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THE EFFECT OF COASTAL DIABATIC HEATING GRADIENTS ON THE DYNAMICS OF COLD FRONTS

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1. INTRODUCTION

Despite cold fronts being an important feature in the mid latitudes there has been little research on the effects of coastlines on their dynamics. Coastlines create large gradients in diabatic heating due to the differing heat capacities of land and water. These gradients interact with surface fronts in the southern parts of Australia where cold fronts cross regularly. Observations also show that frontogenesis is strongest on the western sides of southern hemisphere continents where cold fronts cross from ocean to land.

There has been some previous work on the effect of daytime heating and nocturnal cooling on cold fronts by Reeder and Tory (2005). They investigated the role a homogeneous land mass has on a cold front that develops in a non-linear baroclinic wave. They found that uniform short wave heating is weakly frontolytic, and nocturnal cooling is strongly frontogenetic. The front rapidly strengthens at night because the cross-frontal flow accelerates towards lower pressure once the daytime boundary layer turbulence ceases.

Mills and Xinmei (2005) investigated wind changes, most of which are cold fronts, on significant bushfire weather days in Victoria, Australia. They found that the wind changes crosses Southern Victoria most frequently from late afternoon to evening.

In this paper a cold front is investigated in an idealised framework to determine the effect the coastline plays on frontal passage times.

2. THE NUMERICAL MODEL

The numerical model used is two-dimensional and based on the primitive equations. It is formulated in sigma-co-ordinates on a southern hemisphere f-plane. All moist processes are ignored for simplicity. The problem is constructed such that the x-axis lies across the front and the y-axis along the front. The basic state, sometimes called a pattern of confluent deformation, comprises streamlines which are hyperbolic and constant with height. The location of the background state dilatation axis translates in space using the method eveloped by Cunningham and Keyser (1985).

Boundary layer turbulence is parameterised by the Mellor -Yamada 2.25 Scheme (Mellor and Yamada 1974, 1982). This is a second order closure scheme and is used extensively in modelling studies. The boundary layer has a resolution of approximately 20m in the vertical and 8km in the horizontal. Radiative boundary conditions are applied at the lateral boundaries.

The initial conditions for the numerical model are taken from Keyser and Pecnick (1985). These conditions have a strong southerly along front wind in thermal wind balance with the potential temperature. The model is then run for 24hrs while slowly increasing the deformation strength to generate the associated across-front circulation.

3. Numerical Experiment

The results from four types of numerical experiments are discussed. These experiments are as follows:

1. Land Only
2. Ocean Only
3. Coastline Friction
4. Coastline Heating

The land only experiment has a homogenous land surface without any ocean. Conversely the ocean only experiment has a homogenous ocean surface and no land. Boundary layer processes are included in these two experiments.

In the coastline experiments the domain is split into ocean and land allowing the fronts to cross from ocean to land. The heating experiment includes all the boundary layer processes. The friction experiment has no radiative effects, only frictional processes.

4. RESULTS

Land only numerical experiments of the model show the front strengthening in the evening and weakening during the day. This result

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agrees with Reeder and Tory (2005), that daytime heating is frontolytic and night-time cooling is frontogenetic.

The coastline heating experiment shows the front stalling at the coastline during the day, while daytime heating is taking place. When the turbulent stress in the boundary layer weakens, associated with daytime turbulent mixing, the front accelerates down the pressure gradient and surges on shore. Comparing Fig. 1 and Fig. 2 shows this surge in the across front winds.

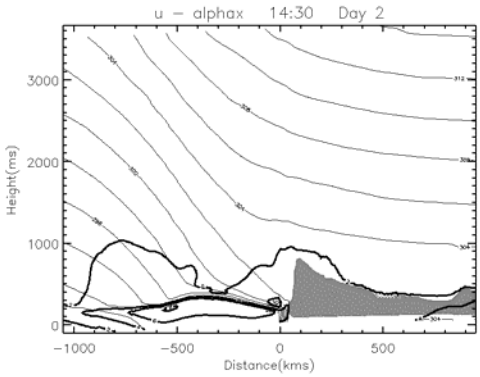

Figure 1. Frontal solution at 2:30pm local time. Bold contours are across-front wind speed, positive being solid and negative dashed. The background contouring is potential temperature. The shading displays regions where $K_H > 20m^2s^{-1}$.

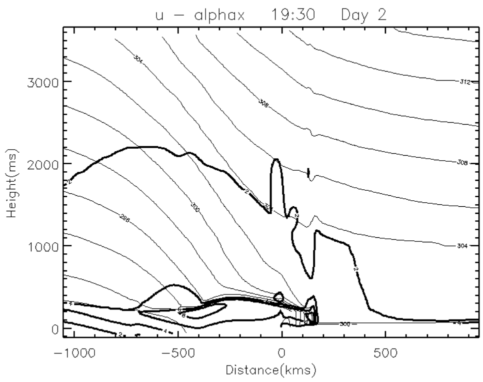

Figure 2. Frontal Solution at 7:30pm local time. The front is now moving onshore after the turbulent mixing has weakened.

The coastline experiments were repeated 11 times, each time with the front a different distance offshore initially. Two points are chosen on the land, one 16km and the other 240km, from the coastline. At each of these points the time of frontal passage is determined and plotted in Fig. 3. Here the front is defined as the position at which the horizontal potential temperature gradient at 40m is greatest. The effect of the diurnal cycle on the movement of the front is made is evident by comparing with the friction only run.

In Fig. 3 the friction only numerical experiment shows a linear relationship between passage time and the initial distances. However when a diurnal cycle is included in the calculation there is a distinct preference for afternoon passage. The point 16km from the coastline shows a preference for passage in the afternoon. The point further inland has a non-linear relationship between frontal passage and distance.

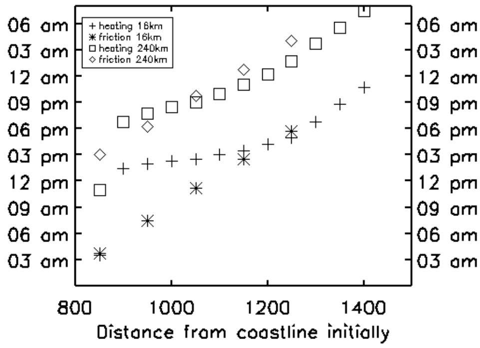

Figure 3. The relationship between frontal timing and distance from the coastline initially. Data from the heating and friction runs are shown at two points at differing distances from the coastline.

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