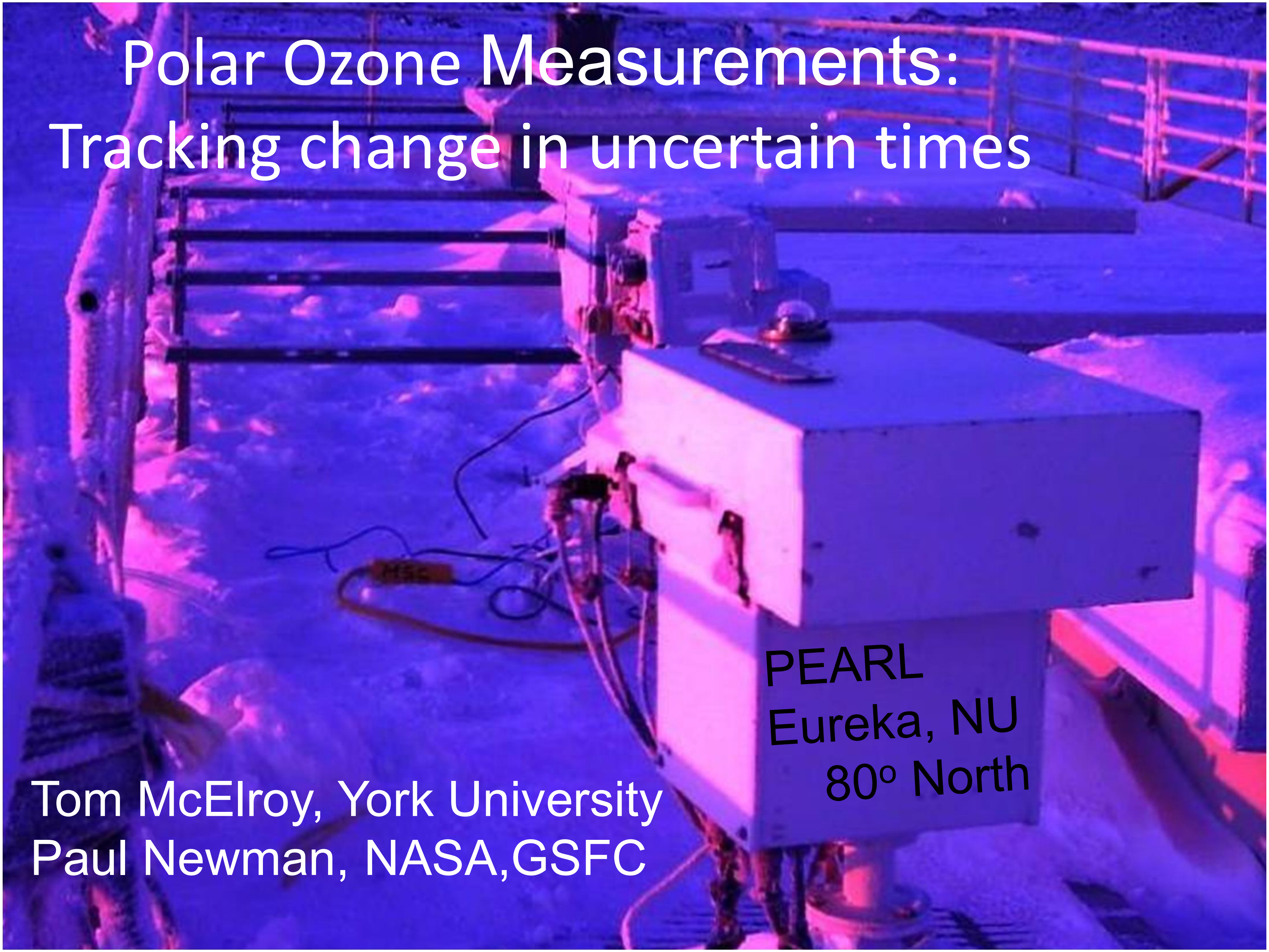
Polar Ozone Measurements: Tracking change in uncertain times



PEARL
Eureka, NU
80° North

Tom McElroy, York University
Paul Newman, NASA,GSFC

Overview

- Summary of stations
- Recovery of the ozone layer
- Need for observations
- Recent ozone ‘incidents’
- Interaction of climate change and ozone
- Summary and conclusions

NDACC List of Polar Stations

Arctic	Latitude	Antarctic	Latitude
Alert	82.5	Marambio	64.23
Heiss Island	80.6	Palmer	64.77
Eureka	80.05	Faraday	65.25
Ny Allesund	78.92	Dumont d'Urville	66.67
Thule	76.53	Rothera	67.57
Resolute	74.7	Syowa Base	69.01
Dikson Island	73.5	Neumayer station	70.62
Summit	72.34	Concordia Dome C	75.1
Barrow	71.32	Arrival Heights	77.83
Scoresbysund	70.48	Scott Base	77.85
Andøya	69.3	McMurdo	77.85
Esrange	67.9	Belgrano	77.87
Kiruna	67.84	Amundsen-Scott	90.00
Sodankylä	67.37		
Søndre Strømfjord	66.99		
Zhigansk	66.8		
Salekhard	66.5		

NH 17 stations
SH 13

Some of the longest and most valuable ozone records are from the Arctic stations

- Resolute Bay: 60+ years for Total Column Ozone (TOC) and 55 years for ozonesondes
- Barrow Observatory: 49 combined years Dobson TOC (1973-82 then 1986- now)
- TOC observations from multiple Arctic stations in Russian Federation for approximately 39 years
- Alert: 37 years for TOC and 35 years for ozonesondes
- Kangerlussuaq (Sondre Stromfjord): 33 years TOC
- Eureka: 30 years TOC and 30 years for ozonesondes
- Ittoqqortoormiit (Scoresbysund): 29 years ozonesondes
- Thule: 23 years TOC
- Fairbanks: 1964-1972 and 1985- now

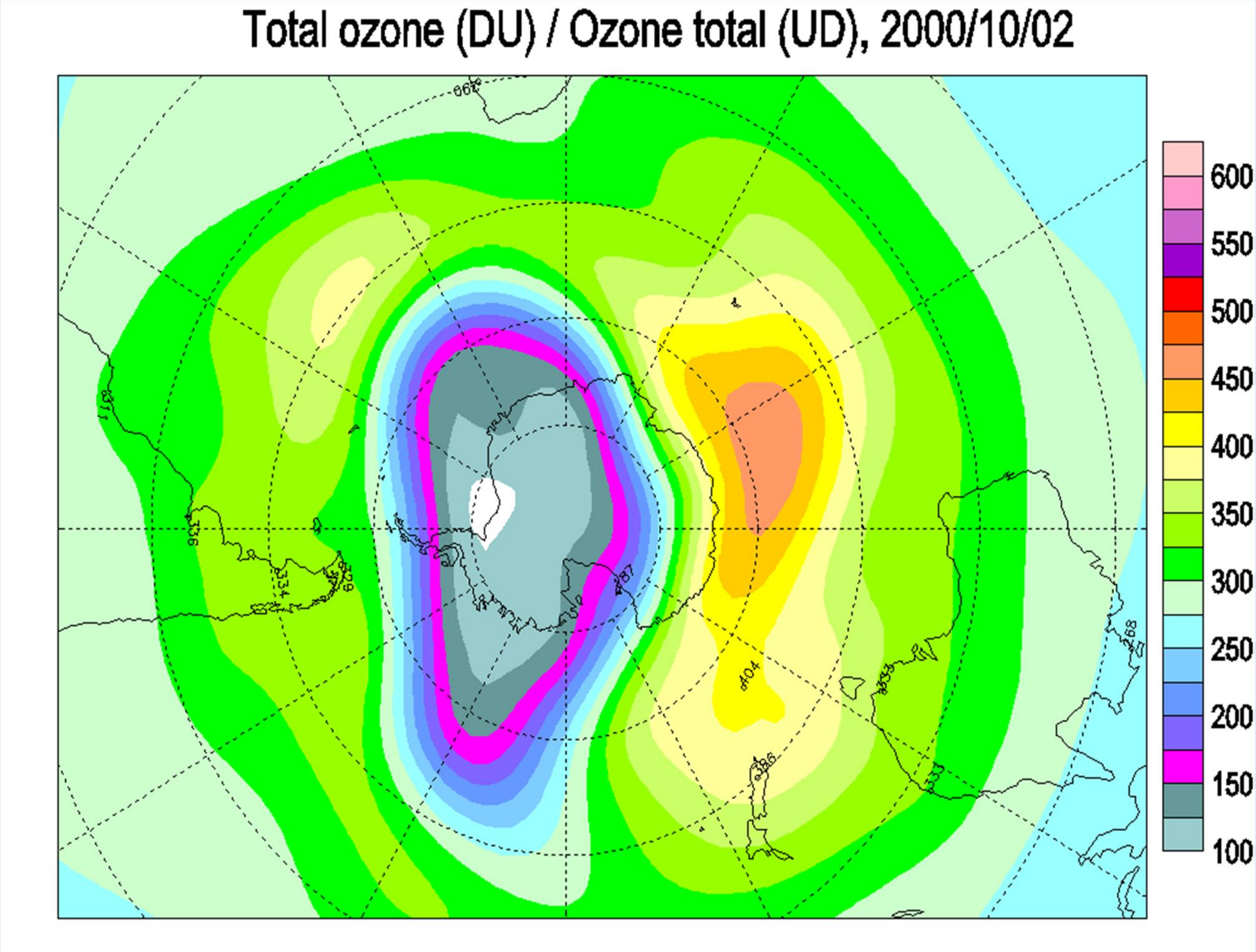
After Stoyka Netcheva, 2023 ORM

The Big Picture

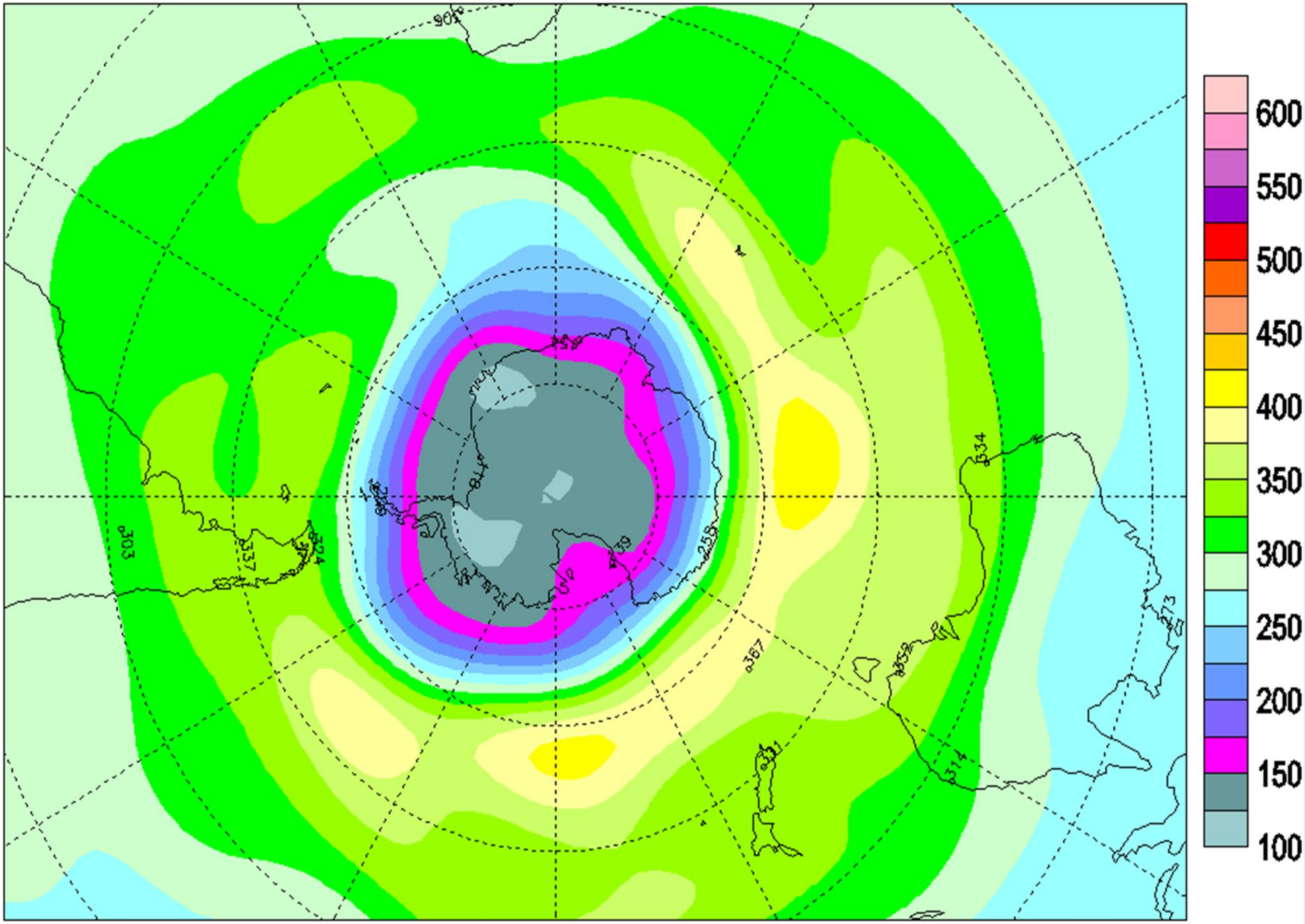
- The major uncertainties in predicting the impacts of climate change are related to aerosol and ozone (IPCC)
- Recovery from the Antarctic ozone hole over the last four years has been slower than expected
- Polar ozone depletion affects mid-latitude ozone, increasing UV-B (When the winter vortex breaks up)
- Increased GHGs in the atmosphere cool the ozone layer
  - Lower stratospheric temperatures may increase ozone depletion (Climate change affects ozone depletion)
- Tropospheric ozone changes affect climate (Radiatively active gas)
- Continued monitoring of polar ozone and aerosol is imperative

And some actual pictures…

- The transport of ozone from the equator to the pole is modulated by the phase of the Quasi-biennial Oscillation (QBO)
- Eddy transport of energy, momentum and ozone is stronger in one phase than the other
- Approximately every other year ozone depletion is stronger
- It is those years that are more interesting to track
- The first set of plots address Antarctic changes, the second, changes in the Arctic


Total ozone (DU) / Ozone total (UD), 2000/10/02
600
550
500
450
400
350
300
250
200
150
100

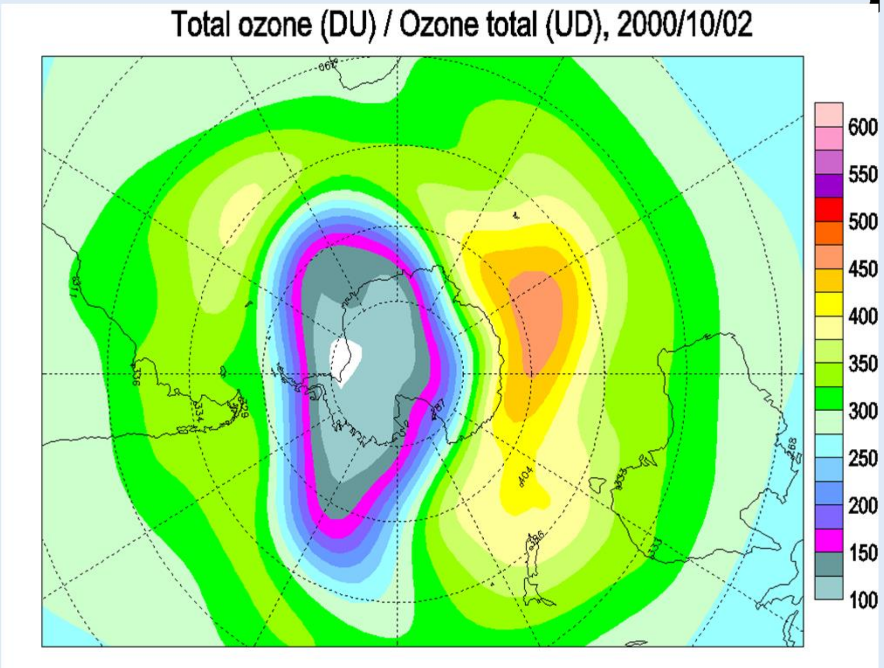
Total ozone (DU) / Ozone total (UD), 2001/10/02

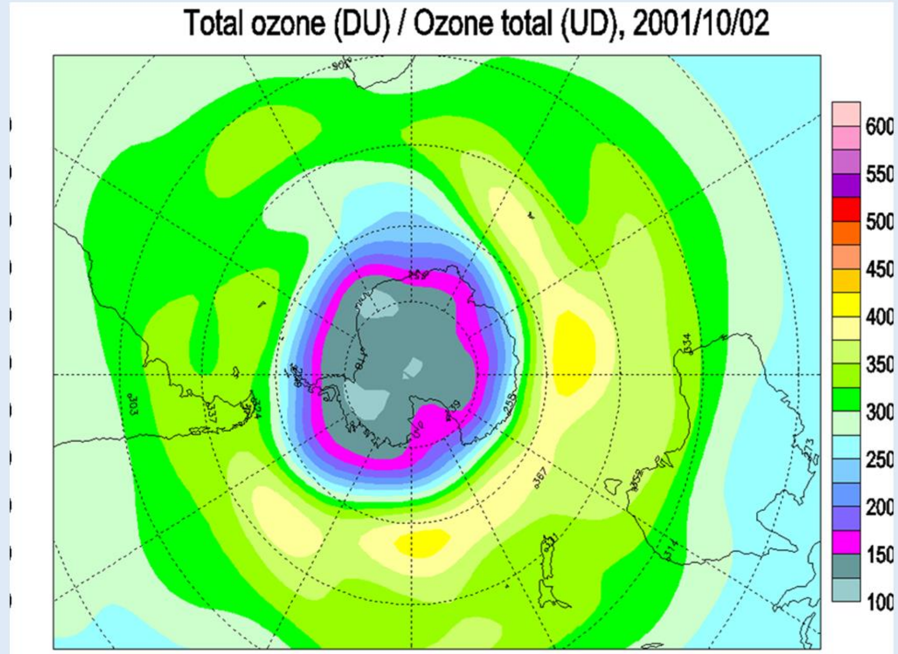


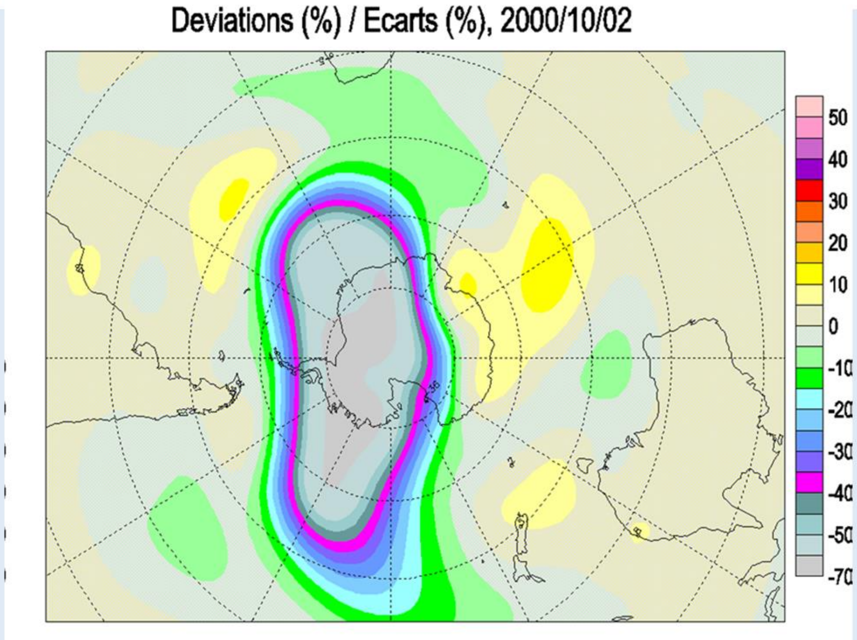
Comparison

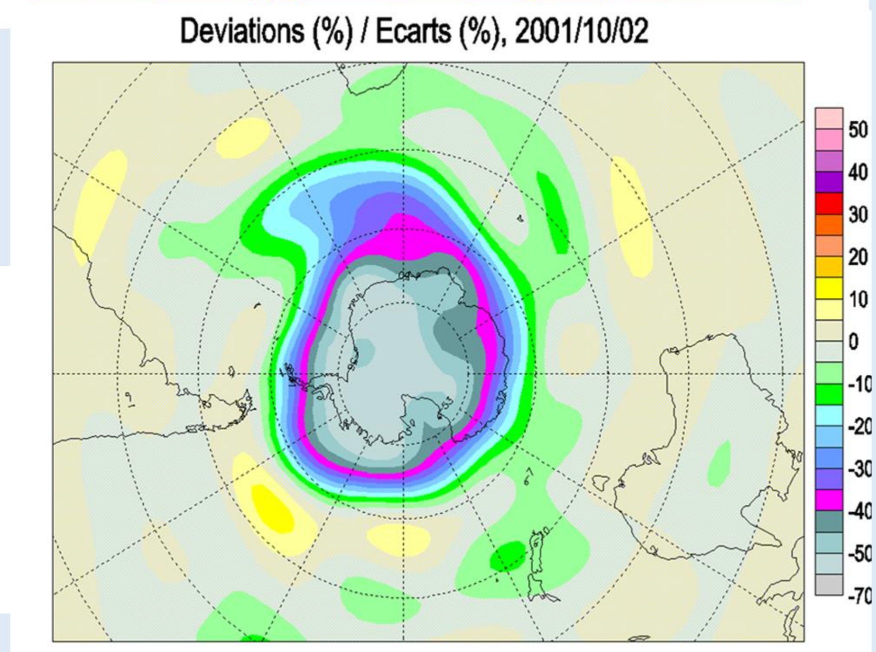
2000 10 02

2001 10 02



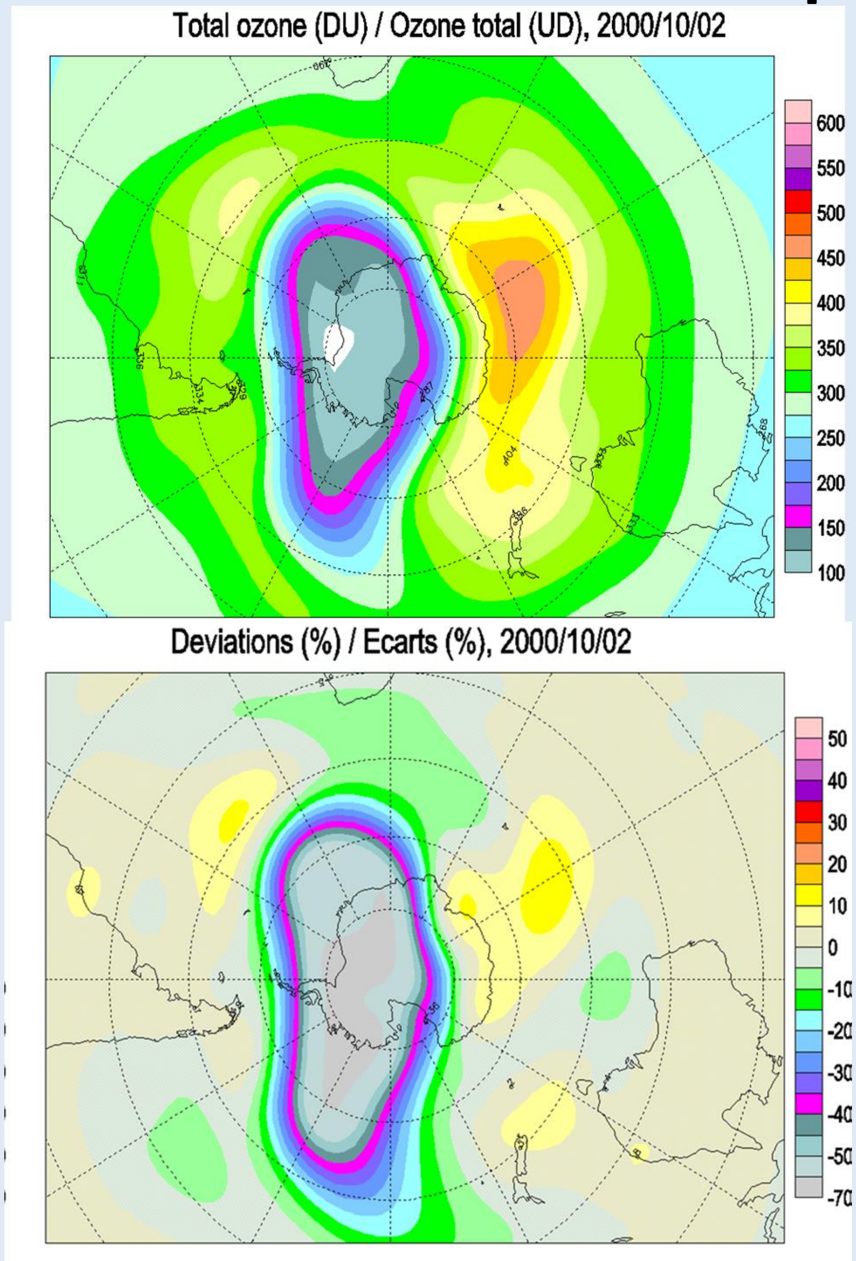




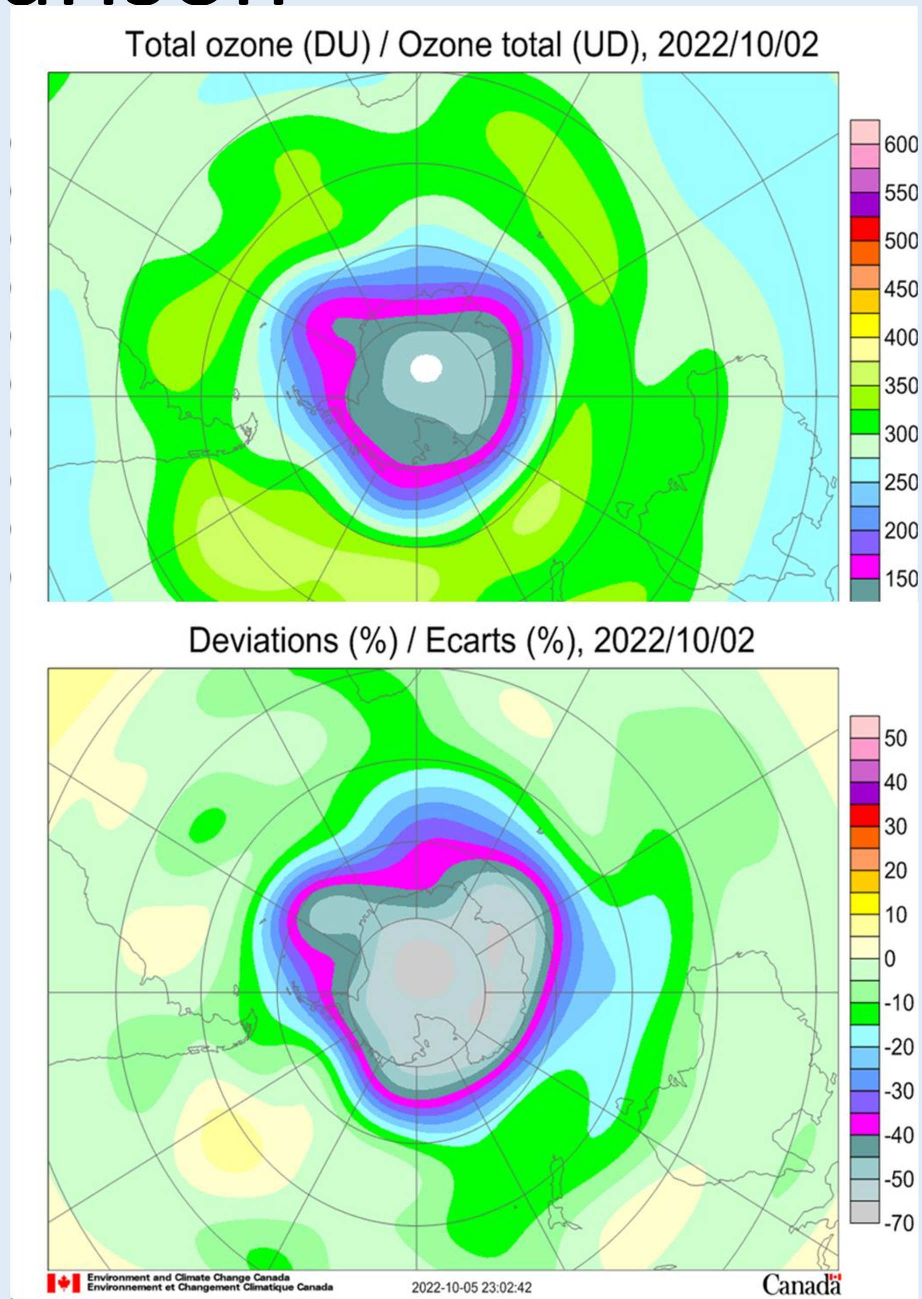


Comparison

2000 10 02

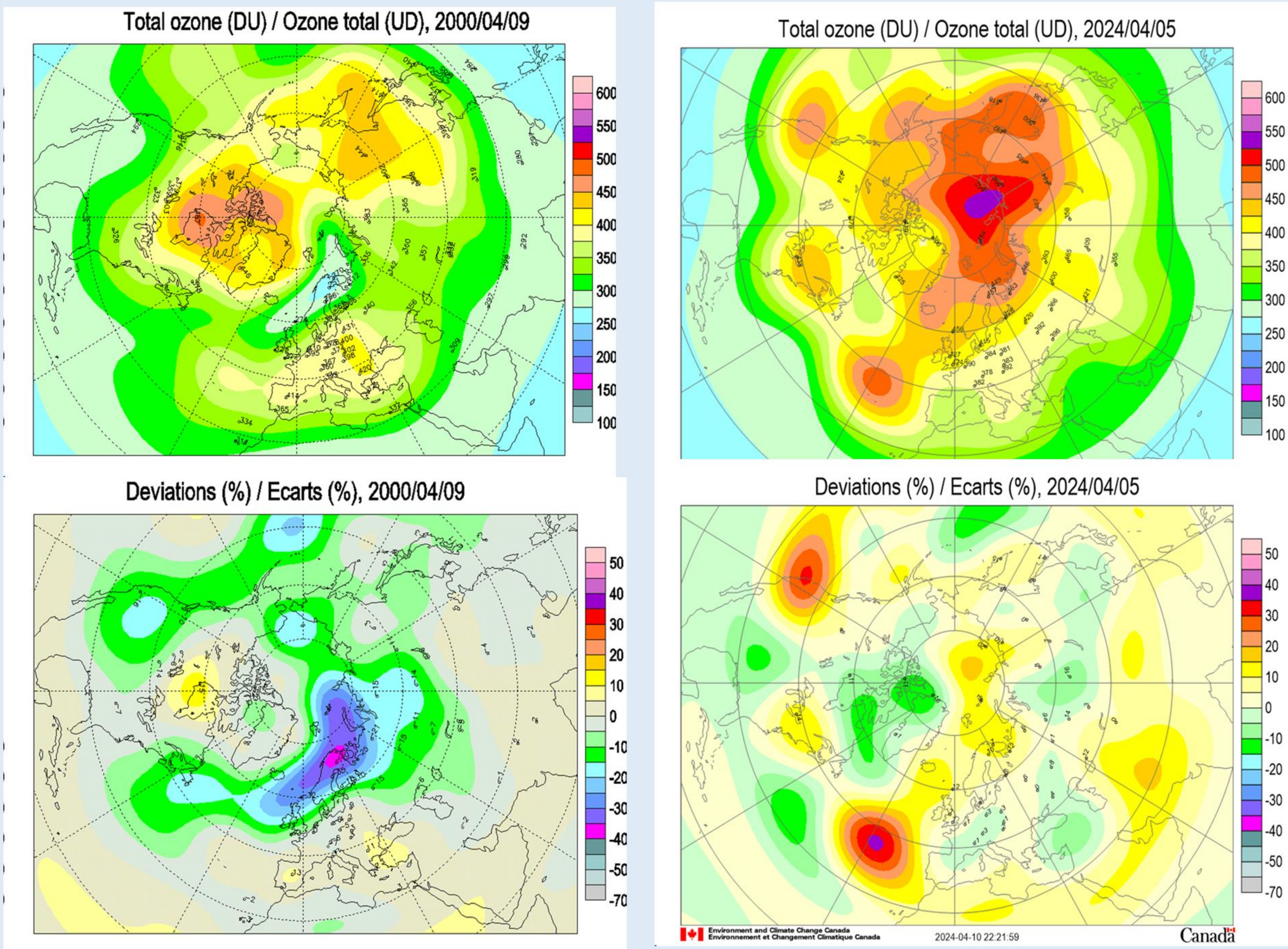


2022 10 02



2000 04 09

Arctic Ozone



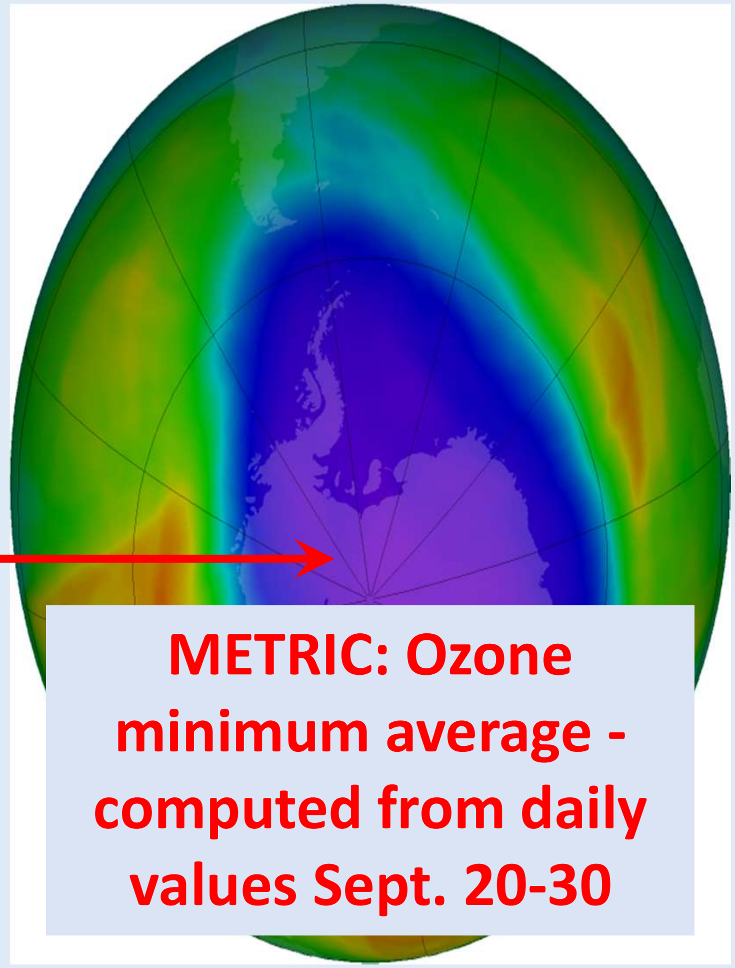
Is Antarctic ozone improving?

30 September 2023

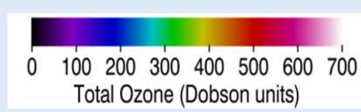
Area = 22.2 Million km^2

Lowest ozone = 115 DU

Polar cap average = 203 DU

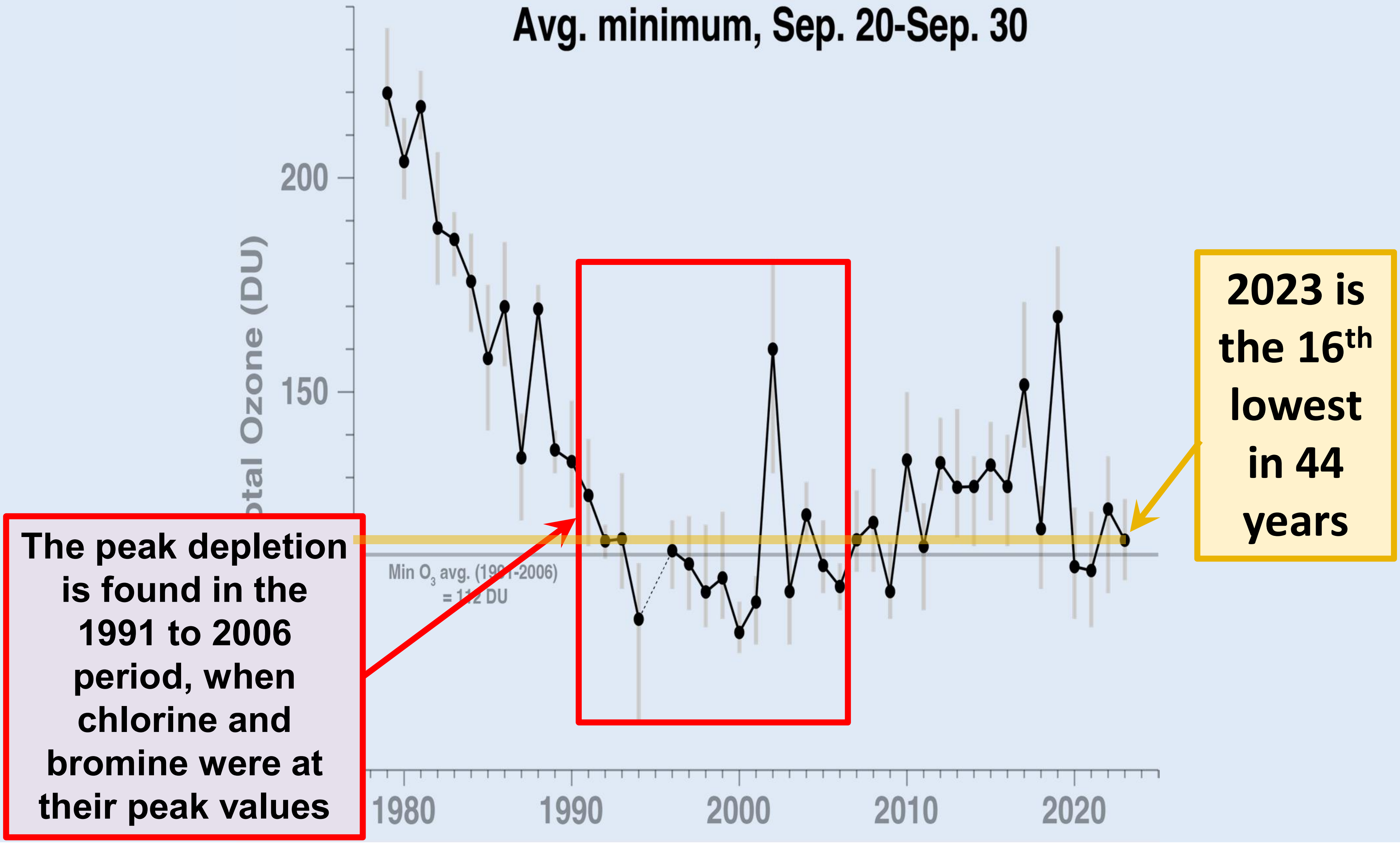


METRIC: Ozone minimum average - computed from daily values Sept. 20-30

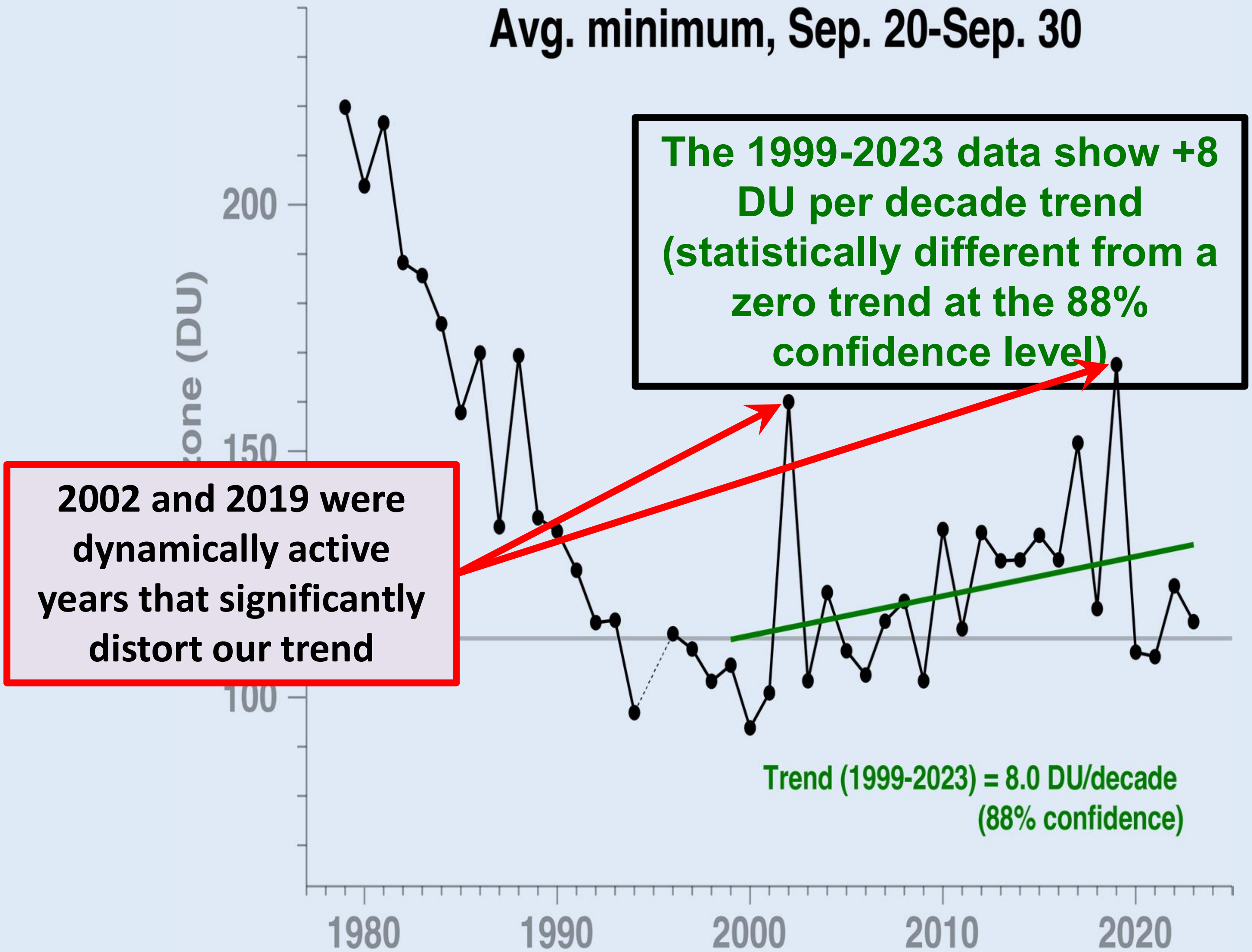


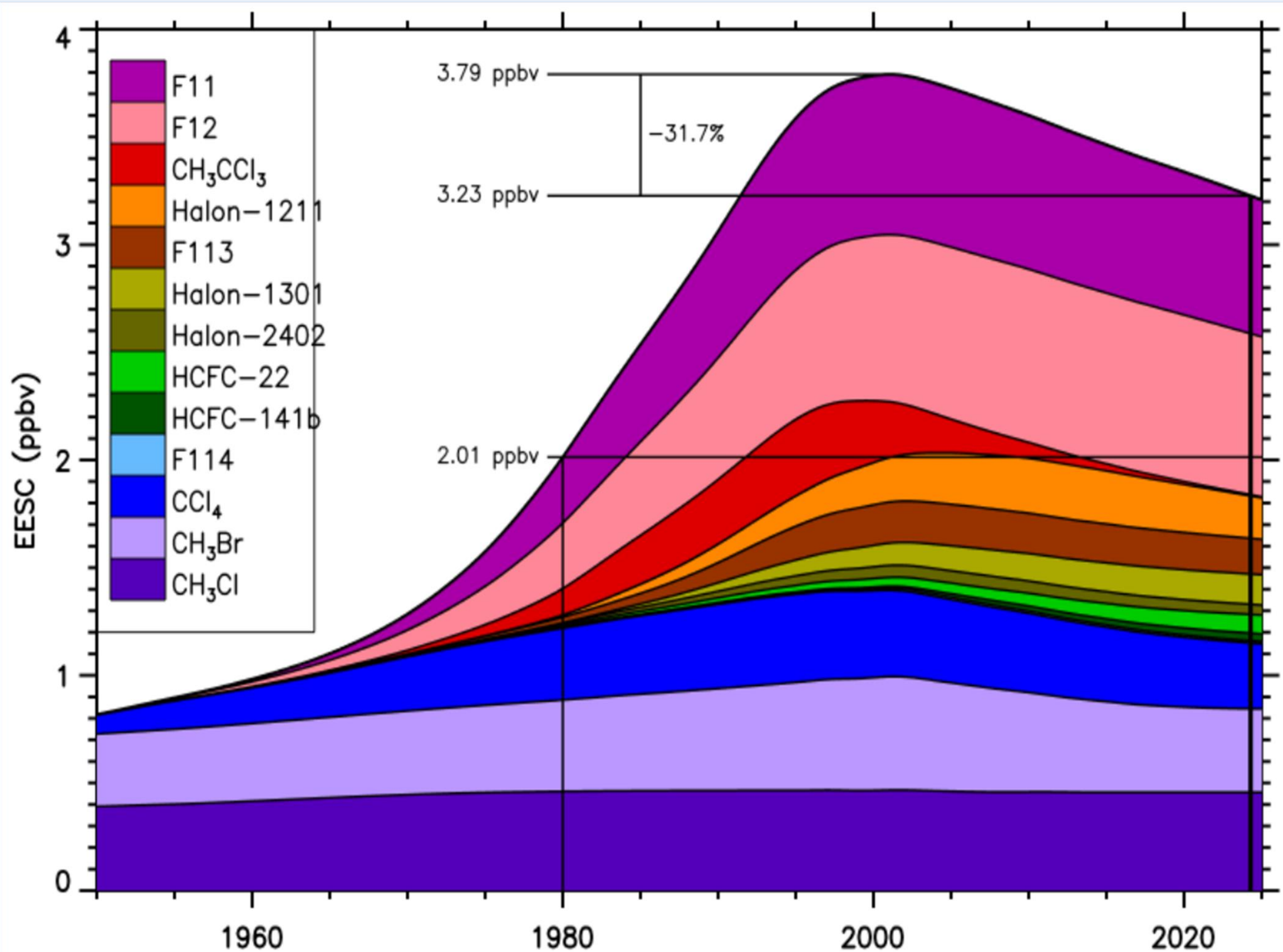
OMPS-NM instrument onboard Suomi NPP

Ozone hole minimum at the end of the austral spring depletion period



Ozone hole minimum at the end of the austral spring depletion period



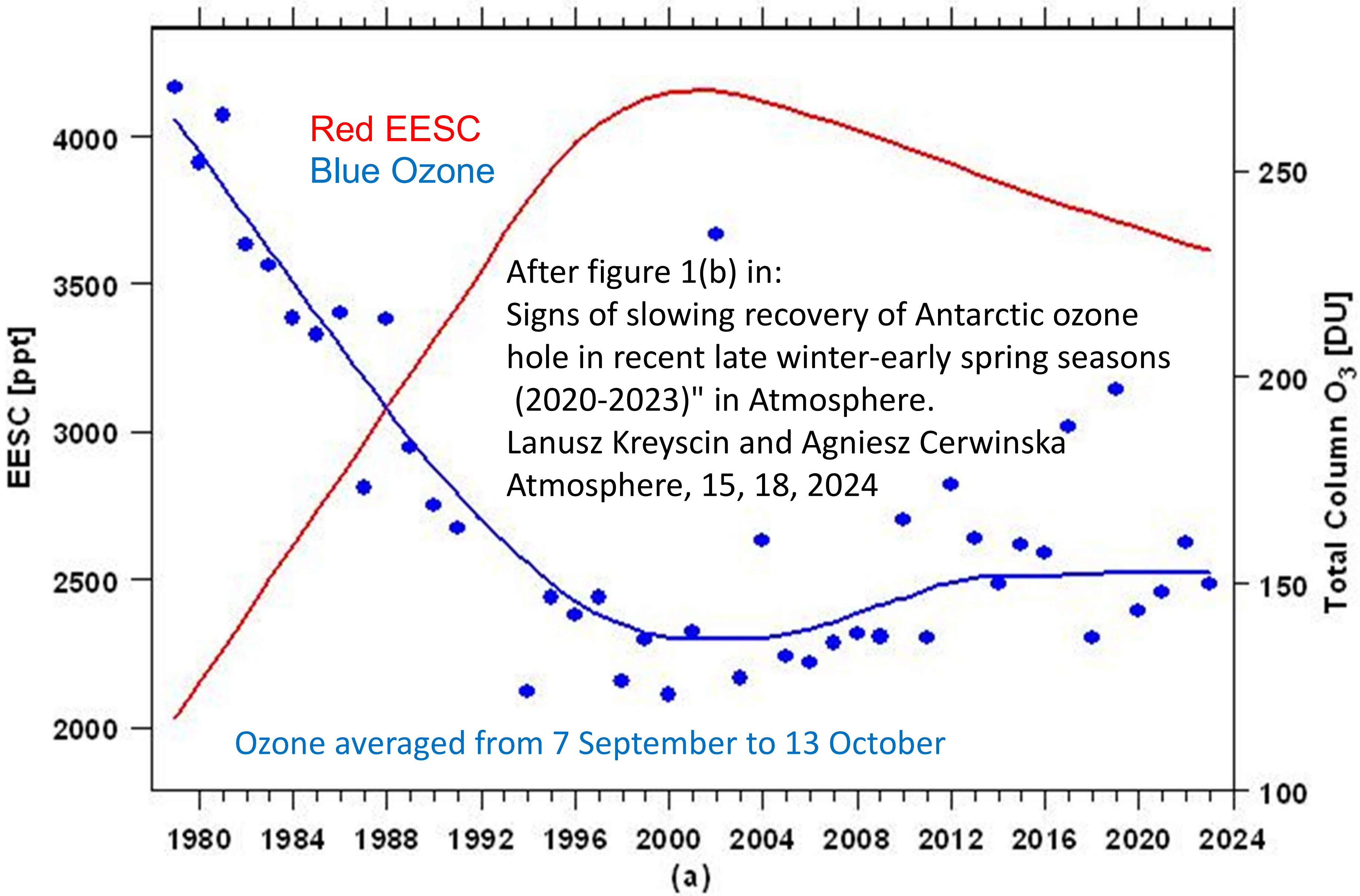


EESC == Equivalent effective stratospheric chlorine

Paul Newman GSFC

Ozone Recovery

- The graph to follow shows ozone change between 1980 and now in the ‘ozone hole period’ at Halley Bay
- It also plots the chlorine equivalent impact of chemistry from most gases affecting the ozone layer as shown in the previous slide
- If other factors are unchanged, the EESC should be controlling the ‘fast’ chemistry and the recovery should respond to EESC as it did in the depletion period
- In fact the ozone is only recovering half as fast as the correlation with EESC would suggest
- Other factors? Temperature, dynamics? Probably the latter



Red EESC
Blue Ozone
After figure 1(b) in:
Signs of slowing recovery of Antarctic ozone hole in recent late winter-early spring seasons (2020-2023)" in Atmosphere.
Lanusz Kreyscin and Agniesz Cerwinska
Atmosphere, 15, 18, 2024
Ozone averaged from 7 September to 13 October
EESC [ppt]
Total Column O_3 [DU]
4000
3500
3000
2500
2000
250
200
150
100
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
2020
2024
(a)

‘Incidents’ - Volcanoes

- Volcanoes inject water and sulphur dioxide high into the atmosphere
- Sometimes high enough to affect ozone concentrations
- But the major impact is on climate with the change in the radiation balance by reflecting solar energy back into space
- This is the basis for advancing some concepts of geoengineering
- However adding sulphate particles to the atmosphere may damage the ozone layer at high altitudes
- The Hunga Tonga-Hunga Ha'apai (HTHH) had an impact on the Antarctic ozone hole (mostly from water injection)

Interpretation

- Assuming other aspects of the chemistry are constant (Like the photolysis of nitric acid for example)
- The correlation between EESC in the declining phase might be expected to hold in the recovery
- In the recovery phase the increase in ozone is about 20% behind the calculated rate based on the correlation between ozone and EESC in the period when ozone was declining
- This seems to be consistent with the longer-term slower than expected recovery after the ozone hole period in the last four years (P. Newman)
- This may well be mostly from dynamical changes, possibly driven by climate change

Main Messages 2023

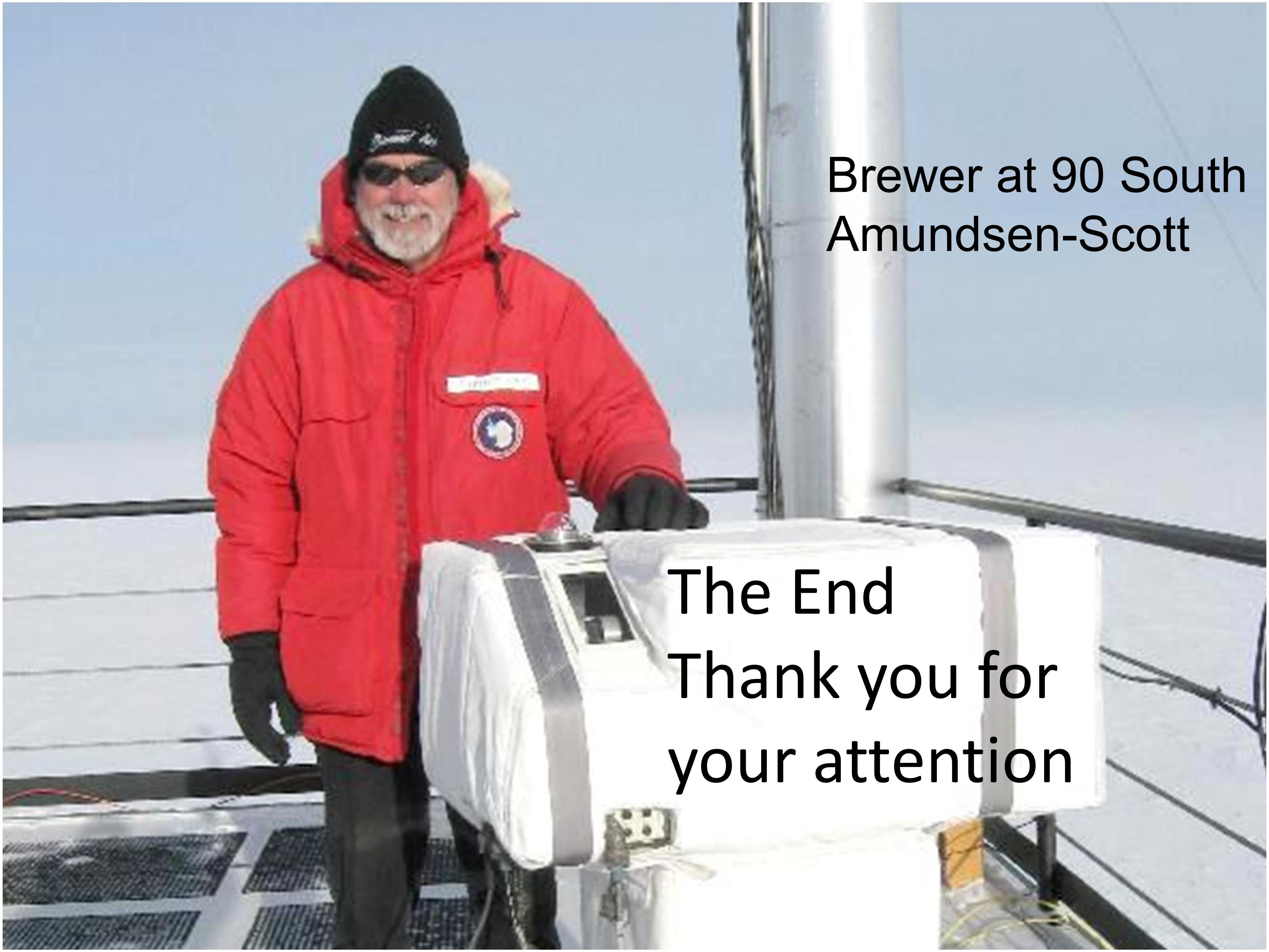
- 2023 ozone hole was large and deep
- 2023 ozone hole was driven by chlorine and bromine
- September ozone hole metrics show an improving Antarctic ozone hole
- Ozone depletion is modulated by dynamical forcing
- HTHH injected substantial water into the stratosphere. This excess water was inside the 2023 Antarctic polar vortex at the winter start but had “frozen” out by mid-winter.
- Models showed additional water added 10-20 DU ozone depletion.
- HTHH may have caused a small additional ozone depletion but is not distinguishable against natural variability (σ=30 DU)

Going Forward

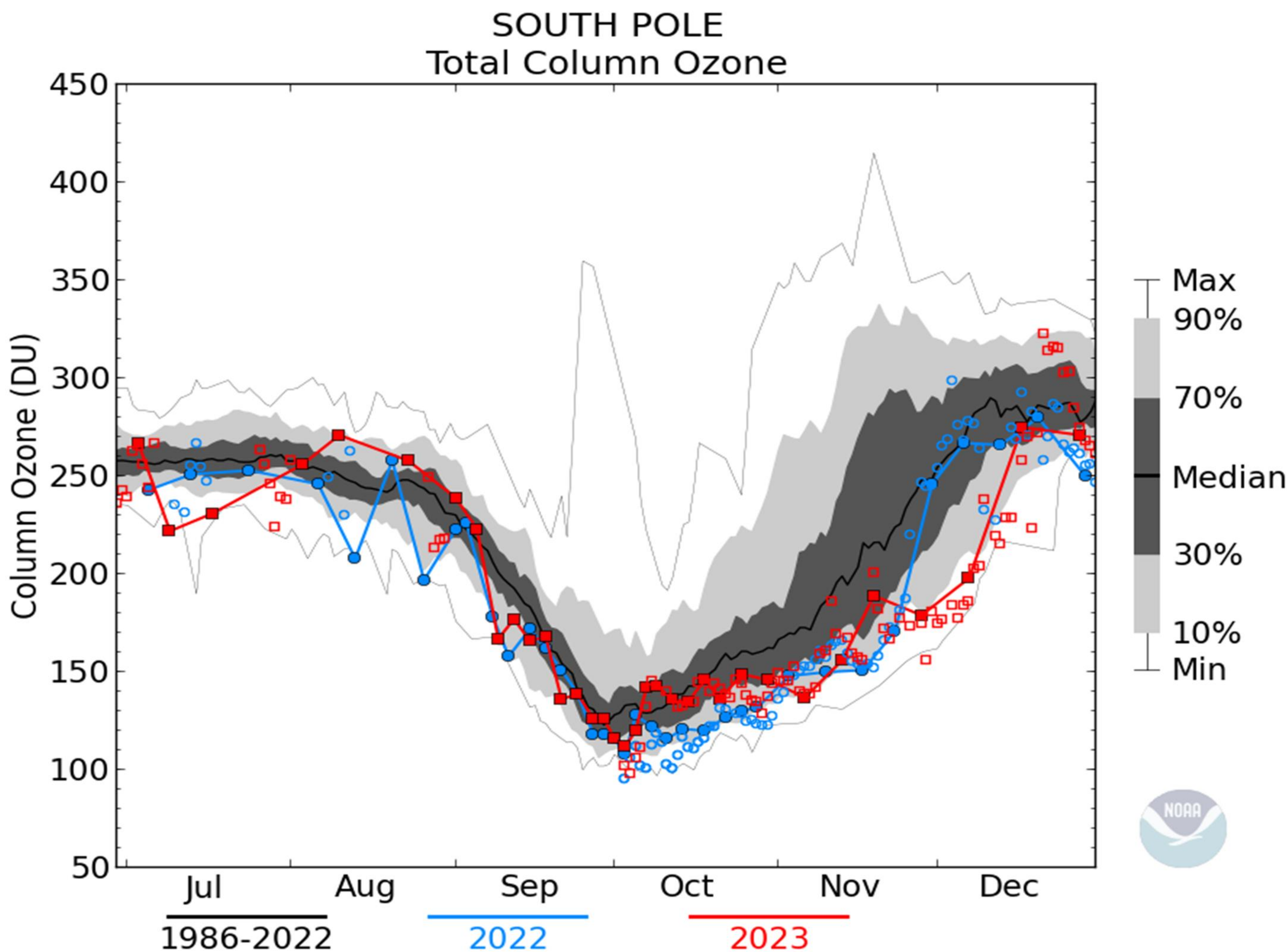
- The science of ozone depletion and climate change must be clearly and simply communicated
- Politicians are not equipped to make scientific judgements
- The most probable outcomes should be communicated, not a collection of choices
- Politics demands that elected representatives be sensitive to many influences, perhaps not weighted by the level of intrinsic importance

Summary & Conclusions

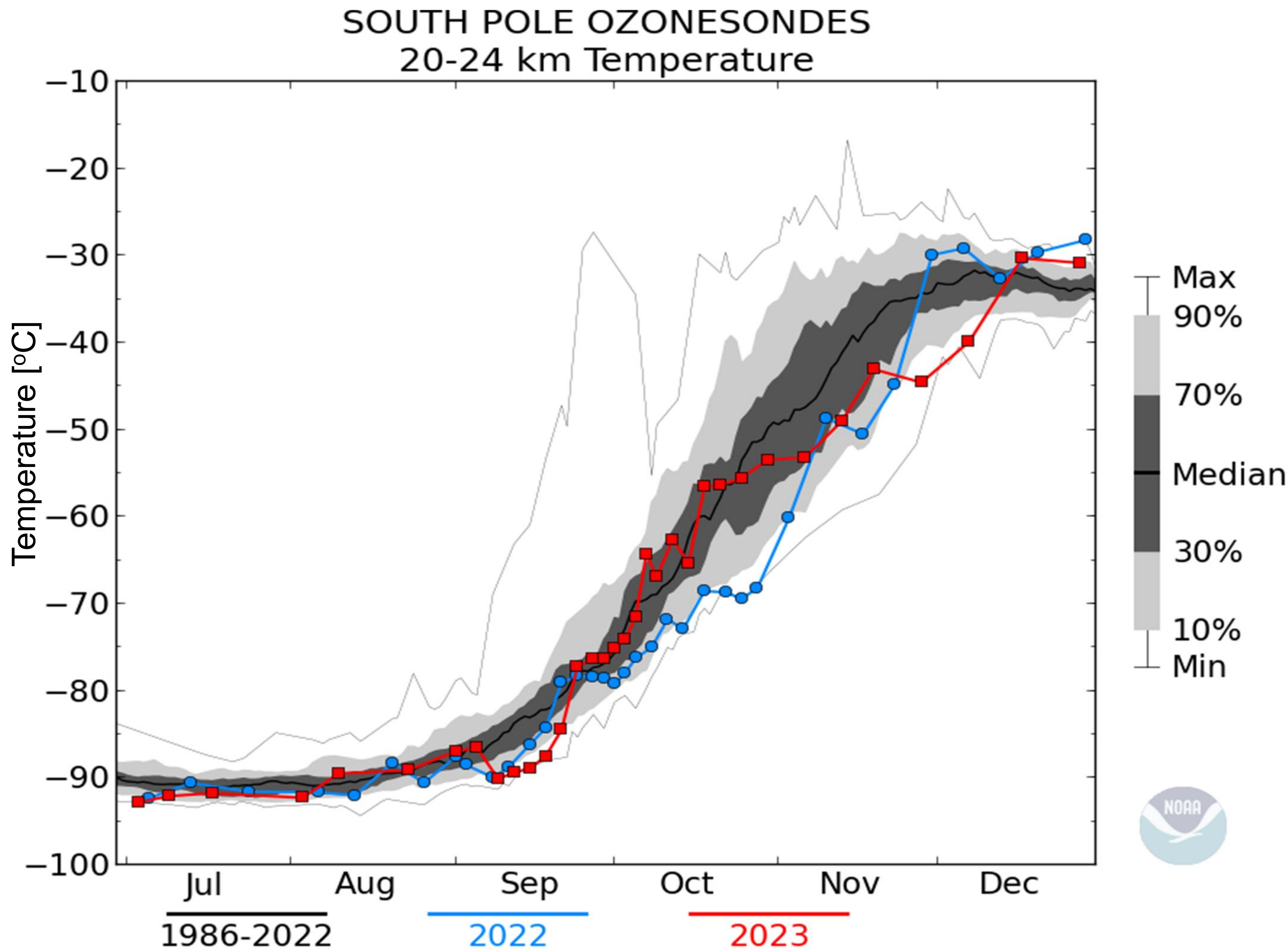
- The ozone layer is recovering, slower than expected
- Climate affects ozone and ozone affects climate
- GHGs increase tropospheric temperature but decrease stratospheric temperatures
- Changes in circulation may increase tropospheric O_3
- Lower Polar temperatures may reduce stratospheric O_3
- The last four years have shown slower recovery from depletions, a phenomenon not yet well understood
- It is imperative to continue to monitor ozone and aerosol, including in the Polar regions
- Monitoring to achieve a better understanding of ozone and aerosol effects may reduce uncertainty in climate models


Brewer at 90 South
Amundsen-Scott
The End
Thank you for
your attention

Extra slides



SOUTH POLE
Total Column Ozone
Column Ozone (DU)
450
400
350
300
250
200
150
100
50
Jul
Aug
Sep
Oct
Nov
Dec
Max
90%
70%
Median
30%
10%
Min
1986-2022
2022
2023



SOUTH POLE OZONESONDES
20-24 km Temperature
Temperature [°C]
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
Jul
Aug
Sep
Oct
Nov
Dec
Max
90%
70%
Median
30%
10%
Min
1986-2022
2022
2023
NOAA