A Case Study of the July 2015 McMurdo Storm

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Scientific Research Corporation
9 July 2015: McMurdo Station and its nearby airfields experience an extreme wind event (EWE) and record-setting snowfall

- Maximum wind gust of 43.7 m/s$^{-1}$ recorded at Building 165
- Maximum sustained wind of 56.6 m/s$^{-1}$ (*with higher gusts*) recorded at Pegasus Field
- Estimated 132.08 cm (52 inches) of snowfall recorded
Overview

- Synoptic and Mesoscale Environment
- Characterization of Mountain Wave & Downslope Wind Environment
- The Question of Pegasus
- Reanalysis of snowfall estimate
Synoptic Environment

08/06Z 500MB

08/06Z MSLP/PRECIP
Synoptic Environment

08/12Z 500MB

08/12Z MSLP/PRECIP
Synoptic Environment

08/18Z 500MB

08/18Z MSLP/PRECIP
Synoptic Environment

09/00Z 500MB

09/00Z MSLP/PRECIP
Synoptic Environment

09/06Z 500MB

09/06Z MSLP/PRECIP
Barrier Wind

08/00Z SFC STREAMLINES

AMPS Init Time: 2015-07-08 / 00 UTC  Forecast Lead Time: 0 Hours
Forecast Valid Time: 2015-07-08 / 00 UTC
Surface Wind Streamlines

08/06Z SFC STREAMLINES

AMPS Init Time: 2015-07-08 / 00 UTC  Forecast Lead Time: 6 Hours
Forecast Valid Time: 2015-07-08 / 06 UTC
Surface Wind Streamlines
Barrier Wind

08/12Z SFC STREAMLINES

AMPS Init Time: 2015-07-08 / 00 UTC  Forecast Lead Time: 12 Hours
Forecast Valid Time: 2015-07-08 / 12 UTC
Surface Wind Streamlines

08/18Z SFC STREAMLINES

AMPS Init Time: 2015-07-08 / 00 UTC  Forecast Lead Time: 18 Hours
Forecast Valid Time: 2015-07-08 / 18 UTC
Surface Wind Streamlines
Barrier Wind

09/00Z SFC STREAMLINES

AMPS Init Time: 2015-07-08 / 00 UTC  Forecast Lead Time: 24 Hours
Forecast Valid Time: 2015-07-09 / 00 UTC
Surface Wind Streamlines

09/06Z SFC STREAMLINES

AMPS Init Time: 2015-07-08 / 00 UTC  Forecast Lead Time: 30 Hours
Forecast Valid Time: 2015-07-09 / 06 UTC
Surface Wind Streamlines
Mesoscale Environment

08/12Z MSLP/PRECIP

08/12 SFC WINDS
Mesoscale Environment

08/18Z MSLP/PRECIP

08/18Z SFC WINDS
Mesoscale Environment

09/00Z MSLP/PRECIP

09/00Z SFC WINDS
Mesoscale Environment

09/06Z MSLP/PRECIP

09/06Z SFC WINDS
Mesoscale Environment

09/04Z AMPS MSLP/PRECIP

09/0425 IR METSAT
Flow Interaction

AMPS Init Time: 2015-07-08 / 00 UTC
Forecast Lead Time: 29 Hours
Forecast Valid Time: 2015-07-09 / 05 UTC
Surface Wind Streamlines

Wind Speed (kts)
0.0 10.0 20.0 30.0 40.0 50.0
Flow Interaction

Wind Speed m/s

8 July 9 July

McM
McM AMPS
PGN
PGN AMPS
Mountain Wave & Downslope Environment

08/12Z UPSTREAM X-SEC

AMPS 1-km WRF
Forecast: 12 h
Valid: 12 UTC Wed 08 Jul 15
Horizontal wind speed
XY = 307.9, 309.5 to 297.7, 438.6
Potential temperature
XY = 307.9, 309.5 to 297.7, 438.6

08/18Z UPSTREAM X-SEC

AMPS 1-km WRF
Forecast: 18 h
Valid: 18 UTC Wed 08 Jul 15
Horizontal wind speed
XY = 307.9, 309.5 to 297.7, 438.6
Potential temperature
XY = 307.9, 309.5 to 297.7, 438.6
09/08Z UPSTREAM X-SEC

AMPS 1.1-km WRF
Init: 12 UTC Wed 08 Jul 15
Valid: 08 UTC Thu 09 Jul 15
Forecast: 20 h

Horizontal wind speed
XY: 307.9, 309.5 to 297.7, 438.6
Potential temperature
XY: 307.9, 309.5 to 297.7, 438.6

09/08Z SFC WINDS

AMPS 1.1-km WRF -- Rose Island Window
Init: 12 UTC Wed 08 Jul 15
Valid: 08 UTC Thu 09 Jul 15
Forecast: 20 h

Horizontal wind speed
at h-index = 60
Terrain height AMSL
Horizontal wind vectors
at h-index = 60
Mountain Wave & Downslope Environment

09/08Z MSLP/PRECIP

09/08Z SFC WINDS
Mountain Wave & Downslope Environment

08/12Z AMPS FCST SOUNDING (BLACK ISLAND)

08/12Z AMPS FCST SOUNDING (PEGASUS)
Mountain Wave & Downslope Environment

08/18Z AMPS FCST SOUNDING (BLACK ISLAND)

08/18Z AMPS FCST SOUNDING (PEGASUS)
Mountain Wave & Downslope Environment

09/00Z AMPS FCST SOUNDING (BLACK ISLAND)

09/00Z AMPS FCST SOUNDING (PEGASUS)
Mountain Wave & Downslope Environment

09/06Z AMPS FCST SOUNDING (BLACK ISLAND)

09/06Z AMPS FCST SOUNDING (PEGASUS)
The Question of Pegasus

Wind Speed m/s

8 July

9 July
The Question of Pegasus
## Technical Specifications

### Propeller
- **Range:** 0 to 100 m/s
- **Threshold:**
  - 1.0 m/s (2.0 Kts) (2.2 mph)
  - 0.5 m/s (1.0 Kts) (1.1 mph) - with special bearings
- **Distance Constant:** 2.7 m (8.9 ft) (63% recovery)
- **Signal Output:** sine wave—90 Hz / 8.8 m/s
- **Resolution:** 0.1 m/s (0.2 Kts) (0.2 mph)
- **Accuracy:** +/- 0.3 m/s (0.6 Kts) (0.7 mph)

### Vane
- **Range:** 360° mechanical, 355° electrical
- **Resolution:** 1°
- **Accuracy:** +/- 3° (2° optional)
- **Survival:** 100 m/s (194 Kts) (224 mph)
- **Threshold:**
  - 1.1 m/s (2.1 Kts) (2.4 mph)
  - 0.6 m/s (1.2 Kts) (1.3 mph) - with special bearings
- **Delay Distance:** 1.3 m (4.3 ft) (50% recovery)

### ENVIRONMENTAL
- **Temperature Range:** -60°C to +70°C
# The Question of Pegasus

## University of Wisconsin-Madison AWS Specifications

From Technical Manual for Automatic Weather Stations, by George A. Weidner, Department of Meteorology (now Atmospheric and Oceanic Sciences), University of Wisconsin-Madison, 1985.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sensor</th>
<th>Specifications</th>
</tr>
</thead>
</table>
| Air Pressure   | Paroscientific Model 215 A  | Range: 0 to 1100 hPa  
|                |                             | Resolution: 0.050 hPa  
|                |                             | Accuracy: +/- 0.2 hPa  
|                |                             | (0.2 hPa/year long term drift)                      |
| Air Temperature| Weed PRT Two-wire bridge    | Range: to -100 C minimum  
|                |                             | Resolution: 0.125 C  
|                |                             | Accuracy: +/- 0.5 C                                        |
| Humidity       | Vaisala HMP-35A (and other models) | Range: 0 to 100%  
|                |                             | Resolution: 1.0 %  
|                |                             | Accuracy: +/- 5.0 % down to -55 C  
|                |                             | Corrections possible for lower temperatures             |
| Wind Direction | 10 K Ohm pot.               | Range: 0 to 355 Degrees  
|                |                             | Resolution: 1.5 Degrees  
|                |                             | Accuracy: +/- 3.0 Degrees                                      |
| Wind Speed     | Bendix/Belfort RM Young Hydro-Tech | Resolution/Accuracy: 0.25 +/- 0.5 m/s  
|                |                             | Resolution/Accuracy: 0.20 +/- 0.5 m/s  
|                |                             | Resolution/Accuracy: 0.33 +/- 0.2%                                    |
| Temperature String | Thermo couple Two junction Copper-Cons. | Resolution: 0.06 C  
|                |                             | Accuracy: +/- 0.125 C                                      |
KEY FACTORS

- Upper-level trough near Cape Adare
- Surface low approaching from a northerly direction
- Barrier wind
- Intensifying PGF
- Contributions from upstream orography
Snowfall Reanalysis
Snowfall Reanalysis

- Precipitation measurements taken every six hours from the top of Building 165.
- Estimated 132.08 cm (52 inches) of snowfall from a liquid water equivalent of 26.41mm (1.04 inches).
- Snowfall ratio of 50:1 applied using a conversion table from the SOPP McMurdo Weather Observer Handbook.
### New Snowfall to Water Equivalent Conversion

<table>
<thead>
<tr>
<th>Melt Water Equivalent (WE) in Inches</th>
<th>New Snowfall (Inches)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>01-M02</td>
<td>0.1-M07</td>
</tr>
<tr>
<td>Trace</td>
<td>Trace</td>
<td>0.1</td>
</tr>
<tr>
<td>.01</td>
<td>0.1</td>
<td>.2</td>
</tr>
<tr>
<td>.02</td>
<td>0.2</td>
<td>.3</td>
</tr>
<tr>
<td>.03</td>
<td>0.3</td>
<td>.5</td>
</tr>
<tr>
<td>.04</td>
<td>0.4</td>
<td>.6</td>
</tr>
<tr>
<td>.05</td>
<td>0.5</td>
<td>.8</td>
</tr>
<tr>
<td>.06</td>
<td>0.6</td>
<td>.9</td>
</tr>
<tr>
<td>.07</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>.08</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>.09</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>.10</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>.11</td>
<td>1.1</td>
<td>1.7</td>
</tr>
<tr>
<td>.12</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td>.13</td>
<td>1.3</td>
<td>2.0</td>
</tr>
<tr>
<td>.14</td>
<td>1.4</td>
<td>2.1</td>
</tr>
<tr>
<td>.15</td>
<td>1.5</td>
<td>2.3</td>
</tr>
<tr>
<td>.16</td>
<td>1.6</td>
<td>2.4</td>
</tr>
<tr>
<td>.17</td>
<td>1.7</td>
<td>2.6</td>
</tr>
<tr>
<td>.18</td>
<td>1.8</td>
<td>2.7</td>
</tr>
<tr>
<td>.19</td>
<td>1.9</td>
<td>2.9</td>
</tr>
<tr>
<td>.20</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>.21</td>
<td>2.1</td>
<td>3.1</td>
</tr>
<tr>
<td>.22</td>
<td>2.2</td>
<td>3.3</td>
</tr>
<tr>
<td>.23</td>
<td>2.3</td>
<td>3.4</td>
</tr>
<tr>
<td>.24</td>
<td>2.4</td>
<td>3.6</td>
</tr>
<tr>
<td>.25</td>
<td>2.5</td>
<td>3.8</td>
</tr>
</tbody>
</table>

**WF Ratio**

1:10 1:15 1:20 1:30 1:40 1:50 1:100

**NOTE:** For temperatures above 54°F (1°C) or for slushy, wet snow, a 1:8 ratio may be appropriate, e.g., 0.10 WE = 0.8" snowfall, 0.15" WE = 1.2" snowfall.

*****Note:** For Water Equivalent over .25 inches, multiply inches by ratio. Example: .26 inches with a temp at -11.26*30=7.8
The problem:

- Persistent wind and blowing snow render traditional measurement procedures inadequate
- The weather itself can make precipitation measurement hazardous to the observing staff
- Estimating snow density and snowfall amounts based solely on surface temperature is not a completely reliable method and does not take cloud and precipitation microphysics or sub-cloud processes into account
- Deposition of blowing snow into collection gauge may also inflate estimates
Inverse relationship between snow density and snow/water ratio (i.e. the more snow density increases, the lower the snow/water ratio)

Snow density is directly related to its crystalline structure and size (Dubé, 2003)
Common Crystal Habits and Formation Conditions

Excess vapor pressure over ice at water saturation

Temperature (°C)

-30 -22 -16 -12 -10 -6 -3 0

Excess vapor pressure over ice (hPa)

0.30

0.20

0.10

From COMET
## Snowfall Reanalysis

### Table 10: Overview of the minimal meteorological parameters to consider.

<table>
<thead>
<tr>
<th>Level</th>
<th>Temperature</th>
<th>Vertical Motion</th>
<th>Relative Humidity</th>
<th>Winds</th>
</tr>
</thead>
<tbody>
<tr>
<td>500mb</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>700mb</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>850mb</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>925mb</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>surface</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ground</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(From Dubé, 2003)
Algorithm:

- **Tatm** (Temperature of the Atmosphere)
- Surface Temperature
- Crystal Type
  - Primary Temperature (intersection of $\omega_{\text{max}}$ and RH > 80%)
  - Secondary Temperature ($\omega < 0^\circ\text{C}, T < 0^\circ\text{C}, \text{and RH} > 80\%$)
- Growth or sub-cloud processes (accretion, fragmentation, etc.)
Snowfall Reanalysis

08/12Z AMPS FCST SOUNCING

ALGORITHM (FROM DUBÉ, 2003)

Determine the crystal type (using the Table below):

<table>
<thead>
<tr>
<th>mixed</th>
<th>needles</th>
<th>spatial dendrites</th>
<th>mixed with s.n.</th>
<th>stars</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
</tr>
</tbody>
</table>

The primary temperature corresponds to the main crystal growth level, that is, at the intersection of 

The secondary temperature corresponds to a level below the main level where $T < 0$, $T < 6°C$ and $RH > 90%$.
FORECAST ALGORITHM (C) (mixed crystals)

Check for presence of significant accretion:

- Supercooled droplets (FZDZ)
- $0 < T_{atm} < -10 \, ^\circ C$
- RH > 95%
- Onshore and/or upslope flow

<table>
<thead>
<tr>
<th>Accretion</th>
<th>No accretion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosis #1</td>
<td>Diagnosis #2</td>
</tr>
<tr>
<td>$R=7$</td>
<td>$R=10$</td>
</tr>
</tbody>
</table>

(From Dubé, 2003)
### Snowfall Reanalysis

<table>
<thead>
<tr>
<th>July</th>
<th>Extreme Maximum Temperature</th>
<th>Extreme Minimum Temperature</th>
<th>Peak Wind Speed, Gust (knots)</th>
<th>Snowfall (inches), Mean</th>
<th>Snowfall (inches), Maximum</th>
<th>Daily Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24°F / -4.4°C</td>
<td>-59°F / -50.6°C</td>
<td>102</td>
<td>5.9</td>
<td>26.8</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Future Directions

- Continue to investigate mountain wave and downslope dynamics in the region
- Develop snowfall estimates based on algorithms prescribed by Dubé
- Ensure training guidance emphasizes model discrepancies in pressure during barrier wind and downslope windstorm events
Acknowledgements

- UCAR AMPS Team
  - Kevin Manning and Dr. Jordan Powers

- AMRC

- Research community

- SPAWAR Office of Polar Programs Team

- Scientific Research Corporation

- COMET/MetEd
Dubé, I. From mm to cm...Study of snow/liquid water ratios in Quebec, 2003: [Available online at http://meted.ucar.edu/norlatisnowdensity/from_mm~to cm.pdf]


Questions?