Understanding weather and the weather forecast

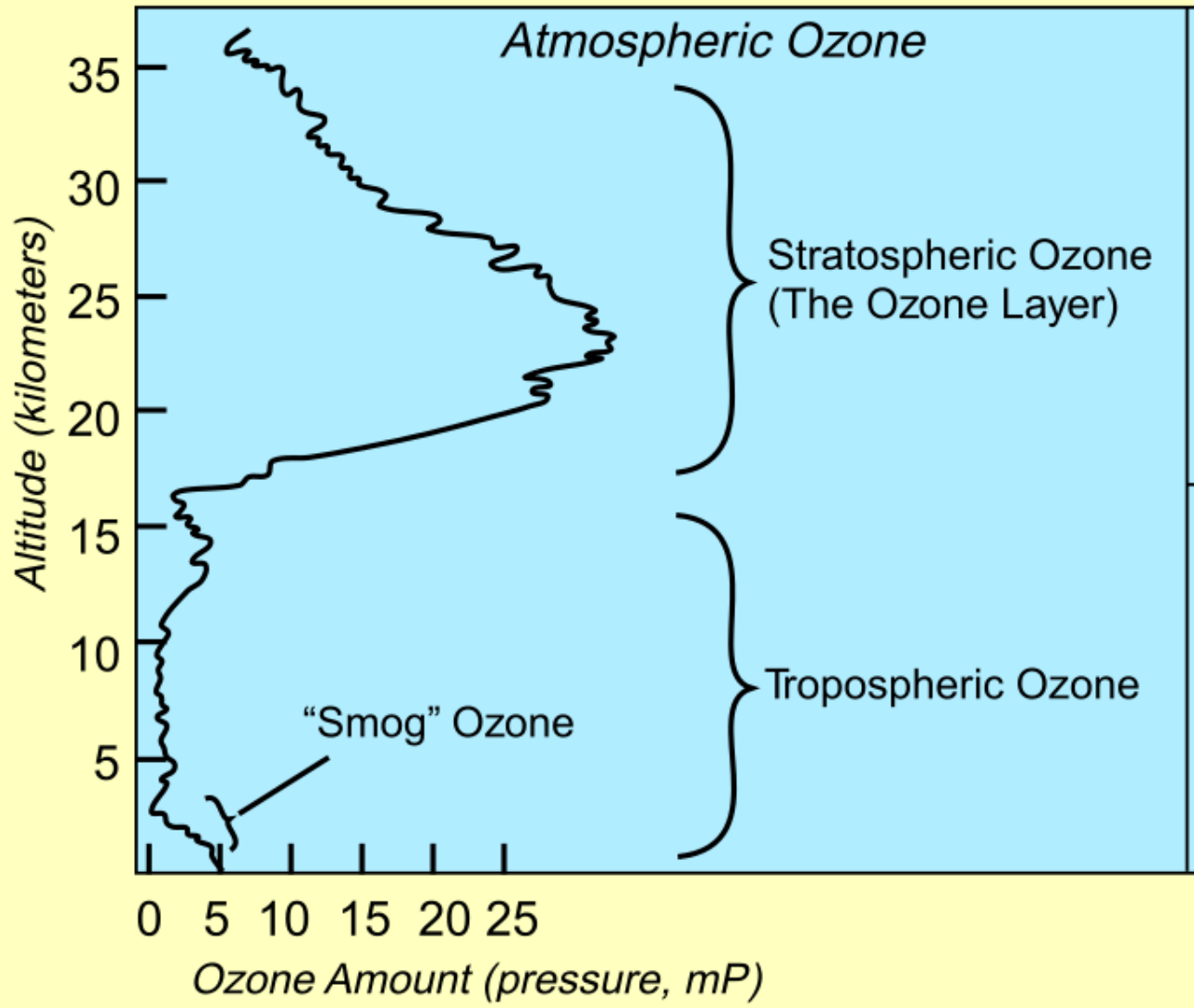
Week 29

Ozone Hole

Forecasting the Weather

Terry Hart

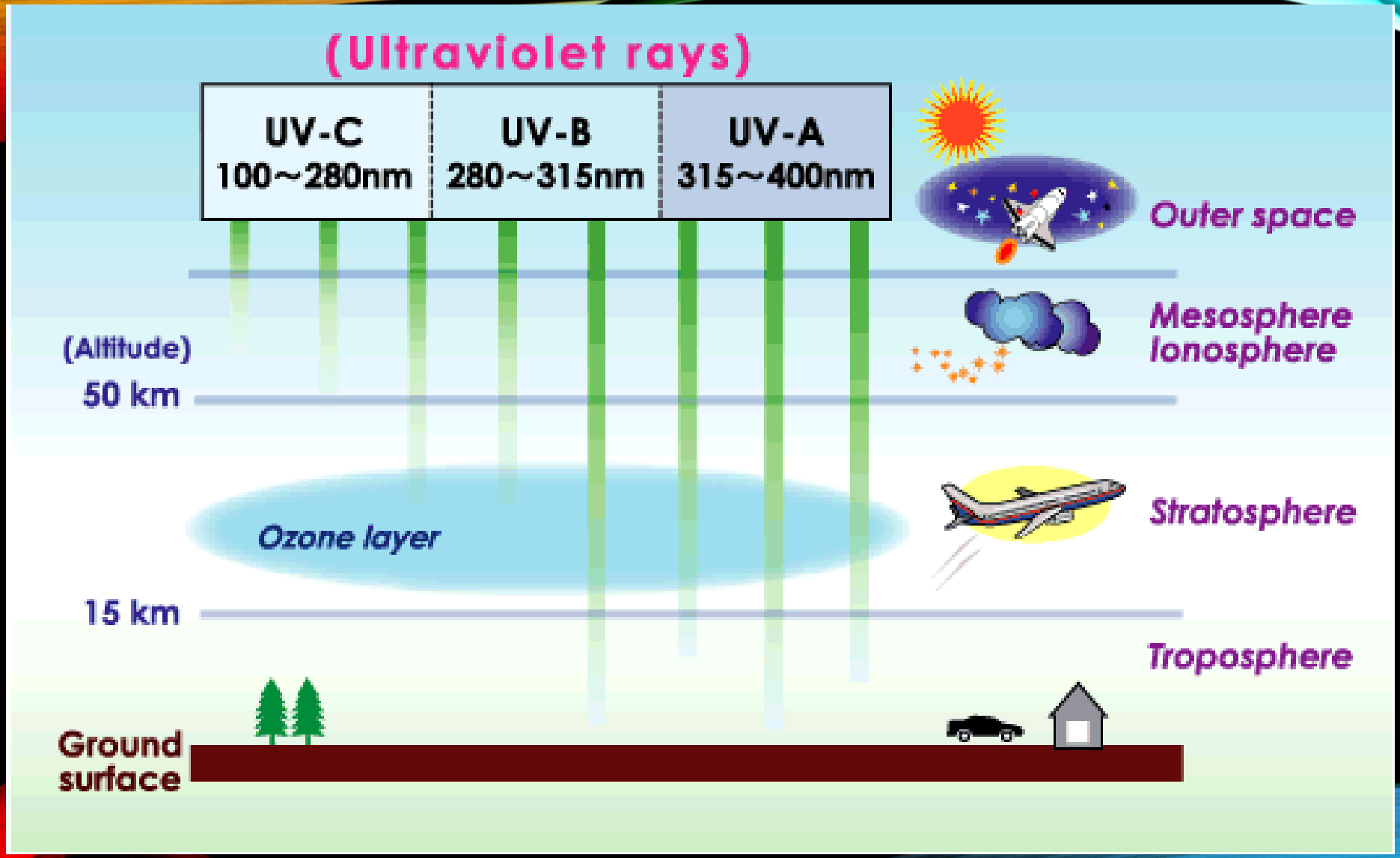
OZONE



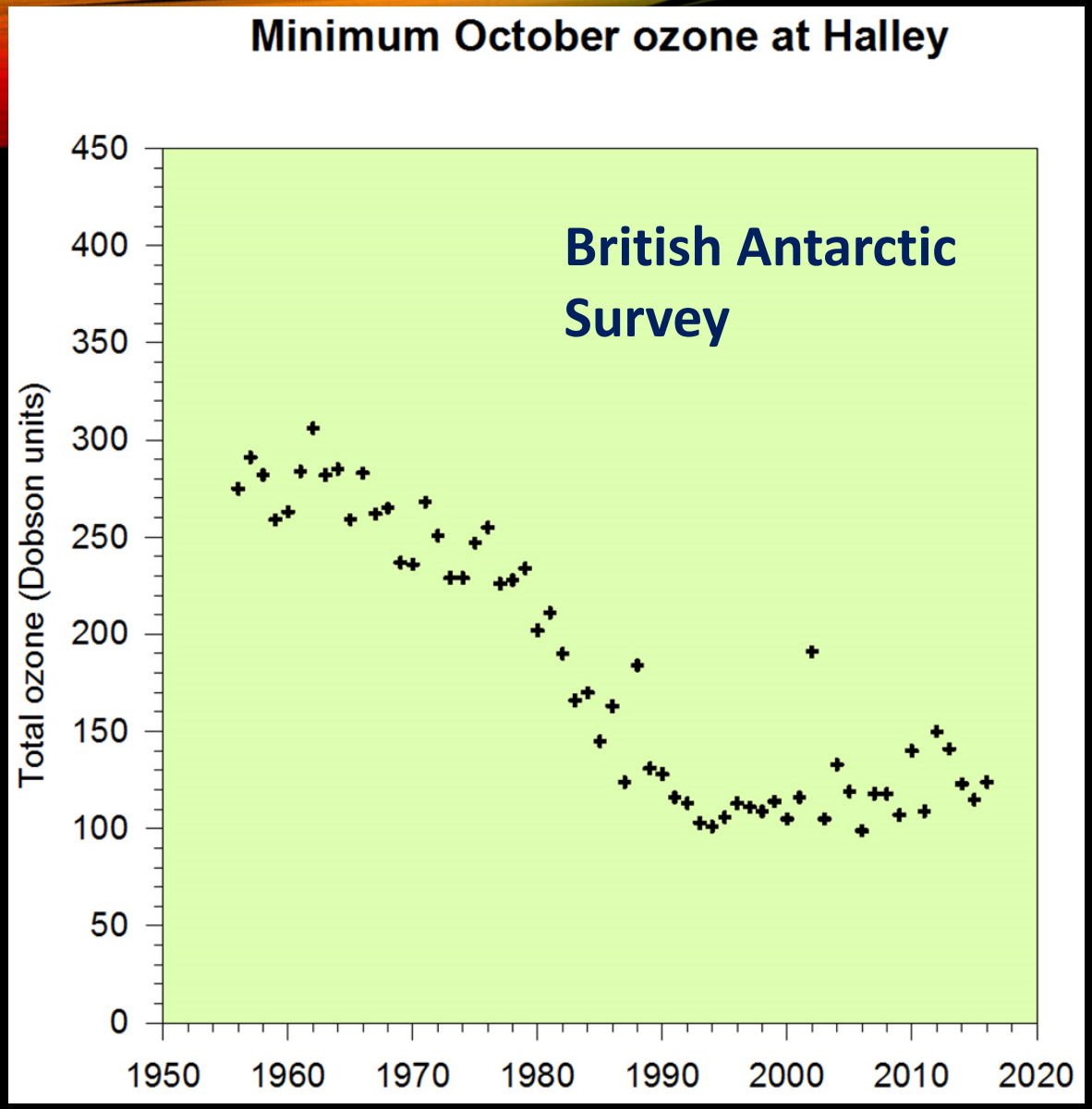
- Contains 90% of atmospheric ozone
- Beneficial role: Acts as primary UV radiation shield
- Current issues:
  - Long-term global downward trends
  - Springtime Antarctic ozone hole each year

- Contains 10% of atmospheric ozone
- Harmful impact: Toxic effects on humans and vegetation
- Current issues:
  - Episodes of high surface ozone in urban and rural areas

At 25 km (20 hPa) ozone concentration is about 15 parts per million



All UV-C and most UV-B are absorbed by ozone and oxygen.
UV-A is not absorbed by ozone

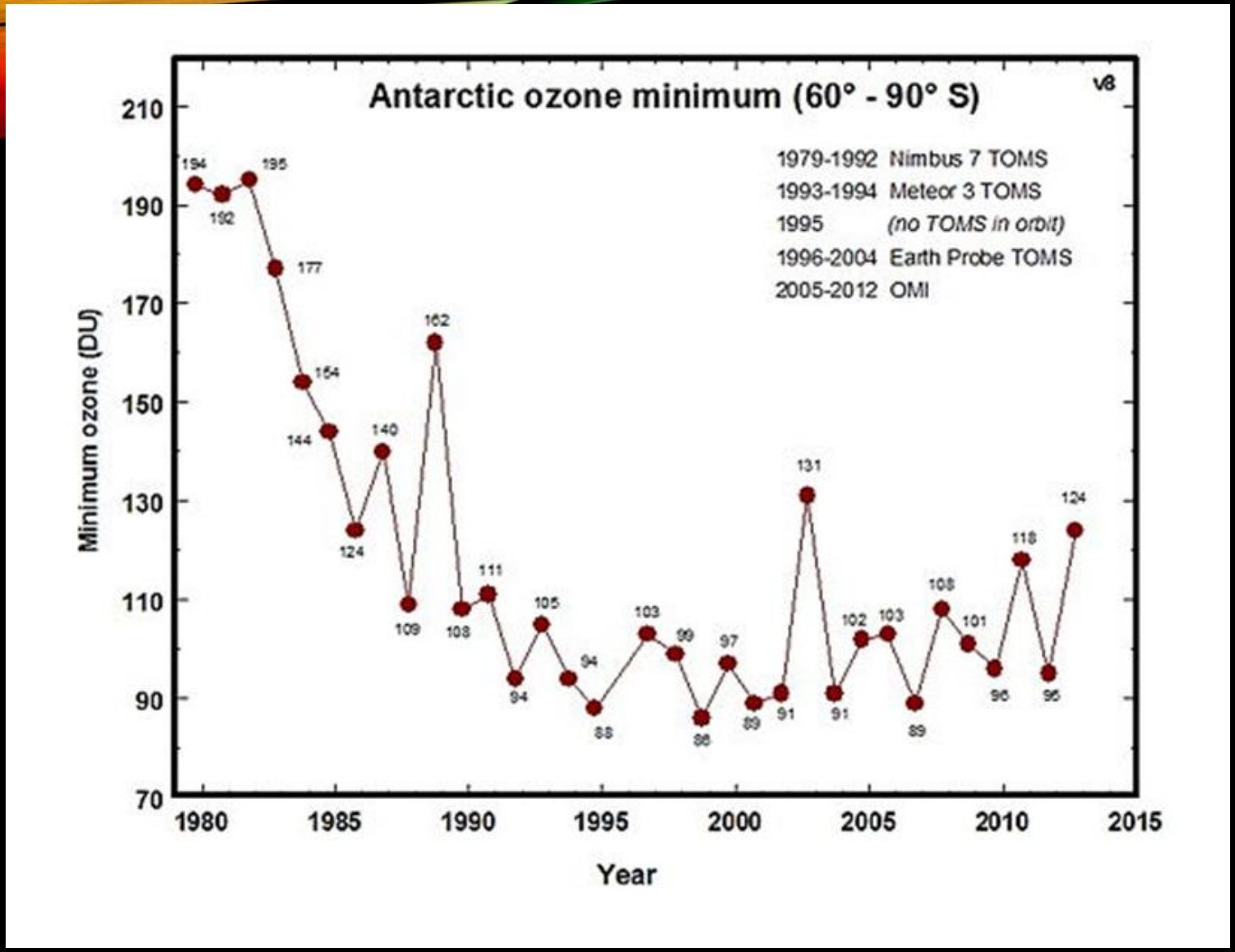


A big surprise in the 1980s

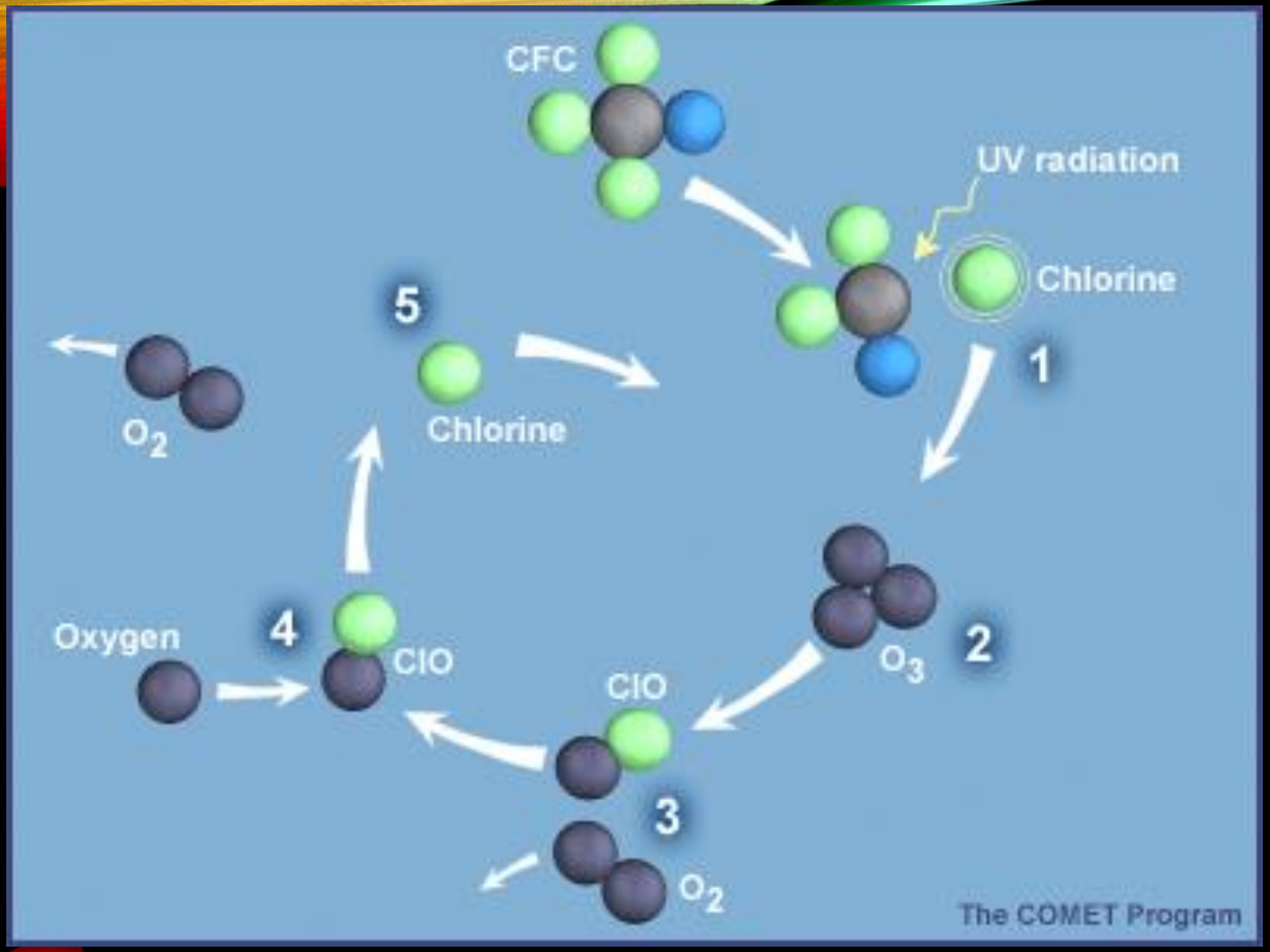
Why didn't the satellite detect it at first?

What was going on?

https://legacy.bas.ac.uk/met/jds/ozone/index.html



In fact, the satellite data did show the decrease, but the low values were attributed to an instrument error.



Could chlorofluorocarbons be the culprit?

One chlorine atom can attack ozone many times over.

However, that reaction seemed too slow to account for such rapid removal of the ozone

Serving the public and science

In exchange for the pleasures of working on challenging questions, scientists have a duty to society, says Susan Solomon, who served as co-chair of the IPCC's Working Group I with Qin Dahe of China from 2002 to 2008.

Susan Solomon says of her scientific career that she's had "a wonderful twenty-five years doing what I want to do."

The panel presented its report, *Climate Change 2007: The Physical Science Basis*, in February 2007. Months later she was still besieged by requests to give talks, and—emphasizing the work of the team—she said, "a lot of great people are involved in this report; many can give better talks than I can."

Before the 1985 discovery of the ozone hole sent her to Antarctica in 1986, Solomon had fo-

has to say. I care so deeply abou
the number one thing. I want
right." Other scientists think they
policy recommendations. "I'm no
and others are wrong" about mak
mendations, but she feels science
story, just one of many factors po
to consider.

Solomon received the 1999 N
Science, the nation's highest sci
her ozone-hole work. Other hono
an Antarctic glacier named after
the American Meteorological S
award—the Carl-Gustaf Rossby R
in 2000.

Solomon continued doing
working on the IPCC report and is
to "more time getting back to thin
me, such as the role of the stratosp
of the Arctic Oscillation, includ
might be involved."

In addition to the scientific a
her 1986 work led to a fascination
which "is not just a place. It's a dis
tear yourself away from." This fasc
write *The Coldest March*, about the
between Robert Falcon Scott's E
Roald Amundsen's Norwegian tea
to reach the South Pole. The Briti
the South Pole in January 1912
Norwegian team's tent already the
beaten by a month. Scott and his f
their way back to their base.

She describes writing *The Co*

Susan Solomon suggested that polar stratospheric clouds could be a catalyst for the destruction of ozone.

Polar stratospheric clouds only form at very cold temperatures (colder than -78^0 C)

Polar Stratospheric Clouds

The colorful clouds near the top of this picture are Polar Stratospheric Clouds (PSCs). The PSCs are flying high above the darker cirrus clouds at the bottom of the picture. Image courtesy of NASA (Paul Newman, GSFC).

The Antarctic ozone hole

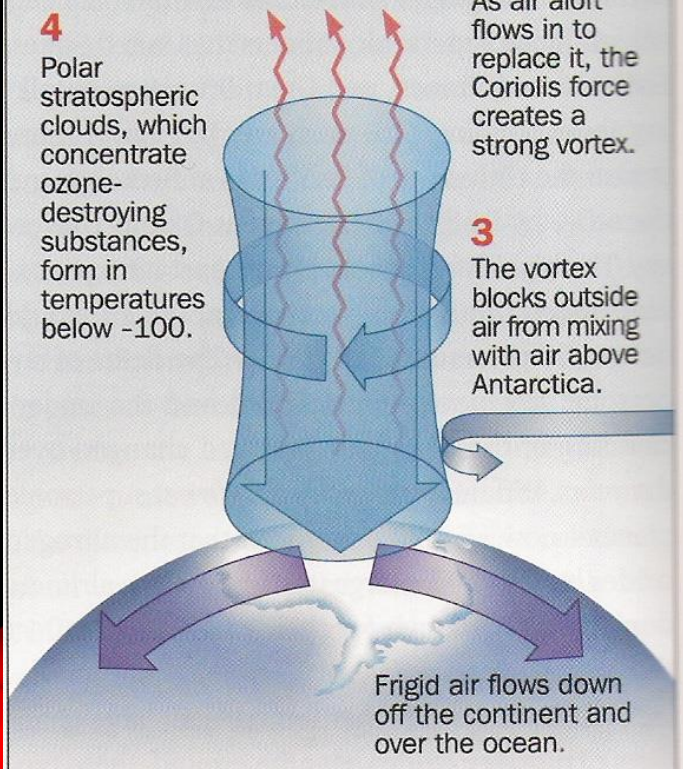
In most of the stratosphere, the atoms and molecules are so far apart that chlorine and similar substances only slowly destroy ozone. The polar stratosphere, especially over Antarctica, however, creates conditions that speed up ozone destruction.

1 After sunset in March, heat rapidly escapes into space, surface temperatures fall to -50°F and colder.

2 Cold air sinks. As air aloft flows in to replace it, the Coriolis force creates a strong vortex.

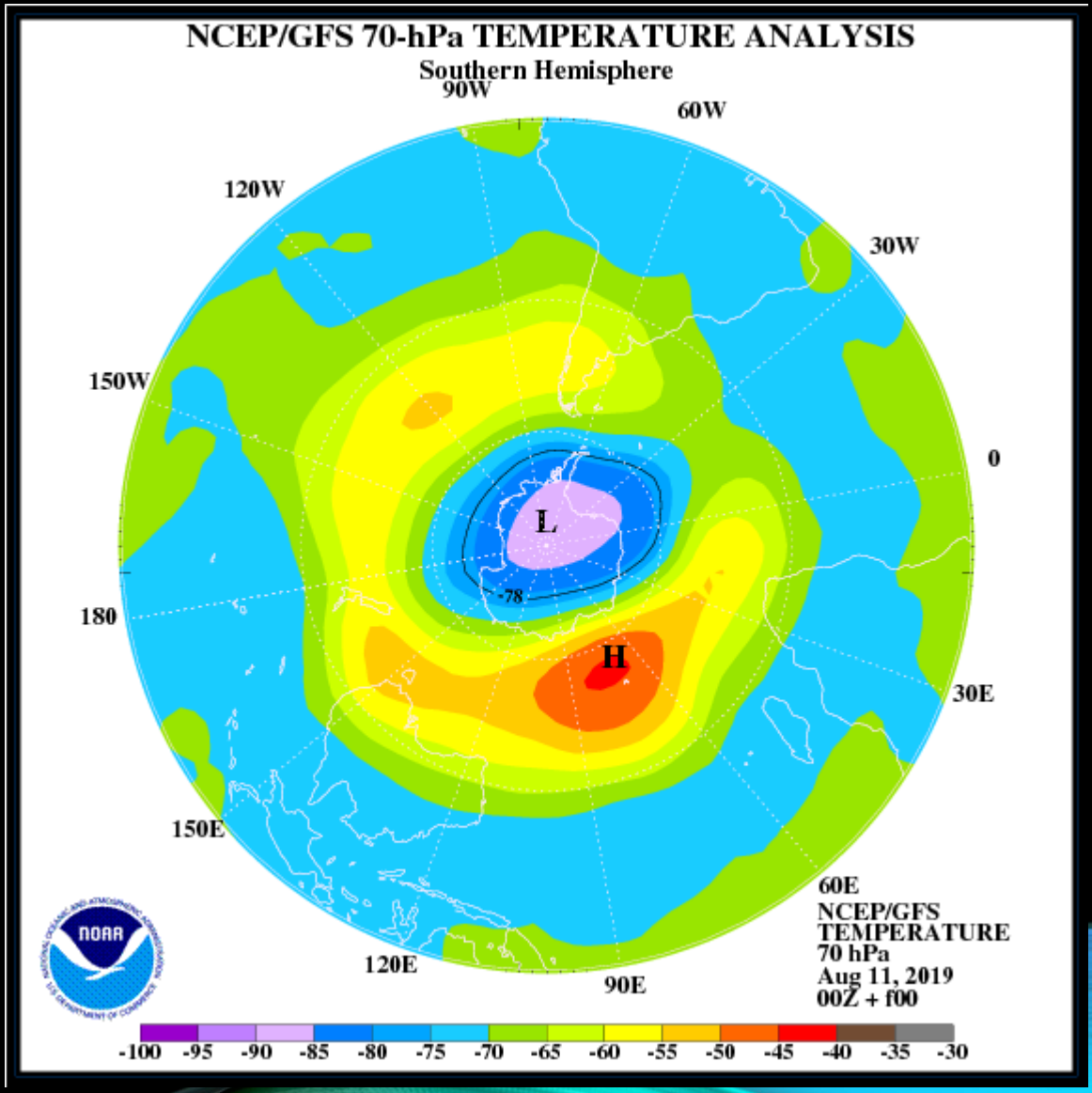
3 The vortex blocks outside air from mixing with air above Antarctica.

4 Polar stratospheric clouds, which concentrate ozone-destroying substances, form in temperatures below -100.

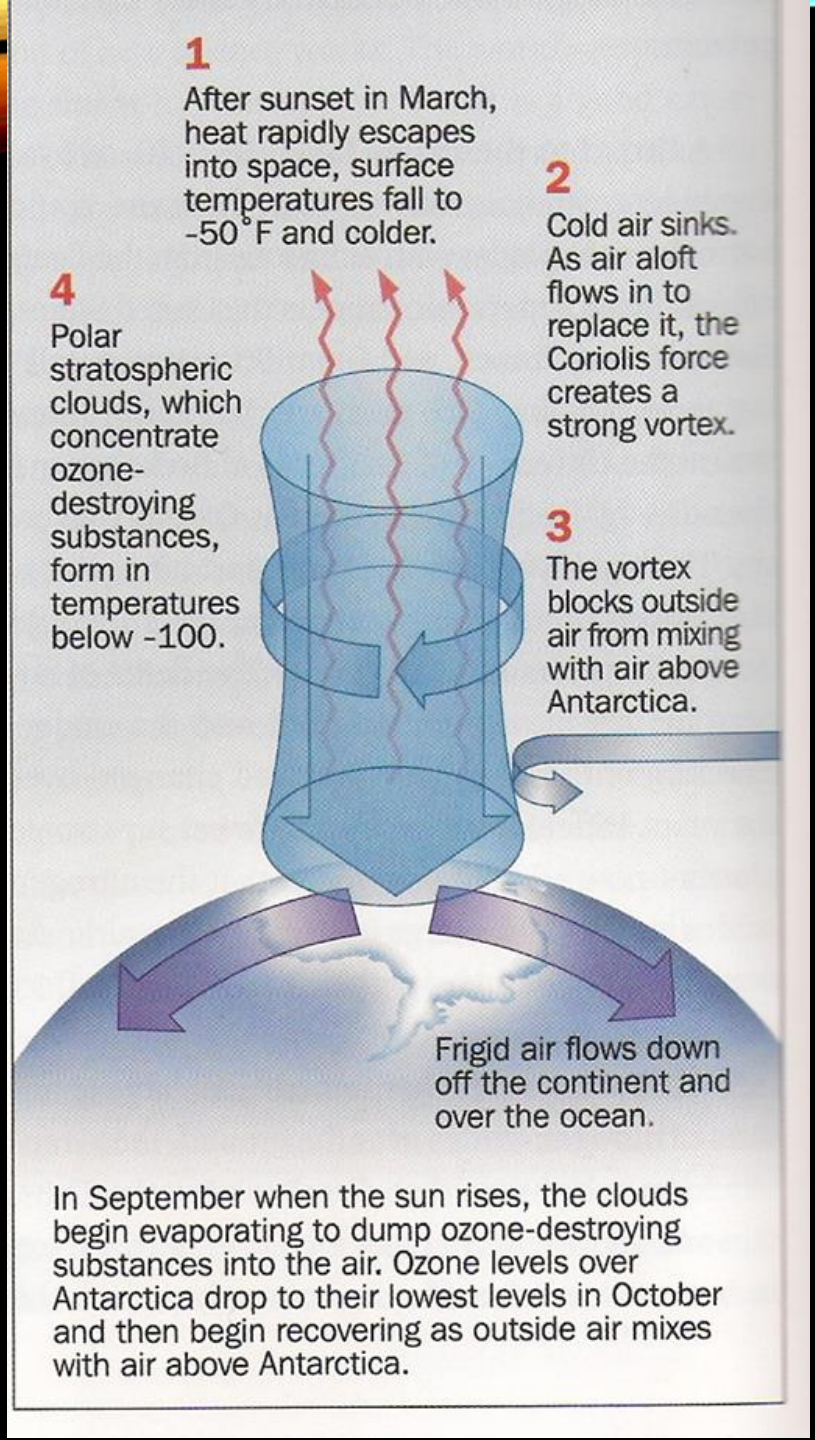


Frigid air flows down off the continent and over the ocean.

In September when the sun rises, the clouds begin evaporating to dump ozone-destroying substances into the air. Ozone levels over Antarctica drop to their lowest levels in October and then begin recovering as outside air mixes with air above Antarctica.



https://www.cpc.ncep.noaa.gov/products/stratosphere/strat_a_f/#emct



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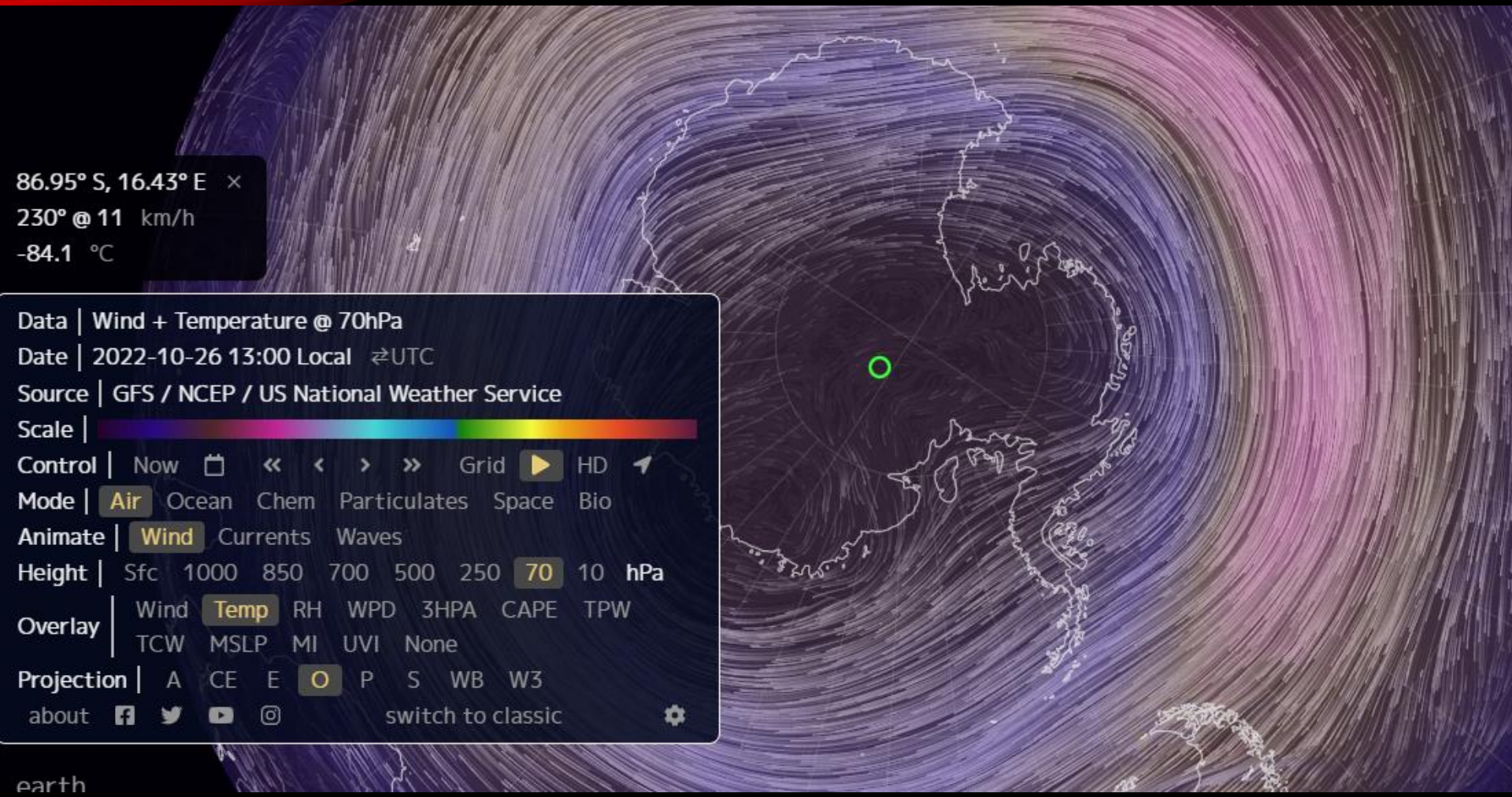
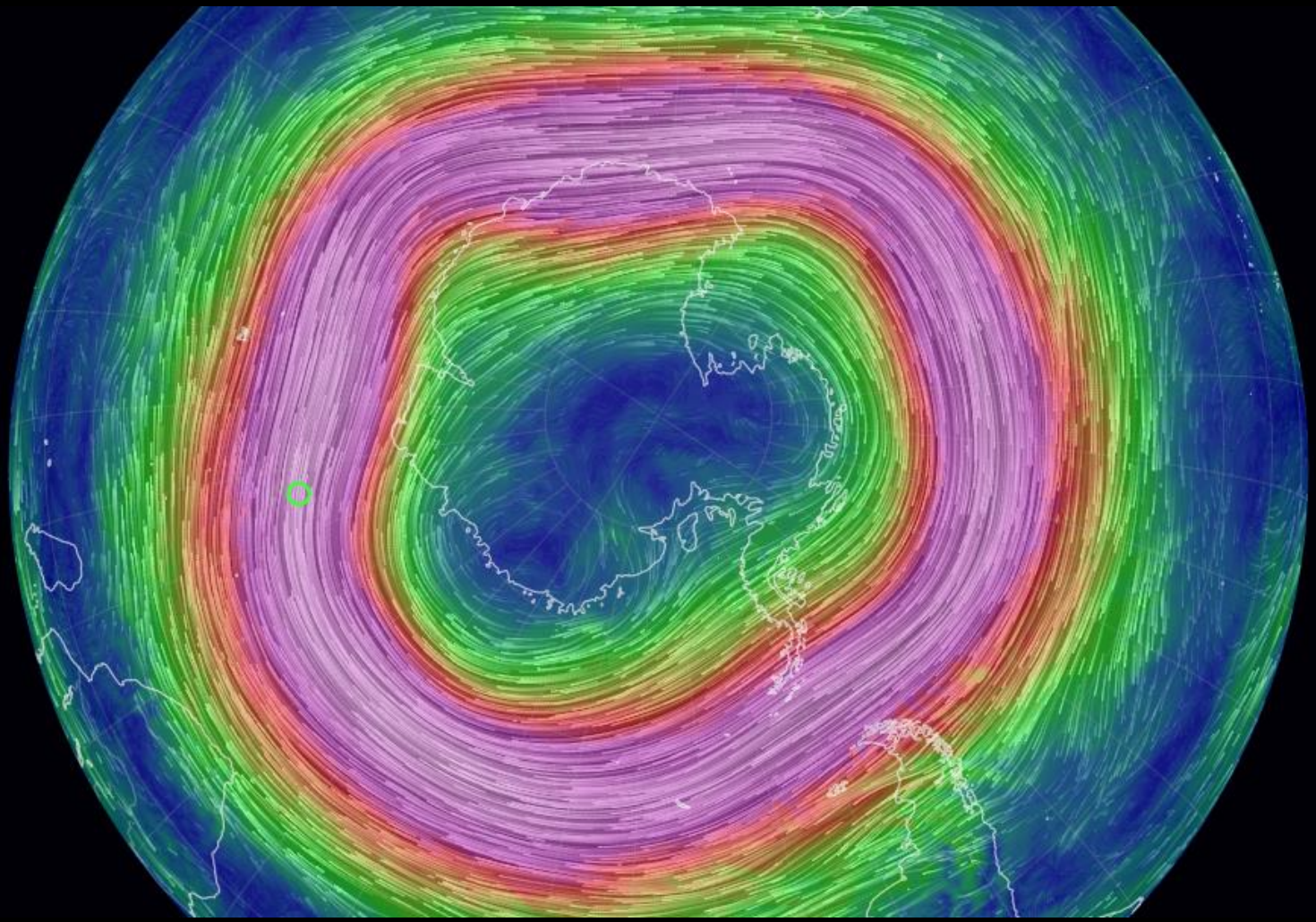
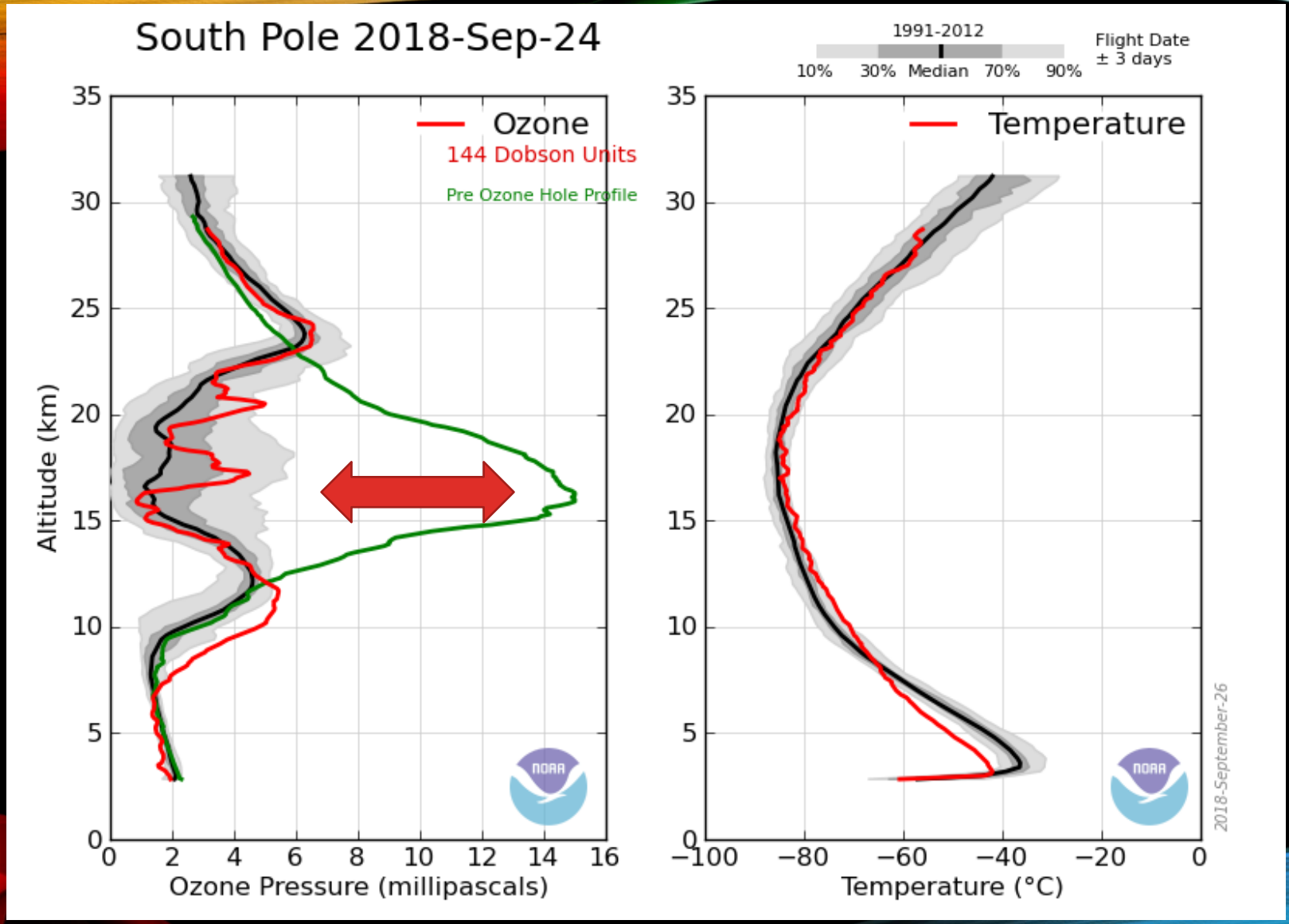


https://earth.nullschool.net/#current/wind/isobaric/70hPa/overlay=temp/orthographic=-199.69,-85.12,281/loc=-168.231,-87.267


55.90° S, 45.92° E ×
295° @ 235 km/h
earth



Animation of what the ozone “hole” looks like.

https://gml.noaa.gov/dv/spo_oz/movies/index.html

Global Monitoring Laboratory

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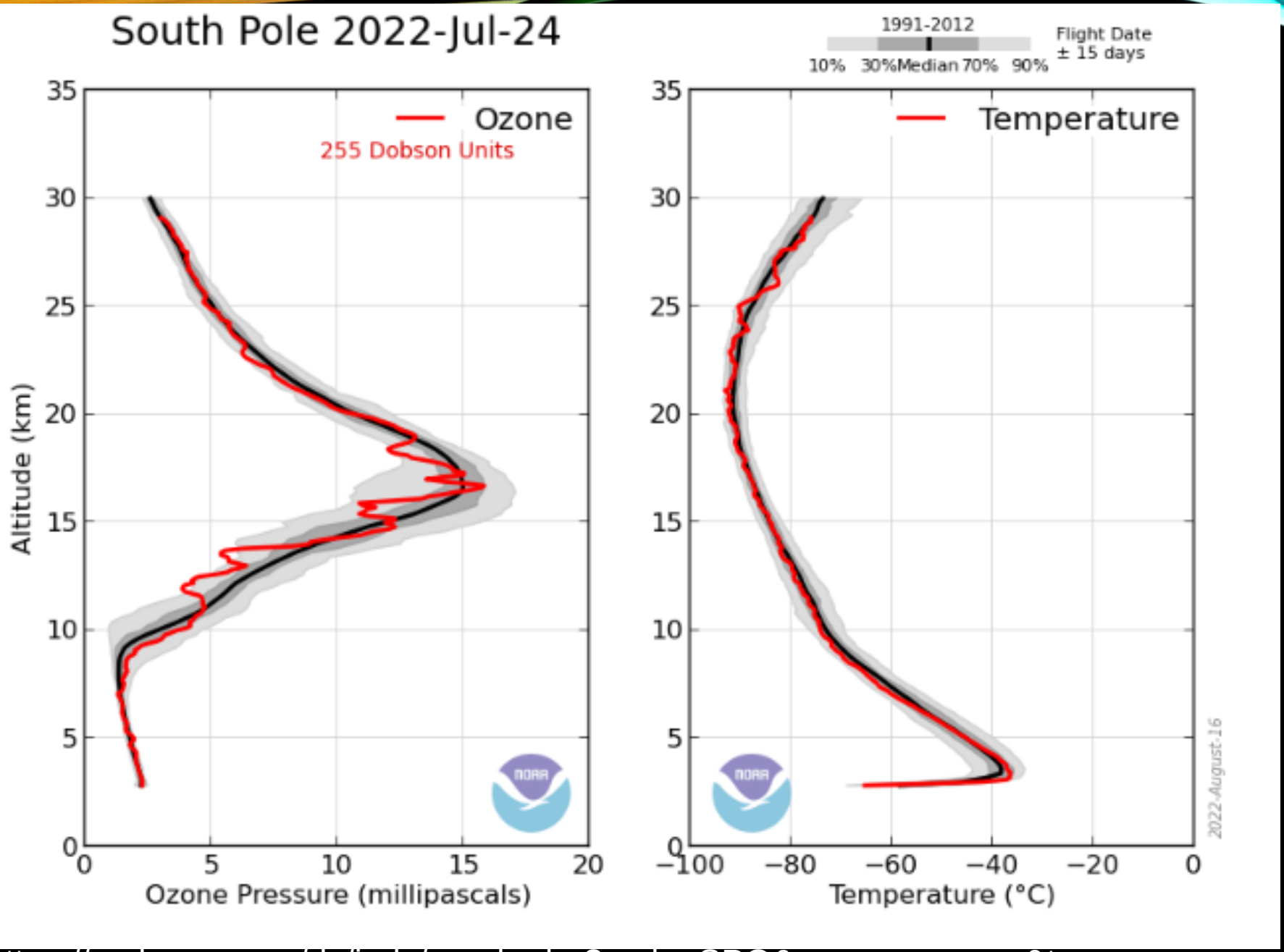
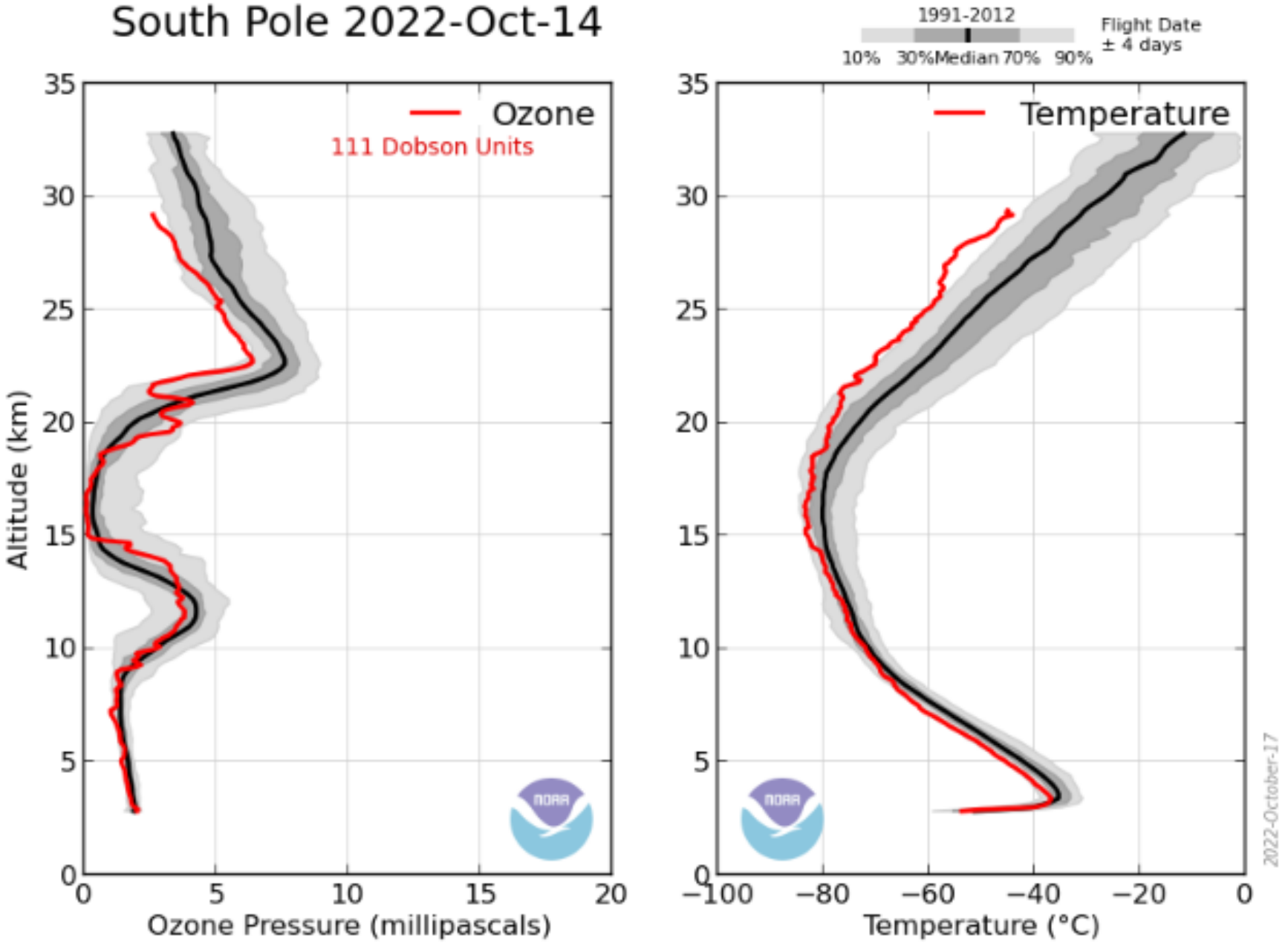
Ozone and Water Vapor

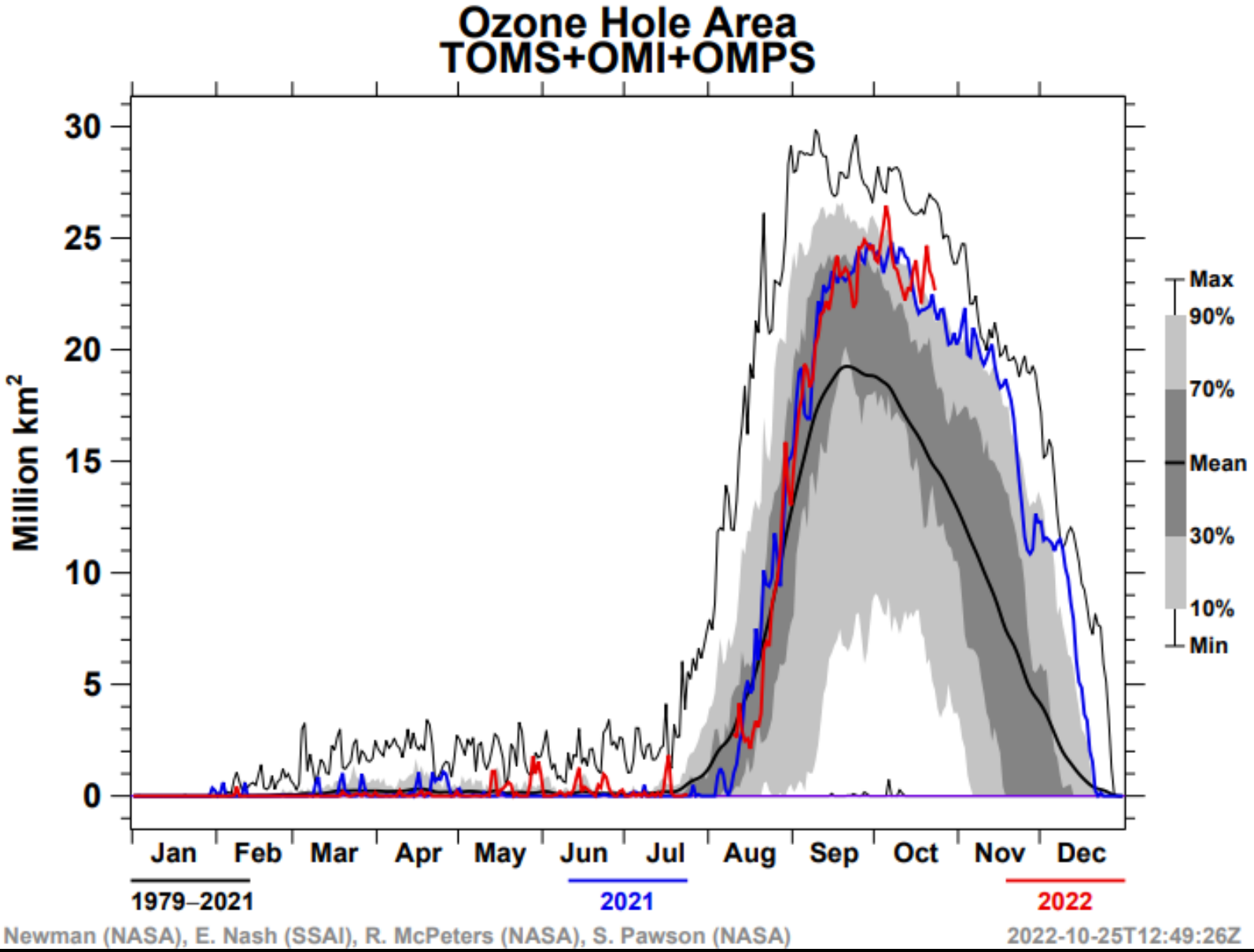
The Ozone and Water Vapor Group conducts research on the nature and causes of the depletion of the stratospheric ozone layer and the role of stratospheric and tropospheric ozone and water vapor in forcing climate change and in modifying the chemical cleansing capacity of the atmosphere. This mission is accomplished through long-term observations and intensive field programs that measure total column ozone, ozone vertical profiles (ozonesondes and umkehrs), ground level ozone, and water vapor vertical profiles in the upper troposphere and stratosphere.

Sites Datasets Data Viewer News



https://gml.noaa.gov/dv/iadv/graph.php?code=SPO&program=ozwv&type=vp

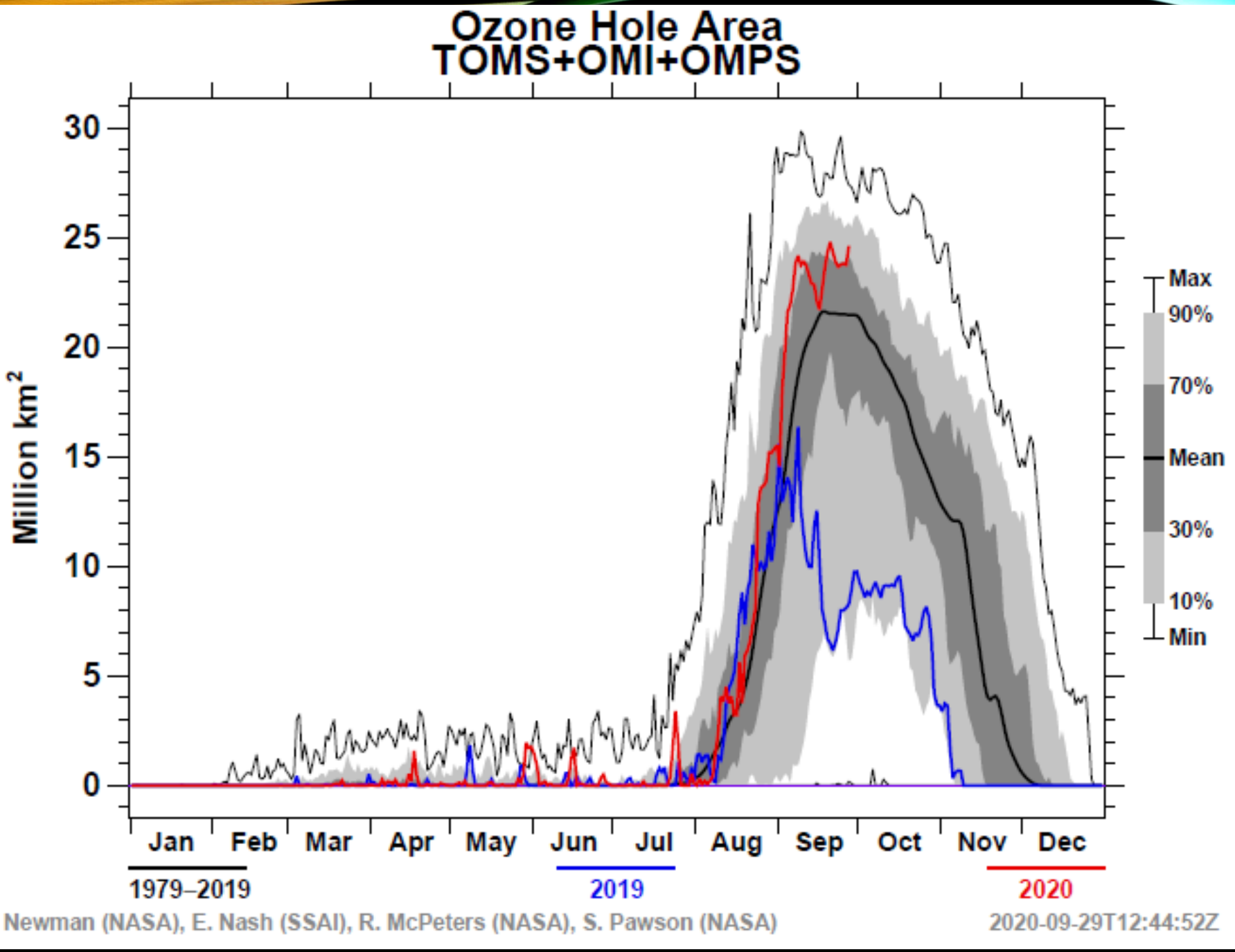

South Pole 2022-Oct-14
1991-2012
10% 30% Median 70% 90%
Flight Date
± 4 days
Ozone
111 Dobson Units
Temperature
Altitude (km)
Ozone Pressure (millipascals)
Temperature (°C)
0
5
10
15
20
25
30
35
−100
−80
−60
−40
−20
NOAA
2022-October-17



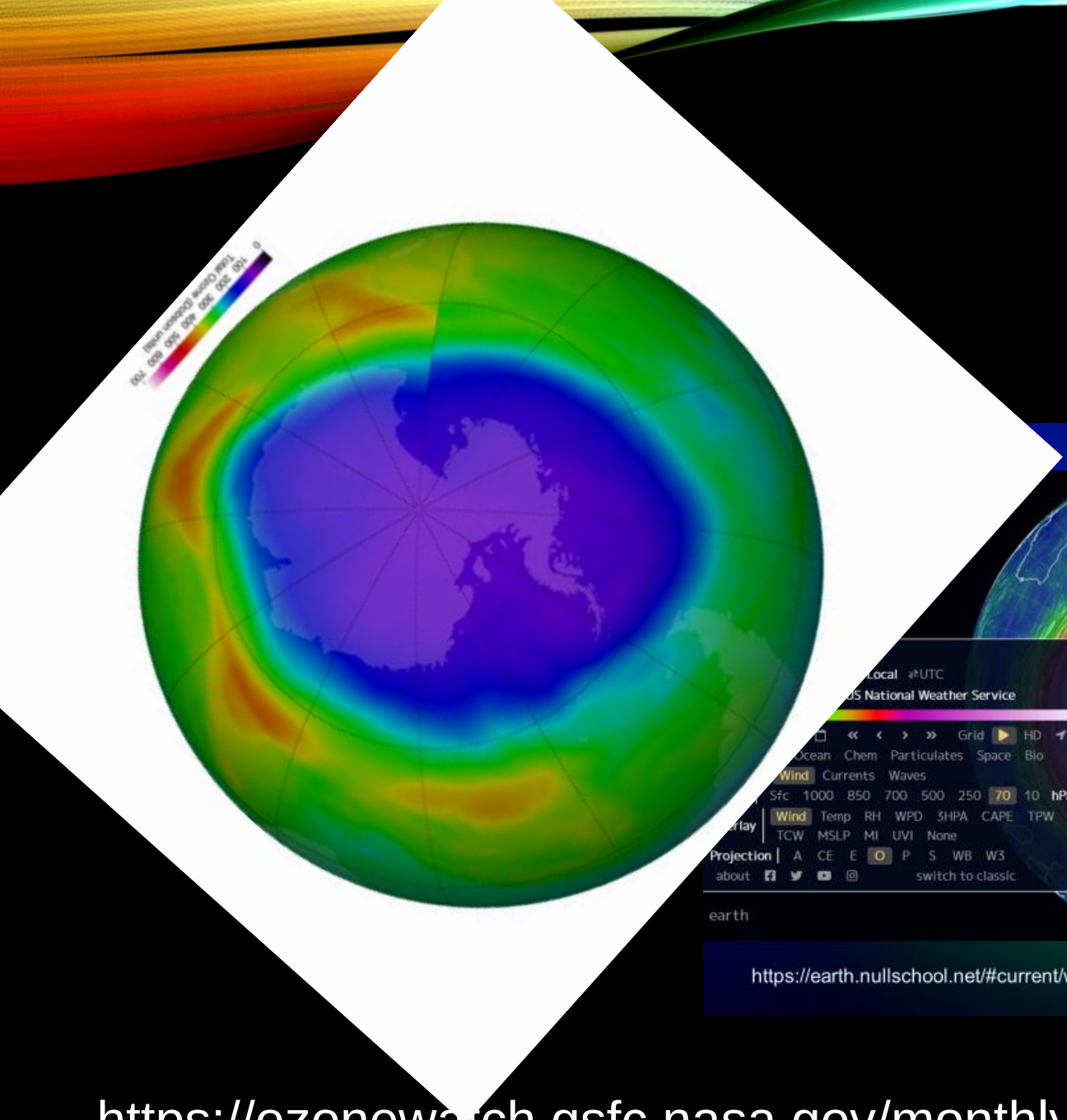
https://ozonewatch.gsfc.nasa.gov/meteorology/SH.html

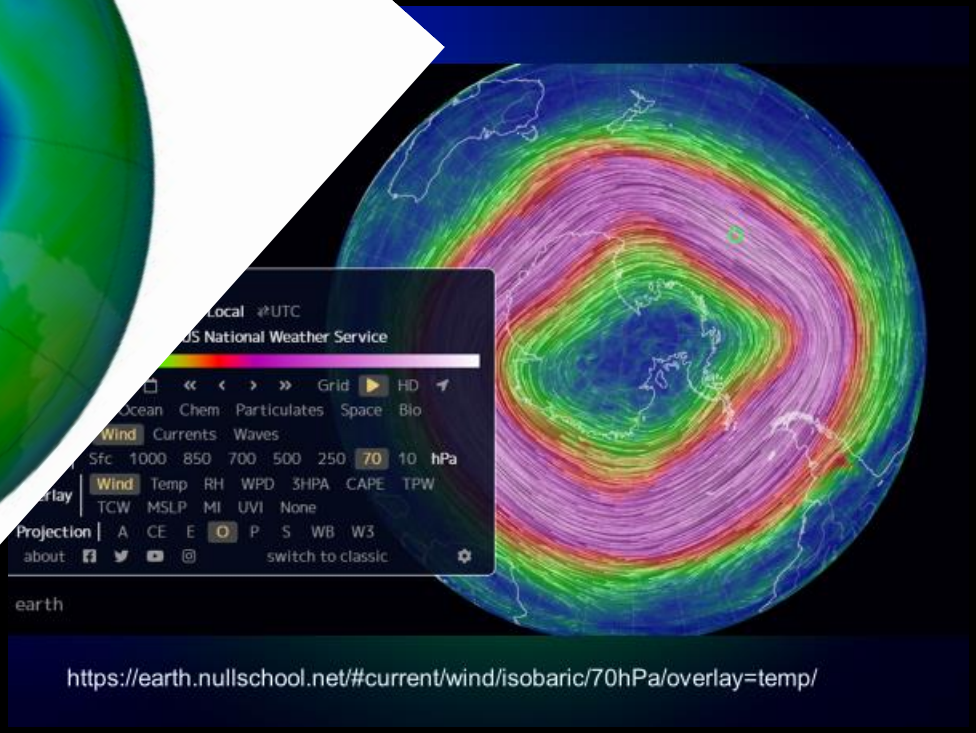
•NASA Paul A. Newman

Ozone hole area: ozone is less than 220 DU

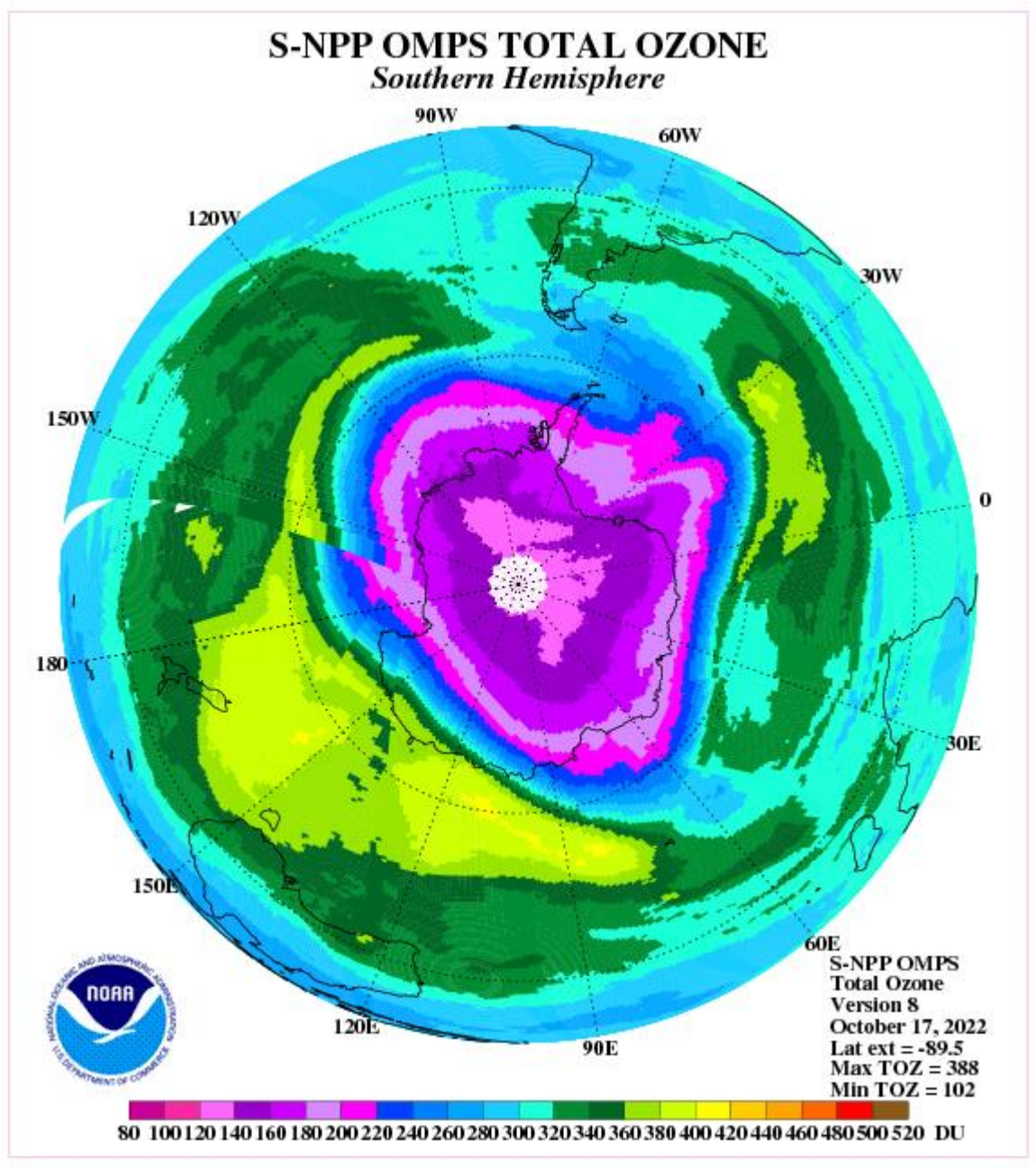

Ozone Hole Area
TOMS+OMI+OMPS
Million km²
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Max
90%
70%
Mean
30%
10%
Min
1979–2019
2019
2020
P. Newman (NASA), E. Nash (SSAI), R. McPeters (NASA), S. Pawson (NASA)
2020-09-29T12:44:52Z

10 October 2021

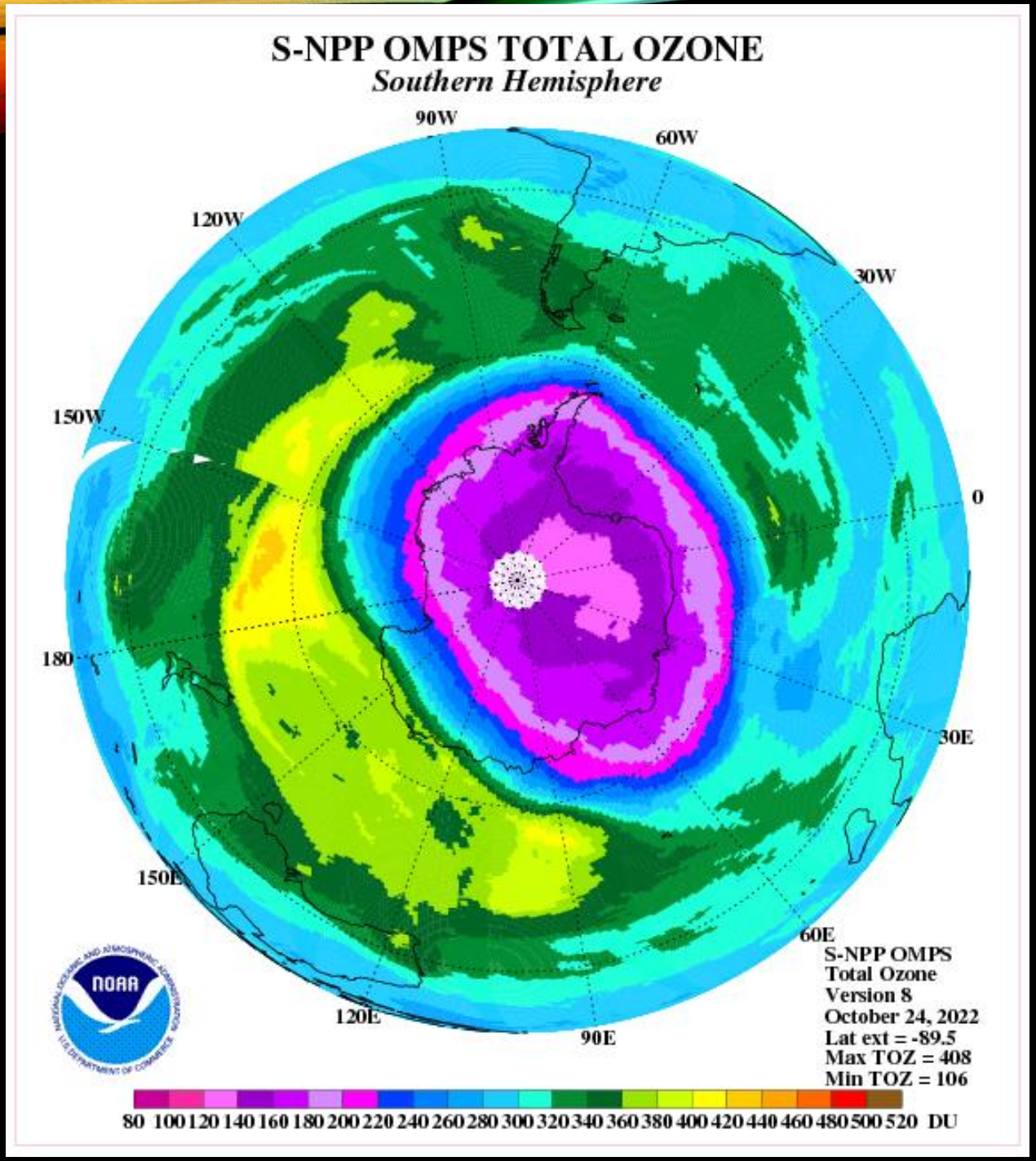


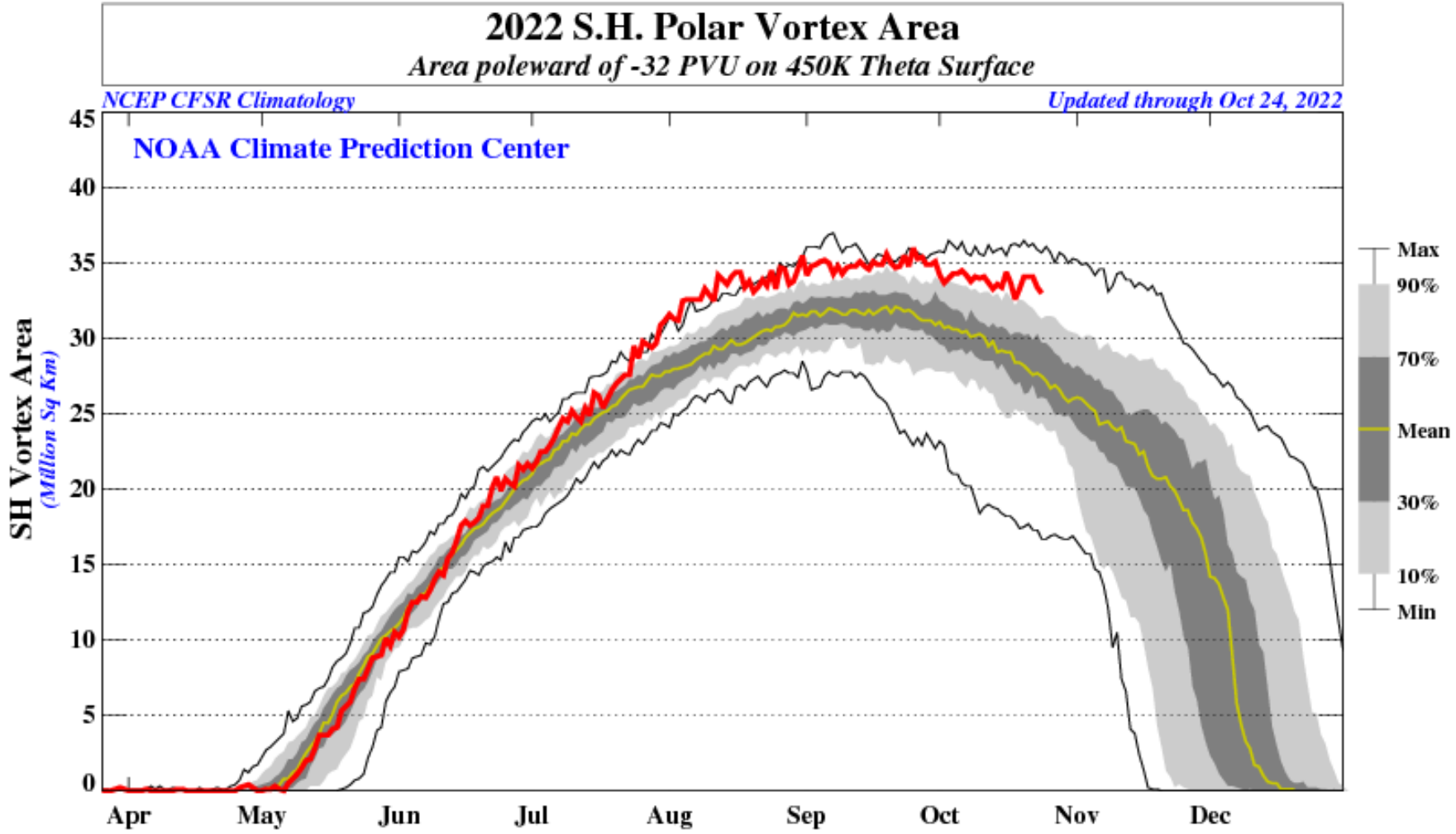


https://ozonewatch.gsfc.nasa.gov/monthly/SH.html



https://www.cpc.ncep.noaa.gov/products/stratosphere/polar/polar.shtml


S-NPP OMPS TOTAL OZONE
Southern Hemisphere
90W
60W
120W
30W
150W
0
180
30E
150E
60E
120E
90E
S-NPP OMPS
Total Ozone
Version 8
October 24, 2022
Lat ext = -89.5
Max TOZ = 408
Min TOZ = 106
80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 DU



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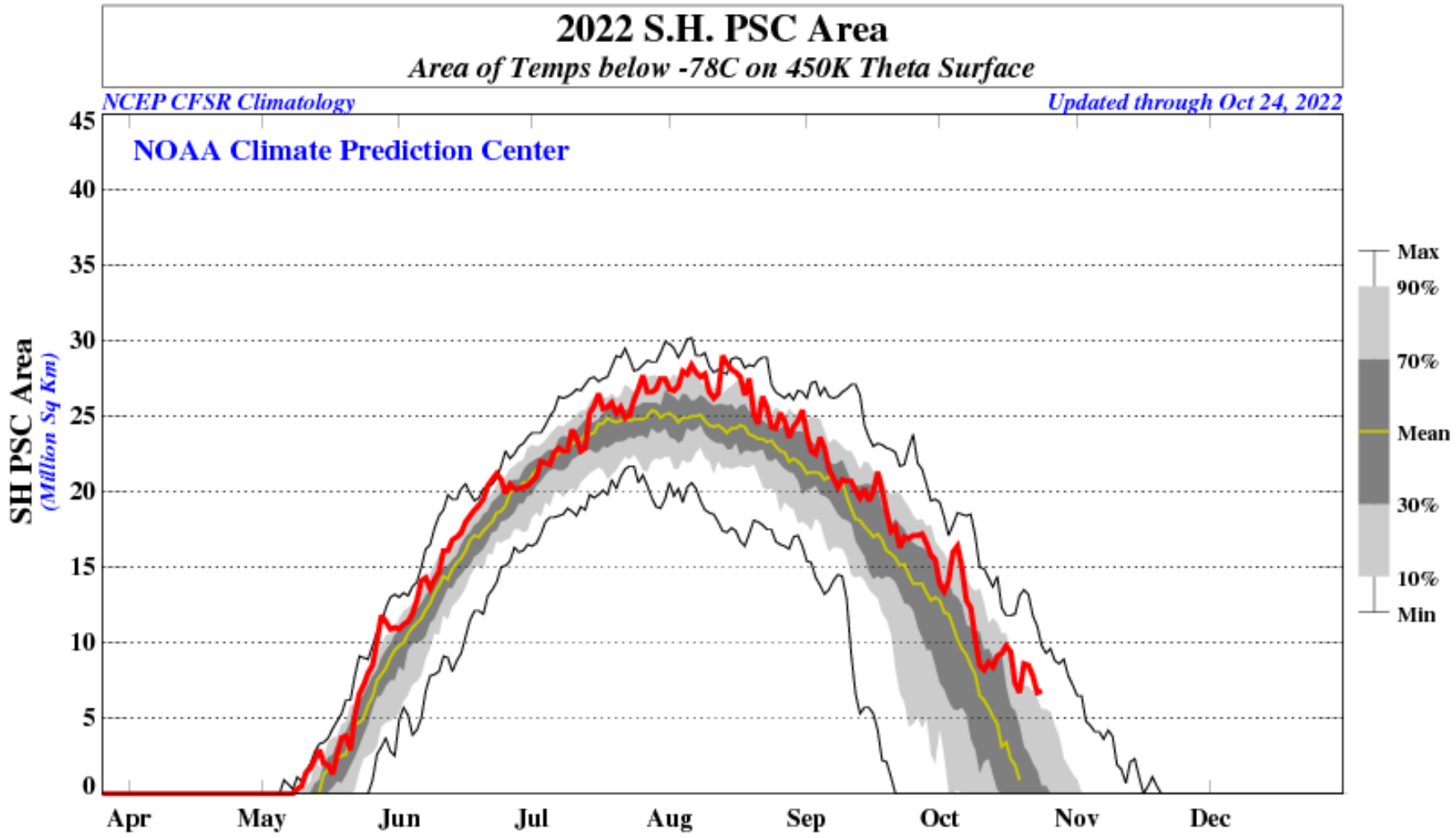
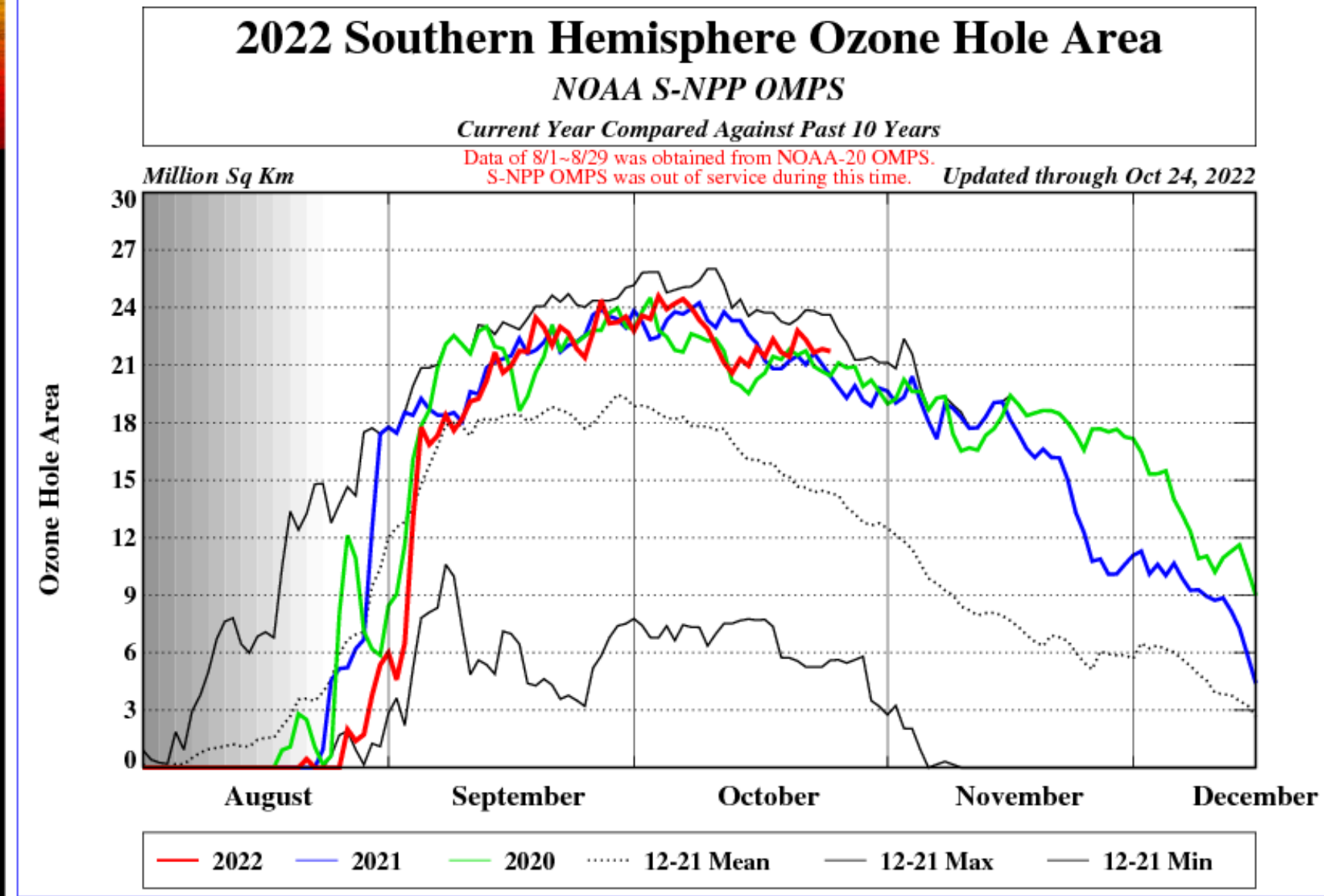
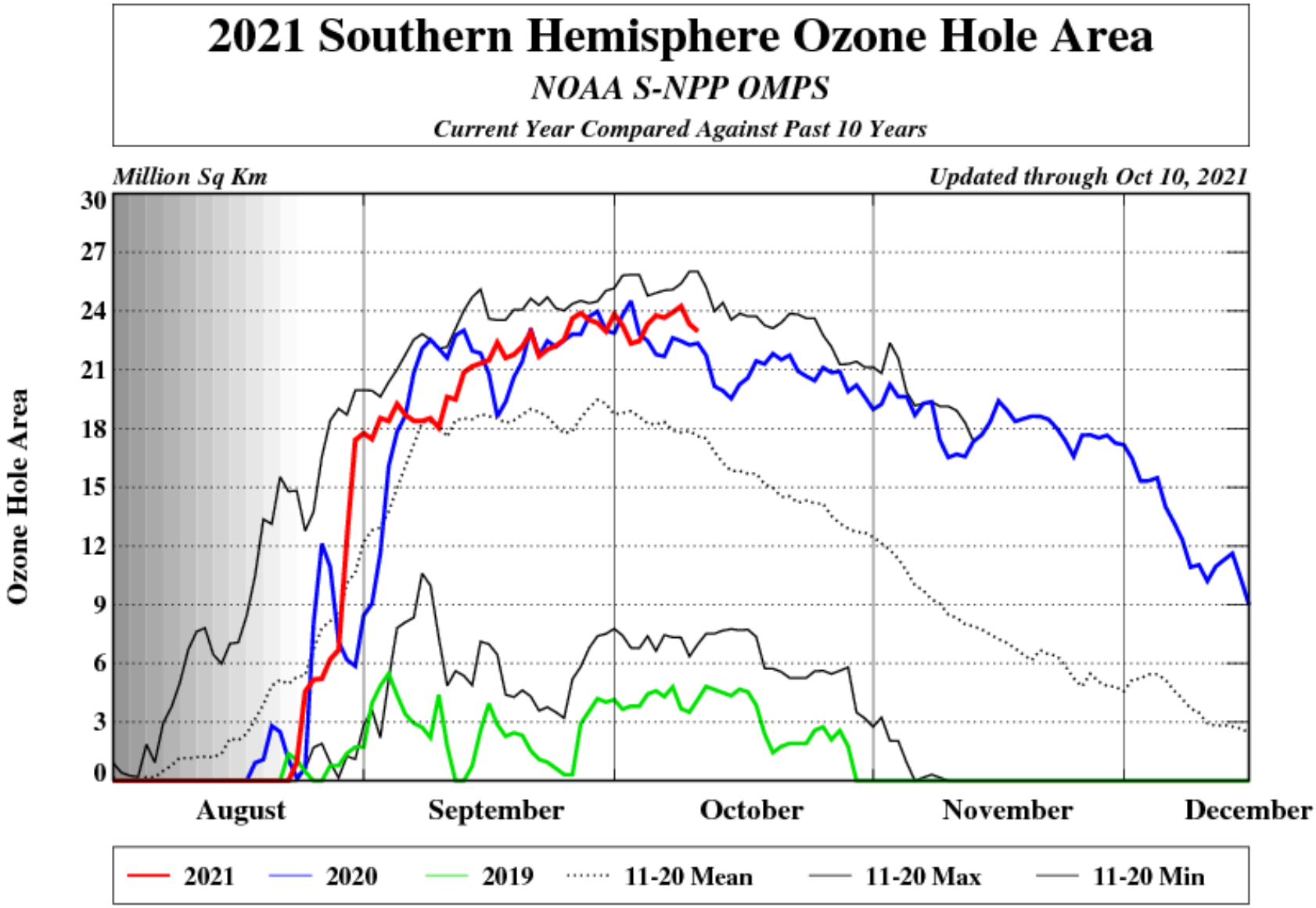


The area of the Antarctic stratosphere with temperatures below -78 ^{o}C where ozone could be destroyed on the polar stratospheric clouds (PSC)

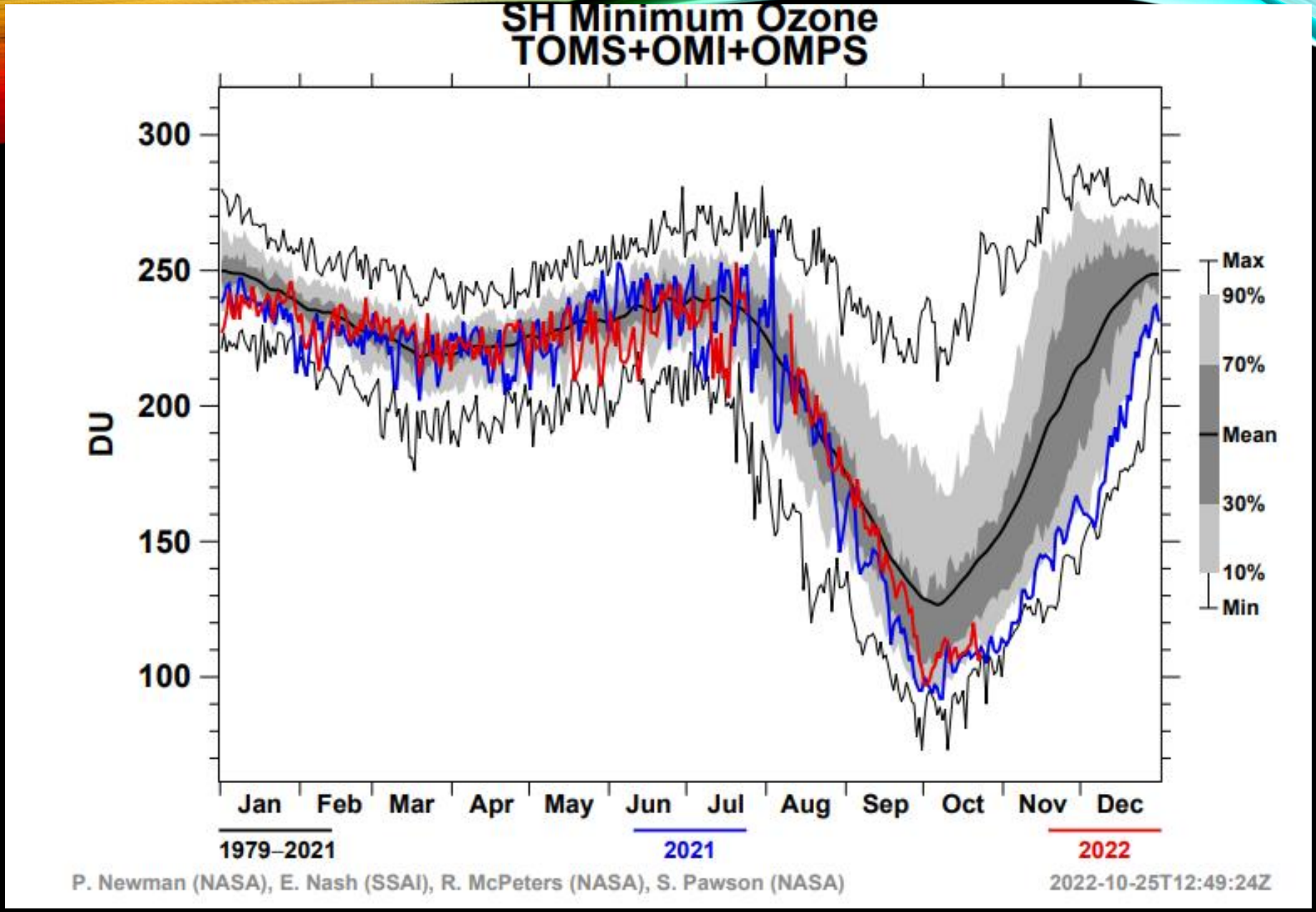
https://www.cpc.ncep.noaa.gov/products/stratosphere/polar/gif_files/psc_sh.png



https://www.cpc.ncep.noaa.gov/products/stratosphere/polar/gif_files/ozone_hole_2022.png



https://www.cpc.ncep.noaa.gov/products/stratosphere/polar/gif_files/ozone_hole_plot.png



https://ozonewatch.gsfc.nasa.gov/meteorology/figures/ozone/to3mins_2022_toms+omi+omps.pdf

References

https://en.wikipedia.org/wiki/Ozone_depletion

UNEP video (about 16 minutes)
https://www.youtube.com/watch?v=AU0eNa4GrgU

Excellent Centre for Research into Atmospheric Chemistry (CRAC) University College, Cork, Ireland About 26 minutes , produced in 1995.
https://www.youtube.com/watch?v=LI_TR7C4xr4

Seeker – Montreal Protocol
https://www.youtube.com/watch?v=CvcvMkFGBi8

https://ozonewatch.gsfc.nasa.gov/meteorology/SH.html

PSC chemistry
http://www.theozonehole.com/psc.htm

https://www.ozonelayer.noaa.gov/data/antarctic.htm

http://www.theozonehole.org/ozonehole2022.htm

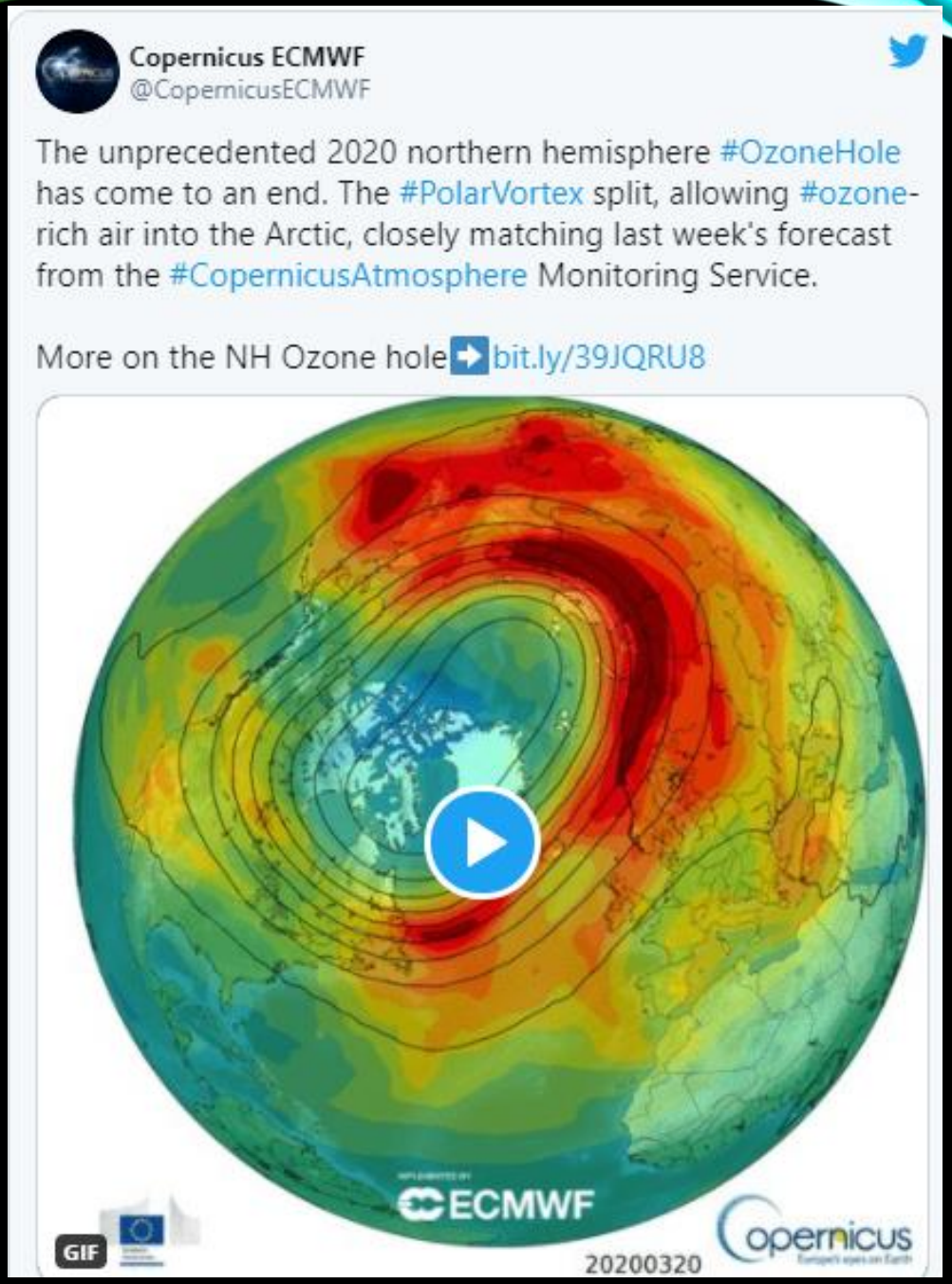
What about the Arctic? Is there an ozone hole there?

There have been a few cases – winter 2004, 2011 and 2020

Generally the polar vortex is not so strong and breaks up earlier (due to the stronger wave patterns in the northern hemisphere).

Cooling of the Arctic stratosphere with increased greenhouse gases could make an Arctic ozone hole more likely.

There have also been small ozone holes over the Tibetan plateau.



Is there any impact on our weather, or vice versa?

Still an area of research – but it is possible that the ozone hole has caused the dominant westerly jet stream in the mid-latitudes to move toward the pole, with an accompanying shift in precipitation patterns associated with the mid- to high latitudes.
https://www.earth.columbia.edu/articles/view/2802

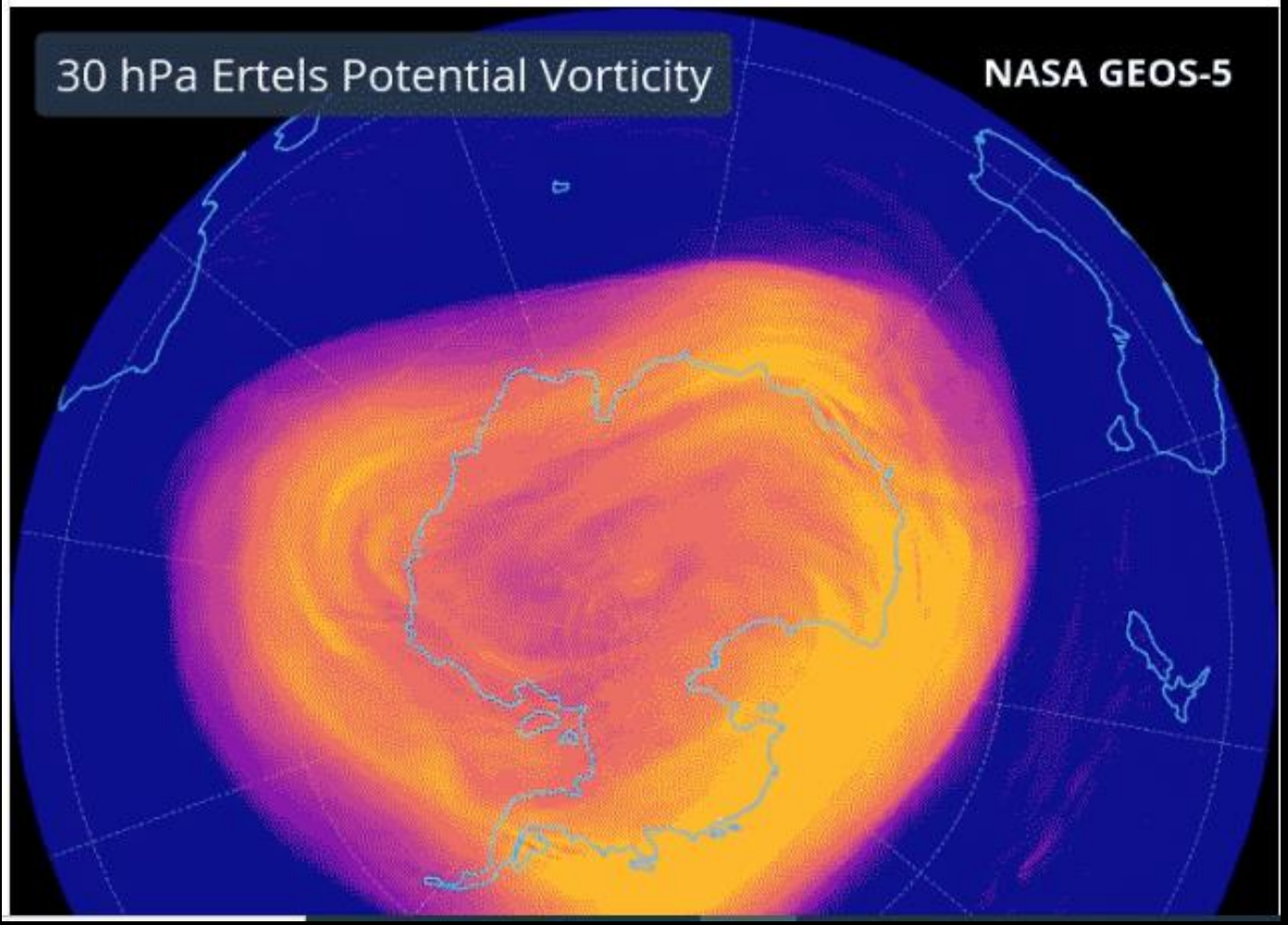
There seems to be a connection between positive Indian Ocean Dipole and Sudden Stratospheric Warmings in the southern hemisphere (although there are only two cases – 2002 and 2019)

Interestingly, the last three years have been La Niña years and the ozone hole has been relatively deep and prolonged.

Strong Antarctic polar vortex adds to south-east Australian rainfall and flood risk, BOM says

ABC Weather / By Ben Deacon

Posted 2h ago



https://www.abc.net.au/news/2022-10-23/antarctic-winds-drive-rain-south-east-australian-flood/101537816

Southern Annular Mode climate driver

Climate scientists call this movement of the belt of westerly winds over the Southern Ocean towards or away from Australia the Southern Annular Mode, or SAM.

The impacts of positive SAM in summer are similar to the impacts of positive SAM in spring. *(Supplied: BOM)*

When the westerly winds move away from Australia in spring, driving an increased chance of rain across south-eastern Australia, it's called a positive SAM.

Is there a connection between the “ozone hole” and greenhouse warming?

They are quite different processes but there is some overlap:

Two factors that lead to a cooler stratosphere and accentuate the ozone hole

- Loss of heating from ozone in the stratosphere
- Greenhouse reduction of outgoing long wave radiation leads to cooling of the stratosphere.

The chlorofluorocarbons were strong greenhouse gases so eliminating them and their replacements reduces that source of heating

Reduced ozone causes the stratosphere to absorb less solar radiation, thus cooling the stratosphere while warming the troposphere; the resulting colder stratosphere emits less long-wave radiation downward, thus cooling the troposphere.

Overall, the cooling dominates.

Because ozone is a greenhouse gas ozone pollution does tend to warm the atmosphere.

Because:

- We live on a spherical planet where the incoming energy from the sun is greater in the tropics than in the polar areas
- We have an atmosphere and ocean which try to even out the energy imbalance
- We live on a rotating planet that complicates the work of the atmosphere and ocean by deflecting winds (and currents) that develop. (Coriolis Force)
- Land and ocean, mountain ranges and different types of surface add their own effects.

Forecasting the Weather

A bit like a consultation with your doctor:

- First step is diagnosis
- Then prognosis and treatment.

In weather forecasting the first step is to analyse the weather now, and then to make a forecast. The "**weather map**" is one of the results from the analysis stage.

The method of making a forecast will depend on factors such as:

- What element are you interested in?
- How far ahead do you need a forecast?

Forecasting the Weather

- Where are you?
- How far ahead are you interested?
- Who are you and what do you want to do?
  - planning a picnic … today, … or next week
  - Going for a camping trip … in the high country
  - Sailing on Port Phillip … or in Bass Strait….
  - An aircraft pilot making a long flight
  - Fighting a bushfire
  - A farmer deciding what to plant and when
  - An astronomer looking for clear skies ….
  - A gardener worried about frost
  - ……
- What weather elements are most important?

	T	rain	cloud	wind	RH	Pheno mena	How far out?
You							
Sailor							
Farmer							
Firefighter							
Aircraft Pilot							

Imagine we are just interested in the general weather for tomorrow? What techniques could we use?

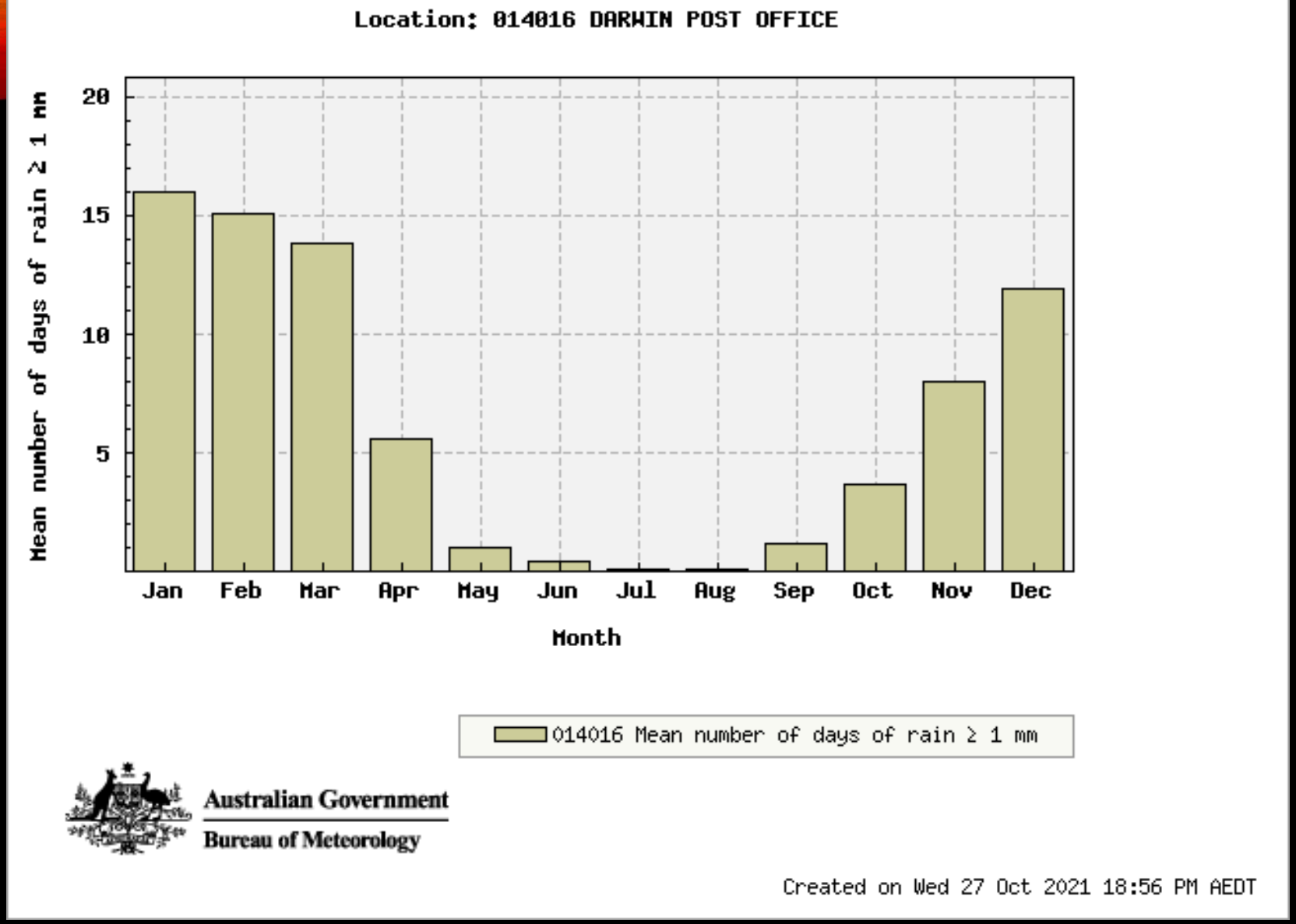
Persistence
Assume tomorrow's weather will be the same as today's

Climatology
Assume that the weather will be typical for the time of year for the location you are interested in

This could include the daily trend and regular features such as a sea breeze.

Rules of thumb or local knowledge
e.g. . rings around the moon are a sign of rain to come
. red sky at night, shepherd's delight, …
. it's always 40 degrees on Christmas Day
. the sea breeze will come in when the cloud clears.

Figure 6.2 Daily mean temperatures during March in Edmonton, Singapore, New Delhi and Canberra during 2000, 2001, 2002 and 2005.



Darwin Post Office – average number of days with rain > 1mm 1869 to 1962

Extrapolation

. Watching the upstream weather

e.g. Melbourne will have tomorrow what Adelaide had today.

. A **useful technique for short-term forecasts based on radar or satellite images.**

Creating a forecast weather chart

Move the weather features on the synoptic chart at the rate at which they have been moving

Look at the pressure changes and project the pressure changes and apply them to the weather chart

Analogue

Find a past weather chart similar to today's and use the weather that happened on that occasion

Looking for some underlying cause

e.g. sunspots, sea surface temperature patterns

Statistical techniques

Seasonal forecasts are mainly statistical – correlations sea surface temperature patterns.

Numerical (Computer) Weather Prediction

Using a computer to analyse the current weather and use equations to predict the weather ahead.

No one method is the best all the time.

All techniques have their appropriate time and place, and method of use.