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Deliverable D1.9
Assessment of the impact of changes in station density on the E-OBS dataset

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Introduction

Gridded datasets for temperature and precipitation have become very popular in the natural sciences for validation purposes, for use as drivers for specific models (like species migration) and for assessments of climate change. The ease of use of gridded datasets and the possibility to make visually appealing maps contribute to this popularity. The widespread use of gridded datasets and the quest for a more detailed representation of climate change and variability fuel the need for datasets that provide both a high spatial resolution and a high temporal resolution. The E-OBS dataset (Haylock et al. 2008) aimed to provide such a high resolution dataset for Europe. Based on the station data from the European Climate Assessment & Dataset (ECA&D, Klein Tank et al. 2002), the E-OBS dataset was aimed initially at the community of researchers needing validation data for their Regional Climate models. In the years since the introduction of the E-OBS dataset in 2008, the use of this dataset has grown considerably and the number of users from the modelling community using E-OBS for validation purposes is now smaller than the communities using it for education or in hydrology, biology or agriculture.

Apart from the use of E-OBS, the number of series used to calculate this dataset has grown as well. The change in the density of the station network used for the E-OBS has had considerable influence on the gridded data. The goal of this document is to give an overview of the impact of changes in station density on the E-OBS daily gridded dataset.

Some areas in Europe now have a high station density where the data providers, usually the national meteorological services, share (almost) their complete station network with ECA&D, while for other areas the data providers share only a subset of their national network and have not increased their contribution over time. In this document we will quantify the impact on the resulting E-OBS dataset when the station density increases considerably. This impact is investigated by analysing the differences between different versions of E-OBS. The reference dataset is the one with the highest station density, in this case E-OBS version 12.0 (released in September 2015). For the dataset with a lower station density, at least in certain areas, E-OBS v2.0 is chosen (released in August 2009). Earlier versions of E-OBS, version 1 or version 1.1, could not be used because of a change in the procedure to calculate E-OBS which can influence the results independent of station density changes.

Changes in station density

The station density of ECA&D has dramatically increased in, for example, Germany, Northern Portugal, Northern Italy, Northeast Spain, Norway, Sweden and Finland (see figures 1 and 2 for mean temperature, and figures 3 and 4 for precipitation). These areas are chosen to analyse the effect of using a higher station density for the calculation of E-OBS. The station density in the UK and France, for example, have not changed between E-OBS version 2.0 and 12.0, while for precipitation the station density in the Netherlands increased with approximately 10%. For temperature the station in the Netherlands has remained more-or-less constant, with two stations (of 35) ceasing operation and one new station. A noteworthy exception is that data from Armagh

Observatory (UK, Northern Ireland) has been added. These countries (UK, France, the Netherlands) are used as a reference with constant station density.

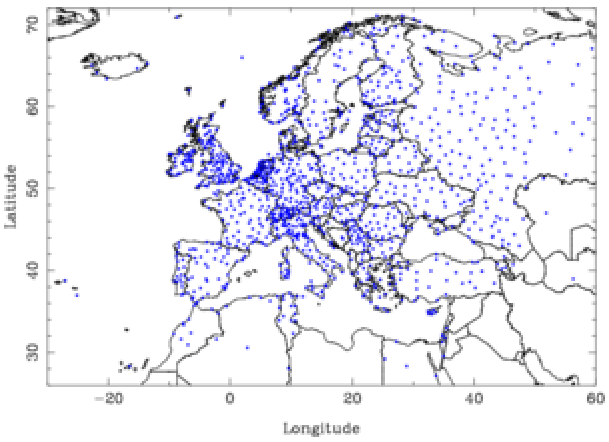


Figure 1: Station density for daily mean temperature in E-OBSv2.0

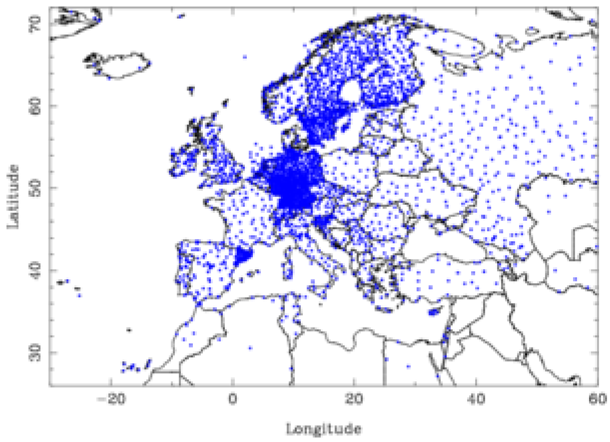


Figure 2: Station density for daily mean temperature in E-OBSv12.0

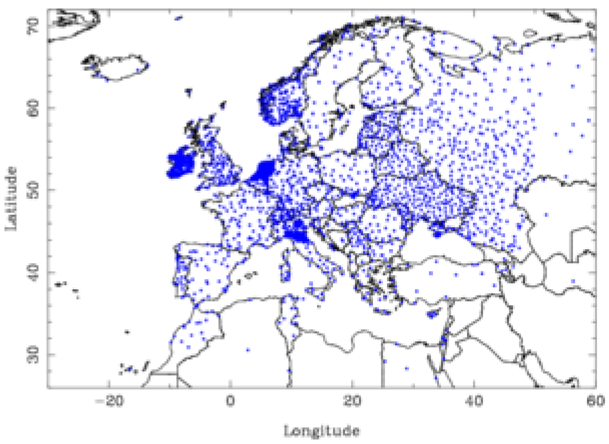


Figure 3: Station density for daily precipitation amount in E-OBSv2.0

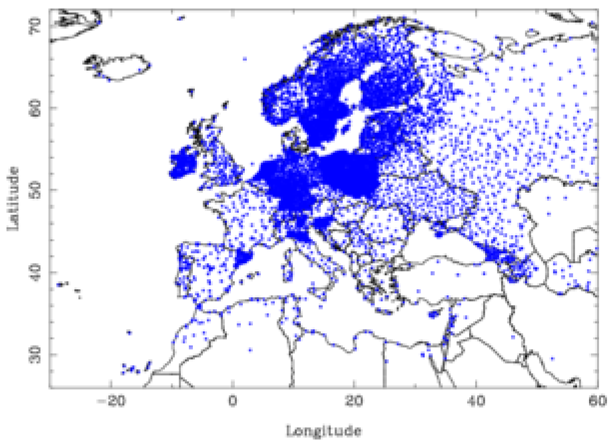


Figure 4: Station density for daily precipitation amount in E-OBSv12.0

Annual and seasonal mean temperature results

Figure 5 shows the annual difference in daily mean temperature between E-OBSv12.0 and E-OBSv2.0 over the period 1981-2008 and figure 6 shows the same for the 4 seasons.

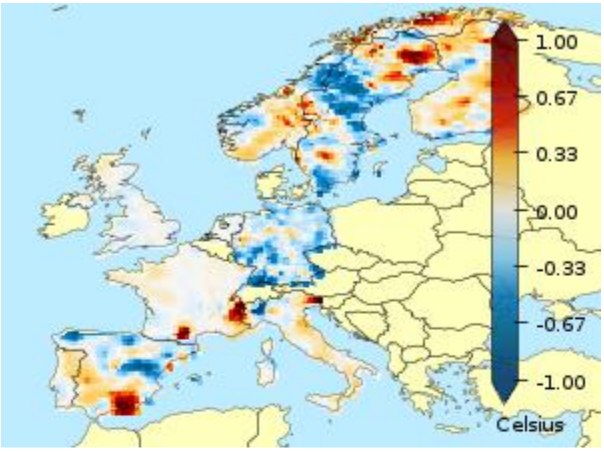
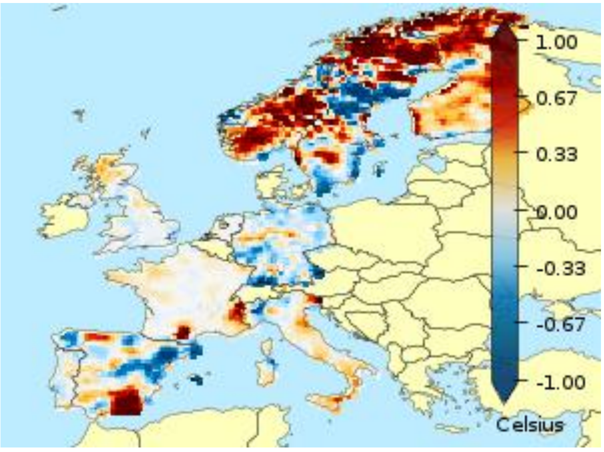


Figure 5: Differences in annual mean temperature for E-OBSv12.0-v2.0 over 1981-2008

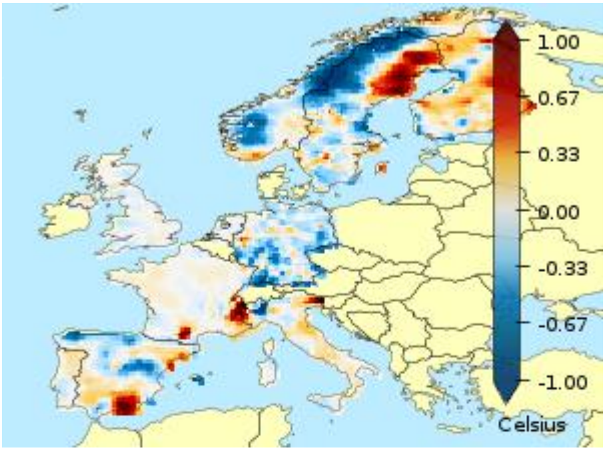
It is seen that in areas where the station density did not change (e.g. France, Netherlands, UK) the differences are very small, with values generally below 0.25°C except near the border with areas which saw a considerable change in station density, like the south of France, just north of the Pyrenees. This is due to the maximum search radius used in the gridding process to calculate the value at a specific grid box. For temperature, this search radius is maximally 500 km, although in areas with a sufficiently dense network, the search radius used is considerably smaller. In areas with a change in station density, the seasonal and annual differences can be quite large, up to a degree or more in comparison with the lower station density. Interesting is that the sign of the change can be both positive or negative. The pattern of the improvement with the increase in station density is perhaps a bit patchy but certainly not noisy; smoothly varying patterns are evident in figure 5. For Germany, the improvement results in an over-all annual correction to cooler conditions, the over-all annual correction for Finland seems to be positive, while the corrections averaged over Norway, Sweden or Spain approximately average-out.

In Scandinavia there is also a seasonal influence visible. In winter, a higher station density results in generally higher mean temperatures, while for summer the reverse is the case. Autumn and spring show more mixed results, with strong contrasts between the area surrounding the northern Baltic sea and the area closer to the Atlantic.

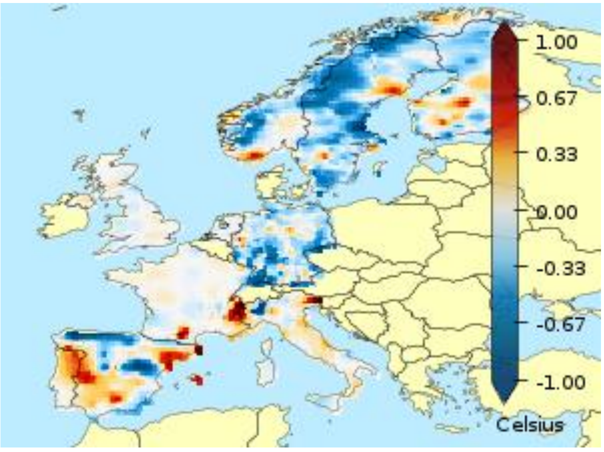
The station density is also increased in Northern Italy near the border with France by including stations from one of the small regional environmental agencies. Since the station density is still relatively low in France, a higher station density just across the border will have an influence on the results there as well. A higher station density in this high elevation area of Italy actually lowers the mean temperature. This can be understood because the gridding procedures interpolates mountainous areas using only lower elevation stations (most of the meteorological stations are in the valleys, being warmer stations). Although the dry adiabatic lapse rate is used in the interpolation, using a low station density apparently overestimates temperatures in E-OBS. Adding higher elevation stations will therefore lower the mean temperature resulting in a better representation of the true mean temperature in that area.



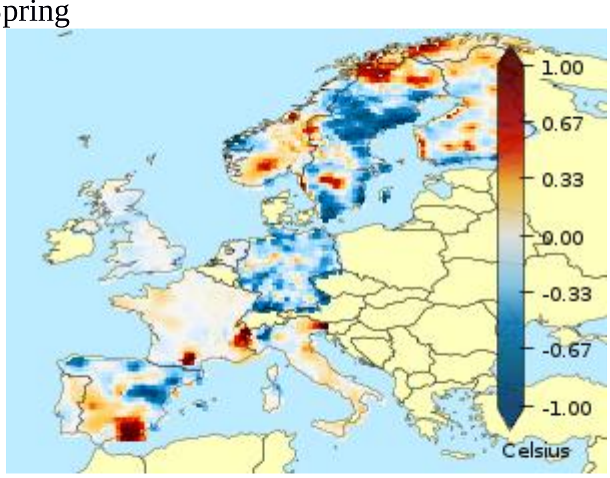
Winter



Spring



Summer



Autumn

Figure 6: Differences in mean temperature for E-OBSv12.0 - v2.0 per season over 1981-2008

The areas around Northern Portugal and Northeast Spain and the corresponding areas across the borders with neighbouring countries also show differences up to several degrees when including a higher station density.

In contrast to these relatively high differences due to the increase in station density, Germany shows lower differences although the station density has been increased there considerably. There seems to be a bit more detail visible, and for most areas a slightly lower temperature, but the differences are small compared to the regions mentioned before. Perhaps the only exception are the foothills of the Alps in the most southern part of Germany, bordering on Switzerland and Austria, where a stronger difference between the two E-OBS versions is found. This suggests that, for long-term averaged temperatures, the strongest improvements in the representation of daily averaged temperature are found in areas with complex topography.

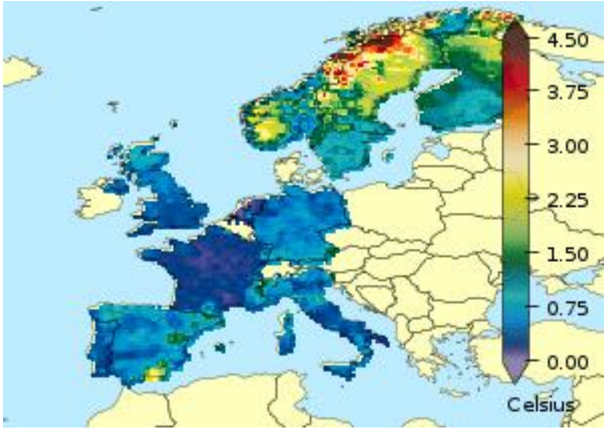


Figure 7: Standard deviation of daily differences in mean temperature between E-OBSv12.0-v2.0 for winter over 1981-2008.

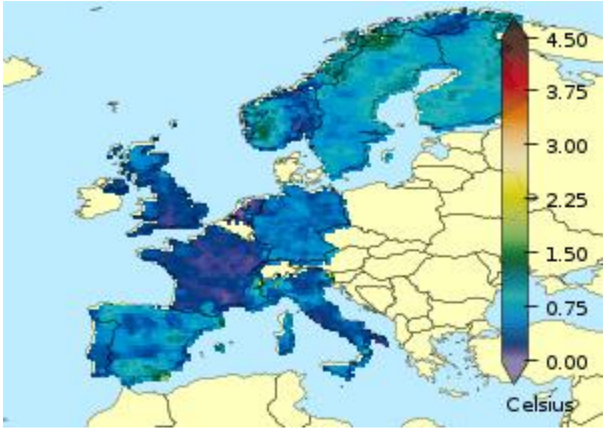


Figure 8: Standard deviation of daily differences in mean temperature between E-OBSv12.0-v2.0 for summer over 1981-2008.

On a daily level, the differences between E-OBSv12.0 and E-OBSv2.0 can be much larger than those in figure 5. Figures 7 and 8 show the standard deviation of the daily differences between these E-OBS versions for winter and summer, respectively. The standard deviation is highest in winter in Scandinavia with values up to 5°C. Except for a few isolated spots, the other areas show standard deviations below 1°C. In summer, all areas except parts of southern Spain and Scandinavia show standard deviations below 1°C.

Annual and seasonal mean precipitation results

Figure 9 shows the differences in annual precipitation amount between E-OBSv12.0 and v2.0 over the period 1981-2008 and figure 10 the differences in seasonal precipitation amount. A striking result is that nearly all of Europe has become wetter in the high-station density E-OBS version with about 10 mm per year or a few mm per season. In the Netherlands, a region with a (nearly) fixed station density over this period, does not show any difference between these E-OBS versions but all other regions do show some differences. Interesting is that the differences are also found in regions where the station density did not increase much, like France and the UK. This shows that replacement of time series can have a strong impact on the resulting gridded datasets. Other issues are the influence of an increased station density just across the border and the strong effect that the addition of one single time series can have in an area with a generally low station density, like Armagh Observatory in Northern Ireland impacting precipitation amounts in Scotland.

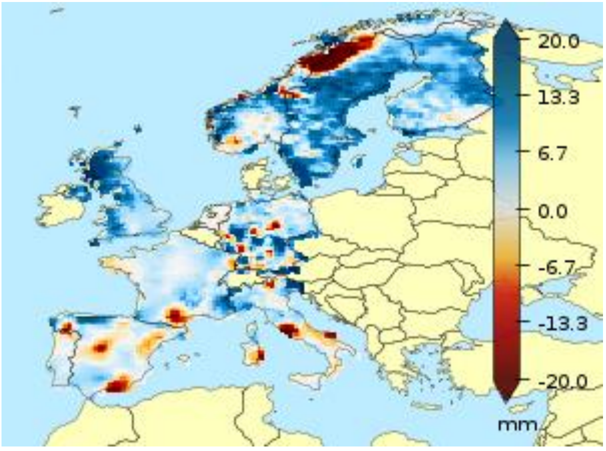
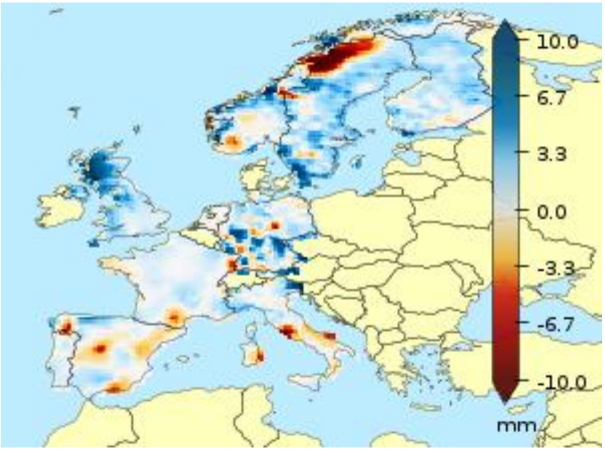
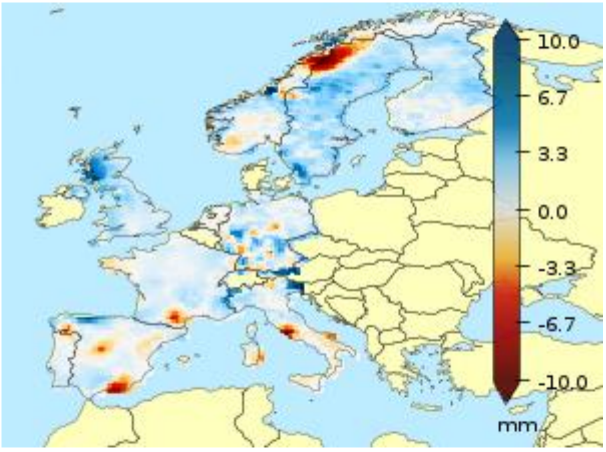


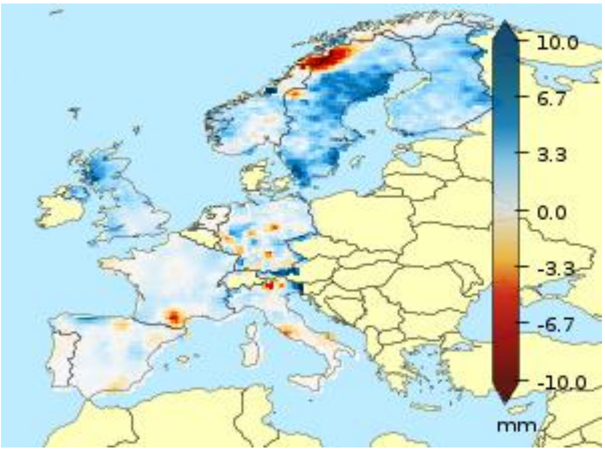
Figure 9: Differences in annual precipitation amount for E-OBSv12.0 - v2.0 over 1981-2008



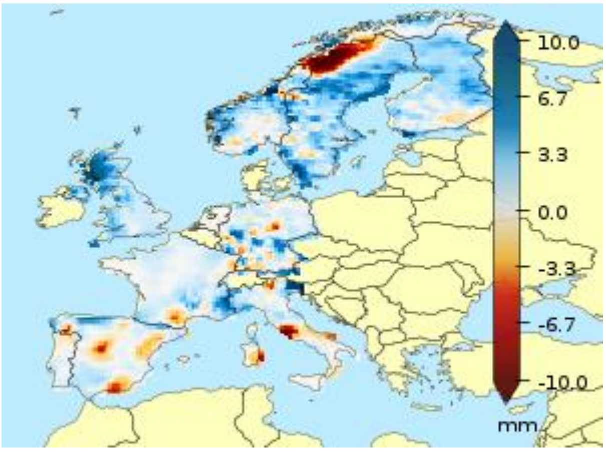
Winter



Spring



Summer



Autumn

Figure 10: Differences in precipitation amount for E-OBSv12.0 - v2.0 per season over 1981-2008

For most of Europe, a higher station density will result in higher precipitation amounts of about 10 mm per year or a few mm per season. Much of the improvement of the precipitation estimate relates to having the extremes captured better with a higher station density. This is corroborated in figures 11 and 12 which show the differences in number of days with at least 10 mm or 20 mm of precipitation, respectively.

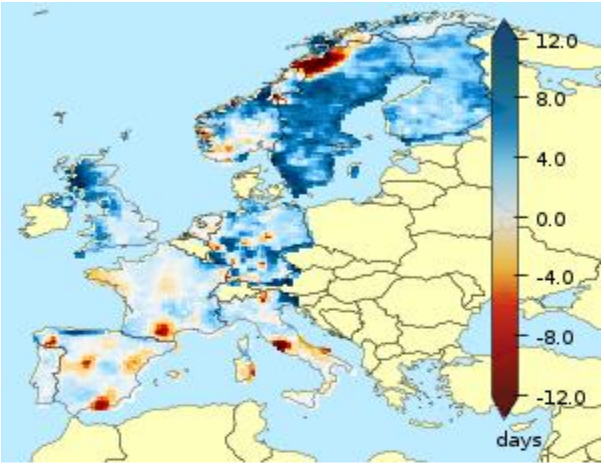


Figure 11: Differences in annual number of days with at least 10 mm of precipitation.

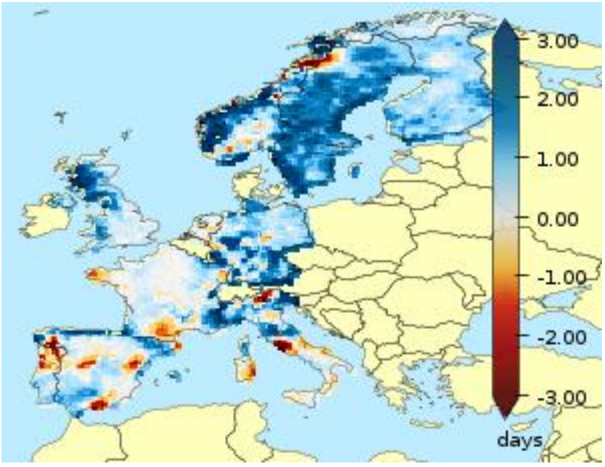


Figure 12: Differences in annual number of days with at least 20 mm of precipitation.

Although most areas have a higher number of days with heavy or very heavy precipitation in E-OBSv12.0, a few areas show a decrease in these extreme precipitation indices, notably Northern Sweden close to the boundary with Norway and Norway. This area shows differences of several tens of mm per year. This relates to having only the rain gauges at low elevations on the Norwegian coast in the low station density E-OBS, which are very wet, and an additional set of stations more inland (which are much drier) for the more recent version of E-OBS.

Furthermore, there are some isolated smaller areas with lower precipitation amounts. These isolated areas are related to one station, which has either been added to ECA&D or has seen a correction. Again, the size of the area affected by one single station in an area with a rather sparse network is evident when comparing Spain and Germany. The latter country has a much higher station density in ECA&D than the former. There does not seem to be much variation throughout the year for the difference in precipitation amount between E-OBSv12 and v2.0.

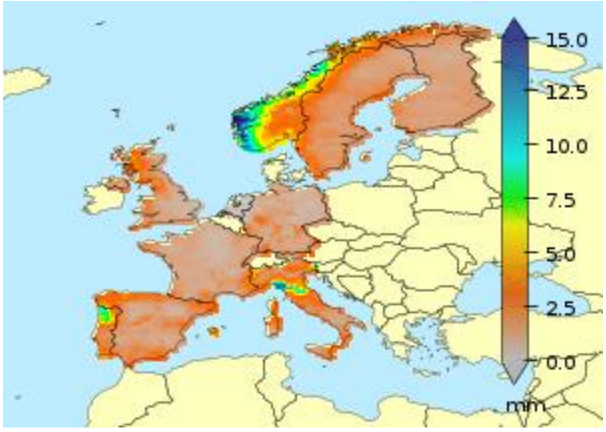


Figure 13: Standard deviation of daily differences in precipitation amount between E-OBSv12.0-v2.0 for winter over 1981-2008.

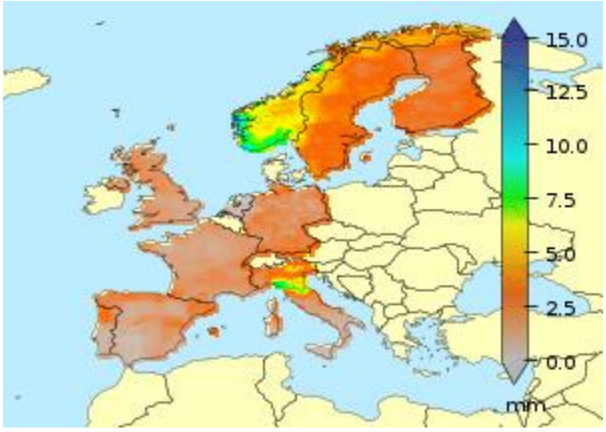


Figure 14: Standard deviation of daily differences in precipitation amount between E-OBSv12.0-v2.0 for summer over 1981-2008.

The standard deviation for the daily differences in precipitation amount are shown in figures 13 and 14 for winter and summer, respectively. The largest standard deviation is seen in Norway and parts of Italy and Portugal. The standard deviation is also dependent on the season, with the southwestern coast of Norway having larger standard deviation in winter, while the southern inland areas close to the Swedish border have larger values in summer. For northern Portugal and Italy the standard deviation is larger in winter as well.

Daily influence and extreme events

To analyse the effect of station density on daily values and an extreme temperature event, the daily maximum temperature on 4 August 2003 in E-OBSv12.0 is shown in figure 15 and the difference between E-OBSv12.0 and v2.0 for that day is shown in figure 16. This day is chosen since it is at the height of the 2003 heat wave that struck western Europe. The differences in some areas can be up to several °C, also in areas were only modest changes in station density are present (e.g. UK). Most areas show a higher maximum temperature in the newest E-OBS version, except in some areas which are mainly higher elevation areas.

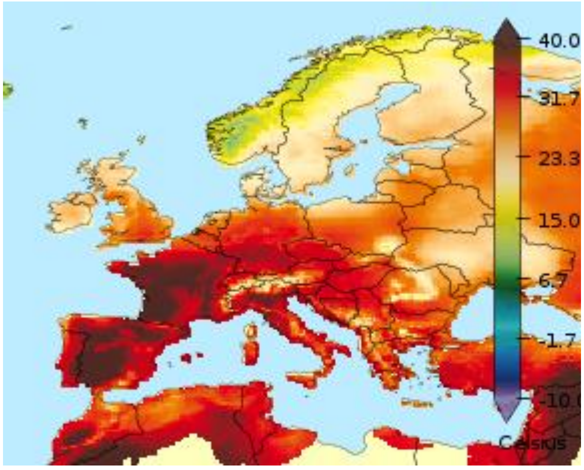


Figure 15: Daily maximum temperature for 4 August 2003 in E-OBSv12.0

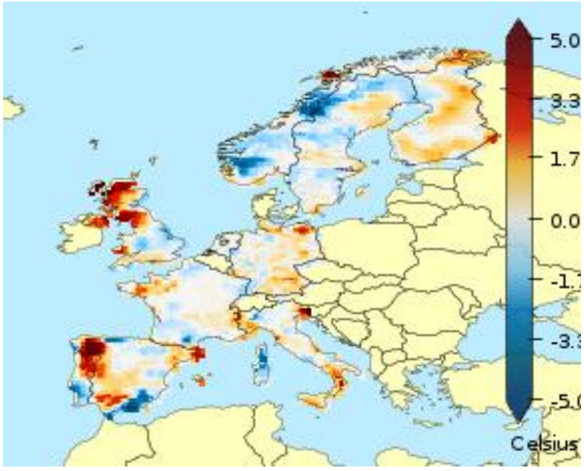


Figure 16: Differences in daily maximum temperature for E-OBSv12.0 - v2.0 for 4 August 2003

On a daily basis, the differences in precipitation amount can be up to 10 mm or more when a higher station density is included. This is shown in figures 17 and 18 for 23 January 2002. No large-scale flooding events are associated with this day, but this day is chosen because of the localized character of the precipitation and the relatively high amounts associated with this event near the Portugal/Spain border as well as near the Italy/France border. Both these areas have seen an increase station density in E-OBSv12.0. The difference plot in fig. 18 shows that the low-station density E-OBS overestimated the precipitation in Scandinavia quite severely (up to 10mm/day), were the more recent E-OBS version does not show that much precipitation.

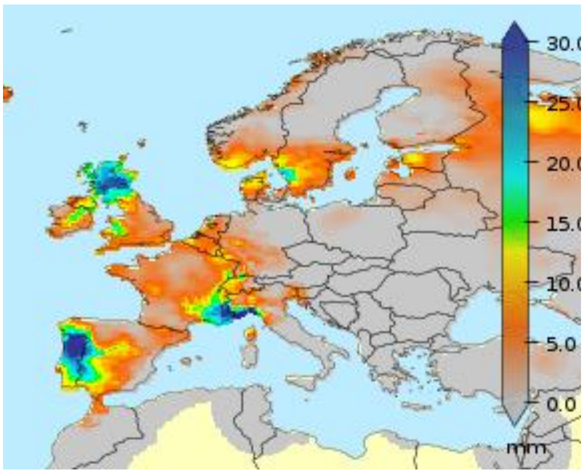


Figure 17: Daily precipitation amount on 23 January 2002 in E-OBSv12.0

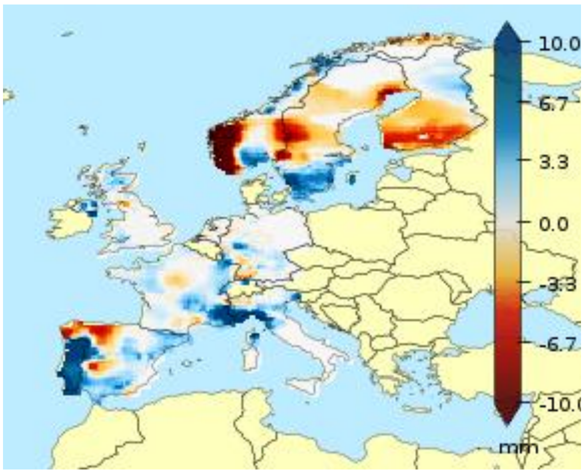


Figure 18: Differences in daily precipitation amount for E-OBSv12.0 - v2.0 for 23 January 2002

Other factors influencing E-OBS

The resulting E-OBS gridded dataset is not only influenced by changes in stations density, but is also affected by changes in the time series themselves. This is the case when a data provider has requested to replace certain time series with e.g. homogenized time series or if errors are found in the time series (like a factor 10 problem, where data are reported in the unit mm rather than 0.1mm). Another influence is due to the (temporary) use of GTS data. Time series are extended by GTS data if they do not run to the present. Extending the series with data from the (unvalidated and less-reliable) GTS is only done for a maximum of ten years. If the data provider does not supply updates, it could be that certain stations are no longer extended by GTS data in newer E-OBS versions. This is the case in parts of France for example, as well as in a few other areas. By comparing different E-OBS versions these effects could also be present in the same areas with a change in station density.

Conclusions

This report is deliverable 1.9 for the UERRA project describing the effect of changes in station density on the resulting E-OBS gridded fields. It is shown that the effect is depending on the area where the station density is changed. In areas with higher elevation, the effect is more pronounced than in relatively flatter areas. For daily mean temperature, there is some seasonal variation present in the effect for certain areas of Europe, while for precipitation the effect is mainly fixed throughout the year. The overall conclusion is that the quality of E-OBS increases significantly when the station network density in ECA&D is increased. The representation of the mean climate is more realistic using a sufficiently dense network of stations, but also the representation of extreme events improves dramatically. This is even more vital for areas with complex terrain than for areas which are relatively flat. In these areas, an increase of station density adds much more detail to the climatic description. On a more critical note, we observe that there are areas in the European domain for which the addition of one single station impacts on a large areas (with diameters of a one to two hundred kilometres). Examples are the addition of data of Armagh Observatory (Northern Ireland, UK) which impacts on the description of the climate of Scotland or the addition of data in Catalonia (northwest Spain) or the Italian Alps, which impact on the description of the climate in neighbouring areas in France. This points to the observation that for some areas the station density in ECA&D is at a critically low level.

References

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Klein Tank, A. M. G. and co-authors. 2002. Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. Intern. J. Climatol. 22:1441-1453. Data and metadata available at http://www.ecad.eu