The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1968-6

Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

Aspects of the theory of teleconnections

HELD Isaac Meyer

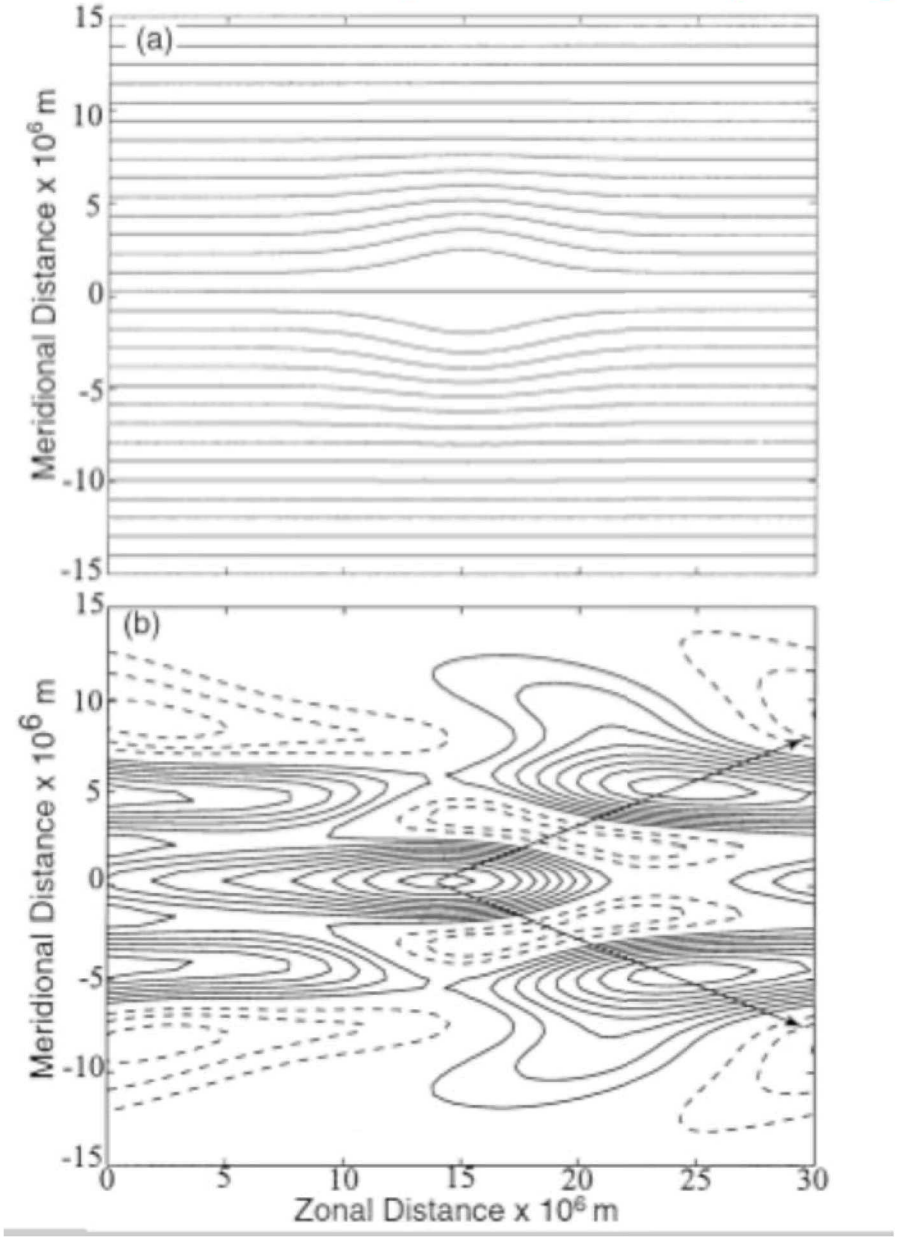
Princeton University, U.S. Department of Commerce N.O.A.A.
Geophysical Fluid Dynamics Laboratory
201 Forrestal Road, Forrestal Campus, P.O. Box 308
08540-6649 Princeton NJ
U.S.A.

Some aspects of the theory of Teleconnections deserving of more attention

- Barotropic Rossby edge wave dynamics
- Effective linear operators
- Pseudo-momentum

Isaac Held
Trieste, Nov. 16, 2008

• Barotropic Rossby edge wave dynamics



Barotropic instability of zonally asymmetric flow

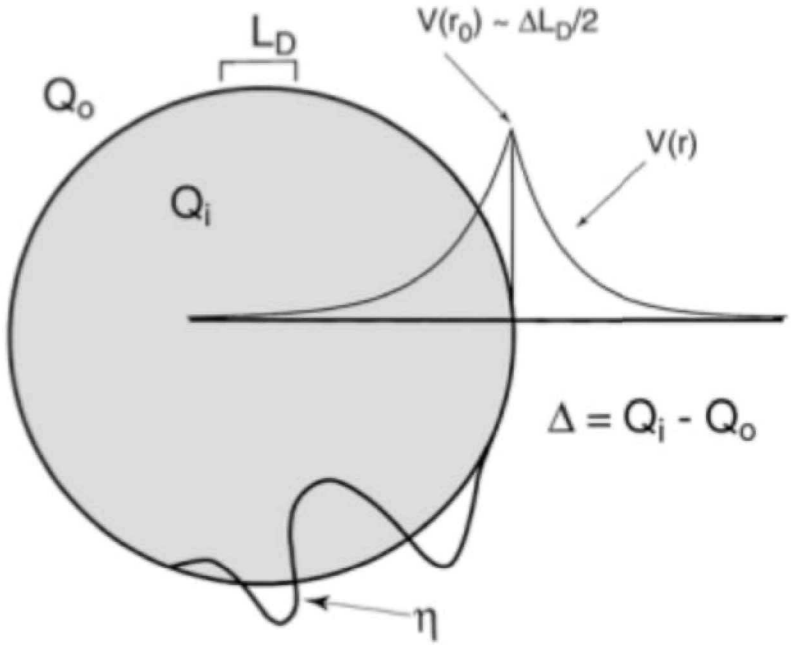
Instability often takes the PNA-like form of waves emanating from jet exit region

But no examples are simple enough that they provide useful intuition into what characteristics of the flow control various features of the instability

Swanson, JAS, 2000

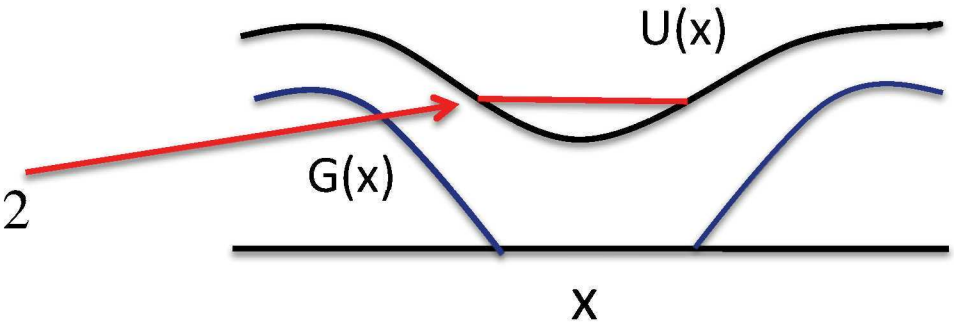
Quasi-geostrophic shallow water vortex

K. Swanson, JAS, 2000
QJRMS, 2001
J. Clim, 2002

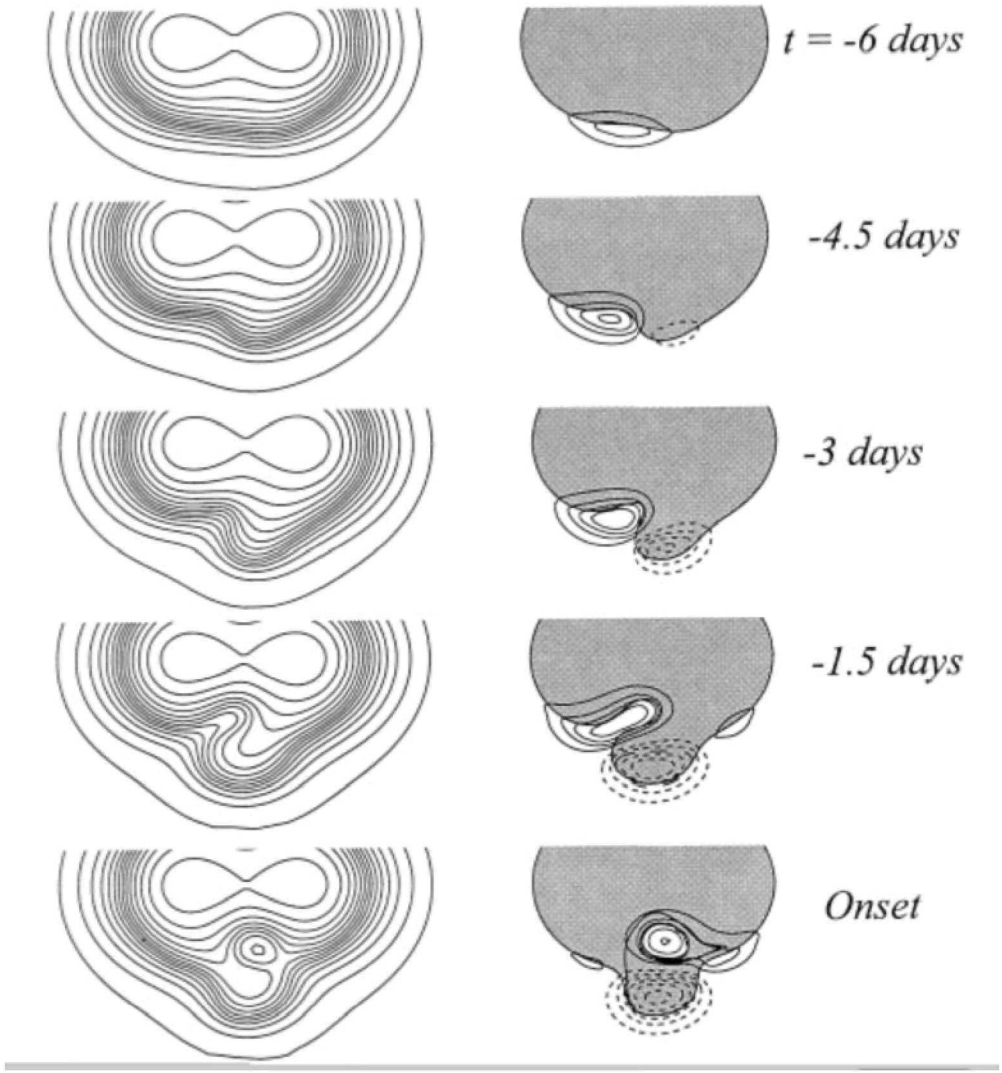


$$\omega = Uk - \frac{\Delta k}{2\sqrt{k^2 + L_D^{-2}}}$$

$$G_X = \frac{\partial \omega}{\partial k} \Rightarrow 0 \quad as \quad U \Rightarrow \Delta L_D / 2$$



Absolute instability – growth in place typically requires that group velocity be zero at some frequency



Nonlinear evolution when vortex is perturbed by topography so that group velocity => 0

Swanson, J. Clim, 2002

Typically evolves towards "blocked" state, but solutions are more wave-like when propagation is enabled by additional contours

- Effective linear operators

Linear stationary wave responses

– linearizing about time mean flow –

not very robust – often need to add arbitrary damping

Complexities

- interactions with transients
- interactions with latent heating
- variability in “mean flow”

Is there a short cut to developing effective linear operators that incorporate all such effects?

How is this effective linear operator related to linearizing about time mean flow

$$\frac{dx}{dt} = N(x) + \delta F$$

$$\delta \overline{x}^{t} = L\delta F \quad or \quad L^{-1}\delta \overline{x}^{t} = \delta F$$

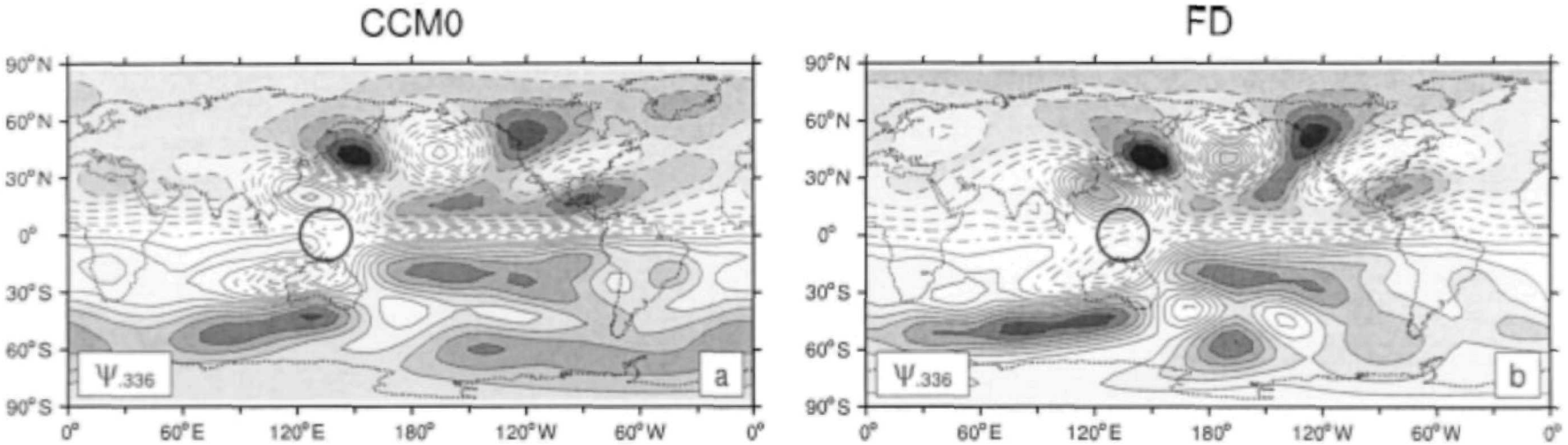
$$L = \int_0^\infty C(\tau)C^{-1}(0)d\tau$$

$$C_{ij}(\tau) = \overline{x_i(t)x_j(t+\tau)}^{t}$$

Leith, JAS, 1975

GCM response to localized equatorial heating

response obtained from fluctuation-dissipation relation



upper tropospheric streamfunction

Gritsun and Branstator, JAS 2007

- Pseudo-momentum

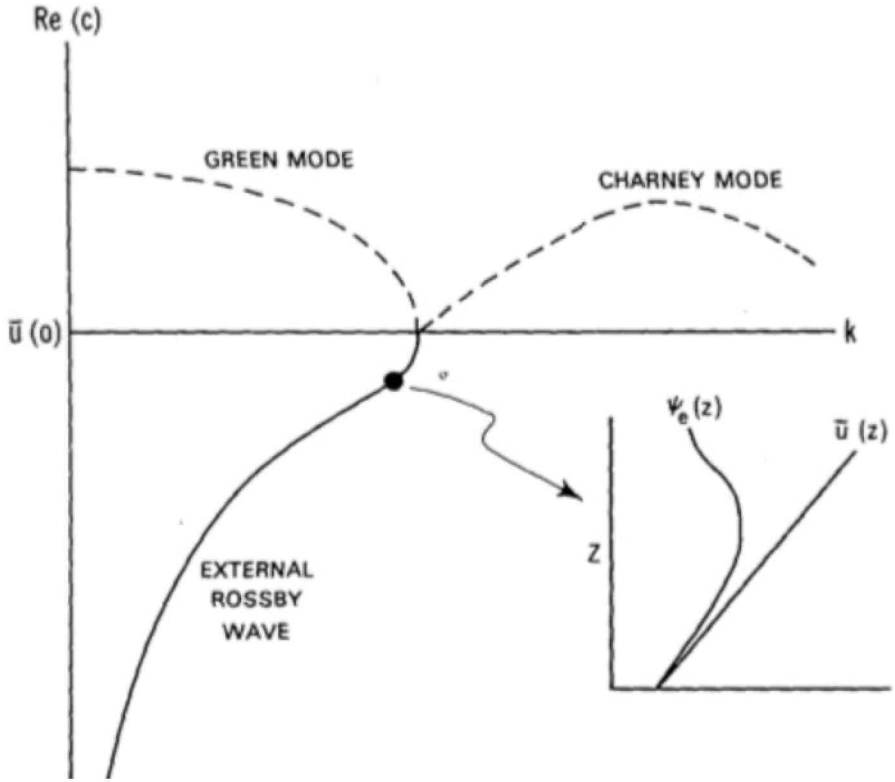
External Rossby waves:

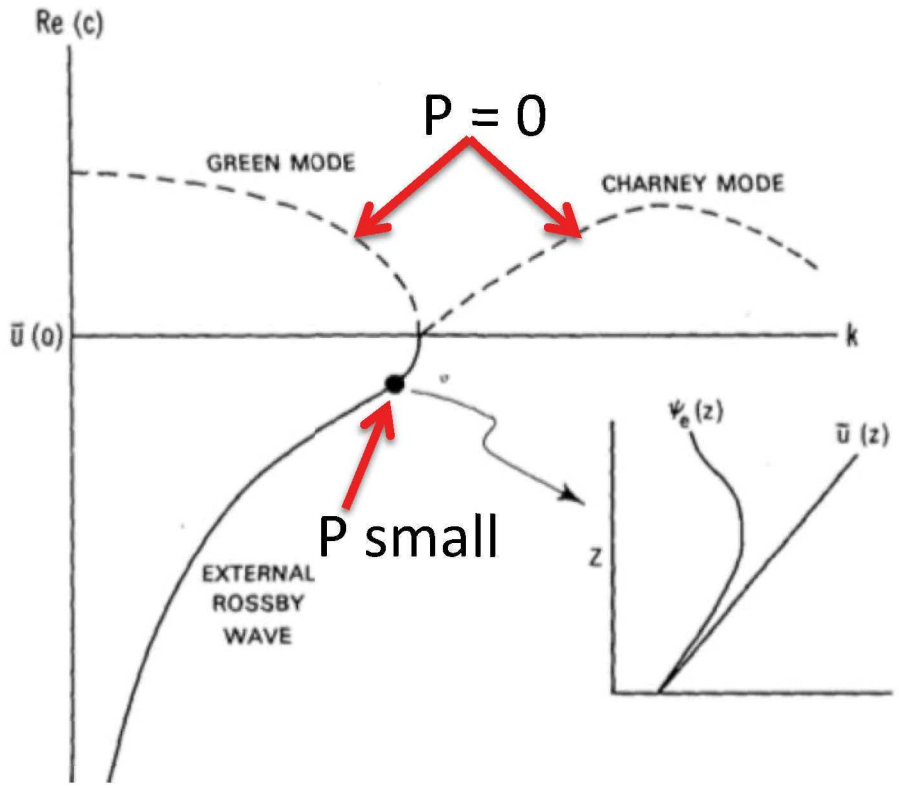
equivalent barotropic:,
EAPE comparable EKE;
top-heavy in EKE, but meridional particle displacements are of the same order in upper and lower troposphere:

$$\eta' \sim \psi'/U$$

Small pseudo-momentum

Dispersion relation for Charney's model





$$P = \int \eta'^2 \frac{\partial q}{\partial y} dz \; - \; \eta'^2 \frac{\partial \Theta}{\partial y}\Big|_{z=0}$$

Implications of the Pseudomomentum of an external Rossby wave being small:

- *Wave is much easier to excite*
  than upper level barotropic disturbance in isolation

- *Damping at low levels increases wave amplitude*

- *Vertically averaged zonal mean flow deceleration that occurs*
  when wave propagates into a region is much smaller
  than would be the case of an upper level disturbance in isolation

- Barotropic Rossby edge wave dynamics

  Best chance for simple models of the dynamics of low-frequency variability?

- Effective linear operators

  Promise to provide more robust linear theories.

  Can one generate these directly from observations?

- Pseudo-momentum

  Low level dynamics can be as important as upper level dynamics for the external Rossby waves that underlie wavelike teleconnection patterns