Extension of the polar vortex into the mesosphere

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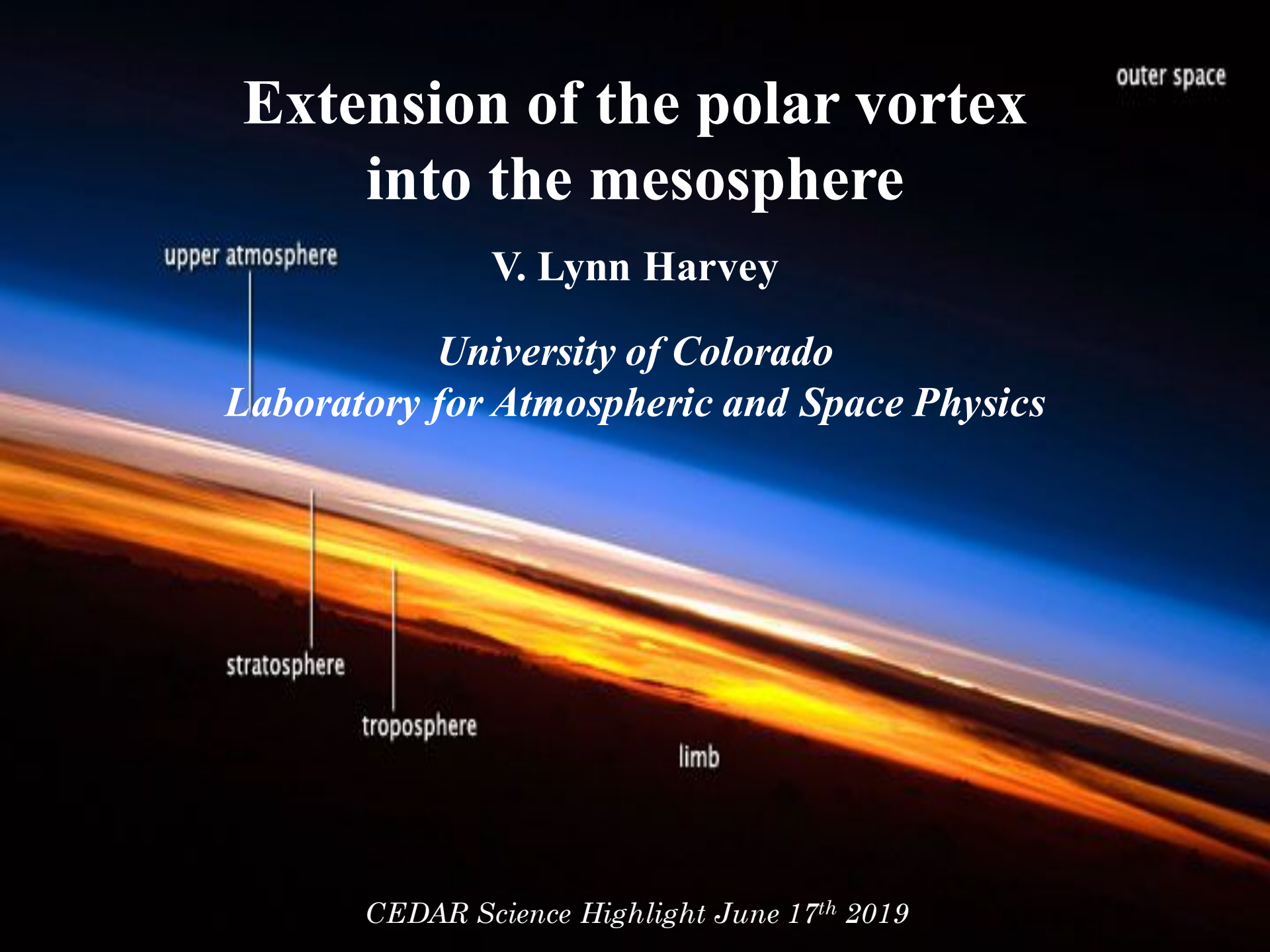

CEDAR Science Highlight June 17th 2019

Outline

- The winter Polar Vortex
- The mean meridional circulation
- Why do we care? Sun-Earth coupling
- Dynamical vs. Chemical vortex definitions
- Stratospheric vs. Mesospheric vortex

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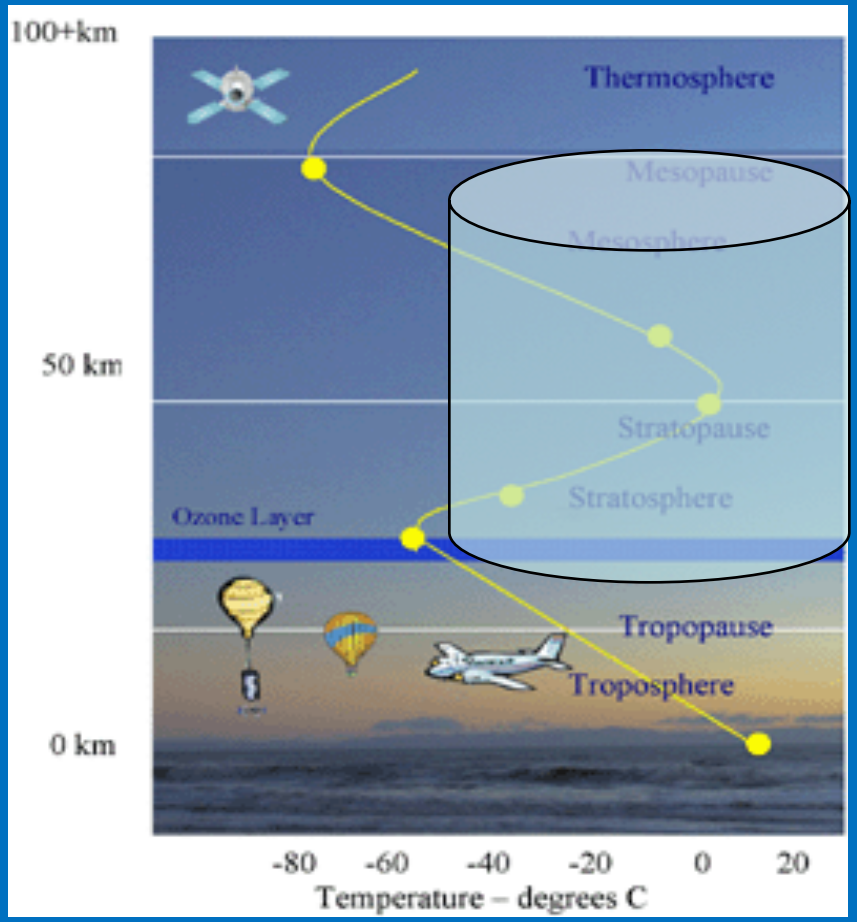
- **The winter Polar Vortex**
- **The mean meridional circulation**
- **Why do we care? Sun-Earth coupling**
- **Dynamical vs. Chemical vortex definitions**
- **Stratospheric vs. Mesospheric vortex**

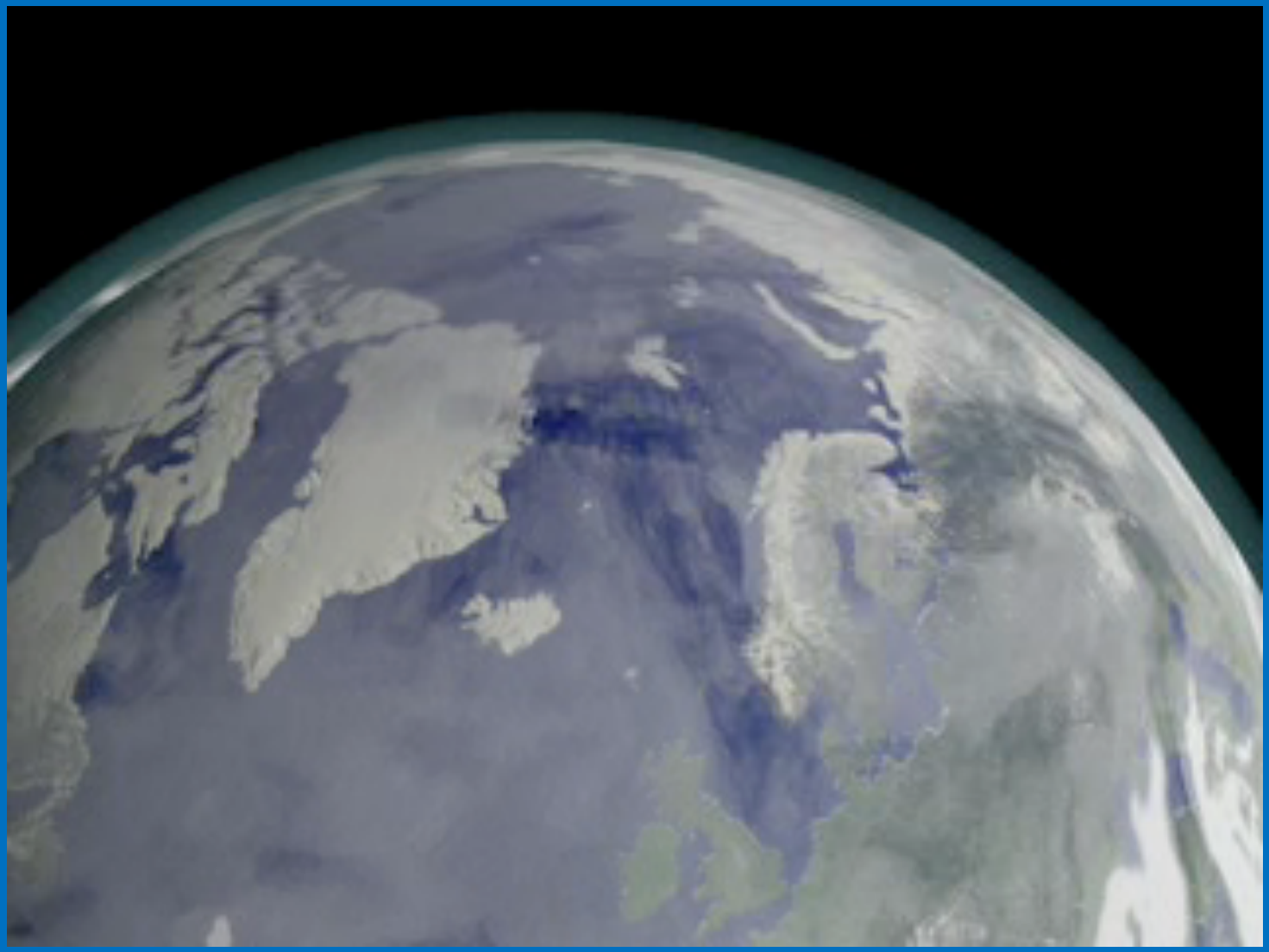
The winter polar vortex in the stratosphere and mesosphere



During winter in the polar night there is no sun to heat O_3

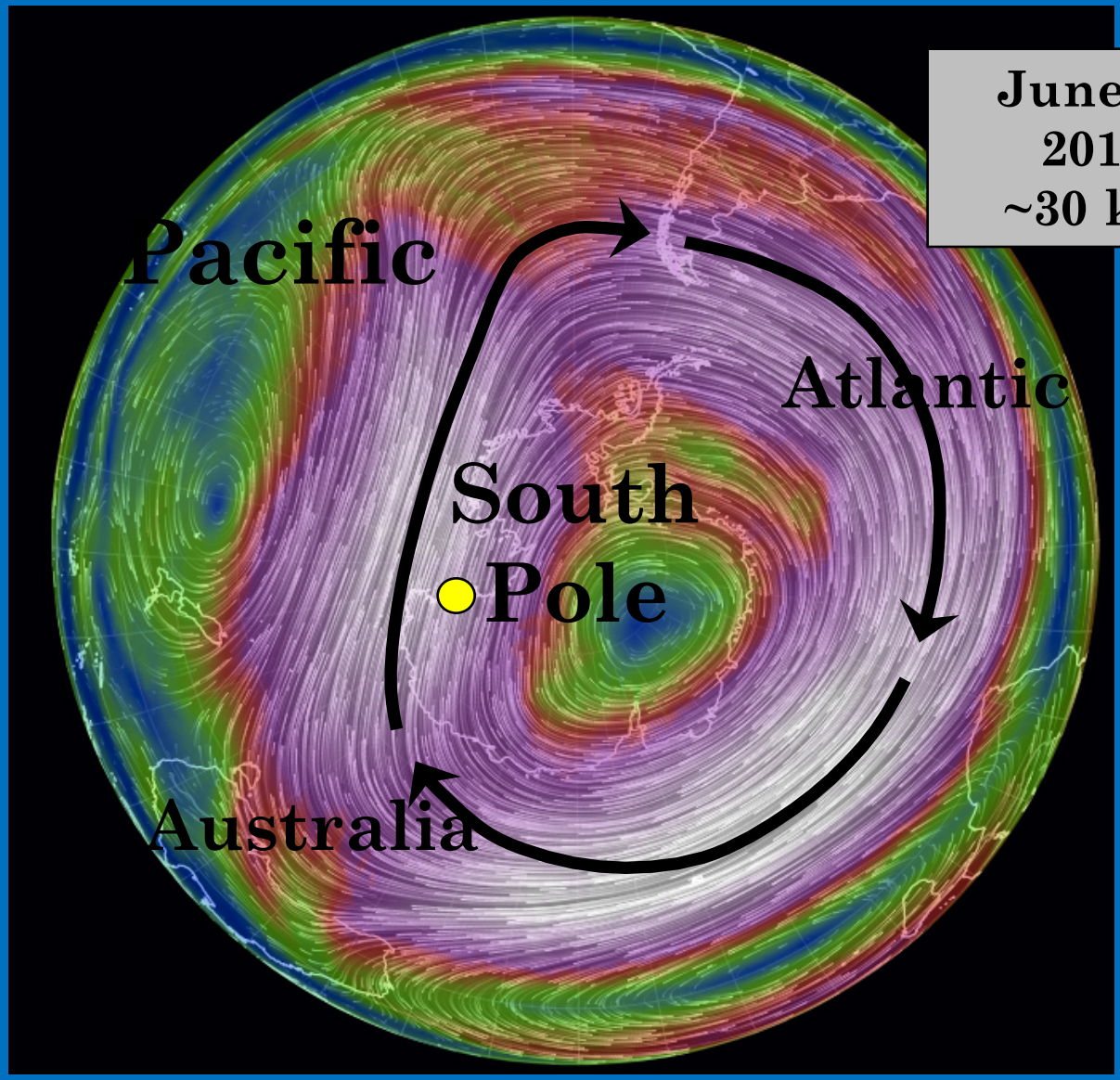
- cold stratosphere
- westerly jet stream

The westerly polar night jet flows around the cold polar vortex



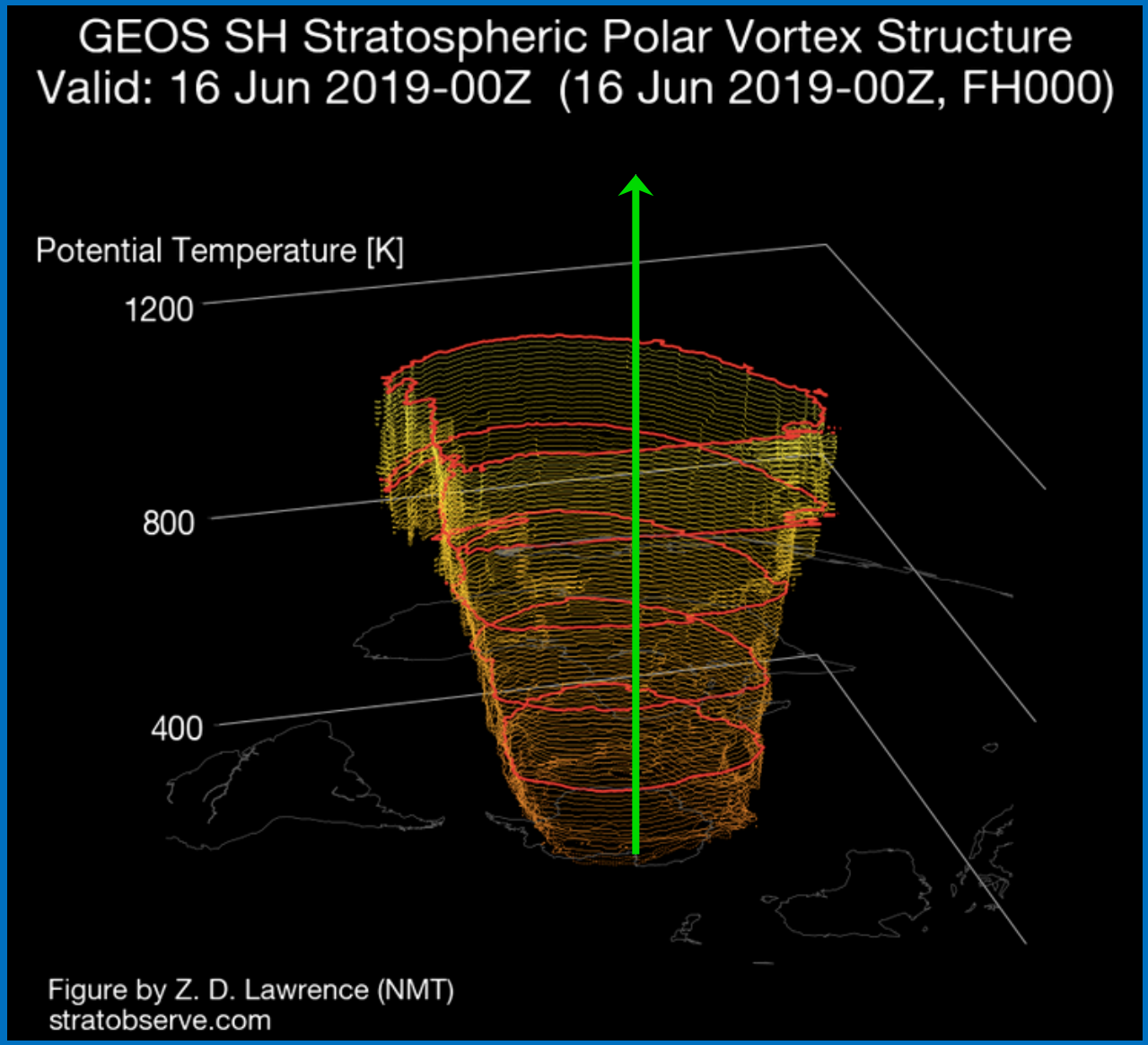
Fastest winds at the vortex edge. Air inside remains isolated.
Daily wobbling and stretching is due to weather below.

The Antarctic Polar Vortex Today



http://earth.nullschool.net

The Antarctic Polar Vortex Today



See https://stratobserve.com/misc_vort3d

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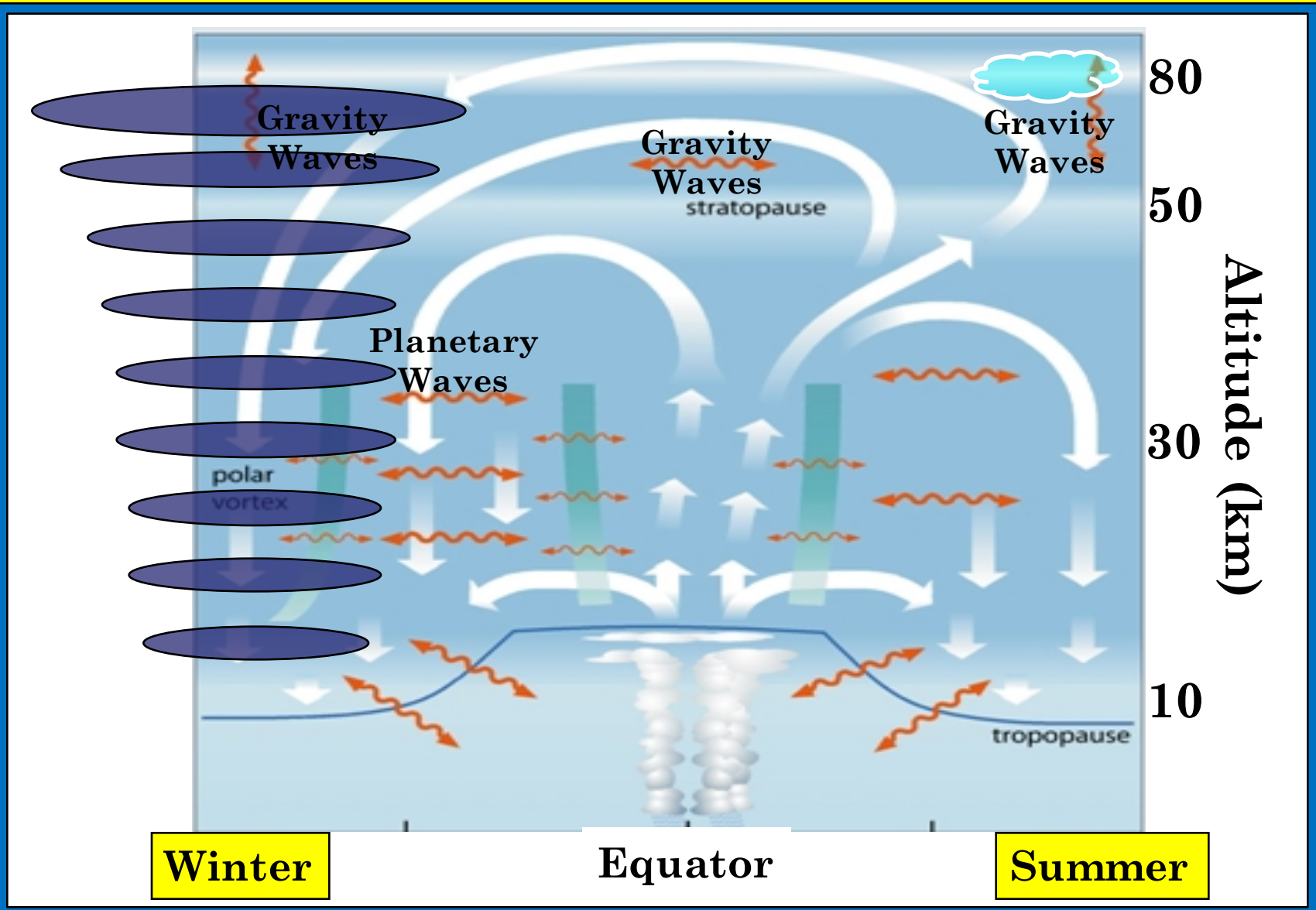
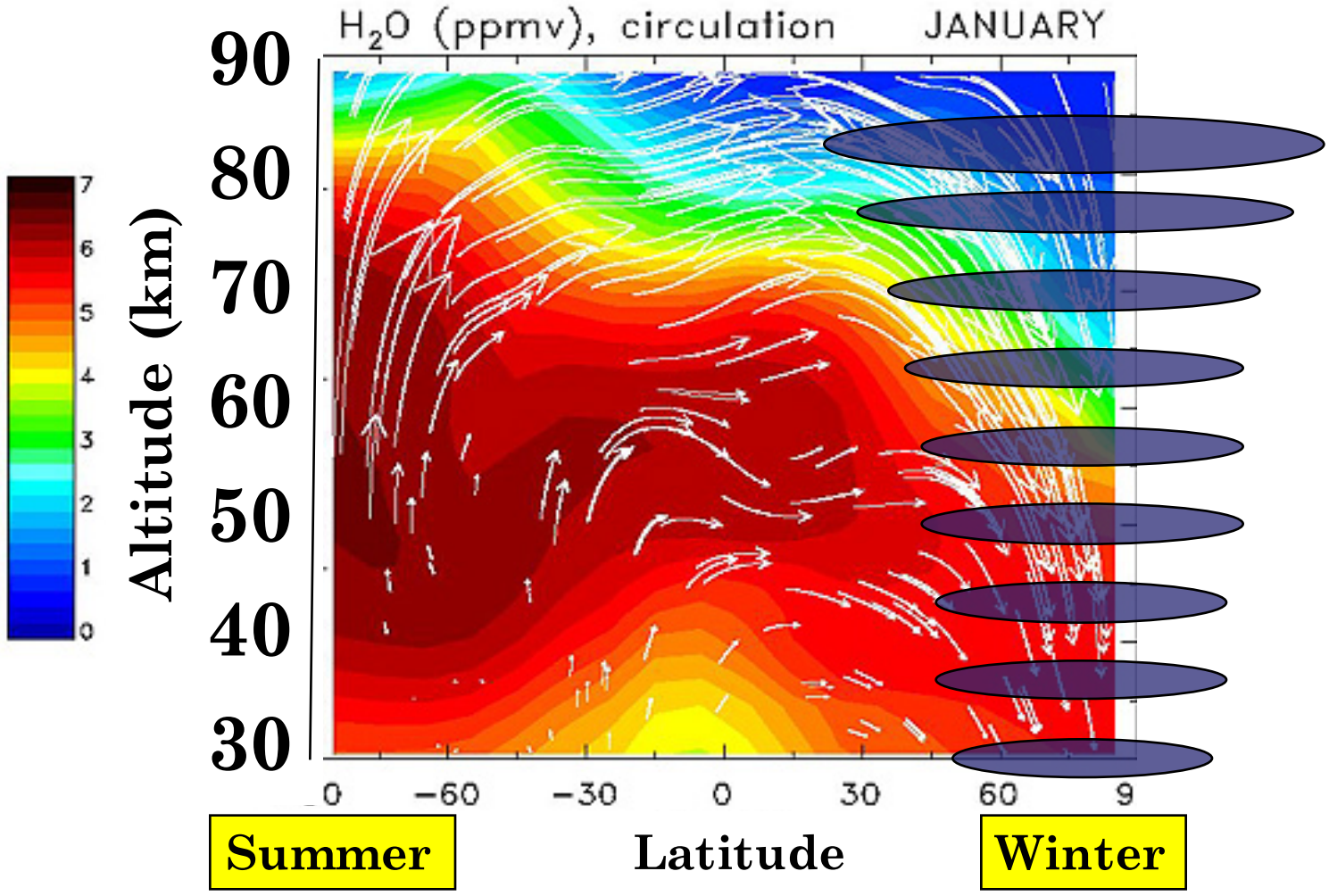
Planetary and Gravity waves drive the Meridional and Vertical "Residual" Circulation



The "Residual" Circulation transports trace gases



Moist air is advected upward in summer and dry air is advected downward in winter

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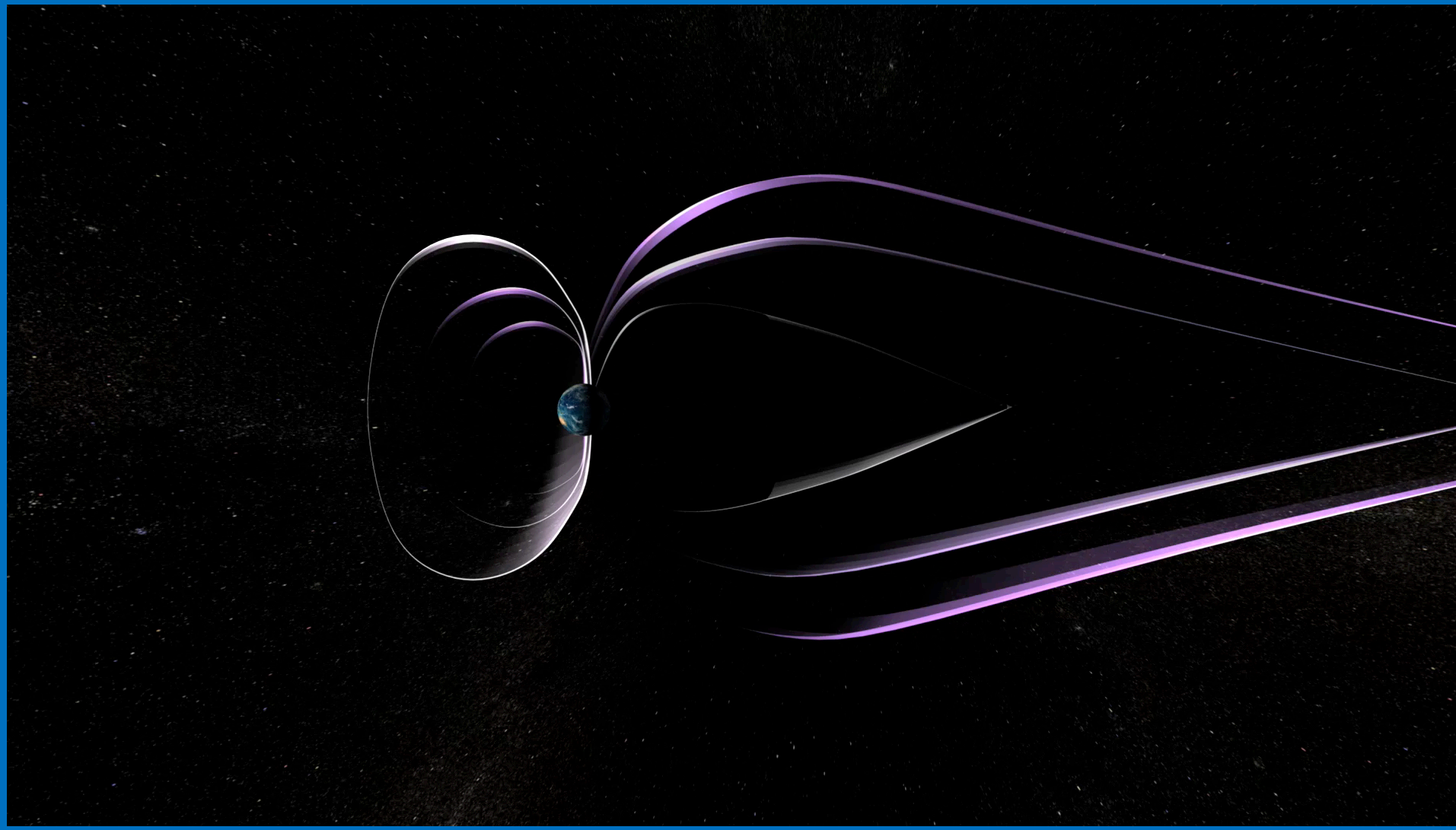
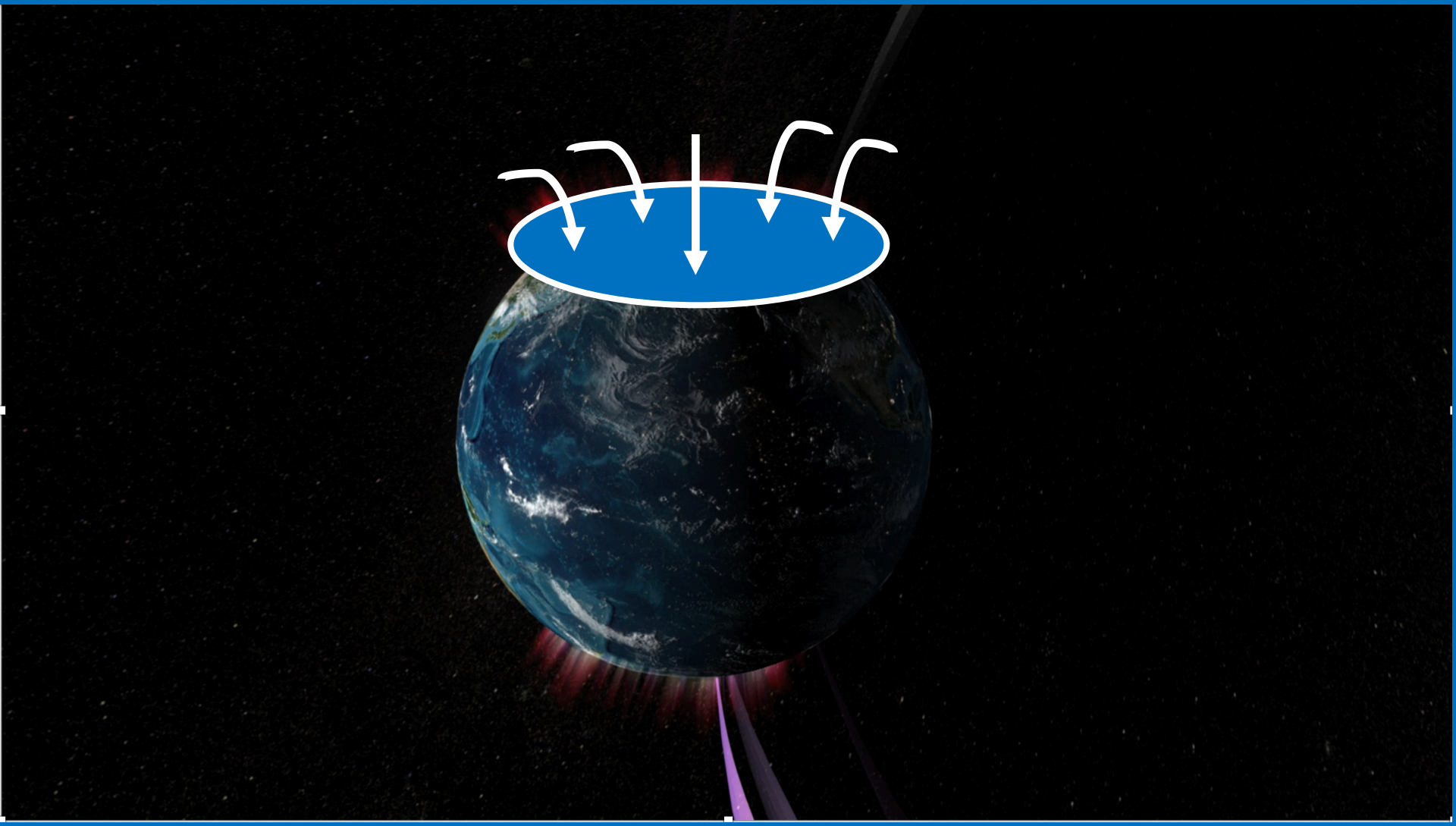
Solar material collides with Earth's magnetosphere injecting energy into near-Earth space triggering the aurora



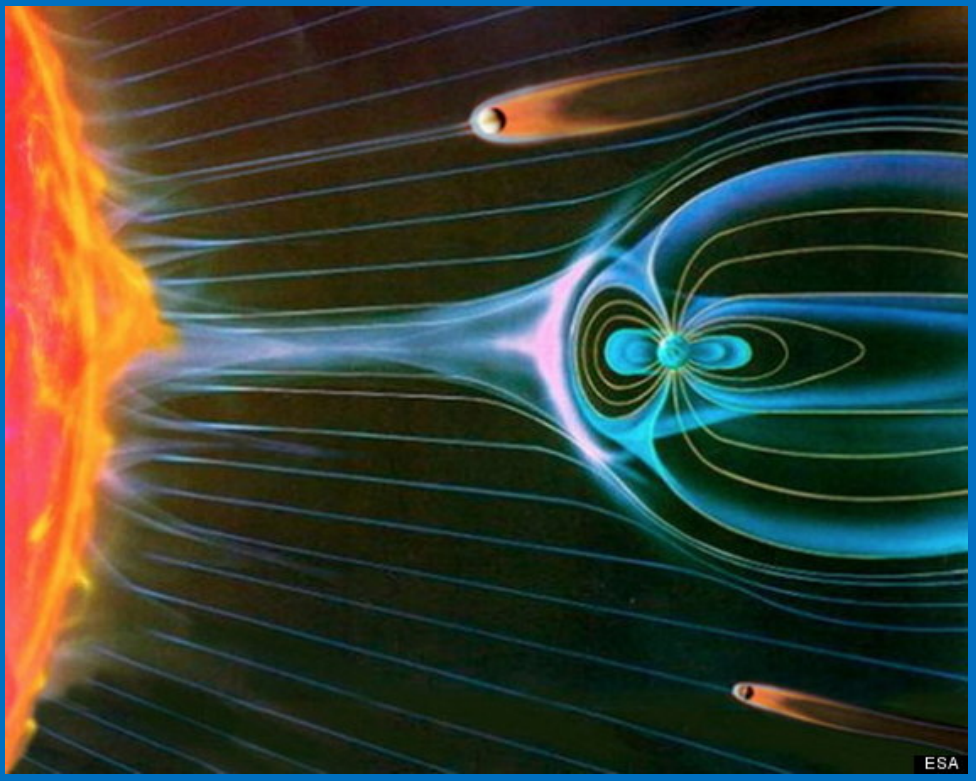
Credit: NASA GSFC/CIL

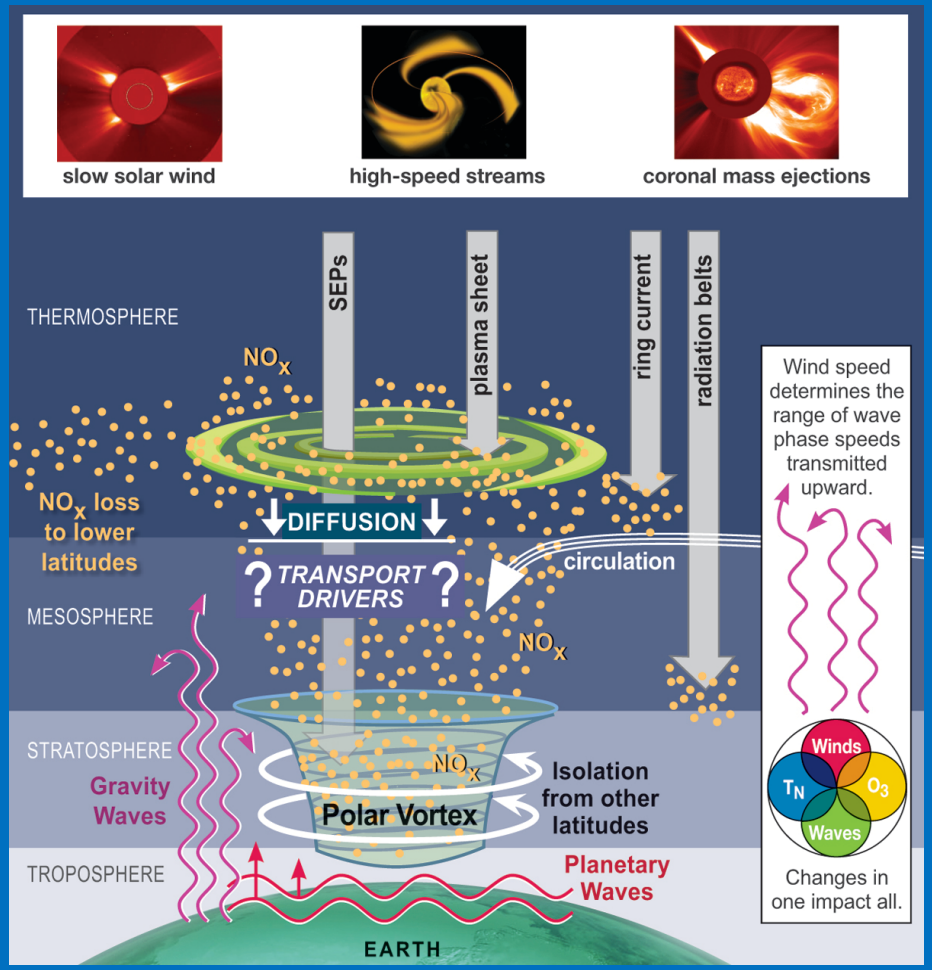
The polar vortex is located where the magnetic field lines converge over the poles



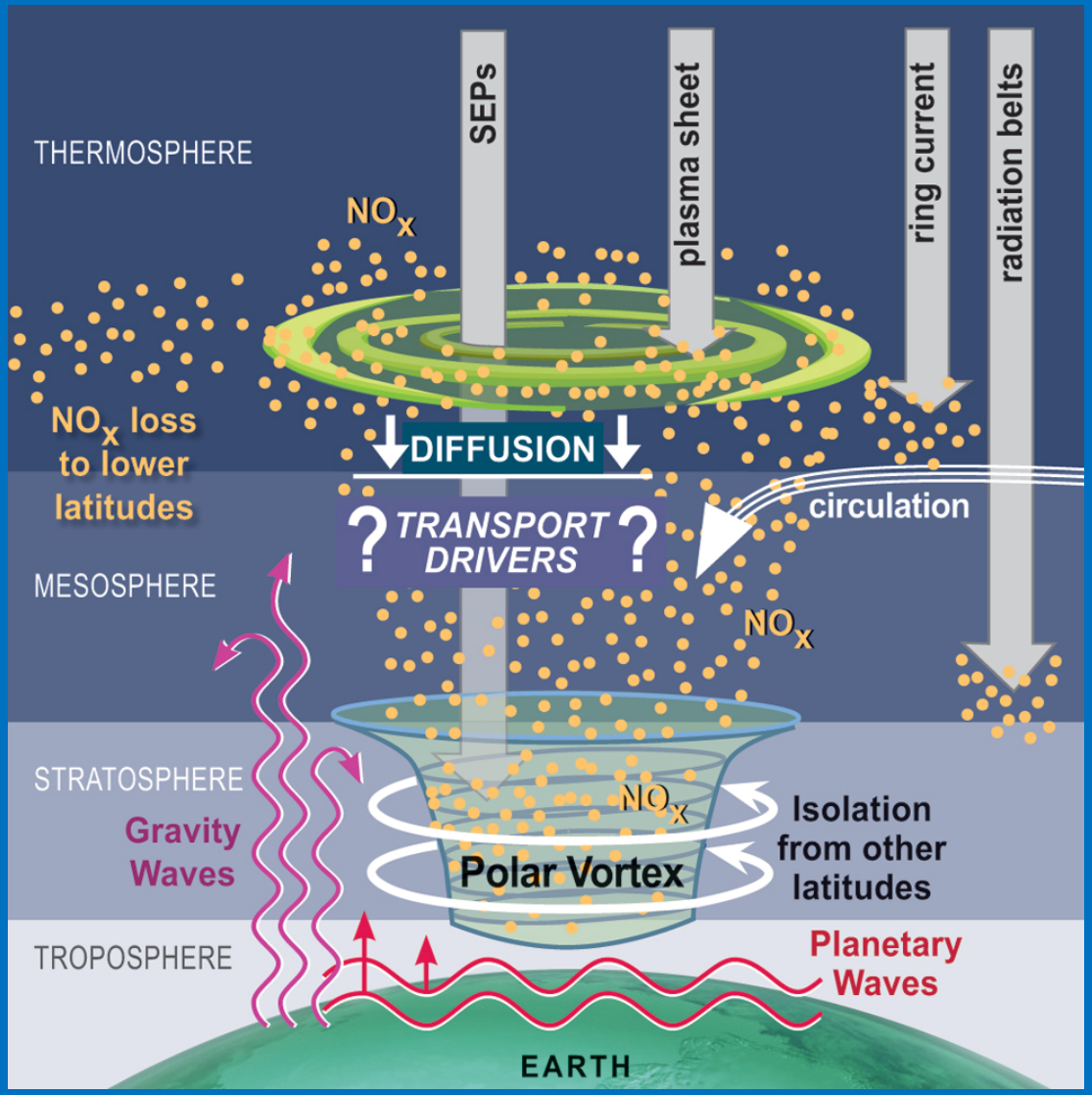
Solar energetic particles produce NOx that descends in the vortex

The vortex links space weather to the lower atmosphere

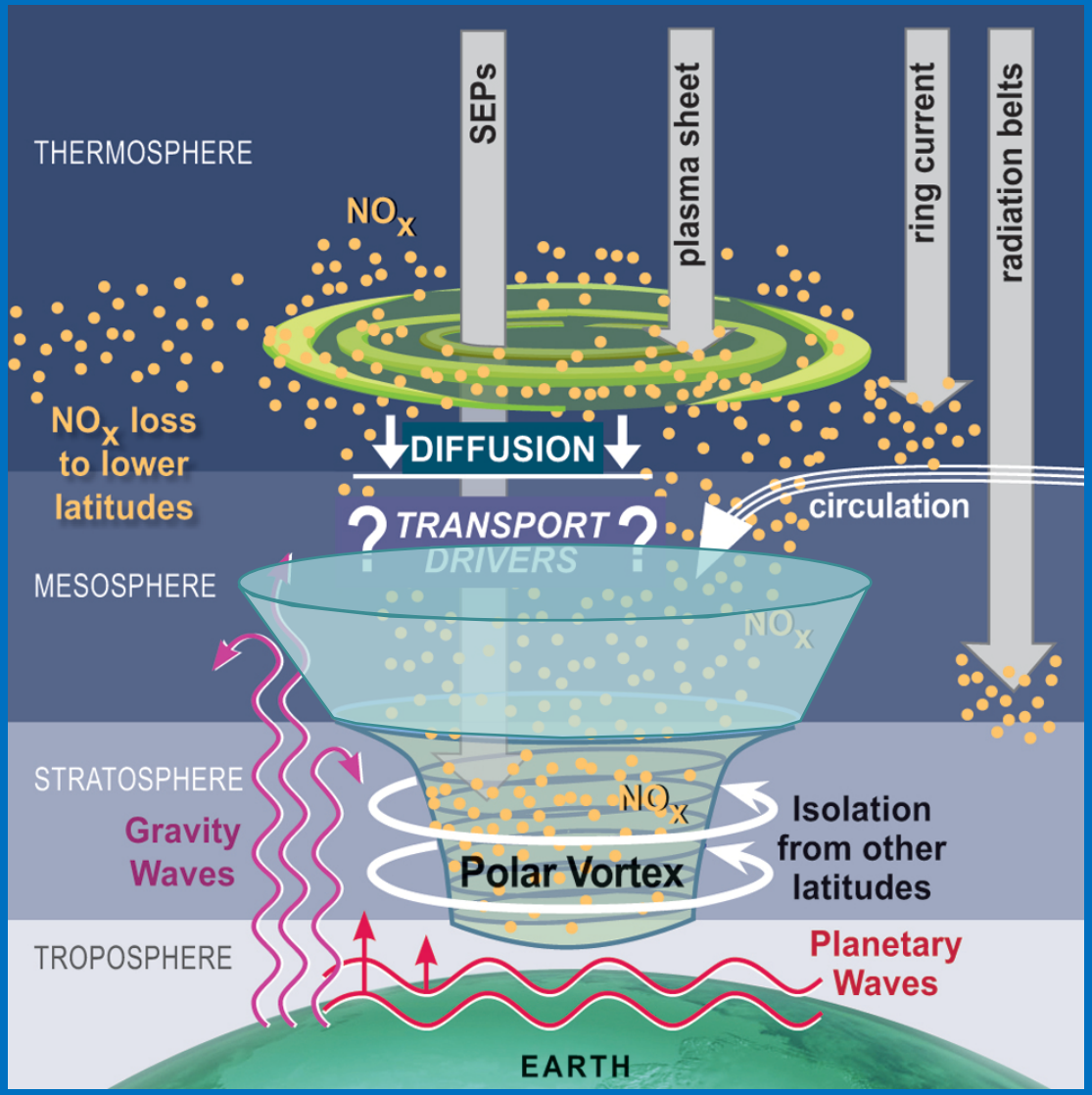




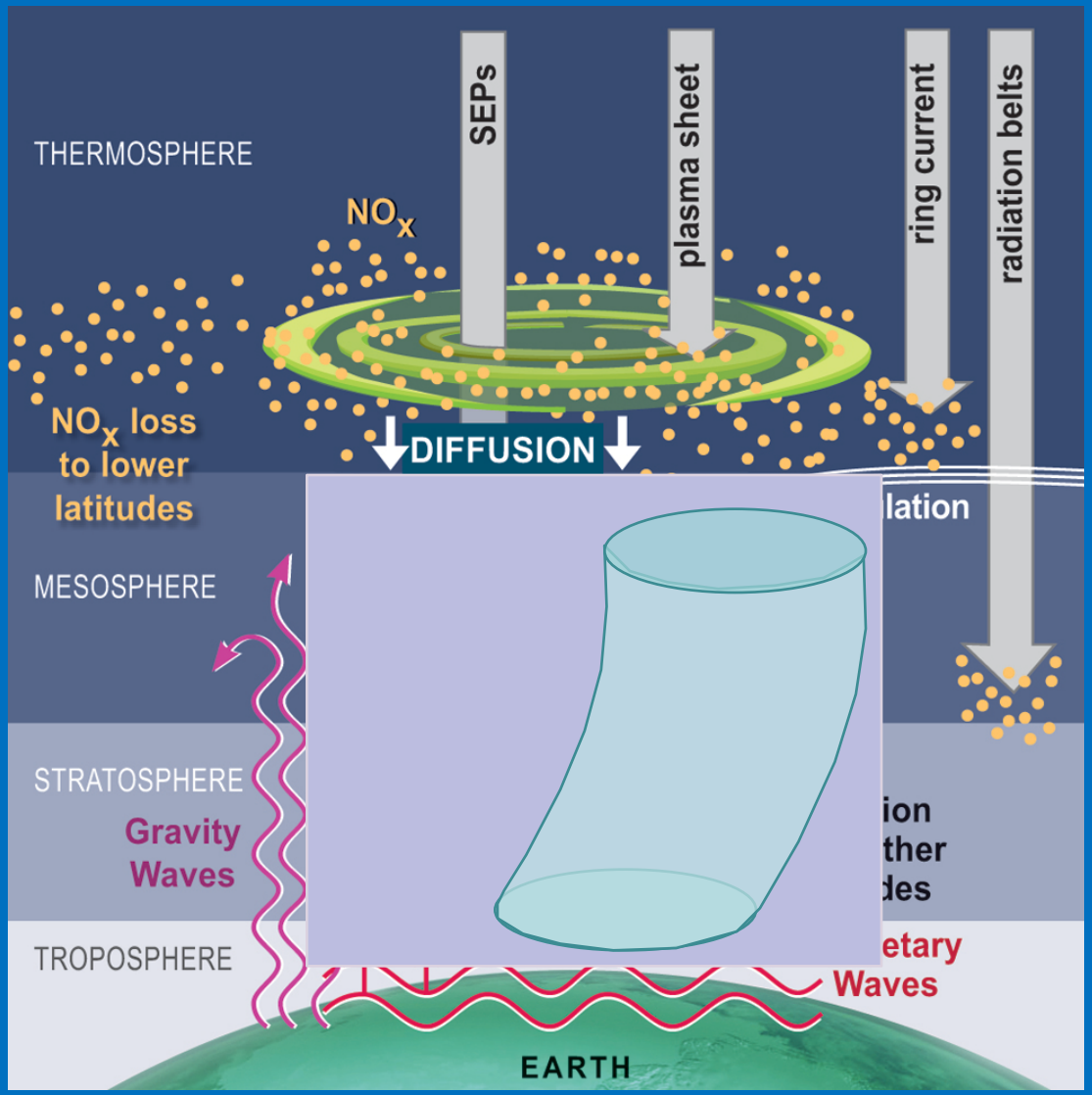
The vortex is shaped like a funnel that broadens with height



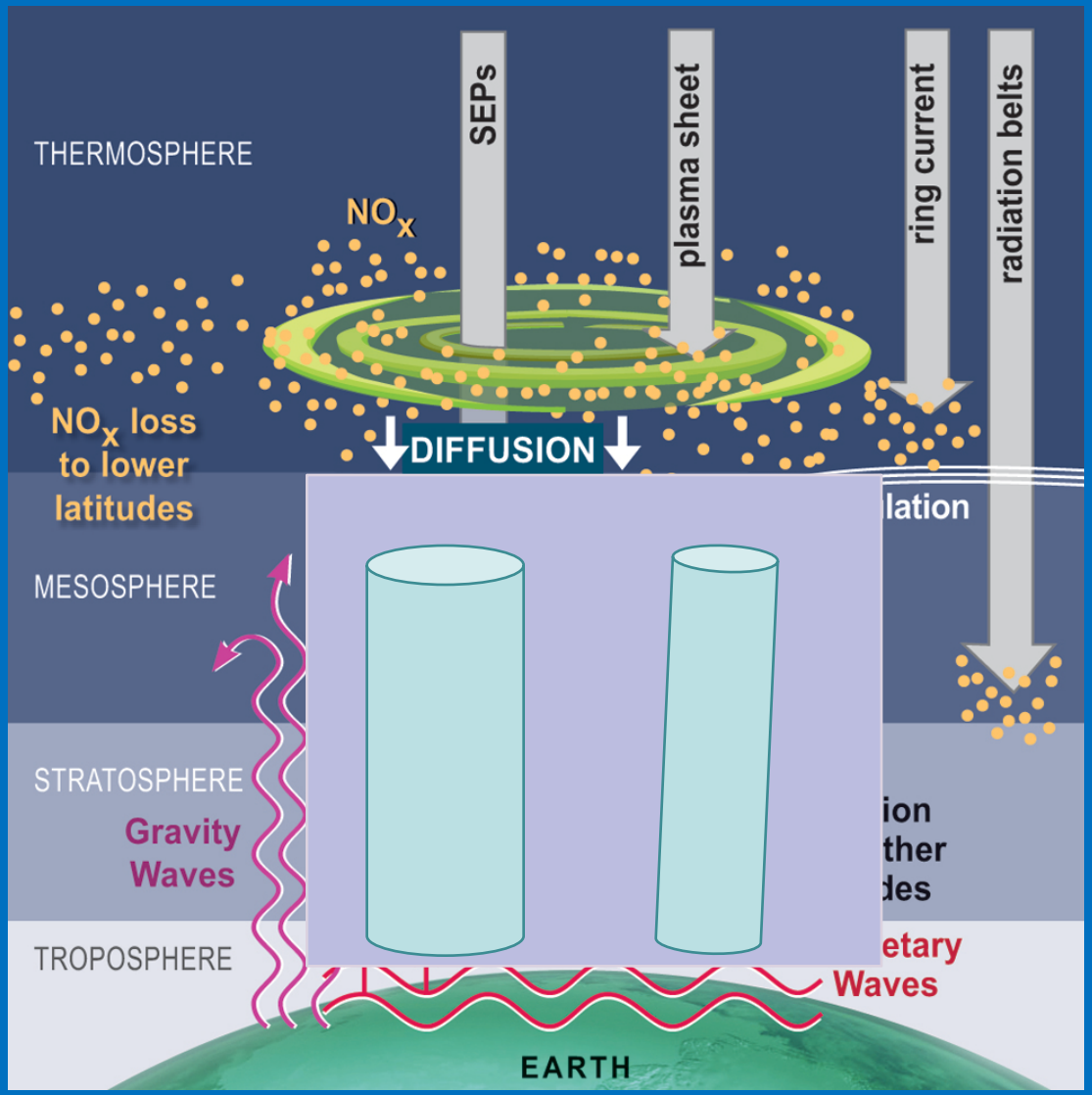
A broadening vortex extends into the mesosphere



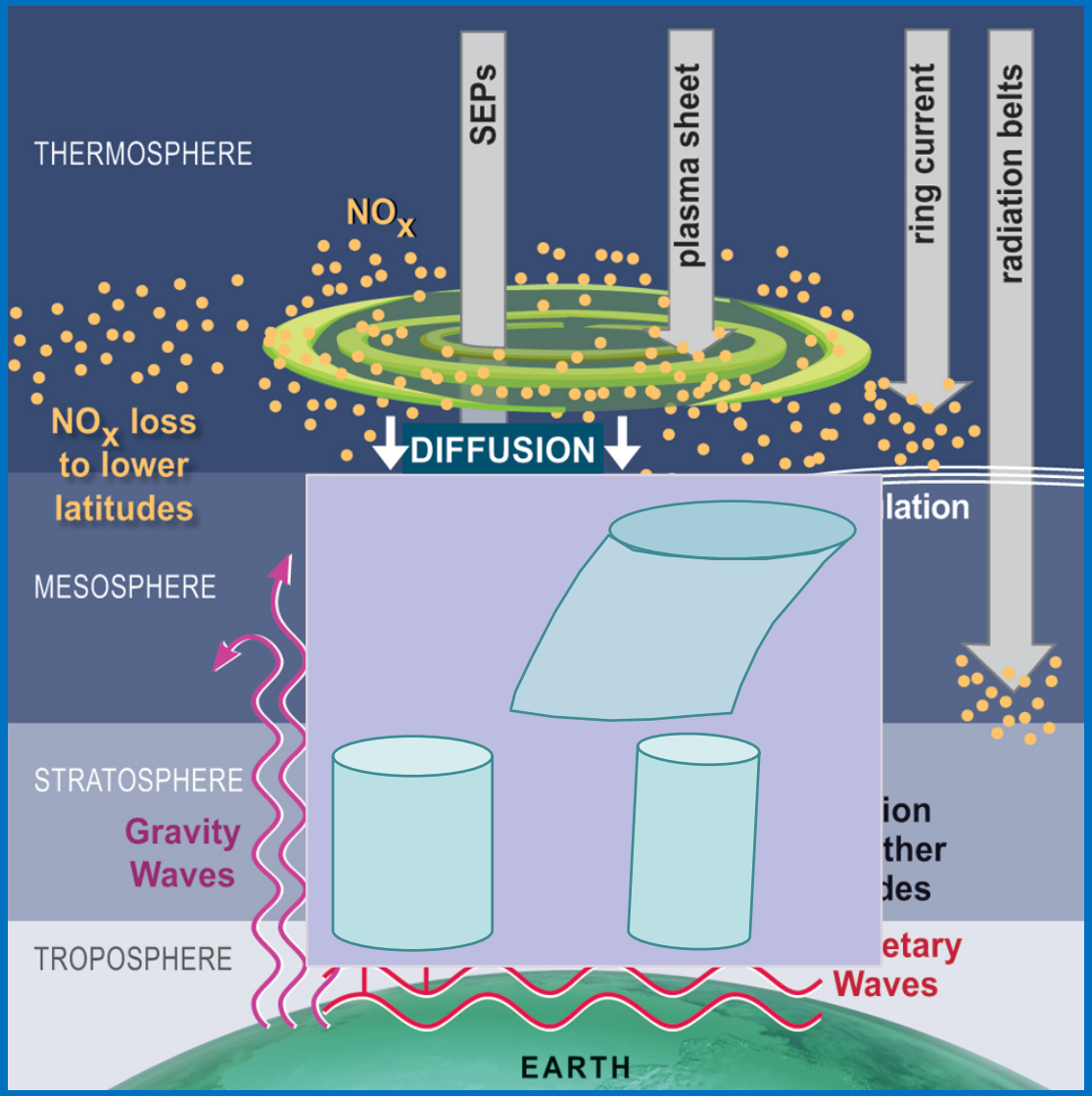
The vortex doesn't have to broaden. And it can be displaced from the pole by planetary waves.



The vortex can split. Two continuous vortices can extend through the stratosphere and mesosphere.



At other times, the mesospheric vortex is detached from the underlying stratospheric vortex.



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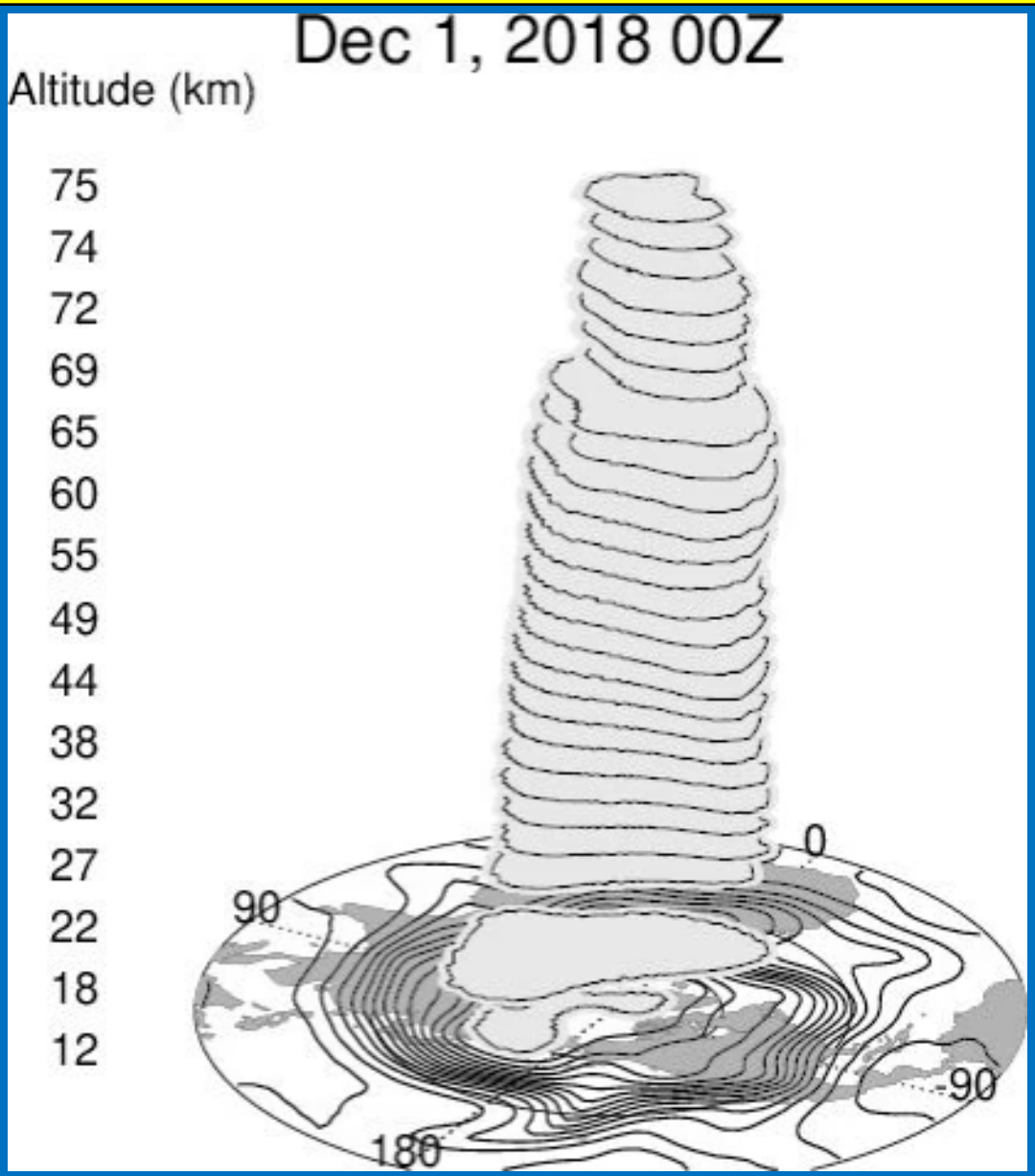
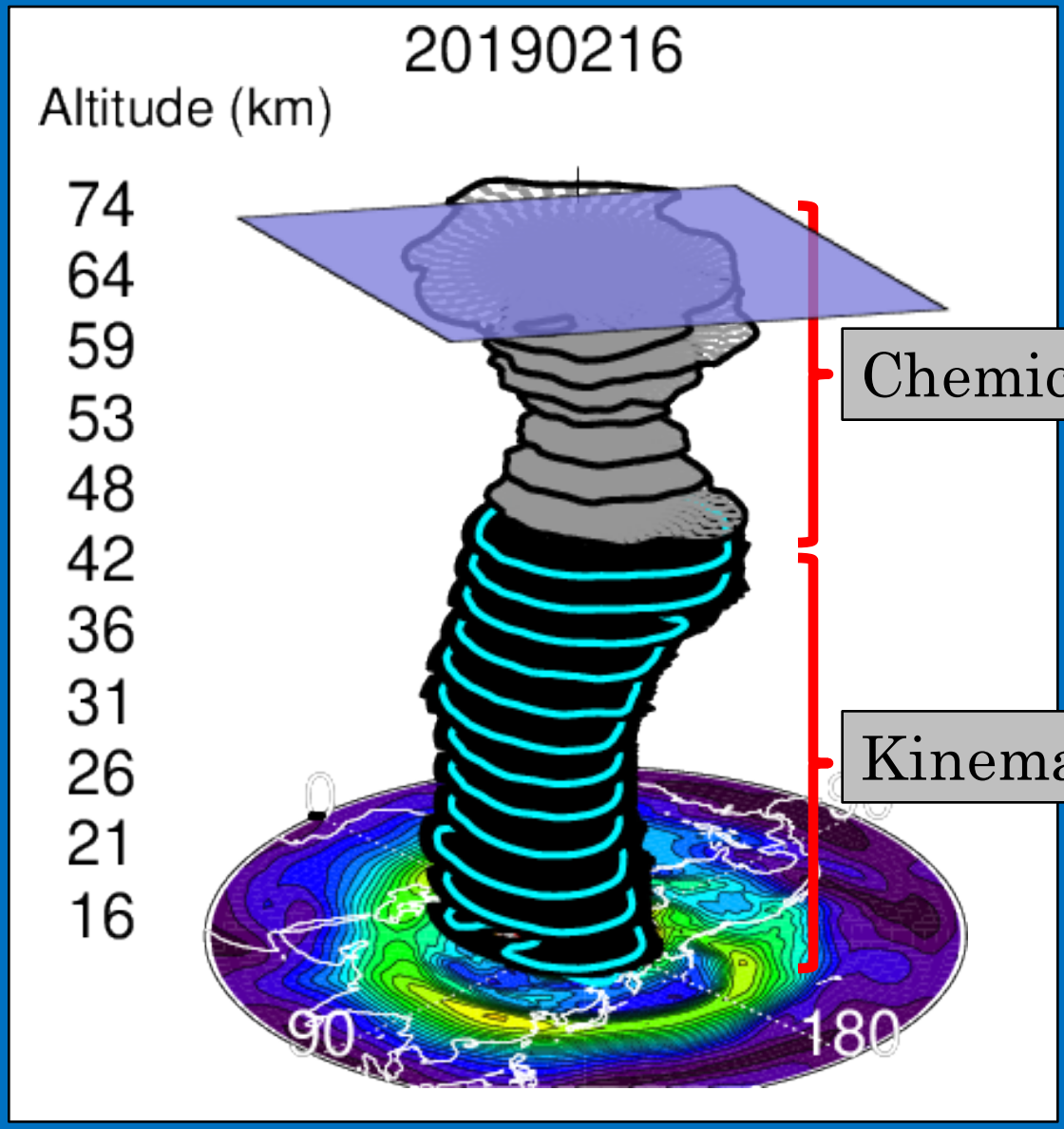
2018/2019 Arctic Vortex
Define using MERRA-2 winds

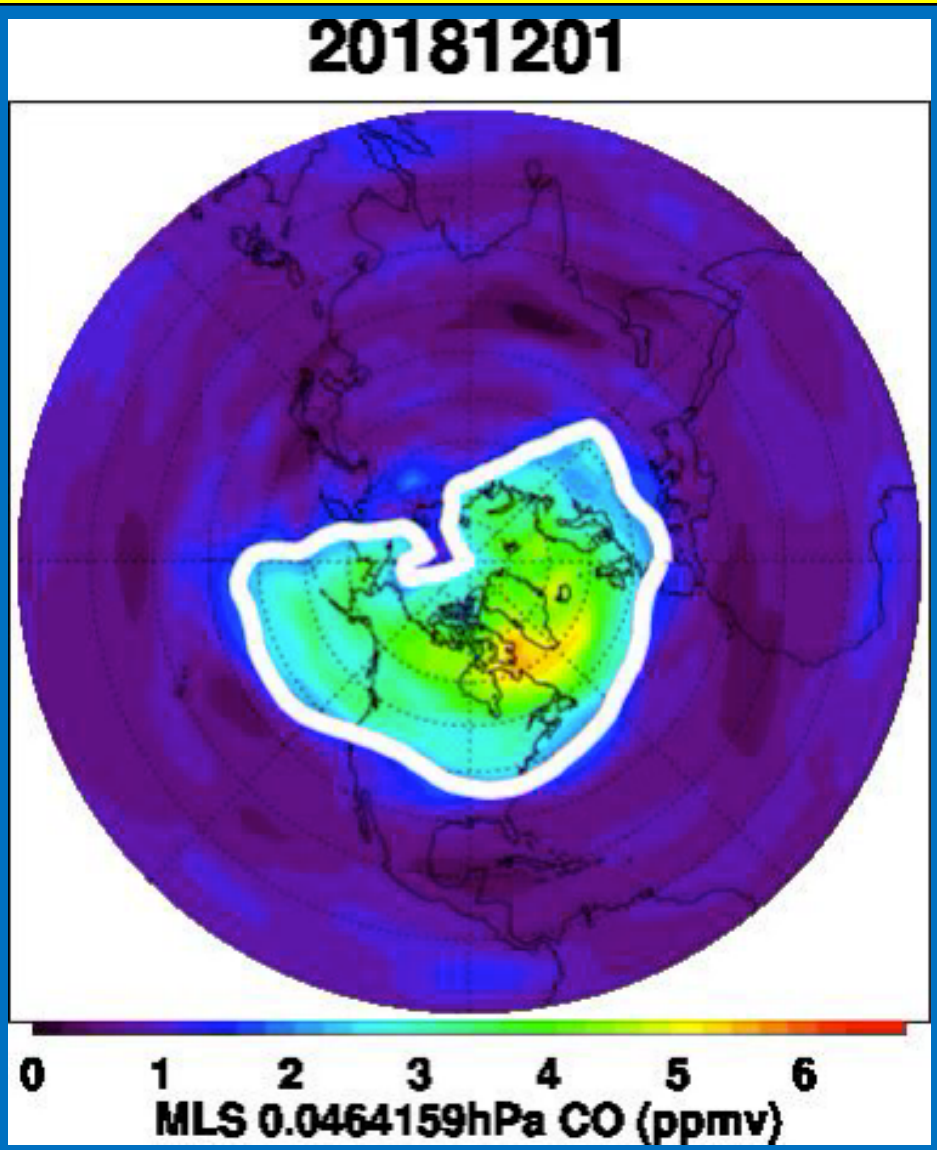


How to define a tornado? – Use fast winds at the edge or high concentration of particulates inside?

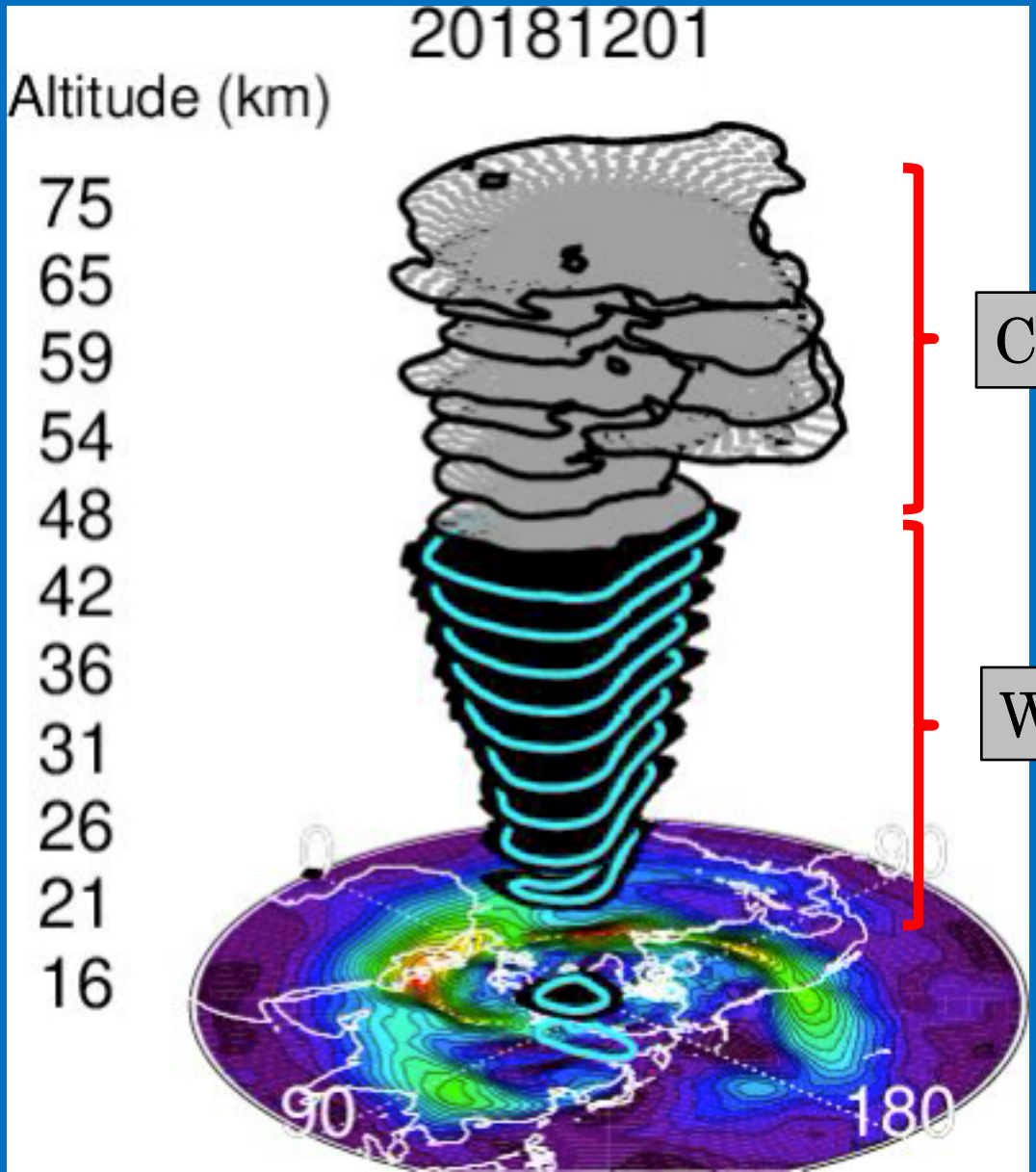
Make use of a chemical definition in the mesosphere



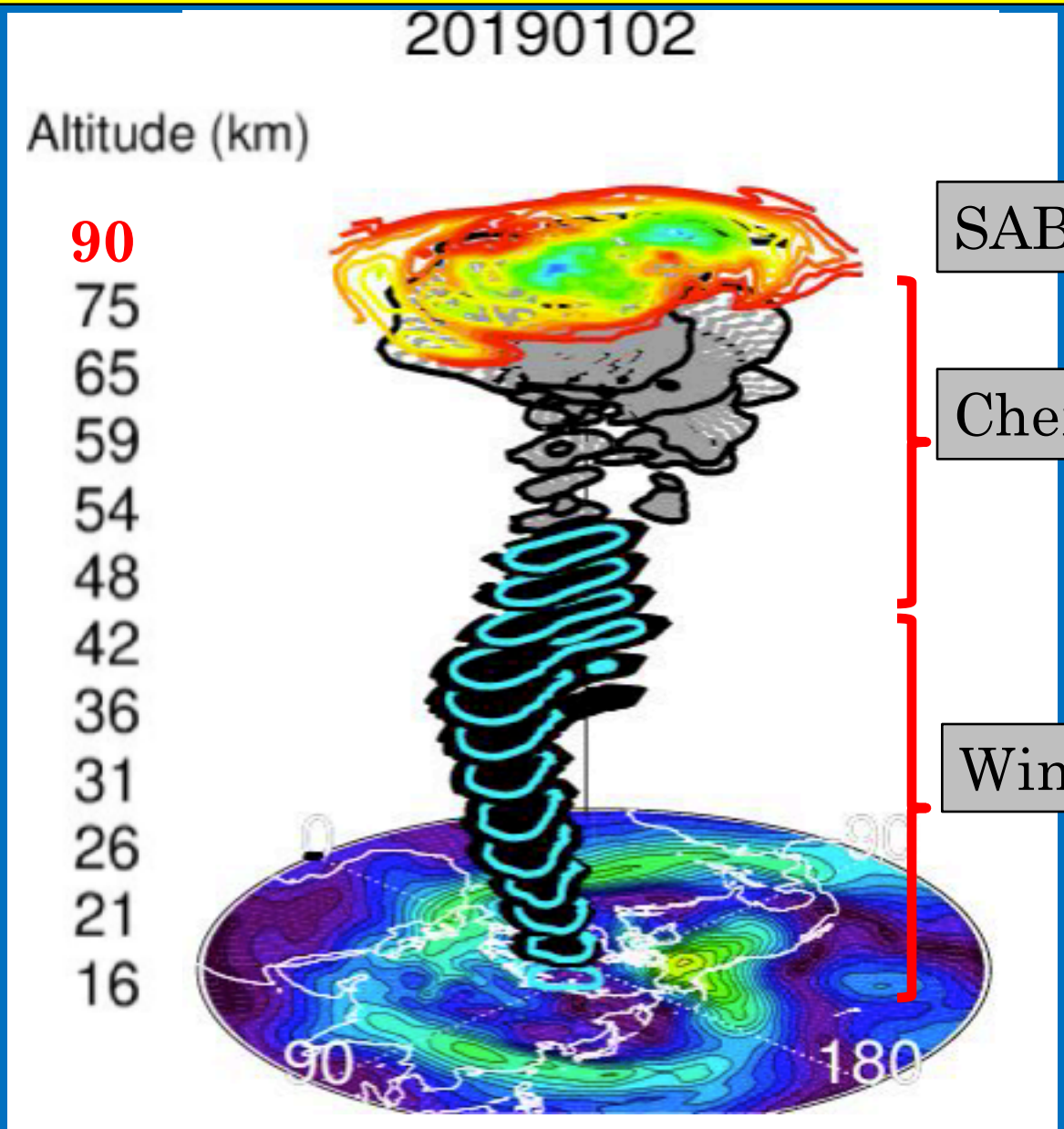
Maximum horizontal gradients in carbon monoxide define the vortex in the mesosphere



3D Arctic vortex defined using winds in the stratosphere and composition in the mesosphere



The Arctic vortex splits at 90 km
4 days after it splits in the stratosphere



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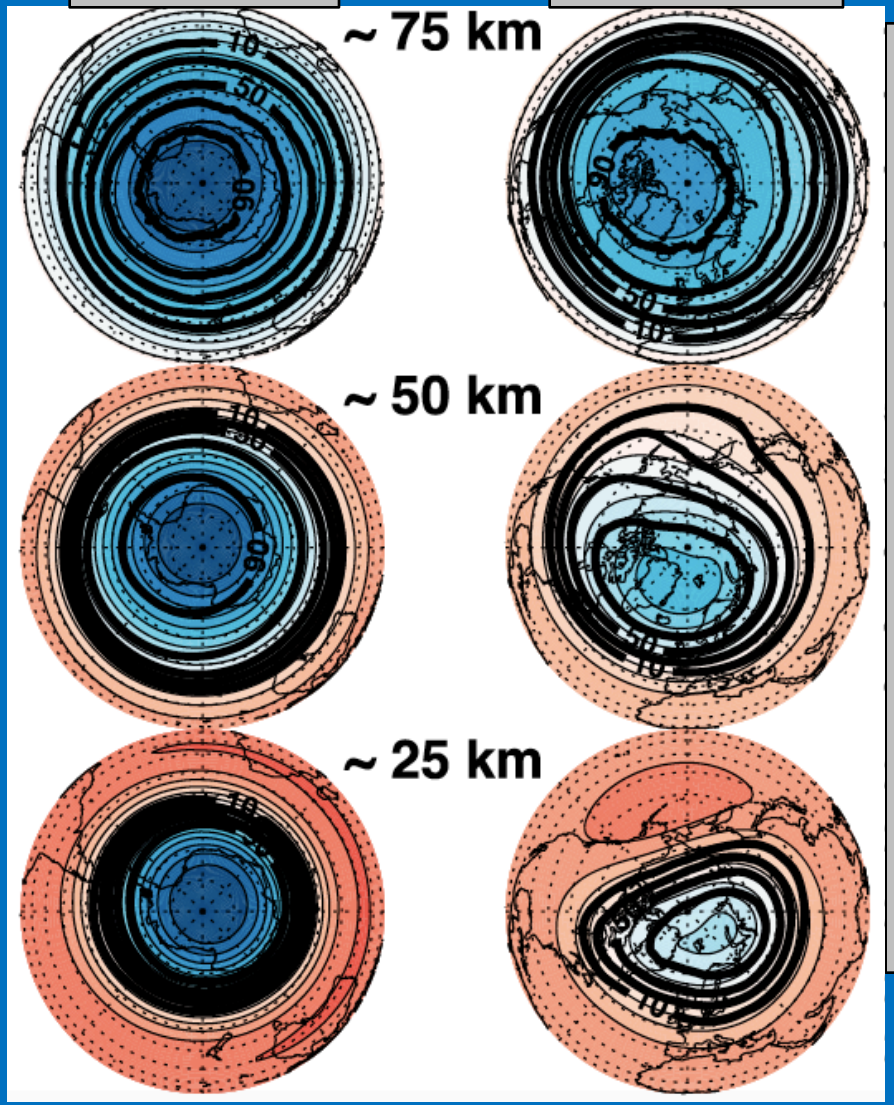
15-year seasonal mean stratospheric and mesospheric frequency of occurrence

SH JJA | NH DJF

mesosphere

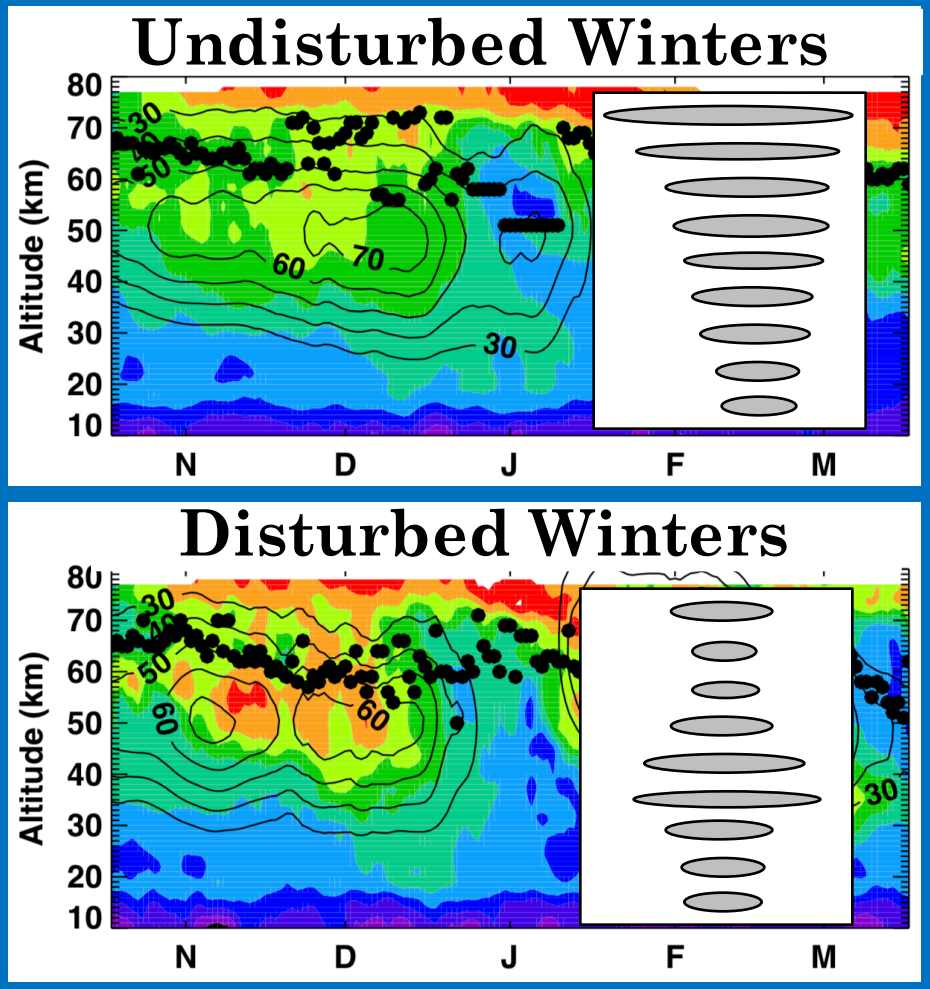
stratopause

stratosphere



- Stronger SH stratospheric vortex
- Broadens with height
- Smaller inter-hemispheric differences in the mesosphere
- Mesospheric vortex is present most of the time
- *Harvey et al.* (2018)

The mesospheric vortex contracts after prolonged planetary wave disturbances



Altitude-time plots of vortex size show vortex broadening at 40 km and contracting at 70 km after PW disturbance

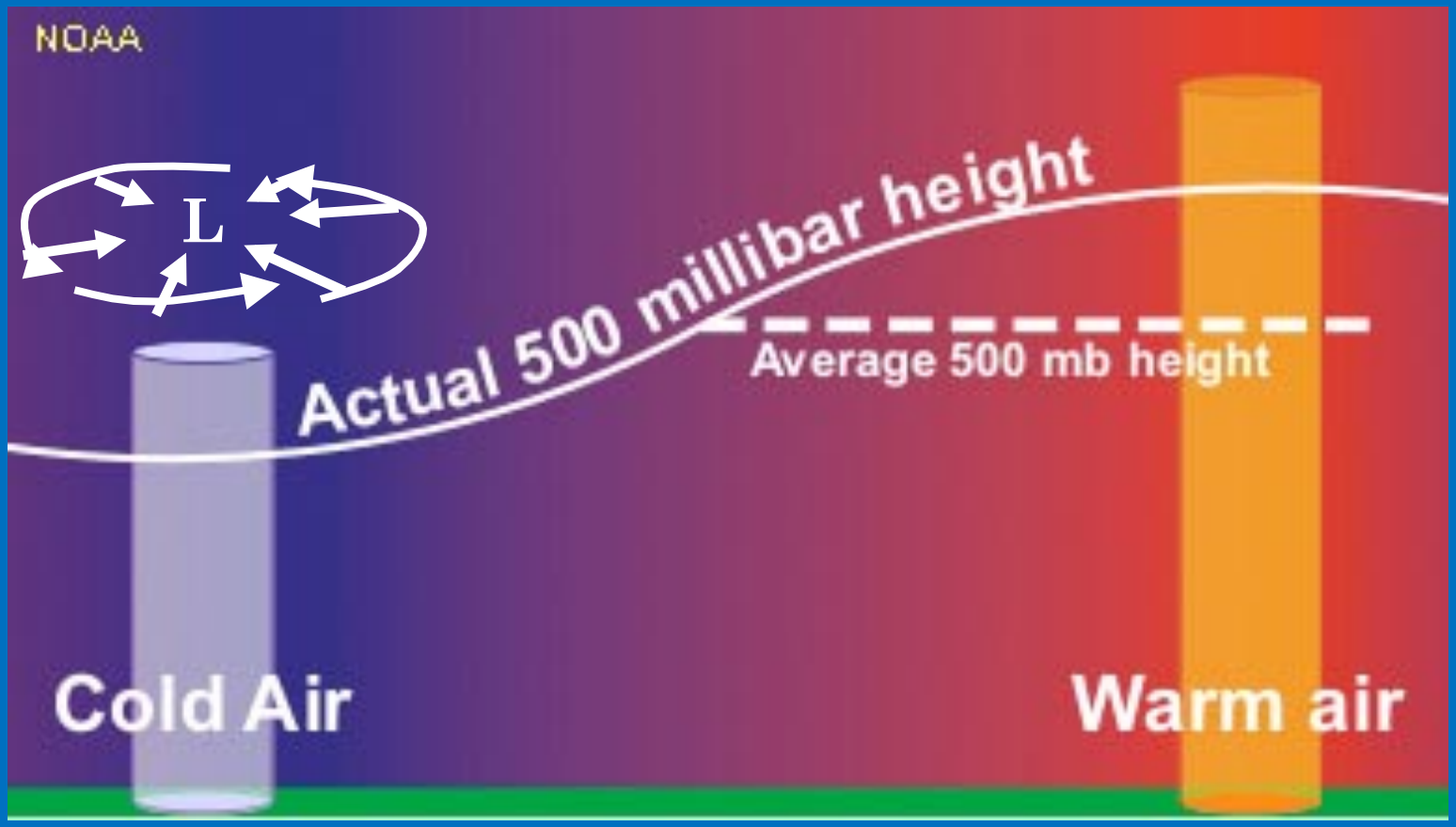
Take away points

- The polar vortex occurs during the dark & cold winter
- Descent couples the thermosphere down to the stratosphere
- In the mesosphere I use a chemical vortex definition
- The polar vortex extends into the mesosphere, possibly the lower thermosphere
- Inter-hemispheric polar vortex differences are smaller in the mesosphere compared to the stratosphere
- The vortex in the mesosphere contracts in response to extreme disruptions to the stratospheric vortex below

Thank You!

Extra Slides

Westerly flow around a circumpolar low



Winter Pole

Equator

Pressure decreases with height. Cold air is more dense than warm air. Lower pressure above cold air vs. the same amount of warm. Air flows toward lower pressure and is deflected to the right.

DIRECT EFFECT

- **NO formed locally in stratosphere**
- **Requires highly energetic particles: Sporadic**

Thermosphere:	< 30 keV electrons < 1 MeV protons
Mesosphere:	30-300 keV electrons (MEE) 1-30 MeV protons
Stratosphere:	> 300 keV electrons > 30 MeV protons

- **Immediately available to destroy ozone**

INDIRECT EFFECT

- Requires efficient downward transport during polar night

- Odd nitrogen lifetime in sunlight:
  - **70-80 km:** Days
  - **50-60 km:** Weeks
  - **<40 km:** Months-Years

- Influenced by Dynamics