# Towards a New Metric for Satellite Drag Studies

## Neutral Density Validation

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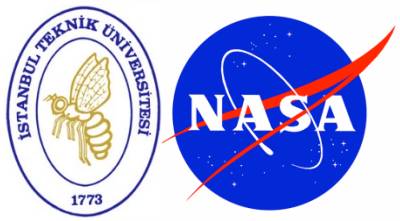


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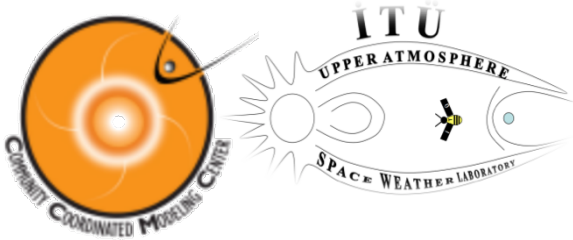
2. Istanbul Technical University, TR



# PURPOSE

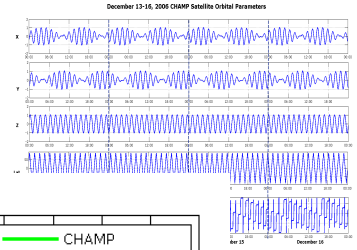
- ✓ Quantify the storm impact acting on the neutral densities
- ✓ Eventually contribute to satellite drag studies

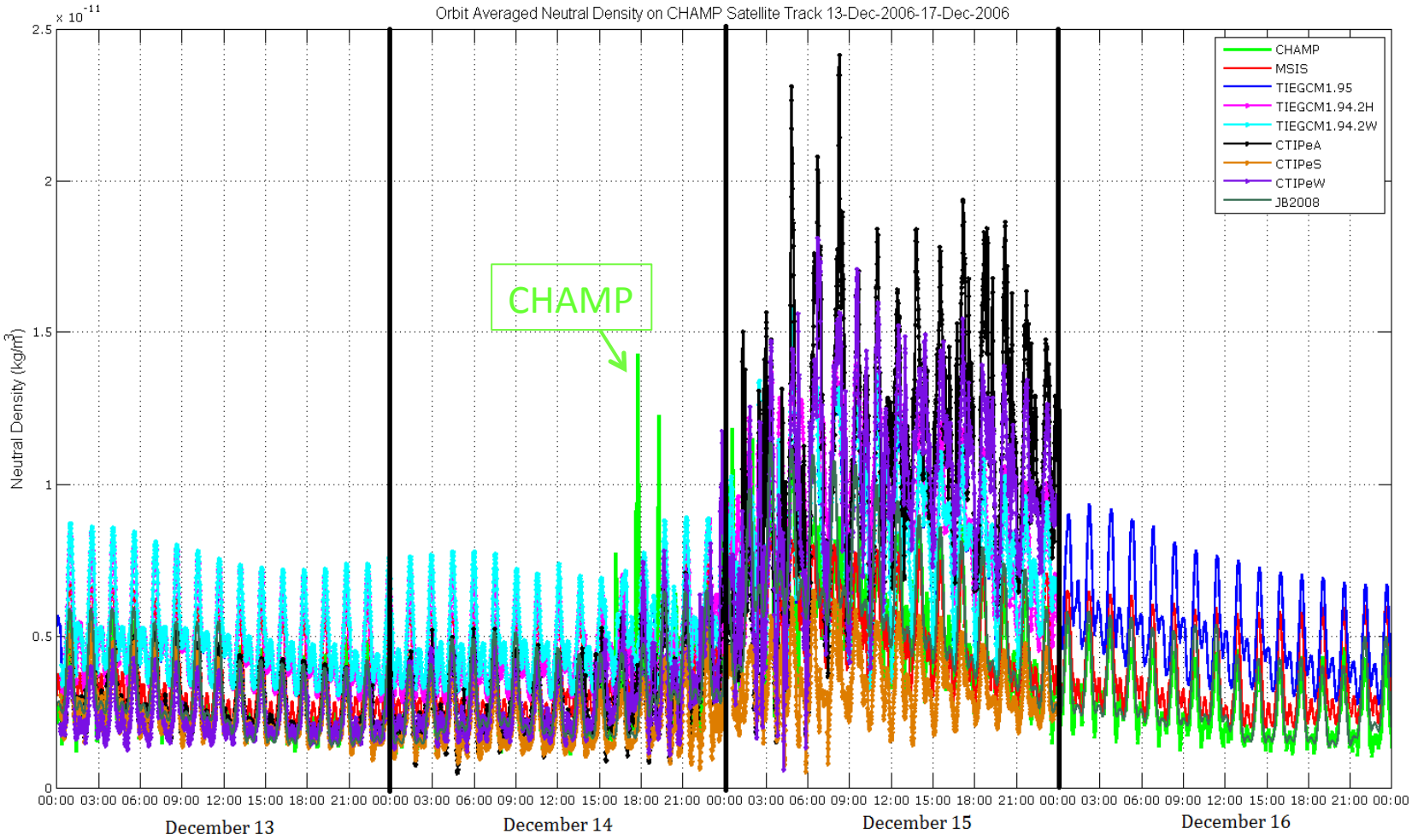
Tools of the trade:

- CHAMP satellite observations
- Empirical and physics-based model estimations

CHAMP

# The Challenge

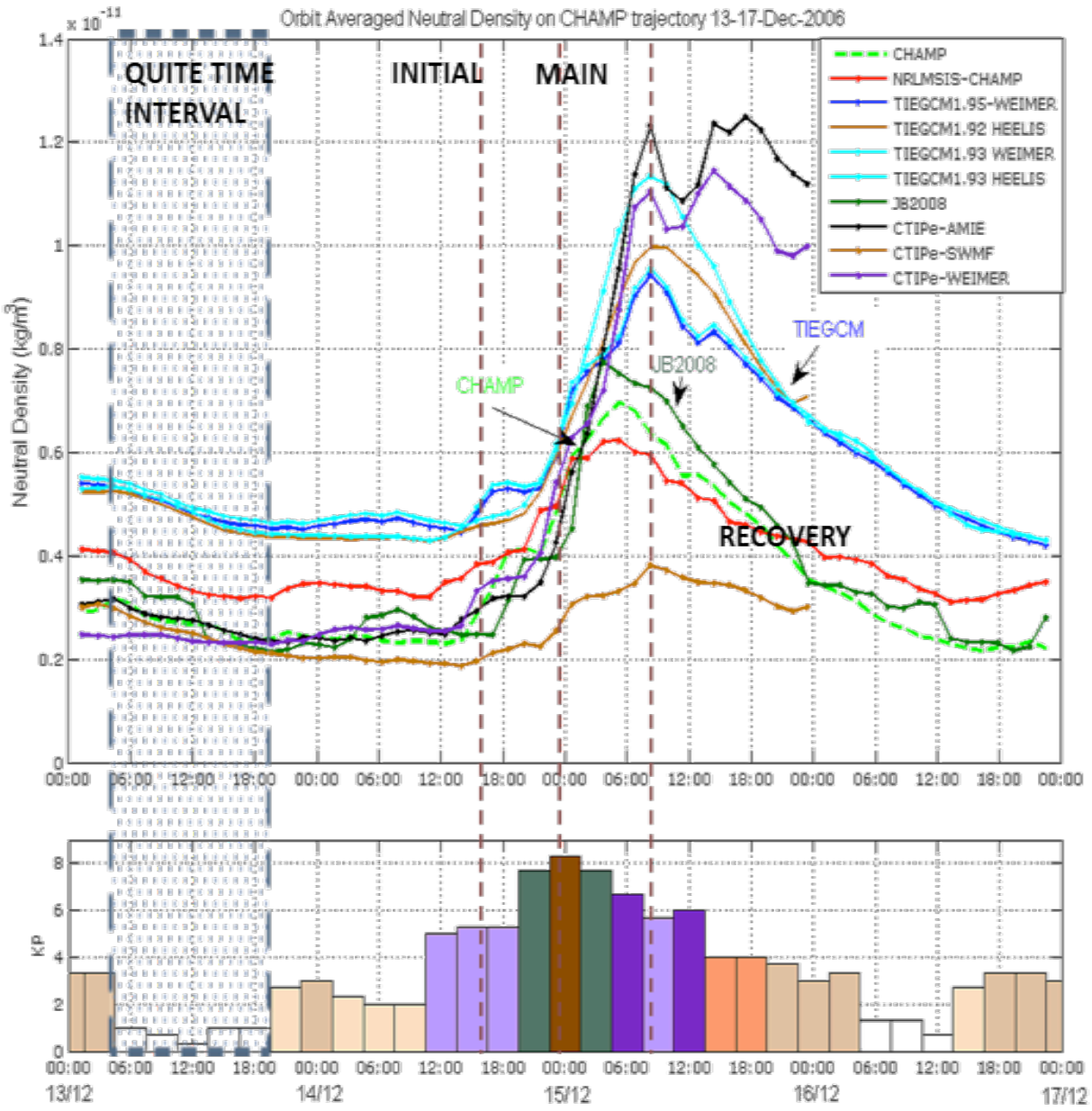





Storm impact is superposed on the background variation. Hard to quantify.

Point to point comparisons of data with models give different skill scores for different metrics (Shim et al., 2012).

# Orbit Averaging




**Advantages:**

1. Easier to determine the global response of the ionosphere-thermosphere system to a geomagnetic storm
2. Local time effects are eliminated

**Stilll:**

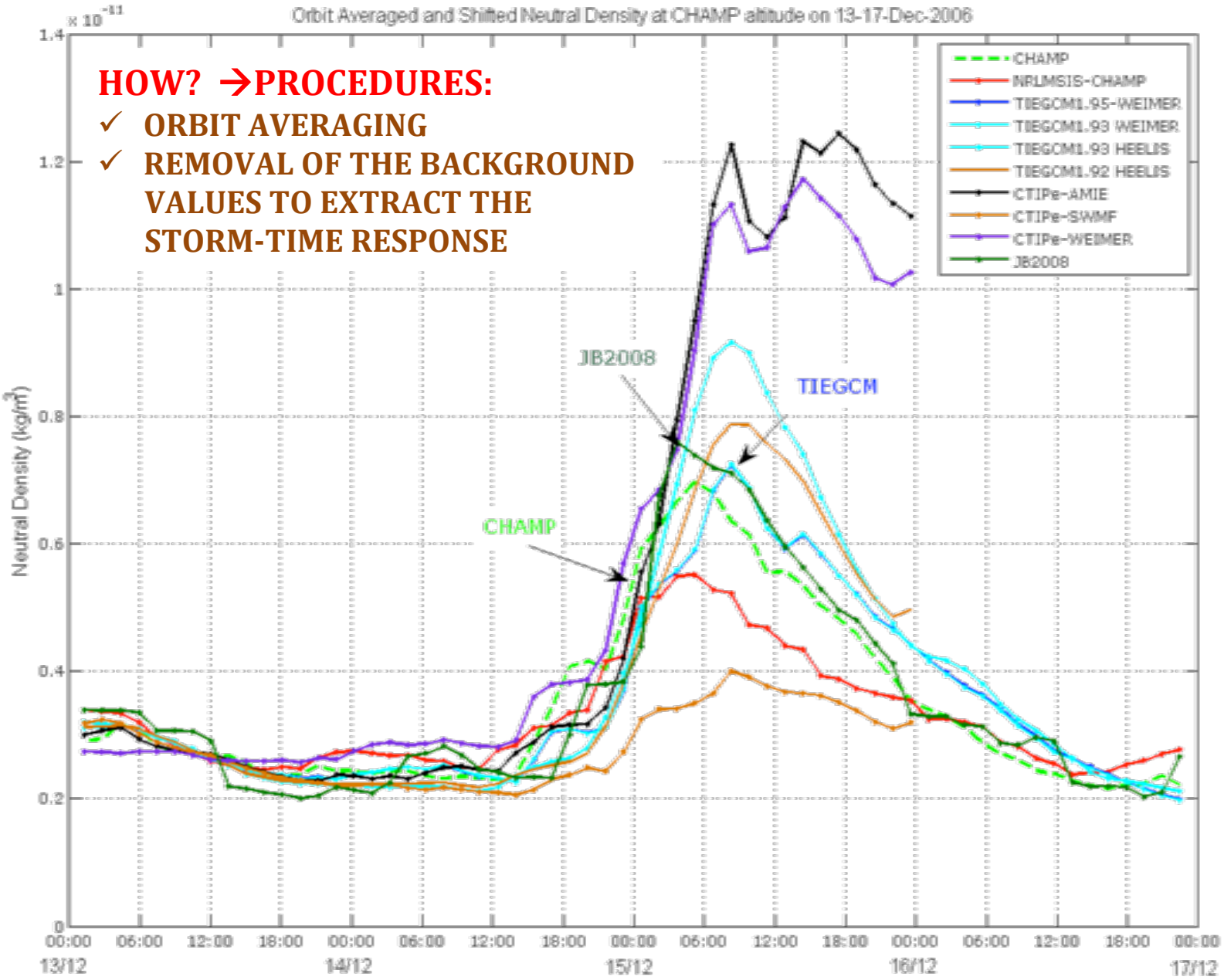
Climatology is affecting the model estimations.

The changes due to the storm impact are difficult to see directly

Quiet Time Climatology:

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

# QUANTIFYING THE STORM TIME RESPONSE



# HOW TO RANK THE MODELS?

**→SELECTED METRICS (selection based on the importance for satellite drag):**

1. **Storm-time average neutral density**
2. **Neutral density peak**
3. **Time of the neutral density peak**

| 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 | JB2008 |
| stormtime density average | 3.91 | 4.29 | 7.01 | 7.10 | 6.23 | 7.65 | 2.92 | 8.12 | 4.98 |
| peak density during the storm | 6.97 | 6.24 | 9.56 | 9.56 | 9.43 | 11.0, 11.4 | 3.81 | 12.3, 12.4, 12.5 | 7.74 |
| 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 | 3:03 |

| Difference from CHAMP according to the storm phases (10^-12 kg/m^3) | MSIS | TIEGCM 1.94.2 Heelis | TIEGCM 1.94.2 Weimer | TIEGCM 1.95 with Weimer | CTIPe-Weimer | CTIPe-SWMF | CTIPe-AMIE | JB2008 |
|---|---|---|---|---|---|---|---|---|
| Main Phase | -0.55 | 0.82 | 1.89 | 1.77 | 2.25 | -3.20 | 2.91 | -0.48 |
| Recovery | -0.18 | 3.51 | 3.00 | 2.88 | 5.58 | -1.66 | 6.71 | 1.14 |

Metrics not very reliable!

It shows MSIS the best performing model

HOWEVER

From the previous plot we know that

MSIS was overestimating the quiet time variations

+

underestimating the storm time increase.

When added together, the metrics shows as if it is the best.

Not consistent for the phases of storm.

# RANKING THE STORM TIME RESPONSE

| 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 | JB2008 |
| stormtime density average | **3.91** | 3.49 | 4.06 | 4.82 | **4.06** | 7.86 | 3.18 | 8.12 | 4.88 |
| 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 | 7.64 |
| time of the peak | **5:12** | **5:12** | 8:16 | 8:16 | 8:16 | 08:16, 14:23 | 8:16 | 08:16, 17:26 | 3:03 |

| Difference from CHAMP according to the storm phases (10^-12 kg/m^3) | MSIS | TIEGCM 1.94.2 Heelis | TIEGCM 1.94.2 Weimer | TIEGCM 1.95 with Weimer | CTIPe-Weimer | CTIPe-SWMF | CTIPe-AMIE | JB2008 |
|---|---|---|---|---|---|---|---|---|
| Main Phase | -1.36 | -3.71 | **-0.39** | **-0.41** | 2.46 | -2.95 | 2.91 | -0.59 |
| Recovery | -0.99 | -2.54 | **0.71** | **0.71** | 5.79 | -1.41 | 6.71 | 1.04 |

1. After background removal: TIEGCM is found to capture the storm time density increase better with a time lag.
2. Metrics for storm time density average and phase-based density averages are consistent with each other.

# Summary and Conclusion

- ✓ Orbit averaging is useful in determining the global response of the thermosphere to the ongoing storm
- ✓ Background removal is especially of use to find the simulated actual storm impact for models which have deviations from CHAMP observations during quiet time intervals
- ✓ Metrics for the modeled storm impact can be misleading without background removal
- ✓ Before removal: Average of the storm density is not very meaningful for metrics concerning the simulated storm impact
- ✓ After removal: Calculating skill scores for capturing the 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
- ✓ Physics-based models are also efficient in the modeling of the density enhancements during the storm.

# Ongoing Studies and Remaining Questions

Remaining Questions:

Are the results sensitive to the background removal method?

-match model results with observations

-make the quiet time variation zero for all observations and model results

- find the storm impact by using background simulations for the day (simulate the day without geomagnetic storm)

When is this approach valid?

Investigation according to KP levels is needed.

Ongoing study: Quantitative analysis of all GEM-CEDAR events for the selected metrics (with and without the background removal)

| GEM-CEDAR STORM EVENTS | | |
|---|---|---|
| Event Date | Kpmax | Classification |
| 13 December- 16 December 2006 | 8.3 | Severe |
| 15 May- 16 May 2005 | 8.3 | Severe |
| 31 August-1 September 2005 | 7 | Moderate |
| 9 July-11 July 2005 | 6.3 | Moderate |
| 22 May-25 May 2007 | 5.3 | Minor |
| 28 February- 01 March 2008 | 5.3 | Minor |
| 01 April-02 April 2007 | 4 | Minor |
| **GEM-CEDAR QUIET DAYS** | | |
| 31 August-1 September 2001 | 4 | Minor-Quiet |
| 20 March-22 March 2007 | 1 | Quiet |
| 9 July- 10 July 2007 | 0.3 | Quiet |
| 7 December-8 December 2007 | 0.6 | Quiet |

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