NOWCASTING AND FORECASTING ALASKAN WEATHER

BY NICOLE MÖLDERS, DON MORTON, GREG NEWBY, ERIC STEVENS, AND MARTIN STUEFER

The challenges in forecasting Alaskan weather as well as the questions about the application of forecasting tools are quite different from those in the contiguous United States. Alaska is the largest state, with the longest coastline, the most volcanoes, the largest area of permafrost and sea ice, the longest snow season, some of the highest mountains, the largest acreage burned annually, and the lowest density in observational networks in the United States. These extremes, in combination with the extreme climate (maximum and minimum temperatures in interior Alaska are 80 K apart; Stafford et al. 2000), mean that operational forecasts have to serve a wide range of users, while there are fewer resources for evaluation/feedback than anywhere else in our nation. Any numerical weather prediction model (NWPM) developed for midlatitude applications and applied to Alaska will operate in a temperature and moisture range at the lower edge or beyond that for which it was designed. Additional processes and/or surface conditions become relevant (e.g., permafrost, sea ice, frequent situations with either high stability or free convection), and must be considered in any polar weather prediction. All of these facts pose a great challenge to scientists modeling Alaskan weather and working to improve forecast methods and/or application products for our nation's largest state.

GREAT ALASKA WEATHER MODELING SYMPOSIUM

WHAT: About 50 scientists, forecasters, decision makers, and others interested in Alaska weather prediction met to present recent research, introduce new application tools, and identify difficulties in Alaska and polar weather forecasting that need to be addressed in future model development.
WHEN: 13–15 March 2007
WHERE: Fairbanks, Alaska

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DOI:10.1175/BAMS-89-4-515

In final form 26 October 2007

Fire weather prediction in Alaska has attained a high priority because wildfires pose a regular threat, which can be compared to tornadoes in the Midwest or hurricanes along the Gulf of Mexico and Atlantic coasts. Smoke plumes from wildfires and ash clouds from volcanic eruptions threaten Alaska's economy, because any transportation of residents, tourists, mail, material, and medical supplies to remote bush villages strongly depends on small aircrafts. As if ash clouds and low visibility caused by wildfires are not enough, there are also other weather conditions, such as summer thunderstorms (aircraft icing) and strong winds, that endanger air traffic. Alaska's complex terrain often channels strong winds resulting in locally strong turbulence and rotors that can lead to shutdowns at airports and air fields, which are located in valleys.

The Great Alaska Weather Modeling Symposium (GAWMS) was convened to present and discuss various application purposes, science transfer, and process studies that apply uniquely to the weather and climate of Alaska. The symposium fostered the interaction between scientists, forecasters, data providers, and users of model products in the Northern Chapter of the American Meteorological Society (AMS) and beyond.

KEYNOTE SPEAKERS. Invited keynote speakers at GAWMS were Georg Grell [the National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado], Keith Hines (The Ohio State University), John Michalakes [National Center for Atmospheric Research (NCAR)], and Peter Olsson (University of Alaska Anchorage).

Michalakes presented the architecture and performance of the Weather Research and Forecasting (WRF; e.g., Skamarock et al. 2005) model and gave a glimpse of future computer capacity. The incredible improvement in supercomputing will permit us to perform more process studies at a higher resolution than today, contributing to the improvement in numerical weather prediction and other operational forecast products and applications in Alaska. Collaboration among NCAR, The Ohio State University, and other interested polar scientists aims at introducing PolarWRF to the operational Antarctic Mesoscale Prediction System (AMPS) for U.S. Antarctic International Polar Year (IPY) operations. WRF developers are currently working on coupling WRF with ocean and sea-ice models. The dialog between the research community and users is important for understanding the users' needs and prioritizing software development. Michalakes perceives that the greatest challenge in future software engineering will be making effective use of the rapid advances in supercomputing, but at the same time keeping the multimillion dollar operational weather and climate modeling software maintainable, extensible, and portable over decades.

Hines reported the current status of PolarWRF, a version of the WRF model that will be optimized for applications in polar regions. In the development of PolarWRF, the polar science community relied upon lessons learned from the development of a polar-optimized version of the fifth-generation Pennsylvania State University (PSU)–NCAR Mesoscale Model (MM5; e.g., Grell et al. 1994), the PolarMM5 (e.g., Bromwich et al. 2001). Experience revealed that applications specific to polar regions need to be optimized and thoroughly evaluated, especially the atmospheric boundary layer parameterization, as well as the handling of cloud and snow surface physics, and sea ice treatment. First, PolarWRF evaluations were performed for a series of 48-h integrations initialized daily at 0000 UTC June 2001 and December 2002 over Greenland. Compared to automatic weather station (AWS) data, the PolarWRF has a similar forecast skill to that of the PolarMM5 for the winter case, but with an improved surface energy balance. For summer, the June 2001 integrations show that PolarMM5 currently outperforms PolarWRF. Hines also presented PolarWRF evaluations using Atmospheric Research Measurement (ARM; e.g., Stokes and Schwartz 1994) observations from the North Slope of Alaska site and the Surface Heat Budget of the Arctic Ocean (SHEBA; e.g., Uttal et al. 2002) study. The results of this work motivated, among other things, improvement to the community NOAH [NCEP (National Centers for Environmental Prediction), Oregon State University, Air Force, Hydrologic Research Lab] land surface model, and the initial snowpack temperature.

Grell discussed the current status of the WRF coupled online with a chemistry package (WRFchem; e.g., Grell et al. 2005). WRFchem describes the trace gas cycle from emission, through all kinds of chemical reactions, to transport, and finally removal from the atmosphere by wet or dry deposition, as well as the complicated interrelations with the energy and water cycles. In contrast to many other chemistry transport models, WRFchem is a fully integrative air quality modeling system, that is, the atmospheric chemistry and physics routines are solved concurrently (cf. Grell et al. 2005). This feature permits WRFchem to consider feedback between chemistry and the meteorological conditions. Inclusion of the feedback mechanism makes air quality predictions more accurate. Predicted concentrations of pollutants can even be used for evaluation purposes because they show much more spatial and vertical details than water vapor in the atmospheric boundary layer. The treatment of chemistry is based on a modified version of the so-called Regional Acid Deposition Model (RADM; Chang et al. 1987) chemical mechanism (Stockwell et al. 1990), modules for determination of dry deposition (Wesley 1989), photolysis, and biogenic and anthropogenic emission rates. Anthropogenic emissions can be computed from the Environmental Protection Agency (EPA) national emissions inventory. The chemical mechanisms consider stable and reactive intermediates and abundant stable inorganic species. They represent atmospheric organic chemistry with stable species, peroxy radicals, and organics. WRFchem considers aerosol chemistry and physics, secondary organic aerosols, and the wet and dry deposition of aerosols. A new feature permits users to easily introduce their chemical equations without large recoding efforts. In the future, photolysis frequencies will be determined with a modified version of Madronich's (1987) module.

Olsson presented a long-term comparison of the performances by the WRF and the Regional Atmospheric Modeling System (RAMS; e.g., Cotton et al. 2001) in forecasting weather over Prince William Sound, a very complex landscape of mountains, glaciers, and ocean. Both models have difficulties with the steepness of the terrain and predicting the extreme precipitation amounts occurring in this area. Olsson also introduced the Alaska Ocean Observing System (AOOS) data bank (available online at http://ak.aoos.org/op/data.php?region=AK) that was used in the evaluation studies. This data bank encompasses data from various sources (buoys, ships, automated weather stations, first-class stations, radiosonde sites, mesonet sites, satellite) of interest for meteorological, hydrological, glaciological, marine ecosystem, and ocean studies. Data availability spans the Gulf of Alaska, the Bering Sea and Aleutian Island regions, the Arctic Ocean, and the Beaufort and Chukchi Seas.

OTHER PRESENTATIONS. In addition to the keynote speakers, the symposium included a poster and several oral sessions, and a panel discussion with Olsson, Tim Flannery (zoologist, and author of the book *The Weather Makers*), and Gerd Wendler (Director of the Alaska Climate Center). The panelists discussed how weather phenomena may change in the next 10, 50, and 100 yr due to global climate change. The distinction between natural variability and anthropogenically caused changes were issues discussed. The discussion was very controversial, especially with respect to the climate impacts (e.g., wildfire frequency, coastal erosion, shifts in ecosystems) and the role of the Pacific decadal oscillation.

The largest session was on wind prediction, which is important for small aircraft, ship traffic, oil spill spread in coastal waters, and coastal erosion. These applications are of great financial relevance for Alaska's economy. Currently, the prediction of local wind systems, such as the Tanana Valley jet, are based on the forecasters' experience of what synoptic situations are likely to produce these events, rather than those explicitly being represented in model output. Finite-element models, such as those used in the engineering of aircraft or car bodies, may be an option to better capture the terrain and, hence, the channeling of the wind.

Themes of great public interest are fire weather and air quality prediction. One session focused on coupled models. Many talks addressed research important to the IPY that started 1 March 2007. Some of these were as follows:

- The rapid update cycle model (RUC; e.g., Benjamin et al. 2004) that provides guidance for forecasts of aviation weather now produces hourly updated forecasts that include the latest hourly aircraft, profiler, aviation routine weather report (METAR), satellite, and radar observations. In the near future, this system will be replaced by the WRF-based rapid refresh (RR) that encompasses North America, including Alaska.
- Satellite data played an important role in data assimilation to establish a PanArctic reanalysis product, model evaluation, and support in processes studies. In coastal areas, wind fields derived from Synthetic Aperture Radar (SAR; e.g., Monaldo 2000) data can be of great use in the evaluation of NWPMs. Various datasets were presented; the main difficulty with Alaska-ground-based measurements is that they are not evenly distributed, and instead are along major haul ways and along the coast for logistic purposes (access, energy supply). The harsh Alaska climate and remote observation sites yield more missing data than in midlatitudes.
- Coupling models from different disciplines would fill an urgent need to provide data that are suitable for risk assessment, warning, and decision making. Coupling a fire danger prediction model

with a weather forecast model yields improved fire weather forecasts; coupling an ash dispersion model with a weather forecast model allows early warning to air traffic of where to expect an ash plume from volcanic eruptions and where to impose air space restrictions.

FUTURE STEPS. Many discussions centered on future model development, improvement, and application. Using data from the various polar-orbiting satellites for better initialization of NWPMs with respect to water vapor, sea ice and snow cover distribution, surface albedo, and emissivity seem promising ways for improving polar weather forecasts.

To improve the simulation of heat and water vapor exchange at the Earth's surface, a sea ice model like that in PolarMM5 (Zhang and Zhang 2004) and subgrid-scale heterogeneity of sea ice of different thicknesses, similar to the treatment in the Community Climate System Model's (Collins et al. 2006) sea ice model (Briegleb et al. 2004), should be incorporated into the WRF.

The National Weather Service produces gridded forecasts with 1–5-km spatial resolution and temporal resolution as fine as 1 h. These forecasts might benefit from the future increase in supercomputing performance. A data bank of high-resolution (1 km, 1 h) WRF simulation data of various synoptic conditions could help meteorologists produce such forecasts. These data can provide a viable first guess that considers the influence of local terrain on the synoptic situation.

The prediction of poor air quality related to wildfires faces various hurdles. Emission models have to be modified for typical Alaska fuel. There are hardly any ground-based or airborne measurements for evaluation. Permafrost soils affect the firebrand, and the uppermost active layer consists of organic material (peat, moss, lichen) that the fire consumes. As the fire burns, permafrost melts and the meltwater affects the fire. Uncertainty in the active layer depth, soil volumetric water content, and fraction of burnable soil components (e.g., peat, moss) enhances the challenge of building fire emission models suitable for use in Alaska.

The huge oil resources on the North Slope and under the Arctic Ocean create a risk for oil spills. Response crews require accurate wind forecasts (speed and direction) to determine wave height, sea ice distribution, and oil spill movement when coordinating their work, making decisions, fighting the spill, and minimizing damage.

PROMISING OUTLOOK. About 15% of the attendees registered for the symposium were graduate students or postdoctoral researchers, that is, the next generation of scientists. This means the ball will keep rolling toward improved models for polar weather prediction—a really enchanting thought.

ACKNOWLEDGMENTS. The Great Alaska Weather Modeling Symposium (GAWMS) was sponsored by the Alaska Ocean Observing System (AOOS), Alaska Region National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS), Arctic Region Supercomputing Center (ARSC), College of Natural Science and Mathematics (CNSM), Geophysical Institute (GI), and International Arctic Research Center (IARC).

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