How Does the Troposphere Amplify Stratospheric Variability?

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Suggested Answers to “Processes” Questions 1, 2, 3, 4

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Processes

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2. Which **tropospheric processes** are important to represent accurately for improved stratospheric predictability?
3. Can we **quantify** the strength of **stratospheric impact** on the troposphere (e.g., following weak and/or strong vortex events) versus the impact of other remote forcers such as MJO and ENSO?

Processes

1. Which **stratospheric processes** are important to represent accurately for improved tropospheric predictability on medium-range to seasonal timescales?
2. Which **tropospheric processes** are important to represent accurately for improved stratospheric predictability?
3. Can we **quantify** the strength of **stratospheric impact** on the troposphere (e.g., following weak and/or strong vortex events) versus the impact of other remote forcers such as MJO and ENSO?
4. What are the best **tools and metrics to objectively evaluate the strength of the stratosphere–troposphere coupling**, and, the skill provided by the stratosphere for tropospheric predictability?

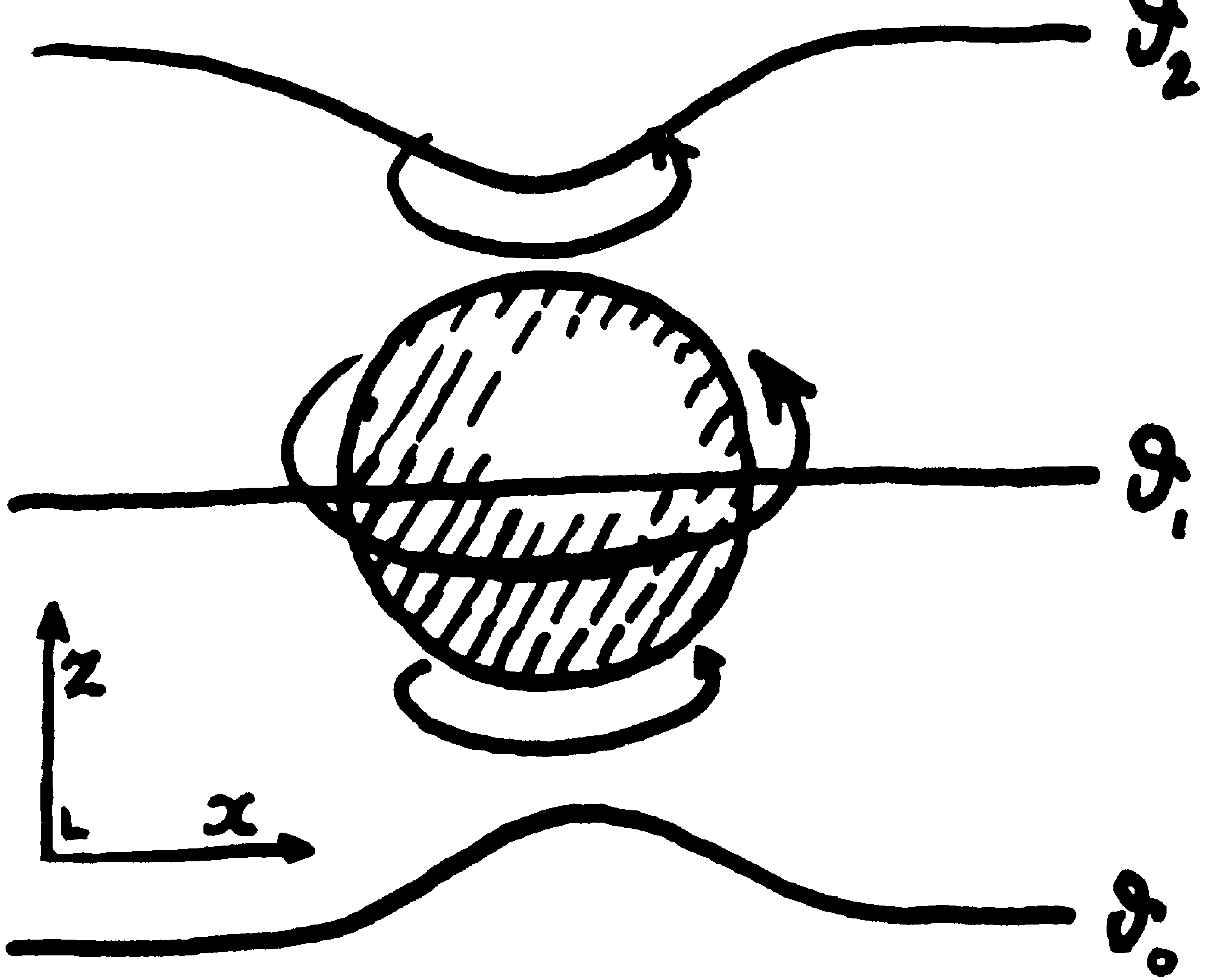
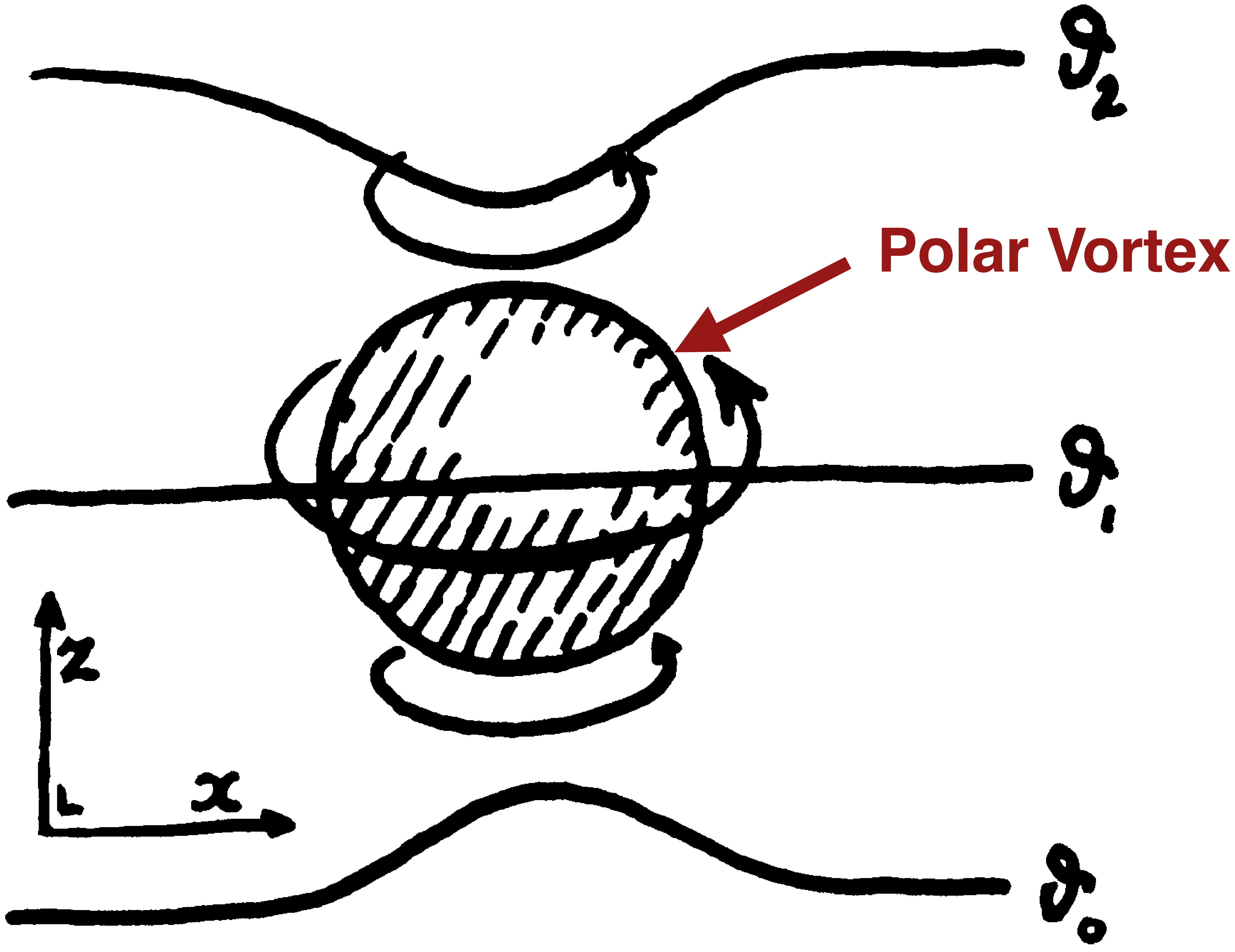


FIG. 4. Schematic of the bending of isentropic surfaces (labeled θ_0, θ_1, and θ_2) toward a positive potential vorticity anomaly. The arrows represent winds associated with the potential vorticity anomaly, becoming weaker away from the anomaly.

Diagram from Ambaum and Hoskins *J Climate* (2002).



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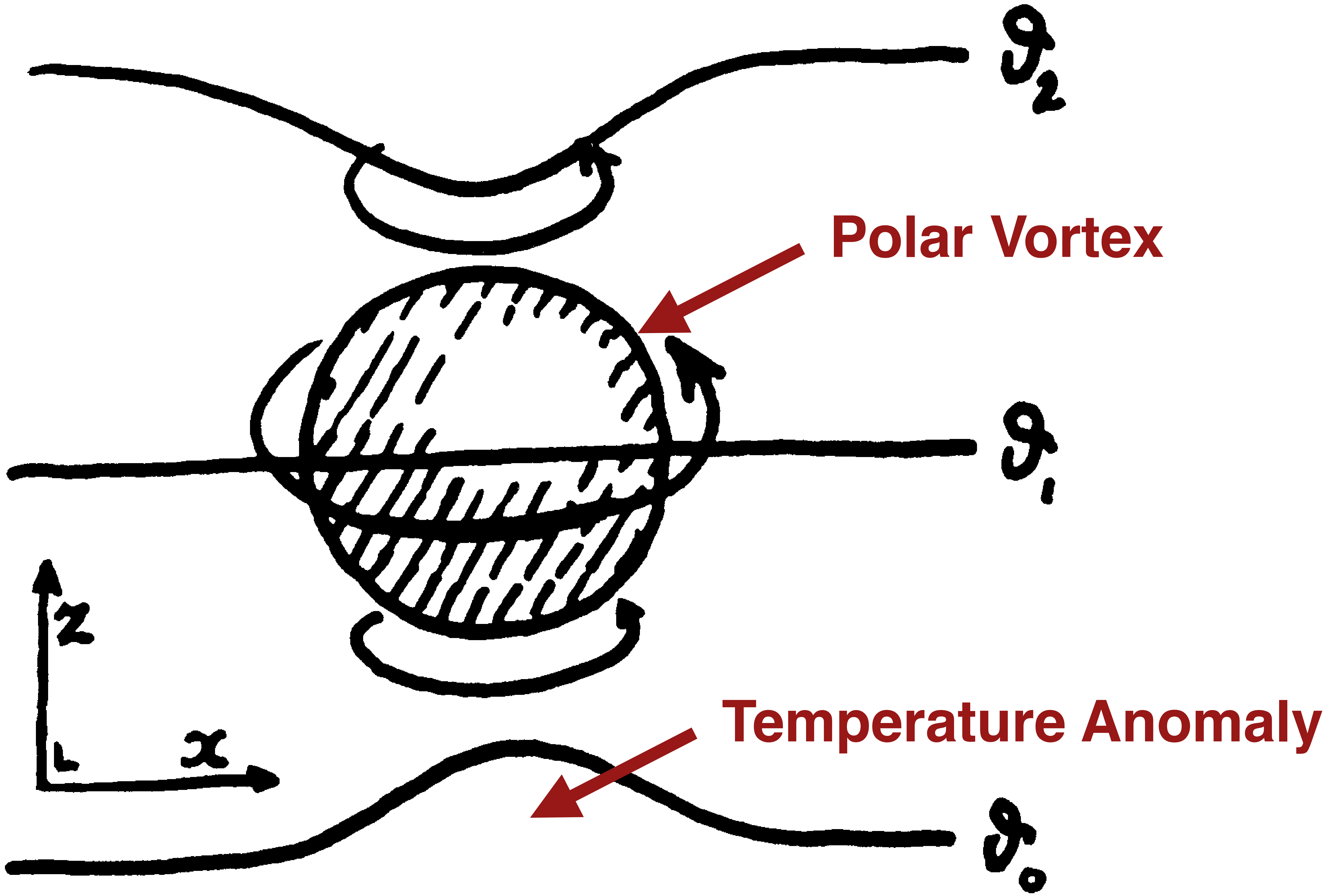

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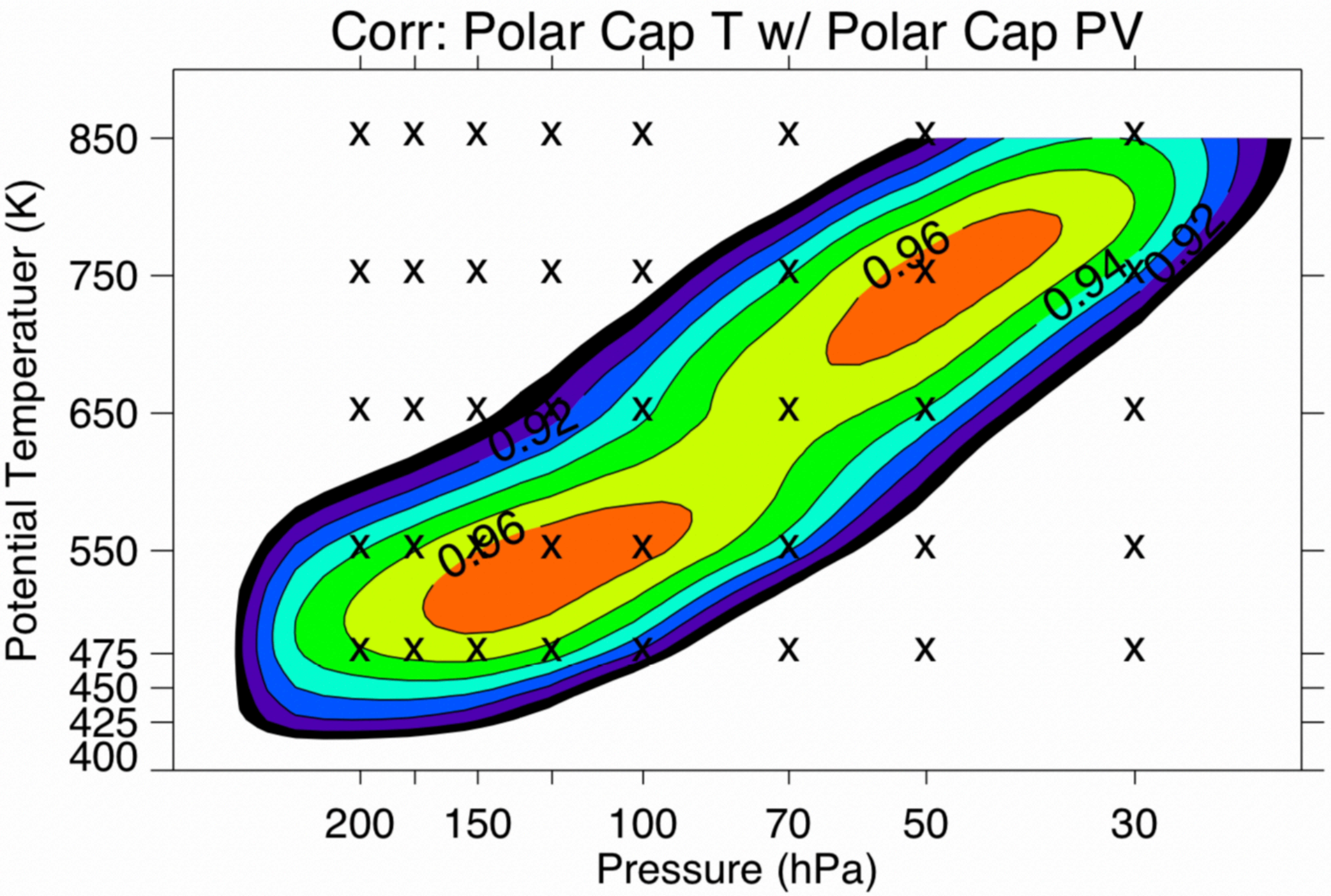
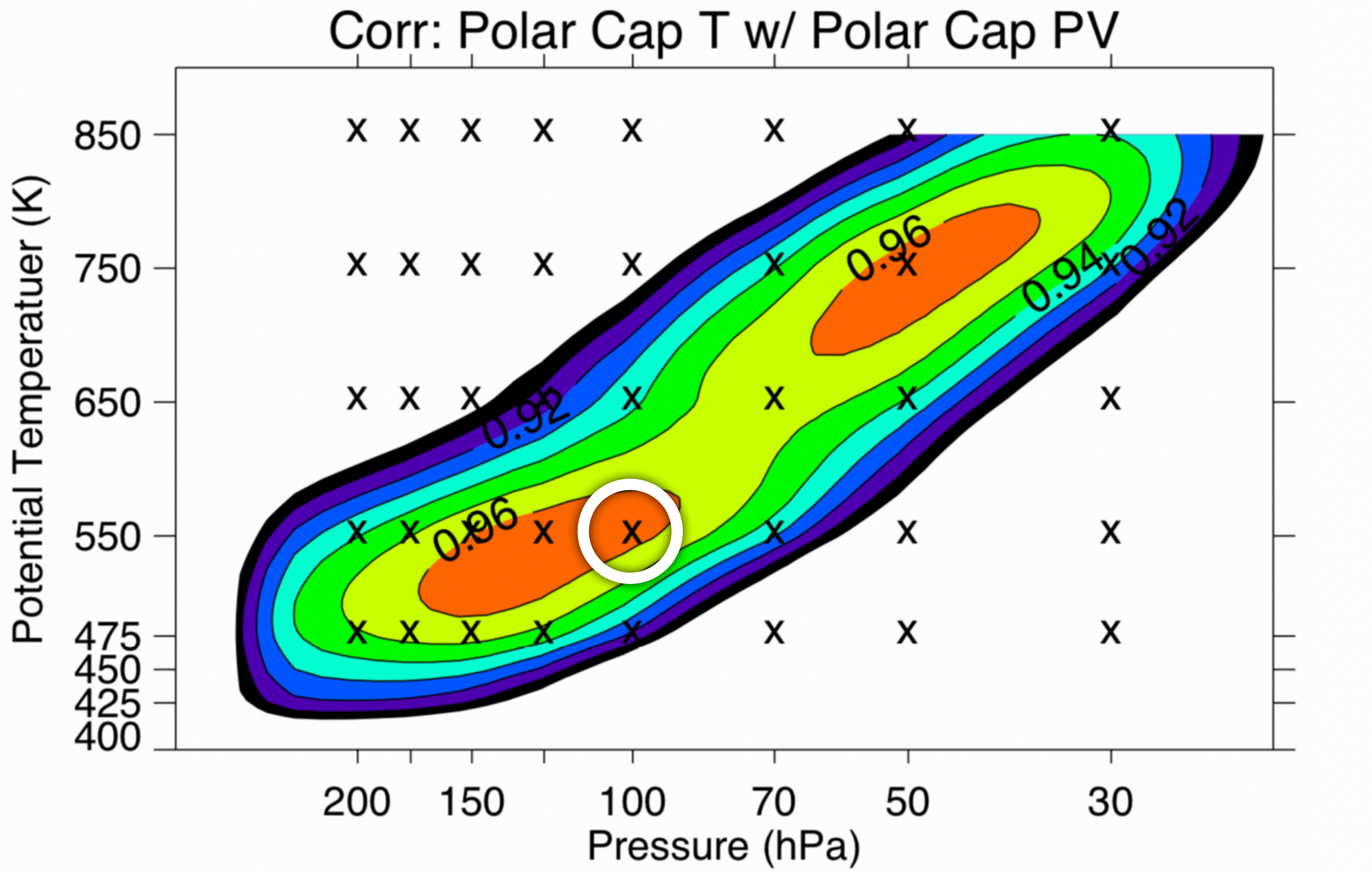
Does this work in JRA-55 reanalysis? Correlate polar cap (65–90ºN) mean PV (on isentropic surfaces) with polar cap mean T on pressure surfaces.



Corr: Polar Cap T w/ Polar Cap PV
Potential Temperatuer (K)
850
750
650
550
475
450
425
400
0.96
0.94
0.92
0.92
0.96
200
150
100
70
50
30
Pressure (hPa)



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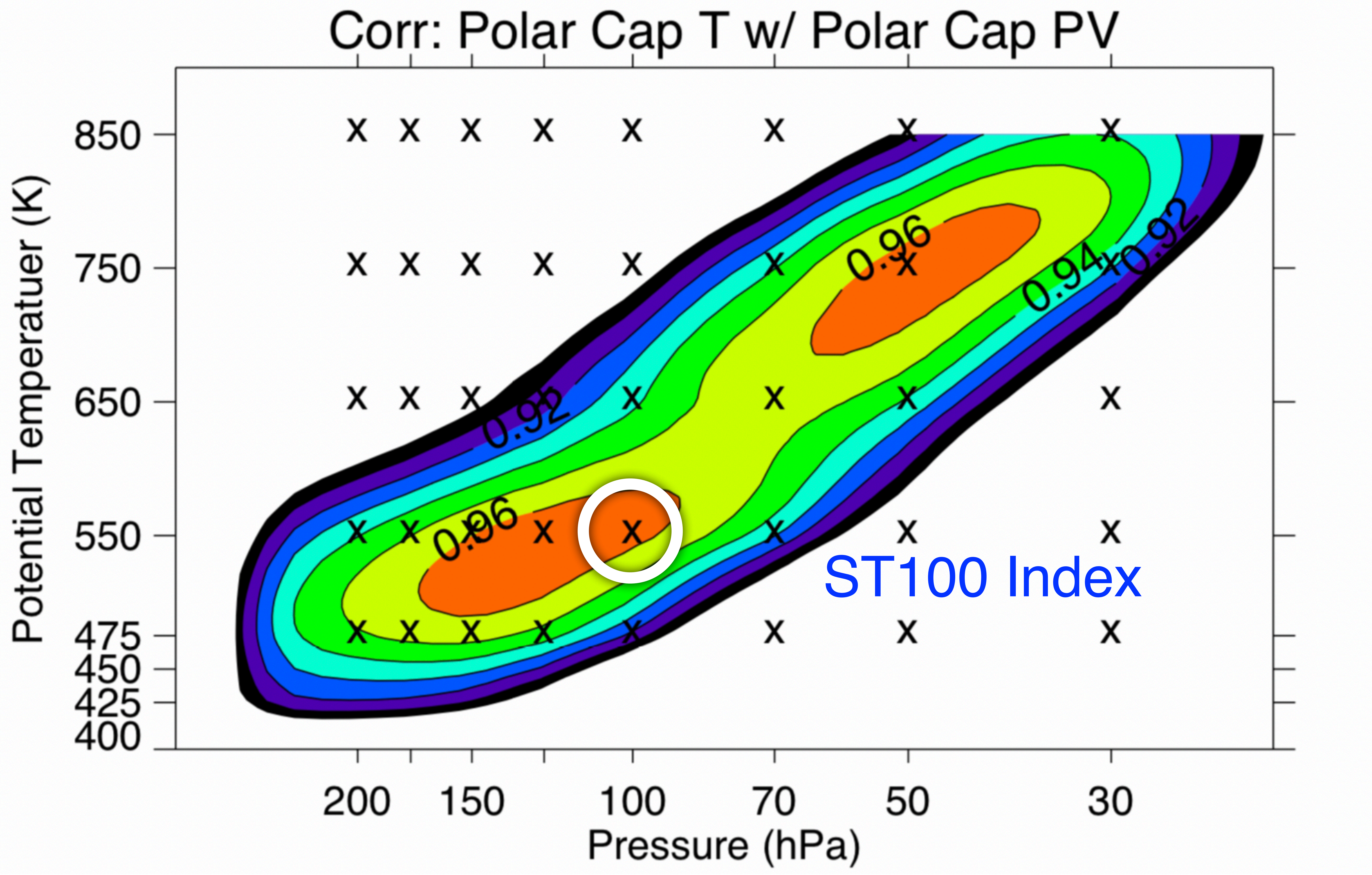

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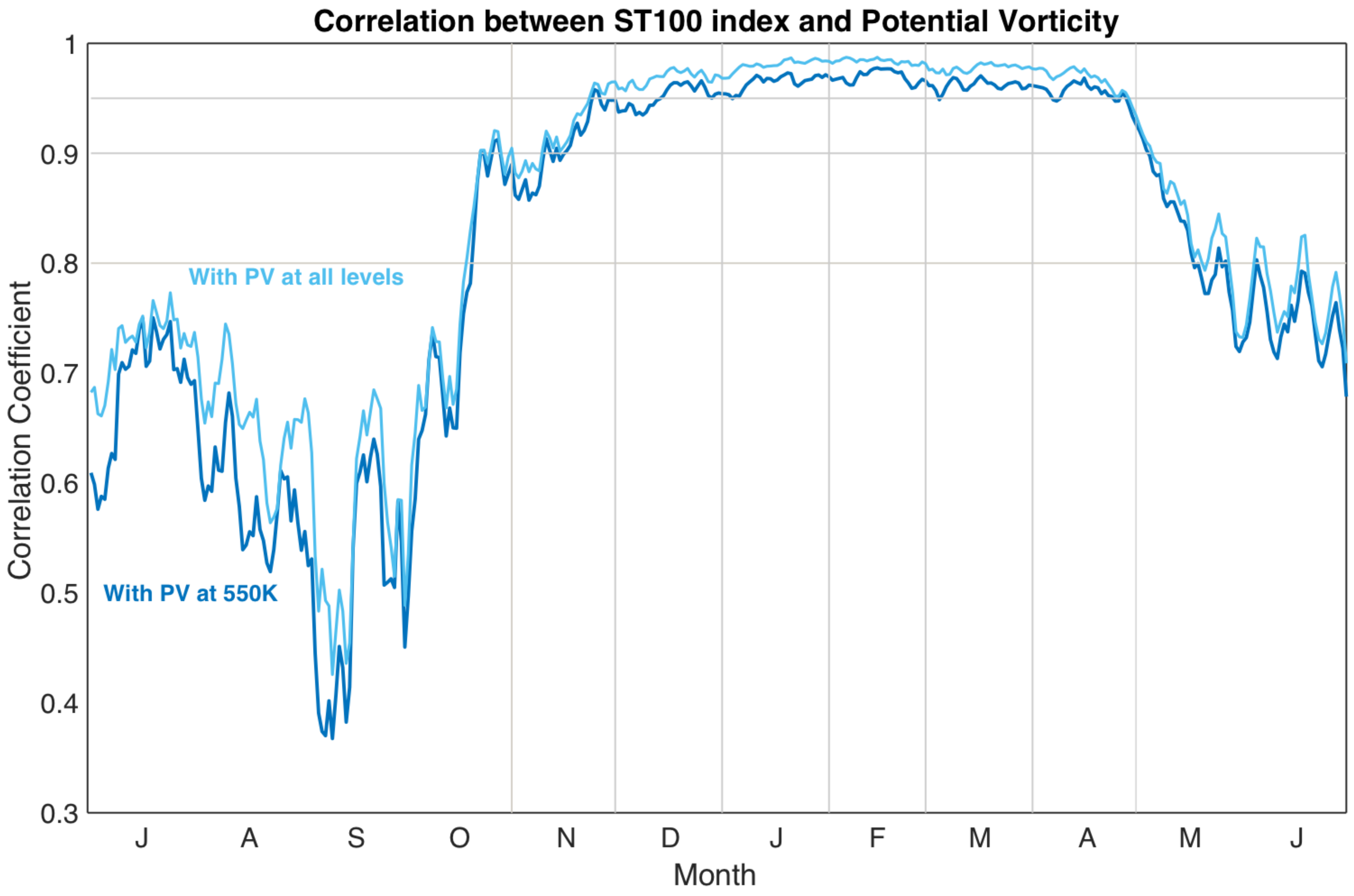
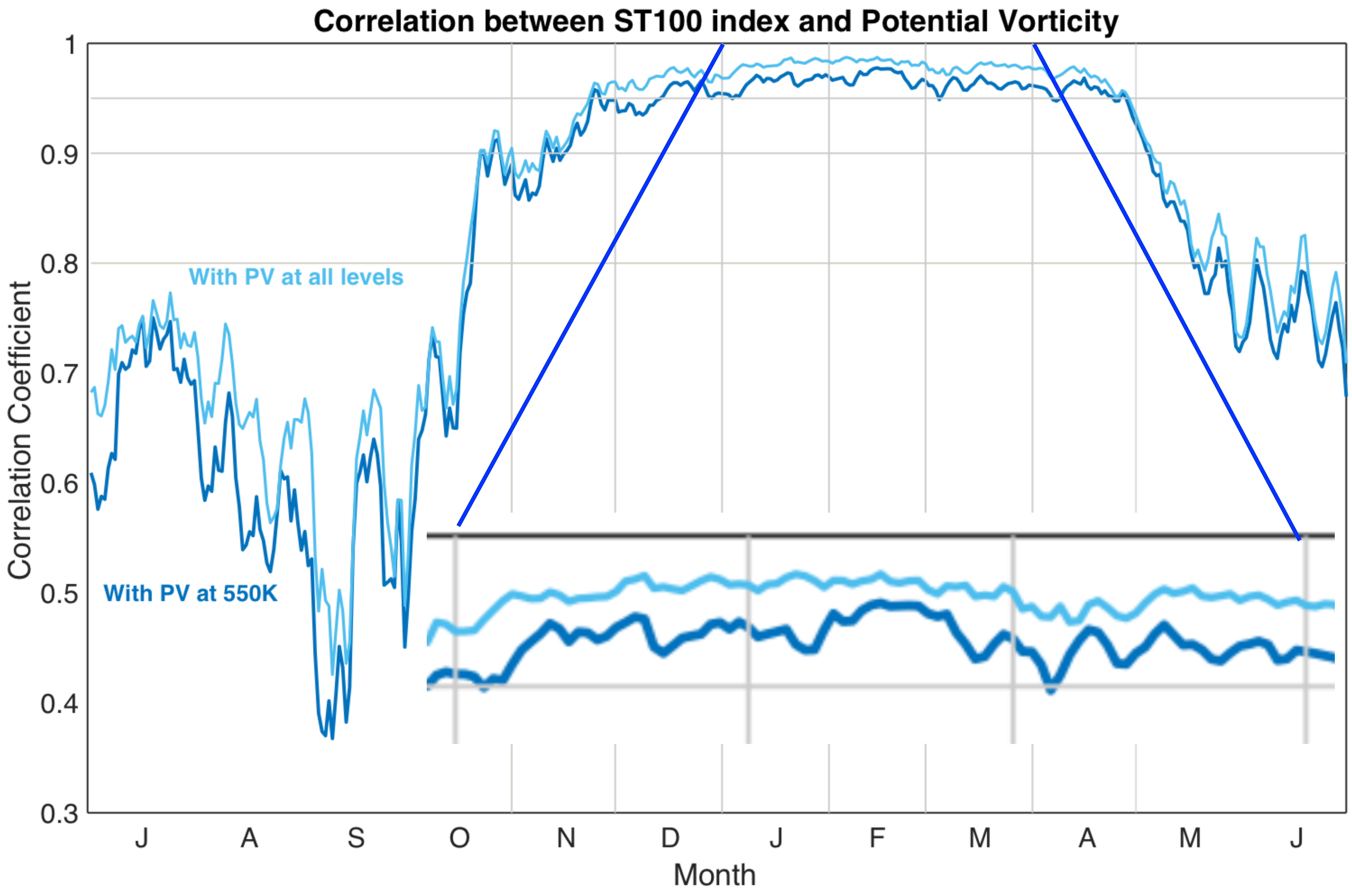
650
550
475
450
425
400
200
150
100
70
50
30
Pressure (hPa)
0.96
0.94
0.92
ST100 Index



Correlation between ST100 index and Potential Vorticity
Correlation Coefficient
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
With PV at all levels
With PV at 550K
J
A
S
O
N
D
J
F
M
A
M
J
Month


Correlation between ST100 index and Potential Vorticity
With PV at all levels
With PV at 550K
Correlation Coefficient
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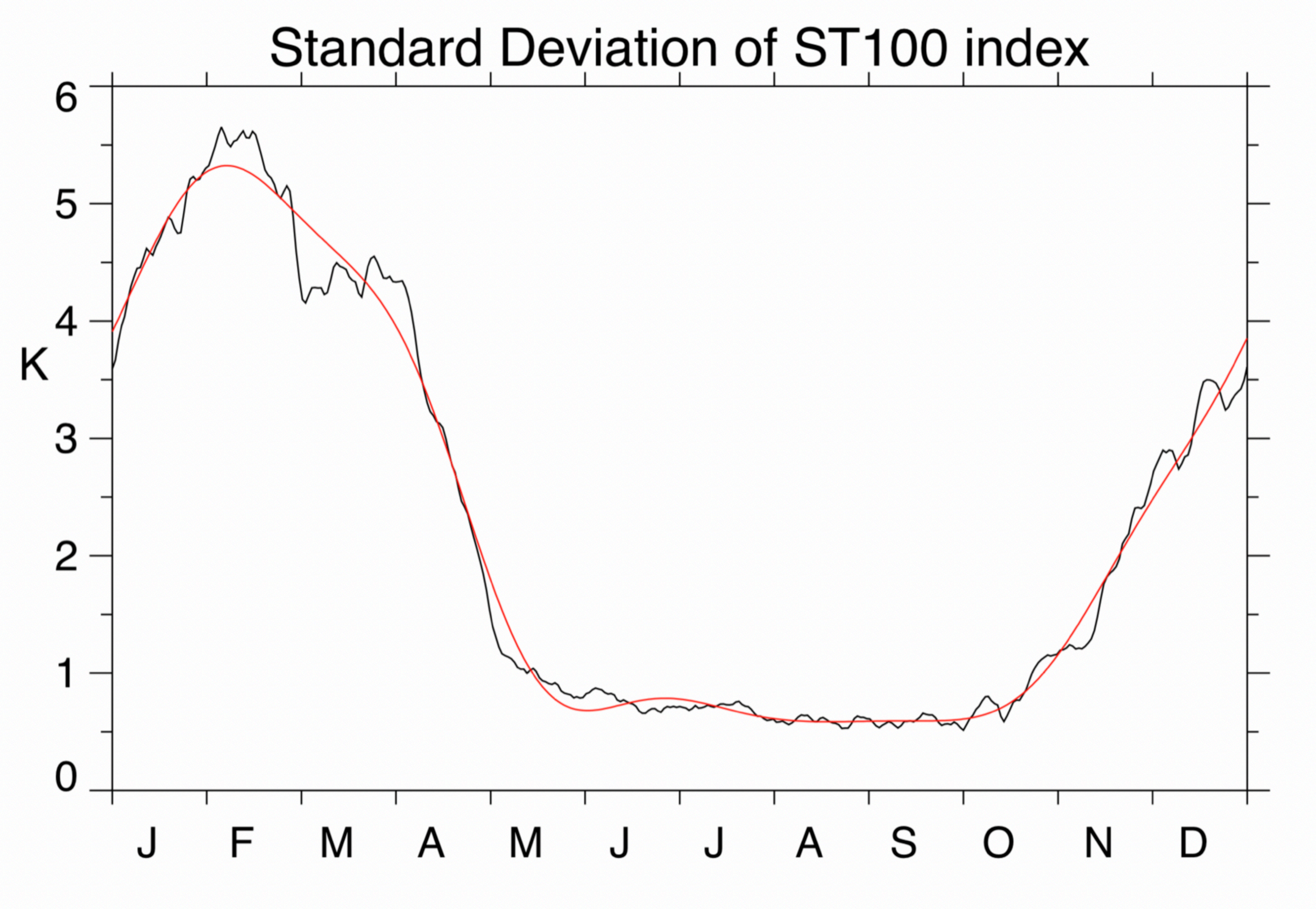
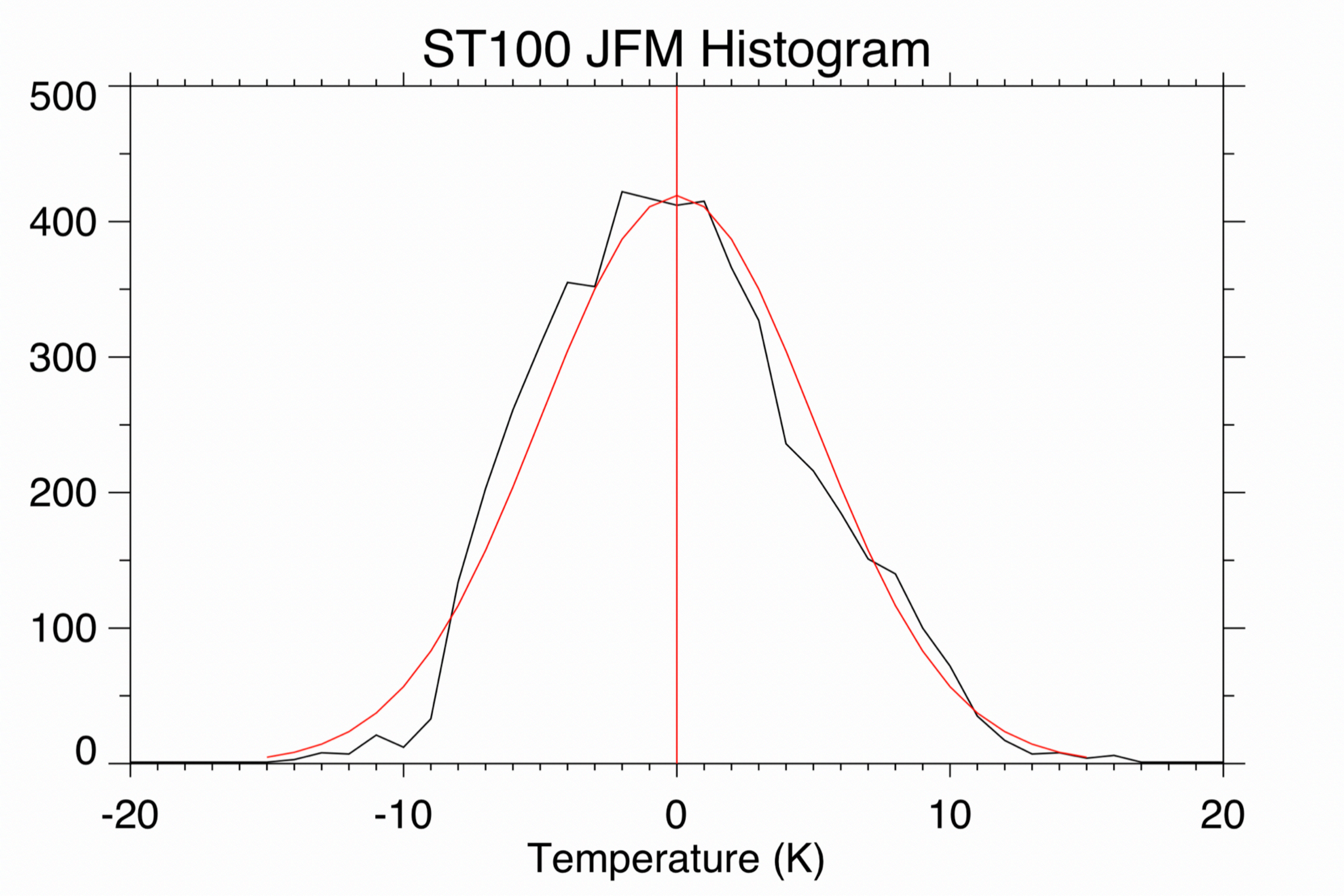
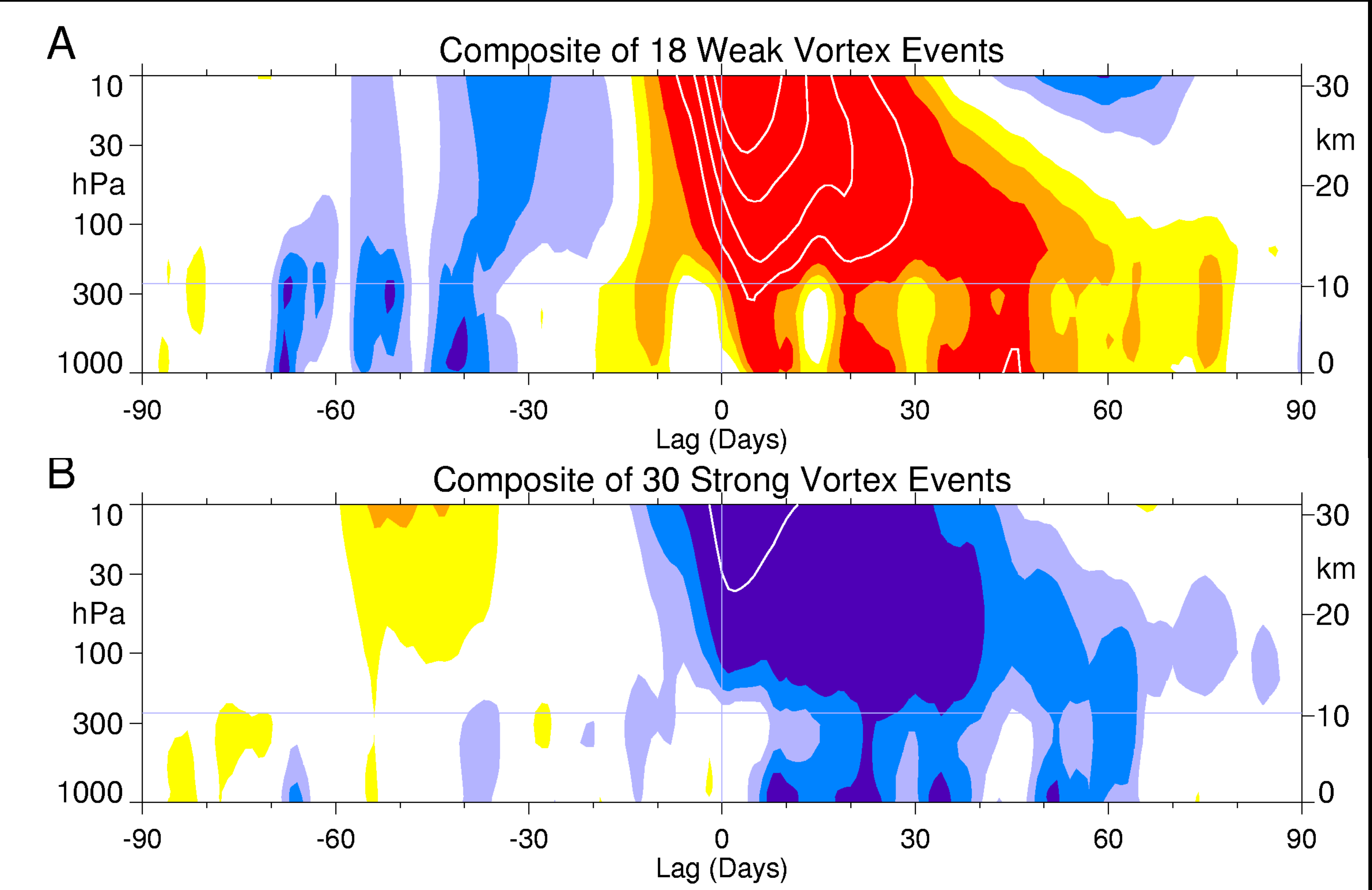
0.9
0.8
0.7
0.6
0.5
0.4
0.3
J A S O N D J F M A M J
Month


Standard Deviation of ST100 index
6
5
4
K
3
2
1
0
J
F
M
A
M
J
J
A
S
O
N
D


ST100 JFM Histogram
500
400
300
200
100
0
-20
-10
0
10
20
Temperature (K)

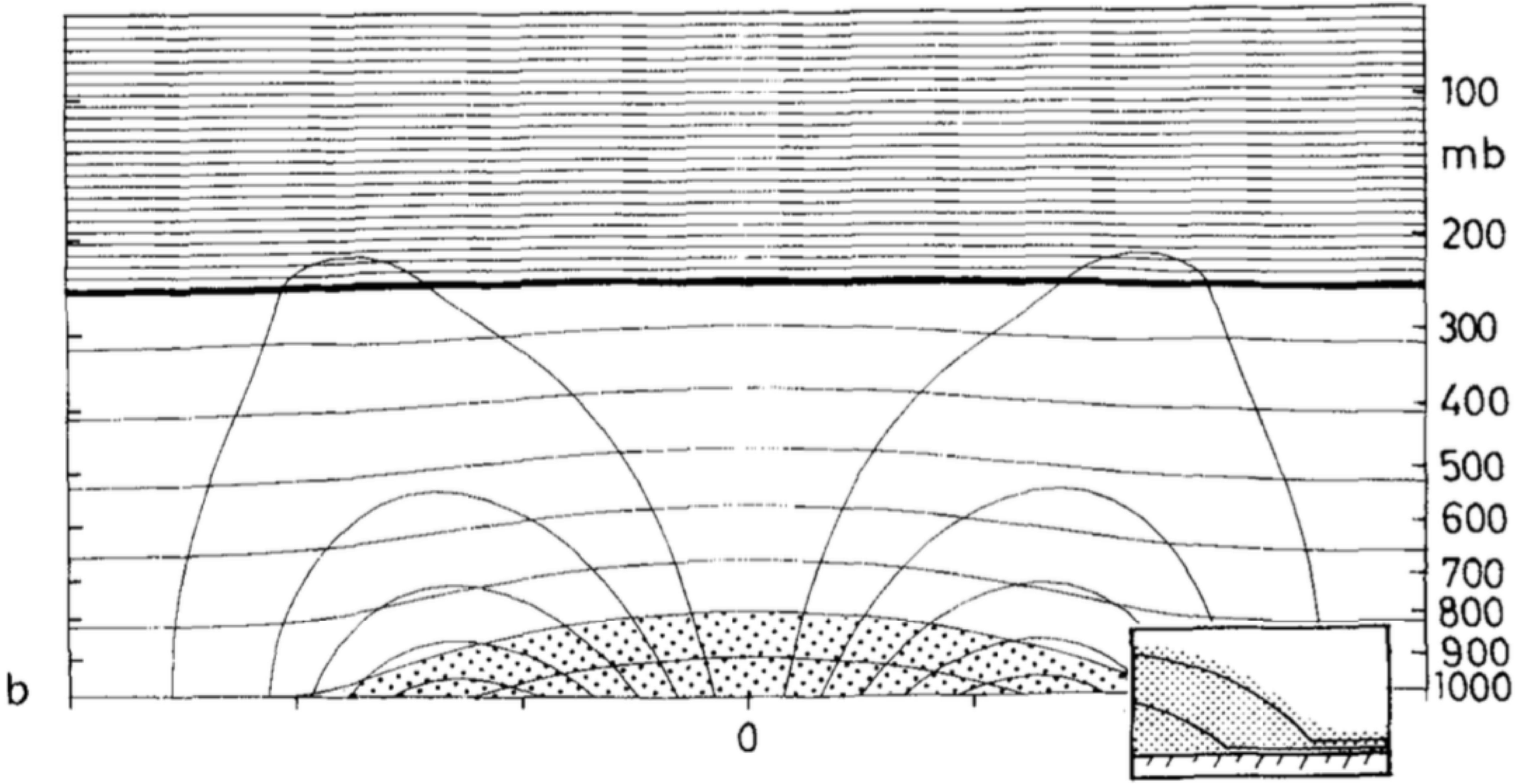


(From Baldwin and Dunkerton, *Science* 2001)

Low-level cold anomalies induce higher surface pressure

- Cold-core anticyclones (such as the wintertime Siberian anticyclone) provide a well-documented example of the effect of radiative cooling on SLP.
- The Siberian region becomes snow-covered in October and high pressure results from **radiative cooling-induced anticyclogenesis**.
- Wexler (1937): if radiative cooling is confined to a restricted area, it will be accompanied by the lowering of isobaric surfaces.
- A compensating inflow of air from adjacent regions will occur, causing SLP to rise.
- Low-level cooling causes the air mass to contract, resulting in inflow, and higher SLP.

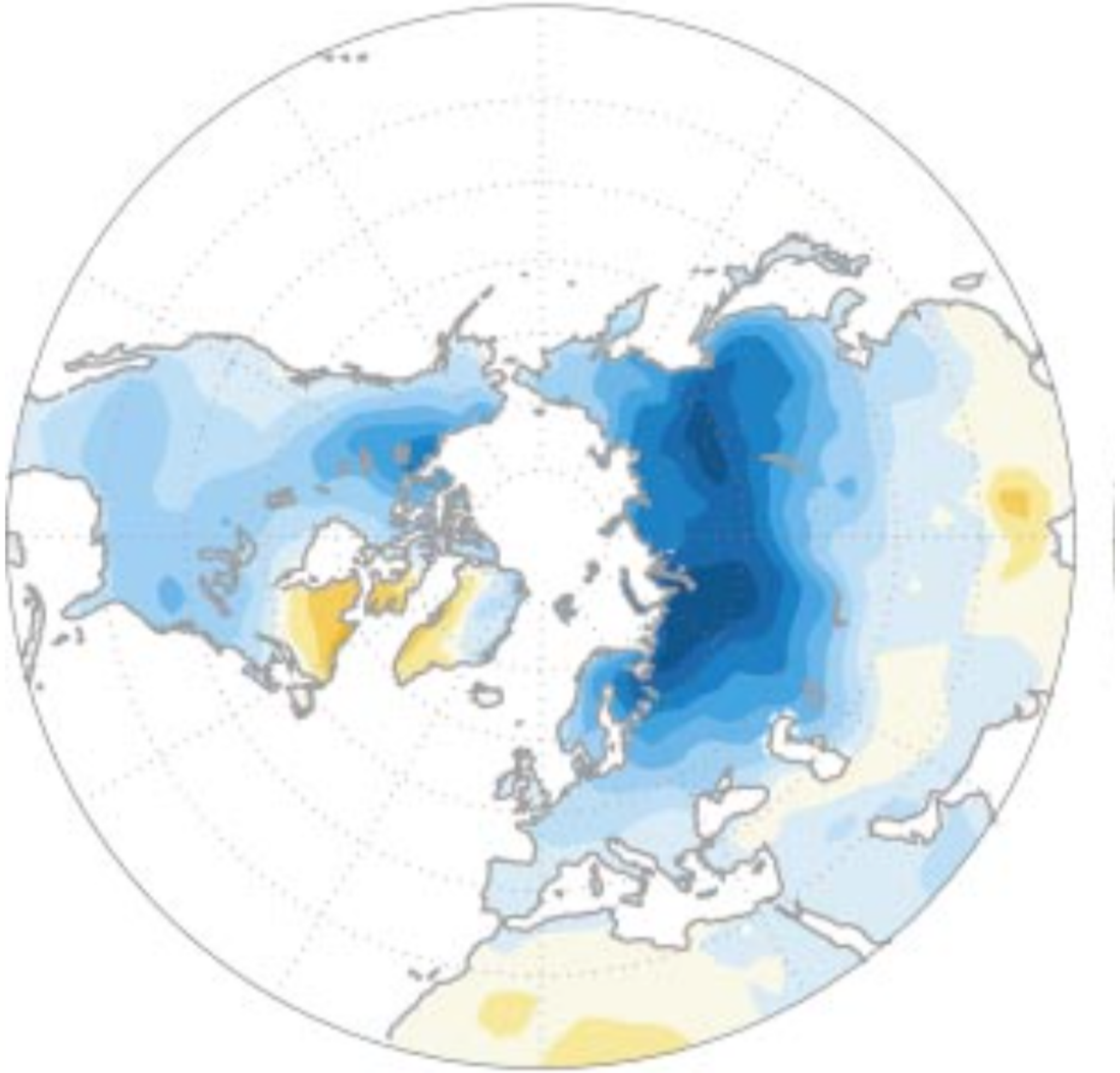
Simulations from Hoskins et al., 1985



A low-level cold anomaly *induces* higher surface pressure.
A low-level warm anomaly *induces* lower surface pressure.

The Arctic is colder following SSWs

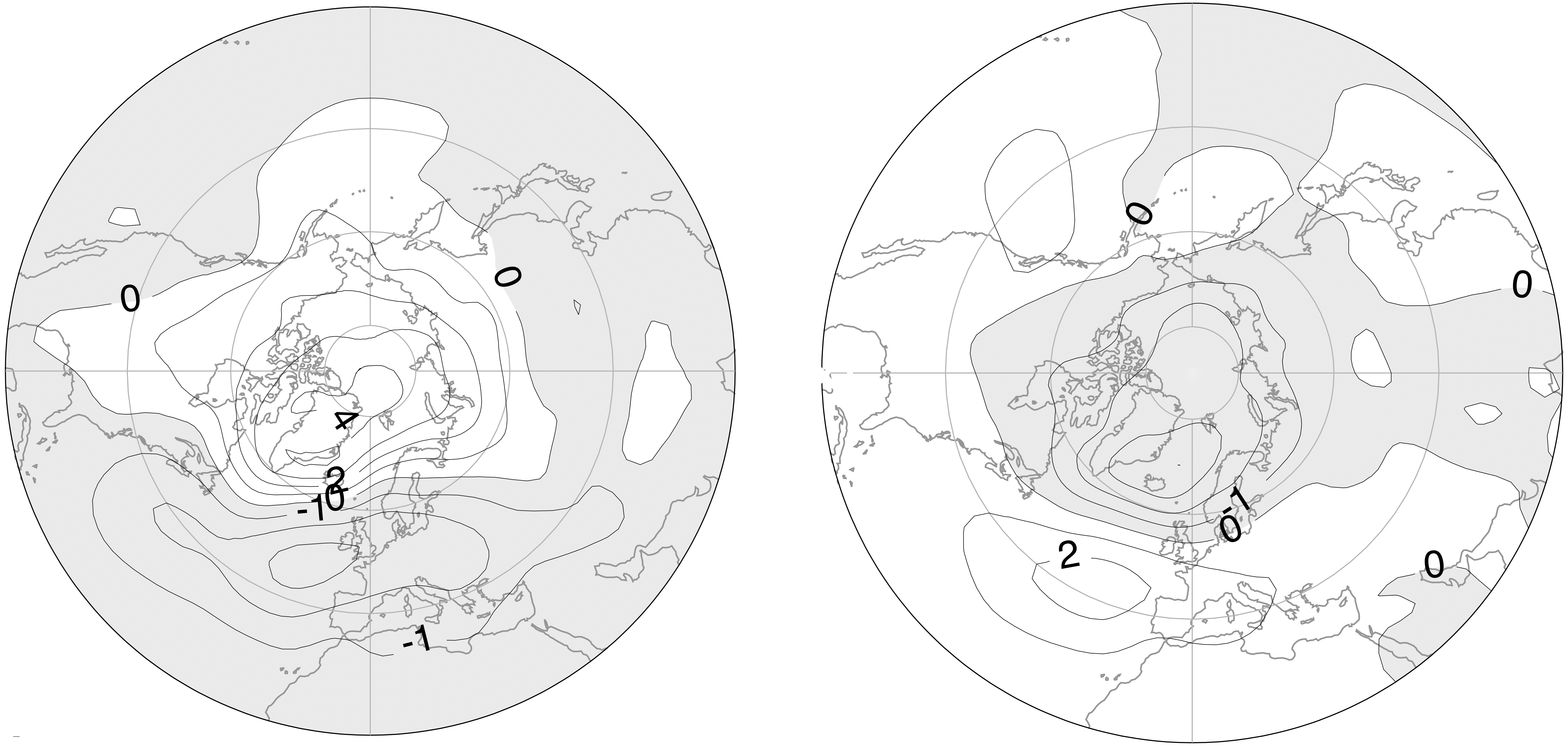
Days 1-60 following stratospheric anomalies



Thompson, Baldwin, Wallace *J Climate* 2002

Observed Average Surface Pressure Anomalies (hPa)

60 days following weak stratospheric winds | 60 days following strong stratospheric winds

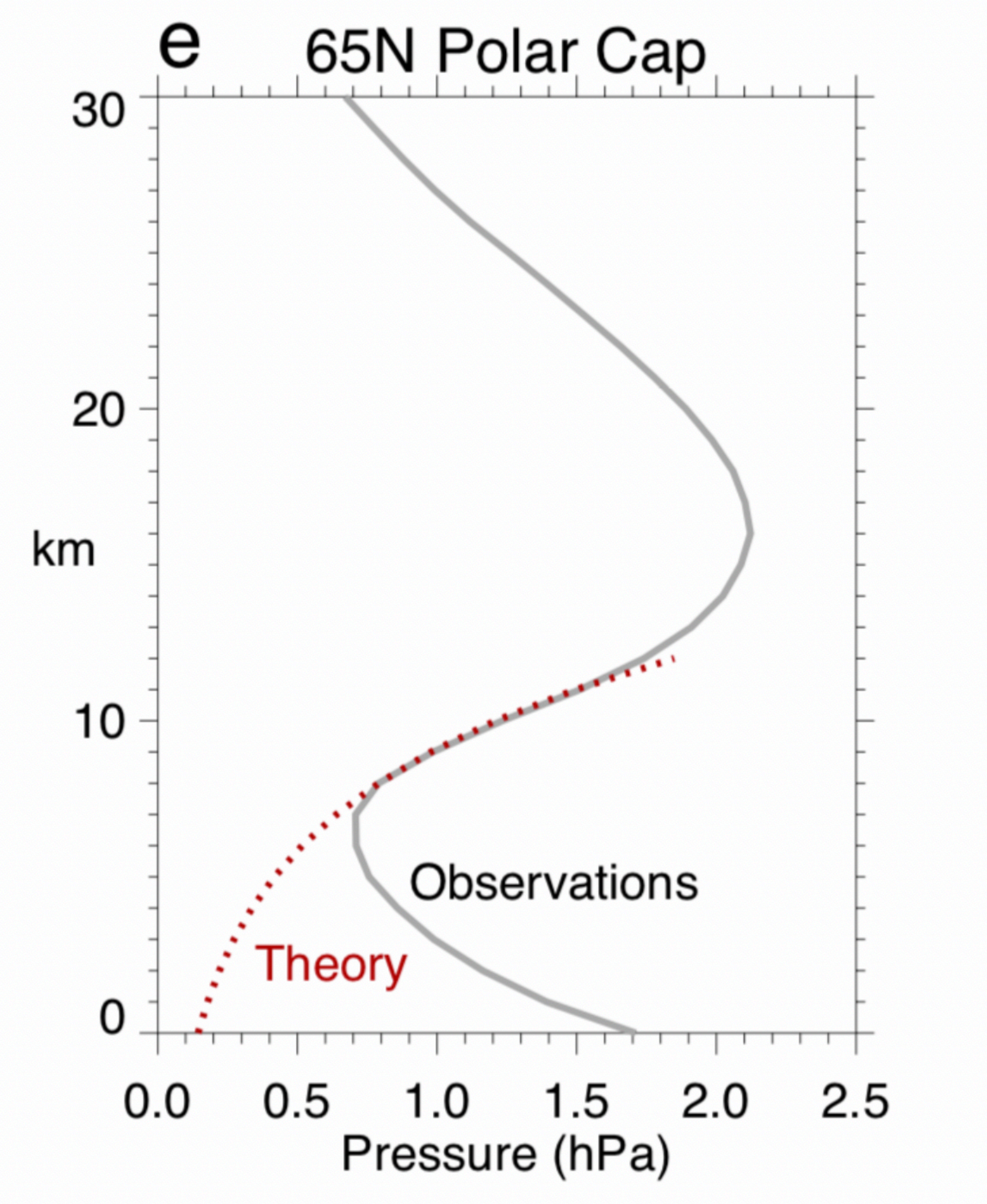


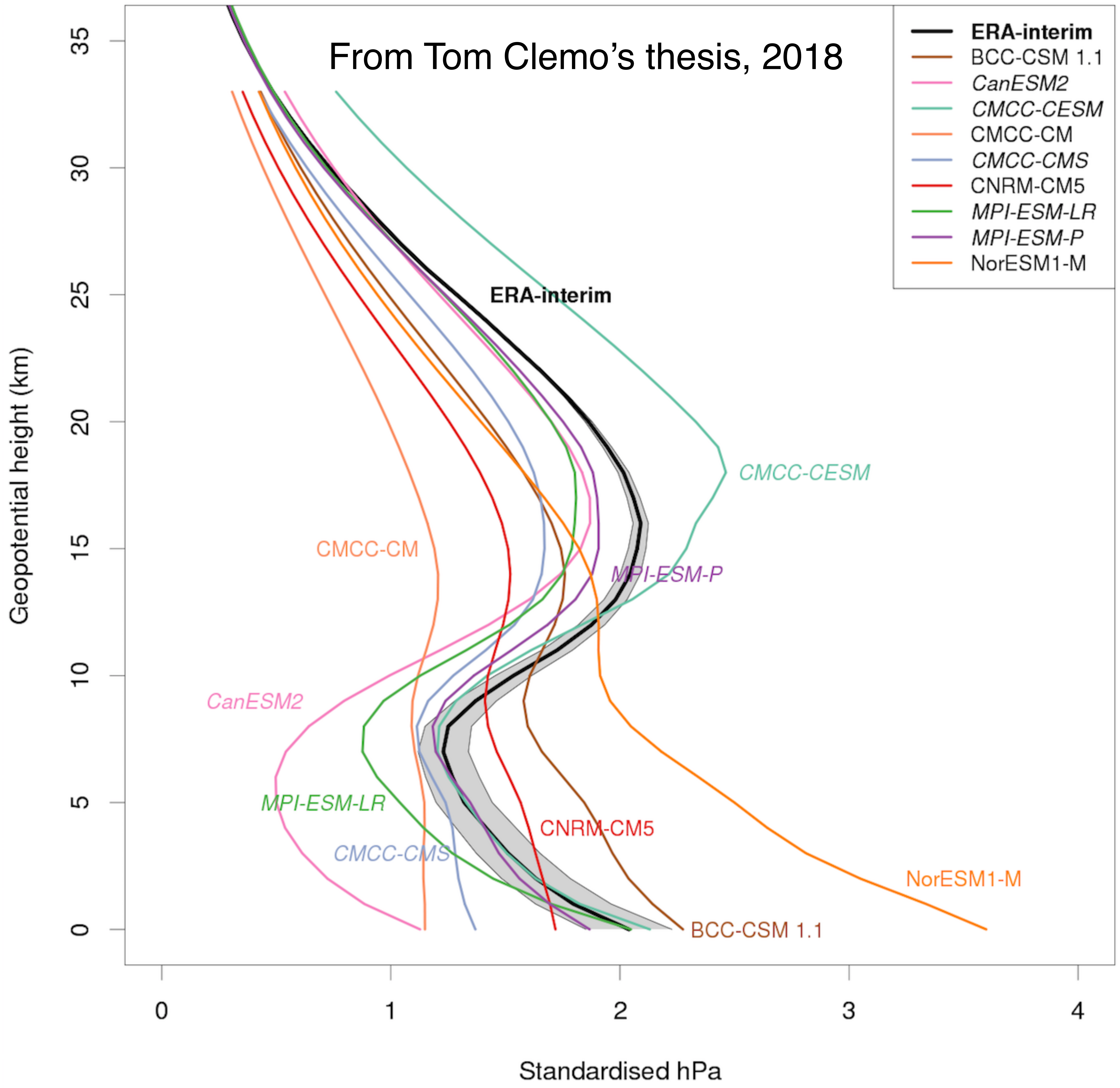
From Baldwin and Dunkerton, *Science* 2001

Regression between ST100 index and polar cap pressure anomalies(Z). JFM.

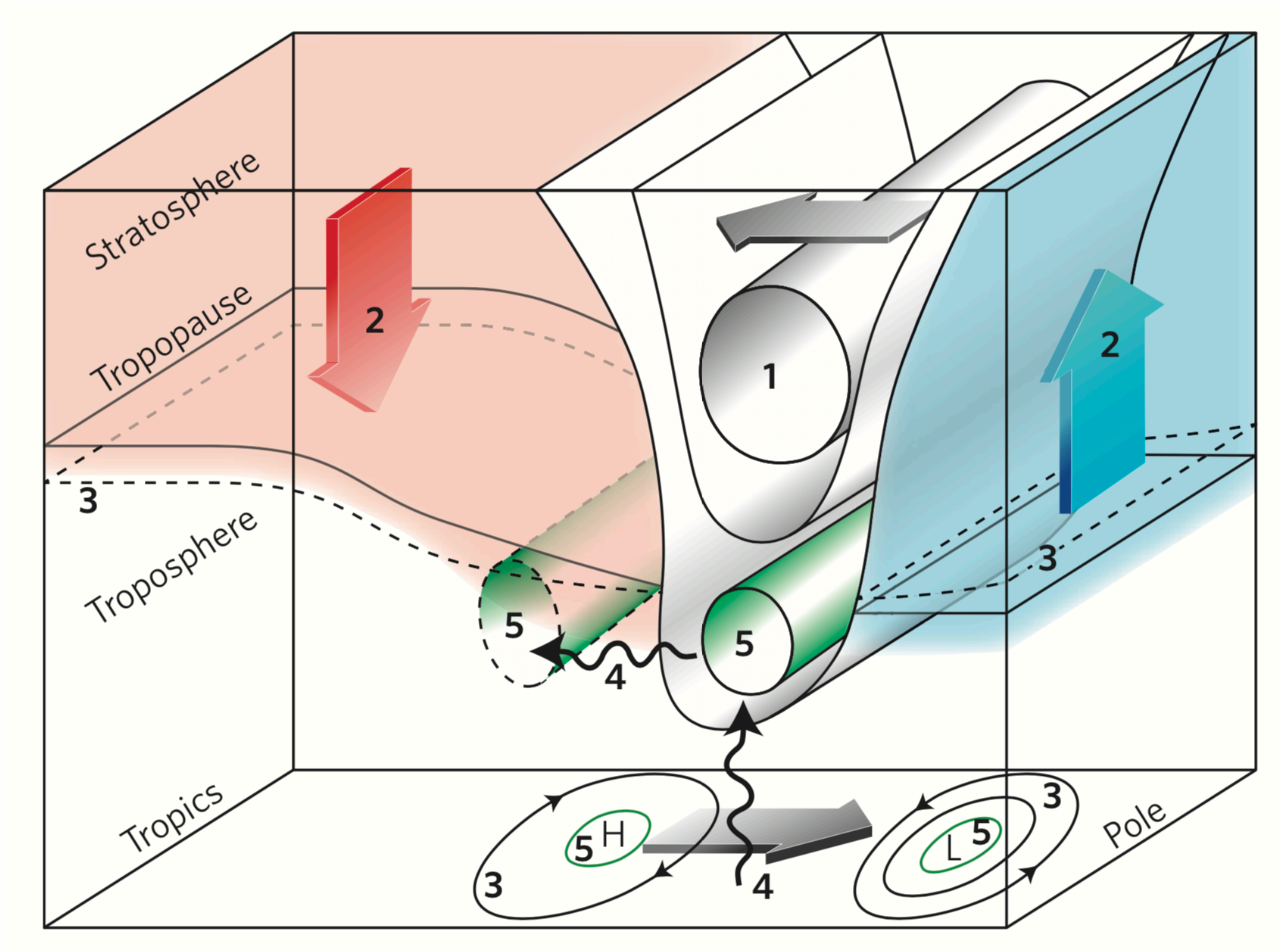
Theory from Ambaum & Hoskins (2002)

This quantifies S-T coupling.

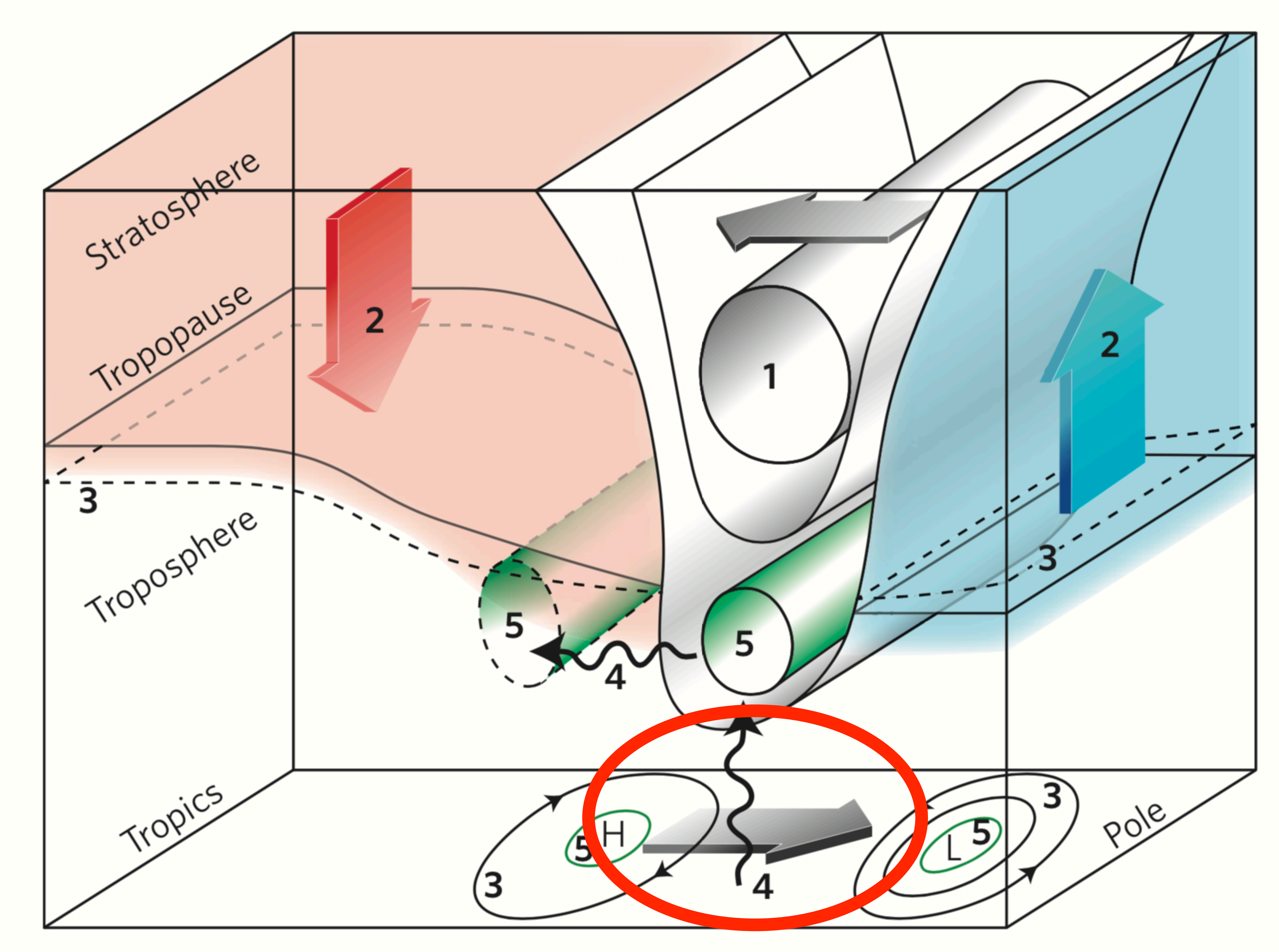




From Tom Clemo's thesis, 2018
ERA-interim
BCC-CSM 1.1
CanESM2
CMCC-CESM
CMCC-CM
CMCC-CMS
CNRM-CM5
MPI-ESM-LR
MPI-ESM-P
NorESM1-M
ERA-interim
CMCC-CESM
CMCC-CM
MPI-ESM-P
CanESM2
MPI-ESM-LR
CNRM-CM5
CMCC-CMS
NorESM1-M
BCC-CSM 1.1
Geopotential height (km)
0
5
10
15
20
25
30
35
0
1
2
3
4
Standardised hPa



From Kidston et al., *Nature Geoscience*, 2015



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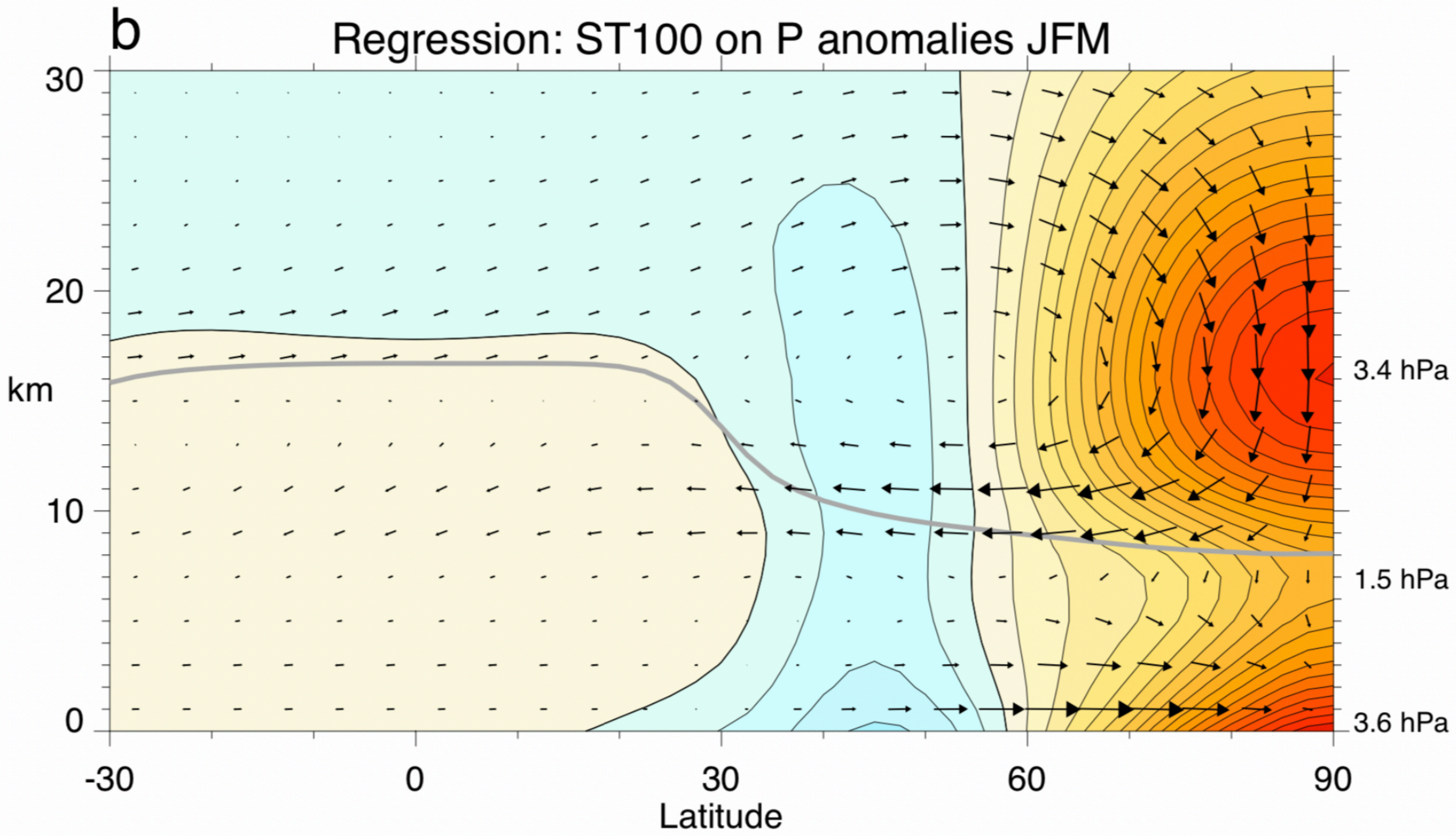
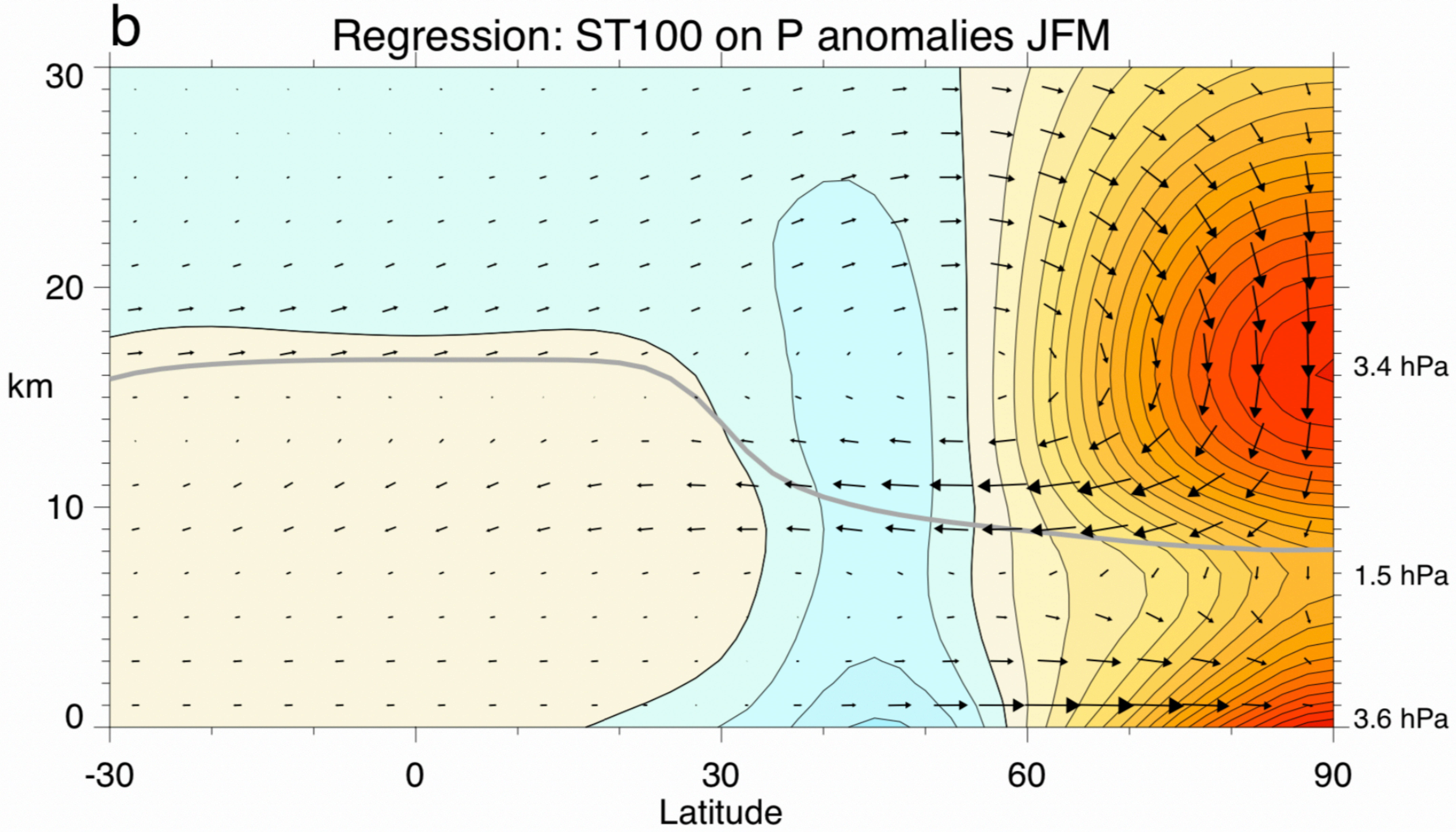
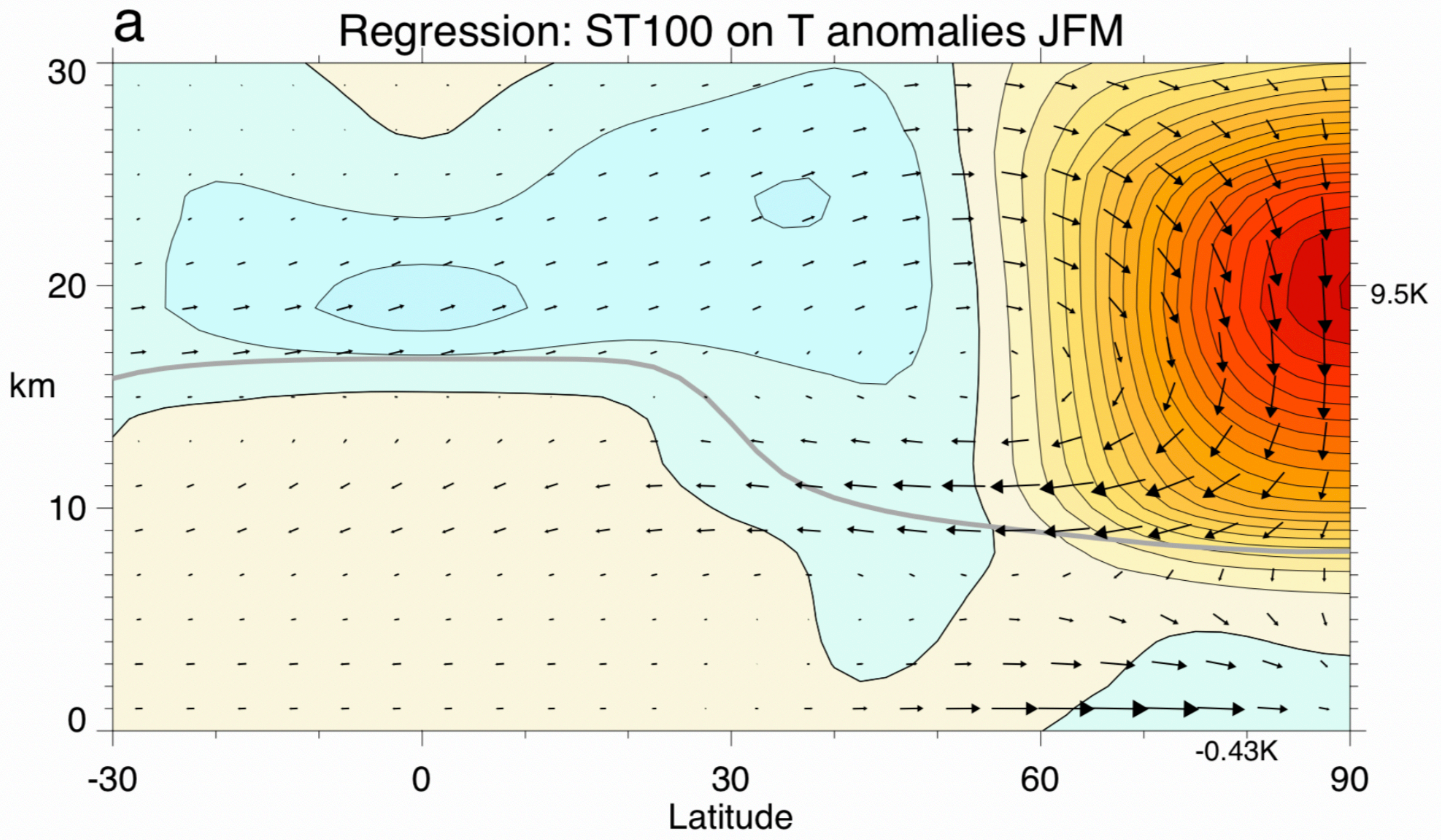
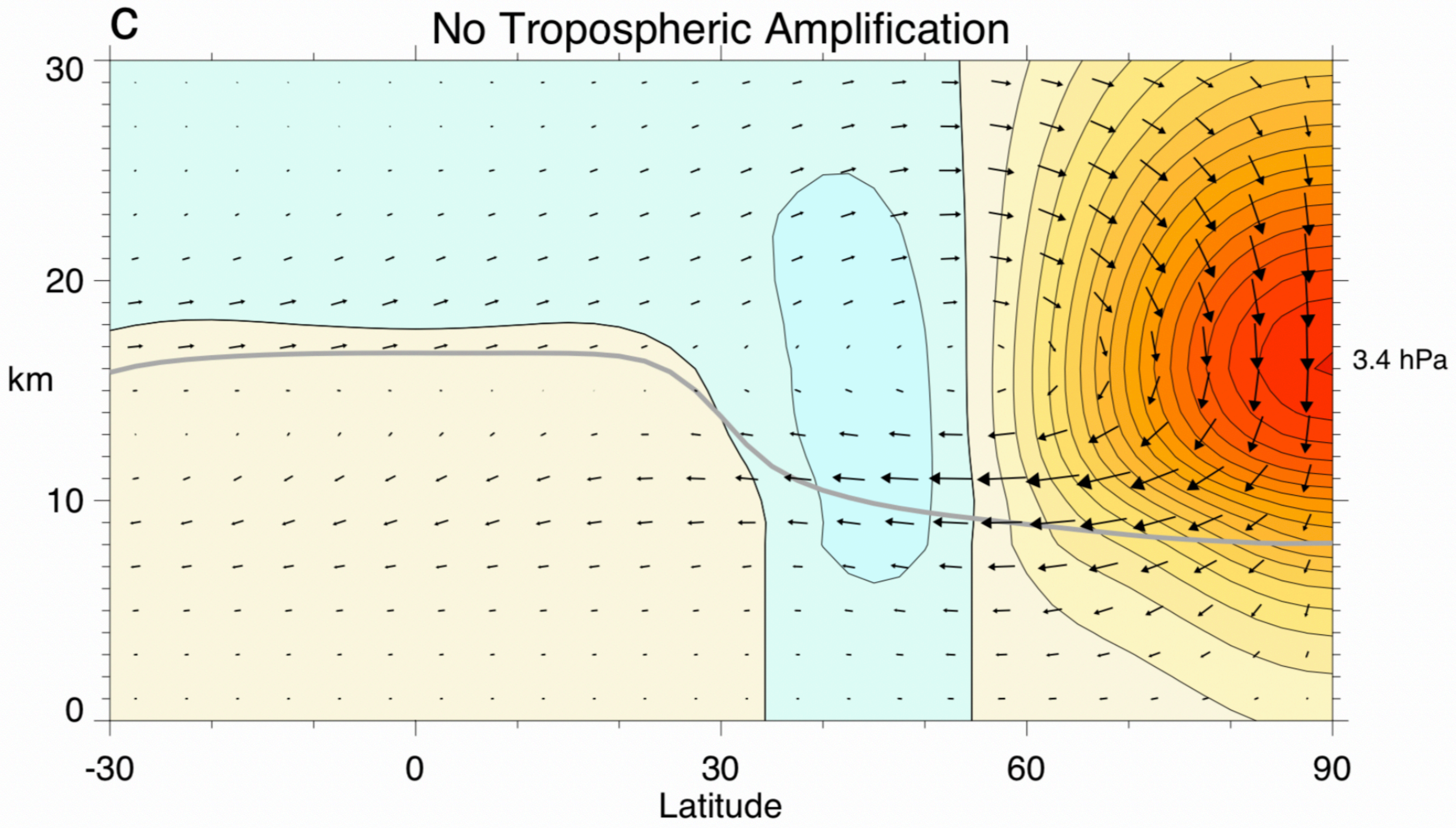

b
Regression: ST100 on P anomalies JFM
km
30
20
10
0
-30
0
30
60
90
Latitude
3.4 hPa
1.5 hPa
3.6 hPa

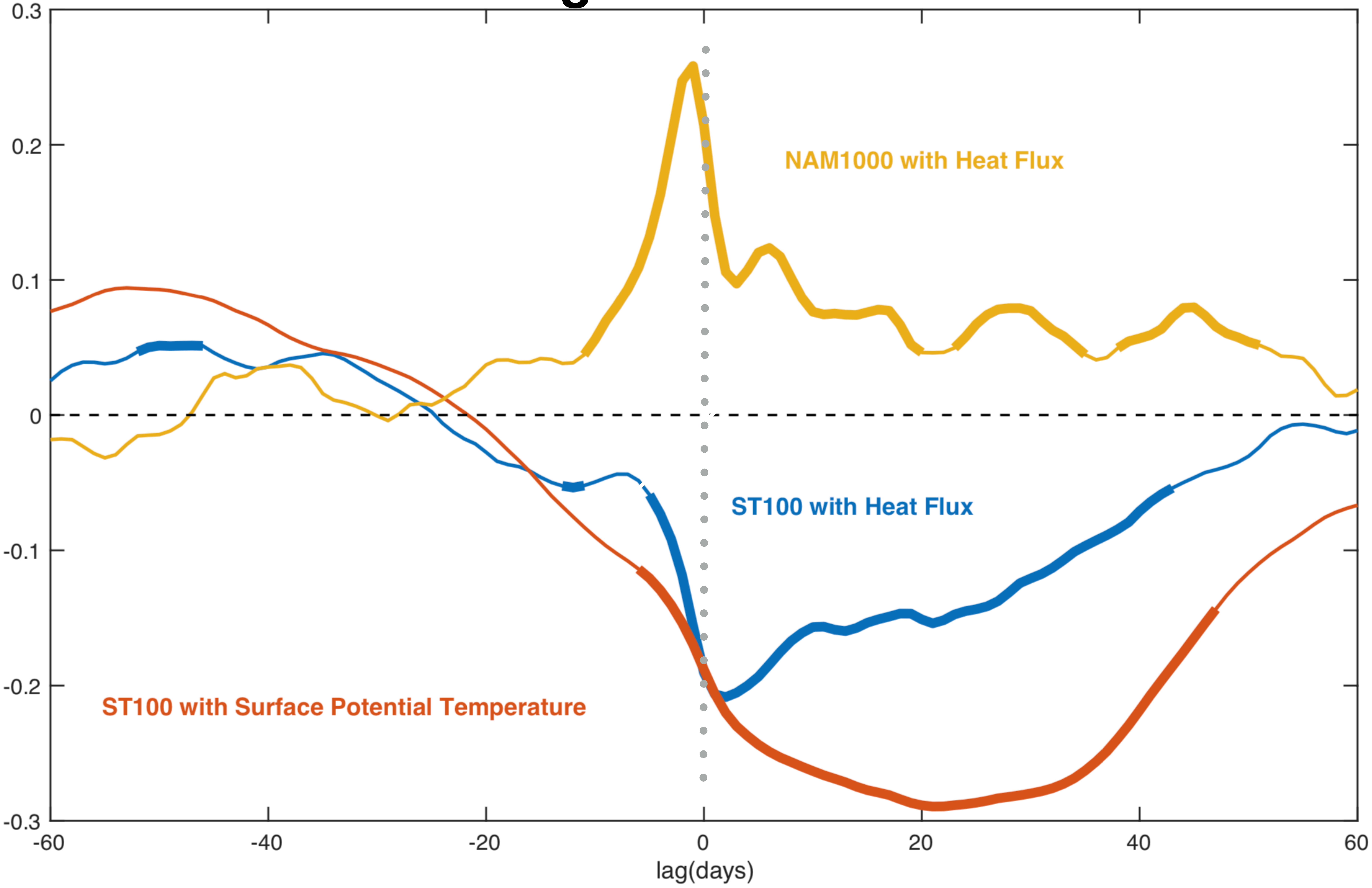


Kidston et al. was wrong about mass movement.


a
Regression: ST100 on T anomalies JFM
30
20
10
0
km
9.5K
-0.43K
-30
0
30
60
90
Latitude


C
No Tropospheric Amplification
30
20
10
0
km
3.4 hPa
-30
0
30
60
90
Latitude

Lag Correlations



Processes

1) Which stratospheric processes are important to represent accurately for improved tropospheric predictability on medium-range to seasonal timescales?

Answer: Variability of the polar lower stratosphere, as quantified by polar-cap mean T anomalies at 100 hPa (ST100 Index). No data above 100 hPa is needed. The model's ST100 index should match closely the observed ST100 index.

Processes

2) Which tropospheric processes are important to represent accurately for improved stratospheric predictability?

Answer: Tropospheric amplification, as quantified by a regression between the ST100 index, and polar cap P anomalies.

Processes

3) Can we quantify the strength of stratospheric impact on the troposphere (e.g., following weak and/or strong vortex events) versus the impact of other remote forcers such as MJO and ENSO?

Yes. The ST100 index could be used like an MJO or ENSO index, and regressions with tropospheric fields quantify the strength. One could also remove stratospheric effects by regression.

Processes

4) What are the best tools and metrics to objectively evaluate the strength of the stratosphere–troposphere coupling, and, the skill provided by the stratosphere for tropospheric predictability?

Partial answer: The strength of coupling can be evaluated by regression ST100 on polar cap P(Z) anomalies. Evaluate skill??