Meeting summary

The 12th international regional spectral model workshop: In memory of Drs. John Roads and Masao Kanamitsu

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General meeting purpose

The twelfth international regional spectral model (RSM) workshop, which was hosted locally by Scripps Institution of Oceanography with committee members from National Centers for Environmental Prediction, US Forest Service, Yonsei University, Cooperative Institute for Climate and Satellites, University of Tokyo, Food and Agriculture Organization of the United Nations, Hokkaido University, Florida State University, and Woods Hole Oceanographic Institution, was held 5 – 9 November 2012 at the Martin Johnson House, Scripps Institution of Oceanography in La Jolla, California. This workshop was held nearly once per year since its first meeting in 1999 at Maui, Hawaii. Details of the workshop's history can be found 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 the National Centers for Environmental Prediction (NCEP). RSM has been used extensively in regional downscaling of coarse resolution forecasts, analyses and simulations, which is one of the hottest topics in atmospheric modeling. Since the NCEP global atmospheric model in GFS was implemented operationally in horizontal resolution of about 25km last year, it is time for regional modeling to move from regional scale (~20 to ~40km) to mesoscale (~5 to ~20) 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 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 Spectral GSM and RSM merged system (G-RSM) at Scripps Institution of Oceanography (SIO), (2) NCEP RSM and MSM, (3) RSM at 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 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 RCM products from impact modelers and practitioners in seasonal forecasts and climate change issues. Therefore, an invitation to participate in the workshop was extended to end-users of the simulation results from RCMs on various time scales for application (climate risk management, wildfire, agriculture, water resources management, energy, etc). In additional to the usual presentations, one day was dedicated to commemorate Dr. 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 Drs. Roads and Kanamitsu

For many years, Drs. John Roads and Masao Kanamitsu were two of the primary prompters of the International RSM Workshop. Sadly, John passed away on June 21, 2008, and Kana passed away during our previous RSM workshop on August 17, 2011. John and Kana worked together very closely at Scripps for years before their passing. During this year's workshop we dedicated one day, November 6, to honor their lives and legacies. The commemoration was open to the community.

The Tuesday morning (November 6) session was dedicated to Dr. John Roads. Several family members, lead by daughter Ms. Emily Roads Boele, were present. Ten scheduled, plus a few unscheduled speakers, reconstructed a rather complete picture of Roads with reminiscences, anecdotes, and overviews of his science contributions and academic life.

Arthur Miller (University of California, San Diego) began the session with reminiscences of his earliest encounters with Roads at SIO. He described many fun memories of traveling with Roads to many interesting parts of the world. Thomas Reichler (University of Utah), a former graduate student of Roads', gave a fairly thorough chronological analysis of Roads' journal publication record. He pointed out that Roads' research output actually reached its peak during the last few years of his career. Soroosh Sorooshian (University of California, Irvine) followed up by describing Roads' contribution to many international

programs, such as GEWEX. With many heart-warming stories and wonderful pictures, Sorooshian also commented on Roads' generous nature, which he observed while traveling with him to many under-developed countries. Steve Brenner (Bar-Ilan University, Ramat Gan, Israel) affirmed Roads' warmth and humanity with stories from their days as fellow graduate students at MIT. Brenner also spoke of Roads' enthusiastic support for his regional climate project over the Mediterranean area. Dian Putrasahan, Roads' last graduate student, told how Roads guided her through her presentation file line-by-line from his sickbed.

After the session break, Francis Fujioka (US 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' 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 to the development of RSM. Shyh Chen (US Forest Service) told interesting stories of his work and travels with Roads to many countries around the world.

The morning session ended with a speech from Roads' daughter Emily Roads Boele, expressing the honor she and the family felt. She 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.

The Tuesday afternoon session was dedicated in memory of Masao Kanamitsu's life and contributions to atmospheric sciences. A tribute session followed.

Songyou Hong (Yonsei University) opened the session by describing Kanamitsu's biography and personal life, focusing on his 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 mesocale circulations over the California coast using the high-resolution downscaled reanalysis. Haiqin Li (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 the weather and research forecasting (WRF) model.

Many personal reminiscences followed, and this session ended with a moment of silence in honor of Kanamitsu.

Dynamic Downscaling

The session on Wednesday morning focused on dynamic downscaling of coarse resolution 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 the tropical part of 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 global climate models (GCMs) conducted in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (AR5). The downscaling will utilize the WRF model that is 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 the WRF model. 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 US. The presentation by Hideki Kanamaru (FAO) cautioned regarding 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 over-interpret the outcomes from the regional models. Kanamaru concluded that stronger linkages between climate scientists and other communities are needed to better guide non-experts 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 non-hydrostatic formulations based on the hydrostatic pressure by Laprise (1992) and Juang (1992). The differences exist in the definition of the geopotential used in the co-ordinate 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 non-hydrostatic regime and suggested options to convert GSM or MSM into a global non-hydrostatic model.

Henry Juang (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 it is used in the spherical transform between the wave and physical spaces at each time step. ALF becomes less accurate as the truncation wave number becomes large due to underflow.

Juang implemented extended-range arithmetic (X-number, Fukushima 2011) to compute associated Legendre functions in GSM to avoid the underflow. The more accurate ALF allows the use of large truncation wave numbers above 2000. Experiments using the operational model show that the more accurate ALF improves the forecast skill. Although the earlier differences are very small, the differences grow over time to be non-negligible. 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 in m, 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 mode, 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 (Florida State University) presented an analysis of the two-tiered Florida Climate Institute-Florida State University Seasonal Hindcast at 50km (FISH50, Misra et al. 2012; Li and Misra 2012). 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: June 1 and December 1 of each year from 1982-2008. The unique aspect of FISH50 is its SST forcing. FISH50 used multi-model, 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 50km 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 20th Century there was a large-scale northward expansion of the summertime North American Monsoon (NAM) precipitation deep into the interior of the western U.S., suggesting that this region may serve as a "sentinel" region in which detectable trends in precipitation characteristics are already emerging from the envelope of inter-annual 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, i.e., isotopologues, data assimilation, downscaling at developing nations were presented. Kei Yoshimura (Atmosphere and Ocean Research Institute, Univ. Tokyo) presented a new trial of data assimilation with water vapor isotopologues (HDO and $H_2{}^{18}O$), which have recently begun to be measured by spectroscopic instruments on some satellites. The OSSE-like experiment showed that the water vapor isotopologues have potential to constrain not only themselves but also the meteorological variables. Nik Buenning (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 3DVAR data assimilation 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 CORDEX-Africa activity and pointed out the global models' performance over the area is still quite poor in some models.

Finally, entire group reached a conclusion to continue RSM workshop once in two years, either by itself or along with other related conferences.