

Byrd Polar and Climate Research Center

**Polar Meteorology Group**

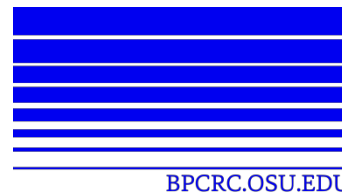
The Ohio State University



# Atmospheric Modeling of the High Southern Latitudes with Polar WRF

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Columbus Ohio



**THE OHIO STATE  
UNIVERSITY**



# Outline

## **Status of Polar WRF**

**Polar WRF**

**History of Polar WRF**

**Polar WRF Components Implemented in WRF**

**Polar WRF Applications**

## **Polar WRF V4.0.3 and V4.1 Simulations**

**Forecast Mode (Short-term, 48hr) Simulations**

**Climate Mode (Monthly) Simulations**

## **Summary**

# **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

## **Polar WRF Applications by OSU PMG**

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





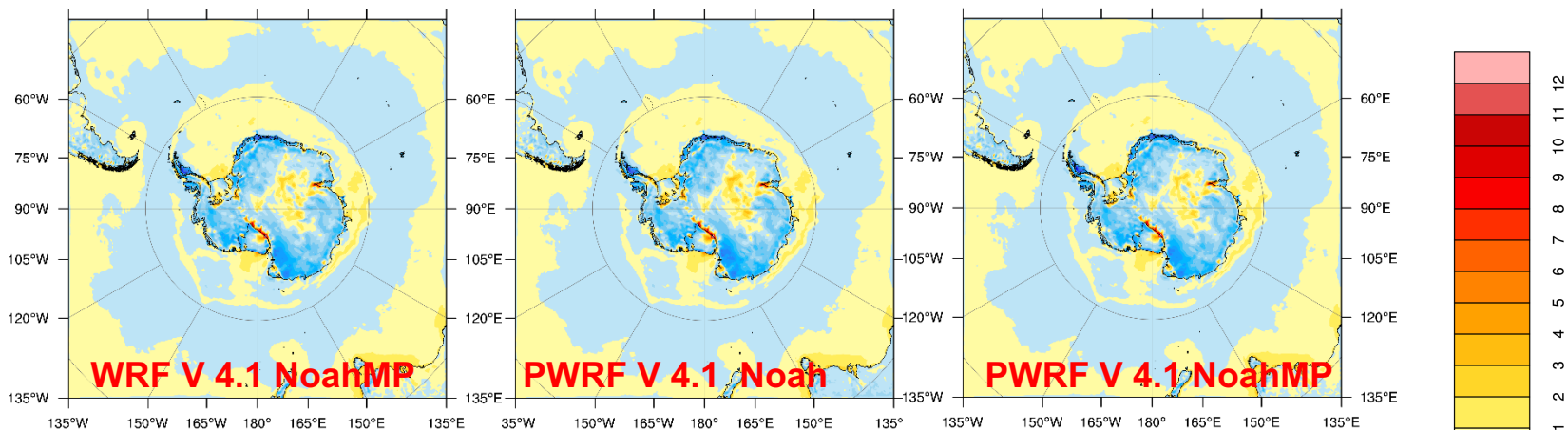
# Polar WRF Set Up

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	Noah NoahMP	
Microphysics	Morrison 2-mom	
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	

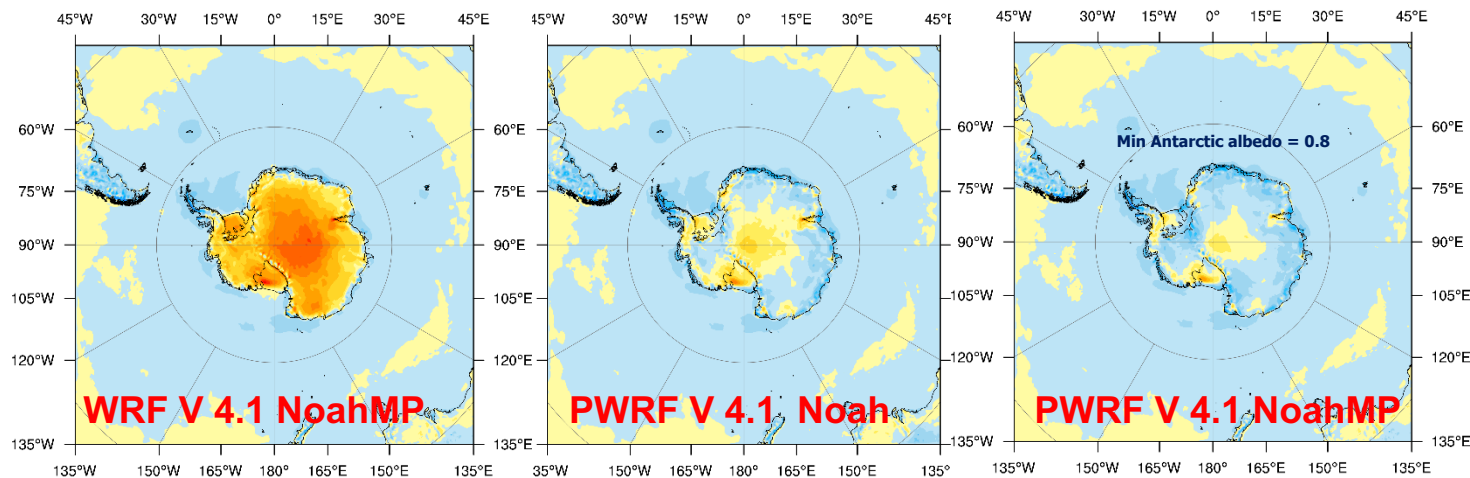


## Forecast Mode Simulations (48hr)

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



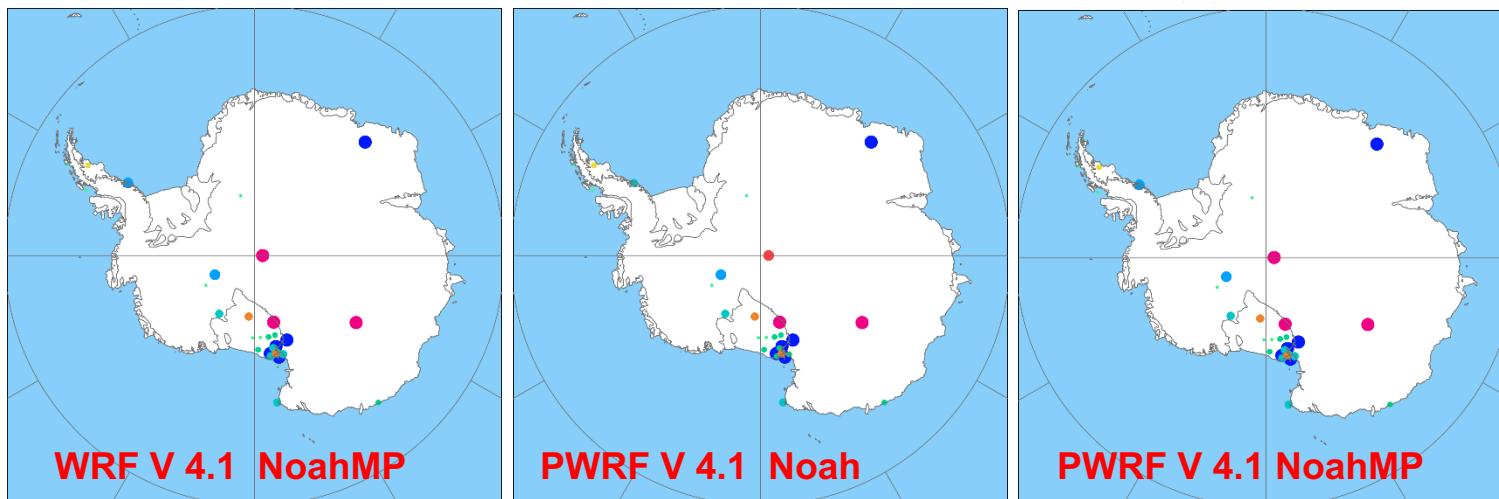
### Temperature Bias at 2m (vs. ERA-Interim) Jan 2009



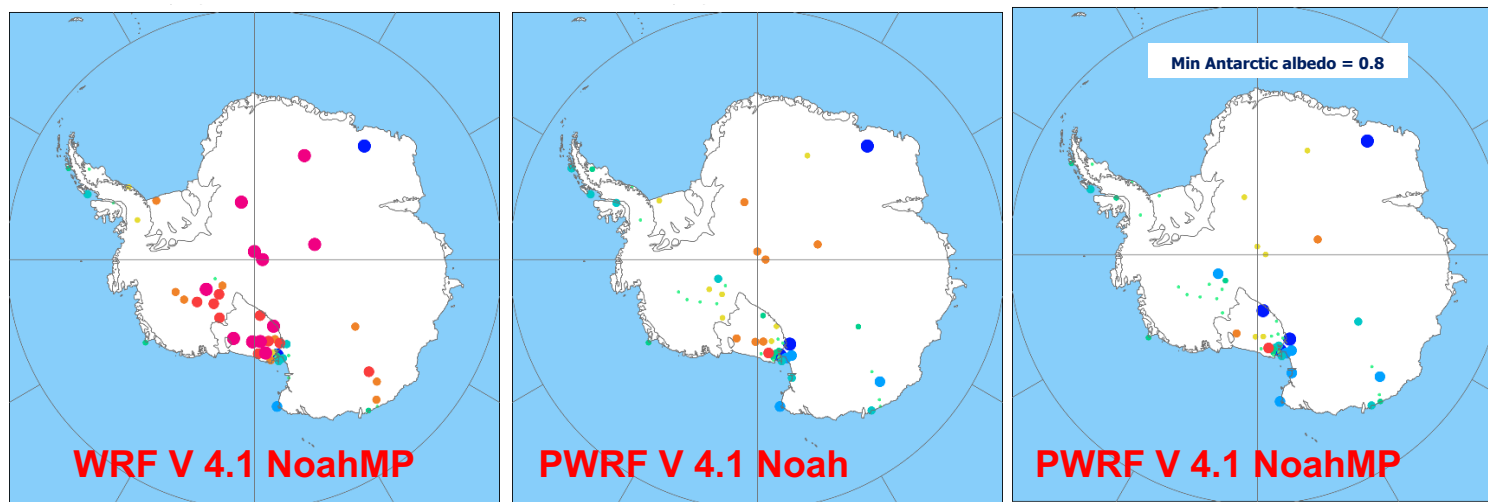


## Forecast Mode Simulations (48hr)

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



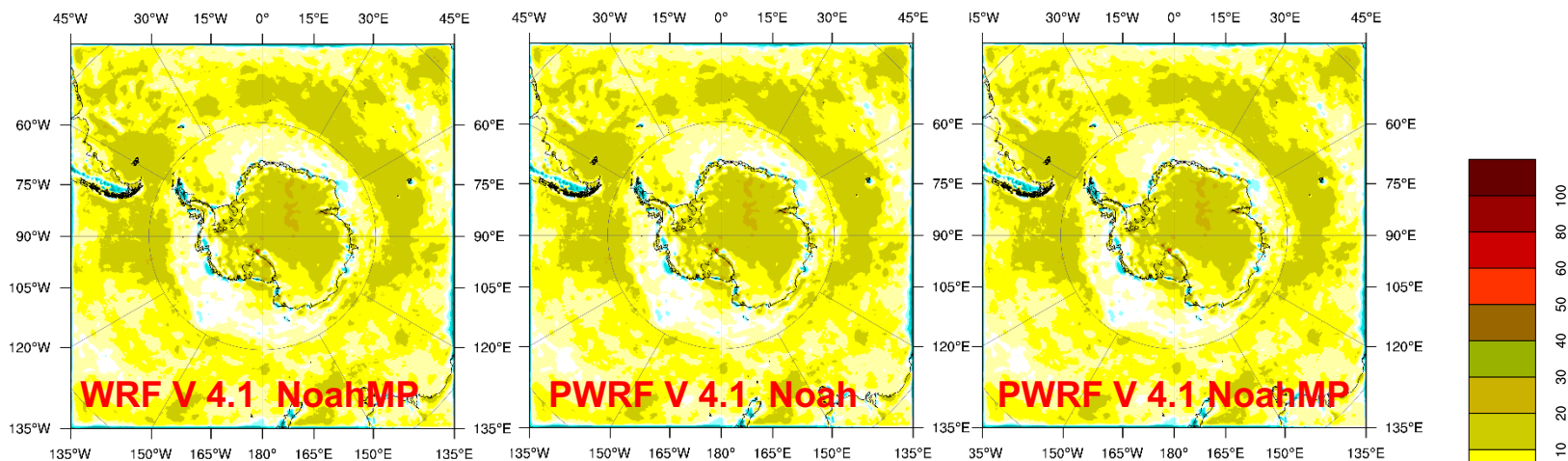
### Temperature Bias at 2m (vs. Observations) Jan 2009



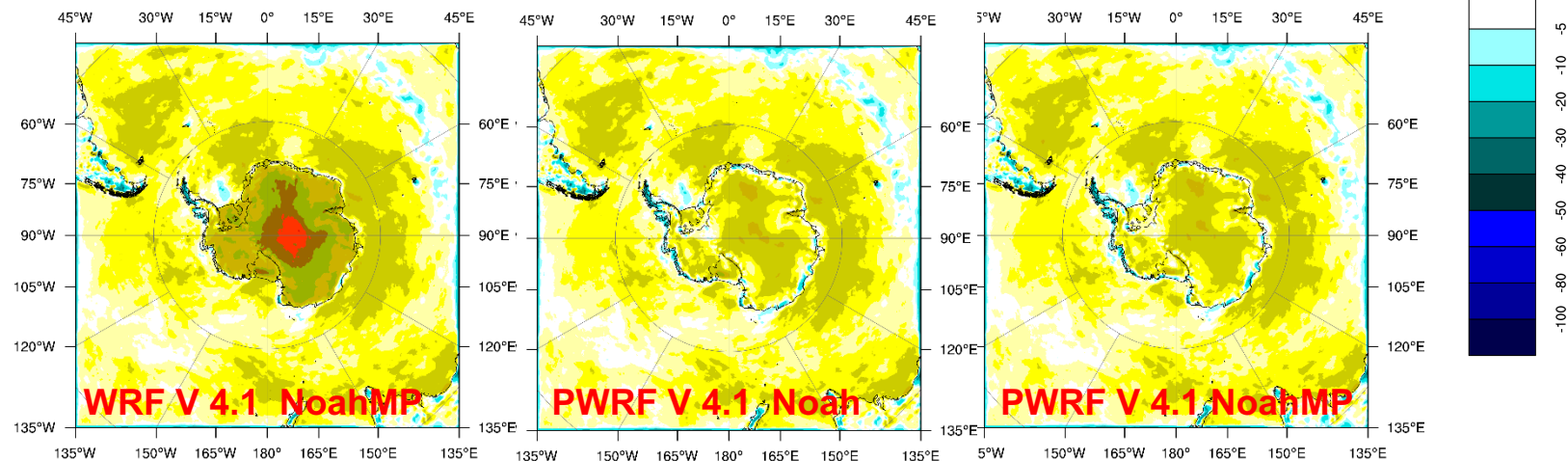


## Forecast Mode Simulations (48hr)

### Longwave Bias (vs. ERA-Interim) July 2008



### Longwave Bias (vs. ERA-Interim) Jan 2009

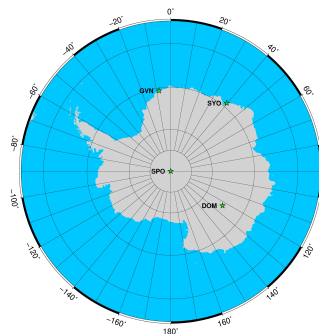
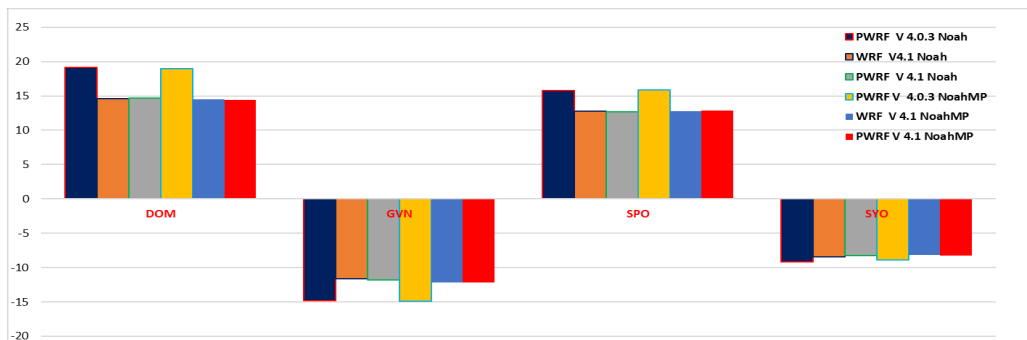




# Forecast Mode Simulations (48hr)

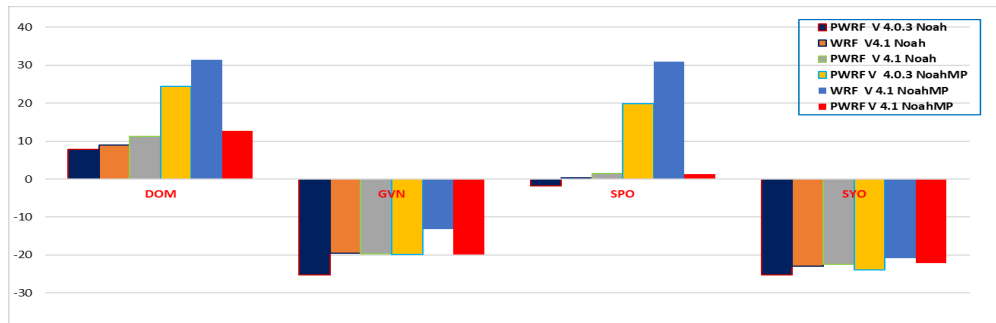
## Longwave Bias July 2008 (vs. Observations)

	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

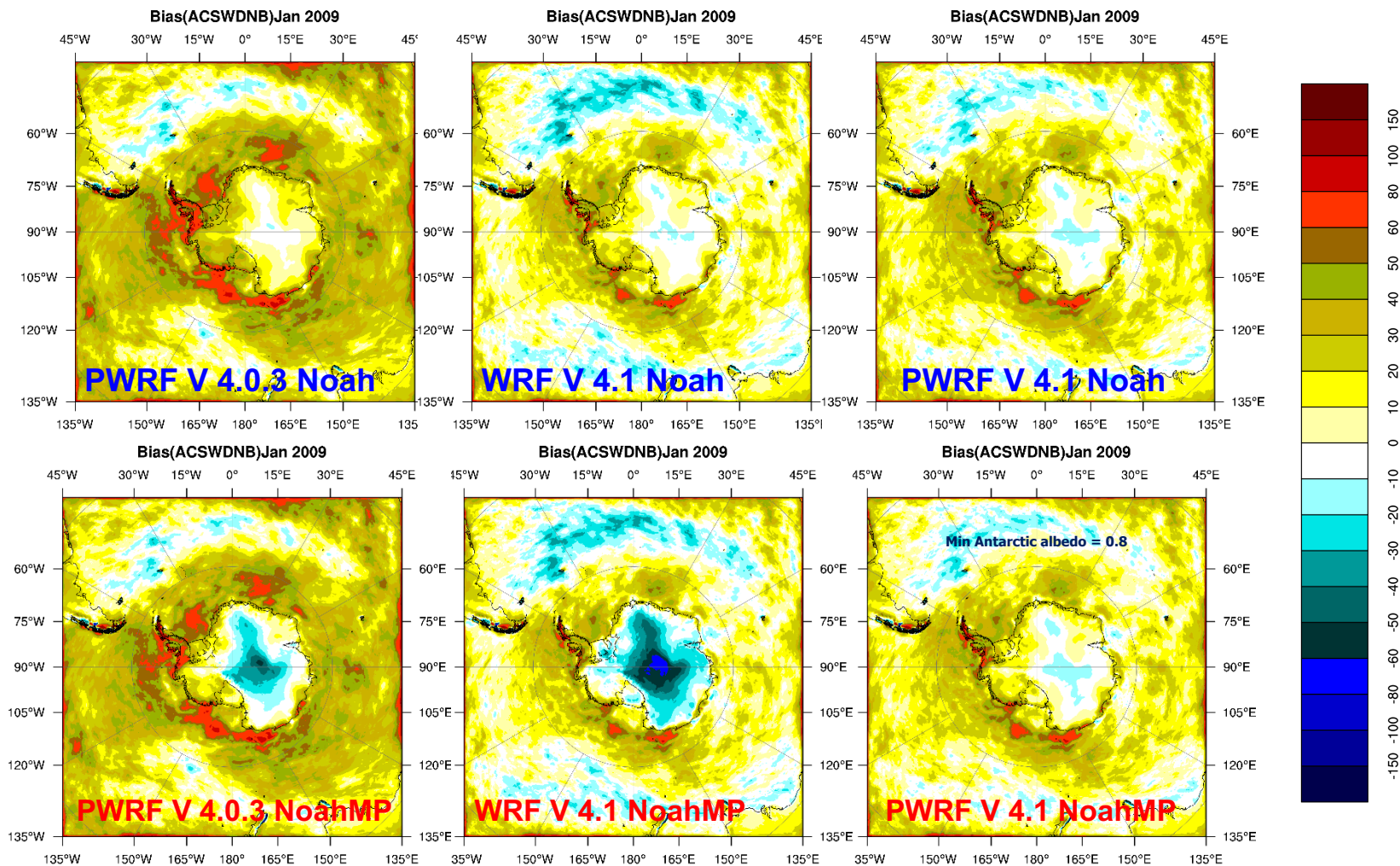






## Forecast Mode Simulations (48hr)

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

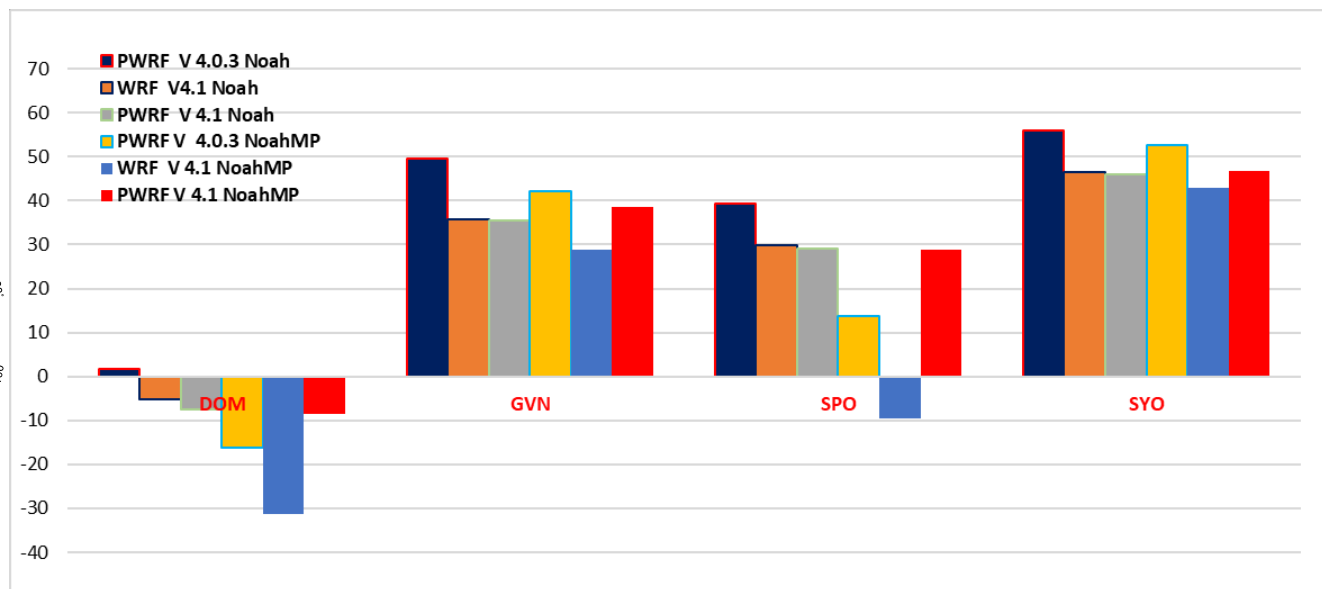
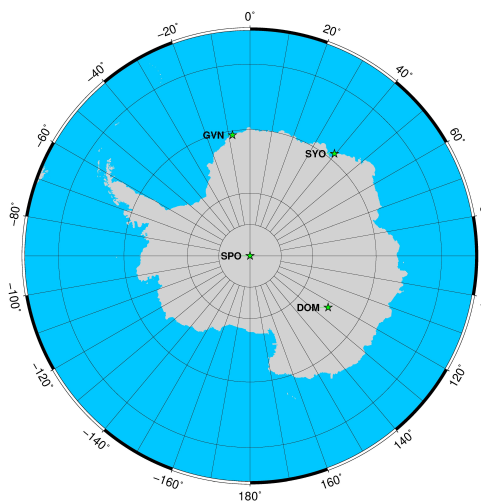




## Forecast Mode Simulations (48hr)

### Shortwave Bias Jan 2009 (vs. Observations)

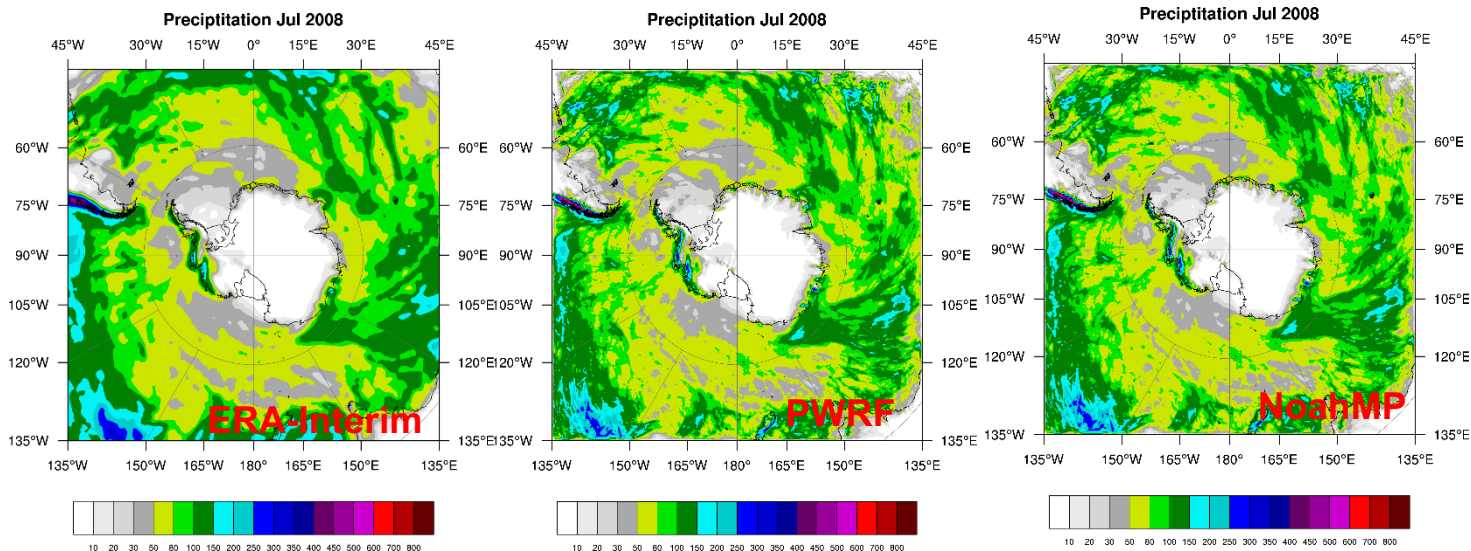
	PWRF V 4.0.3 Noah	WRF V4.1 Noah	PWRF V 4.1 Noah	PWRF V 4.0.3 NoahMP	WRF V 4.1 NoahMP	PWRF V 4.1 NoahMP
DOM	1.679	-5.269	-7.413	-16.146	-31.188	-8.596
GVN	49.541	35.725	35.425	42.062	28.932	38.558
SPO	39.412	29.963	29.203	13.823	-9.656	28.785
SYO	55.84	46.482	46.057	52.712	42.789	46.846



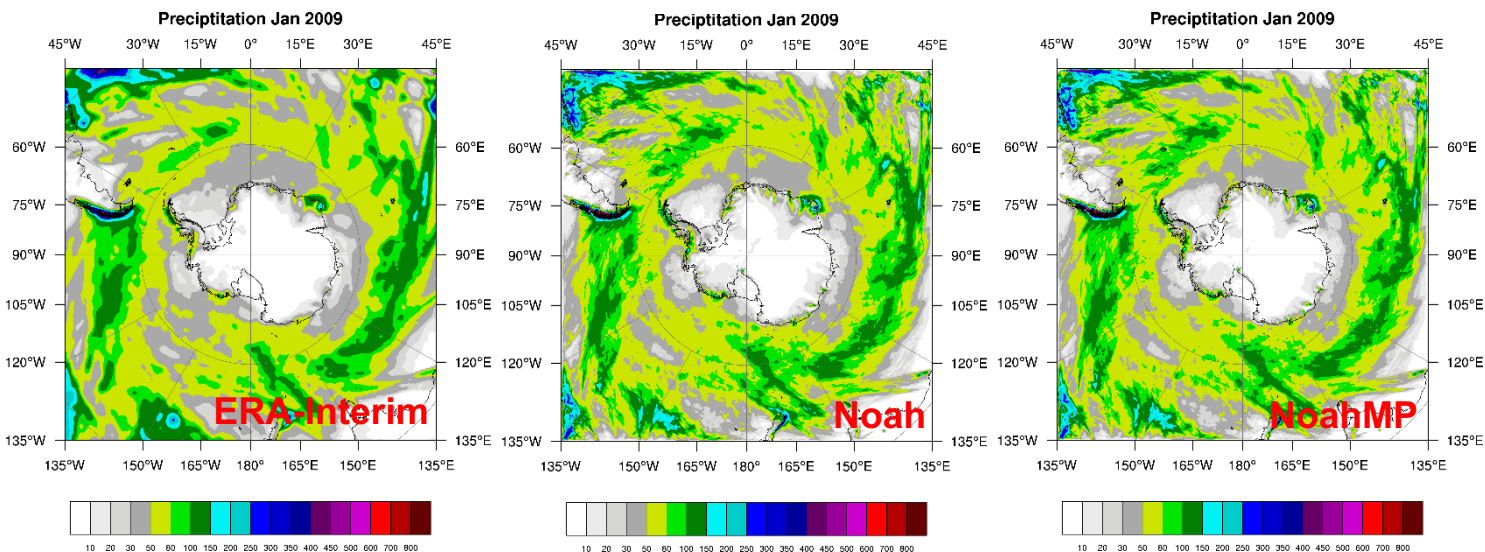


# Forecast Mode Simulations (48hr) Polar WRF V4.1

## Monthly Total Precipitation July 2008



## Monthly Total Precipitation Jan 2009

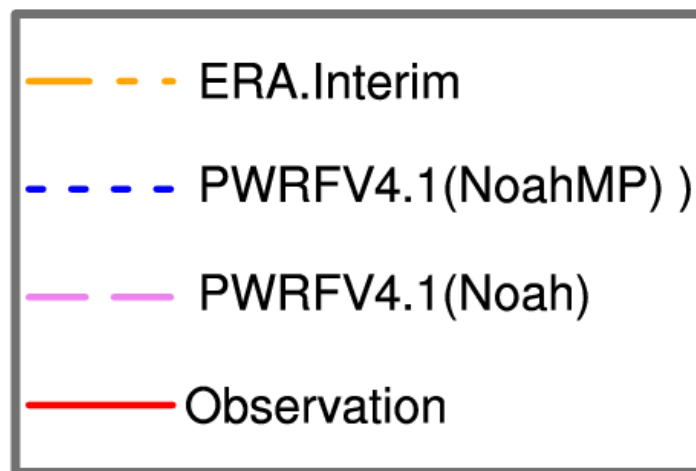
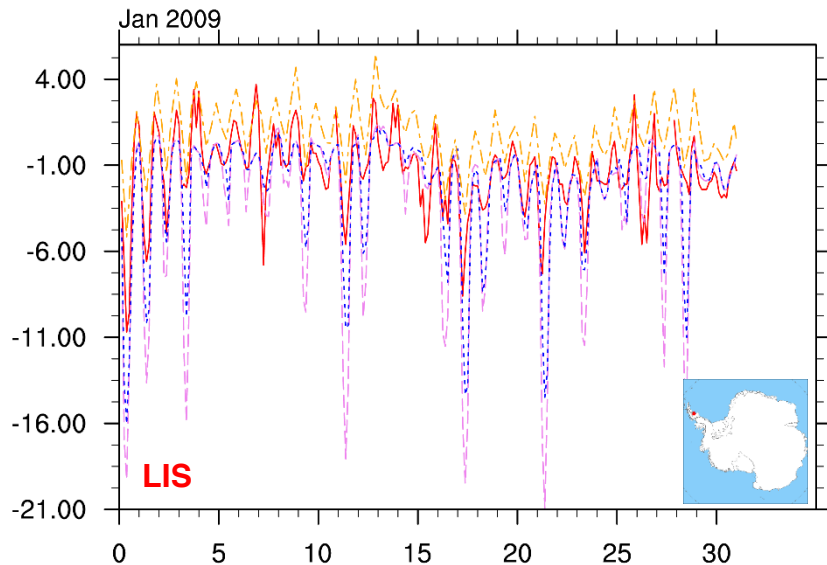
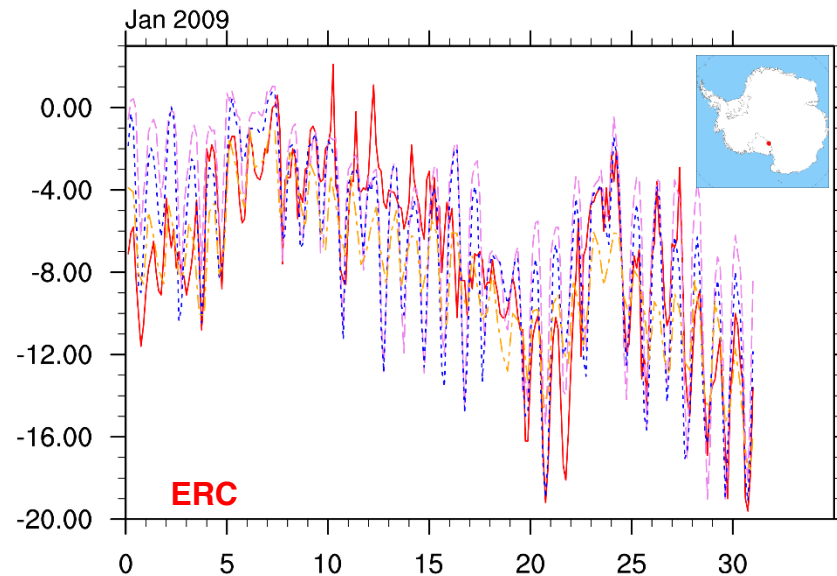
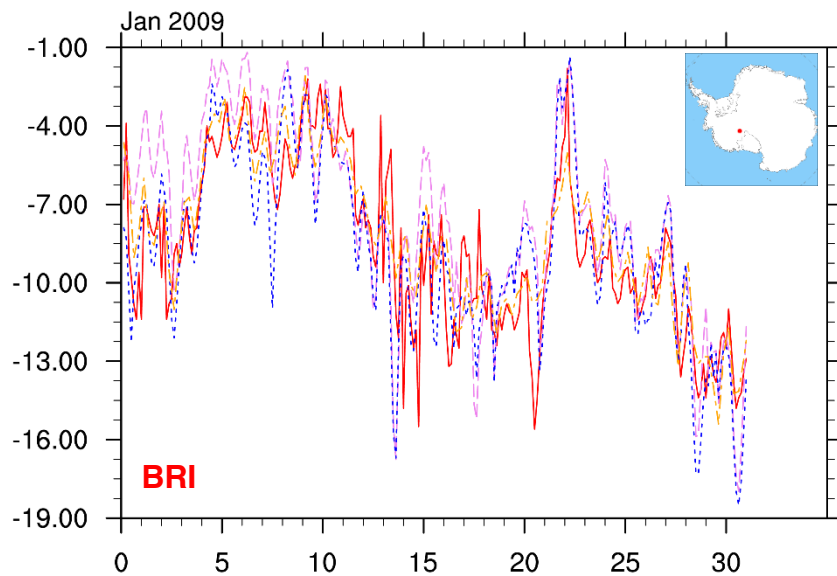






# Forecast Mode Simulations (48hr) Polar WRF V4.1

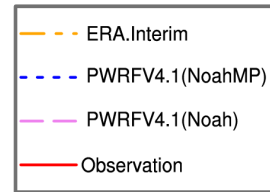
## Temperature Jan 2009



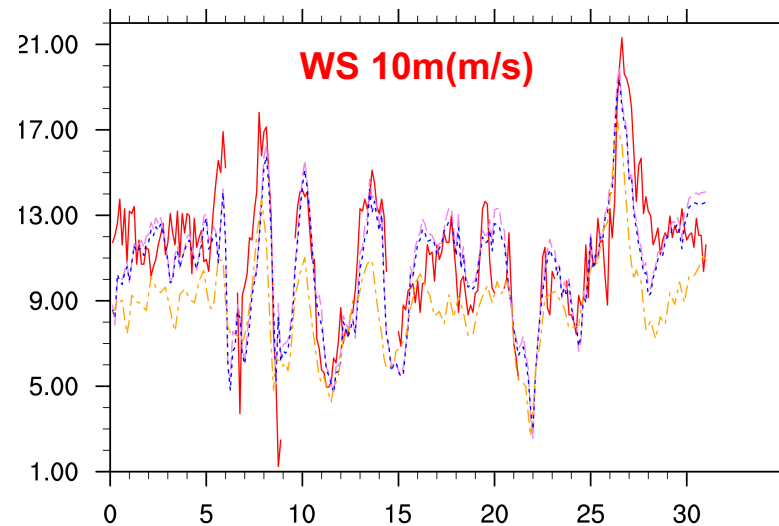
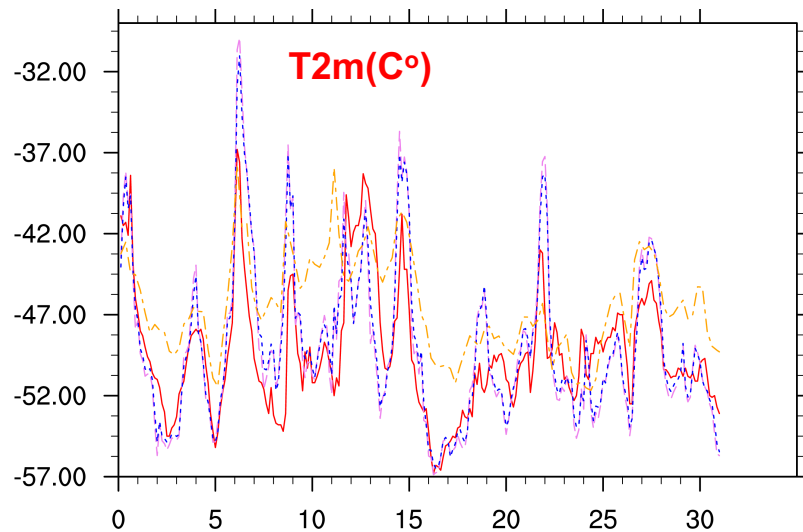


# Forecast Mode Simulations (48hr)

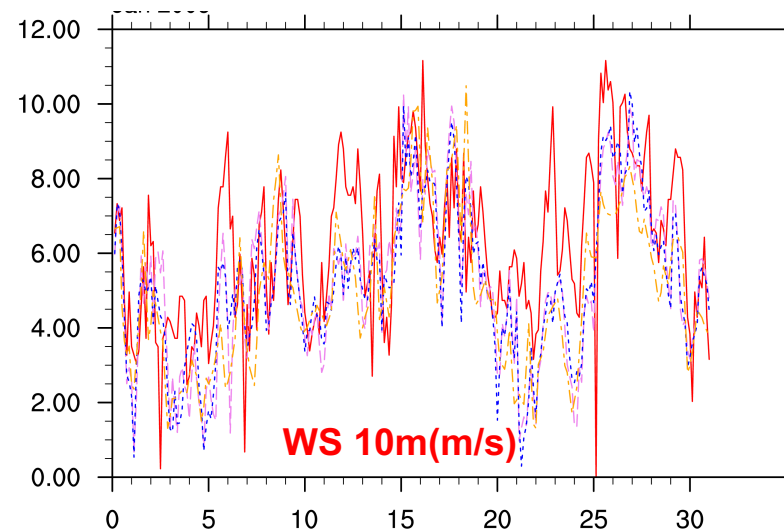
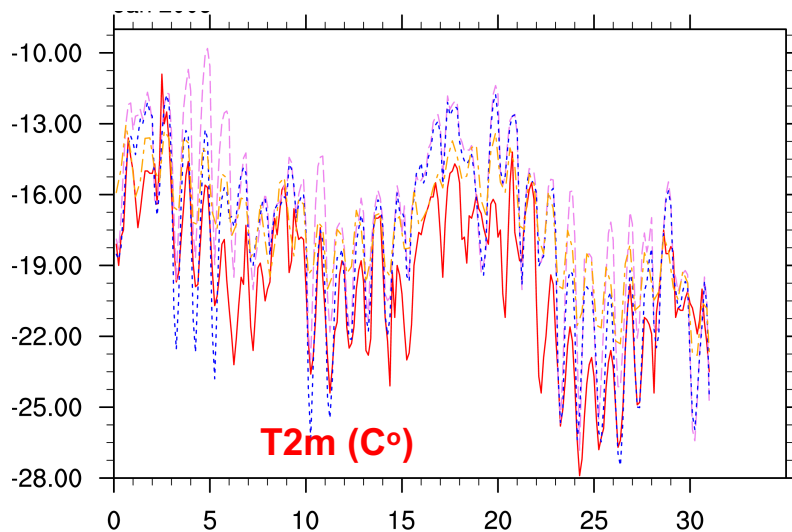
## Polar WRF V4.1



**July 2008**



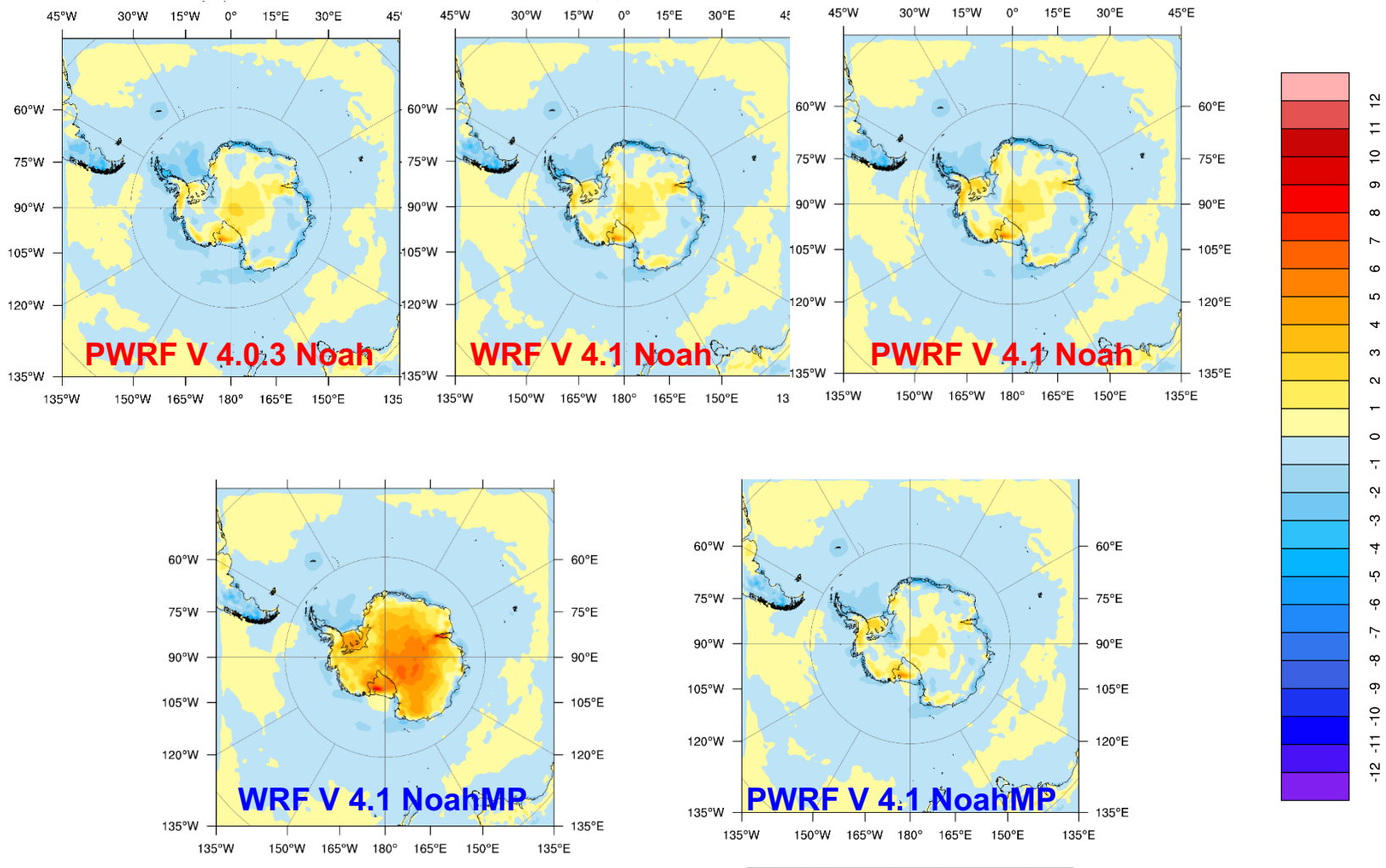
**Jan 2009**





## Climate Mode Simulations (Monthly)

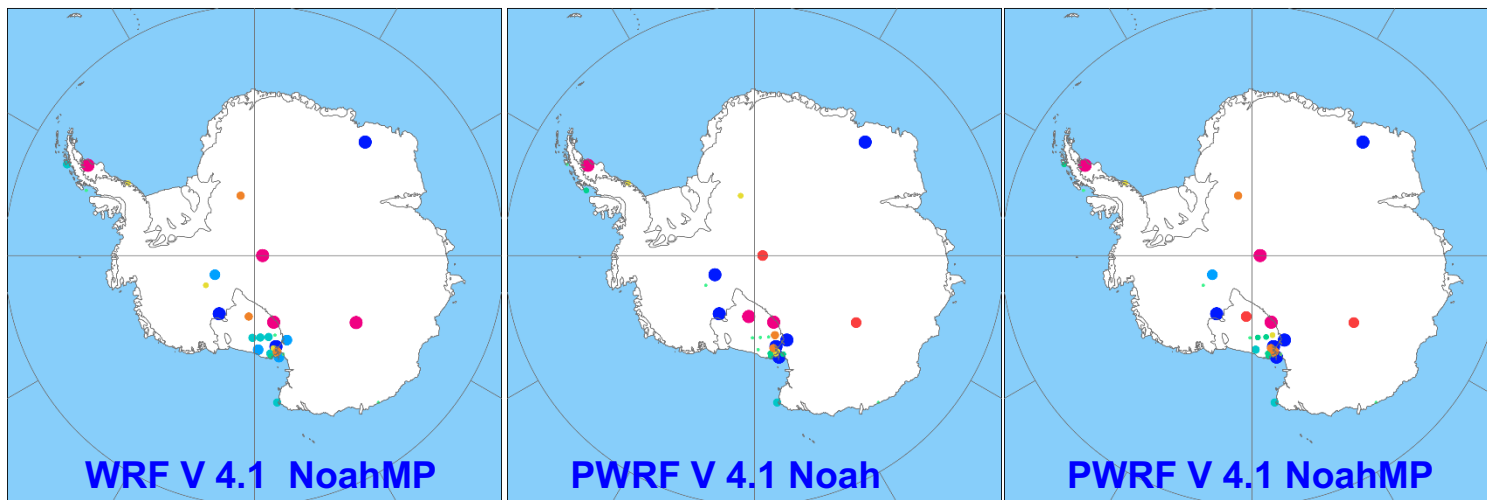
### Temperature Bias at 2m (vs. ERA-Interim) Jan 2009



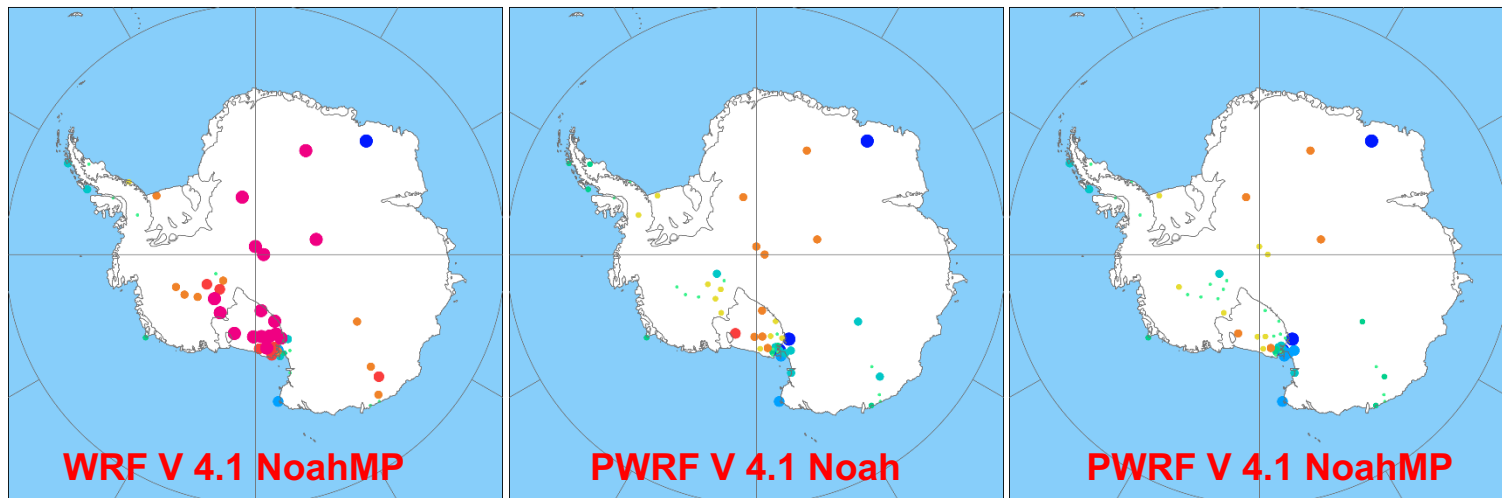


## Climate Mode Simulations (Monthly)

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



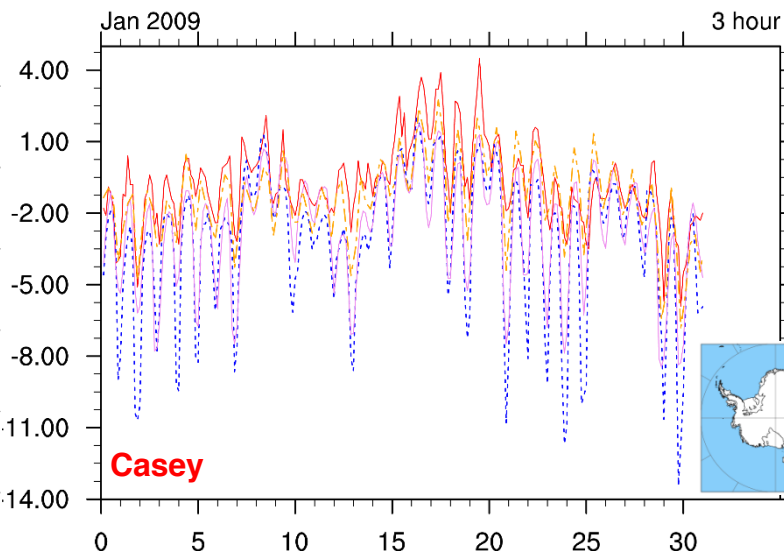
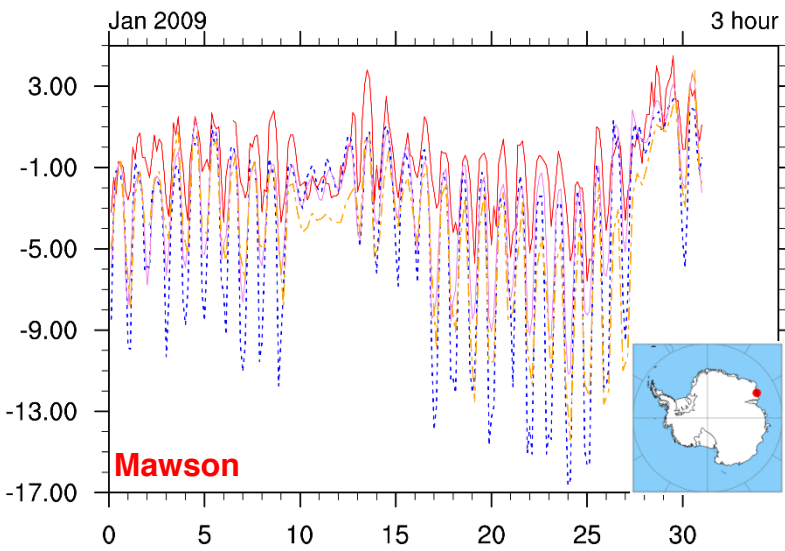
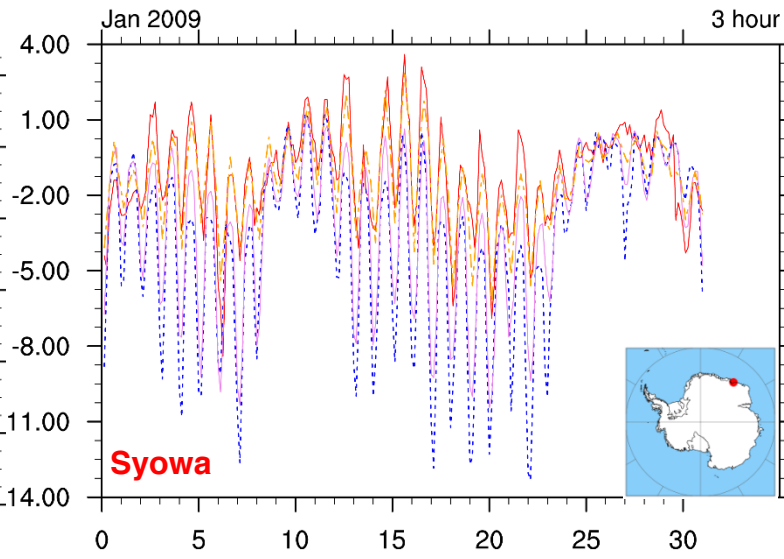
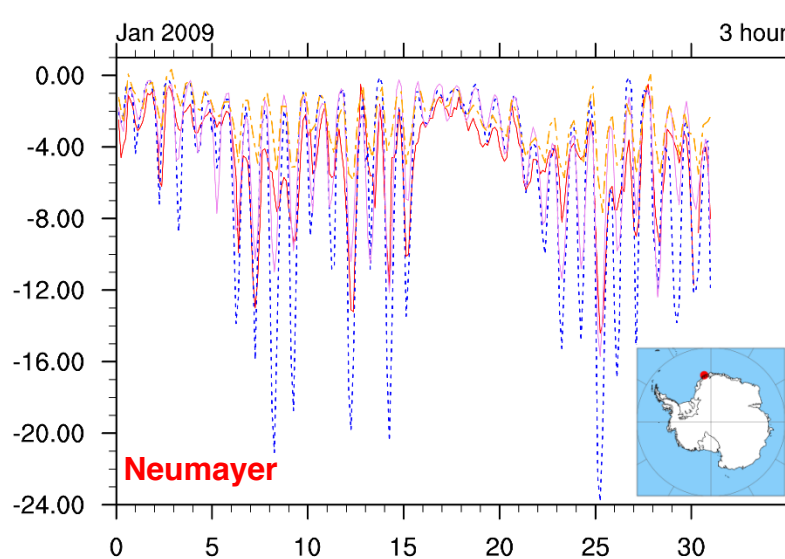
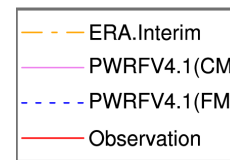
### Temperature Bias at 2m (vs. Observations) Jan 2009





# Coastal Station Diurnal Temperature Cycle

**PWRF V 4.1 NoahMP**  
**FM: Forecast Mode**  
**CM: Climate Mode**



# Summary and Future Work

- Downscaling simulations with forecast mode and climate mode are performed using Polar WRF version 4. Both simulation mode results show that Polar WRF has good performance over Antarctica.
- Upper-Air analysis nudging is important for long term simulation. This means that regional forecast results are dependent on the global model (lateral & upper boundaries) for long term forecasts.
- Modified Noah-MP (min albedo = 0.8 over ice sheet) removed the strong warm bias in summer over Antarctica and has better performance than Noah: reduced the warm bias, the cold bias and the strong near-surface temperature diurnal cycle in summer.
- In WRF version 4.1, a big improvement over the Antarctic region is the reduction in the downward shortwave radiation bias through better cloud fraction and subgrid scale mixing ratios in MYNN PBL scheme.

## Future Work

### Restructuring of Current Polar Mods

- Continue validation and Improvement of Noah-MP over Antarctica to remove strong near-surface temperature diurnal cycle.
- Modify Morrison cloud microphysics by revising the droplet parameter to reduce the radiation biases.
- Investigate the performance of the CLM and RUV land models over Antarctica.

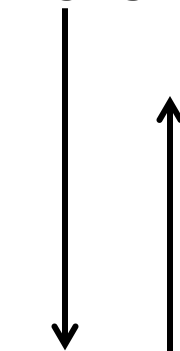
More sensitivity simulations with validation against observations.

Release Polar WRF V4.1 very soon.



# History of Polar WRF

Pre-ASR



ASR



AMPS



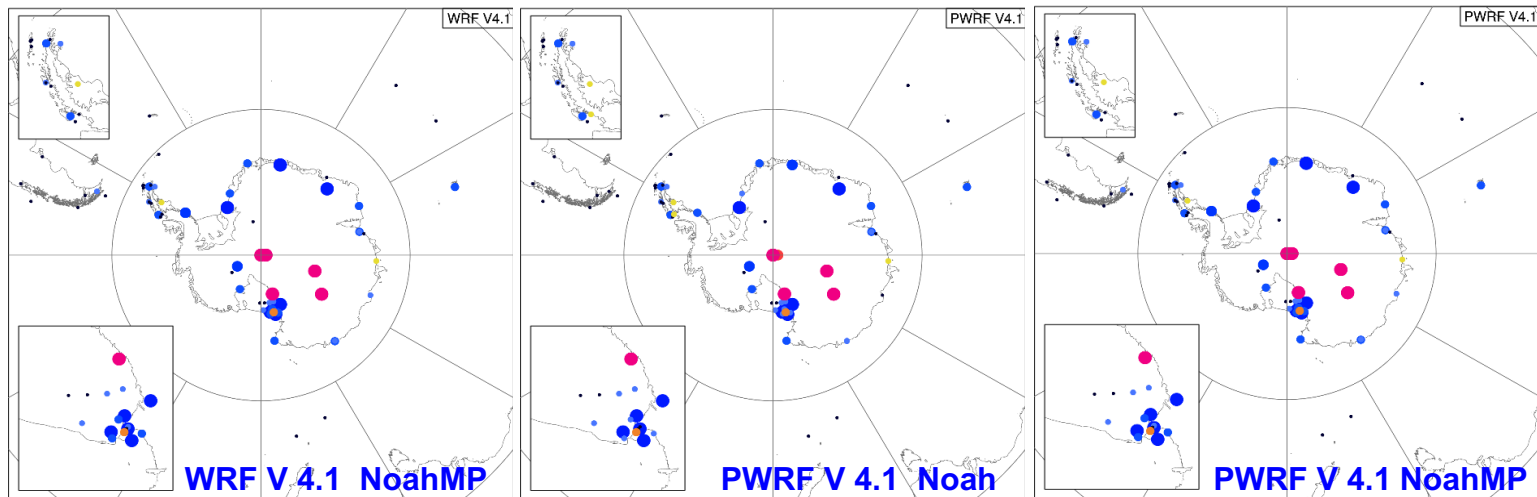
- **Version 2.1.1** ~2006  
snow/ice changes for Noah LSM  
Greenland
- **Version 2.2** 2007  
fractional sea ice  
SHEBA
- **Version 3.0.1.1** August 2008  
Polar WRF goes public  
North Alaska
- **Version 3.1.1** September 2009  
has standard WRF Noah snow improvements  
variable sea ice thickness  
ASR Grid  
Antarctica
- **Version 3.2/3.2.1** August 2010  
MYNN sfc layer consistent with fractional sea ice
- **Version 3.3.1** November 2011
- **Version 3.7.1** October 2015
- **Version 3.8.1** February 2017  
Arctic ARISE
- **Version 3.9.1** January, 2018  
Greenland Arctic Ocean
- **Version 4.1** 2019  
Antarctic Southern Ocean



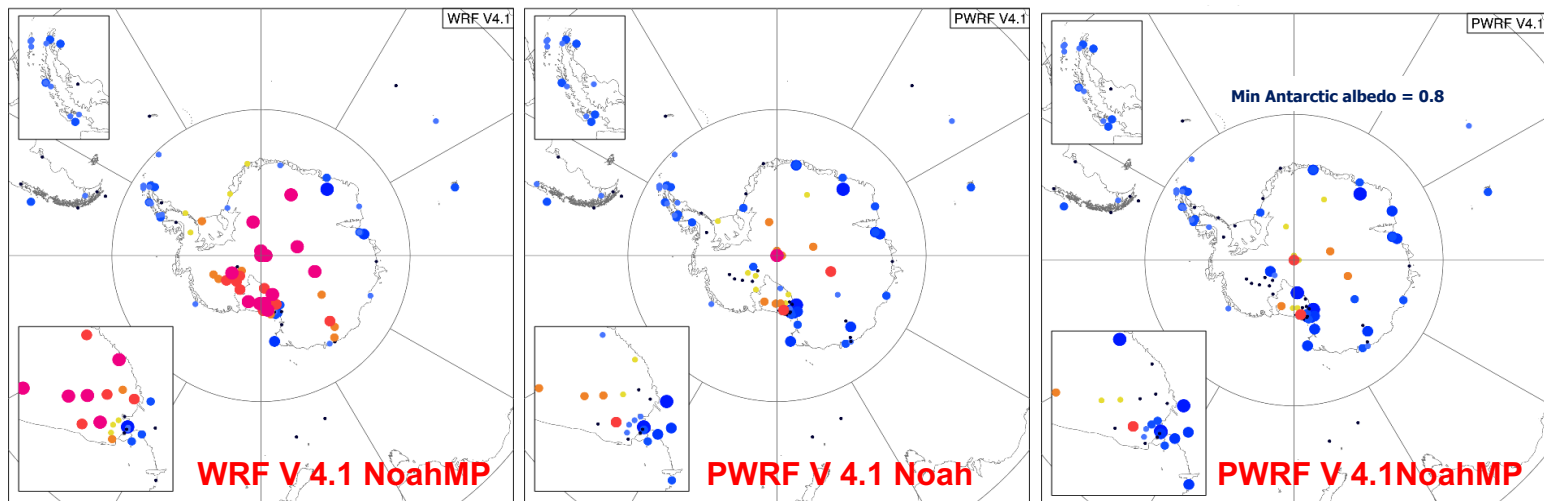


## Forecast Mode Simulation (48hr)

### Temperature Bias at 2m (vs. Observation) July 2008



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

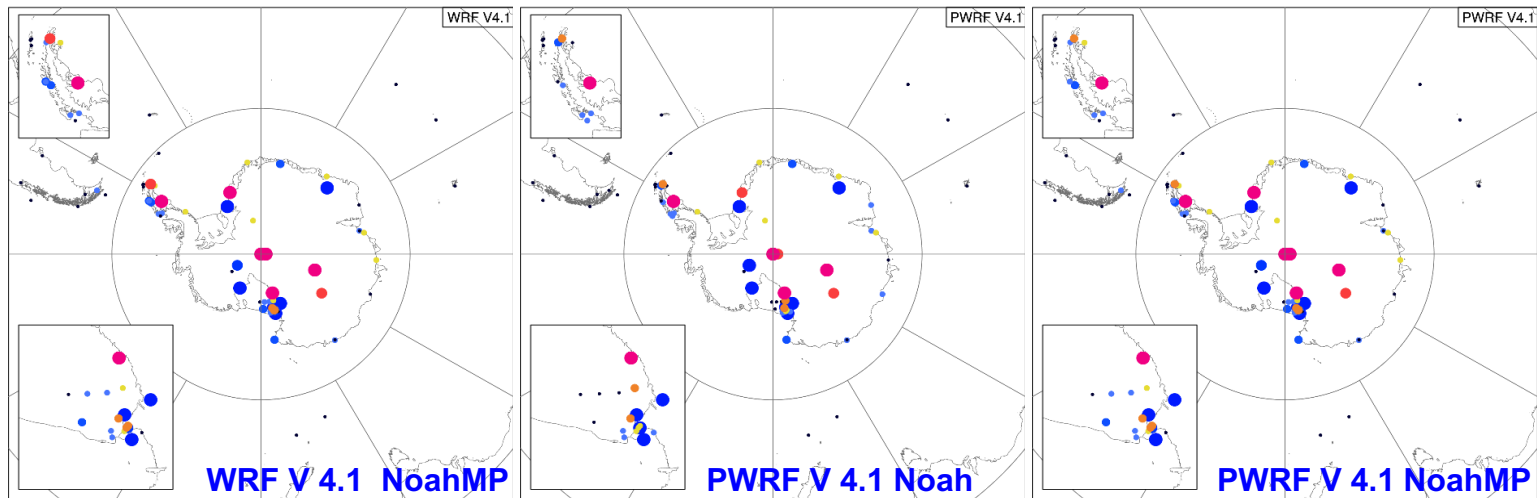




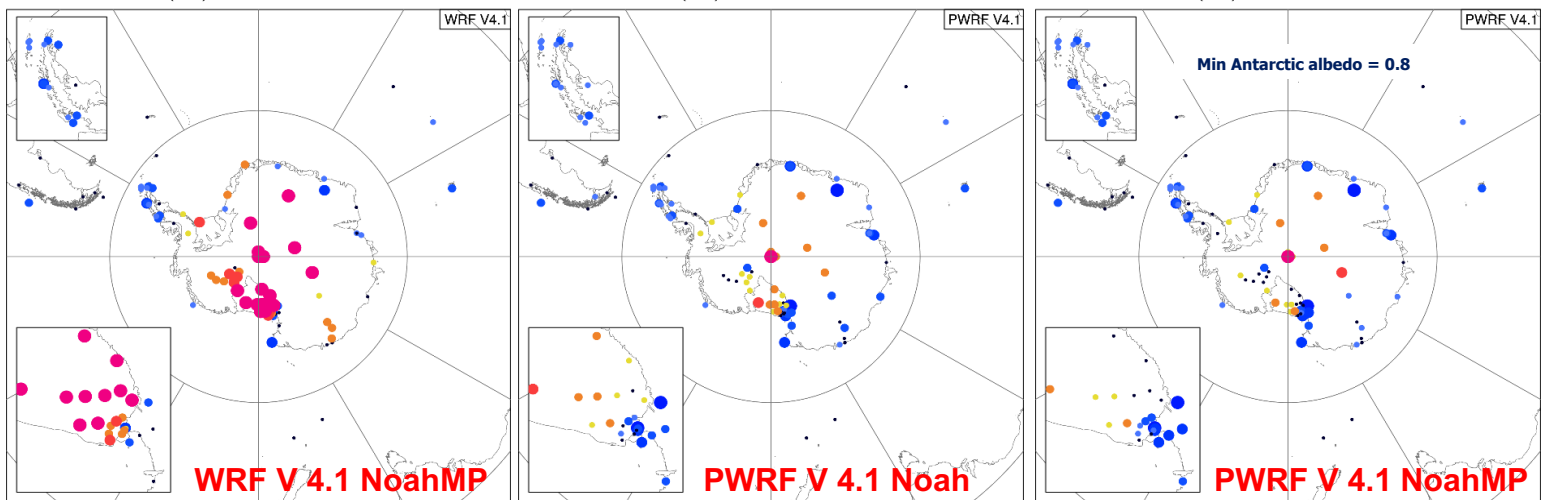


# Climate Mode Simulation (Monthly)

## Temperature Bias at 2m (vs. Observation) July 2008



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

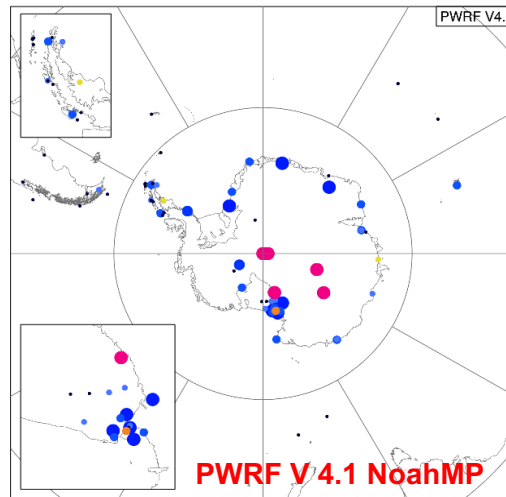
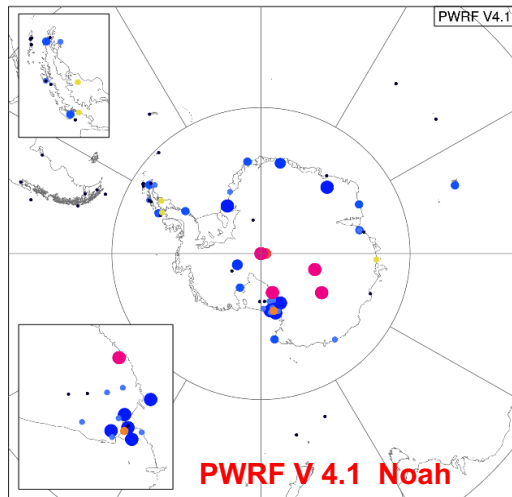




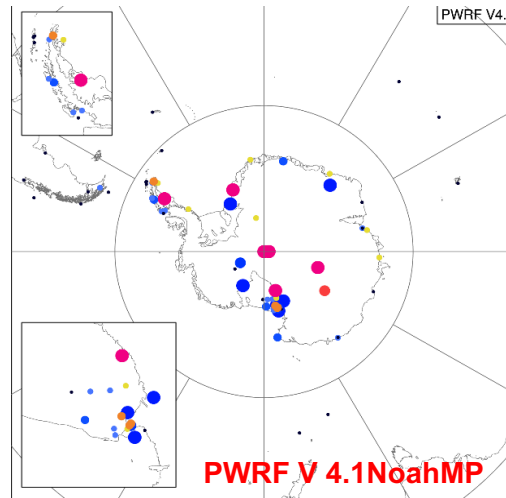
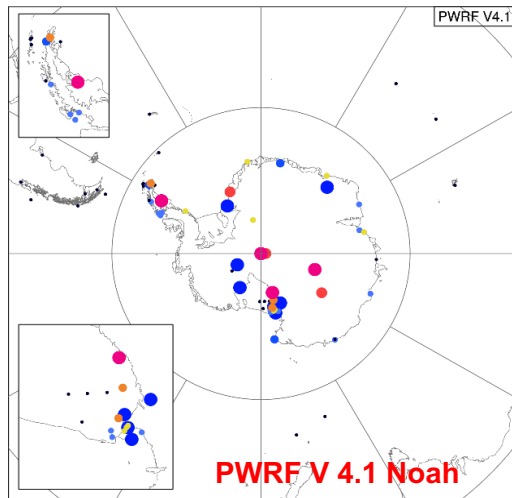
# Temperature Bias of Forecast Mode and Climate Mode

## Temperature Bias at 2m (vs. Observation) July 2008

**Forecast Mode**



**Climate Mode**

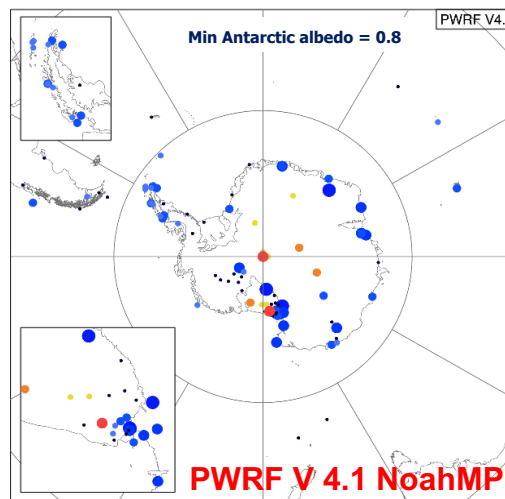
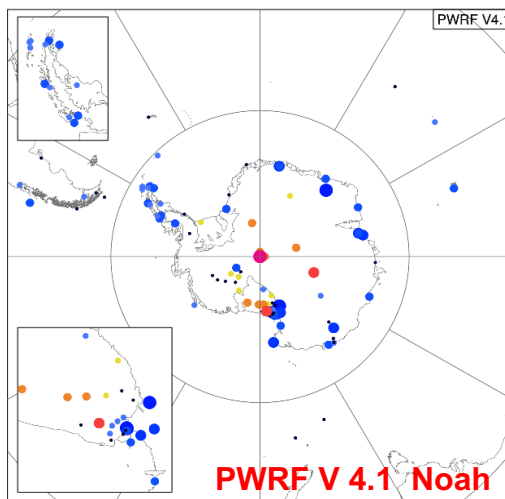




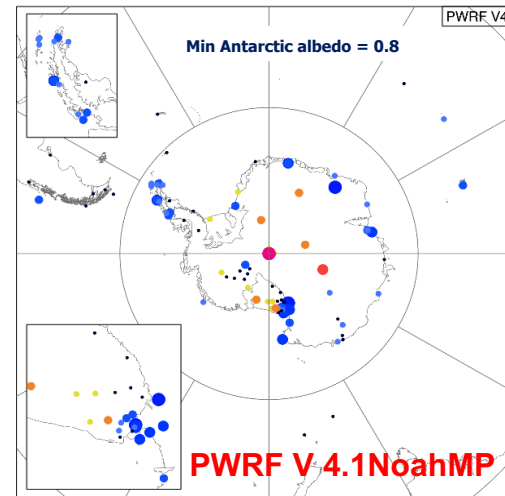
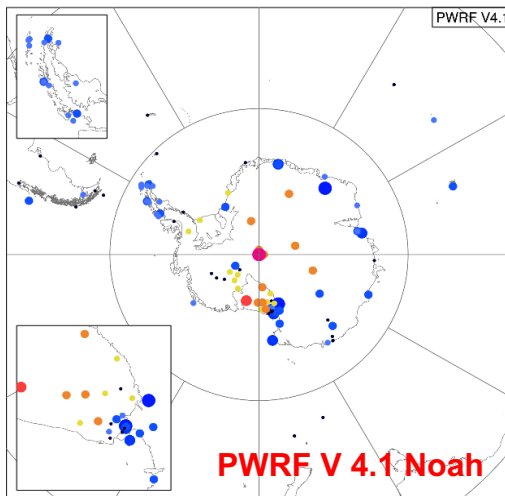
# Temperature Bias of Forecast Mode and Climate Mode

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

Forecast  
Mode



Climate  
Mode



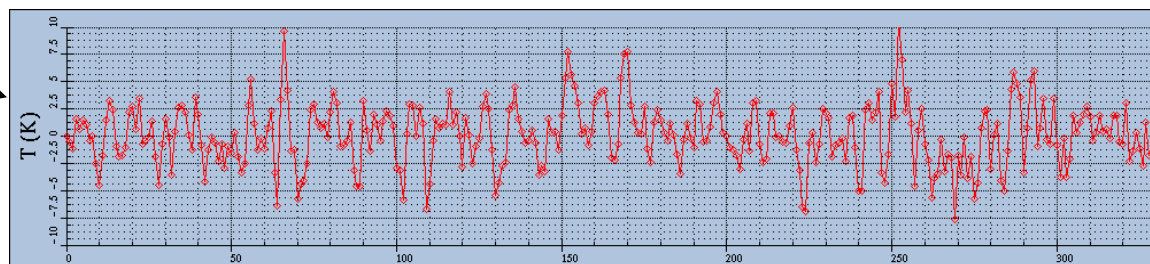


# Nudging Test for Climate Mode

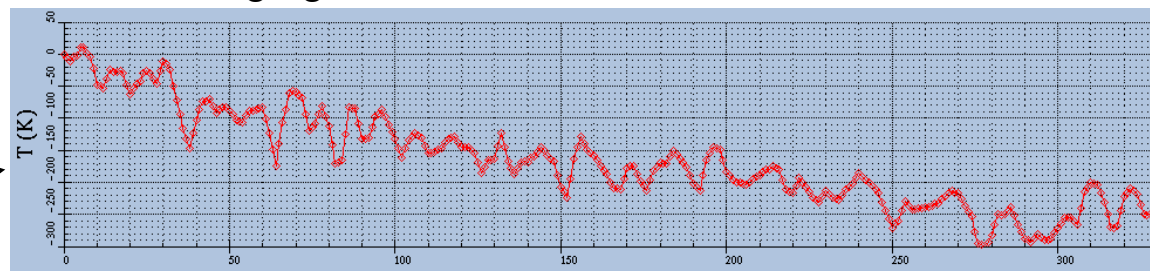
**Model Top Potential Temperature Bias July 2008**

**Polar WRF forecast – ERA-Interim**

With Nudging **bias  $\pm 10$**



Without Nudging **bias -300**



All cases show the similar result

Nudging improve the Model top level forecast skills

