Submesoscale processes in upper ocean fronts: a numerical study using a Reynolds Stress Turbulence Model

Pablo Cornejo.

Mechanical Engineering Departament, University of Concepción, Concepción, Chile.

Departament of Geophysics, University of Concepción, Concepción, Chile.

Abstract

A computational model was implemented to describe fluid dynamics processes associated to midlatitude small scale upper ocean fronts using modified state of the art computational fluid dynamics (CFD) tools. An unforced periodic frontal system was simulated following three different approaches to describe subgrid turbulent structures: 1) Reynolds Stress Model (RSM, seven equation), 2) Standard Smagorinsky Model (SS, zero equation), 3) Modified Smagorinsky Model (MS, zero equation including a non-isotropic turbulence correction). Results show the system evolving in an unstable way generating submesoscale conditions (Ro~1) within mixed layer in the three approaches adopted. However, vertical velocity magnitude estimated with the SS approach was found 50% lower than the RSM and MS estimations which are consistent with predictions of quasigeostrophic theory O(10^{-3} m/s), even when the density and horizontal velocity field were found similar. Below mixed layer results show a low vertical velocities and Ro<1 zone indicating less submesoscale activity. Wavenumber spectra of horizontal velocity were estimated for the structures within and below mixed layer. Modeling results from RSM approach show large scale structures of similar energy level within and below mixed layer, while medium and small scale structures were found more energetic below. Predicted wavenumber spectra slopes for large scale horizontal structures within and below mixed layer were found k^{-3} while medium and small scale fit a k^{-2} slope which are in accordance with the predictions of interior quasigeostrophic theory and surface quasigeostrophic theory including ageostrophic effects.

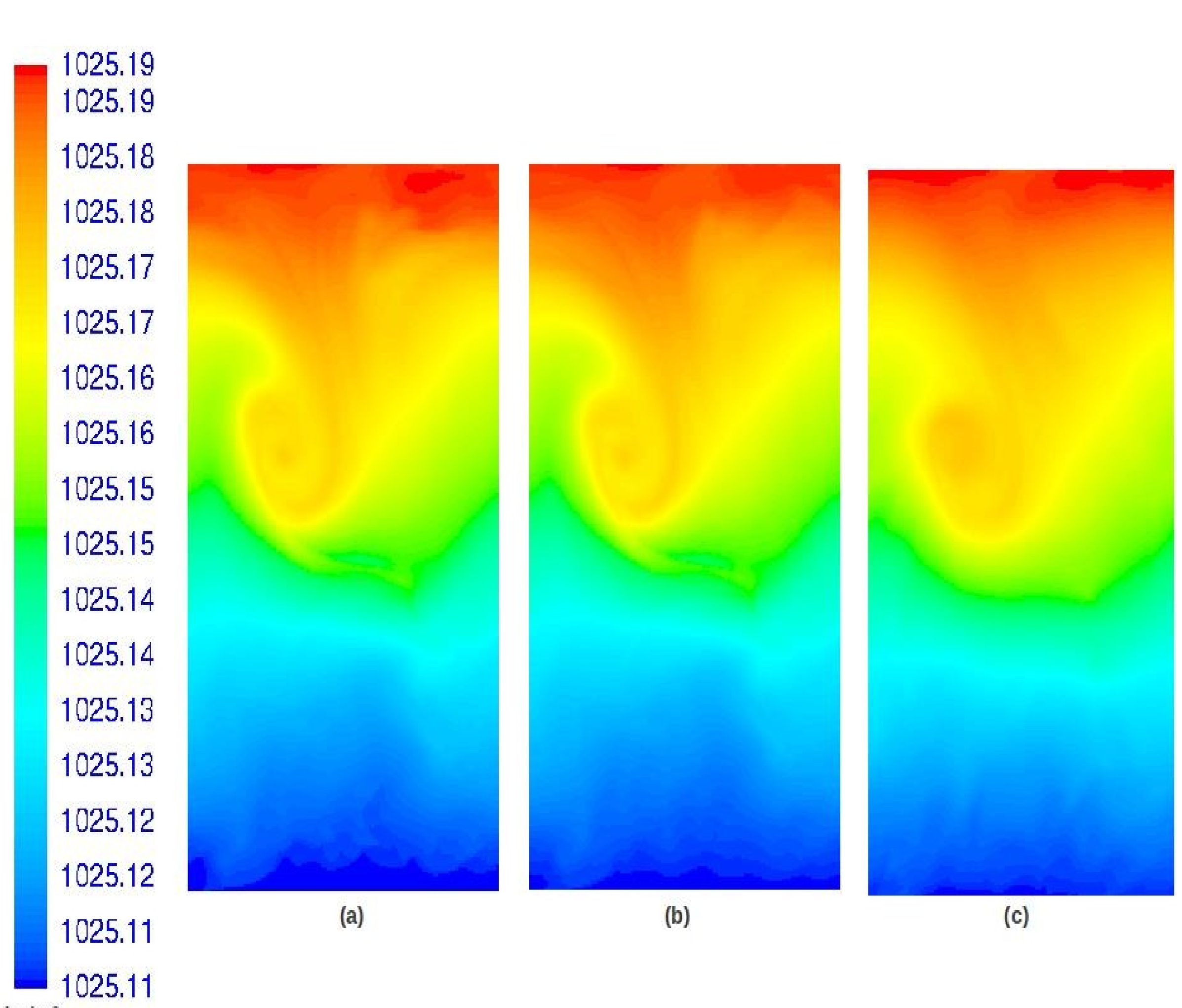
Materials and Method

A state of the arte CFD code was modified including earth rotation and stratification processes. This code was employed to set up a periodic unforzed model depicting a small scale upper ocean front of 10 km long, 3 km wide and 500 m depth. The model was run using three differents turbulent parametrizations: Reynolds Stress Model (seven equation), Smagorinsky model (zero equation) and modified Smagorinsky model (zero equation, including non-isitropic effects following [Scotii et al. 1993]). The control volume was discretized with a computational grid of 30 m and 10 m of horizontal and vertical resolutions. Fields were initialized with a 50 m depth front in geostrophic equilibrium with density varing 0.575 kg/m3 in 4 km. Coriolis parameter was set 10^{-4} asociated to 43° latitud.

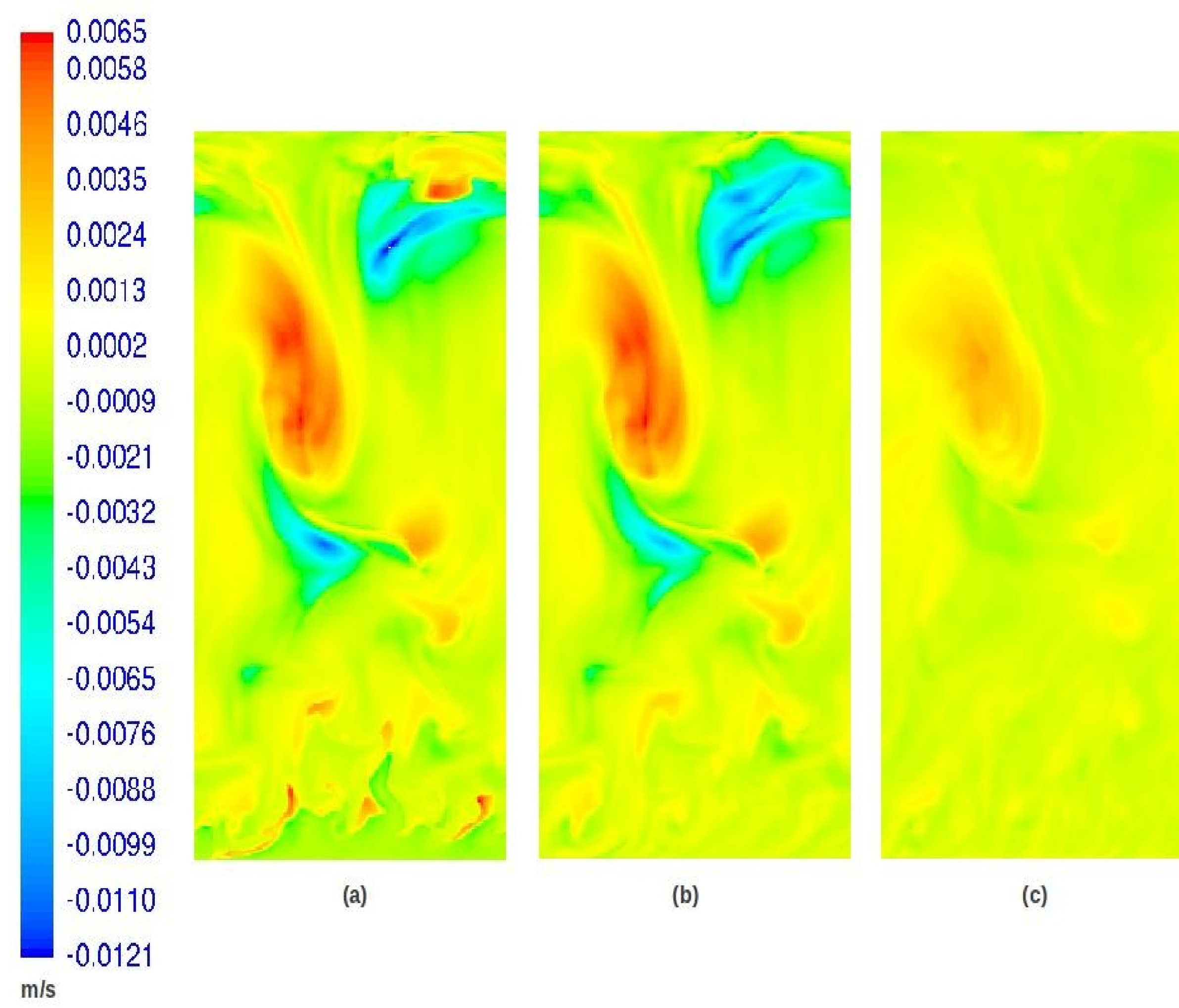
Results

The following figures show the results obtained through numerical simulations 6 days from model initialization. Contour plots show density, horizontal and vertical velocity within mixed layer at 25 m depth. Rossby number distributions are show within and below mixed layer at 25 m and 75 m depth. In the figures letters a), b), c) denote numerical results from approaches RSM, MS and SS respectively.

Density

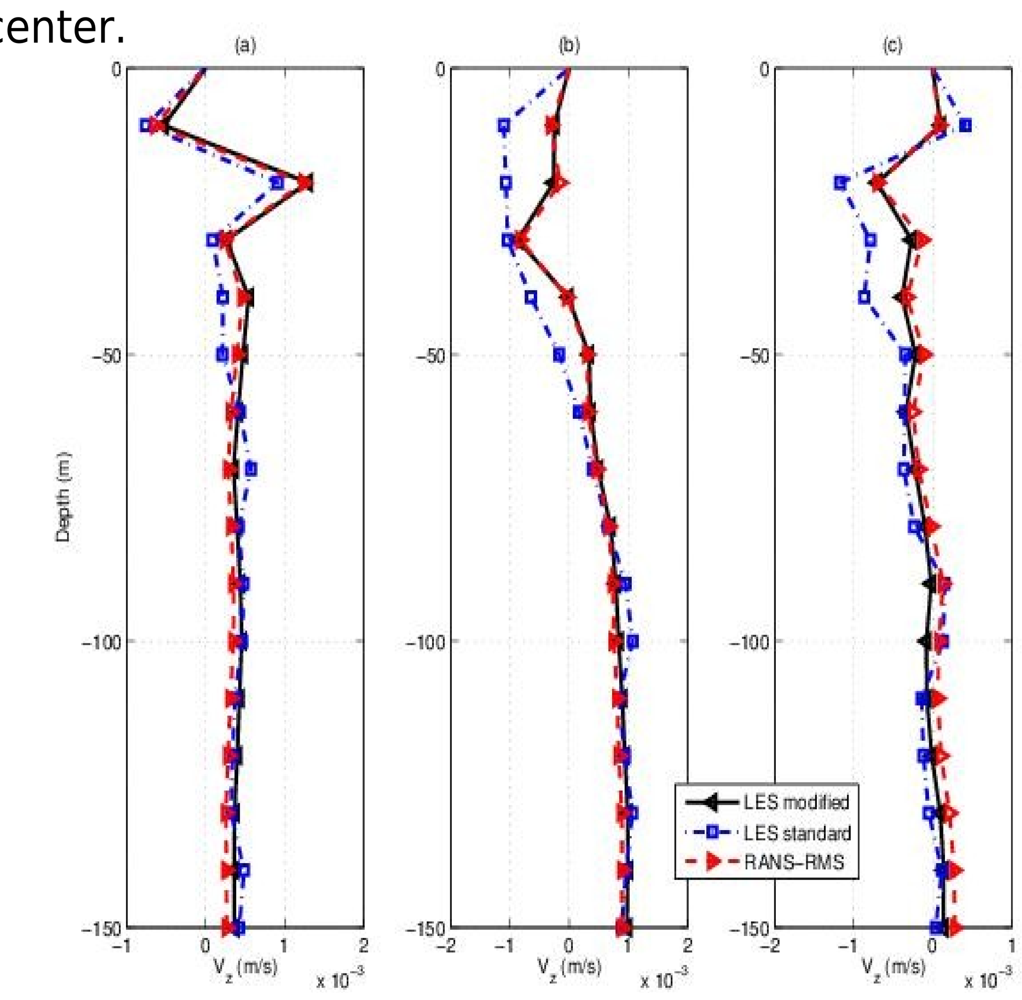


Vertical Velocity

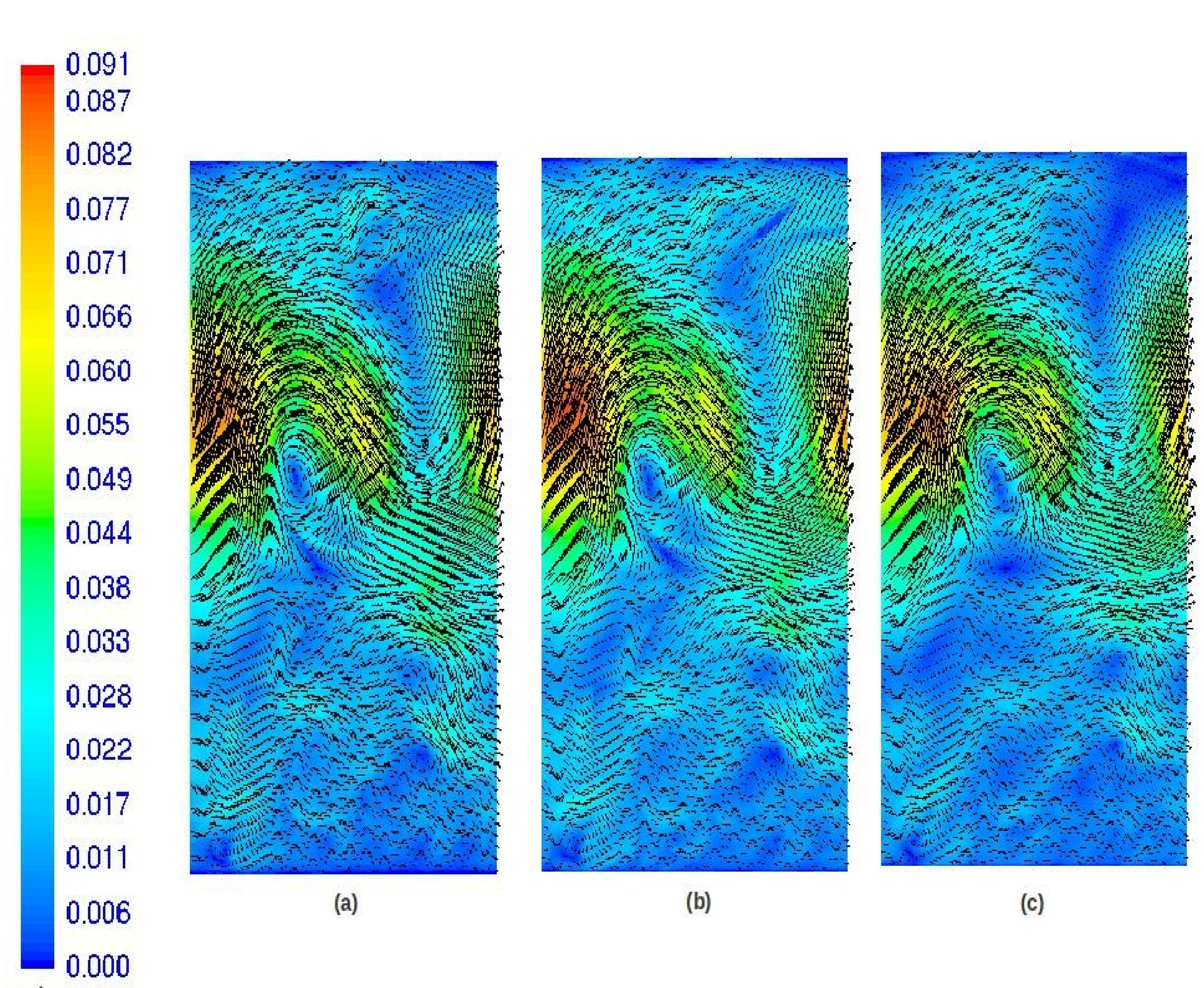


Vertical Velocity Profiles

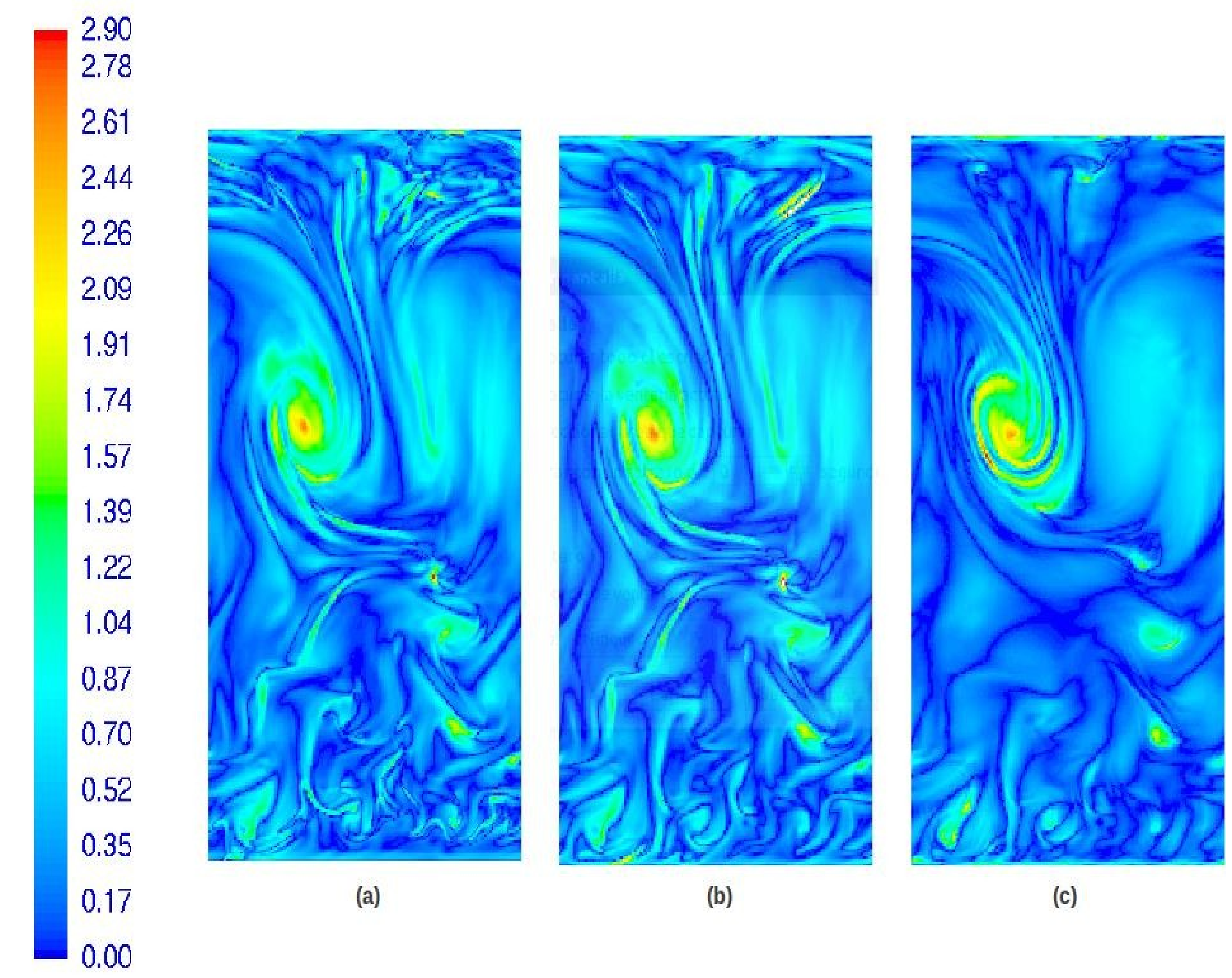
In the Figure: a) 2 km northward from front center, b) in the front center and c) 2 km southward from front center.



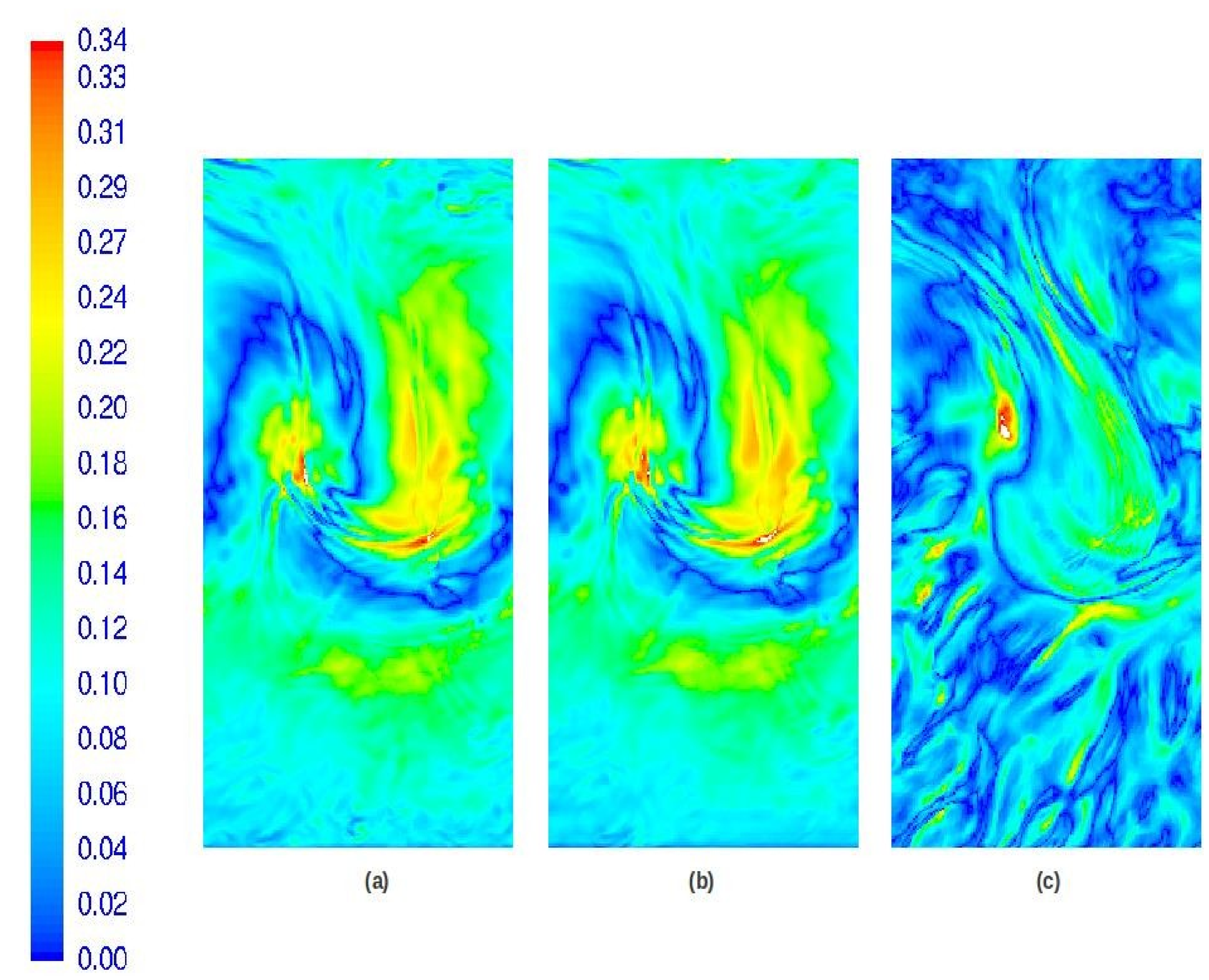
Horizontal Velocity



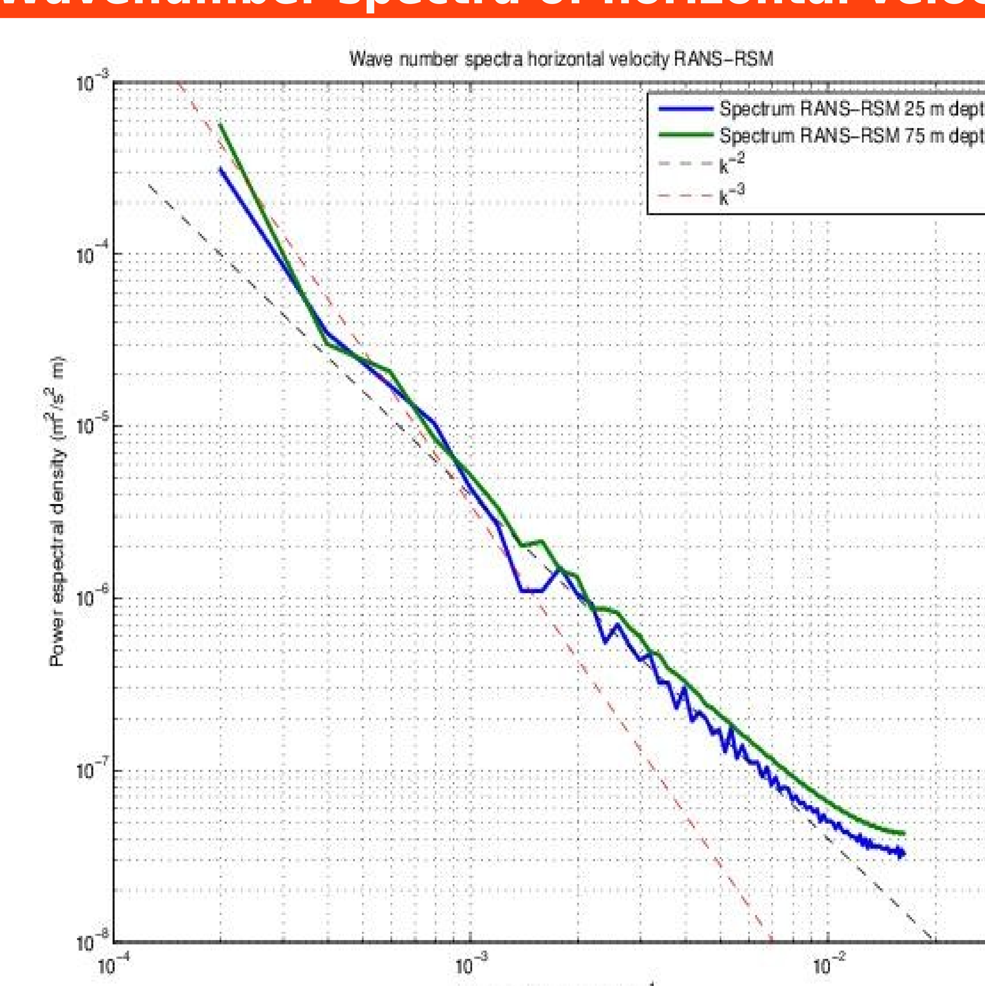
Rossby Number within mixed layer (25m)



Rossby Number below mixed layer (75m)



Wavenumber spectra of horizontal velocity



Conclusions

In order to use a non-isotropic grid the well know algebraic turbulence model of Smagorinsky was modified following [Scotii et al. 1993]. This modification allowed to obtain similar results of a seven equations model (RSM) while maintaining a lower computational cost.

Numerical predictions of vertical velocities and the slopes of horizontal velocity wavenumber spectra fit with theoretical predictions of quasigeostrophic theory.

Contact Information

Point of Contact:

Dr(c). Ing. Pablo Cornejo Olivares

pabcornejo@udec.cl