NAROM

The Earth's Polar Atmosphere

Alexander Biebricher

Norwegian Centre for Space-related Education
(a part of Andøya Space Center)

Picture: Oleg Kuchorenko

ANDØYA SPACE CENTER

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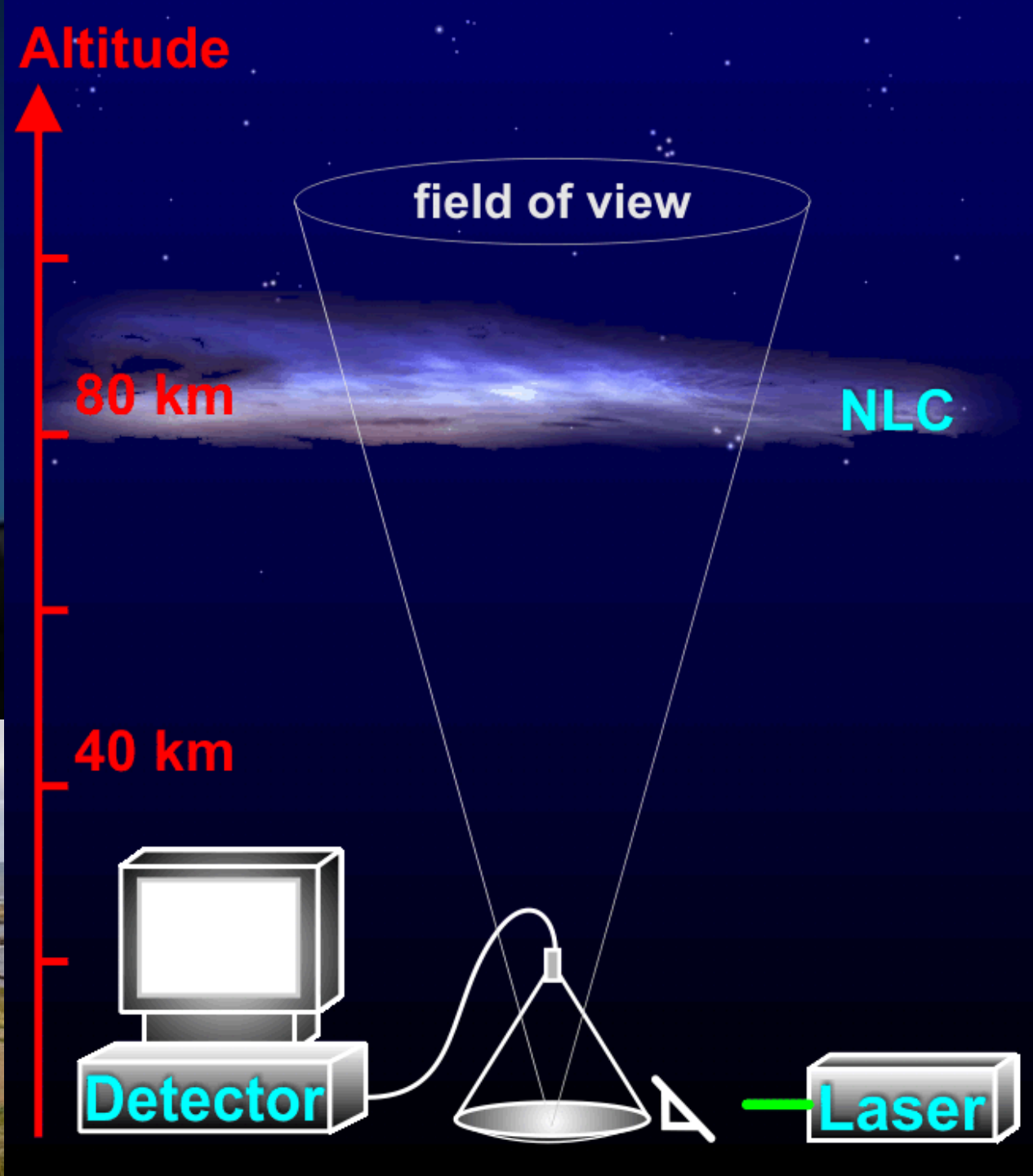
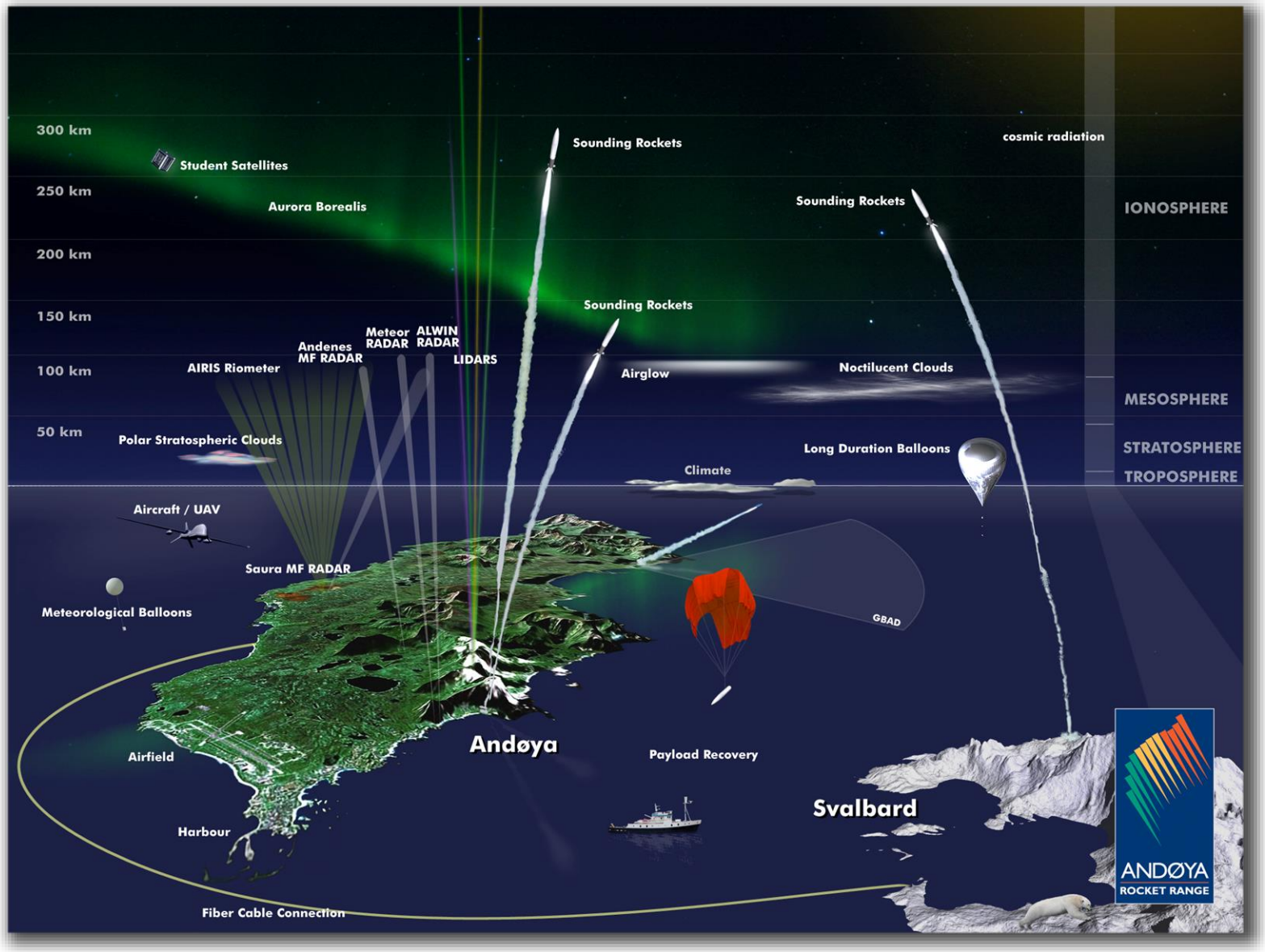
SPACESHIP AURORA

NAROM

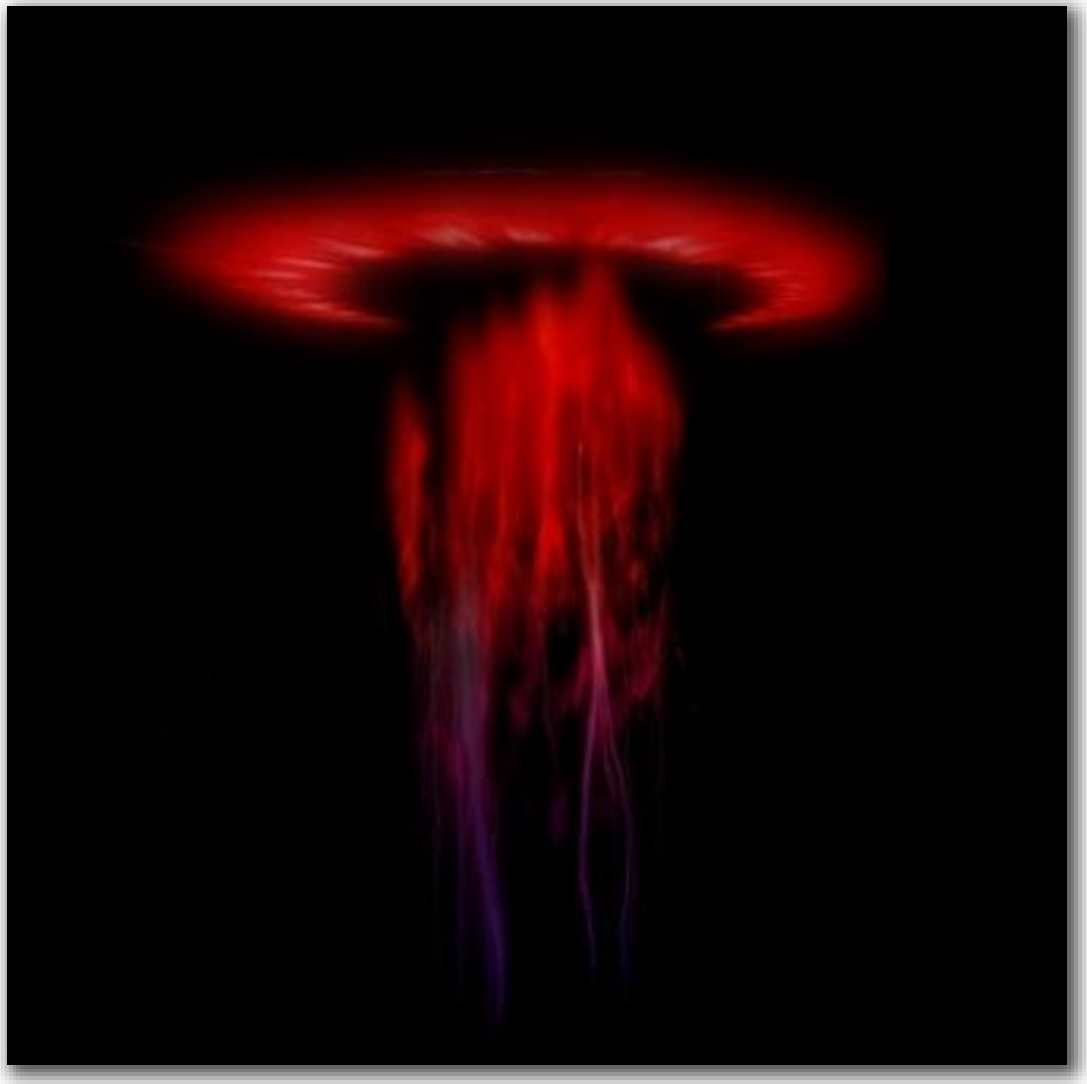
ANDØYA TEST CENTER


Altitude
field of view
80 km
NLC
40 km
Detector
Laser

- Rocket operations
- Rocket payload development
- Technology testing
- Ground-based instrumentation
- Scientific balloons
- Unmanned aerial systems



Picture: Princeharris1993 via Wikimedia Commons

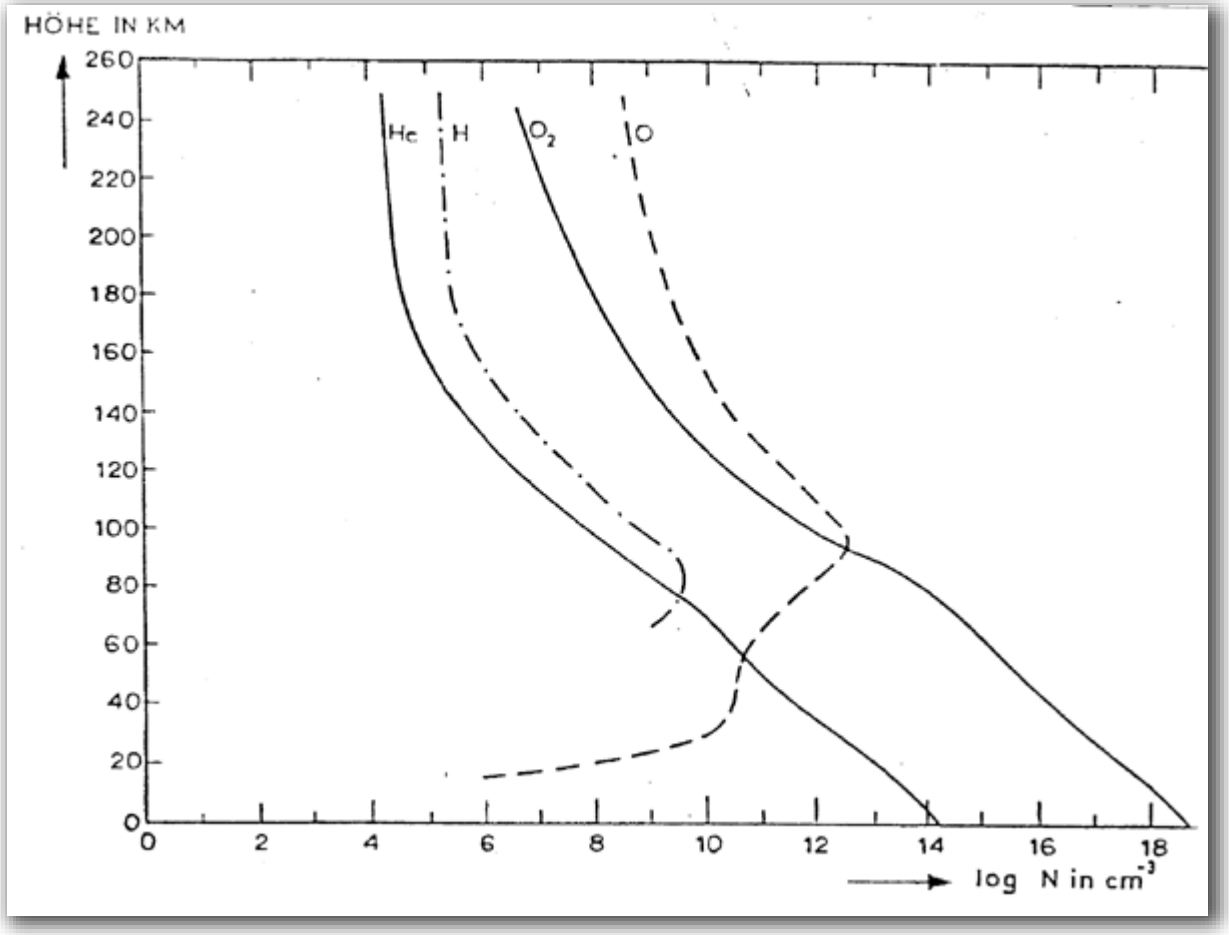


Contents

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere

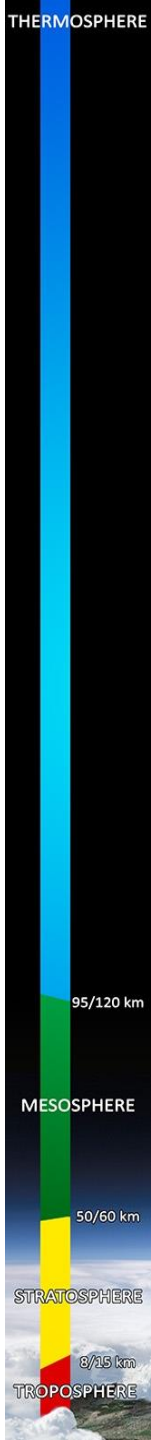
Pictures:
Plot: TU Darmstadt
Tabular: D. Koerner, NAU

Chemistry



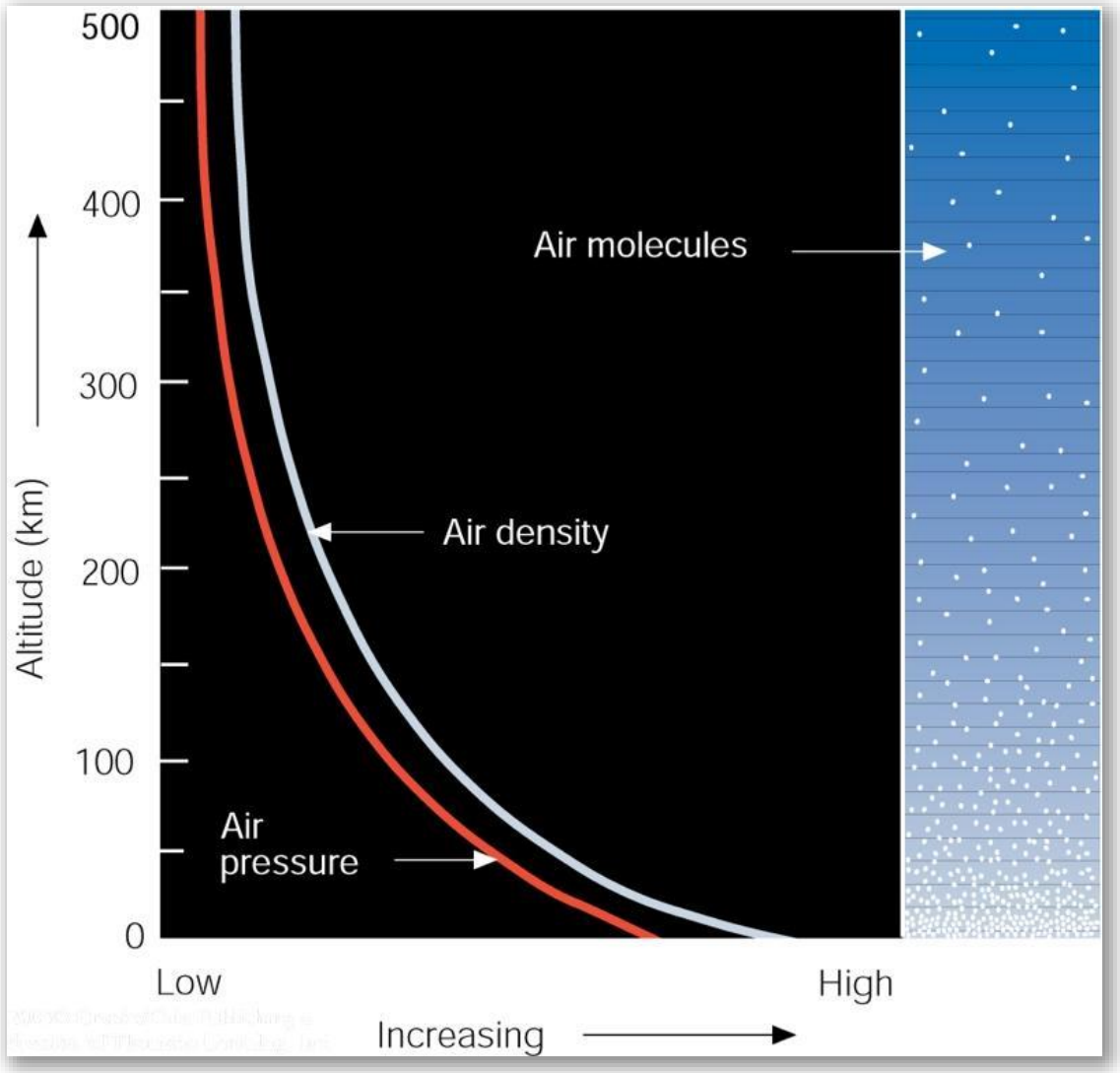
Composition of the Earth's Atmosphere

	Gas	Formula	Abundance percent by volume	Abundance parts per million by volume
1	Nitrogen	N_2	78.084%	780,840
2	Oxygen	O_2	20.9476%	209,476
3	Argon	Ar	0.934%	9,340
4	Carbon Dioxide	CO_2	0.0314%	314
5	Neon	Ne	0.001818%	18.18
6	Helium	He	0.000524%	5.24
7	Methane	CH_4	0.0002%	2
8	Krypton	Kr	0.000114%	1.14
9	Hydrogen	H_2	0.00005%	0.5
10	Xenon	Xe	0.0000087%	0.087



Plot: D. Miller, UNCA

Pressure

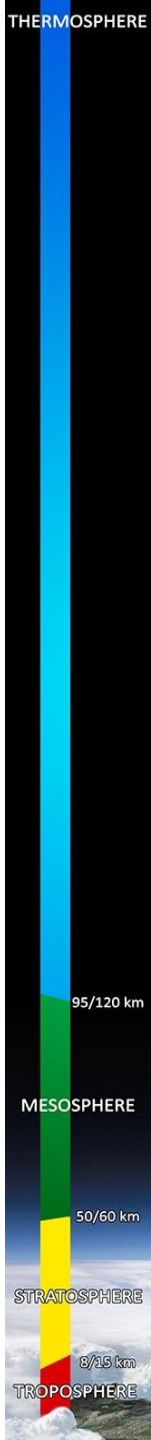


Normal pressure

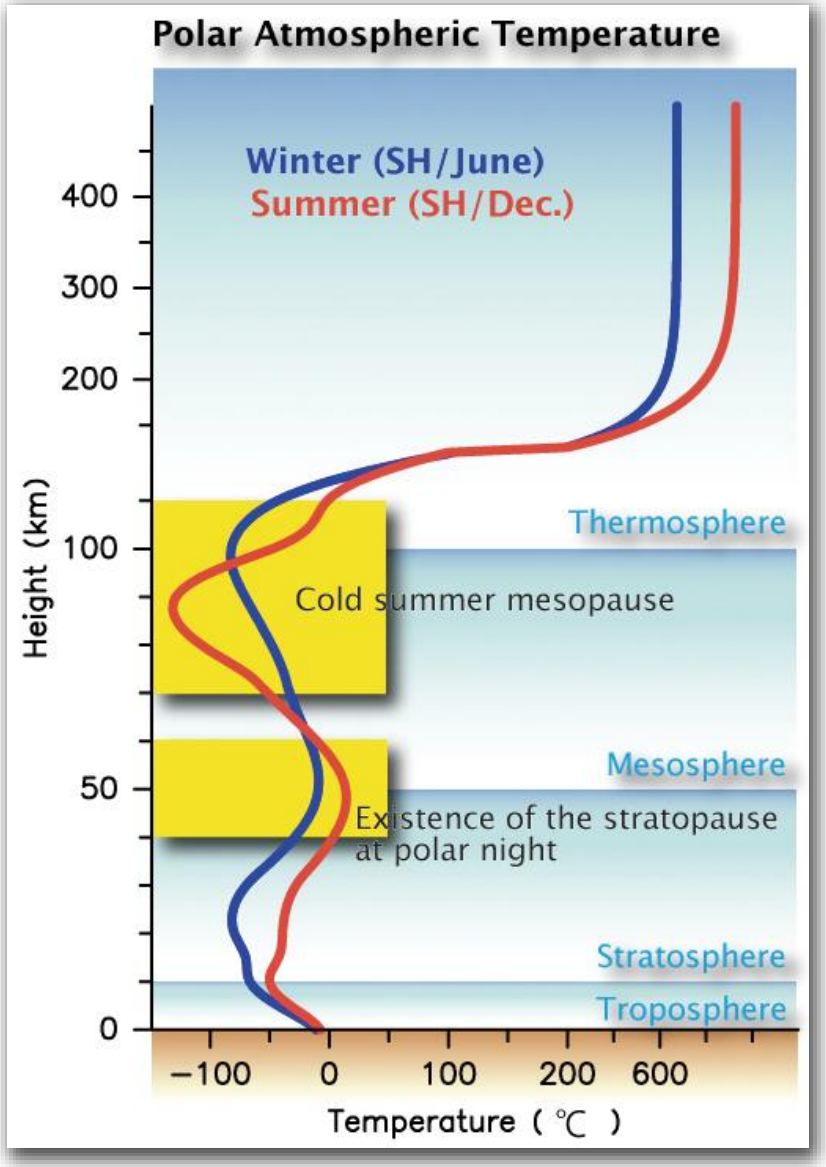
$$p_0 = 1013.25 \text{ mbar}$$

Scale height

$$p = p_0 \, e^{-z/H}$$



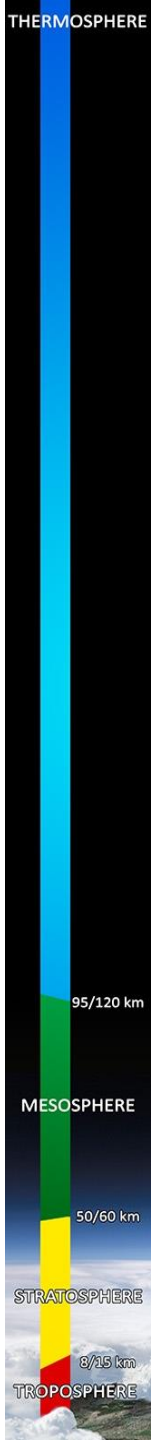
Picture: University of Tokyo



Temperature

- Greek:
  «atmos» = «steam»
  «sphaira» = «sphere»

- Layering:
  temperature
  ionization
  (electron density)



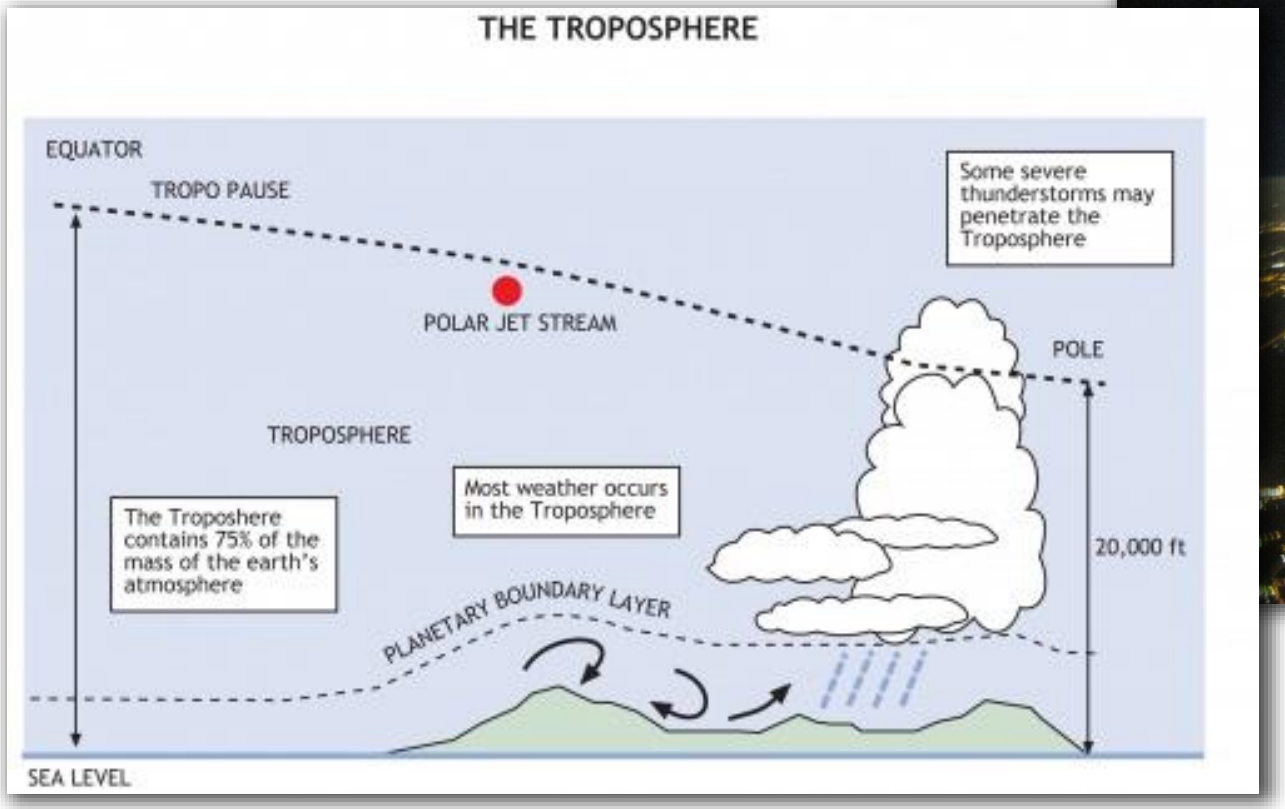
Picture: ARS/NAROM

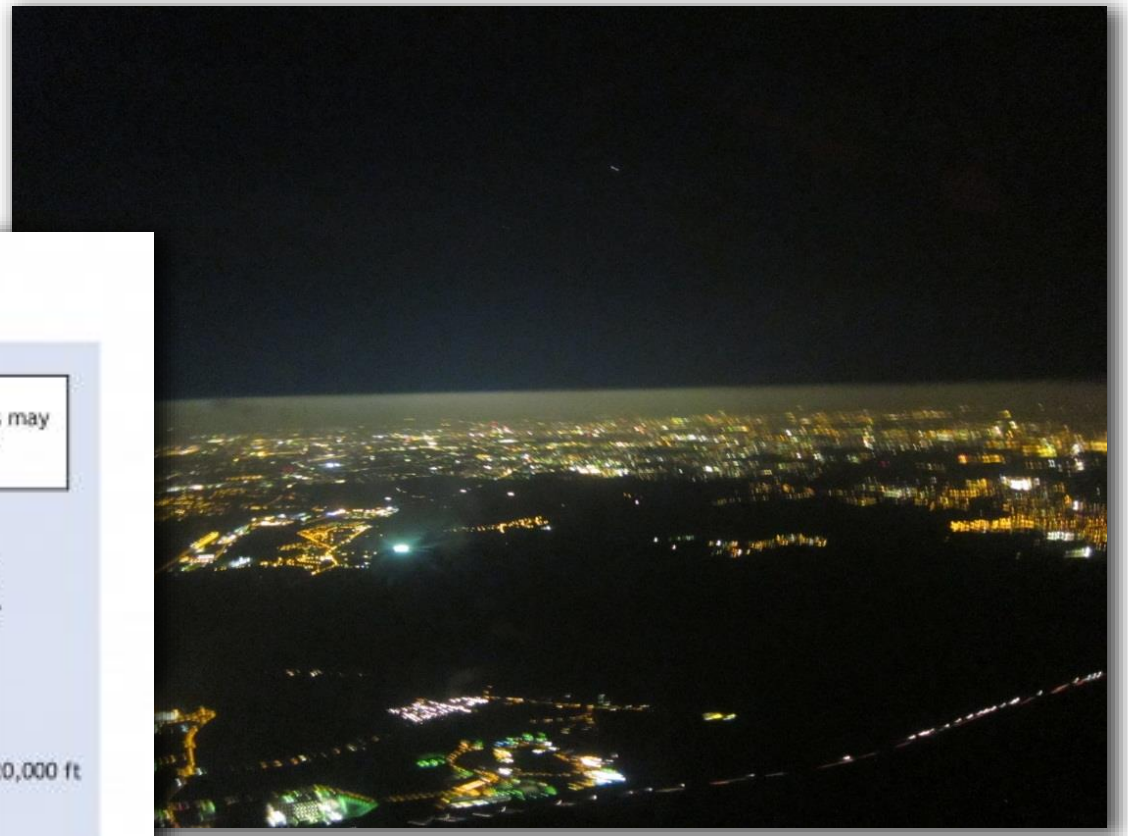
Balloon launch: Troposphere

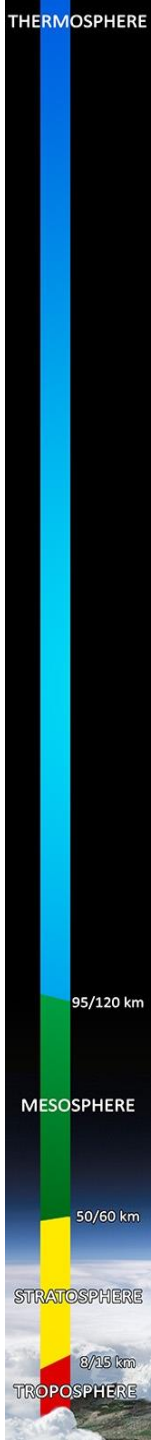
- Maximum altitude: 6 – 18 km
- The Earth's IR dominates (almost) everything
- Greek:
  «Tropos» = «change»

Pictures:
Drawing: Skybrary
Aerosol over Berlin: CCL

Planetary boundary layer





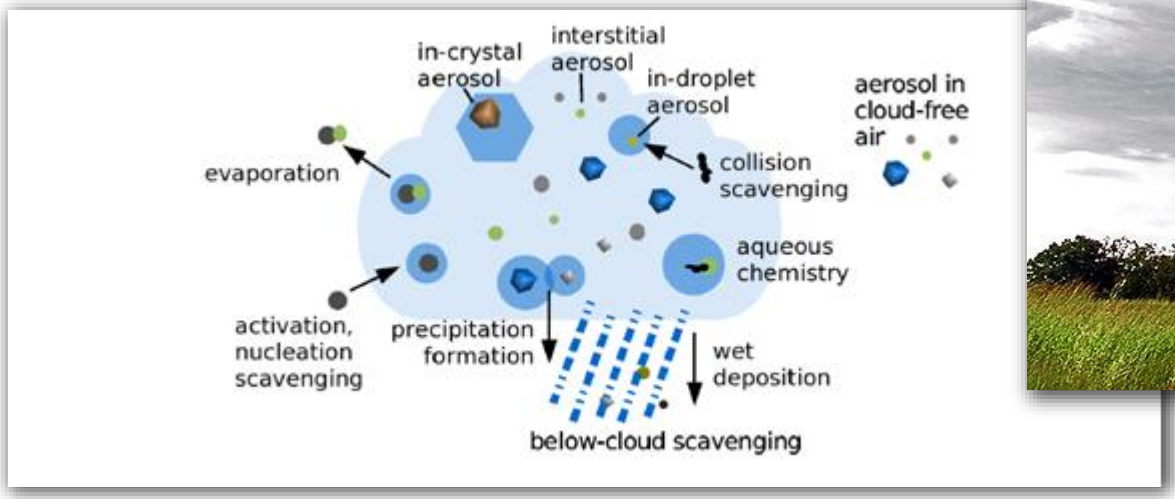


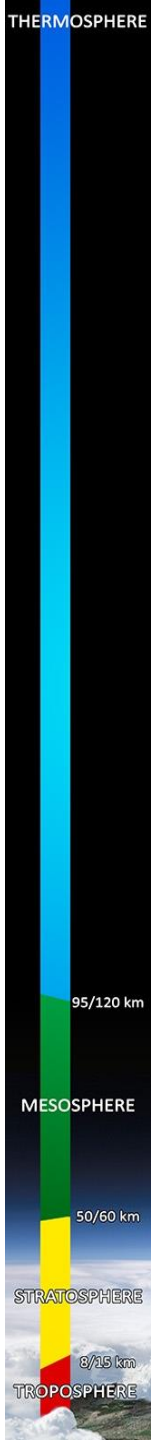
Pictures:
Clouds: PiccoloNamek via Wikimedia Commons
Figure: ETH, based on *Ghan and Schwartz,* 2007

Cloud physics

«Just clouds»:

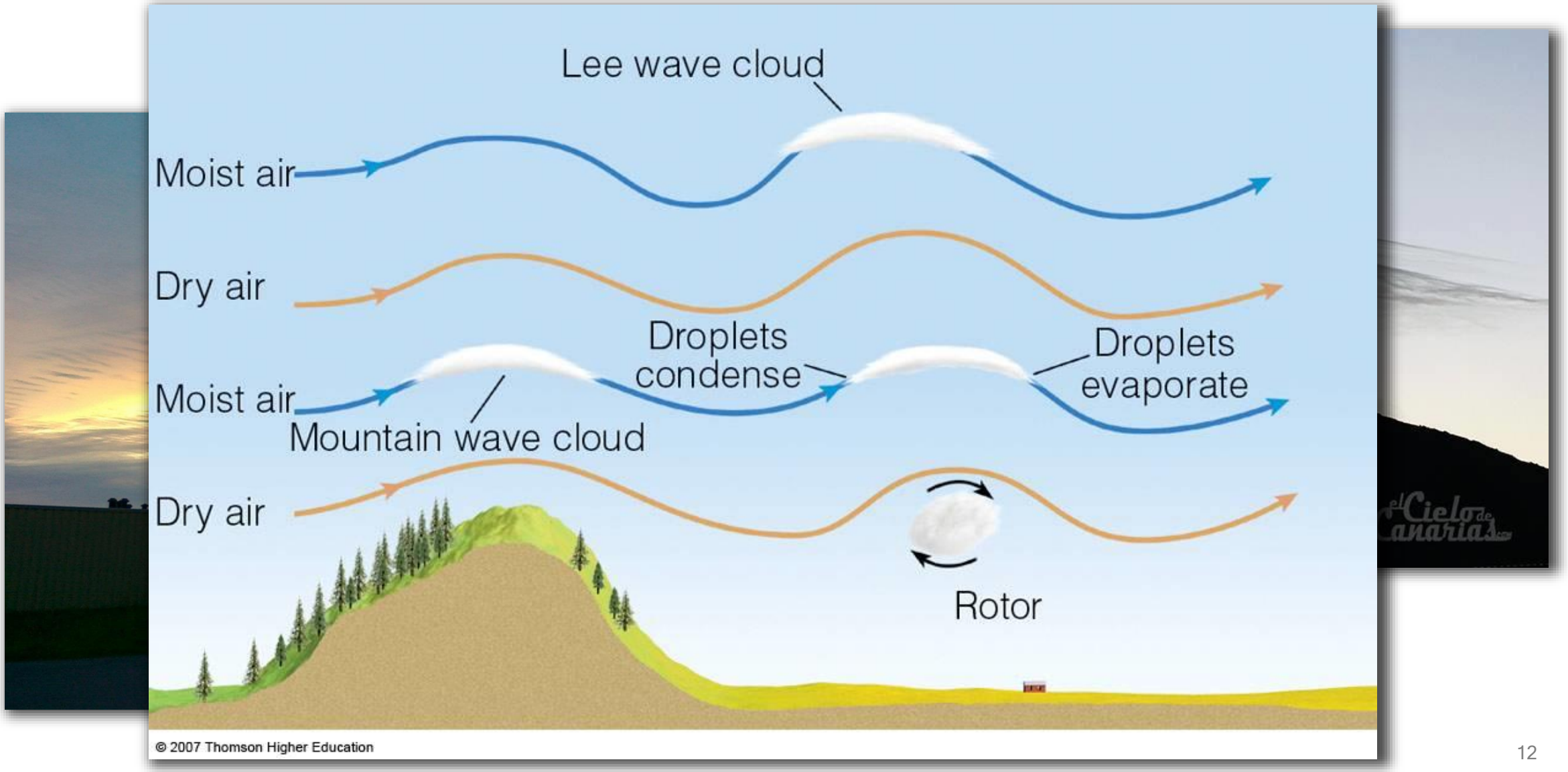
- One of the most difficult fields of research in physics!
- Cloud droplets or crystals are macroscopic.
- Cannot be understood without knowledge of the microscopic.

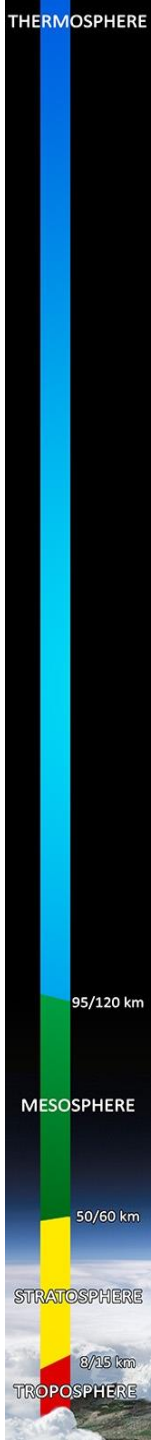




Pictures:
Clouds: A. Biebricher and D. Lopez
Figure: Thomson Higher Education

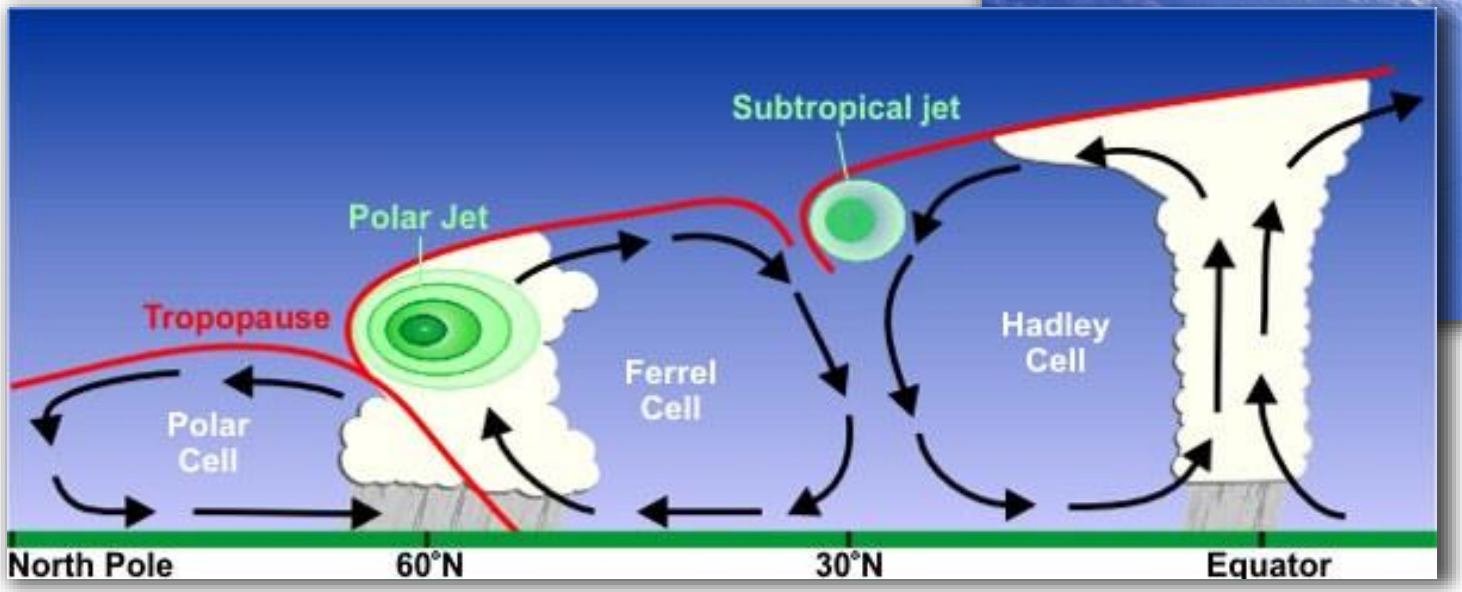
Internal Atmospheric Pressure Waves

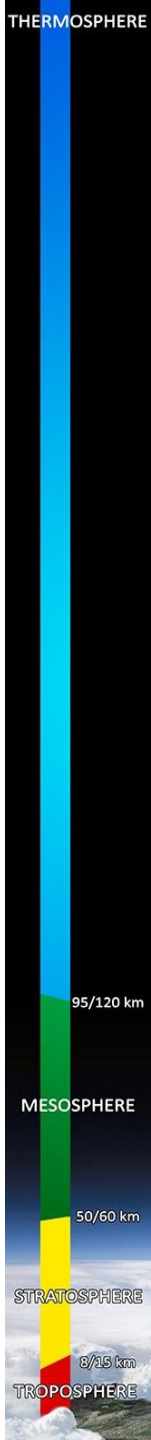




Pictures:
Wind cells: NOAA
Satellite photography: Meteosat

Global wind systems





Pictures:
Graphics: Maricopa Community College
Satelitte picture: NASA

Planetary waves

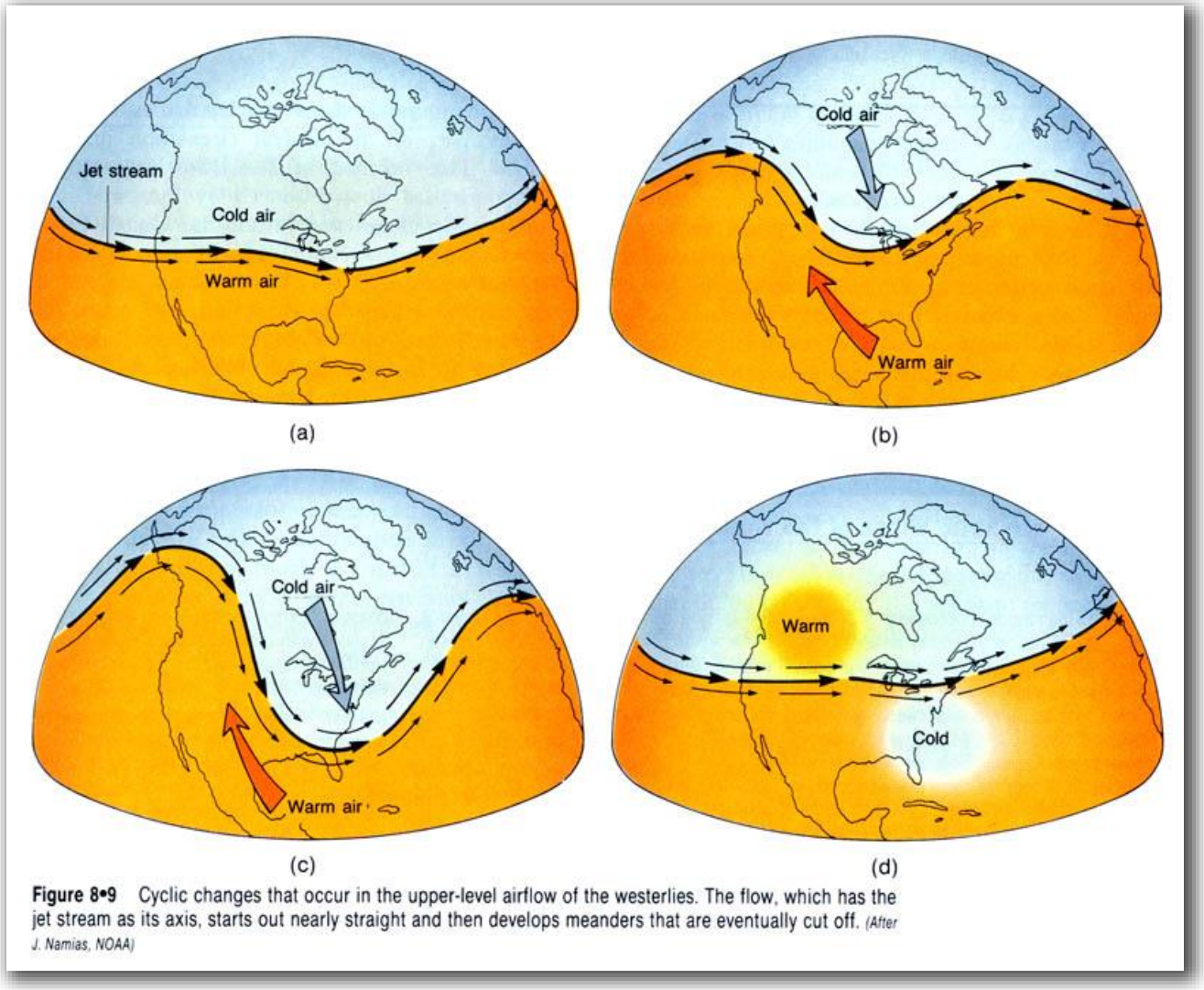
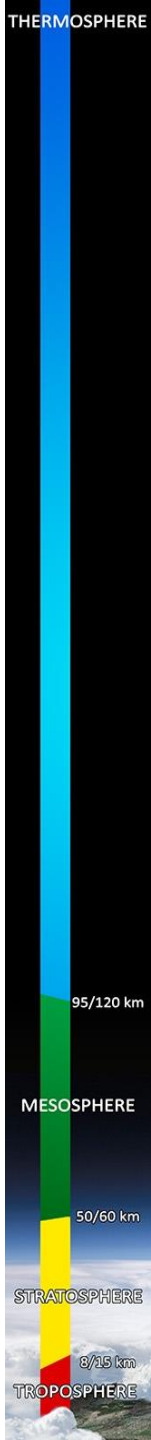
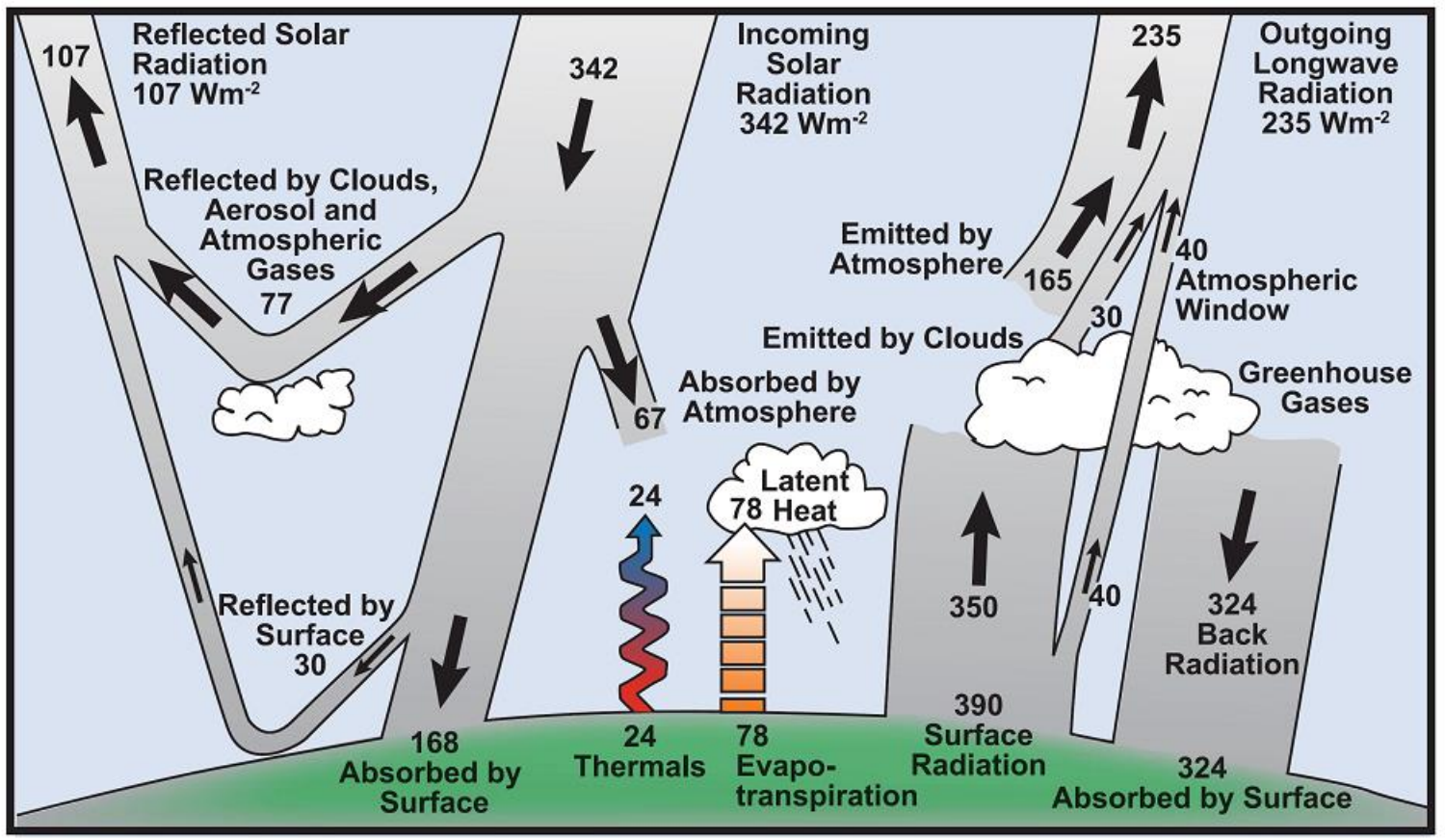


Figure 8•9 Cyclic changes that occur in the upper-level airflow of the westerlies. The flow, which has the jet stream as its axis, starts out nearly straight and then develops meanders that are eventually cut off. *(After J. Namias, NOAA)*

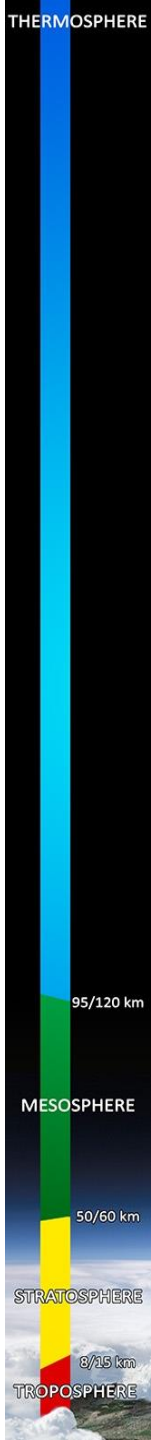


Picture: *Kiehl and Trenberth*, 1997

Energy balance

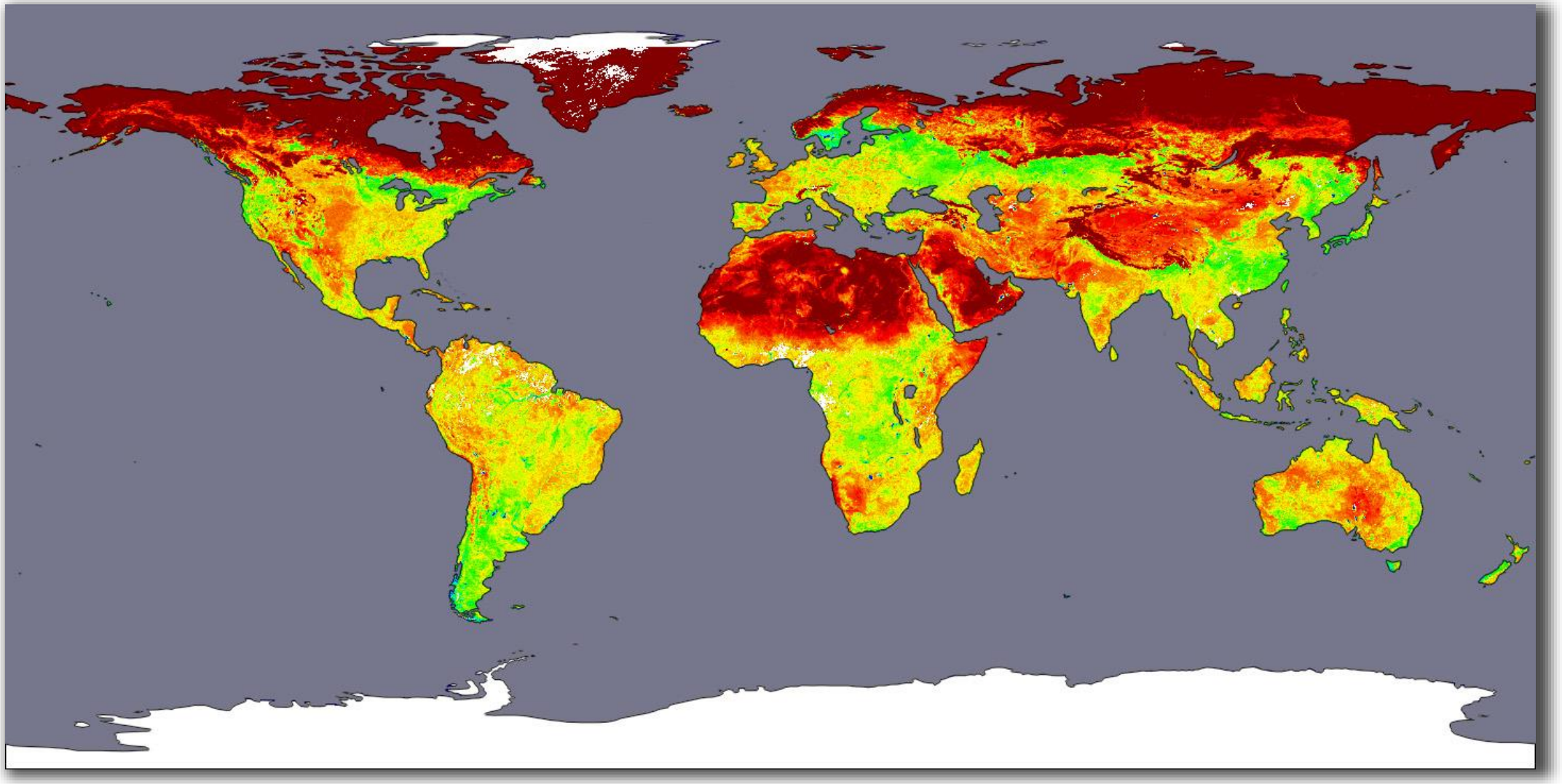


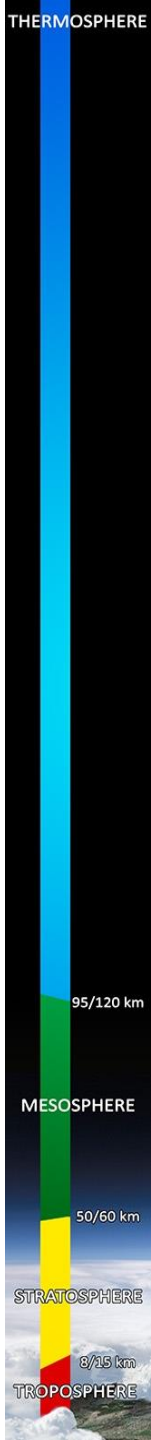
FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*



Picture: NASA

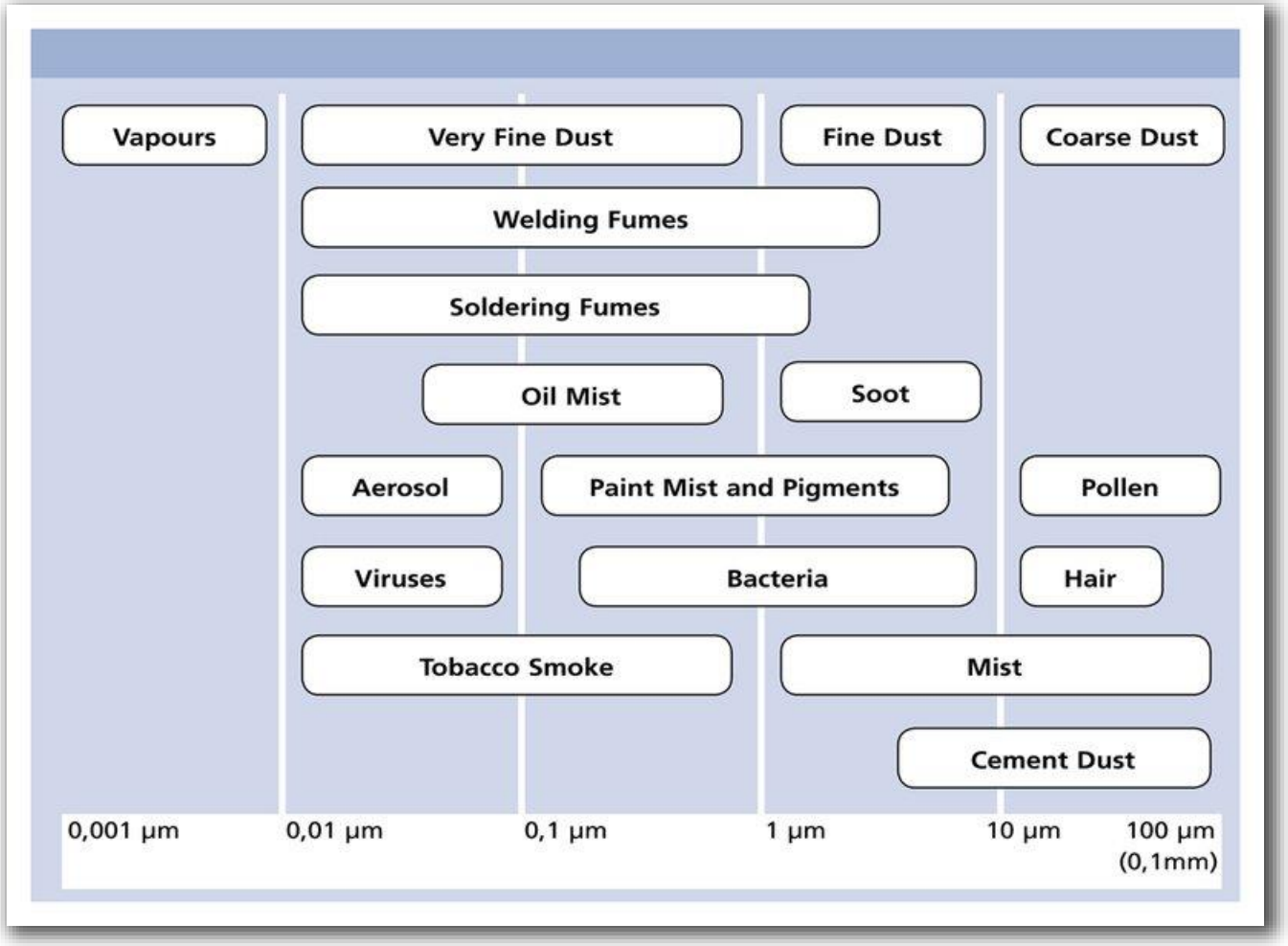
Reflection - albedo

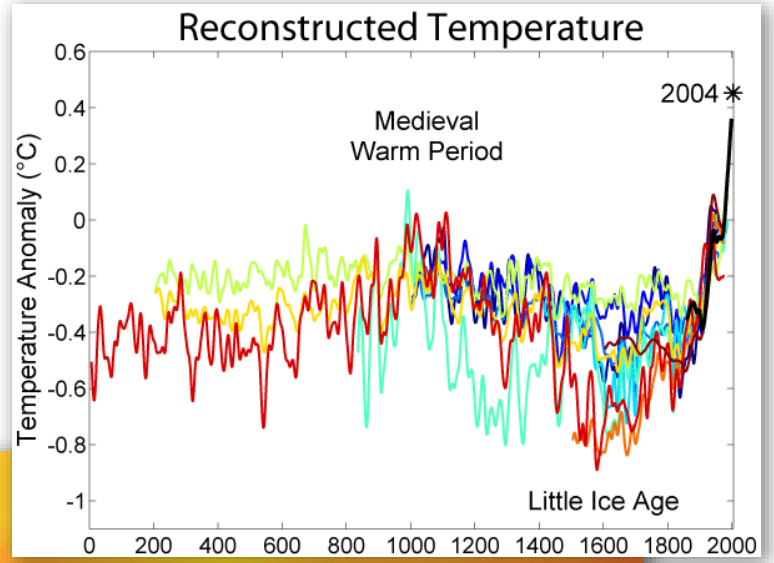


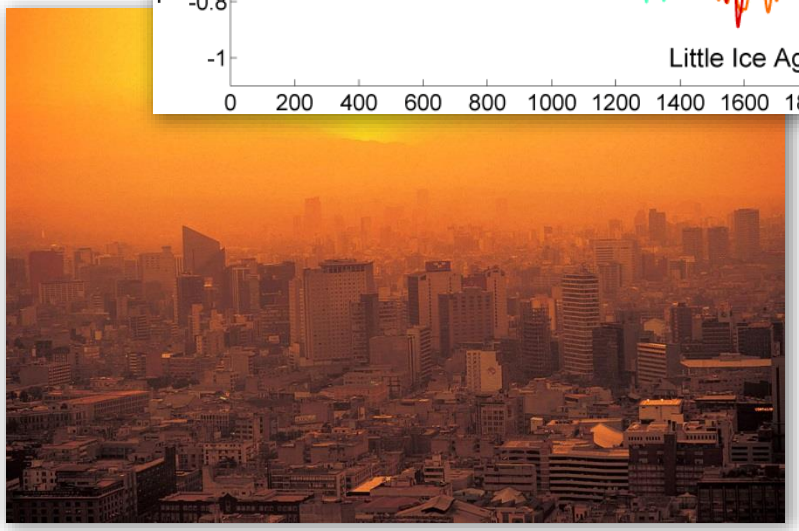


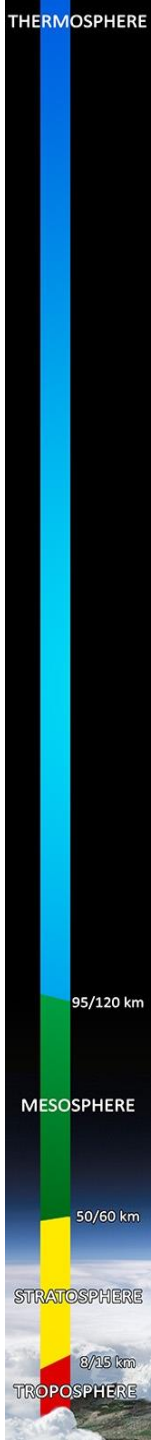
Pictures:
Smog: Earth Talk
Temperature plot: Global Warming Art
Aerosol: www.esta.com

Aerosol



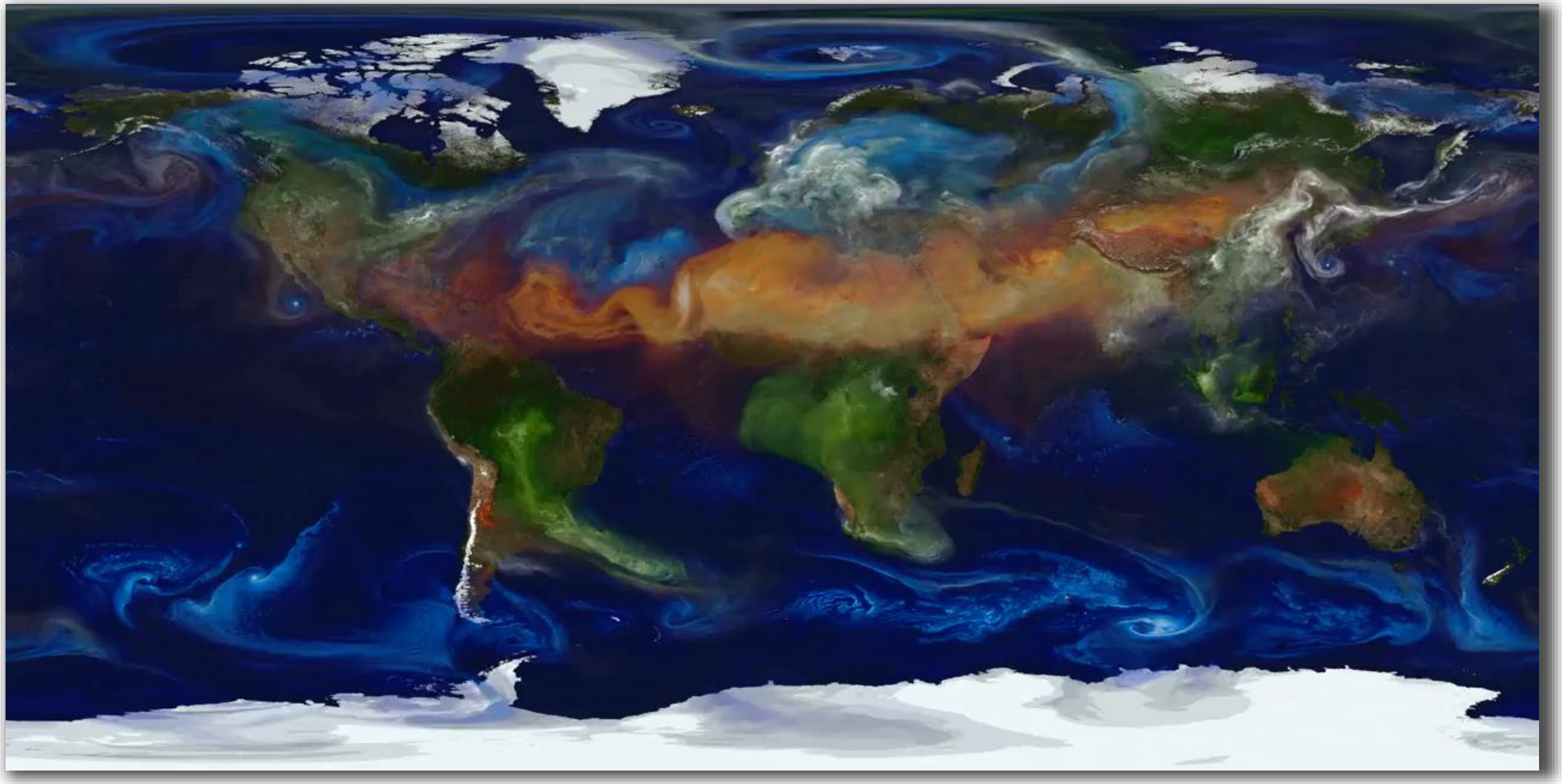


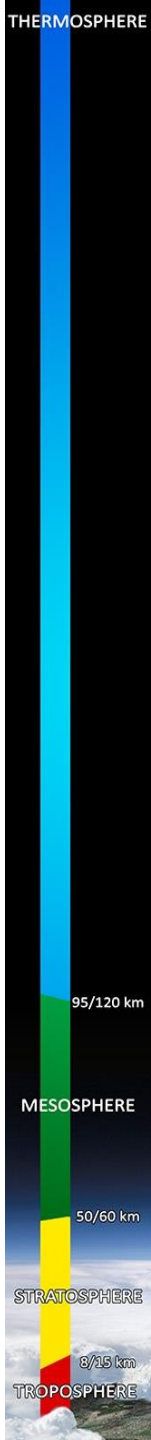




Video: NASA

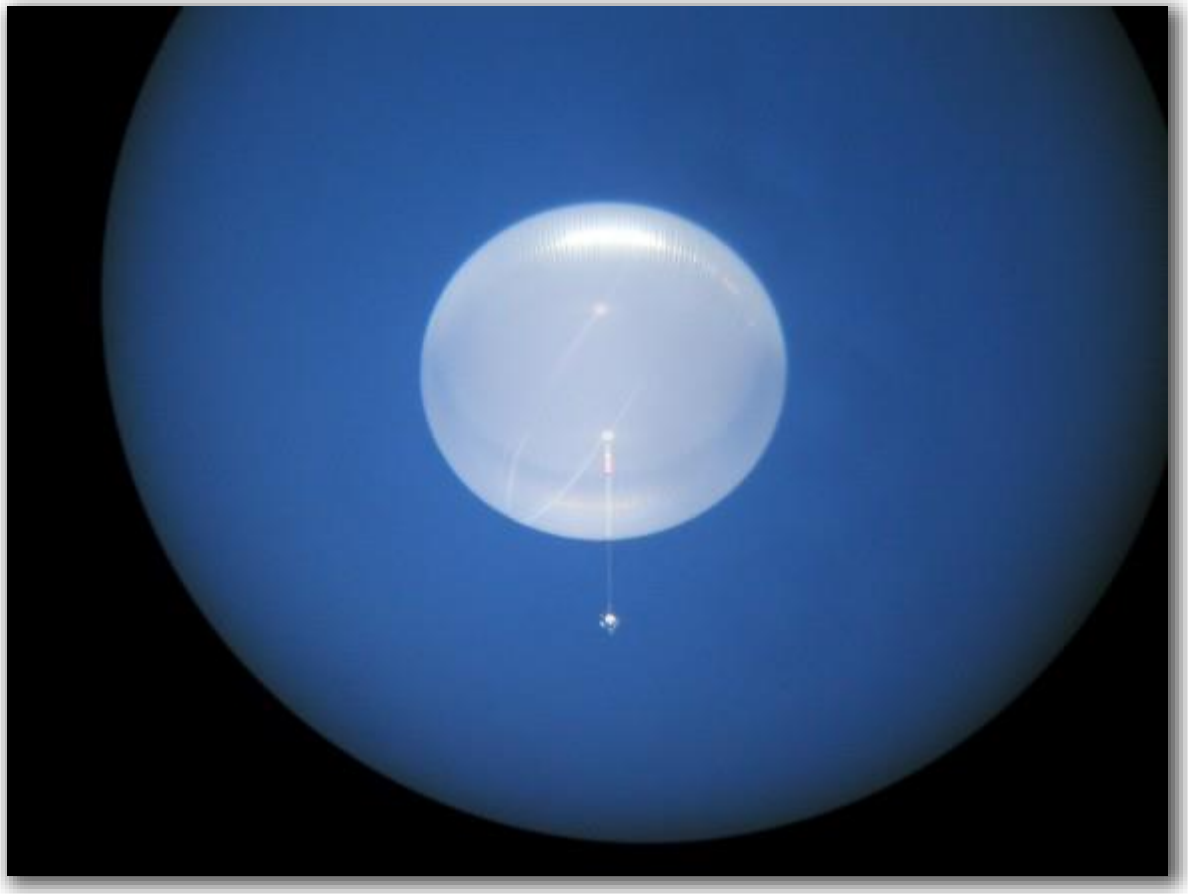
Transport models





Picture: NASA

Stratosphere

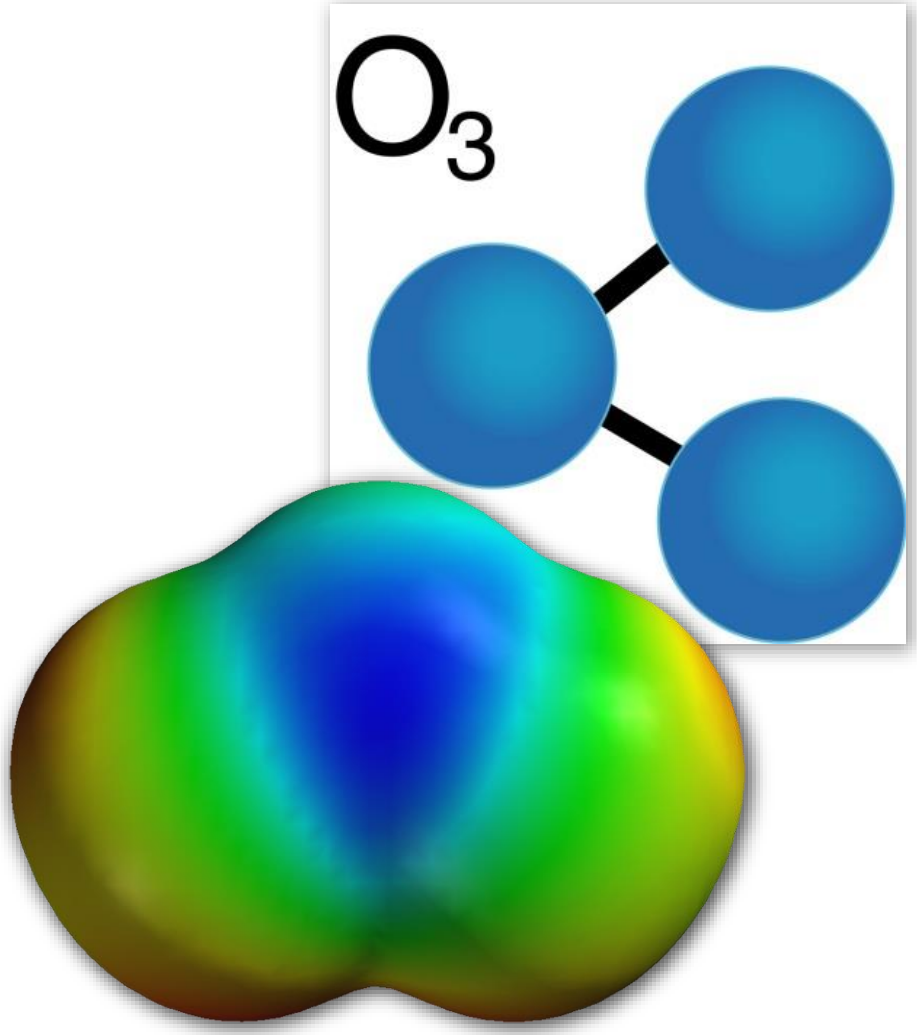


- Maximum altitude: 50 km
- Greek:
  «stratos» = «layer»
- Global winds
- Ozon density determines the temperature

Pictures:
Structure: Think Blue Marin
Orbitals: Public Domain

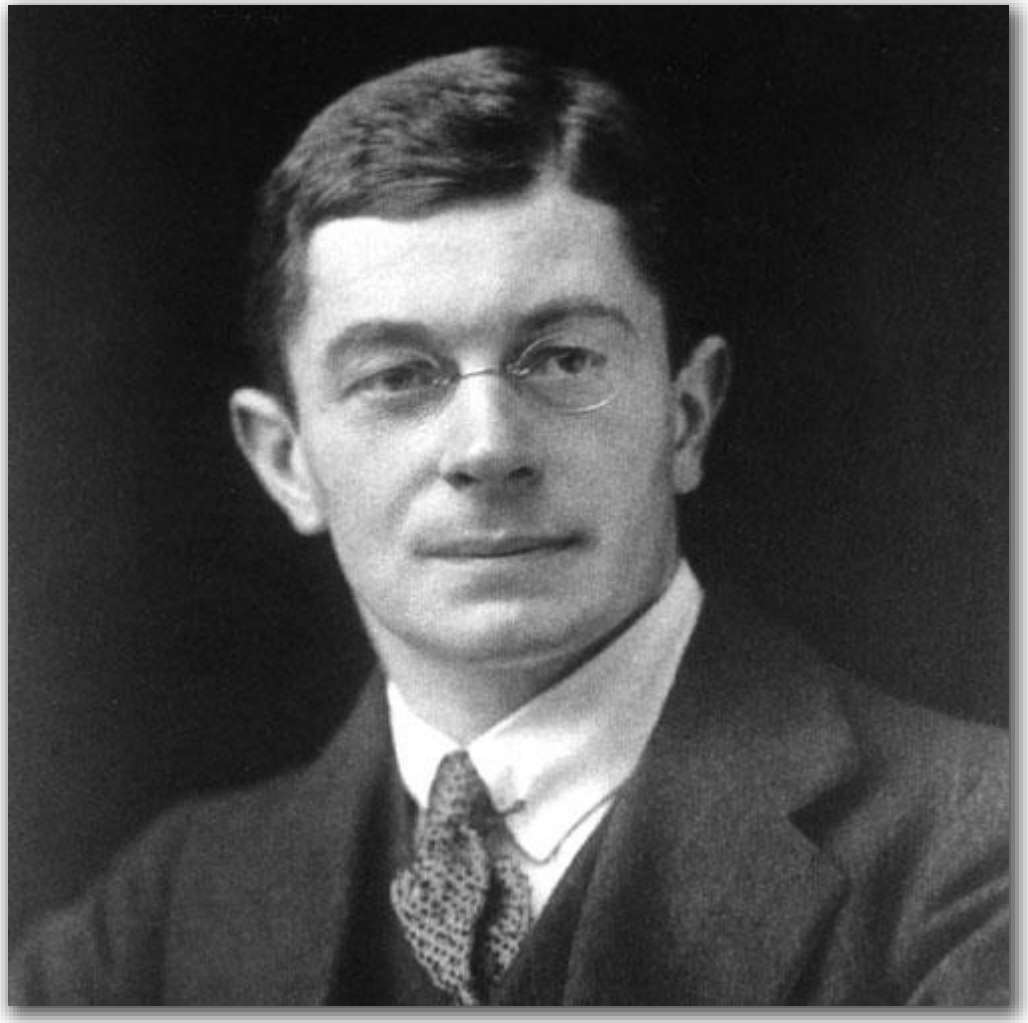
Ozone

- Tri-oxygen
- Greek: «ozein» = «smell»
- Soluble in water
- Deep blue fluid at -112 °C



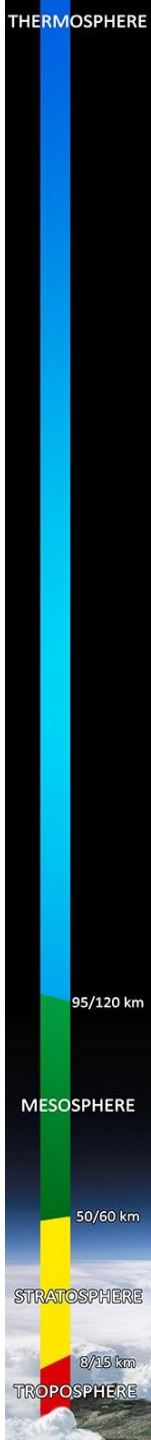
Picture: Sidney Chapman: PD

Ozone



1) $O_2 + h\nu \rightarrow O + O$
2) $O + O_2 + M \rightarrow O_3 + M$

1) $O_3 + h\nu \rightarrow O + O_2$
2) $O + O_3 \rightarrow 2\,O_2$
3) $O + O + M \rightarrow O_2 + M$



Picture: Wikimedia Commons

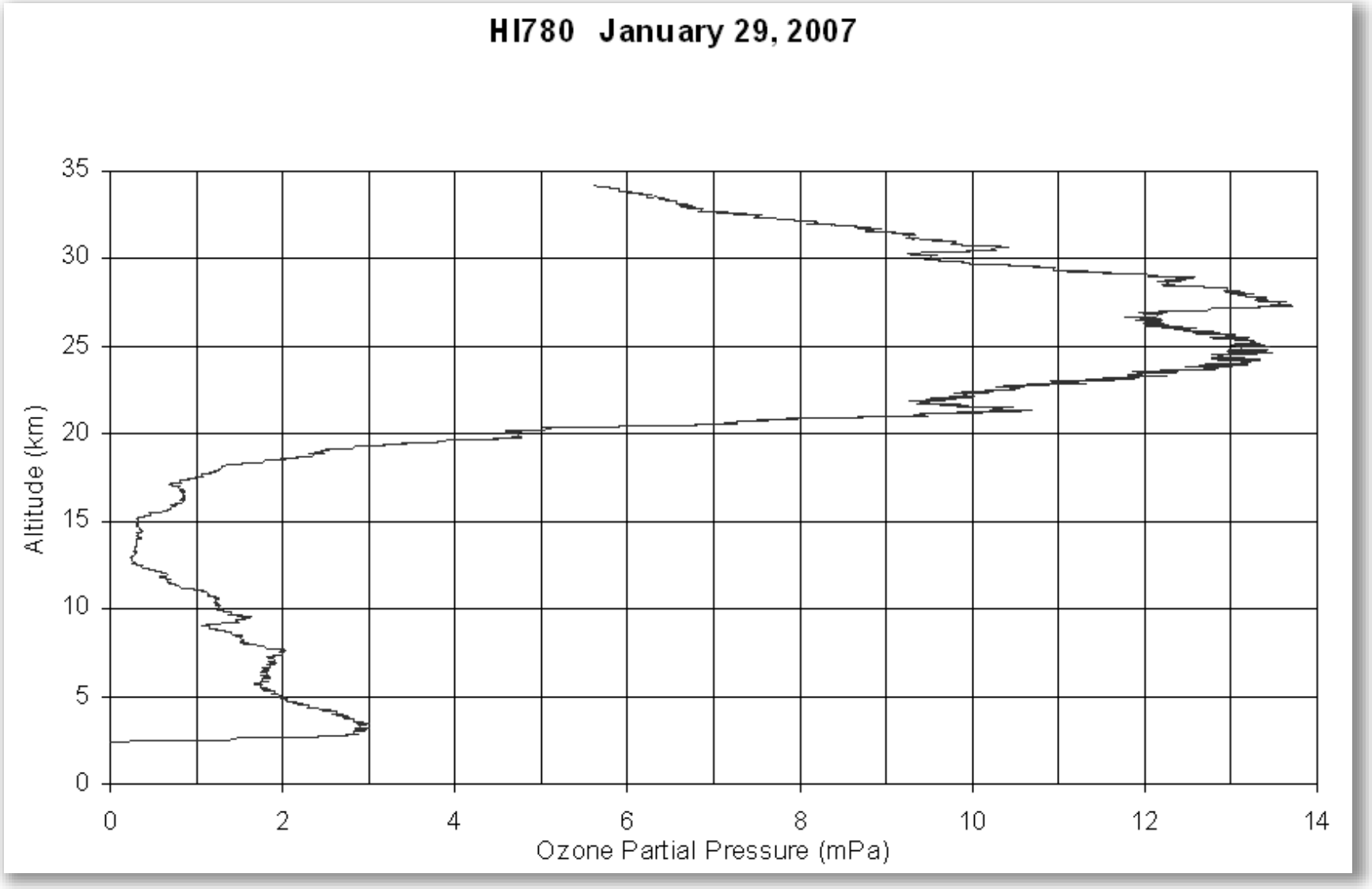
Ozone

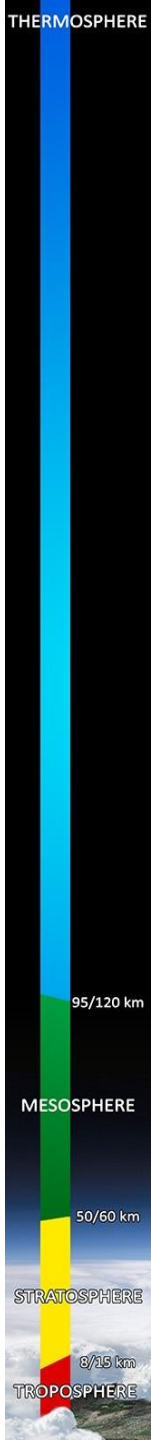
$$1)\quad R + O_3 \rightarrow RO + O_2$$

$$2)\quad RO + O \rightarrow R + O_2$$

Picture: ALOMAR

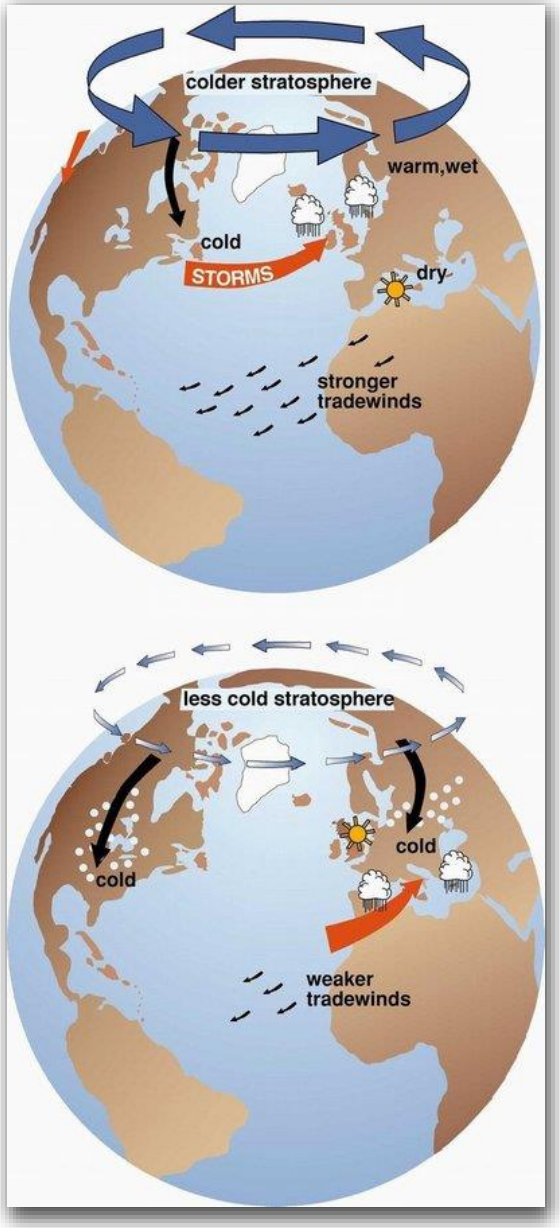
Ozone

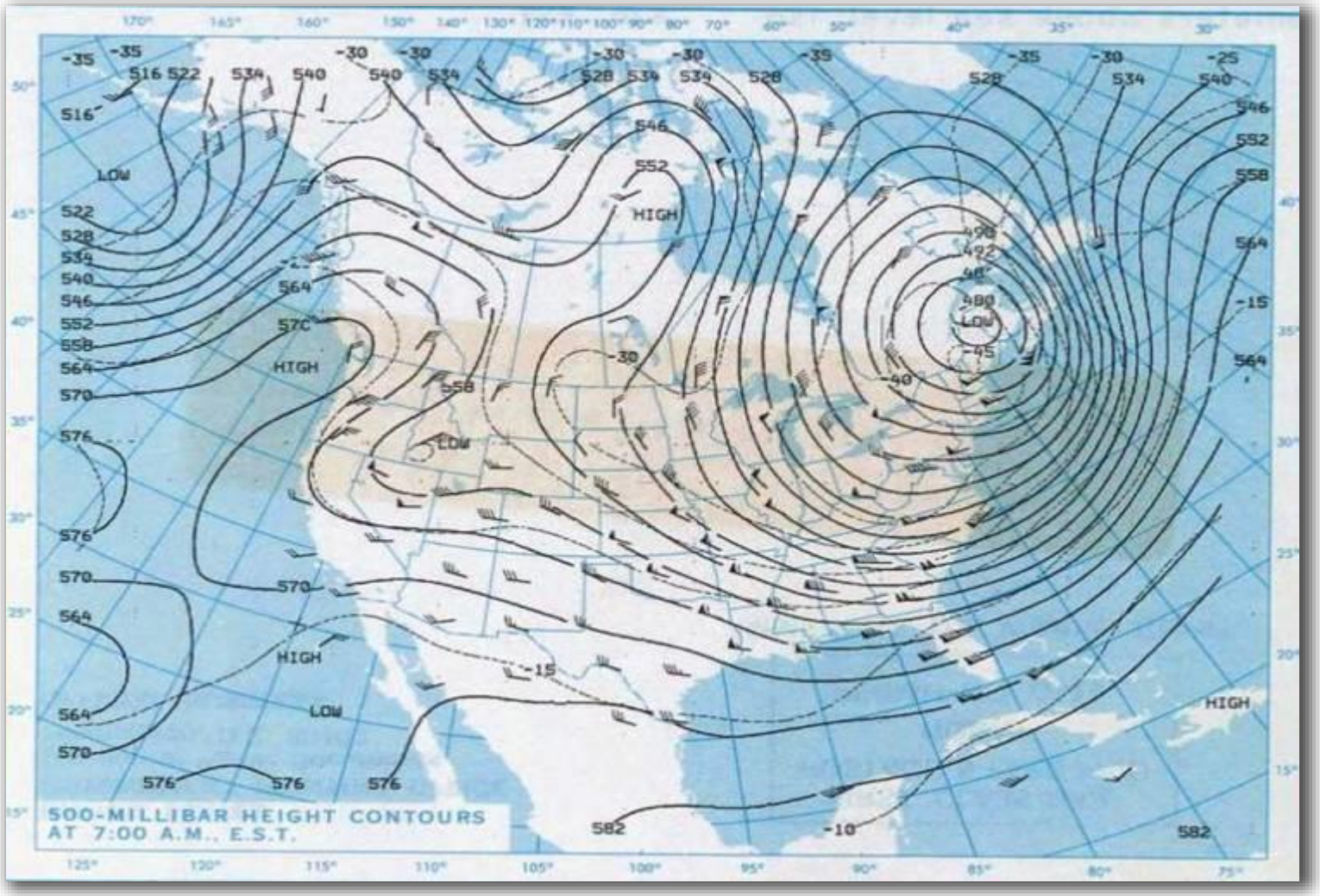


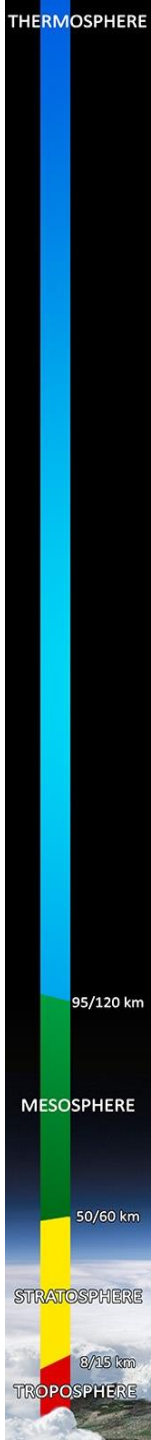


Pictures:
MET: NOAA
Figur: University of Washington

Polar vortex

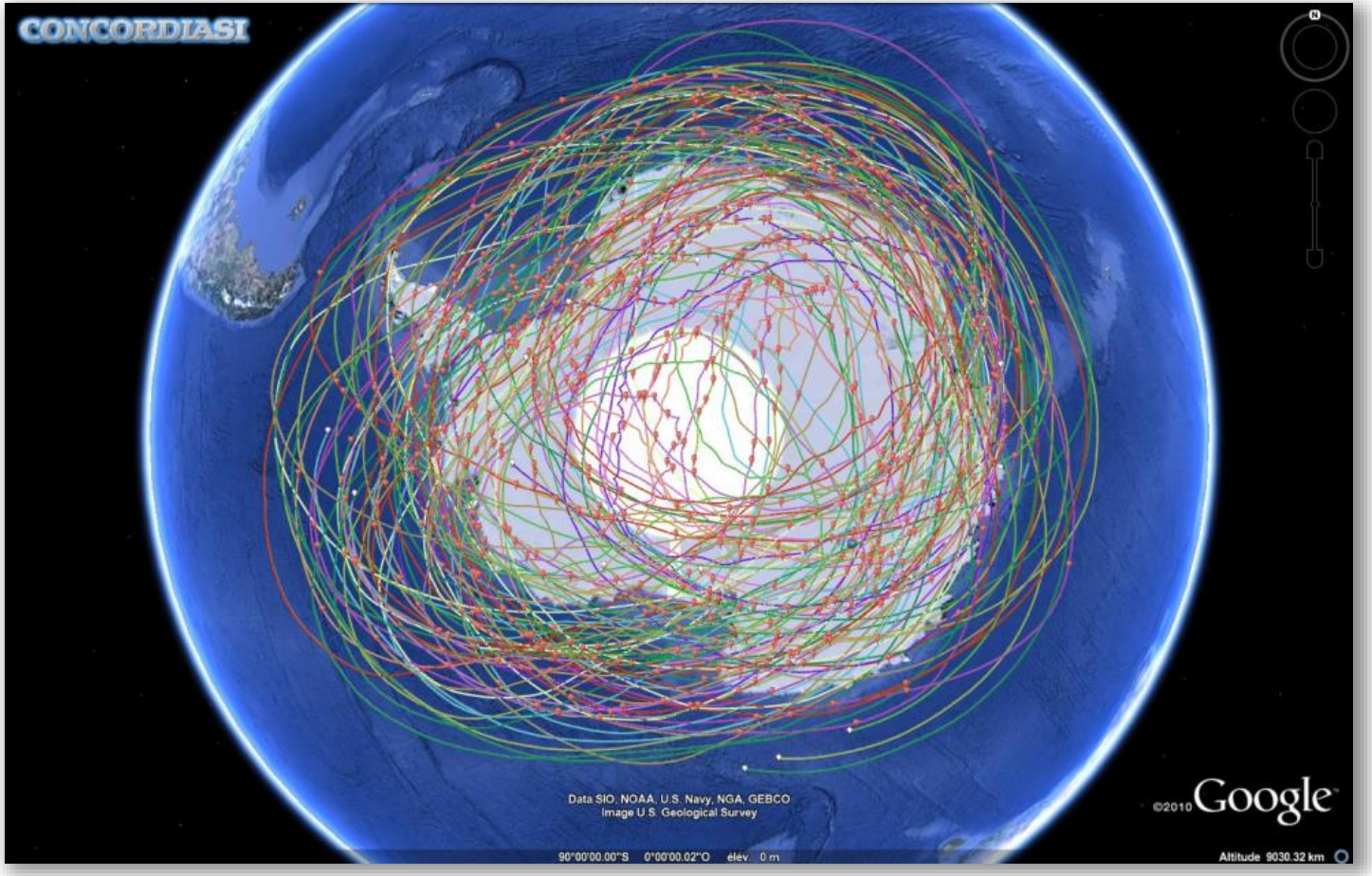


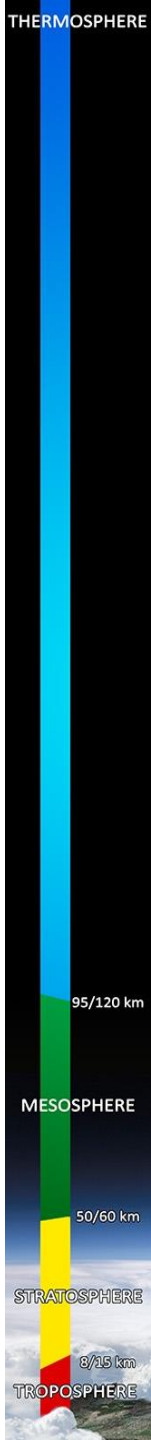




Picture: NASA

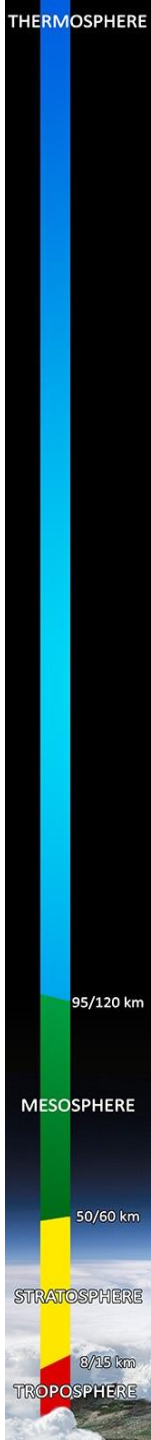
CONCORDIASI 2010





Picture: NASA

Polar stratosphere clouds



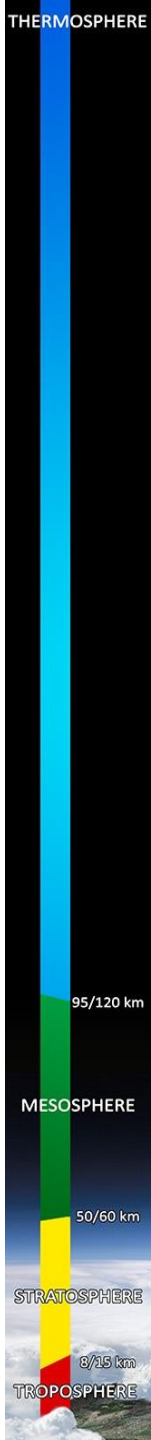
Video: Andøya Space Center

After the break...

Picture: Astronomi.no

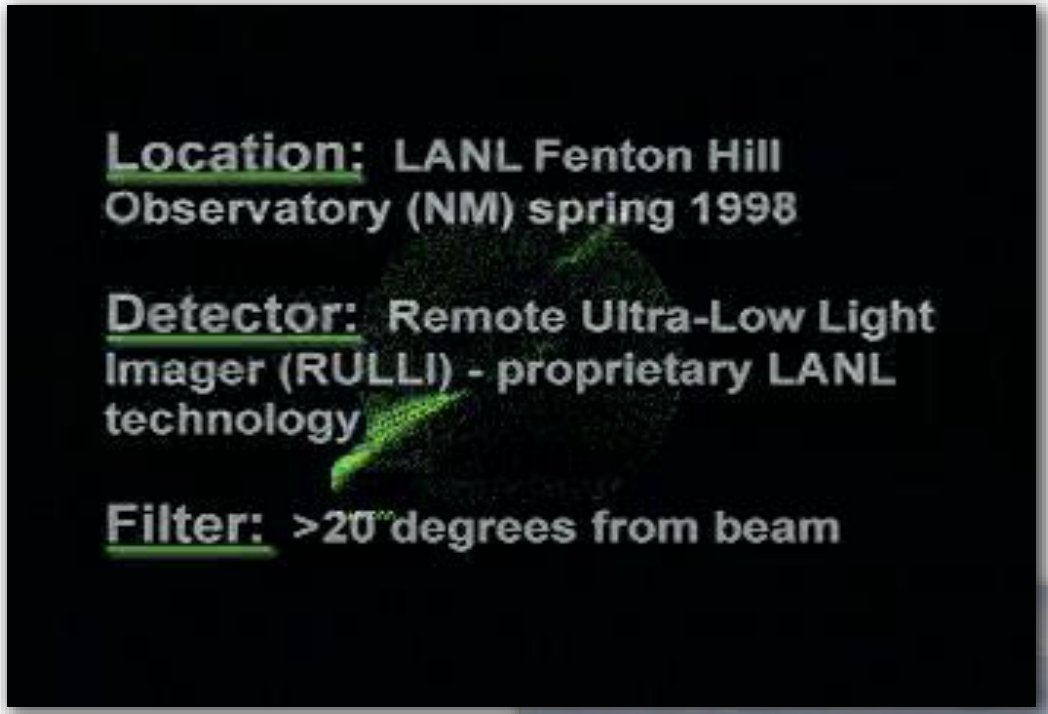
Mesosphere

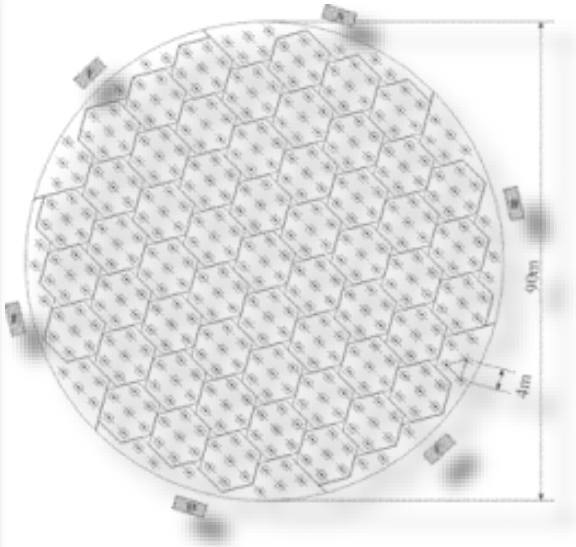
- Greek:
  «Mesos» = «in the middle»
- Nothing is really for certain

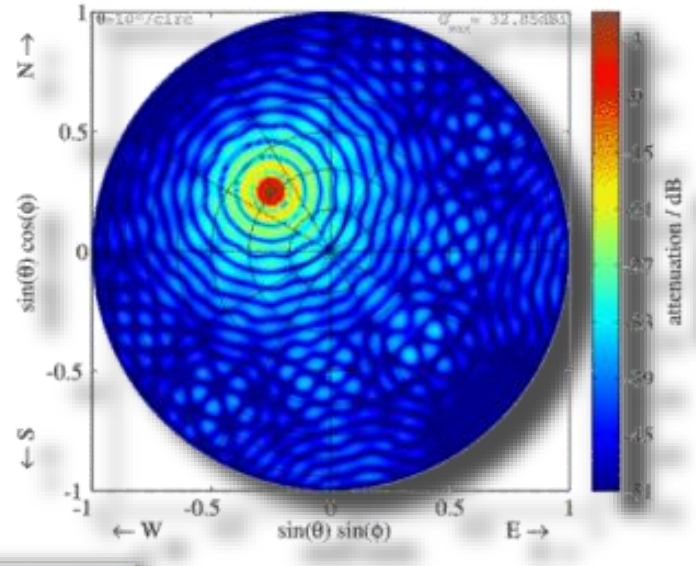


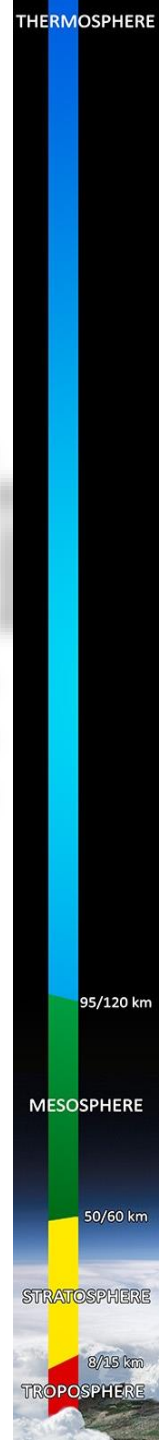
Video: A. Davis
Pictures: IAP

Remote Sensing: RADAR and LIDAR



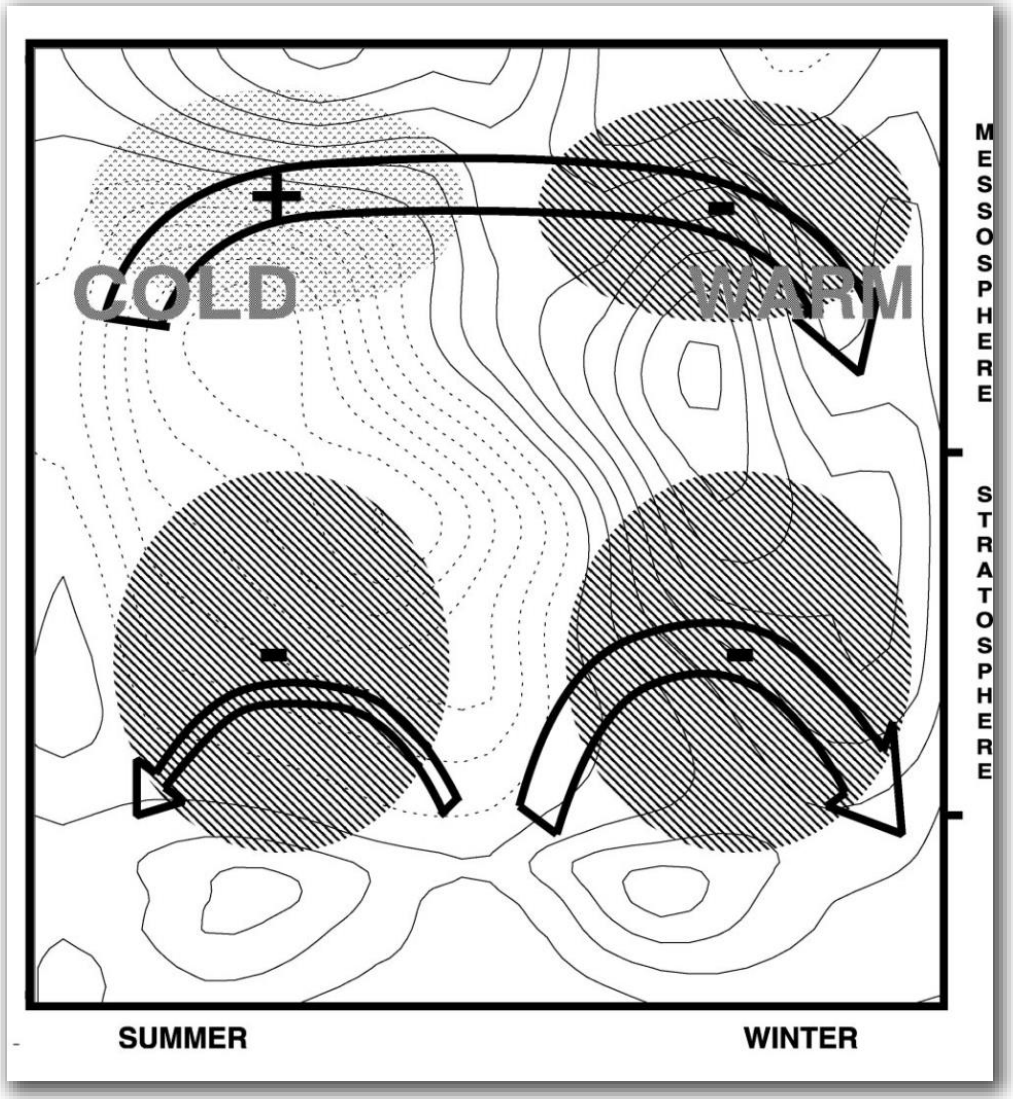


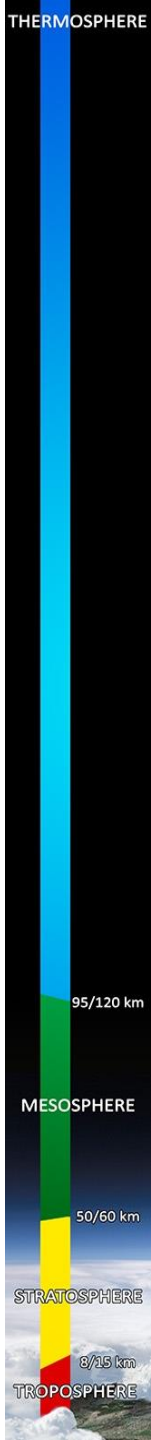




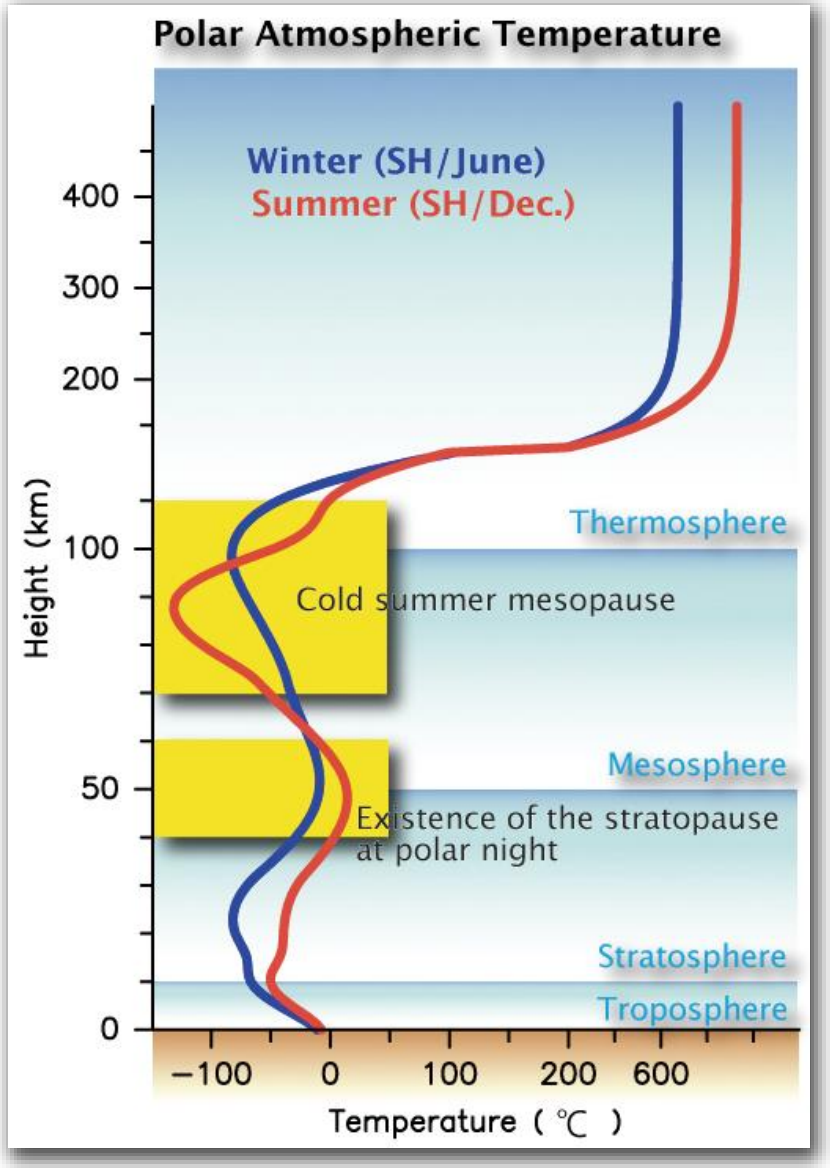
Pictures:
Figure: *Fritts and Alexander,* 2003
Lenticular clouds: A. Biebricher

Global vindsystem



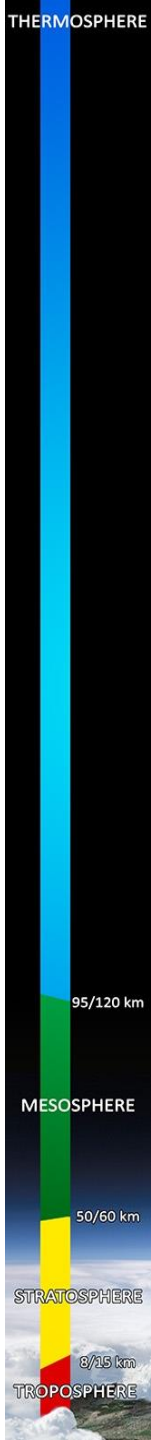


Picture: University of Tokyo



Cold polar mesopause

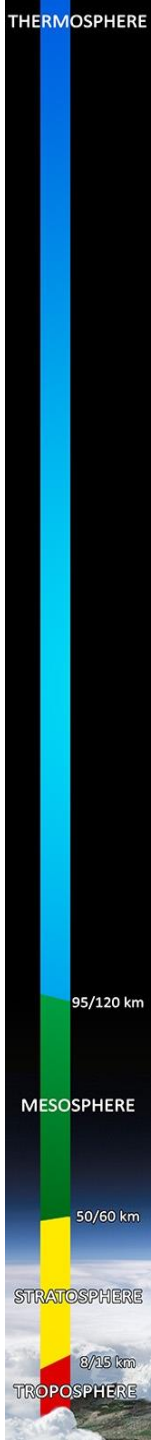
130 K = ca. – 140° C in the polar regions, in summer!



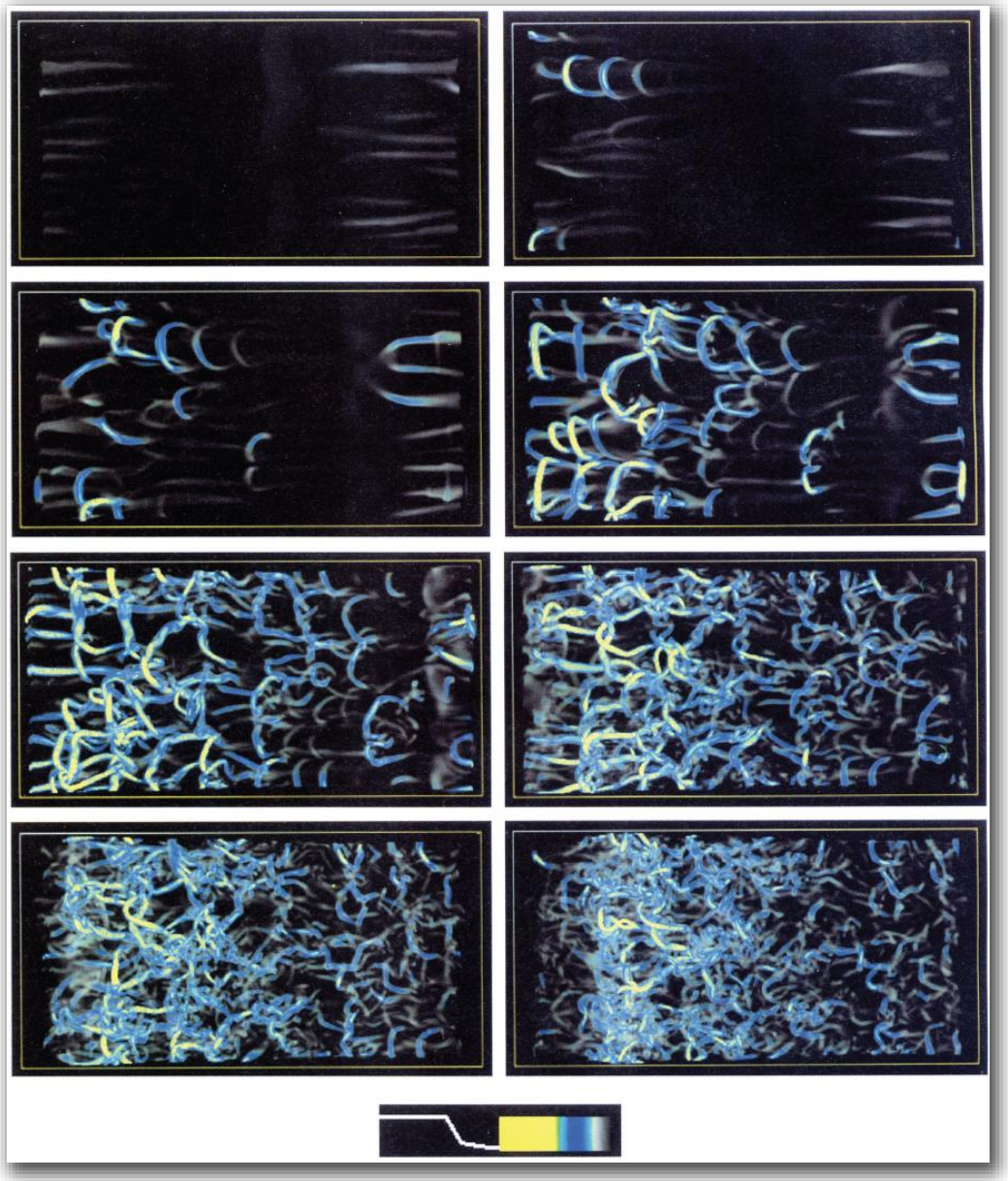
Video: NASA

Meteors

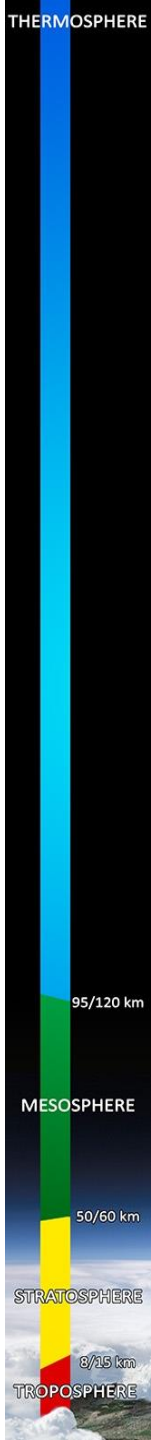
- Meteor = shooting star
- Ablate (mainly) in the mesosphere
- 1-100 t/d!



Picture: *Fritts and Alexander,* 2003

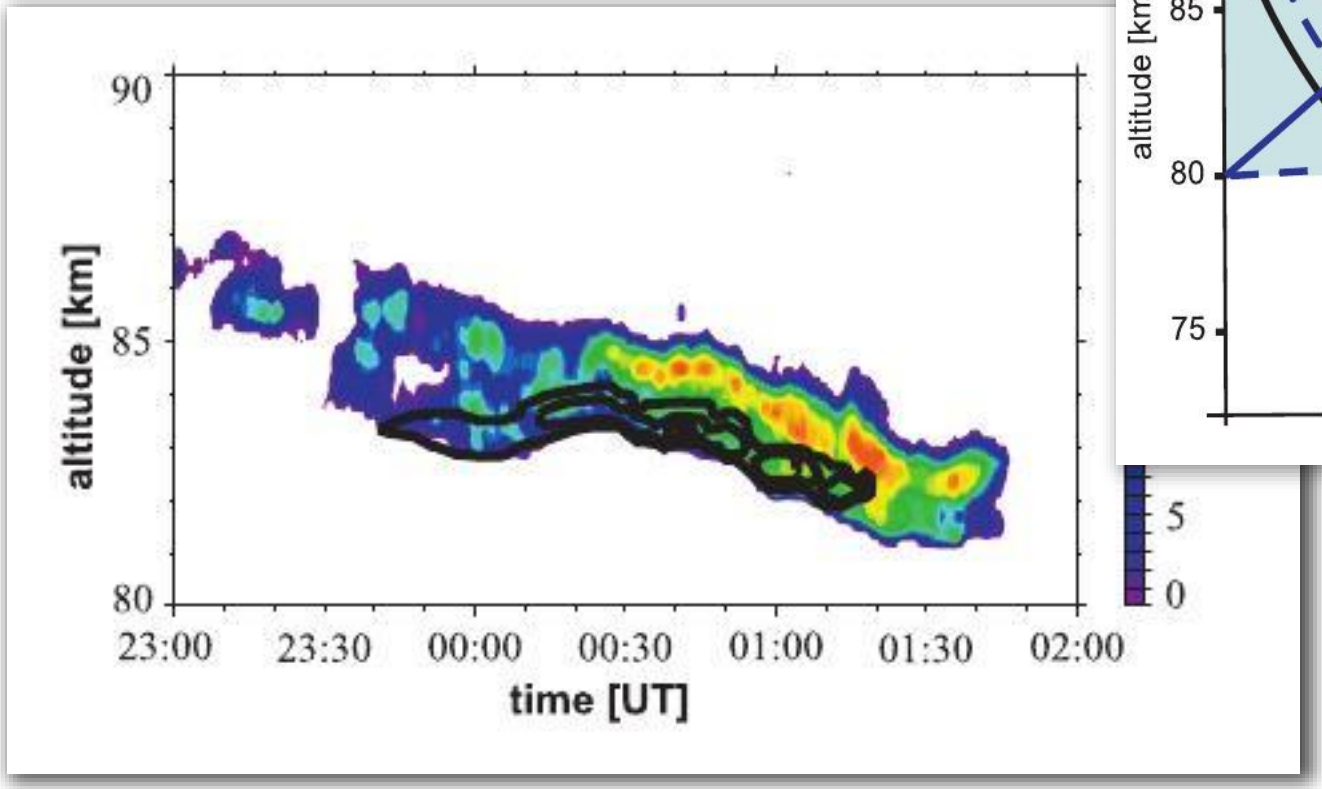


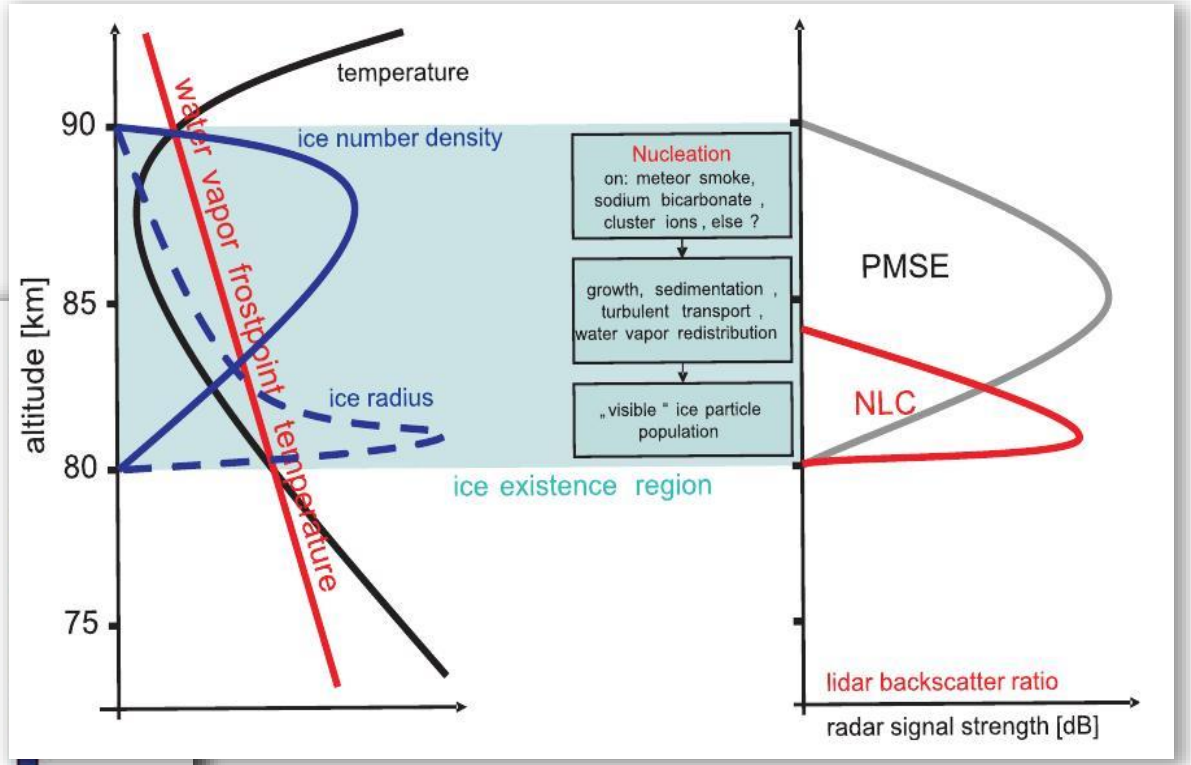
Turbulence

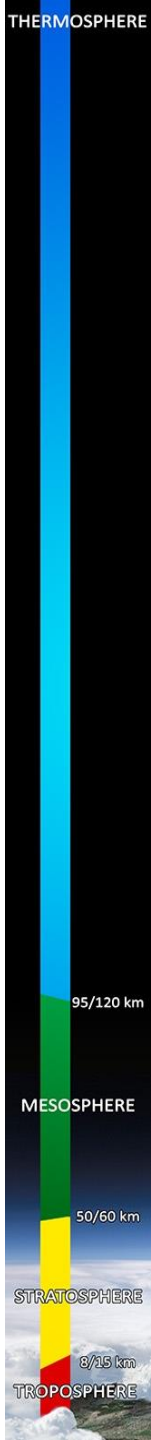


Picture:
Plot: *Rapp and Thomas*, 2006
Lidar: *Nussbaumer et al.*, 1991

Noctilucent Clouds

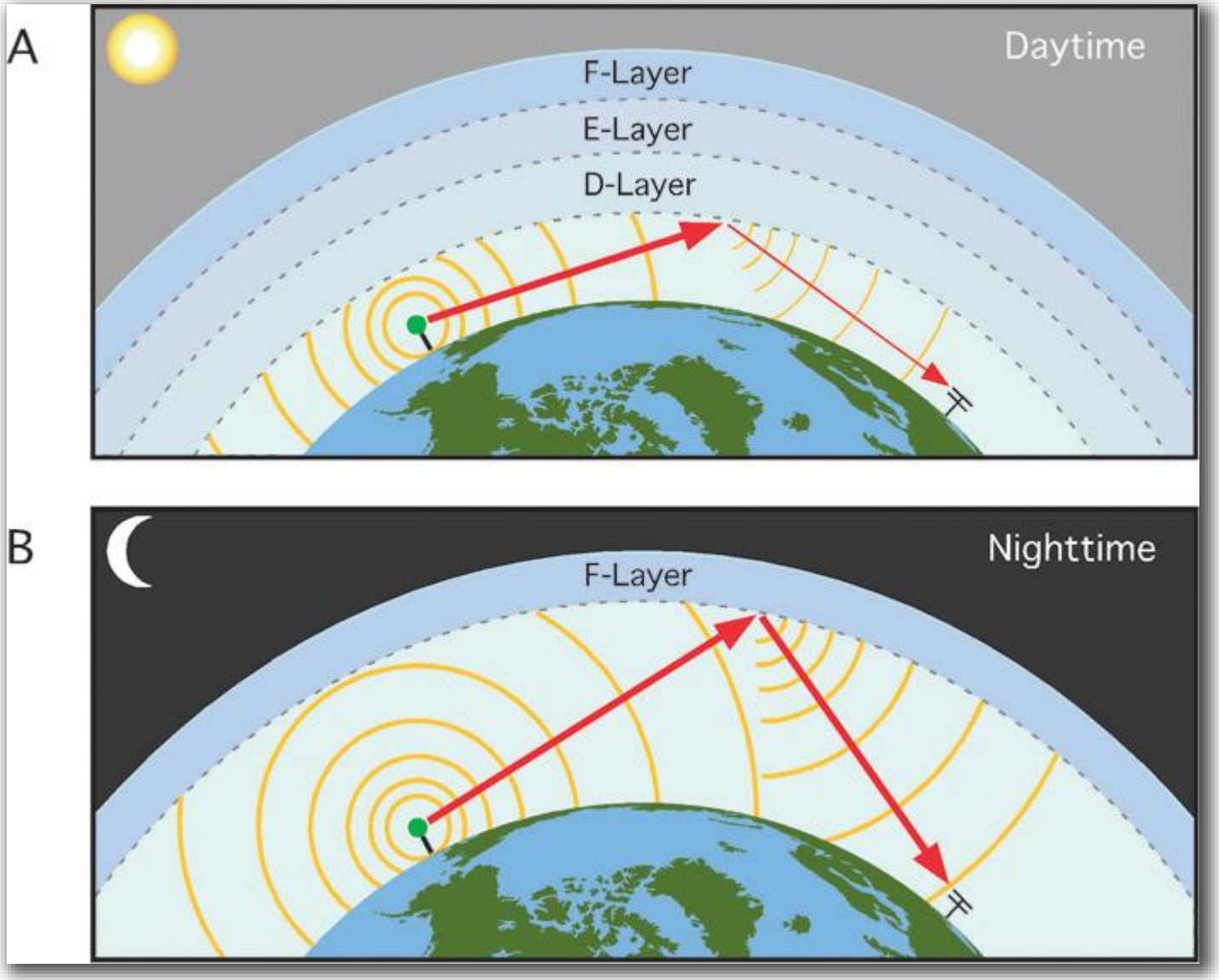


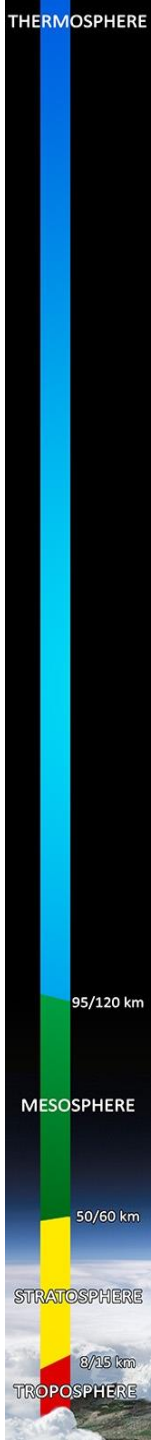




Picture: eoearth.org
Video: J. Stegman

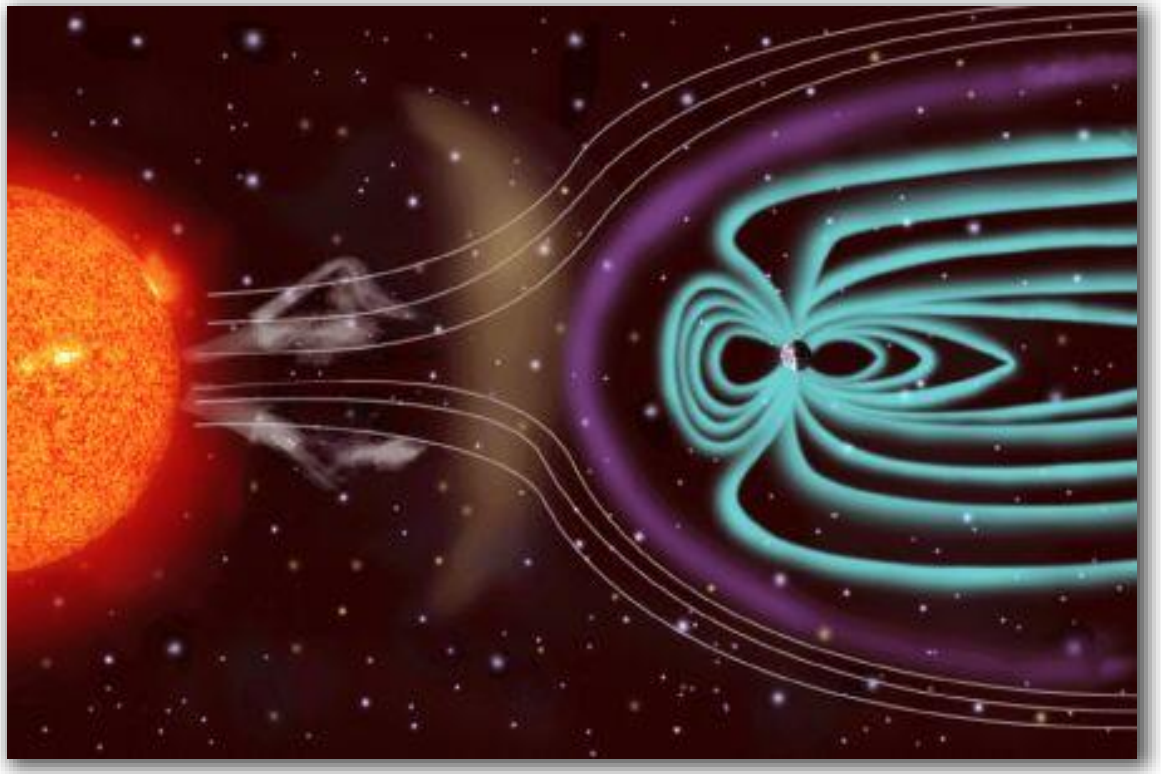
Thermosphere

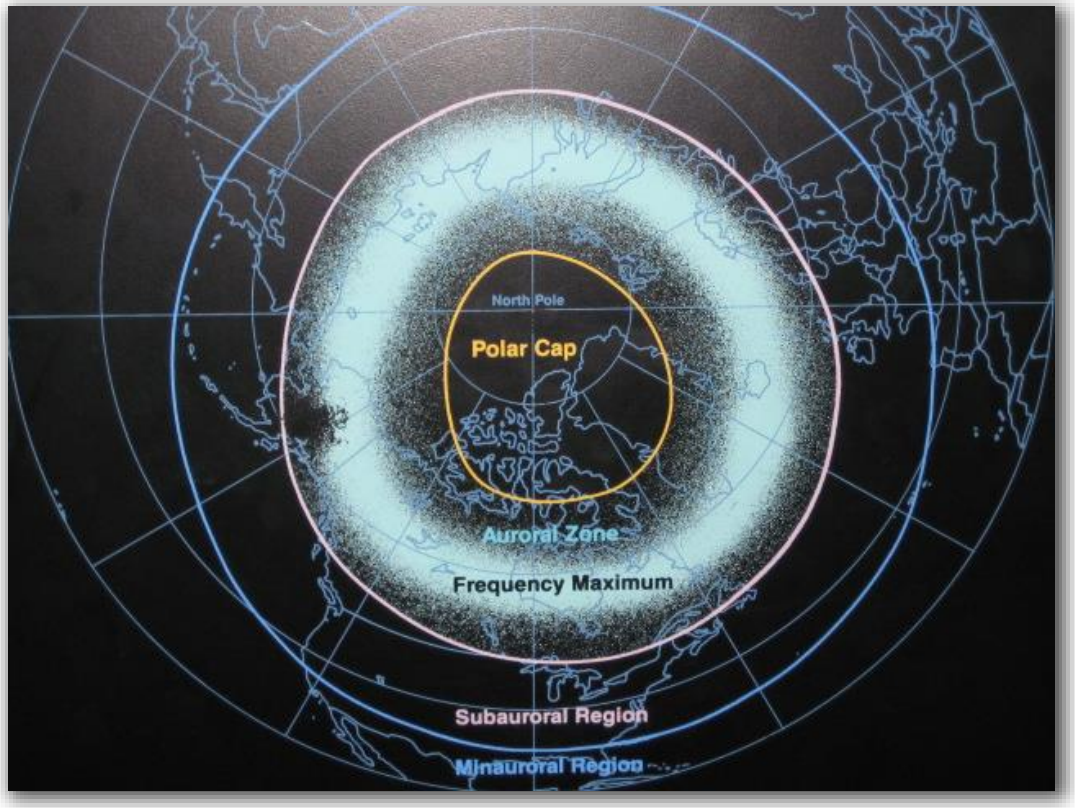


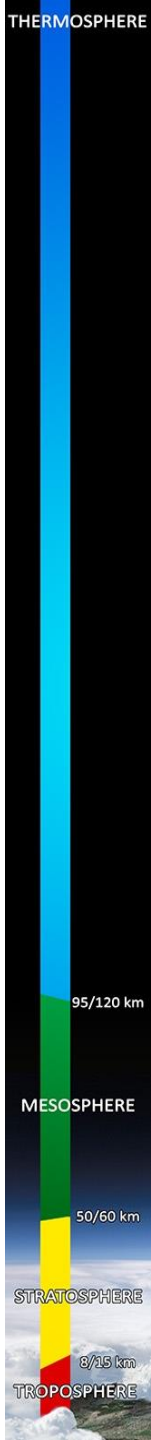


Pictures: NASA

Solar wind

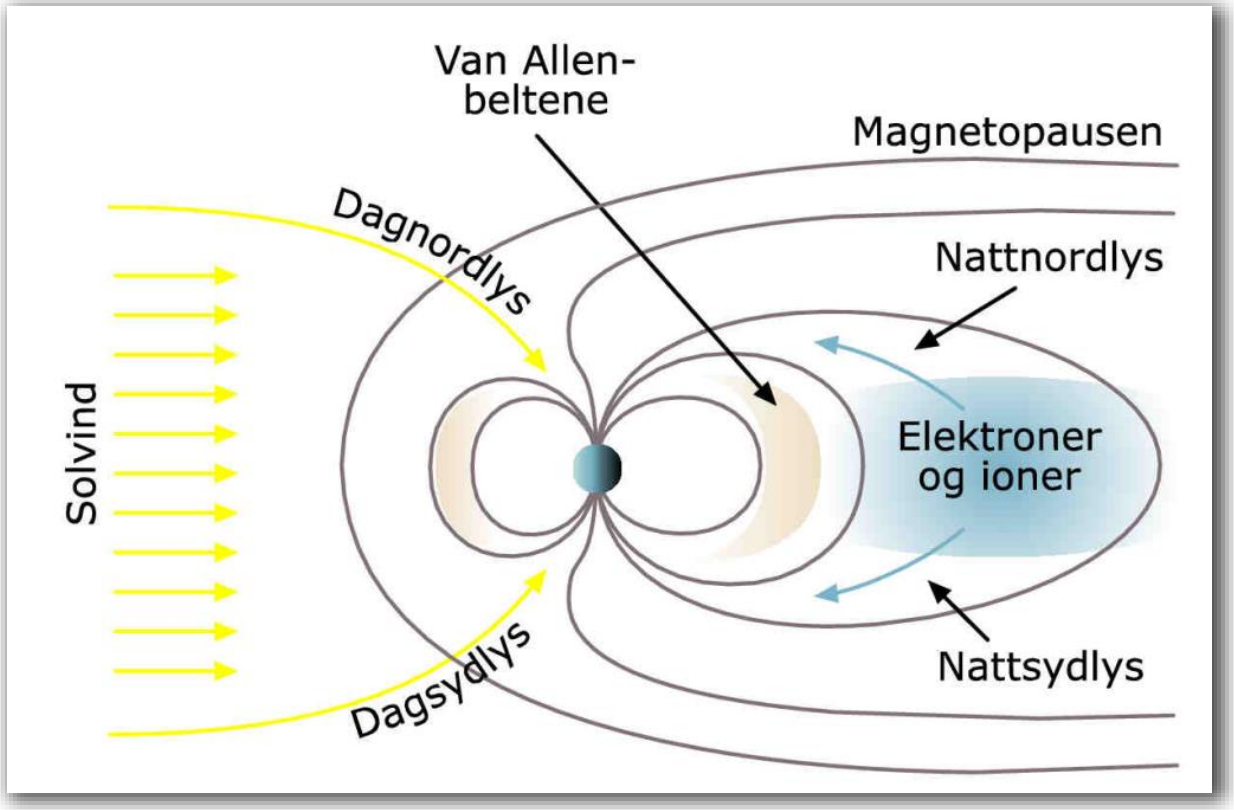






Pictures: NDLA.no

Magnetic recombination



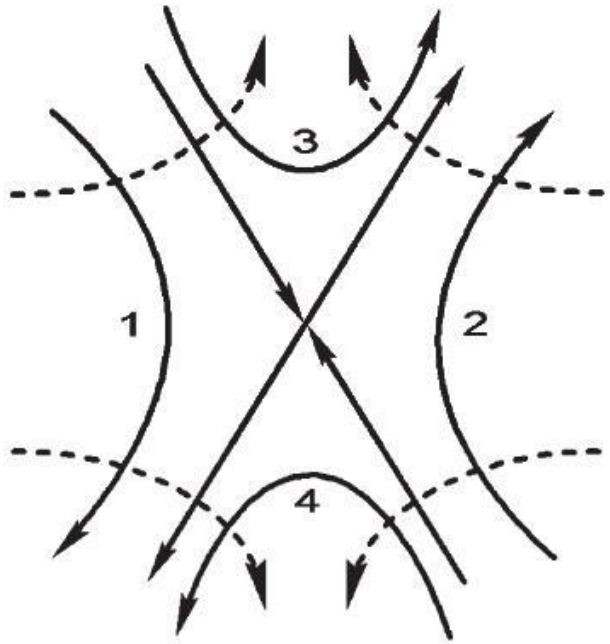
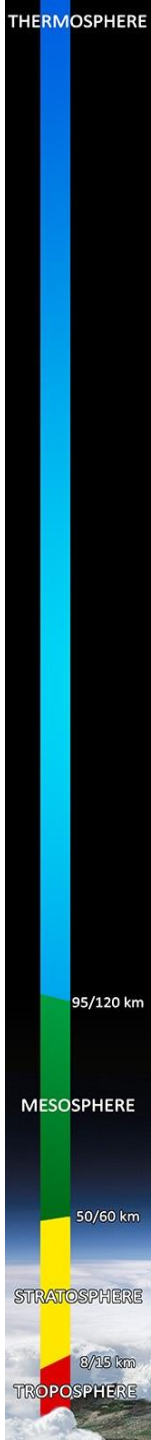
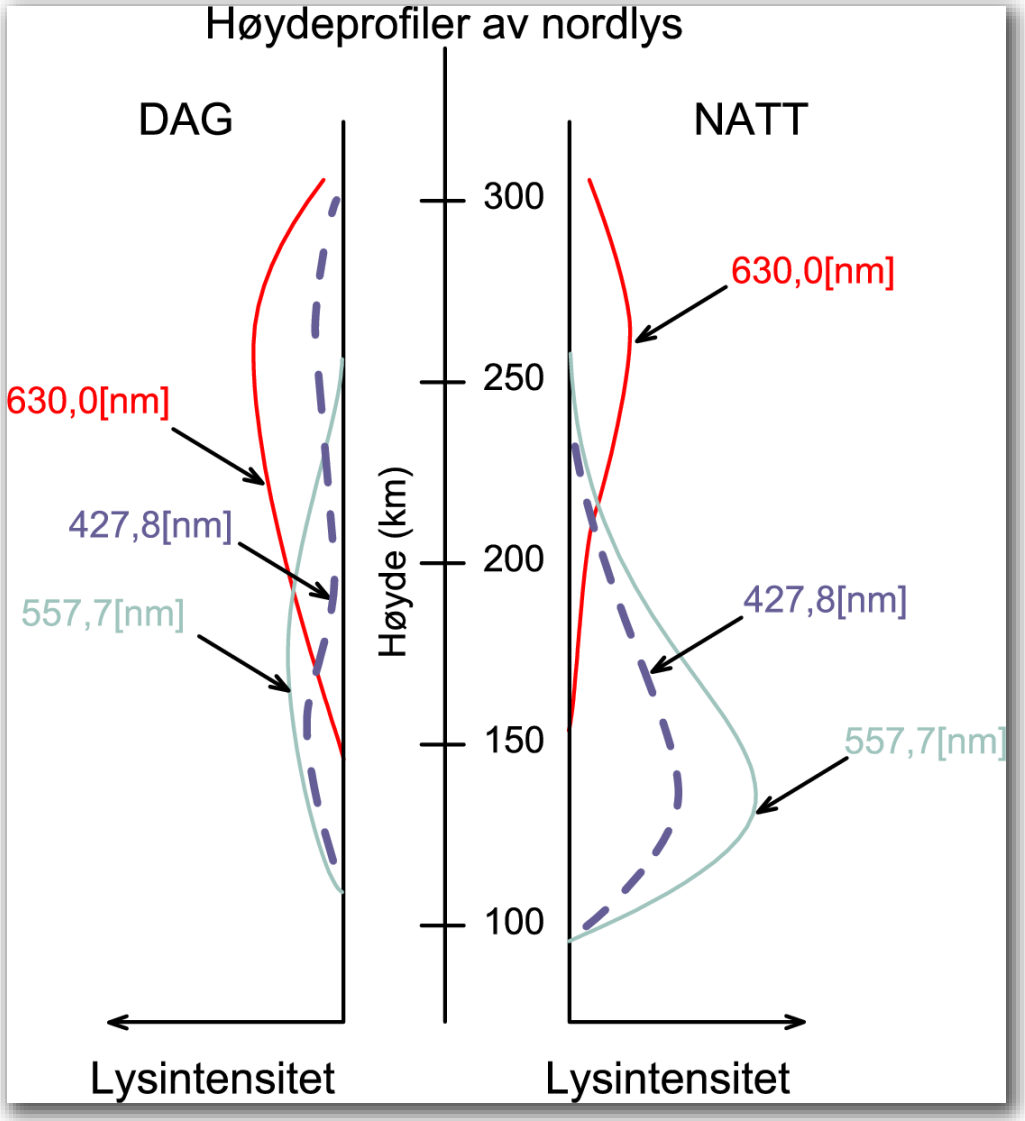


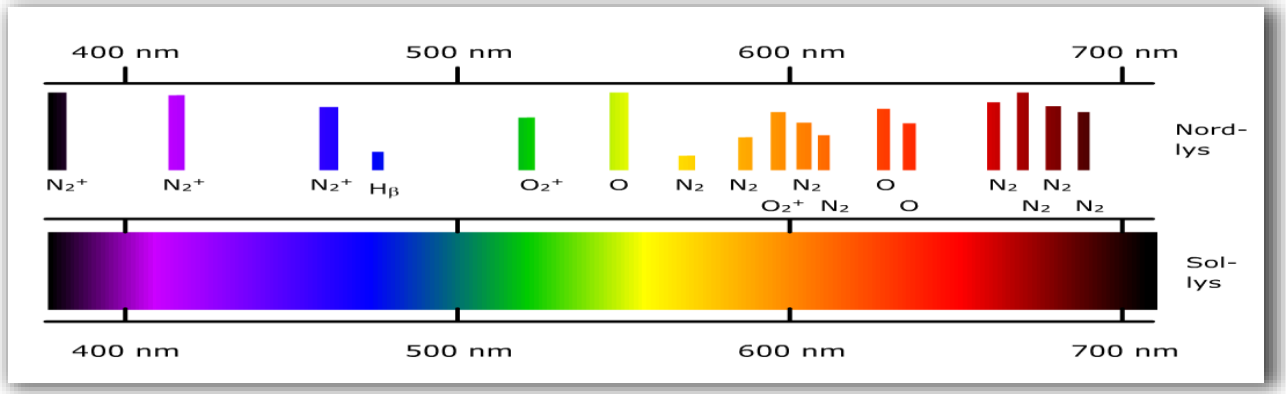
Fig. 1. Concept of magnetic reconnection: magnetic merging at an X-type neutral line. The solid lines are the magnetic field lines, whereas the dashed lines are the plasma flow lines.

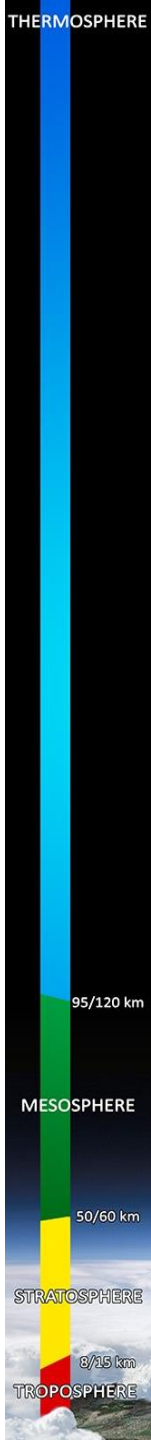


Pictures: NDLA.no

Aurora

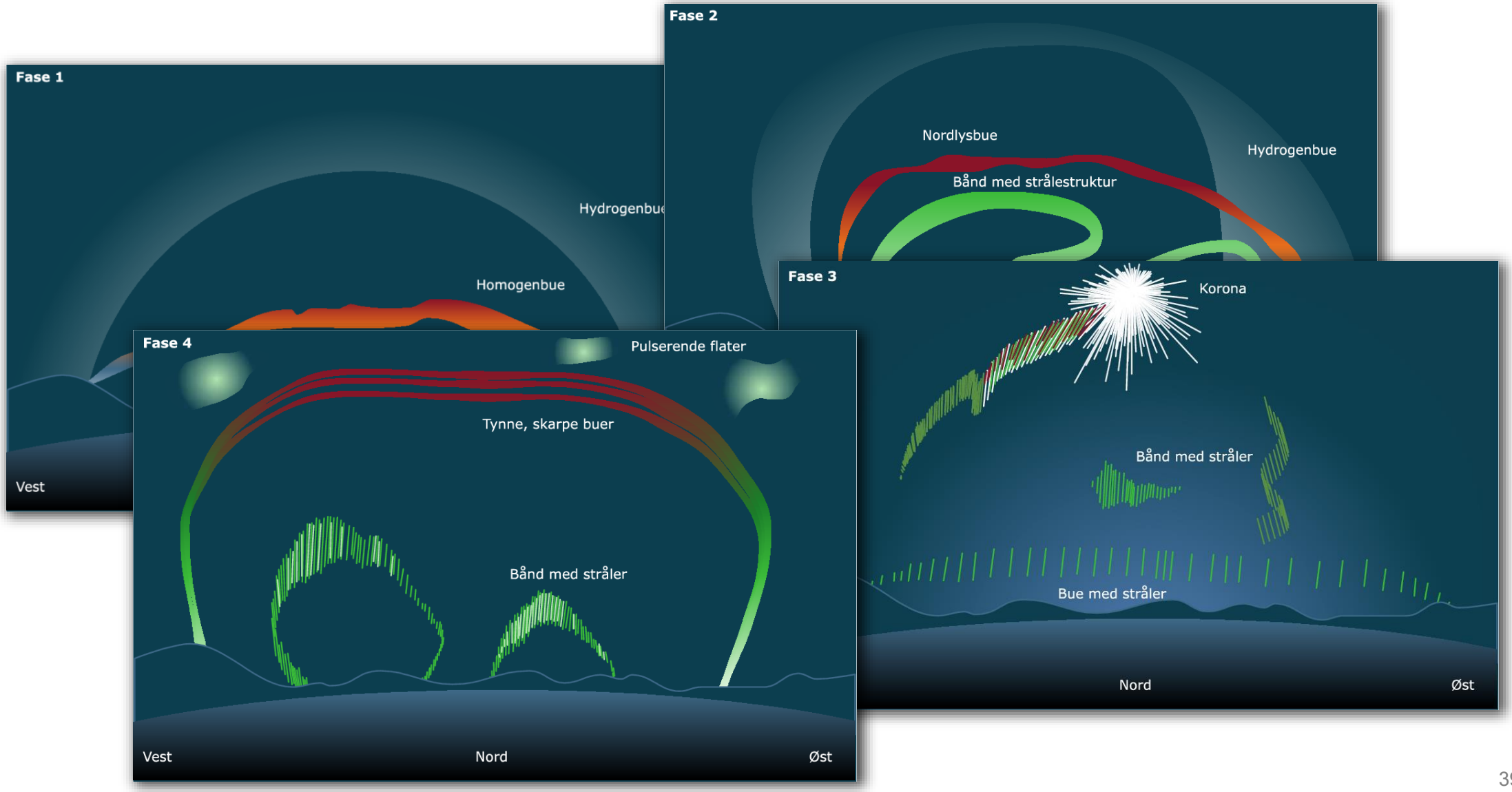


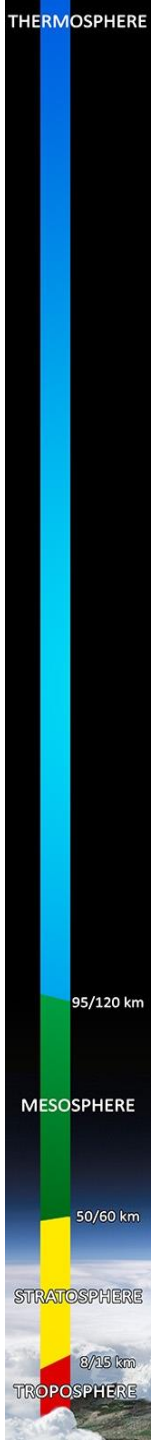




Pictures: NDLA.no

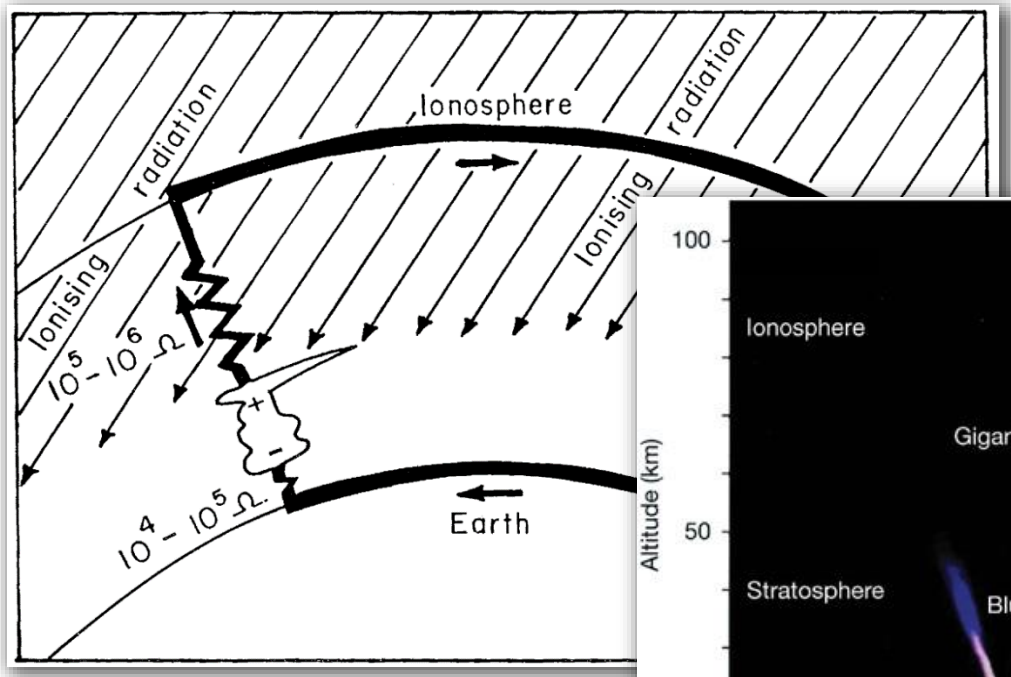
The «rhythm» of the Aurora

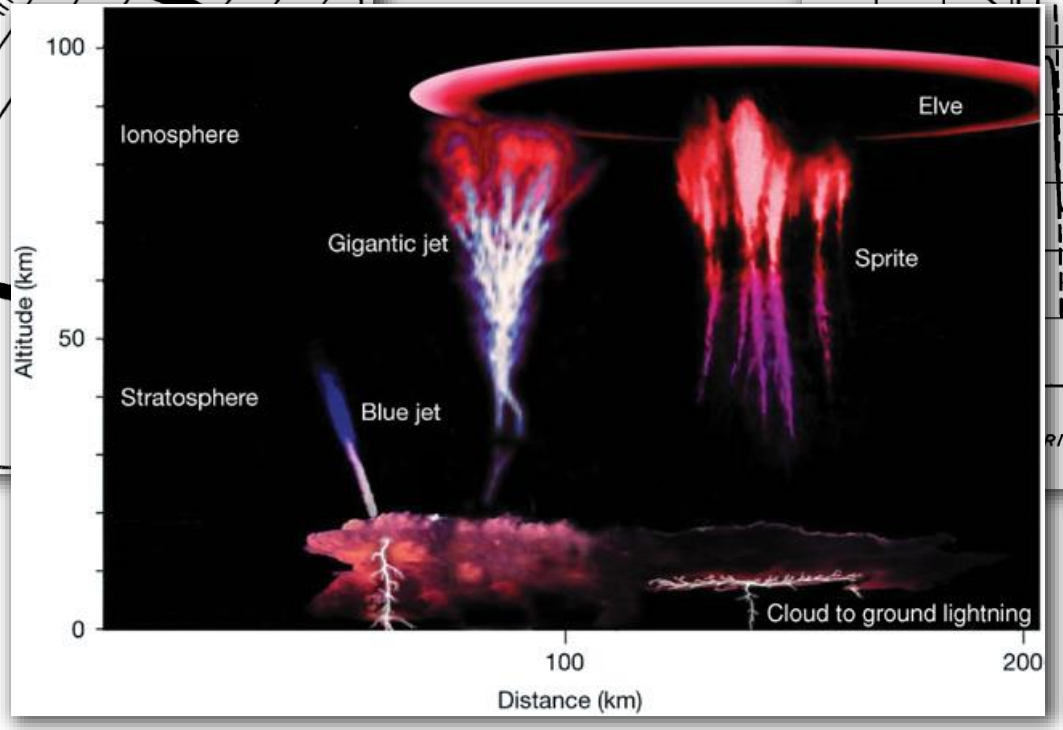


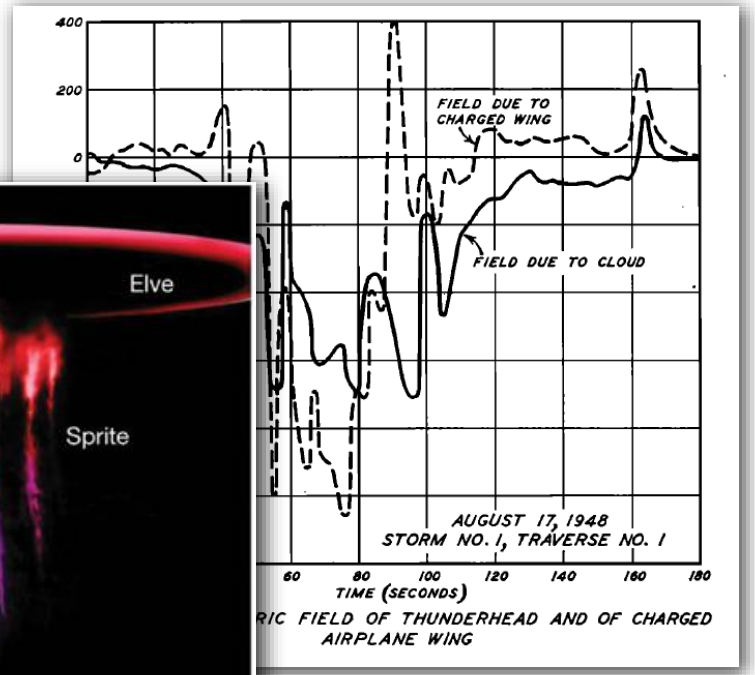


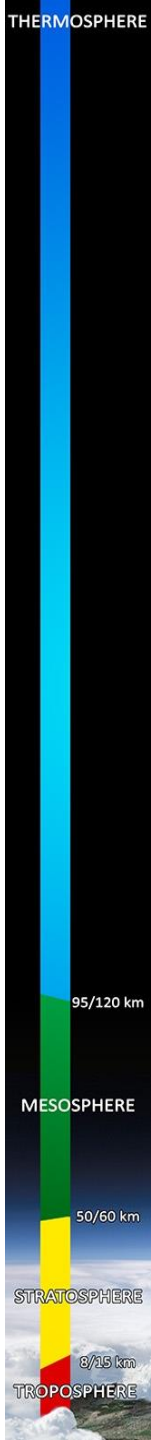
Pictures:
Global electric circuit: Sing *et al.*, 2004
Current plots. Gish and Wait, 1950
TLE: Nature

Global electric circuit



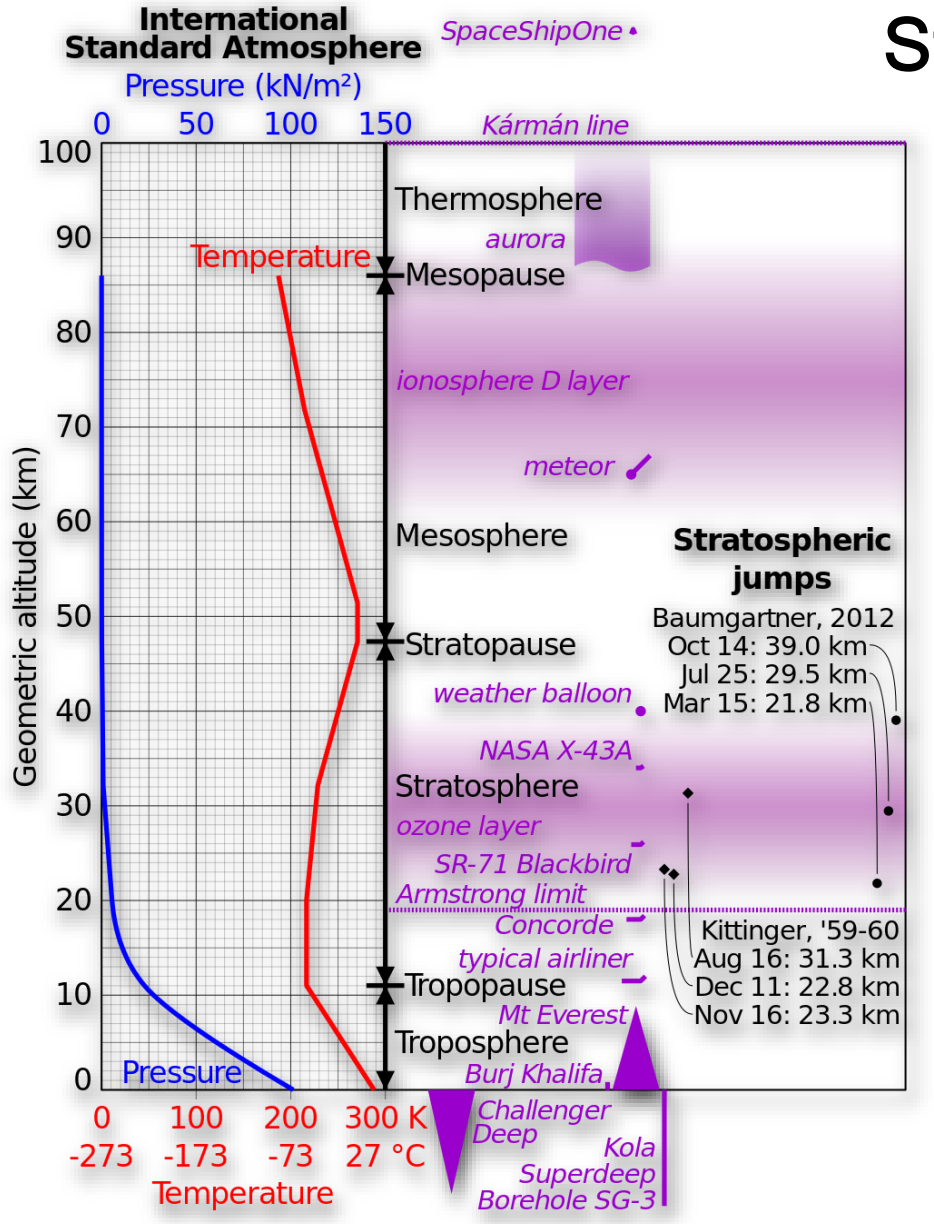


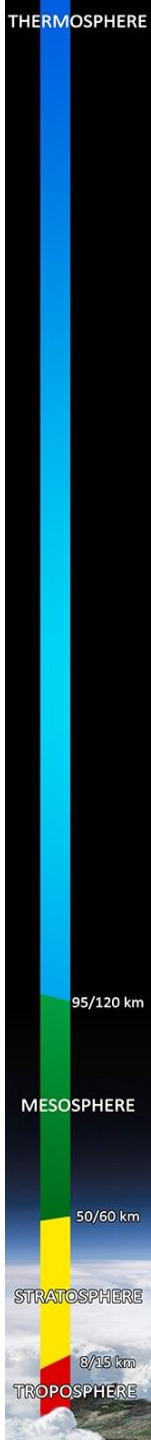




Picture: cmglee via Wikimedia Commons

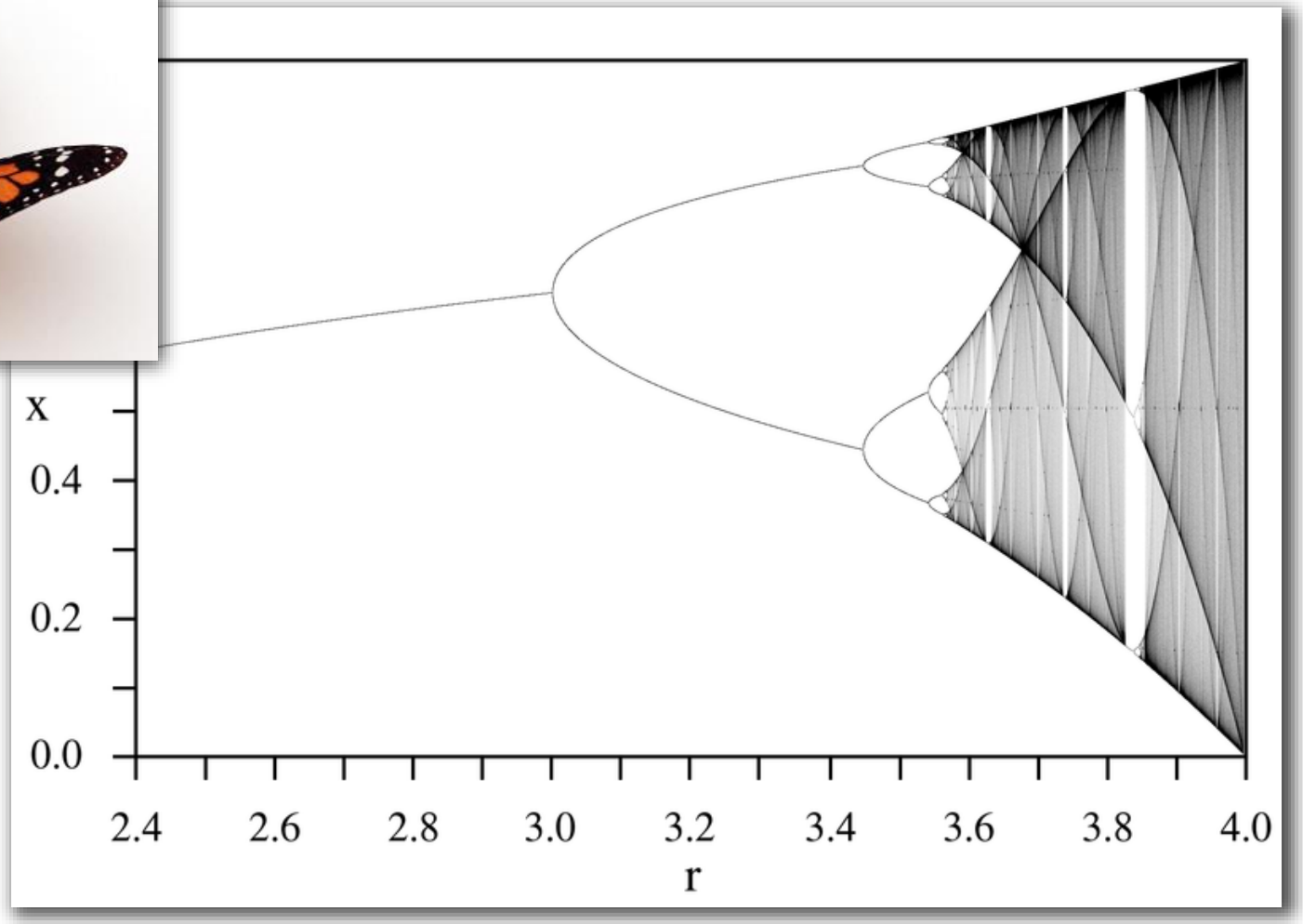
Standard atmosphere

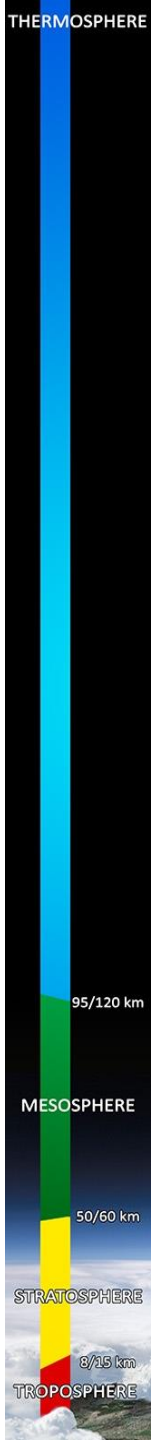




Picture: cosmosmagazine.org
Plot: PAR via Wikimedia Commons

Chaos and randomness





Picture: grapeandgo.deviantart.com

Questions?

NAROM/ASC in social media: *naromasc*
I'm there, too: *alexbiebricher*