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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Recent trends in climate variability at the local scale using 40 years of observations: the case of the Paris region of France" *by* J. Ringard et al.

J. Ringard et al.

justine.ringard@latmos.ipsl.fr

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First of all, we would like to thank the anonymous reviewer for the detailed and rich bibliography return.

The general remark is the non-consideration of temperature-humidity covariance via a pure thermodynamical variable.

1st general comment of reviewer #1: "the authors do not use the correct definition of thermodynamics in their analysis" It is true that our study focused in part on the temperature and humidity, as well as on the precipitation trends observed in the Paris

area. There are many thermodynamical variables in the bibliography proposed by the reviewer #1. Most of them are based on different comfort algorithms as detailed in Buzan et al., 2015. These variables give a better indication of human heat stress, hence the terms "thermal comfort" or "feel-like" temperature are used, as highlighted by Matthews et al., 2017. The majority of these indicators, such as HI (Heat Index), HUMIDEX or Tw (Wet Bulb Temperature), use both temperature and relative humidity and are based on risk levels determined by thresholds. In this study, our objective is not to characterize heat stress via a purely thermodynamic variable but to characterize the part of the changes in temperature and precipitation that are related to thermodynamical processes, i.e all processes which modify the content of heat and moisture of the atmosphere but large-scale advection (through surface heat and radiative fluxes, phase changes, radiative effects of particles, Clausius-Clapeyron equation…). The partitioning method used in the manuscript to determine the dynamical and thermodynamical contributions of the trend is widely used (Cassano et al., 2007; Horton et al., 2015; Screen, 2017; Uotila et al., 2007). This method assumes that each weather regime is stationary in time, which is probably not perfect. Hence, the dynamical contribution corresponds to the changes in the occurrence frequency of each circulation pattern, assuming that the circulation patterns are the same during the two periods (but they have been computed overall years covering at least the two periods so that the differences between the two periods are minimized). The thermodynamical contribution inside a weather regime is the result of influences unrelated to circulation, such as changes in long-wave radiation from increasing greenhouse gas concentrations or different cloud macro and microphysics properties, or changes in surface fluxes of moisture and/or radiation. The third component represents the interaction between dynamic and thermodynamic changes, and captures contributions that result from changes in the dynamical component acting on changes in the thermodynamical component. To better understand the dynamical and thermodynamical terms used here, I will add a paragraph similar to the one above in the manuscript.

Summing the thermodynamical (dynamical) change over all weather regimes gives the total thermodynamical (dynamical) change. For example, the observed trend in summer precipitation (Figure 1) result from thermodynamical changes to 67.8% such as radiation, surface fluxes or moisture change as well as dynamic changes to 32.5% (occurrence of weather regimes). Together, these results suggest that the observed increase in summer precipitation is attributable to both increasing frequency of NAO-weather regimes and changes in the surface water and energy balance. The first version of the manuscript omits the residual term in the contribution tables. In the new version, an additional column will be added, see Figure 1 and 2 below.

2nd general comment of reviewer #1: "Temperature and humidity are analyzed independently, when there is well established literature demonstrating these variables are co-dependent. Temperature and humidity covary together, and non-linearly in extreme regimes. [. . .] I cannot determine if this was taken into account."

Indeed, in this paper, temperature and relative humidity are measured and analyzed independently. The specific humidity q, is computed as a thermodynamical variable based on temperature and relative humidity via the formula below:

q= (0.622* p_sat(T)*RH)/(101325- p_sat(T)*RH)

With p_sat(T)=exp[23.3265- 3802.7/T- (472.68/T)ˆ2]

RH: relative humidity from 0 to 1

T: temperature in Kelvin

psat(T): saturated vapour pressure in Pascal

To address the question of Reviewer #1, we completed our analysis by computing the Wet bulb temperature (Tw) based on the formulation of Davies-Jones, 2008 as advised by the reviewer. The figures below present the analysis of Tw at the Montsouris station because the pressure is required for Tw estimations, and it is available since 1979 only for Montsouris, so we can't do this analysis with the other stations.

From a seasonal analysis (Figure 3) no trend is significant for Tw, unlike T2m. In Summer (JJA), although the PDFs of T2m (in black) present changes in the extreme values, the PDFs of Tw, are very similar especially since the decrease in relative humidity compensate the increase in temperature, causing little change in heat stress. The same characteristics are observed by classifying the summer season into four weather regimes (Figure 4).

The reviewer proposed to change Figure 13 of the manuscript to only represent Tw and PRCP (Figure 5). Although Tw is interesting to analyze we think that Tw does not really reflect our objective, which is relative to the understanding of the modification of the local water cycle, especially the presence of a possible surface drying which will impact the formation of clouds and precipitation. For such topic, relative and specific humidity are better adapted. The other reason is that precipitation depends on temperature and humidity and we need to have these two informations independently.

Figure 6 shows the seasonal averages of the T2m/q relationship and the T2m/Tw relationship (same as figure 14 in the paper but exclusively for Montsouris). Very similar patterns between q and Tw supports the idea that q plays the role of thermodynamic variable without necessarily needing information on heat stress.

The reviewer suggests to use the "maximum wet bulb temperature" used by Sherwood and Huber, 2010 on figure 13 of the manuscript. They calculated Twmax histograms as the annual maxima accumulated over the globe (ERA-Interim grid) and year (1999-2008). In our case if we apply the same method we would have a PDF1979-2002 built with only 24 points (one location, 24 years) and a second PDF2003-2017 built with 15 points. This is a very unrepresentative sample to plot a distribution.

Regarding the calculation of "heat stress", in addition to HI, Diffenbaugh et al., 2007, also use Tmax and Tmin. Mueller and Seneviratne, 2012, who show that surface moisture deficits are a relevant factor for the occurrence of hot extremes, define Tmax over the 90th percentile. In our paper we don't use any co-dependent variables but

Tmax and Tmin are used for extreme index calculations, giving a first indication of the trend of the thermal extremes.

In our paper we focus on the observed trends and we want to keep the independent analysis between temperature and relative humidity, because this surface drying can play a major role in the trend of other variables such as turbulent flows, and thus can intensify or inhibit existing surface-atmosphere feedbacks. Specific humidity allows to account for the link between temperature & humidity. As thermal comfort is not the main object of the article and do not bring very different information compares to specific and relative humidity, the choice was made not to add information on thermal comfort in the article.

The perspective of this study is to use SIRTA supersite (near Paris) which measures more meteorological variables at hourly resolution since 2003, in order to identify the processes explaining the trends and to improve our knowledge on these surface-atmosphere processes at the local scale.

Buzan, J. R., Oleson, K. and Huber, M.: Implementation and comparison of a suite of heat stress metrics within the Community Land Model version 4.5, Geosci. Model Dev., 8(2), 151–170, doi:10.5194/gmd-8-151-2015, 2015.

Cassano, J. J., Uotila, P., Lynch, A. H. and Cassano, E. N.: Predicted changes in synoptic forcing of net precipitation in large Arctic river basins during the 21st century, J. Geophys. Res. Biogeosciences, 112(G4), n/a-n/a, doi:10.1029/2006JG000332, 2007.

Davies-Jones, R.: An Efficient and Accurate Method for Computing the Wet-Bulb Temperature along Pseudoadiabats, Mon. Weather Rev., 136(7), 2764–2785, doi:10.1175/2007MWR2224.1, 2008.

Diffenbaugh, N. S., Pal, J. S., Giorgi, F. and Gao, X.: Heat stress intensification in the Mediterranean climate change hotspot, Geophys. Res. Lett., 34(11), doi:10.1029/2007GL030000, 2007.

Horton, D. E., Johnson, N. C., Singh, D., Swain, D. L., Rajaratnam, B. and Diffenbaugh, N. S.: Contribution of changes in atmospheric circulation patterns to extreme temperature trends, Nature, 522, 465, 2015.

Matthews, T. K. R., Wilby, R. L. and Murphy, C.: Communicating the deadly consequences of global warming for human heat stress, Proc. Natl. Acad. Sci., 114(15), 3861–3866, doi:10.1073/pnas.1617526114, 2017.

Mueller, B. and Seneviratne, S. I.: Hot days induced by precipitation deficits at the global scale, Proc. Natl. Acad. Sci., 109(31), 12398–12403, doi:10.1073/pnas.1204330109, 2012.

Screen, J. A.: The missing Northern European winter cooling response to Arctic sea ice loss, Nat. Commun., 8, 14603, 2017.

Sherwood, S. C. and Huber, M.: An adaptability limit to climate change due to heat stress, Proc. Natl. Acad. Sci., 107(21), 9552–9555, doi:10.1073/pnas.0913352107, 2010.

Uotila, P., Lynch, A. H., Cassano, J. J. and Cullather, R. I.: Changes in Antarctic net precipitation in the 21st century based on Intergovernmental Panel on Climate Change (IPCC) model scenarios, J. Geophys. Res. Atmospheres, 112(D10), doi:10.1029/2006JD007482, 2007.

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	Dynamical contribution [mm (%)]	Thermodynamical contribution [mm (%)]	Residual term [mm (%)]	$\Delta PRCP$ [mm]
SUMMER (JJA)	5.32 (***32.5***)	11.10 (***67.8***)	-0.04 (***-0.3***)	16.38
	Dynamical contribution [mm]	Thermodynamical contribution [mm]	Residual term [mm]	$\Delta PRCP_i$ [mm]
NAO-	20.39	-2.85	-0.02	17.53
Atlantic Ridge	-10.27	3.57	-0.01	-6.71
Blocking	-8.70	9.47	-0.02	0.75
Atlantic Low	3.90	0.90	0	4.81

Fig. 1. Dynamical, thermodynamical and residual contributions of the precipitation change (ΔPRCP) in mm for summer (JJA) and for the four weather regimes in summer. Values in parenthesis give the ratio (in %)

	Dynamical contribution [°C (%)]	Thermodynamical contribution [°C (%)]	Residual term [°C (%)]	ΔT [°C]
WINTER (DJF)	0.06 (***29.6***)	0.17 (***78.9***)	-0.02 (***-8.5***)	0.21
SUMMER (JJA)	-0.05 (***-5.9***)	0.87 (***103.2***)	0.02 (***2.7***)	0.84

Fig. 2. Dynamical, thermodynamical and residual contributions of the temperature change (ΔT) in °C in winter (DJF) and in summer (JJA). Values in parenthesis give the ratio (in %) between the change component

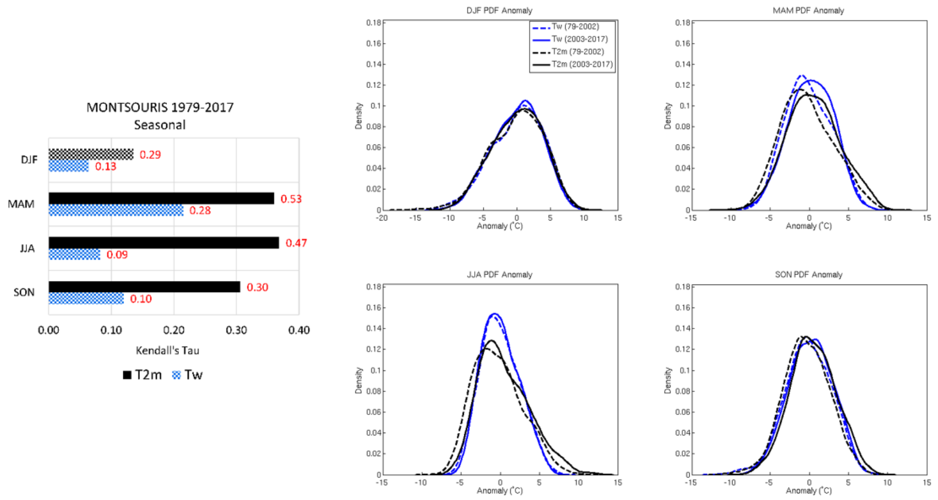

Fig. 3. Left: Mann Kendall seasonal trends for T2m in black and Tw in blue. The red value represents the Sen slope in units per decade. A solid bar indicates a significant trend for a confidence interval of p

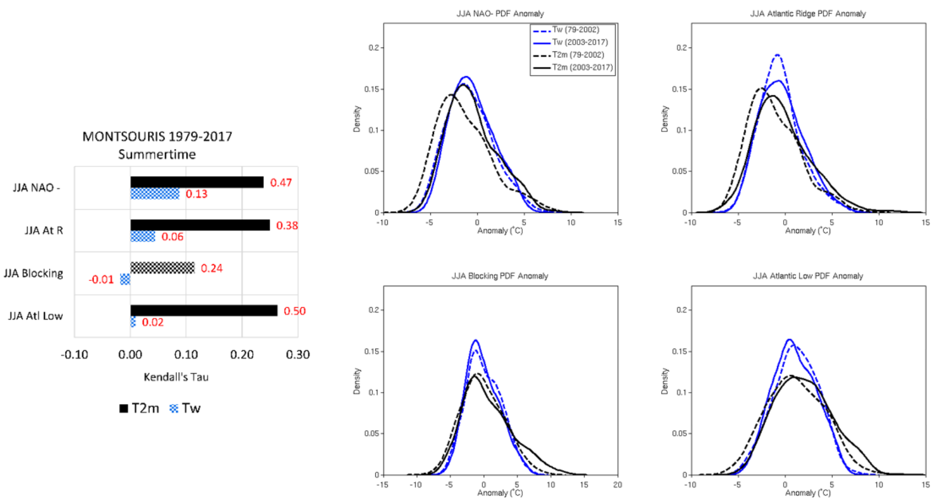

Fig. 4. Same as Figure 3 but for summer weather regimes

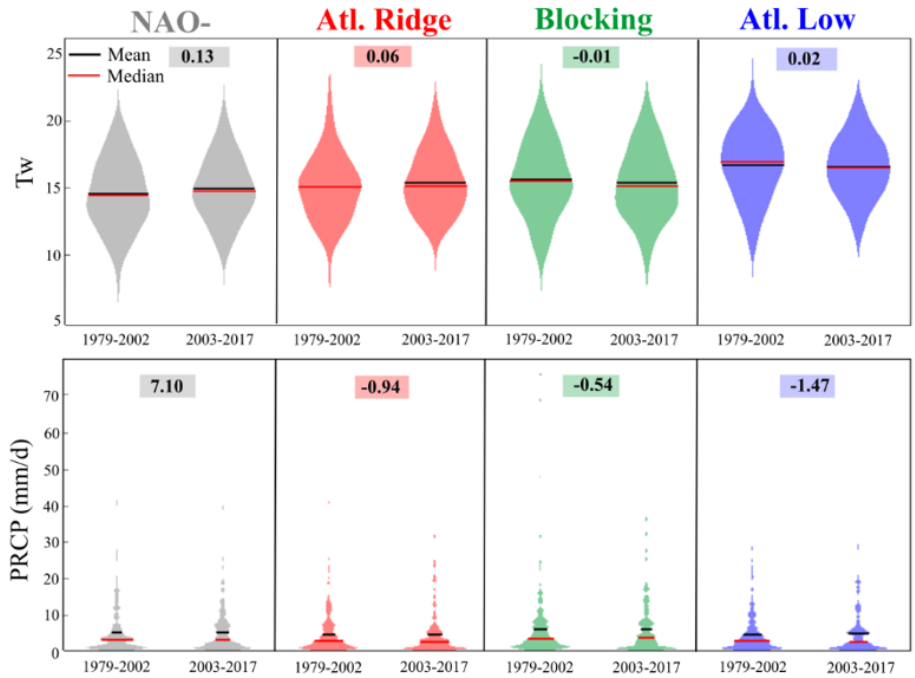

Fig. 5. Violin plot of daily Tw (first line) and PRCP (second line) for the four weather regimes between the periods 1979-2002 and 2003-2017. Box numbers represent trends in unit decade-1 over the period 1979

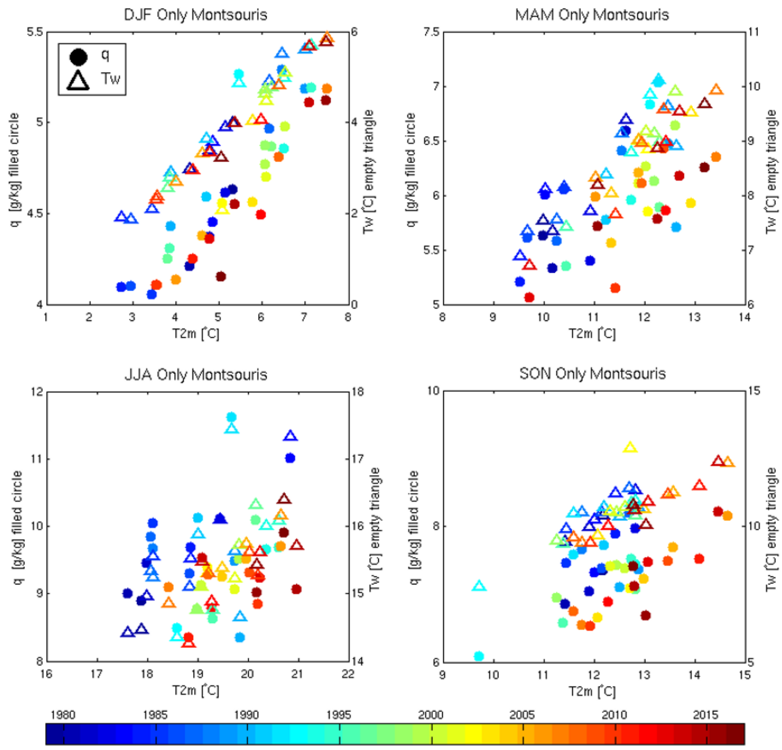

Fig. 6. T2m – q seasonal relationship in Montsouris in filled circle, and T2m – Tw seasonal relationship in Montsouris in empty triangle. Each point represents the seasonal average of one years.