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Hydrology and Earth System Sciences Discussions



# *Interactive comment on* "Local $\delta^{18}$O and $\delta^{2}$H variability in UK rainfall" *by* M. D. Jones et al.

**M. D. Jones et al.**

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We thank the referees and the editor for their comments on our manuscript. Here we review each of the general points made on a case by case basis. We accept the minor comments and will make changes to the manuscript as appropriate.

G. Darling

"18 months' worth of monitoring data is far too short a period on which to base claims such as "d18Op has changed in the UK over the last 20 years..." and that "Local gradients in d18Op appear to be of the same order as national trends...".....With regard to the latter claim, there only needs to be (for example) a major convective rainfall event affecting one of the local sites to skew the weighted average in the short term, potentially giving rise to the kind of difference observed between Keyworth and Sutton Bonington over 18 months."

We accept that the length of our time series are probably too short to support such conclusions and in the resubmitted manuscript will now focus on the observed seasonal changes and climate controls as well as the differences between the sites at shorter e.g. monthly time scales. To quantify the effect of extreme events on longer term averages we have calculated the weighted average d18Op values for all three sites when extreme values (ś 1 and 2 sigma) of both d18Op and rainfall amount are removed. We found that when removing the greater than and les than 2 sigma extreme values weighted average d18Op values changed by only ś 0.2ppt. Changes when removing extremes less than and greater than ś 1 sigma were much greater, up to ś 0.9ppt. Differences were greater when removing the isotope extremes, compared to the rainfall extremes, and, as would be expected, for Watnall and Sutton Bonnington (the higher resolution sites) compared to Keyworth (the lower resolution site). Shifts of this size suggest that any spatial differences observed may be due to extreme events in one or more of the sites.

"Clearly it takes decades of monitoring before baseline changes can be identified with any certainty.""Again, I am afraid that long-term monitoring is the only way in which one could be certain of such a marked local d18Op gradient""I agree the spatial picture is bound to be more complicated than the results from a few GNIP stations can show (Summary conclusions). This was one of the reasons we developed an isotope map of UK groundwaters (Darling et al, HESS vol 7, 183-195, 2003). However, the map indicates that d18Op gradients in the interior of lowland Britain are nowhere near as high as suggested by the short-term dataset provided in the present MS"

Baseline conditions will change at different timescales and this must be taken into account when making comparisons. There will be variability around multi-decadal or centennial baselines and these variations from the long term mean must be driven by shorter term changes in the hydrological cycle which are of interest to Earth Scientists. These multi decadal baselines are also likely to vary around longer term e.g. Holocene baselines, as recorded in the groundwater isomap. Although these long term averages



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are important we feel the short term variability should not be ignored, especially now that geological records can be produced at annual or even seasonal time scales (Jones et al., 2005, JOPL, 34, 391-411). Although this data set is too short to investigate these issues further here, use of the GNIP data sets would allow these issues to be addressed in a quantitative manner.

Anonymous Referee 1

"Although I can not discount the interpretation (page 2410, paragraph 1) that the difference in weighted mean d18O between Watnall and Sutton Bonnington occurs due to a progressive rainout effect, the argument is not convincing. If this process leads to such marked differences between these closely located sites, then how is the relatively modest isotope gradient between Valentia (Ireland) and Keyworth explained?"

Given the points made above regarding the differences between the sites discussions of possible differences will now focus at shorter time scales as the long term rain out gradient can not be investigated with the length of our data set.

"The findings presented here are potentially very important with regards extrapolation of rainfall d18O data, and therefore warrant a more detailed discussion. In particular, it would be useful to present all supporting data for each site - is it possible that the differences can be explained by microclimatic effects, perhaps driven by differing land use/topographic factors?"

We discussed the possible effects of topography in the original manuscript (page 8, line 1). Land use at the three sites is similar and all are recognised Meteorological Office stations so this should not be an effect on precipitation amount.

"If the authors are correct and a rainout effect does exist, are there also significant differences in precipitation amount or humidity between sites? Unless there is a reduction in air temperature, rainout will lead to a reduction in precipitable moisture downwind."

There are not significant differences between monthly average temperature values for the three sites for the years 2004, 2005 and 2006. Temperature trends are also the same for all three sites. Precipitation values are also similar for 2004 and the first 8 months of 2005. For the latter months of 2005 and 2006 total rainfall was higher at Watnall than the other 2 sites. This would not support a rainout hypothesis for the local gradient, however it is difficult to explain this difference as all other factors are similar. Given the comments above the rain out gradient will not be discussed in the resubmitted manuscript.

"Notable amongst the data presented is the marked seasonal variability in d18O, deuterium excess (d-excess), meteoric water line slope and correlation between d18O and climate (temperature/precipitation amount)""where correlations are not found with temperature or precipitation, how is this explained?"

Seasonal variability in d18O is likely due to changes in temperature. The changes in d-excess and slope are not easy to explain, nor the differences in correlations. Correlations break down in the transitional seasons i.e. periods of most change where presumably there are more controls on the system. We accept that these seasonal differences are of note and require more detailed discussion and will include this in the new manuscript. Although definitive explanations of these differences may be difficult it is important that they are noted and recognised.

"Of particular note is the omission of evaporation during rainfall as a potential forcing agent. This might seem an unlikely factor to affect precipitation in the UK, however the occurrence of positive d18O values for summer precipitation, coinciding with marked reductions in the d18O/d2H slope and d-excess strongly suggest that evaporation is taking place. Again, it is impossible to prove/disprove this hypothesis, however a more detailed analysis and discussion of such potential effects should be given."

The summer meteoric water line (MWL) gradients (6.4 to 6.9) do not compare directly to the local evaporation line (LEL) (gradient 4.8; Jones et al, unpublished data). However it is possible to show, as will be in the resubmitted manuscript, that by evaporating winter rainfall values along this LEL gradient, with increasing amounts of evaporation at more positive isotope values (as both evaporation and isotope values are driven by temperature) gradients of around 6.4 can be produced. Therefore, evaporation of rainfall may be a possible control on the summer MWL.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 4, 2403, 2007.