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The variability and change of Italian climate in the last 160 years(*)

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Summary. — The awareness of the importance of data quality and homogeneity issues in the correct detection of climate change has increased rapidly in the last few years. Most of the contributions have been addressed to upper air data, however errors and inhomogeneities also concern surface ones. At surface level it is often assumed that such inhomogeneities have random distribution and that, considering a sufficiently large number of series, average records with negligible bias can be obtained. This assumption is likely to be correct if global or hemispheric averages are considered, but it may not be correct at a regional scale. The aim of the work is a rigorous reconstruction of the Italian climate for the last centuries (the longest series start in the late 1700s), with particular attention to the identification of spurious non-climatic signals introduced by changing instruments and methods in the measurement procedures. A data set of 111 precipitation series, 48 minimum and maximum temperature series and 67 mean temperature series was set up, together with the information about the station history (metadata). The records were subjected to a detailed quality control and homogenisation procedure that was extensively supported by a large metadata availability. The series were grouped by means of Principal Component Analysis and regional average records were obtained and analysed for trends. Trend analysis was performed on seasonal and annual basis by means of the progressive Mann-Kendall statistics and the progressive analysis of the linear regression coefficients. A comparison between the homogenized and the original series and the preliminary results of the analysis are presented. Particular emphasis is given to stress the importance of data homogenisation in the correct detection of long-term trends.

PACS `92.60.Ry` – Climatology.
PACS `92.60.Jq` – Water in the atmosphere (humidity, clouds, evaporation, precipitation).
PACS `92.60.Wc` – Weather analysis and prediction.
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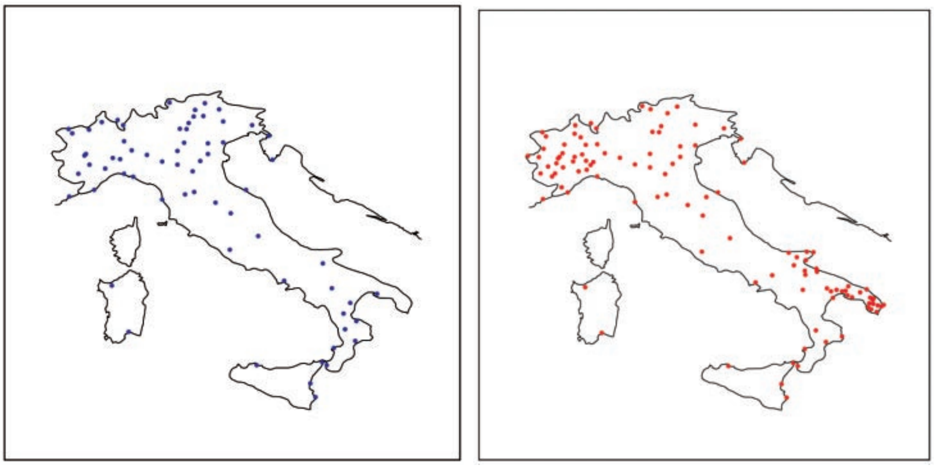


Fig. 1. – Italian stations with secular temperature records (left panel).

Fig. 2. – Italian stations with secular precipitation records (right panel).

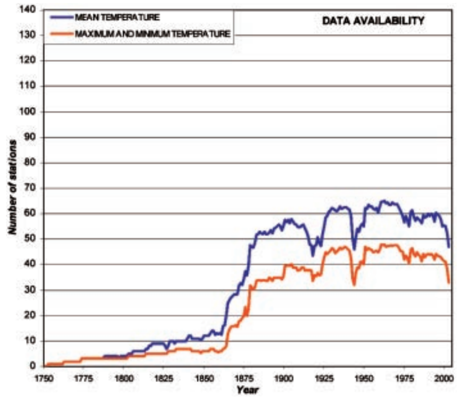
1. – Introduction

The awareness of the importance of data quality and homogeneity issues for a correct detection of climate change has increased rapidly in the last few years. Most of the contributions concern upper air data (see *e.g.* [7,9,8]), however errors and inhomogeneities also concern surface ones. At surface level it is often assumed that they have random disposition and that, considering a sufficiently large number of series, average records with negligible bias can be obtained. This assumption is likely to be correct if global or hemispheric averages are considered, but it may not be correct at a regional scale. A very interesting example of this problem is given by [1] in a paper investigating temperature variability in the Alps and their surroundings based on instrumental series of monthly mean temperatures. In the frame of the EU-project ALPCLIM they subjected around 100 secular temperature records of this area to a detailed quality control and homogenisation procedure and performed a systematic comparison between the original and the corrected records. The results clearly display that the original series are biased by non-climatic noise and, even if the average over all the series is considered, the original data display an error of the long-term amplitude of the temperature evolution in the region of around 0.5 K.

On the light of the results obtained within the ALPCLIM project, in the year 2000 the authors set up a research program with the aim of better investigating the impact of data quality and homogeneity issues on the detection of Italian temperature and precipitation trends in the last two centuries. The final goal was to enlarge, revise, improve and update the data-sets of Italian monthly secular temperature and precipitation series presented in [10, 6] and [2] and to give more reliable long-term trend estimates. The paper displays a synthesis of the preliminary results of the research program. Full details are given in [5].

2. – Data and metadata

Italy boasts a role at the highest level in the development of meteorological observations. As a consequence, a heritage of observed data of enormous value has been accu-



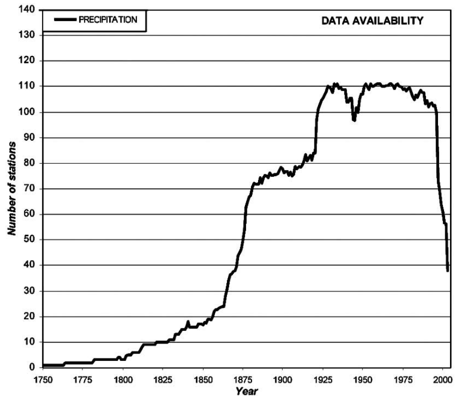


Fig. 3. – Temperature data availability: number of records *versus* time. In case a complete year is missing a record is considered as non available; if the gap is shorter it is considered partially available, according to the fraction of valid data (left panel).

Fig. 4. – Precipitation data availability: number of records *versus* time. In case a complete year is missing a record is considered as non available; if the gap is shorter it is considered partially available, according to the fraction of valid data (right panel).

mulated in Italy within the last three centuries. In spite of its huge heritage of observed data and even if most records have been subjected to some sort of analysis, until a few years ago only a small fraction of Italian data was available in computer readable form. Moreover there was a very poor metadata availability that hampered the possibility to subject the records to an extensively homogenisation procedure. Actually, especially for precipitation records, some series were homogenised [6], however corrections concerned only the most evident breaks, whereas for a large number of minor breaks, due to the lack of metadata, no corrections were performed. So, in the year 2000 a new research programme with the aim of obtaining homogenised Italian secular temperature and precipitation records was established. It was initially developed within a National Project of the Ministry of Agriculture and Forests (CLIMAGRI, see `www.climagri.it`), then an extension of the activities was performed within the EU project ALP-IMP and within two more projects funded by Italian Ministry for Education and Research. Further important activities were developed within the U.S.-ITALY bilateral Agreement on Cooperation in Climate Change Research and Technology. Thanks to the availability of resources from these projects and considering that other activities were in progress in Italy concerning both single stations and Italian regions, the initial objective of homogenising the existing records was enlarged and the construction of a completely new set of data and metadata records was planned too. The monthly precipitation and temperature series included in the new data-set are shown in figs. 1 and 2, whereas figs. 3 and 4 give information on data availability *vs.* time. It is worth noticing that for a significant fraction of the monthly records also daily data are available. This fraction is particularly high for minimum and maximum temperatures whose set of daily data has an availability very close to the one of the monthly data-set. The daily precipitation data-set is presented by [4].

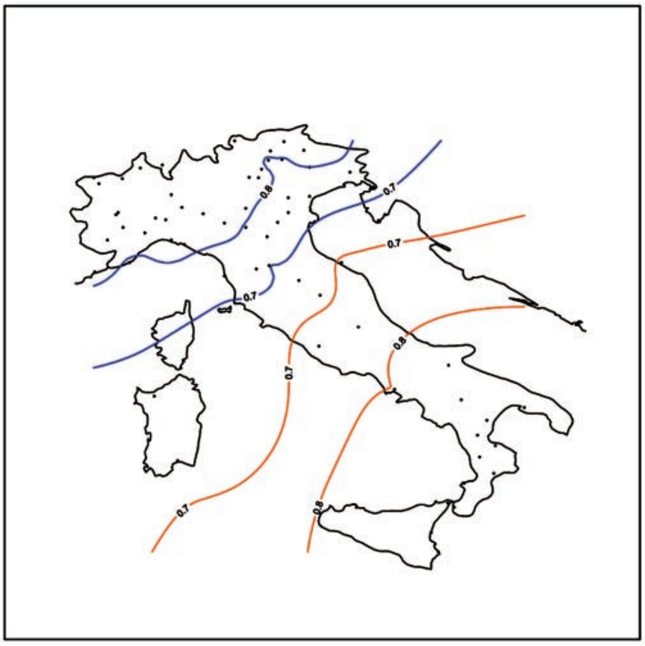


Fig. 5. – Geographical representation of the first two EOFs temperature loadings.

Fig. 6. – Geographical representation of the first six EOFs precipitation loadings.

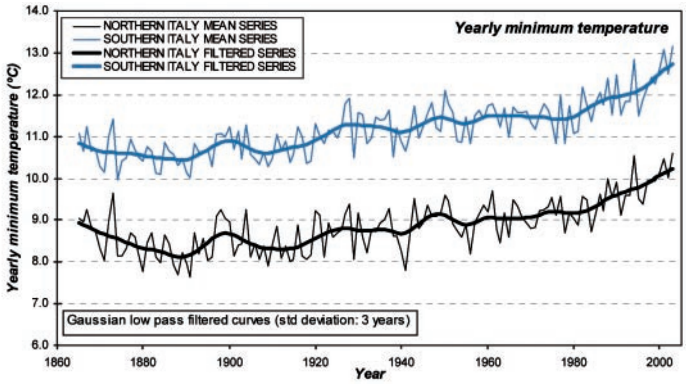


Fig. 7. – Yearly minimum temperature evolution in the 1865-2003 period with Gaussian low-pass filter superimposed.

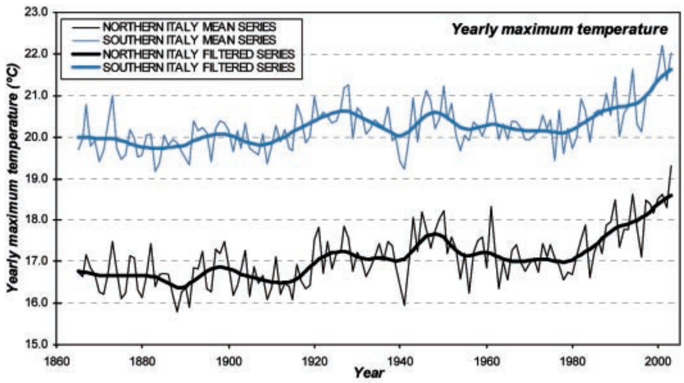


Fig. 8. – Yearly minimum temperature evolution in the 1865-2003 period with Gaussian low-pass filter superimposed.

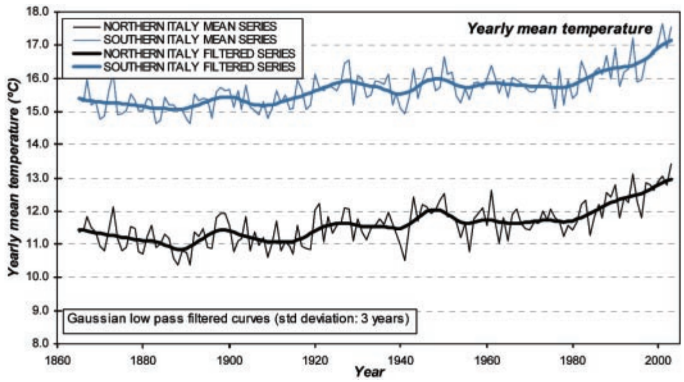


Fig. 9. – Yearly mean temperature evolution in the 1865-2003 period with Gaussian low-pass filter superimposed.

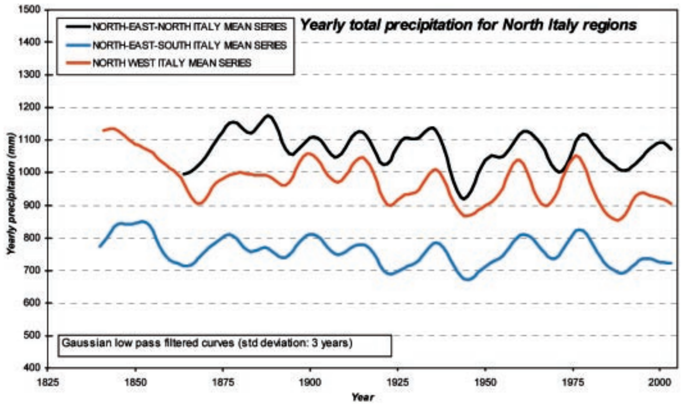


Fig. 10. – Gaussian low-pass filtered yearly precipitation evolution.

3. – Methods and preliminary results

3·1. *Quality check and missing data filling*. – All the daily records were quality checked by a method that consists of carrying out crossed control and individually analysing all the values that markedly disagree with the ones of the surrounding stations. Then some minor gaps in precipitation records were filled by a method discussed in [4] and monthly series were calculated.

3·2. *Homogeneity testing and record adjustment*. – The monthly records were tested for homogeneity by means of a procedure that rejects the *a priori* existence of homogeneous reference series. Each series was tested against each other series in subgroups of 10 series. The break signals of one series against all others were then collected in a decision matrix and the breaks were assigned to the single series according to metadata and/or to probability.

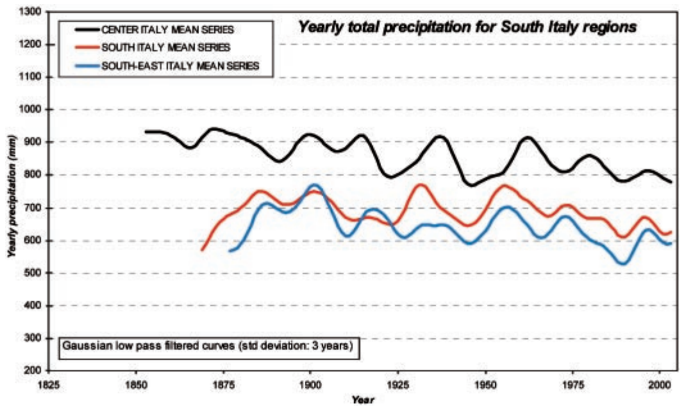


Fig. 11. – Gaussian low-pass filtered yearly precipitation evolution.

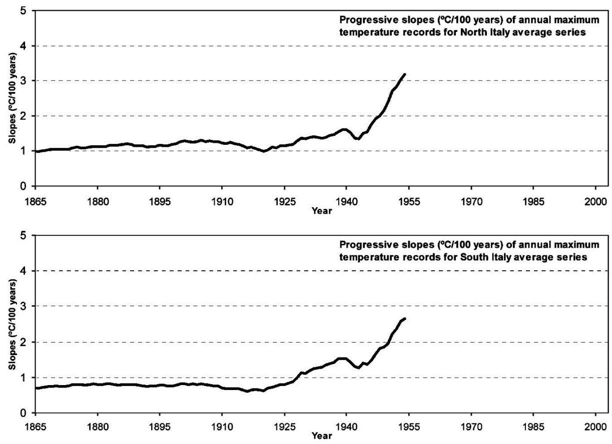


Fig. 12. – Progressive slopes (°C/100 years) of yearly maximum temperature. Thick lines indicate trends with significance level greater than 95%.

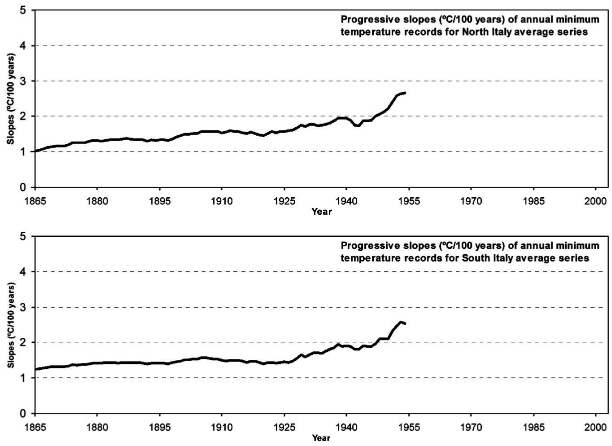


Fig. 13. – As in fig. 12 but for minimum temperature.

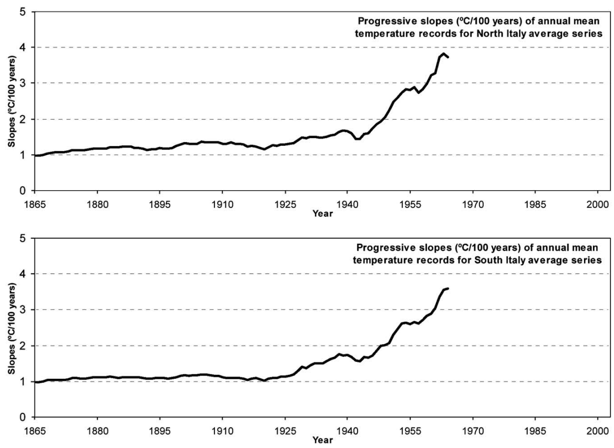


Fig. 14. – As in fig. 12 but for mean temperature.

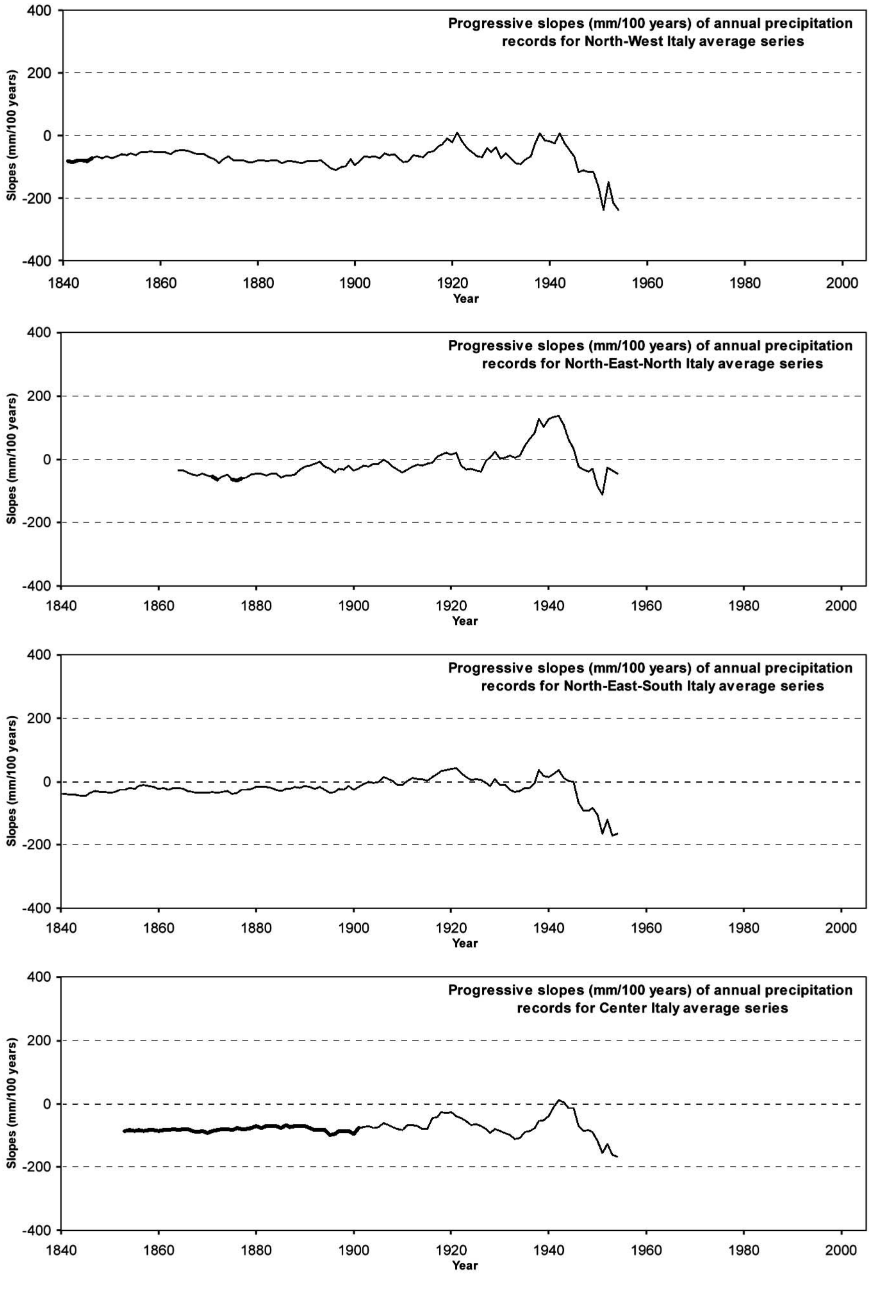


Fig. 15. – As in fig. 12 but for precipitation.

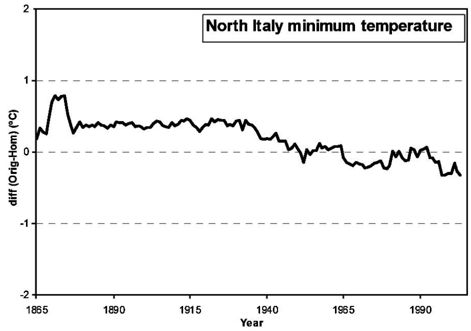


Fig. 16. – Estimated average bias of the Northern Italy original minimum temperature records.

3˙3. *Station clustering and calculation of regional average series.* – The temperature and the precipitation records were clustered into homogeneous regions by means of a Principal Component Analysis (PCA). 2 EOFs, representing Northern and Southern Italy, were extracted both for minimum and maximum temperatures, whereas for Precipitation 6 EOFs were extracted (figs. 5 and 6). The station records of the regions were then averaged and regional average records were obtained. In order to avoid biases due to missing data, the regional records were calculated using a method described in [3]. It consists in adjusting the calculated averages by means of multiplicative (for precipitation) or additive (for temperature) correcting factors. Regional averages for precipitation were calculated only when there were at least five series, whereas, for temperatures, they were calculated simply from 1865 because in the previous period some problems of inhomogeneities still persist. Northern and Southern Italy temperature records are displayed in figs. 7 to 9 together with their Gaussian low-pass filtered, whereas figs. 10 to 11 displays the Gaussian low-pass filtered average records of the 6 regions that were obtained for precipitation.

3˙4. *Trend analysis.* – Trend slopes were calculated by means of least square linear fitting, and their significance levels were estimated by the non-parametric Mann-Kendall test. However, trend analysis was not simply applied to the entire period, but was applied progressively to the series starting from $SY(StartingYear) + j$ and ending in the year 2003. The upper limit for j has been selected in order to perform trend analysis over

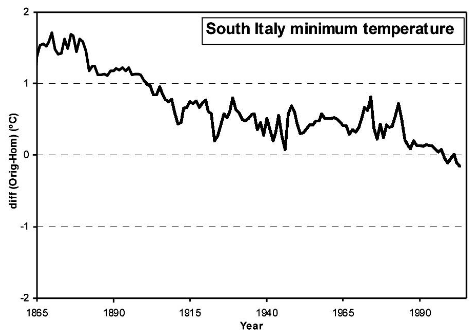


Fig. 17. – Estimated average bias of the Southern Italy original minimum temperature records.

at least 50-year periods. This method allows a better description of the trends of the records, especially when the time evolution is not monotonic. The results of the trend analysis of the yearly temperature and precipitation series are displayed in figs. 12 to 15. A more complete discussion of the trends is presented in [5].

3·5. *Conclusions*. – The comparison between the homogenised and the original temperature data clearly displayed that the original series are biased by non-climatic noise and, even if the average over all the series is considered, the original data display a significant error of the long-term amplitude of the temperature evolution. Figures 16 and 17 display, as an example, the differences between the homogenised and the original Northern and Southern Italy minimum temperature records. The consequence is that the trends of minimum, mean and maximum temperature in the 1865-2003 period estimated according to the new homogenised data-set are significantly different than the ones estimated in previous papers [10, 6, 3].

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