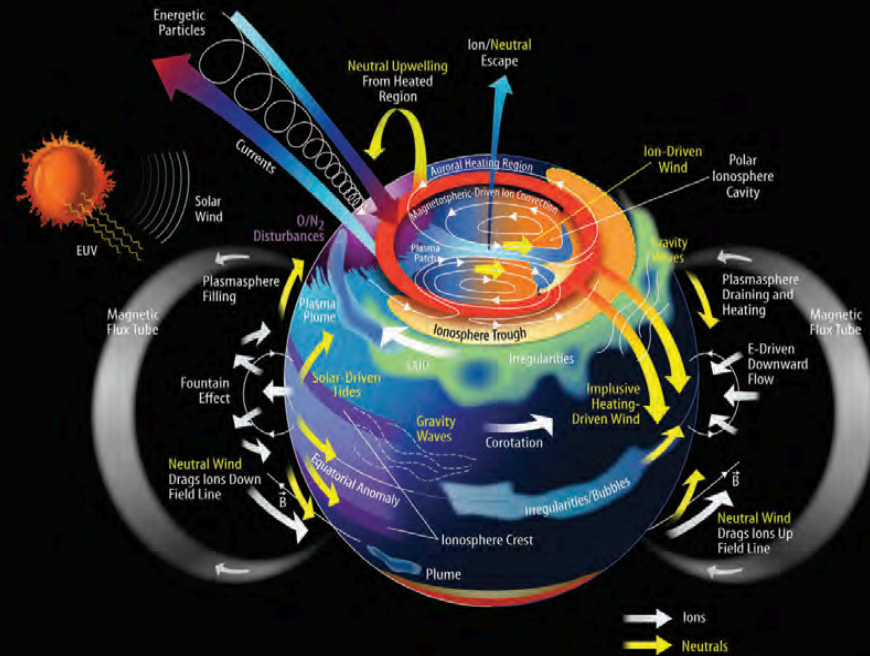




# Introduction to the neutral atmosphere

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J. Grebowsky / NASA GSFC

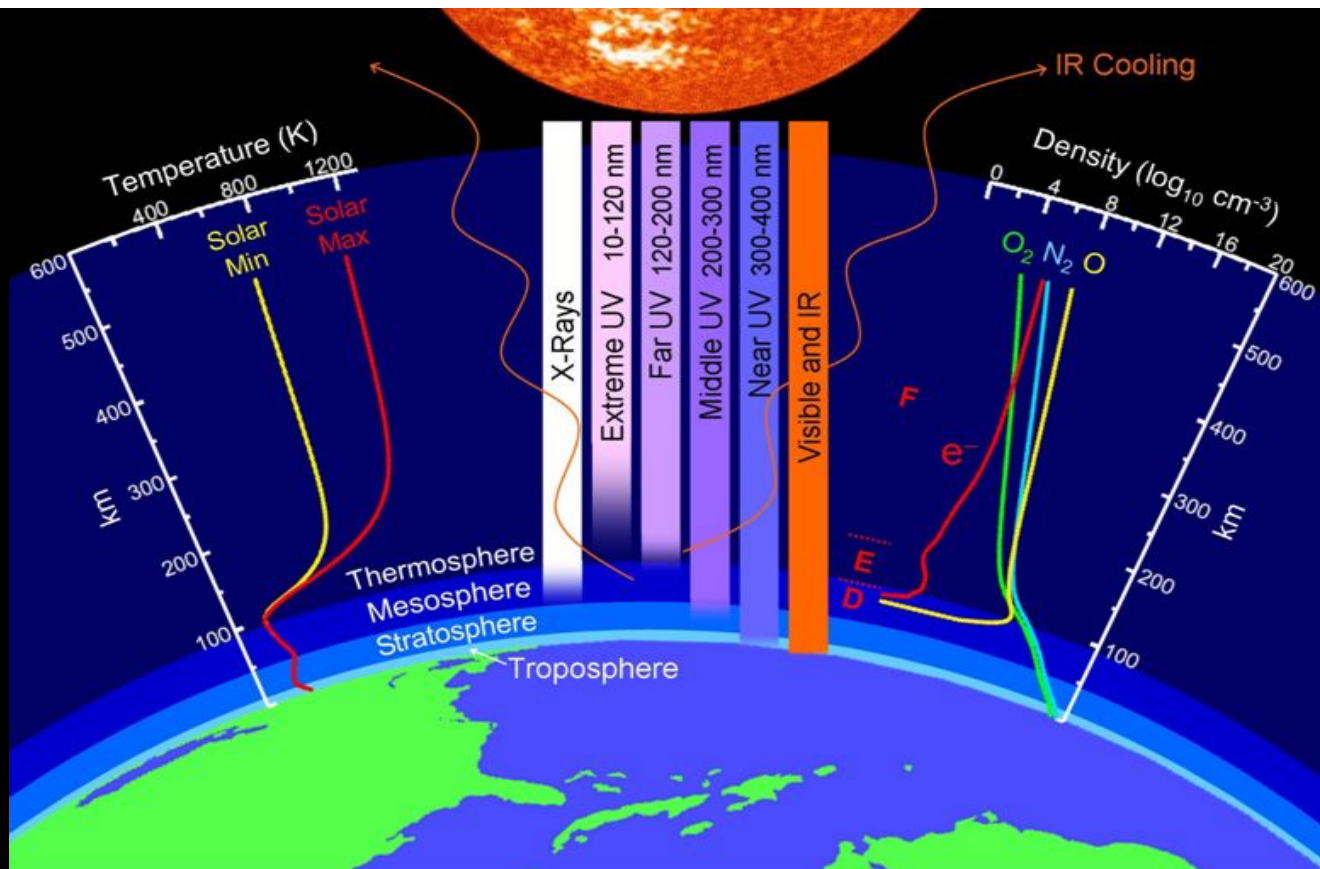


Image credit: John Emmert/NRL

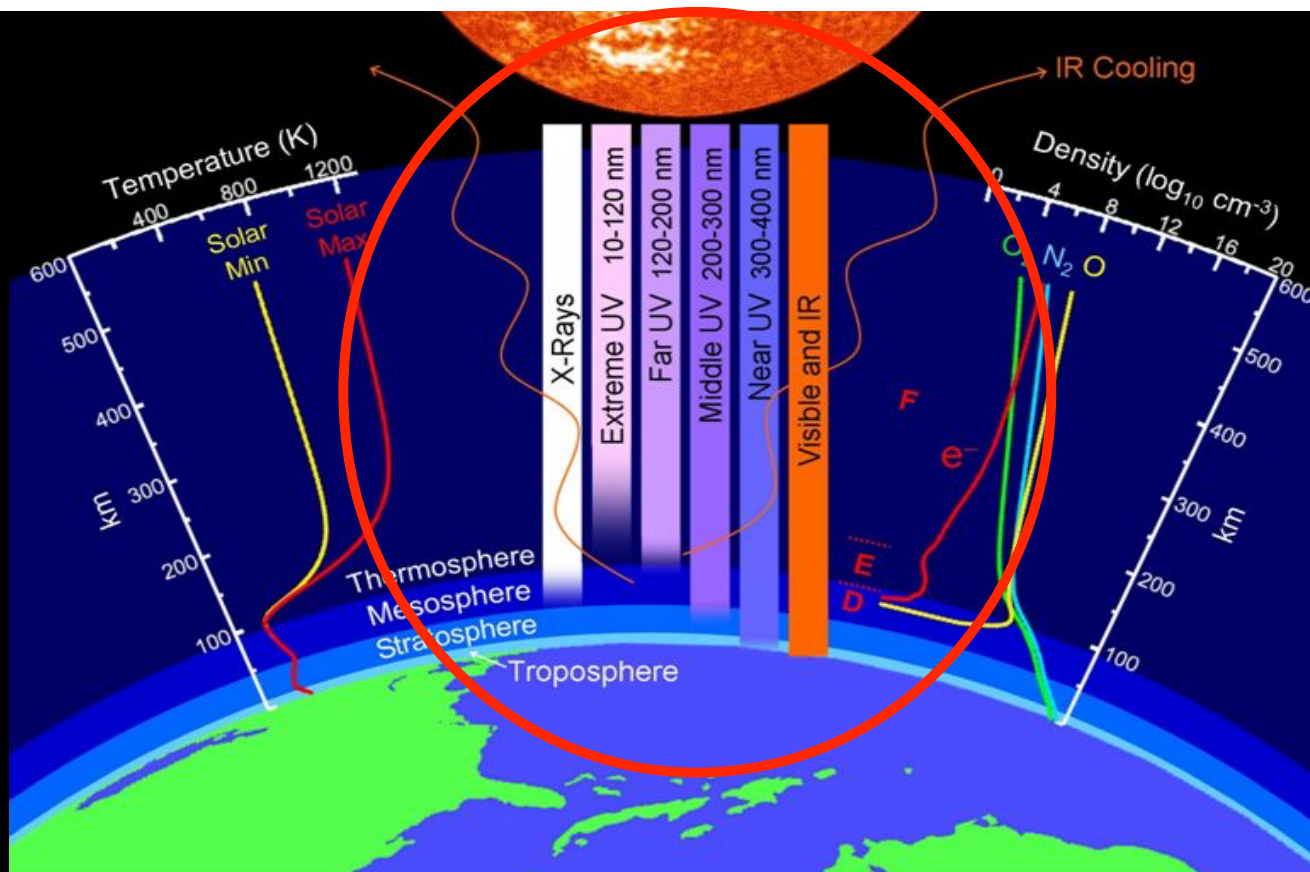
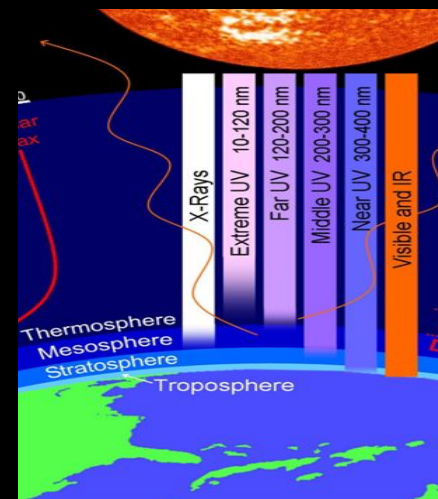
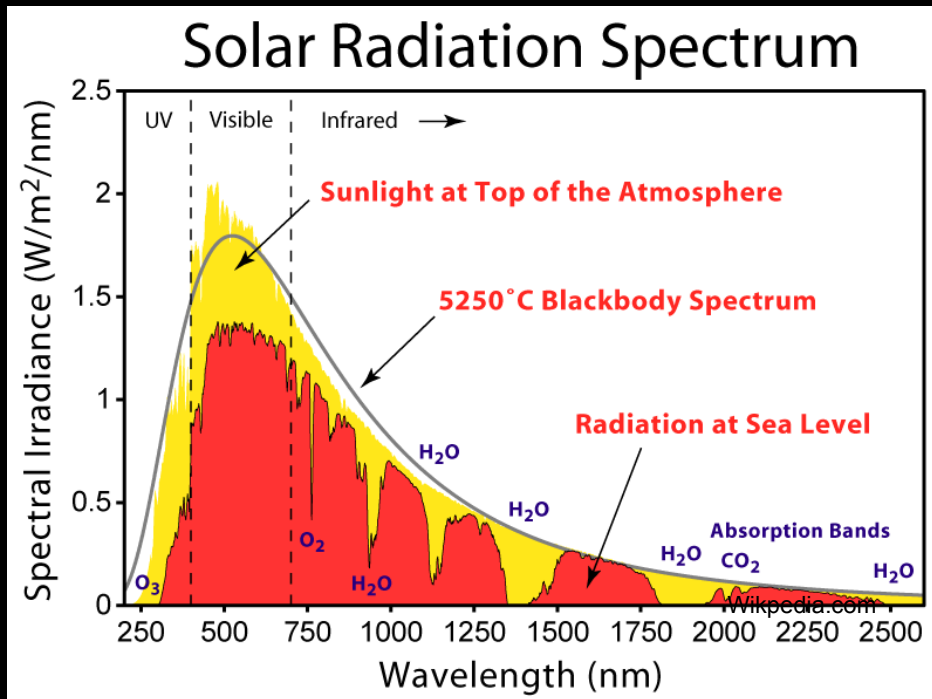
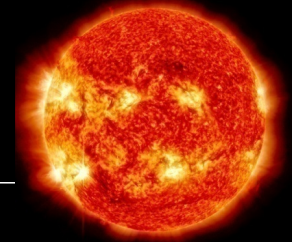


Image credit: John Emmert/NRL

# Absorption of solar radiation





# Greenhouse effect

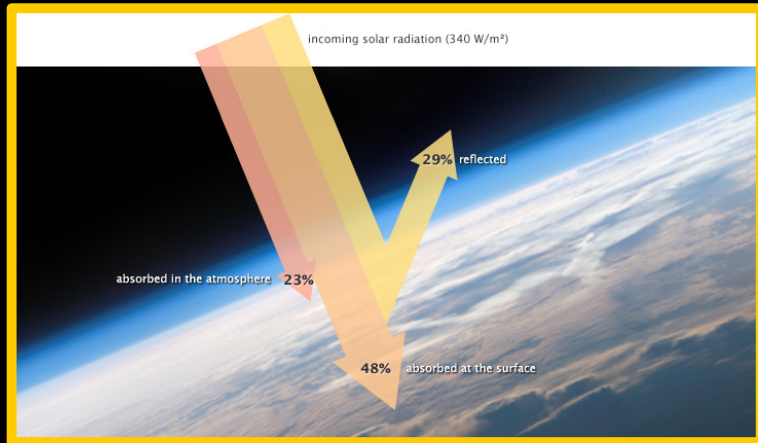


Image: [www.earthobservatory.nasa.gov](http://www.earthobservatory.nasa.gov)

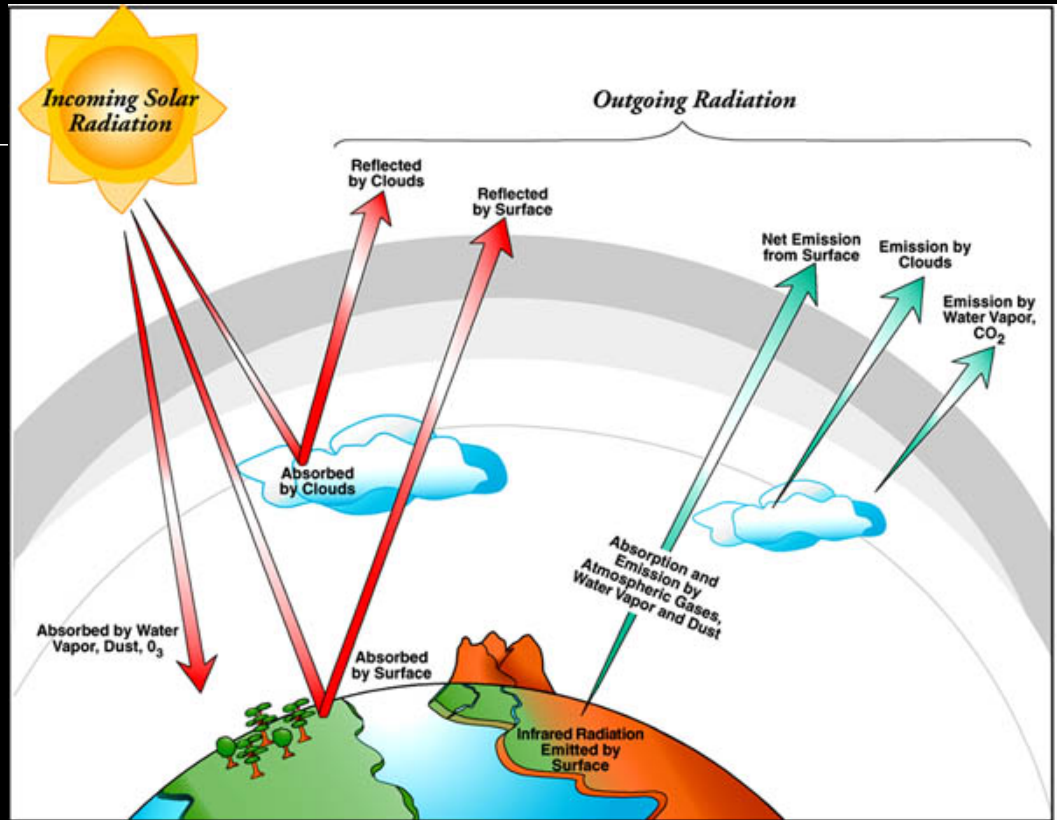


Image: [www.ux1.eiu.edu](http://www.ux1.eiu.edu)

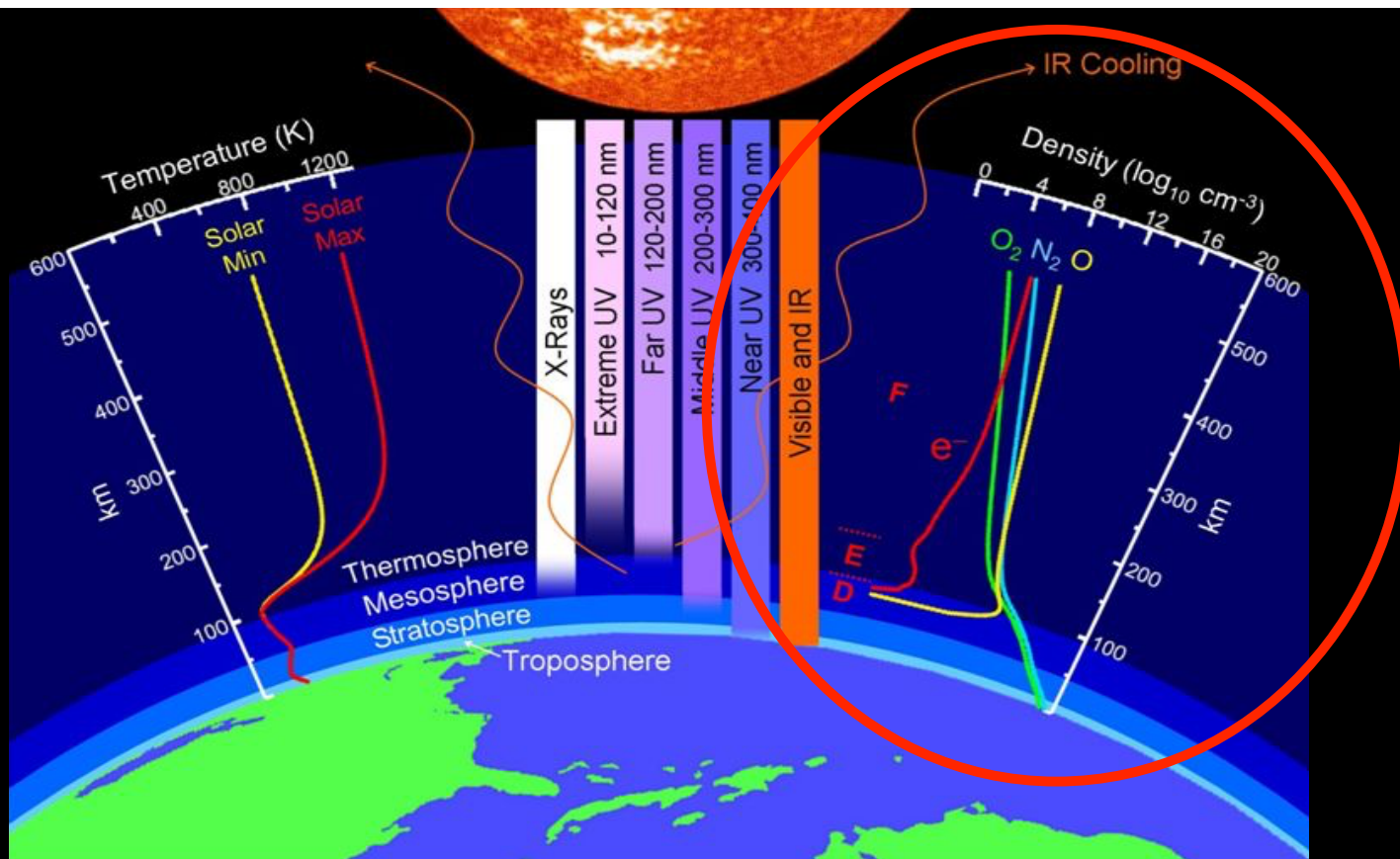
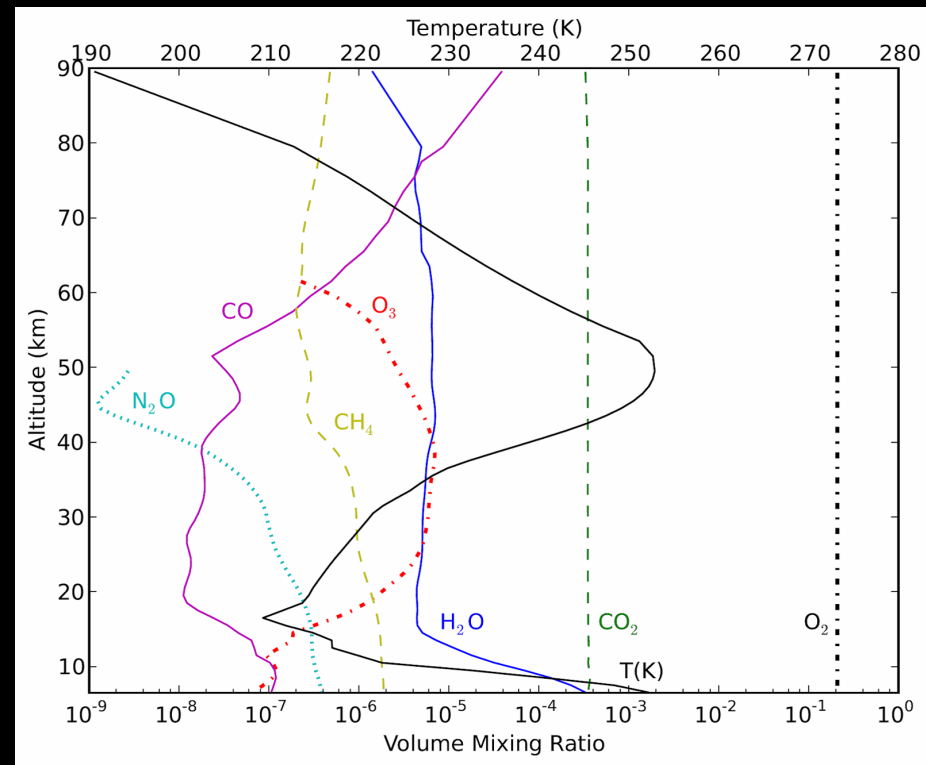


Image credit: John Emmert/NRL

# Air composition

Gas name	Chemical formula	Percent volume (%)
Nitrogen	N <sub>2</sub>	78.08
Oxygen	O <sub>2</sub>	20.95
Water	H <sub>2</sub> O	0-4
Argon	Ar	0.93
Carbon dioxide	CO <sub>2</sub>	0.04
Neon	Ne	<0.01
Helium	He	<0.001
Methane	CH <sub>4</sub>	<0.001
Hydrogen	H <sub>2</sub>	<0.001
Nitrous Oxide	N <sub>2</sub> O	<0.001
Ozone	O <sub>3</sub>	<0.001

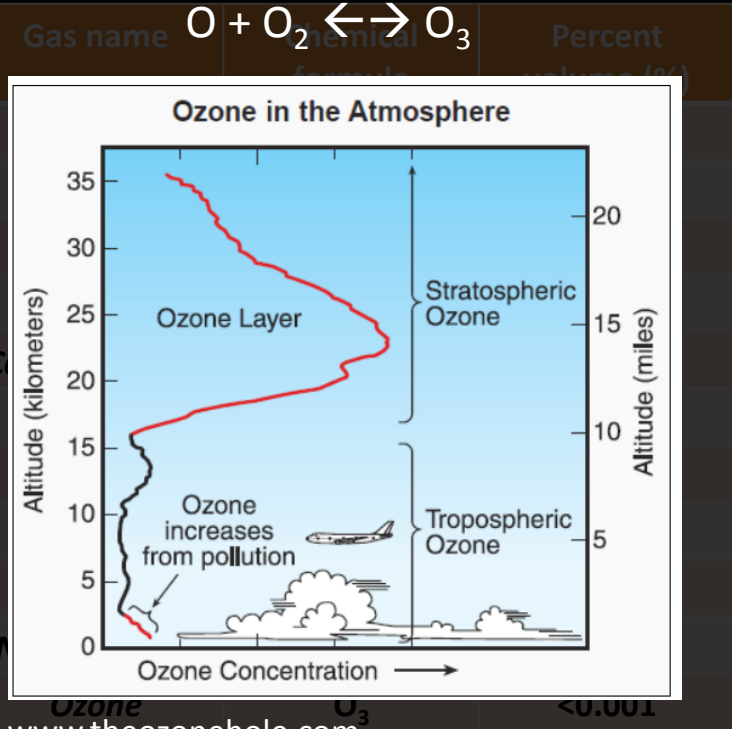


Misra et al. (2014)

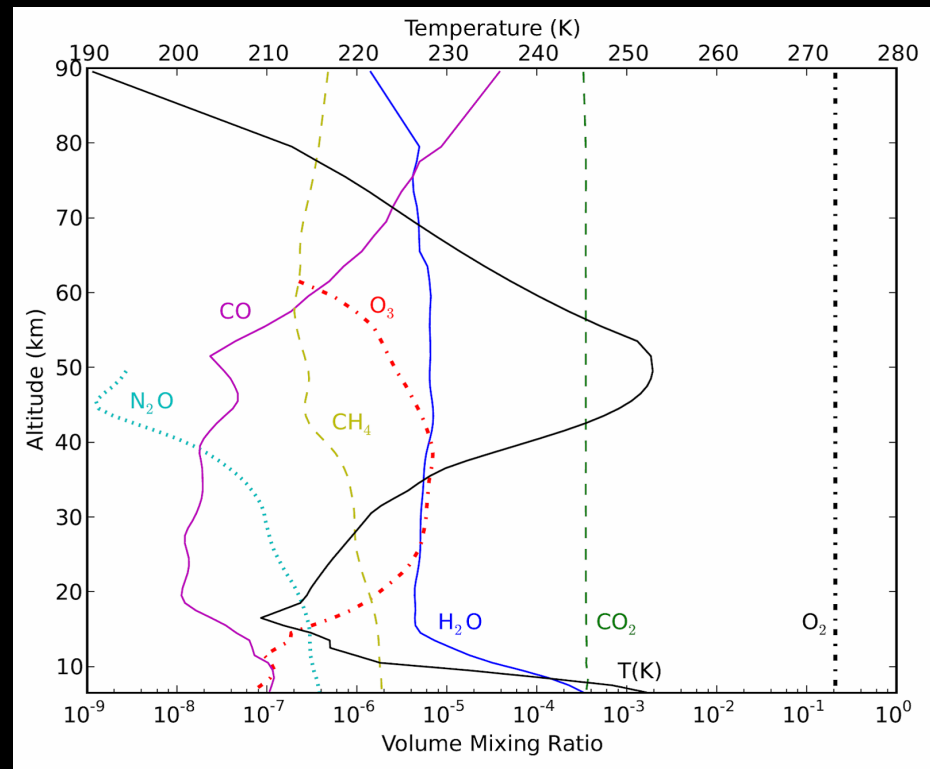
mesosphere  
stratosphere  
troposphere

# Air

## composition



[www.theozonehole.com](http://www.theozonehole.com)



Misra et al. (2014)

mesosphere  
stratosphere  
troposphere

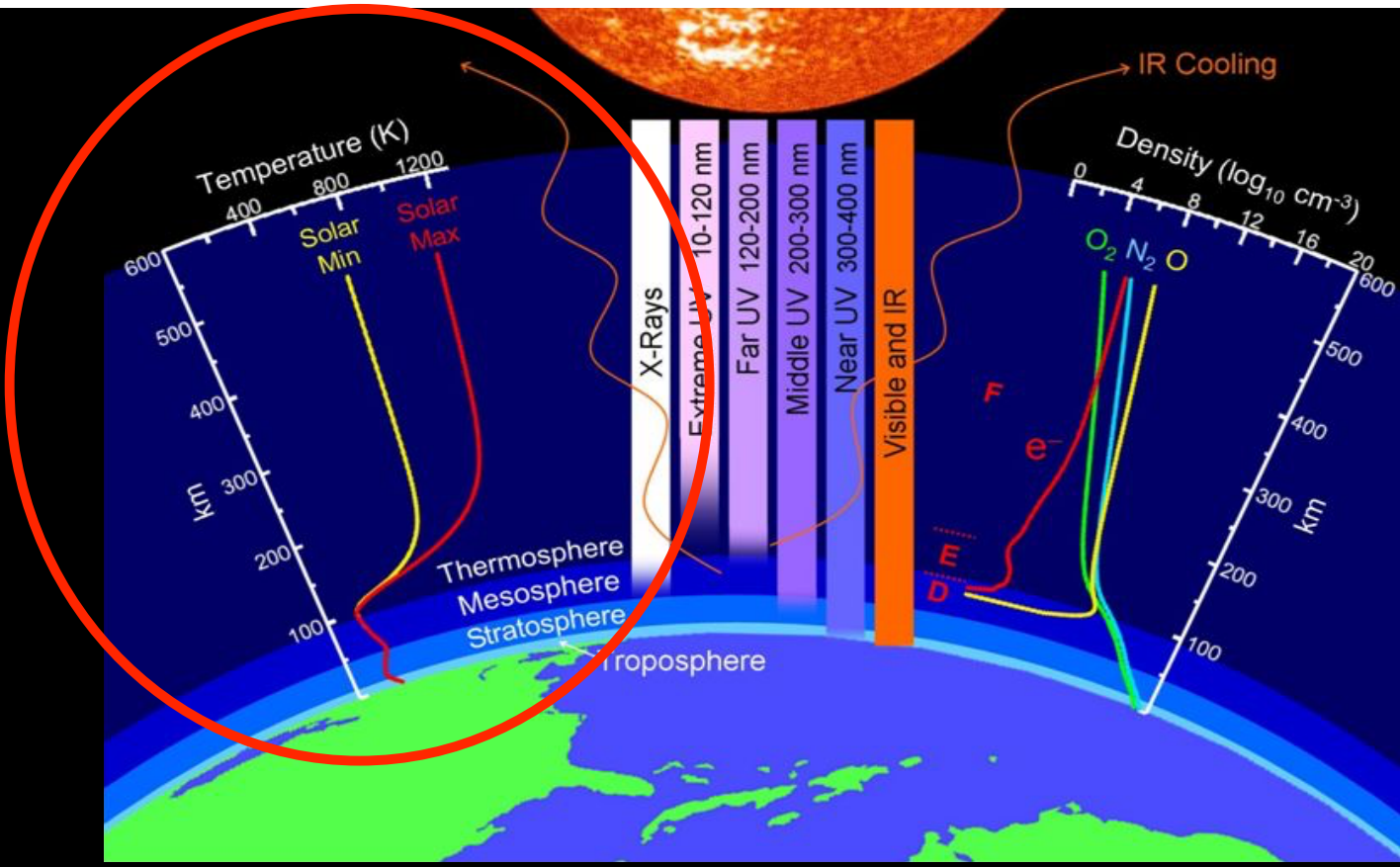
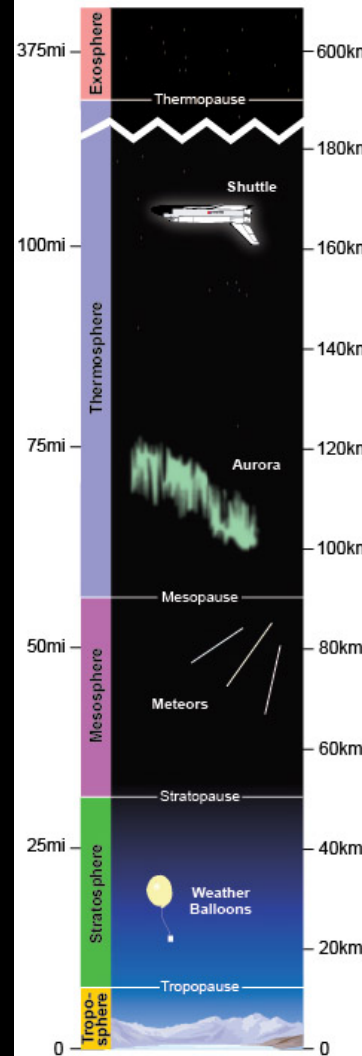
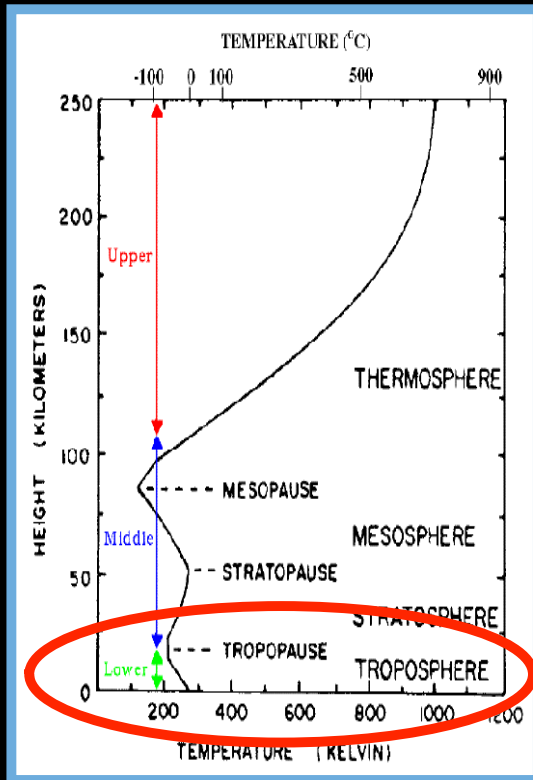


Image credit: John Emmert/NRL



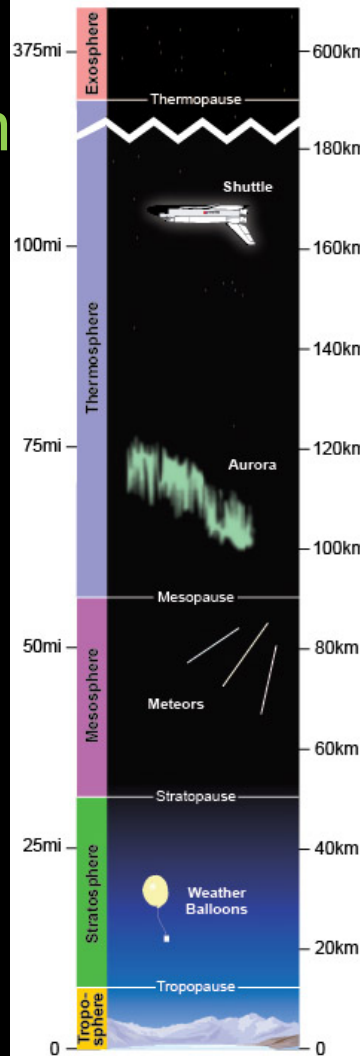
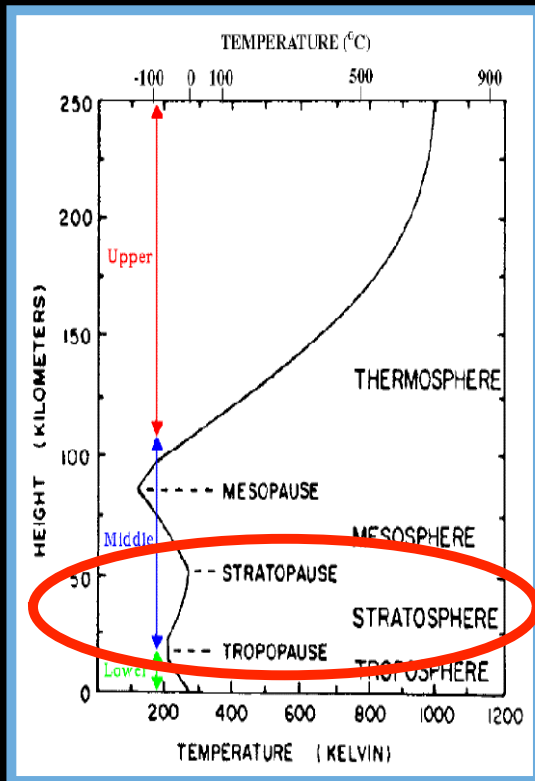
# Troposphere (0-15 km)



- 'Tropo-' ~ turbulent
- ~80% of atmospheric mass.
- Most of our weather occurs within this region.
- Well-mixed.

] troposphere

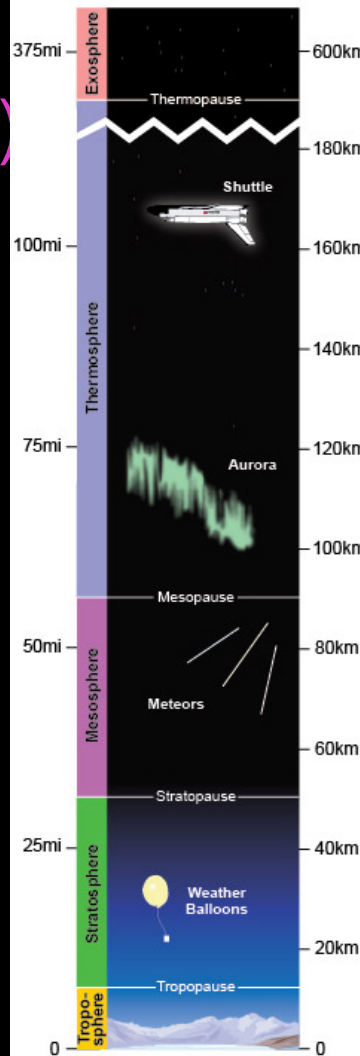
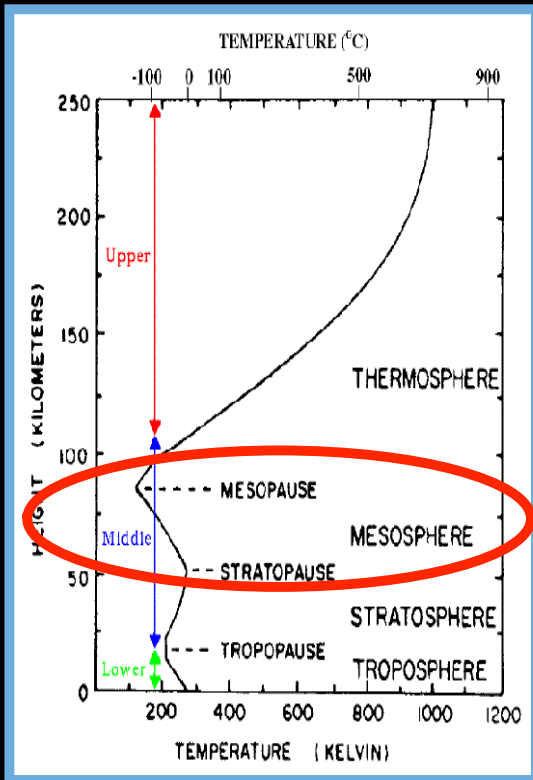
# Stratosphere (15-50 km)



- 'Strato' ~ stable/stratified
- Temperature increases with altitude.
- Ozone layer peak at ~20-30 km, protecting Earth from harmful UV radiation.
- ~19.9% of atmospheric mass

stratosphere

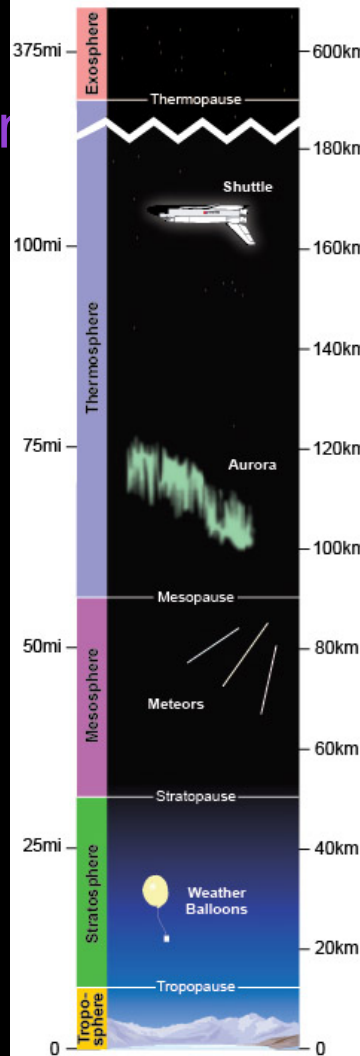
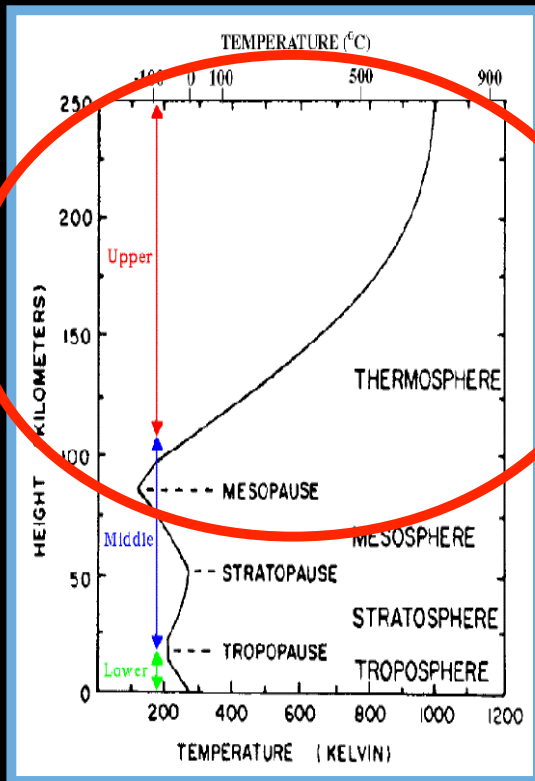
# Mesosphere (50-90 km)



- 'Meso' ~ middle
- Temperature decreases with altitude → limited local heating
- Mesopause is the coldest part of the Earth's atmosphere, with mean T of ~130 K/-143°C/-225°F!
- Noctilucent clouds.
- Meteoroids burn up here.

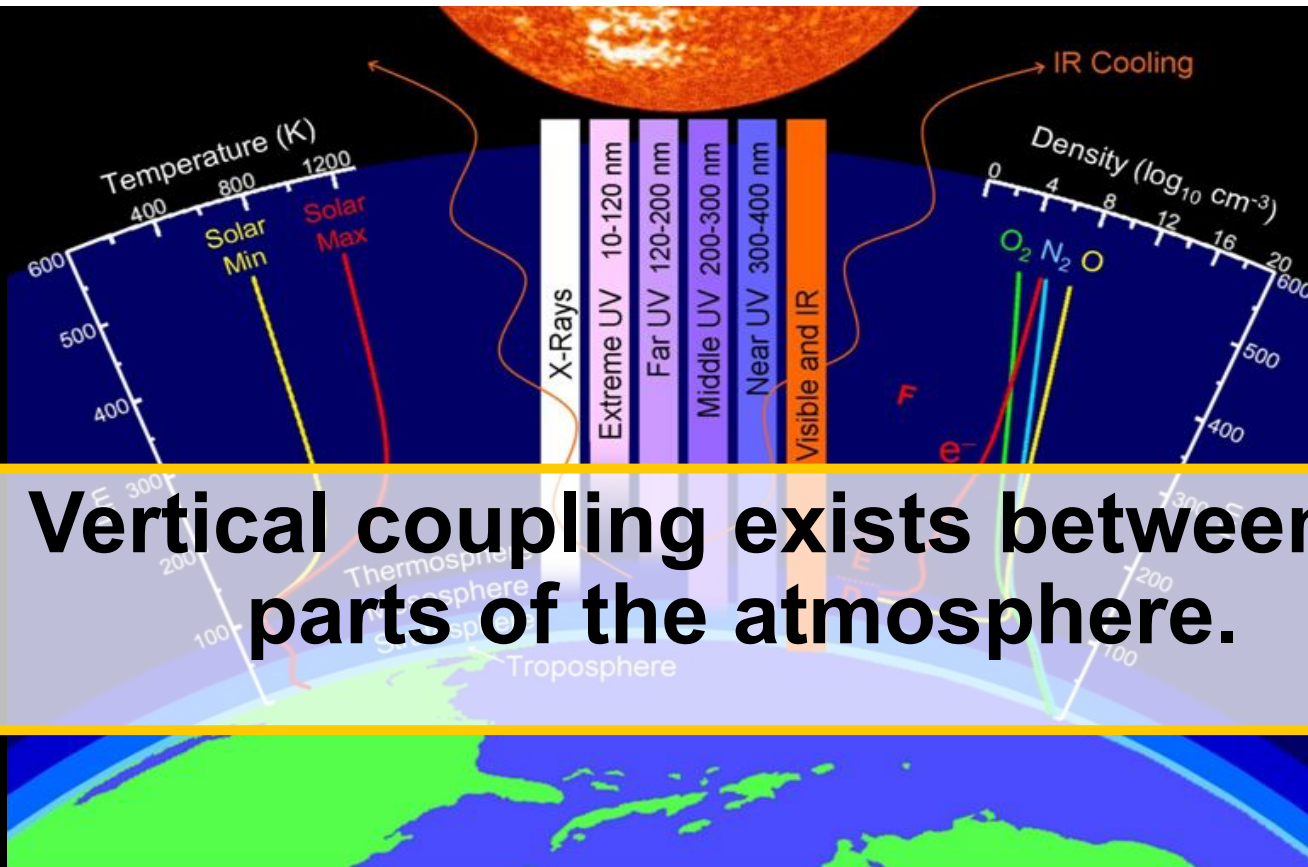
mesosphere

# Thermosphere (90-500+ km)



## thermosphere

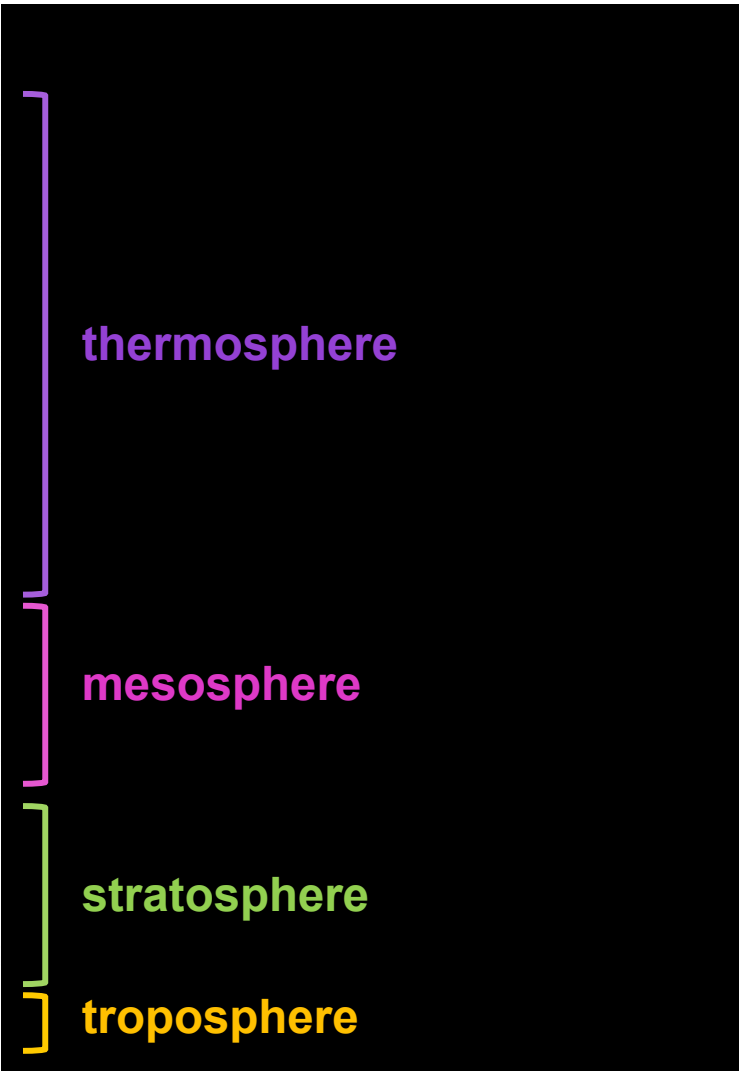
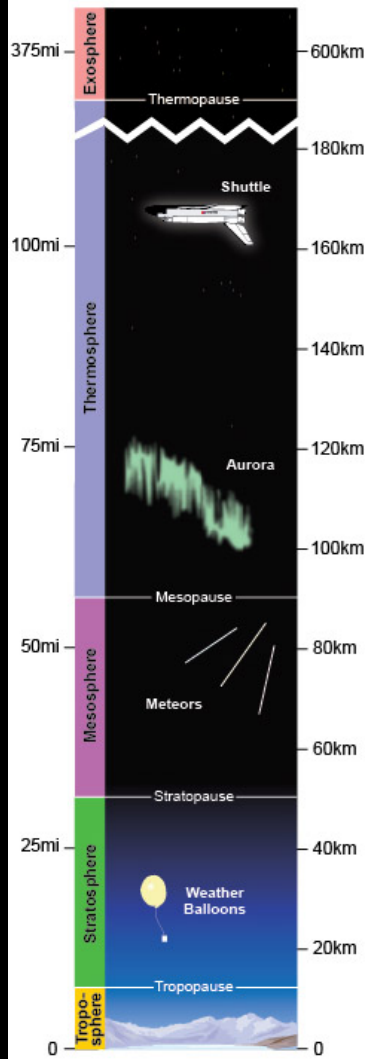
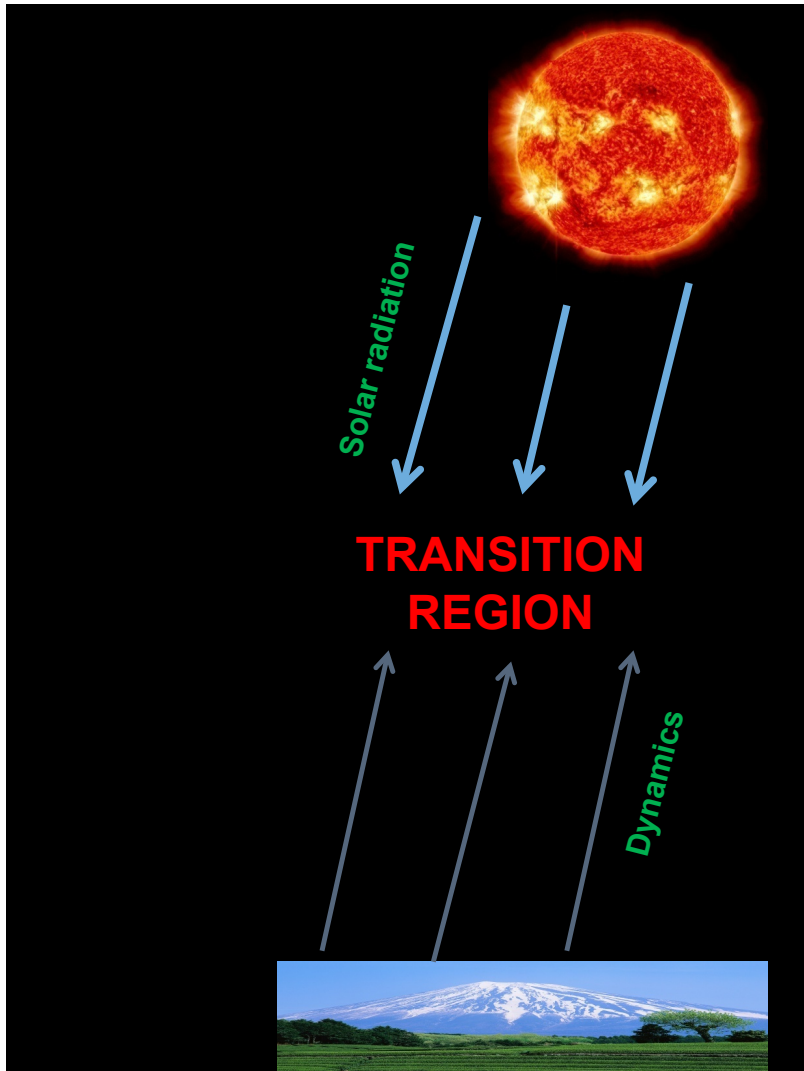
- 'thermo-' ~ heat
- Temperature increases with altitude.
- High T generated from absorption of intense solar radiation by predominantly, O<sub>2</sub> molecules.
- Very low pressure, low density of molecules.
- Gravitational settling of species by mass. Not well-mixed.

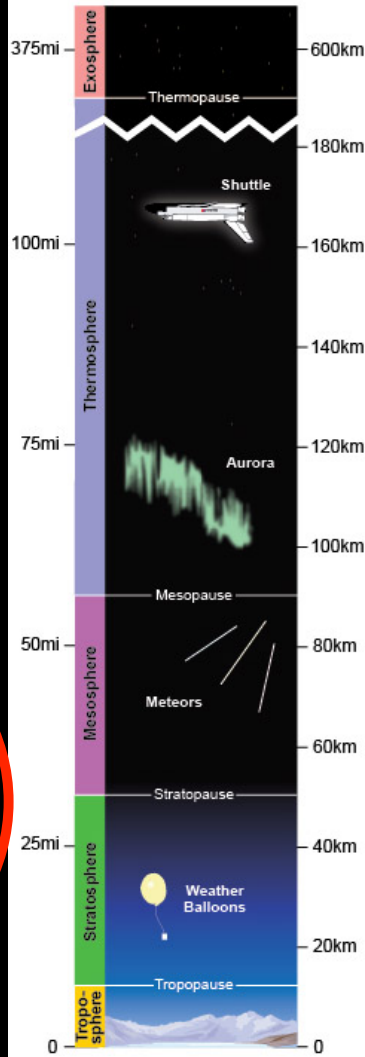
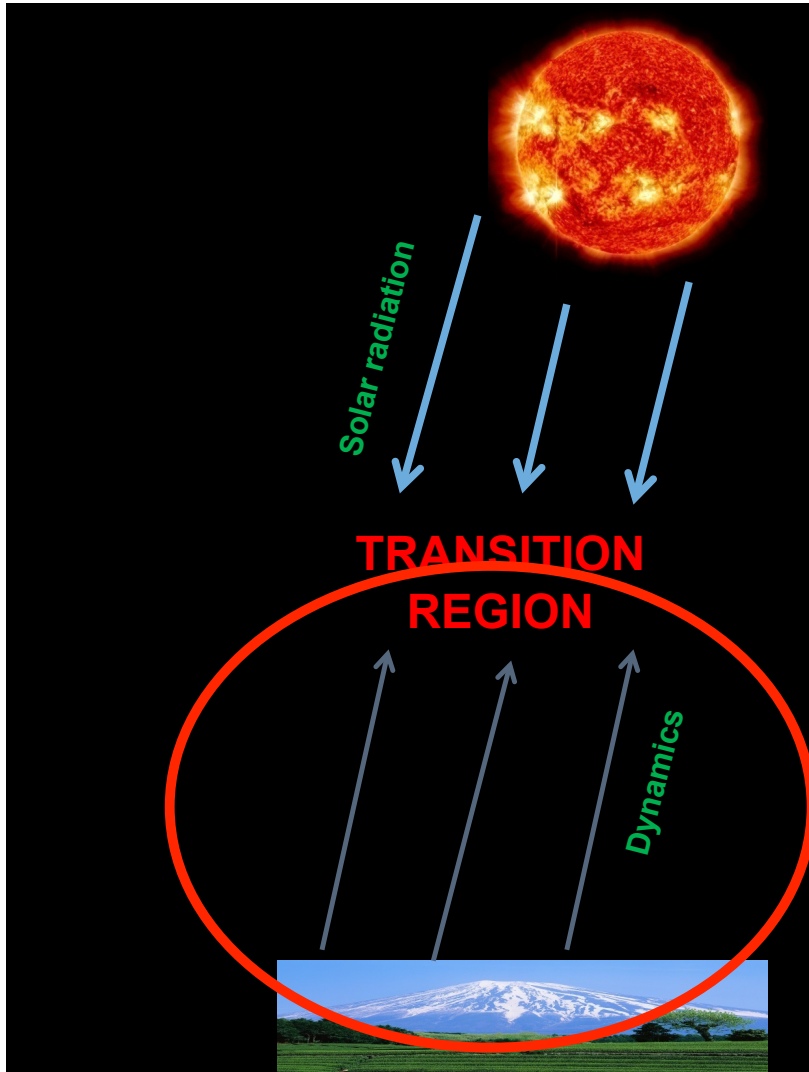


**Vertical coupling exists between all parts of the atmosphere.**

Image credit: John Emmert/NRL







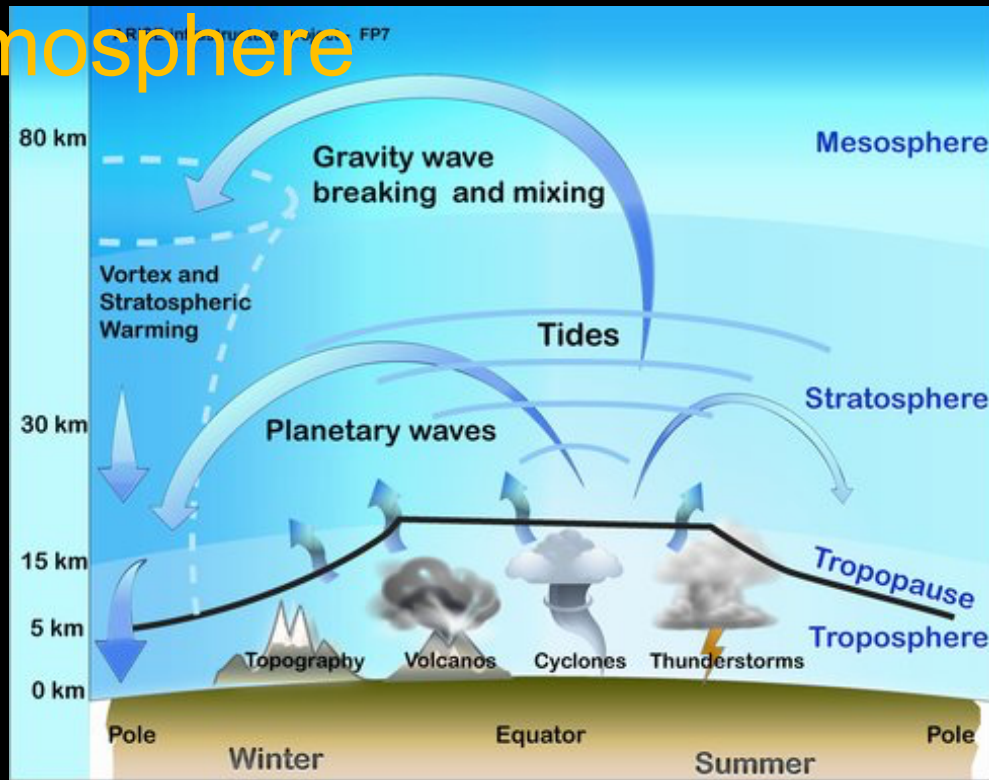
thermosphere

mesosphere

stratosphere

troposphere

# Coupling between the lower and upper atmosphere

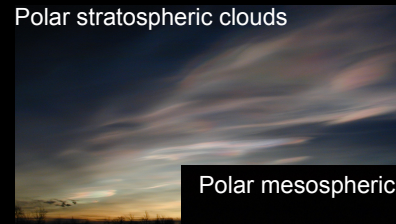


arise-project.eu



Polar stratospheric clouds

NASA/MODIS imagery



Sources:  
nasa.gov

Polar mesospheric clouds (aka noctilucent clouds)

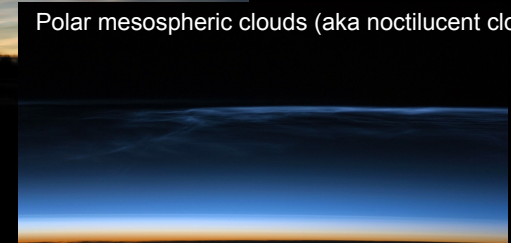
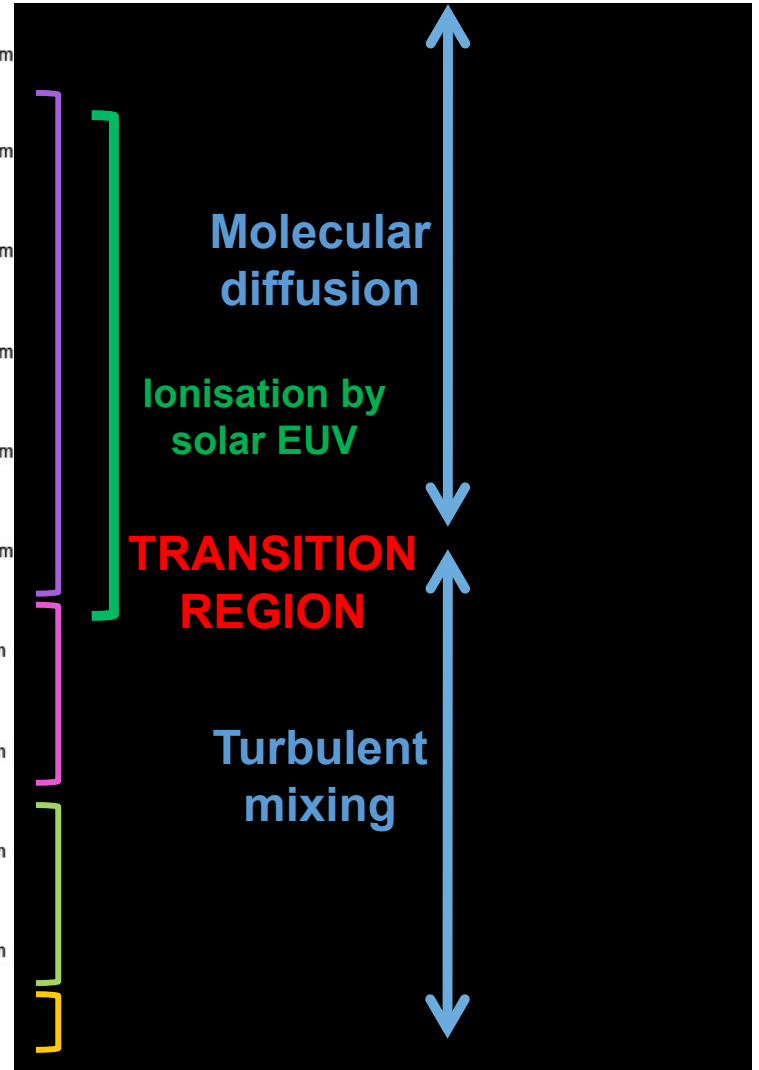
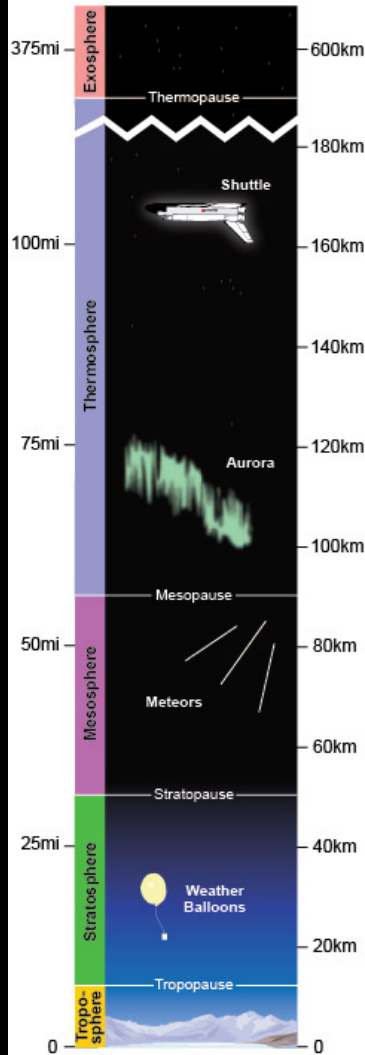
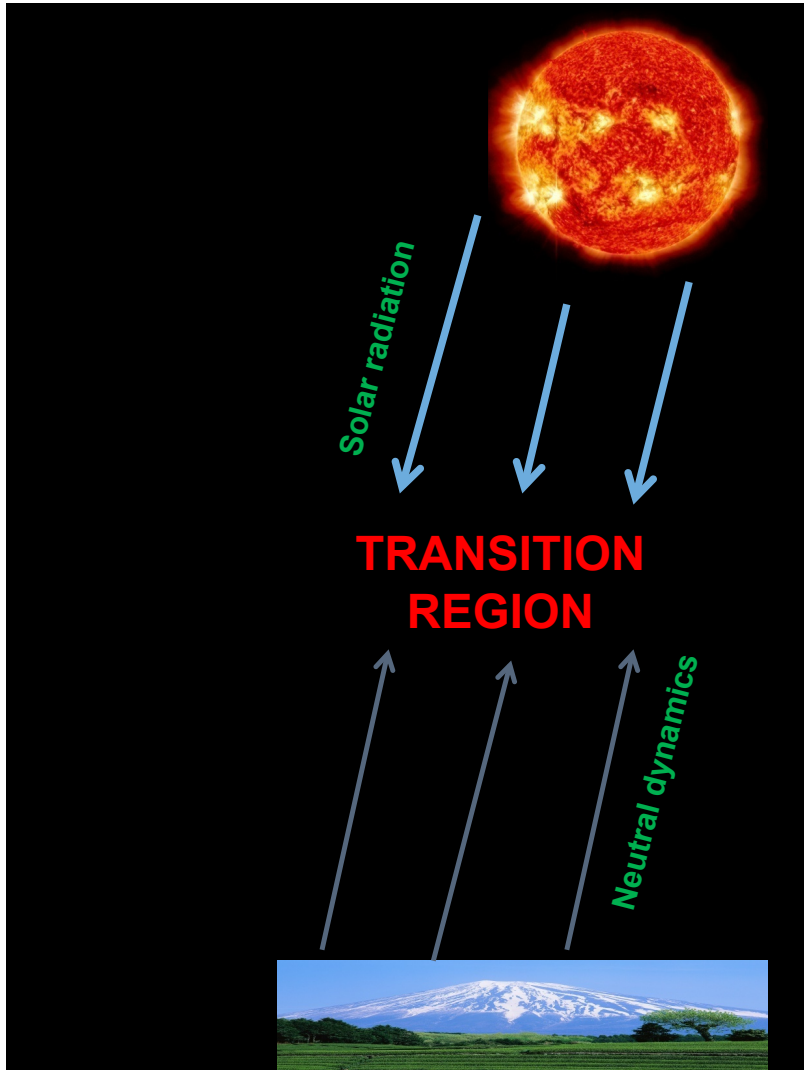


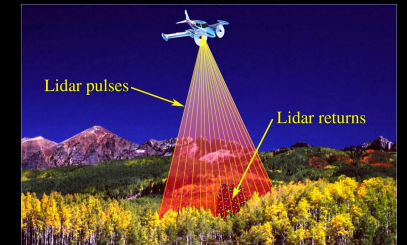
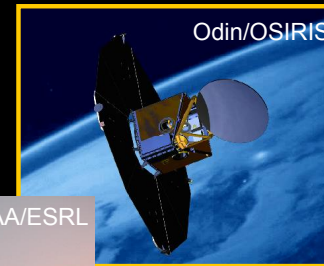
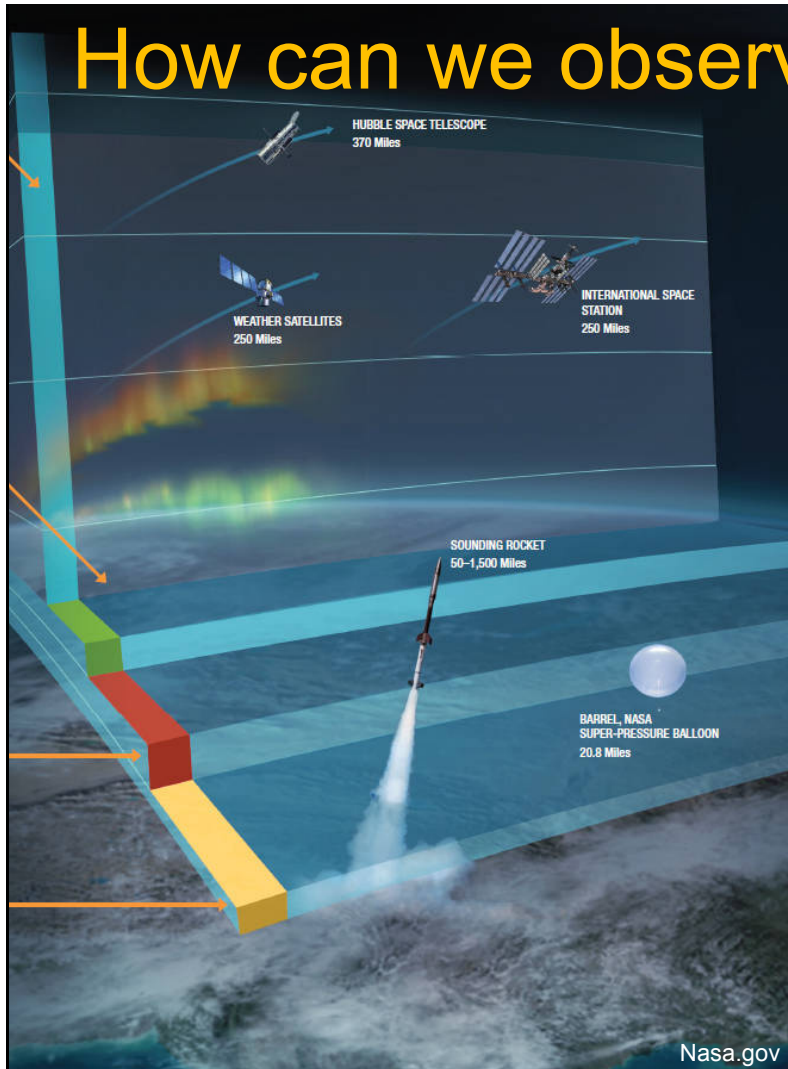
FIGURE 8.5 Schematic of the intertwined pathways that link space weather variability to atmospheric coupling. SOURCE: Courtesy of Cora E. Randall, University of Colorado, Boulder; Janet U. Kozyra, University of Michigan, Ann Arbor; and Scott M. Bailey, Virginia Institute of Technology.



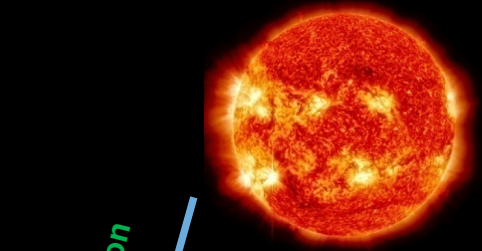


# How can we observe the neutral atmosphere?

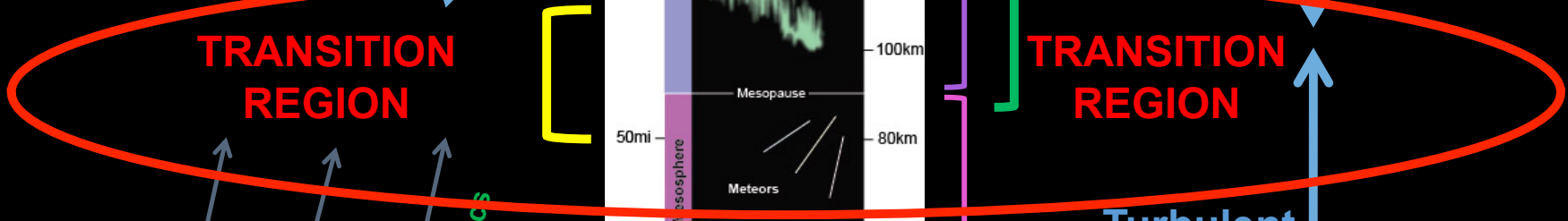
- *In situ* observations
- Remote sensing





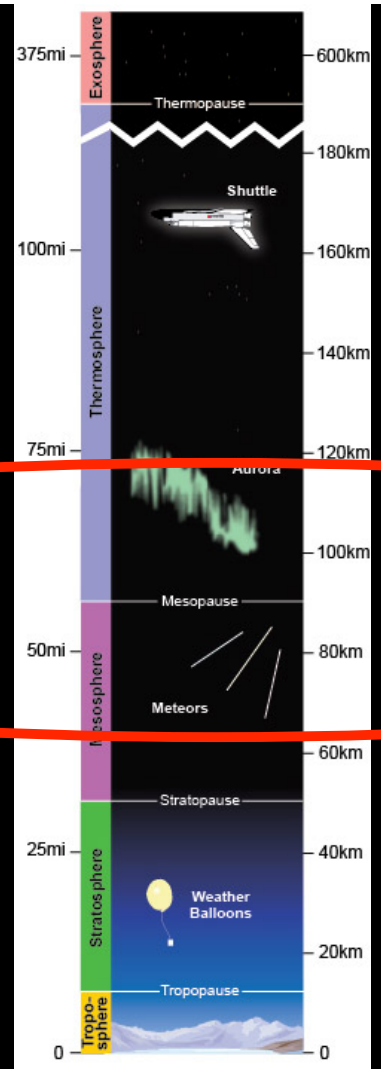


Relatively poorly understood part of the atmosphere



TRANSITION REGION

Dynamics



TRANSITION REGION

Molecular diffusion

Ionisation by solar EUV

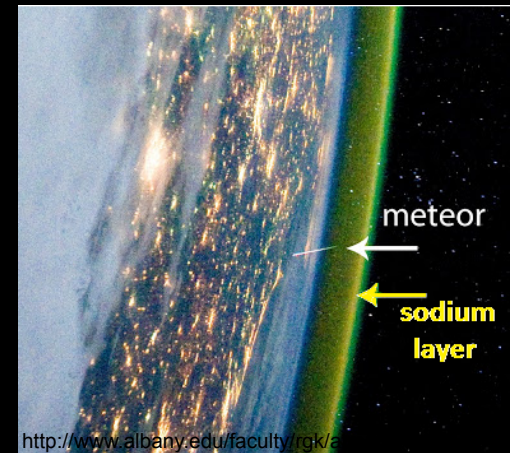
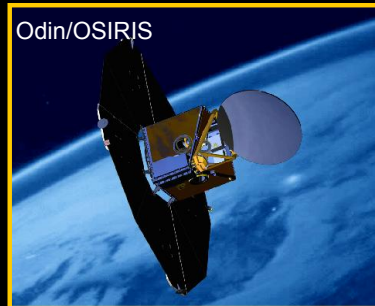
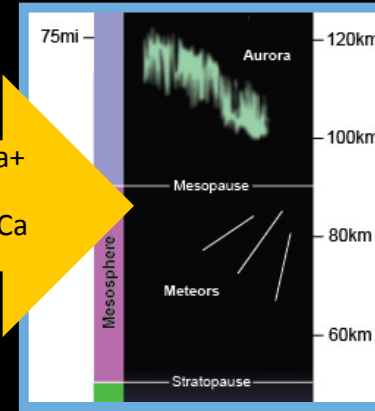
Turbulent mixing



# Observing the MLT

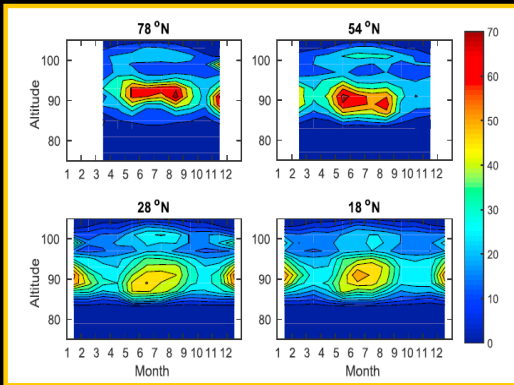
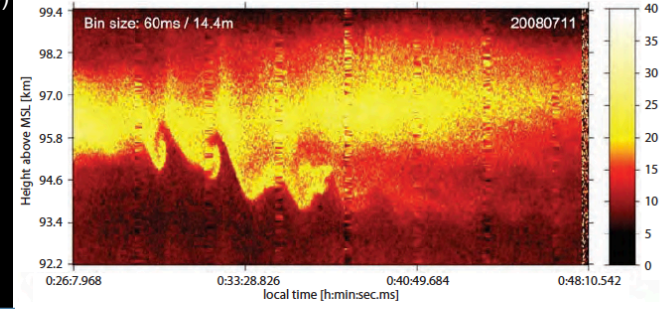


Mg+ Fe Na+ Fe+ Na Fe+ Ca+ Na+  
Fe Mg Na K Na K+ Fe Ca  
Na Na Na Fe Ca Mg Fe Ca

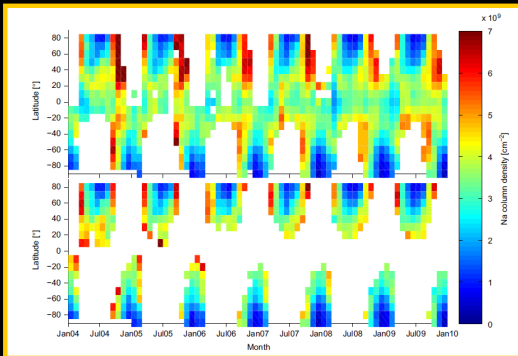


# Observing the MLT: meteoroids and metals.

Pfrommer et al. (2009)

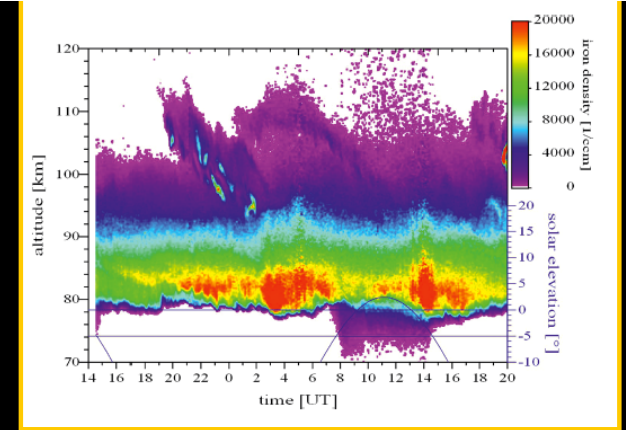


Dawkins et al. (2015)



Hedin and Gumbel (2011)

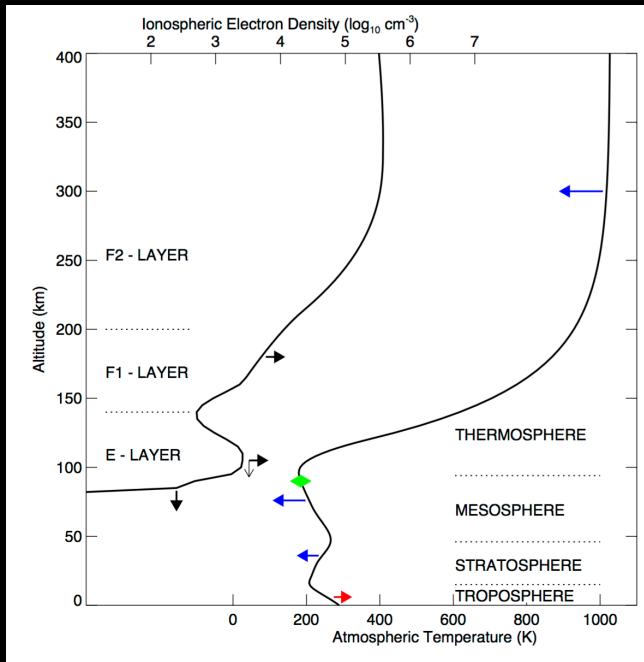
[removed due to file size issues]  
Simulation of global meteoric sodium.



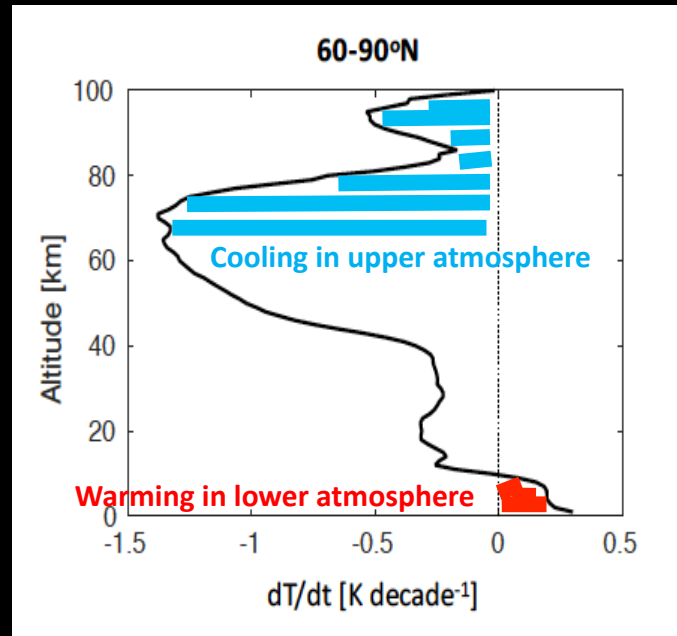
<https://www.iap-kborn.de/>

Courtesy of D. Janches/D. Marsh

# How is our atmosphere changing?



Laštovička et al. 2008



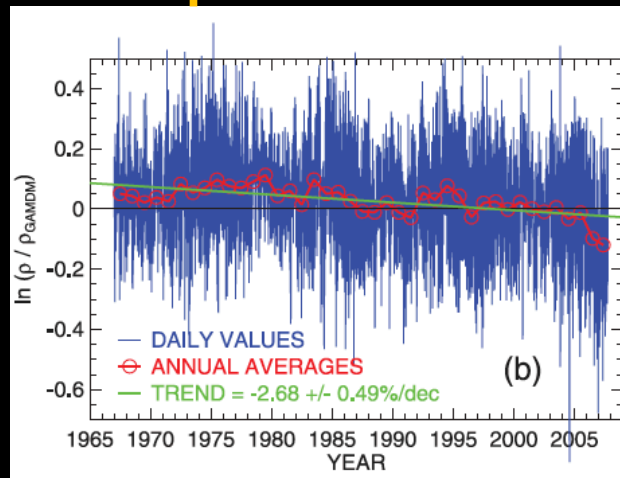
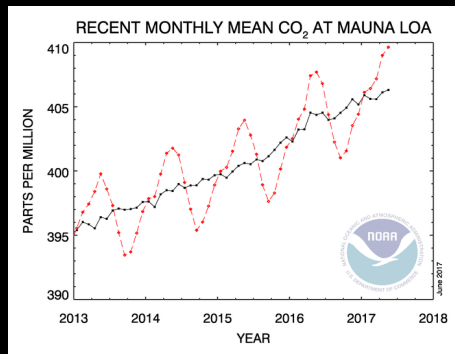
thermosphere

mesosphere

stratosphere

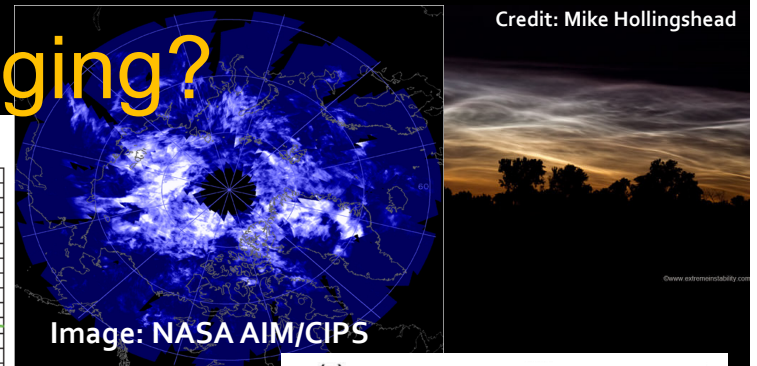
troposphere

# How is our atmosphere changing?

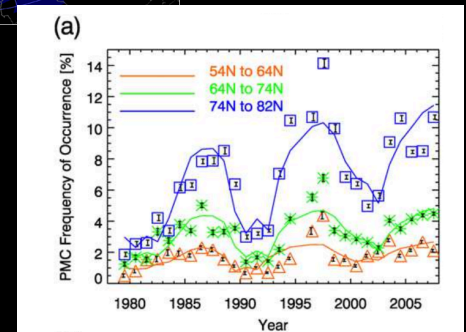


Emmert et al. (2007)

Analyses of satellite drag data indicate a long-term trend of decreasing thermosphere densities.



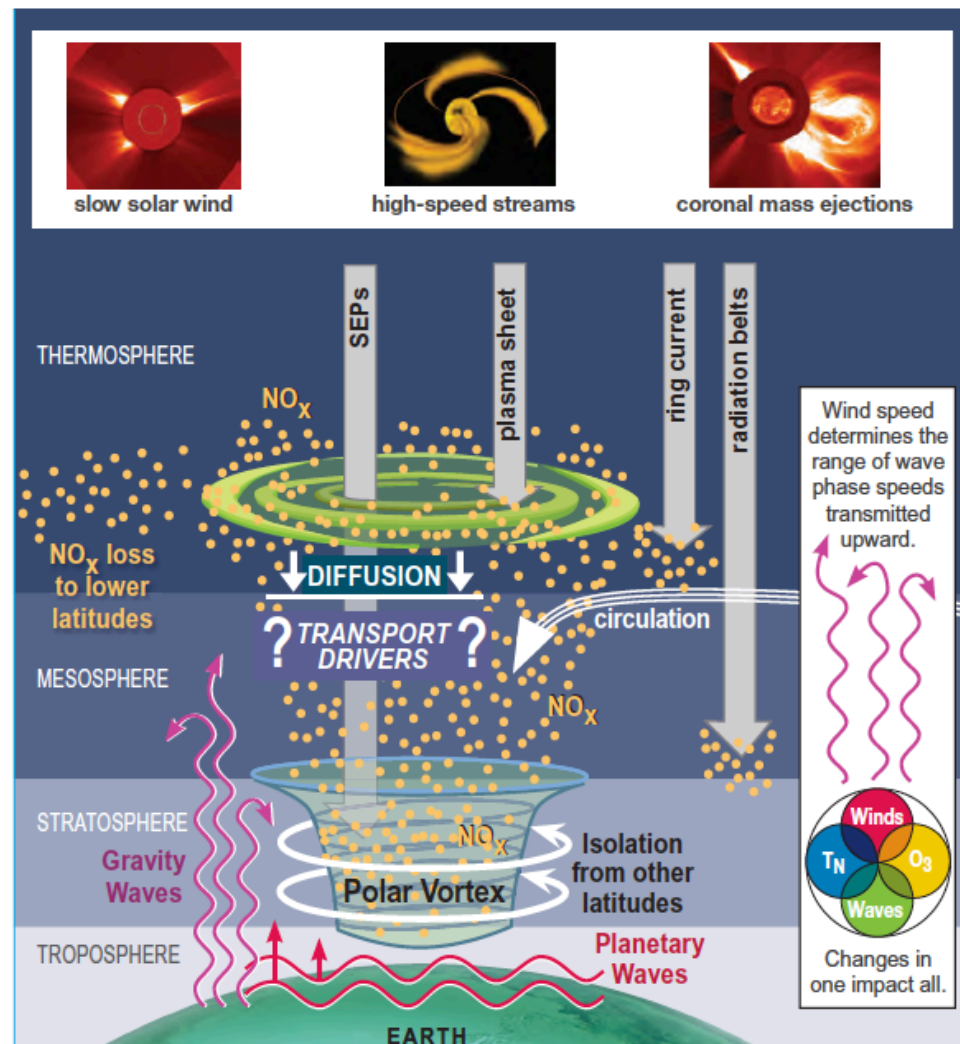
Credit: Mike Hollingshead



Shettle et al. (2009)

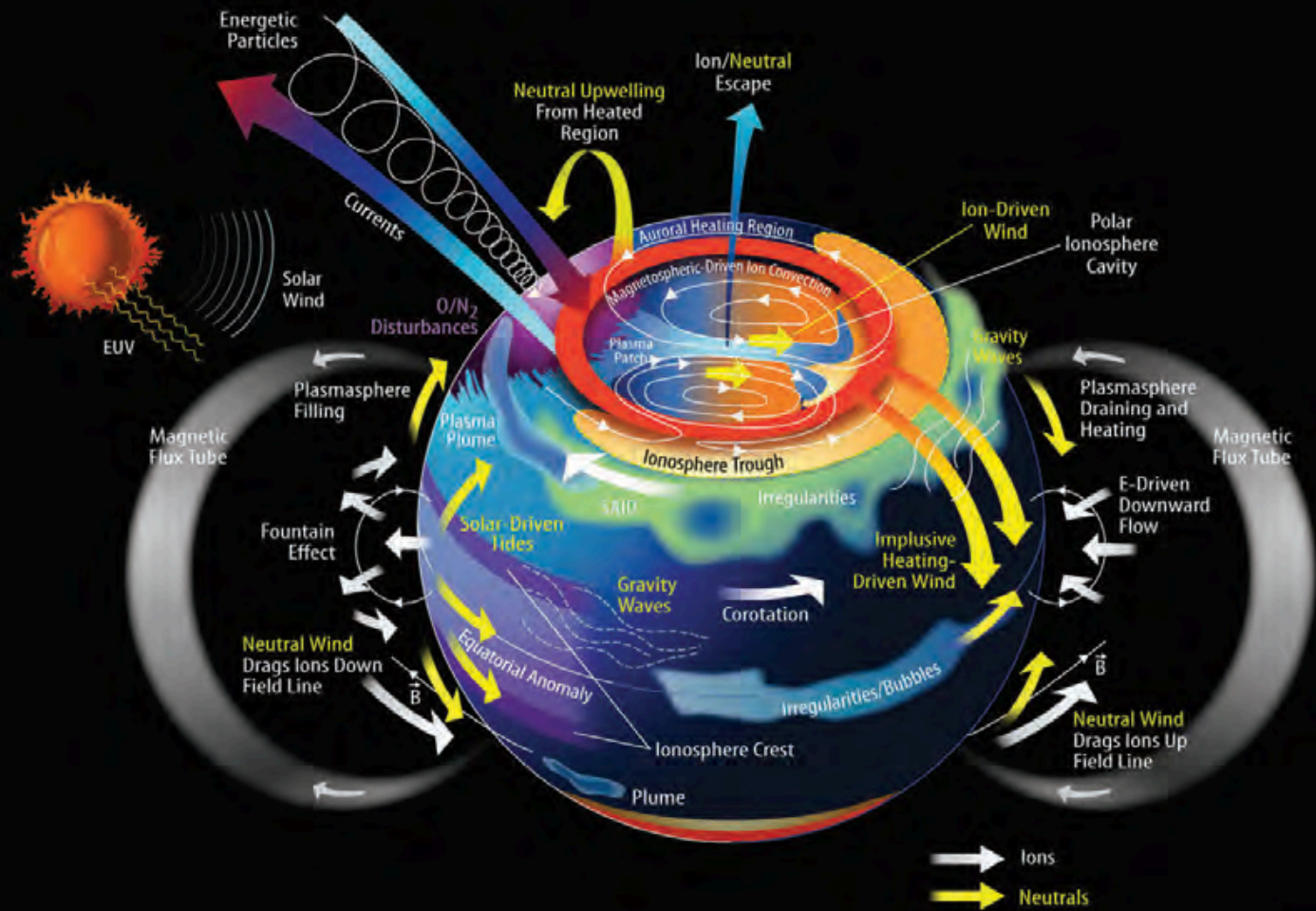


# Space weather and our neutral atmosphere



Randall et al.

FIGURE 8.5 Schematic of the intertwined pathways that link space weather variability to atmospheric coupling. SOURCE: Courtesy of Cora E. Randall, University of Colorado, Boulder; Janet U. Kozyra, University of Michigan, Ann Arbor; and Scott M. Bailey, Virginia Institute of Technology.





# Summary

- Each layer of the atmosphere is well-defined.
- Vertical coupling between all parts of the neutral atmosphere.
- All parts of the Earth-Sun system interlinked.
- Our neutral atmosphere is changing. Important to monitor and improve understanding of these.

# Meteorological Driving of Geospace

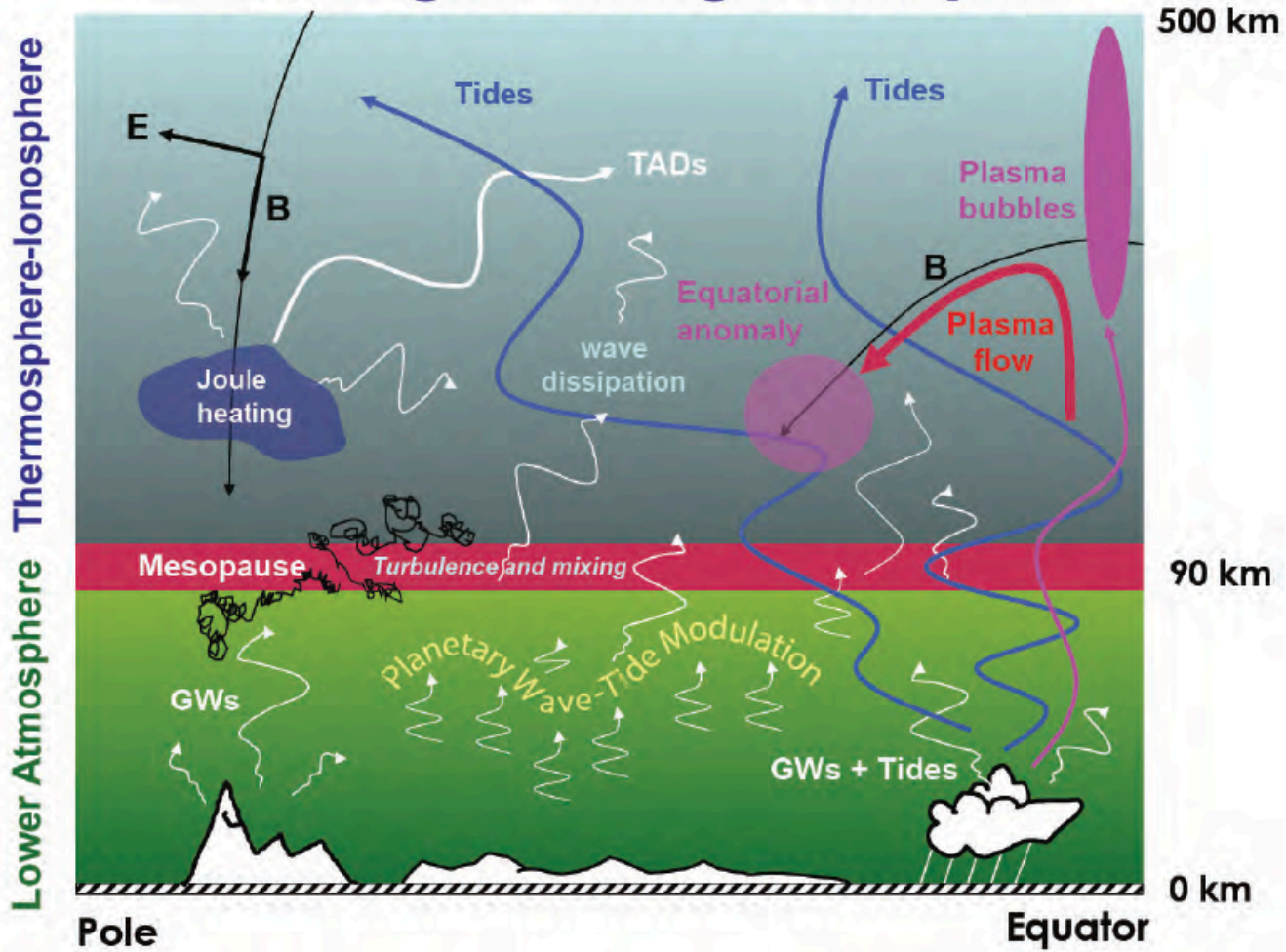


Image: Forbes and Fritts