Met Office
Hadley Centre

Comparison of daily sunshine duration recorded by Campbell-Stokes and Kipp & Zonen sensors

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Outline

- Our maps and statistics of UK weather for each month – including sunshine duration
- Produced from station observations using our gridding method
- But – there are two kinds of instrument for measuring sunshine, and the readings from these are not identical, so we need consistency

Outline

Examples of sunshine anomaly maps

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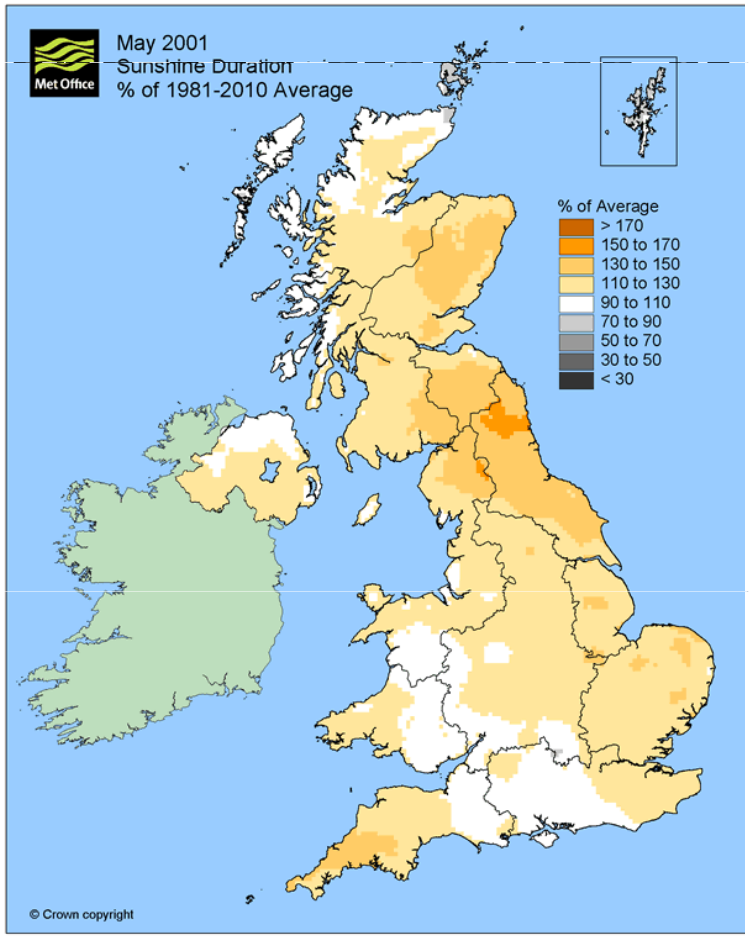

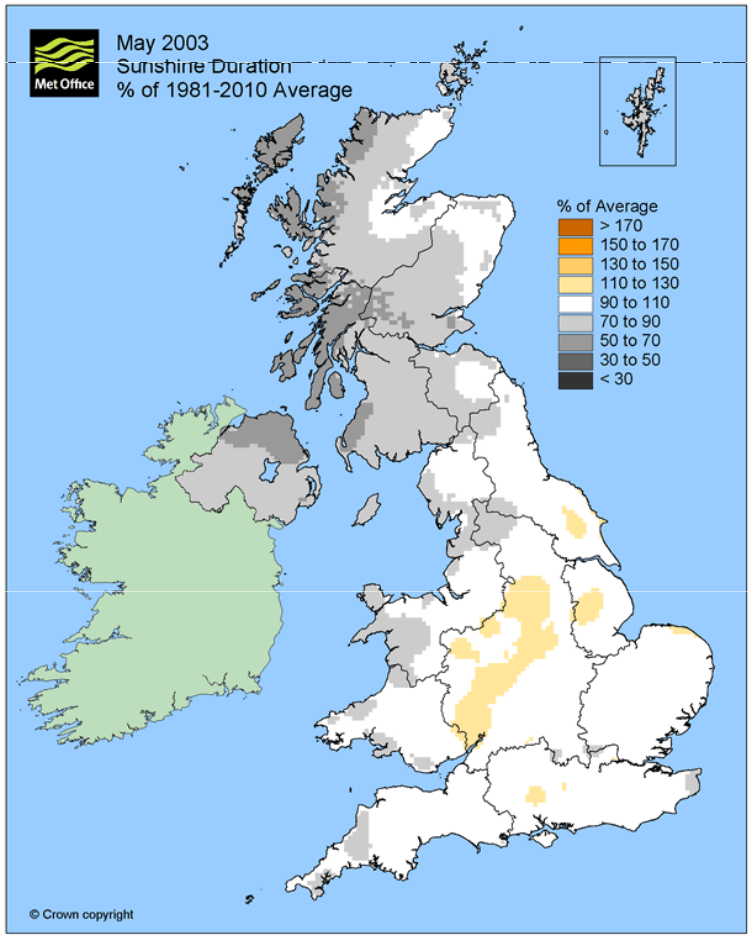

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Background

Background

- The Campbell-Stokes (C-S) sunshine recorder is gradually being replaced by the automatic Kipp & Zonen (K&Z) sensor for the measurement of bright sunshine duration at UK meteorological observation sites, although C-S recorders still currently dominate in the full climatological network.
- Here we demonstrate potential improvements to the method used to homogenise the UK sunshine series, in terms of adjusting K&Z daily sunshine totals to estimated C-S equivalents.

Background

Differences arise between daily sunshine totals measured by the C-S and K&Z instruments, mainly due to the ‘over-burn’ tendency of the C-S recorder in intermittent sunshine.

These differences will depend on the type of weather experienced. The over-reading tendency of C-S recorders should be minimal on days that are overcast or totally sunny, and will be greatest on days of broken cloud when the sun is “in and out”.

Background

Any correction method we use will therefore work best if we can distinguish “broken cloud” days from clear or overcast days.

Our previous work explored relationships between monthly totals measured by K&Z and C-S instruments.

Here we propose to adjust our monthly sunshine totals by obtaining formulae based on individual daily amounts, so we will adjust each individual day’s sunshine amount and then sum all the days to get monthly totals.

This should reduce the uncertainties in estimates of ‘C-S equivalent’ monthly sunshine totals for individual stations.

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Note: although we have noted that the C-S over-reads, our adjustments are made to K&Z to generate ‘C-S equivalent’ estimates of sunshine duration, for historical consistency – in order to maintain homogeneity

This should reduce the uncertainties in estimates of ‘C-S equivalent’ monthly sunshine totals for individual stations.

Methodology

Data used:-

- Sixteen stations operated both C-S and K&Z recorders simultaneously for at least a year; the overlap period was 5-6 years at Camborne, Waddington and Lerwick. Thus we could compare daily sunshine readings from the two instruments.

  The best balance between sample size and capturing true seasonal & geographical variations was achieved by pooling together all stations and generating a separate adjustment equation for each calendar month (with r-squared values mostly 0.95 to 0.97).

Methodology

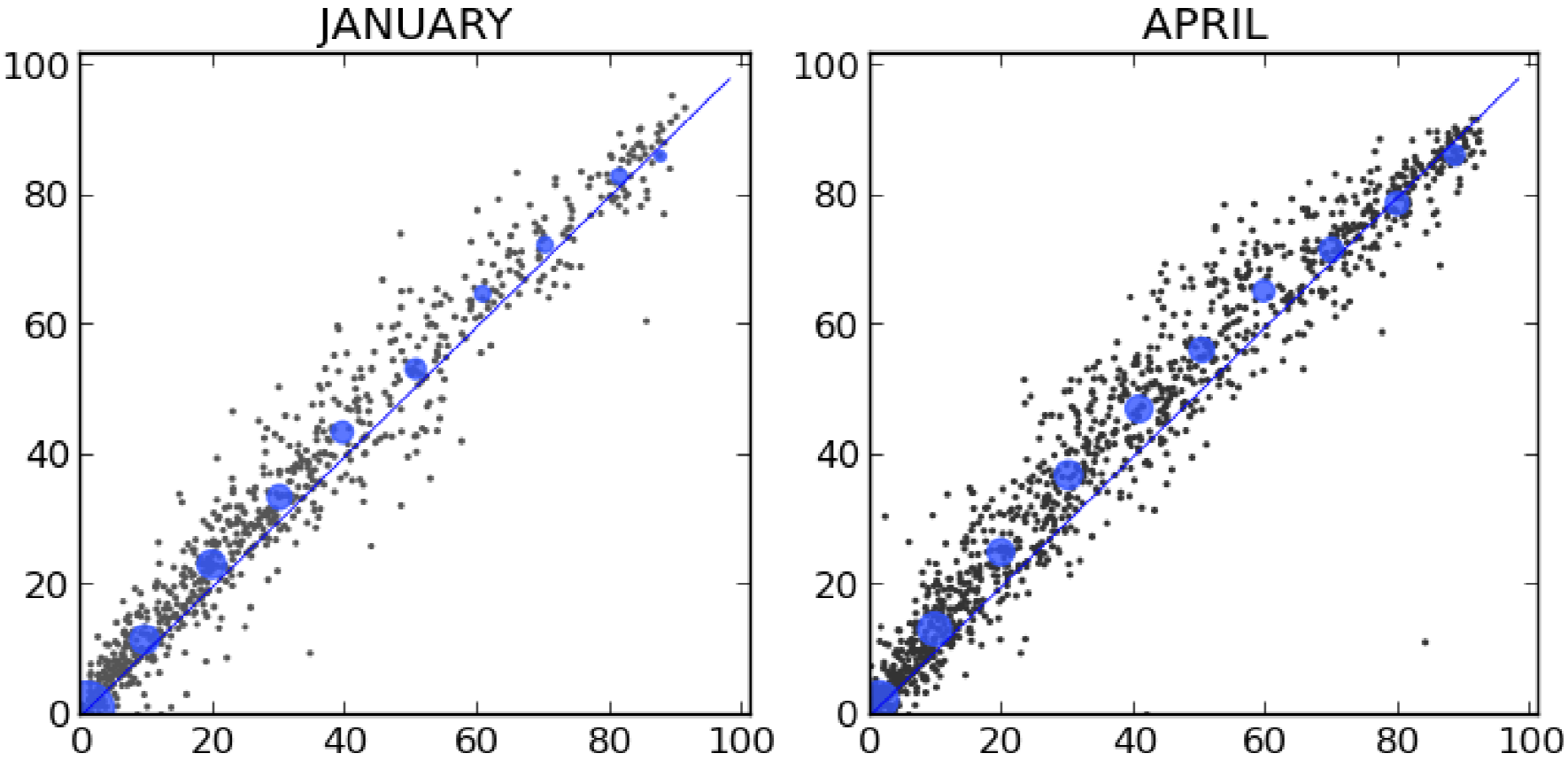
- Scatterplots of the daily C-S v K&Z data (expressed as percentages of the maximum possible daily sunshine amount) are shown on the next two pages, for January, April, July and October.
  Mid-range C-S daily sunshine amounts mostly exceed K&Z, as expected; however at either end values agree more closely.

- A second-order equation (for each calendar month) is used, of the form

  $$CS = c + d.KZ + e.KZ^2$$

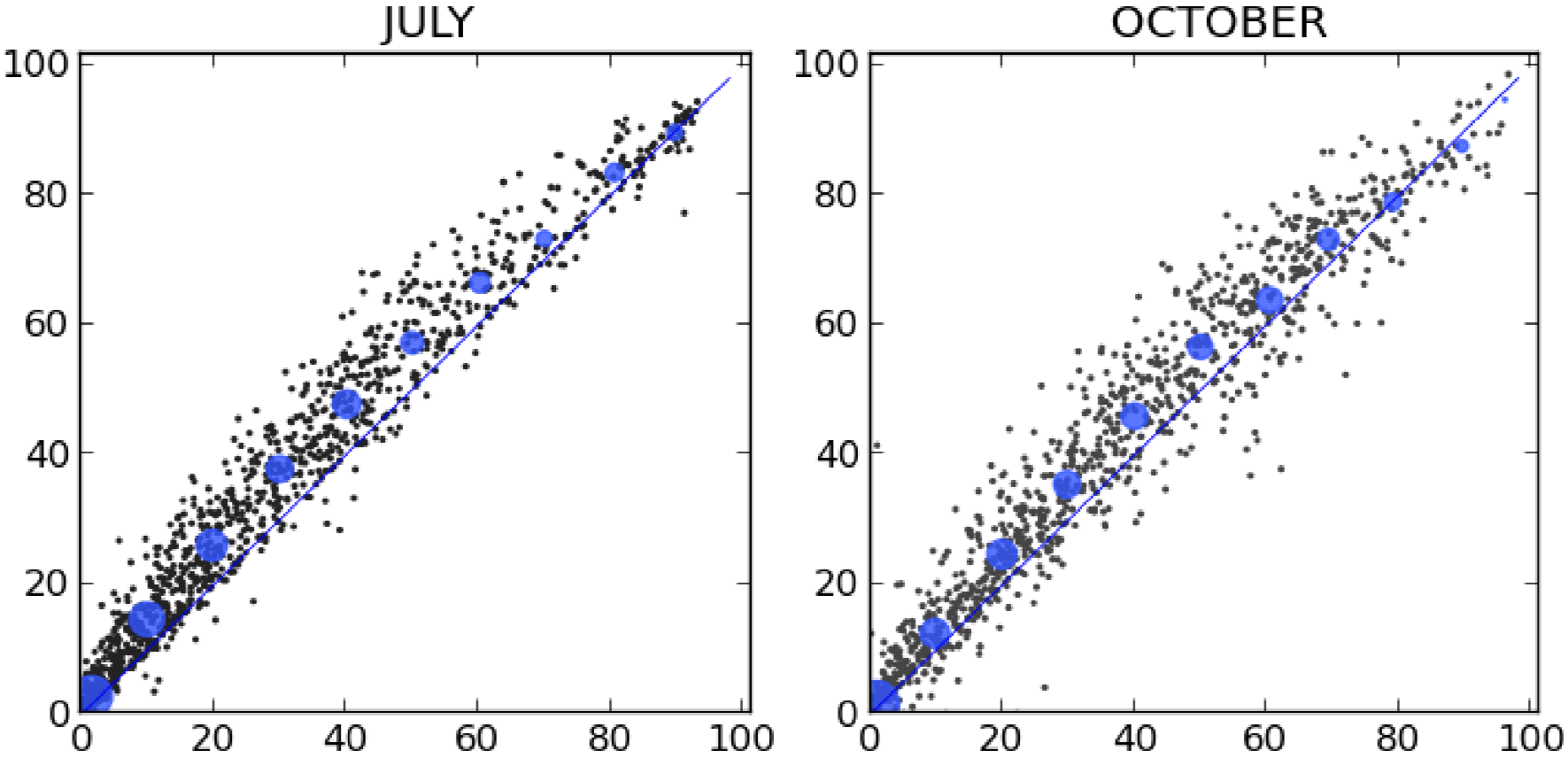
  The relationship is more strongly curved (i.e. the quadratic term ‘e’ is greatest in magnitude) in the spring and summer months.

Scatterplots



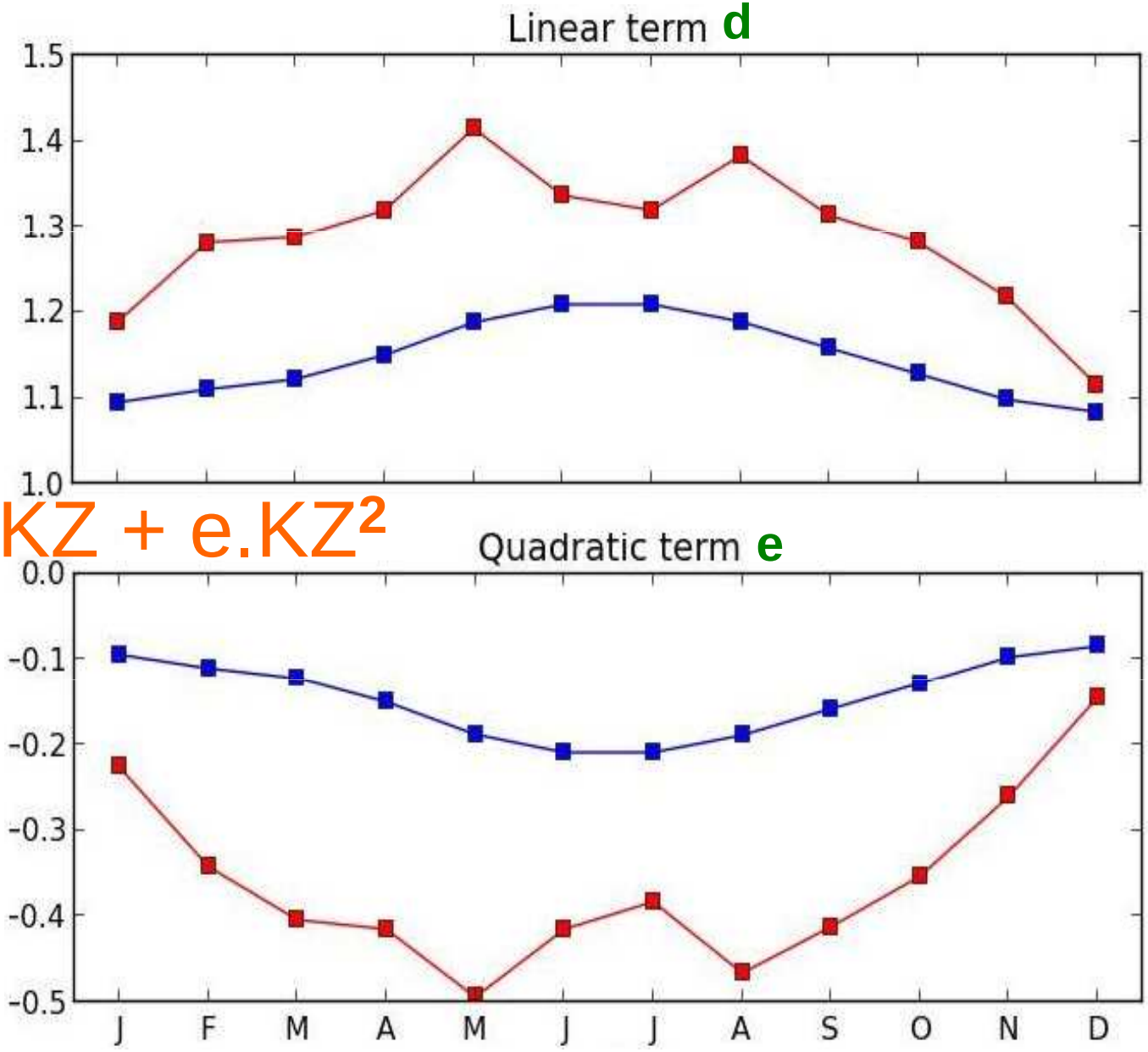
Scatterplots of daily sunshine amounts, expressed as percentages of the maximum possible, from all available station data, during the months of (left) January; (right) April.
X-axis represents K&Z observations, y-axis C-S. Larger blue dots represent these data binned into 10% ranges; size of dots proportional to no. of obs. in each bin.

Scatterplots



Scatterplots of daily sunshine amounts, expressed as percentages of the maximum possible, from all available station data, during the months of (left) July; (right) October.
X-axis represents K&Z observations, y-axis C-S. Larger blue dots represent these data binned into 10% ranges; size of dots proportional to no. of obs. in each bin.

Equations

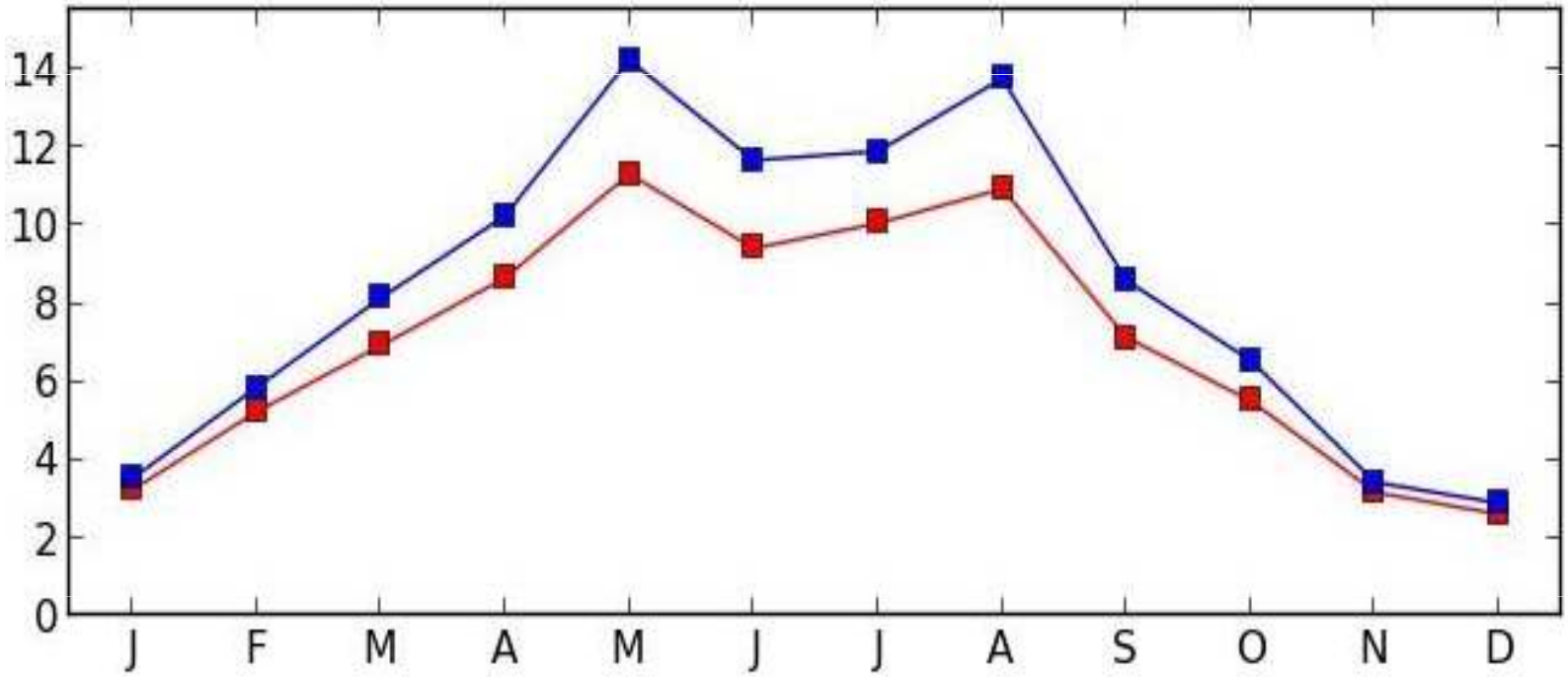


$$CS = c + d.KZ + e.KZ^2$$

Verification : Error statistics

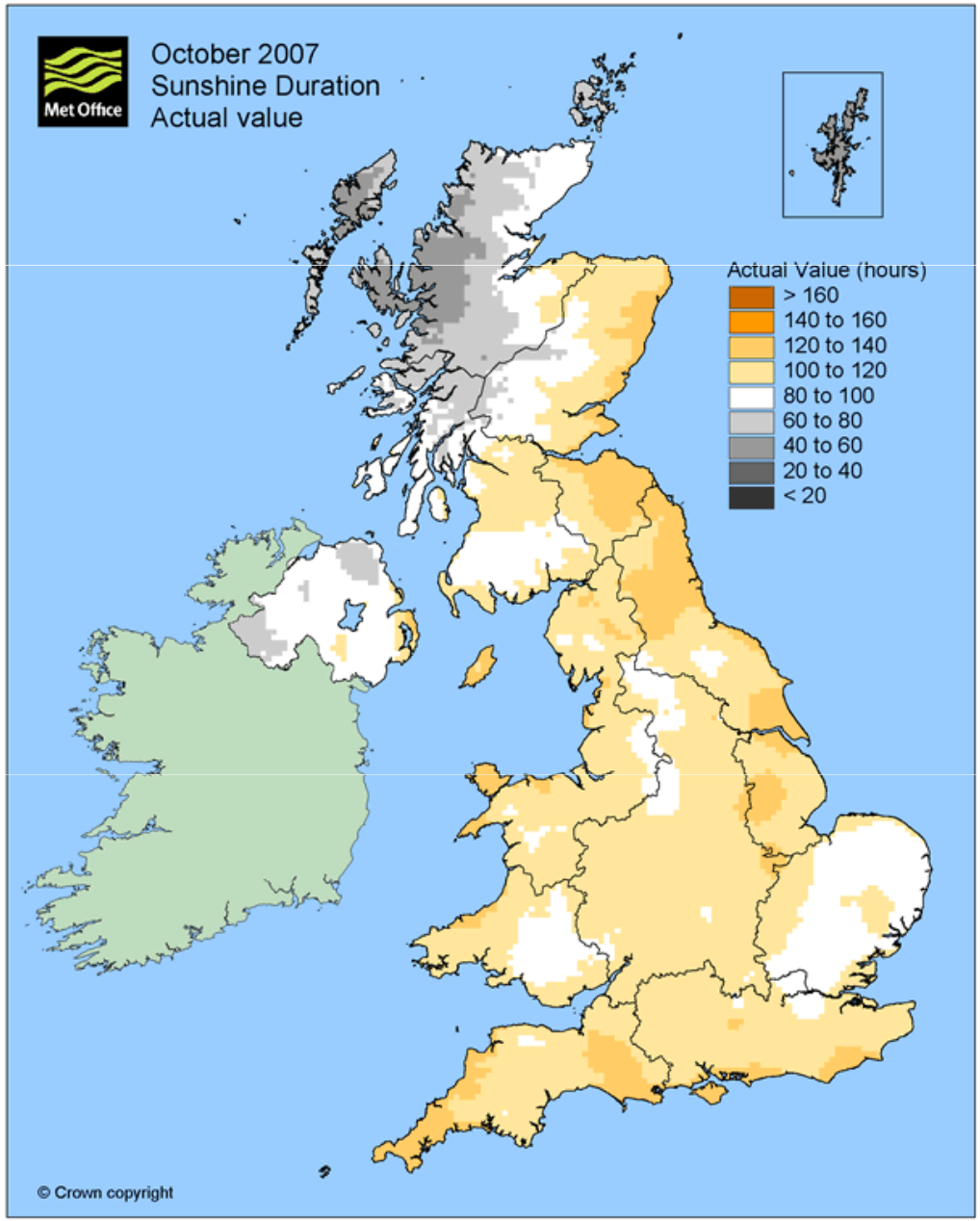
- The K&Z daily sunshine amounts were used with our new equations to ‘predict’ how much sunshine the C-S recorder would have measured, for all days within the overlapping data period.
- Then, for each month at each station, the daily values were summed, and the ‘back-predicted’ monthly C-S totals were compared with the amounts actually measured.
- The performance of the new equations was compared to that of the current equations we use with monthly totals. This showed that the new equations do perform better for all months, especially in spring and summer.

Some results



Root-mean-square errors (hours) of ‘back-predicted’ monthly sunshine totals, from (red) K&Z values and the new *daily* equations; (blue) K&Z values and the old *monthly* equations.

Sunshine map for October 2007



Extending the NCIC series?

- The NCIC historical ‘monthly sunshine’ series, which began in 1929, now covers 85 years. Around 1930 there were approx 100 stations reporting sunshine; this rose to around 300 later in the 20th century but has since tailed off to less than 120. Other work I have done has indicated that this is enough stations for our monthly statistics to be reliable/robust.

- If we could locate additional paper records & manuscripts and digitise these, we could have enough data to extend the series back at least another few years. (The hard work will be digitisation of data records…)

Additional work: Use of satellite cloud data

- We have also started looking at methods for deriving sunshine duration from geostationary satellite data using cloud-type information. This is being explored as a way of improving the spatial interpolation of sunshine from the relatively sparse in-situ network.
- This work is still in progress…

Additional work: Use of satellite cloud data

Satellite – station comparisons

- The in-situ daily sunshine measurements have also been compared with satellite estimates over four months during 2008. This depends partly on an accurate determination of cloud type and thickness: results are notably better when fractional and cirrus cloud types are given a weighting between 0 and 1 for bright sunshine.
- Satellite estimates are closer to K&Z than to C-S.
- For the K&Z, the mean satellite-minus-station daily bias and standard deviation are -0.2 and 1.6 hours, with a correlation of 0.89. For the C-S, the bias and standard deviation are -0.6 and 2.2 hours, with a correlation of 0.82.

Watch this space…

- So I am eagerly looking forward to exploiting the satellite data to get better sampling. Lots more can be done on this – this work is more-or-less open-ended…

Conclusions/Summary

- Due to the character of the over-burn tendency the adjustment of sunshine totals on a daily basis leads to greater homogeneity and reduced uncertainty in our monthly series.
- Using our new “daily” equations to adjust K&Z readings, we expect derived monthly estimates to have a fractional error of less than 3%, a worthwhile improvement on the earlier equations.

References

- *Kerr A, Tabony R. 2004*. Comparison of sunshine recorded by Campbell-Stokes and automatic sensors. *Weather* **59:** 90-95.
- *Perry, M. 2007*. Updated comparison of sunshine duration recorded by Campbell-Stokes and automatic sensors. Published internally as NCIC Memorandum no. 27 (2011); available from National Met. Library, Exeter.
- *Good, E. 2010.* Estimating daily sunshine duration over the UK from geostationary satellite data. *Weather* **65**: 324-328.
- *SAFNWC, 2009*. Algorithm Theoretical Basis Document for "Cloud Products" (CMa-PGE01 v2.0, CT-PGE02 v1.5 & CTTH-PGE03 v2.0). SAF/NWC/CDOP/MFL/SCI/ATBD/01, Issue 2, Rev. 0 (26 February 2009).

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Questions and answers . . .