4B.3 EFFECTS OF RANDOM SAMPLING ERRORS ON TOGA-COARE ATMOSPHERIC BUDGETS

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1. INTRODUCTION

Rawinsondes invariably sample small-scale spatial and temporal fluctuations of the atmospheric flow. In the course of interpolating fields from networks of sounding stations, these fluctuations are aliased onto larger scales, leading to errors in the analyzed fields. Some of these errors are random (e.g., those due to random turbulence or convection), whereas others are nonrandom (e.g., those due to local effects such as topography, instrument biases, etc.). Assuming nonrandom errors or biases can be effectively removed, the remaining sampling errors should be random and therefore reduced by averaging over successively longer time intervals. To date, quantitative estimates of the impacts of random sampling errors on atmospheric budgets have not been made.

In order to address this problem, sounding data from four ships (*Kexue 1, Shiyan 3, Xiangyanghong 5,* and *Moana Wave*) in the TOGA-COARE Intensive Flux Array (IFA) are used to estimate random sampling errors in the moisture and wind fields. Deviations of individual observations from the four-station means form the basis of a 'noise model' that is then applied to the analysis of atmospheric budgets for the four-month Intensive Observing Period (IOP). Since the average separation of these ships is ∼200 km, the noise in many instances reflects the variability associated with mesoscale convective systems.

2. ENSEMBLE RESULTS: VERTICAL MOTION

Random realizations of noise in u, v and relative humidity (RH) are used to "contaminate" the sounding data to simulate the effects of launching the rawinsondes at slightly different locations or times. Since temperature variations are typically small in the COARE region, they are not included in the noise model. The standard deviation σ of the wind speed varies from 2.6 m s^{-1} below 400 hPa to 3.6 m s^{-1} at 150 hPa, while σ for RH increases from 5% in the boundary layer to 10-15% through the rest of the troposphere. Averaging reduces the sampling errors, such that for the IOP, the wind noise is ∼0.1 m s^{-1}; however, errors are amplified in computing divergence. A plot of 20 noise ensemble ω profiles and their mean is shown in Fig. 1. Despite the four-month averaging, the variability in ω at 500 hPa is ∼20%. As will be shown later the variability is greater for shorter averaging periods.

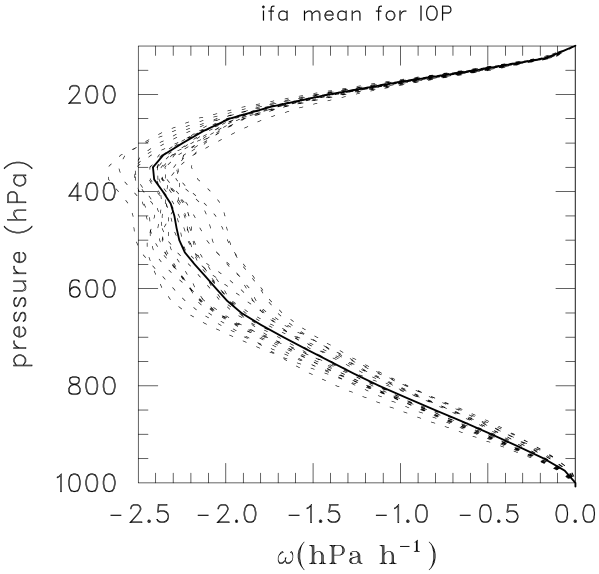

Figure 1: TOGA COARE IFA-mean vertical p-velocity for four-month IOP (dashed profiles for 20 ensembles, solid for the no-noise case).

3. IFA RAINFALL

A time series of IFA rainfall computed from the moisture budget (following the procedure of Johnson and Ciesielski 2000) is shown in Fig. 2. A running five-day mean of daily-averaged rainfall amounts for each of the ensembles is presented so

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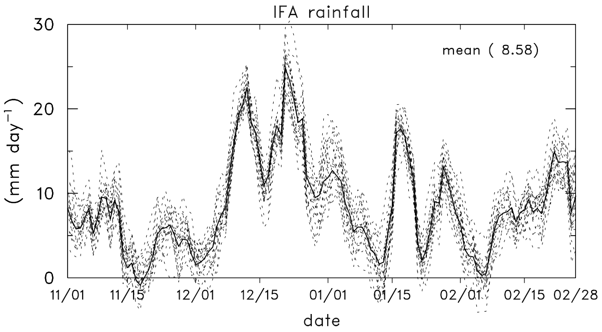

Figure 2: TOGA COARE IFA-mean rainfall rate for four-month IOP (dashed lines for 20 ensembles, solid for mean).

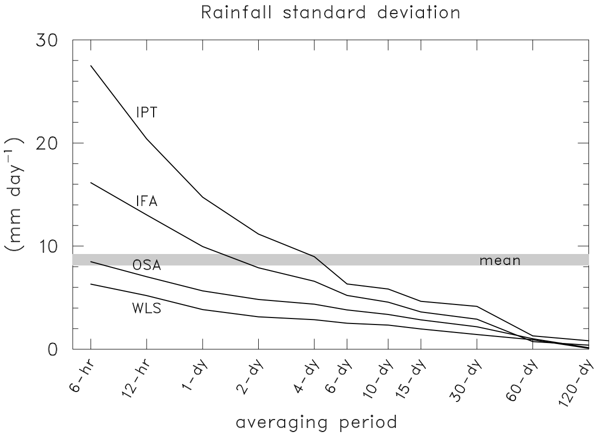

Figure 3: Standard deviation of rainfall rates as a function of averaging period. IPT refers to a point in the IFA, OSA the Outer Sounding Array, and WLS the western portion of the Large Scale Array. An envelope of the IOP-mean rainfall rates for the four areas is denoted by the shaded bar.

that results can be compared directly with those in Johnson and Ciesielski. There is large variability of the mean rainfall rate on weekly and monthly time scales in association with convective disturbances and the Madden-Julian Oscillation. The highest rainfall rates occurred in December during a strong westerly wind burst and the noise in the rainfall estimates was greatest at the end of that period (around January 1), very likely due to the high wind speeds and sharp vertical gradients in moisture at that time.

4. SPATIAL AND TEMPORAL VARIABILITY OF RANDOM ERRORS

Rainfall rates averaged over four different areas and for a range of averaging times have been computed from the moisture budget (Fig. 3). In computations outside the IFA, the noise model for the IFA is extended to the other sounding sites.

The four areas considered are a point in the IFA (denoted IPT), the IFA itself, the Outer Sounding Array (OSA, an area encompassing the IFA but ∼10 times larger), and western Large Scale Array (WLS, 10°S–10°N and 140–170°E). The time range is from the six-hour sampling interval of the soundings to the four-month period of the IOP. Figure 3 shows that sampling errors for a point in the IFA (IPT) and the IFA itself are very large (exceeding the IOP-mean rainrate) on short (∼1–4 day) time scales. Standard deviations of IFA rainfall drop to half the IOP mean only when averaging is done over more than 15 days. Budget estimates for the larger OSA and WLS areas are more reliable at shorter time periods. An encouraging result is that the range of independent estimates of rainfall rate from the atmospheric moisture budget, satellite estimates, and ocean salinity budget reported in Johnson and Ciesielski (2000) all agree within the ∼0.4 mm day^{-1} standard deviation for the IFA for the 120-day IOP.

5. SUMMARY AND CONCLUSIONS

A model has been developed to estimate the random sampling errors in sounding data from the TOGA COARE Intensive Flux Array (IFA). Deviations of wind and moisture from means at four ships in the IFA at six-hourly intervals form the basis of a noise model. Application of this model to moisture budget computations of rainfall rate provide quantitative estimates of sampling errors as a function of area size and averaging period (Fig. 3). This information is of value in comparing budget results to those from other platforms (e.g., satellite) and for assigning uncertainty estimates to rainfall rates assimilated into numerical prediction models.

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6. REFERENCE

Johnson, R. H., and P. E. Ciesielski, 2000: Rainfall and radiative heating rates from TOGA COARE atmospheric budgets. *J. Atmos. Sci.*, **57**, 1497–1514.