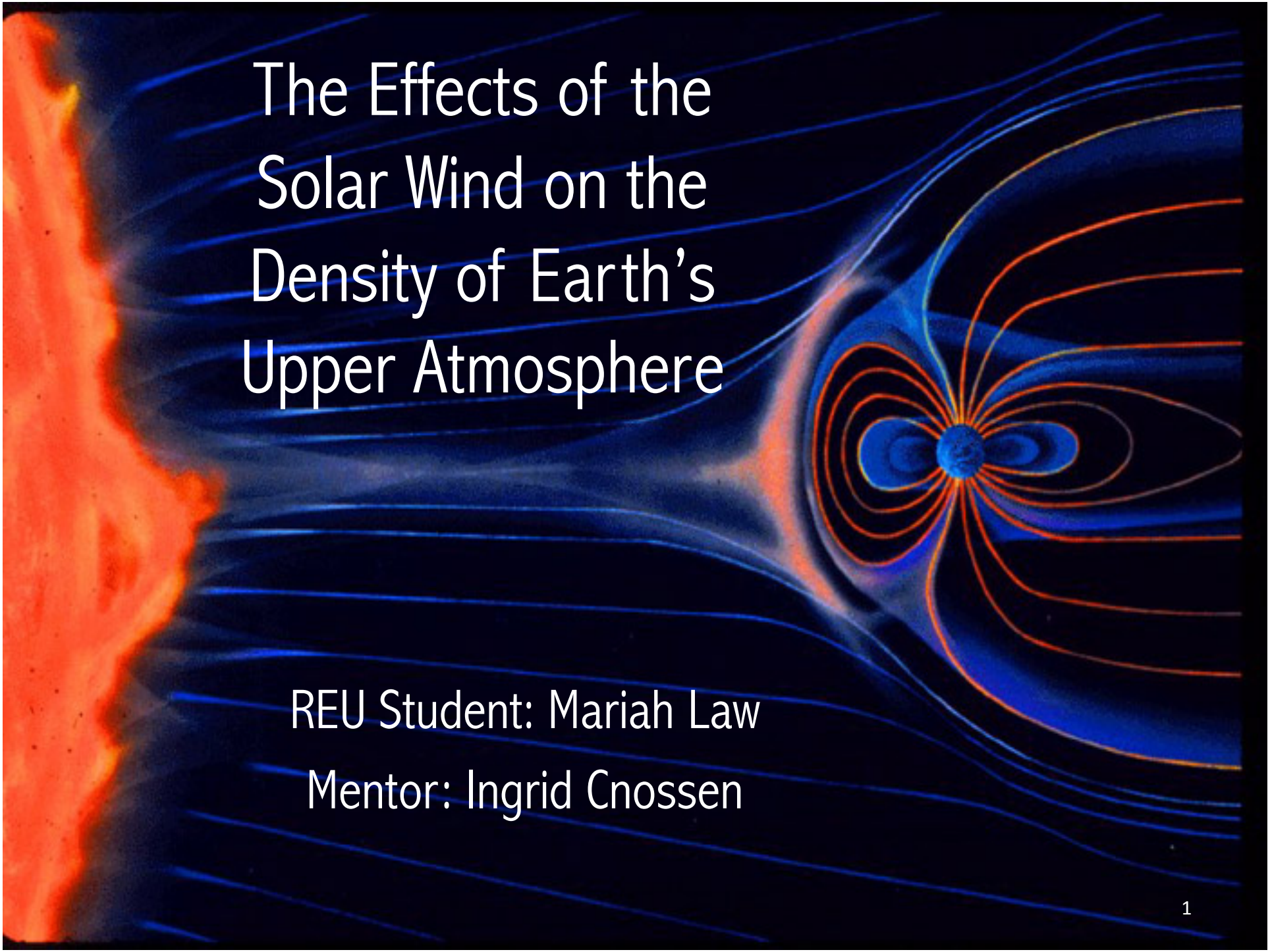


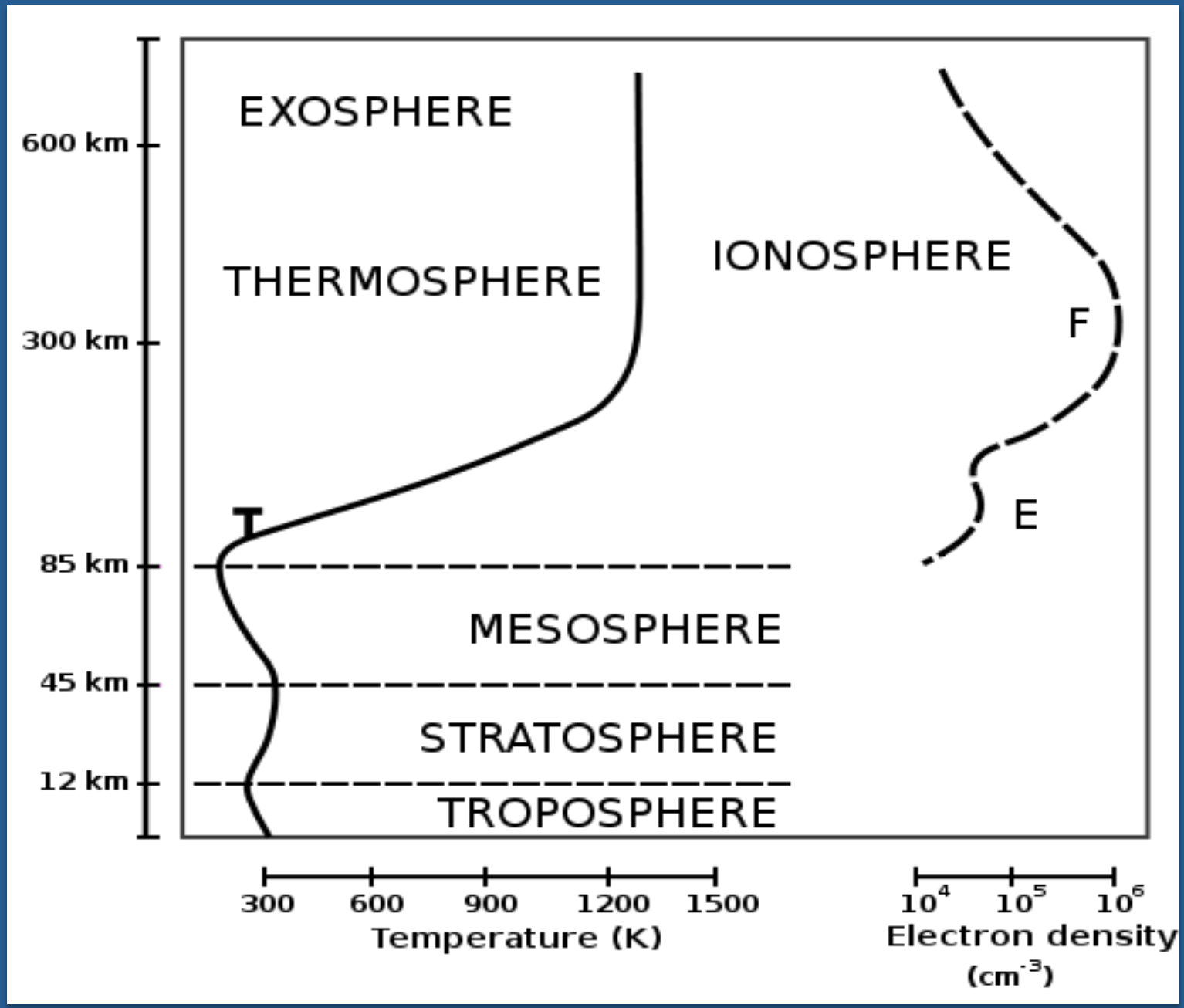
The Effects of the Solar Wind on the Density of Earth's Upper Atmosphere

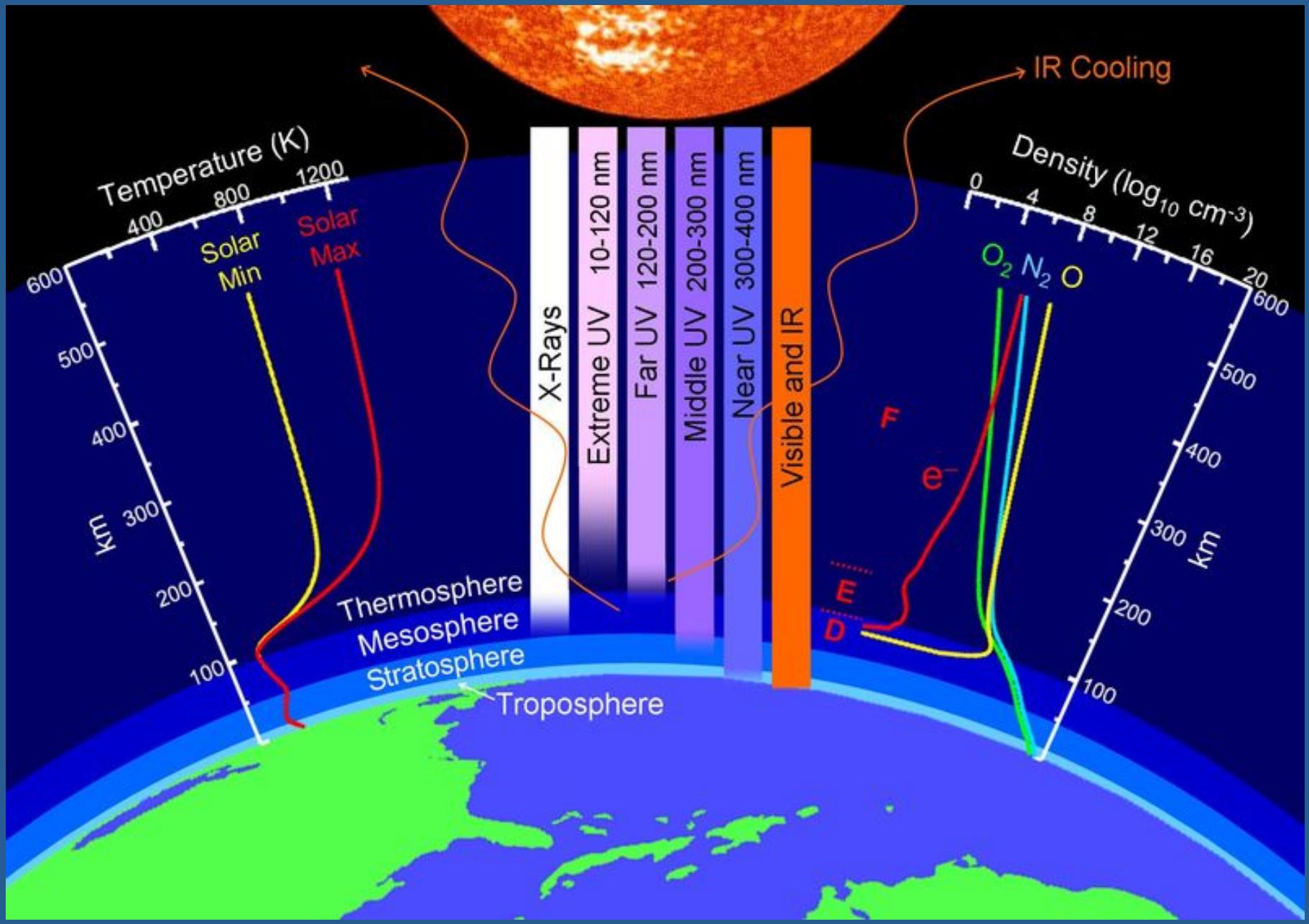
REU Student: Mariah Law

Mentor: Ingrid Cnossen

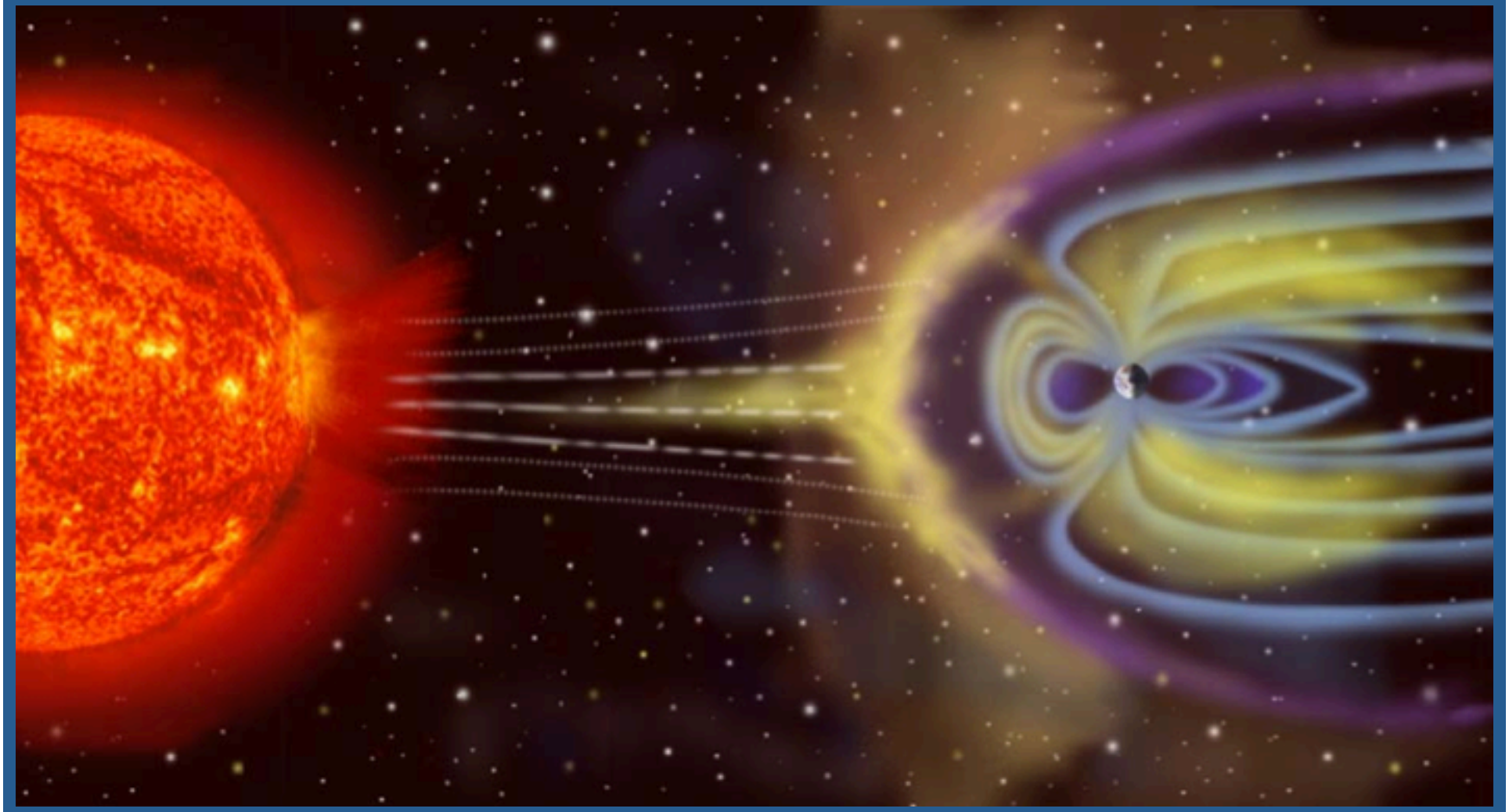
Overview

- Background information
- Previous observations
  - Neutral/electron densities
  - Comparison of 2008 solar minimum to 1996
  - Solar wind
- Goals of this project
- Numerical methods
- Results
- Future plans


EXOSPHERE
600 km
THERMOSPHERE
IONOSPHERE
F
300 km
E
85 km
MESOSPHERE
45 km
STRATOSPHERE
12 km
TROPOSPHERE
300
600
900
1200
1500
Temperature (K)
10^4
10^5
10^6
Electron density
(cm^{-3})



Phillips, Tony.



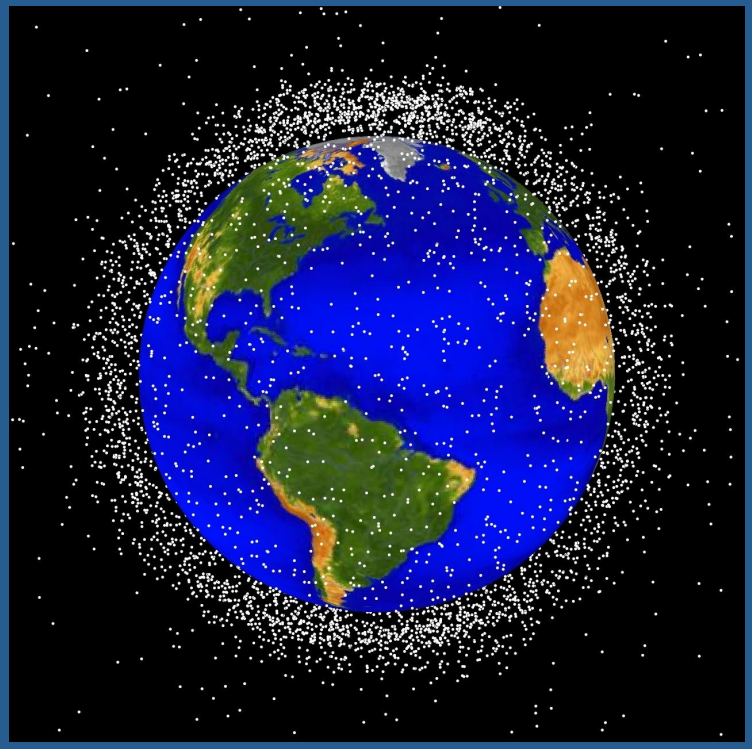
"Geomagnetism: The Magnetic Field of the Earth."

Upper Atmosphere

- Solar Extreme Ultraviolet (EUV) irradiance levels
- Geomagnetic Activity
  - Joule heating
  - Particle precipitation
- Thermal Expansion!
- Density: Atmospheric drag on ~5000 objects orbiting the Earth

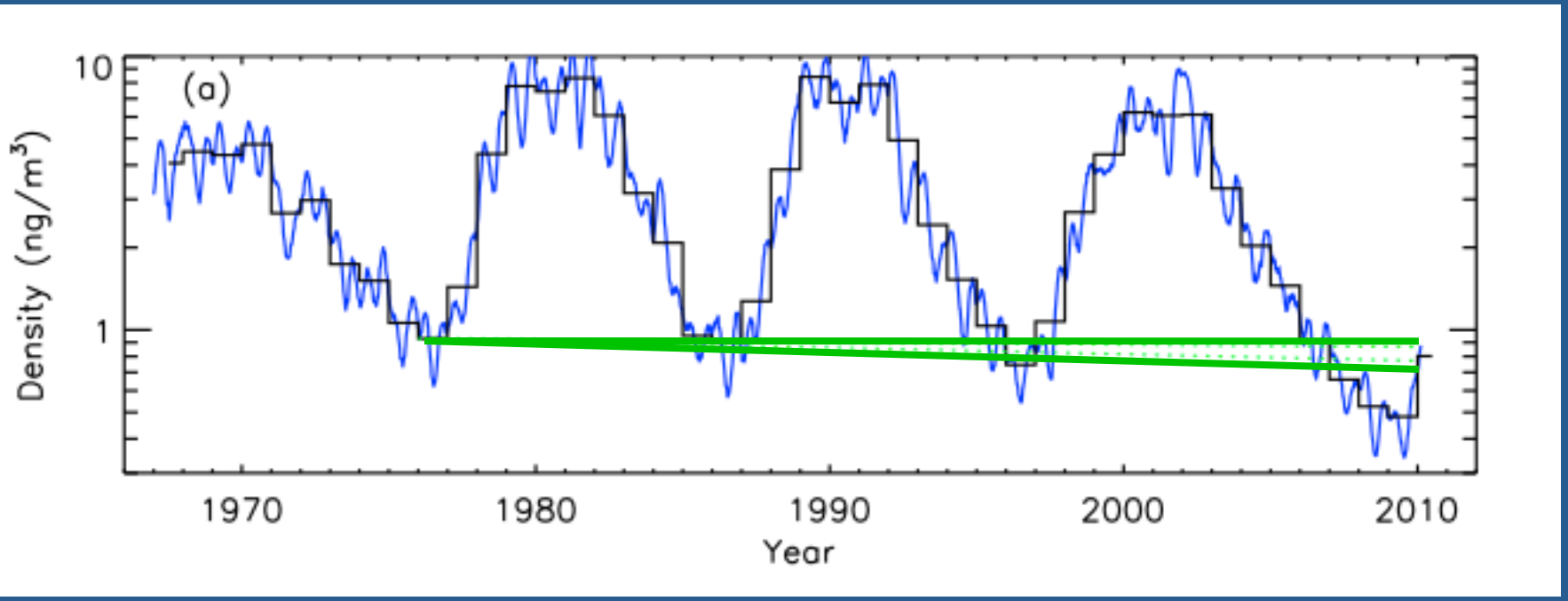
Why do we care?

- Satellites!
  - U.S. Space Surveillance Network (SSN) tracks over 20,000 man made objects larger than 10cm in size
- Trajectories affected by atmospheric drag
  - Difficult force to model
- To better understand the solar wind-magnetosphere-ionosphere-thermosphere relationship



Stansbery, E.

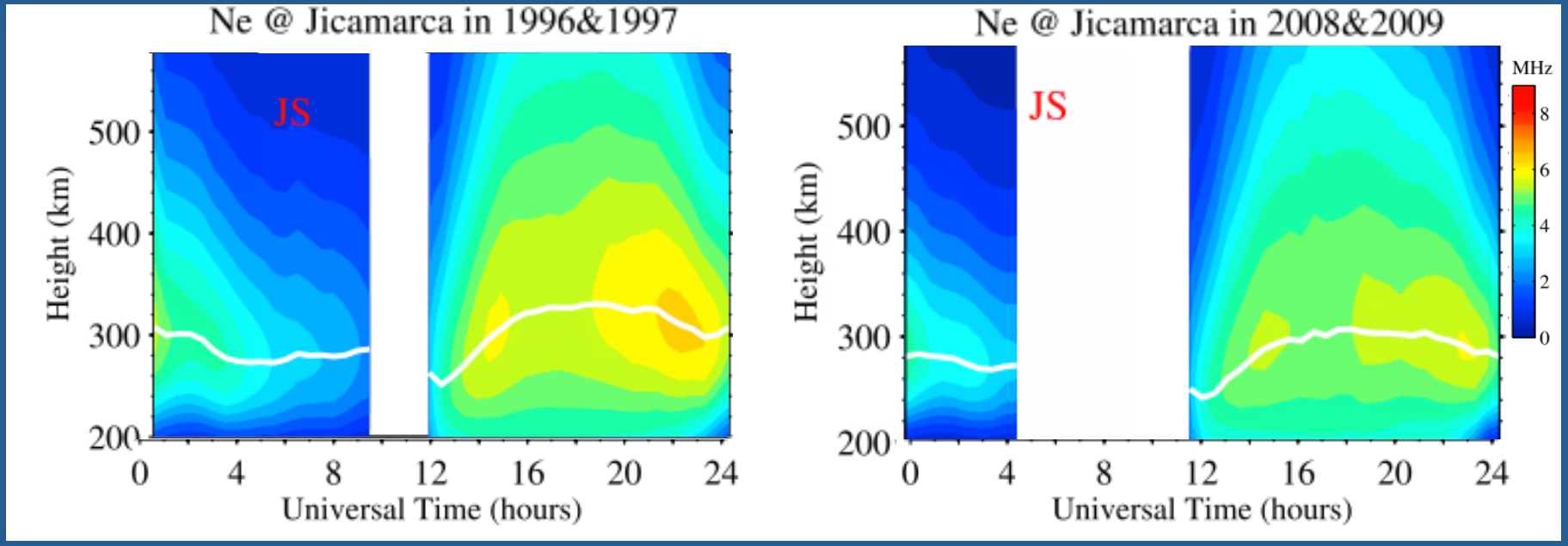
Anomalously Low Thermospheric Density



Solomon et al. (2010)

- Global-average thermospheric density at 400km
- Black Line: annual average; Blue Line: 81-day centered running mean; Green Line: envelope of expected decrease due to CO_2 levels
- 2007-2009 lowest density years on record
- 2008/2009 were 29% lower than predicted

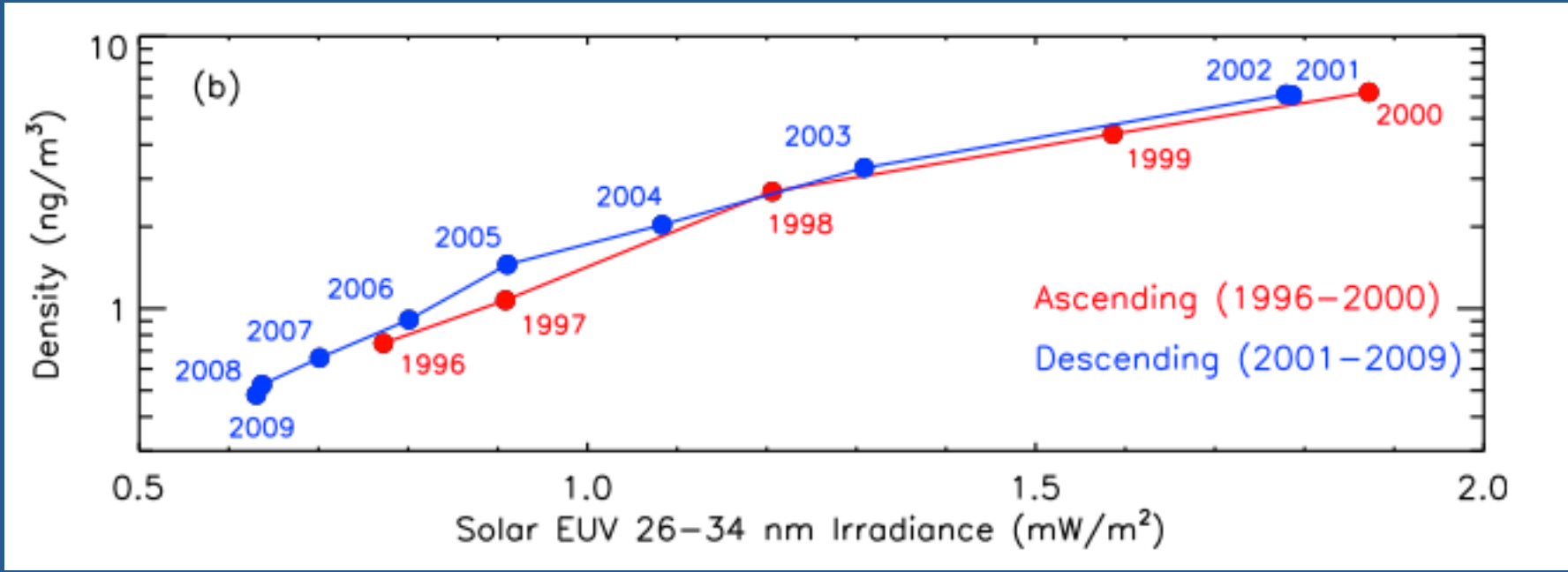
Comparison of Ne over Jicamarca



Liu et al. (2012)

- Seasonal average of electron density
- White lines: H_mF_2 height

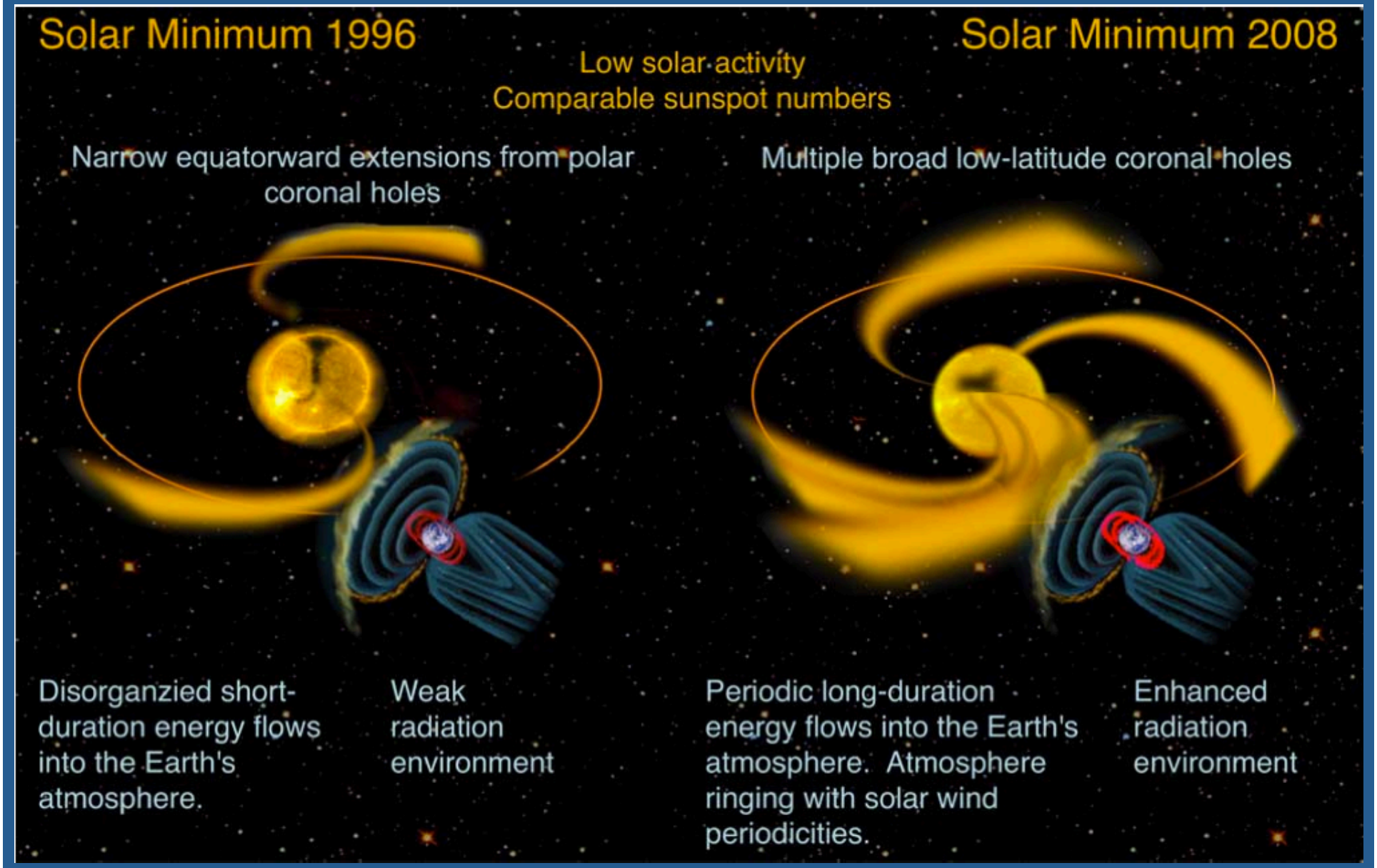
Why So Different?



Solomon et al. 2010

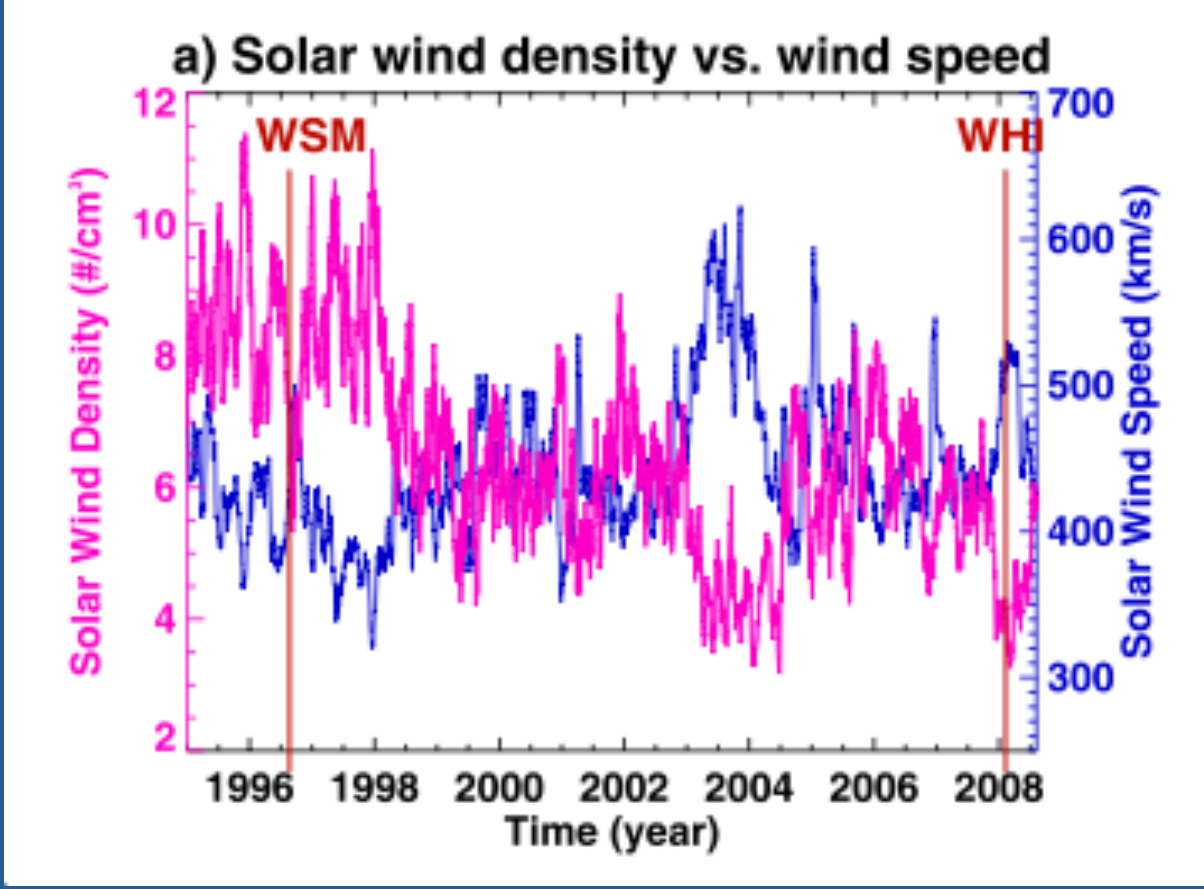
- Low EUV irradiance ~22%
  - EUV and FUV photons are the primary heat source of the thermosphere
  - Expands and contracts in response to temperature change
  - Reduction of ~15% in solar flux

- CO_2 Levels ~%3
- Geomagnetic Activity ~2.2%
- Solar Wind Conditions ~?



Gibson et al. 2009

Comparison of Solar Wind Conditions



Gibson et al. 2009

- Low solar wind magnetic field strength
- Lower solar wind density ~45%
- High solar wind velocity ~13%

Goals

- To understand why the neutral and electron density of 2008 was so unusually low

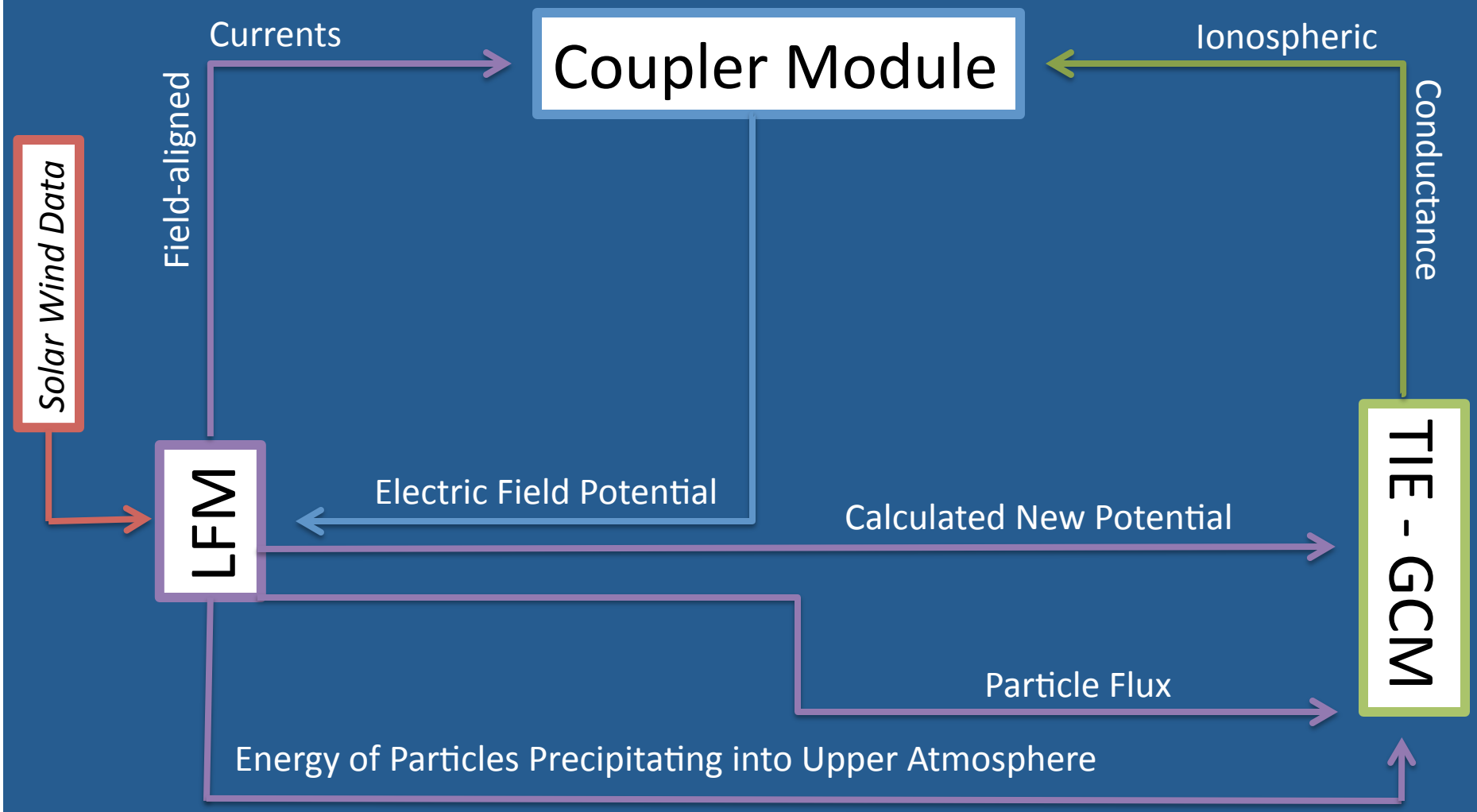
- To understand the effects that different solar wind conditions have on the density of the upper atmosphere through numerical model simulations
  - Solar wind density
  - Solar wind speed

Coupled Magnetosphere Ionosphere Thermosphere model (CMIT)

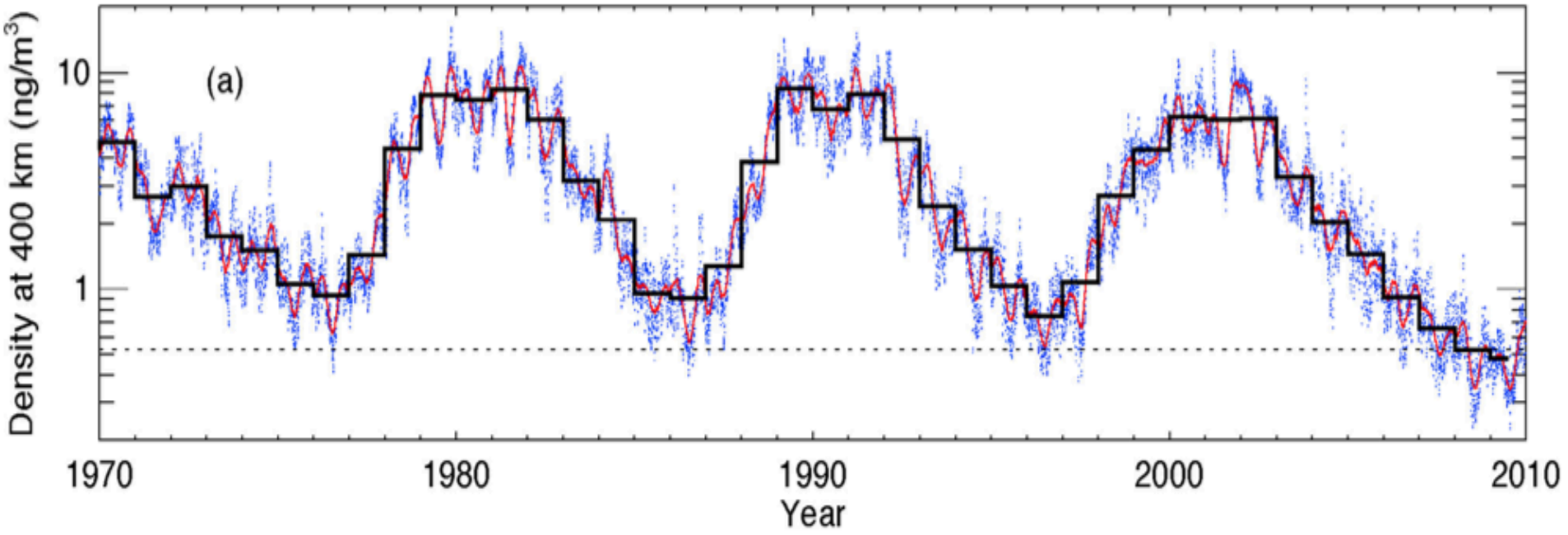
- Lyon Fedder Mobarry (LFM)
  - Responsible for magnetosphere
  - 3D Ideal MHD equations
  - Requires: Solar wind and IMF conditions
  - Requires: Ionospheric inner boundary conditions

- Thermosphere Ionosphere Electrodynamics-General Circulation Model (TIE-GCM)
  - Responsible for thermosphere and ionosphere
  - 5°x5° Global Grid that ranges from 97-500 km
  - Requires: Solar radiation flux
  - Requires: High latitude electric potential
  - Required: energetic particle precipitation

CMIT


Currents
Coupler Module
Ionospheric
Field-aligned
Conductance
Solar Wind Data
LFM
Electric Field Potential
Calculated New Potential
TIE - GCM
Particle Flux
Energy of Particles Precipitating into Upper Atmosphere

Solar Wind Data



Solomon et al. (2011)

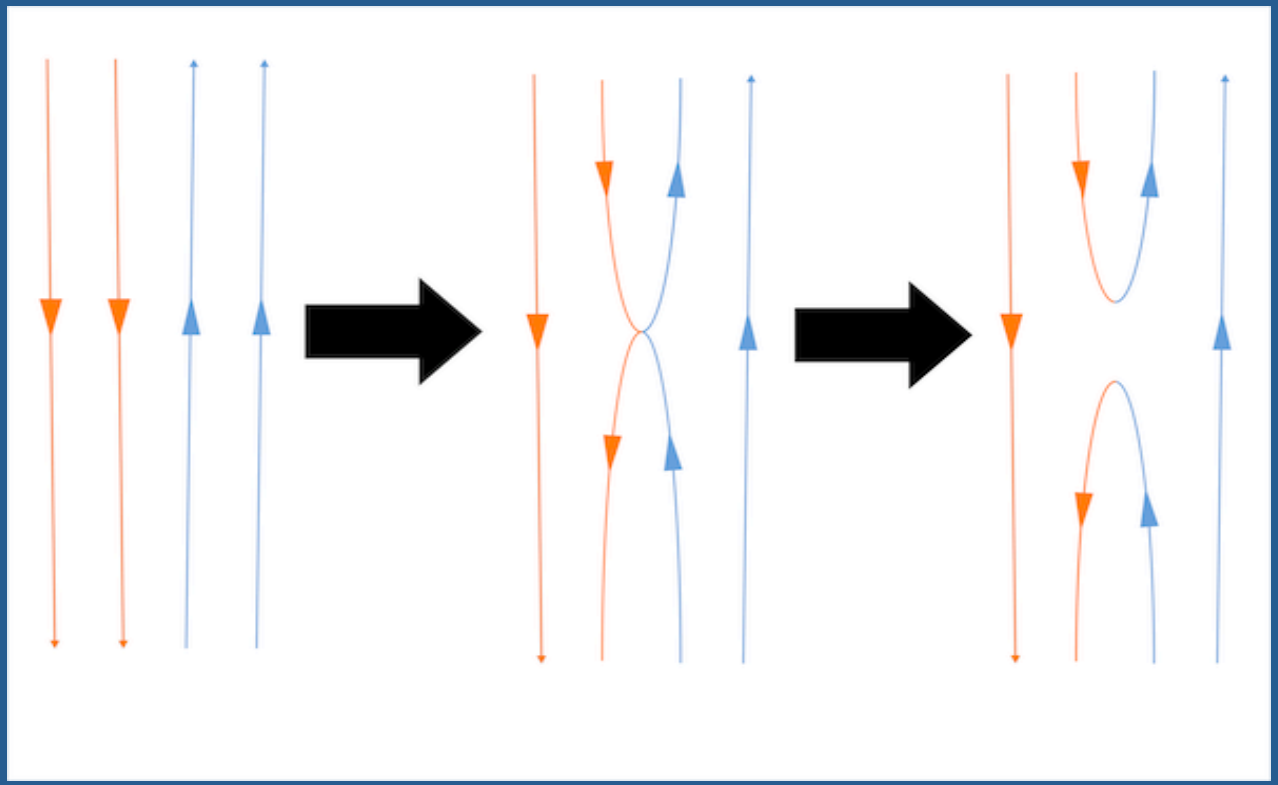
- OMNIweb solar wind data
- ACE, Wind, IMP 8 and Geotail data
- 81 day centered average around June 30th

The Three Simulations

	Control	LowDens	HighVel
Density (cm^{-3})	9.0	4.5	9.0
$Speed_x$ (km/s)	-380.0	-380.0	-450.0
B_z (nT)	-5	-5	-5

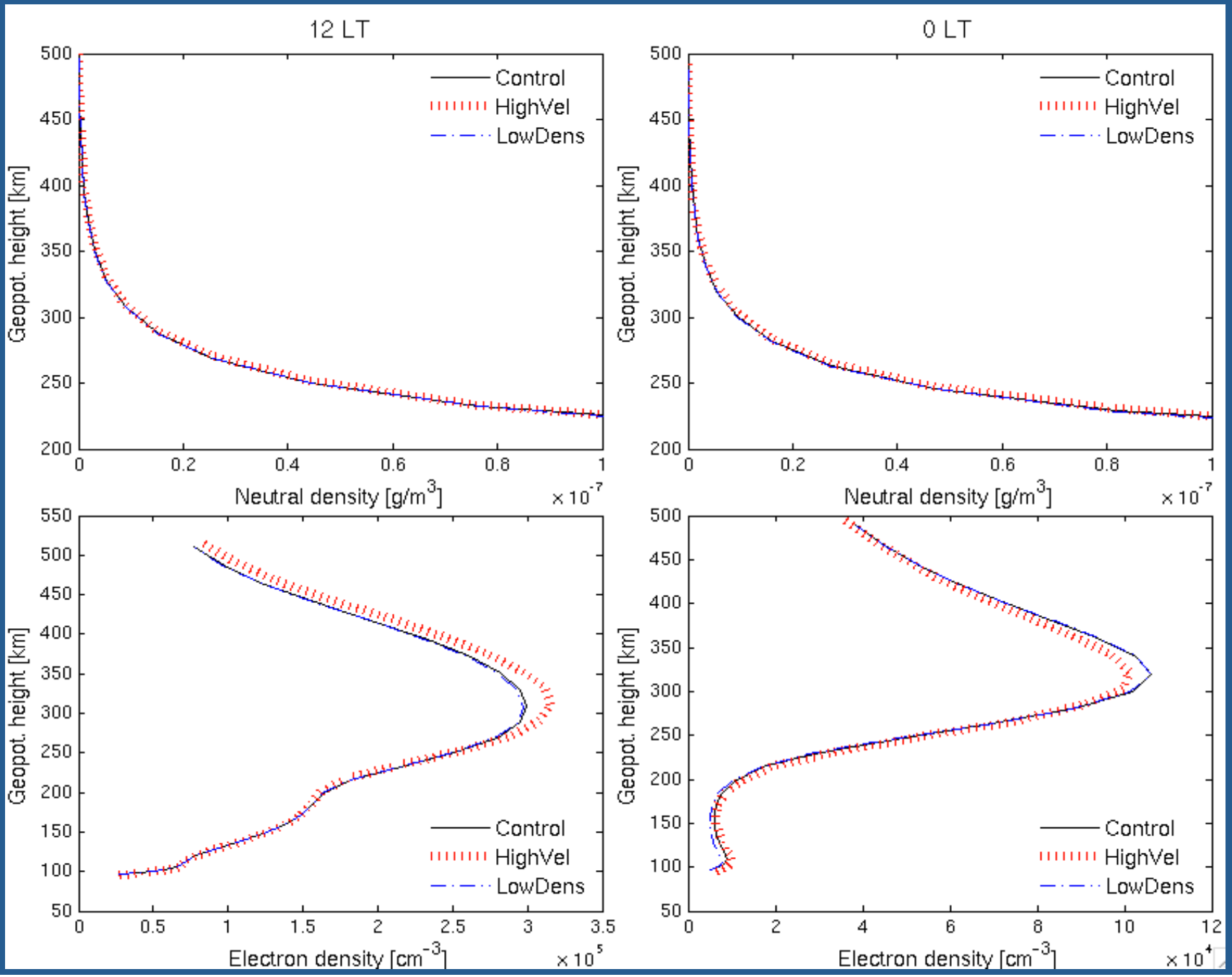
Model Parameters

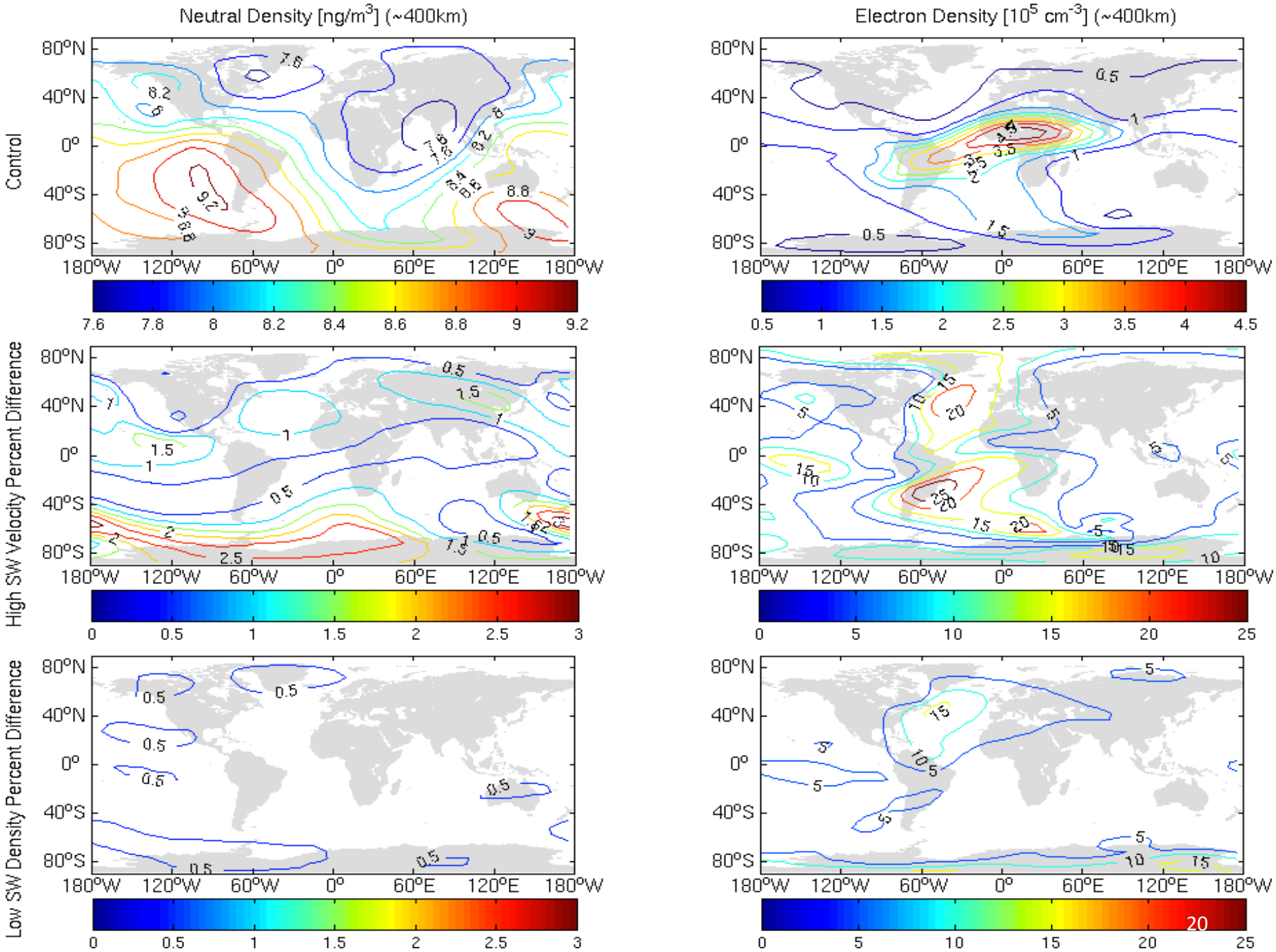
- 36 hour simulations
- IMF was always southward during the last 24hours used for analysis

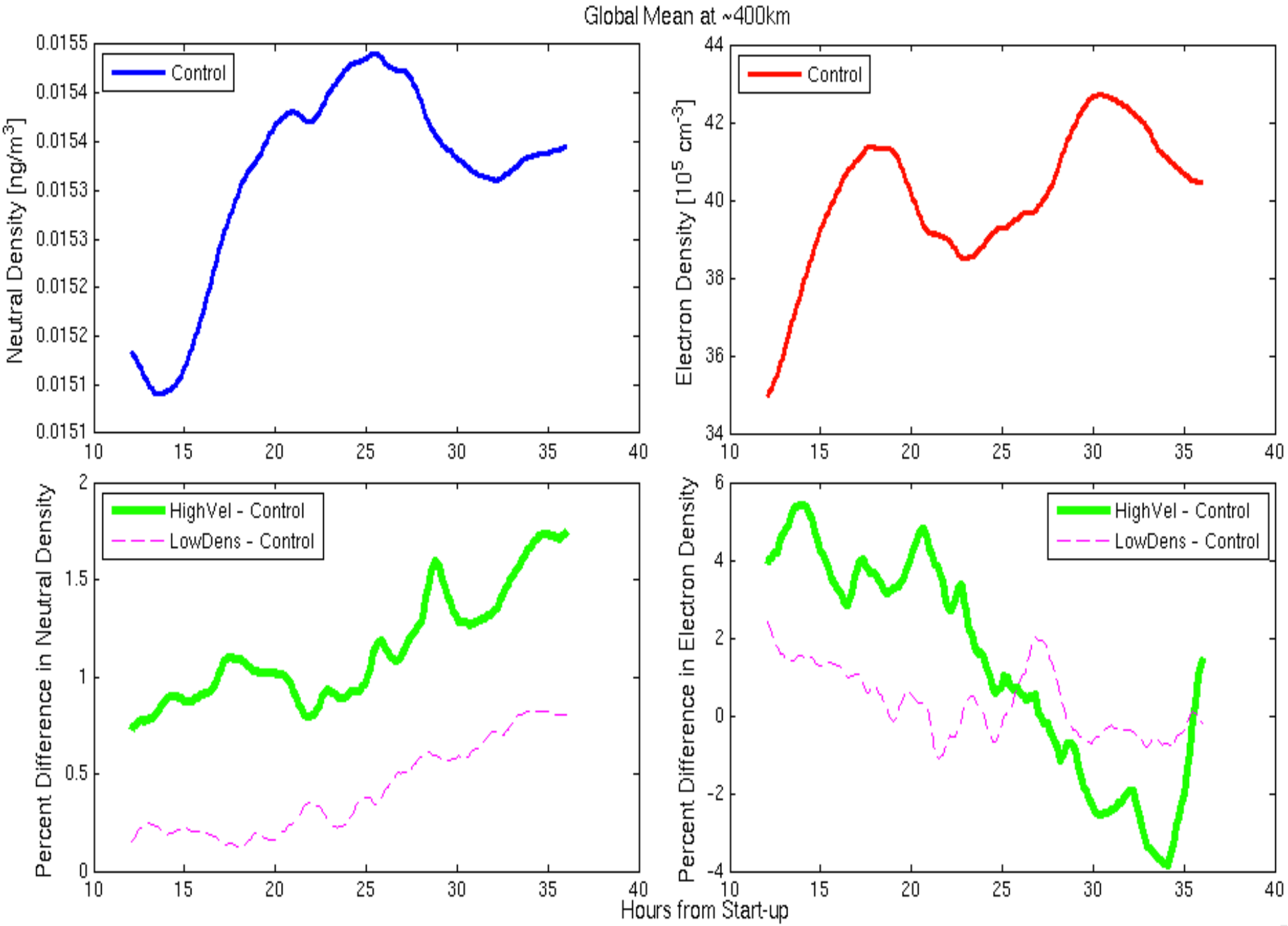


"Magnetic Reconnection: A Prominent Mystery, PartÂ 2..."

Global Mean Profile Plots of Neutral and Electron Density Levels




Neutral Density [ng/m3] (~400km)
Electron Density [10^5 cm^-3] (~400km)
Control
High SW Velocity Percent Difference
Low SW Density Percent Difference
80°N
40°N
0°
40°S
80°S
180°W 120°W 60°W 0° 60°E 120°E 180°W
7.6 7.8 8 8.2 8.4 8.6 8.8 9 9.2
0.5 1 1.5 2 2.5 3 3.5 4 4.5
0 0.5 1 1.5 2 2.5 3
0 5 10 15 20 25


Global Mean at ~400km
Control
Neutral Density [ng/m^3]
0.0155
0.0154
0.0154
0.0153
0.0153
0.0152
0.0152
0.0151
0.0151
10
15
20
25
30
35
40
Control
Electron Density [10^5 cm^{-3}]
44
42
40
38
36
34
HighVel - Control
LowDens - Control
Percent Difference in Neutral Density
2
1.5
1
0.5
0
HighVel - Control
LowDens - Control
Percent Difference in Electron Density
6
4
2
0
-2
-4
Hours from Start-up

Results

LowDens vs. Control	HighVel vs. Control
•Less than 1% higher ND levels @~400km •From 1% lower to 3%higher NE levels@ ~400km •Little difference in vertical profiles from control data	•Larger differences in both ND and NE @~ 400km •Day (12LT) – higher NE levels •Night (0LT)– lower NE levels

Conclusions / Future Plans

- Solar wind density difference between 2008 and 1996 did not have a significant effect on neutral or electron density in the numerical simulations
- Solar wind velocity difference did produce an interesting effect and should be explored further
  - Night: consistent with observed electron density differences
  - Day: produced the opposite effect
- Run the simulations for a longer period of time in order to better analyze the results
- Test IMF strength and direction

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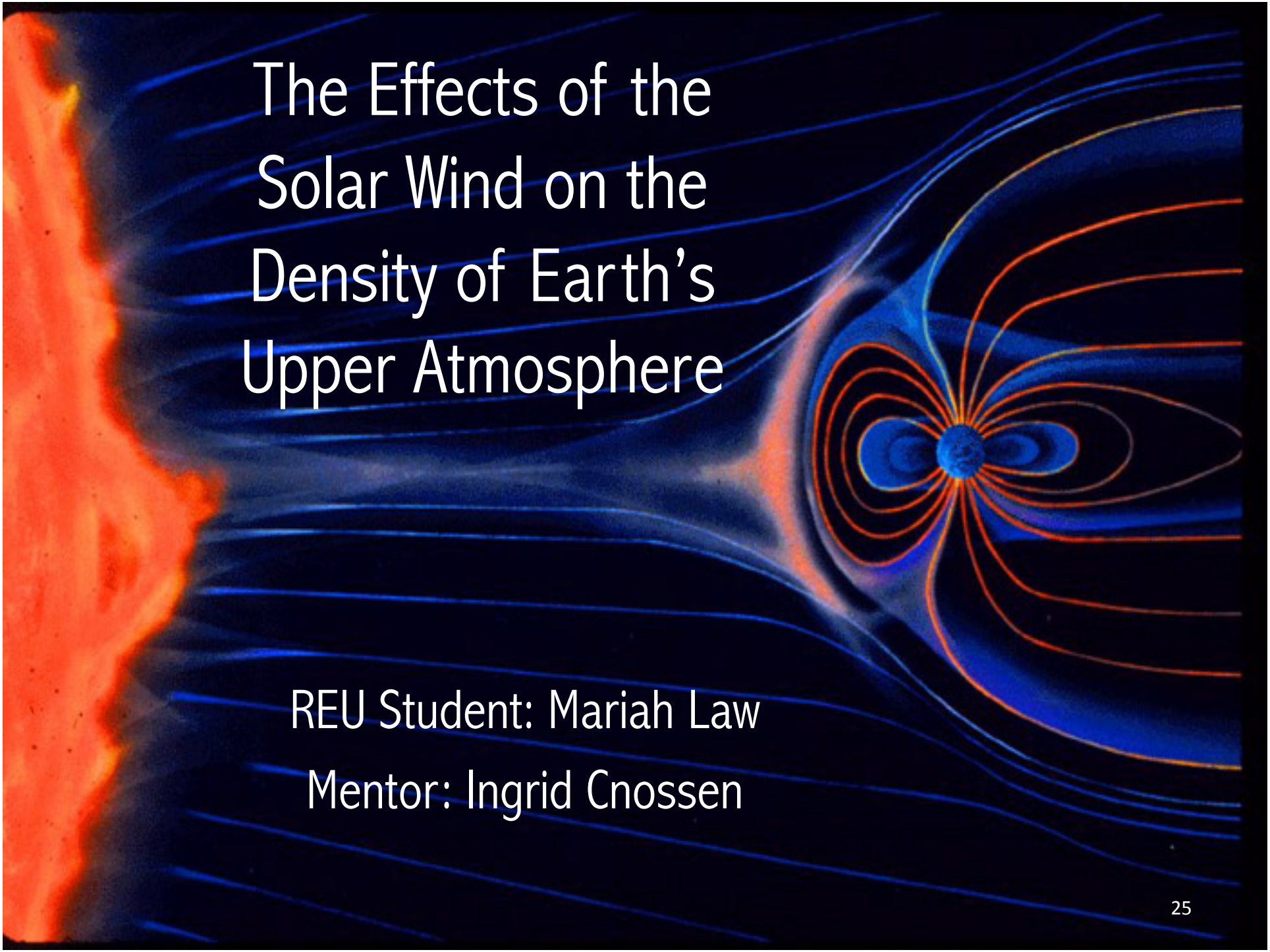
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