Heavy coastal precipitations at Terra Nova Bay during a summertime event

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1. INTRODUCTION.

Several studies have shown that mesoscale development over the Ross Sea is frequently linked to strong katabatic winds descending from the plateau through the main glaciers. Preferential confluence areas are individualized, in particular, around Terra Nova Bay and over the Ross Ice Shelf. Energetic katabatic winds can propagate for long distances far out from the coast along the isobars of synoptic storms in the vicinity, thus following a geostrophic adjustment. Barotropic instability may be the initial trigger mechanism for formation of a mesoscale cyclone, while low level baroclinicity due to strong air-sea interaction can result in deep convection during the mature stage of development, especially in summer. During the Antarctic campaign 2006-2007, an event of heavy coastal precipitations associated with a boundary layer cold front merging with a mesocyclone near Terra Nova Bay was observed. Here is documented this case study.

2. EVENT.

Analyses and observations indicated moderately strong katabatic winds, descending from East Antarctica and splitting around Ross Island in two branches. Strong shear, curvature and stretching vorticity caused a barotropic small-scale disturbance to form in the lee Ross Island. A westward moving boundary layer front formed shortly after from the leftward turning katabatic airstream fast moving to the east of Ross Island, becoming supergeostrophic as a result

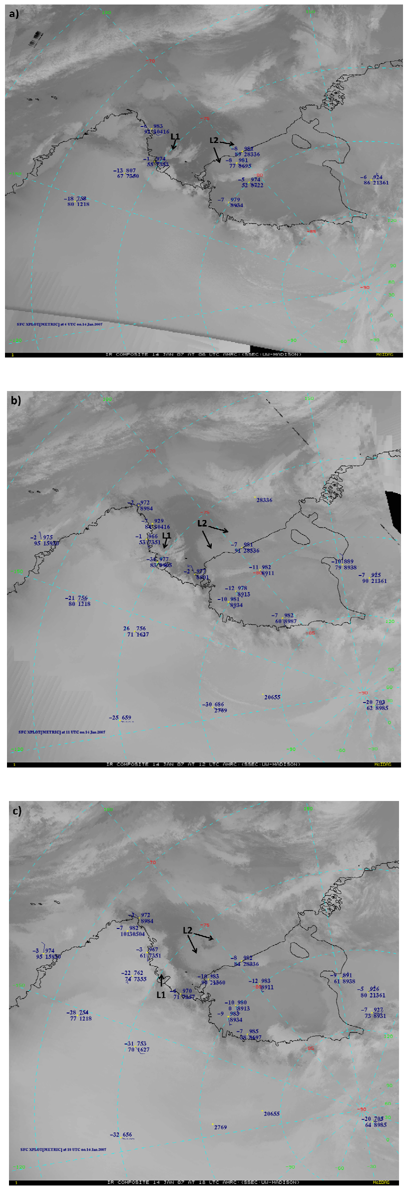

Fig. 1. Thermal infrared composite images from AMRC, a) 0600 UTC, b) 1200 UTC, c) 1800 UTC, January 14, 2007.

of its anticyclonic curvature once reached the tip of the topographic barrier. The surface convergence established on the eastern edge of the small disturbance, in conjunction of a near-neutral stability above the boundary layer, facilitated upward motions and

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convective instability ahead of the anticyclonic pseudoinertial flow. The observed inertial trajectory and an estimation of the radius of curvature suggest that the Coriolis deflection and the large max flux from the Ross Ice Shelf were not sufficient to maintain such airstream so far offshore. It is inferred that the vigorous katabatic airstream was sustained by the strengthening of a sub-synoptic scale circulation settled over the northeastern Ross Ice Shelf, triggered by a midtropospheric trough transiting on the area. In such a situation the highly ageostrophic airflow eventually adjusted to pressure gradient controlled flow around the maritime cyclone, for some distance out over the ice covered northern Ross Ice Shelf, and was able to reach the coast of Victoria Land. The interaction of the boundary layer front with a mesoscale system, approaching Terra Nova Bay from offshore, resulted in enhanced cumulus convection associated with frequent snow showers along the coast. Deep mesoscale cyclones can generate severe weather conditions and thus present a critical forecasting challenge.

3. OBSERVATIONS AND ANALYSES

Observational data, including AWS data and satellite images, and analyses from ECMWF (25Km-grid) were jointly used for this study. The sequence in Fig.1 shows a comma cloud (L1) approaching Terra Nova Bay from offshore, while another cyclogenesis (L2) occurrs on the northern Ross Ice Shelf, slightly moving northward. At 1800UTC, a band of convective clouds is evident (Fig.1c) within the well developed vortex (L1), indicating enhanced convection. According to the 500 hpa geopotential height, showed in Figs. 2a-b-c, advection of cyclonic vorticity in the middle troposphere due to an upper level trough transiting on the area occurs in conjunction with the development of the two

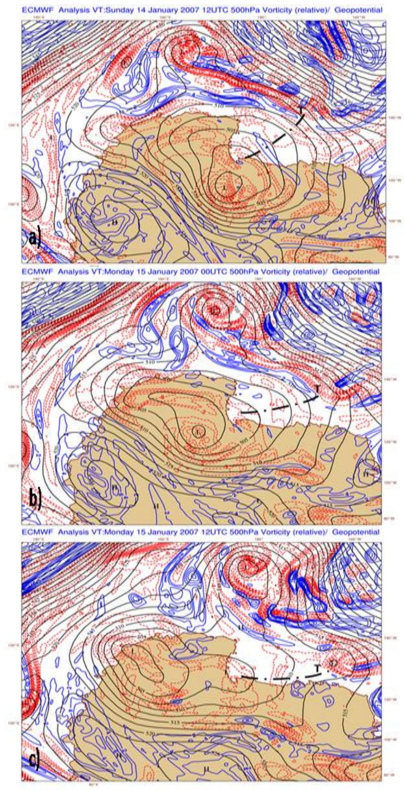

Fig. 2. Upper synoptic analyses. 500-hpa geopotential heights (solid black contours in dam) and relative vorticity (contour interval is 3x10-6s-1, with negative values dashed) from ECMWF at 1200 UTC, January 14 (a), 0000 UTC (b) and 1200 UTC (c), January 15, 2007. 'T' states for upper level trough.

systems. The strengthening of the circulation around the maritime cyclone (L2), in terms of an increasing pressure gradient, is confirmed by the surface pressure and wind (Fig.3). Maximum wind speeds are recorded by 1200 UTC, January 14. At 1200UTC, also a weak small-scale disturbance formed on the lee Ross Island, by the cyclonic branch of the increasing katabatic flow. Strong shear and stretching vorticity constitute the initial dynamic forcing generating the shallow disturbance. Weak surface potential temperature (not shown) and 925/850 hpa geopotential heights (Fig.4) reveal the barotropic signature of the small vortex. A fast moving baroclinic wave, steered by the anticyclonic branch of the low level jet, to the east of Ross Island, appeared soon on the eastern border of the small disturbance, on the area between the two opposite circulations, characterized by strong shear and thermal contrast in the lowest levels. The boundary layer cold front forced the shallow vortex to move northwestward, with a transport of cyclonic vorticity against the pre-existent system (L1), as documented in the sequence of Fig.4 and Fig.3. The highly stable layer, negatively buoyant, inhibits vertical motions with resulting wind approximately parallel to the surface. Above the sea, the stability is almost neutral and the flow is less resistant to vertical displacement, facilitating convection ahead of the cold stable layer, with an increasing of stretching vorticity due to the low level convergence. At 1800 UTC, January 14, a maximum of negative PVA is revealed ahead of the anticyclonic cold airstream approaching longitude 167E (Fig.5) and merging, 6 hours later, with the mesocyclone (L1), with a result of enhancing convection within the system. The propagation of the cold airstream for such a long distance was supported by the near sub-synoptic circulation (L2), along with the katabatic flow became geostrophic for some distances.

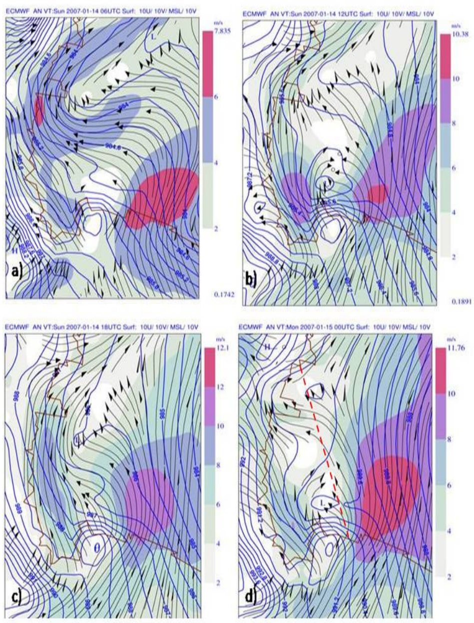

Fig. 3. Analyses of sea level pressure (blue contouring) and surface winds are shown, at 0600 UTC (a), 1200 UTC (b), 1800 UTC (c), 14 Jan 2007 and 0000 UTC 15 Jan 2007 (d). Streamlines show trajectories and shaded colours show scalar average wind speed (m s-1).

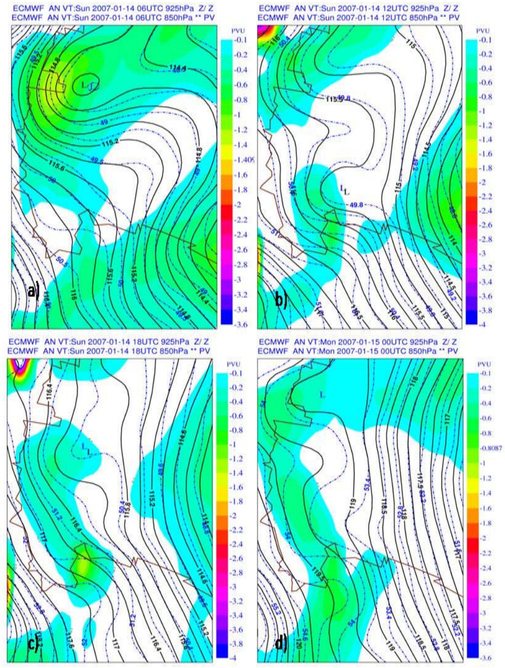

Fig. 4. 925-hpa geopotential heights (blue dashed-dot lines, dam), 850-hpa geopotential heights (solid black lines, dam) and potential vorticity at 850 hpa (PVU units, shaded colours), starting at 0600 UTC, 14 Jan 2007 (a), and terminating at 0000 UTC 15 Jan 2007 (d), evaluated every 6-hrs.

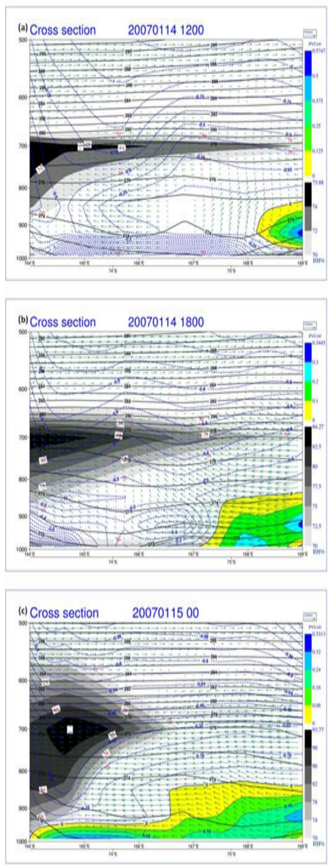

Fig. 5. Cross sections of vertical analyses, along with the red dashed line indicated in fig.3d on the left. Potential temperature (black solid lines, interval=1K), wind arrows (unit=5 m s-1, dark green) potential vorticity (PVU units, shaded yellow/blue colours), relative humidity (grey-scale, min 70%), at 1200 UTC (a), 1800 UTC (b), 14 Jan 2007, at 0000 UTC (c), 15 Jan 2007.

1. SUMMARY

This study suggest that deep features may be linked to strong outbreaks of cold air over the open sea, with convective instability occurring. Lower troposphere baroclinicity plays a key role for the development of mesoscale systems. Diabatic effects are negligible compared to baroclinic instability but may contribute to reduce static stability near the surface, facilitating convection. Synoptic scale support can sustain strong katabatic winds for hundreds kilometers far away from the coastal area, eventually redeveloping decaying cyclonic systems. The effects of katabatic winds and low level baroclinicity on cyclone evolution are therefore a crucial factor to focus.

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