Supporting Information for "Evaluating Radio Occultation (RO) Constellation Designs Using Observing System Simulation Experiments (OSSEs) for Ionospheric Specification"

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Contents of this file

Introduction Contains supporting information for the OSSE results. Here are additional figures showing metrics for quiet and storm period results. Includes the same types of plots used in the main text, shown for other metrics, parameters, solar local times and experiment times.

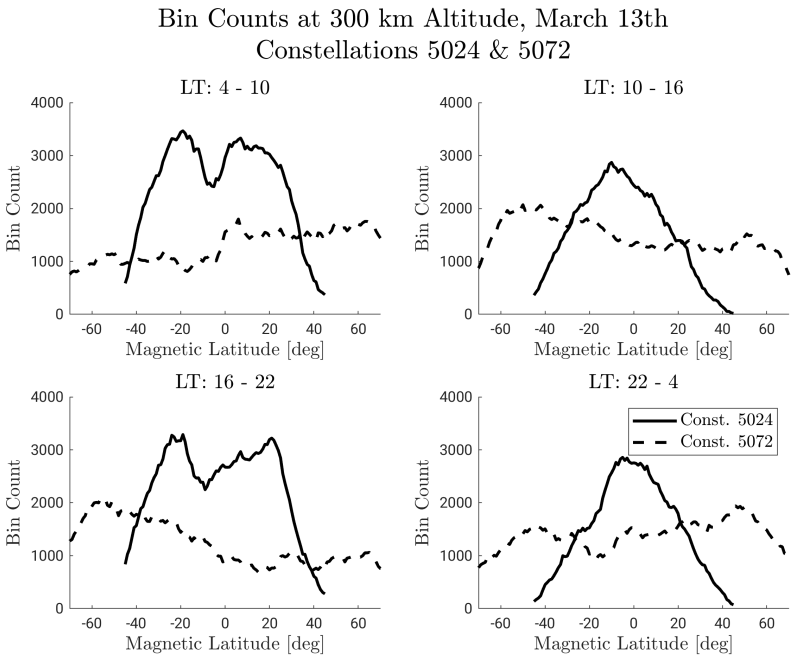

Figure S1. Same as Figure 2 in the paper, shown instead for bin counts used to calculate standard deviation.

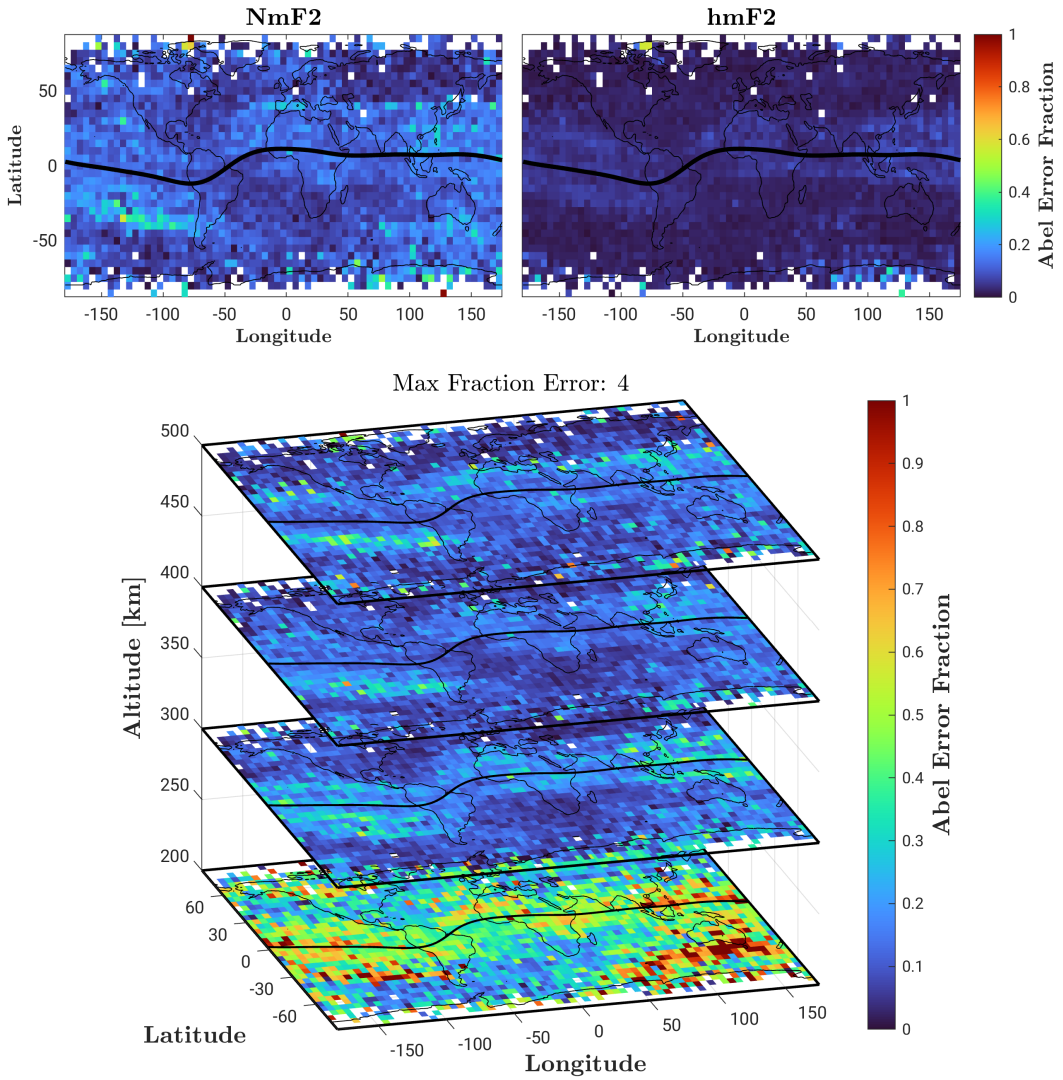

Figure S2. Binned average fractional error due to Abel Retrieval, across local times $10 - 16$. Shown for NmF2, hmF2 and at each EDP altitude, and black line indicates the magnetic equator. Blank regions are due to lack of observation coverage.

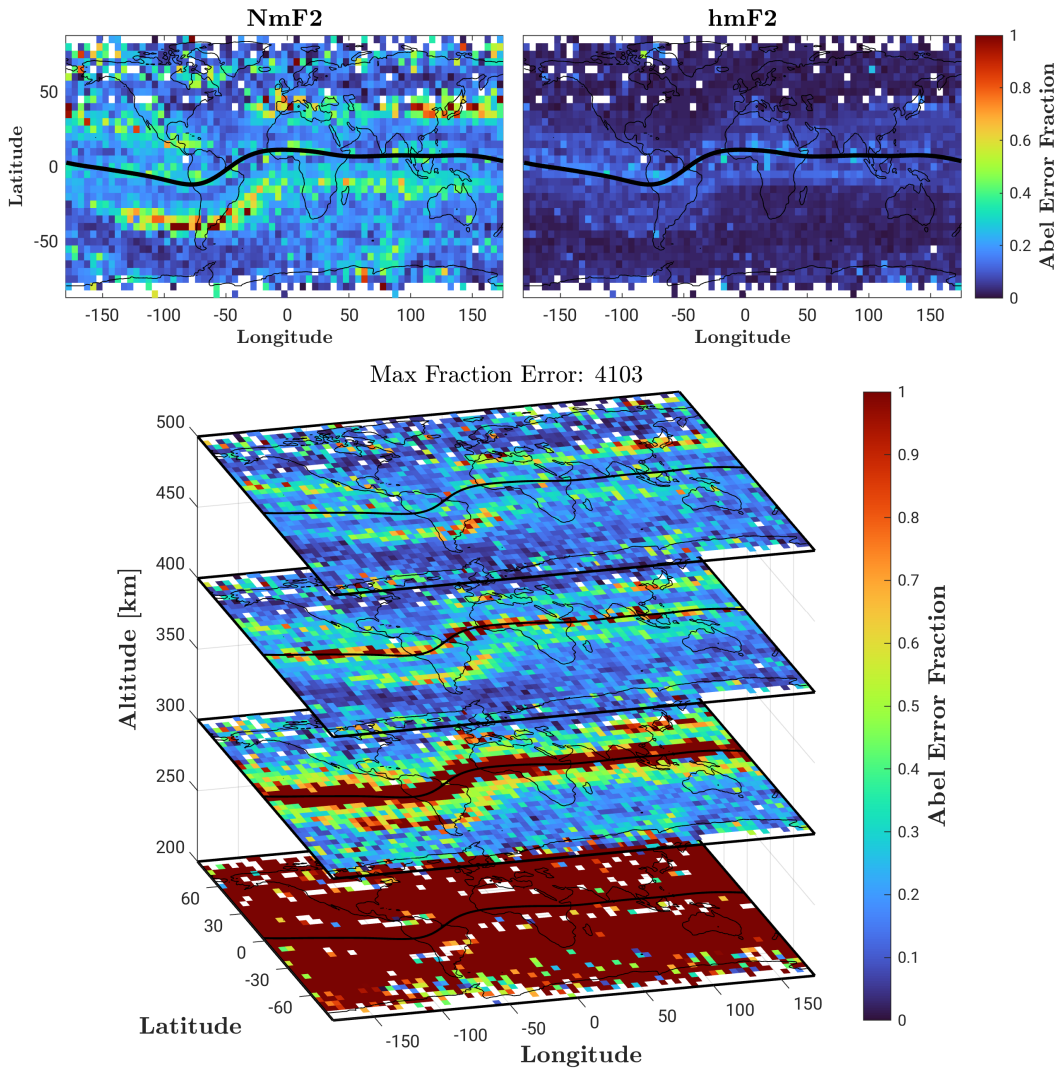

Figure S3. Same as Figure S2, shown for local times 16 – 22

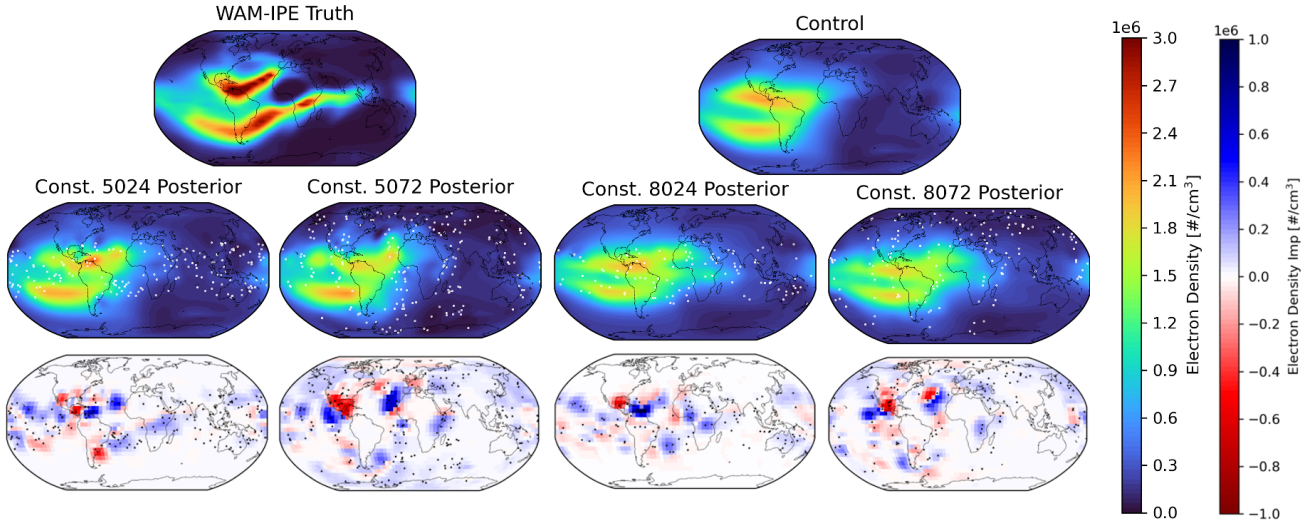

Figure S4. Electron density shown for the truth, control, and OSSEs 1-4 posteriors at 300 km altitude at UT20 on March 17th, during the storm period. The middle row shows posterior states, where white points are the assimilated tangent-point observations at 300 km altitude. Bias improvement, shown on bottom row, is illustrated with blue regions providing improvement and red regions worsening.

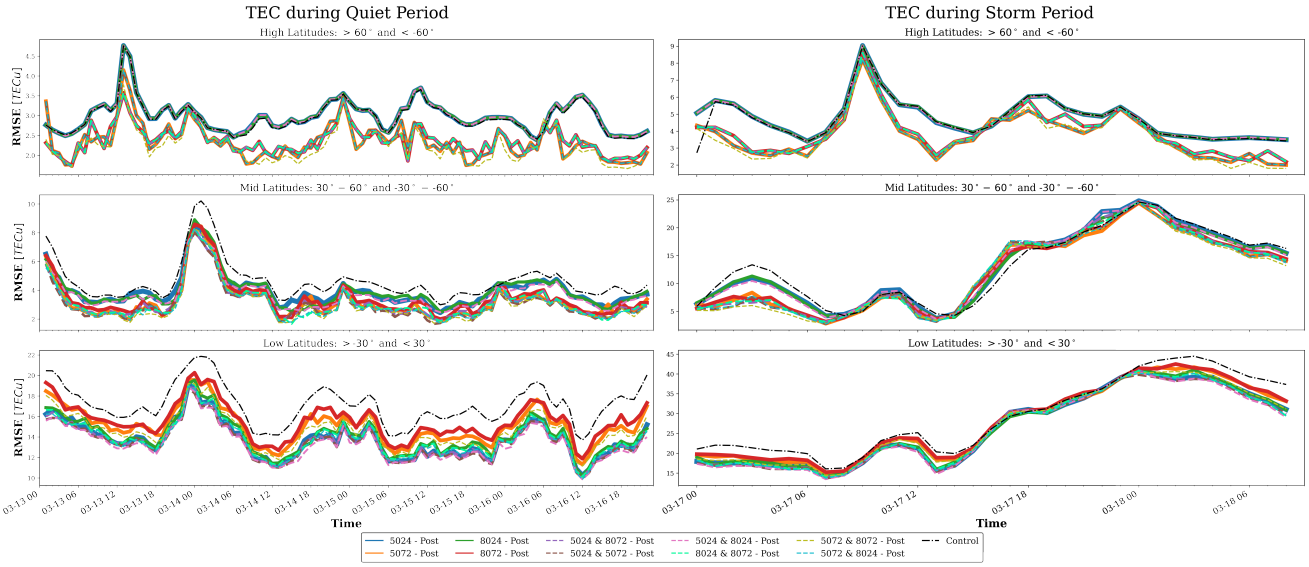

Figure S5. The TEC RMSE for each OSSE throughout the quiet period (left) and storm period (right). Solid lines indicate single constellation OSSEs and dashed lines indicate two constellation OSSEs. Performance is assessed compared to a no-assimilation control in the dashed black curve.

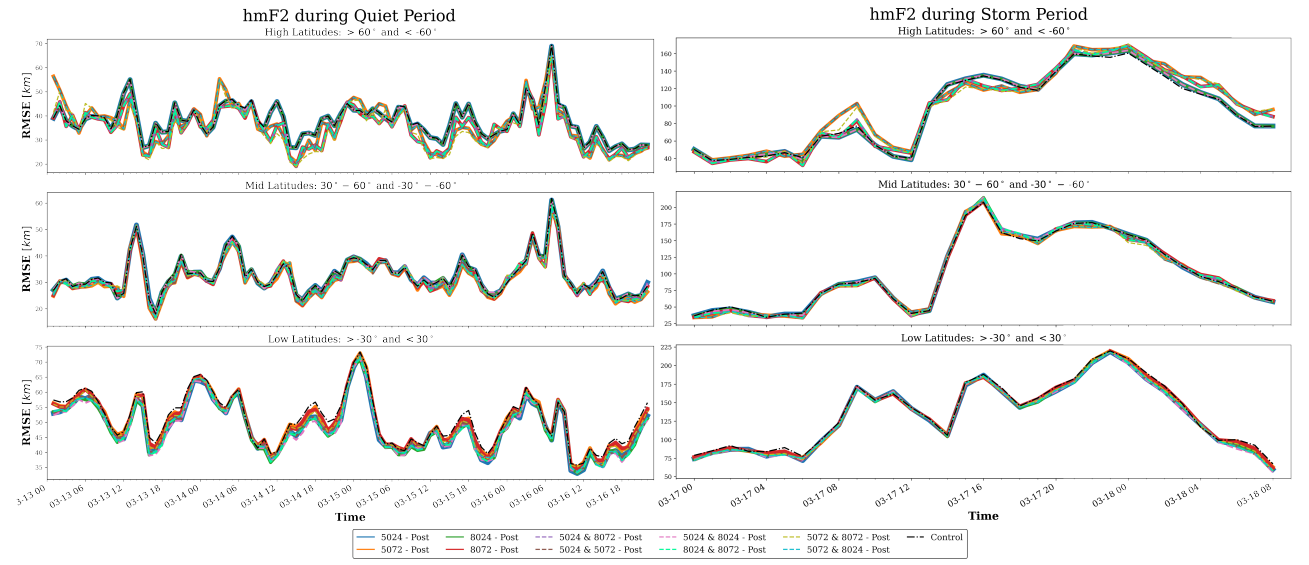

Figure S6. The h_mF_2 RMSE for each OSSE, same as Figure S5.

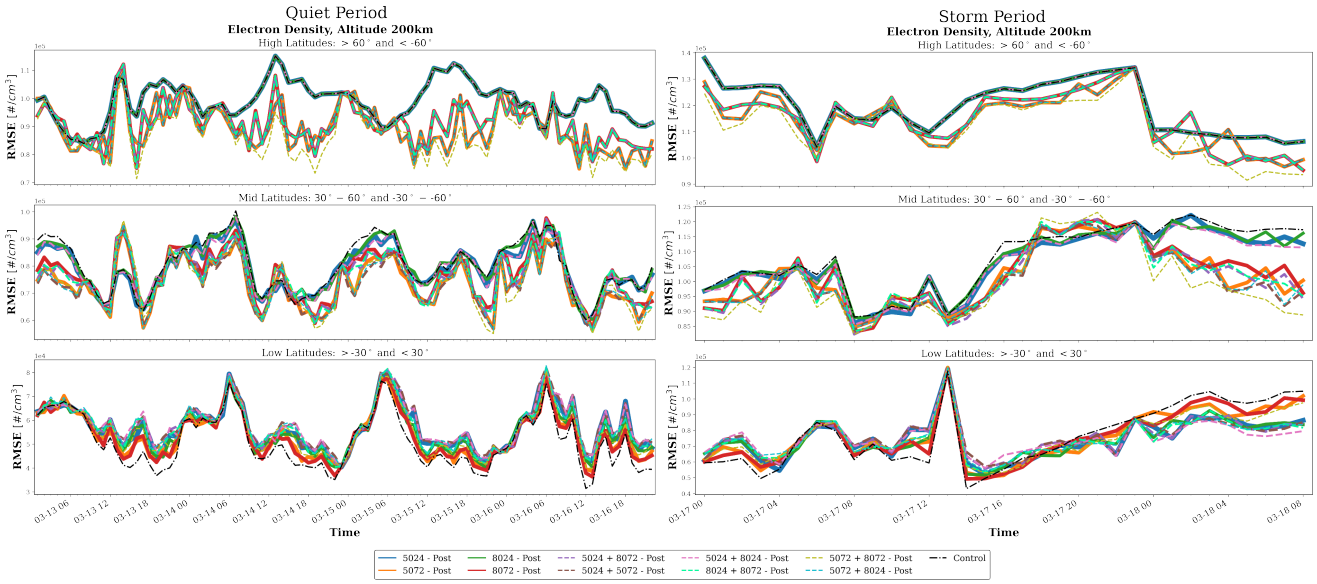

Figure S7. The 200 km electron density altitude RMSE for each OSSE, same as Figure S5.

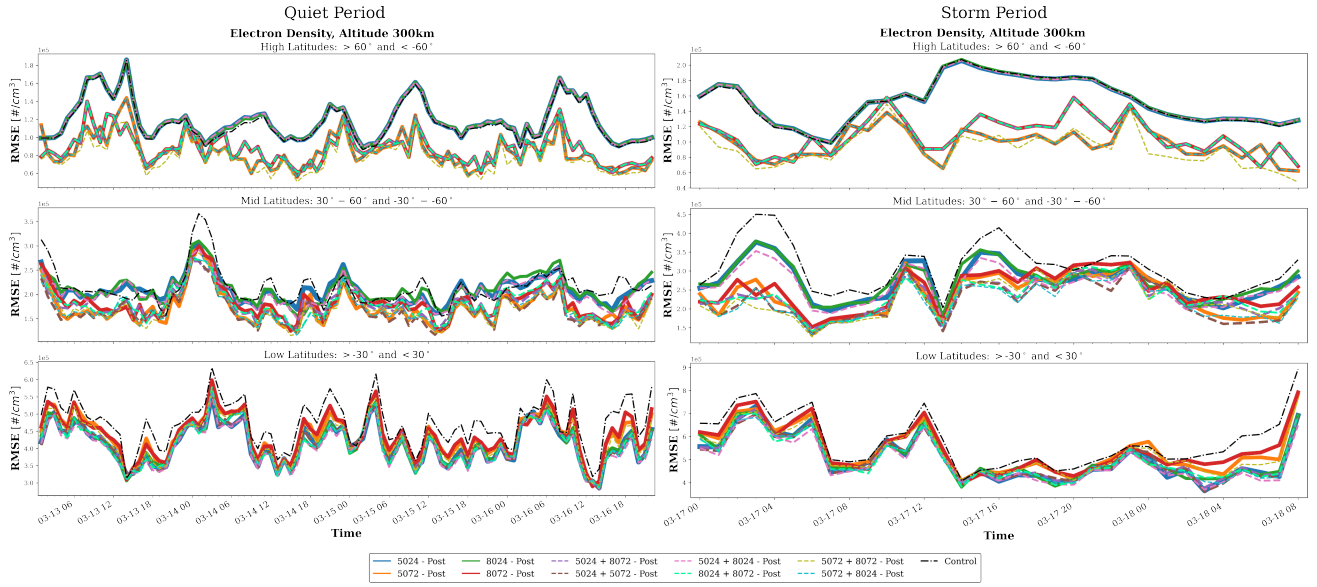

Figure S8. The 300 km electron density altitude RMSE for each OSSE, same as Figure S5.

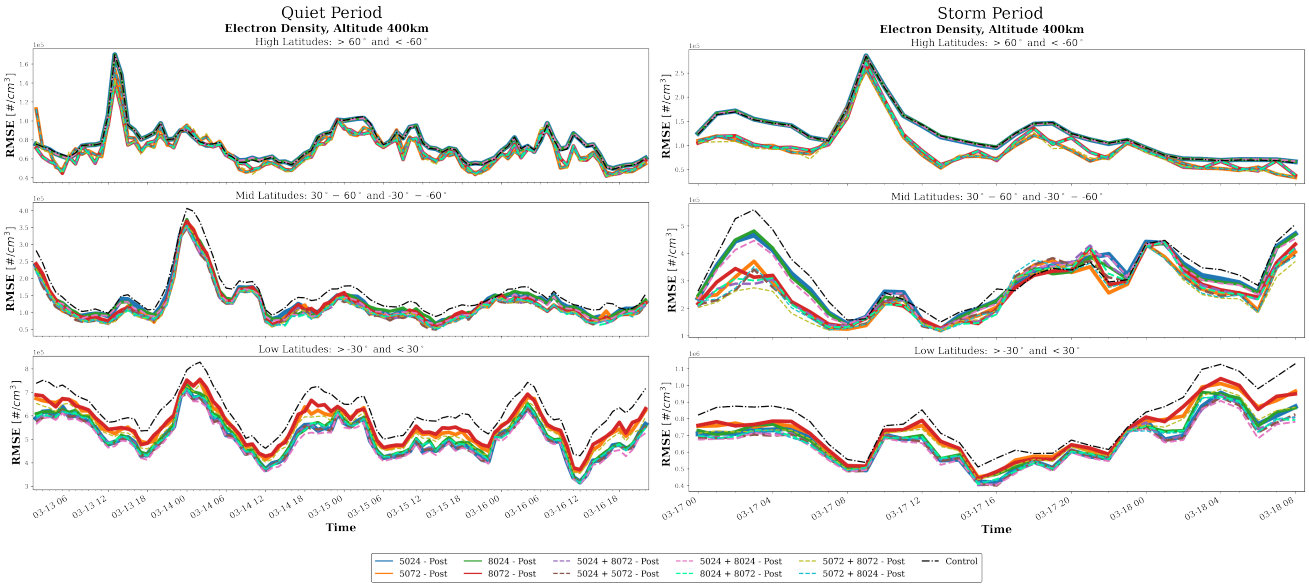

Figure S9. The 400 km electron density altitude RMSE for each OSSE, same as Figure S5.

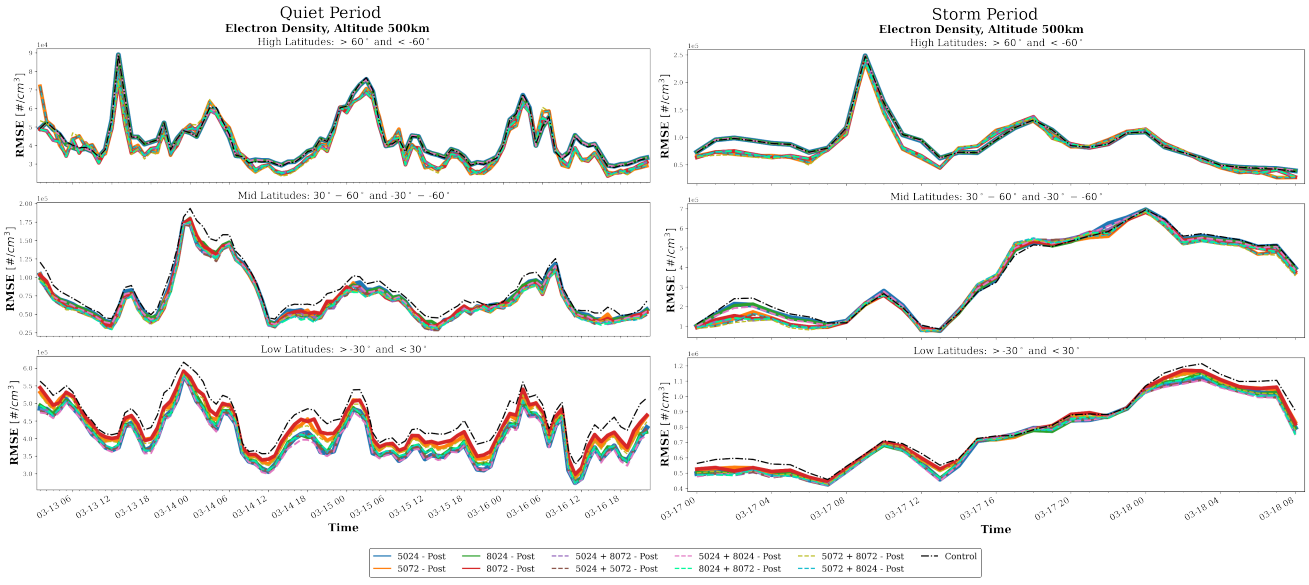

Figure S10. The 500 km electron density altitude RMSE for each OSSE, same as Figure S5.

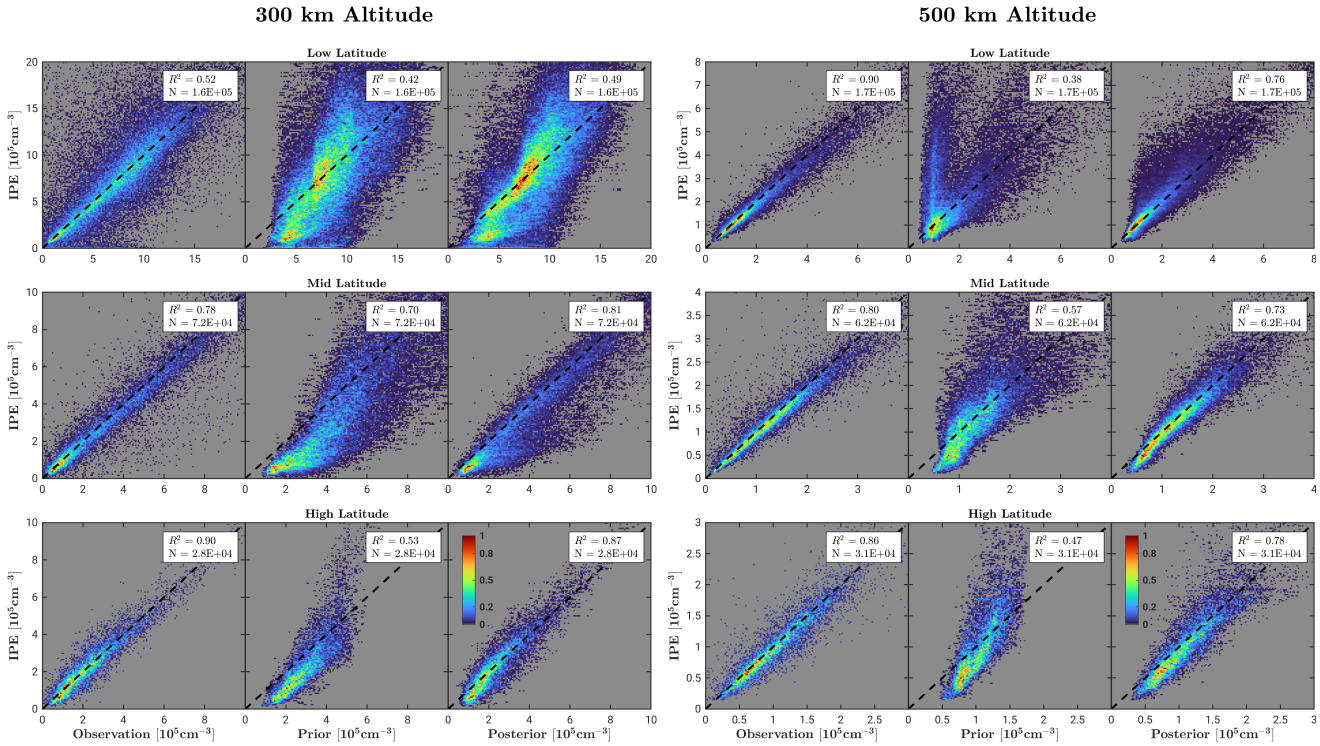

Figure S11. Comparison of electron density observations at given altitudes (300 and 500 km), with the true IPE state shown against the Abel retrieval, TIEGCM prior and TIEGCM posterior states. Density heat maps are shown, with counts normalized by the max bin count for that subplot. Units are all in $10^5 \#/cm^3$.

			Low Lat	Mid Lat	High Lat	Low Lat	Mid Lat	High Lat
Altitude	Experiment Name	Constellations	Quiet			Storm		
200 km	OSSE 1	5024	5.12	7.53	8.36	5	6.67	7.67
300 km			5.24	9	8.49	5.21	7.52	8
400 km			4.71	8.76	8.38	6.27	8.03	8.39
500 km			3.81	8.79	7.57	5.97	7.21	6.58
200 km	OSSE 2	5072	2.72	3.77	4.28	5.27	5.3	4.58
300 km			8.63	3.34	3.71	8.67	5.48	3.64
400 km			9.18	5.9	5.28	9.73	4.61	4.3
500 km			9.1	6.68	5.48	8.39	4.42	4.73
200 km	OSSE 3	8024	4.22	8.22	7.72	5.76	7.85	6.7
300 km			5.34	9.4	9.05	5.94	9.15	8.97
400 km			6.32	8.94	8.12	2.97	7.76	7.03
500 km			5.51	8.47	7.48	4.42	7.27	6.09
200 km	OSSE 4	8072	2.53	6.06	5.32	5.85	6.79	3.85
300 km			9.11	5.87	4.48	7.03	7.61	6.88
400 km			9.82	7.13	4.21	6.61	5.94	5.27
500 km			9.9	6.93	4.77	7.85	6.7	6.18
200 km	OSSE 5	5024 & 8072	7.29	6	5.20	5.73	4.42	5.39
300 km			4	5.04	5.22	4.79	4.64	4.97
400 km			3.65	3.69	3.98	4.73	5.64	4.64
500 km			4.52	3.65	4.40	5.45	5.97	5.09
200 km	OSSE 6	5024 & 5072	8.12	3.28	5.00	6	4.09	5
300 km			4.38	3	4.15	4.33	2.85	3.36
400 km			3.13	2.86	5.05	3.88	4.67	4
500 km			3.26	3.51	5.03	4.21	4.94	4.94
200 km	OSSE 7	5024 & 8024	7.62	7.5	8.20	5.55	6.27	8.58
300 km			2.16	8.12	9.36	2.52	6	8.24
400 km			1	6.83	7.87	2.24	7.24	8.7
500 km			1.02	6.76	7.04	3	6.82	7
200 km	OSSE 8	8024 & 8072	6.11	5.77	4.77	5.12	5.06	5.27
300 km			4.26	5.57	5.05	4.7	4.97	5.3
400 km			5.01	4.21	3.63	5.61	4.7	5.09
500 km			5.63	3.5	4.32	4.52	4.67	5.18
200 km	OSSE 9	5072 & 8072	4.28	3.57	2.05	5.39	3.55	2.97
300 km			7.38	2.63	1.50	7.55	3.91	1.82
400 km			8	3.55	3.84	8.18	2.91	3.3
500 km			8	3.54	4.09	7	2.85	4.82
200 km	OSSE 10	5072 & 8024	7	3.7	4.10	5.61	5	5
300 km			4.2	3.35	3.98	4.27	2.88	3.73
400 km			4.18	3.13	4.64	4.79	3.52	4.27
500 km			4.29	3.18	4.82	4.21	4.15	4.79

Figure S12. OSSE ranking metric for each electron density altitude. Contains quiet period defined from March 13th UT01 to March 16th UT022 and storm period defined from March 17th UT00 to March 18th UT08. Values of 1 indicate the best performance and values of 10 indicate the worst performance.

		Low Lat	Mid Lat	High Lat	Low Lat	Mid Lat	High Lat
Experiment Name	**Constellations**	**Quiet**			**Storm**		
OSSE 1	5024	5.32	9.23	8.70	7	7.7	8.12
OSSE 2	5072	9.1	4.26	3.70	9.39	4.67	3.88
OSSE 3	8024	6.68	9.34	9.05	2.12	8.82	9.18
OSSE 4	8072	9.88	6.49	4.46	4.88	5.82	5.33
OSSE 5	5024 & 8072	3.59	5	5.16	5.82	5.73	4.55
OSSE 6	5024 & 5072	2.65	2.73	4.26	4	4.24	4
OSSE 7	5024 & 8024	1.2	7.88	9.15	2.88	7.03	8.21
OSSE 8	8024 & 8072	4.97	5.09	4.87	6.12	4.85	4.88
OSSE 9	5072 & 8072	7.85	2.15	1.61	8.39	2.85	2.73
OSSE 10	5072 & 8024	3.77	2.95	4.04	4.73	3	4

Figure S13. Same as Figure S12, shown for N_mF_2.

		Low Lat	Mid Lat	High Lat	Low Lat	Mid Lat	High Lat
Experiment Name	**Constellations**	**Quiet**			**Storm**		
OSSE 1	5024	4.31	7.56	7.66	6	5.64	4.36
OSSE 2	5072	9.15	3.21	6.26	7.82	5.97	6.88
OSSE 3	8024	2.9	7.9	7.15	5.06	6.64	4.88
OSSE 4	8072	8.39	4.86	5.40	6.03	5.97	3.73
OSSE 5	5024 & 8072	5.03	5	4.24	5.52	5.58	5.79
OSSE 6	5024 & 5072	6.37	4.03	5.28	5	5.64	7
OSSE 7	5024 & 8024	2.3	8.16	6.52	3.64	4.94	3.82
OSSE 8	8024 & 8072	3.61	5.51	4.11	4.82	5.09	5.64
OSSE 9	5072 & 8072	8.01	4.24	3.52	6.3	4.27	6.06
OSSE 10	5072 & 8024	4.93	4.13	4.86	4.58	5	7

Figure S14. Same as Figure S12, shown for h_mF_2.

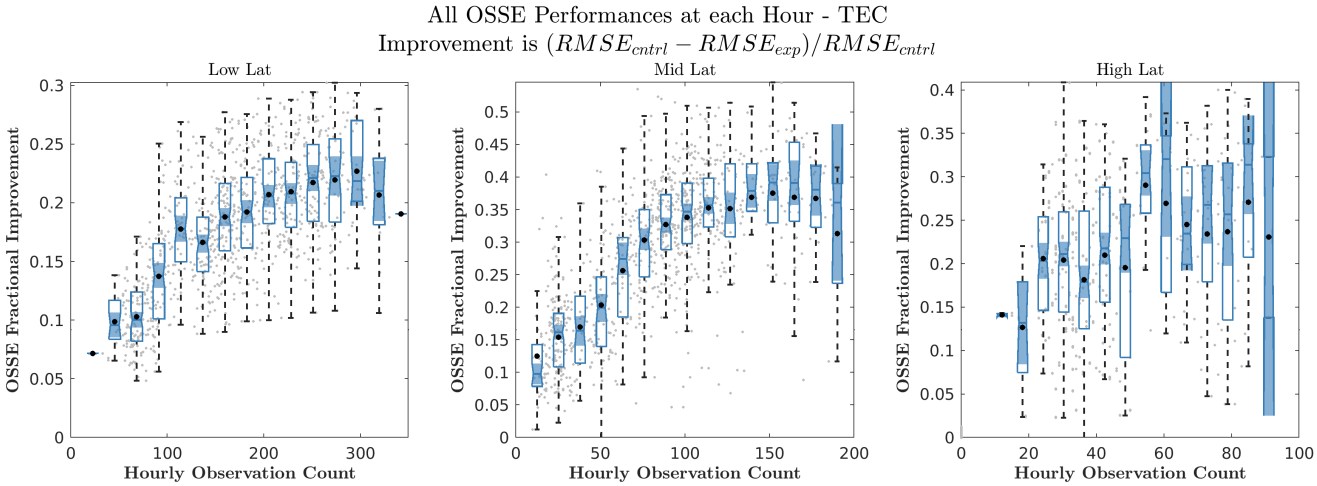

Figure S15. OSSE TEC RMSE fractional improvement over the control as a function of observation count, defined in Equation **??**. Calculated for the entire TEC grid RMSE within each latitude band. Gray points are all samples and averaged over count bins to give the mean (black dots) and notched box plots. Shaded regions not overlapping indicate the significant difference between medians (5% confidence).

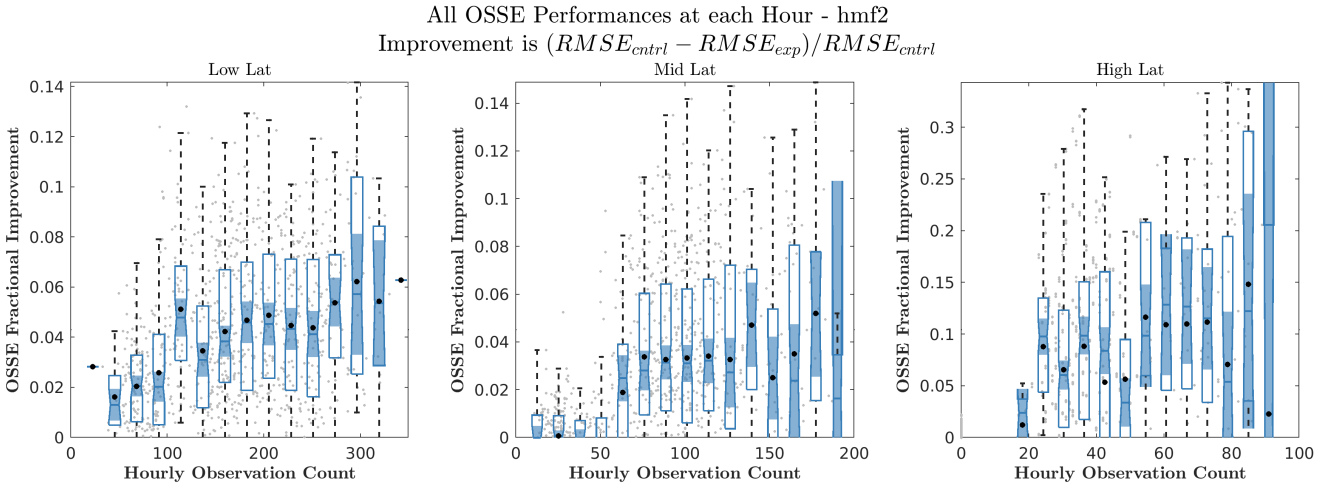

Figure S16. Same as Figure S15, shown for h_mF_2.

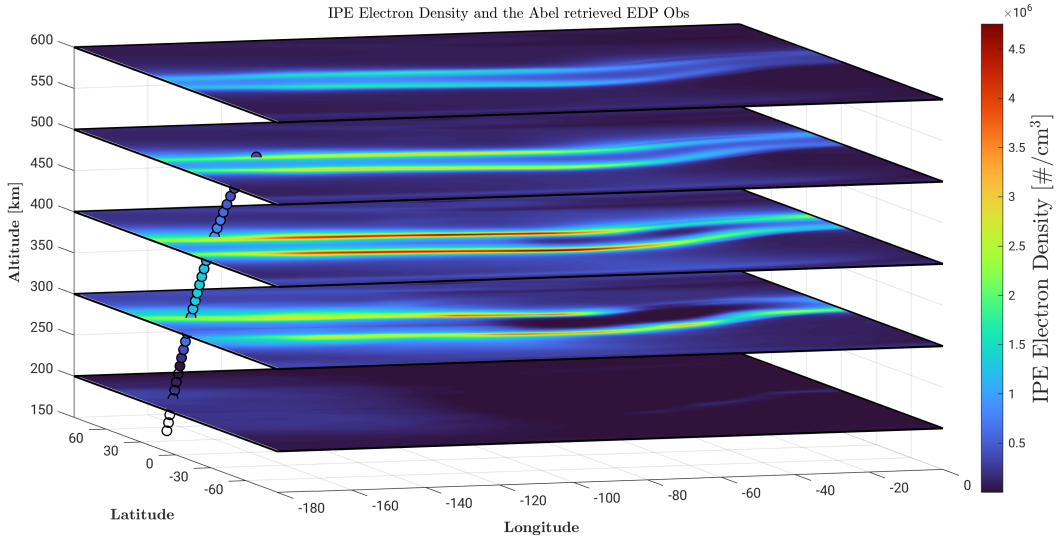

Figure S17. Highlighted poor EDP observation update, with scatter showing the observation EDP and grids showing IPE electron density at that given altitude. RO EDP tangent points are quasi-vertical, with higher altitude tangent points moving into higher density regions, creating a double-peaked structure.