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NOTE ON CLOUD COVER OF THE ECMWF NATURE RUN USED FOR OSSE/NPOESS PROJECT

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1. Introduction

Global atmospheric observing systems, such as those on Polar-orbiting Operational Environmental Satellites (POES), provide the basic data for Numerical Weather Prediction (NWP) forecasts and the means to monitor and assess climate. The National POES System (NPOESS) is scheduled to fly in the 2009-2018 time frame. During the next decade, a considerable amount of effort must take place to define, develop and build the suite of instruments which will comprise the NPOESS. Prior to NPOESS, the NPOESS Preparatory Project (NPP) is schedule to fly by 2005. These experiments known as Observing System Simulation Experiments (OSSEs) is conducted as a part of NPP. While forecast impact of current instruments can be assessed by Observing System Experiments, in which already existing observations are denied or added to observations from a standard data base, the impact of future instruments must be assessed with experiments using simulated observations by OSSE.

For the OSSE, a long integration of an atmospheric general circulation model (GCM) is required to provide a "true atmosphere" or "nature run" (NR) for the experiment. NR needs to be sufficiently representative of the actual atmosphere, but its model must be different from the model used for the data assimilation. For this project, the nature run is provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). Before the OSSE is started, NR must be evaluated to see if it is suitable for the experiment. This note presents an evaluation of the NR cloud cover by comparing it to available cloud datasets.

Cloud evaluation is particularly important for Doppler Wind Lidar (DWL) OSSEs. DWL data can be retrieved from only if DWL shots reach targets and the signals from target can return to the satellite. The clouds are important targets for DWL and also they interfere DWL shot. Therefore, large differences in NR cloud amount will affect the sampling of simulated data. Clouds are also necessary for generating cloud track winds from geostationary platforms. Thus the geographical and frequency distribution of simulated clouds must be similar to real clouds in order to produce comparable simulated observations and credible OSSEs. If the cloud distribution is significantly different from observations, the data impact using simulated NR observations will be different from real data and will cast doubt on the OSSE results.

In general, the NR cloud agrees with observations but large differences are noted for low level cloud (LCC). There are also large differences over both the North and South poles. In addition, NR drift in tropical high level cloud during the first five days and differences between the observed and NR vertical distribution of tropical cloud cover (CCV) are noted.

In section 2 the forecast model used for the NR and in section 3 observed cloud estimates are described. In section 4 comparisons between NR and observations are presented and in section 5 adjustment for LCC is proposed and evaluated. A concluding remarks are in section 6.

2. Nature Run

A one month free run of the ECMWF forecast model, at resolution T213 and 31 levels is used as NR (Becker et al 1996). The 6 hourly data, from 06Z 5 February through 00Z 7 March 1993, were provided by ECMWF, as either T213 spectral coefficients or reduced gaussian grid data at a resolution of approximately 60km. The gridded data were expanded to a 640×320 regular gaussian grid and saved in GRIB format for use in the OSSE. The version of the model used for the NR is same as in the ECMWF Reanalysis (ERA), containing Tiedtke's mass flux convection scheme (Tiedtke 1989) and prognostic cloud scheme (Tiedtke 1993).

3. Observed estimates

At NCEP, U.S.A.F. Real-Time Nephanalyses (RTNEPH, Hamill, 1992) are re-processed daily to produce high, middle, and low level cloud cover (HCC, MCC, and LCC respectively) on a global 1x1 degree grid. The International Satellite Cloud Climatology Project (ISCCP) stage D2, monthly-average data is provided as a satellite-view cloud (Appendix A) estimate at a 2.5 degree resolution. Since higher level cloud will obscure lower level cloud, MCC and LCC are certainly under-estimated in the ISCCP data. The NESDIS experimental product, "Clouds from Advanced Very High Resolution Radiometer"(CLAVR-phase 1), currently contains only total cloud cover (TCC) for February 1993, but future processing will produce layered clouds. The Warren cloud (Warren et al. 1988) is a surface-based cloud observational data set and is a more reliable source for LCC, but not for the HCC. Although not available for February 1993, it is used as a reference and its climatology will be used to construct an adjusted LCC.

4. Evaluation of the Nature Run cloud

a. Overview

Fig.1 shows the mean NR TCC , HCC, MCC, and LCC for the NR period. Fig. 2 shows observed estimated of TCC from RTNEPH, ISCCP, and CLAVR for February 1993. In order to compare LCC and MCC with ISCCP, a satellite-view cloud has been processed for both the NR and RTNEPH data (Appendix A). This procedure does not alter HCC estimates. Note that TCC computed as a sum of satellite-view LCC, MCC and HCC is not identical to the observed TCC. If it is larger (less) than observed TCC, the satellite-view cloud is over (under) estimated. It is found that, in general, a maximum overlap assumption underestimates satellite-view LCC and MCC, while a random overlap assumption overestimates satellite-view LCC and MCC.

Generally, the NR atmosphere is covered by cloud over most of the globe and has less clear sky area compared to observations. The geographical distribution of simulated and observed TCC shows generally good agreement (Fig.1a and Fig.2a-c). Figs. 3(a-d) shows zonal mean TCC, HCC, MCC, and LCC for NR and observations without making any overlap assumption. While zonal mean TCC in NR is in general agreement with observations, except for polar regions (Fig.3a), the HCC in NR is 20%-100% greater than all observations everywhere (Fig.3b). The difference in MCC and LCC depends on latitude and surface type.

1) Tropics

Over the tropical ocean, NR has large amount of HCC (40% in zonal mean) and small amount of LCC (15% in zonal mean), while RTNEPH has large amount of LCC (40%) and small amount of HCC (20%) and ISCCP has small values of HCC (20%) and LCC(25%). The satellite-view LCC for NR is slightly reduced and remains less than ISCCP (Fig.4a). However, when RTNEPH data is processed from a satellite view, its low cloud is reduced and becomes very close to the ISCCP estimate (Fig.4b). Fig.5 shows the longitudinal distribution of cloud averaged over the 10S-10N tropical band without making any overlap assumption. The largest difference in LCC is in the western Pacific. Again the difference between LCC for RTNEPH and ISCCP is significantly reduced when the cloud is processed as a satellite-view cloud (Fig.6b).

In order to analyze the western Pacific region more closely, the area-averaged fractional cloud cover over 10S-10N 150E-180E for high, middle, and low level cloud are shown in Table 1. Even using maximum overlapping (an underestimate), the LCC for RTNEPH is larger than ISCCP, while using random overlapping (an overestimate), the LCC of NR remain smaller than ISCCP values. For reference, the Warren cloud in February 1981 showed 11% cumulonimbus, 21% stratus and stratocumulus, and 16% cumulus in this region, whose values are between NR and RTNEPH values.

Over tropical land there are large discrepancies in LCC (Fig.3d) primarily from the convective area over Brazil. The amount of LCC in RTNEPH over tropical land masses and tropical western Pacific is approximately 60% which is 3-4 times larger than NR and ISCCP (Fig. 3d, Fig 5). By making cloud overlap assumptions, the large LCC from RTNEPH is reduced to 20%, which is quite similar to ISCCP (Fig.6). The decrease in NR satellite-view LCC is less (15% to 10%).

In general, the under-estimation of LCC by NR in the convective region is quite apparent. However, the large differences among NR, RTNEPH, and ISCCP are significantly reduced by re-computing the first two from a satellite's perspective.

2) Mid-latitudes

Observations show more clouds over ocean than land but NR has more cloud over land than ocean. Over the North Pacific, all observations show TCC values of approximately 70-90% (Fig.2), but over the same area, TCC of NR is 40-50% (Fig.1a). On the other hand, over Canada and Siberia, NR cloud is more than 70% while RTNEPH cloud cover is less than 40% and ISCCP and CLAVR cloud are approximately 50-60%. Fig. 3d shows that the difference in land -ocean contrast is primarily from LCC. In midlatitude, the NR has twice as much LCC (50%) as RTNEPH over land but only half (20%) over ocean. This contrast becomes more obvious in satellite-view LCC (Fig.4), where ISCCP cloud agrees with RTNEPH. Therefore, the NR appears to lack sufficient LCC over ocean, yet suffers from excessive LCC over snow-covered land.

3) Polar region

In polar regions, observations disagree among themselves as much as they disagree with NR. In the arctic, NR has more than 80% cloud cover but RTNEPH shows almost clear sky. ISCCP and CLAVR show approximately 60% cloudiness. Over the Antarctica NR and ISCCP show clear sky whereas RTNEPH and CLAVR show large cloud amount. There is some disagreement in the implied cloud height. In the arctic, the NR LCC is 80% while its HCC and MCC is 40%, but both RTNEPH and ISCCP show almost no LCC and HCC, though ISCCP has a value for MCC of over 60%. Low values LCC in ISCCP could be due to overlapping with MCC, but its amount cannot be more than 60%, which is still less than LCC in NR.

b. Statistical comparison between time mean fields of NR and observed cloud

The monthly mean TCC and LCC data from NR are statistically compared with available observational datasets, including the Nimbus 7 climatology (1980-1985). Correlation and bias are computed for 43 regions of the globe, which range from global to regional areas. Comparisons are shown, in tabular form, for 14 regions containing only land points and for 13 regions containing only sea points. In order to compare properly LCC from satellite-only data such as ISCCP, LCC from NR and RTNEPH are recomputed using the cloud-overlap assumptions. These are discussed, below, in section (c).

1) Bias

The bias scores show that the NR generally has less global mean TCC. Global mean cloud fractions for the various February 1993 mean cloud are ISCCP=0.66, CLAVR=0.58, NR=0.53, Nimbus-7=0.52, and RTNEPH=0.50. A review of the bias scores for all 43 regions show the underestimate is of order 0.1-0.2 relative to ISCCP, 0-0.1 relative to CLAVR, but an overestimate of order 0-0.1 relative to the RTNEPH. Separating land and ocean regions (Tables 2a, 2b) shows that the NR underestimates, relative to ISCCP and CLAVR, are primarily an ocean problem. Both RTNEPH and Nimbus-7 have similar biases as the NR over ocean-points. There are large regional variations for land surfaces. In eastern North America, the NR seems as cloudy as both ISCCP and CLAVR, but it overestimates cloudiness on the order of 0.3-0.4 relative to the RTNEPH and Nimbus-7 data. Biases among the various observational datasets generally show as large a range as the various NR scores (Tables 3a, 3b).

The NR shows a negative LCC bias virtually everywhere, except North America, where there is a serious overestimate (Table 4a). The negative ocean bias is quite evident relative to the RTNEPH and, to a lesser extent, ISCCP (Table 4b). The latter is understandable because cloud-overlap is not considered, which accounts for some of the negative bias in ISCCP LCC relative to the RTNEPH.

2) Correlation

The TCC correlation scores for NR, relative to ISCCP/CLAVR, are generally higher than those relative to RTNEPH/Nimbus-7, showing that NR's cloud forecasts are more similar to those observational datasets. Global/hemispheric values are of order 0.5-0.6 relative to ISCCP/CLAVR and somewhat less relative to RTNEPH/Nimbus-7. For reference, correlations among the observational datasets, ISCCP, CLAVR, and RTNEPH, are generally higher, of order 0.5-0.8. For further reference, TCC correlations for NCEP global model forecasts, relative to RTNEPH data, are 0.5 and 0.4 for a month's set of 24-hour and 120-hour forecasts respectively.

The correlation scores are highly variable over land (Table 5a), ranging from some negative correlations relative to RTNEPH/Nimbus-7, to values up to 0.7 relative to ISCCP/CLAVR. Correlations among the observational datasets (Table 6a) show similar regional variability, though at higher values (ranging upward to 0.9). Correlations over ocean points are less variable regionally (Table 5b), and at higher values, than over land points. Correlations among the observational datasets are generally similar to the NR scores, though, again, at values 0.2 higher (Table 6b).

For LCC, correlation scores are not very high and vary around zero (Tables 7a, 7b), even those between the 2 observational datasets. Correlation over North America are quite high between RTNEPH and ISCCP, while the NR has a strong negative correlation with them.

3) Satellite-view cloud

When cloud overlap assumptions are made on the NR data, the LCC biases over land relative to ISCCP are generally improved, especially over North America (compare Table 4a with Table 8a). Since the cloud-overlapped RTNEPH data becomes similar to ISCCP LCC (see Table 8), the inference is that the NR data biases relative to RTNEPH are also improved. However the NR still appears to overestimate low cloud over North America. The NR negative bias, relative to ISCCP, in oceanic LCC is generally degraded by applying the overlap assumptions (compare Table 4b with Table 8a), while the overlapping assumptions dramatically lessen the biases between ISCCP and RTNEPH.

For the ISCCP comparison, the satellite-view NR cloud does not alter the regional variability of the correlation (Tables 9a, 9b), but it does increase its value everywhere. However this increase is small in comparison with the large positive impact on the correlation between the 2 observational datasets themselves (Tables 9a, 9b).

The primary reason for using cloud-overlap is to make fair comparison among NR, RTNEPH, and ISCCP low cloud. The effects on the statistical comparisons are especially strong between the observational data, where negative biases are reduced to zero and correlations are significantly improved. Comparisons between the NR and ISCCP show some small improvement, but not enough to alter conclusions drawn in the previous two sections.

c. Discussion

In general, the agreement between NR TCC and observations is satisfactory. Jacob (1998) compared the ECMWF reanalysis (ERA) and ISCCP total clouds and also was able to show good agreement between them. However, this paper has highlighted some problems with the vertical distribution of NR clouds.

During the initial phases of this project, there were concerns expressed that the over-estimation of HCC and under-estimation of LCC may have been introduced by using high resolution or a prognostic cloud scheme in the forecast model. However, previously published reports have not supported this claim. Tiedtke (1993) reported globally averaged amount of LCC increases with resolution, from 16% for T21L19 to 25% for T106L31, while the HCC decreases from 40% to 33%. Tiedtke also compared the model clouds to the previous ECMWF operational diagnostic cloud scheme (Slingo, 1987), and found that the amount of LCC increases from 14% to 25% and HCC decreases from 41% to 33% in the new scheme (Tiedtke 1993). Thus it is concluded from this indirect evidence, that use of higher resolution and a prognostic cloud scheme both act to produce NR cloudiness which is closer to observed data.

1) High level cloud

Fig.3b shows that NR has larger amount of high level cloud compared to observation. This is also noted by Tietdke in comparison with ISCCP cloud. However, if the cloud amount is redefined using optical depth (emissivity) to produce an "effective cloud", Tietdke (1993) showed that then there is a good agreement with ISCCP cloud (Fig.7). Henderson-Sellers (1986) and Hamill (1992) report that the RTNEPH HCC is underestimated and may be reported as MCC. Finally data obtained from an early lidar experiment (Winker and Emmitt, 1997) found significantly larger amount of HCC, compared to ISCCP. Therefore, it is concluded that there is no strong evidence to "question" the large NR values of HCC.

The model drift toward less CCV in tropical high level cloud (Fig.9) is caused by the NR tending to localize the Hadley cell into narrower band (Saunders personal communication). This problem will be resolved in a future version of model at ECMWF through use of a revised convection scheme.

2) Mid-latitude Low level cloud

The mid-latitude land-ocean contrast in LCC for NR is opposite to observations (Fig.1, Fig.2, Fig.3). LCC over the ocean is less than half of the observation, while it is double the observed LCC over land. Since the purpose of RTNEPH is to produce cloud warnings to pilots, low and mid-level clouds may be over-estimated (Hamill 1992). Other observations have values between the RTNEPH and NR. In the version of the ECMWF model which is used in the NR (and also the ECMWF reanalysis, ERA), low level stratocumulus is underestimated over the ocean and is overestimated over land, due to excessive evaporation from snow. Thus land-ocean contrast in midlatitude cloud is weaker compared to ISCCP cloud (Jakob 1998). Therefore, the problems noted earlier for NR LCC need to be addressed. It is concluded that an adjustment to LCC in midlatitude is needed in order to provide realistic LCC for the OSSE.

3) Tropics

In order to investigate tropical cloud differences in more detail, a snap shot of NR at forecast hour 612 (12z March 2) is studied. Fig.8 shows the vertical cross section across one convective area, between 6S and the equator, with data averaged between 138E-140E. Model cloud cover (CCV), cloud liquid water content (CLW), omega(ω), zonal wind (U), relative humidity(RH) presented. Also shown is CCV computed from RH and CLW using the formula proposed by Randall (1995) (CCV_R) (Hong et al, 1998):

$$CCV\_R = RH[1 - \exp(\frac{-1000 \times CLW}{1 - RH})]$$

The CCV_R is presented because it may be a candidate for adjusted LCC. Model CCV is a predicted variable and its contours will not necessarily follow RH, but contours of CCV_R are very similar to RH. CCV exist in vicinity of rising motion; however, locations of rising motion and CCV do not exactly match, as CCV is also related to CLW and RH. The mid-level peak in CCV may indicate detrainment. (Jakob, personal communication)

In lowest few model levels, CCV_R has larger amounts than CCV, so LCC can be increased by using CCV_R. However, this may not be a suitable cloud adjustment. First, the Randall formula uses CLW, but CLW in ERA, where the same model is used, is less reliable than CCV (Jakob, personal communication). CCV_R uses RH which is computed from grid box averaged values of temperature and specific humidity, while CCV itself is computed from temperature and specific humidity of both cloud and environment within the grid (Jakob, personal communication). Thus, it is concluded that replacing predicted CCV with CCV_R values is improper.

A systematic enhancement of LCC is also considered. However, this is not suitable since the deficiency in LCC depends on cloud type. For example, wide-spread tropical stratocumulus is missing from NR, but there is no indication of any underestimation of convective low and mid level clouds in ERA (Jakob 1998). Thus a CCV adjustment which simply enhances existing LCC will not restore the missing stratocumulus.

4) Polar region

There are large cloud differences among NR and observations over polar regions, however, it is difficult to observe clouds there. The north pole is a region of low sun during February, so satellite visible channel data is used sparingly in the estimate, if at all. Over Antarctica, it is very difficult to distinguish cloud from snow or ice. Since, the NR clouds are dynamically consistent with other variables, they may be more "correct" than any "observed" estimate. NR indicates about 70-90% of cloud cover over the Arctic region. For the Arctic winter 60% of CCV seems reasonable. (R. Grumbine, personal communication). NR and ISCCP show large amount of TCC but NR has large amount of LCC (70%) and MCC (40%), while ISCCP has about 60% MCC but no LCC (satellite-view). Thus, through both ISCCP and NR show large values of TCC over the Arctic, the heights of cloud do not agree.

5. Adjustment of low level cloud

This report has investigated the representativeness of NR cloudiness relative to estimates of the observed atmosphere in February 1993. While some differences appear large, there are enough uncertainties in the observed data, that it is recommended to accept most of NR cloudiness as representative of the atmosphere.

The only exception is LCC, where it appears that the NR underestimates marine stratocumulus and overestimates cloudiness over snow covered land. Since cloud impacts on OSSE tests are most likely important in regions of active divergent atmospheric flow, the lack of NR marine stratocumulus may not be serious. However, this needs to be tested through OSSEs. While a LCC adjustment for stratocumulus is proposed, the NR convective cloud remains unchanged, since there is no clear observational support for adjusting it. The adjusted cloud is made available only to test the impact of DWL sampling at or below the atmospheric boundary layer (approximately 800hPa).

a. Adjustment procedure

In NR, CCV is defined at each model level (C_k). Here, Nature run LCC (NRLCC) represents cloud cover below 800 mb and is derived from cloud cover of each level (C_k) using a combined random-maximum overlapping assumption (Geleyn and Hollingsworth 1979, Appendix A). $NRLCC_{adj}$ represents the adjusted column cloud between 800mb and the earth's surface, which is obtained from the adjusted column cloud cover for each level (C_k^*) using the same cloud overlap algorithm. $NRLCC_{adj}$ is computed simply to show the effect of the adjustment, while C_k^* is used in actual DWL sampling.

1) Ocean

Over the ocean, the lack of stratocumulus data has been noted for NR. Since satellite-based estimates have difficulty in sensing the low level cloud, the Warren (1952-1981), ground -based, stratus and stratocumulus (STW) climatology is used in the adjustment (Fig. 10). The vertical velocity in pressure coordinates (ω) from NR is also used, where the adjustment varies linearly between two vertical velocity in pressure coordinates $\omega 1$ and $\omega 2$ ($\omega 1 < \omega 2$). There is no adjustment if $\omega > \omega 2$, and there is full adjustment if $\omega < \omega 1$. Using an adjustment factor "a", the adjusted layer cloud is written as:

$$C_{k}^{*} = a \times STW + (1.0 - a \times STW) \times C_k$$

where,

$a=0$	If $\omega > \omega 2$: no adjustment
$a=(\omega-\omega 2)/(\omega 1-\omega 2)$	If $\omega 1 < \omega < \omega 2$
$a=1$	If $\omega < \omega 1$: full adjustment

The adjustment is done in regions with rising motion and large amounts of climatological stratus and stratocumulus. In areas of strong sinking motion or small amount of climatological stratus and stratocumulus , the adjustment is not performed.

2) Land

Over the land, an alternative adjustment is used.

$C_k^* = C_k/r$	Over snow
$C_k^* = C_k$	Elsewhere

To define the ratio, r, TCC of NR, ISCCP, CLAVR, and RTNEPH are compared, as well as the LCC and RTNEPH. The ratio between TCC and LCC of NR and RTNEPH is approximately 2.0, while the ratio between TCC of NR and TCC of either ISCCP or CLAVR cloud is about 1.2. It seems that RTNEPH underestimates the LCC over snow while NR overestimates it. A value of r=1.5 has been found optimal for the land adjustment.

b. Evaluation of adjusted LCC

Layer integrated cloud cover rather than each individual cloud layer is used to demonstrate the effect of the adjustment. Vertical motion at model level 25 (~850hPa) is used for this demonstration. Fig. 11 shows NRLCC, $NRLCC_{adj}$ and their difference for 00z 7 February 1993. The $NRLCC_{adj}$ has enhanced cloudiness relative to NRLCC over trade wind regions and east of the ocean weather fronts. The difference between RTNEPH low cloud and time averaged NRLCC (Fig.12a) is reduced in most areas when compared to $NRLCC_{adj}$ (Fig.12b). After the LCC adjustment, the major remaining difference is in the tropical convective areas, where the convective cloud is unchanged.

Zonal averaged NRLCC and $NRLCC_{adj}$ (Fig.13) show that the adjustment reduces LCC over midlatitude land and increases it by 10-20% over ocean for all latitudes. The largest increase occurs over the southern hemisphere midlatitude. Fig.14 shows the geographical area of oceanic cloud cover at 00Z 7th February for CCV in 5% band categories (0-5%, 5-10%,·····). With the adjustment, the area containing less than 5% cloud cover is reduced from 30% to 13 %, and the area containing less than 20% is reduced from 56% to 34%. The geographical area containing 20%-80% CCV is increased by 20%, while the area greater than 80% increased only by 2%. The area with 95- 100% cloud cover remains about 13%. After adjustment the area containing either less than 5% LCC or greater than 95% LCC are similar; producing a more realistic "U" shaped distribution of cloud. Though the LCC adjustment increases cloudiness, it leaves a reasonable area of clear sky for OSSE experiments without increasing the completely overcast conditions.

6. Concluding remark

This report has evaluated the NR cloud by comparing it with available observed estimates. Since realistic cloud in NR is important for simulating the atmospheric data to be used in conducting a reliable OSSE. Although cloud in the NR is not perfect, the LCC adjustment suggested in this report reduces the major problems and provides a reasonable test bed in which to conduct OSSEs.

Throughout this study it became obvious that each of the cloud observational data sets had distinct characteristics that often made it difficult to define the true state of the atmosphere. Further collaboration between the modeling community and the observational community will be necessary to produce reliable cloud estimates, which in turn, will permit more accurate evaluation of model-produced cloud in numerical weather and climate forecasting. DWL, an important instrument for wind measurement, will be examined in an OSSE, however, it will be an important source of valuable cloud information independent from current satellite estimates.

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Appendix A Cloud Overlap

In order to make realistic comparisons of LCC with ISCCP data, the NR and RTNEPH clouds are re-computed from a satellite perspective using different cloud-overlap assumptions (satellite-view cloud). The procedure is to view the cloud layers from the top-of-atmosphere, and in cases where there are multi-layer clouds, to let higher clouds obscure portions of the lower cloud types. The maximum overlap assumption stacks clouds on top of each other. For example, a high cloud of 50% cloud cover will obscure all lower clouds that are less than or equal to 50%. The random overlap assumption is less restrictive; that is, lower clouds can be observed even if their cloud cover is less than that of the higher cloud. The unobscured lower cloud cover is a function of the remaining clear-sky area. For example, where a 50% higher cloud overlays a 50% lower cloud, 25% of the lower cloud will now be visible (*i.e.* 50% of the remaining 50% clear sky).

The overlap calculation should be made for each synoptic time and then merged to obtain the proper monthly mean. Since the daily RTNEPH data is unavailable, an approximate overlap calculation is made on the monthly mean data, itself, for both RTNEPH and NR. In the overlap computation, both MCC and LCC are changed, while HCC remains untouched. The overlapped clouds can be summed to give a computed TCC. Comparisons of the observed TCC and the computed TCC can be instructive in assessing the realism of a particular overlapping. The maximum overlap assumption appears to underestimate the lower unobscured cloud, since the computed TCC is less than the observed TCC (Table 2). This effect is especially strong in the NR over the entire globe. The random overlap assumption appears to overestimate the lower obscured cloud, since the computed TCC is greater than the observed TCC. Again the effect is stronger in the NR, especially over sub-polar oceans. Thus, true overlapping is somewhere between a maximum and random process.

In NR LCC, MCC, and HCC are constructed using random-maximum overlapping. Let LCCNR represent the total low cloud in the atmospheric column below 800mb. It is computed by assuming maximum overlap for vertically adjacent cloud layers and random overlap for cloudy layers separated by a clear layer.

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Figures

Fig.1 NR cloud averaged for the NR period. a)TCC b) HCC, c) MCC d)LCC, contour interval 20%. White contours indicate 20% cloudiness.

Fig.2 Observed estimated total cloud cover during February 1993 (a)RTNEPH, (b) ISCCP, and (c) CLAVR. Contour interval 20%. White contours indicate 20% cloudiness.

Fig.3 a) Zonal mean of TCC, NR(thick solid), RTNEPH (dot), ISCCP (dash), CLAVR (thin solid). Top: include land and ocean, Midlle: over land only, Bottom: over ocean only. (b) Same as (a) but for zonal mean of HCC. (c)Same as (a) but for zonal mean of MCC. (d)Same as (a) but for zonal mean of LCC. CLAVR is included only in TCC.

Fig.4 Zonal mean satellite-view LCC. Top: include land and ocean, Middle: land only, Bottom: ocean only. Solid line is ISCCP cloud. a) Shading: satellite view NR cloud max over lapping and random overlapping. b) Shading: satellite-view RTNEPH cloud.

Fig.5 Cloud cover averaged between 10S to 10N. For both over the land and ocean. NR(thick solid), RTNEPH (dot), ISCCP (dash), CLAVR (thin solid). From top, TCC, HCC, MCC, and LCC. CLAVR is included only in TCC.

Fig.6 The satellite-view MCC (Top) and LCC (bottom) averaged between 10S to 10N. Solid line is ISCCP cloud. a) Shading: satellite-view NR cloud max over lapping and random overlapping. b) Shading: satellite-view RTNEPH cloud.

Fig.7 Figure from Tiedtke (1993). (a) model high level cloud (b) model effective cloud (c) ISCCP high level cloud.

Fig.8 Cross section for CCV, CLW, relative humidity(RH), CCV computed using Randal formula (CCV_R), zonal wind (U), and meridional wind (V) and ω. Values are averaged between 138E and 140E. Name of the values are indicated as subtitle. Contour intervals are 20% for CCV, $50x10^{-6}$ Kg/Kg for CLW, 10% for RH, 20% for CCV, $5ms^{-1}$ for zonal wind. Factor 100 is multiplied to ω to plot with meridional wind V.

Fig.9 Time -latitude section of zonally averaged nature run HCC.

Fig.10 Stratus and Strato cumulus in Warren cloud averaged for December, January, and February from 1952 ro 1981. Contour interval 20%. White contours indicate 20%

cloudiness.

Fig.11 Snap shot NR LCC at 00Z 7 February 1993 a) Adjusted b) without adjustment. c) the difference between b and a.

Fig.12 The difference between time averaged LCC for NR and LCC for February 93 RTNEPH. a) without adjustment (NRLCC-RTNEPH), b) Adjusted ($NRLCC_{adj}$ - RTNEPH)

Fig. 13 Zonal mean LCC. Solid line: without adjustment (NRLCC). Dashed line: with adjustment ($NRLCC_{adj}$).

Fig. 14 Frequency distribution for ocean areas containing cloud cover in 20, 5%-band, categories. Solid line: without adjustment (NRLCC). Dashed line: with adjustment ($NRLCC_{adj}$).

Table 1 Area averaged cloud cover over (10S-10N, 150E-180E).

	TCC	HCC	MCC	LCC
Nature run 5 Feb-7 Mar 93	78	74	19	18
NR Satellite view Max overlap	74 (under-estimate)	74	0	0
NR Satellite view Random overlap	111 (over-estimate)	74	19	18
RTNEPH (Feb 93)	82	35	35	67
RTN Satellite view Max overlap	67 (under-estimate)	35	3	29
RTN Satellite view Random overlap	85 (over-estimate)	35	22	28
NCEP anal (Feb 93)	57	35	28	37
ISCCP satellite view (Feb 93)	86	41	23	21
Warren (Feb 1981)	67	Ci =25 Cb=11	Alt=36 Cb=11	Cu=16 St=21 Cb=11

TABLE 2a TOTAL cloud, BIAS, LAND

REGION	NATisc	NATrtn	NATclv	NATnm7
GLOBAL -LAND- POINTS	-0.068	0.095	0.000	0.105
NORTHERN HEMISPHERE	-0.042	0.150	0.008	0.160
SOUTHERN HEMISPHERE	-0.152	-0.087	-0.029	-0.074
TROPICAL BELT (20N-20S)	-0.118	-0.076	0.038	-0.030
NORTHERN MID-LAT(20-60N)	-0.052	0.115	-0.030	0.122
SOUTHERN MID-LAT(20-60S)	-0.166	-0.030	0.002	-0.025
EAST ASIA	-0.081	0.073	-0.128	0.074
CENTRAL ASIAN DESERT	-0.160	-0.039	-0.131	0.017
CENTRAL SOUTH AFRICA	-0.162	-0.128	-0.006	0.000
NORTH AFRICAN DESERT	0.007	0.108	0.154	0.170
EUROPE	-0.081	0.013	-0.062	0.054
EASTERN NORTH AMERICA	0.045	0.401	0.108	0.322
WESTERN NORTH AMERICA	-0.050	0.239	0.005	0.184
SOUTH AMERICA	-0.150	-0.061	0.032	-0.097

TABLE 2b TOTAL cloud, BIAS, OCEAN

REGION	NATisc	NATrtn	NATclv	NATnm7
GLOBAL -SEA- POINTS	-0.174	0.012	-0.085	-0.028
NORTHERN HEMISPHERE	-0.148	0.024	-0.072	-0.007
SOUTHERN HEMISPHERE	-0.191	0.005	-0.093	-0.041
TROPICAL BELT (20N-20S)	-0.071	0.061	-0.004	-0.001
NORTHERN MID-LAT(20-60N)	-0.205	-0.031	-0.113	-0.057
SOUTHERN MID-LAT(20-60S)	-0.221	-0.021	-0.094	-0.010
EAST PACIFIC (50N-50S)	-0.080	0.077	-0.027	0.030
CENTRAL PACIFIC(50N-50S)	-0.184	-0.004	-0.045	-0.003
NORTHERN PACIFIC(20-60N)	-0.248	-0.067	-0.148	-0.094
SOUTHERN PACIFIC(20-60S)	-0.218	-0.033	-0.093	-0.031
NORTH ATLANTIC (15-60N)	-0.151	0.020	-0.059	-0.014
SOUTH ATLANTIC (15-60S)	-0.210	-0.025	-0.113	0.000
EQUATRL ATLANTC(15N-15S)	-0.018	0.122	0.017	0.040

NATisc=NR.vs.ISCCP, NATrtn=NR.vs.RTNEPH,
NATclv=NR.vs.CLAVR, NATnm7=NR.vs.Nimbus-7

TABLE 3a TOTAL cloud, BIAS, LAND

REGION	ISCrtn	ISCclv	ISCnm7	RTNclv	RTNnm7	NM7clv
GLOBAL -LAND- POINTS	0.163	0.067	0.173	-0.095	0.010	-0.106
NORTHERN HEMISPHERE	0.192	0.050	0.202	-0.142	0.009	-0.151
SOUTHERN HEMISPHERE	0.065	0.123	0.078	0.058	0.013	0.045
TROPICAL BELT (20N-20S)	0.042	0.156	0.088	0.114	0.046	0.068
NORTHERN MID-LAT(20-60N)	0.166	0.021	0.173	-0.145	0.007	-0.152
SOUTHERN MID-LAT(20-60S)	0.137	0.169	0.141	0.032	0.005	0.027
EAST ASIA	0.154	-0.047	0.154	-0.201	0.001	-0.202
CENTRAL ASIAN DESERT	0.121	0.029	0.177	-0.092	0.057	-0.148
CENTRAL SOUTH AFRICA	0.034	0.156	0.162	0.123	0.129	-0.006
NORTH AFRICAN DESERT	0.101	0.147	0.163	0.046	0.062	-0.016
EUROPE	0.094	0.020	0.135	-0.074	0.041	-0.115
EASTERN NORTH AMERICA	0.357	0.064	0.278	-0.293	-0.079	-0.214
WESTERN NORTH AMERICA	0.289	0.055	0.234	-0.234	-0.055	-0.179
SOUTH AMERICA	0.089	0.182	0.052	0.093	-0.036	0.130

TABLE 3b TOTAL cloud, BIAS, OCEAN

REGION	ISCrtn	ISCclv	ISCnm7	RTNclv	RTNnm7	NM7clv
GLOBAL -SEA- POINTS	0.186	0.089	0.146	-0.098	-0.040	-0.057
NORTHERN HEMISPHERE	0.172	0.076	0.141	-0.096	-0.032	-0.065
SOUTHERN HEMISPHERE	0.196	0.097	0.150	-0.098	-0.046	-0.053
TROPICAL BELT (20N-20S)	0.132	0.067	0.070	-0.065	-0.062	-0.003
NORTHERN MID-LAT(20-60N)	0.174	0.091	0.148	-0.083	-0.026	-0.056
SOUTHERN MID-LAT(20-60S)	0.200	0.127	0.211	-0.073	0.011	-0.084
EAST PACIFIC (50N-50S)	0.157	0.053	0.110	-0.104	-0.047	-0.057
CENTRAL PACIFIC(50N-50S)	0.180	0.138	0.181	-0.042	0.001	-0.043
NORTHERN PACIFIC(20-60N)	0.181	0.100	0.154	-0.081	-0.027	-0.053
SOUTHERN PACIFIC(20-60S)	0.185	0.125	0.187	-0.060	0.002	-0.062
NORTH ATLANTIC (15-60N)	0.171	0.092	0.137	-0.079	-0.034	-0.045
SOUTH ATLANTIC (15-60S)	0.185	0.097	0.209	-0.088	0.025	-0.113
EQUATRL ATLANTC(15N-15S)	0.141	0.036	0.059	-0.105	-0.082	-0.023

ISCrtn=ISCCP.vs.RTNEPH, ISCclv=ISCCP.vs.CLAVR,
ISCnm7=ISCCP.vs.Nimbus-7, RTNclv=RTNEPH.vs.CLAVR,
RTNnm7=RTNEPH.vs.Nimbus-7, NM7clv=Nimbus-7.vs.CLAVR

TABLE 4a Low (LCC) cloud, BIAS, LAND

REGION	NATisc	NATrtn	ISCrtn
GLOBAL -LAND- POINTS	0.146	-0.049	-0.188
NORTHERN HEMISPHERE	0.200	0.046	-0.149
SOUTHERN HEMISPHERE	-0.024	-0.346	-0.315
TROPICAL BELT (20N-20S)	-0.023	-0.374	-0.314
NORTHERN MID-LAT(20-60N)	0.162	0.013	-0.146
SOUTHERN MID-LAT(20-60S)	-0.132	-0.249	-0.110
EAST ASIA	0.094	0.023	-0.071
CENTRAL ASIAN DESERT	0.030	-0.103	-0.153
CENTRAL SOUTH AFRICA	-0.041	-0.379	-0.326
NORTH AFRICAN DESERT	-0.140	-0.169	-0.049
EUROPE	0.148	-0.110	-0.258
EASTERN NORTH AMERICA	0.448	0.334	-0.114
WESTERN NORTH AMERICA	0.313	0.139	-0.174
SOUTH AMERICA	-0.039	-0.357	-0.324

TABLE 4b Low (LCC) cloud, BIAS, OCEAN

REGION	NATisc	NATrtn	ISCrtn
GLOBAL -SEA- POINTS	-0.098	-0.242	-0.144
NORTHERN HEMISPHERE	-0.094	-0.232	-0.137
SOUTHERN HEMISPHERE	-0.100	-0.249	-0.148
TROPICAL BELT (20N-20S)	-0.096	-0.215	-0.119
NORTHERN MID-LAT(20-60N)	-0.121	-0.288	-0.166
SOUTHERN MID-LAT(20-60S)	-0.109	-0.266	-0.157
EAST PACIFIC (50N-50S)	-0.097	-0.158	-0.060
CENTRAL PACIFIC(50N-50S)	-0.145	-0.312	-0.167
NORTHERN PACIFIC(20-60N)	-0.161	-0.312	-0.151
SOUTHERN PACIFIC(20-60S)	-0.123	-0.305	-0.182
NORTH ATLANTIC (15-60N)	-0.090	-0.274	-0.183
SOUTH ATLANTIC (15-60S)	-0.086	-0.239	-0.153
EQUATRL ATLANTC(15N-15S)	-0.079	-0.149	-0.070

NATisc=NR.vs.ISCCP, NATrtn=NR.vs.RTNEPH,
ISCrtn=ISCCP.vs.RTNEPH

TABLE 5a TOTAL cloud, CORRELATION, LAND

REGION	NATisc	NATrtn	NATclv	NATnm7
GLOBAL -LAND- POINTS	0.605	0.212	0.561	0.264
NORTHERN HEMISPHERE	0.635	0.110	0.549	0.213
SOUTHERN HEMISPHERE	0.642	0.691	0.618	0.665
TROPICAL BELT (20N-20S)	0.712	0.726	0.711	0.760
NORTHERN MID-LAT(20-60N)	0.568	0.132	0.475	0.175
SOUTHERN MID-LAT(20-60S)	0.586	0.608	0.561	0.511
EAST ASIA	0.309	0.117	0.394	-0.110
CENTRAL ASIAN DESERT	0.391	0.212	0.096	0.103
CENTRAL SOUTH AFRICA	0.637	0.651	0.672	0.658
NORTH AFRICAN DESERT	0.148	0.099	0.075	0.395
EUROPE	0.514	0.571	0.687	0.104
EASTERN NORTH AMERICA	0.352	-0.196	0.359	-0.091
WESTERN NORTH AMERICA	0.567	-0.446	0.200	-0.227
SOUTH AMERICA	0.713	0.789	0.732	0.725

TABLE 5b TOTAL cloud, CORRELATION, OCEAN

REGION	NATisc	NATrtn	NATclv	NATnm7
GLOBAL -SEA- POINTS	0.582	0.482	0.558	0.473
NORTHERN HEMISPHERE	0.600	0.508	0.638	0.473
SOUTHERN HEMISPHERE	0.549	0.443	0.466	0.446
TROPICAL BELT (20N-20S)	0.656	0.669	0.664	0.547
NORTHERN MID-LAT(20-60N)	0.491	0.392	0.569	0.440
SOUTHERN MID-LAT(20-60S)	0.551	0.485	0.470	0.424
EAST PACIFIC (50N-50S)	0.726	0.727	0.707	0.540
CENTRAL PACIFIC(50N-50S)	0.592	0.693	0.589	0.543
NORTHERN PACIFIC(20-60N)	0.485	0.480	0.617	0.517
SOUTHERN PACIFIC(20-60S)	0.473	0.475	0.365	0.295
NORTH ATLANTIC (15-60N)	0.735	0.639	0.739	0.687
SOUTH ATLANTIC (15-60S)	0.515	0.426	0.451	0.511
EQUATRL ATLANTC(15N-15S)	0.460	0.424	0.378	0.323

NATisc=NR.vs.ISCCP, NATrtn=NR.vs.RTNEPH,
NATclv=NR.vs.CLAVR, NATnm7=NR.vs.Nimbus-7

TABLE 6a TOTAL cloud, CORRELATION, LAND

REGION	ISCrtn	ISCclv	ISCnm7	RTNclv	RTNnm7	NM7clv
GLOBAL -LAND- POINTS	0.586	0.670	0.635	0.463	0.795	0.482
NORTHERN HEMISPHERE	0.419	0.722	0.552	0.435	0.715	0.510
SOUTHERN HEMISPHERE	0.879	0.570	0.781	0.684	0.818	0.604
TROPICAL BELT (20N-20S)	0.940	0.940	0.901	0.940	0.884	0.905
NORTHERN MID-LAT(20-60N)	0.499	0.642	0.595	0.423	0.699	0.429
SOUTHERN MID-LAT(20-60S)	0.854	0.842	0.613	0.834	0.672	0.531
EAST ASIA	0.708	0.290	0.729	0.114	0.779	-0.106
CENTRAL ASIAN DESERT	0.520	0.496	0.523	0.462	0.746	0.439
CENTRAL SOUTH AFRICA	0.922	0.923	0.879	0.921	0.894	0.880
NORTH AFRICAN DESERT	0.476	0.690	0.393	0.548	0.273	0.493
EUROPE	0.651	0.718	0.429	0.553	0.494	0.235
EASTERN NORTH AMERICA	-0.020	0.241	0.151	0.070	0.742	0.268
WESTERN NORTH AMERICA	-0.395	0.346	-0.345	-0.019	0.571	0.232
SOUTH AMERICA	0.904	0.878	0.820	0.891	0.869	0.798

TABLE 6b TOTAL cloud, CORRELATION, OCEAN

REGION	ISCrtn	ISCclv	ISCnm7	RTNclv	RTNnm7	NM7clv
GLOBAL -SEA- POINTS	0.755	0.847	0.761	0.641	0.703	0.749
NORTHERN HEMISPHERE	0.853	0.841	0.812	0.751	0.835	0.741
SOUTHERN HEMISPHERE	0.667	0.842	0.696	0.536	0.572	0.740
TROPICAL BELT (20N-20S)	0.895	0.874	0.729	0.912	0.804	0.762
NORTHERN MID-LAT(20-60N)	0.837	0.779	0.867	0.674	0.821	0.700
SOUTHERN MID-LAT(20-60S)	0.756	0.842	0.756	0.782	0.727	0.808
EAST PACIFIC (50N-50S)	0.912	0.908	0.759	0.861	0.697	0.720
CENTRAL PACIFIC(50N-50S)	0.862	0.857	0.697	0.845	0.727	0.746
NORTHERN PACIFIC(20-60N)	0.829	0.694	0.851	0.623	0.792	0.665
SOUTHERN PACIFIC(20-60S)	0.759	0.803	0.726	0.752	0.682	0.812
NORTH ATLANTIC (15-60N)	0.899	0.878	0.928	0.787	0.894	0.830
SOUTH ATLANTIC (15-60S)	0.843	0.914	0.831	0.881	0.850	0.910
EQUATRL ATLANTC(15N-15S)	0.906	0.851	0.747	0.875	0.813	0.803

ISCrtn=ISCCP.vs.RTNEPH, ISCclv=ISCCP.vs.CLAVR,
ISCnm7=ISCCP.vs.Nimbus-7, RTNclv=RTNEPH.vs.CLAVR,
RTNnm7=RTNEPH.vs.Nimbus-7,NM7clv=Nimbus-7.vs.CLAVR

TABLE 7a   Low (LCC) cloud, CORRELATION, LAND

REGION	NATisc	NATrtn	ISCrtn
GLOBAL -LAND- POINTS	-0.303	-0.236	0.123
NORTHERN HEMISPHERE	-0.300	-0.130	0.336
SOUTHERN HEMISPHERE	-0.305	0.082	-0.516
TROPICAL BELT (20N-20S)	-0.057	0.131	-0.456
NORTHERN MID-LAT(20-60N)	-0.148	0.017	0.281
SOUTHERN MID-LAT(20-60S)	-0.119	0.291	-0.355
EAST ASIA	-0.067	0.079	0.564
CENTRAL ASIAN DESERT	-0.009	-0.182	0.307
CENTRAL SOUTH AFRICA	-0.087	0.172	-0.708
NORTH AFRICAN DESERT	0.063	0.501	-0.053
EUROPE	-0.265	0.418	-0.019
EASTERN NORTH AMERICA	-0.431	-0.338	0.495
WESTERN NORTH AMERICA	0.067	-0.536	0.188
SOUTH AMERICA	-0.231	0.075	-0.613

TABLE 7b   Low (LCC) cloud, CORRELATION, OCEAN

REGION	NATisc	NATrtn	ISCrtn
GLOBAL -SEA- POINTS	0.073	0.146	0.208
NORTHERN HEMISPHERE	-0.272	0.088	0.396
SOUTHERN HEMISPHERE	0.344	0.175	0.028
TROPICAL BELT (20N-20S)	-0.010	-0.030	0.110
NORTHERN MID-LAT(20-60N)	-0.316	0.182	0.281
SOUTHERN MID-LAT(20-60S)	0.300	0.346	-0.042
EAST PACIFIC (50N-50S)	0.410	0.321	0.487
CENTRAL PACIFIC(50N-50S)	0.193	0.499	0.038
NORTHERN PACIFIC(20-60N)	-0.272	0.405	0.282
SOUTHERN PACIFIC(20-60S)	0.341	0.342	-0.115
NORTH ATLANTIC (15-60N)	-0.319	0.352	0.144
SOUTH ATLANTIC (15-60S)	0.210	0.500	-0.113
EQUATRL ATLANTC(15N-15S)	0.255	0.034	0.357

NATisc=NR.vs.ISCCP,   NATrtn=NR.vs.RTNEPH,
ISCrtn=ISCCP.vs.RTNEPH

TABLE 8a Low (LCC) cloud, BIAS, LAND

REGION	NATRNisc	NATMXisc	ISCrtnRN	ISCrtnMX
GLOBAL -LAND- POINTS	-0.015	-0.056	-0.067	0.002
NORTHERN HEMISPHERE	0.010	-0.034	-0.066	0.007
SOUTHERN HEMISPHERE	-0.097	-0.129	-0.073	-0.017
TROPICAL BELT (20N-20S)	-0.087	-0.112	-0.080	-0.032
NORTHERN MID-LAT(20-60N)	0.000	-0.048	-0.066	0.009
SOUTHERN MID-LAT(20-60S)	-0.172	-0.200	0.001	0.067
EAST ASIA	-0.017	-0.083	-0.017	0.051
CENTRAL ASIAN DESERT	-0.046	-0.084	-0.059	0.018
CENTRAL SOUTH AFRICA	-0.095	-0.123	-0.092	-0.038
NORTH AFRICAN DESERT	-0.132	-0.135	-0.018	0.046
EUROPE	-0.027	-0.104	-0.133	-0.065
EASTERN NORTH AMERICA	0.149	0.119	-0.046	0.009
WESTERN NORTH AMERICA	0.111	0.069	-0.091	0.000
SOUTH AMERICA	-0.102	-0.129	-0.075	-0.021

TABLE 8b Low (LCC) cloud, BIAS, OCEAN

REGION	NATRNisc	NATMXisc	ISCrtnRN	ISCrtnMX
GLOBAL -SEA- POINTS	-0.215	-0.291	-0.032	-0.004
NORTHERN HEMISPHERE	-0.199	-0.268	-0.034	-0.010
SOUTHERN HEMISPHERE	-0.225	-0.306	-0.030	0.000
TROPICAL BELT (20N-20S)	-0.160	-0.225	-0.006	0.011
NORTHERN MID-LAT(20-60N)	-0.243	-0.316	-0.056	-0.030
SOUTHERN MID-LAT(20-60S)	-0.246	-0.334	-0.042	-0.007
EAST PACIFIC (50N-50S)	-0.187	-0.266	0.003	0.028
CENTRAL PACIFIC(50N-50S)	-0.237	-0.301	-0.027	0.002
NORTHERN PACIFIC(20-60N)	-0.279	-0.354	-0.038	-0.004
SOUTHERN PACIFIC(20-60S)	-0.256	-0.335	-0.064	-0.029
NORTH ATLANTIC (15-60N)	-0.224	-0.295	-0.068	-0.053
SOUTH ATLANTIC (15-60S)	-0.215	-0.307	-0.051	-0.017
EQUATRL ATLANTC(15N-15S)	-0.144	-0.223	0.005	0.029

NATRNisc=NR(random overlap).vs.ISCCP, NATMXisc=NR(max overlap).vs.ISCCP,
ISCrtnRN=ISCCP.vs.RTNEPH(random overlap),ISCrtnMX=ISCCP.vs.RTNEPH(max overlap)

TABLE 9a Low (LCC) cloud, CORRELATION, LAND

REGION	NATRNisc	NATMXisc	ISCrtnRN	ISCrtnMX
GLOBAL -LAND- POINTS	-0.227	-0.229	0.372	0.377
NORTHERN HEMISPHERE	-0.239	-0.243	0.449	0.472
SOUTHERN HEMISPHERE	-0.015	-0.027	0.081	0.038
TROPICAL BELT (20N-20S)	0.221	0.068	0.263	0.166
NORTHERN MID-LAT(20-60N)	-0.105	-0.121	0.380	0.418
SOUTHERN MID-LAT(20-60S)	0.037	0.051	-0.027	-0.002
EAST ASIA	0.015	-0.043	0.606	0.599
CENTRAL ASIAN DESERT	-0.007	0.031	0.487	0.536
CENTRAL SOUTH AFRICA	0.166	0.090	0.220	0.068
NORTH AFRICAN DESERT	0.108	0.019	0.001	0.051
EUROPE	-0.217	-0.181	0.130	0.205
EASTERN NORTH AMERICA	-0.438	-0.440	0.503	0.394
WESTERN NORTH AMERICA	-0.105	-0.017	0.250	0.231
SOUTH AMERICA	0.202	0.046	0.228	0.111

TABLE 9b Low (LCC) cloud, CORRELATION, OCEAN

REGION	NATRNisc	NATMXisc	ISCrtnRN	ISCrtnMX
GLOBAL -SEA- POINTS	0.115	-0.042	0.494	0.485
NORTHERN HEMISPHERE	-0.263	-0.329	0.634	0.612
SOUTHERN HEMISPHERE	0.407	0.275	0.367	0.371
TROPICAL BELT (20N-20S)	0.058	-0.014	0.543	0.490
NORTHERN MID-LAT(20-60N)	-0.193	-0.261	0.546	0.530
SOUTHERN MID-LAT(20-60S)	0.491	0.420	0.357	0.412
EAST PACIFIC (50N-50S)	0.349	0.216	0.674	0.710
CENTRAL PACIFIC(50N-50S)	0.419	0.013	0.567	0.533
NORTHERN PACIFIC(20-60N)	0.056	-0.063	0.564	0.619
SOUTHERN PACIFIC(20-60S)	0.452	0.320	0.234	0.279
NORTH ATLANTIC (15-60N)	-0.166	-0.220	0.461	0.412
SOUTH ATLANTIC (15-60S)	0.524	0.528	0.215	0.285
EQUATRL ATLANTC(15N-15S)	0.287	0.280	0.596	0.595

NATRNisc=NR(random overlap).vs.ISCCP, NATMXisc=NR(max overlap).vs.ISCCP,
ISCrtnRN=ISCCP.vs.RTNEPH(random overlap),ISCrtnMX=ISCCP.vs.RTNEPH(max overlap)

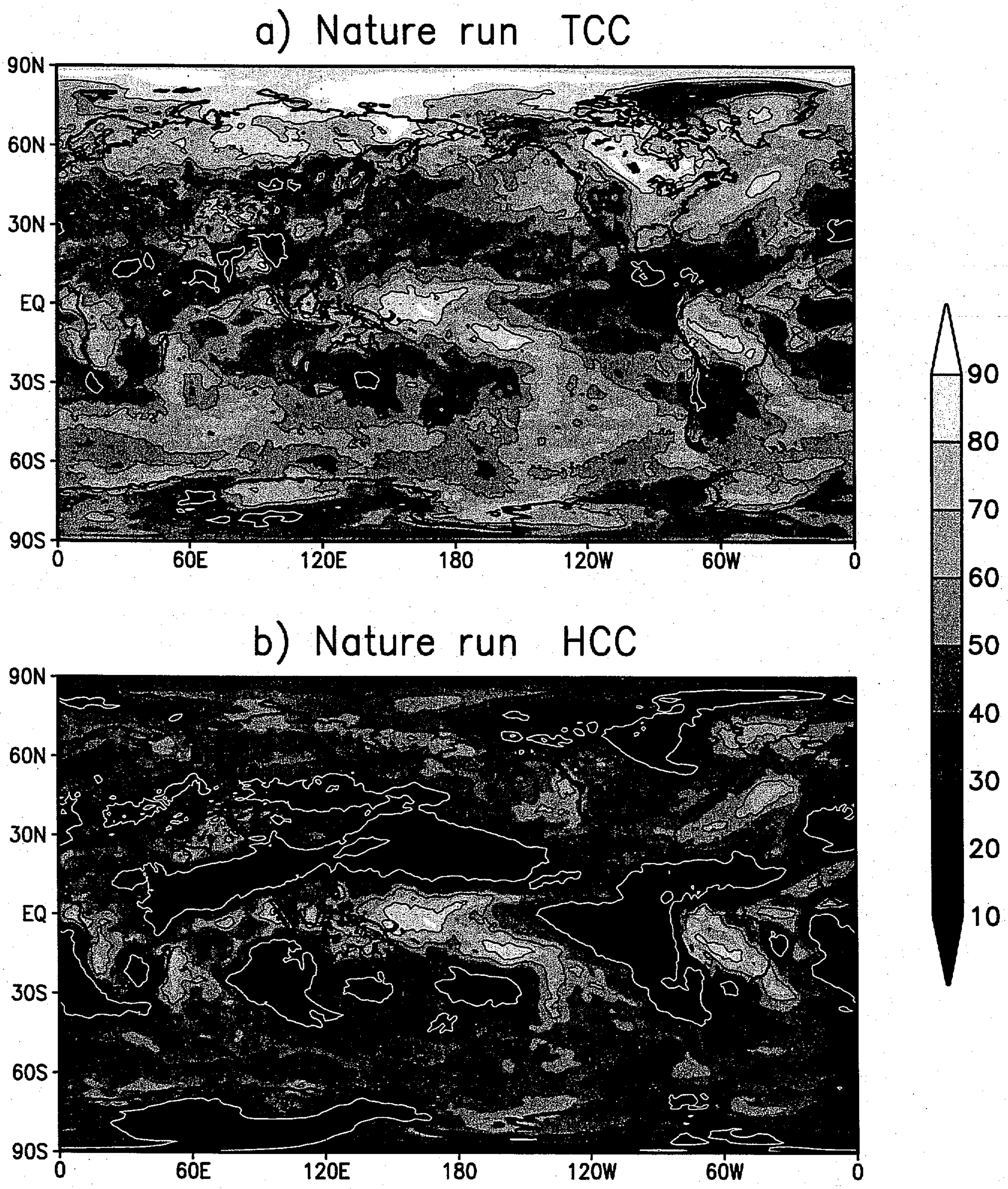

a) Nature run TCC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
b) Nature run HCC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
90
80
70
60
50
40
30
20
10

Fig. 1

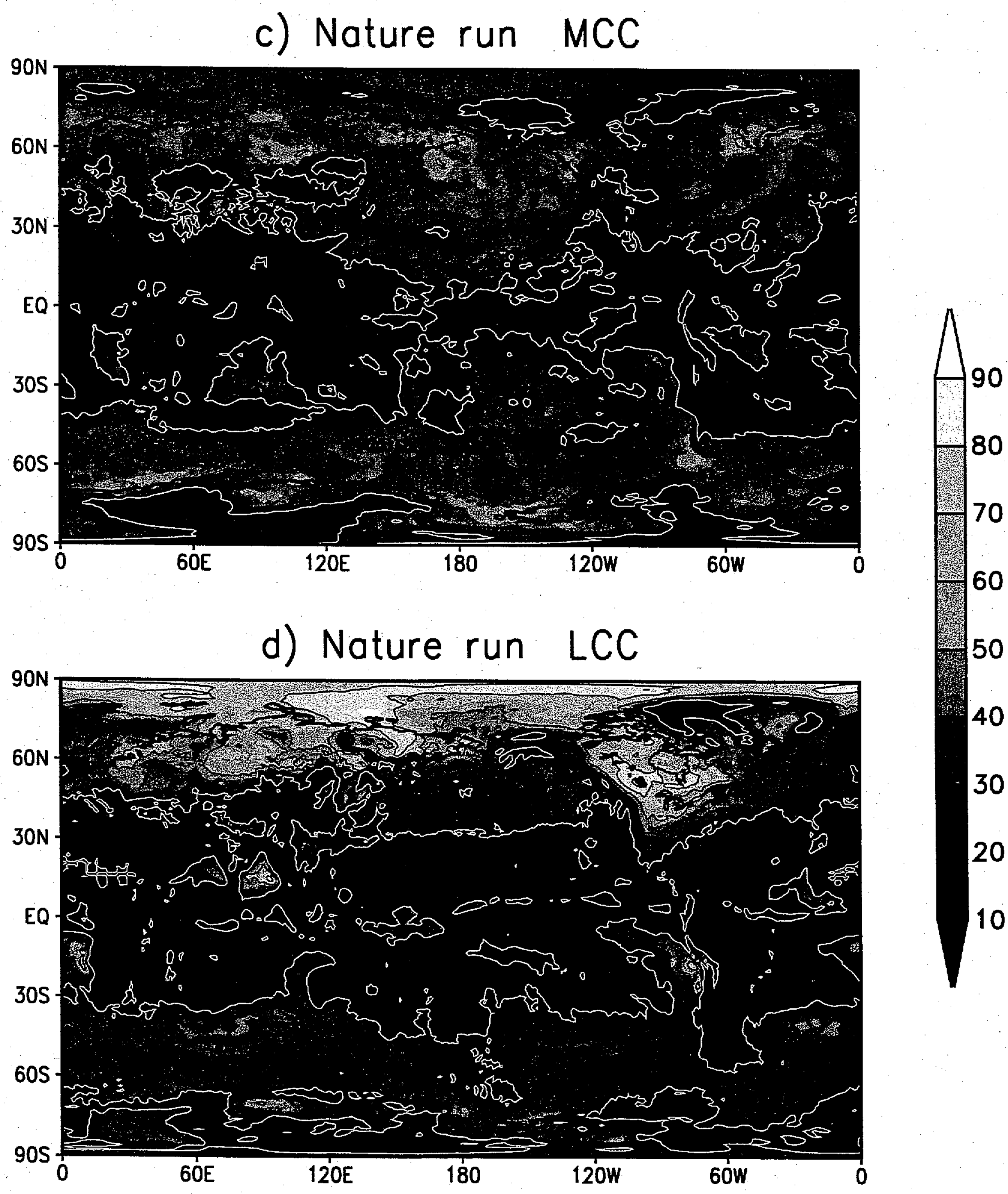

c) Nature run MCC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
d) Nature run LCC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
90
80
70
60
50
40
30
20
10

Fig. 1

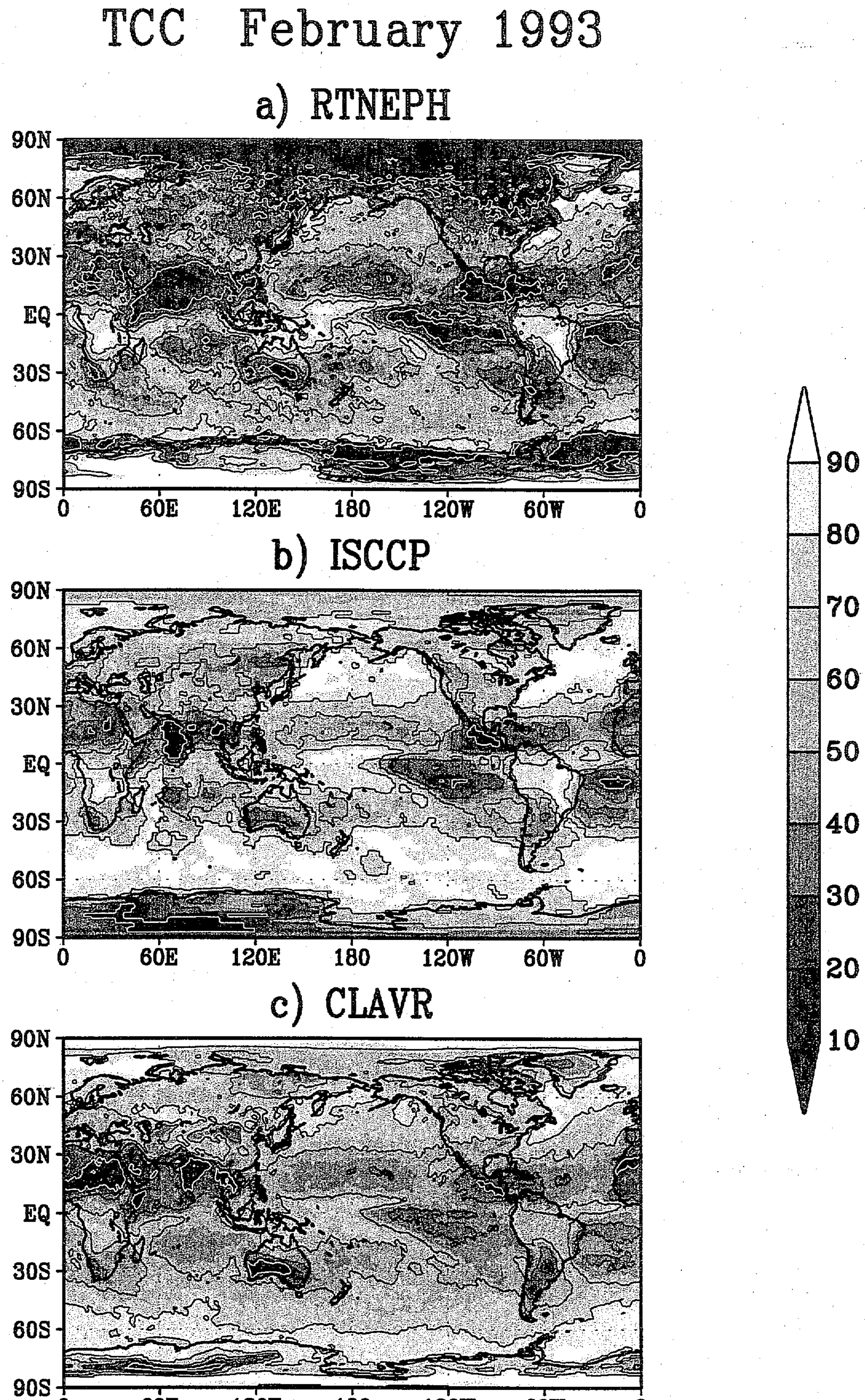

TCC February 1993
a) RTNEPH
b) ISCCP
c) CLAVR
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
90
80
70
60
50
40
30
20
10

Fig. 2

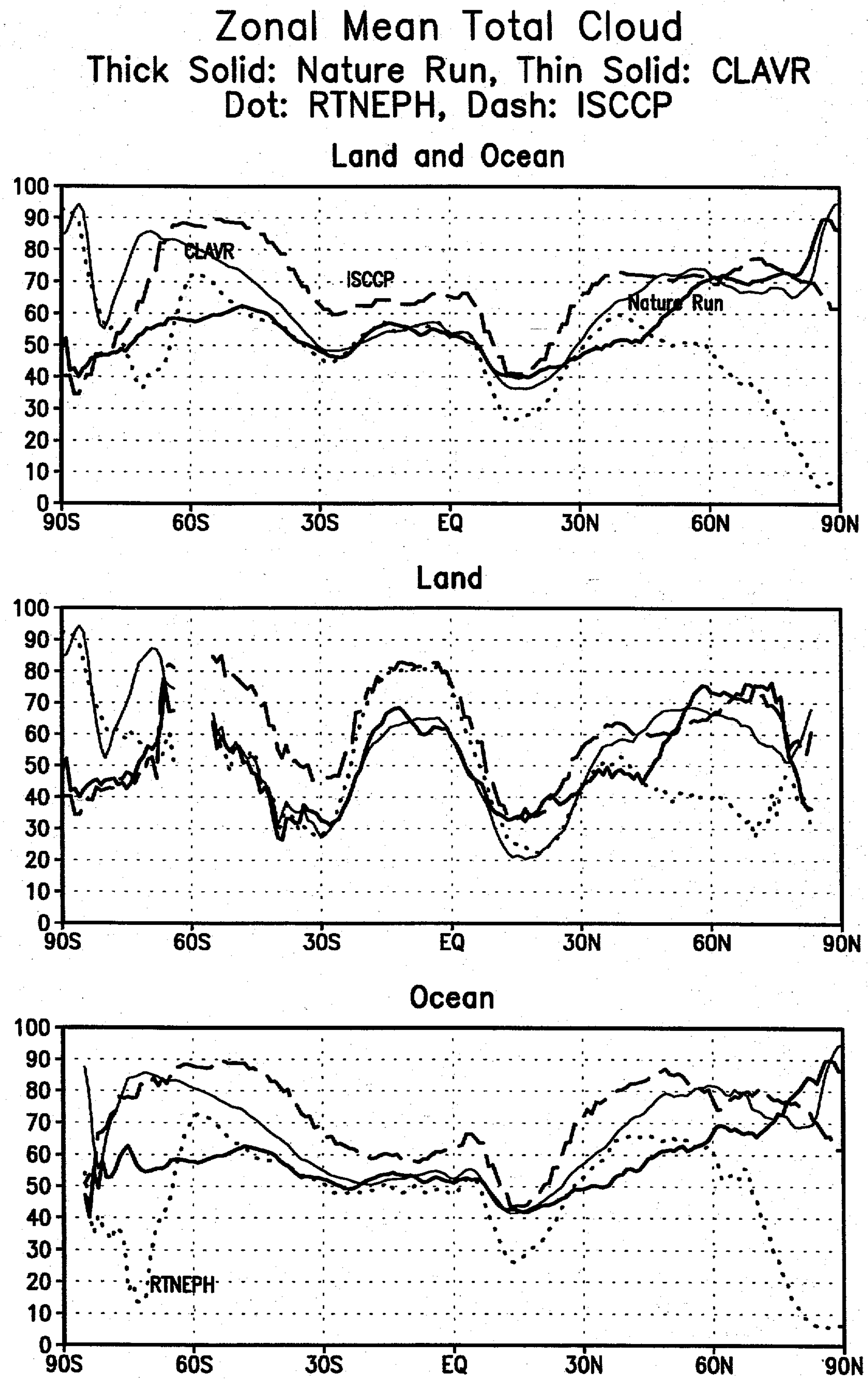

Zonal Mean Total Cloud
Thick Solid: Nature Run, Thin Solid: CLAVR
Dot: RTNEPH, Dash: ISCCP
Land and Ocean
CLAVR
ISCCP
Nature Run
Land
Ocean
RTNEPH
100
90
80
70
60
50
40
30
20
10
0
90S
60S
30S
EQ
30N
60N
90N

Fig. 3a

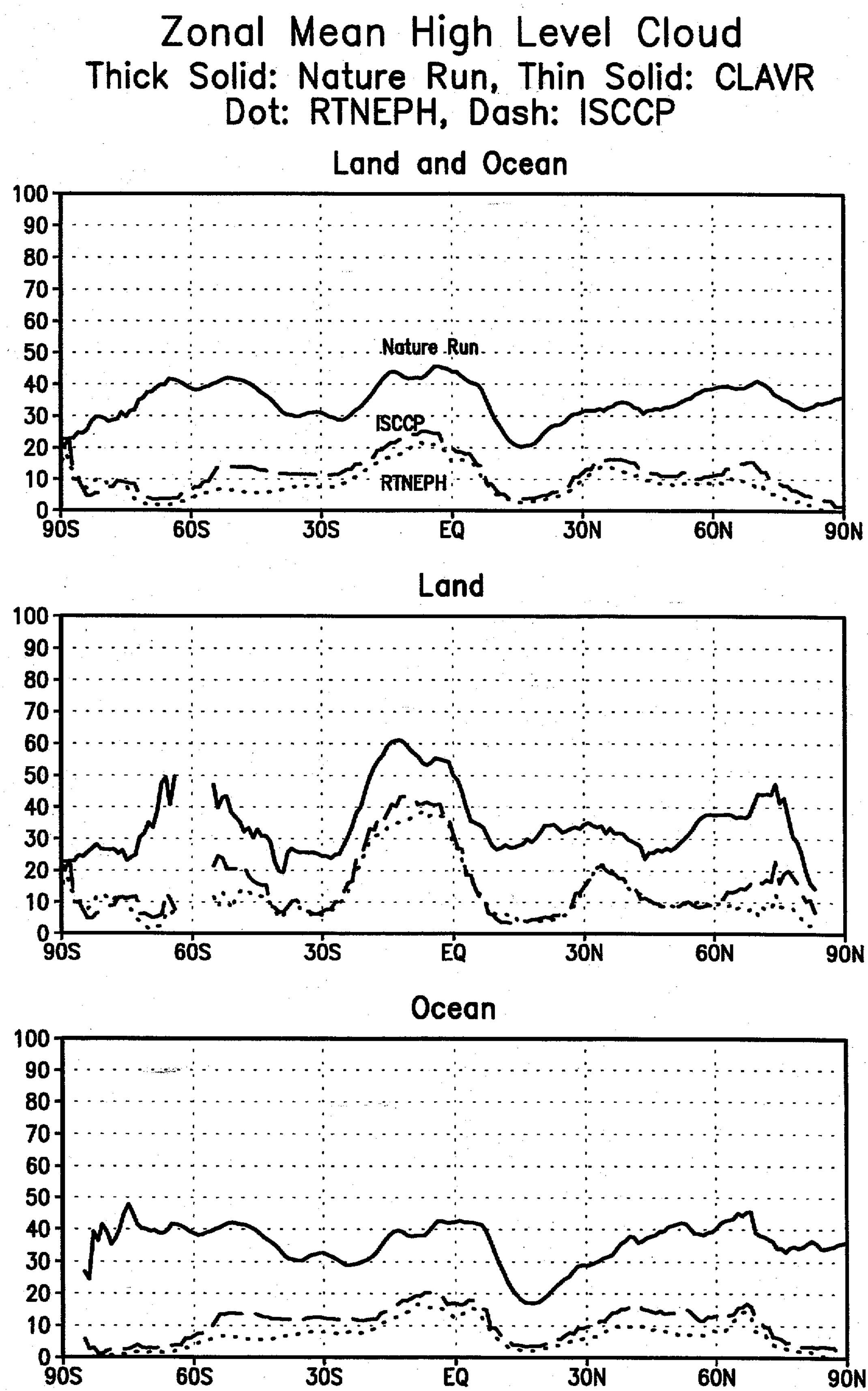

Zonal Mean High Level Cloud
Thick Solid: Nature Run, Thin Solid: CLAVR
Dot: RTNEPH, Dash: ISCCP
Land and Ocean
Nature Run
ISCCP
RTNEPH
Land
Ocean
0
10
20
30
40
50
60
70
80
90
100
90S
60S
30S
EQ
30N
60N
90N

Fig. 3b

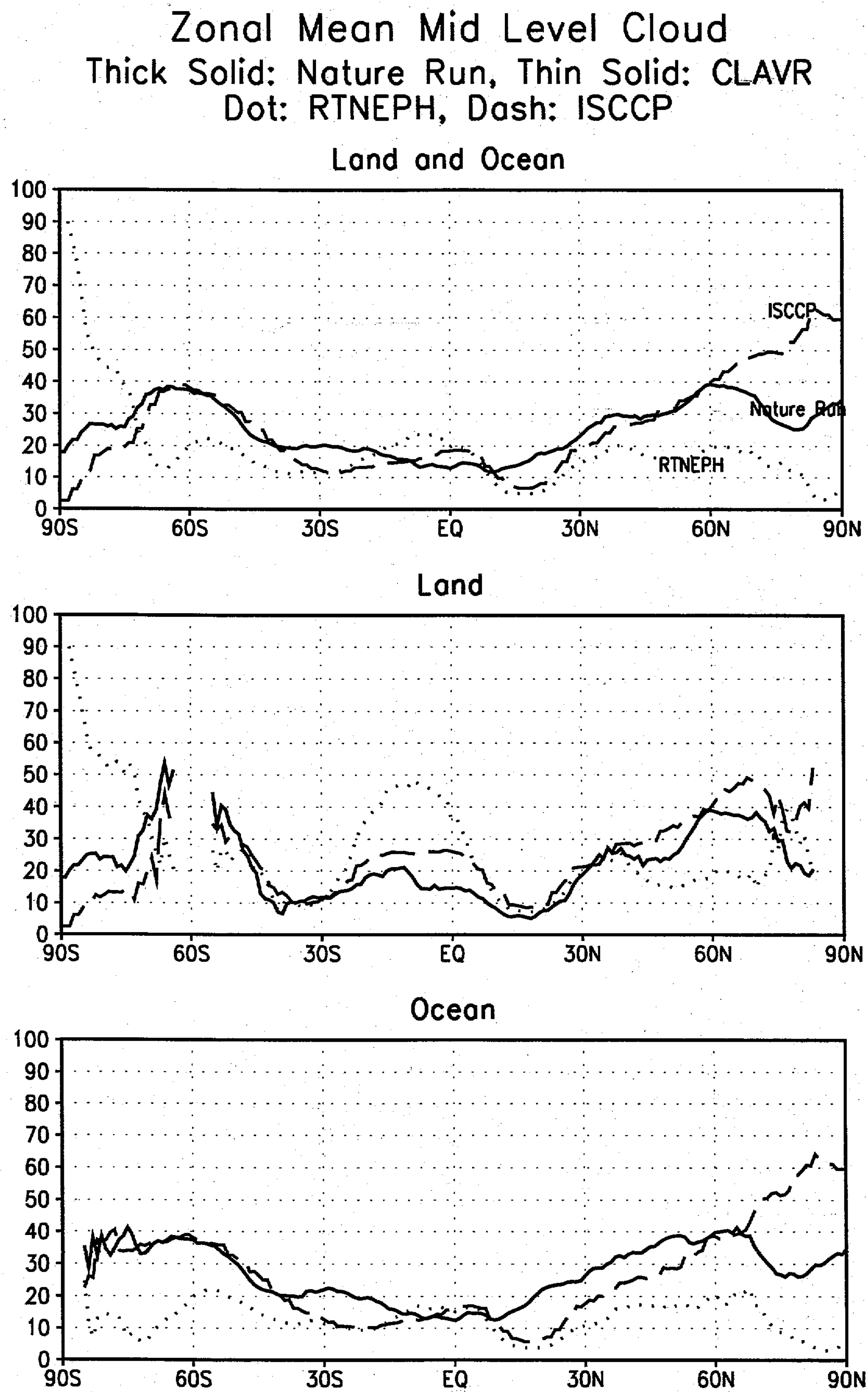
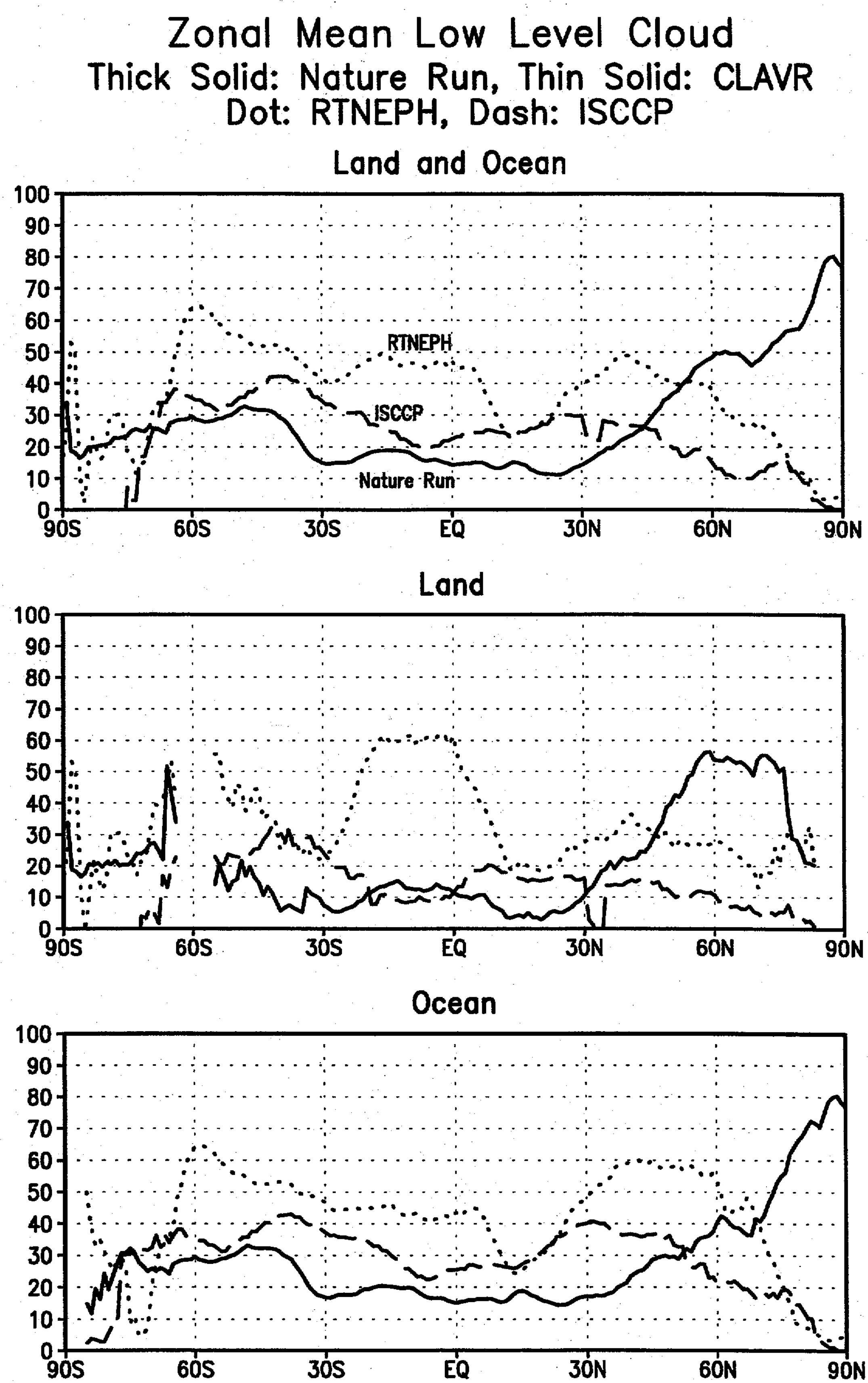

Zonal Mean Mid Level Cloud
Thick Solid: Nature Run, Thin Solid: CLAVR
Dot: RTNEPH, Dash: ISCCP
Land and Ocean
ISCCP
Nature Run
RTNEPH
Land
Ocean
100 90 80 70 60 50 40 30 20 10 0
90S 60S 30S EQ 30N 60N 90N

Fig. 3c



Zonal Mean Low Level Cloud
Thick Solid: Nature Run, Thin Solid: CLAVR
Dot: RTNEPH, Dash: ISCCP
Land and Ocean
RTNEPH
ISCCP
Nature Run
Land
Ocean
100
90
80
70
60
50
40
30
20
10
0
90S
60S
30S
EQ
30N
60N
90N

Fig. 3d

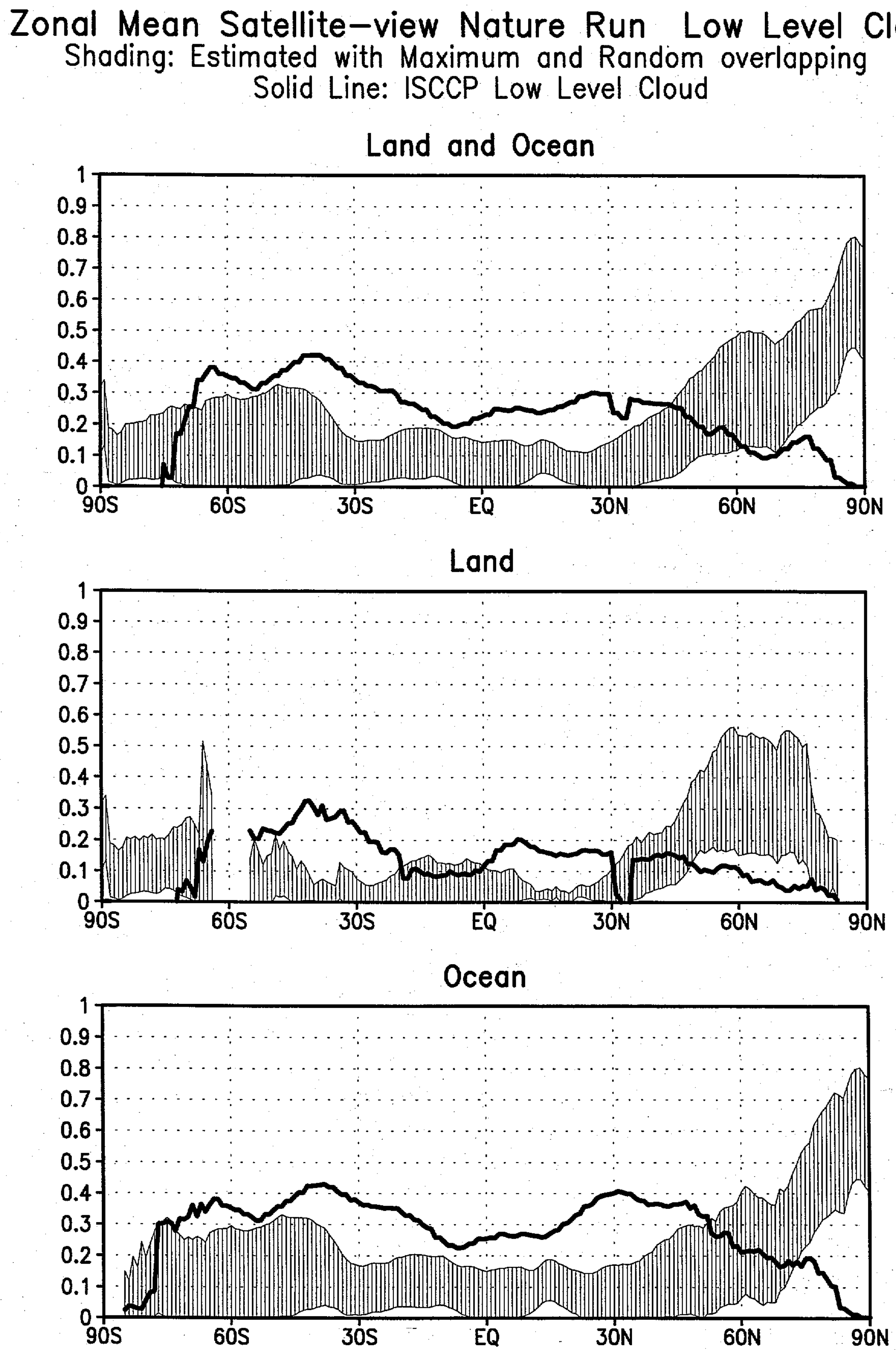

Zonal Mean Satellite-view Nature Run Low Level Cloud
Shading: Estimated with Maximum and Random overlapping
Solid Line: ISCCP Low Level Cloud
Land and Ocean
Land
Ocean
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
90S
60S
30S
EQ
30N
60N
90N

Fig. 4a

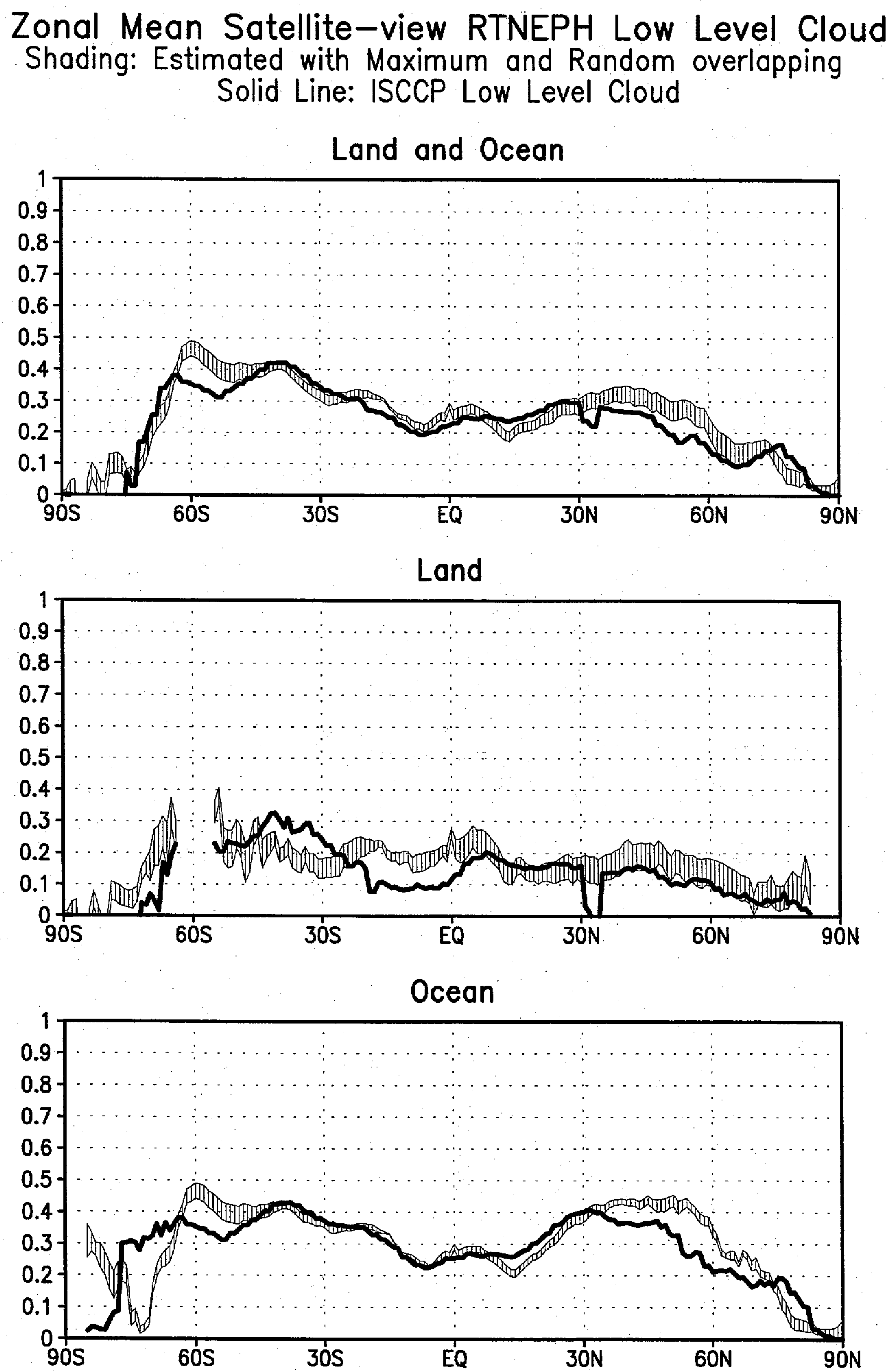

Zonal Mean Satellite-view RTNEPH Low Level Cloud
Shading: Estimated with Maximum and Random overlapping
Solid Line: ISCCP Low Level Cloud
Land and Ocean
Land
Ocean
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
90S
60S
30S
EQ
30N
60N
90N

Fig. 4b

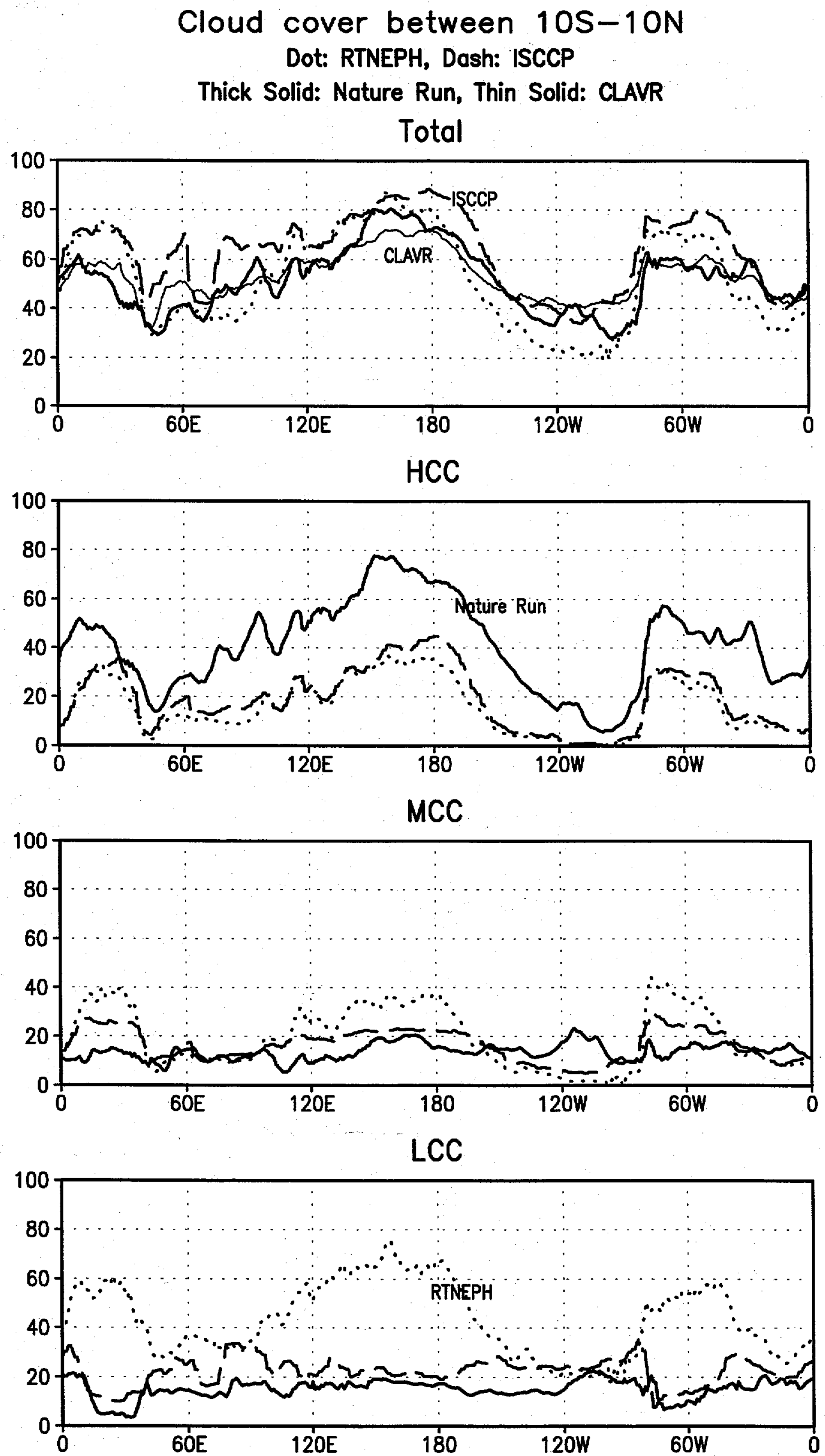

Cloud cover between 10S-10N
Dot: RTNEPH, Dash: ISCCP
Thick Solid: Nature Run, Thin Solid: CLAVR
Total
ISCCP
CLAVR
HCC
Nature Run
MCC
LCC
RTNEPH
100
80
60
40
20
0
0
60E
120E
180
120W
60W

Fig. 5

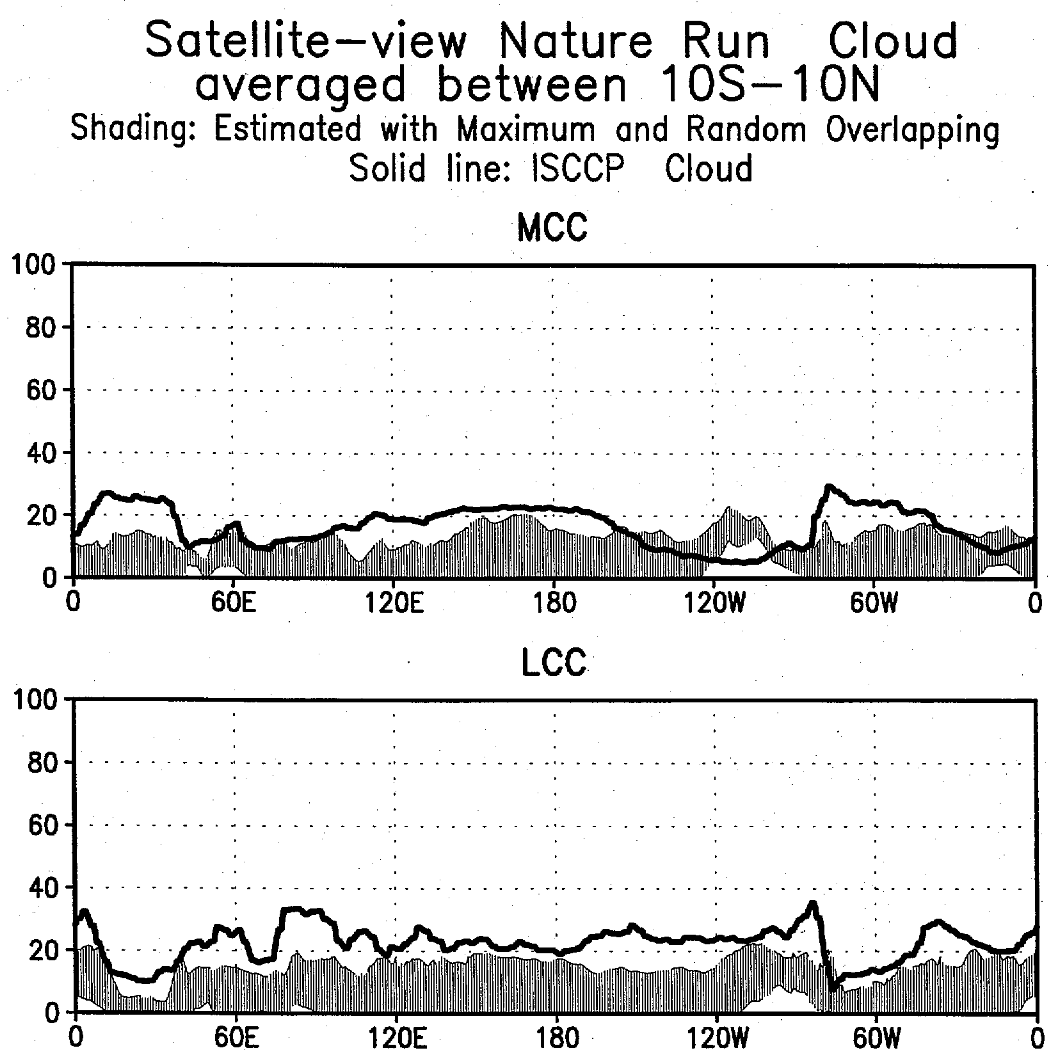

Satellite−view Nature Run Cloud
averaged between 10S−10N
Shading: Estimated with Maximum and Random Overlapping
Solid line: ISCCP Cloud
MCC
100
80
60
40
20
0
0
60E
120E
180
120W
60W
0
LCC
100
80
60
40
20
0
0
60E
120E
180
120W
60W
0

Fig. 6a

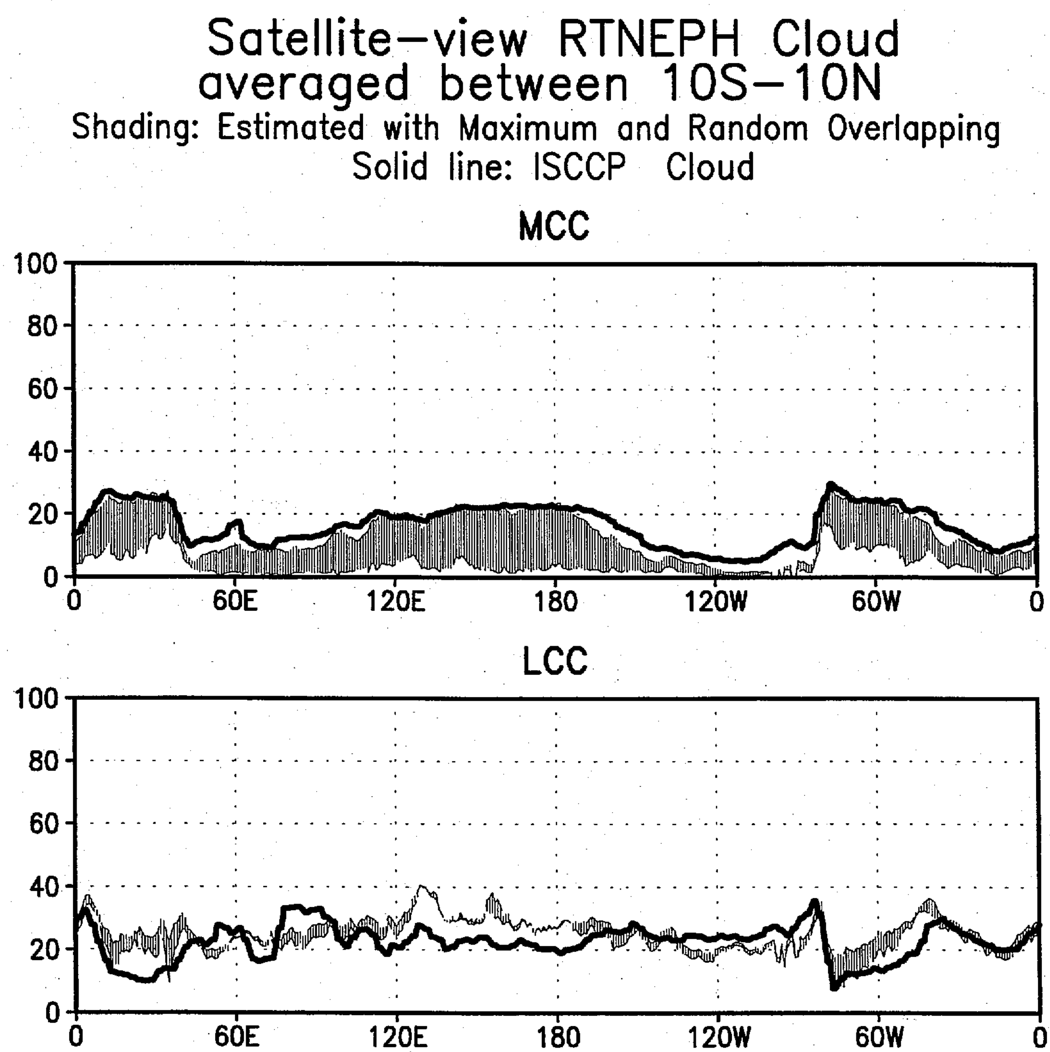

Satellite-view RTNEPH Cloud
averaged between 10S-10N
Shading: Estimated with Maximum and Random Overlapping
Solid line: ISCCP Cloud
MCC
100
80
60
40
20
0
0
60E
120E
180
120W
60W
0
LCC
100
80
60
40
20
0
0
60E
120E
180
120W
60W
0

Fig. 6b

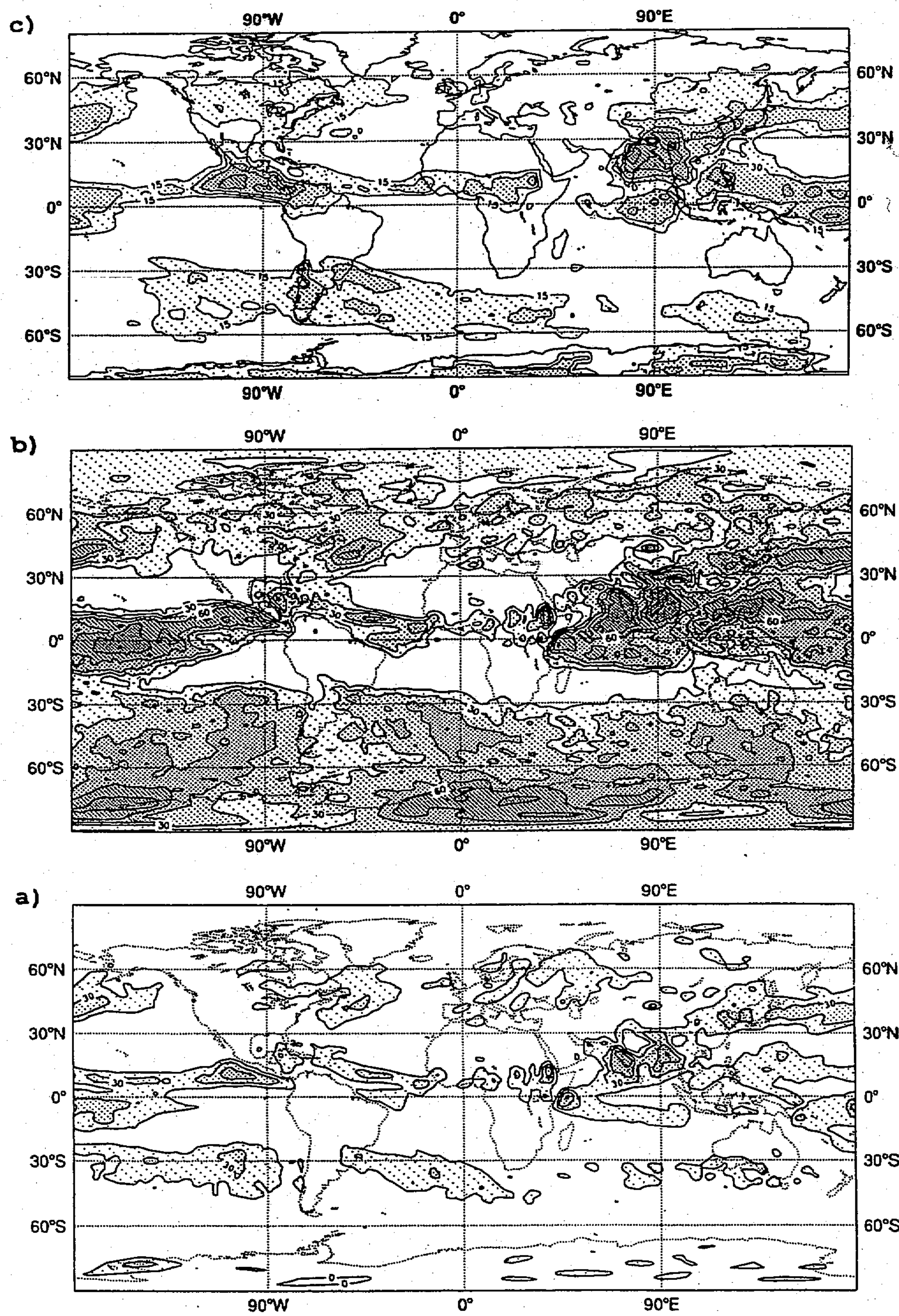


FIG. 2. As Fig. 1 but cloud cover of high-level clouds: (a) model-produced effective cloud cover; (b) model-produced real cloud cover; and (c) observed cloud cover from ISCCP.

Fig. 7

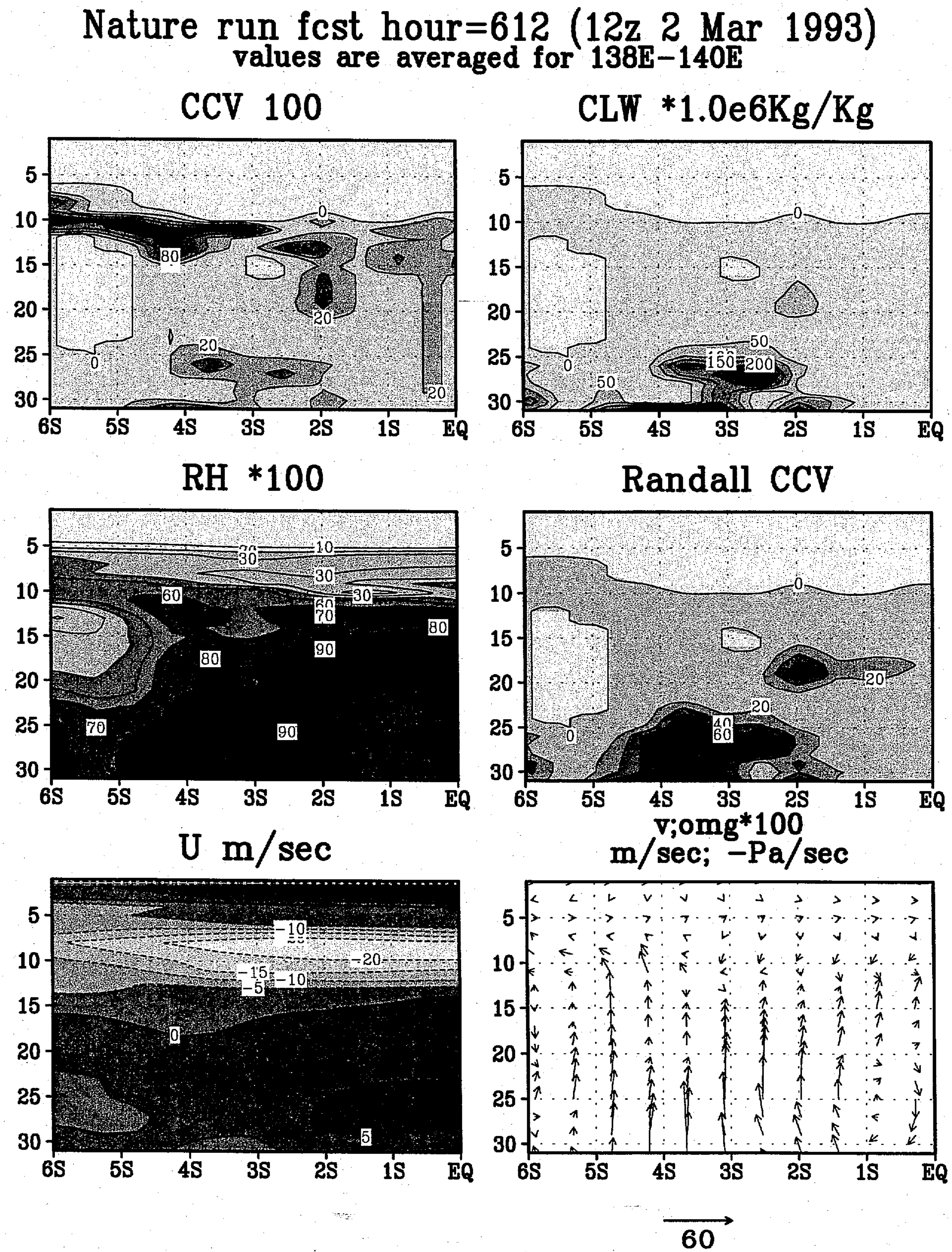

Nature run fcst hour=612 (12z 2 Mar 1993)
values are averaged for 138E-140E
CCV 100
CLW *1.0e6Kg/Kg
RH *100
Randall CCV
U m/sec
v;omg*100
m/sec; -Pa/sec
6S 5S 4S 3S 2S 1S EQ
5 10 15 20 25 30
60

Fig. 8

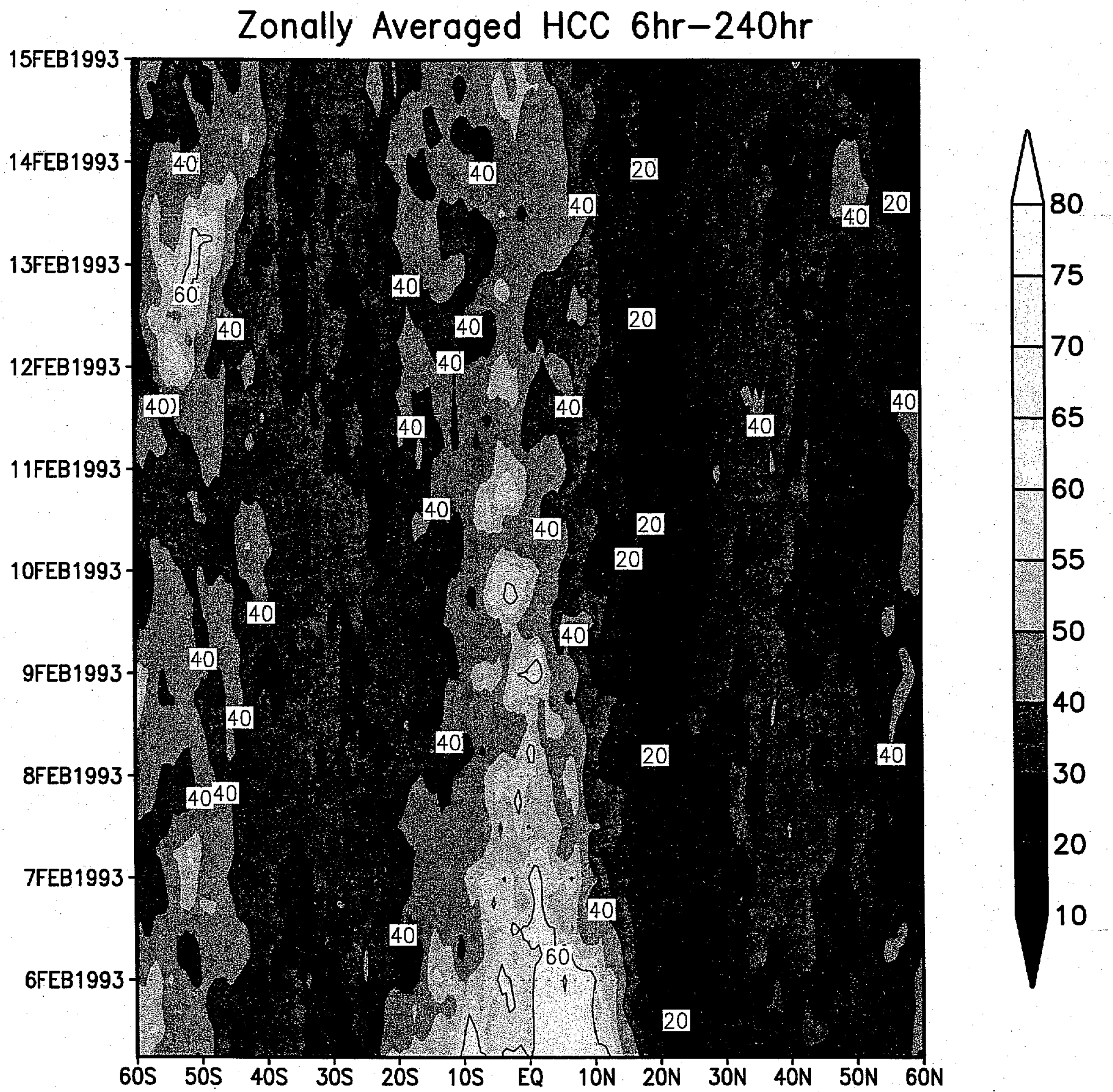

Zonally Averaged HCC 6hr−240hr
15FEB1993
14FEB1993
13FEB1993
12FEB1993
11FEB1993
10FEB1993
9FEB1993
8FEB1993
7FEB1993
6FEB1993
60S
50S
40S
30S
20S
10S
EQ
10N
20N
30N
40N
50N
60N
80
75
70
65
60
55
50
40
30
20
10

Fig. 9

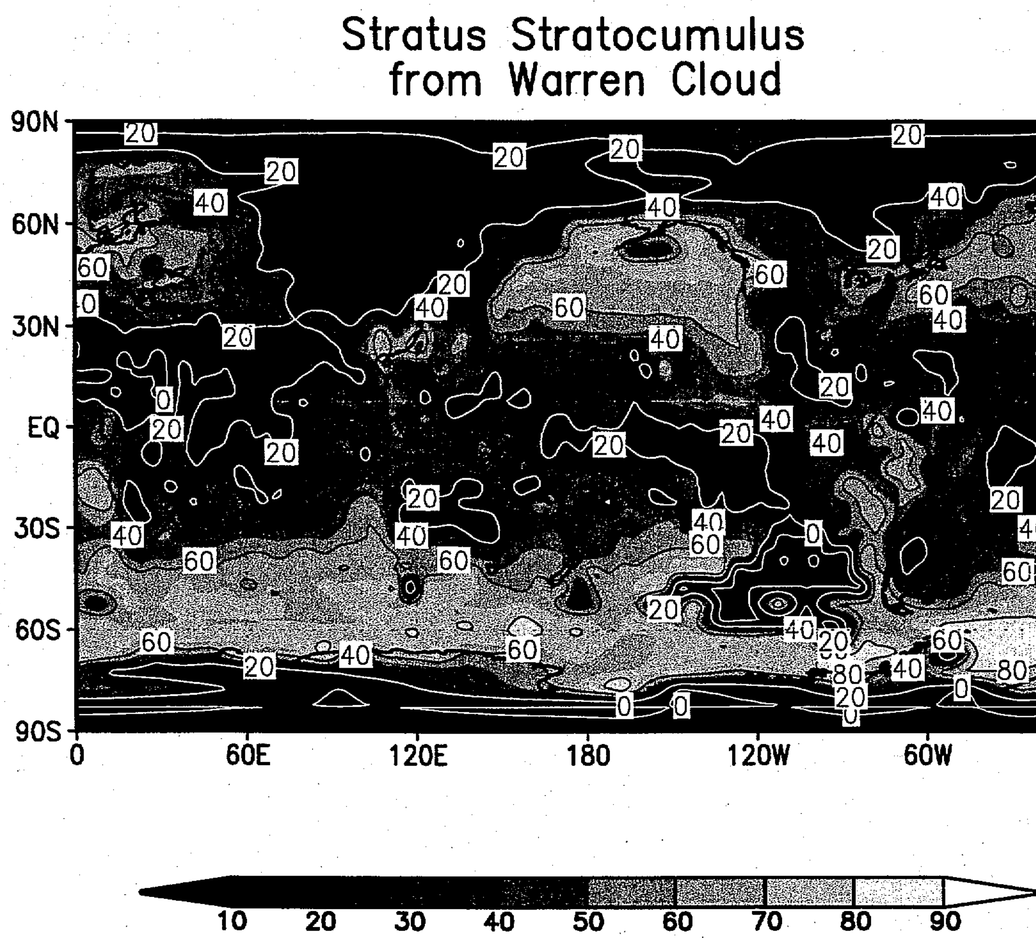

Stratus Stratocumulus
from Warren Cloud
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
10
20
30
40
50
60
70
80
90

Fig. 10

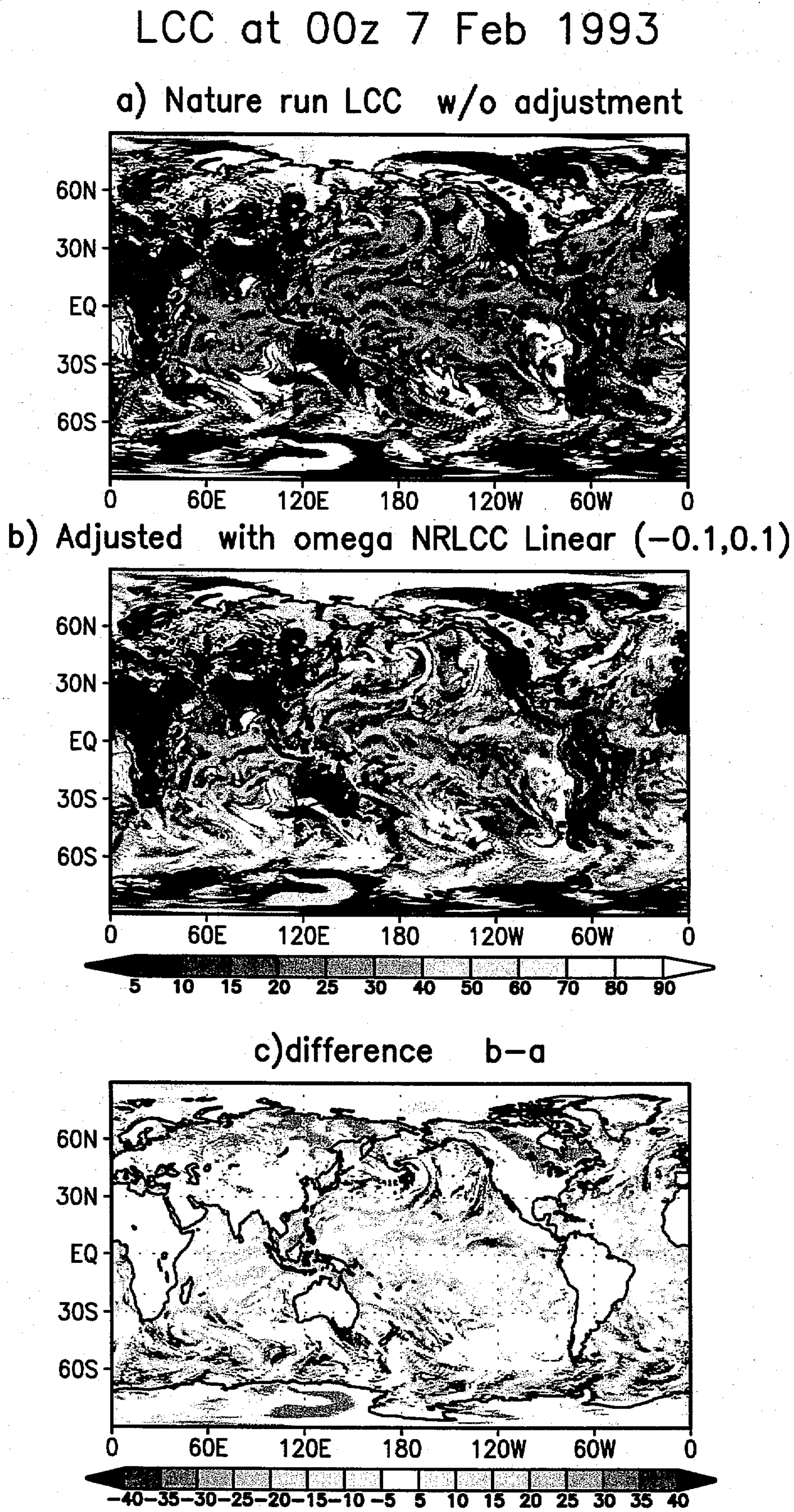

LCC at 00z 7 Feb 1993
a) Nature run LCC w/o adjustment
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
b) Adjusted with omega NRLCC Linear (−0.1,0.1)
5 10 15 20 25 30 40 50 60 70 80 90
c)difference b−a
−40 −35 −30 −25 −20 −15 −10 −5 5 10 15 20 25 30 35 40

Fig. 11

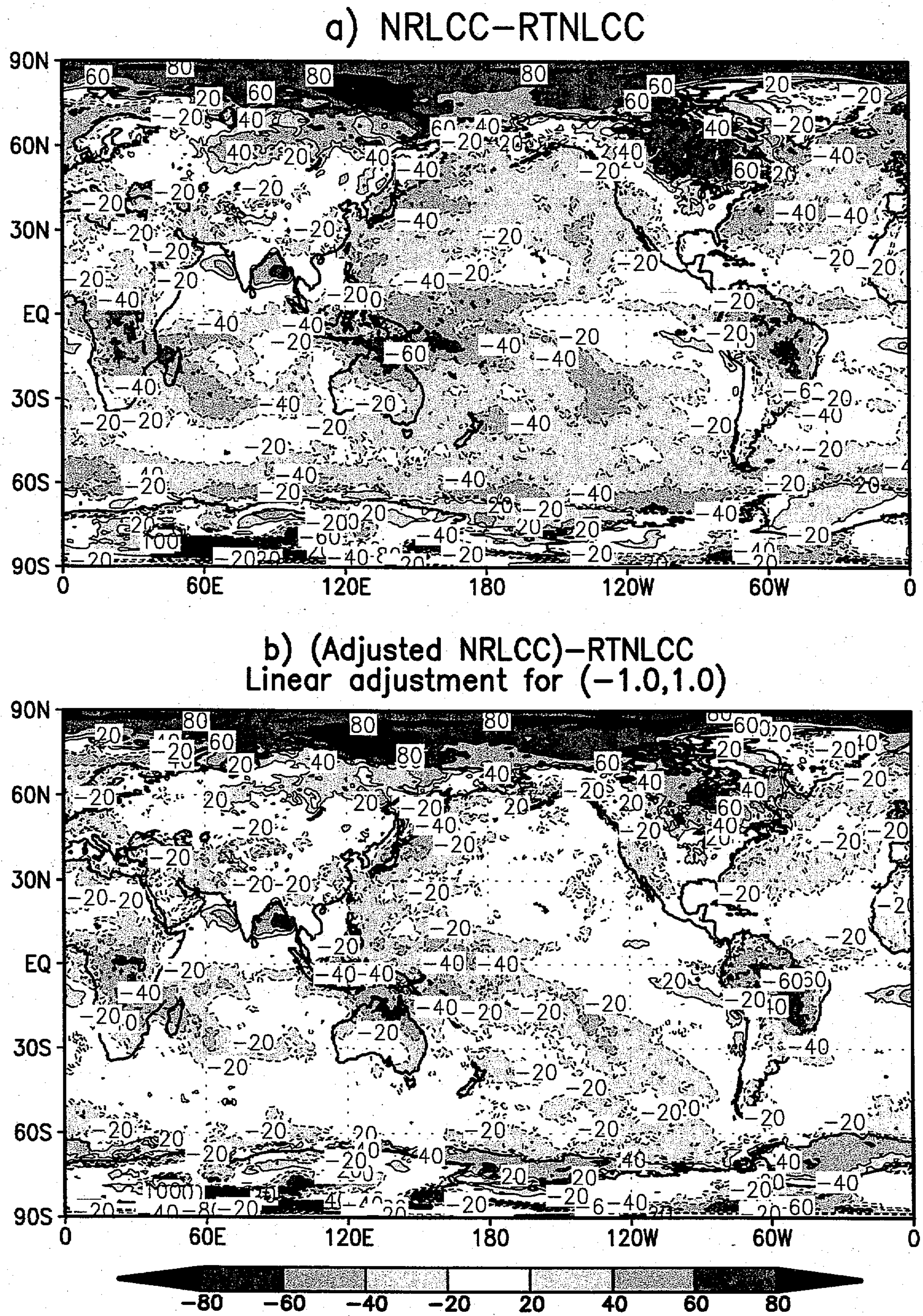

a) NRLCC−RTNLCC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
b) (Adjusted NRLCC)−RTNLCC
Linear adjustment for (−1.0,1.0)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−80
−60
−40
−20
20
40
60
80

Fig. 12

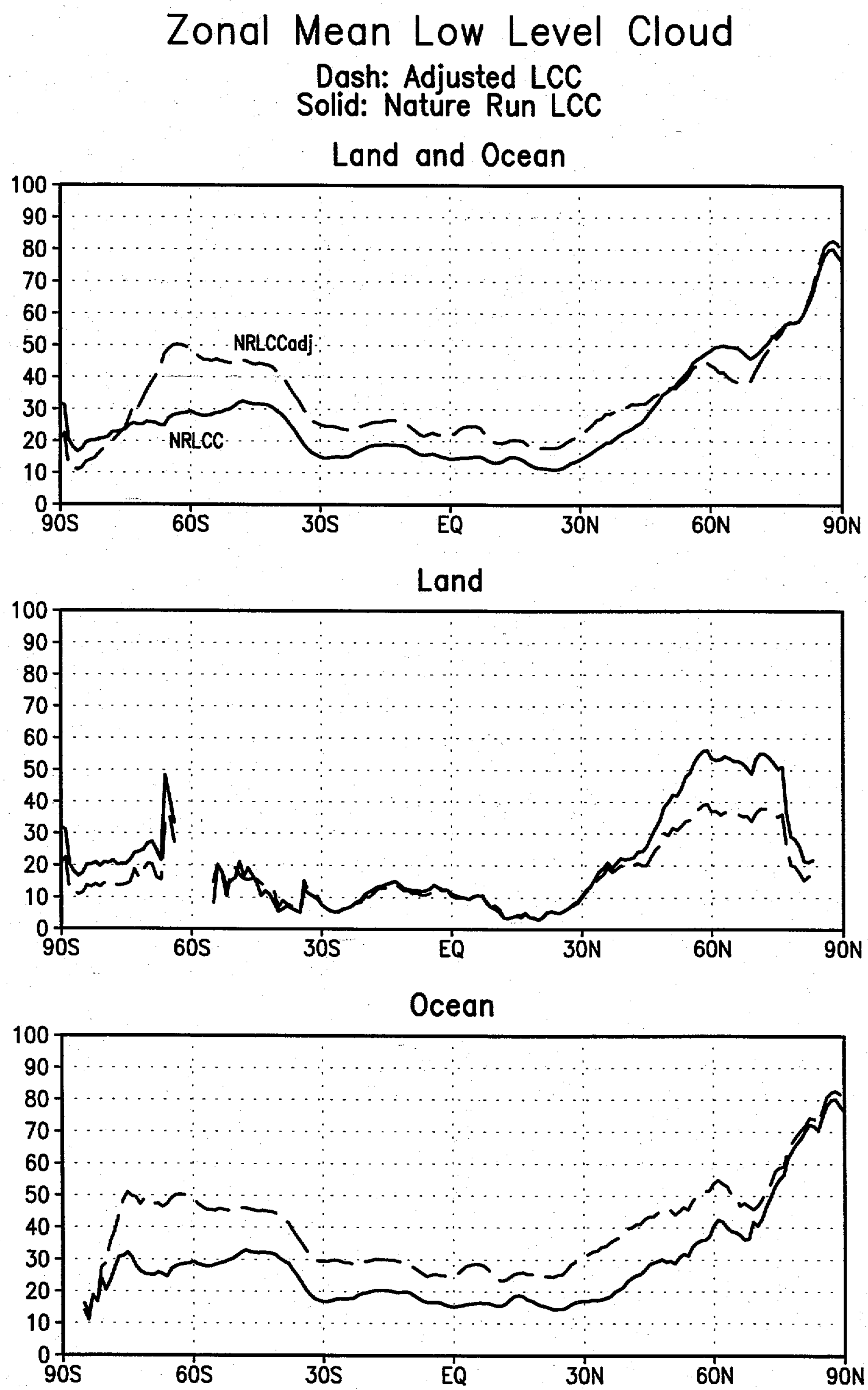

Zonal Mean Low Level Cloud
Dash: Adjusted LCC
Solid: Nature Run LCC
Land and Ocean
NRLCCadj
NRLCC
100
90
80
70
60
50
40
30
20
10
0
90S
60S
30S
EQ
30N
60N
90N
Land
Ocean

Fig. 13

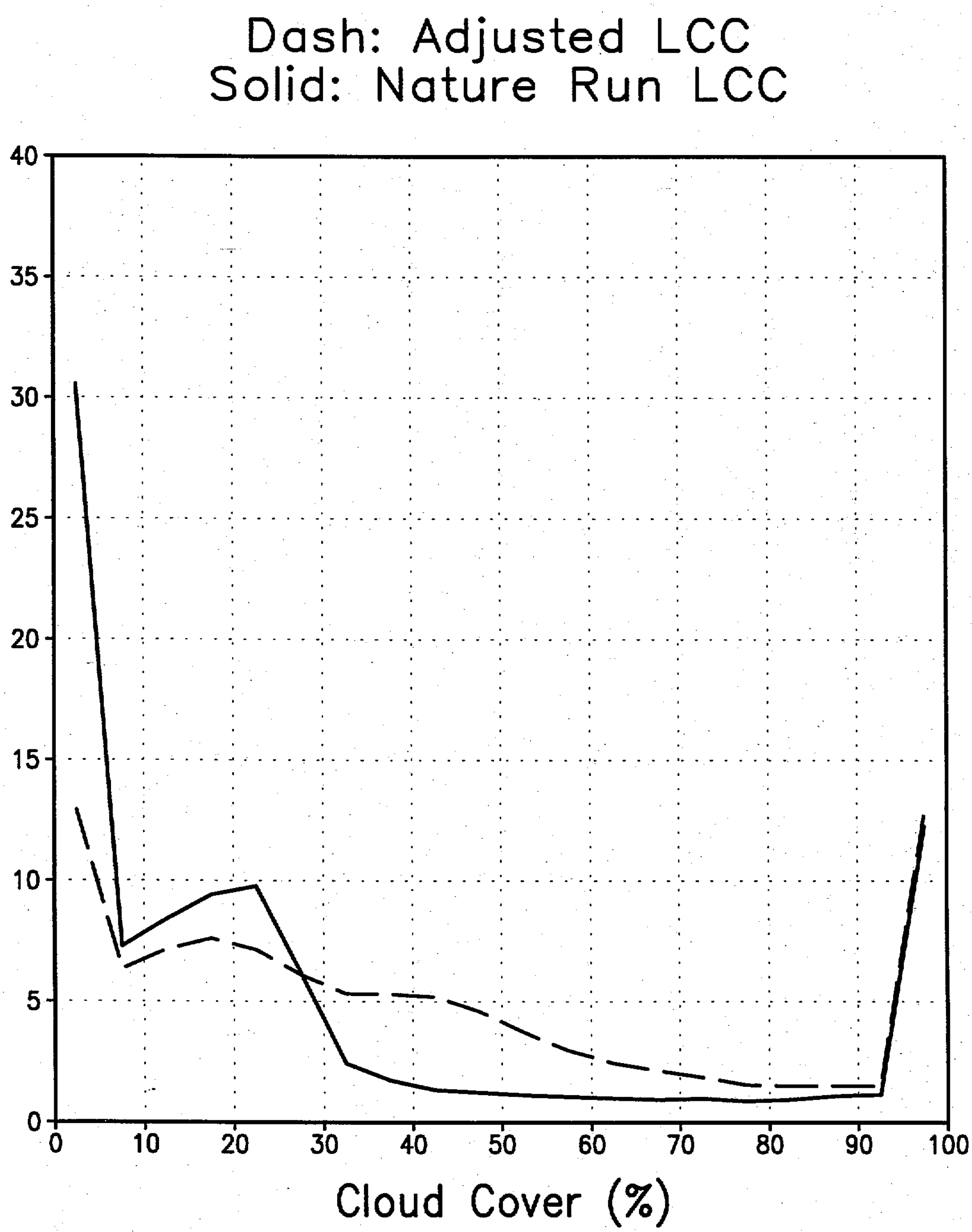

Dash: Adjusted LCC
Solid: Nature Run LCC
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Cloud Cover (%)

Fig. 14