Performance analysis of GNSS-derived VTEC ingestion into IRI2012

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Outline

1. Introduction
2. Method
3. Data Source
4. Global Statistics
5. Conclusion

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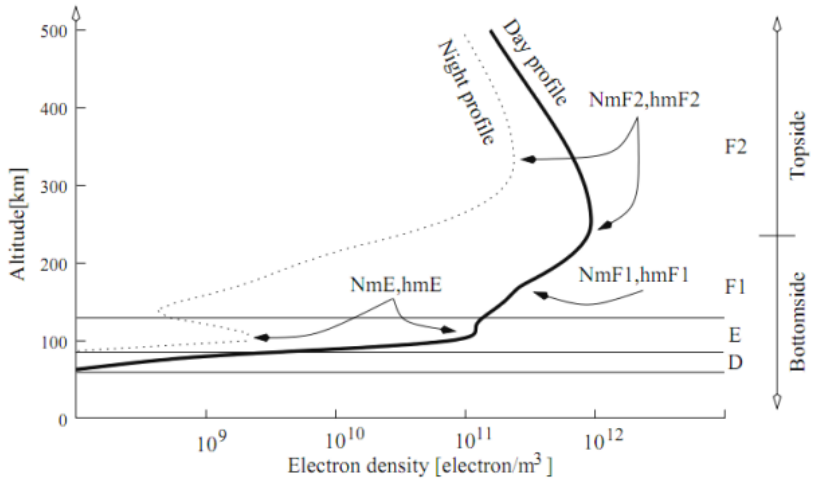
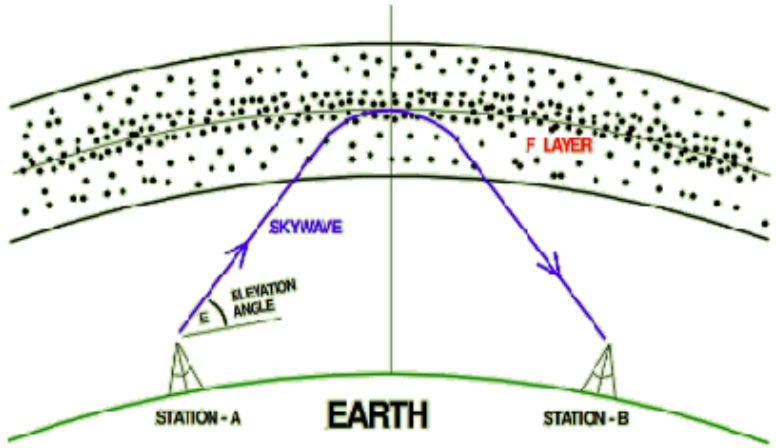
1. 1 Background

- The F2 layer is the most important region of the ionosphere.
- The key parameters of the F2 layer are mainly NmF2(or foF2) and hmF2.

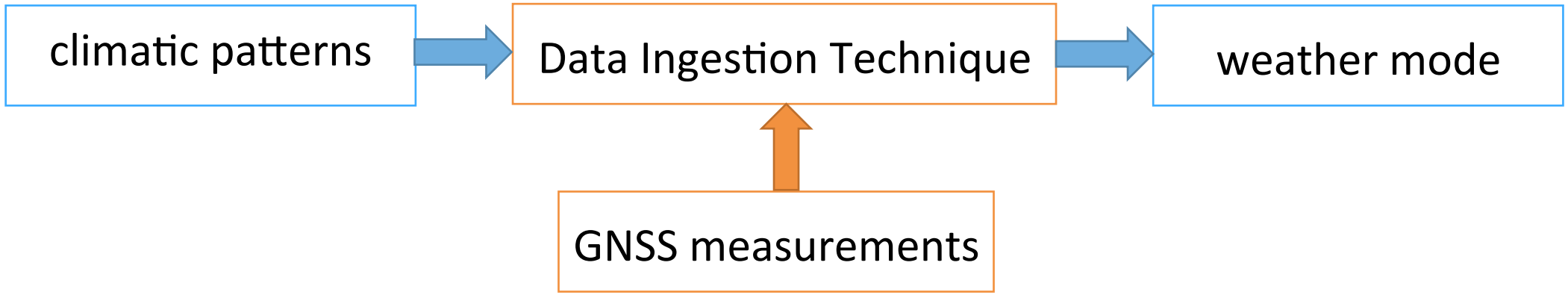


(Garcia-Fernandez, 2004)



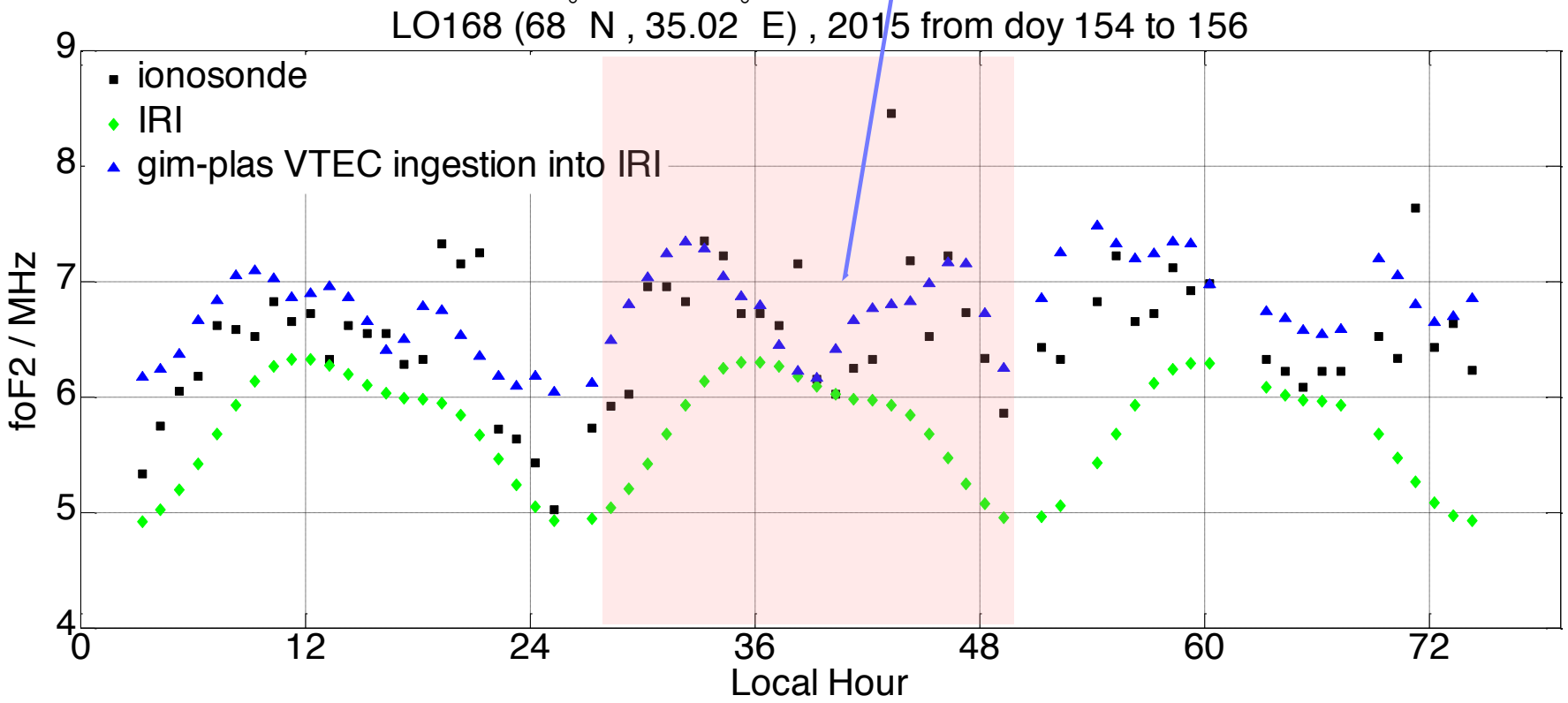
1.1 Background

- Demand:
  - The instantaneous maps of foF2 and hmF2 ⟷ HF communication & SW research
- Status:
  - IRI (International Reference Ionosphere):



1.2 ionospheric weather

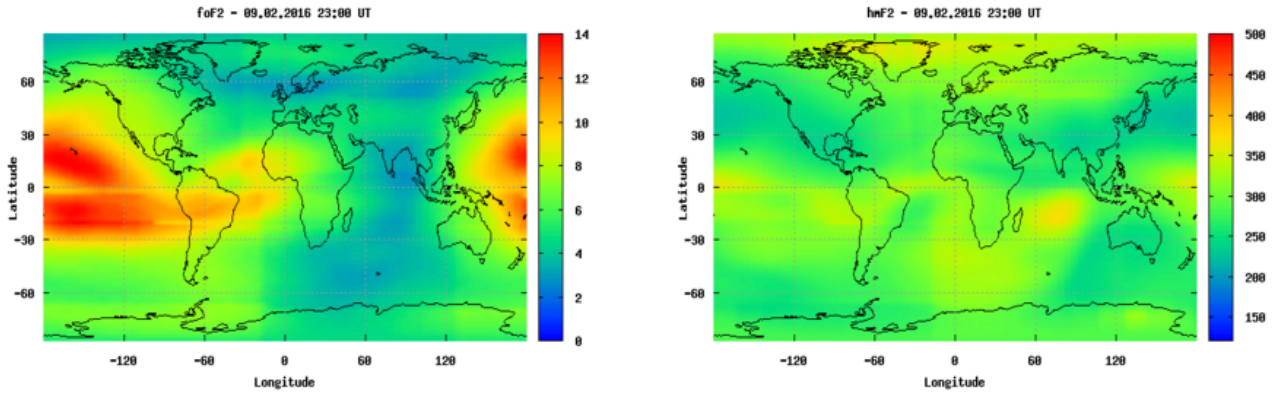
Reproduce the noon bite-out phenomenon



1.3 IZMIRAN product

- Instantaneous maps of the F2 layer peak parameters derived from GIM-TEC maps with **IRI-Plas** (International Reference Ionosphere Extended to Plasmasphere) code
- Output foF2, hmF2, TEC, W-index in IONEX format

foF2 hmF2



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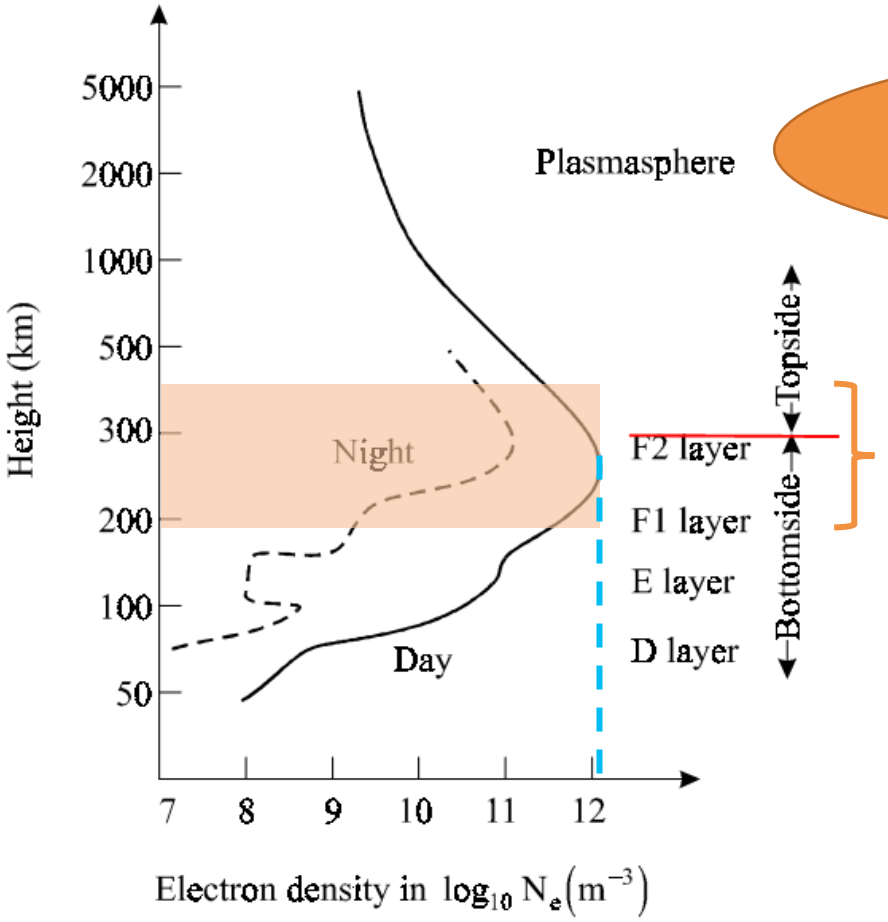
2. 1 Principle



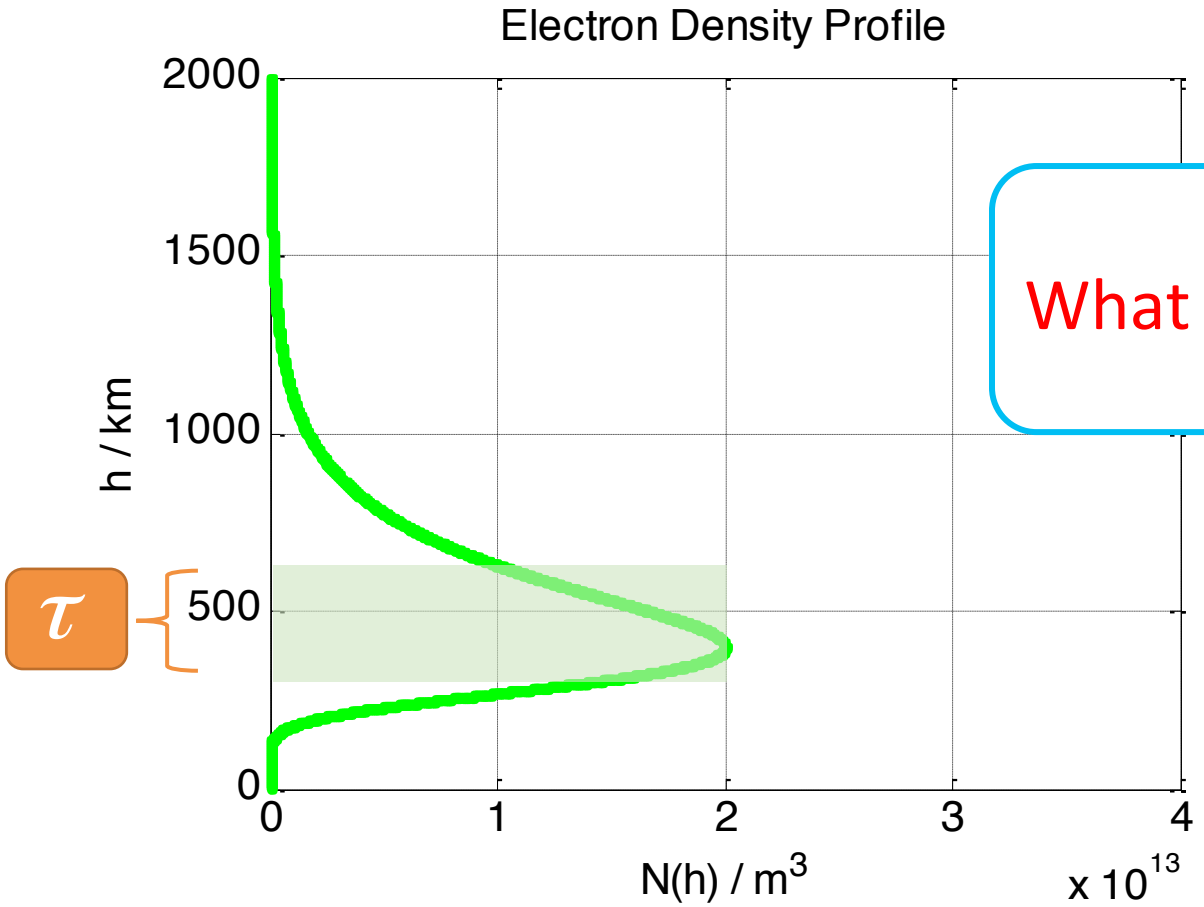
equivalent slab thickness τ

$$VTEC = NmF2 \cdot \tau$$

$$NmF2 = 1.24 \times 10^{10}\ foF2^2$$

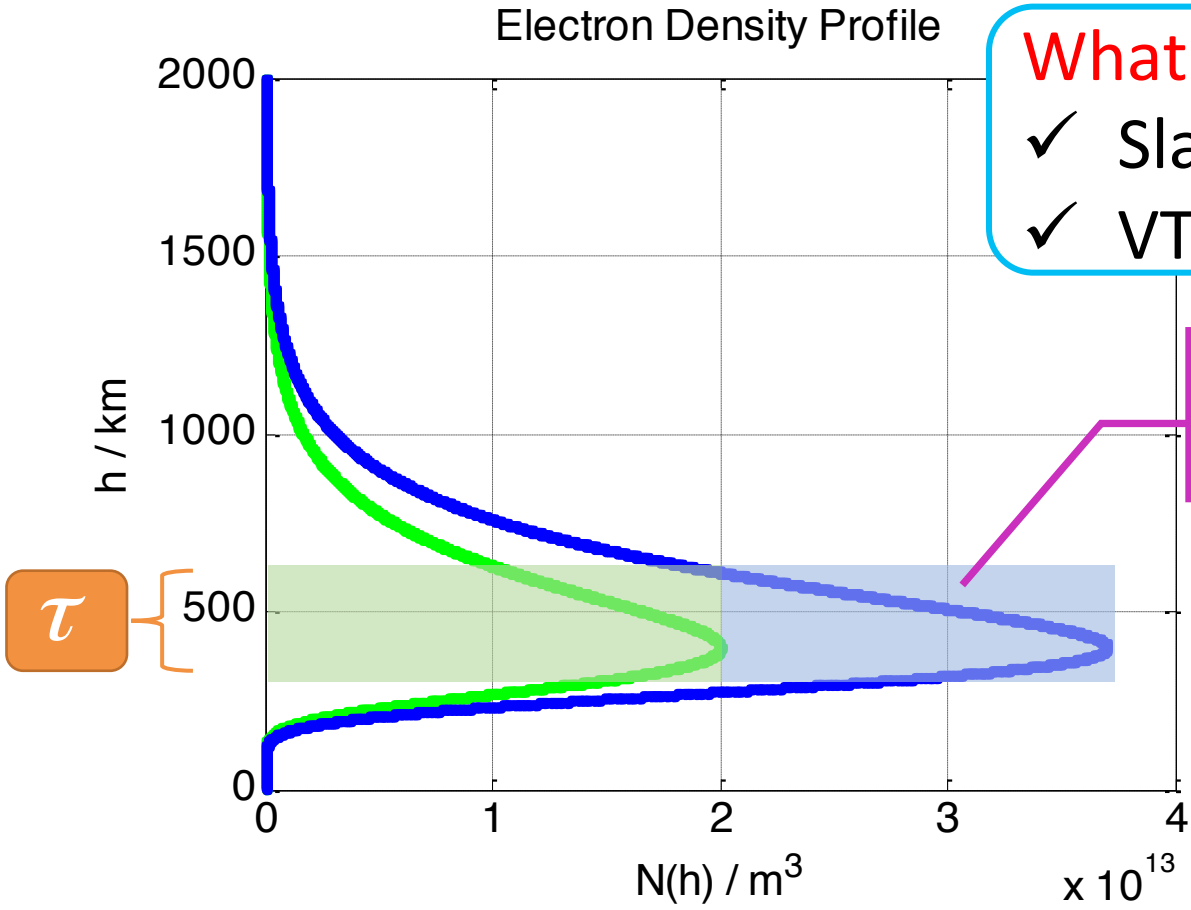
$$\frac{VTEC_{gnss}}{VTEC_{model}} = \frac{foF2^2_{gnss}}{foF2^2_{model}}$$

2. 1 Principle



What would happen if VTEC increases?

2. 1 Principle



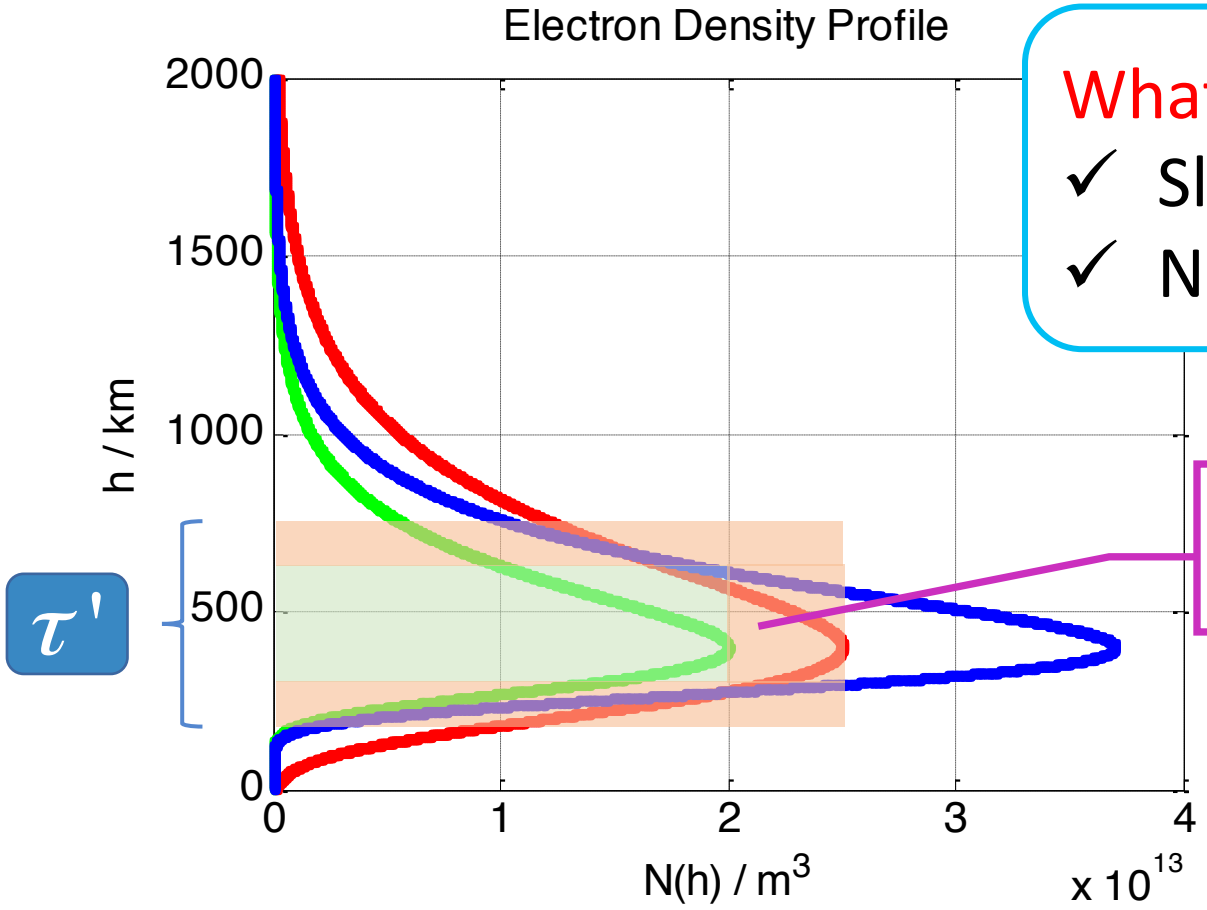
What would happen if VTEC increases?

- ✓ Slab thickness τ remains unchanged
- ✓ VTEC is proportional to NmF2($foF2^2$)

delta(VTEC)

$$\frac{VTEC_{gnss}}{VTEC_{model}} = \frac{foF2^2_{gnss}}{foF2^2_{model}}$$

2.2 WHU algorithm

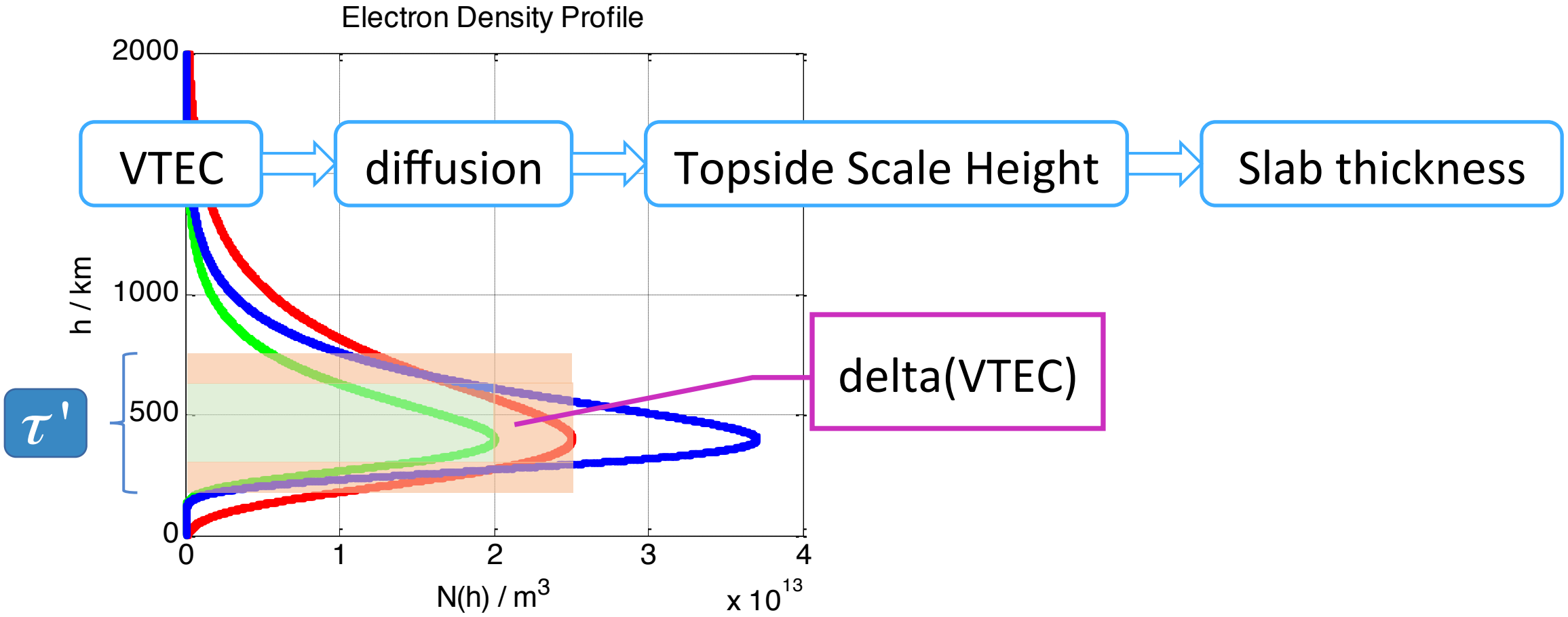


What would happen if VTEC increases?

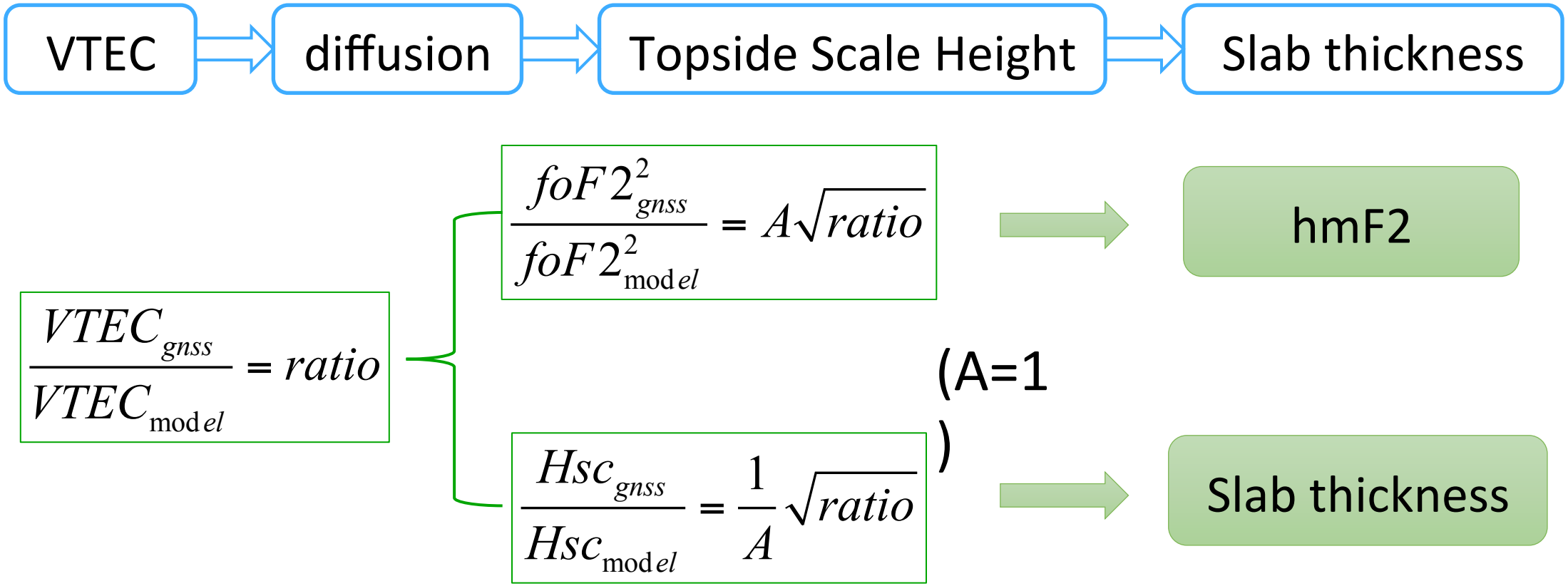
- ✓ Slab thickness τ increases
- ✓ NmF2(foF2^2) also rises

delta(VTEC)

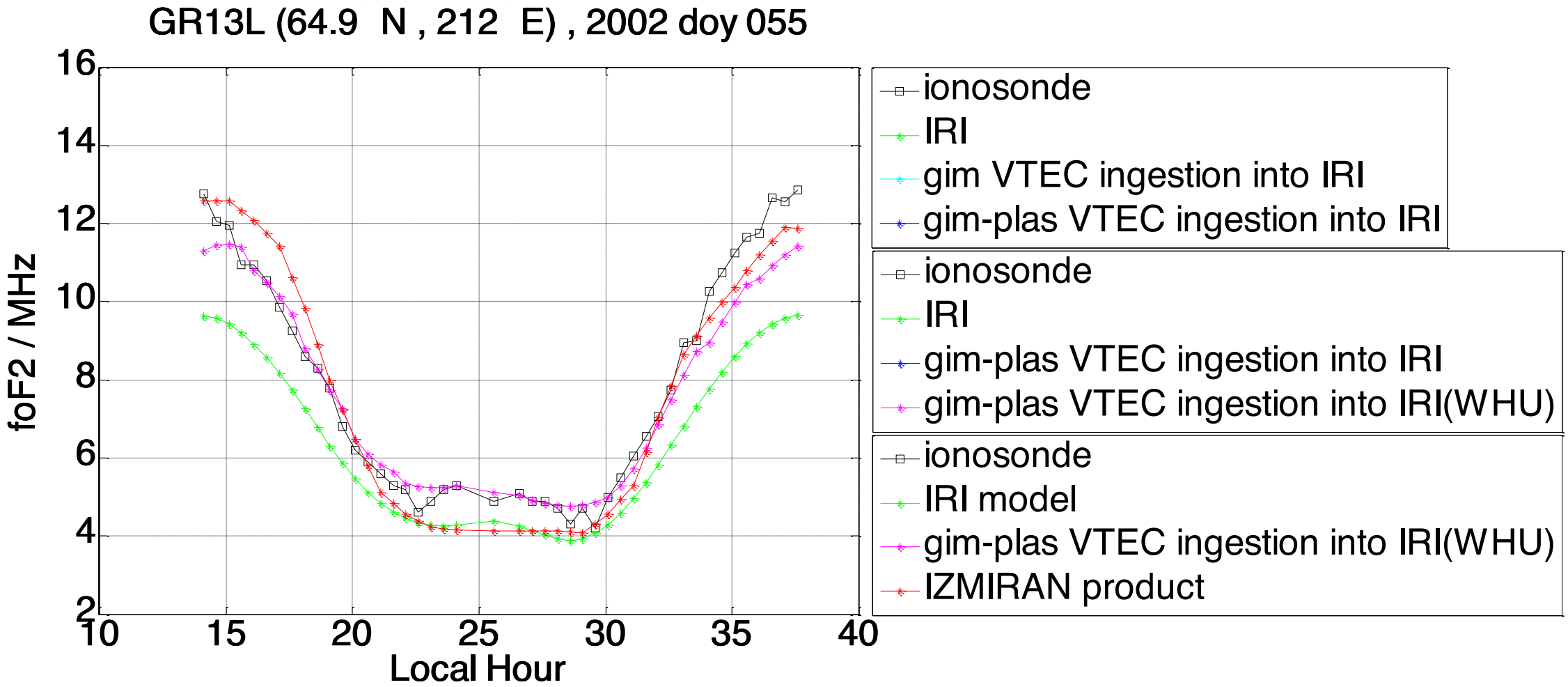
2.2 WHU algorithm



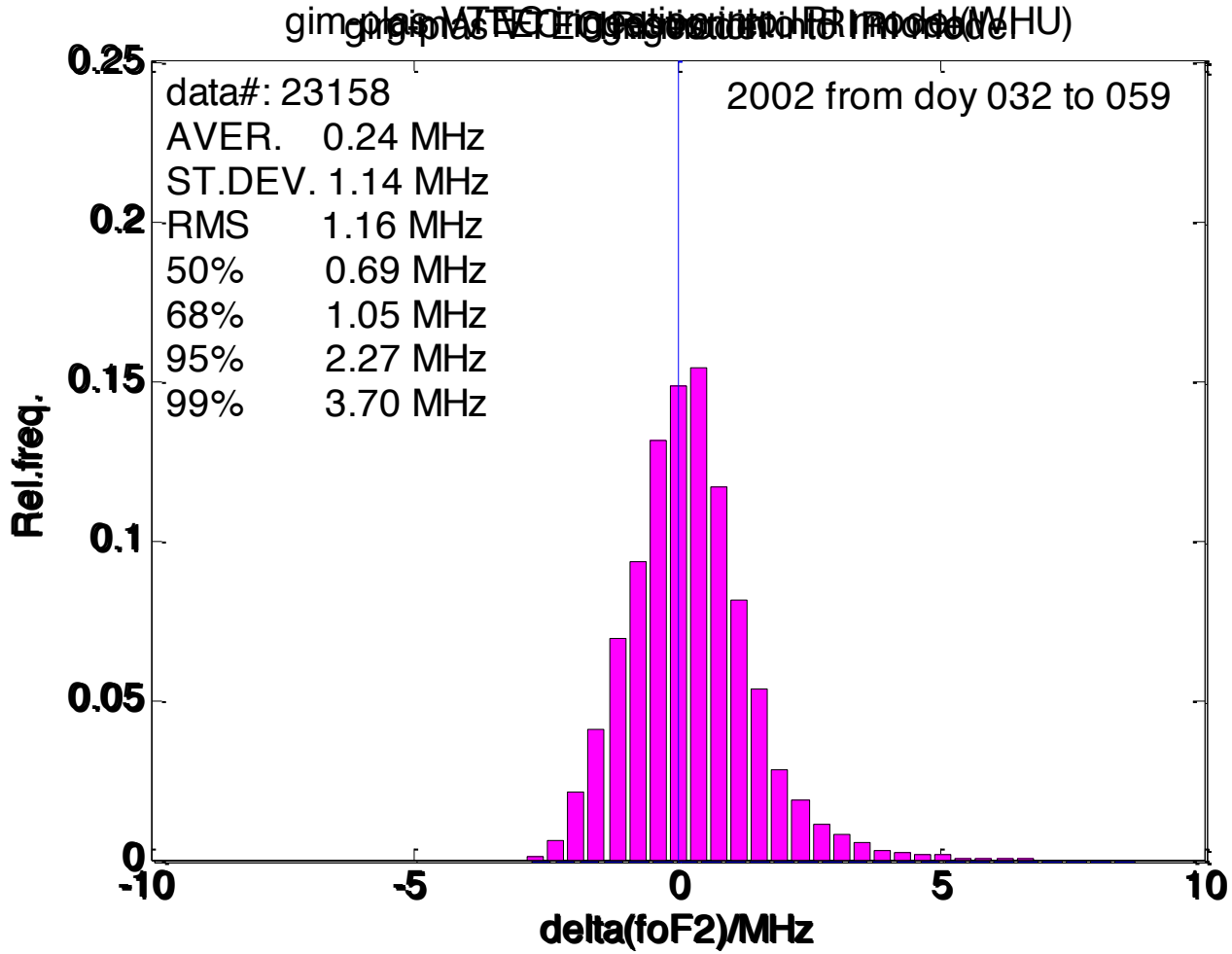
2.2 WHU algorithm



2.2 WHU algorithm



2.2 WHU algorithm



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3.1 Ingestion Data

- VTEC : CODE Global Ionosphere Map (GIM)
- Plasmaspheric Electron Content: IRI-Plas model
- SPIDR ionosonde data (SAO format) for validation
  - Although auto scaled F2 peak values are used, we remove few “outliers” after smooth processing .
  - Several ionosonde stations data with quite low quality are not used.

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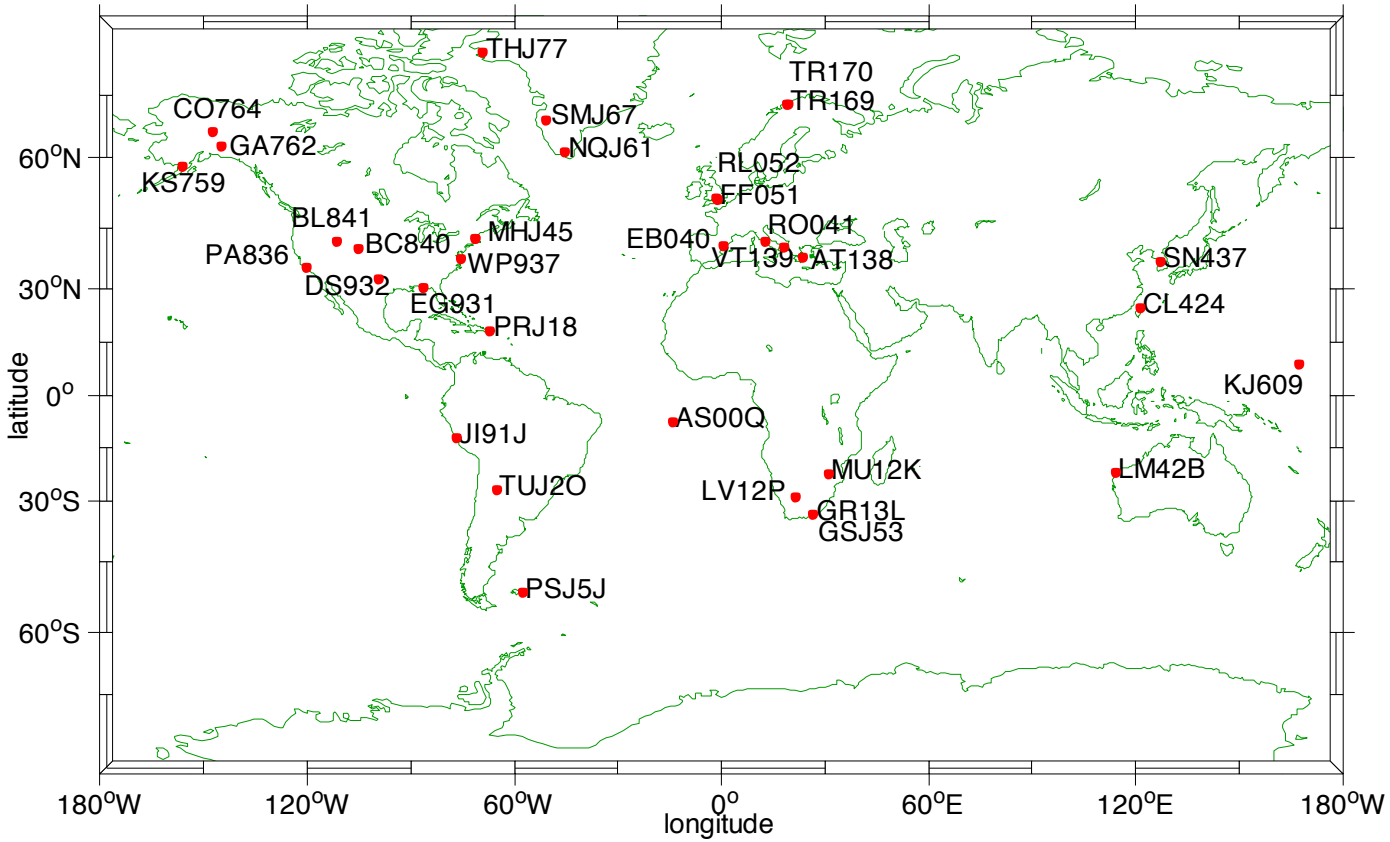
4. Global Statistics

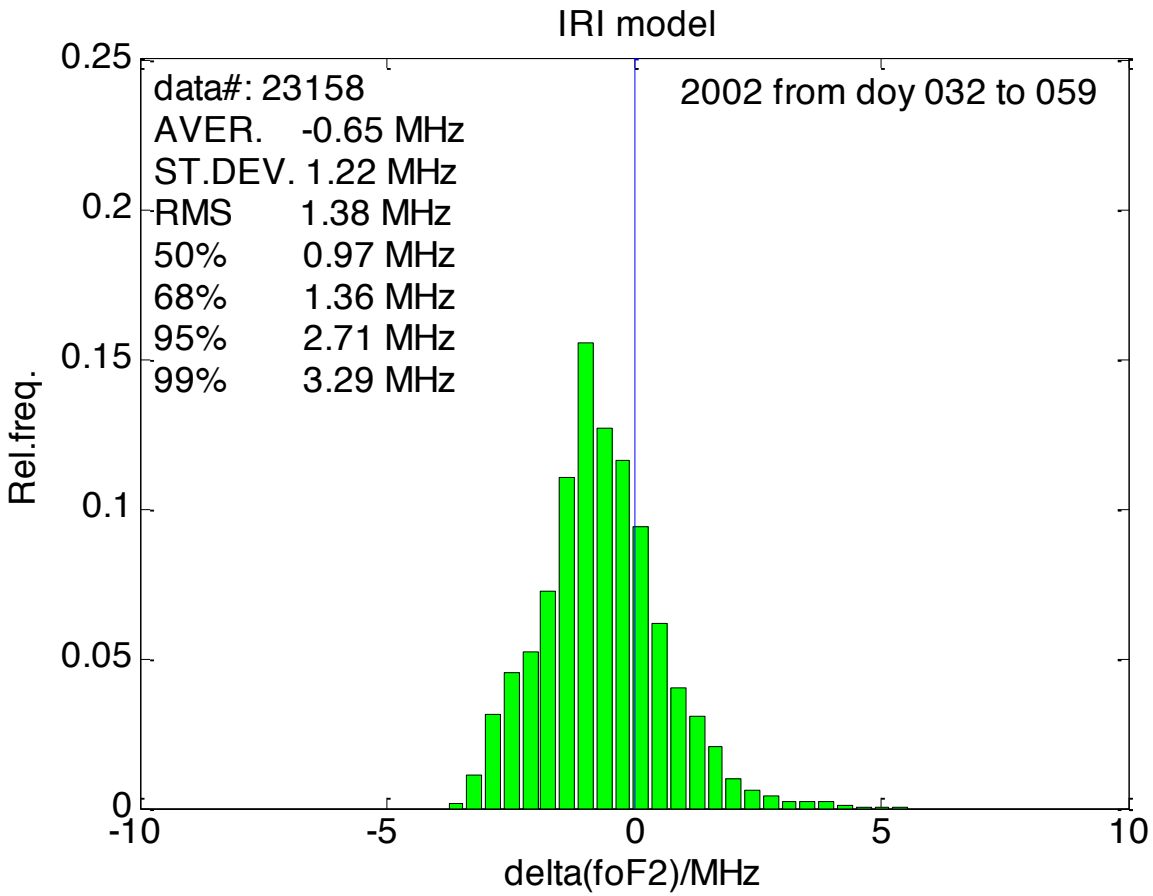
- Selected periods
  - February 2002: High Solar Activity & Quiet Geomagnetic Activity
  - October 2002: High Solar Activity & Major Storm
  - February 2006: Low Solar Activity & Quiet Geomagnetic Activity

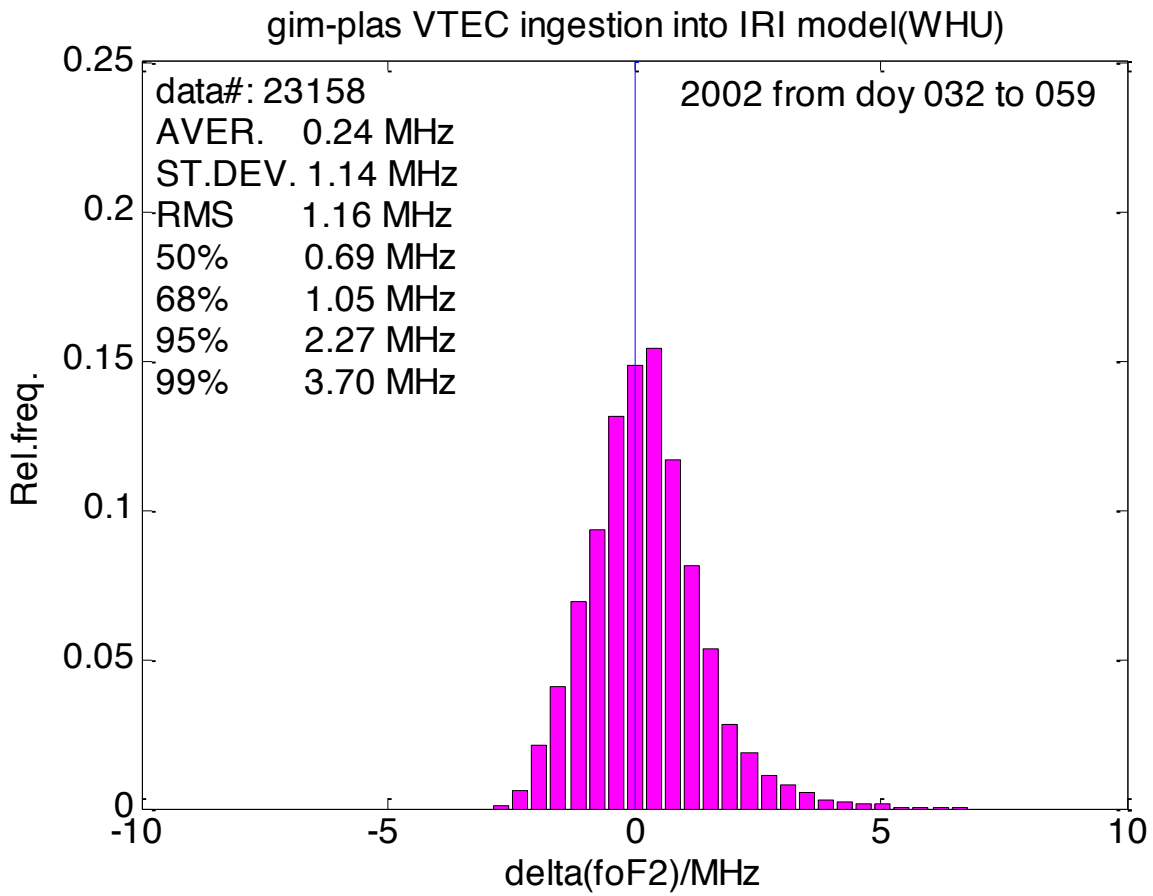
4. Global Statistics

Distribution of the ionosonde stations used in global statistics



4.1 High Solar Activity & Quiet Geomagnetic Activity



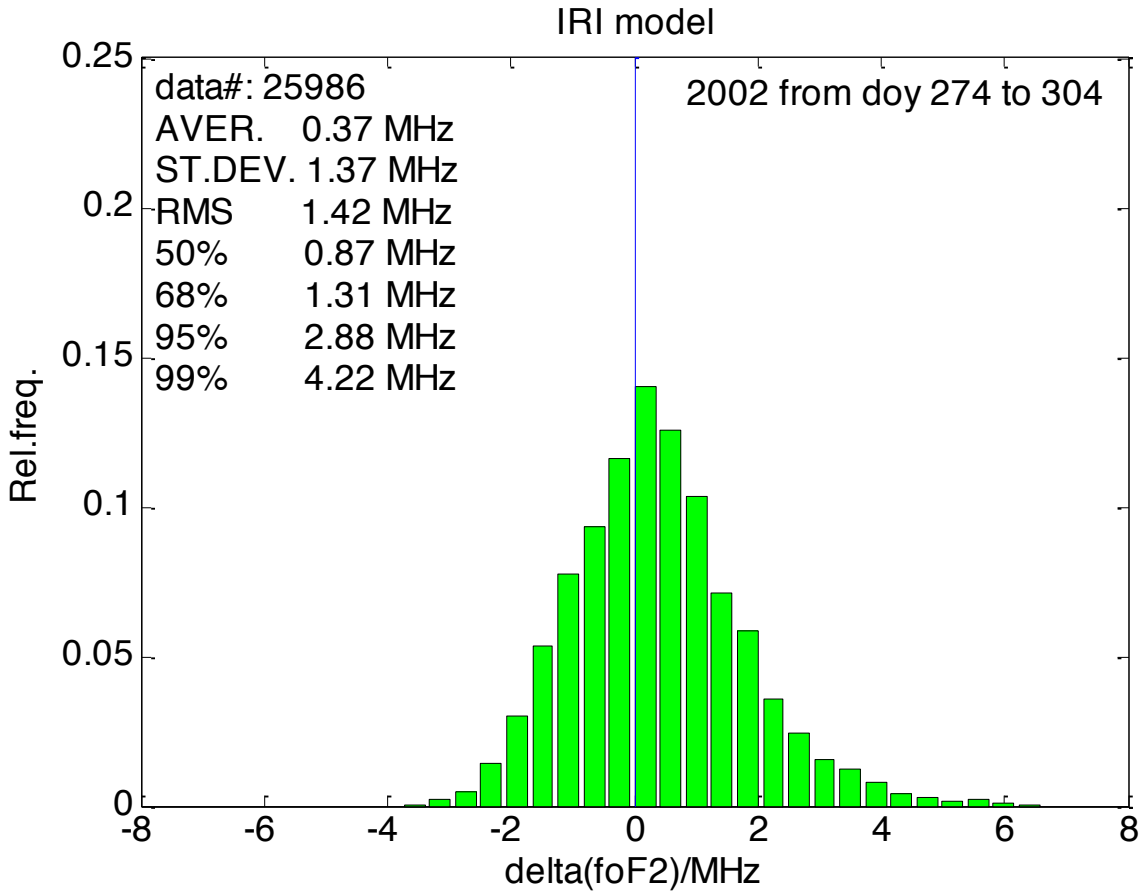


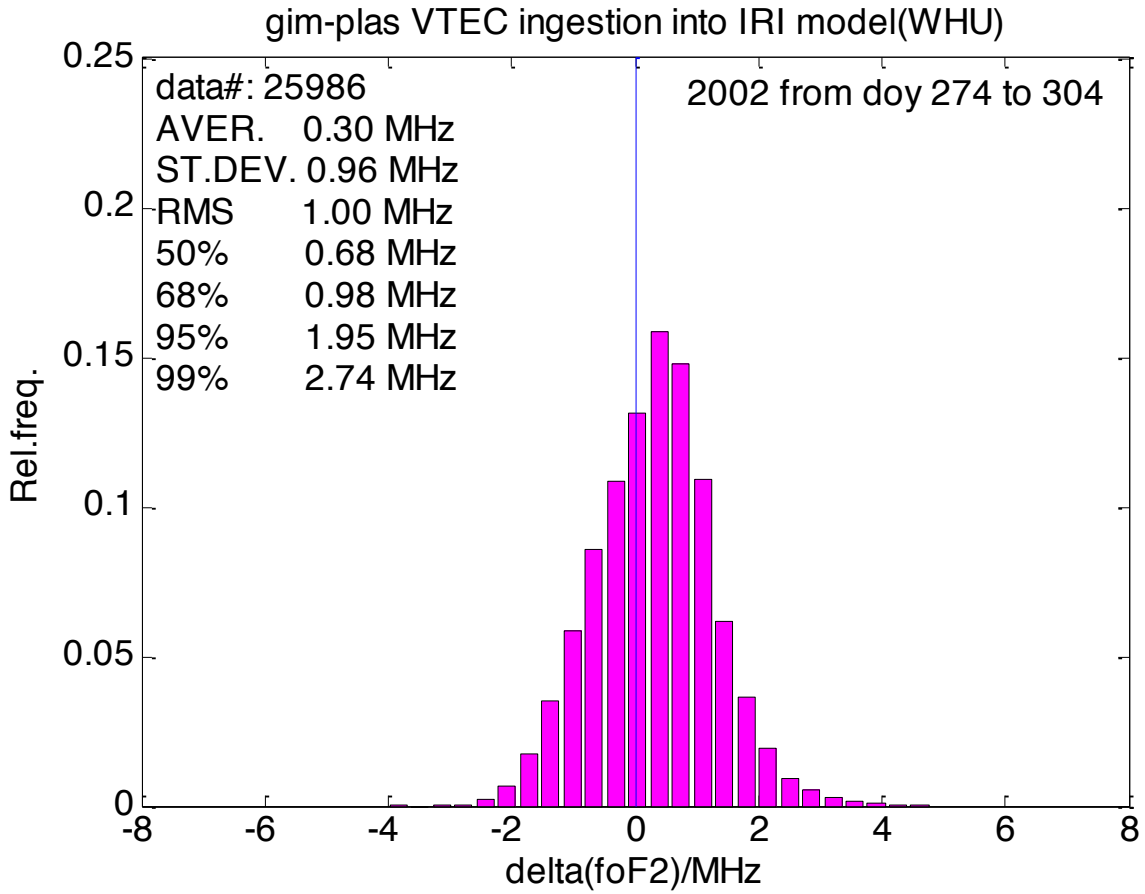
4.1 High Solar Activity & Quiet Geomagnetic Activity

February 2002: Statistics of delta(foF2) (in MHz)

	IRI2012 model	Ingested model(WHU)	IRI-Plas model	IZMIRAN product
Average	-0.65	0.24	-1.57	-0.05
St. Dev.	1.22	1.14	1.23	1.29
RMS	1.38	1.16	1.99	1.29
50%	0.97	0.69	1.62	0.73
68%	1.36	1.05	2.15	1.09
95%	2.71	2.27	3.63	2.66
99%	3.29	3.70	4.21	4.17

4.2 High Solar Activity & Major Storm



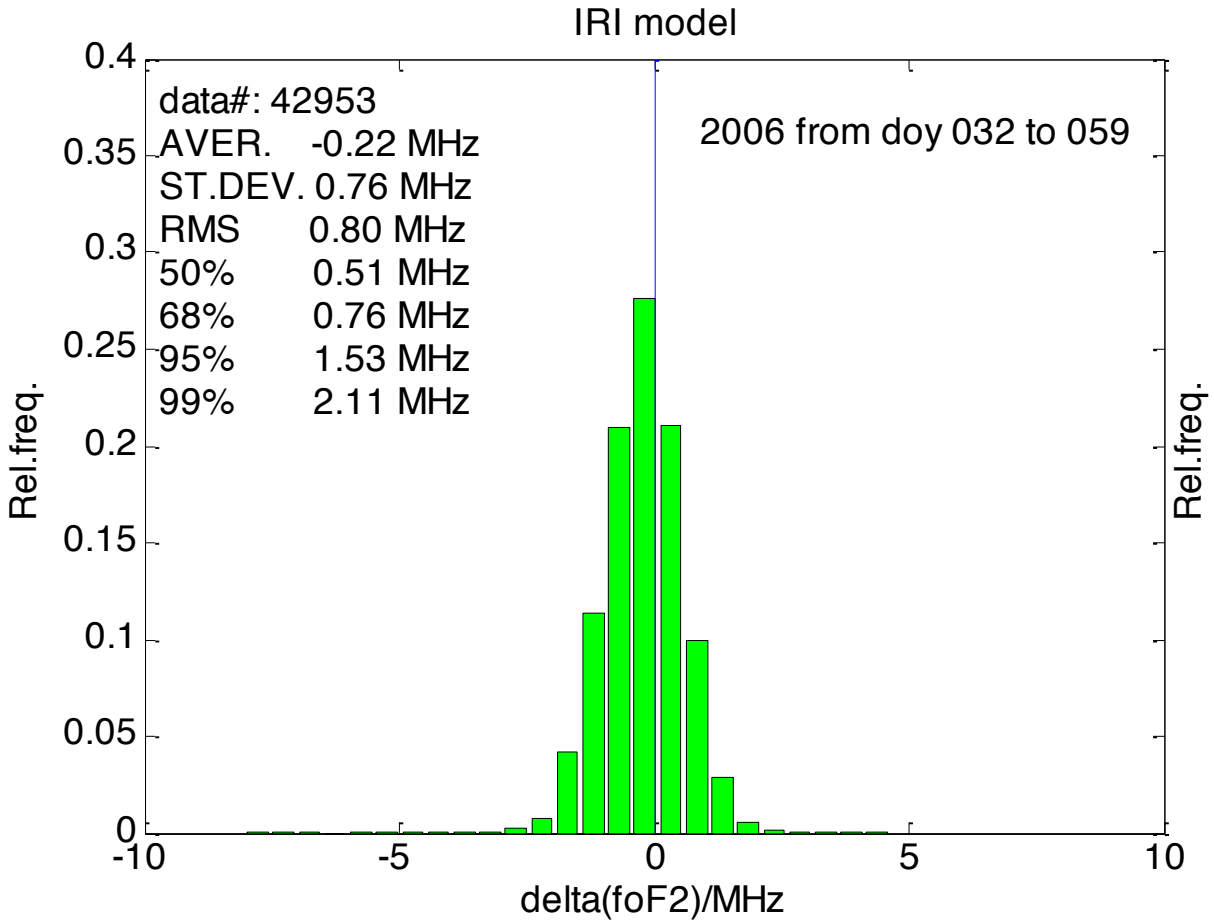


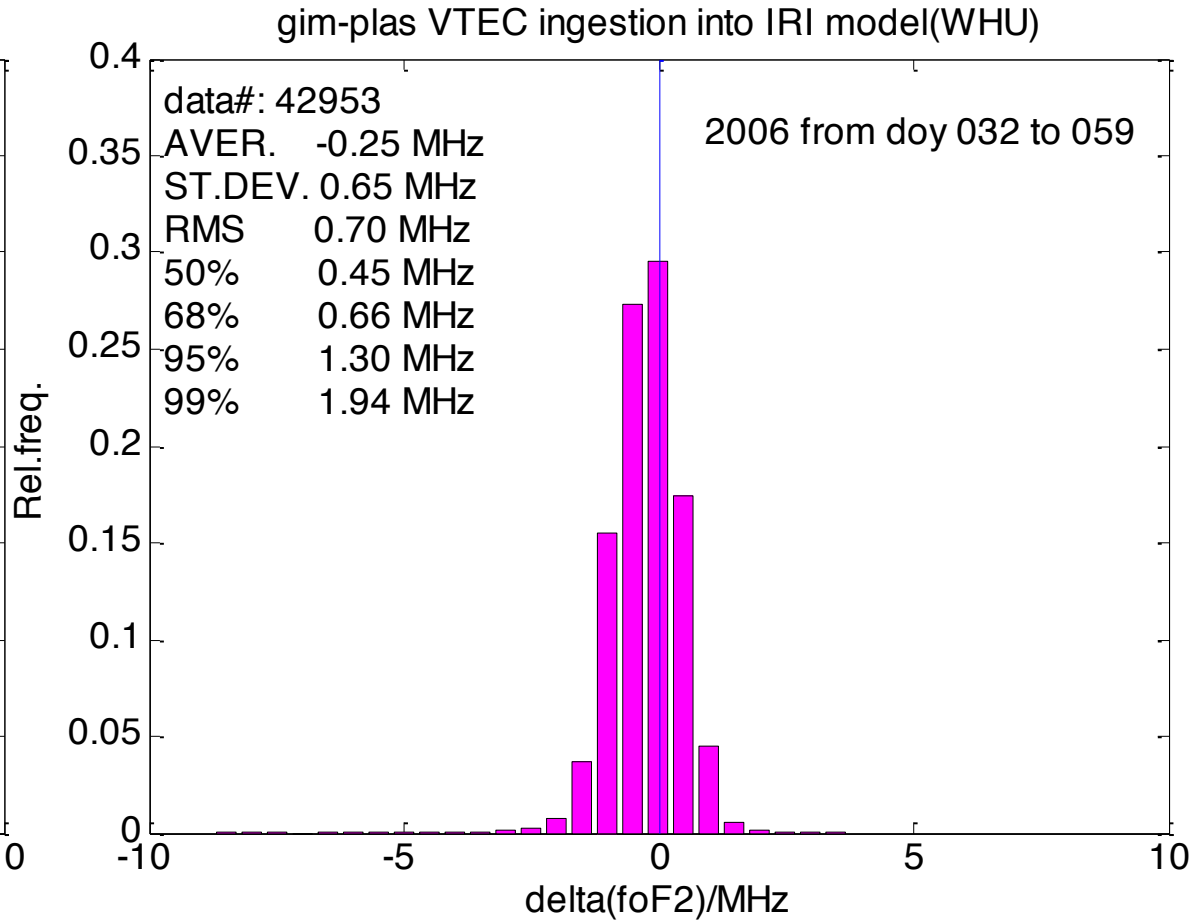
4.2 High Solar Activity & Major Storm

October 2002: Statistics of delta(foF2) (in MHz)

	IRI2012 model	Ingested model(WHU)	IRI-Plas model	IZMIRAN product
Average	0.37	0.30	-0.49	-0.48
St. Dev.	1.37	0.96	1.41	1.02
RMS	1.42	1.00	1.49	1.13
50%	0.87	0.68	1.02	0.68
68%	1.31	0.98	1.50	1.05
95%	2.88	1.95	2.89	2.32
99%	4.22	2.74	3.78	2.98

4.3 Low Solar Activity & Quiet Geomagnetic Activity





4.3 Low Solar Activity & Quiet Geomagnetic Activity

February 2006: Statistics of delta(foF2) (in MHz)

	IRI2012 model	Ingested model(WHU)	IRI-Plas model	IZMIRAN product
Average	-0.22	-0.25	-0.10	-0.63
St. Dev.	0.76	0.65	0.72	0.67
RMS	0.80	0.70	0.73	0.93
50%	0.51	0.45	0.45	0.65
68%	0.76	0.66	0.68	0.94
95%	1.53	1.30	1.40	1.68
99%	2.11	1.94	1.97	2.30

4.4 Question

February 2006: Statistics of delta(hmF2) (in km)

	IRI2012 model	Ingested model(WHU)	IRI-Plas model	IZMIRAN product
Average	3.90	2.49	5.80	12.43
St. Dev.	35.16	34.96	35.11	38.95
RMS	35.38	35.05	35.59	40.88
50%	20.69	19.58	22.15	28.90
68%	29.67	28.66	31.10	39.42
95%	65.76	65.87	64.60	73.20
99%	118.06	120.64	116.30	116.45

4.4 Question

Provided by Manuel Hernández-Pajares

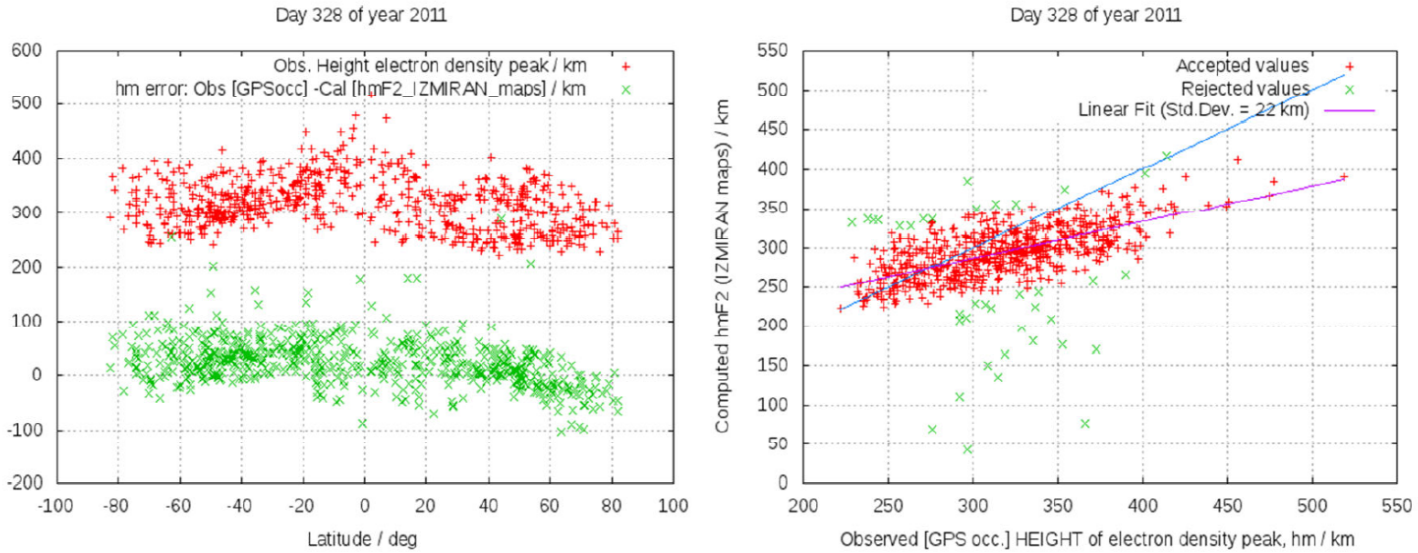
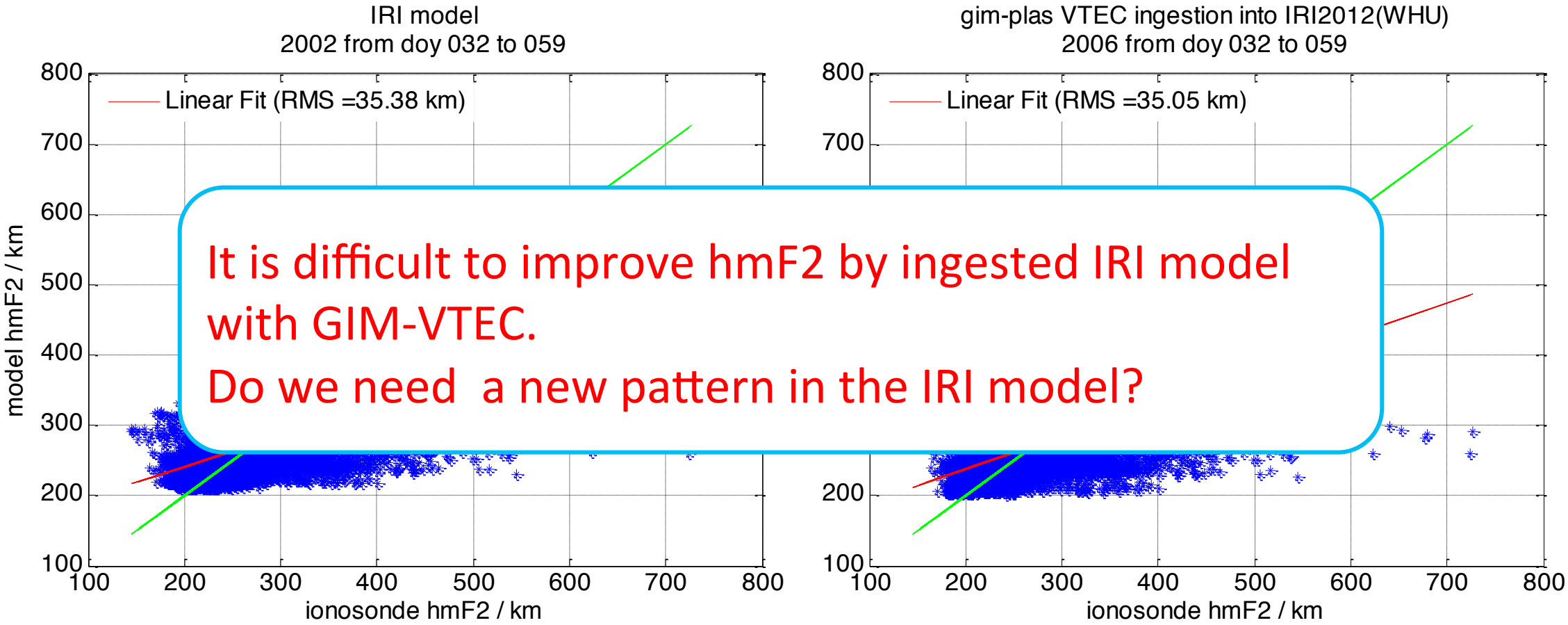


Figure 5: Comparison between electron density height peak, observed from COSMIC GPS occultations (red points at left-hand plot, horizontal axis in right-hand plot), with the values provided by the IZMIRAN maps, adjusting the International Reference Ionosphere (IRI) model with global VTEC ionospheric maps (GVIMs): difference in green points at left-hand-plot, vertical axis in right-hand plot (day 328, 2011). The linear fit is also shown in magenta (right hand plot).

4.4 Question



It is difficult to improve hmF2 by ingested IRI model with GIM-VTEC.

Do we need a new pattern in the IRI model?

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5. Conclusion

- foF2:
  - GIM-VTEC ingestion enhances the performance of the empirical model (IRI2012 and IRI-Plas).
  - Plasmaspheric contribution needs to be considered.
  - During the period of high solar activity, the performance of ingested IRI2012 model with WHU algorithm and IZMIRAN product are at the same level.
  - During the period of low solar activity, ingested IRI2012 model with WHU algorithm performs better than IZMIRAN product.
- hmF2:
  - There exists obvious underestimation for hmF2 values in the IRI model.
  - The ingestion technique with GIM-VTEC has little impact on hmF2.

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Thank you for your attention

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Reference

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