A Synthesis of Arctic Weather and Climate*

David H. Bromwich¹,², and Keith M. Hines¹

¹Polar Meteorology Group
Byrd Polar Research Center
The Ohio State University

²Atmospheric Sciences Program
Department of Geography
The Ohio State University

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Outline

- Arctic System Reanalysis: Why, how and who?

- Polar WRF by the Byrd Polar Research Center
  - 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

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 High Resolution Domain
(45km/15km/71L, 10mb model top)

361x361, 721x721, (61,301), 175W

Inner Grid includes Arctic river basins
Red dots show rawinsonde stations
Testing of Polar Weather Research and Forecasting Model (WRF) by BPRC

1. **Permanent ice sheets**
   Start with Greenland (Follow Polar MM5 path)
   January 2002 (winter) and June 2001 (summer)
   Hines and Bromwich (2008, MWR)
   Also Antarctic AMPS forecasts (NCAR MMM Division)
   Antarctic climate simulations

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**
   Underway
Surface Temperature at Ice Station SHEBA

January 1998

Correlation: 0.83
Bias: -2.20°C
RMSE: 4.29°C

Surface Temperature at Ice Station SHEBA

June 1998

Correlation: 0.38
Bias: 0.42°C
RMSE: 1.05°C

Surface Temperature at Ice Station SHEBA

August 1998

Correlation: 0.46
Bias: 0.20°C
RMSE: 1.15°C
10-m Wind speed (m s\(^{-1}\)) from observations and the Polar WRF simulation at Ice Station SHEBA for January, June and August 1998
Polar WRF for WRF Version 3.0.1

- Tar file supplement to WRF Version 3.0.1 (3.0.1.1)
  - Soil initialization
  - Physics initialization
  - Surface physics driver
  - Noah LSM
  - Hugh Morrison’s 2-moment microphysics

- Distributed to 26 members of the scientific community

- U.S. Users - Researchers at
  NCAR, NCEP, NSI DC, and UCAR
  University of Alaska-Fairbanks, University of Colorado,
  Florida State University, Iowa State University,
  Texas Tech University, University of Wyoming

- International Users - Researchers in
  Finland, New Zealand,
  Norway/ Svalbard, Portugal,
  United Kingdom
Mesoscale Atmospheric Data Assimilation

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(?).
Provisional ASR scheme

WRF-3DVar Analysis will be performed over two nested domains in a 3-h interval

1. Global Fields ERA-Interim
   - Preprocessing (WPS, real)

2. Cycle Background
   - $x^{bc}$

3. Input Data
   - PREPBUFR Radiance BUFR
   - Other spec. data
   - 3h frequency

4. WRF-3DVar
   - $y, R$ (Observed Data)

5. Background Error Generation
   - $B$
   - Seasonal dependent

6. HRLDAS output

7. Update Lateral & Lower BCs (UPDATE_BC)

8. Nested WRF 3h Forecast

9. Verification & Visualization
Satellite retrievals
and other

Layer Thickness from TOVS
Satellite winds (include MODIS winds)
Other obs WRF-Var can Assimilate but not archived
In our little_r data:

SSMIS: PW and surface wind
AIRS retrieval T and Q
Radar: wind and reflectivity
Arctic System Reanalysis
Land Component

Fei Chen and Michael Barlage
Research Applications Laboratory (RAL)
The Institute for Integrative and Multidisciplinary Earth Studies (TIIMES)
National Center for Atmospheric Research
Noah Physics Improvements and Satellite Data Assimilation

- Potential physics improvements (currently)
  - Multi-layer snow pack: 1-5 layer snow included as part of current soil structure
  - Frozen soil physics: hydraulic conductivity adjustments for frozen soil, fraction ice less dependent on potentially unknown model parameters
  - Roughness length adjustment: new formulation for $z_o$ over land and snow
  - Increasing number of soil layers to 15, depth to 10 or 20 meters
  - Iterative canopy/surface energy budget

- Constraining land surface with MODIS observations
  - ~10°x10° tiles in sinusoidal projection, 1km spatial resolution
  - 8-day temporal resolution
  - Data available Feb 2000 - present

- MODIS products currently being tested:
  - BRDF/albedo (MCD43B3)
  - fPAR/LAI (MOD15A2)
  - Land cover (MOD12C1)

- HRLDAS modified to accept MODIS tiles for ease of updating surface properties
Summary of ASR Status

- Development of enhanced components are proceeding, and will soon be merged. Coupled atmosphere-land DA, but not atmosphere-ocean. Enhanced sea-ice representation (fractional coverage, ice thickness, and albedo) will be specified.
- WRF (and Noah LSM) physics are being optimized for polar applications beginning with Greenland and Arctic Ocean domains. Arctic land is underway.
- Atmospheric data assimilation advances at NCAR. Use 3DVAR, but experiments with EnKF planned.
- HRLDAS will provide high-resolution land surface variables on the same grid as WRF-3DVAR.