Implementing the new WRF-Hydro v5.0 model for operational, highly localized land surface and streamflow predictions for Lake George, NY

Campbell D. Watson*, Mukul Tewari, Alvaro B. Buoro, Lloyd A. Treinish, Harry R. Kolar
IBM Research, Yorktown Heights, NY *cwatson@us.ibm.com

Related Presentations

H112 Sensor Networks in Hydrology: The Application of an Internet of Things Cyber-Infrastructure for the Study of Ecology of Lake George in the Jefferson Project (Friday, 1340 - 1800, poster session)

OS31E Integrated Observations and Modeling of Surface Currents, Waves, and Winds: The impact of weather model resolution on a coupled model of lake circulation (Wednesday, 0800 - 1220, poster session)

H43K Water Quality and Watersheds: From Scientific Innovations to Actions III: A Coupled Modelling and Observing System to Assess Water Quality in the Lake George, New York Watershed (Thursday, 1340 – 1800, poster session)

The Jefferson Project at Lake George

The Jefferson Project at Lake George, NY is a multi-year collaborative project between IBM Research, Rensselaer Polytechnic Institute and The FUND for Lake George.

Lake George (Fig. 1) is a dimictic, oligotrophic lake with pristine (AA-special) water quality. A 30-year longitudinal study highlighted three environmental stressors on Lake George – road salt, nutrient loading via storm water runoff and invasive species – and The Jefferson Project is aiming to understand, predict and enable a healthy Lake George ecosystem.

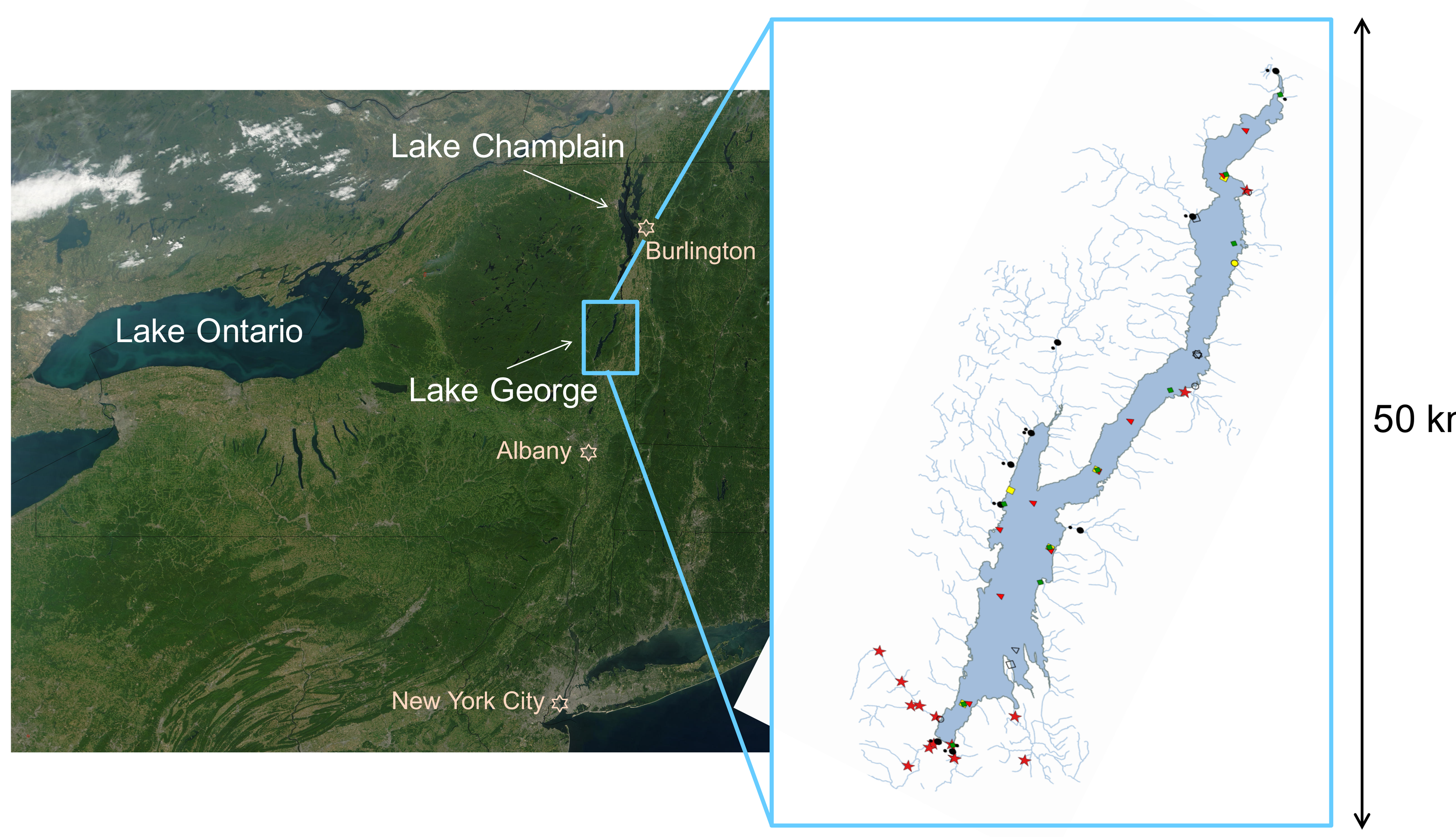

Fig. 1: (Left) Visible image from MODIS aboard NASA's Aqua satellite. **(Right)** The observational instrumentation includes over 50 sensor platforms, 500 sensors and 300 million observations.

The Lake George Watershed

Location: New York, Adirondack Park
Area: 617.4 km^2
Maximal elevation: 806.5 m
Predominant coverage: deciduous forests (maple, yellow birch, beech); limited agriculture usage
Population centers: Lake George Village (south); Ticonderoga (north)
Over 90 inflowing tributaries and one (controlled) outflow at the north end of the lake

The Coupled Models

A core component of the project is to develop a system capable of real-time observations and interactive modeling of the atmosphere, watershed hydrology and lake circulation and biology.

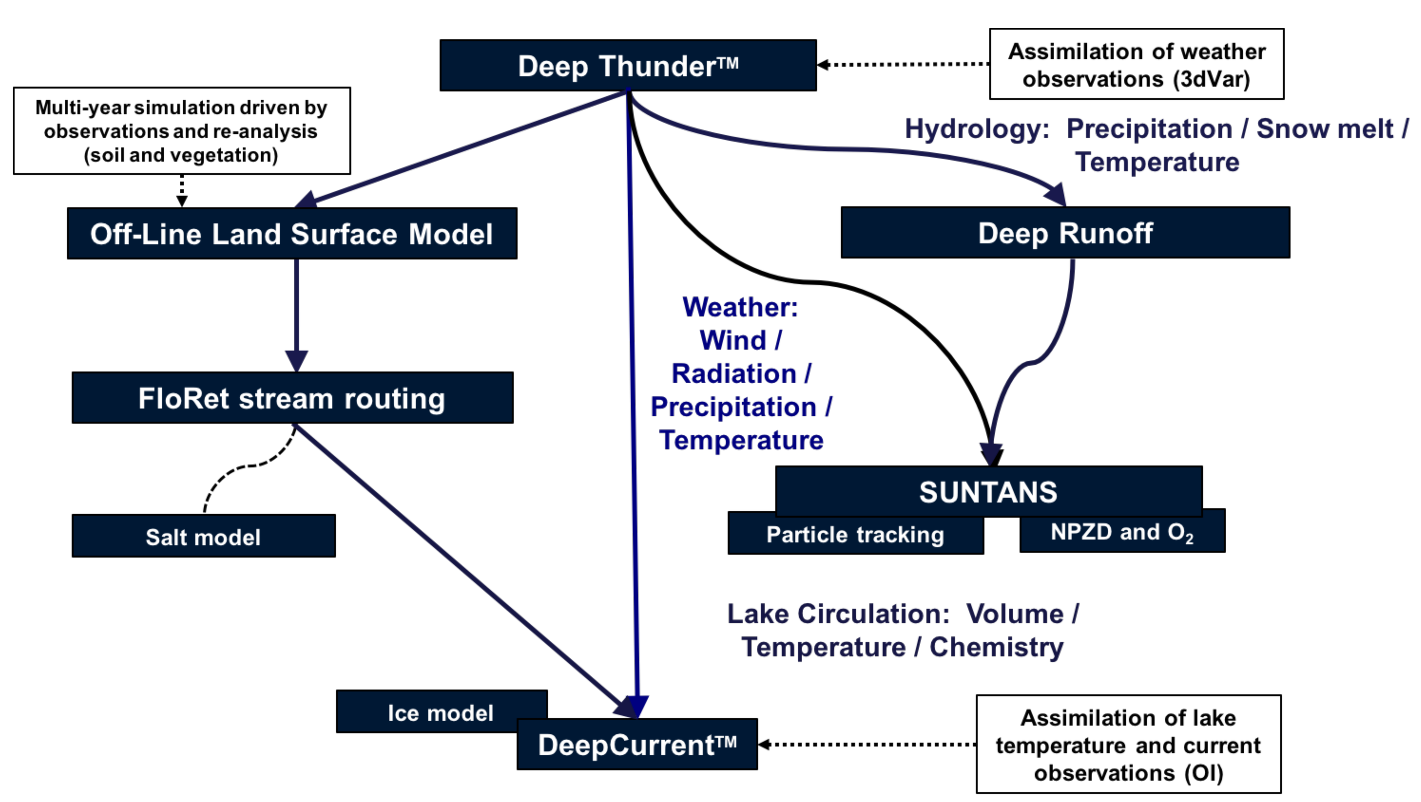

Fig. 2: The model stack is comprised of four coupled physical models (note: particulars of the food web model currently undecided). **(Inset)** The model grid horizontal resolution of the atmospheric, runoff and lake circulation models.

Implementing WRF Hydro v5.0

A critical component of the model stack is the hydrological model. The Jefferson Project has utilized a range of land surface and hydrological models, and the recent release of WRF-Hydro v5.0, including the updated Noah-MP land surface model (Fig. 3), has compelled its inclusion in our coupled-model system.

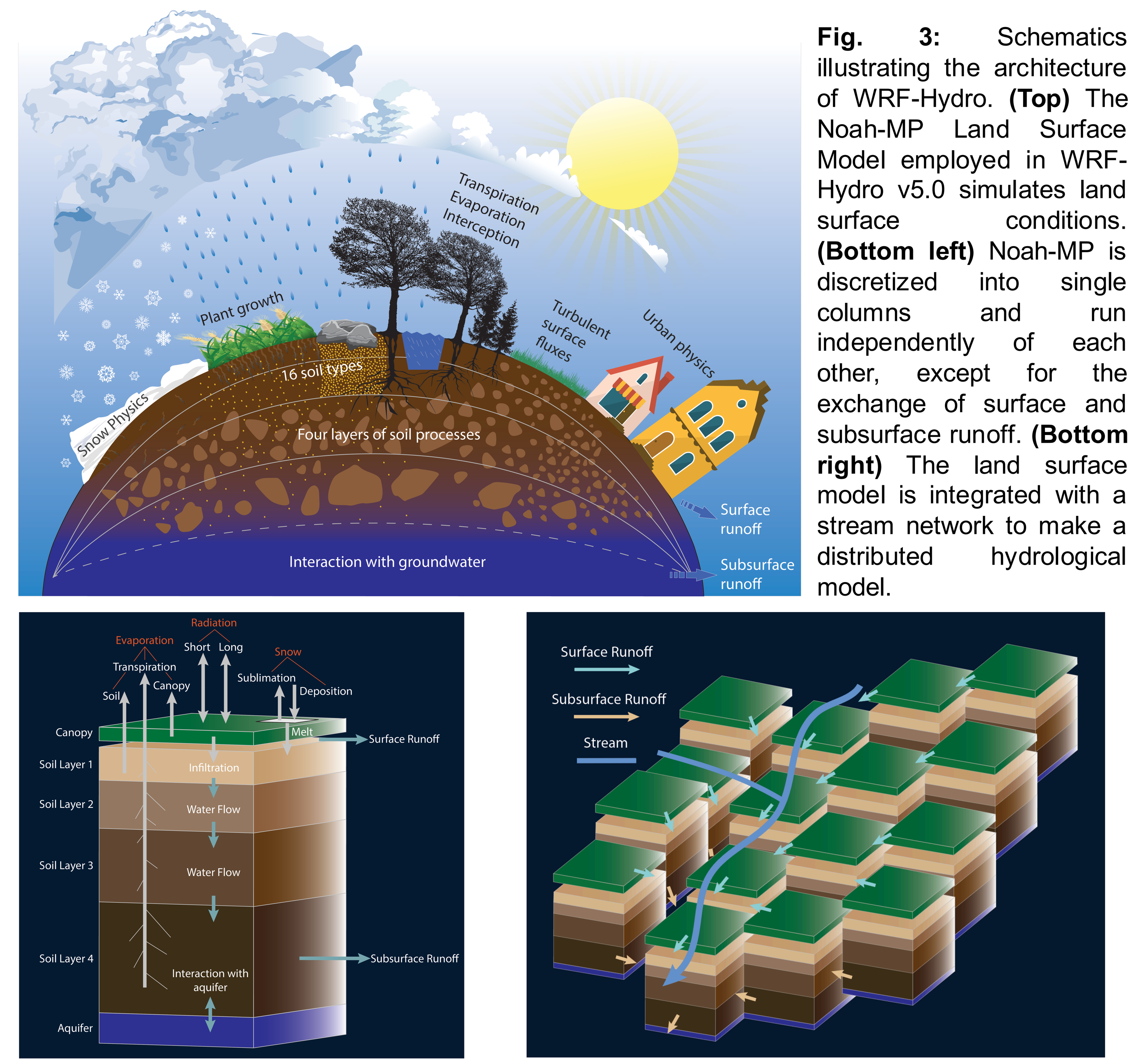

Fig. 3: Schematics illustrating the architecture of WRF-Hydro. **(Top)** The Noah-MP Land Surface Model employed in WRF-Hydro v5.0 simulates land surface conditions. **(Bottom left)** Noah-MP is discretized into single columns and run independently of each other, except for the exchange of surface and subsurface runoff. **(Bottom right)** The land surface model is integrated with a stream network to make a distributed hydrological model.

Deriving the Stream Network

The WRF-Hydro GIS Pre-Processing Tools v5.0 was used to generate the stream network and land surface grids at Lake George in combination with Esri ArcGIS software and the Spatial Analyst Extension.

We have employed both linked and gridded routing. For linked routing, 1563 individual stream segments were derived in the watershed with 182 entering the lake. Over 100 pour points were added to identify gage locations and where streams reach the lake shore. The land surface grid is ~41x41 m.

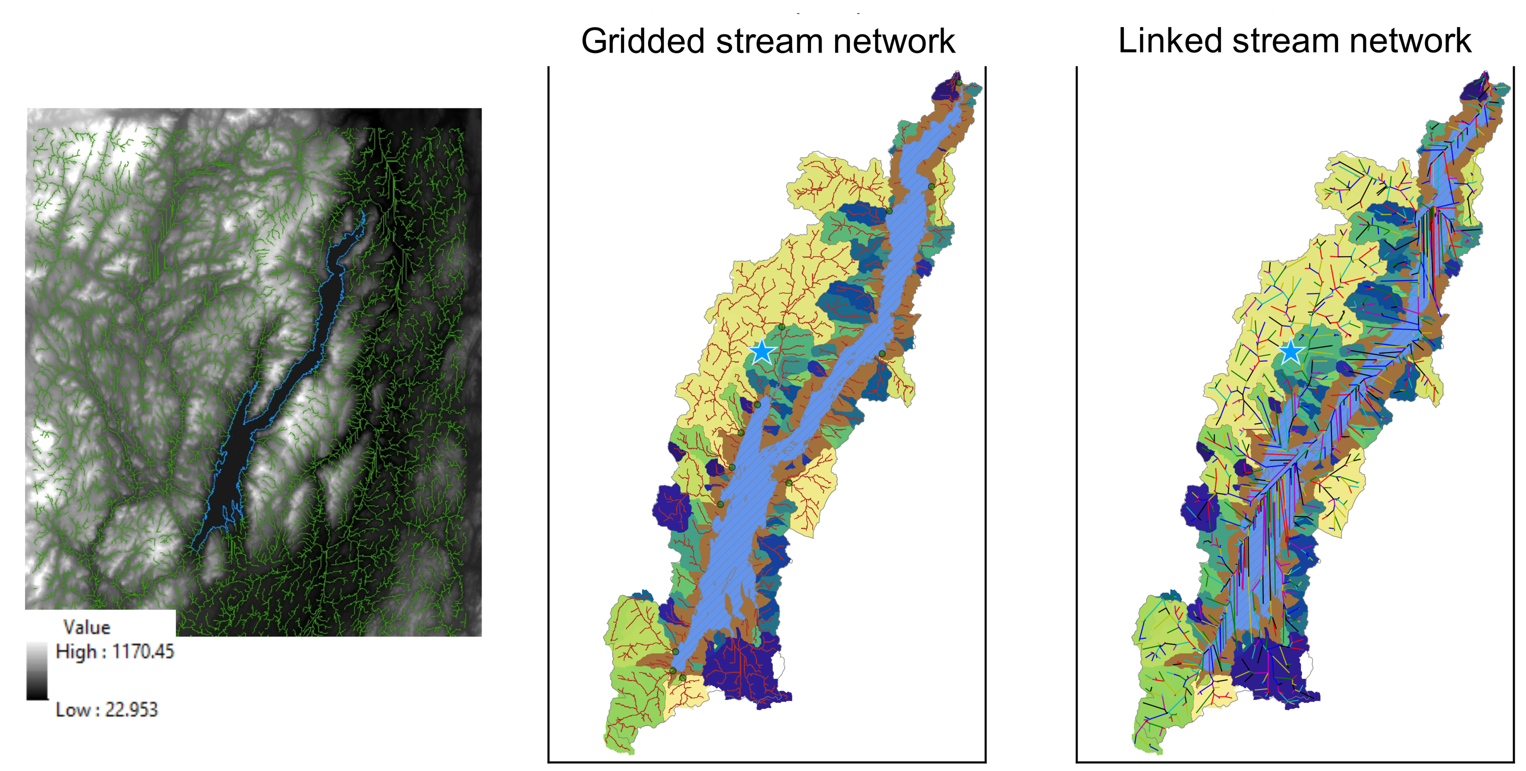

Fig. 5: (Left) Topography around Lake George. **(Middle)** The derived stream network and associated sub-watersheds. **(Right)** The 1563 reaches that comprise the stream network of Lake George when using linked routing. Note that the lake shoreline is not imposed on the linked stream network.

Gridded vs Linked Channel Routing

There are multiple channel routing algorithms available and here we explore two options – gridded and linked – which use the stream networks in the middle and right panels of Fig. 5, respectively.

Specifically, we tested gridded routing using diffusive wave and linked routing using Muskingum-Cunge. As shown in Fig. 6, we found similar base flows however the peak magnitudes were much higher and response times were much faster when linked routing was employed.

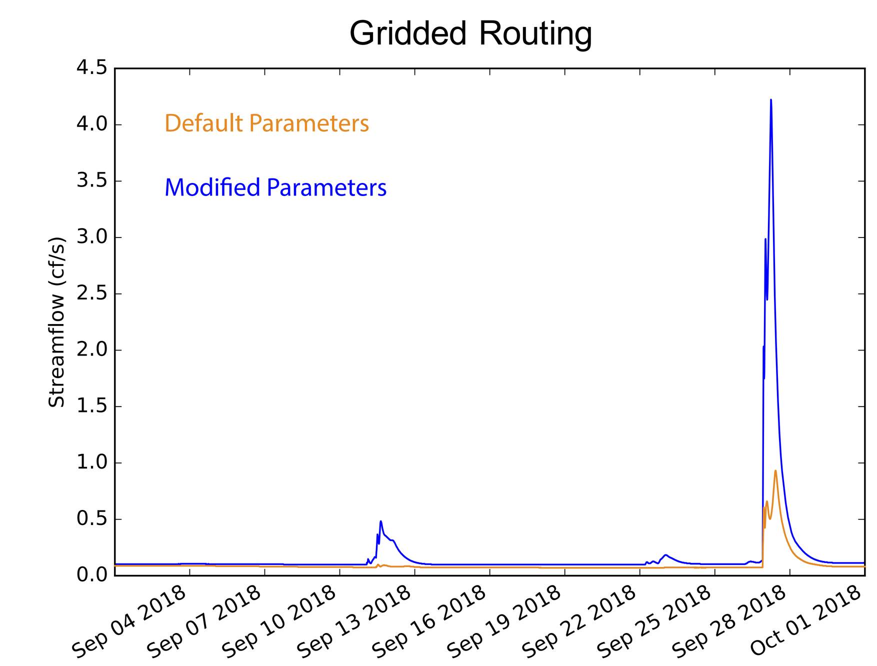

Fig. 6: Hydrographs for September 2018 at Northwest Bay Brook (blue star in Fig. 5) using gridded routing with **(orange lines)** default parameters and **(blue lines)** the following modified parameters: increased slope parameters, reduced soil moisture diffusion, reduced snow surface roughness length, and adjusted soil porosity, field capacity, wilting point, soil conductivity.

Summary and Future Challenges

The hydrology of the Lake George watershed is being simulated by the recently-released WRF-Hydro v5.0. In its current instantiation, it is driven by a 333 m weather model nest and provides boundary conditions to two lake circulation models (and a salt model – see below).

Testing is ongoing and the following items are at various stages of development:

- An automated calibration framework to improve model performance

- Assimilation via nudging real-time observations from our extensive sensor network in the watershed

- Automating the pre-processing steps for any geography to enable rapid deployment without degradation of the stream network

- The inclusion of water temperature in the land surface and routing components of the model following Newton's Law of Cooling

- A salt model for each sub-watershed to better understand the movement of road salt deposited in winter into the small streams and ultimately the lake. Preliminary output from the salt model is shown in Fig. 7.

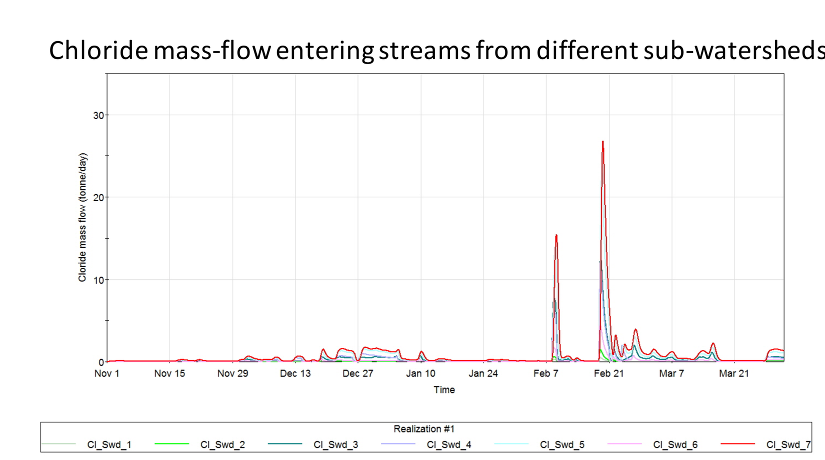

Fig. 7: Salt model predictions at five target sites in the Lake George watershed. This model will eventually be driven by hydrological outputs from WRF-Hydro v5.0.

Acknowledgements: *Esri ArcGIS* for their ongoing support and the *National Center for Atmospheric Research* for their continued development of open-source, state-of-the-art numerical models.