A Description of the Ross Ice Shelf Air Stream (RAS), Based on AWS Observations

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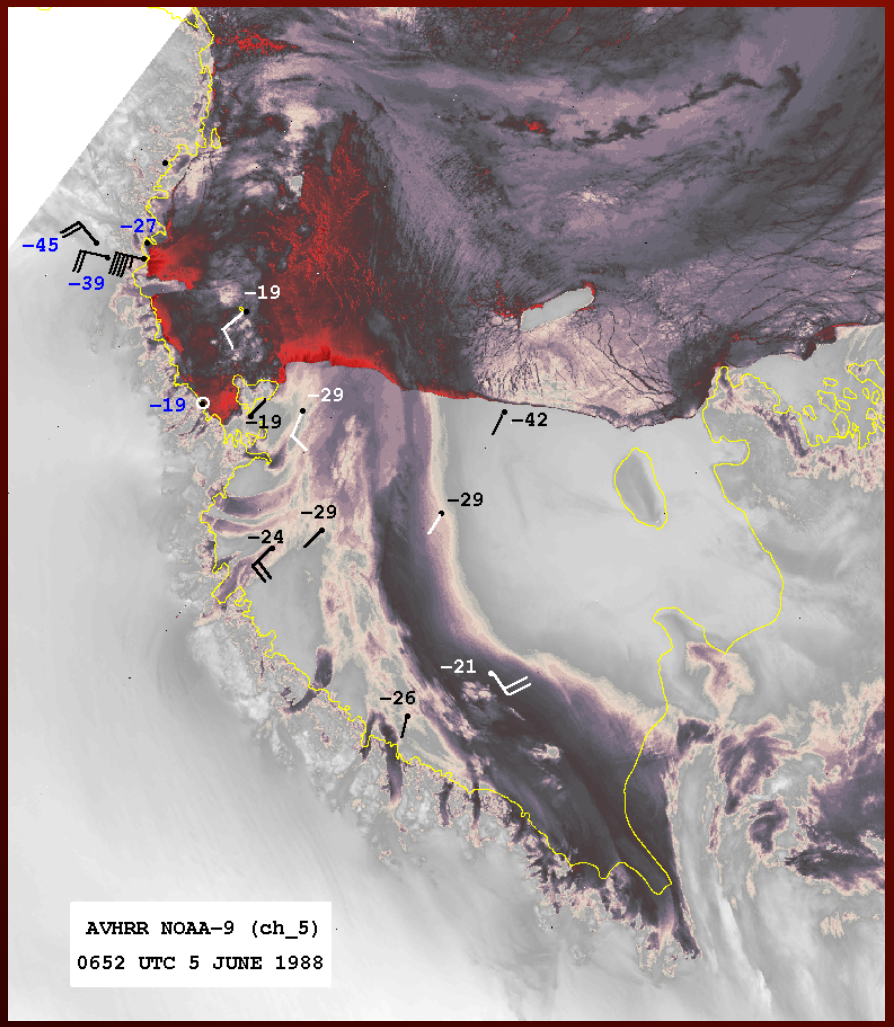
Outline

- Introduction
  - Ross Ice Shelf Air Stream (RAS) – background information
  - RAS – based on monthly/annually averaged AMPS
- Ross Ice Shelf Air Stream (RAS)
  - AWS Wind Rose Analysis – seasonal analyses
  - Dominant Wind Regimes – with case studies
- RAS Events
  - SOM Node Sequencing
  - Case Study
- Future Work

Ross Ice Shelf Air Stream (RAS)

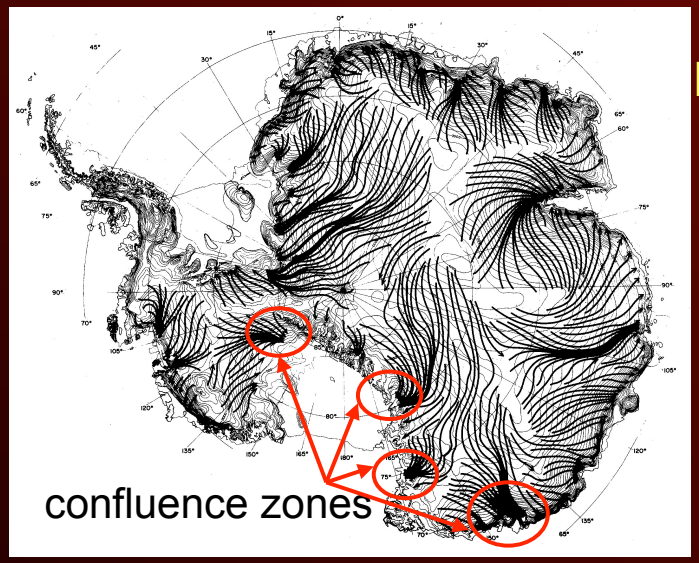
- A dominant and persistent feature in the lower boundary layer of the Ross Ice Shelf
- A northward transport of mass
- Related to:
  - katabatic flow from the Antarctic plateau
  - barrier winds along the Transantarctic Mountains
  - passage of cyclones and mesocyclones in the greater Ross Ice Shelf region



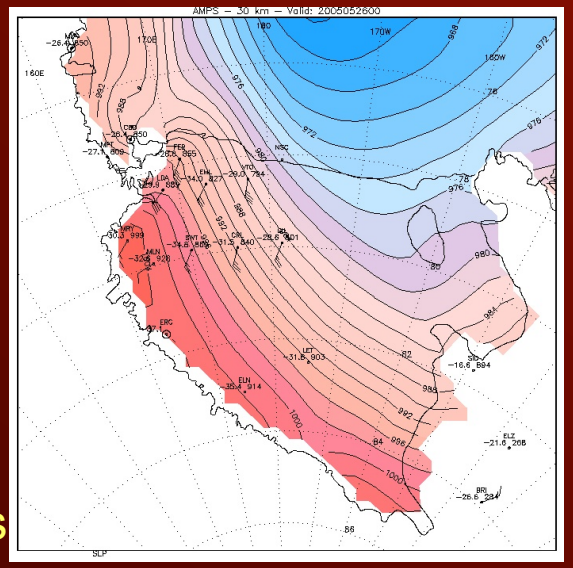
June 5, 1988

(Carrasco and Bromwich, 1993)

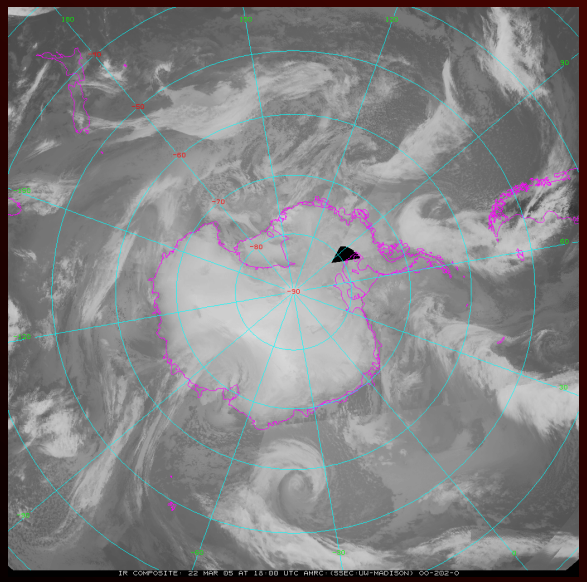
Ross Ice Shelf - Surface Wind Features



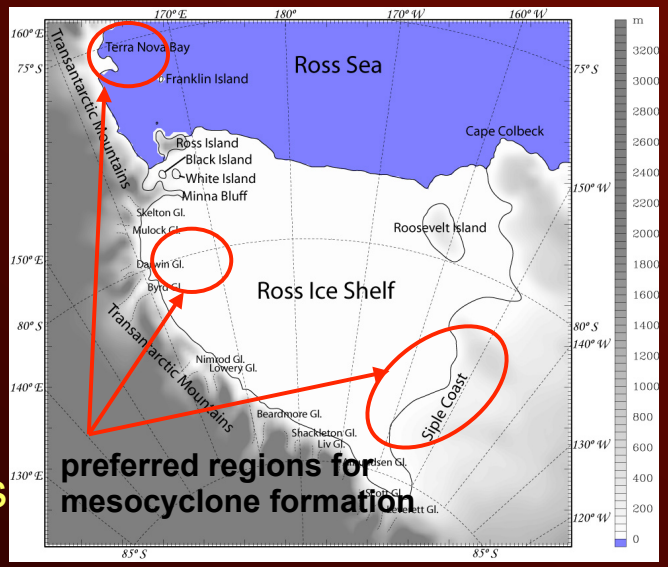
Katabatic Winds



Barrier Winds



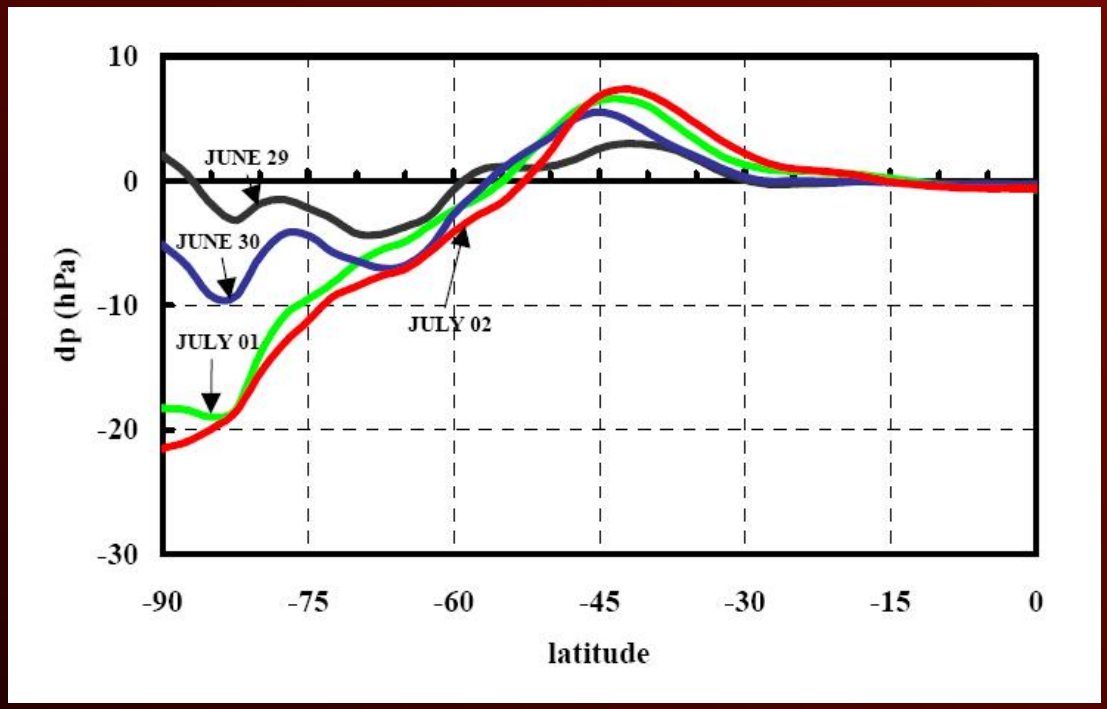
Cyclones



Mesocyclones

Ross Ice Shelf Air Stream (RAS)

- The RAS has been observed in relation to dramatic surface pressure changes in Antarctica:

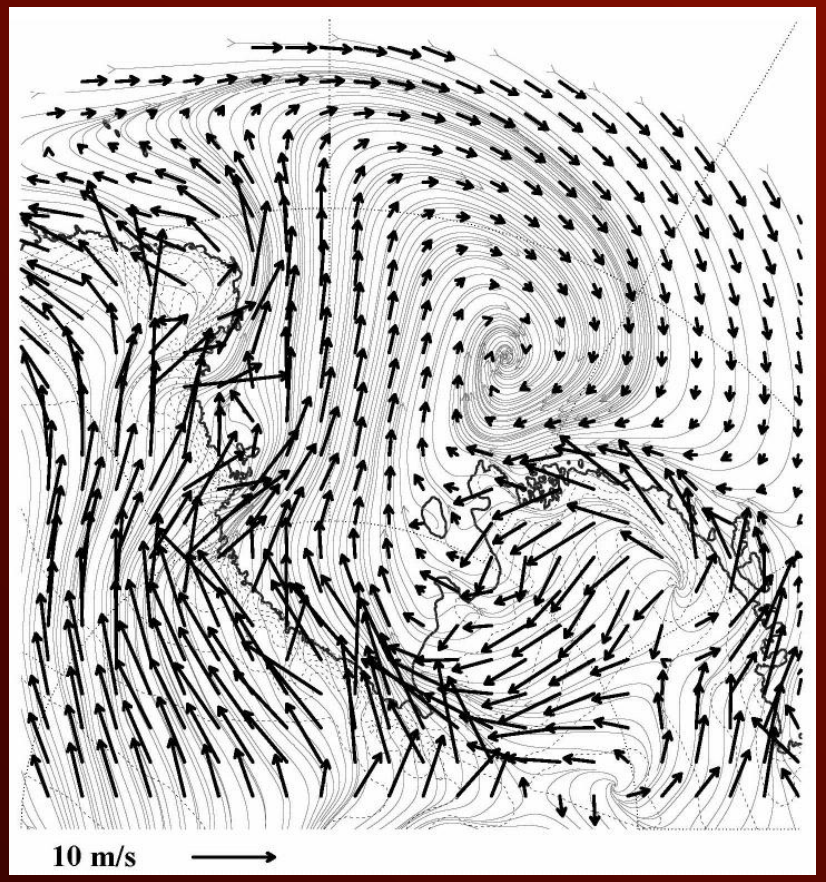


Zonally-averaged changes in surface pressure from 00 UTC 28 June 1988, based on ECMWF analyses.
(Parish and Bromwich 1998)

Ross Ice Shelf Air Stream (RAS)

Parish et al., in-press, JGR:

- The primary source for the RAS is katabatic wind flow over West Antarctica and through prominent glacier valleys in the Transantarctic Mountains
- Significant cyclonic forcing is responsible for the spatial patterns and intensity of the RAS
- The blocking of stable air against the Transantarctic Mountains develops a barrier wind which is a dominant feature of the RAS

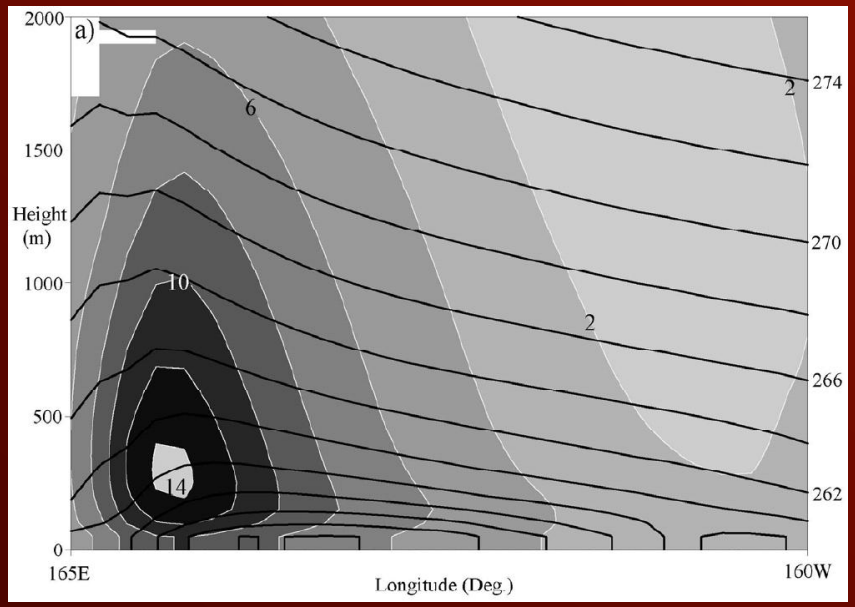


Mean wind vectors and streamlines at σ=0.9981 (~ 13 m) from the AMPS archive for period November 2001 – October 2002.

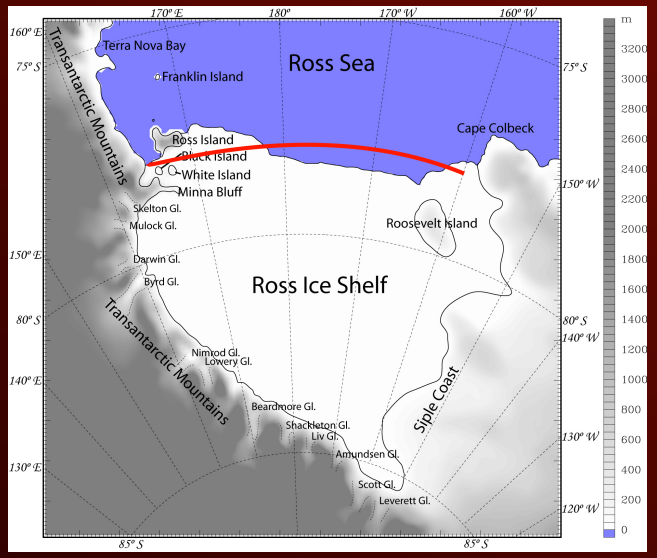
Ross Ice Shelf Air Stream (RAS)

Parish et al., in-press, JGR:

- The RAS is best defined in the lowest levels and maximum winds typically are found at the 300-600 m levels



Vertical profile of wind speed (m s^{-1}) and potential temperature (K) along 78°S from the AMPS archive for period Nov. 2001 – Oct. 2002.

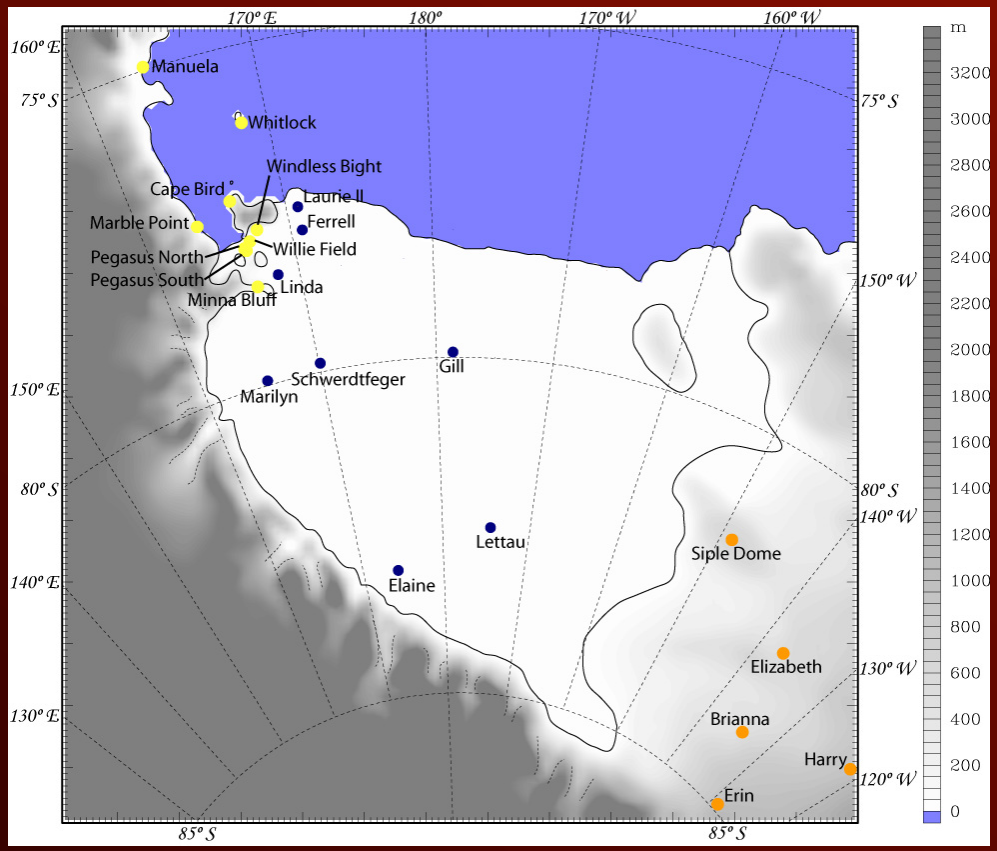


Ross Ice Shelf Air Stream (RAS)

- We do not know some of the basics:
  - What does the RAS look like in observations?
  - What is the frequency of RAS events? Is there a seasonal dependence?
  - What are the forcing mechanisms for the RAS?
- What can be done to increase our understanding of the RAS?
  - Increase surfaces observations (automatic weather stations)
  - Use modeling studies (Polar MM5)

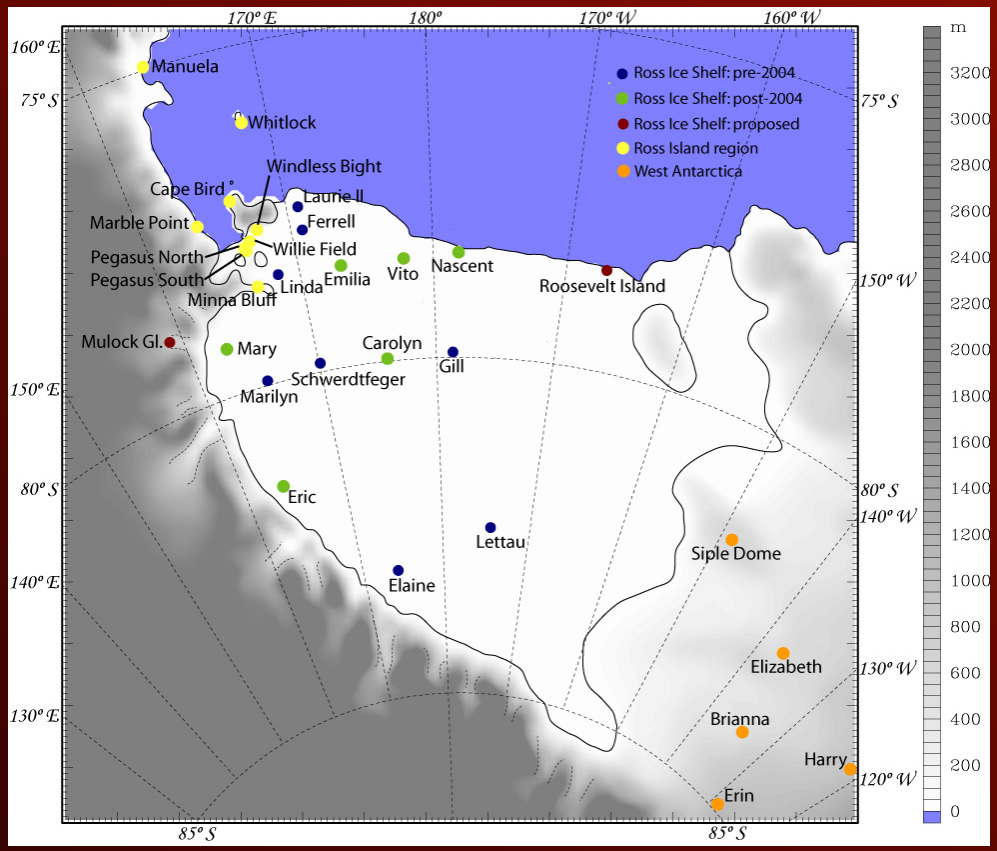
Automatic Weather Stations (AWS)

- Five automatic weather stations have been installed on the Ross Ice Shelf for about 20 years.
- The AWS in the northwest corner of the Ross Ice Shelf have limited usefulness in this study
- There are no regular atmospheric observations above the surface.



Automatic Weather Stations (AWS)

- 2003 – 04 Field Season
  - Two new AWS sites: Emilia, Vito
- 2004 – 05 Field Season
  - Four new AWS sites: Nascent, Mary, Carolyn, Eric
- Represents a doubling of the surface observations across the Ross Ice Shelf
- The AWS in the northwest corner of the Ross Ice Shelf have limited usefulness in this study



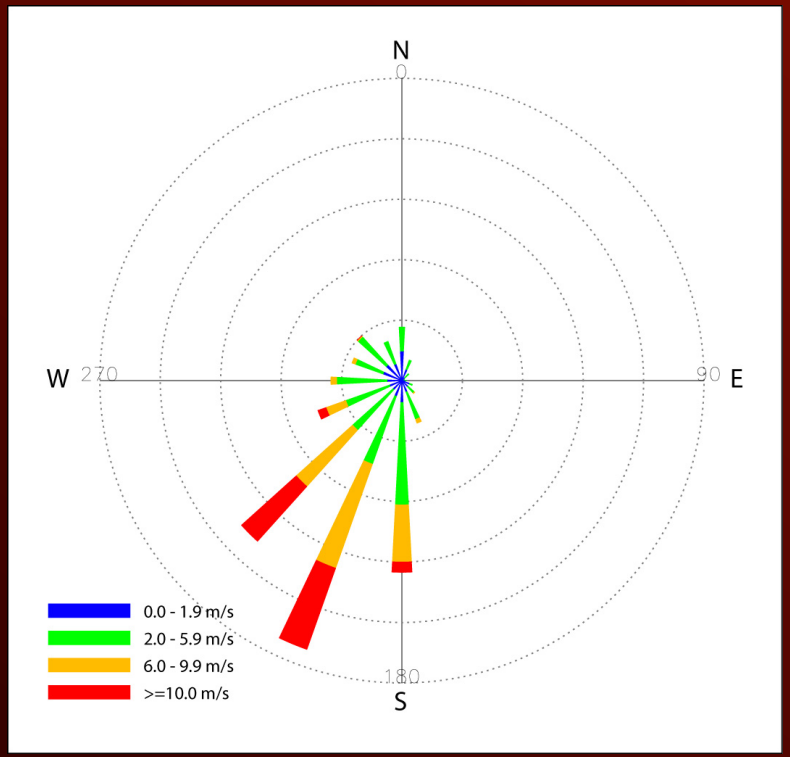
Wind Rose Analysis

- How are these surface wind features depicted in the surface observations?
  - Create a seasonal wind rose analysis for the Ross Ice Shelf

•The petal indicates the direction from which the wind is coming

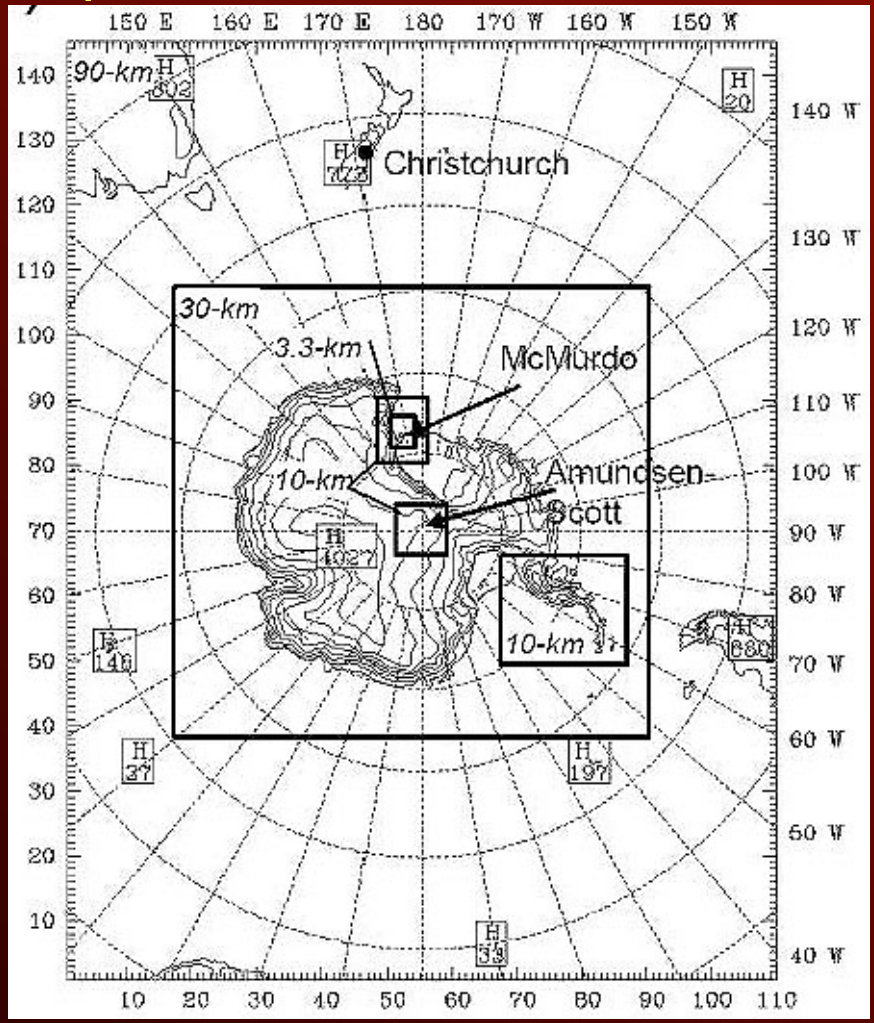
•The length of the petal indicates the frequency. Each ring represents 5%

•The color represents the wind speed



Antarctic Mesoscale Prediction System (AMPS)

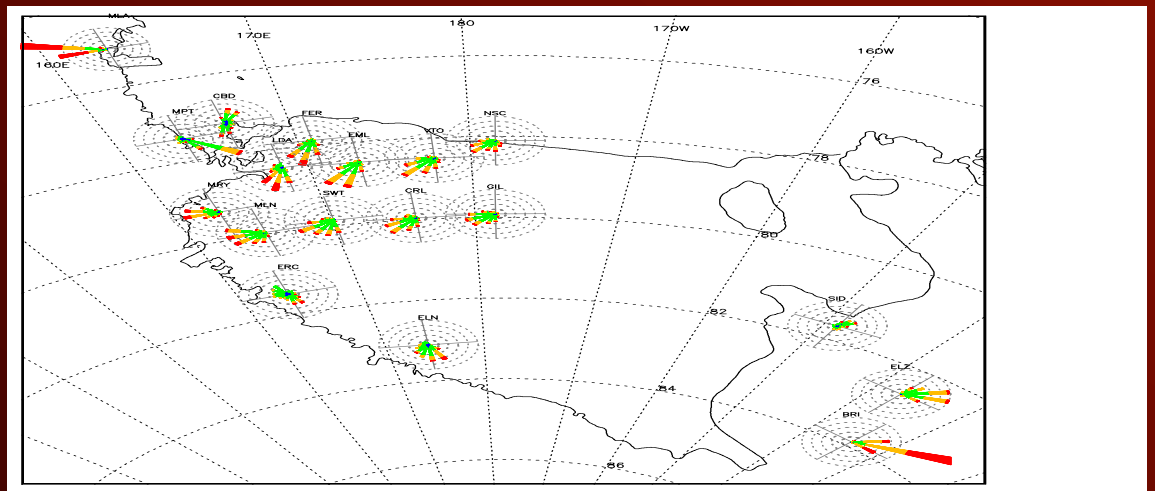
- This study uses the 30-km AMPS domain over the continent for sea-level pressure fields (SLP)
- The 12h, 15h, 18h, and 21h valid forecast hours are used to make a continuous time series

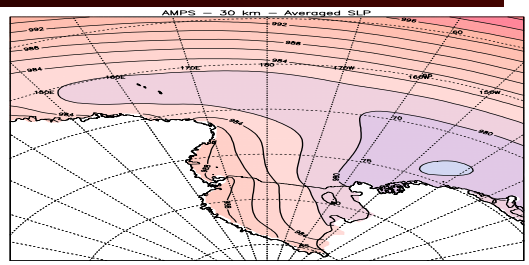


Powers et al. (2003)

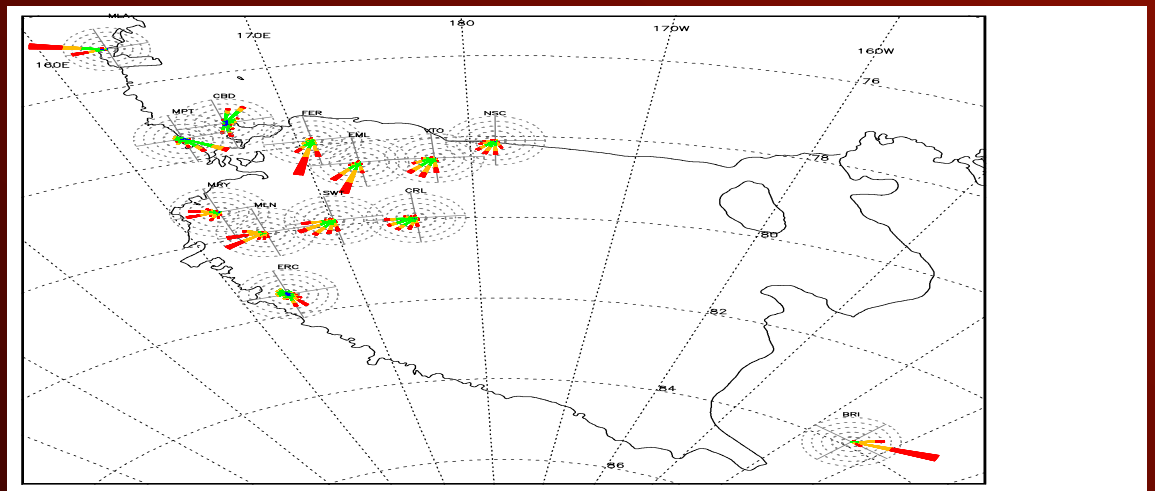
Bromwich et al. (2005)

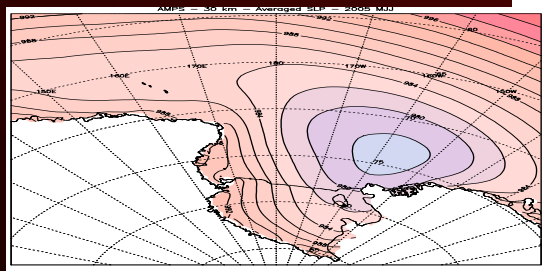
Wind Rose Analysis – Autumn 2005 (FMA)



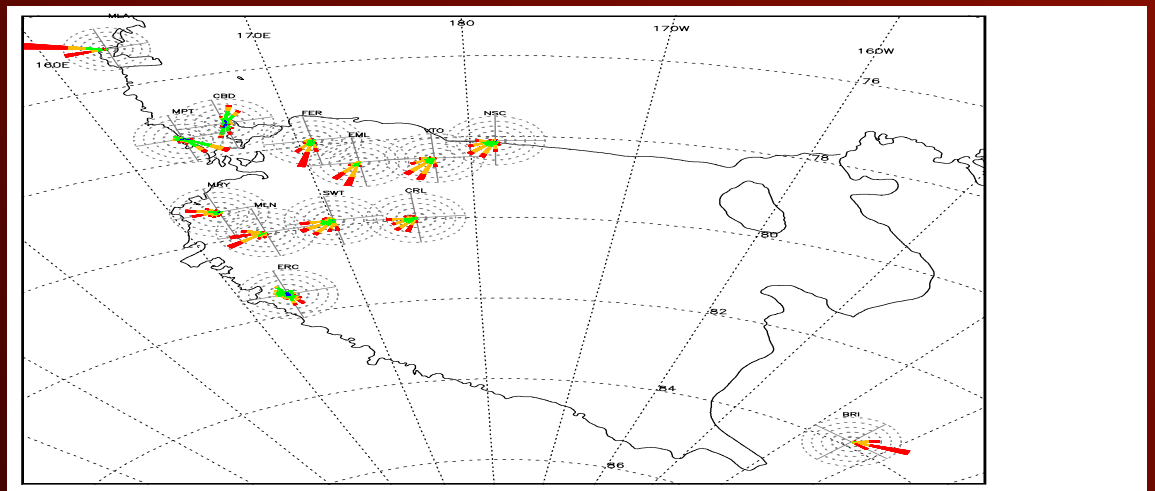


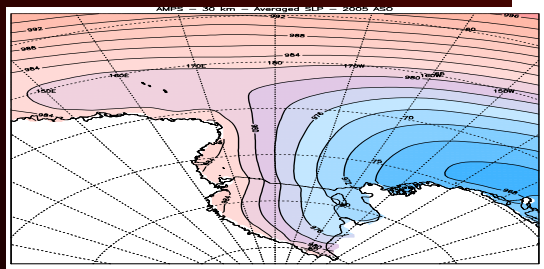
Wind Rose Analysis – Winter 2005 (MJJ)



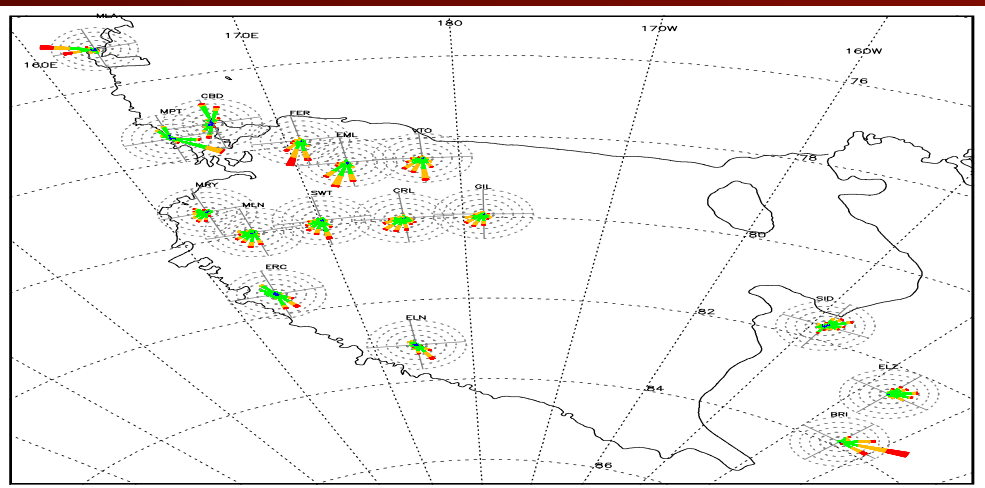


Wind Rose Analysis – Spring 2005 (ASO)





Wind Rose Analysis – Summer 2005 (NDJ)



Wind Rose Analysis – Annual - F2005-J2006

Dominant Wind Regimes

- It is difficult, in the seasonal analysis, to understand how the individual sites are related in time
- Dominant wind regimes are defined to separate the AWS observations into common patterns
  - barrier wind, strong katabatic wind, weak katabatic wind, light wind
- The observations will be selected by matching specified measurements to a set criteria
  - wind speed and wind direction

Barrier Wind Regime - Selection

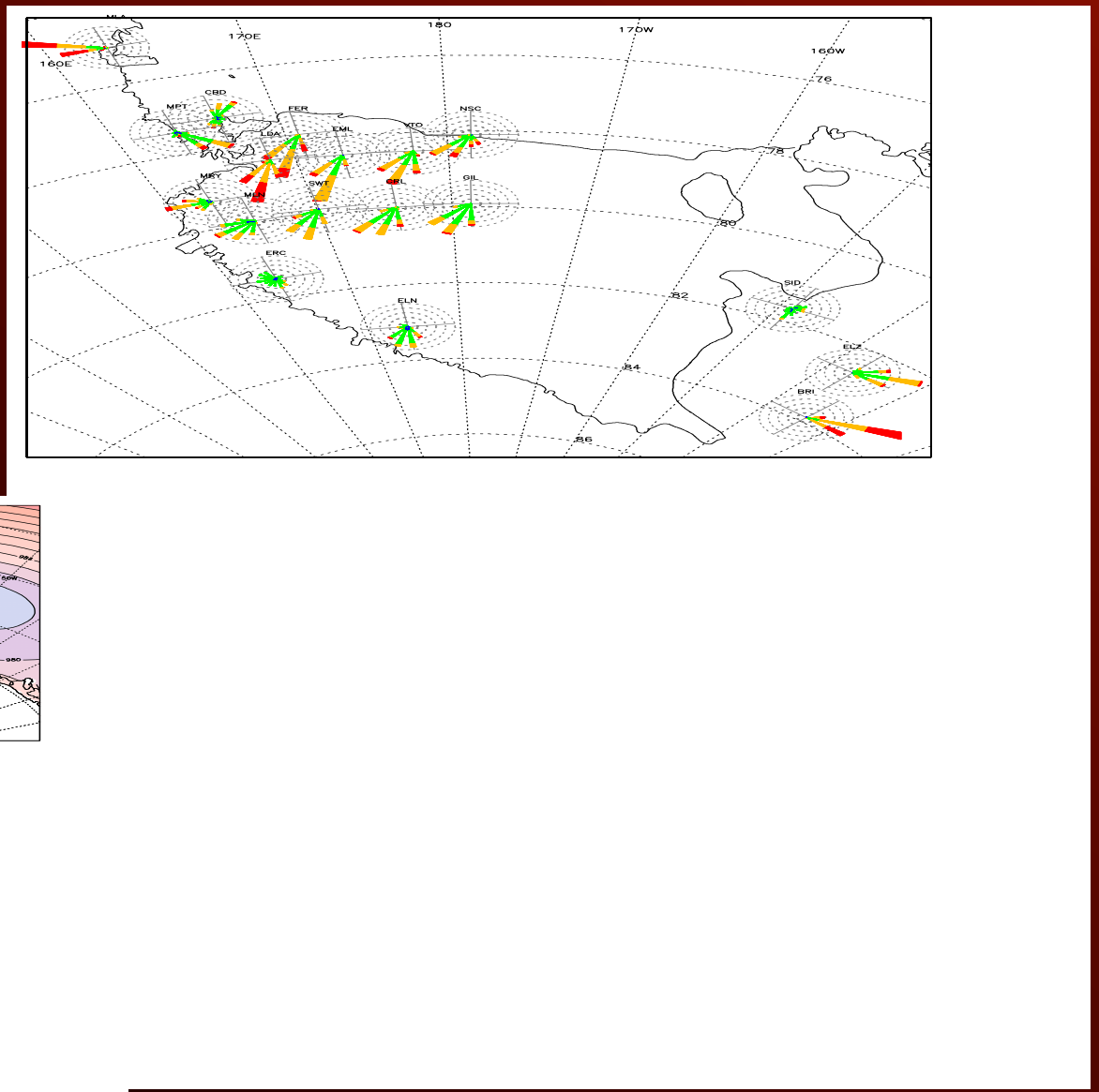
- Previous studies indicate strong southerly wind flow across the western Ross Ice Shelf
- Selection Criteria:

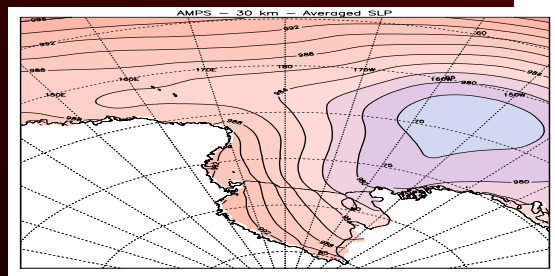
AWS Site	Wind Direction	Wind Speed
Elaine	169º - 213º	-
Emilia	169º - 236º	-
Ferrell	169º - 236º	-
Gill	169º - 236º	-
Linda	169º - 236º	>= 5.0 m s^{-1}
Vito	169º - 236º	-

- If six or more of the seven are matched, it is a valid observation
- Results: 2005 FMA - 350 hours, 16.4% of obs, 21 events

Wind Rose Analysis – Autumn 2005 (FMA)

Barrier Wind Regime





Barrier Wind Regime – Case Study

- Event matching barrier wind selection criteria:

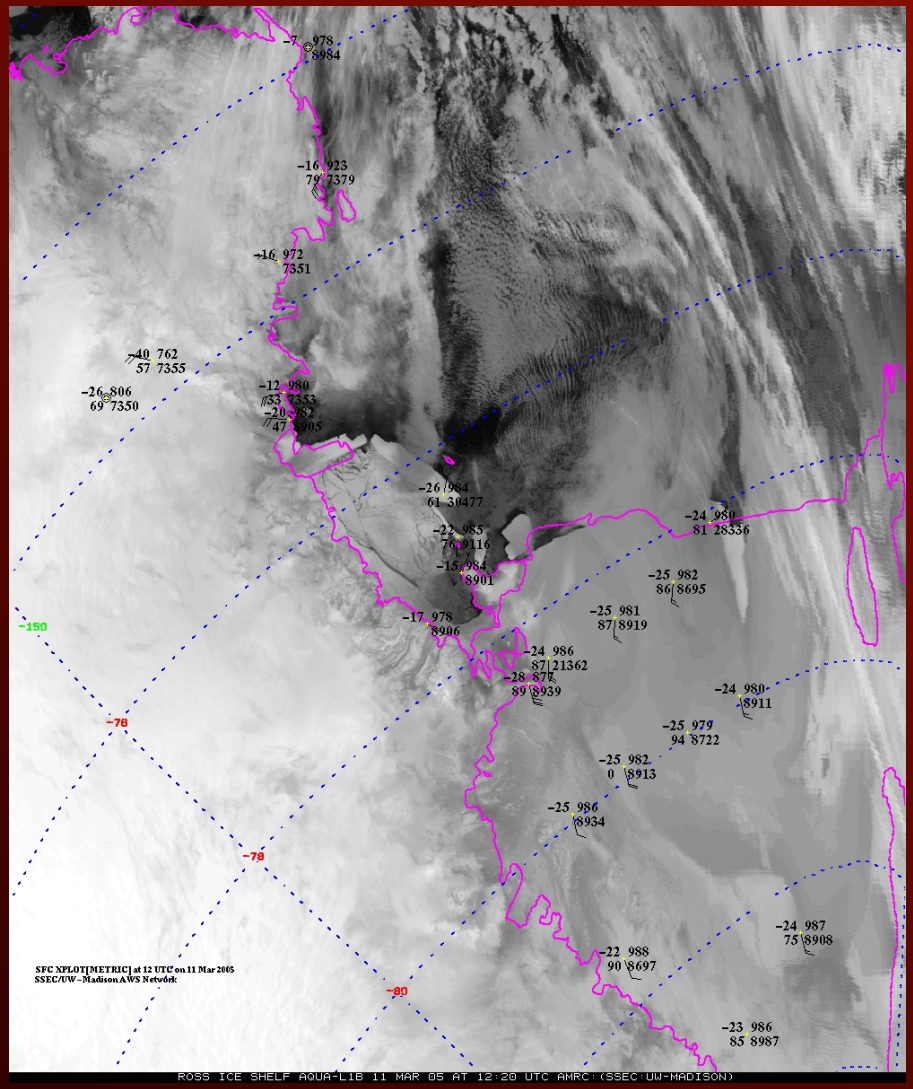
  07 UTC 11 March 2005 –

  23 UTC 11 March 2005
- Case study event:

  18 UTC 10 March 2005 –

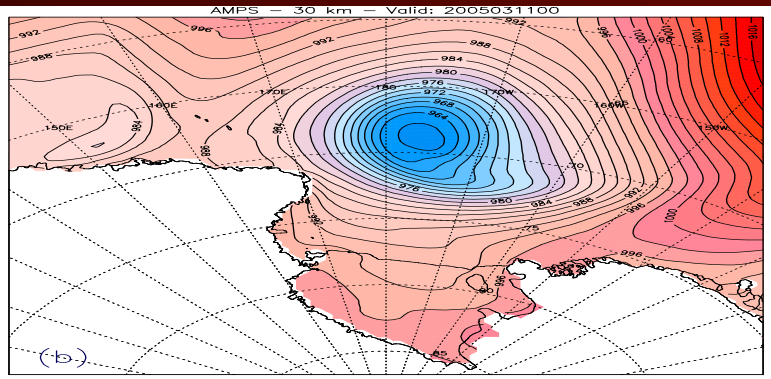
  00 UTC 12 March 2005
- Use a series of SLP analyses for the greater Ross Ice Shelf region, and the Ross Ice Shelf
- AWS station plots will be placed on the SLP analyses

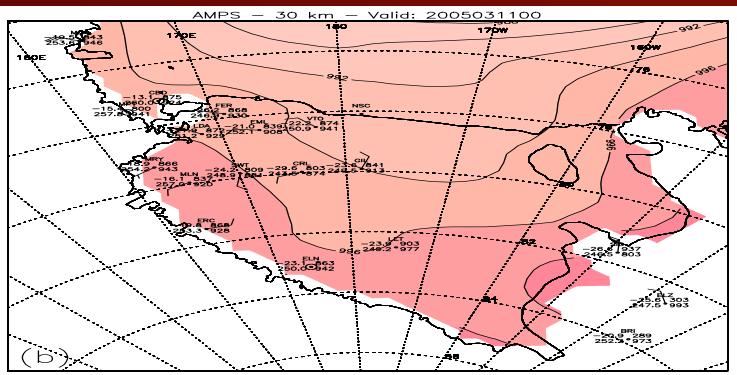
Satellite image courtesy of AMRC, University of Wisconsin



Barrier Wind Regime – Case Study

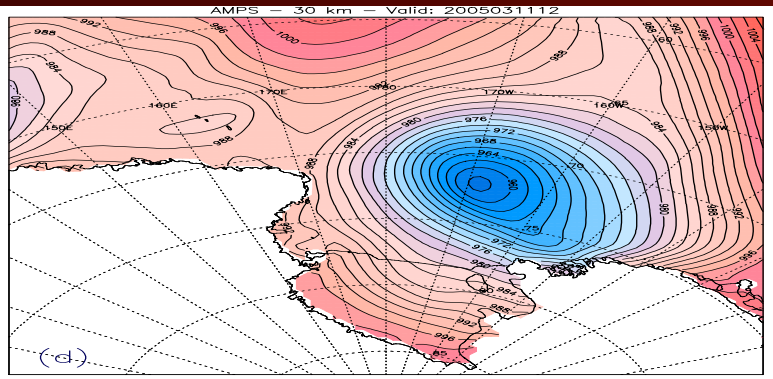
00 UTC 11 March 2005

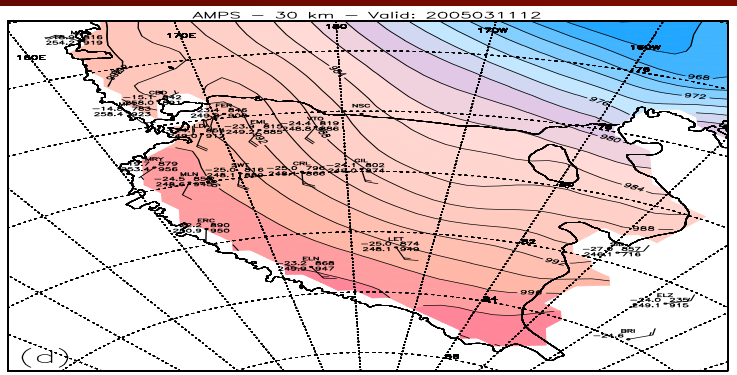




Barrier Wind Regime – Case Study

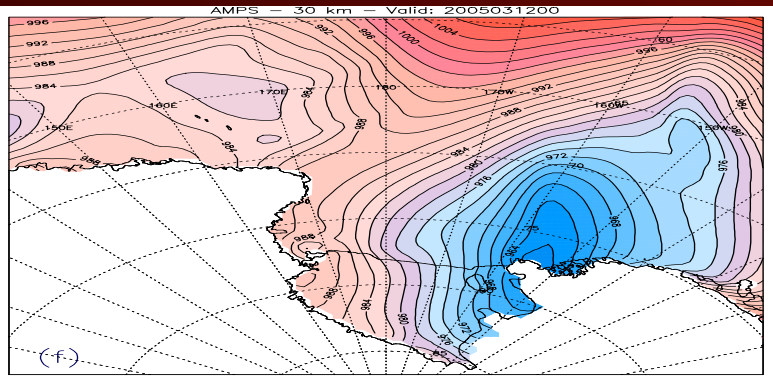
12 UTC 11 March 2005

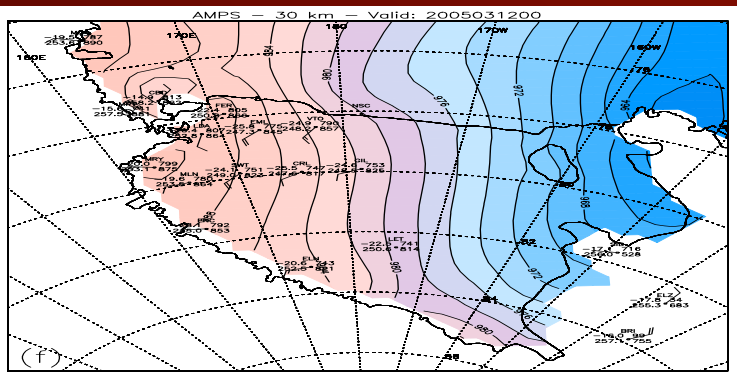




Barrier Wind Regime – Case Study

00 UTC 12 March 2005





Strong Katabatic Wind Regime - Selection

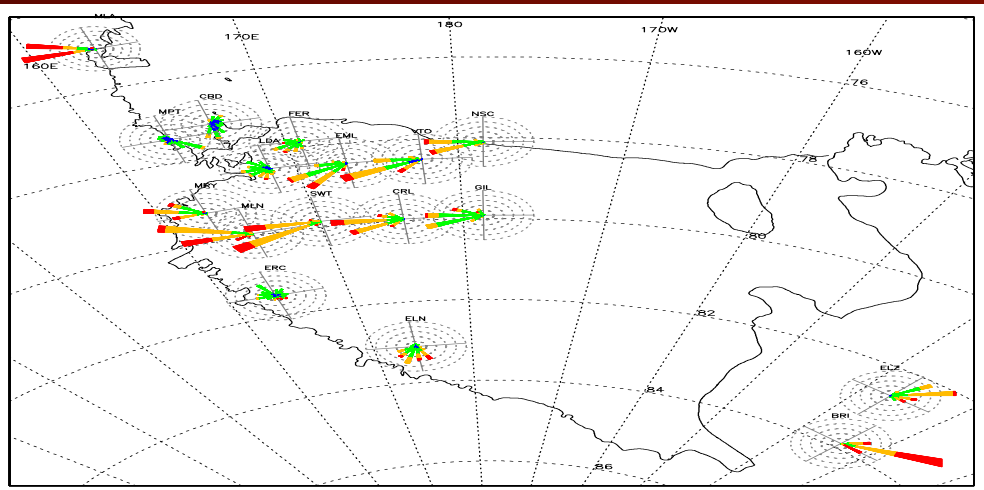
- Identify events where there is katabatic flow down the glaciers and the wind flow continues across the Ross Ice Shelf
- Selection Criteria:

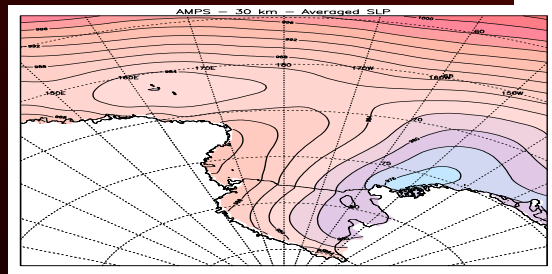
AWS Site	Wind Direction	Wind Speed
Marilyn	236º - 304º	>= 5.0 m s^{-1}
Schwerdtfeger	214º - 304º	>= 5.0 m s^{-1}

- Both criteria must be met for it to be a selected observation.
- Results: 2005 FMA - 278 hours, 13.0% of obs, 13 events

Wind Rose Analysis – Autumn 2005 (FMA)

Strong Katabatic Wind Regime

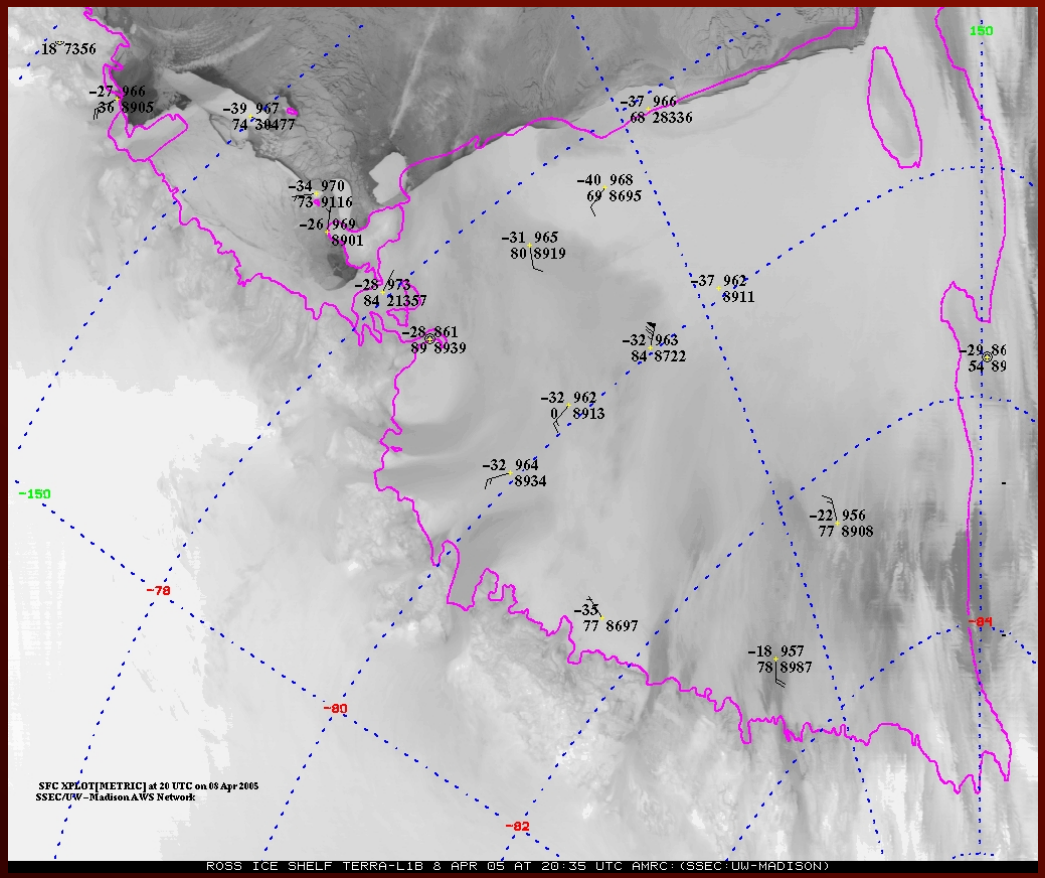




Strong Katabatic Wind – Case Study

- Event matching strong katabatic wind criteria:
  16 UTC 8 April 2005 –
  15 UTC 9 April 2005

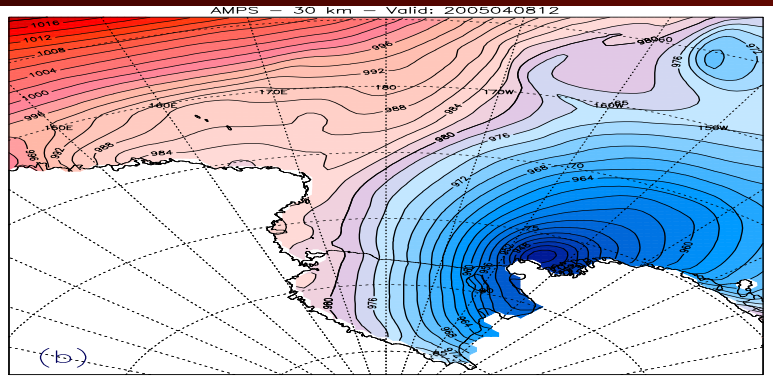
- Case study event:
  06 UTC 8 April 2005 –
  12 UTC 9 April 2005

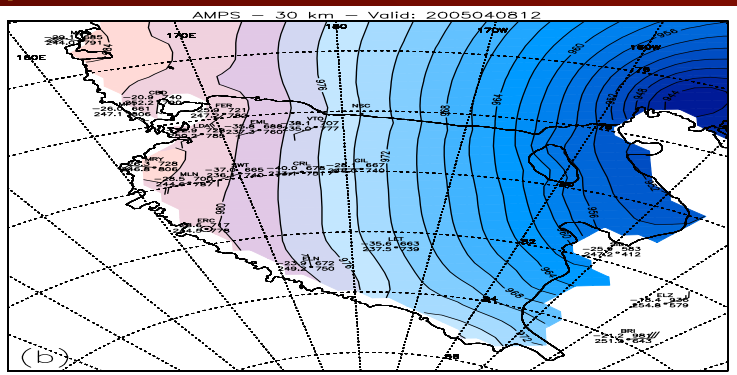


Satellite image courtesy of AMRC, University of Wisconsin

Strong Katabatic Wind – Case Study

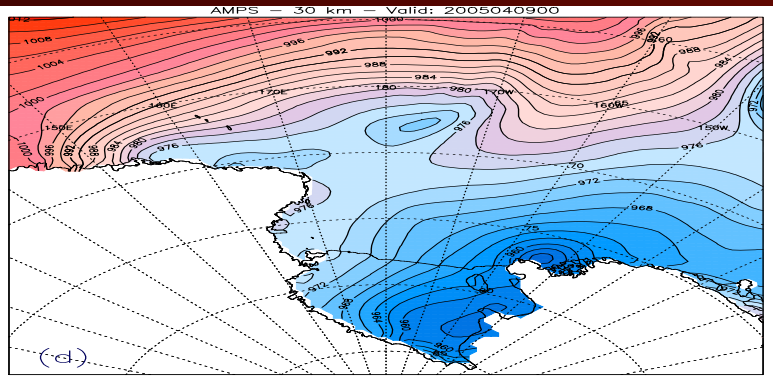
12 UTC 8 April 2005

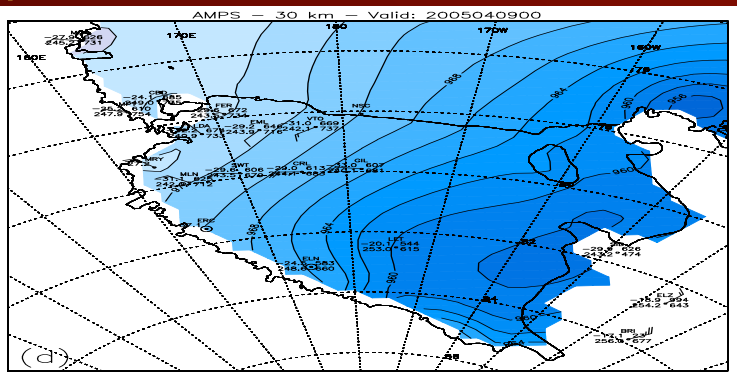




Strong Katabatic Wind – Case Study

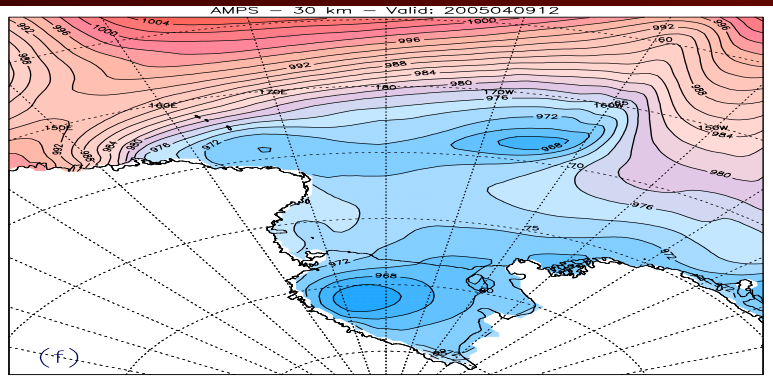
00 UTC 9 April 2005

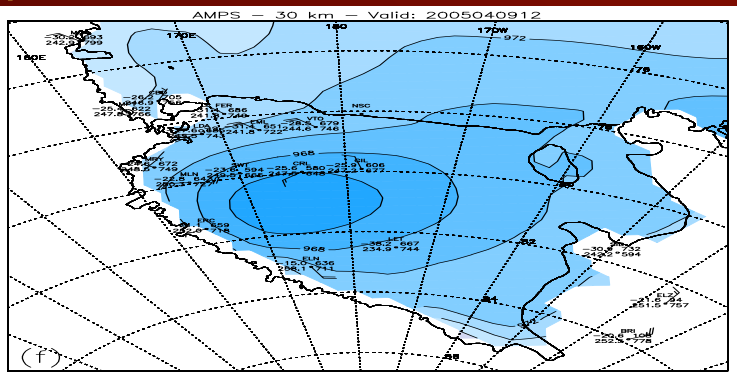




Strong Katabatic Wind – Case Study

12 UTC 9 April 2005





Weak Katabatic Wind Regime - Selection

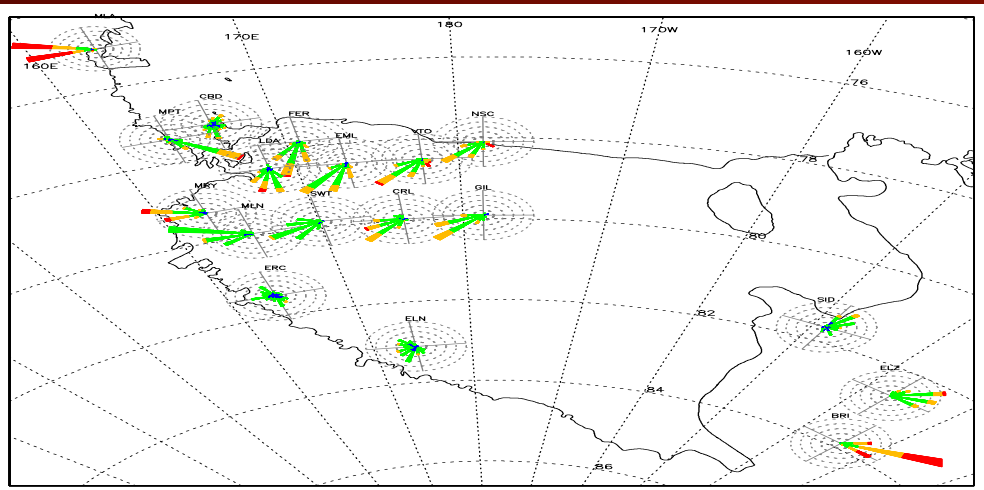
- Identify events where there is katabatic flow down the glaciers with minimal transport across the Ross Ice Shelf
- Selection Criteria:

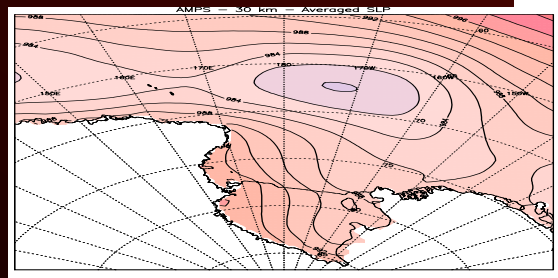
AWS Site	Wind Direction	Wind Speed
Marilyn	236º - 304º	1.0 - 4.9 m s^{-1}
Mary	236º - 326º	
Schwerdtfeger	236º - 304º	1.0 - 4.9 m s^{-1}

- If four or more of the five are matched, it is a valid observation
- Results: 2005 FMA - 227 hours, 10.6% of obs, 12 events

Wind Rose Analysis – Autumn 2005 (FMA)

Weak
Katabatic
Wind
Regime

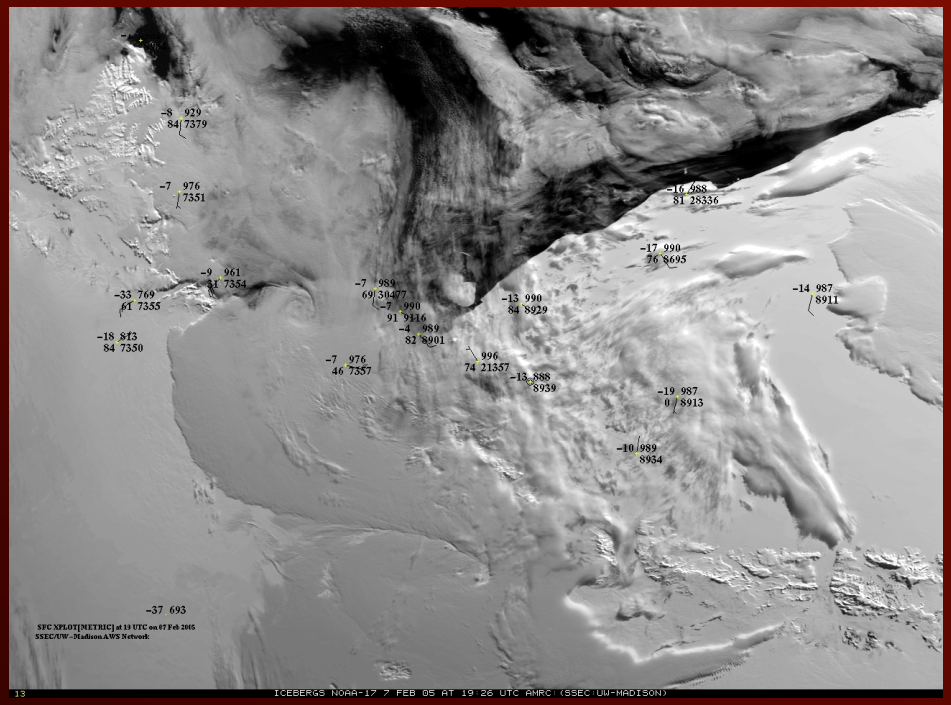




Weak Katabatic Wind – Case Study

- Event matching weak katabatic wind criteria:
  15 UTC 7 February 2005
  – 01 UTC 9 February 2005

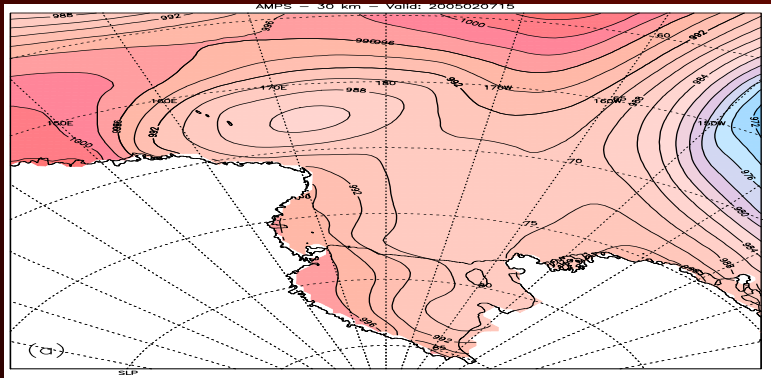
- Case study event:
  15 UTC 7 February 2005
  – 09 UTC 8 February 2005

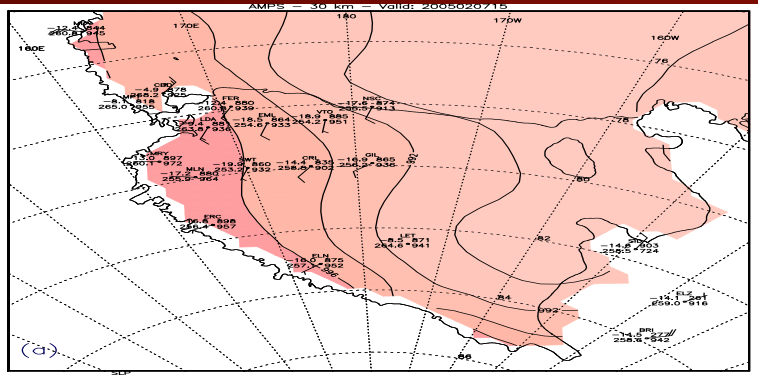


Satellite image courtesy of AMRC, University of Wisconsin

Weak Katabatic Wind – Case Study

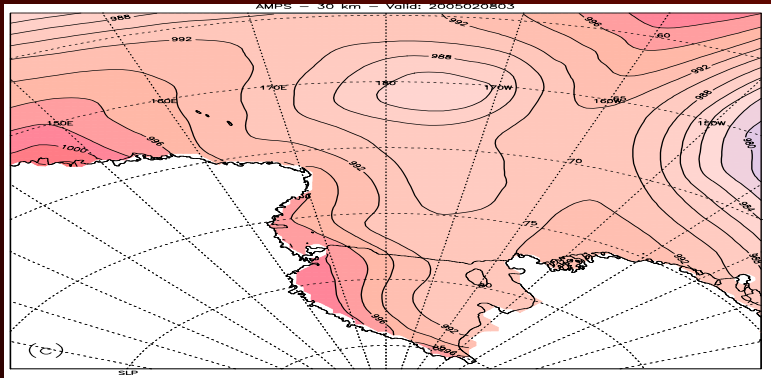
15 UTC 7 February 2005

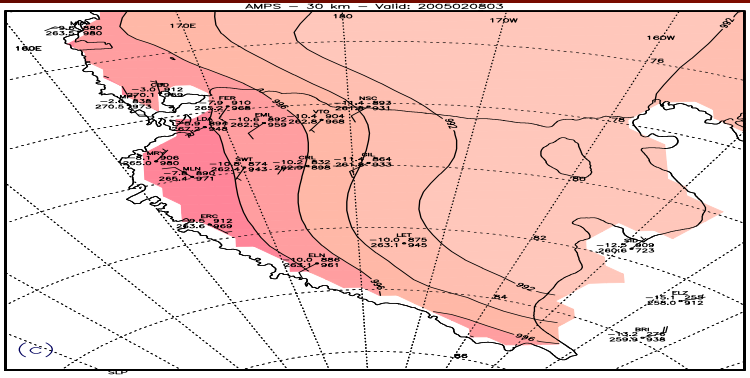




Weak Katabatic Wind – Case Study

03 UTC 8 February 2005





Light Wind Regime - Selection

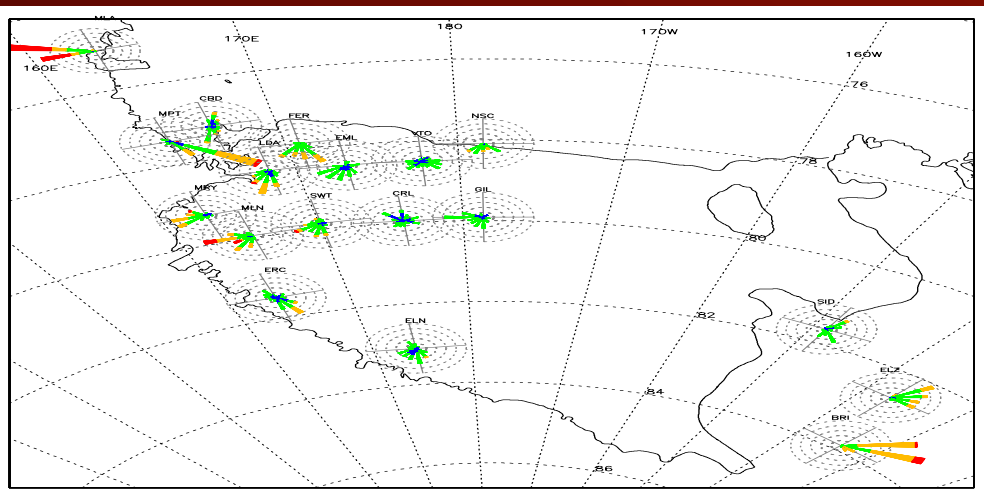
- Light wind at several locations across the Ross Ice Shelf
- Selection Criteria:

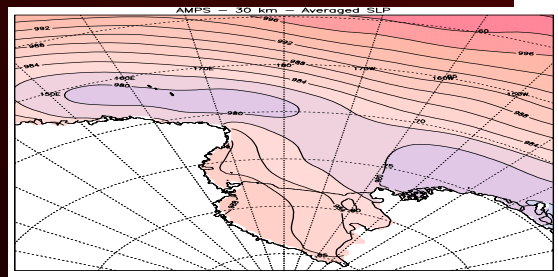
AWS Site	Wind Direction	Wind Speed
Carolyn	-	<= 3.9 m s^{-1}
Emilia	-	<= 3.9 m s^{-1}
Ferrell	-	<= 3.9 m s^{-1}
Schwerdtfeger	-	<= 3.9 m s^{-1}
Vito	-	<= 3.9 m s^{-1}

- If four or more of the five are matched, it is a valid observation
- Results: 2005 FMA - 172 hours, 8.1% of obs, 10 events

Wind Rose Analysis – Autumn 2005 (FMA)

Light Wind Regime





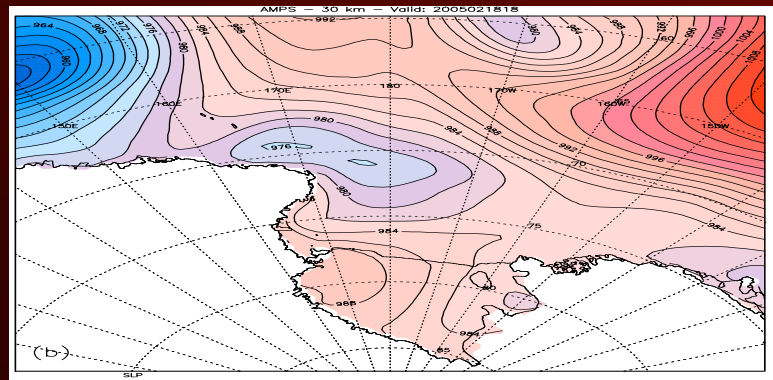
Light Wind – Case Study

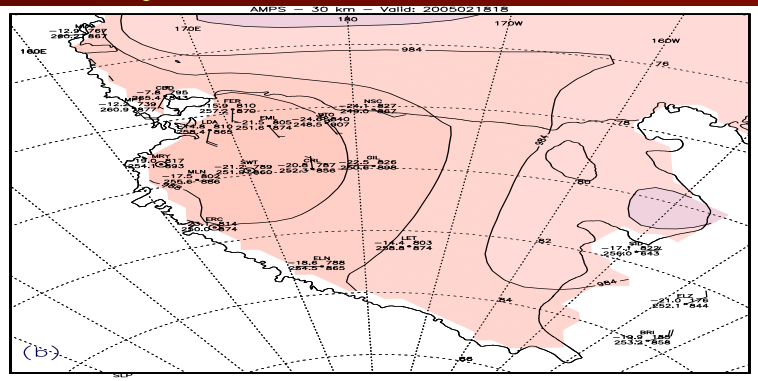
- Event matching weak katabatic wind criteria:
  07 UTC 18 February 2005
  – 07 UTC 19 February 2005

- Case study event:
  12 UTC 18 February 2005
  – 06 UTC 19 February 2005

Light Wind – Case Study

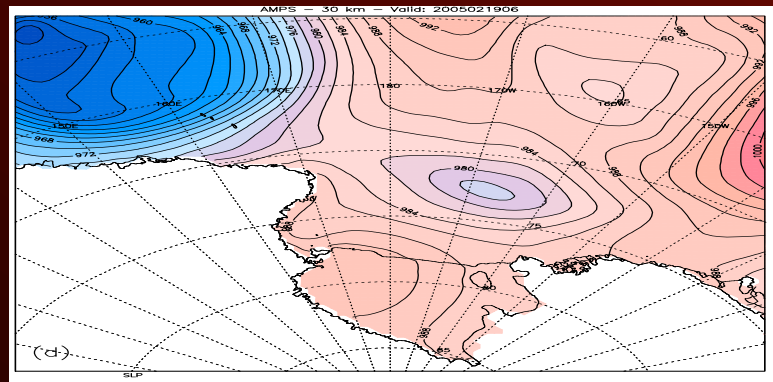
18 UTC 18 February 2005

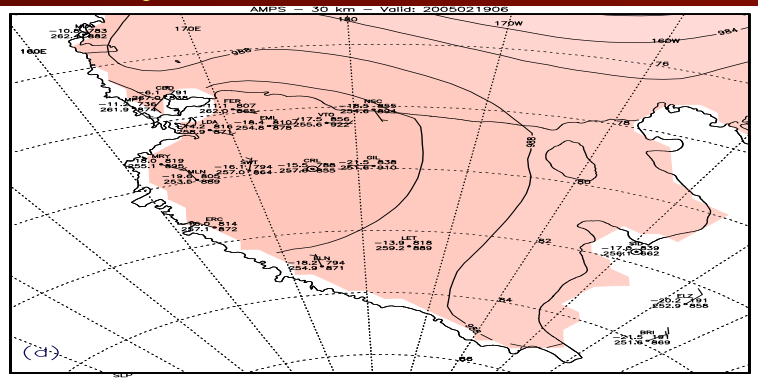




Light Wind – Case Study

06 UTC 19 February 2005



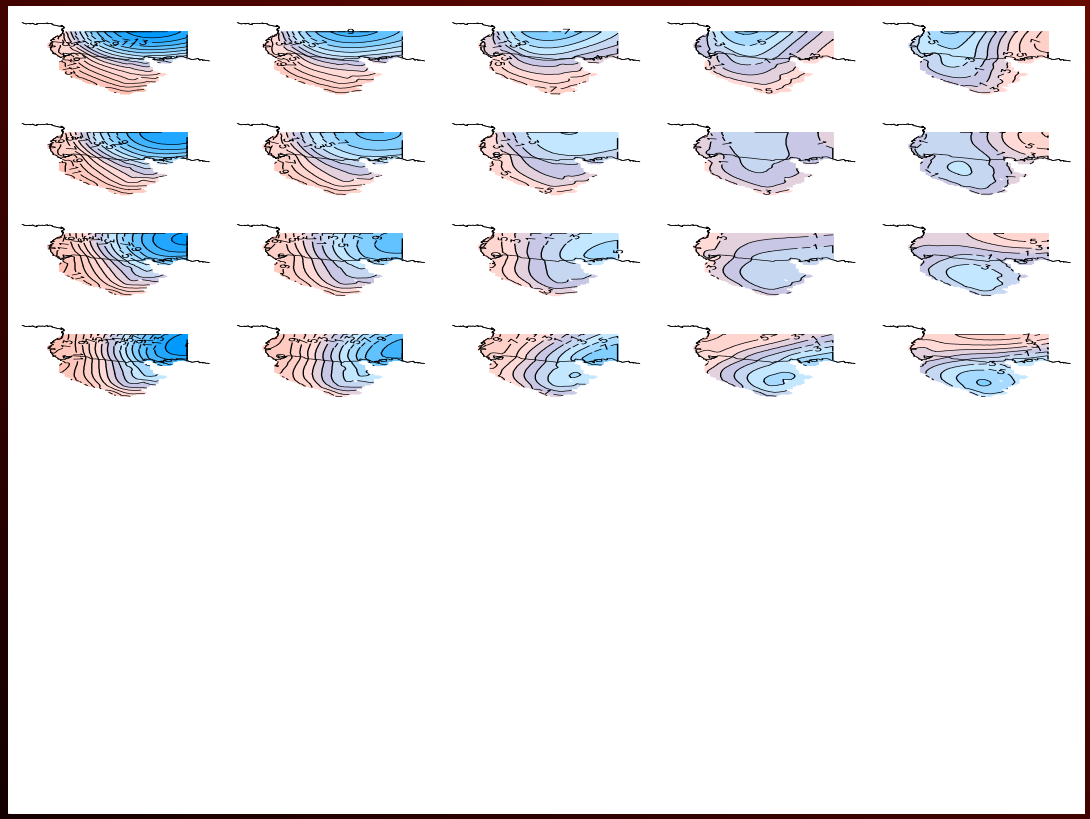


RAS Event

- Through analysis, a pattern was discovered which indicates a typical succession in wind events, associated with the passage of a cyclone in the Ross Sea
- This series of wind events is referred to as a RAS event
- A RAS event is comprised of:
  - barrier wind
  - strong katabatic flow
  - weak katabatic flow and light winds in between events
- RAS events occur routinely during the austral autumn, winter, and spring

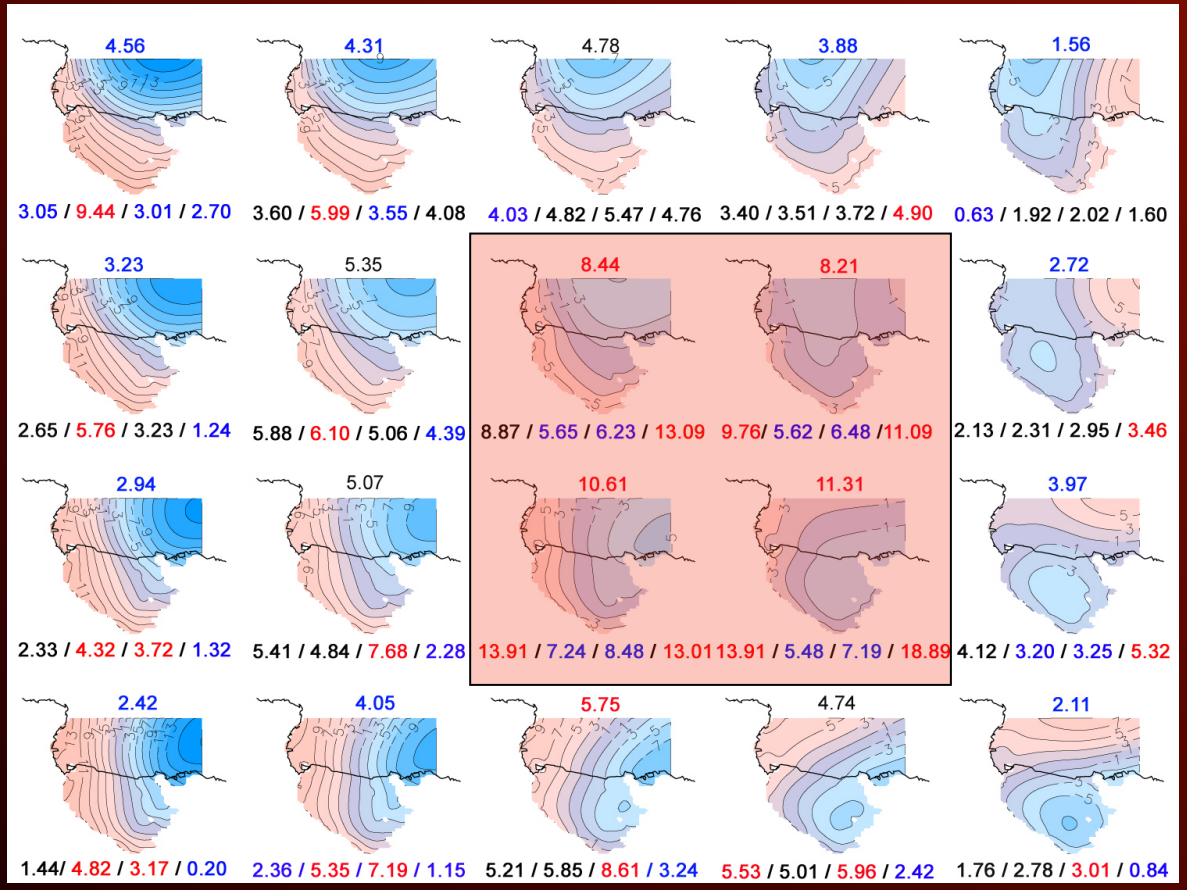
SOM Analysis – A Review

- SOM technique uses an unsupervised learning algorithm
- Clusters data into a user selected number of nodes
- SOM algorithm defines nodes that are representative of the data in the training set
- Train SOM with AMPS SLP data (January 2001 – December 2005)
  - Result is a synoptic pattern classification



SOM - Seasonal Frequency of Occurrence

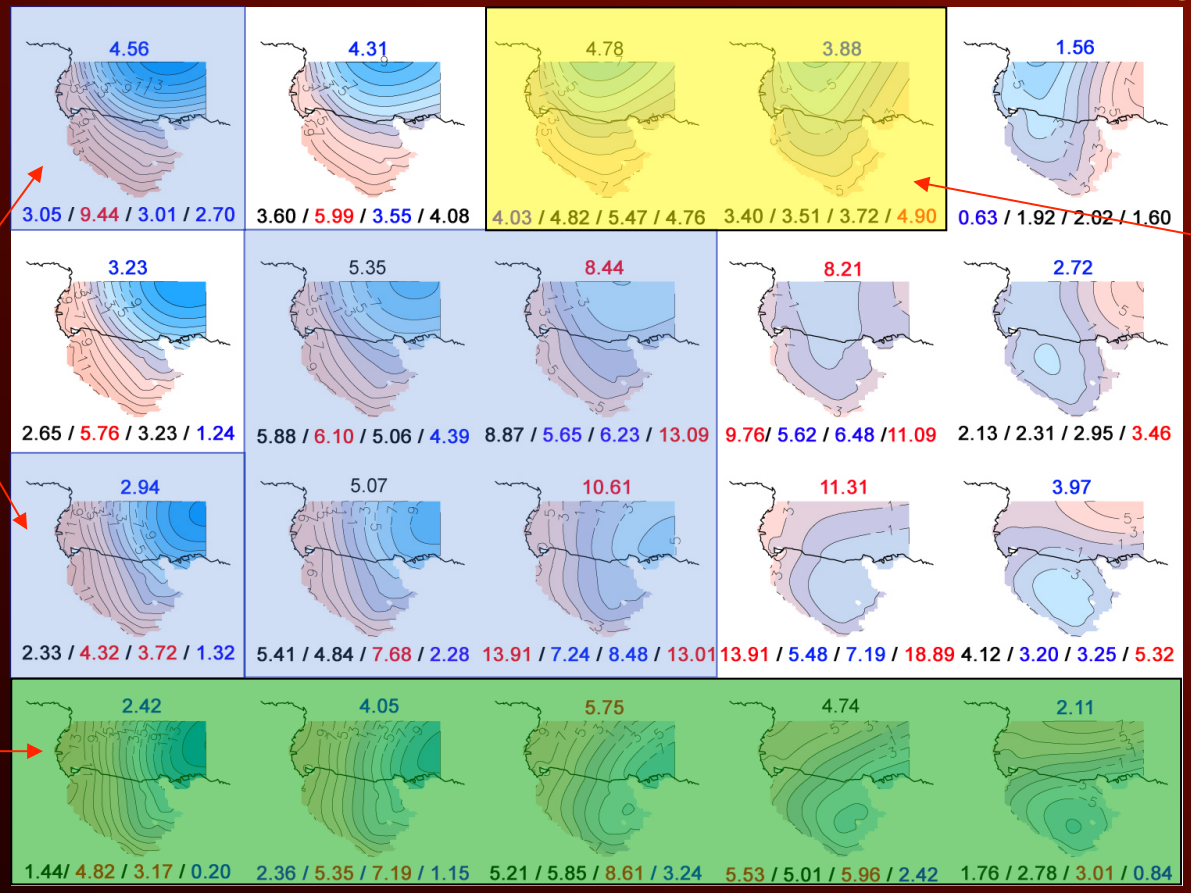
(FMA / MJJ / ASO/ NDJ)



- Nodes 3,3; 4,3; 3,4; 4,4 represent less defined synoptic regimes
  - Represents a large percentage of overall patterns - 39%
  - Even more common in the summer (NDJ) months – 56%

SOM - Wind Regime Frequency of Occurrence

(greater than 20% of AWS observations for a node indicate regime)



Barrier

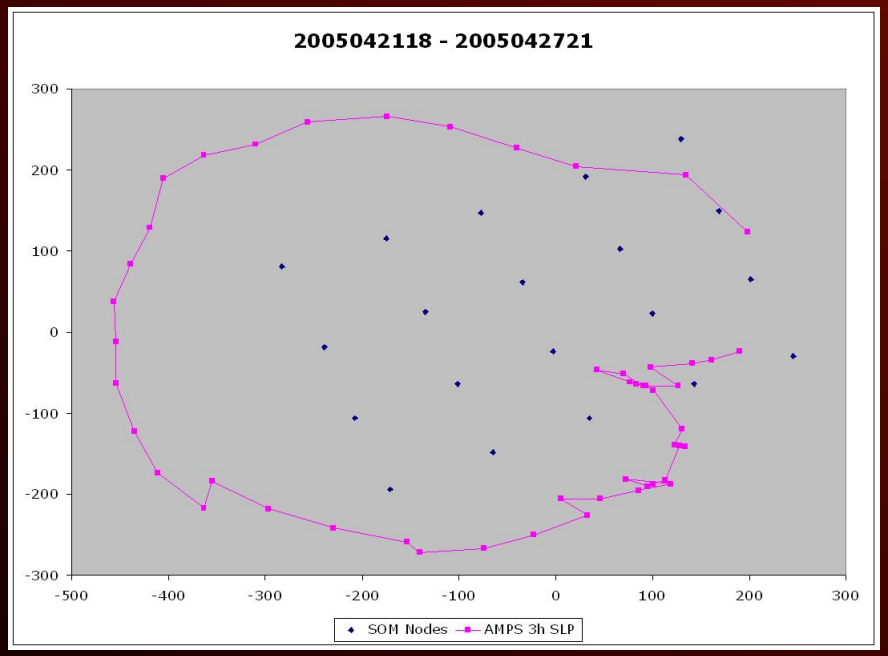
Light Wind

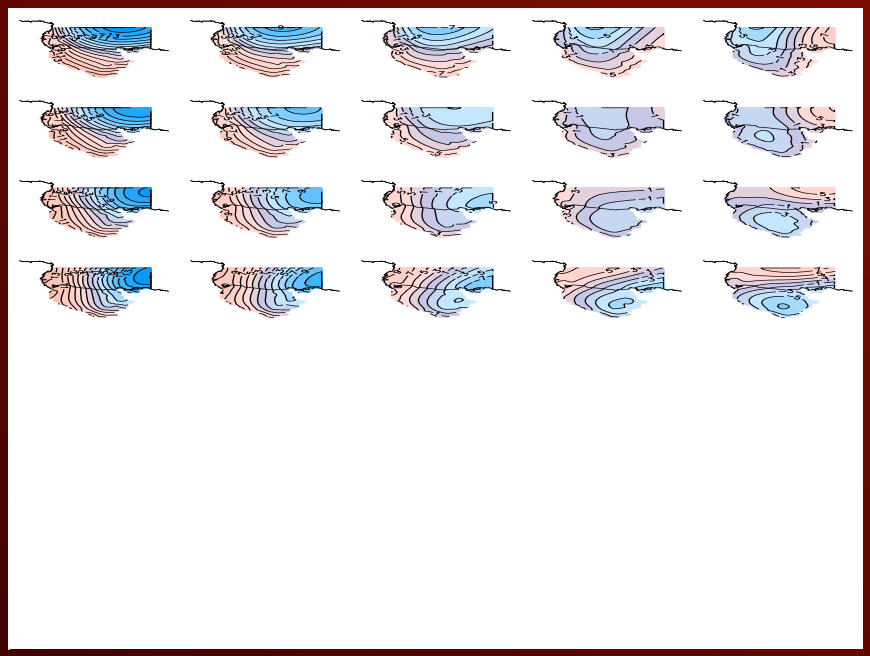
Strong Katabatic

- The outer nodes correspond to a larger percentage of the different dominant wind regimes

RAS Event – SOM Node Sequencing

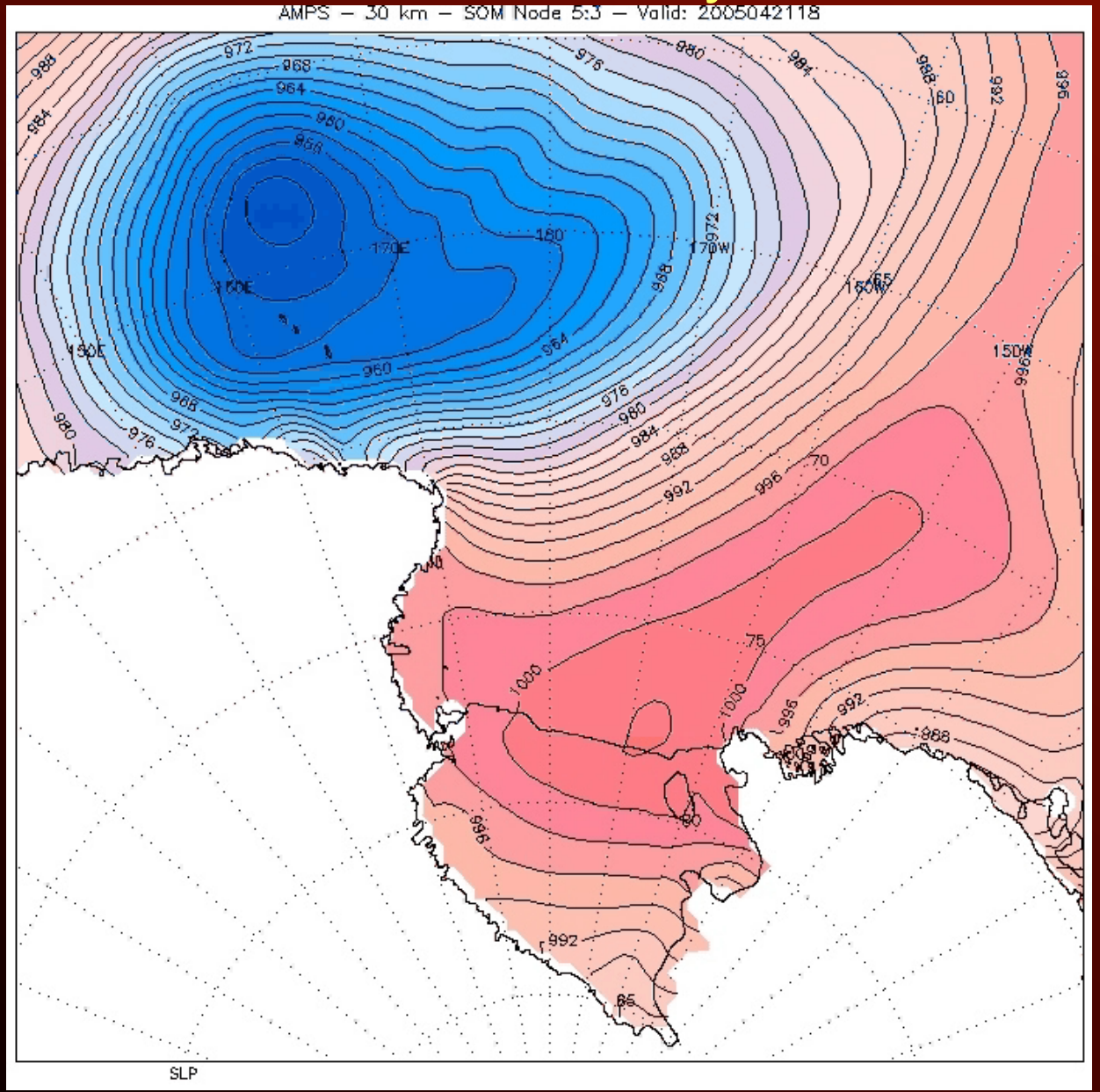
- The sequencing of a RAS event (barrier – strong katabatic – weak katabatic / light wind) often progresses along the outer nodes



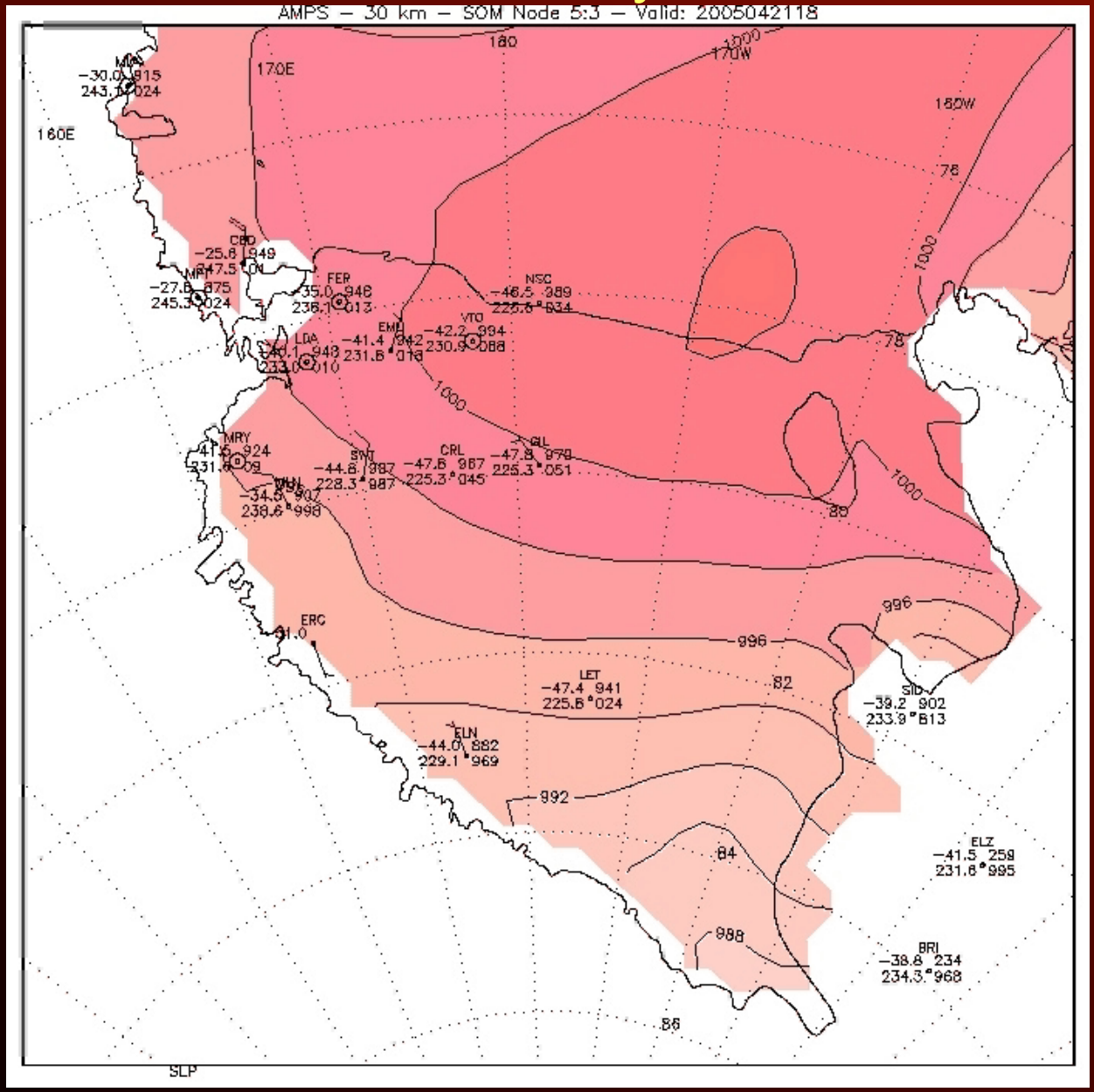


- Case Study: 18 UTC 21 April – 21 UTC 27 April 2005
  - AMPS 3-hour forecasts of sea-level pressure (valid 12h – 21h)
  - University of Wisconsin AWS observations

RAS Event – Case Study – Ross Sea



RAS Event – Case Study – Ross Ice Shelf



RAS Events

- Austral Autumn (FMA) 2005
  - February: 1 event (17%)
  - March: 2 events (27%)
  - April: 4 major events (54%)
    2 minor events (26%)

Conclusions

- The local geography plays a significant role in determining the regional wind field of Antarctica.
- Observations provide the initial ideas as to the surface wind field and a more complete understanding is accomplished through numerical modeling studies.
- The northwest Ross Ice Shelf region experiences a terrain following pattern during light winds with a stable lower atmosphere, and strong southerly flow during high wind events.
- Katabatic wind drainage onto the Ross Ice Shelf is dominant feature and the result of cold and dense air draining from the plateau.
- Cyclones and mesocylones play an active role in driving the surface wind field.
- The Transantarctic Mountains act as a barrier to air flow accumulating on the Ross Ice Shelf, resulting in an increased pressure gradient and strong flow parallel to the barrier.

Future Work – Barrier Wind

- Identification of barrier wind events by AWS wind direction/speed is not adequate and leads to errors.
- A clearer understanding of the characteristics and features of barrier winds needs to be developed.
- Questions to be answered:
  - Why are the strongest winds not at the base of the barrier?
  - How far does the pooling of air extend away from the base of the barrier?
  - What are the differences between barrier wind events and “pseudo-barrier” events (isobars parallel to the barrier, no pooling of air, no increased pressure gradient along barrier)?
  - Why is the wind direction typically at such a large angle to the isobars?

Future Work – Mesocyclones and Cyclones

- The AMPS archive indicates a more significant role of cyclones and mesocyclones across the Ross Ice Shelf than currently understood
- Questions:
  - What are the characteristics of the cyclones and mesocyclones?
  - What role do the cyclones and mesocyclones play in amplifying the katabatic drainage?
  - What mechanisms result in an intensification of cyclones and mesocyclones across the Ross Ice Shelf?

Future Work – RAS Events

- The development of a conceptual model to describe the sequencing of a RAS event.
- Questions:
  - Can a common sequence be defined for RAS events?
  - What does the larger pictures (area, additional levels) indicate as to the differences between RAS events?
  - Can significant northward transport of mass be associated with these RAS events?