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Hydrology and Earth System Sciences
Discussions

Interactive comment on "On the assimilation of environmental tracer observations for model-based decision support" *by* Matthew J. Knowling et al.

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We thank Prof. Ty Ferre for his more detailed review and for his positive sentiments. Below we respond to each of his comments.

Prof. Ferre accurately summarizes our intention to challenge by rigorous investigation the widely accepted perspective among hydrologists and modellers that "more data and more diverse data lead to better model forecasts". Our experience extracting information from hydrologic observations through large, complex models—and the challenges associated with doing so—ultimately led us to undertake this study. We hope that our findings spark important conversations, and that these conversations ultimately lead to

improved decision-support modeling practice.

Prof. Ferre echoes our position that increased model complexity may be required to appropriately assimilate both information-rich data, and data of various types, notwithstanding the additional challenges this added model complexity brings. Striking an appropriate balance between complexity and simplicity in the imperfect model-data assimilation context is an area that requires more attention in our opinion.

We are pleased that Prof. Ferre finds the brevity of the case study details to be appropriate. We believe that this comment will be addressed by the availability of additional details regarding the second case study—the Hauraki Plains paired model analyses used for identifying tracer assimilation-induced bias—following publication of White et al. (forthcoming).

We thank Prof. Ferre for his interesting question on the contextualization and measurement of data worth. While there is probably no single "right" measure of data worth from the perspective of water resource managers across the board, we acknowledge that the assessment of data worth based on changes in the second moment (i.e., variance) of a forecast of management interest is unlikely to express the "full picture" from a decision maker's perspective. This is because decision makers need to evaluate forecast PDFs with respect to carefully defined decision thresholds governing management action. For example, if forecast variance is reduced through data acquisition, but this reduction in variance is of no consequence in terms of our ability to test hypotheses (e.g., if the entire PDF lies on one side of the decision threshold), were the collected data *really* worth it, in terms of the specific decision-support context in question? From the manager's perspective, surely not, as the decision was not made any easier following the acquisition of data.

A more decision maker-focused measure of data worth may therefore be to evaluate forecast PDFs (that are conditioned on different observations) with respect to a specific management decision threshold (or multiple decision thresholds as is more likely the case in practice; e.g., Vilhelmsen and Ferre, 2017). We feel that such a hypothesis testing approach to data worth assessment has significant merit and requires further investigation, notwithstanding that some excellent related works such as Nowak et al. (2012) and Wagner (1999) already exist in the literature. We also feel that identifying optimal monitoring data with respect to "decision difficulty" (e.g., Knowling et al., 2019) has potential.

For the data worth analysis presented in the first case study, it is difficult to anticipate how the specific outcomes of the analysis would be affected through adopting a hypothesis testing approach to data worth. This is due to the fundamental role that a specified decision threshold plays in the assessment of management action success/failure.

We note that robust assessment of data worth in a hypothesis testing framework should ultimately involve non-linear uncertainty quantification such that not only the second moments but also the first moments of forecast PDFs can be assessed with respect to a decision threshold. Such an approach would also allow for the consequences of data assimilation-induced forecast bias in proximity to a decision threshold to be quantified (e.g., where the value of data in terms of variance reduction may be outweighed by its introduction of bias).

More generally, the decision-support context(s) in which the assessment of data worth can be framed is fundamentally important to the current study and more generally. Adopting a decision-support context allows for the prioritization of data collection towards improving the reliability of model forecasts that are used to support management decision-making. Exploring data worth in other contexts can also nevertheless be performed using similar approaches such as FOSM. For example, in the context of aquifer characterization, one can compute the value of, e.g., geophysics data in terms of the reduction in uncertainty associated with key aquifer properties, which may form the basis for improved system process understanding.

We believe that some of the important points above warrant a brief discussion in the

revised manuscript. We will add this to the Discussion and Conclusions section.

We welcome Prof. Ferre to contact us to discuss further some of the ideas above if he is interested.

Matt Knowling

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