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HOMERUN: Relative Homogenisation of the Irish Precipitation Network

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EPA RESEARCH PROGRAMME 2014–2020

HOMERUN: Relative Homogenisation of the Irish Precipitation Network

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EPA Research Report

Prepared for the Environmental Protection Agency

by

Irish Climate Analysis and Research Units

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DISCLAIMER

The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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The Project in Context

Long instrumental records are rarely, if ever, homogeneous and most decade-to-century-scale time series of atmospheric data have been affected by changes caused by climatic and/or non-climatic factors. Nevertheless, accurate climate data are a prerequisite for basing climate-related decision-making on, and quality-controlled homogenised climate data are becoming integral to efforts across many countries to deliver climate services. The aim of homogenisation techniques (i.e. procedures combining detection and correction) is the removal or reduction of any spurious non-climatic signal introducing inhomogeneities to the time series being investigated. Climate change research has also further spurred research and operational work on the homogeneity of climate data based on an increased requirement for good-quality climate data for climate model evaluation.

Homogeneity tests can be broadly divided into “absolute” and “relative” methods. The former are applied to individual candidate stations to identify statistically significant shifts in the section means (referred to as breaks or change points), while relative methods entail comparison of correlated neighbouring stations with a candidate station to test for homogeneity. Relative homogenisation is more robust than absolute methods, provided station records are sufficiently correlated, and, as with homogeneity techniques more generally, benefits from reliable metadata and station histories to account for breaks and potential outliers. Ireland and Northern Ireland have a good repository of monthly precipitation data, although record lengths vary and the extent of the contiguous intact section of the record tends to influence the station data selected for the application of HOMER (Homogenisation Software in R) in particular.

Results Summary

Relative homogenisation of the extended network

A homogenisation analysis is provided for 299 of the available precipitation records for the island of Ireland (Irish Network or IENet) using state-of-the-art relative homogenisation methods. The HOMER and ACMANT (Adapted Caussinus–Mestre Algorithm) programs are applied to a network of station series where contiguous intact monthly records range from ~31 to ~70 years (1941–2010). HOMER detected 58 breaks in total in the country-wide series analysis distributed across 43 stations (~14%) of the 70-year series records analysed. By comparison, ACMANT detected a considerably higher number of breaks across the network, 382 distributed across 164 (~55%) of the records analysed. These do not count breaks with an amplitude of less than approximately ±5% for both HOMER and ACMANT, as these were considered to be within the margins of error for the detection limits of the methods.

The results with HOMER indicate a relatively low proportion of series with detected breaks (~14%), a situation generally reflected in observed later 20th-century precipitation records across Europe. However, the geographical distances between base and reference series for the HOMER-identified sub-networks are low (mean ~19 km) and the spatial correlations obtained between series by ACMANT for the series are high (mean > approximately 0.8 km). Consequently, both HOMER and ACMANT are detecting breaks of relatively small magnitude; therefore, the relatively high detection frequencies may be only an artefact of the network density and the climatic characteristics of the region.

Key results

Based on the considerable number of network experiments leading to the version of IENet reported on here and on the evaluation of the two relative homogenisation methods applied to monthly precipitation data, the following are some of the key results:

- HOMER has a lower tolerance of missing values than ACMANT.
- ACMANT is better suited to the automation and rapid processing of larger networks, but it offers

no scope for metadata integration or for graphical interpretation by the user.

- By comparison, HOMER offers metadata integration and excellent graphical support for the user, but it is better suited to small to medium networks and interactive use in the current state of development.
- Break detection and assignation for precipitation series in ACMANT appears to be more sensitive to seasonal wet/dry month sequences than in HOMER.

Specific Recommendations

If the ultimate goal of homogeneity research is considered to be establishing data products that can be regularly updated and used operationally, part of the process of improving these products involves comparing different homogeneity methods and evaluating their advantages and disadvantages. Based on the results of this project, the recommendations provided here will help advance this goal for Ireland while maintaining and extending the capacity developed:

1. The modern relative homogenisation programs applied to Irish precipitation data in this work have had limited application to observed precipitation data and few or no results applying the methods to precipitation data have been published to date. Features of Ireland's maritime climate and the relatively dense network of high-value quality-controlled data available lend themselves to the ongoing test development of relative homogenisation programs such as HOMER and ACMANT. It is therefore suggested that the work applying relative homogenisation methods to the excellent test resource that Irish data provide should continue. This offers the win–win prospect of method development gains for the wider homogenisation community and a spin-off for Ireland via the provision of high-quality datasets for improved climate-based decision-making and climate model evaluation.

2. Such ongoing work should proceed synchronously with expanded data rescue activities to provide the community and decision-makers with more homogenised long series on which to base climate change adaptation decisions. HOMER's worth in this regard has already been proven by helping to provide a valuable 1850–2010 reference precipitation series for the island of Ireland.

3. Overall, and based on a first comprehensive application to observed precipitation data, there is considerable scope to refine and develop both methods for application to monthly precipitation data. For example, ACMANT's apparent sensitivity to seasonal wet/dry month sequences in the present state of development could be further explored. Similarly, HOMER's sensitivity to sequences of missing data values may be improved with ongoing testing and development.

4. A consequence of this, e.g. in the current state of HOMER's development, is that the user has to proceed with caution in relation to missing values for the evaluation of networks based on considerable insights into the data. Resolving HOMER's lower tolerance of missing data than ACMANT is realistically likely to be a development and code refinement issue for the wider homogenisation community. However, Bayesian refinements to the detection algorithm component of HOMER currently under way at Météo-France (O. Mestre, Météo-France, September 2016, personal communication) offer the prospect that a revised version of HOMER could be usefully piloted and tested on some of our Irish networks. This also offers the prospect that, by working with HOMER's main developers, a more operationally useful version of HOMER could be developed.

5. The performance of HOMER, and to a lesser extent of ACMANT, depends on the parameter settings and the nature of the inhomogeneities, but, as things stand, both methods still require the judgement and insight of experienced practitioners. Therefore, tackling these current aspects of both methods by increasing automation but retaining accuracy would further help the goal of homogenisation research more generally by providing improved products that could be more easily used operationally.

1 Introduction

Climate change studies based only on raw long-term data are potentially flawed as a result of the many breaks introduced from non-climatic sources; consequently, quality-controlled and homogenised climate data are desirable for basing climate-related decision-making on. Fundamentally, the quality of long-term climate analysis depends on the homogeneity of the underlying time series (Vertačnik *et al*., 2015). This also reflects a growing demand for climate information or climate services more generally (e.g. Buontempoa *et al*., 2014; Vaughan and Dessai, 2014), sometimes expressed as "actionable knowledge" (Asrar *et al*., 2013; Kirchoff *et al*., 2013), for use across a range of decision-making environments. Seasonal cycles of precipitation in Ireland are projected to become more marked as the climate changes (e.g. Nolan *et al*., 2013), and regional extremes in summer dry spells and winter precipitation have been recorded in recent years. Therefore, to analyse and monitor the evolution of precipitation patterns across Ireland, quality-controlled and homogeneous climate series are needed.

A homogeneous climate time series is defined as one in which variability is caused only by changes in weather or climate (Freitas *et al*., 2013). Most decade- to century-scale time series of atmospheric data have been adversely impacted by inhomogeneity caused by, for example, changes in instrumentation or observer practices or station moves or changes in the local environment (e.g. urbanisation). Some of these factors can cause abrupt shifts, while others cause gradual changes over time; these can hamper identification of genuine climatic variations or lead to erroneous interpretations (Peterson *et al*., 1998). Since these shifts are often of the same magnitude as the climate signal (Auer *et al*., 2007; Menne *et al*., 2009), a direct analysis of the original data series can lead to incorrect conclusions about the evolution of climate.

Homogeneity tests can be broadly divided into "absolute" and "relative" methods. The former are applied to individual candidate stations to identify statistically significant shifts in the section means (referred to as breaks or change points), while the latter entail comparison of correlated neighbouring stations with a candidate station to test for homogeneity. Thus, relative homogenisation algorithms use the difference time series of a candidate station with neighbouring stations to identify such breaks. Reference series, which have ideally experienced all of the broad climatic influences of the candidate but no artificial biases, are commonly used to detect inhomogeneity in relative methods (WMO, 2011) as well as to assess the quality of the homogenisation process (Kuglitsch *et al*., 2009). Reference series themselves do not need to be homogeneous (Szentimrey, 1999; Zhang *et al*., 2001; Caussinus and Mestre, 2004), but they must encompass the same climatic signal as the candidate (Della-Marta and Wanner, 2006). Relative homogenisation is more robust than absolute methods, provided station records are sufficiently correlated (Venema *et al*., 2012). However, relative approaches can be confounded by a lack of long records at neighbouring stations for comparison and by simultaneous changes in measuring techniques across a network (Peterson *et al*., 1998; Wijngaard *et al*., 2003). Relative homogenisation algorithms use the difference time series of a candidate station with neighbouring stations to identify breaks.

Homogeneity approaches benefit from reliable metadata and station histories to account for breaks and potential outliers. Metadata can provide information such as location of station instruments, when and how observations were recorded, notes on instrument changes and malfunctions or any environmental changes (such as vegetation encroachment at the site; Aguilar *et al*., 2003). This information is often useful in interpreting statistical homogeneity tests and for informing the nature and magnitude of adjustments that might be applied to data.

New techniques are emerging for the detection and adjustment of inhomogeneity in climate series (Cao and Yan, 2012; Toreti *et al*., 2012; Freitas *et al*., 2013; Mestre *et al*., 2013) and the correction of multiple change points using reference series (Peterson *et al*., 1998; Menne and Williams, 2005; Toreti *et al*., 2012). Modern multiple breakpoint methods search for the optimum segmentation characterised by minimum internal variance within the segments and maximum external variance between the segment means (Caussinus and Mestre, 2004; Lindau and Venema, 2015). A comprehensive assessment of homogenisation techniques for climate series was included in the scientific programme of the COST Action HOME ES 0601 (Advances in Homogenisation Methods of Climate Series: An Integrated Approach). The HOME objective was to test the existing statistical homogenisation techniques and develop a standardised method for homogenising climate datasets. This led to the release of two modern, multiple breakpoint homogenisation packages: (1) HOMER (Homogenisation Software in R), for the homogenisation of monthly temperature and precipitation, and which can consider metadata (HOME, 2013; Mestre *et al*., 2013); and (2) ACMANT (Adapted Caussinus–Mestre Algorithm), which is fully automatic and homogenises temperature and precipitation data on either a monthly or a daily scale (Domonkos, 2011a, 2015a; Domonkos and Coll, 2016). The high performance of HOMER and ACMANT is based on their mathematical background. Note that HOME found three more statistical methods that are also effective (MASH, Szentimrey, 1999; USHCN, Menne *et al*., 2009; and the Craddock test, Craddock, 1979) and recommended their use alongside HOMER and ACMANT (Venema *et al.*, 2012).

In this study we will use both HOMER and ACMANT to make comparisons between the homogenisation results for a medium-sized station network. As far as we are aware, this is a first such application of both methods to a sizeable network of precipitation stations.

2 Methodology

2.1 Study Area

The study area is the whole island of Ireland, which covers ~84,421 km^2 on the Atlantic margin of north-west Europe, between ~51° and 56° N. Elevations reach up to 1038 m above sea level (a.s.l.) (Corrán Tuathail, Co. Kerry). Much of the island is lowland, partly surrounded by mountains, with a characteristic temperate oceanic climate. On average, annual precipitation ranges from 750 to 1000 mm in the drier eastern half of the country and > 3000 mm yr^{-1} in parts of the western mountains (Rohan, 1986).

2.2 Dataset and Quality Control

Associated with Ireland's maritime location and the prevailing wind direction, the bulk of precipitation receipts come primarily from the Atlantic south-west quadrant and to a lesser extent from the north-west quadrant, whereas cold and dry weather comes from the east and continental Europe. Rainfall has been measured in Ireland since the early 19th century, with a peak of over 800 rainfall stations in the late 1950s, and currently rainfall is recorded at synoptic and climatological weather stations. In addition, there is a wide network of voluntary rainfall observers (Walsh, 2012). The selected stations for this work are distributed across the country (Figure 2.1). Based on an audit and set of quality control procedures, the contiguous intact monthly records for this group of 299 stations ranged from ~31 to 70 years for the period 1941–2010. Station elevations were within the range of 5–701 m a.s.l., with a mean elevation of ~110 m.

Following initial quality control on the data, an exploratory statistical analysis of the data was also undertaken to characterise the properties of the series as well as to identify missing values and outliers. Figure A1.1 provides a HOMER-derived summary of the extent of the intact months and missing records across all the stations in the network and illustrates that most missing data are associated with the pre-1950s and post mid-1980s. Issues with missing data in climate time series can be tackled with temporal interpolation using data from the same series before and after the gap, or with spatial interpolation using data from nearby stations (WMO, 2011). Recent work on establishing new 1981–2010 long-term averages for Ireland involved the implementation of comprehensive quality control procedures on all Met Éireann's digital temperature and rainfall data (Walsh, 2013). The extension of this work involved backfilling the available precipitation records to 1941 using three methodologies: weighted ratios of nearby stations, weighted spatial regression and spatial interpolation of monthly data from nearby stations (Walsh, 2012). However, in the homogenisation here, we use only the raw datasets with missing values retained, since both programs have inbuilt functionality to cope with missing values.

The UK Meteorological Office (UKMO) also supplied all available monthly precipitation data records data for Northern Ireland (NI) for the period 1941–2010. For the analysis here we latterly included 12 NI station series selected on the basis that they had the lowest number of missing values and somewhat improved the spatial coherence of the Irish Network (IENet). In total, UKMO supplied 207 monthly series for NI but, based on experience with previous networks and HOMER's low tolerance of missing values, and following an audit, other candidate series were excluded to avoid any complications. Despite these exclusions, with a mean density of ~0.03 stations per km^2, the IENet coverage is considerably more dense than that of HOMER network experiments so far reported elsewhere (Vertačnik *et al*., 2015; Gubler *et al*., 2017).

2.3 Data Homogenisation Process

Both HOMER and ACMANT include the optimal step function fitting (optimal segmentation; Caussinus and Mestre, 2004) with dynamic programming (Hawkins, 1972, 2001) for break detection and the network-wide minimisation of residual variance for correcting inhomogeneities [analysis of variance (ANOVA); Caussinus and Mestre, 2004; Mamara *et al*., 2014; Domonkos, 2015a]. These techniques are known to be the most effective statistical tools in the homogenisation of climatic time series with multiple breaks (Domonkos, 2011b, 2013; Caussinus and

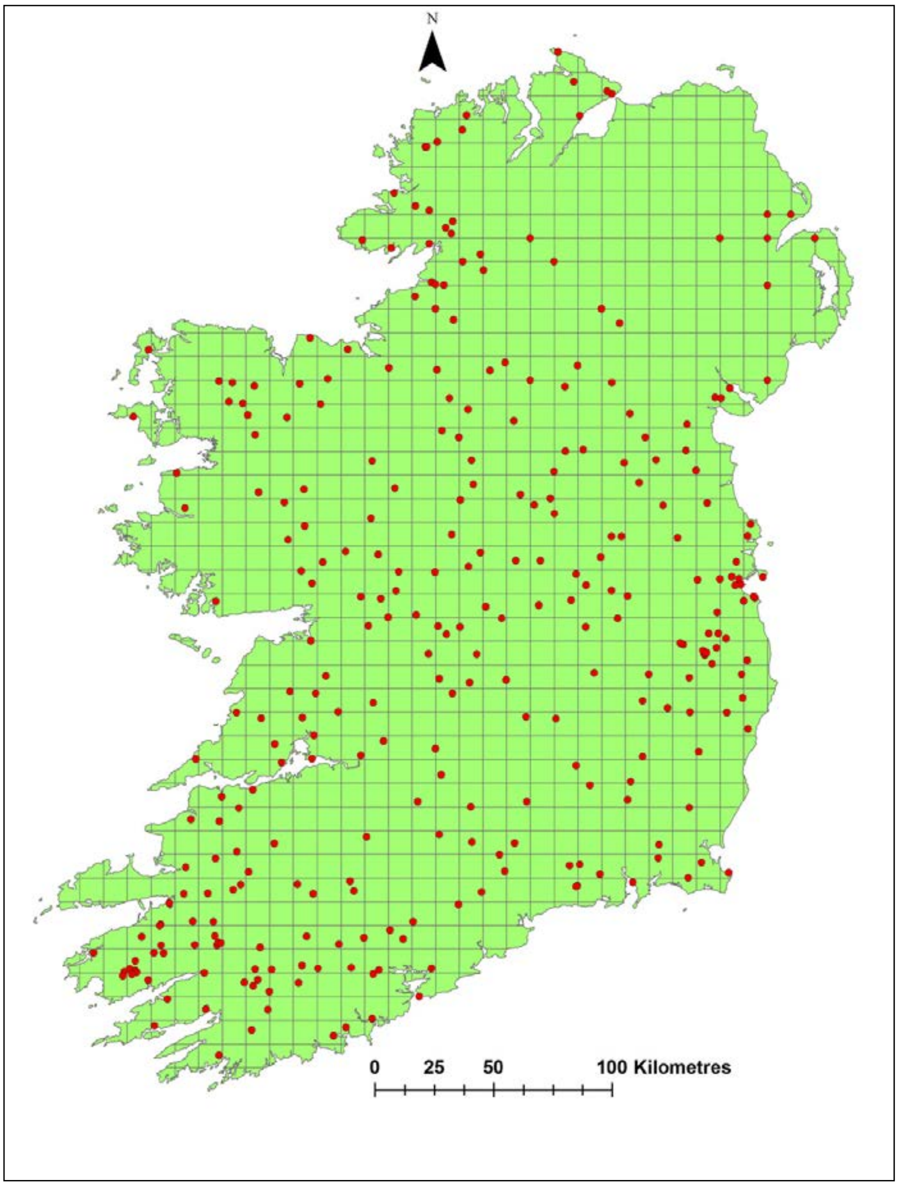

Figure 2.1. Annotated map of the island of Ireland showing the selected Met Éireann and UKMO monthly station locations for the network of 299 stations (IENet). Precipitation stations that have been homogenised by both HOMER and ACMANT are denoted by red circles. Station locations are overlain on a regular 10 × 10 km grid to give an indication of density.

Mestre, 2004; Domonkos *et al*., 2011). Both HOMER and ACMANT use some derivatives of the Caussinus–Lyazrhi criterion (Caussinus and Lyazrhi, 1997) for calculating the number of homogeneous segments. This criterion is based on information theory and the penal term included in it impedes the inclusion of insignificant breaks.

In spite of the similarities, some important differences exist between HOMER and ACMANT. Perhaps the most important difference is that while ACMANT uses composite reference series (Peterson and Easterling, 1994; Alexandersson and Moberg, 1997) for the time series comparison, HOMER applies pairwise comparison (Menne *et al*., 2009; Dunne *et al*., 2014), allowing detailed analysis of individual breaks and user intervention when it is beneficial. HOMER is best suited for small to medium-sized networks, as well as for homogenisation with the use of metadata, while ACMANT is a more useful tool for the automatic homogenisation of large networks.

2.3.1 Homogenisation with HOMER

The HOMER package was a key deliverable of the COST Action HOME and represents a synthesis of homogenisation approaches (Mestre *et al.*, 2013), including some homogenisation routines of PRODIGE (Caussinus and Mestre, 2004), ACMANT (Domonkos, 2011a) and the network-wide joint segmentation method of Picard *et al.* (2011), as well as some common quality control and visualisation routines of the CLIMATOL homogenisation method (Guijarro, 2011). HOMER is an interactive, semi-automatic method for homogenisation, whereby the user can take advantage of available metadata in the detection and correction of time series (Vertačnik *et al.*, 2015). We deploy HOMER to detect and correct inhomogeneity in the 299 IENet monthly series and to extend all records to a common period (1941–2010).

In the pairwise comparison, reference series are treated as sections of the time series between two change points. Reference series are compared with all others from the same climate region to produce series of differences between the candidate and others in a defined network. Difference series are then tested for change points (Mamara *et al.*, 2014). Once detected breaks have been checked against metadata, non-homogeneous series are corrected using the ANOVA model.

Creation of a reference network for a given candidate station is a key step in the homogenisation process. The network can be defined based on geographical proximity or station correlation. To ensure that candidate stations have sufficient reference stations for each year of the series, it is necessary to set the minimum number of reference stations (Vertačnik *et al.*, 2015). Rather than use first difference (increment) correlation options for our wider IENet network of 299 stations, for the analysis reported here we chose to use the geographical distance selection in HOMER. This selection of 15 neighbours for each base series facilitated the homogenisation and extension of all series to a common period, 1941–2010, while avoiding a known limitation of the software to correct when there are many blocks of missing contiguous data distributed across candidate and/or reference series (Coll *et al.*, 2015a). In addition, and as far as we are aware, IENet is a novel application of HOMER to such a sizeable precipitation station network, and for some series high numbers of default –999.9 entries may be creating spurious correlations in some of the sub-networks identified by HOMER.

We adopted a three-stage application of HOMER to allow greater scrutiny of detected inhomogeneity before corrections were applied. First, basic quality control and a network analysis were performed. Outliers were identified using both HOMER and visual inspection by defining minimum and maximum monthly outliers as values exceeding ±1.96 standard deviations from the respective series mean. Outliers were checked against a number of the nearest reference stations, as well as metadata, and any likely cases were removed. Second, HOMER was run to identify breaks within each time series. Detected breaks were not corrected automatically; all were checked for consistency with correlated reference stations and by scrutiny of metadata. Third, following confirmation of breaks with available metadata, HOMER was used to correct series for inhomogeneity and missing values (Figure 2.2). Following the recommendations of HOME (2013), we applied annual corrections in PRODIGE with multiplicative corrections applied using the amplitude of detected breaks. Hence, for an amplitude of say +0.15, data before the detected break were multiplied by 1.15 (increase in mean of 15%). As a final step, HOMER is used to infill missing data for all series back to 1941, based on the corrected values of partner series in the network.

2.3.2 Homogenisation with ACMANT

The development of the ACMANT homogenisation method has been continued after HOME, and a full description of version 2 of the software (ACMANT2) and an application of precipitation homogenisation with ACMANT2 were recently published (Domonkos, 2014, 2015a). For the homogenisation of IENet, a new and refined version of ACMANT was developed (ACMANT3); for more information, the interested reader is directed to Domonkos and Coll (2016).

ACMANT is a fully automatic homogenisation method, and an automatic control of monthly outlier values is provided based on the spatial comparison of simultaneous data. Infilling of missing data is a part of the ACMANT procedure, and the user may

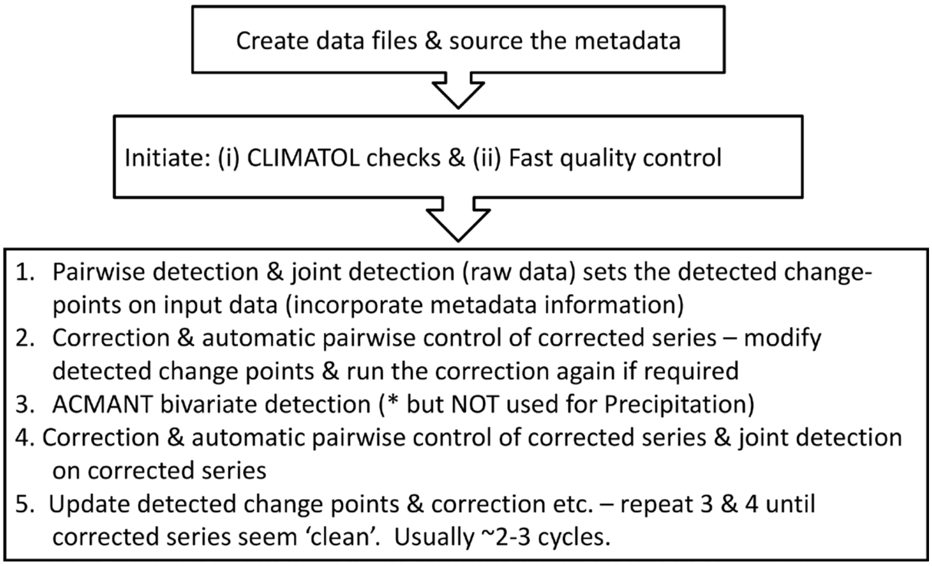

Figure 2.2. Tasks flow chart of HOMER applied for the precipitation series of IENet. Source: adapted from Mestre *et al.* (2013).

choose whether the homogenised output with the completed data or the output with the gaps in the raw data is required. A special feature of precipitation homogenisation with ACMANT is that the year can be split seasonally to account for differential receipts of precipitation, such as snow and rain and where the snow precipitation dominates in winter. However, as snow precipitation is rare in Ireland, no seasonal difference was applied for the homogenisation of our Irish data (see also discussions about the seasonality of precipitation inhomogeneities in Auer *et al*., 2005 and Domonkos, 2015a).

3 Results and Discussion

3.1 Homogenisation with HOMER

Intact record lengths across the IENet stations range between ~31 and 70 years and the station series have variable amounts of missing monthly data (Tables A1.1 and A1.2). Based on the network selection choices available, HOMER identified 15 reference stations within the network for each candidate station for pairwise comparison and joint detection of possible breaks. Figure 3.1 provides a summary of the HOMER sub-networks and shows the overall range of the geographical distance between each base series and its neighbours for all of the IENet station series. HOMER was first run on all series with known outliers included, and the results were then scrutinised. It was recognised that this is not good practice, as it can lead to spurious breaks. However, as a test application to a dense precipitation network, we wished to explore HOMER's sensitivity to outliers. The series were then re-processed in HOMER following the removal of outliers.

In total, 256 stations were found to be homogeneous, but 58 breaks were detected by HOMER across the other 43 stations (~14%) and multiple breaks were found in 12 records (~4%). Metadata scrutiny, where available, revealed that 24 of the detected breaks coincided with issues such as changes in gauge size and position, station closures and moves. There is some consistency in timing of break detection throughout the network, with most breaks (18) occurring in the 1960s (Figure 3.2). However, the number of break detections in the 1950s and 1990s (eight in each decade) is perhaps more surprising, given the lower quantity of data available for these decades in the network analysis (Figure A1.1),

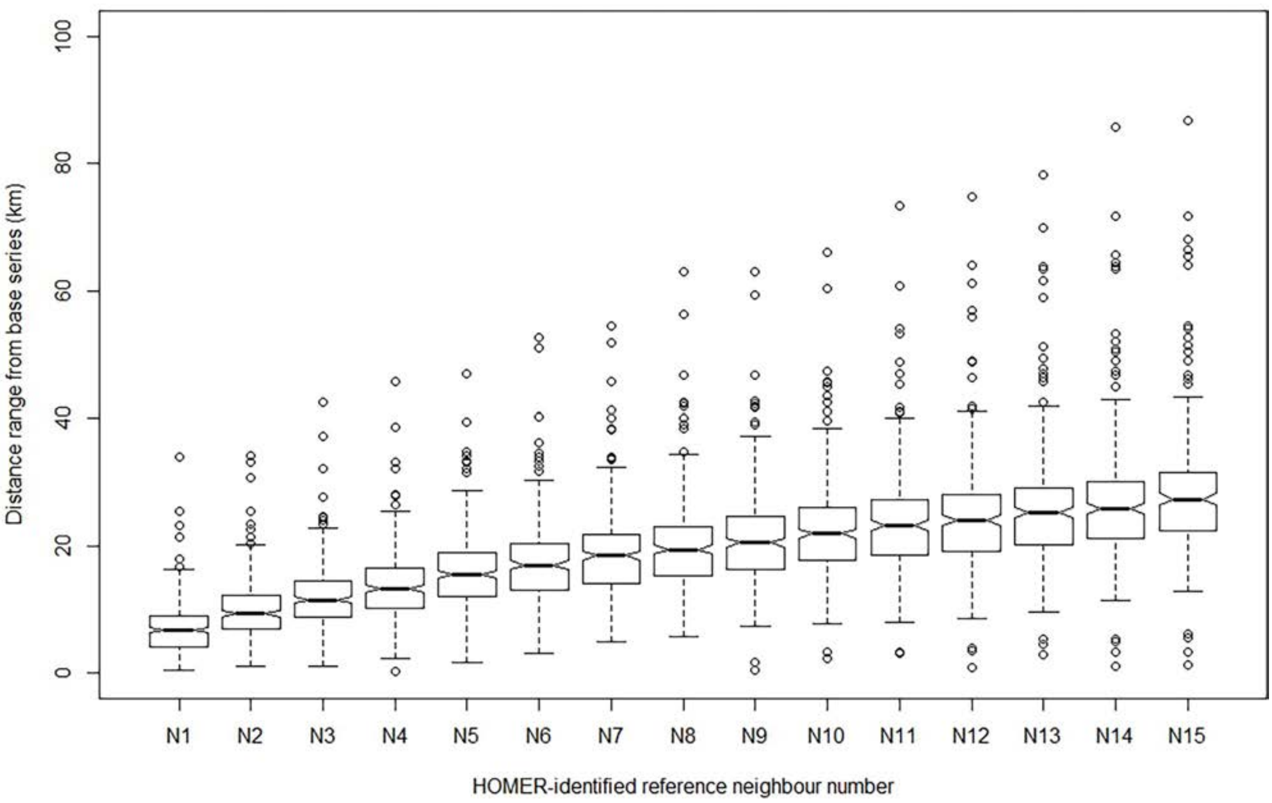

Figure 3.1. Waisted boxplots summarising the HOMER-derived geographical distance range for the base series and the corresponding 15 reference series. The plots describe a summary for all 299 IENet stations and 4485 reference series for each of the HOMER-identified sub-networks. Boxes, interquartile range; whiskers, 5th and 95th percentiles; black circles, outlying data points.

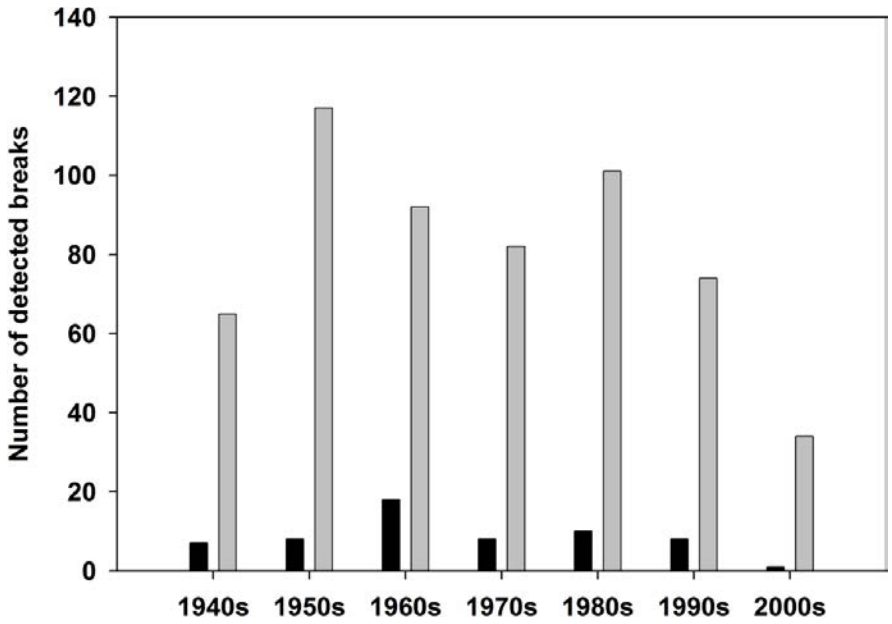

Figure 3.2. Histogram break detection count summary by HOMER and ACMANT for the 1941–2010 IENet precipitation series by decade. Black bars denote HOMER break detection counts; grey bars denote ACMANT break detection counts.

with metadata support available for some of the breaks (Table 3.1). However, overall break detection frequencies are consistent with other studies in Europe (e.g. Domonkos, 2015a and references therein). To provide some cross-validation support for the HOMER detections, ACMANT detections by year, month and amplitude are also provided in Table 3.1 where these occur within ~3 years of the HOMER-detected breaks. In many cases, these are closely coincident in time, and, with the exceptions of Glenamaddy Gortnagier and Carrigadrohid General Station, the sign and magnitude of the corrections are also similar.

The range of magnitude for the breaks detected by HOMER varied. Magnitude provides an indication of the size of the breaks detected, as well as the amount of adjustment needed to correct the inhomogeneity. Across all stations and detected breaks the amplitude ranges from –0.64 to +0.59. The largest break associated with a positive adjustment (amplitude 0.59) was found for Glenvickee (Caragh River Area) in 1963 and has no metadata support. The largest break associated with a negative adjustment (amplitude –0.67) was found in 1967 also for Glenvickee (Caragh River Area), but with metadata support (faulty gauge report; Table 3.1).

Detected breaks were corrected annually with multiplicative adjustments relative to the break amplitude applied equally across monthly series. This decision was made because the COST Action HOME found the application of yearly corrections by PRODIGE to be more stable and accurate, and hence these are currently recommended for homogenisation of precipitation networks (HOME, 2013). In a maritime climate such as Ireland's, variability of precipitation from month to month is low enough to allow such correction; in addition, Auer *et al*. (2005) and Moisselin and Canellas (2005) recommend that the same annual adjustment factor be applied to all months.

Previous work applying HOMER in Ireland reveals that geographical or correlation distance selections in HOMER yield overlapping neighbour series, which are largely statistically and spatially coherent (Coll *et al*., 2014). Such relationships should largely be expected in a maritime context; when compared with a more continental setting, the range of variation in overall precipitation receipts between stations is lower (Coll *et al*., 2015a).

However, compared with previous work, here we work on a larger and denser network overall, and there is a higher proportion of missing values throughout the data in IENet (Table A1.1). A potentially important finding in the current analysis, at least for such a dataset and in our climatic context, is that a geographical distance selection of neighbours when

Table 3.1. Collated list of HOMER-identified breaks for 44 stations and metadata explanations where available, or otherwise indicated as none available. ACMANT-identified breaks and amplitudes are provided for the same or nearby years in brackets. Cases where no approximately corresponding ACMANT detections were found are denoted (–) for year, month and amplitude

HOMER ID Code	Break year	Break month	Amplitude (%)	Station name	Metadata explanation
10040001	1954 (1956)	12 (9)	–11.0 (–10.0)	Roche's Point	Switch to new station, Dec 1955
10180001	1949 (1949)	12 (11)	9.0 (6.0)	Lisacasey GS	None available
10420001	2000 (2002)	12 (12)	–10.0 (–5.0)	Pettigo Lough Derg	None available
10900001	1956 (1957)	9 (1)	–20.0 (–23.0)	Tralee Clash	New observer, May 1956
11370001	1948 (–)	1 (–)	16.0 (–)	Kilnaleck GS	Station moved, Mar 1949
14140001	1966 (–)	12 (–)	–43.0 (–)	Bagenalstown Fenagh Hse	None available
14310001	1962 (1963)	12 (1)	–6.0 (–17.0)	Mullagh GS	Gauge replaced, Jan 1963
15140001	1946 (1948)	3(3)	13.0 (12.0)	Edenderry The Tunnel	Gauge levelled, Apr 1946
15290001	1965 (1966)	12 (12)	–22.0 (–21)	Drumsna Albert Lock	None available
16050001	1963 (1963)	12 (9)	59.0 (49)	Glenvickee Caragh River Area	None available
16100001	1995 (–)	12 (–)	34.0 (–)	Brosna Mount Eagle	None available
16120001	1962 (1964)	12 (9)	12.0 (10.0)	Portlaw Mayfield	None available
16190001	1946 (1947)	12 (8)	–10.0 (–9.0)	Birdhill Parteen Weir	None available
17140001	1978 (1978)	12 (9)	–7.0 (–3.0)	Daingean GS	None available
19290001	1958 (1959)	12 (5)	–7.0 (–9.0)	Athlone OPW	None available
22230001	1966 (1966)	3 (4)	–16.0 (–13.0)	Dún Laoghaire Harbour Yard	Defective gauge, Apr 1966
23220001	1980 (1982)	12 (9)	6.0 (4.0)	Boora	None available
25140001	1949 (1949)	12 (12)	19.0 (22.0)	Lullymore Bord na Móna	Gauge replaced, Jan 1950
26350001	1976 (1976)	6 (6)	6.0 (4.0)	Derryhillagh	Gauge dug up and re-levelled, Jul 1976
30140001	1980 (–)	12 (–)	26.0 (–)	Stradbally GS	None available
30230001	1967 (–)	12 (–)	–8.0 (–)	Howth Danesfort	None available
30350001	1986 (–)	12 (–)	–13.0 (–)	Castlebar Burren	None available
31270001	1967 (1967)	12 (12)	–9.0 (6.0)	Glenamaddy Gortnagier	None available
31350001	1983 (1984)	9 (5)	–15.0 (–7.0)	Cloonacool Lough Easkey	Inner parts of rain recorder replaced, Oct 1983
32230001	1984 (1980)	12 (9)	12.0 (9.0)	Glenbride Lodge	New observer and gauge mistakenly read weekly, Oct 1984
35130001	1972 (1973)	12 (7)	9.0 (6.0)	Slieve Bloom Mountains Nealstown	None available
35190001	1982 (1984)	12 (6)	–10.0 (–9.0)	Cloughjordan GS	None available
36040001	1990 (1991)	7 (11)	–15.0 (8.0)	Carrigadrohid Generating Station	Rain recorder adjusted, Aug 1990
50120001	1997 (1998)	12 (12)	–9.0 (–13.0)	Bansha Aherlow WW	None available
54200001	1960 (1963)	12 (12)	–6.0 (–15.0)	Greencastle	None available
61700001	1949 (1949)	12 (3)	10.0 (9.0)	Miltown Malbay GS	Broken rain measure, Jan 1950
62600001	1975 (1977)	8 (4)	–17.0 (–11.0)	Delphi Lodge	New site, Sept 1975 (100 yard move)
82000001	1984 (–)	2 (–)	9.0 (–)	Moneystown	Gauge shaded by tree, Mar 1984
83400001	1943 (1943)	12 (12)	–31.0 (–29.0)	Keel GS	Gauge leaking reported, Oct 1944
84400001	1970 (1970)	4 (10)	18.0 (22.0)	Creeslough Brockagh	Guard rail broken and too near gauge, May 1970
89050001	1982 (1985)	8 (12)	19.0 (26.0)	M Beenreagh Mountain	New observer and new gauge, Sept 1982
92200001	1966 (1966)	12 (3)	–17.0 (–21.0)	M Duff Hill	None available
94030001	1994 (1995)	12 (3)	–22.0 (–32.0)	M Cummeragh No. 4	None available

Table 3.1. Continued

HOMER ID Code	Break year	Break month	Amplitude (%)	Station name	Metadata explanation
95030001	1956 (1954)	5 (9)	13.0 (13.0)	M Cummeragh No. 5	Broken rain measure, Jan 1957
95050001	1957 (1955)	12 (8)	–10.0 (–16.0)	M Torc Mangerton No. 4	None available
98040001	1987 (–)	7 (–)	6.0 (–)	M Ballyvourney Knockacommeen	New observer, Nov 1987
99040001	1956 (1955)	5 (12)	8.0 (10.0)	M Inchigeelagh Pipe Hill	Gauge interfered with, Jun 1956
99380001	1969 (–)	12 (–)	–7.0 (–)	M Dundalk Ballymakellett	None available

GS, Garda Station; M, Mountain; OPW, Office of Public Works; WW, Water Works.

applying HOMER may be more appropriate. While not reported here, previous network configurations and the current version of IENet were also processed in HOMER, using the first difference correlation option for neighbour selection.

However, when using the correlation option for 22 of the HOMER-selected sub-networks with the same station series configuration for a previous version of IENet reported here (comprising 345 station series), post-processing analysis revealed spurious correlations related to the distribution of –999.9 missing value default entries between some of the series. In turn, this suggests that HOMER needs further testing and development on real-world precipitation data for medium to large networks with data characteristics analogous to IENet. Alternatively, geographical distance should be the neighbour selection of choice for climate series in such a maritime context and where a relatively dense network is available; otherwise, the user needs to carefully pre-screen prospective candidate series and their constituent sub-network components to avoid this issue arising.

Based on a substantial number of previous network experiments with considerably more station series, but with many more missing values, an interesting feature of IENet, as reported here, is that our operational deployment independently approached the series selection criteria used by Météo-France. In their homogenisation of shorter time series, Météo-France apply a 10% missing value tolerance, which is extended to 15% for longer series (B. Dubuisson, Météo-France, September 2016, personal communication). With the obvious exception of Farranfore (Scartaglin), most of the series in IENet fall within, or are at least close to, the guideline tolerances applied at Météo-France (Table A1.1).

3.2 Homogenisation with ACMANT

ACMANT consistently detected more breaks than HOMER in all decades, with the biggest disparities in break detection rates in the 1950s and 1980s (Figure 3.2). In total, 135 stations were found to be homogeneous, but 382 breaks were detected by ACMANT across the other 164 stations (~55%) and multiple breaks were found in 141 records (~47%).

3.3 Homogenisation Results

3.3.1 ACMANT–HOMER results comparison

Overall, ACMANT detected more multiple breaks in stations across the country than HOMER. A larger number of breaks detected with ACMANT than with HOMER have also been reported in a comparative study on the homogenisation of temperature data in the Spanish Pyrenees (Pérez-Zanón *et al.*, 2015), so it seems that this kind of difference is more because of the homogenisation methods themselves rather than the data subjected to homogenisation. For instance, in recent work, homogenising precipitation data in Norway, MASH was found to detect six times more breaks than HOMER (Lundstad *et al.*, 2017). This also could be expected, as MASH and ACMANT share a number of features in common, including components for applying seasonal adjustments. It is, for example, also possible that the seasonal adjustment component of ACMANT is more sensitive to shifts in series values than when applying the HOME-recommended annual corrections in HOMER for precipitation.

Certainly, when testing and refining ACMANT3 (Domonkos and Coll, 2016) for application to IENet, it was noted that ACMANT tended to treat wet/dry summer and dry/snowy winter months in the Irish records as outliers. It is also worth noting that we cannot conclude anything about the accuracy of homogenisation from the number of breaks detected by both programmes, as the latter does not provide any indication of the similarity between the true climate signal and that of the homogenised time series.

The full inter-comparison of the homogenised results via HOMER and ACMANT for IENet 299 is still under way for inclusion in a future publication. In the interests of providing a valid inter-comparison of the homogenised results both methods provide, Figure 3.3 provides a comparison for part of a previously published network experiment where the results for both HOMER and ACMANT were collated across a regional sub-network of 38 stations for north-west (NW) Ireland (Coll *et al*., 2015a). The plots provide a summary of the monthly range of the homogenised results across all 38 stations and a comparison between them for HOMER and ACMANT.

Figure 3.3 provides a comparison for a regional sub-set of 38 stations based on a previous network homogenisation exercise in which 198 series were split into four regional sub-sets of data for a period centred on 1950–2010. This was to accommodate the limitations of ACMANT2 at that development stage, where network *n* had to be fewer than 100 and the maximum number of years for processing in a series was ~60. Nevertheless, the comparisons of the results are valid and demonstrate that the final homogenised end products from both HOMER and ACMANT are largely similar. This should not be surprising, as both use some derivatives of the Caussinus–Lyazrhi criterion (Caussinus and Lyazrhi, 1997) for calculating

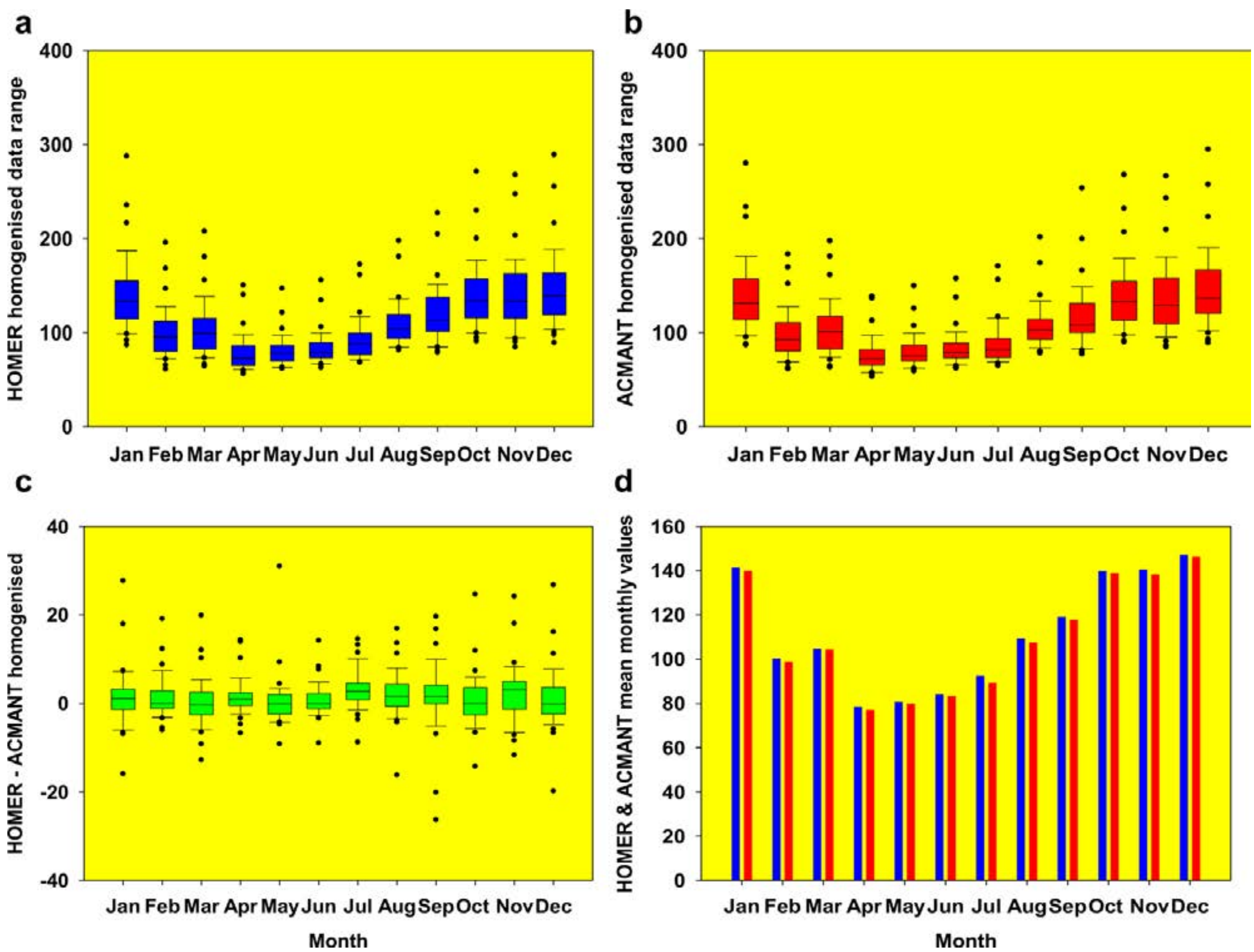

Figure 3.3. (a) Boxplot summary of the range of HOMER-homogenised monthly values for the 38 series in the NW network. (b) Boxplot summary of the range of ACMANT-homogenised monthly values for the 38 series in the NW network. (c) Boxplot summary of the range of difference for HOMER- and ACMANT-homogenised monthly values for the NW network. Boxes, interquartile range; whiskers, 5th and 95th percentiles; black circles, outlying data points. (d) Histogram comparison of HOMER-homogenised (blue bars) and ACMANT-homogenised (red bars) mean monthly values for the NW network. All units are in mm.

the number of homogeneous segments, and ANOVA is the underpinning correction method in both HOMER and ACMANT. The interested reader is also directed to Table 1 in Domonkos and Coll (2016) for a further comparison of similarities and differences between the methods.

3.3.2 HOMER IENet characteristics

In terms of the HOMER-computed IENet network characteristics, the geographical distance range for all 299 of the IENet base series and their 15 closest neighbours are summarised for all the series used in Figure 2.2. As HOMER processes the data, it is clear that the distance (km) between the base and neighbour series steadily increases from neighbours 1 to 15 and that the range of distances between the neighbours and their associated outliers also increase. As might be expected for a small country, the range of geographical distances between the neighbours constituting the sub-networks within IENet are relatively small, and these are summarised in Table 3.2.

3.4 Adjusted Trends for HOMER-corrected Series

A key task of statistical climatology is the description of climate variability, and by removing extraneous influences homogenised climate series should provide a better estimation of the true climate signal. As is common with trend analysis elsewhere in climatology, some of the inbuilt functionality of HOMER estimates the pre- and post-homogenisation trend based on the least squares (LS) method. This estimator is optimal if the residuals follow a Gaussian distribution, which may not always be the case (e.g. Trömel and Schönwiese, 2008).

Thus, while a Gaussian assumption might be feasible for precipitation accumulated to annual totals (e.g. Maraun *et al.*, 2010), on shorter time scales precipitation intensities become more skewed, and daily precipitation is commonly modelled with a gamma distribution (e.g. Katz, 1977). Therefore, it may be the case that a generalised linear modelling (GLM) framework may offer a more flexible extension to linear regression by allowing the predictand to follow a wider range of distributions. As far as we are aware, none of the HOMER development literature or other published work applying the software has explored the underpinning assumptions of the LS method. Although beyond the scope of the work reported here, future research on the application of HOMER to precipitation could explore whether it would be feasible to modify the code to allow integration of GLM or generalised additive modelling flexibility to vary the distribution assumptions.

Table 3.2. Summary statistics for the HOMER-derived sub-networks based on geographical distance selection for the 299 IENet series. The neighbour number refers to the reference neighbour number selected by HOMER

Neighbour number	Mean distance (km)	Median distance (km)	Neighbour network range (km)
1	6.91	6.74	0.40–33.88
2	9.63	9.25	0.92–34.13
3	11.82	11.39	1.04–42.47
4	13.62	13.23	0.19–45.72
5	15.41	15.43	1.68–46.87
6	16.99	16.93	2.95–52.63
7	18.38	18.43	4.91–54.39
8	19.78	19.32	5.59–63.08
9	21.07	20.44	0.44–63.08
10	22.30	21.86	2.25–66.05
11	23.54	23.07	2.97–73.39
12	24.62	23.92	0.85–74.79
13	25.78	25.11	2.90–78.15
14	26.79	25.82	0.92–85.74
15	27.93	27.31	1.19–86.75

This more theoretical consideration aside, the pre- and post-HOMER LS trend estimates and their associated two-sided Mann–Kendall test *p*-values are provided for the 44 IENet series adjusted by HOMER (Table 3.3). Depending on the correction amplitudes applied by HOMER, it is clear that both the sign and magnitude of the pre- and post-trend estimates and their associated *p*-values can vary markedly. The Mann–Kendal test can be stated most generally as a test for whether the dependent variable values tend to increase or decrease with time, i.e. indicate a monotonic change.

In this application within HOMER, the Mann–Kendal non-parametric test is used to estimate the existence, magnitude and statistical significance of potential trends in the raw and corrected time series to assess the impacts of homogenisation. For IENet overall, the HOMER homogenisation reduces the variability of the LS-adjusted trends across all 299 stations (Figure 3.4), and summaries of the pre- and post-homogenised LS trend estimates are provided for each of the HOMER-corrected series (Table 3.3). However, this reduction in variability should be an

Table 3.3. Summary trend adjustment statistics for the HOMER-corrected series. Raw and HOMER-corrected LS trend estimates and the associated two-sided Kendall *p*-values are provided for the 44 series

Met Éireann ID	Station name	Raw LS trend estimate	Raw Kendall *p*-value	Corrected LS trend estimate	Corrected Kendall *p*-value
1004	Roche's Point	–2.73	0.30	0.89	0.13
1018	Lisacasey GS	–0.22	0.94	1.35	0.26
1042	Pettigo Lough Derg	2.41	0.13	2.90	0.03
109	Tralee Clash	2.77	0.01	1.89	0.02
1137	Kilnaleck GS	2.45	0.13	0.47	0.62
1414	Bagenalstown Fenagh House	0.04	0.98	0.49	0.52
1431	Mullagh GS	–2.68	0.18	0.35	0.46
1514	Edenderry The Tunnel	2.11	0.06	0.65	0.22
1529	Drumsna Albert Lock	1.37	0.23	1.30	0.18
1605	Glenvickee Caragh River Area	–6.37	0.33	5.97	0.05
1610	Brosna Mount Eagle	6.25	0.02	1.06	0.43
1612	Portlaw Mayfield	3.45	0.01	1.13	0.20
1619	Birdhill Parteen Weir	1.32	0.19	1.73	0.03
1714	Daingean GS	–1.48	0.43	0.70	0.12
1929	Athlone OPW	–2.75	0.07	0.10	0.99
2223	Dún Laoghaire Harbour Yard	–2.53	0.14	0.61	0.76
2322	Boora	1.37	0.08	0.25	0.43
2514	Lullymore Bord na Móna	0.98	0.43	0.47	0.27
2635	Derryhillagh	0.21	0.97	4.15	0.02
3014	Stradbally GS	–0.60	0.57	–2.88	0.00
3023	Howth Danesfort	–1.68	0.23	–0.13	0.82
3035	Castlebar Burren	0.62	0.30	3.09	0.00
3127	Glenamaddy Gortnagier	–2.08	0.02	0.42	0.32
3135	Cloonacool Lough Easkey	–1.51	0.41	3.41	0.00
3223	Glenbride Lodge	4.26	0.03	1.93	0.09
3513	Slieve Bloom Mountains Nealstown	2.30	0.04	0.07	0.53

Table 3.3. Continued

Met Éireann ID	Station name	Raw LS trend estimate	Raw Kendall *p*-value	Corrected LS trend estimate	Corrected Kendall *p*-value
3519	Cloughjordan GS	–3.34	0.02	0.21	0.64
3604	Carrigadrohid Generating Station	2.14	0.14	1.26	0.17
5012	Bansha Aherlow WW	–1.06	0.50	1.56	0.13
542	Greencastle	2.24	0.15	2.25	0.02
617	Miltown Malbay GS	1.31	0.61	1.52	0.15
626	Delphi Lodge	–5.99	0.08	4.61	0.02
820	Moneystown	5.16	0.01	1.46	0.53
834	Keel GS	8.99	0.00	2.91	0.00
844	Creeslough Brockagh	–3.24	0.35	2.12	0.06
8905	M Beenreagh Mountain	9.80	0.24	5.93	0.02
9220	M Duff Hill	2.87	0.50	0.64	0.55
9403	M Cummeragh No. 4	–4.96	0.02	6.39	0.17
9503	M Cummeragh No. 5	5.26	0.59	–0.11	0.53
9505	M Torc Mangerton No. 4	–12.39	0.02	3.97	0.05
9804	M Ballyvourney Knockacommeen	5.26	0.00	2.35	0.06
9904	M Inchigeelagh Pipe Hill	2.13	0.23	0.40	0.70
9938	M Dundalk Ballymakellett	–1.52	0.07	0.38	0.65

GS, Garda Station; M, Mountain; OPW, Office of Public Works; WW, Water Works.

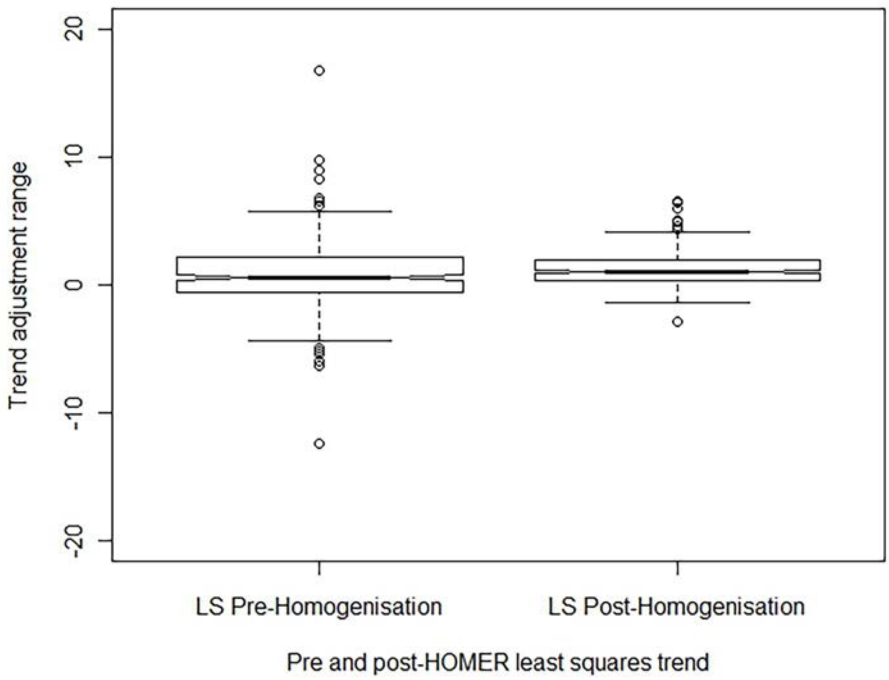

Figure 3.4. Waisted boxplots summarising the pre- and post-HOMER LS-adjusted trends for IENet. The plots describe a summary of all 299 IENet stations' trend estimates before and after homogenisation. Boxes, interquartile range; whiskers, 5th and 95th percentiles; black circles, outlying data points.

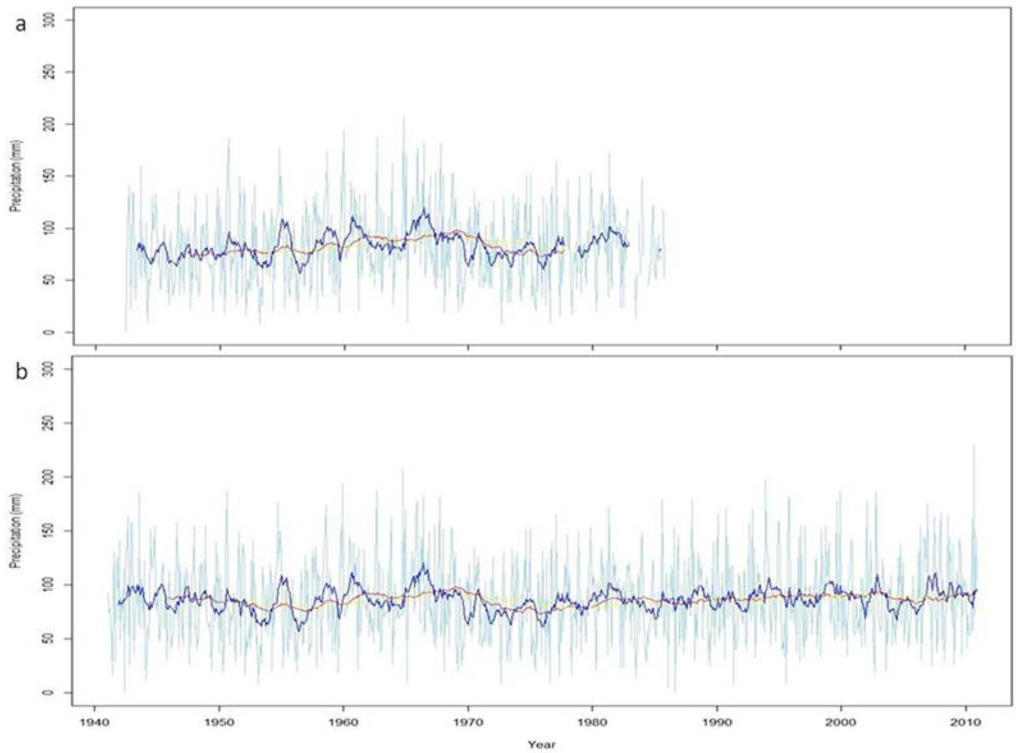

Figure 3.5. 1941–2010 exemplar monthly and smoother filtered plots for monthly precipitation. (a) Kilnaleck Garda Station raw data series; (b) Kilnaleck Garda Station HOMER-corrected data series. The light blue line denotes individual monthly totals, the dark blue line a yearly running mean. The red and yellow lines denote 5- and 10-year running means, respectively.

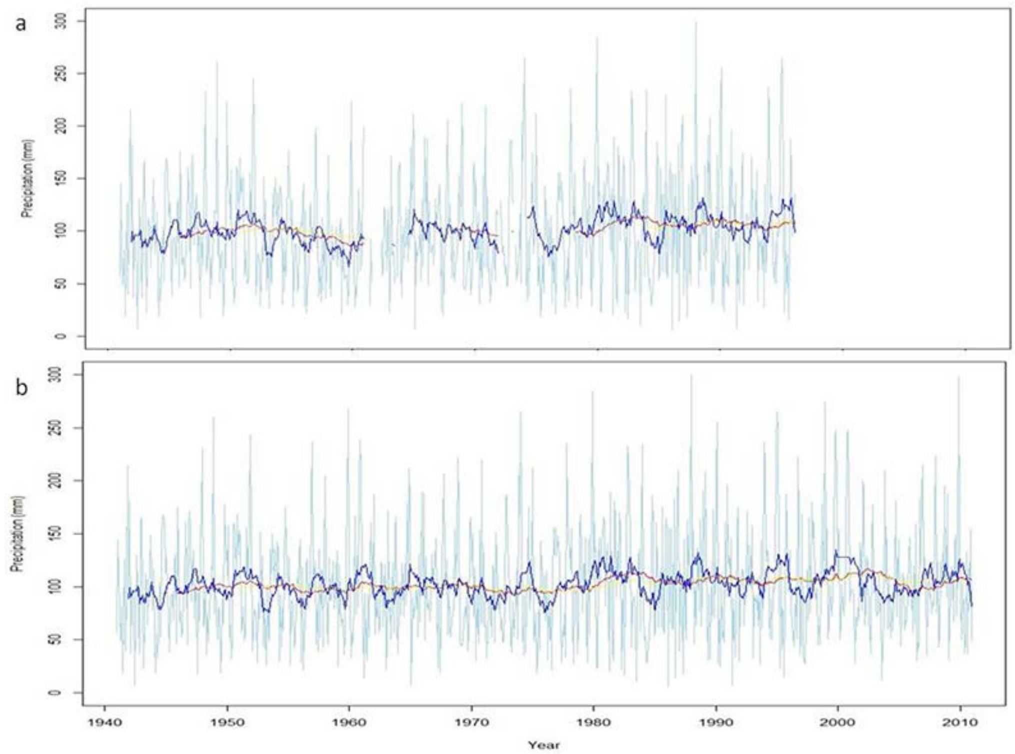

Figure 3.6. 1941–2010 exemplar monthly and smoother filtered plots for monthly precipitation. (a) Tralee Clash raw data series; (b) Tralee Clash HOMER-corrected data series. The light blue line denotes individual monthly totals, the dark blue line a yearly running mean. The red and yellow lines denote 5- and 10-year running means, respectively.

expected consequence of the homogenisation, since in a sense the software corrections are a data-smoothing manipulation.

Some exemplar plots are provided to illustrate the effect of HOMER corrections on some raw station series and to provide a visual indication of the effect of filtering the trends on the raw versus homogenised series. For precipitation, the HOMER amplitude corrections are multiplicative (O.M. Mestre, Météo-France, June 2015, personal communication); therefore, illustrations are provided for one positively and one negatively adjusted series, which reflect some of the range of adjustment across IENet.

Figure 3.5 shows the effect of a HOMER amplitude correction of +0.16 (~+16%) to the Kilnaleck Garda Station series. By contrast, Figure 3.6 shows the effect of an amplitude correction of –0.20 (~–20%) for the Tralee Clash series.

For the corrected series examples provided, it is clear that the homogenised series provide a more useful product for establishing variations and trends in the data. After replacing the segments and contiguous blocks of missing data in the original station series with values derived from the local reference network, in the case of these exemplar series, HOMER provides a longer and locally adjusted series for further analysis.

4 Conclusions

HOMER consistently detected fewer breaks than ACMANT for the current IENet 299 precipitation series. ACMANT detects more overall and more multiple breaks than HOMER and has a different spatial pattern of detections. Of the 58 breaks identified by HOMER, 24 (~41%) were confirmed by the metadata. In the case of ACMANT, 67 (~18%) were confirmed by the metadata, while 225 had no metadata explanation. However, metadata were not available for all the station series in the current network; in the case of the checks for the ACMANT-identified breaks, for example, metadata were not checked as being available for 104 of the stations. In the interests of brevity and on account of the number of ACMANT break detections, the detail and metadata support are not presented here, but these are available for the interested reader upon request.

The spatial characteristics of the IENet precipitation records, i.e. a relatively dense network allied to the climatic characteristics of a maritime region with low amplitudes of variation between series compared with, for example, a more continental climate regime result in relatively close geographical proximities and high correlation coefficients among many series. These properties of the data and the network are useful for the test application of relative homogenisation methods such as HOMER and ACMANT for observed precipitation series.

The analysis using ACMANT has been extended to a wider network of more than 700 series and the results have been processed. However, it is unlikely that full metadata support will be available to check all the ACMANT detections for this larger network. Despite considerable effort, it has not been possible to apply HOMER to this larger network for a full comparison with the ACMANT results because of complications with missing data in many of the candidate series in that network previously evaluated for inclusion in IENet. HOMER was never fully evaluated for the homogenisation of precipitation data at the end of the COST Action HOME. Consequently, and despite many network configuration experiments not reported here with a start point of more than 700 series, it was not possible to configure HOMER to fully homogenise a network of this size with many missing values. However, some interim results in which this was attempted using different network configurations are reported (Coll *et al*., 2015a,b). Therefore, until refinements are made to HOMER so that it can handle missing data better, practitioners should apply a ~10–15% missing value threshold criterion to candidate series being evaluated for inclusion in any network where HOMER is to be applied.

Therefore, and given the current state of HOMER's development for application to real-world precipitation series, the user should proceed with caution and undertake a rigorous post hoc scrutiny of results for any network analysis. HOMER remains better suited to small to medium-sized networks where the operator carefully controls the quality of the input data and the homogenisation options selected. Used in this way, HOMER can produce valuable reference series for small long-series networks in a relevant climatic setting, and the results can be further tested against medium-density networks, e.g. for at least some of the later instrumental records (Noone *et al*., 2015).

The robustness of some of the large corrections for which no supporting metadata are available is questionable; this is particularly the case for the large HOMER adjustments at Glenvickee (Caragh River) around the 1963–1967 segment of the data, and the lead author certainly wishes to continue investigating the results for this sub-network based on some new analyses. One possible option would be to use high-resolution numerical weather prediction reanalysis products to provide independent estimates of monthly precipitation. Global reanalyses have been used similarly to complement temperature observations (Simmons *et al*., 2016), but the lack of spatial resolution has, up until now, precluded their usefulness for regional precipitation estimates. However, a preliminary assessment of recent high-resolution climate simulations over Ireland suggests that monthly rainfall estimates, and trends, from such models (e.g. McGrath and Nolan, 2016) are now of sufficient quality to provide independent material that could perhaps be used to support homogenisation-based changes to the observations. Likewise, in more recent times, radar-derived precipitation estimates might be similarly used, although there are difficulties with the quality and continuity of records.

By incorporating new station data and varying the period of the instrumental record analysed using relative homogenisation, Ireland could continue to be a useful case study location for the application of the methods. For example, we would consider that the prospects for further evaluating variations in network density and record length on the break detection frequency of methods such as HOMER and ACMANT for real-world precipitation time series are excellent. For instance, different network combinations could be evaluated if the baseline homogenisation period was shifted from 1941–2010 to circumvent the current missing values sensitivity of HOMER. If, for example, a new 1961–2015 baseline was selected, the spatial coverage of Northern Ireland series included could be expanded and more combinations of Met Éireann series could be included. In general, for both jurisdictions, there are fewer missing data for HOMER to have to deal with after the 1960s, and in the near term it looks unlikely that HOMER will be modified to deal better with missing data (O. Mestre and B. Dubuisson, Météo-France, September 2016, personal communication).

A further potential future line of enquiry is that, while relative homogenisation methods such as HOMER and ACMANT are particularly effective in identifying step changes in precipitation, the gradual encroachment of urbanisation may have a less readily identifiable impact for some stations. A recent review in China using homogenised data considered that the effect of urbanisation was less marked than, for example, that of temperature; however, different synoptic conditions and the extent of urbanisation can result in a more spatially variable pattern for precipitation in and around cities, and further work is needed to improve understanding (Yan *et al.*, 2016). It is certainly the case that Dublin and other cities in Ireland have experienced a very rapid growth in recent decades, although no changes for the stations in and around Dublin were detected in the current version of IENet. Future work could potentially examine any available longer series in and around urban areas on smaller and denser sub-networks to determine if such changes can be detected.

Finally, there is also considerable scope for developing this work, and for the wider application of HOMER and ACMANT to monthly precipitation data over a wider Ireland–Great Britain domain, providing appropriate regional series were selected and carefully tested. Undertaken alongside targeted data rescue activities to extend the existing long records available for subsequent homogeneity assessment in HOMER and ACMANT, such initiatives would deliver improved baseline data for climate services and climate-based decision-making at important sentinel locations in NW Europe.

5 Future Prospects

5.1 Capacity Building and Publications

The work to date has included a number of conference papers, including a published extended paper. In addition, the work has developed some strategically important collaborations and has made important contributions to two papers in the *International Journal of Climatology*, namely Noone *et al*., 2015 and Domonkos and Coll, 2016. In addition to these, a further two draft manuscripts are, at the time of writing, at an advanced stage of preparation for submission to good-quality international journals. These extend the collaboration with Universitat Rovira i Virgili and build a new collaboration with researchers at University College Dublin.

The lead author here will continue the research as part of a new lectureship commencing at Maynooth University. Reflecting this, a “Ulysses” scheme funding bid in partnership with Météo-France was submitted in September 2017 to support a new collaboration. This aims to apply a new version of HOMER that incorporates automated pairwise comparison utilising a new Bayesian algorithm developed by researchers at Météo-France (Hannart *et al*., 2014) to some of our Irish datasets. Based on our experiences here, it is hoped that this collaboration may help shape a new version of HOMER that is more tolerant of missing values. In addition, by sharing approaches, it might be hoped that a more operationally useful series of protocols for the operational deployment of HOMER can be developed. The respective Heads of Division at Météo-France and Met Éireann are supportive, but future collaboration will be subject to funding.

5.2 Homogenisation of Daily Data

Homogenised daily precipitation series will become increasingly important, both for the improved validation of climate model projections and for extreme value analysis in relation to historical flood detection and the future projection of flood events. Delivering on daily homogenised series will be much more challenging, as the inherently high temporal and spatial variability of precipitation makes homogenisation of daily records more difficult to accomplish than for, for example, temperature.

Therefore, for many climatologists, homogenisation of daily data is still considered to be in its infancy and is a much more challenging problem than homogenisation at monthly or annual scales. There is also contention surrounding the underpinning mathematical theory of some of the methods currently being applied (Szentimrey, 2013a). However, the most recent versions of MASH (v3.02 and v3.03) have been extended to tackle the homogenisation of daily precipitation data based on a procedure in accordance with the multiplicative (or cumulative) model that is assumed for monthly precipitation sum data (Szentimrey, 2013b).

Nonetheless, even for seasoned homogenisation practitioners, tackling daily homogenisation is a considerable technical challenge. For example, in trying to develop the planned new CLIMATOL 3.0 software, Guijarro reports considerable difficulties in trying to homogenise daily values (J.A. Guijarro, Agencia Estatal de Meteorología, Spain, June 2016, personal communication). Thus, while detection methods for daily data need to be developed, methods that may also detect changes in the tails of the distribution not affecting the mean are also needed. Therefore, correction methods that estimate the level of detail that is needed and possible should be developed, and, overall, a better understanding of the nature of daily inhomogeneities and better tools to correct them will be the main challenges for the coming years (V. Venema, University of Bonn, September 2017, personal communication). Overall, then, given the challenges we faced with monthly data, and based on a series of conversations with colleagues around the European homogenisation community, we consider that tackling daily precipitation homogenisation would have to be part of a new and highly collaborative initiative.

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Abbreviations

ACMANT	Adapted Caussinus–Mestre Algorithm
a.s.l.	Above sea level
GLM	Generalised linear modelling
HOME	Advances in Homogenisation Methods of Climate Series: An Integrated Approach
HOMER	Homogenisation Software in R
IENet	Irish Network
LS	Least squares
NI	Northern Ireland
NW	North-west
UKMO	United Kingdom Meteorological Office

Appendix 1

Table A1.1. The list of Met Éireann station identifiers with corresponding geographical data and percentage of entire months missing values, 1941–2010

Station name	Met Éireann ID	Easting	Northing	Elevation (m)	Months missing (%)
Foulkesmills (Longraigue)	108	284100	118400	71	0.0
Tralee (Clash)	109	84700	114400	15	21.2
Convoy GS	142	221400	401400	49	5.5
Glengarriff (Ilnacullin)	201	93200	54700	7	0.2
Kenmare (Sheen Falls)	203	92500	70000	15	1.4
Baldwinstown GS	208	296700	110200	15	7.3
Carndonagh (Rocksmount)	245	248400	446000	30	1.5
Valentia Observatory (Manual)	305	45799	78549	24	0.0
New Inn GS	321	167000	227700	88	3.9
Skerries (Milverton Hall)	332	323100	259300	64	0.0
Emyvale GS	339	267700	344200	56	9.1
Gap of Dunloe	405	88500	81900	34	3.5
Inagh (Mt Callan)	417	116500	177500	122	0.0
Dromoland Castle	418	138700	170300	12	11.3
Ballyjamesduff GS	430	252300	290800	110	3.1
Glenties Hatchery	441	181600	393600	44	0.0
Killarney (St Finan’s Hosp)	505	96400	91600	55	8.7
Kilkee GS	517	89000	160100	11	6.8
Shannon Airport	518	137900	160300	15	0.0
Rathdrum (Avondale)	520	319700	186000	131	6.0
Kinvara GS	521	137400	210200	11	1.1
Finea GS	530	240100	281400	68	6.1
Dublin Airport	532	316900	243400	71	0.0
Dundalk (Annaskeagh WW)	538	308000	312800	61	0.0
Dunlewy	541	190900	420500	113	3.6
Greencastle	542	264600	440800	53	2.2
Malin Head (Manual)	545	241900	458600	22	0.0
Castletownbere (Filane West)	601	71500	47800	168	1.5
Kenmare (Derreen)	603	77100	58900	24	0.1
Killarney (BVM Park)	605	97000	85700	34	11.9
Carrickbyrne GS	608	284300	124100	85	9.2
Miltown Malbay GS	617	106100	179800	55	5.0
Ennis GS	618	133900	177800	6	16.7
Delphi Lodge	626	84400	266100	32	1.1
Ahascragh (Clonbrock)	628	174500	239200	58	1.1
Edgeworthstown GS	630	225900	271700	104	14.9
Lusk GS	632	321700	254300	23	2.1
Louisburgh GS	633	80800	280900	9	12.7
Markree Castle	636	170300	325200	39	0.0
Nobber	638	283000	286500	60	4.4
Waterville Octive No. 9	703	58800	70600	110	1.4

Table A1.1. Continued

Station name	Met Éireann ID	Easting	Northing	Elevation (m)	Months missing (%)
Killorglin (Callinafercy)	705	77900	99400	14	0.7
Mallow (Hazelwood)	706	155600	104500	94	0.0
Duncannon GS	708	273300	108200	24	13.2
Corofin	718	128700	188700	29	7.9
Bonniconlon GS	735	132800	318500	75	4.4
Kingscourt GS	738	278600	295900	105	6.9
Carrick GS	740	159200	379100	32	3.9
Clogher GS	741	172600	398900	15	7.9
Beaufort GS	805	87800	91800	35	7.2
Ballyduff GS	810	87000	134800	36	6.4
Crusheen GS	818	139500	187900	34	3.6
Moneystown	820	319200	195900	207	0.8
Multyfarnham GS	830	240200	263800	74	14.0
Keel GS	834	62600	304600	40	3.4
Easkey GS	836	137200	337900	15	5.0
Shercock GS	837	272100	305900	110	7.8
Mountcharles GS	840	187400	377500	91	5.3
Creeslough (Brockagh)	844	201400	425600	119	1.4
Cork (Univ Coll)	904	166300	71300	17	10.6
Castlemaine GS	905	83900	103300	8	10.1
Knocknagoshel GS	910	106200	121100	152	6.6
Hollyford GS	912	192500	153600	194	6.3
Johnstown Castle	915	302300	116600	49	0.0
Aughrim GS	920	312900	179800	75	5.4
Taughmaconnell GS	928	189800	238900	59	6.7
Rathowen GS	930	231800	267400	77	11.8
Kells (Headfort)	931	276100	276900	67	7.9
Bellacorrick (Moneynierin)	934	98800	319700	88	1.3
Carrowkeel	942	251000	431500	15	1.3
Creeslough (Carrownamaddy)	944	203200	431800	88	1.1
Roche's Point	1004	183100	60100	43	0.8
Farranfore GS	1005	94000	103400	43	7.0
Enniscorthy (Voc Sch)	1015	297100	139700	30	1.5
Lisacasey GS	1018	122200	166500	81	12.9
Arklow WW	1020	321900	173000	34	1.6
Loughrea GS	1021	161800	216500	85	12.2
Roundwood (Filter Beds)	1024	321600	201800	195	2.9
Kilconnel GS	1028	173400	231200	91	8.3
Duleek GS	1032	304700	268200	29	4.3
Belmullet (Manual)	1034	69100	332900	9	1.2
Aclare GS	1035	141600	310000	64	9.6
Skreen	1036	153100	333100	26	1.8
Pettigo (Lough Derg)	1042	209000	373000	146	1.8
Sneem	1103	68900	66900	14	9.9
Ballinacurra	1104	188500	72000	7	2.1
Cappoquin (Mt Melleray)	1106	209500	104100	213	5.0
Listowel GS	1110	99000	133900	47	11.1

Table A1.1. Continued

Station name	Met Éireann ID	Easting	Northing	Elevation (m)	Months missing (%)
Loughglinn	1128	163400	286000	98	6.4
Coole (Coolnagun)	1130	238400	270100	67	2.5
Kinnegad GS	1131	259700	245400	78	4.1
Kilnaleck GS	1137	244800	290100	113	29.1
Killybegs	1140	171300	375800	15	1.7
Moyvane GS	1210	107000	139600	62	10.1
Tulla	1218	148900	180100	61	0.8
Athenry (Attymon)	1221	158500	228500	78	3.8
Costelloe Fishery	1225	97500	226700	12	1.6
Ballintubber GS	1228	172900	274500	78	7.8
Carrigallen GS	1237	223100	302900	88	1.6
Louth GS	1238	296100	301400	37	2.7
Kiltyclogher	1240	197700	345500	70	1.7
Cork (Univ Coll Farm)	1304	163800	69600	23	1.0
Newmarket GS	1306	131800	107400	157	6.6
Tournafulla GS	1310	122100	124500	160	9.7
Shanaglish GS	1318	143900	195300	40	8.0
Moate (Coolatore)	1322	224000	243900	112	4.9
Omeath	1338	314200	316600	12	1.9
Kinlough GS	1340	181400	355300	43	5.1
Oolagh (Caragh River Area)	1405	74200	90400	98	1.3
Kanturk (Voc Sch)	1406	138400	103300	104	2.0
Ballylongford GS	1411	99900	144400	9	2.5
Bagenalstown (Fenagh Hse)	1414	277400	161300	106	0.5
Tullamore GS	1422	233700	225100	58	12.0
Mullagh GS	1431	269600	285100	107	11.1
Redhills GS	1437	244700	317300	66	7.0
Pettigo (Meensheefin)	1440	201600	370100	148	1.0
Rathduff GS	1504	159800	84800	138	2.0
Lyreacrumpane (Reenagown)	1510	97300	118200	187	2.8
Kildysart GS	1511	125200	158800	36	15.1
Edenderry (The Tunnel)	1514	264400	231300	81	1.4
Meelick (Victoria Lock)	1519	194600	212900	39	0.6
Hollymount GS	1527	126200	268500	39	4.7
Drumsna (Albert Lock)	1529	200000	295800	45	0.0
Drimoleague GS	1602	112500	45800	61	3.3
Macroom GS	1604	133700	73200	75	11.0
Glenvickee (Caragh River Area)	1605	74300	81700	128	2.0
Buttevant GS	1606	154100	108700	96	7.3
Brosna (Mt Eagle)	1610	111200	112500	238	2.8
Portlaw (Mayfield)	1612	246600	115200	8	0.9
Clonsast (Bord Na Móna)	1614	253500	216000	73	1.0
Carnew (Voc Sch)	1615	301200	163300	99	4.1
Birdhill (Parteen Weir)	1619	168100	167900	34	0.4
Partry GS	1627	115400	272700	30	3.7
Cloondra OPW	1629	206000	276000	48	9.3
Crossmolina GS	1635	113700	317600	26	1.5

Table A1.1. Continued

Station name	Met Éireann ID	Easting	Northing	Elevation (m)	Months missing (%)
Keshcarrigan GS	1637	203800	307700	69	10.6
Ballydehob GS	1702	98700	35100	20	2.9
Cloone Lake (Caragh River Area)	1705	71200	78400	122	1.8
Knockaderry Resv No. 1	1712	249800	106700	71	0.0
Durrow GS	1713	240800	177200	85	6.4
Daingean GS	1714	247200	227100	78	2.0
Banagher (Canal Hse)	1719	200400	216000	37	2.9
Dublin (Phoenix Park)	1723	310000	236100	49	0.0
Drumshanbo	1729	196000	312500	54	2.1
Ballivor GS	1731	268500	254200	68	2.8
Tarelton GS	1804	132300	65800	155	11.5
Waterford (Tycor)	1812	259400	111600	49	4.2
Rathdowney GS	1813	228300	178100	102	4.8
Portumna OPW	1819	187200	204600	35	0.2
Ferbane GS	1822	211300	224400	47	10.4
Dublin (Glasnevin)	1823	315000	237000	21	0.0
Kilconly GS	1827	134900	258500	46	7.5
Mount Bellew (For Stn)	1828	165900	246400	67	5.2
Dromod (Ruskey)	1829	205300	286200	42	2.1
Ardee (St Brigid's Hosp)	1838	295700	290400	32	7.0
Lough Eske (Edergole)	1840	197400	387000	94	3.5
Timoleague GS	1902	147000	43500	12	6.3
Knockaderry Resv No. 2	1912	249400	106500	62	0.7
Ballytore GS	1914	280000	196000	99	2.7
Castletowngeoghan GS	1922	234300	243900	102	17.9
Glenasmole DCWW	1923	309000	222200	158	0.0
Athlone OPW	1929	203900	241300	37	1.1
Lough Eske (Drimnacarry)	1940	196700	381900	43	1.7
Castleisland (Glountaine)	2005	107800	107300	241	0.8
Glin GS	2011	113000	147200	20	8.2
Cashel (Ballinamona)	2012	204900	140000	80	8.0
Castledermot GS	2014	277500	184800	82	1.7
Rathvilly GS	2015	288000	181700	122	5.0
Dún Laoghaire (People's Park)	2023	324800	228100	8	7.1
Corofin GS	2027	142600	243200	34	11.3
Collon GS	2031	300000	282000	128	18.8
Cuilcagh Mtns	2037	213000	324100	290	1.0
Farranfore (Scartaglin)	2105	104700	105000	213	70.1
Glencairn (St Mary's Abbey)	2106	199800	98900	52	8.6
Clonmel (Ballingarrane)	2112	217100	119800	73	2.0
Hacketstown (Voc Sch)	2115	297500	179900	189	1.2
Barnaderg GS	2127	152100	247800	61	5.5
Foxford GS	2135	127300	304400	23	2.4
Bennettsbridge GS	2213	255300	149100	37	3.6
Dún Laoghaire (Harbour Yd)	2223	324300	228700	16	17.0

Table A1.1. Continued

Station name	Met Éireann ID	Easting	Northing	Elevation (m)	Months missing (%)
Carndolla	2227	133500	239500	24	4.4
Lanesboro OPW	2229	200600	269500	46	1.1
Rhode GS	2231	253600	233600	94	4.6
Ballyshannon (Cathleen's Fall)	2237	188400	361300	38	1.4
Mooncoin (Voc Sch)	2312	251000	115800	53	0.0
Boora	2322	218000	219700	58	1.6
Laghtgeorge GS	2327	138000	234300	14	5.1
Eskeragh	2335	104300	319000	85	1.0
Ballyshannon (Cliff Hse)	2337	193500	360100	50	7.2
Dunmanway (Inchanadreen)	2402	119400	54500	125	0.8
Watergrasshill	2404	176400	84400	184	3.1
Glenville GS	2406	170900	88100	152	3.5
Kilmallock GS	2411	160900	127400	89	1.9
Borris GS	2414	272400	150700	85	6.3
Glen Imaal (For Stn)	2415	297200	194600	213	0.5
Dublin (Clontarf)	2423	318100	236300	5	0.3
Shrule GS	2427	127800	252700	32	5.9
Keenagh Beg	2435	103000	311000	91	1.1
Clones	2437	250000	326300	89	0.0
Kilbrittain GS	2502	152300	47000	32	1.8
Rathcormac GS	2506	180600	91600	55	3.4
Lullymore (Bord Na Móna)	2514	271100	228900	84	2.0
Dublin (Ringsend)	2523	318900	233900	7	6.0
Glasson GS	2529	209000	247200	48	12.3
Navan	2531	286100	267200	50	0.1
Cloughbrack Far	2535	110900	305300	81	3.4
Pettigo	2537	210400	366400	88	2.8
Ballyvourney (Clountycarty)	2604	121000	71500	152	0.1
Rosslare	2615	313700	112200	26	2.1
Kilrickle GS	2619	170000	220100	100	12.1
Derryhillagh	2635	108800	310200	104	1.1
Gouganebarra	2704	109500	66000	183	0.3
Kiltormer	2719	181900	221000	78	9.5
Stillorgan (Vartry Hse)	2723	320200	226800	80	9.9
Claremorris	2727	134500	273900	69	9.9
Carrick-on-Shannon ESB	2729	192700	298800	56	2.5
Ballivor (Hill of Down)	2731	264400	254100	81	2.6
Rockcorry	2737	264600	319000	99	2.4
Kinsale (Voc Sch)	2802	163300	50800	43	2.8
Donoughmore	2804	149200	82100	200	1.0
Eyrecourt GS	2819	191100	216300	58	12.0
Ballinagree (Mushera)	2904	135700	85500	351	7.6
Rathangan GS	2914	267000	219600	79	2.7
Warrenstown	2931	292100	253500	90	1.6
Ballingeary (Voc Sch)	3004	115000	67100	91	2.5

Table A1.1. Continued

Station name	Met Éireann ID	Easting	Northing	Elevation (m)	Months missing (%)
Stradbally GS	3014	257000	196600	91	11.4
Howth (Danesfort)	3023	328200	236900	122	2.0
Castlebar (Burren)	3035	114000	297000	137	2.1
Swanlinbar	3037	219400	327500	69	0.9
Oola GS	3119	182500	142200	84	9.4
Glenamaddy (Gortnagier)	3127	162900	261600	84	1.0
Cloonacool (Lough Easkey)	3135	144600	320700	204	1.2
Glenbride Lodge	3223	303700	204100	363	5.2
Ballyshannon (Cherrymount)	3237	190100	360400	30	1.0
Poulaphuca (Gen Stn)	3323	294500	208600	174	0.2
Borrisokane GS	3419	191600	194100	59	10.9
Derrygreenagh	3431	249300	238200	90	0.4
Slieve Bloom Mtns (Nealstown)	3513	219900	193600	219	0.6
Cloughjordan GS	3519	197200	187900	94	5.1
Carrigadrohid (Gen Stn)	3604	140500	72000	67	1.7
Ballymacarbery GS	3612	219300	112800	59	2.4
Kilkenny	3613	249400	157400	65	1.0
Graiguenamanagh	3614	271100	143100	27	1.2
Shinrone GS	3619	204500	192500	70	6.6
Inishcarra (Gen Stn)	3704	154500	72200	24	0.3
Ballymore Eustace DCWW	3823	293300	209200	172	4.1
Dublin (Merrion Square)	3923	316400	233500	13	0.0
Drumkeeran (Voc Sch)	3929	190600	324500	110	5.9
Ardnacrusha (Gen Stn No. 2)	4011	158500	161800	28	1.6
Drangan (Moanvurrin)	4112	228500	142200	122	1.1
Lecarrow	4129	196900	254900	47	0.3
Leixlip (Gen Stn)	4223	300700	235800	42	0.5
Scariff GS	4519	163900	184000	46	4.3
Cahir (Voc Sch)	4612	205400	125200	53	5.3
Silvermines Mtns (Curreeny)	4819	190100	164700	312	0.6
Birr	4919	207400	204400	72	1.3
Bansha (Aherlow WW)	5012	191700	128400	128	1.2
Clonmel (Redmondstown)	5512	223400	124700	64	0.8
Glenasmole (Castlekelly)	5523	310200	220800	183	1.4
M Beenreagh Mtn	8905	66100	85400	491	8.5
M Ballaghbeama Gap	9005	75500	78300	311	1.3
M Cummeragh No. 1	9103	61000	71700	305	1.7
M Cummeragh No. 2	9203	63400	71200	404	1.3
M Oolagh Mtn	9205	73700	90000	235	5.3
M Duff Hill	9220	308700	207200	701	5.2
M Cummeragh No. 3	9303	64100	70400	543	4.4
M Cummeragh No. 4	9403	62000	69400	494	4.1
M Cummeragh No. 5	9503	58200	68700	396	4.3
M Torc Mangerton No. 4	9505	97900	81700	701	7.4
M Cummeragh No. 6	9603	63400	75100	351	5.4

Table A1.1. Continued

Station name	Met Éireann ID	Easting	Northing	Elevation (m)	Months missing (%)
M Ballingeary (Meelin Mtn)	9604	114000	71600	341	6.0
M Torc Mangerton No. 4A	9605	98400	82900	518	6.6
M Glentornan (Grogan More)	9641	185700	418500	442	9.2
M Ballingeary (Tooreenaneen)	9704	113100	64500	323	1.4
M Torc Mangerton No. 5	9705	99600	82600	283	7.3
M Glentornan (L Nabruckbaddy)	9741	186400	418400	366	11.4
M Ballyvourney (Knockacommeen)	9804	116000	80700	415	1.9
M Owenea (Lough Shivnagh)	9841	187400	391600	276	7.3
M Inchigeelagh (Pipe Hill)	9904	120100	62100	299	3.7
M Dundalk (Ballymakellett)	9938	310600	312500	232	2.0
M Lough Eske (Burns Mtn)	9940	194300	384200	274	4.6
M Greencastle (Craughaulin Mtn)	9942	262500	442000	320	4.9
M Ballinatona	19023	305300	213300	297	7.4
M Brockey Lodge	19123	309400	213200	305	10.9
M Moanbane No. 1	19323	303300	204700	500	4.7
M Moanbane No. 2	19423	302900	206000	643	7.8
M Moanbane No. 4	19523	304400	205100	354	4.6
M Sally Gap	19723	312600	211100	462	5.4
M Wicklow Gap	19923	306700	200500	415	6.6

GS, Garda Station; M, Mountain; OPW, Office of Public Works; WW, Water Works.

Table A1.2. The list of UKMO NI station identifiers with corresponding geographical data and percentage of entire months missing values, 1941–2010

Station name	UKMO SRC ID	Easting	Northing	Elevation (m)	Entire months missing (%)
Armagh	1530	260000	350000	62	0.0
Annalong Valley	16478	330000	320000	130	0.9
Copeland Res	16353	340000	390000	118	5.1
Crom Castle	16507	230000	320000	58	1.4
Dorisland Res	16365	330000	380000	131	2.6
Woodburn North Reservoir	1478	330000	390000	217	2.5
Aldergrove	1450	310000	380000	68	9.9
Hillsborough	1489	330000	360000	116	3.1
Barons Court	1544	230000	380000	132	11.2
Orlock Resv	16421	350000	380000	34	18.6
Beleek	16548	190000	350000	47	25.7

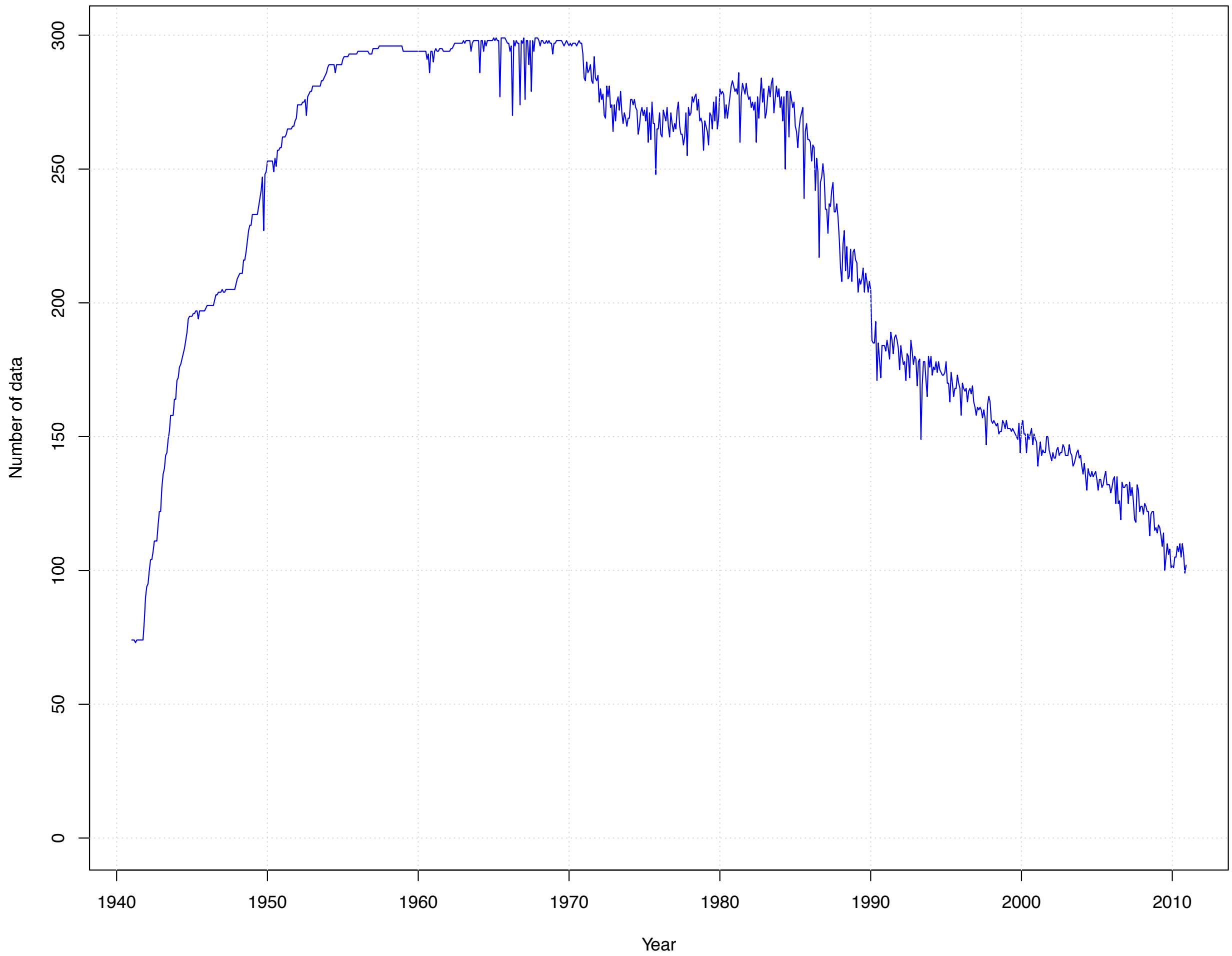

Figure A1.1. HOMER-derived summary of the overall intact and absent monthly data for the 299 series in the 1941–2010 IENet analysis. The blue line denotes the greater number of available records for the 1960s–1980s, relative to the earlier and later decades.

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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HOMERUN: Relative Homogenisation of the Irish Precipitation Network

Climate - Water - Sustainability
Identifying pressures • Informing policy • Developing solutions

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Identifying Pressures

A homogeneous climate time series is defined as one where variability is only caused by changes in weather or to the climate. Most decade to century-scale time series of atmospheric data have been adversely impacted by inhomogeneity caused by, for example; changes in instrumentation or observer practices, station moves, or changes in the local environment. Some of these factors can cause abrupt shifts; others gradual changes over time, which can hamper identification of genuine climatic variations or lead to erroneous interpretations. The increasing interest in climate modelling has also spurred the need for homogenized data in order to improve confidence in the observed series against which model simulations can be evaluated. In the work here we present selected results from two state of the art relative homogenization methods applied for the first time in Ireland.

Informing Policy

Accurate climate data is an essential prerequisite for basing climate related decision making on. Hence the provision of quality controlled homogenized climate data are becoming integral to efforts across many countries to deliver climate services. Such quality controlled and homogenised series will become one part of an envisaged delivery chain for endpoint data provision to the impacts and policy communities. Recognising this, there is already an identified need for Ireland to engage with the current EU Joint Programming Initiative Climate and Horizon 2020 initiatives in order that an entity or consortium to provide climate services can be provided. The work presented and ongoing collaborations extending the methods and scale of the network will deliver a repository of homogenous and robust precipitation time series to help inform future decisions in Ireland.

Developing Solutions

The modern relative homogenization methods applied to Irish precipitation data presented here have had limited application to observed precipitation data and relatively few results applying the methods to precipitation data have been published to date. Features of Ireland's maritime climate and the dense network of quality controlled station data available lend themselves to the ongoing test development of relative homogenization methods such as HOMER and ACMANT. It is proposed that the work applying these and other relative homogenization methods to the excellent resource that Irish data provides should continue. This offers the win-win prospect of method development gains for the wider homogenization community and a spin-off for Ireland via the provision of high quality datasets for improved climate-based decision making and climate model evaluation.

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