EGU2016-735: On The Generation of Oceanic Internal Gravity Waves by Polar Lows

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Motivation

Polar low pressure systems with strong winds significantly impact the subpolar gyre circulation, regional sea surface temperature changes and deep water formation. Thus they are expected to play a key role in a variety of energy transport mechanisms. The present study investigates the generation of internal gravity waves by an idealized polar low in an axisymmetric geometry. The effect of the mixed layer depth in the initial stratification on the radiated energy is examined.

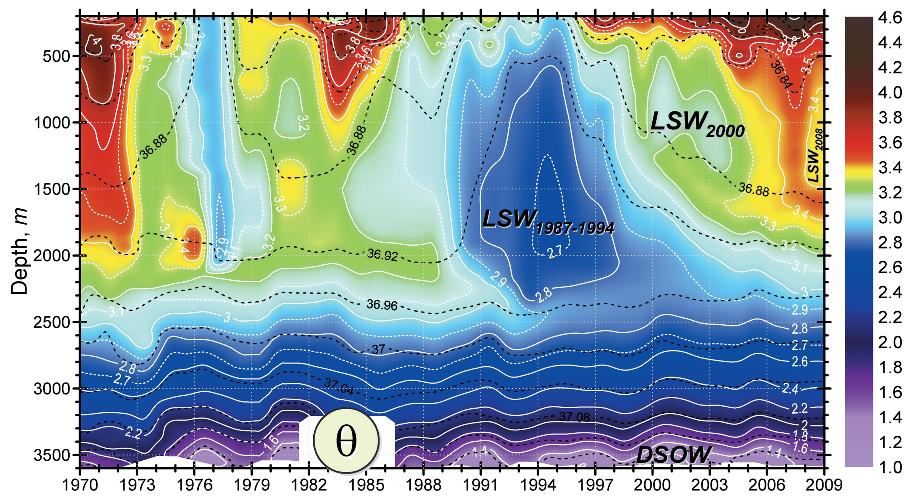
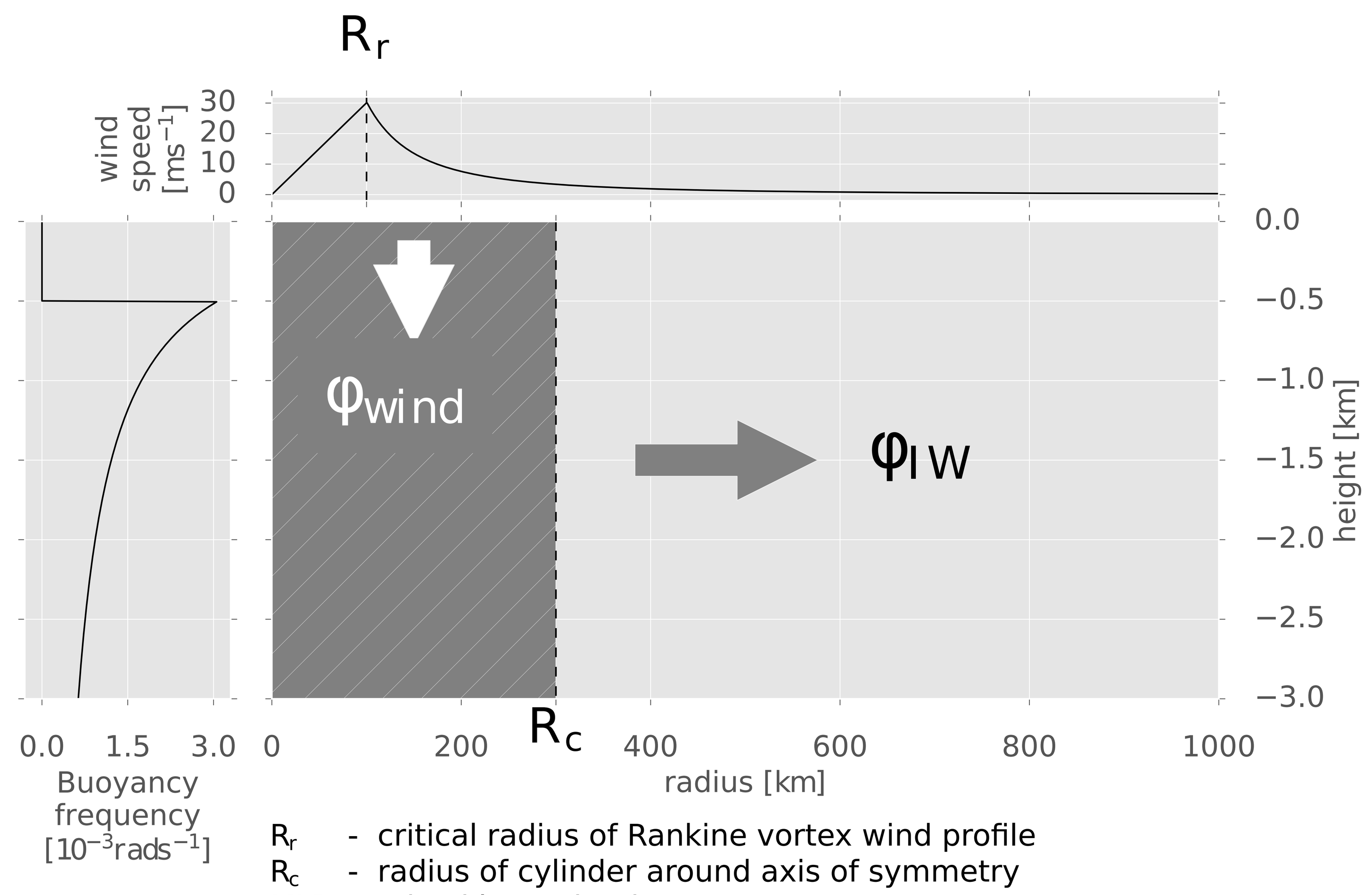


Fig. 1: Observations of deep convection events with strongly variable mixed layer depths. From Yashayaev and Loder (2009)

The Model

- axisymmetric (all azimuthal derivatives are zero)
- Boussinesq approximation
- free-slip (no friction) condition at origin and bottom
- open boundary (10-point flow relaxtion scheme) at radial edge



R_r - critical radius of Rankine vortex wind profile
R_c - radius of cylinder around axis of symmetry
MLD - mixed layer depth
ϕ_{wind} - vertical energy flux into the ocean due to wind
ϕ_{IW} - radial energy flux through the cylinder with radius R_r

Fig. 2: Schematic of the model setup. An azimuthal wind with Rankine vortex structure is supplied on the surface with a defined time evolution (top panel). An initial stratification with mixed layer depth is given (left panel). The initial conditions for all velocities are zero.

Setup and Results I

- radial resolution 980m, vertical resolution 23.5m, time step 18s
- vertical viscosity $\nu_v = 0.1\mathrm{m^2s^{-1}}$, horizontal voscosity $\nu_h = 1\mathrm{m^2s^{-1}}$
- azimuthal wind profile is a Rankine vortex (see figure 2) with $R_r = 50\mathrm{km}$ and maximum value $v_{max}^{wind} = 30\mathrm{ms^{-1}}$
- the azimuthal wind increases from zero to it's maximum for 12h, is constant for 24h and then decreases to zero linearly for 12h
- initial stratification is constant in radius and follows Gill (1984):

$$N|_{z<mld} = \frac{D_0 N_0}{Z_0 - Z} \qquad \begin{aligned} D_0 &= 200\mathrm{m} \\ N_0 &= 0.01\mathrm{s^{-1}} \\ Z_0 &= 150\mathrm{m} \end{aligned}$$

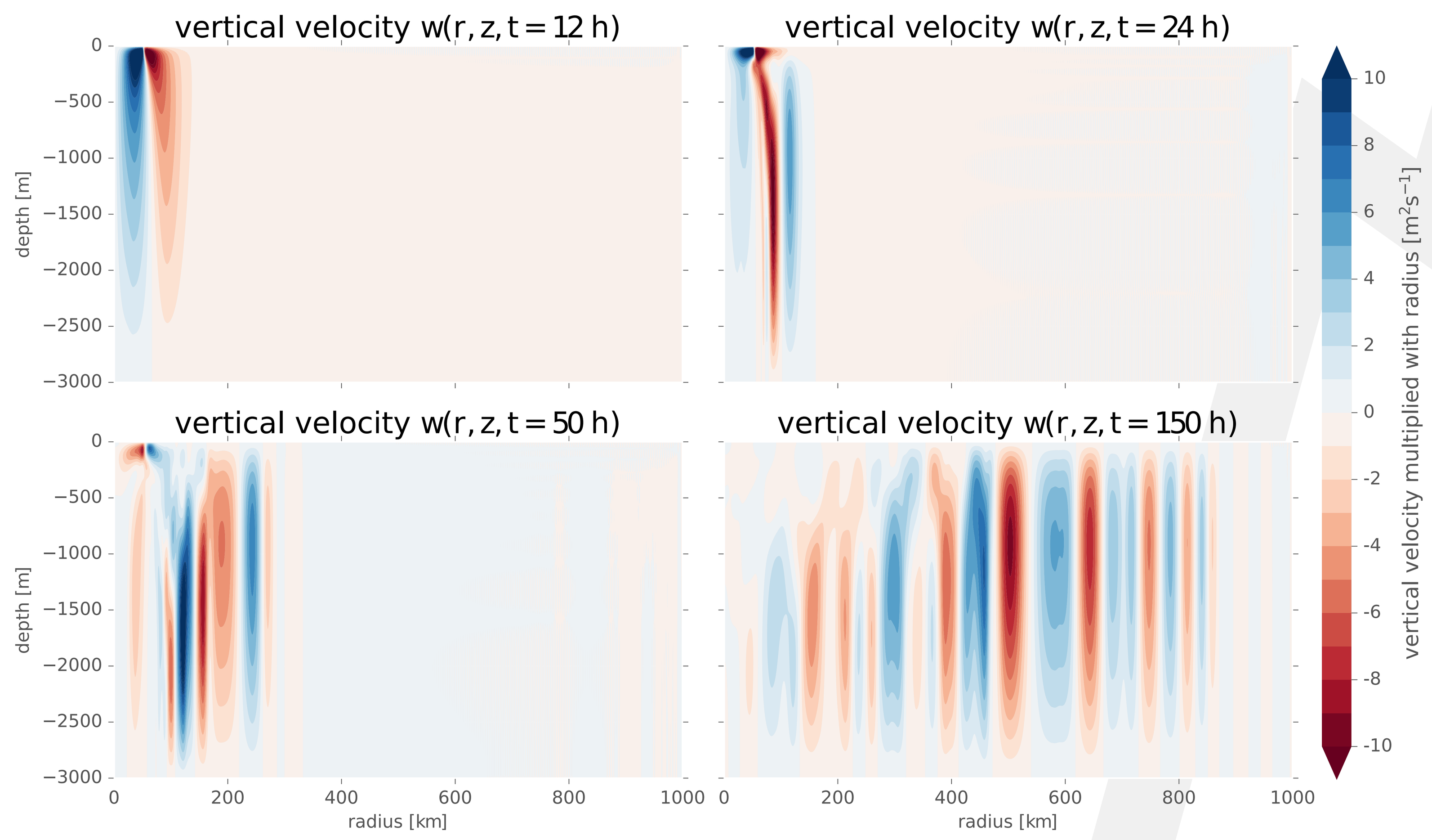


Fig. 3: Vertical velocity snapshots from a typical simulation for times equal to 12h, 24h, 50h and 150h. The field has been multiplied by the radius to account for the decay due to the increase of of the circumference. Higher modes are present but vertical mode 1 waves are dominant.

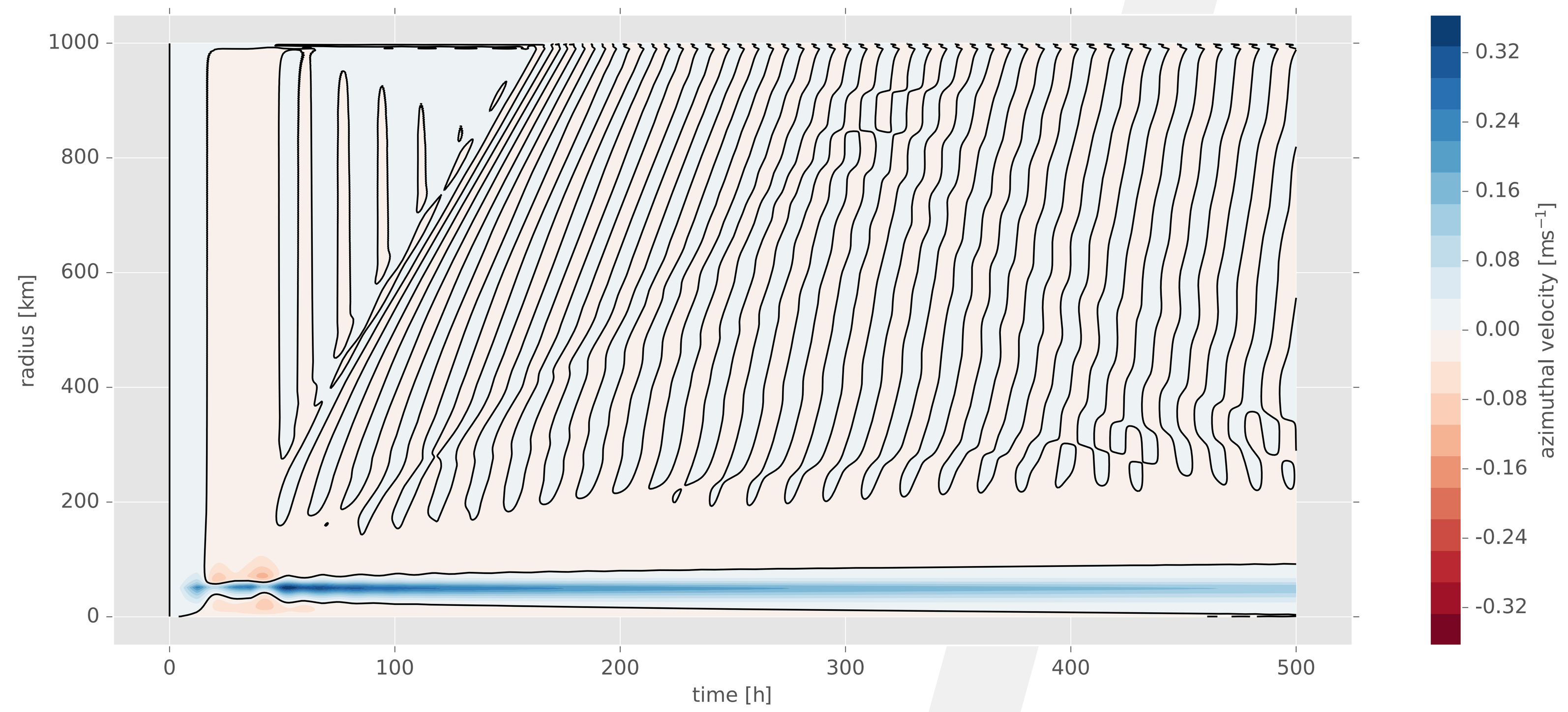


Fig. 4: Azimuthal surface velocity as function of time and radius. The contours mark zero velocity. The slopes of the contour lines show waves with distinct group velocity i.e. distinct vertical modes.

Results II

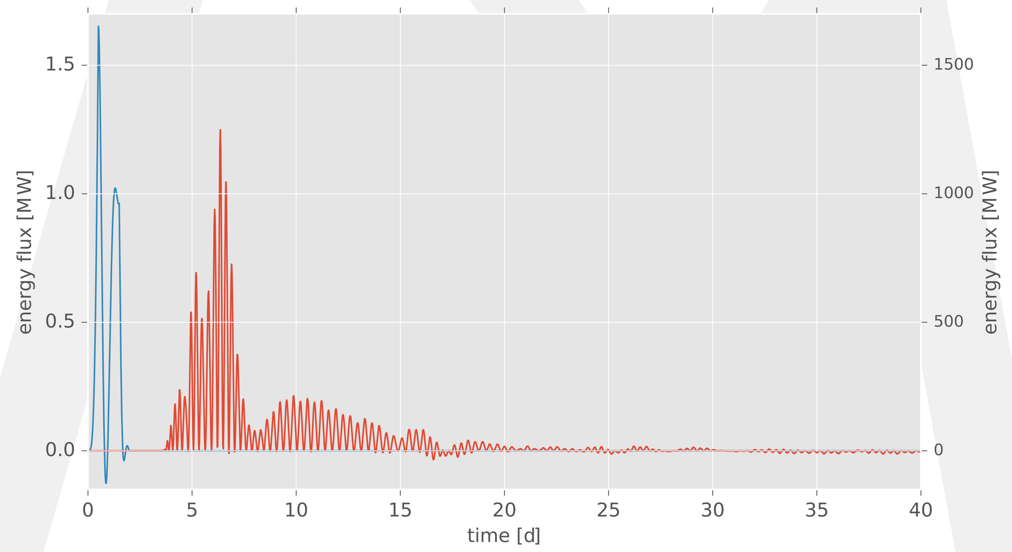


Fig.5: Time series of the integrated energy flux through a cylinder with radius $R_c = 500\mathrm{km}$ (red, left axis) and integrated energy flux through the corresponding disk on the surface (blue, right axis). There are distinct wave packets with similar frequency. They correspond to wave packets with different associated vertical wave number. The ratio of radiated energy to wind energy input is of the order 0.001.

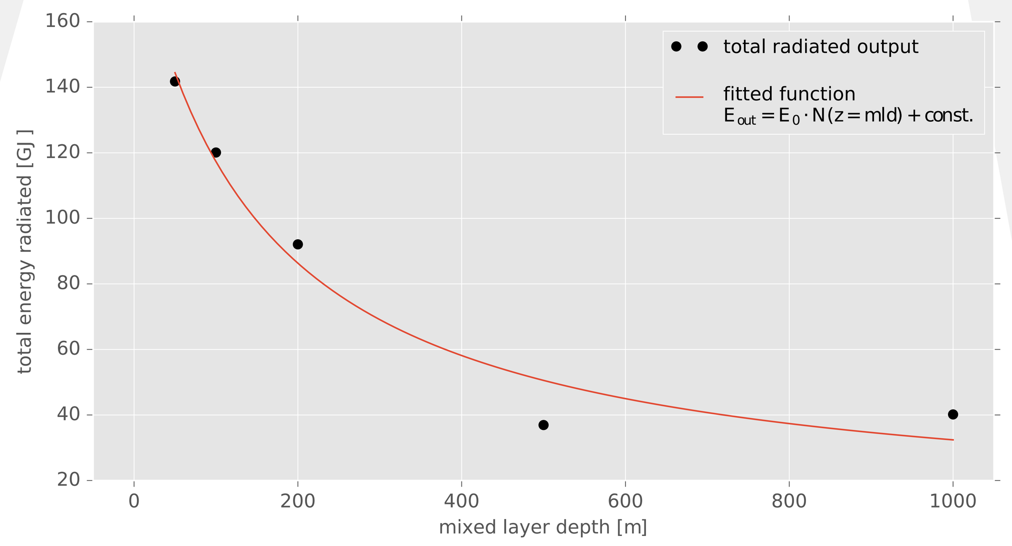


Fig. 6: Total energy radiated as function of mixed layer depth. The black scatter points correspond to time series integrals from model output. The red line is a least square fit with the indicated formula and parameters shown below.

$$\begin{aligned} E_0 &= 1.356 \cdot 10^4\mathrm{Js} \\ const. &= 8.823\mathrm{J} \end{aligned}$$

Conclusion and Discussion

- polar lows can act as generators of internal gravity waves
- the ratio of radiated energy to wind energy input is of the order 10^{-3}
- the generation of wave energy is weak compared to that excited by near inertial oscillations (see Alford 2003)
- the radiated energy depends linearly on the stratification below the mixed layer
- a dependence on the mixed layer depth or the depth of the stratified region could not be identified
- vertical and horizontal kinematic voscisity may play a role in wave attenuation and vertical momentum transfer

Acknowledgement

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