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Comment on "Winter 'weekend effect' in southern Europe and its connection with periodicities in atmospheric dynamics" by A. Sanchez-Lorenzo et al.

H. J. Hendricks Franssen,[1,2] Thomas Kuster,[2] Peter Barmet,[2,3] and Ulrike Lohmann[2]

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1. Introduction

[1] There is an on-going scientific debate whether meteorological variables show a weekly cycle or not. *Sanchez-Lorenzo et al.* [2008] (hereinafter referred to as SL08) find a significant weekly cycle in Spanish meteorological data and argue that this cycle is linked with a weekly cycle in European air pressure (p_{air}) distributions. Their two main arguments are: 1) The Spanish p_{air} data show a significant weekly cycle, 2) The frequency of circulation pattern number 3 (with an anticyclone above the British Islands) shows a significant difference between Sunday and Monday on one hand and Wednesday on the other hand.

[2] In this paper, we present our analysis of the Spanish p_{air} data, based on Monte Carlo (MC) analysis, non-parametric tests and Fourier analysis and conclude that no significant weekly cycle in these data is present. It is explained why SL08 find a significant cycle and what was, in our opinion, the reason that they came to this erroneous conclusion. It is also argued that the second main argument of SL08 for a weekly cycle (on the basis of circulation patterns over Europe) is the result of a misinterpretation of the statistical test results.

2. Data and Methods

[3] The same p_{air} data from 12 Spanish meteorological stations were used for analysis as SL08 did. The data were kindly provided to us by A. Sanchez-Lorenzo. The time series of average p_{air} over the 12 Spanish stations was calculated for the winter months in the period January 1961–December 2004. If the p_{air} measurements were not available for all 12 Spanish stations, the average was calculated over the smaller subset of meteorological stations (like SL08 did). The mean weekly cycle of p_{air} anomalies that *Sanchez-Lorenzo et al.* [2008, Figure 1f] found could be exactly reproduced. Although we use the same data as SL08 did, we would like to criticize the data selection because no physical explanation is provided for only analyzing data from the winter season. Only p_{air} was analyzed as data for the other meteorological variables show a less pronounced weekly cycle, with an anomaly that is always smaller than two standard deviations of the mean (Figure 1 of SL08 plots one standard deviation around the mean).

[4] The time series of average Spanish p_{air} was analyzed with help of a MC technique. The complete time series was 1000 times randomly shuffled (the same measurement data are used), and for each of these simulated realizations of the random function the weekly cycle of p_{air} was calculated. Any weekly cycle present in the original data should be removed with this procedure. Therefore, the simulated realizations help to find out to what extent a weekly cycle is present under "random conditions". For each of the simulated realizations the maximum p_{air} anomaly with respect to the overall mean (0.40 hPa for the original time series), the number of days with an anomaly larger than 0.30 hPa (3 for the original time series) and the weekly cycle of the p_{air} anomaly (0.79 hPa for the original time series) were calculated, and probability density functions of these measures were derived. As these analyses do not test the shape of the weekly cycle, three other tests were carried out. First, 1000 simulated realizations of 44 winter seasons of p_{air} were generated with temporal autocorrelation, using sequential Multi-Gaussian simulations. The statistics needed to generate these realizations (mean, variance, temporal autocorrelation) were estimated from the Spanish measurement data. It was tested that, on average, the 1000 realizations have the same mean, variance and temporal autocorrelation as the original data. The weekly cycle in the realizations was analyzed according to:

[5] 1. Individual weekdays that had an average p_{air} above the overall mean p_{air} were assigned the value "1", individual weekdays with a value below the mean were assigned the value "0". The number of jumps J between "1" and "0", cycling through all the weekdays (i.e., from Sunday to Monday, Monday to Tuesday, until Saturday-Sunday) was counted. If the weekdays are perfectly separated in a block with positive anomalies and another block with negative anomalies, $J = 2$, as was the case for the Spanish data. For each of the 1000 simulated realizations J was determined.

[6] 2. The p_{air} anomalies for the different weekdays were ranked: 1 for the largest negative anomaly, 2 for the second largest negative anomaly, and so on until 7 for the largest

[1]Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland.
[2]Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland.
[3]Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen, Switzerland.

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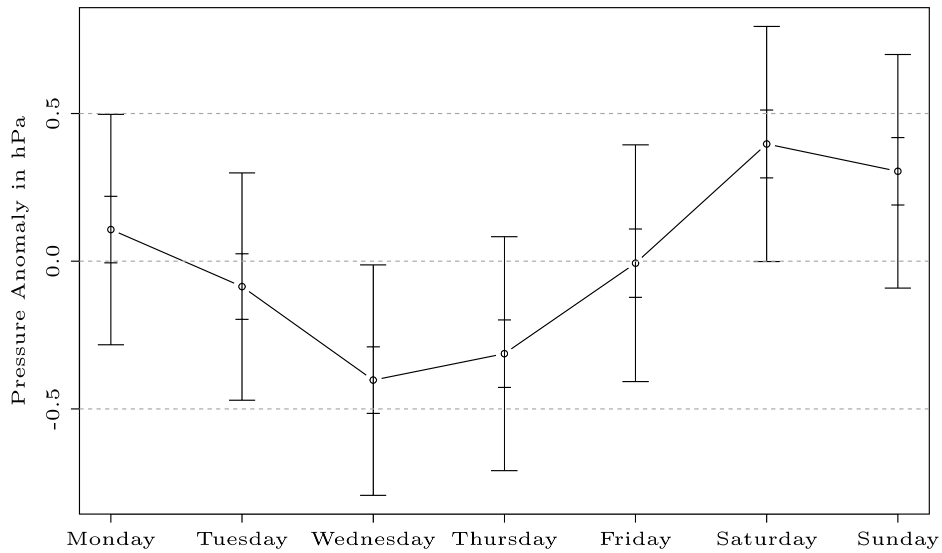

Figure 1. Mean weekly anomalies for p_{air}, averaged over the 12 Spanish time series in the 1961–2004 period. Error bars show the standard deviation of the everyday mean. The smaller intervals correspond to calculations where the time series are considered to be independent, whereas the larger intervals were obtained taking correlations between stations into account. Compare with Figure 1f of SL08.

positive anomaly. The smoothness S of the weekly cycle is measured by summing up the differences in ranking between subsequent weekdays (i.e., Sunday versus Monday, Monday versus Tuesday, until Saturday versus Sunday), cycling through all week days. The lower S, the smoother the weekly cycle. For the Spanish p_{air} measurements $S = 12$ (from Figure 1f in SL08). Here it was checked how many of the simulated realizations had $S \leq 12$ (i.e., were equally smooth or smoother than the Spanish data).

[7] Second, the original time series of p_{air} data was analyzed further with the Kruskal-Wallis test, a non parametric method for testing the equality of medians among the groups (week days). The null hypothesis is that the mean ranks of the groups do not differ substantially, while the alternative is that they differ for at least one pair of groups. Third, the data were analyzed with help of a Fourier analysis [*Barmet et al.*, 2009].

3. Results

[8] The MC analysis on the basis of random shuffling the data revealed that p_{air} anomalies of at least 0.40 hPa with respect to the overall mean occurred in 78% of the simulated realizations. 42% of the simulated realizations had at least three days with a p_{air} anomaly of at least 0.30 hPa. For 67% of the simulated realizations the weekly amplitude of p_{air} anomalies is larger than for the Spanish time series (0.79 hPa). All these results indicate that the p_{air} anomaly for the Spanish data is not significant.

[9] A simple calculation can make clear that the anomalies for individual weekdays that SL08 found are not significant. The standard deviation for p_{air} for a given weekday lies between 8.0 hPa and 8.4 hPa (depending on the day). Assuming a normal distribution (which underestimates in this case somewhat the uncertainty of the mean) for the p_{air} data (and on the basis of in total 567 observations per weekday (winter months between 1961 and 2004)), the standard deviation of the estimated mean is 0.34 hPa. This standard deviation is much larger than the one provided by SL08 in Figure 1f. Why do SL08 underestimate the standard deviation of the mean? We get very similar standard deviations of the mean as the ones SL08 provided if we assume $567 \times 12 = 6804$ observations. This would imply that SL08 calculated weekly cycles for each of the individual stations, averaged them, and calculated confidence intervals as if they would have 6804 independent observations (i.e., neglecting statistical dependency between time series of different stations). However, the p_{air} time series of the twelve meteorological stations are strongly correlated and even the time series of the two stations that are furthest separated in geographical space (Malaga and San Sebastian) show a linear correlation of 0.74. We recalculated Figure 1f of SL08, assuming the meteorological stations to be independent on one hand, and found similar results as SL08, and considering – correctly – the correlation between stations on the other hand. The results of these calculations are shown in Figure 1. Figure 1 illustrates that the confidence intervals are much broader if the statistical dependency between stations is taken into account.

[10] Next, the smoothness of the Spanish weekly cycle was investigated as outlined in Section 2. It was found that for 532 out of 1000 simulated realizations $J = 2$ and therefore equal to the Spanish time series. Random effects also can explain the smoothness of the Spanish measurement data: 212 out of 1000 simulated realizations had a smoothness value $S \leq 12$. Therefore, the weekly cycle in the Spanish data is not significantly smoother than a random weekly cycle (in order to be significant on the 95% level, less than 50 out of 1000 simulated realizations should have a smoothness value $S \leq 12$). The Kruskal-Wallis test and the Fourier analysis confirm the findings from the MC experiments: the deviations from the medians are not significant, neither for the average over all stations nor for

a single one and the Fourier analysis provides a periodogram without a clear peak at 1/7 d^{-1}.

[11] The second main argument of SL08 is that the frequency of circulation pattern number 3 varies significantly between some days of the week. SL08 analysed nine circulation patterns, and for one of them they found some significant differences between weekdays at the 95% level. If assuming that some weekly cycles occur by chance, one would obtain $0.05 \times 9 = 0.45$ of the circulation patterns to be statistically significant. Statistically one would therefore expect that in nearly half of the cases that nine circulation patterns are tested on a statistically significant weekly cycle at the 95% level, a significant cycle is found for one of them, although it is random.

4. Summary and Conclusions

[12] Weekly periodicity of winter p_{air} data of 12 Spanish meteorological stations for the period 1961–2004 was investigated. Contrary to SL08, no significant weekly cycle in the p_{air} data was found. MC analysis of the Spanish data shows that two-third of stochastic realizations have larger weekly amplitudes of p_{air} deviations from the overall mean than the weekly amplitude of the measurement data. Also the shape of the weekly cycle can be explained by randomness, as the MC analysis and additional statistical testing showed. The results from SL08 can be reproduced if the p_{air} time series are assumed to be independent. However, all the different time series of p_{air} data are strongly correlated. SL08 also found that one of nine European atmospheric circulation patterns differed significantly between different weekdays. However, the fact that only one out of nine circulation patterns shows a significance at the 95% level is itself not significant. Therefore, the supposed statistically significant weekly cycle of meteorological variables is not significant (and therefore not proven) and the result of a statistical analysis that neglected the statistical dependency between p_{air} time series. However, this does not mean that such a weekly cycle would not exist. *Bäumer and Vogel* [2007] found a weekly cycle in German meteorological data, but the significance of that cycle for precipitation and sunshine duration was questioned [*Hendricks Franssen*, 2008; *Barmet et al.*, 2009]. *Laux and Kunstmann* [2008] concluded that temperature exhibits a significant weekly cycle in Europe, whereas precipitation and sunshine duration do not.

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P. Barmet, T. Kuster, and U. Lohmann, Institute for Atmospheric and Climate Science, ETH Zurich, Universitätsstrasse 16, CH-8092 Zurich, Switzerland.

H. J. Hendricks Franssen, Institute of Environmental Engineering, ETH Zurich, Wolfgang-Pauli-Strasse 15, CH-8093 Zurich, Switzerland. (hendricks@ifu.baug.ethz.ch)