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Homogenization of Norway's mean monthly temperature series

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Abstract

This report presents the homogenization of Norway's mean monthly temperature time series primarily for the purposes of calculating new standard climate normals for the period 1991-2020. Climate normals play an important role in weather and climate studies, and therefore require good basic data that are consistent and homogenous. The HOMER software package was applied to detect and adjust inhomogeneities of 108 Norway's mainland mean series, for the period 1961-2018, with a maximum of 10-year missing values. The analysis was conducted on 145 series (including 30 Swedish series and 7 Finnish series) from the ClimNorm temperature dataset, 48% of which were merged series. The analysis was done in two separate networks (network 1 with 99 series while network 2 had 51 series)

The results of the homogeneity testing indicate that approximately 92% of the series had inhomogeneities. Nine series were classified as homogeneous without need for any adjustments while 99 series presented one or more breaks. These inhomogeneities were adjusted accordingly following the documented procedure. 99% of the breaks were confirmed by metadata. The annual adjustment factor ranged from −0.94 to 1.01 °C. Relocation of the station was the most common reason for inhomogeneity, explaining more than 40 % of the inhomogeneities found by HOMER. Inhomogeneities found in the Swedish and Finnish series were mostly adjusted without metadata. Results further demonstrated the benefits of including Swedish and Finnish series as reference series in the homogeneity testing of Norway's temperature.

Comparison of the homogenization results in network 1 between HOMER and Climatol showed that both homogenisation methods captured inhomogeneities in most of the series. However, HOMER detected and corrected more breaks (158) than Climatol (57). The adjusted breaks in HOMER were justified by metadata unlike most

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in Climatol. Annual and seasonal anomalies series using 1961-1990 as the reference period for the raw and homogenized series were used to evaluate the impact of homogenization on the temperature series. Results showed a wider range of anomalies in the raw series than in homogenized series confirming that homogenizations contributes to better spatial consistency of the temperature series. This clearly provides a strong guidance on the reliability of the adjusted dataset

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1 Introduction

This study presents homogenization of monthly mean temperature time series for Norway. The primary objective of the study is to establish a high quality temperature reference dataset for calculating new standard climate normal for the period 1991-2020 and for climate monitoring services. Climate normal play an important role in weather and climate studies and have two major purposes: (a) as an indicator of the conditions most likely to be experienced at a given place under the current climate and (b) as a reference against which climate conditions at a given region in a given time can be compared (WMO 2017). These purposes require good basic data that are consistent and homogenous. Climate normals are calculated for 30-year periods (WMO 2011) and up to now, WMO has operated with standard normal periods that are subsequent 30-year periods (1901-1930, 1931-1960, 1961-1990 and the coming 1991-2020). Climate normals were traditionally defined as an average over 30 years, however the WMO Congress in 2015 decided that the standard normal period should now be the last 30-year period ending with a year ending with 0 (WMO 2017).

The current climate normal in Norway represent the period 1961-1990, and was prepared in the early 1990s (Aune 1993a, 1993b, Førland 1993). Work to calculate 1981-2010 normals was later initiated a few years ago by the meteorological institute. This was however not completed because there were major and extensive changes with the station network, and as a result great challenges with homogeneity and consistency of the observational data. Several efforts have been made to homogenize long temperature and precipitation series (Andresen 2011, Lundstad 2016, Lundstad and Tveito 2016). These studies showed promising results, however, they either did not cover the entire period 1961-2018 and/or were done for a small number of stations. Considerable work therefore remained to establish robust and homogenous data for calculating the new climate normal 1991-2020.

To overcome the existing challenges in establishing climate normals, which included geographical relocation of stations, observation series that do not cover entire periods or have missing values, change in instruments, and change of observer and observation routines, extensive work has been undertaken by the Norwegian Meteorological Institute (MET Norway) under the “Klimanormaler 1991-2020” project. Construction of temperature dataset to ensure availability of complete data that meet the requirements in Guide to Climatological Practices (WMO, 2011), was undertaken in Nordic Framework for climate services (NFCS) “ClimNorm” project, Tveito et al. (2020). The guide recommends at least 80% data coverage to calculate monthly normals. 207 stations series were available for analysis for the period 1961-2018 for Norway. Out of these, 54% met the recommendations and were therefore used for further analysis

As mentioned above, one of the main prerequisites to establish these climate normals is to ensure that the data used is as homogenous as possible i.e. it represents only natural variations in weather and climate. However, climatic observations are often influenced by inhomogeneities because of a variety of external influences. The main causes of inhomogeneity are relocation of stations and the change of instrumentations that mainly has been triggered by the advent of newer automatic sensors, and recalibration of existing instruments. Other causes include changes of observer and/or observing practices, and changes in the surrounding environment that have an impact in the observations (Aguilar et al. 2003). Most of such changes introduce artificial shifts (change points) in the time series that are abrupt, while some, particularly urban development, lead to gradual increasing biases from real macro-climatic characteristics. Time series with such changes no longer describe natural variability or trends and therefore require homogenization before making any climate assessment.

Various statistical procedures have been developed for the detection and homogenization of inhomogeneities in observed climate data (Alexandersson 1986, Gullett et al. 1990, Førland and Hanssen-Bauer 1994, Easterling and Peterson 1995, Frich et al. 1996, Peterson et al. 1998, Vincent 1998, Mestre 1999, Szentimrey 1999, Perreault et al. 2000, Moberg et al. 2002, Ducre-Robitaille et al. 2003, Caussinus and Mestre 2004, Beaulieu et al. 2008, Menne and Williams 2009, Domonkos and Štěpánek 2009, Guijarro 2011). Domonkos et al. (2012) gave an overview of the development of homogenization methods. Homogeneity assessment and adjustment can be quite complex (Aguilar et al. 2003, Vincent et al. 2002). This and the existence of different homogenization methods necessitated an intercomparison analysis to evaluate these methods. In the European COST Action ES0601 HOME (www.homogenization.org), most of the homogenization methods were tested with an aim of producing a software that would synthesize the best aspects of some of the most efficient methods (HOME 2011, Venema et al. 2012).

In Scandinavia, extensive analysis and achievement in homogenization of climate series have been realized. These were largely inspired by the development of the Standard Normal Homogeneity Test (SNHT) by Alexandersson (1984, 1986), Alexandersson and Moberg (1997). In Norway, the Norwegian Meteorological Institute has made great efforts to provide homogenous climate data series. Analysis of long temperature and precipitation series were carried out in the early 1990s (Hanssen-Bauer and Førland 1994, Hanssen-Bauer et al. 1996, Nordli et.al. 1996, 1997) and monthly precipitation (Hanssen-Bauer and Førland 1994). In these analyses, SNHT method (Alexandersson 1984, 1986, 1997) was applied. Studies of long temperature series was first done by Nordli (1995) by the analysis of Dombås series. More recently, a homogeneity analysis of monthly Norwegian temperature series has been carried out (Andresen 2010, 2011) where SNHT implemented in AnClim (Štěpánek 2008) was applied. They also tested some alternative settings using the European Cost action ES0601 Benchmark data set (Mestre et al. 2011). Gjelten et al. (2014) also used SNHT to homogenize the climate series at Ås. The most recent analyses at MET Norway done on temperature has been within the MIST-2 project, a collaboration between MET Norway and Statkraft, (Lundstad and Tveito 2016, Tveito 2016) where five temperature series representing five different energy consumption regions in Norway were homogenized. The analysis applied the homogenization method developed in COST action HOME: HOMER (Mestre et al. 2013) and SPLIDHOM (Mestre et al., 2011). HOMER was applied to detect homogeneity breaks in monthly series, while SPLIDHOM was used to adjust these breaks in daily time series.

MET Norway has continued to test and adapt tools for homogeneity testing in its effort to provide homogenous and consistent climate data series. This report summarizes the main results of the homogenization of monthly mean temperature for Norway's mainland stations for calculating the new standard climate normals. The analysis was based on 145 series including 30 Swedish series and 7 Finnish series).

The report:

- presents a new homogenized dataset —which will provide good foundation for calculating climate normal
- discuss quality control and the homogenization procedure using HOMER software package,
- gives a brief comparison of breaks detections results in CLIMATOL homogenization procedure vs HOMER and why HOMER was the preferred method and finally
- analyse and discuss some examples of the new homogenized records

2 Background

Detection and attribution of climate change rely on time series of meteorological observations. Such time series will always be associated with a number of uncertainties such as their representativity and station exposure, instrumentation and observation procedures. The World Meteorological Organisation (WMO) gives guidelines (WMO 2006) for observation network design for different purposes with respect to representativity and exposure. They also prescribe precisely the observation procedures in order to keep those identical all over the world. These guidelines are, however, not always possible to follow strictly due to local conditions.

When addressing long-term variability and trends other issues get important. Observation techniques and sensors have developed over time, so have the observation procedures. The environment surrounding the meteorological stations will naturally change over time. This will introduce inhomogeneities in the time series, either as a gradual change or as sudden shifts. That is why sometimes questions arise if these records are reliable or perhaps unfit for climate applications (Davey and Pielke 2005).

Problems might arise when observation times are changed as most of the meteorological elements show daily cycles (Vose et al. 2003, Keevallik et al. 2001). In addition, changes in the algorithms for calculating daily mean temperatures could have an influence on the consistency and homogeneity of the time series (Nordli and Tveito 2008). Precipitation records are sensitive to measurement equipment and corrections for wind, wetting and evaporation (Ungersböck et al. 2001, Keevallik et al. 2001). Wind speed is affected by local orography and the openness of the measurement field as well as by replacing traditional wind vane with an anemometer or an automatic device (Keevallik et al. 2010).

Even in cases where there are no changes in measuring equipment and routine, time series of meteorological data may be affected by changes in the surroundings. One such widely known problem is urbanization that may contribute to the artificial increase of surface air temperature (see e.g. Ren and Ren 2011). An opposite effect is also possible, as the radiation protection of the thermometers has improved over time (Parker 1994) and for the Nordic countries (Nordli et al. 1997). Relocations of stations is the best-known cause of artificial discontinuities in temperature time series. This is well demonstrated by Taiwan temperature series in Hung (2009). Biased data during some period may lead to false estimates of long-term changes in the meteorological regime. This is for example the case of the temperature time series of Stockholm, where the period before about 1860 have been affected by sunshine on the wall cage so that measured summer temperatures in the period were too warm (Moberg et al. 2003). Such problems lead to development of the methods and procedures to detect inhomogeneities in observed data series.

In the previous homogenization analyses of Norwegian precipitation and temperature series, the SNHT method was mostly used. Hanssen-Bauer et al. (1991) and Førland and Hanssen-Bauer (1992, 1994) presented the first results. Both results were on long-term precipitation series. The homogenization activities concerning long-term temperature series were largely inspired and coordinated by the North Atlantic Climatological Dataset (NACD) project for development of unique high quality monthly dataset covering the North Atlantic region (Frich et al. 1996). In the analysis of the NACD temperature series (Hanssen-Bauer et al. 1996), nine Norwegian arctic series were tested; seven were classified as homogeneous while two were found to have at least one break. Further results were also documented in Nordli et al. (1996). The study was further extended to include 13 more stations from mainland Norway (Nordli 1997). Homogeneity testing identified inhomogeneities in 13 of 22 long-term series. The majority of the breaks resulted from relocations (37%). 24% of the breaks were caused by sunshine on the radiation screen cage and 16% by changes on the instruments. More recently, as a part of the European COST HOME initiative (Mestre et al. 2011), a comprehensive homogeneity analysis of monthly temperature series of mainland Norway was carried out (Andresen 2010, 2011). Andresen (2011) analysed 231 station series with SNHT homogenization method. 99 of those series were reconstructed (combined) while 132 were single station series. Inhomogeneities were found in 148 series, however only 100 series were adjusted. 83 series contained no inhomogeneities, as there were no traceable breaks. Nordli et al. (2014) applied SNHT to analyse annual and seasonal temperature series in Svalbard airport. Five series were included in the analysis. The series were found to contain inhomogeneities and were adjusted. This resulted in a homogenized composite series. Gjelten et al. (2014) detected five inhomogeneities in the Ås temperature series in the period 1874–2011. The most recent analysis on homogenization of temperature series in MET Norway have been by Lundstad and Tveito (2016a) and Tveito (2016). In the first analysis, daily mean temperature series representing five different energy consumption regions in Norway were homogenized. The analysis included temperature series from 44 locations into the five networks. 85 breaks were detected in the 44 stations series analysed. The homogenization method developed in COST action HOME, HOMER (Mestre et al. 2013) and SPLIDHOM (Mestre et al. 2011) was applied. Tveito 2016 analysed the effects of applying homogenized daily temperatures and precipitation series as input to spatial interpolation method. Results showed that applying homogenized input series had no systematic effect on the grid estimates.

3 Data and methods

3.1 Temperature dataset and data process

The temperature time series used in this study were extracted from the ClimNorm temperature dataset[1] (Tveito et al. 2020) and covers the period from 1961 to 2020. The ClimNorm dataset includes monthly mean temperature and precipitation totals from 1901 to present (2018) from six countries in the Nordic region (Denmark, Estonia, Finland, Latvia, Norway and Sweden). A total of 2322 original temperature series were available for the entire region, with 2003 original series covering the entire or parts of the analysis period 1961-2018. Only 74 of these series were complete for the entire period, and 157 series had less than one year of missing data. During the last twenty to thirty years, the observation network has been modernized and a large number of stations have been relocated in that process. By merging, 693 merged series with more than 55 years of data became available. Merging of the series was only done if they met two conditions: (1) that there was a maximum horizontal distance of 10 km and (2) maximum vertical distance of 100 m between stations. 207 Norwegian series in the ClimNorm dataset were available for analysis for the period 1961-2018. Out of these series, 40 stations had almost complete series with only short gaps (<=2 years). 71 station series had a minimum length of 30 years and 96 of these were merged series.
In the context of climate normals, the guide to Climatological practices (WMO 2011) recommends that data should be available for at least 80% of the years in the averaging period, for a normal to be calculated. This is to ensure that the new normal calculated will represent the climate and the observed trend as best as possible. The selection of meteorological station series to be used for homogenization in this study was therefore based on data completion; a maximum of 10 years of missing data in the period 1961-2018 was allowed which corresponds to just above 80% data coverage in the period. This also ensures that the results will provide a good reference dataset that can be used further in the interpolation and homogenization of data series with poorer data coverage.

Out of the total 977 stations in Norway's entire historical temperature station network, 207 (≃22%) original stations were available for the study. However, 115 series satisfied the criteria of a minimum of 80% data coverage. 51.3% of these were merged series. The merged series used in the study were reconstructed from up to five original series. Fig. 1 illustrates the reconstruction of the Førde-Tefre (47057420) series from four original series due to several relocations. 30 series from Sweden and 7 from Finland were included in the analysis. These series were used as reference series in the homogeneity analysis (as guidance in the break detection). These Swedish and Finnish stations series were selected

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[1] Since the data source is the ClimNorm data set the station numbers presented in this report is a combination of a national prefix (470 for Norway, 460 for Sweden and 358 for Finland) and the national station number.

based on their location i.e. proximity to the Norwegian series and to their degree of data completeness.

Some series were removed from the analysis either due to duplication (station appearing as a separate single series, as well as one of the series in a merged series as in the case of 47007010 Rena-Haugedalen and 47093300 Suolovuompi) or due to an unresolved error in the homogenization software as in the case of 47053101 Vangsnes (see section 4.3.2.2). The stations in Svalbard and Jan Mayen were not included in this analysis and will be homogenized in a separate analysis. In the end, 108 station series from Norway, 30 from Sweden and 7 from Finland were used in the homogenization process (Fig. 2). 48% of the all series used were merged.

Ideally, the homogenization procedure should have been run in one-step. HOMER however can only test a maximum of 99 stations at a time. The analysis was therefore carried out in two separate runs. Two networks were established to represent the northern and southern regions of Norway. Table 1 provides the number of series used in each network. Appendix A contains a detailed summary of the series used in this study.

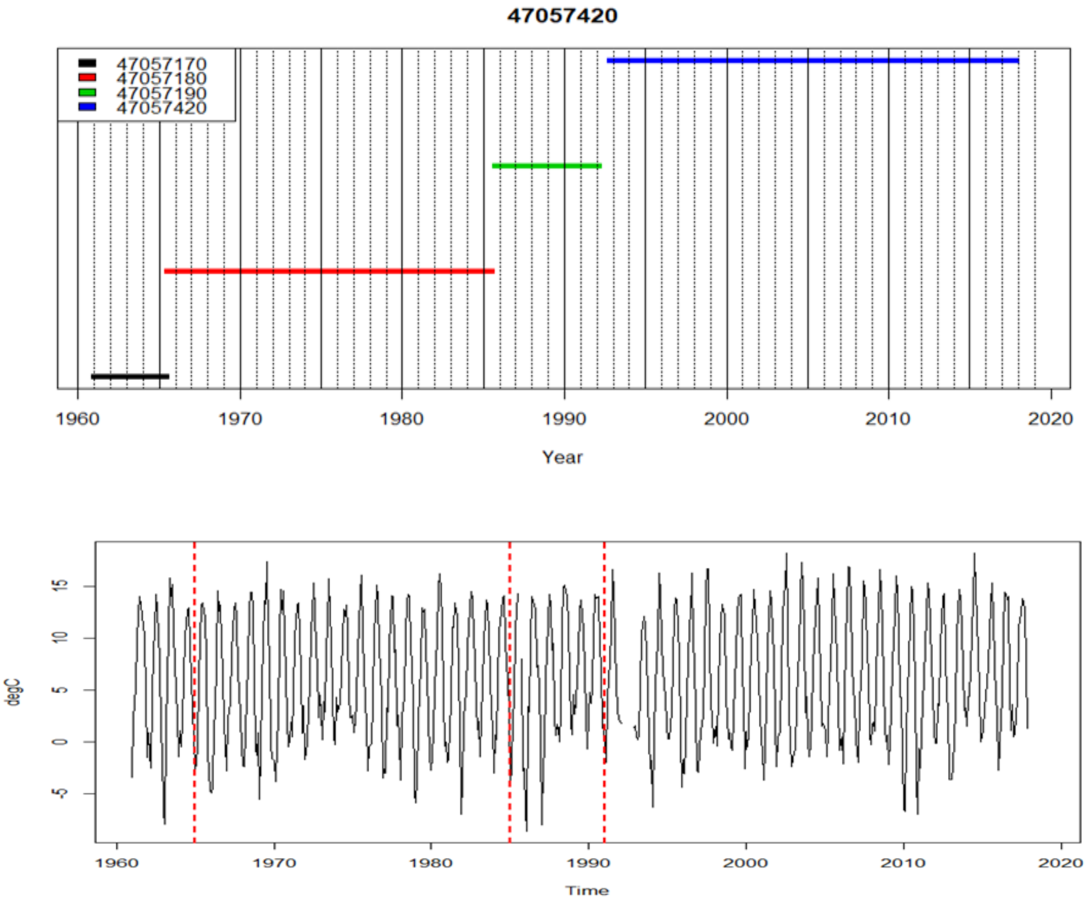

Fig 1: An example of a merged series. The upper panel indicates the original series coverage, while the lower panel shows the raw merged series (Tveito et al. 2020).

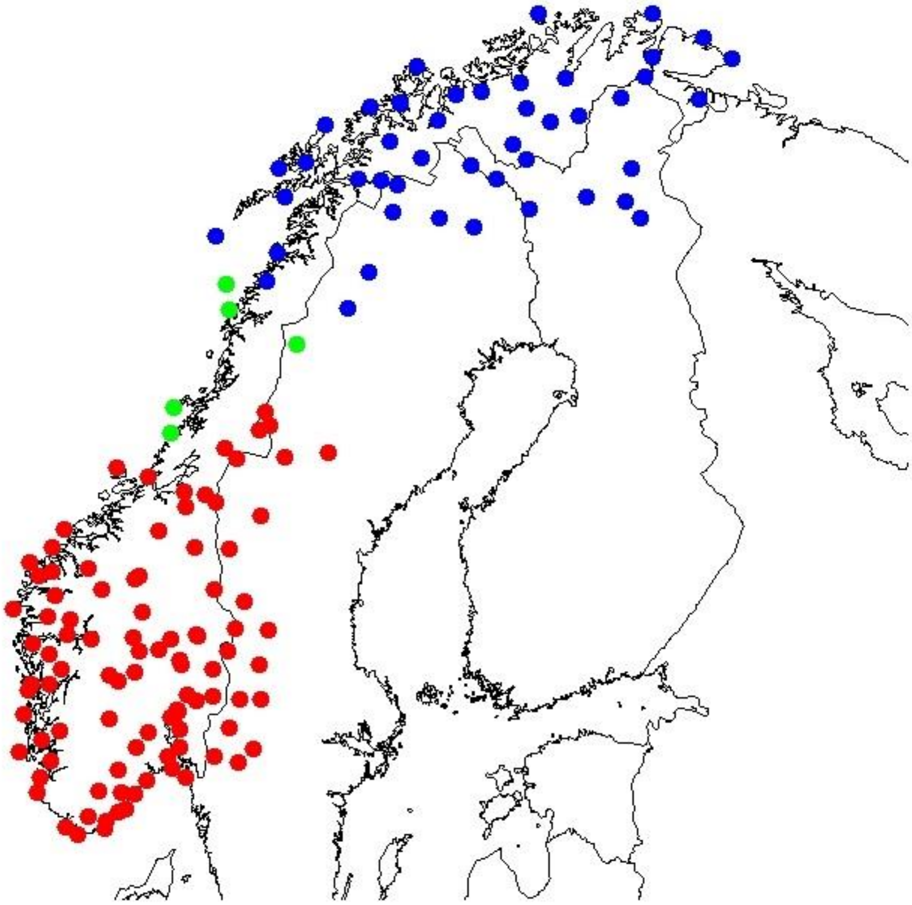

Fig 2: Location of stations used in the study in network 1 (red circles), network 2 (blue circles) and stations used in both networks (green circles).

Table 1: Number of series used in each network.

	Norway (candidate series)	Sweden	Finland	Total
Network1	76	20	0	96
Network 2	32	10	7	49

3.2 HOMER

HOMER (Homogenization softwarE in R) (Mestre et al. 2013) is a software for homogenizing essential climate variables at monthly and annual time scales developed within the scientific programme of the European COST Action HOME ES601. The HOMER homogenization method has been constructed exploiting the best characteristics of several other state-of-the art homogenization methods, i.e. PRODIGE (Caussinus and Mestre 2004), ACMANT (Domonkos 2011, Domonkos et al. 2011), Climatol (Guijarro 2011), and the recently developed joint-segmentation method (cghseg). PRODIGE and ACMANT are based on the methodology of optimal segmentation with dynamic programming (Hawkings 2001). The application is based on a formula for determining the number of segments in time series and of a network-wide unified correction model ANOVA (Caussinus and Mestre 2004). HOMER also includes a tool to assess trend biases in urban temperature series (UBRIS).

HOMER is a relative homogenization method, meaning that it relies on neighbouring stations in the analysis. Reference series has been the most extensively employed approach to relative change point detection. It assumes that when a change point is revealed, the difference or ratio series is formed between the candidate and its reference stations, and only then is an artificial shift is present in the candidate series

HOMER's approach to the final homogenization results is iterative. An interactive semi-automatic method that takes advantage of metadata. The basic features of HOMER are:

1. Basic exploratory statistical analysis (Climatol Checks) of the network which is adapted from CLIMATOL
2. The fast quality control of the series as provided by PRODIGE method
3. The main homogenization procedure which is a combination of three different detection algorithms:
    a. Pairwise-univariate detection, derived from (PRODIGE)
    b. Two factor for joint detection (Picard et al. 2011)
    c. ACMANT-bivariate detection
4. Finally, ANOVA is used for the correction of non-homogeneous datasets.

Step 3 and 4 is then repeated until the corrected series are considered homogenous enough (usually 2-3 cycles)

A comprehensive homogenization procedure using HOMER has been well documented by Lundstad and Tveito (2016).

3.3 Homogenization procedure

3.3.1 Reference series for homogeneity testing

The first step of the homogeneity testing is to define reference stations that will be used in the homogenization procedure. Good reference series must ideally encompass similar climatic signals as the candidate station. In HOMER, the reference stations can be chosen according to their horizontal and vertical distance from the candidate station and/or their cross correlation coefficient. While a high correlation coefficient is very important, the distance criterion ensures that the candidate and reference time series represent the same climatological features. In this study, we used correlation coefficients to choose reference stations for the candidate series - a minimum coefficient of 0.95 was chosen. However, a minimum number of eight reference stations per candidate series was also set as a criterion, meaning that all candidate series would have at least eight reference stations regardless of the correlation coefficient.

3.3.2 Creating the data files

For data to be properly read by the homogenization function the station, coordinates and the climatological data must be provided in a predefined format (Lundstad and Tveito 2016). The input data is prepared in two plain text formats: (a) the stations file and (b) the raw data file which in it is written the year + 12 months (missing values marked by -999.9). The station ID (code) must be correctly recorded as it is linked to the station file. In this study, all the raw data files extracted from the ClimNorm dataset were correctly identified by a combination of the national station code and a national prefix.

3.3.3 Quality Control

3.3.3.1 Climatol Checks (i)

HOMER includes functions from the Climatol method (Guijarro 2011) which produces descriptive summaries of the raw input data such as station density plots, correlograms, histograms, box-plots, and cluster analysis. Presence of anomalous values or major problems in the input data would be evident in these graphics and therefore provide the possibility for correction before the homogenization process. Other resulting graphics show the spatial climate variation of the series based on their correlations and hence classification of the series in groups of similar variability.

3.3.3.2 Fast Quality Control (QC) (f)

The input data is subjected to fast QC checks using the PRODIGE method for detection of outliers. The program provides plots of the difference between candidate and reference series per month. Outliers can then be determined by visual analysis of the anomaly time series output. Consequently, in this study, as defined in HOMER, values were classified as outliers if the candidate series values were outside the reference series range (abnormal high and low values). A file listing the outliers is created in HOMER and later in the process an outlier removal action then changes all entries to missing (-999.9) in the corresponding data files.

It should be mentioned here that for the purpose of this study, the detected outliers were not all removed. Excluding outlying extreme values solely due to their extremeness can distort the results of the study by removing information about the variability inherent in the study area. It is therefore recommended to use a combination of methods that can give satisfactory results and suppress false detections (Stepanek et al. 2009). Candidate series with extreme high or low values above/below the reference range were subjected to further investigation. We sought to determine if (a) there were errors in the data entry and/or data processing error, or (b) the extreme values were legitimate observations that were due to natural variations. This was achieved by inspection of daily values of the candidate station and neighbouring stations. If the outlier in question was as a result of data entry or processing error, the value was corrected. We kept those that were thought to be legitimately true outlier observations. Outlying values that corresponded to flagged modelled daily values were removed. It should also be noted that because the procedure for outlier detection is manual, the process can be tedious especially when dealing with a large dataset as in the case in this study. Moreover, the outlier file creation process is equally manual posing significant challenge in the creation and correction procedure.

3.3.4 Pairwise detection

Pairwise detection is the first step of homogenization procedure in HOMER after quality control checks. The detection of change points in pairwise series is based on three different statistical tools: (1) the model-which is based on the formula:

$$\overline{Y} = \frac{1}{n}\sum_{i=1}^{n} Y_i$$

Where Y is the annual or seasonal difference between two series.

(2) Dynamic programming (DP), where a DP algorithm is performed for change points in a normal sample and (3) selecting the number of change points using the signal (amplitude of change) and standard deviation ratio.

In pairwise detection, a candidate series is compared to neighbouring series in the same climatic area by computing a series of differences that then is tested for breaks. The assumption here is that if the detected change points remains constant throughout the comparison between the candidate station and its neighbours, then the break can be attributed to the candidate series. This approach therefore (a) avoids creation of composite reference series averaging non-homogeneous series and (b) the detections in the series relies on an efficient univariate procedure whose level of power is regulated. In some instances however, the randomness of the difference series or the breakpoints of weak amplitudes can lead to false detection or in some case no detection at all. These ambiguities can be removed by considering the whole set of comparisons and/or using metadata.

To ensure that the pairwise detected breaks in this study were attributed to the candidate station, we set two main criteria:

- with no metadata explaining a break, the change points should be seen in > 80% of the pairwise difference series

- with supporting evidence from metadata, the change points should be seen in at least three of the pairwise difference series

In this study, pairwise detection was applied on the annual and seasonal temperature series. The seasons were defined as winter (DJF), spring (MAM), summer (JJA), and autumn (SON). Because we were working with a large dataset, a non-interactive pairwise detection approach was performed instead of the manual interactive approach, which is known to be very tedious and time consuming.

After the detection of breaks, there is often the challenge of determining the optimal position of the break and the determination of the number of significant breaks in the series. This is the most common problem in the homogenization process. Multiple breakpoints problem is solved traditionally by applying a single breakpoints algorithm multiple times (Easterling and Peterson 1995). First algorithms solving the problem directly are MASH where the problem is solved with a computationally expensive search (Szentimrey 2008) and PRODIGE method where the problem is solved in two steps. First, the optimal position of the break is found using the fast optimization approach called dynamic programming (Lavielle 1998, Hawkings 1972, 2001). Second, the number of breaks is determined by minimizing the internal variance within the sub-periods between two consecutive breaks plus a penalty for every additional break proposed by Caussinus and Lyazrhi (1997). The penalty is intended to avoid adding insignificant breaks. However, Lindau and Venema (2013) showed that to characterise breaks within a time series, it is important to decompose total variance into either internal or external variance. They therefore showed that the external variance, defined as the variance of the sub-periods means, is the key parameter to detect breaks in climate records and that the decomposition with the maximum external variance defines the optimum positions of breaks for a given number of breaks.

3.3.4.1 *Metadata*

In this study, not all the detected breaks in pairwise were adjusted. After the breakpoint identification in pairwise comparison, an intensive process of compiling available metadata to illustrate how the detected breakpoints are related to documented changes was carried out. To overcome the discussed detection problem, the change points were compared with metadata to validate if there were actually inhomogeneities in the series. The other two detection algorithms in HOMER (joint detection and ACMANT) (to be discussed later), were equally applied. Only then would a decision be made regarding which of those points will be regarded as true inhomogeneities.

Metadata was collected from different sources. Some metadata are available digitally in MET Norway database. Metadata was also collected from publications and reports (Lundstad and Tveito 2016, Andresen 2011, Nordli 1997). The paper archive of station files at MET Norway was also used as a source if no metadata for suspected break points was found using the digital sources.

3.3.5 Joint detection (*multiseg function*)

Joint detection of Picard et al. (2011) was developed to solve the multiple breakpoint problem as well as determination of the number of breaks problem in pairwise detection. It is an alternative two-factor model approach where the whole set of series in the network are jointly taken into account for optimization. The *multiseg* function determines the optimum number of change points using the Modified Bayes Information Criterion. Picard et al. (2011) proposed a '2-stage' computational algorithm in joint segmentation in order to apply Dynamical Programming (DP). This is because the classical DP could not be applied due to computational complexities (Caussinus and Mestre 2004). The first stage entailed finding all optimal solutions for each factor separately and the second stage uses outputs from the first stage to optimally allocate the number segment to each factor.

The *multiseg* function in HOMER provides a graphical user interface that is interactive and allows the automatic attribution of changes. In other instances the pairwise detected breaks allow us to put evident changes that were not automatically detected by *multiseg.* For better control of the results, we used metadata to manually validate or reject joint detection breaks.

3.3.6 ACMANT detection

ACMANT is a fully automatic homogenization procedure developed from PRODIGE. This step follows the first cycle of detection and correction of obvious breaks detected with pairwise and joint detection. This is because one of the main features of ACMANT detection is that it relies on pre-homogenized reference series. Other important features are coordination of the operations at different time-scales (i.e. multi-annually to monthly scales) and identification of inhomogeneities with a strong seasonal behaviour especially in temperature series that are often hardly detectable on annual means but clearly detectable with ACMANT bivariate detection. An additional useful feature of ACMANT that has been included in HOMER is the detection with monthly preciseness

Similar to joint detection, ACMANT is equally provided with an interactive interface that allows user intervention either to remove automatic detected breaks or to add new breaks. Metadata knowledge was applied at this stage before validating automatic ACMANT detected inhomogeneities.

After the ACMANT detection process, the inhomogeneities detected were corrected using the ANOVA correction method. The correction process ends, whenever pairwise, joint-detection, and ACMANT bivariate detection find no additional changes on the corrected series (Mestre et al. 2013). The homogenization process on the other hand ends with the determination of the precise month in which the break occurred and the final correction.

3.3.7 ANOVA correction method

ANOVA is based on minimisation of variance of the homogenized data based on assumptions that: the series belong to the same climatic area such that the climate signal a sum of a climatic effect, a station effect and a random white noise. This is the simple two-factor analysis of variance model without interaction denoted by ANOVA. The two-factor model takes into account the change points in the series.

Let X be a matrix of n observations X_{ij} on p series where i=1,..., n is the time index and j=1,..., p is the station index. Let k_j be the number of change points, and $\tau_{1,j}, \tau_{2,j}, \dots, \tau_{k_j,j}$ the positions of K_j change points. Let $K_j = (\tau_{1,j} \dots, \tau_{k_j,j})$ be the set of change points and outliers for series j.

Let μ_i be the climate effect at time i and υ_{jh} the station effect of station j for the level L_{jh}. Level denotes a homogeneous sub-period between two discontinuities in a given series. Thus L_{jh} is the hth homogeneous sub-period between two discontinuities. If there are no outliers, the data are described by the linear model:

$$E\, X_{ij} = \mu_i + \upsilon_{jh(i,j)} Var(X) = \sigma^2 I_{np}$$

Once segmentation has been achieved in the joint-detection step, correction was computed. Let L_{jk_j} be the last level of series j and $\hat{\upsilon}_{jk_j}$ the corresponding estimation of the station effect. Then, for every$X_{ij} \in L_{jh}$ $(1 \leq h \leq kj + 1)$, the corrected X_{ij} is X^*_{ij} and is given by:

$$X^*_{ij} = X_{ij} - \hat{\upsilon}_{jh(i,j)} + \hat{\upsilon}_{j,k_j+1}$$

It is at this stage that the model allows for the imputation of missing data and the correction of outliers. For any missing data or outlier (i,j) the completion is given by:

$$\hat{X}_{ij} = \hat{\mu}_i + \hat{\upsilon}_{jh(i,j)}$$

Unbiased reconstitution of missing values was achieved because the two-factor model took into account the change points in the series.

In this study, the correction was applied to the monthly data series. It should be noted that the correction is always performed on the input files (initial data) and not on already corrected data. This is achieved by updating the set of validated change points before running ANOVA.

4 Analysis and results

Homogenization of monthly mean temperature has been performed on 108 series in Norway's mainland. The main analyses were based on 2 networks consisting of a total of 146 series (including 31 Swedish series and 7 Finnish series) (Fig. 2), which all have at least 80% data coverage in the 60-year period 1961-2020 (Fig. 3). Swedish and Finnish series were mainly used as reference series in the homogeneity analysis with HOMER.

4.1 Quality control

Fig. 4 provides a sample monthly box-plot for the month of August in network 2. Results reveal anomalous values in one of the Swedish stations, 46178970 Tarfala A. In practice, this series would have been corrected and/or removed from the network before further analysis. We however tolerated this anomaly because the deviation was not present throughout the year but only in May, June, July and August.

Fig. 5 shows the correlogram (correlation coefficient vs distance plot) which is effective to assess the smoothness of spatial climate variation, or otherwise the existence of possible factors (e.g. mountain ridges) responsible for sharp transition between different climates. We can see that as much as correlation generally decreases with distance, high and low correlation (with respect to our set limit of 0.95) co-exist at short distances, implying a possible impact of topography between the stations.

A cluster analysis based on the correlation matrix was then performed and produced a) a dendrogram (not shown) which gives an overall view of how the stations are grouped according to the similarities of their data regimes, and b) a map of the stations (Fig. 8), identified by their station numbers and in different colours to identify groups of stations with similar climate variability. In this study, results of the cluster analysis in Climatol were used as an approximation of climatic classification of the countries temperature regions (Fig 8). The map of stations as well as the correlogram show that all stations used in the analysis were within reasonable distance with each other. This includes the Swedish and Finnish stations.

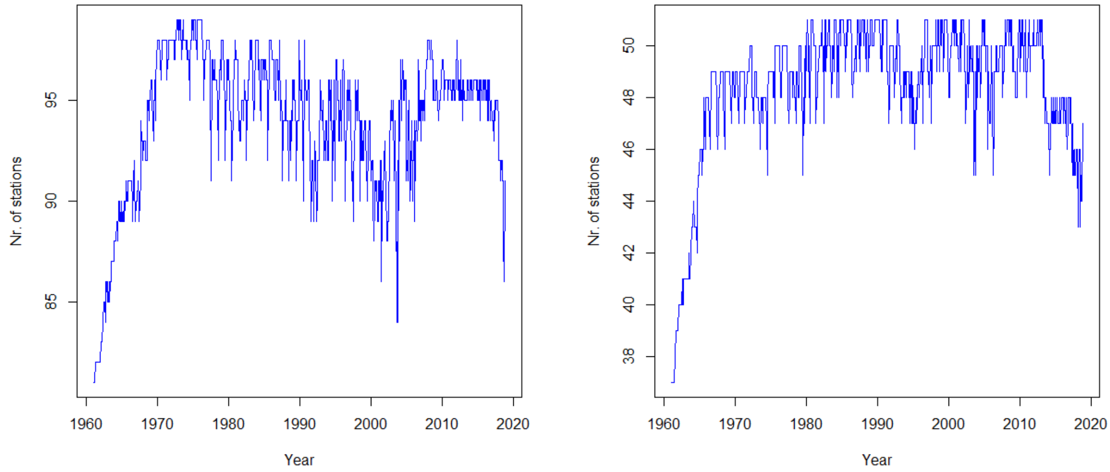

Fig 3: Data availability plot for network 1 (left) and network 2 (right).

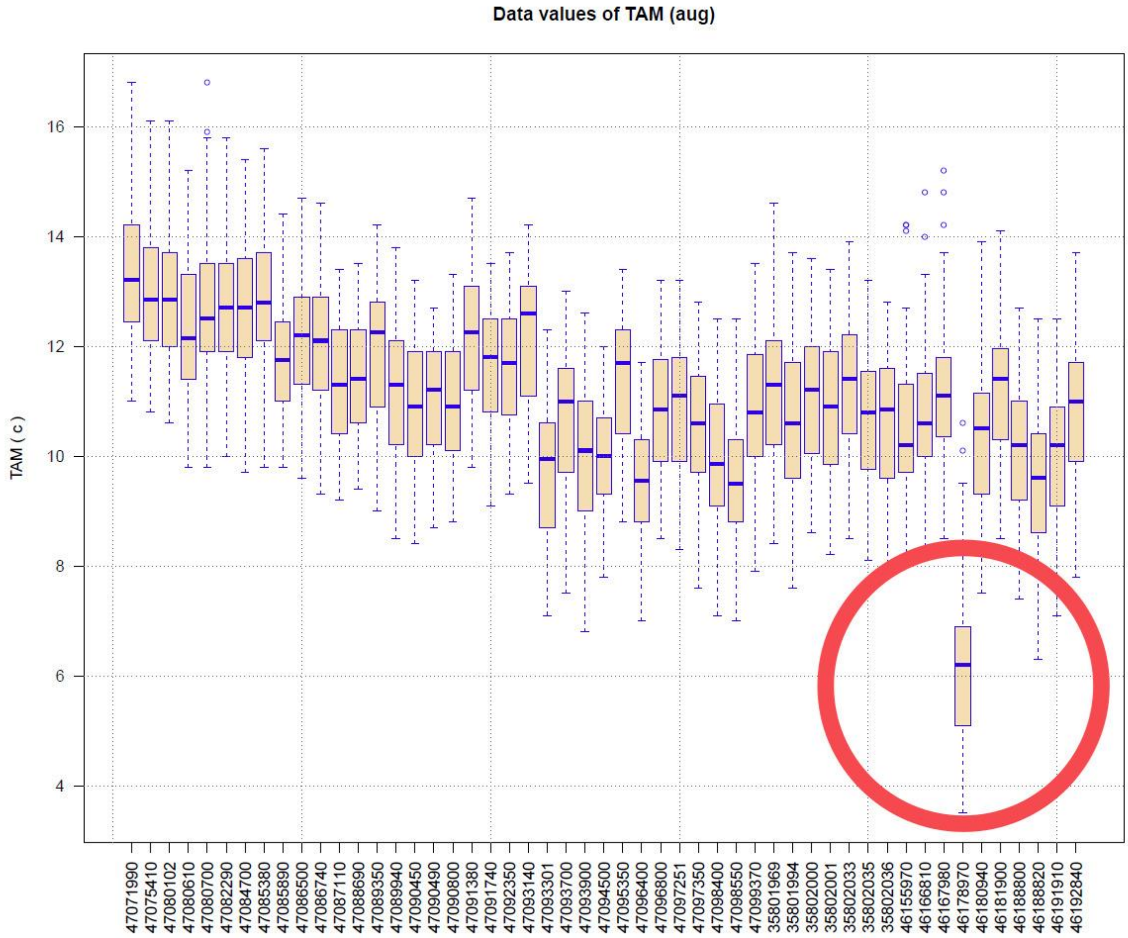

Fig 4: Sample monthly box-plots of the data at every station in network 2 in August. Note the anomalous value of station 46178970 Tarfala A.

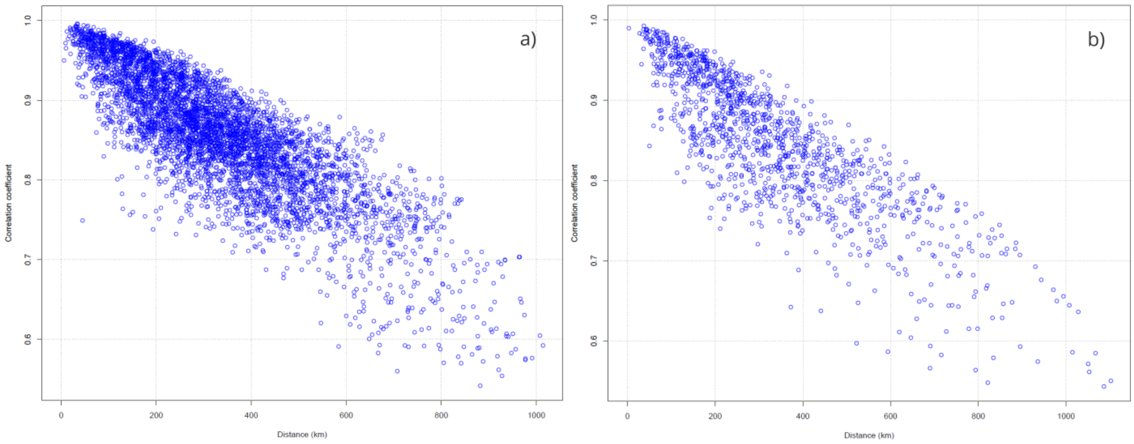

Fig 5: Correlogram (correlation-distance plot) of series for (a) network 1 and (b) network 2.

4.1.1 Outlier detection

Visual inspection of the anomaly time series output of the fast quality control revealed outliers. Fig. 6 highlights an example of such outliers detected in June and July 2011 in 47004920 Årnes series. Outliers were detected in 43 (40%) of all the series analysed. This includes 28 (37%) candidate series in network 1 and 15 (47%) candidate series in network 2. There were in total 90 suspected outlier values (65 and 25 in network 1 and 2, respectively). Eight values were found to be outliers because of data entry/processing error and therefore corrected (Table 2). The great majority of the detected outliers (61 values) were confirmed to be legitimate observations with lower or higher daily average temperature with respect to their neighbouring time series. There was therefore no justifiable reason to remove these data points and as such, we retained them in our data. The final 21 values from eight candidate series were characterized as true outliers and marked for removal in HOMER in the homogenization process, Table 3. These values were in most cases modelled daily values that were flagged as very uncertain and/or erroneous. In one case (47011500 Østre Toten Apelsvoll (in 1992 and 1993) the values were considered to have poor quality and they accounted for 38% of all the flagged data. The total number of outliers in the Swedish series that were flagged were 35 (22 and 13 in network 1 and 2 respectively). These flagged outliers were all excluded from further analysis. No outliers were detected in the Finnish series. Table 3 shows the outliers that were removed in the homogenization process.

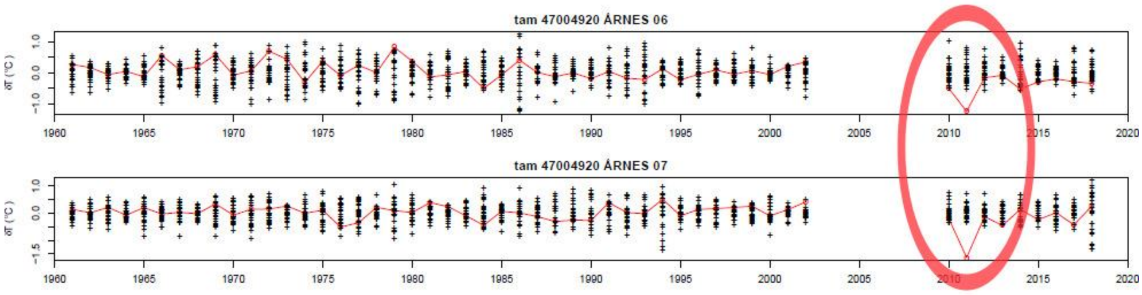

Fig 6: Output from the fast quality control in HOMER for 47004920 Årnes in June and July. The red line is the series from Årnes while the black points show the other reference series. Possible outliers in 2011 are marked by red circle.

Table 2: Overview of all outliers' values that were corrected.

Stn nr	series	yyyy.mm	Outlier values	Corrected to
47019710	Asker	2008.07	15.1	17.4
47024890	Nesbyen-Todokk	2004.03	-4.3	-0.3
		2003.11	-4.3	-1.9
47046610	Sauda	2017.03	4	4.1
47057420	Førde	1993.09	8.3	8.2
47089950	Dividalen	1997.04	0.1	-3.8
47098550	Vardø radio	2007.09	8.6	7.8
47071990	Buholmråsa Fyr	2007.06	13.8	11.4

Table 3: Outliers in network 1 and 2 that were removed.

Station number	**Name**	**Outlier (yyyy.mm)**
Network 1		
47011500	Østre Toten-Apelsvoll	1992.03, 1992.08, 1992.09, 1992.12, 1993.01, 1993.04, 1993.09, 1993.10
47046610	Sauda	2016.06, 2016.10, 2016.11, 2017.01, 2017.02, 2017.03, 2017.05
47050310	Kvamskogen-Jonshøgdi	2015.05
47052310	Modalen III	2015.08
47055820	Fjærland-Bremuseet	2013.03, 2016.06
47059680	Ørsta Volda lufthavn	2010.11
47066720	Berkåk-Terminalveien	2012.04
46092410	SVE-Arvika A	2003.10, 2006.02, 2006.03
46102540	SVE-Höljes	1973.05, 1974.04, 1974.07
46103080	SVE-Torsby	2008.05, 2009.05, 2010.05
46112170	SVE-Grundforsen	1962.09
46132590	SVE-Edevik	1966.11
46134590	SVE-Almdalen	1978.12
46146050	SVE-Hoting A	1980.11, 2009.02, 2014.02, 2015.02

46155970	SVE-Hemavan Flygplats	1967.12, 1968.10, 1978.12, 1982.02, 1991.02, 2003.02
Network 2		
47088690	Hekkingen fyr	2018.07
46155970	SVE-Hemavan Flygplats	1978.12, 2018.03
46167980	SVE-Kvikkjokk-Årrenjarka	2004.01, 2018.01
46178970	SVE-Tarfala A	1981.05, 1986.06, 1987.01, 1988.09, 1988.10, 2004.07, 2014.11
46181900	SVE-Vittangi	2013.10, 2013.11

4.1.2 Selection of reference series

As described earlier the reference series in this study will form the basis for change points detection and are based on a high correlation threshold ($\rho > 0.95$) and/or minimum of eight stations to be used for intercomparison to ensure similar variability with the candidate series. These neighbouring reference series are ranked according to their correlation with the candidate series (Table 4). Results as illustrated in Fig. 7 show that the number of reference series paired by the different candidate series ranged from 8 (our set limit) to 39 station series for Network 1 (N1) and 8 to 22 station series in Network 2 (N2). Most candidate series (31%) had eight reference series. Results showed that Swedish and Finnish stations were highly correlated with the Norwegian series analysed and in some cases, having better comparison than the Norwegian neighbours as in the case of 47099370 Kirkenes Lufthavn (Table 4). It is important to note that correlations of the Norwegian series to those from Sweden and Finland were equally very high. For the Swedish stations in N1, the number of reference series paired with those series ranged from 8 to 36 neighbour stations. Only four had eight reference stations, the rest had more. In N2, on the other hand the reference series ranged from 8 to 18. This therefore implied that even the Swedish and Finnish series fulfilled our requirements in HOMER for homogenization.

The highest number of paired reference series in N1 was 47017850 Ås with 39, followed by 4718700 Oslo Blindern and 47021680 Vest Torpa II both with 38 reference stations. Candidate series in N2 with the highest number of paired series were 47093700 Kautokeino and 47093900 Sihccajavri with 22 and 21 reference series respectively. Swedish and Finnish stations with the highest number of reference stations were 46092130 Blomskog A and 35802036 Utsjoki Nuorgam with 36 and 17 respectively.

It should however be noted that some of the candidate series with the minimum set number of neighbours (eight) had lower correlations than the set limit of 0.95 with its paired neighbours. The lowest correlation coefficient recorded was 0.925 in N1 and 0.904 in N2; which shows that the correlations were still quite high for the entire dataset.

Table 4: Small extract, showing reference stations (station number, correlation coefficient and station name) used in the homogeneity analysis for selected stations in network 1 and network 2.

47018700 OSLO BLINDERN	**47050540 BERGEN FLORIDA**	**47069100 VÆRNES**
===============================	===============================	===============================
47019710 0.992 ASKER 47017850 0.992 ÅS 47017150 0.983 RYGGE 47004780 0.983 GARDERMOEN 47032060 0.982 GVARV-NES 47012680 0.980 LILLEHAMMER-SÆTHER 47004920 0.980 ÅRNES 47021680 0.979 VEST-TORPA II 46092100 0.979 SVE-46092100 46081540 0.977 SVE-46081540 47028380 0.977 KONGSBERG-BRANNSTASJON 46092130 0.975 SVE-46092130 47006020 0.975 FLISA II 47027450 0.975 MELSOM 46093220 0.973 SVE-46093220 47005590 0.972 KONGSVINGER 47007950 0.970 RENA-FLYPLASS 47034130 0.968 JOMFRULAND 47011500 0.967 ØSTRE-TOTEN-APELSVOLL 47039750 0.967 BYGLANDSFJORD-NESET 46103410 0.963 SVE-46103410 47027500 0.962 FÆRDER-FYR 46092410 0.962 SVE-46092410 47018950 0.961 TRYVANNSHØGDA 46114140 0.960 SVE-46114140 47023500 0.959 LØKEN-I-VOLBU 47036560 0.959 NELAUG 46112170 0.959 SVE-46112170 46103080 0.959 SVE-46103080 47035860 0.959 LYNGØR-FYR 47036200 0.954 TORUNGEN-FYR 47024890 0.954 NESBYEN-TODOKK 46103090 0.954 SVE-46103090 47012550 0.952 KISE PA HEDMARK 47038140 0.951 LANDVIK 47023160 0.951 ÅBJØRSBRÅTEN 46113420 0.951 SVE-46113420 46102540 0.950 SVE-46102540	47052860 0.993 TAKLE 47046930 0.980 VATS-I-VINDAFJORD 47057420 0.977 FØRDE-TEFRE 47050310 0.975 KVAMSKOGEN-JONSHØGDI 47058070 0.974 SANDANE 47050500 0.972 FLESLAND 47045870 0.972 FISTER-SIGMUNDSTAD 47048330 0.971 SLÅTTERØY-FYR 47059610 0.968 FISKÅBYGD 47057770 0.958 YTTERØYANE FYR 47052310 0.956 MODALEN-III 47047300 0.952 UTSIRA-FYR	47068290 0.989 SELBU II 47069380 0.983 MERÅKER-VARDETUN 47070850 0.970 SNÅSA-KJEVLIA 47071550 0.966 ØRLAND-III 47066720 0.964 BERKÅK TERMINALVEIEN 46132170 0.958 SVE-46132170 46133050 0.958 SVE-46133050 47073500 0.954 NORDLI-HOLAND 46132590 0.954 SVE-46132590

47080102 SOLVÆR-III	**47090450 TROMSØ**	**47099370 KIRKENES LUFTHAVN**
===============================	===============================	===============================
47080610 0.993 MYKEN 47075410 0.986 NORDØYAN-FYR 47080700 0.985 GLOMFJORD 47082290 0.978 BODØ-VI 47071990 0.958 BUHOLMRÅSA-FYR 47086740 0.956 BØ-I-VESTERÅLEN III 47087110 0.955 ANDØYA 47084700 0.955 NARVIK-LUFTHAVN 47085380 0.951 SKROVA-FYR	47088690 0.990 HEKKINGEN-FYR 47090490 0.985 TROMSØ-LANGNES 47087110 0.973 ANDØYA 47090800 0.972 TORSVÅG-FYR 47086500 0.971 SORTLAND 47092350 0.956 NORDSTRAUM-I-KVÆNANGEN 47086740 0.948 BØ-I-VESTERÅLEN III 47084700 0.947 NARVIK-LUFTHAVN	35802033 0.969 FIN-358102036 35802036 0.963 FIN-358102001 47098550 0.959 VARDØ-RADIO 47096800 0.956 RUSTEFJELBMA 47096400 0.954 SLETTNES-FYR 47098400 0.954 MAKKAUR-FYR 35802035 0.950 FIN-358102000 35802001 0.948 FIN-358102035

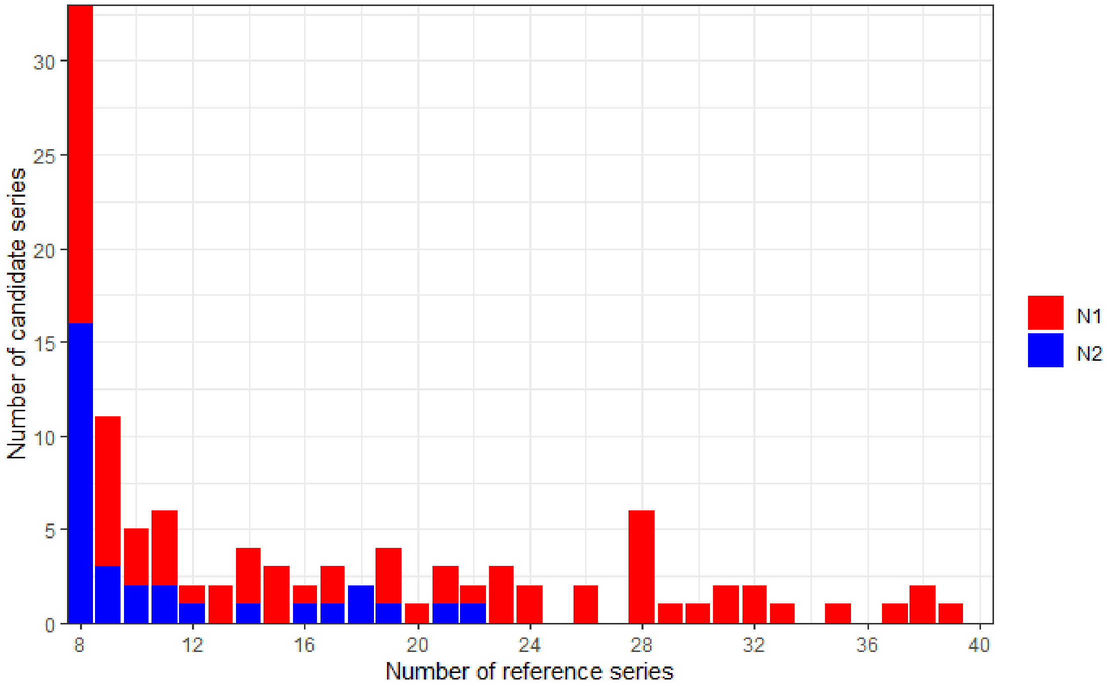

Fig 7: Number of reference series per candidate series in network 1 (red) and network 2 (blue).

4.2 Network adjustments

Detection and correction of inhomogeneities are significantly impacted by the choice reference series (Szentimrey 2010). Because the number of series to be homogenized is limited to 99 in HOMER, the temperature series in our study were split into two networks. The number of series in each network was therefore varied to ensure that they included the best-correlated reference series. A check to assess if any of the bordering stations in network 1 should be included in network 2 and vice versa was conducted. This optimizes the selection of best reference series for each candidate station and captures any boundary effect.

Adding stations from N2 to N1 improved the reference station selection for two of the original N1-stations: 47071990 Buholmråsa Fyr and 47075410 Nordøyan Fyr. Adding stations from N1 to N2 was beneficial for three candidate series in N2: 47080102 Solvær III, 47080610 Myken and 47080700 Glomfjord. One Swedish station, 46155970 Hemavan Flygplats, also benefited from the added stations. The series affected by the network changes were those located on the boundaries of each network. As a result, the series 47071990 Buholmråsa Fyr, 47075410 Nordøyan Fyr, 47080102 Solvær III, 47080610 Myken and 46155970 Hemavan Flygplats were included in both N1 and N2 to avoid any border effect in the homogeneity testing, see Fig. 2 and Table 4. It should however be mentioned here that incorporating series at a greater distance from the candidate series might simply cause the incorporation of additional noise due to climate differences. This was evident at some point in our network adjustments analysis in N2 where more series were included in the adjustment.

Including stations from N2 to N1 also affected the cluster analysis of the network – the cluster analysis now showed three different temperature regions instead of two. Adding stations from N1 to N2 did not affect the clusters in network 2 – there were still three temperature regions.

The resulting six temperature regions in this study (Fig. 8) are similar to those identified by Hanssen-Bauer and Nordli (1998). They applied a combination of principal component analysis and cluster analysis to divide Norway into six temperature regions. There are differences in the boundaries between the temperature regions, but this is not surprising as the number of stations are different in the two analyses. Hanssen-Bauer and Nordli (1998) used 46 stations while the study presented here uses 145 stations.

After this final network adjustment, we now had quality-controlled series ready for further homogenization analysis.

Table 4: Number of series used for homogenization process in each network.

	Candidate stations	**Additional reference stations**				**Total**
		South Norway	**North Norway**	**Sweden**	**Finland**	
Network 1	**76**	**0**	**2**	**21**	**0**	**99**
Network 2	**32**	**2**	**0**	**10**	**7**	**51**

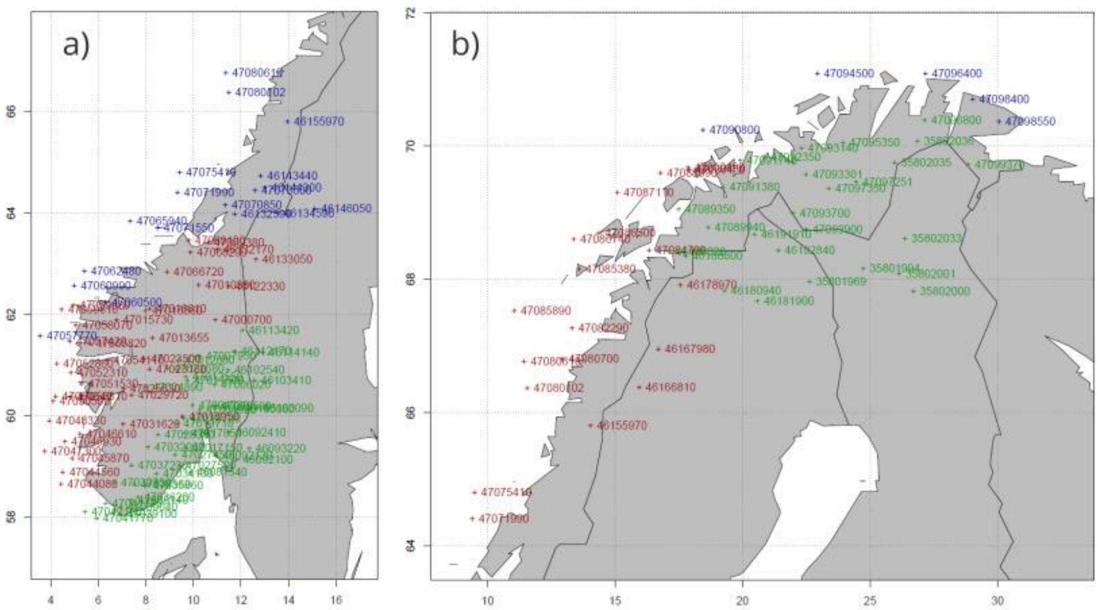

Fig 8: Map of station locations for network 1(left) and network 2 (right). The colours identify station clusters with similar variability.

4.3 Homogenization analysis

4.3.1 Pairwise detection

Pairwise detection analysis was done on all the 145 series (including 30 Swedish series and 7 Finnish series). Pairwise detection discovered several breaks of homogeneity in almost all the Norwegian temperature series. The pairwise test showed that only five series in N1 and four series N2 were unaffected by any artificial shifts. The breakpoint results in both the annual and seasonal series are provided in appendix C.

We can consider the 47004780 Gardermoen airport series as an example. Sample graphical output of pairwise detection is provided in Fig. 9 showing breaks in 1967 or 1969, 1980 or 1983 and 1996 in the annual time series. Fig. 10 shows shifts in 1963, 1987 and 1996 in the winter series, 1976 and 1980 in the summer, 1965, 1981/82/83 and 1996 in spring and 1967, 1980 and 1996 in the autumn series. Here we see some of the most common problems in homogenization procedure: Using our criteria, there is evidence of multiple breaks detected in almost consecutive years (e.g. 1967 and 1969, 1980 and 1983 if we consider breaks in just annual series). Hence, the challenge is to determine the optimal position of the break and the number of significant breaks in the series.

In total, pairwise comparison detected nine different breaks of homogeneity in the Gardermoen temperature series. This is a considerably high number of change points as a result of multiple breaks detected in consecutive years and because there were different breaks in the different seasons. The graphs for Gardermoen series (Fig. 10) illustrates how some breaks in the seasonal series were consistent with those in the annual series. Nevertheless, some were distinct with specific seasons. Five of these breaks were supported by metadata. The minor break in the 1967 annual series that was very evident in the autumn series was caused by relocation of the radiation screen in December 1967. The rather obvious break in the 1980 annual series was equally evident in the spring (1981), summer, and autumn series. Painting of the radiation screen and a small relocation of the radiation screen because of new buildings were the cause of this break. The break in 1997 resulted from construction of a new main airport that led to relocation of the observation site and change of the environment. The station was also automated during the same time. This break could be observed in all the seasons except the summer series. The other breaks were only specific to different seasons, for example the 1987 break caused by a new thermometer could only be observed in the winter series.

Fig. 9 and 10 shows the different graphical representation of pairwise detected breaks in HOMER. Vertical lines in Fig. 9 depict detected breaks. In Fig. 10, the inverted triangle (∇) denotes the year of probable break. Blue filled inverted triangle filled suggests a possible negative adjustment while those in yellow suggest a positive adjustment. The triangles have different colours for the different seasons (∇ - annual series, ∇- winter, ∇- summer, ∇- spring, and ∇ - autumn). The left y-axis of each plot shows the reference series which are sorted according to their cross correlation with the candidate station. The first station on the y-axis represents the series with the highest correlation to the candidate station. The pairwise comparison is sorted based on increasing values of standard deviations (σ, upper left corner of each plot). This standard deviation is very useful because detection power is directly related to the amplitude of change. The smaller values of standard deviation ensure detections that are more accurate.

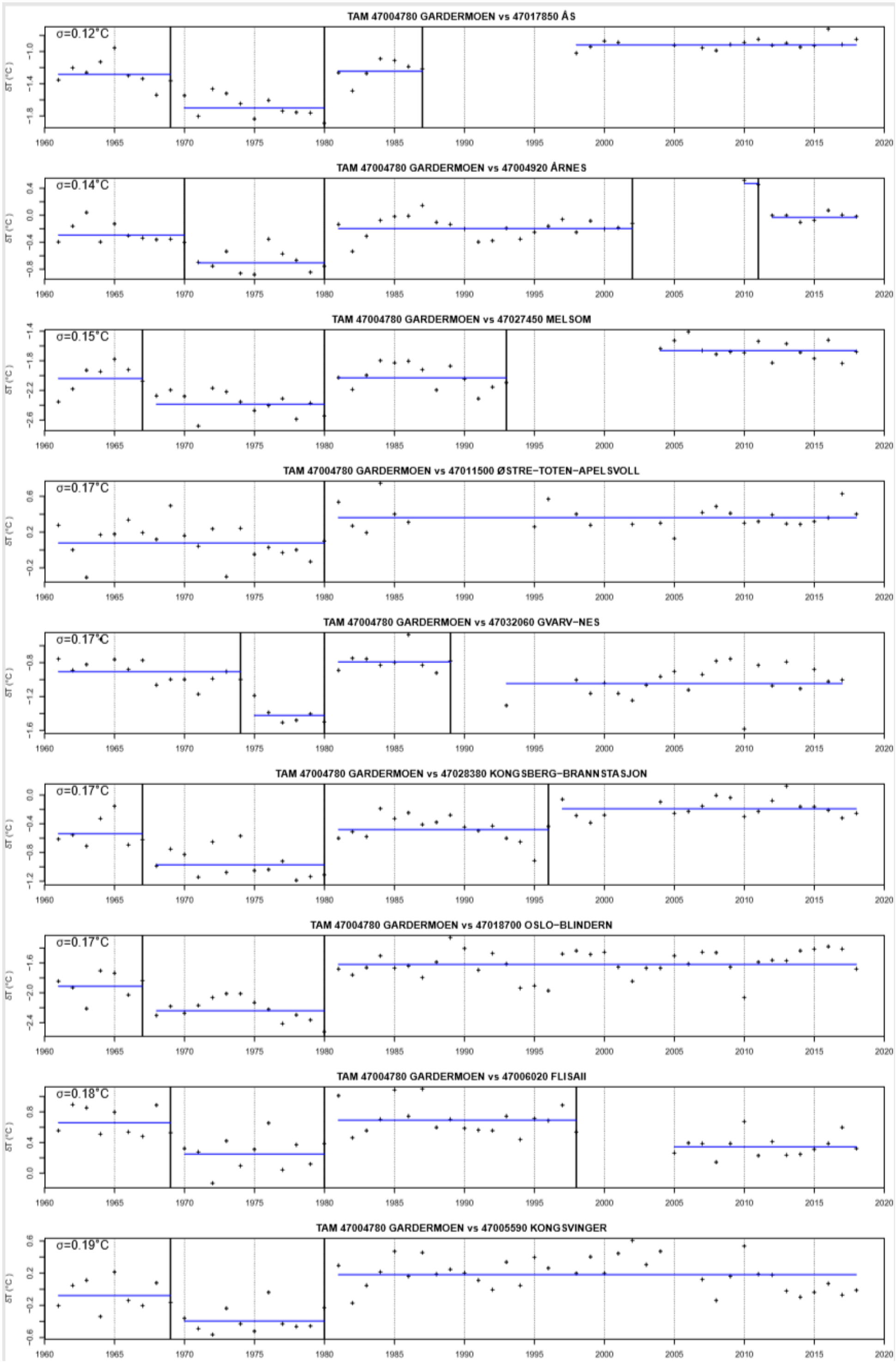

Fig 9: Pairwise comparison between Gardermoen annual series and its neighbours. Vertical black lines denote the year of probable break. Comparisons are sorted according to increasing values of σ (noise standard deviation, upper left corner of each plot). Only eight comparisons with the smallest noise are shown.

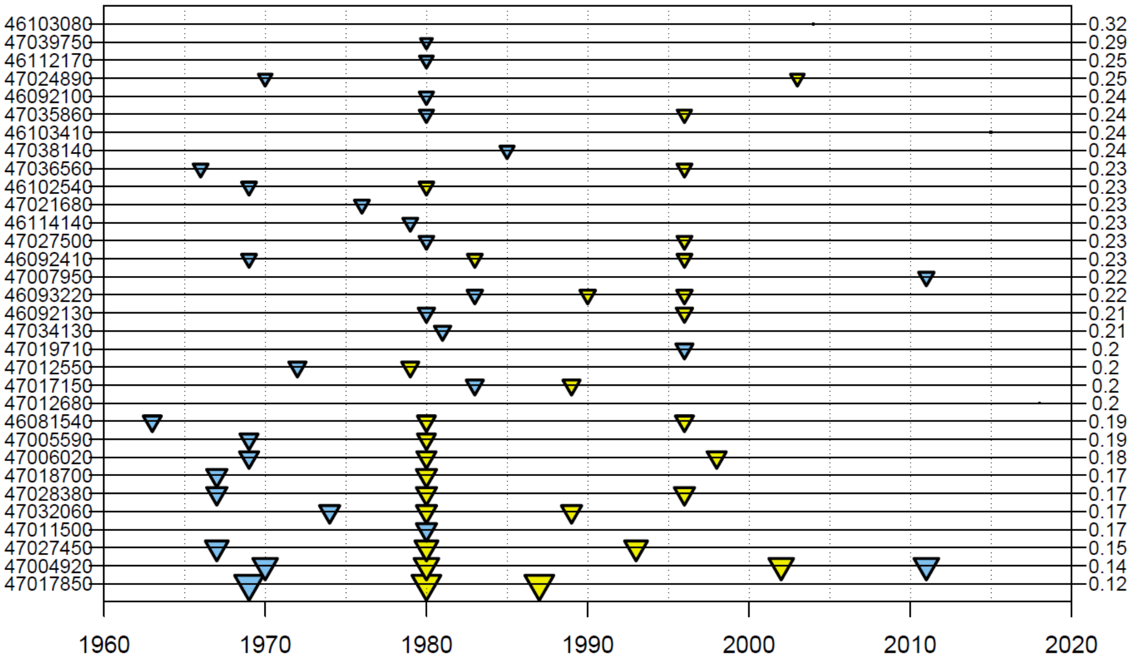

Fig 10a: Pairwise comparison between 47004780 Gardermoen and all its reference stations for the annual series. ∇ denotes year of probable break.

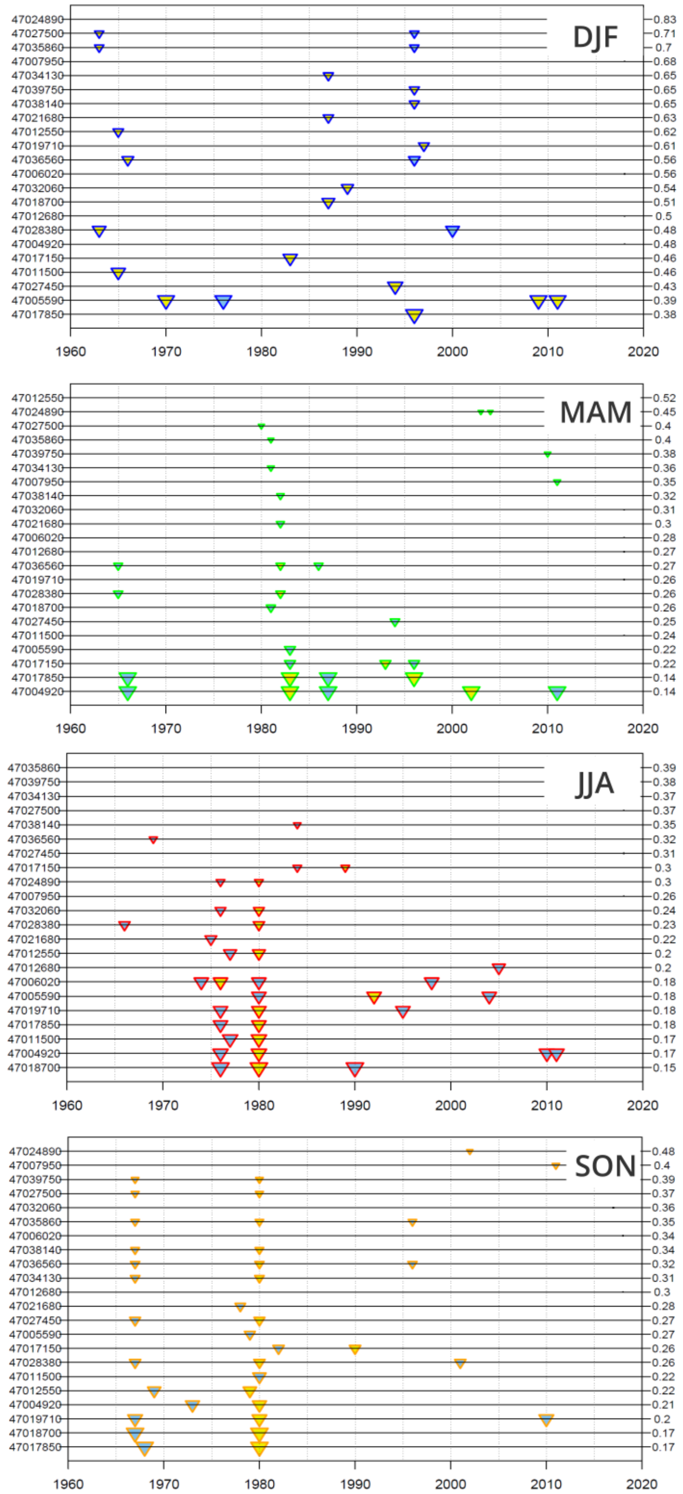

Fig 10b: Pairwise comparison between 47004780 Gardermoen and its neighbouring stations for the seasonal series. Winter (DJF), spring (MAM), summer (JJA) and autumn (SON). ∇ denotes year of probable break.

4.3.2 Joint detection

The second homogenization step consists of running the joint segmentation method. Fig. 11 provides HOMER joint detection graphical output where pairwise and joint detection are compared to allow for better control of the results. Note the good agreement in the amplitudes of the change points in joint detection (⊕) with those of pairwise comparison (▽) in 1980 and 1996. Black inverted triangles (▽) represent breaks detected on the pairwise annual series, blue and red triangles represent winter and summer series respectively.

Automatic joint detection is not perfect. Rather obvious changes in 1980 and 1995 in the Oslo Blindern series when considering pairwise comparison were not detected by joint detection *multiseg* function (Fig. 12). The interactive nature of joint detection however allowed for such breaks to be validated manually. This was done using the graphical user interface (large +) by clicking on the interactive window. Notice also 1971, 1984, 1988 pairwise detected breaks in 4701750 Rygge series (Fig. 13) were missed by joint detection except the 1994 break whose amplitude was comparable to that of pairwise detection. At this point, available metadata of all the pairwise detected breaks had been gathered. This allowed for a better control on the optimal position of breaks that we manually validated using the graphical user interface. As illustrated in Fig. 13, 1972 was validated instead of 1971 (where there was a break) and 1984 validated using the graphical user interface. The 1988 break, which had supporting metadata, was not validated at this point. This is because it is recommended to avoid close change points. Therefore emphasis was put on the 'dominant' metadata. (i.e. new radiation screen in 1984 vs new thermometer in 1988).

Results of Sørkjosen Lufthavn series (Fig. 14) provides a good example on how metadata was used for the determination of the optimal position of the breaks. *Multiseg* detected changes in 1993 and 2004, which were in agreement with the pairwise detected break. However, when conferring metadata the detected inhomogeneities were in fact connected to changes that happened in different years - there was a relocation in 1992 and a relocation combined with automation of the station in 2005. The break years were corrected by first rejecting the detected breaks (large + in the same year) and then adding new change points by clicking on the correct years.

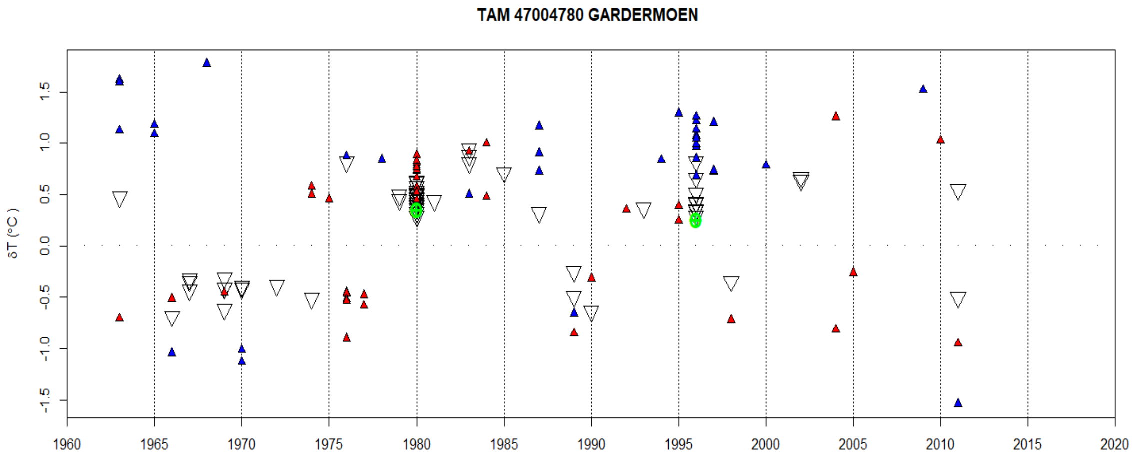

Fig 11: Joint detection interactive window for 47004780 Gardermoen. Years along x-axis and amplitude of detected change points along y-axis. Joint detected breaks (⊕), triangles show breaks from pairwise comparison for annual (black), winter (blue) and summer (red) series.

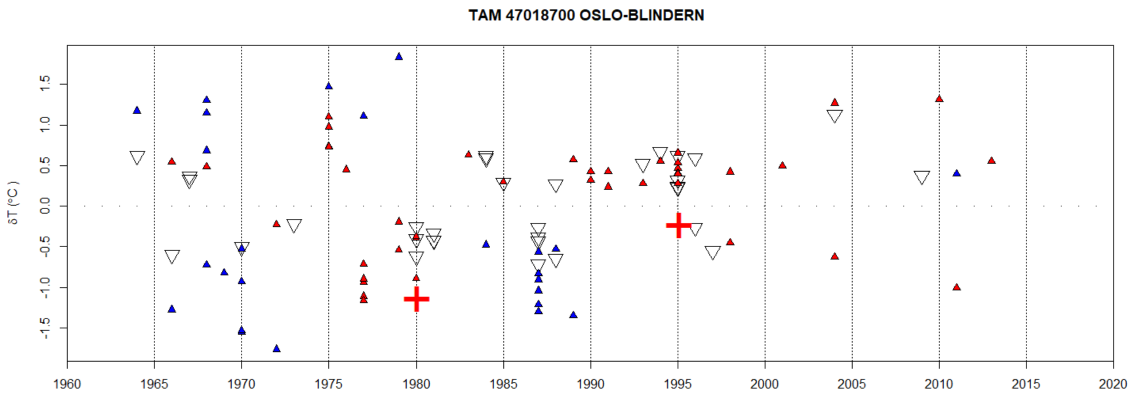

Fig 12: Joint detection interactive window for 47018700 Oslo Blindern. Years along x-axis and amplitude of detected change points along y-axis. Triangles show breaks from pairwise comparison for annual (black), winter (blue) and summer (red) series. Large + marks user interventions.

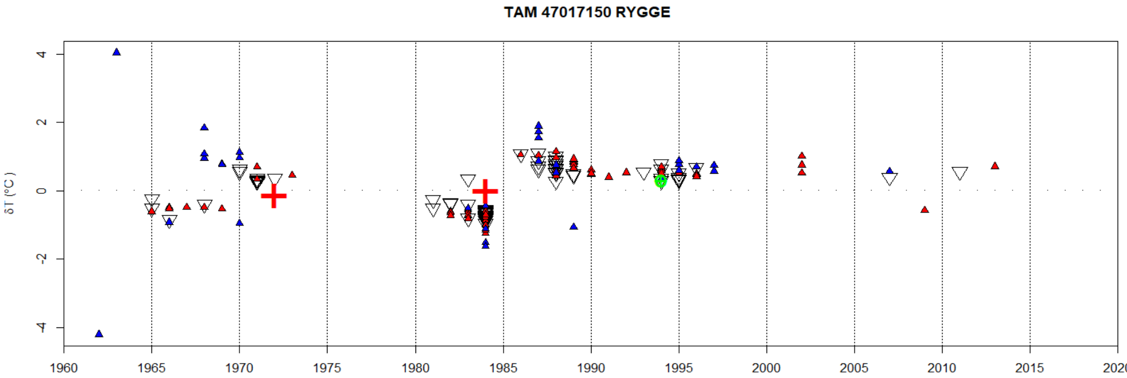

Fig 13: Joint detection interactive window for 4701750 Rygge. Years along x-axis and amplitude of detected change points along y-axis. Joint detected breaks (⊕), triangles show breaks from pairwise comparison for annual (black), winter (blue) and summer (red) series. Large + marks user interventions.

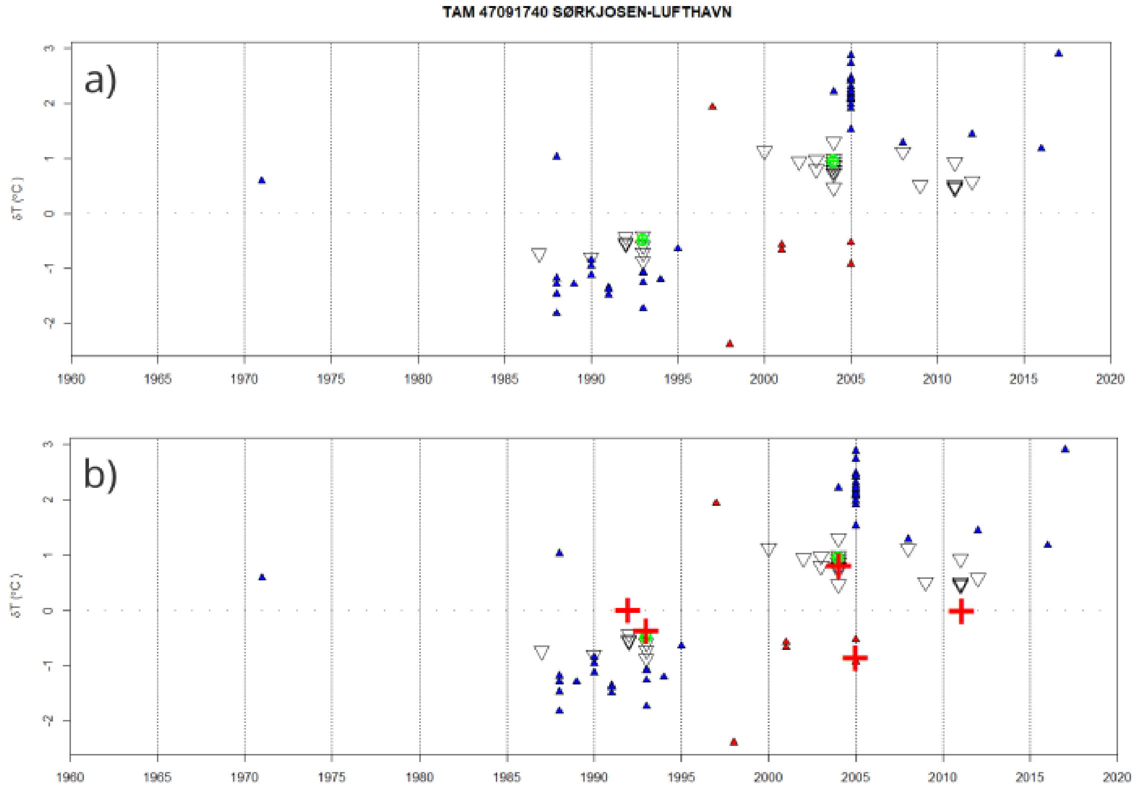

Fig 14: Joint detection interactive window (a) before and (b) after user intervention for 47091740 Sørkjosen. Years along x-axis and amplitude of detected change points along y-axis. Joint detected breaks (⊕), triangles show breaks from pairwise comparison for annual (black), winter (blue) and summer (red) series. Large + marks user interventions.

4.3.2.1 *The late 80s "climate shift"*

In some cases, *cghseg* joint-detection, detected changes that were not supported by either pairwise comparison and/or metadata. The *multiseg* incorrectly attributed inhomogeneities in series especially in the second and subsequent correction cycle using HOMER. In N1 for example, *multiseg* detected breaks in 1987 on most stations analysed (56 out of the total 76 candidate stations). Careful consideration was given to the 1987 joint detected breaks. This is because the period corresponds to a 'climate shift' in most parts of southern Norway (most evident in S and E, Lundstad and Tveito (2016)). To avoid masking possible climatic changes in the series, these 'wrong' breaks were prudently analysed and manually rejected (large +**)** when they did not have supporting metadata. Out of the 56, 24 were supported by metadata and therefore those breaks adjusted for. The rest were invalidated by manually rejecting the breaks due to lack of evidence (metadata).

Network 2 on the other hand had 1988 as the common year with which *multiseg* detected breaks in 21 out of the total 32 series. The joint breaks were equally detected in the second joint detection cycle. Only eight series had supporting metadata for the same year and 18 series in the years between 1986-1990. It should be mentioned here that a 'climate shift' had been observed in Northern Norway too as described by Lundstad and Tveito (2016). Fig. 15 of 47084700 Narvik Lufthavn provides a good illustration of such breaks. Note that there was no joint detected break (⊕) in the first joint detection cycle, Fig. 15a, and with an unattributed break by *Multiseg* (⊕) on the second joint detection cycle, Fig. 15b. This break was rejected (large +).

The analysis by Lundstad and Tveito (2016) therefore demonstrates that the joint detection algorithm in HOMER is sensitive to shifts in climate such that whenever there is an abrupt regional change in temperature, e.g. a strong increase as in our case, the detection algorithm identifies that as a break since the response at the stations in the network might differ. This explains the 1987-1988 breaks in most series where there was a strong temperature increase. This was mostly evident in the winter series.

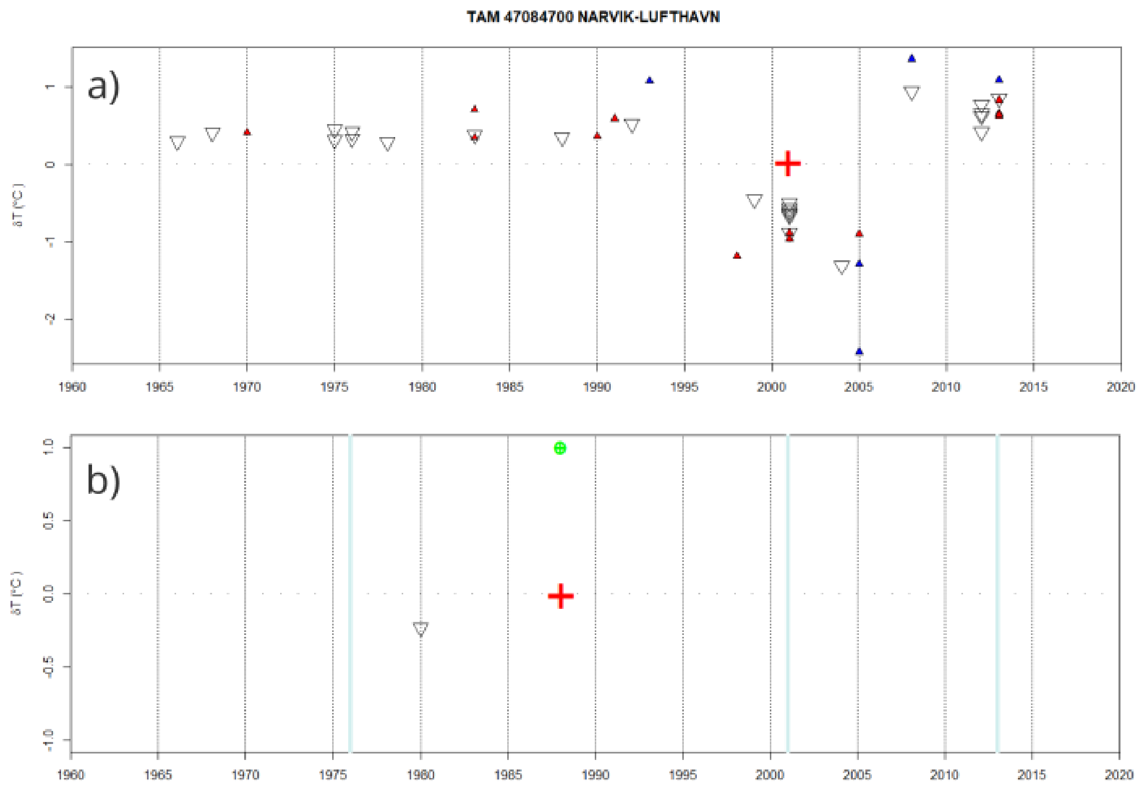

Fig 15: Interactive window for 47084700 Narvik Lufthavn from the (a) first joint detection cycle and (b) second joint detection cycle. Joint detected breaks (⊕), triangles show breaks from pairwise comparison for annual (black), winter (blue) and summer (red) series. Large + marks user interventions. Blue vertical lines denote previous corrected breaks.

The raw and corrected Gardermoen annual series after final correction is provided in Fig. 16. The figure shows an annual increase in the average temperature for Gardermoen throughout the study period, 1961-date. A clear 'climate shift' can be observed in 1988 where the most temperature increase occurred. Since then there were only two main cold years (blue). This climate shift was present in all the Norwegian temperature series analysed from 47039040 Kjevik in the south to 47099370 Kirkenes Lufthavn in the north of the country. This could be the main reason why HOMER specifically in the second cycle of joint-detection (*multiseg* function) introduced unattributed breaks in most series (71% of all series analysed). We considered these detected breaks in 1986-1987-1988-1989 to be as a result of regional climate shift caused by changes in the general large-scale atmospheric circulation, and not artificial shifts caused by non-climatic effects at the stations. These breaks were therefore ignored for as long as they had no supporting metadata. These results on the mean temperature trend are consistent with those obtained by Lundstad and Tveito (2016).

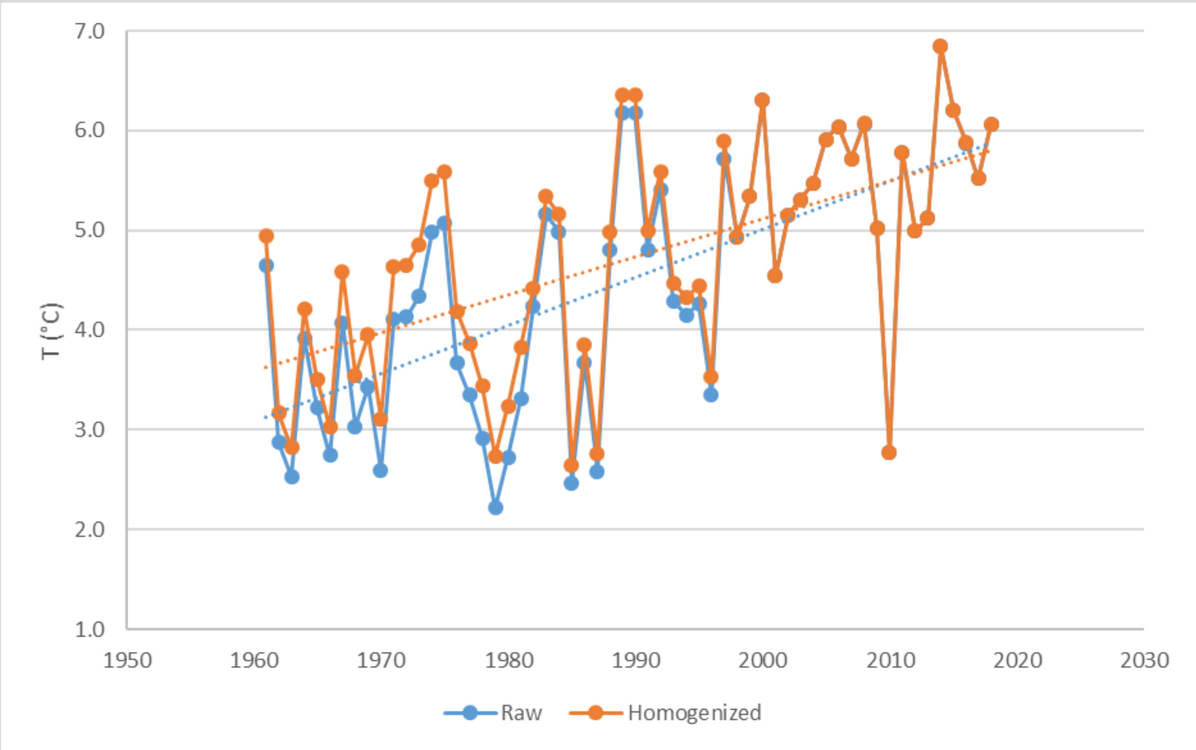

Fig 16: Raw and homogenized annual time series for Gardermoen. Linear trend lines for both series are added.

4.3.2.2 *Unresolved occurred errors*

While running HOMER in the automatic mode of joint-detection and the correction step, we encountered errors in the homogenization software. Some of the errors could be resolved while others could not. The first error in the program was observed in the early stages of homogenization (first cycle of joint detection). This was resolved by removing the 'problematic' series from the network file. While this action fixed the problem, homogenization results in the new joint detection run, appeared with a one-step lag. This was solved by removing the said series and all its corresponding results. The homogenization procedure was then started afresh. This is the reason why Vangsnes series was removed from the dataset. Later in the process in the subsequent joint detection cycle, we encountered similar errors in the Svinøy Fyr (47059800) series. This time eliminating the 'problematic' series did not resolve the error; instead, different series now appeared with similar errors. Convergence problems in the multivariate detection algorithm could be the possible reason for this, and upon inquiry, it was proposed by Olivier Mestre to skip the joint detection phase if the error persists and investigate the pairwise detection before another correction cycle. We followed the approach in further analysis of network 1

Errors in the correction step were a result of having change points in dates with data inconsistencies (missing values) in the raw data file. This was a very common error in our analysis. As in the case of 47073500 Nordli-Holand series, the error message was 'Warning! No data for series 47073500 during the period 1987 - 1987 and month 8'.

Automatic joint detection had set a break in 1987 that we had accepted because of supporting metadata (station relocation). This however corresponded to when there were missing values in the series (August 1987 to July 1988). This change points was therefore removed, particularly because there was already an accepted break due to relocation of the station in 1984. In other instances the change points was simply adjusted to when there was available data. For example, the case of 47068290 Selbu II series, where a change points of November 2006 that was due to relocation of the station was adjusted one month earlier (October) because there were missing values between 11/2006 to 09/2007.

4.3.3 ACMANT

ACMANT detection step ran after the first round of correction of the obvious breakpoints in pairwise and joint detection. ACMANT detection results for Gardermoen, the same example presented in both pairwise and joint detection is presented in Fig. 17. ACMANT detected breakpoints in 1976, 1980 and 1996 (black dotted lines). Two change points in 1980 and 1996 were in agreement with pairwise (▽) and joint (⊕) detection. The third in 1976 was manually rejected (large +) because there was no sufficient evidence (including metadata) to validate the break. In other instances, ACMANT detected breaks that were not supported by either joint and/or pairwise detection, but were accepted based on support from metadata. A good example is the 1972 ACMANT detected break in 47016560 Dombås-Nordigard (figure not shown). This break corresponds to when there was relocation of the station.

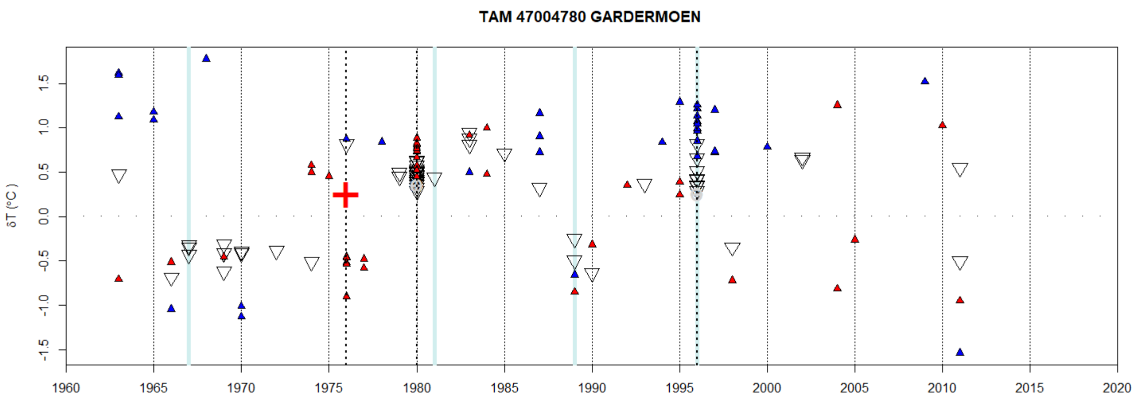

Fig 17: Interactive window in ACMANT for 47004780 Gardermoen. ACMANT detected breaks are represented by dotted black lines. (⊕) symbols represent previous joint detection breaks. Large + marks user interventions. Triangles show breaks from pairwise comparison for annual (black), winter (blue) and summer (red) series. Blue vertical lines denote previous corrected breaks.

4.3.3.1 *Assessing month of change for breaks*

With ACMANT, detection with monthly preciseness of when breaks occurred is possible. If the precise month of change is not known, the default is to validate the break at the end of the year, since detection is mainly performed on annual indices. The month of occurrence of the breaks can be added manually with availability of quality metadata. Table 5 presents an example of the month of change file result for Gardermoen series in HOMER. Determination of the month of change in HOMER was executed after the second correction cycle. The months of change was later updated manually to match available metadata for the station. For example March 1981 break was revised to January 1981, June 1996 break to January 1997 so that they reflect the exact month that there were changes at the station (metadata). The 1976 break was invalidated because there was no metadata to support the break. The joint detected break in 1987 had supporting metadata but was not confirmed because of the recommendations to avoid close change points (close breaks reduces the reliability of the homogenized results). The revised month of change was therefore revised, Table 5. This therefore confirms that metadata increases the detection rate significantly.

Fig. 18 shows the final pairwise comparison of the corrected Gardermoen series with its corrected neighbours. This pairwise comparison of corrected series is characteristic of a good homogenization since throughout all the comparison there is no evidence of remaining inhomogeneities.

The general results of the homogeneity analysis and break adjustment for Gardermoen series were similar to results obtained in previous homogenization studies in Norway. Lundstad and Tveito (2016) found breaks in 1967, 1981 and 1997 while Andresen (2011) found breaks in 1968 and 1981.

Table 5: Detected breaks for Gardermoen. The second column shows the estimated month of change for the detected breaks. The third column says whether a break was confirmed and thereby adjusted. The fourth column lists the available metadata for each break.

Detected break	**ACMANT month of change break**	**Confirmed break**	**Metadata**
1967/12	1966/11	1966/11	Relocation of the radiation screen 20m NW
1976/12	1977/3	Not confirmed	
1980/12	1981/3	1981/1	Radiation screen painted and a small relocation of the screen 180 m SSW because of new building
1987/12	1987/12	Not confirmed	New minimum thermometer
1996/12	1996/6	1997/1	Construction of a new airport, hence relocation of the observation site. Automation of the station

After the homogenization process was finalized and the specific month of break found, a re-evaluation of all the adjusted inhomogeneities was done for possible exclusion of some of the breaks. The reason for exclusion of detected breaks has been well summarized by Domonkos (2014). For this study, it was mainly done to ensure that all the adjusted breaks were as a result true inhomogeneities in the series. We therefore assessed the credibility of all the adjusted breaks in each series that were only present in either joint and/or ACMANT detection step but not reflected in the pairwise detection. This was also evaluated against the available metadata. Some of the adjusted breaks were removed if they did not meet these criteria. The correction step was then repeated. The process ended when no changes were present on the corrected series. We therefore in the end excluded insignificant breaks, see Table 5 and Fig. 18.

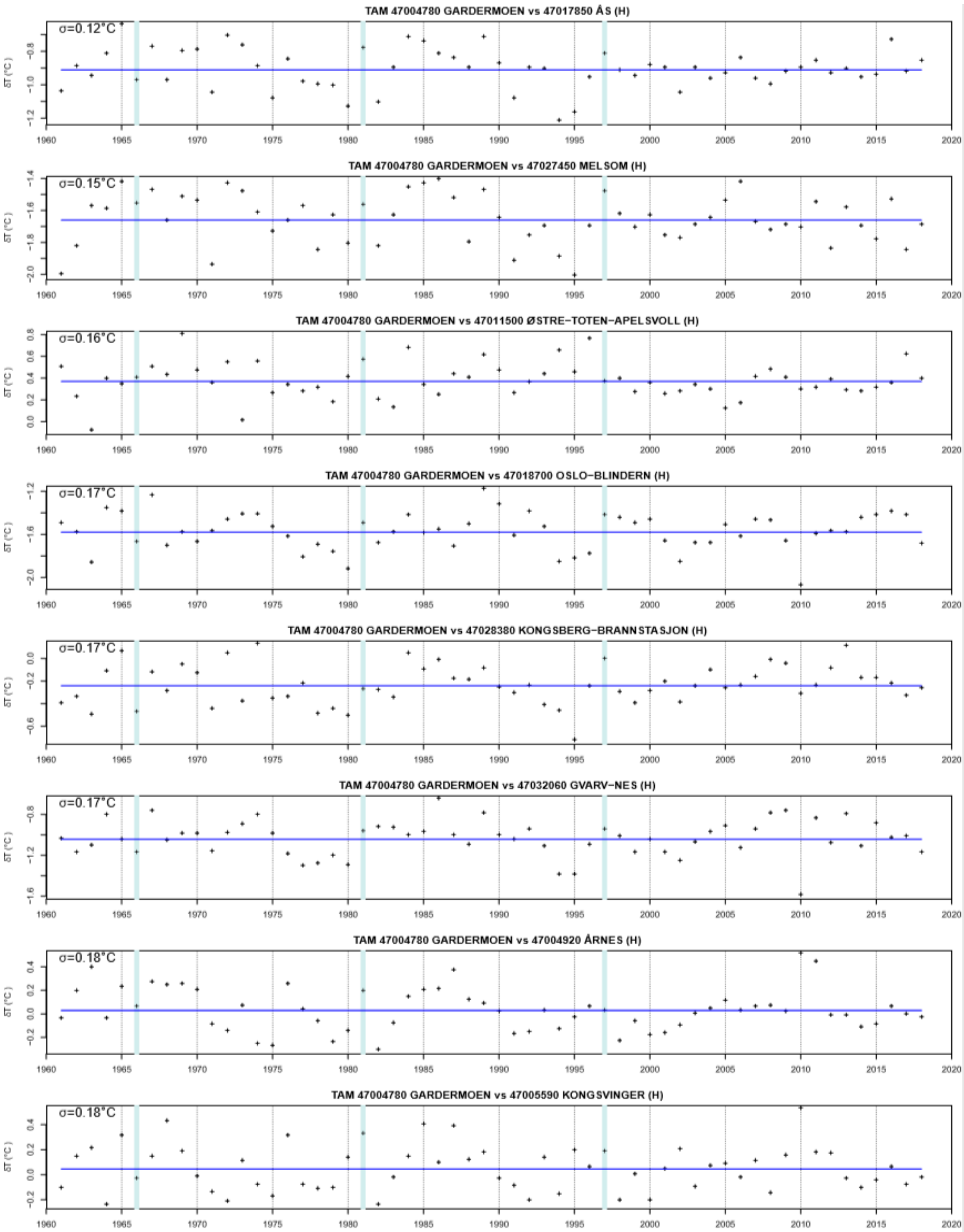

Fig 18: Pairwise comparison between the corrected annual series of Gardermoen and its neighbours. Light blue vertical lines denote the breaks that have been adjusted. Comparisons are sorted according to increasing values of σ (noise standard deviation, upper left corner of each plot). Only eight comparisons with the smallest noise are shown. The list has changed slightly compared to Fig. 9 due to slight variation in the noise standard deviation estimates.

4.3.4 Homogenization of Swedish and Finnish series

In the homogenization of the Swedish and Finnish series, the same procedure defined in section 3.3 was employed. The detected inhomogeneities were however adjusted for without metadata support. This therefore means that no break in the 30 Swedish 7 Finnish stations (Appendix A, III) included in this study were confirmed by metadata. It is however important to note that this was the case for all series except for those that had been merged, implying that the station had been relocated. A careful consideration was given to all the detected breaks in HOMER especially all breakpoints automatically detected by joint and ACMANT detection. With user intervention, all automatically detected change points that were not in agreement with those detected by the pairwise detection were removed. This was actualized for as long as there were no traces of extensive breaks in subsequent correction cycles, and when the automatic breaks were assumed a reflection of true inhomogeneities in the series. Careful attention during user intervention was necessary to avoid redundant breaks. This can be exemplified in the case of 46093220 Karlstad Flygplats, a Swedish station where pairwise detection showed breaks in 1983/84 and 1996/97, Fig 20. There was good agreement in the amplitudes of the change points in joint detection (⊕) with those of pairwise comparison (▽) in 1984 and 1996, Fig. 21a. However the automatic joint-detection detected a break in 1990 that was not supported by pairwise comparison and therefore was rejected (large +) because metadata to validate that assertion was unavailable. Similar to joint, automatic ACMANT bivariate detection confirms breaks in 1984 and 1996, Fig 21b. It also cited breaks in 1955, 1990 and 2006. We therefore chose to discard those breaks (large +) mainly because they were not supported by any pairwise comparison.

In the end, the final pairwise comparison of the corrected 46093220 series with its corrected neighbours, Fig. 22, suggest a good homogenization without the need for five breaks adjustments as deduced by the automatic ACMANT detection.

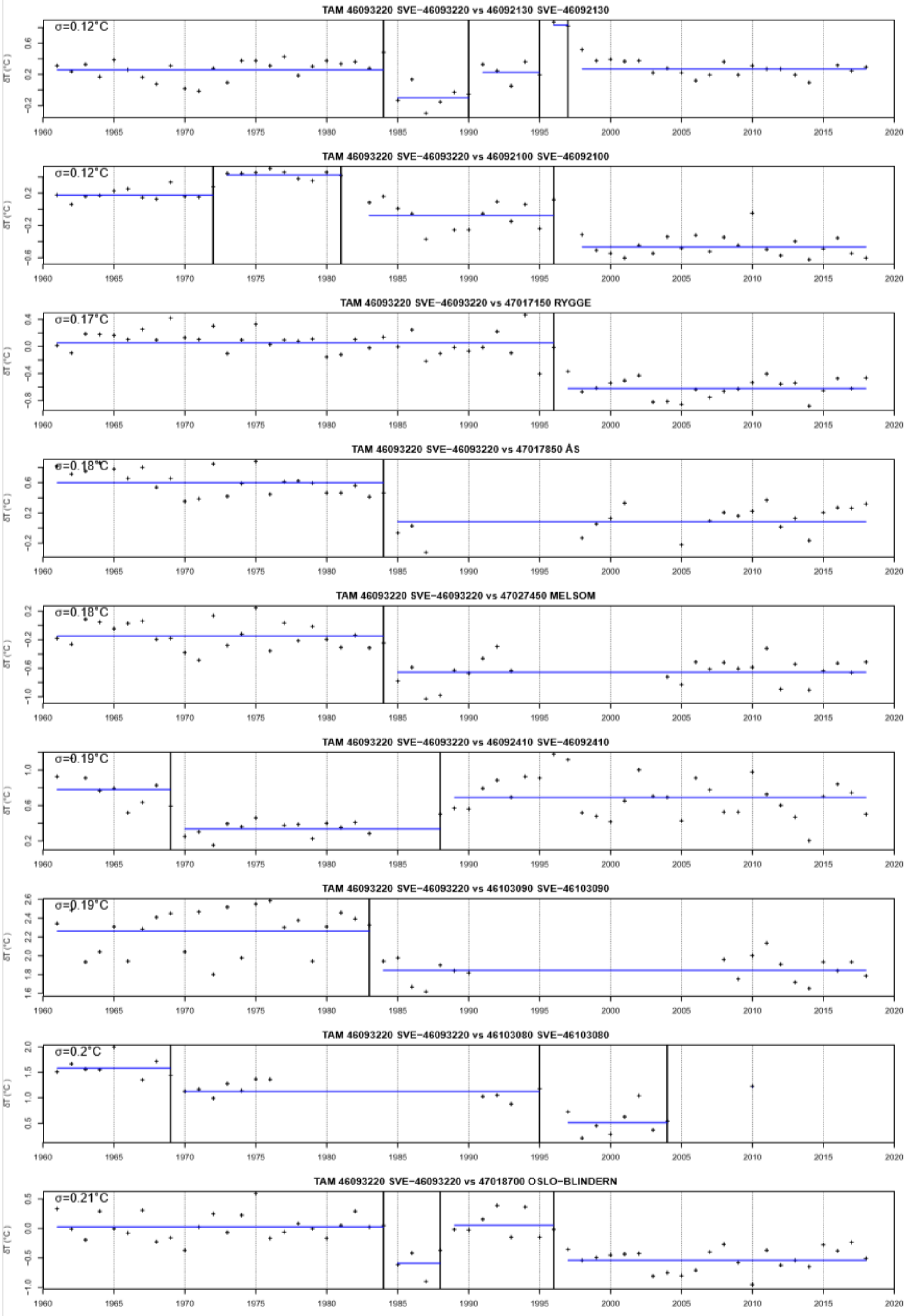

Fig 20: Pairwise comparison between 46093220 Karlstad Flygplats annual series and its neighbours. Nine comparison with the smallest noise are shown. Black vertical lines denote detected breaks.

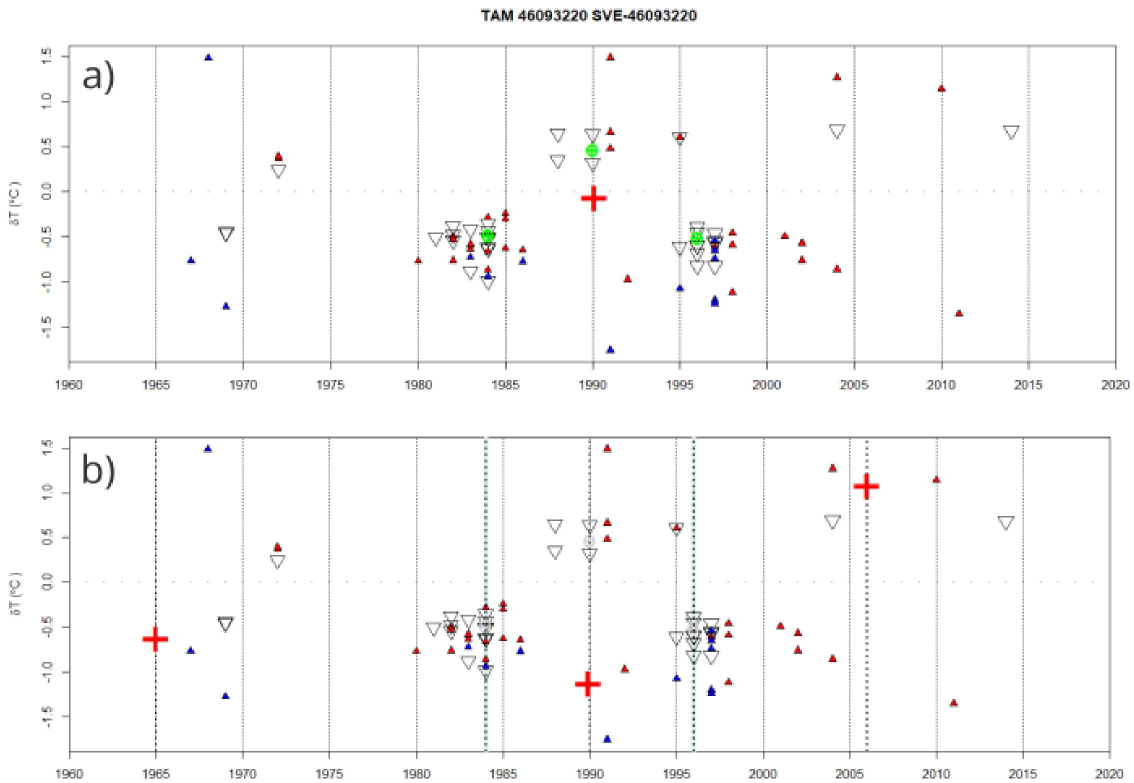

Fig 21: Output of (a) Joint detection and (b) ACMANT detection for 46093220 Karlstad Flygplats. ⊕ denotes joint detected breaks; triangles show breaks from pairwise comparison for annual (black), winter (blue) and summer (red) series. Large + marks user interventions. ACMANT detected breaks are represented by dotted black lines. ⊕ represent previous joint detection breaks. Blue vertical lines denote previous corrected breaks.

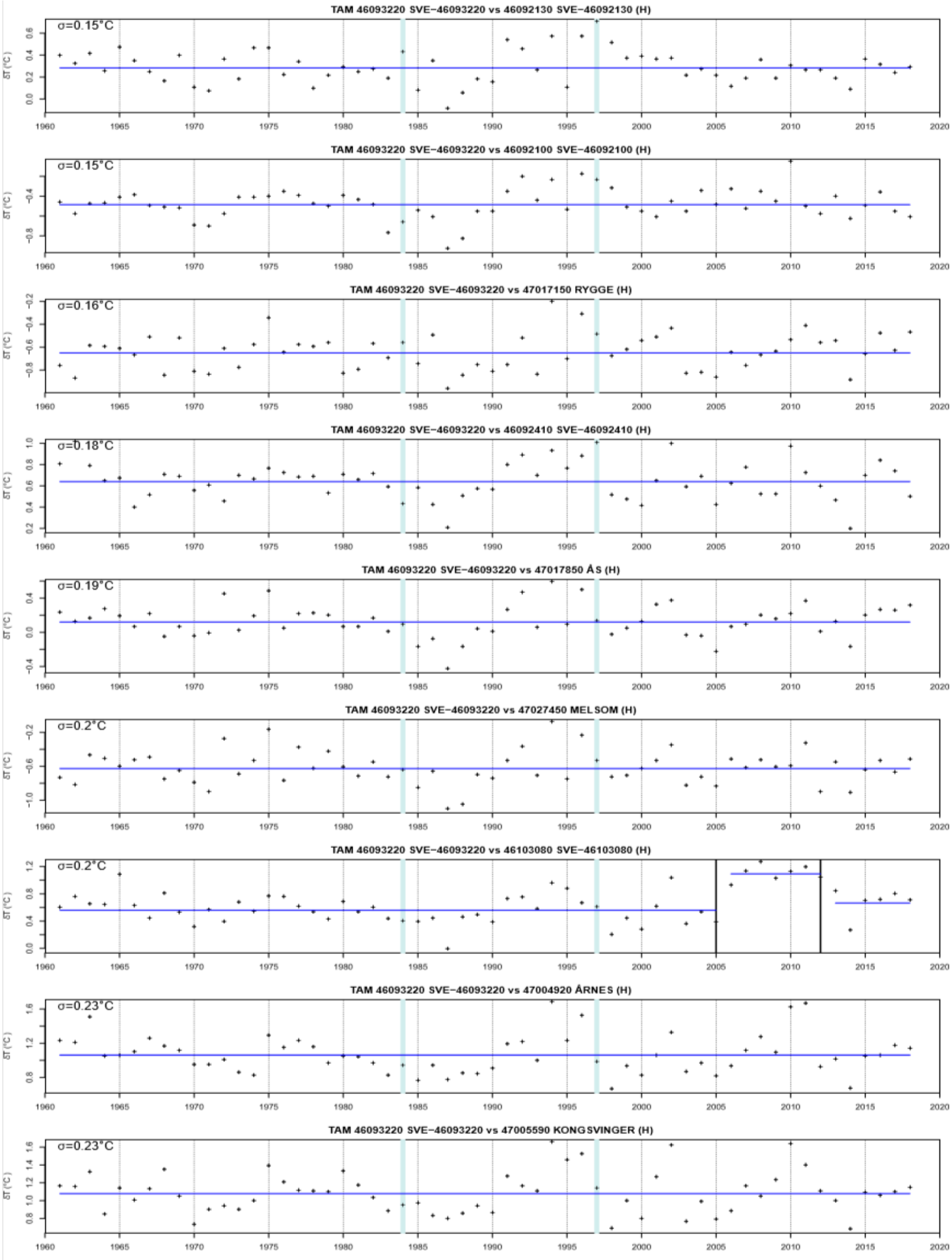

Fig 22: Pairwise comparison between the corrected annual series of Karlstad Flygplats and its neighbours. Black vertical lines denote detected breaks while light blue vertical lines denote the breaks that have been adjusted. Comparisons are sorted according to increasing values of σ (noise standard deviation, upper left corner of each plot). Only eight comparisons with the smallest noise are shown. The list has changed slightly compared to Fig. 20 due to slight variation in the noise standard deviation estimates.

4.3.5 Impact of the Swedish and Finnish series in homogenization of the Norwegian temperature series

All the Swedish and Finnish stations exhibited inhomogeneities in their time series except for one Swedish station. As earlier stated, the homogenization of these series was done without information of station history (metadata). The annual adjustments in the temperature series were in the range of -0.96°C to 0.58°C. We sought to determine if removing these Swedish and Finish series would have an impact in homogenization results of the Norwegian temperature series. This is based on these results and the assumption that the selection of reference series and how they are applied in the homogenization process can significantly influence the detection and the correction of inhomogeneities in the candidate series (Szentimrey 2010).

This experiment was carried out to ascertain the differences in the dependence on the reference series number based on their geographical location and its impact on the detection of breaks in the candidate series. A new homogenization process using HOMER was therefore carried out. The input dataset was varied (excluding all Swedish and Finnish stations) but we maintained our default conditions for reference series choice (0.95 correlation with the candidate series, and a minimum of 8 reference series).

Quality control checks on the new input data consisted of network analysis by Climatol method and fast quality control to detect outliers and selection of reference series. The results revealed two notable differences:

I. Difference in number of station clusters: the map of stations Fig 23 can confirm this. The analysis with the Swedish and Finnish stations resulted in six temperature regimes for Norway that were consistent with that found by Hanssen-Bauer and Nordli (1998). Without these stations yielded five clusters, Fig 23, two in network 1 and three in network 2.

II. Difference in number of reference series paired with the candidate series: The removal of adjacent series implied that the dependence on the number of reference series for the individual candidate series would decrease. This was especially evident in the candidate stations geographically located near the border. Table 9 is a short extract, showing the difference in the number of reference series.

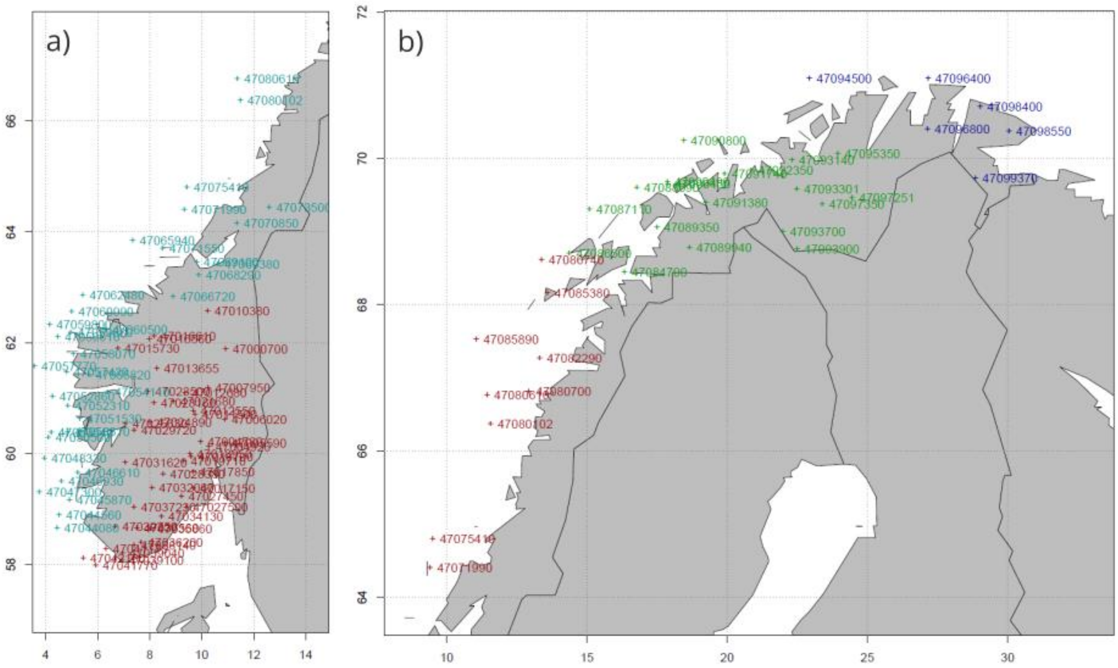

Fig 23: Map of station locations for (a) network 1 and (b) network 2 after excluding all Swedish and Finnish stations. Colours identify station clusters with similar variability.

Table 9: Short extract, showing the difference in number of reference series with removal of Swedish and Finnish (SweFin) series.

Station number	Station Name	With SweFin	Without SweFin
Network 1		Nr of ref. series	Nr of ref. series
47000700	Drevsjø	21	15
47004780	Gardermoen	32	22
47004920	Årnes	34	23
47005590	Kongsvinger	27	15
47017150	Rygge	33	24
47017850	Ås	39	28
47018700	Oslo Blindern	38	25
Network 2			
47093140	Alta Lufthavn	18	10
47093301	Suolovuopmi Lulit	19	10
47093700	Kautokeino	22	10
47093900	Sihccajavri	21	10
47095350	Banak	15	9
47097251	Karasjok Markannja	16	8
47097350	Cuovddatmohkki	18	9

The homogenization process was carried out after the quality control checks. The basic principles described in section 3.3 above were applied in determining inhomogeneities in these time series. It was apparent that the reduction of reference series had an impact on the breakpoint detection. Visual comparison of homogenization output before and after the removal of SweFin series revealed the benefits of having more reference series in detection of inhomogeneities. Fig. 24 illustrates a case for Kongsvinger (47005590) series. One of the candidate series close to Norwegian-Swedish border with the largest reduction in number of reference series (28 to15).

Pairwise comparison of the annual series in the analysis without SweFin stations Fig 24b suggests there were no possible breaks in the series, whereas that with SweFin stations revealed a break in 2004. This break could be explained by station history i.e. relocation of the station. The most pronounced difference was found in the summer series (Fig. 25). While the results with SweFin series detected six breaks (1969, 1973, 1978, 1983, 1989 and 2004), there were only three breaks (1973, 1978 and 2004) in the analysis without SweFin series. In the end, we only adjusted for three breaks although four of them were supported by metadata. They were 1978 (inhomogeneity due to relocation of radiation screen), 1989 (because of new maximum thermometer) and in 2004 (caused by relocation of the radiation screen). The fourth break with metadata (change of observer) in 1969 was ignored because it was only present in the automatic ACMANT detection and not in either joint or pairwise detection. Its absence also did not compromise the Kongsvinger series homogenized results.

Another main difference in this analysis is the change in the monthly break amplitude. Fig. 26 shows the difference in adjustments with and without Swedish and Finnish stations for Kongsvinger. The largest difference can be seen in the winter months (DJF) where the adjustments are fairly larger when excluding the Swedish and Finnish stations.

These results therefore suggest that adding Swedish and Finnish series as reference series in the homogeneity testing of Norway's temperature series is very beneficial. Domonkos and Coll (2017) showed that the inclusion of reference series from adjacent climatic areas is often favorable for the efficiency of homogenization, even when the candidate series has several reference series in the same climatic area. The two interpretations given by Domonkos and Coll (2017) were very consistent with the results of this experiment. They were:

- The detection of inhomogeneities is safer with a large number of partner series than in small networks, while climatic differences between adjacent regions tend to have smaller impact on the accuracy of the results than inhomogeneity detection errors.
- The low frequency climate variability has higher spatial similarity than month-to-month changes, with which the spatial correlation is characterised in this study.

The advantage of using larger reference datasets is that you then use the common properties of the series that are included in the reference. This avoids to greater extent single incidents in the reference basis that cause false inhomogeneities. As the inhomogeneities of individual reference series are usually independent, the noise of the relative time series is expected to decrease with increasing number of reference series Lindau and Venema (2016).

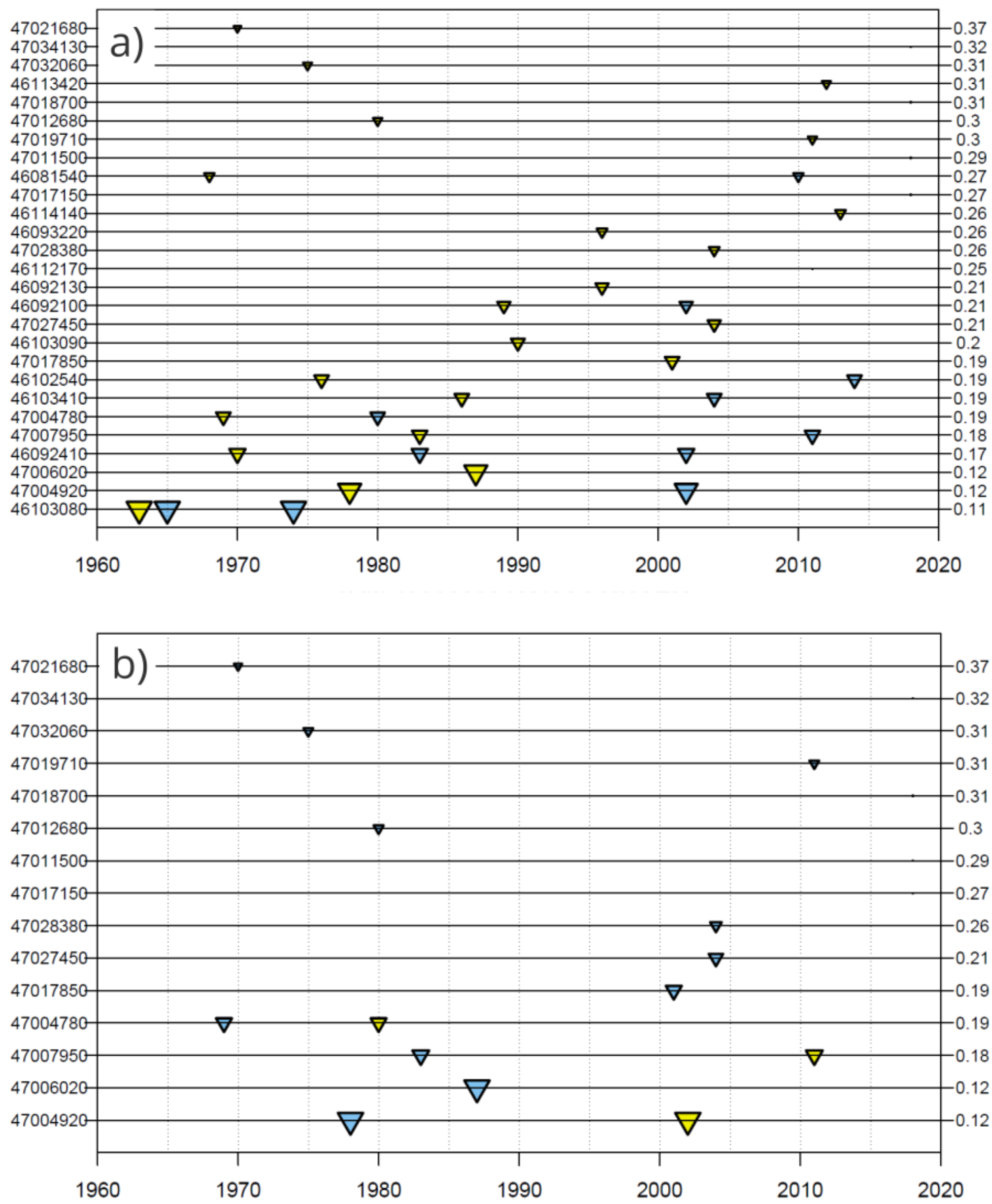

Fig 24: Pairwise comparison between 47005590 Kongsvinger annual series and its neighbours (a) with Swedish station series and (b) without Swedish stations.

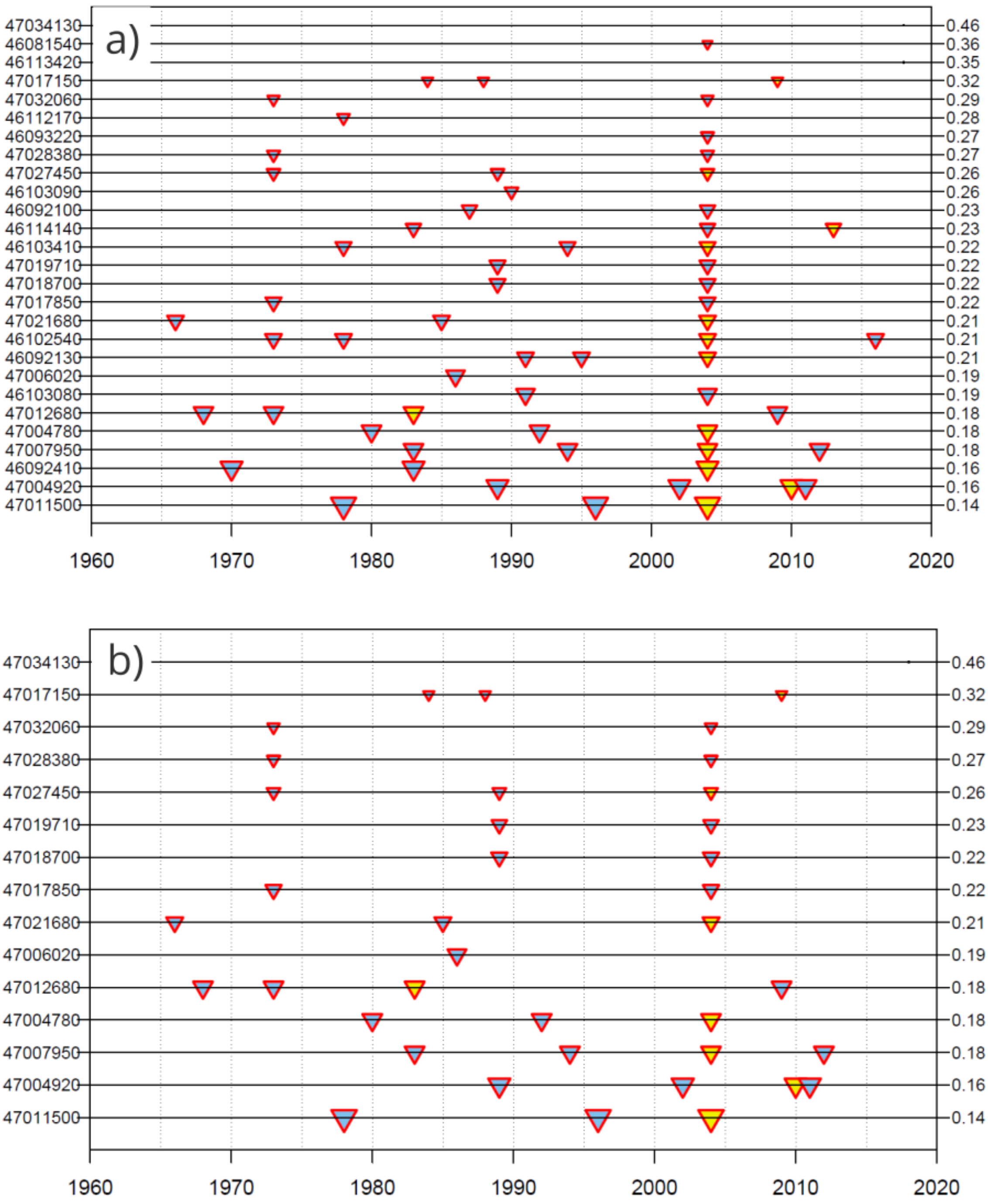

Fig 25: Pairwise comparison between 47005590 Kongsvinger summer (JJA) series and its neighbours (a) with Swedish station series and (b) without Swedish stations.

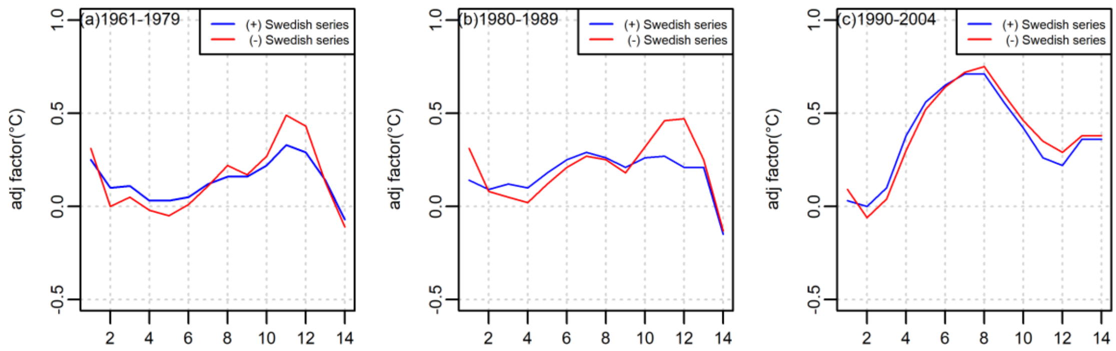

Fig 26: Amplitude of breaks (°C) for the three different breakpoints in the Kongsvinger series for the analysis including (blue) and excluding (red) Swedish and Finnish series. The y-axis is as follows: 1-12 months. 13 annual. 14 break amplitude.

4.4 Homogeneity breaks

In this study, nine candidate series were unaffected by any artificial discontinuities in the stations and were considered homogeneous without any necessary adjustments or correction. These stations are 47018950 Tryvannshøgda, 47054110 Lærdal IV, 47060500 Tafjord, 47070850 Snåsa-Kjevlia and 47071990 Buholmråsa Fyr in network 1 and 47080102 Solvær III, 47090800 Torsvåg Fyr, 47094500 Fruholmen Fyr and 4796400 Slettnes Fyr in network 2. This is despite the fact that five of the series (Tryvannshøgda, Lærdal IV, Tafjord, Buholmråsa Fyr and Solvær III) had relocated, up to more than once during the study period. All the nine stations had either instrument replacement and/or painting or relocation of the radiation screen. This clearly shows that in some instances external changes in the station may not necessarily cause discontinuities in climate series. The remaining 99 series had 1 to 4 breaks. A majority of the inhomogeneous series had two breakpoints. Table 7 presents a summary of the number of inhomogeneities detected in the analysis. The annual adjustment factor in N1 ranged from -0.74 to 0.76°C while in N2 ranging from −0.94 to 1.01 °C. The highest adjustments in the series were observed when there were relocations of the station. A detailed summary of the adjustment factor is provided in Appendix B. It is important to note that if the homogenization were only focused on the correction of annual series, there would be fewer breaks detected. When analysing the seasonal series we discovered breaks that were specific to the seasonal series and not present in the annual series. This explains why the sample homogenization analysis with Climatol (Guijarro, 2014), detected fewer breaks than what was found in HOMER, (see section 4.4.1)

Table 6: Monthly, annual adjustment factors and annual break amplitudes[2] for the 47004870 Gardermoen series.

	Break amplitude in °C		
Month	I: Nov 1966	II: Jan 1981	III: Jan 1997
Jan	0.65	0.73	0.45
Feb	0.44	0.75	0.33
Mar	0.40	0.74	0.29
Apr	0.23	0.53	0.12
May	0.13	0.38	0.05
Jun	0.08	0.34	-0.03
Jul	0.11	0.35	0.01
Aug	0.14	0.48	0.05
Sep	0.25	0.56	0.12
Oct	0.27	0.64	0.18
Nov	0.55	0.65	0.30
Dec	0.54	0.61	0.36
Annual	0.27	0.5	0.15
Break Amplitude	-0.23	0.35	0.15

Using again the example for Gardermoen, we illustrate the monthly and annual amplitude of breaks detected with HOMER in Table 6. The reason for these breaks have been presented in Table 5.

These break amplitudes are similar to the results of Lundstad and Tveito (2016) where the break amplitudes were I: -0.33, II: 0.4 and III: 0.11 respectively. A summary of the break amplitudes to all the series analysed is included in the metadata table in Appendix B.

From the 108 homogenized series, 18 annual series in N1 and 12 in N2 had no evidence of possible remaining breakpoints throughout the comparison. The majority 72% exhibited traces of isolated breaks even after adjustments probably due to first kind errors. In some cases possible breaks were ignored because of no metadata e.g. 47000700 Drevsjø in 1975.

[2] Break amplitude on annual coefficient is the difference between two consecutive annual correction coefficients (which are not used - data are corrected monthly).Amplitude tells how large the break was, but does not give the correction, since data are corrected according to the last homogeneous period (the most recent period), not the preceding one.

4.4.1 Comparing HOMER and Climatol

This analysis was done to compare our results from HOMER against the automatic homogenization method in Climatol; which provides automatic quality control, missing data attribution and homogenization (break detection and correction).

The comparison between HOMER and Climatol was performed with N1 series. HOMER detected at least one break in all series but in the end, only five series were considered homogeneous without adjustment. Climatol on the other hand did not detect any break in 36 of the 76 series analysed. HOMER has a total of 158 corrected breaks against 57 corrected breaks in Climatol in the 76 series analysed. To assess the similarity between the results obtained by these homogenization methods, break points per year for each station were compared. This was done with the consideration that the timing of a breakpoint can differ by up to three years between both methods due to the difference in the computation rules for the break points. HOMER detected 43 breaks that were also detected by Climatol. In some instances, the number and timings of breaks were similar for some series in both methods. This was the case for seven series i.e. 47004780 Gardermoen, 47029720 Dagali Lufthavn, 47034130 Jomfruland, 47050500 Flesland, 47052310 Modalen III, 47059800 Svinøy Fyr and 47069100 Værnes. The total number of breaks is presented in Table 7. While HOMER is an interactive homogenization method that allows user intervention to decide about the significance of indicated breaks, based on metadata, Climatol is fully automatic. This could explain the differences in results.

4.4.2 Main reasons for inhomogeneities

All the detected inhomogeneities (Table 6) that were adjusted for in the study could be substantiated by metadata except for one break in 2013 in 47038140 Landvik and in 2011 in the 47094500 Sørkjosen Lufthavn series. Fig. 27 provides a summary of the causes of all the inhomogeneities detected in this analysis. Relocation of the station was the most common reason for inhomogeneity, explaining more than 40 % of the inhomogeneities found by HOMER. Small relocations led to breaks in some cases, for instance at 47005590 Kongsvinger where a relocation of 10 m led to warmer temperature registrations (0.16 °C warmer in the annual mean temperature). New observer is listed as a reason for inhomogeneities. In theory that should not affect the measurements, but sometimes a change in observer leads to a change in routines, and that might cause inhomogeneities. About 2 % of the breaks could not be explained by the documented station history.

Table 7: Number of breaks detected with HOMER in network 1 and 2 and Climatol in network 1.

Number of breaks	**No of series (N1)**	**Percentage**	**No of series (N2)**	**Percentage**	**CLIMATOL (N1)**
0	**5**	6.6	**4**	12.5	**36**
1	**12**	15.8	**10**	31.3	**27**
2	**35**	46.1	**12**	37.5	**9**
3	**20**	26.3	**4**	12.5	**4**
4	**4**	5.3	**2**	6.3	**0**
TOTAL	**76**	100	**32**	100	**76**

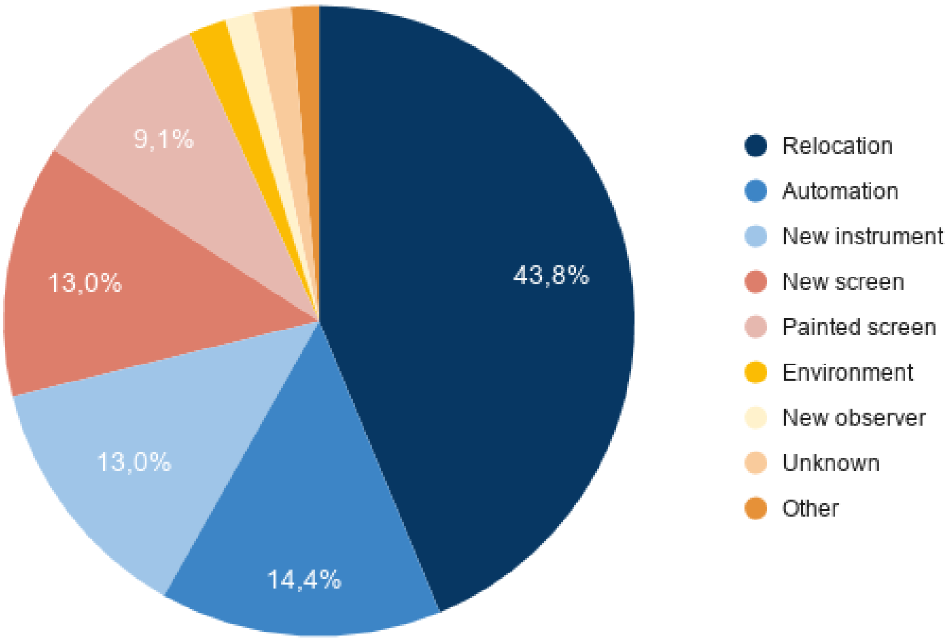

Fig 27: Main reasons for inhomogeneities in % of the total amount of breaks. The reasons are relocation, automation, change of instruments, change or painting of radiation screen, change of observer, changes in the surrounding environment, in addition to unknown and other causes.

51.8% of all the homogenized series in the study were merged series. This explains why relocation of stations accounted for the most known causes of inhomogeneity. In most cases, HOMER rightly captured inhomogeneities as a result of relocation of the station. This can well be summarized in the case of the 47057420 Førde-Tefre series. The Førde-Tefre series comprises four different original series (Fig 1). All the 15 neighbouring stations series paired with the Førde-Tefre series were highly correlated. The series with the lowest correlation was 47048330 Slåtterøy-Fyr with 0.951, which was above the limit we set of 0.95. HOMER homogeneity testing detected three breaks in the series. All these inhomogeneities coincide with the years the station was relocated. Pairwise detection on the annual series, put into evidence clear breaks in 1991. The other change points were clearly captured in different seasons. The inhomogeneity in 1985 was clearly captured in the winter series while the 1965 break was well highlighted by the summer series. The relocation in 1992 was well detected in the spring and autumn series. There was also very good agreement in the change points detected in both pairwise comparison, the automatic joint-detection and ACMANT detection. ACMANT detection actually confirmed all the three pairwise detected change points of 1965, 1984 and 1991 while *multiseg* only captured the 1991 inhomogeneity. This example highlights the importance of analysing breaks in seasonal series as well as in the annual series. This way we unmask all the potential breaks present in the series. Table 8 provides a summary of the detected breaks and the reasons for the breaks for Førde-Tefre. Causes of inhomogeneities in all the candidate series analysed in this study can be found in Appendix B.

Table 8: Detected inhomogeneities in HOMER for Førde-Tefre (47057420).

Station Name	Original Series	Station Name	Start	End	Breaks	Reason for break
FØRDE- TEFRE 47057420	47057170	FØRDE I SUNNFJORD	jan.61	jun.65	6/1965	Relocation of the station from 1400m towards NNW
	47057180	FØRDE I SUNNFJORD II	jul.65	jul.85	7/1985	Relocation 3km towards SE.
	47057190	FØRDE - VIE	okt.85	feb.92	11/1992	New station Førde-Tefre, 57420.
	47057420	FØRDE - TEFRE	nov.92	nov.17		

4.5 Impact of homogenization on the temperature series

To evaluate the impact of homogenization on the temperature series, the anomaly series of the raw and the homogenized series were compared. The raw and homogenized annual and seasonal series were converted into standardized anomalies series using 1961-1990 as the reference period. The results using the Gardermoen series as an example are illustrated in figure 28. The highest and lowest annual and seasonal anomalies for Gardermoen series, before and after homogenization are aggregated in Table 9. Results shows that the homogenized series had lower anomaly values than the raw series. The highest annual anomaly corresponds to 2014, which was the warmest year in Norway since 1900 where the country's average temperature was 2.2℃ above normal. 2018 was the year with the highest summer anomalies, which corresponds to the sixth warmest summer in the country with an average temperature of 1.8℃ above normal. The highest winter anomaly occurred in 1989.

Table 9: Highest and lowest annual and seasonal anomalies for the Gardermoen series

	Highest Values		**Lowest Values**	
	Raw	Homogenized	Raw	Homogenized
Annual	3.0	2.6	-1.6	-1.5
Winter	5.6	5.4	-5.4	-5.4
Spring	3.3	3.1	-2.4	-2.6
Summer	3.0	3.2	-1.9	-1.8
Autumn	3.1	3.5	-2.1	-2.3

Analysis of the annual series shows a sharp temperature increase in the late 90s, which are the warmest years since 1961 with a mean annual temperature of 5.7°C between 1988 and 1992. The lowest anomaly values for all seasons were actually observed before the late 90s (annual ~ 1985, winter ~ 1966, spring and summer ~ 1962, autumn ~ 1975). Based on the annual series and all seasons, raw results differ from the homogenized series. The anomalies of the homogenized series are lower compared to the original series. This result show that the homogenized series are more spatially coherent that the raw series implying that homogenization contributes to the understanding of climate variation both in space and time.

The analysis of seasonal series gives evidence that, besides some common features between the raw and homogenized series, there are also significant differences. The rather sharp temperature increase in the late 90s is observed more in the winter season than in summer. This shows that the trend observed in the annual series around 1990 is due to increasing winter temperatures rather than the summer temperatures. The winter anomalies have also been affected more by the homogenization. Generally, the amplitude of the anomalies of the raw series are higher than that of the homogenized series. An important common feature by visual comparison between raw and homogenized annual and seasonal series reveals a clear warming trend after 1989 of Gardermoen mean temperature.

The influence of inhomogeneity on each climatic region represented by 47018700 Oslo Blindern, 47050540 Bergen Florida and 47070850 Snåsa Kjevlia for N1 and 47090450 Tromsø, 47097251 Karasjok Markannjarga and 47098550 Vardø Radio in N2 are illustrated in Fig. 29. 5-year Gaussian density function 'normal' average for the annual, summer and winter anomalies were calculated for the raw and homogenized temperature series with respect to the 1961-1990 reference period. As in the Gardermoen case, results show a wider range of anomalies in the raw series than the homogenized series. The results confirms that homogenisations contributes to better spatial coherence of time series therefore providing a strong guidance on the reliability of the adjusted dataset. Nevertheless, the homogenous series preserves the general statistical distribution of the raw series. We can note the warming trend in both the raw and homogeneous series especially after the late 90s. This concluding results on the impact of homogenisation is consistent with those reported other homogeneity studies including, (El Kenawy et al. 2013, Mamara et al. 2014, Fioravanti et al. 2019)

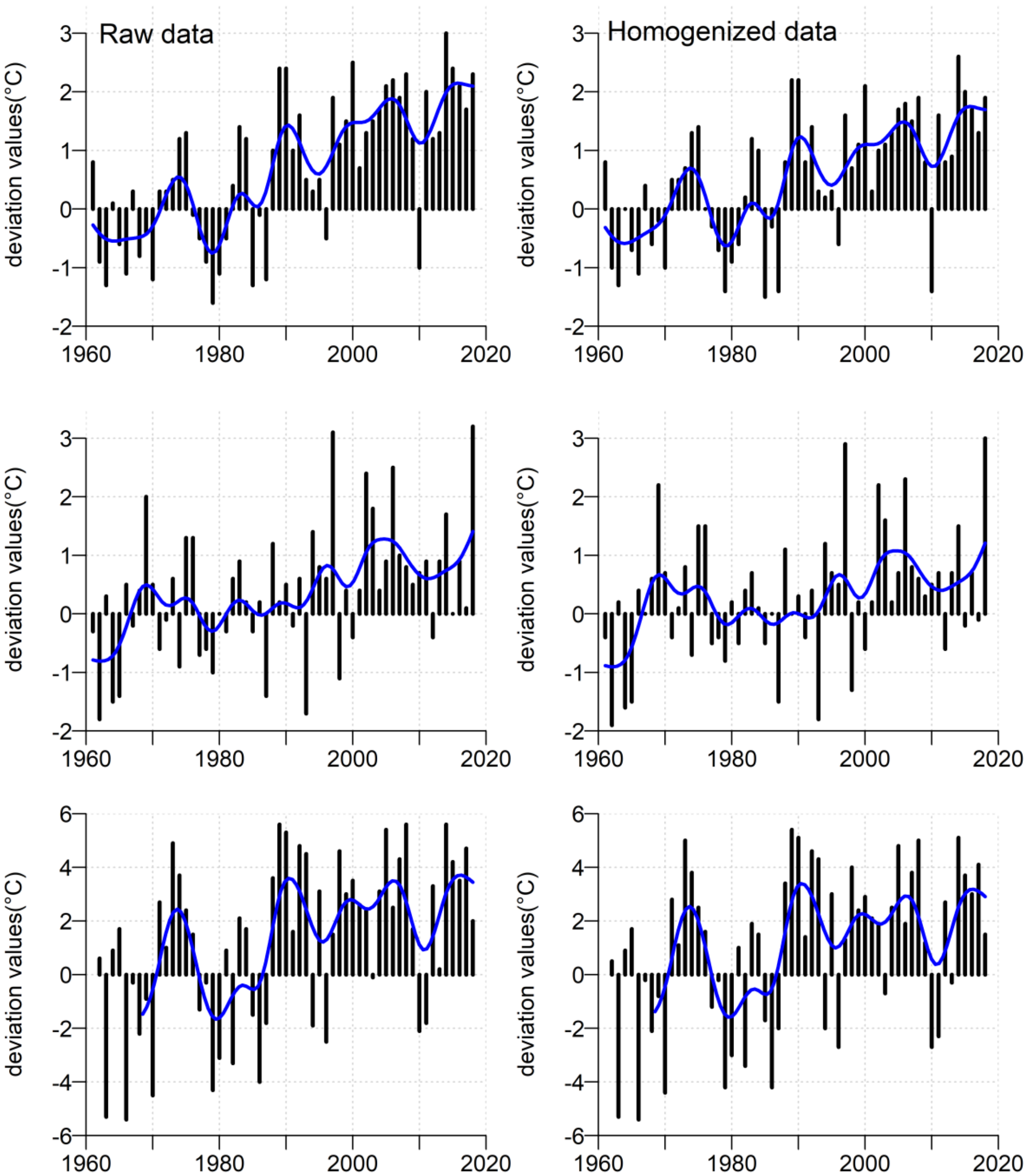

Fig. 28 Deviation of the annual (top) and seasonal (summer middle and winter bottom) temperature from the mean (1961-1990) before and after homogenization. Raw data is presented on the left and homogenized data on the right. The series are displayed together with a 5-year Gaussian density function 'normal' kernel regression smoother (blue line)

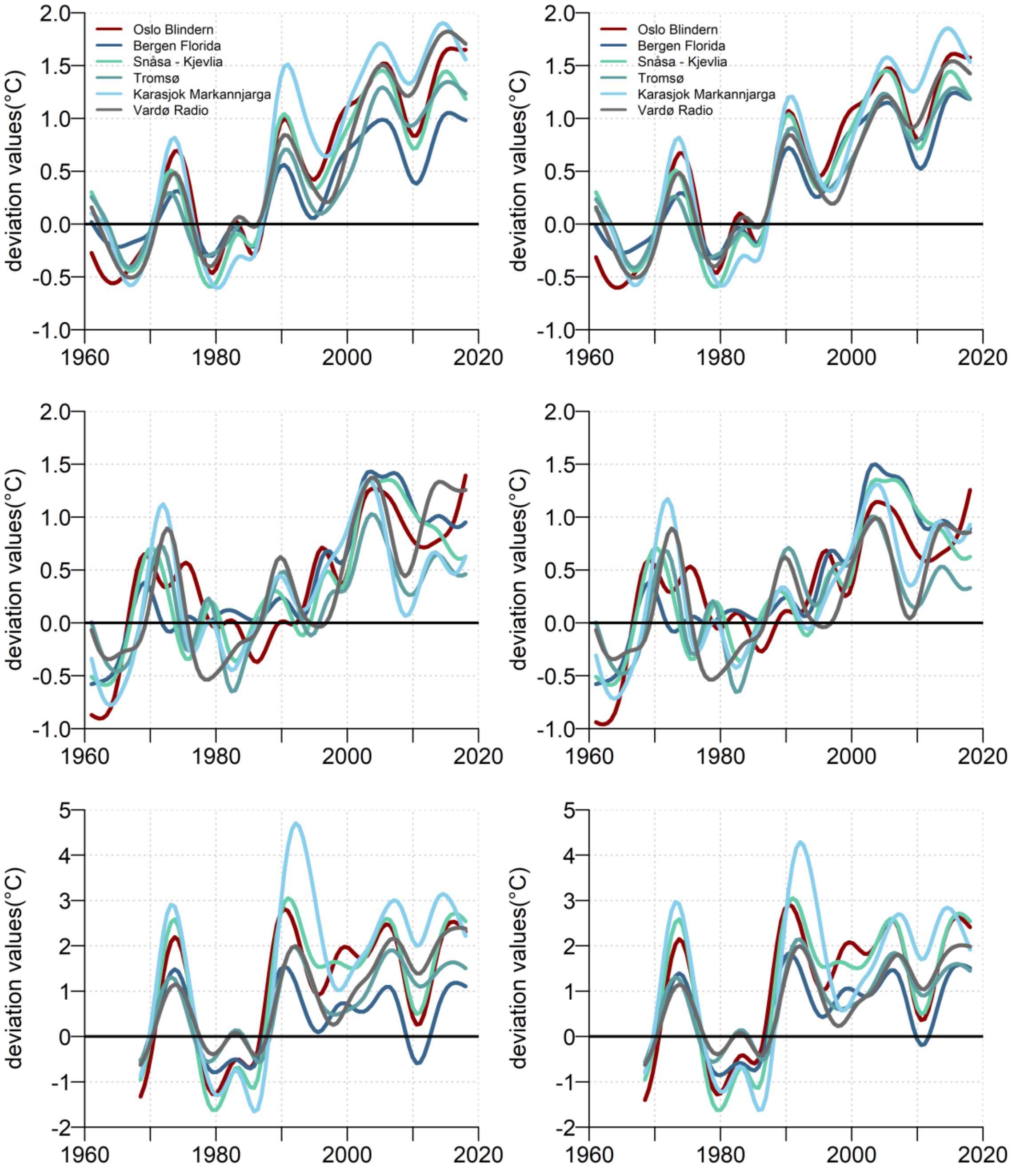

Fig. 29 Deviation of the annual (top), summer (middle) and winter (bottom)for each climatic region with respect to 1961-1990 mean before (left) and after homogenization (right)

5 Summary and Conclusion

In the study presented here, the HOMER homogenization method was applied for detection and correction of inhomogeneities of Norway's mean monthly temperature series for the period 1961-2018. In the analysis a total 145 series were homogenized. 48% of these series were merged. This includes 108 temperature series from Norway (53 of which were merged series), 30 from Sweden and 7 from Finland. The analysis was done in two separate networks (Fig.2) because the homogenization procedure in HOMER only can test a maximum of 99 series at a time. Network 1 included 99 series while network 2 had 51 series (Table 4).

The temperature series were homogenized by varying the network combinations in order to ensure that they included the best-correlated reference series for homogenization. The results also includes an analysis comparing homogenization results with HOMER against the automatic homogenization method in Climatol

The results of homogeneity testing indicate that approximately 92% of the series analysed were inhomogeneous. The number of breakpoints in the temperature time series ranged from 1-4 with most series having two breakpoints. In total the analysis homogenized 212 (158 in N1 and 54 in N2) detected breaks in 108 Norwegian series. Nine series (Five in N1 and four in N2) were classified as homogeneous without need for any adjustments even though five of the stations had relocated up to three times in some cases. 71 breaks were adjusted in the 37 Swedish and Finnish series. The result in HOMER also confirmed that Norway is divided into six temperature regions.

The differences in the number and magnitude/amplitudes of the breaks in each candidate series have been highlighted. The highest annual adjustments in the series corresponded to when there were relocations of the station. All adjusted breaks were confirmed by metadata except on two occasions (one in each network) where supporting metadata was unavailable. Relocation of the station was the most common reason for inhomogeneity, explaining more than 40 % of the inhomogeneities found by HOMER. The Swedish and Finnish series were adjusted without any metadata except for those that had been merged, implying that the station had been relocated. It should be noted that all breaks before 1965 were ignored and they were not adjusted for even with metadata. The study also demonstrated that in some instances external changes in the station did not necessarily cause discontinuities in the climate series. This was well evidenced in the series that were classified as homogeneous with no adjustment and had in some cases up to three relocations of the stations within the study period. It should also be mentioned that not all detected breaks with supporting metadata were adjusted for. Validation of detected breaks was done subjectively by comparing the proposed adjustment with station metadata. Very close breaks were rejected and weight was placed on obvious break with supporting metadata. The process of change points validation (metadata) is time consuming. This is because metadata had to be assessed for all the individual original series.

The analysis showed that the joint detection algorithm is sensitive to regional climate shifts and in most cases indicated homogeneity breaks in the time series between 1987-1988. This period corresponds to when there was an abrupt increase in temperature, especially in winter. We also encountered errors that could not be resolved in the joint detection step of our analysis. This was very persistent especially in the second joint detection cycle that was possibly as a result of convergence problems in the multivariate detection algorithm.

Comparison of the homogenization results between HOMER and Climatol for network 1 showed that both homogenisation methods captured inhomogeneities in most of the series. However, HOMER detected and corrected more breaks (158) than Climatol (57). The adjusted breaks in HOMER were justified by metadata unlike most in Climatol. This shows the advantage of using the interactive homogenization method in HOMER. It is worth noting however that in HOMER, one can end up with many breaks and in some cases which are supported by station history that are not 'necessary'. Careful consideration is therefore needed when adjusting for breaks. The assessment of similarity between the two methods showed that HOMER and Climatol were in good agreement with respect to 43. The number and timings of breaks were similar for seven series.

In the case study to ascertain the impact of Swedish and Finnish series in the homogenization of Norwegian series, results demonstrate that including these series as reference series in the homogeneity testing of Norway's temperature series were very beneficial. This is because inclusion of several reference series from adjacent similar climatic areas is often favourable for the efficiency of homogenization, and avoids to a greater extent that single incidents in the reference basis cause false inhomogeneities.

In order to evaluate the impact of homogenization on the mean temperature series, annual and seasonal anomalies were computed with 1961-1990 as the reference period for the raw and homogenized series. The 5-year Gaussian density function 'normal' average for the annual, summer and winter anomalies for the 6 climatic region indicate that the amplitude of the anomalies of the raw series are higher than that of the homogenized series. In addition, the results showed a wider range of anomalies in the raw series than the homogenized series confirming that homogenizations contributes to better spatial consistency of the temperature series. This clearly provides a strong guidance on the reliability of the adjusted dataset.

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Appendix

A - Stations analysed

Names, geographical location and covered period of the original series used for homogenization.

Network 1

Analysed series	Station Name	Original Series	Station Name	Lat (°)	Lon (°)	Alt (m)	Start	End	original series nr
47000700	Drevsjø	47000700	Drevsjø	61.8872	12.048	672	jan.-61	des.-18	1
47004780	Gardermoen	47004780	Gardermoen	60.2065	11.0802	202	jan.-61	des.-18	1
47004920	Årnes	47004930	Hvam	60.1024	11.3849	162	jan.-61	jul.-83	3
		47004940	Hvam - Tolvhus	60.1057	11.4017	159	aug.-83	apr.-03	
		47004920	Årnes	60.1268	11.3933	160	jan.-10	des.-18	
47005590	Kongsvinger	47005650	Vinger	60.2198	12.028	175	jan.-61	des.-04	2
		47005590	Kongsvinger	60.1903	12.1967	148	jul.-06	2018	
47006020	Flisa II	47006040	Flisa	60.6173	12.017	184	jan.-61	des.-98	2
		47006020	Flisa II	60.6141	12.0125	185	des.-03	des.-18	
47007010	Rena - Haugedalen	47007010	Rena - Haugedalen	61.1603	11.4427	240	jan.-61	jan.-13	1
47007950	Rena Flyplass	47007010	Rena - Haugedalen	61.1603	11.4427	240	jan.-61	jan.-13	2
		47007950	Rena Flyplass	61.1847	11.3747	255	des.-11	des.-18	
47010380	Røros Lufthavn	47010400	Røros	62.5742	11.3787	628	jan.-61	aug.-03	2
		47010380	Røros Lufthavn	62.5773	11.3518	625	aug.-02	des.-18	
47011500	Østre Toten - Apelsvoll	47011500	Østre Toten - Apelsvoll	60.7002	10.8695	264	jan.-61	des.-18	1
47012550	Kise Pa Hedmark	47012550	Kise Pa Hedmark	60.7733	10.8055	128	jan.-61	des.-18	1
47012680	Lillehammer - Sætherengen	47012660	Lillehammer II	61.0958	10.4742	226	jan.-61	jul.-69	3
		47012640	Lillehammer III	61.0808	10.4756	271	okt.-69	jul.-81	
		47012680	Lillehammer - Sætherengen	61.0917	10.4761	240	des.-82	des.-18	
47013655	Skåbu	47013670	Skåbu - Storslåen	61.5152	9.3823	890	okt.-68	mar.-10	2
		47013655	Skåbu	61.5308	9.4023	928	jun.-11	des.-18	
47015730	Bråtå - Slettom	47015720	Bråtå	61.9067	7.86	712	okt.-65	jun.-98	2
		47015730	Bråtå - Slettom	61.8957	7.8955	664	nov.-98	des.-18	
47016560	Dombås - Nordigard	47016550	Dombås II	62.0767	9.1285	643	jan.-61	jun.-72	5
		47016540	Dombås - Kirkenær	62.0757	9.1232	645	jul.-72	mai-76	
		47016740	Kjøremsgrende	62.0938	9.0436	626	jun.-76	des.-09	
		47016551	Dombås - Kirstistugu	62.0732	9.1123	653	nov.-88	aug.-96	
		47016560	Dombås - Nordigard	62.0717	9.1147	638	nov.-06	des.-18	

47016610	Fokstugu	47016600	Fokstua	62.1188	9.277	973	jan.-61	mai-68	2
		47016610	Fokstugu	62.1133	9.2862	973	jun.-68	des.-18	
47017150	Rygge	47017150	Rygge	59.3742	10.798	40	jan.-61	des.-18	1
47017850	Ås	47017850	Ås	59.6605	10.7818	92	jan.-61	des.-18	1
47018700	Oslo - Blindern	47018700	Oslo - Blindern	59.9423	10.72	94	jan.-61	des.-18	1
47018950	Tryvannshøgda	47018950	Tryvannshøgda	59.9847	10.6693	514	jan.-61	des.-75	2
		47018960	Tryvasshøgda II	59.9886	10.6678	528	jan.-76	jun.-97	
		47018950	Tryvannshøgda	59.9847	10.6693	514	des.-97	des.-18	
47019710	Asker	47019710	Asker	59.8558	10.4358	163	jan.-61	aug.-77	2
		47019720	Asker Brannstasjon	59.8335	10.4358	112	des.-78	des.-82	
		47019710	Asker	59.8558	10.4358	163	jan.-83	des.-18	
47021680	Vest-torpa II	47021670	Aust-torpa II	60.9417	10.1208	485	okt.-63	apr.-79	3
		47021690	Vest-torpa	60.9355	10.0347	562	okt.-80	mai-86	
		47021680	Vest-torpa II	60.9345	10.0358	542	aug.-86	des.-18	
47023160	Åbjørsbråten	47023160	Åbjørsbråten	60.918	9.2893	639	jan.-61	des.-17	1
47023500	Løken I Volbu	47023500	Løken I Volbu	61.122	9.063	521	okt.-61	des.-18	1
47024890	Nesbyen Todokk	47024870	Nesbyen II	60.5667	9.1333	165	jan.-61	okt.-76	3
		47024880	Nesbyen - Skoglund	60.5685	9.122	167	nov.-76	des.-03	
		47024890	Nesbyen - Todokk	60.567	9.1323	166	nov.-03	des.-18	
47025630	Geilo - Oldebråten	47025610	Geilo - Strand	60.5294	8.2118	768	jan.-61	jul.-66	3
		47025590	Geilo - Geilostølen	60.5263	8.223	795	sep.-66	nov.-05	
		47025630	Geilo - Oldebråten	60.53	8.1948	772	aug.-06	des.-08	
47027450	Melsom	47027450	Melsom	59.23	10.3483	26	jan.-61	des.-18	1
47027500	Færder Fyr	47027500	Færder Fyr	59.0272	10.5242	6	jan.-61	des.-18	1
47028380	Kongsberg Brannstasjon	47028360	Kongsberg II / III	59.6633	9.6483	171	jan.-61	sep.-79	3
		47028370	Kongsberg IV	59.663	9.65	168	okt.-79	aug.-02	
		47028380	Kongsberg Brannstasjon	59.6247	9.6377	170	feb.-03	des.-18	
47029720	Dagali Lufthavn	47029770	Dagali - Fagerlund	60.4166	8.453	871	jan.-61	okt.-88	3
		47029790	Dagali II	60.4113	8.4444	828	nov.-88	des.-05	
		47029720	Dagali Lufthavn	60.4188	8.5263	798	okt.-02	des.-18	
47031620	Møsstrand II	47031610	Møsstrand	59.8522	8.0648	948	des.-63	apr.-76	2
		47031620	Møsstrand II	59.8397	8.1785	977	nov.-80	des.-18	
47032060	Gvarv - Nes	47032100	Gvarv	59.3885	9.1723	26	jan.-61	jul.-89	3
		47032080	Gvarv-lindem	59.3868	9.202	71	des.-89	jul.-94	
		47032060	Gvarv - Nes	59.3822	9.2128	93	mai-97	des.-18	
47034130	Jomfruland	47034120	Jomfruland Fyr	58.8653	9.5975	12	jan.-61	nov.-93	2
		47034130	Jomfruland	58.8565	9.5745	3	feb.-95	des.-18	
47035860	Lyngør Fyr	47035860	Lyngør Fyr	58.6361	9.1479	4	jan.-61	des.-18	1
47036200	Torungen Fyr	47036200	Torungen Fyr	58.3988	8.7893	12	jan.-61	des.-18	1
47036560	Nelaug	47036580	Nelaug - Øynes	58.6705	8.617	147	jan.-61	jun.-66	2
		47036560	Nelaug	58.6582	8.63	142	jul.-66	des.-18	
47037230	Tveitsund	47037230	Tveitsund	59.0257	8.5187	252	jan.-61	des.-18	1
47038140	Landvik	47038140	Landvik	58.34	8.5225	6	jan.-61	des.-18	1
47039040	Kjevik	47039040	Kjevik	58.2	8.0767	12	jan.-61	des.-18	1
47039100	Oksøy Fyr	47039100	Oksøy Fyr	58.0732	8.0532	9	jan.-61	des.-18	1
47039750	Byglandsfjord - Neset	47039710	Byglandsfjord II	58.6655	7.8117	206	jan.-61	okt.-69	3

		47039690	Byglandsfjord - Solbakken	58.6662	7.8085	212	des.-69	sep.-11	
		47039750	Byglandsfjord - Neset	58.6863	7.803	207	sep.-11	des.-18	
47041175	Laudal - Kleiven	47041660	Konsmo - Eikeland	58.25	7.3167	260	jul.-64	mai-89	3
		47041670	Konsmo - Høyland	58.267	7.3807	263	jan.-92	jun.-16	
		47041175	Laudal - Kleiven	58.2772	7.4388	280	aug.-16	des.-18	
47041770	Lindesnes Fyr	47041760	Lindesnes Fyr	57.9828	7.0467	17	jan.-61	mar.-69	2
		47041770	Lindesnes Fyr	57.9826	7.0478	16	apr.-69	des.-18	
47042160	Lista Fyr	47042160	Lista Fyr	58.109	6.5675	14	jan.-61	des.-18	1
47044080	Obrestad Fyr	47044080	Obrestad Fyr	58.6592	5.5553	24	jan.-61	des.-18	1
47044560	Sola	47044560	Sola	58.8843	5.637	7	jan.-61	des.-18	1
47045870	Fister - Sigmundstad	47045900	Fister	59.1767	6.0683	1	jan.-61	jul.-91	3
		47045880	Fister - Tønnevik	59.16	6.0365	50	jun.-92	jun.-07	
		47045870	Fister - Sigmundstad	59.16	6.0365	30	jun.-07	des.-18	
47046610	Sauda	47046610	Sauda	59.6478	6.35	5	jan.-61	des.-18	1
47046930	Vats i Vindafjord	47046910	Nedre Vats	59.484	5.7507	64	jan.-69	jan.-12	2
		47046930	Vats i Vindafjord	59.4927	5.7208	20	okt.-11	des.-18	
47047300	Utsira Fyr	47047300	Utsira Fyr	59.3065	4.8723	55	jan.-61	des.-18	1
47048330	Slåtterøy Fyr	47048330	Slåtterøy Fyr	59.9083	5.0683	25	jan.-61	des.-18	1
47050310	Kvamskogen - Jonshøgdi	47050300	Kvamskogen	60.3933	5.9133	408	jan.-61	jun.-06	2
		47050310	Kvamskogen - Jonshøgdi	60.3887	5.964	455	sep.-06	des.-18	
47050500	Flesland	47050500	Flesland	60.2892	5.2265	48	jan.-61	des.-18	1
47050540	Bergen - Florida	47050540	Bergen - Florida	60.383	5.3327	12	jan.-61	des.-18	1
47051530	Vossevangen	47051580	Voss - Tvilde	60.6377	6.452	121	jun.-62	mai-67	3
		47051590	Voss - Bø	60.6421	6.4893	125	jun.-67	des.-02	
		47051530	Vossevangen	60.625	6.4262	54	mar.-04	des.-13	
47052310	Modalen III	47052300	Modalen	60.8383	5.9333	104	jan.-61	mai-80	3
		47052290	Modalen II	60.841	5.9533	114	jun.-80	sep.-08	
		47052310	Modalen III	60.8562	5.9733	125	okt.-08	des.-18	
47052860	Takle	47052860	Takle	61.0272	5.3813	38	jan.-61	des.-18	1
47053101	Vangsnes	47053100	Vangsnes	61.1722	6.6435	51	jan.-61	apr.-94	2
		47053101	Vangsnes	61.1724	6.6452	49	mai-94	des.-18	
47054110	Lærdal Iv	47054130	Lærdal - Tønjum	61.0617	7.5167	36	jan.-61	apr.-96	3
		47054120	Lærdal - Moldo	61.0663	7.5142	24	jun.-96	sep.-08	
		47054110	Lærdal IV	61.1033	7.5025	2	okt.-08	des.-18	
47055820	Fjærland - Bremuseet	47055840	Fjærland - Skarestad	61.4352	6.7707	10	jan.-61	des.-04	2
		47055820	Fjærland - Bremuseet	61.4233	6.7642	3	des.-05	des.-18	
47057420	Førde - Tefre	47057170	Førde I Sunnfjord	61.454	5.8608	3	jan.-61	jun.-65	4
		47057180	Førde I Sunnfjord II	61.4647	5.8412	41	jul.-65	jul.-85	
		47057190	Førde - Vie	61.4505	5.8845	11	okt.-85	feb.-92	
		47057420	Førde - Tefre	61.4647	5.9212	64	nov.-92	nov.-17	
47057770	Ytterøyane Fyr	47057760	Kinn	61.5641	4.7905	10	jan.-61	okt.-67	3

		47057750	Kinn	61.5612	4.7697	9	nov.-67	mai-88	
		47057770	Ytterøyane Fyr	61.5717	4.6817	26	sep.-84	des.-84	
47058070	Sandane	47058070	Sandane	61.788	6.1837	51	jan.-61	des.-17	1
47059610	Fiskåbygd	47059610	Fiskåbygd	62.103	5.5817	41	jul.-69	des.-18	1
47059680	Ørsta-volda Lufthamn	47059710	Ørstavik - Velle	62.2025	6.1323	35	jan.-61	apr.-96	2
		47059680	Ørsta-volda Lufthavn	62.181	6.0807	74	mai-03	des.-18	
47059800	Svinøy Fyr	47059800	Svinøy Fyr	62.3293	5.268	38	jan.-61	des.-18	1
47060500	Tafjord	47060500	Tafjord	62.2305	7.4218	11	jan.-61	des.-18	1
47060990	Vigra	47060990	Vigra	62.5617	6.115	22	jan.-61	des.-18	1
47062480	Ona II	47062500	Ona	62.8634	6.5443	11	jan.-61	mar.-63	3
		47062490	Ona - Husøy	62.8589	6.5388	8	mai-63	mai-78	
		47062480	Ona II	62.8585	6.5378	20	sep.-78	des.-18	
47065940	Sula	47065950	Sula Fyr	63.8475	8.4537	28	jan.-61	des.-74	2
		47065940	Sula	63.8467	8.4667	5	jan.-75	des.-18	
47066720	Berkåk - Terminalveien	47066700	Berkåk	62.8287	10.1992	424	jan.-61	aug.-67	4
		47066710	Berkåk II	62.8266	10.0108	441	sep.-67	jan.-80	
		47066730	Berkåk -Lyngholt	62.8227	10.02	475	okt.-82	sep.-08	
		47066720	Berkåk - Terminalveien	62.8332	10.0188	440	aug.-11	des.-18	
47068290	Selbu II	47068300	Selbu	63.2058	11.111	197	jan.-61	jun.-76	4
		47068310	Selbu - Bogstad	63.191	11.0875	181	nov.-76	mai-79	
		47068340	Selbu - Stubbe	63.2058	11.1175	242	sep.-79	okt.-06	
		47068290	Selbu II	63.2248	11.1975	160	okt.-07	des.-18	
47069100	Værnes	47069100	Værnes	63.4597	10.9305	12	jan.-61	des.-18	1
47069380	Meråker - Vardetun	47069360	Meråker II	63.4229	11.7604	218	jan.-61	aug.-69	5
		47069340	Meråker - Lillesve	63.4382	11.6915	115	nov.-69	aug.-73	
		47069330	Meråker - Krogstad	63.4431	11.6992	145	nov.-74	nov.-93	
		47069370	Meråker - Utsyn	63.4188	11.7588	239	aug.-94	jul.-04	
		47069380	Meråker - Vardetun	63.4115	11.7277	169	jun.-04	des.-18	
47070850	Snåsa - Kjevlia	47070850	Snåsa - Kjevlia	64.1587	12.4692	195	jan.-61	des.-18	1
47071550	Ørland III	47071550	Ørland III	63.7045	9.6105	10	jan.-61	des.-18	1
47071990	Buholmråsa Fyr	47071980	Kalværet	64.3346	10.3195	12	jul.-63	aug.-65	2
		47071990	Buholmråsa Fyr	64.4013	10.455	18	nov.-65	des.-18	
47073500	Nordli - Holand	47073470	Nordli III	64.4619	13.5916	402	jan.-61	des.-66	3
		47073490	Nordli - Brattvold	64.4473	13.713	462	aug.-67	sep.-84	
		47073470	Nordli III	64.4619	13.5916	402	okt.-85	jul.-87	
		47073500	Nordli - Holand	64.4458	13.7181	433	aug.-88	des.-18	

Network 2

Analysed series	Name	Original Series	Name	Lat (°)	Lon (°)	Alt (m)	Start	End	original series Nr
47080102	Solvær III	47080100	Nord-solvær	66.3683	12.6445	7	jan.-61	aug.-98	3
		47080101	Solvær - Sleneset	66.3663	12.6153	6	okt.-98	sep.-05	

		47080102	Solvær III	66.3708	12.6108	10	nov.-07	des.-18	
47080610	Myken	47080600	Myken	66.7605	12.4775	19	jan.-61	jul.-91	2
		47080610	Myken	66.7628	12.486	17	okt.-92	des.-18	
47080700	Glomfjord	47080700	Glomfjord	66.8102	13.9793	39	jan.-61	des.-18	1
47082290	Bodø VI	47082290	Bodø VI	67.267	14.3637	11	jan.-61	des.-18	1
47084700	Narvik Lufthavn	47084790	Narvik II	68.4688	17.4922	32	jan.-61	aug.-75	3
		47084800	Narvik III	68.4697	17.4983	17	sep.-75	mai-02	
		47084700	Narvik Lufthavn	68.4397	17.3887	31	sep.-02	apr.-17	
47085380	Skrova Fyr	47085380	Skrova Fyr	68.1535	14.6485	14	jan.-61	des.-18	1
47085890	Røst Lufthavn	47085900	Røst	67.5061	12.069	8	jan.-61	okt.-69	4
		47085910	Røst II	67.5063	12.0762	10	jan.-79	jun.-97	
		47085891	Røst III	67.525	12.104	4	apr.-98	des.-08	
		47085890	Røst Lufthavn	67.5267	12.1038	4	okt.-02	des.-18	
47086500	Sortland	47086520	Sortland - Kleiva	68.648	15.2832	14	jan.-61	aug.-91	2
		47086500	Sortland	68.7033	15.4157	3	jan.-85	des.-18	
47086740	Bø I Vesterålen III	47086760	Bø I Vesterålen II	68.6322	14.463	12	jul.-61	jun.-01	3
		47086780	Litløy Fyr	68.5932	14.3103	30	sep.-94	mai-03	
		47086740	Bø I Vesterålen III	68.6067	14.4333	8	mar.-03	des.-18	
47087110	Andøya	47087110	Andøya	69.3073	16.1312	10	mar.-62	des.-18	1
47088690	Hekkingen Fyr	47090280	Sommarøy I Senja	69.6332	18.0106	2	jan.-61	jun.-67	3
		47088680	Leirkjosen	69.5517	17.9128	9	nov.-67	apr.-79	
		47088690	Hekkingen Fyr	69.6013	17.8303	33	nov.-79	des.-18	
47089350	Bardufoss	47089350	Bardufoss	69.0577	18.5437	76	jan.-61	des.-18	1
47089940	Dividalen II	47089950	Dividalen	68.7783	19.71	228	jan.-61	mai-09	2
		47089940	Dividalen II	68.7817	19.7017	204	nov.-09	des.-18	
47090450	Tromsø	47090450	Tromsø	69.6536	18.9368	100	jan.-61	des.-18	1
47090490	Tromsø - Langnes	47090490	Tromsø - Langnes	69.6767	18.9133	8	okt.-64	des.-18	1
47090800	Torsvåg Fyr	47090800	Torsvåg Fyr	70.2452	19.4997	21	jan.-61	des.-18	1
47091380	Skibotn II	47091350	Skibotn	69.3777	20.3024	46	jan.-61	apr.-72	4
		47091360	Skibotn - Melå	69.3667	20.2833	8	aug.-74	aug.-84	
		47091370	Skibotn - Fossbakk	69.3683	20.2683	5	sep.-84	sep.-04	
		47091380	Skibotn II	69.3875	20.2823	20	nov.-04	des.-18	
47091740	Sørkjosen Lufthavn	47091750	Nordreisa	69.7412	21.0235	1	jan.-61	jun.-92	3
		47091760	Nordreisa - Øyeng	69.7468	21.0267	5	jul.-92	jul.-06	
		47091740	Sørkjosen Lufthavn	69.7887	20.9553	6	sep.-05	des.-18	
47092350	Nordstraum I Kvænangen	47092350	Nordstraum I Kvænangen	69.8362	21.8958	20	aug.-65	des.-18	1
47093140	Alta Lufthavn	47093150	Alta Aeradio	69.9715	23.3587	62	jan.-63	nov.-63	2

		47093140	Alta Lufthavn	69.9775	23.3582	3	des.-63	des.-18	
47093301	Suolovuopmi - Lulit	47093300	Suolovuopmi	69.5883	23.5317	377	okt.-63	okt.-04	2
		47093301	Suolovuopmi - Lulit	69.5797	23.5345	381	nov.-04	des.-18	
47093700	Kautokeino	47093700	Kautokeino	68.9968	23.0335	307	jan.-61	okt.-70	2
		47093710	Kautokeino II	69.0167	23.034	330	nov.-70	jan.-96	
		47093700	Kautokeino	68.9968	23.0335	307	aug.-96	des.-18	
47093900	Sihccajavri	47093900	Sihccajavri	68.7553	23.5387	382	jan.-61	des.-18	1
47094500	Fruholmen Fyr	47094500	Fruholmen Fyr	71.0937	23.9817	13	jan.-61	des.-18	1
47095350	Banak	47095430	Brennelv	70.0667	25.1167	35	aug.-61	des.-81	2
		47095350	Banak	70.06	24.99	5	aug.-65	des.-18	
47096400	Slettnes Fyr	47096400	Slettnes Fyr	71.0888	28.217	8	jan.-61	des.-18	1
47096800	Rustefjelbma	47096800	Rustefjelbma	70.3968	28.1928	10	jan.-61	mai-13	1
47097251	Karasjok - Markannjarga	47097250	Karasjok	69.4683	25.4817	155	jan.-61	aug.-04	2
		47097251	Karasjok - Markannjarga	69.4635	25.5023	131	aug.-04	des.-18	
47097350	Cuovddatmohkki	47097350	Cuovddatmohkki	69.3695	24.4312	286	aug.-66	des.-18	1
47098400	Makkaur Fyr	47098400	Makkaur Fyr	70.7057	30.07	9	jan.-61	des.-18	1
47098550	Vardø Radio	47098550	Vardø Radio	70.3707	31.0962	10	jan.-61	des.-18	1
47099370	Kirkenes Lufthavn	47099370	Kirkenes Lufthavn	69.7255	29.8977	89	feb.-64	des.-18	1

Network Swedish and Finnish series

Analysed series	Name	Original Series	Name	Lat (°)	Lon (°)	Alt (m)	Start	End	Original series nr
46081540	Nordkoster A	46081640	Ursholmen	58.8333	11	6	1961	1965	2
		46081540	Nordkoster A	58.892	11.0038	33	1967	2018	
46092100	Säffle	46092100	Säffle	59.1407	12.9336	53	1961	2018	1
46092130	Blomskog A	46091130	Bredviken	59.2184	11.9858	100	1961	1995	2
		46092130	Blomskog A	59.2213	12.0754	170	1995	2018	
46092410	Arvika A	46092400	Arvika	59.6658	12.591	77	1961	1995	2
		46092410	Arvika A	59.6743	12.6354	66	1995	2018	
46093220	Karlstad Flygplats	46093220	Karlstad Flygplats	59.4446	13.3374	107	1961	2018	1
46102540	Höljes	46102540	Höljes	60.9066	12.5843	230	1961	2018	1
46103080	Torsby	46103080	Torsby	60.1075	12.9908	127	1961	2014	1
46103090	Gustavsfors	46103090	Gustavsfors	60.1514	13.7975	190	1961	2018	1
46103410	Malung	46103410	Malung	60.6717	13.7058	310	1961	2017	1
46112170	Grundforsen	46112170	Grundforsen	61.2797	12.8568	412	1961	2012	1
46113420	Särna A	46113410	Särna	61.7068	13.1335	437	1961	2000	2
		46113420	Särna A	61.6912	13.1865	425	2000	2018	
46114140	Älvdalen A	46114160	Älvdalen II	61.2549	14.0348	250	1968	1995	2
		46114140	Älvdalen A	61.2536	14.0355	252	1995	2018	
46122330	Ljusnedal	46122330	Ljusnedal	62.5493	12.6043	585	1961	2018	1

46132170	Storlien-Storvallen A	46132180	Storlien-Visjövalen	63.3028	12.1253	642	1962	2010	2
		46132170	Storlien-Storvallen A	63.2826	12.1218	583	2010	2018	
46132590	Edevik	46142030	Björkede	64.0432	12.9414	451	1961	1980	2
		46132590	Edevik	63.9812	12.8709	425	1980	2018	
46133050	Höglekardalen	46133050	Höglekardalen	63.0785	13.7488	595	1962	2018	1
46134590	Almdalen	46134590	Almdalen	63.9967	14.6701	615	1965	2018	1
46143440	Jormlien	46143440	Jormlien	64.7291	13.9819	383	1967	2018	1
46144300	Gäddede	46144300	Gäddede	64.5037	14.1596	328	1961	2008	1
46146050	Hoting A	46146070	Hoting	64.1236	16.2149	240	1970	1996	2
		46146050	Hoting A	64.0875	16.2356	242	1996	2018	
46155970	Hemavan Flygplats	46155940	Hemavan	65.821	15.086	482	1966	2008	2
		46155970	Hemavan Flygplats	65.8077	15.0854	458	2008	2018	
46166810	Jäckvik	46166810	Jäckvik	66.3874	16.9714	434	1961	2018	1
46167980	Kvikkjokk-Årrenjarka	46167980	Kvikkjokk-Årrenjarka	66.8876	18.0179	314	1961	2013	1
46178970	Tarfala A	46178970	Tarfala A	67.9124	18.6101	1144	1965	2018	1
46180940	Kiruna Flygplats	46180940	Kiruna Flygplats	67.827	20.3387	459	1961	2018	1
46181900	Vittangi	46181900	Vittangi	67.6943	21.6335	250	1961	2018	1
46188800	Abisko	46188800	Abisko	68.3557	18.8206	388	1961	2018	1
46188820	Katterjåkk	46188830	Riksgränsen	68.4284	18.1302	508	1961	1969	2
		46188820	Katterjåkk	68.4218	18.1698	515	1969	2018	
46191910	Naimakka A	46191900	Naimakka	68.6779	21.5277	403	1961	1996	2
		46191910	Naimakka A	68.6762	21.5229	402	1995	2018	
46192840	Karesuando A	46192830	Karesuando	68.4421	22.4502	330	1961	2008	2
		46192840	Karesuando A	68.4418	22.4435	330	2009	2018	
358101969	Muonio Alamuonio	358101969	Muonio Alamuonio	67.969	23.672	252	1961	2013	1
358101994	Kittilä Pokka	358101994	Kittilä Pokka	68.17	25.783	276	1971	2018	1
358102000	Sodankylä Lokka	358102000	Sodankylä Lokka	67.822	27.746	240	1962	2018	1
358102001	Sodankylä Vuotso	358102001	Sodankylä Vuotso	68.084	27.185	248	1970	2018	1
358102033	Inari Ivalo lentoasema	358102033	Inari Ivalo lentoasema	68.613	27.419	140	1961	2018	1
358102035	Utsjoki Kevo	358102035	Utsjoki Kevo	69.756	27.007	107	1961	2018	1
358102036	Utsjoki Nuorgam	358102036	Utsjoki Nuorgam	70.082	27.897	22	1961	2018	1

B: Metadata for the homogeneity breaks

Network 1

Number	Station	Year	Month	Break amplitude (°C)*	Annual Adjustment	Reason for Break

					factor(°C)	
47000700	Drevsjø	1965	6	−0,25	−0,26	Radiation screen painted
		1987	10	0,15	−0,01	Relocation of the station 75 m WNW
		2002	11	−0,16	−0,16	Automation of the station
47004780	Gardermoen	1966	11	−0,23	0,28	Relocation of radiation screen 20m NW
		1981	1	0,35	0,51	Radiation screen painted and a small relocation of radiation screen 180 m SSW because of new buildings
		1997	1	0,15	0,15	Construction of a new airport, hence relocation of observation site. Automation of the station
47004920	Årnes	1983	8	−0,03	−0,06	New station Hvam-Tolvhus (4940): Relocation approx.1 km towards NW from Hvam(4930)
		2010	8	−0,03	−0,03	New station Årnes (4920). Relocated 2 km N from Hvam – Tolvhus (4940)
47005590	Kongsvinger	1980	9	−0,08	0,15	Radiation screen relocated 10 m N
		1990	3	−0,13	0,23	New maximum thermometer
		2004	12	0,36	0,36	Relocation of the station from Vinger, 5650 to Kongsvinger, 5590 (3km towards S) (active since 8/2006)
47006020	Flisa Ii	1974	5	0,01	0,5	Inspection with remarks
		1998	12	0,48	0,48	Flisa 6040 closed down. Relocated 0.4km SW. New station Flisa II 6020 began operation 11/2003. (1/2004- temp data)
47007950	Rena Flyplass	1983	12	0,28	−0,17	New minimum thermometer
		2011	12	−0,45	−0,45	New station Rena Flyplass 7950. Relocation of 5 km towards NW -1/2013 from Rena-Haugedalen(7010)
47010380	Røros Lufthavn	1972	8	0,12	−0,19	Radiation screen cleaned and painted.
		2002	8	−0,31	−0,31	New station Røros Lufthavn (10380) which is an automatic station. Relocation from Røros-10400 1.4km towards W
47011500	Østre Toten - Apelsvoll	1965	7	−0,17	0,07	Radiation screen painted
		1987	5	0,24	0,24	Automation of the station
47012550	Kise Pa Hedmark	1980	9	0,26	0,26	Automation of the station
47012680	Lillehammer - Sætherengen	1969	8	−0,16	0,29	Relocation of Lillehammer II,12660 2 km toward S to Lillehammer III, 12640
		1981	8	0,34	0,45	Relocation of Lillehammer III, 12640 1.2km towards N to Lillehammer-Sætherengen, 12680, (active from 1983)
		2005	6	0,11	0,11	New temperature sensor (PT100)
47013655	Skåbu	1994	6	−0,22	−0,55	Radiation screen painted during inspection
		2011	6	−0,33	−0,33	New station Skåbu, 13655 an Automatic station. Relocation of 2 km towards NE in 2010 from Skåbu-Storslåen, 13670..
						New temperature sensor (PT100)
47015730	Bråtå - Slettom	1994	9	0,26	0,26	Radiation screen painted,
						Minor adjustment to the station coordinates (61 °, 54.4'N 7 ° 51.6'E to 61 ° 54.3'N 7 °51.8'E)
47016560	Dombås - Nordigard	1965	6	−0,3	−0,05	Relocation of the station. Dombås II 600m towards NE and name of change
		1972	6	0,14	0,25	Relocation of the station -Dombås II, 16550 325m WSW. New station Dombås- Kirkenær, 16540 (active 7/1972)
		1988	10	0,11	0,11	New station Dombås -Kirstitugu, 16551.

						New maximum and minimum thermometers(at , Kjøremsgrende, 16740)
47016610	Fokstugu	1968	6	0,64	0,76	Fokstua, 16600 closed down. Relocated 0.8m towards SE. New station Fokstugu,16610 (active 6/1968)
		1997	8	−0,29	0,12	New radiation screen MI-33 and PT100 temperature sensor
		2008	10	0,41	0,41	Automation of the station
47017150	Rygge	1967	9	−0,18	0,13	New Tetalux. New minimum thermometer
		1972	10	0,26	0,31	New maximum thermometer
		1984	10	−0,38	0,05	New radiation screen
		1994	10	0,44	0,44	New MI-46 radiation screen (Station automated
47017850	Ås	1969	12	0,2	−0,11	Radiation screen painted
		1983	5	−0,02	−0,21	Relocation of station 93.3m towards S
		1987	12	−0,06	−0,19	The station closed down temporarily. Relocation.
		1996	8	−0,13	−0,13	Automation of the station
47018700	Oslo - Blindern	1980	12	−0,16	−0,04	Radiation screen painted
		1995	12	0,11	0,11	Automation of the station
47018950	Tryvannshøgda					No break
47019710	Asker	1982	12	0,1	0	Relocation of the station approx. 300m E to the same position in 1977.Asker 19710 restored
		1993	9	−0,1	−0,1	Radiation screen washed and painted. The instruments therein also washed.
47021680	Vest-torpa Ii	1979	4	−0,31	−0,45	Relocation of Aust Torpa, 21670 to Vest Torpa 21690 (active from 1/1980). Also New observer
		1986	5	−0,12	−0,14	Relocation of Vest Torpa, 21690 0.1km towards SE to Vest Torpa II (Active from 8/1986)
		2013	11	−0,02	−0,02	Automation of the station
47023160	Åbjørsbråten	1997	5	0,07	0,07	New PT100 temperature sensor and thermometers (main, min and max thermometers)
47023500	Løken I Volbu	1987	3	0,07	0,24	Automation of the station
		2009	12	0,17	0,17	Relocation of the radiation screen
47024890	Nesbyen - Todokk	1976	10	0,44	0,13	Relocation of Nesbyen II 500m NW direction to Nesbyen-Skoglund 24880-(active from 11/1976)
		2003	11	−0,31	0,31	New station Nesbyen-Todokk, 24890. An automatic station + New PT100 temperature sensor
47025630	Geilo - Oldebråten	1966	7	0,25	0,25	Relocation of Geilo Strand, 25610 0.7km towards SE to Geilo-Geilostølen, 25590(active 9/1966-11/2005))
47027450	Melsom	1969	6	0,12	−0,04	Radiation screen scraped and painted
		1984	10	0,05	−0,16	New max and min thermometers
		1994	8	−0,2	−0,2	Replacement of thermometer. (***break should be 2/1999-Automation of station-but due to missing data Homer crashes)***
47027500	Færder Fyr	1970	12	−0,07	−0,17	New observer
		1986	7	−0,07	−0,1	New maximum thermometer
		1999	9	−0,07	−0,03	Automation of the station. New radiation screen TYPE 33, New temp sensor PT100
		2010	5	0,04	0,04	MI-46 radiation screen installed
47028380	Kongsberg Brannstasjon	1967	9	0,23	0,11	Radiation screen relocated 13m towards NE

		1979	9	−0,1	−0,12	Relocation from Kongsberg II/II, 28360 0.1km towards E. New station Kongsberg IV, 28370.(Active 10/1979-8/2002)
		1987	12	−0,02	−0,02	New maximum thermometer
47029720	Dagali Lufthavn	1988	10	−0,28	−0,66	Relocation of Dagali-Fagerlund, 29770 0.8km towards SW to Dagali II, 29790 (Active 11/1988-5/2005)
		2002	10	−0,38	−0,38	New station Dagali Lufthavn, 29720 -an Automatic station
47031620	Møsstrand Ii	1976	4	0,05	−0,17	Relocation of Møsstrand, 31610 7 km towards E. New station Møsstrand II, 31620 (active since 11/1980)
		2013	11	−0,22	−0,22	New MI-2001B radiation screen
47032060	Gvarv - Nes	1966	7	0,05	0,59	Radiation screen cleaned and painted.
		1974	1	0,2	0,54	Inspection with minor adjustments. New minimum thermometer,
		1989	8	0,34	0,34	Relocation of Gvarv 1.7km towards E to Gvarv-Lindem, 32080 (active 12/1969-7/1994)
47034130	Jomfruland	1993	11	0,13	0,13	Station relocation Jomfruland Fyr, 34120 1.7 km towards SW. New station -Jomfruland -34130-an automatic station (active since 1994)
47035860	Lyngør Fyr	1967	9	−0,05	−0,19	Change of observer
		1989	8	−0,14	−0,14	New MI- 46 radiation screen
47036200	Torungen Fyr	1988	12	−0,06	−0,06	New minimum and maximum thermometers
		1997	8	0,01	0,01	New maximum and minimum thermometer
47036560	Nelaug	1966	6	0,63	0,63	Relocation of Nelaug-Øynes 36580 1.6km towards SE and change of station number 36560-Nelaug (active since 7/1966 -New MI-46 radiation screen)
		1986	9	0	0	Station relocation 70m SSW. New ht because of relocation(H)
47037230	Tveitsund	2008	11	−0,17	−0,17	Relocation and automation of the station.
47038140	Landvik	1987	3	−0,3	−0,18	Automation of the station.
		2013	12	0,11	0,11	Unknown
47039040	Kjevik	1986	12	0,2	−0,06	Relocation of the radiation screen.
		1995	5	−0,25	−0,25	Automation of the station
47039100	Oksøy Fyr	1988	9	−0,07	−0,1	New MI-46 radiation screen placed approx. 5.1m NE of the old one.
		2016	5	−0,03	−0,03	New MI-2001B radiation screen and new PT-100 temperature sensor
47039750	Byglandsfjord - Neset	1969	10	0,1	0,07	Relocation of station Byglandsfjord II, 39710 0.2km towards NW. New station Byglandsfjord-Solbakken (active 12/1969-9/1011).
						11/1969-Change of observer.
		2011	11	−0,03	−0,03	Automation of station
47041175	Laudal - Kleiven	1989	5	−0,3	−0,4	Relocation of Konsmo-Eikeland, 41660 4 km towards NE. New station, Konsmo -Høyland (active 1/1992-6/2016)
		2016	6	−0,1	−0,1	Relocation of Konsmo -Høyland 4 km towards E. New station Laudal-Kleiven , 41175 (active since 8/2016)
47041770	Lindesnes Fyr	1969	4	−0,3	−0,11	Relocation of Lindesnes Fyr, 41760 0.1km towards SE. New station Lindesnes Fyr, 41770(active since 4/1969)
		1977	8	0,19	0,19	New maximum thermometer
47042160	Lista Fyr	1970	9	−0,21	−0,27	**Inspection**
		1988	3	−0,1	−0,06	Radiation screen painted
		1994	6	0,04	0,04	Automation of the station
47044080	Obrestad Fyr	1967	12	−0,19	−0,03	New MI- 46 radiation screen in 6/1964)

		1989	9	0,16	0,16	Radiation screen painted- (Station automated oct-1993)
47044560	Sola	1989	6	0,01	0,09	New MI- 46 radiation screen
		2003	12	0,09	0,09	Automation of the station
47045870	Fister - Sigmundstad	1966	8	0,1	0,18	Radiation screen's roof painted. New minimum thermometer
		1991	9	−0,06	0,09	Relocation of Fister 45900 3km towards SW. New station Fister-Tønnevik ,45880 (Active 6/1992- 6/2007)
		2007	6	0,15	0,15	New station Fister-Sigmundstad, 45870 -An automatic station
47046610	Sauda	1988	10	0,04	0,04	New MI- 46 radiation screen
47046930	Vats I Vindafjord	1988	11	0,21	−0,09	Radiation screen painted
		2011	10	−0,3	−0,3	New station Vats i Vindafjord, 46930 an automatic station. Relocation 2 km towards NW from Nedre Vats,46910
47047300	Utsira Fyr					No breaks
47048330	Slåtterøy Fyr	1976	12	−0,06	0,06	New MI-46 radiation screen
		1997	10	0,12	0,12	Automation of the station. New radiation screen MI- 33
47050310	Kvamskogen - Jonshøgdi	1966	6	0,04	−0,23	New radiation screen MI-33
		2006	9	−0,28	−0,28	Relocation of Kvamskogen, 50300 3 km towards E. New station Kvamskogen-Jonshøgdi, 50310 (active since 9/2006)
47050500	Flesland	1980	7	−0,32	−0,11	New maximum and minimum thermometers
		1989	11	0,21	0,21	New MI- 46 radiation screen
47050540	Bergen - Florida	1987	2	−0,21	−0,19	Relocation of the station 2km.
		2006	12	0,02	0,02	Rehabilitation and renewal of the station. New Automatic weather station and mast to be installed
47051530	Vossevangen	1967	6	0,37	0,71	Relocation of the station from Voss-Tvilde, 51580 approx. 2.1km towards E. New station Voss-Bø, 51590 (6/1967-12/2002). New MI-46 radiation screen
		2003	1	0,17	0,34	Relocation of Voss-Bø, 51590 4 km towards SW. New station Vossevangen (active since 1/2004)
		2011	12	0,18	0,18	Some tall pines have grown relatively close to the station (15-20m) to East and South East
47052310	Modalen III	1967	6	0,15	−0,22	Radiation screen painted. Also change of observer (11/1967)
		1987	5	−0,12	−0,37	Radiation screen painted and change of observer
		2008	10	−0,25	0,25	Relocation of the station from Modalen II, 52290 2 km towards NE. New station Modalen III (active since 10/2008)
47052860	Takle	1970	12	−0,18	−0,25	2 houses near the radiation screen are demolished and a garage build up
		1986	4	−0,01	−0,07	Relocation of the radiation screen 5m northwards.
		2014	5	−0,06	−0,06	Automation of the station. New MI-2001B radiation screen. New temp sensor PT100, = Station automated (new instruments)
47054110	Lærdal IV					No break
47055820	Fjærland - Bremuseet	1986	9	0,27	−0,47	Inspection with remarks and adjustment-(Minimum thermometer to be changed)
		2005	11	−0,74	−0,74	New station Fjærland-Bremuseet-An automatic station. Relocation from Fjærland-Skarestad, 55840 1.4km towards S

47057420	Førde - Tefre	1965	6	−0,04	−0,62	Relocation of the station from Førde i Sunnfjord , 57170 relocated 1400 m towards NNW and now called Førde i Sunnfjord II, 57180- (7/1965-7/1985)
		1985	7	−0,26	−0,59	Relocation of Førde i Sunnfjord II, 57180 3 km towards SE. New station Førde-Vie, 57190 (10/1985-2/1992)
		1992	10	−0,33	0,33	New station Førde-Tefre, 57420.
47057770	Ytterøyane Fyr	1967	11	−0,27	−0,07	Relocation of the station 120m towards N.
		1976	8	−0,04	0,19	New thermometer
		1984	9	−0,03	0,24	MI-33 radiation screen installed
		1999	9	0,26	0,26	Automation of the station. New radiation screen MI- 46.
47058070	Sandane	1981	12	0,17	0,17	Inspection with remarks and adjustments. New thermometer
47059610	Fiskåbygd	2003	6	−0,24	−0,24	Inspection with remarks-radiation screen to be washed and painted
47059680	Ørsta-volda Lufthamn	1996	4	−0,38	−0,38	Relocation of the station. From Østavik-Velle, 59710 4 km towards SW to Østra-Volda Lufthavn, 59680. (active since 5/2003)
47059800	Svinøy Fyr	2005	8	0,26	0,26	Automation of the station.
47060500	Tafjord					No breaks
47060990	Vigra	1984	11	−0,12	0,13	Station relocation - moved 330 SW. In addition, the Tetalux replaced with MITEF.
		1998	11	0,26	0,26	Temperature sensor PT100-replaced and installed in the radiation screen
47062480	Ona II	1974	12	−0,14	−0,03	New map with new positioning. Also small trees have grown near the radiation screen
		2013	4	0,11	0,11	New MI-2001B radiation screen
47065940	Sula	1974	12	0,19	0,16	Relocation of the station, Sula Fyr, 65950 600m towards E to Sula 65940 (active since 1/1975)
		1990	8	−0,03	−0,03	Relocation of the station 330m SSW.
47066720	Berkåk - Terminalveien	1980	1	−0,38	−0,4	The station (Berkåk II, 66710) closed down temporarily. Restored and relocated 0.6km towards SE in 10/1982 as Berkåk-Lyngholt
		2011	9	−0,02	−0,02	New station Berkåk-Terminalveien, 66720. Relocated from Berkåk-Lyngholt,66730 1.2km towards E.
						Dense forest around the station was cleared (1/2011)
47068290	Selbu Ii	1976	6	−0,14	−0,13	Relocation of the station, Selbu, 68300 2 km towards SW to Selbu-Bogstad (68310) (11/1976 -5/1979)
		2006	10	−0,16	−0,16	Relocation of Selbu-Stubbe, 68340, 6 km towards W. New station Selbu II, 68190, (active since 10/2007)
47069100	Værnes	1978	1	0,39	0,02	New temperature sensor MITEF
		1994	12	−0,37	−0,37	Relocation of radiation screen 800m NE
47069380	Meråker - Vardetun	1967	8	0,14	0	New MI-46 radiation screen and instruments mounted therein
		1986	6	0	−0,14	Inspection with remarks and adjustments-(Difficulty in reading temperature from thermometers therefore need for replacement). New thermometers
		1993	12	−0,13	−0,13	Relocation of the station Meråker- Krogstad,69330 4km SE to Meråker -Utsyn,69370 (8/1994- 7/2004)
47070850	Snåsa - Kjevlia					No breaks
47071550	Ørland Iii	1985	12	−0,16	0,15	New MI-46 radiation screen

		2002	5	0,31	0,31	New thermometer
47071990	Buholmråsa Fyr					No breaks
47073500	Nordli - Holand	1966	12	−0,1	0,24	Nordli III, 73470-closed down temporarily and relocated 6 km towards E. New station Nordli-Brattvold, 73490 (1/1967-9/1984)
		1984	9	0,06	0,35	Relocation/Restoration of Nordli-Brattvold 6km E to its previous position.
		1994	11	0,29	0,29	New minimum thermometer. 1/1996-New maximum and minimum thermometers
47075410	Nordøyan_fyr	1989	4	0,02	0,02	New radiation screen MI-33

Network 2

Number	Station	Year	Month	Break amplitude (°C)	Annual Adj factor (°C)	Reason for Break
47080102	Solvær Iii					no break
47080610	Myken	1967	5	−0,1	−0,02	Relocation of radiation screen 22m towards the S
		1987	12	0,08	0,08	Change of observer
47080700		2003	6	−0,19	−0,19	Fail with the temperature sensors-error in the temp measurement due to electronic/conductor breaks in the Radiation screen
47082290	Bodø Vi	1991	8	0,15	0,15	Temperature sensor in the radiation screen changed upon Inspection
47084700	Narvik Lufthavn	1975	8	0,31	0,45	Relocation of station from Narvik II, 84790 0.3km toward E. New station Narvik III, 84800 (active 9/1975-5/2002)
		2002	5	−0,46	0,14	Relocation of station from Narvik III, 84800 6 km towards SW to Narvik Lufthavn (active 9/2002-4/2017)
		2010	7	0,6	0,6	Relocation of MI-2001B radiation screen closer to the mast-
47085380	Skrova Fyr	1989	3	−0,06	0,21	Change of observer. Radiation screen painted upon inspection (6/1989)
		2008	5	0,27	0,27	Automation of the station
47085890	Røst Lufthavn	1969	10	0,06	−0,33	Relocation of the station from Røst, 85900 0.3km E to Røst II, 85910 (1/1979-6/1997)
		1986	6	−0,28	−0,39	New radiation screen (MI-74)
		2004	11	−0,11	−0,11	Automation of the station
47086500	Sortland	1974	8	0,08	−0,13	Radiation screen painted. Also slight relocation of the screen to a little higher ground than before.
		1985	1	−0,21	−0,21	Relocation of station, from Sortland-Klevia, 86520 8 km towards NE to Sortland, 86500 (active since 1/1985)
		2002	7	0	0	New MI-46 radiation screen
47086740	Bø I Vesterålen III	2003	3	0,39	0,39	New station Bø i Vesterålen III, 86740. Relocation from Litløy Fyr, 86870 5 km towards E.
47087110	Andøya	1972	3	−0,17	−0,17	Relocation of the station 1 km SSE
47088690	Hekkingen Fyr	1967	6	−0,41	−0,17	Relocation of the station from Sommarøy i Senja, 90280 10 km SW to Leirkjosen, 88680 (11/1967-4/1979)

		1979	4	0,31	0,25	Relocation of station from Leirkjosen, 88680 6 km towards NW to Hekkingen Fyr, 88690 (active since 11/1979)
		1998	7	0,06	−0,06	Automation of the station
		2015	6	−0,12	−0,12	New MI-2001B Radiation screen
47089350	Bardufoss	1988	9	0,46	−0,41	Relocation of radiation screen 150m S
		2000	11	−0,41	−0,85	Construction of an extension to the fire station and new parking place at the airport
		2014	1	−0,45	−0,45	Automation of the station (New radiation screen (MI-2000) 12/2011)
47089940	Dividalen II	1968	5	−0,09	−0,94	Radiation screen painted
		2009	5	−0,84	−0,84	Relocation of the station from Dividalen, 89950 0.5km towards NW. New station Dividalen II, 89940 (active since 11/2009), an automatic station
47090450	Tromsø	1987	12	−0,22	0,1	New maximum thermometer. Also inspection with remarks
		2003	6	0,31	0,31	Automation of the station
47090490	Tromsø - Langnes	1977	10	−0,2	−0,4	Relocation of the station 38m towards S
		1985	9	0,2	0,2	Relocation of radiation screen 450m SE
47090800	Torsvåg Fyr					no break
47091380	Skibotn Ii	1972	4	−0,06	−0,55	Relocation of station from Skibotn, 91350 1.4km towards SW to Skibotn-Mela, 91360 (active 8/1974-8/1984)
		2004	9	0,49	0,49	Relocation of station from Skibotn-Fossbakk, 91370 2 km towards N. New station Skibotn II, 91380 an automatic station (active since 11/2004)
47091740	Sørkjosen Lufthavn	1974	8	0,1	0,68	New MI-74 radiation screen
		1992	7	−0,43	0,58	New station Nordresia-Øyeng, 91760 (active 7/1992-7/2006). Relocation from Nordresia, 91750:6/1992 0.6km Northwards.
		2005	8	0,64	1,01	New station Sørkjosen Lufthavn, 91740(Automatic). Relocation:7/2006 from Nordresia-Øyeng, 91760 5 km towards NW
		2011	12	0,37	0,37	unknown 6/2012 inspection
47092350	Nordstraum I Kvænangen	2006	7	0,03	0,03	New thermometer
47093140	Alta Lufthavn	1971	6	0,13	−0,14	Relocation of the radiation screen 83m W. New TETALUX installed (10/1971)
		2010	2	−0,27	−0,27	Cluttered observation basis between 2004 and 2010
47093301	Suolovuopmi - Lulit	1997	4	0,03	−0,61	Automation of the station
		2004	10	−0,64	−0,64	Relocation of station from Suolovuompi, 93300 1km S. New station Suolovuopmi-Lulit, 93301 (active since 11/2004).
						New radiation screen MI-2001B and new max thermometer
47093700	Kautokeino	1970	11	0,18	0,14	New station Kautokeino II, 93710. Relocation:10/1970 from Kautokeino, 93700 (2 km N)
		1996	7	−0,04	−0,04	Relocation and restoration of Kautokeino, 93700, approx. 300m from the old position. New radiation screen (MI-46)
47093900	Sihccajavri	1999	9	0,15	0,28	Radiation screen painted
		2009	9	0,14	0,14	Automation of the station

47094500	Fruholmen Fyr					No breaks
47095350	Banak	1984	7	−0,2	−0,14	Radiation screen removed. Instead MITEF with maximum and minimum temperature were installed
		2004	11	0,05	0,05	Automation of station
47096400	Slettnes Fyr					No break
47096800	Rustefjelbma	1968	8	−0,03	−0,03	Relocation of the radiation screen
47097251	Karasjok - Markannjarga	1988	6	0,38	0,08	New radiation screen (MI-46)
		2004	8	−0,3	−0,3	Relocation of the station from Karasjok, 97250 (1km SE) to Karasjok-Markannjarga, 97251 (active since 8/2004)
47097350	Cuovddatmohkki	1987	9	0,05	0,05	Radiation screen painted
47098400	Makkaur Fyr	2005	9	−0,15	−0,15	Automation of the station
47098550	Vardø Radio	2000	8	0,27	0,27	New radiation screen (MI-46)
47099370	Kirkenes Lufthavn	2004	11	0,17	0,17	Automation of the station

Swedish and Finnish stations

Analysed series		Year	Month	Break amplitude (°C)	Annual Adj factor (°C)	Reason for Break
46081540	Nordkoster A	1965	12	−0,5	−0,8	Relocation of the station 46081640. New station 46081540 began operation in 1967
		1984	3	−0,17	−0,3	
		1997	10	−0,13	−0,13	
46092100	Säffle	1968	12	−0,21	0,01	
		1988	12	0,22	0,22	
46092130	Blomskog A	1975	12	−0,2	−0,71	
		1995	7	−0,51	−0,51	Relocation of the station 46091130. New station 46081540 began operation in same year
46092410	Arvika A	1969	5	0,39	−0,57	
		1984	1	−0,63	−0,96	
		1995	5	−0,32	−0,32	Relocation of station: 46092400. New station46092410 active from 1995
46093220	Karlstad Flygplats	1984	11	−0,33	−0,68	
		1997	8	−0,34	−0,34	
46102540	Höljes	1967	7	0,35	0,57	
		1976	1	0,22	0,22	
46103080	Torsby	1970	5	0,31	0,31	
		2005	12			This break could not be adjusted in HOMER because of missing data
46103090	Gustavsfors	1977	12	−0,06	−0,28	

		1990	12	−0,22	−0,22	
46103410	Malung	1987	3	0,23	0,12	
		2005	1	−0,11	−0,11	
46112170	Grundforsen	1965	5	−0,37	−0,28	
		1997	12	−0,11	0,09	
		2002	12	0,2	0,2	
46113420	Särna A	1972	1	0,27	−0,18	
		1981	7	−0,55	−0,45	
		2002	12	0,1	0,1	Station relocation 2000
46114140	Älvdalen A	1991	12	0,11	−0,13	Relocation in 1995!
		2013	12	−0,24	−0,24	
46122330	Ljusnedal	1965	6	−0,26	−0,31	
		1977	12	−0,14	−0,05	
		1987	1	0,09	0,09	
46132170	Storlien-Storvallen A	2010	12	0,04	0,04	Relocation
46132590	Edevik	1980	3	0,34	0,41	Relocation
		2006	12	0,07	0,07	
46133050	Höglekardalen	1988	12	0,03	0,03	
46134590	Almdalen	1976	12	−0,02	−0,02	
46143440	Jormlien	1986	1	0,07	0,37	
		2006	12	0,08	0,3	
		2012	8	0,22	0,22	
46144300	Gäddede	1983	12	−0,08	−0,08	
46146050	Hoting A	1977	12	−0,5	−0,07	
		1986	1	0,13	0,57	
		1995	12	0,44	0,44	Relocation,
46155970	Hemavan Flygplats	1972	12	−0,12	0,07	
		1987	12	0,43	0,2	
		2009	12	−0,24	−0,24	Relocation
46166810	Jäckvik	1969	12	−0,04	0,45	
		1987	10	0,49	0,49	
46167980	Kvikkjokk-Årrenjarka	1965	10	−0,46	−0,5	
		1998	12	−0,05	−0,05	
46178970	Tarfala A	__	__			No break
46180940	Kiruna Flygplats	1999	2	0,3	0,58	
		2009	12	0,28	0,28	
46181900	Vittangi	1987	3	0,19	0,19	
46188800	Abisko	1969	12	0,06	0,06	
46188820	Katterjåkk	1966	6	−0,28	−0,17	Relocation 1969

		1998	12	0,11	0,11	
46191910	Naimakka A	1998	12	−0,02	−0,02	Relocation-1996
46192840	Karesuando A	1965	3	−0,26	−0,1	
		1987	6	0,39	0,16	
		2002	12	−0,23	−0,23	Relocation 2008
35801969	Muonio Alamuonio	1987	12	0,17	0,17	
35801994	Kittilä Pokka	1991	12	0,24	0,23	
		2003	12	−0,01	−0,01	
35802000	Sodankylä Lokka	1968	12	−0,01	−0,01	
35802001	Sodankylä Vuotso	1982	8	0,06	−0,01	
		2001	2	−0,08	−0,08	
35802033	Inari Ivalo lentoasema	1978	12	−0,15	0,13	
		2003	8	0,28	0,28	
35802035	Utsjoki Kevo	2003	12	0,04	0,04	
35802036	Utsjoki Nuorgam	1997	1	−0,11	−0,32	
		2008	12	−0,21	−0,21	

C: Pairwise, joint and ACMANT detected breaks

Network 1

	Probable breaks (Pairwise)					1st correction cycle		2nd correction cycle	
Name	Annual	DJF	JJA	MAM	SOND	Joint	acmant	Joint	acmant
DREVSJØ	__	1964/65, 1987	1973/74, 1980,1999	__	__	__	1986-C	__	1986-c
	1964	1965	__						
GARDERMOEN	1967, 1969, 1980, 1983, 1996	1963, 1987, 1996	1976, 1980,	1965, 1981/82, 1996	1967, 1980, 1996	1980, 1996	1976, 1980, 1996	1987	1963-c, 1976,1980, 1996
		1965'	2001'	__	__				
ÅRNES	1982/83, 2002, 2011	1963, 1965, 1968	1982/83, 2002, 2010-OL	1962, 1975, 1983, 2002	1973, 1996/97	__	1963	1987	1963
	__	__	2010	__	1972, 1978				
KONGSVINGER	2002, 2004	2011	1973, 1978,	1983, 1989/90, 2004	2004	2004	1989, 2004	1987-c	1969, 1989, 2004

			1983, 1989, 2004						
	__	1963	__	__	__				
FLISA II	1981/1982, 1997/1998	1997	1973/74, 1998	1991, 1996, 1998,	1996,1998, 2004	1997-c	1969-c, 1998	1987-c	1969-c, 1998
	1963	1963	__	__	__				
RENA FLYPLASS	1982/83, 2011	1974, 2011	1983/1984, 2001/02	2011	1988/89, 1996, 2011	1982, 2011	1987, 2006-c	1987	1987, 2006-c
	1963'	__	2002	__	__				
RØROS LUFTHAVN	2002	__	__	2003	__	__	__	__	__
	__	__	__	1971	__				
ØSTRE TOTEN - APELSVOLL	1970, 1996, 2004	1965,1968, 1996	2012,	1996	1996/97	1996	1996	1965, 1987, 1991-c, 1993-c	1996
	1965, 1991/93-ol	1965, 1992/93-ol	__	__	1992/93-ol				
KISE PA HEDMARK	1980	1965	1974, 1977	1972, 1975	1998	1980	__	1987-c	1980
	__	__	__	__	__				
LILLEHAMMER - SÆTHERENGEN	1980	__	1968, 1980, 1984, 2004	1983	1972, 1980, 1997	1980	1980	1987-c	1980
	__	1964/65	__	__	__				
SKÅBU	1996/97	__	__	__	__	1987 , 1997	1997	__	1997
	__	__	__	1986	__				
BRÅTÅ - SLETTOM	1993	__	1996	1998	_	1993	1992-c	1987-c, 1998-c	1992-c
	__	__	1998'	__	__				
DOMBÅS - NORDIGARD	1964/65	1965/66, 1987	__	__	__	__	1972	__	1972
	__	__	__	__	__				
FOKSTUGU	1967, 2008	1968, 1987	__	__	1967	1967, 2003(C), 2008	1967, 1996, 2009-c	1987-c	1967, 1996, 2009-c
	__	__	__	__	__				
RYGGE	1971, 1984, 1988, 1994/95	1968/69, 1984,1987, 1995	1983/84, 1988/89, 1994, 2002	1983/84	1967, 1971, 1984, 1990,1993/94	1994	1967, 1984, 1988, 1994	1987-c	1968, 1971, 1984, 1988, 1994
	__	1963/64-ol	__	__	__				
ÅS	1965, 1968/69, 1984, 1987	1968	1973/74, 1984, 1997	1962, 1969,1987	1984, 1996,	__	1965	1987	1967-c
	__	__	__	__	__				(remove 1965)
OSLO - BLINDERN	1980/81, 1987, 1995	1968, 1970, 1987	1975, 1977, 1980, 1995	1995/96	1967, 1973, 1997	__	1999-c	__	1999-c

	1962'		1975', 1977',	1962'	1967,				
TRYVANNSHØGDA	1987/88	__	__	__	1984	__	__	__	1965
	__	__	__	__	__				
ASKER	1995/96	1986/87	1983, 1996,, 2004	1977, 1979	1982, 1984, 1993, 1996	__	__	1987-c	1994-c
	__	__	__	__	1982'				
VEST-TORPA II	1970, 1976, 1981, 1988	1968, 1982, 1987	1966, 1970, 1976, 1991	1976/77, 1981, 1987	1978	1970	1970	1987	1976
	__	1965'	__	__	__				
ÅBJØRSBRÅTEN	1996, 2002	2016	1994	1994	__	__	1992-c	__	1992-c
	__	1964'	__	__	__				
LØKEN I VOLBU	1965, 1984,2006, 2010	1965, 1987	1983, 2012	__	1985	__	__	__	__
	__	1965'	__	__	__				
NESBYEN - TODOKK	1970, 2000, 2002	1966	1974	2003-OL	2002	1981 (C), 2002	1970	1987-c, 2013	1970
	__	__	__	2003-ol	__				
		1987	**1998**	**1974/75, 2003**					
GEILO - OLDEBRÅTEN	__	1966	__	__	__	1965	1965, 1996	__	1965, 2007-c
	__	__	1988' 2006'	__	__				
MELSOM	1968, 1985, 1993	1968, 1970, 1994	1973, 1994	1994	1968, 1985, 1993	__	__	1987-c	__
	__	1963'	__	1963	__				
		1970-nope	**1973-nope**		**1985-nope**				
FÆRDER FYR	__	1968	1991	__	1968, 1973, 1992	__	__	1987	1996-c
	__	1970', 1995'	__	__	2011'				
KONGSBERG BRANNSTASJON	1965, 1980	1963	1966, 1976, 1995/96	1962, 1965	1998, 2001	__	__	1987	__
	__	1963'	__	1963'	__				
DAGALI LUFTHAVN	1987, 2001	1988, 2002	__	__	1982, 1986	1987-c, 2001	1988, 2002-c	__	1988, 2002-c
	__	__	__	__	__				
MØSSTRAND II	__	__	1987	1975, 1986,1997	1974/75	__	__	1987-c	__
	__	__	__	__	__				
			2013/14	**1973-75-OL**					

GVARV - NES	1968, 1973, 1975, 1988/1989	1968, 1989, 1991	1982, 1989	1962-OL, 1975	1987, 1992, 2002	1988	1964-c, 1989	1987-c	1964-c, 1989
	__	__	__	1963	__				
			1966/67						
JOMFRULAND	1988, 1990	1970,1988, 1993	1974, 1987, 1992	__	1978, 1993, 2002	__	1975	1987-c	1975
	1962'	__	1996'	1962	1997'				
					171,6				
LYNGØR FYR	1962, 1970/71, 1995/96	1968	1987/88	1962	1992	__	__	1987-c	1996
	__	__	__	1962	1983', 2003'				
			1995/96?						
TORUNGEN FYR	1984	1970, 1987	1987, 1996	__	__	__	1996	__	1996
	__	1987'	__	__	__				
		1968		**1962**	**1962**				
NELAUG	1966, 1989	1966	1966, 1982, 1986	1966, 1986	1966, 1976	1966	1966, 1988-c	1987-c	1966, 1988-c
	__	__	__	__	__				
TVEITSUND	__	1987	1986	__	2002	__	__	1987-c, 2007-c	1967-c, 2007-c
	__	__	__	__	__				
LANDVIK	1986, 2013	1968/69, 1987	1986, 1996	1962	1986	__	1986	1987-c	1986
	2013'	__	1975'	1962'	__				
				1975					
KJEVIK	_	__	1983, 1986	1986/87	1977	__	1981-c, 1994-c	1987	1982, 1994-c
	__	__	__	1962'	__				
OKSØY FYR	1988	1970, 1987	1976, 1986, 2017	1962	__	__	1987-c, 2016	1987-c	1988, 2016
	__	1987'	1979'	1962'	__				

BYGLANDSFJORD - NESET	1988	1968, 1987	1974	1975, 2010	1992, 2009	__	1967-C, 2008-C	1987-c	1968, 2010-c
	__	__	__	2010'	2009				
LAUDAL - KLEIVEN	1987/88	1987, 2014	1984, 1986, 2017?	__	1995/96, 2015?	1988	1988, 2015-c	1987-c	1994-c, 2015-c
	__	1988'	1984	__	__				
LINDESNES FYR	1968	1970	1979	__	__	1968, 1978	1979-c	1987	1987
	__	1987	1996'	__	__				
LISTA FYR	__	1970, 1987	1996, 2017	__	__	__	1996	1970, 1987-c	1996
	__	1970	__	__					
					__				
OBRESTAD FYR	__	__	2017	__	__	__	__	1987	__
	1967	1987	2017		__				
SOLA	__	__	1967, 1978	__	1990/91	__	1978	1987-c	1968, 1978
	2016/17-ol	__	__	__	1991'				

FISTER - SIGMUNDSTAD	1990	__	__	__	2000, 2005	__	__	1987-c	1988
	2006'	__	__	__	1999-ol, 2006				
SAUDA	__	2016	2015	__	2015-ol	2015	1998, 2015	1987-c	1998, 2015
	1964,	__	__	__	__				
		No brk 2016	**1994**		**No brk 2015**				
VATS I VINDAFJORD	2011	__	__	1991	1995, 2010	__	1977-c, 1988-c, 2011	1987	1977, 1988-c, 2011
	1987', 1991/92	__	1991'	1989, 1991	__				
					1989				
UTSIRA FYR	__	__	__	1987	__	__	__	1987	1988-c
	1987'	__	__	1987	__				
SLÅTTERØY FYR	1998'	__	__	1987	__	1987	__	1987	1987
	__	__	__	1975', 1987'	__				
KVAMSKOGEN - JONSHØGDI	2007	1970	__	__	2005/06	__	2005-c	1987-c	2005-c
	__	__	__	__	__				
		1998							
FLESLAND	1979, 1991	__	1979	1979	__	__	1979, 1991	1987-c	1979, 1991-c
	__	__	__	1975', 1987'	__				
BERGEN - FLORIDA	1986/87	1982, 1987	__	1986/87	2001	__	1982, 2005	1987	1982, 2005-c
	__	__	__	__	_-				
VOSSEVANGEN	2010	1970, 1987?	2002	__	__	1987	2009-c	1970-c,1975-c,1987,	2009-c

	1966'	__	__	__	__			2009-c,2010	
MODALEN III	2010	1986/87	1990/91, 2008/09	1970, 2008	__	1987	2007-c	1987	1986-c, 2007-c
	__	__	__	__	__				
TAKLE	1970	__	__	1969/70	2000/01	__	1970	1987	1987
	2006'	__	2017'	1976', 1987'	__				
VANGSNES	__	__	__	__	__				
LÆRDAL IV	__	__	__	__	__	1987	__	1987	1988
	__	__	2011'	__	__				
FJÆRLAND - BREMUSEET	2004	__	2004	2004	1986, 2004	1986	2004	1987	2004
	__	__	__	__	__				
FØRDE - TEFRE	1991	1985	1965	1991	1989, 1991	1991	1965, 1984-c, 1991	1987-c	1965, 1984-c, 1991
	__	__	__	_-	__				
	1986								
YTTERØYANE FYR	1999	__	1967	1976	2001	1967, 1987, 1999	1968, 1983-c	1987-c	1975-c
	__	__	__	1976	__				
SANDANE	1981	__	__	1963	__	__	__	1987-c	__
	1965'	__	__	__	__				
FISKÅBYGD	__	__	2001	2003/04	2001	__	1992-c	__	1992-c
	2004	__	2003	2003	2007				
ØRSTA-VOLDA LUFTHAMN	1995, 2010-ol	__	1976	__	__	__	1995	1965	1965, 1995
	2009-ol	2009-ol	1976	1970	2010				
	no ol in 2010								
SVINØY FYR	__	__	__	__	2002	1998	2002-c	__	2002-c
	2004'	__	__	__	2002'				
TAFJORD	__	__	__	__	__	1998-c	__	__	1972-c
	__	__	1969'	__	__				

VIGRA	__	__	__	__	__	1996-c	1984, 1990-c	1997-c	1975-c, 1984, 1990-c, 2002-c
	2001'	__	1996'	__	__				
ONA II	__	__	__	__	__	__	1988	__	__
	1970', 2009-ol	__	__	__	2012'				
SULA	1975	__	1976, 1988?	__	__	__	1973-c	__	1973-c, 1987-c
	__	__	__	__	1989'				
BERKÅK - TERMINALVEIEN	1979	1987	1983	1978	1978/79	__	1964-c, 1979, 1987	1987	1964-c, 1979, 2005-c
	__	__	2011	__	__				
SELBU II	1975, 1988	1970, 1976, 1979, 2008	2006	2008/09	1975	__	1980, 2004-c	1987-c	1980, 2004
	__	__	__	__	__				
VÆRNES	1977, 1994	1987/88	__	1977, 2000	1977, 1992	1977	1977, 1994	1987-c	1977, 1994
	__	__	__	2000-ol	__				
MERÅKER - VARDETUN	__	1968, 1987	__	1993	__	__	1965, 2005	1987	1968
	__	__	__	__	__				
SNÅSA - KJEVLIA	__	__	__	__	1979	__	__	1987-c	1979, 1981-c
	__	__	__	__	__				
ØRLAND III	2000	__	2001	__	1990	2001	1990-c,2001,2004-c	__	1990-c, 2001
	1990, 1998'	1987'	__	1989	1982, 1990				
BUHOLMRÅSA FYR	__	__	__	__	__	__	__	__	1975-c
	__	1970	__	__	__				
NORDLI - HOLAND	1994	1984, 1987-ol	1966, 1984	2001	1994	1986, 2000	1983-c	1987-c	1986-c, 1999-c
	__	1978'	1966, 1984	__	1967'				
NORDØYAN_FYR	__	__	__	__	__	__	2009	1987-c	2009
	__	__	__	__	__				

Network 2

	Probable breaks					1st cycle		2nd Cycle	
Name	**Year**	**DJF**	**JJA**	**MAM**	**SOND**	**Joint-Detection**	**Acmant-detection**	**Joint detection**	**Acmant-detection**
SOLVÆR III	__	__	__	__	__	__	__	1988	
	__	__	1980'	__	__		__		
MYKEN	__	__	__	1969	1985/87	__	__	1988	
	__	__	__	__	__		1966		

GLOMFJORD	2001/02	1987?,	__	1973	2001, 2006	__	2006	1988	
	__	__	__	__	__		2009		
BODØ VI	1991?	__	__	__	__	1991	__	1988-C	
							__		
NARVIK LUFTHAVN	1975/76, 2001, 2012	__	2013	1974/75, 2002,2012	2000/01, 2004/05	__	1976, 2001, 2013	1988-c	
	__	__	__	__	__				
SKROVA FYR	2007/08	__	2001	__	2011/12	2007	1986-C, 2007	1988	
	__	__	__	__	__				
RØST LUFTHAVN	2014 OL	1987/88, 2002	1969, 1980, 2013	2014-OL	__	1988	2008, 2016	1988-C	
	__	__	1980	__	__		1968, 2013, 2016		
SORTLAND	1983/84,	__	1980, 1983/84	__	__	1988	1976, 1978-C, 1984	__	
	__	__	1980, 2001	__	__			1988-c	
BØ I VESTERÅLEN III	2000/2001	2001	2001	__	1999/2000	2000-C	2000	1988-C	
	__	__	__	__	__				
ANDØYA	1971,	2001/02	__	__	1970/71	1988	__	1988	
	__	__	__	__	__		1988		
HEKKINGEN FYR	1966, 1980,2001/02	1967, 1979	2017	1967/68	1966, 1978	1966, 1988-C	1966, 1978, 1988, 2013-C	__	
	__	__	2017	__	__			1967, 1988	
BARDUFOSS	1989/90, 2011/12	1988, 2011/12, 2017	1998	1990,	1990	1988, 2011	1988, 2011	1975	
	__	__	__	__	__			1975, 1988, 2011	
DIVIDALEN II	1987/88, 2008	2007/08, 2011	2008	1974, 1998, 2008	2008	1989, 2008	1970-C, 1988, 2008	__	
	__	__	__	1971,1974	__		1971, 1988,2008	1988	

TROMSØ	2002	__	__	2001/02	1977/78	1988-C, 2002	1988-C, 2002	__	
	1988	__	1988'	__	__			1988	
TROMSØ - LANGNES	1978, 1984	1984	__	1984	__	1978, 1988-C	1972-c, 1978	1988	
TORSVÅG FYR	__	__	__	__	__	__	__	1988-C	
SKIBOTN II	1999	1988, 2004/05	2000	2005	1998	__	1999	__	
	1971', 2007	1971'	__	1971, 2006/2007	__				
SØRKJOSEN LUFTHAVN	1993, 2004, 2011	1988, 1993, 2005	__	2004, 2011	1991, 2004	1993, 2004	1990-C, 2005	__	
	2011	__	2010	1971, 2011	__				
NORDSTRAUM I KVÆNANGEN	__	__	2004/05	__	__	__	1988-C	1988	
	__	1987'	2004/05	2006/07	__				
ALTA LUFTHAVN	1971, 2004, 2010	2003/04	__	1975/76	__	__	__	__	
	1971, 2004, 2010	1971, 2003/04	__	1975/76	__				
SUOLOVUOPMI - LULIT	2002	2003	2002	1981, 1994/95, 2004/05	2004	2002	2002		
	2002	2003	2003	1981, 1994/95, 2005	2004				
KAUTOKEINO	__	1995	__	1970/71, 1975	__	__	2001-C, 2003	1988	
	1988'	1995	__	1970/71, 1974, 1988	__				
SIHCCAJAVRI	1998/99	2003/04	1996/97, 2003/04	1994, 2005	2008	__	2008	__	
	1998/99	2004	1996/97, 2003/04	1994, 2005	2008				
FRUHOLMEN FYR	__	__	__	__	__	__	2012-C	__	

	__	__	__	2001'	__			1988	
BANAK	1985	__	1984/ 85	2008- OL	__	__	1963-C, 1979, 1988-C	__	
	2008		1979/ 80	2008	__				
		2004/5?							
SLETTNES FYR	1986'	__	__	__	__	__	1977-C, 1988, 2001-C, 2003	__	
	2004'	2004'	__	__	__				
RUSTEFJELBMA	__	1965	__	__	__	__	__	1988-C	
	__	1965, 1968'	__	2009'	__				
KARASJOK - MARKANNJARGA	1988	1962, 1989	2004	1971, 1988, 2004	__	1988	__	__	
	1988	1962, 1989	2004	1971, 1988, 2004	__				
CUOVDDATMOHKKI	__	1988	__	__	__	__	__	__	
	2002'	1975', 1988, 2003'	__	__	2002'				
MAKKAUR FYR	2008	__	__	__	__	_-	__	__	
	2007	__	__	__	__				
VARDØ RADIO	__	__	__	__	__	2000	1975, 1988-C	1988	
	1999'	__	__	__	__			1988, 1997	
KIRKENES LUFTHAVN	__	__	__	2007/0 8	__	__	__	__	
	__	__	__	2007/0 8	__				