The application of Bayesian approaches in water quality modelling

Session conveners: Miriam Glendell\textsuperscript{ECS}, Ibrahim Alameddine, Lorenz Ammann\textsuperscript{ECS}, Hoseung Jung\textsuperscript{ECS}, James E. Sample

HS2.3.3/BG4.28
EGU General Assembly 2020
Presentations
## Presentations

<table>
<thead>
<tr>
<th>Key challenge</th>
<th>Key finding</th>
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<tbody>
<tr>
<td><strong>Craig Stow: Process based or probabilistic models?</strong></td>
<td>**<a href="https://doi.org/10.5194/egusphere-egu2020-9925**">https://doi.org/10.5194/egusphere-egu2020-9925**</a></td>
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<tr>
<td>• Are complex models better?</td>
<td>• The benefits of Bayesian approaches</td>
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<td>• The need for explicit uncertainty analysis of process-based models</td>
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<td>• Specification of prior distribution</td>
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<td>• Computational challenges</td>
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<td><strong>Song Qian: A normative definition of a Bayesian prior</strong></td>
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<td><strong><a href="https://doi.org/10.5194/egusphere-egu2020-17978">https://doi.org/10.5194/egusphere-egu2020-17978</a></strong></td>
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<tr>
<td>• How to derive and formulate a prior distribution?</td>
<td>• Two case studies presented:</td>
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<td>• Prescriptive definition of a Bayesian prior</td>
<td>• Modelling of cyanobacterial toxins</td>
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<td>• Improvement of chemical calibration curve</td>
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<tr>
<td><strong>George Arhonditsis:</strong> Castles built on sand or predictive limnology in action? The importance of Bayesian ensembles to support our ecological forecasts</td>
<td>• Many different model structures and many different parameter sets within a chosen model structure can acceptably reproduce the observed behavior of a complex environmental system</td>
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<td>• Need to adopt a multi-model strategy rather than the single “best-fit” model Present a methodological framework to develop multi-model ensembles</td>
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<td>• Implemented framework on 2 cases studies</td>
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<td><strong>Yong Liu and Sifeng Wu:</strong> Resilience indicator for ecosystems subject to high risk of irreversible degradation: a probabilistic method based on Bayesian inference</td>
<td>• Ecosystem degradation is usually abrupt with unexpected shifts</td>
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<td>• Some ecosystems might be subject to high risks of irreversible degradation because of strong undesirable resilience</td>
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<td>• A practical framework to identify sensitive regions for conservation as well as opportunities for mitigation</td>
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<td>• Method implemented on lake eutrophication</td>
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<td>Key challenge</td>
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| **Daniel Obenour et al.**  
Assessing within-lake nutrient cycling through multi-decadal Bayesian mechanistic modeling | • Bayesian calibration of a mechanistic model to understand nutrient recycling from lake bottom sediments  
• Combine mass-balance model with Bayesian inference  
[https://doi.org/10.5194/egusphere-egu2020-4232](https://doi.org/10.5194/egusphere-egu2020-4232)  
Nutrients stored in lacustrine sediment are an important source of internal loading to the reservoir for multiple decades, and will dampen the effects of external watershed loading reductions |
| **Ibrahim Alameddine and Eliza Deutsch**  
Understanding Harmful Algal Bloom Dynamics in a Mediterranean Hypereutrophic Reservoir insights from a Bayesian Network and a Structural Equation Model | • Identifying pathways between the physical lake conditions and the nutrient loads on one hand and ecological endpoint on the other  
• Comparing BN and SEM model structures  
[https://doi.org/10.5194/egusphere-egu2020-6709](https://doi.org/10.5194/egusphere-egu2020-6709)  
Prior model structure not supported by data  
Models largely concur in structure  
Both models capture temperature effects and direct nutrient pathways and highlight the importance of internal loading |
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<td><strong>Danlu Guo et al.:</strong> A Bayesian hierarchical model to predict spatio-temporal variability in river water quality at 102 catchments</td>
<td>Model improvements should focus on:</td>
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<tr>
<td>Challenges to explain temporal variability in water quality using statistical models</td>
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<td>Linear statistical models are limited in representing water quality datasets with large proportions of below-detection-limit records</td>
<td>• Alternative statistical model structures to improve fitting for truncated data</td>
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<td>• Better representation of non-conservative constituents by accounting for biogeochemical processes</td>
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<tr>
<td><strong>Minkyu Jung et al.:</strong> A Hierarchical Bayesian Model for Spatio-Temporal Water Quality Modeling in a Changining Climate in South Korea</td>
<td>Hierarchical Bayesian model can capture the key aspects of the water quality parameters in terms of seasonality and their uncertainty</td>
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<tr>
<td>Difficult to obtain accurate predictions of water quality due to the large spatio-temporal variability in a changing climate</td>
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https://doi.org/10.5194/egusphere-egu2020-4725  
https://doi.org/10.5194/egusphere-egu2020-21271
### Key challenge

**Lorenz Ammann et al.: Patterns in time-dependent parameters reveal deficits of a catchment-scale herbicide transport model**

Deterministic dynamic water quality models are too rigid: they do not allow for the stochastic nature of the system and are susceptible to structural errors

### Key finding

Introducing stochasticity through time-dependent parameters can reveal deficits in model structure and can allow for a better description of the intrinsic uncertainty of dynamic water quality models

**Sakari Kuikka: Experiences in applying Bayesian network models in interdisciplinary water quality decision analysis**

Developing integrative Bayesian models in interdisciplinary analysis

Different traditions and quality criteria of different scientific fields create both technical and human challenges to the modelling tasks

### Key finding

Applications are based mainly on the use of expert knowledge, especially for decision options that have not been applied before

**Bayesian decision analysis for management provides scientifically justified uncertainty estimates**
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<td><strong>Camilla Negri et al.:</strong> Modelling phosphorus pollution risk in agricultural catchments using a spatially distributed Bayesian Belief Network**</td>
<td>Model captures the difference in P loss risk between catchments, probably caused by contrasting hydrological characteristics and soil P sources. Climate change and land use change scenarios crucial to inform targeting of mitigation measures</td>
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<tr>
<td>Diffuse pollution of phosphorus (P) from agriculture is a major pressure on water quality</td>
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<td>Need to develop Decision Support Tools that can account for the uncertainty in both data and models</td>
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<td><strong>Magnus Norling: Rapid development and evaluation of fast process-based models in Mobius</strong></td>
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<tr>
<td>Build and explore many model structures and evaluate model uncertainty</td>
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<td>Modelling frameworks are a good alternative to one-size-fits-all models, and we hope Mobius will be a useful tool for promoting more robust modelling</td>
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Discussion
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<th>Challenge</th>
<th>Question</th>
<th>Examples</th>
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<tr>
<td><strong>Model complexity and uncertainty assessment</strong></td>
<td><strong>Do we need simpler models, faster models, or both?</strong>&lt;br&gt;Developments in computational capacity have led to more complex models, not necessarily to better predictive performance</td>
<td>Craig Stow Magnus Norling</td>
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<td><strong>Prior distributions</strong></td>
<td><strong>What is a good prior?</strong>&lt;br&gt;Expert elicitation, informative, and non-informative priors</td>
<td>Song Qian Daniel Obenour</td>
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<tr>
<td><strong>Model structural uncertainty</strong></td>
<td><strong>Is our model structure adequate?</strong>&lt;br&gt;Model ensembles, flexible and fast frameworks for controlled model comparison, flexibility in model structure through time-dependent parameters</td>
<td>George Arhonditsis Ibrahim Alameddine Magnus Norling Lorenz Ammann</td>
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<tr>
<td><strong>Representing spatio-temporal variability in models</strong></td>
<td><strong>Is our input data adequate?</strong>&lt;br&gt;<strong>How do you decide on your spatio-temporal scale?</strong>&lt;br&gt;Data resolution – spatial &amp; temporal, uncertainty in model predictions</td>
<td>Minkyu Jung Danlu Guo</td>
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## Discussion Points

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| Need for decision support tools with explicit uncertainty quantification | What is the way forward in using models for decision support?             | Sakari Kuikka  
Camilla Negri  
Craig Stow |
|                                                                           | Are we effectively integrating uncertainties in our decision making process? |                                               |
|                                                                           | • Different traditions and quality criteria from different scientific     |                                               |
|                                                                           |   fields (biology, sociology and environmental economics) create both   |                                               |
|                                                                           |   technical and human challenges to the modelling tasks                  |                                               |
|                                                                           | • Bayesian decision analysis for management provides scientifically       |                                               |
|                                                                           |   justified uncertainty estimates                                         |                                               |
| Ecological system complexity and resilience – impacting effectiveness of  | How best to simulate complex biophysical systems?                         | Yong Liu  
Daniel Obenour  
Ibrahim Alameddine |
|   mitigation interventions                                                | • Accounting for unexpected shifts in ecosystem states                    |                                               |
|                                                                           | • Modelling nutrient recycling from sediments                             |                                               |
|                                                                           | • Identifying pathways and feedbacks between drivers and response         |                                               |
|                                                                           |   variables                                                                |                                               |
Important announcements
Thank you for supporting this session in this **EXCEPTIONAL** year – we look forward to meeting you in person in Vienna at EGU 2021!

**SPECIAL ISSUE ALERT**

- We are proposing a *Special Issue* on ‘**Frontiers in the application of Bayesian approaches in water quality modelling**’ in the EGU *Hydrology and Earth Systems Science Journal*
- Open both to presenters at this session over the past two years and to the wider community
- Interested to contribute to the Special Issue? Please get in touch with **miriam.glendell@hutton.ac.uk**