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

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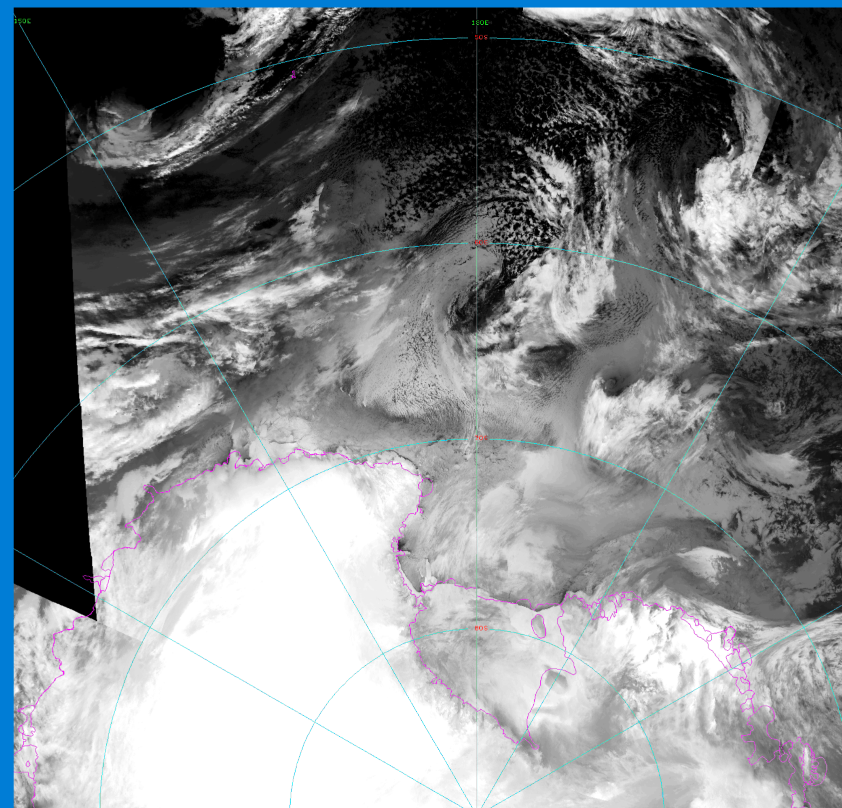

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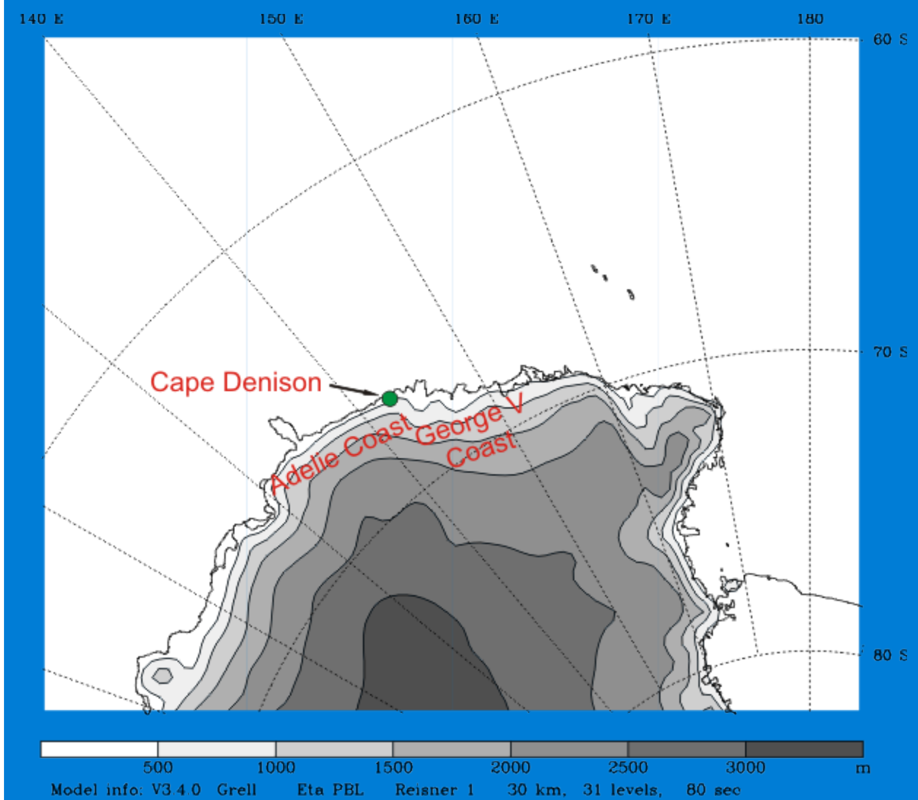
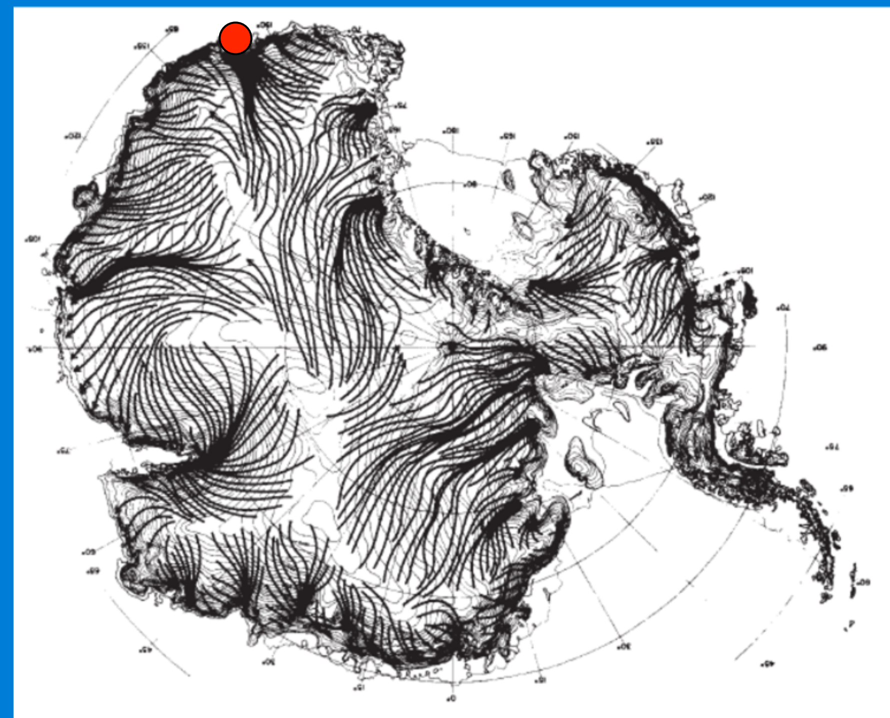
Introduction





- 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)
  – Carleton and Fitch (1993): Winter genesis region near coast at 150°E (2 yr period of DMSP IR, 1988-89)
  – Simmonds et al. (2003): Winter genesis maxima at 145°E near coast (cyclone tracking from NCEP-DOE Reanalysis II, 1979-2000)
  – Hoskins and Hodges (2005): Similar results to Simmonds et al. (from ERA-40, 1958-2001)

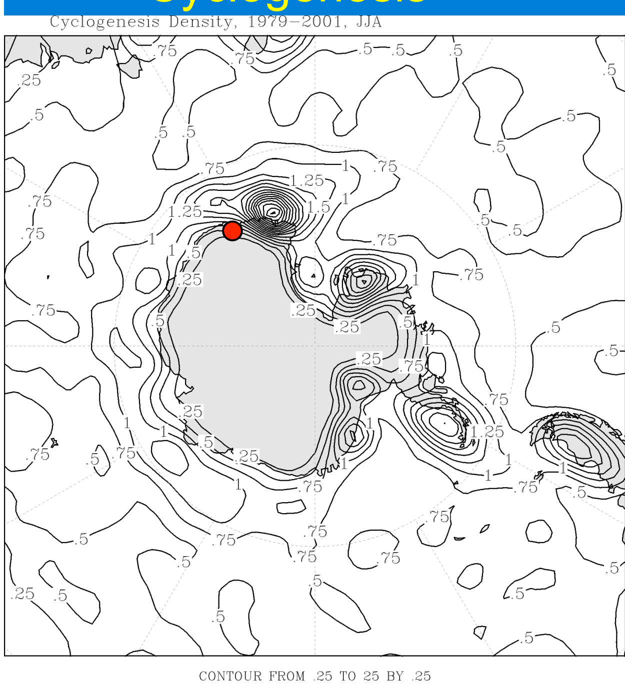
Motivation

- 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?

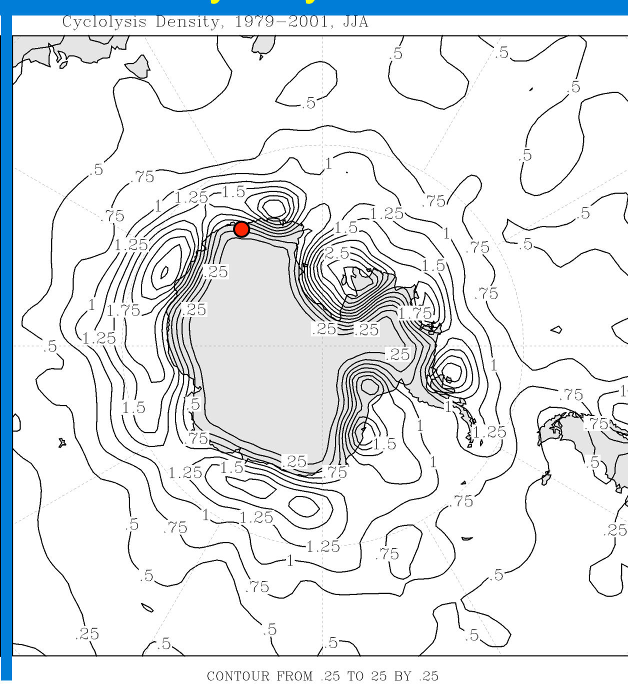
Climatology

- 1979-2001 ERA-40 Cyclogenesis / Cyclolysis Density (1979-2001) using Simmonds tracking scheme (uses MSLP)
  - 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)

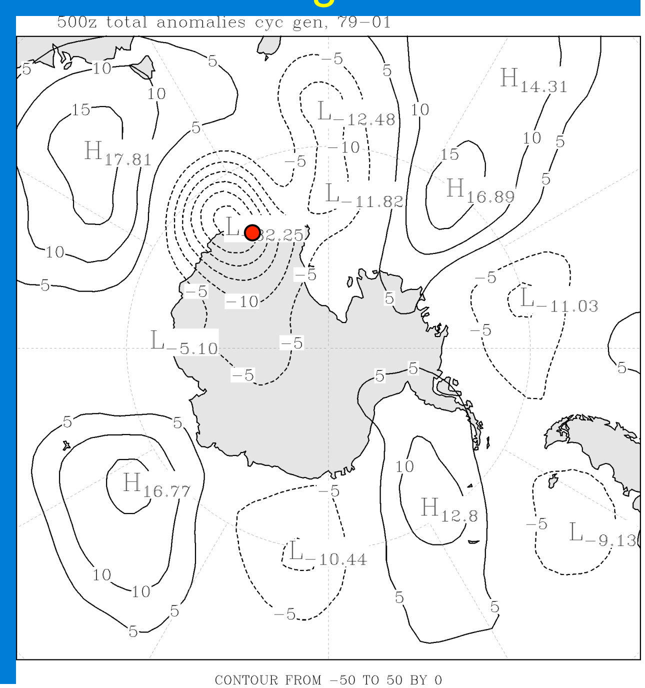
Cyclogenesis



Cyclolysis



500 hPa height anomalies



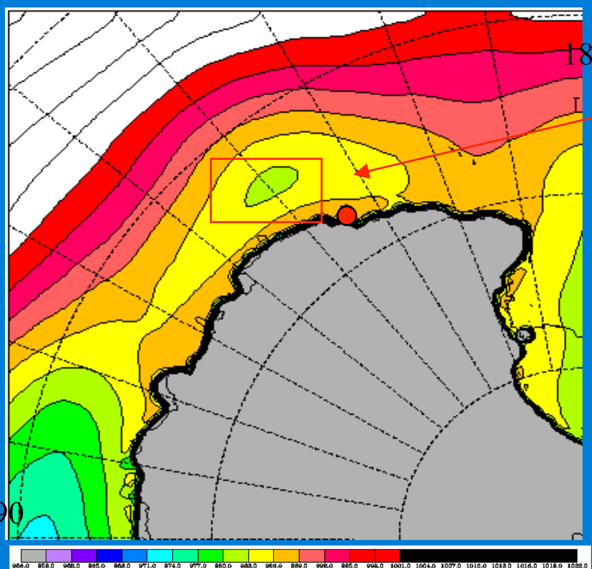
Cyclone Development

- 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

Redevelopment

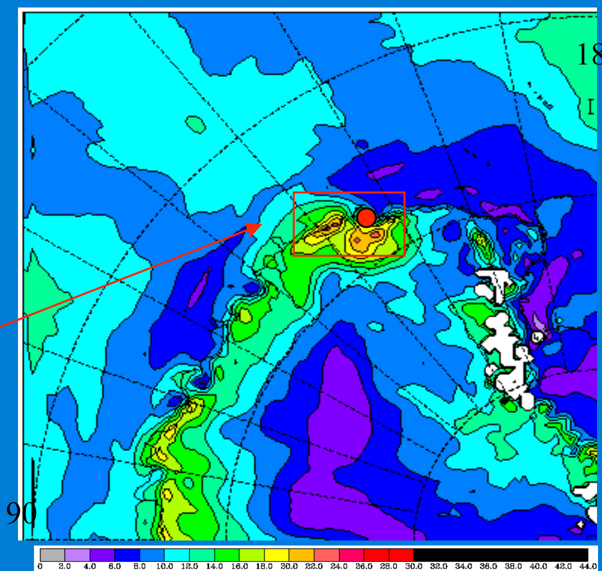
12 and 6 hours prior to genesis
10 events

Sfc. Pres.



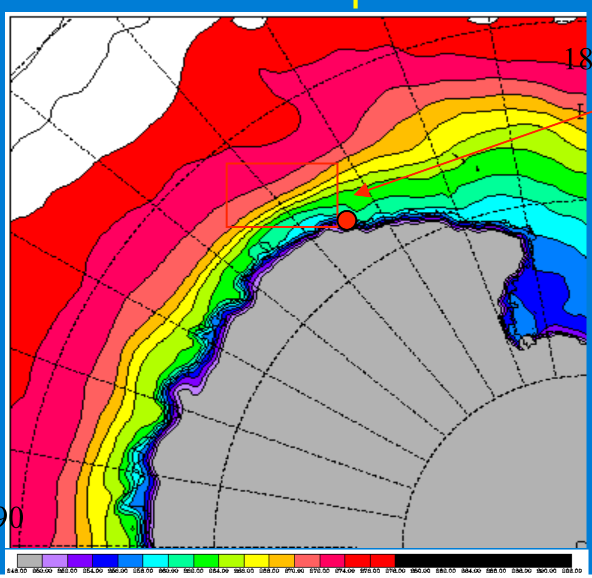
Weak existing system

Sfc. Wind Speed



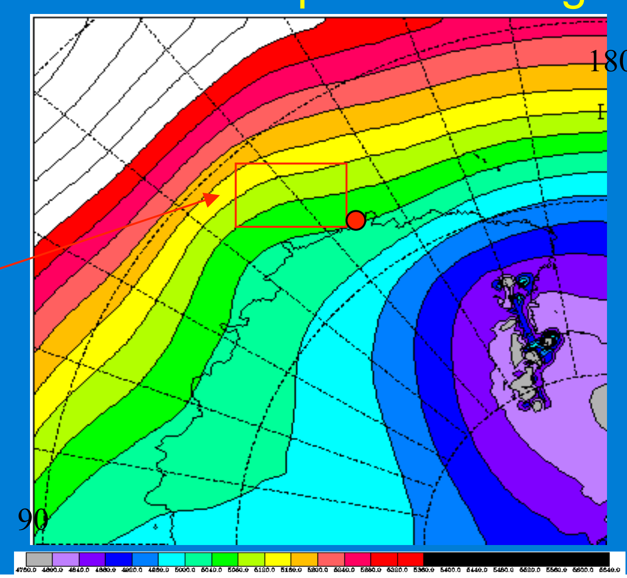
Strong downslope winds, secondary maximum offshore

Sfc. Temp.



Strong baroclinicity

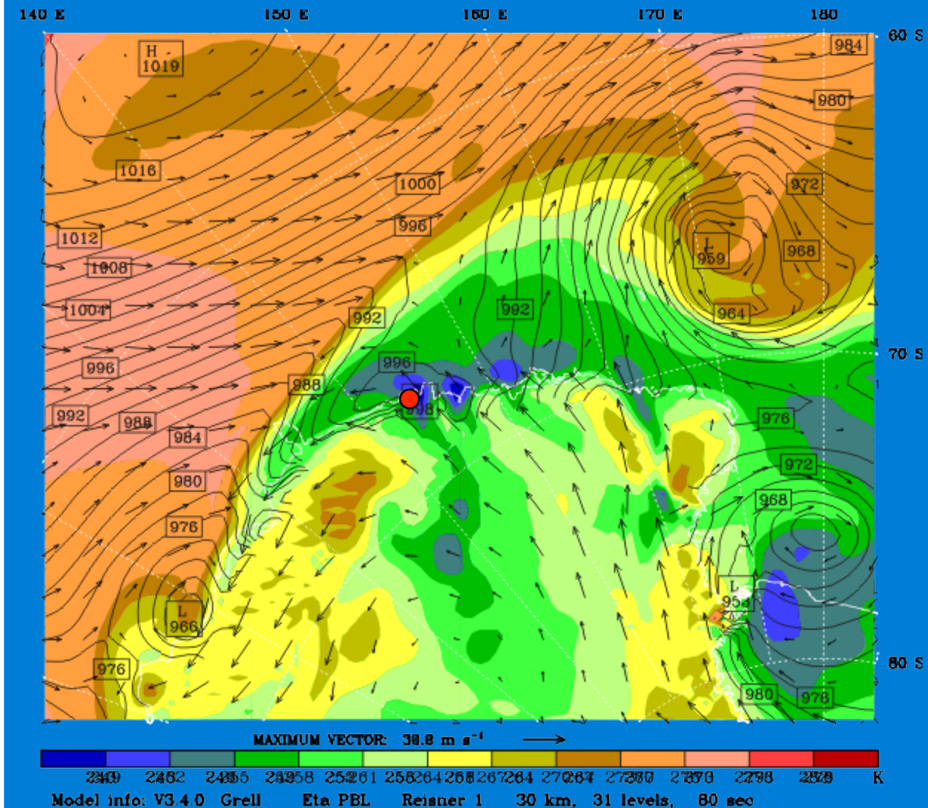
500 hPa Geopotential Height



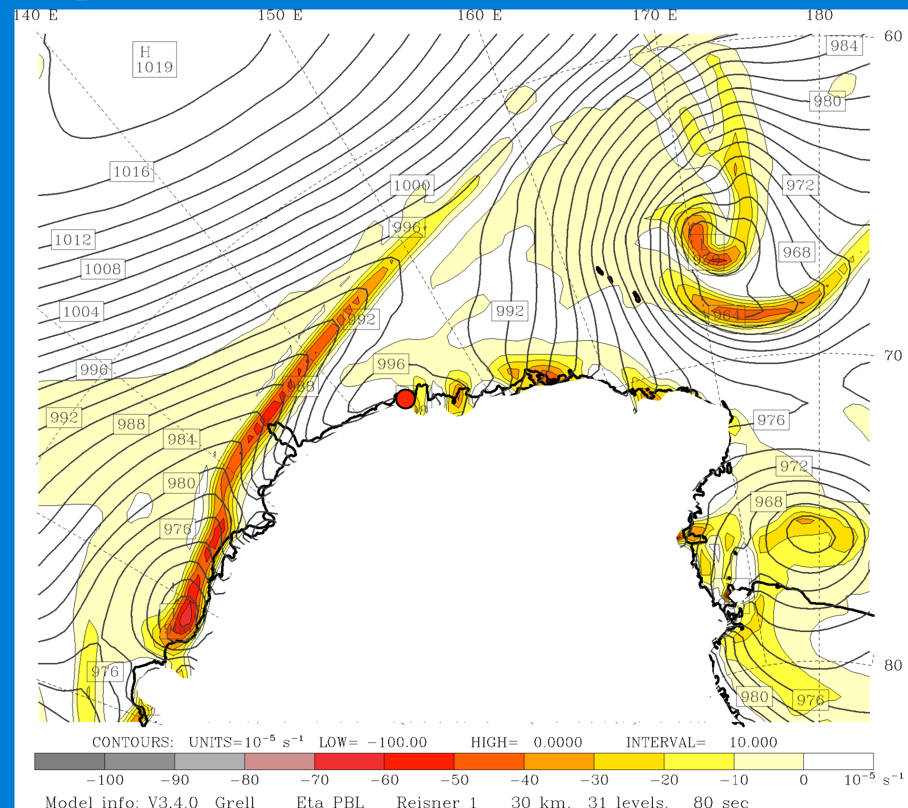
Downstream of weak upper level trough (not always present?)

15 April
1200 UTC

Redevelopment



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

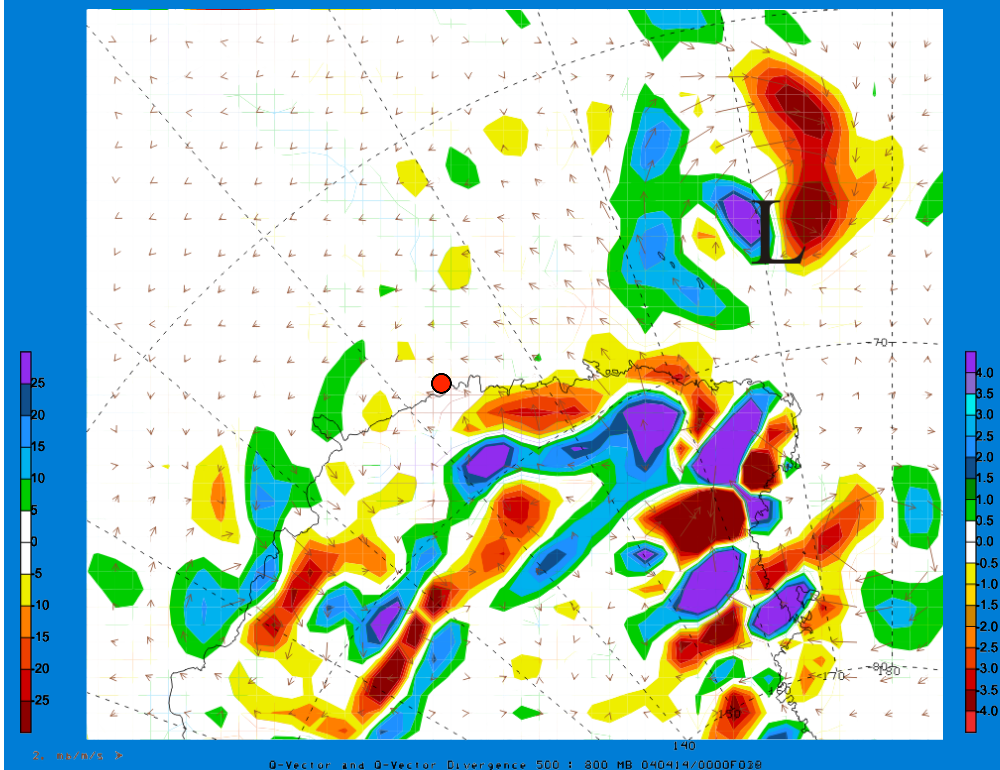


Sea-level pressure (contours)
Surface relative vorticity (shaded)

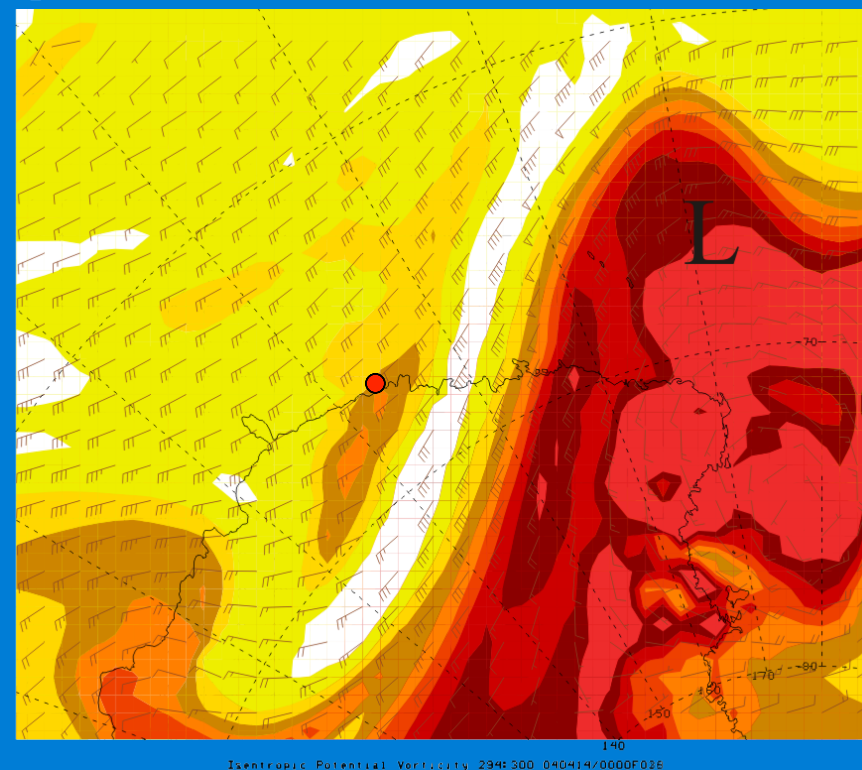
- Development occurs where front edge of existing circulation to west and off-shore winds interact to increase low-level vorticity
- Development is confined to surface – little signature of cyclone even at 850 hPa
- Baroclinic zone enhanced by cold katabatic winds, appears to play role in cyclone intensification

15 April
1200 UTC

Redevelopment



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



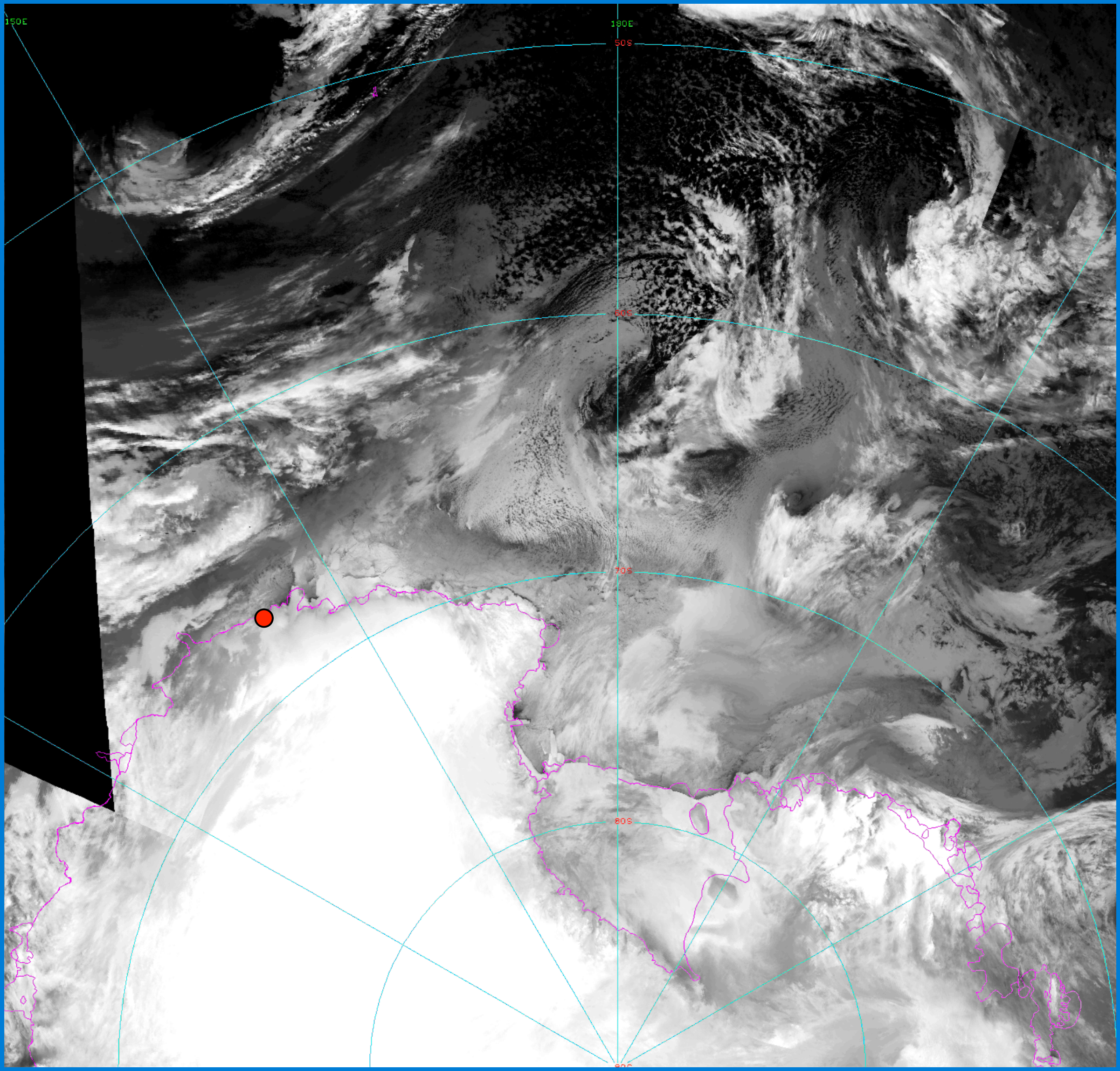
294-300 K Potential Vorticity (shaded)
297 K wind vectors (barbs)

- 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

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

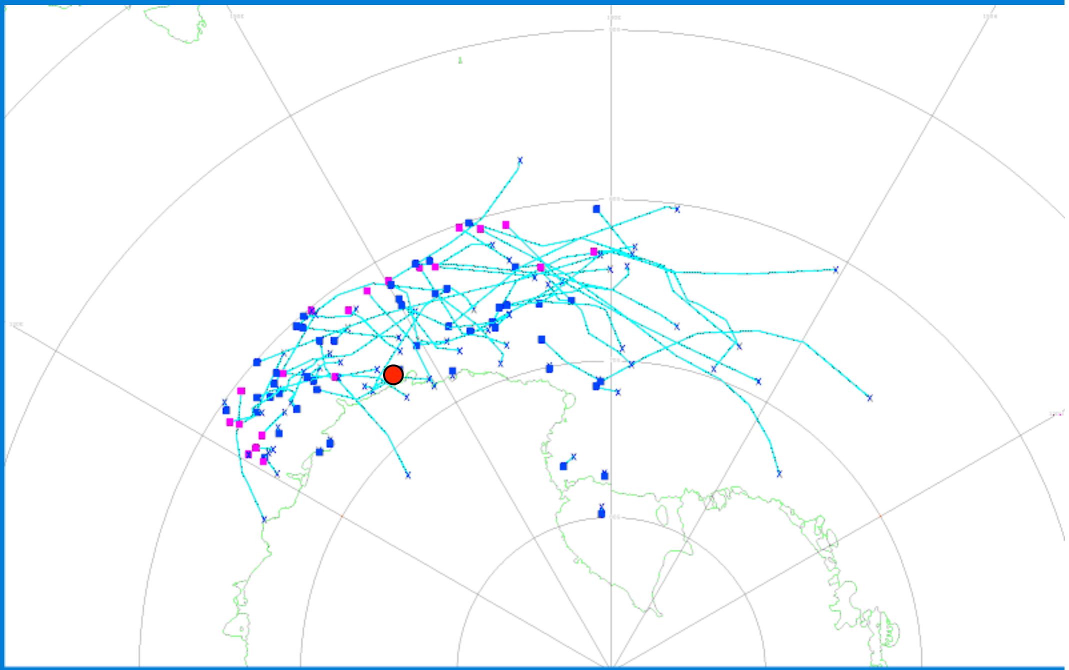
- More climatology
  - Analyze model output to determine frequency of occurrence for redevelopment and coastal cyclogenesis
  - Continue satellite climatology, but needs to be more focused towards locating developing systems
    - High frequency of dissipating and developing systems, along with shallow 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

Extra Slides

Satellite Climatology

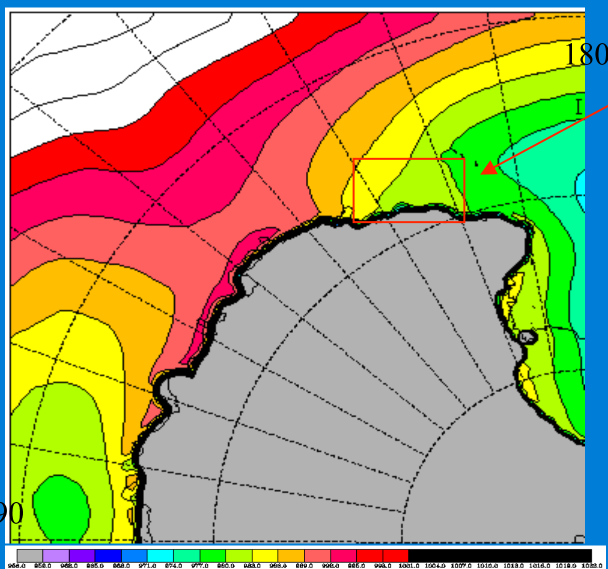
- Manual cyclone tracking MODIS 3-km IR composites – April-June 2004
  - Systems forming west of 140°E don't propagate past 150°E – average movement of all systems 711 km
  - Systems from mid-latitudes "spiral in" to the region and decay (Taljaard 1972, Hoskins and Hodges 2005)



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

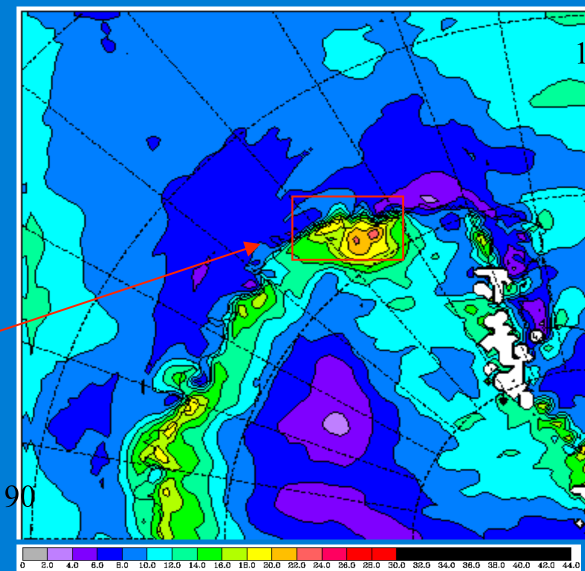
Cyclogenesis

Sfc. Pres.



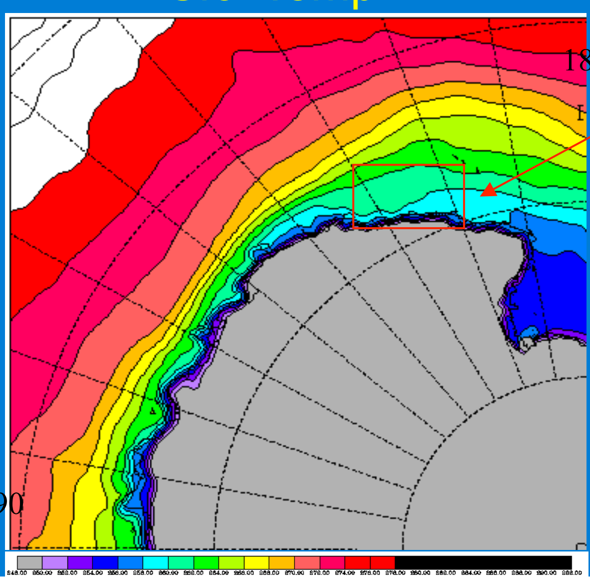
Back end of existing system

Sfc. Wind Speed



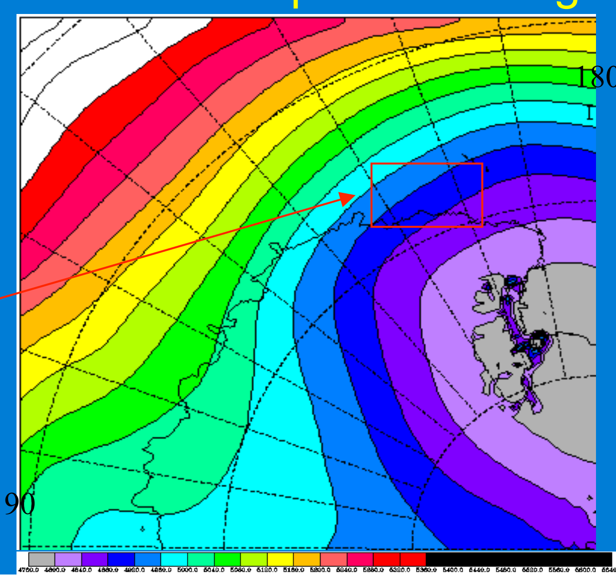
Strong downslope winds

Sfc. Temp.



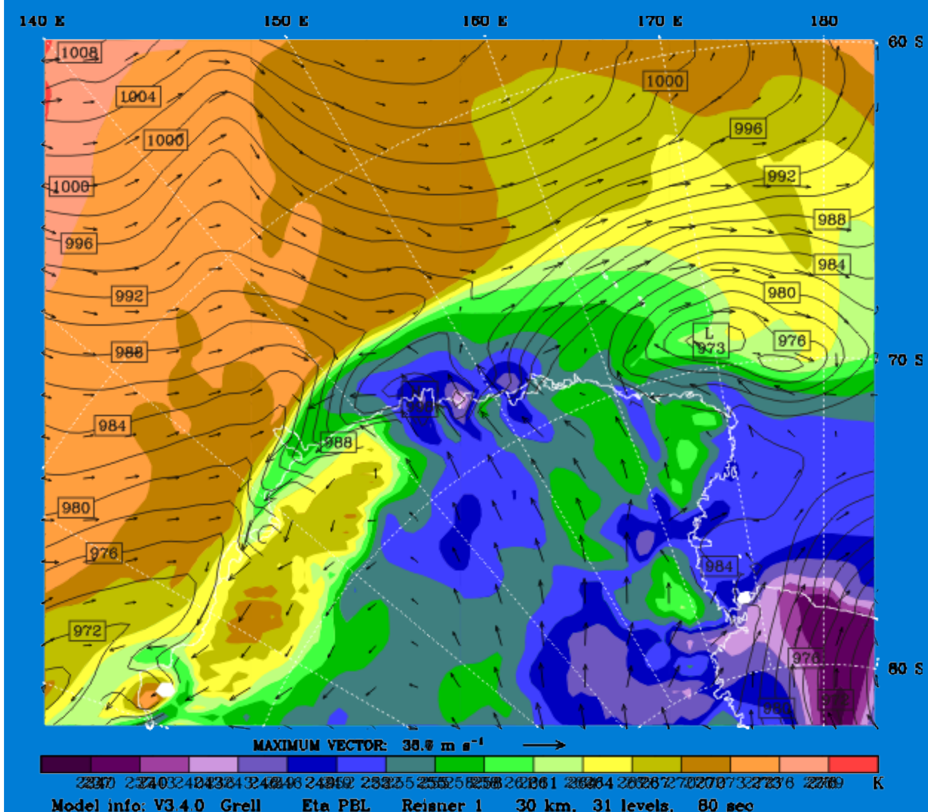
Weak baroclinicity

500 hPa Geopotential Height



Development downstream of upper-level trough

Cyclogenesis



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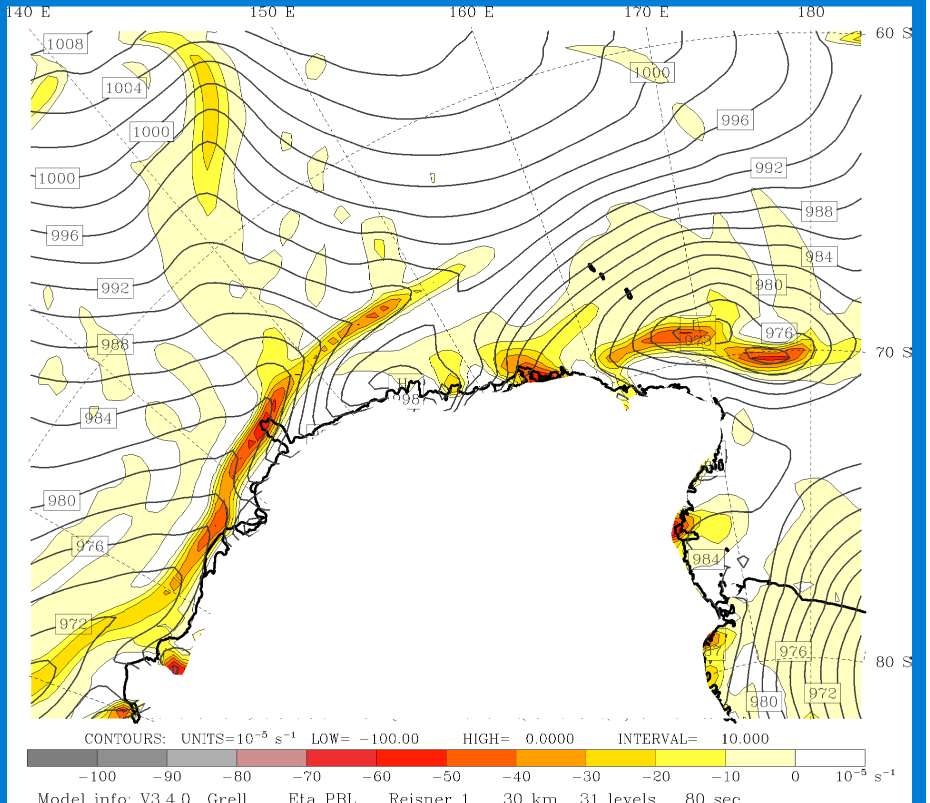
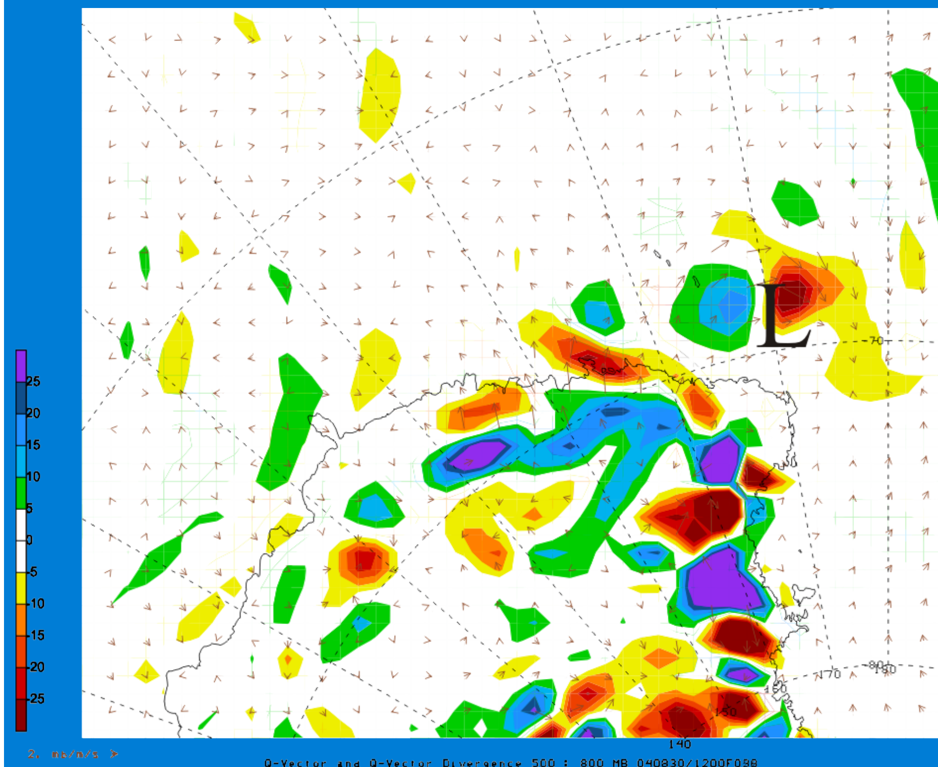


Sea-level pressure (contours)
Surface relative vorticity (shaded)

- 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

Cyclogenesis



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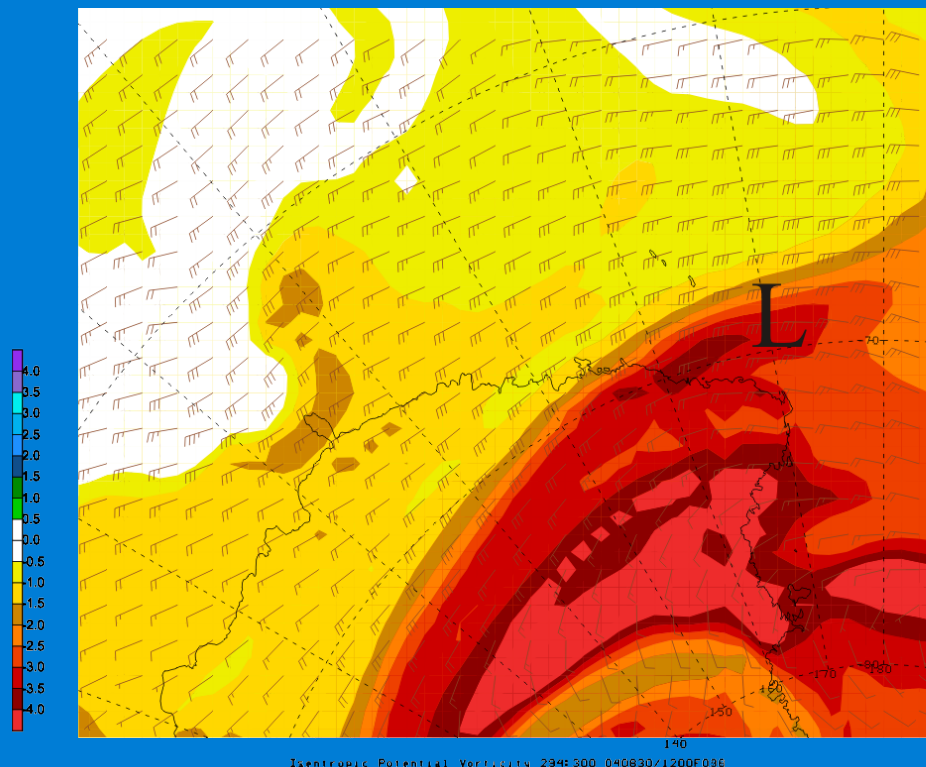
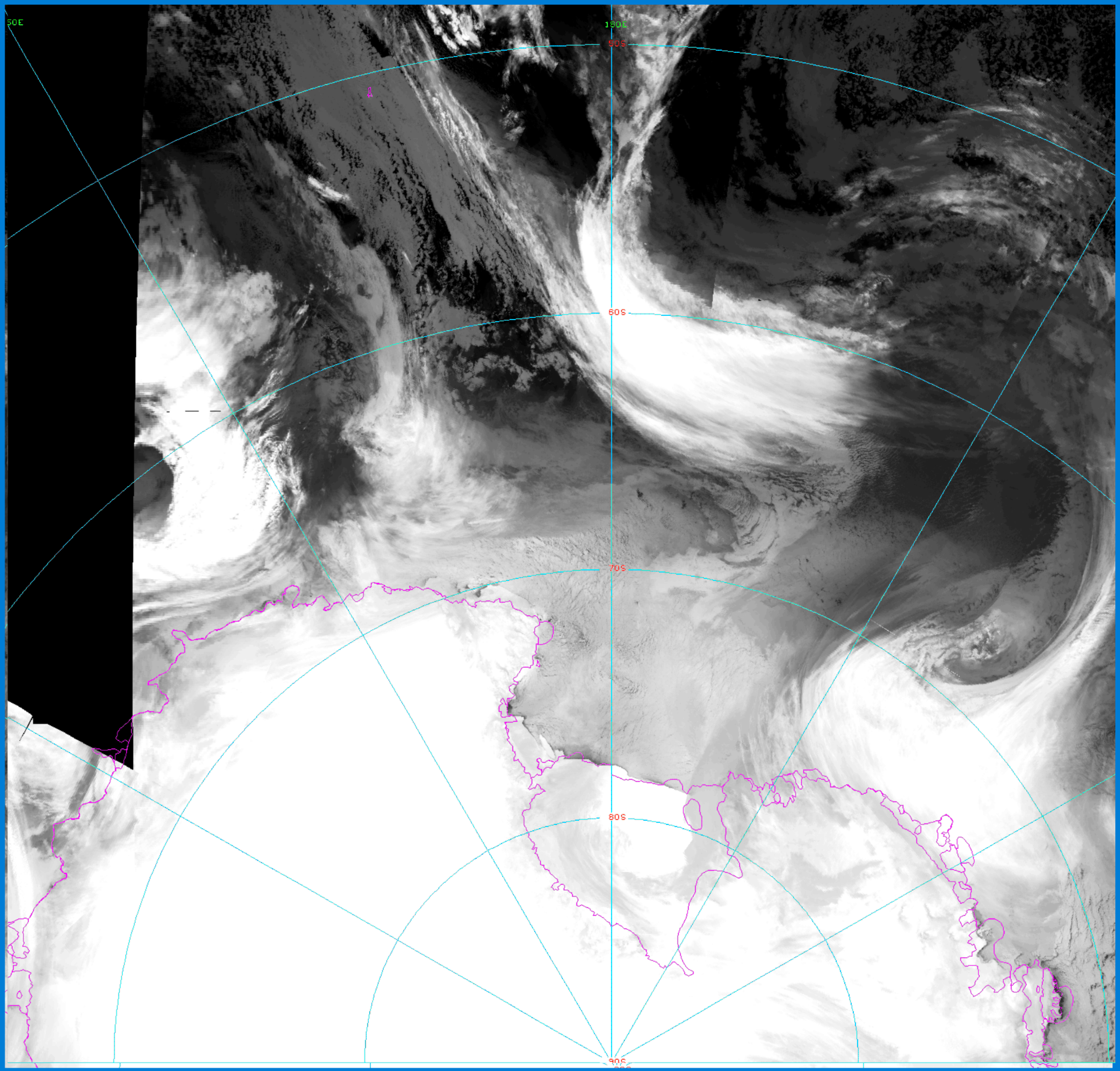


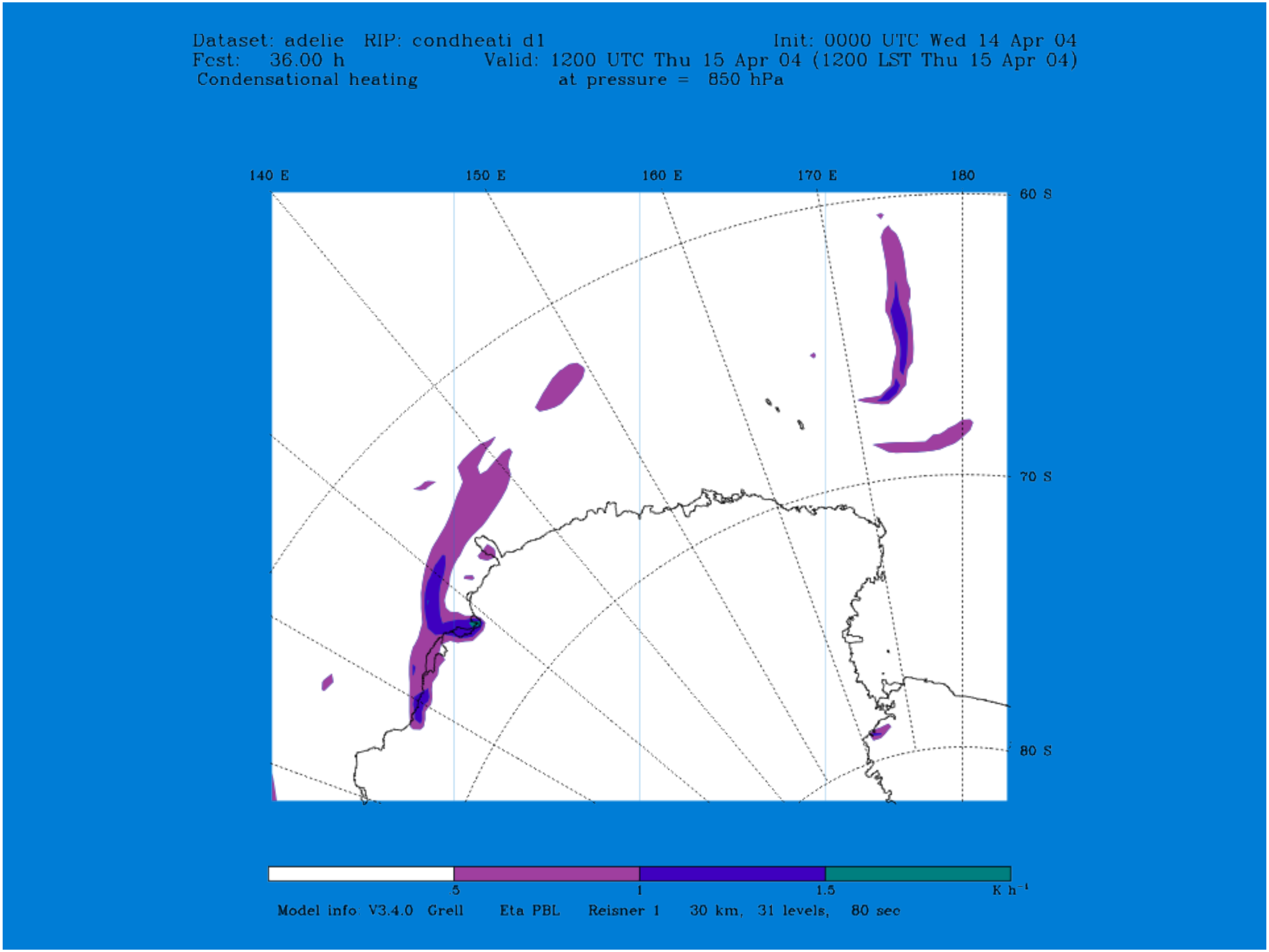
294-300 K Potential Vorticity (shaded)
297 K wind vectors (barbs)

- 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

Cyclogenesis

1 September
1800 UTC

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Fcst: 36.00 h
Valid: 1200 UTC Thu 15 Apr 04 (1200 LST Thu 15 Apr 04)
Condensational heating
at pressure = 850 hPa
140 E
150 E
160 E
170 E
180
60 S
70 S
80 S
.5
1
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K h⁻¹
Model info: V3.4.0 Grell Eta PBL Reisner 1 30 km, 31 levels, 80 sec