



4 August 2010

# MODELING THE DENSITY OF THE THERMOSPHERE

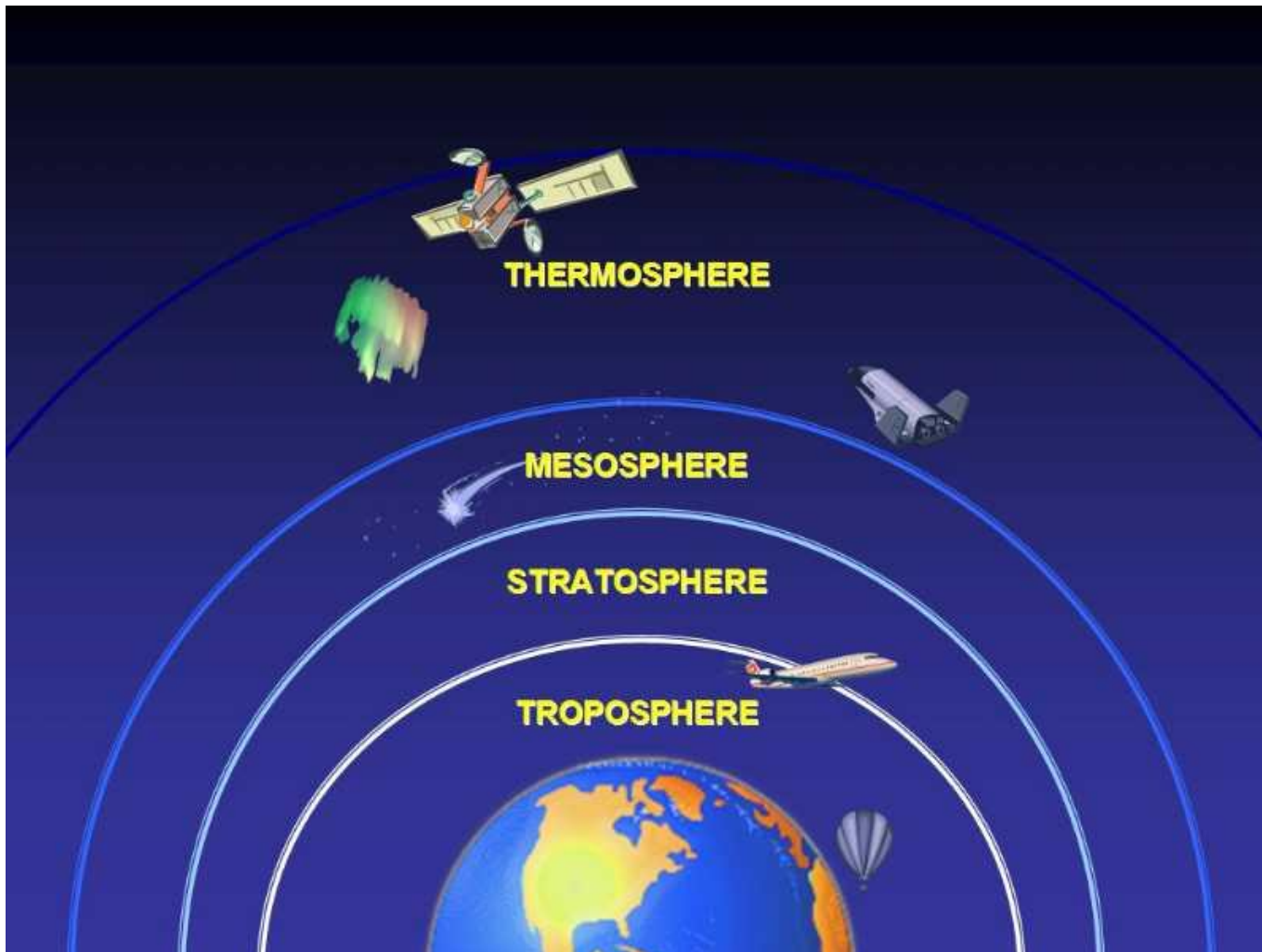
Suzanne Smith

Mentor: Tomoko Matsuo

Site: National Oceanic & Atmospheric Administration,  
NOAA

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# EARTH'S ATMOSPHERE





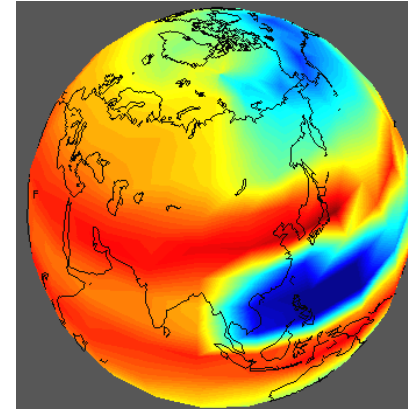
# IMPORTANCE OF MODELING THE THERMOSPHERE

- Height of satellites and space shuttles orbit.
- The neutral density of the thermosphere effects the amount of drag present.
- With increased density and drag the shuttles and satellites are slowed and the orbiting altitude is decreased.
- Having an efficient and accurate model of thermospheric density is a valuable asset.

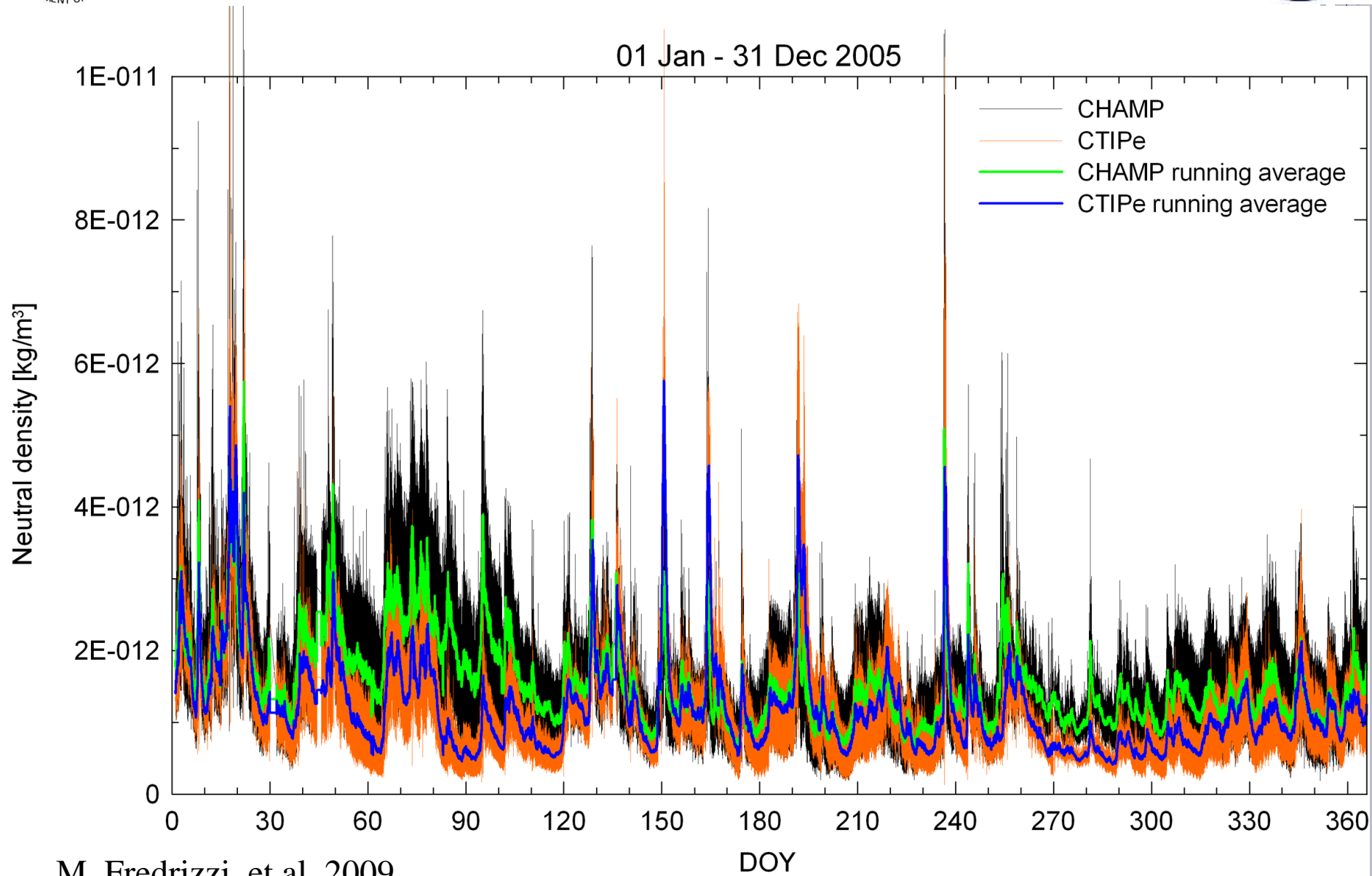


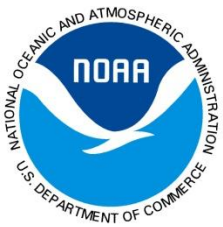
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# INTRODUCTION



- General Circulation Model, GCM
- Previous work
  - CTIPe model: The Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics Model, Tim Fuller-Rowell et al. 1996
    - Global Thermosphere 80-500km: solves momentum, energy, composition
    - Ionosphere 80-10,000km: solves continuity, momentum, energy, etc.
    - Forcing: solar UV and EUV, empirical high latitude electric field and auroral precipitation models, tidal forcing.
  - CHAMP Satellite: Challenging Minisatellite Payload Satellite
    - height~ 400km; 90min orbital period; Launched date: July 2000.
  - 2005 CTIPe 5-min Run, Mariangel Fedrizzi



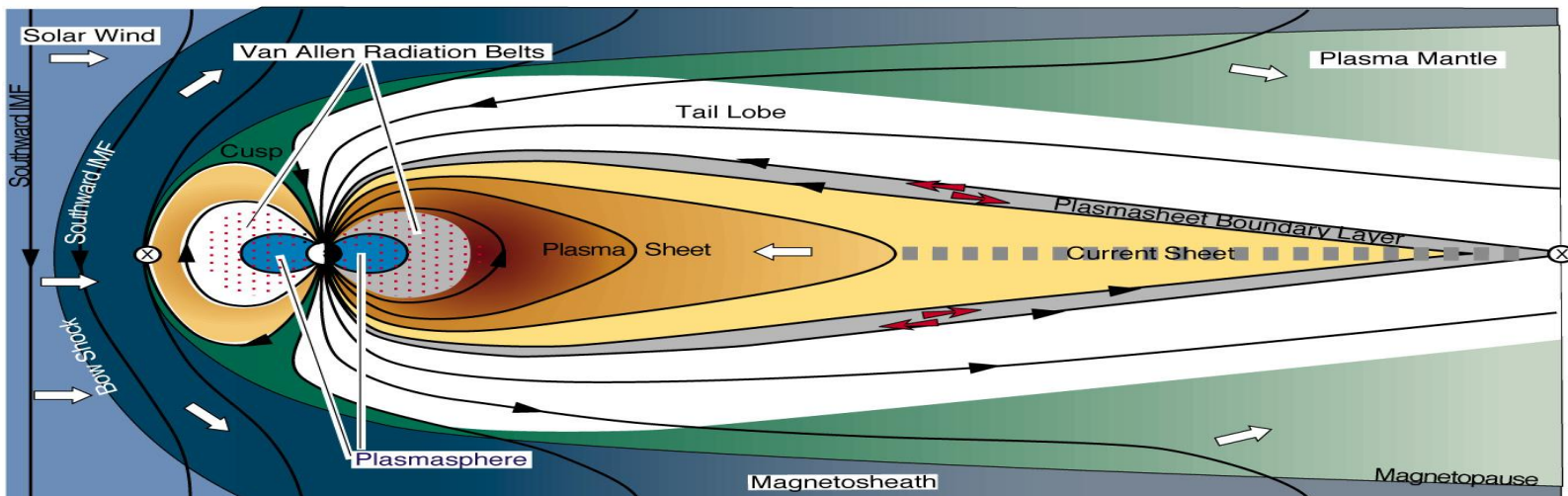
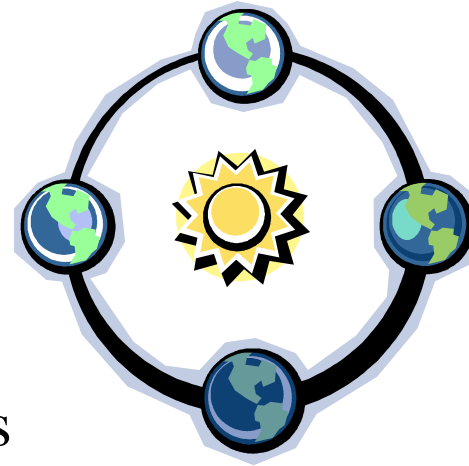


## INTRODUCTION, CONT.

- My Work
- Used multi-dimensional GCM (CTIPe) output and reduced it to a low-dimension model.
- Specifically, conducted Singular Value Decomposition (SVD) Analysis of CTIPe 5-min model output from 2005, and constructed a model of thermospheric density.
- Density in terms of position and time:
  - $\rho(\mathbf{r}, t) = \Phi_1(\mathbf{r}) \alpha_1(t) + \Phi_2(\mathbf{r}) \alpha_2(t) + \dots + \Phi_n(\mathbf{r}) \alpha_n(t)$
- $\Phi_n(\mathbf{r}) = \text{EOF}$
- $\alpha_n(t) = \text{Amplitude}$

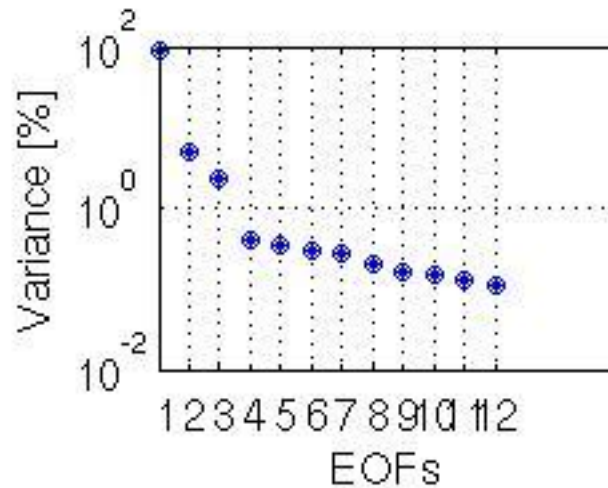
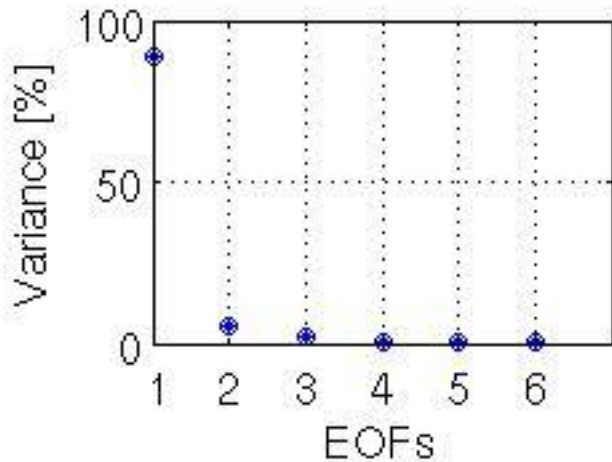
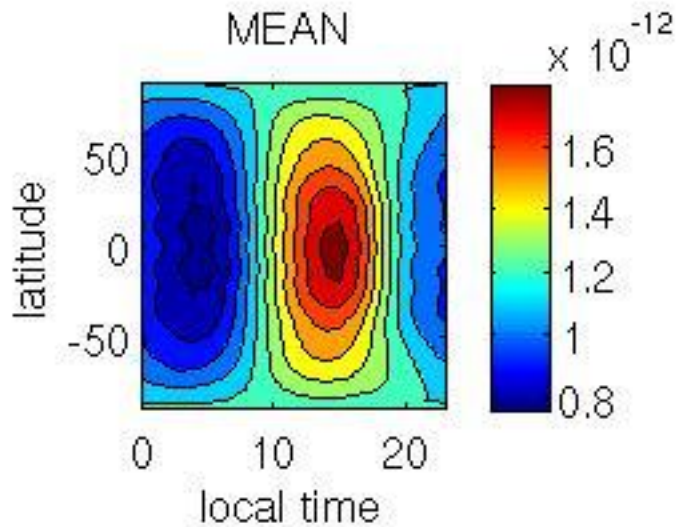
# DRIVERS OF DENSITY CHANGE

- Extreme Ultra Violet(EUV)
  - Diurnal
  - Seasonal
- Solar wind/Magnetosphere Interactions
  - Auroral Activity



# YEAR MEAN & EOF AMPLITUDE VARIANCE

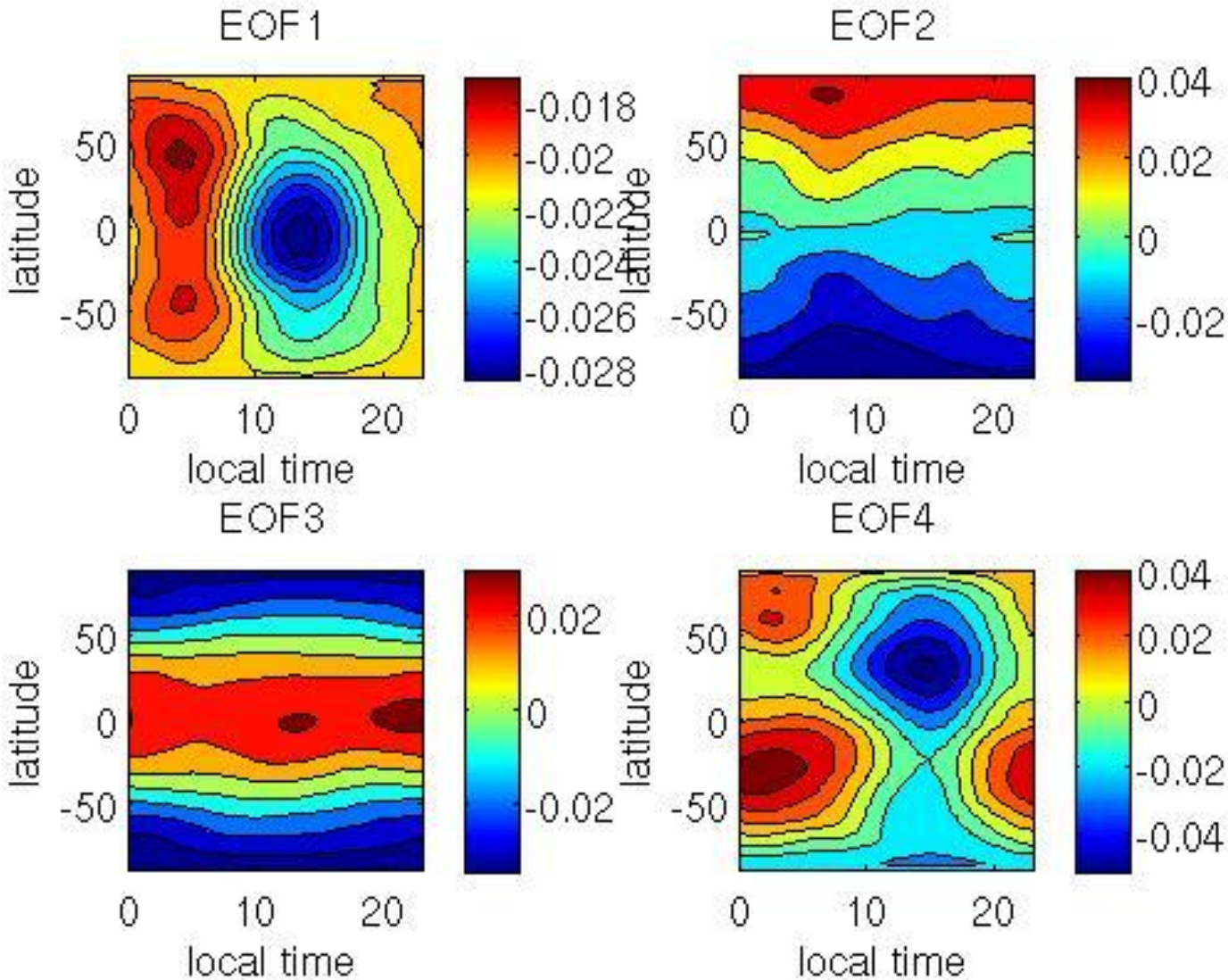
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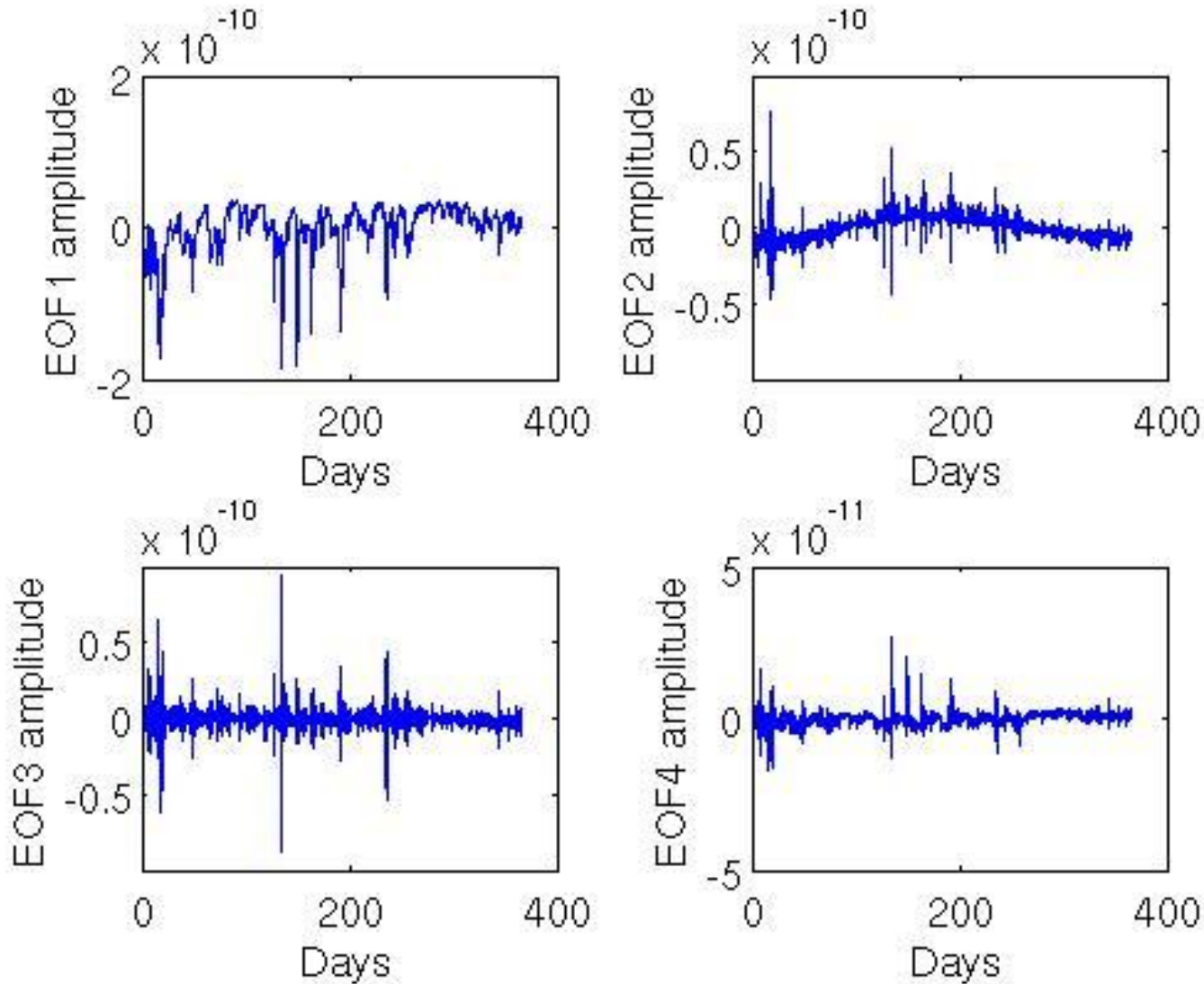


# YEARS WORTH OF EMPIRICAL ORTHOGONAL FUNCTIONS (EOFs), $\Phi$

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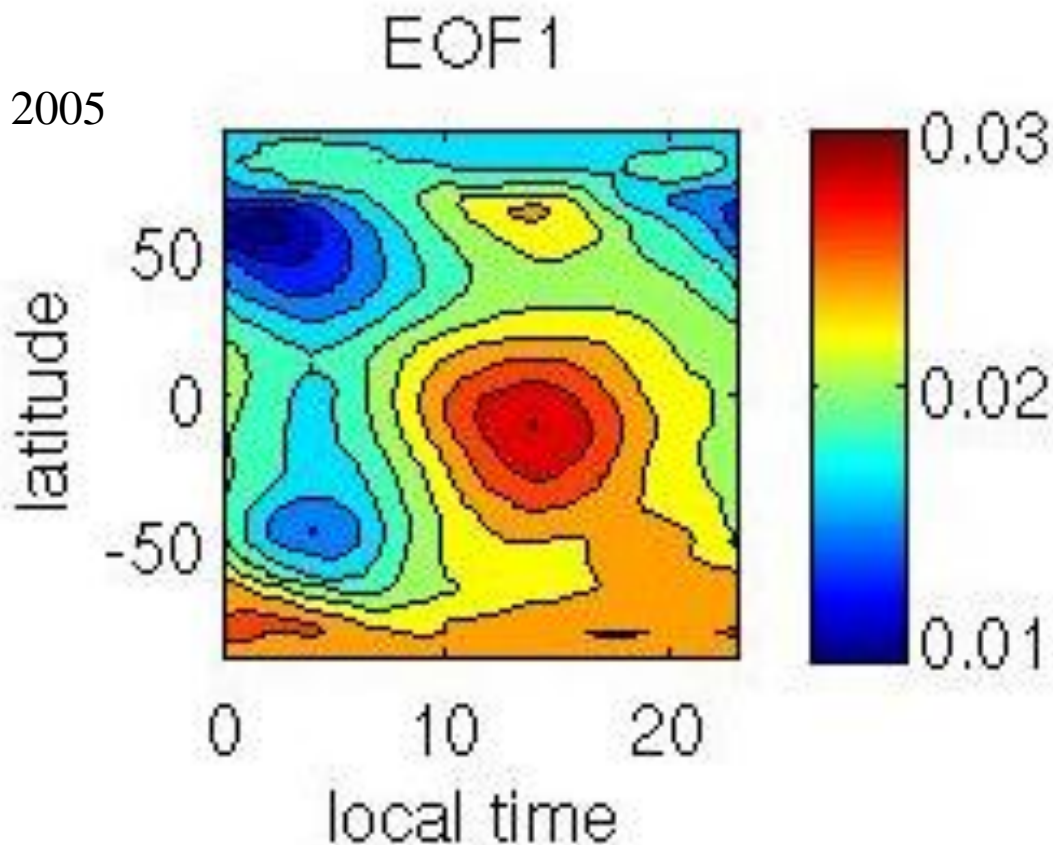
# EOF AMPLITUDES, $\alpha$



# MODE #1: DIURNAL EUV

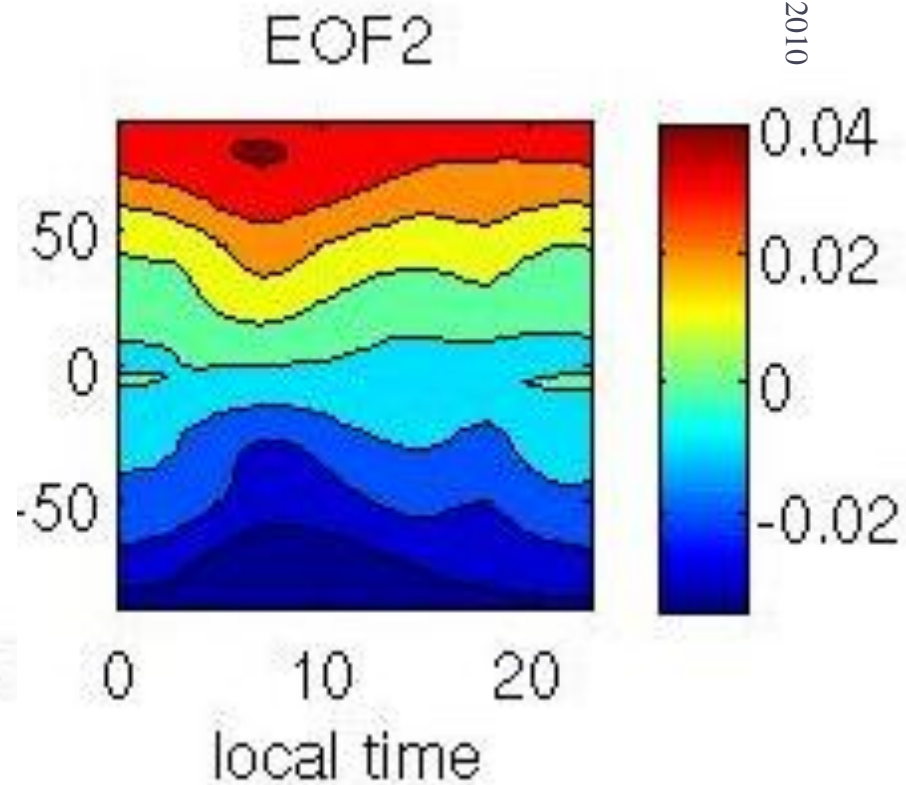
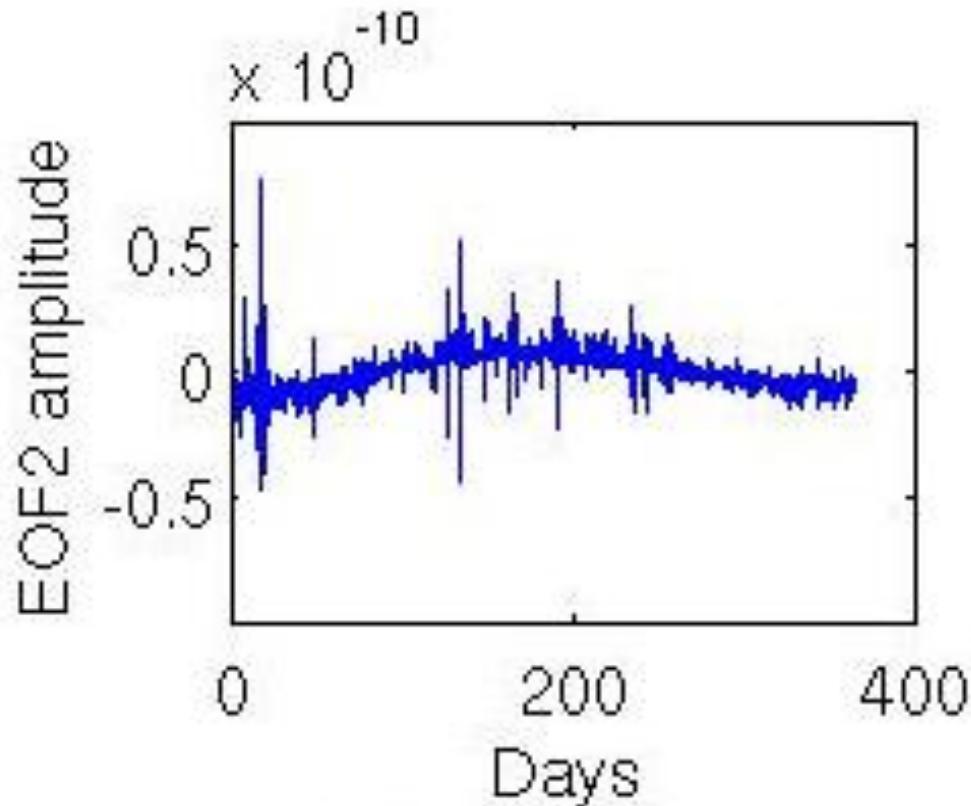
- Caused by the earth's daily rotation.
- The day side's density increases because of the increased EUV.

August 2005



# MODE #2: SEASONAL EUV

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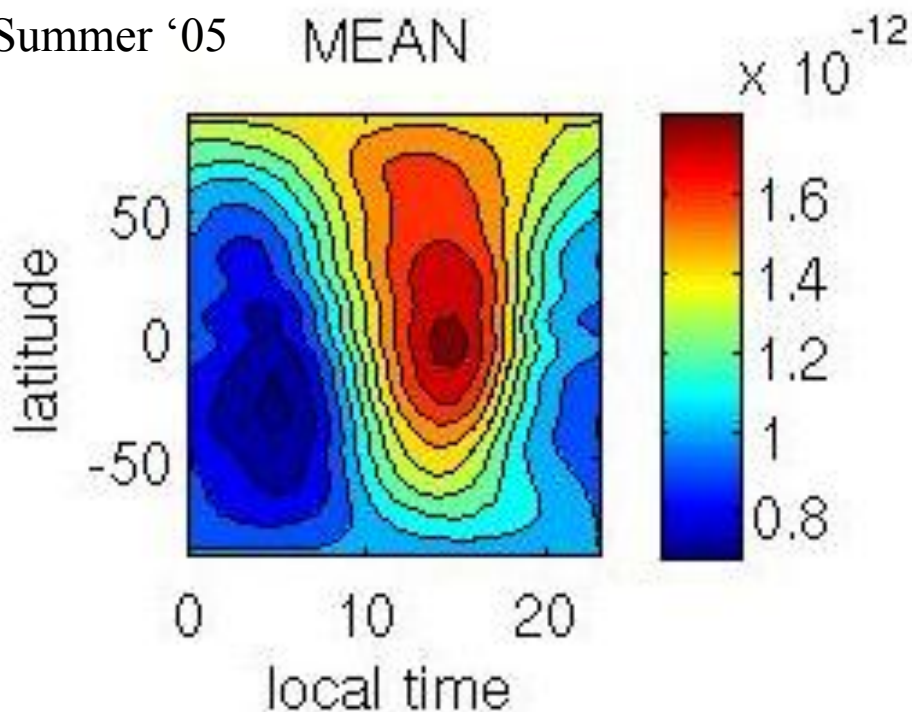
## MODE #2: SEASONAL EUV CONT.

- Caused by the earth's yearly revolution around the sun.
- In our summer months the northern hemisphere is pointed towards the sun which results in a greater amount of EUVs.

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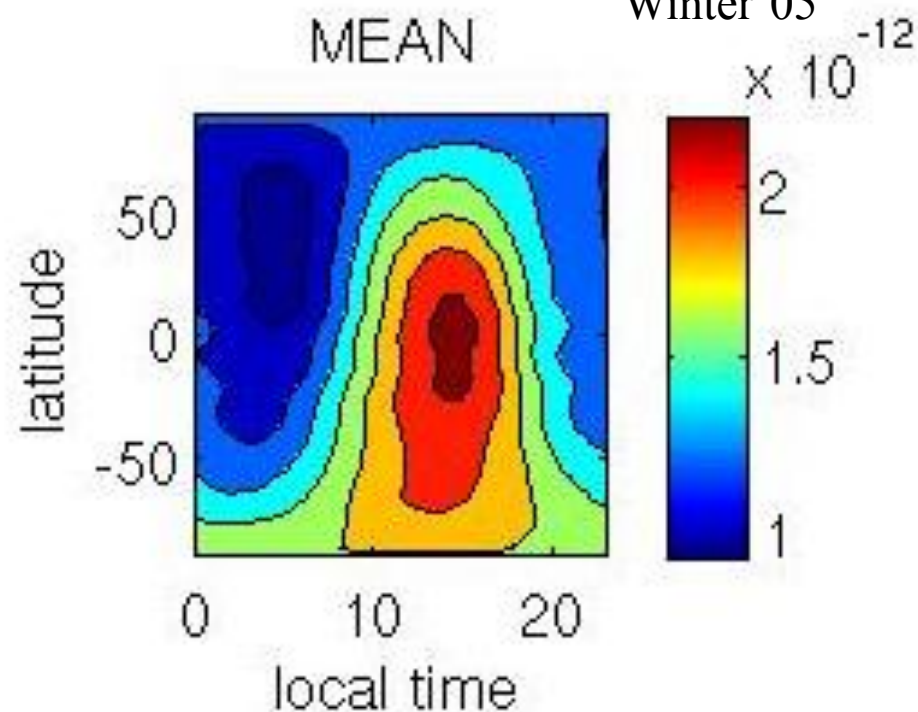
Summer '05

MEAN



Winter '05

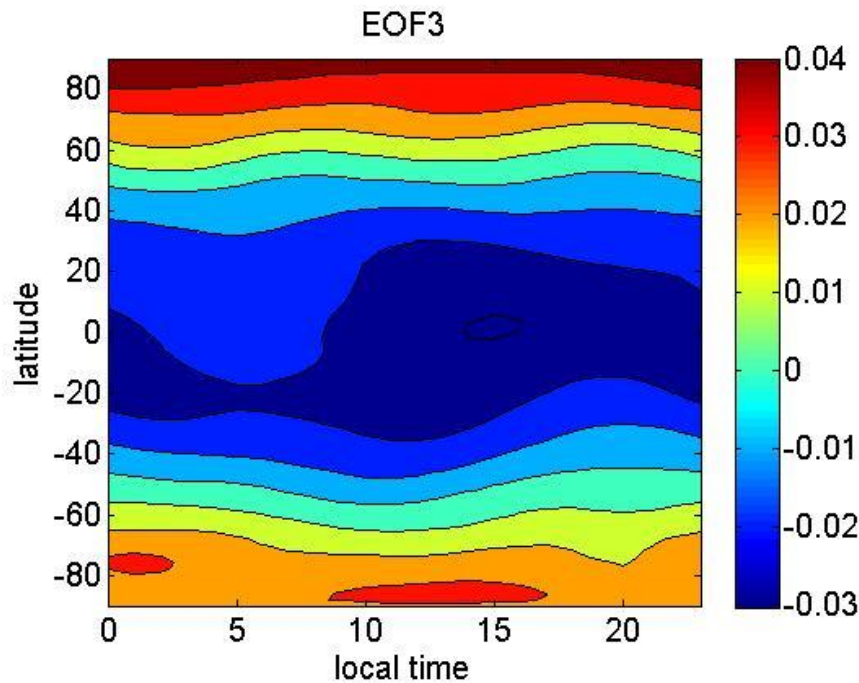
MEAN



## MODE #3: AURORAL ACTIVITY

- Cause by high latitude electromagnetic forcing resulted from the interaction between Solar Wind and the earth's magnetosphere (i.e., auroral activity).
- Aurora occur both in the Northern and Southern hemisphere creating a symmetric pattern in the EOF contour plots.

Oct 2005





# RESOURCES: DRIVERS OF DENSITY CHANGE

- Ap Index (Kyoto): A measure of the level of geomagnetic activity over the globe taken every 3hrs.
- Solar Wind (NASA OMNIWeb): collection of different data sets that help to display storm conditions.
- Joule Heating (CTIPE Model): integrated over the globe
- F 10.7 (Ottawa 10.7cm flux): EUV index

# PROVING MODE #3 IS AURORAL ACTIVITY

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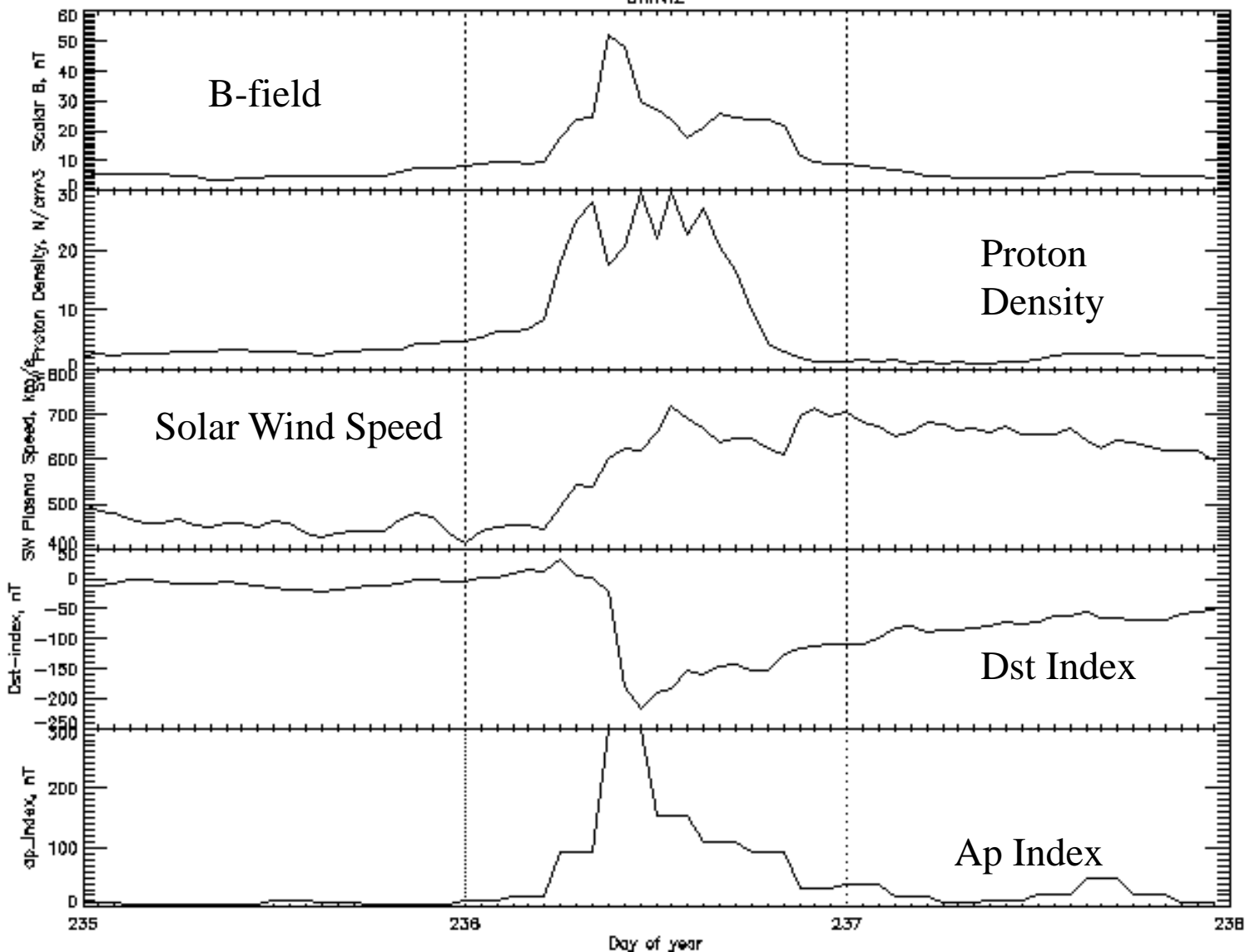
	F10.7	Ap	Ap > 150
EOF 1	0.5163	0.4411	0.3068
EOF 2	0.0410	0.0345	0.2714
EOF 3	0.0388	0.0097	0.2548
EOF 4	0.6221	0.0364	0.3659

- Correlating the different EOFs with EUV Index: F10.7 (daily value), and Geomagnetic Index: Ap (taken every three hours).
- Surprising lack of correlation between Ap and EOF3.



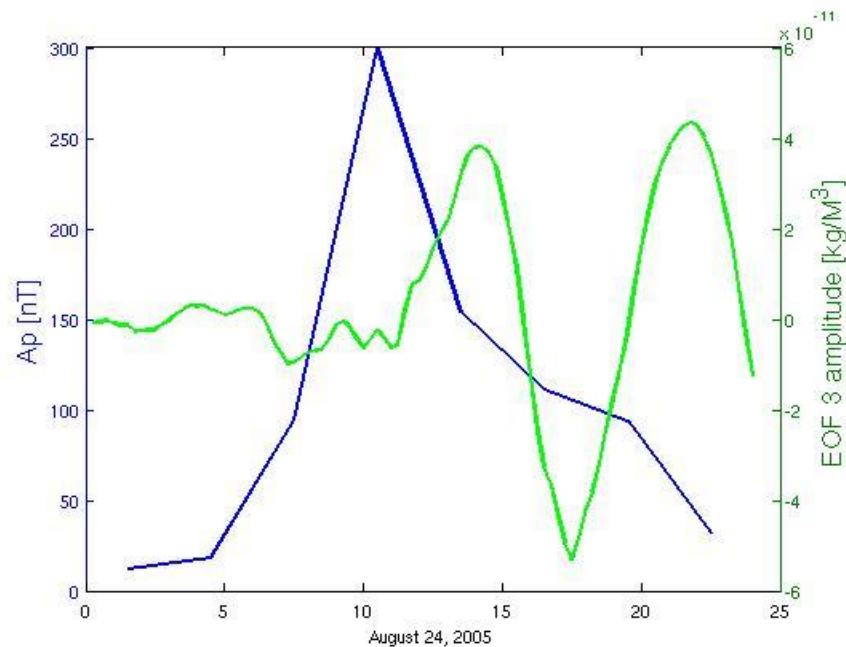
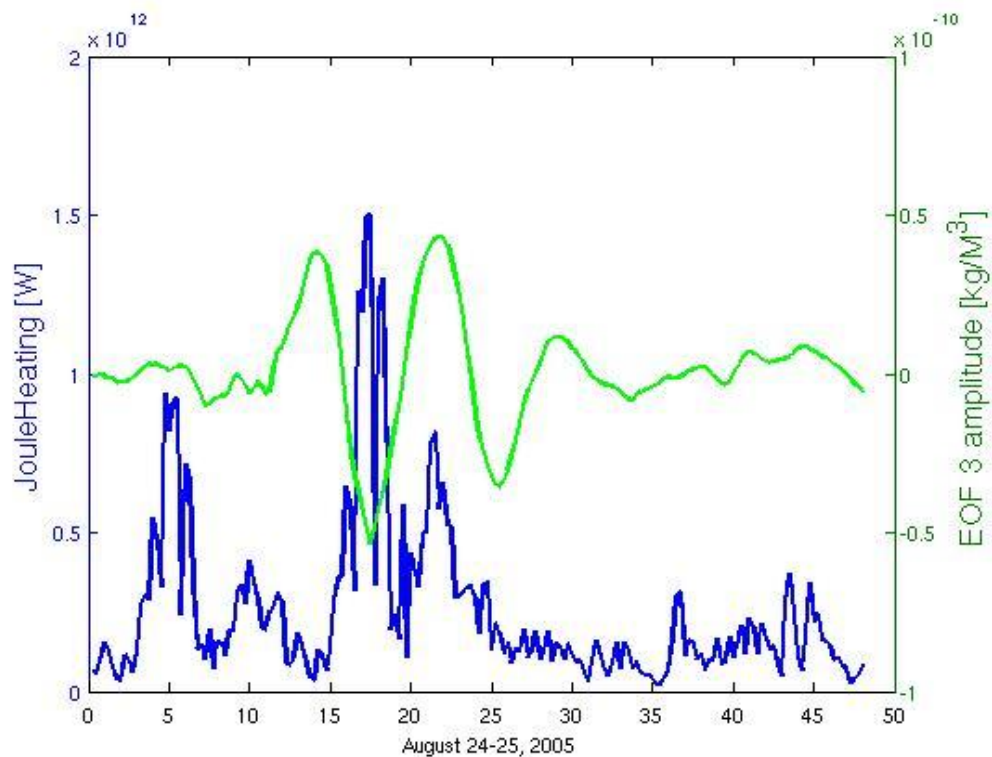
# AUGUST 24<sup>TH</sup>: SOLAR WIND DATA(OMNI)

OMNI2



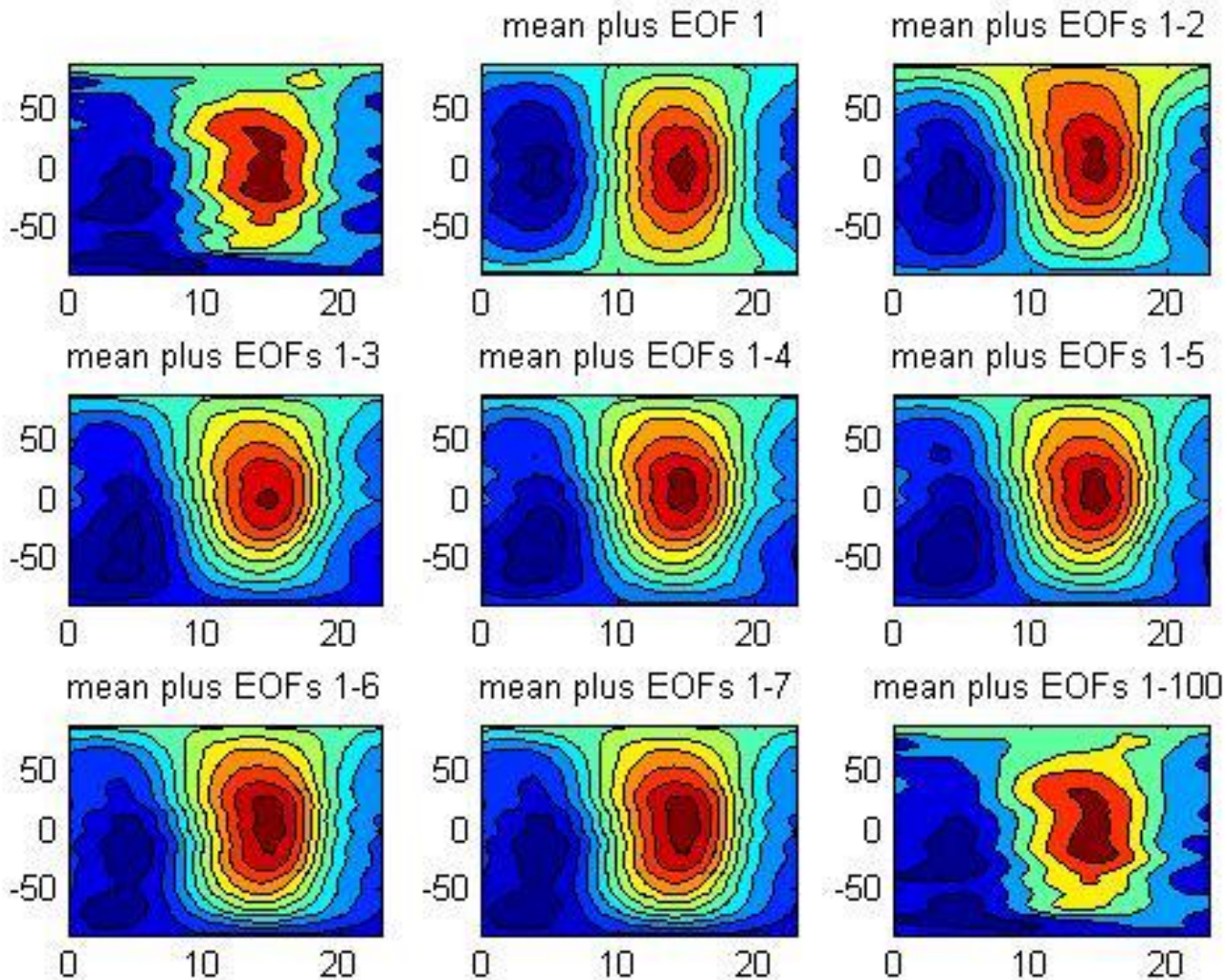
# AUGUST 24<sup>TH</sup>: AP INDEX & JOULE HEATING

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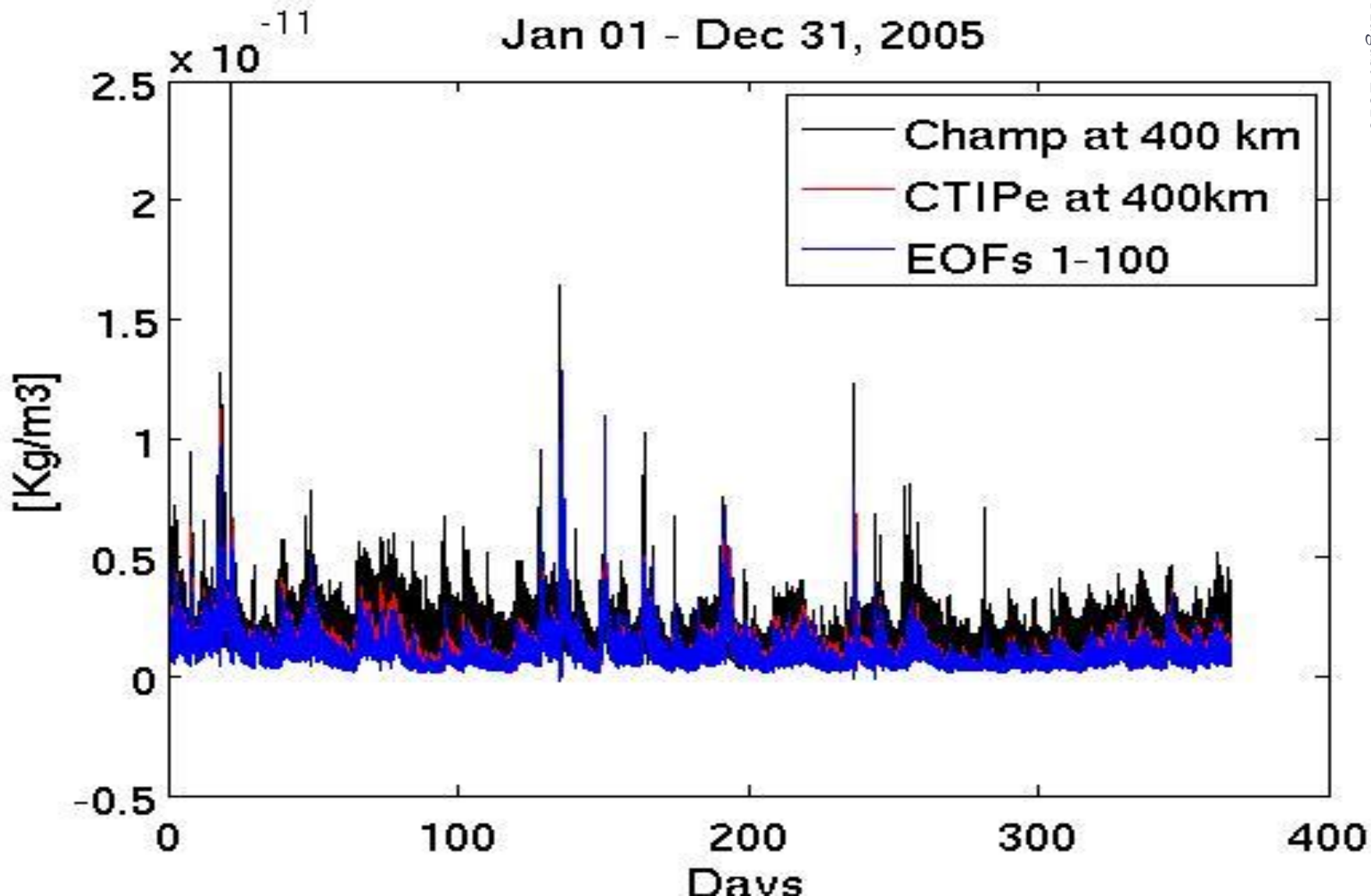
# AUGUST 24<sup>TH</sup>: THERMOSPHERIC DENSITY RECONSTRUCTION USING EOFs

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# FINISHED PRODUCT

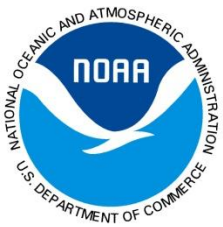
Jan 01 - Dec 31, 2005





# ACKNOWLEDGEMENTS

- Tomoko Matsuo, mentor
- Mariangel Fredrizzi, officemate & CTIPe Data
- Timothy Fuller-Rowell, CTIPe model & mentoring
- Rodney, dark chocolate covered acia berries
- Doug Biesecker
- Mike Crumly, vouching for me
- Russ Henson, technology help
- National Oceanic & Atmospheric Administration, NOAA
- Space Weather Prediction Center, SWPC
- MatLab



## REFERENCE

- NOAA Crest, <http://www.thebradentontimes.com/clientuploads/webpages/noaa-logo.jpg>.
- Lycoming Crest, [http://upload.wikimedia.org/wikipedia/en/thumb/1/1d/Lycoming\\_College\\_logo.png/175px-Lycoming\\_College\\_logo.png](http://upload.wikimedia.org/wikipedia/en/thumb/1/1d/Lycoming_College_logo.png/175px-Lycoming_College_logo.png).
- Earth's Atmosphere, <http://www.vtaide.com/png/images/atmosphere.jpg>.
- CHAMP & CTIPe data plot, Mariangel Fredrizzi, et al.
- Ap Index, <http://wdc.kugi.kyoto-u.ac.jp/kp/index.html>.
- Solar Wind Data, NASA OMNIWeb, <http://omniweb.gsfc.nasa.gov/>
- Joule Heating, CTIPe Model
- F 10.7, Daily F 10.7 index, the Ottawa 10.7cm (2800 MHz) radio flux



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QUESTIONS?