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Hydrology and Earth System Sciences
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Discussions



# *Interactive comment on* "Natural stochasticity vs. management effort: use of year-to-year variance for disentangling significance of two mutually confounding factors affecting water quality of a Norwegian cold dimictic lake" *by* A. T. Romarheim et al.

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In the responses below, please refer to the track-change manuscript produced by the difflatex utility. The page numbers reflect the page numbers on this track change PDF file.

RC:



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Discussion Paper

My main concerns are; firstly, while meteorological forcing and external nutrient load may exhibit somewhat stochastic behavior, they are indeed linked (as the authors also acknowledge in the discussion). One could therefore argue, that a methodology (such as that developed in the study) that attempts to discriminate between effects of weather and nutrient runoff is irrelevant, as there is a natural covariance between, for exam- ple, precipitation and nutrient runoff (which is time-scale dependent).

AR:

The discrimination between the effects of weather and nutrient loading is based on a modelling approach. Year to year variations in weather and nutrient loading are used as input variables, and by combining these variables into different scenarios.

The transfer of nutrients from the terrestrial to the aquatic environment shows a great variability, depending on runoff conditions, which to a large extent is regulated by weather conditions. As pointed out, this is now included in the main text, please see the changes below. Even though there is a link between weather and nutrient loading, the model approach give information on how climate drivers (time and extent) impact the water quality (tot P and algae growth) under the given P-catchment pool in our study area.

Furthermore, the approach will also be useful in future evaluations of mitigation strategies (is the P-pool in the catchment really reduced? How large is the nutrient loading under "similar weather conditions"? Will the lake show the same sensitivity to variable weather conditions in future as in the present study? If not, reduced nutrient loading might prove to be the case. Thus, the present results might reveal new drivers, or the efficacy of countermeasures in future.

Changes:

P2L11. '(management) and weather (the confounding natural stochasticity)' is now changed to 'in runoff and meteorology on the lake'.

P3L4. A new sentence is inserted: 'In particular, nutrient loading is determined both by hydrology (partially determined by meteorological forcing on land) and by the management effort (agriculture and urban related nutrient loading). Furthermore, weather may also be directly consequential in the alek processes such as algal growth.

RC:

Also, should the manuscript be relevant for the broader audience of HESS, I would also have liked to see more in-depth reflections on how the methodology would be relevant for - and transferred to - other systems.

AR:

A new paragraph elaborating on this very point is now inserted as the second last paragraph of the Introduction.

Changes:

P5L16. The new paragraph reads as the following. The separation of two temporarily varied factors affecting the same environmental receptor is not only useful in the lake water quality modeling. For example, agricultural yield and forestry are affected by weather, soil conditions, diseases, and tilling and fertilisation amount and timing. Other examples may be climate change impacts on physical landscape, such as glacial extent or surface water ice cover, which are affected by stochastic meteorological conditions and warming forcing which are mostly anthropogenic but also of natural origin (e.g., volcanic activities), as well as regional multi-year fluctuation such as the North Atlantic Oscillation or El Nino.

RC:

Secondly, the results of using the methodology on a Norwegian case-study lake mainly repeats well established scientific understanding. Examples from the abstract are: "Thermal related properties in the lake were mostly determined by weather conditions" and "loading was the most important factor for phy- toplankton biomass".



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AR:

The main aim of the study has been to evaluate the relative importance of year-to-year variations of two major factors, namely meteorological forcing and nutrient loading by the use of a modeling approach covering great variations in weather conditions. Our finding suggests relevance of climate change impacts on areas applying counter-measures to improve water quality, and understandings and knowledge presented are existing knowledge, but we keep them in the future context.

We augment this message by improving one sentence in the Introduction. and adding new sentences in the Discussion.

Changes:

P3L11. We improved the sentence from 'The present study illustrates how a variance-based modelling method could answer scientific and managerial questions with a test case study of water quality of Norwegian lake" to "The present study illustrates how a variance-based modelling method could disentangle two major factors affecting a lake, with a test case study of eutrophication recovery of a Norwegian lake.

P18L13. Added the following sentences. The limnological and biogeochemical knowledge of this lake identified by decomposing year-to-year variation of the two factors, carries potential in connecting future management. Runoff is partially controlled by precipitation which in turn is predicted to change, and so are air temperature and global radiation.

RC:

Specific comments The case study itself is somewhat difficult to follow. One of the key data inputs of the study is external nutrient load to the lake. This has been estimated from a combination of flow and nutrient scaling factors for some subcatchments and an additional lake model application for the largest subcatchment (as this particular area contains a lake that drains into the authors' case study lake). Presumably, the year-



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to-year variations in nutrient loads (which are used for analysis) therefore also rely on these estimates, and therefore it would have been appropriate to illustrate how well the estimated external nutrient load matches that of the actual nutrient load (and particularly how well the estimates matches year-to-year variations).

AR:

We unfortunately do not know exactly how much nutrient loading was introduced into the lake Årungen through direct measurements. This is both due to the considerable amount of the surface runoff by the lake shoreline that is not carried via streams and due to the study design that allocated more of the research resource for obtaining accurate measurements in the Skuterud subcatchment. The subcatchment measurements were volume corrected and therefore able to provide the flux or amount of water and nutrients, and these measurements were then scaled up according to the land usage, including agriculture, sewage and urban contributions.

The description of the reference report (Askilsrud, 2010) in the manuscript is improved (originally p.12494 lines 22-) to make clear what type of scaling was used. In addition, the fact that direct measurements of runoff is not available at the study lake is added after the 2nd sentence of section 2.3 (originally lines 17-).

Changes:

P7L4-L17. The relevant sentences have been improved and read as the following. Direct measurements of daily runoff volume, runoff water temperature, and fluxes of suspended inorganic particles and total phosphorus to the study lake Årungen was not available. However these values were estimated using the Skuterud monitoring station (Fig. 1) with a hydrovolumetric weir at which these runoff variables were monitored (1994–2010), providing accurate flux at this subcatchment. In order to account for runoff contributions of different types of landuse in other subcatchments, such as agriculture and urban build up, we used previously determined scaling factor that both correct for flow and nutrient factors (Askilsrud, 2010). The monitoring station is located at an inlet stream to Østensjøvann (59o41’18”N, 10o49’45”E), a small lake of 0.4 km2 which drains into the lake Årungen (Deelstra et al., 2007).

RC:

Also, in the results section, the authors reflect on how variations in external nutrient load and weather (air temperature and precipitation) influence inter-annual variations in water quality at- tributes such as phosphorus levels and phytoplankton biomass as predicted by the lake model (MyLake). However, the conceptual lake model may not be an appropriate ba- sis for such evaluation, as this, for example, do not discriminate between properties of phytoplankton that are typical of Spring and Summer periods, respectively. At least this is the impression that I get when reading the description of the model (and the paper by Saloranta and Andersen 2007 that is used as a reference).

AR:

Another version of MyLake is actually able to consider up to two algal species with different optimal temperature levels and different shading properties in the water. This was originally introduced to study competition between two types of algae in the summer, but a preliminary model calibration study at a nearby lake did not converge among the parameters between these two algae, due to strong covariance structures among these parameters. This version could have been used to study different types of algae in two different seasons as suggested. But, because of the difficulty in deterministically predicting the community structure, the single typical algae type strategy was the appropriate balance between accountable model structure and real complexity of the abstracted system (i.e., lake). The lake model does have a capability in responding to water temperature to influence for example algal growth, and different growth elasticity levels among different algae typical of different seasons can be to some extent accounted for by the temperature function of algal growth in the lake model, and the algal growth parameters that were calibrated (Table 2) and historical in-lake measurements produced (Figure 2).

We added a sentence at original page 12495 line 26, to explain that a single algal design of the model was meant to represent a community of different algae through parameter calibration.

Changes:

P8L15. New sentences are: For example, algal growth in the MyLake model is a function of nutrient concentration, light availability and water temperature, and amplitude of these factors were controlled by parameters. In the present study, runoff was given as external input to the model, and water temperature and underwater light conditions were determined in the first stage of MCMC. Therefore, for the example of algal growth, the second stage of MCMC only changed the amplitude of algal growth in response to these external factors.

RC:

Technical corrections There are a few typos, listed below. P124496 L23: achived should be achieved P124496 L24: imporantce should be importance P124496 L25: metrological should be meteorological P124497 L1: albal should algal (?)

Changes:

These typos were corrected at P9L22, P9L23, P9L24, and P9L28, respectively.

RC:

Figure 3: it would perhaps be more relevant to plot the relative standard deviation (in %) of the variables (rather than the absolute standard devitation), as this would make it easier to compare between variables.

AR:

Relative standard deviation is only useful if all the variables are scalars. In other words, a value of zero should mean nothing in all variables, and doubling of a value should mean doubling the content. This is not the case with water temperature in degrees



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Celsius. Moreover, water temperature in Kelvin will result in small relative standard deviation which does not imply insignificance of variation. We therefore kept the figure content to be absolute standard deviation, but corrected the inappropriate lower ends of the y-axes (originally fixed to zero).

Changes:

Please refer to the new Figure 3. Now the y-axes were zoomed in to show better variability of 365 daily standard deviations, and do not imply the significance of zero for all the variables.

RC:

Figure 4: I had a difficult time understanding the content of this figure. The colors of the bands demonstrated in the figure are not referred to in the figure caption.

AR:

We have changed the figures to 4 lines, each representing the scenario.

Changes:

Please refer to the new Figure 4.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 12489, 2014.