A MULTI-YEAR ARCTIC SYSTEM REANALYSIS

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1. Introduction

In the polar regions, it is often difficult to place current weather and climate trends in a long-term climatological perspective as the meteorological records there are limited in time and space in comparison with other regions of the globe. The low spatial density of polar meteorological data makes it challenging to separate local changes from regional or even continental-scale changes. In response to these complexities and the Arctic's importance for climate change, the Study of Environmental Arctic Change (SEARCH) project encourages extensive, interdisciplinary, multi-scale studies of high northern latitudes. Reanalyses are an appropriate integrating tool for Arctic studies as they assimilate all available observations from the surface, atmosphere and satellites into physically-consistent, regularly-spaced and comprehensive datasets. The pronounced impacts of global climate change manifested recently in Arctic land ice, sea ice, and permafrost regions make such efforts especially timely.

Global reanalyses, which are not optimally designed for high latitudes, continue to face substantial challenges in these unique environments (See the differences in the representations of Arctic temperature change in Figure 1). A new physically-consistent integration of Arctic data will be achieved through a tailored high-resolution reanalysis of the northern high latitude region, spanning poleward from the headwaters of the northward flowing rivers. The Arctic System Reanalysis (ASR, http://polarmet.mps.ohio-state.edu/PolarMet/ASR.html) is a collaboration of the Byrd Polar Research Center (BPRC) and Ohio Supercomputer Center (OSC) along with the National Center for Atmospheric Research (NCAR), the University of Colorado (including the National Snow and Ice Data Center), the University of Illinois, the University of Alaska Fairbanks, and the Arctic Region Supercomputing Center (ARSC). Initially, the U.S. National Oceanic and Atmospheric Administration (NOAA) provided seed money to lay the groundwork. Then recently, the initial phase of the ASR was funded by the National Science Foundation as an International Polar Year (IPY 2007-2009) project.

Gridded output fields from the ASR will serve a variety of uses. For instance, the ASR will permit detailed reconstructions of the Arctic system's variability and change, thereby complementing efforts of the global reanalyses. The project will also shape the legacy observing network of the IPY by providing a vehicle for observing system sensitivity studies of the Sustained Arctic Observing Network (SAON).

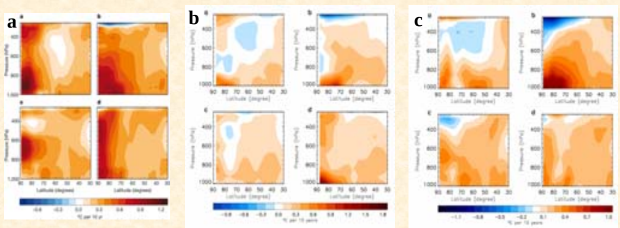
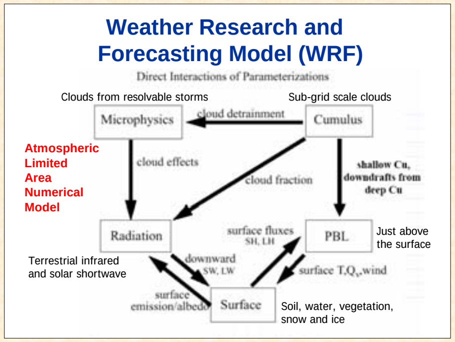


FIGURE 1. The latitudinal and vertical structure of the Arctic warming during the 1980s and 1990s, based on the (a) ERA-40 reanalysis, (b) NCEP/NCAR Reanalysis, and (c) JRA-15 Reanalysis . Averaged temperature trends around latitude circles for 1979–2001 plotted versus latitude and height for the four seasons. Notice the large variance in pattern in this key climate trend between the three reanalyses. (From Graversen et al. 2008).

2. Brief summary of the ASR

The first generation ASR will span the will span the Observing System (EOS) era of 2000-2010. To achieve its goals, the ASR will require an Arctic-friendly atmospheric numerical model with state-of-the-art dynamics. Therefore, the Weather Research and Forecasting (WRF, Skamarock et al. 2006, http://www.wrf-model.org/index.php) model is being optimized for the polar regions, and the resulting model is known as Polar WRF (http://polarmet.mps.ohio-state.edu/PolarMet/pwrf.html) and the WRF data assimilation capabilities being developed. Various input data consideration issues, reanalysis verification and reanalysis output tasks are being addressed by the University of Colorado and the University of Illinois. Computing platforms to be utilized include those of OSC and the ARSC. The Arctic model development is being carried out by Polar Meteorology Group of the BPRC. Data assimilation capabilities for WRF (WRF-Var) and ASR are developed by the WRF-Var Development Team (http://www.mmm.ucar.edu/wrf/WG4/wrfvar/wrfvar.htm) of NCAR's Mesoscale and Microscale Meteorology Division (MMM). The NCAR MMM is also the main portal for the distribution and developmental organization of the Advanced Research WRF (WRF-ARW). The current data assimilation plan for ASR is to use 3DVAR initially, and to consider a transition to ensemble Kalman filter (EnKF, Wang et al. 2007). An advantage to EnKF is that it estimates reanalysis uncertainty. Arctic land and sea ice will be treated with the Noah LSM. High resolution land data assimilation (HRLDAS) capabilities for Noah are being developed



The polar-optimized version of WRF (Polar WRF) will serve as the base model for the ASR

High Resolution Land Data Assimilation (HRLDAS)

MODIS 1km Vegetation Data June 18, 2002

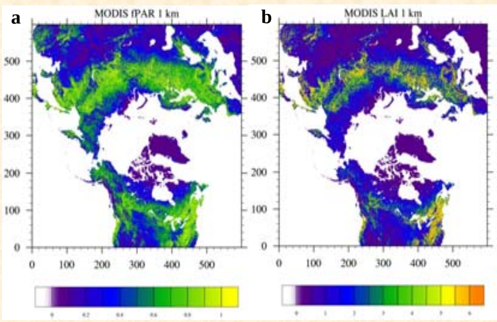


Figure 2. Use of MODIS retrievals for time-dependent surface conditions.

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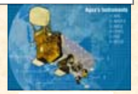
Data Assimilation with WRF-Var – A critical component of ASR

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(?).

WRF-Var Radiance Assimilation Status

NOAA (HIRS, AMSU)



Aqua (AMSU, AIRS)
DMSP(SSMI/S)

- BUFR 1b radiance ingest.
- RTM interface: RTTOV8_5 **or** CRTM
- NESDIS microwave surface emissivity model
- Range of monitoring diagnostics.
- Quality Control for HIRS, AMSU, AIRS, SSMI/S.
- Bias Correction (Adaptive, *Variational in 2008*)
- Variational observation error tuning
- Parallel: MPI
- Flexible design to easily add new satellite sensors

3. More details

The ASR encompasses a broad surface domain within the high-resolution region inside the boundaries. The planned ASR high-resolution grid shown in Fig. 3 includes all of the watersheds of the northward flowing rivers emptying into the Arctic Ocean. A lower resolution outer grid feeds the high resolution domain. The third-generation European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis (ERA-Interim) or the U.S. National Centers for Environmental Prediction Global Forecast System (GFS) will also be used to drive the ASR. To treat the Arctic land regions, the ASR will also include optimized high-resolution land data assimilation (HRLDAS) capabilities. Current work at NCAR on the Noah land surface model (LSM), a feature within the WRF model (Chen and Dudhia 2001; Skamarock et al. 2006), includes HRLDAS development for the ASR. This involves the blending of atmospheric and land-surface observations with the LSM, with the goal of providing a long-term evolution of soil and vegetation features, the surface hydrologic cycle, and the surface energy cycle.

The ASR will provide a high resolution description in space (~ 15 km) and time (1-3 h) of the coupled atmosphere-sea ice-land surface system of the Arctic. Ingested historical data streams will drive the ASR. Gridded output fields from the ASR will serve a variety of uses. Evaluations and improvements to Polar WRF have already been performed in correspondence with simulations over the Greenland Ice Sheet and the Arctic pack ice (Hines and Bromwich 2008; Bromwich et al. 2008). Work over the Arctic land mass is now beginning.

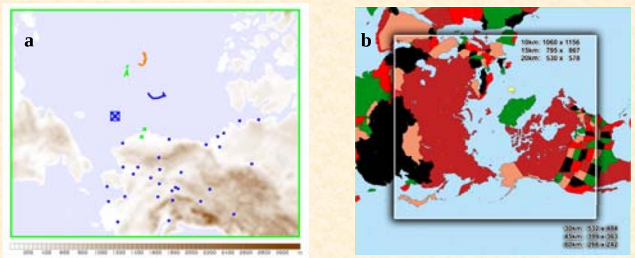


Figure 3. Polar WRF domains for (a) Arctic sea ice and Arctic land tests and (b) provisional ASR grid.

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