Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2019-136-AC1, 2019

Hydrology and
Earth System
Sciences
Discussions
Open Access

Interactive comment on “Determinants of thermal regime influence of small dams” *by* André Chandesris et al.

André Chandesris et al.

andre.chandesris@irstea.fr

Received and published: 15 July 2019

Dear Editor and Referees,

Thank you for the quality of your proofreading and comments; they have greatly improved the manuscript. We also appreciate your interest in the subject matter, which we think is of critical importance to managers across France and the world who are dealing with issues of small dam removal and ecological integrity. We believe we have substantially addressed all of the outstanding comments and issues, and we look forward to your second review of the work. All of the referees remarked on the issue of data representativeness, so we will briefly discuss this issue here. Data scarcity (i.e., lack of data across years within sites) is a primary challenge for understanding thermal

effects of small dams, and it is one of the primary reasons that we used a compiled dataset with data from field operators, which we bolstered with our own sampling. We acknowledge that using these two data sources may make reading and understanding a little more difficult, but we believe it enriches the analysis by increasing the number of time series and across-year examples, (though we agree this dataset is probably still insufficient to draw broad conclusions). Hence, we are aware of the issues with the dataset, and we have added text throughout to underscore this issue. However, we feel that the analysis and general results are valid and useful, regardless of data scarcity issues, which every study must deal with. Throughout the manuscript, we have made major revisions based on the referees comments and suggestions. The major changes are: - use of new statistical analysis methods to strengthen the robustness of the results, - improved consistency between points raised in the comments and proposed figures, - grammatical quality review: a final revision of English was done by a native speaker.

General comments : " the presentation of the results to be mainly using individual sites as examples that are difficult to judge if they are representative."

Response: An improvement in the presentation and choice of sites selected as examples has been modified in the final text.

Specific comments: "1. Figure 2 – why present years in reverse chronological order? Also, why this stream and these years? If possible, it would be preferable to compare 2014 (cold wet year) with 2015 (warmest, dry year in data set)."

Response: The aim was to highlight that the same site presented the same "patterns" of summer time-series for different years, regardless of the climatic characteristics of the year. Based on this comment, we have changed this example (new Figure 2) to compare a cold and humid year (2014) with a normal and dry year (2016) at another site (Veyle stream, Fretaz site): the structure of the thermal patterns between upstream and downstream is preserved.

The new text L180 to 189 is modified as

Previous text: L180 to 189 These periods vary from one year to another, likewise the intensity of the increases, but the general pattern remains the same, as demonstrated by the case of the dam Champagne (Renon stream), monitored in 2009 and 2015 (Fig. 2). Furthermore, the average temperature downstream of the structure was systematically higher or equivalent than that measured upstream. Different types of time-series were observed regarding the difference between upstream and downstream temperatures: The most frequent (7/13) is the type observed on the dam of Champagne (Renon stream) in 2009 and 2015; the minimum 185 daily temperatures (T min) are, most usually, higher downstream of the structure, but the maximum daily temperatures (T max) remain within the same magnitudes (Fig. 2, only one example is presented here). In the other cases (6/13), both the minimum and maximum daily temperatures are higher downstream of the structure, which results in a homothetic lag between the two temperature time-series (Fig. 3).

Replaced by

These periods vary from one year to another, likewise the intensity of the temperature increases, but the general pattern remains the same, as demonstrated by the case of the dam Fretaz (Veyle stream), monitored in 2014 (a cold and humid year) and 2016 (a more normal year, Fig. 2; Table 2). We observed two consistent pattern in upstream/downstream thermal regimes. In the first pattern, the daily minimum temperature is higher downstream, but the daily maximum temperature stays relatively constant (Fig. 2). We note that these upstream/downstream differences were muted in 2014, the cold and humid year (Fig. 2). This thermal pattern (i.e., where the minimum temperature increases downstream, but not the maximum temperature) is observed in 7 out of 13 cases (Table 3). In the other cases (6 out of 13; Table 3), we observed a second pattern, where both the minimum and maximum daily temperatures are higher downstream of the structure, which results in a consistent shift between the two temperature time-series (Fig. 3, selected examples: Dompierre dam 2010 and Peroux dam 2015, Veyle stream).

"2. General – figures don't do a very good job of illustrating points made in text in results. I question whether all the figures are needed (e.g., Figure 3). "

Response: Fixed; see above

"Figure 5 – presenting time-series does not show correlation between two variables –one would need to plot air temp vs. water temp to show directly. "

Response: We modify Figure 5 and the text as follows:

Previous text: L200 to 204 During the summer season, the differences in the daily mean temperatures upstream / downstream, are close or staggered during all the season. It is notable that the variability of the summer air temperature is much higher (range 17°C) than stream temperature (range 7.5°C) for these examples (Fig. 5), and that the daily water temperature is not well correlated to air temperature.

Replaced by

During the summer season, the upstream/downstream daily maximum water temperature differences are not well correlated with air temperature for the same periods. For example, a simple linear regression between daily maximum air temperature and daily maximum water temperature differences indicates that air temperature explains only 0.3% of the variability in upstream/downstream thermal regime shifts (Fig. 5).

"Figure 4 – never covered in results section."

Response: We previously covered figure 4 in section 3.2 but now we changed the text to better explain the observed pattern. We also changed the site "Neuf" to "Fretaz 2014".

Previous text: L 191 to 194 The two dominant patterns can be illustrated by plotting the minimum and maximum temperature values at the site "Dompierre 2010" with a difference of order of + 1.5°C between the upstream and downstream of the site, comparing to "Neuf 2016", where these values are the same for minimum daily temperatures, or even slightly negative for the maximum temperatures (Fig. 4).

Replaced by

The two dominant patterns of temperature differences are further illustrated by plotting the minimum and maximum temperature values at the site. For example, at Dompierre in 2010, we observed a consistent shift of approximately +1.5°C (both maximum and minimum daily temperature) between the upstream and downstream of the dam (Fig. 4A). In contrast, at Fretaz in 2014, this shift is dampened, and temperature values between upstream and downstream follow a 1:1 relationship (Fig. 4B).

"3. The authors mention differences in mean temperature, but never provide this information in a table. Further, they report median differences without justifying why this metric instead of means. I feel medians can be a useful indicator of central tendency, but the mean is also useful, and needs to be presented if it is discussed."

Response: To avoid any confusion, we eliminate any reference to daily mean temperature. We also have modified the section 2.4 Data analysis to remove any confusion about using mean temperature (L 156 to 159).

Previous text: L156 to 159 To determine if the dams alter the temperature regime, the minimum, average and maximum temperatures and amplitudes were calculated for each full day recorded, and the median values were recorded for the period. The calculations of daily differences of maximum and minimum water temperatures were performed for each pair of upstream/downstream records, and the median of these differences over the recording period was calculated.

Replaced by

To characterize the influence of dams on stream thermal regimes we first calculated three variables: daily difference between upstream and downstream temperature 1) maximums, 2) minimums, and 3) ranges for each site and year. (..). With these data,

we then conducted the following analyses: 1. Median summer differences in maximum, minimum, and range between upstream and downstream (median is used instead of mean to characterize a season in order to limit the effect of a specific weather event), 2. . ..

"Section 3.4 – authors state that air and water temperatures do not correlate, but did not perform a correlation analysis".

Response: Fixed with a new figure 5

"5. Section 3.5 – how were these groups distinguished (meaning, what formal method was used). My impression is that the investigators did this “by eye”, which is not acceptable in my view. A formal cluster analysis would be much more appropriate. Moreover, I think it is hard to defend splitting out groups with such a small number of sites."

Response: The requested additional statistical analysis has been completed and we propose the following changes

We add description of the statistical method used Previous text: L 159 Finally, we propose a classification of the observed thermal behavior in 3 groups, based on differences between upstream and downstream dam daily maximum temperature, daily minimum temperature and daily amplitudes.

Replaced by 2.5 Site typology analysis We observed different thermal regimes in our data and wanted to classify them. To do so, we carried out a hierarchical cluster analysis using Euclidian dissimilarities matrix according to the Ward’s method (1963) using daily dataset (n=807) of upstream/downstream differences between maximum and minimum temperatures obtained over all time-series. We forced the classification to integrate the different time-series effect by adding a complete disjunctive table differentiating each time-series to the data set. This procedure makes it possible to group the data first by time-series, then in a second step to differentiate them from each other (i.e., to differentiate site thermal regimes).

Previous text: L 204 to 217 3.5 Site typology based on summer thermal regime The median values of the daily temperature variables calculated over summer (from 01/07 to 01/09) permit distinguishing two major types of response to the presence of a small dam (Table 3). A first group (A) is characterised by: - a median of the differences upstream/downstream of the maximum daily temperatures lower than 0.5°C; - a median of the differences upstream/downstream of the minimum daily temperatures between + 0.4 and 1.3°C; - a median of the differences in daily amplitudes lower than - 0.2°C. A second group (B) is characterised by: - a median of the differences upstream/downstream of the maximum daily temperatures higher than 0.5°C; - medians of the differences upstream/downstream of the maximum and minimum daily temperatures in the same order of amplitude. In addition two subgroups can be distinguished: subgroup (B2) with medians of upstream/downstream differences of daily maximum and minimum temperatures higher than 1°C, i.e. net warming between upstream and downstream, and subgroup (B1) with values ranging from 0.3 – 0.8°C. Replaced by

3.5 Site typology The hierarchical cluster analysis applied on the values of the daily temperature variable differences over summer (from 1 July to 31 August) distinguished three groups: - a first group (A) characterized by: - a median of the differences upstream/downstream of the maximum daily temperatures less than 0.5°C; - a median of the differences upstream/downstream of the minimum daily temperatures between + 0.4–1.3°C; - a median of the differences in daily amplitudes less than -0.2°C. - a second group (B1) characterized by: - a median of the differences upstream/downstream of the maximum daily temperatures ranging from +0.6–1.2 °C; - a median of the differences upstream/downstream of the minimum daily temperatures between +0.3–1.1°C. - a third group (B2) is characterized by medians of upstream/downstream differences of daily maximum and minimum temperatures both higher than 1.2 °C (i.e., net warming between upstream and downstream)

Figure 6 changed.

"6. Section 3.6 – in the methods, the authors state that they used mean temperatures

in the PCA analysis, but this doesn't show up in the results. Further, the reporting of the PCA results is very incomplete. Loadings of the various variables is needed, as is some criterion for determining what are the significant correlations. I can't say I understand fully how to interpret the circle correlation plot."

Fixed; we have added new clarifying text.

Previous text: L 166 to 170 2.5 PCA analysis In order to identify the characterization of the impacts of the different dams, a principal component analysis (PCA) was carried out using the software XLStat (ADDINSOFT™) on the water temperature variables: downstream / upstream difference of the maximum, average and minimum daily temperature and daily temperature amplitude. The physical characteristics of the structures (Table 1) were used as illustrative variables to evaluate the correlations with the temperature variables

Replaced by

2.5 Ordination analysis To characterize the impacts of the different dams, a principal component analysis (PCA) was carried out using the software XLStat (ADDINSOFT™) on the three water temperature variables: downstream/upstream difference of the maximum and minimum daily temperature and daily temperature range. We used the median values for variables on each time-series in order to build an input matrix (13 occurrences for three variables). Then a complementary redundancy analysis (RDA) with automatic stepwise variable selection procedure was used to identify the physical dam characteristics (Table 1) that significantly explain the PCA results (ter Braak 1986). After the RDA identified the relevant physical dam characteristics, we conducted multiple linear regression between these characteristics and temperature variables to determine specific effect sizes of these characteristics on thermal regime. Ter Braak, C. J. F.: Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis, Ecology, 67, 1167-1179, 1986.

Previous text: L 220 232 3.6 PCA results The first axis of the PCA analysis (78.3 %) is correlated to all temperature daily variables (calculated as differences between downstream versus upstream), in particular to the maximum daily temperature difference (Tmax_diff). The second axis discriminates the daily amplitude difference (Range_diff) with the minimum temperature (Tmin_diff) difference (Fig. 7). For the determinants, the water residence time is the most correlated variable to the first axis F1, the size of the reservoir (surface, volume, length) correlates to both the first and second axis. The other physical-geographical characteristics related to the size of the watercourse (watershed, distance to the source), are correlated with the daily maximum temperature and associated with the second axis F2 (20.7 %); dam height has a very weak correlation with the axis F1. The projection of the site series on these axes shows a strong spreading along the first axis. The dams measured two different years stay within the same range on this axis (Fretaz and Champagne) (Fig. 8). Groups B1 and B2 are distinguished by respectively the first and second axis association. This can be linked to the determinants of strong residence time influence for group B2, whereas group B1 is mainly characterized by the size of the impoundment (large impoundments, yet with relatively smaller residence time and thus less exacerbated thermal regime effects).

Replaced by

3.6 Ordination results The first axis of the PCA analysis (74.1% of total inertia) is correlated to all temperature daily variables (calculated as differences between downstream versus upstream), in particular to the maximum daily temperature difference (Tmax_diff). The second axis (25.3%) discriminates the daily amplitude difference (Range_diff) with the minimum temperature difference (Tmin_diff) (Fig. 7). Results of the RDA show that the water residence time and the impoundment surface explain 95.2% of the PCA structure (time series plotted on the first and second axis).The projection of the site series on these axes shows a strong spreading along the first axis. The dams that had two different measurement years stay within the same range on this first axis (i.e., Fretaz and Champagne) (Fig. 8).

Multiple regression analyses between the temperature variables (median values of

Tmin_diff and Tmax_diff) and the physical characteristics obtained by the RDA (residence time and impoundment surface) resulted in high explanatory power (R2 ≈ 0.7). These regressions identified the significant contribution of residence time for Tmin_diff and Tmax_diff, whereas only surface area had a significant contribution for Tmax_diff (Table 4).

Figure 7 and 8 changed

A new table is added

Table 4. Results of multiple linear regressions performed on the 2 indicators Tmin_diff, Tmax_diff using the physical characteristics: i) surface, ii) residence time. Significant pvalue are in bold.

Dependent variable Independent variable physical characteristics R2 standardized coefficient pvalue

Tmax_diff surface 0.72 0,39 0.041 residence time 0.80 0.001

Tmin_diff surface 0.68 -0.13 0.48 residence time 0.80 0.001

"7. Section 3.7 – this section does not provide a synthetic view of any of the data, and the intent of this section is unclear. Suggest removing it entirely."

We agree, and have added new text section 3.7 L 234 to 239 to present a more synthetic view of the data. We hope that we have made the intent more clear.

L 234 Focus on temperature pattern in short period of time in intra-daily temperature variation. Previous text: L 235 239 Looking more specifically on a short period of time (three consecutive days), differences in the diurnal variation of the temperature of the river upstream and downstream of the dam shows that for the first group A, the maximum water temperatures upstream and downstream are close, while the minimum temperature downstream does not return to that of upstream (Fig. 9A). In the second group B the water temperature difference between upstream and downstream are more important and remain persistent during all the day period (Fig. 9B). Replaced by To further illustrate the different thermal regime effects from our typology analysis, we compare intra-daily temperature variations for a three-day time series in group A (small thermal effect) with group B (large thermal effect; Fig. 9): - In the example of group A (Fig. 9A), the downstream temperature is generally warmer than the upstream temperature (observed difference of 1°C warmer) except for a few hours during the three day sample observation period. The biological benchmark of 22°C is exceeded both upstream and downstream during the day of August 20. The rest of the time, temperatures are below this threshold. From a biological point of view, the duration above the thermal threshold is short, preceded and followed by more favorable temperatures (i.e., the remission period). - In the example of group B (Fig. 9B), the downstream temperature is systematically higher than that of the upstream, with a temperature difference varying between +0.8–2.4°C. The 22°C threshold is exceeded downstream for a cumulative 42 h over the three-day period. August 15 and 16 have downstream temperatures that rarely go below 22°C, leaving no time for thermal remission (return to a temperature that is better tolerated physiologically by fish). At the same time, the upstream part of the stream is maintained at daily temperatures not exceeding this threshold. - Additionally; differences in the diurnal temperature variation upstream and downstream of the dam shows that for group A, the maximum water temperatures are close, whereas the minimum temperature downstream does not return to that of upstream (Fig. 9A). In group B the water temperature difference between upstream and downstream are persistent throughout the diurnal cycle (Fig. 9B). For all sites, by studying the average daily duration with a temperature exceeding 22°C continuously, we can see (Fig. 10): - downstream durations are always greater than or equal to that of the upstream durations, regardless of site typology, - the largest upstream/downstream differences occur in the group B2 group, - group A is generally not affected by an upstream/downstream increase, except for two sites which exhibit a two hour increase.

In addition, we added the following new text in 2.4 Data Analysis to further clarify the point of this section about biological importance of thermal effects.

To assess the potential biological importance of dam thermal effects, we also calculated 1) the number of days that water temperatures were greater than 22°C, and 2) the mean of the maximum daily duration (in hours) where water temperature was greater than 22°C. We chose 22°C as an illustrative threshold known to be a thermal stress benchmark value for salmonids (Elliott and Elliot, 2010; Ojanguren et al., 2001).

Previous text : L 162 (iv) the dam thermal effect considering an arbitrary threshold of 22 °C, with a calculation of the number of days above this threshold.

We also added a new synthetic analysis of intra-daily durations above the defined biological threshold. So, we added this text to the data analysis section:

4. calculation of the number of days above the biological 22°C threshold, and 5. calculation of the average maximum daily duration (in hours) above the biological 22°C threshold.

And we further added a sentence to clarify why the threshold was chosen L346: The threshold temperature of 22 °C known to be a thermal stress benchmark value for salmonids especially for brown trout (Salmo trutta) is also known to be important for the life cycle of aquatic invertebrates (Ward, 1976; Brittain and Salveit, 1989).

"8. Section 3.8 – the arbitrary nature of this analysis provides little insight or direct ecological interpretation. In the discussion the authors correctly indicate that the choice of a 22 degree is actually not arbitrary, but has a basis in that temperatures above this point are generally deleterious to salmonids. Although I think this section could be a valuable contribution by the research, the fragmented presentation leads me to suggest removing it entirely."

Fixed; see above.

"9. In the discussion, the authors talk about different years (hot vs. cool, or wet vs. dry), but none of the analysis really looks into this. I think it is an important point, so would like the authors to explore and quantify this in a reasonable way. "

Response: Fixed with new fig. 2 and fig. 5

"10. In the introduction and discussion, the authors talk about the importance of dam and reservoir size, but don’t do any formal analysis. At a basic level, it would seem that correlation or regression of reservoir area, and another analysis with residence time, on the response variables of mean temperature difference, mean difference in maximum temperature, and mean difference in minimum temperature would be an important starting point."

Response: The new statistical analyses (Redundancy analysis, multiple regressions) developed above answer this question.

"11. The discussion of biological effects was quite thorough."

Technical Comments: "1. Many grammatical errors – far more than is appropriate for a scientific reviewer to make edits on, but these need to be addressed before publication."

Fixed.

"2. The citation for Dunham et al. is incomplete, but I applaud investigators for addressing instrument calibration issues, which are often ignored!"

Fixed.

We hope we have satisfactorily replied to your comments and issues, which we believe substantially increased the readability and understanding of this manuscript.

Best regards,

The AuthorsâĂČ

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-136/hess-2019-136-AC1-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-136, 2019.

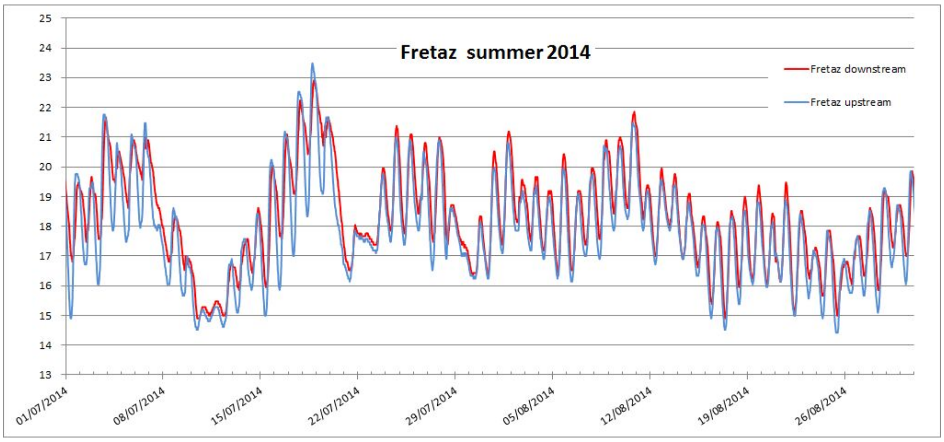

Fig. 1. Figure 2. Time-series of water temperature (°C) upstream (blue) and downstream (red) of the dam Fretaz, Veyle stream, respectively in years 2014 and 2016.

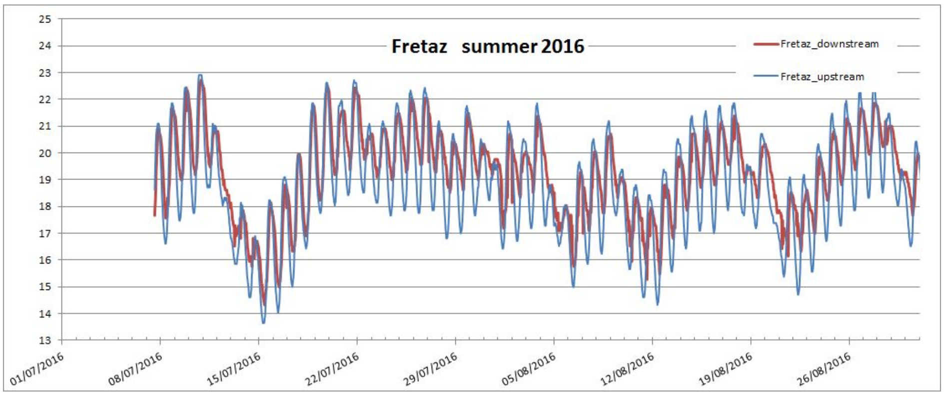

Fig. 2. Figure 2. Time-series of water temperature (°C) upstream (blue) and downstream (red) of the dam Fretaz, Veyle stream, respectively in years 2014 and 2016.

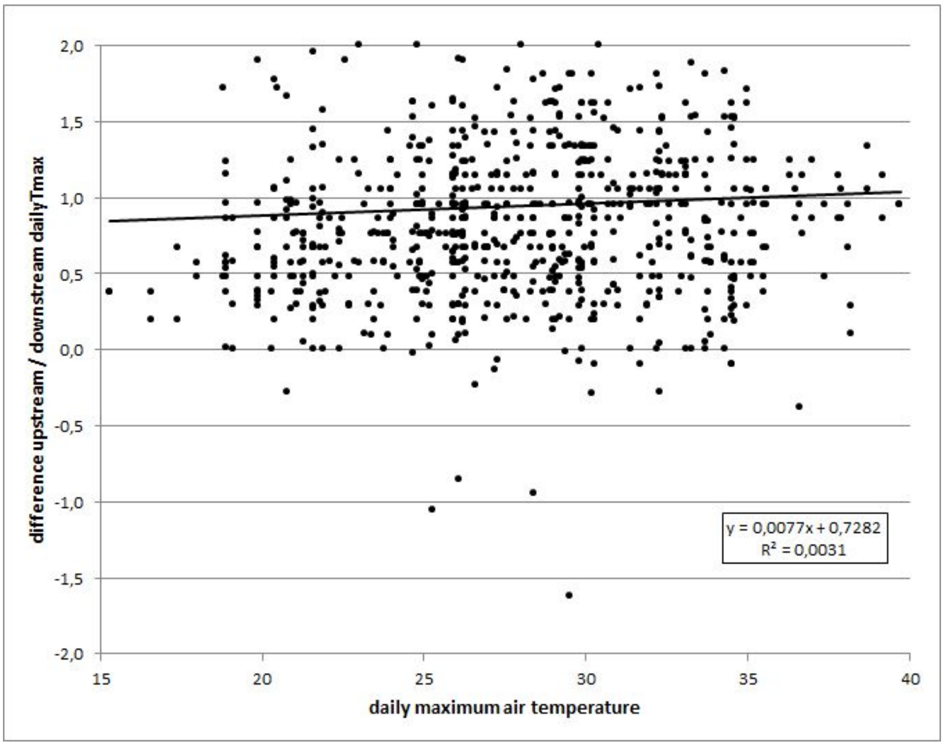

Fig. 3. Figure 5. Relation between daily maximum air temperatures (°C), daily upstream/downstream temperature differences for all the data available for the study.

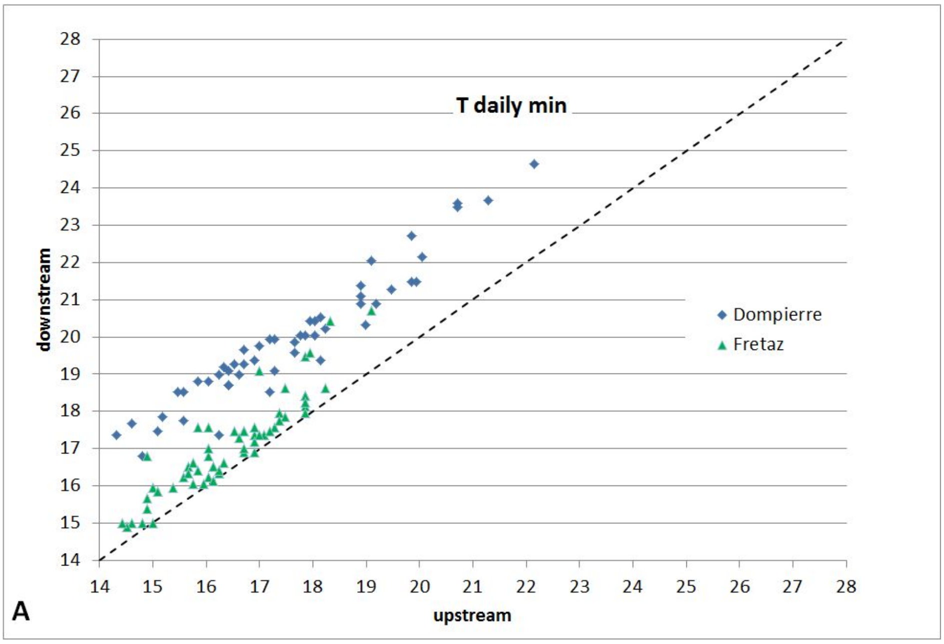

Fig. 4. Figure 4. Minimum (A) and maximum (B) daily temperatures upstream and downstream of the dams-of-the river (Dompierre site, Veyle stream in 2010; Fretaz site, Veyle stream in 2014). Dashed line is 1:1

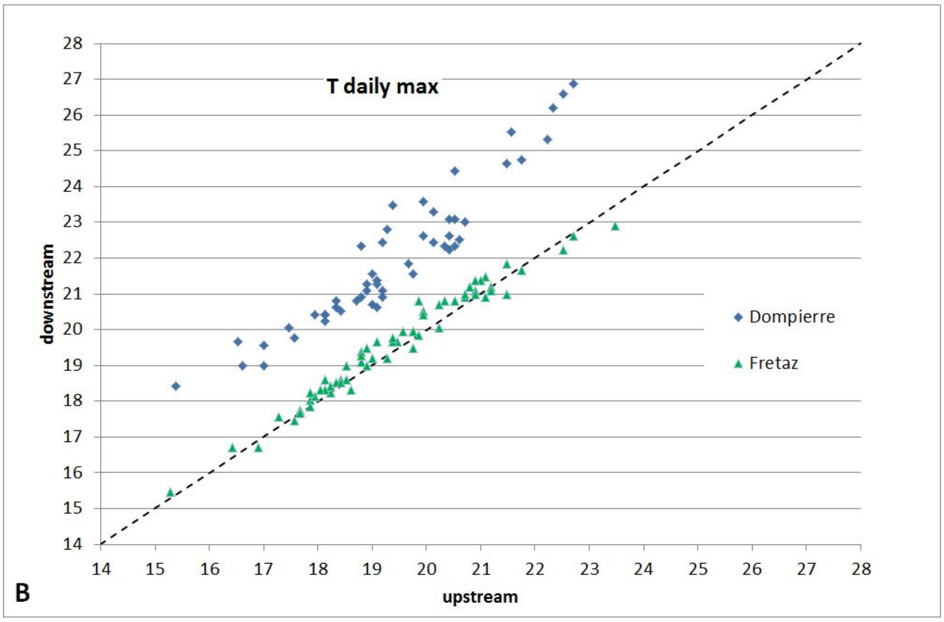

Fig. 5. Figure 4. Minimum (A) and maximum (B) daily temperatures upstream and downstream of the dams-of-the river (Dompierre site, Veyle stream in 2010; Fretaz site, Veyle stream in 2014). Dashed line is 1:1

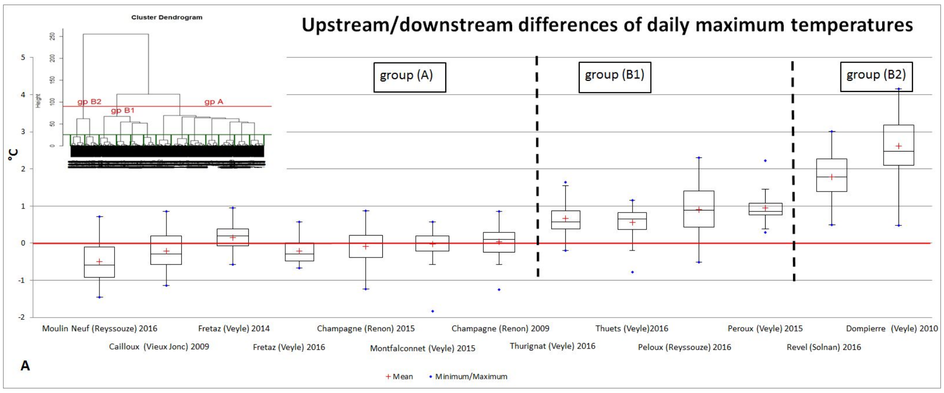

Fig. 6. Figure 6. Box-plot distribution (25% - 75 %) of upstream/downstream differences of daily maximum (A) and minimum (B) temperatures for all the time-series studied. (Red lines: 0°C for daily maximum te

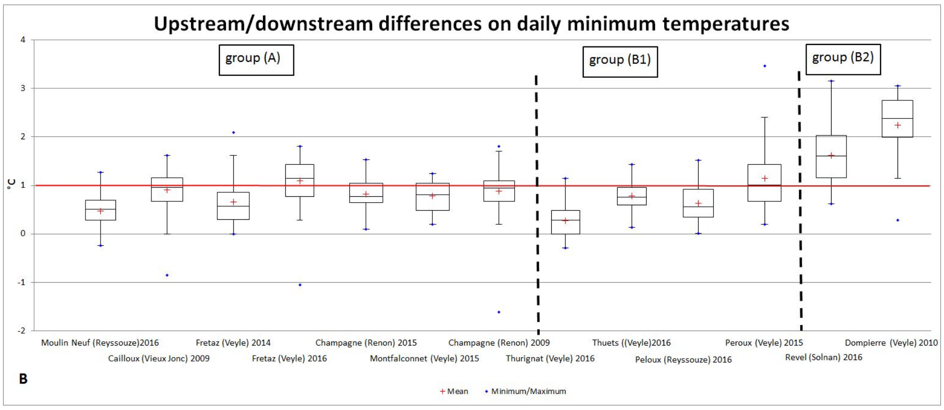

Fig. 7. Figure 6. Box-plot distribution (25% - 75 %) of upstream/downstream differences of daily maximum (A) and minimum (B) temperatures for all the time-series studied. (Red lines: 0°C for daily maximum te

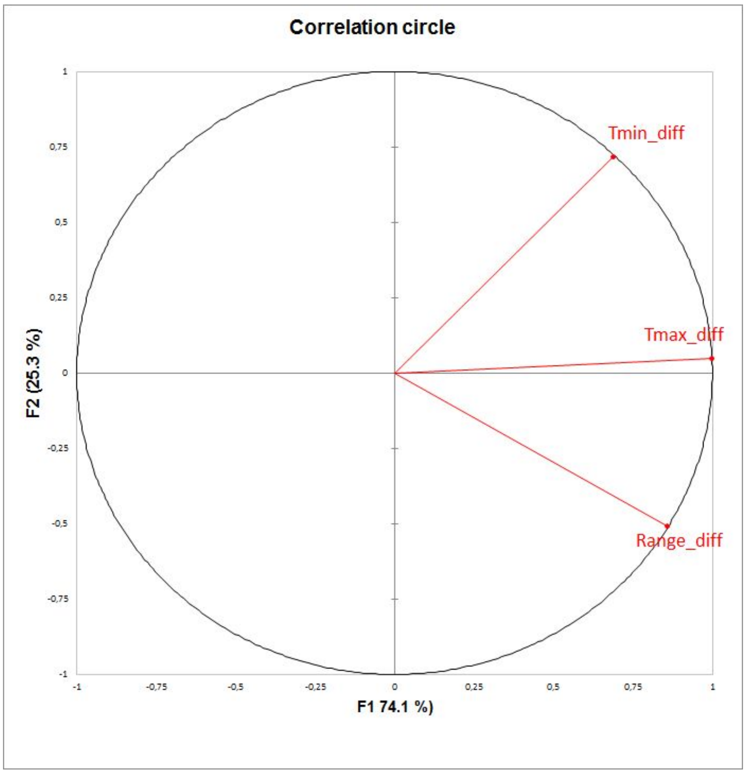

Fig. 8. Figure 7. PCA analysis. Correlation circle with temperature as active variables

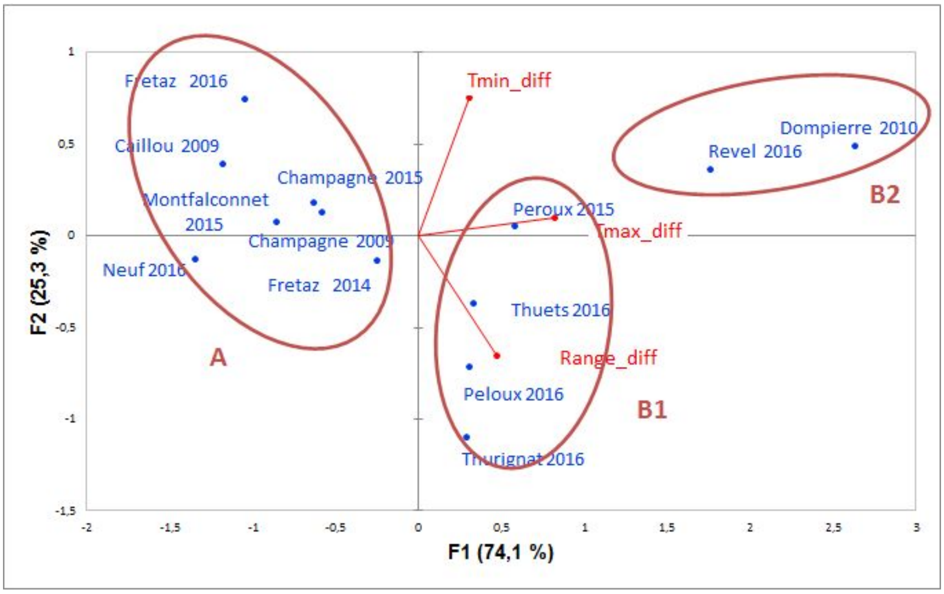

Fig. 9. Figure 8. PCA analysis. Scatterplot of time series. Ellipses are drawn to visualize the groups obtained with the hierarchical cluster analysis

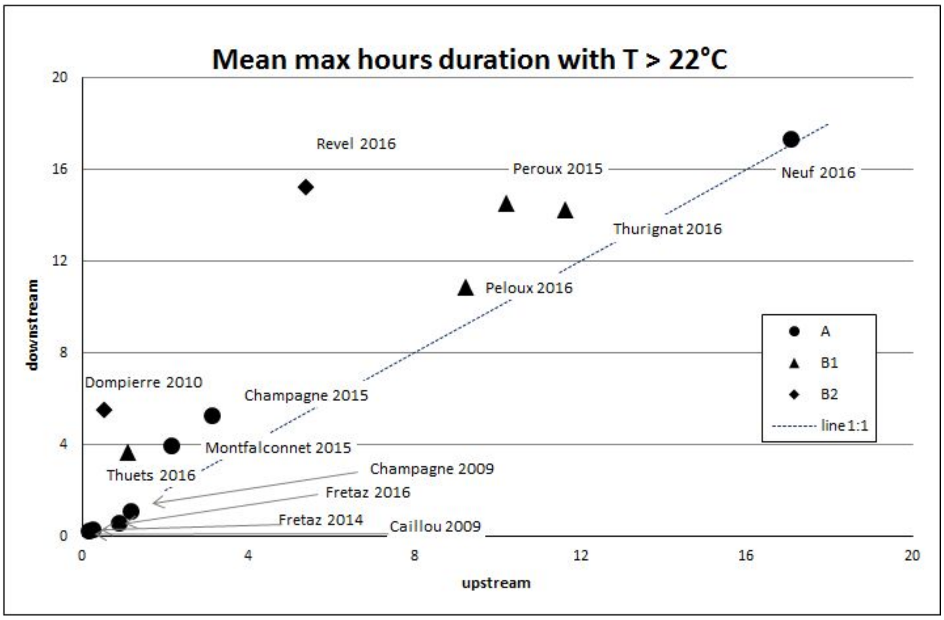

Fig. 10. Figure 10. Mean of the daily maximum duration with T above 22 °C , upstream and downstream each site monitored in the study. A (circles), B1 (triangles), B2 (rhombus) are the groups of sites resulting