The Impact of the Adélie Land Katabatic Wind Regime on Coastal Cyclogenesis

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The most intense katabatic wind regime in Antarctica is located along the coast of Adélie Land, where the annual mean wind speed recorded at Cape Denison in 1912-13 by Sir Douglas Mawson’s Australasian Antarctic Expedition was 19.4 m s\(^{-1}\).
Introduction (Cont’d)

• Katabatic winds found to be important in off-shore cyclogenesis in other regions of Antarctica (e.g. Western Ross Sea – Carrasco and Bromwich (1994))

• Other studies have shown the off-shore region near 150°E features intense cyclogenesis
  – Carleton (1979): winter genesis/dissipation frequency high near coast (5 yr period of NOAA IR in 1970s)
  – Hoskins and Hodges (2005): Similar results to Simmonds et al. (from ERA-40, 1958-2001)
Motivation

• With high-resolution MODIS IR imagery and mesoscale model data (AMPS/Polar MM5), can we confirm the Adélie Land coast to be a region of frequent cyclogenesis?

• What are the physical mechanisms responsible for cyclogenesis, and what role do katabatic winds have?
Climatology

  - Maximum cyclogenesis region just downstream of 150°E
  - Cyclolysis maxima upstream and downstream of 150°E
  - 500 hPa geopotential height anomalies for cyclogenesis events – negative anomaly near 150°E – cyclogenesis associated with existing systems, vertical depth (Hoskins and Hodges 2005)
Cyclone Development

• Perusal of 6-hourly AMPS surface pressure plots from 2004 shows two types of cyclone development near 150°E
  – Redevelopment of dissipating systems upstream of katabatic jet (around 140°E)
  – Cyclogenesis near the coast around 155°E (cyclonic-shear side of katabatic jet)

• Composites of precursor conditions made for redevelopment and cyclogenesis events, case studies analyzed

• We’ll focus on redeveloping systems here
12 and 6 hours prior to genesis
10 events

Weak existing system

Strong downslope winds, secondary maximum offshore

Strong baroclinicity

Downstream of weak upper level trough (not always present?)
Redevelopment

- Development occurs where front edge of existing circulation to west and off-shore winds interact to increase low-level vorticity
- Development is confined to surface – little signature of cyclone even at 850 hPa
- Baroclinic zone enhanced by cold katabatic winds, appears to play role in cyclone intensification

Sea-level pressure (contours)
Surface potential temperature (shaded)
Surface wind vectors (arrows)
Redevelopment

- Upward vertical motion and subsequent “spin-up” of low-level vorticity from QG-omega equation (vorticity advection, temperature advection) in mid-upper troposphere become important later in development – initial development confined to surface
- Upper-level PV distribution becomes more favorable with time as well

500-800 hPa Q-vectors (arrows)
500-800 hPa Q-vector divergence (shaded)

294-300 K Potential Vorticity (shaded)
297 K wind vectors (barbs)
Redevelopment
MODIS 3-km IR composites

15 April
1800 UTC
Discussion

• For redeveloping systems, katabatic winds appear to be a factor in cyclone development
  – Winds interact with synoptic flow to produce large values of low-level vorticity
  – Baroclinicity enhanced by cold outflow

• Upper level support necessary for development and propagation
  – Other cases with consistent upper level support develop faster and are deeper

• Signatures of cyclone development not clear in satellite imagery
  – Lack of moisture, especially in katabatic flow
  – Surface development obscured
  – Often multiple weak vortices, difficult to discern circulation
Future Work

• **More climatology**
  – Analyze model output to determine frequency of occurrence for redevelopment and coastal cyclogenesis
  – Continue satellite climatology, but needs to be more focused towards locating developing systems
    • High frequency of dissipating and developing systems, along with shallow vortices, may be causing “chaotic” cloud signatures

• **Extend dynamical analysis**
  – More analysis of composites
  – Sensitivity studies using Polar MM5 / WRF to analyze role of surface wind regime
  – Determine role of diabatic effects (especially for redevelopment cases)
The End
- Manual cyclone tracking MODIS 3-km IR composites – April-June 2004
  - Systems forming west of 140°E don’t propagate past 150°E
  - Average movement of all systems 711 km
  - Systems from mid-latitudes “spiral in” to the region and decay (Taljaard 1972, Hoskins and Hodges 2005)

Magenta boxes – systems moving into study region from north of 60°S or west of 120°E)
Cyclogenesis

- **Sfc. Pres.**: Back end of existing system
- **Sfc. Temp.**: Weak baroclinicity
- **Sfc. Wind Speed**: Strong downslope winds
- **500 hPa Geopotential Height**: Development downstream of upper-level trough
Cyclogenesis

- Low-level vorticity increases on cyclonic-shear side of katabatic jet (interaction of katabatic winds with ambient pressure gradient)
- Maxima in low-level vorticity a semi-permanent feature off-shore with katabatic outflow

Sea-level pressure (contours)  
Surface potential temperature (shaded)  
Surface wind vectors (arrows)
Cyclogenesis

- Vertical motion diagnosed by Q-vectors favorable for development and propagation throughout time period
- System has some vertical depth
- Upper-level PV and surface cyclone in phase for development

500-800 hPa Q-vectors (arrows)
500-800 hPa Q-vector divergence (shaded)

294-300 K Potential Vorticity (shaded)
297 K wind vectors (barbs)
Cyclogenesis

1 September 1800 UTC