National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Inertial Instabilities in Geophysical Datasets

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Overview

- HIRDLS Scientific Objectives
- Inertial Instabilities: Theory & Observations
- 'New Dynamics' Unified Model
- Science Questions

HIRDLS: Scientific Objectives

- Understand chemical processes, transports and mixing in the upper-troposphere/lower stratosphere.
- Understand stratosphere-troposphere exchange of a variety of gases/aerosols at a fine scales
- Better evaluate the budgets of; momentum, energy, heat and PV, which help mitigate this exchange
- To provide data to help constrain and validate models.

Inertial Instabilities

- Arise due to a mismatch between centrifugal and pressure gradient forces.
- A zonally symmetric flow is unstable to zonally symmetric disturbances when;

$$f\bar{P} < 0$$

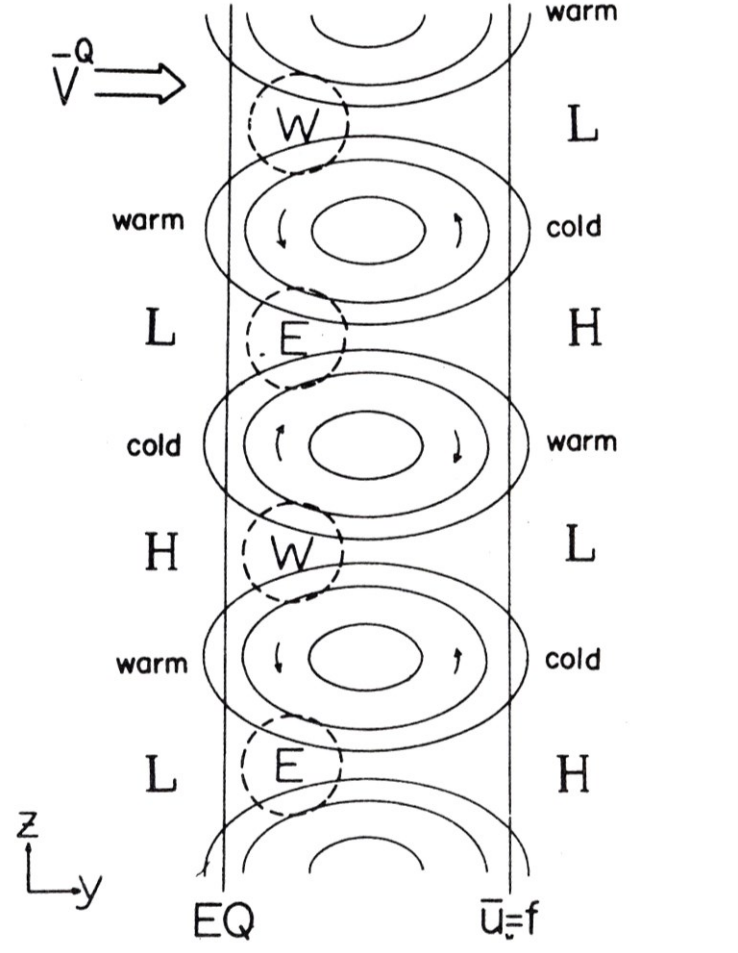
- Or for barotropic flow when,

$$f\left(f - \bar{u}_y\right) < 0$$

Observations

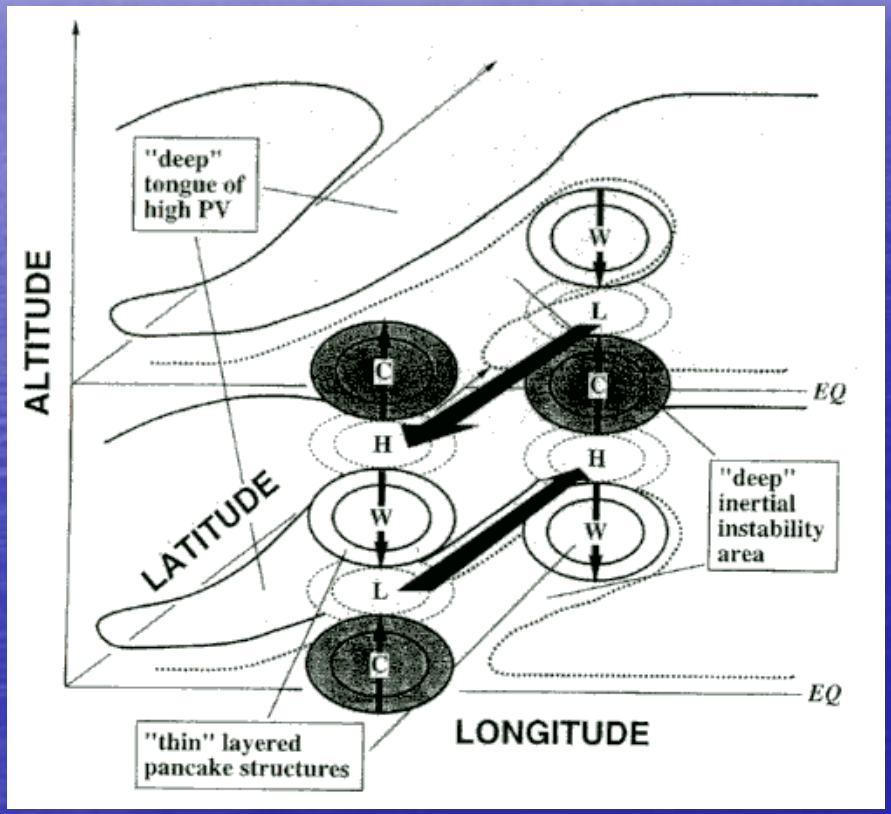
- 'Pancake' structures seen in LIMS data in the equatorial lower mesosphere (Hitchman et al., 1987).
- Climatology compiled using UKMO assimilated analyses (1991-2004) of 'inertial instability frequency' by Knox and Harvey (2005). Strengthened link with periods of Rossby wave breaking.
- Also has been associated with the 2-day wave (Orsolini et al., 1997; Limpasuvan et al., 2000) and stratospheric sudden warmings (Rosier and Lawrence, 1999)

Theoretical Development of Inertial Instabilities

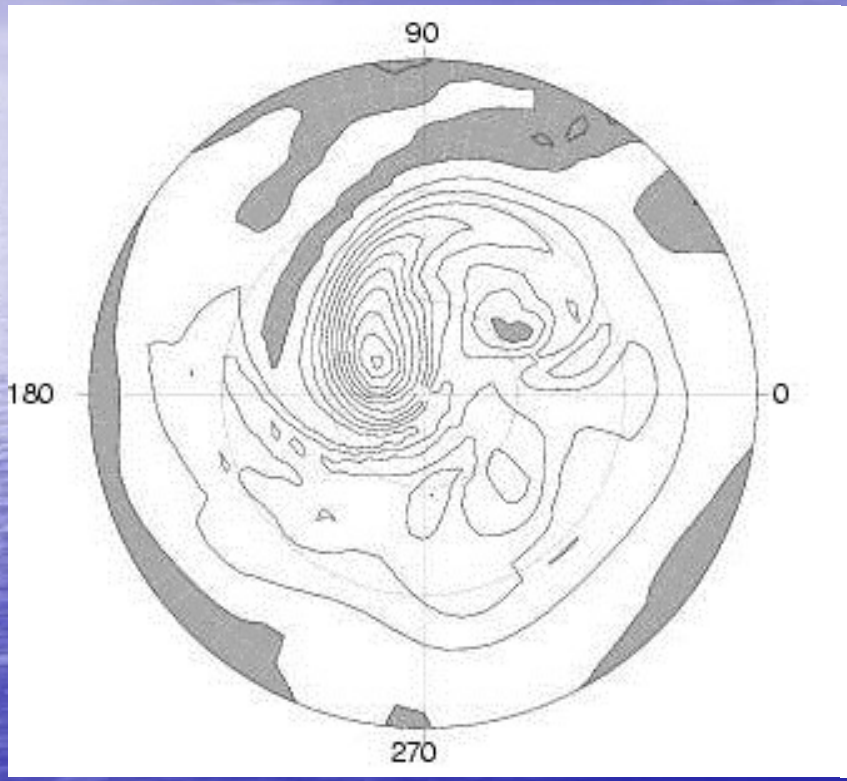


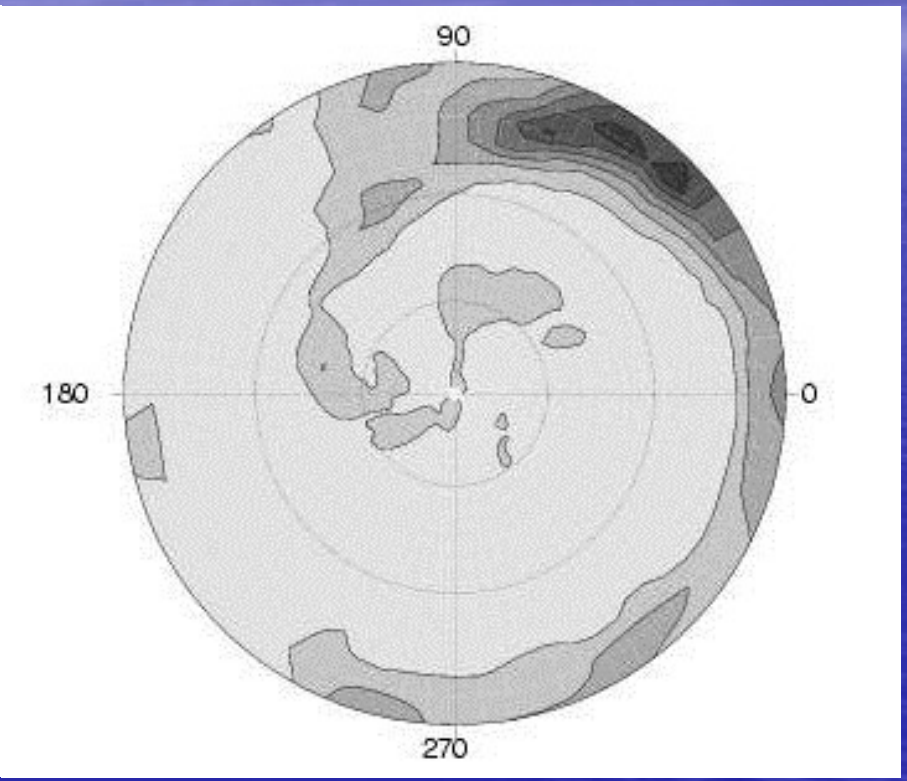
After Dunkerton (1981) *JAS*, 38, 2354-2364

Locally Confined IS



PV and Inertial Instability



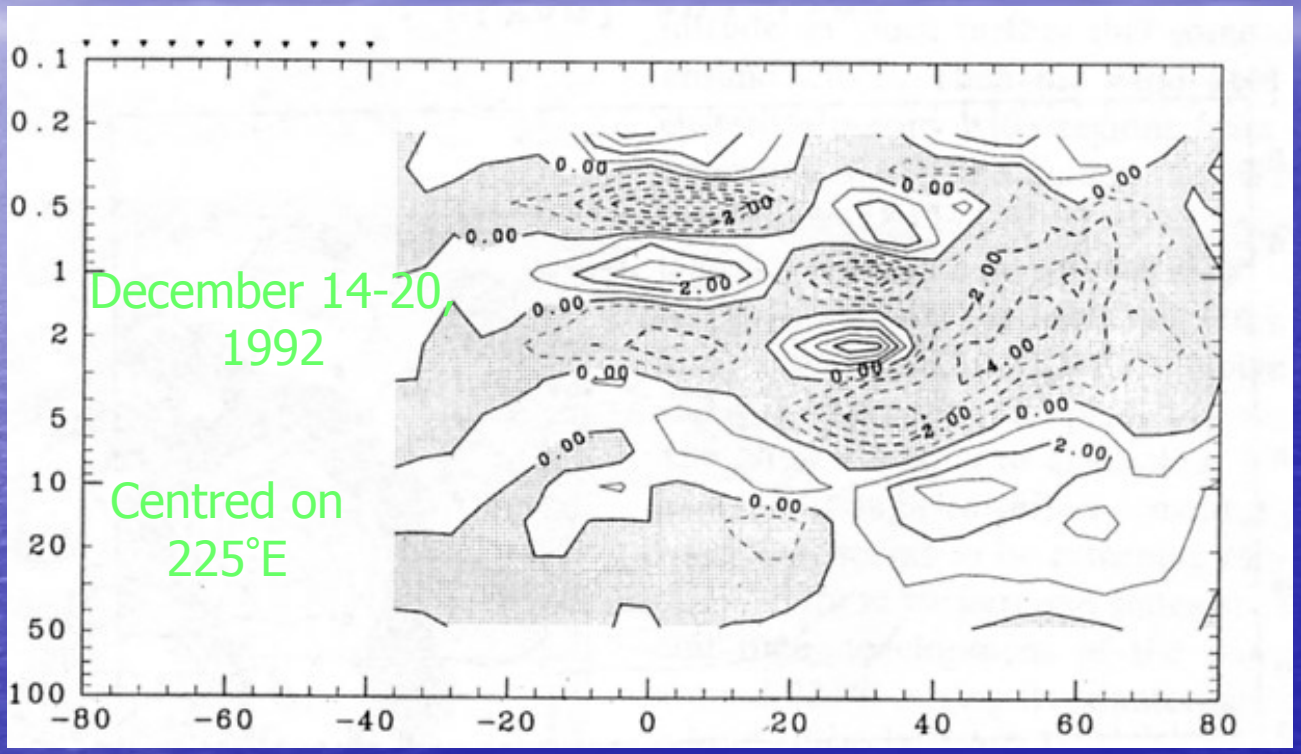


PV

III

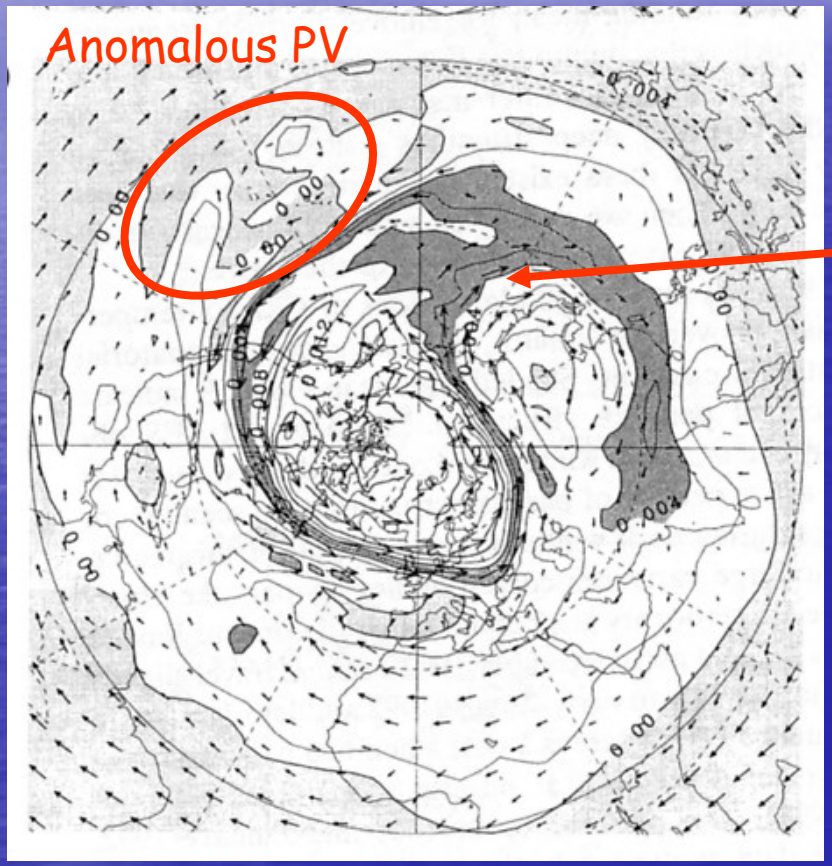
Courtesy of Alan Iwi, RAL

CLAES Temperature Anomalies



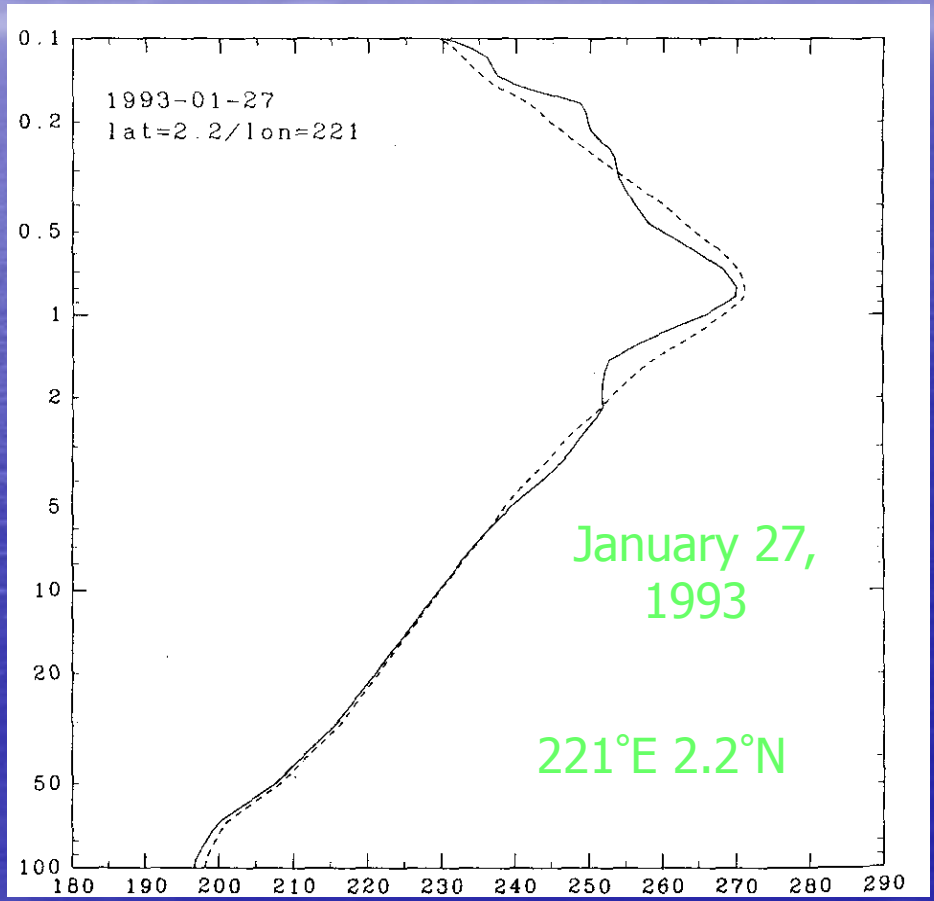
Hayashi et al., 1998, JGR, 103 (D16)

Northern Hemisphere PV

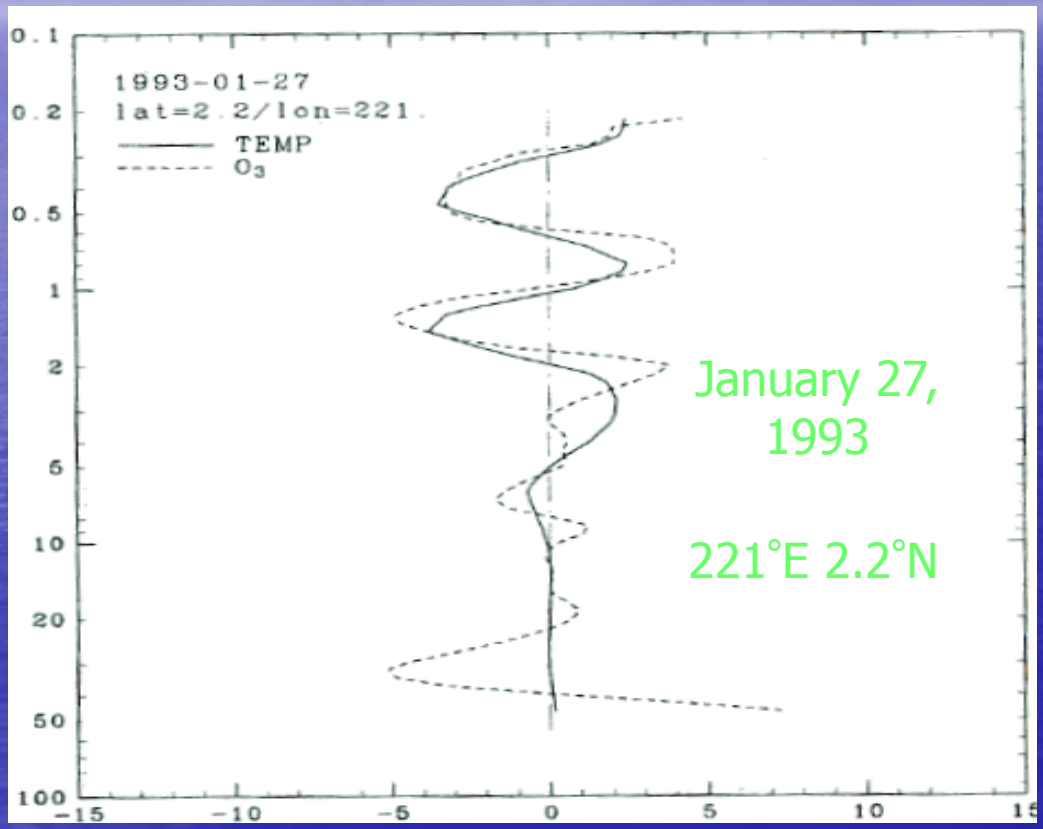


PV 1850K,
December 17, 2002

HALOE Temperature



'Pancake Structure'



Temperature (K)

Ozone Mixing Ratio

The New Dynamics Unified Model

- Solves a non-hydrostatic, semi-Lagrangian system using a semi-implicit time-stepping scheme
- Thought better able to accommodate changes in spatial resolution.
- Arakawa C-grid with Charney-Philips staggering in the vertical ('scalar': θ, w, tracers; 'vector': P, ρ, u)
- Will also be able to better resolve particular phenomena e.g. associated with Inertial Instabilities

Science Questions

- With a change in UM grid structure better able to accommodate flow adjustments due to Inertial Instability, what will be the consequences in relation to; the circulation about the tropical upper troposphere and stratosphere and the distribution of chemically and radiatively important gases/aerosols?
- How well expressed are these phenomena in observations? (HIRDLS)