Dynamic Downscaling As a Tool for Providing Actionable Climate Information

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1. Why Dynamic Downscaling?

✧ Climate modeling is not only important for understanding how the climate system works, but also crucial for informing decisions for issues with enormous economic ramifications. Global climate models (GCMs) are run with a coarse resolution that cannot resolve mesoscale atmospheric features and the land-surface heterogeneity. Consequently, GCMs may not be able to accurately represent temperature and precipitation extremes. Fine-scale and accurate climate information is urgently needed for regional decision making. Dynamical downscaling using a regional climate model (RCM) has been an effective tool to provide actionable regional climate information (Fig. 1).

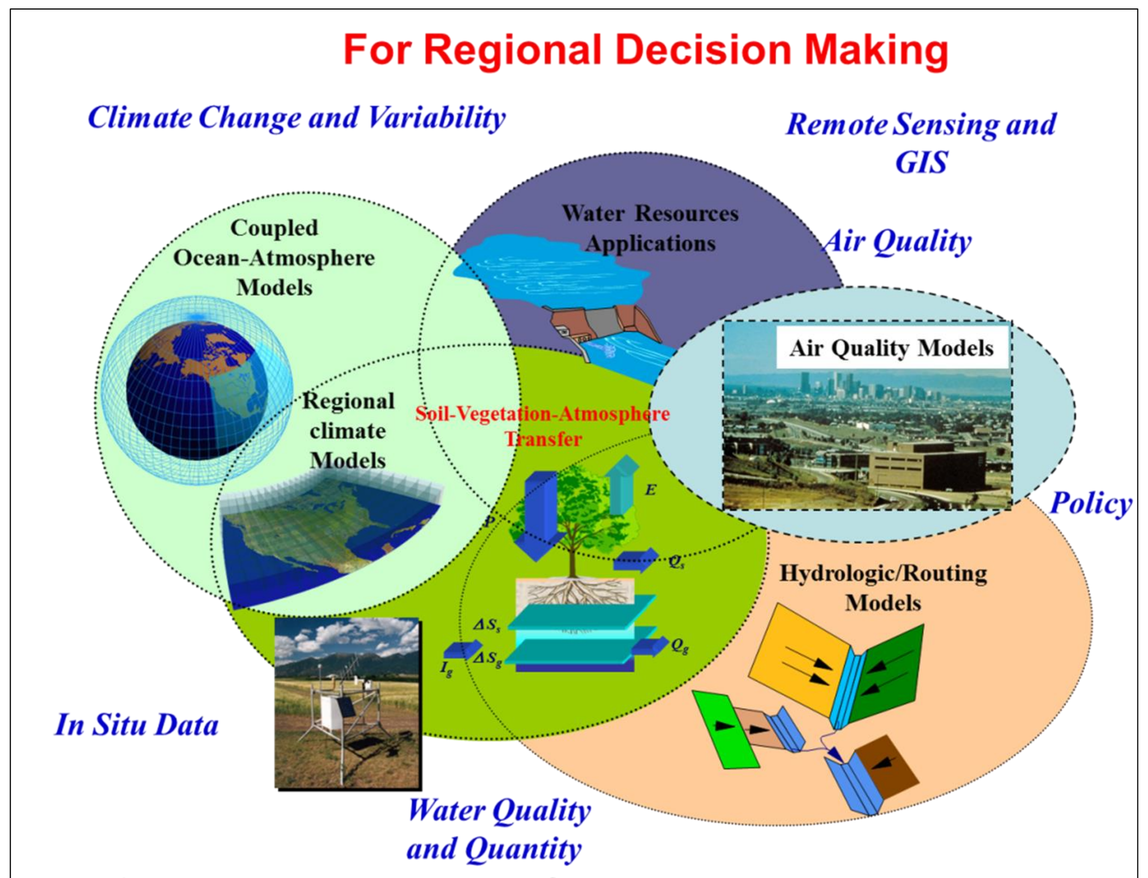

Fig.1 An integrated model of models constrained by observations and tailored for decision-makers

2. Data Assimilation in Dynamic Downscaling

Reanalysis-driven RCM: importance of data assimilation

✧ Interior nudging (or data assimilation) is one of the powerful methods to force RCM simulation towards large-scale driving data, which introduces the large-scale forcing information throughout the RCM domain rather than just limiting them to the initial and lateral boundary conditions. The downscaling simulations using analysis nudging (Figs. 2b–d), which constrains the error growth in large-scale circulation during the long simulation, show higher skills than the traditional RCM integration with reanalysis as lateral boundary conditions (Fig. 2a). The WRF run with 4D data assimilation (FDDA) above the planetary boundary layer (Fig. 2b) performs slightly better than the other nudging experiments (Figs. 2c–d).

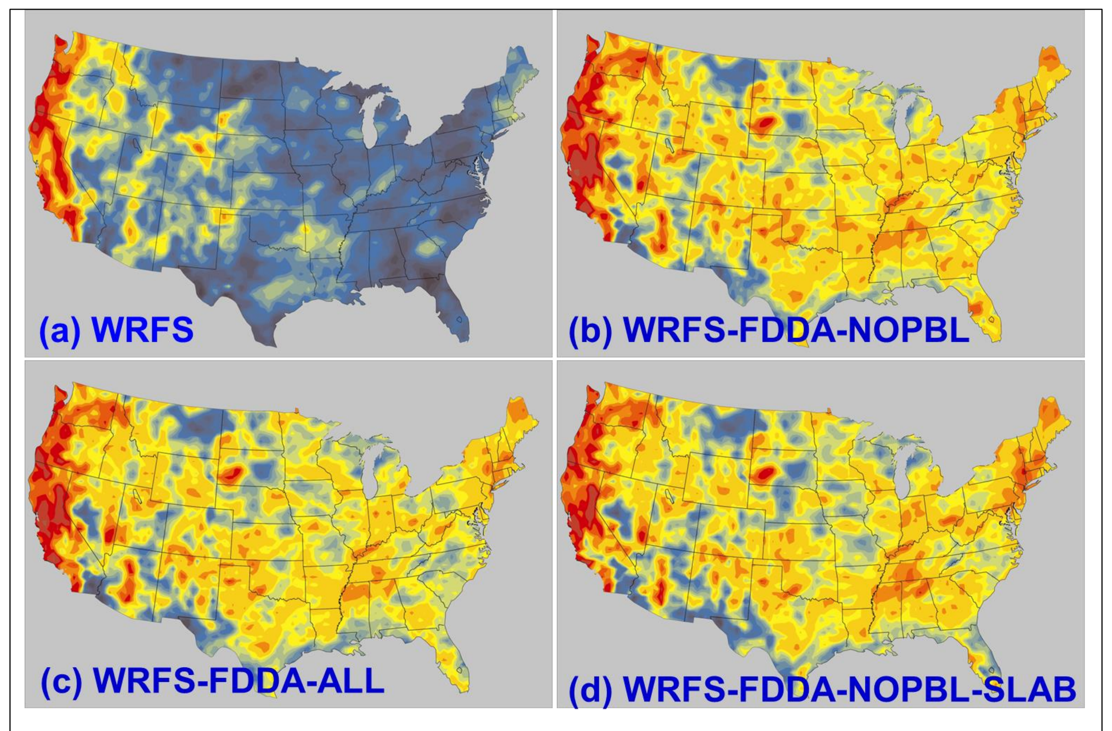

Fig. 2 Correlation between time series of 24-h accumulated precipitation simulations and observed values from NARR at every grid point for Jan–Dec 2000 (Lo et al., 2008)

3. Bias Correction in Dynamic Downscaling

GCM-driven RCM: importance of bias correction

✧ For future projections of regional climate, only GCM outputs can be used to drive RCMs. GCMs are known to suffer from systematic biases. The traditional dynamical downscaling approach (TDD) brings GCM biases into RCMs through the lateral boundary conditions and degrades the downscaled simulation. We have developed an improved dynamical downscaling method (IDD) in which the GCM climatological means and amplitudes of interannual variations are adjusted based on the National Centers for Environmental Prediction (NCEP)–National Center for Atmospheric Research (NCAR) global reanalysis products (NNRP) before using them to drive WRF. The results show that IDD greatly improves the downscaled climate in both climatological means and extreme events relative to TDD. In addition, IDD produces a more realistic probability distribution in summer daily maximum temperature over the central United States–Canada region (Fig. 3). The variance bias correction does not impact the downscaled mean climate, but it does significantly improve the downscaled extreme events.

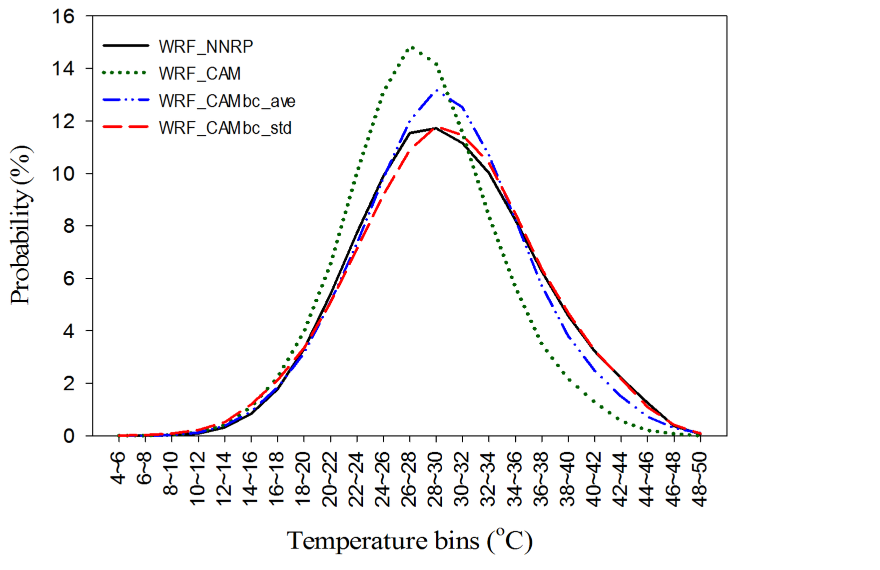

Fig.3 Probability distribution of daily maximum temperature over the central U.S. region (40°–50°N, 100°–85°W). (Xu and Yang, 2012)
WRF_NNRP: WRF simulation driven by NNRP;
WRF_CAM: WRF simulation driven by CAM output without GCM bias corrections.
WRF_CAMbc_ave: With GCM mean value bias correction;
WRF_CAMbc_std: With GCM mean value and variance bias corrections

4. Applications and Prospects

✧ RCMs are crucial for providing fine-scale climate information for both current climate and future climate. Such fine-scale climate information can be used by a wide variety of users including farmers, hydropower system managers, insurance companies, and national security planners. Figure 4 shows an example of how to produce and use the fine-scale climate information for water resources assessments.

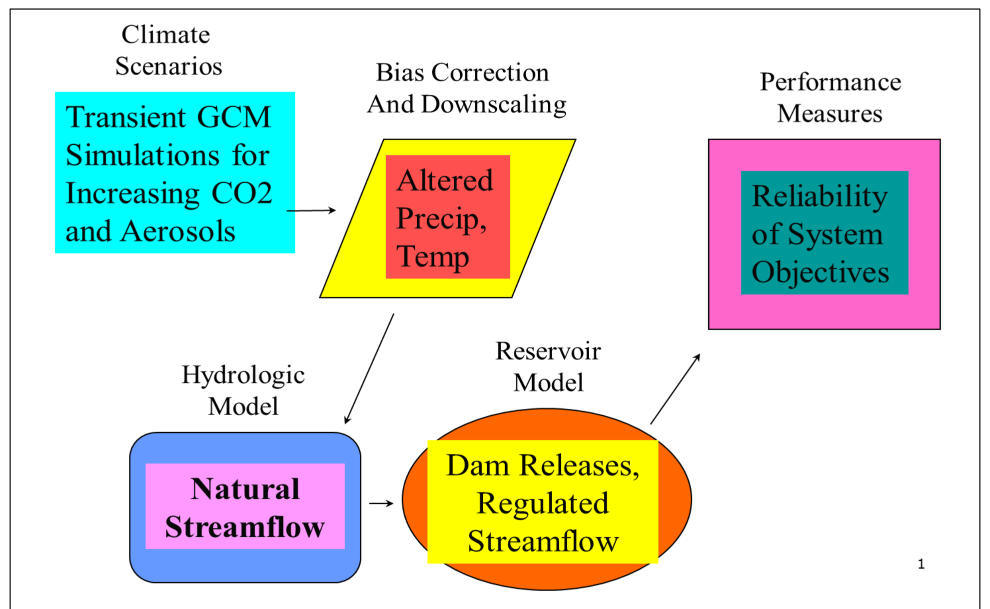

Fig.4 Schematic overview of water resources assessments using climate change information (Courtesy of Dennis Lettenmaier)

More efforts are needed to develop a grand strategy to help move toward the next generation of RCMs. Key steps include working toward a common software infrastructure shared by modelers and users, promoting increased collaboration through a national centralized well-coordinated forum, nurturing an integrated regional earth system modeling effort, and developing a program to support those who must interpret regional climate modeling data to make decisions.

References

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