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Forecasting flow in every river everywhere all at once: Advances in continental-scale hydrologic modelling and simulation

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Abstract: Accurate, high-resolution forecasting of streamflow on a massive, continental-scale is an incredible grand-challenge that was inconceivable only a decade ago. And yet, such forecasts have the potential to be a critical tool for numerous applications, including water resource management, flood prediction, environmental planning, and emergency response. This presentation will explore two major advances in continental-scale streamflow prediction: the U.S. National Water Model (NWM) developed by the NOAA National Weather Service and the GEOGloWS Global Streamflow Service developed by Brigham Young University and The European Centre for Medium-Range Weather Forecasts (ECMWF). The current capabilities of each system will be presented, together with ongoing research and exciting developments.

The NWM employs the WRF Hydro model, a land surface runoff model, combined with a simple Muskingum routing technique to provide streamflow forecasts at 2.8 million stream segments across the United States. This approach is also used by the GEOGloWS model to provide streamflow forecasts in remote, ungagged, and other river basins throughout the world. The technique, while effective in generating basic streamflow forecasts in real-time, has several limitations. One notable limitation is the generalized representation of river behaviour, without accounting for local variations in landscape, soil, and vegetation. Additionally, water diversions and reservoir storage are not considered, further adding to the uncertainty of the forecasts.

Acknowledging these limitations, ongoing improvements to the NWM and GEOGloWS are being pursued. In the case of the NWM, the Cooperative Institute for Research to Operations in Hydrology (CIROH) is leading efforts to enhance the system's modularity and adaptability. By using the CSDMS Basic Model Interface (BMI), the monolithic model is being deconstructed into individual components. This approach enables the addition and removal of model components interchangeably, facilitating improvements in regions with better data or alternative modelling techniques and physics. Integration of machine learning-based model components is also being explored. Furthermore, the NWM is being made more accessible through web services, leveraging the infrastructure provided by Google Cloud Services. Similarly, the GEOGloWS model is undergoing enhancements to address bias discrepancies between the global model and observed streamflow. Advanced bias correction tools and techniques are being developed to improve the local calibration of the global model, ensuring a better fit with observed or expected streamflow in each region of the world.

By highlighting the current state of the science and future improvements in continental scale streamflow prediction, this presentation aims to foster a deeper understanding of the challenges and opportunities in forecasting flow in every river, everywhere, all at once.

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