Byrd Polar and Climate Research Center
Polar Meteorology Group
The Ohio State University

Atmospheric Modeling of the High Southern Latitudes with Polar WRF

David H. Bromwich, Jianjun Xue, Lesheng Bai, and Keith M. Hines

Polar Meteorology Group
Byrd Polar and Climate Research Center
The Ohio State University
Columbus Ohio

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THE OHIO STATE UNIVERSITY

Polar Meteorology Group, Byrd Polar and Climate Research Center, The Ohio State University, Columbus, Ohio

Polar WRF

(Version 3. 1 – 4.1)

Developed and maintained by the Polar Meteorology Group

The key modifications for Polar WRF are:

Optimal turbulence (boundary layer) parameterization

Implementation of a comprehensive sea ice description in the Noah LSM

Improved treatment of heat transfer for ice sheets and revised surface energy balance calculation in the Noah LSM

Improved cloud microphysics for polar regions

Model evaluations of Polar WRF simulations have been performed in the Arctic and Antarctica

Polar WRF is used by forecasters as part of the National Science Foundation sponsored Antarctic Mesoscale Prediction System.

Polar WRF is used by more than ~400 users for polar region climate change simulation and weather system modeling

Polar WRF Components Implemented in WRF

- Improved heat transfer for ice and snow
- Sea ice fraction specification (mosaic method)
- Specified variable sea ice thickness (ASR-inspired)
- Specified variable snow depth on sea ice (ASR-inspired)
- Sea ice albedo seasonal specifications (ASR-inspired)
- MYNN surface boundary layer works with fractional sea ice

Main Polar WRF Applications by OSU.

- ❑ Arctic System Reanalysis (ASR)
- ❑ AMPS— The Antarctic Mesoscale Prediction System
- ❑ OSU Antarctic Mesoscale Prediction System (AMPS) Database
- ❑ Numerical Weather Prediction (NWP) at OSU

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Polar WRF Set Up

Description	Forecast Mode	Climate Mode
Horizontal Resolution	15km	60km
Simulation	Forecast Mode 48 hour	Climate Mode Monthly
Spin-up	24 hours	10 days
Initial and Lateral Boundary	ERA-Interim	
Vertical Levels	71, Model top level at 3hPa	
Coordinate	Hybrid Vertical Coordinate, eta = 0.3	
Land Surface Models	Noah NoahMP	
Microphysics	Morrison 2-moment	
PBL Scheme	MYNN2	
Short/Long Wave	Both RRTMG	
Cumulus	Kain-Fritsch	
Surface Layer	MYNN	
Sea ice	SEAICE_THICKNESS_DEFAULT = 1.0, SEAICE_SNOWDEPTH_MAX = 0.05(Jul.) , 0.02 (Jan.) SEAICE_SNOWDEPTH_MIN = 0.02(Jul.), 0.002(Jan.) SEAICE_ALBEDO_DEFAULT = 0.80	
Spectral Nudging	Wave number 7, u, v, t, ph, above 200 mb to ERA-Interim	

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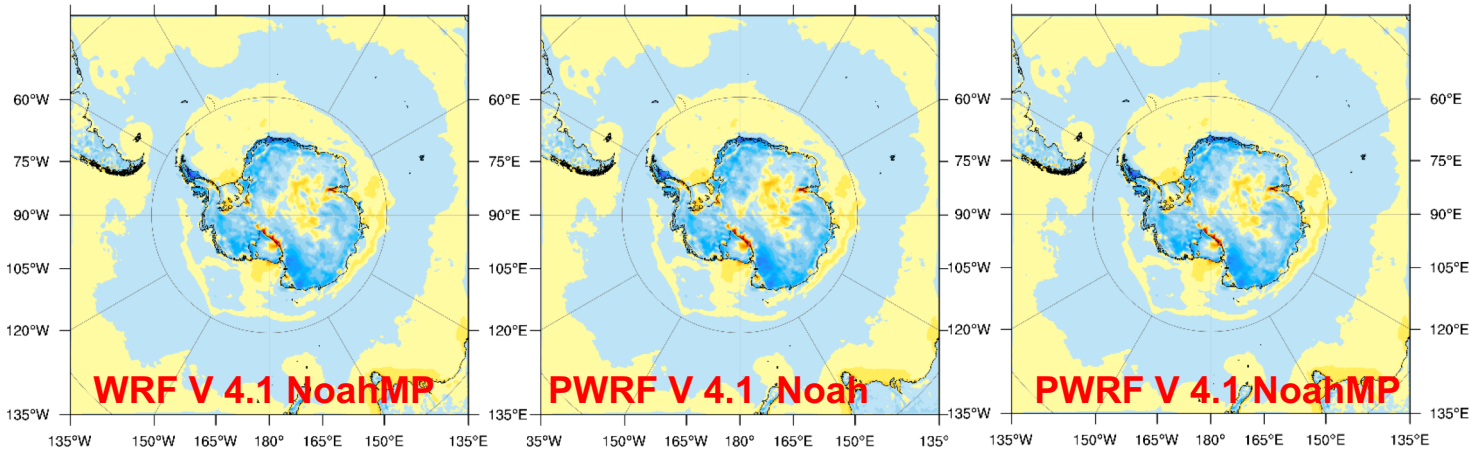
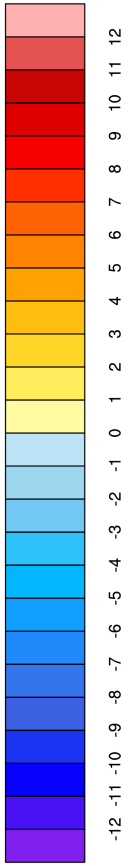
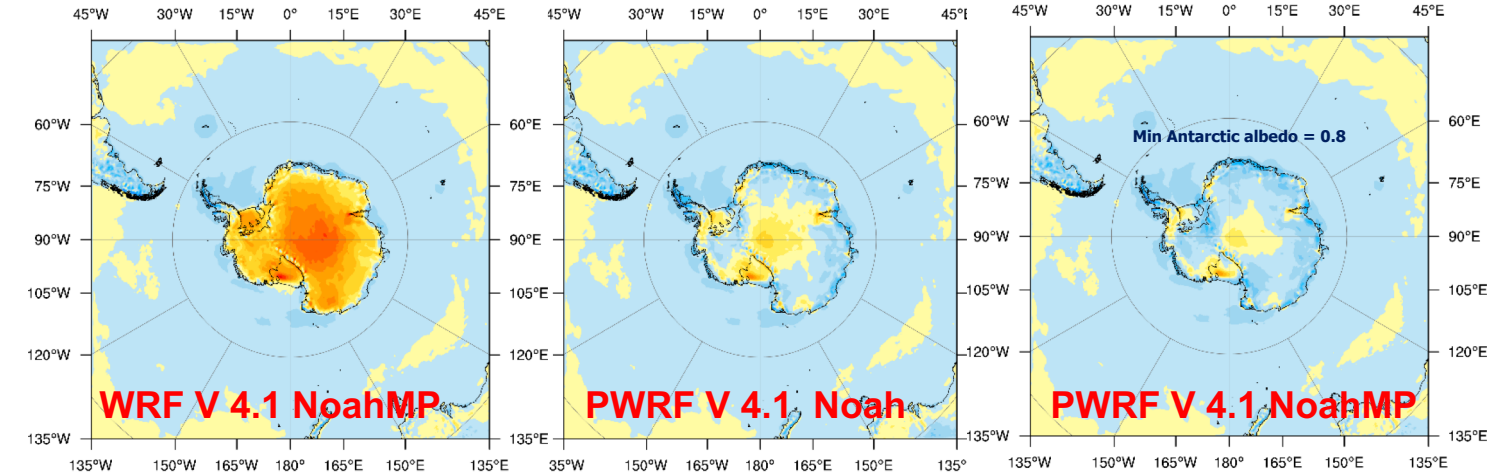
Forecast Mode Simulation (48hr)

Temperature Bias at 2m (vs. ERA-Interim) July 2008





Temperature Bias at 2m (vs. ERA-Interim) Jan 2009



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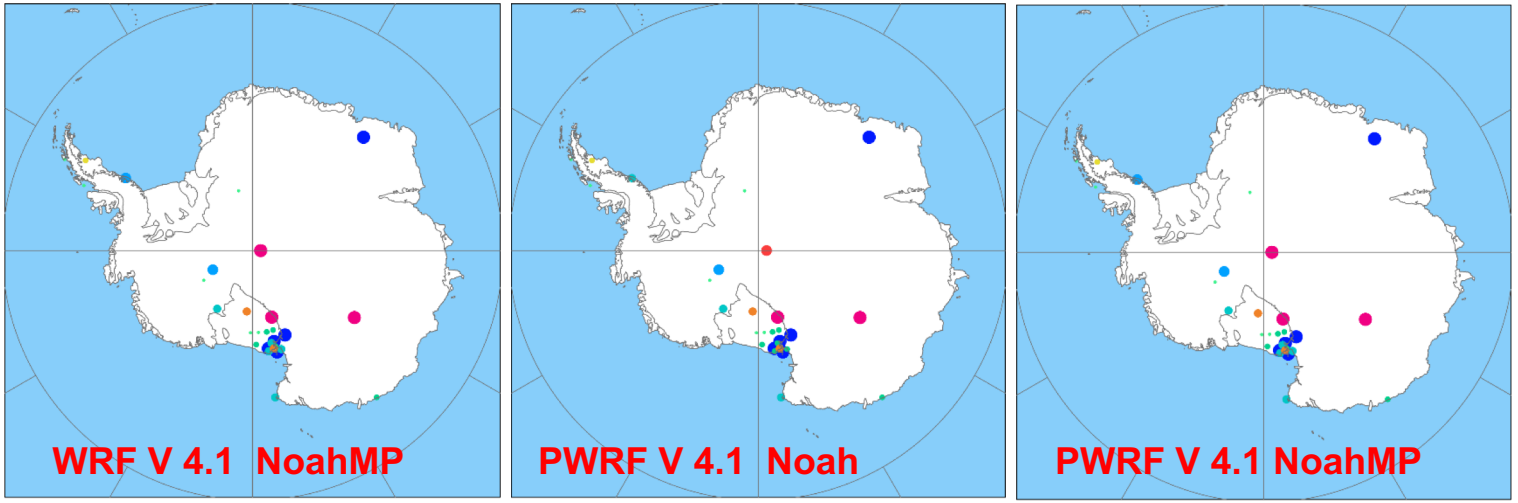
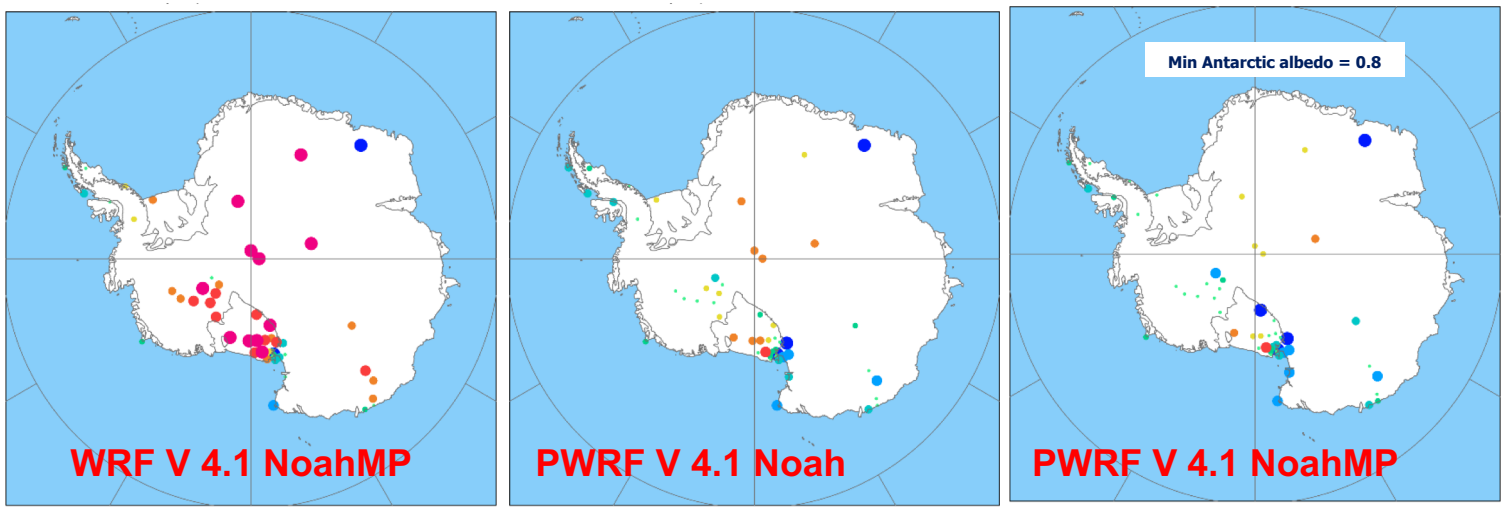
Forecast Mode Simulation (48hr)

Temperature Bias at 2m (vs. Observations) July 2008



Temperature Bias at 2m (vs. Observation) Jan 2009



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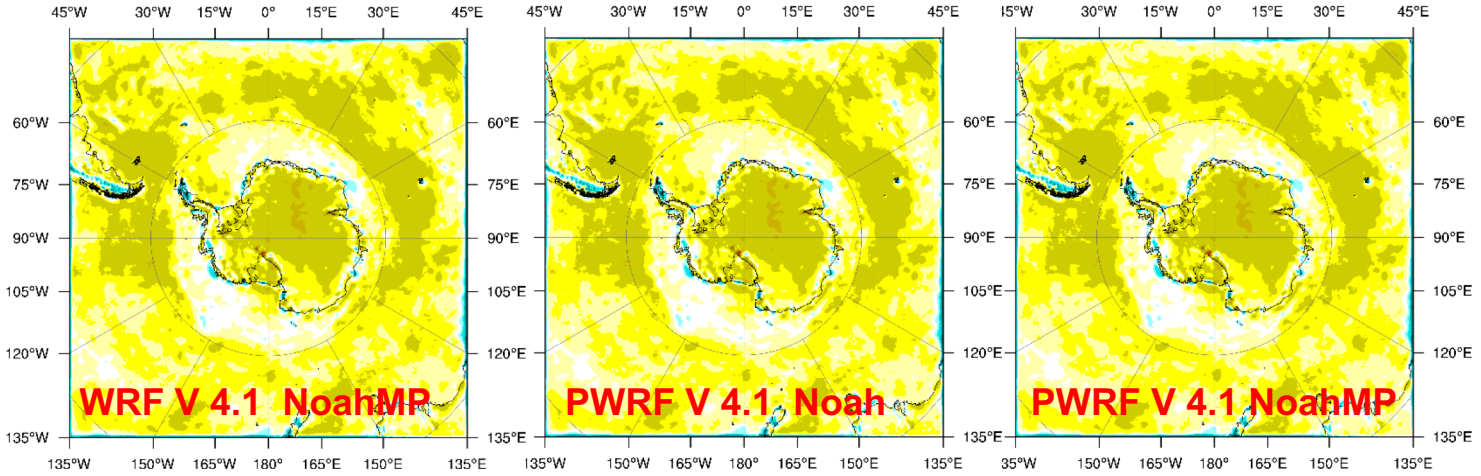
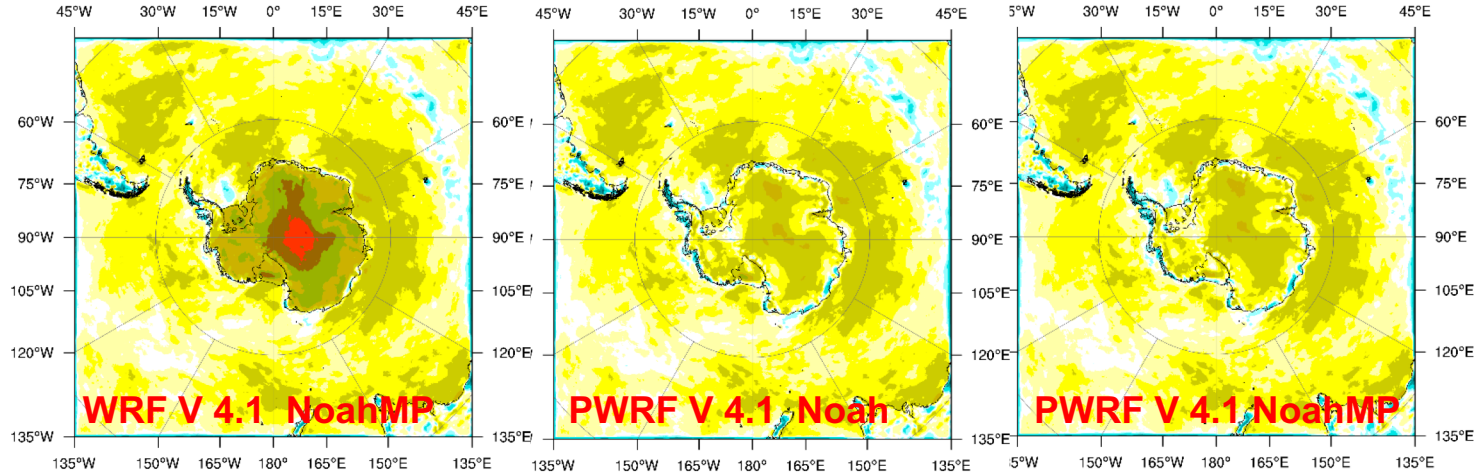
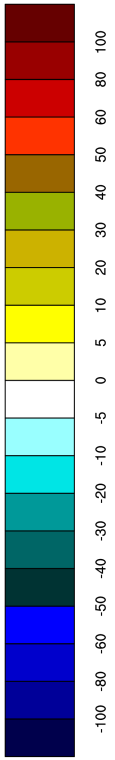
Forecast Mode Simulation (48hr)

Longwave Bias (vs. ERA-Interim) July 2008



Longwave Bias (vs. ERA-Interim) Jan 2009





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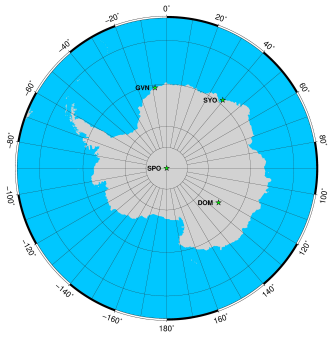
Forecast Mode Simulation (48hr)

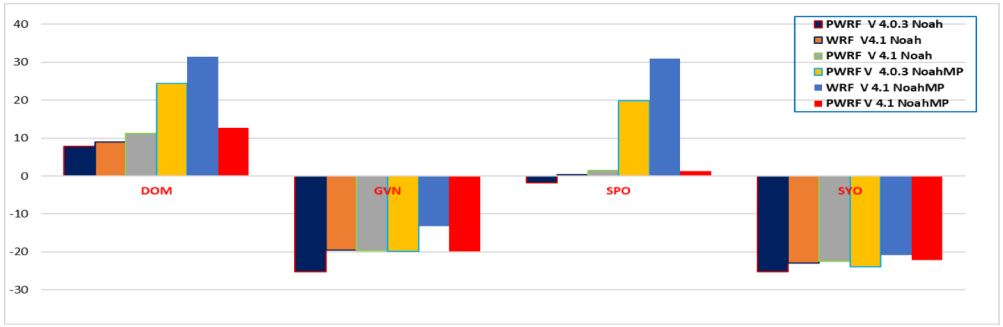
Longwave Bias July 2008 (vs. Observations)

	PWRF V 4.0.3 Noah	WRF V4.1 Noah	PWRF V 4.1 Noah	PWRF V 4.0.3 NoahMP	WRF V 4.1 NoahMP	PWRF V 4.1 NoahMP
DOM	19.2	14.6	14.7	19.0	14.5	14.4
GVN	-14.8	-11.6	-11.8	-15.0	-12.2	-12.2
SPO	15.8	12.8	12.7	15.9	12.8	12.8
SYO	-9.1	-8.4	-8.3	-8.9	-8.2	-8.2



Longwave Bias Jan 2009 (vs. Observations)

	PWRF V 4.0.3 Noah	WRF V4.1 Noah	PWRF V 4.1 Noah	PWRF V 4.0.3 NoahMP	WRF V 4.1 NoahMP	PWRF V 4.1 NoahMP
DOM	7.9	8.9	11.4	24.4	31.5	12.7
GVN	-25.2	-19.5	-19.6	-19.9	-13.2	-19.9
SPO	-1.8	0.3	1.5	19.8	30.9	1.4
SYO	-25.2	-23.0	-22.4	-23.9	-20.9	-22.2



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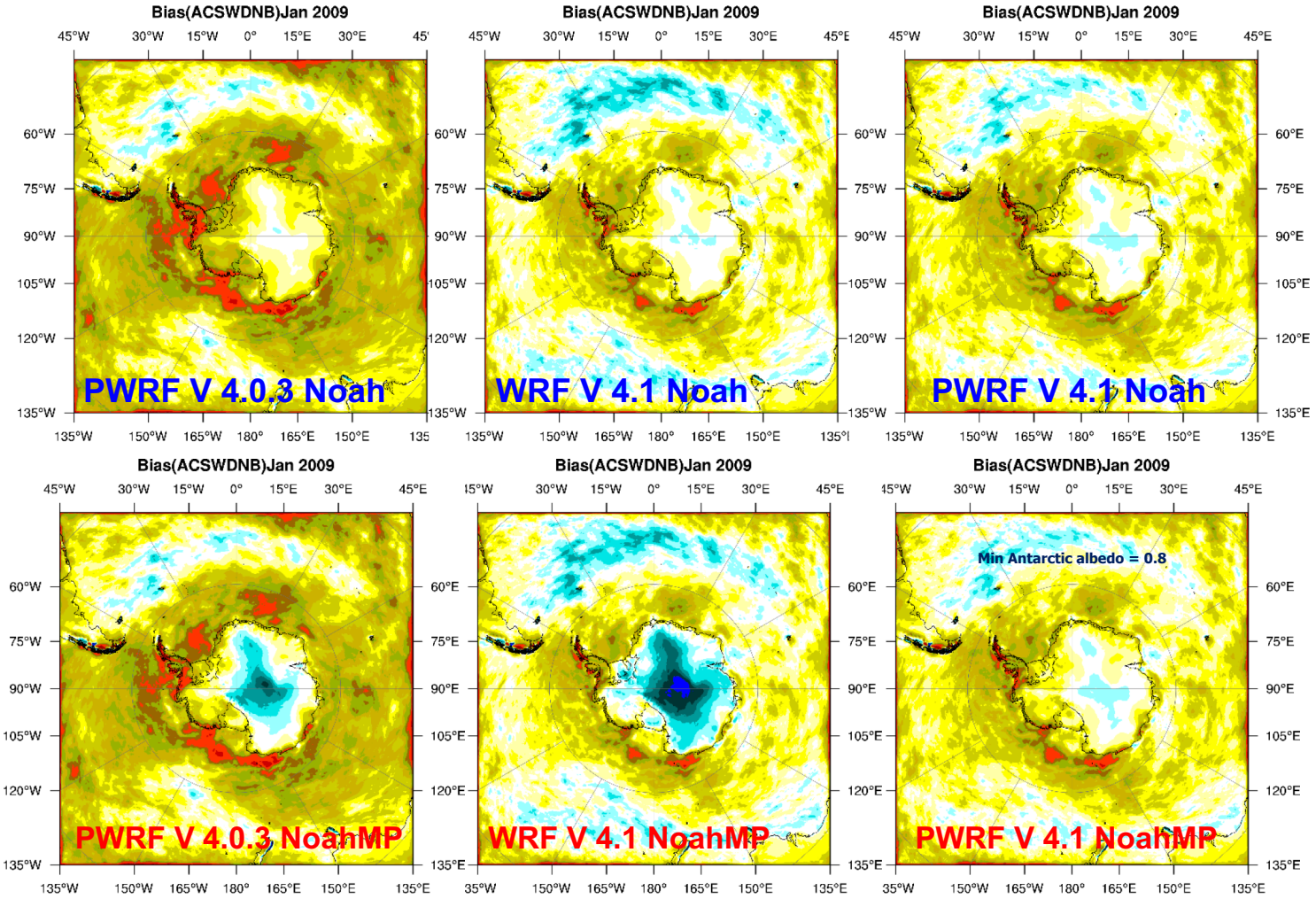
Forecast Mode Simulation (48hr)

Shortwave Radiation Bias Jan 2009 (vs. ERA-Interim)



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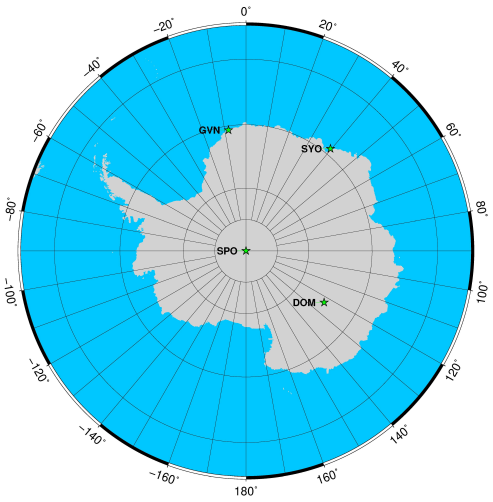
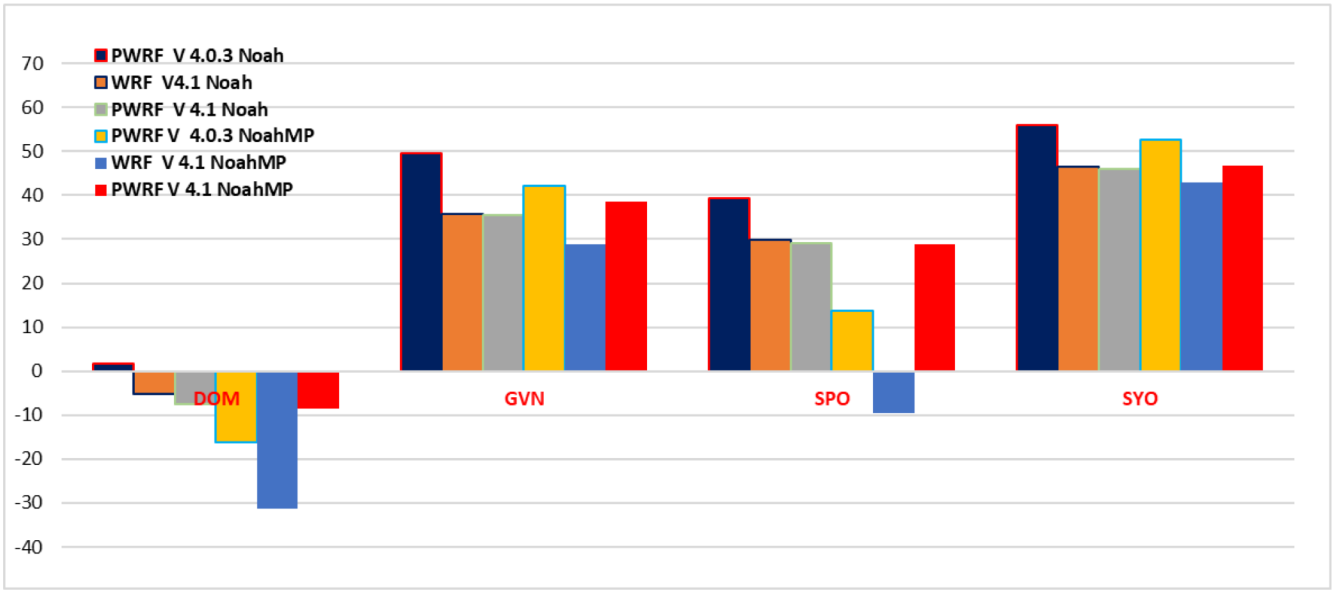
Forecast Mode Simulation (48hr)

Shortwave Bias Jan 2009 (vs. Observations)

	PWRF V 4.0.3 Noah	WRF V4.1 Noah	PWRF V 4.1 Noah	PWRF V 4.0.3 NoahMP	WRF V 4.1 NoahMP	PWRF V 4.1 NoahMP
DOM	1.679	-5.269	-7.413	-16.146	-31.188	-8.596
GVN	49.541	35.725	35.425	42.062	28.932	38.558
SPO	39.412	29.963	29.203	13.823	-9.656	28.785
SYO	55.84	46.482	46.057	52.712	42.789	46.846





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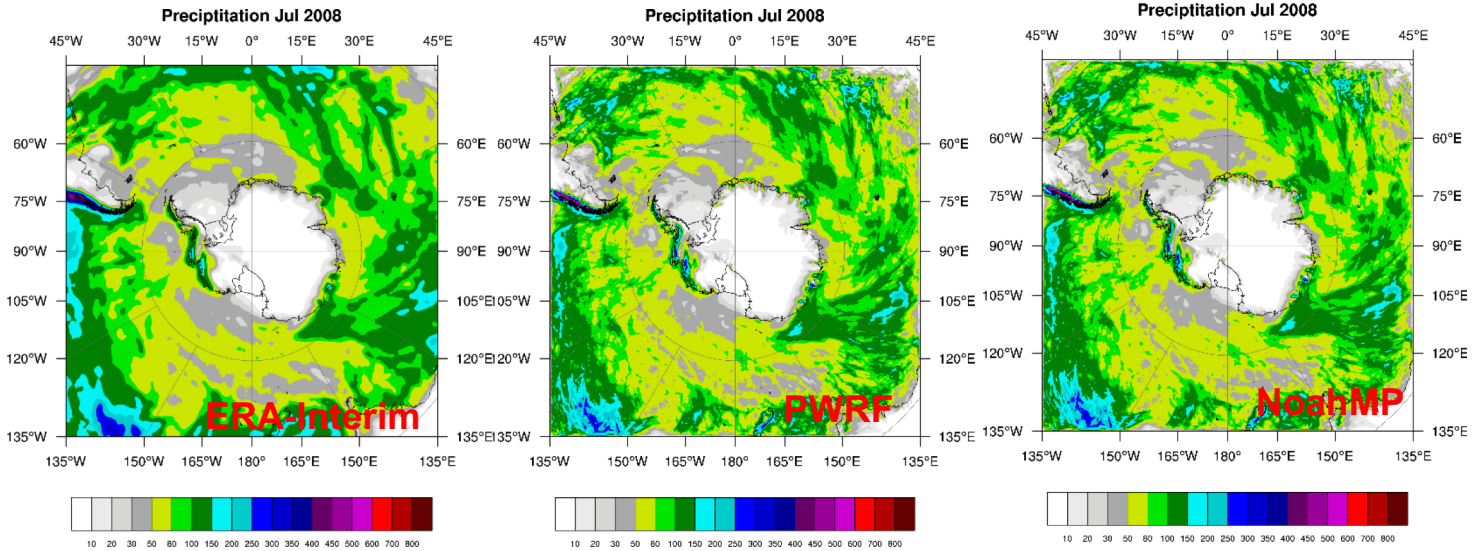
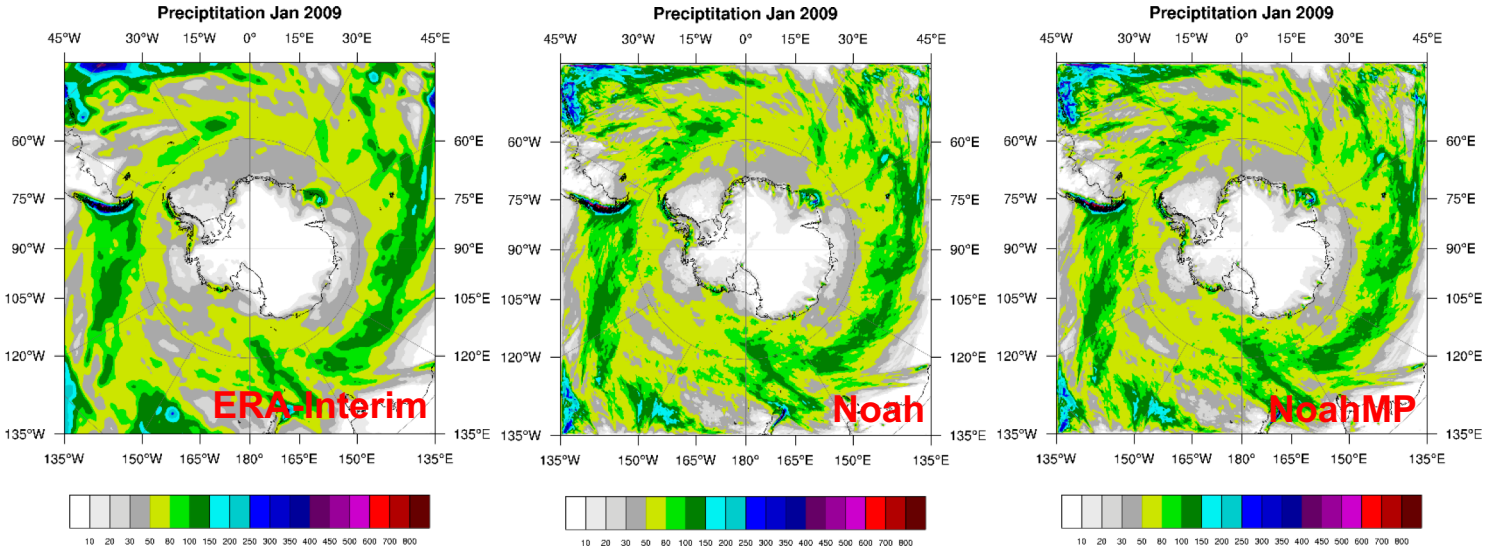
Forecast Mode Simulation (48hr)
Polar WRF V4.1

Monthly Total Precipitation July 2008



Monthly Total Precipitation Jan 2009



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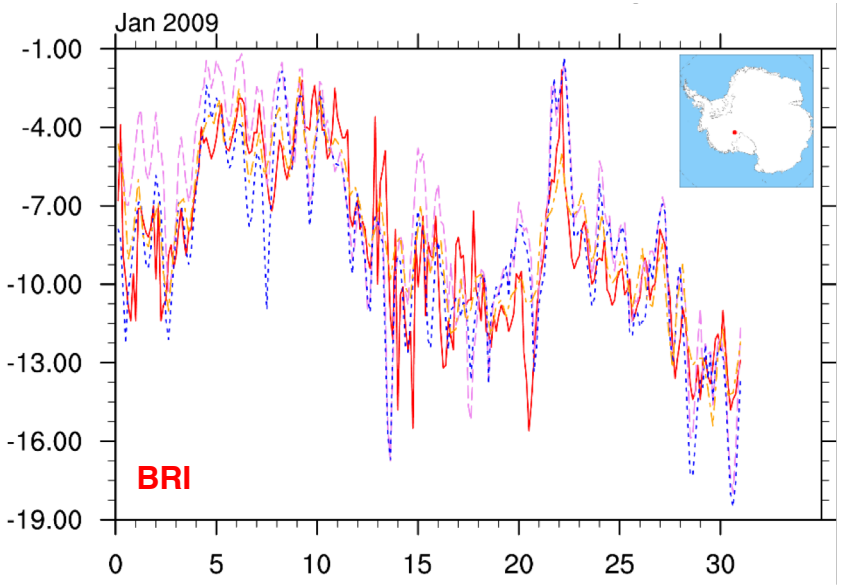
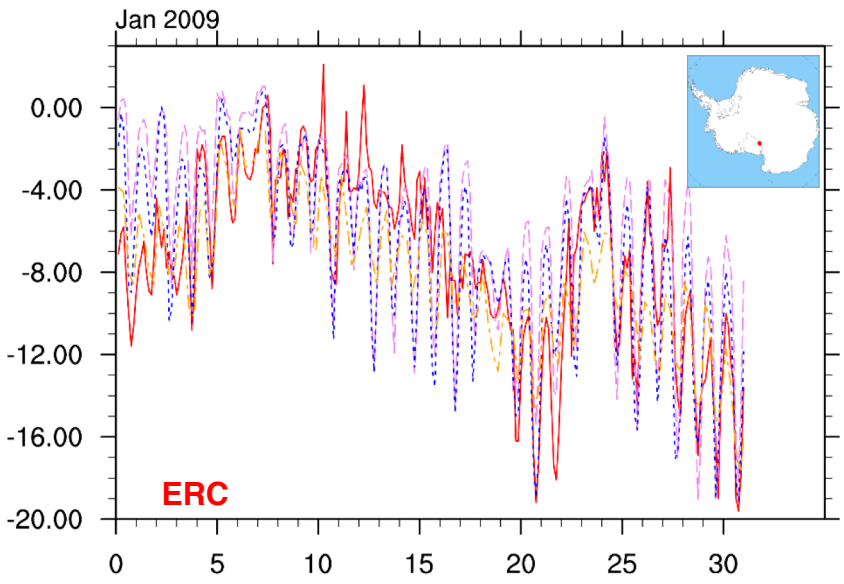
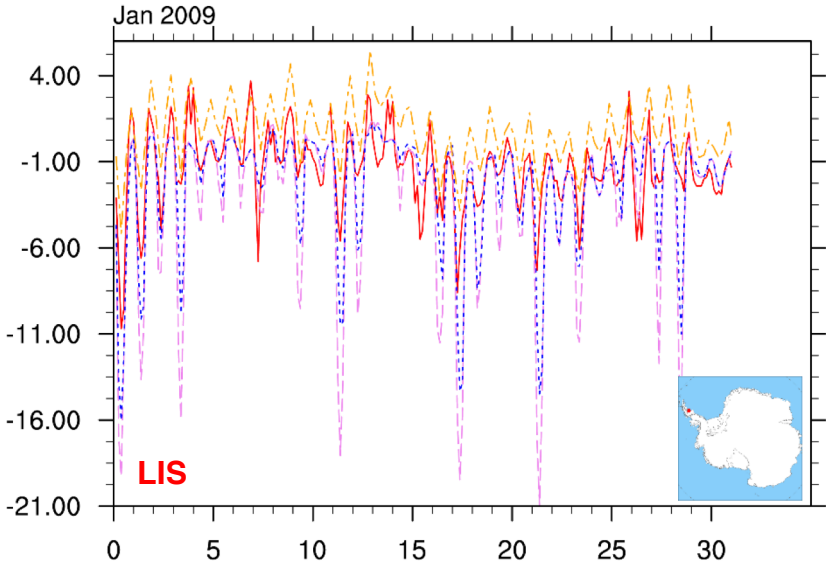
Forecast Mode Simulation (48hr)

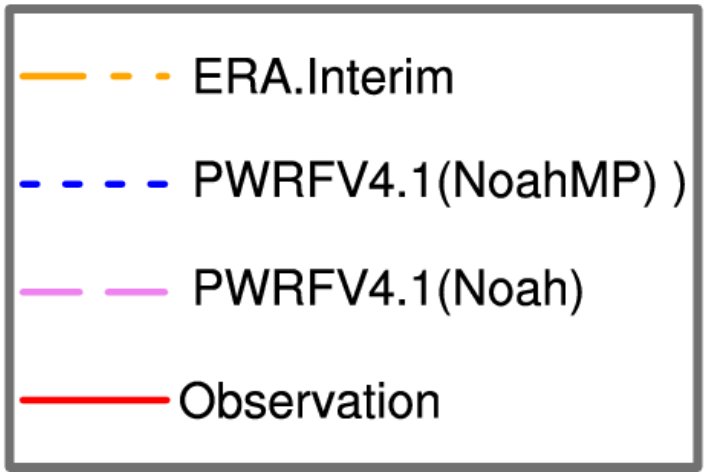
Polar WRF V4.1

Temperature Jan 2009









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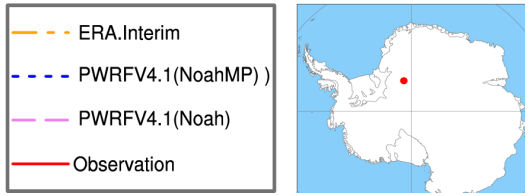
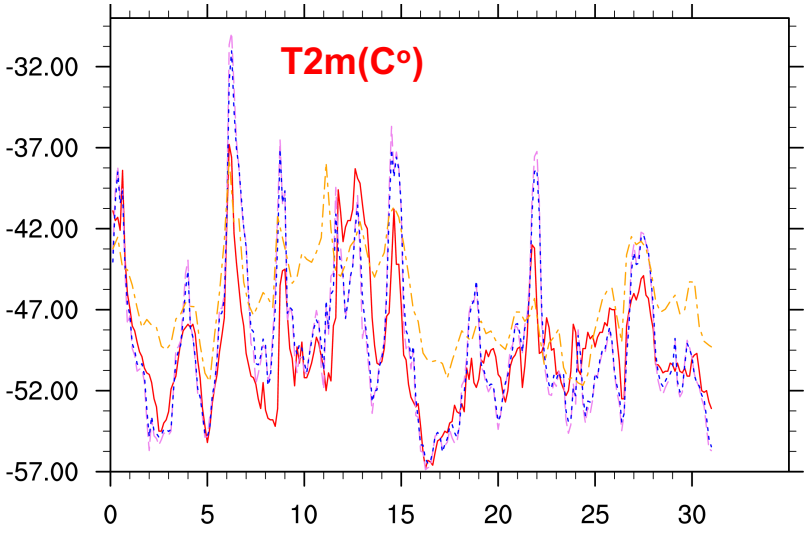
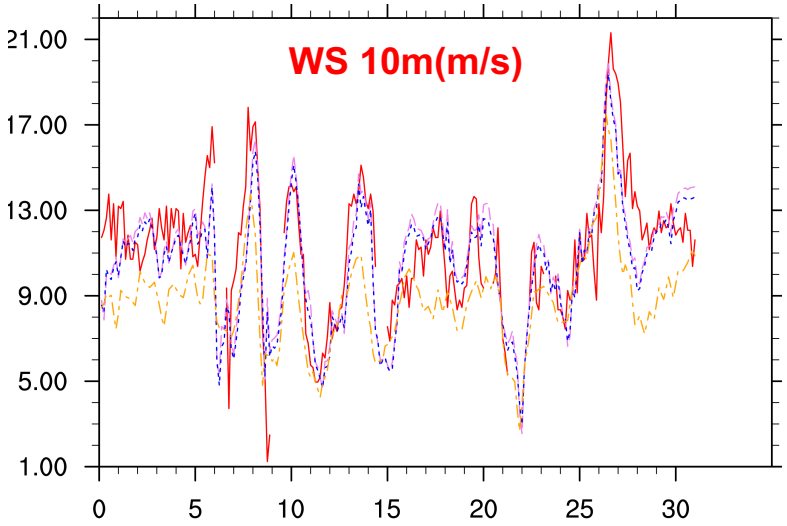
Forecast Mode Simulation (48hr)

Polar WRF V4.1

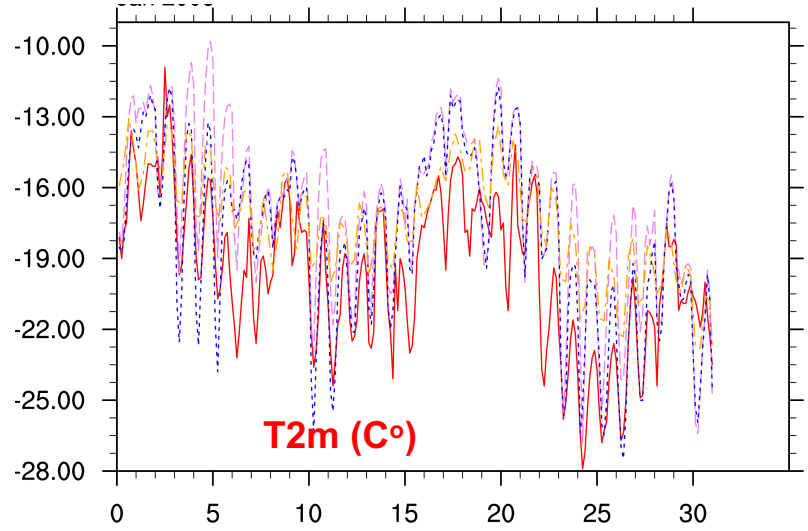


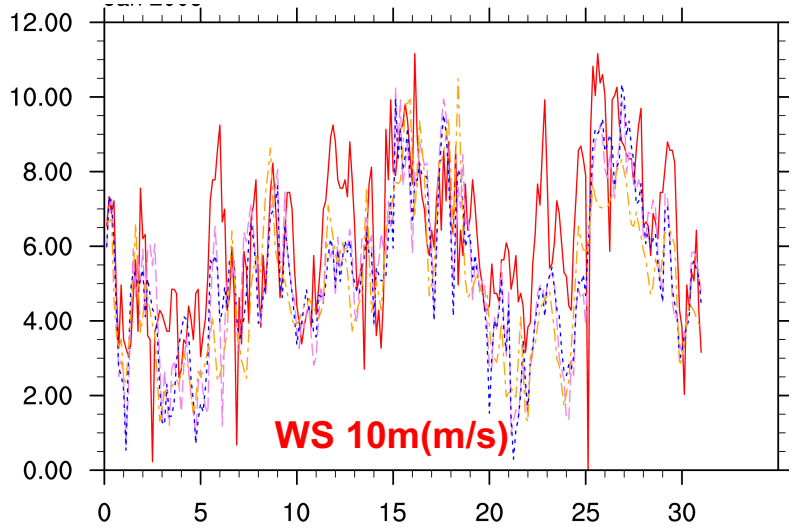
July 2008





Jan 2009





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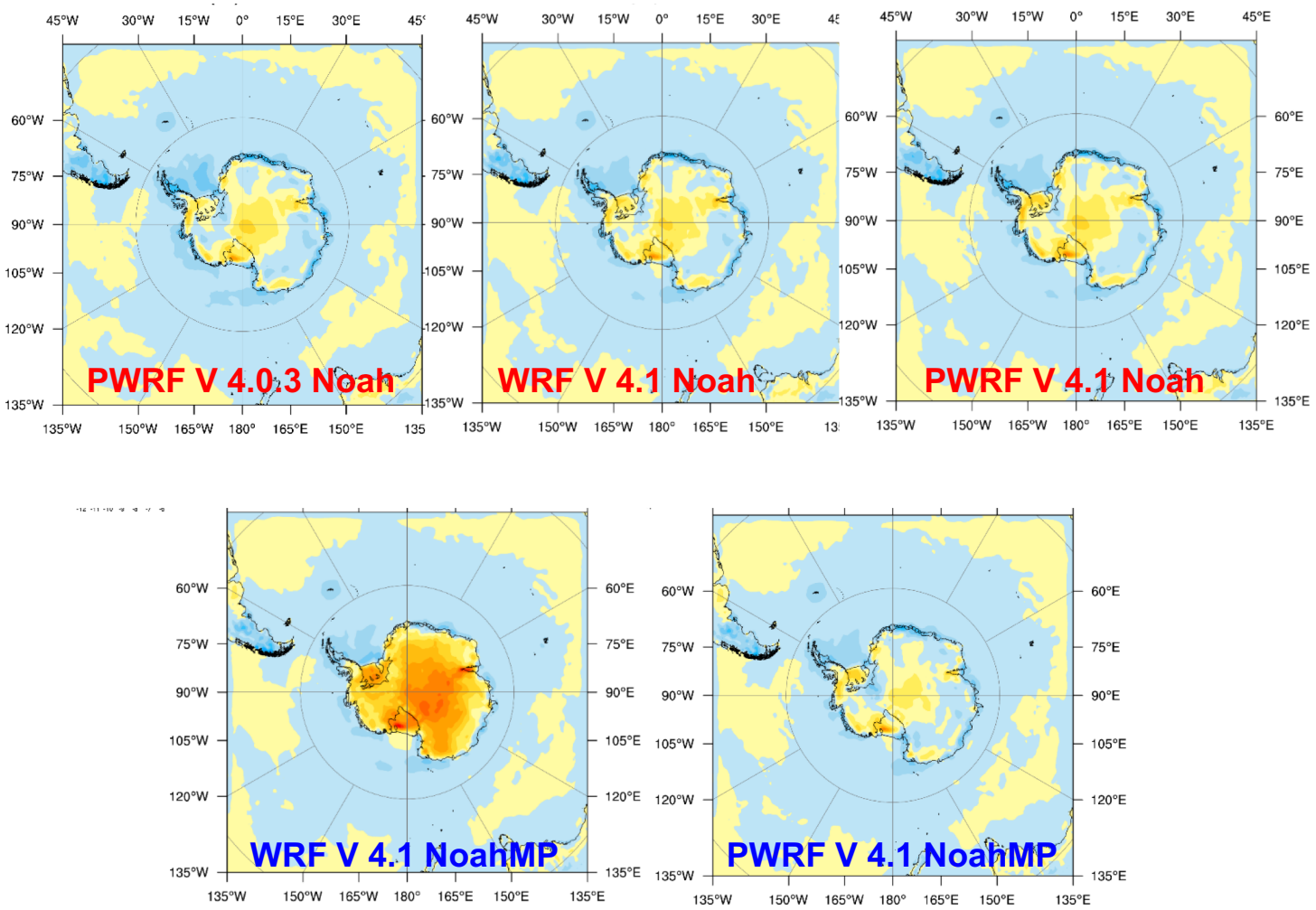
Climate Mode Simulation (Monthly)

Temperature Bias at 2m (vs. ERA-Interim) Jan 2009



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Climate Mode Simulation (Monthly)

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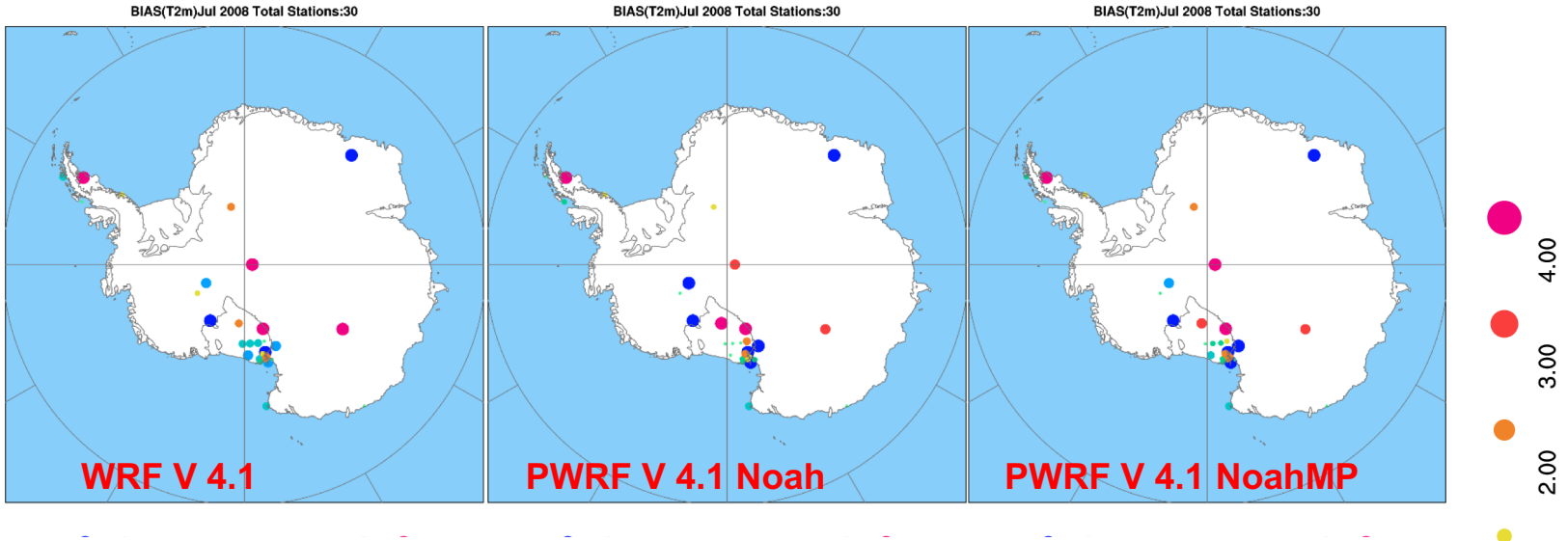
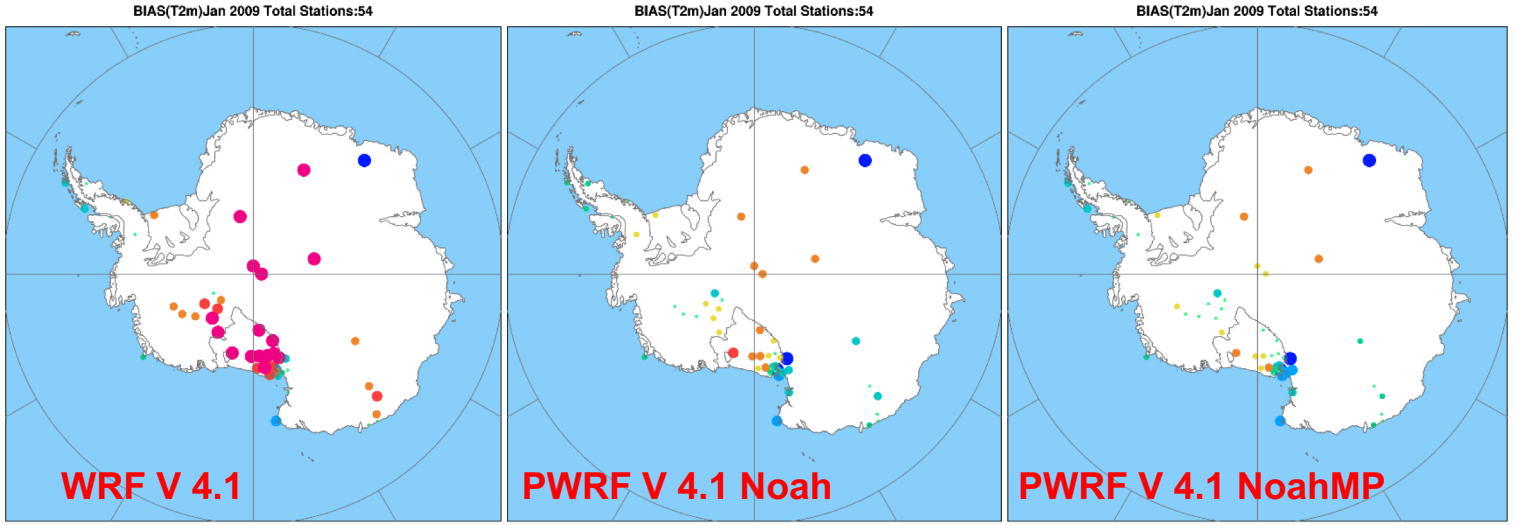


Temperature Bias at 2m (vs. Observations) Jan 2009



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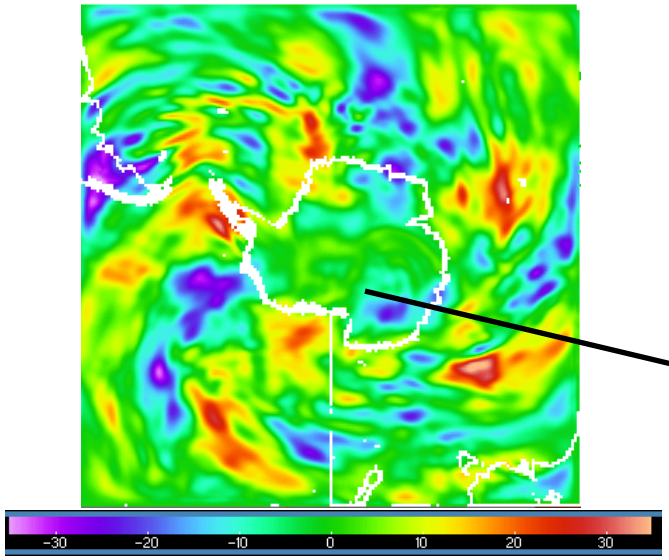
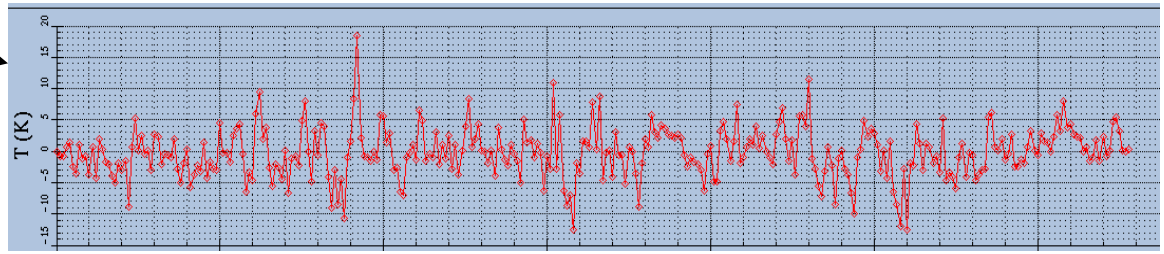
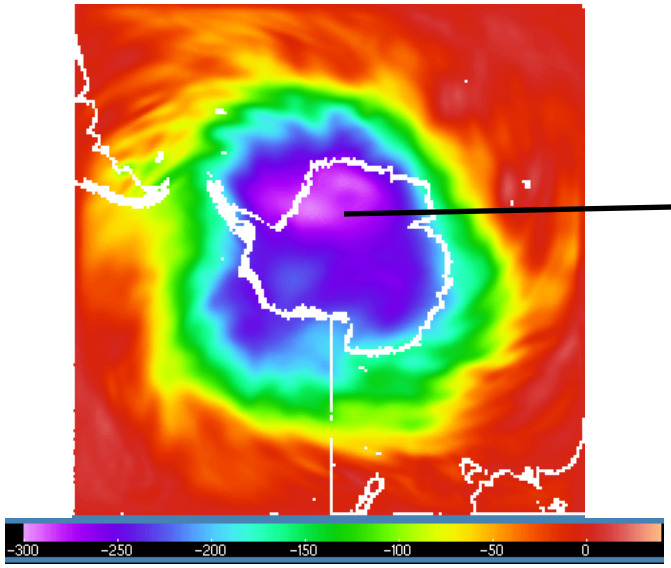
Nudging Test for Climate Mode



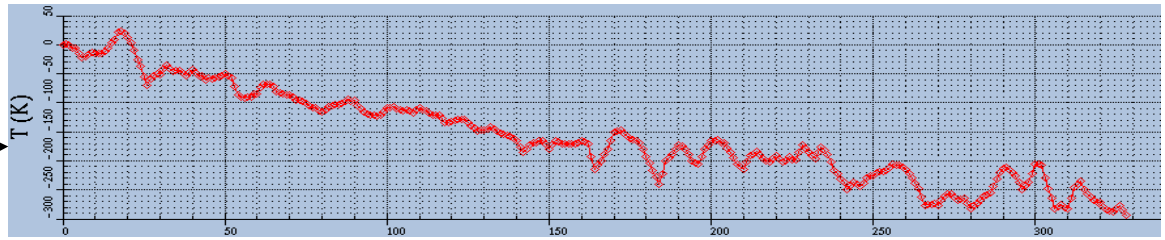
Model Top Temperature Bias July 2008
Polar WRF forecast – ERA-Interim

With Nudging **bias ±15**





Without Nudging **bias -300**



All cases show the similar result

Nudging improves the model top level forecast skill

Summary and Future Work

- Downscaling simulations with forecast mode and climate mode have been performed using Polar WRF version 4. Both simulation modes show that Polar WRF has good performance over Antarctica.
- Upper-air analysis nudging is important for long-term simulation. It means that regional forecast results are dependent on the global model (lateral and upper boundary conditions) for long-term forecasts.
- Modified Noah-MP (limit albedo not less than 0.8 over ice sheet) has better performance than Noah over Antarctica.
- In WRF version 4.1, a big improvement is the reduction in the downward shortwave radiation bias through better cloud fraction and subgrid scale mixing ratios in MYNN; results in better performance over the Antarctic region.

Future Work

Refinement of Current Polar Mods

- Continue improvement of Noah-MP over ice Antarctica to remove strong T diurnal cycle.
- Make the droplet concentration in Morrison microphysics scheme variable
- Validate CLM and RUC land models over Antarctica

More sensitivity simulations and validation work for Antarctica

Release Polar WRF V4.1, should be soon.