The Anomalous Warming of the SH Subtropical Lower Stratosphere and Implications for Detecting Antarctic Ozone Recovery

Aodhan Sweeney

COSMIC/JCSDA IROWG-10

September 17th, 2024

Many thanks to coauthors: Qiang Fu, Stephen Po-Chedley, Susan Solomon, John M. Wallace, Thomas Birner, Bill Randel, Andrea Steiner, Pu Lin

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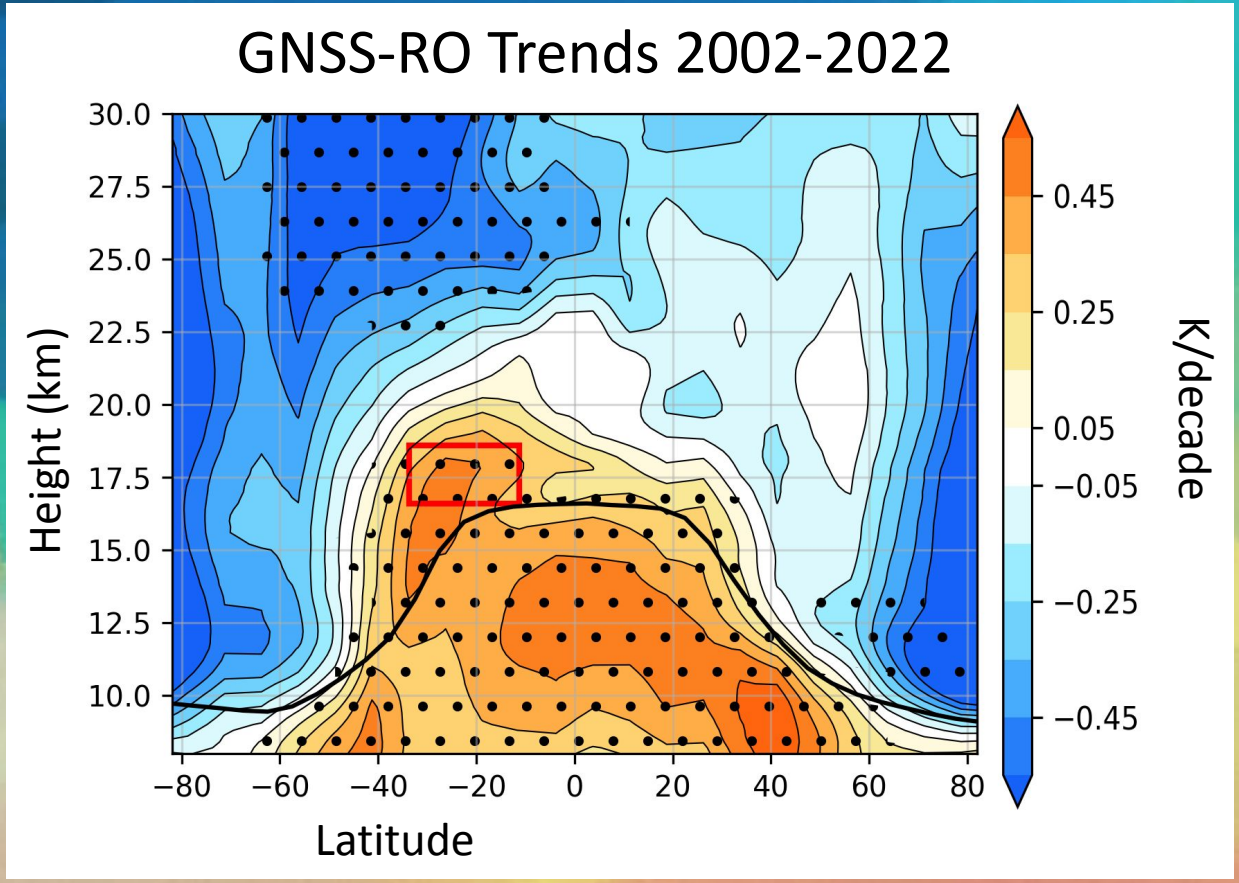

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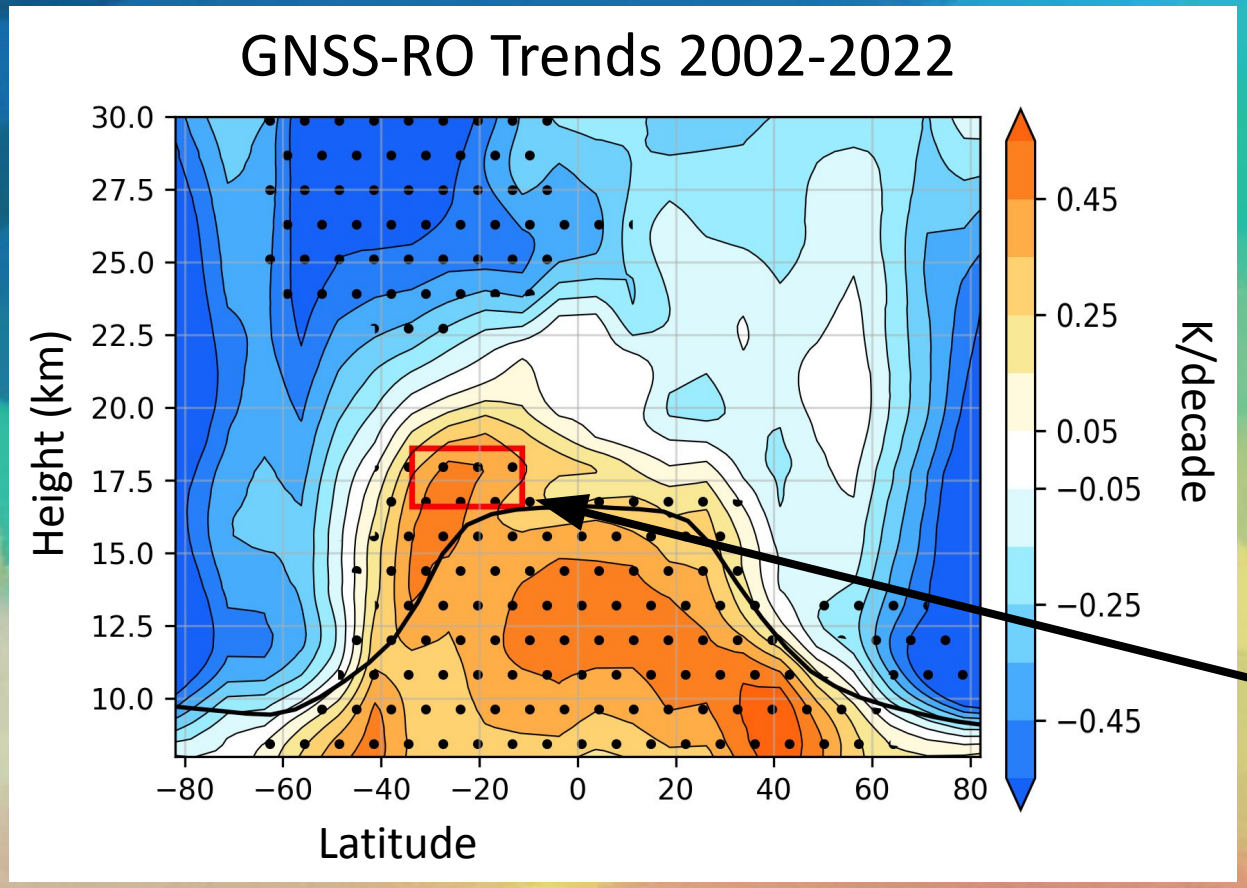

Anomalous Warming of the Lower Stratosphere (AWLS)

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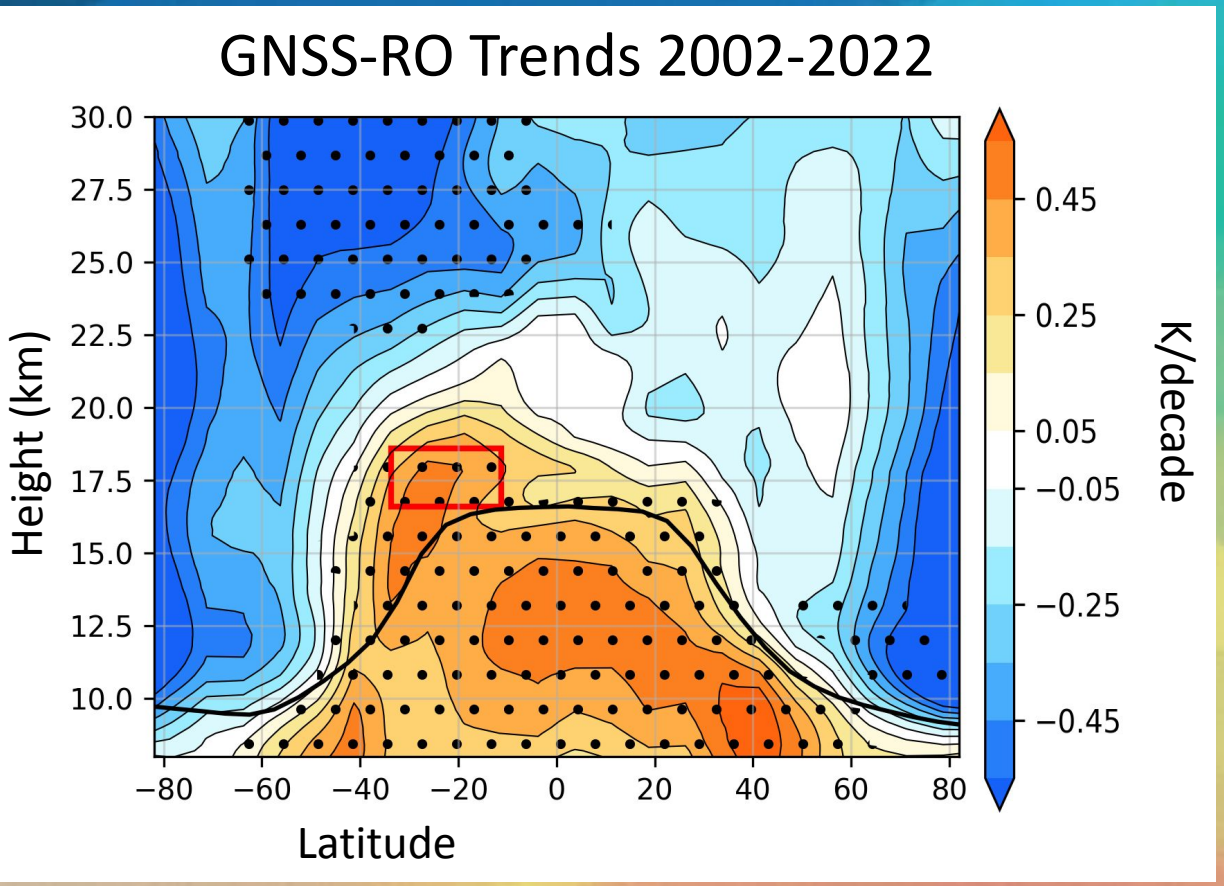

Outline/ Main Points:

1. The AWLS is dynamically induced

2. Dynamics may mask signal of ozone recovery

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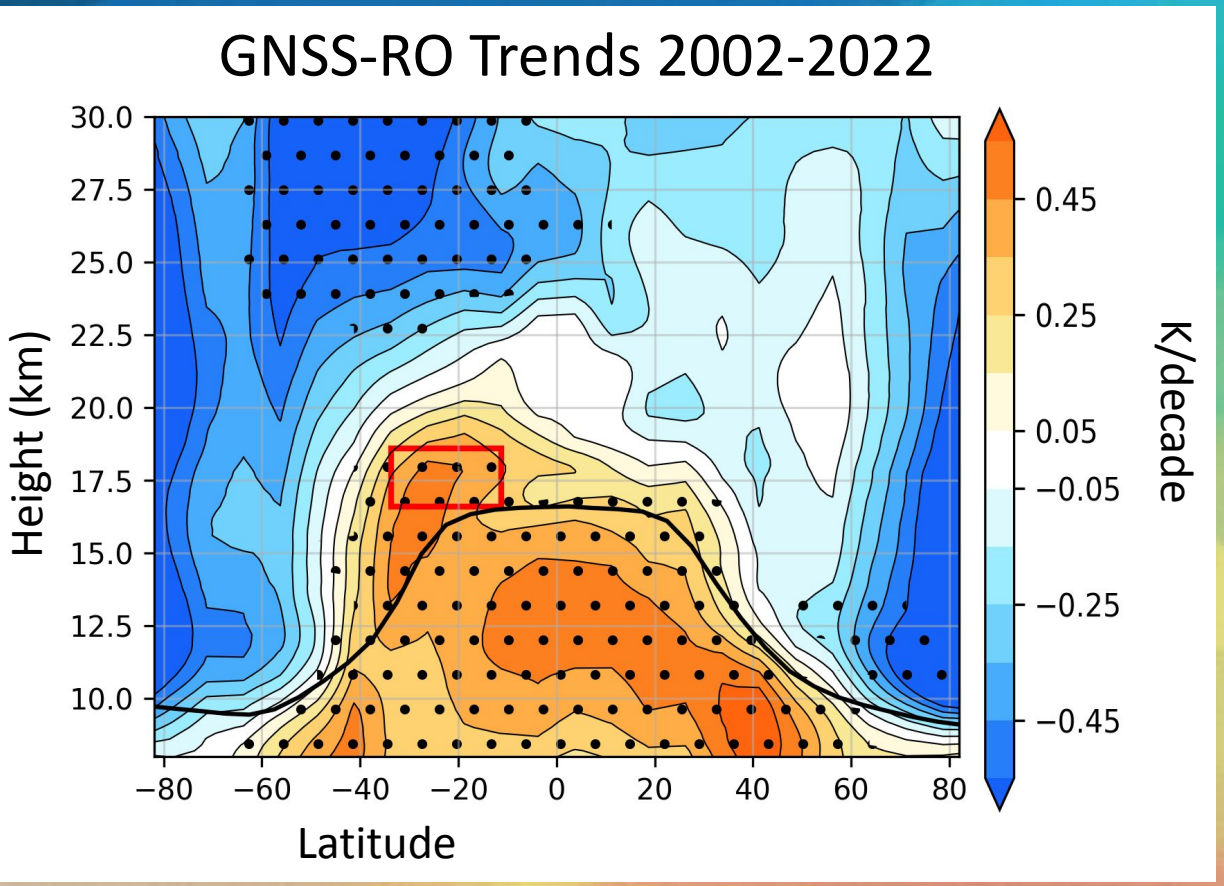

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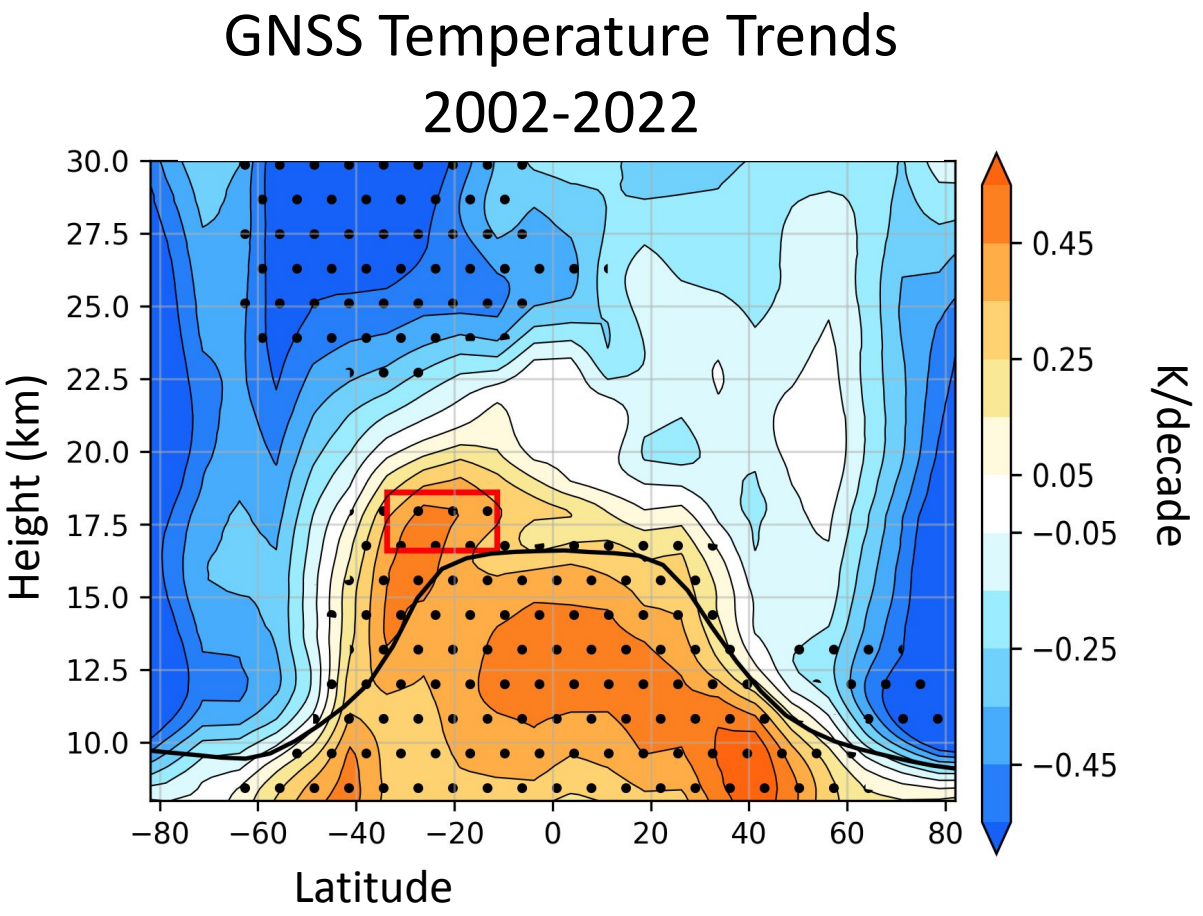

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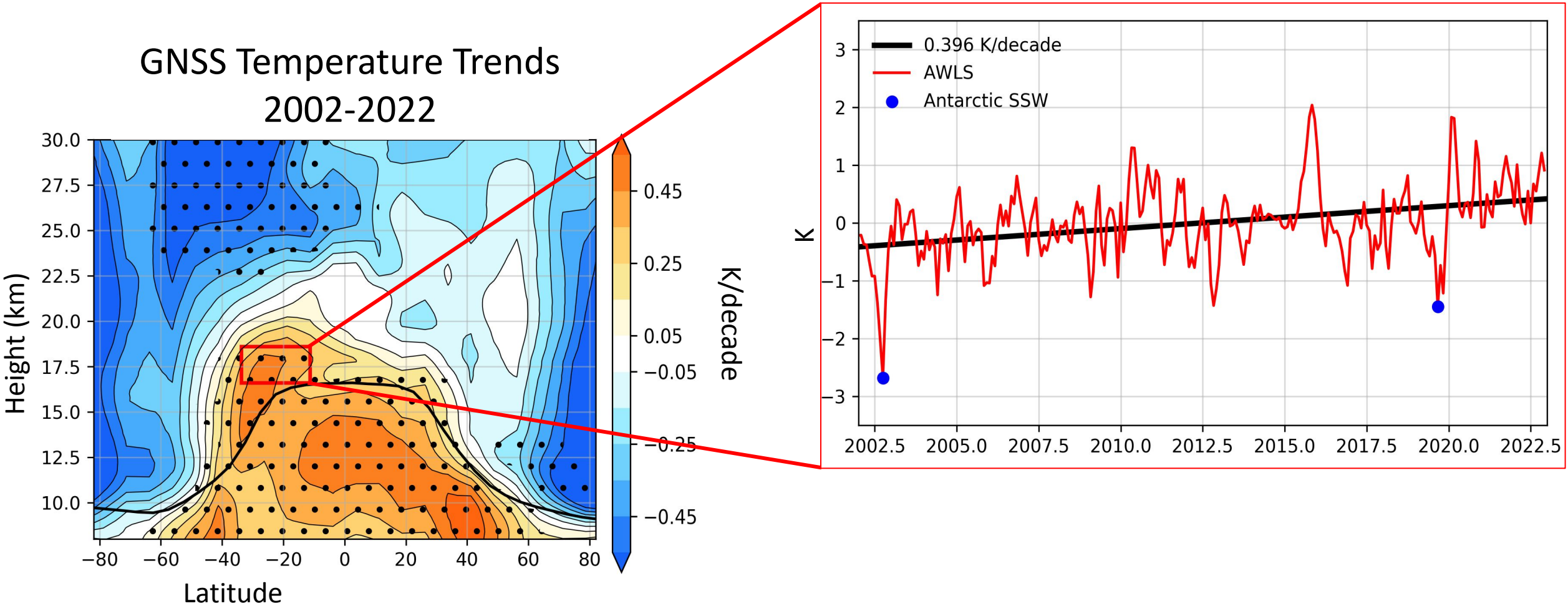

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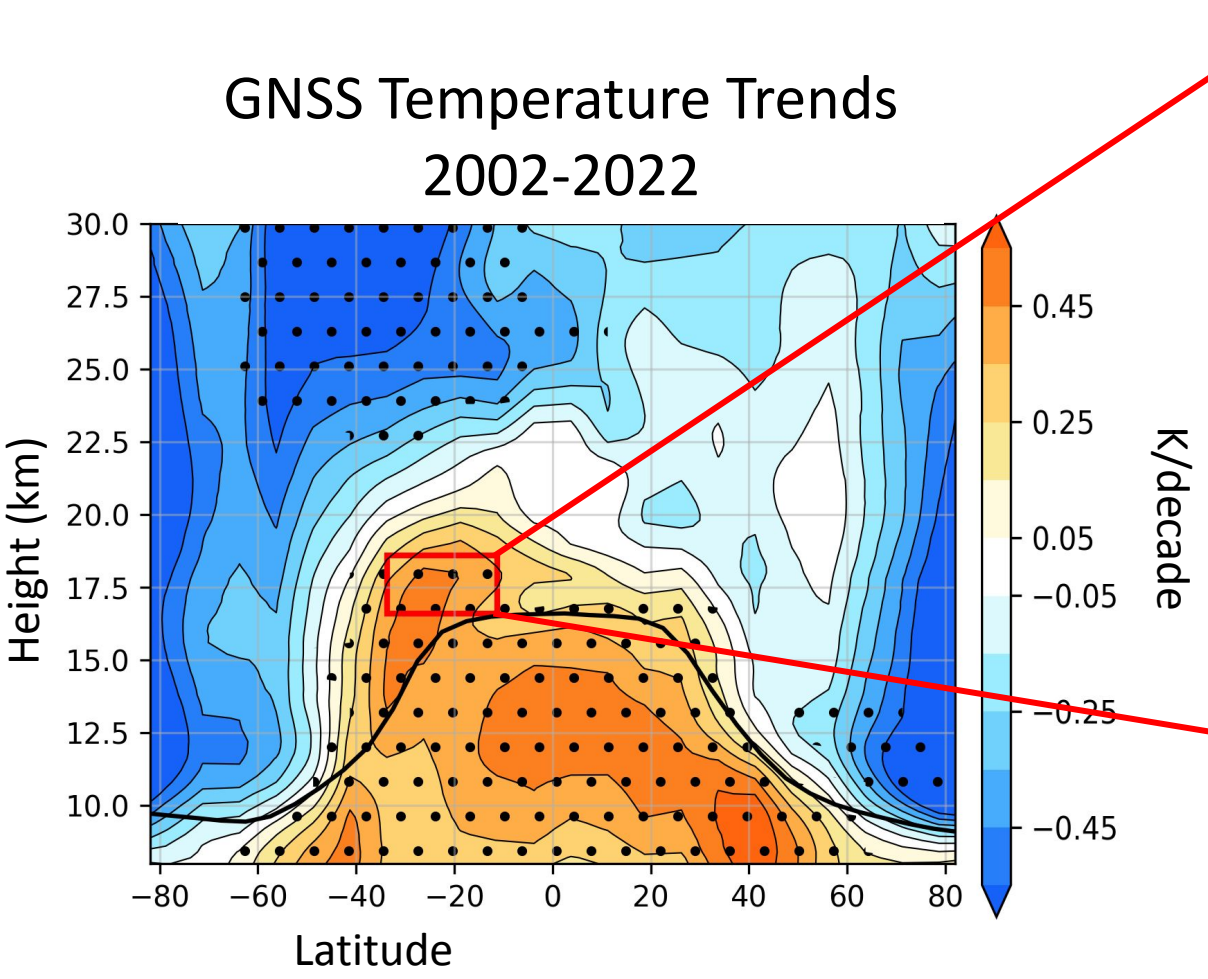
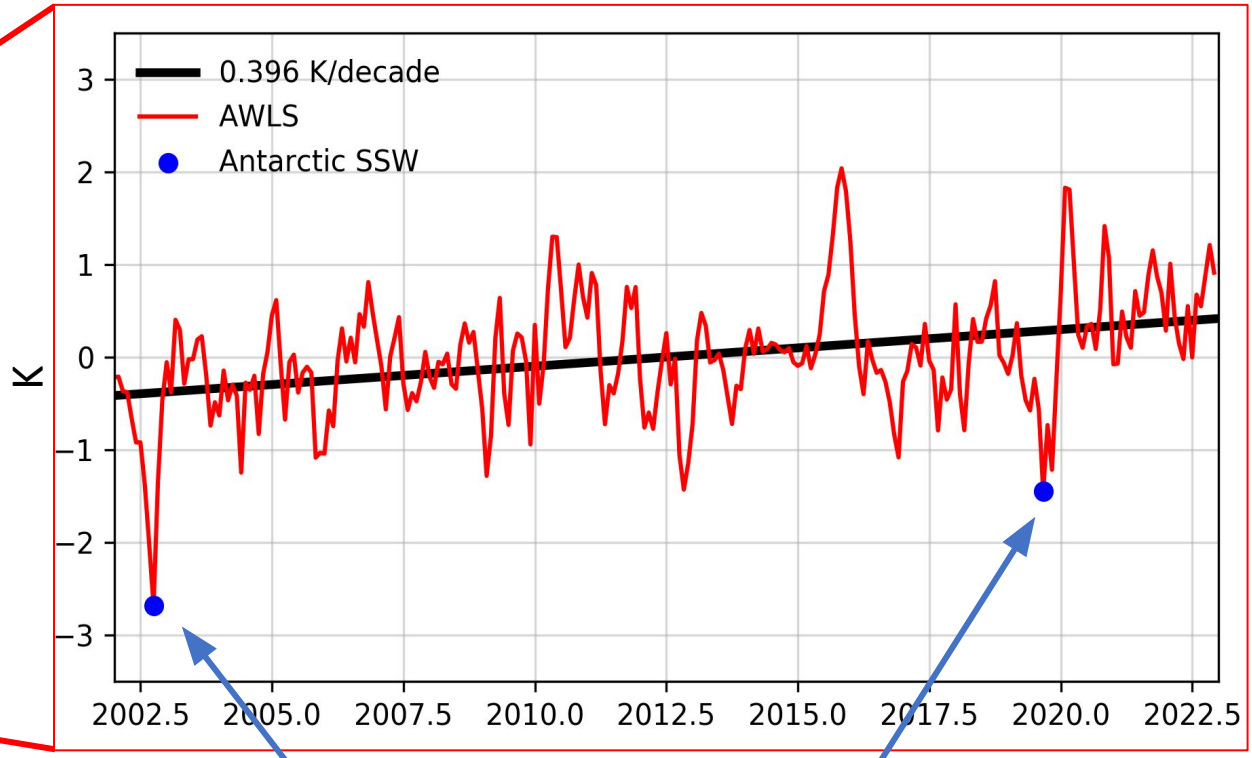
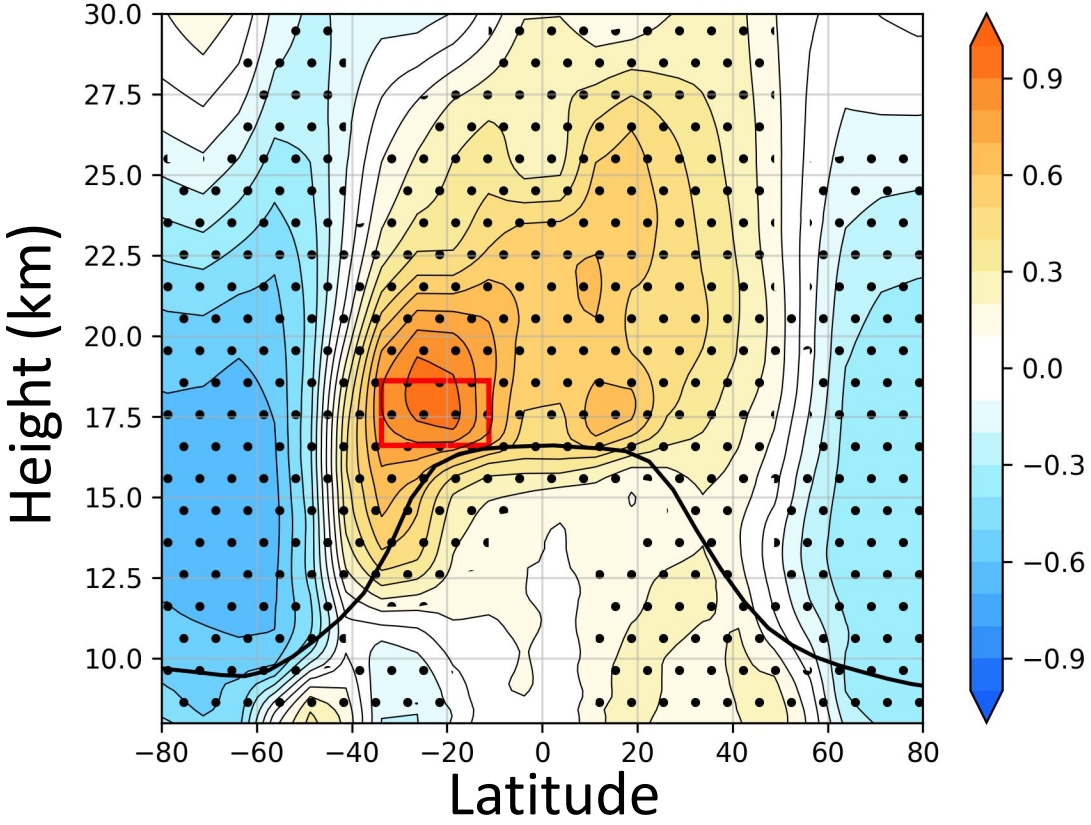




The 2002 and 2019 Antarctic Sudden Stratospheric Warmings

The AWLS is dynamically induced

Correlations of AWLS and Temperature (detrended)



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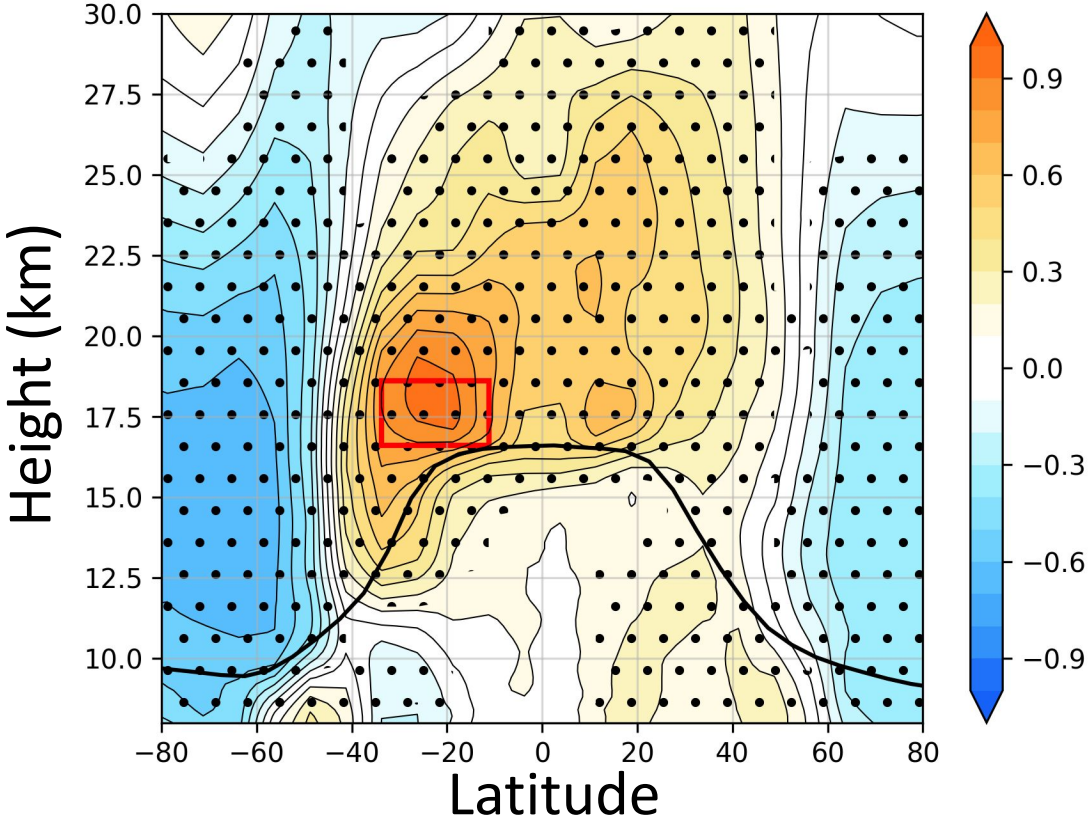
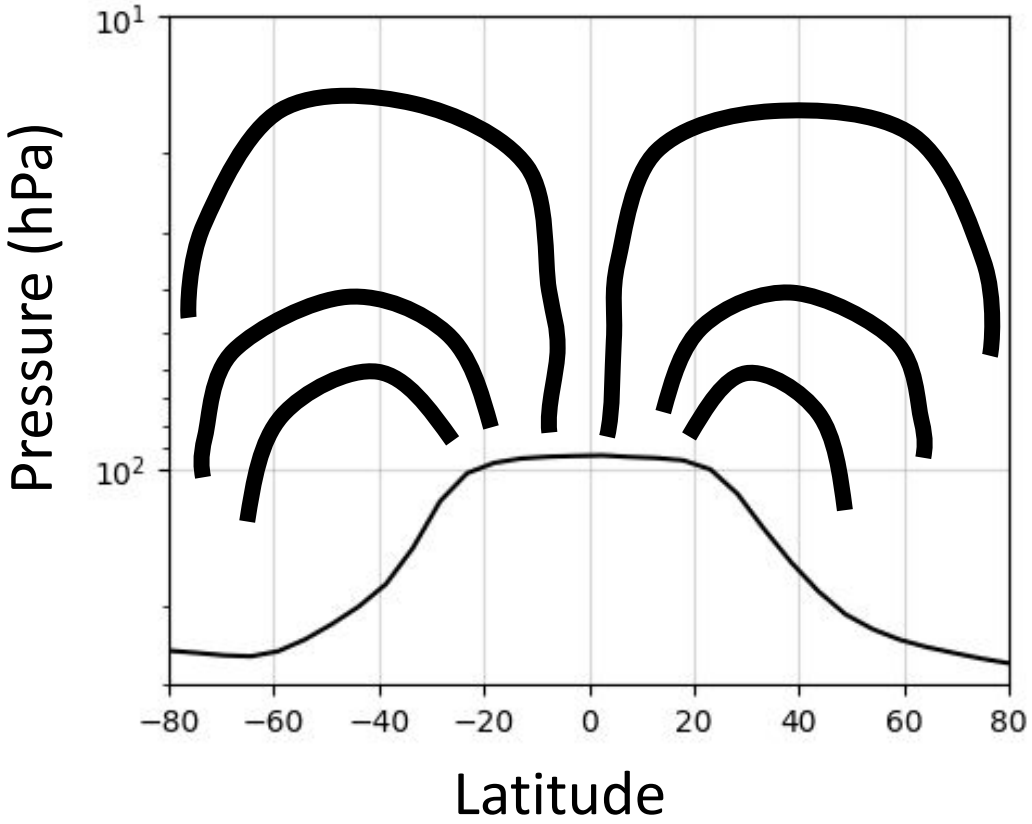


Schematic of Stratospheric Circulation



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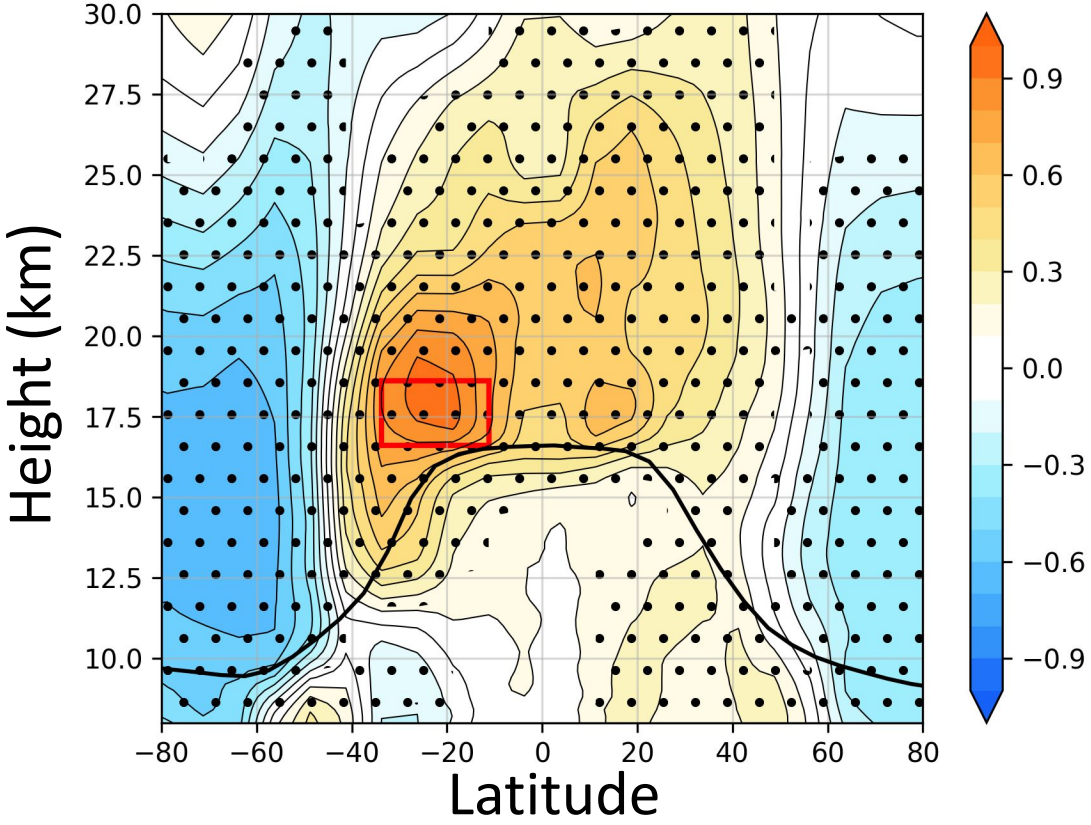
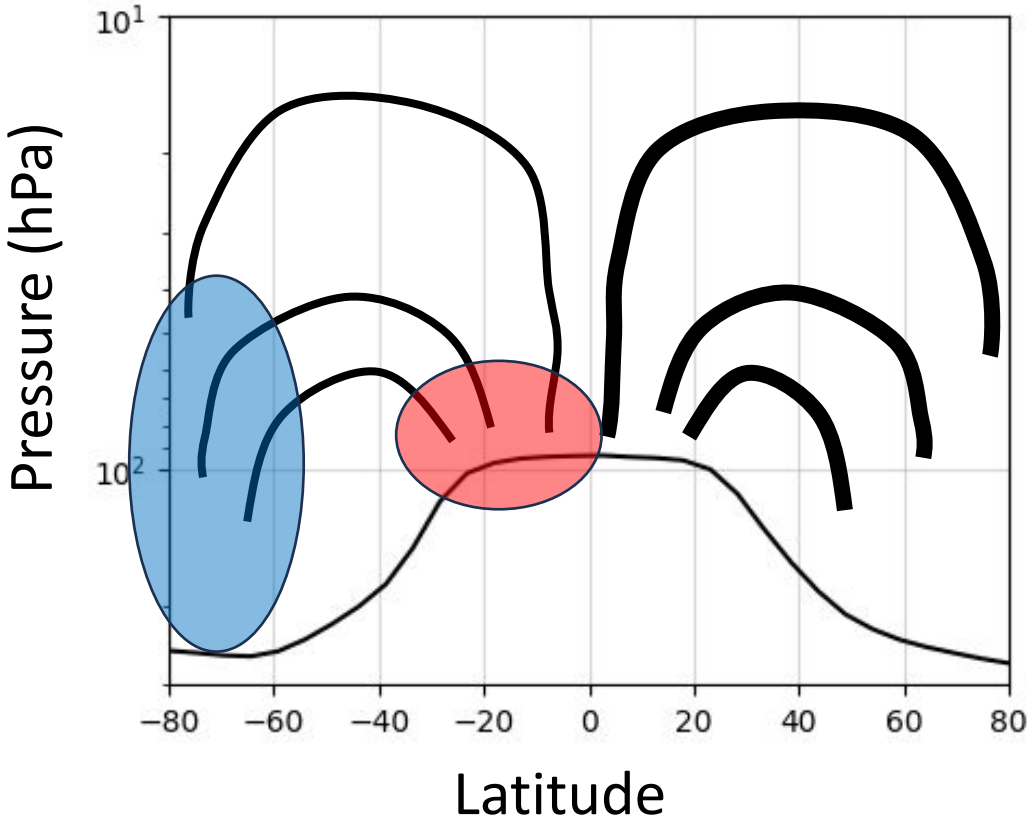
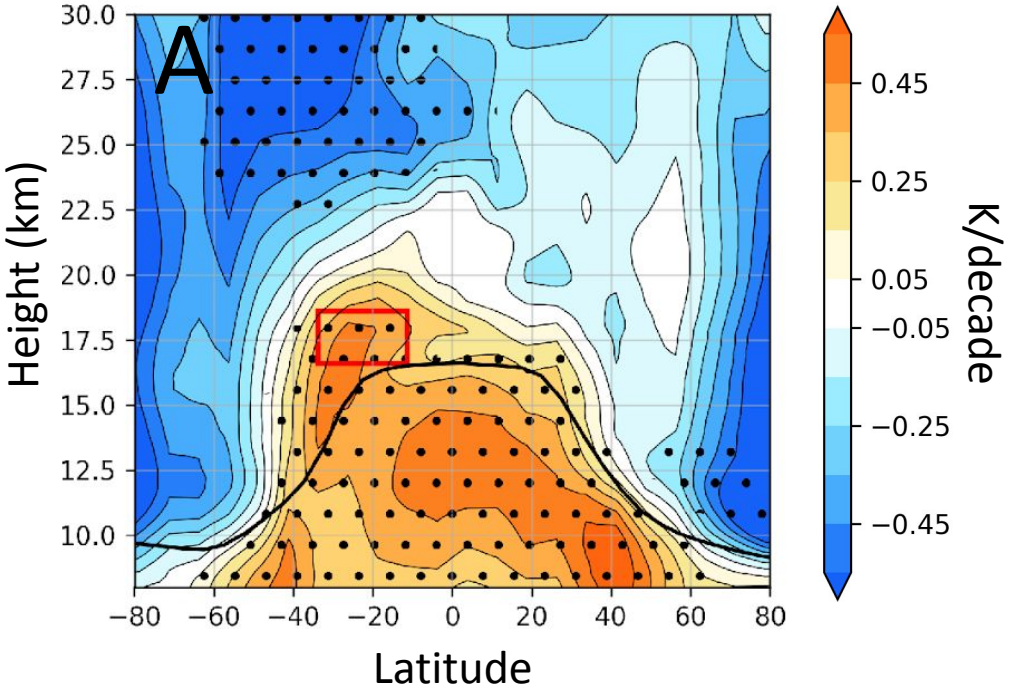


Weakened Stratospheric Circulation



The AWLS is dynamically induced

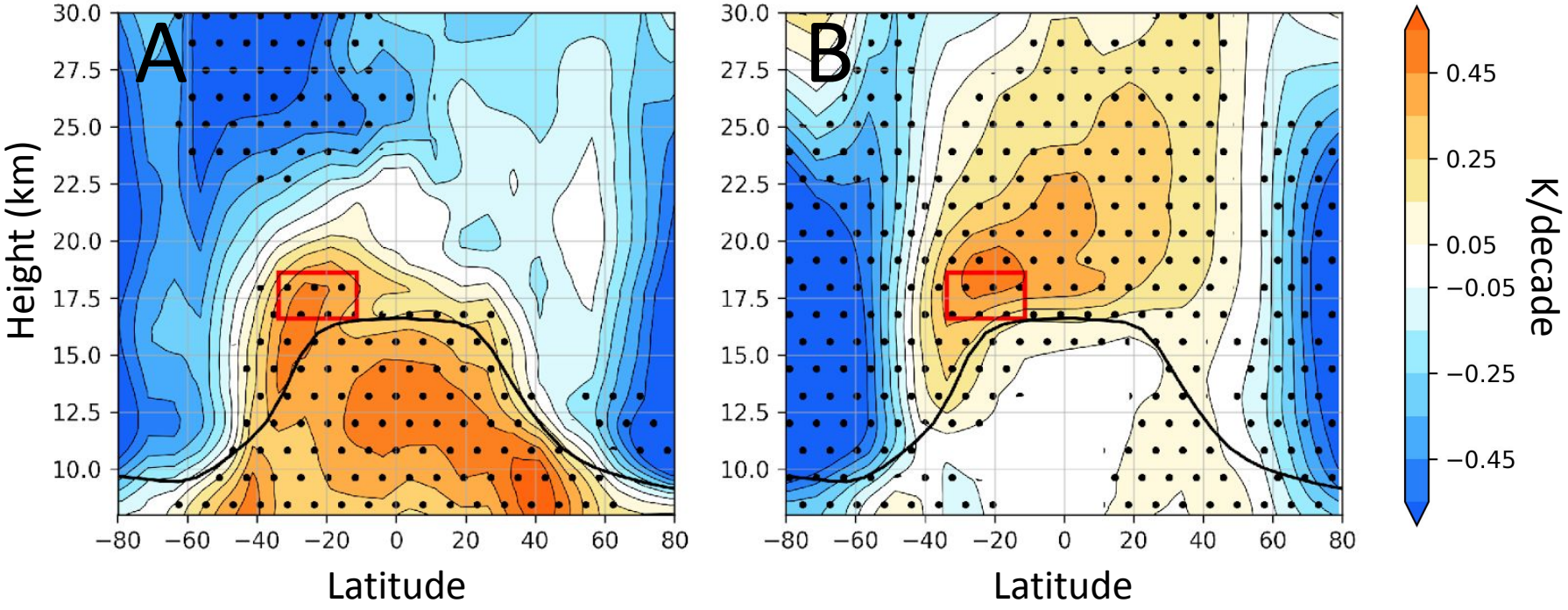
Temperature Trends
(2002-2022)



The AWLS is dynamically induced

Temperature Trends (2002-2022)

Trends from Circulation Regression



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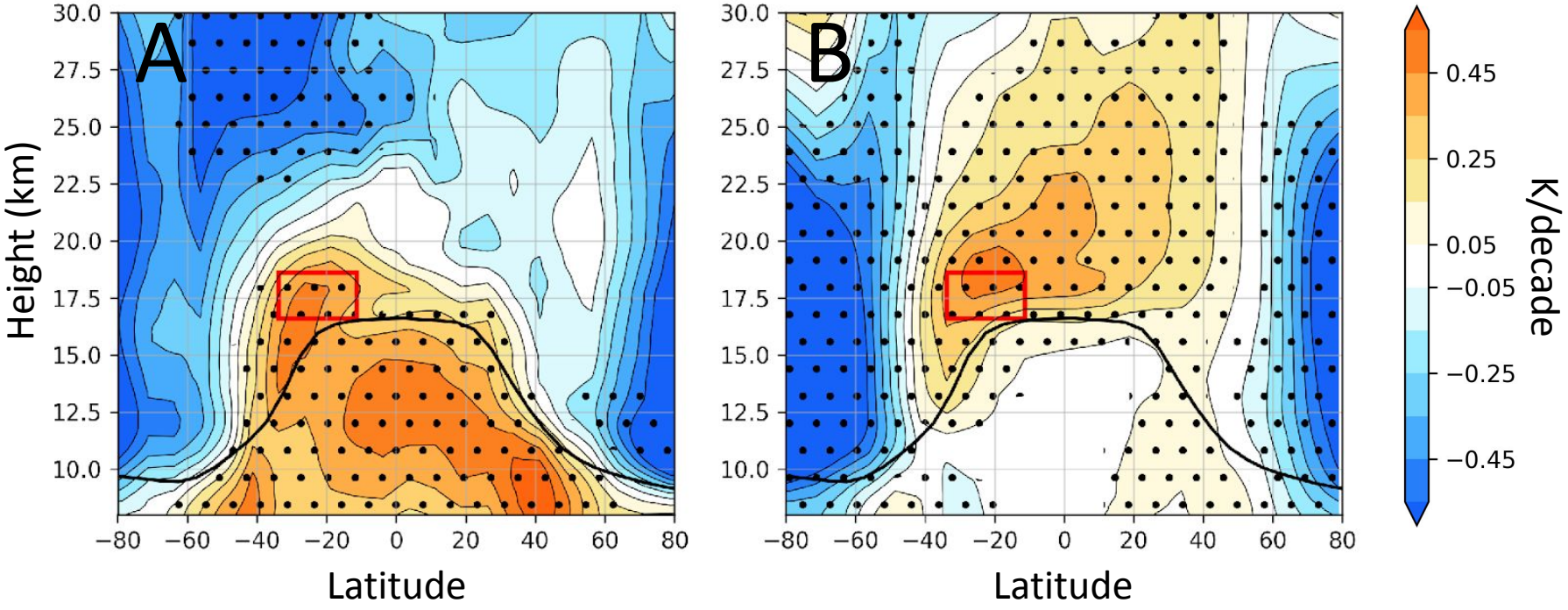

The trends associated with the AWLS have a dynamical signature

The AWLS is dynamically induced

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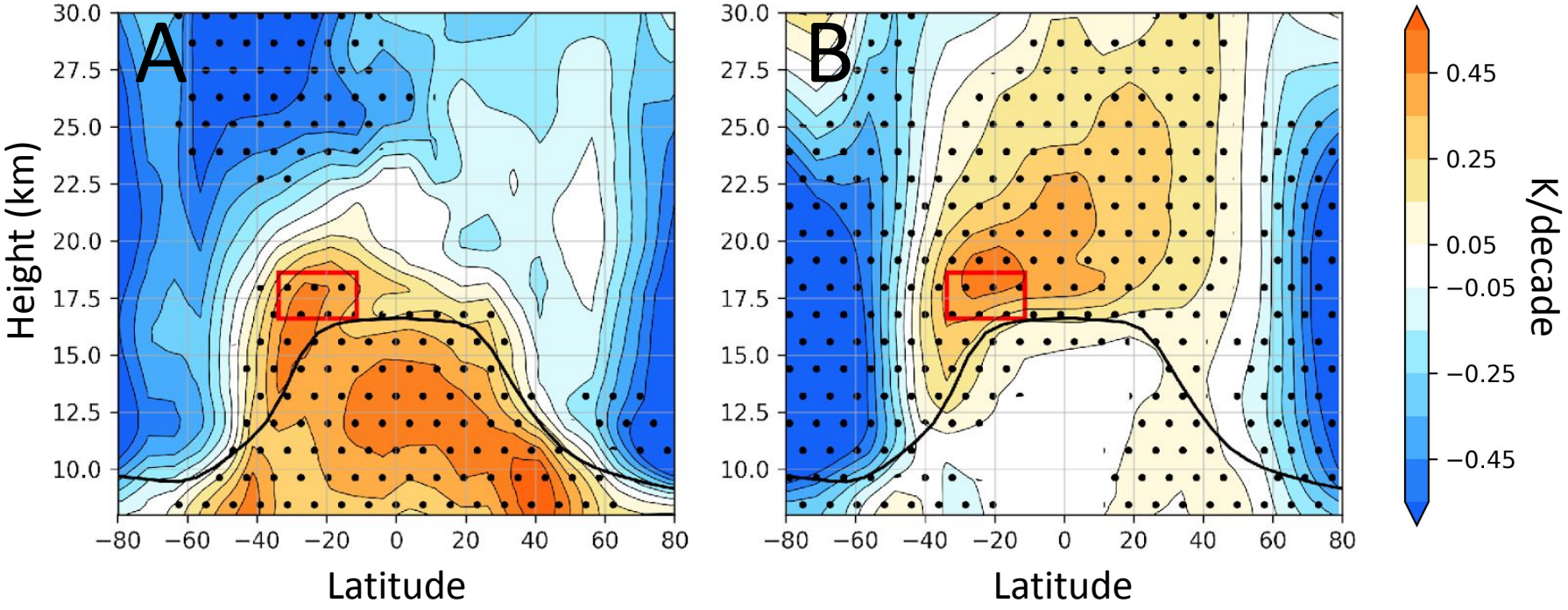

Radiation Model suggests composition changes alone would have *cooled* the AWLS region

The trends associated with the AWLS have a dynamical signature

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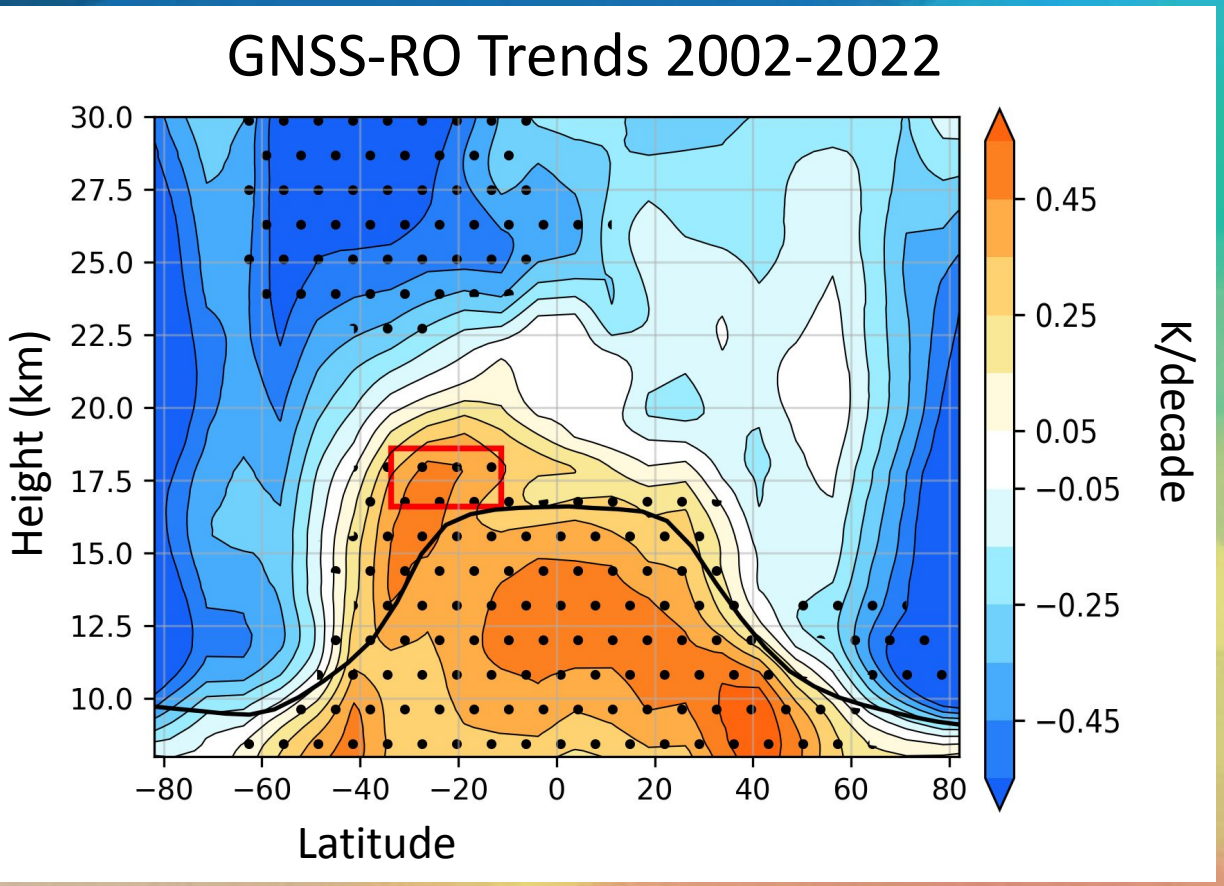

Outline/ Main Points:

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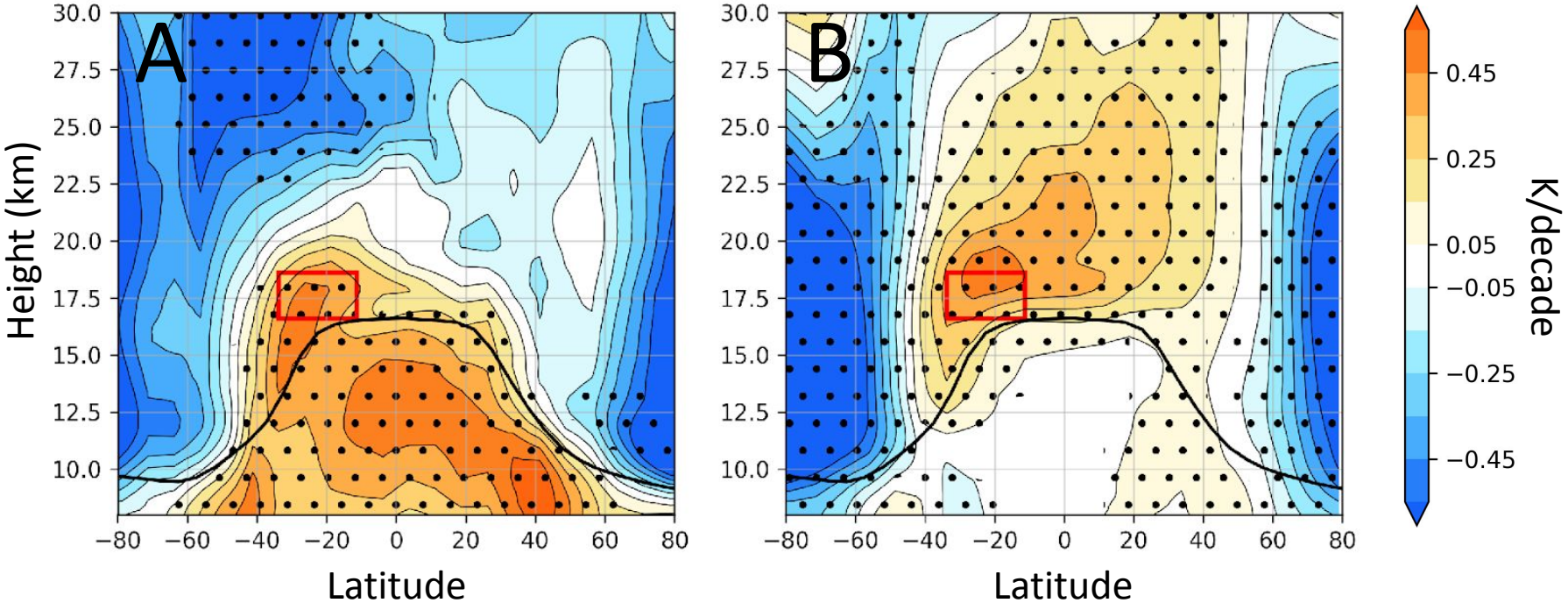
2. Dynamics mask signal of ozone recovery

Dynamics mask signal of ozone recovery

Temperature Trends (2002-2022)

Trends from Circulation Regression



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Dynamics mask signal of ozone recovery

Temperature Trends (2002-2022)

Trends from Circulation Regression

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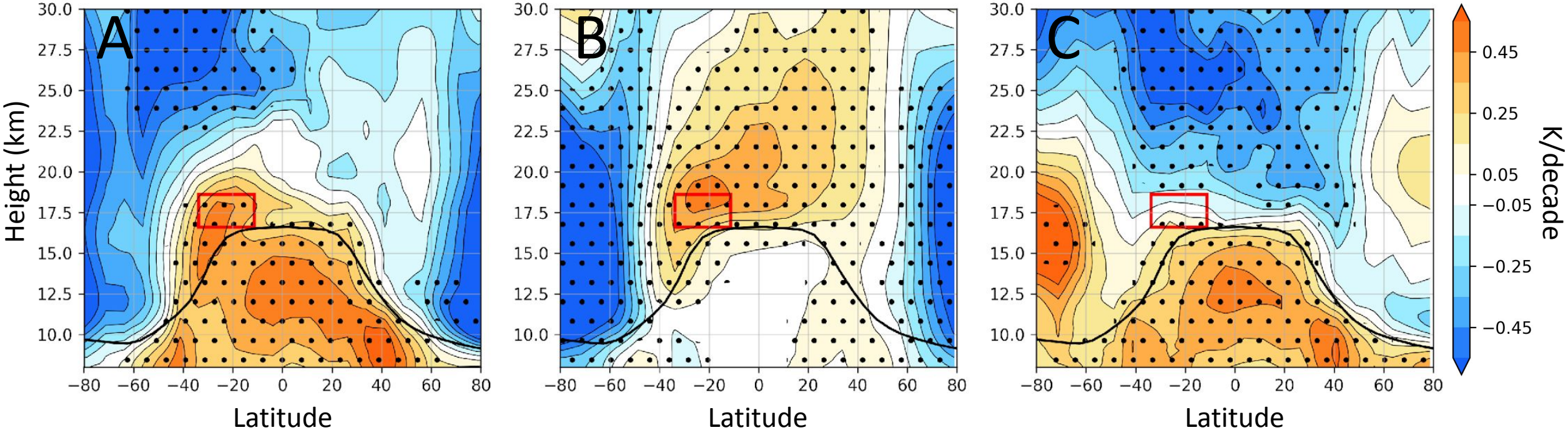
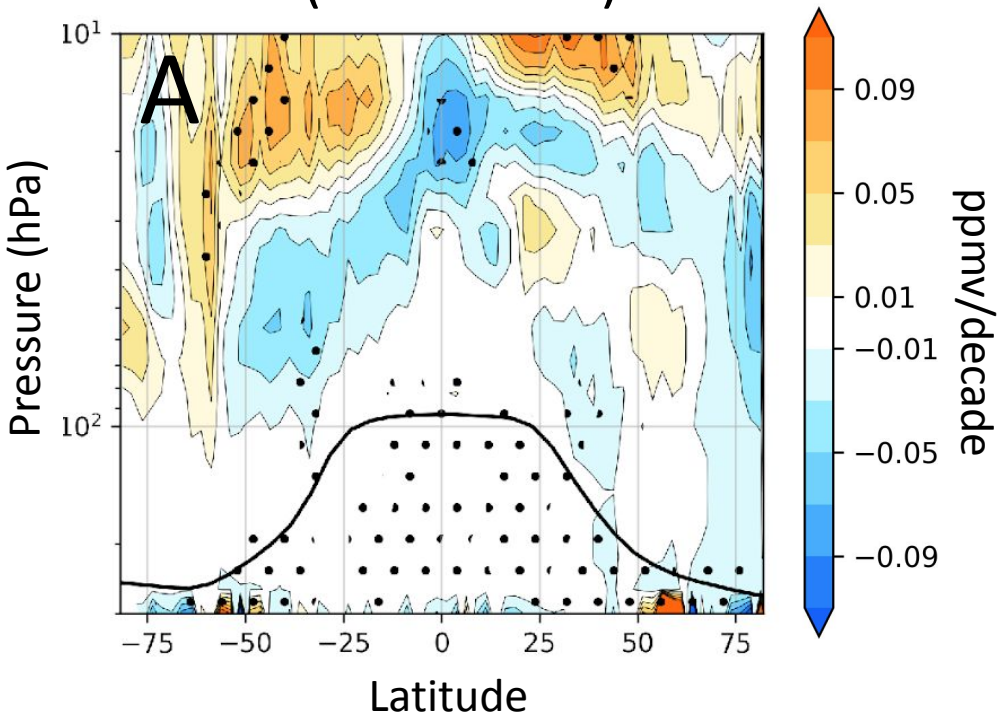


The Difference trends (C) have a radiative signature

Dynamics mask signal of ozone recovery

Ozone Trends SWOOSH
(2002-2022)



Dynamics mask signal of ozone recovery

Ozone Trends SWOOSH
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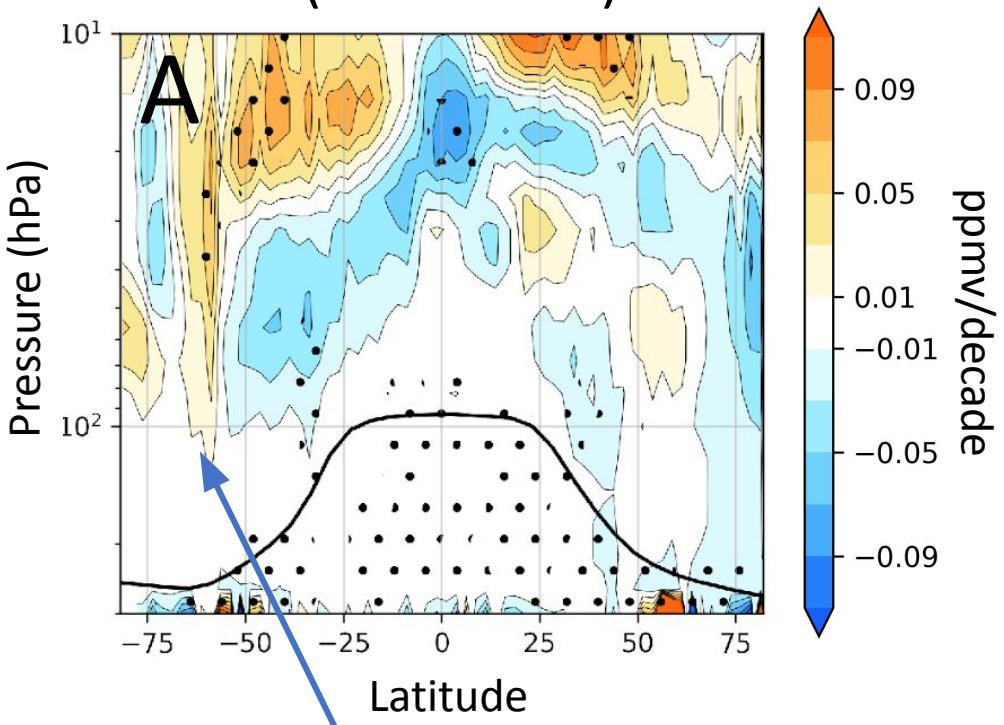
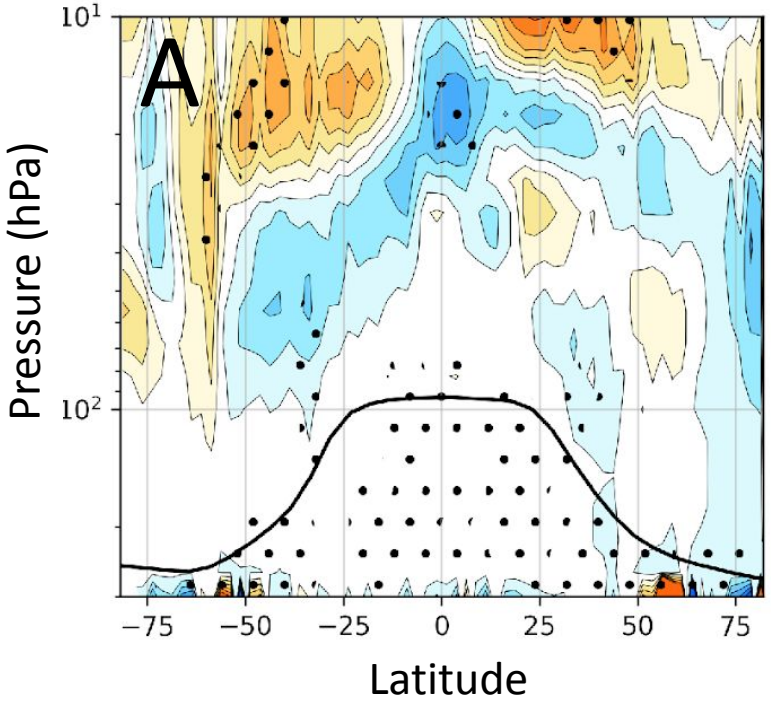


Observations do not show an obvious Antarctic ozone recovery

Dynamics mask signal of ozone recovery

Ozone Trends SWOOSH (2002-2022)



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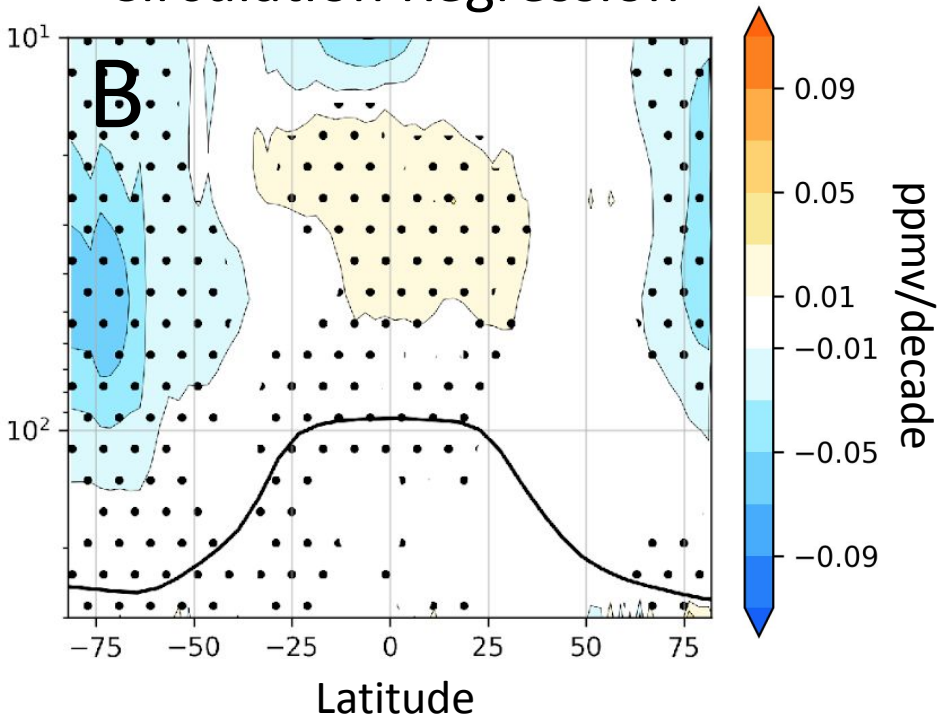
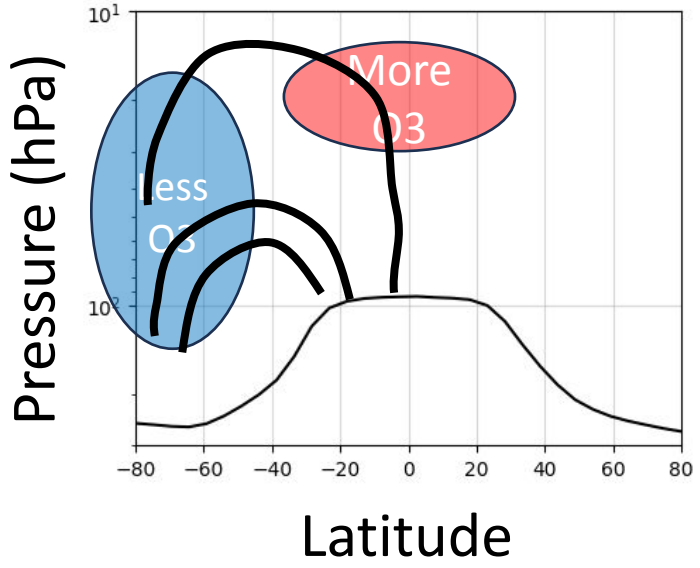


Weakened Southern Hemisphere Stratospheric Circulation



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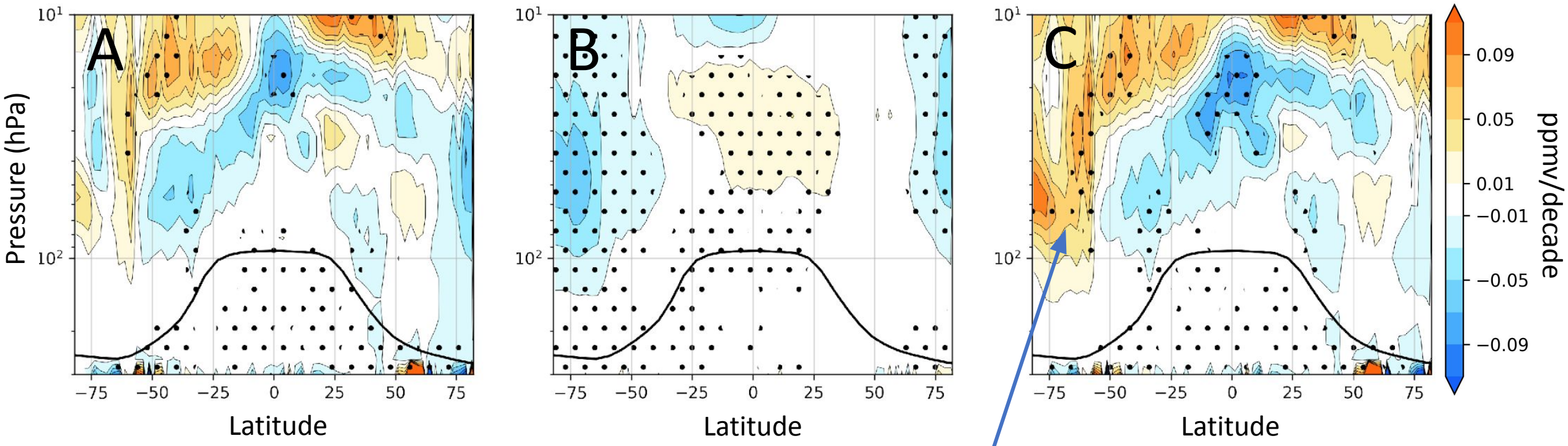

Removing dynamical processes reveals an Antarctic ozone recovery

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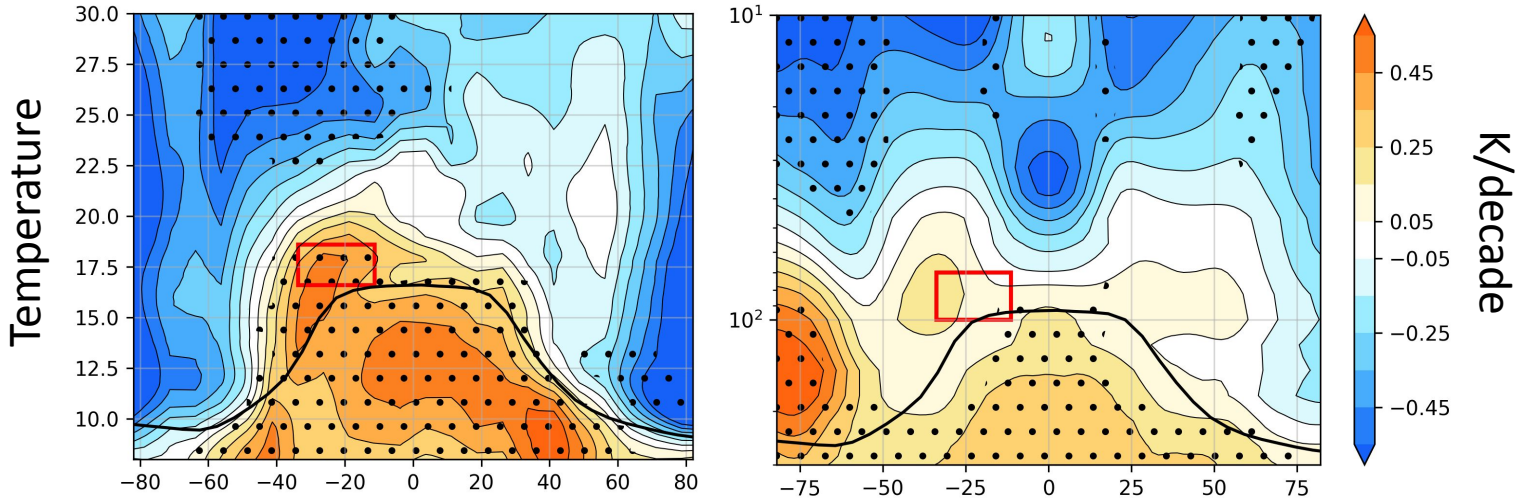
1. The AWLS is dynamically induced
   - The inferred changes look like a slowdown of the stratospheric circulation

2. Dynamics may mask signal of ozone recovery
   - A stratospheric circulation slowdown weakens poleward transport of ozone rich air

Dynamics mask signal of ozone recovery

Temperature Trends

WACCM Ensemble Mean

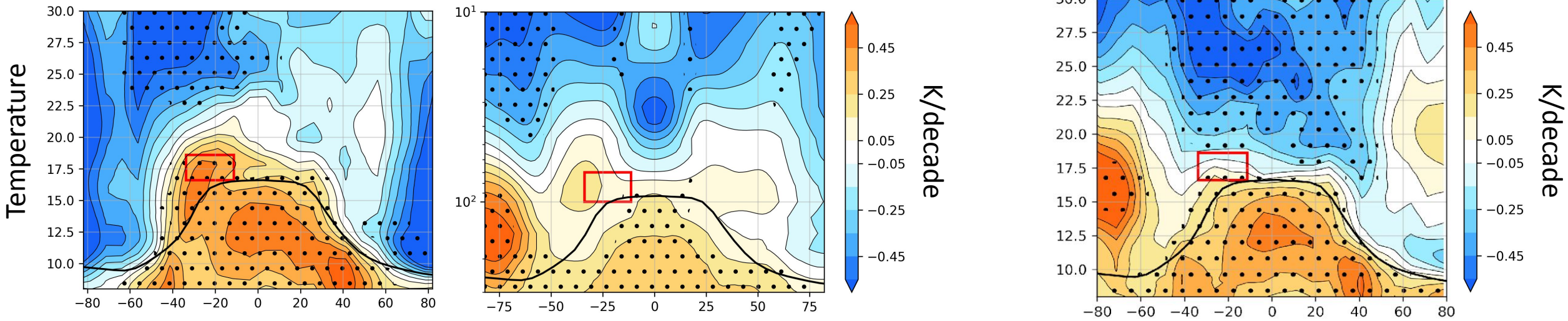


Dynamics mask signal of ozone recovery

GNSS-RO

WACCM Ensemble Mean

GNSS-RO Minus Dynamics



Removing dynamical trends leads to closer agreement between observations and models

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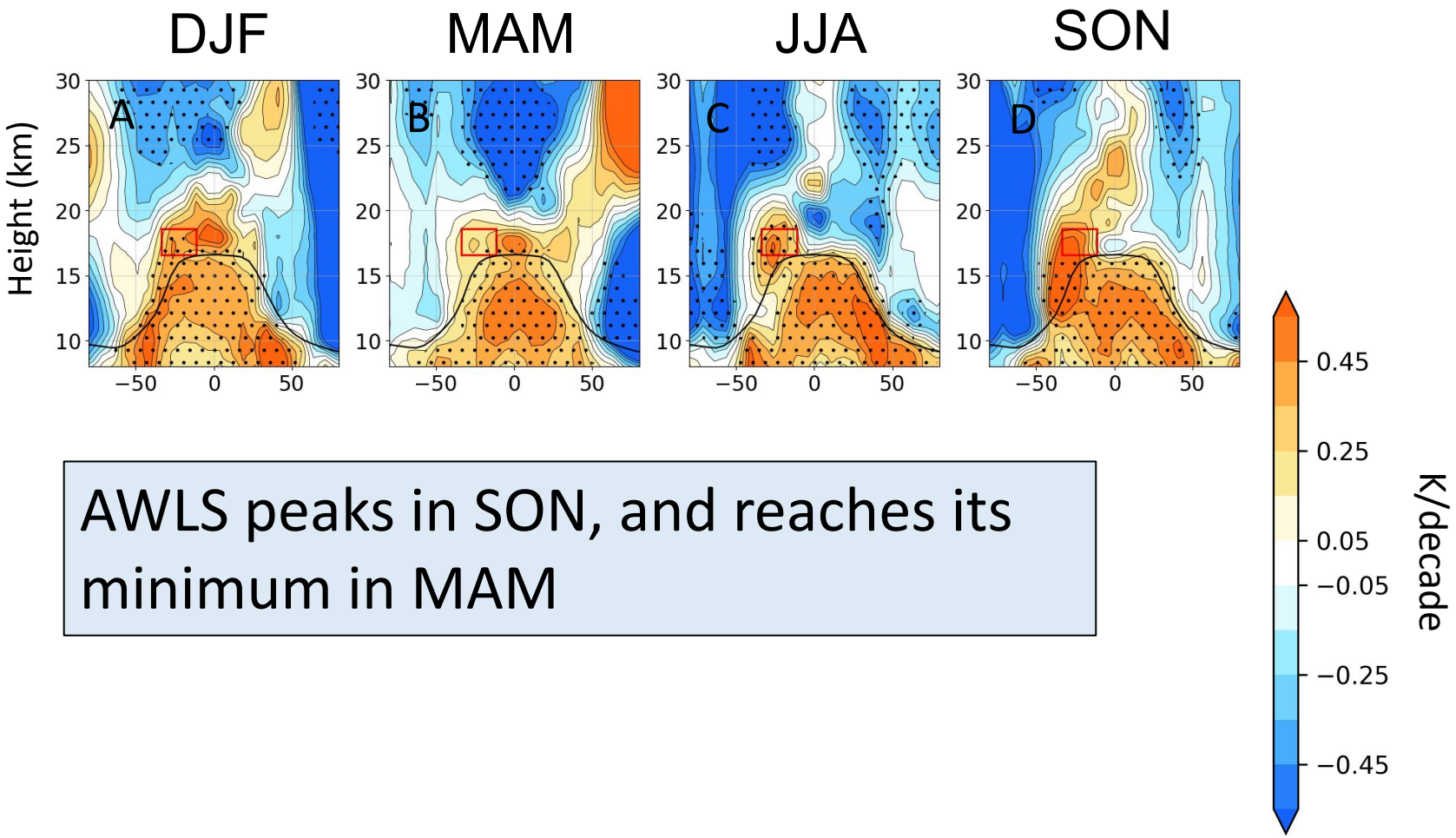
Dynamics mask signal of ozone recovery

Temperature Trends

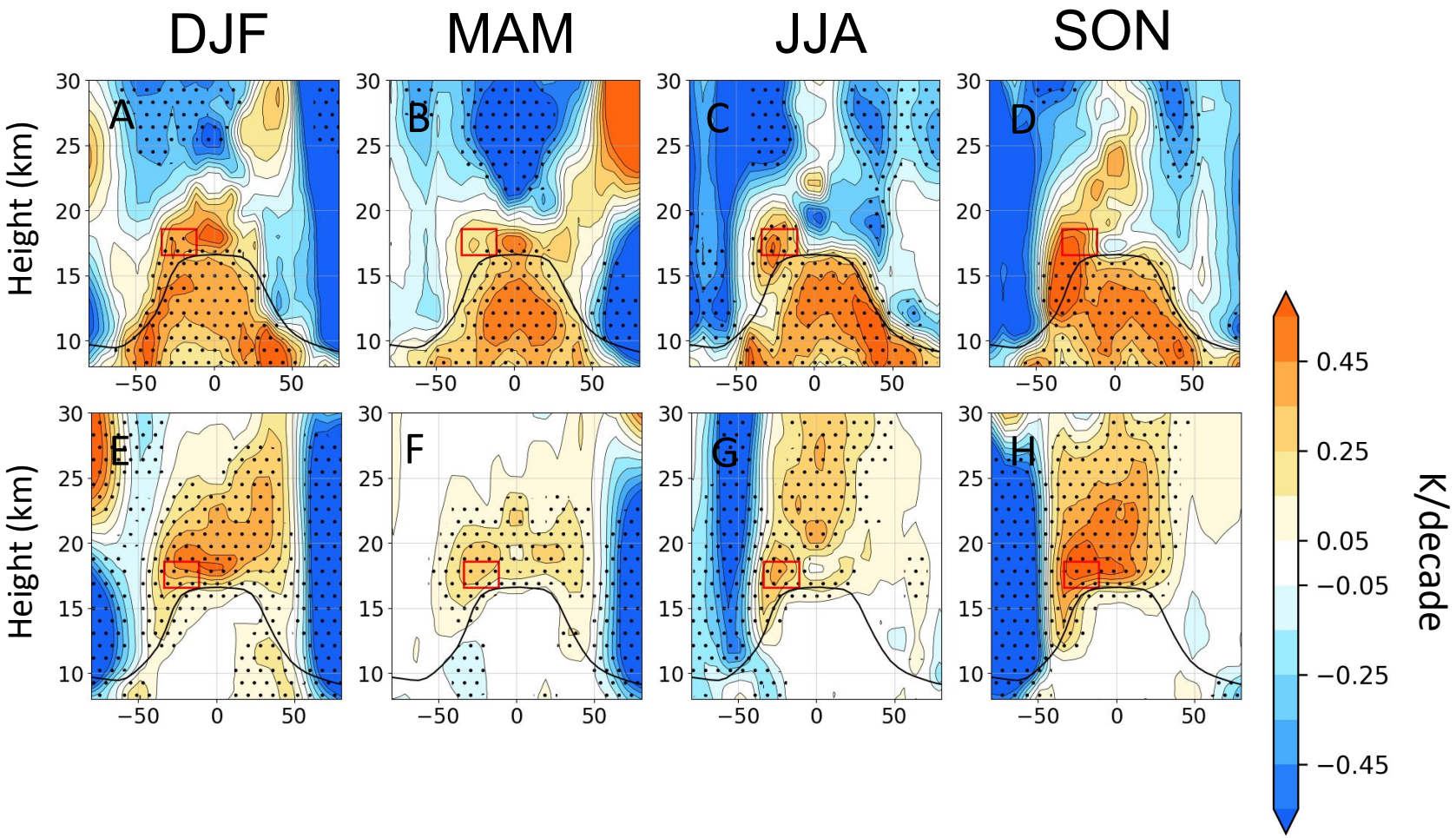


AWLS peaks in SON, and reaches its minimum in MAM

Dynamics mask signal of ozone recovery

Temperature Trends

Trends from Circulation Regression



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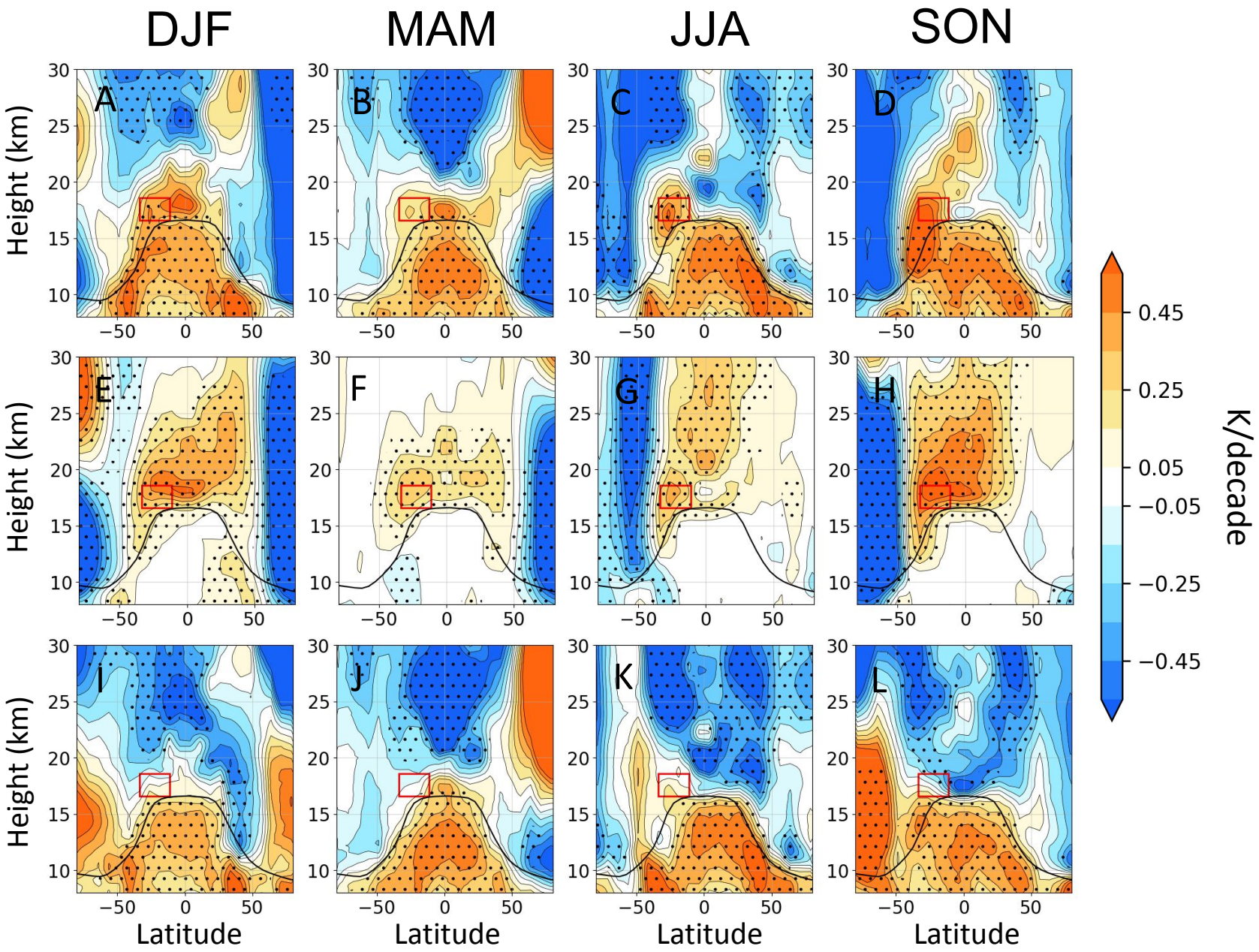

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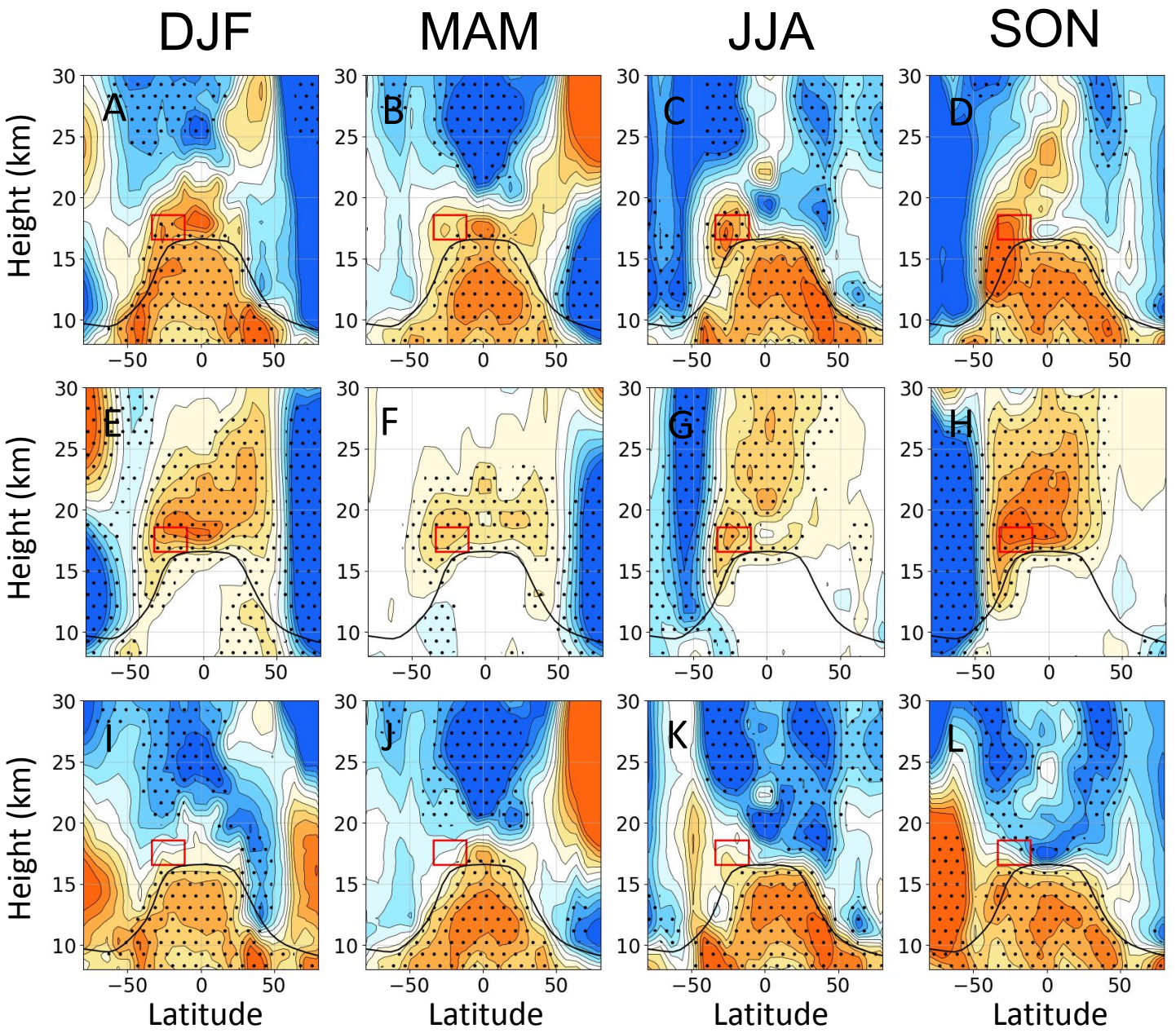
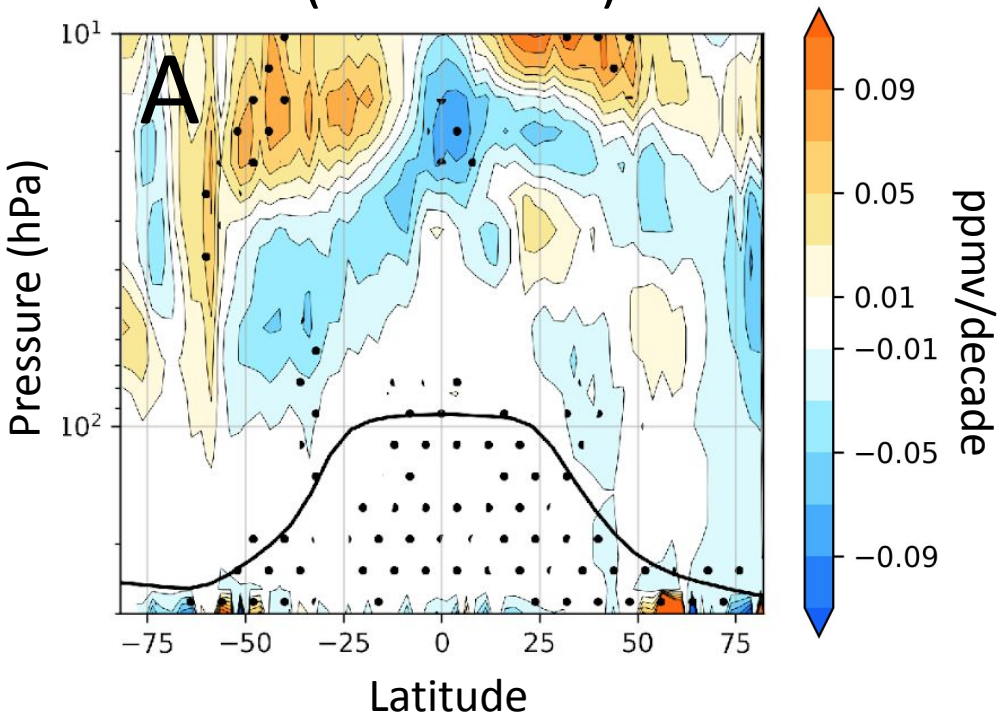


Removing dynamical processes reveals strong warming in SON

Dynamics mask signal of ozone recovery

Ozone Trends SWOOSH
(2002-2022)



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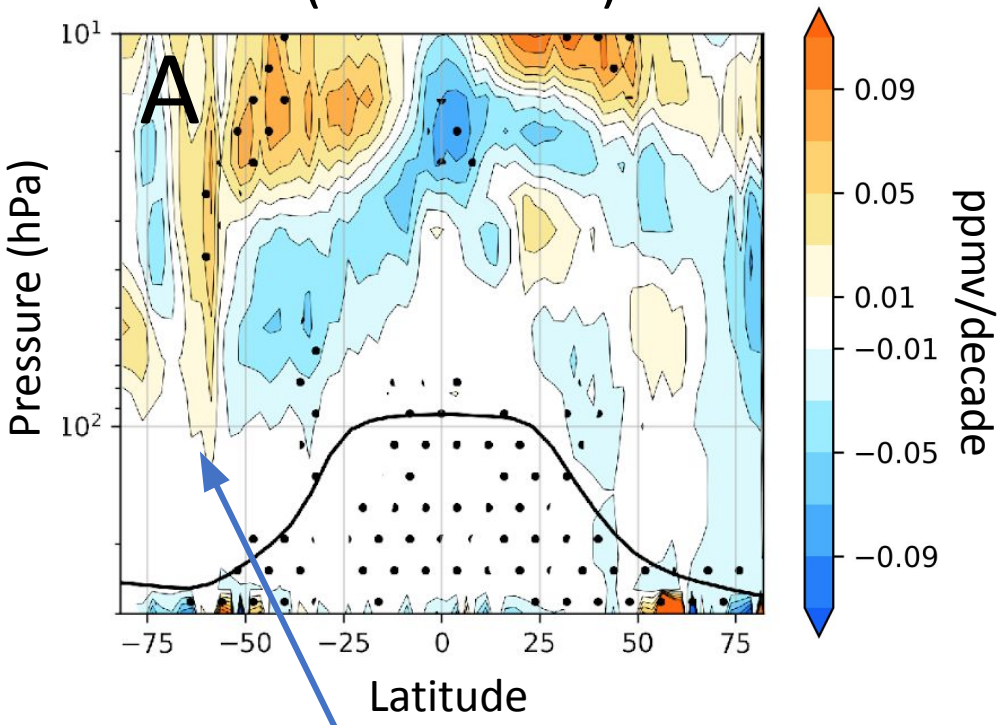

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Dynamics mask signal of ozone recovery

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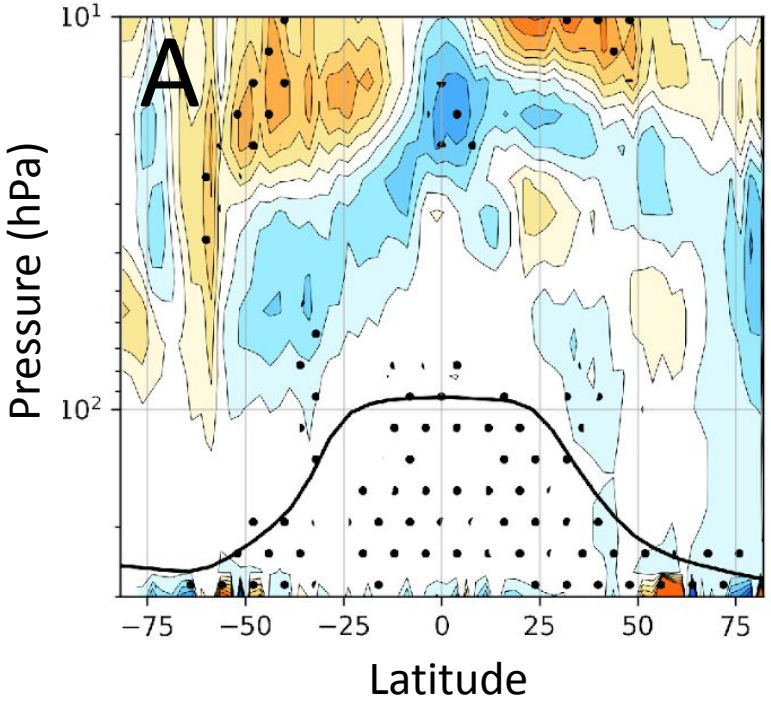
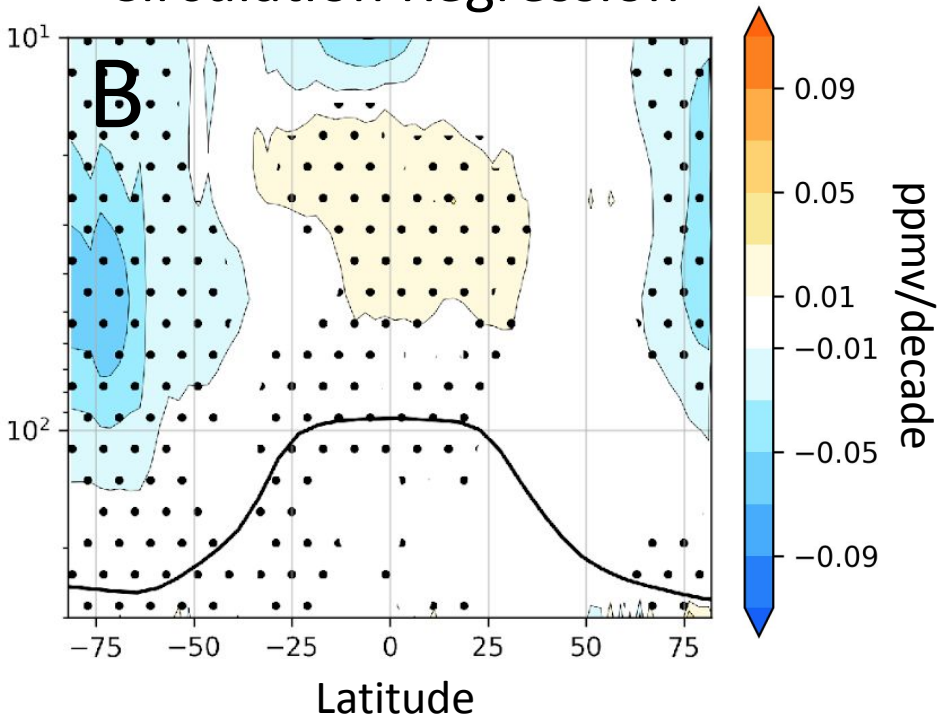


Trends from Circulation Regression



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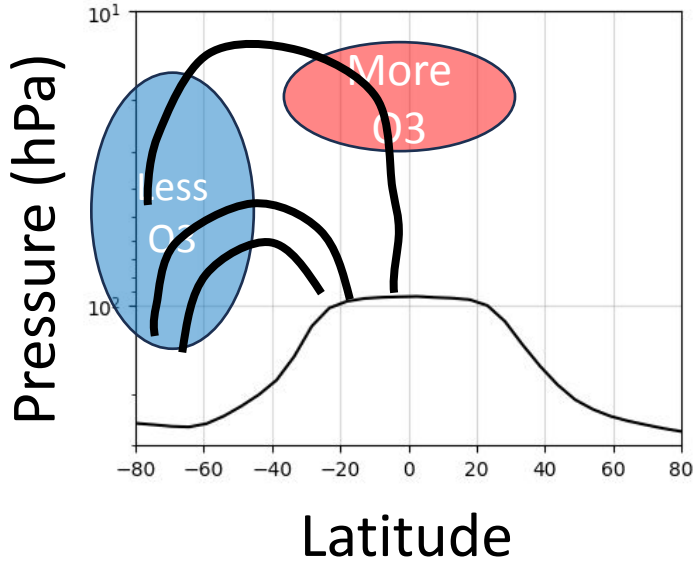

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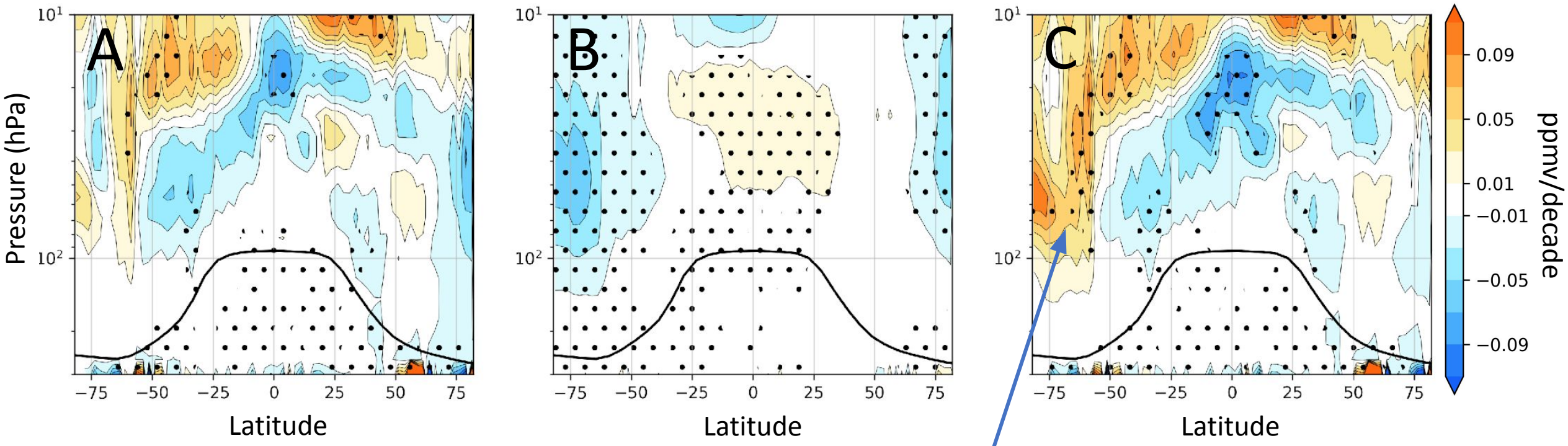
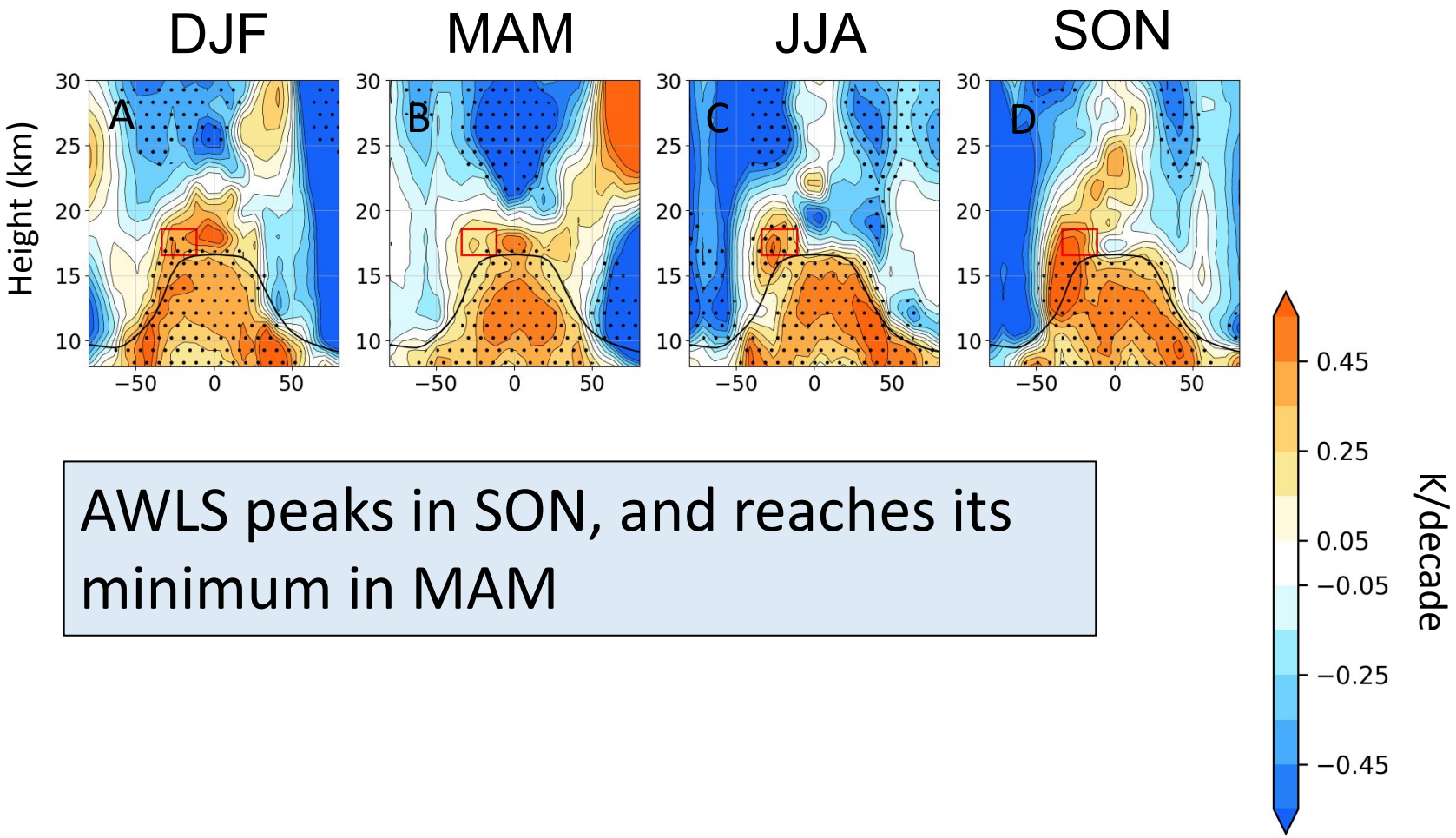


Removing dynamical processes reveals an Antarctic ozone recovery

Dynamics mask signal of ozone recovery

Temperature Trends



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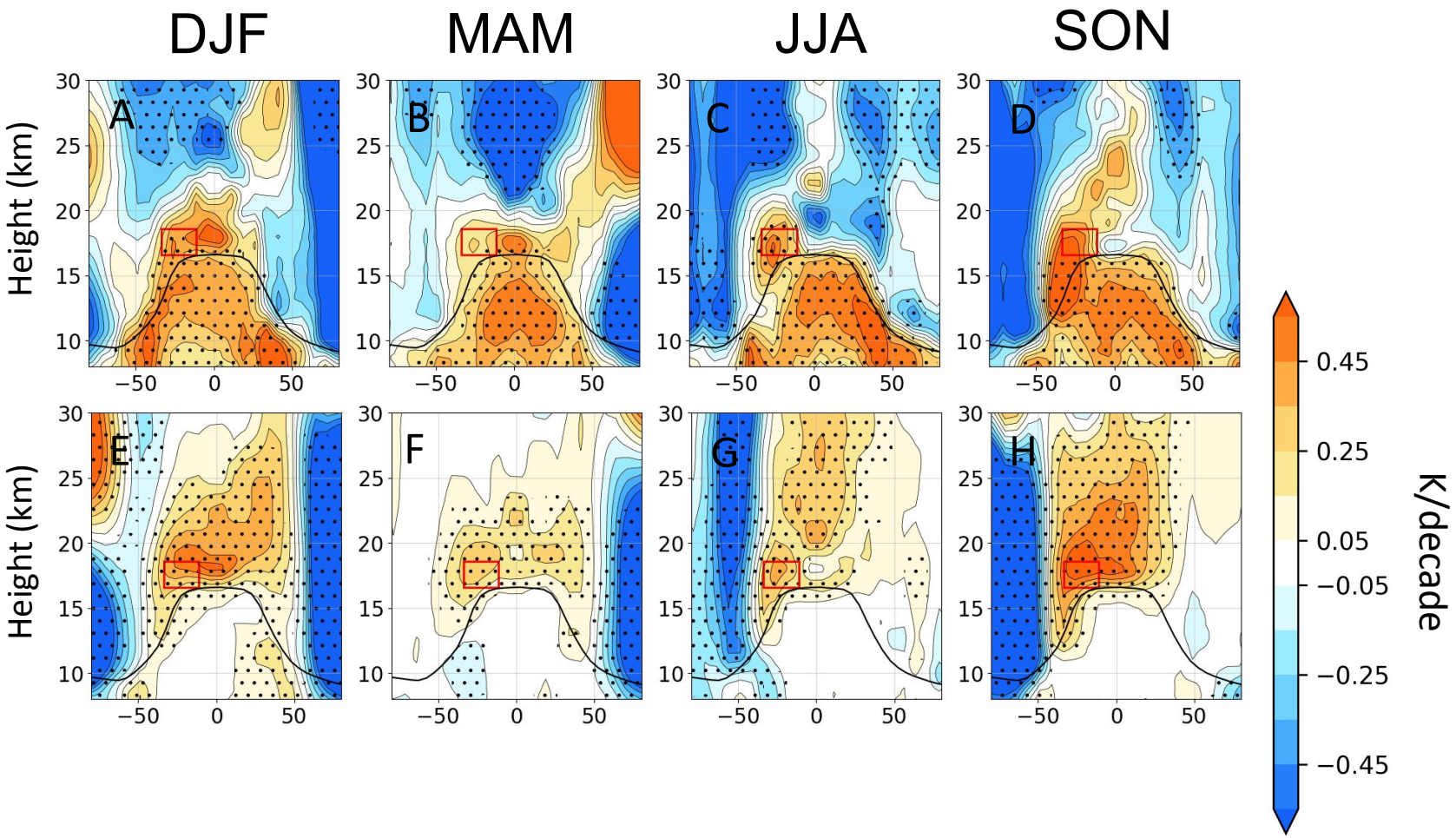
Dynamics mask signal of ozone recovery

Temperature Trends

Trends from Circulation Regression



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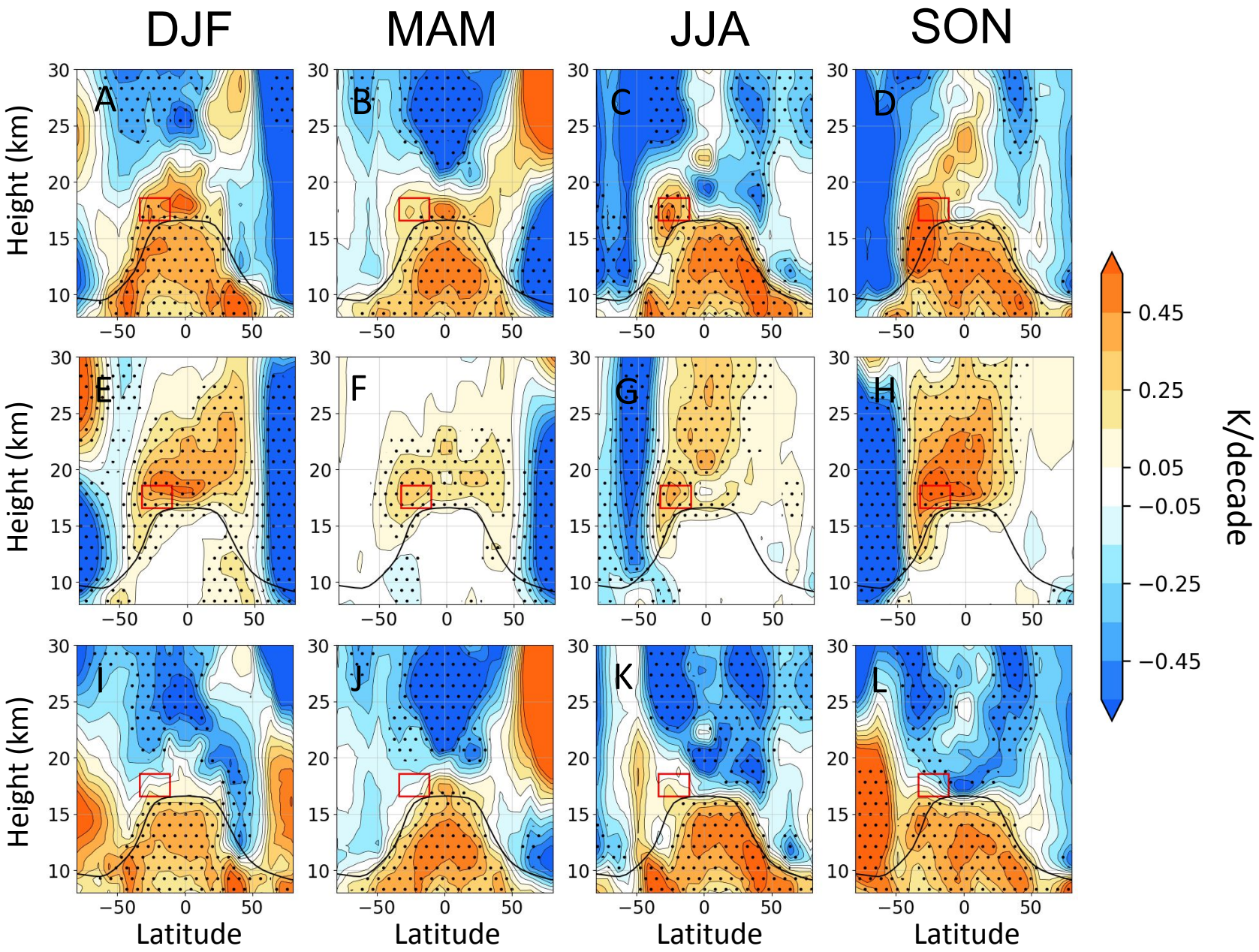

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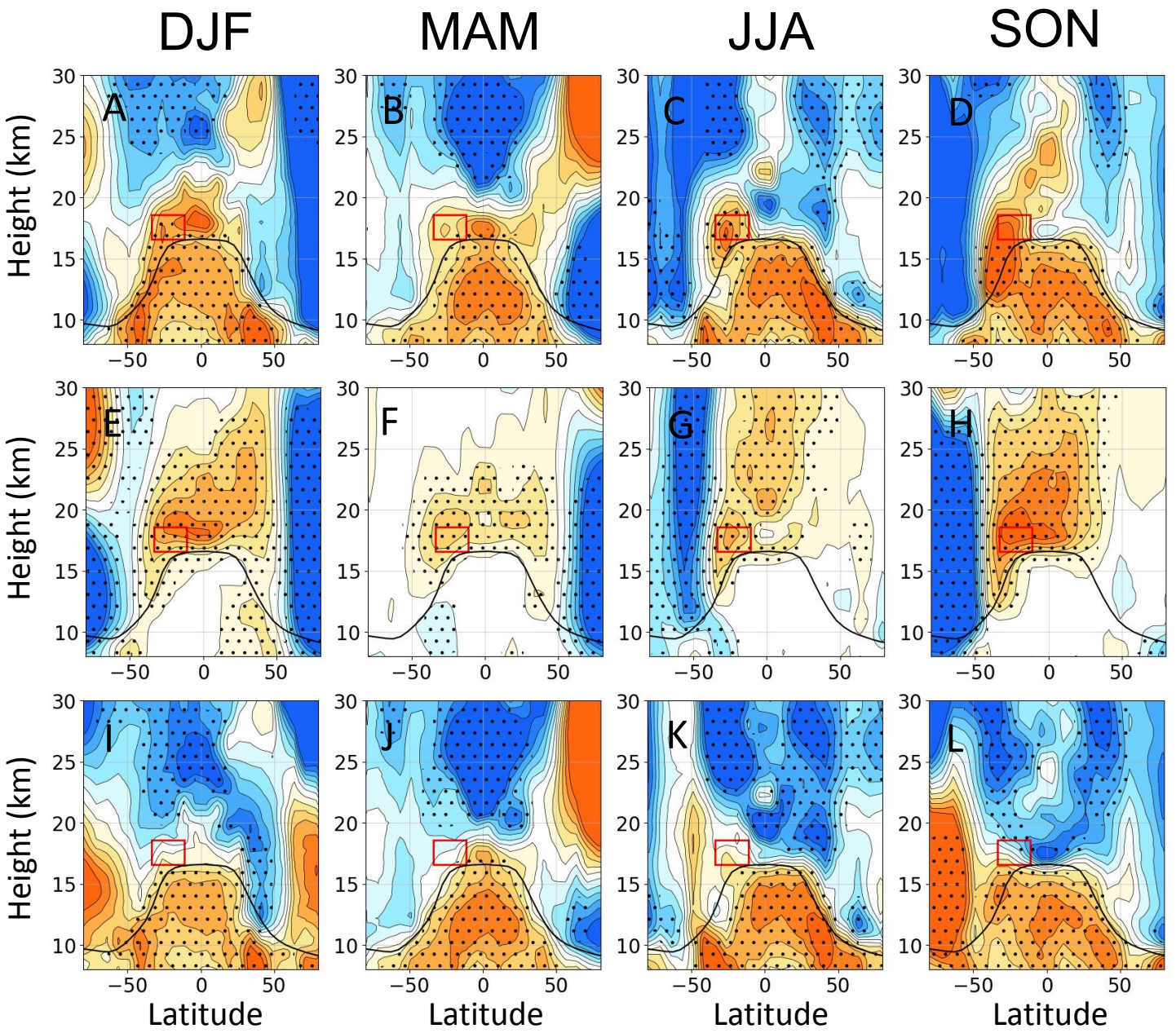

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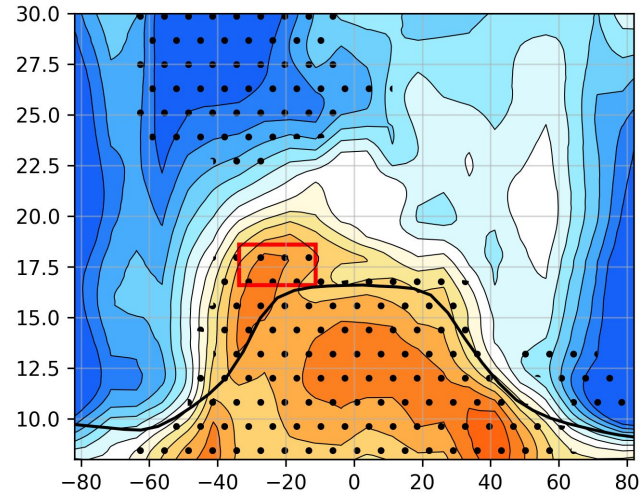
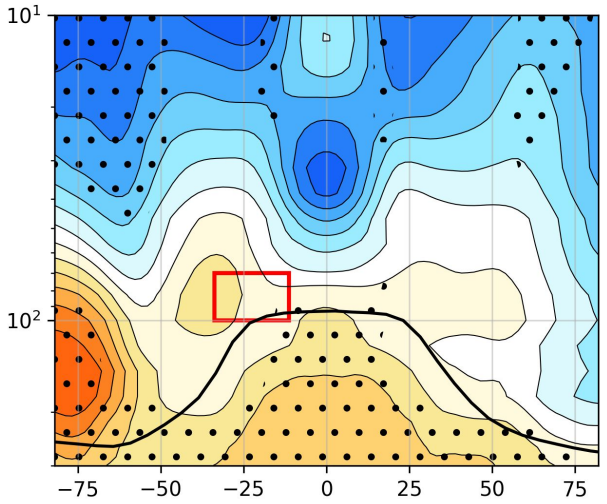
Observations

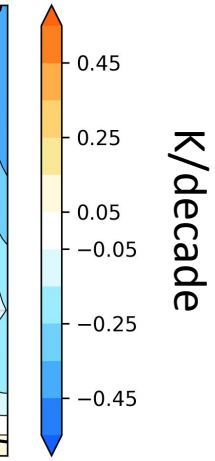
WACCM Ensemble Mean

Observations Minus Dynamics

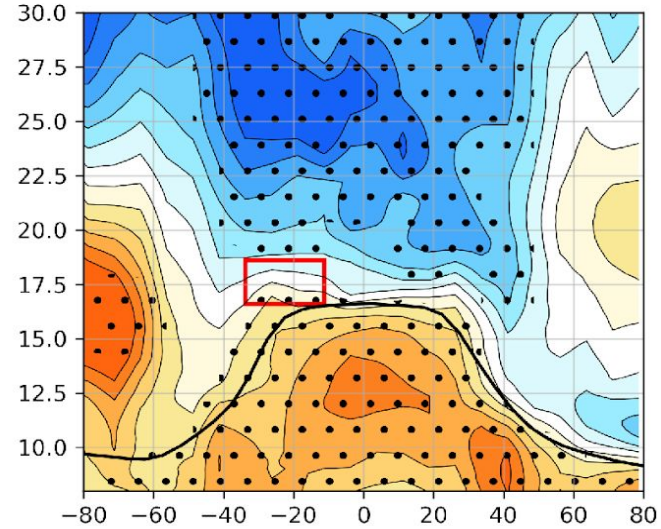
Temperature



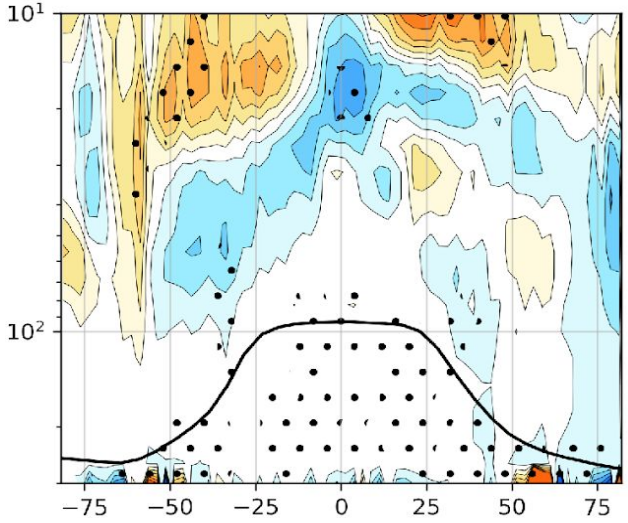


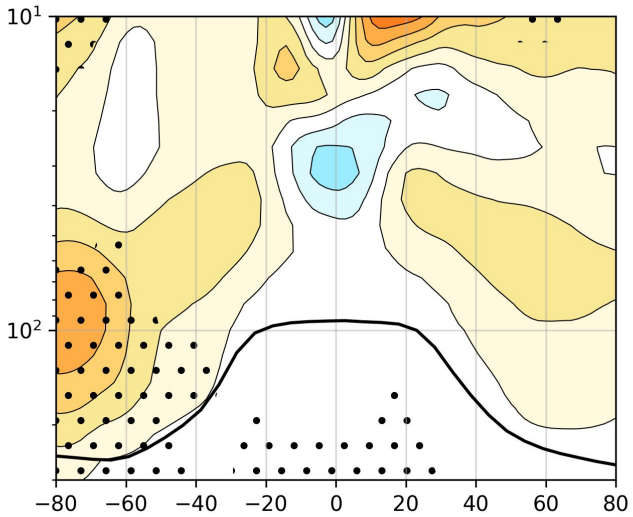


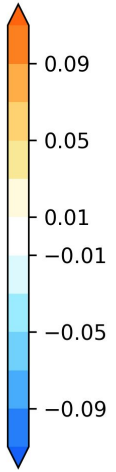
K/decade



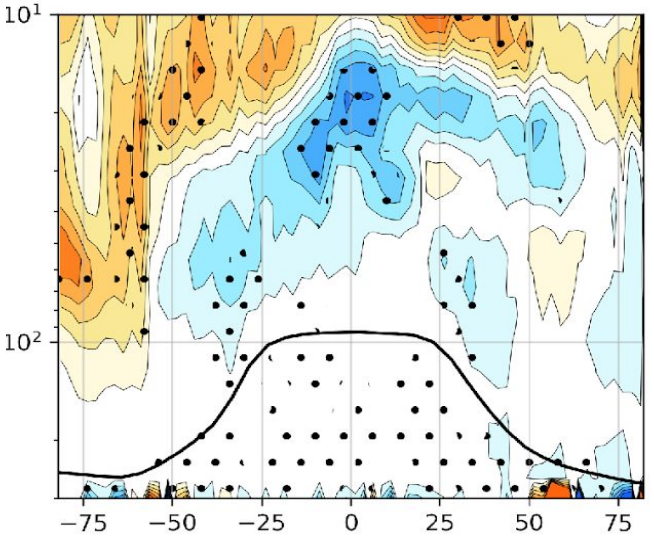
Ozone





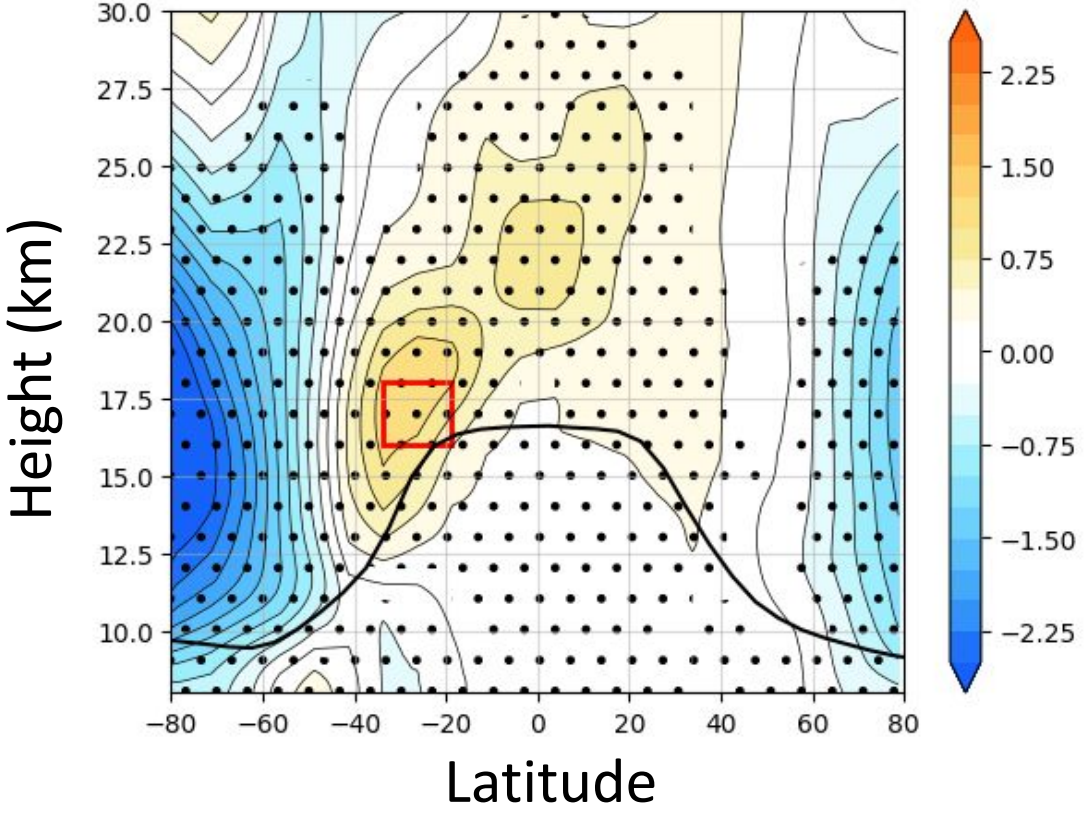


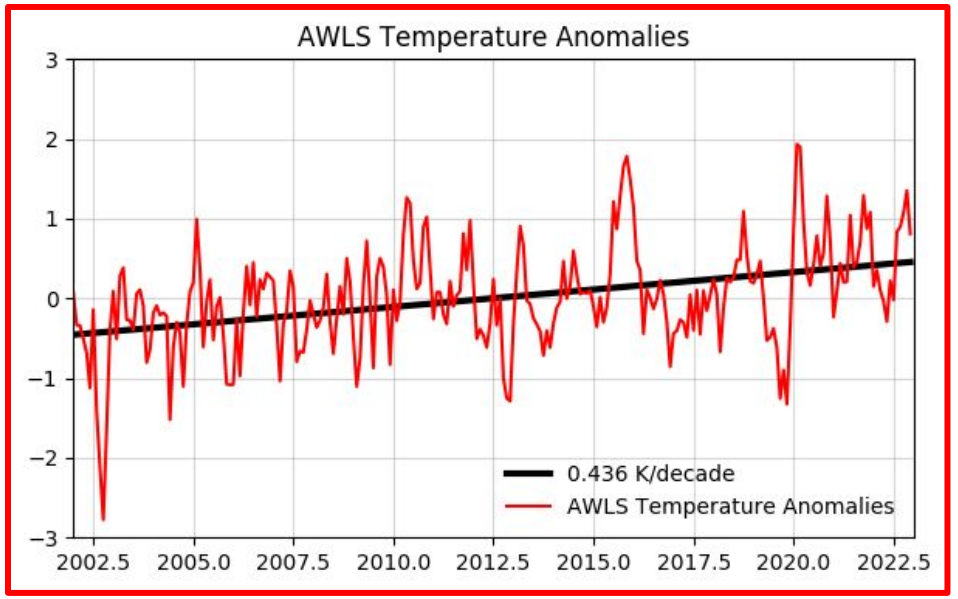
ppmv/decade

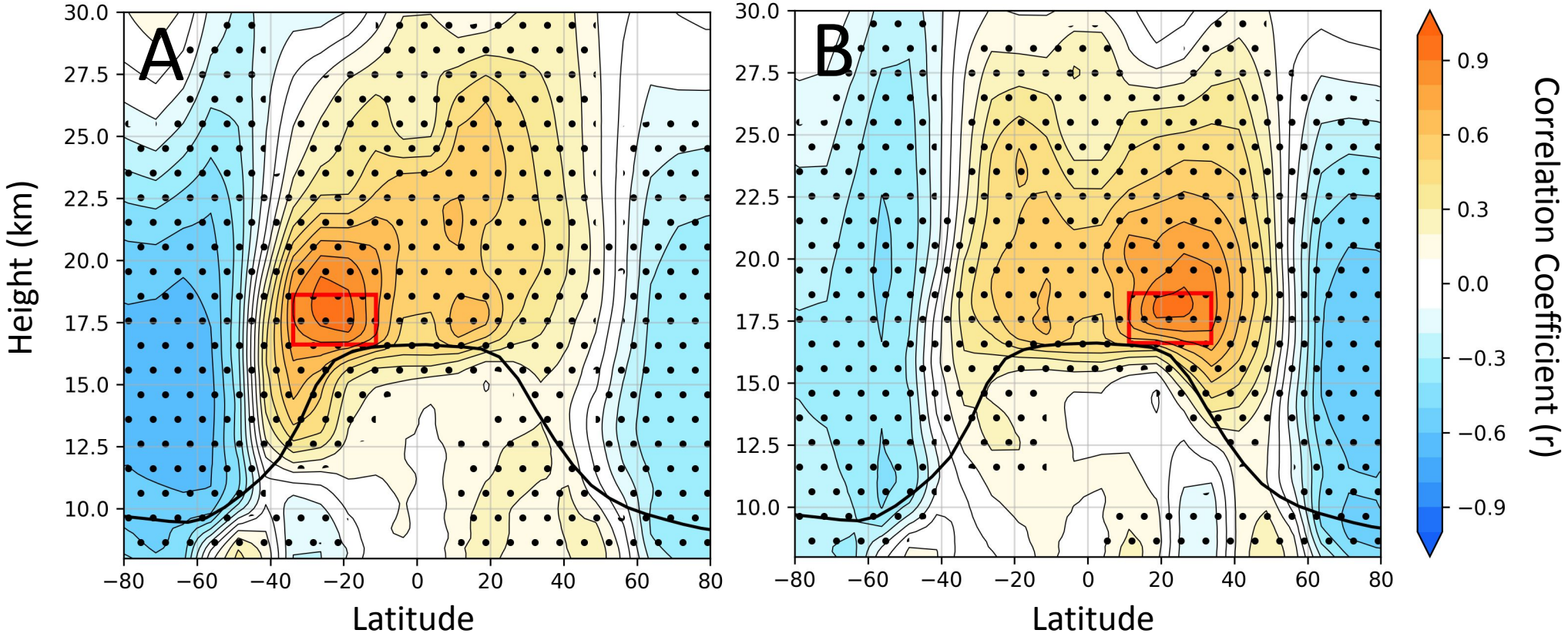


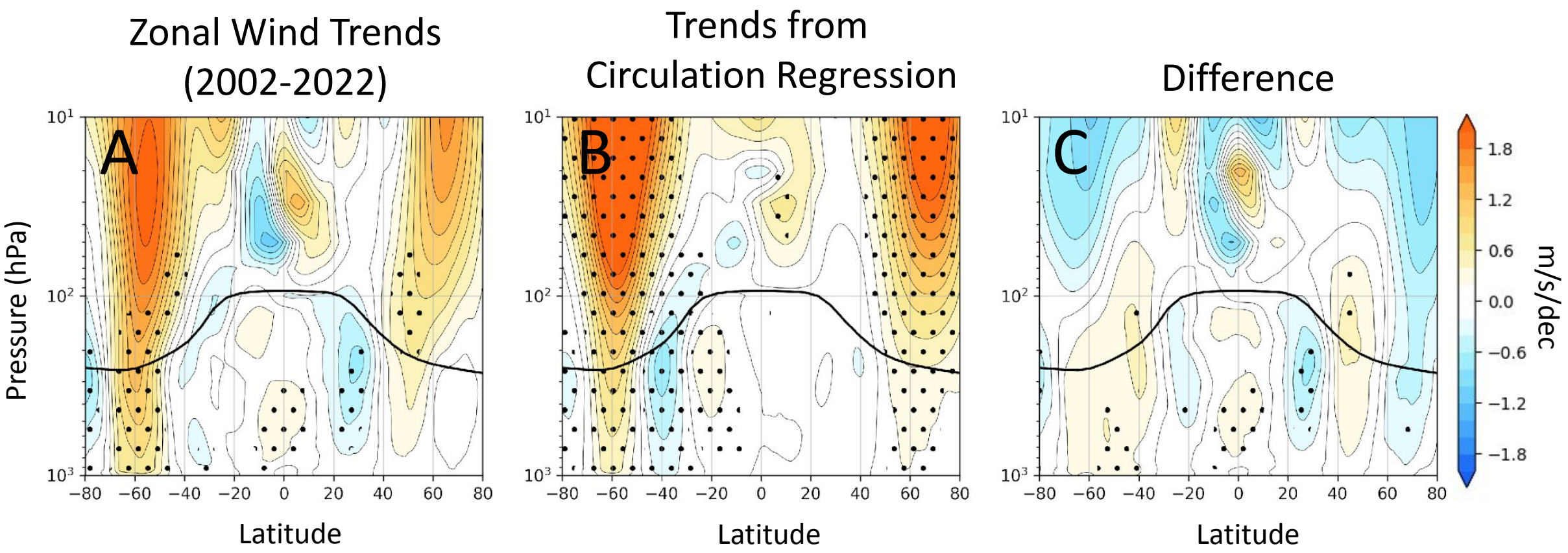
The AWLS is dynamically induced

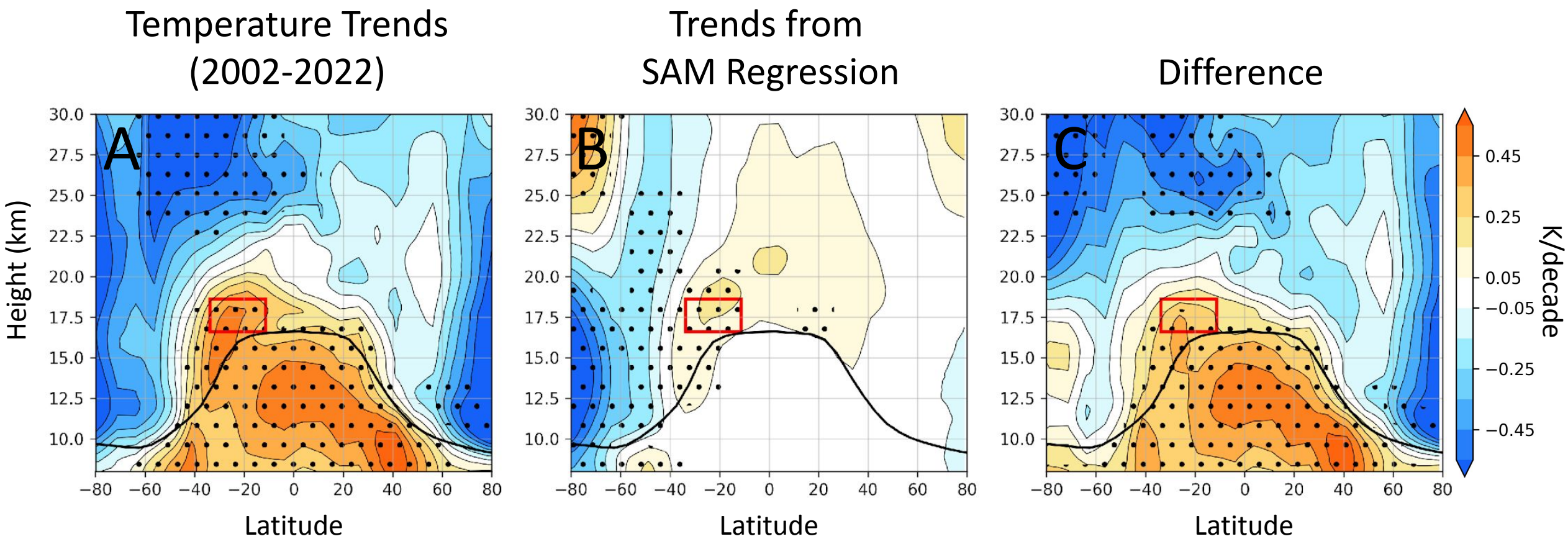
Regression Coefficients of AWLS and Temperature (detrended)



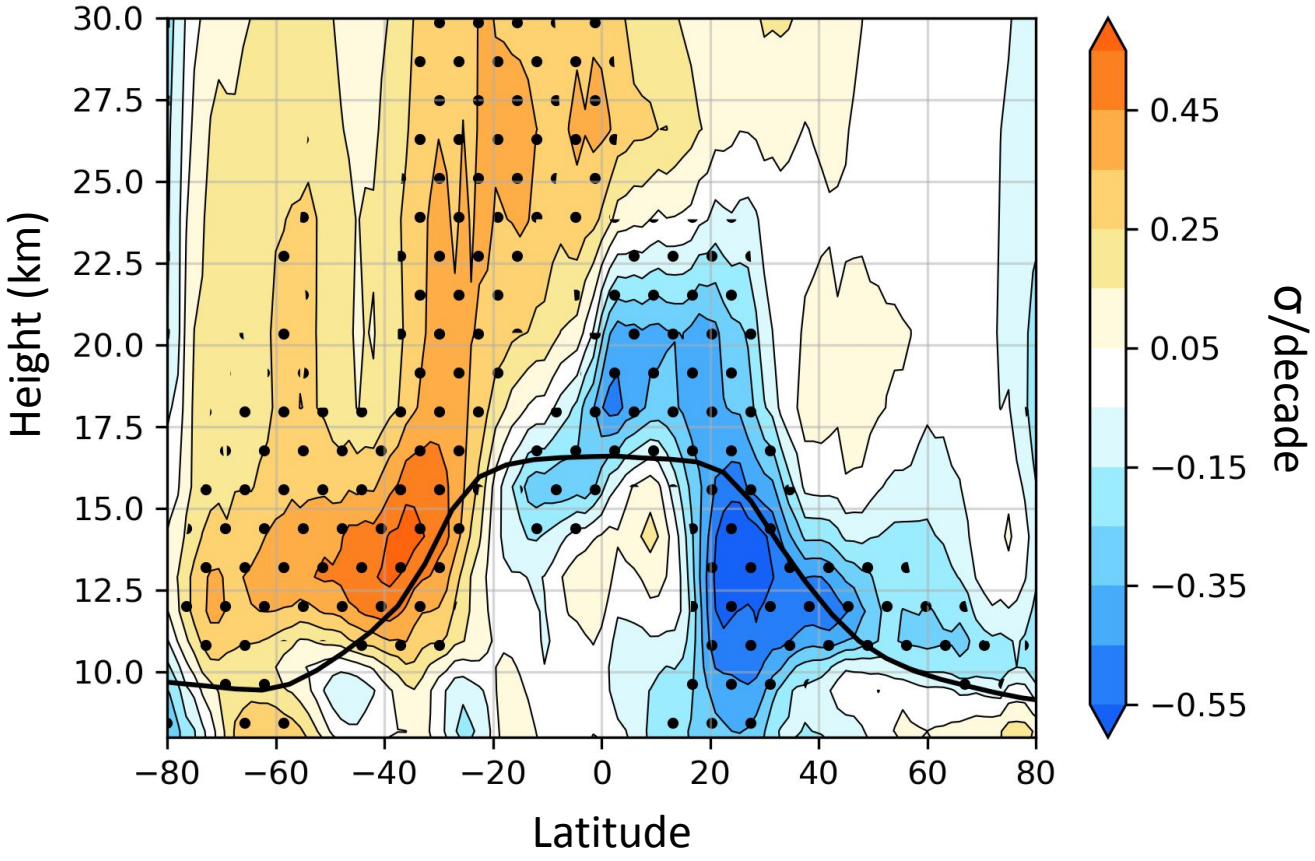


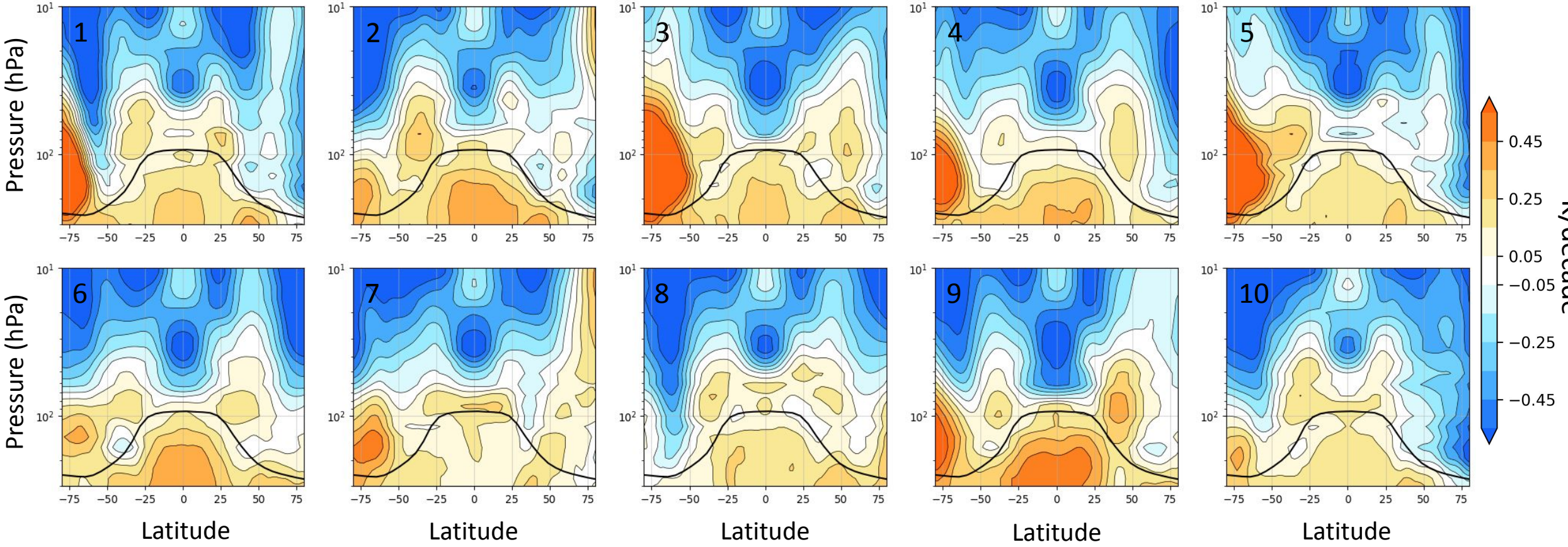

A
B
Height (km)
Latitude
Latitude
Correlation Coefficient (r)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
−80
−60
−40
−20
0
20
40
60
80
0.9
0.6
0.3
0.0
−0.3
−0.6
−0.9

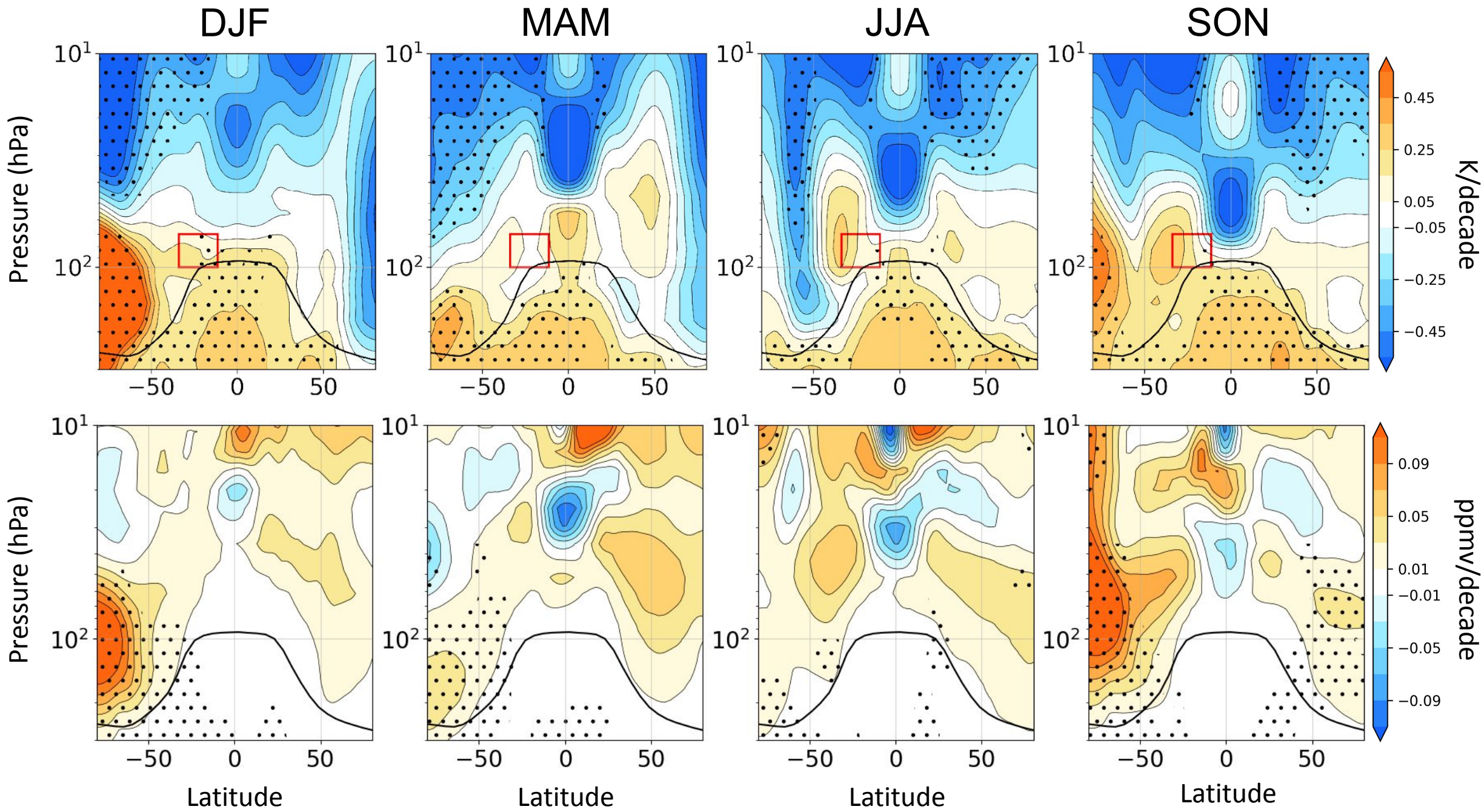

Zonal Wind Trends
(2002-2022)
Trends from
Circulation Regression
Difference
A
B
C
Pressure (hPa)
10^1
10^2
10^3
−80 −60 −40 −20 0 20 40 60 80
Latitude
1.8
1.2
0.6
0.0
−0.6
−1.2
−1.8
m/s/dec

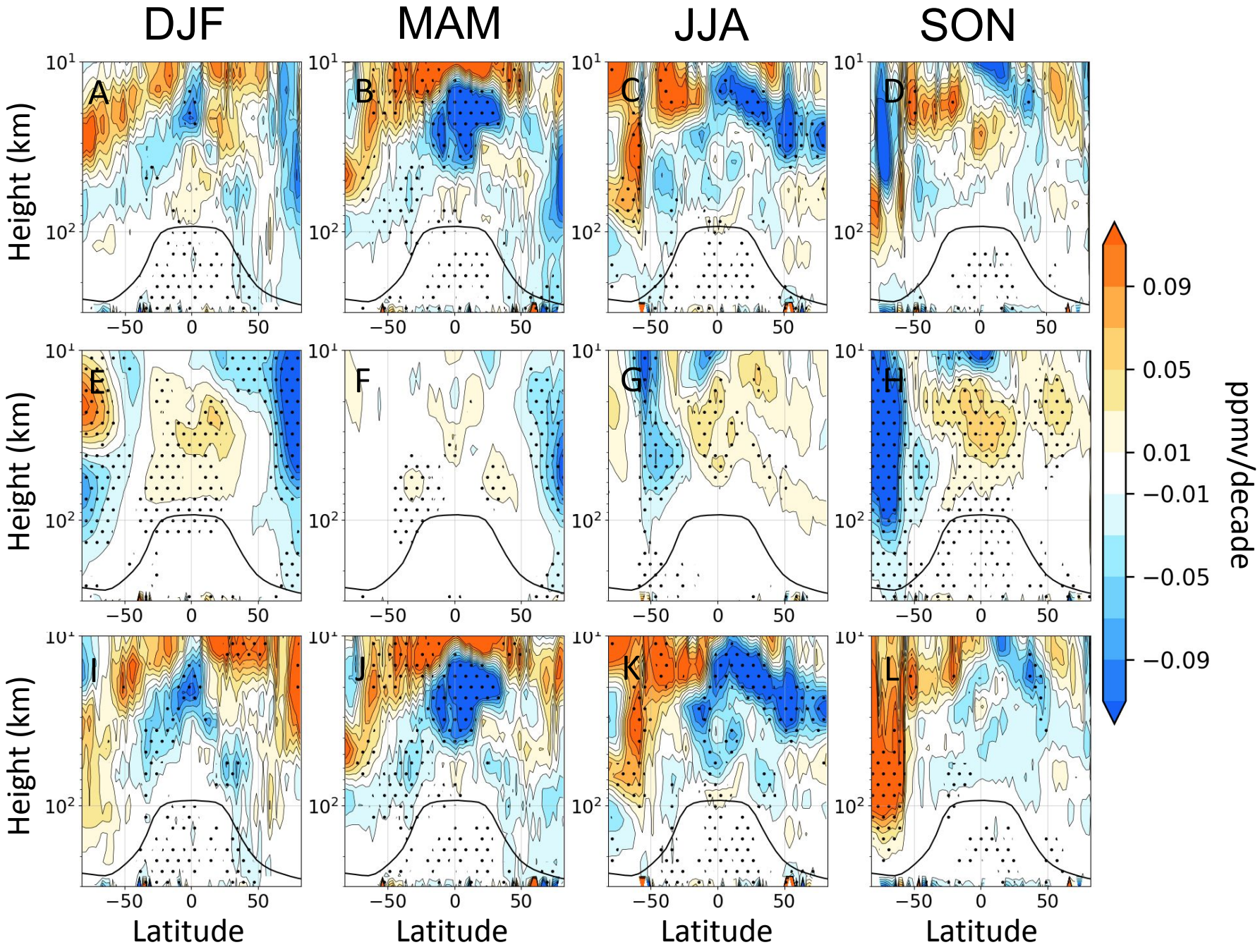

Temperature Trends
(2002-2022)
Trends from
SAM Regression
Difference
A
B
C
Height (km)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
−80 −60 −40 −20 0 20 40 60 80
Latitude
0.45
0.25
0.05
−0.05
−0.25
−0.45
K/decade

Residual Stream Function (Ψ*) Trends 2002-2022




1
2
3
4
5
6
7
8
9
10
Pressure (hPa)
Latitude
K/decade
0.45
0.25
0.05
−0.05
−0.25
−0.45


DJF
MAM
JJA
SON
Pressure (hPa)
10^1
10^2
−50
0
50
Latitude
0.45
0.25
0.05
−0.05
−0.25
−0.45
K/decade
0.09
0.05
0.01
−0.01
−0.05
−0.09
ppmv/decade


DJF
MAM
JJA
SON
Ozone Trends
Trends from circulation Regression
Difference
Height (km)
Latitude
A
B
C
D
E
F
G
H
I
J
K
L
0.09
0.05
0.01
−0.01
−0.05
−0.09
ppmv/decade