Use of the UW-NMS to Simulate the Flow Around Ross Island on 3 September 2003

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On 3 September 2003 a cyclone moved over the Ross Ice Shelf resulting in winds greater than $46 ms^{-1}$ at the Ferrell AWS. The strong synoptically forced winds were modified by the severe topography near Ross Island providing hazardous conditions at McMurdo, and an interesting case for studying the flow around Ross Island. High-resolution simulations of the flow around Ross Island were conducted using the University of Wisconsin-Madison Nonhydrostatic Modeling System (UW-NMS).

The UW-NMS is a nonhydrostatic, quasi-compressible, enstrophy conserving model formulated in the non-Boussinesq framework (Tripoli, 1992). This three dimensional, fully scalable numerical weather prediction model is capable of multiple two-way interactive grid nesting. One of the truly unique features of the UW-NMS is the use of a variable step topography system. Unlike other topography systems, the UW-NMS system is based on a surface coordinate step of variable depth, chosen to exactly match surface elevation (Figure 1). This allows the UW-NMS to represent slopes as steep as 90 degrees while also being capable of representing even the subtlest topography. Finite differencing advection cast in vorticity/kinetic energy form and directly specifying vorticity and kinetic energy at topographical boundaries ensures the UW-NMS of a vectorally consistent numerical treatment of flow interacting with topographical or structural barriers. As a result, competent simulations of flow around topographical obstacles are possible even in the severe Antarctic flow regimes, where low Froude numbers often dominate the flow. A topographical dataset with 1km resolution is used with the UW-NMS.

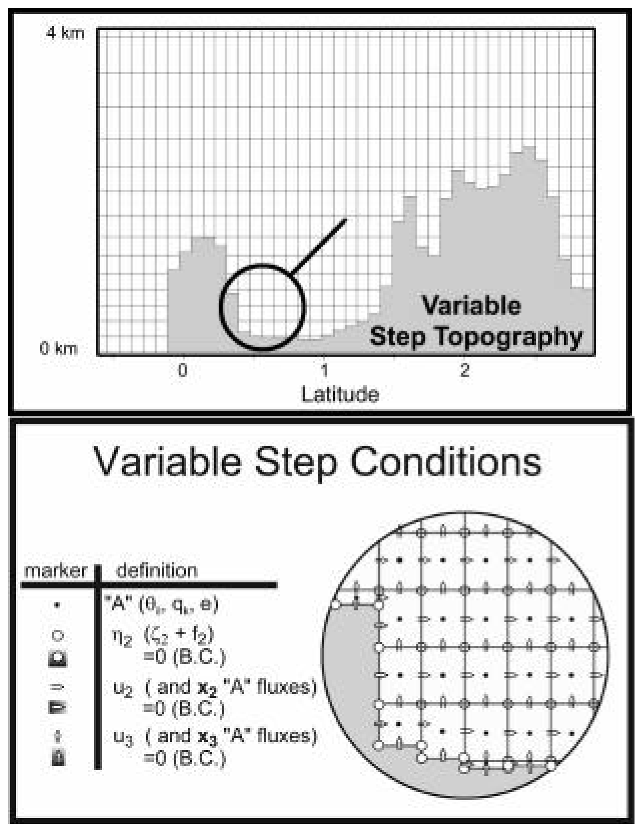

Figure 1: Schematic of variable step topography used in the UW-NMS. Notice how the lowest grid boxes vary in depth, in order to exactly match terrain.

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A series of five nested grids was employed to simulate the airflow near and around Ross Island. The resolution of grids 1, 2, and 3 were 60km, 15km, and 5km respectively (Figure 2). A fourth grid was run at both 1.25km and 1km resolution. The innermost grid was run with resolutions of only a few hundred meters.

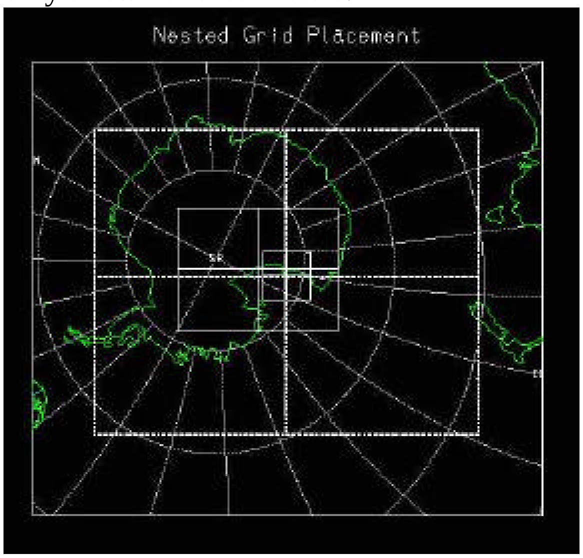

Figure 2: Domains of the 3 outermost grids used by the UW-NMS.

The UW-NMS simulations show the strong influence that the Ross Island topography has on the wind, pressure and temperature fields around Ross Island. The high peaks of Mt. Erebus and Mt. Terror on Ross Island create a virtual barrier in the flow, which caused the flow to slow down as it approached Ross Island and build up on the windward side generating a localized area of high pressure (Figure 3). A compensating area of localized low pressure developed on the leeward side of Ross Island resulting in a strong pressure gradient across the island, which accelerated the wind around the sides of Ross Island.

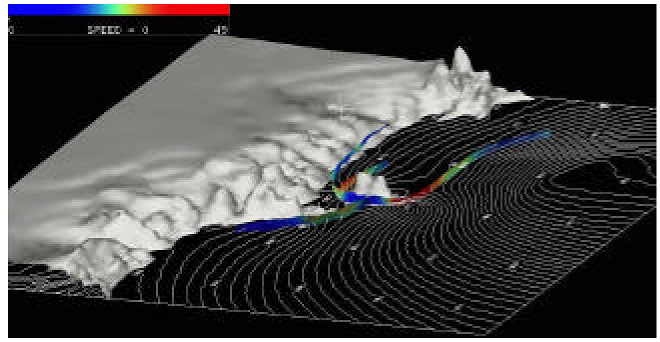

Figure 3: Results from grid 3 (dx=dy=5km), valid at 1100 UTC, 3 September 2003. Trajectories colored by speed show the winds slowing down as they approach Ross Island, and then accelerating around the sides. The contours are mean sea level pressure in 1mb increments.

While the flow near the surface split and went around Ross Island, flow higher up was able to travel over Ross Island. The flow that traveled over Ross Island crashed to the surface upon reaching the leeward side. This downsloping produced localized adiabatic warming on the leeward side, as well as being responsible for transporting high momentum air down to the surface. The transport of high momentum air resulted in fast winds near the surface flowing out of the area of localized low pressure (Figure 4). The high-resolution simulations performed also show the development of several rotor like circulations on both the windward and leeward side of Ross Island as well as cold air damming on the windward side of Ross Island (Figure 5).

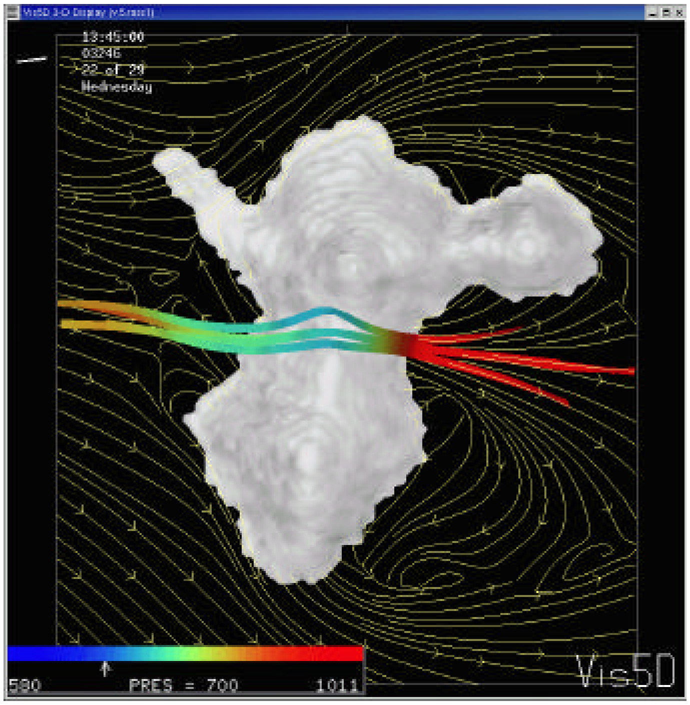

Figure 4: Grid 5, with dx=dy=500m, valid at 1345 UTC 3 September 2003. Surface streamlines (yellow) show the surface flow splitting and traveling around Ross Island, while trajectories (colored by pressure level using scale shown) show strong downsloping on the leeward side due to the flow higher up that is able to go over Ross Island.

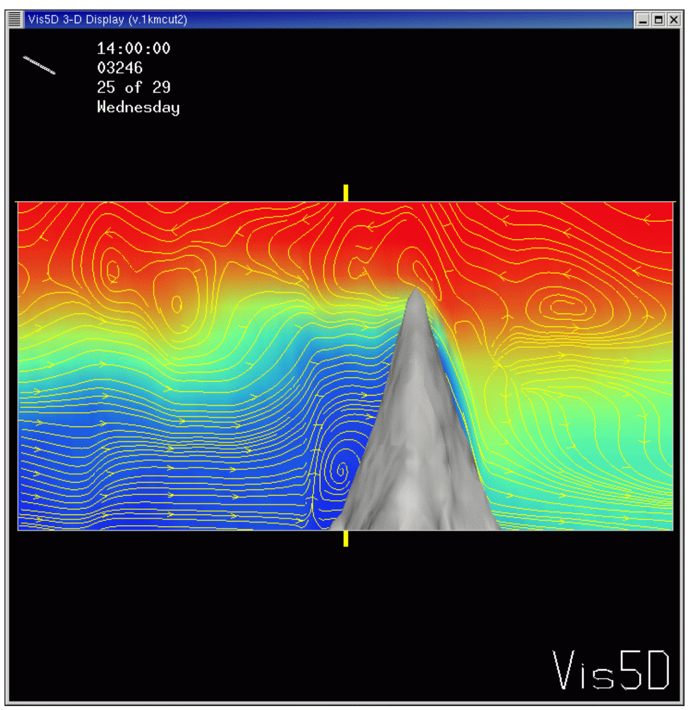

Figure 5: Grid 4, with dx=dy=1km, valid at 1400 UTC 3 September 2003, looking from the east towards Ross Island. Vertical streamlines show the development of a rotor like circulation on the windward side of Ross Island, with in the cold air dome (color-fill is potential temperature). Also of note is the downsloping on the leeward side of Ross Island.