Quantifying the storm effects on the modeled neutral density variations on the CHAMP satellite track

December, 2006 storm

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Purpose and Methodology

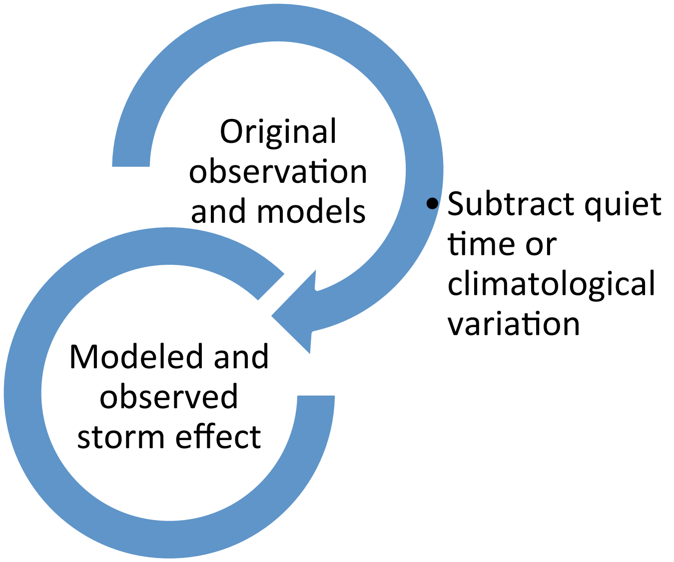
Purpose: Investigate the storm effect on the neutral density estimation of IT models

Key points of this study:

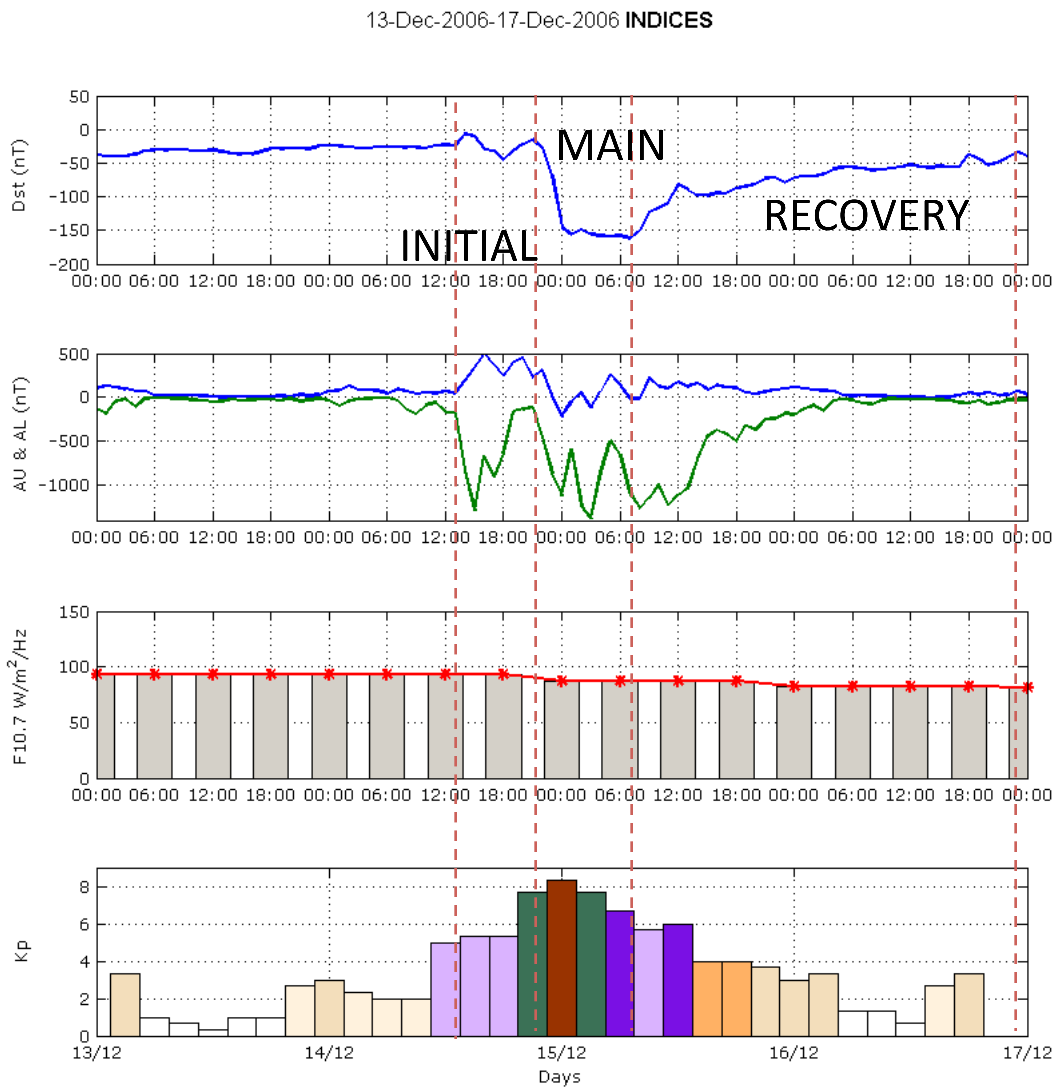
1. The use of orbit averaged values: Important for satellite drag applications and parameters which are dependent on energy storage and release with time
2. Removal of the background values using different approaches

How to filter storm effect

1) Quick and Dirty: Shift all the quiet time model estimations to CHAMP quiet time observations (data shift to CHAMP)
2) Quick and dirty-2:Remove the quiet time average from CHAMP observations and each model
3) More tedious: Subtract the climatological background variations from the observation and models

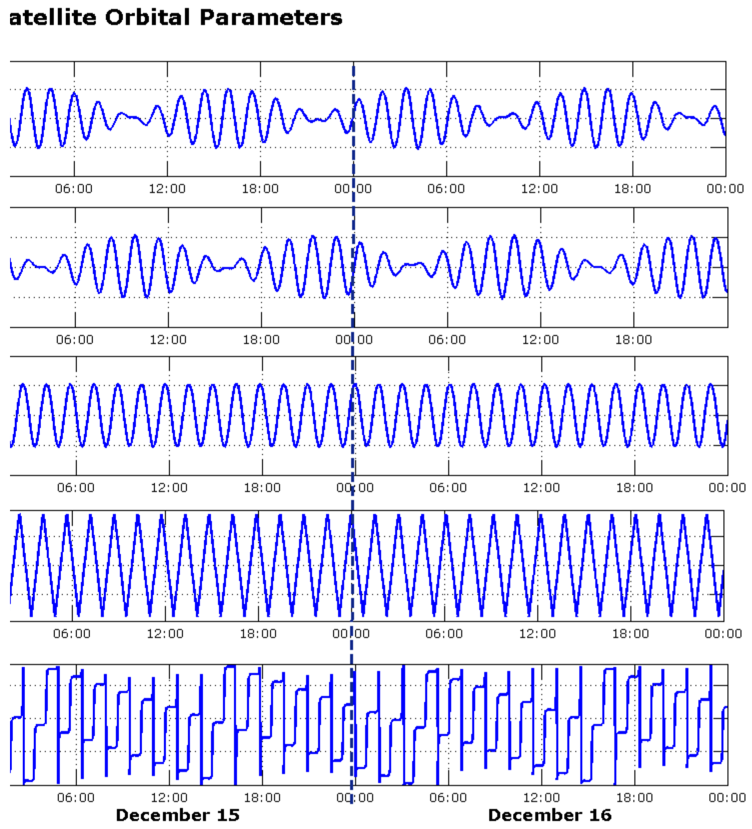


Event: 13-17 December, 2006 storm

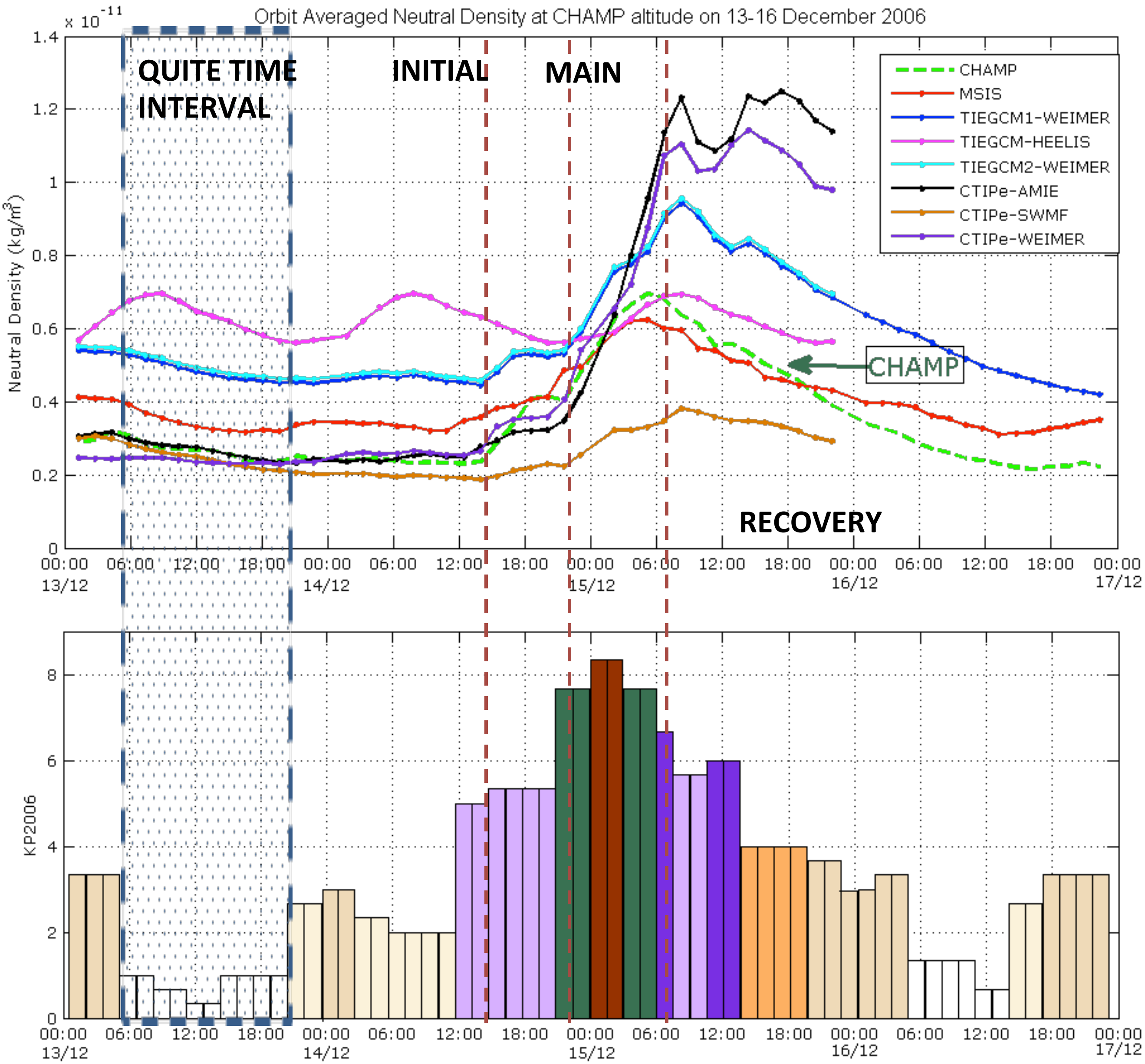


CHAMP satellite

Approximately 15 orbits per day



Unshifted Orbit Averaged Model Results and CHAMP observations



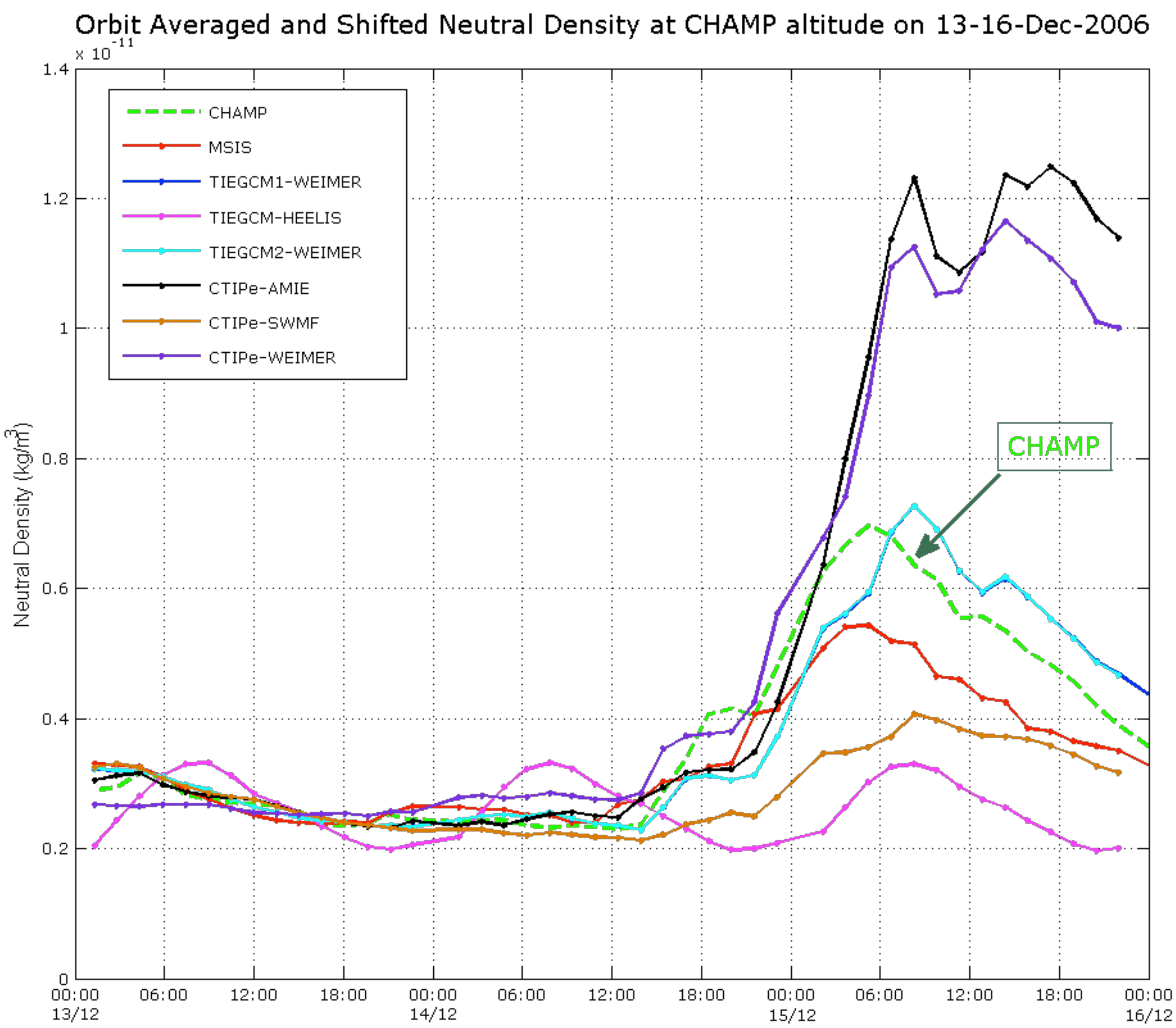
Quiet Time:

1. CTIPe-SWMF, CTIPe-AMIE, CTIPe-Weimer estimations are close to CHAMP
2. MSIS, TIEGCM versions with Heelis and Weimer overestimate the quiet time density

Storm Time enhancements cannot be directly seen.

Climatology is affecting the model estimations.

Quick & Dirty: Quiet time Model values shifted to quiet time CHAMP values



Storm-time behavior of the models are filtered

For example:
Without shift: TIEGCM seems to overestimate the storm effects

With shift: TIEGCM depicts better performance in the estimation of storm effect on neutral density

Comparison between unshifted and shifted model performances

Parameters chosen: Quiet time density average, storm time density average, peak density during the storm, time of the peak

DIRECT MODEL RESULTS

UNSHIFTED MODEL RESULTS AND CHAMP COMPARISON								
Neutral Density (10^-12 kg/m^3)	CHAMP	MSIS	TIEGCM 1.94.2 Heelis	TIEGCM 1.94.2 Weimer	TIEGCM 1.95 with Weimer	CTIPe-Weimer	CTIPe-SWMF	CTIPe-AMIE
quiet time density average	**2.64**	3.39	6.38	4.95	4.84	2.37	2.43	**2.66**
stormtime density average	**4.82**	4.84	6.14	7.10	6.99	7.65	2.92	8.12
peak density during the storm	**6.97**	6.24	**6.93**	9.56	9.43	11.0, 11.4	3.81	12.3, 12.4, 12.5
time of the peak	**5:12**	**5:12**	8:16	8:16	8:16	08:16, 14:23	8:16	08:16, 14:23, 17:26

FILTERED STORM EFFECT

SHIFTED MODEL RESULTS AND CHAMP COMPARISON (DENSITIES SHIFTED TO CHAMP)								
Neutral Density (10^-12 kg/m^3)	CHAMP	MSIS	TIEGCM 1.94.2 Heelis	TIEGCM 1.94.2 Weimer	TIEGCM 1.95 with Weimer	CTIPe-Weimer	CTIPe-SWMF	CTIPe-AMIE
quiet time density average	**2.64**	2.59	2.75	**2.66**	**2.66**	2.58	2.68	**2.66**
stormtime density average	**4.82**	4.03	6.99	**4.82**	**4.81**	7.86	3.18	8.12
peak density during the storm	**6.97**	5.43	3.30	**7.27**	**7.26**	11.3, 11.65	4.07	12.3, 12.49
time of the peak	**5:12**	**5:12**	8:16	8:16	8:16	08:16, 14:23	8:16	08:16, 17:26

ZOOMING INTO THE STORM PHASES: COMPARISON OF MEAN NEUTRAL DENSITIES

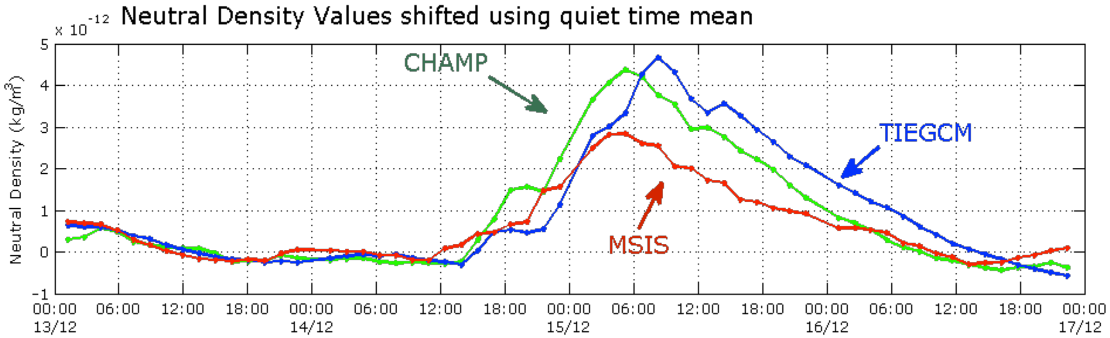
UNSHIFTED MODEL RESULTS

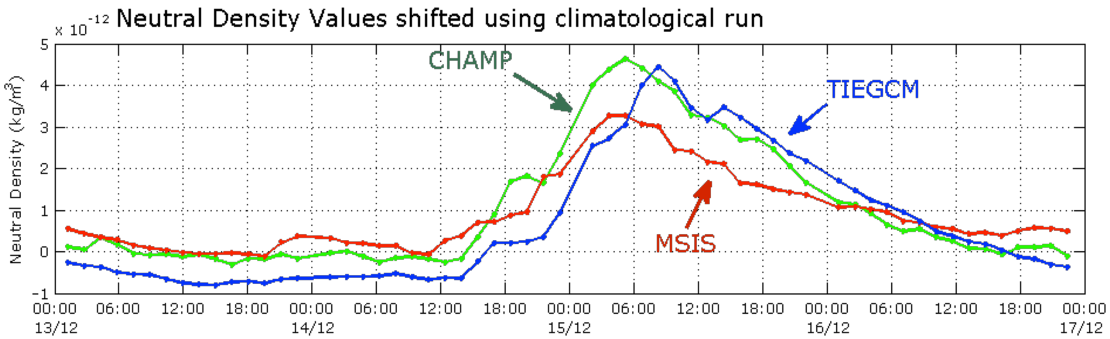
Mean Neutral Density according to the storm phases	CHAMP	MSIS	TIEGCM 1.94.2 Heelis	TIEGCM 1.94.2 Weimer	TIEGCM 1.95 with Weimer	CTIPe-Weimer	CTIPe-SWMF	CTIPe-AMIE
Initial Phase	**3.50**	4.10	5.94	5.21	5.10	**3.58**	2.14	3.19
Main Phase	**6.61**	6.06	**6.53**	8.50	8.38	8.86	3.41	9.52
Recovery	**5.01**	**4.83**	6.11	8.01	7.89	10.59	3.35	11.72
Quiet Time	**2.64**	3.39	6.38	4.95	4.84	2.37	**2.43**	2.37

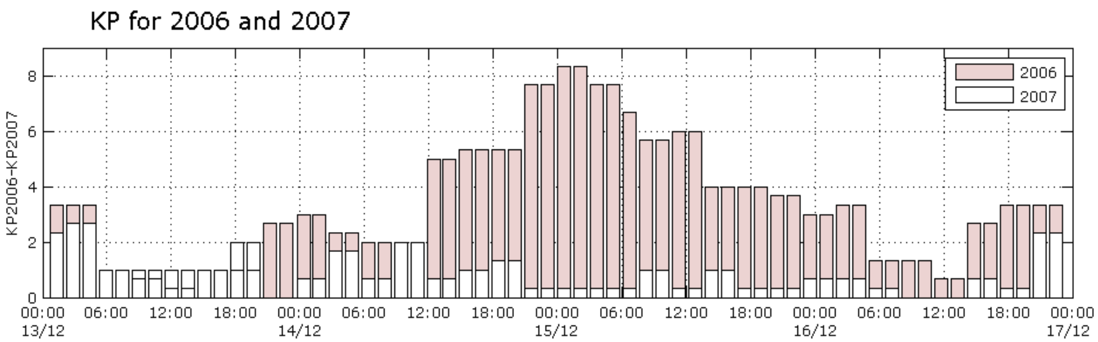
SHIFTED MODEL RESULTS

Mean Neutral Density according to the storm phases	CHAMP	MSIS	TIEGCM 1.94.2 Heelis	TIEGCM 1.94.2 Weimer	TIEGCM 1.95 with Weimer	CTIPe-Weimer	CTIPe-SWMF	CTIPe-AMIE
Initial Phase	**3.50**	**3.29**	2.31	2.92	2.92	3.79	2.39	3.19
Main Phase	**6.61**	5.25	2.90	**6.22**	**6.20**	9.07	3.66	9.52
Recovery	**5.01**	4.02	2.47	**5.72**	**5.72**	10.80	**3.60**	11.72
Quiet Time	**2.64**	2.59	2.75	**2.66**	**2.66**	2.58	2.68	**2.66**

Other Shifting Methods and Comparison between the methods: Sample: CHAMP, MSIS and TIEGCM with WEIMER







Shift1	Quiet time model values shifted to CHAMP quiet time values (data shifted to CHAMP)
Shift2	Quiet time variations removed from each
Shift3	Comparison between the same days with no disturbance

Difference from CHAMP in Average Quiet Time Density	**MSIS**	**TIEGCM**
Shift1	0.05	-0.02
Shift2	0.05	-0.02
Shift3	-0.13	0.58

Difference from CHAMP in Storm Time Average Density	**MSIS**	**TIEGCM**
Shift1	0.42	-0.15
Shift2	0.79	0.01
Shift3	0.69	0.46

Difference from CHAMP in Peak Density	**MSIS**	**TIEGCM**
Shift1	1.54	-0.29
Shift2	1.54	-0.29
Shift3	1.37	0.20

Storm time average density difference from CHAMP is affected by the shifting method chosen. However, choosing methods 1 or 2 don't exhibit any significant difference from each other in average quiet time and peak density differences from CHAMP.

Discussion and Conclusion

For this sample event:

- ✓ Orbit averaging is proven to be useful in determining the global response of the thermosphere to the ongoing storm
- ✓ Background shifting is especially efficient for the models which have deviations from CHAMP observations during quiet time
- ✓ Results can be misleading without shifting
- ✓ Without shift: Average of the storm density is not very meaningful
    - ✓ Best performing model changes according to the storm phase under investigation
- ✓ With shift: Taking storm time density average becomes meaningful:
    - ✓ Best performing model according to the storm phase doesn't change and is consistent with the model performing best in capturing the storm time density average
- ✓ Using shifting methods 1 or 2 doesn't make any significant change in the model performance calculations (each can be chosen as the quick and dirty method)
- ✓ However, removing the background variations as in Shift3 should be studied in more detail as it exhibits difference and gives information about the climatology.

<u>Discussion:</u>

Storm Phase integrated values

Event averaging=one number for event?

Orbit averaging challenge

This work has been conducted via the international collaboration between Istanbul Technical University Upper Atmosphere and Space Weather Lab (**ITU-UASW**), TR and the NASA-GSFC/CCMC, with financial support from TUBITAK International Doctoral Research Fellowship Programme, TINCEL foundation and ITU.