Modeling Polar Clouds of the ARISE and ASCOS Projects

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NASA ARISE C-130
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 North Alaska
  Polar WRF goes public

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

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

- Version 3.3.1 November 2011
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
  ARI SE Real Time Forecasts

- Version 3.6.1 November 2014
  ARI SE 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
Previous Testing of Polar Weather Research and Forecasting Model (WRF) by BPCRC

1. **Permanent ice sheets**
   - Greenland (Hines and Bromwich 2008, MWR)
   - Antarctic climate simulations (Bromwich et al. 2013, JGR)
   - Antarctic AMPS forecasts (NCAR)

2. **Polar pack ice**
   - Use 1997/1998 Surface Heat Budget of the Arctic (SHEBA) observations on drifting sea ice for selected months
     - Bromwich et al. (2009, JGR), Hines et al. (2015, MWR)

3. **Arctic land**
   - Northern Alaska (Hines et al. 2011, J. Climate)

4. **Arctic System Reanalysis Grid**
   - Wilson et al. (2011, JGR), Wilson et al. (2012)
How to use Polar WRF?

• Download the version 3.7.1 of WRF from NCAR (http://www2.mmm.ucar.edu/wrf/users/downloads.html)

• Register at http://polarmet.osu.edu/ PWRF to obtain Polar WRF supplemental files

• Follow instructions in the README file

• Select your options through the compiler options
  • Options need to be consistent between files

• Run WPS preprocessing with supplementary files for sea ice concentration, sea ice thickness, sea ice albedo as needed.
  • Consider editing the METGRID.TBL and Vtable for best settings of the additional variables

• Questions? Email: hines@polarmet1.mps.ohio-state.edu
New files to replace WRF 3.7.1 files

PWRF3.7.1/
files
phys:
  module_sf_noahlsm.F.PWRF3.7.1
  module_sf_noahdrv.F.PWRF3.7.1
  module_sf_noah_seaice.F.PWRF3.7.1
  module_surface_driver.F.PWRF3.7.1
  module_sf_noahlsm_glacial_only.F.PWRF3.7.1
  module_mp_morr_two_moment.F.PWRF3.7.1
  module_sf_clm.F.PWRF3.7.1
share:
  module_soil_pre.F.PWRF3.7.1
dyn_em:
  module_first_rk_step_part1.F.PWRF3.7.1
  module_big_step_utilities_em.F.PWRF3.7.1
run:
  LANDUSE.TBL.PWRF3.7.1
  VEGPARM.TBL.PWRF3.7.1

Noah LSM
Landuse tables
Compiler Directives in Polar WRF

How to use them?

module_sf_noahls.F.PWRF3.7.1:

MODULE module_sf_noahls

#ifdef BPRC_MODS
(define BPRC_MODS
!!!define ORGANIC_TUNDRA
!!!define ALTERNATE_SFCT

USE module_model_constants, only : CP, R_D, XLF, XLV, RHOWATER, STBOLT, KARMAN

REAL, PARAMETER :: CP = 1004.5
REAL, PARAMETER :: RD = 287.04, SIGMA = 5.67E-8, &
CPH2O = 4.218E+3, CPICE = 2.106E+3, &
LSUBF = 3.335E+5,
#endif BPRC_MODS
New Polar WRF simulations to study the model representation of Arctic low-level clouds
Use ASCOS (August - September 2008) in the Eastern Arctic near the North Pole as a comparison/analog for ARISE in the Western Arctic (September 2014).

- Use extensive observations from the Swedish Icebreaker Oden, and nearby ice camps
- Aerosol - cloud connection was an important component of the Arctic Summer Ocean Cloud Study (ASCOS)
- Test sensitivity of Polar WRF with Morrison 2-moment microphysics scheme to specification for liquid cloud droplet concentration (CCN/ aerosols)
- Apply findings to the ARISE simulations
PWRF 3.7.1 produces a reasonable simulation of the temperature in the lower troposphere during ASCOS.
Control simulation produces about three times the liquid water path than measured by MWR.

ASCOS divided into regimes (four or five) by several researchers.

Run PWRF simulations for 10 August to 3 September 2008.
Simulated temperature sensitivity during the four ASCOS regimes primarily in the lowest 1500 m.

Condensate dominated by liquid cloud water in the lowest 2000 m. Snow is second most common condensate.
Reducing liquid water droplet concentration reduces simulated liquid cloud water path to realistic values. The Morrison 1 cm-3 sensitivity test shows some skill for the tenuous cloud regime during Regimes 2 and 4.
Sedlar et al. (2011) estimated cloud forcing at ASCOS

Tenuous cloud regime (Regime 2 and 4)

Setting the liquid cloud droplet number to 1 cm$^{-3}$ shows some skill in capturing the tenuous cloud regime.

Polar WRF Cloud Forcing (longwave, shortwave and net) is reasonable
Adjusting for the reduced Arctic CCN concentration reduces PWRF liquid water content in low clouds.
ASCOS has detailed aerosol observations.

**PWRF 3.7.1 Control**
With Standard Morrison Microphysics

**PWRF 3.7.1 With**
20 cm$^{-3}$ Droplet Concentration

Adjusting for the reduced Arctic CCN concentration improves simulation of shortwave radiation.
Arctic Radiation-IceBridge Sea and Ice Experiment (ARISE)

• Arctic warming at twice the global average with largest sea ice loss near summer/fall transition

• NASA remote sensing measurements of climate change for land, ice, atmosphere, and clouds

• NASA aircraft flights complement satellite remote sensing

• IceBridge

• September-October 2014 C-130 flights out of Eielson AFB (near Fairbanks, Alaska)
ARISE Science Objectives

Overall Objective:

Acquire well calibrated datasets using aircraft and surface-based sensors to support the use of NASA satellite and other assets for developing a quantitative process level understanding of the relationship between changes in Arctic ice and regional energy budgets as influenced by clouds.

Specific Objectives:

1. From the NASA C-130, measure radiative flux profiles, quantify surface characteristics, cloud properties, and other atmospheric state parameters under a variety of atmospheric and surface conditions (including water, sea ice, and land ice), and coinciding with satellite overpasses when possible.

2. Acquire detailed measurements of land and sea ice characteristics to help bridge a gap in NASA satellite observations of changing Arctic ice conditions.

3. Utilize surface-based targets of opportunity to complement ARISE sampling strategies with the NASA C-130.
Instrumented aircraft flights out of Eielson AFB to open water and sea ice of the Arctic Ocean mostly in early and middle September 2014
Regime Change During Arise: Offshore high during early flights, followed by colder, more unsettled weather
Real-time forecasts show different conditions over Arctic sea ice and open water (also observed). Northerly winds occasionally brought cold air and low static stability in the lower boundary layer over the southern Arctic Ocean.
Most C-130 flights during Regime 1 and Regime 2

Show MSLP for two Arctic Ocean points. Both real-time PWRF forecasts and new research simulation.
Real-time forecasts show different conditions over Arctic sea ice and open water (also observed). Northerly winds occasionally brought cold air and low static stability in the lower boundary layer over the southern Arctic Ocean.

Temperature at 2 Arctic Ocean Points

Temperature (°C)

September 2014

Regime 1

Regime 2

Regime 3

Regime 4

Primarily Sea Ice

ARISE Field Program

Open Ocean
Coupled Modeling of Polar Environments

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

Water Substance Path, Open Water Point, 73 N, 150 W

- Cloud Liquid Water Path
- Cloud Ice Path
- Rain Water Path
- Snow Ice Path
- Graupel Path

Regime 1: Much less cloud ice mass than cloud water mass
Regime 2
Regime 3
Regime 4

Abundant Liquid Water in Clouds over Open Ocean

Regime 1

Water Substance Path, Sea Ice Point, 73 N, 133 W

- Cloud Liquid Water Path
- Cloud Ice Path
- Rain Water Path
- Snow Ice Path
- Graupel Path

Less Liquid Water in Clouds over Sea Ice than over Open Ocean

Regime 1
Regime 2
Regime 3
Regime 4

September 2014
Seasonal temperature falls faster at 2000 m than the surface, changing the static stability.

Regimes 1 and 2 have stable layers.

Near surface layer of low static stability near surface over open water.

1000 m deep stable layers over sea ice for Regimes 1 and 2.
Most simulated cloud water over sea ice for Regimes 1 and 2. Primarily below 250 m.

Over open water for Regimes 1 and 2 liquid cloud water shows a maximum somewhere between 300-750 m.

More cloud ice path for ARISE (2014) than ASCOS (2014)
Summary of Preliminary Findings from New ARI SE Simulations

Differences in cloud characteristics seen between open-water and sea ice grid points in the southern Arctic Ocean

Simulated low-level cloud water for ARI SE in amounts similar to MWR observations during ASCOS

More cloud ice in ARI SE simulations than ASCOS simulations.

Unlike ASCOS simulated middle cloud water substance is similar to that of low clouds

Horizontal advection of cold air from the northeast is an important influence on low-level atmospheric stability
Summary and Future Work

- ARISE (September 2014) and ASCOS (August 2008) are used to test the simulated Arctic clouds by Polar WRF

- NASA ARISE aircraft observations presents another opportunity to study Arctic late summer clouds

- Polar WRF simulations for ASCOS are sensitive to settings of liquid droplet concentration in the Morrison 2-moment microphysics scheme

- Preliminary results suggest simulated ARISE cloud characteristics are somewhat different than those of ASCOS

- High-resolution ARISE simulations will test changes to the WRF cloud microphysics

Need Antarctic cloud tests too