Advanced Prediction of Upper Atmospheric Neutral Density Using Measurements from Solar Wind Sentinels

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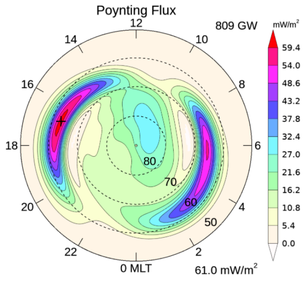
The goal of this project is to develop an operational product capable of real-time density predictions, using input from solar wind sentinels at L_1, such as DSCOVR

Based the EXospheric TEMperatures on a PoLyhedrAl gRid model (EXTEMPLAR) to calculate exospheric temperatures (*Space Weather*, doi:10.1029/2019SW002355, 2020.)

IMF

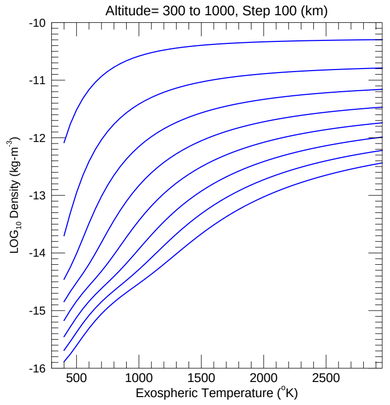
W05 model



Total Poynting flux , derived ΔT

NRL MSIS 2.0

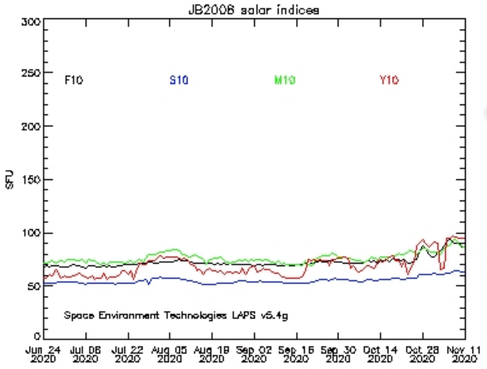
T∞

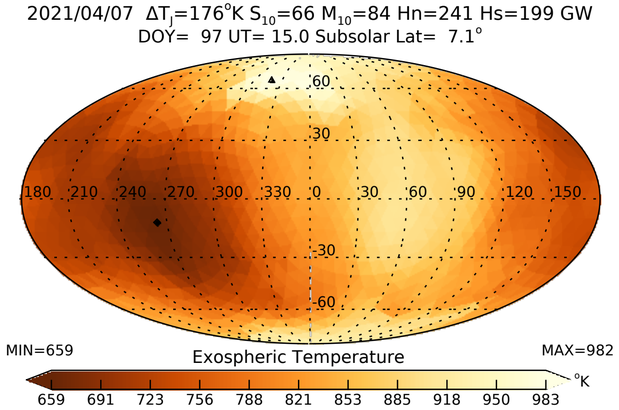


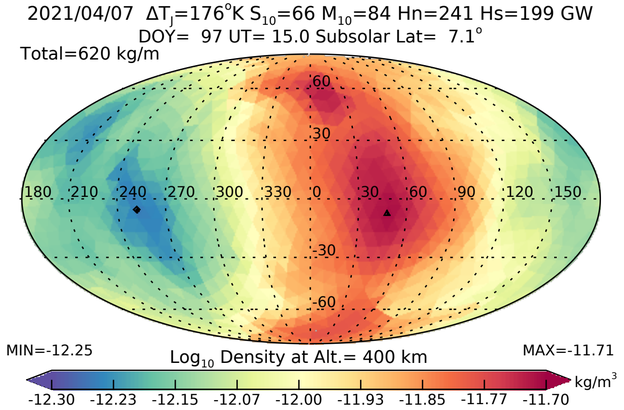
EXTEMPLAR

Neutral densities

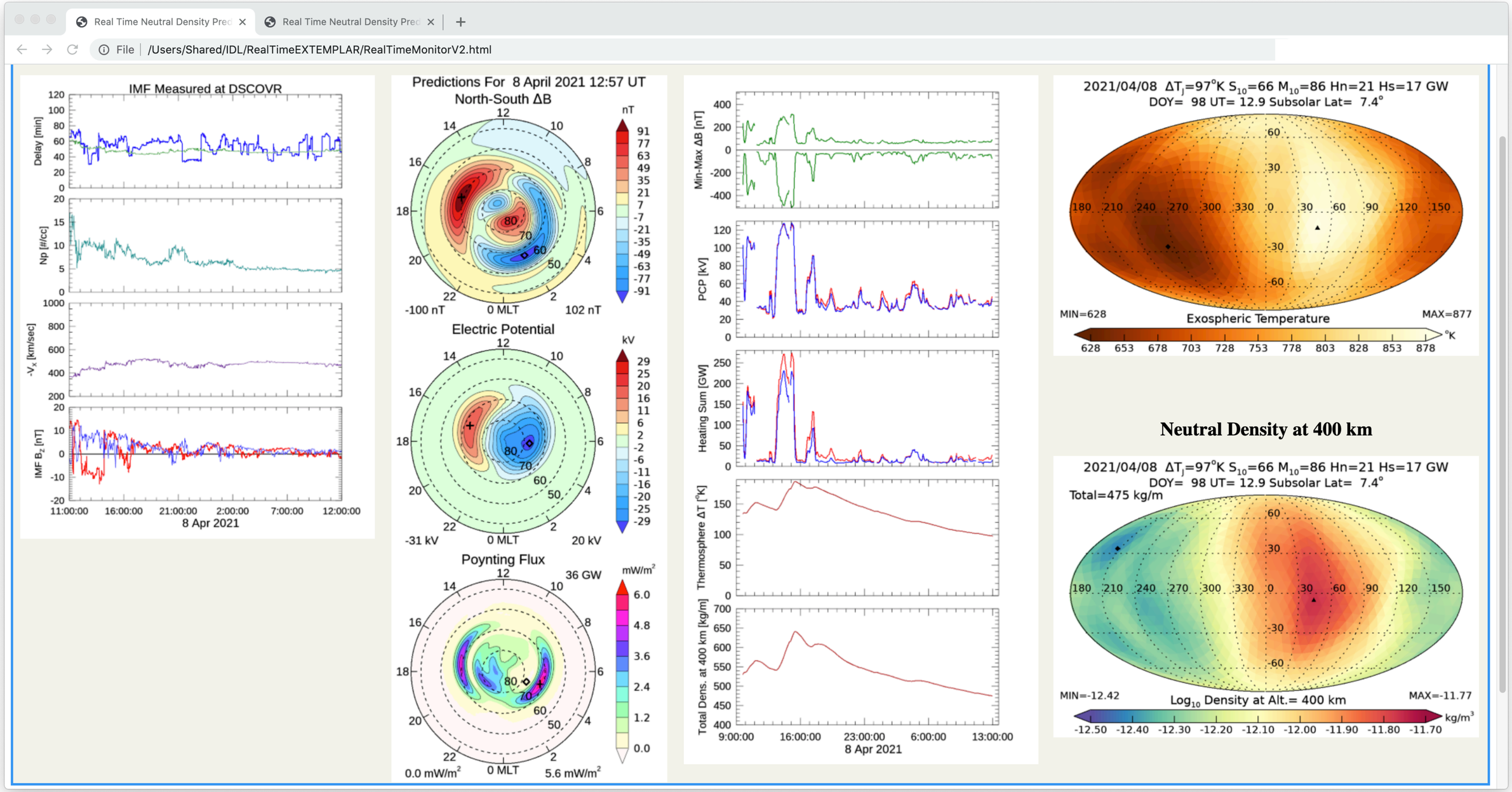
Solar Indices







Initial trials of real-time predictions started just last month

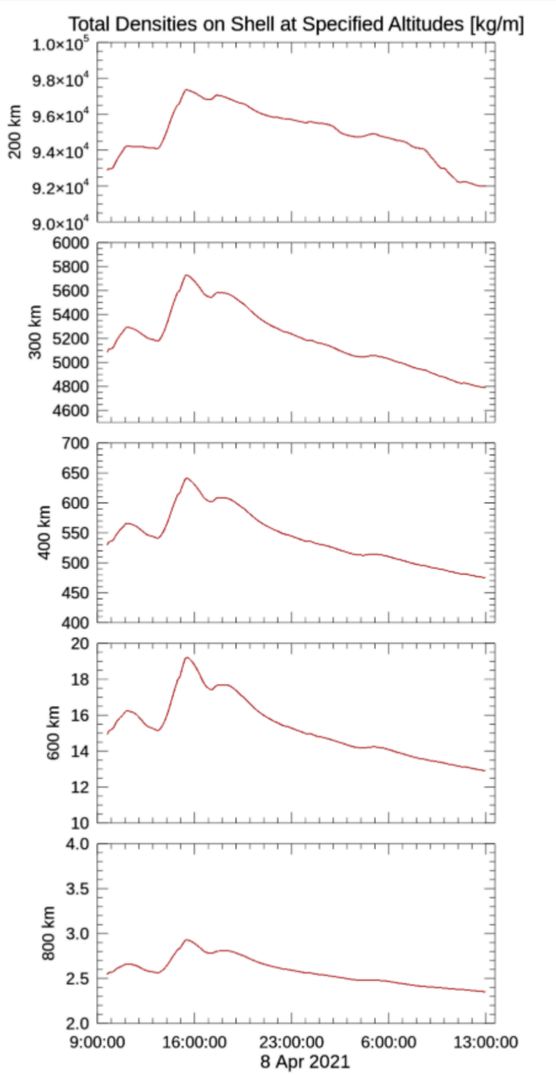


Initial trials of real-time predictions started just last month

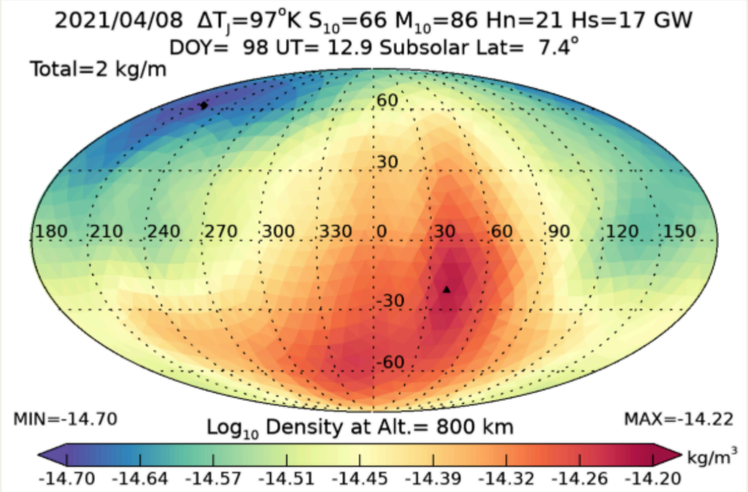
Real Time Neutral Density Pred | Real Time Neutral Density Pred

File | /Users/Shared/IDL/RealTimeEXTEMPLAR/RealTimeDensitiesV2.html

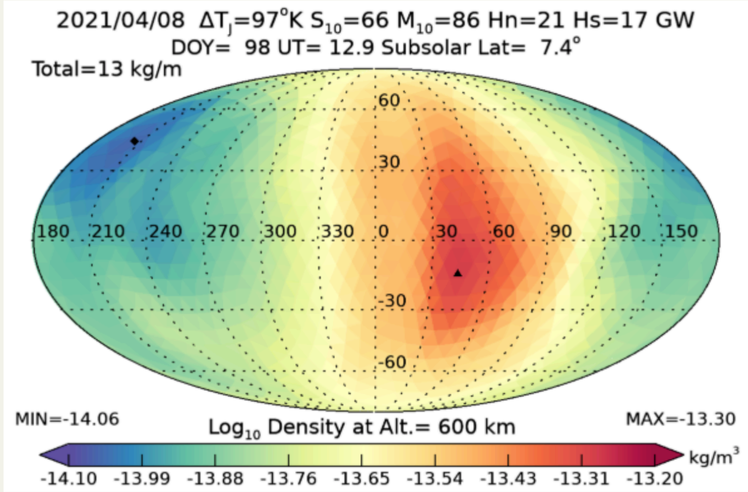
Total Densities



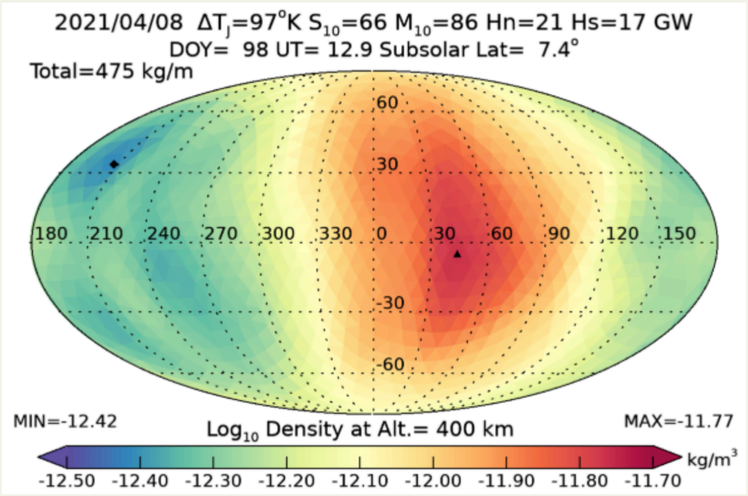
Neutral Density at 800 km Altitude



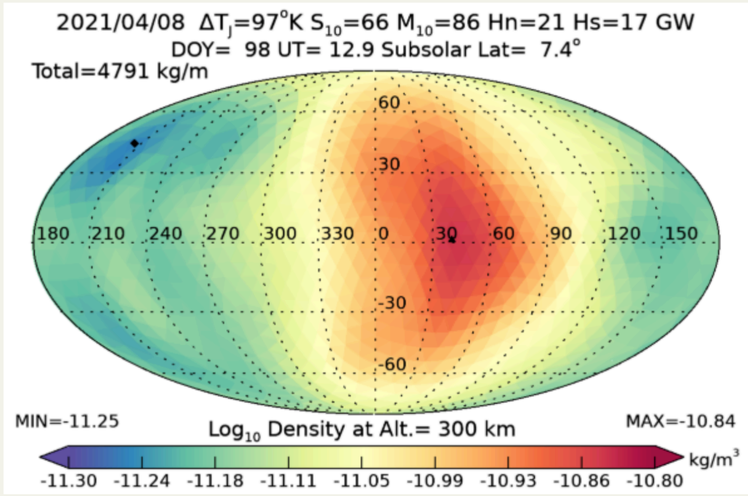
Neutral Density at 600 km Altitude



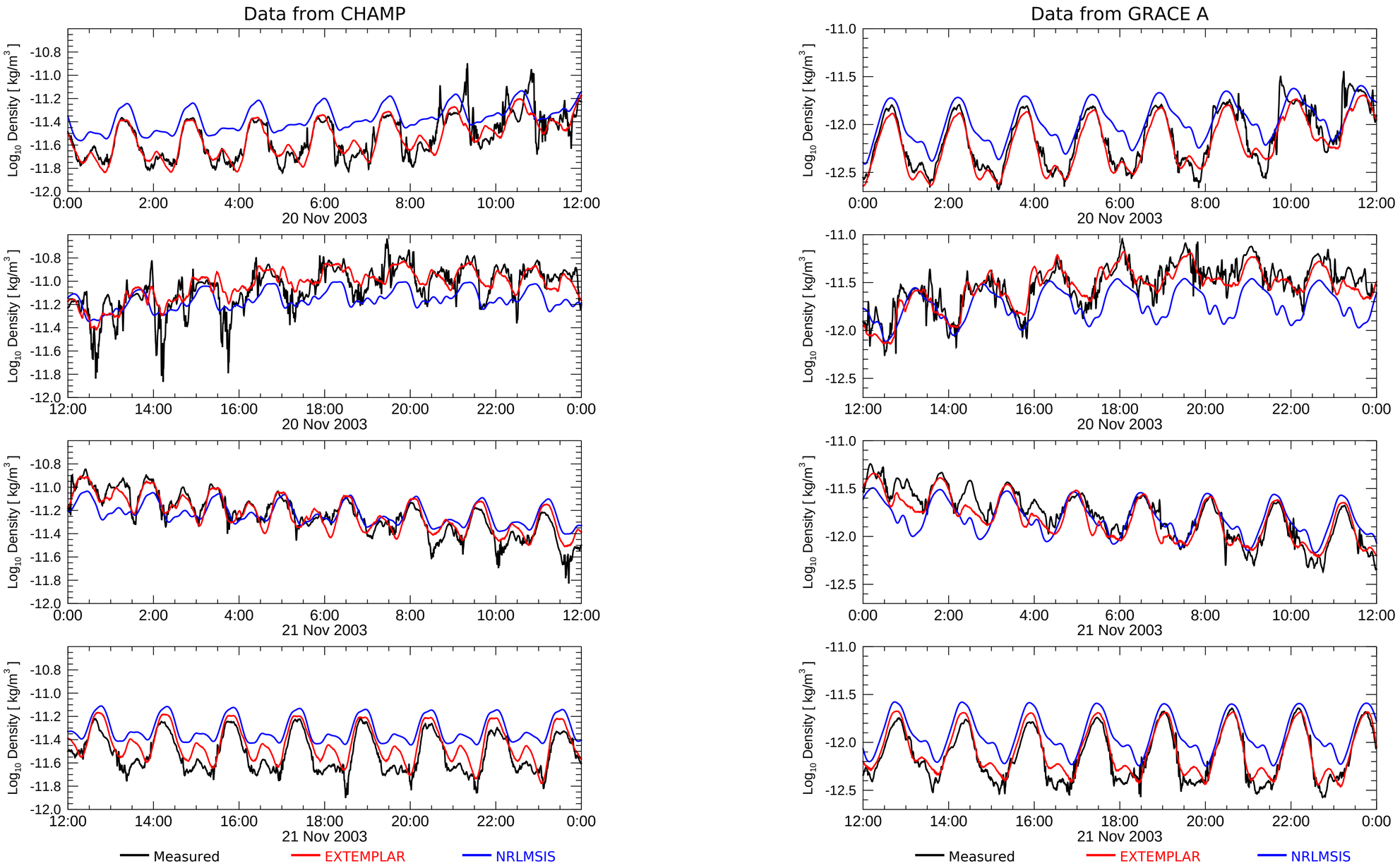
Neutral Density at 400 km Altitude

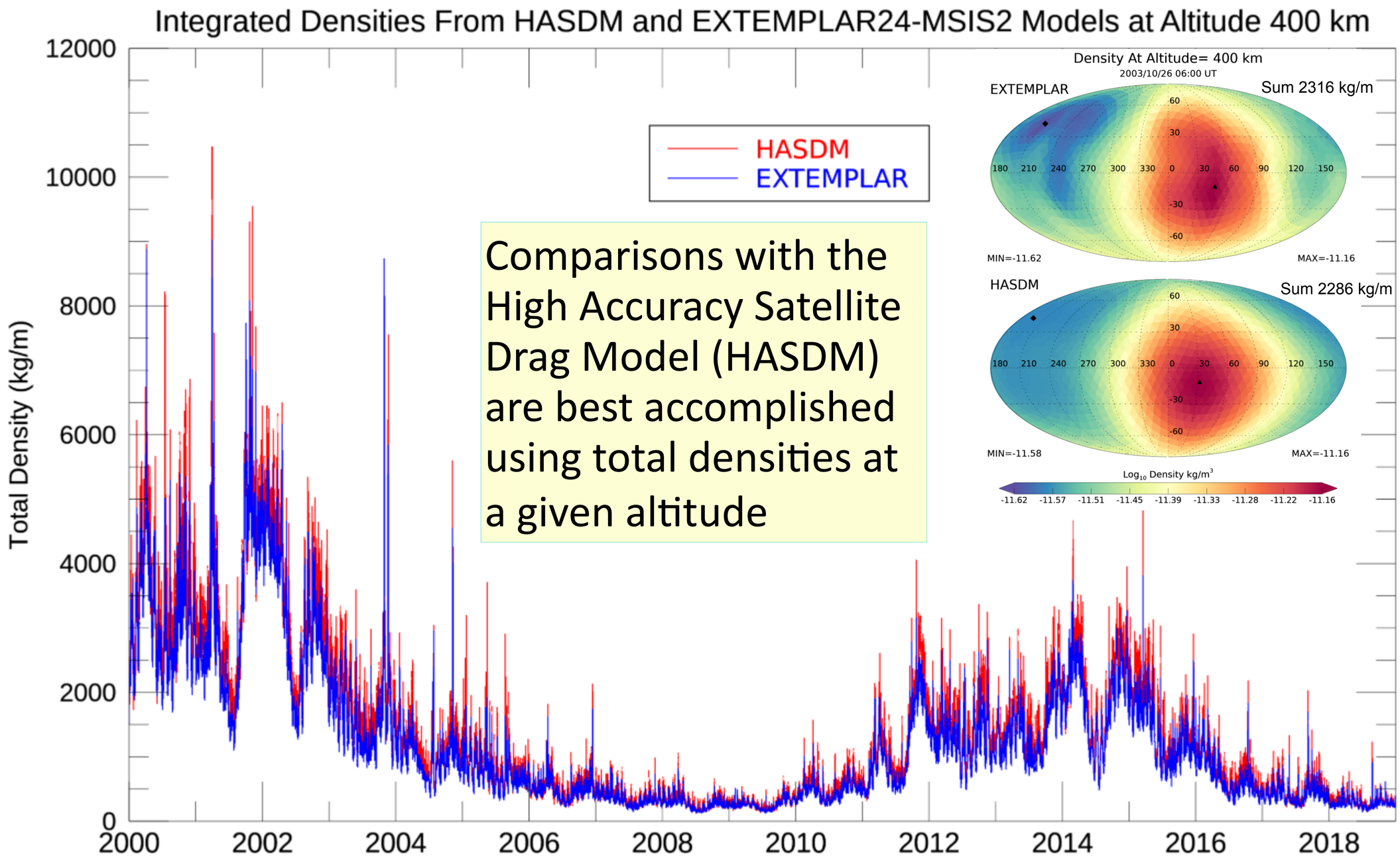


Neutral Density at 300 km

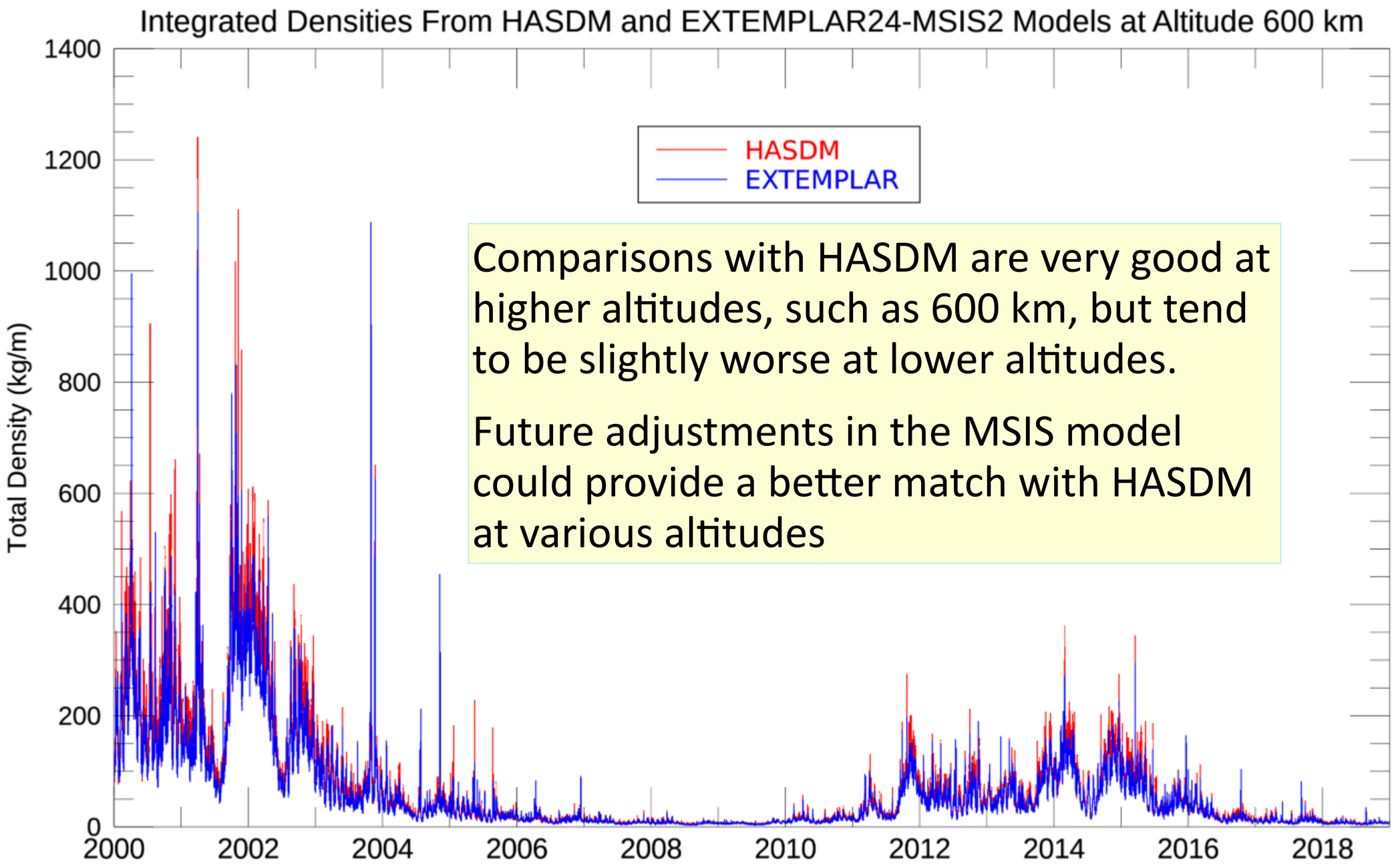


Comparisons with CHAMP and GRACE measurements



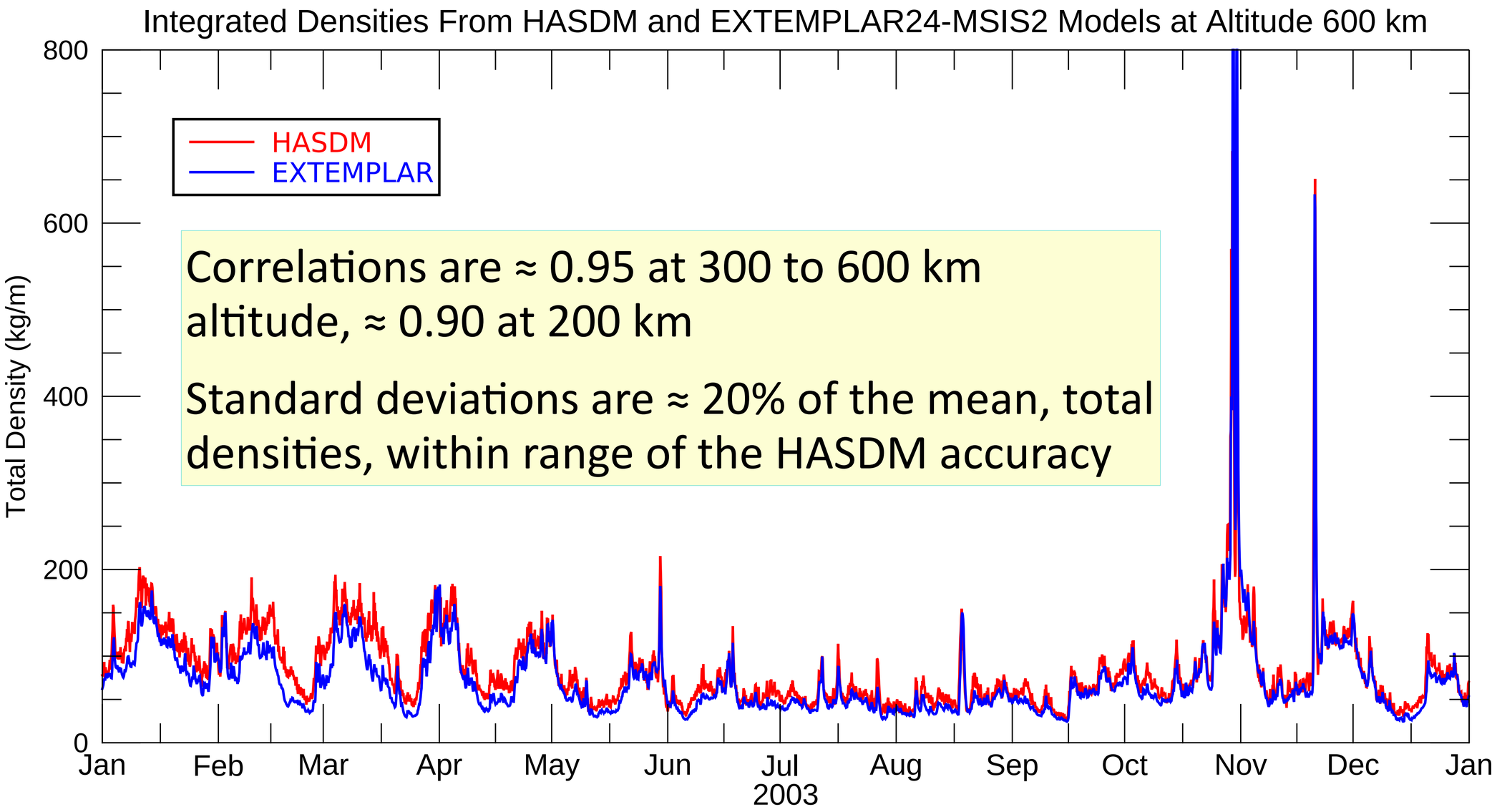


Comparisons with the High Accuracy Satellite Drag Model (HASDM) are best accomplished using total densities at a given altitude



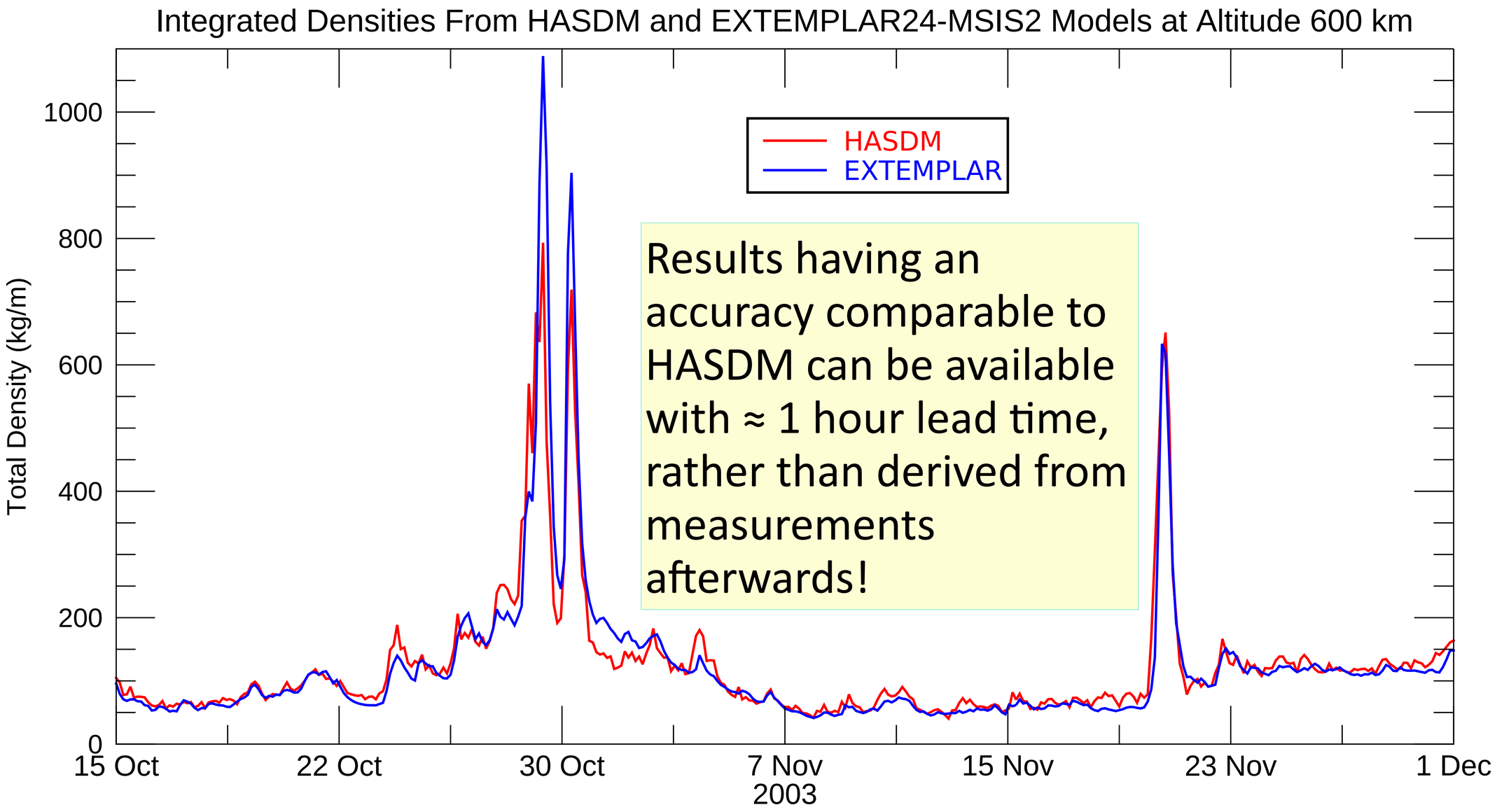
Comparisons with HASDM are very good at higher altitudes, such as 600 km, but tend to be slightly worse at lower altitudes.

Future adjustments in the MSIS model could provide a better match with HASDM at various altitudes



Correlations are ≈ 0.95 at 300 to 600 km altitude, ≈ 0.90 at 200 km

Standard deviations are ≈ 20% of the mean, total densities, within range of the HASDM accuracy


Integrated Densities From HASDM and EXTEMPLAR24-MSIS2 Models at Altitude 600 km
Total Density (kg/m)
0
200
400
600
800
1000
15 Oct
22 Oct
30 Oct
7 Nov
2003
15 Nov
23 Nov
1 Dec
HASDM
EXTEMPLAR
Results having an accuracy comparable to HASDM can be available with ≈ 1 hour lead time, rather than derived from measurements afterwards!

(future improvements)

EXTEMPLAR-ML

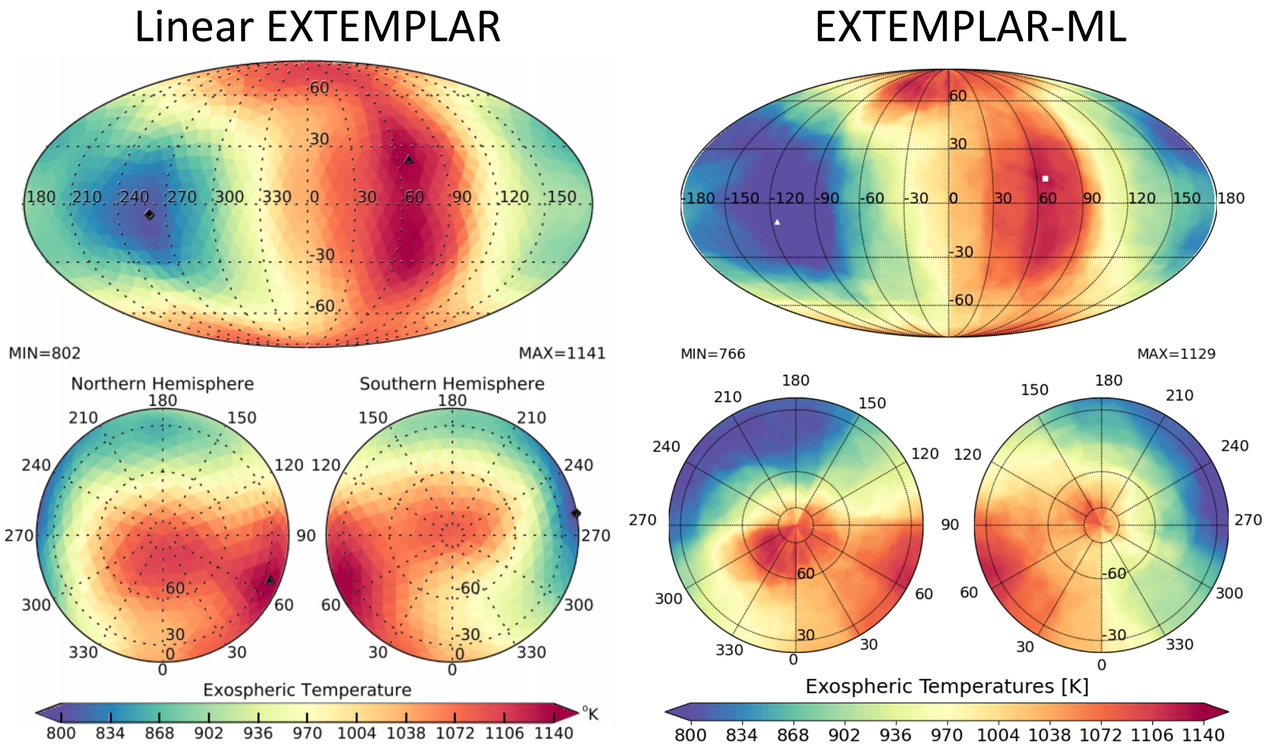
- Nonlinear machine-learned regression model (EXTEMPLAR-ML) was trained on 60 million samples
  - Remaining 20+ million samples used for validation

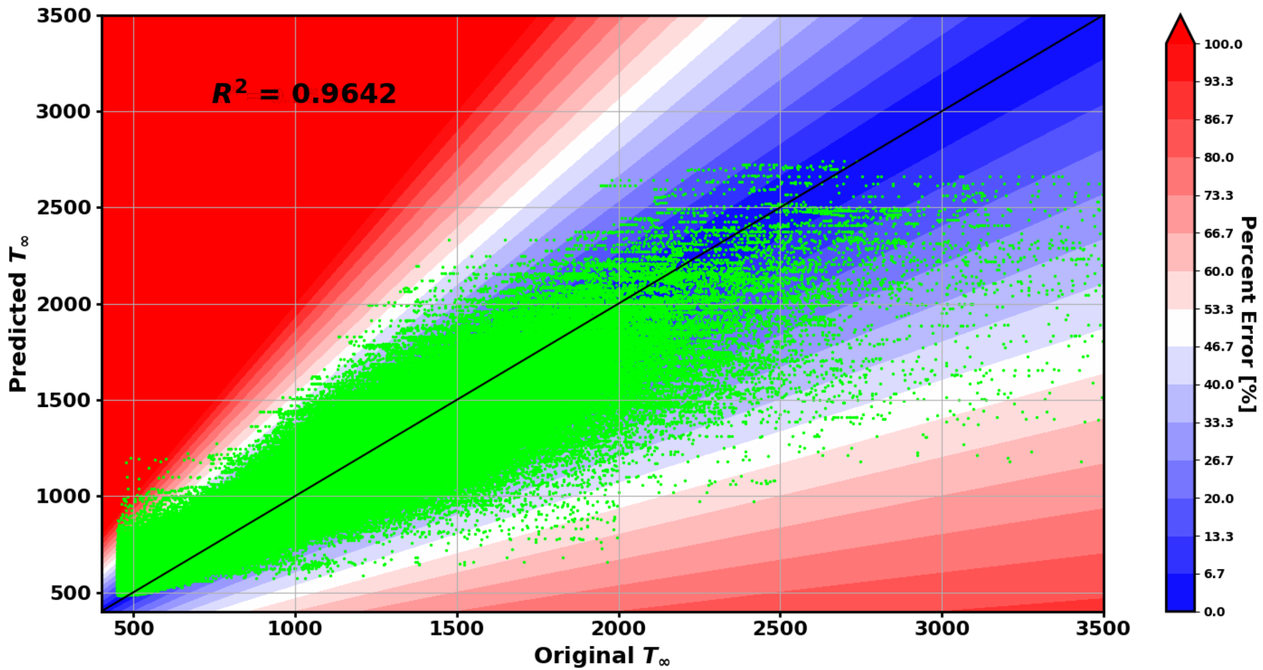
- Resulting model is well-generalized with near-identical metrics between training & validation performance
  - Mean absolute error: 2.81%
  - Mean Absolute Difference: 23.72 K
  - Standard Deviation: 34.11 K

- These results are improvements on linear EXTEMPLAR
  - Mean Absolute Difference: 27.92 K
  - Standard Deviation: 37.53 K

- EXTEMPLAR-ML uses fewer drivers than linear version
  - All operational drivers

(Prepared by R. Licata, West Virginia Univ.)





References

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Weimer, D. R., P. M. Mehta, W. K. Tobiska, E. Doornbos, M. G. Mlynczak, D. P. Drob, J. T. Emmert, Improving Neutral Density Predictions Using Exospheric Temperatures Calculated on a Geodesic, Polyhedral Grid, *Space Weather*, doi:10.1029/2019SW002355, 2020.

Emmert, J. T., D. P. Drob, J. M. Picone, D. E. Siskind, M. Jones Jr, M. G. Mlynczak, P. F. Bernath, X. Chu, E. Doornbos, B. Funke, L. P. Goncharenko, M. E. Hervig, M. J. Schwartz, P. E. Sheese, F. Vargas, B. P. Williams, and T. Yuan, NRLMSIS 2.0: A whole-atmosphere empirical model of temperature and neutral species densities, *Earth and Space Science*, e2020EA001321, 2020.

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