Very High Resolution 
Arctic System Reanalysis 
for 2000-2011

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University of Colorado

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University of Illinois

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Outline

• The Arctic System Reanalysis (ASR)
• ASR Components
• Atmospheric Data Assimilation
• Polar WRF
• Data for ASR
• ASR-Interim
• ASR-Interim Results
• Summary
Arctic System Reanalysis Motivation

1. Rapid change is happening in the Arctic climate system. A comprehensive picture of the interactions is needed.

2. The ASR is using the best available depiction of Arctic processes with improved temporal resolution and much higher spatial resolution than the global reanalyses.

3. A system-oriented approach provides community focus with the atmosphere, land surface and sea ice communities.

4. The ASR provides a convenient synthesis of Arctic field programs (SHEBA, LAI I/ATLAS, ARM, ...).
ASR Outline

A physically-consistent integration of Arctic and other Northern Hemisphere data

High resolution in space (10 km) and time (3 hours)

Begin with years 2000-2010 (Earth Observing System)

Participants:

Ohio State University - Byrd Polar Research Center (BPRC)
National Center Atmospheric Research (NCAR)
University of Colorado-Boulder
University of Illinois at Urbana-Champaign
Ohio Supercomputer Center (OSC)
ASR Components

The polar-optimized version of the Weather Research and Forecasting model (Polar WRF) which includes an improved Noah land surface model and specifications for the following sea ice attributes: extent, concentration, thickness, albedo and snow cover (Bromwich et al. 2009, Hines et al. 2011, Hines and Bromwich 2008). (http://polarmet.osu.edu/PolarMet/pwrf.html)


High Resolution Land Data Assimilation System (HRLDAS) (Chen et al. 2001), HRLDAS is a vital component of ASR that assimilates snow cover and depth, observed vegetation fraction and albedo. The current HRLDAS uses NASA, NESDIS, and NOAA satellite observations to describe these surface properties.
ASR Data Assimilation

WRF-3DVar HRLDAS POLAR-WRF

ASR performed in a 3-h interval

Lateral BCs Boundary

PREPBUFR data

WRF-Var

Update Lateral Lower BCs

Land and Sea Ice Data

HRLDAS

DFI

Polar WRF 3h Forecast

Init Land Cold Start HRLDAS

Analysis

Verification Monitor

ASR OUTPUT

Analysis output

Forecast output

Seasonal dependent Background Error (gen_be)
Implementation of a fractional sea ice description in the Noah LSM + variable ice thickness and snow cover
Improved treatment of heat transfer for ice sheets and revised surface energy balance calculation in the Noah LSM

Model evaluations through Polar WRF simulations over Greenland, the Arctic Ocean (SHEBA site), Alaska, and Antarctica have been performed.

Polar WRF is used by ASR.
Numerical and Physics options for Polar WRF

Non hydrostatic dynamics;
5th order horizontal advection (upwind-based);
3rd order vertical advection;
Positive-definite advection for moisture;
6th-order horizontal hyper diffusion;
Grid nudging to ERA-Interim (top 20 levels);
Upper damping;
Morrison double-moment scheme;
New Grell sub-grid scale cumulus scheme;
RRTMG atmospheric radiation scheme;
RRTMG shortwave scheme;
MYNN planetary boundary layer scheme;
MYNN surface layer;
Noah land surface model;
Gravity wave drag;
Sea ice.
Data for ASR

ERA-Interim reanalysis model level data

The T255 (0.7 degrees) horizontal resolution ERA-Interim reanalysis surface and upper air model level data are used to provide the background initial, lateral boundary conditions and statistical background error for the ASR Interim.

Atmospheric observation data (3-hour time window)

**PREPBUFR** (including synop, metar, ship, buoy, qscat, sound, airep, profiler, pilot, satob, ssmi_retrieval_sea_surface_wind_speed, ssmi_retrieval_pw, gpspw)

**Radiances** different sensors (amsua, amsub, mhs, hirs3, hirs4) in separate BUFR files

**GPS** (GPSRO, GPSIPW)

*Obtained from Jack Woollen of NCEP*

Sea ice data

Concentration, thickness, albedo and snow cover.

Land data

Snow cover, depth and age, vegetation fraction and albedo from NASA, NESDIS, and NOAA satellite observations for High Resolution Land Data Assimilation System (HRLDAS).
ASR-Interim 11 Year Data Assimilation

Period: 2000~ 2010

Reduced Resolution: 30km-90km/ 71L, 10mb top

ERA-Interim reanalysis model level data as BC and LB

Full 3-hourly cycling run on OSC supercomputers

Polar WRF (V3.3.1), WRF-Var (V3.3.1) and HRLDAS are used for the data assimilations.
Domain for ASR-Interim

361 x 361 30km

181 x 181 90km
Near Surface Variable Statistics

The data used for the surface statistics:

ERA-Interim

Surface stations

(More than 5000 obtained from the National Climatic Data Center (NCDC) and Greenland Climate Network (GC-NET))
Average statistics from comparing **ASR-Interim** and **ERA-Interim** with observations for **2000-2010**

<table>
<thead>
<tr>
<th>Name</th>
<th>10m Wind Speed</th>
<th>2m-Temperature</th>
<th>2m-Dew point</th>
<th>Surface pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bias  rmse  corr</td>
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<td>ERA</td>
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<td>0.32  2.01  0.92</td>
<td>0.27  2.12  0.89</td>
<td>0.00  0.99  0.99</td>
</tr>
</tbody>
</table>
Average statistics from comparing ERA-Interim (ERA) and ASR-Interim (ASR) with observations for 2000-2010

10m Wind Speed Correlation

10m Wind Speed RMSE

ERA  ASR

[Graphs showing correlation and RMSE for each month from January to December for ERA and ASR]
Average statistics from comparing ERA-Interim (ERA) and ASR-Interim (ASR) with observations for 2000-2010
Average statistics from comparing
ERA-Interim (ERA) and ASR-Interim (ASR)
with observations for 2000-2010
Average statistics from comparing ERA-Interim (ERA) and ASR-Interim (ASR) with observations for 2000-2010

Surface Pressure RMSE

Surface Pressure Correlation
ASR Data Assimilation Result
between ASR-Interim (ERA-Interim) assimilation and observations
ASR Data Assimilation Result
between ASR-Interim (ERA-Interim) assimilation and observations
ASR Data Assimilation Result: Polar Low

10 m Wind and Satellite Image

06 h DEC 20, 2007
ASR Data Assimilation Result: Polar Low
10 m Wind and Satellite Image

03h Mar 16, 2007
ASR Data Assimilation Result: Polar Low
10 m Wind and Satellite Image

18h Jan 12, 2007
ASR Preliminary Meeting Boulder, Colorado
Polar Meteorology Group, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio

ASR Data Assimilation Result: Arctic Weather System
10 m Wind

09h Feb 02, 2010
One-Month Cycling Run Results

Precipitation (Monthly Total in August 2008, Unit: mm)

ASR-Interim

ERA-Interim
ASR Data Assimilation Result

Precipitation

Yearly Total 2007, Unit: cm
Summary

The ASR-Interim data assimilations with reduced resolution with nested grids (90 km outer domain; 30 km primary domain) have been performed from 2000 to 2010 at OSC. The results are very encouraging.

Polar WRF, WRF-3DVar and Noah Land Data Assimilation will be updated to correct the bias in $Q_{2m}$, $T_{2m}$, precipitation and to improve ASR performance, and used for the final run.

Based upon the ASR-Interim results and improvement of ASR system, the ASR team will perform 12 years (2000-2011) at 10 km resolution. The target date for completion is September 2012.

ASR data are distributed by NCAR's Research Data Archive and NOAA Earth System Research Laboratory (ESRL).
Average statistics from comparing **ASR-Interim** and **ERA-Interim** with observations for **2000-2010**

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