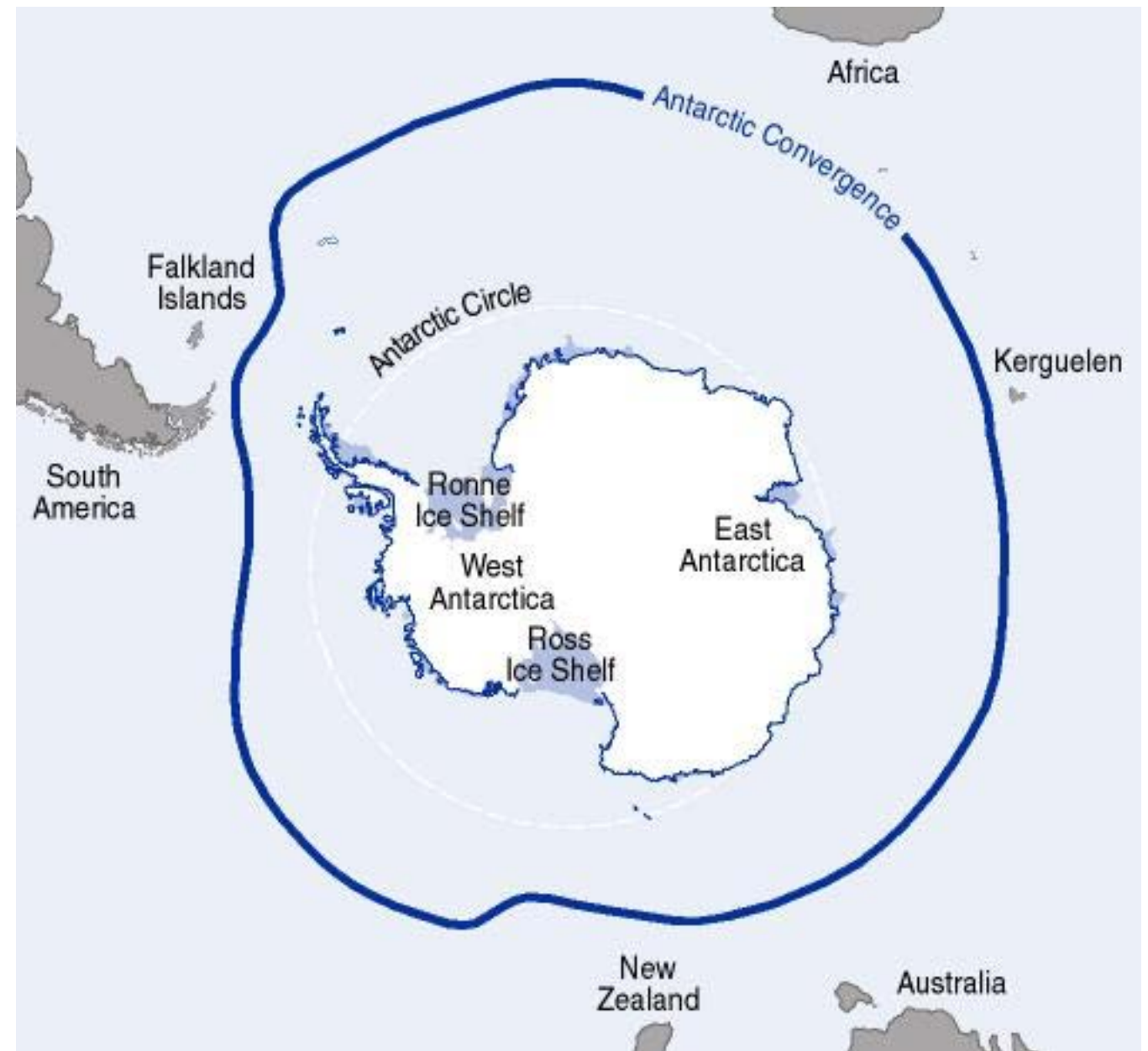


Air-sea interactions : Polar regions #2

ATM2106

The Antarctic



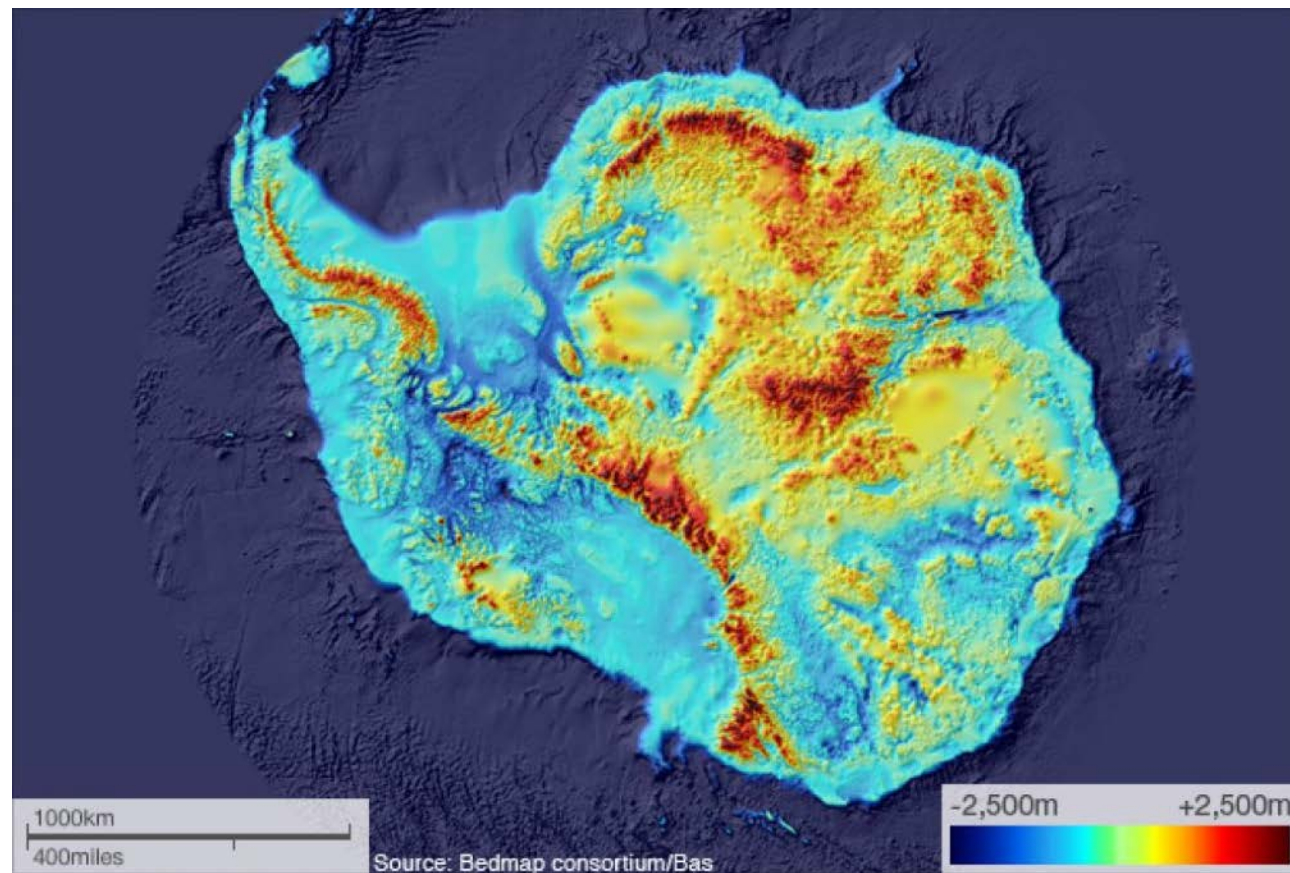
About Antarctica

- 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.

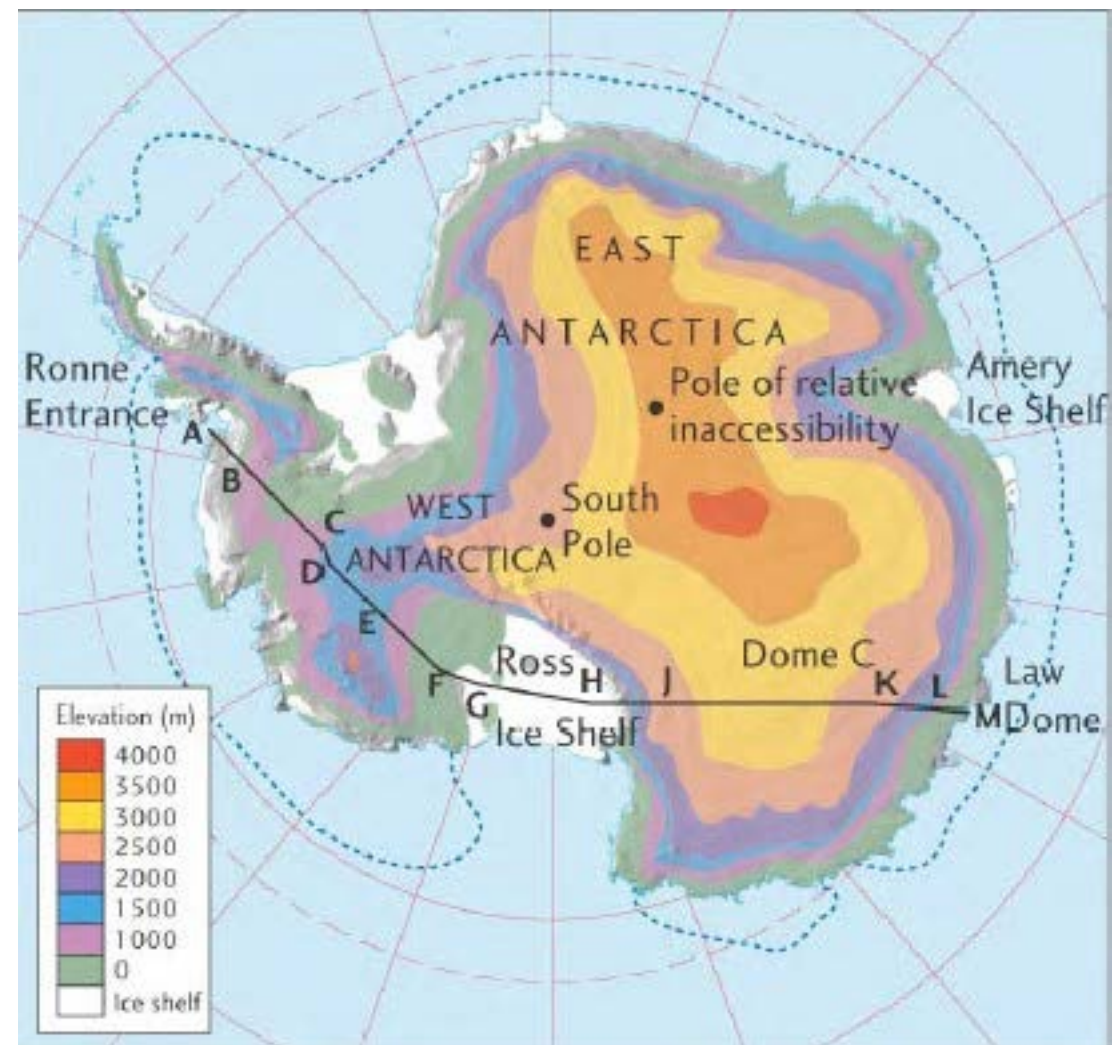


Antarctica

Without ice

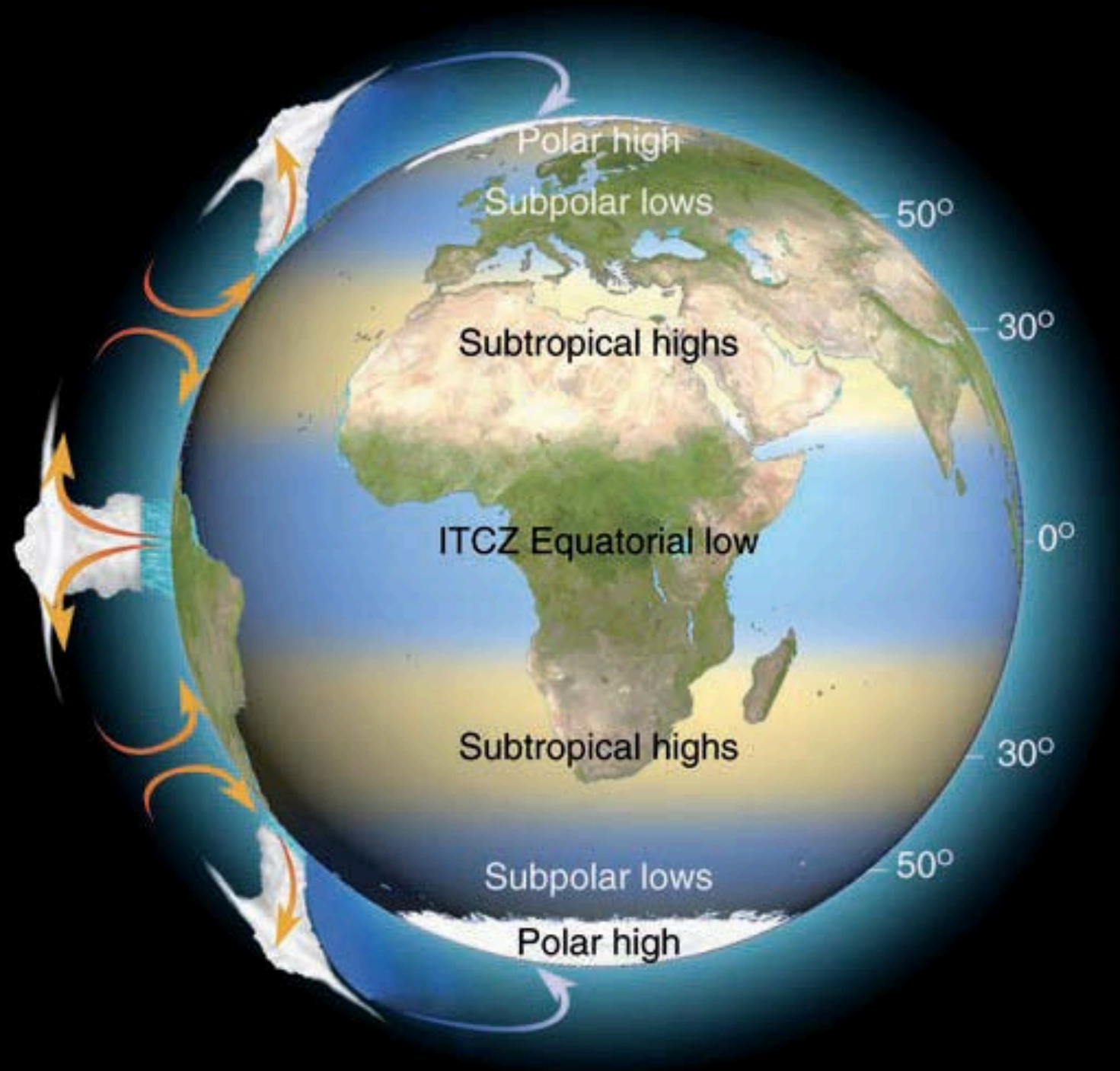


With ice

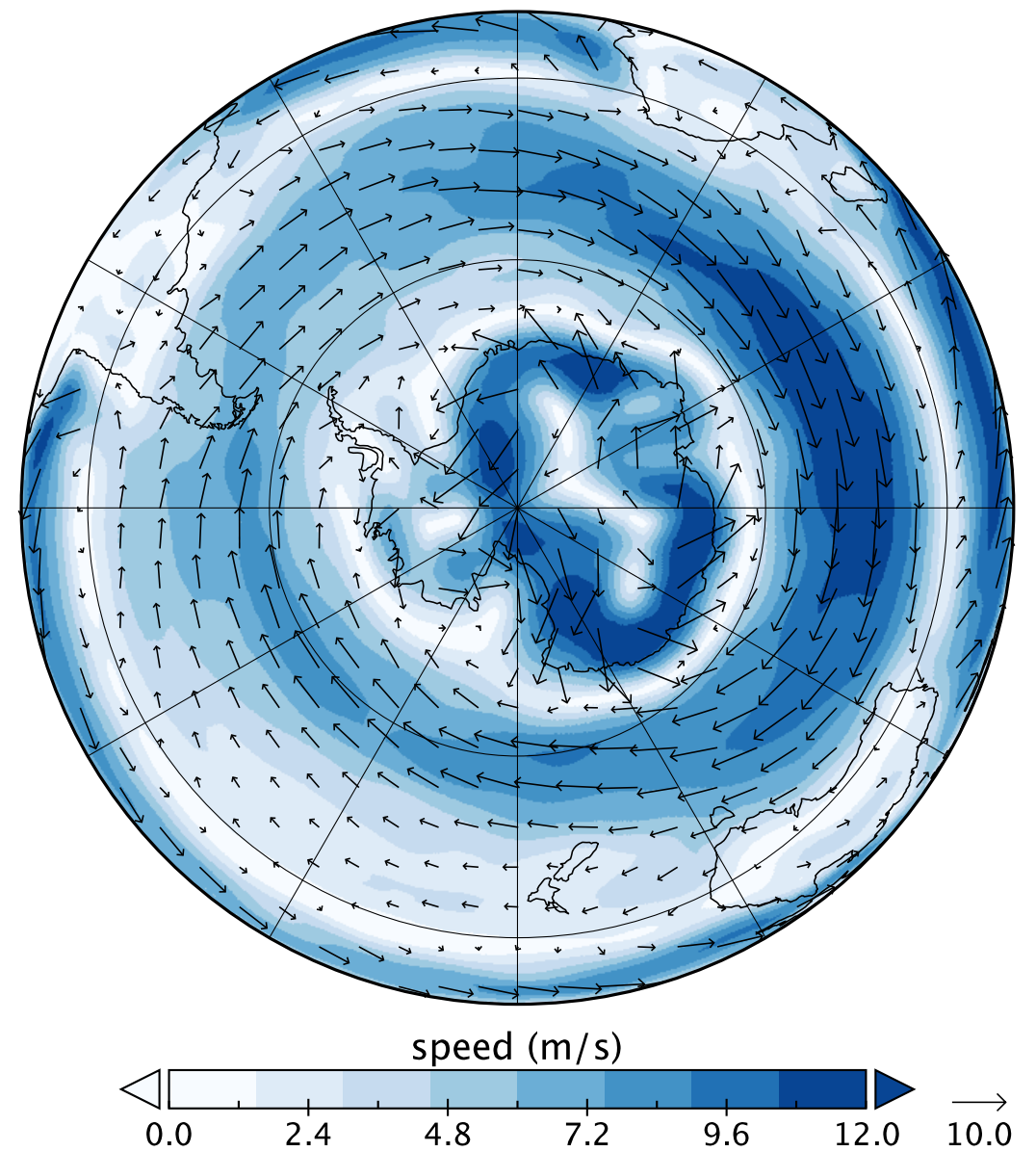
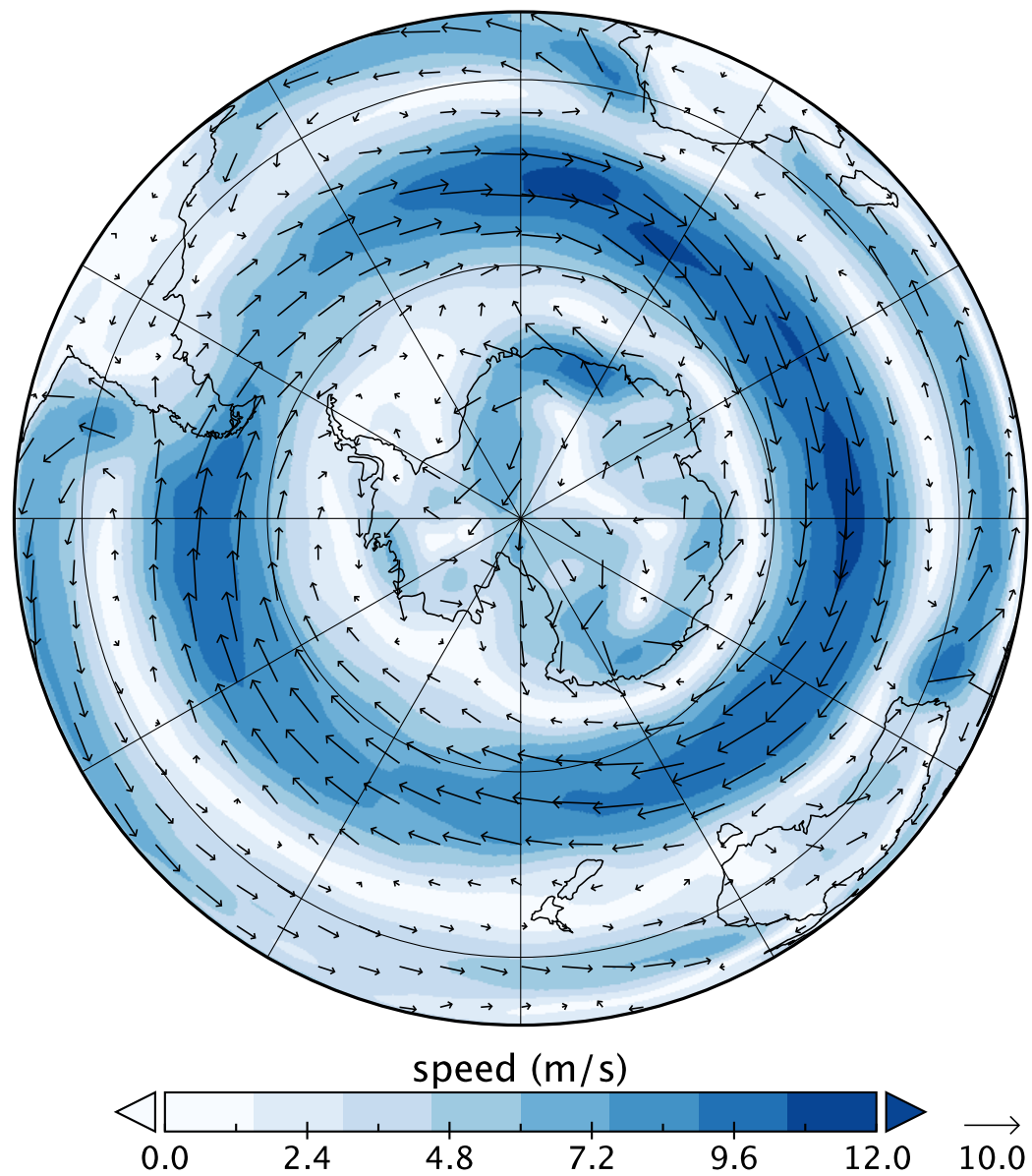


From <http://www.antarctica.gov.au/science/cool-science/2011/bedrock-map-reveals-ice-free-antarctica> and <https://lima.nasa.gov/antarctica/>

Meridional circulation

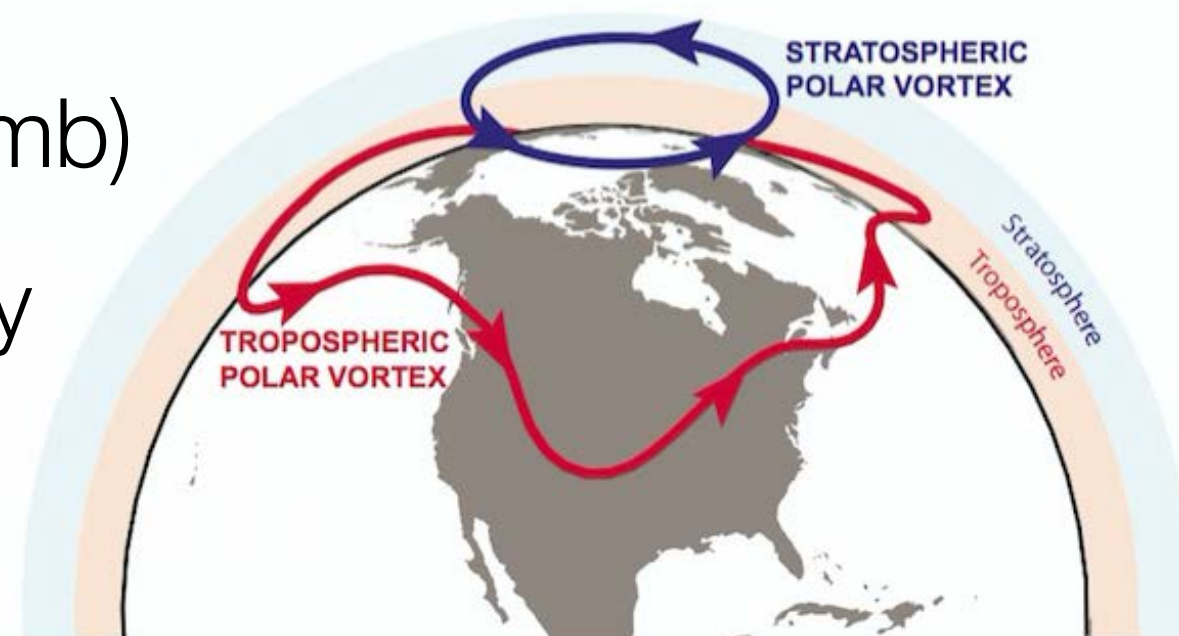


Winds at the surface



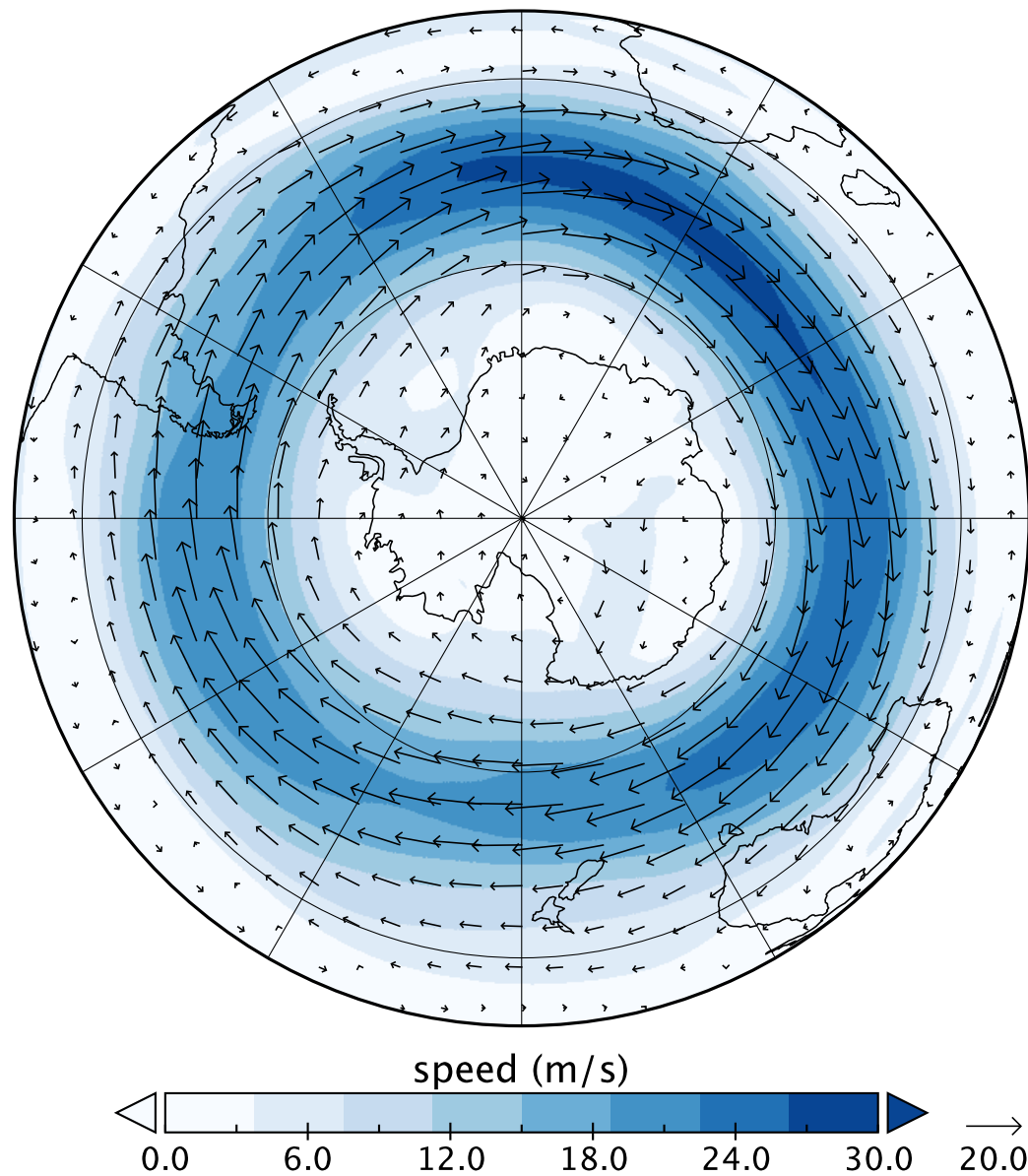
Polar vortex

- 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)

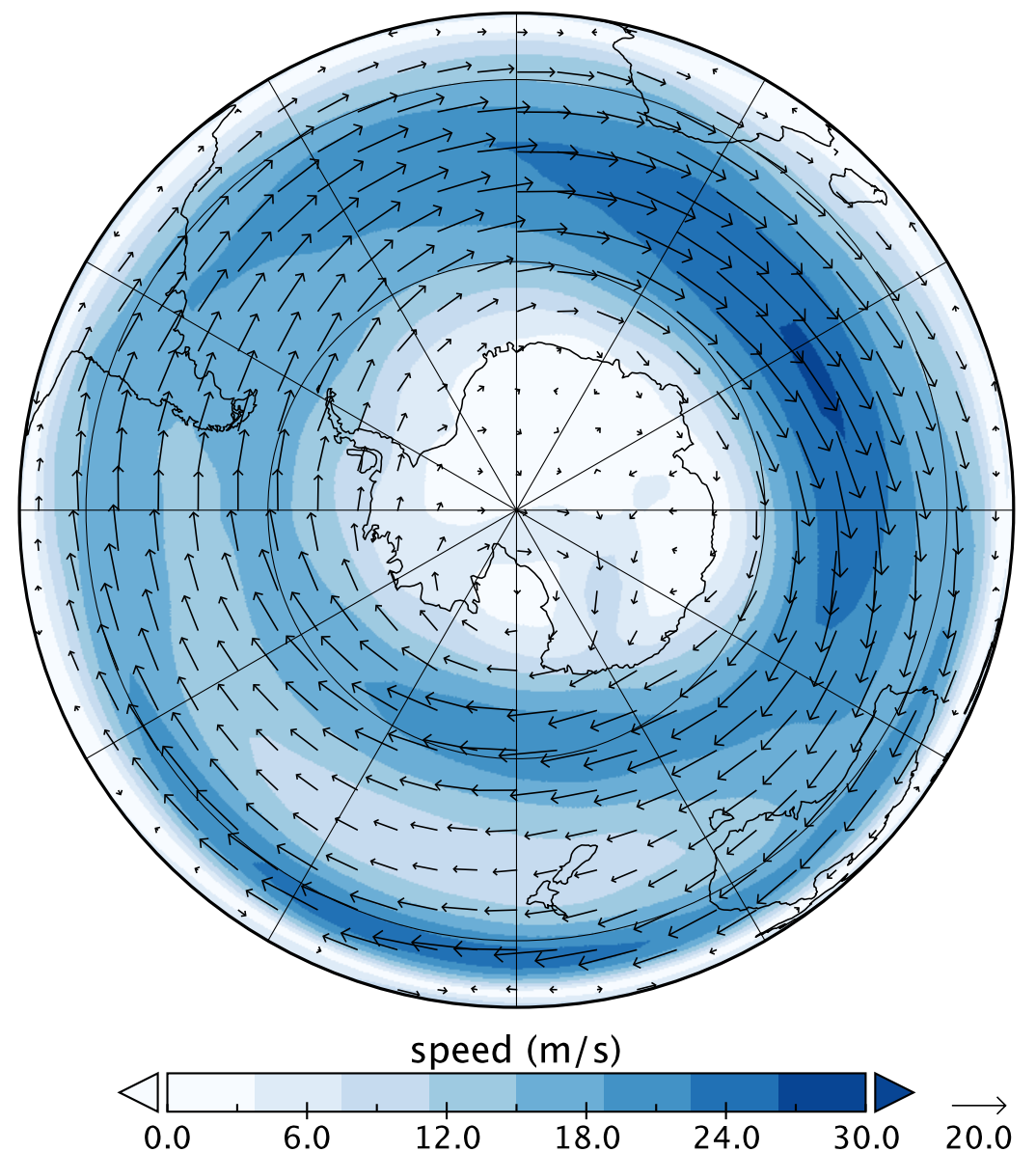


Winds at 500mb (Tropospheric polar vortex)

February

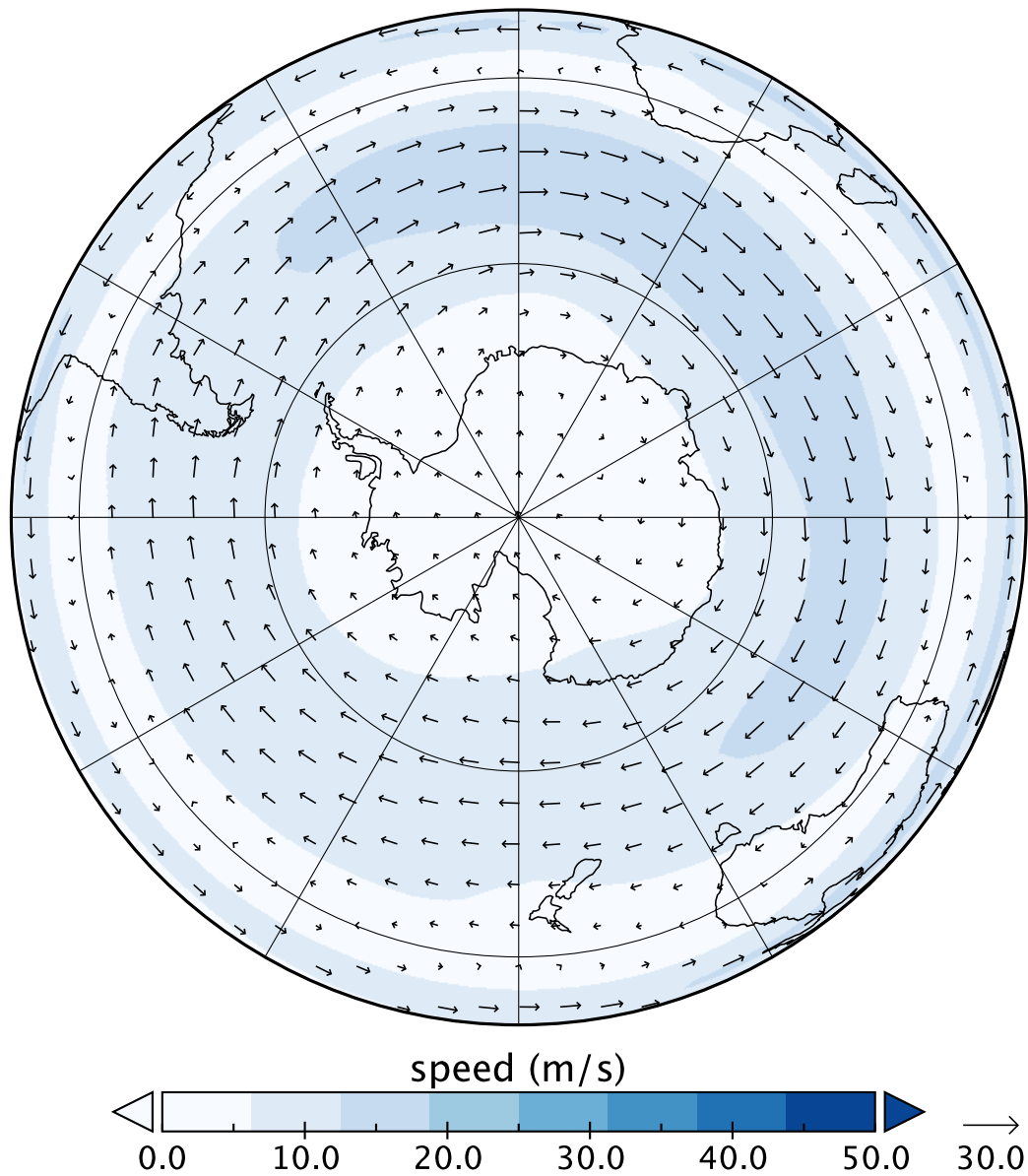


August

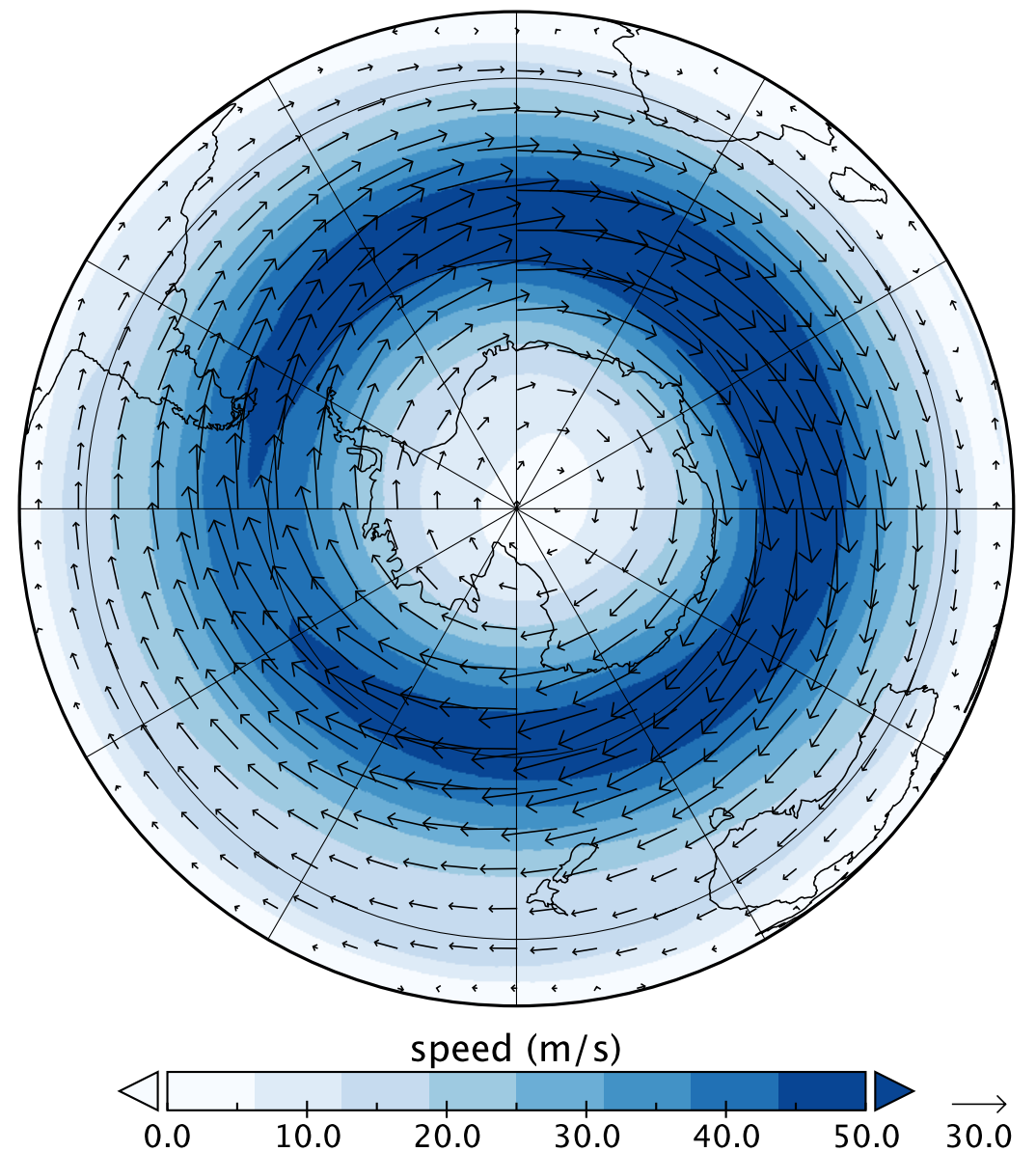


Winds at 70mb (Stratospheric polar vortex)

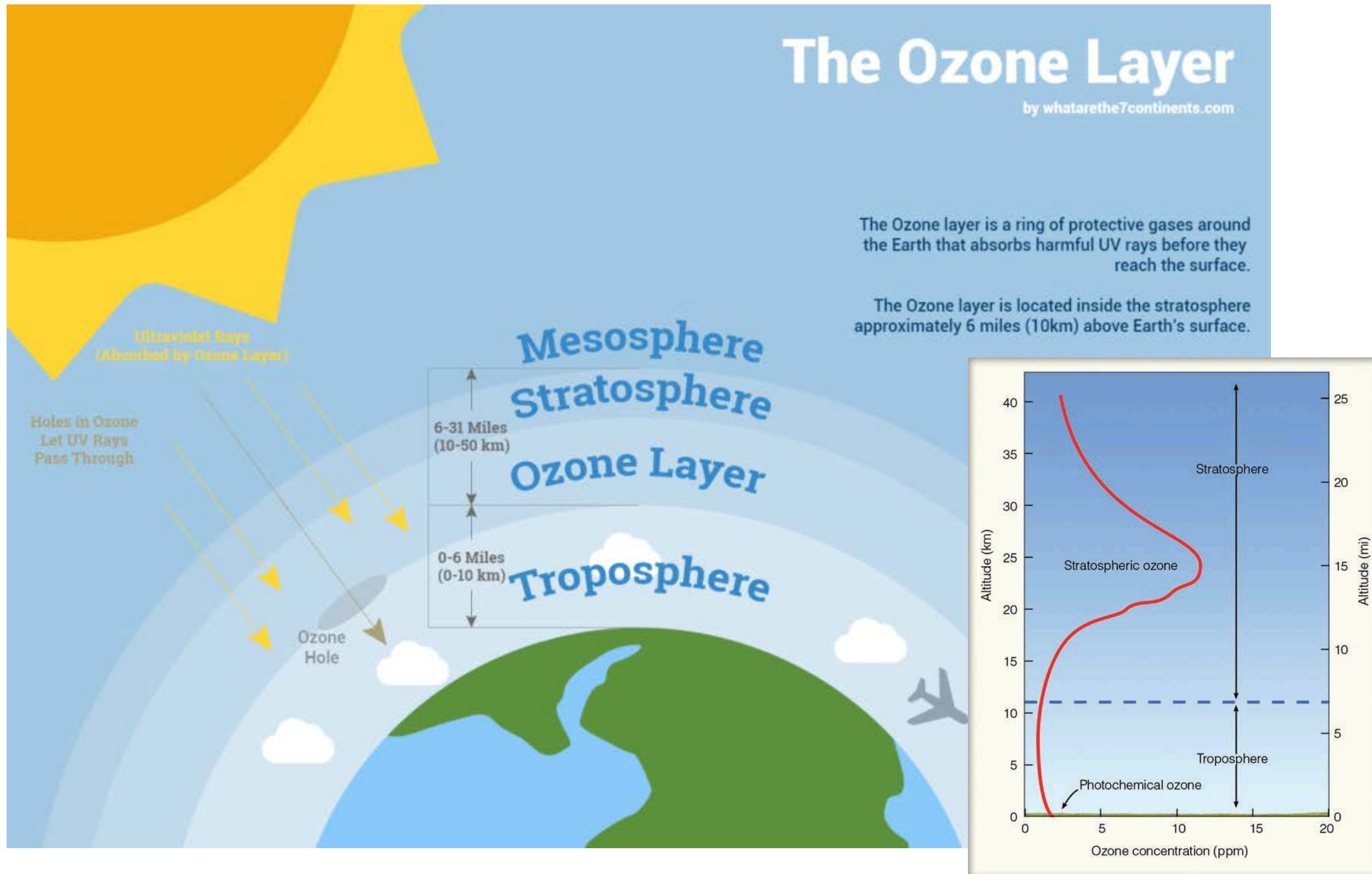
February



August

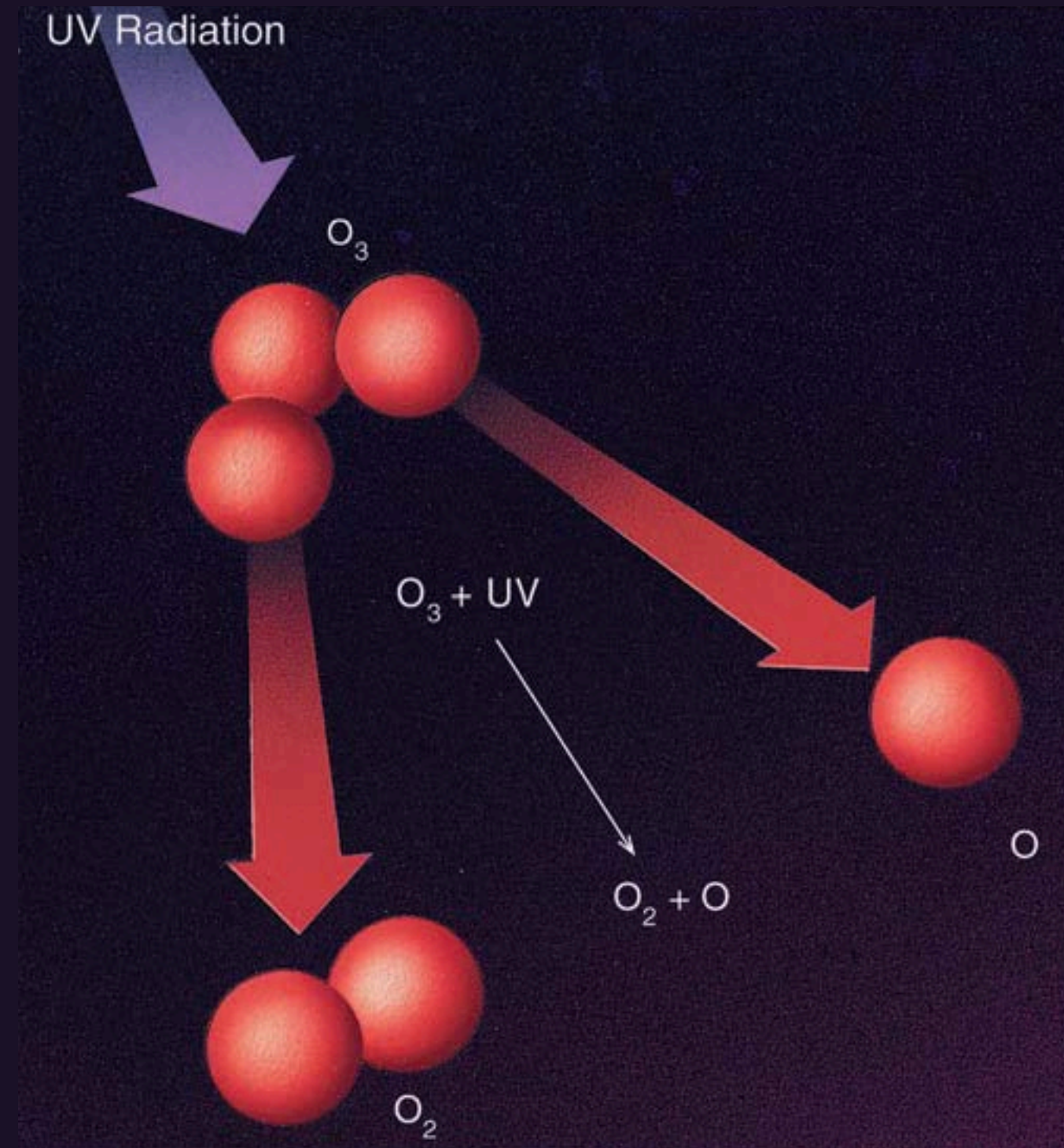


Ozone



Ozone

- Ozone forms naturally in the stratosphere by the combination of atomic oxygen (O) and molecular oxygen (O₂).
- By absorbing ultraviolet (UV) ozone is broken down into O and O₂.
- Ozone helps warming up the stratosphere.
- Ozone can be also broken down by colliding with O or another O₃.



Destruction of ozone

- Cosmic rays and solar particles as well as human activities provides nitrogen atom (N) or nitric oxide (NO) and nitrogen dioxide (NO₂)
 - $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2$
 - $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$
- Man-made chlorofluorocarbons (CFCs) can be very destructive to ozone in the form of chlorine monoxide (ClO).
 - $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$
 - $\text{ClO} + \text{O} \rightarrow \text{Cl} + \text{O}_2$
 - $\text{ClO} + \text{NO}_2 \rightarrow \text{ClONO}_2$



Can remove 100,000 O₃ molecules!



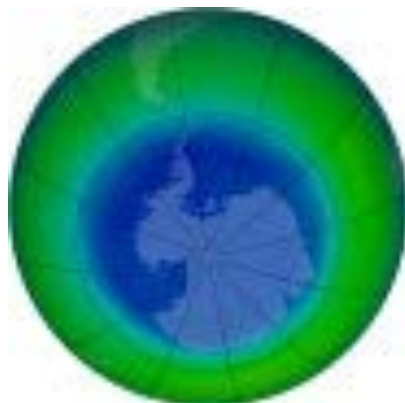
The removal process of ClO

Breaking up ozone

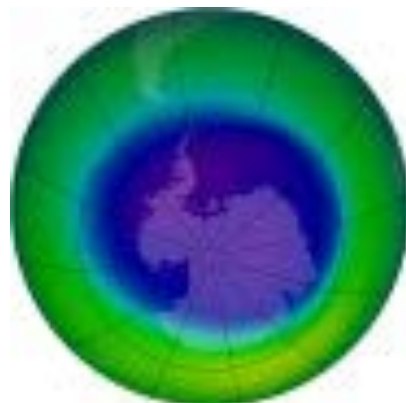
- CFCs are very stable in the troposphere
- They enter the stratosphere
 - near breaks in the tropopause
 - through thunderstorms
- In winter, the polar vortex develops over Antarctica.
- Polar stratospheric clouds form under the condition of extremely low temperature, facilitating chemical reaction.



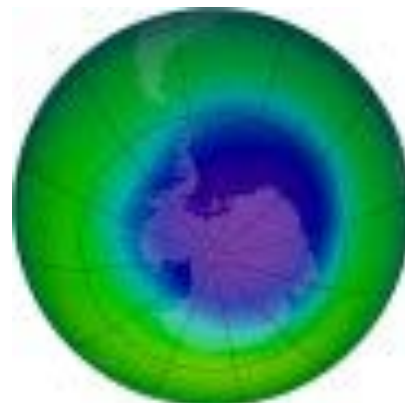
July



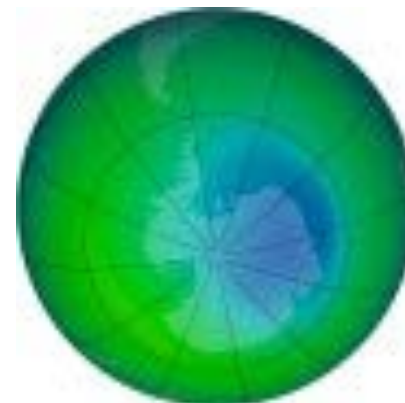
August



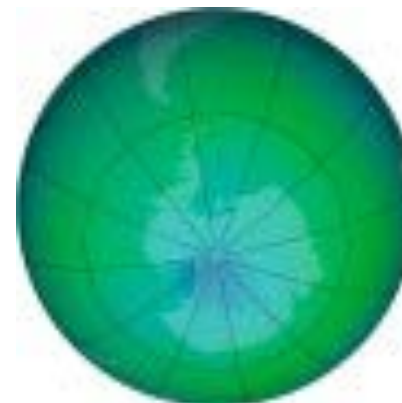
September



October



November



December

Southern Annular Mode (SAM) or Antarctic Oscillation

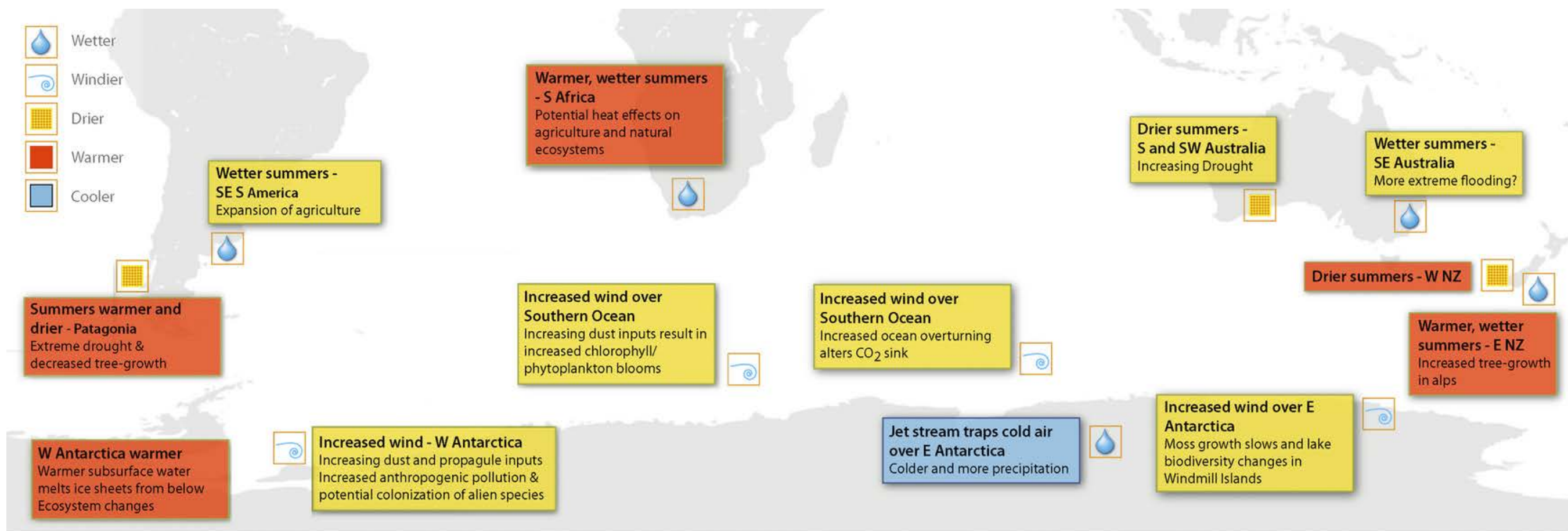
- A low frequency mode of atmospheric variability
- Expressed as the north-south movement of the westerly winds
- As the westerly winds change the location, so does the storm track and precipitation
- Two phases : A positive or a negative phase
- Southern Annular Mode (SAM) can last several weeks, but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

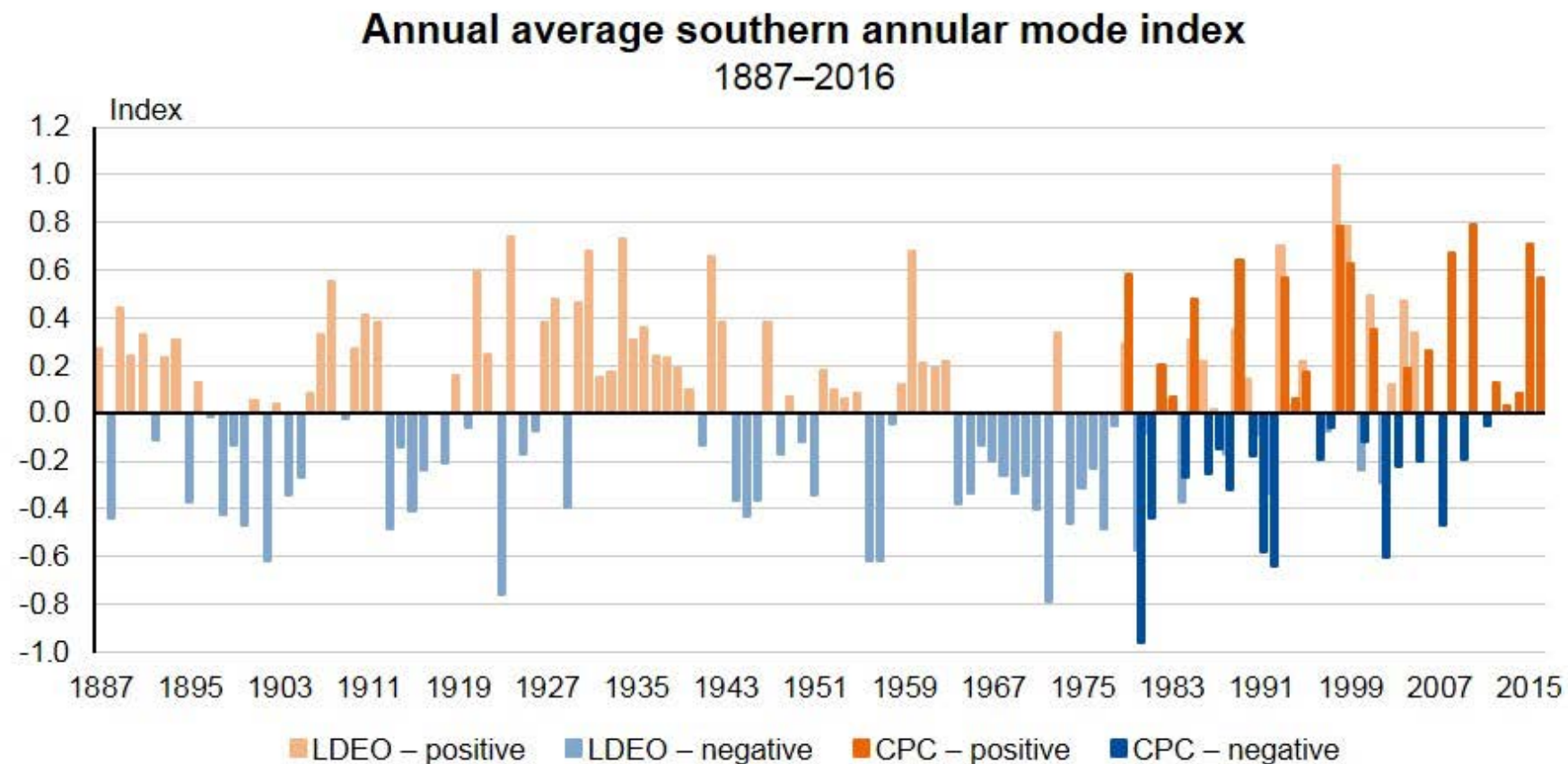
The impact of SAM on the weather

Video about SAM



Southern Annular Mode

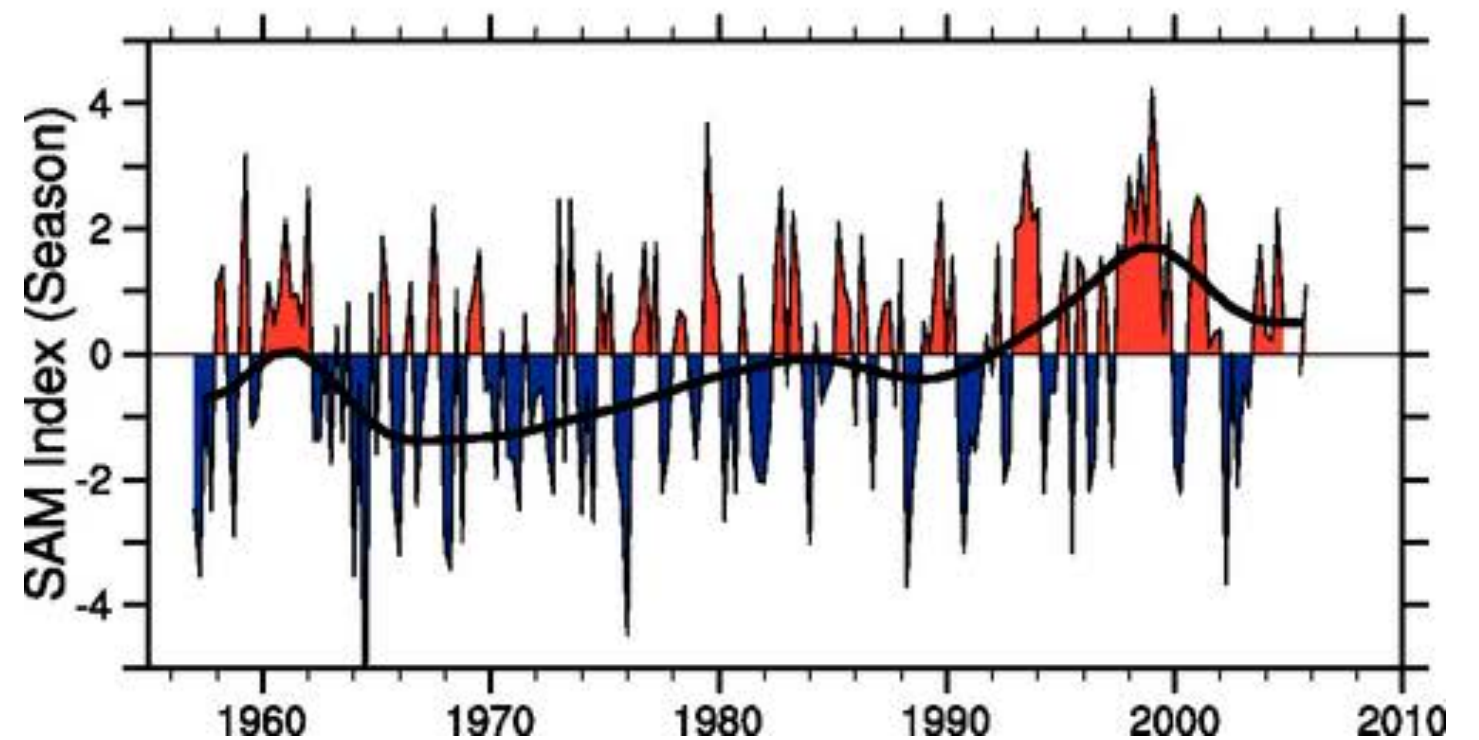
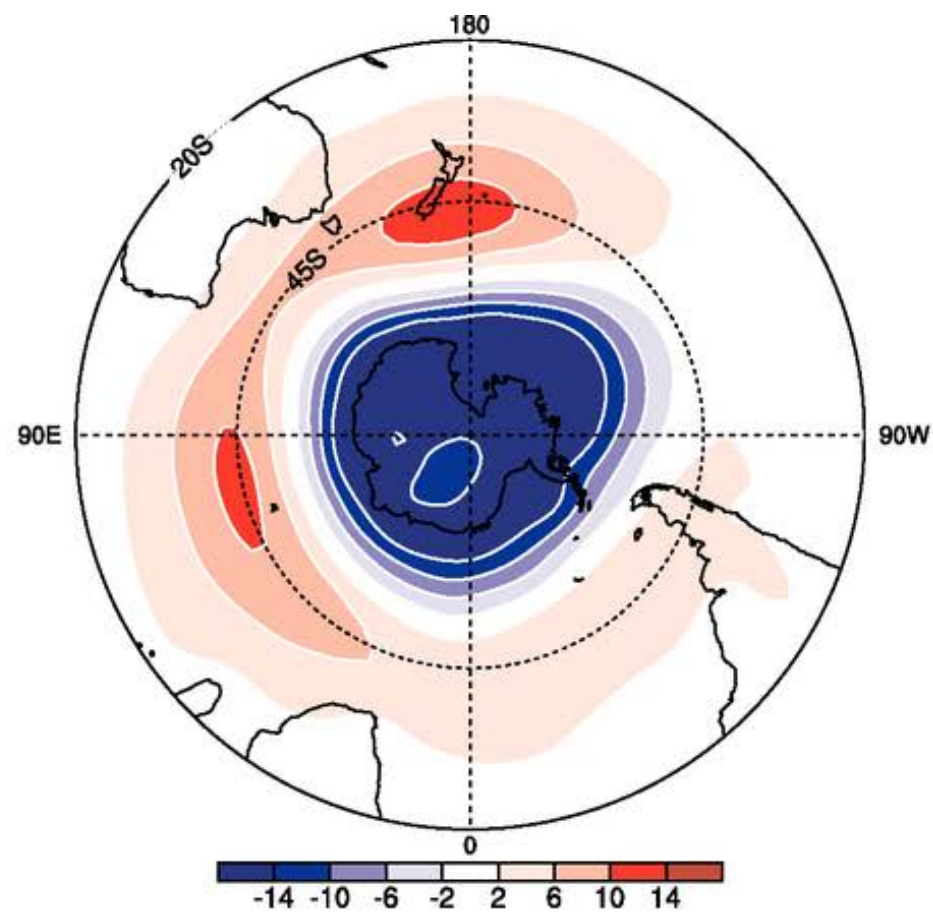
- SAM values can vary widely over time periods of weeks or months.
- The Southern Annular Mode (SAM) has been increasing (becoming more positive) since 1970.



Source: GEOMAR, Helmholtz Centre for Ocean Research Kiel (Visbeck LDEO);
National Weather Service Climate Prediction Center (CPC)

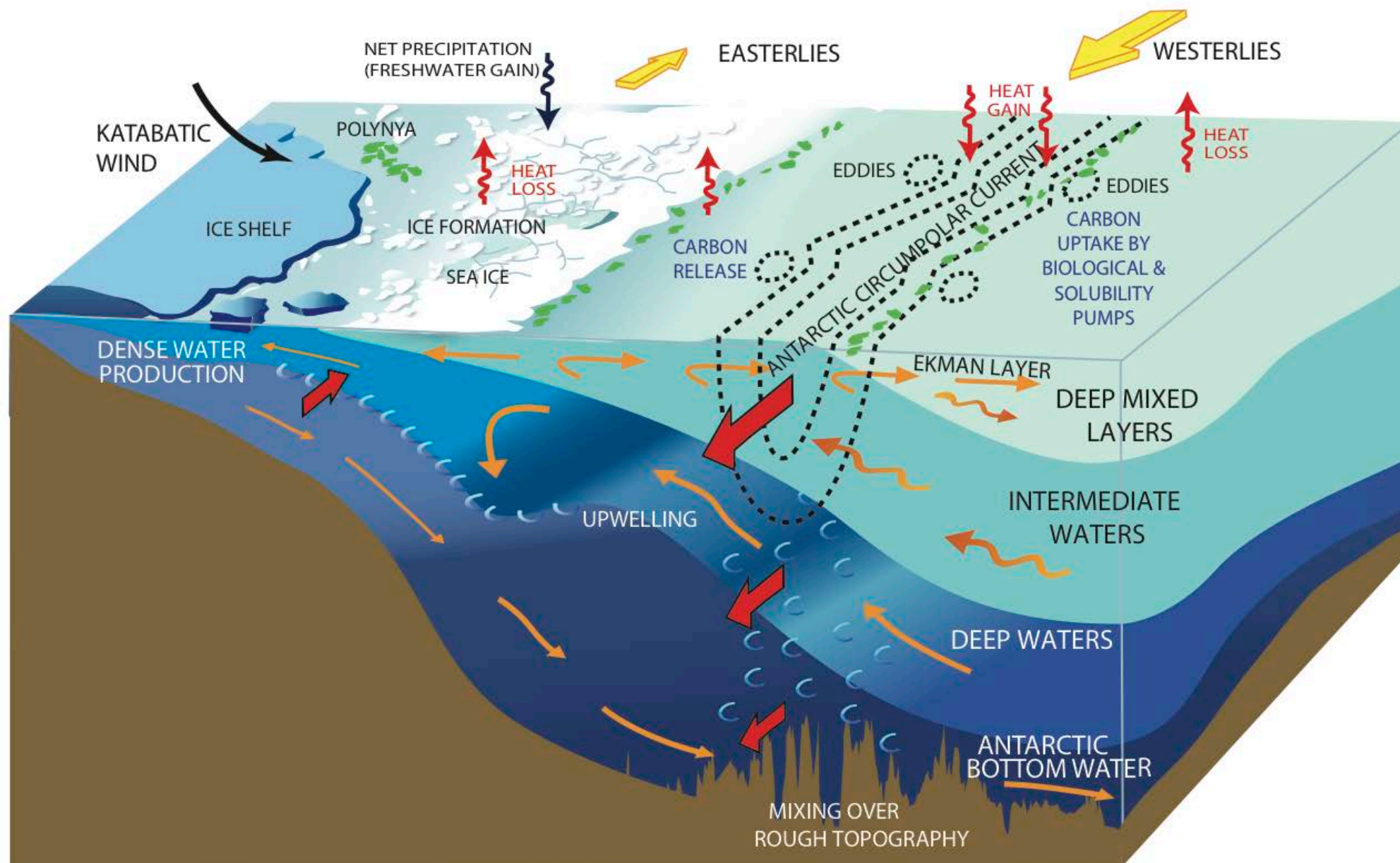
From http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Atmosphere-and-climate/southern-annular-mode.aspx

Southern Annular Mode

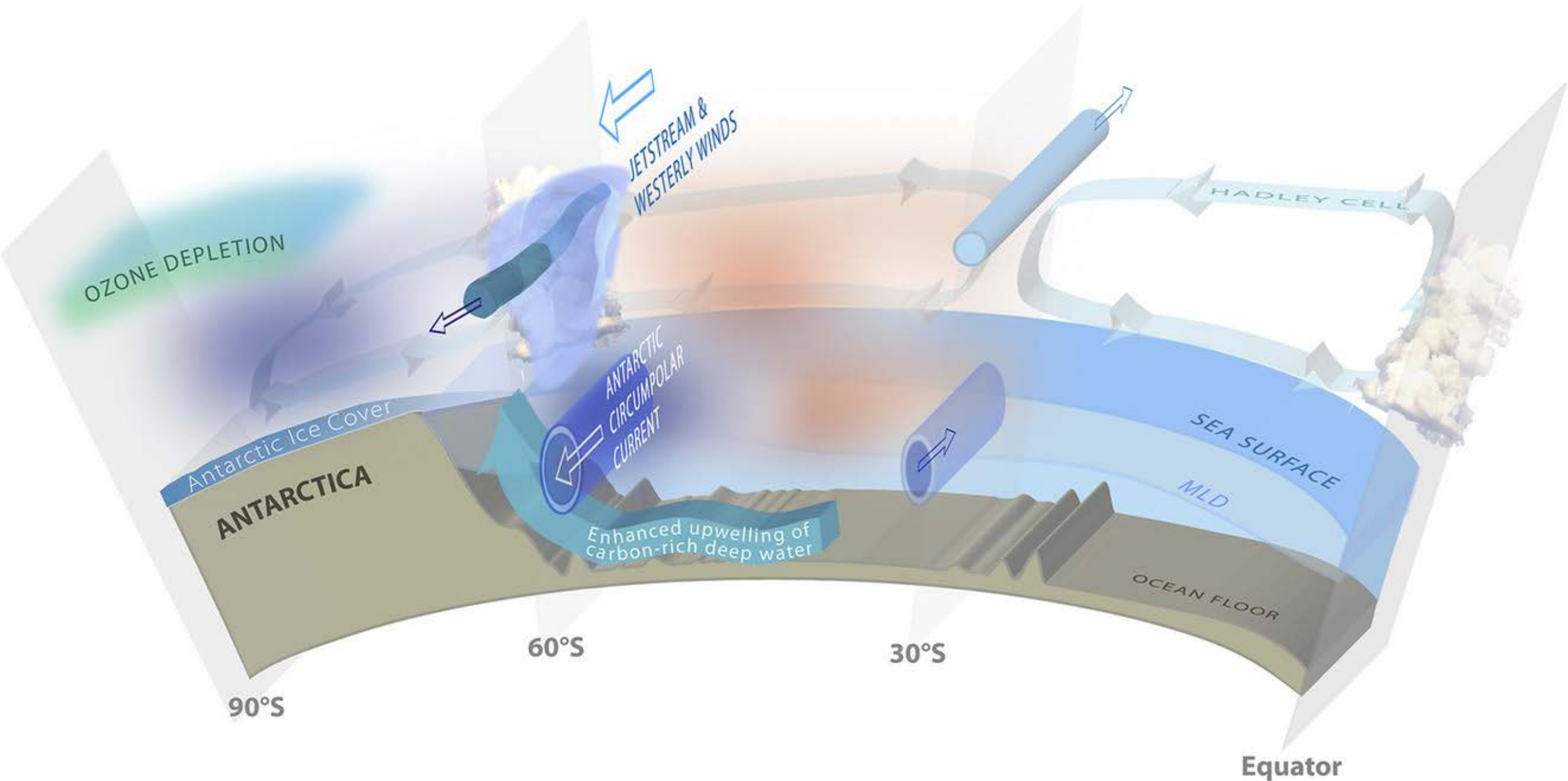


The Southern Ocean

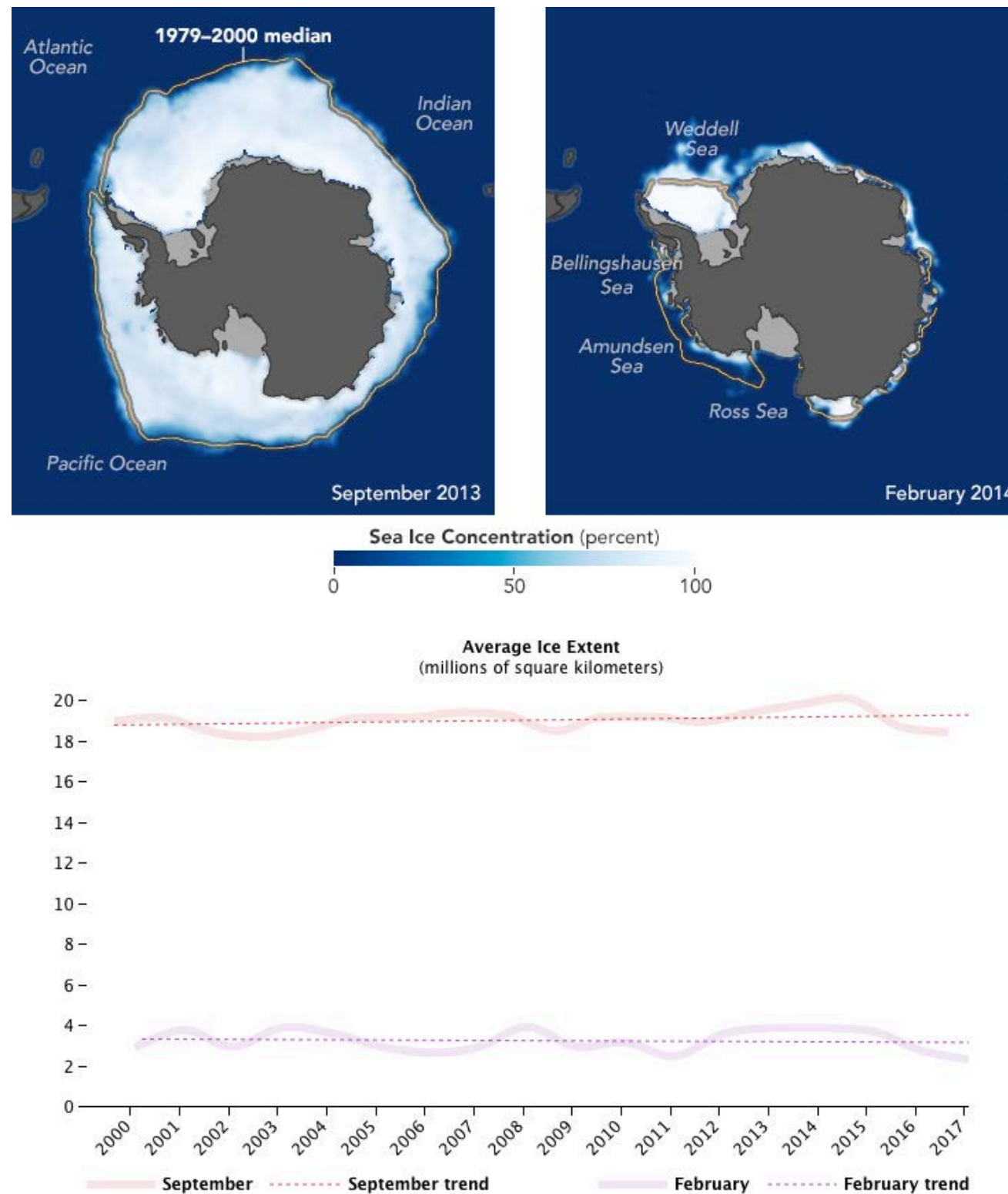
- Waves in the southern ocean
- Overturning circulation



Ozone hole, SAM and ocean



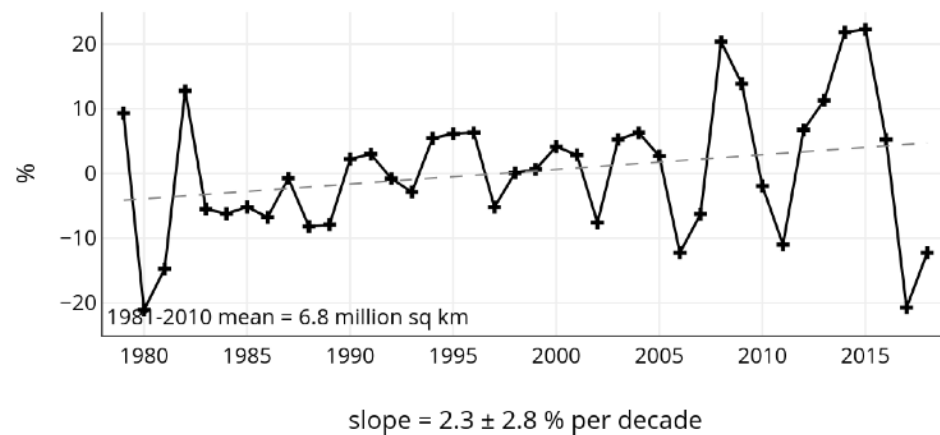
The sea-ice in the Antarctica



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

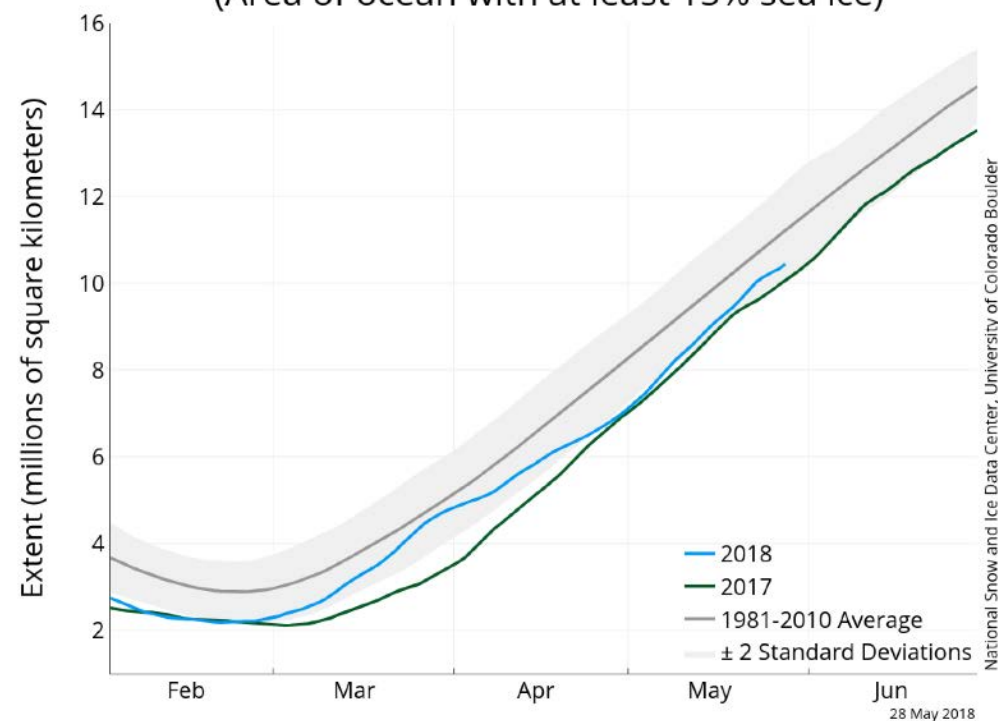
The Antarctic sea-ice in recent years

Southern Hemisphere Extent Anomalies Apr 1979 - 2018



National Snow and Ice Data Center, University of Colorado, Boulder

Antarctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)



National Snow and Ice Data Center, University of Colorado Boulder

Sea Ice Concentration Anomalies, Apr 2018

