



University of  
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Magnetosphere Ionosphere Research Lab  
Space Science Center  
Institute for the Study of Earth, Oceans, and Space

# Ionosphere/Thermosphere

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# Structure of the Atmosphere

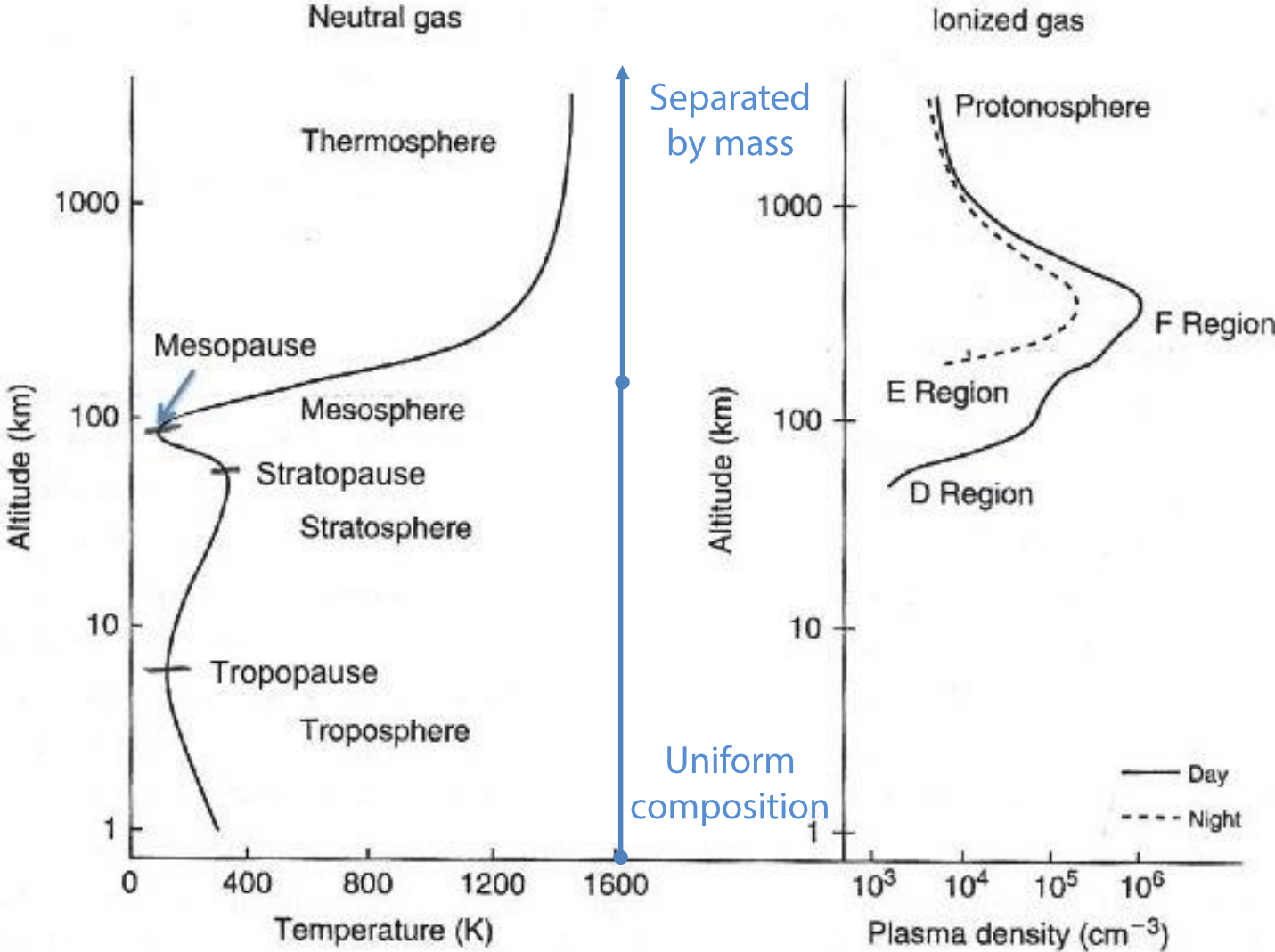
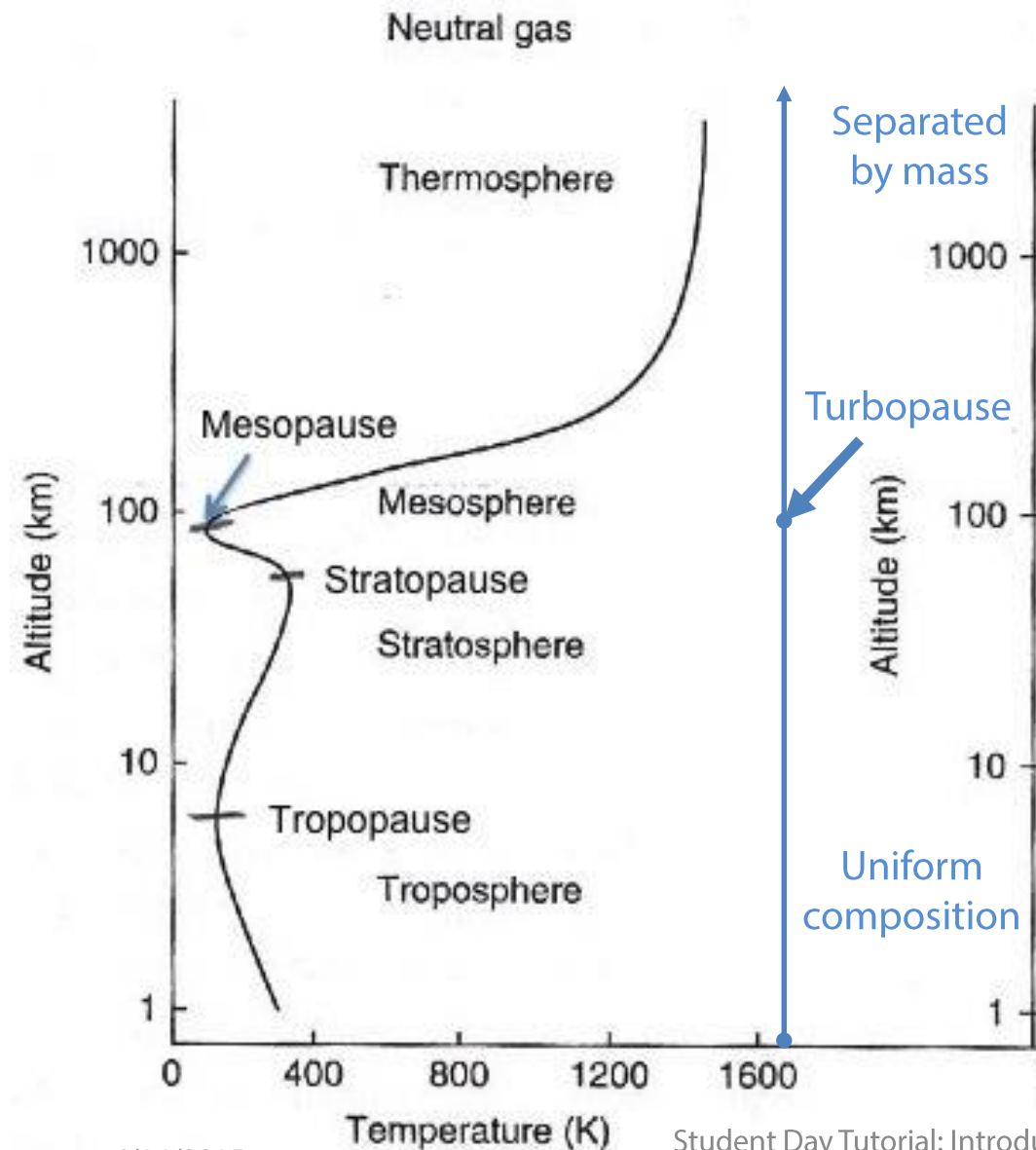


Figure adapted from Kelley [2009]

# Thermosphere Basics



- Differentiated by height due to gravity (mass)
- Neutral density varies based on temperature

# Thermospheric Dynamics

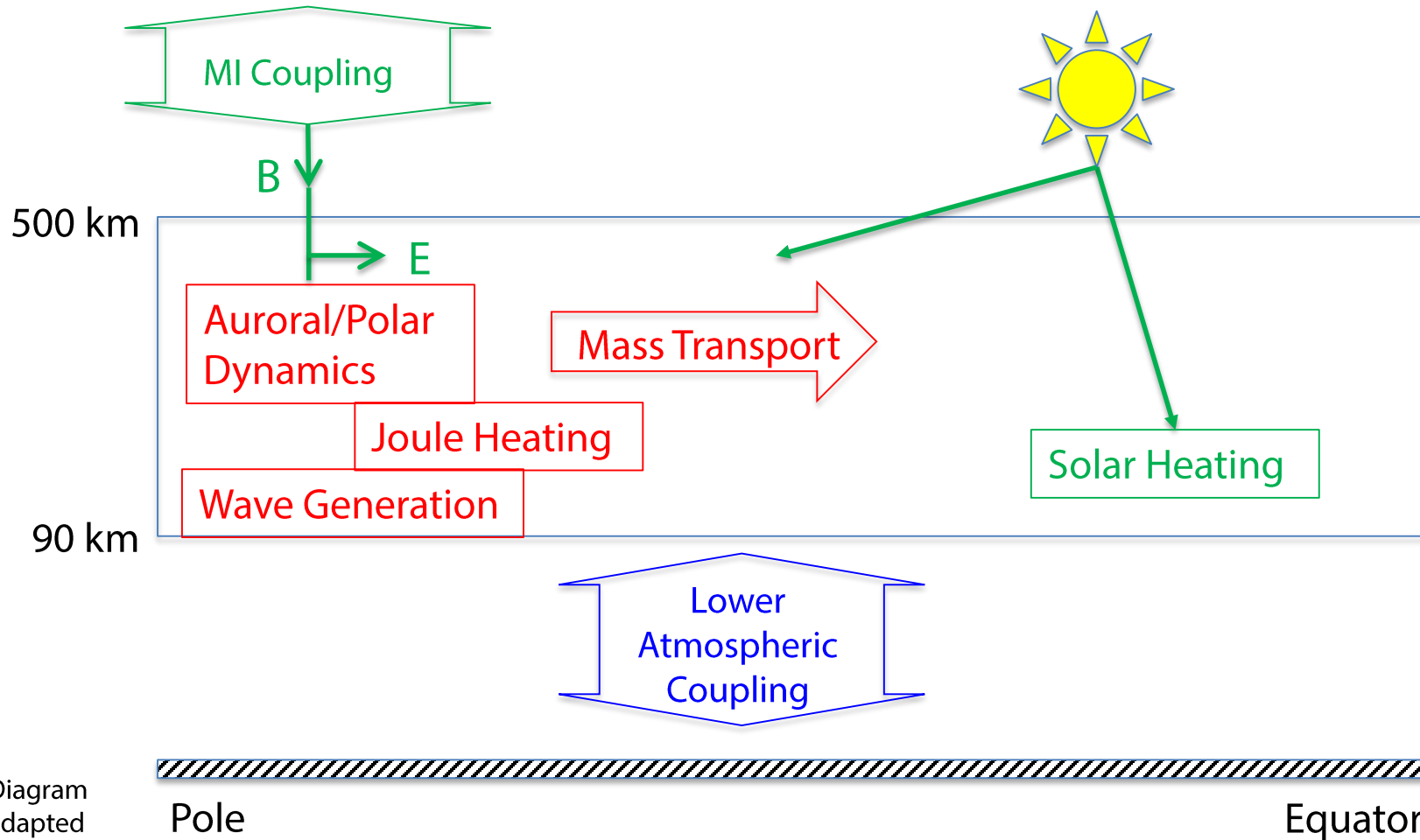


Diagram adapted from Forbes [2007]

# Neutral Upwelling

- Thermal upwelling of neutrals (from thermosphere) can cause satellite drag
- Observations from CHAMP showed “bumps” in deceleration near cusp region

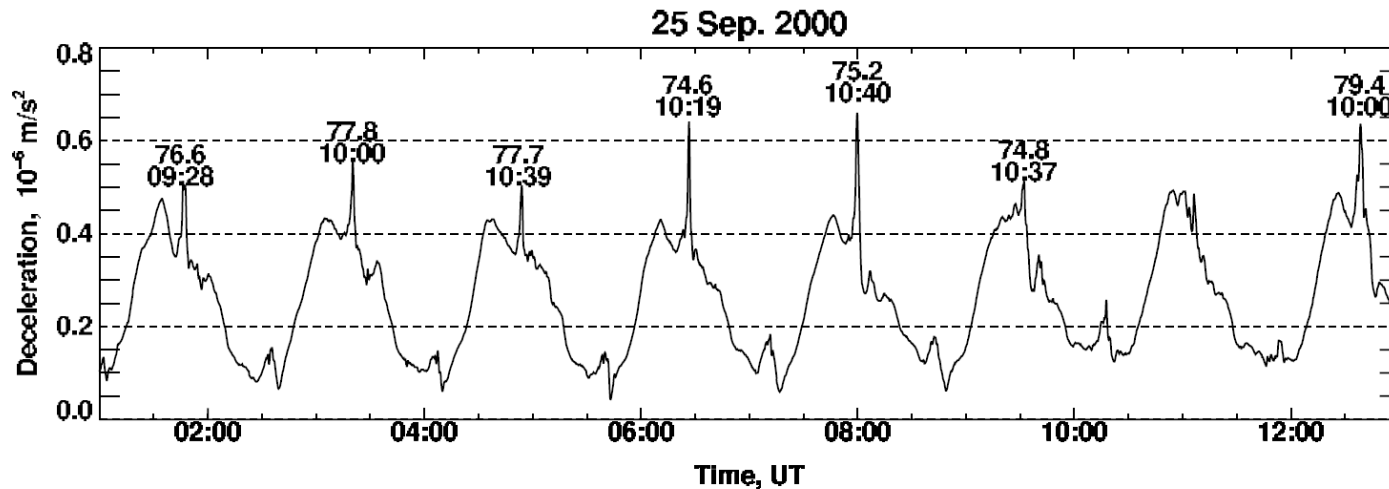
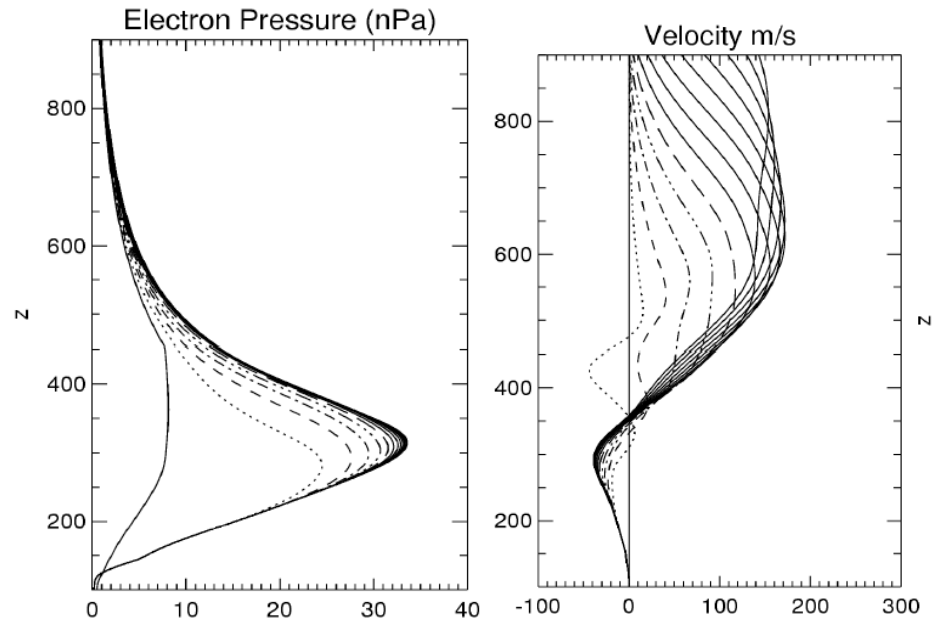


Figure from Luhr *et al.* [2004]

# Neutral Upwelling

1. Combination of ion outflow and electron precipitation cause neutral upwelling (model by *Otto et al.* [2003])
2. Direct collisional excitation of neutrals by electron precipitation directly (*Clemmons et al.* [2008])
3. Small-scale Joule heating at higher altitudes (model by *Zhang et al.* [2012])



# Structure of the Atmosphere

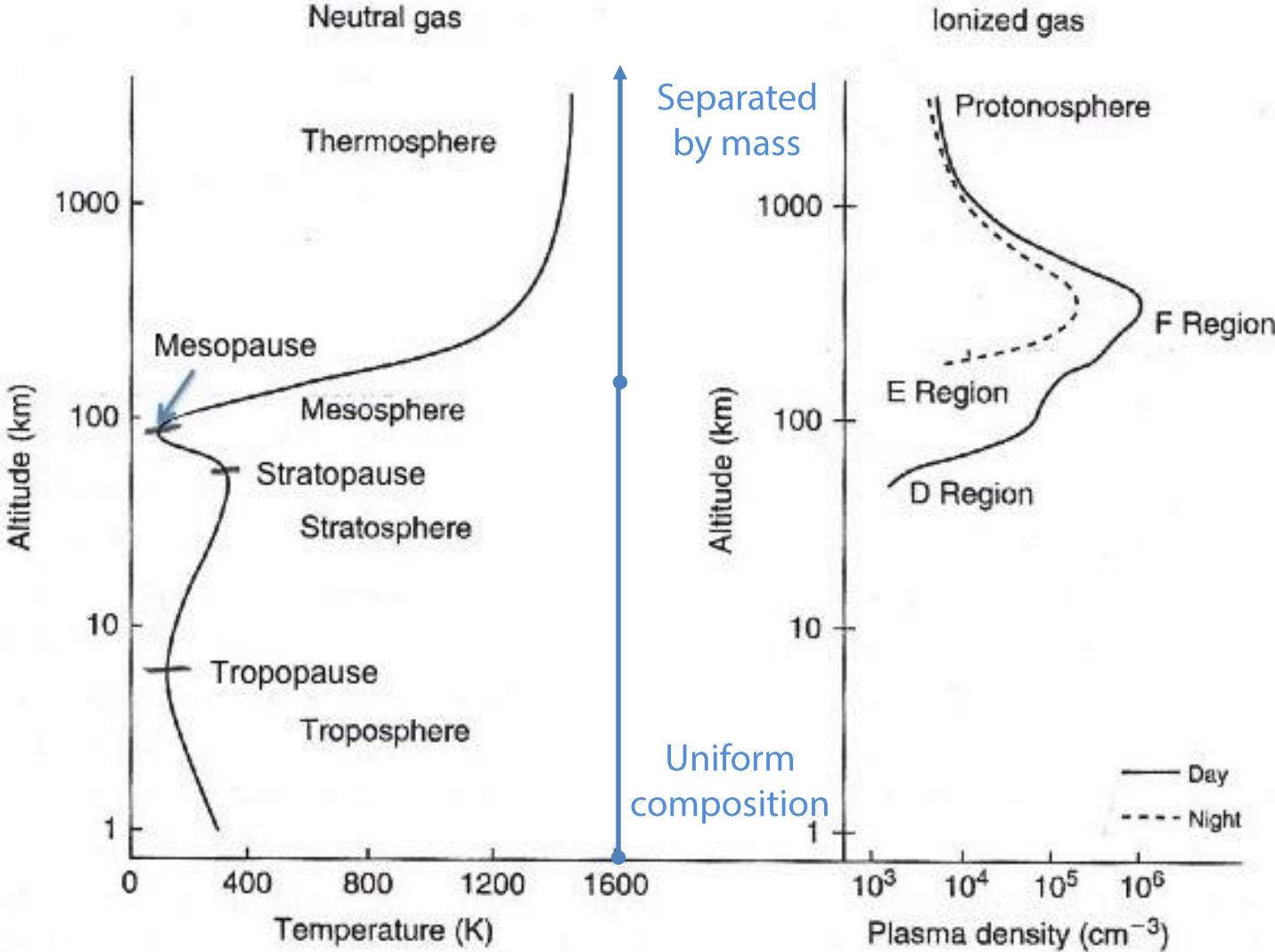


Figure adapted from Kelley [2009]

# Structure of the Ionosphere

- Separated into regions based on ion density
  - “Topside ionosphere” [ $> 500$  km]
  - F region [ $\sim 150$ - $500$  km]
    - density peaks here (“F peak”)
    - often separated into F1 & F2 regions (molecular ions)
  - E region [ $\sim 90$ - $150$  km]
  - D region [ $< 90$  km]
    - disappears at night because solar radiation isn’t present

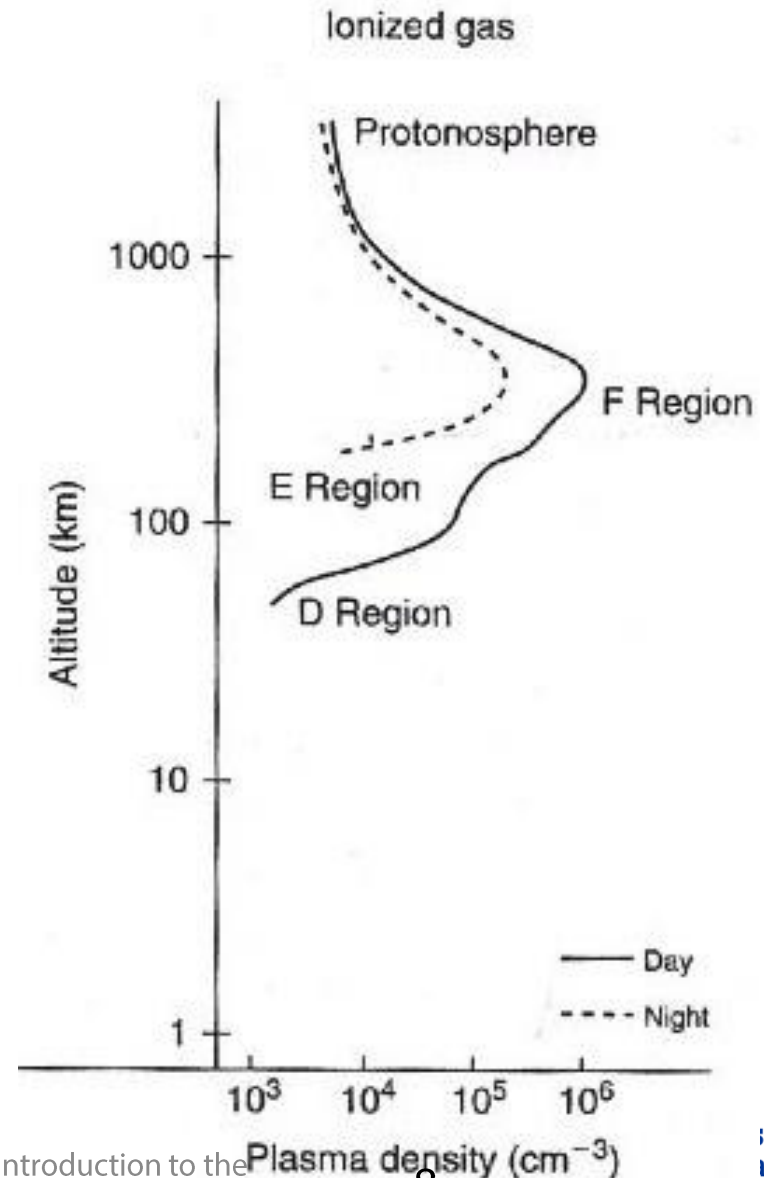


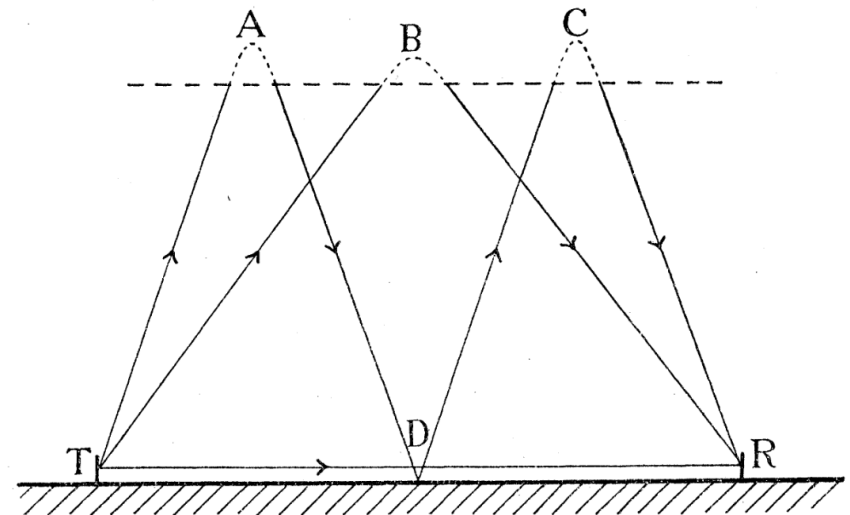
Figure adapted from Kelley [2009]

6/14/2015



# Ionosphere Background

- First wireless trans-Atlantic transmission heard in 1901 by Marconi
- Conducting layer described in 1902 by Kennelly & Heaviside
- Confirmed by Appleton & Barnett in 1924 [1947 Nobel Prize]



# Ionospheric Dynamics

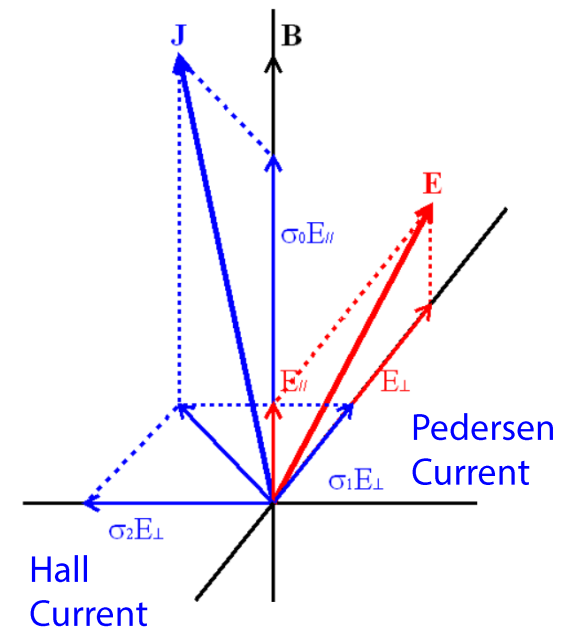
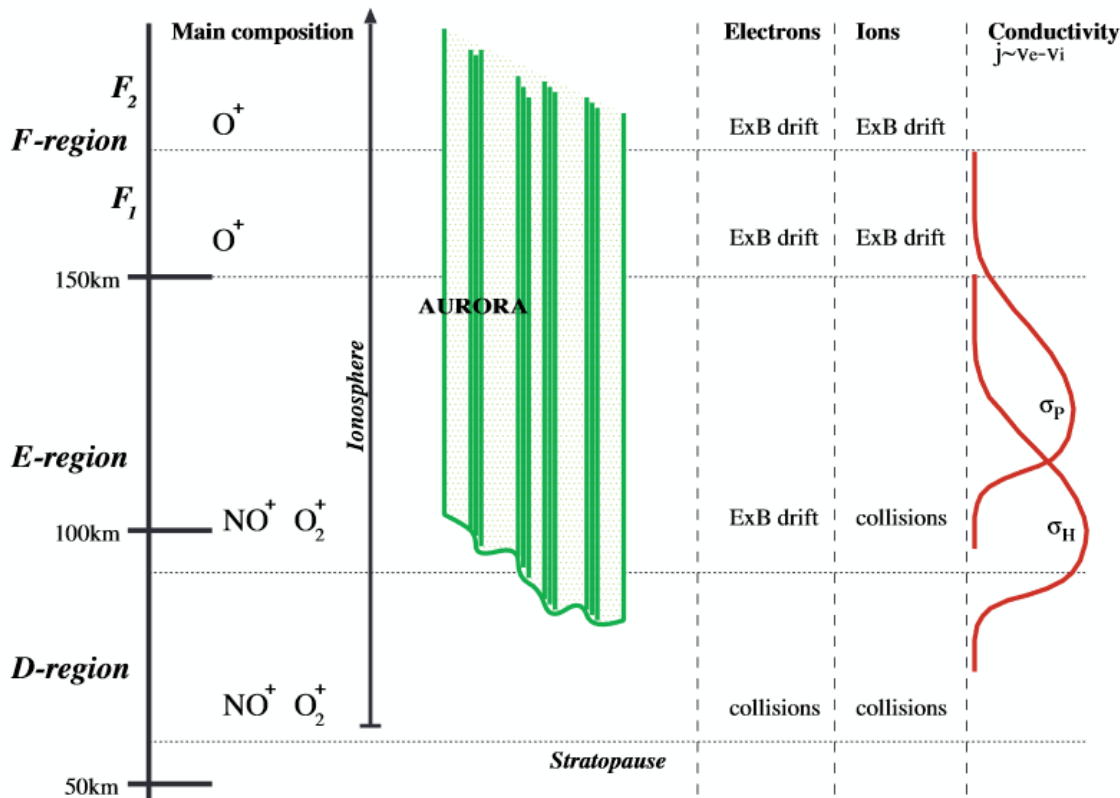
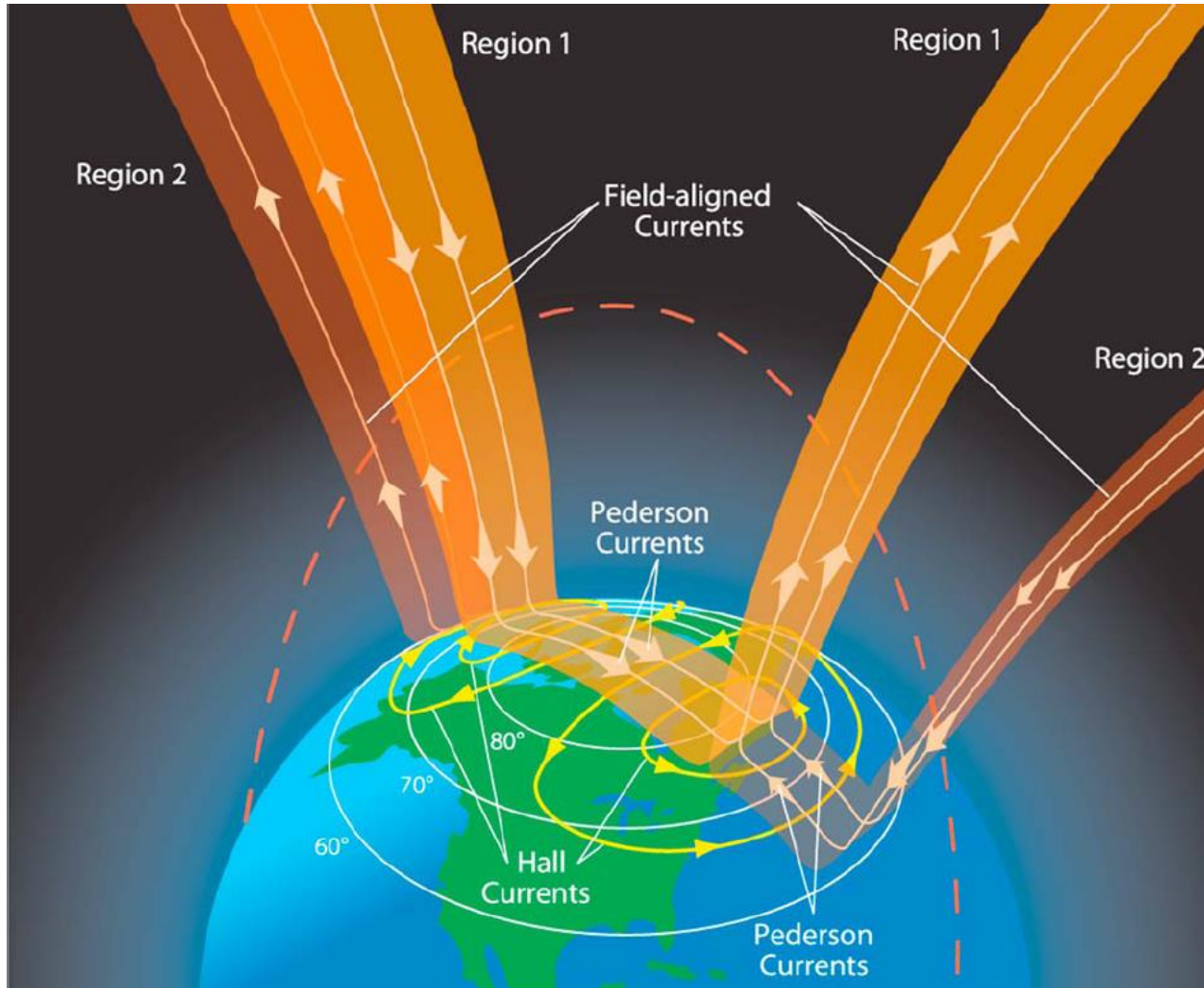


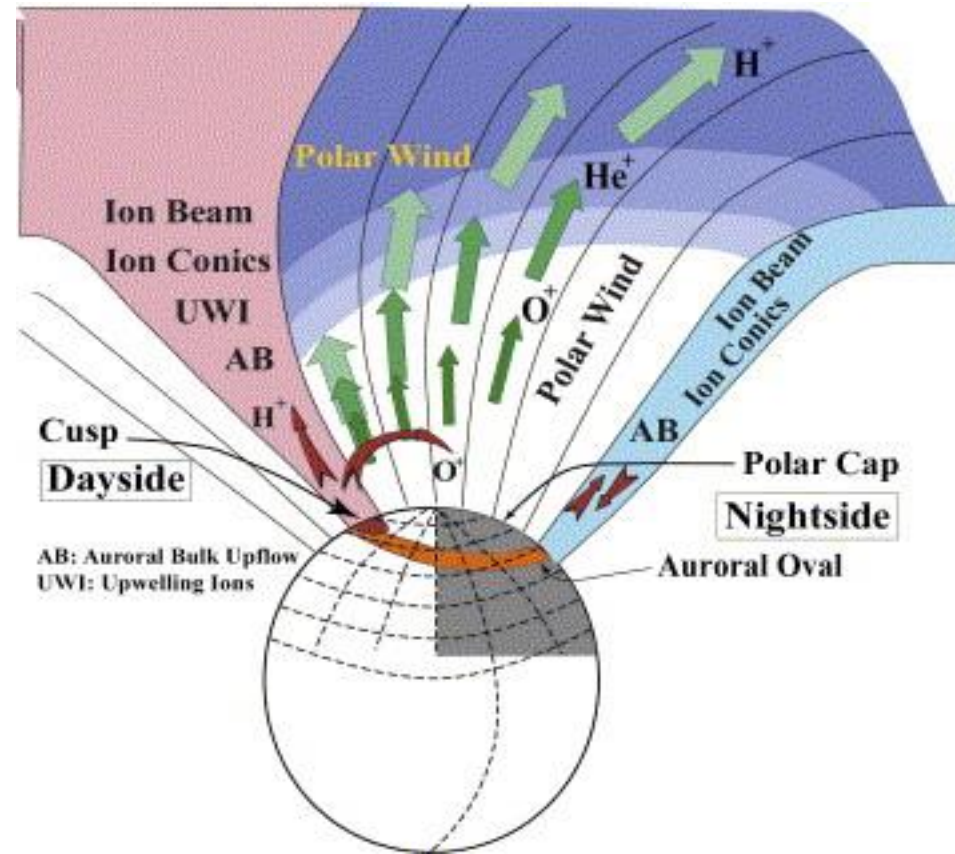
Figure from Noora Partamies  
6/14/2015

# Ionospheric Dynamics



# Ion Outflow

- Loss of ionospheric ions to magnetosphere
- Two stage process required for ions to reach escape velocity
  - Type 1 outflow related to Joule heating
  - Type 2 outflow results from soft electron precipitation
- Significant source of ions in plasma sheet



from *Yau et al.* [2006]

# Significance of Thermosphere/Ionosphere to GEM

## Overlap region between GEM and CEDAR communities

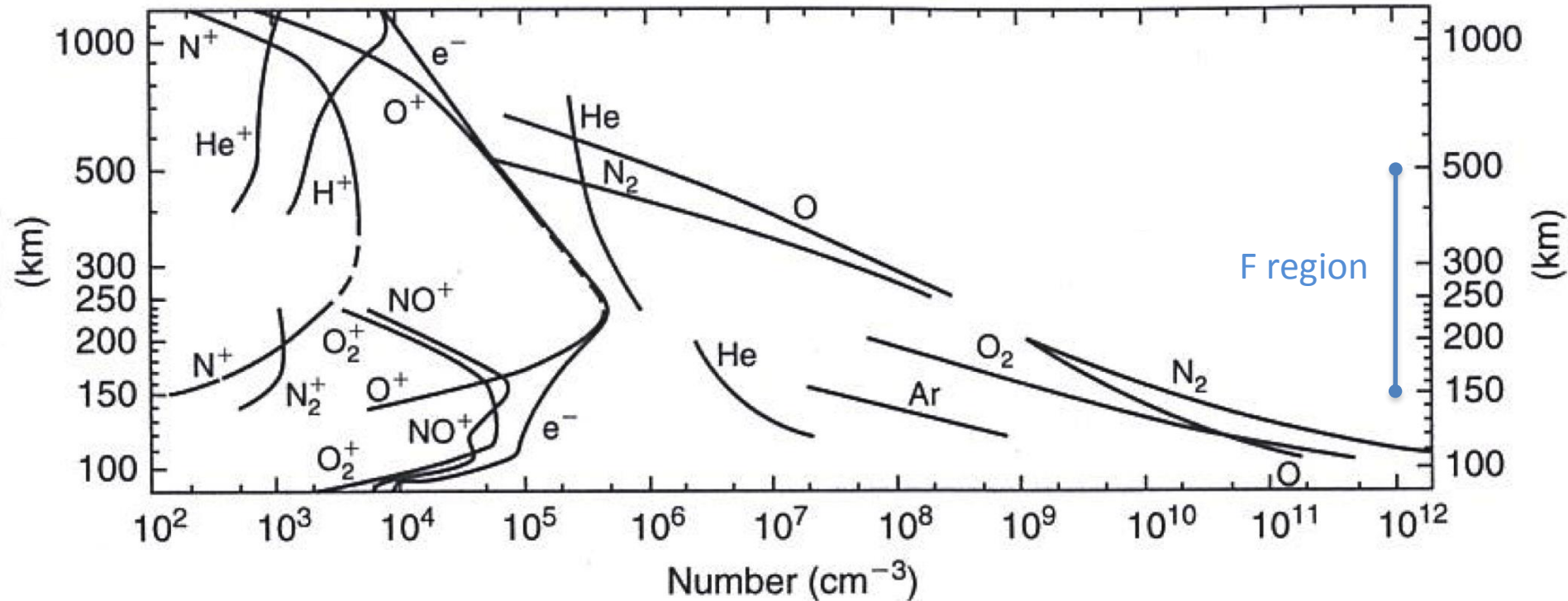
1. Magnetosphere-Ionosphere (MI) coupling is integral to magnetospheric models
2. Plays important role in current closure with magneto-tail
3. Ion outflow (from ionosphere) provides mass-loading in magnetosphere
4. Neutral upwelling has an important effect on dynamics in the thermosphere/ionosphere

More than just a boundary layer!

# Thank you



# Atmospheric Composition



From Kelley [2009]

NOTE:  $\sim 10^8$  fewer ions than neutrals