Investigating the role of surface water vapour in recent climate change

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PROJECT SUMMARY

AIM:

to create a global gridded dataset of vapour pressure anomalies from 1945 to the present

MOTIVATION:

Water vapour is the most important greenhouse gas and has significant implications for the global energy budget and hydrological cycle. It likely plays a key role in modulating the climate's response to external forcings through feedback processes. The accurate quantification of recent changes in water vapour content is imperative to our ability to further understand, and reduce uncertainties surrounding future climate.

THE PLAN:

COMPILE A SET OF QUALITY STATIONS OF OBSERVATIONAL SURFACE HUMIDITY DATA
Stations must have a 30yr climatology and an accurate and consistent longitude/ latitude/ elevation / WMO number.

CONVERT ALL DATA TO VAPOUR PRESSURE
Vapour pressure has been converted from temperature and dewpoint temperature using the Magnus Equation. This variable has been chosen for consistency across datasets. It is preferred to relative humidity because it is a fairly good measure of total atmospheric water vapour and because it is not directly influenced by changes in atmospheric temperature.

CREATE A MONTHLY CLIMATOLOGY FOR EACH STATION
A 30 year climatology will be chosen that maximises the number of usable stations.

CONVERT TO MONTHLY MEAN ANOMALIES
Do monthly means sufficiently represent vapour pressure? How sensitive are they to differing methods for creating monthly means and number / timing of daily observations?

HOMOGENISE
Account for any changes in instrumentation / observation method, location, changes in surrounding topography. Currently we intend to use the method proposed by Thorne *et al.* (in prep) for use with vertical temperature trends.

MERGE WITH MARINE DATA
A similar approach will be used with the ICOADS data to that employed for SST and SLP analyses – Rayner *et al.*, (in prep).

GRID UP INTO 5 BY 5°

ANALYSE TRENDS
Seasonal and annual

COMPARE OBSERVATIONAL TRENDS WITH MODEL OUTPUT FROM HADCM3 AND HADGEM

PREVIOUS ANALYSES

Surface humidity observational studies are sporadic and data are littered with problems. Instruments have been changed on large-scale without sufficient overlap to quantify discontinuities. Topography can change around stations (e.g. urbanisation or the disappearance/ appearance of large water sources). Errors in data communication, changes in station or instrument location and confusion regarding actual location are also common. There is a lack of quality metadata documenting such changes. Furthermore, instrumental errors occur associated with freezing temperatures and screen ventilation.

Radiosonde and satellite studies are not without their problems but generally agree that atmospheric moisture has increased over the latter part of the 20th century with some exceptions (e.g. Canada and Alaska) (Ross & Elliott, 1996; Gutzler, 1992; Zhai & Eskridge, 1997).

There are a number of surface humidity observational studies of annual and seasonal trends for example: the USA (Gaffen & Ross, 1999); Canada (van Wijngaargen & Vincent, 2004); China (Wang & Gaffen, 2001); and 'global' (New *et al.*, 2000).

New *et al.* (2000) 's 'global' land observational humidity dataset merges monthly mean vapour pressure (*e*) and conversions from monthly mean temperature and relative humidity (*h*) for 1975-1995. They found nominally significant increases in *e* over large proportions of the Northern Hemisphere (IPCC, 2001). However, data quality is an issue here, especially with the synthetic data which has issues due to indirect conversions from monthly means and 'best-guess' data resulting from spline interpolation. Furthermore, coverage is for land only, largely isolated to the Northern Hemisphere and leaves large areas without data.

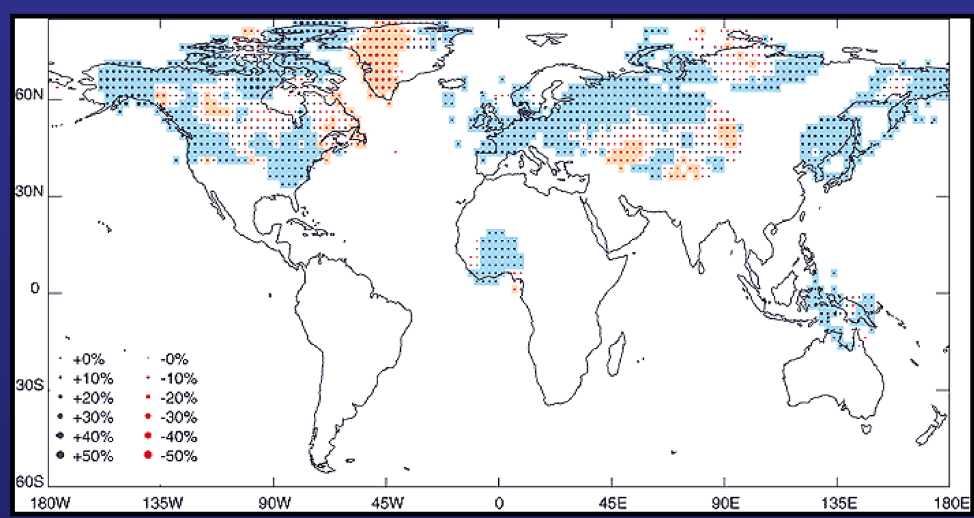

Figure 1: *Trends in annual mean surface water vapour pressure, 1975 to 1995, expressed as a percentage of the 1975 to 1995 mean. Areas without dots have no data. Blue shaded areas have nominally significant increasing trends and brown shaded areas have significant decreasing trends, both at the 5% significance level. Biases in these data have been little studied so the level of significance may be overstated. From New et al. (2000) in: IPCC (2001).*

Gaffen & Ross (1999) used 170 US stations of hourly specific humidity (*q*) and relative humidity (*h*) data for 1961-1995. They found positive trends in *q* over most of the country (winter, spring and summer), and small negative trends in Hawaii (winter and spring) and in Northeast and south-central regions (autumn). Generally, nighttime trends exceeded daytime trends, consistent with findings for China by Wang & Gaffen (2001). *h* trends lacked statistical significance and did not show strong spatial consistency. They investigated the effect of inhomogeneities due to large-scale instrumentation changes in the US in the early 1960s and mid-1980s. Any resulting inhomogeneities were deemed insignificant.

van Wijngaarden & Vincent, (2004) analysed 75 Canadian airport stations of hourly relative humidity (*h*) data over 1953-2003. A substantial decrease in *h* during winter and spring was found to be consistent throughout all Canada. For western Canada and the Arctic this coincided with increases in winter temperature and very large decreases in precipitation.

Wang & Gaffen (2001) studied six-hourly surface observations of relative humidity (*h*) and conversions to specific humidity (*q*) for 1951-1994 at 196 stations in China. Annual mean trends in humidity were overwhelmingly positive with the largest and most significant trends in the northeast and northwest. *q* showed large increases in the northwest and in the Yangtze and Yellow River basins but the rest of the country had little evidence of spatially coherent change. *h* decreased at most stations but it was only significant in the northeast.

THE LAND DATA

The dataset potentially covers 1945-2003. At present it consists of three land datasets: NEW; HAHN; and ISH. Marine data from ICOADS will later be merged. Stations have been accepted for use on the following criteria:

- **≥ 3 decades of data** – to create a climatology
  - **≥ 5 yrs of data per decade** – (2 or 3 yr max consecutive gap to be decided)
    - **≥ 3 seasons of data per yr**
      - **≥ 2 months of data per season**
        - **≥ 75% days of data present within a month**

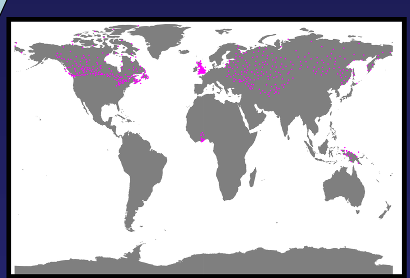

Figure 2: *Station coverage for* ***Mark New's*** *monthly mean vapour pressure* ***1945-2003***

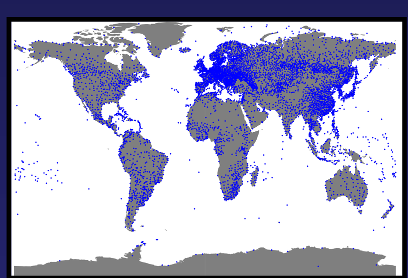

Figure 3: *Station coverage for* ***Hahn & Warren's*** *3 hourly synoptic data converted to monthly mean vapour pressure using the Magnus Equation from dewpoint temperature and temperature* ***1971-1996***

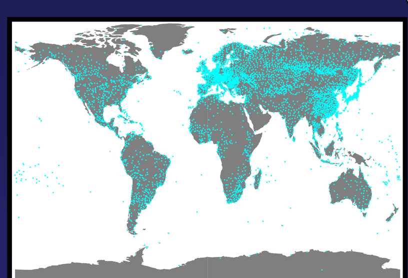

Figure 4: *Coverage of stations that can provide a climatology for* ***NCDC Integrated Surface Hourly (ISH)*** *data converted to vapour pressure using the Magnus Equation from dewpoint temperature and temperature* ***1945-2003***

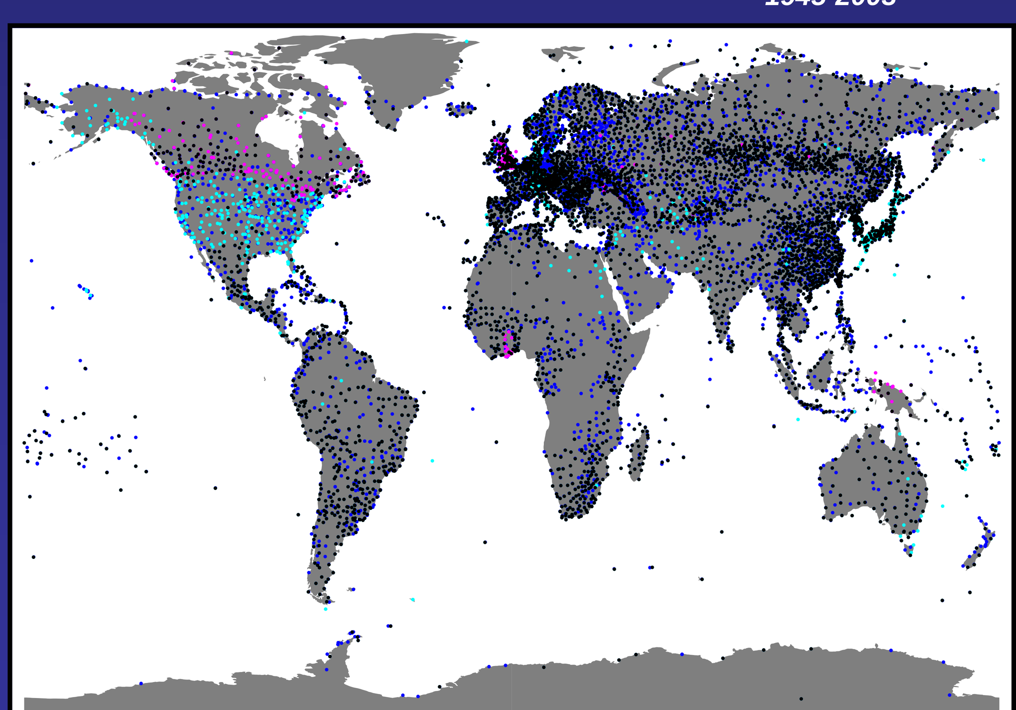

Figure 5: *Global Coverage of Land-based Stations. Pink dots =* ***NEW*** *stations. Dark blue dots =* ***HAHN*** *stations. Sky blue dots =* ***ISH*** *stations. Black dots = stations that have data from at least two of the above sources.*

INVESTIGATIONS

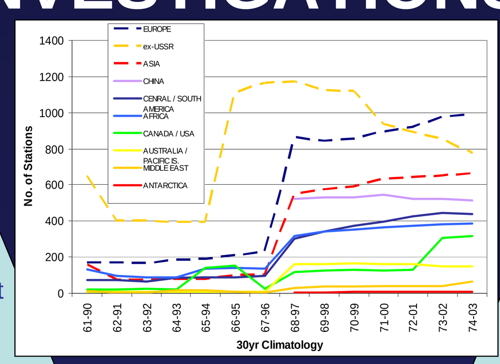

Figure 6: *Geographical distribution of usable ISH stations for each 30 year climatology. A considerable number of US stations are yet to be retrieved from the raw datafile.*

Climatologies

Using a non-standard climatology maximises usable stations.

The ISH data have been analysed for every 30 yr period from 1961-1974. The number of station climatologies doubles post 1968-97 (see Fig. 7). Regions such as China and Antarctica cannot be used unless a post 1968 climatology is used (see Fig. 6).

There will be a trade off of some geographic regions for others whatever climatology is used. Ex-USSR stations decrease considerably post a 1970-99 climatology but Canadian, northern USA and European stations increase considerably (see Fig. 6).

The climatology period must take into account the extra HAHN stations too as these only have data from 1971-1996.

Homogenisation

- background field of neighbour composite stations
- monthly resolution difference series (station value - neighbour composite)
- non-parametric test to identify potential break points / spurious trends (i.e. due to urbanisation around a station)
- Analysis to match 'jumps' with metadata / climatic event / actual trend
- Bootstrap technique to create an estimate of the required adjustment
- Multiple iterations until no more 'jumps' appear

This method has been modified from its original application with vertical temperature trends (Thorne *et al.*, in prep.). Various studies will test its versatility and usefulness in surface observations.

Monthly Means

The data combine monthly means and hourly observations. This provides the opportunity to test the sensitivity of the monthly mean and how well it represents vapour pressure.

Does the number / time of measurements in a day significantly change the character of monthly means? Should there be nighttime / daytime monthly means? How many days / adjacent days of missing data can be allowed?

METHOD:

$$\mathrm{Jan00}_{mean} = \frac{\sum \mathrm{Jan00}_{1945\text{-}2003}}{n}$$

Make a mean for each hour (00…23) of each month (Jan…Dec) over the whole of the dataset

$$\mathrm{Jan00}_{anom95} = \mathrm{Jan00}_{mean} - \mathrm{Jan00}_{95}$$

Make hourly anomalies for each observation for each day of each month of each year by subtracting the hourly mean from each observation

$$\mathrm{JanDay}_{meananom95} = \frac{\sum \mathrm{Jan00}_{anom95} \ldots \mathrm{Jan23}_{anom95}}{n}$$

Make daily mean anomalies from all hourly anomalies for each day of each month of each year

$$\mathrm{Jan}_{Normal} = \frac{\sum \mathrm{Jan00}_{mean} \ldots \mathrm{Jan23}_{mean}}{n}$$

Make monthly normals from original hourly means

$$\mathrm{JanDay}_{mean95} = \mathrm{Jan}_{Normal} + \mathrm{JanDay}_{meananom95}$$

Make daily means for each day of each month of each year by adding the normal to daily mean anomalies

$$\mathrm{Jan}_{mean95} = \frac{\sum \mathrm{JanDay}_{mean95}}{n}$$

Make monthly means from the daily means for each year

Analyses

Case studies will be undertaken on how anomalies / trends differ:

- between stations at different elevations (case study of stations in the Alps / Himalayas)
- between stations near large water bodies and those in arid areas
- between coastal and inland stations
- between rural and urban stations
- between different climatic regimes (tropical, polar, temperate)

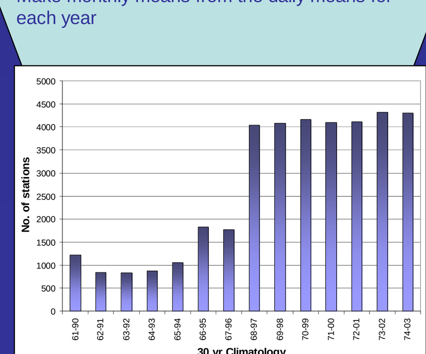

Figure 7: *Number of useable ISH stations for each 30 year climatology*

Merging and Gridding

The combined product of the HAHN, ISH and NEW datasets will be merged with the ICOADS marine dataset of vapour pressure. This will be gridded up to a 5 by 5 ° resolution to show seasonal and annual trends.

This will hopefully significantly build on New *et al.* (2000)'s work providing much more comprehensive coverage especially in the Southern Hemisphere.

Comparisons will be made of the final gridded product with output from various runs of the Hadley Centre models (HadCM3 / HadGEM) to address the question as to whether models adequately resolve both the variability and trends.

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