The Stratosphere

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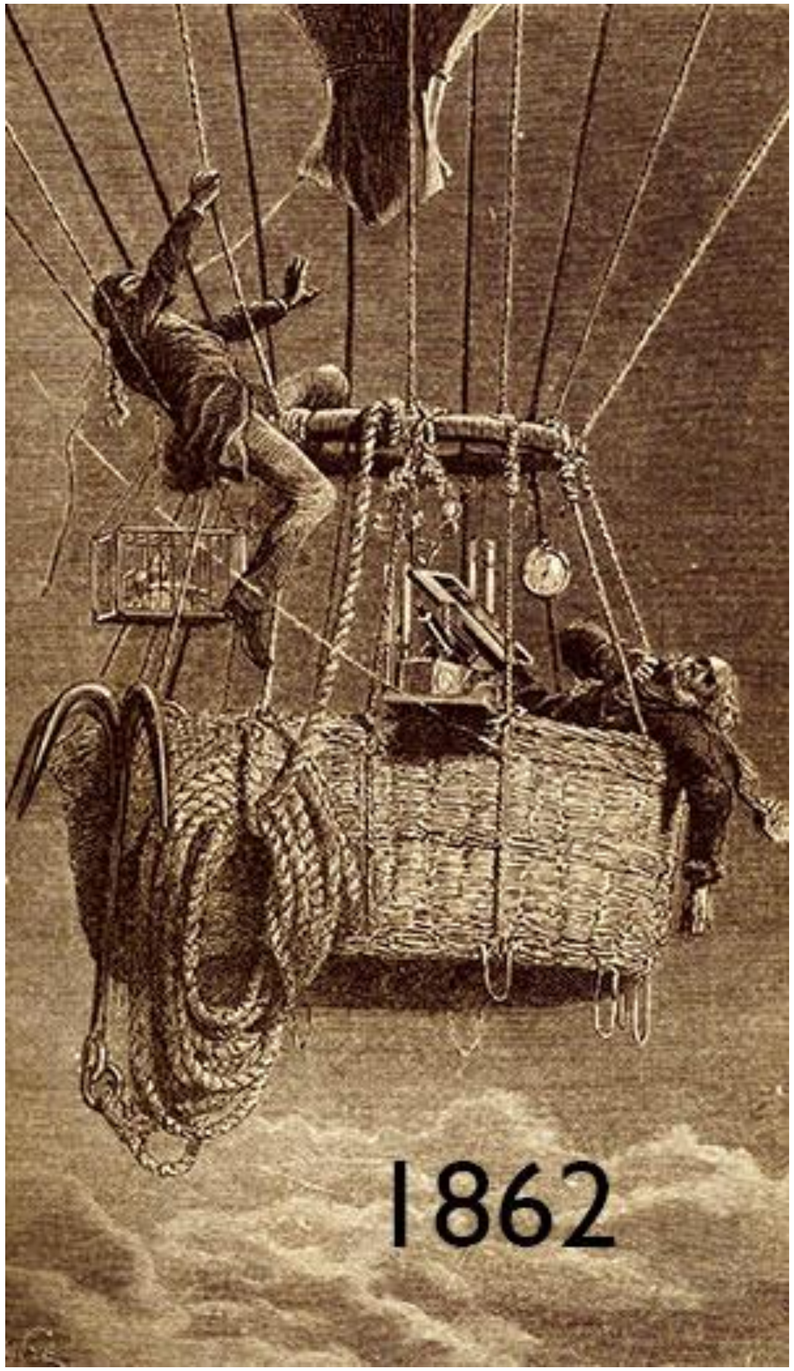
Timeline of our Understanding of the Stratosphere

- The existence of the stratosphere its was unknown until 1902.
- 1913: Ozone layer was discovered.
- 1923–1947: discovery of the stratopause and mesosphere.
- 1949–1956 Brewer-Dobson circulation proposed; not understood until 1970s
- 1952: stratospheric sudden warmings discovered; explained ~1970.
- 1961: Quasi-biennial Oscillation (QBO) discovered; explained 1968.
- 1970s–1980s: Advances in Dynamics; Potential Vorticity.
- ~1978 Satellite observations of the stratosphere.
- 1980s: Ozone depletion recognised and explained.
- 1990s to 2000s: discoveries that stratospheric variability (including ozone depletion) has surface weather effects.
- 2000s: Weather forecast & climate models start to have realistic stratospheres

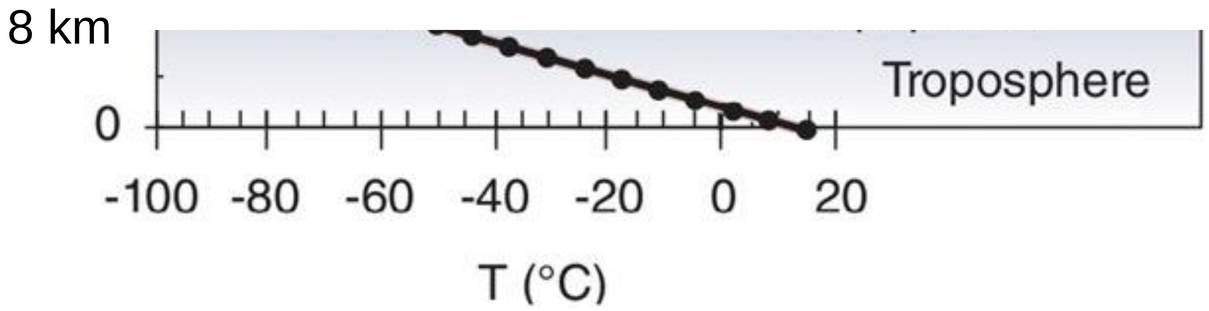
The discovery of the stratosphere



In 1862 Henry Coxwell & James Glaisher became unconscious ~10km

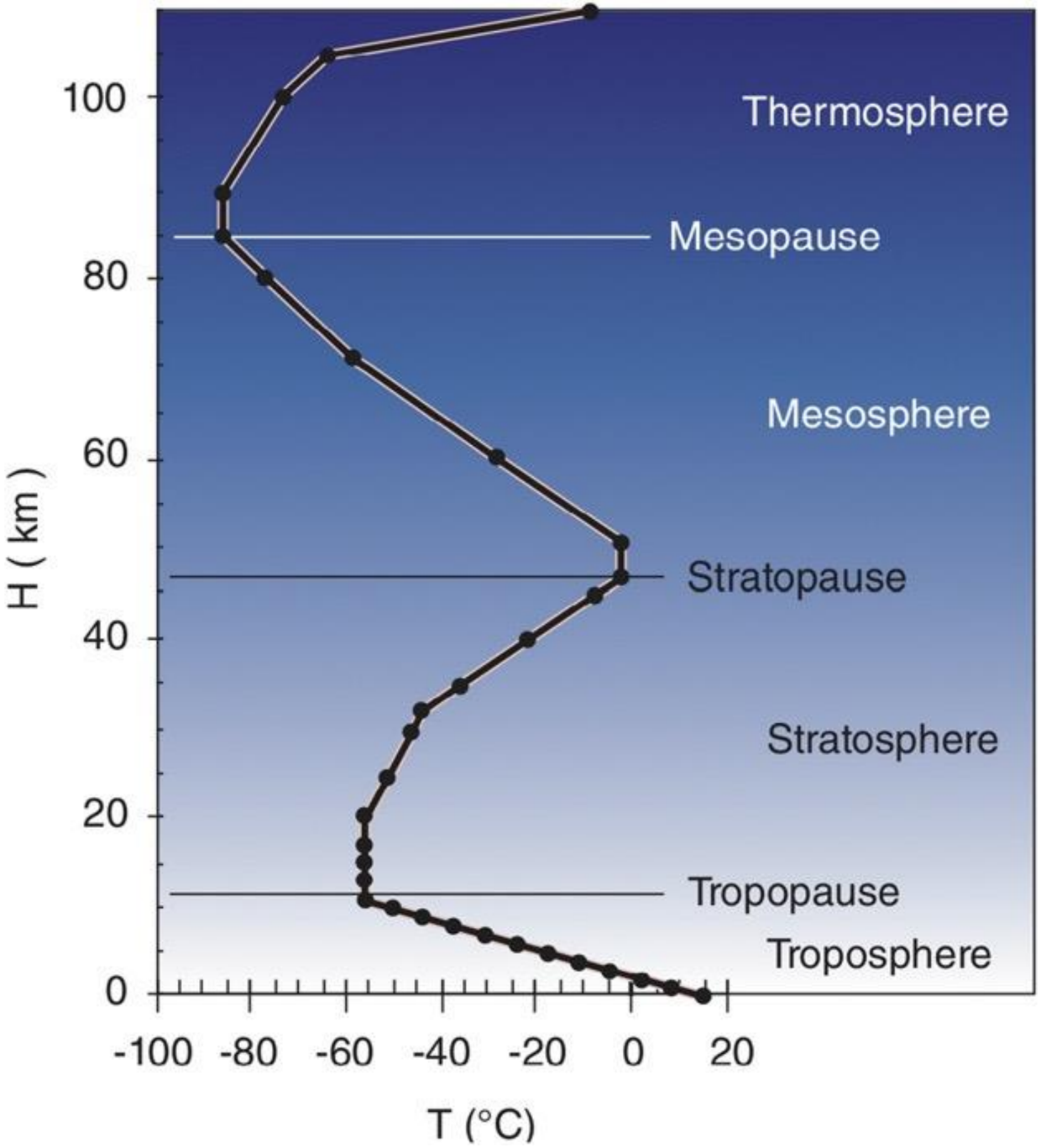
Year 1873

?



1902: **Tesserenc de Bort** & **Assmann**
discover the stratosphere
Using ~200 unmanned balloon soundings

Felix Baumgartner, 2012


Thermosphere
Mesopause
Mesosphere
Stratopause
Stratosphere
Tropopause
Troposphere
H (km)
100
80
60
40
20
0
-100
-80
-60
-40
-20
0
20
T (°C)

Year 2023

Global circulation of the Stratosphere (The Brewer-Dobson Circulation)

551.510.5

EVIDENCE FOR A WORLD CIRCULATION PROVIDED BY THE MEASUREMENTS OF HELIUM AND WATER VAPOUR DISTRIBUTION IN THE STRATOSPHERE

By A. W. BREWER, M.Sc., A.Inst.P.

(Manuscript received 23 February 1949)

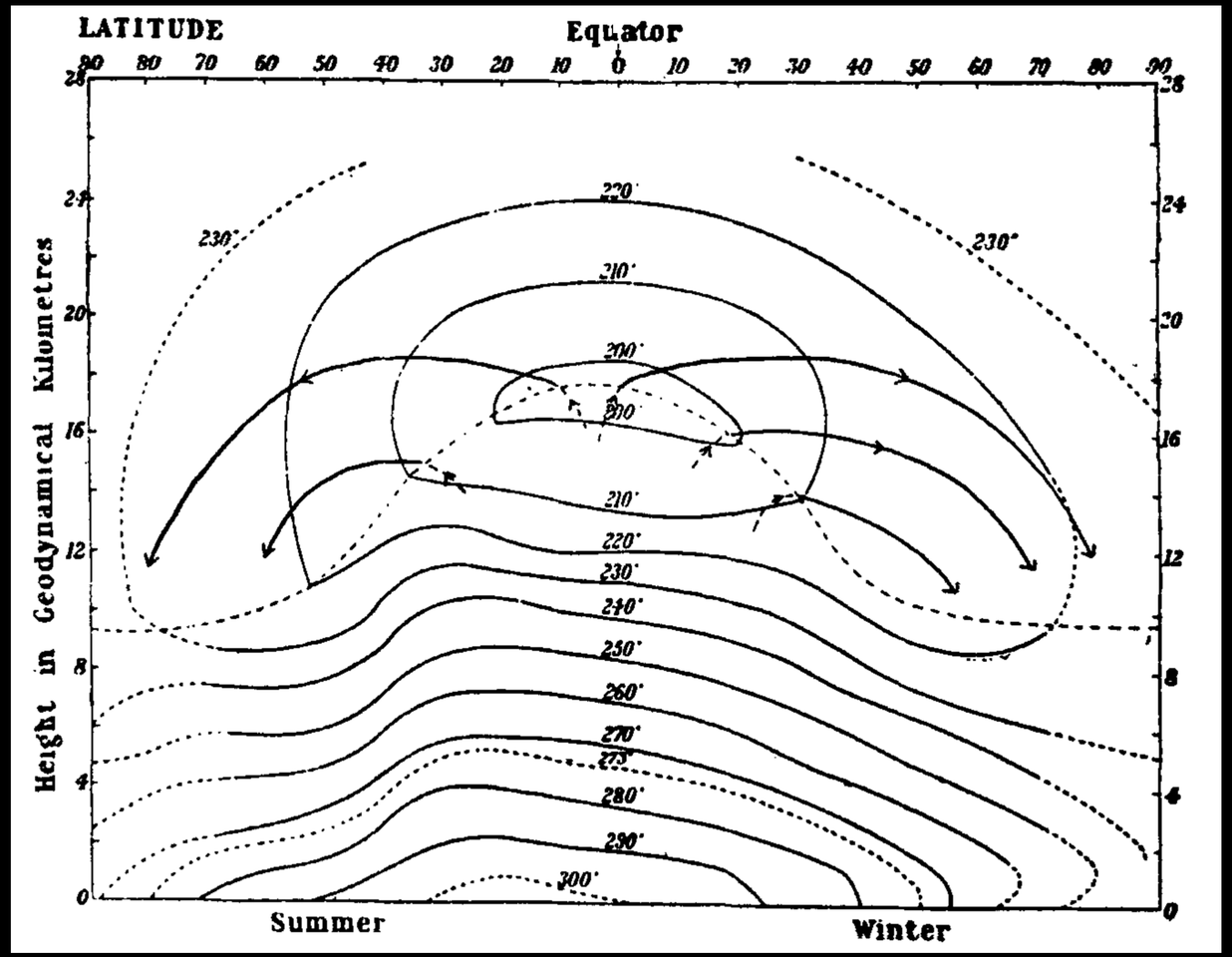
Brewer, 1949
QJRMS

SUMMARY

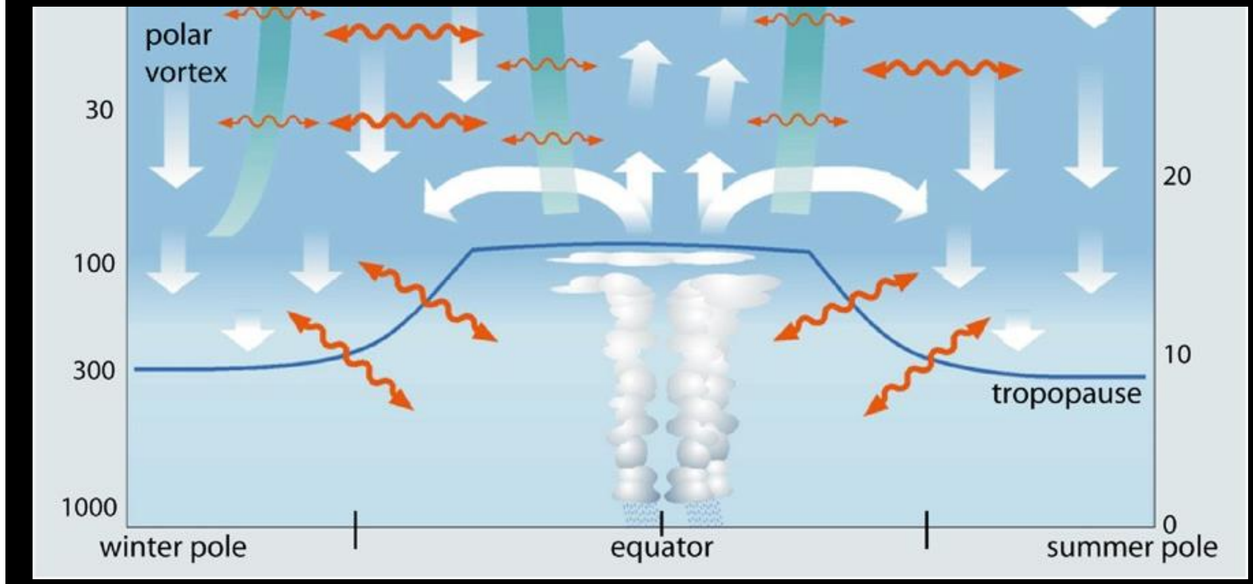
Information is now available regarding the vertical distribution of water vapour and helium in the lower stratosphere over southern England. The helium content of the air is found to be remarkably constant up to 20 km but the water content is found to fall very rapidly just above the tropopause, and in the lowest 1 km of the stratosphere the humidity mixing ratio falls through a ratio of 10—1.

The helium distribution is not compatible with the view of a quiescent stratosphere free from turbulence or vertical motions. The water-vapour distribution is incompatible with a turbulent stratosphere unless some dynamic process maintains the dryness of the stratosphere. In view of the large wind shear which is normally found just above the tropopause it is unlikely that this region is free from turbulence.

Brewer, 1949 QJRMS.
Brewer-Dobson circulation



2019



Advances in Dynamics (1970s–1980s)

- Waves
- Transformed Eulerian Mean, wave fluxes
- Potential Vorticity thinking

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Quart. J. R. Met. Soc. (1985), **111**, pp. 877–946 551.509.3:551.511.2:551.511.32

Hoskins et al., 1985 QJRMS

On the use and significance of isentropic potential vorticity maps

By B. J. HOSKINS[1], M. E. McINTYRE[2] and A. W. ROBERTSON[3]

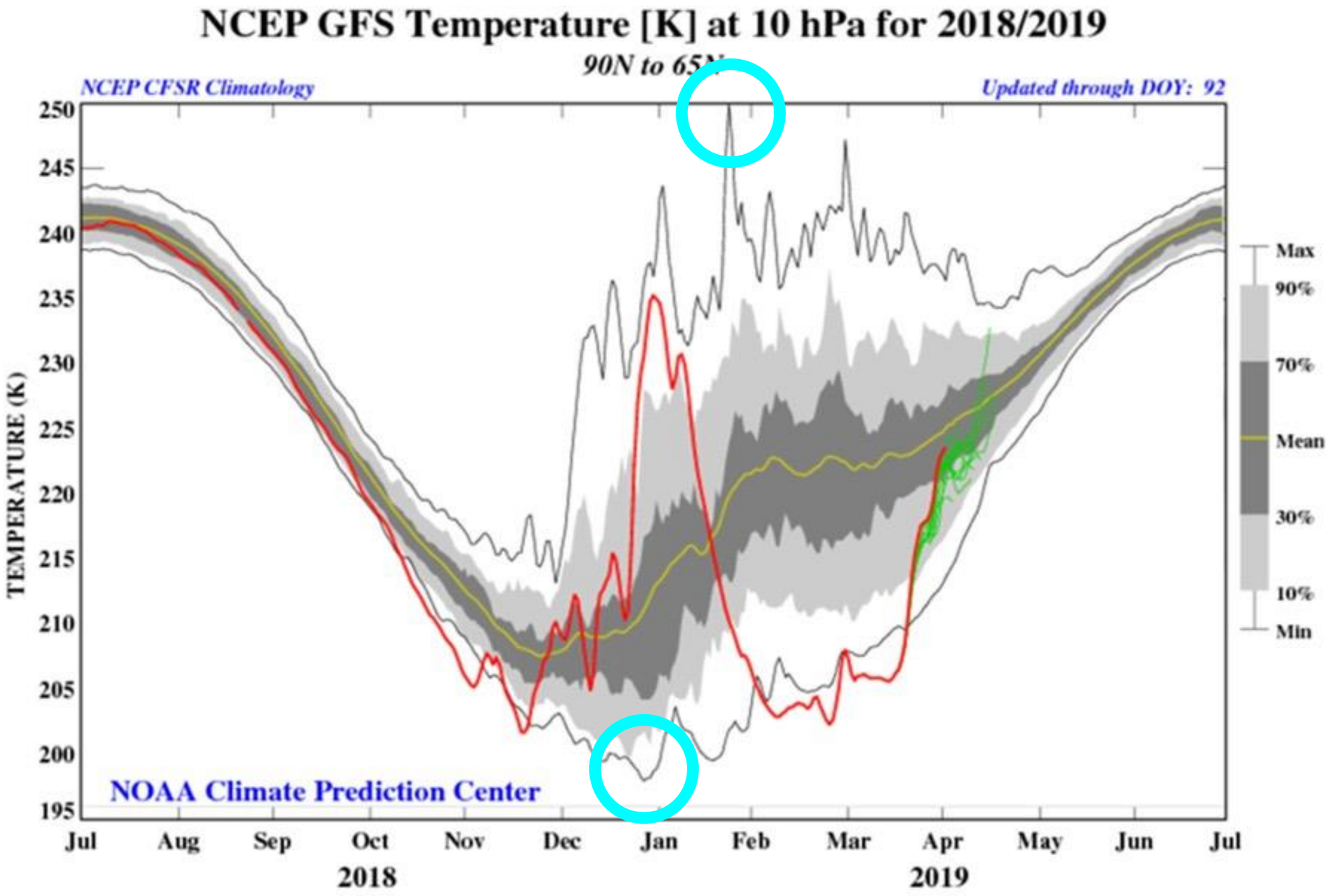
[1] *Department of Meteorology, University of Reading*
[2] *Department of Applied Mathematics and Theoretical Physics, University of Cambridge*
[3] *Laboratoire de Physique et Chimie Marines, Université Pierre et Marie Curie*, 75230 *Paris Cédex* 05

(Received 12 February 1985; revised 2 July 1985)

Stratospheric Sudden Warmings

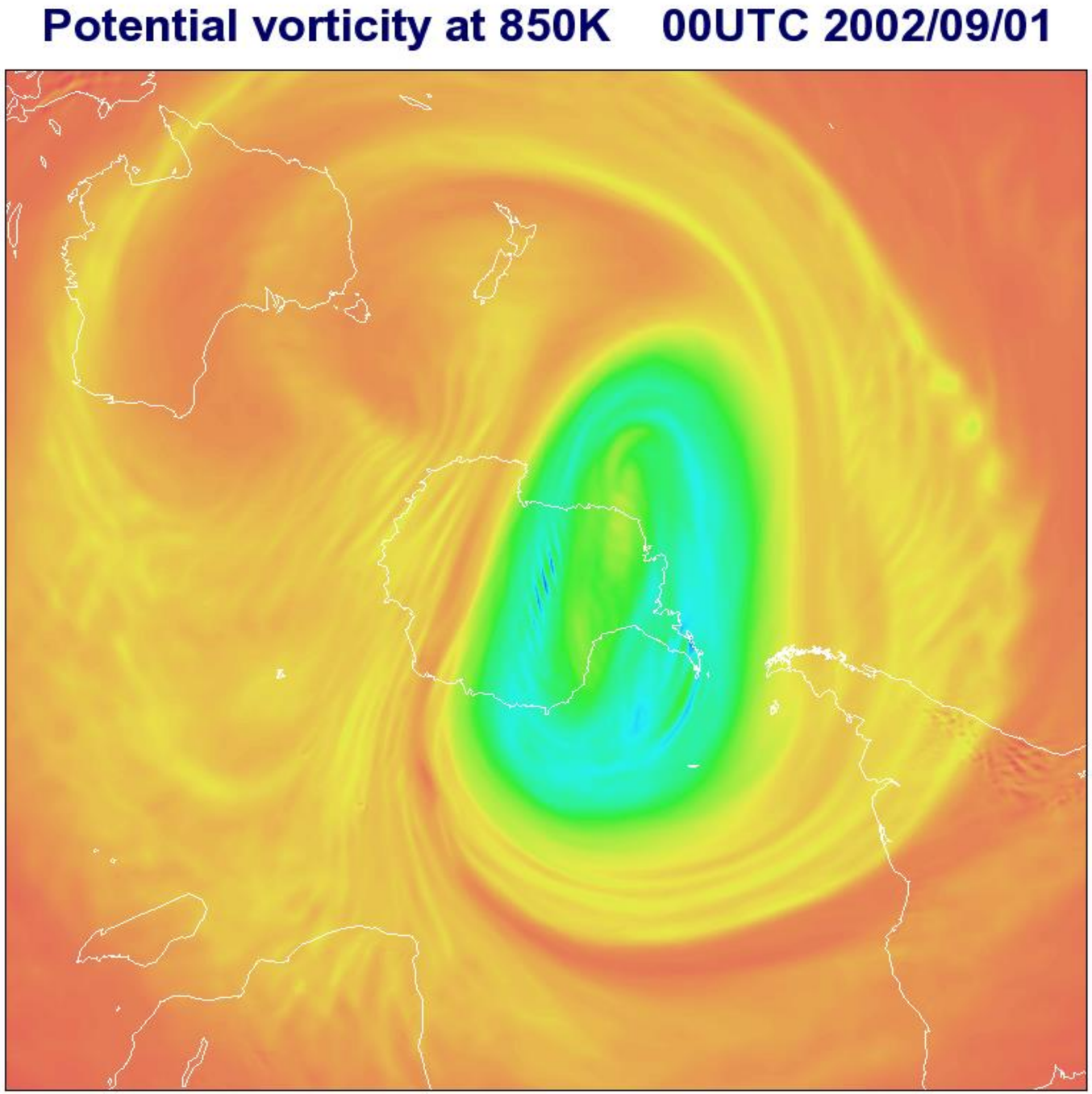
- Discovered by Scherhag,1952
- Modelled by Matsuno. 1971

Stratospheric Sudden Warmings



Mixing predicted by McIntyre & Palmer (1982,1983)

Southern Hemisphere 2002

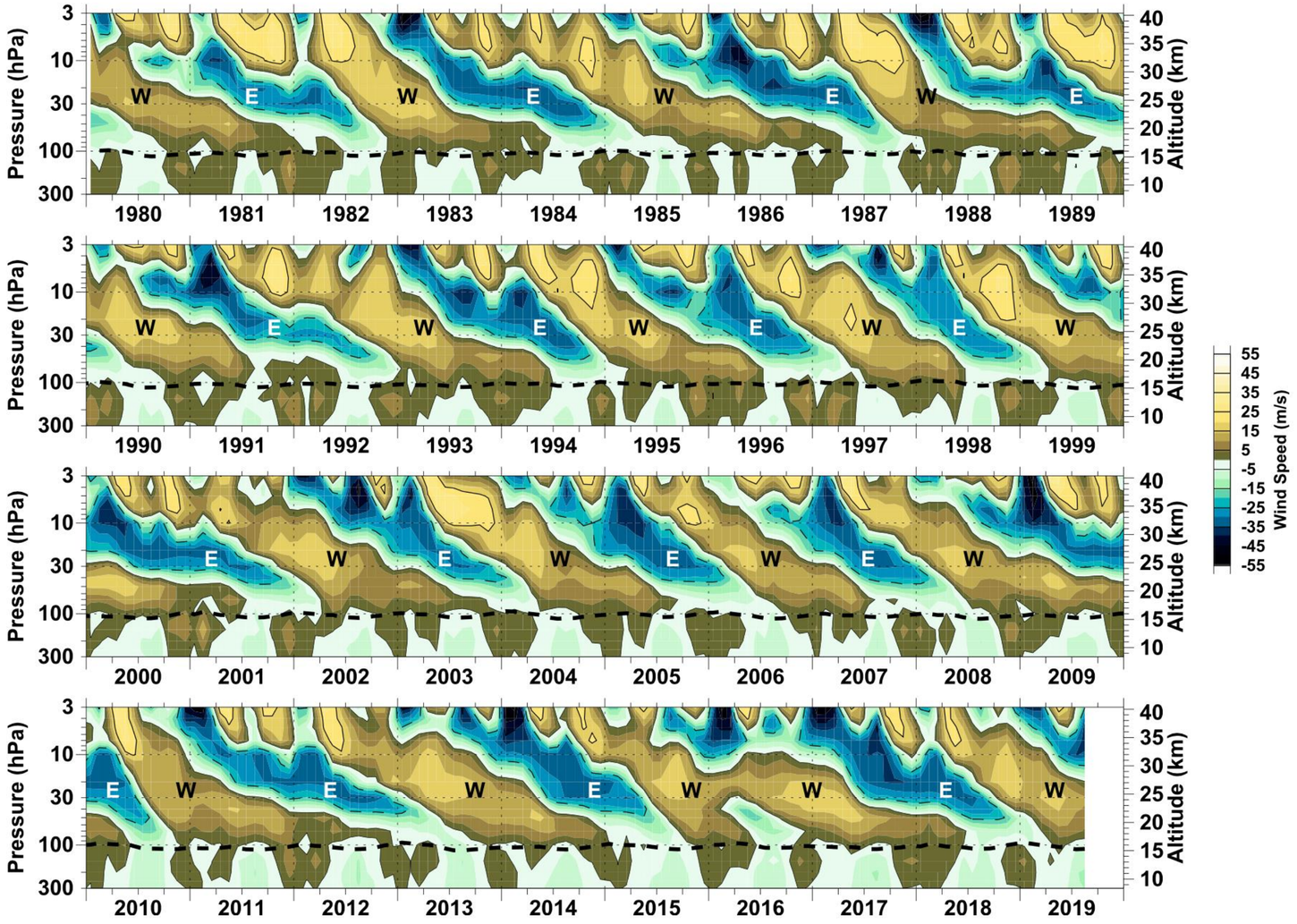


Quasi-biennial Oscillation (QBO)

- Discovered by Reed, 1961; Ebdon and Veryard, 1961
- Modelled by Lindzen and Holton, 1968

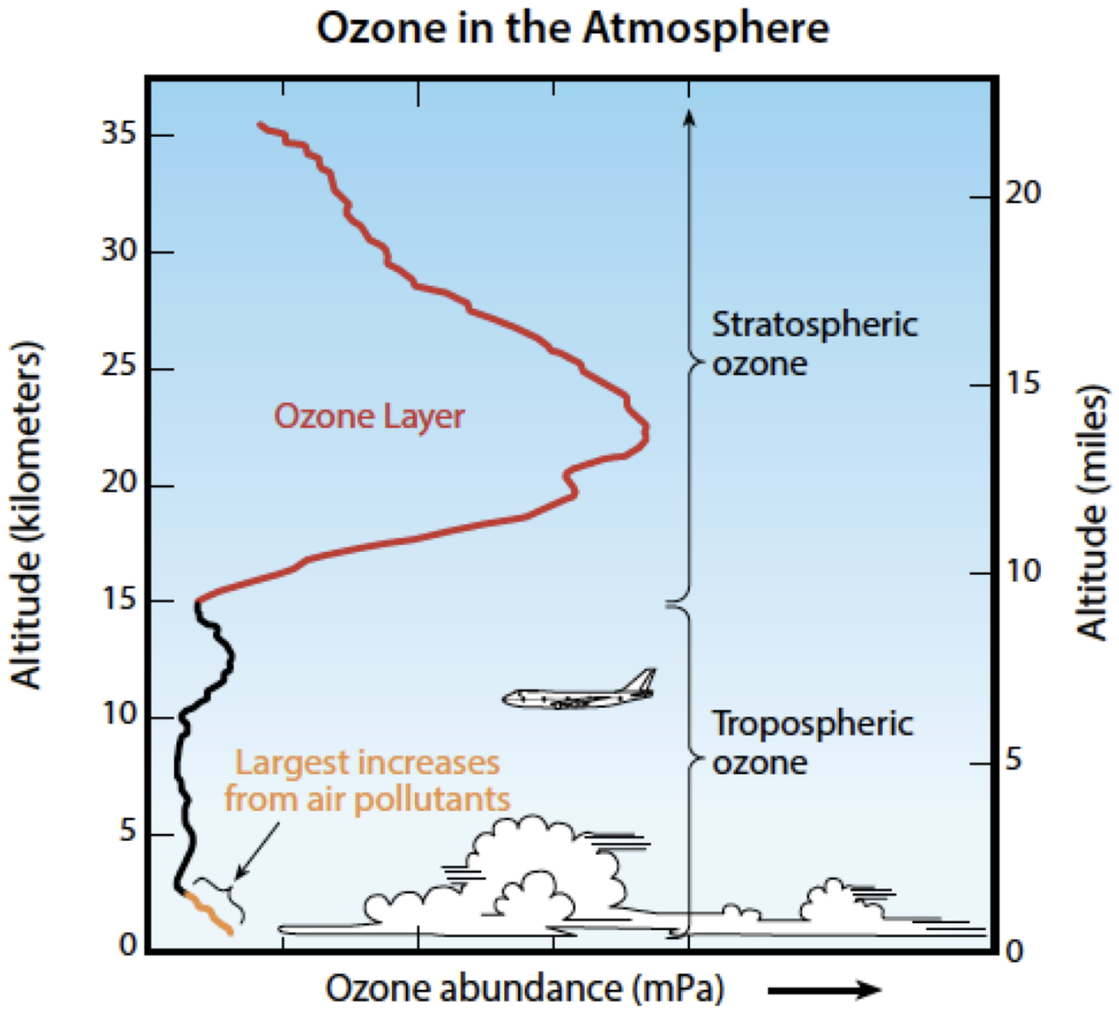
1961: Quasi-biennial Oscillation (QBO)

1968: QBO explained by theory & modelling



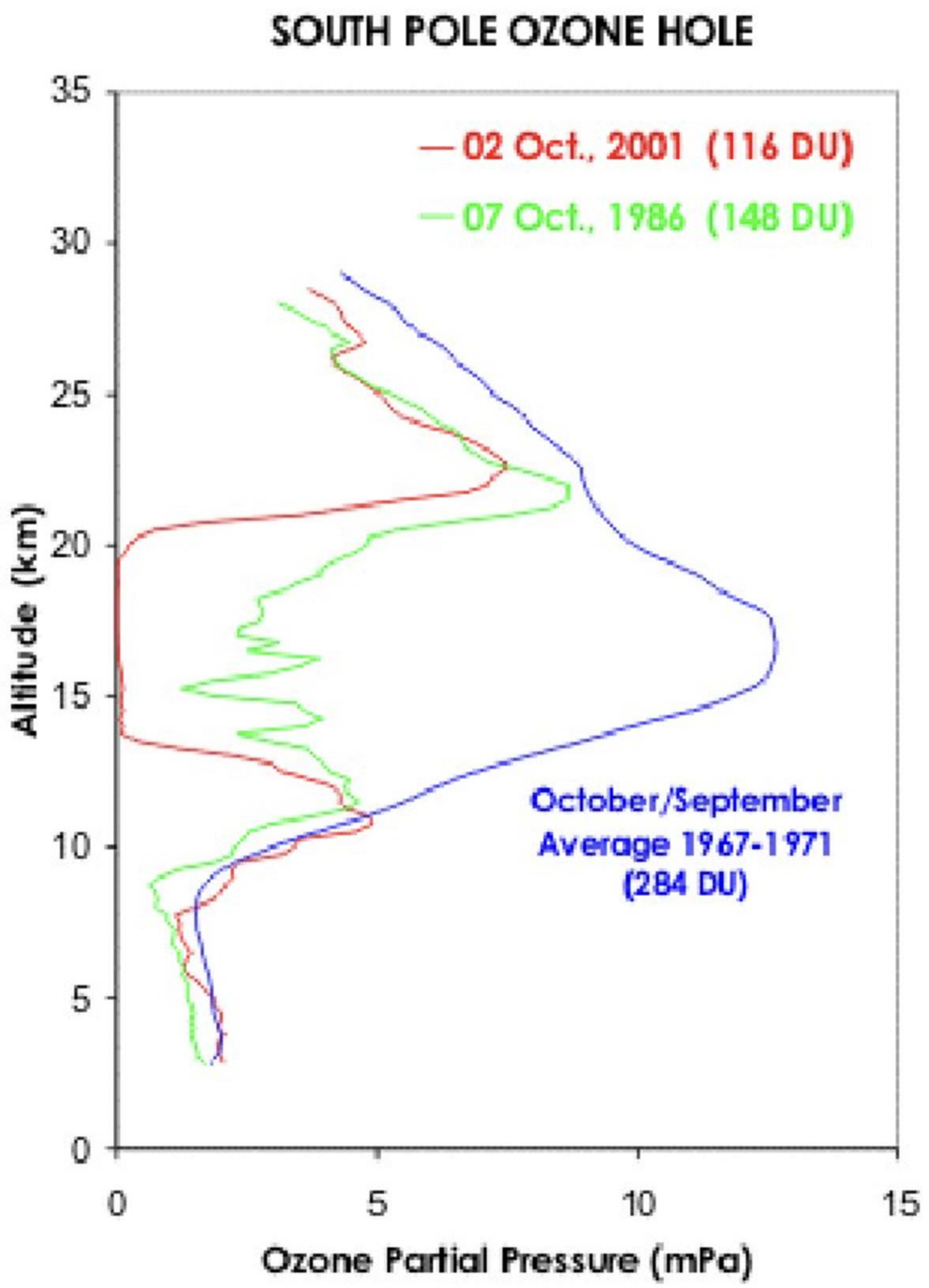
Ozone Hole
(Discovered 1985; Explained late 1980s)

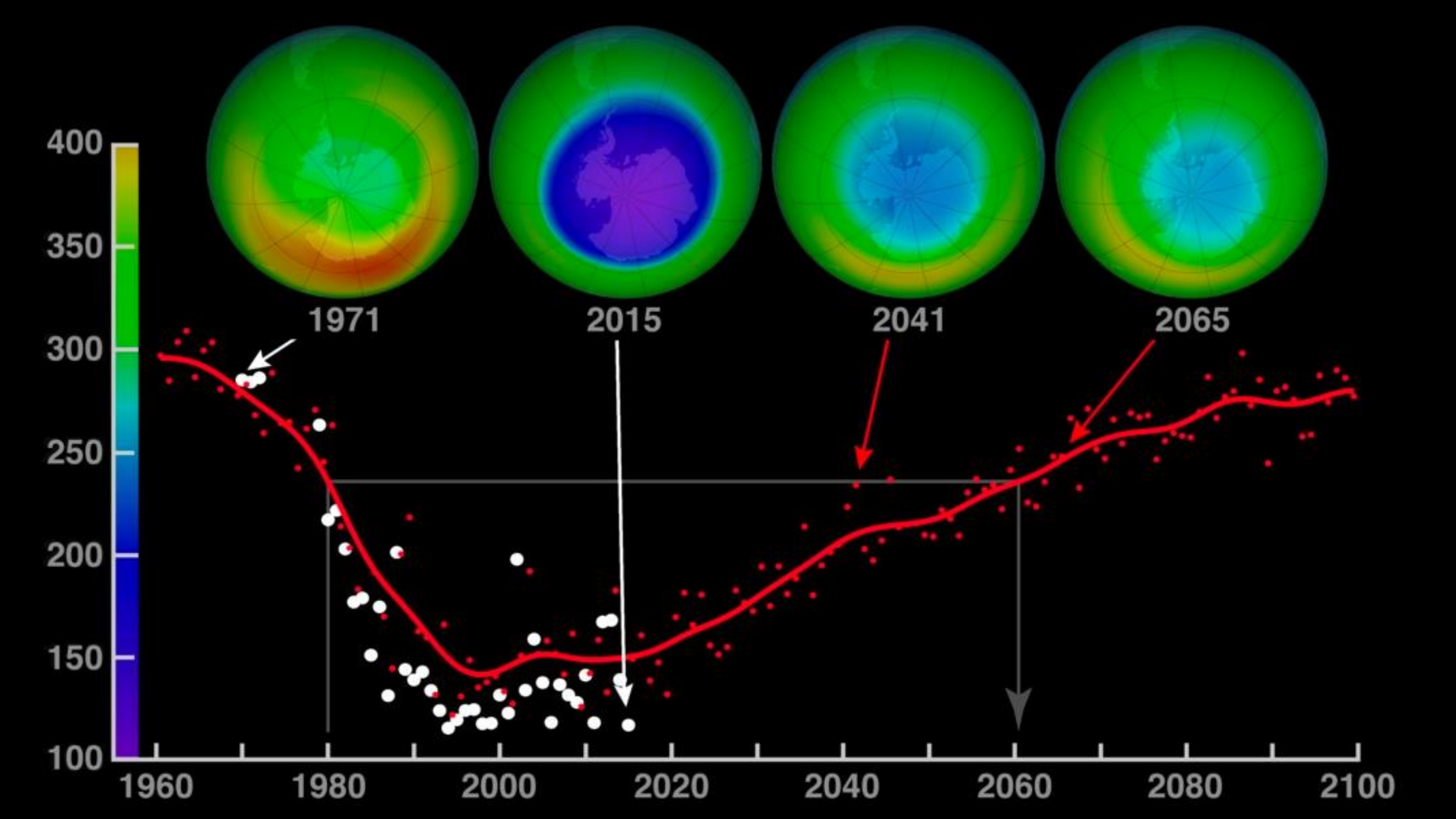
The Ozone Hole



Discovered by Farman et al. 1985.

Explained by Solomon, late 1980s.

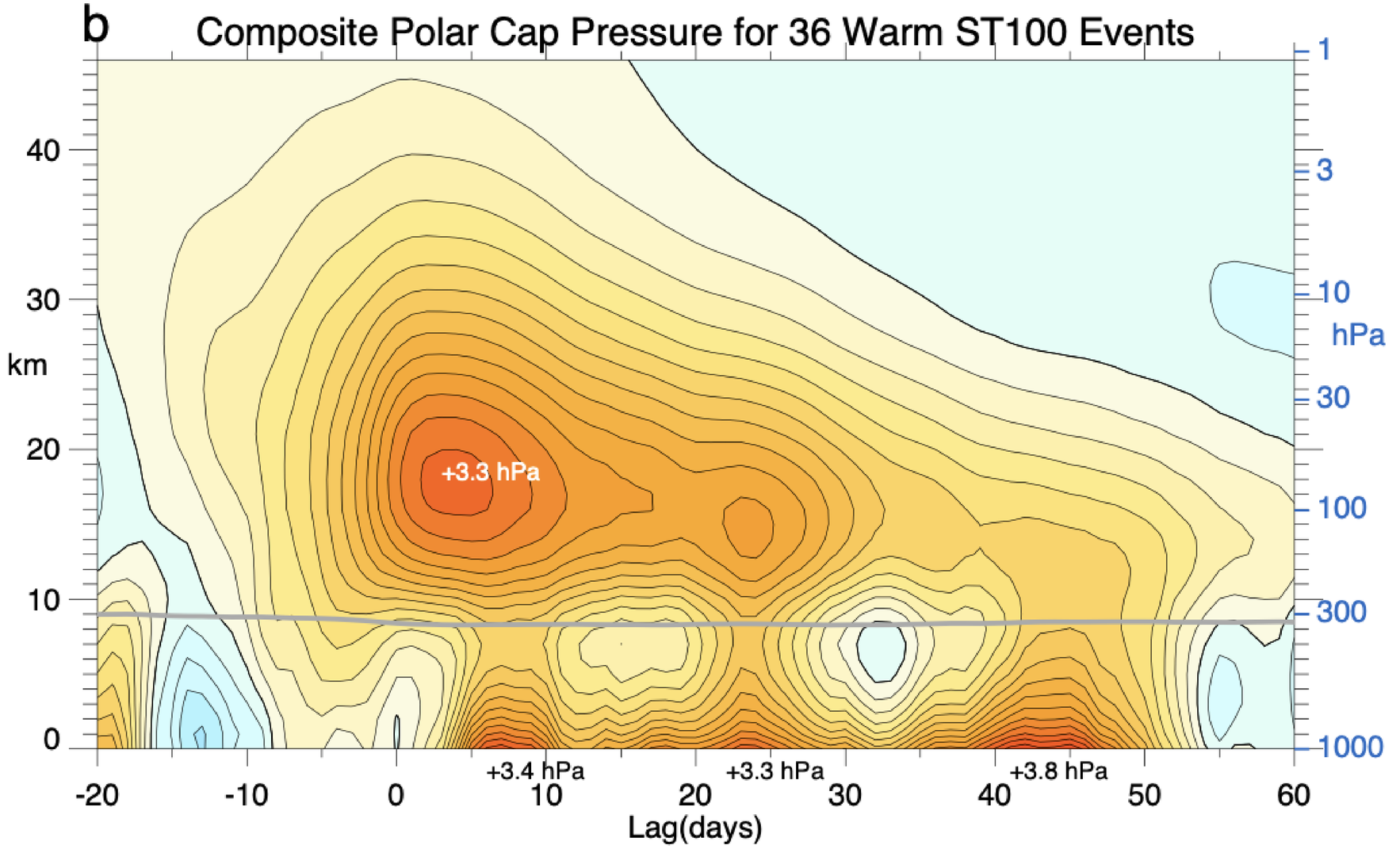

SOUTH POLE OZONE HOLE
02 Oct., 2001 (116 DU)
07 Oct., 1986 (148 DU)
October/September
Average 1967-1971
(284 DU)
Altitude (km)
Ozone Partial Pressure (mPa)
0
5
10
15
20
25
30
35


1971
2015
2041
2065
400
350
300
250
200
150
100
1960
1980
2000
2020
2040
2060
2080
2100

Surface weather effects

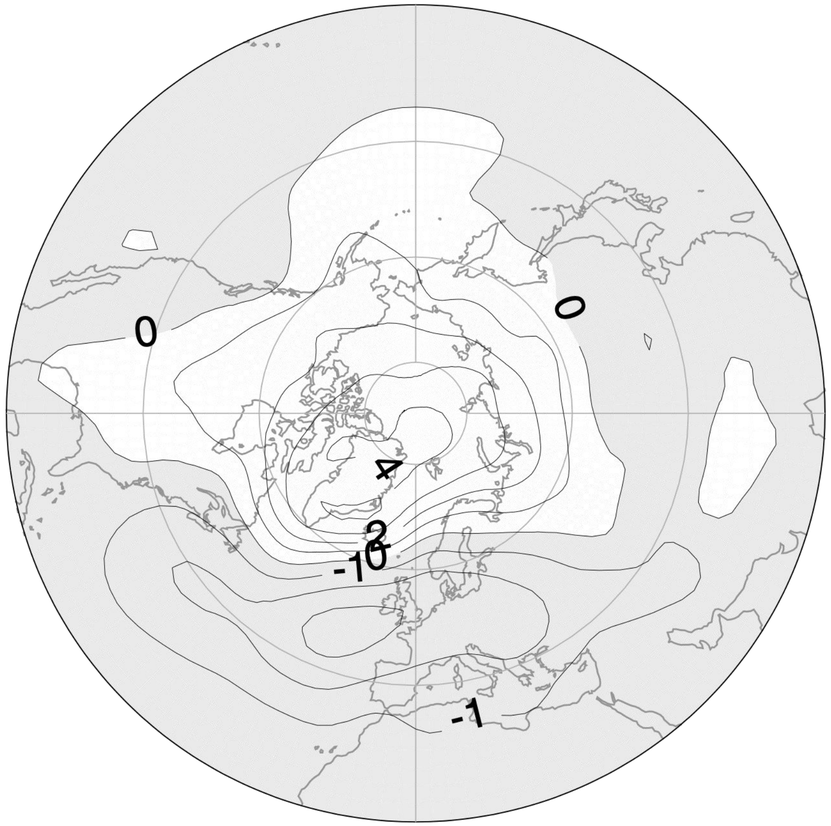
- Polar vortex/Stratospheric Sudden Warmings
- Ozone loss

Stratospheric Sudden Warmings have surface weather effects

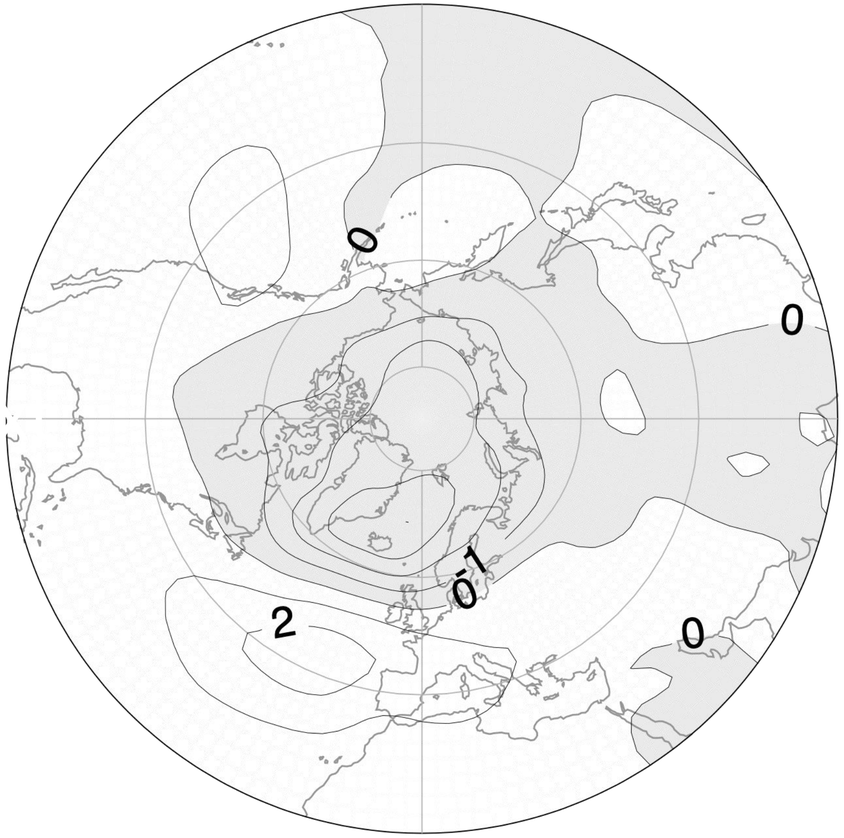


Observed Average Surface Pressure Anomalies (hPa)

60 days following weak stratospheric winds



60 days following strong stratospheric winds

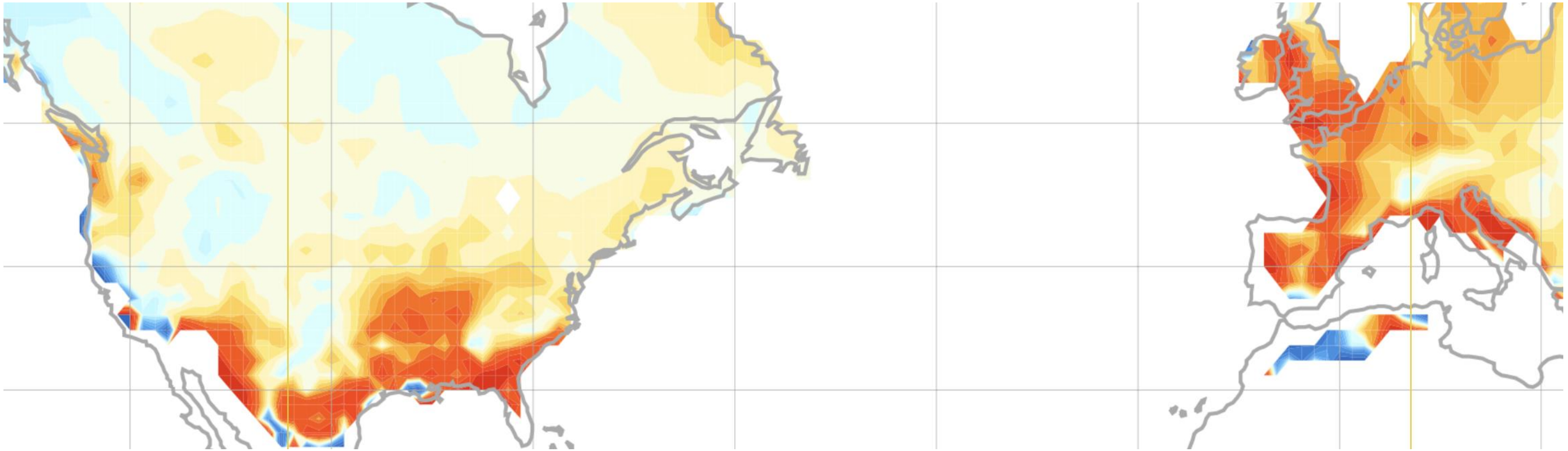


From Baldwin and Dunkerton 2001

Stratospheric Sudden Warmings make snow more likely where snow is unusual.

Ozone loss has increased draughts in Australia,
by shifting the jet stream and storm tracks.

Stratospheric Sudden Warmings make snow more likely where snow is unusual.



The Future

- Poor track record of predicting the next stratospheric phenomenon to be observed
- Ozone recovery/Climate change
- Volcanoes
- Pyrocumulonimbus Clouds