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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Reply to D. L. Peters' comment on "Streamflow input to Lake Athabasca, Canada" by Rasouli et al. (2013)" *by* K. Rasouli et al.

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Hydrol. Earth Syst. Sci. Discuss., 11, 12257–12270, 2014 Paper title: "Reply to D. L. Peters' comment on "Streamflow input to Lake Athabasca, Canada" by Rasouli et al. (2013)" Authors: K. Rasouli, M. A. Hernández-Henríquez, and S. J. Déry

This is a response to the comments from Referee 1, Dr. Stewart Rood:

Dear Dr. Stewart Rood,

We sincerely thank you for your very constructive comments on our reply that we prepared in response to comments from D. L. Peters (P14) on our earlier submission,

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Rasouli et al. (2013) (R13), to Hydrology and Earth System Sciences. Please consult the revised version of the text for further details on the revisions we have performed.

We have addressed your comments as follows:

Comment I. Analyses of historic hydroclimatic records will probably provide the most confident strategy for considering trends and near-future prospects for the Lake Athabasca watershed due to the uncertainties in downscaling from global circulation models.

Response: In this study, we have focused on streamflow, lake inflow, and lake level records. Thus the scope of R13 and Rasouli et al. (2014) (R14) did not take into consideration all water balance components, such as evaporation, groundwater recharge, inflow, and precipitation. We agree that trend analysis of historic hydroclimatic records from which water balance variables can be estimated is very useful for near future predictions. However, for long-term projections, high resolution Regional Climate Model (RCM) or Global Climate Model (GCM) outputs are needed.

We have added the following sentence to the end of the fourth recommendation for future research efforts (page 11 - lines 208-211 in revised text):

"In addition, trend analysis of historical hydroclimatic records can only provide near future hydrological prospects of the Lake Athabasca system and thus climate models are needed for long-term projections."

Comment 2. A subsequent problem arises with shorter-term trend analyses since a PDO phase-transition occurred around 1970 and this may provide a stronger hydrologic impact than the gradual influence such as from climate change or due to water withdrawal for oil-sands developments.

Response: We agree and this is one of the reasons why multiple common-time periods (1960-2010, 1970-2010, and 1977-2010) were employed in the trend analysis that was performed.

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Comment 3. For Rasouli et al.'s (2013) investigation of the coordination between river flows and Lake Athabasca levels, this complexity is less serious. Conversely, as they and others seek to extend recent historic patterns into the future, the influence of the PDO and other climate patterns should be further explored. This provides another complexity.

Response: This issue was also raised by Dr. David Sauchyn (Referee 2), thus we have proceeded to expand on the fifth recommendation for future research efforts that encompasses projections of future inflows to Lake Athabasca. In particular, we note that GCMs that capture large-scale teleconnection patterns (e.g., PDO and ENSO) should be considered in future climate model simulations of the Lake Athabasca system due to streamflow regimes being affected by these large-scale climate signals.

The following sentence has been modified in the fifth recommendation for future research efforts (page 12- lines 215-221 in revised text):

"These climate model simulations require full consideration of anthropogenic influences (i.e., land cover/use changes, flow regulation and retention, and water extraction), climate variability (i.e., impacts of the phase change of large-scale teleconnections such as El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) on lake inflows), in addition to a range of climate change scenarios to assess the potential future freshwater supply in the Lake Athabasca drainage."

This is a response to the comments from Referee 2, Dr. David Sauchyn:

Dear Dr. David Sauchyn,

We thank you kindly for taking the time to review R14 and providing us with your insightful comments. We have addressed each of your comments and proceeded to address them in the following manner:

Comment 1. Based on the hydrometric and lake level trends, and previous studies of the paleo-limnology of the region, they conclude that lake levels may drop by 2-3 meters by the end of the century.

Response: In R13, we concluded that streamflow input to Lake Athabasca has dropped significantly over 1960-2010. We would like to clarify that the suggestion in R13 that Athabasca Lake levels may drop 2-3 meters by 2100 if the linear trend continues into the future was a point of discussion, rather than a conclusion. We agree that the extrapolation of a linear trend cannot project the future streamflow input in a complex hydroclimatic system, such as that governing Lake Athabasca.

Comment 2. They investigated lake level fluctuations from the perspective of climate variability whereas P14 takes a different approach focusing on the hydraulic and geomorphic constraints on lake levels, including physical controls on outflow.

Response: Thank you for this comment. We agree and thus made sure that the focus of the research was emphasized in R13 and R14. Of note, investigating morphological changes by anthropogenic activities or projecting the climate of the study area was not in the scope of our original study (R13). The main focus of the study was to investigate the variability of streamflow input from different tributaries flowing into Lake Athabasca, in addition to lake level variability independent of external driving forces.

Comment 3. A more substantive criticism of R13, mentioned but not emphasized by Peters, is the great deal of uncertainty inherent in their extrapolation of recent water level trends in a non-stationary hydro-climatic regime.

Response: Please see response for Comment 1 by Dr. David Sauchyn.

Comment 4. R13 used the low middle Holocene lake levels to support their projection of a 2-3 m decline by 2100. As P14 points out, R13 chose not to refer to the higher LIA lake levels.

Response: We believe that lake levels were higher during the Little Ice Age (LIA) period when water was abundant and western Canada was developed (Wolfe et al., 2011) as a result of the prior glacier expansion period. However, unlike the LIA period when water

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was plentiful, we argue that much drier times are ahead and future water availability is likely to resemble that of the midâĂŘHolocene period due to the following reasons: (1) global air temperatures are expected to continue increasing significantly, especially in northern latitudes (i.e., over 5oC; Nogués-Bravo et al., 2007); (2) there are no signs of a second ice age occurring before 2100 to provide increases in available water resources; and (3) water extraction for oil exploitation will continue and amplify in the Peace-Athabasca Delta region and ongoing power generation from the rivers feeding into Lake Athabasca during the 21st century.

Please note that his has been reflected in the first paragraph of section 1.3: "Future Lake Athabasca levels" (pages 8 - lines 128-137 in revised text)

Wolfe, B. B., Edwards, T.W. D., Hall, R. I., and Johnston, J.W.: A 5200-year record of freshwater availability for regions in western North America fed by high-elevation runoff, Geophys. Res. Lett., 38, L11404, doi:10.1029/2011GL047599, 2011.

Nogués-Bravo, D., Araújo, M. B., Errea, M. P. and Martinez-Rica, J. P.: Exposure of global mountain systems to climate warming during the 21st Century. Glob. Env. Chan. 17, 420-428, 2007.

Comment 5. On the contrary, natural low-frequency hydroclimatic variability is very relevant. It tends to confound the detection of trends in instrumental time series and the projection of climate changes. Various recent papers (e.g., Deser et al., 2012; Knutti and Sedlácek, 2013) conclude that natural variability is the largest source of uncertainty in climate modeling and that it "poses inherent limits to climate predictability".

Response: Please see response to Comment 3 from Referee 1 as this was also an issue raised by Dr. Stewart Rood.

Comment 6. The rigour of GCMs or RCMs projection would depend very much on the degree to which the chosen GCMs or RCMs are able to simulate the internal variability of the climate system and the natural forcing of inter-annual to decadal variability of the

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hydrologic regime of the Lake Athabasca basin.

Response: Yes, we agree that application of climate models introduces a higher degree of uncertainty. However, careful selection of an ensemble of climate models that are able to capture the internal variability of a climate system can provide reliable projections. Thus in the recommendations for future research work, we recommend that appropriate climate models should be employed to capture inter-annual and decadal variability of the hydroclimatological variables in the Lake Athabasca basin.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/11/C6063/2015/hessd-11-C6063-2015-supplement.pdf

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 12257, 2014.

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