Improving Rainfall Estimates from Voluntary Observing Ships

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

David I. Berry, National Oceanography Centre, Southampton, UK

email: dyb@noc.soton.ac.uk

Introduction

Precipitation over the oceans forms an important part of the global water and energy cycle. Vast amounts of energy and moisture are transferred many miles from source before being released by precipitation, warming the atmosphere and freshening the ocean surface. This freshening influences the density of the surface waters and hence the strength of the overturning circulation.

Whilst precipitation plays an important role there are few in-situ measurements. Instead indirect estimates from ship observations of the weather, satellite measurements and model output are used. Each source has associated problems and uncertainties. Satellites measurements span less than 30 years and do not form a homogeneous record due to changing platforms and technologies. They do provide near global estimates on short time scales. Ship based estimates suffer from sampling problems, which change with time, and problems with the parameterisations but provide a time series extending up to 100 years. They also report from most regions. Reanalysis models also provide globally complete time series up to 50 years but suffer from inhomogeneities due to changing sources of data being assimilated. They also suffer from problems with their rainfall and cloud parameterisations.

In this poster we focus on the ship based estimates, using a recent merged satellite / rain gauge dataset to highlight problems with the parameterisation and suggest improvements.

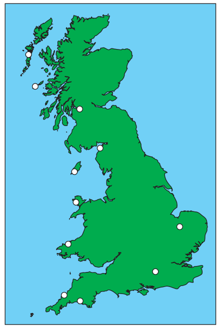
Data

Individual ship observations from ICOADS (Worley *et al.*, 2005) have been used to estimate the monthly average precipitation using the method of Tucker (1961) and Dorman and Bourke (1978). Monthly mean wind speeds have also been calculated together with the wind speed components in the zonal and meridional directions.

Monthly mean precipitation estimates from the Global Precipitation Climatology Project (GPCP) Version 2 Combined Data Set (Adler et al., 2003; GPCP hereafter) have been used as a comparison for the ship based estimates. GPCP contains precipitation estimates from satellite microwave and infrared measurements merged with rain gauge observations globally on a 2.5 x 2.5 degree grid. GPCP covers both the land and ocean and we have masked the land values in this poster.

Ship Estimates of Precipitation

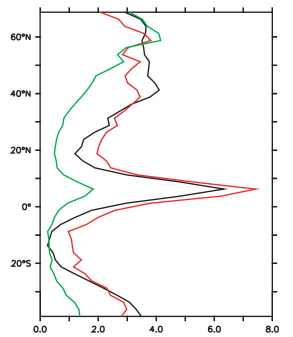
Tucker (1961) and Dorman and Bourke (1978) have been used in most recent ship based estimates of precipitation (e.g. da Silva, 1991; Josey et al., 1999). The ships make descriptive weather reports such as "drizzle, not freezing, intermittent" or "thunderstorm, slight or moderate with hail at time of observation". Tucker (1961) assigns these reports to different categories based on the intensity and character of precipitation. Each category is then assigned a rain rate based on an empirical relationship between the measured precipitation at a number of coastal stations in the UK (see map) and the frequency of the different categories.



Whilst Tucker (1961) gives good estimates of the precipitation in the mid latitudes it underestimates the more intense precipitation typical of the tropics due to the limited geographic region in which it was developed. Dorman and Bourke (1978) attempt to correct this by applying a temperature dependent adjustment to estimates made using Tucker (1961). Whilst the correction of Dorman and Bourke (1978) increases the precipitation rates in the tropics there has been debate over its suitability, hence in this poster we examine both corrected and uncorrected estimates.

Comparison to GPCP

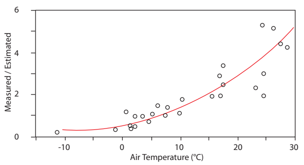
The plot below shows zonally averaged precipitation estimates for the Atlantic from ships using Tucker (1961) with (red) and without (green) the correction of Dorman and Bourke (1978). Also shown are precipitation estimates from the GPCP. Monthly estimates have been averaged over the period 1990 - 1999. Similar results are found on shorter time scales.



Zonally averaged precipitation rates (mm day^{-1}) for the Atlantic over the period 1990 - 1999 from GPCP (black), ship estimates using Tucker (1961) and Dorman and Bourke (1978) (red) and ship estimates using Tucker (1961) (green).

The underestimation of precipitation in the uncorrected ship estimates is clearly visible with tropical precipitation underestimated by a factor of 4 or 5 compared to GPCP. This underestimation is present over much of the Atlantic except in the higher latitudes. In contrast, the corrected ship estimates show a much better agreement with the zonal averages from GPCP. However, there are still systematic differences present. At lower latitudes the ship estimates are 1 - 2 mm day^{-1} larger than the GPCP values. This reverses to 1 - 2 mm day^{-1} lower at higher latitudes. The latitudinal dependence of these differences suggests that, zonally, the correction of Dorman and Bourke (1978) is overcorrecting at lower latitudes and undercorrecting at higher latitudes.

The suitability of Dorman and Bourke (1978) has been previously questioned. For example, Reed (1981) highlights the large scatter at higher temperatures in Figure 2 of Dorman and Bourke (1978) with the ratio of measured to estimated precipitation ranging from 2 - 5 under higher temperatures (see plot). Reed (1981) also suggests that no temperature correction is needed to Tucker (1961) north of 23 N based on rain gauge measurements and estimates based on weather reports made on board the NOAA ship Oceanographer.

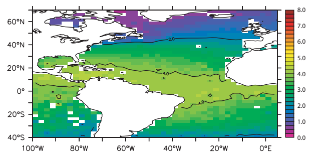


Air temperature correction based on yearly average data. The curve is a least squares fit to the data (after Fig. 2 of Dorman and Bourke, 1978).

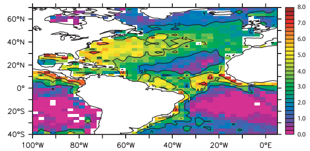
Another example can be found in Jarrett et al. (1990) where the spatial variability in the accuracy of the temperature correction is highlighted. Jarrett et al. (1990) highlight the correction having little effect on the accuracy of the precipitation estimates at coastal stations in Norway whilst it significantly improves them over the Bahamas and makes them significantly worse over the Cape Verde Islands.

An explanation for this can be seen in the plots below. The top plot shows the ratio of the corrected to uncorrected ship estimates of precipitation, i.e. the correction factor of Dorman and Bourke (1978), averaged over 1990 - 1999. The bottom plot shows the ratio of GPCP to the uncorrected ship estimates. If the correction of Dorman and Bourke (1978) accurately captured the regions of heavy precipitation we would expect the two plots to show similar spatial patterns.

However, from the two plots it is clear the correction of Dorman and Bourke (1978) does not accurately capture these regions. Instead, the correction increases or decreases the precipitation across wide latitude bands. As a result the extremes in precipitation are missed. For example, the bottom plot suggest that over the western boundary current in the North Atlantic Tucker (1961) underestimates the precipitation by a factor of 4 or more. In contrast, the correction factor from Dorman and Bourke (1978) only ranges from 2 to 4. At the other end of the scale, the precipitation over the sub-tropical dry zones, such as the Cape Verde Islands, is increased by a factor of 3 - 4 by the temperature correction. The bottom plot suggests no increases is needed in these regions.



Average correction factor from Dorman and Bourke (1978) for the period 1990 - 1999, i.e. the ratio of corrected precipitation estimates to uncorrected precipitation estimates.



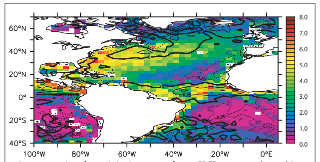
Average ratio of precipitation estimates from GPCP to ship based estimates using Tucker (1961) over the period 1990 - 1999.

Whilst these plots highlight problems with Dorman and Bourke (1978) they also highlight that a correction is needed for the method of Tucker (1961) and that it is needed over most latitudes.

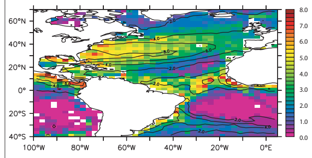
A New Correction?

The previous plots show Tucker (1961) to underestimate the precipitation in the tropics and over the western boundary currents. These are regions of strong atmospheric convection and increased storminess. Hence a measure of atmospheric convection or storminess may be a better predictor or correction factor for heavy rainfall than temperature.

The plots below show two examples of measures which, with further work, could be used to improve the precipitation estimates. The top plot shows the convergence of the wind field (contours) averaged over 1990 - 1999 and overlain onto the ratio of precipitation estimates from the GPCP to uncorrected ship estimates. Positive values indicates a convergence of the wind field and regions of strong atmospheric convection. Negative values indicate a divergence of the wind field. In the tropics a qualitively good agreement can be seen between the regions of convergence and the regions where precipitation is underestimated. There may also be some agreement over the western boundary currents, however this is less clear.



Average ratio of precipitation rates from GPCP compared to ship estimates using Tucker (1961) for the period 1990 - 2000. The contours indicate a measure of the average wind convergence over the same period.



As plot above, but with the contours showing a measure of the wind direction variability.

The second plot shows a measure of the wind direction variability (contours) overlain on the ratio of GPCP to uncorrected ship estimates. High values indicate a high variability in the wind direction and increased storminess. Low values indicate a low variability. Again, in the tropics, there is a good agreement between the regions where precipitation is underestimated and regions of increased variability. There is also a good agreement over the western boundary currents between the regions of high variability and underestimated precipitation.

Summary

Estimates of precipitation from ship observations made using the most commonly used parameterisation have been compared to the Version 2 GPCP merged satellite / rain gauge dataset. This has highlighted systematic biases in the parameterisation used for ship estimates and a potential solution has been proposed.

- Current ship estimates overestimate the precipitation in the subtropical dry zones and underestimate over the western boundary currents
- This is due to the temperature correction applied which increases or decreases the precipitation across wide latitude zones depending on the air temperature.
- It has been shown that measures based on the wind field may be better predictors of heavy rainfall than temperature

New precipitation estimates are currently being developed at NOCS

References

Adler, R. F., G. J. Huffman, A. Chang, R. Ferraro, P. Xie, J. Janowiak, B. Rudolf, U. Schneider, S. Curtis, D. Bolvin, A. Gruber, J. Susskind and P. Arkin, 2003: The Version 2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979 - present). *J. Hydrometeor.*, **4(6)**, 1147 - 1167.

da Silva, A. M., C. C. Young and S. Levitus, 1994: *Algorithms and Procedures. Vol. 1, Atlas of Surface Marine Data, Algorithms and Procedures*, NOAA Atlas NESDID 6, 83 pp.

Dorman, C. E. and R. H. Bourke, 1978: A temperature correction for Tucker's ocean rainfall estimates. *Quarterly Journal of the Royal Meteorological Society*, **104**, 765-773.

Jarrett, T., A. K. Goroch and M. J. Vanderhill, 1990: Oceanic precipitation rate climatology. *IEE Proceedings*, **137 (2)**, 125 - 132.

Josey, S A., E. C. Kent and P. K. Taylor, 1999: New insights into the ocean heat budget closure problem from analysis of the SOC air - sea flux climatology. *J. Climate*, **12**, 2856 - 2880.

Klepp, C., S. Bakan and H. Grabl, 2003: Improvements in Satellite Derived Cyclonic Rainfall over the North Atlantic. *J. Climate*, **16**, 657 - 669.

Reed, R. K., 1981: Reply. *Journal of Applied Meteorology*, **21**, 114 - 115.

Tucker, G. B., 1961: Precipitation over the North Atlantic Ocean. *Quarterly Journal of the Royal Meteorological Society*, **87**, 147 - 158.

Worley, S. J., S. D. Woodruff, R. W. Reynolds, S. J. Lubker and N. Lott, 2005: ICOADS Release 2.1 data and products. *Int. J. Climatol.*, **25**, 823 - 842.