Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
38th NOAA Annual Climate Diagnostics and Prediction Workshop
College Park, MD, 21-24 October 2013

Recent Science Advancement in Seamless Weather to Climate Modeling and Prediction

Jiayu Zhou, S&TI Climate Mission, Office of Science and Technology, NWS/NOAA
Wayne Higgins, Climate Program Office, OAR/ NOAA
Mike Halpert, Climate Prediction Center, NCEP/NWS/NOAA

1. Overview

The climate-weather-water connection is a grand challenge for NOAA. The weather to climate continuum demands a unified modeling and seamless prediction framework. Since the predictability of long-term climate is largely uncertain and demands increased basic research, the service is advised to put the emphasis on short-term climate applications, by expanding the current weather service to provide much needed weather-climate services, incorporating short-term climate monitoring and prediction with reliable and skillful information.

2. Long-term climate is what you get

a. Correction on weather-climate classification

According to an analysis of observed variability characterized by spectral composites (Lovejoy and Schertzer 2013), only the average of short-term climate/macroweather (10 days to 10-30 years) converges to normal, so that products of probabilistic prediction with shallow uncertainty are well justified for application uses. However, long-term climate processes (10-30 years to 100,000 years) are "weather-like", of which the variability grows with an increase of time scale.

This important characteristic is known to be missing in current Earth system model simulations due to a lack of internal long-term processes that interact with boundary conditions and are coupled with external forcings (Lovejoy, Schertzer and Varon 2013).

b. Profound uncertainties in long-term projection

Natural long-term climate change at any time or place is (qualitatively and quantitatively) unexpected in very much the same way that the weather is unexpected due to the variability growing with time. Most people understand the greenhouse effects of anthropogenic greenhouse gases. The real problem is the projection of future long-term climate, for which greenhouse gases are only one of the players. The others and interactions among all players with chaotic internal dynamics are far from well explored and understood, which brings out concerns about the reliability of current long-term climate projection products and present a barrier to clear-cut policy and decision making.

i) Climate change on hold?

Recent CO_2 emissions have actually risen even more steeply than people feared. As a result, according to most climate models, the temperature should have risen about 0.25°C over the past 10 years. However, the increase over the last 15 years was just 0.06°C. Model deficiencies are increasingly getting the attention of climate scientists as to what could be the fundamental problems (von Storch et al. 2013).

ii) Warming of deep ocean

Warming really means heating that could be felt in many ways. Recent observational studies show ongoing warming of deep oceans at an alarming rate (Balmaseda 2013), which could be related to the slowdown of global surface air temperature rising. This part of the energy imbalance induced by the greenhouse gases was not observed throughout previous record.

Correspondence to: Jiayu Zhou, Office of Science and Technology, NOAA's National Weather Service, Silver Spring, MD 20910; E-mail: jiayu.zhou@noaa.gov.

iii) Cooling in near future?

Though greenhouse gases play a role in the earth's energy balance by trapping energy and radiating it back to earth, the ultimate heat source of the Earth-atmosphere system is incoming solar radiation. By analyzing the average annual balance of the thermal budget, it has been demonstrated that the negative energy balance that has occurred since the 90's (Abdussamatov 2012), will likely continue during the next a few 11-year solar cycles.

3. Toward unified probabilistic modeling for reliable weather-climate seamless prediction

No forecast can be considered reliable without an accurate assessment of forecast uncertainty. With the power law behavior for atmospheric energy, uncertainties in subgrid processes propagate upscale by nonlinear dynamical effects. The errors with conventional numerical algorithms based on deterministic closures, which represent subgrid processes by the bulk-average effect of some putative large ensemble, appear to lead to substantial biases and considerable uncertainty in simulating climate. With increasing resolution, the convergence to the 'true' underlying equations is exceptionally slow.

The development of explicitly probabilistic weather and climate models, in which the inherent uncertainty is recognized explicitly without scale separation (Palmer 2012), gives more reliable estimates of uncertainty that pave the way for significant advancement of weather-climate prediction.

4. Guidance for effective development

a. Embrace seamless prediction and unified modeling framework

The seamless prediction concept, which emphasizes the interdependency in predictability between weather and climate, is increasingly recognized as a critical paradigm. In particular, a unified modeling framework for seamless prediction is required not only to optimize the usage of NOAA modeling resources but also accelerate improvement of the weather-climate model performance.

b. Meet challenges

NOAA is facing considerable challenges in continuously improving its operational Climate Forecast System, finding the resources needed to develop multiple climate models with high resolution and full physics, and at the same time running large ensemble integrations from states initialized with contemporary observations. To be successful, the agency is reorganizing to mobilize all positive factors by remove obstacles, *e.g.* fragmentation etc. (Rood 2013).

References

Abdussamatov, H.I., 2012: Bicentennial decrease of the total solar irradiance leads to unbalanced thermal budget of the Earth and the Little Ice Age. *Appl. Phys. Res.*, **4**, 178-184.

Balmaseda, M.A., K.E. Trenberth, and E. Källén, 2013: Distinctive climate signals in reanalysis of global ocean heat content. *Geophys. Res. Lett.*, **40**, 1754–1759.

Lovejoy, S., 2013: What is climate? *Eos*, Transactions, AGU, **94**, 1-2.

Lovejoy, S., D. Schertzer, and D. Varon, 2012: Do GCMs predict the climate ... or macroweather? *Earth Syst. Dynam.*, **4**, 439–454.

Palmer, T.N., 2012: Towards the probabilistic Earth-system simulator: a vision for the future of climate and weather prediction. *Q. J. R. Meteorol. Soc.*, **138**, 841-861.

Rood, R.B., 2013: To be the best in weather forecasting: Why Europe is beating the U.S. Capital Weather Gang blog (03/08), *Washington Post*.

Von Storch, H., A. Barkhordarian, K. Hasselmann, and E. Zorita, 2013: Can climate models explain the recent stagnation in global warming? *Academia.edu*, https://www.academia.edu/4210419/Can_climate_models_explain_the_recent_stagnation_in_global_warming