# The Dynamics of the Stratospheric Polar Vortex

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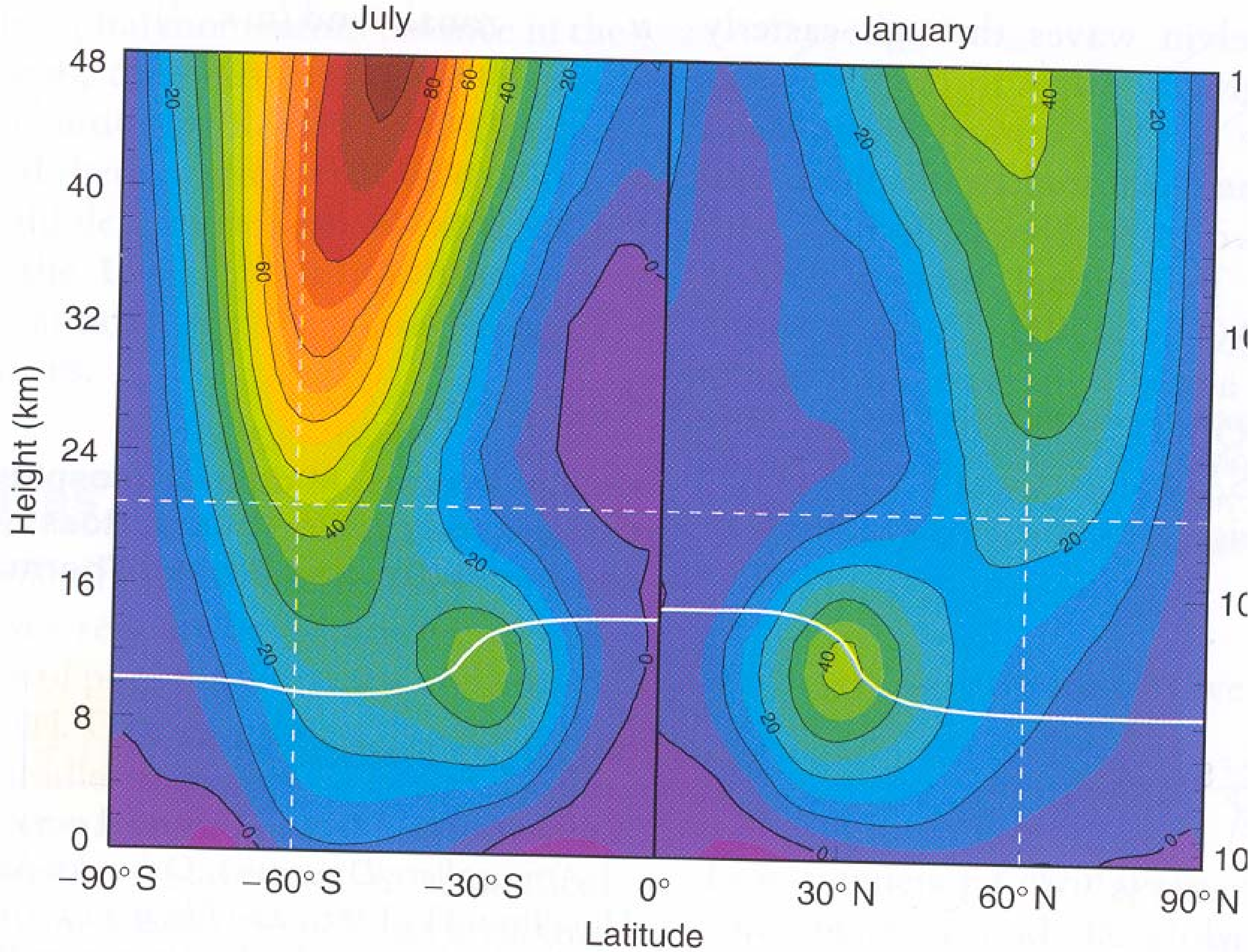
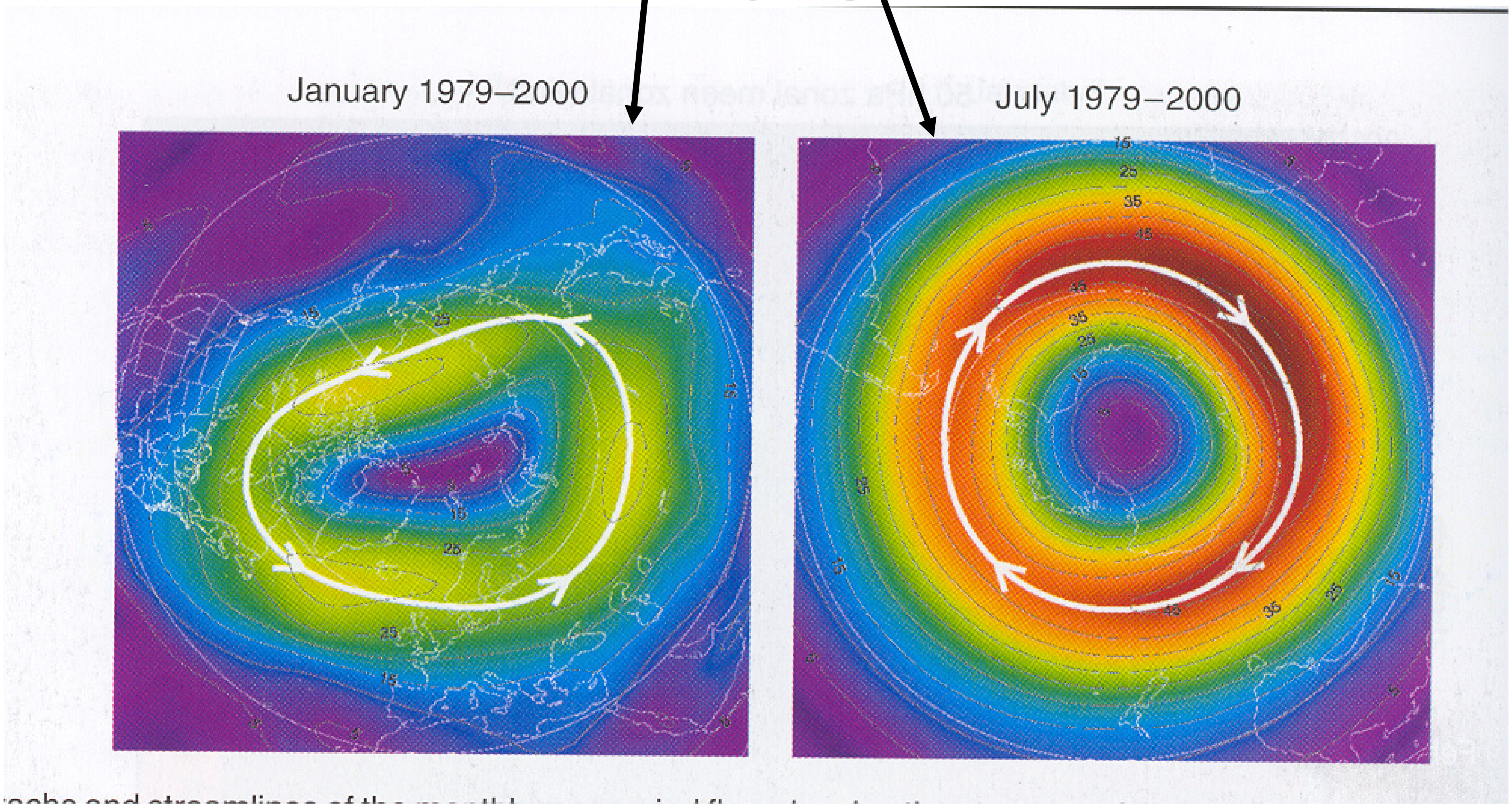
# Outline

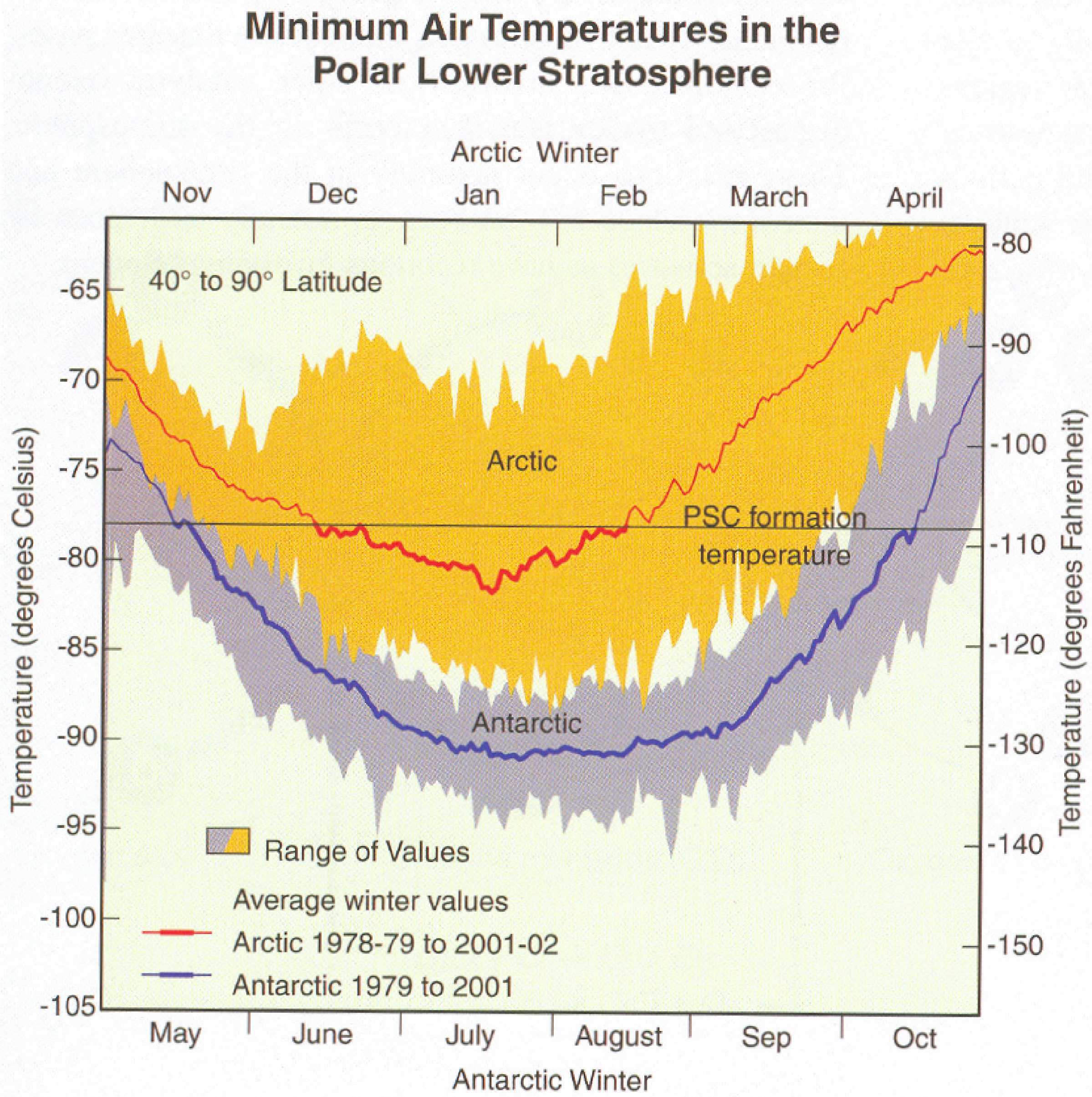
- Structure of the stratospheric polar vortex
- Phenomenology
  - vortex-vortex interactions during stratospheric sudden warmings
  - impacts (on trace gases & on troposphere)
- Some theoretical considerations

# Zonal-mean Wind



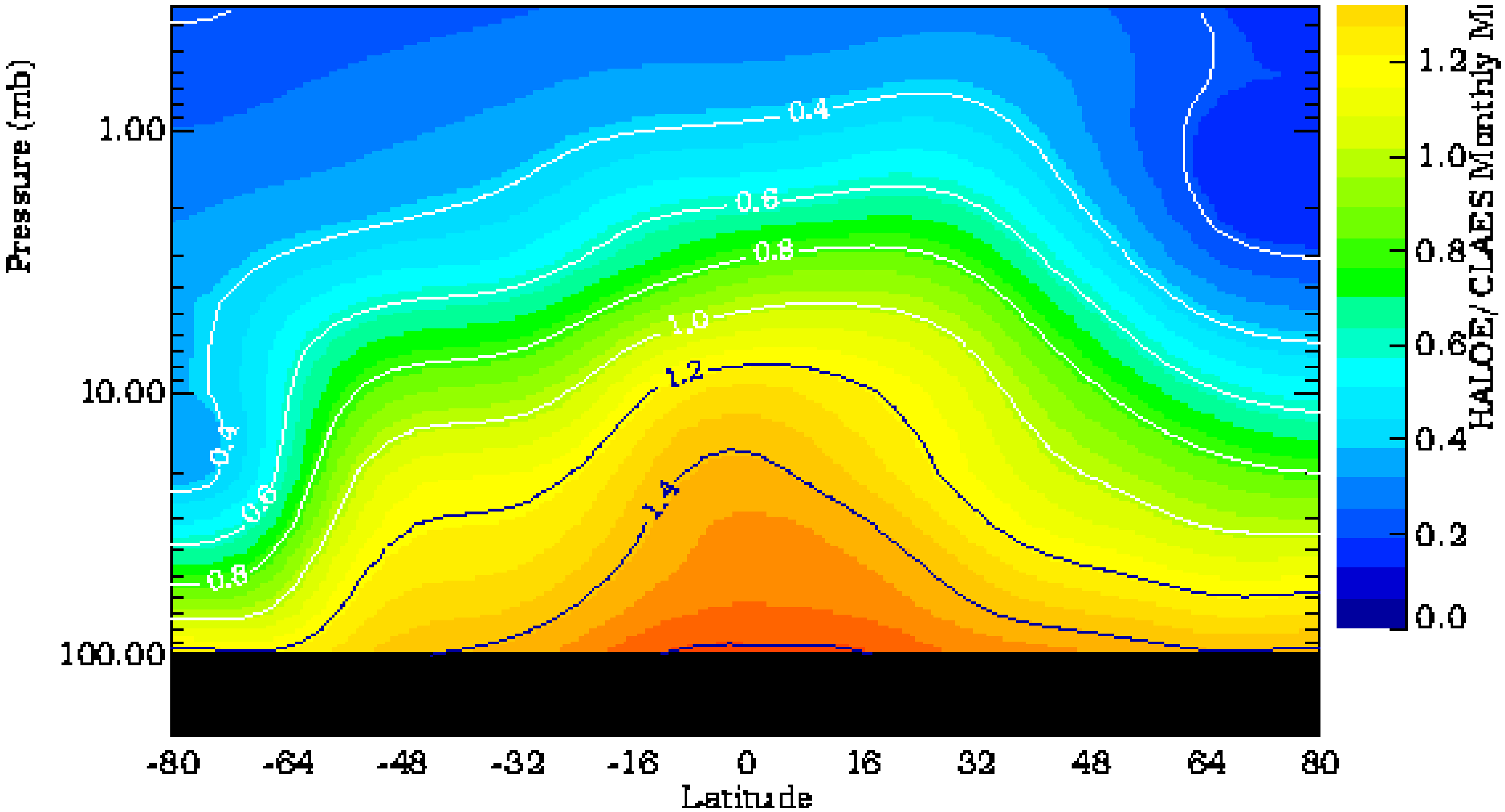
# Stratospheric Polar Vortices
# 50 mb (about 20 km)
# NH & SH



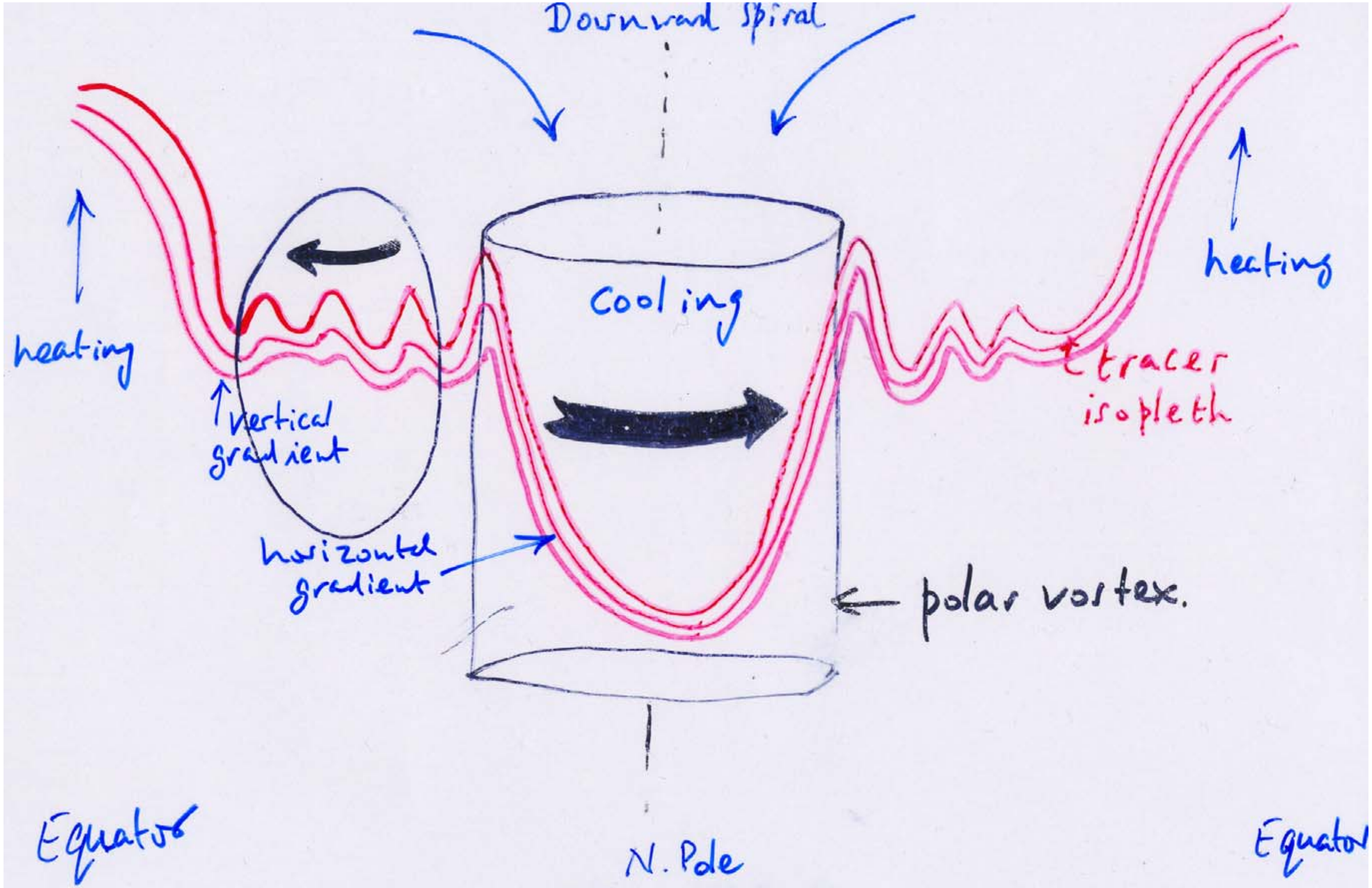


Minimum Air Temperatures in the
Polar Lower Stratosphere
Arctic Winter
Nov
Dec
Jan
Feb
March
April
40° to 90° Latitude
Arctic
PSC formation
temperature
Antarctic
Range of Values
Average winter values
Arctic 1978-79 to 2001-02
Antarctic 1979 to 2001
-65
-70
-75
-80
-85
-90
-95
-100
-105
Temperature (degrees Celsius)
-80
-90
-100
-110
-120
-130
-140
-150
Temperature (degrees Fahrenheit)
May
June
July
August
Sep
Oct
Antarctic Winter

# Cross-Section of Methane October

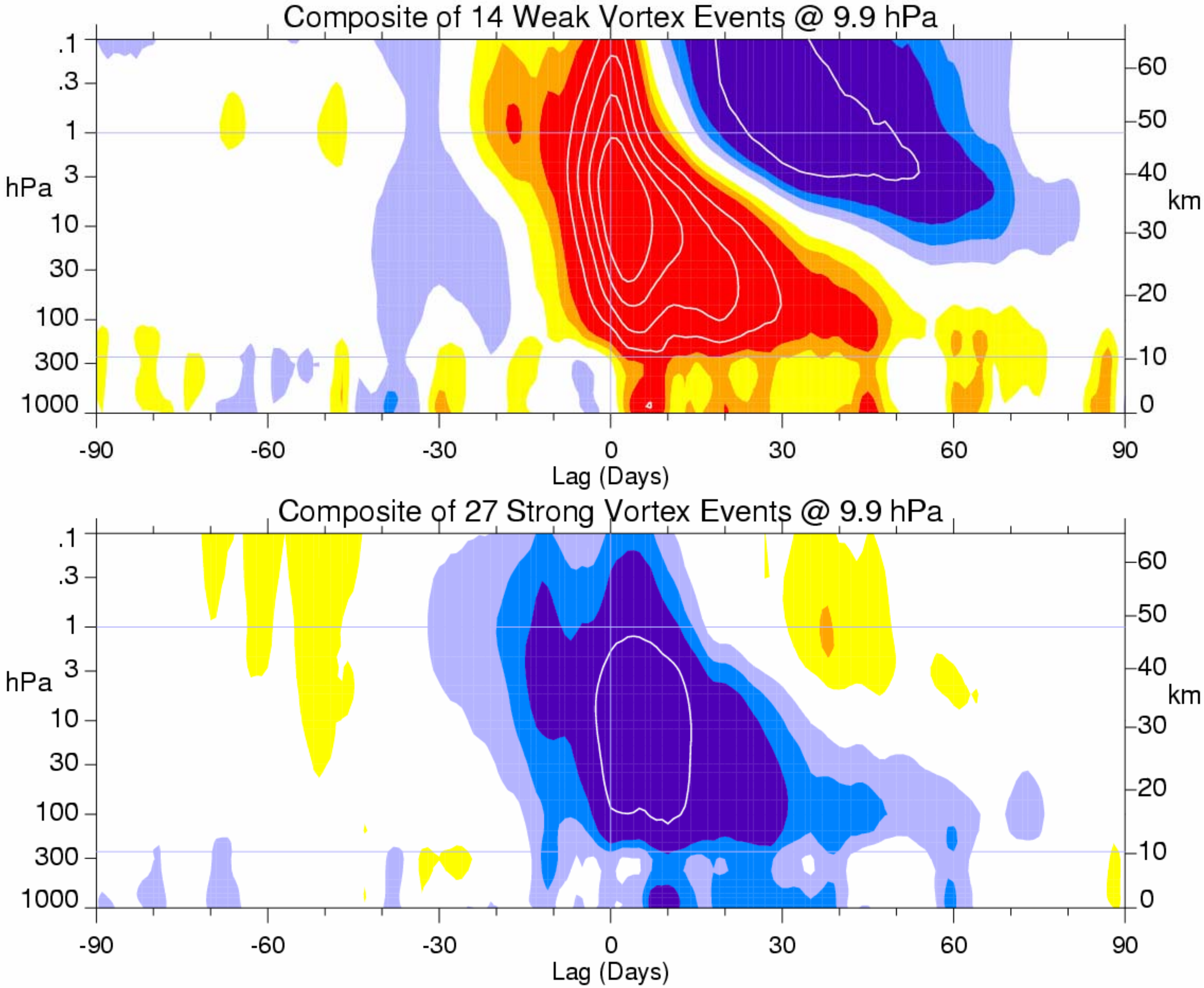



**UARS Climatology Pressure vs Equivalent Latitude October**



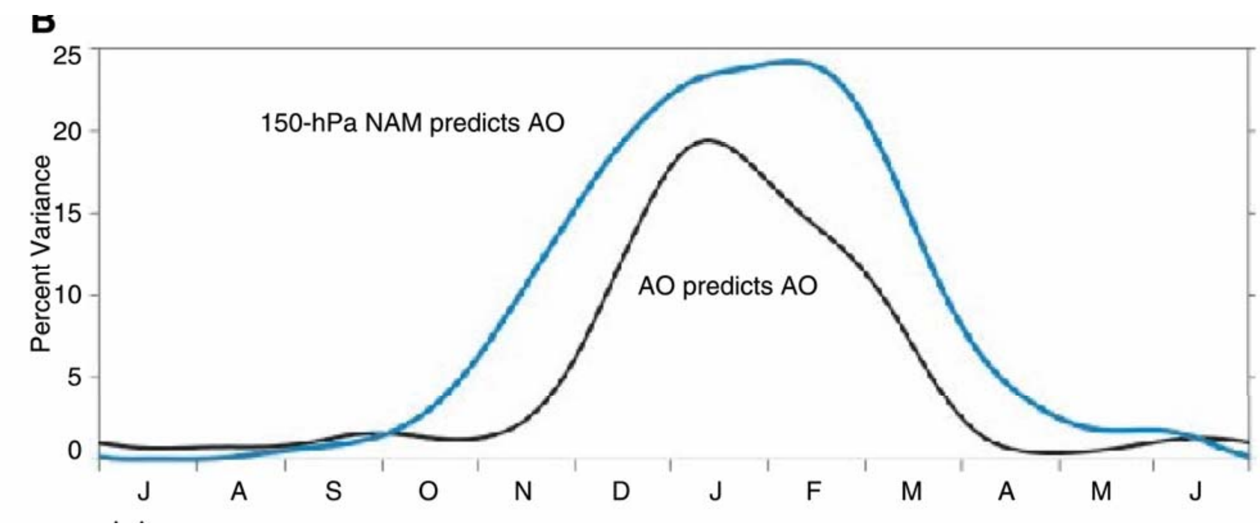

STRATOSPHERIC POLAR VORTEX

# Courtesy of Mark Baldwin



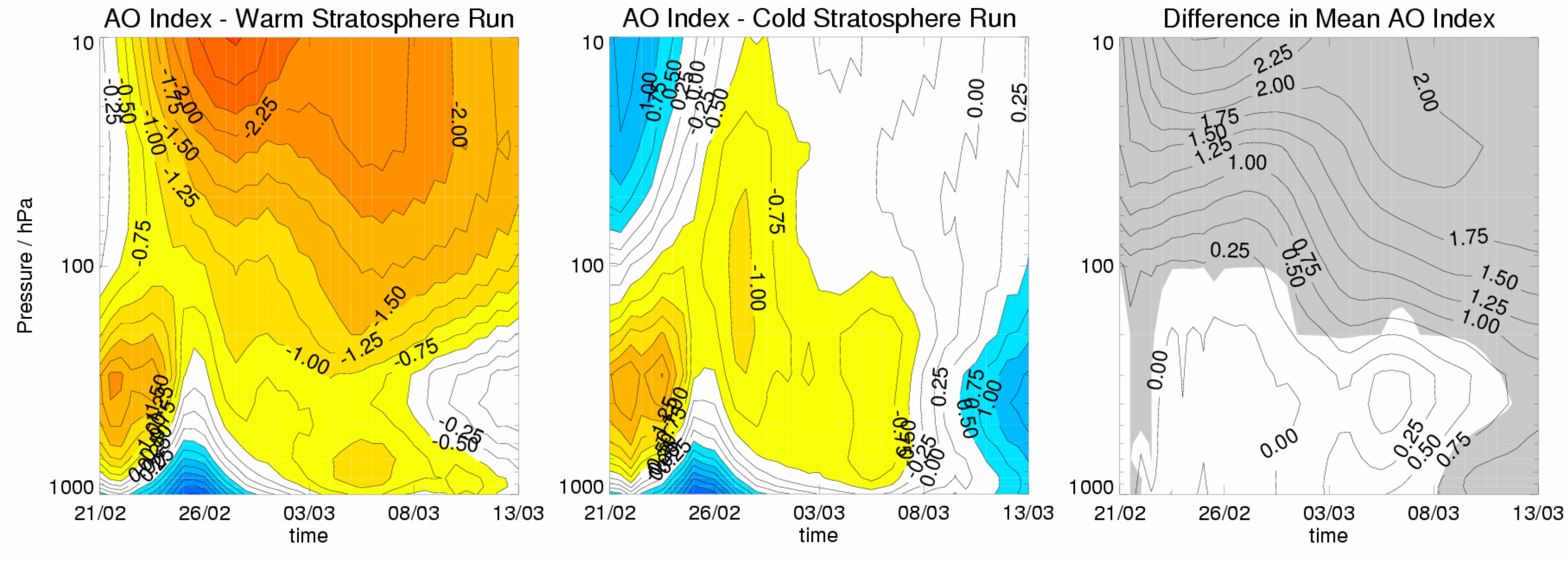
# Consequence 1: Forecasting

- If the stratosphere has an impact on the tropospheric state 10-60 days in the future then there is potential to use this information for sub-seasonal forecasting




Baldwin et al. (2003)

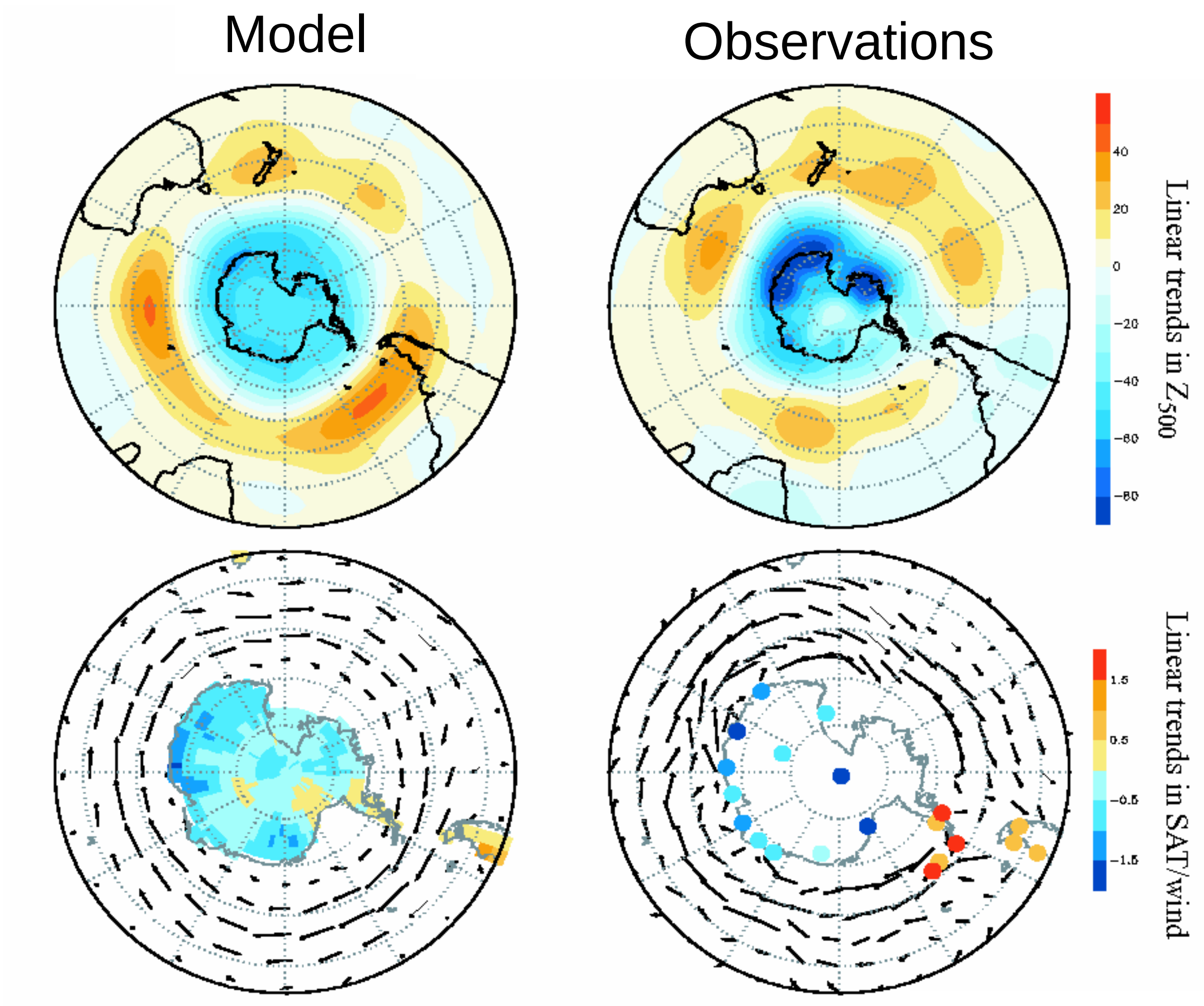
# Impact of Stratosphere 2




Charlton et al.

- Changing the stratospheric initial conditions results in a tropospheric impact 15-20 days into the run.

# Effect of SH Ozone Depletion




- Recent trends in the Antarctic can be well simulated by forcing a model with ozone trends confined to the stratosphere

Gillett and Thompson (2003)

# Two Dynamical Paradigms for Dynamical Variability of the Stratospheric Polar Vortex

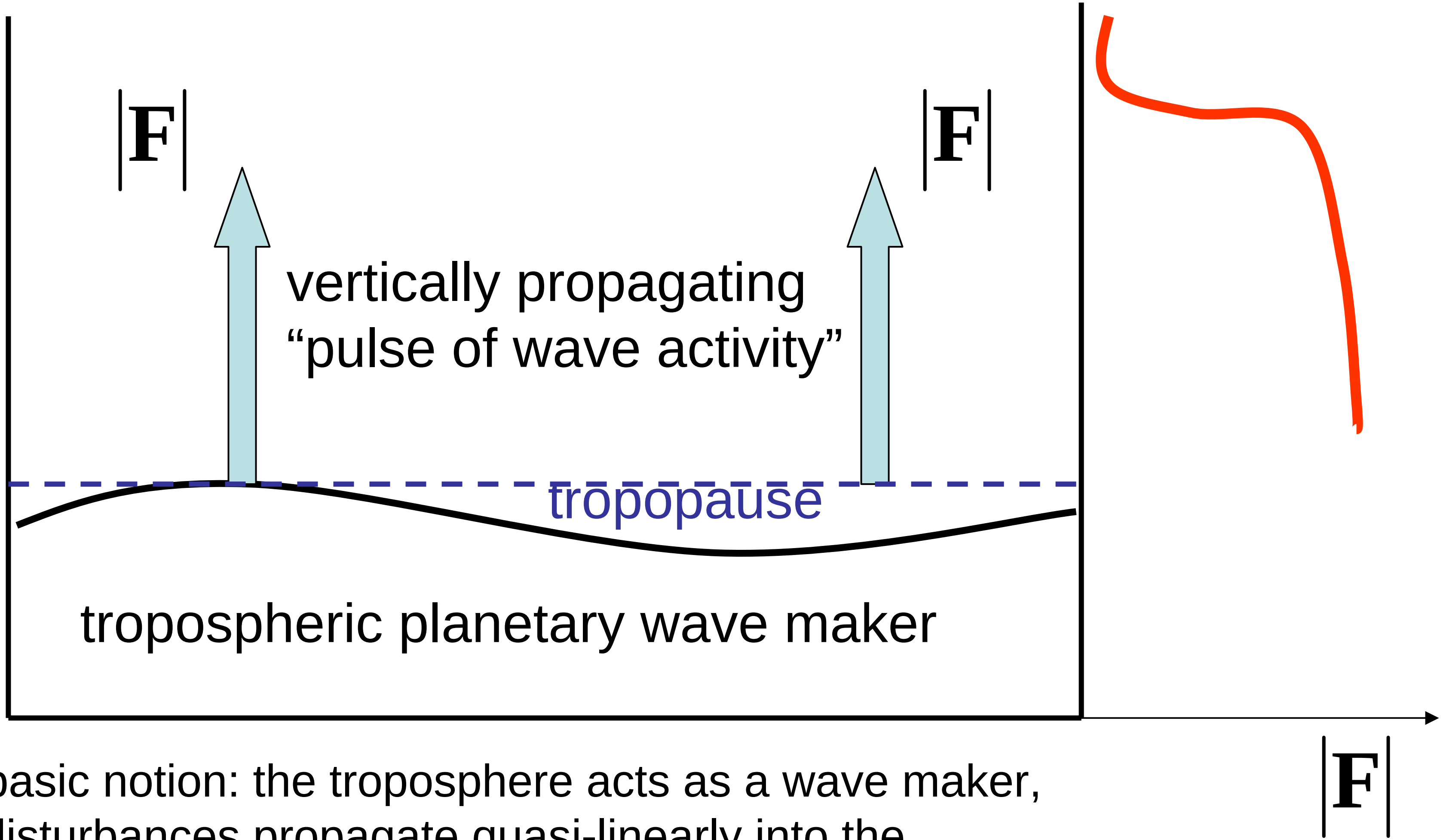
- Wave, mean-flow interaction.
- Vortex-vortex interaction.

# Some Textbook Quotes

- "Numerous observational studies confirm that enhanced propagation of planetary waves from the troposphere, primarily zonal wavenumber 1 and 2, is essential for the development of warmings."
- "Most of the dramatic mean-flow deceleration that occurs during a sudden warming is caused by amplification of quasi-stationary planetary waves in the troposphere followed by propagation into the stratosphere."
- "It is generally accepted that sudden warmings are an example of transient mean-flow forcing due to planetary wave driving."

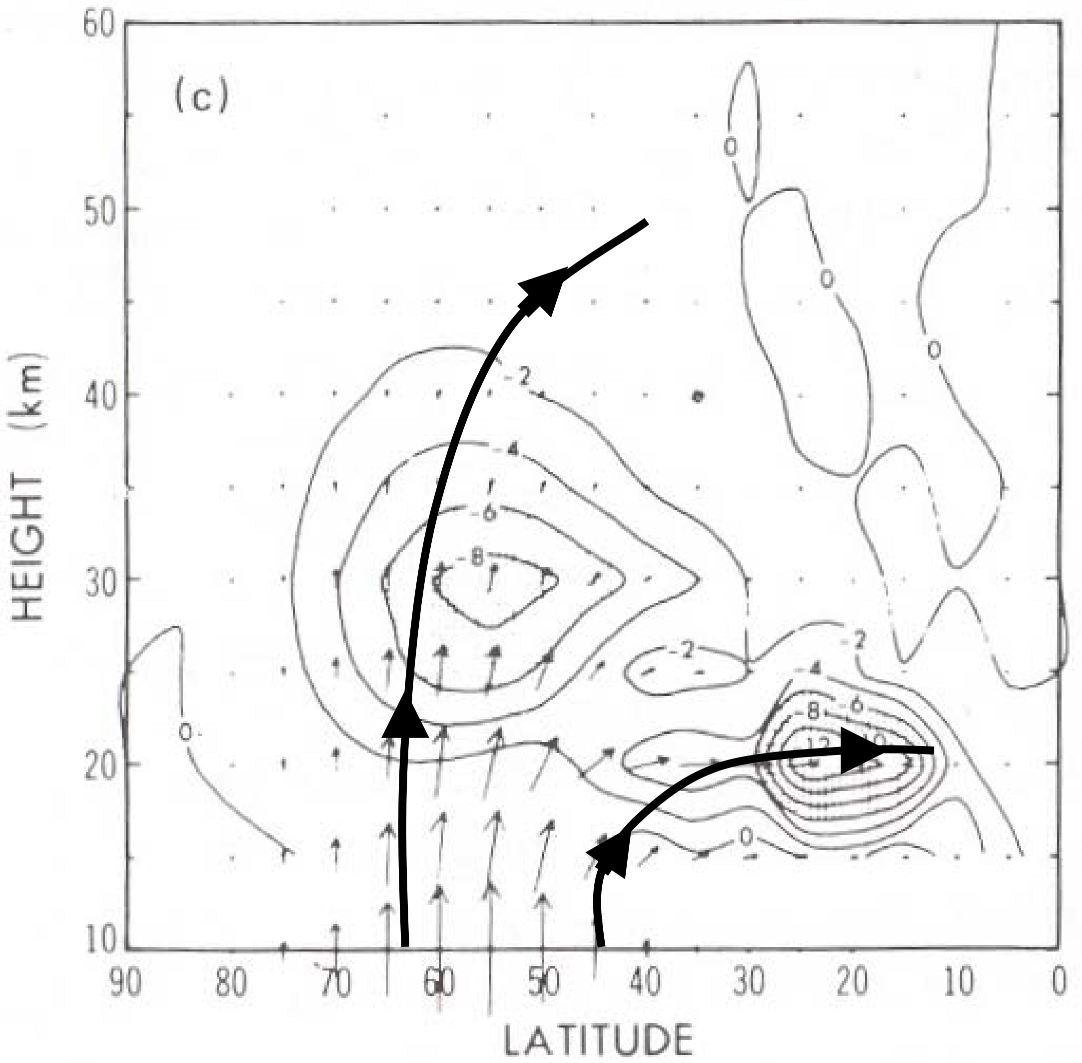
*An Introduction to Dynamic Meteorology, 4th edition (2004), James R Holton, Elsevier, p. 425.*

# Schematic of a possible mechanism for a SSW




The basic notion: the troposphere acts as a wave maker, and disturbances propagate quasi-linearly into the stratosphere where they "break".

# EP Fluxes and Divergence




*Adapted from Dunkerton et al., 1981*

# The Seductive Transformed Eulerian Mean Momentum Equation

$$\frac{\partial \overline{u}}{\partial t} - f \ \overline{v}^{*} = \rho_{0}{}^{-1} \nabla \cdot \mathbf{F}$$

$$\frac{\partial \overline{u}}{\partial t} - f \ \overline{v}^{*} - \rho_{0}{}^{-1} \nabla \cdot \mathbf{F} = 0$$

# Idealised 3D Vortex-Vortex Interactions in the Winter Stratosphere

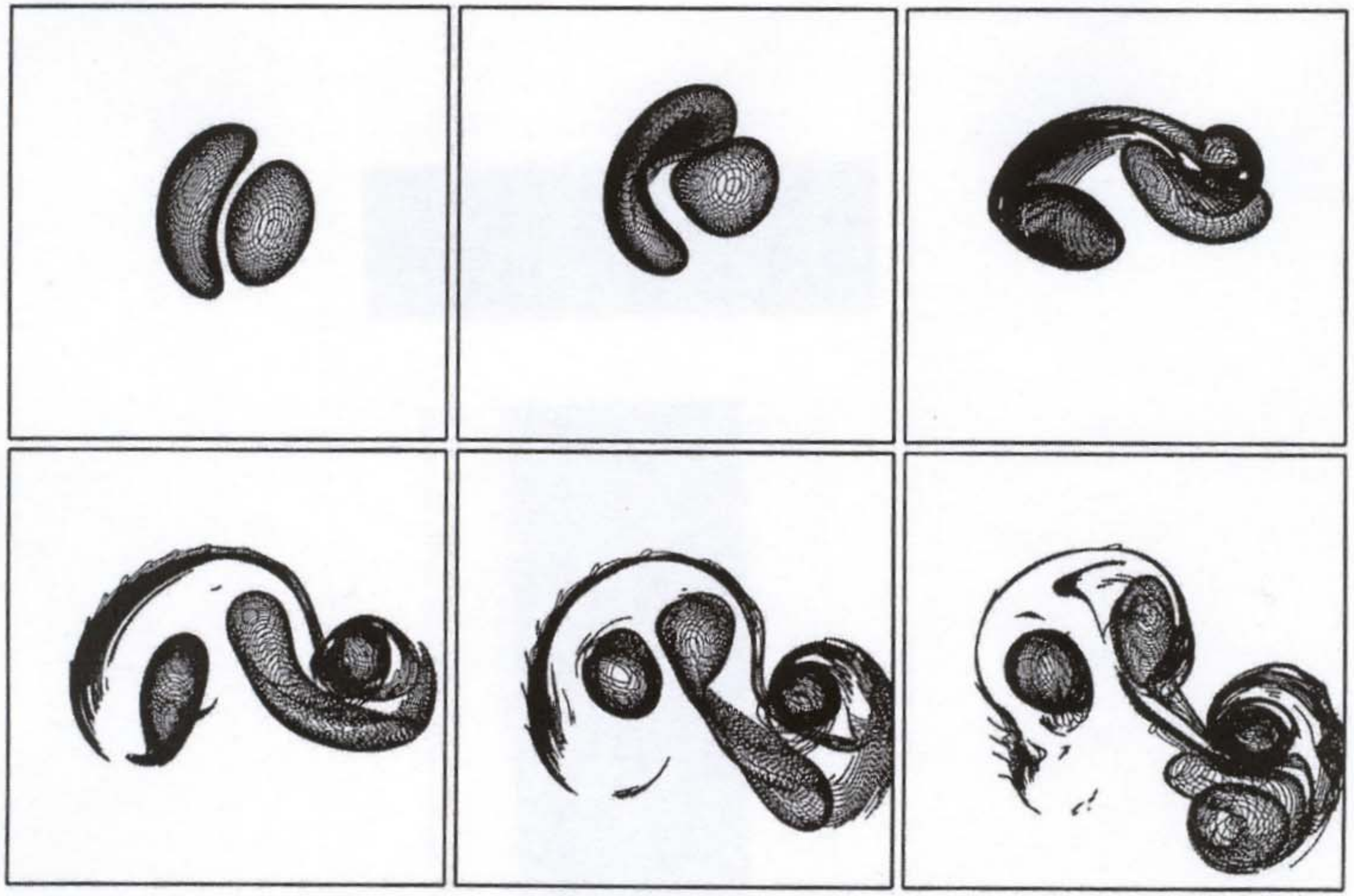


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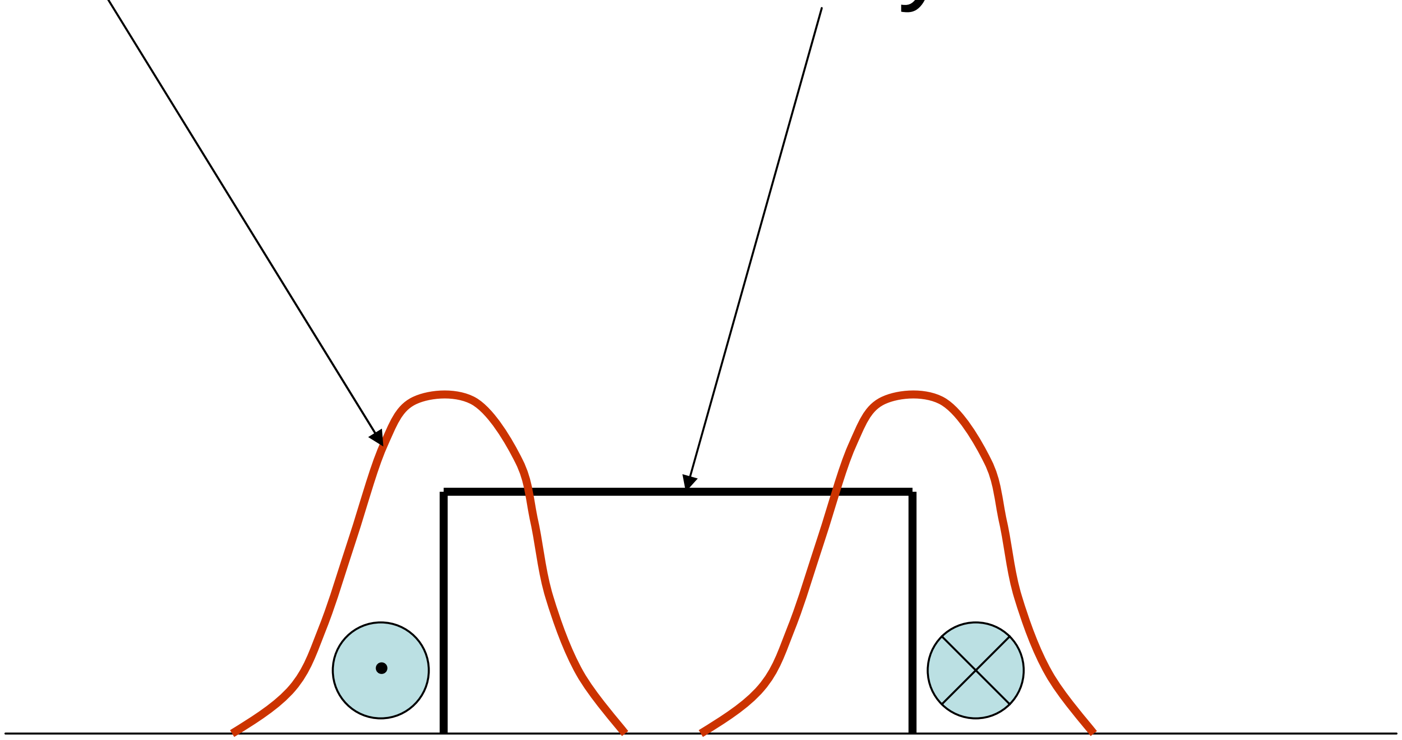
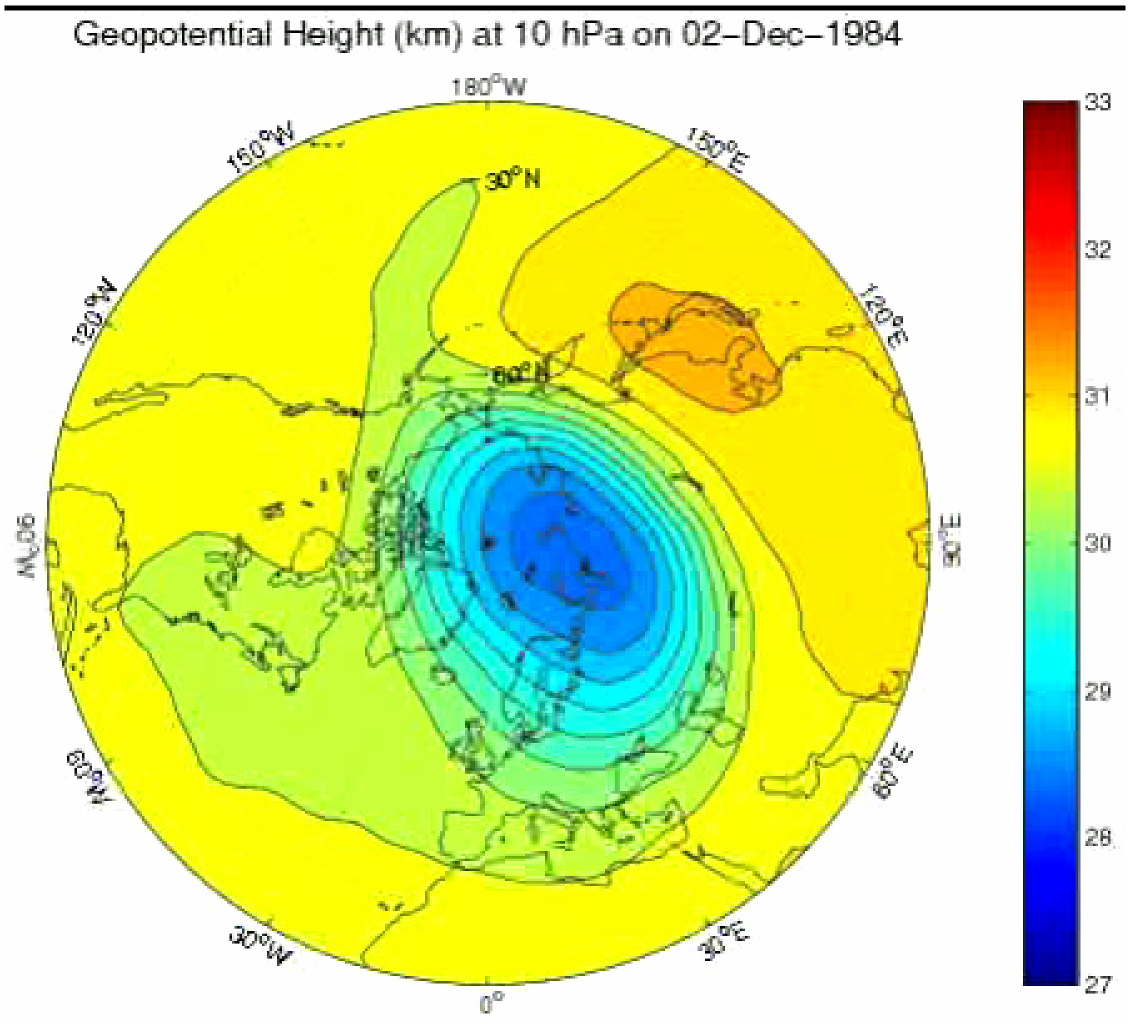
FIG. 9. Evolution for $-\kappa_2/\kappa_1 = 0.8$, $z_2 - z_1 = 0$, at $t = 0, 4, 8, 12, 16$, and 20 days (from upper left to lower right; top view).

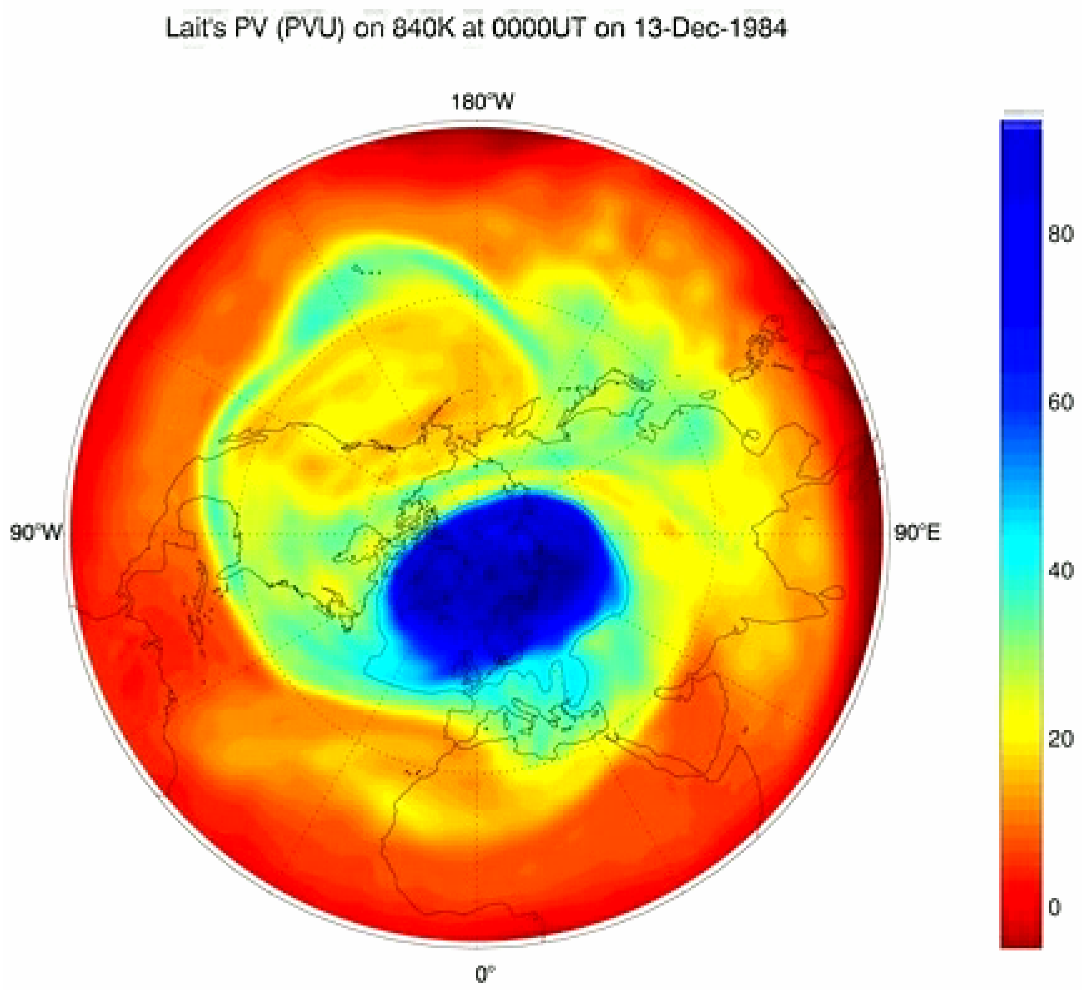
# Wind Speed Near Localised PV Anomaly



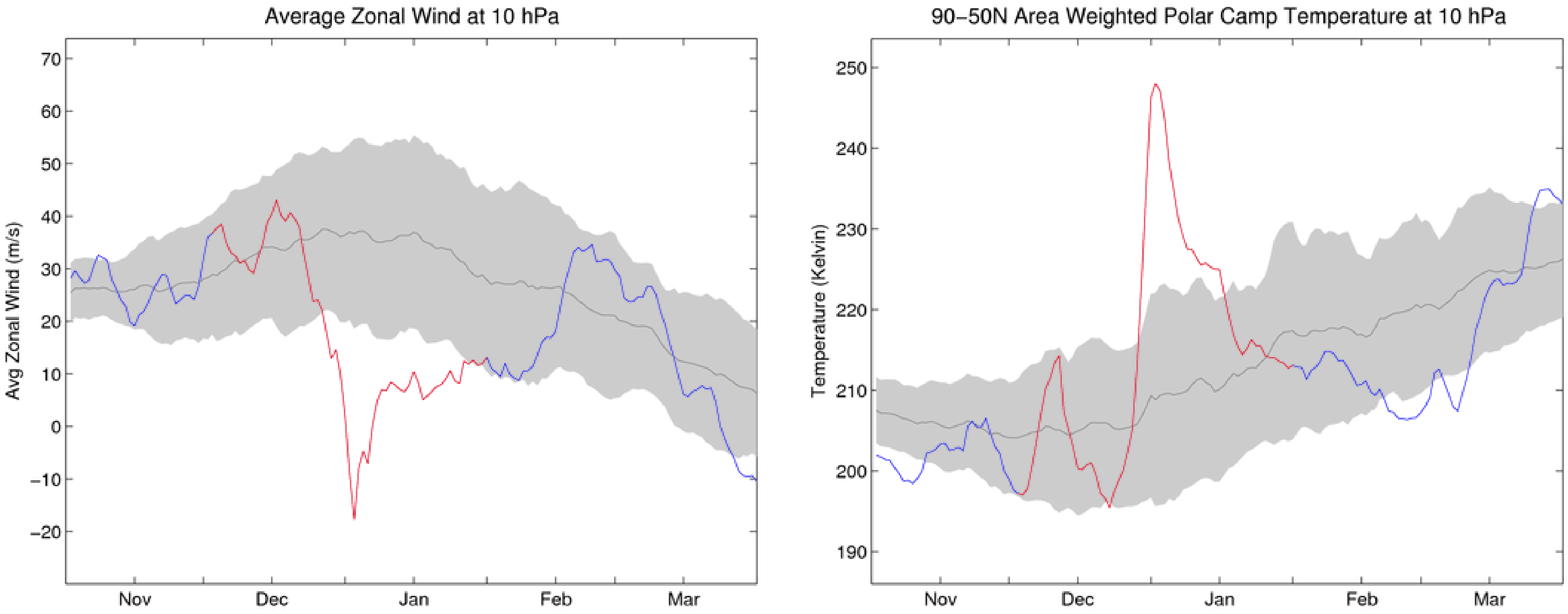
# NH Dec/Jan 84/85: Geo Ht 10 hPa



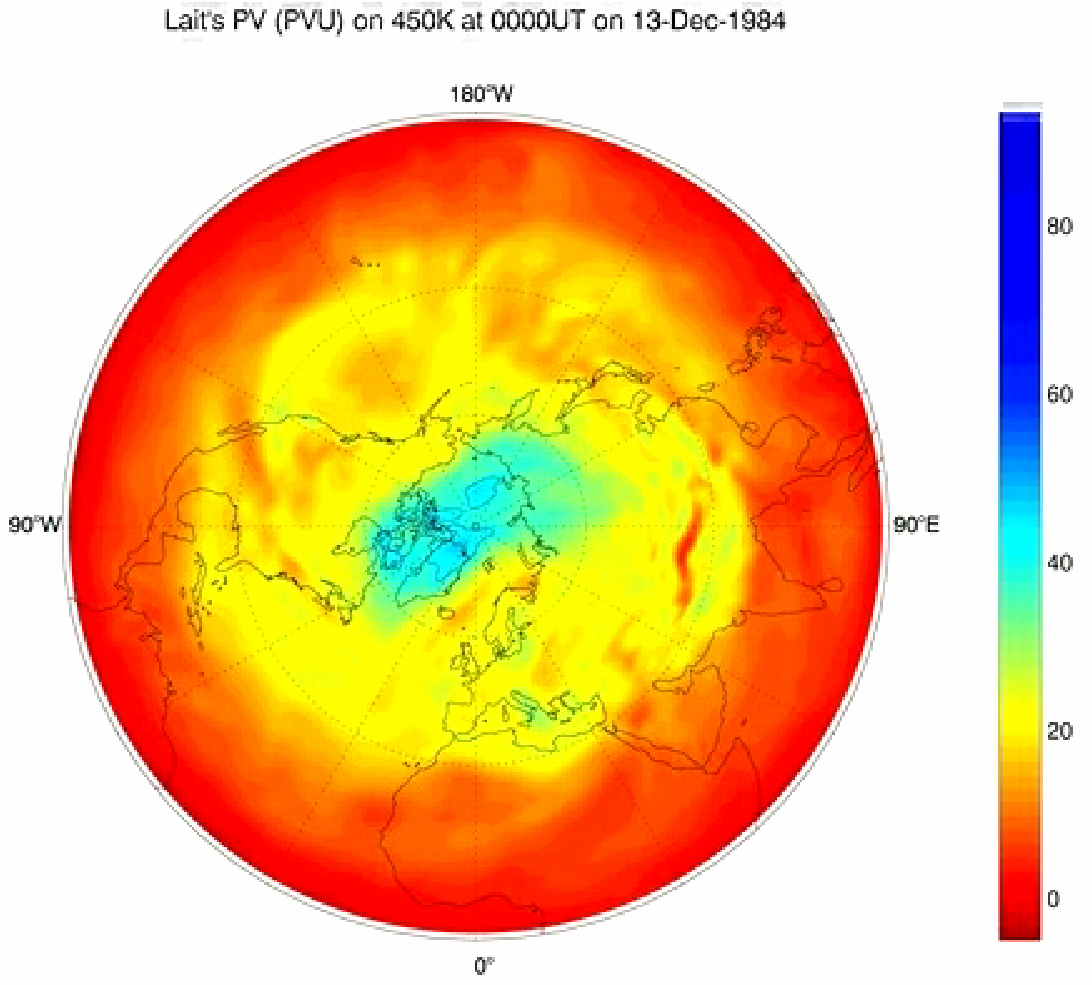
# NH Dec/Jan 84/85: PV 840K



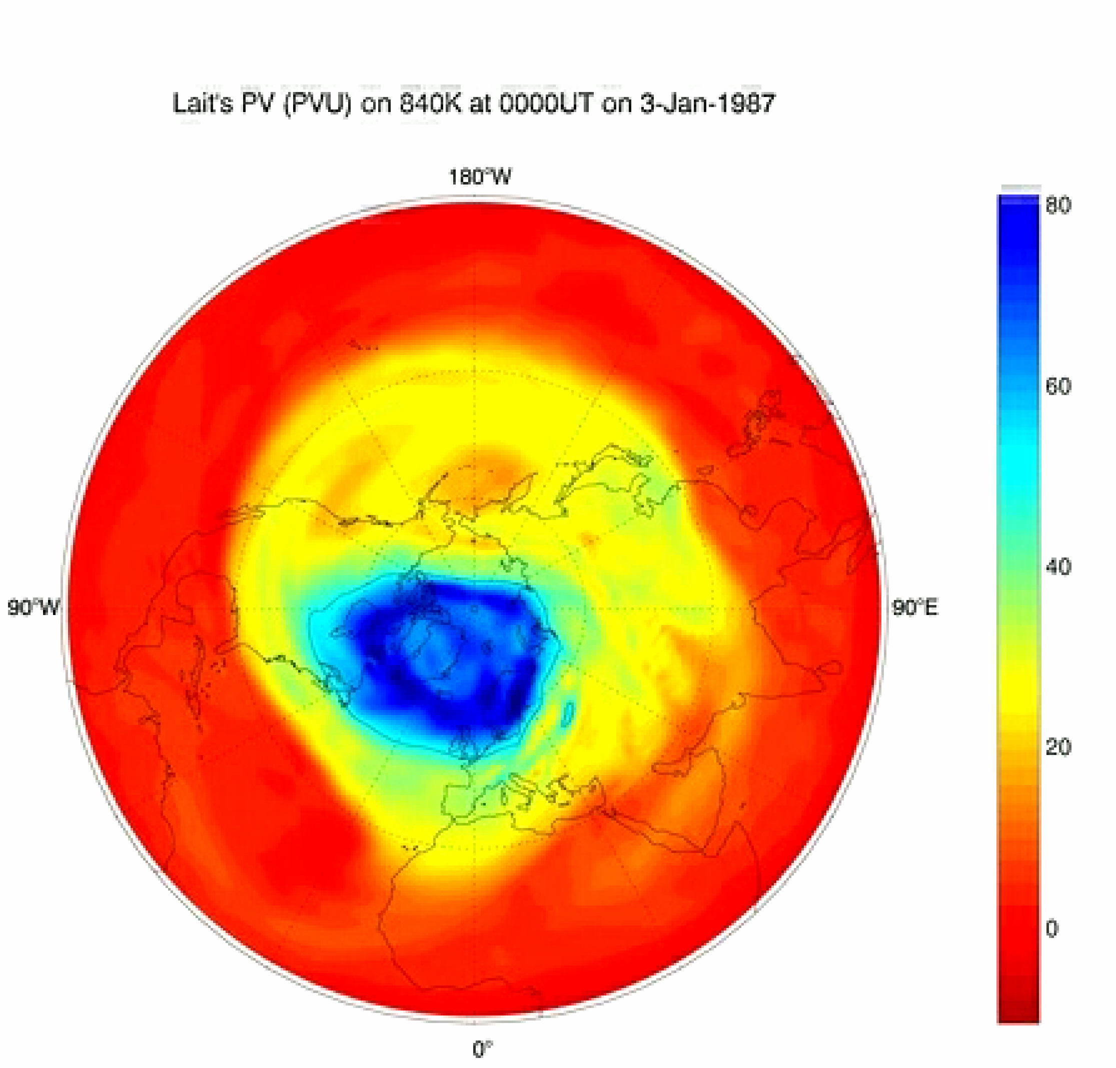
# Zonal-mean wind & polar cap temperature, 10 hPa, NH winter 1984/85



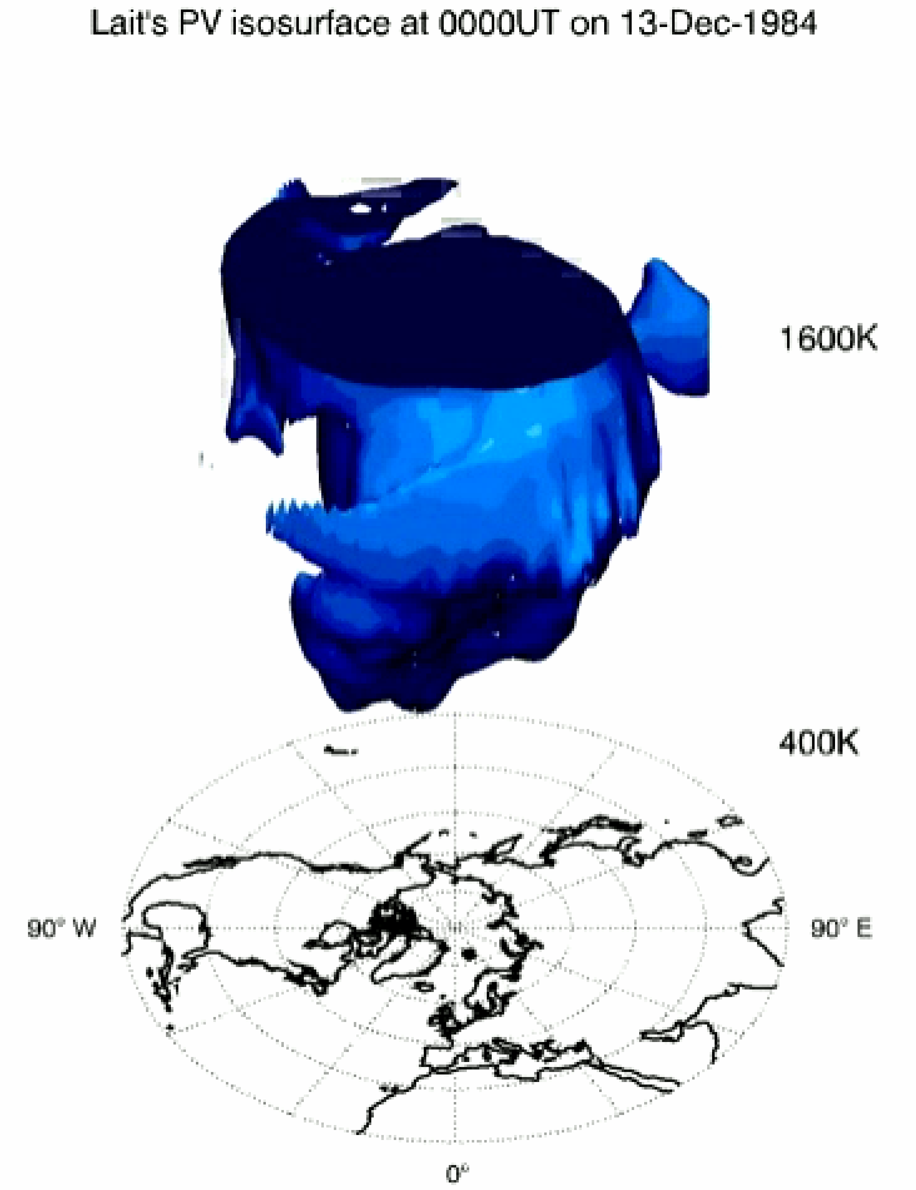
# NH Dec/Jan 84/85: PV 450K



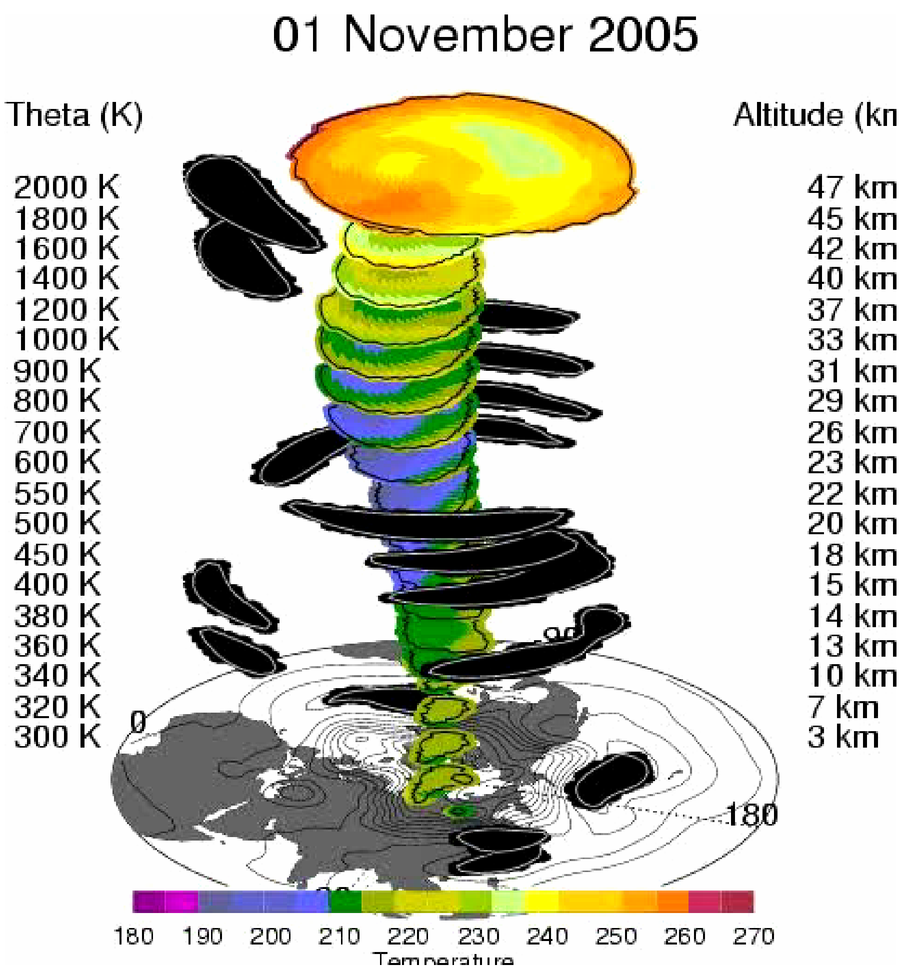
# NH Jan 87: PV 840 K



# NH Dec/Jan 84/85: PV isosurface



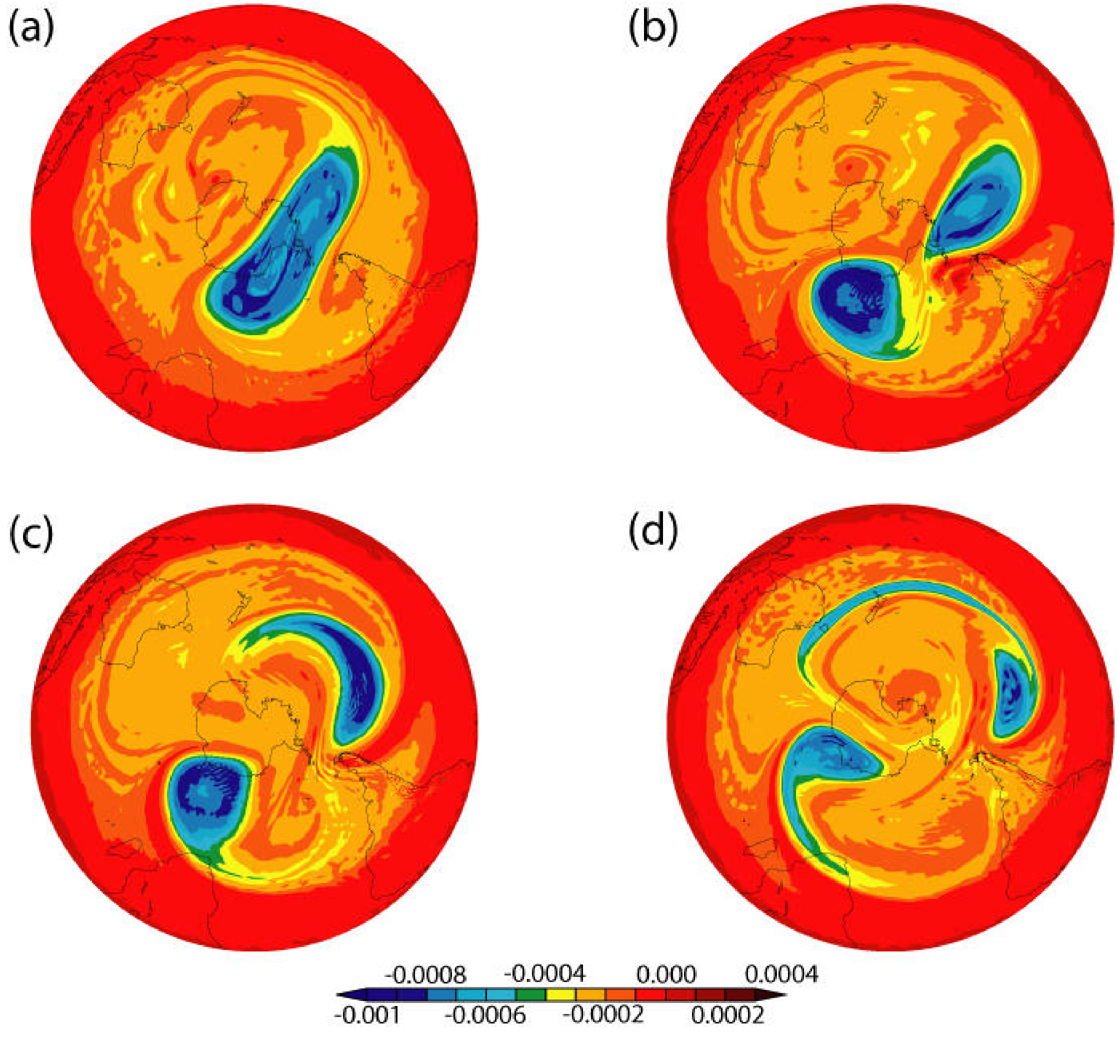
# The Polar Vortex: NH 2005/6



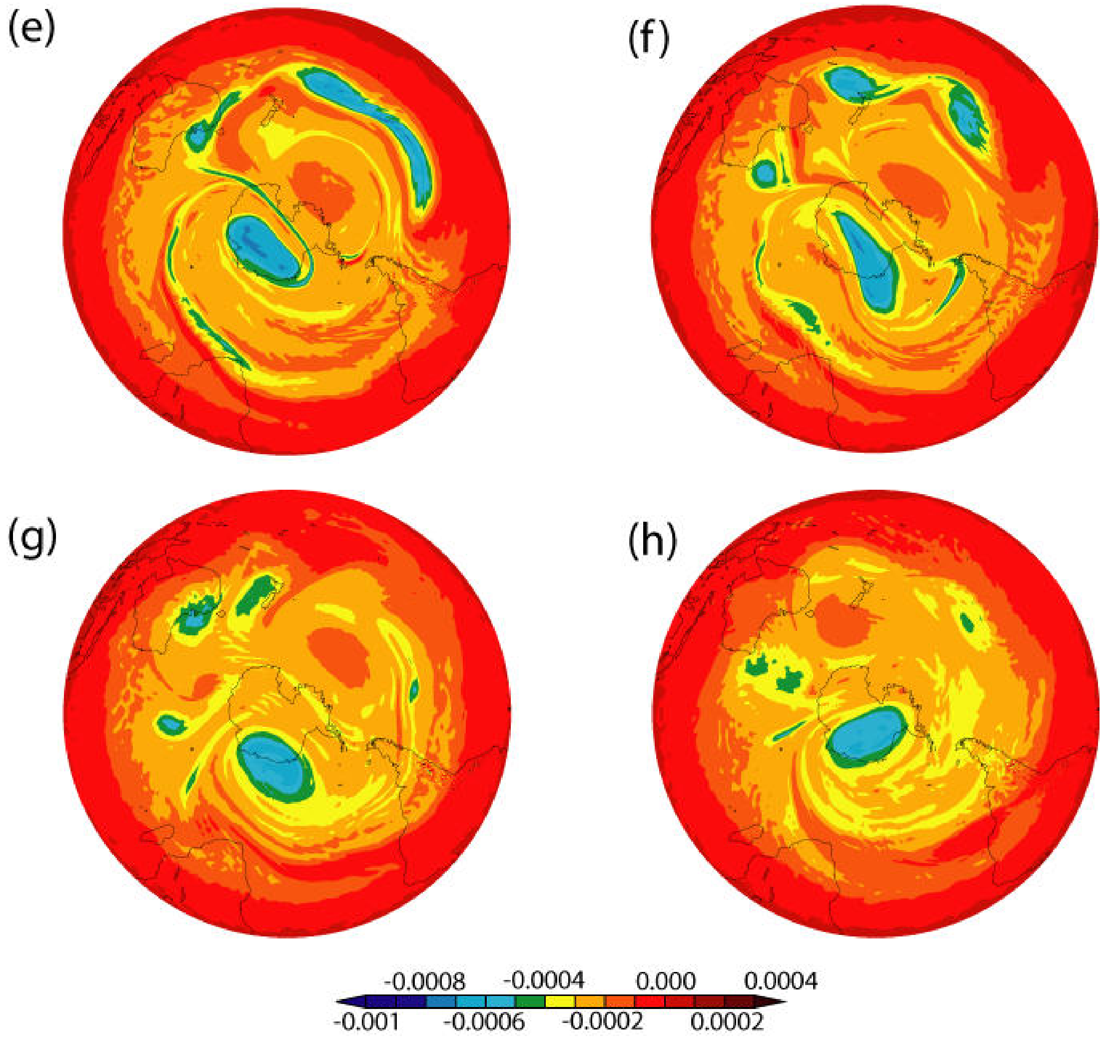

Courtesy of Lynn Harvey

# SH Sep 2002: 850K PV

| | |
|---|---|
| 1 | 22 |
| 25 | 28 |



# SH Oct 2002: 850K PV

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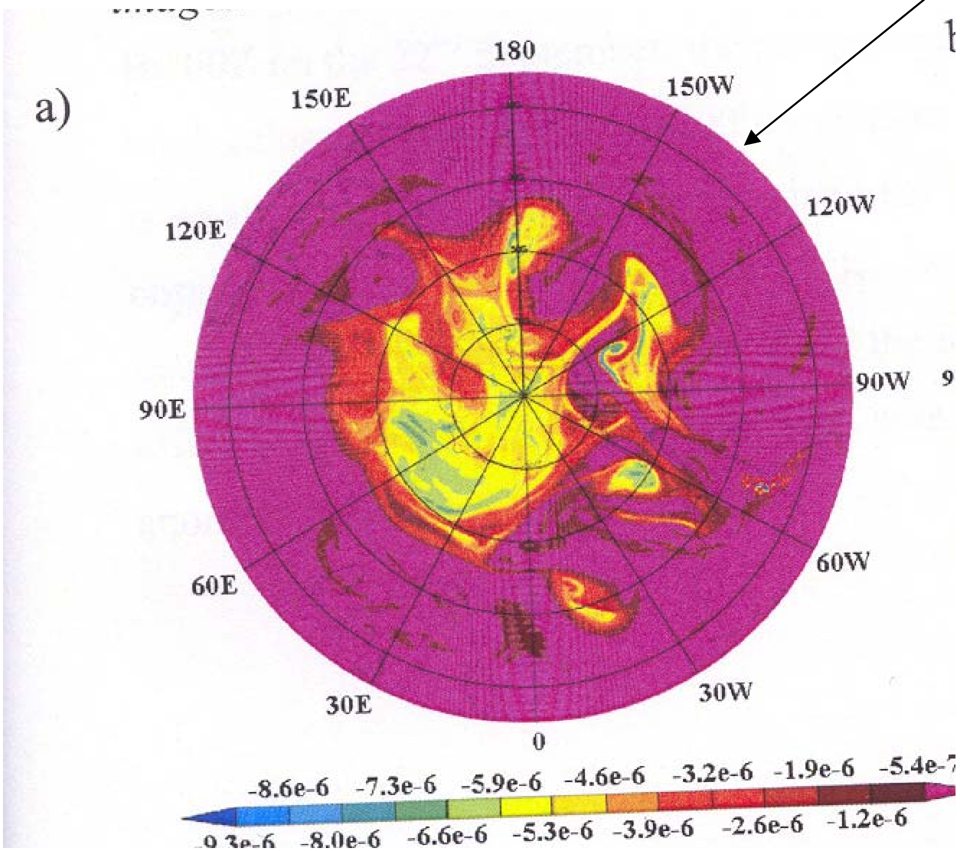
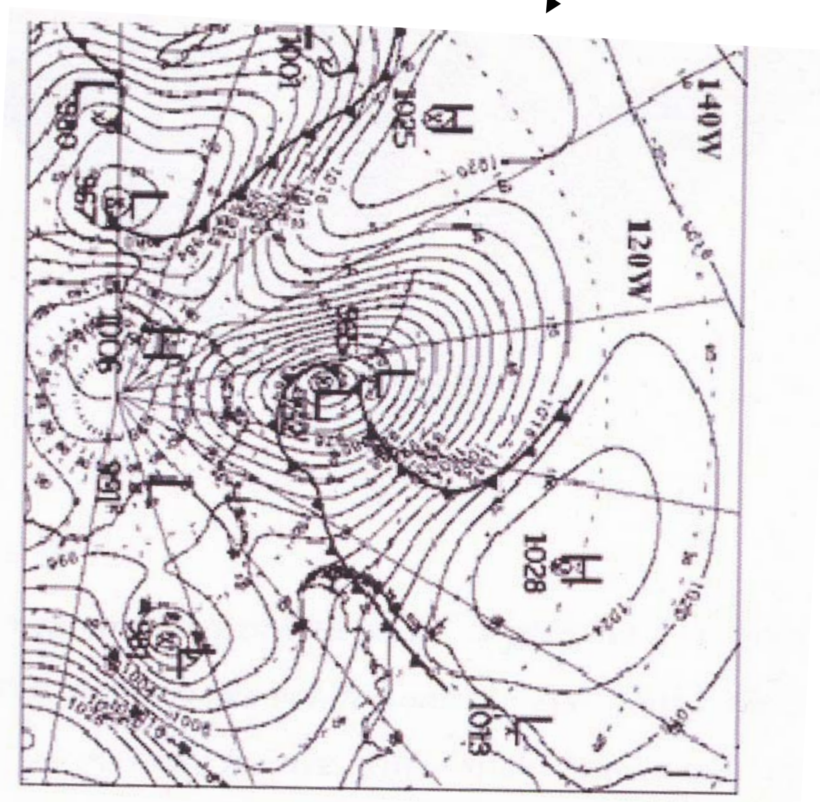
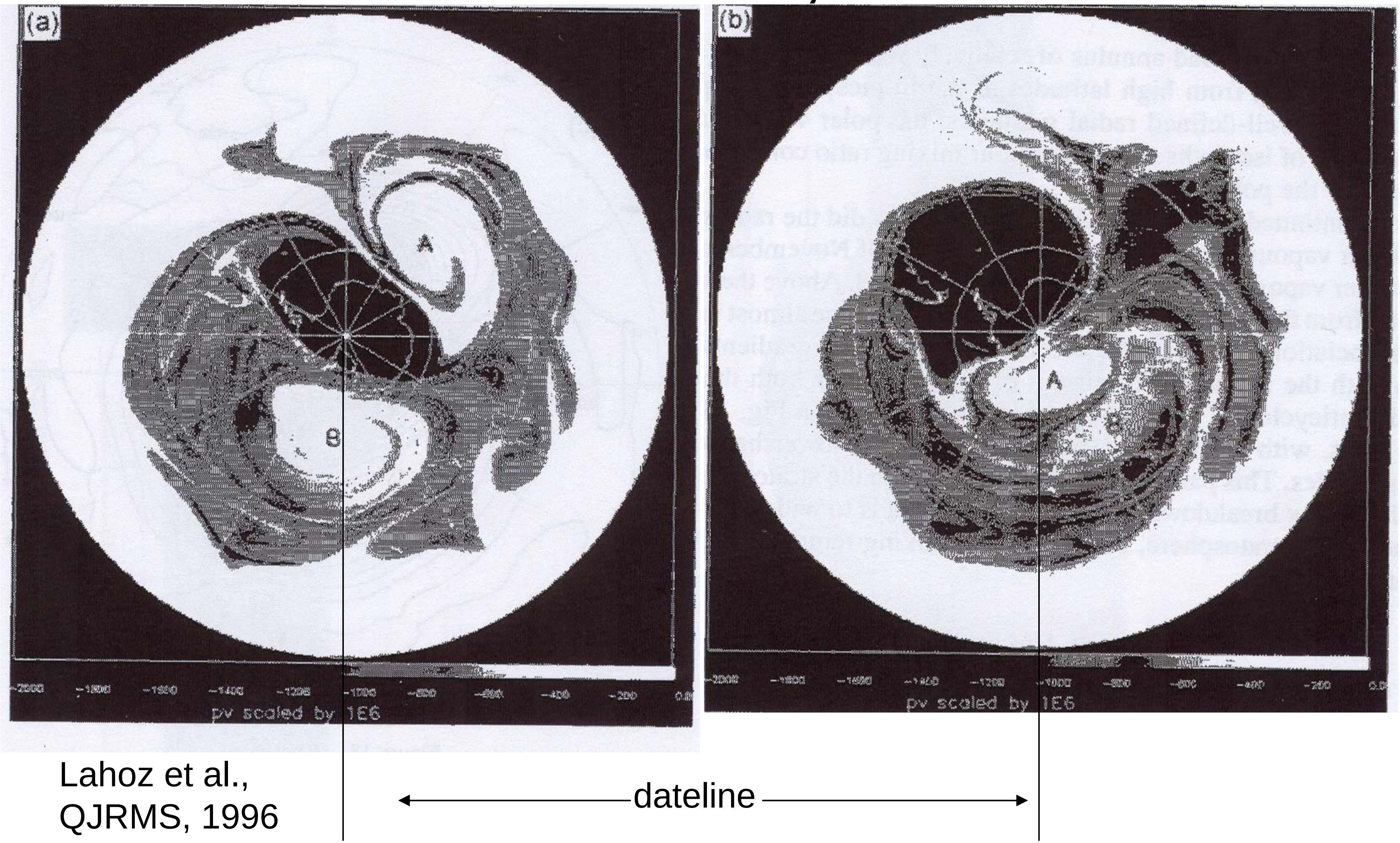
# SH 21 Sep 2002: PV 350K & $p_*$



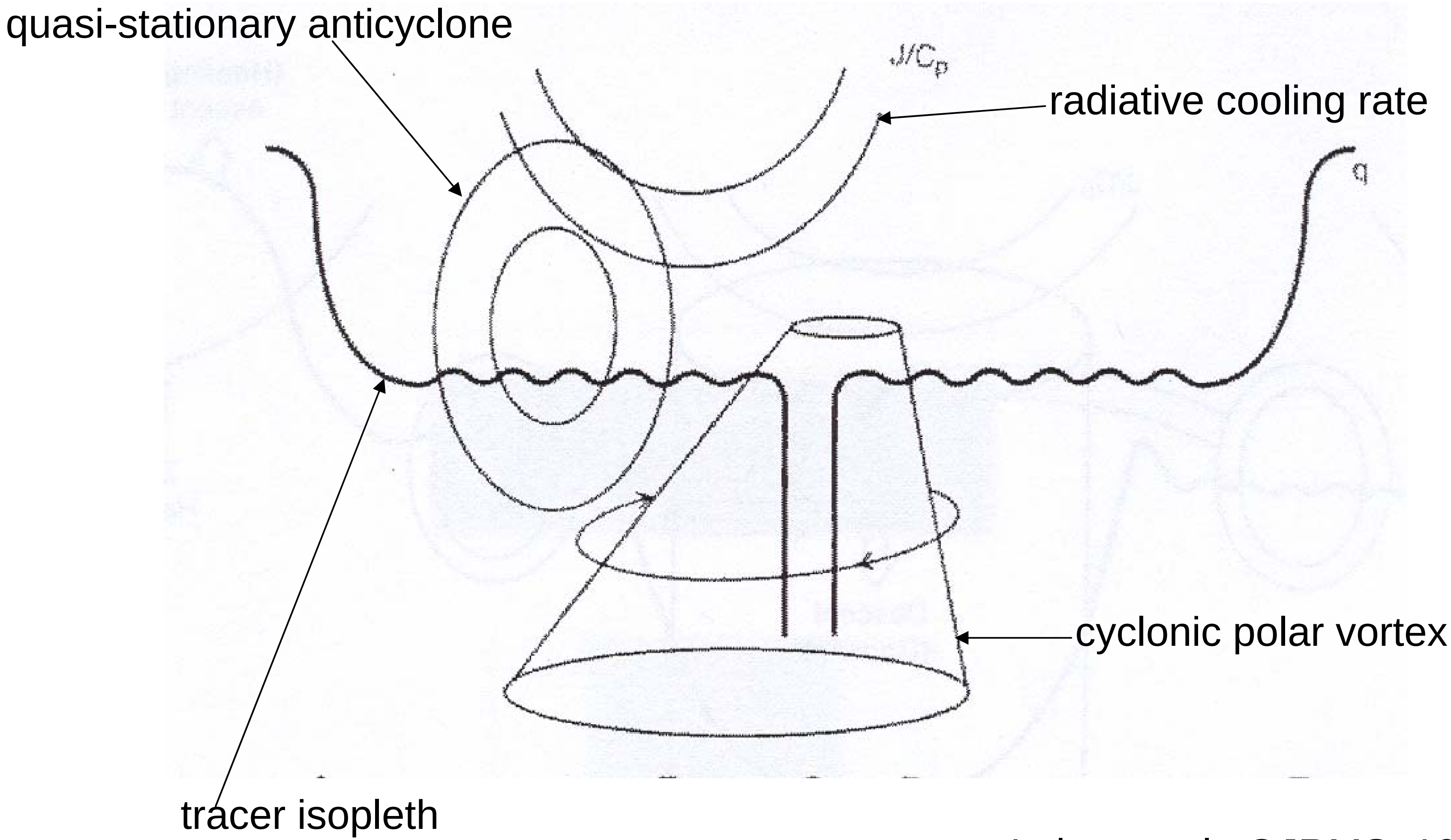

*f mean sea level pressure for 00Z 21st September 20*

# Merger of anticyclones, SH, 10 & 13 Oct 1992, PV 1100K




Lahoz et al., QJRMS, 1996

# Schematic of Top-Down Breakdown of SH Polar Vortex




Lahoz et al., QJRMS, 1996

# Variability of the Polar Vortex

- Evolution of coherent vortical structures, involving strongly local, nonlinear dynamics (e.g. during vortex merger) and the interaction of anticyclones with the polar vortex.
- Deep, nonlinear evolution between axi-asysmmetric states in the upper troposphere and stratosphere.
- Possibility for instability of highly distorted polar vortex to finite-amplitude perturbations (e.g. cyclogenesis in the troposphere).
- Tropospheric wave maker & vertical propagation?
- Troposphere-stratosphere as a coupled system?

# SPARC & IPY

- Characterise the structure and evolution of the (meteorological and chemical) of the stratospheric polar vortex (NH & SH).
- Archive of data or metadata at the SPARC Data Centre

End