

MEETING SUMMARIES

REGIONAL SPECTRAL MODEL WORKSHOP IN MEMORY OF JOHN ROADS AND MASAO KANAMITSU

BY HANN-MING HENRY JUANG, SHYH-CHIN CHEN, SONGYOU HONG, HIDEKI KANAMARU, THOMAS REICHLER, TAKESHI ENOMOTO, DIAN PUTRASAHAN, BRUCE T. ANDERSON, SASHA GERSHUNOV, HAIQIN LI, KEI YOSHIMURA, NIKOLAUS BUENNING, AND DIANE BOOMER

The committee for the 12th International Regional Spectral Model (RSM) Workshop drew its members from the National Centers for Environmental Prediction (NCEP), the U.S. Forest Service, Yonsei University, the Cooperative Institute for Climate and Satellites, the University of Tokyo, the Food and Agriculture Organization of the United Nations (FAO), Hokkaido University, The Florida State University, and Woods Hole Oceanographic Institution. Details of the workshop history since its first meeting in 1999 can be found online (at <http://rsm-workshop.wikispaces.com>).

The purpose of this workshop, as in past years, was to discuss the development and applications of the RSM, originally developed at NCEP. RSM has been used extensively in regional downscaling of coarse-resolution forecasts, analyses, and simulations:

12TH INTERNATIONAL REGIONAL SPECTRAL MODEL WORKSHOP

WHAT: A quasi-annual international gathering studies development and application of a model often used in the past for regional downscaling and now poised to become nonhydrostatic and move into the mesoscale.

WHEN: 5–9 November 2012

WHERE: Scripps Institution of Oceanography, La Jolla, California

one of the hottest topics in atmospheric modeling. Since the NCEP global atmospheric model in the Global Forecast System (GFS) was implemented operationally in a horizontal resolution of about

AFFILIATIONS: JUANG—Environmental Modeling Center, DOC/NOAA/NWS/NCEP, Washington, D.C.; CHEN—Pacific Southwest Research Station, USDA Forest Service, Riverside, California; HONG—Department of Atmospheric Sciences, Yonsei University, Seoul, South Korea; KANAMARU—Food and Agriculture Organization of the United Nations, Rome, Italy; REICHLER—Department of Atmospheric Sciences, University of Utah, Salt Lake City, Utah; ENOMOTO—Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan; PUTRASAHAN—Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida; ANDERSON—Department of Earth and Environment, Boston University, Boston, Massachusetts; GERSHUNOV AND BOOMER—Scripps Institution of Oceanography, University of California,

San Diego, La Jolla, California; LI—Center for Ocean–Atmospheric Prediction Studies, The Florida State University, Tallahassee, Florida; YOSHIMURA—Atmosphere and Ocean Research Institute, University of Tokyo, Chiba, Japan; BUENNING—Department of Earth Sciences, University of Southern California, Los Angeles, California

CORRESPONDING AUTHOR: Dr. Hann-Ming Henry Juang, DOC/NOAA/NWS/NCEP/EMC, 5830 University Research Court, College Park, MD 20740
E-mail: henry.juang@noaa.gov

DOI:10.1175/BAMS-13-00124.1

In final form 30 October 2013
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25 km last year, it is time for regional modeling to move from regional scale (~20 to ~40 km) to mesoscale (~5 to ~20 km) by using a nonhydrostatic version of RSM. Thus, one of the major purposes of this year's workshop was to introduce a nonhydrostatic version of RSM, called the Mesoscale Spectral Model (MSM). Additionally, the workshop provided opportunities for the RSM community to exchange regional downscaling modeling findings using different versions of the model. Those versions are 1) the Global Spectral Model (GSM) and RSM merged system (G-RSM) at the Scripps Institution of Oceanography (SIO); 2) NCEP RSM and MSM; 3) RSM at the International Research Institute (IRI); 4) GSM, RSM, and MSM at Yonsei University; 5) Central Weather Bureau (CWB) of Taiwan RSM at CWB; 6) RSM/MSM at the National Defense University at Taiwan; and others. The RSM workshops are designed to gather together international regional model developers and users and to learn the latest modeling features being developed. Through these discussions, we formulate future plans for RSM development. Thus, this workshop did not exclude participation by modelers other than GSM, RSM, and MSM users. In fact, we strongly encouraged people who engage with other models to attend, compare results, and discuss general regional-model-related problems. There is increasingly high demand for

regional climate model (RCM) products from impact modelers and practitioners in seasonal forecasts and climate change issues. Therefore, end users of RCM simulation results—who represent wildfire, agriculture, water resources, energy, and other sectors—were invited to participate. In addition to the usual presentations, one day was dedicated to commemorate John Roads and Masao Kanamitsu.

OVERVIEW OF RSM DYNAMICS AND PHYSICS. Henry Juang gave a brief overview of the workshop's history and reviewed the dynamics aspect of spectral modeling. The concept of spectral computation, model equation discretization, and some common numerics for model stable integration were presented. The numerics include spectral horizontal diffusion, semi-implicit time scheme, and time filter. The scale representation in regional model through its domain and resolution was illustrated. A brief on future modeling for RSM was presented.

Songyou Hong presented lectures on physical processes in atmospheric models. The lectures included a fundamental concept regarding the subgrid-scale representation of physics processes, and overviews on existing algorithms for radiation, land surface hydrology, turbulence, gravity wave drag, and precipitation processes.

IN MEMORY OF ROADS AND KANAMITSU

For many years, John Roads and Masao Kanamitsu were two of the primary promoters of the International RSM Workshop. Sadly, John passed away on 21 June 2008 and Kana passed away during our previous RSM workshop on 17 August 2011. John and Kana worked together very closely at Scripps for years.

The session dedicated to John Roads—attended by several family members, including his daughter Emily Roads Boele—presented reminiscences, anecdotes, and overviews of his science contributions and academic life. Arthur Miller (University of California, San Diego) related early days with Roads at SIO and described fun memories of traveling with Roads to interesting parts of the world. Thomas Reichler (University of Utah), a former graduate student of Roads, chronicled Roads's journal publication record. He pointed out that Roads's

research output actually peaked during the last few years of his career. Soroosh Sorooshian (University of California, Irvine) followed up by describing Roads's contribution to many international programs, such as the Global Energy and Water Cycle Experiment (GEWEX). With many heartwarming stories and wonderful pictures, Sorooshian also commented on Roads's generous nature, which he observed while traveling with him to many underdeveloped countries. Steve Brenner (Bar-Ilan University, Ramat Gan, Israel) affirmed Roads's warmth and humanity with stories from their days as fellow graduate students at the Massachusetts Institute of Technology (MIT). Brenner also spoke of Roads's enthusiastic support for his regional climate project over the Mediterranean area. Dian Putrasahan, Roads's last graduate student, told how Roads guided her through her

presentation file line by line from his sickbed.

Francis Fujioka (U.S. Forest Service, retired) shared stories of his first meeting with Roads in a tiny and crowded trailer in Colorado while both were still undergraduate students. Fujioka also described how Roads, as a pioneer, brought weather and climate forecasts into wildland fire danger prediction. Bruce Anderson (Boston University), Roads's first graduate student, was still amazed how Roads could work so efficiently after beers at the regular Friday working lunch. After realizing how beneficial the weekly working lunch with Roads was to his development, Anderson vowed to retain this wonderful tradition with his own students. Songyou Hong (Yonsei University) described his last visit to Roads at the hospital. Henry Juang (NCEP) expressed his gratitude to Roads for his support and contribution

DYNAMIC DOWNSCALING. Wednesday morning was focused on dynamic downscaling of coarse-resolution global climate model (GCM) output. Thomas Reichler (University of Utah) presented a new effort to simulate, understand, and predict changes in climate and water resources over mountains. The selected prototypical study region of this research is tropical South America with its high Andean Mountains and extreme gradients in topography. The study intends to downscale for the region the coarse-scale output from five different GCMs conducted in support of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change. The downscaling will utilize the Weather Research and Forecasting Model (WRF) coupled to a hydrological snow/glacier model. The coupled system will be used to perform decade-long high-resolution simulations at the 3–1-km scale. Reichler presented validation outcomes using Taylor diagrams and a large number of sensitivity experiments with different versions of WRF. Since the South and North American monsoon systems share many important features, the outcomes from this study are also expected to be relevant for the climate prediction problem over the mountainous western United States. The presentation by Hideki Kanamaru (FAO) cautioned against the improper use of downscaled climate model output. The users of such products are typically not part of the climate science

community but rather belong to the impact assessment and adaptation community, and large amounts of funding are often provided to these communities. These users, however, are often not aware of the limitations, assumptions, and uncertainties that are inherent in downscaled products. Users therefore tend to overinterpret the outcomes from the regional models. Kanamaru concluded that stronger linkages between climate scientists and other communities are needed to better guide nonexperts in the use of downscaled data. Hideki further proposed to consider alternate methods to dynamical downscaling such as statistical approaches. Such methods could then be used to further test the robustness of the different outcomes.

NUMERICAL MODELING. Presentations on numerical methods were emphasized on Wednesday afternoon. Takeshi Enomoto (Kyoto University) compared two similar but distinct nonhydrostatic formulations based on the hydrostatic pressure by Laprise (1992) and Juang (1992). The differences exist in the definition of the geopotential used in the coordinate conversion. Laprise (1992) uses the full density to define the geopotential and Juang (1992) introduces the hydrostatic basic state. In the warm bubble experiment using MSM, results from both formulations are identical except for pressure perturbations. A hint of sound waves exists in Laprise's

formulation. In the cold bubble experiment, integration blows up quickly in Laprise's formulation with the numerics of MSM. As an alternative to the prognostic hydrostatic temperature (Juang 2000), Enomoto proposed a spatial average of the full temperature as the hydrostatic temperature and applied it successfully in the warm and cold bubble experiments. Finally, he argued that the spectral transform method is still a viable approach in the nonhydrostatic regime and suggested options to convert GSM or MSM into a global nonhydrostatic model.

Henry Juang [National Oceanic and Atmospheric Administration/National Centers for Environmental Prediction/Environmental

to the development of RSM. Shyh Chen (U.S. Forest Service) told interesting stories of his work and travels with Roads to many countries around the world.

Roads's daughter Emily Roads Boele thanked all the presenters and everyone who participated in the commemoration session for sharing their stories of Roads, many of which were little known to the family.

Songyou Hong (Yonsei University) focused on Kanamitsu's major achievements in atmospheric modeling and reanalysis. Henry Juang (NCEP) recalled the constant encouragement he received from Kanamitsu on any new areas in model dynamical cores, which ultimately challenged him to succeed. Hideki Kanamaru (Food and Agriculture Organization of the United Nations) and Kei Yoshimura (University of Tokyo), who did not have any previous experience in atmospheric

modeling, attributed their achievements in global and regional climate modeling studies to Kanamitsu's mentorship. Dan Cayan (University of California, San Diego), a collaborator of Kanamitsu's at SIO, talked about the scientific broadening in mesoscale circulations over the California coast using the high-resolution downscaled reanalysis. Haiqin Li (The Florida State University), who completed Kanamitsu's final modeling project, discussed the 10-km ocean-atmospheric coupled regional modeling system and its success on downscaled climatology in mesoscale atmospheric circulations as well as in oceanic features. Songyou Hong described a newly developed global/regional integrated model system (GRIMs), which incorporates Kanamitsu's numerical algorithms in addition to physics algorithms in WRF. The session ended with a moment of silence in honor of Kanamitsu.

Modeling Center (NOAA/NCEP/EMC)] presented an improvement of NCEP GSM for horizontal resolution of $O(1-10)$ km. Associated Legendre functions (ALF) have profound importance on the accuracy of the dynamical core of spectral transform models, since they are used in the spherical transform between the wave and physical spaces at each time step. ALF become less accurate as the truncation wavenumber becomes large because of underflow. Juang implemented extended-range arithmetic to compute associated Legendre functions in GSM to avoid the underflow. The more accurate ALF allow the use of large truncation wavenumbers above 2000. Experiments using the operational model show that the more accurate ALF improve the forecast skill. Although the earlier differences are very small, the differences grow over time to be nonnegligible. Enomoto commented on Juang's presentation that the X number produces more accurate associate Legendre functions of very small values that are suited for parallelization, but the four-point recurrence is a few digits more accurate in the Legendre transform.

Dian Putrasahan (University of Miami) discussed mesoscale-coupled atmosphere-ocean dynamics in the Humboldt Current system and in the Kuroshio Extension region. A novel strategy was introduced to study the dependence of ocean-atmosphere coupling on various spatial scales through the implementation of a spatial smoother in a coupled framework. Putrasahan studied the spatial-scale dependence of surface wind response to mesoscale SST in the Kuroshio Extension region via two well-known mechanisms, the vertical mixing mechanism and the pressure adjustment mechanism. In the study, Putrasahan found significant coupling between SST, wind speed, and latent heat flux on the mesoscale and insignificant coupling on large-scale and full-scale modes, suggesting that the influence of mesoscale SST on latent heat flux is through both direct flux anomalies and indirectly through changes in the stability of the overlying atmosphere, which in turn affects the wind speeds and thus latent heat flux.

SEASONAL PREDICTION. Haiqin Li (The Florida State University) presented an analysis of the two-tiered Florida Climate Institute-Florida State University Seasonal Hindcast at 50 km (FISH50). Six ensemble members for each of the seasonal hindcasts were run for a 6-month period. FISH50 was initialized at two different times of the year: 1 June and 1 December of each year from 1982 to 2008. The unique aspect of FISH50 is its SST forcing. FISH50

used multimodel, monthly-mean forecasted SST from two coupled ocean-atmosphere models, which were bias corrected without using observations in the forecast period. The bias correction was done with a time-varying observed climatology that had the climate change signal and very low-frequency variations of SST prior to the forecast period. The time-varying CO_2 concentration in the atmosphere was also applied to the seasonal hindcasts. The demonstrable improvement of predictability of zero lead and one season lead in FISH50 was shown in comparison with two other contemporary operational coupled ocean-atmosphere climate models from which the forecasted SST anomaly was borrowed. Li attributed the improvement in FISH50 to the relatively high resolution of the 50-km grid and the unique SST forcing used in the seasonal hindcasts. The probabilistic skill analysis shows that significant forecast skill can be harvested from these seasonal hindcasts relative to the deterministic skill analysis. Li concluded from this study that the coupled ocean-atmosphere seasonal hindcasts have reached a reasonable fidelity to exploit their SST anomaly forecasts to force such relatively higher-resolution two-tier prediction experiments to glean further seasonal prediction skill.

DOWNSCALING APPLICATION I. Bruce Anderson (Boston University) reviewed recent observational results indicating that over the course of the twentieth century there was a large-scale northward expansion of the summertime North American monsoon (NAM) precipitation deep into the interior of the western United States, suggesting that this region may serve as a "sentinel" region in which detectable trends in precipitation characteristics are already emerging from the envelope of interannual to decadal variability. Given the inability of global climate models to simulate many of the important rainfall-producing phenomena in this region, Anderson then highlighted that only through regional climate model experiments like those pioneered by John Roads would the community be able to diagnose and analyze the mesoscale, regional, and large-scale dynamic, thermodynamic, and hydrologic features of this northward expansion of the North American monsoon.

DOWNSCALING APPLICATION II. In this section, novel applications of G-RSM (e.g., isotopologues, data assimilation, downscaling at developing nations) were presented. Kei Yoshimura (Atmosphere

and Ocean Research Institute, University of Tokyo) presented a new trial of data assimilation with water vapor isotopologues (HDO and H₂¹⁸O), which have recently begun to be measured by spectroscopic instruments on some satellites. The observing system simulation experiment (OSSE)-like experiment showed that the water vapor isotopologues have the potential to constrain not only themselves but also the meteorological variables. Nik Buening (University of Southern California) presented that, with vapor tagging simulations, the modeled year-to-year changes in precipitation isotope ratios were also connected to variations in condensation height. The multiple influences complicate the interpretation of western U.S. climate proxies that are derived from the isotopic composition of precipitation. Mohan Das (Meteorological Research Centre, Bangladesh) presented the application of three-dimensional variational data assimilation (3DVAR) on their weather prediction. With the new radar network, the prediction skill was clearly improved. Finally,

Abdoulaye Sarr (National Meteorological Agency of Senegal) presented the Coordinated Regional Climate Downscaling Experiment in Africa (CORDEX-Africa) activity and pointed out the global models' performance over the area is still quite poor in some models. Finally, the entire group reached a conclusion to continue the RSM workshop once in two years, either by itself or along with other related conferences.

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