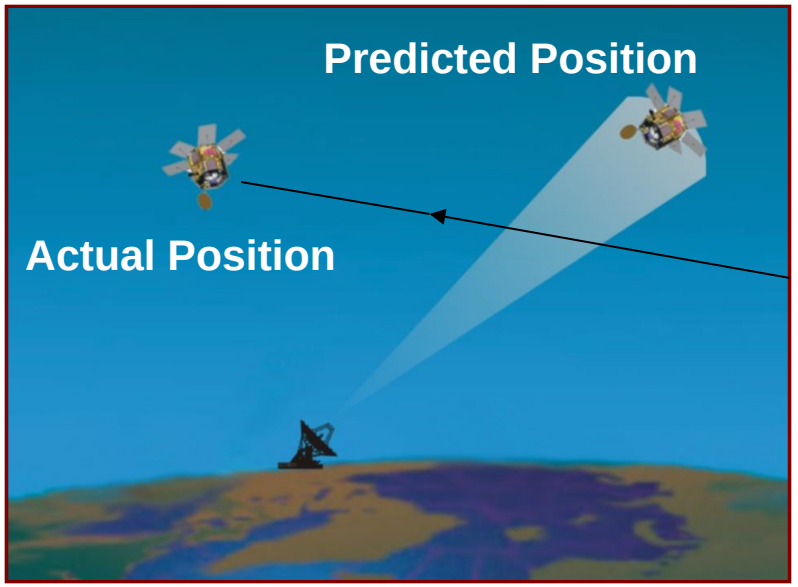
NADIR: Neutral Atmosphere Density Interdisciplinary Research - Recent Progress and Transition Plans

A Multidisciplinary University Research Initiative (MURI)
Sponsored by the Air Force Office of Scientific Research

The **objective** of NADIR is to significantly advance understanding of drag forces on satellites, including density, winds, and factors affecting the drag coefficient.

We seek a level of understanding that will enable specification and prediction at the “next level” of performance.

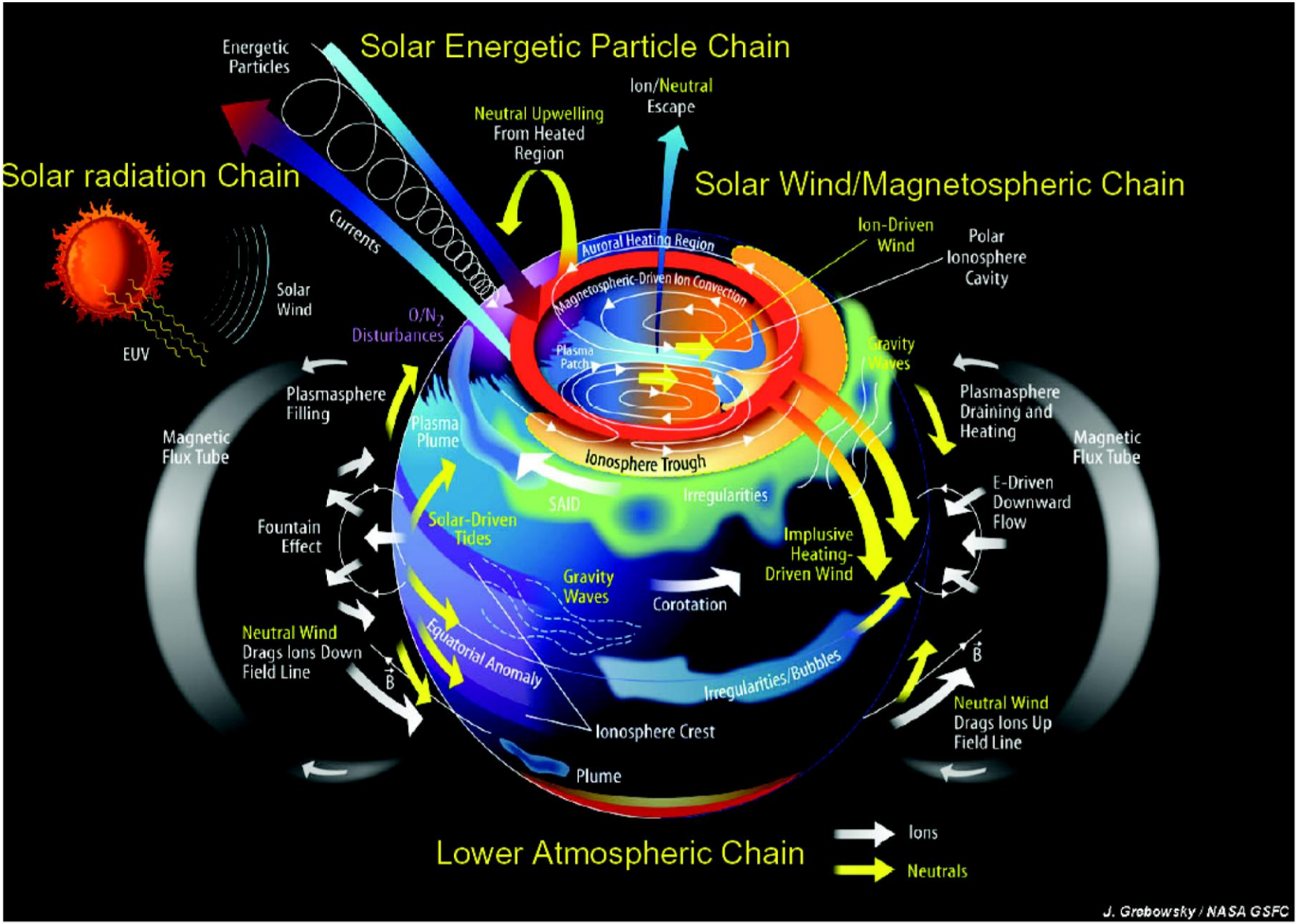


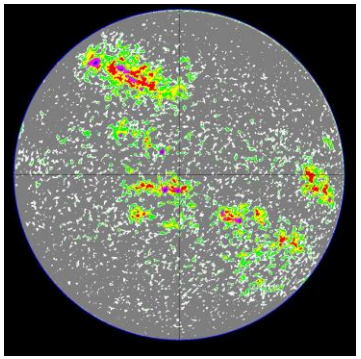
Co-Principal Investigators:
Jeff Forbes and Tim Fuller-Rowell
University of Colorado at Boulder

Aug 2007 - Aug 2012

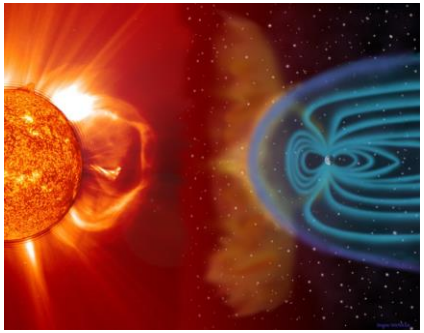
http://ccar.colorado.edu/muri/

Terrestrial Processes and Sources Impacting Neutral Density





Focus Areas



I. Scales of Density Variability, Winds, and Drag Prediction
II. Internal Processes and Thermosphere-Ionosphere Coupling
III. Energy Partitioning at High Latitudes and Density Implications
IV. Wave Forcing from the Lower Atmosphere
V. Forecasting Geomagnetic Activity
VI. Forecasting Solar EUV/UV Radiation
VII. Driver-Response Relationships
VIII. Satellite Drag in the Transition Region

NADIR Participants

Co-Investigators

- Brian Argrow,
- George Born,
- Geoff Crowley, UTSA
- David Falconer, UAH
- Delores Knipp, USAFA
- Juan Fontenla,
- Tomoko Matsuo,
- Dusan Odstrcil, /GMU
- Joachim Raeder, University of New Hampshire
- Jeff Thayer,

Administration
Sarah Melssen, CU

Collaborators

- Jeffrey Anderson, NCAR
- Eugene Avrett, Harvard-SAO
- Christopher Bass, AFSPC
- Bruce Bowman, AFSPC
- Gary Bust, UTSA
- Mihail Codrescu, SEC, NOAA
- Doug Drob, NRL
- Irene Gonzalez-Hernandez, NSO
- Cheryl Huang, AFRL
- Chin Lin, AFRL
- Charles Lindsey, Co-RA
- Frank Marcos, AFRL
- Matthew McHarg, USAFA
- Craig McLaughlin, U Kansas
- Rashid Akmaev, NOAA
- Steve Nerem, CU
- Andrew Nicholas, NRL
- Jens Oberheide, U Wuppertal
- Vic Pizzo, SEC, NOAA
- Eric Quemaris, CNRS
- Arthur Richmond, NCAR
- Stan Solomon, NCAR
- Houjun Wang
- Thomas Woods, CU

DoD Oversight

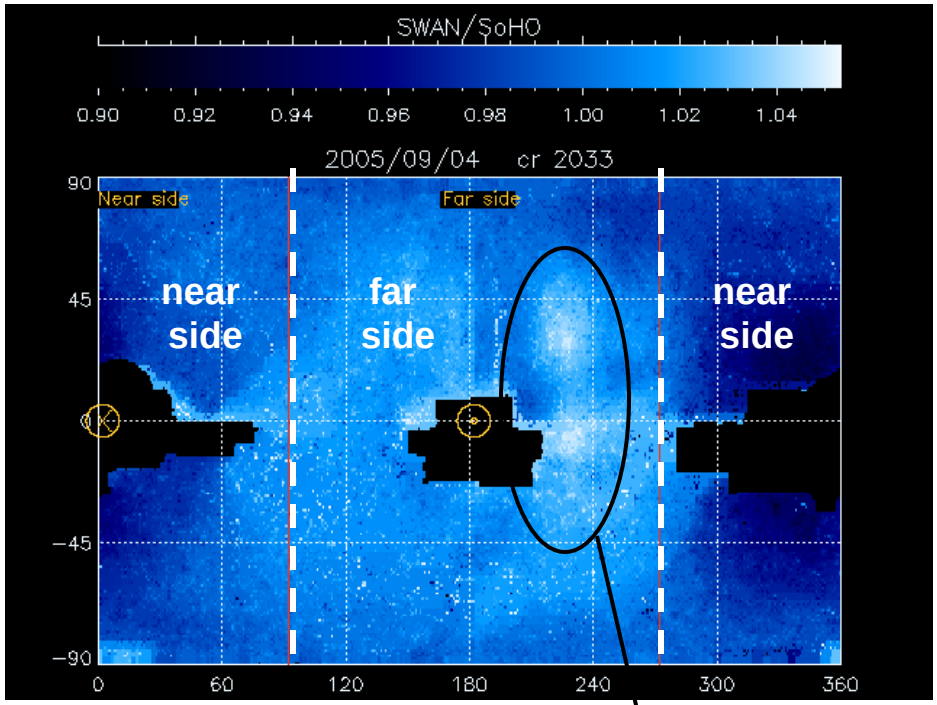
Cassandra Fesen, Kent Miller, AFOSR; Michelle Gaudreault, AFSPC; Robert McCoy, ONR

~ Selected Recent Highlights ~

VI. Forecasting Solar EUV/UV Radiation, *Juan Fontenla*

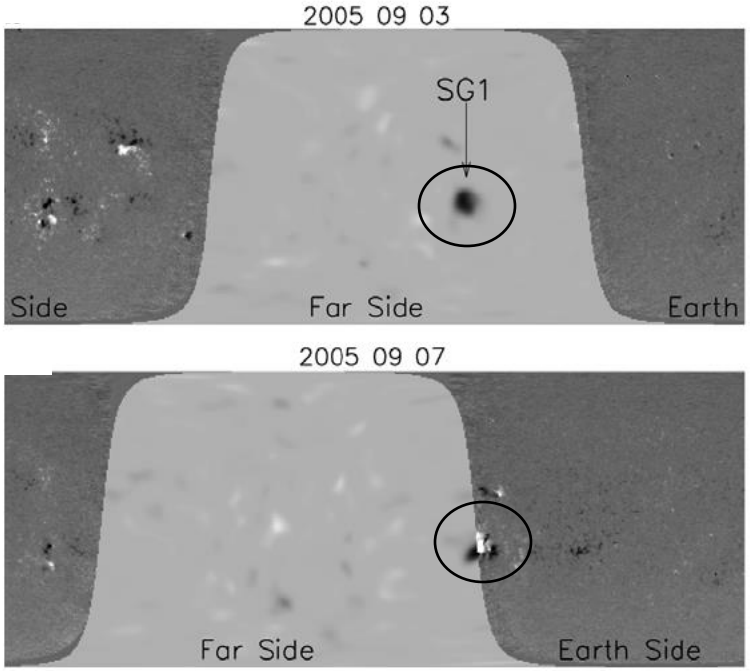
HIGHLIGHT: Far-Side Imaging

L-α radiation far-side back-scattering
(Quemerais, Bertaux et al.)



Enhanced L-α radiation from active regions on the far side of the Sun, resonantly back-scattered from H atoms in the inner heliosphere.

Phase-sensitive helioseismic holography
(Lindsey, Braun et al.)



Active regions on the far side of the Sun can be detected due to the difference in travel time between going into and out of an active region. This phase sensitivity is observed in waves appearing on the surface one the near side of the Sun.

V. Forecasting Geomagnetic Activity

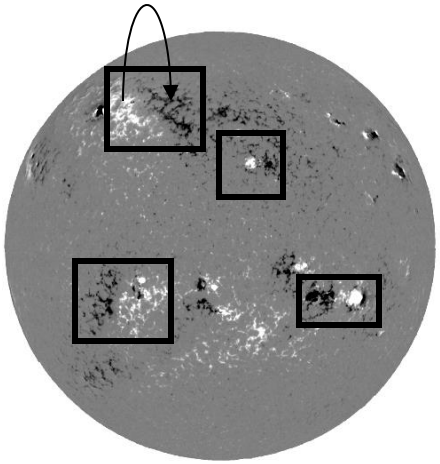
HIGHLIGHT: Forecasting Solar Events Using Solar Magnetograms,

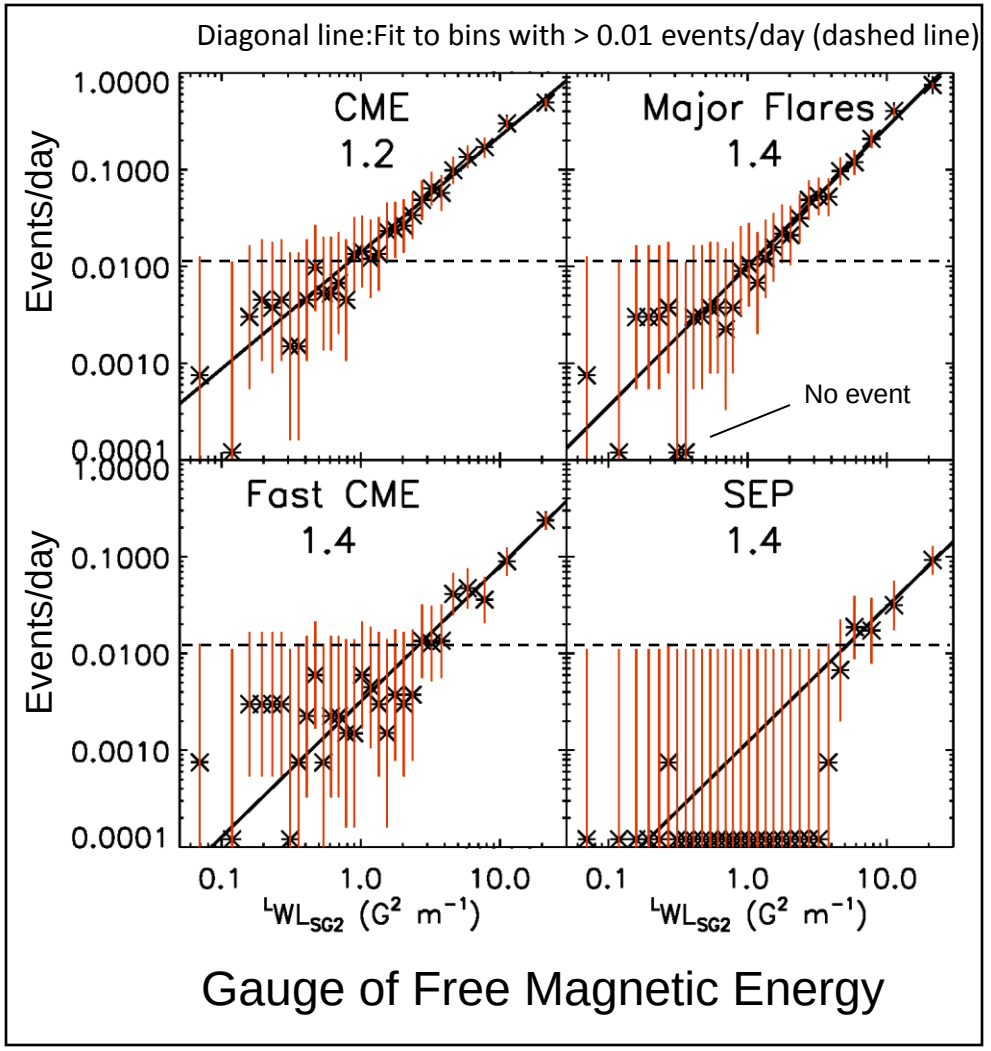
David Falconer, Co-I

Phase I: Utilize "free magnetic energy" (~twist x size) of active regions on the Sun as a predictor of CMEs, Flares and SEP events.

Based on ~40,000 magnetograms from 1,300 Active regions (AR), 1996-2004, and NOAA's flare, CME and Solar Energetic Particle (SEP) event catalog.

SOHO Michelson Doppler Imager (MDI)

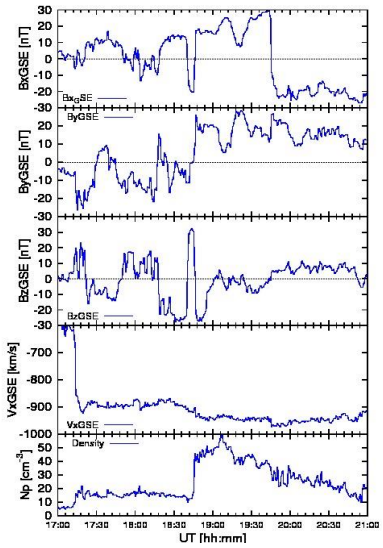




Phase II: Find secondary measures that influence an AR's probability of producing an event, e.g., **size, flare history, magnetic isolation** (fewer flares for > 10 active regions on disk).

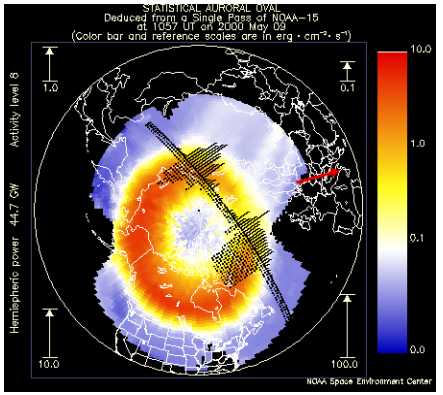
III. Energy Partitioning at High Latitudes and Density Implications

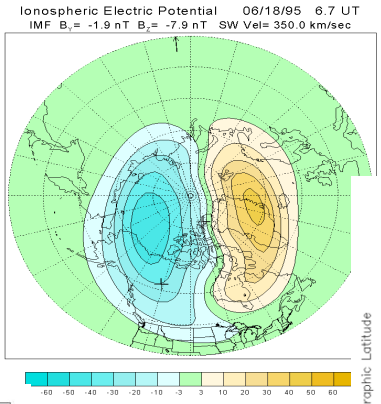
Highlight: Replacing A_p and D_{ST} with Joule Heating: Fedrizzi et al.



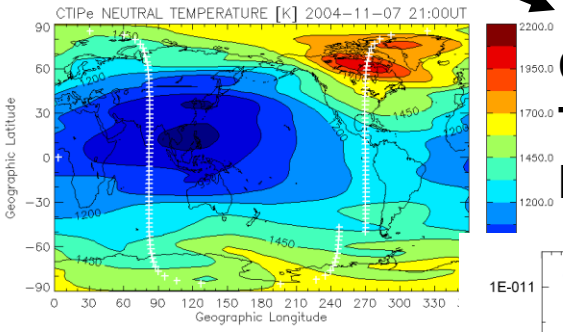
ACE Solar Wind IMF, velocity, density

TIROS/NOAA auroral precipitation

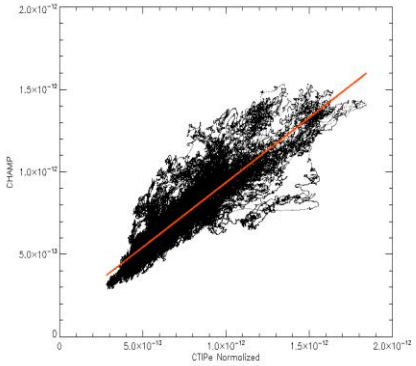




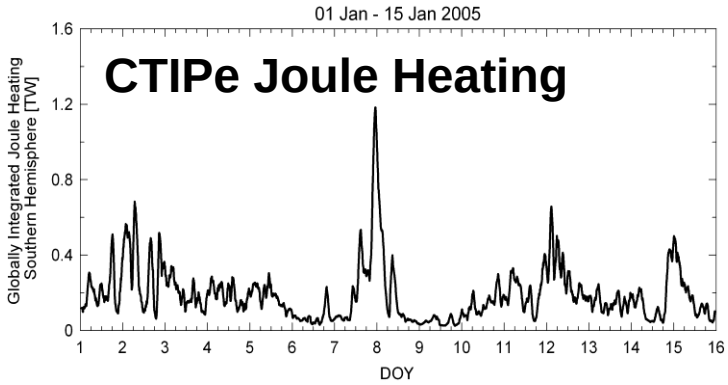
Weimer mag. convection

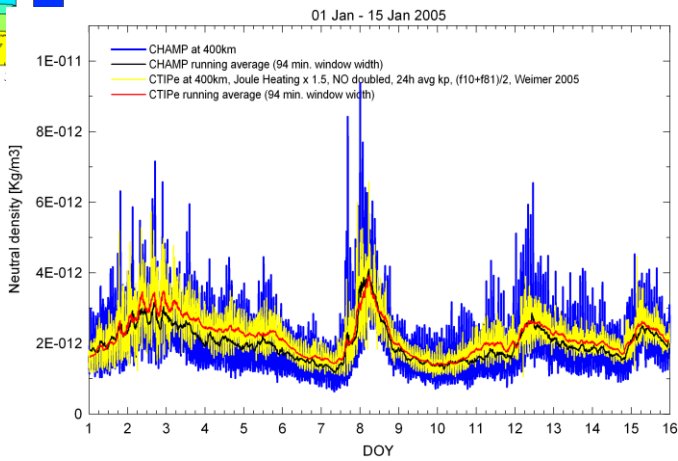


CTIPe Physical Thermosphere-Ionosphere model



CHAMP/CTIPe Correlation: 0.89





CTIPe vs CHAMP density

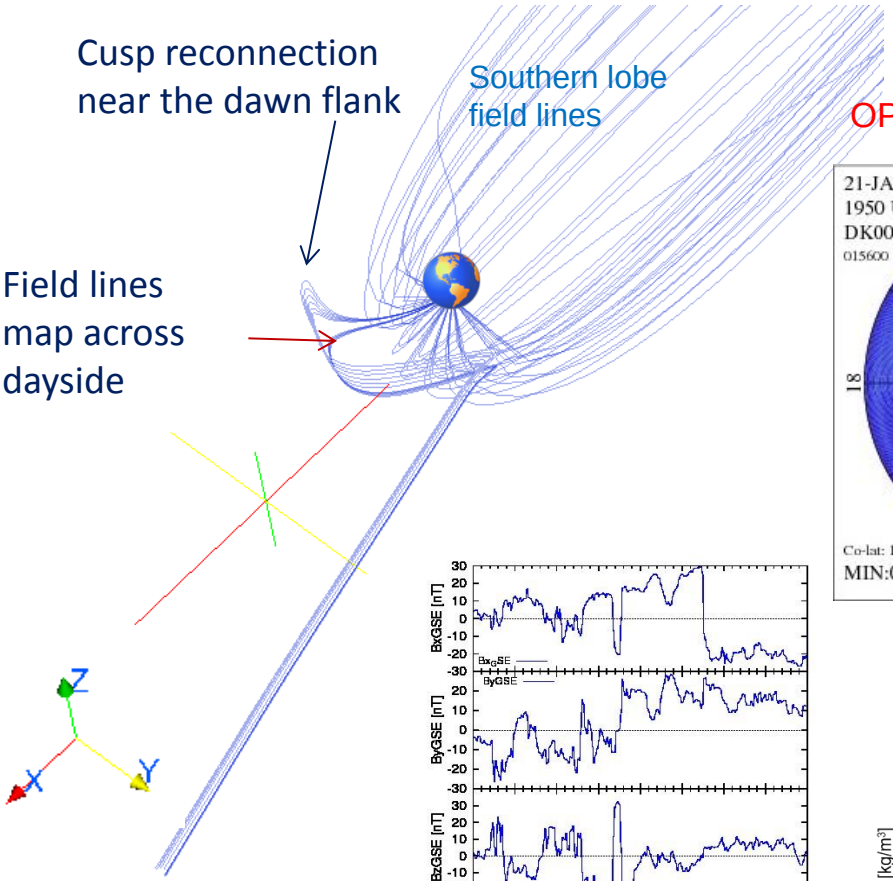
III. Energy Partitioning at High Latitudes and Density Implications

Highlight: Cusp energy source during strong IMF By: Li et al.

Cusp reconnection near the dawn flank

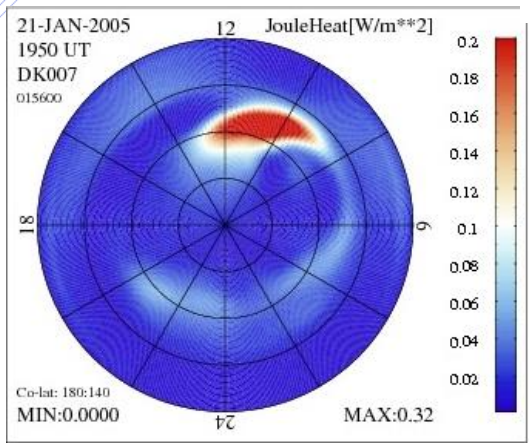
Southern lobe field lines

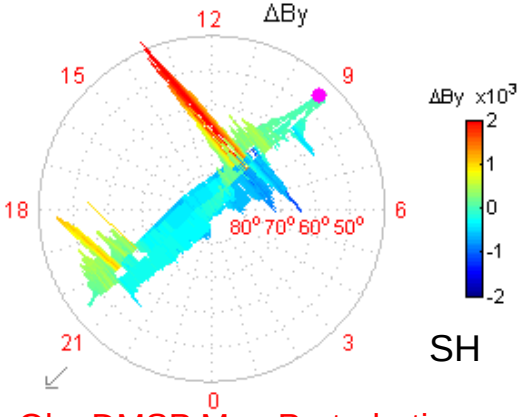
Field lines map across dayside



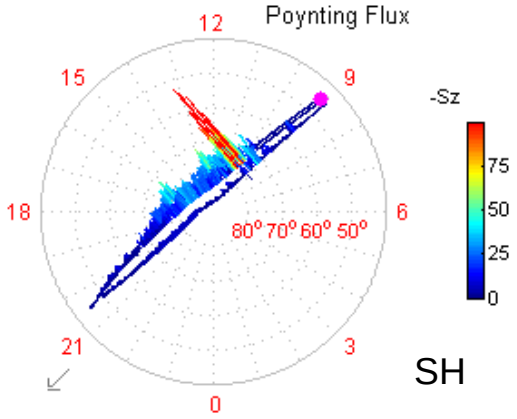
B_z ~+10nT
B_z ~+25nT
V_{SW} ~ 950 km/s

OPENGGCM Joule Heating SH

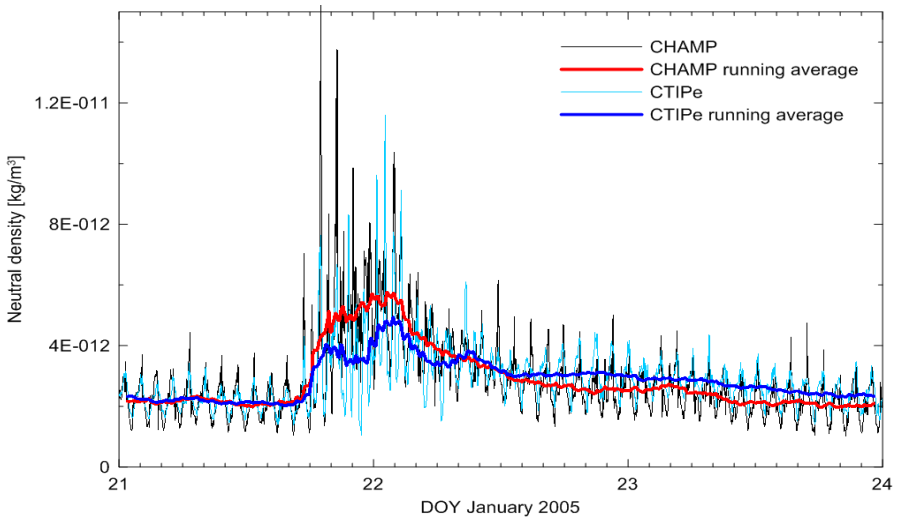




Obs DMSP Mag Perturbations



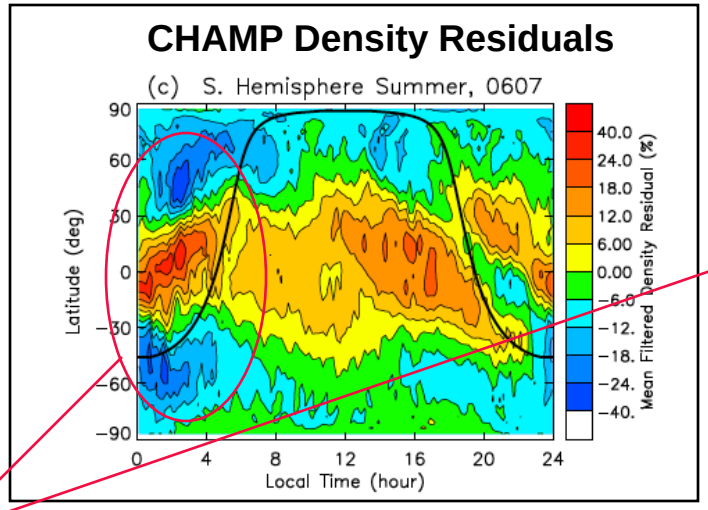
Calculated DMSP Poynting Flux

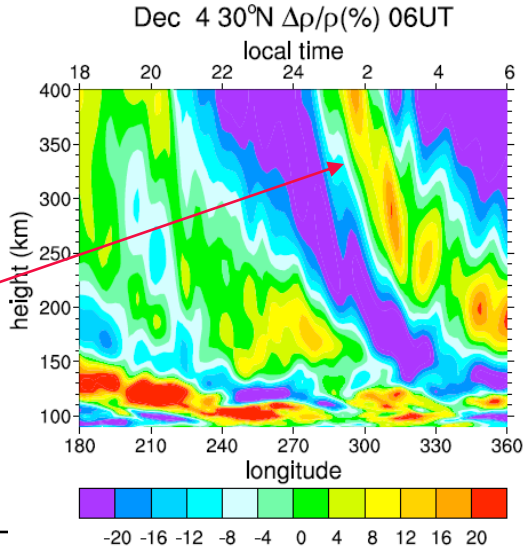


Courtesy Delores Knipp

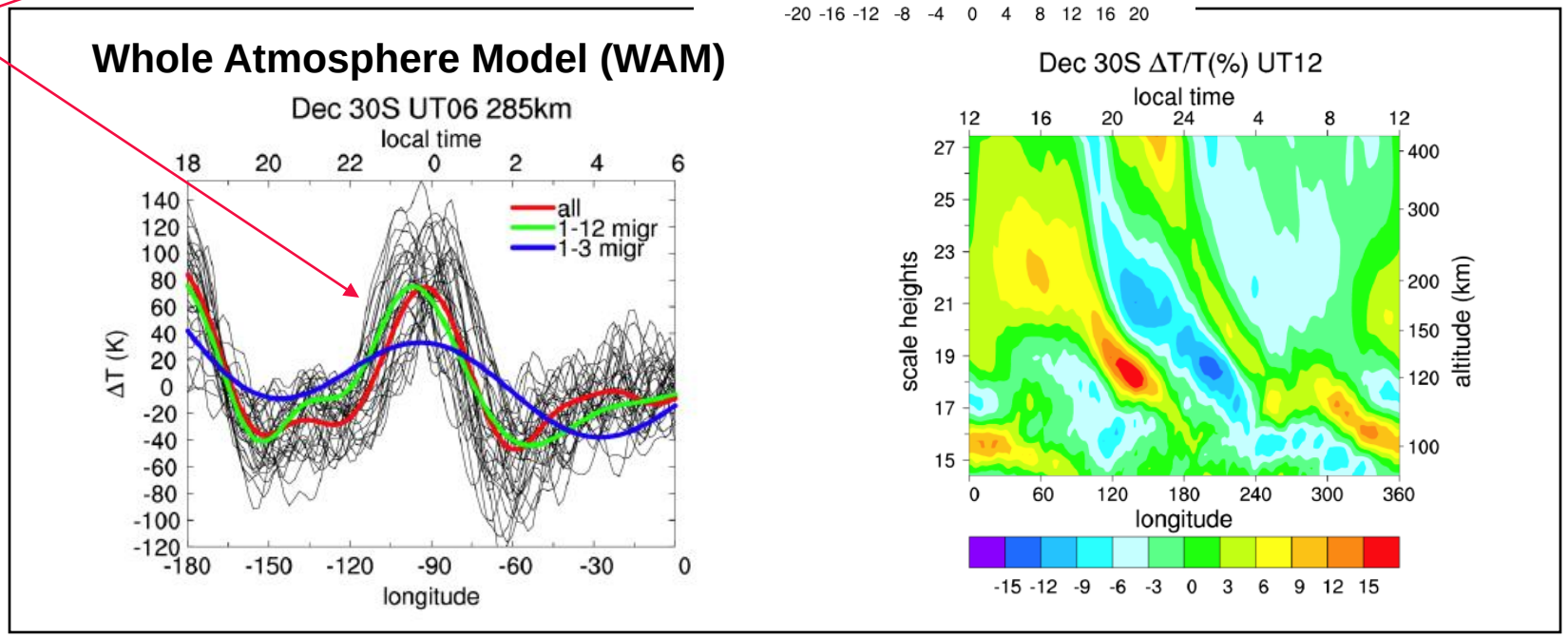
IV. Wave Forcing from the Lower Atmosphere

HIGHLIGHT: Midnight Temperature and Density Maximum, Akmaev et al.



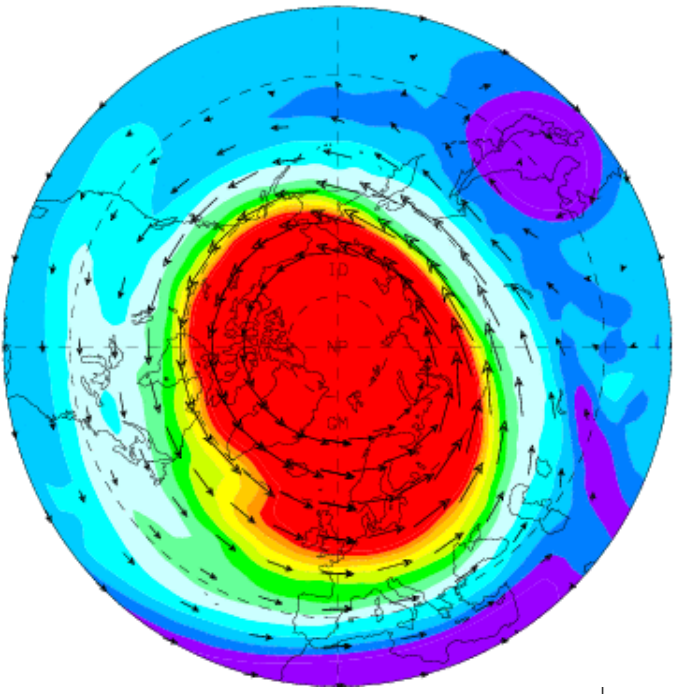


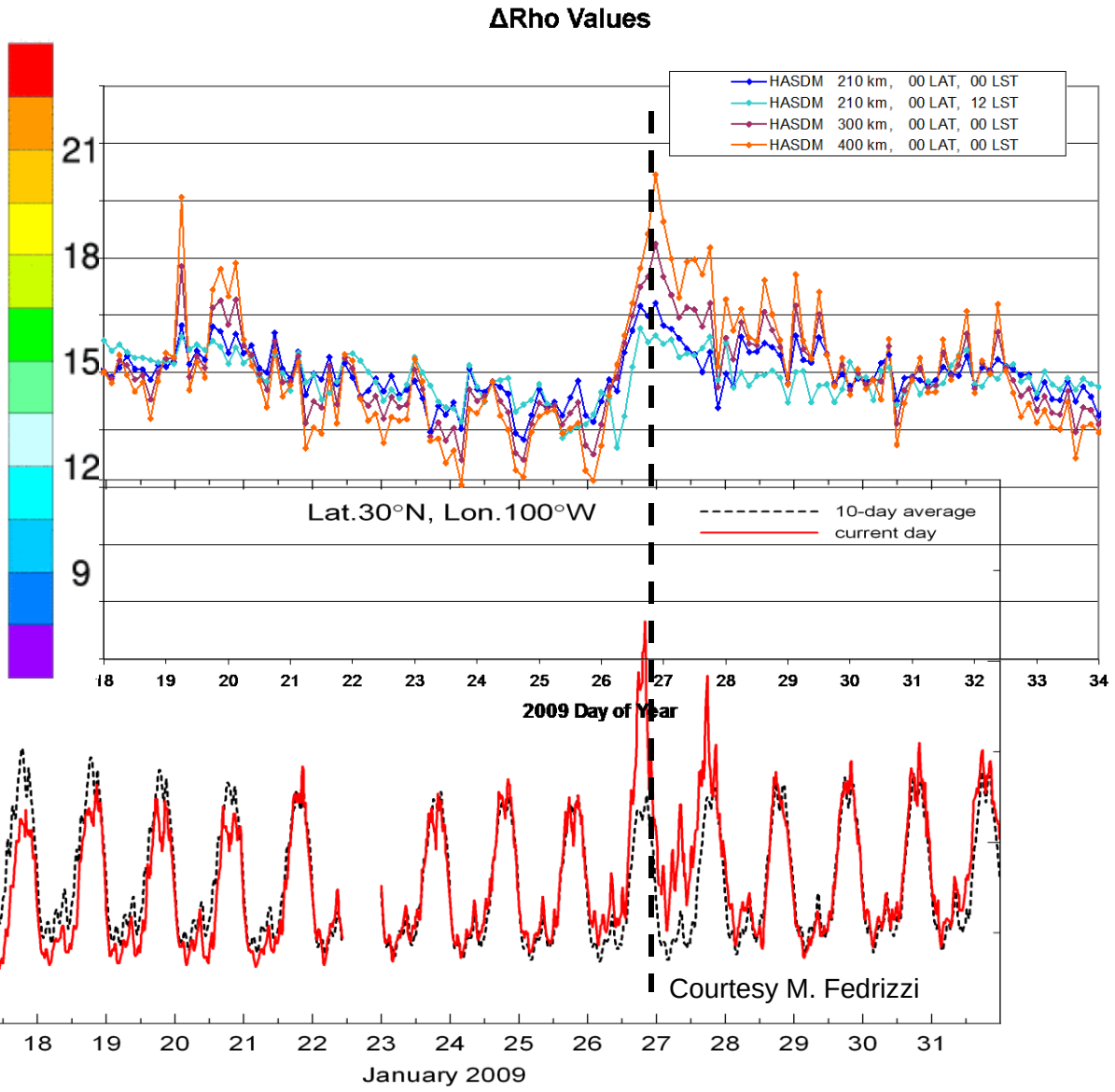
WAM is the first model to capture the seasonal-latitudinal and amplitude of the MTM and MDM, and to account for its lower-atmosphere origin



IV. Wave Forcing from the Lower Atmosphere

HIGHLIGHT: Stratospheric Warming Effects on the Thermosphere, *Fuller-Rowell et al.*





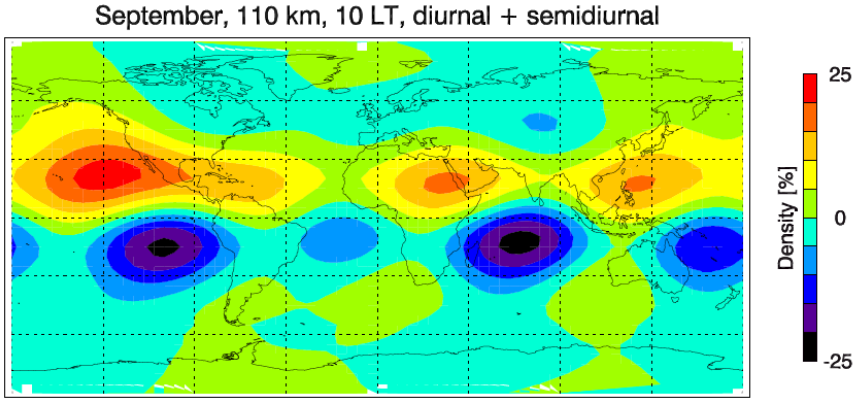
- **Recent ionospheric and satellite drag data reveal potential signatures of stratwarm effects.**

NOAA's US-TEC operational product

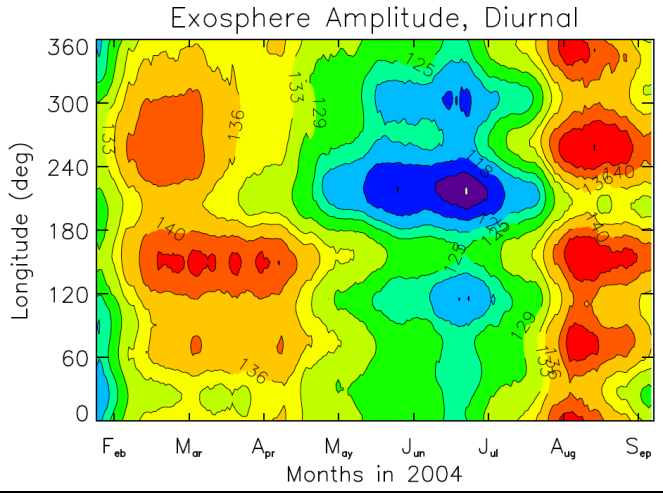
VII. Satellite Drag in the Reentry Region

HIGHLIGHT: Large Longitudinal Density Variations Derived from SABER Temperature Measurements, *Forbes, Bruinsma, Oberheide*

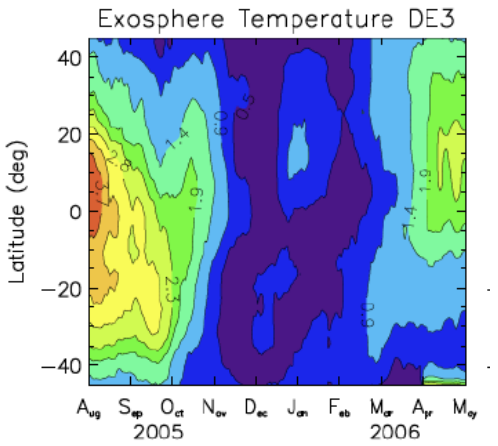
Use tidal theory, wind and temperature Observations to model density variability in the re-entry regime.

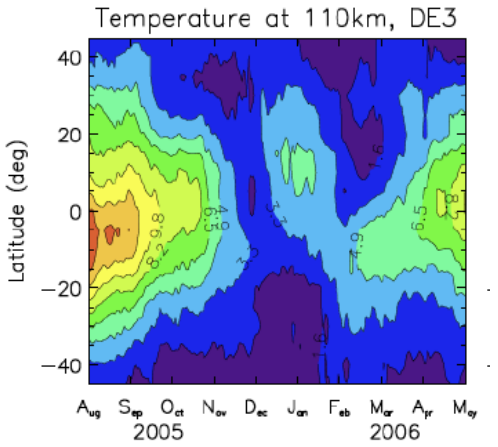


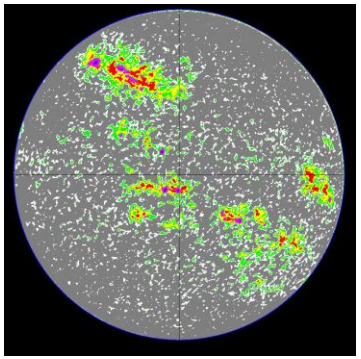
Longitude variability in density is observed near 400 km that is consistent, within the context of tidal theory, with the density variability derived between 80 and 110 km



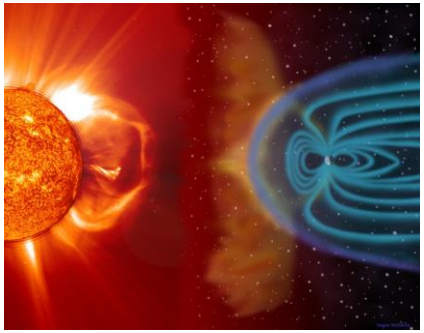
Validation with CHAMP Data





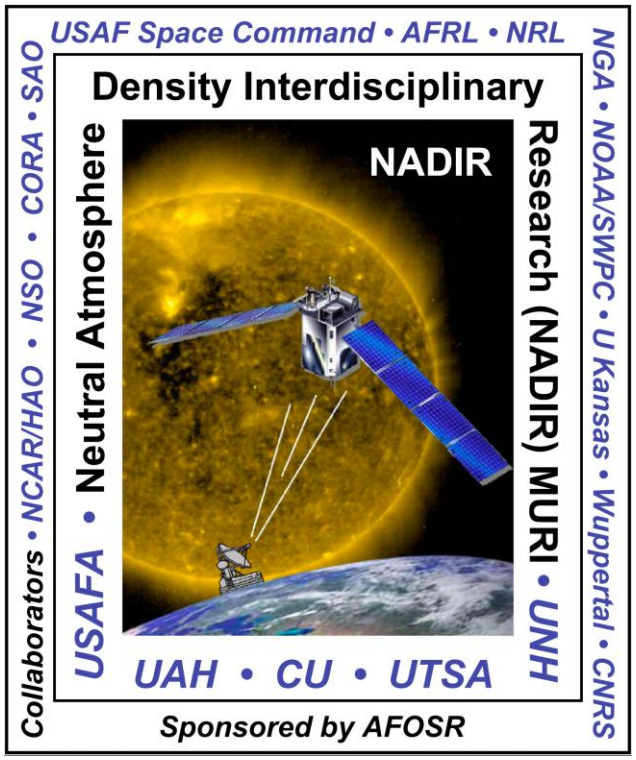


Initial Transition Opportunities



- Provide time series of Joule Heating to Space Command (Bowman) to test replacement of Ap and DST in JB2008 as geomagnetic index
- Use SDO-EVE real-time data stream and EUV forecast in CTIPe in test operational mode
- Transition DMSP visualization tool to AFRL
- Utilize output of ENLIL at L1, which is being transitioned at SWPC
- Replace NWS GFS-GSI forecast model/data assimilation system with WAM-GSI-IAU to provide specification and forecast of lower atmosphere tidal forcing
- Make available updated CTIPe, TIEGCM, WAM to AFRL and CCMC for testing

CONCLUSIONS



• Through NADIR we are understanding better the physical processes that drive satellite drag variability and that underly a predictive capability.

• The quiet Sun has enabled us to better isolate drag variability associated with “meteorological influences” from below.

• We look forward to new insights that derive from increasing levels of solar activity and different types of solar wind - magnetosphere - ionosphere - thermosphere coupling.