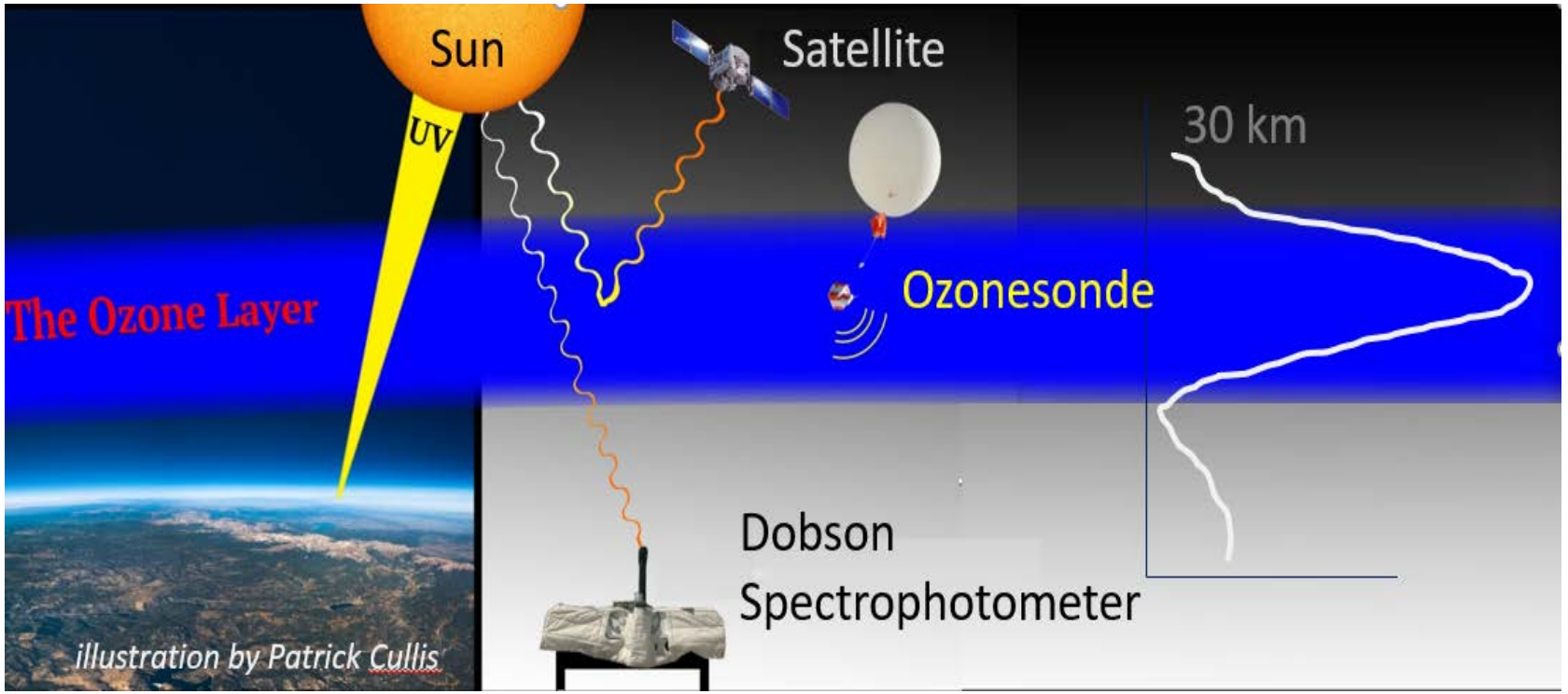
# South Pole Ozonesondes: 34-years
# Ozone Hole Metrics Trending Higher After 2001.

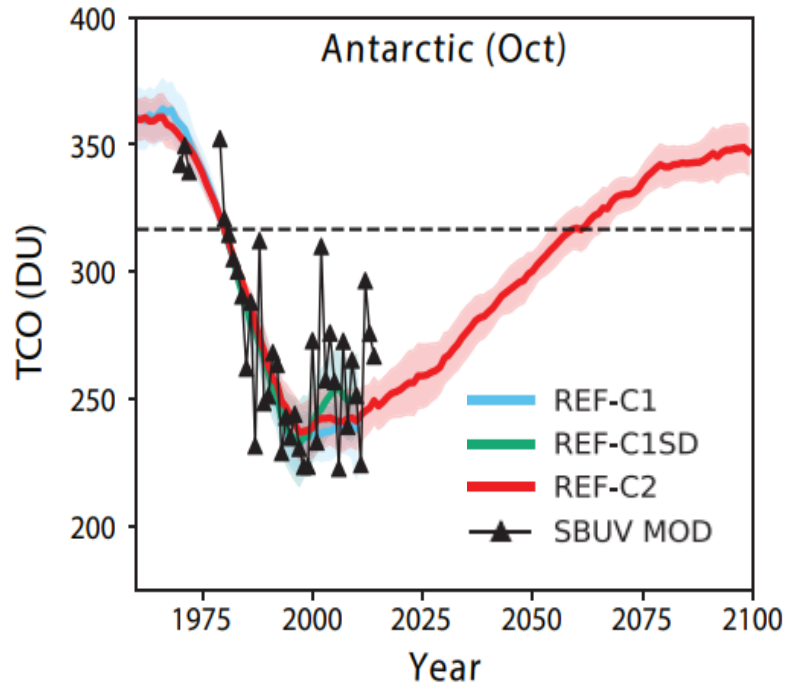
Bryan Johnson[1], P. Cullis[2], J. Booth[1] G. McConville[2], A. Jordan[2], A. McClure[2], I. Petropavlovskikh[2]
[1] *NOAA Earth System Research Laboratory, Global Monitoring Division, Boulder, Colorado, USA*
[2] *CIRES, University of Colorado, Boulder, USA*

# South Pole Ozonesondes: 34-years Ozone Hole Metrics Trending Higher After 2001.

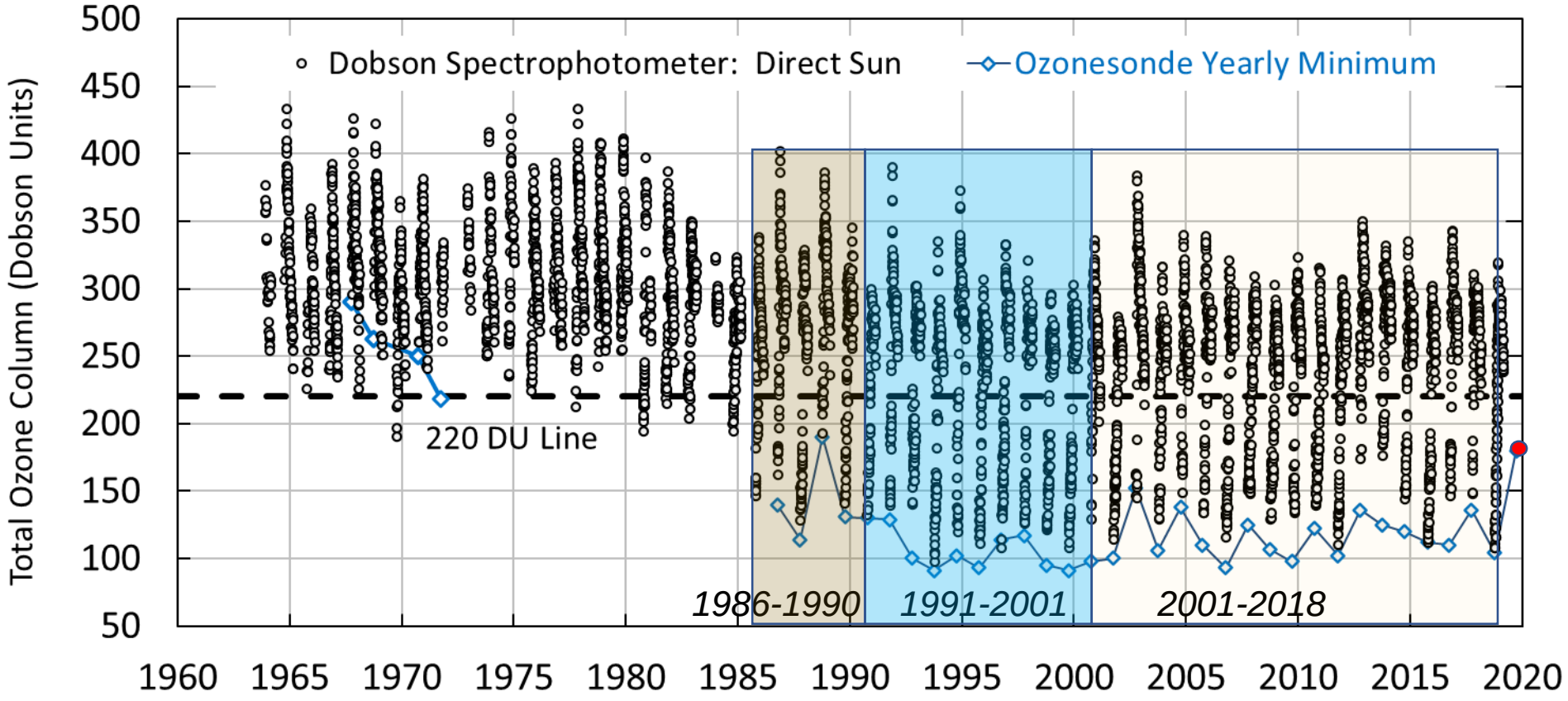
**WMO 2018 Ozone Assessment:**

- Statistically significant trends (*September & October*) since the year **2000** identified showing increase in observed ozone and a decrease in ozone hole size and depth.
- natural variability is challenging, yet evidence from statistical analyses and modeling studies suggests that the decline in ODSs made a substantial contribution to these trends.



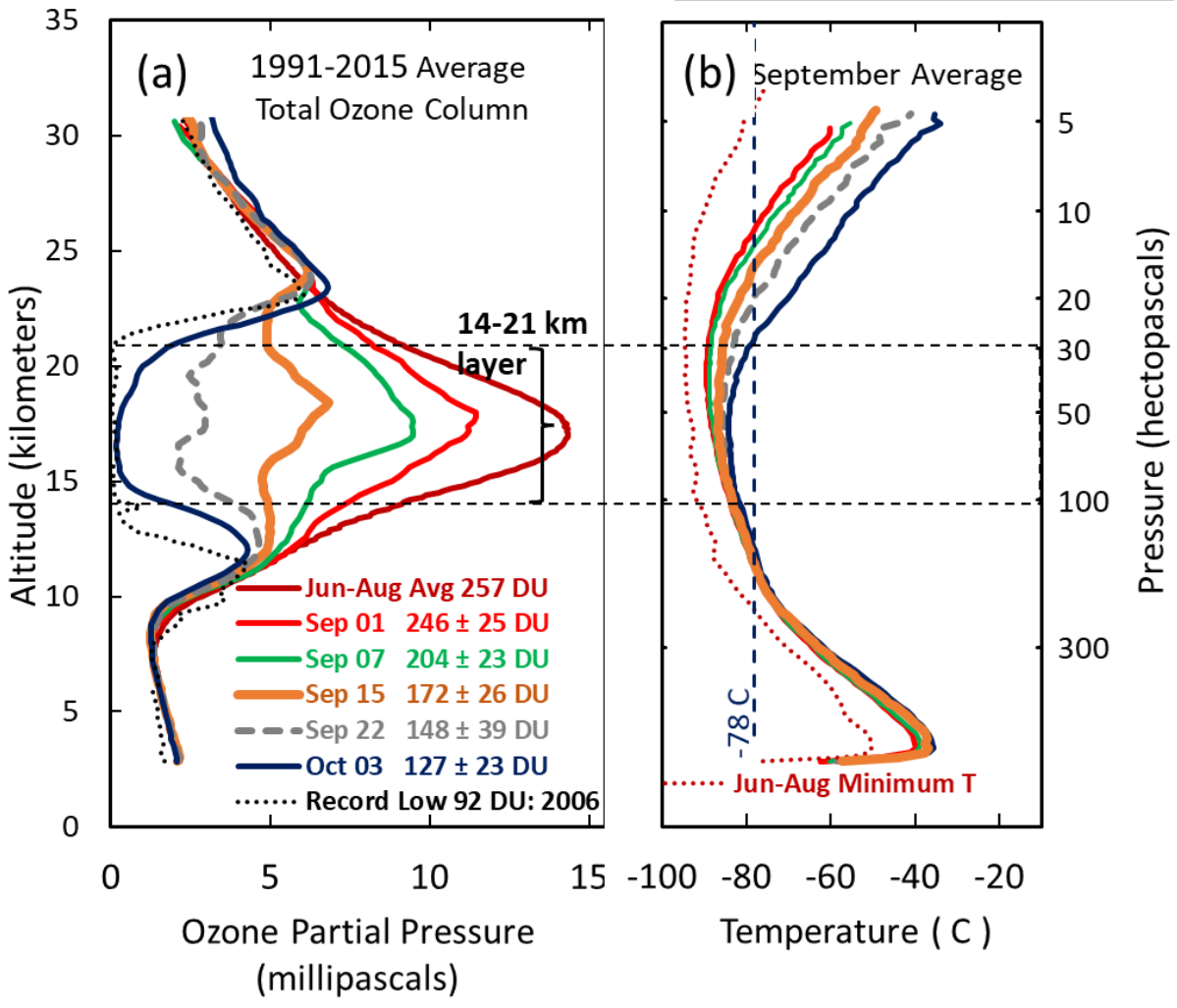



# South Pole 1963 - 2020
# Dobson Spectrophotometer Total Column $O_3$



# South Pole Ozonesondes Ozone Hole Metrics

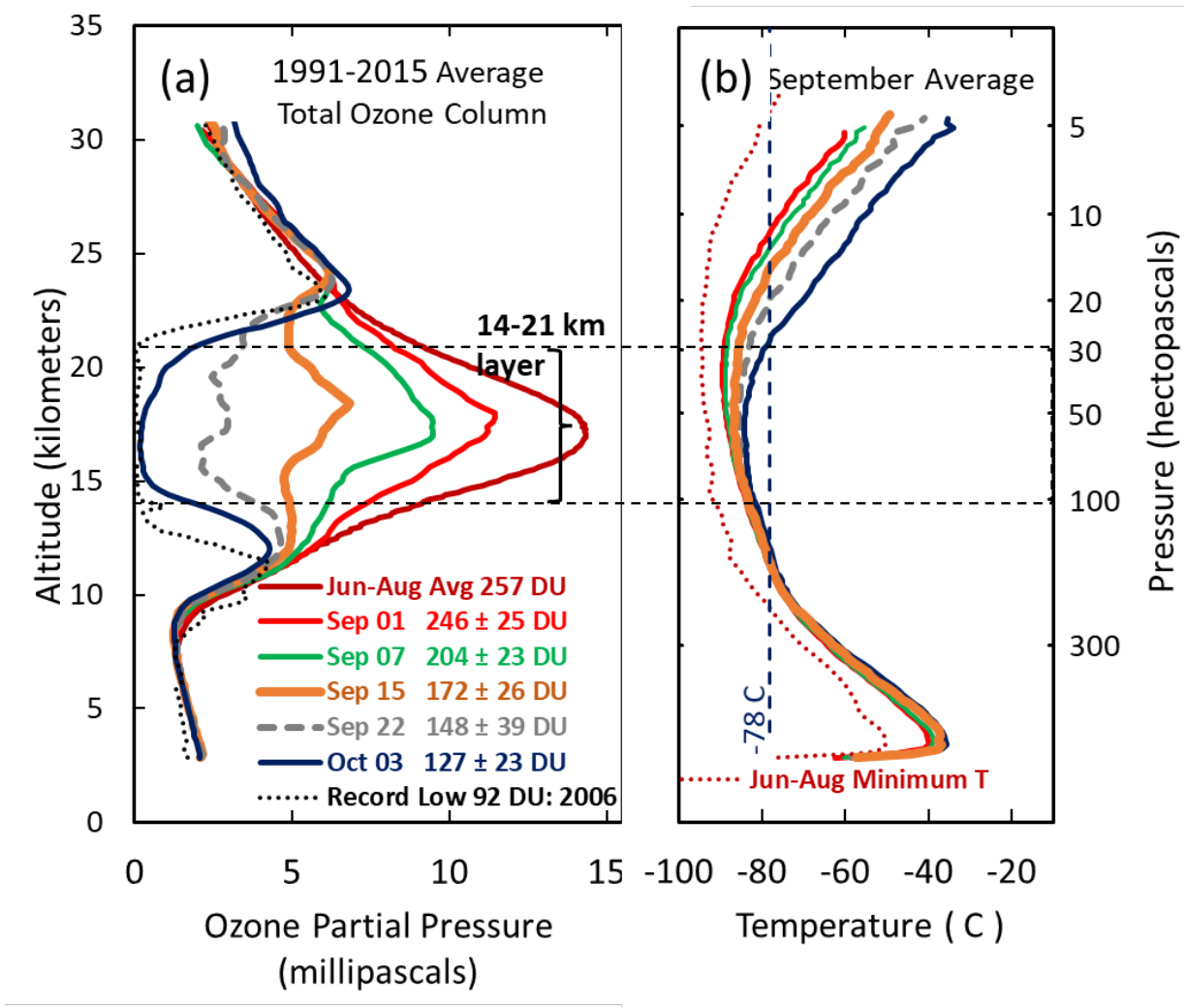
## During September rapid ozone loss

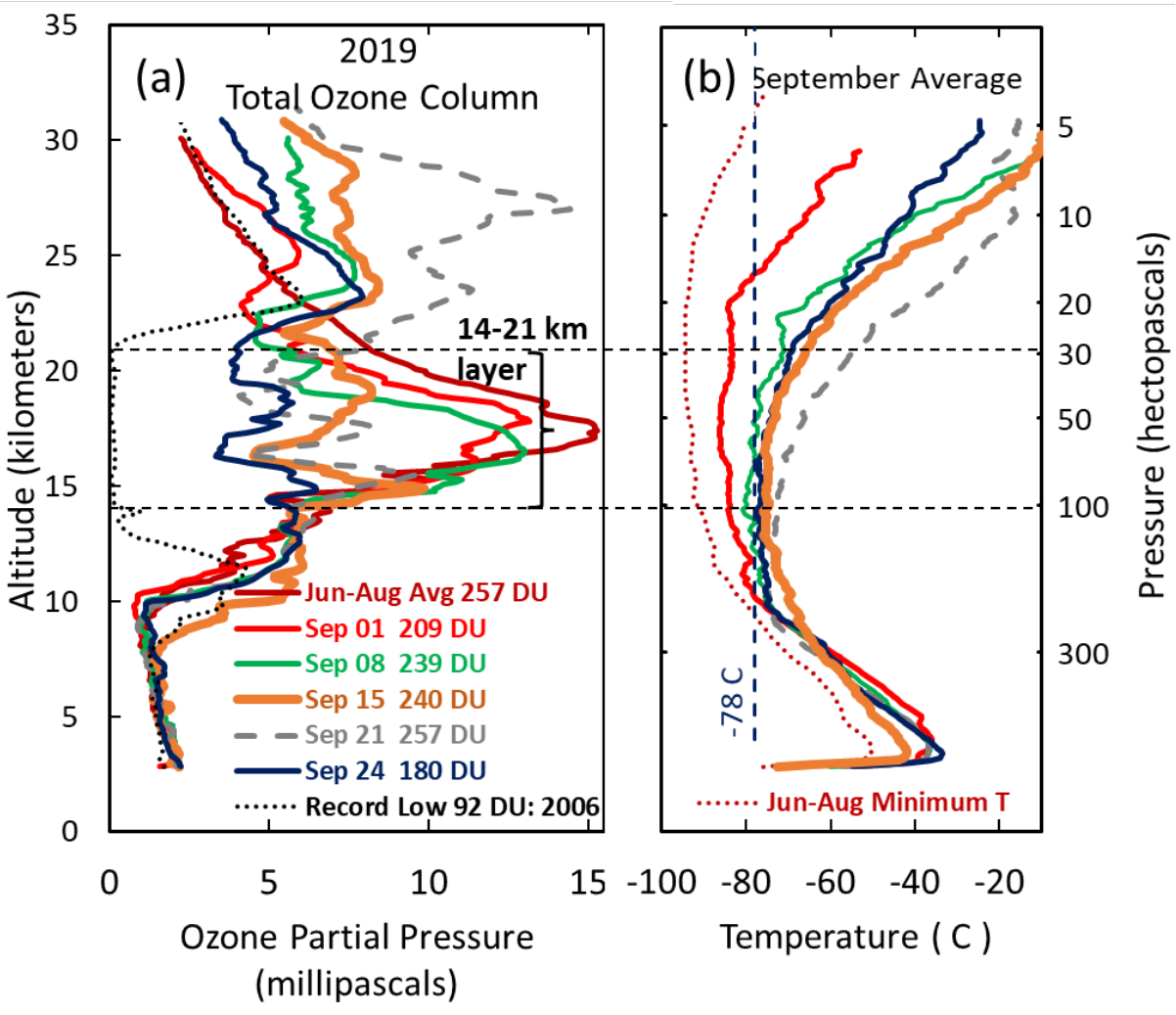


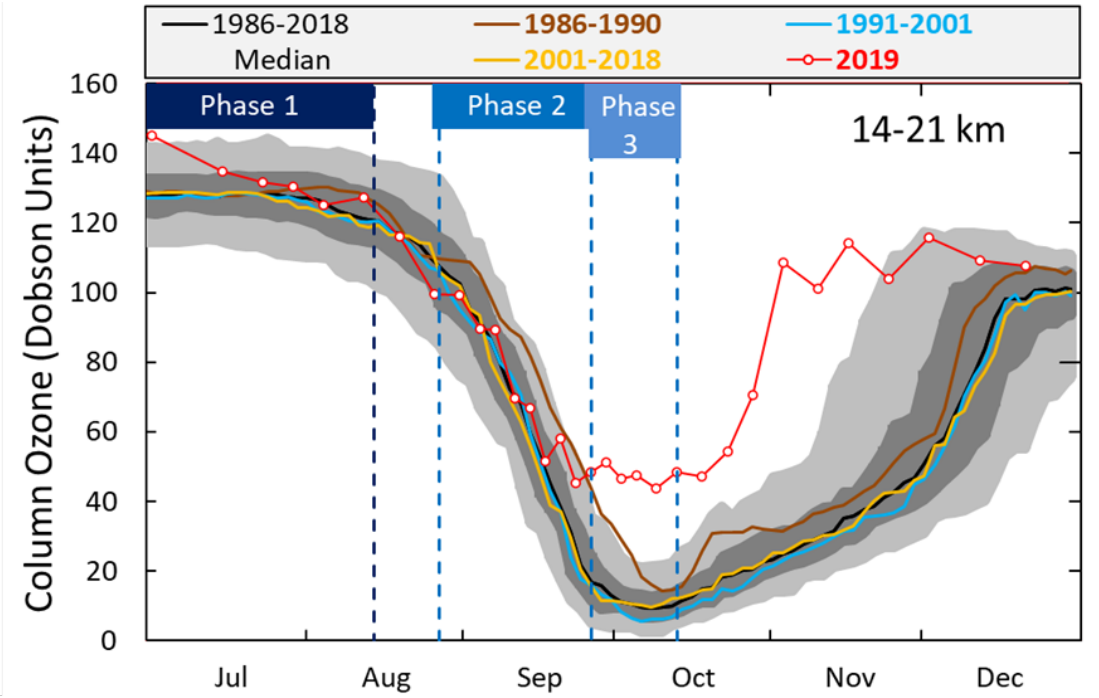

1. **Total Ozone Column: Dobson Units (DU)**
2. **14-21 km Ozone Column**
   a. Minimum (DU) Sept 24 – Oct 14
   b. September 15th (DU)
   c. September Ozone Loss Rate (DU/day)
3. **Saturation loss (zero ozone layer depth)**

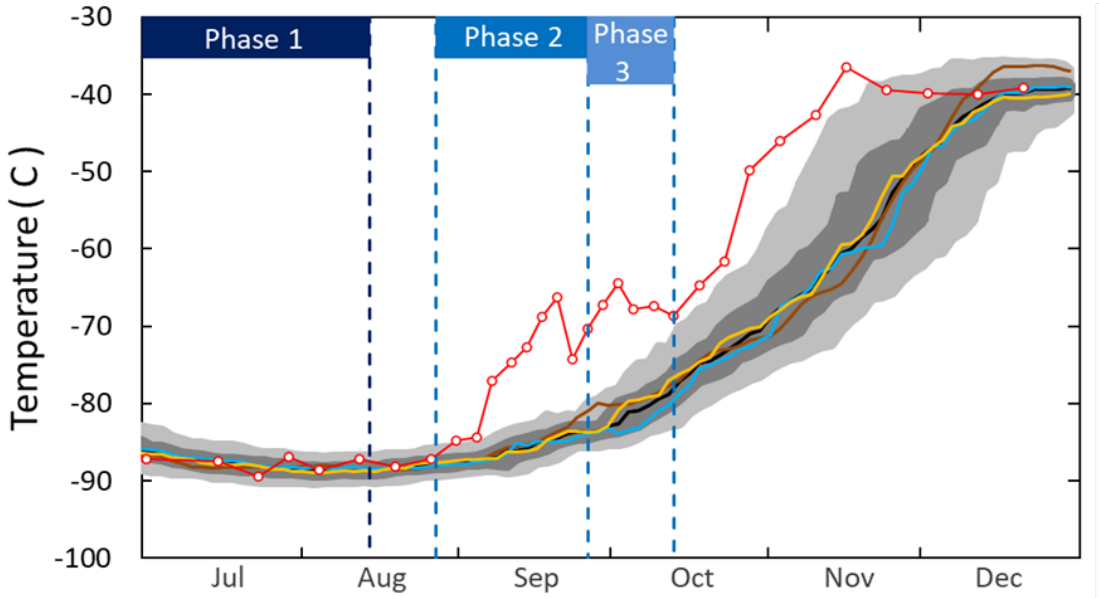
*temperature*

# South Pole Ozonesondes: 2019






# 14-21 km Column Ozone

**3 phases of the yearly ozone hole**

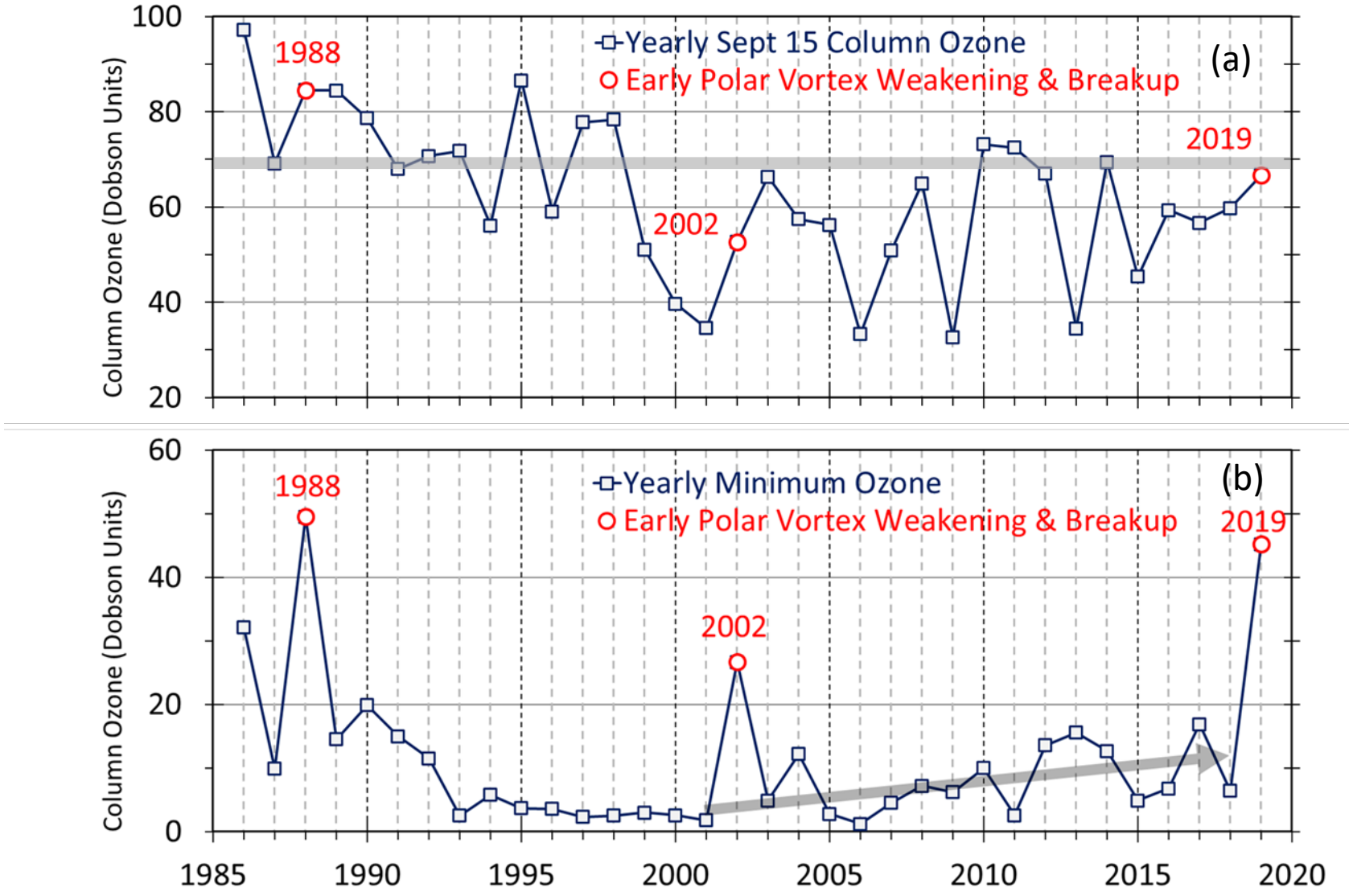
1. pre-ozone hole (June 15 – Aug 15)
2. Rapid linear ozone loss (September)
3. Ozone hole minimum:

**3 multi-year time periods (median values)**

1. **1986-1990**
2. **1991-2001**
3. **2001-2018 (recovery begins)**
4. 2019 September vortex shift and weakening.

September Column Ozone at
(a) Midway & (b) Minimum

# 14-21 km Column Ozone

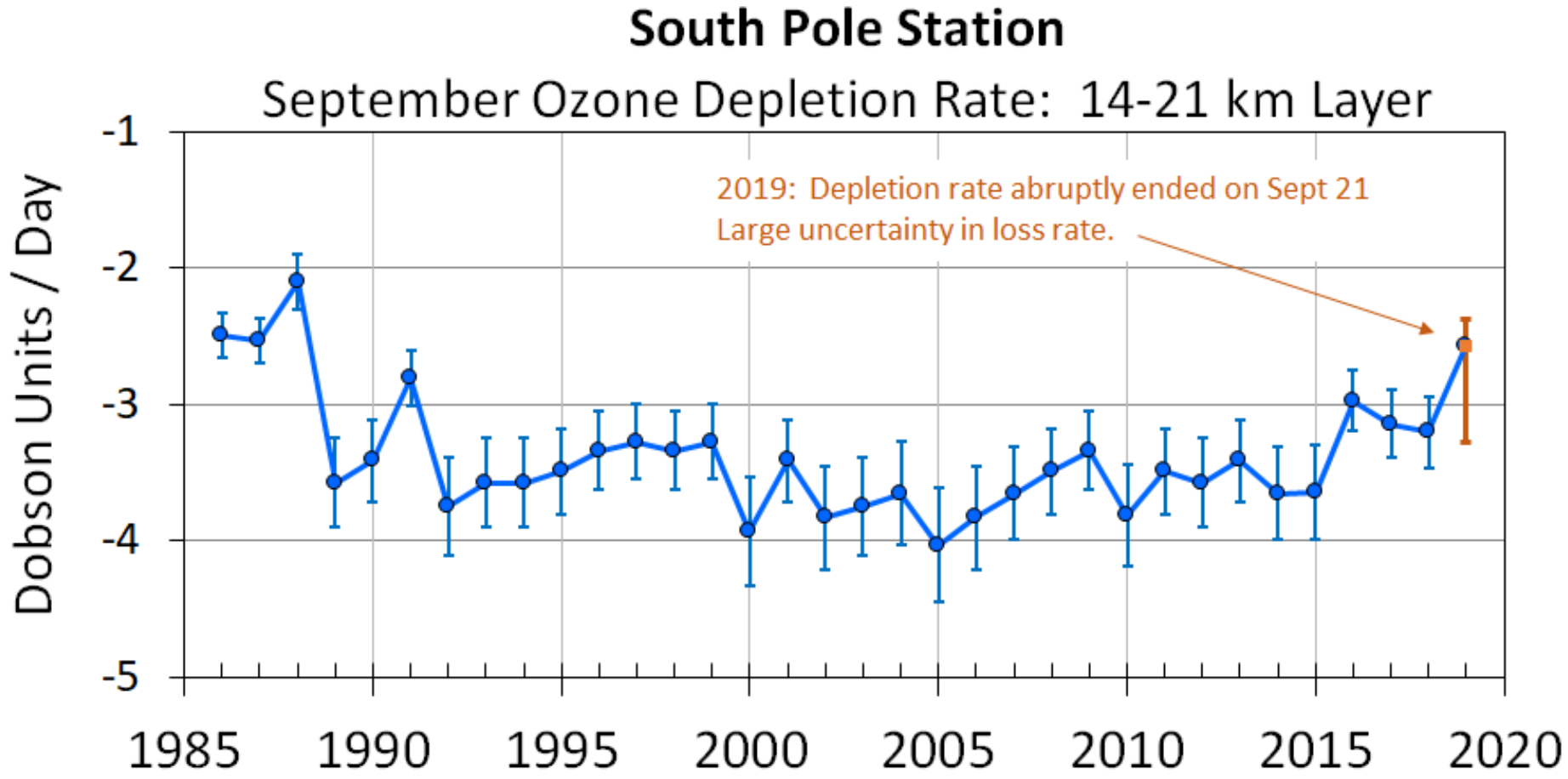



SEPT 15

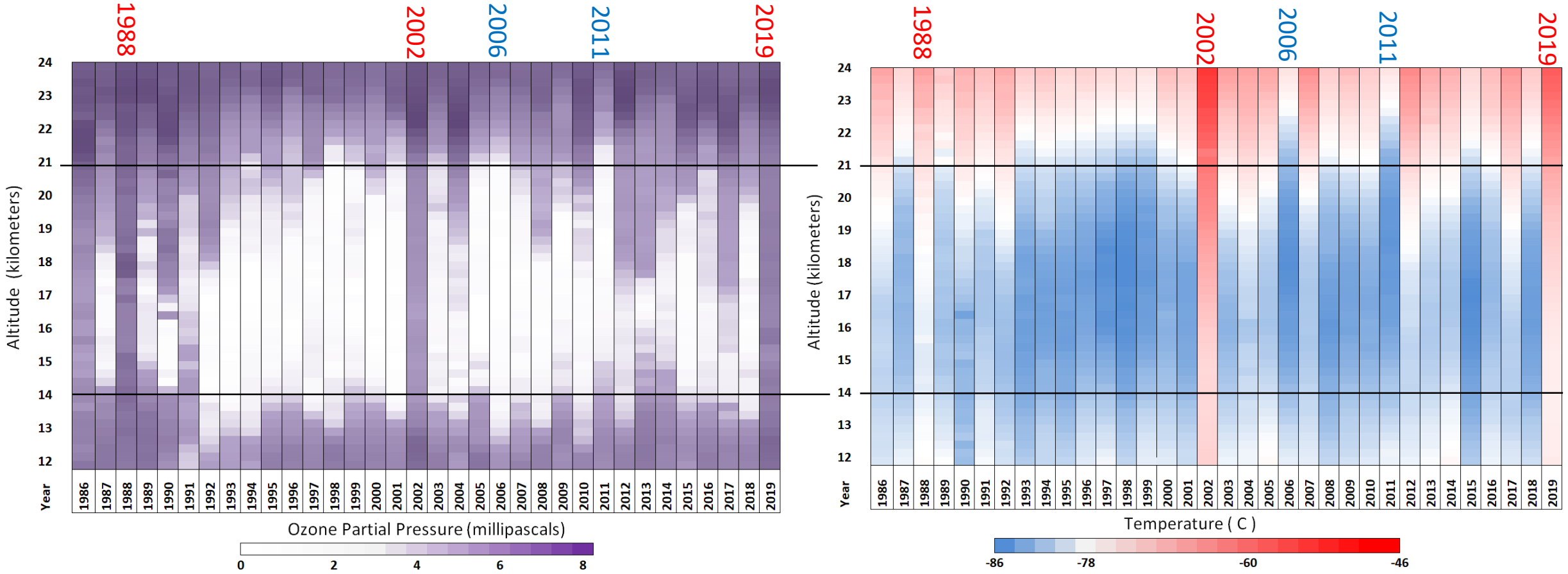
Minimum

September Loss Rates
Dobson Units / Day

# 14-21 km Column Ozone



# Saturation Loss (zero ozone) yearly minimums from September 24 – October 14




PSC temperatures < -78 C

Vertical extent of zero ozone region appears to be less since 2001 but warmer temperatures correlating with less ozone loss may be responsible.

# South Pole Ozonesondes
# Ozone Hole Summary

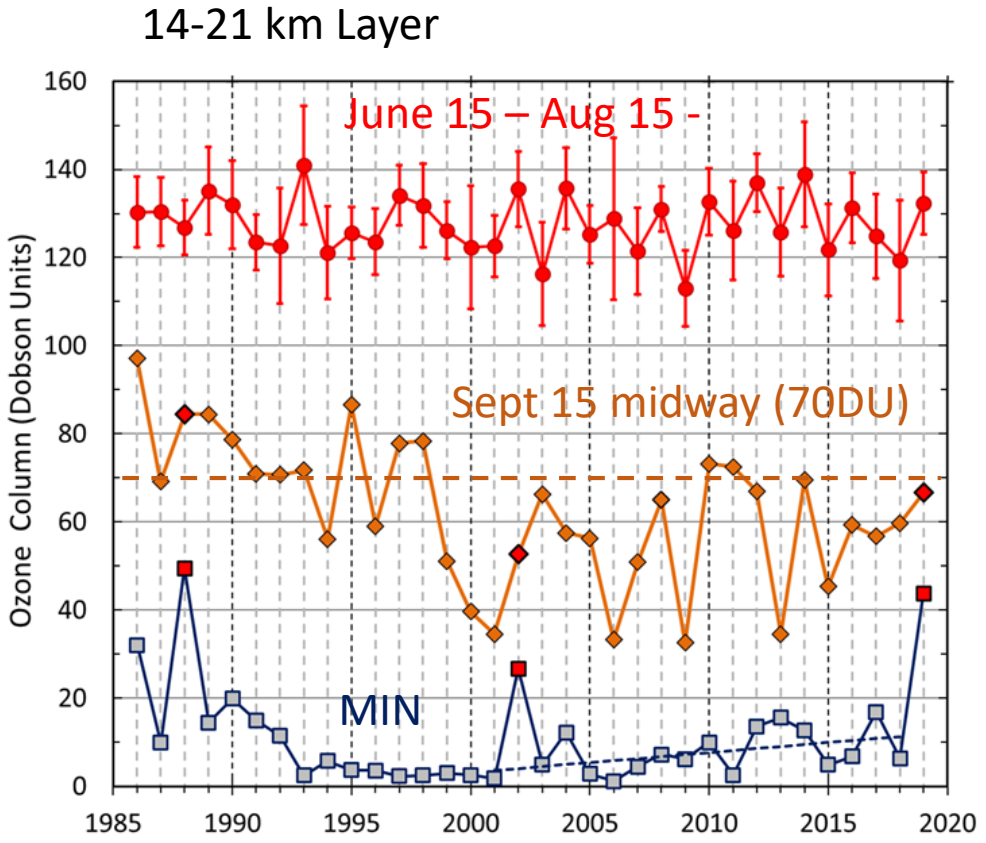
Ozonesondes confirm upward trend (improvement) since 2001

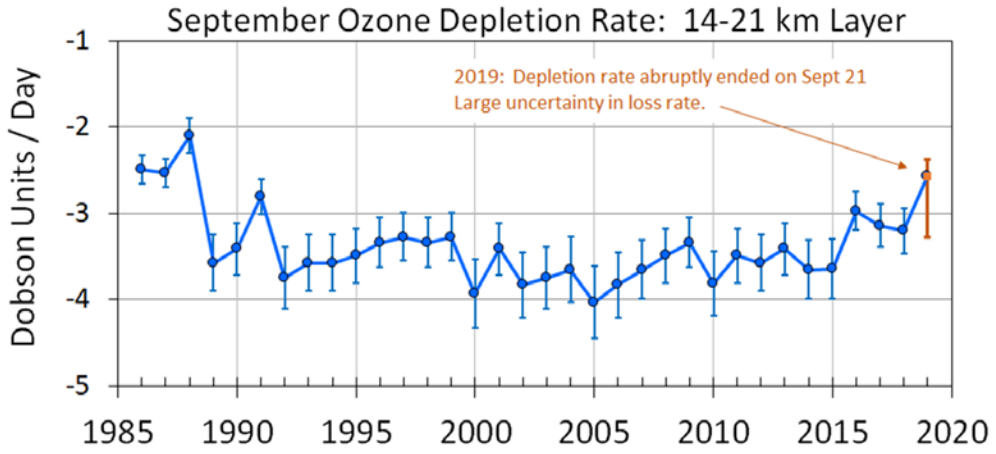
- Sept 15 column (70 DU level).
- Year 14-21 km minimum.
- Sept linear loss rate is close to the -3 DU/Day level.
- Vertical extent of saturation is declining but temperature is a factor.

- 2019 - Abnormally warm temperatures in the stratosphere over Antarctica dramatically limited ozone depletion in September and October, resulting in the smallest ozone hole observed since 1982, NASA and NOAA press release.

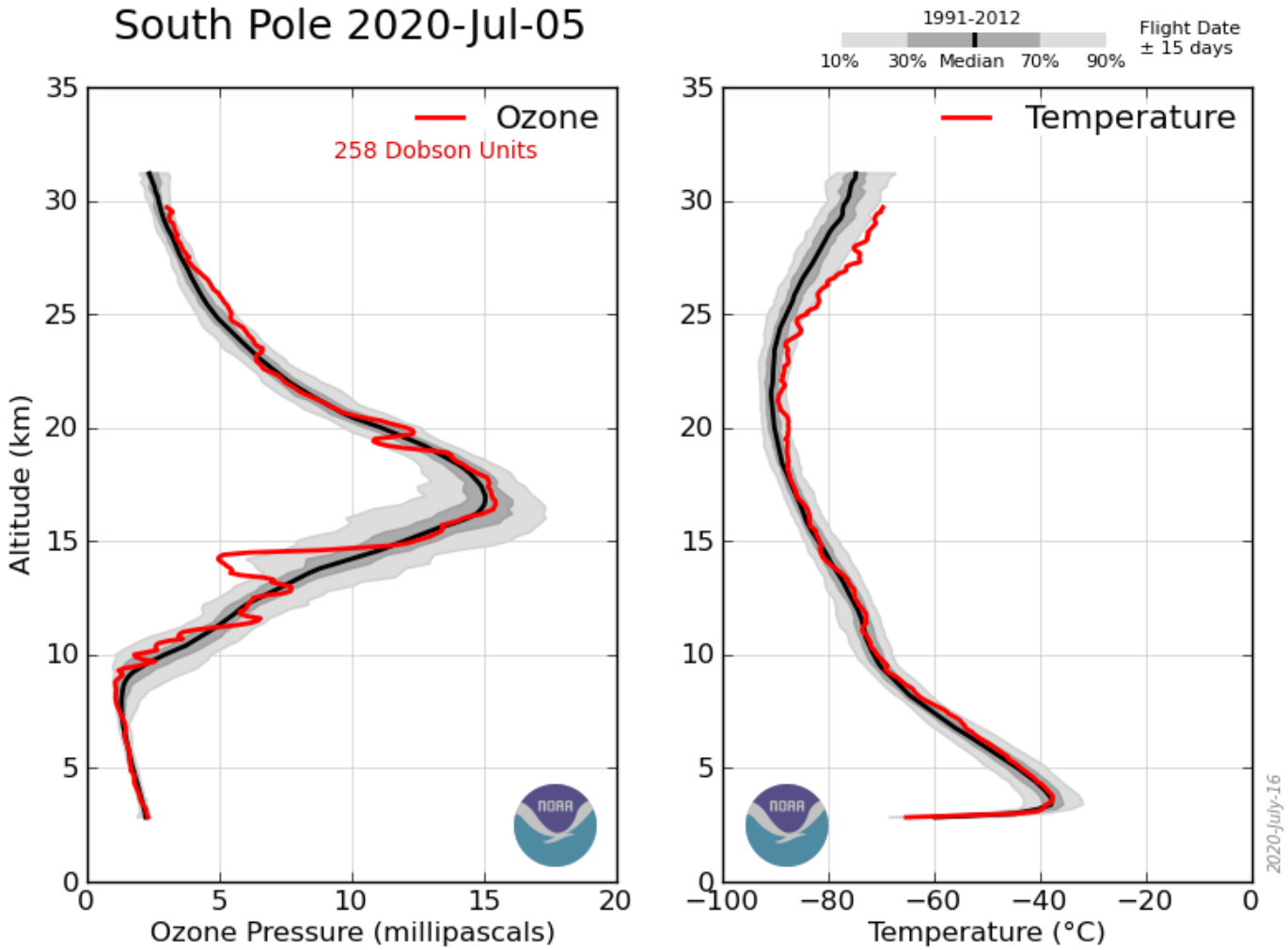
TOTAL COLUMN OZONE RECORDS from Ozonesondes:

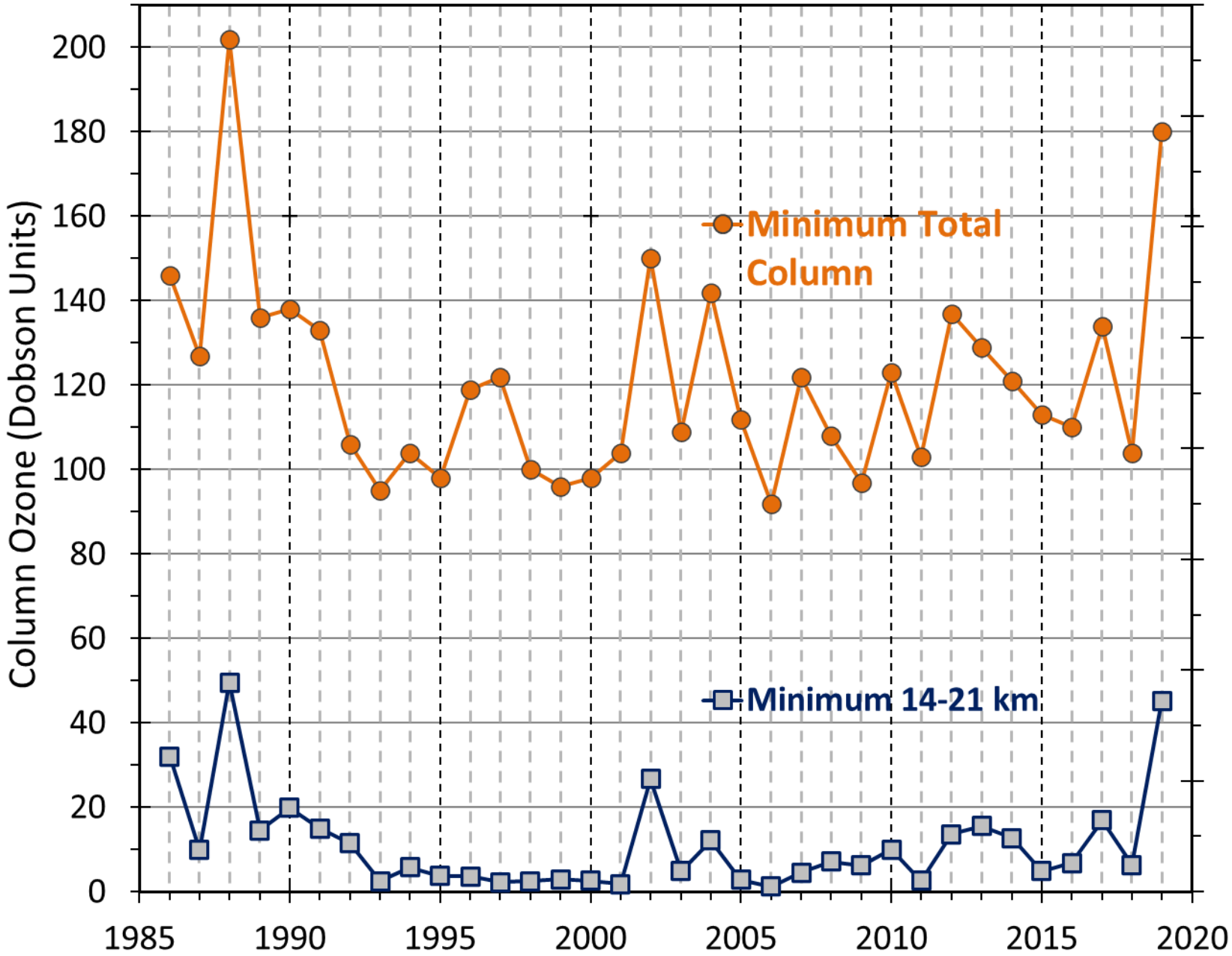
| | | |
|---|---|---|
| RECORD HIGH = | 198 DU | 1988 (October 10) |
| 2019 = | 180 DU | 2019 (September 24) |
| RECORD LOW = | 92 DU | 2006 (October 6) |



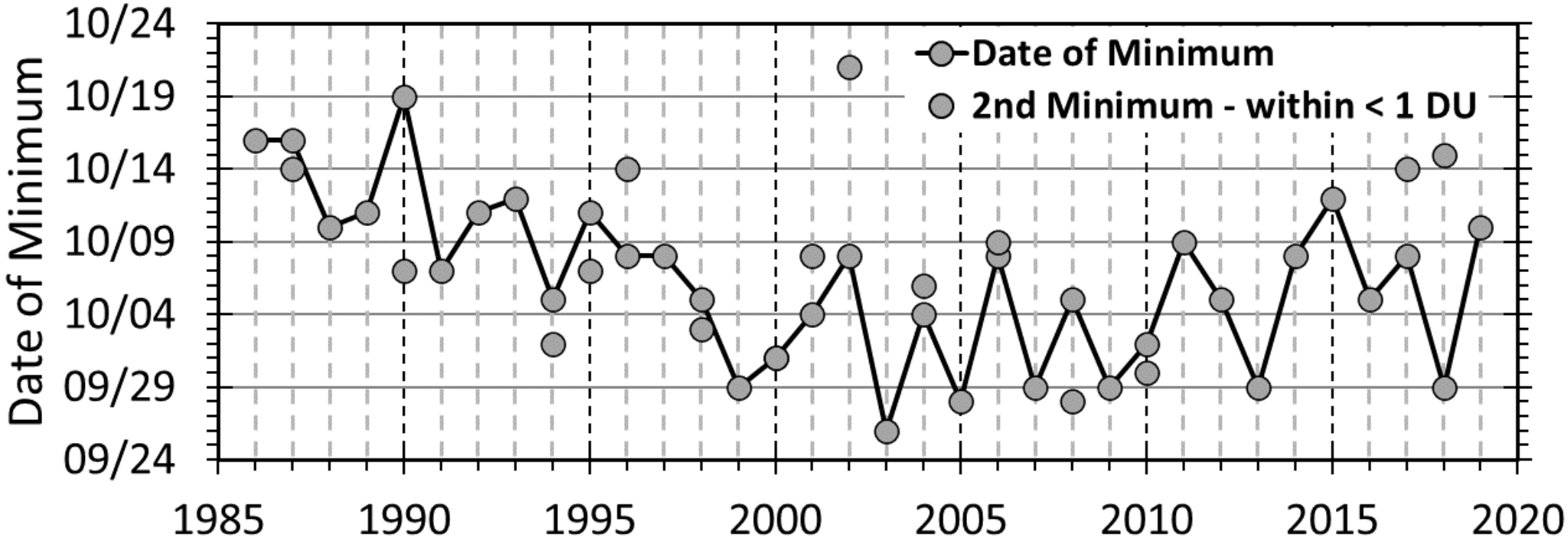



# South Pole Ozonesondes
# 2020 Update – July 5th profile (phase 1  pre-depletion)




Column Ozone (Dobson Units)
200
180
160
140
120
100
80
60
40
20
0
1985
1990
1995
2000
2005
2010
2015
2020
Minimum Total Column
Minimum 14-21 km

# South Pole Ozonesondes: Ozone Hole Metrics



| Phase | Date interval | Day# | Sonde Launch Frequency |
|---|---|---|---|
| 1) Pre-ozone hole | June 15 – Aug 15 | *166-227* | 2-4 /month |
| 2) Rapid linear loss | Aug 28 – Sept 27 | 240-270 | 3 /week |
| 3) Minimum ozone | Sept 24 – Oct 14 | 267-287 | 3-4/week |

| Year | Date interval excluded | Event |
|---|---|---|
| 1988 | Aug 11 – Dec 01 | Early vortex weakening in August |
| 2002 | Sept 22 – Dec 15 | Sudden stratospheric warming / split vortex |
| 2012 | Oct 12 – Dec 01 | Sudden vortex shift observed over South Pole |
| 2019 | Full year | Early vortex weakening in Sept. - plotted as full year |

| Altitude Layer | Metric – plotted data |
| --- | --- |
| Surface – 35 km | Total Ozone Column (TOC) in Dobson Units (DU) minimums |
| 14-21 km | Column ozone minimums (DU) loss rates (DU/day) & temperature |
| 10-24 km - 2 km layers | Ozone column (DU) and temperature |
| 10-24 km – curtain plot | Saturation ~ zero ozone (mPa) layers during minimum (phase 3) |
| Pressure: 200 – 10 hPa | September mixing ratio loss rate profiles (ppmv/day) |