Project Titles: CLIMATE DATA, ANALYSIS AND MODELS FOR THE STUDY OF NATURAL VARIABILITY AND ANTHROPOGENIC CHANGE (DE- SC0005689, July 2011-June 2014 and DE-FG02-98ER62601, May 2007- April 2010)

Both projects were structured with two main parts: Climate Data and Analysis and GCM/RCM Evaluation. This section is structured according to the sub-sections of the original proposals.

Gridded Temperature

Under prior/current support, we completed and published (Jones et al., 2012) the fourth major update to our global land dataset of near-surface air temperatures, CRUTEM4. This is one of the most widely used records of the climate system, having been updated, maintained and further developed with DoE support since the 1980s. We have continued to update the CRUTEM4 (Jones *et al*., 2012) database that is combined with marine data to produce HadCRUT4 (Morice *et al*., 2012). The emphasis in our use of station temperature data is to access as many land series that have been homogenized by National Meteorological Services (NMSs, including NCDC/NOAA, Asheville, NC). Unlike the three US groups monitoring surface temperatures in a similar way, we do not infill areas that have no or missing data. We can only infill such regions in CRUTEM4 by accessing more station temperature series. During early 2014, we have begun the extensive task of updating as many of these series as possible using data provided by some NMSs and also through a number of research projects and programs around the world. All the station data used in CRUTEM4 have been available since 2009, but in Osborn and Jones (2014) we have made this more usable using a Google Earth interface (http://www.cru.uea.ac.uk/cru/data/crutem/ge/).

We have recently completed the update of our infilled land multi-variable dataset (CRU TS 3.10, Harris et al., 2014). This additionally produces complete land fields (except for the Antarctic) for temperature, precipitation, diurnal temperature range, vapour pressure and sunshine/cloud. Using this dataset we have calculated sc-PDSI (self-calibrating Palmer Drought Severity Index) data and compared with other PDSI datasets (Trenberth et al., 2014). Also using CRU TS 3.10 and Reanalysis datasets, we showed no overall increase in global temperature variability despite changing regional patterns (Huntingford et al., 2013). Harris et al. (2014) is an update of an earlier dataset (Mitchell and Jones, 2005) which also had earlier DoE support. The earlier dataset has been cited over 1700 times according to ResearcherID on 31/July/2014 and the recent paper has already been cited 22 times.

Analyses of Temperature Data

Using the ERA-Interim estimate of the absolute surface air temperature of the Earth (instead of in the more normal form of anomalies) we compared the result against estimates we produced in 1999 with earlier DoE support. The two estimates are surprisingly close (differing by a couple of tenths of a degree Celsius), with the average temperature of the world (for 1981-2010) being very close to 14°C (Jones and Harpham, 2013). We have assessed ERA-Interim against station temperatures from manned and automatic weather station measurements across the Antarctic (Jones and Lister, 2014). Agreement is generally excellent across the Antarctic Peninsula and the sparsely sampled western parts of Antarctica. Differences tend to occur over eastern Antarctica where ERA-Interim is biased warm (up to 6°C) in the interior of the continent and biased cool (up to 6°C) for some of the coastal locations.

Opportunities presented themselves during 2012 for collaborative work with a couple of Chinese groups. Three papers develop new temperature series for China as a whole and also for the eastern third of China (Wang *et al*., 2014, Cao *et al*., 2013 and Zhao *et al*., 2014). A dataset of ~400 daily Chinese temperature stations has been added to the CRU datasets. The latter paper finds that urban effects are generally about 10% of the long-term warming trend across eastern China. A fourth paper (Wang et al., 2013) illustrates issues with comparisons between reanalyses and surface temperatures across China, a method that has been widely used by some to suggest urban heating effects are much larger in the region. ERA-Interim can be used but NCEP/NCAR comparisons are very dependent on the period analysed. Earlier a new temperature dataset of homogenized records was developed for China (Li et al., 2009).

Urbanization has also been addressed for London (Jones and Lister, 2009) where two rural sites have not warmed more than a city centre site since 1900. Additionally, in Ethymiadis and Jones (2010) we show that land air temperatures agree with marine data around coastal areas, further illustrating that urbanization is not a major component of large-scale surface air temperature change.

Early instrumental data (before the development of modern thermometer screens) have always been suspected of being biased warm in summer, due to possible direct exposure to the sun. Two studies (Böhm et al., 2010 and Brunet et al., 2010) show this for the Greater Alpine Region (GAR) and for mainland Spain respectively. The issue is important before about 1870 in the GAR and before about 1900 in Spain. After correction for the problems, summer temperature estimates before these dates are cooler by about 0.4°C. In Jones and Wigley (2010), we discussed the importance of the biases in global temperature estimation. Exposure and to a lesser extent urbanization are the most important biases for the land areas, but both are dwarfed by the necessary adjustments for bucket SST measurements before about 1950. Individual station homogeneity is only important at the local scale. This was additionally illustrated by Hawkins and Jones (2013) where we replicated the temperature record developed by Guy Stewart Callendar in papers in 1938 and 1961.

Analyses of Daily Climate Data
Work here indicates that ERA-Interim (at least in Europe, Cornes and Jones, 2013, discussed in more detail in this proposal) can be used to monitor extremes (using the ETCCDI software – see Zhang *et al.*, 2011). Additionally, also as a result of Chinese collaboration, a new method of daily temperature homogenization has been developed (Li *et al.*, 2014). In Cornes and Jones (2011) we assessed storm activity in the northeast Atlantic region using daily gridded data. Even though the grid resolution is coarse (5° by 5° lat/long) the changes in storm activity are similar to those developed from the pressure triangle approach with station data.

Analyses of humidity and pressure data
In Simmons et al. (2010) we showed a reduction in relative humidity over low-latitude and mid-latitude land areas for the 10 years to 2008, based on monthly anomalies of surface air temperature and humidity from ECMWF reanalyses (ERA-40 and ERA-Interim) and our earlier land-only dataset (CRUTEM3) and synoptic humidity observations (HadCRUH). Updates of this station-based humidity dataset (now called HadISDH) extend the record, showing continued reductions (Willett *et al.*, 2013).

Analyses of Proxy Temperature Data
In Vinther et al. (2010), relationships between the seasonal stable isotope data from Greenland Ice Cores and Greenland and Icelandic instrumental temperatures were investigated for the past 150-200 years. The winter season stable isotope data are found to be influenced by the North Atlantic Oscillation (NAO) and very closely related to SW Greenland temperatures. The summer season stable isotope data display higher correlations with Icelandic summer temperatures and North Atlantic SST conditions than with local SW Greenland temperatures. In Jones et al. (2014) we use these winter isotope reconstructions to show the expected inverse correlation (due to the NAO) with winter-season documentary reconstructions from the Netherlands and Sweden over the last 800 years. Finally, in this section Jones et al. (2013) shows the agreement between tree-ring width measurements from Northern Sweden and Finland and an assessment of the link to explosive volcanic eruptions. An instrumental record for the region in the early 19th century indicates that the

summer of 1816 was only slightly below normal, explaining why this year has normal growth for both ring width and density.

GCM/RCM/Reanalysis Evaluation

In this section we have intercompared daily temperature extremes across Europe in Cornes and Jones (2013) using station data, E-OBS and ERA-Interim. We have additionally considered the impact of the urban issue on the global scale using the results of the Compo et al. (2011) Reanalyses, 20CR. These only make use of SST and station pressure data. Across the world's land areas, they indicate similar warming since 1900 to that which has occurred (Compo et al., 2013), again illustrating that urbanization is not the cause of the long-term warming.

Changes in HadCRUH global land surface specific humidity and CRUTEM3 surface temperatures from 1973 to 1999 were compared to the CMIP3 archive of climate model simulations with 20th Century forcings (Willett et al., 2010). The models reproduce the magnitude of observed interannual variance over all large regions. Observed and modelled trends and temperature-humidity relationships are comparable with the exception of the extra-tropical Southern Hemisphere where observations exhibit no trend but models exhibit moistening.

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