The dynamics of the stratospheric polar vortex

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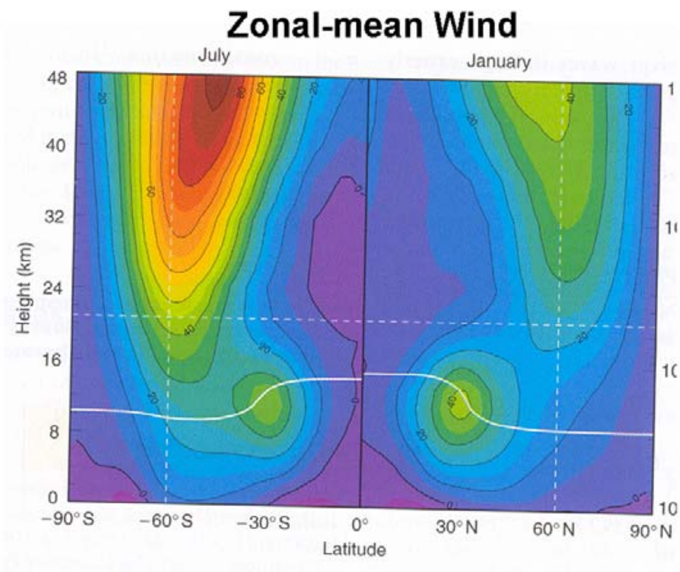
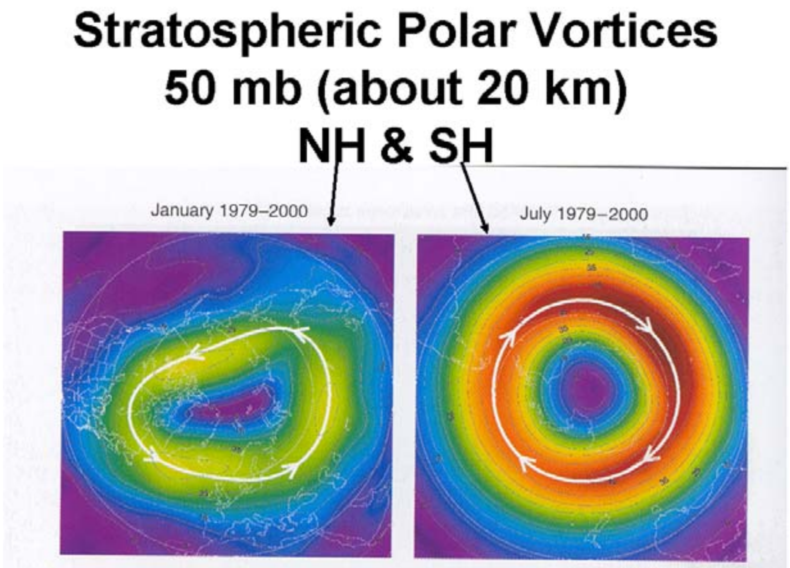
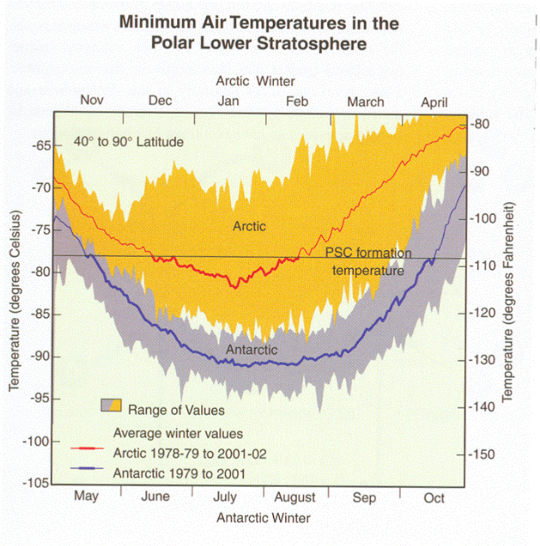
Outline

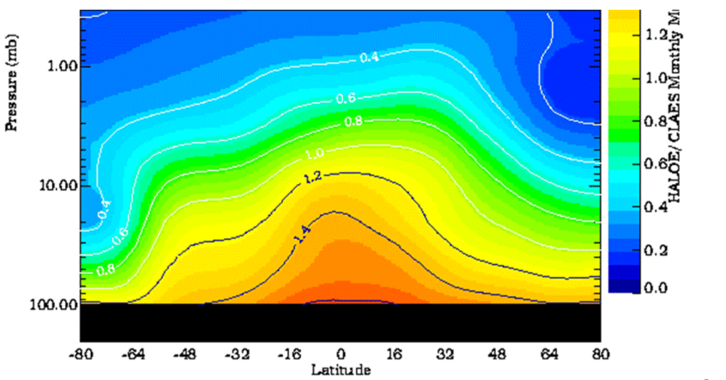
- Structure of the stratospheric polar vortex
- Phenomenology
  - vortex-vortex interactions during stratospheric sudden warmings
  - impacts (on trace gases & on troposphere)
- Some theoretical considerations



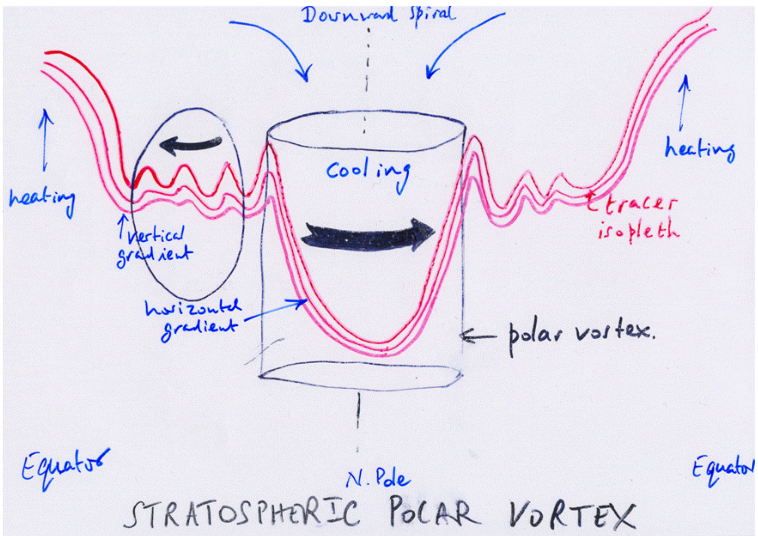




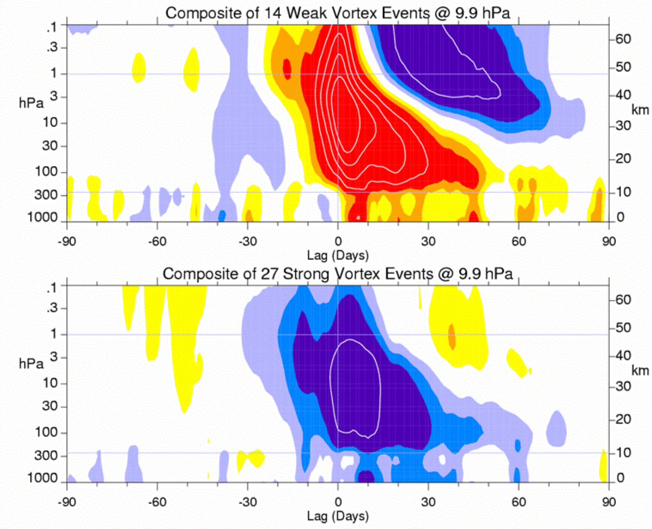
Cross-Section of Methane October



UARS Climatology Pressure vs Equivalent Latitude October

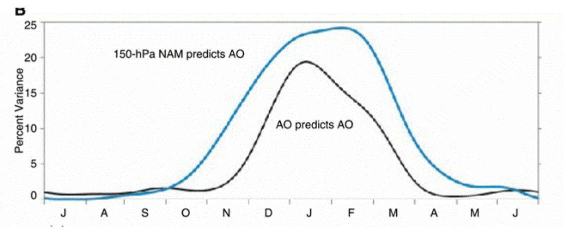


Courtesy of Mark Baldwin



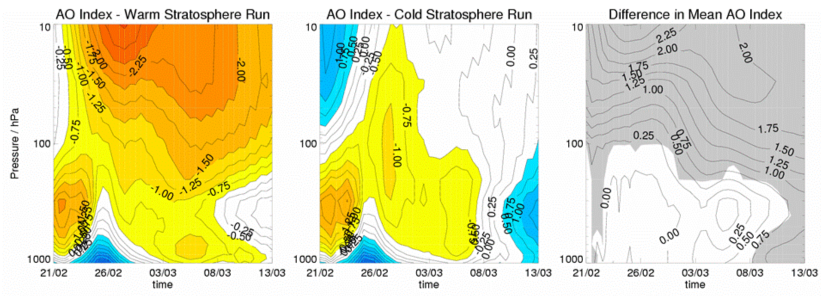
Consequence 1: Forecasting

- 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)

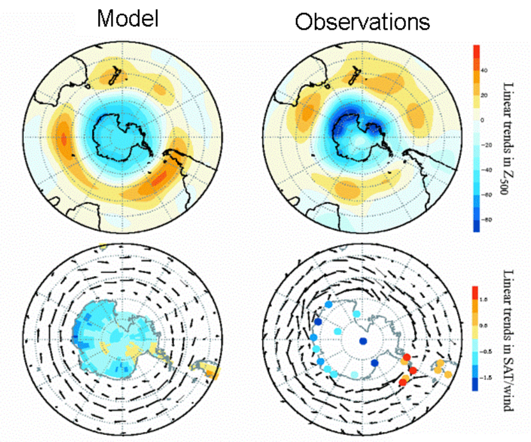
Impact of Stratosphere 2



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

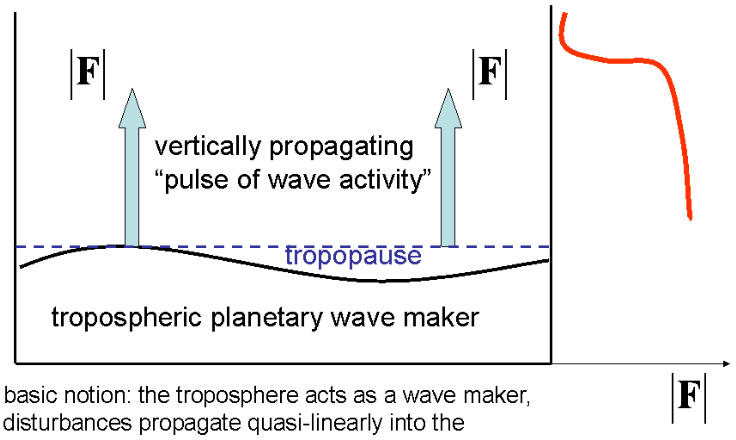
- Wave, mean-flow interaction.
- Vortex-vortex interaction.

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."

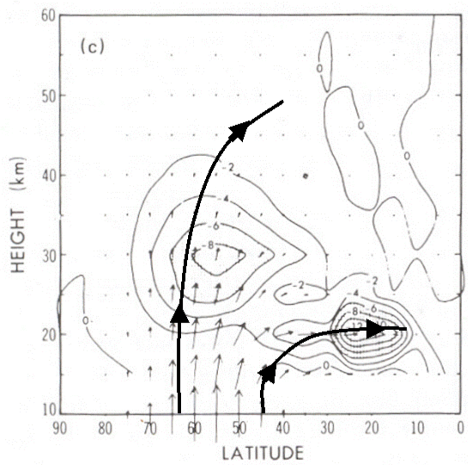
An Introduction to Dynamic Meteorology, 4th edition (2004), James R Holton, Elsevier, p. 425.

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

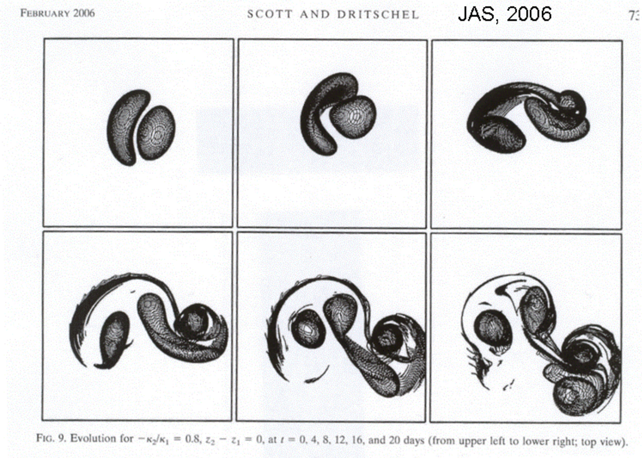
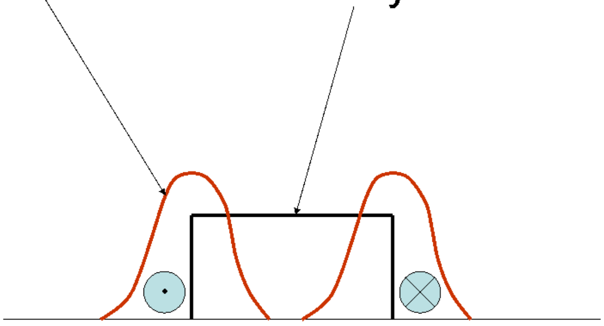
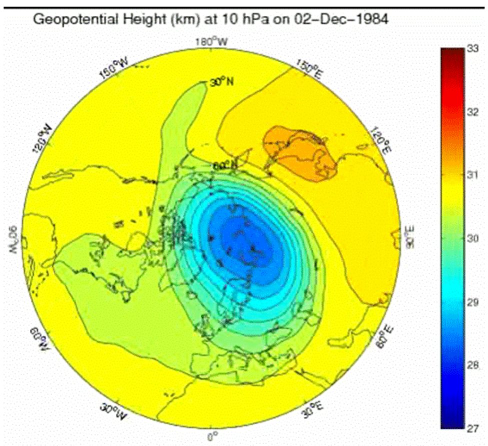


FIG. 9. Evolution for $-\kappa_2/\kappa_1 = 0.8$, $z_2 - z_1 = 0$, at $t = 0, 4, 8, 12, 16$, and 20 days (from upper left to lower right; top view).

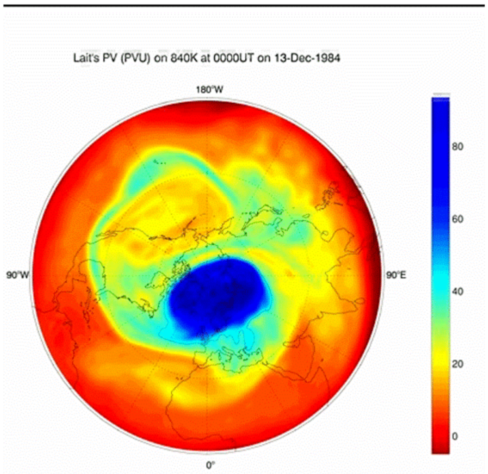
Wind Speed Near Localised PV Anomaly



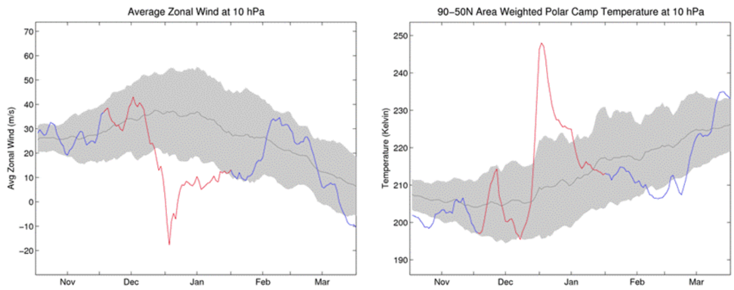
NH Dec/Jan 84/85: Geo Ht 10 hPa



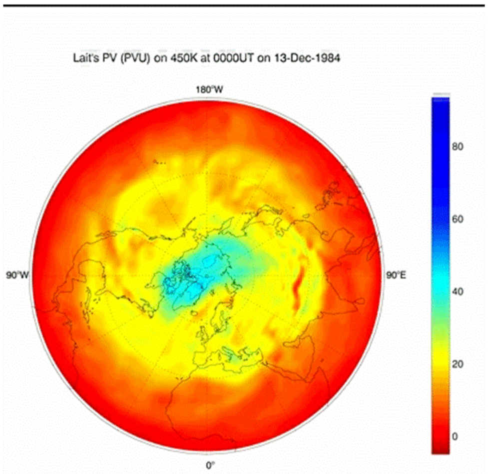
NH Dec/Jan 84/85: PV 840K



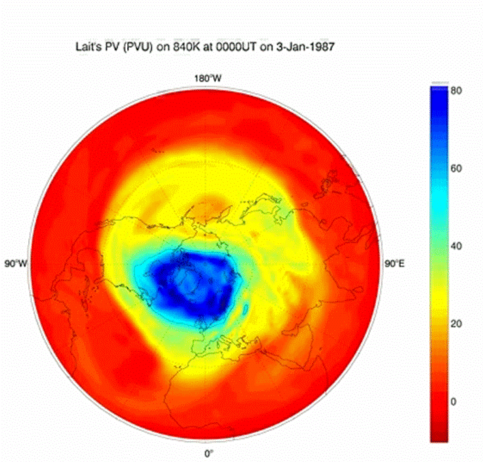
Zonal-mean wind & polar cap temperature, 10 hPa, NH winter 1984/85



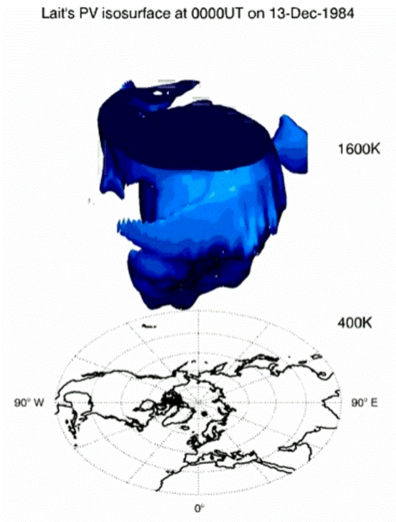
NH Dec/Jan 84/85: PV 450K



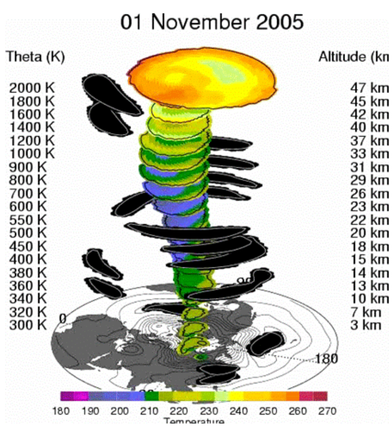
NH Jan 87: PV 840 K



NH Dec/Jan 84/85: PV isosurface

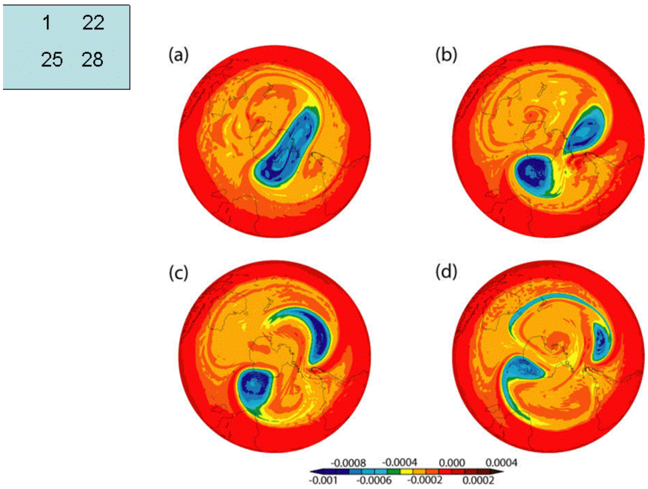


The Polar Vortex: NH 2005/6

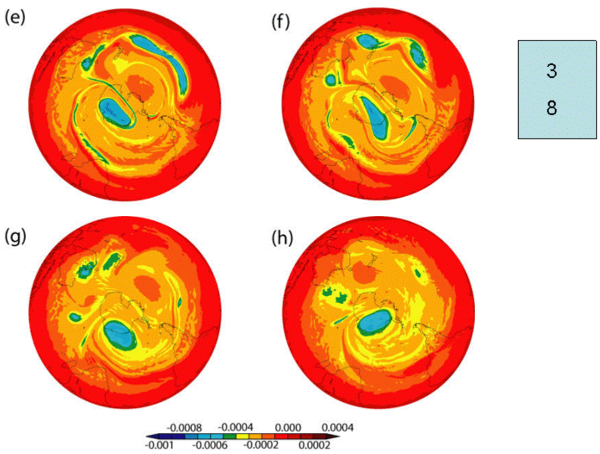


Courtesy of Lynn Harvey

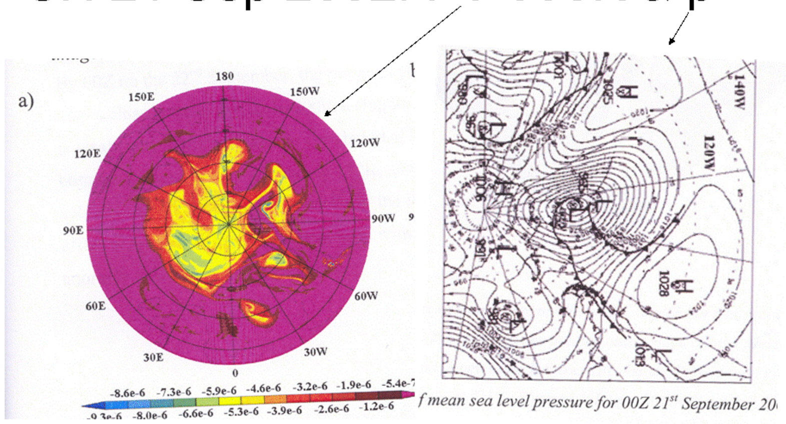
SH Sep 2002: 850K PV



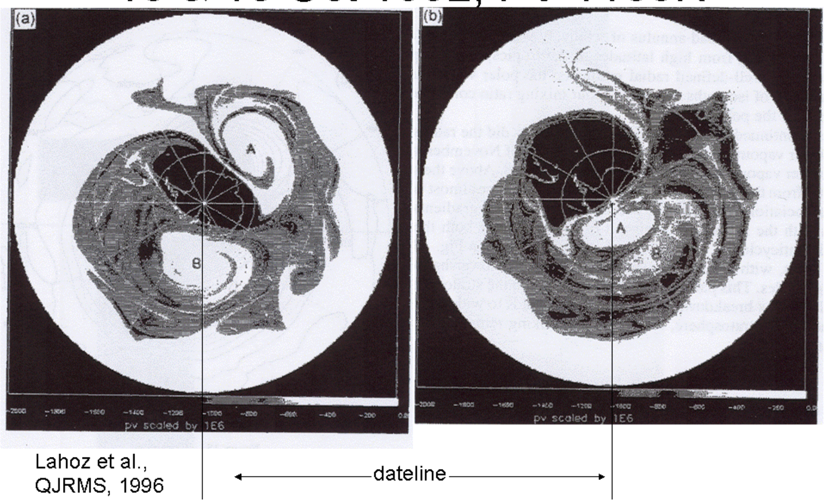
SH Oct 2002: 850K PV



SH 21 Sep 2002: PV 350K & p*

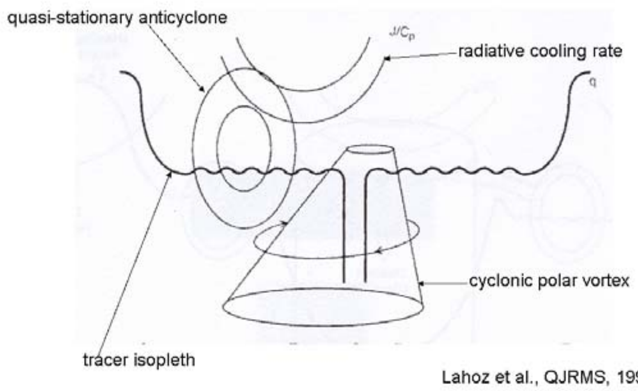


Merger of anticyclones, SH, 10 & 13 Oct 1992, PV 1100K



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