DATA ASSIMILATION CHALLENGES FOR HIGH-RESOLUTION REANALYSES IN THE POLAR REGIONS

THE ARCTIC SYSTEM REANALYSES


Supported by NSF, NOAA, and DOE
Outline

- The Arctic System Reanalysis (ASR)
- Polar WRF
- Atmospheric Data Assimilation
- Noah Land Surface Data Assimilation
- Ohio Supercomputer Center
- One-Month Cycling Runs
- Summary
Arctic System Reanalysis

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 will use the best available depiction of Arctic processes with improved temporal resolution and much higher spatial resolution.

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

4. A system-oriented approach is intended to provide a common focus for the atmosphere, land surface and sea ice communities.

5. The ASR will provide a convenient synthesis of Arctic field programs (SHEBA, LAI1/ 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)
   - convenient for synoptic and mesoscale studies

Begin with years 2000-2010 (Earth Observing System)

Participants:
Ohio State University - Byrd Polar Research Center (BPRC)
   - and Ohio Supercomputer Center (OSC)
National Center Atmospheric Research (NCAR)
Universities of Colorado and Illinois.

Also Interested:
NOAA (Also provided start-up funds)
NASA
U.S. Department of Energy
Polar WRF

Based on extensive experience with mesoscale modeling in the polar regions by the Polar Meteorology Group of the Byrd Polar Research Center at The Ohio State University, WRF has been modified for use in the Polar Regions (referred to as the Polar WRF).

The key modifications for Polar WRF are:

- Optimal turbulence (boundary layer) parameterization
- Implementation of a fractional 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

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

Polar WRF is used by forecasters as part of the National Science Foundation sponsored Antarctic Mesoscale Prediction System.

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

Non hydrostatic dynamics;
Rigid lid upper boundary condition;
5th order horizontal advection (upwind-based);
3rd order vertical advection;
Positive-definite advection for moisture;
6th-order horizontal hyper diffusion;
Full horizontal diffusion;
**Grid nudging near the model top**;
2d deformation;
Upper damping, w-damping, divergence damping and time off-centering (epssm);
WRF Single-Moment 6-class scheme;
New Grell sub-grid scale cumulus scheme;
RRTM atmospheric radiation scheme;
Goddard shortwave scheme;
Mellor-Yamada-Janjic (and MYNN) planetary boundary layer scheme;
Eta similarity surface layer (and MYNN);
Noah land surface model;
Fraction Sea ice and SST.
Domain for ASR

ASR high resolution system:
- Outer domain 361 x 361 45km
- Inner domain 721 x 721 15km
- Lower-left corner 61,61

ASR low resolution system:
- Inner domain 361 x 361 30km
- Outer domain 181 x 181 90km
- Lower-left corner 31,31
ASR Preliminary Meeting Boulder, Colorado

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

ASR  WRF-3DVar / WRF Modeling System

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

Atmospheric Data Assimilation
Atmospheric Data Assimilation

Observation Data for ASR

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

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

Newly developed to be used in WRF-Var: GPS-RO

Under consideration: GPS-I PW
Atmospheric Data Assimilation

Observation Data for ASR
Atmospheric Data Assimilation

Observation Data for ASR
ASR Land Modeling Approach

HRLDAS and WRF coupled simulations

HRLDAS communicates to WRF

Blended Hourly Forcing Data
- WRF: T, q, U, SW, LW
- CMAP: precipitation
- GDAS: snow, SW, LW
- Air Force: snow
- GLDAS: SW, LW

Improved Land Surface States
- Snow
- Soil Moisture/Temperature
- Land Surface Temperature

2000 Blended WRF Input to HRLDAS 2010
IBM e1350 (Glenn)

- 877 System x3455 compute nodes
  - Dual socket, dual core 2.6 GHz Opterons
  - 8 GB RAM
  - 48 GB local disk space in /tmp
- 88 System x3755 compute nodes
  - Quad socket, dual core 2.6 GHz Opterons
  - 64 GB (18 nodes), or 16 GB (70 nodes) RAM
  - 1.8 TB (10 nodes) or 218 GB (76 nodes) local disk space in /tmp
- 1 e1350 Blade Center
  - 4 Dual Cell based QS20 blades
  - Voltaire 10 Gbps PCI Express adapter
- 4 System x3755 login nodes
  - Quad socket 2 dual core 2.6 GHz Opterons
  - 32 GB RAM
- All connected together by 10 Gbps Infiniband
One-Month Cycling Runs

- **Period:** 2007/12/01 ~ 2007/12/31
- **Reduced Resolution:** 90km/30km/71L, 10mb top. Nudging top 10 levels.
- **Observations in 3-hour time window**
  - PREPBUFR
    - satellite radiance data (AMSU-A)
  - NCAR archived NCEP FNL analysis (1º x 1º) as BC and LB
  - WRF-3DVar/WRF version 3.1
  - WRF-Var background error statistics for the same month from WRF version 3.1 forecasts
- **Full 3-hourly cycling run on OSU Glenn cluster**
One-Month Cycling Run Results

Precipitation (Monthly Total in Dec 2007, Unit: mm)

ERA-Interim

ASR
One-Month Cycling Run Results
Verification Against AVN FNL

\[ P_{\text{surface}} \]

BIAS  RMS  CORR
0.11  1.37  0.99

Correlation

BIAS
RMSE

[Images of maps showing BIAS, Correlation, and RMSE]
One-Month Cycling Run Results
Verification against AVN FNL

\[ T_{2m} \]

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<thead>
<tr>
<th>BIAS</th>
<th>RMS</th>
<th>CORR</th>
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<td>-1.05</td>
<td>2.93</td>
<td>0.90</td>
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One-Month Cycling Run Results
Verification Against AVN FNL

$Q_{2m}$

BIAS   RMS   CORR
0.28   0.69   0.89
One-Month Cycling Run Results
Verification Against AVN FNL

\[ U_{10m} \]

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<td>-0.06</td>
<td>1.75</td>
<td>0.91</td>
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Correlation

BIAS
RMSE
One-Month Cycling Run Results
Verification Against AVN FNL

$V_{10m}$

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<td>-0.08</td>
<td>1.82</td>
<td>0.92</td>
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One-Month Cycling Run Results

P' (wrf-da(blue), avn(red), hPa) at model bottom
31th day cycling run
One-Month Cycling Run Results

10 m wind field 12/31/2007, 31st day cycling run

AVN ASR
Summary

Big progress has been made. Test month results look very encouraging.

Still quite some testing to do to optimize the assimilation, especially the nudging, physics, and land surface modeling/assimilation.

The next test month will be August 2008, a summer period of intensive observations near the North Pole.

To engage the community in early ASR evaluation and use, a 30-km, 3-h assimilation is planned to be completed for 6/2007-9/2009 by end of this calendar year. Interested users are very welcome.