A Long Relative Humidity Series for Armagh Observatory

Its relevance to the occurrence of 19th century potato famines in Ireland and atmospheric warming in the 20th century

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Introduction: John Tyndall first showed that water vapour played a major role in the radiative balance of the atmosphere, dwarfing the contributions of other greenhouse gases including carbon dioxide. It is surprising, therefore, how few studies of the long-term variability of atmospheric water content have been made. Though a relative humidity series, like all other meteorological series, is essentially local, it will contain elements of variability which derive from a wider region. It is in this context, we describe here some of the features of the Armagh RH series.

Data: Wet and dry bulb thermometer readings have been recorded daily at Armagh Observatory since 1838. Recently, these data has been corrected for instrumental error and changes in the time of reading to produce a homogeneous series covering all of the 20th and most of the 19th century. This is the longest such series in the world to be presented so far (Butler & García-Suárez, 2011).

The Relative Humidity Time Series: In Figure 1, we plot the mean seasonal and annual relative humidity at Armagh for the period 1838 to 2008. A strong seasonal shift in RH is evident; i.e. a mean winter level ~90%, spring and summer levels ~80% and autumn ~85%. Noticeable also, is a clear year-to-year variation with peaks and troughs that correspond closely between seasons. As each seasonal dataset is independent, this implies that the year-to-year variability operates over a characteristic interval longer than a year. In fact, the variability, when averaged over a year (see bottom panel), looks distinctly cyclic on decadal timescales, with peaks around 40 years apart. Also, we note that the two peaks that occur in the 19th century, the first in the mid-1840s and the second in 1878/9, both coincide with major infestations of potato blight in Ireland. It is well known that potato blight, caused by *phytophthora infestans ,* is highly humidity sensitive.

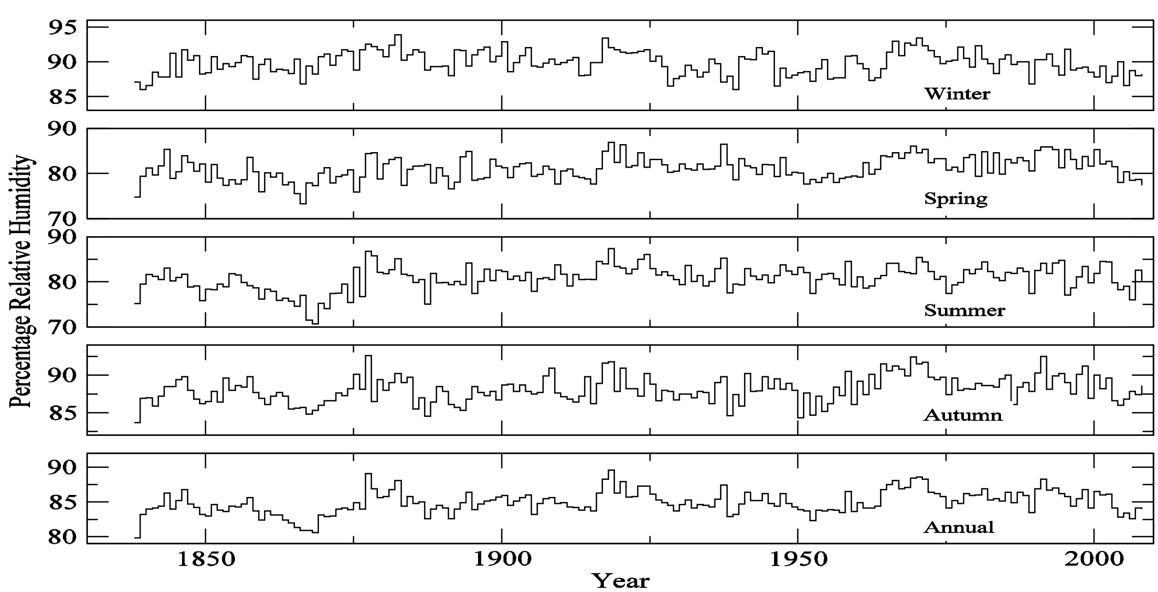

Figure 1. Time profiles of the mean seasonal and annual relative humidity at Armagh at 09:00 GMT

In order to examine the apparent cyclic nature of relative humidity at Armagh, we have submitted each seasonal and annual series to wavelet analysis. Wavelets are used to identify transient cyclic effects in time series and give an estimate of their significance (Torrence and Compo, 1998). In Figure 2 we see that two strong periodicities are present in almost all seasonal and annual series, the shorter with a period of 23.4 to 25.5 years and the longer with period of 36-51 years. The wavelets power is shown in the right hand panel of Figure 2.

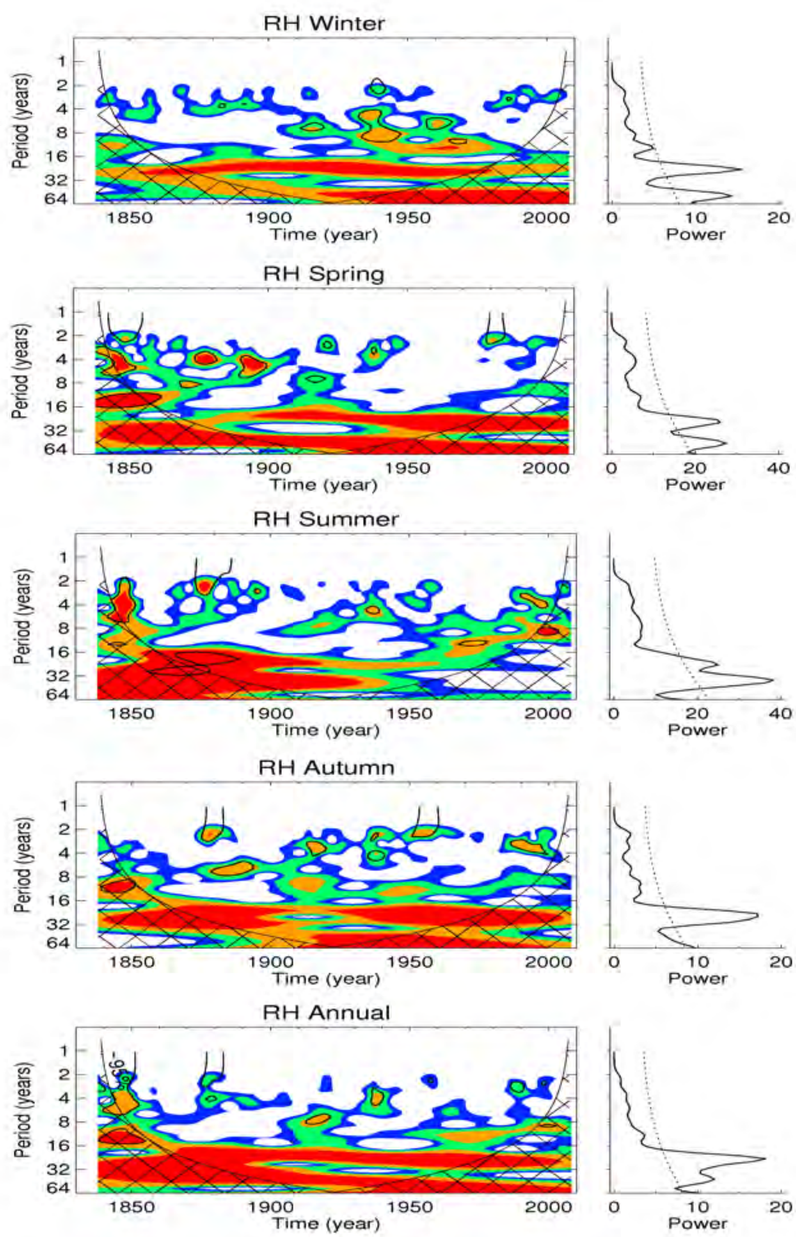

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Figure 2. Wavelet plots for seasonal and annual mean RH at 09:00 GMT. The left panel shows the power plotted against period (vertical axis) and epoch (horizontal axis) and the right hand panel the power integrated over all epochs. The dotted line in the right hand panel indicates the 95% confidence level.

Possible causes of the cyclic variability: Humidity in Ireland is influenced by the oceanic and atmospheric circulations of the North Atlantic region. These in turn are subject to fluctuations in the pressure regime of the North Atlantic (*N. Atlantic Oscillation*) and a more remote and less periodic *Arctic Oscillation*.

A number of mechanisms which derive from natural oscillations in the atmosphere and large ocean basins of the Pacific and Atlantic have been proposed by Marshall *et al*. (2001), Delworth and Mann (2000) and Gallego and Cessi (2000) to explain the cyclic behaviour seen in meteorological parameters. These include variations in sea-surface temperature, ocean currents and atmospheric circulation patterns. In a paper by Delworth *et al*. (1993) it was shown that coupled ocean/atmosphere models of the North Atlantic can exhibit irregular oscillations with multi-decadal periods of approximately 50 years duration. These oscillations originate in density anomalies in the sinking region of the thermohaline circulation between 52º and 72º N, and bear some resemblance to those seen in our RH series. With the prevailing westerlies passing over these regions and crossing the Atlantic, it is feasible that such oscillations could affect relative humidity over Ireland. More recent computations by Park and Latif (2010) predict oscillations with periods of 45 and 60 years in the Pacific and the Atlantic, respectively. Whilst it is evident that more work is required to tie down the origin of the oscillations in RH at Armagh, *these studies strongly suggest that the underlying cause of the 19th century potato famines in Ireland lies in oscillations in the ocean-atmosphere circulation of the Atlantic or Pacific Oceans.*

The Role of Water Vapour in Atmospheric Temperature at Armagh: Water vapour is generally believed to provide a positive feedback to atmospheric warming from other causes (e.g. CO_2 or Solar) due to the increase in total water vapour content (*specific humidity*) as the lower atmosphere warms at constant *relative humidity*. Effectively, the additional water vapour taken up by the atmosphere, leads to increased *greenhouse* forcing, and an additional component to the temperature rise.

Gerald Stanhill has used the Armagh *RH* series to assess the strength of the water vapour feedback at this site. He has calculated the contributions to downward directed radiation by direct solar radiation and long wavelength radiation from the atmosphere above (*greenhouse*) using the mean monthly Armagh series (see http:\\climate.arm.ac.uk) for: sunshine, atmospheric pressure and RH, and mid-20th century radiation measurements from Aldergrove and Valentia (see Stanhill, 2011). He concludes that "*three quarters of the significant increase and long decadal variation in atmospheric long wavelength radiation (at Armagh) was associated with the concurrent changes measured in specific humidity; the remaining quarter with CO_2 and other greenhouse gases."* These results imply a high level of water vapour feedback at this site.

Stanhill continues his study by correlating the observed mean monthly temperatures at Armagh with the downward directed solar and long wavelength heating. He finds "*Eighty percent of the increases in annual mean temperatures (at Armagh) were associated with those in the downwelling radiation fluxes"*. There are two ways in which these results can be explained; either the forcing arising from increased water vapour is significantly larger than expected, or temperature is associated with humidity due to parallel changes in advection (circulation) and temperature. In fact, in Ireland, the latter would not be unexpected due to the warmth of the prevailing southwesterlies in winter which also, have significantly higher RH (see Butler & Garcia-Suarez, 2011, fig 6). Nevertheless, it is of interest to record that similar conclusions were reached by a study of the influence of water vapour on the temperature of the lower troposphere in Eastern and Central Europe, a significantly different climatic regime to Ireland, by Philipona, et al. (2005), where they found additional water vapour forcing to be approximately three times greater than that from other *greenhouse* gases.

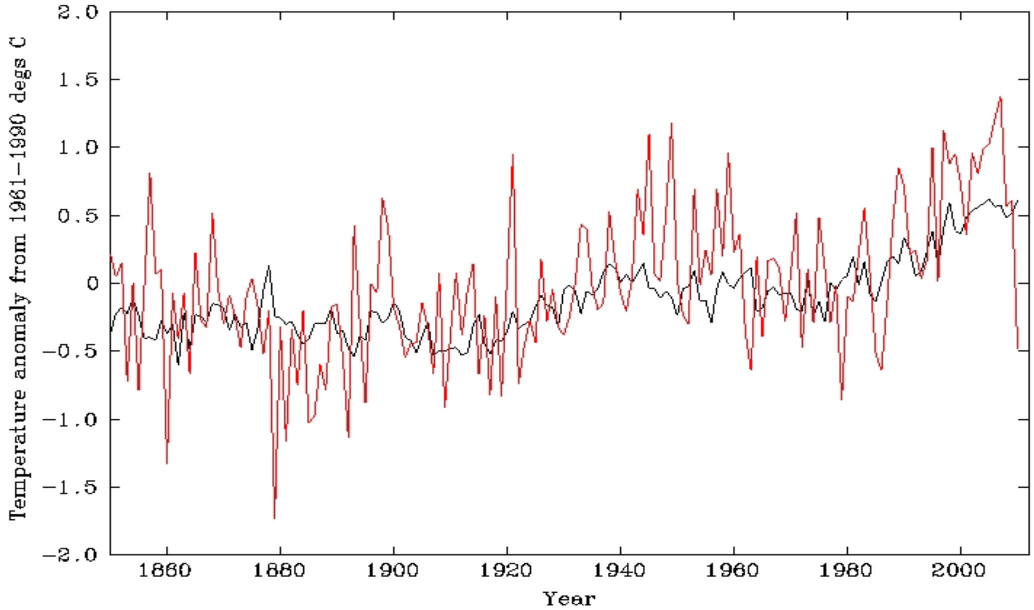

Figure 3. Annual mean temperature anomalies for Armagh (*red*) and the Northern Hemisphere - HadCRUTvnh, (black).

Are these results relevant to the *Global Warming* discussion? Maybe, as the Armagh temperature series closely parallels the mean Northern Hemisphere Temperature Series as shown in Figure 3.

If the water vapour feedback were stronger than previously believed over a substantial part of the globe, this would not only increase the contribution from anthropogenic greenhouse gases but would also amplify the contribution to the warming of the lower atmosphere from other causes, such as changes in the solar irradiance or atmospheric/ocean oscillations. Previously, for instance, an observed change in solar irradiance during the solar 11-year cycle of ~0.1% has been calculated to give a contribution to warming of only ~0.15 ^{o}C. With increased water vapour feedback the solar contribution could be significantly higher.

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