CLIMATE AND VARIABILITY OF WATER VAPOUR IN THE TROPOSPHERE

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[1] Thesi Introduction

Water vapour is a key greenhouse gas within the atmosphere which influences (directly and indirectly) the radiative balance of the Earth as well as surface fluxes and soil moisture. It is sufficiently abundant and short lived that it is essentially under natural control [1], with a predominant capacity for positive feedback making it critical for climate studies [2]. The role of tropospheric water vapour in atmospheric processes extends over a wide range of spatial and temporal scales, from the global climate to microscale meteorology [3].

Water vapour concentrations within the atmosphere and their variability may be changing indirectly as a result of climate change and changes in surface characteristics. Therefore the goal of this project is to build a framework for combining different satellite data sets in a consistent manner for climate research, i.e. to better characterise the changing mean state of water vapour and its variability. For this project, data from infrared sounders with a high vertical resolution (e.g. MetDB) with near infra-red and thermal infra-red spectrometers (which only offer column water vapour) with a higher spatial resolution than the radiosonde profiles will be utilized in order to produce a combined climate data set on a regular grid. Furthermore the project will investigate the variability based on geophysical regimes, major land biomes and atmospheric circulation processes which effect water vapour variability. A primary goal will be to establish mean states with consistent estimates of seasonal and interannual variability.

Such data will be highly beneficial for both improved numerical weather prediction schemes (weather forecasting) as well as climate research. The starting point for this study will be to assess the integration of these data sets at selected, high-quality radiosonde sites.

[2] Radiosondes

Since the late 17th century instruments have been developed to automatically record meteorological data. As technology has advanced the methods used have also become increasingly more sophisticated, for example the adoption of radio transmission in the 1920s [2]. This process led to the development of instruments called radiosondes which are used to primarily collect temperature, pressure and humidity data from high altitude balloon flights. Modern radiosondes also carry GPS allowing for accurate position and wind velocity data to be taken. From 1939 the ‘Kew’ Met Office radiosonde was the first successful operational radiosonde used in the UK with it being replaced by the MKZ, which operated from 1945 up to the 1960s [3]. Since then generations of increasingly accurate radiosondes have taken their place with the most recent being the Vaisala RS92 family.

For several decades radiosondes have been the primary means of obtaining vertical profile data between the surface and the upper troposphere lower stratosphere (UTLS) region for use in meteorological forecasts, as well as more recently for assessment of climate trends from archived data and validation of satellite retrieval[s]4. The RS92 is not only the most accurate but is also the most accurate (Figure 3), and has been operational since 2004. This suggests that post 2004 is a good time to establish a climate baseline for water vapour.

[3] Correction of Radiosonde Humidity Data

Relative humidity measurements (RH) from radiosondes, like any measurement, are prone to systematic errors. Correction for these errors has been developed over the years and are well documented, especially for the work of Miloshevich [4][5], in which to correct a RS92 radiosonde three corrections need to be implemented. The first error that needs to be accounted for is a sensor time-lag error which is caused by slow sensor response to temperature changes below -45°C. Secondly there is the mean calibration bias which corrects for the inaccuracy in the factory calibration, and third is the solar radiation error correction. This is a dry bias caused from solar heating which makes the humidity sensor warmer than the surrounding air temperature [6]. These can be implemented in five steps:

STEP 1: Reduce data onto 6-6 second grid

STEP 2: Smooth reduced resolution profile using derivative based function - third back derivative

STEP 3: Apply Time-lag correction to the reduced resolution profile

STEP 4: Integrate low resolution radiosonde data onto 6-6 second grid

STEP 5: Apply Empirical Mean Bias Correction

Where:

\[ RH_{corrected} = RH_{original} \times C_1 \times C_2 \times C_3 \]

Where:

- RH is the relative humidity, C1 is the correction factor for the time-lag, C2 is the correction for the mean bias, and C3 is the correction for the solar radiation error.


The first objective of this study is to compare high resolution radiosonde data with satellite retrieved total column profile data, and the first radiosonde data from the Water Vapour Validation Experiment (WAVE) will be used in conjunction with L2 data from AIRS. This work with this study is to develop a precise methodology for best comparing radiosonde-satellite datasets such as a radiosonde/AIRS or radiosonde/MERIS.

AIRS has been chosen for the initial comparison as radiosonde were used for validation during the AIRS Water Vapour Experiment-Ground (AWEX-G) and used similar corrections to the RH profiles. The first step is to take the high resolution RS92 profile and apply the AIRS Trapezoidal smoothing functions and averaging kernels for a like-for-like comparison.

The second step in this duality comparison is to use a radiative transfer model to simulate brightness temperatures (or their equivalent) of the satellite instruments from the radiosonde profiles. This comparison in radiosonde space, as suggested by Buehler and Jobe [11] for their AMSU/radiosonde comparisons over Europe, offers the advantage of a direct consistency check which is not subject to a priori or interpolation errors. Such a comparison may highlight systematic biases, for example, in the match to the varying satellite instrument measurements.

[5] Future Work

The next steps in this project are:

- Complete the AIRS-radiosonde comparisons and compare against previous results.
- Extend this time period to other satellite instruments starting with IASI (similar to AIRS) and MERIS.
- Move from the study to incorporate a global radiosonde dataset for which Met Office MetDB data will be used. This data set has been chosen over Met Office radiosonde data as it contains the raw data files transmitted from source (e.g. SYNOP, METARS, TEMP message types) which are decoded within the MetDB system. Specifically the TEMP and PILOT files will be used in this study as they contain all the data and information about the radiosonde whereas Met Office radiosonde data only contains radiosonde data on a base vertical grid.

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