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

<table>
<thead>
<tr>
<th>CTRL</th>
<th>No data assimilation</th>
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</thead>
<tbody>
<tr>
<td>STD</td>
<td>Standard AMPS data only</td>
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<tr>
<td>ALL</td>
<td>Standard AMPS data + all MODIS data</td>
</tr>
<tr>
<td>MOD1</td>
<td>Standard AMPS data + filtered MODIS data</td>
</tr>
<tr>
<td>MOD1_60</td>
<td>As in MOD1 with 60/20/6.7/2.2-km domains</td>
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<tr>
<td>AMPS MM5</td>
<td>Standard AMPS data only</td>
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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$^{-1}$)

STD

MOD1

CTRL

ALL

SLP (hPa)
Arrival Heights Winds

Wind Speed (ms\(^{-1}\))

Hr from 00 UTC 15 May

25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50

STD
MOD1
MOD1_60
ALL
OBS:
WRF:

28.2 m/s
26.0
33.6
35.5

event

Hr from 00 UTC 15 May

Hr from 00 UTC 15 May
Pegasus North Winds

Wind Speed (ms\(^{-1}\))

**OBS:**

- **STD:** 31.5 m/s
- **WRF:**
- **ALL:** 29.3 m/s

**MOD1:**

- **MOD1:** 35.3 m/s
- **MOD1_60:** 37.2 m/s

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)

<table>
<thead>
<tr>
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<th>Bias</th>
<th>MAE</th>
<th>RMSE (ms⁻¹)</th>
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Testing of Differences of Experiment Mean Errors

\[ H_0: \mu_1 - \mu_2 = 0 \quad \text{Error means of two experiments} = 0 \]
\[ H_1: \mu_1 - \mu_2 \neq 0 \quad \text{One-tailed test for } |\mu_1| < |\mu_2| \quad \alpha = .05 \]

“EXPT” error mean lower at 95% level / EXPT\textsubscript{90} 90% level I = Inconclusive, 90% level

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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

- Standard obs only: Expt 7
- Unfilt’d= Unfiltered MODIS + std: Expt 8
- Filt’d= Filtered MODIS + std: Expt 9

o = Statistically significant difference

↑>: Better than
May 2004 Testing— T Biases

- Standard obs only: Expt 7
- Unfilt’d= Unfiltered MODIS + std: Expt 8
- Filt’d= Filtered MODIS + std: Expt 9

<> : Better than

\[ \text{Std} \uparrow> \text{Unfilt’d} \]

\[ \text{Filt’d} \uparrow> \text{Unfilt’d} \]

\[ \text{Std} \uparrow> \text{Unfilt’d} \]

\[ \text{Filt’d} \uparrow> \text{Std} \]

\( = \) 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

  – Ongoing work

    * Finer-grid (20-km) focus on Antarctica
    
    * Verification focus on Antarctica
WRF Sfc Winds

MOD1 3.3 km

Sfc Winds (ms⁻¹)  MOD1_60 2.2 km

SLP (hPa)

2300 UTC 15 May (Hr 23)
Testing of Differences of Experiment Mean Errors

“EXPT” error mean lower at 95% level / \( \text{EXPT}_{90} \) 90% level

\( I = \) Inconclusive, 90% level \hspace{1cm} \text{MOD1}_60 = \text{MOD1}_60

### Hours 0–48

<table>
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<td>( \text{MOD1}<em>60</em>{90} )</td>
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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)**

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

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"EXPT" error mean lower at 95% level / EXPT\_90 90% level I= Inconclusive, 90% level

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Testing of Differences of Experiment Mean Errors

“EXPT” error mean lower at 95% level / EXPT$_{90}$ 90% level I= Inconclusive, 90% level
MOD1$_{60}$= MOD1$_{60}$

<table>
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<tr>
<th>Expt 1</th>
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<th>Hours 12–30</th>
<th>Hours 0–48</th>
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<td>I</td>
<td>MOD1$_{60,90}$</td>
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McMurdo Windstorm Low

IR Imagery 15–16 May 2004

1810 UTC 15 May
2125 UTC 15 May
0435 UTC 16 May
May 2004 Low Tracks

\[ L = \text{Period of observed high winds} \]
McMurdo Windstorm Low — Track

L = Period of observed high winds
Pegasus North

Wind Speed (m/s\(^{-1}\))

MOD1

Wind Speed (m/s\(^{-1}\))

AMPS MM5

Hr from 00 UTC 15 May

OBS: 

WRF: 

Date/Time UTC

35.3

22.0

31.5
Marilyn Winds

Wind Speed (ms\(^{-1}\))

Hr from 00 UTC 15 May

OBS:  

WRF:  

STD

MOD1

ALL

MOD1_60

Hr from 00 UTC 15 May
## Cumulative Comparisons

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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.