

On the Impact of MODIS Winds on AMPS WRF Forecasts

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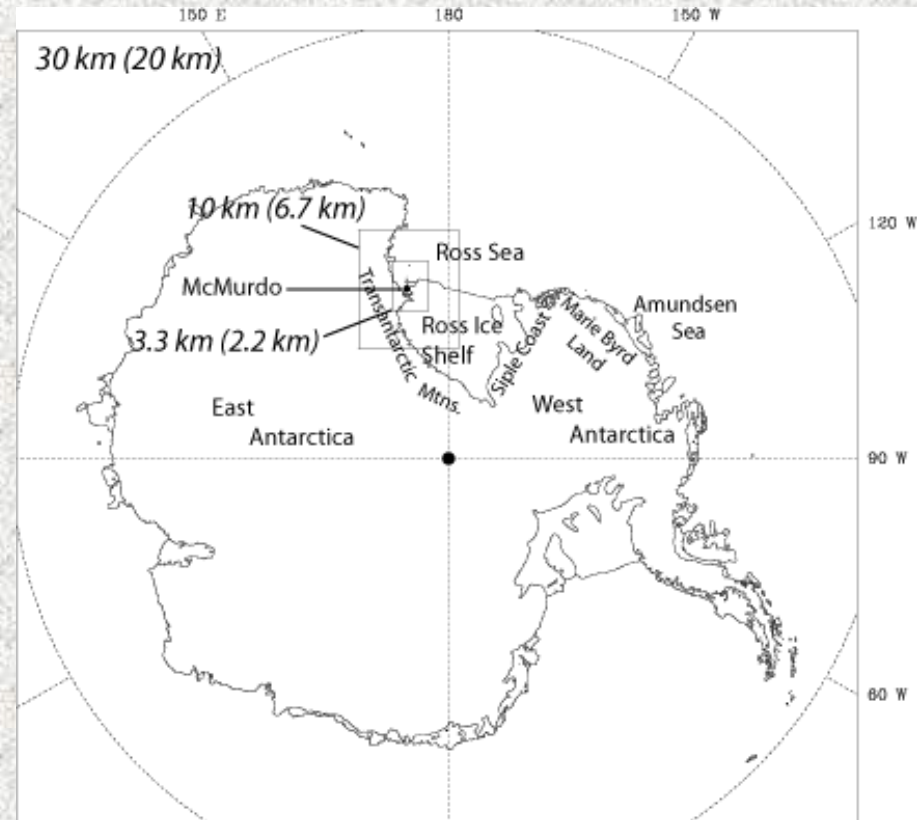
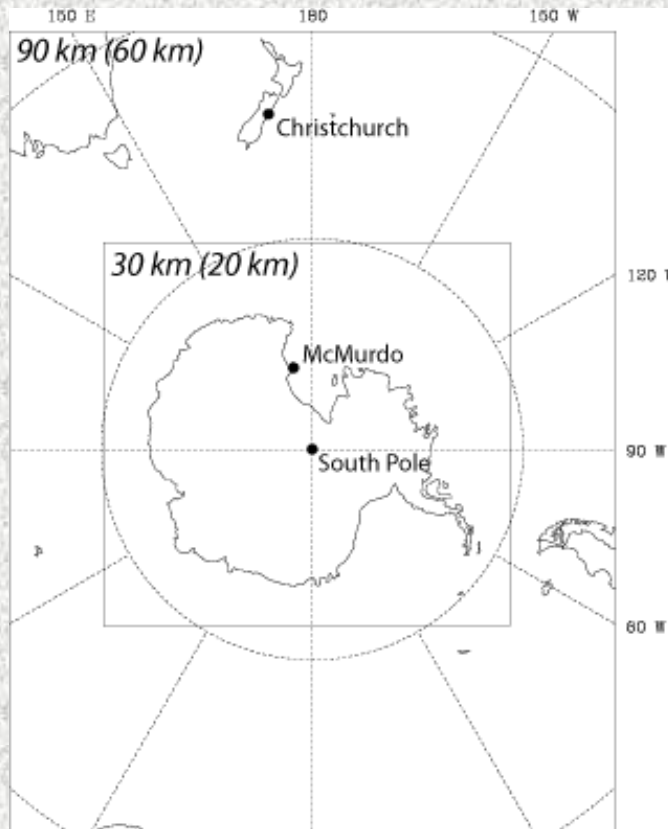
- Background
- WRF Simulations and Statistical Evaluation
- Summary and Conclusions



I. Background

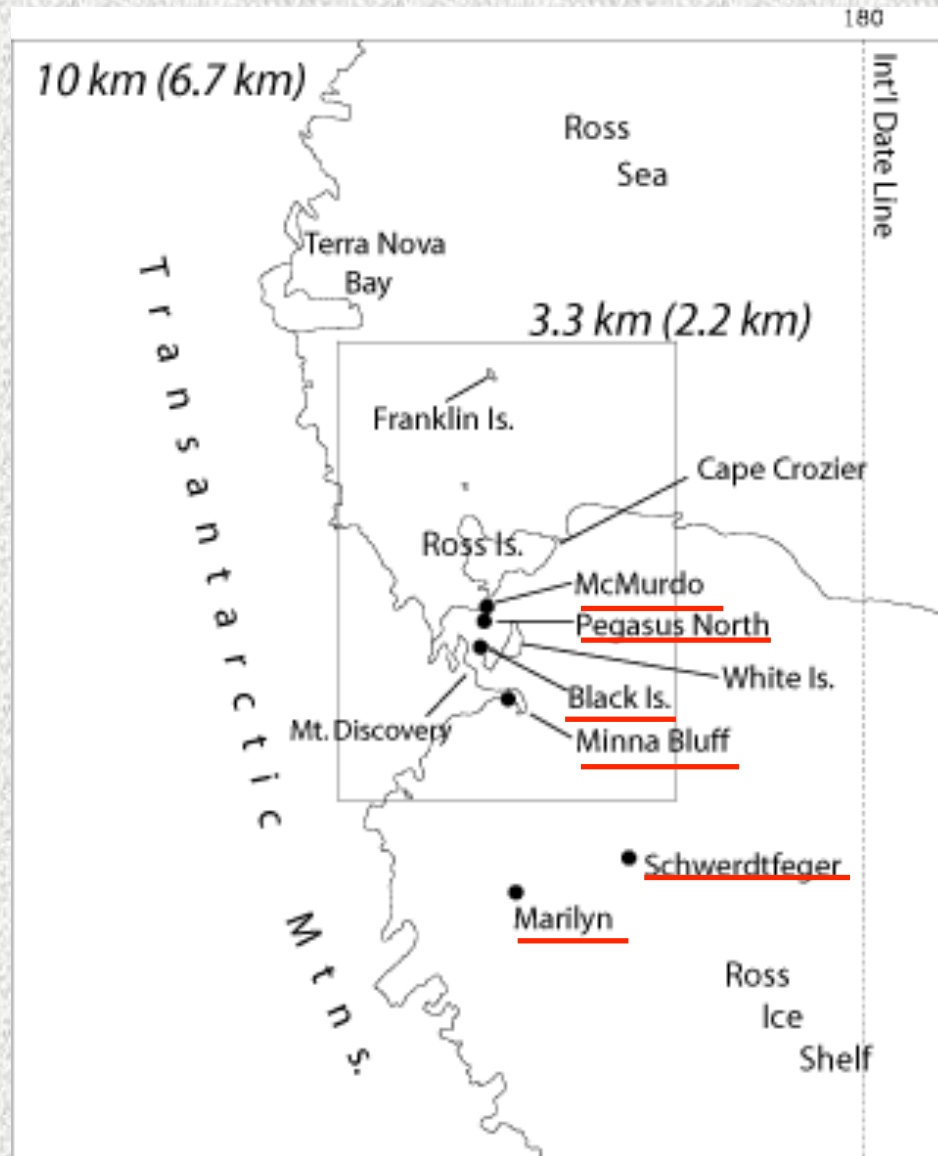
- **15 May 2004 McMurdo Windstorm**
 - Winds: **>99 kt (50 ms⁻¹)** in McMurdo area
possible gusts to 139 kt (71 ms⁻¹)
 - Significant damage to structures and instruments
 - Synoptics: Passage of deep synoptic low across Ross Ice Shelf and near Ross Island
- **Weather Research and Forecasting (WRF) Model Used**
 - Implemented in AMPS with MM5: October 2005

- **Experiment Grid Configurations**



NB: No Peninsula or South Pole grids for WRF May windstorm simulations

Western Ross Sea / Ross Is. grids



— : Sites statistically examined

II. WRF Simulations and Statistical Evaluation

- 1) 15 May 2004 Windstorm Event Simulations
- 2) May 2004 Forecasts (Preliminary)

• 15 May 2004 WRF Experiments and AMPS MM5 Forecast

- Init: 0000 UTC 15 May 2004
- Data assimilation: **WRF-Var**
- **Standard AMPS data**: Sfc repts, AWS, upper-air, ships, buoys, AMDAR, AIREPS, cloud-track winds

CTRL No data assimilation

STD Standard AMPS data only

ALL Standard AMPS data + *all* MODIS data

MOD1 Standard AMPS data + *filtered* MODIS data

MOD1_60 As in MOD1 with **60/20/6.7/2.2-km domains**

AMPS MM5 Standard AMPS data only

MODIS Winds

- Moderate-Resolution Imaging Spectroradiometer
- Source: CIMMS (Cooperative Inst. for Meteorological Satellite Studies, Univ. of Wisconsin)
- **Filtering Criteria** (see Key et al. 2003; Bormann and Thépaut 2004)

Retain obs as follows / Reject otherwise

IR, WV= Infrared and water vapor channels of MODIS

Ocean

IR: Above 700 hPa

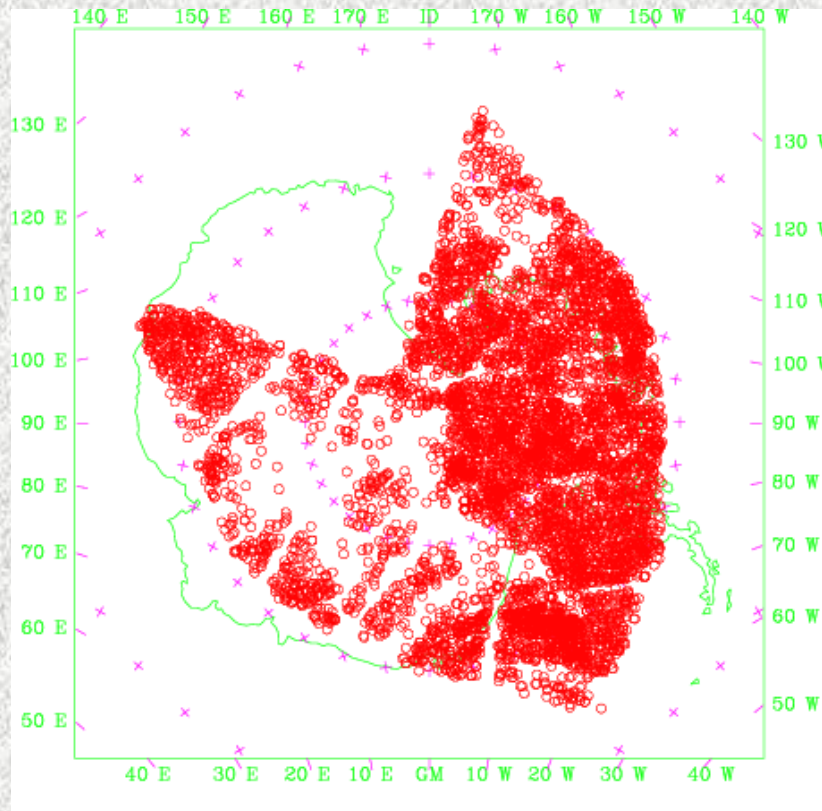
WV: Above 550 hPa

Land

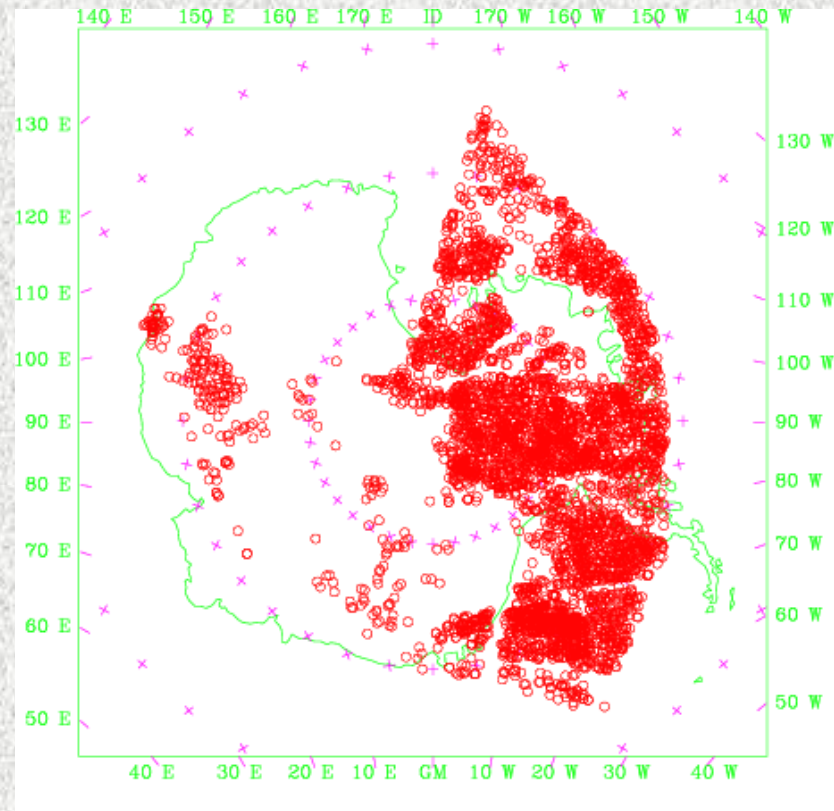
IR: above 400 hPa

WV: above 400 hPa

MODIS Wind Retrieval Filtering



Unfiltered— ALL

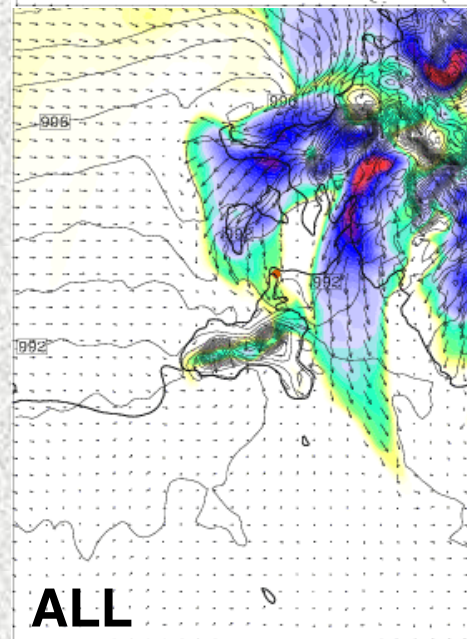
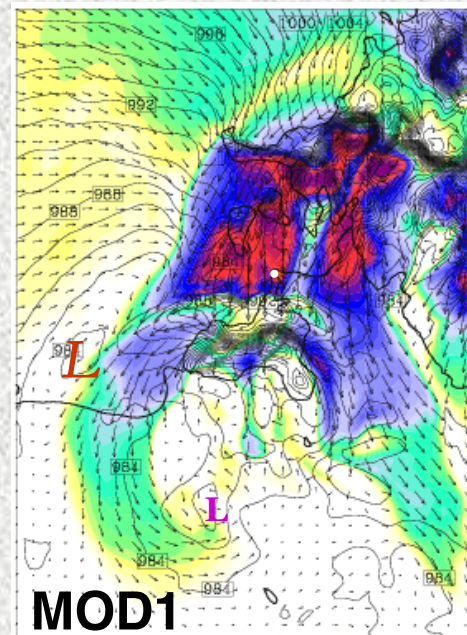
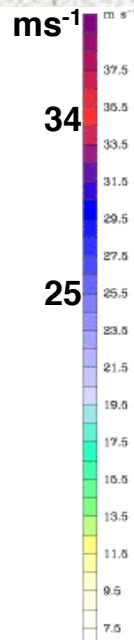
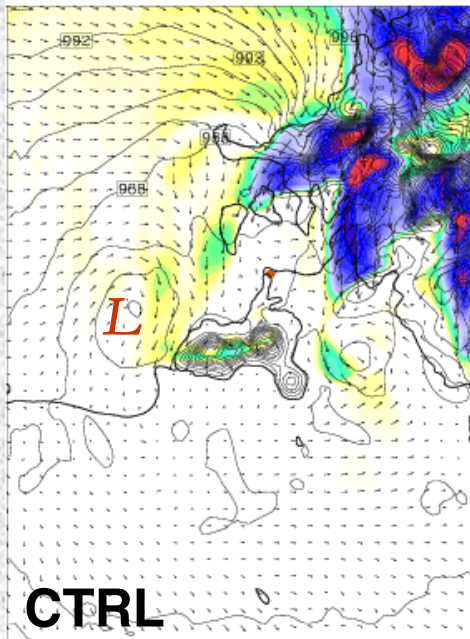
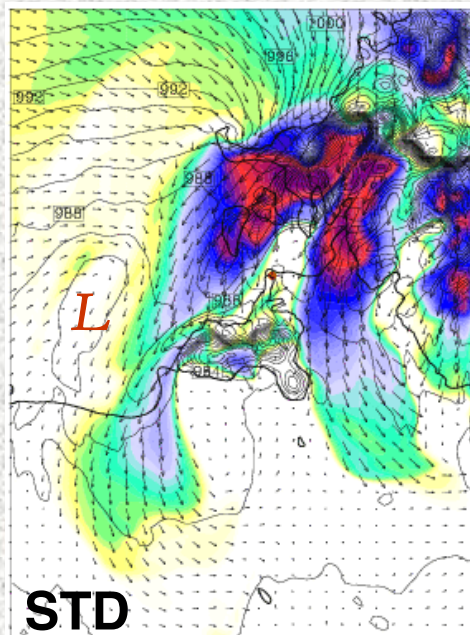


Filtered— MOD1

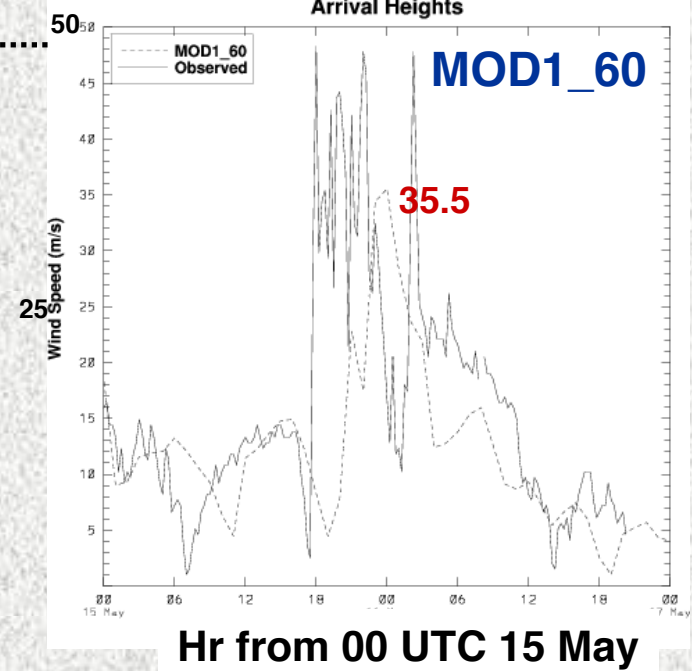
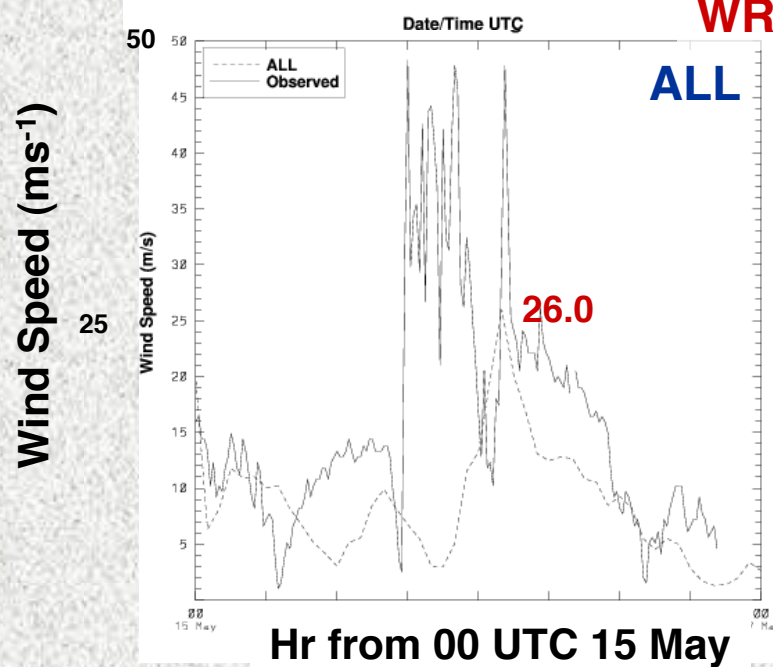
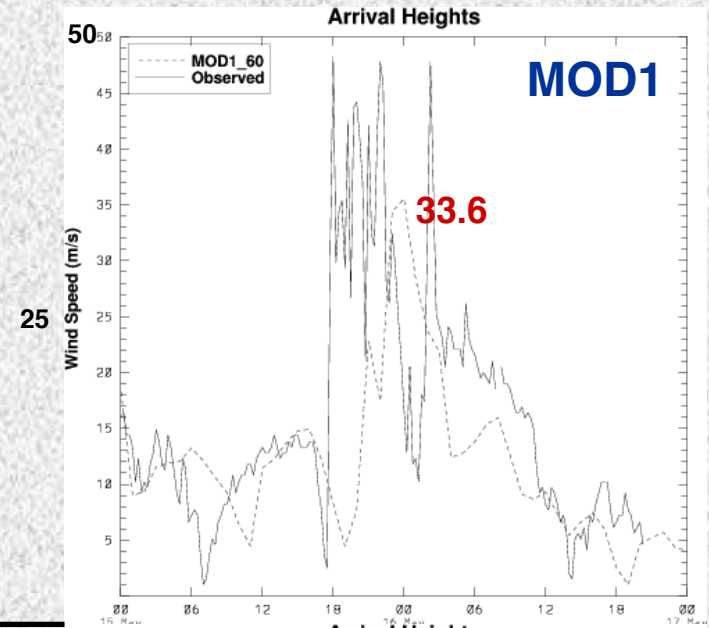
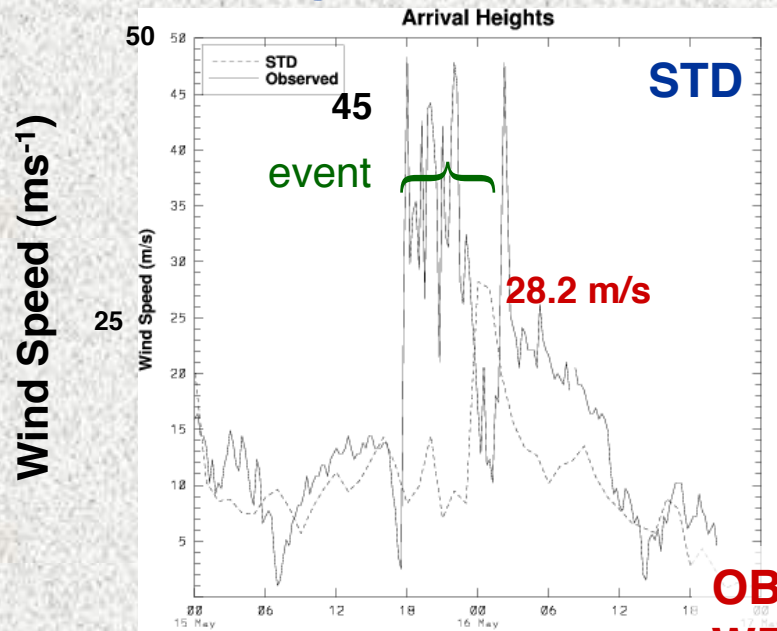
0000 UTC 15 May 2004 Init

Experiment Results— WRF Sfc Winds 2300 UTC 15 May (Hr 23)

Sfc Winds (ms^{-1})
SLP (hPa)

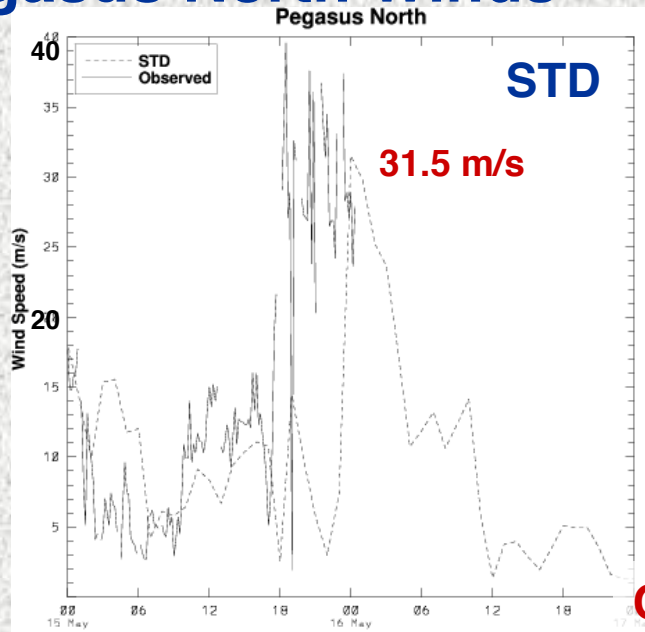


Arrival Heights Winds



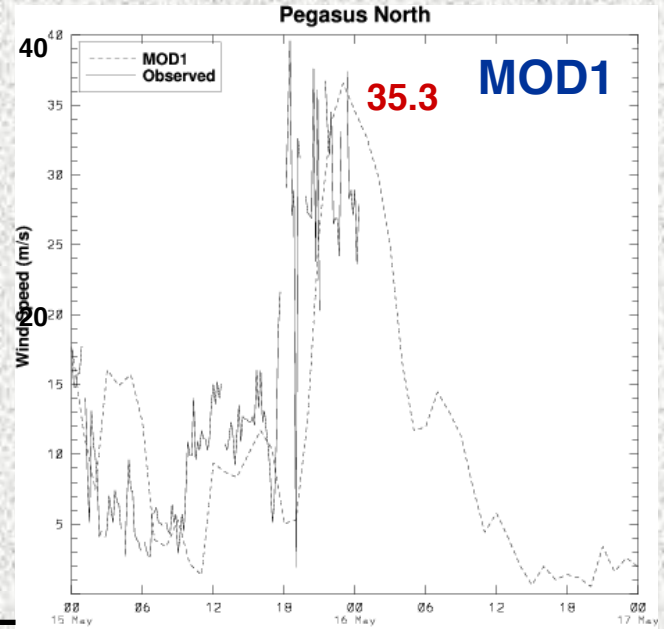
Pegasus North Winds

Wind Speed (ms^{-1})

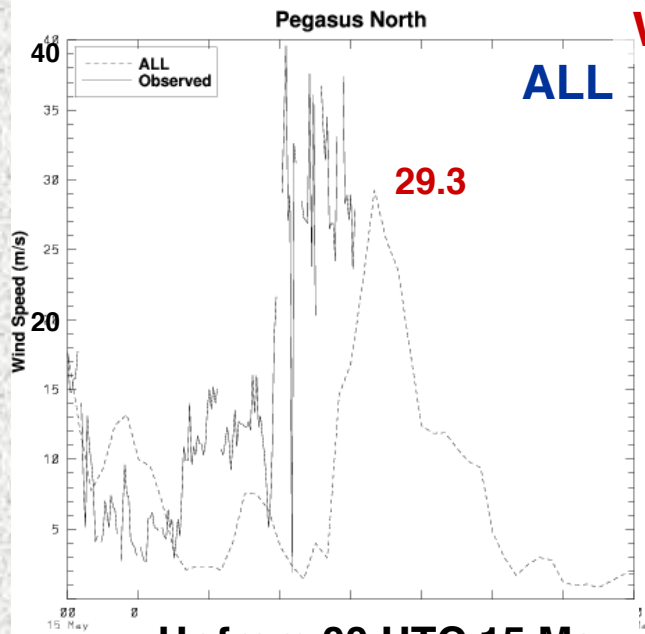


OBS: —

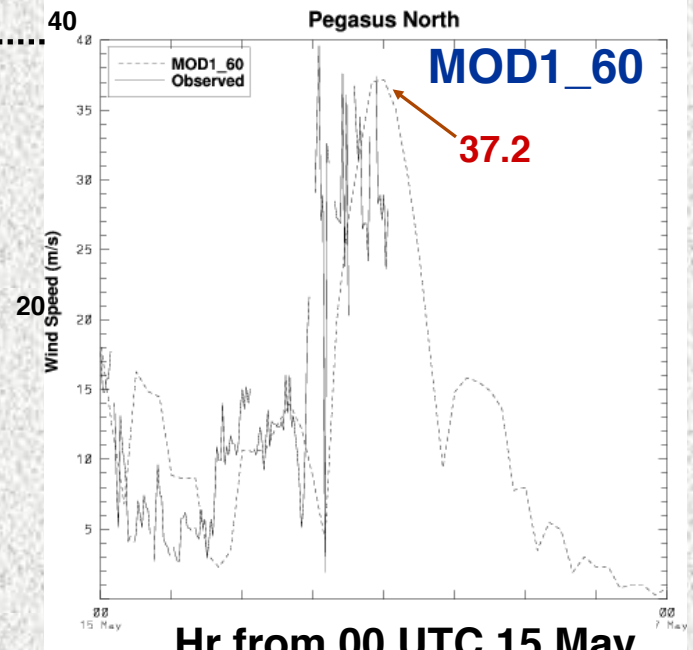
WRF: - - -



Wind Speed (ms^{-1})



Hr from 00 UTC 15 May



Hr from 00 UTC 15 May

Wind Speed Errors

Average: Arrival Heights, Pegasus N., Black Is., Minna Bluff,
Marilyn, Schwerdtfeger

Forecast: Hours 0–48 (0000–0000 UTC 15–17 May)

<u>Expt</u>	<u>Bias</u>	<u>MAE</u>	<u>RMSE</u> (ms ⁻¹)
CTRL	-9.9	10.8	13.9
<u>STD</u>	<u>-6.7</u>	<u>9.1</u>	<u>11.8</u>
ALL	-11.4	12.4	15.5
<u>MOD1</u>	<u>-5.8</u>	<u>8.2</u>	<u>10.5</u>
MOD1_60	-5.0	7.8	10.2
MM5	-5.5	8.5	10.7

Testing of Differences of Experiment Mean Errors

$H_0: \mu_1 - \mu_2 = 0$ Error means of two experiments = 0

$H_1: \mu_1 - \mu_2 \neq 0$ One-tailed test for $|\mu_1| < |\mu_2|$ $\alpha = .05$

“EXPT” error mean lower at 95% level / EXPT₉₀ 90% level I = Inconclusive, 90% level

Hours 0–48

<u>Expt 1</u>	<u>Expt 2</u>	<u>Bias</u>	<u>MAE</u>
STD	CTRL	STD	I
ALL	CTRL	I	I
MOD1	CTRL	MOD1	MOD1
MOD1_60	CTRL	MOD1_60	MOD1_60
<u>ALL</u>	<u>STD</u>	<u>STD</u>	<u>STD</u>
<u>MOD1</u>	<u>STD</u>	<u>MOD1</u>	<u>MOD1</u>
MOD1_60	STD	MOD1_60	MOD1_60
ALL	MOD1	MOD1	MOD1
<u>MOD1_60</u>	<u>MOD1</u>	<u>I</u>	<u>MOD1_60₉₀</u>
MOD1_60	ALL	MOD1_60	MOD1_60

Preliminary May 2004 MODIS Assimilation Tests

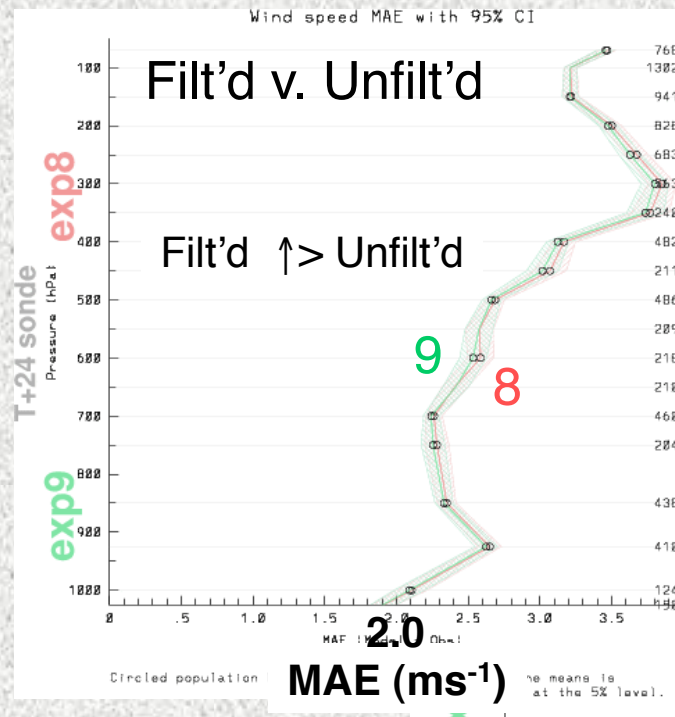
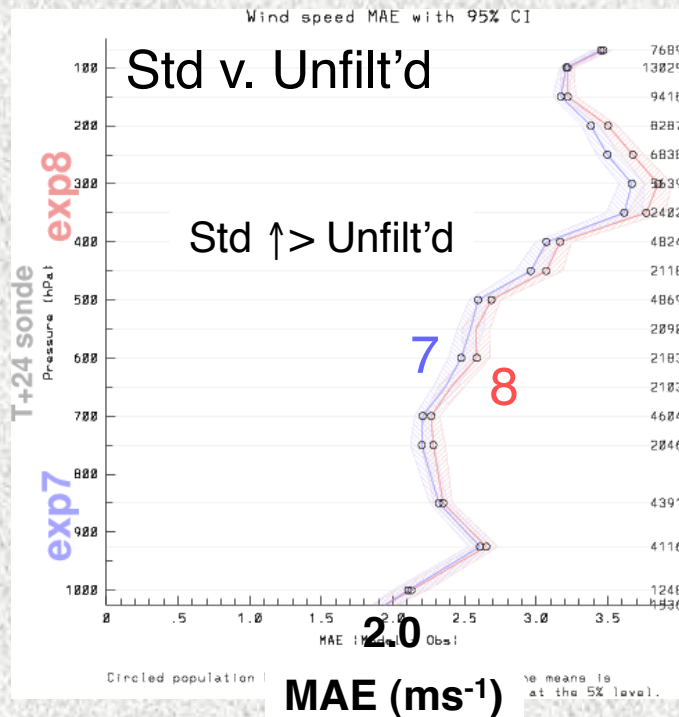
- 60-km domain only
- 0000 UTC and 1200 UTC 48-hr forecasts
- GFS first-guess

Expt 7 — Assimilation of standard obs only (STD)

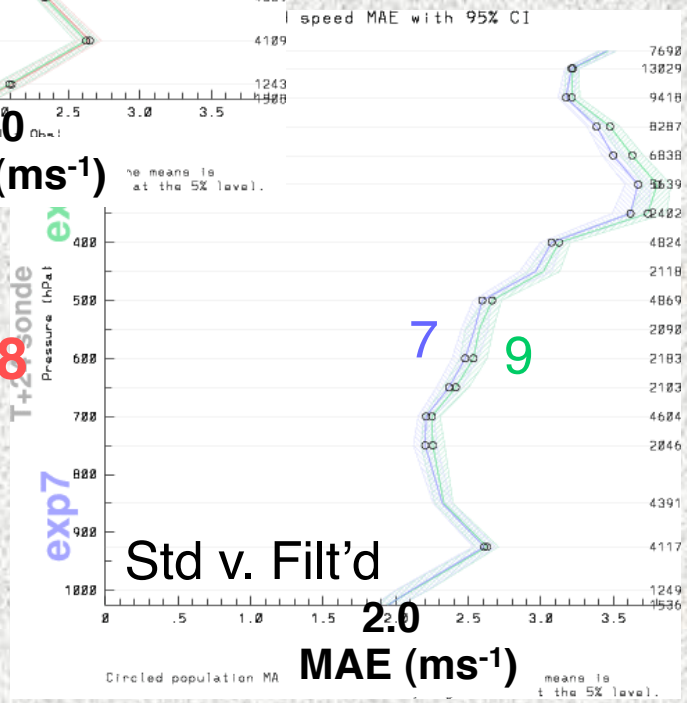
Expt 8 — Std + Unfiltered MODIS (ALL)

Expt 9 — Std + Filtered MODIS (MOD1)

May 2004 Testing — Wind Speed MAEs

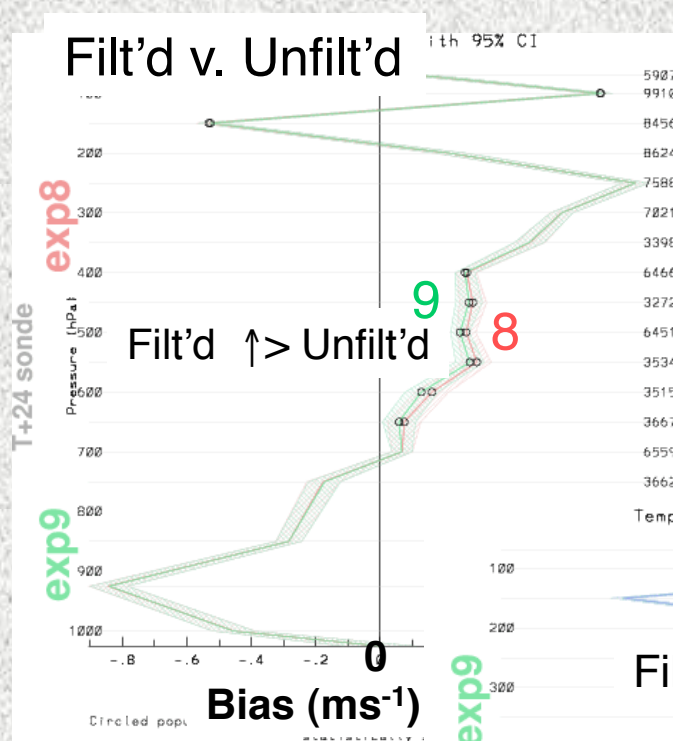
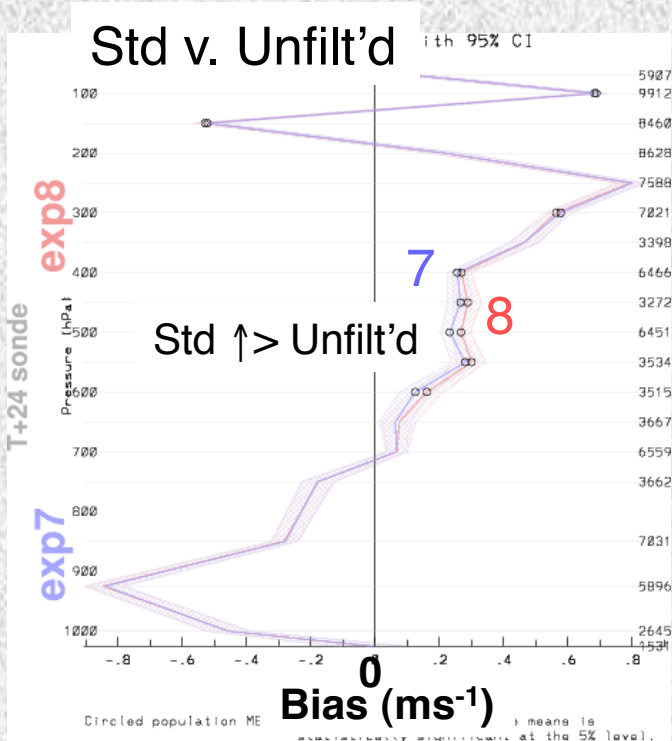


↑> : Better than

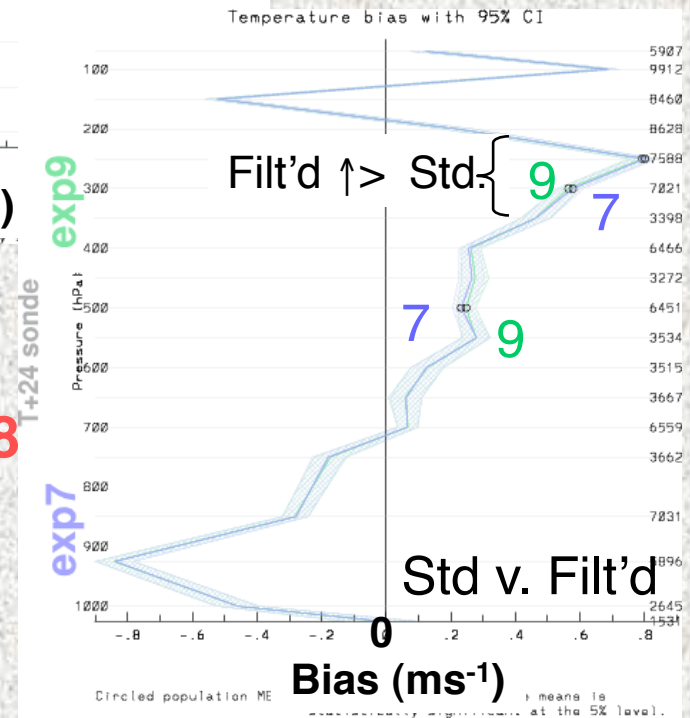


- Standard obs only: Expt 7
 - Unfilt'd= Unfiltered MODIS + std: Expt 8
 - Filt'd= Filtered MODIS + std: Expt 9
- o = Statistically significant difference

May 2004 Testing— T Biases



↑> : Better than



- Standard obs only: Expt 7
 - Unfilt'd= Unfiltered MODIS + std: Expt 8
 - Filt'd= Filtered MODIS + std: Expt 9
- o = Statistically significant difference

III. Summary and Conclusions

- **Positive Impact of MODIS Polar Winds for May 2004
McMurdo Windstorm Forecast**
 - *Filtering based on channel / ob height / surface necessary*
 - *Stronger, more faithful reproduction of mesoscale wind event with filtered MODIS ingest*
- **Statistically Significant Lower Errors w/Filtered MODIS**
 - *Wind speed forecast improvements over:*
 - a) Unfiltered MODIS*
 - b) Standard obs*

- **Preliminary Monthly Statistical Results Mixed**

- *Consistent improvements*

- a) *Standard data > unfiltered MODIS*

- b) *Filtered MODIS > unfiltered MODIS*

- *Improvements from filtered MODIS v. standard data variable*

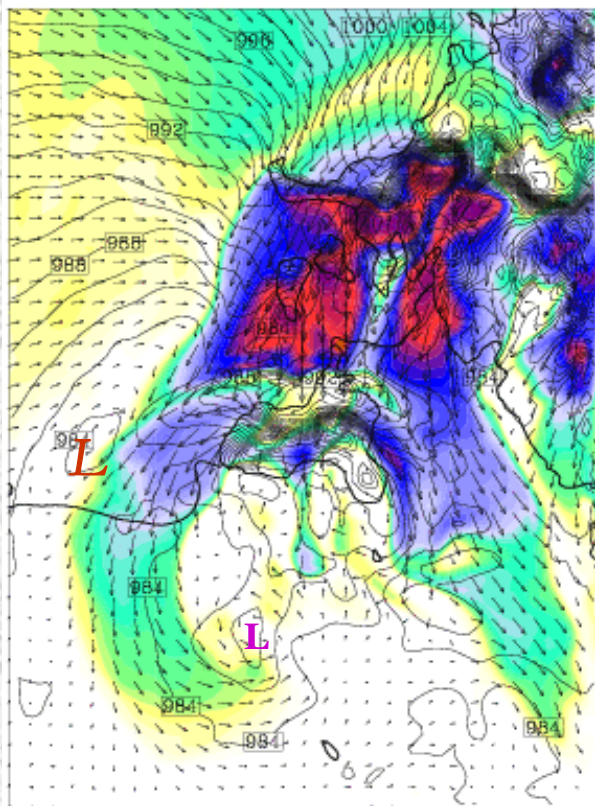
- *Ongoing work*

- * *Finer-grid (20-km) focus on Antarctica*

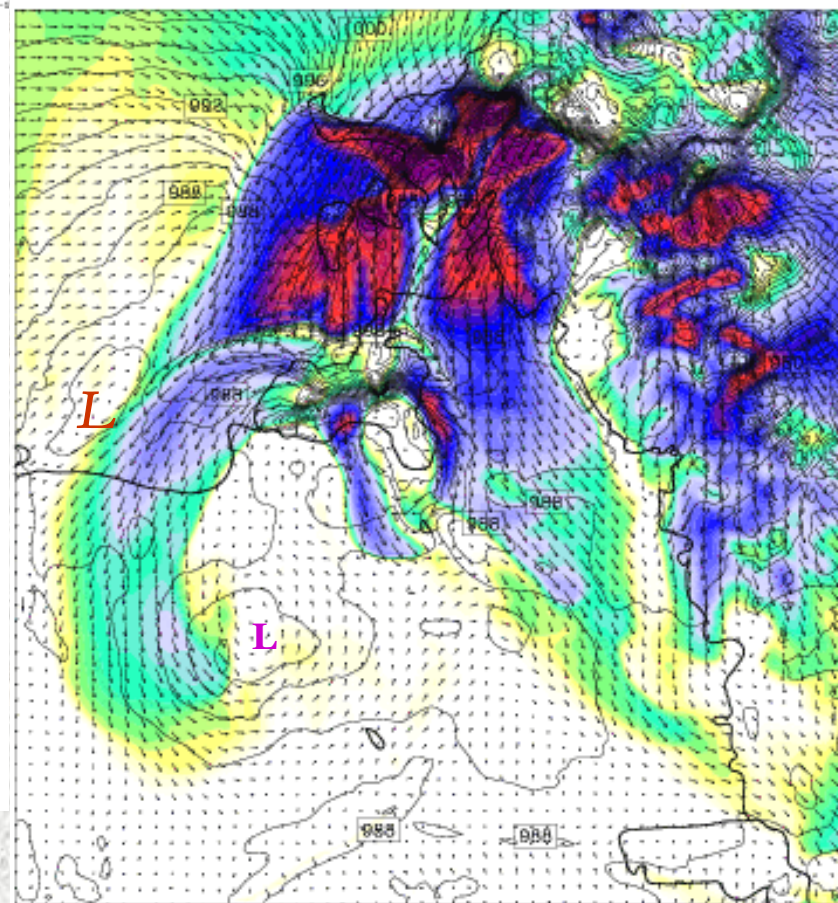
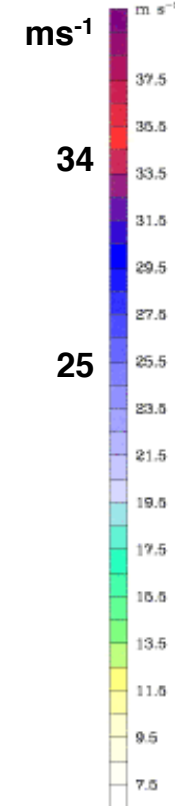
- * *Verification focus on Antarctica*

WRF Sfc Winds

2300 UTC 15 May (Hr 23)



MOD1 3.3 km



MOD1_60 2.2 km

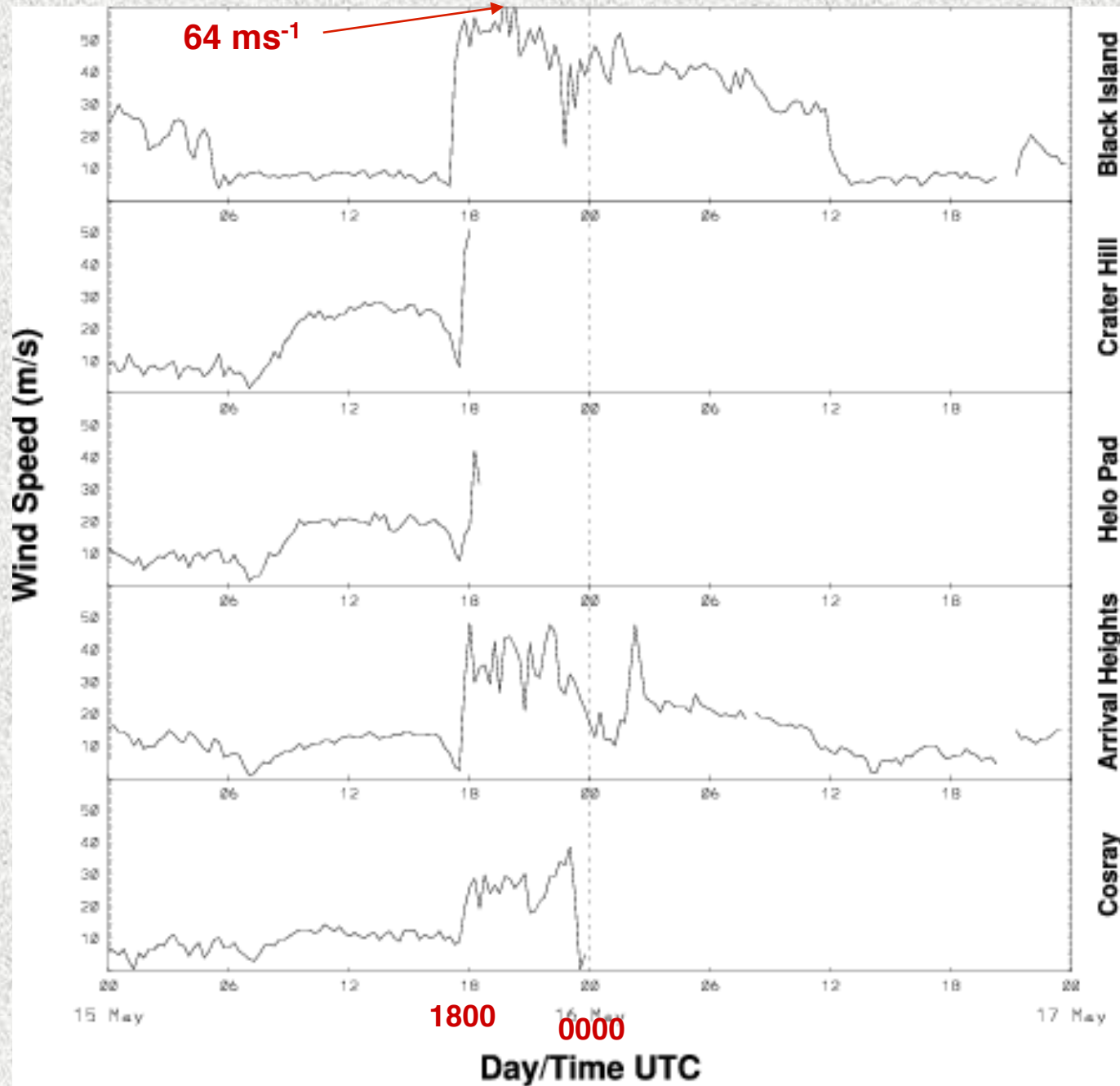
Sfc Winds (ms⁻¹)
SLP (hPa)

Testing of Differences of Experiment Mean Errors

“EXPT” error mean lower at 95% level / EXPT₉₀ 90% level
I= Inconclusive, 90% level MOD1_60= MOD1_60

Hours 0–48

<u>Expt 1</u>	<u>Expt 2</u>	<u>Bias</u>	<u>MAE</u>
CTRL	MM5	MM5	I
STD	MM5	MM5	I
<u>ALL</u>	<u>MM5</u>	<u>MM5</u>	<u>MM5₉₀</u>
<u>MOD1</u>	<u>MM5</u>	<u>I</u>	<u>I</u>
<u>MOD1_60</u>	<u>MM5</u>	<u>I</u>	<u>MOD1_60₉₀</u>



**McMurdo Region
Winds (ms⁻¹)**

15–17 May 2004

Wind Speed Errors

Avg. for: Arrival Heights, Pegasus N., Black Is., Minna Bluff, Marilyn, Schwerdtfeger

Forecast: Hours 0–48 (0000–0000 UTC 15–17 May)

<u>Expt</u>	<u>Bias</u>	<u>MAE</u>	<u>RMSE</u> (ms ⁻¹)
CTRL	-9.9	10.8	13.9
STD	-6.7	9.1	11.8
ALL	-11.4	12.4	15.5
MOD1	-5.8	8.2	10.5
MOD1_60	-5.0	7.8	10.2
MM5	-5.5	8.5	10.7

Episode: Hours 12–30 (1200 UTC 15–0600 UTC 16 May)

<u>Expt</u>	<u>Bias</u>	<u>MAE</u>	<u>RMSE</u> (ms ⁻¹)
CTRL	-6.2	7.5	10.6
STD	-4.4	6.9	9.4
ALL	-5.9	7.8	11.1
MOD1	-2.9	6.1	8.3
MOD1_60	-2.4	5.8	7.9
MM5	-3.1	6.9	8.9

Testing of Differences of Experiment Mean Errors

$H_0: \mu_1 - \mu_2 = 0$ Population (error) means of two experiments = 0

$H_1: \mu_1 - \mu_2 \neq 0$ One-tailed test for $|\mu_1| < |\mu_2|$ $\alpha = .05$ MOD1_60 = MOD1_60

“EXPT” error mean lower at 95% level / EXPT₉₀ 90% level I = Inconclusive, 90% level

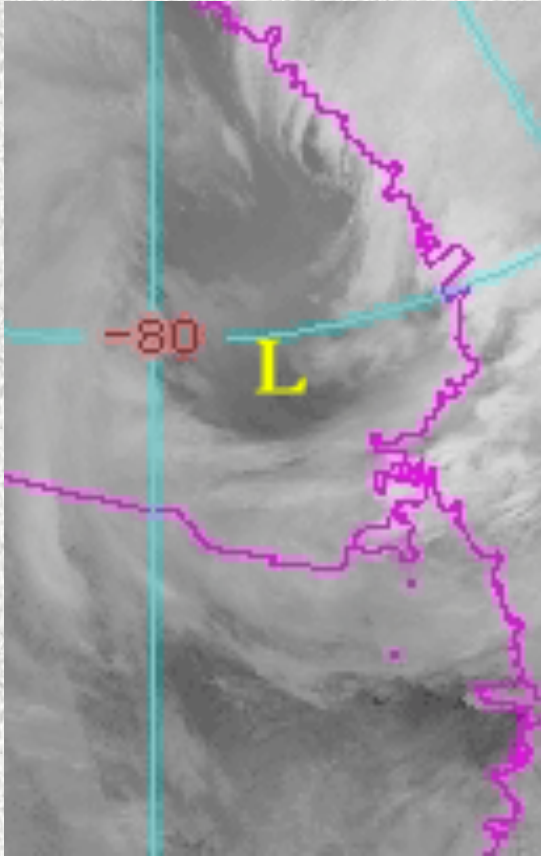
		Hours 12–30		Hours 0–48	
<u>Expt 1</u>	<u>Expt 2</u>	<u>Bias</u>	<u>MAE</u>	<u>Bias</u>	<u>MAE</u>
STD	CTRL	STD	I	STD	I
ALL	CTRL	CTRL	CTRL	I	I
MOD1	CTRL	MOD1	MOD1	MOD1	MOD1
MOD1_60	CTRL	MOD1_60	MOD1_60	MOD1_60	MOD1_60
	MOD1_60				
<u>ALL</u>	<u>STD</u>	<u>STD</u>	<u>STD</u>	<u>STD</u>	<u>STD</u>
<u>MOD1</u>	<u>STD</u>	I	I	<u>MOD1</u>	<u>MOD1</u>
MOD1_60	STD		MOD1_60 ₉₀	MOD1_60 ₉₀	MOD1_60
	MOD1_60				
ALL	MOD1	MOD1	MOD1	MOD1	MOD1
<u>MOD1_60</u>	<u>MOD1</u>	<u>MOD1_60</u>	<u>MOD1_60₉₀</u>	I	
	<u>MOD1_60₉₀</u>				
MOD1_60	ALL	MOD1_60	MOD1_60	MOD1_60	MOD1_60
	MOD1_60				

Testing of Differences of Experiment Mean Errors

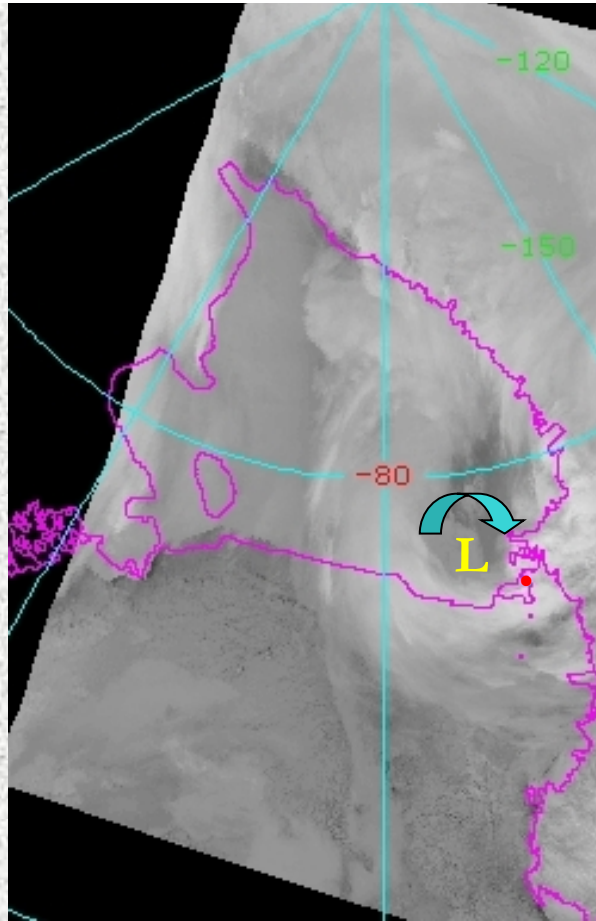
“EXPT” error mean lower at 95% level / EXPT₉₀ 90% level | = Inconclusive, 90% level
 MOD1_60= MOD1_60

<u>Expt 1</u>	<u>Expt 2</u>	Hours 12–30		Hours 0–48	
		<u>Bias</u>	<u>MAE</u>	<u>Bias</u>	<u>MAE</u>
CTRL	MM5	MM5	CTRL ₉₀	MM5	
STD	MM5	STD ₉₀		MM5	
<u>ALL</u>	<u>MM5</u>	<u>MM5</u>	<u>MM5</u>	<u>MM5</u>	<u>MM5₉₀</u>
<u>MOD1</u>	<u>MM5</u>				
<u>MOD1 60</u>	<u>MM5</u>				<u>MOD1 60₉₀</u>

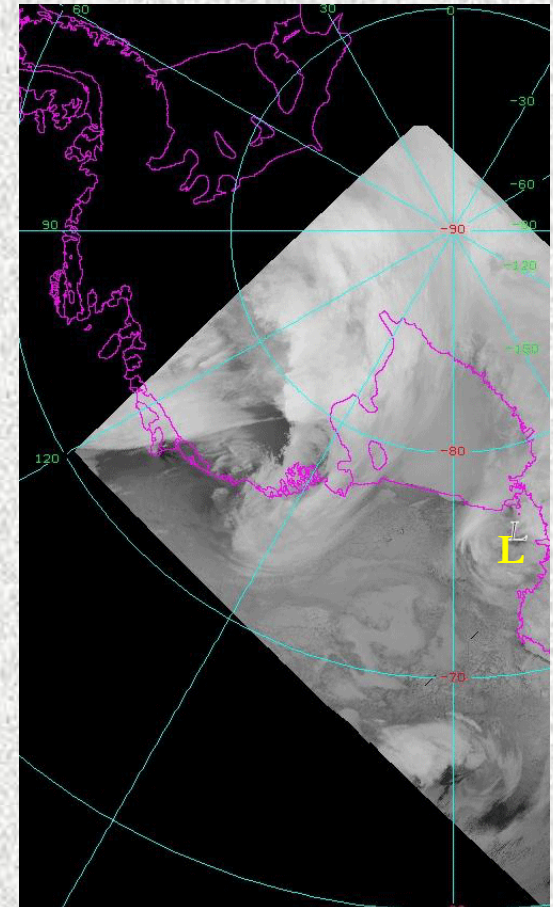
McMurdo Windstorm Low



1810 UTC 15 May



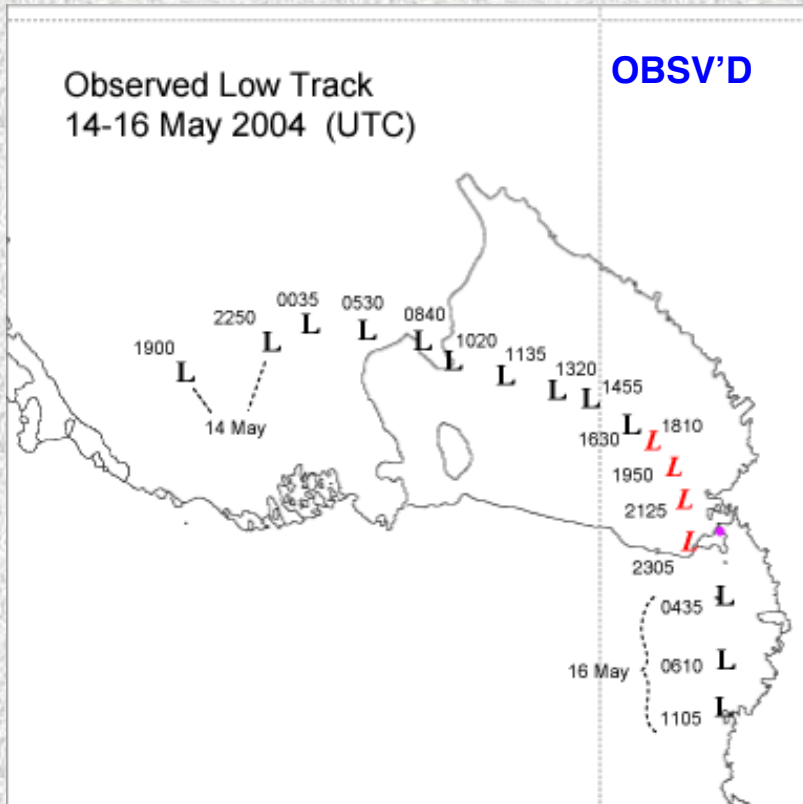
2125 UTC 15 May



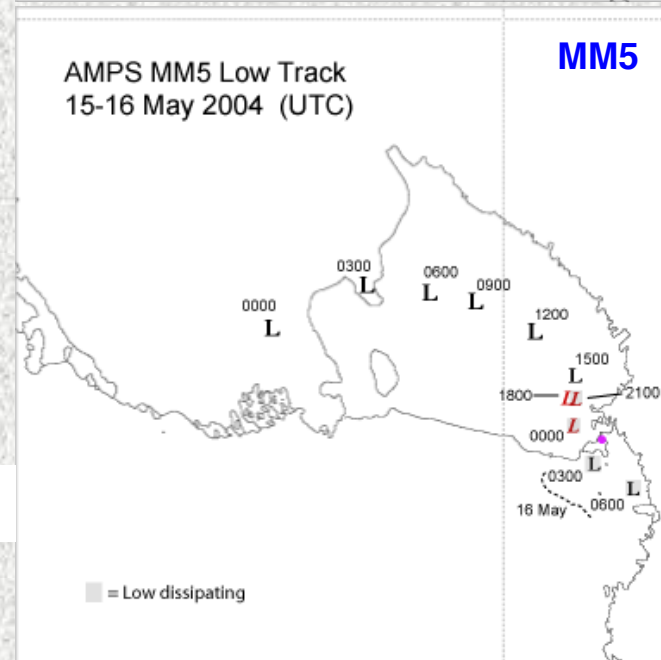
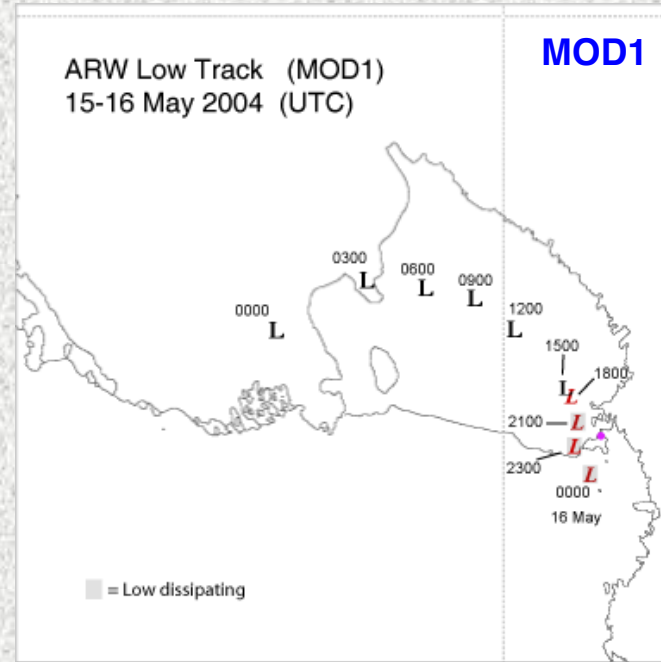
0435 UTC 16 May

IR Imagery 15–16 May 2004

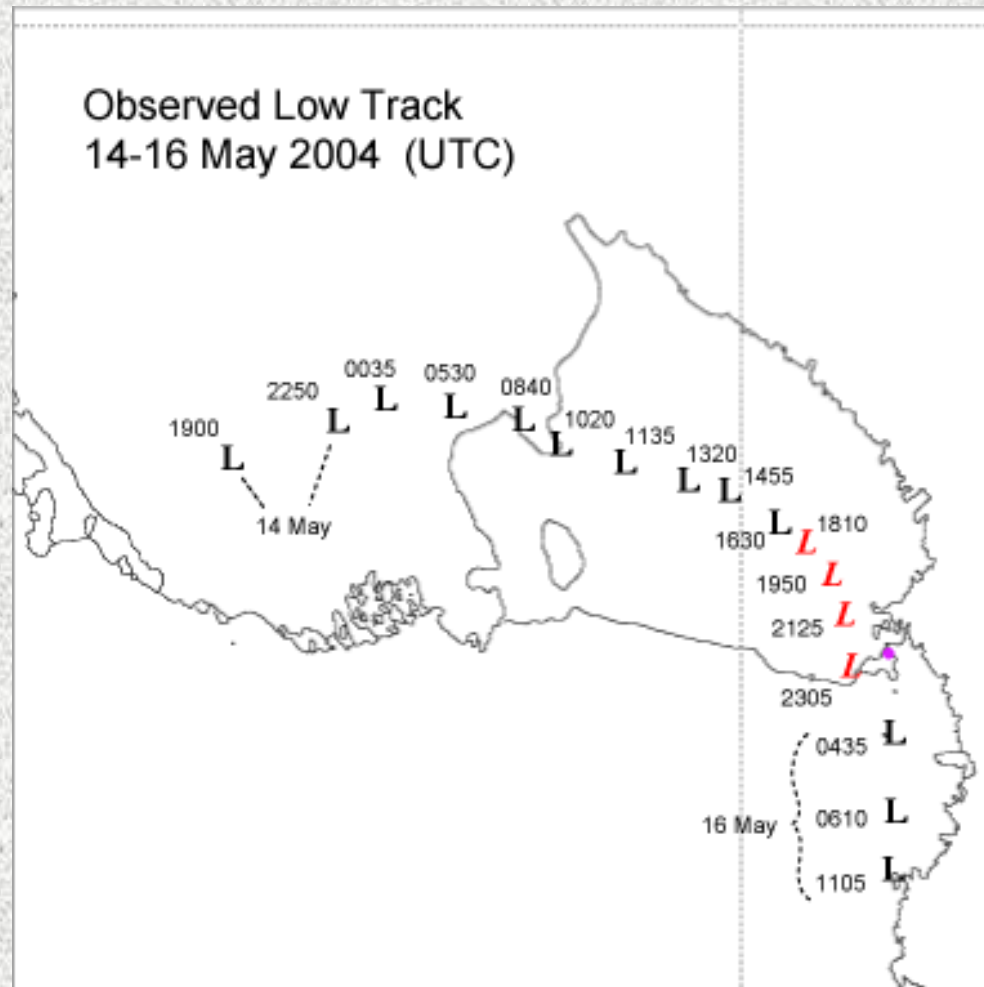
May 2004 Low Tracks



L = Period of observed high winds

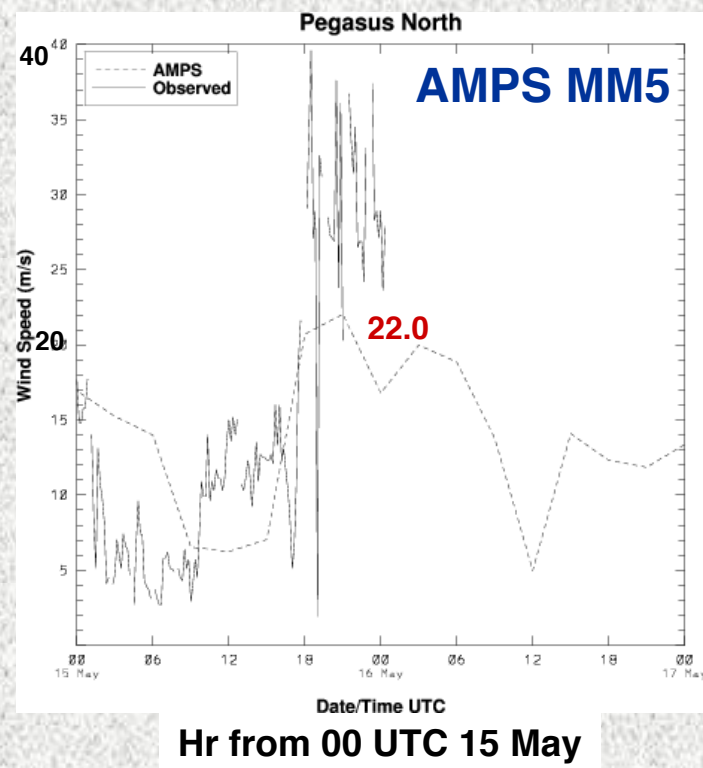
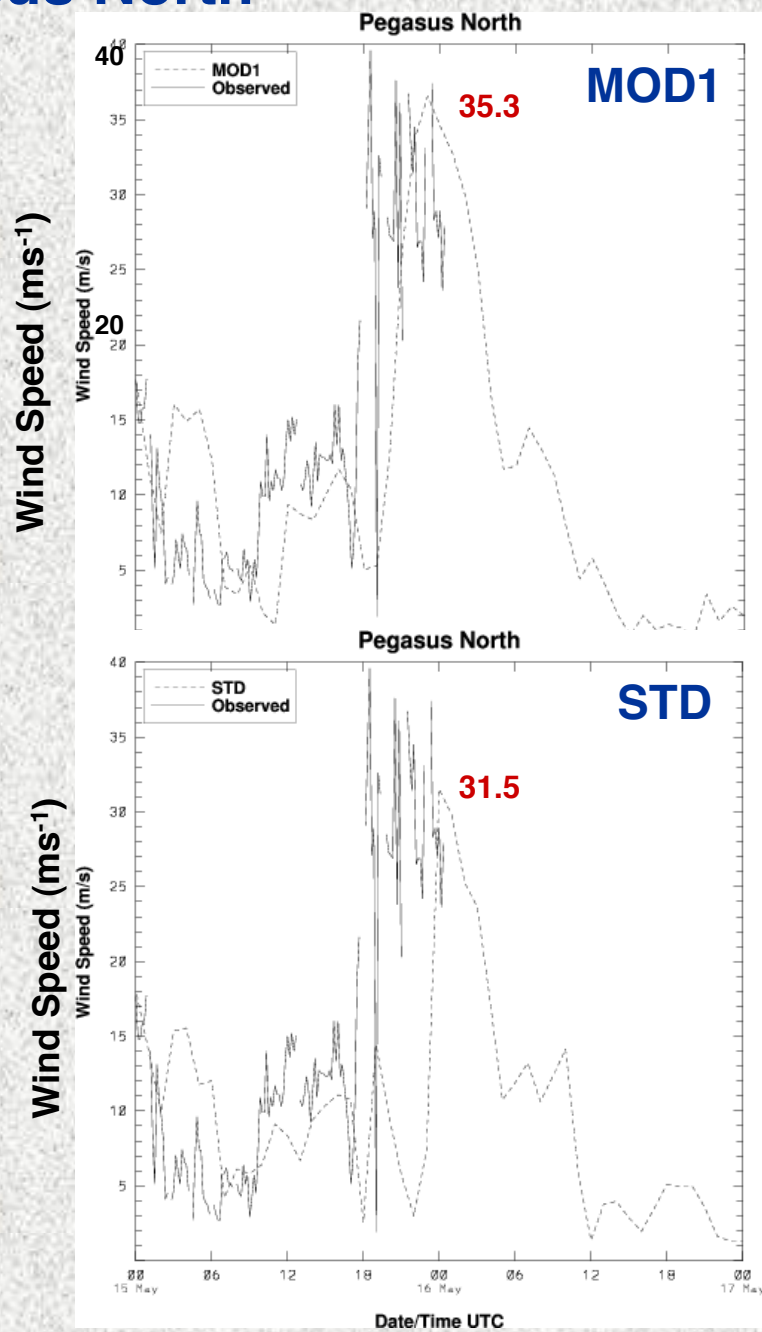


McMurdo Windstorm Low— Track



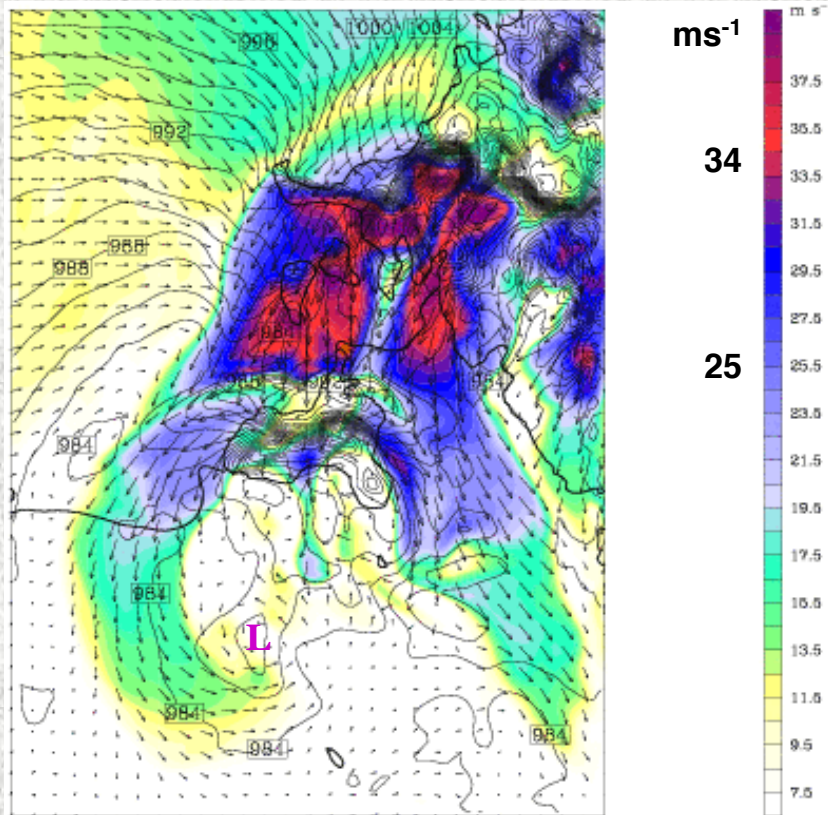
L = Period of observed high winds

Pegasus North

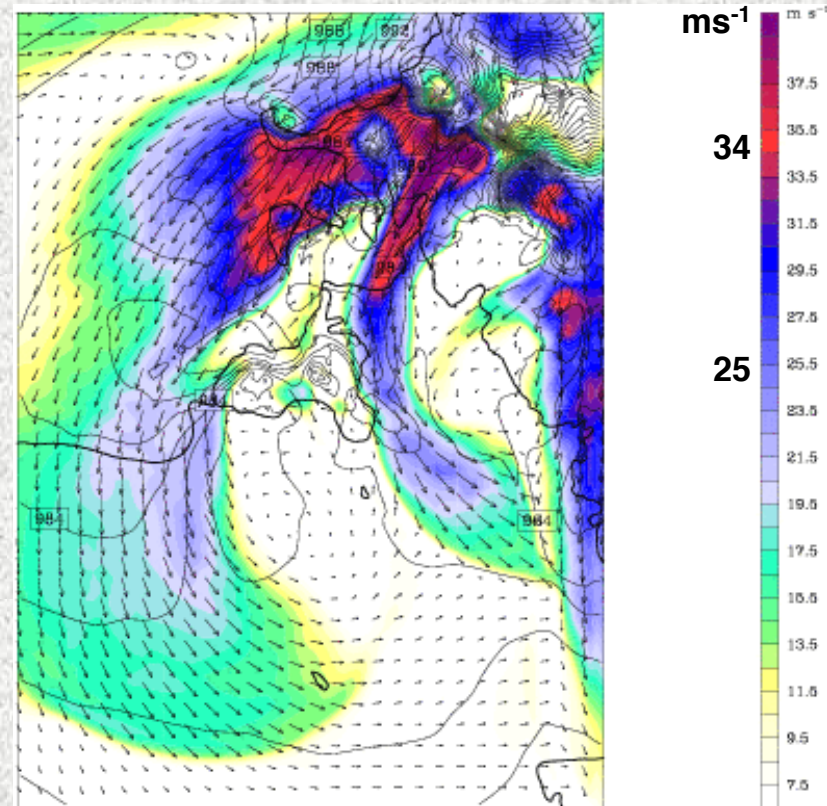


OBS: ———
WRF: ·····

WRF Sfc Winds 2300 UTC 15 May (Hr 23)



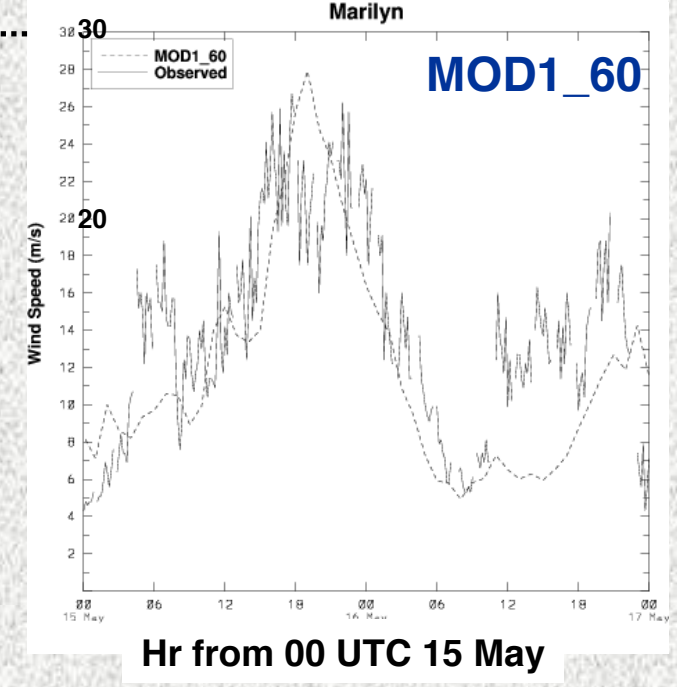
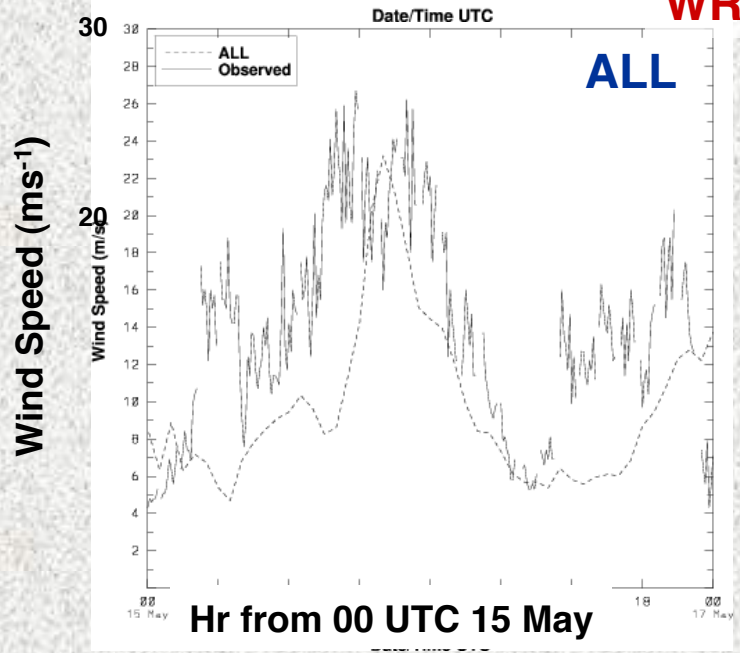
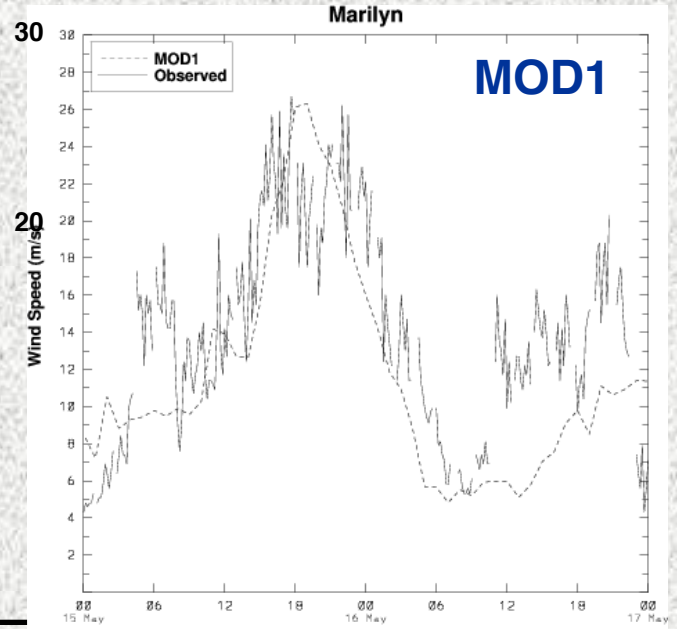
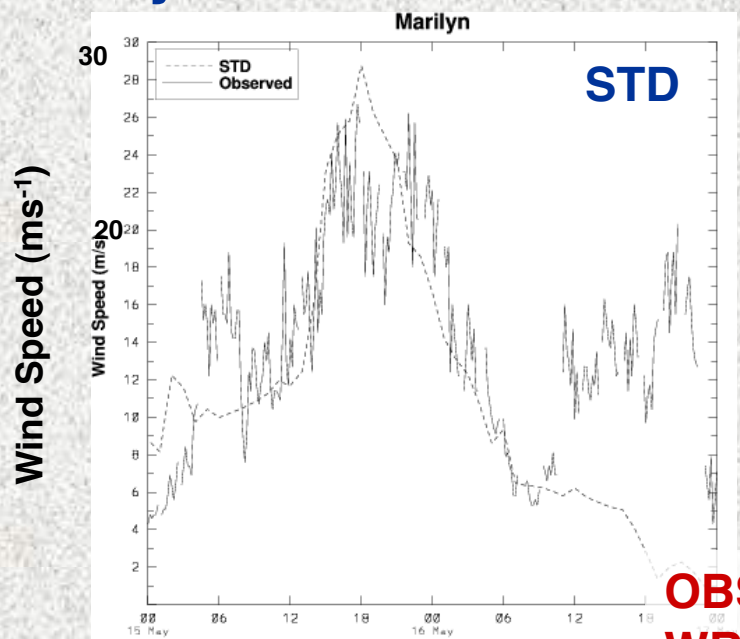
MOD1 3.3 km



MM5 3.3 km

Sfc Winds (ms^{-1})
SLP (hPa)

Marilyn Winds



OBS: —
WRF: - - -

Hr from 00 UTC 15 May

Hr from 00 UTC 15 May

Cumulative Comparisons

Hours 12–30

Bias

MAE

MOD1_60

MOD1_60

MOD1, STD

MOD1, STD

CTRL

CTRL

ALL

ALL

Hours 0–48

Bias

MAE

MOD1, MOD1_60

MOD1, MOD1_60

STD

STD

CTRL, ALL

CTRL

ALL

Experiments listed by scores computed from summing values from comparisons: +1 for a significantly better (95% level) error than another expt, -1 for a significantly worse error, and 0 for an indistinguishable error.

Experiments sharing lines have same sums.