Arctic System Reanalysis*

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Outline

- Arctic System Reanalysis: Why, how and who?
- Polar WRF Development at Ohio State
  - Polar WRF vs. AWS and Polar MM5
  - Greenland: Dec. 2002 + June 2001
  - SHEBA 1997/98
  - Arctic land in progress
- Atmospheric Data Assimilation at NCAR
- Noah Land Surface Modeling at NCAR
- Summary

Arctic System Reanalysis Motivation

1. Rapid climate change is happening in the Arctic, as illustrated by the all-time minimum of summer sea ice extent in September 2007. A comprehensive picture of the climate interactions is needed.

2. Global reanalyses encounter many problems at high latitudes. The ASR would use the best available depiction of Arctic processes with improved temporal resolution and much higher spatial resolution.

3. The ASR would provide fields for which direct observation are sparse or problematic (precipitation, radiation, cloud, ...) at higher resolution than from existing reanalyses.

4. A system-oriented approach would provide community focus with the atmosphere, land surface and sea ice communities.

5. The ASR would provide a convenient synthesis of Arctic field programs (SHEBA, LAII/ATLAS, ARM, ...).

ASR Outline

A physically-consistent integration of Arctic data,
including enhanced observations of the Sustained Arctic Observing Network (SAON)

Participants:

Ohio State University - Byrd Polar Research Center (BPRC)
- and Ohio Supercomputer Center (OSC)
National Center Atmospheric Research (NCAR)
University of Colorado
University of Illinois
University of Alaska Fairbanks

High resolution in space (~15 km) and time (3 hours)

Begin with years 2000-2010 (EOS coverage)

Supported by NSF as an IPY project

ASR Duty Roster

Polar WRF Model Development and Optimized Sea Ice Representation

OSU BPRC Polar Meteorology Group, PI

Mesoscale Atmospheric Data Assimilation

NCAR MMM (D. Barker + Y.-H. Kuo)

Land Surface Treatment and Data Assimilation

NCAR (F. Chen, developer of the Noah LSM)

University of Colorado (M. Serreze)

Data Ingest, Data Monitoring, and Quality Control

University of Illinois (J. Walsh) and U. Colorado

Computing

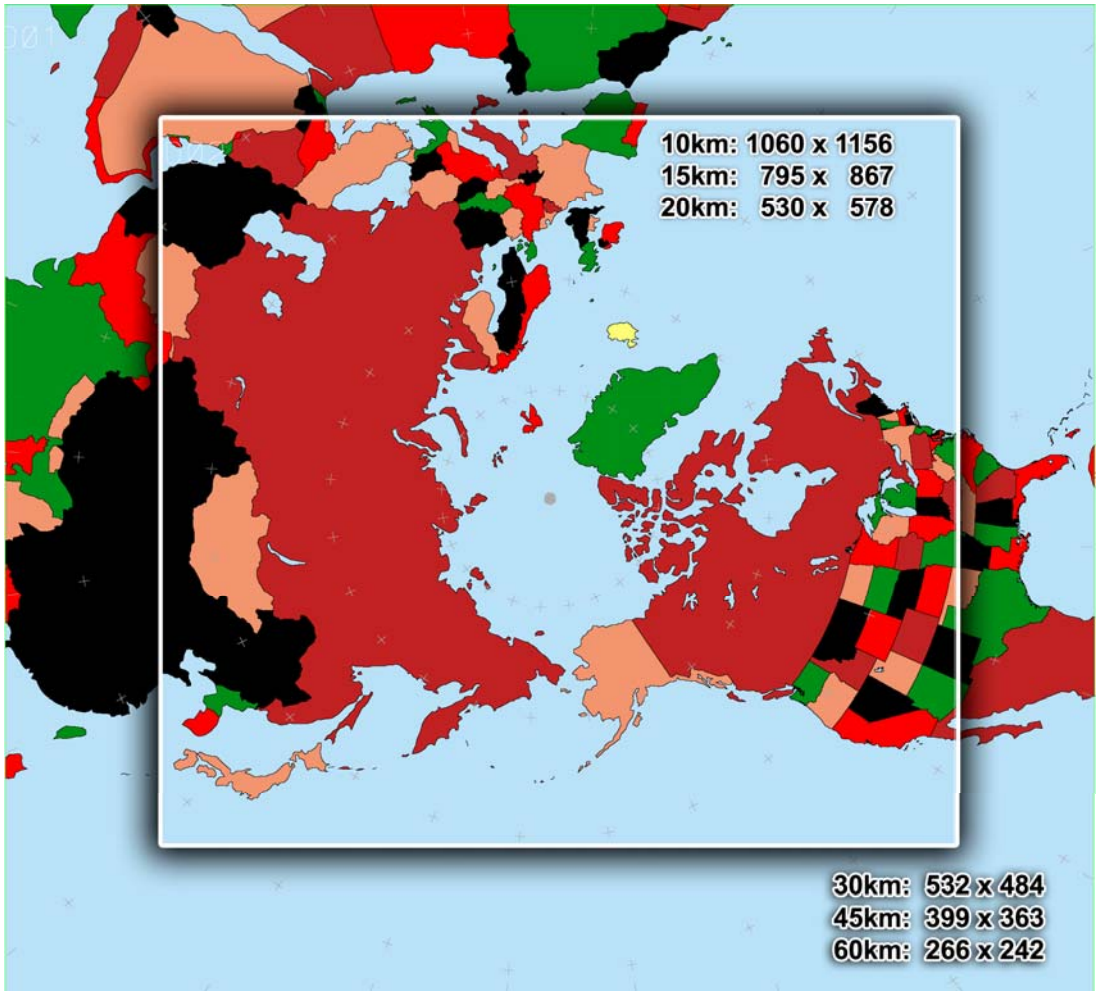
Ohio Supercomputer Center

Arctic Regions Supercomputer Center?

Reanalysis Distribution to the Community

U. Illinois/NOAA CDC?/NCAR?

ASR High Resolution Domain



Outer Grid:
~45 km resolution

Inner Grid:
~15 km resolution

Vertical Grid:
~60 levels

Inner Grid includes Arctic river basins

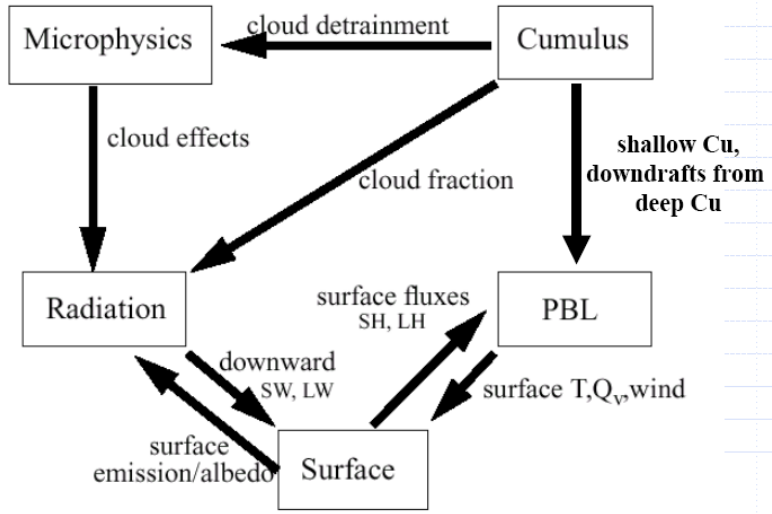
ASR Numerical Model: Polar WRF

Weather Research and Forecasting Model

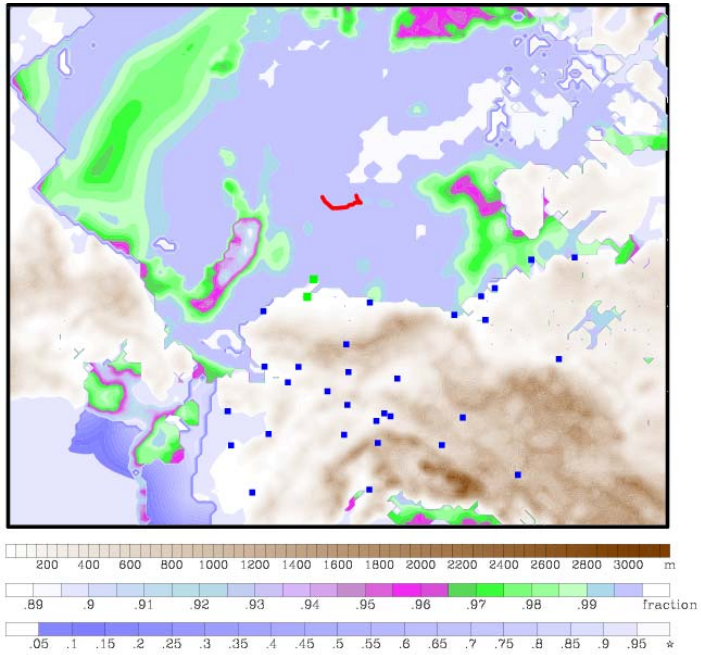
Polar Optimization at Ohio State:

- Fractional sea ice
- Sea ice albedo
- Morrison microphysics (2-moment)
- Noah LSM modifications
- Heat transfer through snow and ice

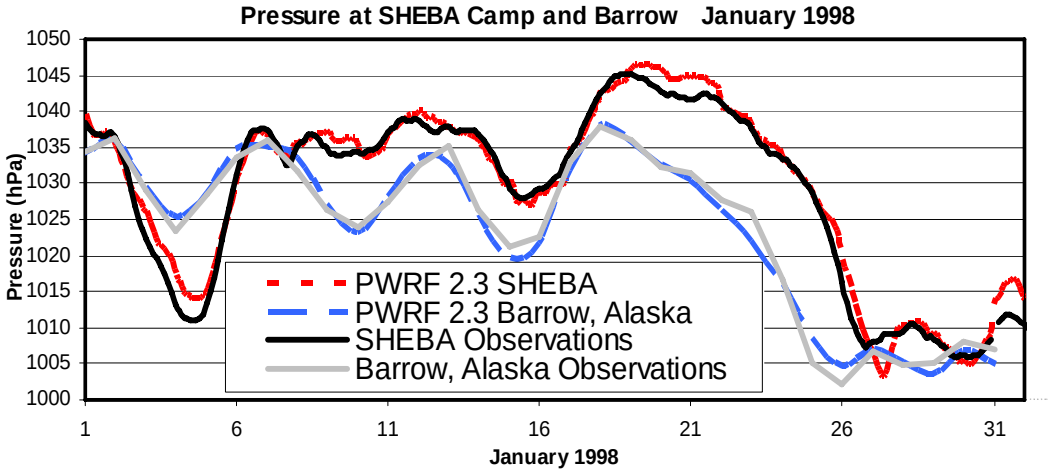
Direct Interactions of Parameterizations

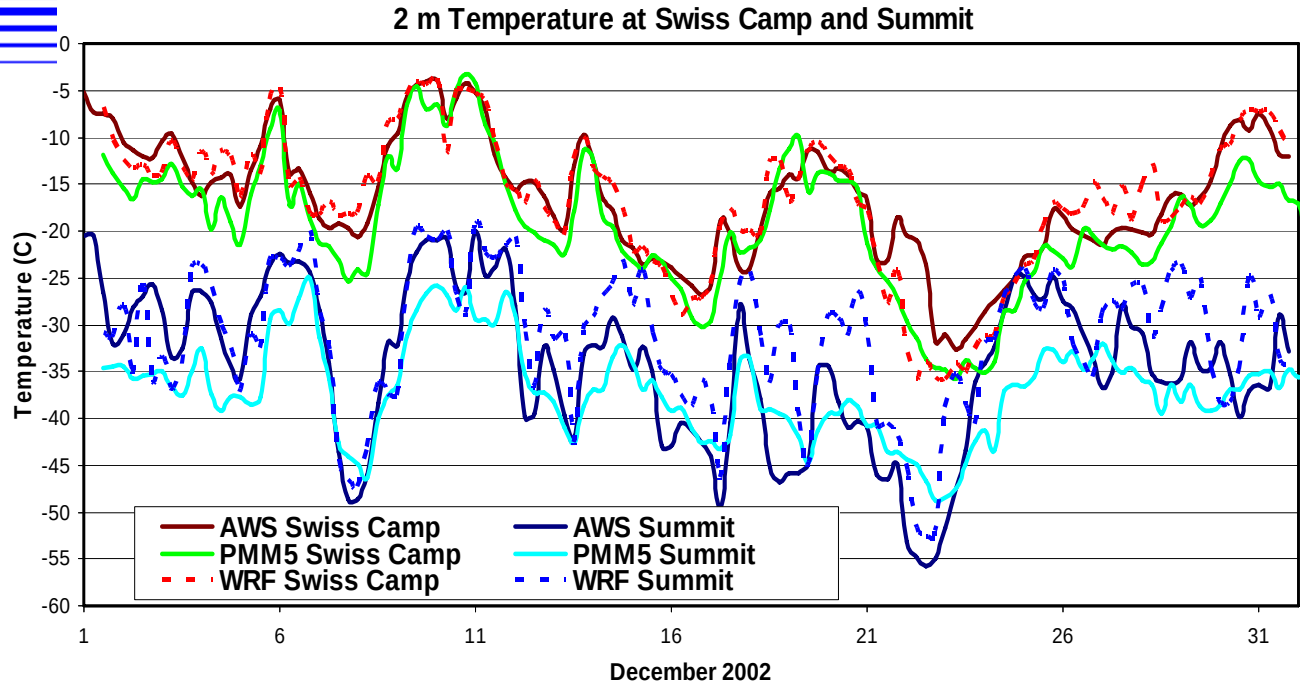


SHEBA 1997/8 Grid



January 1998 SHEBA Results





Summit

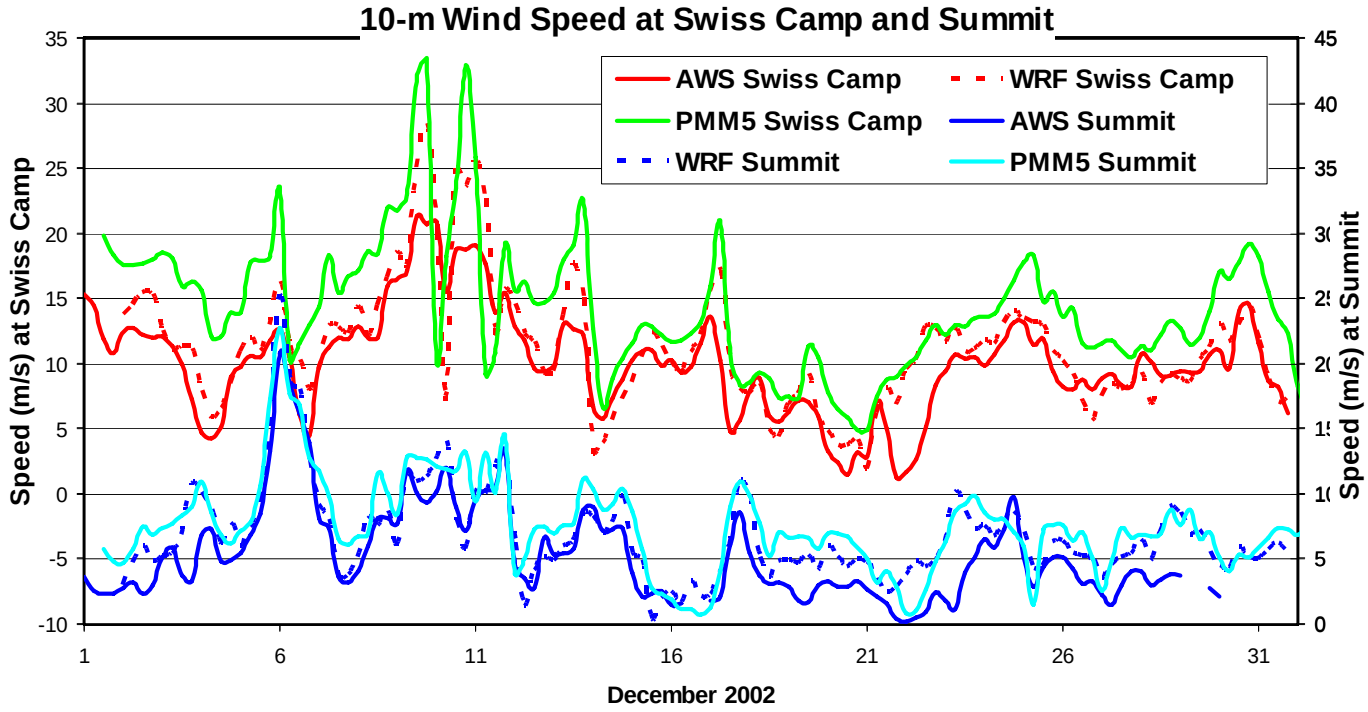
Polar MM5

Correlation	0.84
Bias	-2.3
RMSE	5.6

Polar WRF

Noah + MYJ + WSM5

Correlation	0.80
Bias	3.0
RMSE	6.0

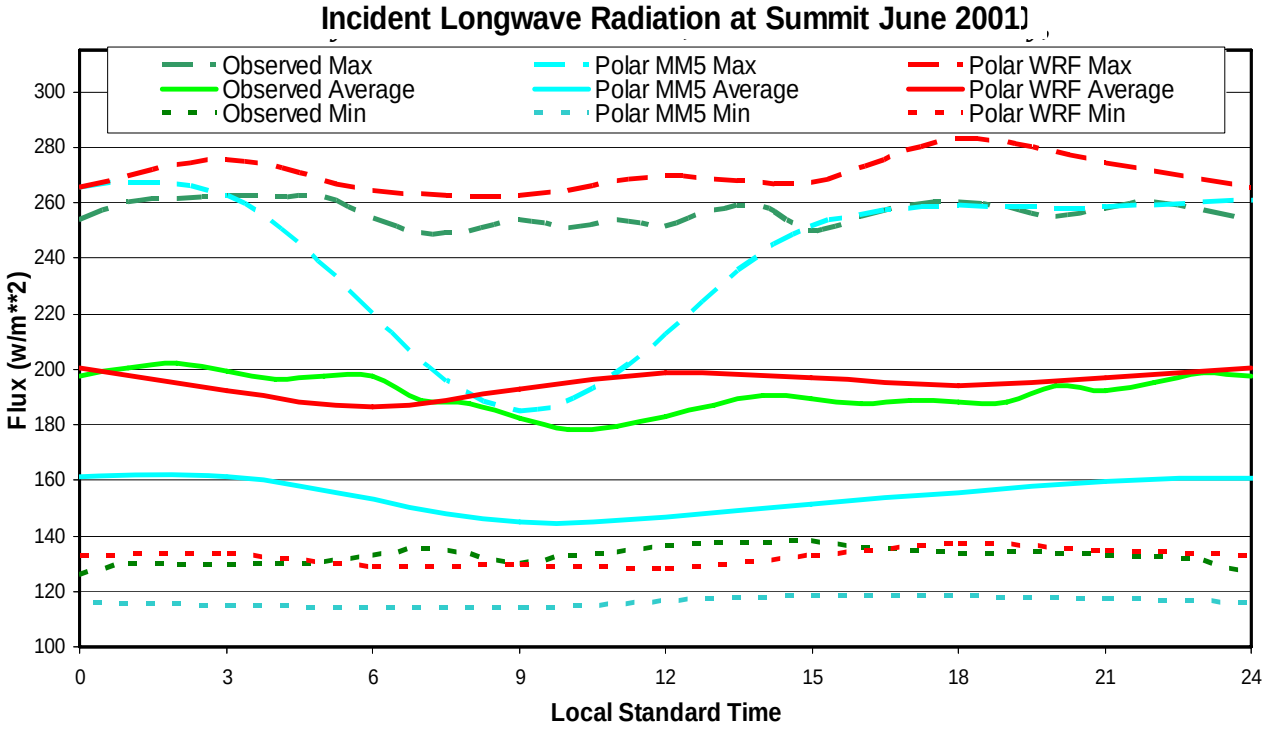


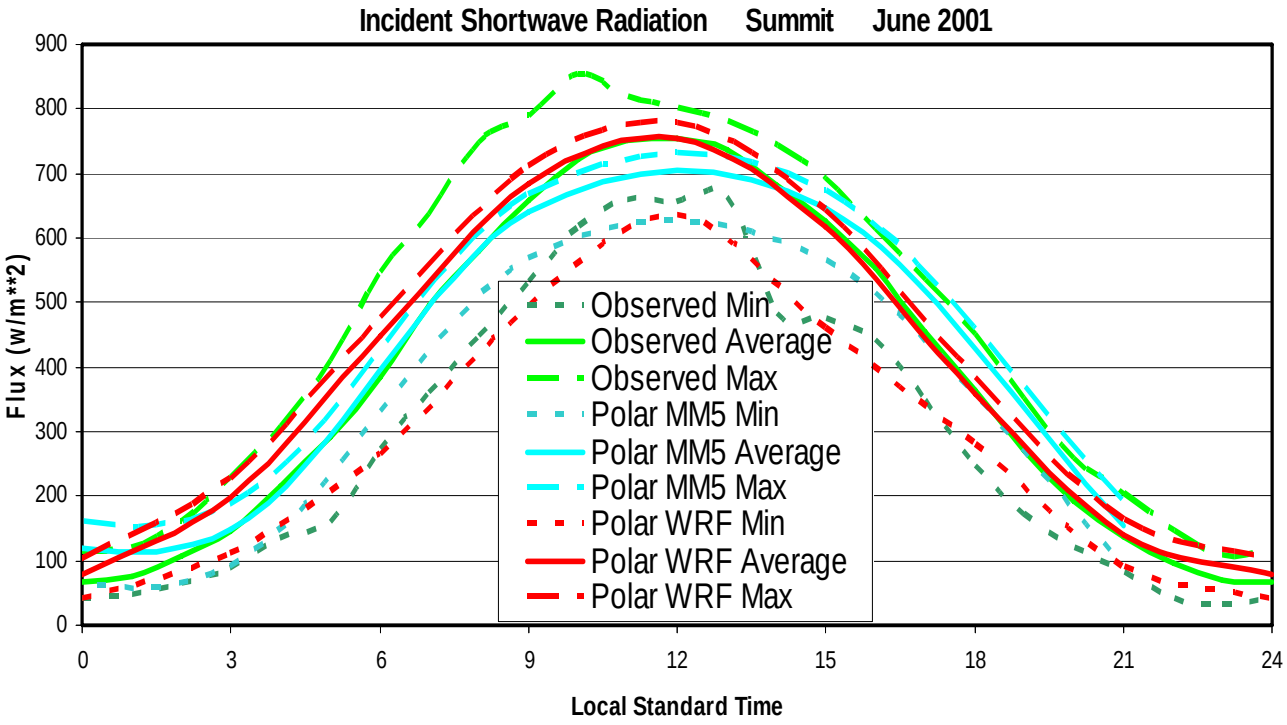
Polar MM5

Correlation	0.87
Bias	2.5
RMSE	3.1

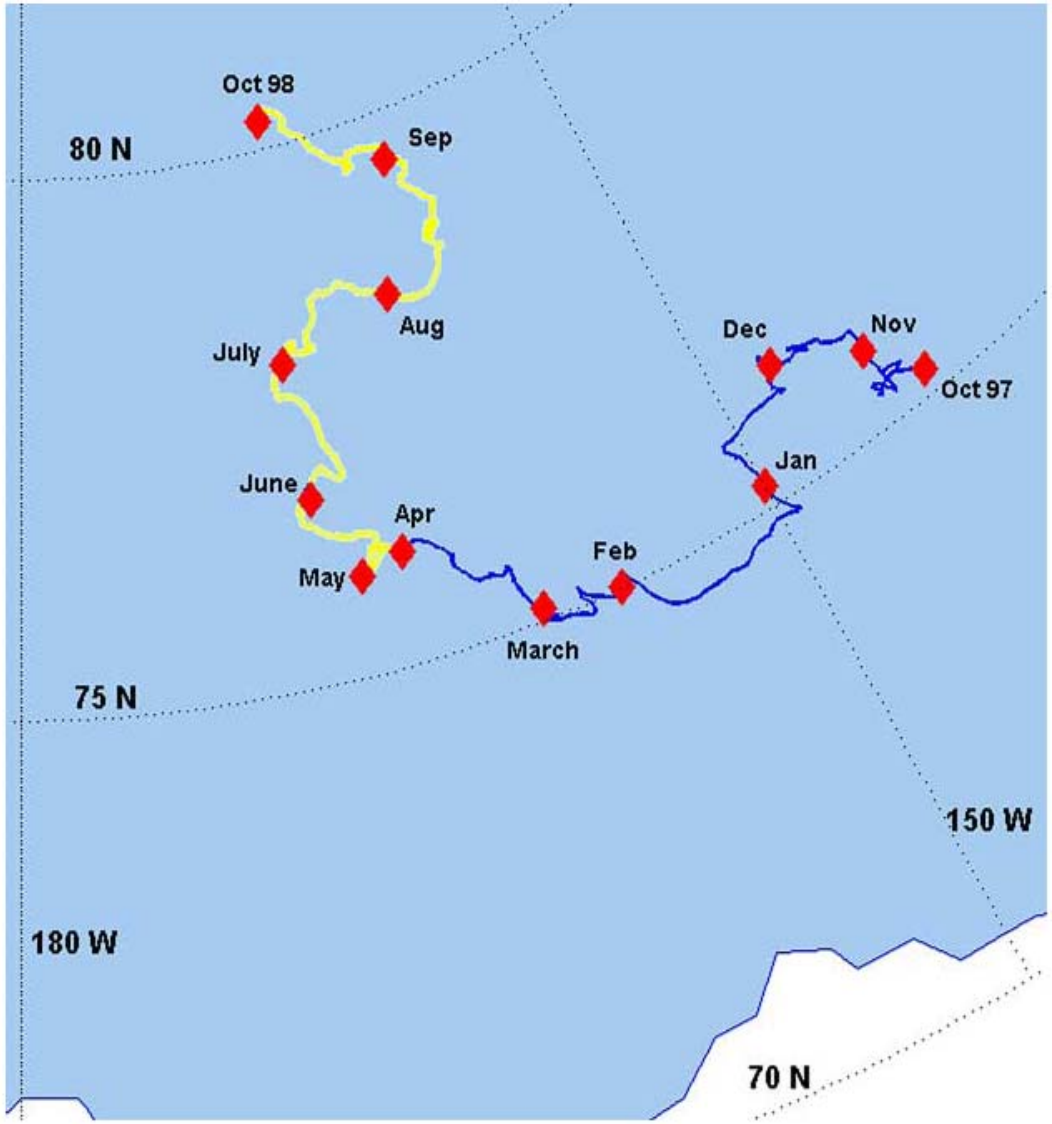
Polar WRF

Correlation	0.85
Bias	1.5
RMSE	2.4


Incident Longwave Radiation at Summit June 2001
Observed Max
Observed Average
Observed Min
Polar MM5 Max
Polar MM5 Average
Polar MM5 Min
Polar WRF Max
Polar WRF Average
Polar WRF Min
Flux (w/m**2)
Local Standard Time


Incident Shortwave Radiation Summit June 2001
Observed Min
Observed Average
Observed Max
Polar MM5 Min
Polar MM5 Average
Polar MM5 Max
Polar WRF Min
Polar WRF Average
Polar WRF Max
Flux (w/m**2)
Local Standard Time

Test Polar WRF for Arctic Ocean/sea ice with selected SHEBA case studies (1997/1998)



SHEBA Location (from Perovich et al. 2007)

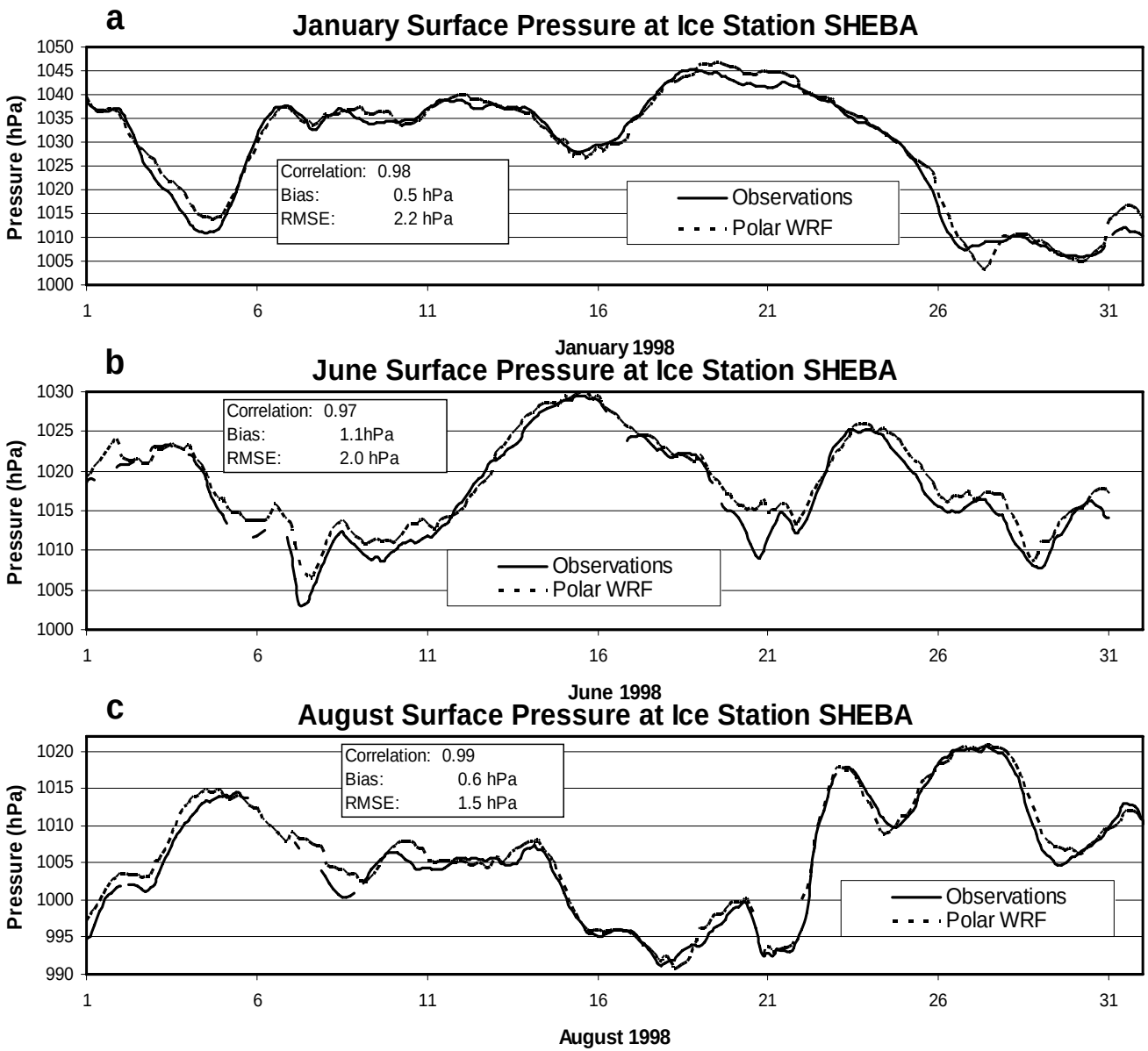


Figure 7. Surface pressure (hPa) from observations and Polar WRF at Ice Station SHEBA for January 1998, June 1998, and August 1998

Mesoscale Atmospheric Data Assimilation

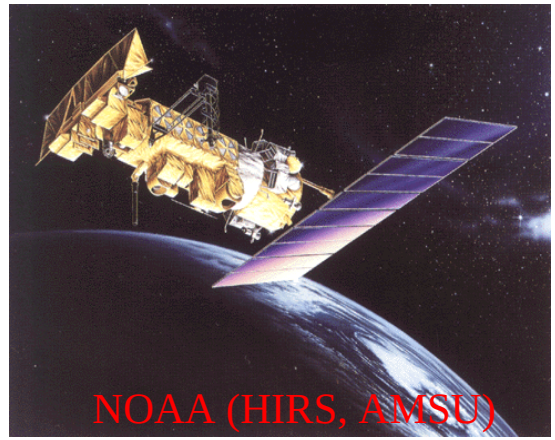
Dale Barker
NCAR MMM

WRF-Var Observations for ASR

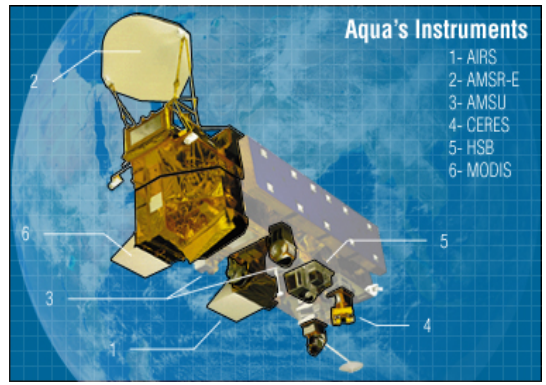
- **In-Situ:**
  - Surface (SYNOP, METAR, SHIP, BUOY).
  - Upper air (TEMP, PIBAL, AIREP, ACARS).
- **Remotely sensed retrievals:**
  - Atmospheric Motion Vectors (e.g. MODIS).
  - Ground-based GPS Total Precipitable Water.
  - SSM/I oceanic surface wind speed and TPW.
  - Scatterometer oceanic surface winds.
  - Wind Profiler.
  - Radar radial velocities and reflectivities.
  - Satellite temperature/humidities (e.g. TOVS, AIRS?).
  - GPS refractivity (e.g. COSMIC).
- **Radiance Assimilation:**
  - Microwave: AMSU, SSM/I, SSMI/S(?)
  - Infrared: HIRS, AIRS(?), IASI(?).

WRF-Var Radiance Assimilation Status

- BUFR 1b radiance ingest.
- RTM interface: RTTOV8_5 **or** CRTM
- NESDIS microwave surface emissivity model
- Range of monitoring diagnostics.
- Quality Control for HIRS, AMSU, AIRS, SSMI/S.
- Bias Correction (Adaptive, *Variational in 2008*)
- Variational observation error tuning
- Parallel: MPI
- Flexible design to easily add new satellite sensors



NOAA (HIRS, AMSU)



Aqua (AMSU, AIRS)

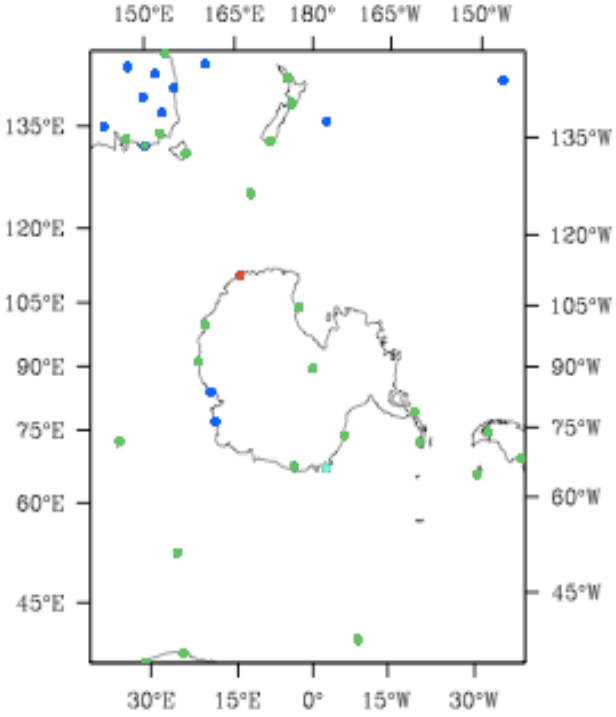
DMSP(SSMI/S)

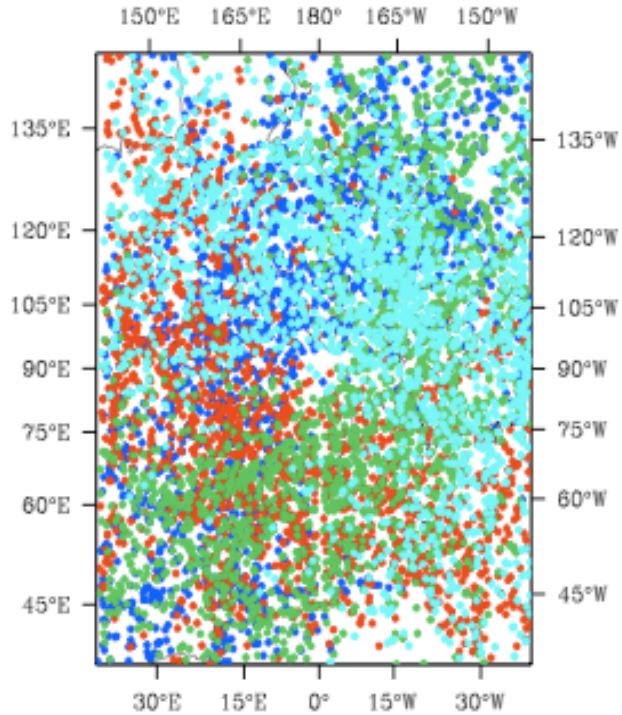
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

DATC Antarctic Testbed

Hui Shao, DATC

Sonde Coverage





COSMIC Coverage

Testbed Configuration (from MMM/AMPS):

- **Model:** WRF-ARW, WRF-Var (version 2.2).
- **Namelists:** 60 km (165x217), 31 levels, 240 s timestep.
- **Period:** October 2006.
- **Suite:** NoDA, 3D-Var (6-hourly full cycling).

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

Land Component for Arctic System Reanalysis

Fei Chen and Michael Barlage

Research Applications Laboratory (RAL)

The Institute for Integrative and Multidisciplinary Earth Studies (TIIMES)

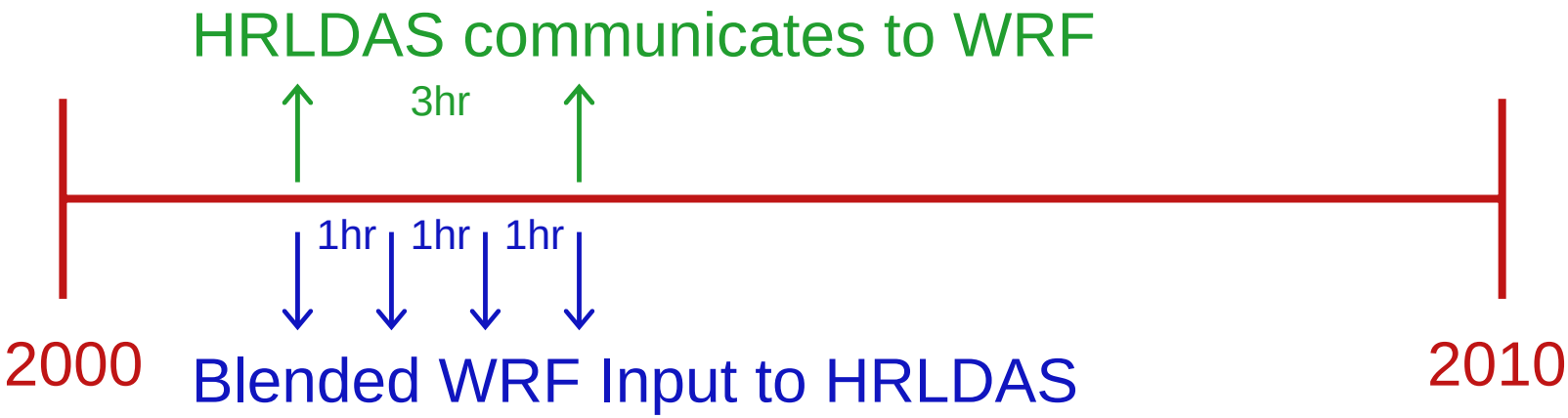
National Center for Atmospheric Research

High-Resolution Land Data Assimilation System (HRLDAS) for ASR

- Blending atmospheric and land-surface observations and land surface model
- To provide land state variables for driving the coupled Polar WRF/Noah modeling system
  - Soil moisture (liquid and solid phase)
  - Soil temperature
  - Snow water equivalent and depth
  - Canopy water content
  - Vegetation characteristics
- To provide long-term evolution of the above variables plus surface hydrological cycle (runoff, evaporation) and energy cycle (surface heat flux, ground heat flux, upward long-wave radiation)

ASR Land Modeling Timeline

HRLDAS and WRF coupled simulations



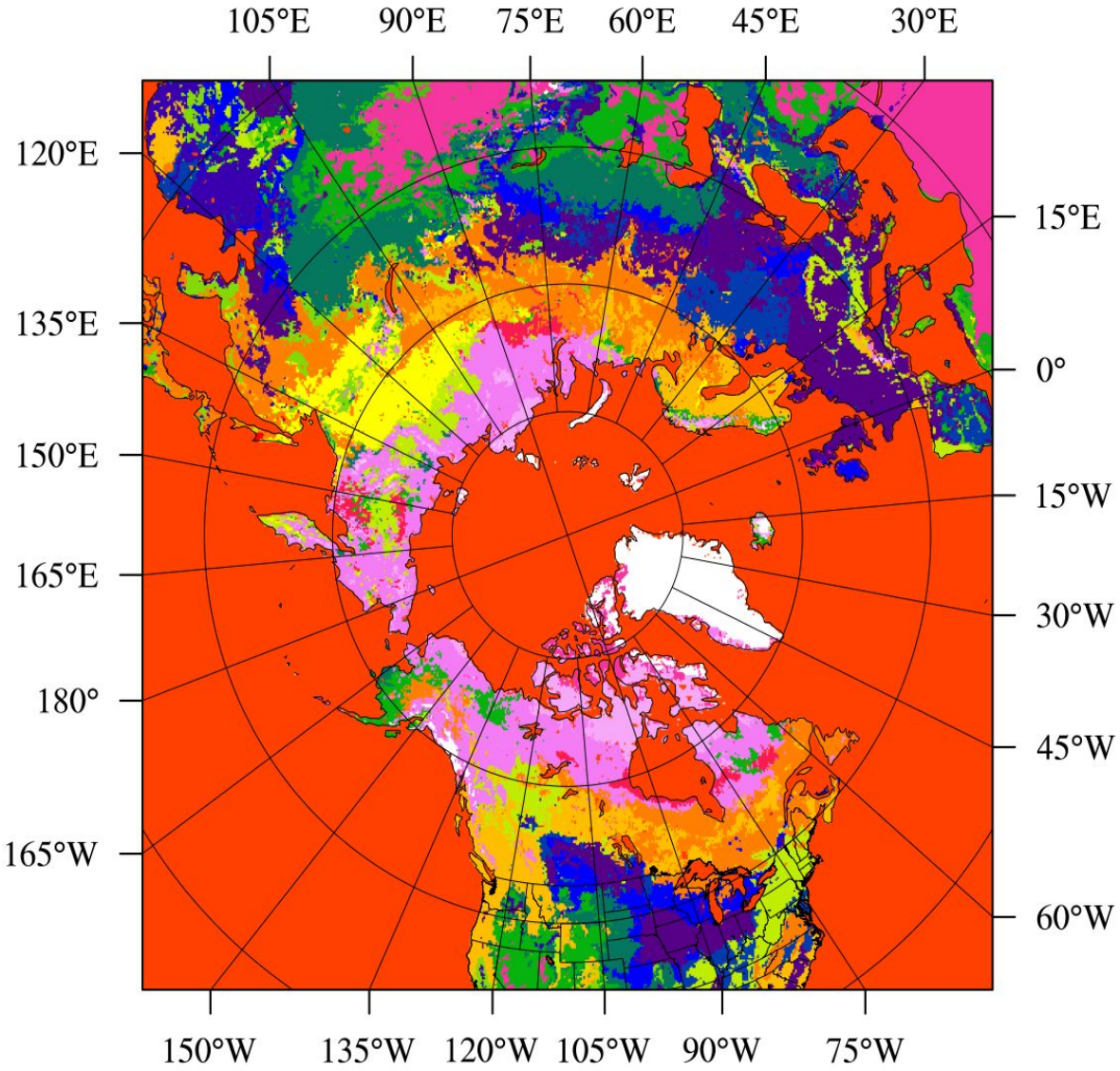
<u>Blended Hourly Forcing Data</u>
WRF: T,q,U,SW,LW
CMAP: precipitation
GDAS: snow, SW, LW
Air Force: snow
GLDAS: SW, LW

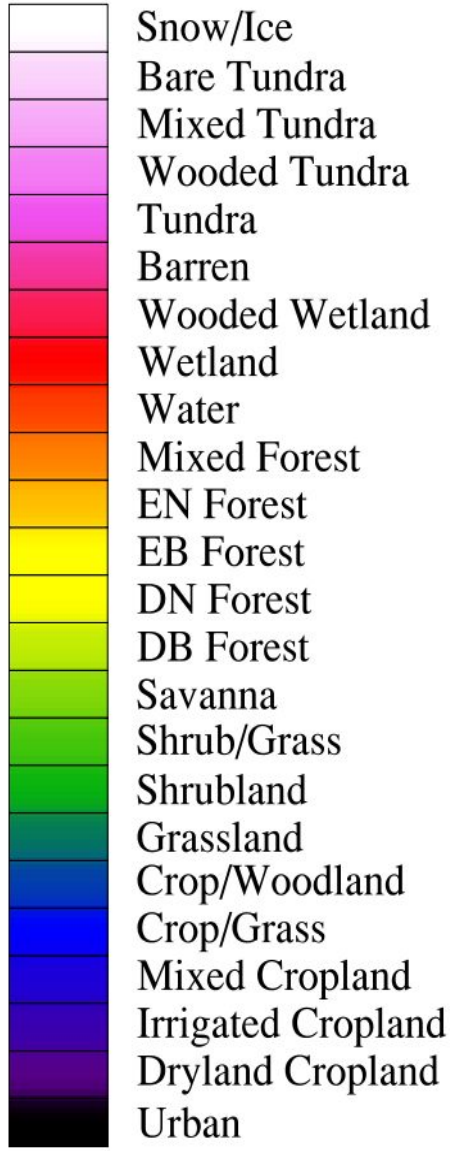
<u>Improved Land Surface States</u>
Snow
Soil Moisture/Temperature
Land Surface Temperature

WRF domain

- 600 x 600 cells
- 20 km
- polar projection

- ref_lat = 90
- ref_lon = 0
- truelat = 70
- stand_lon = -110





Summary of ASR Status

- ASR grew out of Antarctic NWP. Development of enhanced components are proceeding, and will soon be merged. Coupled atmosphere-land DA, but not atmosphere-ocean. Arctic ocean DA being done by others that offers the prospect of enhanced ocean conditions (e.g., sea ice thickness).
- WRF (and Noah LSM) physics are being optimized for polar applications beginning with Greenland and Arctic Ocean domains. Arctic land is next.
- Atmospheric data assimilation advances at NCAR. Start with 3DVAR, but transition to 4DVAR or EnKF anticipated.
- HRLDAS will provide high-resolution land surface variables on the same grid as WRF-3DVAR.
- Timeline: Completion of 2000-2010 by 2011. Second phase is anticipated to cover 1958-present in a climate monitoring capacity with major NOAA participation likely.