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Assessment of electron density profiles over the Brazilian region using radio occultation data aided by global ionospheric maps

(Preliminary results)

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IonSAT

Introduction

Radio occultation can provide relevant information from regions not accessed by other techniques.

Two types of comparisons are usually applied for the assessment of RO profiles retrieval when real data is used[1,2,3]:

(i) comparisons between close occultations or different methods of inversion;

(ii) comparisons between data from RO profiles and measurements from ionosondes close to the RO occurrence.

This research aims to assess radio occultation (RO) ionospheric profiles over the Brazilian area using ionosonde data aided by Global Ionospheric Maps (GIM) information.

[1]Hernández-Pajares, M., Juan, J. M., & Sanz, J. Improving the Abel inversion by adding ground GPS data to LEO radio occultations in ionospheric sounding. Geophysical research letters, v. 27, n. 16, p. 2473-2476, 2000.

[2]García-Fernández, M., Aragón, A., Hernandez-Pajares, M., Juan, J. M., Sanz, J., & Rios, V. Ionospheric tomography with GPS data from CHAMP and SAC-C. In: Earth Observation with CHAMP. Springer, Berlin, Heidelberg, 2005. p. 453-458.

[3]Garcia-Fernandez, M., Hernandez-Pajares, M., Juan, J. M., & Sanz, J. Performance of the improved Abel transform to estimate electron density profiles from GPS occultation data. GPS Solutions, v. 9, n. 2, p. 105-110, 2005.

Method

Assessment of radio occultation (RO) ionospheric profiles over the Brazilian area using ionosonde data aided by Global Ionospheric Maps (GIM) information

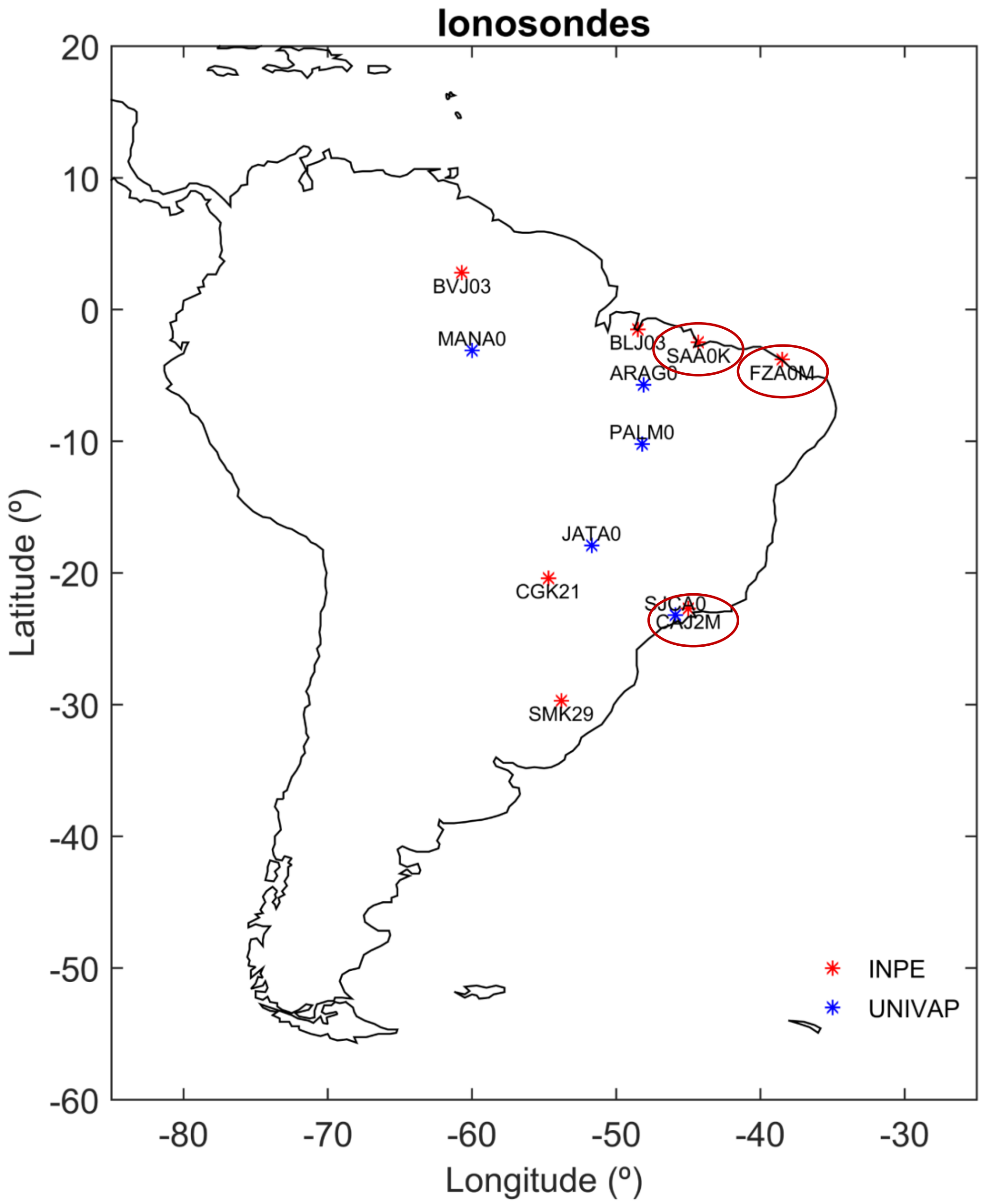
Considering that the occultation occurrence is different from the ionosondes position, in order to compare RO data with ionosonde date, we used two approaches:

Assessment

- **Simple difference (RO – Ionosonde)**
- **Difference considering the variability of ionosphere from GIM (VTEC variability)**

$$\mathrm{foF2\_ROtoIONO} = \mathrm{foF2\_RO}\,\frac{\mathrm{VTEC\_IONO\_GIM}}{\mathrm{VTEC\_RO\_GIM}}$$

Data



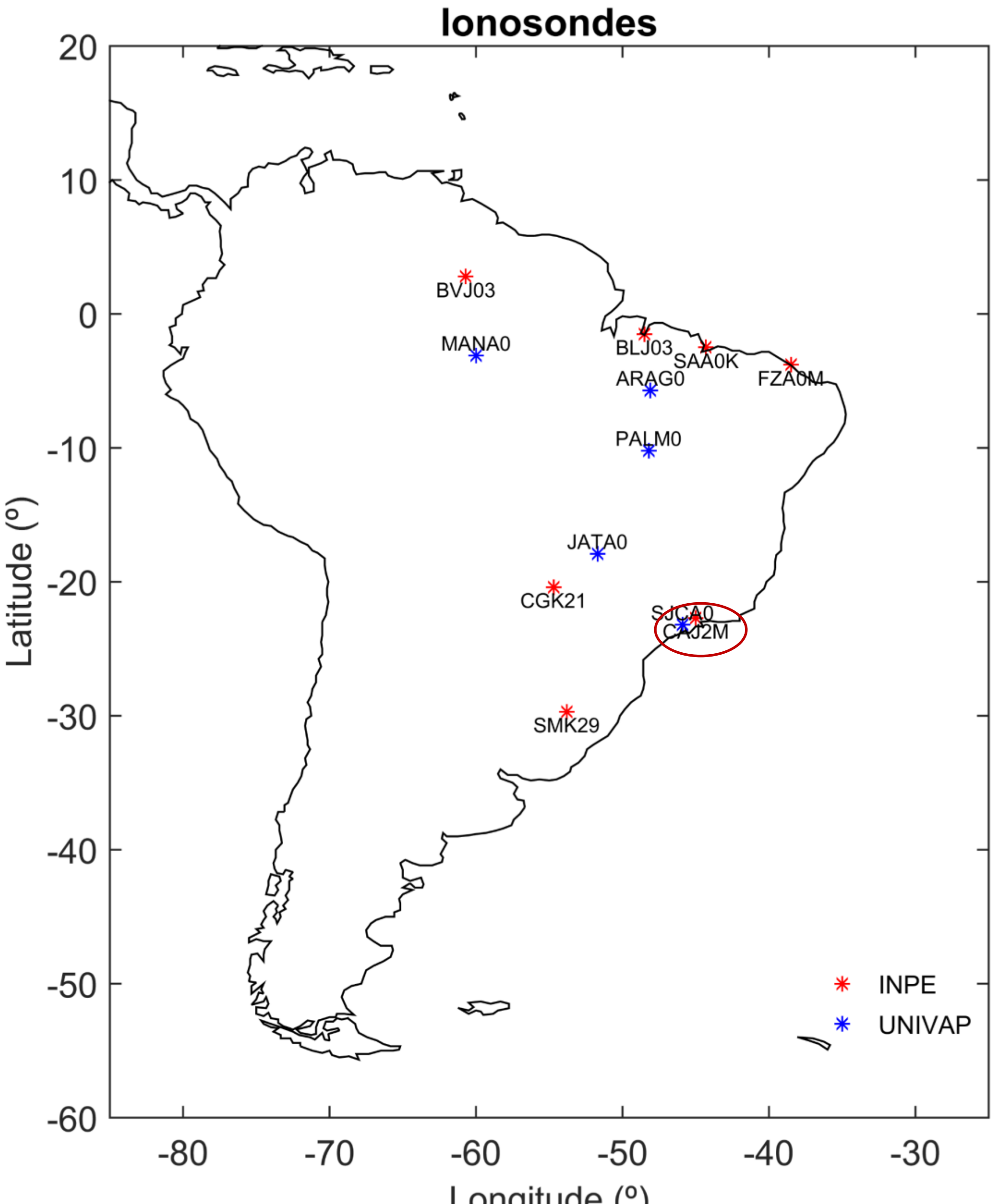
Doy 001-007/2012

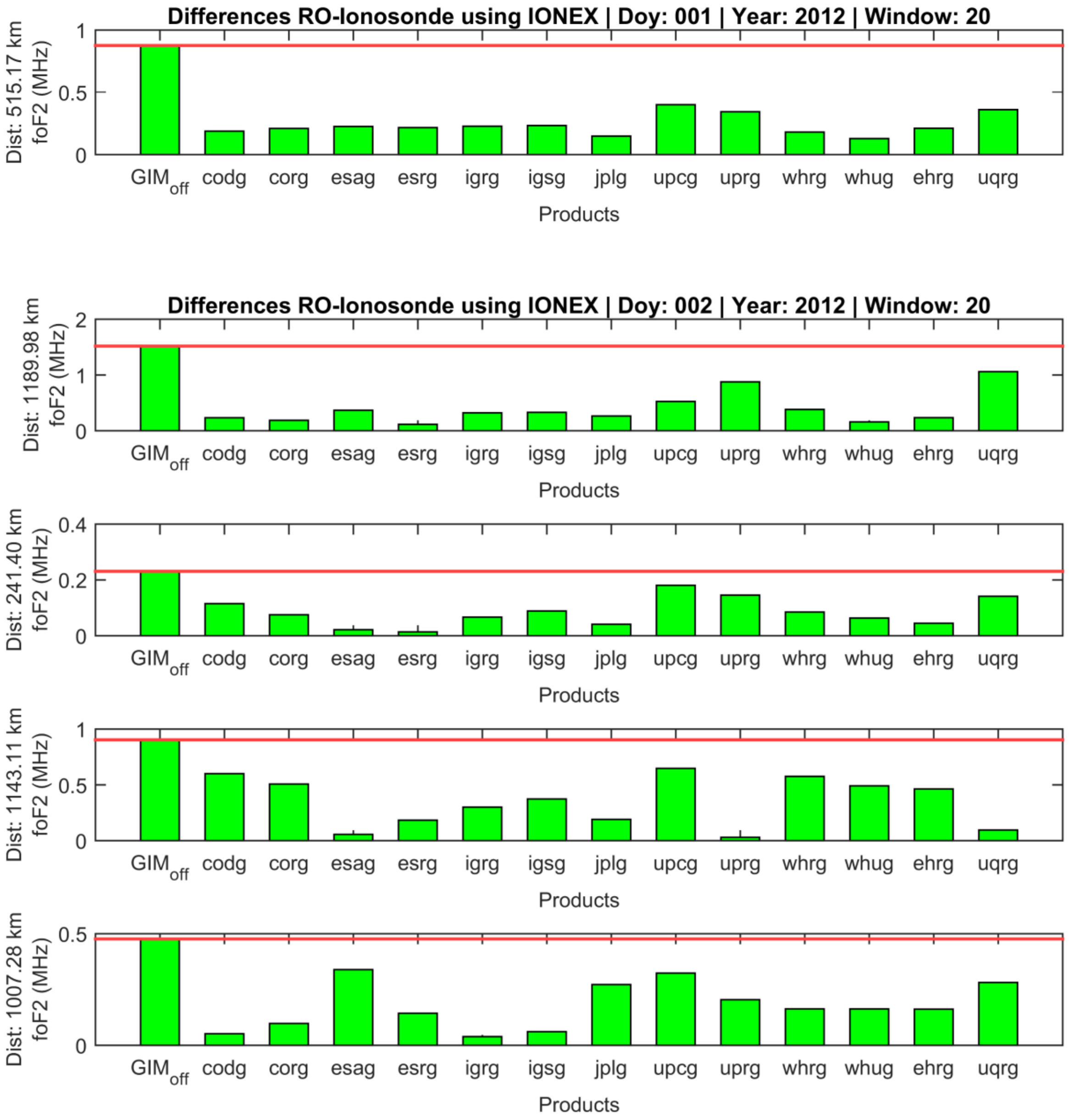
RO data: COSMIC mission

GIMs: codg | corg | esag | esrg | igrg | igsg | jplg | upcg | uprg | whrg | whug | ehrg | uqrg

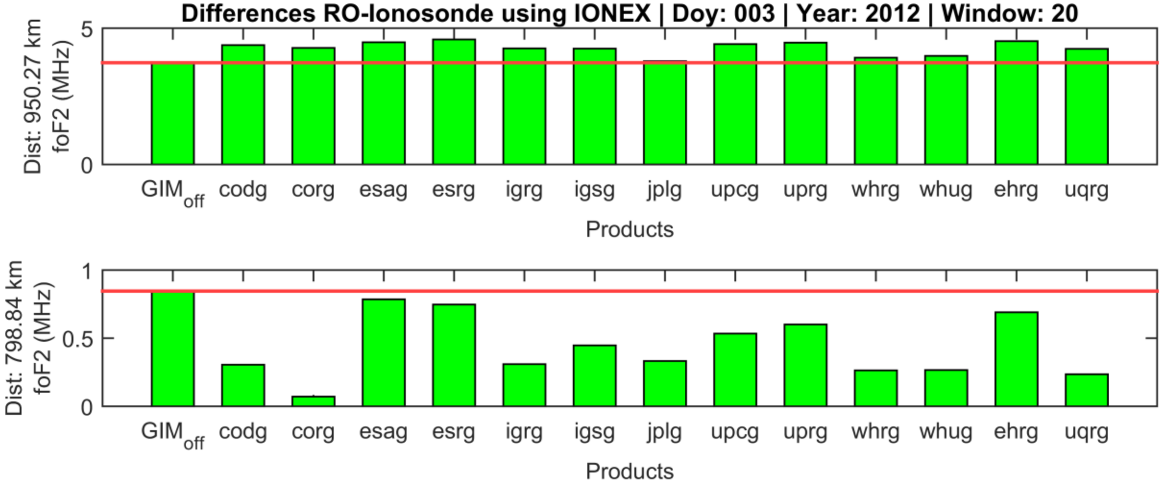
Search window: 20° x 20° (lat x lon)

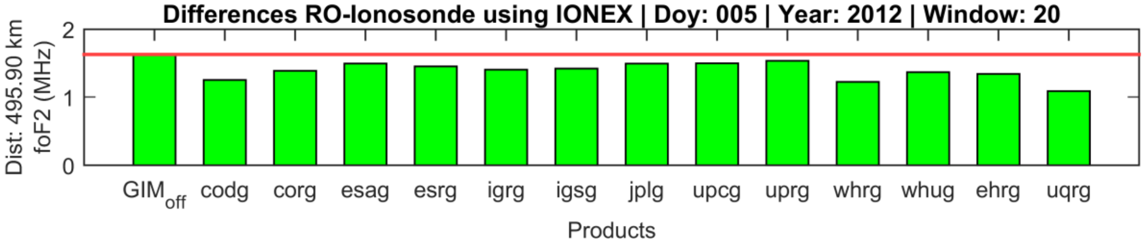
Results: CAJ2M

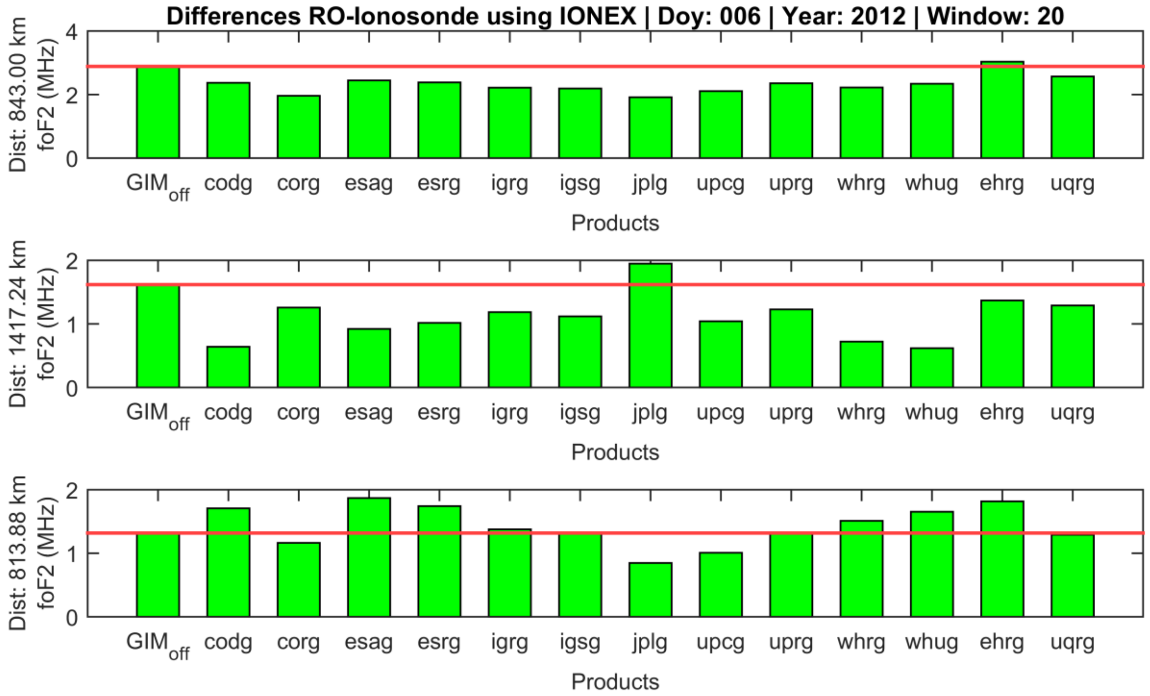


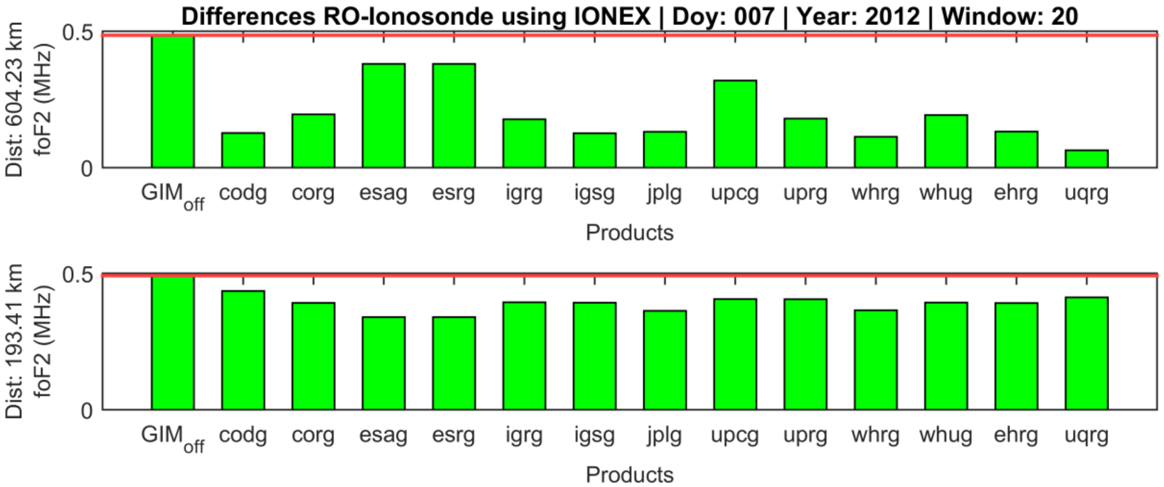


Results: CAJ2M



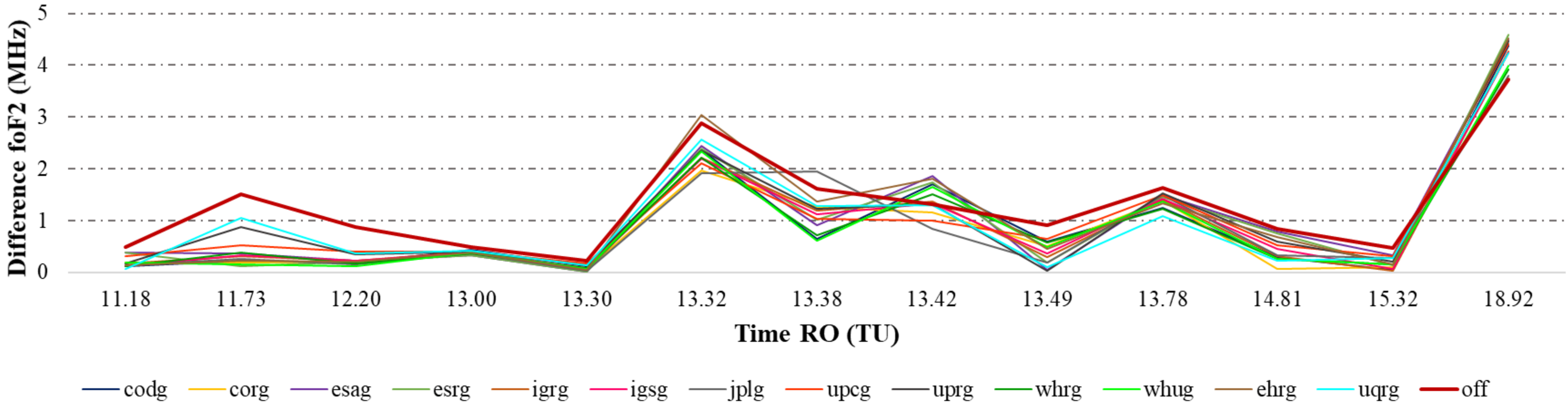


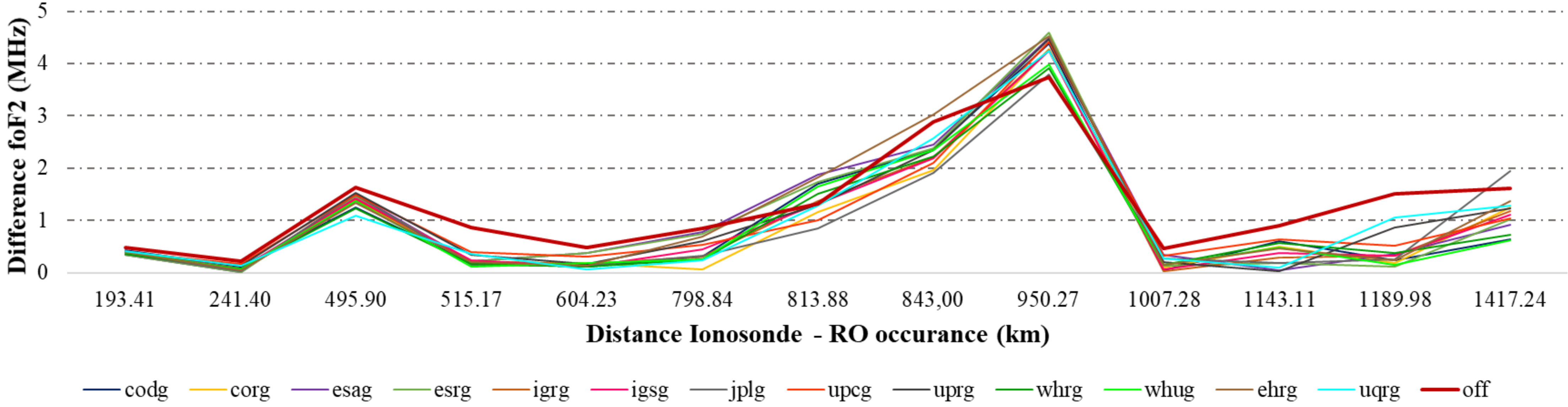




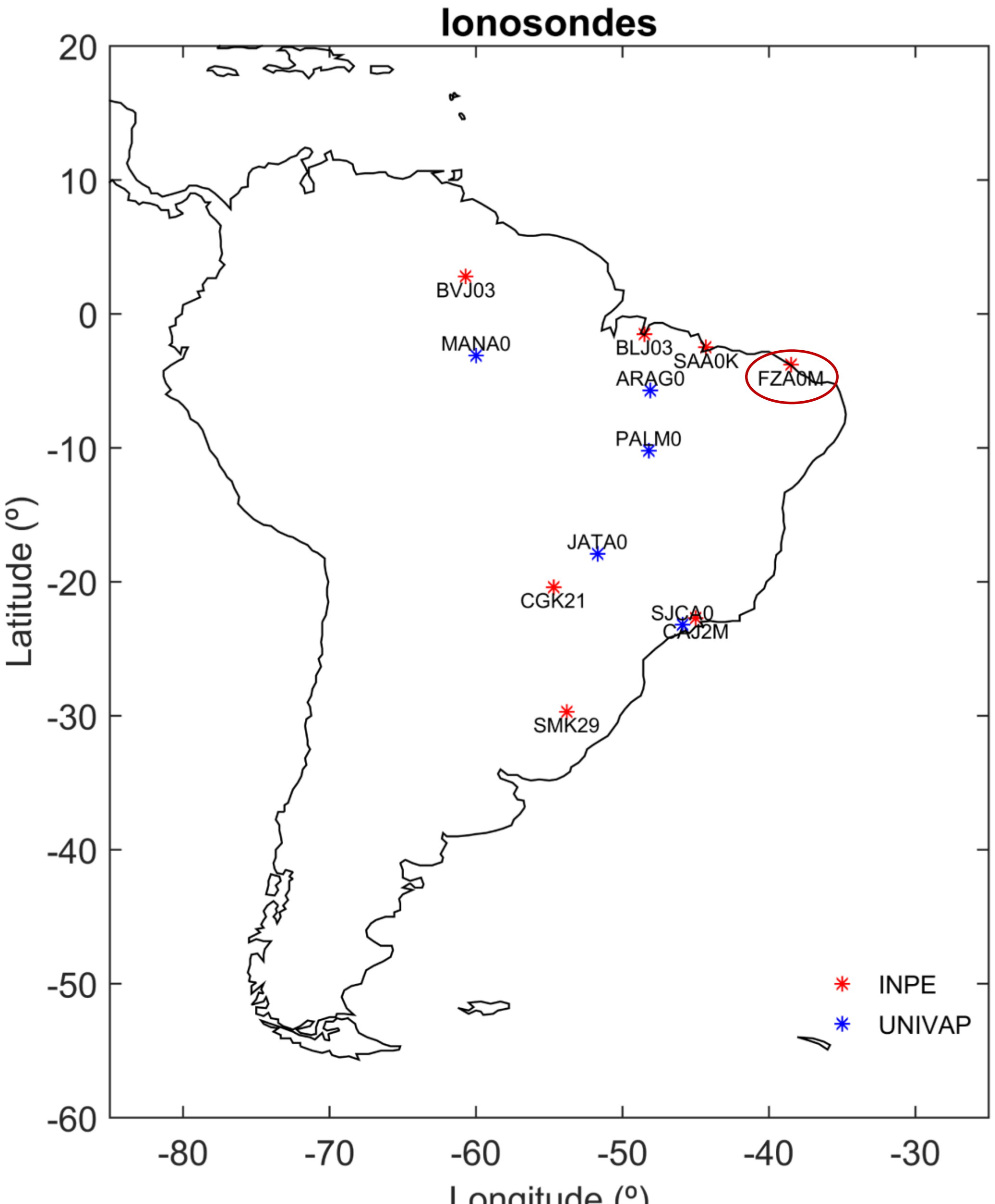
Results: CAJ2M

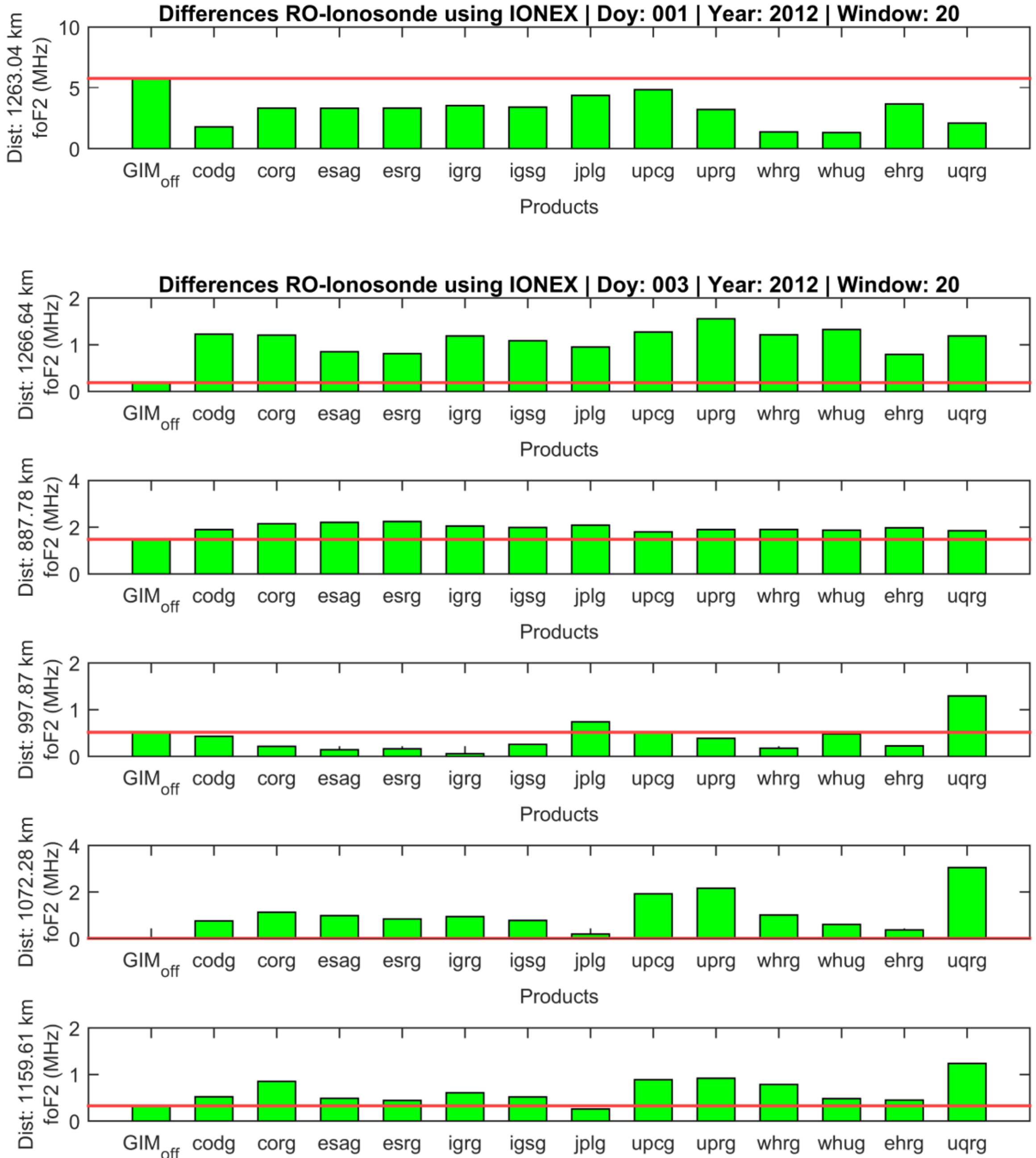
Differences between RO and ionosonde data using GIMs



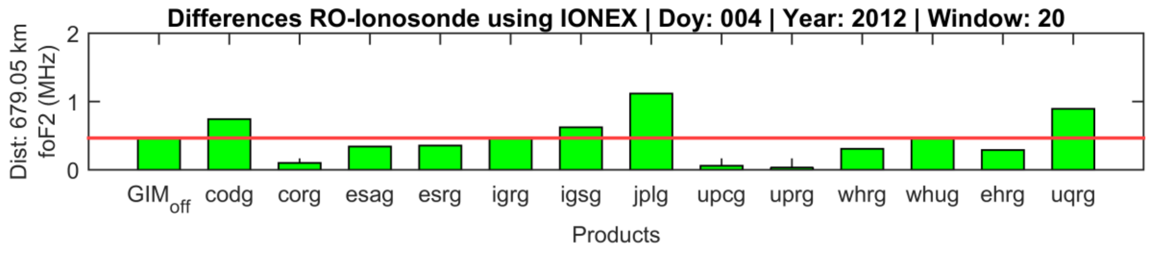


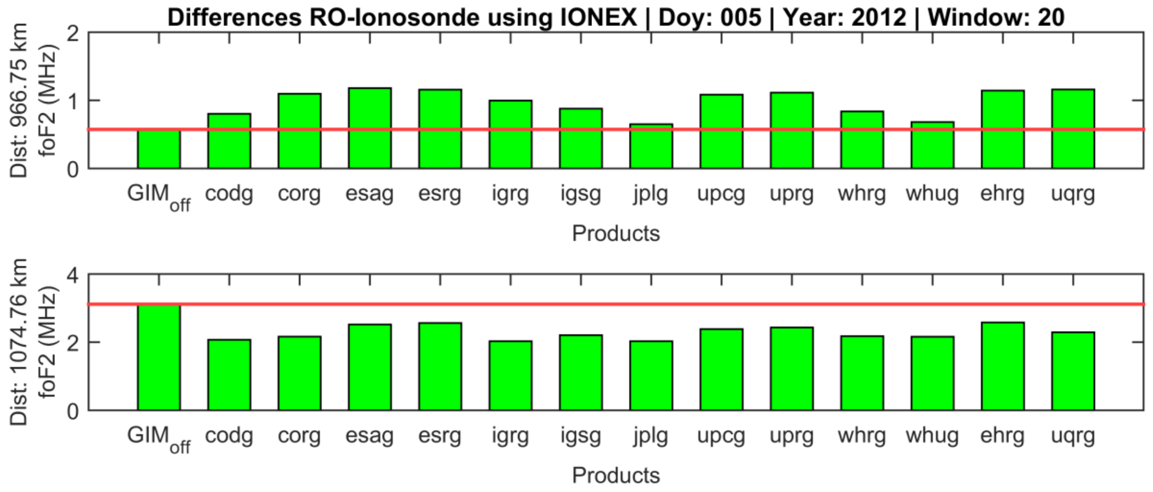
Results: FZA0M

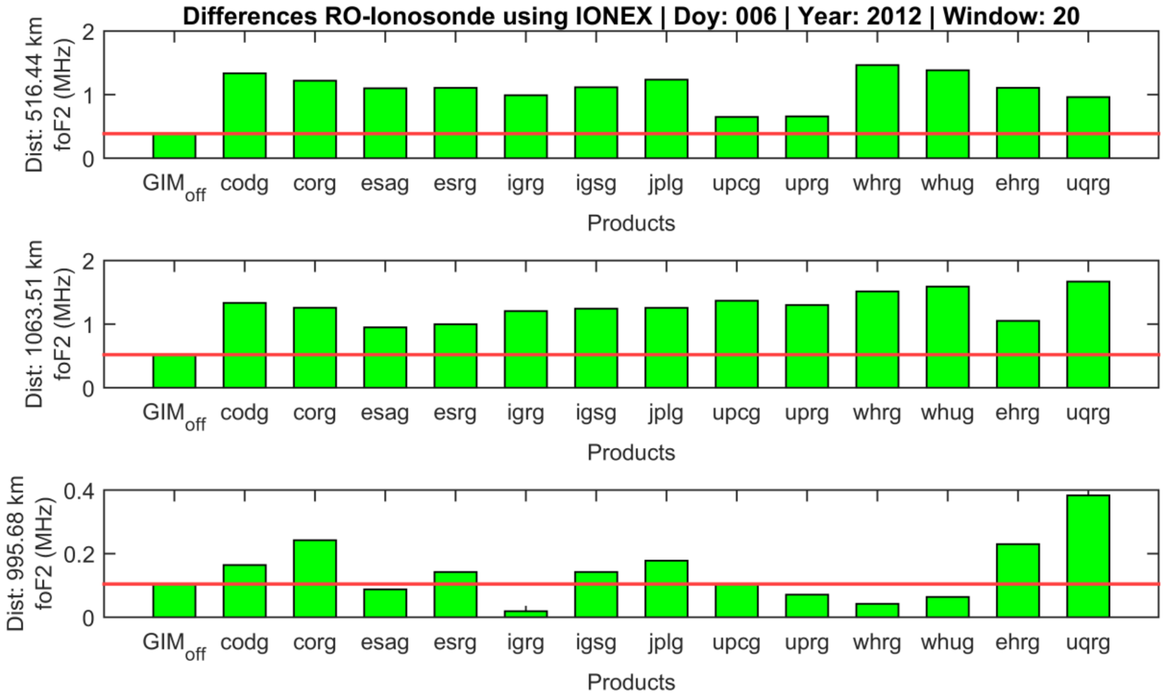




Results: FZA0M

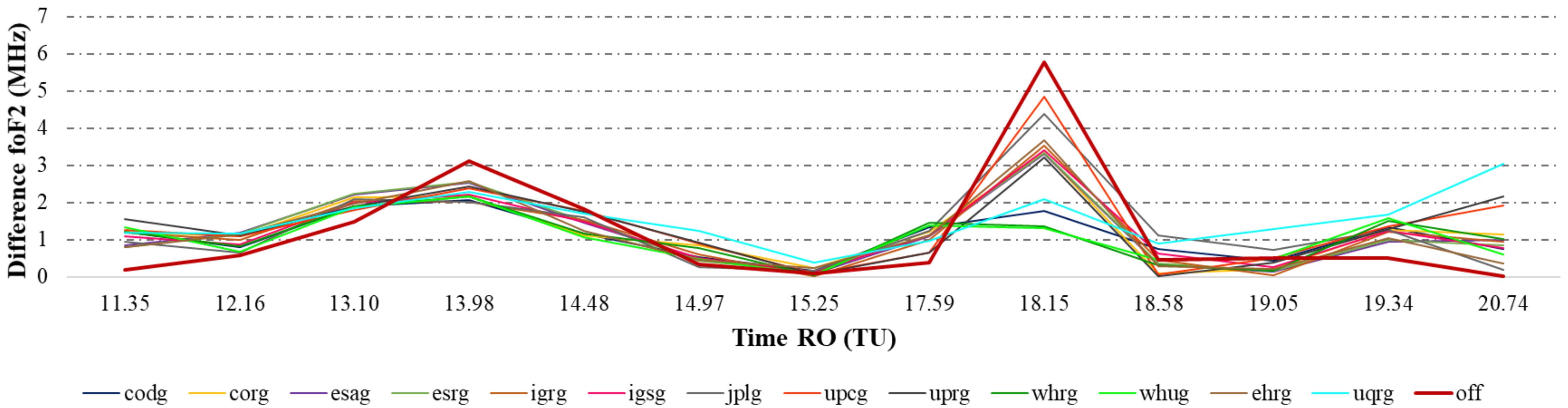


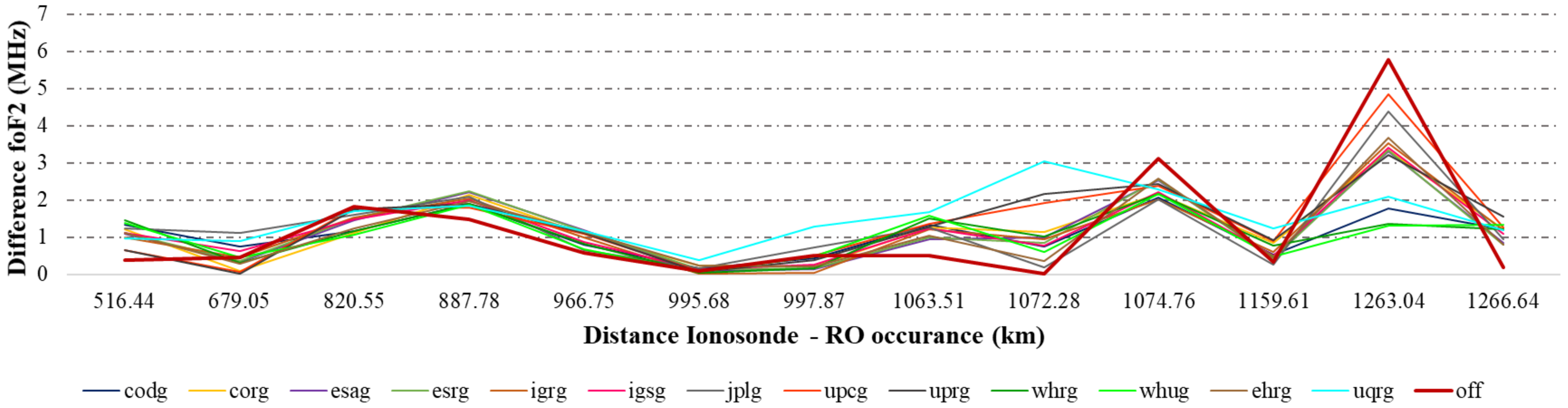




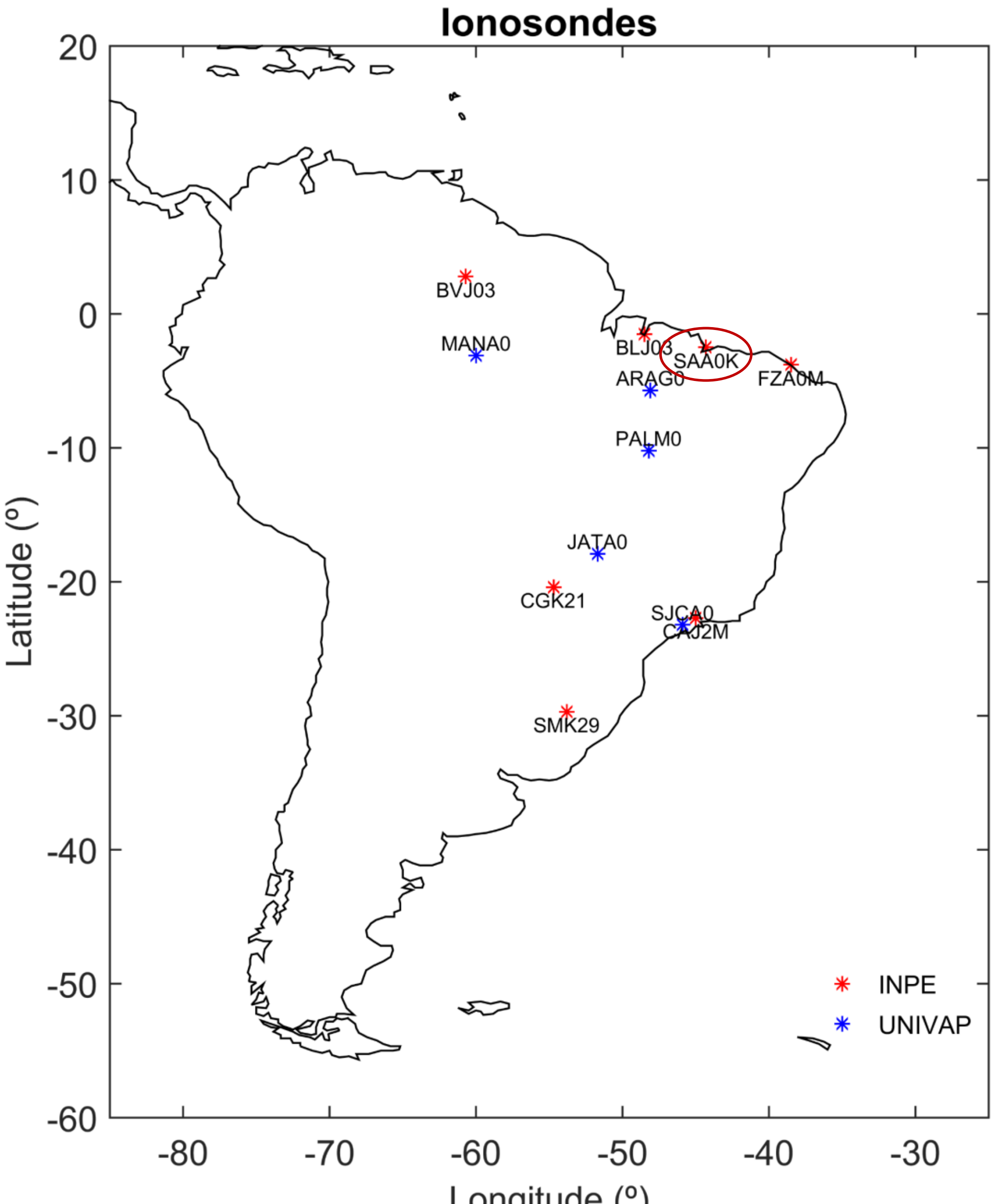
Results: FAZ0M

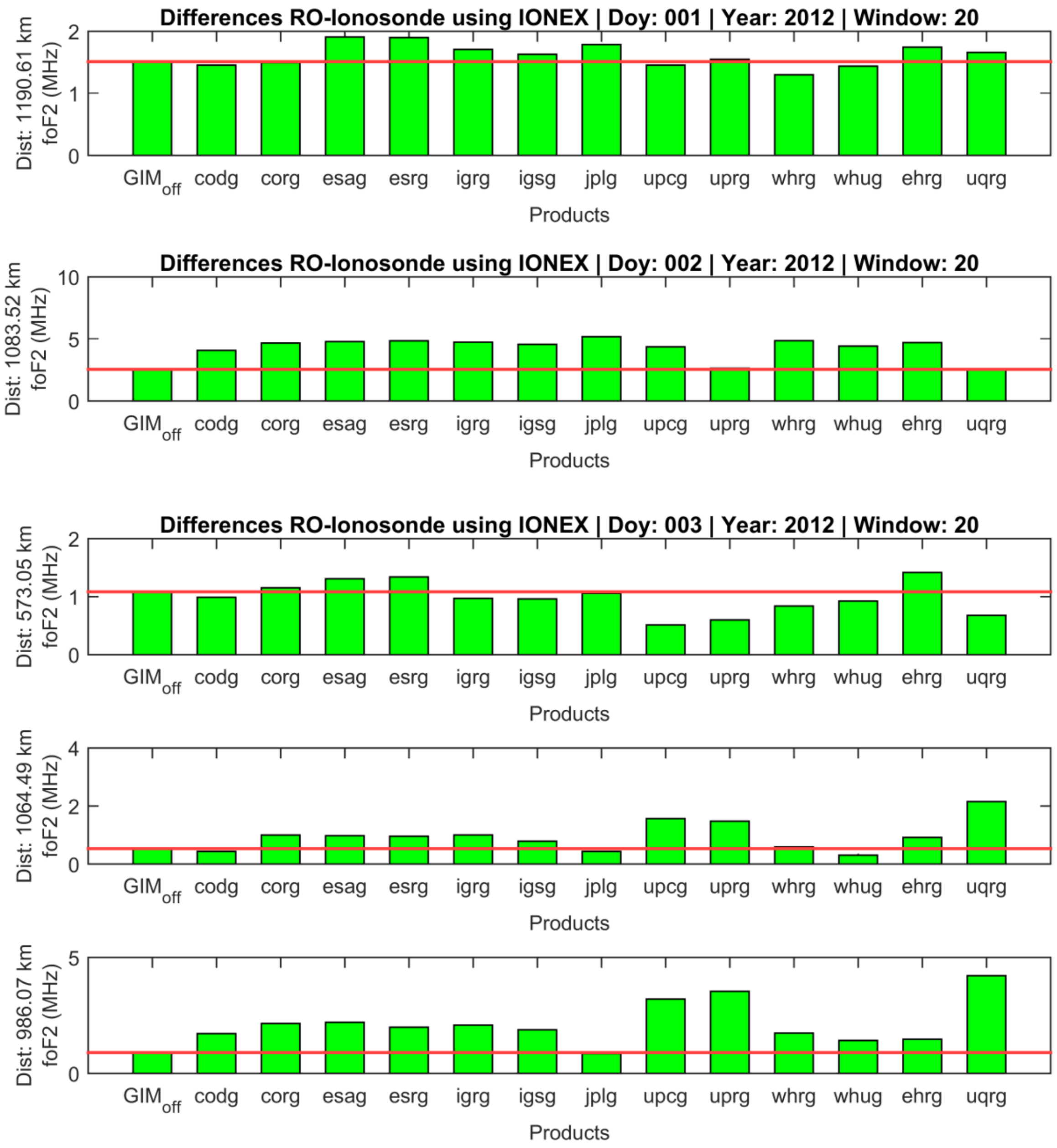
Differences between RO and ionosonde data using GIMs



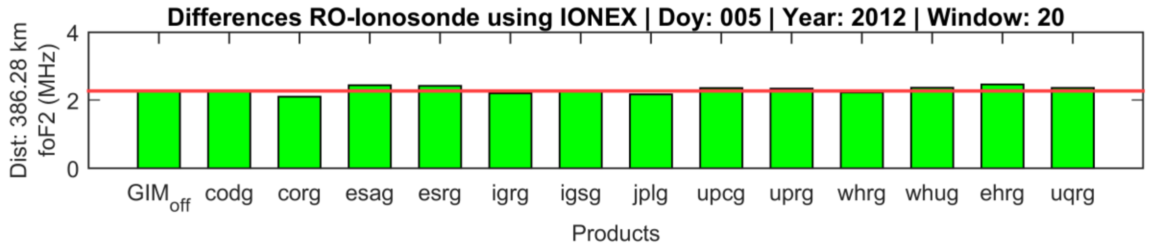


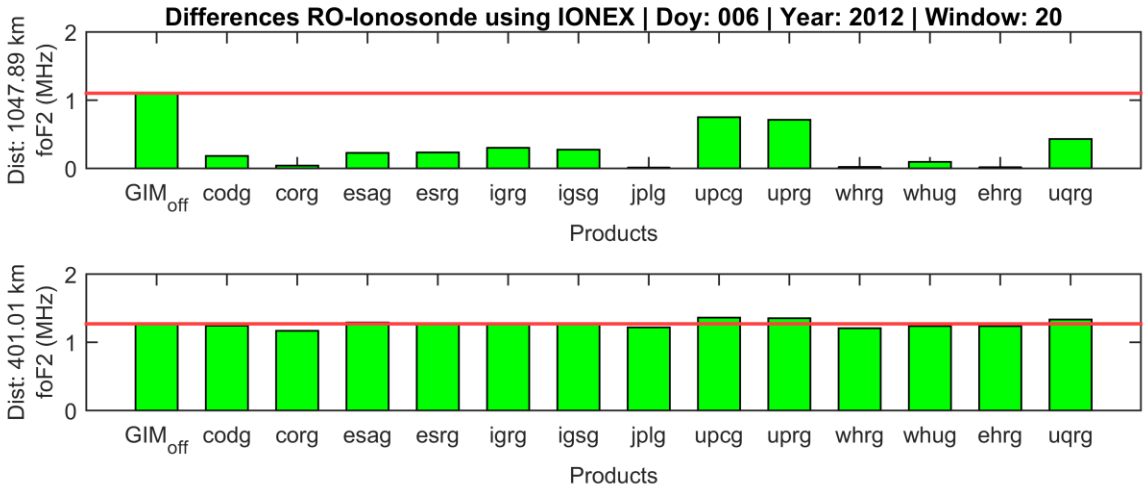
Results: SAA0K

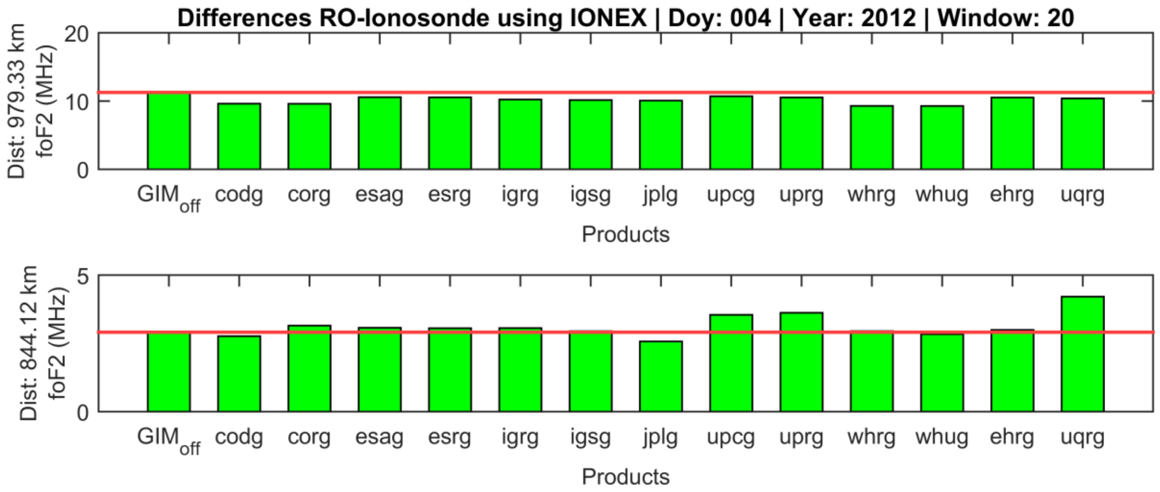


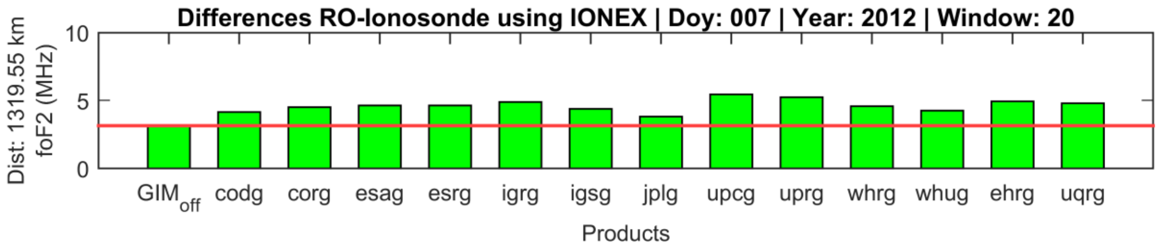


Results: SAA0K



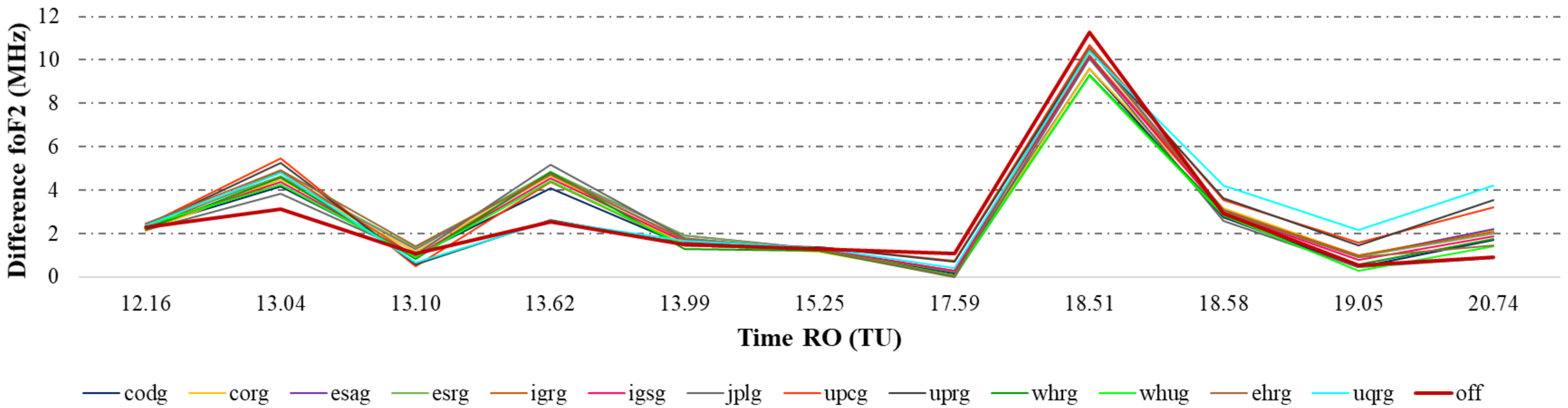


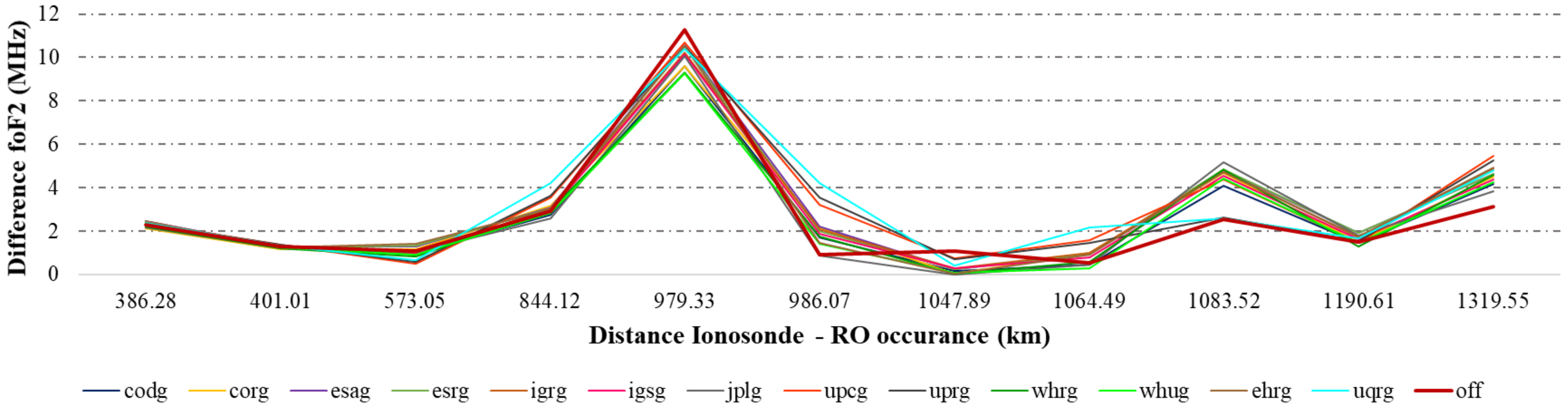




Results: SAA0K

Differences between RO and ionosonde data using GIMs





Results: Summary

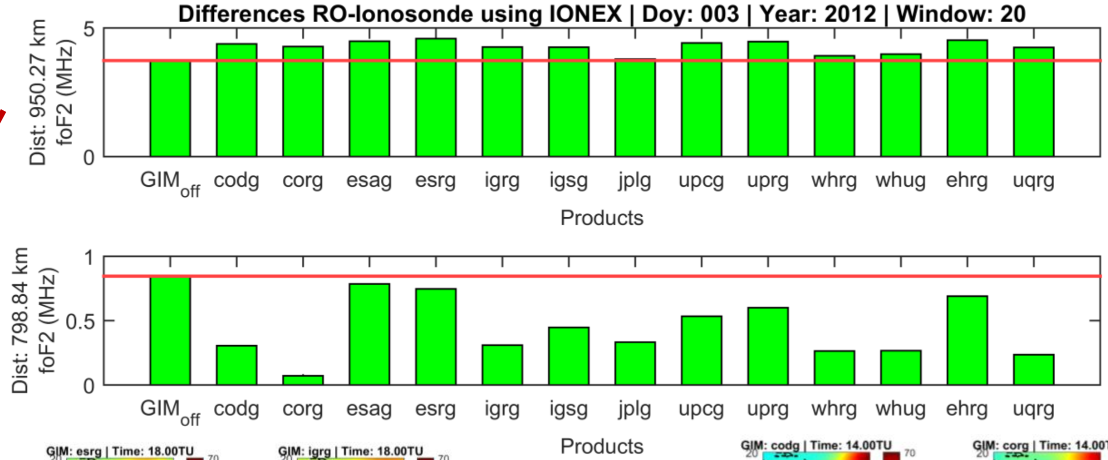
Ionosonde	Differences foF2 ROtoIONO by product (MHz)																	
	Doy	Time_iono	Time_ro	Distance	off	codg	corg	esag	esrg	igrg	igsg	jplg	upcg	uprg	whrg	whug	ehrg	uqrg
CAJ2M	1	12,17	12,20	515,17	0,876	0,188	0,210	0,226	0,216	0,228	0,233	0,148	0,400	0,344	0,180	0,129	0,211	0,361
	2	11,67	11,73	1189,98	1,519	0,234	0,188	0,368	0,116	0,323	0,330	0,265	0,525	0,877	0,382	0,158	0,235	1,059
	2	13,33	13,30	241,40	0,231	0,115	0,075	0,022	0,014	0,067	0,089	0,041	0,181	0,146	0,085	0,063	0,045	0,141
	2	13,50	13,49	1143,11	0,904	0,601	0,508	0,057	0,184	0,301	0,374	0,191	0,648	0,030	0,576	0,492	0,463	0,096
	2	15,33	15,32	1007,28	0,477	0,052	0,098	0,339	0,144	0,039	0,061	0,272	0,323	0,205	0,163	0,163	0,162	0,282
	3	18,83	18,92	950,27	3,733	4,380	4,276	4,483	4,586	4,259	4,251	3,790	4,417	4,469	3,918	3,983	4,524	4,242
	3	14,83	14,81	798,84	0,846	0,305	0,071	0,785	0,747	0,309	0,447	0,333	0,534	0,601	0,264	0,266	0,690	0,235
	5	13,83	13,78	495,90	1,630	1,254	1,389	1,496	1,454	1,406	1,422	1,495	1,500	1,536	1,226	1,368	1,343	1,090
	6	13,33	13,32	843,00	2,885	2,370	1,961	2,445	2,382	2,216	2,190	1,915	2,107	2,355	2,222	2,340	3,034	2,569
	6	13,33	13,38	1417,24	1,618	0,640	1,257	0,921	1,016	1,185	1,118	1,949	1,041	1,228	0,722	0,618	1,369	1,289
	6	13,50	13,42	813,88	1,318	1,707	1,164	1,869	1,742	1,376	1,328	0,847	1,007	1,310	1,511	1,653	1,817	1,292
	7	11,17	11,18	604,23	0,485	0,127	0,195	0,380	0,380	0,177	0,126	0,131	0,319	0,180	0,113	0,193	0,132	0,064
	7	13,00	13,00	193,41	0,491	0,435	0,392	0,340	0,340	0,394	0,392	0,362	0,406	0,405	0,365	0,393	0,391	0,412
FAZ0M	1	18,17	18,15	1263,04	5,776	1,784	3,327	3,317	3,329	3,535	3,412	4,373	4,845	3,214	1,370	1,313	3,665	2,091
	3	11,33	11,35	1266,64	0,189	1,226	1,206	0,850	0,810	1,188	1,086	0,951	1,273	1,556	1,214	1,326	0,792	1,188
	3	13,17	13,10	887,78	1,484	1,899	2,148	2,208	2,244	2,050	1,989	2,089	1,801	1,900	1,903	1,874	1,977	1,850
	3	19,00	19,05	997,87	0,518	0,431	0,216	0,143	0,163	0,058	0,258	0,740	0,511	0,387	0,176	0,483	0,224	1,295
	3	20,67	20,74	1072,28	0,011	0,760	1,133	0,988	0,843	0,946	0,779	0,198	1,923	2,162	1,013	0,608	0,371	3,053
	3	15,00	14,97	1159,61	0,328	0,522	0,852	0,490	0,443	0,608	0,518	0,260	0,889	0,920	0,786	0,483	0,451	1,238
	4	18,50	18,58	679,05	0,466	0,742	0,100	0,341	0,355	0,466	0,623	1,117	0,059	0,033	0,307	0,459	0,290	0,893
	4	14,50	14,48	820,55	1,815	1,163	1,125	1,456	1,498	1,531	1,480	1,611	1,767	1,762	1,160	1,065	1,248	1,713
	5	12,17	12,16	966,75	0,573	0,802	1,096	1,179	1,157	0,996	0,878	0,650	1,083	1,113	0,837	0,681	1,144	1,160
	5	14,00	13,98	1074,76	3,116	2,071	2,163	2,519	2,562	2,028	2,206	2,027	2,384	2,431	2,176	2,160	2,578	2,291
	6	17,67	17,59	516,44	0,386	1,335	1,219	1,099	1,107	0,991	1,115	1,236	0,649	0,658	1,464	1,383	1,107	0,962
	6	19,33	19,34	1063,51	0,519	1,334	1,258	0,949	0,998	1,205	1,244	1,257	1,368	1,300	1,514	1,591	1,051	1,669
	6	15,33	15,25	995,68	0,104	0,164	0,242	0,088	0,142	0,019	0,142	0,178	0,106	0,071	0,042	0,064	0,230	0,383
SAA0K	1	13,83	13,99	1190,61	1,511	1,455	1,496	1,908	1,900	1,707	1,630	1,786	1,455	1,548	1,299	1,439	1,744	1,660
	2	13,67	13,62	1083,52	2,548	4,076	4,668	4,783	4,848	4,735	4,560	5,179	4,364	2,639	4,858	4,424	4,703	2,601
	3	13,17	13,10	573,05	1,084	0,989	1,152	1,308	1,339	0,970	0,961	1,058	0,512	0,599	0,838	0,923	1,416	0,677
	3	19,00	19,05	1064,49	0,532	0,435	0,999	0,976	0,959	1,002	0,787	0,435	1,566	1,477	0,590	0,305	0,917	2,152
	3	20,67	20,74	986,07	0,899	1,715	2,153	2,203	1,989	2,080	1,880	0,855	3,204	3,537	1,736	1,420	1,470	4,211
	4	18,50	18,51	979,33	11,267	9,616	9,602	10,562	10,538	10,214	10,147	10,060	10,699	10,521	9,290	9,278	10,512	10,381
	4	18,50	18,58	844,12	2,909	2,763	3,150	3,070	3,054	3,059	2,947	2,571	3,545	3,619	2,949	2,839	2,991	4,211
	5	12,17	12,16	386,28	2,273	2,296	2,105	2,442	2,423	2,206	2,296	2,174	2,359	2,342	2,229	2,368	2,466	2,363
	6	17,67	17,59	1047,89	1,102	0,183	0,041	0,227	0,234	0,302	0,275	0,012	0,751	0,713	0,022	0,095	0,017	0,431
	6	15,17	15,25	401,01	1,271	1,244	1,168	1,290	1,265	1,265	1,271	1,219	1,362	1,353	1,206	1,238	1,237	1,335
	7	13,00	13,04	1319,55	3,147	4,151	4,511	4,638	4,638	4,893	4,388	3,817	5,454	5,246	4,581	4,258	4,939	4,797

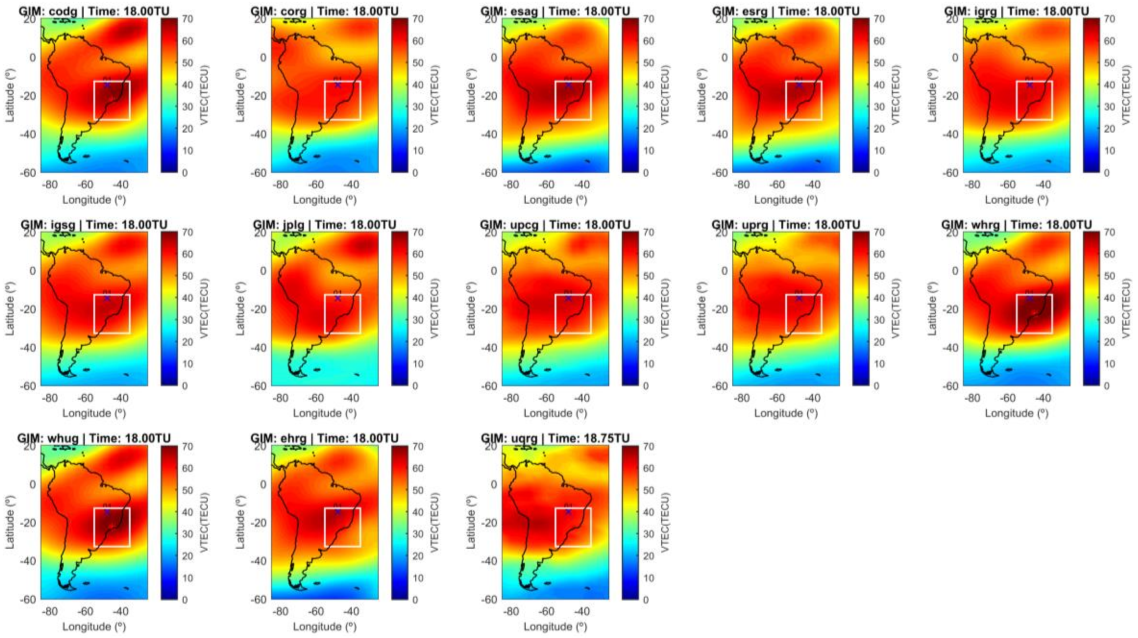
Results: Summary

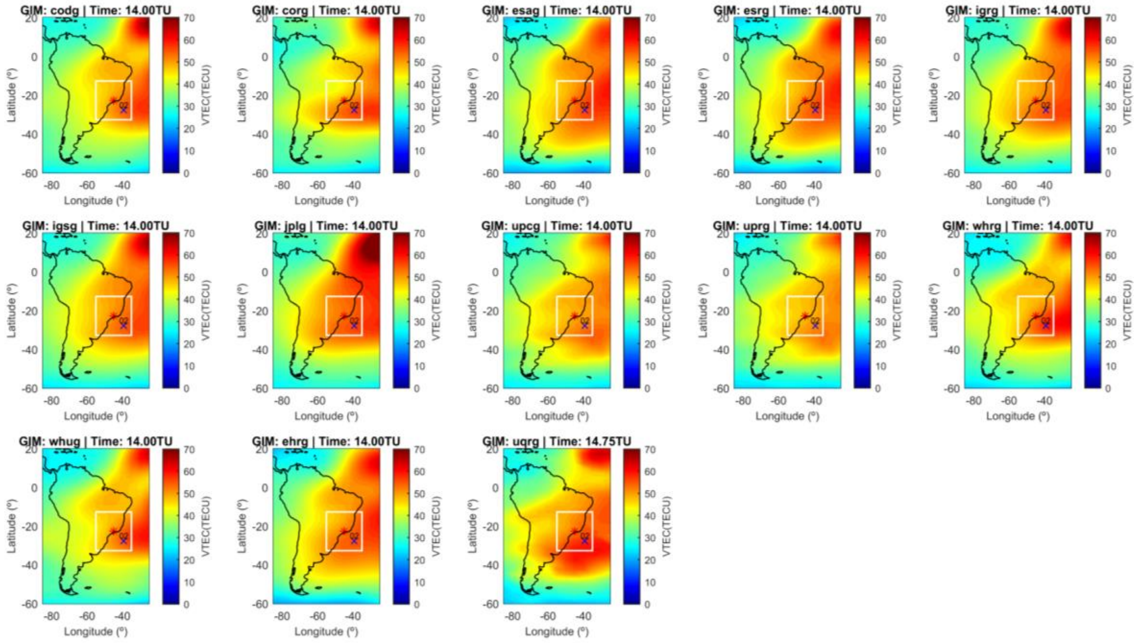
Ionosonde	Relative differences foF2 ROtoIONO by product (%)																	
	Doy	Time_iono	Time_ro	Distance	off	codg	corg	esag	esrg	igrg	igsg	jplg	upcg	uprg	whrg	whug	ehrg	uqrg
CAJ2M	1	12,17	12,20	515,17	9,62	2,06	2,30	2,48	2,38	2,50	2,56	1,63	4,40	3,78	1,98	1,41	2,32	3,96
	2	11,67	11,73	1189,98	22,01	3,38	2,72	5,33	1,68	4,67	4,79	3,84	7,61	12,71	5,54	2,30	3,40	15,35
	2	13,33	13,30	241,40	2,52	1,25	0,82	0,23	0,15	0,73	0,97	0,45	1,97	1,59	0,92	0,69	0,49	1,54
	2	13,50	13,49	1143,11	9,82	6,53	5,52	0,61	2,00	3,27	4,06	2,07	7,04	0,33	6,26	5,34	5,03	1,04
	2	15,33	15,32	1007,28	4,17	0,45	0,86	2,97	1,26	0,34	0,53	2,38	2,83	1,79	1,43	1,43	1,42	2,46
	3	18,83	18,92	950,27	27,55	32,32	31,56	33,09	33,85	31,43	31,37	27,97	32,60	32,98	28,91	29,40	33,39	31,31
	3	14,83	14,81	798,84	7,62	2,75	0,64	7,07	6,73	2,79	4,03	3,00	4,81	5,41	2,38	2,40	6,22	2,12
	5	13,83	13,78	495,90	18,52	14,25	15,79	17,00	16,52	15,98	16,16	16,99	17,04	17,45	13,93	15,55	15,26	12,39
	6	13,33	13,32	843,00	33,45	27,47	22,74	28,34	27,62	25,69	25,39	22,20	24,43	27,31	25,76	27,13	35,18	29,78
	6	13,33	13,38	1417,24	18,76	7,42	14,57	10,67	11,78	13,74	12,97	22,59	12,07	14,24	8,37	7,17	15,87	14,95
	6	13,50	13,42	813,88	14,02	18,16	12,38	19,88	18,53	14,64	14,12	9,01	10,72	13,94	16,07	17,59	19,33	13,75
	7	11,17	11,18	604,23	5,14	1,34	2,07	4,02	4,02	1,88	1,33	1,39	3,38	1,90	1,20	2,04	1,40	0,67
	7	13,00	13,00	193,41	5,14	4,56	4,10	3,56	3,56	4,12	4,11	3,80	4,25	4,24	3,82	4,11	4,09	4,31
FAZ0M	1	18,17	18,15	1263,04	70,44	21,76	40,57	40,45	40,60	43,11	41,60	53,32	59,08	39,20	16,70	16,01	44,70	25,50
	3	11,33	11,35	1266,64	2,21	14,34	14,10	9,95	9,47	13,90	12,70	11,12	14,89	18,20	14,20	15,50	9,27	13,90
	3	13,17	13,10	887,78	18,78	24,04	27,19	27,95	28,41	25,95	25,18	26,44	22,80	24,05	24,08	23,72	25,02	23,41
	3	19,00	19,05	997,87	5,54	4,61	2,31	1,53	1,74	0,62	2,75	7,92	5,47	4,14	1,88	5,17	2,40	13,85
	3	20,67	20,74	1072,28	0,11	7,71	11,50	10,03	8,56	9,61	7,91	2,01	19,52	21,95	10,29	6,18	3,77	30,99
	3	15,00	14,97	1159,61	3,81	6,06	9,91	5,69	5,15	7,07	6,03	3,02	10,33	10,70	9,14	5,62	5,24	14,39
	4	18,50	18,58	679,05	4,88	7,77	1,05	3,57	3,72	4,87	6,52	11,70	0,62	0,35	3,22	4,80	3,03	9,35
	4	14,50	14,48	820,55	24,36	15,61	15,10	19,55	20,11	20,55	19,86	21,62	23,72	23,65	15,58	14,30	16,75	23,00
	5	12,17	12,16	966,75	7,70	10,77	14,71	15,83	15,53	13,37	11,78	8,72	14,54	14,94	11,23	9,14	15,35	15,56
	5	14,00	13,98	1074,76	43,28	28,76	30,04	34,98	35,58	28,16	30,63	28,16	33,11	33,76	30,22	30,00	35,81	31,81
	6	17,67	17,59	516,44	3,68	12,72	11,61	10,47	10,54	9,43	10,62	11,77	6,18	6,26	13,94	13,17	10,55	9,16
	6	19,33	19,34	1063,51	5,38	13,82	13,03	9,84	10,34	12,48	12,89	13,02	14,18	13,48	15,69	16,48	10,89	17,30
	6	15,33	15,25	995,68	1,23	1,93	2,85	1,03	1,67	0,22	1,67	2,09	1,25	0,83	0,50	0,75	2,70	4,51
SAA0K	1	13,83	13,99	1190,61	20,15	19,40	19,94	25,44	25,33	22,76	21,73	23,82	19,40	20,64	17,32	19,18	23,25	22,13
	2	13,67	13,62	1083,52	32,88	52,60	60,24	61,71	62,55	61,10	58,83	66,82	56,30	34,05	62,69	57,08	60,68	33,56
	3	13,17	13,10	573,05	13,05	11,92	13,88	15,75	16,14	11,68	11,57	12,74	6,17	7,21	10,10	11,12	17,06	8,15
	3	19,00	19,05	1064,49	6,41	5,24	12,03	11,76	11,55	12,07	9,48	5,24	18,87	17,79	7,11	3,67	11,04	25,92
	3	20,67	20,74	986,07	10,03	19,13	24,02	24,58	22,20	23,21	20,97	9,54	35,75	39,46	19,37	15,84	16,41	46,98
	4	18,50	18,51	979,33	182,46	155,73	155,49	171,04	170,65	165,40	164,32	162,91	173,26	170,37	150,44	150,24	170,23	168,12
	4	18,50	18,58	844,12	47,11	44,75	51,01	49,72	49,46	49,54	47,73	41,63	57,40	58,61	47,76	45,97	48,44	68,20
	5	12,17	12,16	386,28	39,54	39,93	36,62	42,47	42,14	38,37	39,94	37,81	41,03	40,74	38,77	41,18	42,88	41,09
	6	17,67	17,59	1047,89	12,23	2,03	0,46	2,52	2,60	3,35	3,05	0,14	8,33	7,91	0,24	1,06	0,19	4,78
	6	15,17	15,25	401,01	17,83	17,46	16,40	18,10	17,75	17,75	17,84	17,10	19,11	18,99	16,92	17,37	17,37	18,73
	7	13,00	13,04	1319,55	35,12	46,32	50,34	51,75	51,75	54,59	48,96	42,59	60,85	58,54	51,12	47,51	55,11	53,53

Results

Some results did not present the same pattern, considering distance or region. Some of them could be explained by the ionospheric variability.







Conclusions and future works

- Significant part of the GNSS RO-derived electron density profiles presented better agreement of the critical frequency foF2 with the direct ionosonde measurements results when GIM VTEC information is considered;

- Some dependency with the ionospheric intensity could be noticed, as well as dependency with the distance between the ionosonde and the occultation occurrence (in some cases);

- Some results did not present the same pattern, considering distance, region or ionospheric variability.

- Further investigation of the method considering the VTEC variability relation with the squared frequency, and the influence of the larger RO inversion error due to the larger variability of electron density over Brazil, should be performed in the next steps of this research;

- We also intend to expand the analysis to more days and other RO missions.

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Thank you!

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