Second Annual Open Science Meeting, May 15-17, 2019

Global Water Futures

Hydrological modelling in the Lake Erie and Nelson-Churchill River Basins using HYPE

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01. Introduction

The Hydrology research group of the University of Manitoba participated in the IMPC sub-component A2 on the Nelson-Churchill River Basin (NCRB) and sub-component A5 on the Lake Erie Basin (LEB) by adapting the hydrological model HYPE to the selected watersheds.

Objectives:

- O_1-LEB: Modelling every locations of Lake Erie watershed (monitoring points with low human impact upstream);
- O_2-LEB: Modelling only inflows to Lake Erie watershed;
- O_1-NCRB: Analyse the sensitivity of model parameters in HYPE for NCRB based on seasonality;
- O_2-NCRB: Analyse the time-varying sensitivity of model parameters in HYPE for NCRB using different window periods.

- Computer-based watershed models are powerful tools for the simulation of the effects of watershed processes and management options on water quantity and quality (Daniel et al. 2011);
- HYdrological Predictions for the Environment (HYPE) model is developed by the Swedish Meteorological and Hydrological Institute (SMHI) and used for operational application and climate impact studies in many countries (Lindström et al. 2010);
- HYPE is selected for hydrological modelling in LEB and NCRB because it is a continental-scale, semi-distributed and cold regions model. The model is highly flexible and open source;
- Global Sensitivity Analysis (GSA) of the model parameters in HYPE is performed using Variogram Analysis of Response Surfaces (VARS) (Razavi and Gupta, 2016). Sensitivity analysis is necessary to identify important parameters and precision level required for calibration.
- Automatic calibration of key model parameters was based on the Differential Evolution Markov Chain (DEMC) algorithm.

02. Study Areas: LEB & NCRB

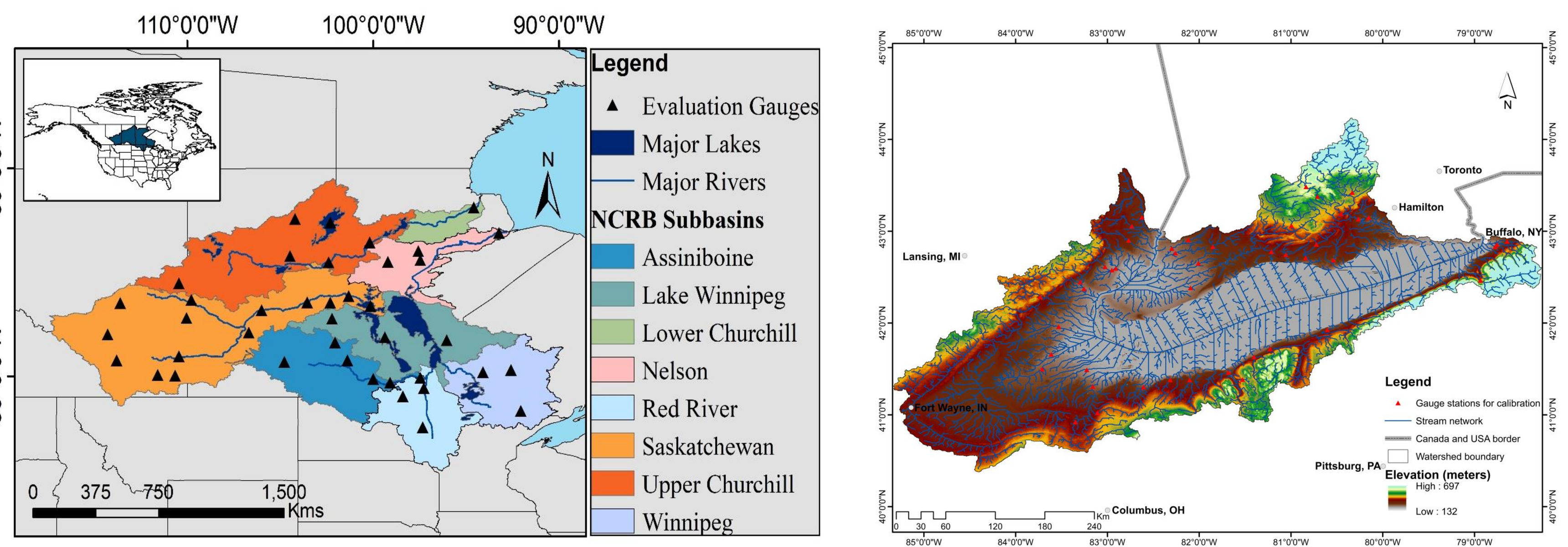
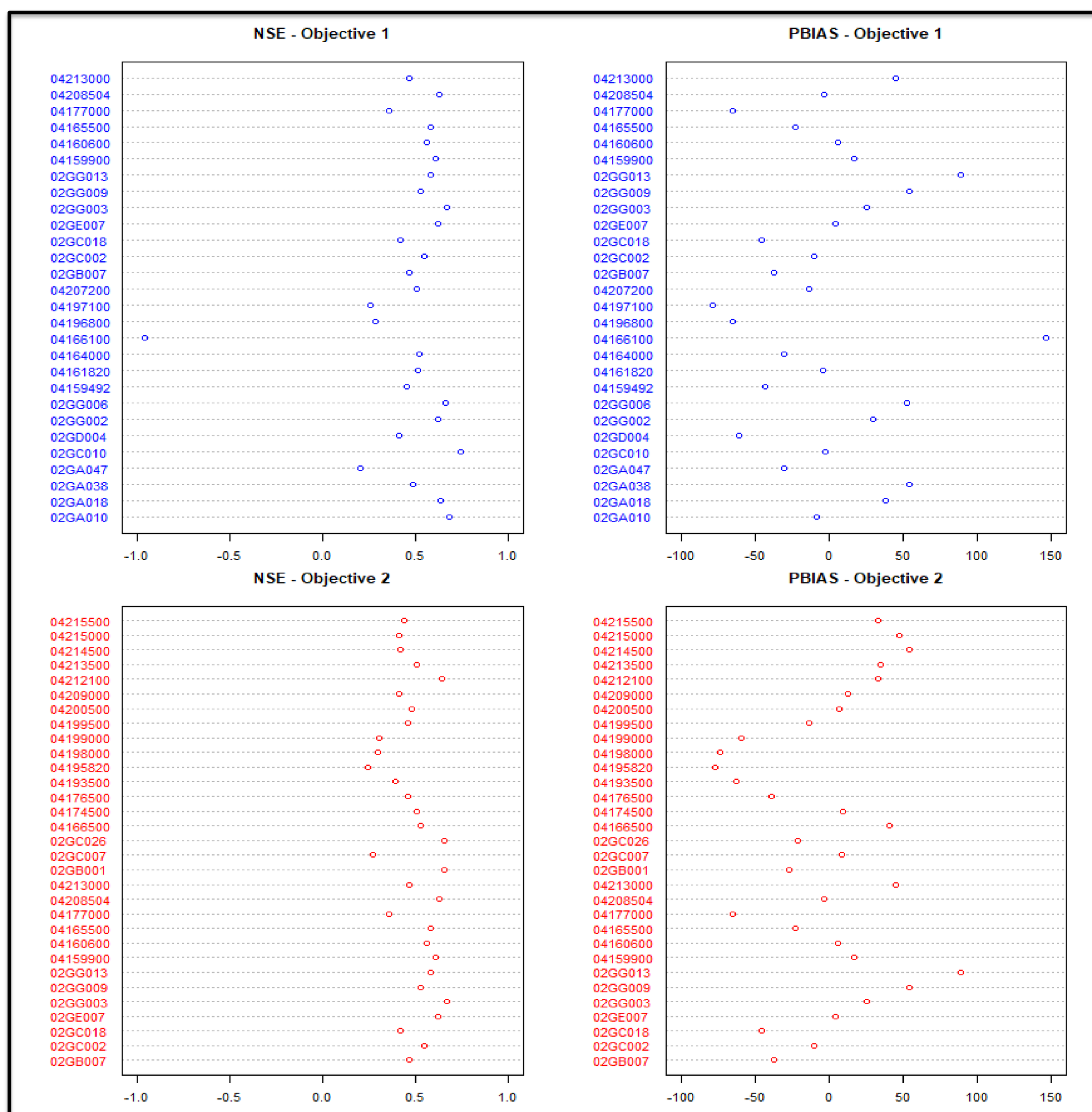


Figure 1 Maps of Nelson-Churchill River Basin (left) and Lake Erie Basin (right)

- Third largest catchment in North America with an approximate drainage area of 1.4 million, the Nelson-Churchill River Basin is a transboundary watershed and extends from the Rocky Mountains in the west to Lake Superior in the east, with elevation ranging from sea level at the outlets draining to the Hudson Bay to 3550 m above mean sea level in the Rocky Mountains.
- Southern most and smallest of the 5 Great Lakes Basins, the Lake Erie Basin covers portions of Ontario and the states of Indiana, Michigan, Ohio, Pennsylvania and New York. It extends from Lake Michigan basin in the west to Niagara falls in the east with elevation ranging from 132 m to 697 m above sea level.

03. HYPE performance for the Lake Erie Basin



- HYPE is calibrated for the Lake Erie Basin using RDRS climate data for 2011-2014;
- For O_1-LEB and O_2-LEB median values of NSE are 0.52 and 0.48 respectively;
- 04166100 --> NSE = -0.96 --> River Rouge at Southfield MI
- 02GC010 --> NSE = 0.74 --> Big Otter Creek at Tillsonburg
- 02GG003 --> NSE = 0.67 --> Sydenham River at Florence

Figure 2 HYPE performance for objectives 1 & 2 on Lake Erie Basin (2011-2014)

04. Seasonal Analysis of Parameter Sensitivity for HYPE - NCRB

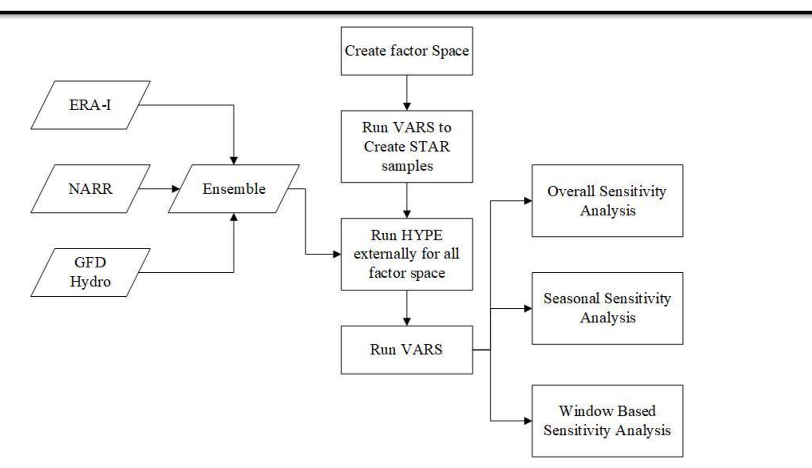


Figure 3 Methodological Framework for GSA

- Most parameters exhibited only slight variation in seasonality of the sensitivity whatever the error metrics used;
- Across seasons and evaluation metrics the crop coefficient factor kc is always dominant;
- Some lake discharge and routing parameters are most dominant during the high flow months (May and June) while using NSE only;
- Parameters such as the outlet lake rating curve parameter olrratp(4) and the soil parameter wp_corr are more sensitive to normal flows variability.

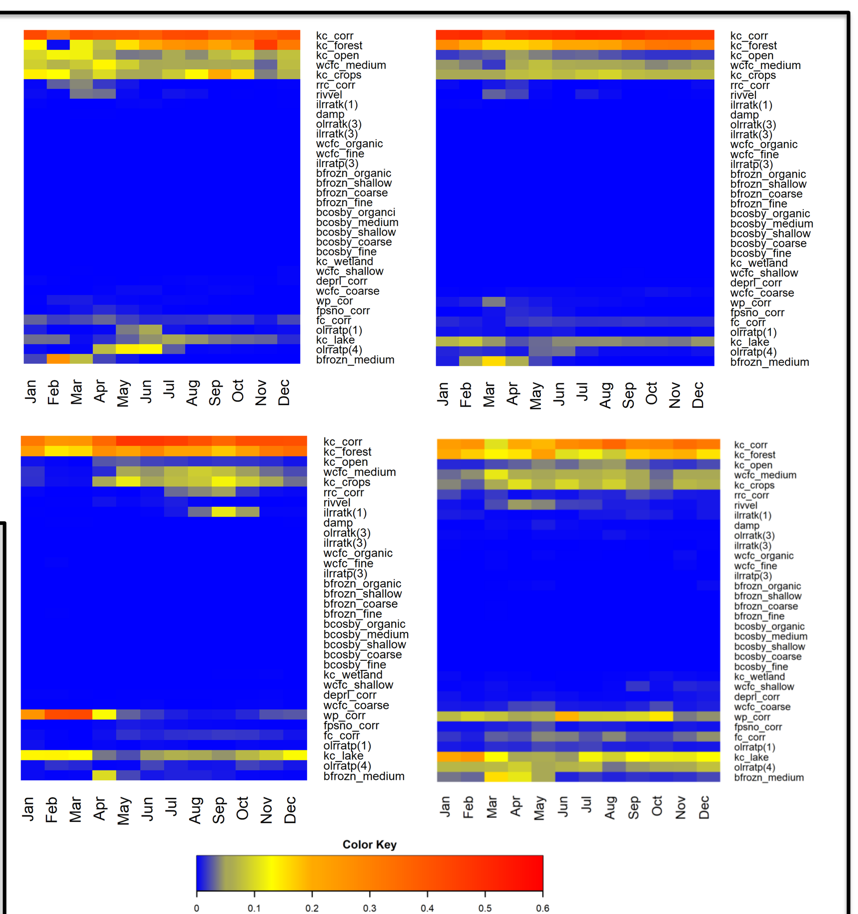
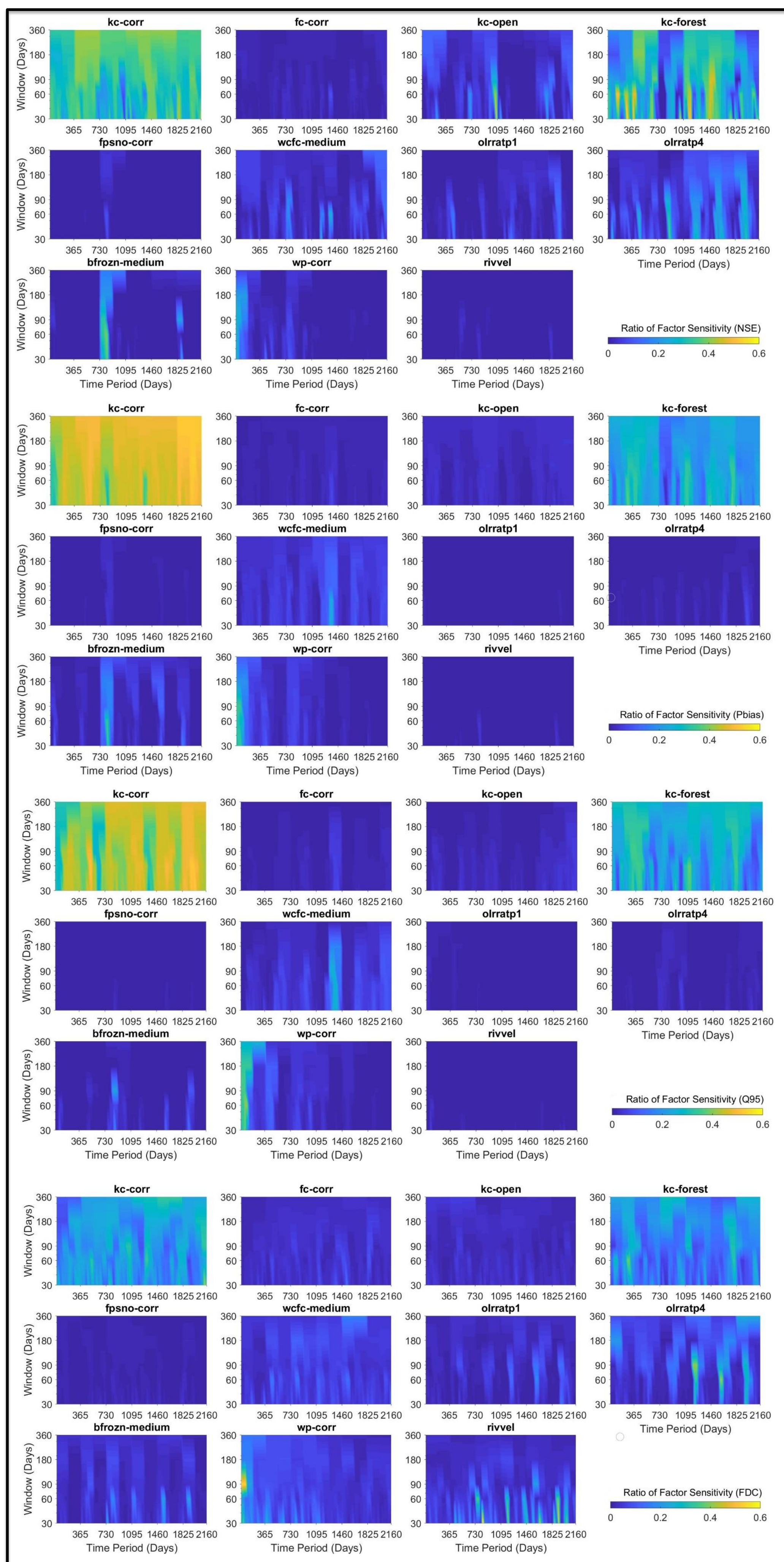
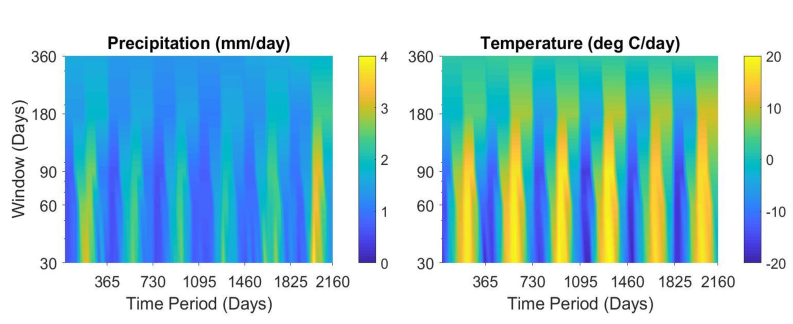


Figure 4 Ratio of factor sensitivity based on NSE (upper left), Pbias (upper right), 3 day-averaged Q95 (lower left) and FDC (lower right) for 1981-2010 in NCRB

05. Time-varying sensitivity characteristics of HYPE parameters





- The crop coefficient parameter related with evapotranspiration were found to be most sensitive compared to other parameters.
- The time varying sensitivity analysis was carried out with VARS using window period of 30 days, 60 days, 90 days, 180 days and 360 days, with the smallest window period being most influential in detecting the sensitivity signals.
- The specific period of 2000 to 2005 were chosen taking into account the extremes of dry and wet cycle within the evaluation period of 30 years.
- In contrast to conventional metrics, the use of flow signatures such as slope of the flow duration curve as evaluation criteria, allowed VARS to capture the sensitivity signals more consistently for major parameters throughout all years and time period, but with varying magnitude.
- The sensitivity of some of the parameters such as the routing parameter (rivvel) were identifiable only during the analysis using smaller window size less than 90 days.

Figure 5 Precipitation and temperature sensitivity, and ratio of factor of sensitivity for various moving windows from 2000-01-01 to 2005-11-29 using NSE, Pbias, Q95 and slope of flow duration curve (FDC) for NCRB

06. Discussion and Conclusions

- HYPE shows relatively good performance for the Lake Erie Basin (LEB) and is thus well suited for modelling hydrological processes in this watershed as well.
- Sensitivity analysis of HYPE parameters on monthly basis for the Nelson-Churchill River Basin (NRCB) highlighted the dominant parameters and processes based on seasonality.
- For HYPE application in NCRB crop coefficient parameters are most sensitive during spring and summer, and frozen soil parameters and snowmelt parameters are mostly dominating during spring.
- The use of smallest window is very influential in detecting time-varying sensitivity signals.
- As opposed to conventional evaluation metrics, using flow signatures (e.g. FDC) as evaluation criteria is very helpful for capturing the sensitivity signals more consistently for major parameters throughout years and time periods.
- Time varying sensitivity analysis is thus essential for identifying parameters that are seasonally dominant and could be influential in effective calibration of hydrological model.

References & Acknowledgements

Daniel, E.D. et al. (2011). Watershed Modeling and its Applications: A State-of-the-Art Review. *The Open Hydrology Journal*, 5, 26-50

Lindström, G. et al. (2010). Development and test of the HYPE (Hydrological Predictions for the Environment) model – A water quality model for different spatial scales. *Hydrology Research,* 41 (3–4), 295–319.

Razavi, S., & Gupta, H. V. (2016). A new framework for comprehensive, robust, and efficient global sensitivity analysis: 1. Theory. *Water Resources Research*, *52*(1), 423-439.

Acknowledgements

We thank Environment and Climate Change Canada for providing the RDRS data sets used for the calibration of the Lake Erie model. We are also grateful to SMHI for providing the HYPE model and the HydroGFD data, ECMWF for ERA-Interim and NCEP for providing the NARR sets of data used for the NCRB model.