Polar WRF

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Outline

- Status of Polar WRF
- Polar WRF Applications
  - Arctic System Reanalysis (ASR)
  - AMPS— The Antarctic Mesoscale Prediction System
  - OSU Antarctic Mesoscale Prediction System (AMPS) Database
  - Numerical Weather Prediction (NWP) at OSU
- Polar WRF Development
  - Polar COAWST
- Summary and Future Work
Status of Polar WRF

- Polar WRF
- History of Polar WRF
- Polar WRF Components Implemented in WRF
- Current Version Polar WRF 3.7.1
Polar WRF

(Version 3.1 – 3.7.1)

Developed and maintained by the Polar Meteorology Group

- The key modifications for Polar WRF are:
  - Optimal turbulence (boundary layer) parameterization
  - Implementation of a comprehensive 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
  - Improved cloud microphysics for polar regions

- Model evaluations of Polar WRF simulations have been performed in the Arctic and Antarctica

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

- Polar WRF is used by more than 250 users for polar region climate change simulation and weather system modeling
History of Polar WRF

- Version 2.1.1 ~2006
  snow/ice changes for Noah LSM
  Greenland

- Version 2.2 2007
  fractional sea ice
  SHEBA

- Version 3.0.1.1 August 2008
  Polar WRF goes public
  North Alaska

- Version 3.1.1 September 2009
  has standard WRF Noah snow improvements
  ASR Grid
  variable sea ice thickness
  Antarctica

- Version 3.2/3.2.1 August 2010
  MYNN sfc layer consistent with fractional sea ice

- Version 3.3.1 November 2011

- Version 3.7.1
History of Polar WRF

- Version 3.3.1  November 2011
  Registration implemented for PWRF
- Version 3.4.1  October 2012
- Version 3.5.1  February 2014
  Sea Ice Thickness Tests
  ARISE Real Time Forecasts
- Version 3.6.1  November 2014
  ARISE Research Simulations
  Polar Winds Real-Time Forecasts
- Version 3.7.1  October 2015
  ASCOS Research Simulations
Polar WRF Components Implemented in WRF

- Improved heat transfer for ice and snow
- Sea ice fraction specification (mosaic method)
- Specified variable sea ice thickness (ASR-inspired)
- Specified variable snow depth on sea ice (ASR-inspired)
- Sea ice albedo seasonal specifications (ASR-inspired)
- MYNN surface boundary layer works with fractional sea ice
Polar WRF 3.7.1

- Over 250 registered users and over 175 international users
- Based upon WRF 3.7.1
- Supplemental files to replace standard WRF files
- Supplemental files have compiler directives with options
  power of Polar WRF is based upon best selection of options for your case
- Run WPS supplements first to produce sea ice concentration, Arctic sea ice thickness, Arctic snow on sea ice, and Arctic sea ice albedo

Arctic sea ice WPS files are available for 1998-2015

- WRF has option for temperature-based, non-specified sea ice albedo from William Chapman (designed for Arctic)
- Recent testing for Arctic cloud specifications
Polar WRF Applications

- Arctic System Reanalysis (ASR)
- AMPS— The Antarctic Mesoscale Prediction System
- OSU Antarctic Mesoscale Prediction System (AMPS) Database
- Numerical Weather Prediction (NWP) at OSU
The Arctic System Reanalysis

ASRV Components

**Polar WRF version 3.6**
- Noah land surface model
- Model top at 10 mb, 71 vertical levels and the lowest level at 4 meters
- Lateral boundary: ERA-Interim
- Model horizontal resolution:
  - Low resolution version: 30km
  - High resolution version: 15 km

**Atmospheric data assimilation**
- WRFDA version 3.3.1

**Land Data Assimilation**
- Noah High Resolution Land Data Assimilation Framework

**Data for ASR**

**Atmospheric Observation data in 3-hour time window**
- NCEP PREPBUFR (conventional and satellite data)

**Sea ice**: Specified fraction, variable sea ice thickness, variable snow cover depth on sea ice, variable albedo and melt pond coverage

**Land data**: Snow cover, vegetation fraction and albedo from satellite data.

**ASR Output**

- 3hr cycling
- Full analysis: 3 hours
- Forecast: 3 hours

2000 - 2012
### ASR data assimilation results

Average statistics from comparing ERA-Interim, 30km ASR and 15km ASR with observations for 2007

<table>
<thead>
<tr>
<th>NAME</th>
<th>Wind Speed</th>
<th>2m-Temperature</th>
<th>2m-Dew point</th>
<th>Surface pressure</th>
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<tr>
<td>ERAI</td>
<td>0.41 2.12 0.64</td>
<td>0.29 1.99 0.92</td>
<td>0.33 2.05 0.89</td>
<td>-0.06 0.98 0.98</td>
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<tr>
<td>ASR30KM</td>
<td>-0.24 1.77 0.70</td>
<td>0.10 1.33 0.96</td>
<td>-0.03 1.72 0.92</td>
<td>0.03 0.83 0.99</td>
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<tr>
<td>ASR15KM</td>
<td>0.24 1.40 0.80</td>
<td>-0.04 1.08 0.97</td>
<td>0.23 1.53 0.94</td>
<td>-0.01 0.70 0.99</td>
</tr>
</tbody>
</table>

**ASR data assimilation resutls**

ASR30KM  PWRF v3.3.1  WRFDA v3.3.1

ASR15KM  PWRF V3.6  WRFDA v3.3.1 (with 2 outer loops)  15KM BE
Monthly Total Precipitation Jan 2007

ERA-Interim

ASR 30km

ASR 15km

mm
Monthly Total Precipitation Jul 2007
The Antarctic Mesoscale Prediction System – AMPS

Polar WRF Real-Time Modeling in Antarctica

Mesoscale and Microscale Meteorology Division
NCAR Earth System Laboratory
National Center for Atmospheric Research

Polar Meteorology Group
Byrd Polar and Climate Research Center
The Ohio State University
AMPS— The Antarctic Mesoscale Prediction System

- Real-time WRF to support US Antarctic Program
  Antarctic weather forecasting and science

- AMPS effort includes:
  (i) WRF polar performance analysis
  (ii) Physics improvement

http://www2.mmm.ucar.edu/rt/amps
AMPS WRF

Version 3.7.1

Note: The official, released version of WRF has been “Polar” since WRF V3.1, April 2009

6 Grids: 30-, 10-, 3.3-, x,1.1-km, 3.3 km
AMPS Database at OSU

- To provide an easily accessible subset of AMPS output
  - Focuses on most frequently used variables
  - Approximates observed conditions
- Data in NetCDF format
- Compute monthly means for selected variables
- Will provide support for additional processing as a result of user requests. For example, Antarctic petrel flight patterns are currently being studied in relation to AMPS winds.
Antarctic petrel flight study

Departure (upper panel) and return (lower panel) sections of 79 Antarctic petrel GPS flight tracks recorded during three breeding seasons (2012-2014) in Queen Maud Land, Antarctica. Rose diagrams show the frequency distribution of the wind speed/direction (to) and bird track directions.

(Tarroux et al, 2016: Flexible flight response to challenging wind conditions in a commuting Antarctic seabird. *Behavioural Ecology.*)
PWRF NWP at OSU

- Models run at
  - Arctic (30km)
  - Antarctic (20km)
  - Greenland (8km)
  - Ohio (10km)

- The current model uses the Polar WRF 3.6.1
  - The model runs twice a day (00, and 12Z) for 96/120 forecast hours
  - 48 vertical levels
  - The model uses real time NCEP GFS data and near real time SST and sea ice NISE data from NSIDC
NWP model domain maps

Arctic (30km)

Antarctic (20km)

Greenland (8km)

Ohio (10km)
Polar COAWST

Based on the COAWST (the Coupled Ocean – Atmosphere – Wave – Sediment Transport modeling system), the POLAR COAWST modeling system is being developed by a team of researchers at The Ohio State University (OSU), New York University (NYU), Old Dominion University (ODU) and North Carolina State University (NCSU) to model the multi-disciplinary processes impacting atmosphere, land, ocean, sea ice, wave and interactions between them in the polar regions, and to simulate climate changes of Antarctica and the Arctic.

The Polar COAWST component models:

1. The polar version of the Weather Research and Forecasting atmospheric model (with Noah and CLM land model) (Polar WRF; Bromwich et al. 2013; Hines et al. 2015)
2. The ROMS ocean model
3. The Budgell sea ice model in ROMS or the Los Alamos sea-ice model (CICE)
4. The SWAN (Simulating WAves Nearshore) wave model

The models are coupled through the flux coupler, Model Coupling Toolkit (MCT).
Exchanged Fields between **Polar WRF, ROMS, Sea Ice and Wave**

**WRF-ROMS** (Sea ice) - **SWAN**

**ATMOSPHERE**

**Polar WRF**
(Land: Noah or CLM)

**Polar COAWST**

**OCEAN**

**SEA ICE**

**WAVE**

**Exchange Fields**

- SST, fractional sea ice, albedo
- $u_{bot}$, $v_{bot}$, $\eta$, bath, $Z_0$
- $H_{wave}$, $L_{mwave}$, $L_{pwave}$, $D_{wave}$, $T_{psurf}$, $T_{mbott}$, $Q_b$
- Diss$bot$, Diss$surf$, Diss$wcap$, $U_{bot}$

**Exchanged Fields**

- $U_{wind}$, $V_{wind}$, $Patm$, $RH$, $Tair$
- cloud, rain, evap, SWrad, Lwrad
- LH, HFX, $U_{stress}$, $V_{stress}$

**Sea ice and Wave?**
Summary and Future Work

1) Restructuring of Current Polar Mods
   – Replace Noah LSM with CLM LSM
   – Improved High-latitude Cloud Representation
   – CLM Land data assimilation

2) Update Polar WRF from version 3.7.1 to 3.8.1

2) Developing a Fully Coupled Modeling System
   Atmosphere – Ocean - Sea Ice -Wave - Land
   Based on the COAWST System