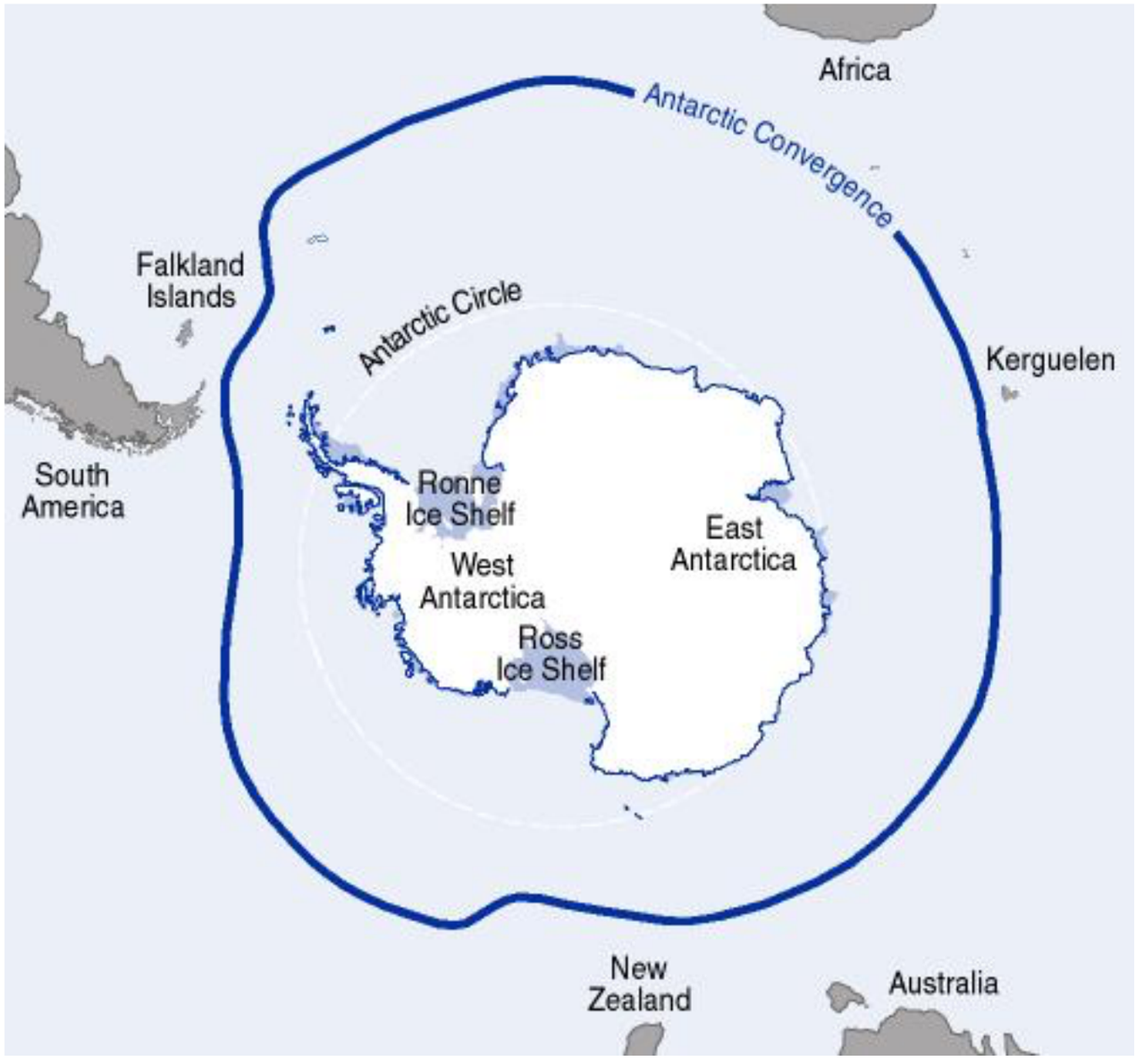
# Air-sea interactions : Polar regions #2

ATM2106

# The Antarctic



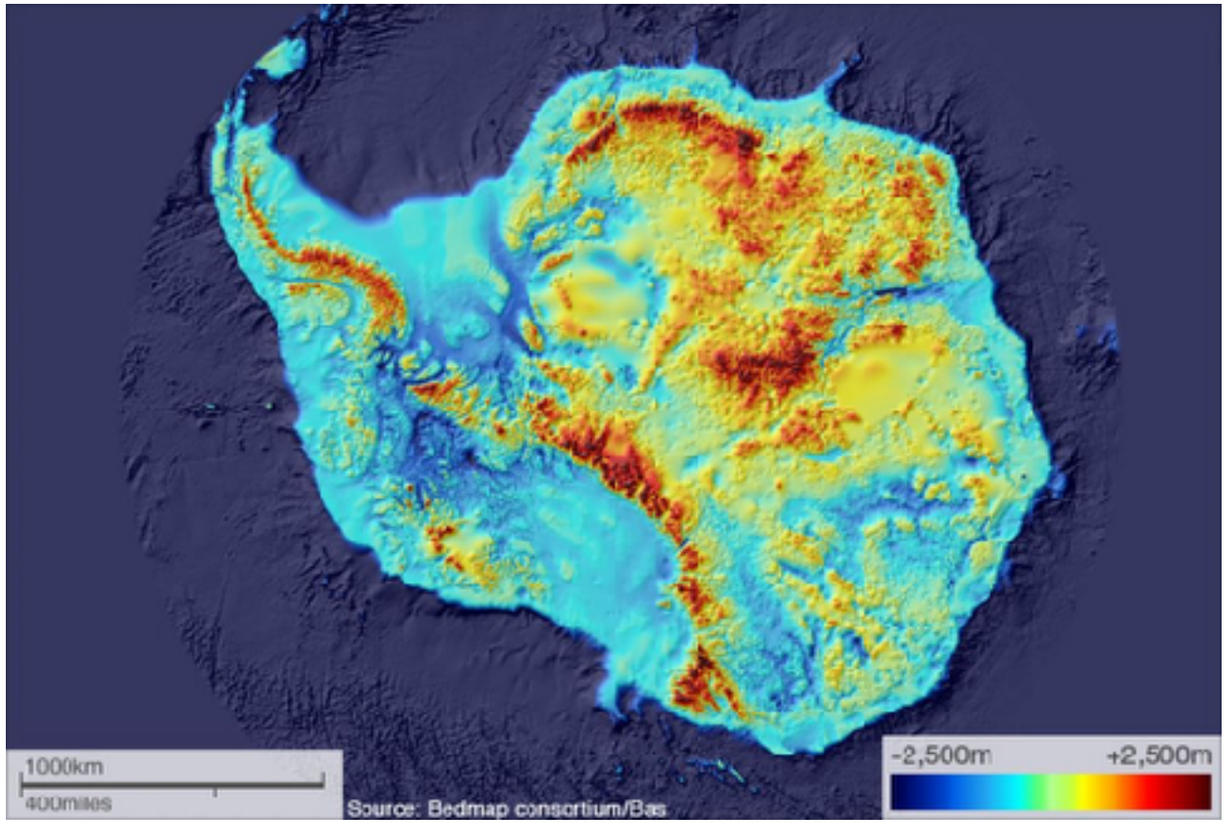
# About Antarctica

- The highest, driest, coldest, windiest and brightest continent
- It roughly has the size of the United States and Mexico combined.
- A layer of ice with more than 1 mile thickness covers the continent.
- This ice results from the accumulation of snowfall over millions of years and accounts for 90% of the ice on Earth.

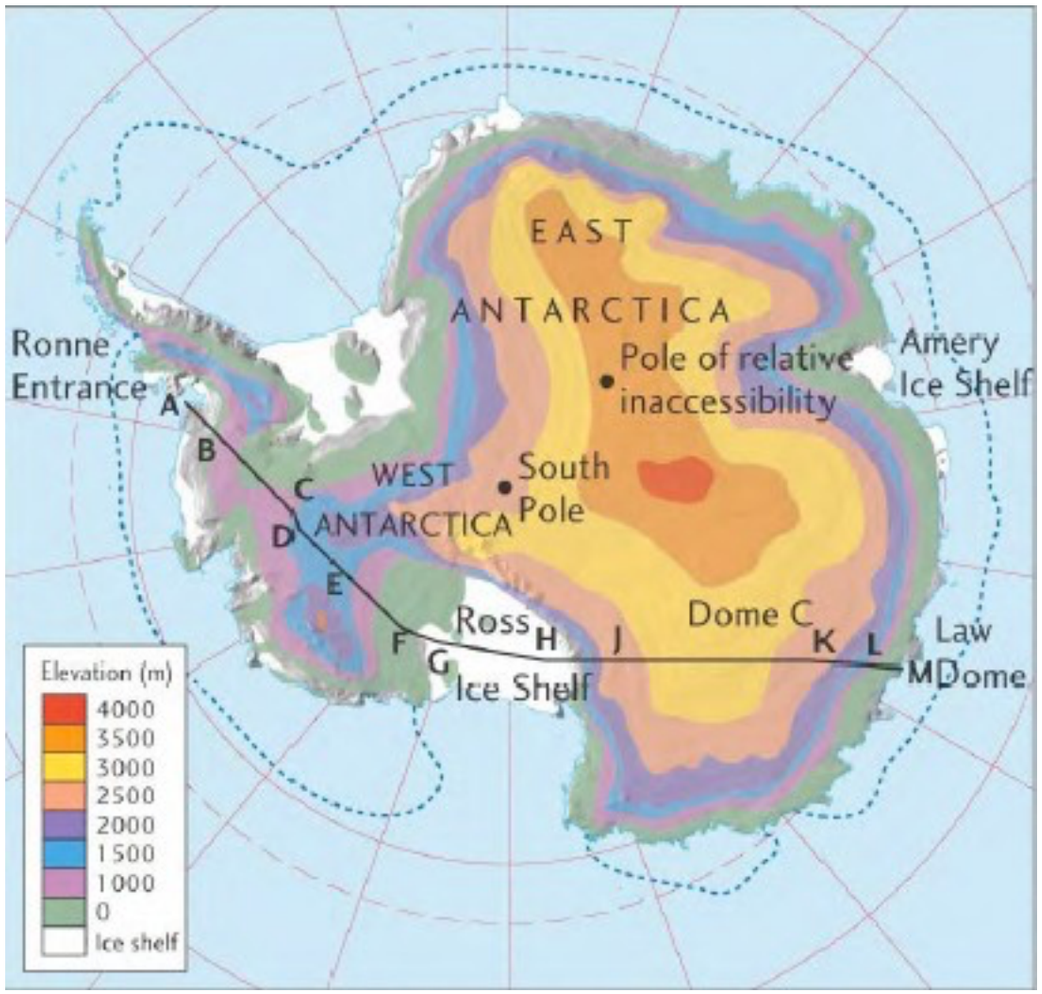
From https://lima.nasa.gov/antarctica/

# Antarctica

Without ice

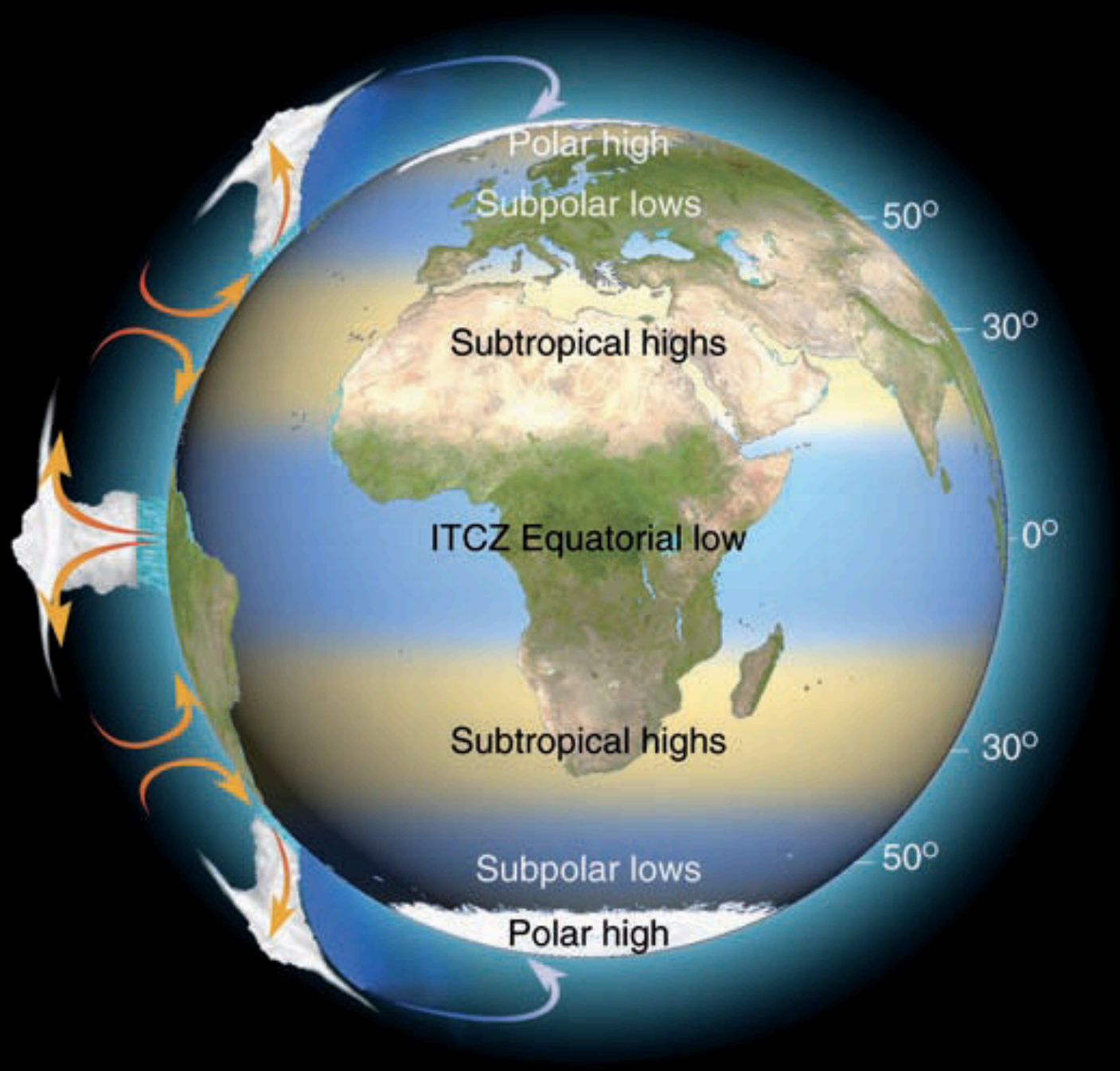



With ice

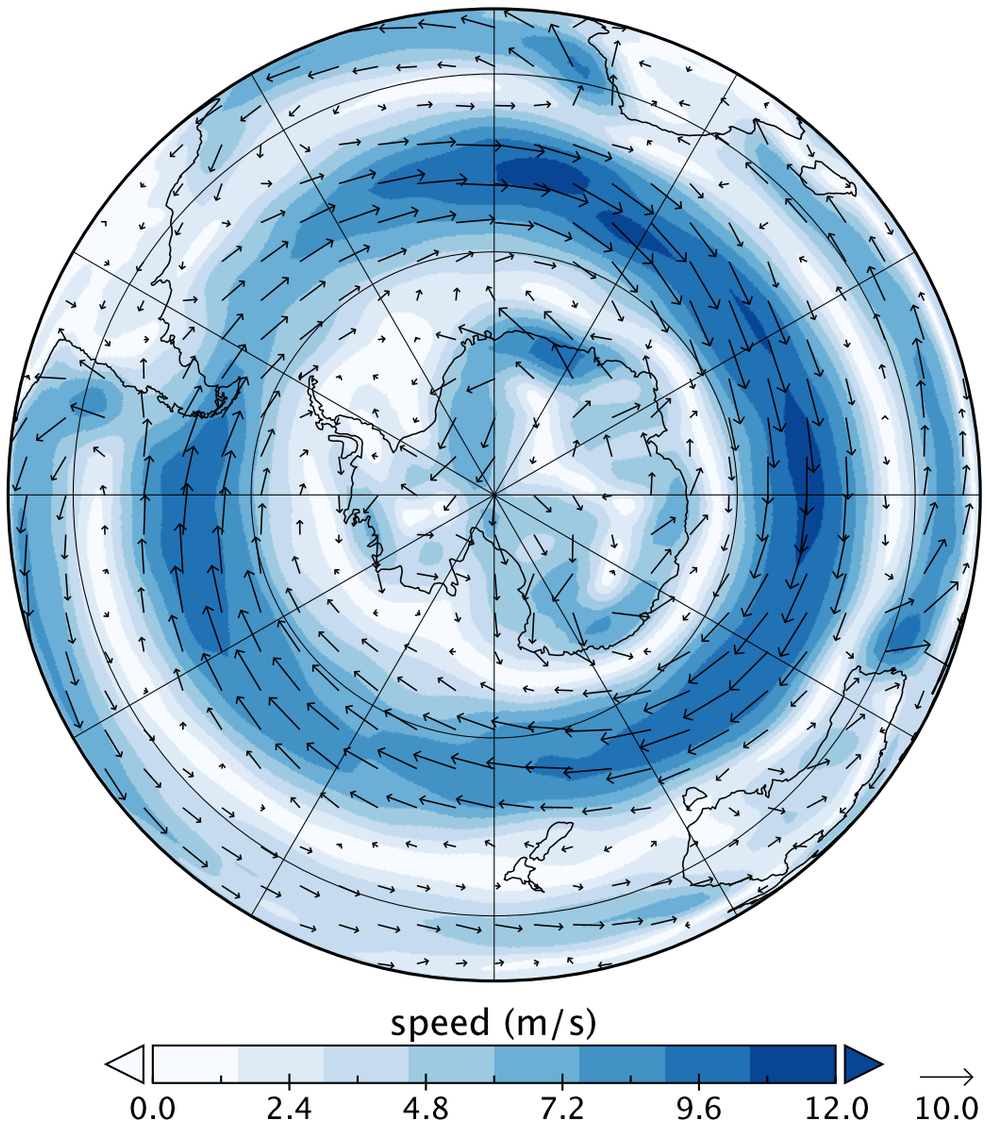


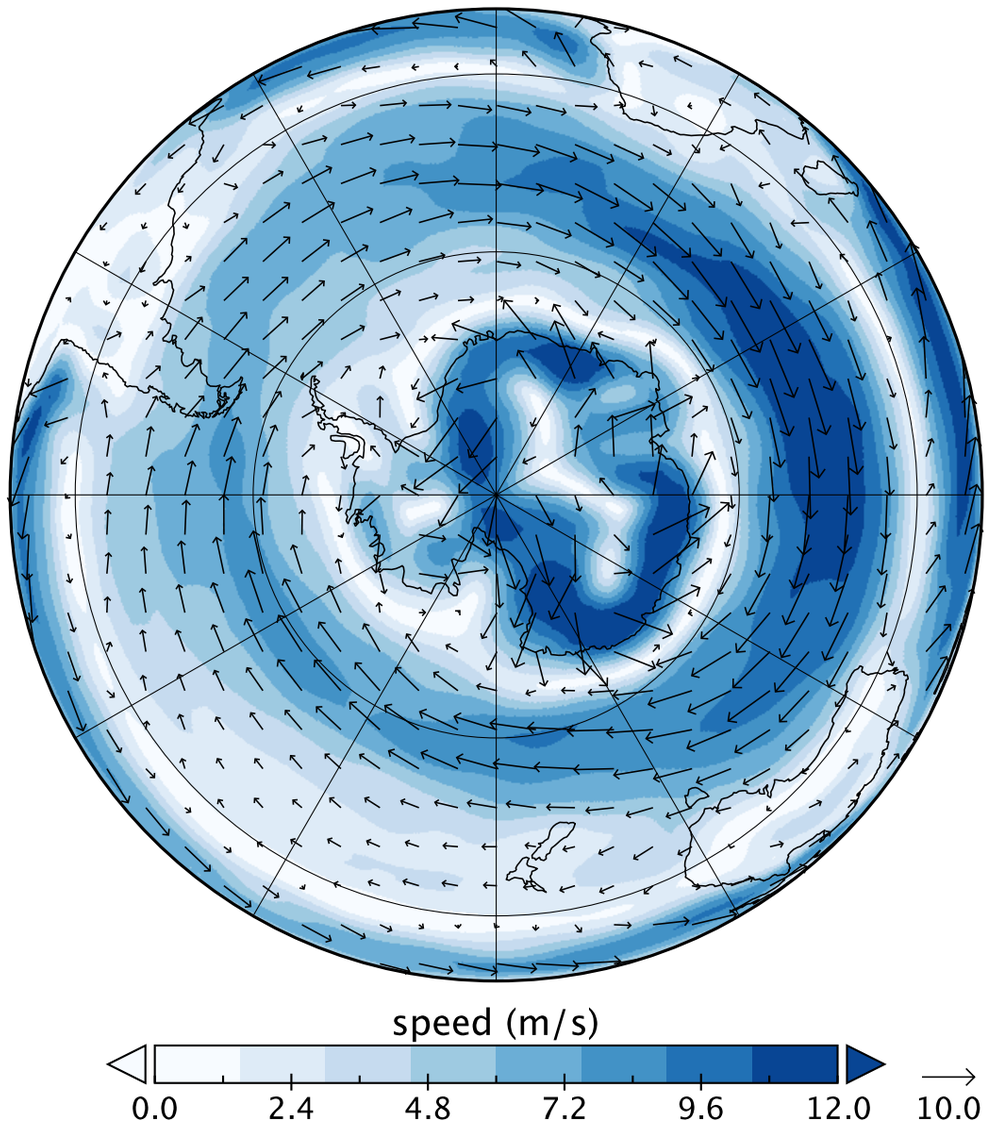

From http://www.antarctica.gov.au/science/cool-science/2011/bedrock-map-reveals-ice-free-antarctica and https://lima.nasa.gov/antarctica/

# Meridional circulation



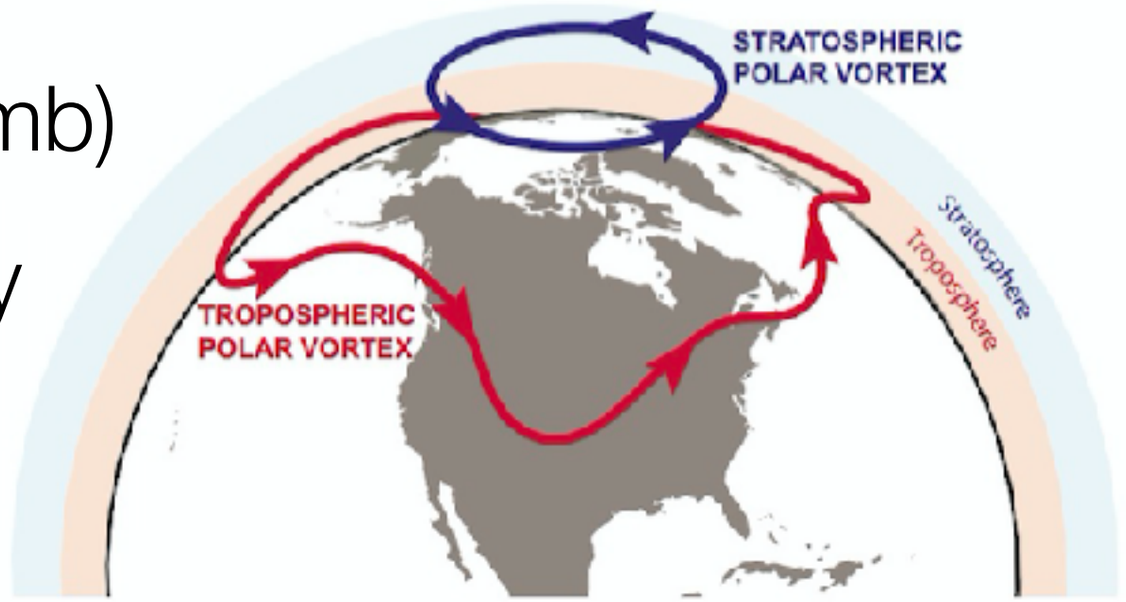
# Winds at the surface



# Polar vortex

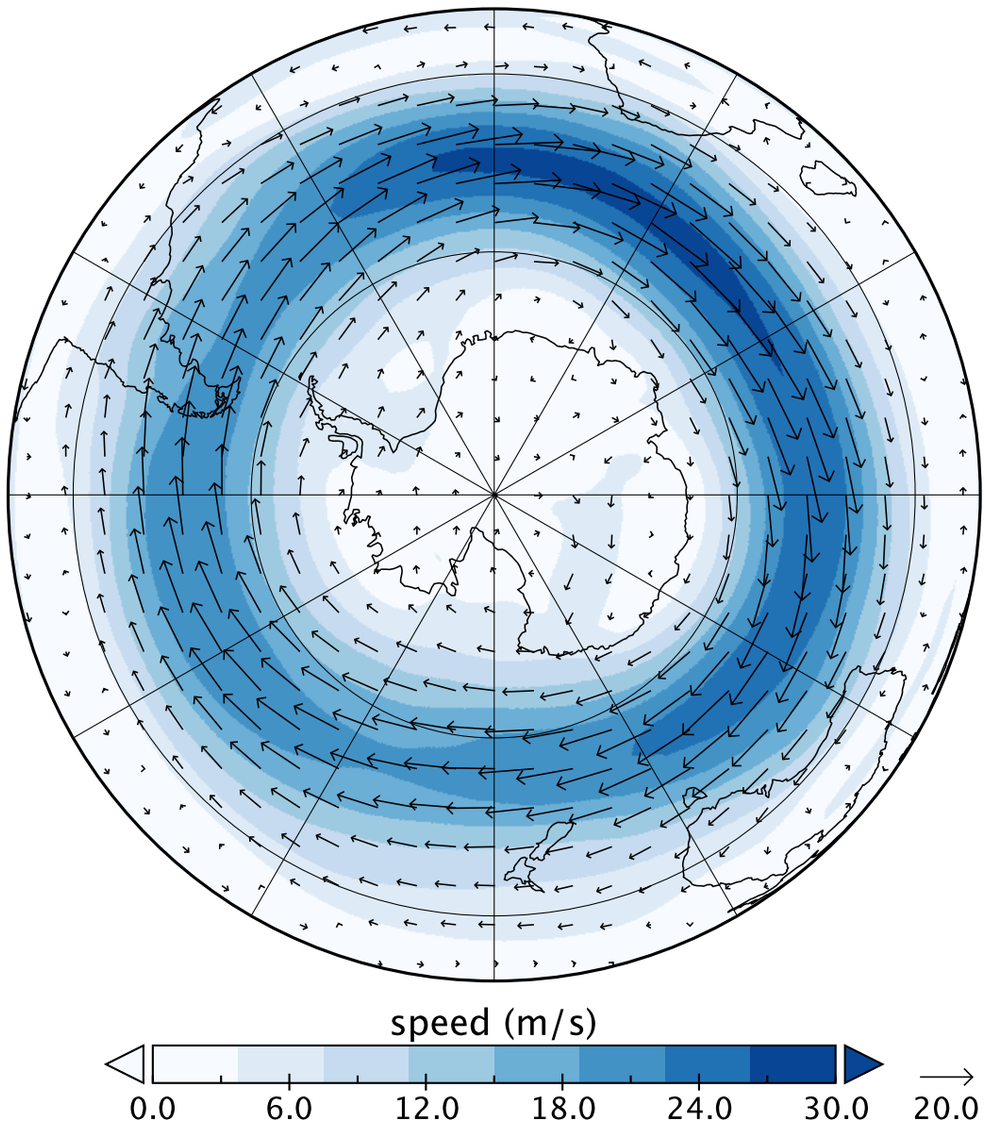
- Tropospheric polar vortex:
  - Exists all year round
  - The 300-500 mb geopotential height contours are usually used to define it.
    - It is associated with extreme weather events.
- Stratospheric polar vortex:
  - above the tropopause (~100mb)
  - Appears in fall and winter only (no solar radiation)



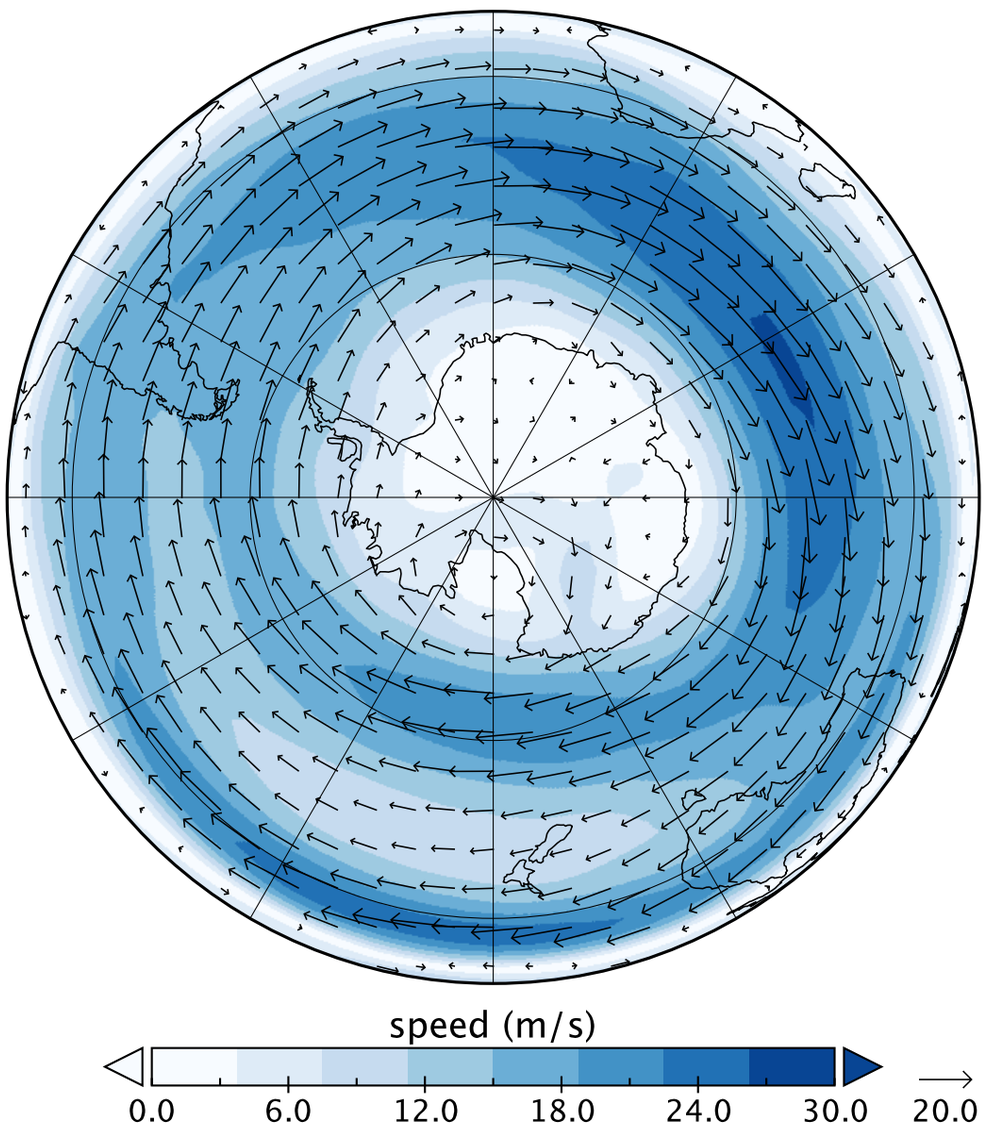

http://sites.krieger.jhu.edu/waugh/research/polarvortex/

# Winds at 500mb (Tropospheric polar vortex)

February

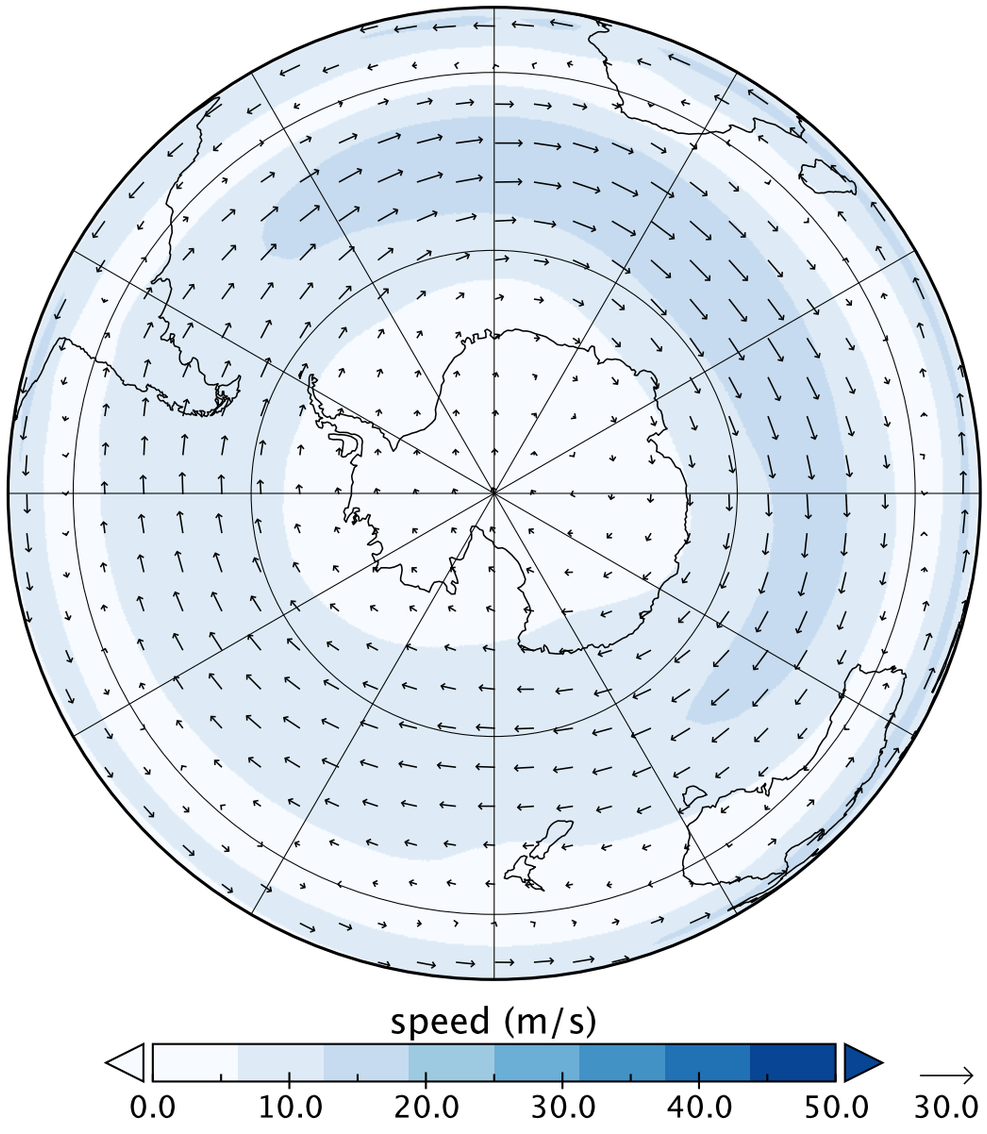



August

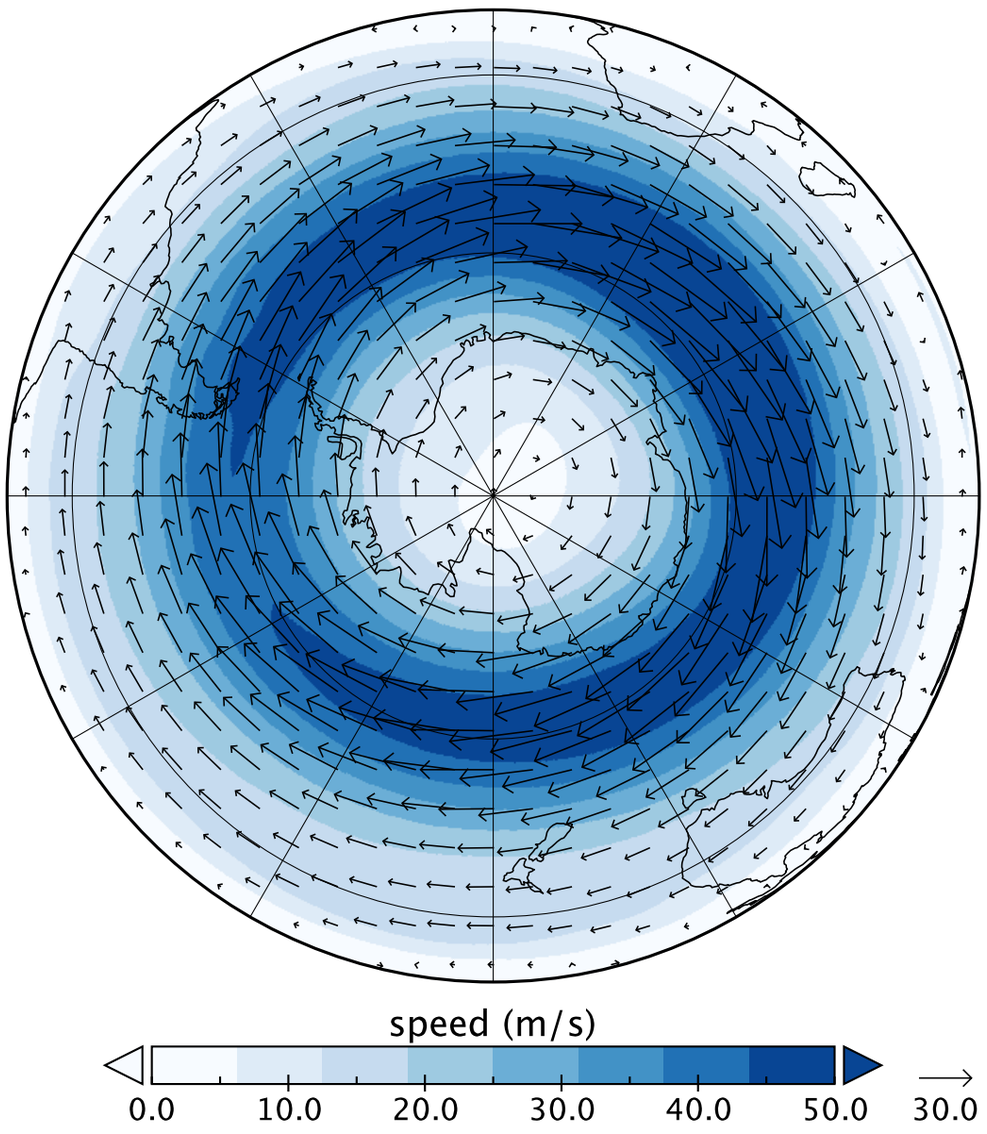


# Winds at 70mb (Stratospheric polar vortex)

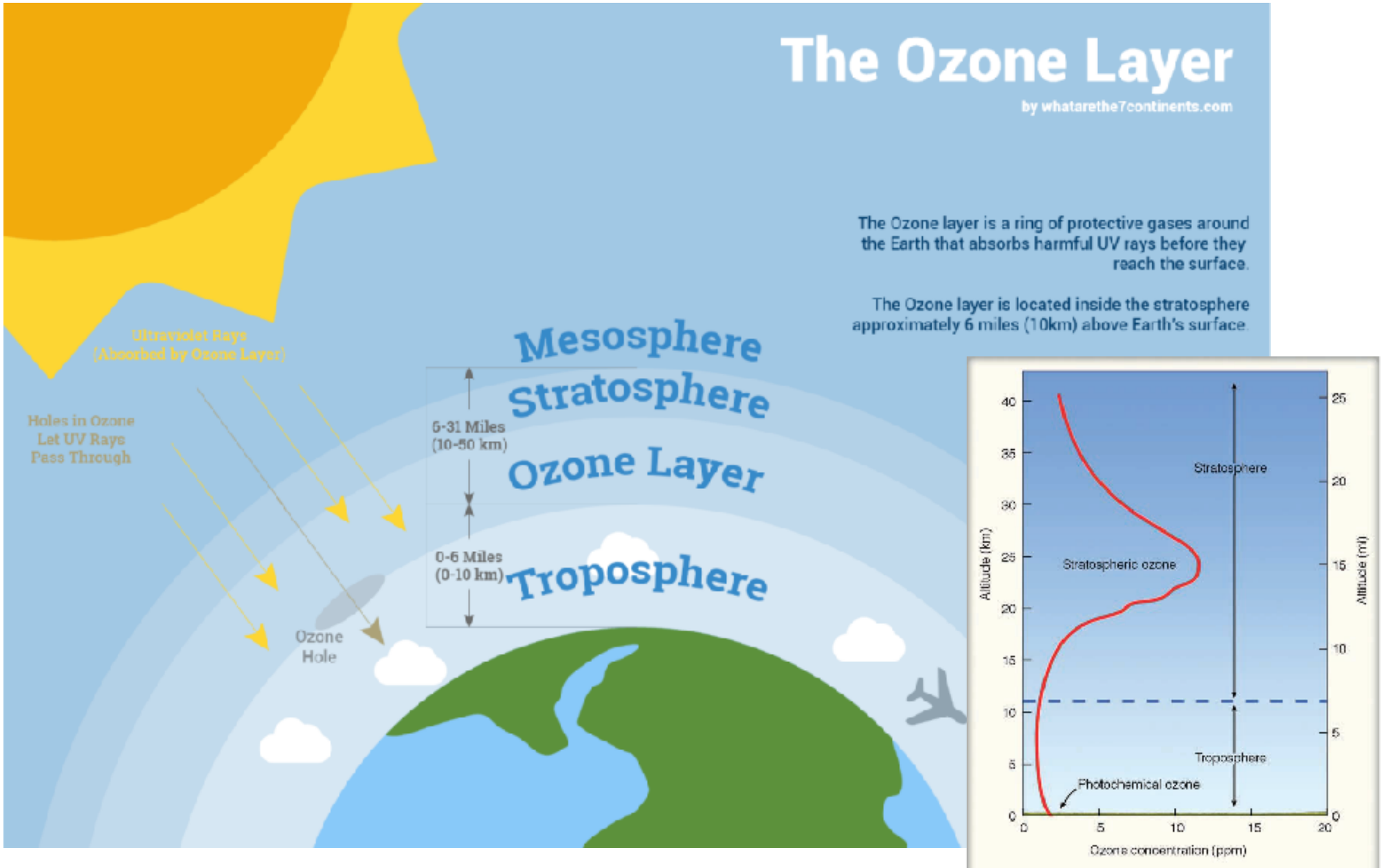
February




August



# Ozone

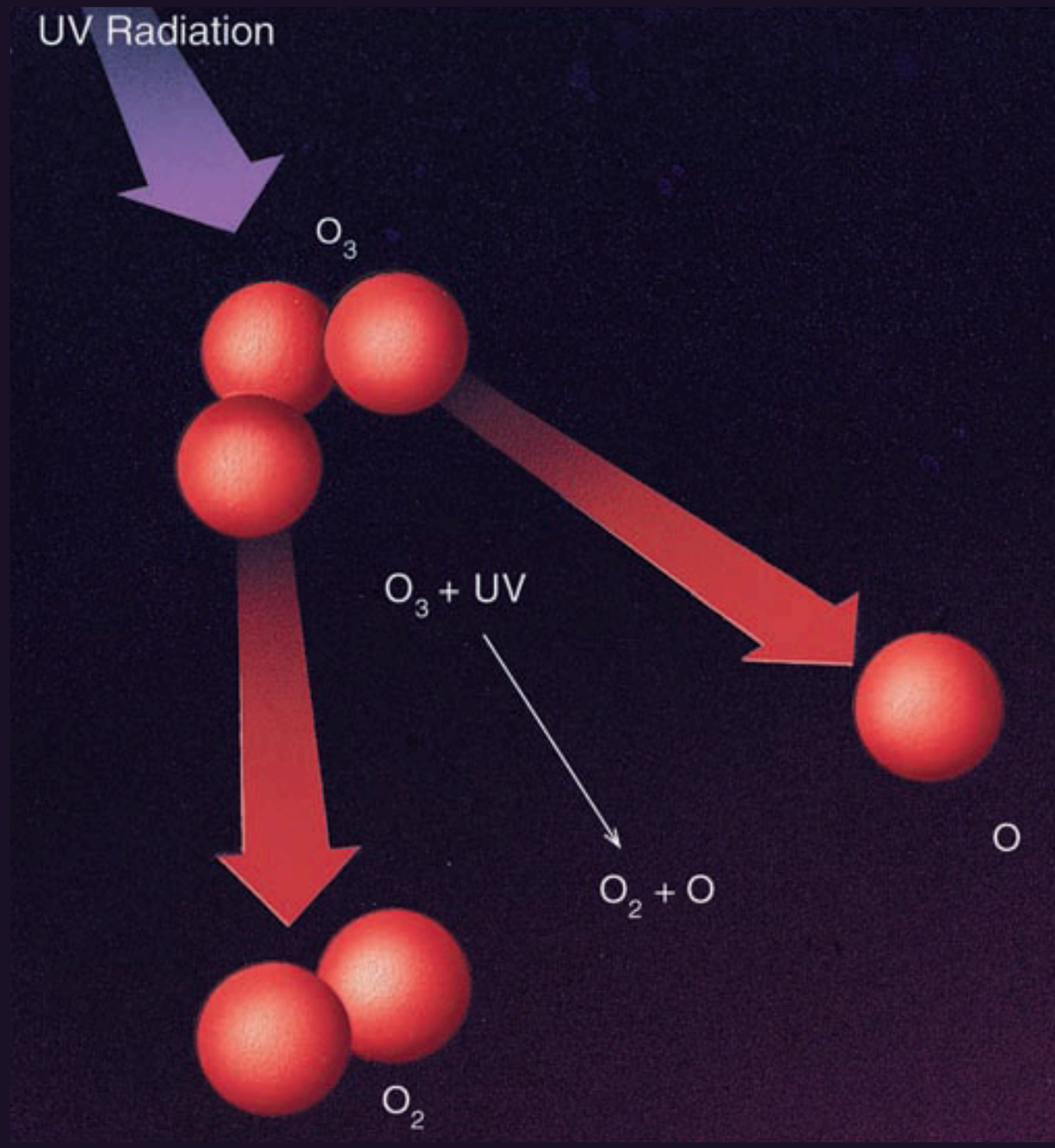

The Ozone Layer
by whatarethe7continents.com
The Ozone layer is a ring of protective gases around the Earth that absorbs harmful UV rays before they reach the surface.
The Ozone layer is located inside the stratosphere approximately 6 miles (10km) above Earth's surface.
Ultraviolet Rays
(Absorbed by Ozone Layer)
Holes in Ozone
Let UV Rays
Pass Through
Mesosphere
Stratosphere
Ozone Layer
Troposphere
6-31 Miles
(10-50 km)
0-6 Miles
(0-10 km)
Ozone
Hole
Stratosphere
Stratospheric ozone
Troposphere
Photochemical ozone
Altitude (km)
Altitude (mi)
Ozone concentration (ppm)

# Ozone

- Ozone forms naturally in the stratosphere by the combination of atomic oxygen (O) and molecular oxygen ($O_2$).
- By absorbing ultraviolet (UV) ozone is broken down into O and $O_2$.
- Ozone helps warming up the stratosphere.
- Ozone can be also broken down by colliding with O or another $O_3$.

$$O_3 + O \rightarrow 2\ O_2$$

$$O_3 + O_3 \rightarrow 3\ O_2$$



# Destruction of ozone

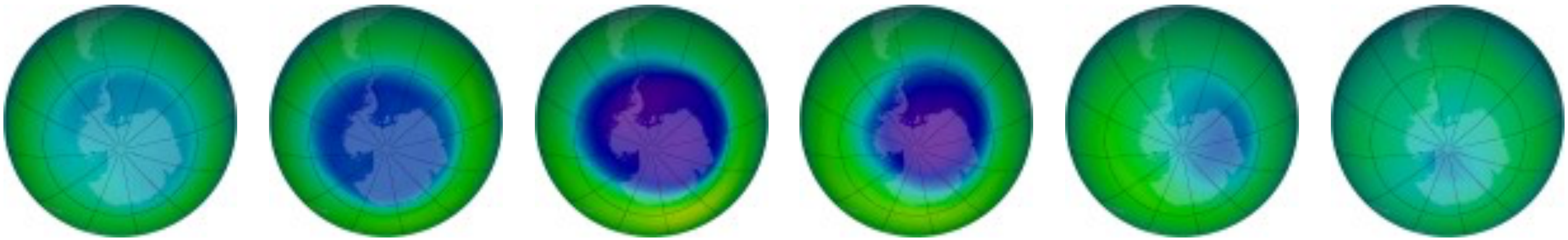
- Cosmic rays and solar particles as well as human activities provides nitrogen atom (N) or nitric oxide (NO) and nitrogen dioxide ($NO_2$)
    - $NO_2 + O \rightarrow NO + O_2$
    - $NO + O_3 \rightarrow NO_2 + O_2$
- Man-made chlorofluorocarbons (CFCs) can be very destructive to ozone in the form of chlorine monoxide (ClO).
    - $Cl + O_3 \rightarrow ClO + O_2$
    - $ClO + O \rightarrow Cl + O_2$

    Can remove 100,000 $O_3$ molecules!
    - $ClO + NO_2 \rightarrow ClONO_2$ ⟶ The removal process of ClO

# Breaking up ozone

- CFCs are very stable in th
- They enter the stratosphe
  - near breaks in the tropo
  - through thunderstorms

- In winter, the polar vortex develops over Antarctica.
- Polar stratospheric clouds form under the condition of extremely low temperature, facilitating chemical reaction.



# Southern Annular Mode (SAM) or Antarctic Oscillation

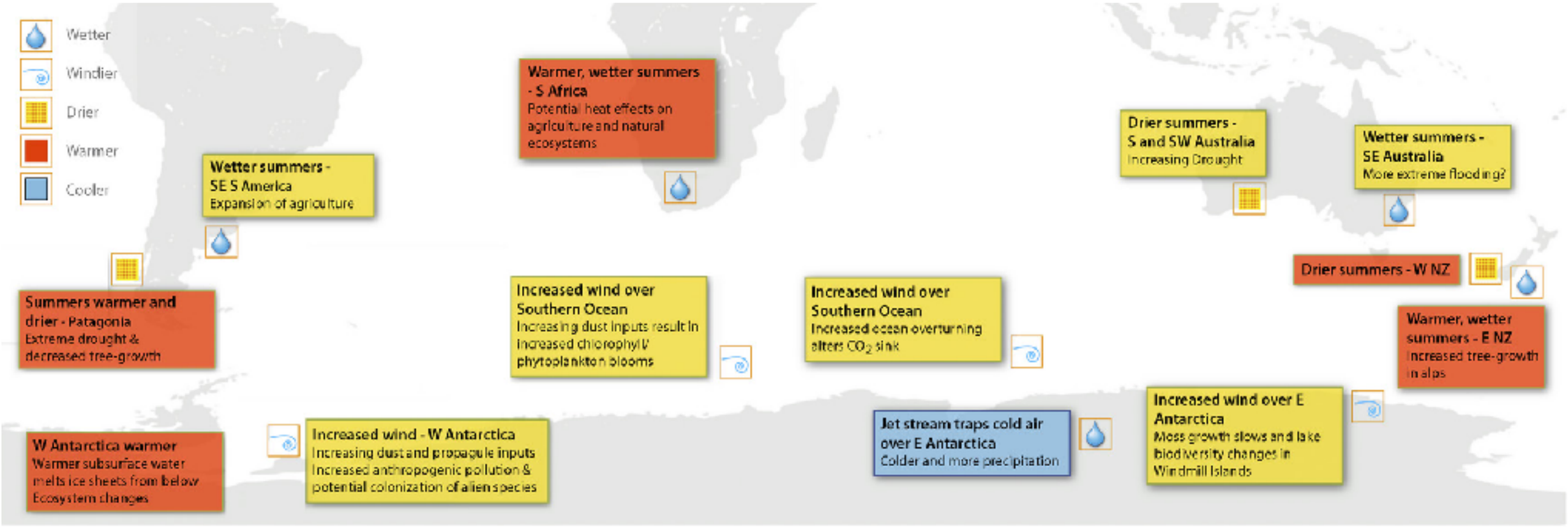
- A low frequency mode of atmospheric variability
- Expressed as the north-south movement of the westerly winds
- As the westerly winds change the location, so does the storm track and precipitation
- Two phases : A positive or a negative phase
- Southern Annular Mode (SAM) can last several weeks, but changes phases quickly and unpredictably.

# Southern Annular Mode (SAM) or Antarctic Oscillation

- The index of SAM is defined as the difference of zonally-averaged sea-level pressure between the latitude of 40°S and 65°S
- A negative SAM phase (less pressure difference) has an equatorward shift of the westerly winds.
    - More storm activities over Australia and New Zealand.
    - Decreases in temperature there
- During a positive SAM phase (greater pressure difference), strong westerly winds shift towards Antarctica.
    - Less rain over Australia and New Zealand
    - Warmer weather there

# The impact of SAM on the weather

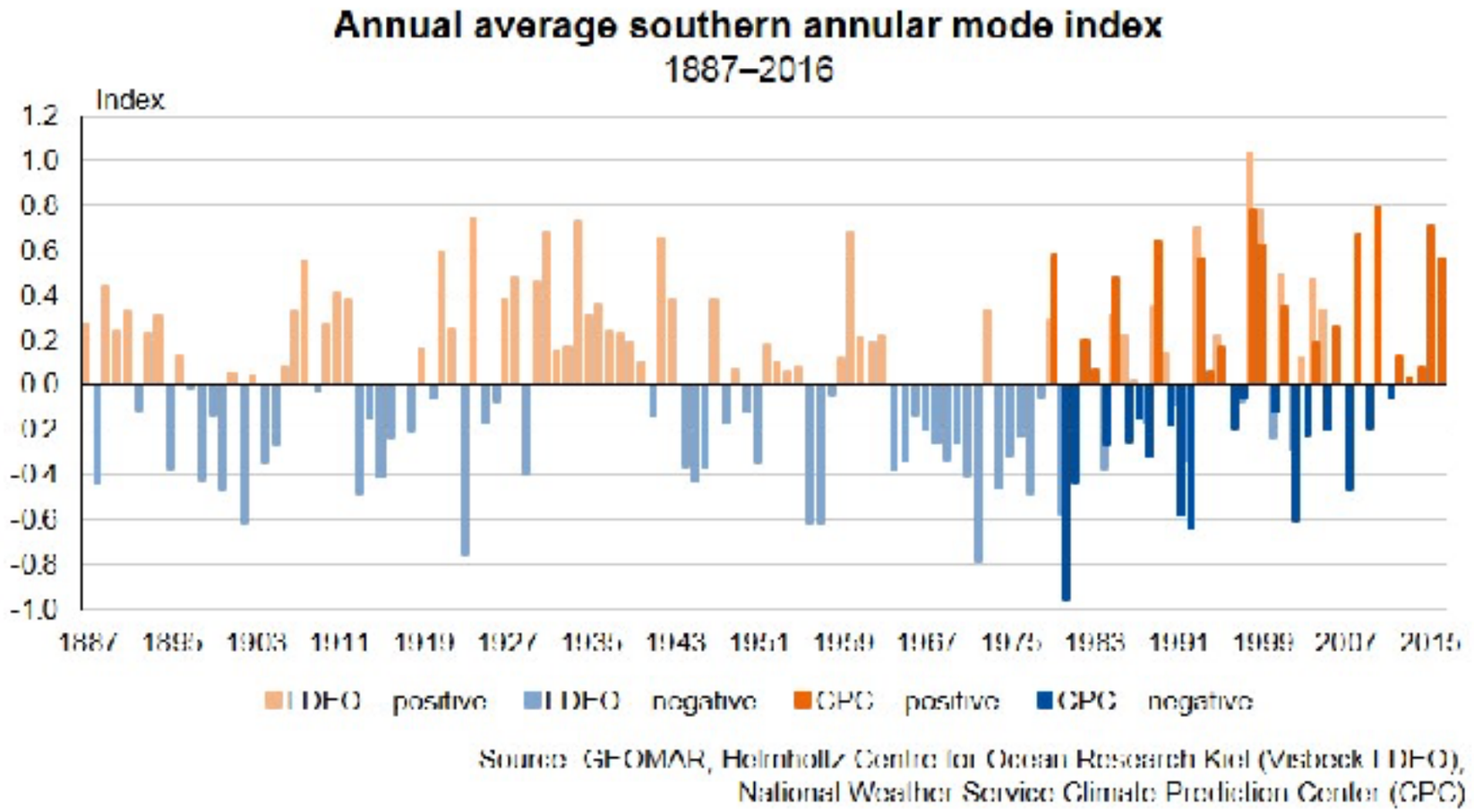
**Video about SAM**




Robinson and Erickson III, 2014

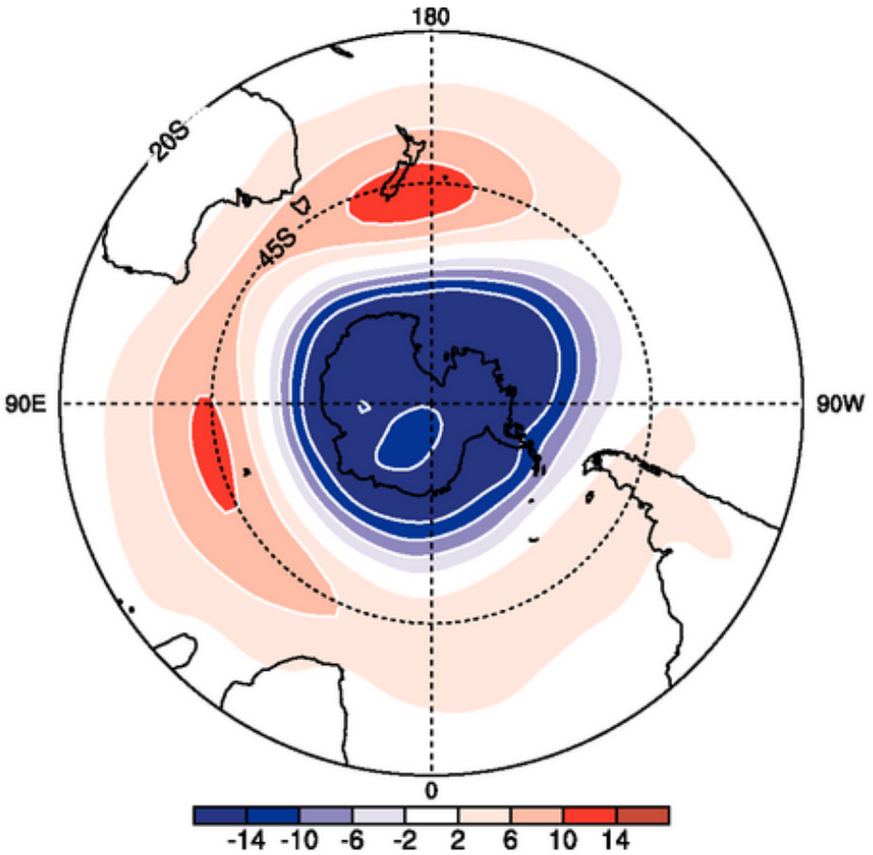
# Southern Annular Mode

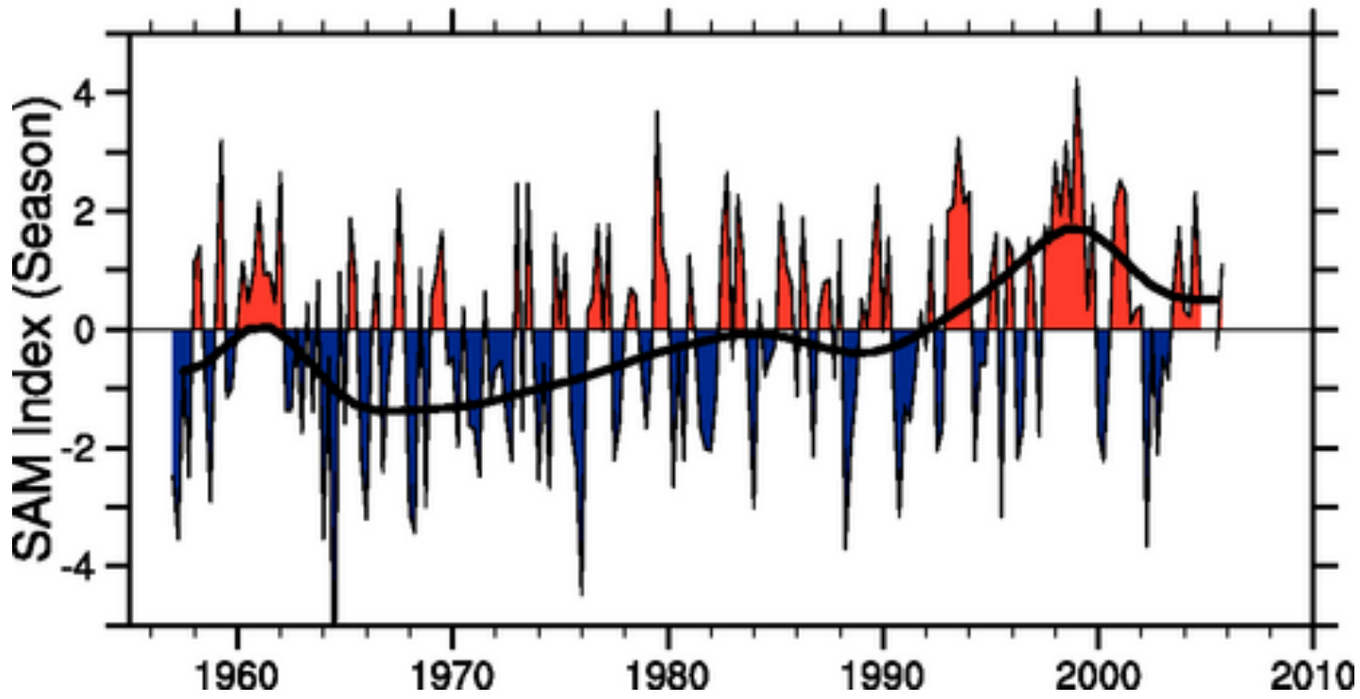
- SAM values can vary widely over time periods of weeks or months.
- The Southern Annular Mode (SAM) has been increasing (becoming more positive) since 1970.




From http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Atmosphere-and-climate/southern-annular-mode.aspx

# Southern Annular Mode

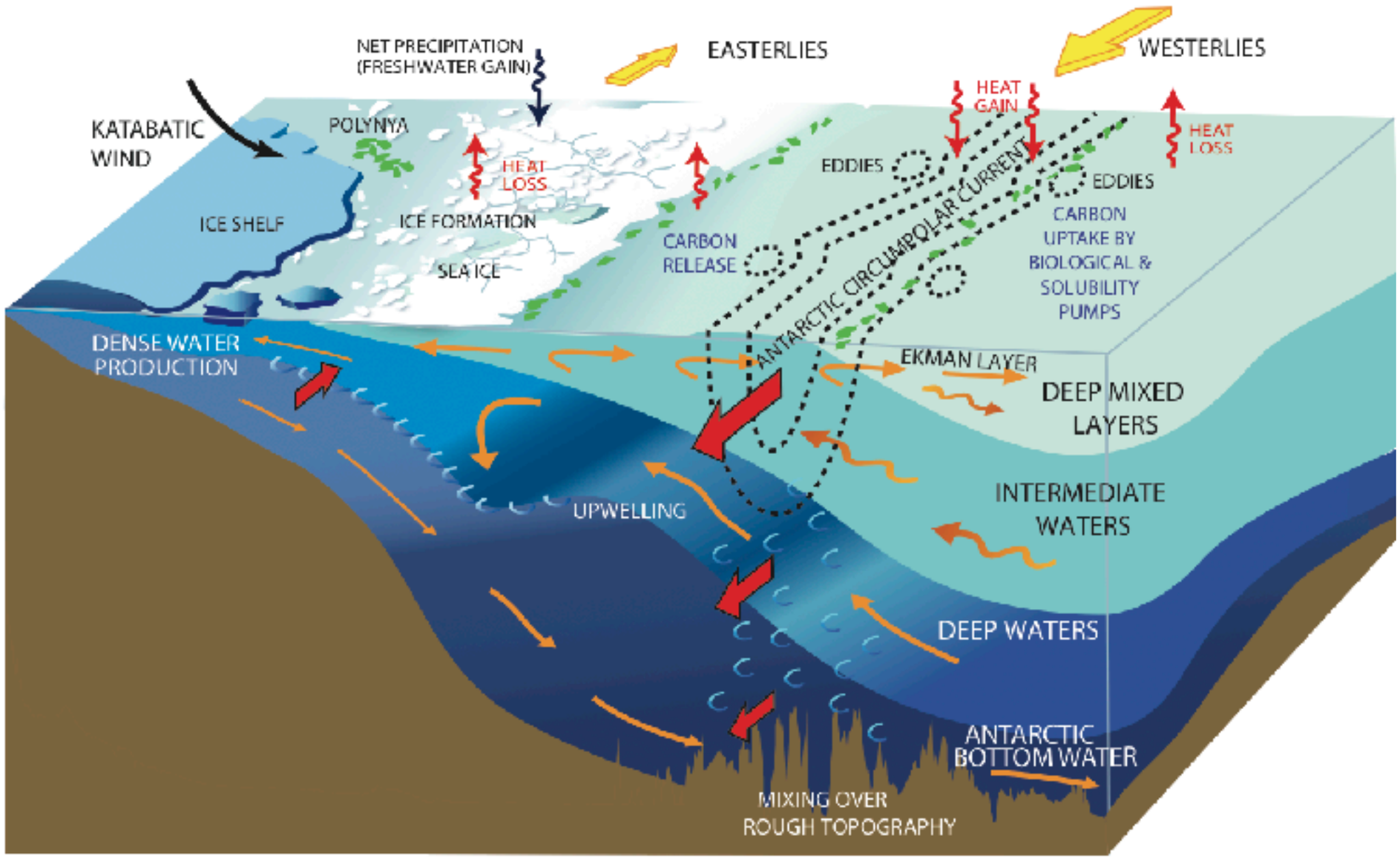


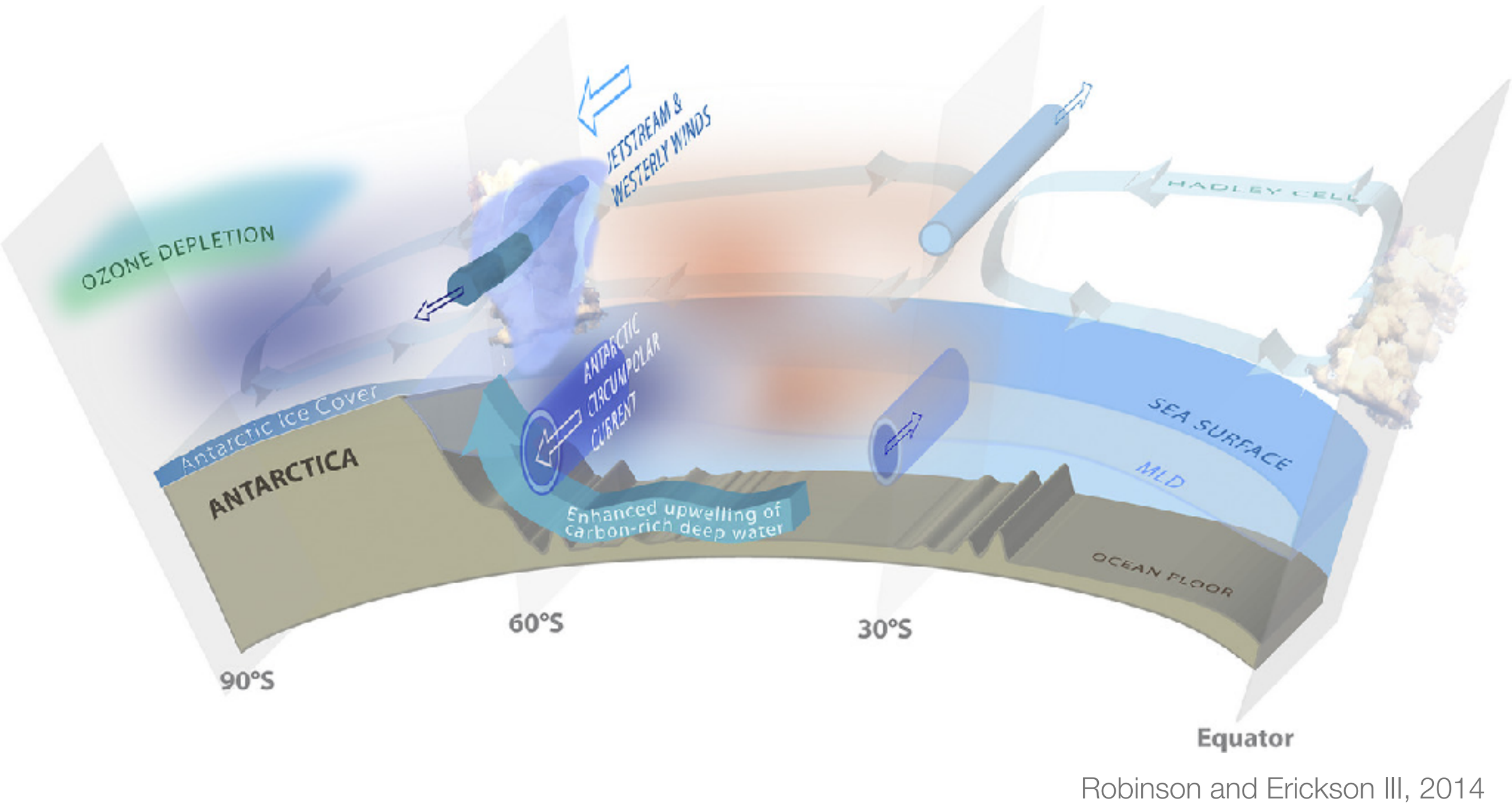

From https://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-3-32.html

# The Southern Ocean

- Waves in the southern ocean
- Overturning circulation



# Ozone hole, SAM and ocean

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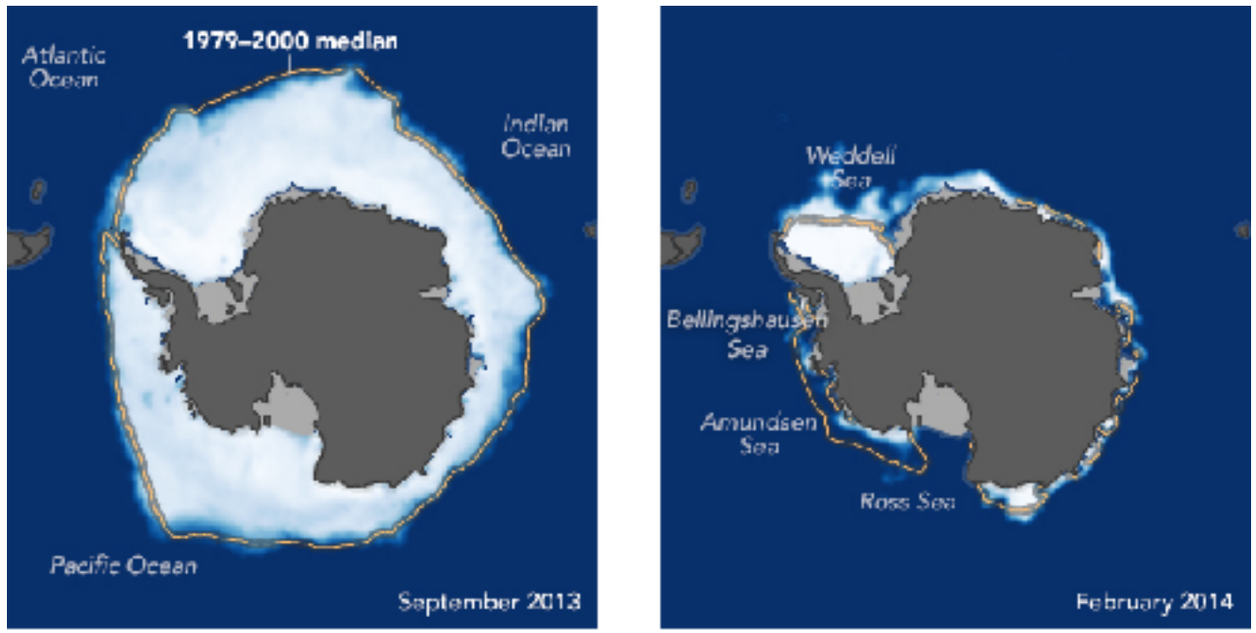
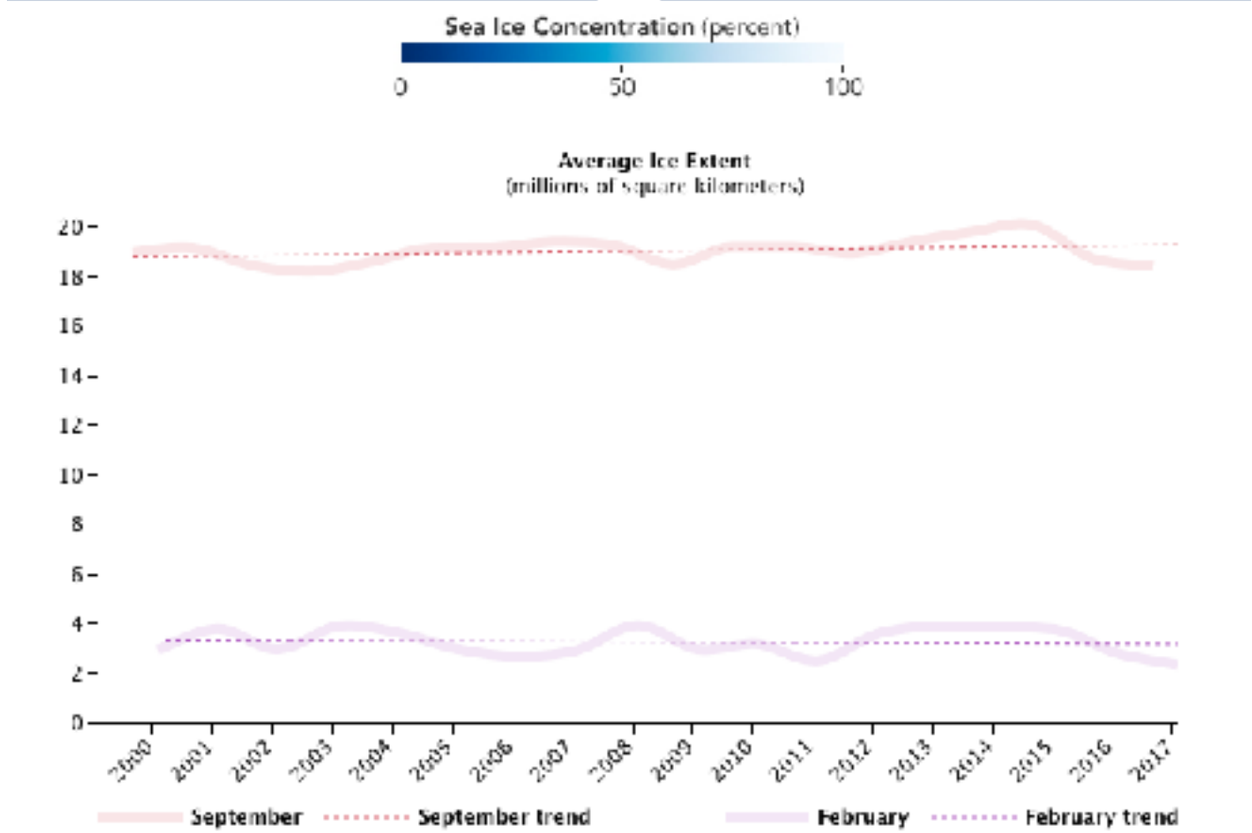
# The sea-ice in the Antarctica




From https://earthobservatory.nasa.gov/Features/WorldOfChange/sea_ice_south.php

# The Antarctic sea-ice in recent years