UK CLIMATE PROJECTIONS

Modifications to fix the discrepancies between observed baseline climatology and future change in sunshine and vapour pressure

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In September 2010, a UKCP09 user brought to our attention that the outputs from the Weather Generator showed unrealistic changes in future sunshine hours when compared to changes in future cloud cover. We (UEA, BADC & Met Office Hadley Centre) have investigated the issue and this document explains where the problem comes from and how it can be rectified. It is important to note that the problem does not stem from errors in either the probabilistic data or the Weather Generator (WG). It is due to the choice of observed baseline climatology used in generating change factors from the probabilistic projections to drive the Weather Generator. A related issue also occurs with vapour pressure, but the effect is smaller.

Explaining the discrepancies

Before we explain the problem it is useful to clarify the role of change factors in UKCP09. The WG requires a set of future changes from the UKCP09 probabilistic projections. The code behind the User Interface (UI) samples the UKCP09 probabilistic projections to generate the change factors. When the WG is run it reads in these change factors and uses them to perturb the future climate being simulated.

1. Calculating Sunshine

Most of the variables required in the change factors (such as temperature and precipitation) are available in the projections but some have to be derived algorithmically from the available variables. Sunshine is one of these variables and it is calculated from the total cloud cover assuming the following relationship:

SUNSHINE_FRACTION = (1 – CLOUD_FRACTION)

NOTE: This algorithm requires that absolute values are known rather than relative change.

This assumes that the daily fraction of sunshine and the daily fraction of cloud sum to 1. Based on this relationship you would expect a small reduction in cloud cover to result in a small increase in sunshine. Conversely, an increase in cloud cover would lead to a reduction in sunshine.

2. Calculating Vapour Pressure

Vapour pressure is also calculated from other variables derived from the projections, namely relative humidity (RH) and temperature, using the following relationship:

VAP = (17.38 * TEMPERATURE_MEAN)/ (239.0 + TEMPERATURE_MEAN)

SATURATION_VAPOUR_PRESSURE = 6.107 * EXP (VAP)

VAPOUR_PRESSURE = (RH / 100) * SATURATION_VAPOUR_PRESSURE

This relationship will be exact for individual values of vapour pressure, temperature and RH, but will not give the exact answer when the data are expressed as monthly averages, due to the non-linearity of the formula. The change factors used within UKCP09 are monthly averages, so transforming between RH and vapour pressure at this time scale will not give exactly the same as if monthly averages were calculated from daily values.

Method for calculating future change in sunshine and vapour pressure

In order to calculate the future change in sunshine we have to perform the following steps:

1. Take the future change in cloud cover from the probabilistic projections.
2. Combine the future change in cloud cover with an observed baseline climatology[1] (1961–1990 for cloud cover) to get the absolute future cloud cover (rather than relative change).
3. Calculate the absolute future daily fraction of sunshine (using the above equation).
4. Remove the observed baseline climatology of sunshine from the absolute future daily fraction of sunshine to get the future change in daily fraction of sunshine.

The problem that has been identified with sunshine change factors is caused by the use of observed baseline climatologies for which the relationship in the above equation [Sunshine fraction= (1-cloud fraction)] does not hold true. Having corresponded with the producers of the baseline climatologies we can

1 The baseline climatologies are available from the Met Office at: http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/index.html

confirm that the observational baselines, cloud and sunshine, are derived from different measurements and do not always follow the above equation. This is not a problem with the climatologies, the projections or the weather generator. The problem lies in the assumptions that the project team took when deciding how to create the change factors.

For vapour pressure the issue is related. The calculation for this variable has the following steps:

1. Take the future change in relative humidity (RH) and temperature from the probabilistic projections.
2. Combine the future change in RH and temperature with observed baseline climatologies1 (1961-90 for RH and temperature) to derive the absolute future change in vapour pressure (rather than relative change).
3. Remove the observed baseline climatology (of vapour pressure) from the absolute future value of vapour pressure to get the future change in vapour pressure.

The problem with vapour pressure is that three baseline climatologies are used (RH, temperature and vapour pressure). The vapour pressure derived from RH and temperature will differ slightly from that calculated directly from observed monthly vapour pressure averages.

Fixing the problem

The proposed method for fixing the problem is that we create a new baseline climatology from the cloud baseline so that the above relationships remain constant for both the baseline and the future climate. We have discussed this and we believe it is the most appropriate solution. The example calculation below shows the effect of using the existing and proposed methods.

Course of action to make the correction

1. Generate a new baseline climatology for sunshine (derived from cloud cover) and vapour pressure (derived from RH and temperature).
2. Create validation plots of the new climatology to show the difference from the current sunshine and vapour pressure climatologies.
3. Implement the change under the UI so that the new climatologies are used when calculating change factors.

Appendix 1 shows differences in the two observationally-based climatologies for annual and summer averages of sunshine hours and vapour pressure.

Example

The following example demonstrates how a small change in cloud can result in a big change in sunshine using the method that had been used.

DAYLIGHT_HOURS = 10

Using the existing method

Observed baseline climatology values (1961–1990):

BASELINE_CLOUD_FRACTION	=	0.70
BASELINE_SUNSHINE (HOURS/DAY)	=	2
BASELINE_SUNSHINE_FRACTION	=	BASELINE_SUNSHINE (HOURS/DAY) / DAYLIGHT_HOURS
	=	2 / 10
	=	0.2

Future change (UKCP09 probabilistic projections):

CHANGE_IN_CLOUD	=	2% (percentage change)

Future absolute cloud fraction (combining observed baseline and future change):

ABS_CLOUD_FRACTION	=	0.70 + ((2 / 100) * 0.70)
	=	0.714

Future absolute sunshine (derived from future absolute cloud fraction):

ABS_SUNSHINE_FRACTION	=	1 – ABS_CLOUD_FRACTION
	=	1 – 0.714
	=	0.286
ABS_SUNSHINE_HOURS	=	ABS_SUNSHINE_FRACTION * DAYLIGHT_HOURS
	=	0.286 * 10
	=	2.86 (HOURS/DAY)

Future change in sunshine (subtracting observed baseline):

CHANGE_IN_SUNSHINE_FRACTION	=	ABS_SUNSHINE_FRACTION – BASELINE_SUNSHINE_FRACTION
	=	0.286 - 0.2
	=	0.86
PC_CHANGE_IN_SUNSHINE	=	(CHANGE_IN_SUNSHINE_FRACTION / BASELINE_SUNSHINE_FRACTION) * 100
	=	(0.86 / 0.2) * 100
	=	43% (percentage change)

A +43% change in sunshine from a +2% change in cloud is clearly unrealistic.

Correcting the method

Alternatively, we can use the baseline CLOUD to calculate a proxy for baseline SUNSHINE. In the equations below "M2" refers to "Method 2" which calculates the baseline sunshine fraction from the baseline cloud fraction.

Baseline climatology values (1961–1990):

M2_BASELINE_SUNSHINE_FRACTION = 1 – CLOUD_FRACTION
= 1 – 0.70
= 0.30

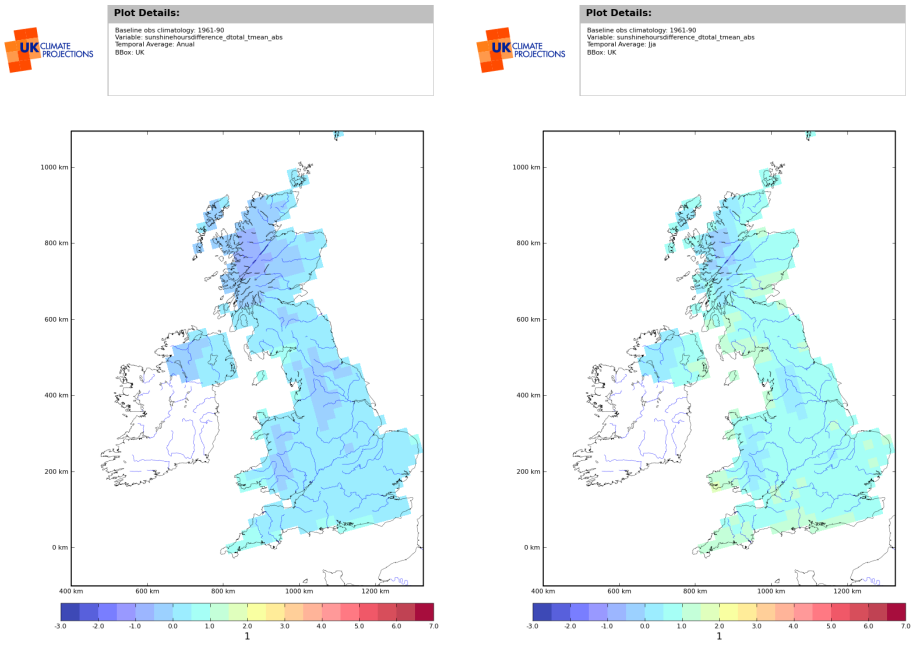
Future change (subtracting baseline derived from cloud):

CHANGE_IN_M2_SUNSHINE_FRACTION = ABS_SUNSHINE_FRACTION – M2_BASELINE_SUNSHINE FRACTION
= 0.286 – 0.3
= -0.014

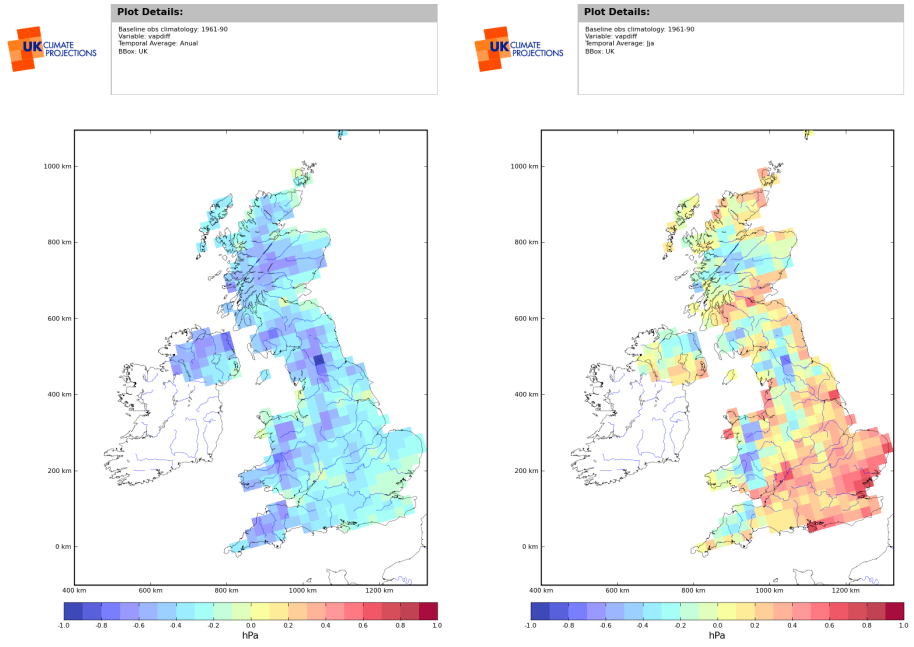
PC_CHANGE_IN_M2_SUNSHINE = (CHANGE_IN_M2_SUNSHINE FRACTION / M2_BASELINE_ SUNSHINE_FRACTION) * 100
= (-0.014 / 0.30) * 100
= -4.67% (percentage change)

A -4.67% change in sunshine from a 2% change in cloud is realistic given that most of the day in question was cloudy. Also, contrary to method 1, an increase in cloud results in a decrease in sunshine. This is the expected relationship between the two variables.

Appendix 1: Differences in the climatologies



a) Sunshine [As measured (OLD) minus Derived from cloud (NEW)] – plotted in hours



b) Vapour pressure [Derived from RH and temperature (NEW) minus Derived from vapour pressure (OLD)] – plotted in hPa