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Short Communication

Updated and extended European dataset of daily climate observations

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ABSTRACT: The European Climate Assessment (ECA) dataset of daily observations, which has been widely used for studies on climate extremes, has been updated and extended. It now contains observational series of 2191 stations located in Europe and the Mediterranean (average inter-station distance: ∼75 km). About 1200 precipitation series and 750 temperature series cover the period 1960–2000. For a small number of stations (<15%) air pressure, cloud cover, sunshine duration, snow depth and relative humidity series have been collected. All series are quality controlled and the homogeneity of the precipitation and temperature series is assessed. About 50% of the daily series are publicly available for climate studies through the website http://eca.knmi.nl. The main potential of the ECA dataset follows from its daily resolution, enabling studies of impact relevant climate extremes and variability. To guide these studies, climate indices calculated from the ECA series are presented on the website too. Besides, gridded versions of the daily ECA data are available for easy comparison with climate model simulations. A trend analysis for the diurnal temperature range (DTR) demonstrates the utility of the dataset. Seasonal and annual DTR trends were calculated for 333 homogeneous temperature series in ECA and a Europe average trend was estimated. In spring and summer, the DTR increased from 1979 to 2005, whereas in autumn and winter the DTR generally decreased. The European average trend in annual DTR was 0.09 °C decade^{-1}. Copyright © 2008 Royal Meteorological Society

KEY WORDS daily climate series; dataset; climate extremes; climate indices; Europe; Mediterranean; diurnal temperature range; observations

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Introduction

The European Climate Assessment (ECA) dataset contains long series of daily station observations such as air temperature and precipitation. Since its presentation (Klein Tank *et al*., 2002), this dataset has been effectively used for climate extremes studies on a regional scale (Haylock and Goodess, 2004; Klein Tank *et al*., 2005; Moberg and Jones, 2005; Zolina *et al*., 2005; Moberg *et al*., 2006; Norrant and Douguédroit, 2006; Della-Marta *et al*., 2007; Fischer *et al*., 2007) and global scale (Frich *et al*., 2002; Alexander *et al*., 2006). Its utility rests in the compilation of a large number of quality-controlled daily series from all European countries, as well as its public accessibility through the Internet (http://eca.knmi.nl).

Monitoring and analysing climate variability and extremes, such as wet spells and heat waves, are very important because of the large impacts of climate extremes on society and environment. Consequently, climate extremes were given much attention in the latest IPCC report (Trenberth *et al*., 2007). It was concluded from observations that the number of warm extremes and the duration of heat waves have increased for all regions with data and the number of daily cold extremes has decreased. The daily resolution of the ECA dataset supports this type of climate analyses. For this purpose, an internationally agreed-upon set of climate change indices (in particular, for weather and climate extremes see Peterson, 2005) is calculated for each station, year and season. These index series are presented on the ECA website too.

The ECA dataset has been updated and extended over the past years. The number of stations is at present 2191 (Figure 1), a tenfold increase over the number in 2002. With an average distance between the stations of 75 km, the spatial resolution is high enough for gridding and comparison to simulations with regional climate models, which is done as part of the EU-ENSEMBLES project (Hewitt and Griggs, 2004; Haylock *et al*., 2008). This short communication presents the new version of the dataset. The climate series and data providers are described in Section 2, and the quality control and homogeneity testing procedures are presented in Section 3. A more extensive description of the dataset including data formats is given in Klein Tank (2008). An illustration

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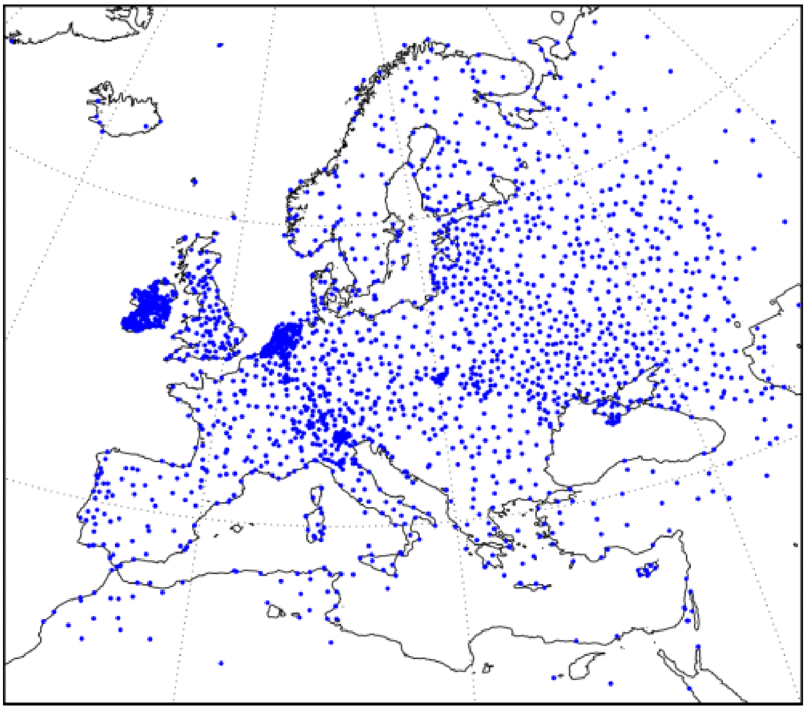

Figure 1. Station network of the dataset (August 2007 status). This figure is available in colour online at www.interscience.wiley.com/ijoc

of the dataset, a study on trends in the diurnal temperature range (DTR), is given in Section 4, and an outlook concludes this short communication.

Daily climate series

The new ECA dataset includes station series for nine daily climate variables: minimum, mean and maximum temperature, precipitation amount, sea level air pressure, snow depth, sunshine duration, relative humidity and cloud cover. The total number of series in the dataset is highest for temperature and precipitation. For the other variables the total number is relatively low (Table I), since their gathering has only just started. The dataset exists on daily time series provided by the National Meteorological Services of all countries in the region, augmented with data from other institutes and from earlier research projects. Appendix I presents the full list of data sources.

All series in the ECA dataset are continually updated by near real-time station reports (SYNOP messages) from the ECMWF MARS-archive (ECMWF, 2006) to enable near real-time climate monitoring. Updating from this source is necessary, because updates from the data providers are usually received with some delay and the insertion of the series in the database takes time. Data obtained from SYNOP messages are considered preliminary, and are not quality controlled. When quality-controlled data become available from a participating country, the corresponding SYNOP data are replaced. SYNOP messages and also data from nearby stations are sporadically used to fill gaps in the series, provided that they are measured within 25-km distance and 50-m height difference.

Table I. For each climate variable, the number of series in the database and the percentage that is publicly available from the ECA website (August 2007 status).

Climate variable	Number of series (and percentage publicly available)
Maximum temperature	1368 (48%)
Minimum temperature	1371 (48%)
Mean temperature	1233 (42%)
Precipitation	2052 (48%)
Air pressure	321 (53%)
Snow depth	187 (24%)
Relative humidity	189 (71%)
Cloud cover	128 (70%)
Sunshine duration	184 (59%)

Despite WMO's intentions of standardization, the observation time for minimum and maximum temperatures or accumulated 24-h rainfall amounts sometimes differs between countries and even within countries between stations. For instance, precipitation observations made early in the morning are frequently recorded on the same day, whereas other stations may record those observations on the previous day (i.e. date shifting). An additional complication is that observation rules sometimes change within a series over time. This leads to problems if for instance the relationship between daily temperature and daily rainfall is analysed or if daily values are interpolated onto daily grids. Therefore, each single series in the database is identified with an element code as much as possible, providing information about the measurement procedure.

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About 50% of all daily series in the dataset is currently publicly available (August 2007 status; Table I) and can be downloaded from the ECA website. For the other half, only the (lower time-resolution) series of derived climate change indices (Section 1) can be released because of data policy restrictions. Figure 2 shows the total number and the number of public daily series in the dataset for each variable and year. The plots illustrate that the totals for precipitation are greatest. The strong decline in the number of precipitation series over the last 15 years is mainly caused by series from the former Soviet Union, ending in the early 1990s. In 1995, the number of temperature series abruptly increases, primarily because of a rise in series from Russia and Ukraine. For all variables, the data coverage is best between 1960 and 2000. About 1200 precipitation series and 750 temperature series cover this period. Unfortunately, data from the most recent years are often missing, even though SYNOP data have been considered to update the series.

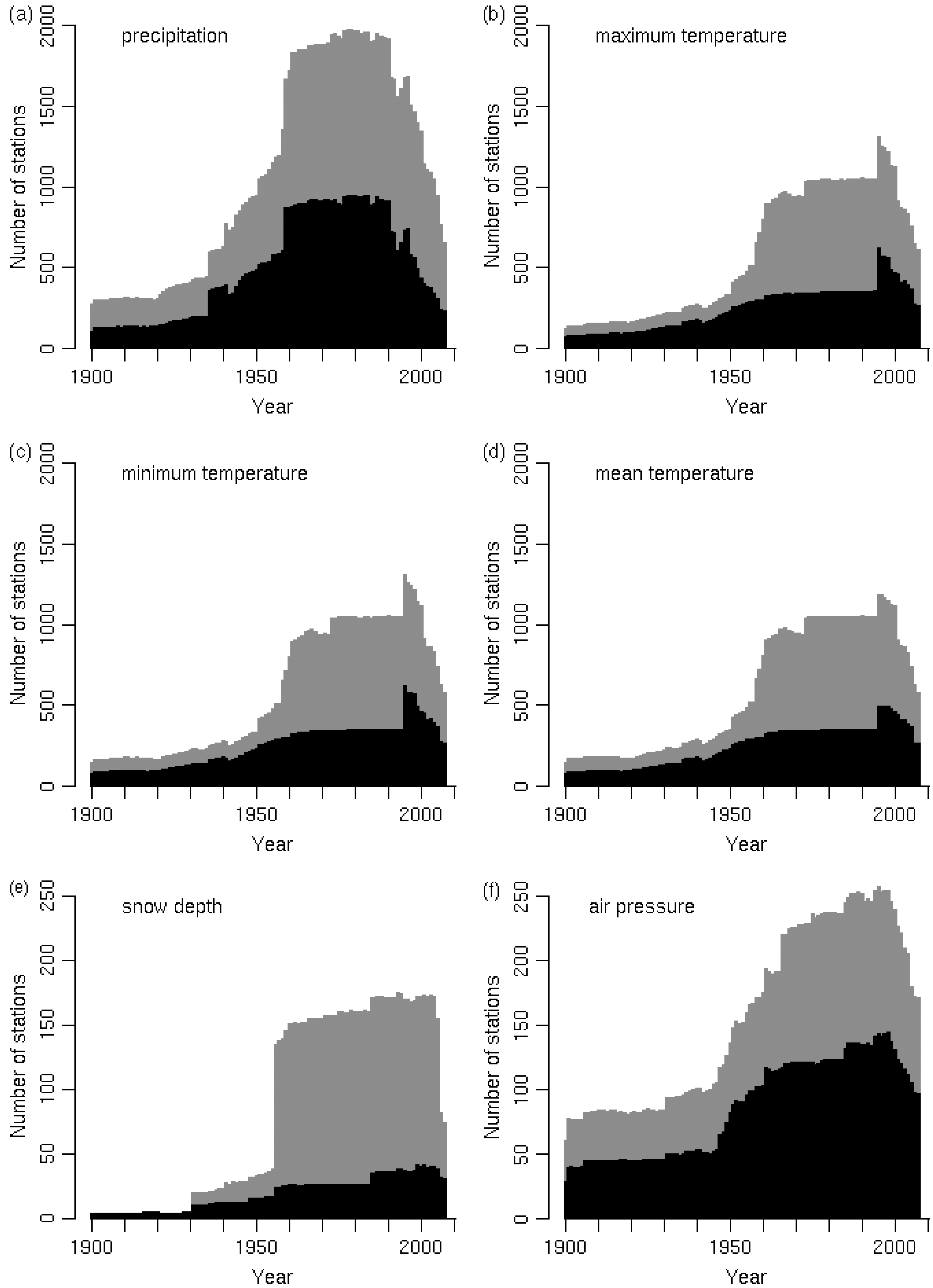

Figure 2a. Number of series for each year for precipitation (a), maximum temperature (b), minimum temperature (c), mean temperature (d), snow depth (e), air pressure (f), relative humidity (g), cloud cover (h) and sunshine duration (i) (August 2007 status). The grey bars indicates the total number of series, and the black bars the number of publicly available series. Note the two different y-scales for plots (a)–(d) and (e)–(i).

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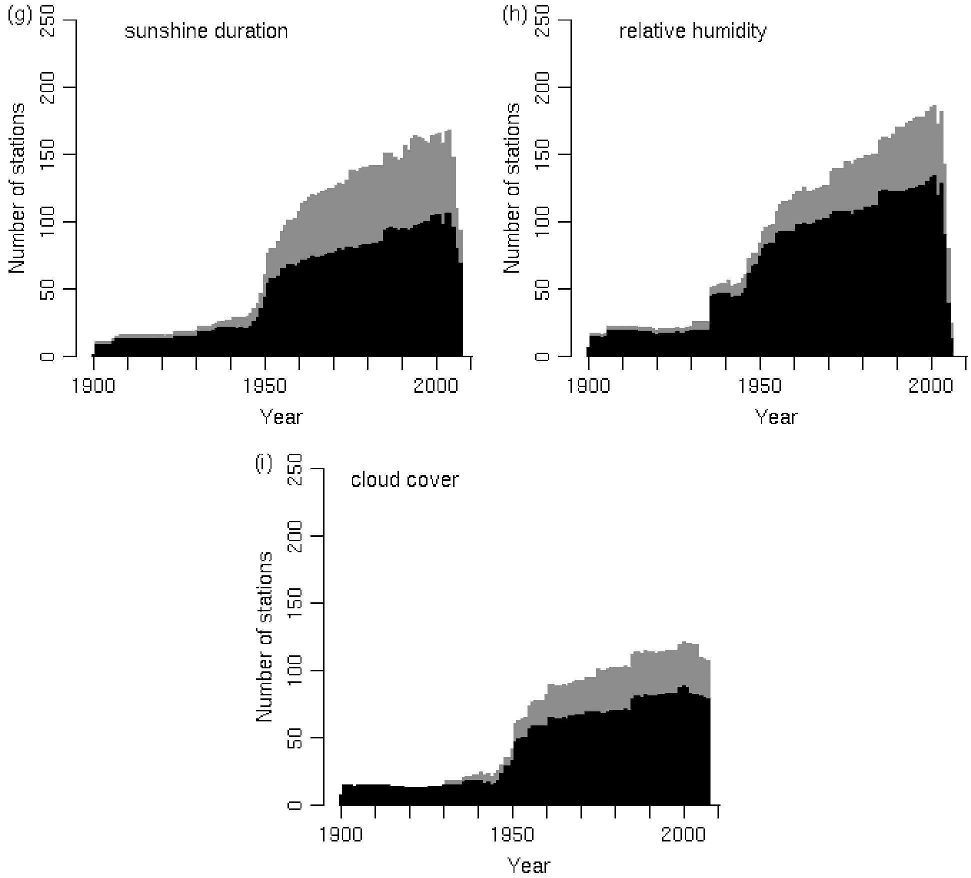

Figure 2. (*Continued*).

Data quality and homogeneity

The data in all series are automatically quality checked and flagged accordingly as useful (i.e. the data value passes the test), suspect (i.e. the data value does not pass the test) or missing. Aside from replacing missing or suspect data with SYNOP-derived data or data from a neighbouring station (Section 2), no other corrections or adjustments are made to the data values.

All quality tests are absolute, implying that data are not compared with respect to neighbouring station series. The quality checks detect several types of errors: anomalous values (e.g. temperatures exceeding 60 °C, precipitation values exceeding 300 mm day^{-1} or negative precipitation values), repetitive values (i.e. repetitive precipitation data over more than 10 days of non-zero values), outliers (i.e. temperatures that exceed a certain z-score in the normal distribution for that calendar day) and inconsistencies (i.e. minimum temperatures that exceed the daily maximum). According to these checks, about 0.5% of all data values in the ECA dataset are currently considered suspect. This low percentage reflects that most data undergo various quality controls at the home institutions of the data providers. In some cases, the automatically generated quality control flags have been overruled by manual intervention. This is for example necessary for extreme precipitation events exceeding 300 mm day^{-1}, such as occasionally occur at Locarno (Switzerland), Genoa (Italy) or Mont-Aigoual (France).

Long climatological time series often contain variations because of non-climatic factors, such as site-relocations, or changes in instrumentation and observing practices. This can lead to shifts in the mean or the variance and to spurious trends. High-quality meta-data reports of observational changes are generally lacking or the reports come in non-standardized formats, which are difficult to interpret. Only few series in ECA contain associated meta-data that can help identify potential inhomogeneities. As inhomogeneities can distort or even hide the true climatic signal, statistical techniques for homogeneity testing is a key tool for climate change studies. Within ECA, the procedure of Wijngaard *et al.* (2003) is used to test the precipitation and temperature series. This method classifies the series in three homogeneity classes: useful, doubtful and suspect, depending on the number out of four statistical tests that reject the null hypothesis of no break in the series. The station-by-station results of these tests are available from the ECA website. Table II summarizes the homogeneity results of the precipitation and temperature series that are complete for the periods 1961–2006 and 1901–2006. The percentage of useful series (rejection of 0 or 1 test) is smaller for the latter period, since the number of detected breaks increases when the period of investigation is extended. The percentage of precipitation series classified as useful is much larger than the percentage of useful temperature series. This is partly because of the high variability

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Table II. Total number of precipitation and temperature series that covers the periods 1961–2006 and 1901–2006 and the number (percentage) classified as useful, doubtful and suspect following the homogeneity test of Wijngaard *et al*. (2003).

Period	Climate variable	Total number	Useful	Doubtful	Suspect
1961–2006	Precipitation	843	793 (94%)	21 (3%)	29 (3%)
	Temperature	642	345 (54%)	56 (9%)	241 (7%)
1901–2006	Precipitation	267	186 (70%)	26 (10%)	55 (20%)
	Temperature	107	5 (5%)	3 (3%)	99 (92%)

of precipitation, which hampers the detection of breaks in series. With regard to the total number of precipitation (temperature) series in the dataset, 39% (25%) is homogenous (i.e. useful) over 1961–2006. Note that according to this strict test only 5 out of 107 temperature series covering the period 1901–2006 are useful.

Similar results for the number of homogeneous series were found using an alternative homogeneity testing method, which was recently applied to the same dataset by Begert *et al*. (2008). This method involves an automated relative homogenization procedure to detect shift inhomogeneities in climatological time series. It combines Vienna Enhanced Resolution Analysis Quality Control (VERAQC) (Steinacker *et al*., 2000) output with Alexandersson's Standard Normal Homogeneity Test (Alexandersson, 1986). The results of this procedure show that 59% (20%) of all precipitation (temperature) series are classified as homogeneous over the period 1960–2004.

Demonstration of the dataset: changes in the DTR

As an illustration of the utility of the ECA dataset, we describe in this section the European trends in the DTR as derived from the daily maximum and minimum temperature series in ECA. Globally, maximum and minimum temperatures have increased at similar rates between 1979 and 2005, with no trend in DTR (Vose *et al*., 2005; Trenberth *et al*., 2007). Using the ECA data, we estimated the contribution of Europe to this basically trendless global DTR and investigated the seasonal DTR trends in more detail.

Figure 3 shows the annual and seasonal DTR trends (using least squares regression) for 1979–2005 as derived from 333 maximum and minimum temperature series in ECA that are labelled 'useful' for this period. An overall DTR increase is evident in spring and summer, with more increasing than decreasing trends (Table III). Also annually, the number of series with an increasing DTR trend exceeds the number of series with a decreasing trend. For autumn and winter, the DTR generally decreased, but the pattern is less consistent with decreasing trends in southern Europe in autumn and in northern Europe in winter.

A Europe average DTR trend was calculated by first averaging all 333 DTR series and then doing the trend analysis. The trend in the Europe average DTR is positive for the year, spring and summer and negative for the autumn and winter (Table III). Although none of these average trends is statistically significant at the 5% level, the trends in the annual, summer and winter DTR are significant at the 10% level. Since for all seasons, minimum as well as maximum temperatures have increased from 1979 to 2005 (not shown), positive (negative) DTR trends are associated with maximum temperatures having increased at a larger (smaller) rate than minimum temperatures. The results indicate that Europe contributed to a positive trend in global annual DTR in recent decades that must have been compensated elsewhere (Vose *et al*., 2005; Trenberth *et al*., 2007). Whether this is related to specific regional changes in factors such as cloud cover or precipitation or to variations in larger-scale atmospheric circulation is a topic for future research.

Outlook

Besides the production of European high-resolution gridded daily datasets on the basis of the series in ECA (Haylock *et al*., 2008), other prospects for the ECA dataset are

Table III. Number of series with increasing, decreasing and insignificant (t test) trends in annual and seasonal DTR for 1979–2005 at the 25% (5%) level.

Season	Increasing	Decreasing	Not significant	Average trend (°C decade^{-1})
Annual	125 (52)	41 (14)	167 (267)	0.09 (0.00–0.18)
Winter (DJF)	49 (15)	83 (43)	201 (275)	−0.11 (−0.21–0.00)
Spring (MAM)	146 (56)	18 (8)	169 (269)	0.15 (0.00–0.30)
Summer (JJA)	140 (52)	26 (5)	167 (276)	0.14 (−0.03–0.31)
Autumn (SON)	47 (11)	72 (29)	214 (293)	−0.01 (−0.14–0.11)

The last column presents the trend in the European average DTR with the 95% confidence interval in parentheses.

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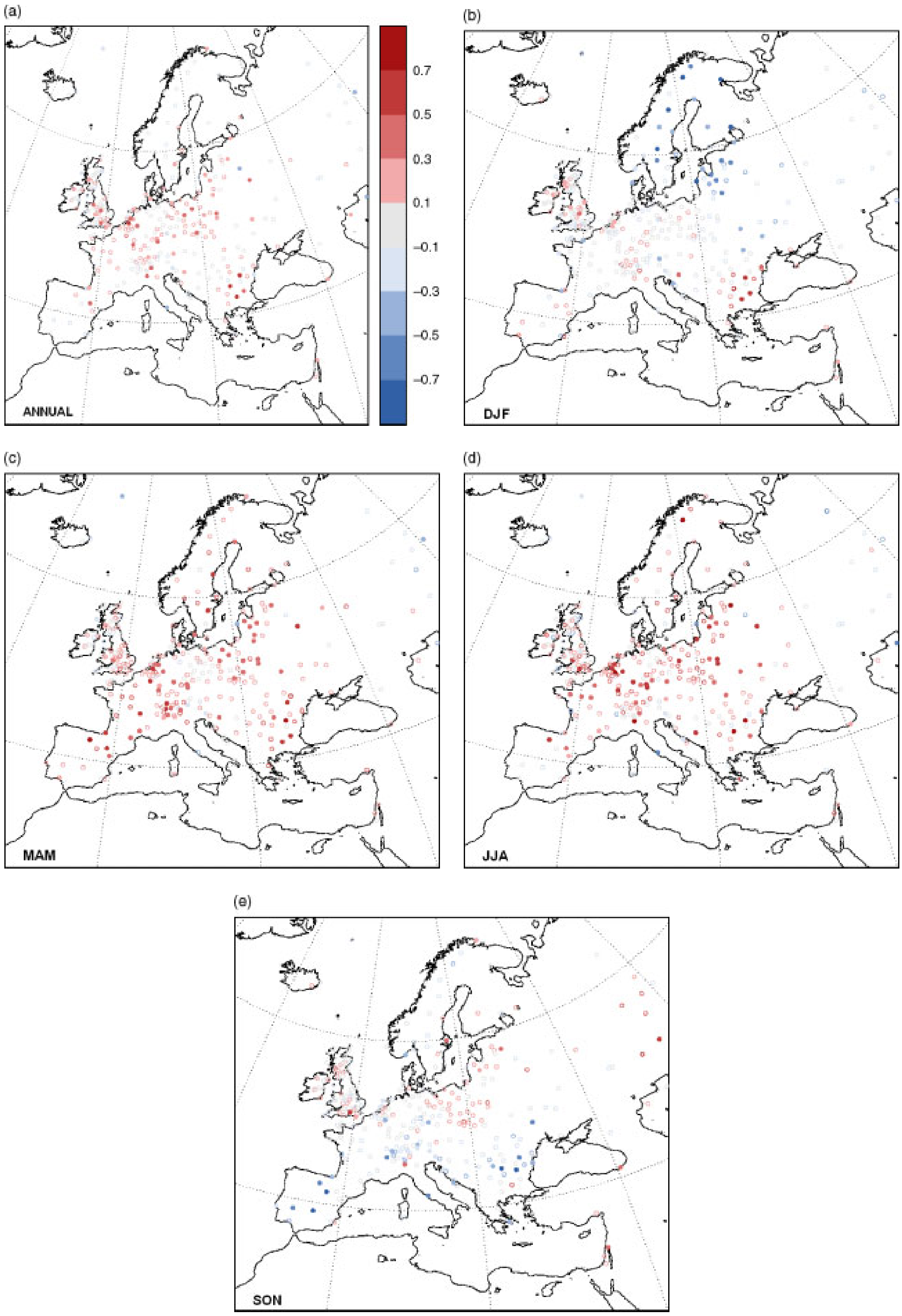

Figure 3. Linear trend in the annual and seasonal mean DTR for the period 1979–2005 (°C decade^{-1}). Trends significant at the 5% level are indicated by solid dots, and insignificant trends by open dots. This figure is available in colour online at www.interscience.wiley.com/ijoc

a continuous improvement of the number and length of the series, especially for the new variables air pressure, snow depth, sunshine duration, cloud cover and relative humidity. The ultimate target would be to collect the daily series of a network comparable with all SYNOP stations in Europe (~3000). As the number of series of the new variables will grow, indices of climate extremes on the basis of these variables will be analysed and presented on the website (e.g. the number of snow days, heat wave indices taking into account air humidity, drought indices).

We also started to collect more meta-data of the station series (such as dates of station relocations and important instrumental changes, pictures of all station surroundings

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and information on soil type and land use). This will aid the interpretation of the homogeneity test results. At present, a minority of the series (roughly 30%) is labelled 'useful' on the basis of the Wijngaard *et al*. (2003) procedure. When new techniques (e.g. Vincent *et al*., 2002; Della-Marta and Wanner, 2006) for homogenizing large numbers of daily series have been widely tested and accepted, the series labelled 'doubtful' or 'suspect' may also be used for climate change analysis after correction. At present, no attempt has been made to correct for inhomogeneities in the series, because it is unclear how the variance and higher-order moments of daily series should be treated in a way that preserves the extremes.

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Appendix

Table AI. List of data providers.

ECA participants	
Climate variables: rr, tx, tn, tg, pp, rh, sd, cc, ss; 989 stations	
Hydrometeorological Institute	Albania
Office National de la Météorologie	Algeria
Hydrometeorology and Environmental Agency	Armenia
Central Institute for Meteorology and Geodynamics	Austria
Koninklijk Meteorologisch Instituut	Belgium
Federal Meteorological Institute of Bosnia and Herzegovina	Bosnia and Herzegovina
National Institute of Meteorology and Hydrology	Bulgaria
Meteorological and Hydrological Service of Croatia	Croatia
Meteorological Service of Cyprus	Cyprus
Czech Hydrometeorological Institute	Czech Republic
Danish Meteorological Institute	Denmark
Estonian Meteorological and Hydrological Institute	Estonia
Finnish Meteorological Institute	Finland
Météo-France	France
Deutscher Wetterdienst	Germany
Hellenic National Meteorological Service	Greece
Hungarian Meteorological Service	Hungary
Icelandic Meteorological Office	Iceland
Met Éireann	Ireland
National University of Ireland, Galway	Ireland
Israel Meteorological Service	Israel
Universita degli Studi di Milano	Italy
Servizio Meteorologico dell' Aeronautica	Italy
Latvian Hydrometeorological Agency	Latvia
Institute of Geology and Geography	Lithuania
Service Météorologique du Luxembourg	Luxembourg
Centre de Recherche Public Gabriel Lippmann	Luxembourg
Royal Netherlands Meteorological Institute	The Netherlands
Det Norsk Meteorologiske Institutt	Norway
Institute of Meteorology and Water Management	Poland
University of Lodz	Poland
University of Silesia	Poland
Instituto de Meteorologia	Portugal
Universidade do Algarve	Portugal
Republic Hydrometeorological Institute	Republic of Macedonia
National Institute of Meteorology and Hydrology	Romania
Russian Federal Service for Hydrometeorology and Environmental Monitoring	Russian Federation
Republic Hydrometeorological Institute of Serbia	Serbia and Montenegro
Slovak Hydrometeorological Institute	Slovakia
Environmental Agency of the Republic of Slovenia	Slovenia
Instituto Nacional de Meteorologia	Spain
Swedish Meteorological and Hydrological Institute	Sweden

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Table AI. (*Continued*).

Stockholm University	Sweden
MeteoSwiss	Switzerland
Devlet Meteoroloji Genel Mudurluou	Turkey
Central Geophysical Observatory	Ukraine
Met Office	United Kingdom
EMULATE[a] data providers http://www.cru.uea.ac.uk/cru/projects/emulate/ Climate variables: rr, tx, tn, tg, pp; 197 stations	
Central Institute for Meteorology and Geodynamics	Austria
Meteorological and Hydrological Service of Croatia	Croatia
Czech Hydrometeorological Institute	Czech Republic
Finnish Meteorological Institute	Finland
Potsdam Institute for Climate Impact Research	Germany
Universität Augsburg, Institut für Geographie	Germany
National Observatory of Athens	Greece
Icelandic Meteorological Office	Iceland
Universitá di Milano, Instituto di Fisica Generale Applicata	Italy
Instituto Nazionale di Astrofisica, Osservatorio Astronomico di Palermo	Italy
Royal Netherlands Meteorological Institute	The Netherlands
University of Barcelona, Department of Astronomy and Meteorology	Spain
Universitat Rovira I Virgili, Physical Geography	Spain
Swedish Meteorological and Hydrological Institute	Sweden
Uppsala University, Department of Earth Sciences, Air and water Science-Meteorology	Sweden
MeteoSwiss	Switzerland
Met Office	United Kingdom
Armagh Observatory	United Kingdom
STARDEX[b] data providers http://www.cru.uea.ac.uk/cru/projects/stardex/ Climate variables: rr, tx, tn, tg; 248 stations; series cover the period 1958–2000 only	
Central Institute for Meteorology and Geodynamics	Austria
Czech Hydrometeorological Institute	Czech Republic
Danish Meteorological Institute	Denmark
Finnish Meteorological Institute	Finland
Meteo France	France
Deutscher Wetterdienst	Germany
Department of Meteorology and Climatology, Aristotle University of Thessaloniki	Greece
Hungarian Meteorological Service	Hungary
Servizio Meteorologico Regional, ARPA-Emilia Romagna	Italy
Royal Netherlands Meteorological Institute	The Netherlands
Det Norsk Meteorologiske Institutt	Norway
Instituto de Meteorologia	Portugal
Russian Federal Service for Hydrometeorology and Environmental Monitoring	Russian Federation
Instituto Nacional de Meteorología	Spain
Swedish Meteorological and Hydrological Institute	Sweden
MeteoSwiss	Switzerland
University of East Anglia, Climate Research Unit	United Kingdom
MAP[c] data providers http://www.map.meteoswiss.ch/ Climate variables: rr, tx, tn, tg; 108 stations; Italian series only	
Ufficio Idrografico Provincia Autonoma di Trento	Italy
Servizio Meteorologico dell' Aeronautica	Italy
GCOS Surface Network[d] http://www.wmo.ch/web/gcos/gcoshome.html Climate variables: rr, tx, tn, tg, pp; 47 stations	
National Climate Data Center	USA
GHCND[e] http://www.ncdc.noaa.gov/oa/climate/research/ghcn/ghcn.html Climate variables: rr, tx, tn, tg; 642 stations; version DSI-9300	
National Climate Data Center	USA
Mars-Stat Database[f]	

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Table AI. (*Continued*).

http://agrifish.jrc.it/marsstat/ Climate variables: rr, tx, tn, tg; 263 stations Joint Research Centre, Ispra	Italy
SYNOP/CLIMAT http://www.ecmwf.int/ Climate variabless: rr, tx, tn, tg, pp, rh, sd, cc, ss; 1291 stations ECMWF	United Kingdom

Abbreviations: rr, precipitation; tx, maximum temperature; tn, minimum temperature; tg, mean temperature; pp, sea level pressure; rh, relative humidity; sd, snow depth; cc, cloud cover; ss, sunshine duration.

[a] EMULATE (European and North Atlantic daily to MULtidecadal climATE variability, Moberg and Jones, 2005; and Ansell *et al*., 2006) is a European 5th framework programme.

[b] STARDEX (Statistical and Regional dynamical Downscaling of Extremes for European regions, Haylock and Goodess, 2004) is a European 5th framework programme.

[c] The Mesoscale Alpine Programme (MAP) is a project that investigated the atmospheric and hydrological processes over the Alps (Bougeault *et al*., 2001).

[d] GCOS is the Global Climate Observing System. The GCOS Surface Network (GSN) is a global surface reference climatological station network (Peterson *et al*., 1997).

[e] The Global Historical Climatology Network – Daily (GHCND) is developed by the National Climatic Data Center (NCDC, 2004).

[f] The Joint Research Centre in Ispra, Italy houses the MARS-STAT Database containing daily series to develop an interpolated 50-km meteorological European dataset for crop forecasting (Genovese, 2001).

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