

Atmospheric and Oceanic Flows

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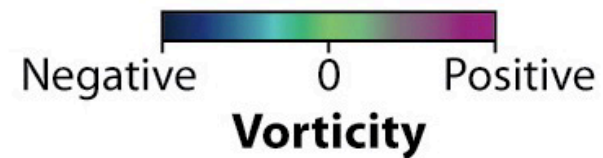
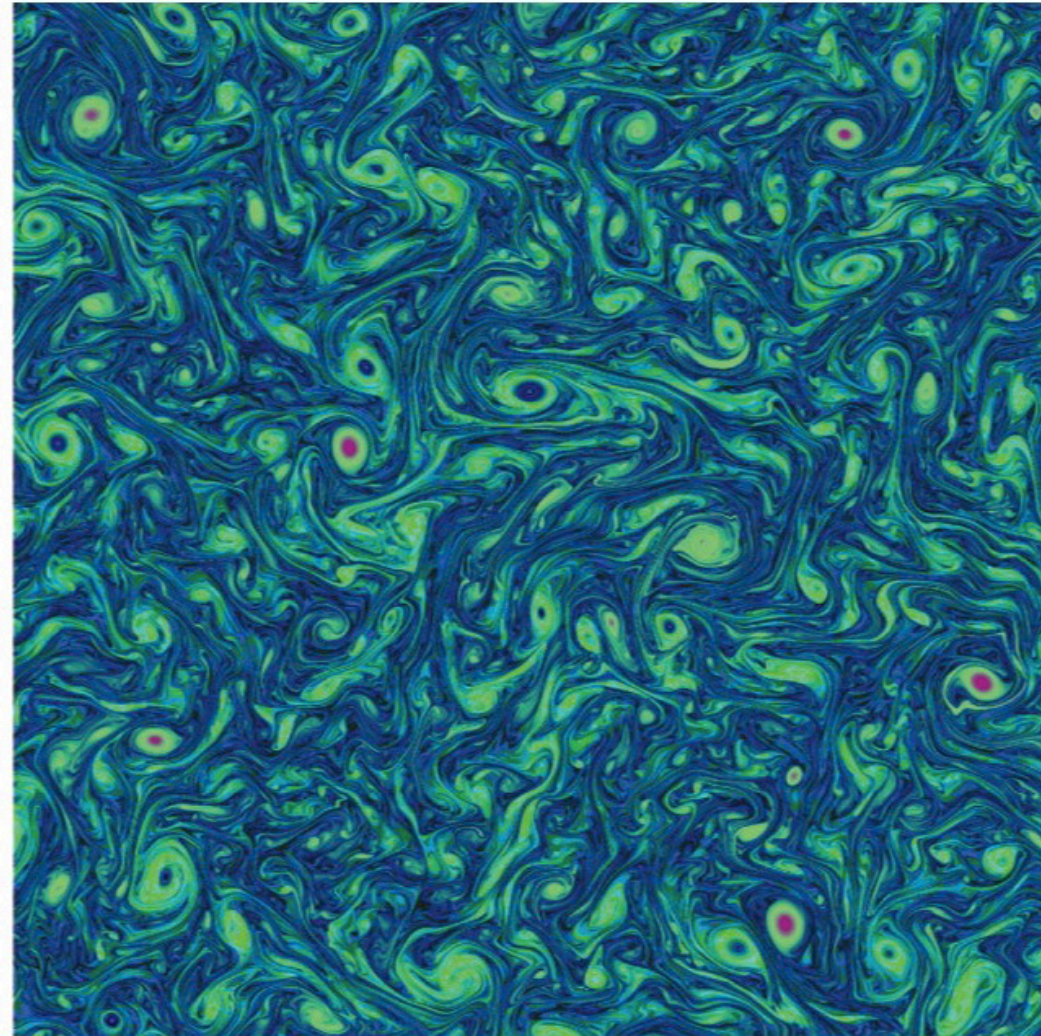
DAMTP

CCfCS



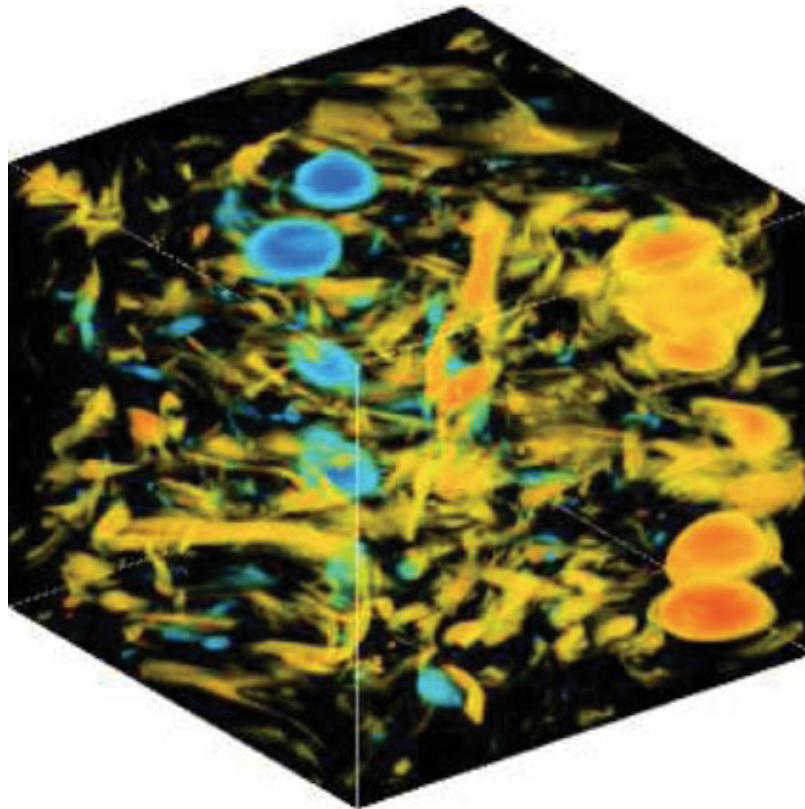
2-D turbulence

(Boffetta and Ecke 2012)

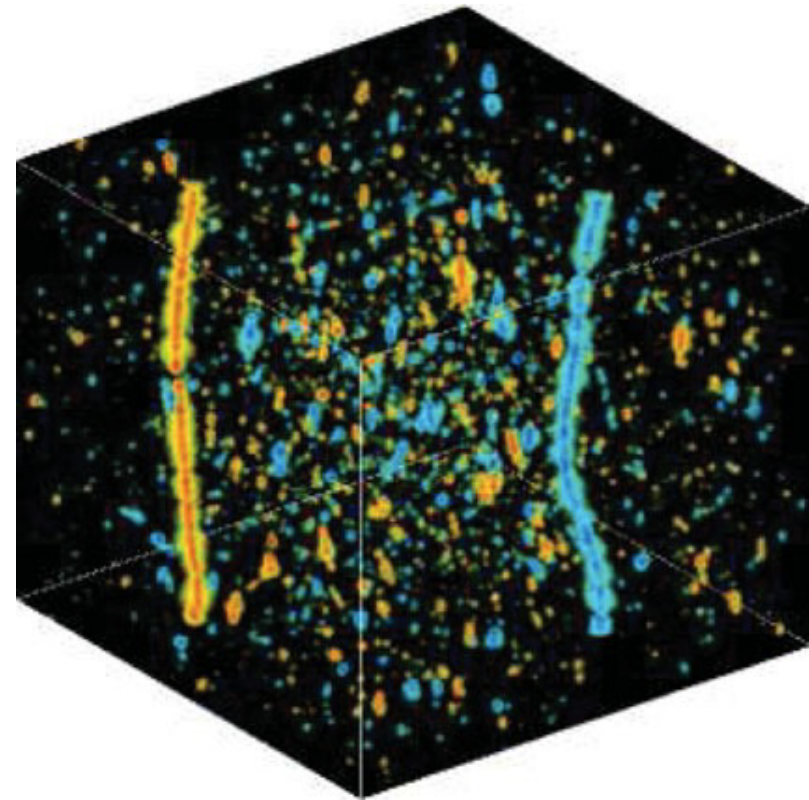


Quasi-geostrophic turbulence

1024³ numerical simulations (Vallgren and Lindborg 2010)



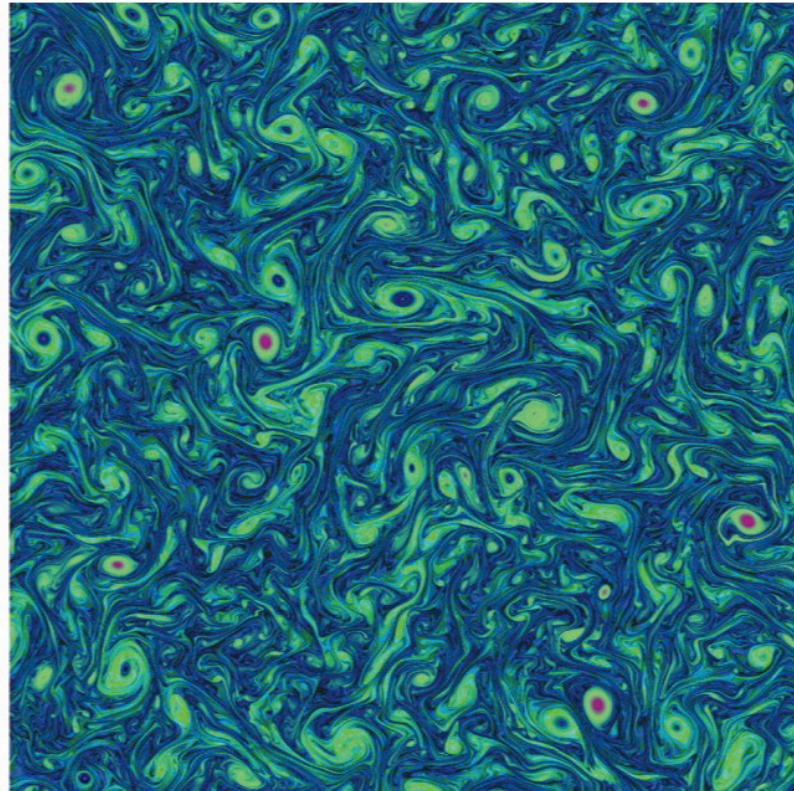
large-scale forcing



small-scale forcing

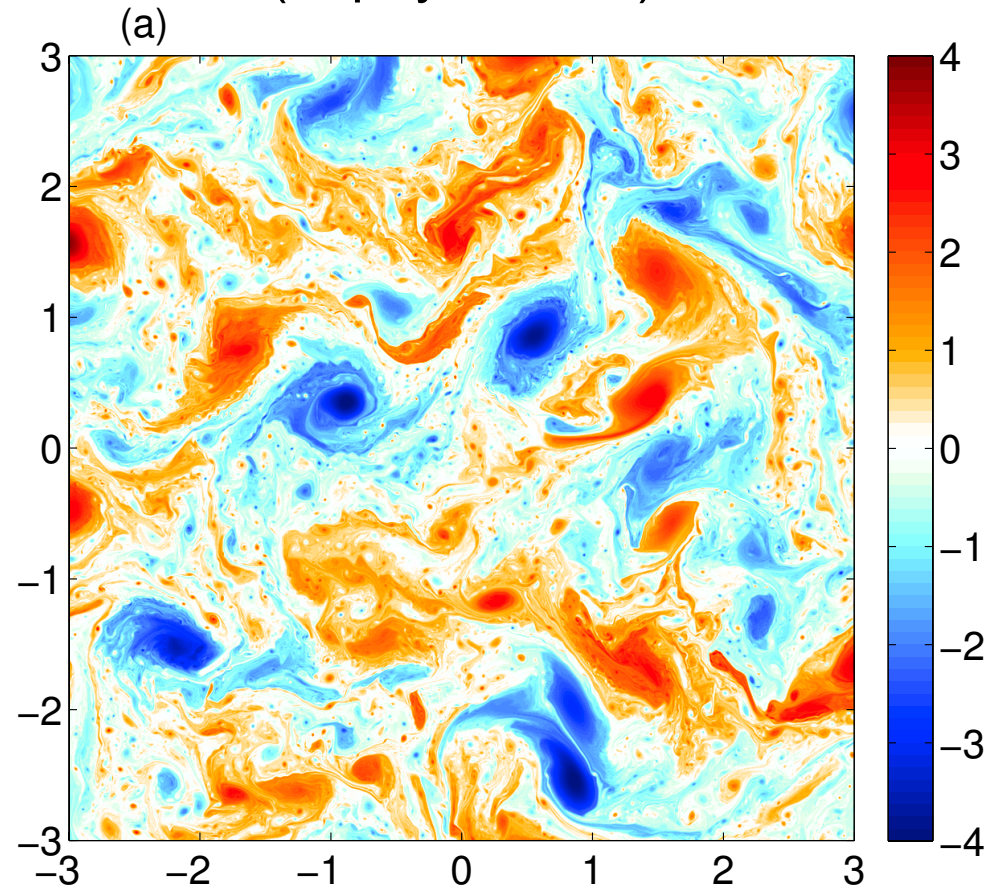


2-D turbulence
(Boffetta and Ecke 2012)



Negative 0 Positive
Vorticity

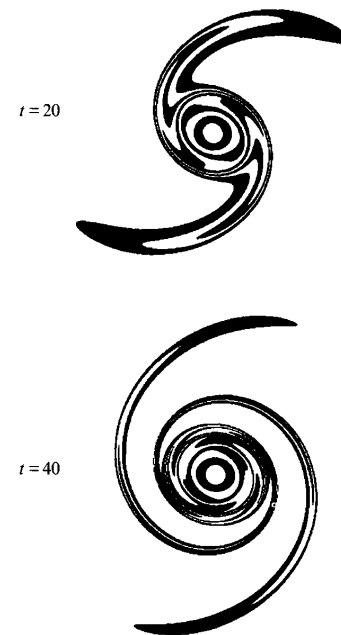
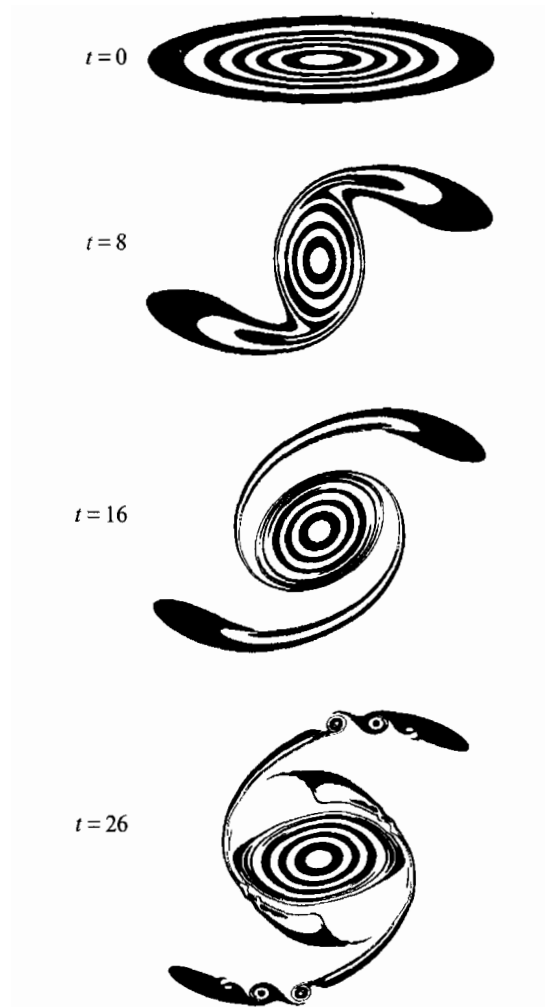
SQG turbulence
(Lapeyre 2017)



4
3
2
1
0
-1
-2
-3
-4



SQG vortex dynamics 2D vortex dynamics

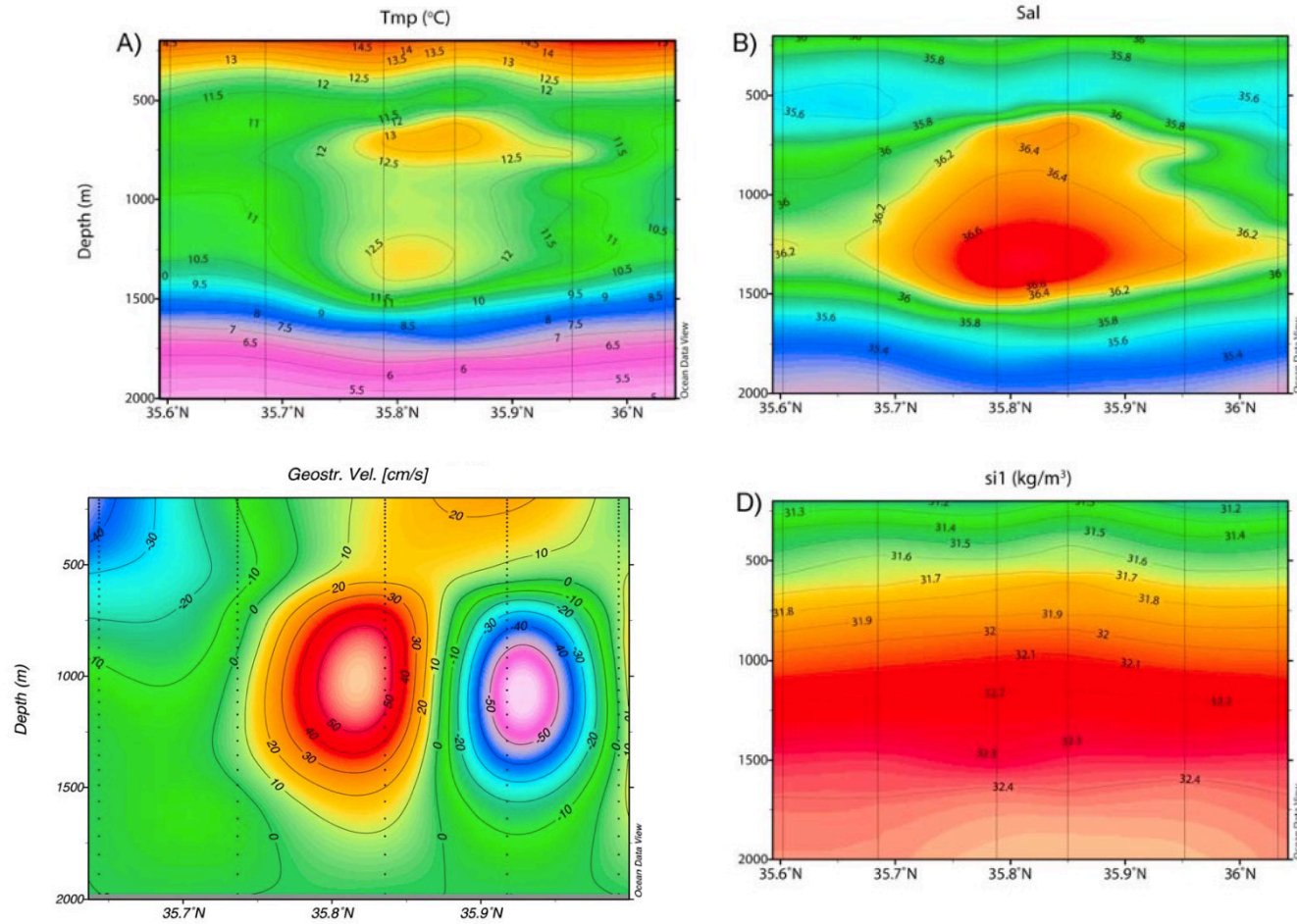


Held et al 1995



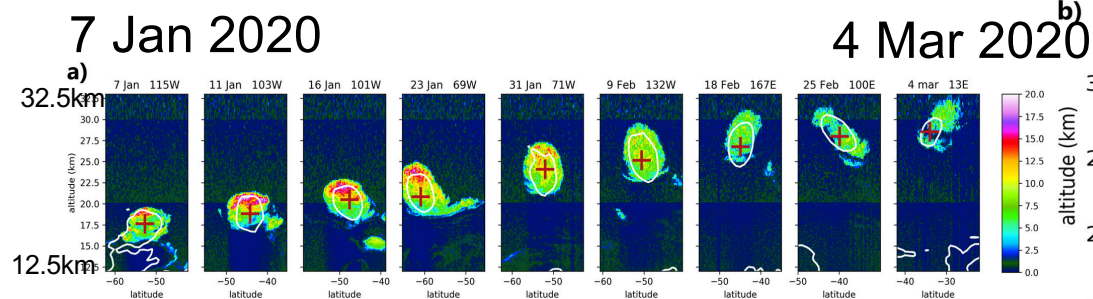
Density and temperature structure of 'meddy'

Carton et al 2010



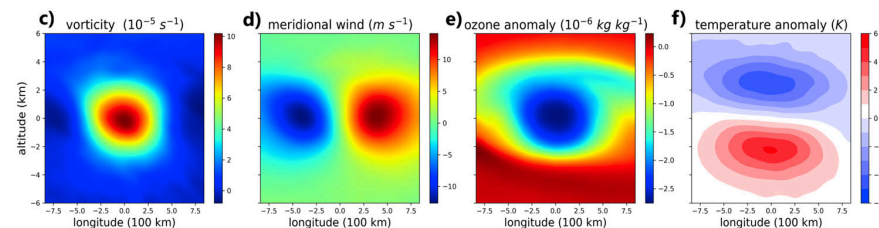
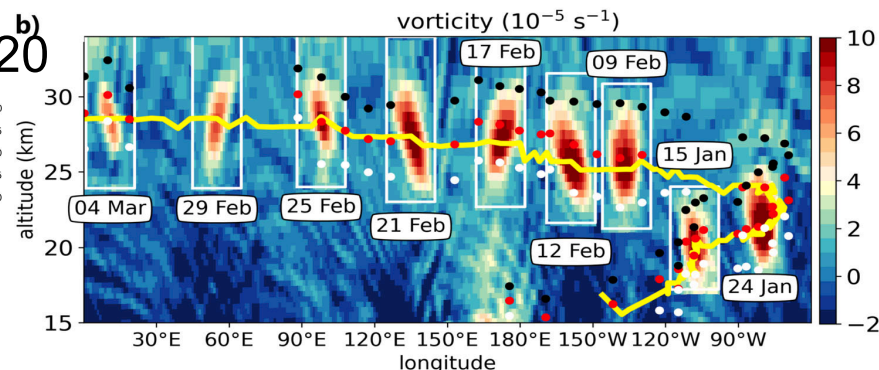
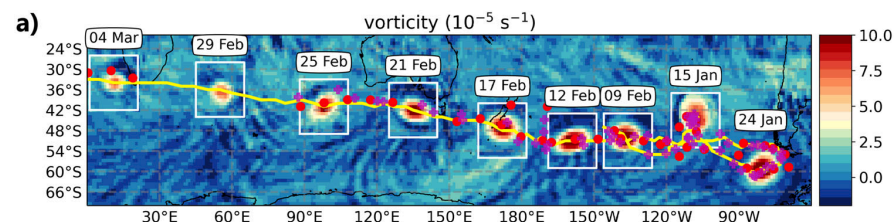
Australian wildfire smoke results in stratospheric vortices

Khaykin et al 2020, Comm. Earth Env.

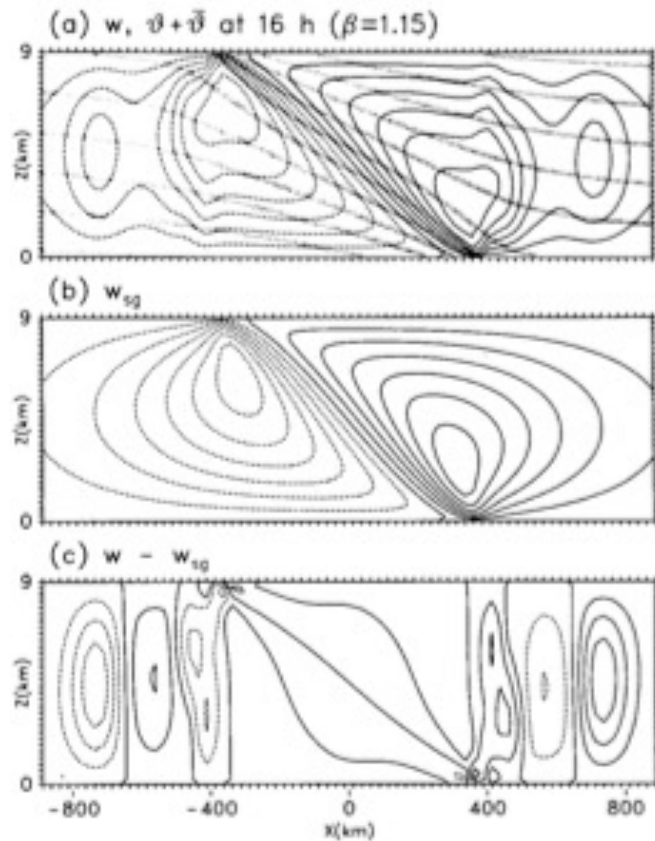


CALIOP scattering ratio (smoke)

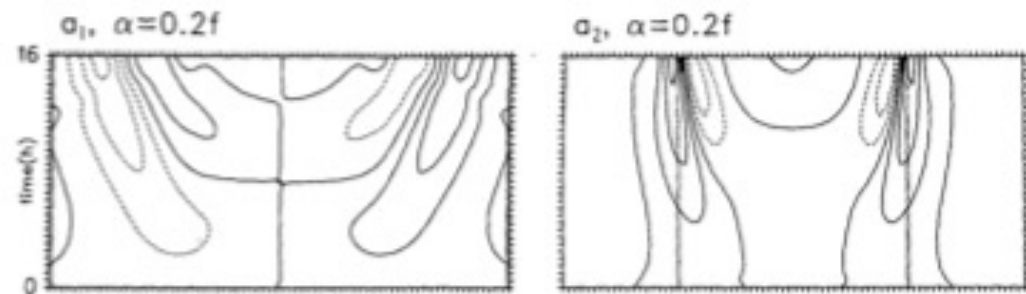
Kablick, G. P. III, et al, 2020: Geophys. Res. Lett. ,
 Schwartz, M. J., et al, 2020: Geophys. Res. Lett.,
 Gonzalez, R., et al, 2020: Remote Sensing,
 Lestrelin, H., et al , 2021: Atmos. Chem. Phys.



Numerical solutions of frontal collapse



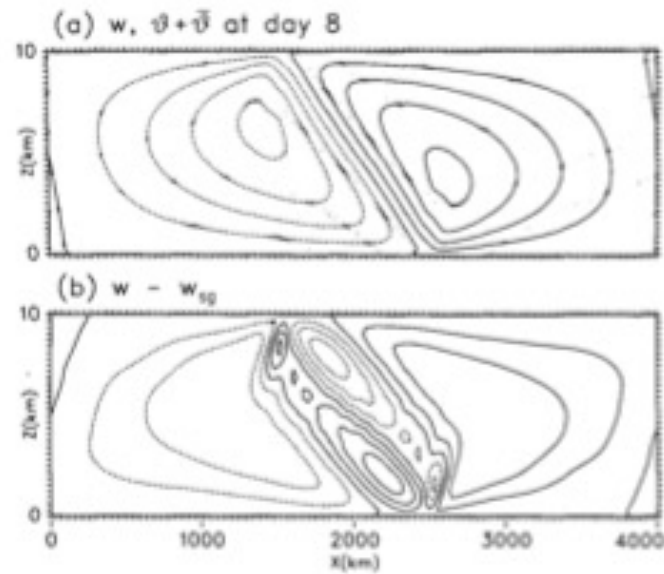
‘horizontal deformation’ front



Snyder et al 1993



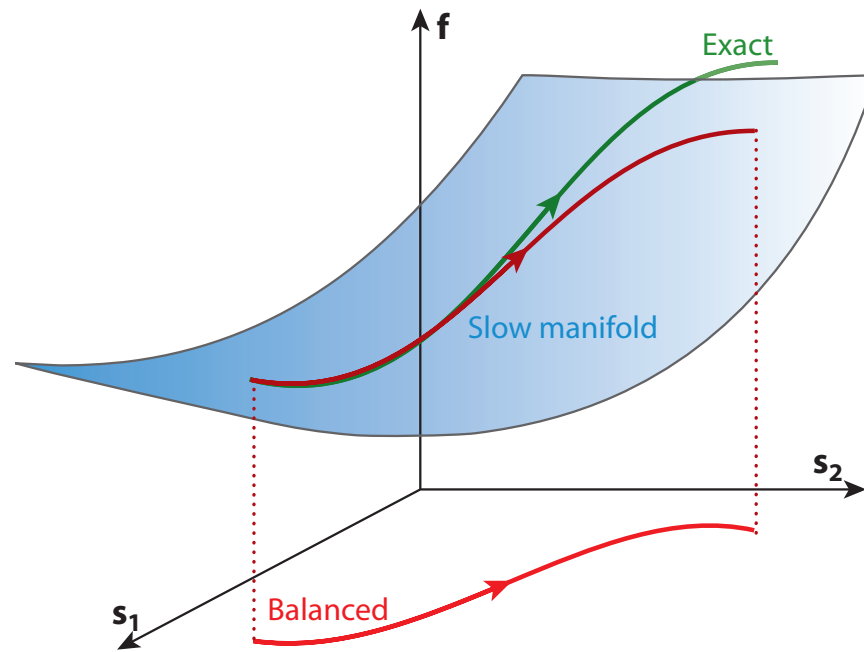
Numerical solutions of frontal collapse



‘horizontal shear’ front

Snyder et al 1993





Vanneste 2013



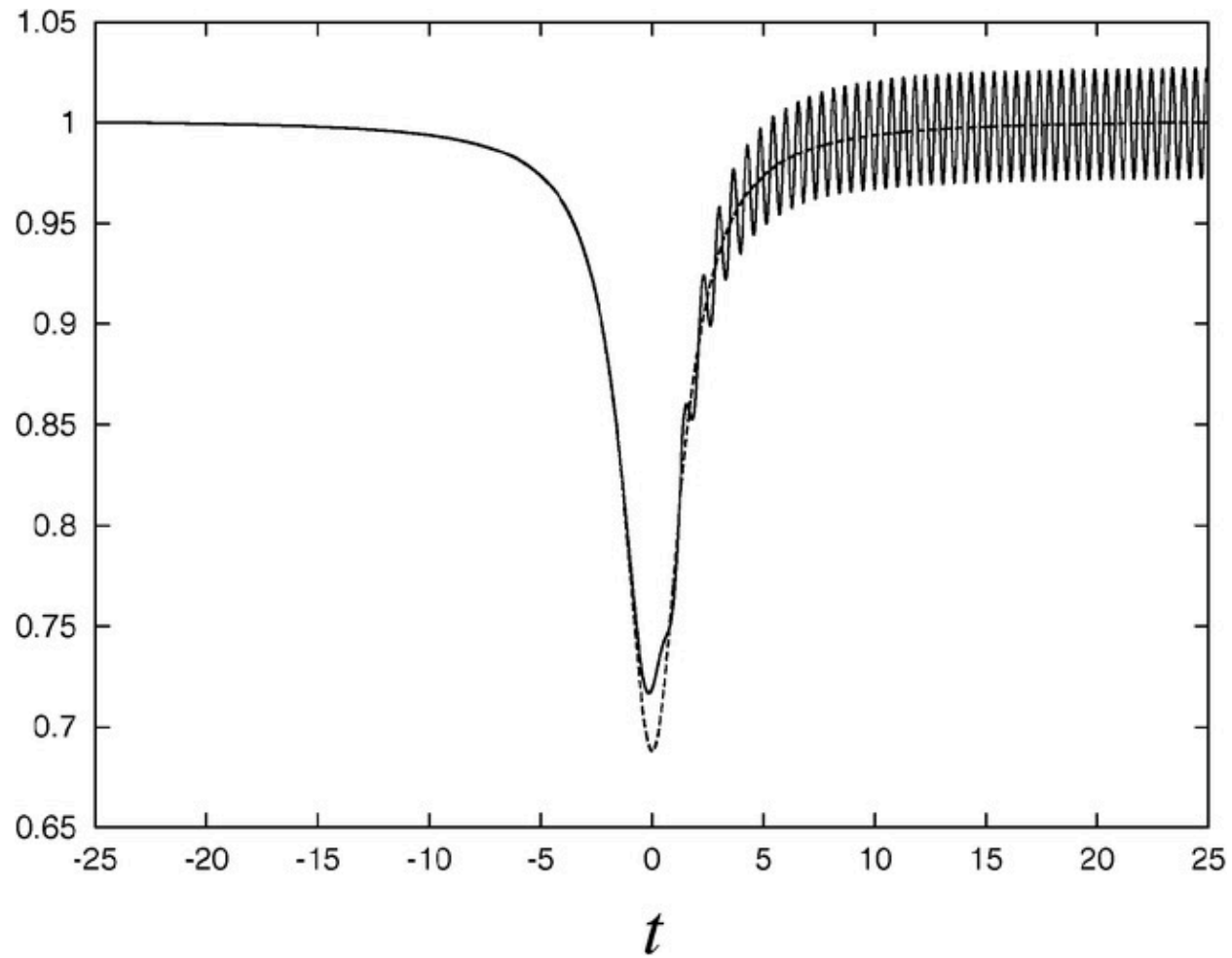
$$\epsilon[\ddot{\zeta} + b(t)\dot{\zeta}] + c(t)\zeta = \frac{S(1 + t^2)}{(1 + \delta^2 + t^2)}$$

$$b(t) = -\frac{2\delta^2 t}{(1 + t^2)(1 + \delta^2 + t^2)}$$

$$c(t) = \frac{\delta^2(1 \mp \epsilon)}{1 + \delta^2 + t^2} \left(1 \mp \frac{2\epsilon}{1 + t^2}\right) + \frac{S(1 + t^2)}{1 + \delta^2 + t^2}$$

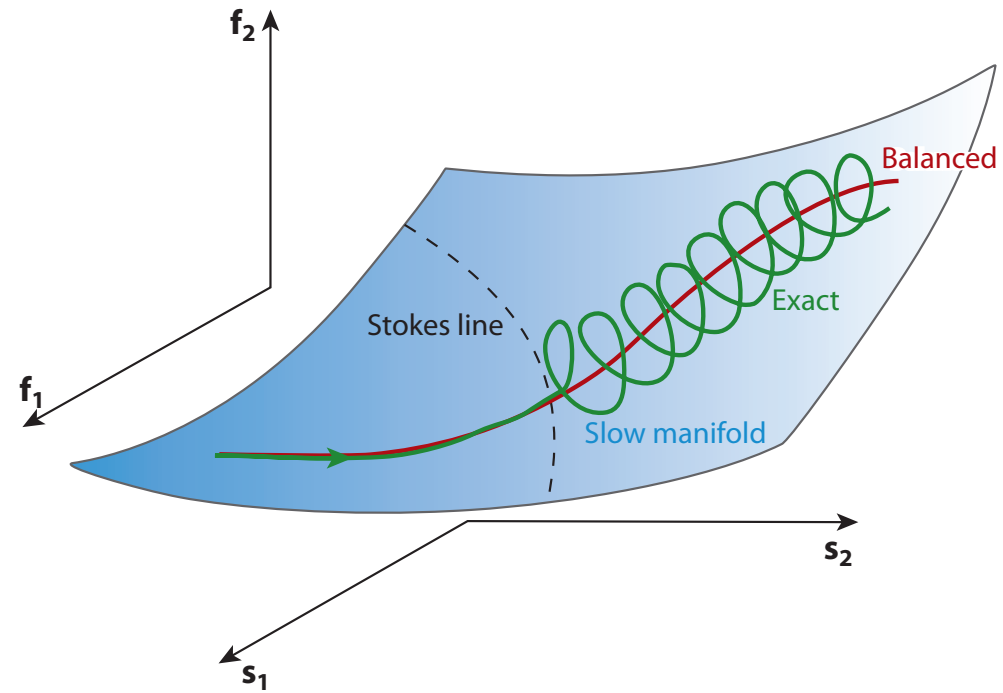
Vanneste and Yavneh 2004





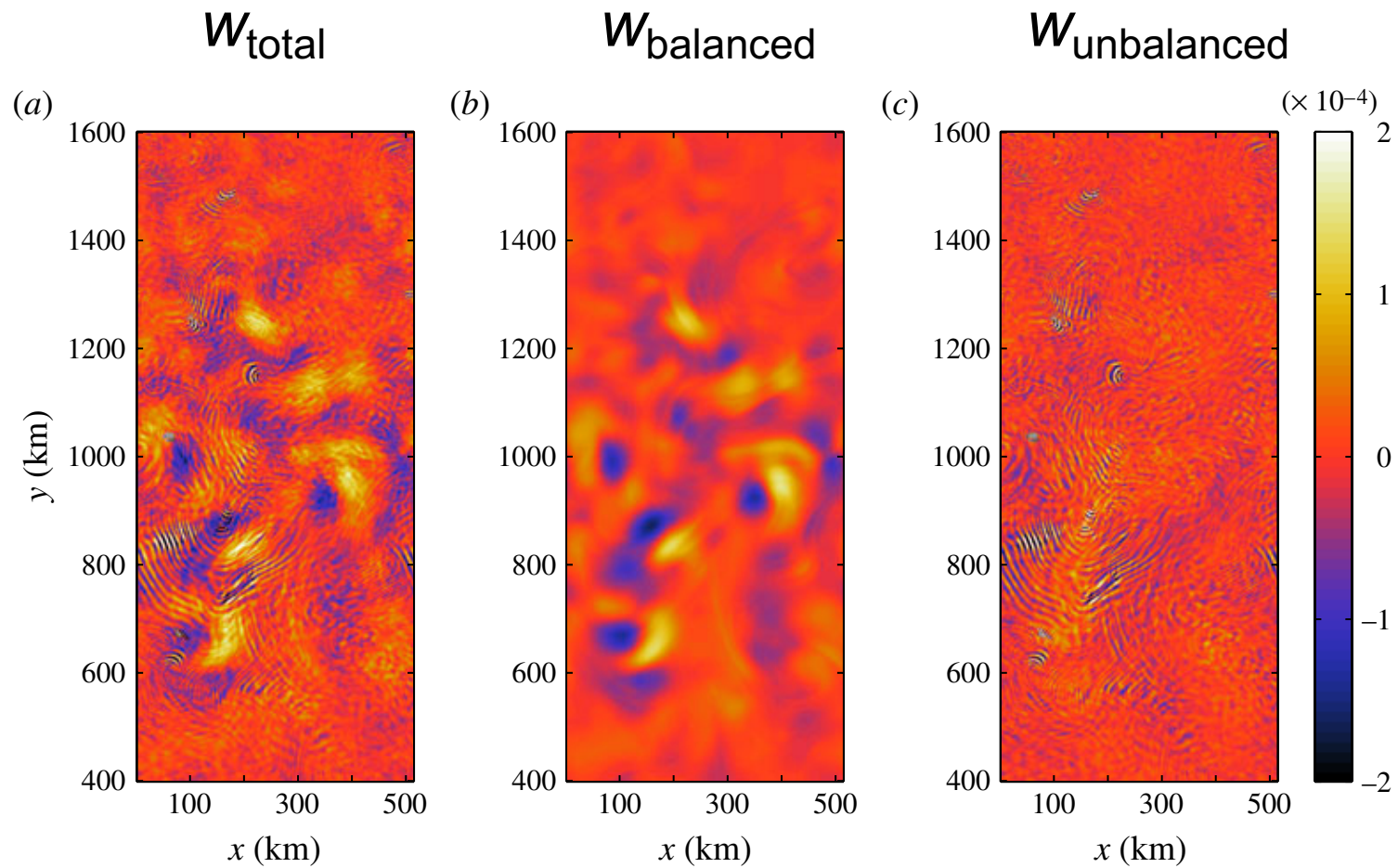
Vanneste and Yavneh 2004





Vanneste 2013

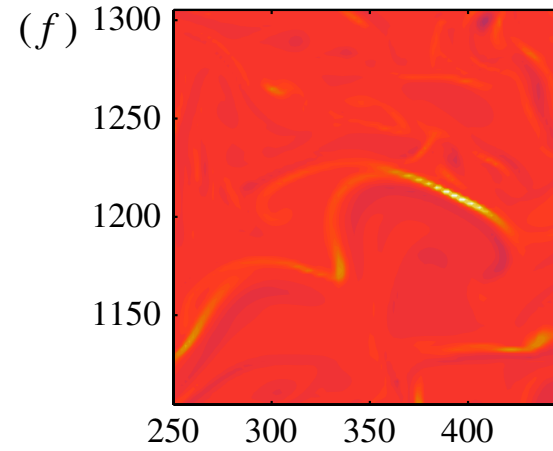
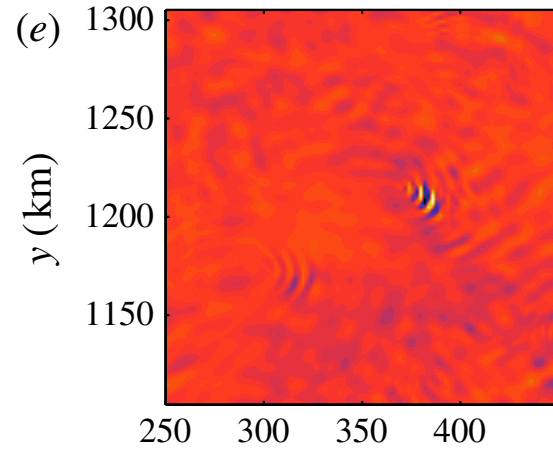




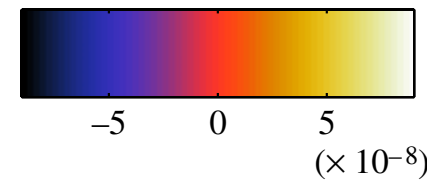
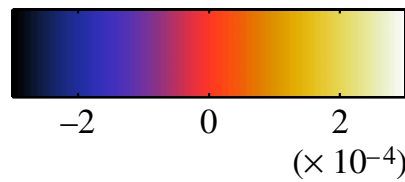
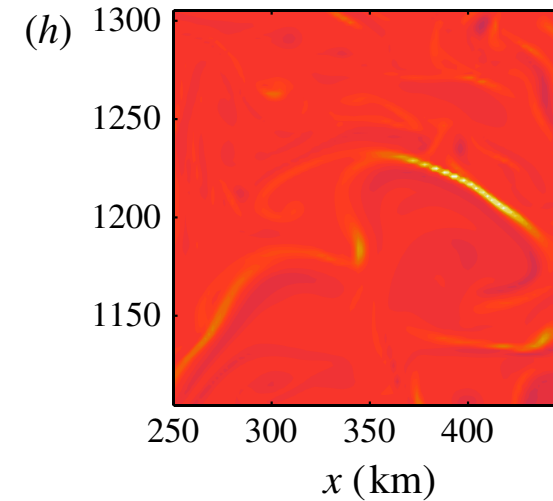
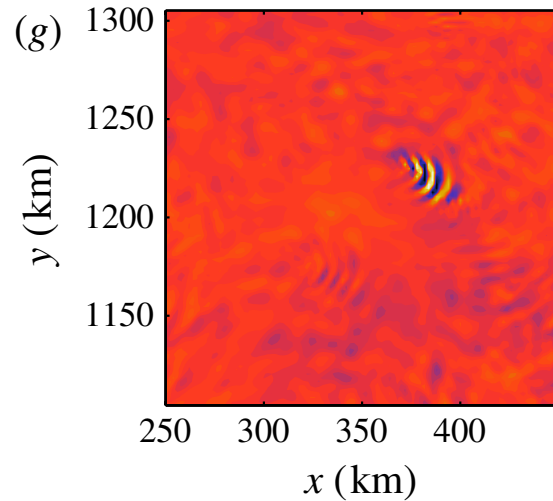
Danioux et al 2012



$W_{\text{unbalanced}}$
(interior)



T_{surface}

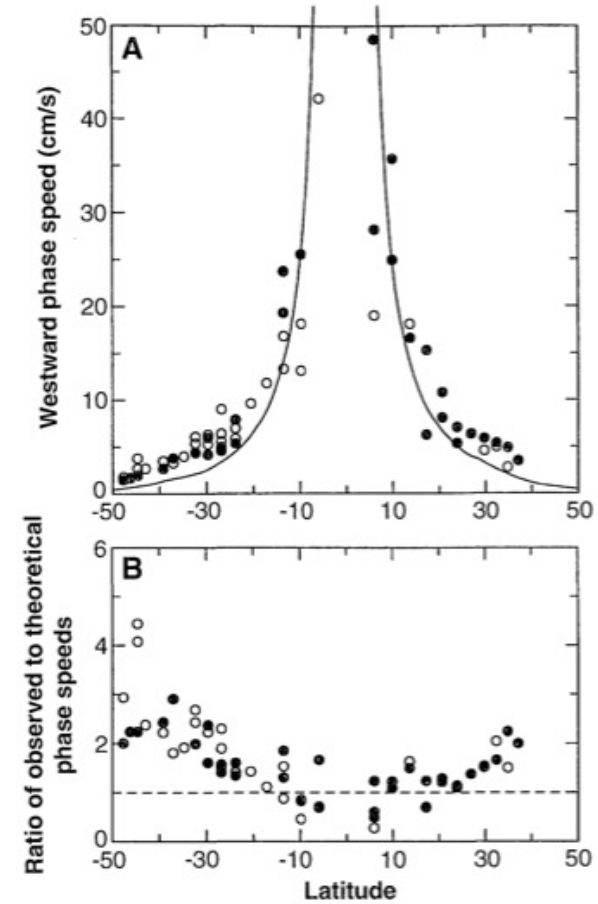
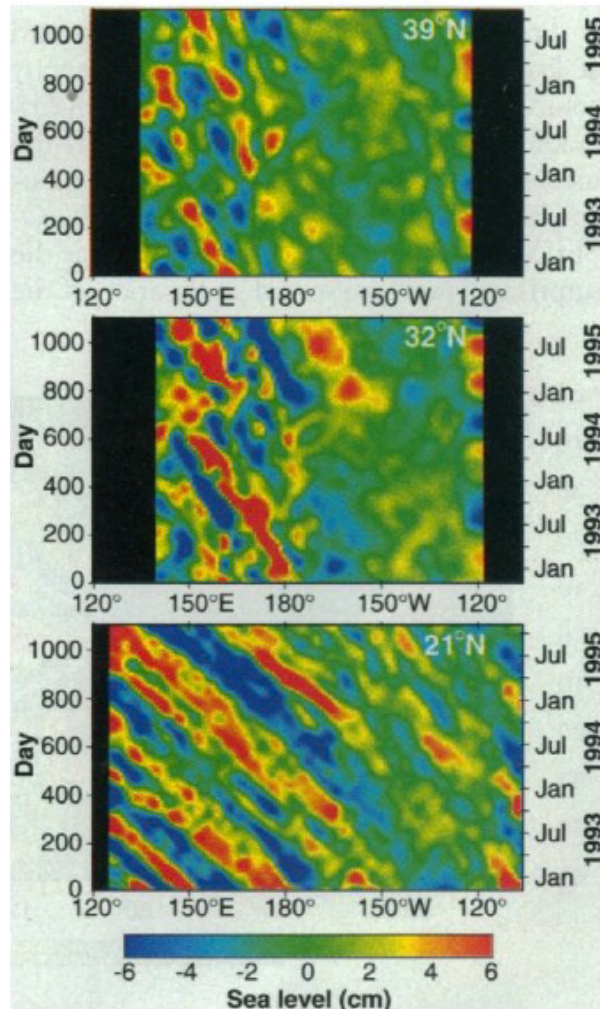


Danioux et al 2012



Global observations of oceanic Rossby waves

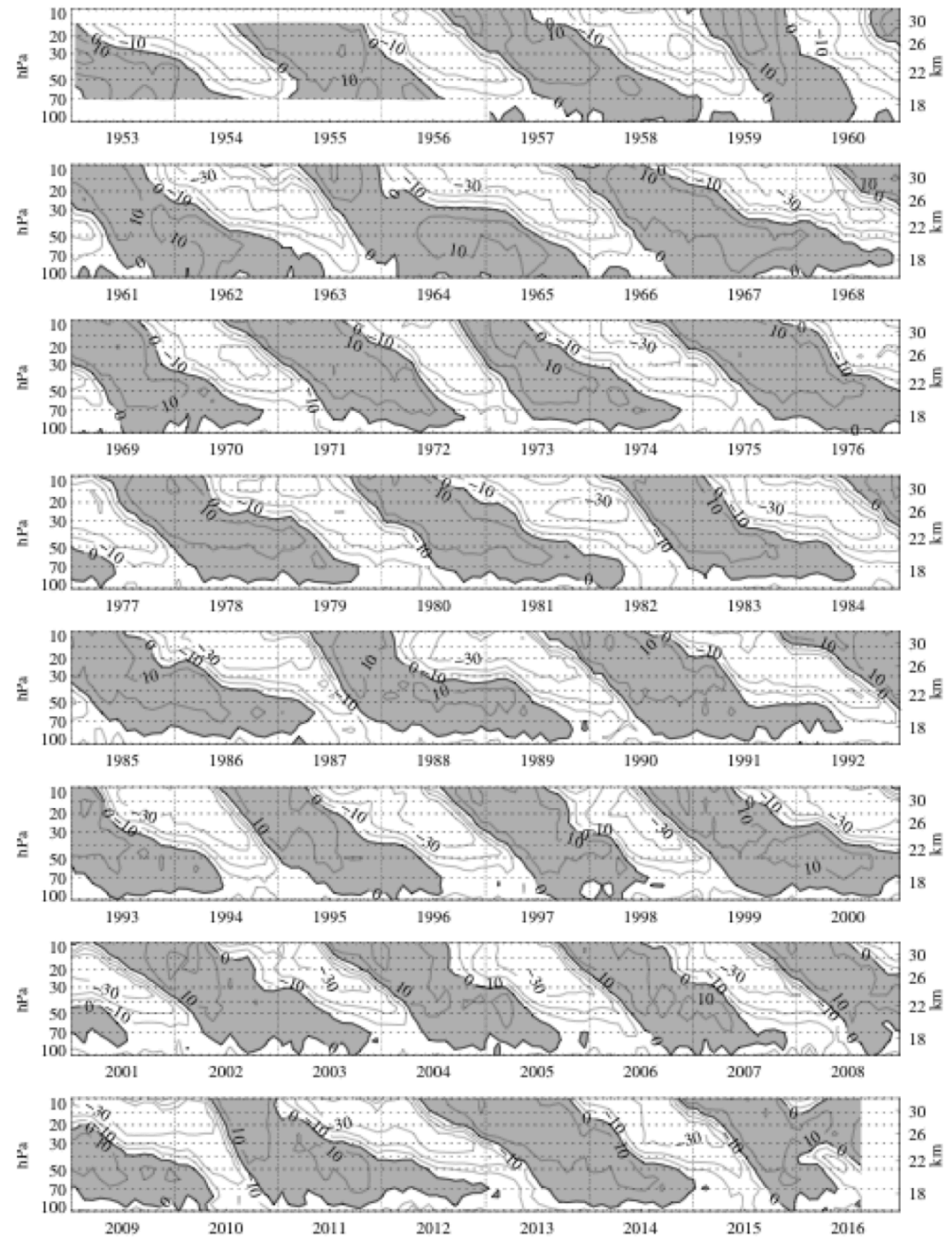
Chelton and Schlax 1996



Comparison with theoretical predictions of Rossby wave phase speed



QBO time series (FUB)



Simple model of equatorial Quasi-Biennial Oscillation

$$\frac{\partial \bar{u}}{\partial t} - \nu \frac{\partial^2 \bar{u}}{\partial z^2} = - \sum_i \frac{\partial F_i}{\partial z}$$

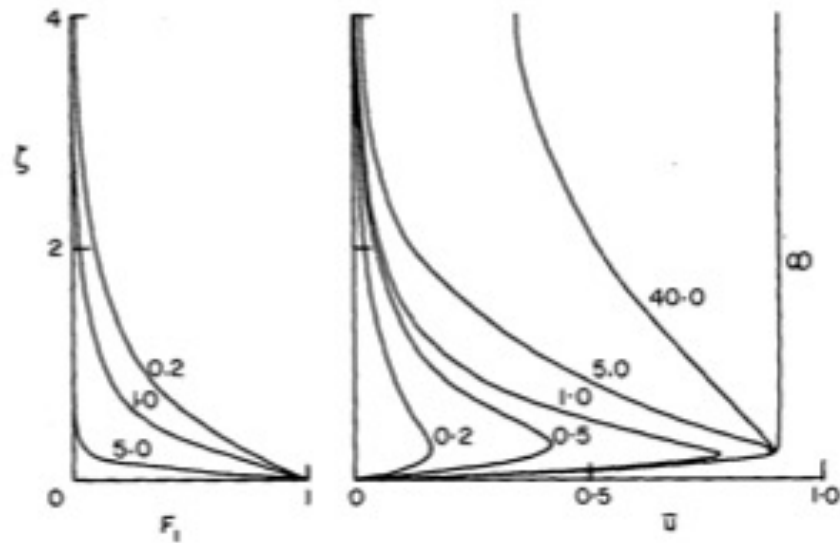
$$F_i(z, t) = F_{i0} \exp\left(- \int_0^z \frac{N \mu}{k_i (u(z', t) - c_i)^2} dz'\right)$$

$i = 1, 2$

Plumb (1977)

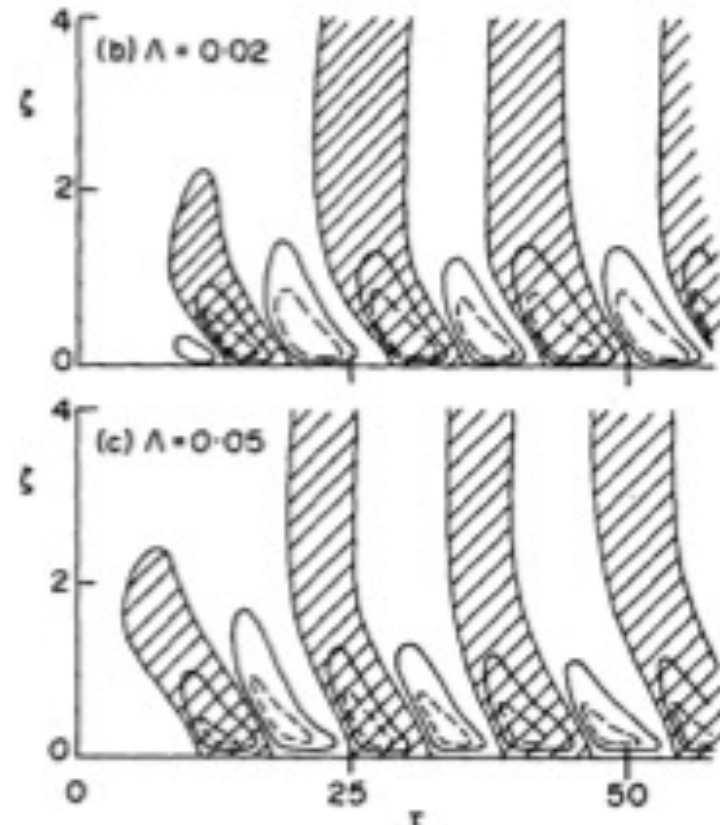


$$\Lambda = \frac{\nu N \mu}{k c F_0}$$



$\Lambda = 0.1$

$\Lambda = 0.02$

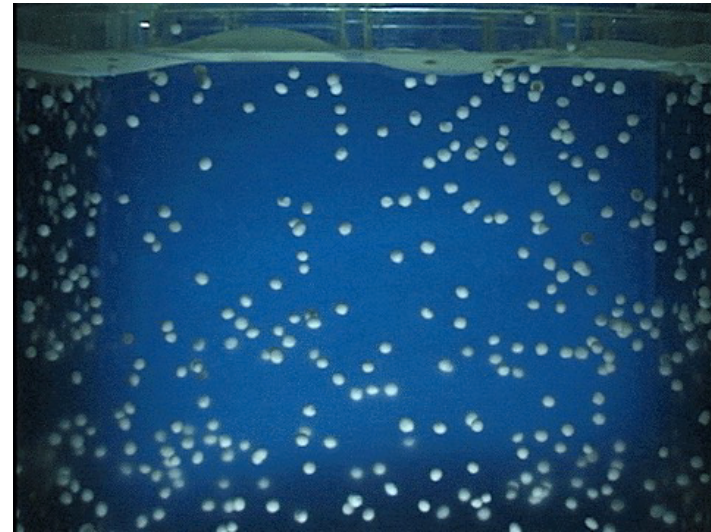


$\Lambda = 0.05$

Plumb (1977)



Laboratory realisations of QBO mechanism



http://dennou-k.gfd-dennou.org/library/gfd_exp/exp_e/exp/bo/1/res.htm

