Future changes in fog frequency from the UKCP09 ensemble of regional climate model projections

UKCP09 additional product
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1 Introduction

The UK Climate Projections 2009 (UKCP09) were launched in June 2009. The centrepiece of these consisted of probabilistic projections of changes in a set of key climate variables, expressed as changes in 30-year averages for a set of overlapping periods during the 21st century, relative to a baseline historical period of 1961–1990. Projections were provided for each of three separate ‘High’, ‘Medium’ and ‘Low’ pathways of possible future emissions of greenhouse gases and aerosols. For each emissions scenario, results were provided on a 25 km grid, and also for aggregated river-based and administrative regions. The projections were derived from a comprehensive methodology involving several ‘perturbed physics ensembles’ of global projections carried out using alternative variants of version 3 of the Met Office Hadley Centre (MOHC) climate model. These were designed to sample uncertainties in model parameters controlling the simulation of key physical and biogeochemical processes. The ensembles amounted to more than 300 simulations in all, augmented by projections from an ensemble of 12 alternative global climate models developed by international modelling centres. These were converted into probabilistic projections using a statistical framework designed specifically for the task, which allowed the model projections to be combined with expert assessment of uncertainties in model parameters, and observational constraints on model credibility derived through evaluation against a set of historical climate observations. Finally, the global model results were downscaled to a resolution of 25 km using 11 variants of the MOHC regional climate model (RCM), (Murphy et al. 2009).

However, it was not possible to produce probabilistic projections for all climate variables of potential interest to users, for a variety of reasons. Therefore, a further set of reports is being produced to summarise the advice that can be given for several additional variables, specifically wind speed, fog, lightning and snow. In all cases, the advice is based on an ensemble of 11 RCM projections run at 25 km resolution, forming part of the wider suite of simulations carried out for UKCP09 (see Section 4 for more details). This report describes projections of the frequency of occurrence of fog derived from the RCM simulations.
2 Why are we interested in changes in fog frequency?

Fog consists of an aggregation of suspended water droplets or ice crystals immediately above the surface of the Earth, giving rise to a reduction in visibility below 1000 m. It can have a substantial effect on transport activities, road, rail, air and marine, causing widespread disruption, accidents and deaths, and resulting in significant financial costs. Hence there is a requirement for projections in changes to the frequency of fog due to man-made greenhouse gas and aerosol precursor emissions. The report accompanying the UKCIP02 projections (Hulme et al. 2002) comments that, for the Medium–High Emissions scenario by the 2080s, some 20% fewer fog days in winter might be expected across all areas of the UK.

Fog forms when moist air is cooled below its dew point or frost point and some of the water vapour condenses into water droplets or ice crystals. This cooling can occur in several ways; in the UK the main causes are (a) when moist air is blown up the slope of a hill and the ascent causes it to cool (hill fog), (b) when the ground cools on clear still nights and cools the air above it by contact (radiation fog), and (c) when mild, moist air (typically from the west or southwest) is cooled as wind blows it over cold ground (advection fog).

3 How do we estimate the occurrence of fog from the regional climate model simulations?

The RCM calculates visibility using the scheme of Clarke et al. (2008). Using a visibility threshold of 1000 m as an indicator of the presence of fog, it calculates at each model time step the probability of the grid box having a visibility below this threshold value. This can be interpreted as the fraction of the grid box that has fog (the fog fraction, FF). Visibility depends upon relative humidity (RH) and aerosol number density, although in this case we assume a constant value for the aerosol number density. Using the fog fraction output, we have defined a fog day as one on which the maximum FF at any timestep during the 24 hour period is 1.0. The value of 1.0 was chosen because the fog climatology derived from it is in closest agreement with observations (though not perfect – see section 6.3). There is a degree of interpretation involved in this definition, as discussed in Section 6.3. Fog may occur due to different mechanisms, as described above, but the phenomenology is not considered here.

4 What projections can we give for changes to fog?

As mentioned in the Introduction, the UKCP09 methodology included an ensemble of 11 variants of the MOHC regional climate model, each sampling different but plausible values for multiple model parameters controlling key surface and atmospheric physical processes. This RCM ensemble provided downscaling information which was used to convert projections specified at 300 km scale from GCM simulations to a finer resolution of 25 km, hence playing a key role in the probabilistic projections made for UKCP09. It is this ensemble of RCM variants that are used in this report to provide projections of changes in the number of fog days.

The 11 RCM variants were run from 1950 to 2099 under the UKCP09 Medium Emissions scenario, using the European domain shown in Figure 3.8 of Murphy et al. (2009). They were driven at the lateral boundaries by a time series of atmospheric variables (such as temperature and winds) saved from an ensemble of projections using 11 variants of the MOHC GCM. Time series of sea surface temperatures and sea-ice extents were also prescribed from the GCM simulations. Each of the 11
variants in the RCM ensemble was configured from the corresponding variant of the GCM ensemble, using the same representations of atmospheric dynamical and physical processes, including perturbations to model parameters matching those implemented in the relevant driving global projection. Like most global climate models, members of the GCM ensemble simulate the main characteristics of the observed atmospheric circulation with considerable skill, however there are inevitably also biases at regional scales.

The potential advantages of projections from RCMs are that they can capture detailed spatial contrasts not resolved in the global models, particularly those arising from mountains and coastlines, and that they can capture climate variability and extreme events more faithfully, particularly aspects arising from regional-scale processes. However, they also inherit larger scale biases from their driving global simulations. In addition, the way in which fog is diagnosed in the model is also subject to uncertainties.

5 Why couldn’t we give probabilistic projections of changes to fog in UKCP09?

Fog fraction, the specific diagnostic required for our calculation of fog occurrence, was archived from the 11-RCM projections discussed above, but not from the larger suite of 300-plus GCM projections used to produce probabilistic projections. It is not possible to provide probabilistic projections without appropriate data from the GCM projections, as the RCM ensemble in isolation only samples a subset of the range of the known modelling uncertainties which must be accounted for to provide credible probabilities (see also Section 6.3). Even if the fog fraction diagnostic had been saved from the GCM projections, the same diagnostic would not have been available from other international climate models which are included in the probabilistic methodology. We use one particular approach in this report (see Section 3), but other plausible methods would need to be considered in any probabilistic calculation.

UKCP09 does include probabilistic projections of relative humidity. However, these are monthly (or longer) averages, and a probabilistic estimate of changes in fog days derived from RH would require probabilistic projections of how often the daily maximum RH exceeds the value needed to give a fog fraction of 1.0. In addition, there is uncertainty in how fog is derived from climate model output, and we have investigated only one plausible method containing a number of assumptions, as discussed in Section 3.
6 Validation of fog in the RCM ensemble

Before using climate model simulations to estimate future changes in any variable, it is important to validate the model's historical simulation of that variable, by comparing simulated and observed climatological values for a baseline period – taken here as 1961–1990.

6.1 Observations for validation
Ideally, the model simulation of a particular climate variable is compared with a gridded observed field at the same resolution, which is generated from observations at a large number of stations. Unfortunately, no gridded observations are available of any measure of fog. Instead we use what is available, namely 30 years (1961–1990) of observations of fog occurring at 09Z from 10 (geographically widely spread) stations around the UK — see map of locations in Figure 1. Table 1 shows this analysis; data is from the CARLOS database of the Met Office's National Centre for Climate Information which derives its station statistics from the MIDAS database (Ward and Cowley, 1997).

6.2 Model simulations
The fog fraction diagnostic from the RCMs was used as described in Section 3, to decide if a particular model day was a fog day. The number of fog days in each season was accumulated, then averaged over the 30 year baseline period, and then finally averaged over all eleven RCM variants. The maps of simulated number of fog days are shown in Figure 2. In order to compare with observations, the seasonal means for RCM grid squares containing the observation stations in Table 1 were output.

Table 1: Mean number of days with fog at 09Z in each season, over the period 1961–1990. Winter is December, January and February (DJF), spring is March, April and May (MAM), summer is June, July and August (JJA) and autumn is September, October and November (SON).
6.3 Comparison of model and observed climatology

The modelled and observed annual numbers of fog days at each station, averaged over 1961–1990, are shown in Table 2. The ratio of modelled value to that observed is shown in the last column; it varies considerably from station to station, and also from season to season (not shown). The modelled annual number of fog days averaged over all stations is a factor of 1.36 bigger than that observed.

There could be several possible reasons for this discrepancy:

a. We are comparing fog at a single time (09Z) in the observations, with a model diagnostic based on selecting the time of day most likely to have given fog on any given day. In the absence of other sources of bias, this would tend to lead to an overestimation of an observed frequency based on one specific time of day.

b. There could be biases in the relative humidities simulated by the RCM. To examine this possibility we compared 1961–1990 seasonal mean RH fields (averaged over all 11 RCM variants) from the model with those in gridded observations supplied by NCIC. In general the model simulations replicate the observed values quite well (not shown), however even relatively small biases in the mean RH could potentially affect the frequency of occurrence of the high values of RH associated with fog formation (see also section 7.1). The RCM ensemble tends to overestimate slightly observed mean values of RH over much of Scotland and Northern Ireland in autumn and winter, which is likely to contribute to the large positive biases in fog days found at Dyce, Turnhouse and Aldergrove (Table 1).
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In order to see how the seasonal pattern and the geographical pattern of days with fog compared between modelled and observed, each of the observations was multiplied by a factor of 1.36, to bring the annual average over all stations into agreement with the model simulation.

<table>
<thead>
<tr>
<th>Station</th>
<th>Observation</th>
<th>Model mean</th>
<th>Model/Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyce</td>
<td>4.6</td>
<td>15.5</td>
<td>3.370</td>
</tr>
<tr>
<td>Turnhouse</td>
<td>7.9</td>
<td>16.1</td>
<td>2.038</td>
</tr>
<tr>
<td>Aldergrove</td>
<td>7.7</td>
<td>14.3</td>
<td>1.857</td>
</tr>
<tr>
<td>Valley</td>
<td>4.2</td>
<td>2.7</td>
<td>0.643</td>
</tr>
<tr>
<td>Ringway</td>
<td>10.4</td>
<td>16.9</td>
<td>1.625</td>
</tr>
<tr>
<td>Watnall</td>
<td>26.9</td>
<td>18.2</td>
<td>0.677</td>
</tr>
<tr>
<td>Rhoose</td>
<td>10.7</td>
<td>15</td>
<td>1.402</td>
</tr>
<tr>
<td>Heathrow</td>
<td>11</td>
<td>12.6</td>
<td>1.145</td>
</tr>
<tr>
<td>St Mawgan</td>
<td>10.9</td>
<td>17.8</td>
<td>1.633</td>
</tr>
<tr>
<td>Hurn</td>
<td>4.9</td>
<td>6</td>
<td>1.224</td>
</tr>
<tr>
<td>All stations</td>
<td>99.2</td>
<td>135.1</td>
<td>1.362</td>
</tr>
</tbody>
</table>

Table 2. Annual average number of fog days, 1961–1990, as observed at 10 stations, as simulated by the RCM ensemble mean for the corresponding grid squares, and the ratio of model simulation to observation.

summer, the simulated mean values of RH are typically several percent too low over much of southern and central England, however this will have only a limited influence on the results of Table 1, as the annual average values of fog days are dominated by contributions from the autumn and winter seasons. More generally, we note that the simulated frequency of fog for any location and season will also depend on how well the model replicates the observed variability of daily values of RH, as well as the long term mean value. However, a detailed analysis of the characteristics of simulated RH time series is beyond the scope of this report.

c. The parametrisation which calculates fog fraction within the model could contain biases. For example, the aerosol density was a fixed number for all seasons and places, and this is likely to be a source of error.

d. We are comparing observations at a single point with model simulations over a 25 km x 25 km grid square. Our calculation (section 3) actually produces a diagnostic representing the fraction of a model grid box covered by fog. This is not directly comparable with an observed dataset based on discrete yes/no observations at a single site. We convert our time series of spatial coverage diagnostics into an estimated discrete time series for a point location by specifying a value of unity only if the spatial coverage is predicted to be 100%, specifying zero (no fog) otherwise (see Section 3). However the threshold for converting the spatial coverage diagnostic into a yes/no specification for a point location is not well defined. In practice we chose 100% because this gives the best verification against the observations (Table 1).
Figure 3 shows a seasonal comparison, aggregated over all stations. It is seen that the basic observed seasonal distribution, with most fog occurring in winter, followed by autumn then spring and finally summer, is replicated qualitatively in the model. However the normalised values still show a positive bias in winter, with a compensating negative bias in summer. This supports the suggestion in section 5.3b that the seasonal cycle of biases in mean RH may be a contributory factor to the biases in fog frequency.

![Figure 3: Comparison of observations of total number of fog days at all stations, for each season and annually, multiplied by a factor of 1.36, averaged over 1961–1990 (pink), and as simulated by the 11–RCM mean (blue). The annual totals have been forced to agree.](image1)

Figure 4 shows comparisons of the normalised annual totals at each station. Station-by-station variations in the observed totals are tracked by the simulated values to some extent, although there are significant differences at Watnall, Dyce and Valley. This shows that biases in the simulated annual totals vary with location, and cannot in reality be characterised by a single number.

Given that the average factor of 1.36 difference between observed and modelled frequency of fog days is not unduly large, and can probably be explained by some combination of the potential causes discussed above, and that the model simulates a reasonable seasonal and geographical behaviour, we conclude that the RCM simulations can be used to investigate plausible projections of changes to fog in the future. These are shown in the next section.

![Figure 4: Comparison of observations of annual number of fog days multiplied by a factor of 1.36 averaged over 1961–1990, at each station (pink), and as simulated by the 11 RCM mean (blue).](image2)
This raises the question of whether the biases in the historical simulation of number of fog days, shown and discussed above, affect the credibility of the future changes projected by the RCMs. In general, regional changes in climate in response to anthropogenic forcing can arise from a complex combination of many potential remote and local influences. The relative influences of processes that drive the changes may not necessarily be the same as those responsible for present day climate. While the evaluation of past performance in simulating fog is an important check, it should not be assumed either that a reasonable historical simulation guarantees a credible projection of future changes, or that the presence of biases in the historical simulations (provided they are not too large) precludes the possibility of obtaining credible future projections.

7 Predicted changes in fog days by the 2080s

7.1 Changes at 25 km resolution

Each of the RCM variants was run from 1950 to 2099, forced from 1990 by the UKCP09 Medium Emissions scenario (IPCC SRES A1B). The fog fraction diagnostic from each of the RCM simulations was used, as explained in Section 3, to calculate the number of fog days in each season, and this was averaged over two 30 year periods: 1961–1990 (also used for the validation described earlier) and the 2080s (2070–2099). For each RCM variant, the change between the values for the 2080s and those in the baseline period of 1961–1990 was calculated as a percentage. The percentage changes from all 11 variants were then averaged, and this average change is shown in Figure 5, for each season. Note that although we have chosen here to average changes from all the 11 RCM ensemble members, there is no guarantee that the ensemble average will then represent either a ‘most likely outcome’, or an outcome that is more credible than any of the individual projections.

The map of changes shows, in summary, that reductions in the number of days with fog are projected for most places and seasons, with the main exception being southern Britain in winter.

- **In winter**, when fog days are most numerous, the general picture shows that reductions of 50% or more are projected in many areas of northern Britain and north Wales, with increases (in the range 0–30%) over southern and midland areas of England.

- **In spring**, the pattern is similar to that in winter, but reductions tend to be greater. In England, south of a line from Humber to Severn reductions amount to 10–30%, but with some areas where reductions are considerably greater. In north Wales and the rest of the UK, changes are several tens of percent, appearing to be largest on high ground.

- **In summer**, large reductions are projected in most parts of England – but of course these are reductions from what are already generally small frequencies. In parts of northern Scotland and Northern Ireland changes tend to be smaller or, in the case of a few grid squares in Scotland, positive.

- **In autumn**, reductions over most of the UK are generally 10–30%, but much greater than this over the Scottish highlands. As in other seasons, some Scottish islands show increases in fog frequency.
The projected changes in fog days are determined by changes in the frequency with which RH values in RCM grid boxes exceed the value required to give a modelled fog fraction of 1.0 (see Section 3). Changes in the exceedence of this threshold can be affected both by changes in the long term average values of RH, and changes in variability about the average value (see also section 6.3). Typically, the mean values of RH tend to reduce in the future projections (while noting that changes do vary with location and ensemble member, and season – some instances of small increases are also found). Whilst the simulated reductions in mean RH (where they occur) are relatively small (generally 1–2% only in winter, spring and autumn, somewhat larger in summer), these are sufficient in many cases to drive much larger changes in the frequency of exceeding the RH threshold for a fog day, explaining the substantial reductions in fog day frequency shown at many locations in Figure 4.
7.2 Changes in means over administrative regions

The UKCP09 projections are presented at the full resolution of 25 km, and also aggregated in to several larger areas, including administrative regions; these are shown in Figure 1.2b of Murphy et al. (2009). Table 3 shows changes in number of fog days averaged over all locations within each of the UKCP09 administrative regions. The averaging over an administrative region was done by including in the region all model 25 km grid squares which have >50% of their area within the region, and then averaging the changes over all grid squares counted in the region on that basis.

Both the Isle of Man and the Channel Islands exhibit changes which are often out of line with those for their nearest administrative areas over the mainland, so are not included in the following summary.

For all regions outside Scotland, greatest reductions in the number of days with fog (up to –70% in SE England) are projected in summer; in Scotland the greatest reductions (up to –57%) are in spring. The smallest reductions are projected in autumn in the more northerly regions, and in winter in the more southerly regions of the UK where some regions show increases — up to +20% in London.

<table>
<thead>
<tr>
<th>Administrative region</th>
<th>DJF</th>
<th>MAM</th>
<th>JJA</th>
<th>SON</th>
<th>ANN</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Scotland</td>
<td>–45</td>
<td>–57</td>
<td>–43</td>
<td>–28</td>
<td>–47</td>
</tr>
<tr>
<td>Isle of Man</td>
<td>–4</td>
<td>–7</td>
<td>–50</td>
<td>–27</td>
<td>–27</td>
</tr>
<tr>
<td>East Midlands</td>
<td>+2</td>
<td>–34</td>
<td>–66</td>
<td>–20</td>
<td>–25</td>
</tr>
<tr>
<td>West Midlands</td>
<td>+2</td>
<td>–37</td>
<td>–69</td>
<td>–19</td>
<td>–22</td>
</tr>
<tr>
<td>SE England</td>
<td>+7</td>
<td>–42</td>
<td>–70</td>
<td>–31</td>
<td>–24</td>
</tr>
</tbody>
</table>

Table 3. Model projection of percentage changes in number of fog days, from 1961 to 1990 to the 2080s, averaged over administrative regions, for each season and annually. Projections are for Medium emissions, mean of the 11 RCM ensemble members.

Summary of projected changes in the number of days with fog averaged over administrative regions (excluding the Isle of Man and the Channel Isles) for the 2080s under the UKCP09 medium emission scenario:

- **In winter**, Wales, Northern Ireland and northern Britain, administrative regions show reductions of –20% to –55%, with the generally larger reductions further north. Southern, eastern England and the Midlands show changes within a few percent of zero. London shows the largest increase, of 20%.
• **In spring, summer and autumn**, the number of fog days reduces in averages over all administration regions.

• **In spring**, reductions are largest in Scotland (up to –57%) and somewhat smaller further south, with East of England showing –33%.

• **In summer**, reductions are generally greater as we move further south. Fog days are reduced by between –35 and –48% in Scotland and Northern Ireland, but reduced by up to –70% in SE England.

• **In autumn**, reductions are between –11% and –41% everywhere.

Annual mean changes in the number of fog days are negative in all averages over administrative regions, tending to be more negative (~29% to ~52%) in northern Britain, Northern Ireland and Wales, less negative (~19% to ~25%) in southern Britain.

As with other variables, changes in number of fog days in specific 25 km squares within an administrative region can be very different (both in magnitude and sign) from the spatial average of the administrative region shown in the table above. Numbers in this table represent the average changes in fog frequency for 25 km squares within the region, and not the percentage change in the number of days when the entire administrative region is covered in fog.

### 7.3 Uncertainty in changes in fog

So far, we have shown changes averaged over all 11 RCM variants. In order to assess uncertainties in these estimates, we show in Figure 6 maps of percentage change in fog days from all 11 RCM variants separately. It is immediately apparent that there are substantial differences from variant to variant; for example, over central England one model variant shows increases of over 100%, whereas another shows decreases of a few tens of percent. Over northern Scotland all variants simulate reductions at most non-coastal locations, however the magnitudes vary substantially.

In order to try and make this uncertainty easier to assimilate, we show in Figure 7 three maps for each season: the mean over all 11 RCM variants (centre; identical to that in Figure 5), the lowest values of change in every grid square shown by any of the 11 variants (left column) and the highest value of change (right column). Note that, because in the ‘highest changes’ map values can come from any of the 11 RCM variants, adjoining grid squares may have values taken from different model variants. The same applies to the maps showing the lowest changes.

It can be seen that the highest and lowest changes in any grid square can depart considerably from the ensemble mean, and this gives an indication of the uncertainty which should be attached to these estimates. However, the 11 member RCM ensemble represents only a subset of the range of modelling uncertainties included in the UKCP09 probabilistic projections. The latter projections account for a wider range of uncertainty by sampling fully the expert-specified parameter space of surface and atmospheric processes in HadCM3, and also by estimating the effects of uncertainties arising from structural modelling errors in these processes by including results from other climate models, plus further uncertainties arising from carbon cycle, sulphur cycle and ocean transport processes (see also Chapter 5 of Murphy et al. 2009). Consequently, it should not be assumed that even the spread of projections from the 11 RCM variants can be taken as the full range of uncertainty consistent with current understanding.
Figure 6: Model projections of change (%) in the number of fog days in winter, from 1961–1990 to the 2080s under Medium emissions, from each of the 11 RCM variants.
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Figure 7: Projected seasonal mean changes (%) in number of fog days, 1961–1990 to 2080s, under Medium emissions. The centre panels show the mean of all 11 RCM variants, the left and right panels show the projected minimum values and maximum values of change, respectively, for each grid square. Blank grid squares are where the calculation of percentage would have required dividing by zero.
Users who wish to assess more fully the modelling uncertainty could potentially compare the spread of RCM derived results shown in this report with those from other model projections of time-evolving 21st century climate. Sources would include:

- The 17-member GCM ensemble of perturbed physics variants of HadCM3 global model carried out for UKCP09, which samples a somewhat wider range of process uncertainties than those sampled in the 11 RCM projections.

- The multi-model ensemble of projections from alternative global climate models, available from the archive of simulations run for the IPCC Fourth Assessment report (Meehl et al. 2007).

- The results from the EU ENSEMBLES project completed during 2009, where projections are available from a number of alternative RCMs, driven by several GCM projections contributed by different European modelling centres.

In principle, each of these data sources could be used to provide information on changes in fog. However, there are potential complications associated with this. Firstly, some (perhaps most) models do not diagnose and output a fog parameter directly. Even if they do, the type of variable, and the way it has been defined and calculated, is likely to be different from that we have described above in the MOHC RCM. The lack of a direct estimation of fog in a model could be overcome by using an offline calculation, but the required model output to do this (e.g. the maximum RH found within a day) may not have been archived. Users could potentially employ alternative related variables if available, such as the average value of RH within a day, or the instantaneous value at some particular time of day. However, this raises the second issue, namely that users would then have to use a different off-line relationship to infer fog. The nature of the off-line relationship would also likely depend on which climate model projection was being used. For example, output from coarse-resolution global simulations would need different conversion relationships to output taken from regional model simulations, due to the issues in converting grid box climate model variables covering some spatial region into estimates of discrete fog day time series typical of point locations (see Section 6.3d). The existence of appropriate off-line algorithms to deduce fog from other climate model projections would need to be explored. Thirdly, simulations (for a baseline period, for example 1961–1990) would need to be validated against observations. Fourthly, as in the case of the Met Office Hadley Centre RCM ensemble, none of the other ensembles of projections listed above include the effect of feedbacks in the carbon cycle and its associated uncertainties (which are included in UKCP09 probabilistic projections).
8 Summary

The occurrence of fog is important to many sectors of the economy, in particular transport. Projections of future changes in the occurrence of fog can therefore help users plan any required adaptation. No method to credibly derive probabilistic projections of changes in fog has been developed, but a fog diagnostic from the 11-member perturbed physics ensemble of RCM variants used in UKCP09 is used in this report to derive seasonal changes in fog, as measured by the frequency of occurrence of fog days.

A comparison of fog data from the model with that from observations, over the period 1961–1990, shows that the simulations capture observed seasonal and spatial variations reasonably well, although systematic biases are also found. The results indicate that the RCM ensemble can be used to provide plausible estimates of future changes.

Projected changes in the number of fog days, from 1961 to 1990 to the 2080s under Medium Emissions scenario, averaged over all 11 RCM variants can be summarised as follows:

- **In winter**, when fog days are observed to be most numerous, the general picture shows that reductions of 50% or more are projected in many areas of northern Britain and north Wales, with increases (in the range 0–30%) over southern and midland areas of England.

- **In spring**, the pattern is similar to that in winter, but reductions tend to be greater. In England, south of a line from Humber to Severn reductions amount to 10–30%, but with some areas where reductions are considerably greater. In north Wales and the rest of the UK, changes are several tens of percent, appearing to be largest on high ground.

- **In summer**, large reductions are projected in most parts of England – but of course these are reductions from what are already generally small frequencies. In parts of northern Scotland and Northern Ireland changes tend to be smaller or, in the case of a few grid squares in Scotland, positive.

- **In autumn**, reductions over most of the UK are generally 10–30%, but much greater than this over the Scottish highlands. As in other seasons, some Scottish islands show increases in fog frequency.

By examining projections from all 11-RCM variants, we show that the uncertainty in the estimated changes given above is substantial. However, even these uncertainties, derived as they are from a small number of variants of one model, are incomplete, and suggestions are made for sources of information which would allow a more thorough analysis.
References


