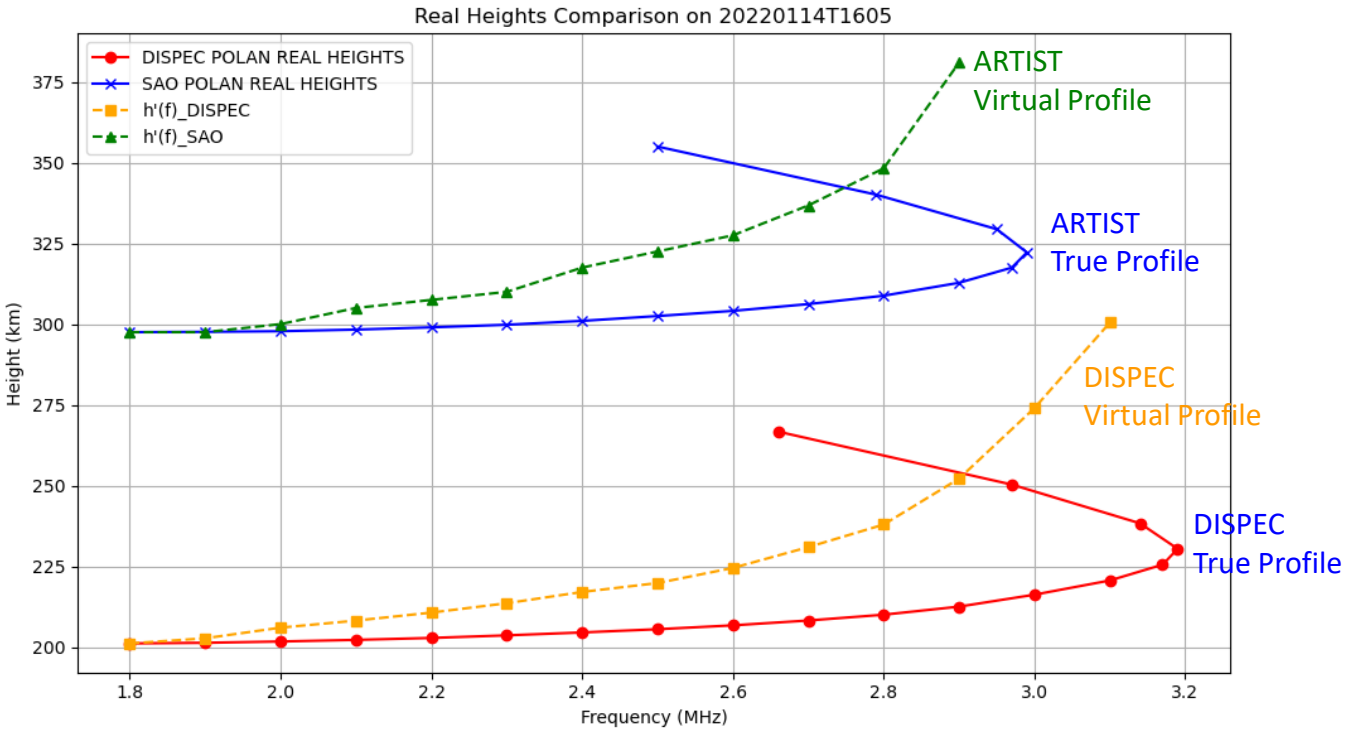
The automatic solution by ARTIST



The automatic solution by DISPEC

ARTIST solution: hmF2 = 322 km, foF2 = 2.97 MHz

DISPEC solution: hmF2 = 230 km, foF2 = 3.18 MHz



Proposed High-Level Data Products

1. **Ne(h) profiles** from DISPEC/POLAN and from ARTIST/NHPC
   - For user selected Digisonde locations and time stamps
   - With associated Confidence Scores

2. **Clean time series** of foF2, hmF2 – combines ARTIST and DISPEC results based on the highest confidence score.
   - For user selected Digisonde locations and time intervals
   - With associated Confidence Scores

Conclusions and outlook

- **DISPEC-enhanced autoscaling** significantly improves reliability of ionospheric characteristics under disturbed or complex conditions.
- The **HyNT hybrid model (NeQuick + DISPEC + TaD)** provides a superior reconstruction of Ne profiles from the bottomside to the topside.
- Sensitivity analysis shows that uncertainty in autoscaling directly affects HF communication parameters; DISPEC reduces this vulnerability.
- HyNT demonstrates **improved performance** during MSTIDs, storms, and multipath reflections, offering more effective HF propagation predictions.
- **High-Level Data Products** with confidence scores support real-time quality assessment.
- **DISPEC demonstrator** provides open access to the HyNT results; further improvements are under development, especially to validate the model performance at low and high latitude regions.

Thank you for your attention!

WEB: https://dispec.eu

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