# A Comparison of COADS and Nimbus-7 Cloud Statistics

Bryan C. Weare
Atmospheric Science Unit
Department of Land, Air and Water Resources
University of California, Davis, CA 95616

## Abstract

Comprehensive Ocean Atmosphere Data Set (COADS) cloud fraction statistics are compared to those derived from Nimbus-7 satellite analyses. The comparisons utilize means, variances and correlations, the latter two of which have been modified to adjust for inflation of variance due to low sampling in the COADS for many regions south of 20°N. The COADS total cloudiness values are found to be about 10% larger nearly everywhere. On the other hand the variances of monthly Nimbus-7 cloud amounts minus the annual mean are usually more than twice those of the COADS values. Both cloudiness data sets show significant regional correlations with local surface temperatures and relative humidities.

## 1. Introduction

The COADS (Woodruff et al., 1987), which has measures of both cloudiness and large-scale surface variables, is a potentially useful data available to supplement the satellite sources in cloud/climate studies. The problems with the COADS or similar data sets have been well documented. The most important is the very irregular sampling in both space and time. The sampling problems are especially severe in the Southern Hemisphere oceans in which observations are extremely rare and in coastal regions in which sharp gradients may prohibit large spatial averaging.

Since satellite data sets are the result of at least daily sampling at a relatively high spatial resolution, they are apparently free of most of the severe sampling uncertainties associated with the COADS. This makes them ideal for detailed budget and statistical studies. On the other hand they are subject to special uncertainties of their own. For the satellite data the most important is related to the fact that the directly measured satellite radiances usually must be transformed using statistical relationships to more traditional meteorological variables to aid interpretation or inclusion in theory and models. Therefore, nearly all satellite cloud research rely upon a number of very empirical "tests" of the satellite radiances and sometimes auxiliary data to develop secondary variables such as total cloud amount, cloud forcing or cloud top temperatures.

## 2. Adjustment of Variances and Correlations

Even though a 10°xl0° latitude-longitude region may have a sampled monthly average, if the number of individual observation or subsamples making up that average is small, it is likely that the sample average will be far from a "true" value. This can be expressed by

$$x_i = x_{ti} + \varepsilon_i(n_1) \qquad (1)$$

where $x_i$, represents the sampled average value at time i, $x_{ti}$ the true value of the average for that region under the conditions of a large number of individual observations, and $\varepsilon_i(n_i)$ is the error introduced by the sampling of only $n_i$ subsamples.

It is reasonable to assume that over a long time with N samples that the sampled mean will approach the true mean so that the sum of the ε's will approach zero. It may also be assumed that for large N, the sum of the products of the errors and any other quantity are uncorrelated. These two conditions may be summarized as

$$\sum_{i=1}^{N} x_i/N = \sum x_{ti}/N \tag{2}$$

$$\sum_{i=1}^{N} \varepsilon_i Z_i = 0 \; for \; any \; Z \tag{3}$$

With these definitions and assumptions an estimate of the variance of N samples may be given by

$$s_x^2 = s_{xt}^2 + \sum \varepsilon_i(n_i)^2/N-1 = s_{xt}^2 + s_\varepsilon^2 \tag{4}$$

It will be further assumed that the functional relation between the mean number of subsamples n in a sample and the variance of the error *F*, is proportional to the inverse of the mean number of subsamples such that

$$s_\varepsilon^2 = \boldsymbol{b}(1/n - 1/n_o) \tag{5}$$

$$where \; as \; \boldsymbol{n} \to n_o s_\varepsilon^2 \to 0$$

In this case it has been assumed that the variance of the sampling error is zero if there are at least $n_o$ subsamples in a mean. A best fit estimate of the unknown b in Eqn. 5 may be found if one has a sufficiently large group of means in which the number of subsamples **n** varies from near zero to the maximum $n_o$. This may be found by grouping data over approximately homogenous climatic regions such that the relation between $s_\varepsilon^2$ and **n** might be expected to be nearly constant. Given a geographic area defined by the index j an estimate <b> may be calculated from the solution of the linear regression

$$s_{xj}^2 = \boldsymbol{s_{xjt}^2} + b(1/\boldsymbol{n}_j - 1/n_o) \tag{6}$$

In this case the best fit estimate of the true variance at a location j adjusted for the number of observations $\mathbf{n}_j$ is

$$s^2_{xtj} = s^2_{xj} - \langle b \rangle (1/\boldsymbol{n}_j - 1/n_o) \qquad (7)$$

A comparable derivation may be made to estimate an adjusted correlation. The adjustments for total cloud amount explained more than 70% of the random variance and were applied to all grids with less than 100 observations in a month.

## III. Comparisons

Monthly mean COADS total cloudiness for the period January 1980 through December 1984 for 10° grids was compared to the average of day and nighttime observations of the analysis derived from the Nimbus-7 satellite (Stowe et al., 1988, 1989). Monthly means of these data, which are available on an approximately equal area $(500\text{km})^2$ grid, were interpolated to the 10° COADS grid using cubic splines. Figure 1a shows the differences between the COADS and the Nimbus-7 annual means for the 5 years, 1980/84. Regions which are significantly different at the 95% level are stippled in Fig. 1 and subsequent maps. The Nimbus-7 estimates are usually more than 10% smaller except in the convective areas of equatorial western Pacific. The differences in the persistent stratus regions of the eastern oceans are especially large.

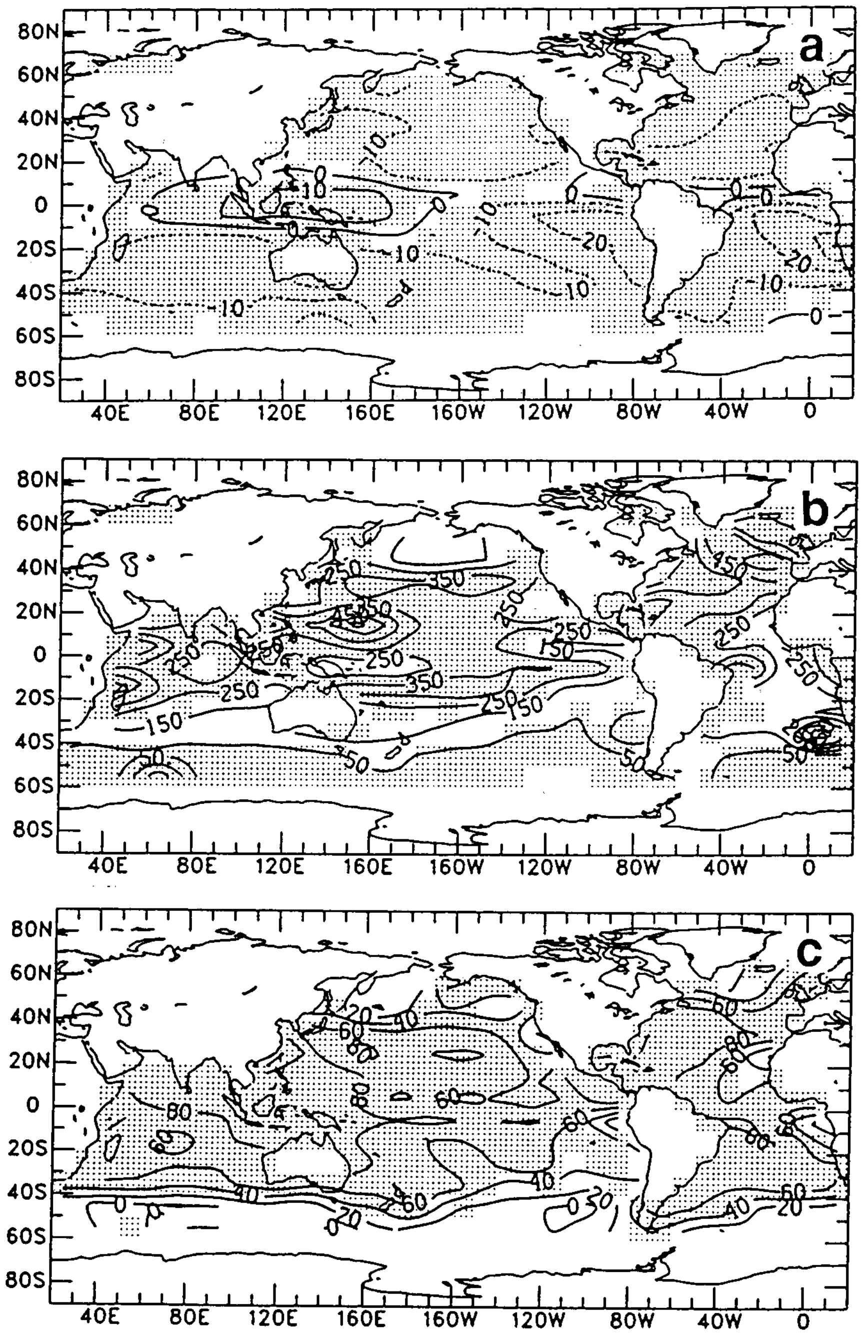


Figure 1. Statistical comparisons of Nimbus-7 total cloudiness and COADS cloudiness for 1980-84. a) Nimbus-7 minus COADS annual means (%), b) ratios (%) of Nimbus-7 over COADS variances calculated as departures from the annual means, and c) correlations (%) between Nimbus-7 and COADS departures from their annual means. In each case regions where the values are found to differ at the 95% confidence level are stippled.

Figure lb shows the ratio of the adjusted annual variances of COADS cloud fractions relative to unadjusted values for the Nimbus-7 estimates for the same five years. In general over much of the ocean the Nimbus-7 seasonal variability is significantly larger at the 95% confidence level. Only south of about 40°S, where COADS variances undoubtedly remain inflated by a lack of observations, is COADS variability greater.

Fig. 1c shows the adjusted correlations of the COADS cloud fractions and Nimbus-7 total cloud estimates for the five years of overlapping data. Significant positive correlations exist for nearly all regions between 40°N and 40°S. Maxima exist in broad areas of the tropics with the exception of the eastern oceans of substantial stratus cover, where local minima exist. In addition minima exist at the northern latitudes of both the Atlantic and Pacific Oceans in regions of substantial summer low cloud.

Another possible measure of the realism of the COADS data and their relationships to “modern” satellite analyses are the statistical relationships between cloudiness and thermodynamic variables. To illustrate Fig. 2 shows the point correlations between departures of individual monthly mean COADS total cloudiness from the annual means and comparable departures of COADS surface air temperature (SAT) and relative humidity (SRH). Figure 2a shows moderate negative correlations between total cloudiness and SAT over much of the world ocean. Small areas of significant positive correlations exist in the tropics.

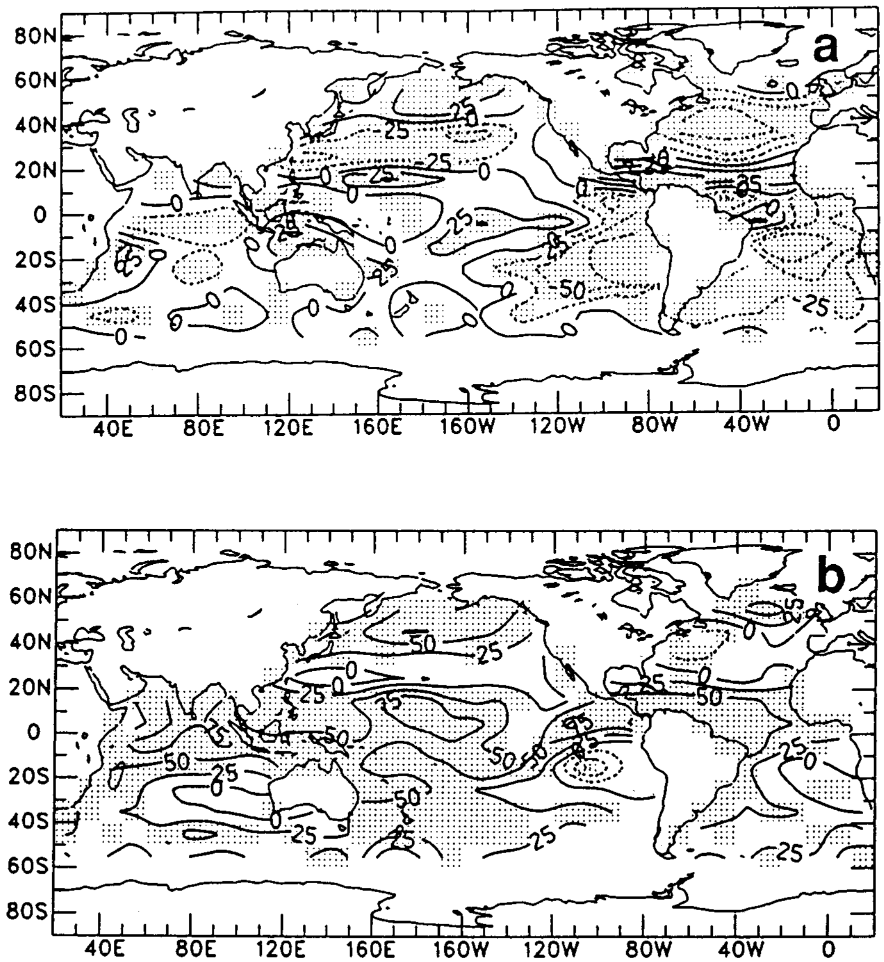


Figure 2. Intra-annual correlation as in Fig. 1 between a) COADS cloud fractions and surface air temperatures, and b) COADS cloud fractions and surface relative humidities for 1980-89.

Figure 2b, showing the correlations between departures from the annual means of COADS total cloudiness and surface relative humidities, indicates even stronger relationships between these variables than between SAT and cloudiness. Figure 2b suggests moderate to strong positive relationships over most of the tropical oceans except the eastern Pacific and Atlantic. This implies that as a region goes into its season of maximum convection that increases in cloudiness are accompanied by increases in surface relative humidity. From the information in Fig. 2a, this link is not primarily related to associated changes in SAT. In addition there are relatively strong links between the variables in both the far northern Pacific and Atlantic Oceans.

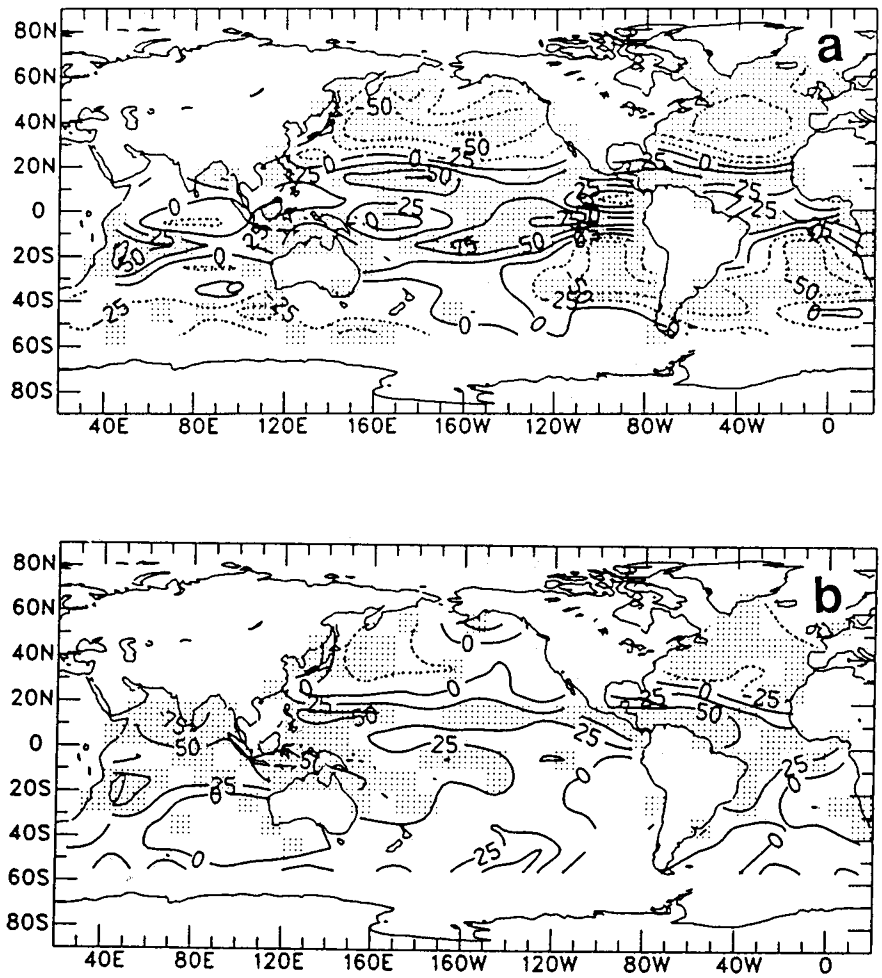


Figure 3. Intra-annual correlations as in Fig. 1 between a) Nimbus-7 total cloud amounts and COADS surface air temperatures and b) Nimbus-7 total cloud amounts and COADS surface relative humidities for 1980-84.

The relationships between total cloud amount and SAT and SRH may be compared to those which may be derived between Nimbus-7 total cloud amounts and COADS SAT and SRH. Figure 3 shows correlations for these data corresponding to those of Fig. 2. There are a number differences in the SAT correlations shown in Fig. 2a and 3a. In general with the Nimbus-7 data the areas of positive correlations in the tropics are more extensive and have greater maxima. Another difference between Fig. 2a and 3a is in the North Pacific where the COADS-only data suggest moderate positive correlation, whereas the Nimbus-7 cloud data indicate moderate negative correlations.

Fig. 3b, showing the correlations between Nimbus-7 total cloud amounts and COADS SRH, may be compared to Fig. 2b for COADS-only data. In the tropics the COADS cloudiness show more extensive and larger positive correlations. These differences are especially evident in the equatorial Pacific. At higher latitudes of the Pacific Fig. 2b shows moderate to strong positive correlations, whereas the Nimbus-7 data show weak negative correlations. Thus the two cloud data sets show a substantially different relationship with SRH in the North Pacific. Both sets of correlations show weak, generally insignificant correlations for the North Atlantic.

## Acknowledgement

The Nimbus-7 data were kindly provided by the National Space Science Data Center and the COADS data by the National Center for Atmospheric Research.

## References

Stowe, L.L., Wellemeyer, G.G., Eck, T.F., and Yeh, H.Y.M., 1988: Nimbus 7 global cloud climatology. Part I. Algorithms and validation. *Journal of Climate*, **1**, 445-470.

—,Yeh, H.Y.M., Eck, T.F., Wellemeyer, C.G., Kyle, H.L., and the Nimbus 7 cloud data processing team, 1989: Nimbus 7 global cloud climatology. Part IL First year results. *Journal of Climate*, **2**, 671-709.

Weare, B.C., 1989: Uncertainties in estimates of surface heat fluxes derived from marine reports over the tropical and subtropical oceans. *Tellus*, **41A**, 357-370.

Woodruff, S.D., Slutz, R.J., Jenne, R.L. and Steurer, P.M., 1987: A comprehensive ocean-atmosphere data set. *Bulletin of the American Meteorological Society*, **68**, 1239-1250.