Part III Fluid Dynamics of Climate

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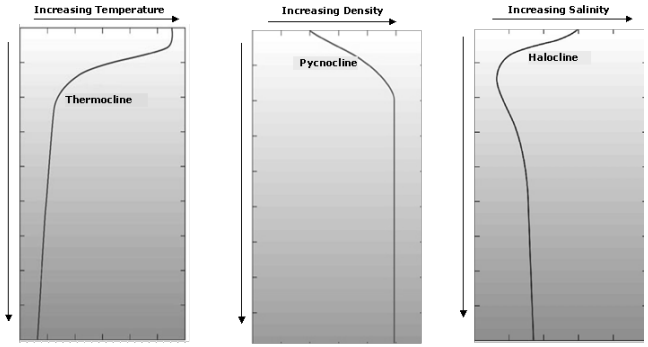
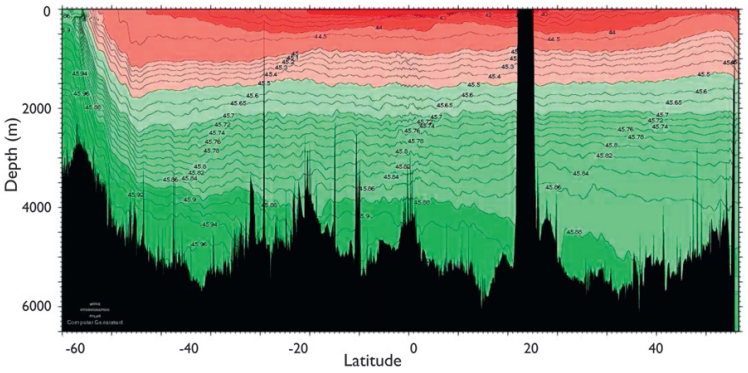
DAMTP

CC*f*CS

Ocean – density variation



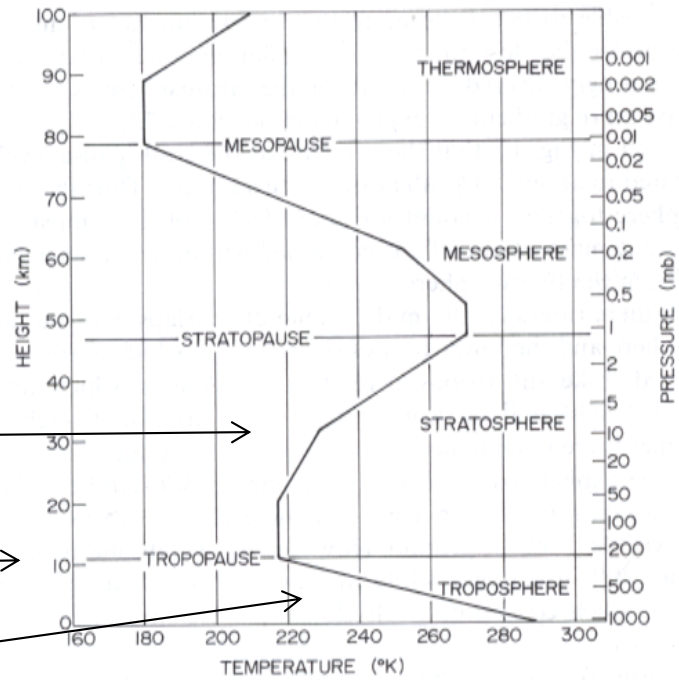
Schematic of typical temperature, salinity and density profiles in the ocean



WOCE potential density σ_4 (~150^{o}W)

Nikurashin and Vallis (2011)

Atmosphere – temperature variation



stratosphere

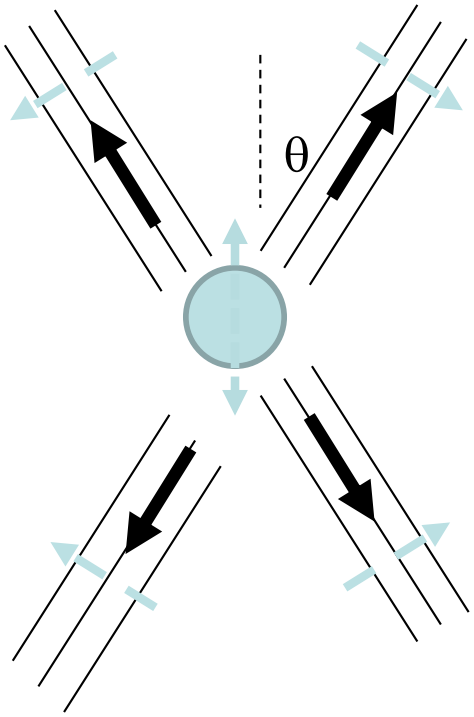
tropopause

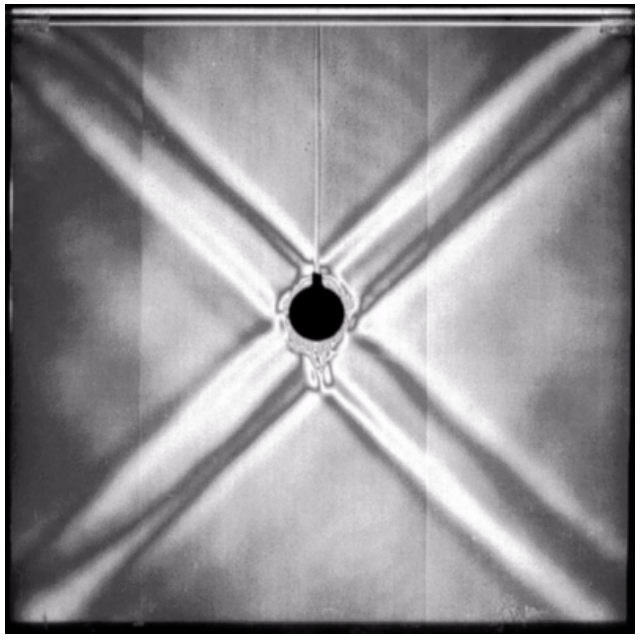
troposphere

Oscillating sphere

http://dennou-k.gfd-dennou.org/library/gfd_exp/exp_e/index.htm

(Dr Satoshi Sakai)

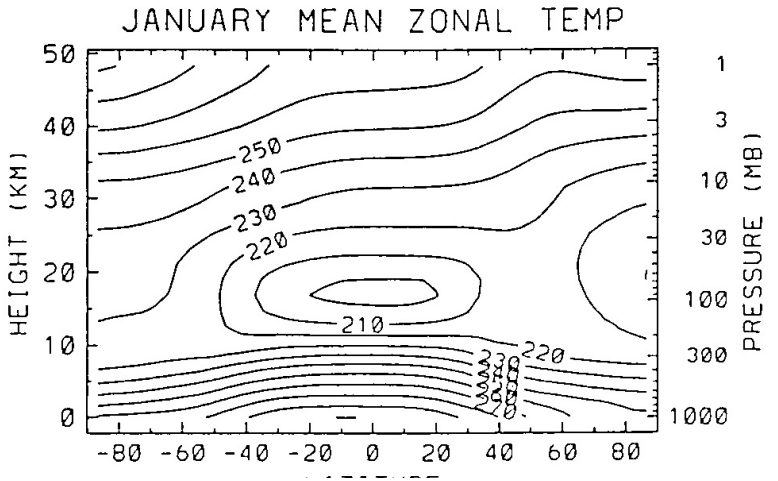


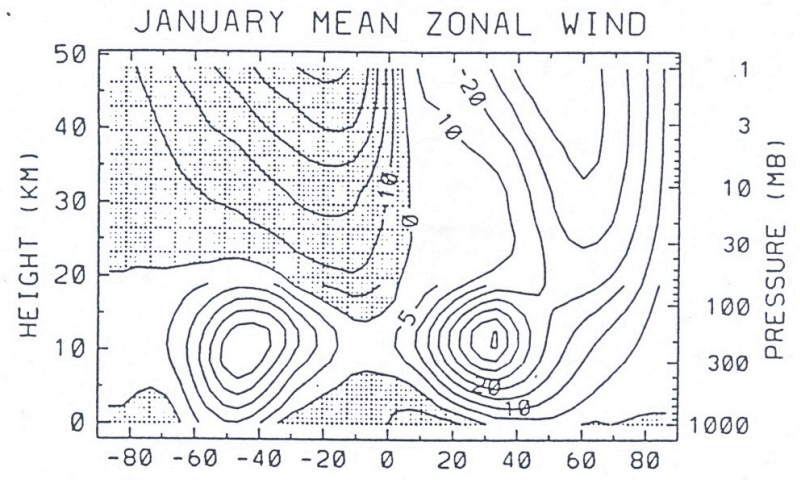


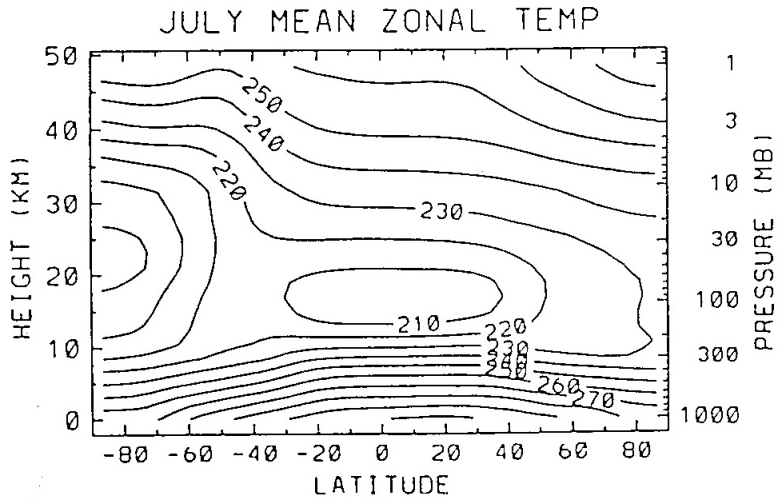
Direction of group propagation

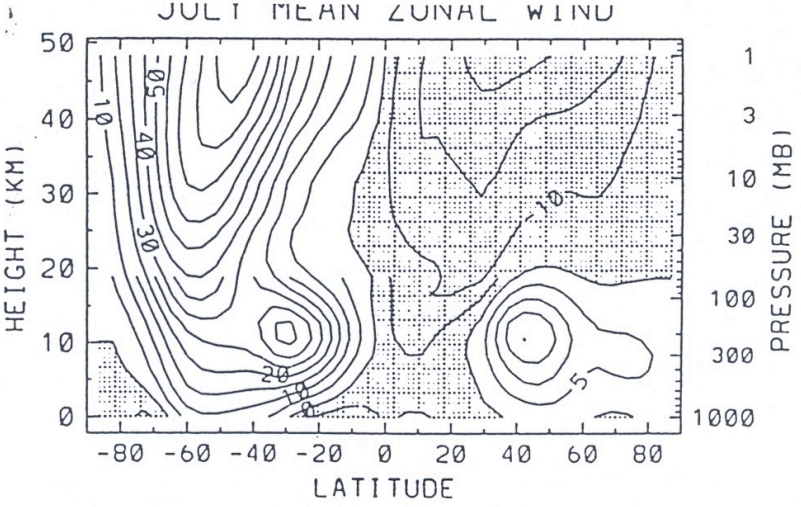
Direction of phase propagation

Atmosphere -- zonal average temperature and zonal winds







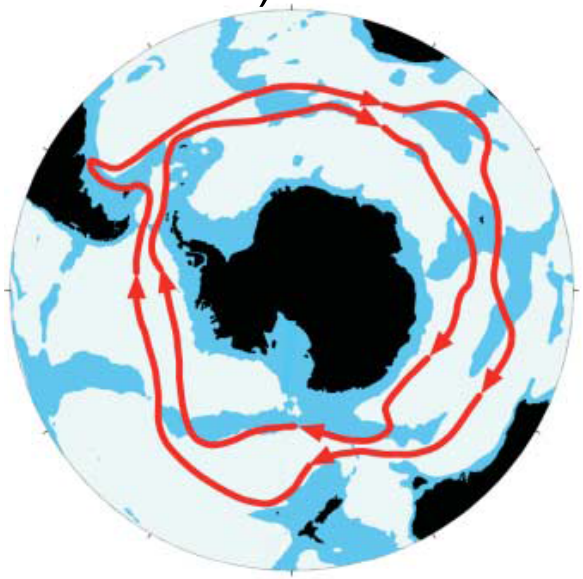


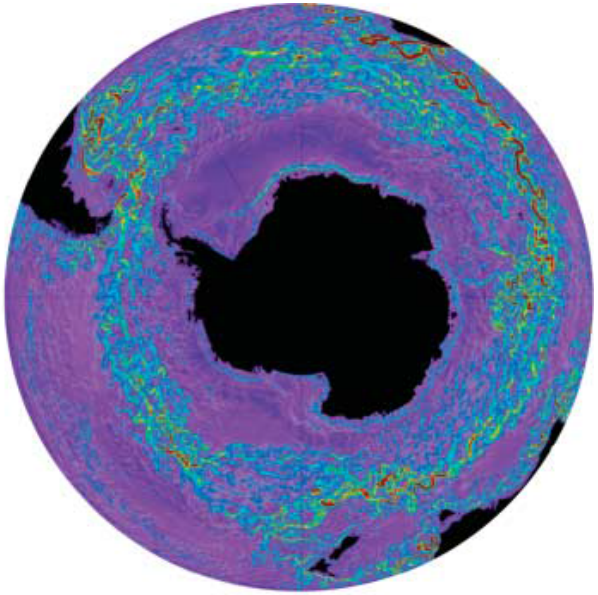
'zonal' = 'longitudinal'

Randel (1992)

Ocean – current and density in ACC

Surface current: schematic (Thompson 2008), numerical simulation (Coward and Lee 2003)





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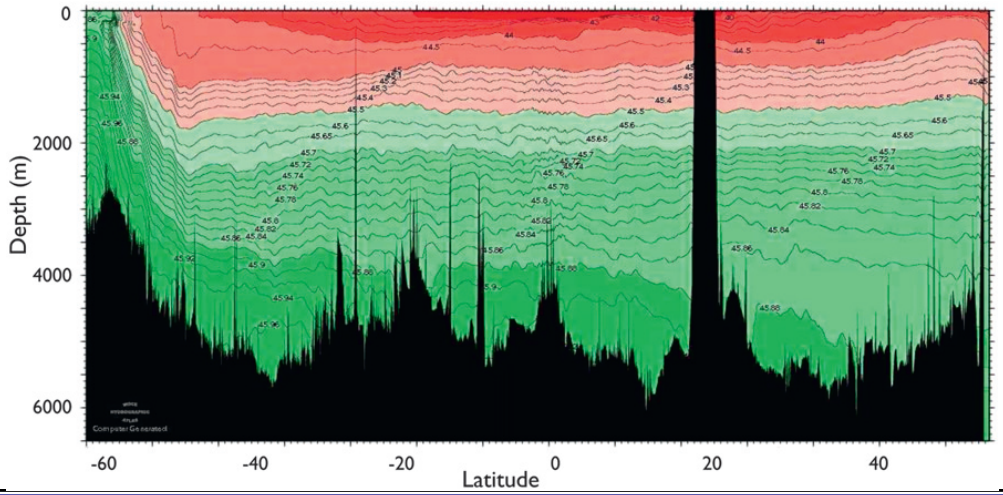
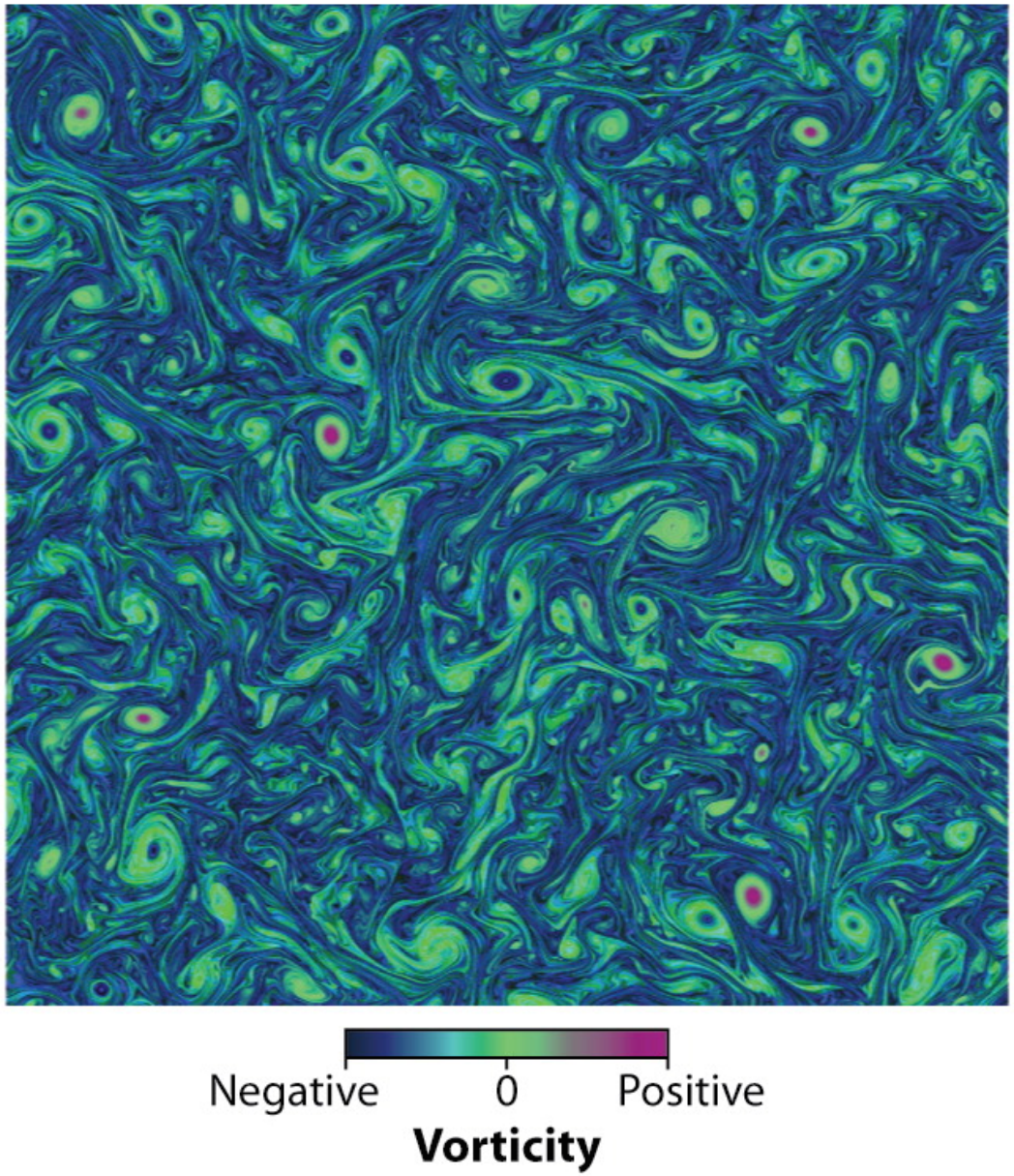


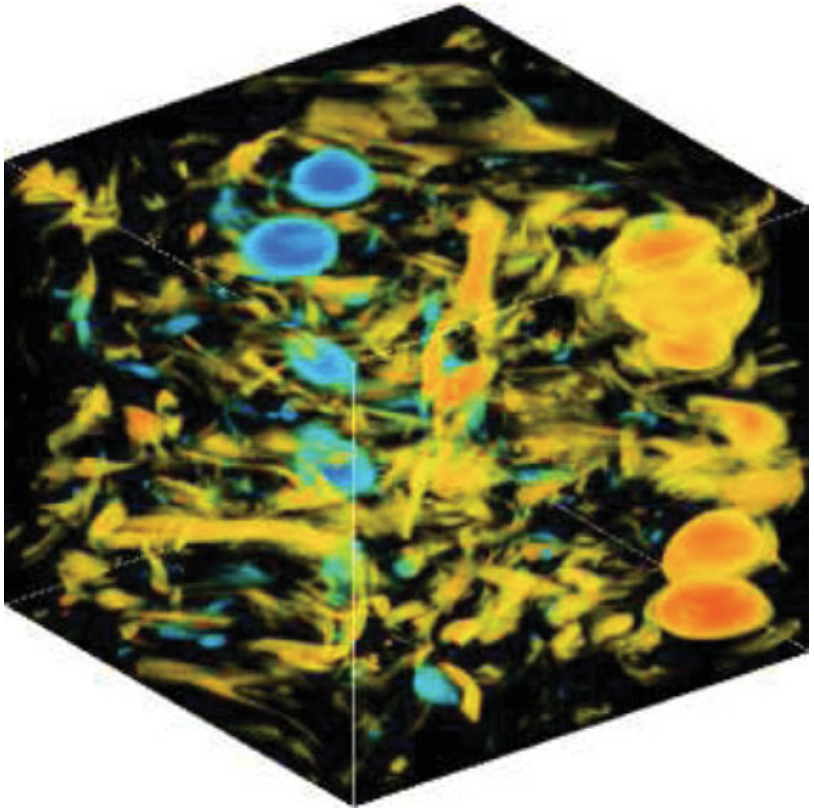
2-D turbulence

(Boffetta and Ecke 2012)

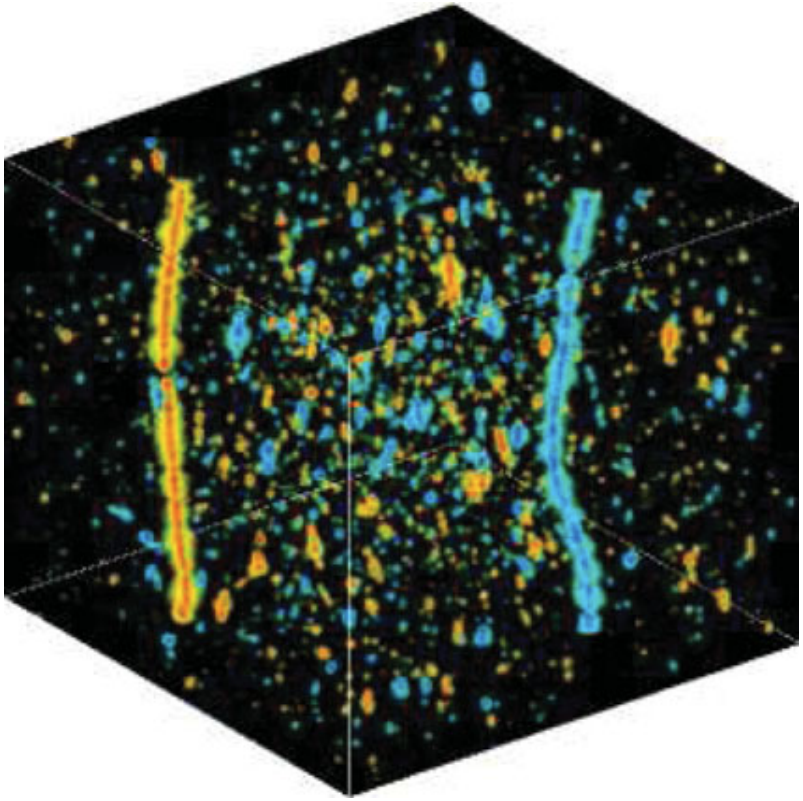


Quasi-geostrophic turbulence

1024^3 numerical simulations (Vallgren and Lindborg 2010)

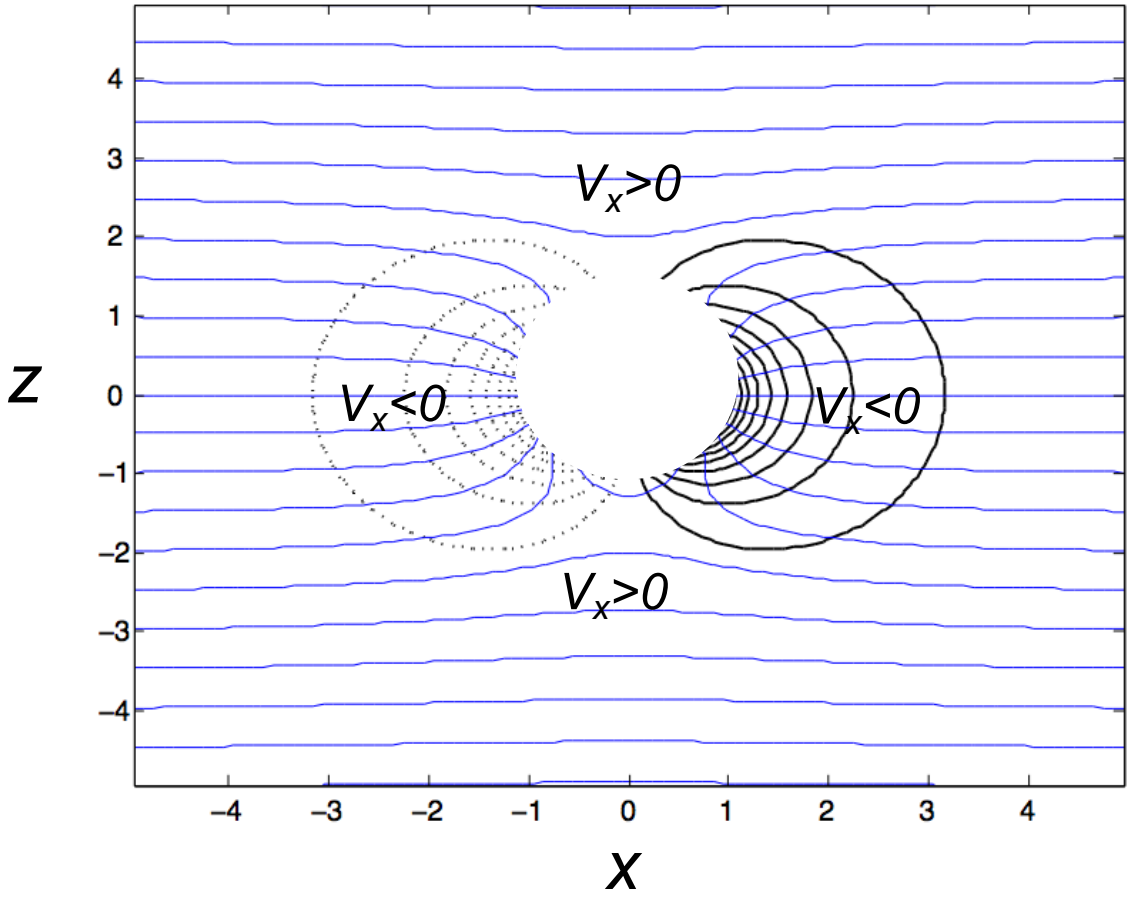


large-scale forcing



small-scale forcing

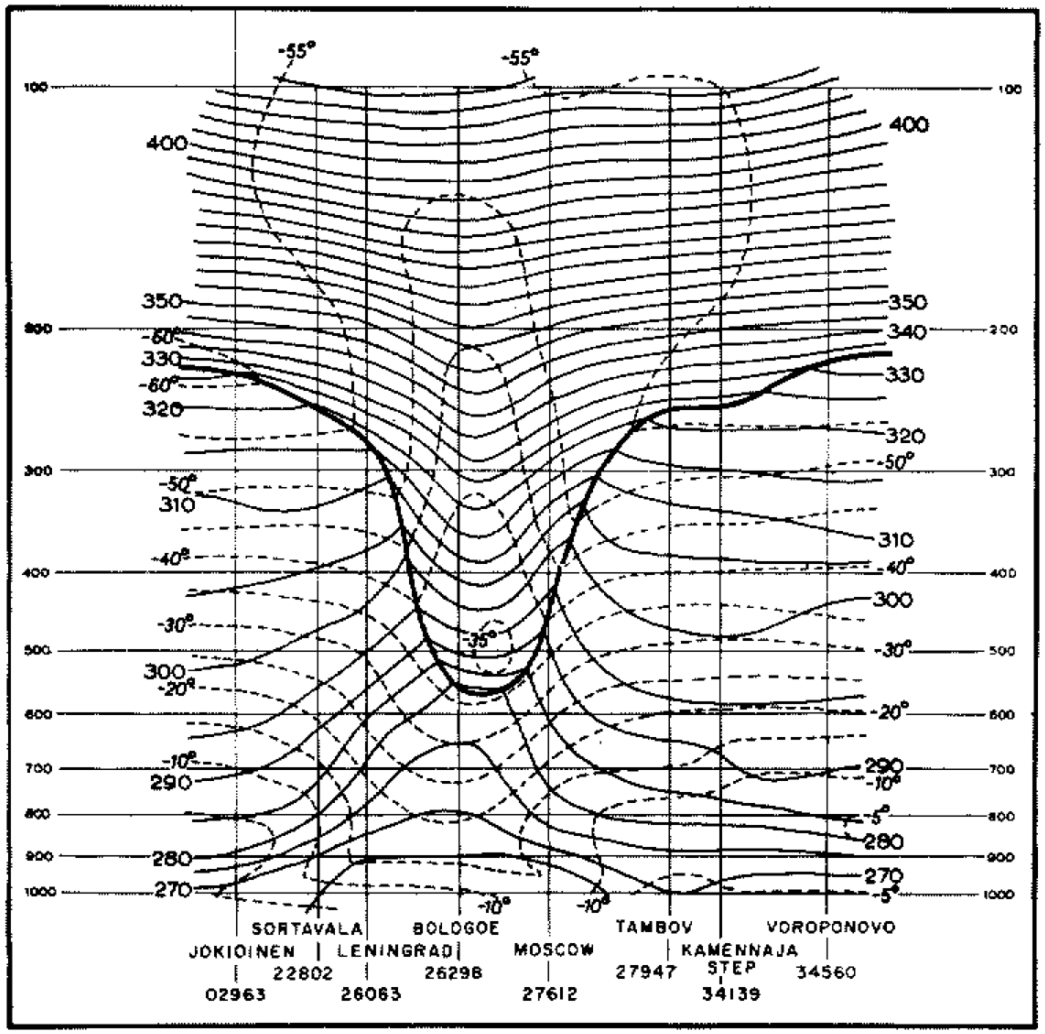
Circulation outside a positive quasi-geostrophic point vortex



(Viewed in the *y=0* plane.) The region around the singularity at the origin is obscured. Blue contours – density (including background stratification). Black contours – *v* (positive values solid, negative values dashed). Note that in regions where $v_x<0$ density surfaces are relative closer (compression) and in regions where $v_x>0$ they are relatively further apart (stretching)

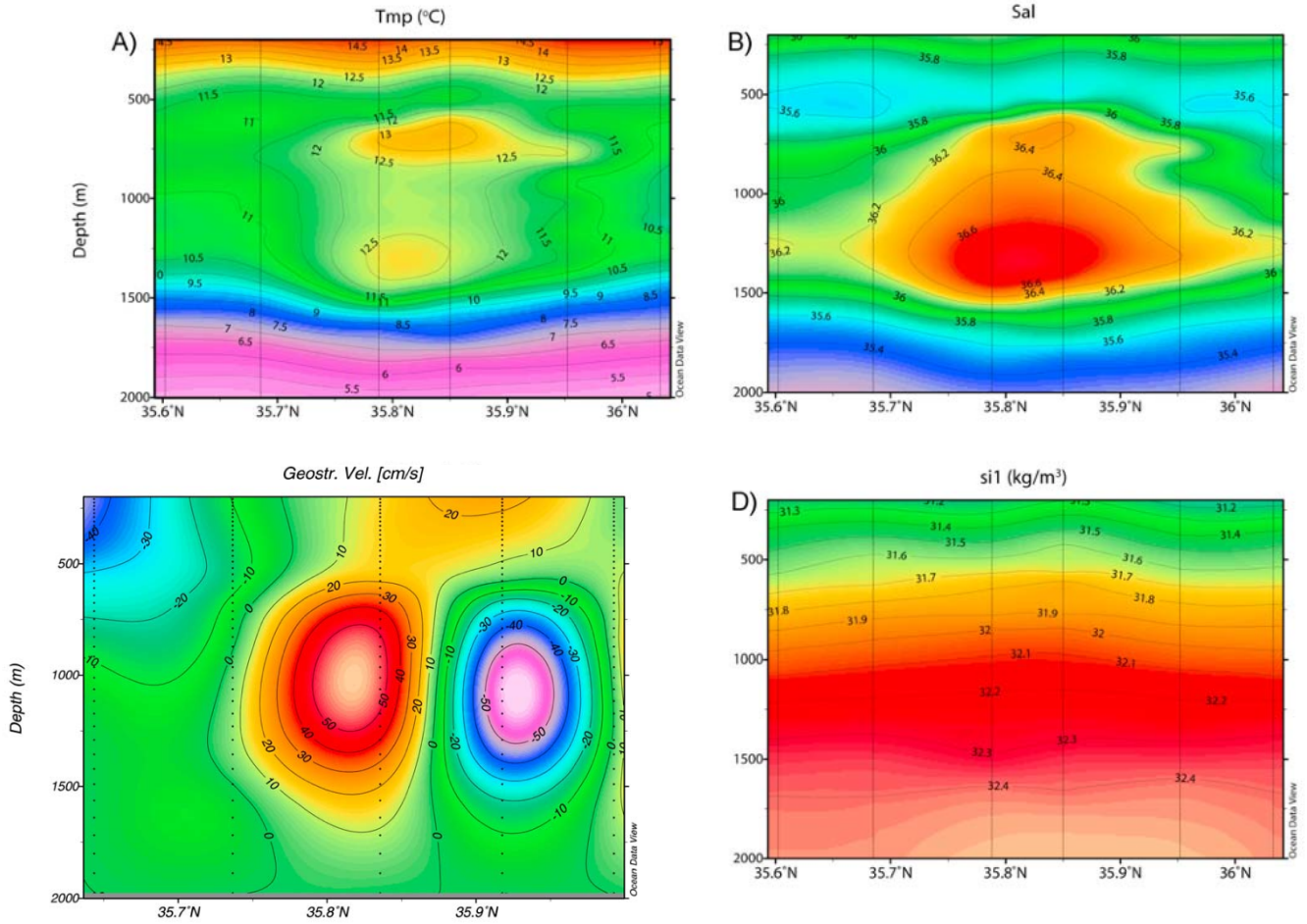
Temperature structure of a ‘cut-off cyclone’

Hoskins et al 1985



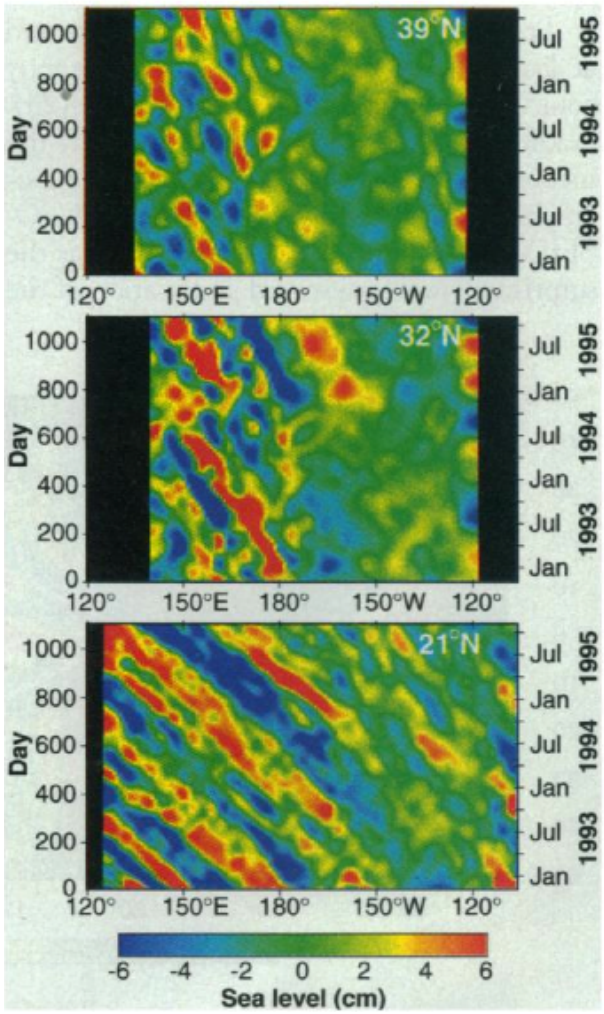
Density and temperature structure of ‘meddy’

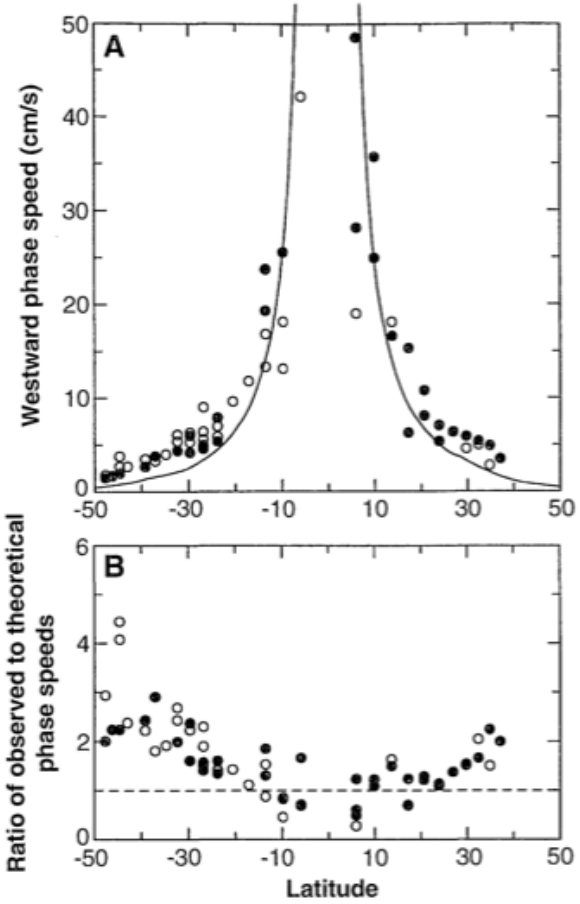
Carton et al 2010



Global observations of oceanic Rossby waves

Chelton and Schlax 1996





Comparison with theoretical predictions of Rossby wave phase speed

Rossby wave dispersion relation

Single layer with deformation radius R_d

Plane waves $\psi' = \mathrm{Re}(\hat{\psi}\, e^{i(kx+ly-\omega t)})$

Dispersion relation $\omega = \dfrac{-\beta k}{k^2 + l^2 + R_d^{-2}}$

Group velocity $(c_g^{(x)}, c_g^{(y)}) = \dfrac{\beta(k^2 - l^2 - R_d^{-2}, 2\beta kl)}{(k^2 + l^2 + R_d^{-2})^2}$

Stratified fluid with buoyancy frequency N

Plane waves $\psi' = \mathrm{Re}(\hat{\psi}\, e^{i(kx+ly+mz-\omega t)})$

Dispersion relation $\omega = \dfrac{-\beta k}{k^2 + l^2 + f_0^2 m^2/N^2}$

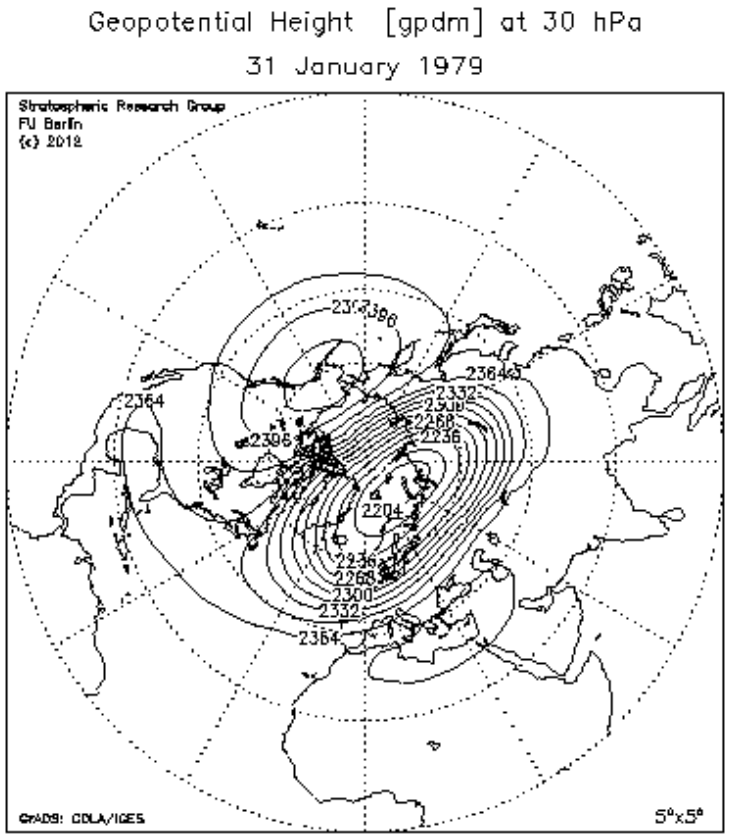
Vertical propagation (m real) if $-\dfrac{\beta}{k^2 + l^2} < \dfrac{\omega}{k} < 0$

Vertical group velocity $c_g^{(z)} = \dfrac{f_0^2}{N^2} \dfrac{2\beta km}{(k^2 + l^2 + f_0^2 m^2/N^2)^2}$

Winter-Summer differences

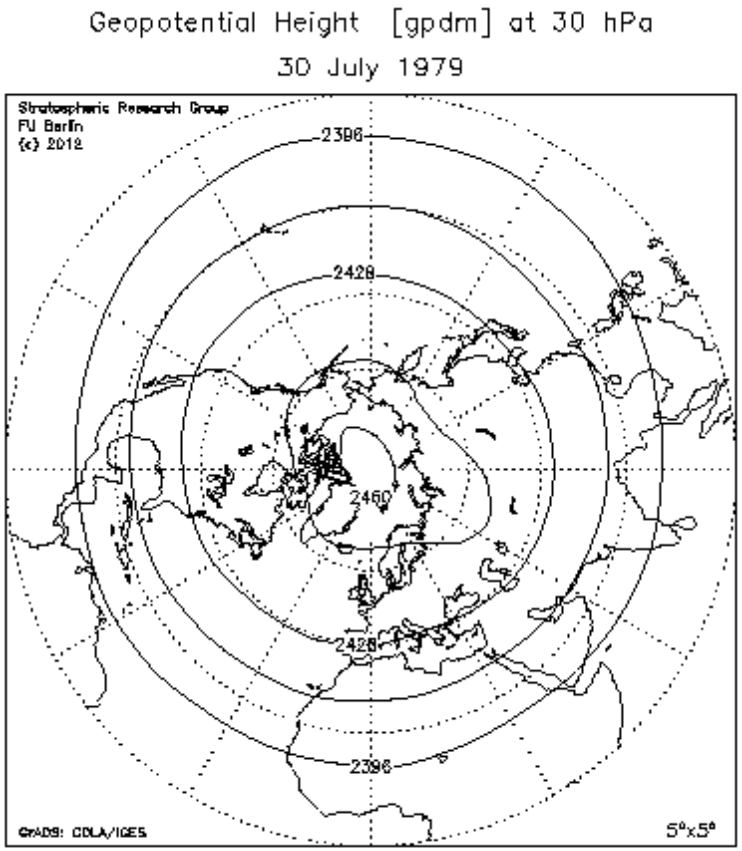
30hPa
(~25km)

NH winter



Plots of more than 30 years of daily data available at http://strat-www.met.fu-berlin.de/products

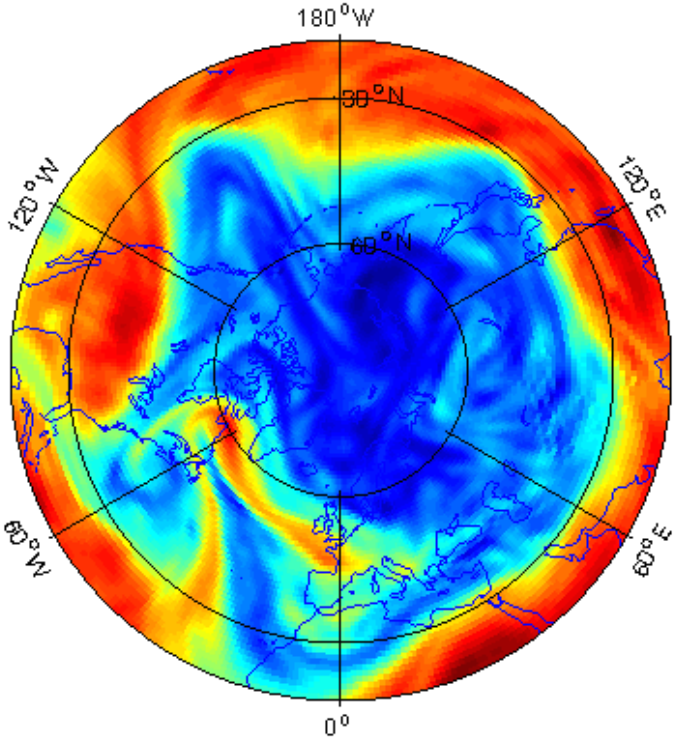
NH summer



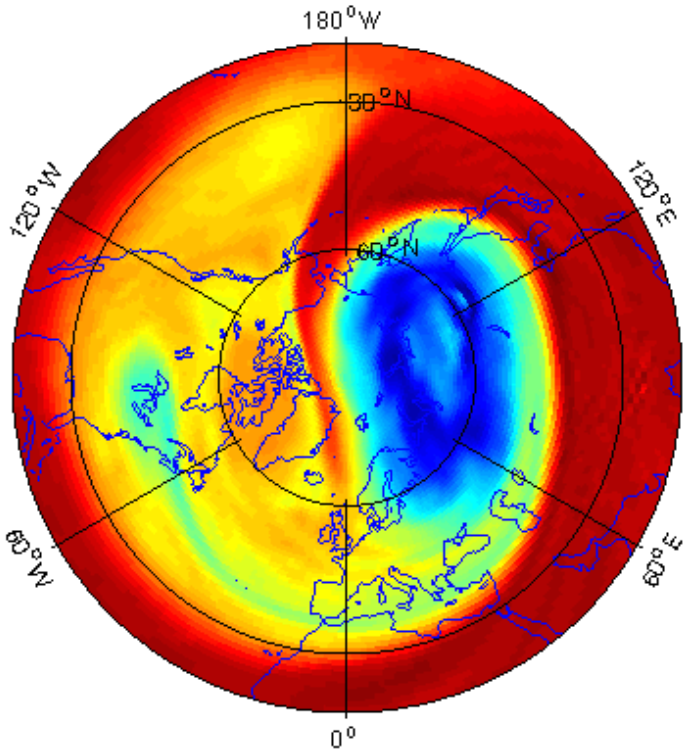
Plots of more than 30 years of daily data available at http://strat-www.met.fu-berlin.de/products

Troposphere-Stratosphere differences

(NH winter)

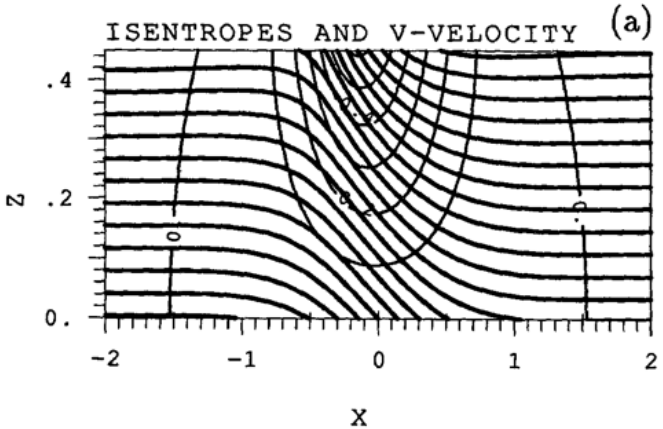


Potential Vorticity on 360K (~10km)



Potential Vorticity on 850K (~30km)

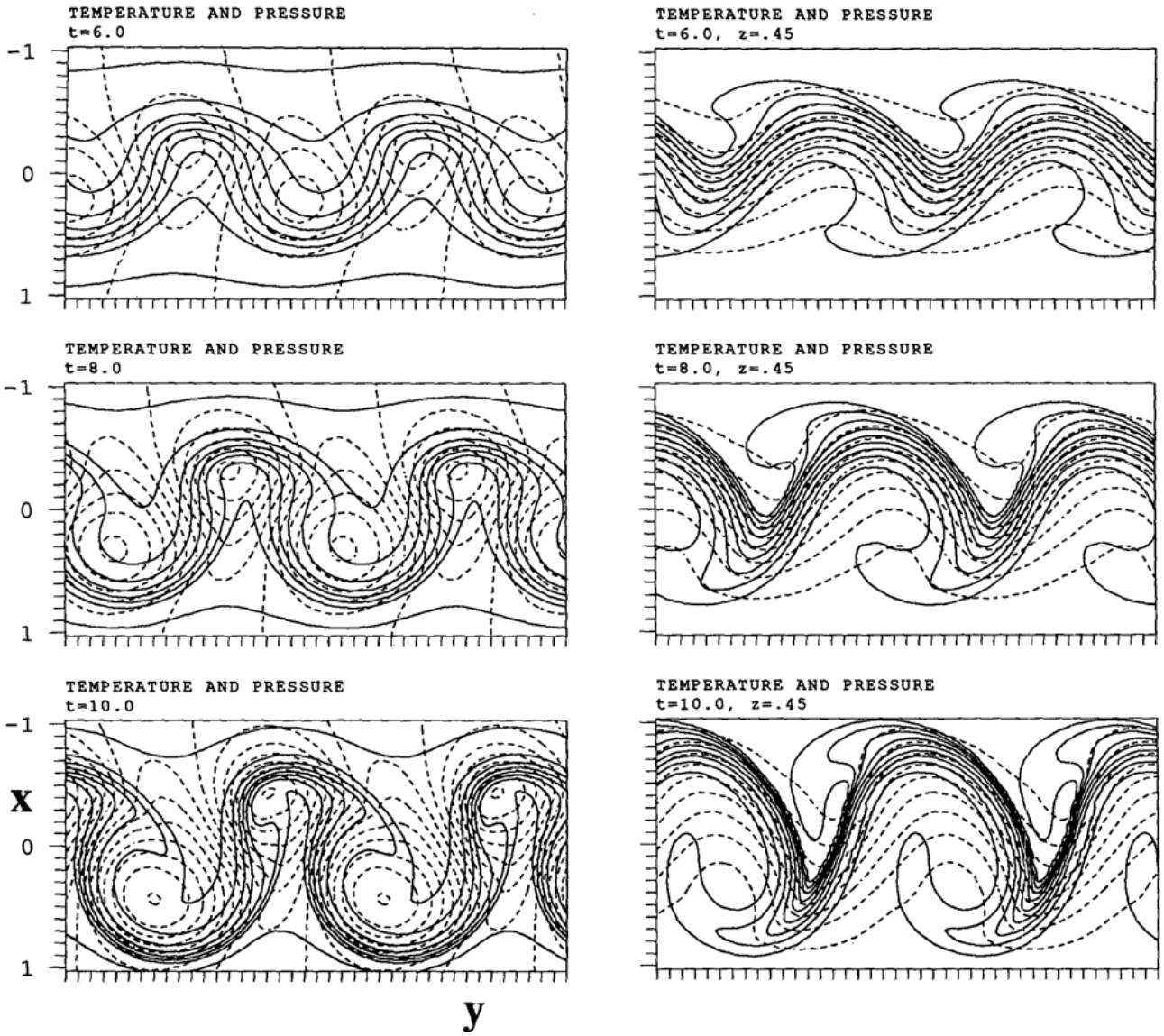
Baroclinic instability in an Eady-like configuration



Initial state

Bottom boundary

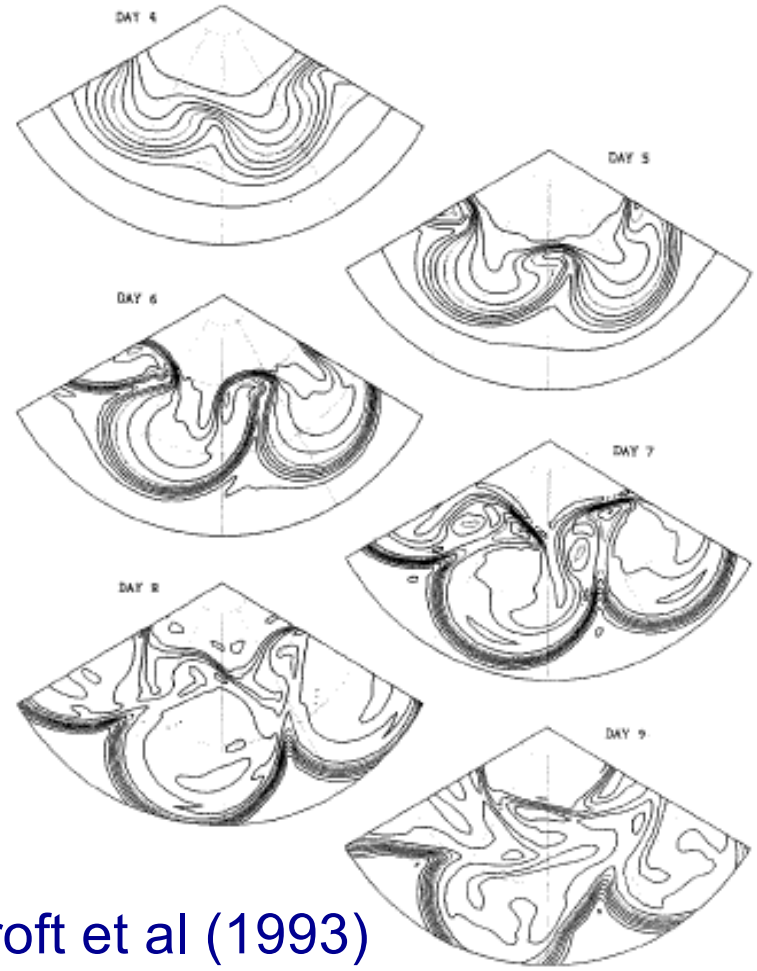
Top boundary



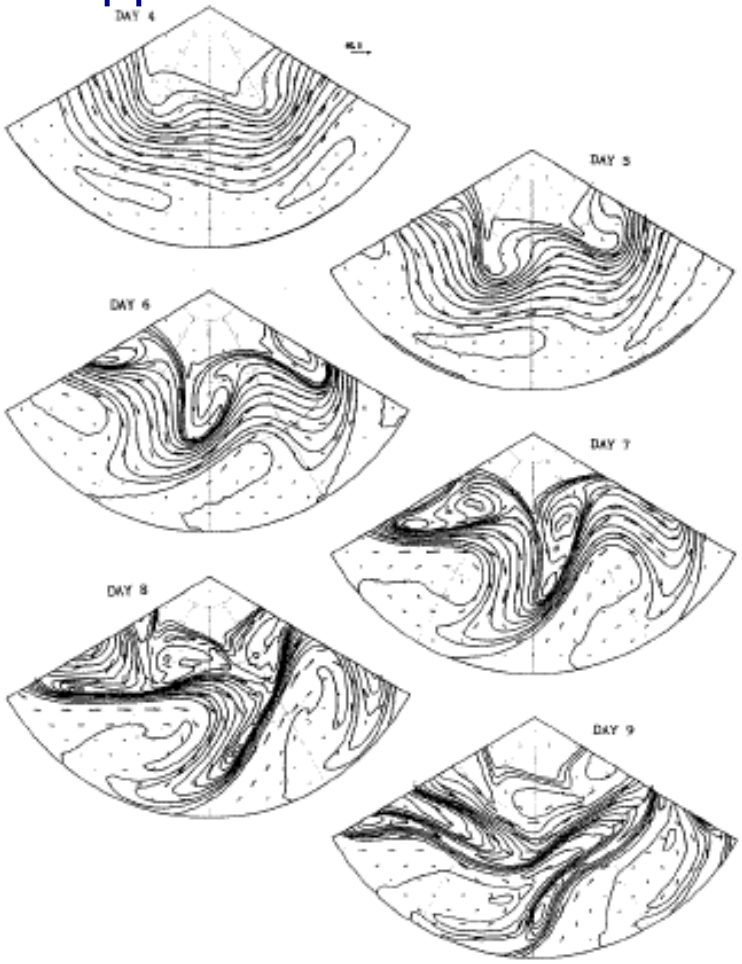
Davis et al (1991)

Baroclinic lifecycle

Low-level temperature



Upper-level PV



Thorncroft et al (1993)