NOTES AND CORRESPONDENCE

On Trends and Possible Artifacts in Global Ocean Cloud Cover between 1952 and 1995

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ABSTRACT

Synoptic surface cloud observations are used to examine interdecadal variability in global ocean cloud cover between 1952 and 1995. Global mean total cloud cover over the ocean is observed to increase by 1.9% (sky cover) between 1952 and 1995. Global mean low cloud cover over the ocean is observed to increase by 3.6% between 1952 and 1995. Trends in zonal mean total and low cloud cover in 10°-latitude bands between 40°S and 60°N are all positive, and trends in the Southern Hemisphere and Tropics are generally as large or larger than trends in the midlatitude Northern Hemisphere. This argues against attribution of increased cloud cover to increased anthropogenic aerosol. Although it is possible that global cloud cover is responding to some other global parameter, perhaps global temperature, it is not clear what underlying physical mechanism would cause substantially different processes in the Tropics, subtropics, and midlatitudes to all produce increasing cloudiness. On the other hand, the fact that ships with a common observing practice travel over most of the global ocean suggests a possible observational artifact may be largely responsible for the upward trends observed at all latitudes. Potential causes of artifacts are examined but do not provide likely explanations for the observed interdecadal variability. Thus, it remains uncertain whether the observed increases in global mean ocean total and low cloud cover between 1952 and 1995 are spurious. Corroboration by related meteorological parameters and satellite-based cloud datasets should be required before the trends are accepted as real.

1. Introduction

Although cloudiness is one of the most important variables influencing the earth's radiation budget, our present understanding of the role of cloudiness in the climate system is limited. Current general circulation models do not consistently and correctly simulate cloudiness (e.g., Cess et al. 1996; Weare et al. 1996), and satellite cloud datasets such as the International Satellite Cloud Climatology Project (ISCCP; Rossow and Schiffer 1991) have records too short to examine interdecadal variability. For these reasons, studies involving surface cloud observations are crucial for investigating cloud–climate interaction. Most investigations of interdecadal variability in cloudiness have examined total cloud cover over land regions (e.g., Angell 1990; Henderson-Sellers 1989, 1992; Jones and Henderson-Sellers 1992; Karl and Steurer 1990; among many others), but an increasing number are examining cloud amount and type over the ocean (Bajuk and Leovy 1998b; London et al. 1991; Norris and Leovy 1994, 1995; Norris et al. 1998; Parungo et al. 1994; Warren et al. 1988). The results of the ocean studies indicate that significant trends in cumulonimbus, low-level stratiform cloudiness, and mid-level stratiform cloudiness have occurred over various regions of the ocean in recent decades, but the very large magnitudes of some of the trends raises questions as to whether they are real or spurious (Nicholls et al. 1996). In fact, Bajuk and Leovy (1998a) conclude that interdecadal variability in the frequency of occurrence (FQ) of various low cloud types is dominated by observational artifacts. Considering the large impact that cloudiness has on the climate system, it is essential to both document interdecadal variability in cloudiness and examine the likelihood that the observed variability is real, especially those variations possibly related to climate change.

The present study discusses possible sources of spurious interdecadal variability in surface-observed cloud datasets and investigates the reliability of the observed variability in ocean cloudiness between 1952 and 1995. Total cloud cover was chosen as the primary cloud parameter for examination since it is of greatest general interest and simplicity. In this way, total cloud cover

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presents the most rudimentary test of the reliability of a cloud dataset. Because it is more difficult for an observer to identify low cloud type than to estimate total cloud cover, the fact that the interdecadal variability in the FQ of various low cloud types is dominated by artifacts (Bajuk and Leovy 1998a) does not necessarily imply that interdecadal variability in total cloud cover will also be dominated by artifacts. However, if global total cloud cover is dominated by artifacts, it is likely that every other global surface-observed cloud parameter is dominated as well. Since several recent studies have investigated interannual and interdecadal variability in low cloud types over the ocean (Norris and Leovy 1994; Bajuk and Leovy 1998b; Norris et al. 1998), low cloud cover was also evaluated.

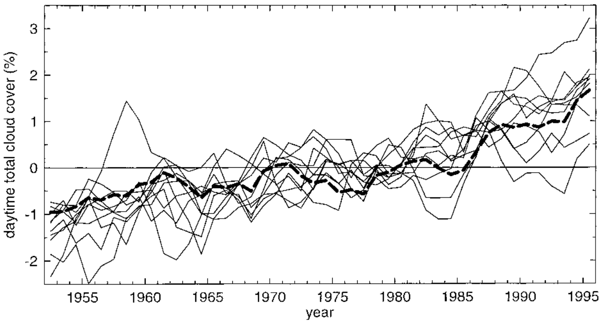

FIG. 1. Yearly global mean departure (thick dash) and zonal mean departures (thin) from long-term mean daytime total cloud cover over the ocean. Zonal means are for 10°-lat bands between 60°N and 40°S. Units are percent sky cover. Three-year running mean smoothing was applied.

2. Surface cloud observations and artifacts

The greatest source of long-term cloud information over the global ocean are synoptic reports collected in the Comprehensive Ocean–Atmosphere Data Set (COADS; Woodruff et al. 1987). Cloud observations, primarily provided by volunteer observing ships, are reported according to World Meteorological Organization (WMO) code (WMO 1974). Total cloud cover (N) is estimated to the nearest okta (eighth), where $N = 0$ is clear sky and $N = 8$ is overcast. When the sky is obscured (most commonly due to fog), $N = 9$ is reported. At some unknown time, a rule was introduced to report any cloud, no matter how small, as $N = 1$, and any break in overcast, no matter how small, as $N = 7$ (Wright 1986). This will cause a slight overestimation of cloud cover for nearly zero cloudiness and a slight underestimation of cloud cover for nearly overcast cloudiness. Cloud cover by low clouds (N_h) is similarly estimated, where $N_h = 0$ is no low cloudiness and $N_h = 8$ is overcast low cloudiness. If no low clouds are present (a rare occurrence over open ocean), observers are instructed to instead report N_h as cloud cover by middle clouds; however, for the purposes of consistency, the present study will treat N_h as zero if no low clouds are present.

Artifacts in observational datasets in general and surface-observed cloud cover in particular can arise from three broad sources: 1) changes in observing practice, official or otherwise; 2) artifacts created by incorrect archiving of individual observations; and 3) biases introduced by improper data reduction.

Two significant changes in the observing procedure for cloud cover have occurred in the last five decades. The more recent change, in 1982, allowed observers to report N_h as ‘‘/’’ (no low cloud cover information) instead of zero for conditions of clear skies ($N = 0$). This creates a potential bias in low cloud cover since a small fraction of ships routinely report N but not N_h (Hahn et al. 1996). Prior to 1982 these reports could be excluded from calculations of average low cloud cover because N_h was recorded as /, but after 1982 it was no longer possible to distinguish between ships that normally reported N_h and those that did not. Ships that did not normally report N_h would contribute to calculations of average low cloud cover only when skies were clear, thus creating a potential clear-sky bias. Since N_h is not reported when the sky is obscured ($N = 9$), there is a similar potential sky-obscured bias. These biases are small globally because clear sky and sky obscured are rare over most of the ocean; nonetheless, the biases are avoided in the present study by calculating average low cloud cover using a somewhat unconventional method described in the appendix. Total cloud cover is unaffected by this bias.

The earlier change, in 1949, changed reporting of cloud cover in logbooks from tenths to oktas (Elms et al. 1993). Confusion related to this change appears to have sometimes caused mistakes in the archiving of observations. Because cloud cover transmitted over radio was reported in oktas even before 1949, Elms et al. (1993) suggested that some observers may have also recorded logbook cloud cover in oktas prior to 1949, which later archivists mistakenly assumed to be in tenths. This may account for the large 2% increase in total cloud cover between the decade of the 1930s and the years following 1950 [displayed in Fig. 1 of Parungo et al. (1994)]. It is interesting to note that similar large increases in total cloud cover between the early 1930s and early 1950s have occurred over several land regions (Henderson-Sellers 1989; Jones and Henderson-Sellers 1992), at least some of which are not consistent with observations of sunshine duration (Karl and Steurer 1990) and some of which may be attributed to confusion between cloud cover reported in oktas and cloud cover reported in tenths (Henderson-Sellers 1992).

A change from reporting in tenths to reporting in oktas would be easy to accommodate if all observers immediately adopted the new procedure, but instead some nations (NCDC 1962) and apparently many ships continued reporting in tenths for several years after 1949. It is possible that other unrecorded changes in training procedures have occurred over the years. Such artifacts are extremely difficult to identify because offending ships travel over large areas of the global ocean; thus, it is not possible to compare observations with those from nearby locations, as can be done for land stations. Indeed, if offending ships travel over most of the global ocean, then it is likely that their contribution to spurious variability will tend to be globally uniform, as concluded by Bajuk and Leovy (1998a). A nation with a different but nevertheless temporally consistent observing practice can also produce spurious interdecadal variability if the relative contribution of that nation to global shipping changes over the years. This is different from the situation over land, where different national observing practices instead produce spatial inhomogeneities. Discussion of other minor biases can be found in Warren et al. (1988).

Improper data reduction can also produce spurious interdecadal variability, and datasets processed from the COADS archive are particularly susceptible to sampling biases. Because the distribution of shipping over the global ocean is very nonuniform, simple averages may be heavily weighted toward one particular area of a grid box. As shipping routes change over time, the most heavily weighted region within a grid box can vary and consequently generate spurious variability if strong spatial gradients in cloudiness exist within the grid box. For example, the large 10° lat × 20° long grid boxes along 40°N in the central Pacific from the Hahn et al. (1988) dataset exhibit a spurious upward trend in cloudiness due to a slight northward shift in the major trans-Pacific shipping routes toward climatologically cloudier regions from the 1950s to the 1980s. This problem can be minimized by averaging observations in grid boxes sufficiently small that climatological cloud properties do not vary significantly across the grid box. These small grid box averages can subsequently be aggregated into larger grid boxes without weighting by the number of observations to reduce statistical noise. A similar sampling bias can arise if the relative contribution of daytime and nighttime observations changes over time in the presence of a diurnal cycle in cloudiness.

3. Total and low cloud cover between 1952 and 1992

Interdecadal variability in total and low cloud cover between 1952 and 1995 was examined using observations from a preliminary release of the Extended Edited Cloud Report Archive (EECRA), an updated version of the Edited Cloud Report Archive (Hahn et al. 1996). Observations from Ocean Weather Station (OWS) locations were not used to prevent a potential bias resulting from slightly differing observing practices between the OWS and nearby volunteer observing ships (Warren et al. 1988). Observations from the Historic Sea Surface Temperature (HSST) project (decks 150, 151, 152, 155, and 156) and a few other minor sources (decks 118, 666, 667, and 891) were also not used because the N_h report in these observations was transcribed only when $N = 0$ (Warren et al. 1988); furthermore, these observations almost never include reports of $N = 9$. Because observers often have difficulty estimating cloud cover under conditions of poor illumination (Hahn et al. 1995), the number of usable nighttime observations is much less than the number of daytime observations. For this reason, only daytime (defined in the present study as daylight plus twilight) cloud cover is presented. This also avoids a diurnal sampling bias resulting from the increase in the fraction of total global daytime observations from about 60% to about 65% between 1952 and 1995 (not shown).

Daytime monthly mean total cloud cover at 2.5° lat × 5° long resolution between December 1951 and November 1995[1] was obtained by averaging all contributing individual daytime observations in the EECRA. Daytime monthly mean low cloud cover for the same resolution and time period was obtained by averaging all contributing individual daytime observations using the method described in the appendix to avoid biases resulting from the 1982 change in observing procedure. The 2.5° lat × 5° long monthly means were averaged to 5° lat × 10° long seasonal means with weighting by area but not by the number of contributing observations, so as to reduce sampling biases. The long-term mean was removed from the time series of seasonal-mean cloud cover in each 5° × 10° grid box, and the departures from the long-term mean from every season in a single year and every grid box in global and zonal domains were averaged to provide yearly values of global and zonal cloud cover. To reduce sampling biases in global and zonal averages, the 5° × 10° grid boxes were weighted by area but not by the number of observations contributing to the grid box values.

No minimum number of observations was required to use a grid box value, and the considerable statistical noise in poorly traveled regions of the ocean was minimized by the use of very large averaging domains. However, a large number of grid boxes in the Southern Ocean have substantial missing data. The effect of averaging the departures from the long-term mean instead of the raw values in each grid box is to assume that missing grid box values equal the long-term mean. Thus, yearly values of global cloud cover anomaly have a slight bias toward better-sampled regions of the ocean. Yearly values of zonal mean ocean cloud cover in 10°-lat bands are presented only between 60°N and 40°S because higher latitudes are poorly sampled.

Figures 1 and 2 show yearly global mean departure from the long-term mean for daytime total and low cloud cover over the ocean between 1952 and 1995, along

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[1] The annual average for each year is defined as December–November instead of January–December, to be consistent with seasonal definitions of December–February, March–May, June–August, and September–November.

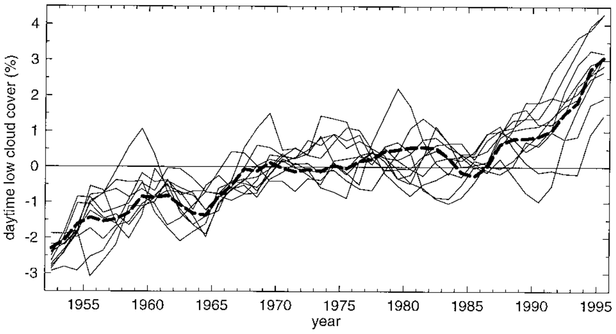

FIG. 2. Yearly global mean departure (thick dash) and zonal mean departures (thin) from long-term mean daytime low cloud cover over the ocean. Zonal means are for 10°-lat bands between 60°N and 40°S. Units are percent sky cover. Three-year running mean smoothing was applied.

TABLE 1. Percent variance explained by and significance level* of linear trends displayed in Fig. 3.

	Total cloud		Low cloud	
Region	Variance explained (%)	Significance level (%)	Variance explained (%)	Significance level (%)
Global	62	99.7	75	99.9
50°–60°N	10	95.9	26	98.2
40°–50°N	5	85.1	11	86.9
30°–40°N	55	99.8	67	99.3
20°–30°N	56	99.8	70	99.5
10°–20°N	56	98.6	64	99.7
0°–10°N	33	99.2	54	99.3
0°–10°S	69	99.8	67	99.8
10°–20°S	73	99.8	56	99.9
20°–30°S	52	99.8	51	99.9
30°–40°S	63	99.7	62	99.8

* Significance was calculated as the percentage of 10 000 random orderings of the time series with trend absolute magnitudes less than the observed trend absolute magnitude. Autocorrelation was taken into account by fitting the observed time series to a first-order autoregressive model and reordering the temporally independent residuals.

with zonal means in 10°-lat bands between 60°N and 40°S. A 3-yr running mean was applied to the global and zonal time series to focus on lower-frequency variability. Although higher-frequency variability is present, both the global and zonal time series are dominated by an upward trend. Upward trends are also evident if regional averages (North Pacific, tropical Pacific, South Pacific, North Atlantic, tropical Atlantic, South Atlantic, tropical Indian, and South Indian) are used instead of zonal means (not shown). The fact that the low cloud trend is greater than the total cloud trend suggests that the increase in low cloud cover may be largely responsible for the increase in total cloud cover. This would argue against attribution of increased total cloud cover primarily to the increased frequency jet-induced cirrus contrails (e.g., Changnon 1981). Low cloud cover also appears to have zonally coherent variations at shorter timescales.

Figure 3 shows changes in zonal and global mean daytime total and low cloud cover over the ocean between 1952 and 1995 accounted for by least squares linear trends. Table 1 lists the percent variance explained by and significance level of each trend in Fig. 3. The

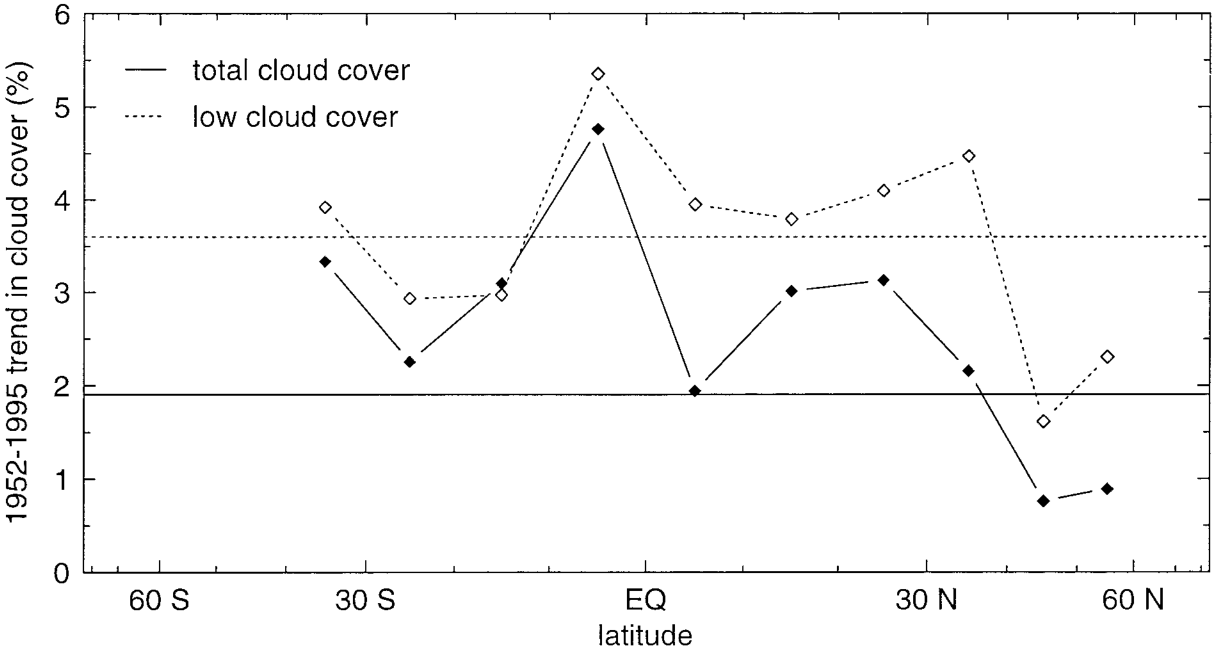

FIG. 3. Change in daytime total (solid) and low (dotted) cloud cover over the ocean between 1952 and 1995 for zonal (connected diamonds) and global (horizontal lines) averages.

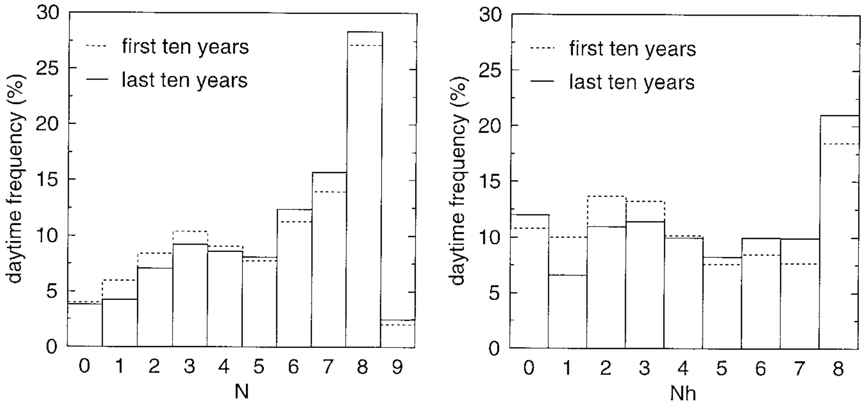

FIG. 4. Histograms of global ocean average daytime FQ of $N = 0$ through $N = 9$ (left) and $N_h = 0$ through $N_h = 8$ (right) for 1952–61 (dotted) and 1986–95 (solid).

changes in total and low cloud cover exhibit similar meridional variations and are uniformly positive. The fact that trends in the Southern Hemisphere and Tropics are generally as large or larger than trends in the midlatitude Northern Hemisphere argues against attribution of increased cloud cover to increased anthropogenic aerosol. Given that processes responsible for generating cloudiness in the Tropics, subtropics, and midlatitudes are substantially different, it is surprising that total and low cloud cover have increased between 1952 and 1995 in every latitude band with sufficient sampling. Although it is possible that global cloud cover is responding to some other global parameter, perhaps global temperature, our present state of knowledge provides little physical basis to expect this. On the other hand, the fact that ships with a common observing practice travel over most of the global ocean suggests that a possible artifact may be largely responsible for the observed trends. However, it is difficult to attribute a gradual trend to a change in observing procedure.

4. Possible observational artifacts

Trends in total and low cloud cover can be investigated in greater detail by examining changes in the frequency of each N and N_h okta category that is reported. Yearly global mean daytime FQ of $N = 0$ through $N = 9$ and $N_h = 0$ through $N_h = 8$ over the ocean between 1952 and 1995 was calculated in a manner similar to that for total cloud cover. Because individual N and N_h okta categories are dominated by trends (not shown), long-term changes can be concisely summarized by displaying N and N_h histograms for the first 10 yr and last 10 yr of the record (Fig. 4). It is apparent that the observed upward trends in total and low cloud cover are largely due to increased reporting of 6, 7, and 8 oktas and decreased reporting of 1, 2, and 3 oktas. The fact that the FQ of $N = 8$ and $N_h = 8$ did not decrease over the time period suggests that the change to reporting any break in overcast, no matter how small, as $N = 7$ or $N_h = 7$ did not significantly affect the trends. Similarly, the fact that $N_h = 0$ did not decrease over the time period suggests that the change to reporting any cloud, no matter how small, as $N_h = 1$ did not significantly affect the trends, at least for low cloud cover. The increase in the FQ of $N = 9$ is consistent with the phase out of observations measuring total cloud cover in tenths, which did not report sky-obscured (J. Elms 1997, personal communication), but this also has little affect on trends in cloud cover.

Although WMO instructions for reporting cloud cover did not change between 1952 and 1992, it is possible that national observing practices for volunteer observers may have changed. The U.S. *Mariners Weather Log* and the U.K. and Commonwealth *Marine Observer* are issued to volunteer observers and sometimes contain instructions on how to measure cloud cover. Every issue of the *Mariners Weather Log* since 1964 and the *Marine Observer* since 1962 was examined, and no change in instructions were found over the time period. Thus, the evidence available to the author indicates that cloud cover observing practice has remained constant at least since the 1960s for volunteer observers recruited by the United States and the United Kingdom. Since these observers contribute a large portion of the observations archived in COADS, it seems unlikely that the observed trends merely result from changes in training over time.

It is also possible for an artifact to result if the relative contribution to world shipping of two nations with different observing practices changes over time. Since some of the source card decks contributing to COADS include observations from only one nationality (Slutz et al. 1985), this hypothesis was examined by averaging low cloud cover separately for each of the seven primary card decks (116, 128, 555, 888, 892, 926, and 927), which contributed at least half of the monthly number of observations over the global ocean during some part of 1952–95. Six out of the seven card decks examined exhibited upward trends in global ocean low cloud cover over the time periods for which they had observations.

This indicates that if an artifact exists within the general 1952–95 time period, it is within individual source card decks.

5. Conclusions

An analysis of synoptic surface cloud observations indicates that global ocean total cloud cover has increased by 1.9% and global ocean low cloud cover has increased by 3.6% between 1952 and 1995. Upward trends are evident in every 10°-lat band between 60°N and 40°S. Although no physical mechanism has been identified that would produce increasing cloudiness at all latitudes, the uniform upward nature of the trends is consistent with a possible observational artifact produced by ships traveling over most of the global ocean. However, no evidence could be found for a change in observing practice, at least for volunteer observing ships recruited by the United States and the United Kingdom. Furthermore, no evidence was found that the observed 1952–95 global trend was produced by changes in the relative contributions of the primary source card decks archived in COADS. Thus, it cannot be positively established that the observed increases in global ocean total and low cloud cover are spurious.

Investigations that focus on smaller regions and interannual variability are less likely to suffer from the potential biases described in the present study because real fluctuations in cloud cover are relatively stronger on smaller spatialscales and timescales. These real fluctuations tend to cancel each other as the spatial and temporal averaging domain becomes large and any systematic biases become relatively more significant. In fact, several recent studies corroborate increases in cloud cover over specific regions of the global ocean. Norris and Leovy (1994) and Norris et al. (1998) found trends in related meteorological parameters that were consistent with increased cloudiness over the midlatitude North Pacific and North Atlantic. Chu and Wang (1997) and Waliser and Zhou (1997) documented a decrease in outgoing longwave radiation over the tropical western Pacific and Indian Oceans, consistent with increased cloudiness in this region. Further investigation is needed to corroborate increases in cloud cover elsewhere in the Tropics and over the Southern Hemisphere oceans.

At the present time it is not possible to validate global changes in surface-observed cloudiness with global changes in ISCCP satellite-observed cloudiness because the ISCCP data suffer from lack of calibration between satellites (Klein and Hartmann 1993). This situation will change when ISCCP data with corrected radiances (Brest et al. 1997) are available for a sufficiently long time period. If changes in global and zonal cloud cover between 1983 and 1995 observed by satellite and from the surface are demonstrated to be consistent, this would provide confidence that the global increase in ocean cloud cover since 1952 is real.

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APPENDIX

Calculation of Low Cloud Cover

Clear-sky and sky-obscured biases were avoided by calculating average low cloud cover ($\overline{N_h}$) only when $1 \le N \le 8$ and then normalizing by the frequency that $1 \le \mathrm{N} \le 8$; that is,

$$\overline{N_h} = \frac{\sum N_h}{n_{\mathrm{low}}} \times \frac{n_{\mathrm{all}} - n_{\mathrm{clr}} - n_{\mathrm{obs}}}{n_{\mathrm{all}}} + \frac{8 \times n_{\mathrm{obs}}}{n_{\mathrm{all}}}, \tag{A.1}$$

where the summation is over all observations contributing to n_{low}; here n_{low} is the number of observations when N_h is reported and $1 \le N \le 8$; n_{all} is the number of all observations; n_{clr} is the number of observations of clear sky ($N = 0$); and n_{obs} is the number of observations of sky obscured ($N = 9$). The right-hand term proceeds from the assumption that low cloudiness is overcast when the sky is obscured. In the case that N_h is always reported, $n_{\mathrm{low}} = n_{\mathrm{all}} - n_{\mathrm{clr}} - n_{\mathrm{obs}}$.

REFERENCES

Angell, J. K., 1990: Variation in United States cloudiness and sunshine duration between 1950 and the drought year of 1988. *J. Climate,* **3,** 296–308.

Bajuk, L. J., and C. B. Leovy, 1998a: Are there real interdecadal variations in marine low clouds? *J. Climate,* **11,** 2910–2921.

——, and ——, 1998b: Seasonal and interannual variations in stratiform and convective clouds over the tropical Pacific and Indian Oceans from ship observations. *J. Climate,* **11,** 2922–2941.

Brest, C. L., W. B. Rossow, and M. D. Roiter, 1997: Update of radiance calibrations for ISCCP. *J. Atmos. Oceanic Technol.,* **14,** 1091–1109.

Cess, R. D., and Coauthors, 1996: Cloud feedback in atmospheric general circulation models: An update. *J. Geophys. Res.,* **101,** 12 791–12 794.

Changnon, S. A., 1981: Midwestern cloud, sunshine, and temperature trends since 1901: Possible evidence of jet contrail effects. *J. Appl. Meteor.,* **20,** 496–508.

Chu, P.-S., and J.-B. Wang, 1997: Recent climate change in the tropical western Pacific and Indian Ocean regions as detected by outgoing longwave radiation records. *J. Climate,* **10,** 636–646.

Elms, J. D., S. D. Woodruff, S. J. Worley, and C. S. Hanson, 1993: Digitizing historical records for the Comprehensive Ocean–Atmosphere Data Set (COADS). *Earth Syst. Monit.* **4,** 4–10.

Hahn, C. J., S. G. Warren, J. London, R. L. Jenne, and R. M. Chervin, 1988: Climatological data for clouds over the globe from surface observations. Rep. NDP-026, 54 pp. [Available from Carbon

Dioxide Information Analysis Center, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6050.]

——, ——, and ——, 1995: The effect of moonlight on observation of cloud cover at night, and application to cloud climatology. *J. Climate,* **8,** 1429–1446.

——, ——, and ——, 1996: Edited synoptic cloud reports from ships and land stations over the globe, 1982–1991. Rep. NDP026B, 45 pp. [Available from Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6050.]

Henderson-Sellers, A., 1989: North American total cloud amount variations this century. *Global Planet. Change,* **1,** 175–194.

——, 1992: Continental cloudiness changes this century. *GeoJournal,* **27,** 255–262.

Jones, P. A., and A. Henderson-Sellers, 1992: Historical records of cloudiness and sunshine in Australia. *J. Climate,* **5,** 260–267.

Karl, T. R., and P. M. Steurer, 1990: Increased cloudiness in the United States during the first half of the twentieth century: Fact or fiction? *Geophys. Res. Lett.,* **17,** 1925–1928.

Klein, S. A., and D. L. Hartmann, 1993: Spurious changes in the ISCCP dataset. *Geophys. Res. Lett.,* **20,** 455–458.

London, J., S. G. Warren, and C. J. Hahn, 1991: Thirty-year trend of observed greenhouse clouds over the tropical oceans. *Adv. Space Res.,* **11,** 45–49.

NCDC, 1962: History of the international code. TDF-13 Reference Manual, pp. 0.6–0.10. [Available from National Climatic Data Center, Federal Building, 151 Patton Ave., Asheville, NC 28801-5001.]

Nicholls, N., G. V. Gruza, J. Jouzel, T. R. Karl, L. A. Ogallo, and D. E. Parker, 1996: Observed climate variability and change. *Climate Change 1995: The Science of Climate Change,* J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell, Eds., Cambridge University Press, 133–192.

Norris, J. R., and C. B. Leovy, 1994: Interannual variability in stratiform cloudiness and sea surface temperature. *J. Climate,* **7,** 1915–1925.

——, and ——, 1995: Comments on ‘‘Trends in global marine cloudiness and anthropogenic sulphur.’’ *J. Climate,* **8,** 2109–2110.

——, Y. Zhang, and J. M. Wallace, 1998: Role of low clouds in summertime atmosphere–ocean interactions over the North Pacific. *J. Climate,* **11,** 2482–2490.

Parungo, F., J. F. Boatman, H. Sievering, S. W. Wilkison, and B. B. Hicks, 1994: Trends in global marine cloudiness and anthropogenic sulfur. *J. Climate,* **7,** 434–440.

Rossow, W. B., and R. A. Schiffer, 1991: ISCCP cloud data products. *Bull. Amer. Meteor. Soc.,* **72,** 2–20.

Slutz, R. J., S. J. Lubker, J. D. Hiscox, S. D. Woodruff, R. L. Jenne, D. H. Joseph, P. M. Steurer, and J. D. Elms, 1985: Comprehensive Ocean–Atmosphere Data Set Release 1. NOAA Environmental Research Laboratories, 268 pp. [NTIS PB86-105723.]

Waliser, D. E., and W. Zhou, 1997: Removing satellite equatorial crossing time biases from the OLR and HRC datasets. *J. Climate,* **10,** 2125–2146.

Warren, S. G., C. J. Hahn, J. London, R. M. Chervin, and R. L. Jenne, 1988: Global distribution of total cloud cover and cloud type amounts over the ocean. Rep. NCAR/TN-317+STR, 42 pp and 170 maps. [Available from NCAR, P.O. Box 3000, Boulder, CO 80307-3000.]

Weare, B. C., and Coauthors, 1996: Evaluation of the vertical structure of zonally averaged cloudiness and its variability in the Atmospheric Model Intercomparison Project. *J. Climate,* **9,** 3419–3431.

Woodruff, S. D., R. J. Slutz, R. L. Jenne, and P. M. Steurer, 1987: A comprehensive ocean-atmosphere data set. *Bull. Amer. Meteor. Soc.,* **68,** 1239–1250.

WMO, 1974: Manual on Codes. WMO Publ. 306, Vol. 1. [Available from World Meteorological Organization, Avenue Giuseppe-Motta 41, CP2300, 1211 Geneva 2, Switzerland.]

Wright, P. B., 1986: Problems in the use of ship observations for the study of interdecadal climate changes. *Mon. Wea. Rev.,* **114,** 1028–1034.