A Comparison of Polar WRF and Polar MM5 in Antarctic Surface Forecasts

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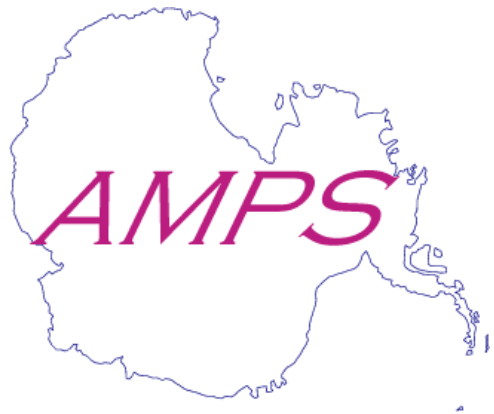


- Testing Performed and Polar WRF
- Statistical Evaluations and Comparisons
- Summary and Conclusions

NCAR

I. Testing Performed and Polar WRF

- **Polar-modified Versions of MM5 and WRF Run in AMPS**
  - Modifications: Improved representations of characteristics and processes over ice sheets, sea ice
  - Polar mods for WRF developed by:
    - Polar Meteorology Group, The Ohio State University
    - NCAR
    - NCEP
- **Simulation Periods**
  - 26 January–15 February 2007 (warm season)
  - 6–23 April 2007 (cold season)

- **WRF Polar Modifications**
  - Fractional sea ice representation
  - Noah Land Sfc Model adjustments
    - ✓ Latent heat of sublimation used over ice surfaces
    - ✓ Adjustment of snow density, heat capacity, and thermal diffusivity (subsurface)
    - ✓ Assumption of ice saturation for calculating sfc saturation mixing ratios over ice
    - ✓ Sensible heat / latent heat / radiation balance at surface enforced (modified skin temp calculation)
    - ✓ Increased snow albedo and emissivity

- **WRF Polar Modifications (cont'd)**

  – Modified initialization of low-level air temps

    - *Interpolation of low-level air temps and subsurface temps*

  – Cycling of subsurface soil temps

  – Decreased shortwave radiation scattering parameter

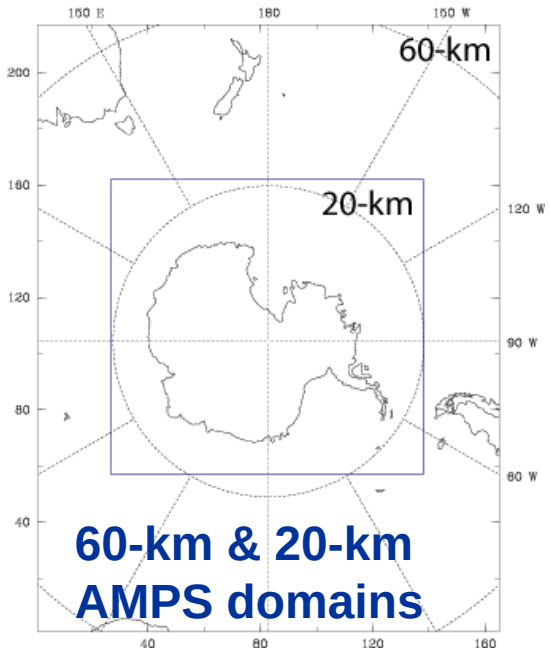
  – Stability-dependent formulation of thermal roughness length (z_{0t})

- **Forecasts and Statistical Analyses**

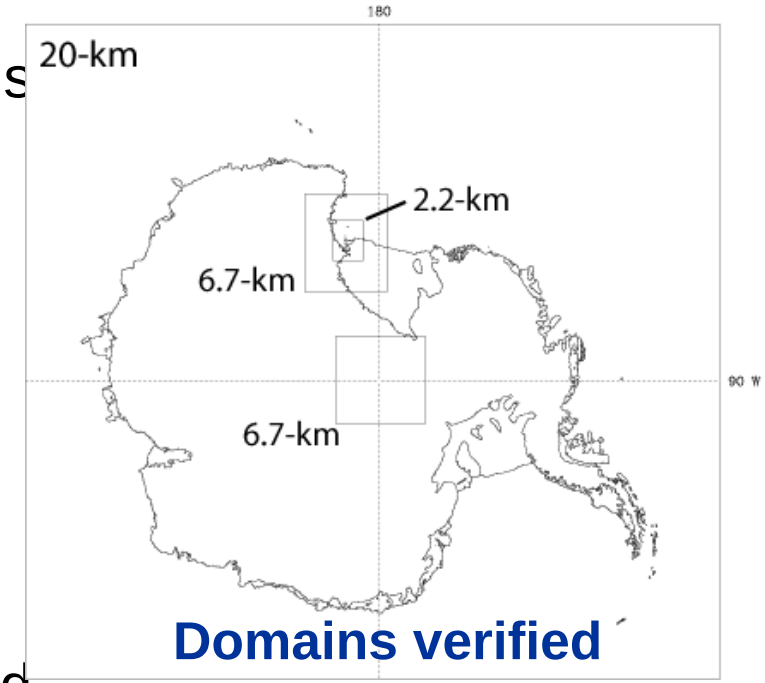
  – 5 AMPS domains run / 4 domains verified
  20-km, 6.7-km (South Pole, W. Ross Sea), 2.2-km

  – 0000 & 1200 UTC initializations

  – 48-hr forecasts



60-km & 20-km AMPS domains



Domains verified

  – Variables analyzed

Surface T (lowest model half-level) (T)

2-m T (T2)

Surface wind speed (WSP)

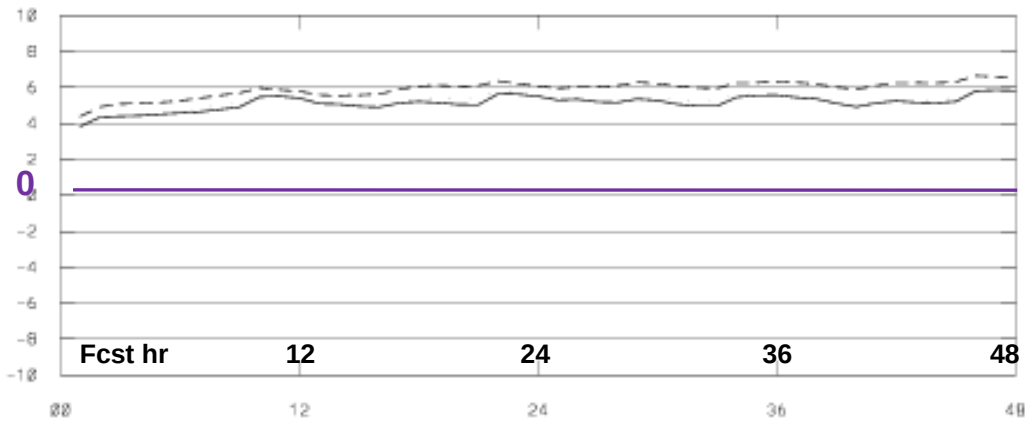
- **Forecasts and Statistical Analyses (cont'd)**
  - Error statistics computed from verifications at sfc stations and AWS sites
  - Statistics computed
    - Bias (Mean Error— ME)
    - Mean Absolute Error (MAE)
    - RMSE
  - Significance testing performed
    - Student's t-tests applied on mean error differences

      Ex: $\overline{MAE}_{WRF} - \overline{MAE}_{MM5}$, where $\overline{\quad}$ denotes avg over sites in given domain / given fcst hr /month / variable
    - 95% confidence level

II. Statistical Evaluations and Comparisons

Domain 4 South Pole— Sfc T Errors (°C)

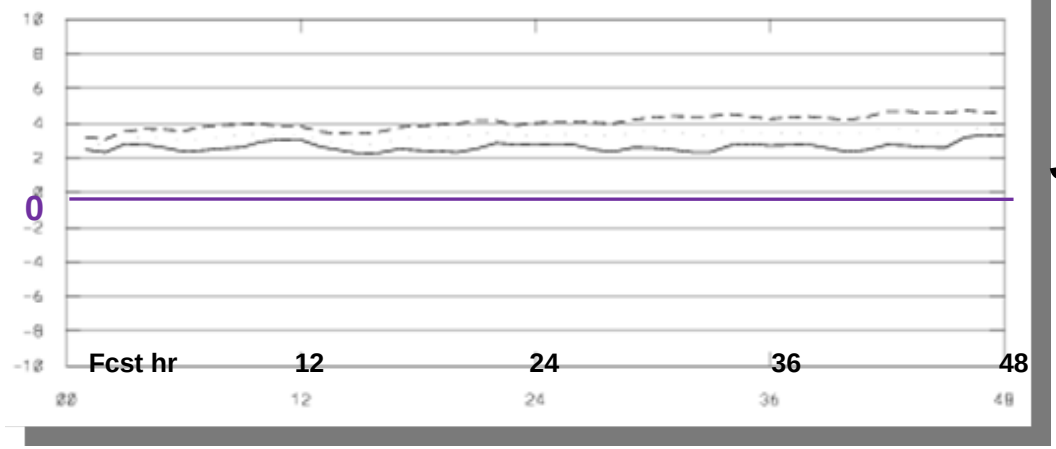
avg bias = 5.132 avg RMSE = 5.916 avg MAE = 5.216



Jan.-Feb. MM5

Bias— Solid
RMSE— Dashed
——— : 0 °C

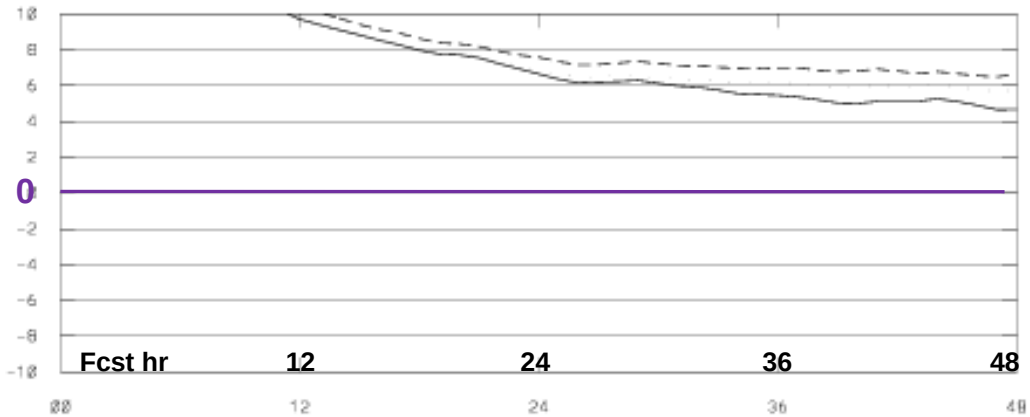
avg bias = 2.633 avg RMSE = 4.045 avg MAE = 3.307



Jan.-Feb. WRF

Domain 4 South Pole— Sfc T Errors (°C)

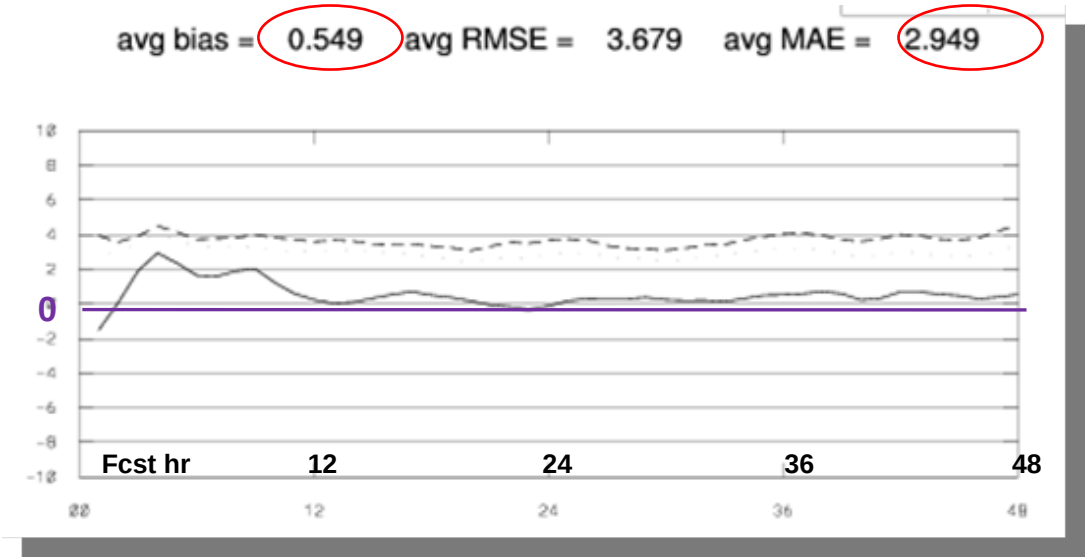
avg bias = 8.095 avg RMSE = 9.190 avg MAE = 8.428



April MM5

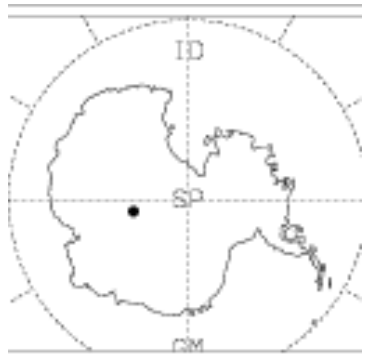
Bias— Solid
RMSE— Dashed

avg bias = 0.549 avg RMSE = 3.679 avg MAE = 2.949

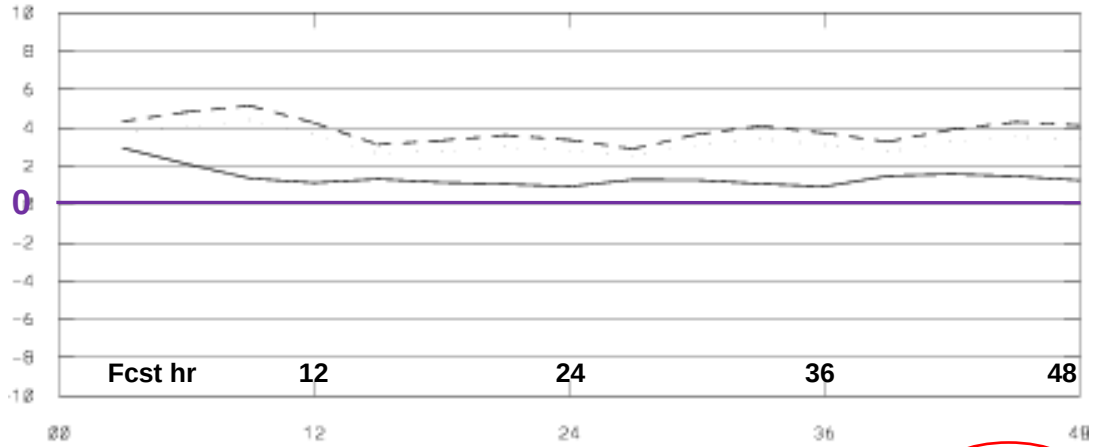


April WRF

Domain 2 Dome A— Sfc T Errors (°C)

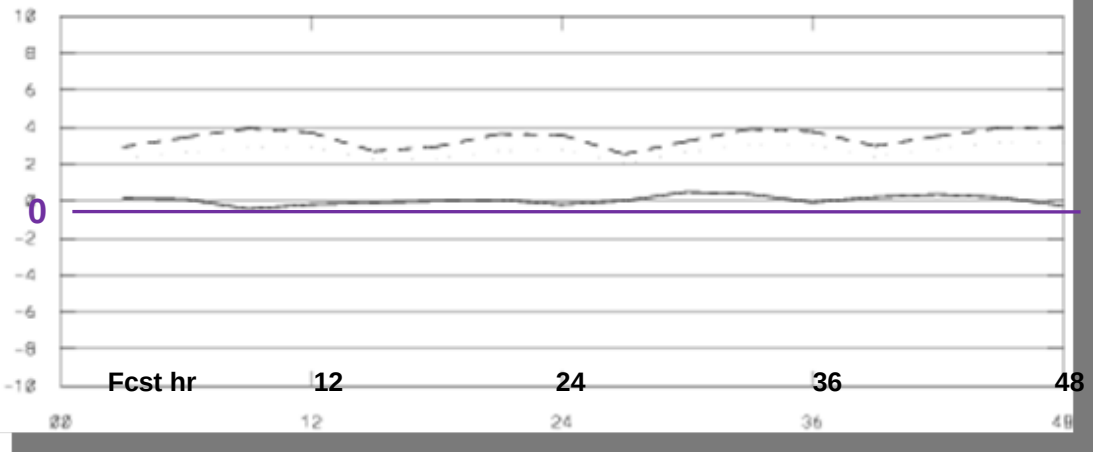


avg bias = 1.390 avg RMSE = 3.870 avg MAE = 3.259



Jan.-Feb. MM5

avg bias = 0.043 avg RMSE = 3.415 avg MAE = 2.687

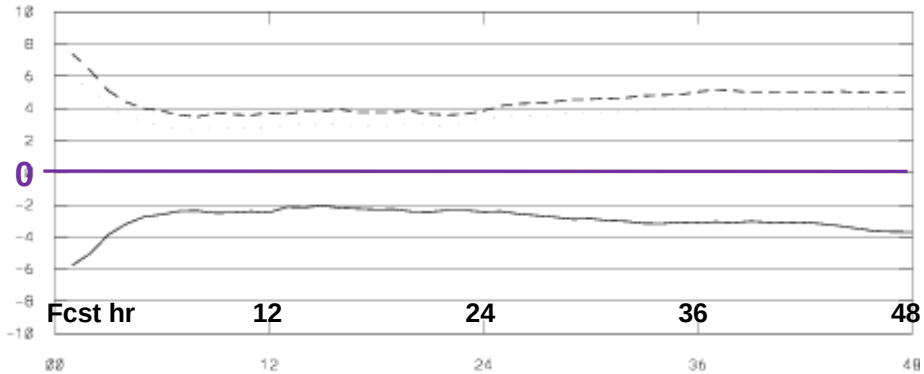


Bias— Solid
RMSE— Dashed

Jan.-Feb. WRF

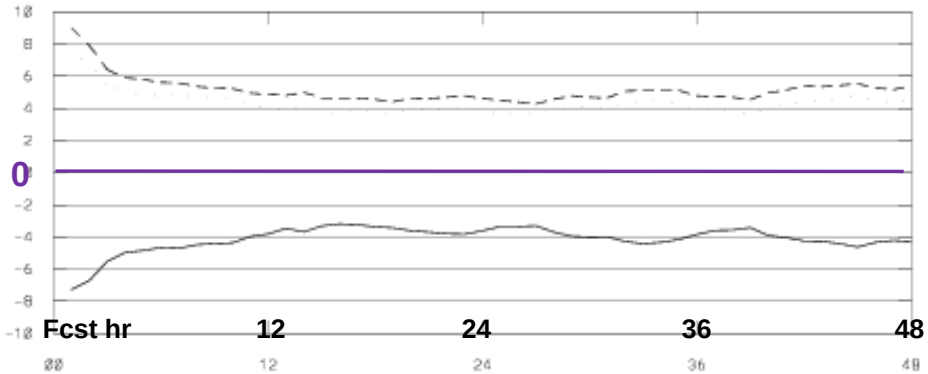
Domain 5 Pegasus North— Sfc T Errors (°C)

avg bias = -2.909 avg RMSE = 4.435 avg MAE = 3.537



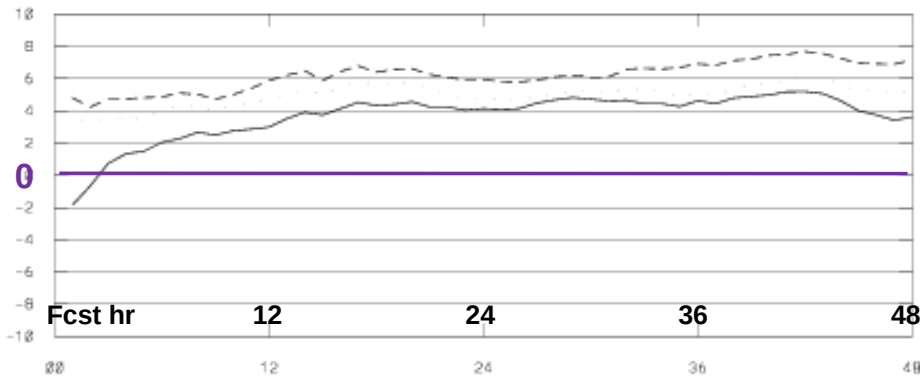
Jan.-Feb. MM5

avg bias = -4.123 avg RMSE = 5.131 avg MAE = 4.329



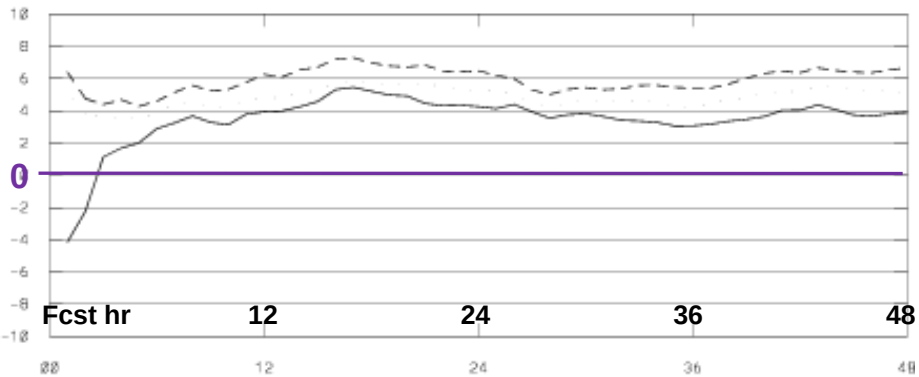
Jan.-Feb. WRF

avg bias = 3.679 avg RMSE = 6.179 avg MAE = 4.946



April MM5

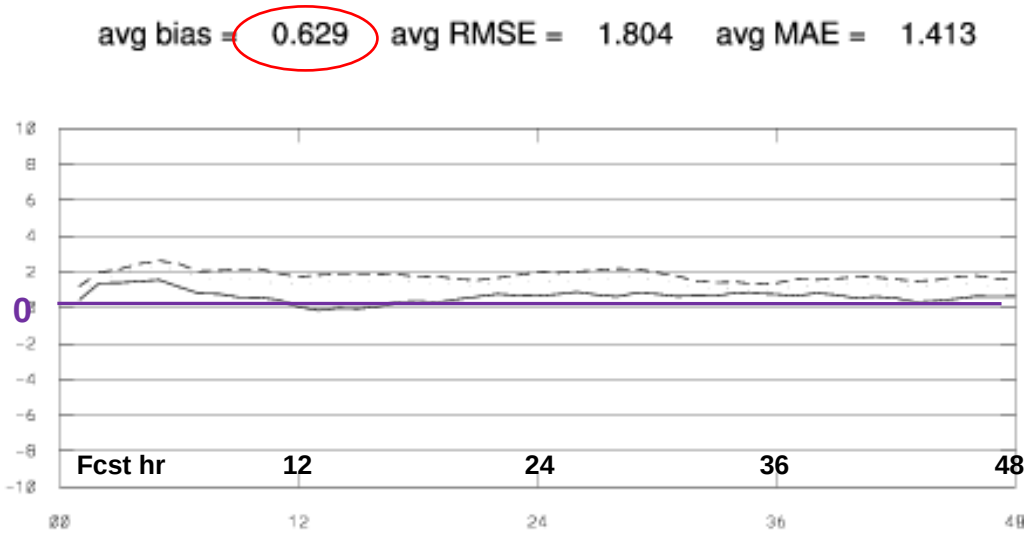
avg bias = 3.477 avg RMSE = 5.918 avg MAE = 4.835

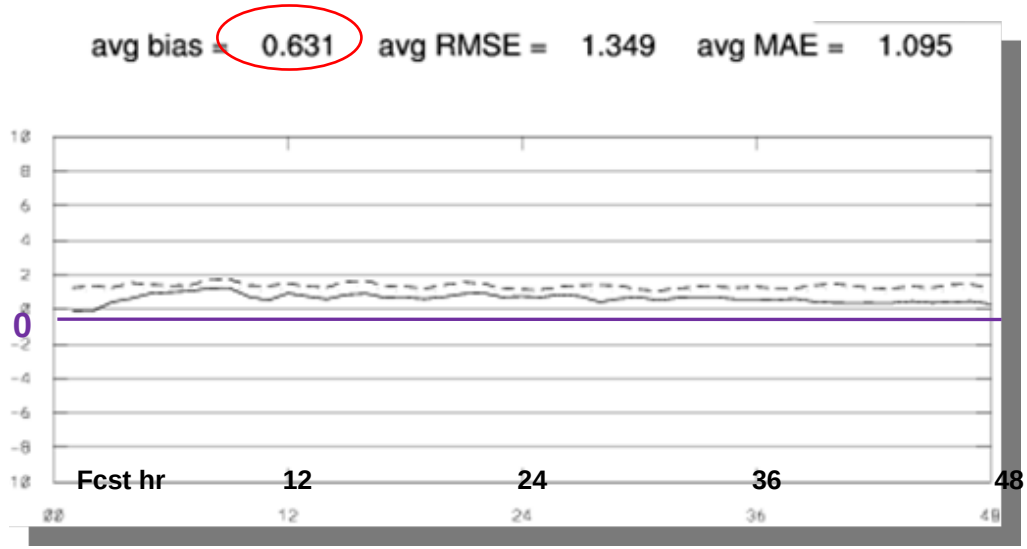


April WRF

Bias— Solid
RMSE— Dashed

Domain 4 South Pole— Sfc Wind Speed Errors (ms^{-1})





Jan.-Feb. MM5

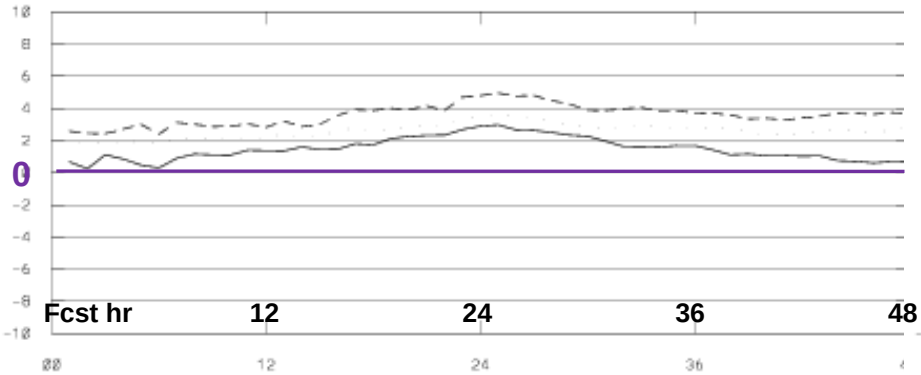
Bias— Solid
RMSE— Dashed

——— : 0 ms^{-1}

Jan.-Feb. WRF

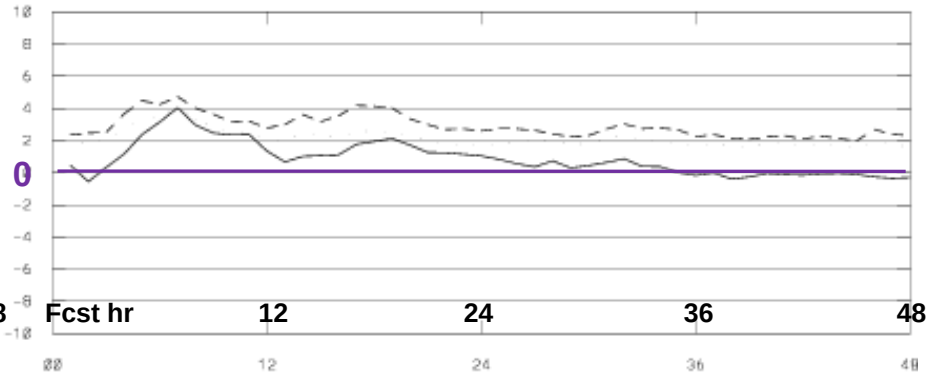
Domain 5 Pegasus North— Sfc Wind Speed Errors (ms^{-1})

avg bias = 1.483 avg RMSE = 3.584 avg MAE = 2.592



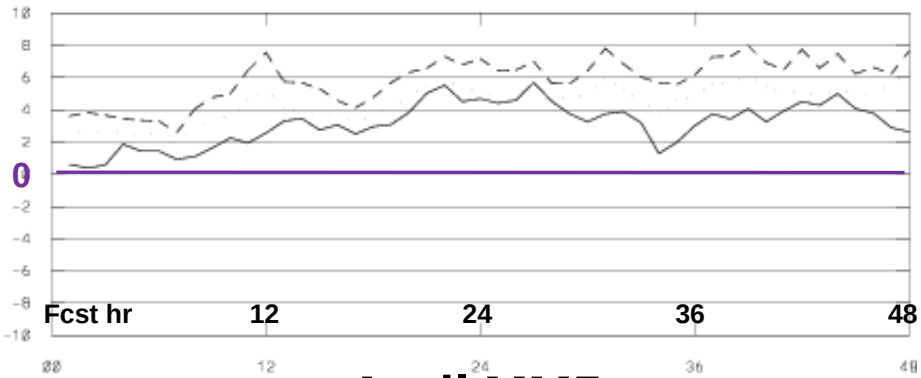
Jan.-Feb. MM5

avg bias = 0.865 avg RMSE = 2.898 avg MAE = 2.128



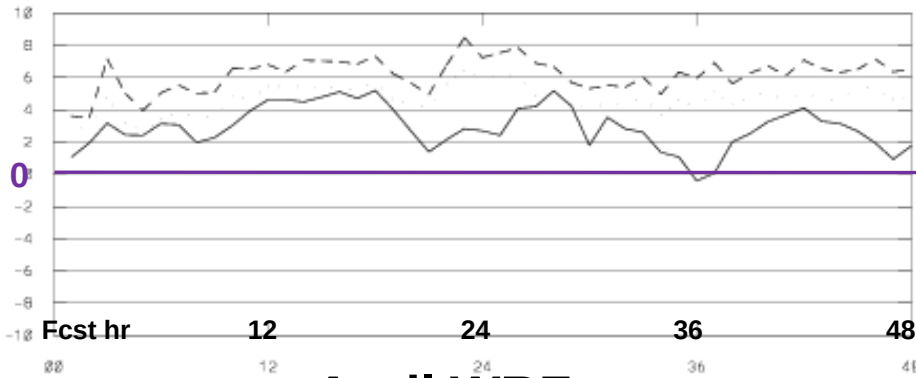
Jan.-Feb. WRF

avg bias = 3.127 avg RMSE = 5.866 avg MAE = 4.458



April MM5

avg bias = 2.914 avg RMSE = 6.184 avg MAE = 4.676



April WRF

Bias— Solid
RMSE— Dashed

Domain 2 Statistics

January Surface Temp (°C)

	Bias			RMSE			MAE		
	WRF	MM5	Δ	WRF	MM5	Δ	WRF	MM5	Δ
HR 12	-1.73	**-1.24**	-0.50	3.36	3.48	-0.12	2.85	2.91	-0.06
HR 24	-1.70	-1.58	-0.12	3.35	3.59	-0.24	2.82	2.97	-0.15
HR 36	-1.67	-1.71	0.04	**3.50**	3.84	-0.34	**2.93**	3.23	-0.29
HR 48	-1.66	-1.66	0.00	**3.55**	3.85	-0.30	**2.96**	3.20	-0.24

April Surface Temp (°C)

	Bias			RMSE			MAE		
	WRF	MM5	Δ	WRF	MM5	Δ	WRF	MM5	Δ
HR 12	-0.77	0.61	-1.39	4.24	4.79	-0.56	3.47	4.02	-0.55
HR 24	-0.36	-0.22	-0.14	4.50	4.90	-0.39	3.69	4.03	-0.34
HR 36	0.18	-0.32	0.50	4.67	4.91	-0.24	3.74	4.07	-0.33
HR 48	0.63	-0.52	1.14	4.96	5.07	-0.10	3.96	4.16	-0.20

Δ = Error difference (°C) PWRF–PMM5

-1.24 (-0.50) = Statistically significant lower error (actual error difference)

Domain 2 Statistics

January Surface Wind Speed (ms^{-1})

	Bias			RMSE			MAE		
	WRF	MM5	Δ	WRF	MM5	Δ	WRF	MM5	Δ
HR 12	2.18	**1.27**	0.91	3.30	3.20	0.10	2.79	2.62	0.17
HR 24	1.94	**1.52**	0.42	3.31	3.56	-0.25	2.75	2.85	0.10
HR 36	1.75	1.44	0.31	3.33	3.48	-0.15	2.75	2.82	0.07
HR 48	1.81	**1.27**	0.53	3.43	3.50	-0.07	2.82	2.79	0.02

April Surface Wind Speed (ms^{-1})

	Bias			RMSE			MAE		
	WRF	MM5	Δ	WRF	MM5	Δ	WRF	MM5	Δ
HR 12	4.07	**2.20**	1.87	5.61	**4.79**	0.81	5.00	**4.05**	0.95
HR 24	3.76	**3.07**	0.69	5.48	5.26	0.22	4.83	4.56	0.27
HR 36	3.21	2.89	0.32	5.21	5.03	0.18	4.50	4.35	0.15
HR 48	2.95	2.82	0.14	5.21	5.09	0.12	4.35	4.29	0.06

Δ = Error difference (ms^{-1}) PWRF–PMM5

1.27 (0.91) = Statistically significant: Lower error (difference)

Mean Error Comparisons: Significance Testing

- **96 tests total**
- **# tests with no significant difference or WRF better / MM5 better shown**

4 domains × 2 periods × 4 forecast times (12,24,36,48) × 3 variables (Sfc T, T2, WSP)

	No significant difference		WRF lower error		MM5 lower error	
MAE	**77** / 96	80.2%	9 / 96	9.4%	10 / 96	10.4%
RMSE	**73** / 96	76.0%	12 / 96	12.5%	11 / 96	11.5%
MAE (T, WSP)	51 / 64	79.7%	6 / 64	9.4%	7 / 64	10.9%

III. Summary and Conclusions

- Polar-modified MM5 and WRF run in AMPS
  - *Warm and cold season periods: Jan.–Feb. 2007 & April 2007*
  - *Surface parameters verified and statistical significance of error differences tested*
- Polar WRF and Polar MM5 performance comparable
  - *75–80% of T, T2, and WSP RMSE and MAE differences **not** statistically significant*
  - *Nos. of significant differences split b/t PMM5 and PWRF*
    - Note: Practical differences typically small
  - *Error time series: Similar model performance revealed*

III. Summary and Conclusions (cont'd)

- Positive findings with PWRF
  - *Little error growth seen over 48 hrs of forecast period*
    - Consistent across seasons and domains
  - *No large warm surface temperature bias in PWRF (!)*