Arctic and Antarctic tests of Polar WRF

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Testing of Polar Weather Research and Forecasting Model (WRF) by BPRC

1. Permanent ice sheets

   Greenland (Hines and Bromwich 2008, MWR)

   Antarctic climate simulations (Francis Otieno at OSU)

   Antarctic AMPS forecasts (NCAR MMM Division)

2. Polar pack ice

   Use 1997/1998 Surface Heat Budget of the Arctic (SHEBA) observations on drifting sea ice

   Selected months: January, June, and August

   Bromwich et al. (2009, JGR)

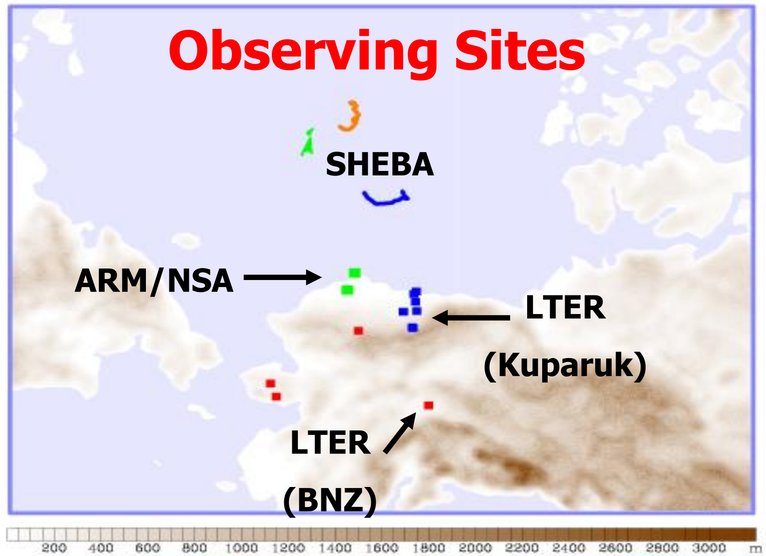
3. Arctic land

   Northern Alaska (Hines et al. 2010, J. Climate)

   Arctic System Reanalysis Grid (Wilson 2010, M.S. Thesis)

Western Arctic Domain

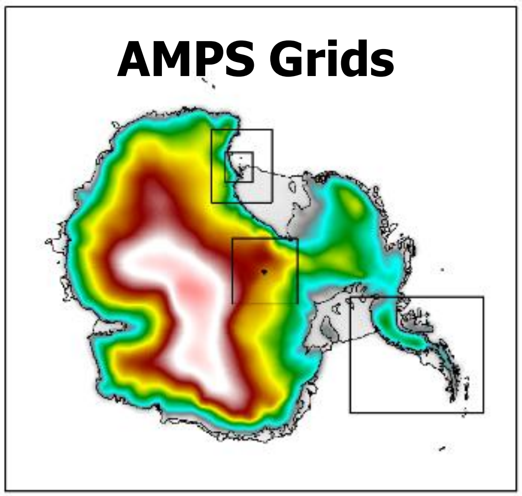
Comparison with ARM-NSA, Arctic LTERs in Kuparuk Basin and at Bonanza Creek

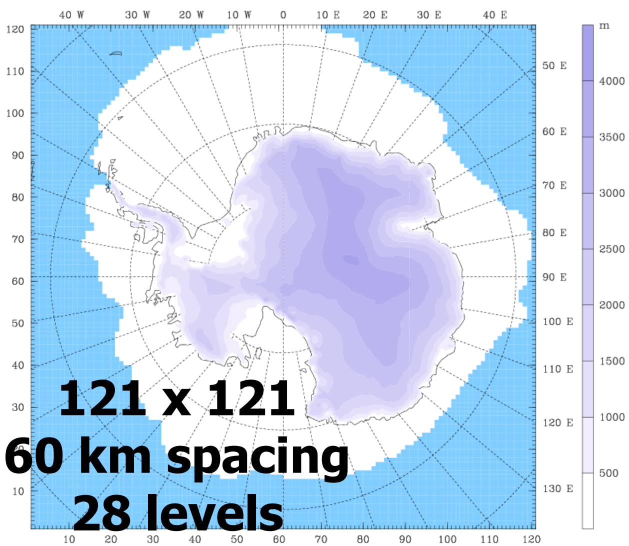


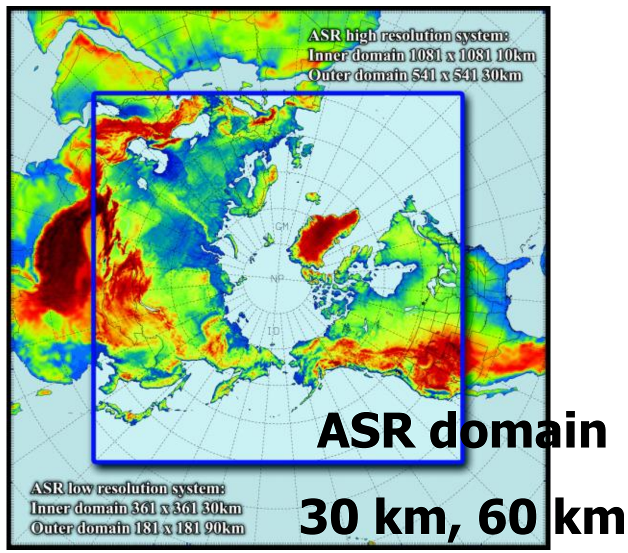
141 x 111 pts

25 km spacing

28 levels





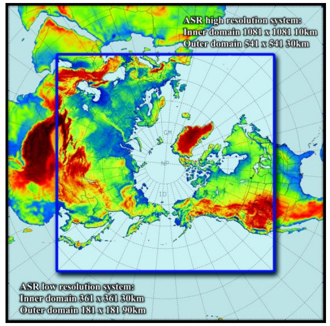


Polar WRF for WRF Version 3.1.1

- Tar file supplement to WRF Version 3.1.1 **(Oct. 5, 2009)**
  - Specified variable sea ice thickness (ASR-inspired)
  - Specified variable snow depth on sea ice (ASR-inspired)
  - 2 sfc temperature calculation options for permanent ice
  - Sea ice albedo seasonal specifications
  - Sea Ice fraction initialization (AMSR-E or bootstrap sea ice)
- Sea ice fraction is standard WRF option for Noah or RUC
- Standard WRF 3.1.1 updates to Noah snow pack

  heat transfer

  snow albedo – improved, Livneh et al. (2010)



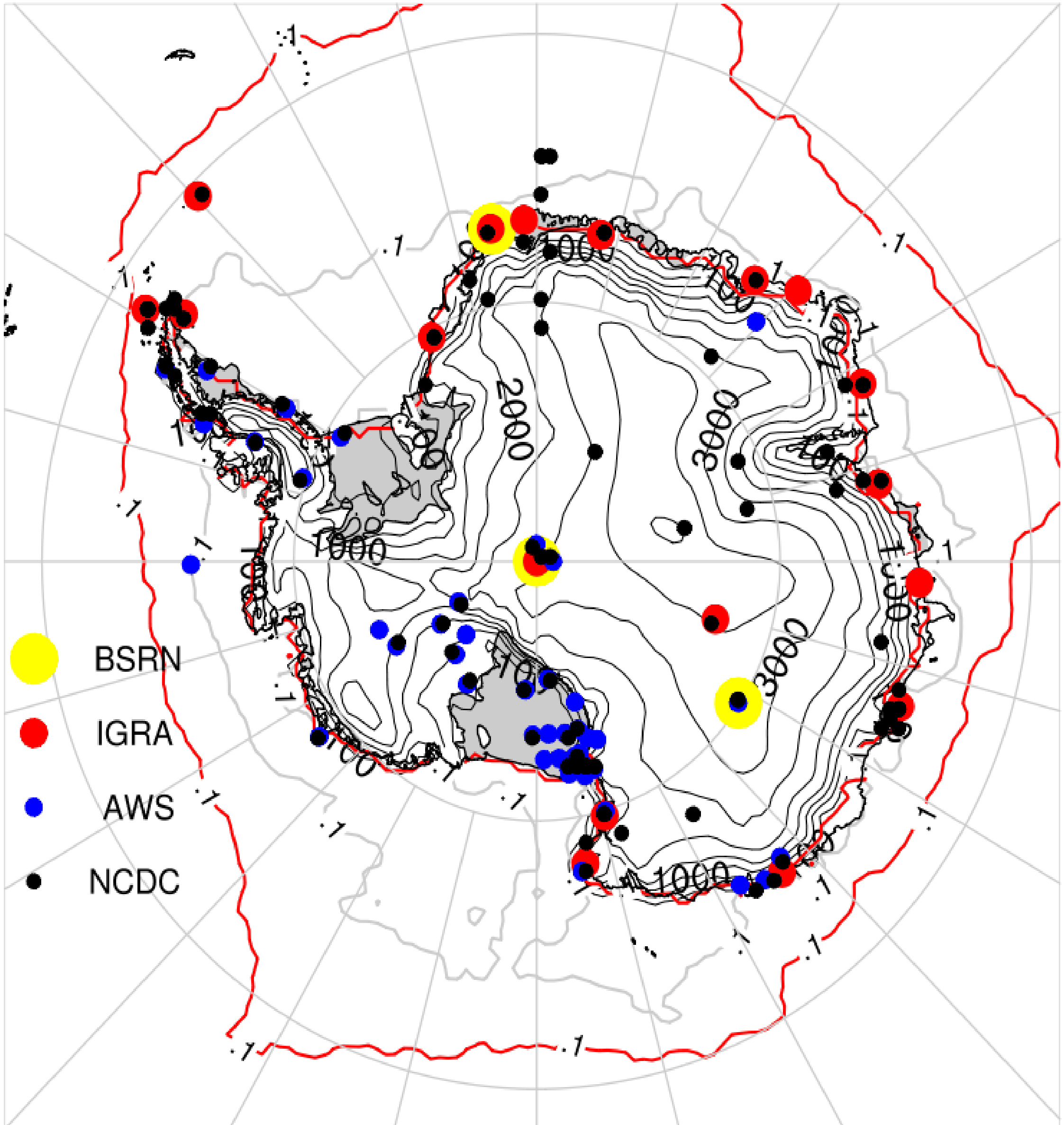
- Distributed to 45 members of the scientific community

  NCAR, NCEP, NSIDC, UCAR, NASA and PNNL
  16 U.S. Universities
  18 International users
  1 Business user
- <u>Coming to WRF 3.2 in July 2010 – with additional testing</u>

Polar WRF 3.0.1.1

Antarctic results

Domain showing terrain, sea ice extent and station sites



Most of the stations are located in low lying coastal regions

Only two Upper Air stations on the plateau

Most AWS stations are on the Ross Ice Shelf and the Peninsula

At 60 km some Island stations around the Peninsula are not identifiable in the model leading to large errors

Sharp gradients in the terrain pose serious challenges for verification using coastal stations

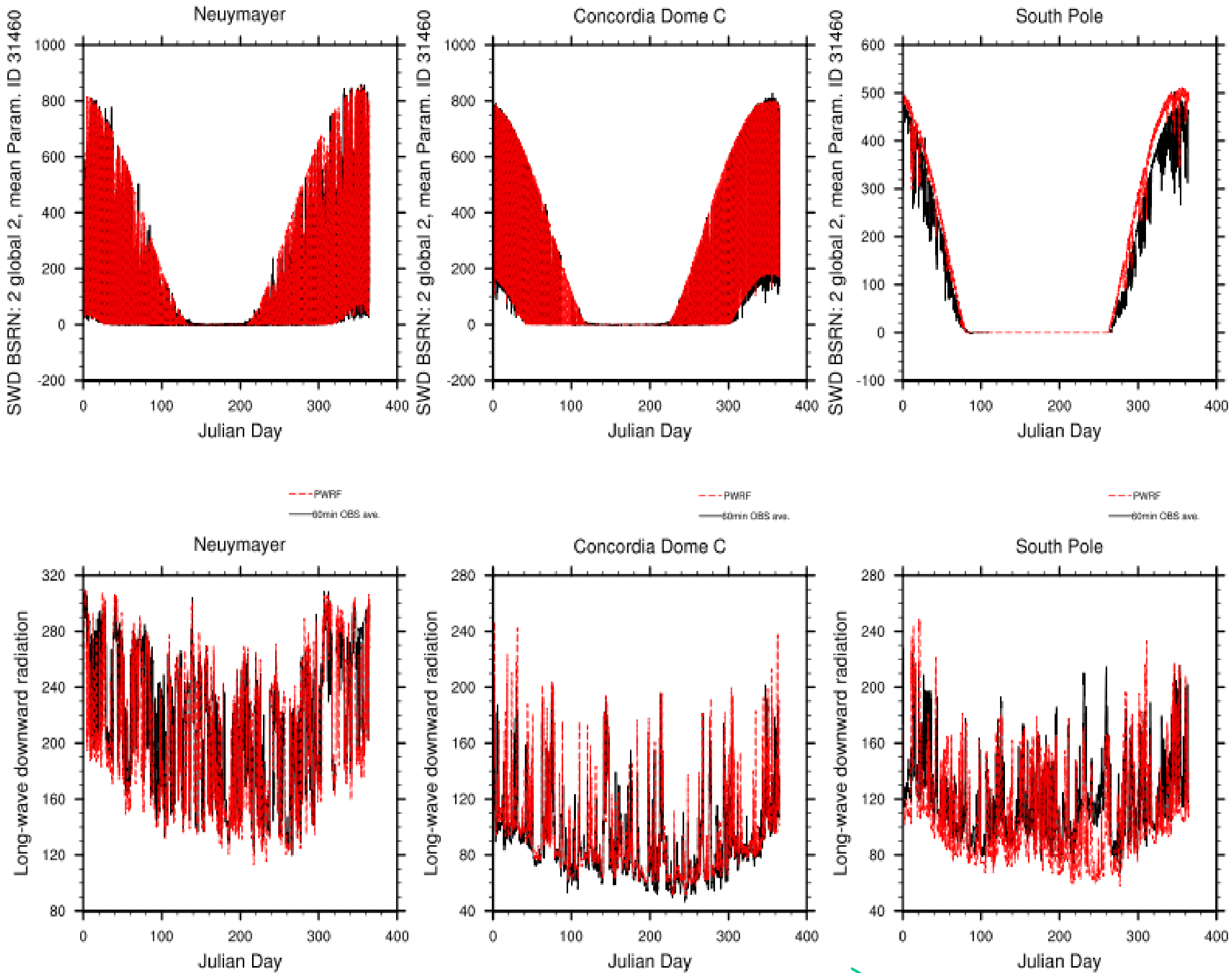
BSRN-Baseline radiation Network
IGRA-*Integrated Global Radiosonde Archive (NCEP)*
AWS- *Automatic Weather Stations (AMRC)*
NCDC *–National Climatic Data Center (NOAA)*

Polar WRF represents the variability of downward shortwave accurately for most of the year

Polar WRF does have excess shortwave reaching the surface in the summer; Differences a re more pronounced at the South Pole

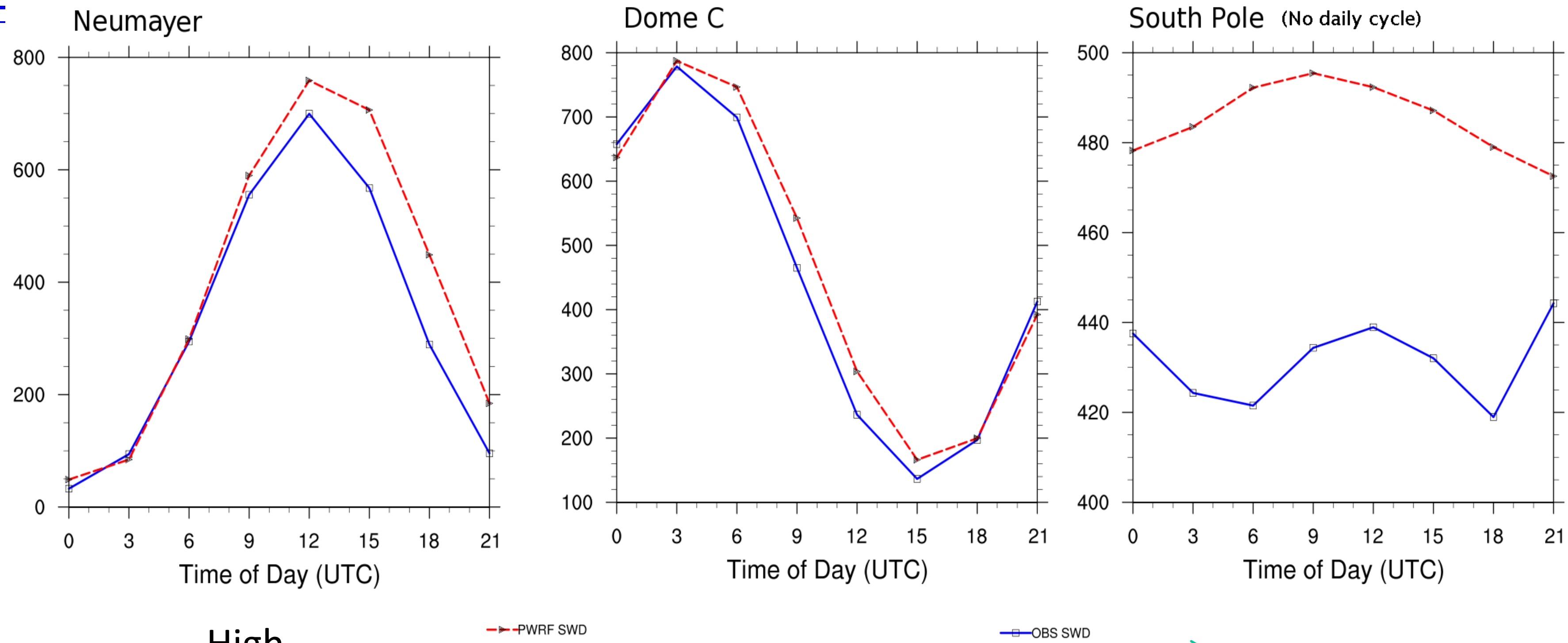
The variability at the South Pole is substantially smaller in the model than in the observations.

The variability of the LWD, responsible for surface heating during the long Antarctic winters ,is also accurately represented



High latitude

South Pole



High latitude

South Pole

More SWD (~40 W/m2) at the surface evident across the continent

Occurs mostly in the 12 hours following local noon

Polar WRF 3.0.1.1 vs 9 IGRA Upper Air Stations for 2007

	Temperature			Geopotential			Wind Speed			U-Wind			V-Wind		
	BIAS	RMSD	CORR	BIAS	RMSD	CORR	BIAS	RMSD	CORR	BIAS	RMSD	CORR	BIAS	RMSD	CORR
850	1.04	2.57	**0.94**	-6.26	23.67	**0.96**	1.42	5.44	**0.69**	0.24	5.39	**0.69**	0.45	5.34	**0.65**
700	0.87	2.46	**0.92**	0.63	26.17	**0.89**	1.27	4.78	**0.68**	0.96	4.90	**0.69**	-1.76	6.58	**0.57**
500	0.03	1.77	**0.96**	-1.27	29.56	**0.97**	0.51	4.95	**0.77**	0.83	6.07	**0.67**	-0.14	6.43	**0.69**
400	0.07	1.70	**0.88**	2.2	33.13	**0.98**	0.38	5.93	**0.77**	0.43	7.11	**0.67**	0.24	7.74	**0.70**
300	0.90	2.01	**0.65**	5.38	36.26	**0.98**	-0.24	6.50	**0.80**	0.21	7.67	**0.67**	0.44	8.39	**0.70**
250	0.76	2.28	**0.86**	22.47	41.3	**0.98**	0.04	5.48	**0.83**	0.08	6.73	**0.68**	0.39	7.47	**0.70**
200	0.04	1.96	**0.93**	36.98	48.74	**0.99**	0.45	4.19	**0.86**	0.12	5.29	**0.70**	0.45	6.04	**0.70**

Biases in Polar WRF simulations are small between 850 and 300 hPa

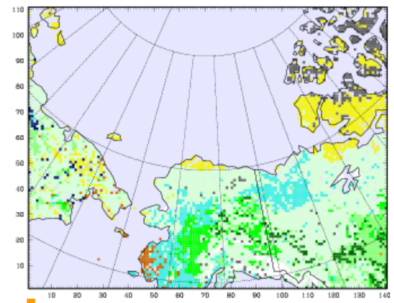
Geopotential errors become larger above 300 hPa (small percentage differences)

Preliminary surface verification show comparable skill but data are more problematic

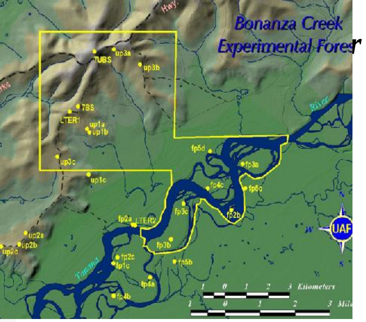
Overall Polar WRF shows skill levels in the SH that are comparable to those in the NH

Polar WRF Test – Phase III: Arctic Land

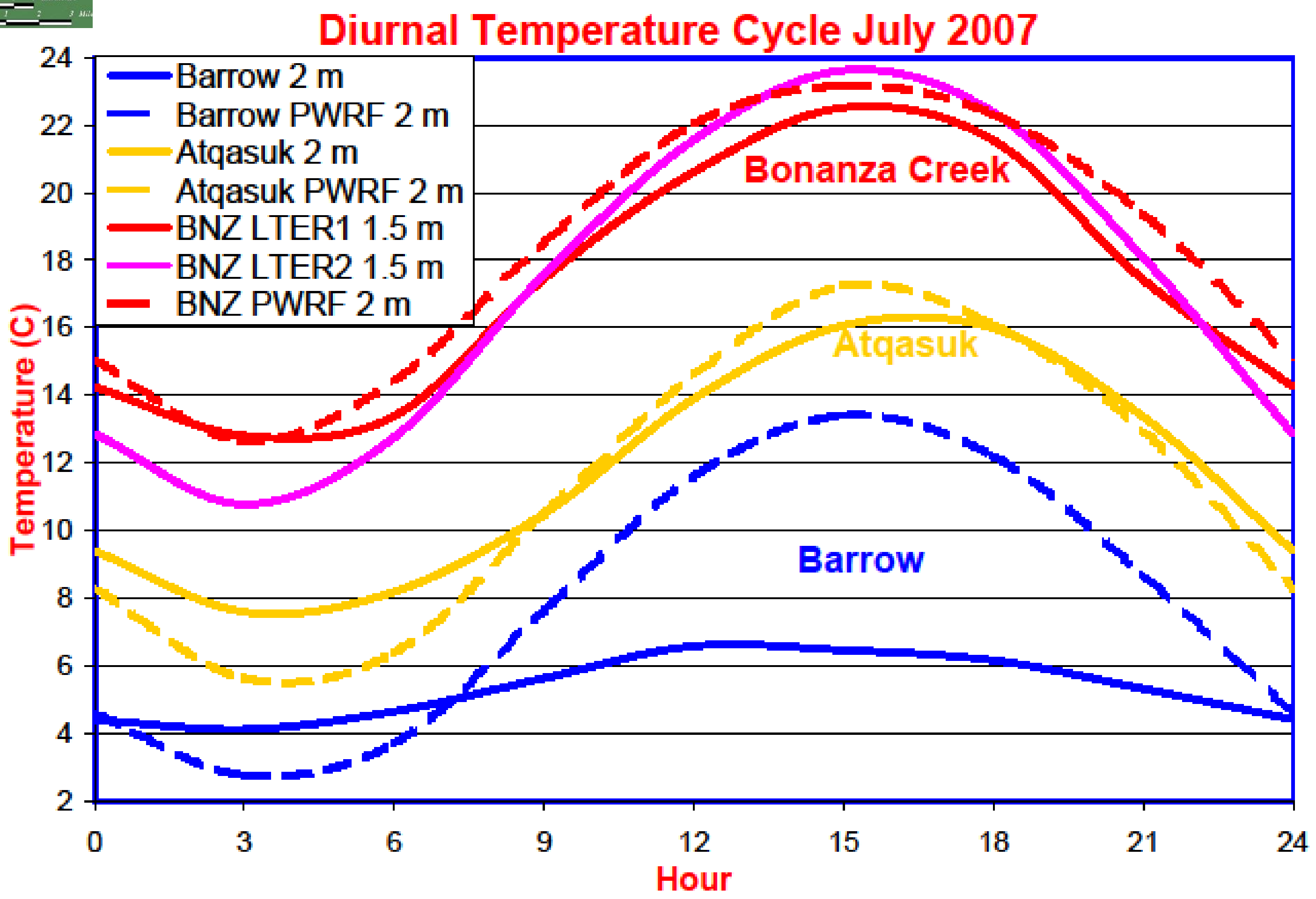
- Polar WRF with WRF version 3.0.1.1
- Western Arctic Grid 141 x 111 points, 25 km spacing, 28 levels
- Atmospheric Initial and Boundary Conditions: GFS FNL
- Sea Ice Fraction: NSIDC/WIST AMSR-E (25 km)



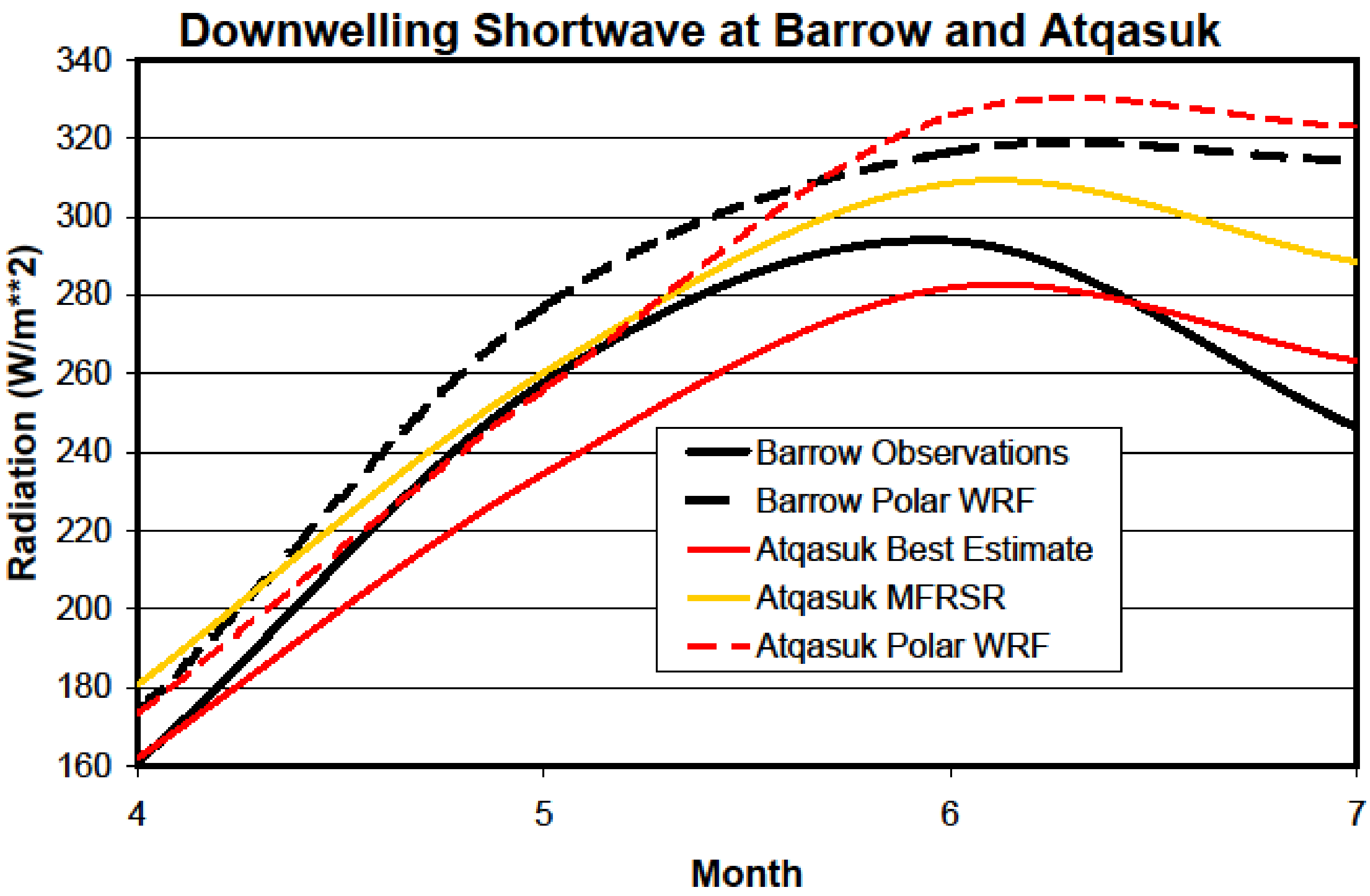
- Soil Initial and Boundary Conditions
  - Fixed Temperature at 8 m depth from Drew Slater
    - bottom of the phase change boundary temperature
  - Initial Soil Temperature and Soil Moisture from Mike Barlage
    - 10-year Noah Arctic run for spin-up driven by JRA-25
    - start set for 0000 UTC 15 November 2006
- Run for November 2006 to July 2007
  - 48-hour Simulations with GFS Atmospheric I.C.
  - Cycle Soil Temperature, Soil Moisture, Skin Temperature
    - 48-hr output Day X run → I.C. for Day X+2 run
  - Runs on OSC Glenn Cluster

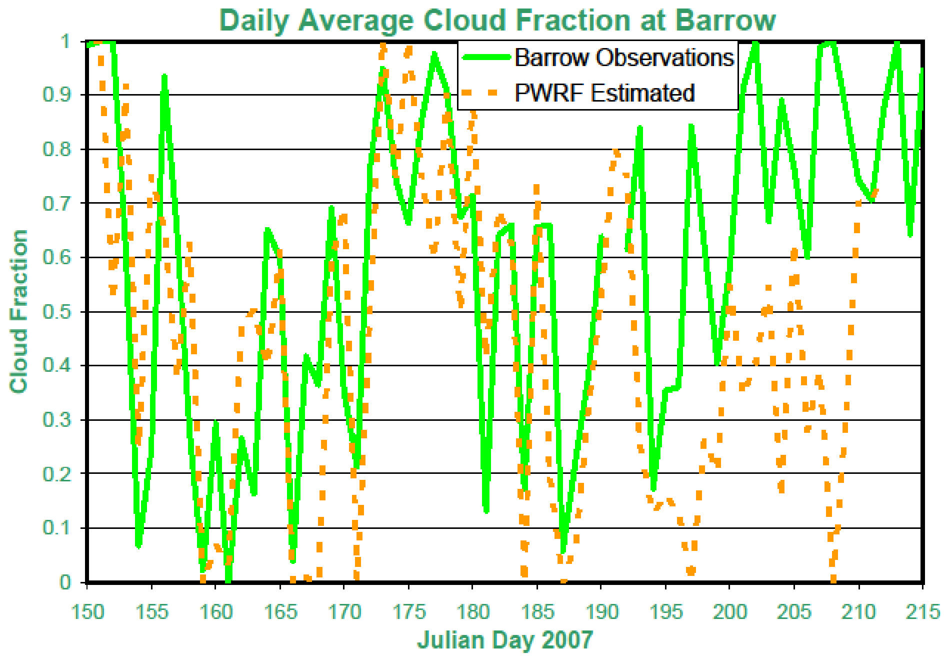

Bonanza Creek
Experimental Forest
UAF


Barrow
Atqasuk
ALASKA
Nome


Diurnal Temperature Cycle July 2007
Barrow 2 m
Barrow PWRF 2 m
Atqasuk 2 m
Atqasuk PWRF 2 m
BNZ LTER1 1.5 m
BNZ LTER2 1.5 m
BNZ PWRF 2 m
Bonanza Creek
Atqasuk
Barrow
Temperature (C)
Hour
24
22
20
18
16
14
12
10
8
6
4
2
0
3
6
9
12
15
18
21
24


Barrow
Atqasuk
ALASKA
Nome

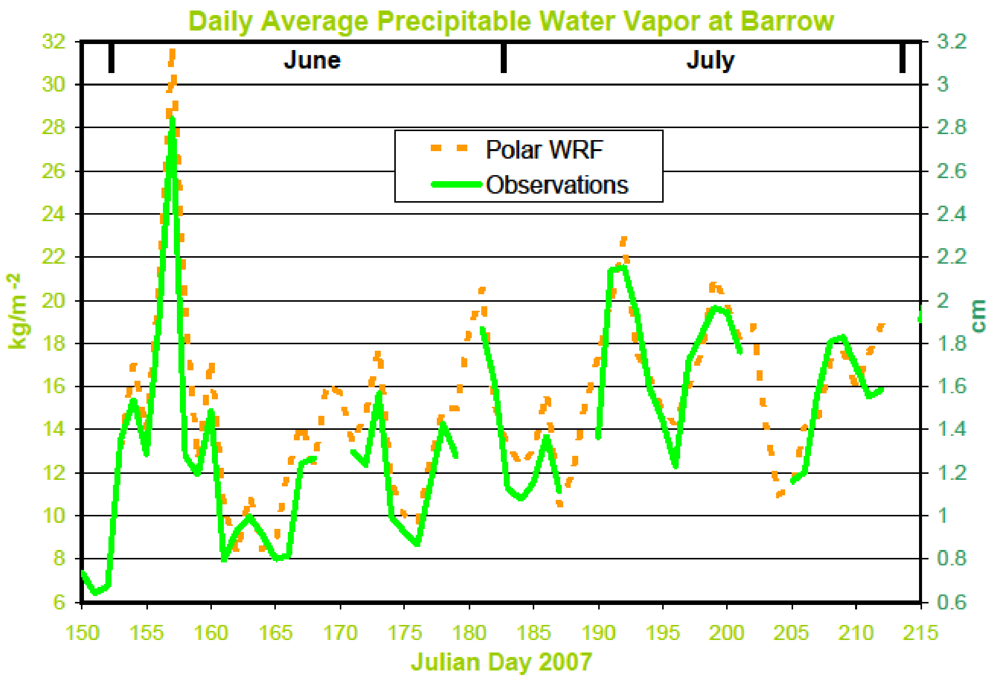

Downwelling Shortwave at Barrow and Atqasuk
Radiation (W/m**2)
340
320
300
280
260
240
220
200
180
160
4
5
6
7
Month
Barrow Observations
Barrow Polar WRF
Atqasuk Best Estimate
Atqasuk MFRSR
Atqasuk Polar WRF



WRF Estimated Cloud Fraction

CF = A_{LIQ} CLWP+ A_{ICE} CIWP

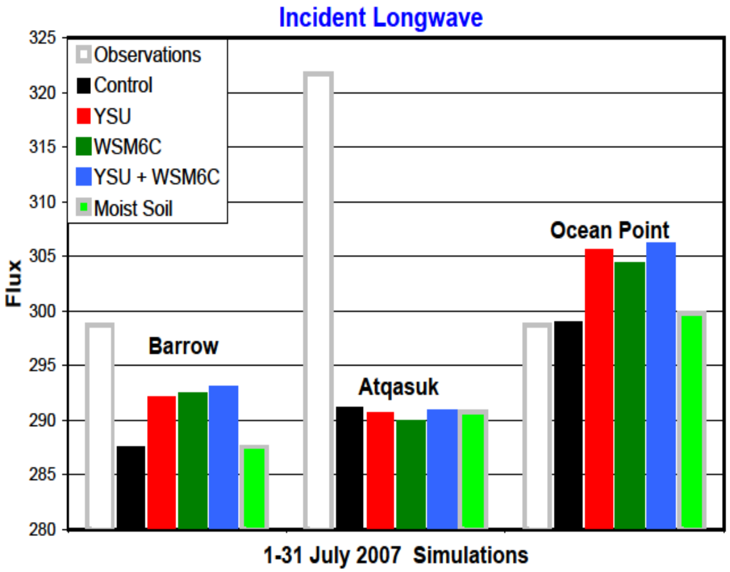
(Fogt and Bromwich 2008)

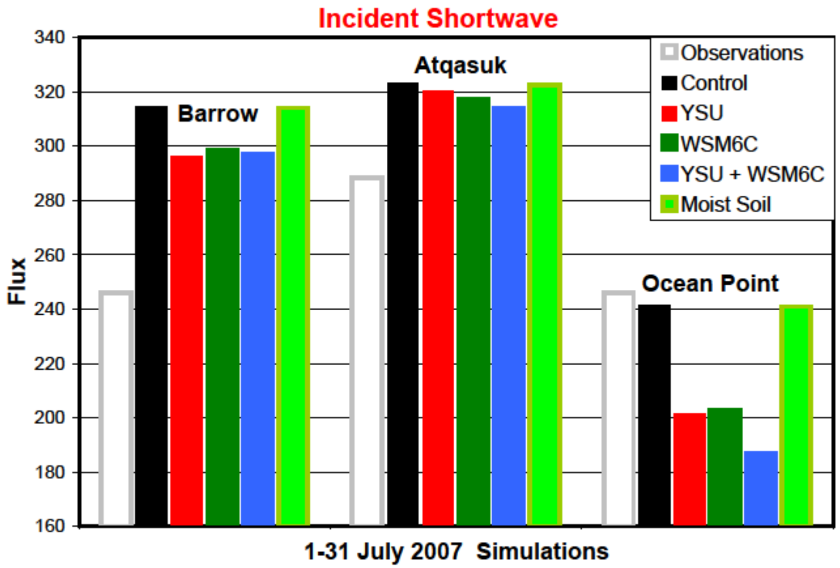


Summer PWV over Arctic land is good, but cloud cover shows a deficit.

Result: excessive incoming shortwave at surface

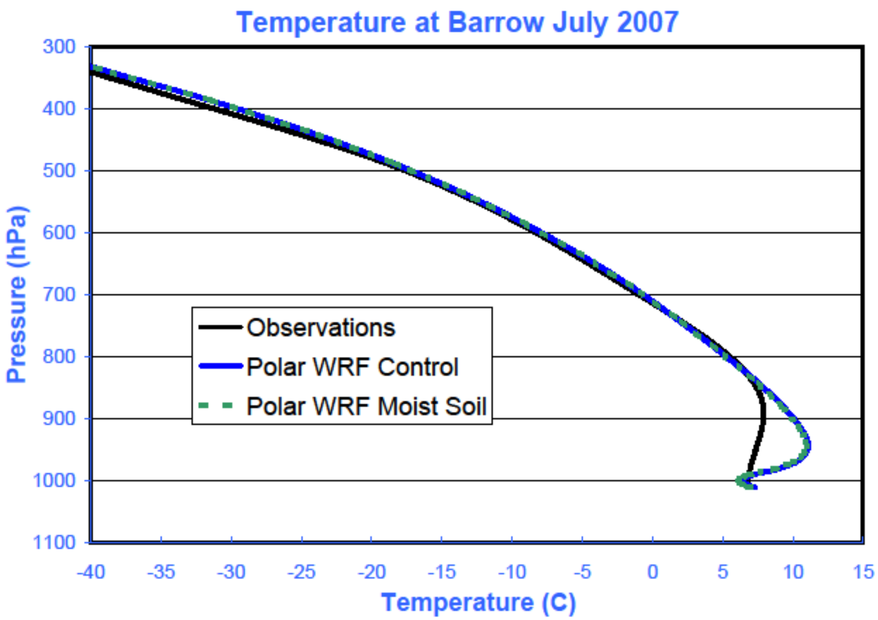
<u>Sensitivity Tests</u>: change PBL, change microphysics, add soil moisture





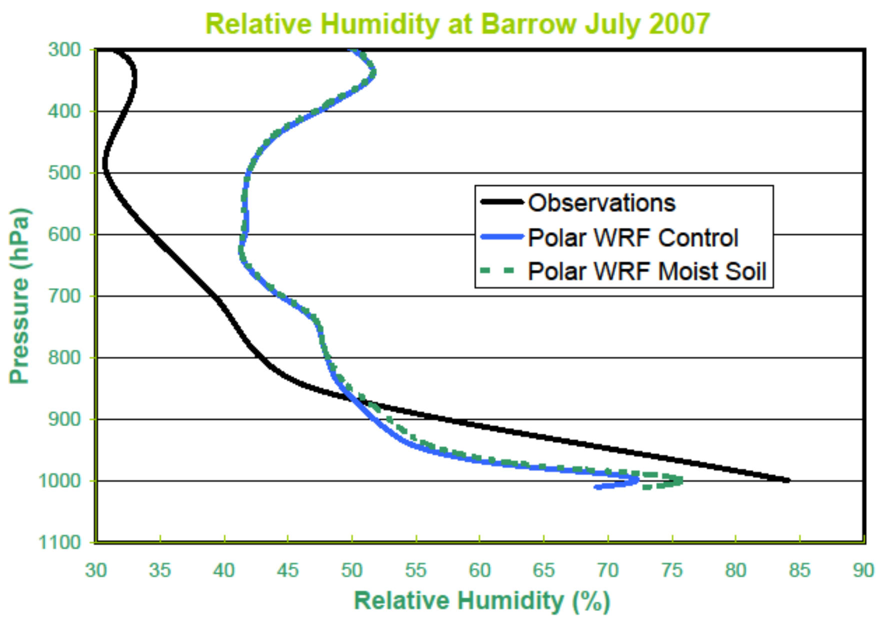
<u>Results</u>: The PBL and microphysics impact the Arctic stratus over the Arctic Ocean, but little impact over land at Atqasuk.

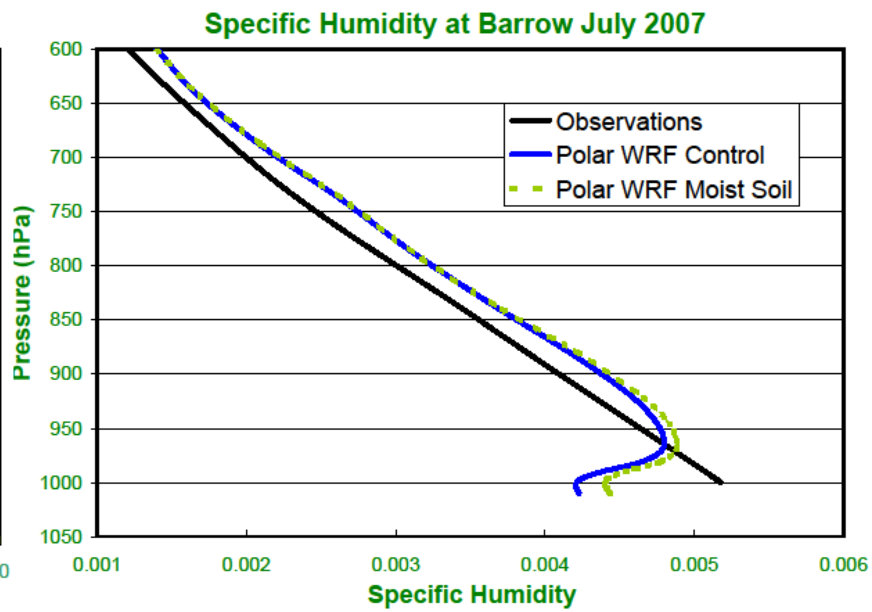
Added soil moisture doesn't increase cloud cover.

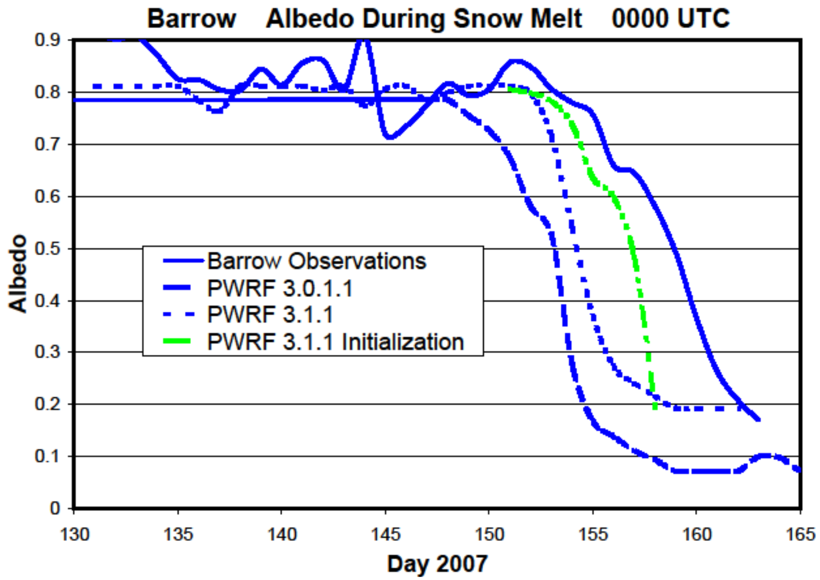


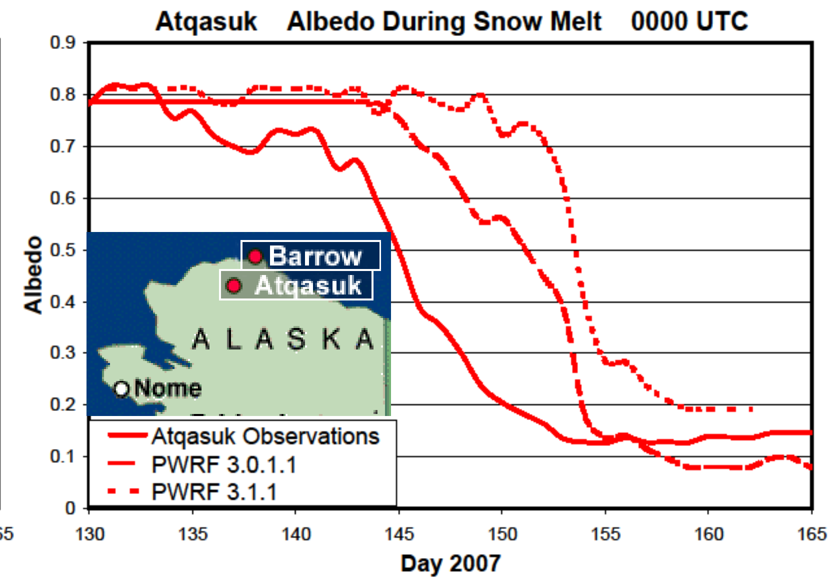
The temperature profile is well captured above the boundary layer. Simulated relative humidity and specific humidity are too large above the boundary layer.

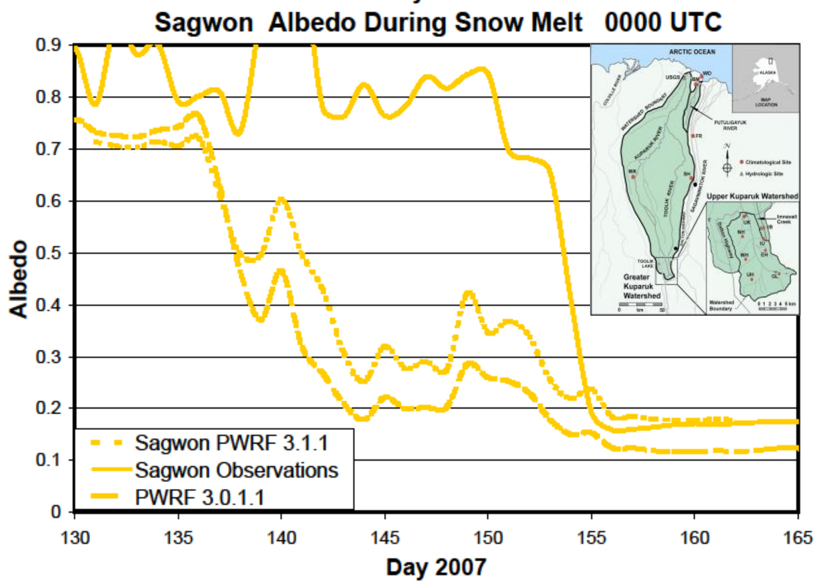
Is too much moisture mixed out of the boundary layer?











WRF Noah 3.1.1's new snow albedo predicts high snow albedo prior to snow melt and rapid decrease of albedo once snow melt begins. User specification of snow albedo is no longer required.

Albedo results at Barrow and Sagwon Hill are improved.

Summary

- Polar WRF has been tested for Greenland, the Arctic Ocean, northern Alaska and Antarctica
- The tar file supplement for Polar WRF (3.1.1) is the current public version
- Polar WRF 3.2 coming in July 2010
- Continuing tests over Arctic land show
  - -A deficit in summer cloud cover that could be related to vertical mixing.
  - -Increased soil moisture does not increase summer cloud cover.
  - -Improved soil temperature and ground heat flux with organic (low heat conductivity) soil.
  - -Improved snow albedo in WRF Noah 3.1.1 (Livneh et al. 2010 snow albedo).