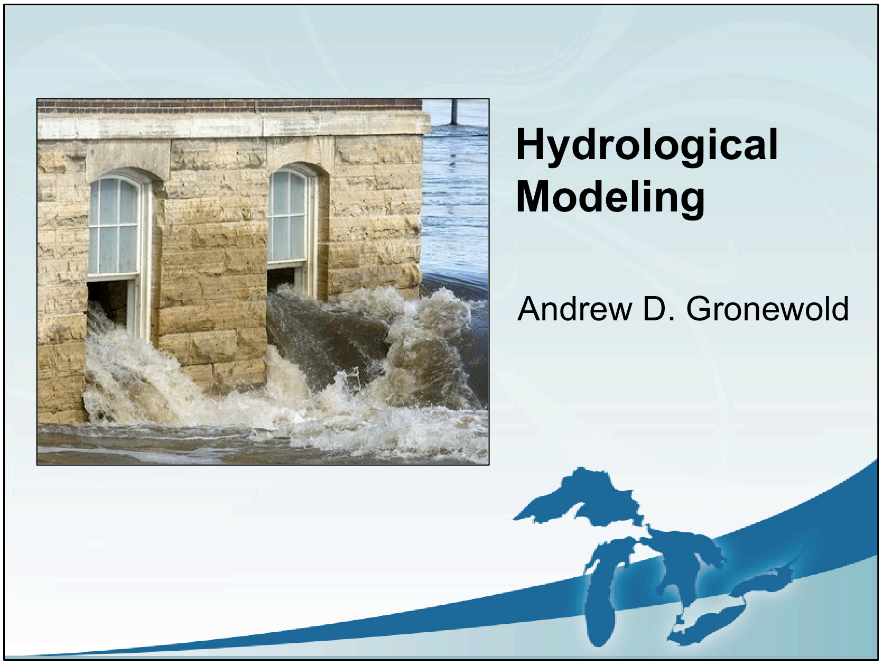
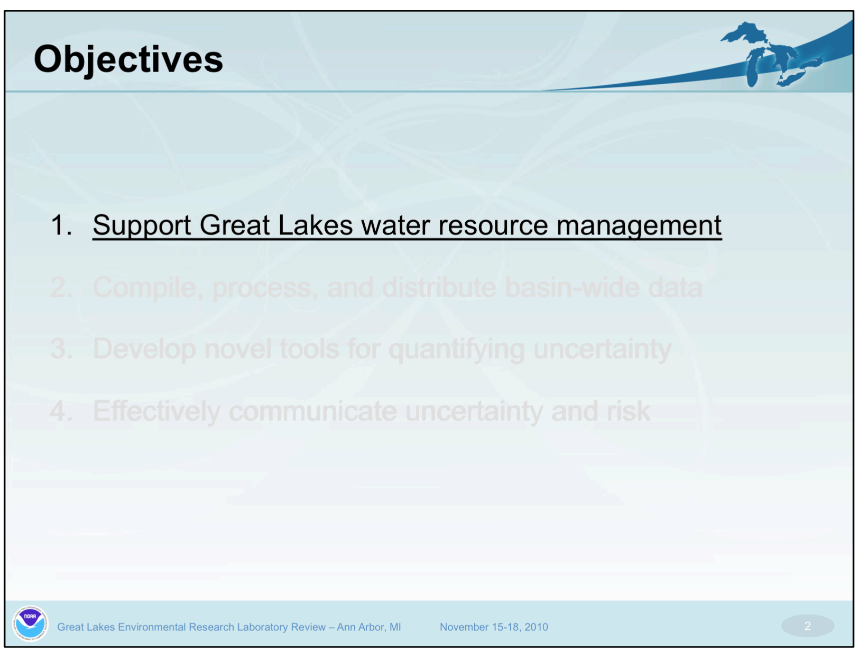


• Current team members: Andrew Gronewold, Tim Hunter, and Anne Clites

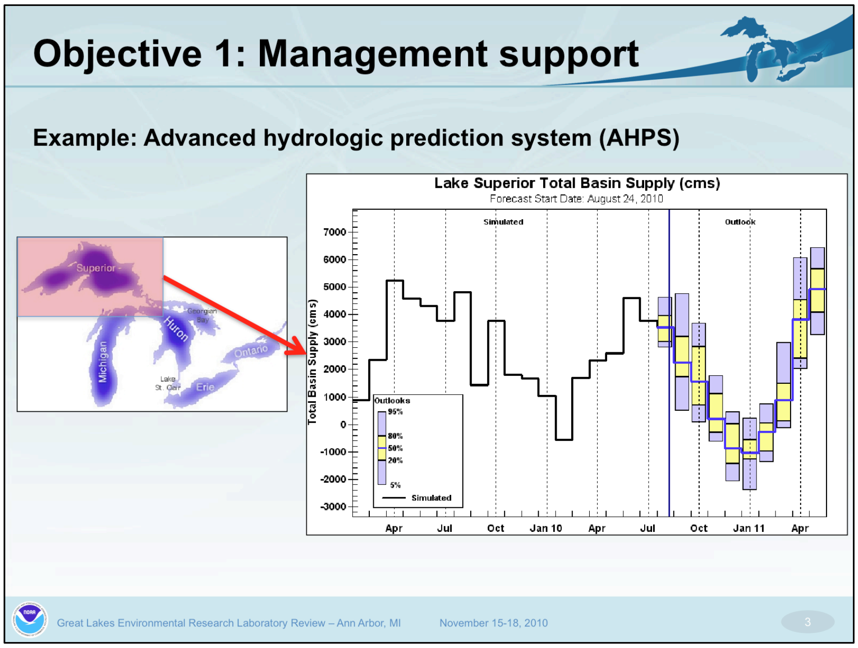
• Take home message: unique opportunity to pursue new research trajectories while building on solid foundation



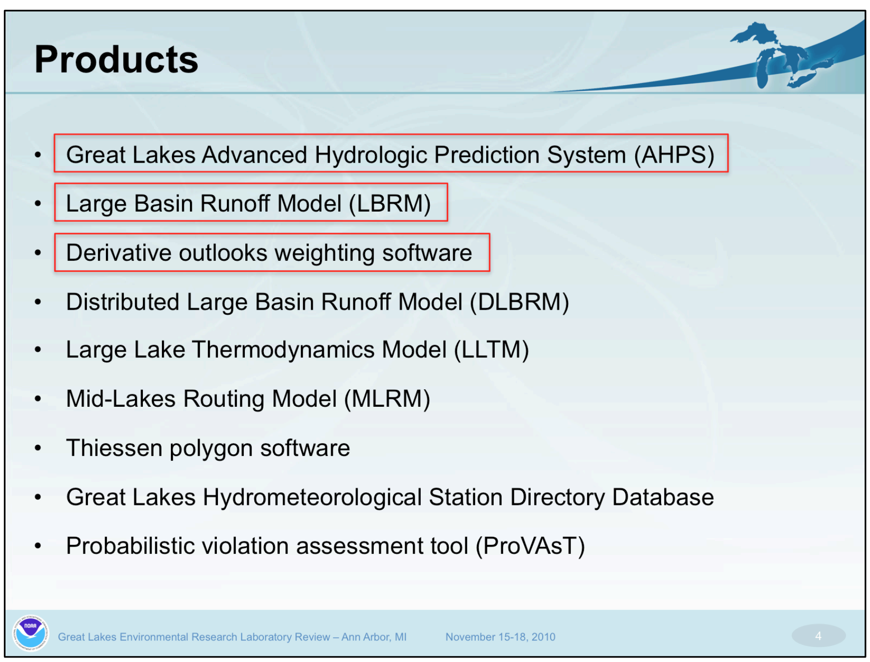
• GLERL hydrological modeling program → four main objectives

• First, we provide technical support for large-scale water resource management decisions

• We do this, in part, by developing, applying, and distributing hydrological modeling and forecasting tools.



• Example: Great Lakes Advanced Hydrologic Prediction System (AHPS)
• Graphical user interface (GUI)-based software with wide variety of hydrological data and model forecasts
• On this slide, we show AHPS probabilistic forecast of Lake Superior total basin supply
• Take home message: probabilistic forecasts are a key GLERL contribution to Great Lakes hydrological research



• List of main GLERL hydrology program products
• Red boxes indicate products with significant impact on Great Lakes water resource management
• These products were recently identified by Environment Canada representatives as “The Golden Standard”
• Take home message: ongoing effort to upgrade and integrate products in a new ensemble forecasting system

Stakeholders and partners

Government agencies:

- United States Army Corps of Engineers (USACE)
- Environment Canada (EC)
- United States Geological Survey (USGS)
- United States Environmental Protection Agency (USEPA)

Management authorities and utilities:

- New York Power Authority (NYPA)
- Ontario Power Generation (OPG)

Academic and research institutions:

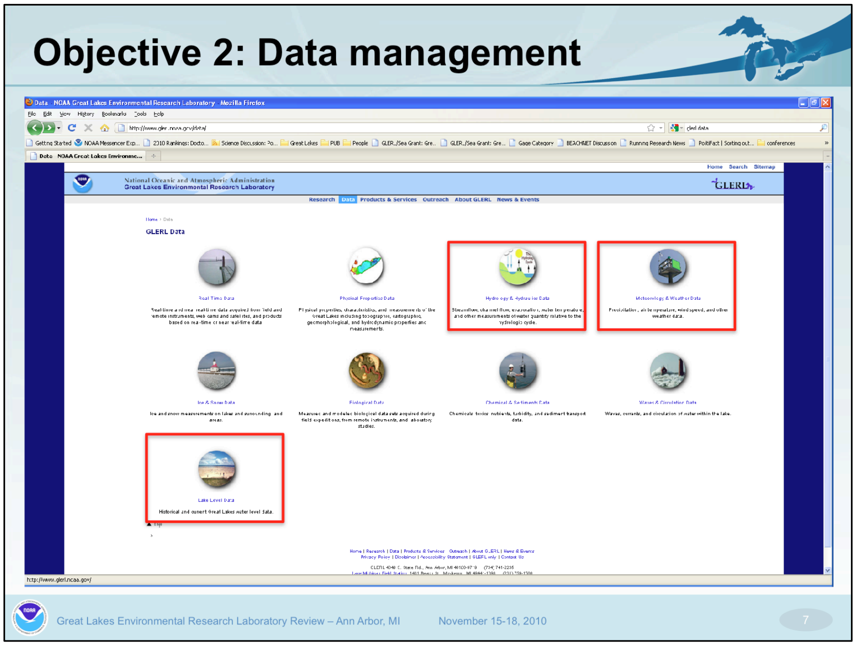
- University of Michigan
- Wayne State University
- Case Western Reserve University
- Duke University
- Western Michigan University
- Other academic institutions

• Red boxes indicate stakeholders for whom we provide explicit water resource management support
• Example 1: Our model forecasts are used by USACE and EC to generate official Great Lakes water level reports
• Example 2: Our model forecasts are used by NYPA and OPG to assess hydropower potential
• Take home message: These are just examples –hundreds of documented users from a variety of sectors

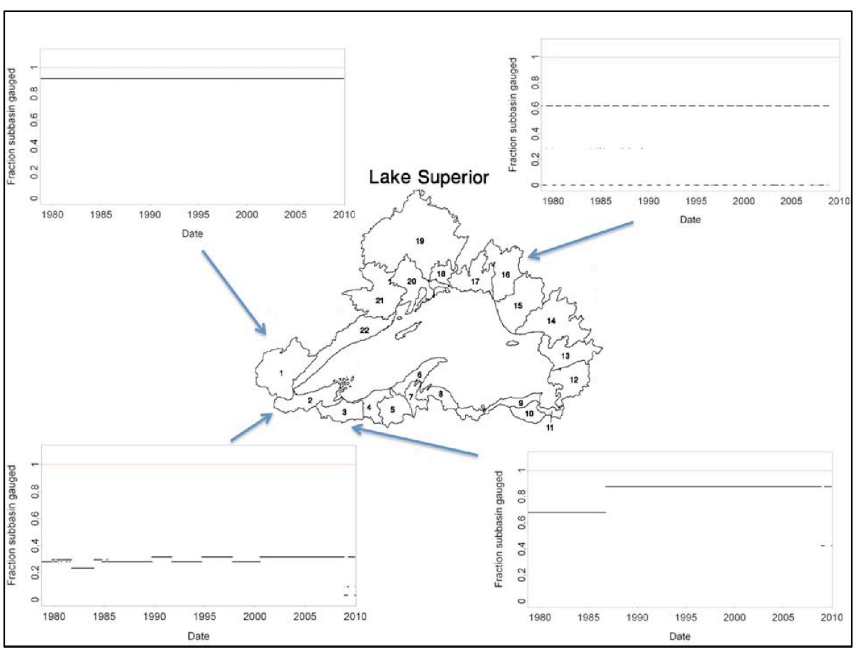
Objectives

1. Support Great Lakes water resource management
2. Compile, process, and distribute basin-wide data
3. Develop novel tools for quantifying uncertainty
4. Effectively communicate uncertainty and risk

• Second major objective: compile, process, and distribute Great Lakes meteorological and hydrological data



• Snap shot of GLERL data web page. Red boxes indicate data resources supported by hydrology team
• Hydrology and hydraulics data: runoff, evaporation, net basin supply, connecting channel flows (among others)
• Meteorology and weather data: precipitation, evaporation, temperature
• Lake level data: Great Lakes water levels (1860 – present)



• Lake Superior basin divided into 22 subbasins – the building blocks of regional hydrological modeling
• For 4 representative subbasins, time series plots (1980 – 2010) of fraction of subbasin area gauged
• Roughly 92% of subbasin 1 is consistently gauged (as good as it gets!) but pattern varies throughout the basin
• Take home message 1: missing information represents a major challenge to hydrological forecasting (only 50 – 60% of the basin is gauged)
• Take home message 2: areas of the world with greatest need for water have very little flow information – the tools we are developing for predicting flows in ungauged basins have regional and global implications

Products

- Great Lakes Advanced Hydrologic Prediction System (AHPS)
- Large Basin Runoff Model (LBRM)
- Derivative outlooks weighting software
- Distributed Large Basin Runoff Model (DLBRM)
- Large Lake Thermodynamics Model (LLTM)
- Mid-Lakes Routing Model (MLRM)
- Thiessen polygon software
- Great Lakes Hydrometeorological Station Directory Database
- Probabilistic violation assessment tool (ProVAsT)

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• Products directly linked to data management in blue boxes

Stakeholders and partners

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• Blue box around all stakeholders and partners – the data we compile and distribute is used broadly

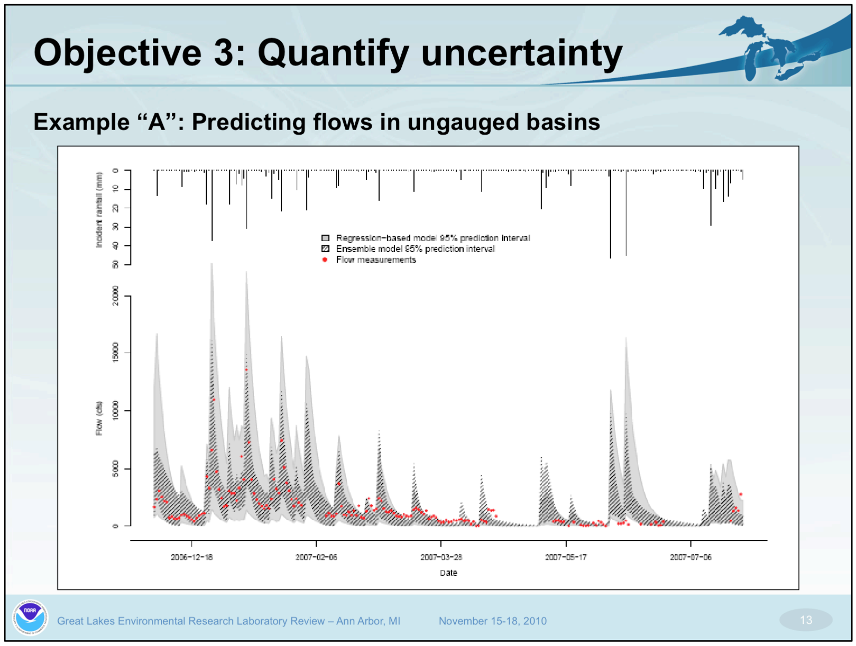
Objectives

1. Support Great Lakes water resource management
2. Compile, process, and distribute basin-wide data
3. Develop novel tools for quantifying uncertainty
4. Effectively communicate uncertainty and risk

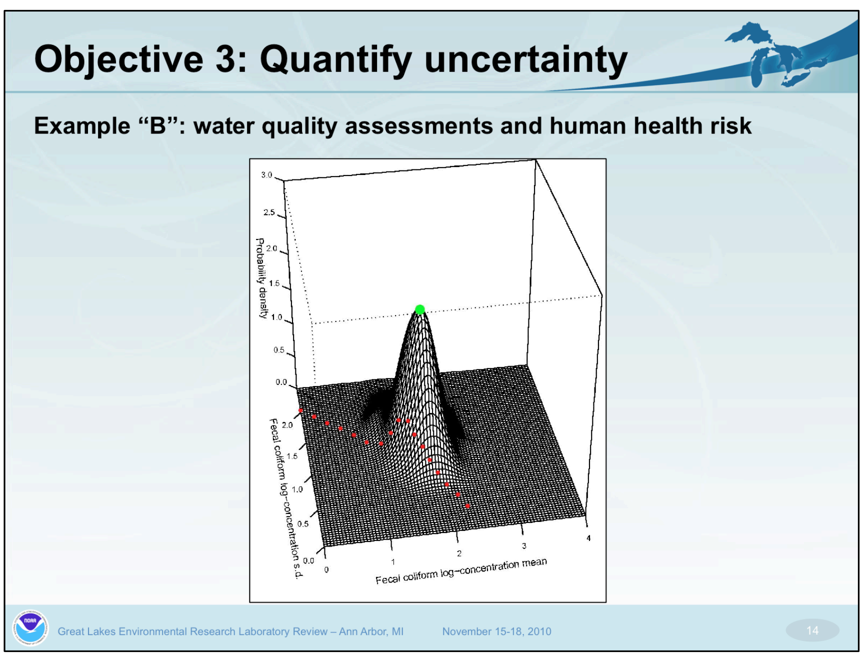
• Third objective, develop novel tools for quantifying uncertainty and variability

Objective 3: Quantify uncertainty

• Dire need for tools which address uncertainty and variability – arising not just from data (e.g. gauge data)…
• …but from non-stationarity, including climate and land use change (as indicated in recent Science article above)
•We are developing novel tools utilizing probabilistic and Bayesian statistical methods to address this need
• Let's look at examples…



• Comparison between two different flow prediction schemes applied to an ungauged basin
• <u>Take home message</u>: Prediction intervals for two schemes are different. Which model has greater "skill"?



• A new approach to assessing water quality through a joint probability density function and it's relationship to water quality standards (red dotted line) and conventional deterministic (i.e. without uncertainty) assessments (green dot).

• The "risk" of violating a water quality standard in this slide is represented by the volume of the shape above and to the right of the red dotted line.

Objective 3: Quantify uncertainty

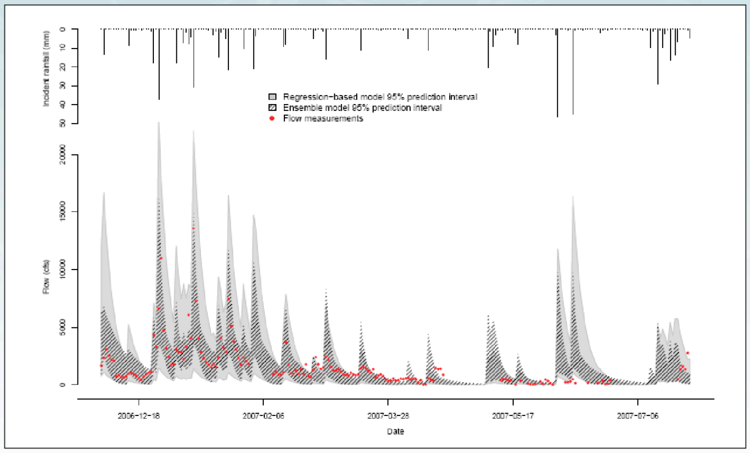
Example "B": water quality assessments and human health risk

Objectives

1. Support Great Lakes water resource management
2. Compile, process, and distribute basin-wide data
3. Develop novel tools for quantifying uncertainty
4. Effectively communicate uncertainty and risk

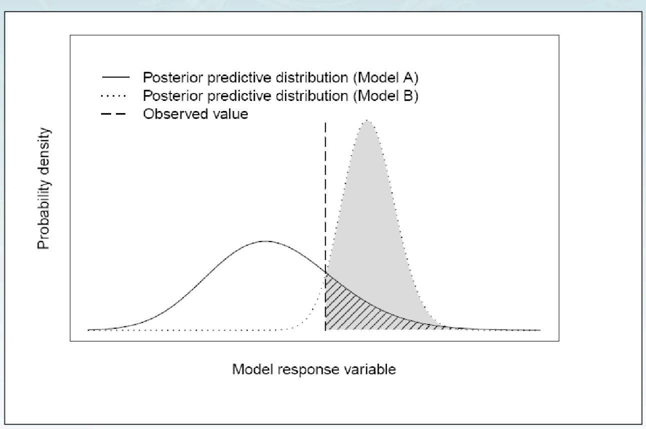
Objective 4: Communicate risk

Example: probability and impact of extreme events



Objective 4: Communicate risk

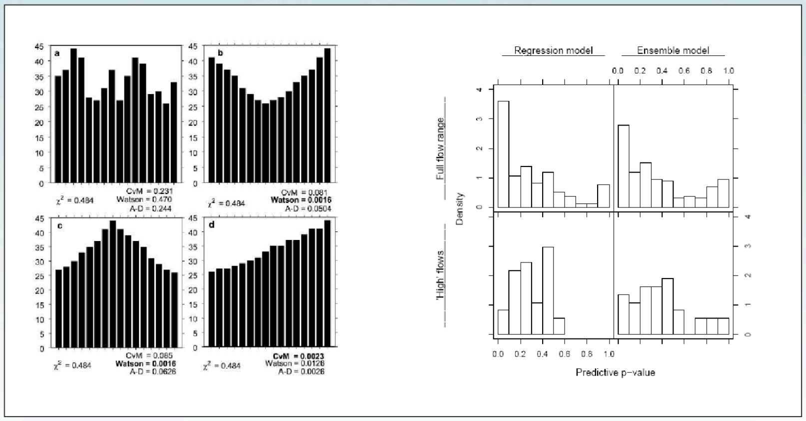
Example: probability and impact of extreme events (continued)



• Posterior predictive p-values are the shaded area under each curve, and represent (for a given probabilistic model forecast) the probability of an observation *as or more extreme* than that observed (observed value represented by the vertical dashed line).
• Histograms of posterior predictive p-values represent model skill in a new and insightful way…

Objective 4: Communicate risk

Example: probability and impact of extreme events (continued)

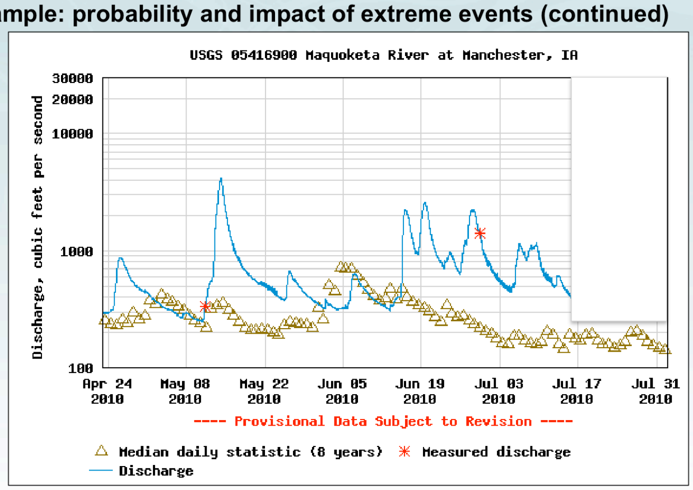


• Here, we see (on the left) four simulated histograms which demonstrate (clockwise from upper left) a reasonable model fit (approximately uniform distribution), underdispersion (weight in tails), bias, and overdispersion.

• Results of our recent study (on the right) suggest that an ensemble model provides a reasonable explanation of variability in relatively high flows, particularly with respect to other model alternatives.

Objective 4: Communicate risk

Example: probability and impact of extreme events (continued)



Objective 4: Communicate risk

Example: probability and impact of extreme events (continued)

Objective 4: Communicate risk

Example: probability and impact of extreme events (continued)

Hydrological Modeling: summary

1. Hydrology program cornerstones → solid foundation
2. Applying novel tools and filling gaps in research
3. Exciting transition period

Hydrological Modeling: summary