# A Comparison Between Satellite-Defined and Parameterized Land–Water Differences in Emitted Longwave Radiation

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ABSTRACT

An analysis is performed to qualitatively compare the seasonal variation in emitted longwave radiation over land and over water areas as determined from 12 months of Nimbus 6 satellite data with that defined from parameterizations of this radiation budget component. These variations are noted when land and water surface areas are mapped to corresponding areas at the "top" of the atmosphere. Variations of a surface-temperature-dependent parameterization of emitted longwave radiation originally suggested by Budyko (1969) are considered. The longwave radiation parameterizations indicate small differences between land and water profiles of emitted longwave radiation at the top of an atmospheric column in low latitudes in comparison to large differences in this feature shown to exist in the satellite data. The small differences are noted in linear parameterizations of emitted flux when zonally-averaged satellite data are used to define equation coefficients.

## 1. Introduction

Energy balance climate models (EBCM) are being used extensively to investigate the seasonal variation of our global climate (e.g., Cess, 1976; North and Coakley, 1979; Robock, 1978; and Sellers, 1974). The models used by several of these authors approximate the global climate based upon a zonally defined area grid which longitudinally accounts for the proportion of land and water in a given zone. In this study, a comparison is made between a linear parameterization of emitted longwave (LW) radiation that is currently used in several EBCM and a satellite data representation of the same radiation budget variable. The LW radiation data used in this study were derived from measurements retrieved by the Earth radiation budget (ERB) wide-field-of-view (WFOV) instrument aboard the Nimbus 6 satellite during the 12-month period from July 1975–June 1976 (Bess *et al.*, 1981). The LW radiation parameterization, as well as the satellite-data-derived LW radiation, approximate the emitted LW radiation field at the top of an atmospheric column directly above land and water areas on the Earth. This study focuses upon the inadequacy associated with the use of a linear, temperature-dependent parameterization in approximating the zonal character of the Earth–atmosphere emitted LW radiation separately over land and water surfaces. This inadequacy is clearly noted when comparisons are made between profiles of emitted LW radiation as determined from linear parameterizations and satellite data.

The satellite data indicate sharp differences between monthly averaged profiles of emitted LW radiation over land and over water surfaces equatorward of 25°. These differences range from 33 W m$^{-2}$ in January to 5 W m$^{-2}$ in June. In contrast, small differences in the emitted LW radiation are shown to exist in midlatitudes during the monthly progression, even though a significant seasonal variation in temperature is present between land and water surfaces in this region.

Several temperature-dependent LW radiation parameterizations presently being used in climate sensitivity studies are linear in form. This type of equation, as originally suggested by Budyko (1969), is of the form

$$I(x, T, A_C) = A_0 + A_1T(x) + A_2A_C(x) + A_3T(x)A_C(x), \quad (1)$$

where $I$ is the emitted LW flux given as a function of latitude $x$, $T(x)$ is the latitude-dependent surface temperature, $A_C(x)$ is the latitude dependent fractional cloud cover, and $A_0$, $A_1$, $A_2$ and $A_3$ are constants which are determined as "best fits" to climatological data sets. Several authors have adopted this linear equation form for use in climatological studies.

North and Coakley (1979) modified this equation for use in a seasonally and zonally averaged EBCM (land and ocean surface proportions separately approximated). Their modified equation is of the form

$$I(x, T) = A + BT(x), \quad (2)$$

where

$$A = 203.3\ \mathrm{W\ m^{-2}},$$

$$B = 2.09\ \mathrm{W\ m^{-2}\ ^\circ C^{-1}}.$$

These coefficients only apply to their symmetric Northern Hemisphere model case. Even though (2) is still linear in form, it is now not explicitly dependent upon fractional cloud cover. Cess (1976) performed a linear regression on annually-averaged LW radiation satellite observations to determine the coefficients which best fit the Earth's Northern Hemisphere. He found these coefficients to be

$$A_0 = 257\ \mathrm{W\ m^{-2}},$$

$$A_1 = 1.63\ \mathrm{W\ m^{-2}\ ^\circ C^{-1}},$$

$$A_2 = -91\ \mathrm{W\ m^{-2}},$$

$$A_3 = -0.11\ \mathrm{W\ m^{-2}\ ^\circ C^{-1}}.$$

Cess used fractional cloud cover as given by London (1957) and zonally averaged temperatures for the Northern Hemisphere from Crutcher and Meserve (1970). Both the North and Coakley and the Cess studies used radiation budget data from Ellis and Vonder Haar (1976). Other authors (e.g., Coakley and Wielicki, 1979) have obtained similar regression equations having different coefficients by using different climatological data sets.

This study investigates whether or not a linear regression equation fitted to zonally-averaged data should be used to separately approximate the land and ocean features of emitted LW radiation. The approach taken is to define zonally averaged profiles of surface temperature, fractional cloud cover and emitted LW radiation. A linear regression is then performed based upon these data for the Earth to determine the coefficients of an equation in the form of (1). Next, separately defined land and ocean profiles of surface temperature and fractional cloud cover are then substituted into the linear equation to determine whether or not the land and ocean differences of emitted LW radiation as determined from the satellite data can be reasonably characterized with the zonally-averaged equation. Then, linear regressions were performed on the separate land and water data profiles of surface temperature, fractional cloud cover and emitted LW radiation. Finally, a comparison was made between the coefficients of the three linear equations: zonally averaged, land and water.

## 2. Satellite-defined longwave radiation

An understanding of the nonuniform distribution of LW radiation emitted by the Earth–atmosphere system is necessary to analyze interactions between the Earth's radiation field and its climate. Data retrieved during the Earth radiation budget experiment (Smith *et al.*, 1977) aboard the Sun-synchronous Nimbus 6 satellite were used for this analysis. The LW radiation is defined here as the difference between the measurements of total radiant flux and shortwave flux as retrieved by the satellite. For this study, a deconvolved empirical formulation of the emitted LW radiation data for the 12 month period from July 1975–June 1976 is used (Bess *et al.*, 1981).

Due to the Sun-synchronous orbital pattern of the Nimbus 6 satellite, having equatorial crossings at local noon and local midnight, data were extremely sparse for latitudes poleward of 80.1°. The empirical equation representing the data, therefore, partially extrapolates in the Northern and Southern Hemispheres in the areas poleward of 80.1°.

The process of deconvolving the satellite measurements adjusts the effective height of data retrieval from satellite altitude, 1100 km, to an approximate top of the atmosphere at 30 km. This adjustment of LW radiation is strictly a geometrical adjustment with no modifications made for the actual depletion of radiation by atmospheric attenuators during its propagation from the 30 km altitude to satellite altitude.

The deconvolved representation of the Nimbus 6 satellite measurements of emitted LW radiation was used to define zonally-averaged values of emitted LW radiation for each of the 18 10°-latitude bands for each of the 12 calendar months. Longwave radiation profiles were defined separately over water and land surfaces from the deconvolved satellite data for comparison with linear empirical formulations of emitted LW flux. To achieve this, land and water grid areas were mapped from the Earth's surface to their respective areas at the top of an atmospheric column. There appeared to be no discernible pattern associated with the presence of maximum and minimum regions of emitted LW radiation in the data. That is, the emitted flux was not consistently high over continental areas nor low over water areas during any particular time of the year. The LW radiation data were, therefore, estimated separately over both land and water surfaces based upon an area-weighted average of the LW radiation in 10° × 10° grid boxes. The average LW radiation for each grid box was defined from the average of 25 values of LW radiation calculated from the empirical deconvolutions. Because there was little variation in emitted LW radiation measurements within a 10° × 10° grid box, 25 values were deemed reasonable for computing averages from the deconvolved equation. The area-weighted averaging was performed by first obtaining an estimate of the fractional area occupied by land and by water in each of 648 10° × 10° boxes across the globe. The surface feature most prevalent in the box—land or water—was identified. Land and water features were defined separately to correlate the LW measurement field at the top of the atmosphere with spatial details of land and water areas on the Earth. After land and water fractional areas were defined for each of 648 global grid boxes, zonal averages of emitted LW radiation were computed separately over land and over water areas. These averages were determined as follows:

1) The average emitted flux calculated for a grid box was attributed to land if land covered the dominant portion of surface area (dominant meaning surface area > 50%), or to water if the dominant surface area was covered by water. If the grid box appeared to have approximately even portions of land and water, then the emitted LW radiation for the grid box was used in calculating both the land and water zonal averages.

2) After each of the 648 global grid boxes was designated as either land or water or both, zonal averages were defined for all land areas and water areas separately based upon a simple arithmetic mean. Fig. 1 shows the calculated LW radiation field

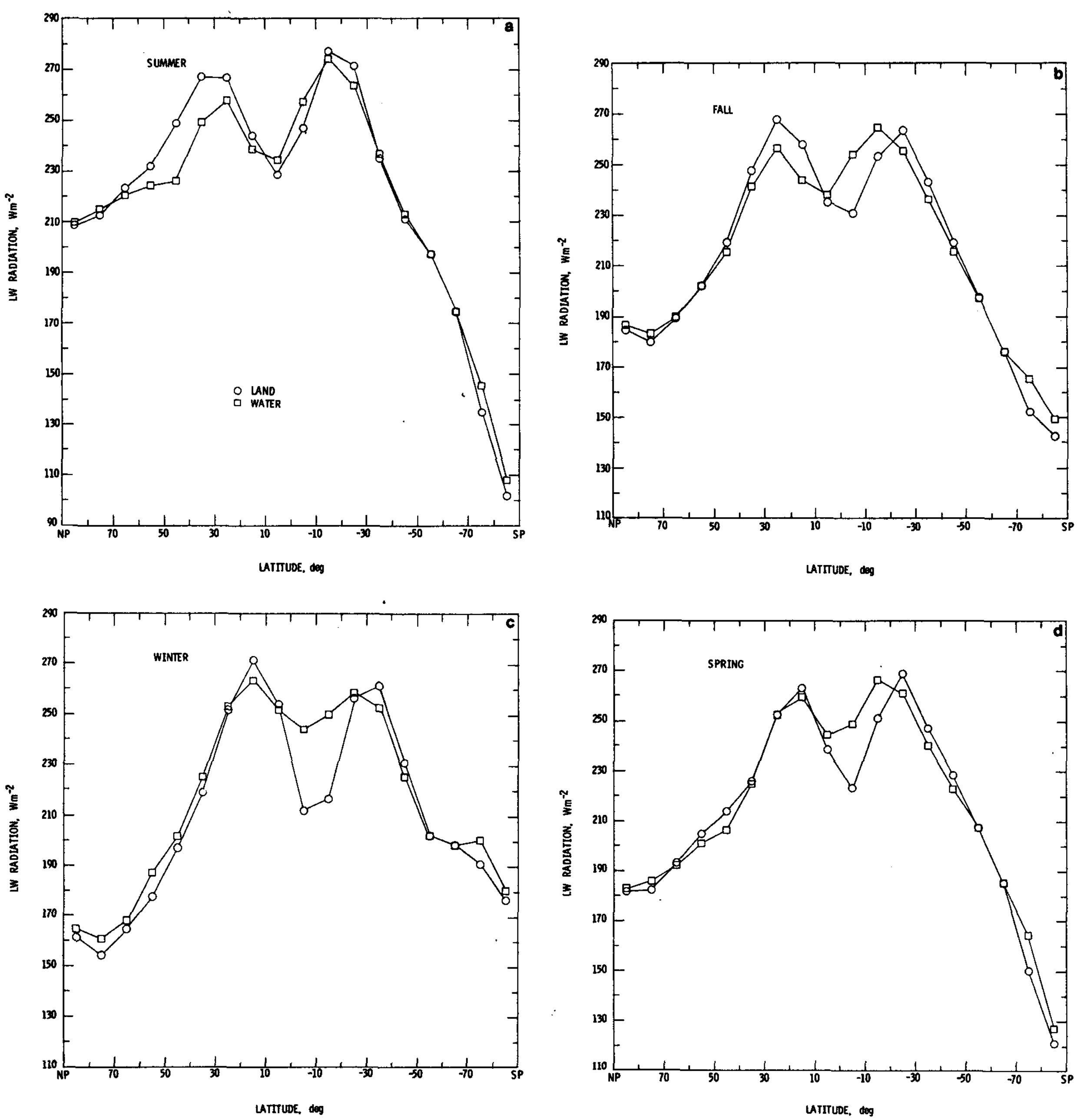


FIG. 1. Emitted longwave radiation profiles averaged over zonal land and water surfaces for the four Northern Hemisphere seasons, (a) summer, (b) fall, (c) winter and (d) spring.

for land and water for the four Northern Hemisphere seasons (summer—June, July, August; fall—September, October, November; winter—December, January, February; and spring—March, April, May), based upon the procedure just described.

A pronounced seasonal variation in LW radiation is shown to exist over land surfaces in the equatorial region, in comparison to the seasonal variation in the emitted LW radiation over water; however, a small seasonal change in the position of maximum amplitude occurs over water. Since the heat capacity of water is much larger than that for land, differences in the surface temperature over land and water are possibly due, in part, to the different heat capacities of each. The variation in specific heat capacities and incoming solar radiation affects the seasonal temperature distribution above these surfaces and, in turn, the emitted LW flux is affected to some degree by the variation in temperature. In addition to the differences in heat capacities of land and ocean areas, the turbulent convective mixing which occurs in the upper ocean layer aids in stabilizing the ocean temperatures in contrast to the small effect of molecular mixing contributing to the redistribution of heat in continental layers. The combination of these effects partially accounts for surface variations in emitted longwave radiation and, therefore, probably affects the character of the emitted longwave radiation aloft. Also, the effect of the surface temperature variation upon the formation and dissipation of clouds will influence the amount of emitted LW radiation through the "greenhouse effect." Further investigation into the mesoscale relationship between emitted LW radiation over land and water areas at the surface and this radiation at the top of the atmosphere is needed to draw any definitive conclusions concerning the monthly and seasonal behavior of the Nimbus 6 LW radiation profile as shown in Fig. 1.

## 3. Global cloud cover model

Monthly cloud cover was specified for this analysis from the cloud cover study of Sherr *et al.* (1968). Sherr's work compiles statistical data on world-wide cloud cover and summarizes these data for use in computer simulations. Cloud statistics defined in the Sherr study were used for this analysis to formulate a monthly-averaged fractional cloud cover model defined separately over land and water surfaces for each of 18 global 10° latitude bands.

The Sherr study divided the Earth's surface into 29 cloud regions, each specified as having a reasonably homogeneous cloud cover distribution. Cloud information characterizing each region was obtained from general cloud summaries, satellite observations, and selected ground-based and ship stations. For each region, the cloud data obtained from a single observing station were used to characterize the cloudiness of a particular region deemed to have homogeneous cloud cover characteristics. Cloud probability distributions for five cloud cover categories were defined for eight equally-spaced daily local times beginning with 0700 hours. The five cloud cover categories included one for clear and one for overcast sky conditions while the other three categories represented varied degrees of cloudiness between these two extremes. A monthly average was then defined for each of the eight local times. The Sherr data set provides both conditional and unconditional probability distributions relating to the existence of various cloudiness conditions. The unconditional distribution defines the probability of having certain cloudiness conditions in a designated area, while the conditional statistics incorporate the time and space dependence of a particular cloud regime at one point to that of another point which is "nearby" in either space or time. The unconditional statistics were based upon ground and ship observations. Data characterizing Southern Hemisphere regions having a scarcity of observing stations were represented by seasonal reversals of spatially correlated Northern Hemisphere stations.

The cloud model developed for this study incorporates only the unconditional cloud statistics of Sherr *et al.* (1968) and defines a fractional cloud cover for each of the 648 10° × 10° grid areas across the Earth for each of the 12 months in the year. The unconditional cloud statistics were used instead of the conditional cloud statistics because of the larger degree of uncertainty associated with the conditional statistics. An area-weighted, average fractional cloud amount defined separately over both land and water was calculated based upon the approximate area covered by either land or water in each of the 10° × 10° grid areas. This averaging was performed in the same manner as the emitted LW radiation profiles. An area-weighted, longitudinal average was calculated to specify monthly averaged, fractional cloud cover separately over land and over water surfaces for each of the 18 global 10° latitude bands. The Sherr data produced an annually averaged, area-weighted, fractional global cloud cover over land of 0.52 and a value of 0.61 over water surfaces. Table 1 contains seasonally averaged cloud cover for each of the 18 global 10° latitude bands. The seasonal averages are for winter, spring, summer, and fall with months as previously specified.

The zonally-averaged Nimbus 6 LW radiation data set for the entire Earth was shown to be inversely correlated with the Sherr cloud data set for Northern Hemisphere spring and fall and to be positively correlated in winter and summer. In contrast, the monthly data sets over land were inversely correlated for all months and the same trend as existed for the zonally averaged data was present over water; that is, an inverse correlation for the spring and fall

TABLE 1. Seasonally-averaged cloud cover.

| Latitude | Winter Land | Winter Water | Spring Land | Spring Water | Summer Land | Summer Water | Fall Land | Fall Water |
|---|---|---|---|---|---|---|---|---|
| 85 N | 0.37 | 0.37 | 0.45 | 0.45 | 0.75 | 0.75 | 0.77 | 0.77 |
| 75 | 0.37 | 0.37 | 0.45 | 0.45 | 0.75 | 0.75 | 0.77 | 0.77 |
| 65 | 0.53 | 0.57 | 0.51 | 0.57 | 0.60 | 0.70 | 0.65 | 0.74 |
| 55 | 0.58 | 0.69 | 0.55 | 0.71 | 0.60 | 0.78 | 0.63 | 0.75 |
| 45 | 0.56 | 0.69 | 0.56 | 0.70 | 0.49 | 0.70 | 0.41 | 0.63 |
| 35 | 0.50 | 0.64 | 0.48 | 0.66 | 0.37 | 0.70 | 0.31 | 0.49 |
| 25 | 0.47 | 0.56 | 0.47 | 0.55 | 0.43 | 0.61 | 0.38 | 0.52 |
| 15 | 0.51 | 0.54 | 0.42 | 0.45 | 0.46 | 0.66 | 0.45 | 0.68 |
| 5 | 0.59 | 0.63 | 0.51 | 0.53 | 0.70 | 0.73 | 0.72 | 0.77 |
| −5 | 0.72 | 0.57 | 0.67 | 0.54 | 0.59 | 0.49 | 0.60 | 0.50 |
| −15 | 0.70 | 0.59 | 0.70 | 0.59 | 0.48 | 0.59 | 0.46 | 0.55 |
| −25 | 0.50 | 0.53 | 0.50 | 0.52 | 0.40 | 0.58 | 0.35 | 0.59 |
| −35 | 0.43 | 0.75 | 0.41 | 0.46 | 0.60 | 0.66 | 0.54 | 0.69 |
| −45 | 0.74 | 0.73 | 0.69 | 0.68 | 0.75 | 0.74 | 0.75 | 0.73 |
| −55 | 0.87 | 0.87 | 0.83 | 0.83 | 0.78 | 0.78 | 0.81 | 0.81 |
| −65 | 0.79 | 0.79 | 0.79 | 0.79 | 0.52 | 0.52 | 0.58 | 0.58 |
| −75 | 0.75 | 0.75 | 0.77 | 0.77 | 0.37 | 0.37 | 0.45 | 0.45 |
| −85 S | 0.75 | 0.75 | 0.77 | 0.77 | 0.37 | 0.37 | 0.45 | 0.45 |

months and positive correlation for the winter and summer months.

## 4. Comparisons and results

A comparison is made among the LW radiation profiles calculated from the parameterization indicated by (2), those defined from the Nimbus 6 satellite data, and linear regression equations corresponding to the Nimbus 6 data. These profiles are defined separately over land and over water surfaces and were averaged for the Northern Hemisphere winter months—December, January and February. Values of winter (Northern Hemisphere) sea level temperatures used for this analysis are shown in Fig. 2. Monthly averaged temperatures over land and over water surfaces were supplied by Dr. W. Sellers, University of Arizona, Tucson, Arizona (pers. comm., 1981).

Commonly in the literature, climatological radiation budget data sets present zonally averaged results in table form rather than distinguishing between land and water surface area characteristics (e.g., Ellis and Vonder Haar, 1976; Campbell and Vonder Haar, 1980) even though contour maps are generally presented of longitudinal variations. Because of this, the linear regression equations which have been previously developed generally do not distinguish between these surface features, even though the equations are frequently used to simulate profiles separately over land and water surface areas in climate models. Energy balance climate models which separately approximate land and water areas need to minimize the relative error between these surface features in order to enhance the zonal reliability of the model.

The zonal variation in emitted LW radiation over land and over water surfaces as derived from the Nimbus 6 ERB measurements shown in Fig. 1c has particularly interesting features at mid and low latitudes. At the midlatitudes, there is very little variation between emitted LW radiation over land and over water, even though there is a relatively large seasonal variation in the temperature above these surfaces as shown in Fig. 2. The reverse is shown to

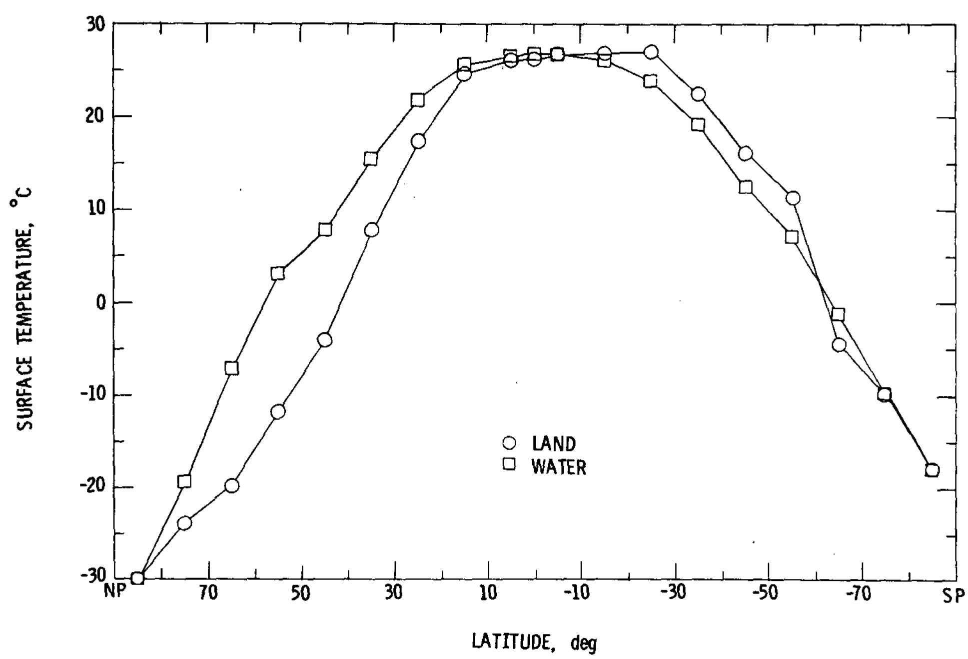


FIG. 2. Land (circles) and water (squares) sea level temperatures for Northern Hemisphere winter.

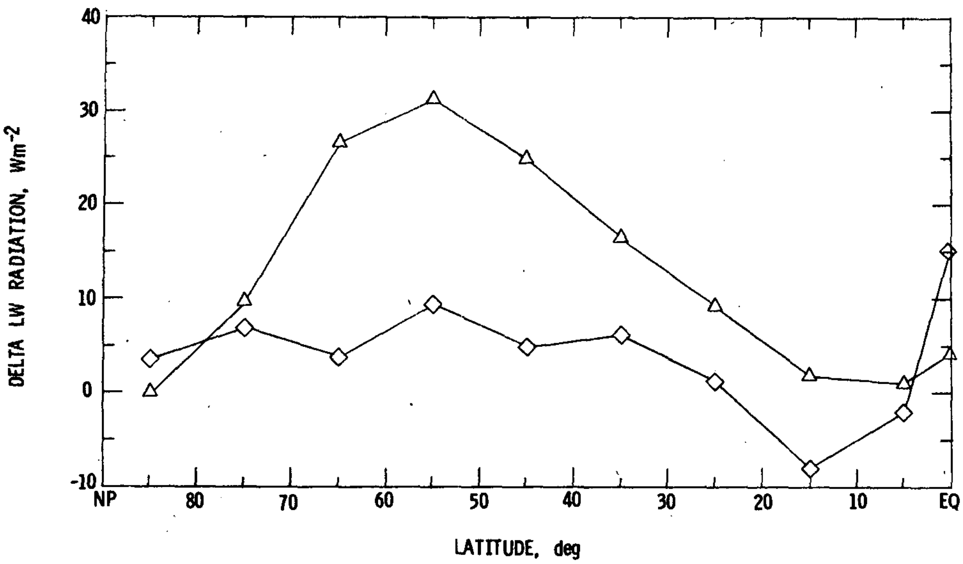


FIG. 3. Winter averaged water minus land differences in emitted longwave radiation profiles as derived from the Nimbus 6 wide field-of-view ERB data for the Northern Hemisphere (diamonds) and Eq. (2) (triangles).

exist in low latitudes. That is, a small seasonal temperature variation exists between land and water surfaces, but the Nimbus 6 data indicates the existence of a large seasonal variation between emitted LW radiation above land and above water surfaces. The parameterizations primarily dependent upon surface temperatures, presently being used to define the emitted LW radiation separately over land and water surfaces as in (2), cannot estimate this variation in emitted flux shown to exist in the Nimbus 6 ERB data. This situation applies in both low- and mid-latitude regions.

The coefficients defined for (2) were based upon zonally averaged satellite data as analyzed by Ellis and Vonder Haar (1976). Fig. 3 compares the actual water minus land difference in emitted LW radiation as determined from (2) with that determined from the Nimbus 6 measurements for Northern Hemisphere winter. This difference is represented as

$$\Delta I = A\Delta T, \qquad (3)$$

where $\Delta$ will hereafter be used to represent "water minus land" differences in the indicated variable. Even though the dependent variable, emitted LW radiation, in (2) is defined based upon a different radiation budget set, it is thought that the relative water minus land difference should be of the same order of magnitude and qualitative sign. The figure shows extreme differences between the water minus land difference in emitted LW radiation as determined from (2) and the Nimbus 6 satellite data analysis.

Using this as an initial impetus, a test is made to determine how well a linear equation using zonally averaged data in fitting its coefficients approximates the separate land and water characteristics of emitted LW radiation. Linear regression equations of the form indicated by (1) have been defined for this study separately for three types of longitudinal averages. These are zonally averaged, land averaged and water averaged surface areas. The method assumes emitted LW radiation as the dependent variable, and surface temperature, fractional cloud cover and surface temperature multiplied by fractional cloud cover as the independent variables as indicated in (1). There has been no weighting incorporated into the approximation of the linear regression coefficients. Monthly, seasonal and annual regression equations have been developed, but only the winter-averaged results will be detailed. Separate equations were also developed based upon 18 10° latitude bands, (i.e., one equation for the entire Earth) and 9 10° latitude bands (i.e., a separate regression equation for each hemisphere). Because the linear regression equations which approximated the emitted LW radiation separately for each hemisphere produced significantly better relative results, these equations were used for the present analysis. There will be a comparison among the profiles of water minus land differences in emitted LW radiation as approximated by

1) A regression equation whose coefficients were defined with zonally averaged surface temperature and zonally averaged fractional cloud cover data, but with separate land and water profiles of the independent variables actually used to generate emitted LW radiation profiles;

2) Two regression equations which employed separate land data and water data of surface temper-

TABLE 2a. Northern Hemisphere linear regression equation coefficients, winter.

$I(x, T, A_c) = A_0 + A_1T(x) + A_2A_c(x) + A_3T(x)A_c(x)$

| Coefficients | $A_0$ (W m$^{-2}$) | $A_1$ (W m$^{-2}$ °C$^{-1}$) | $A_2$ (W m$^{-2}$) | $A_3$ (W m$^{-2}$ °C$^{-1}$) | rms error (W m$^{-2}$) |
|---|---|---|---|---|---|
| Zonal | 251.8 | 1.9 | −93.5 | 0.51 | 7.2 |
| Land | 262.8 | 2.91 | −111.5 | −1.6 | 6.3 |
| Water | 252.2 | 0.18 | −111.8 | 4.4 | 7.3 |

TABLE 2b. Southern Hemisphere linear regression equation coefficients, winter.

$I(x, T, A_c) = A_0 + A_1T(x) + A_2A_c(x) + A_3T(x)A_c(x)$

| Coefficients | $A_0$ (W m$^{-2}$) | $A_1$ (W m$^{-2}$ °C$^{-1}$) | $A_2$ (W m$^{-2}$) | $A_3$ (W m$^{-2}$ °C$^{-1}$) | rms error (W m$^{-2}$) |
|---|---|---|---|---|---|
| Zonal | 337.36 | −2.81 | −178.5 | 5.8 | 6.7 |
| Land | 191.4 | 5.51 | 9.2 | −6.46 | 7.7 |
| Water | 358.44 | −3.74 | −202.8 | 7.14 | 5.4 |

ature and fractional cloud cover in defining their respective coefficients; and

3) The Nimbus 6 Earth radiation budget measurements.

Table 2 lists the coefficients determined for the linear regression equations for the Northern and Southern Hemispheres along with the root-mean-square (rms) error which is associated with each. Fig. 4 depicts the water minus land differences in emitted LW radiation as determined by the three methods listed above. Large differences are noted when comparisons are made between the equations having coefficients defined with zonal Nimbus 6 LW radiation data and the Nimbus 6 measurements defined separately over land and over water surfaces. The linear regression equations defined with separate land and water data do, of course, approximate the satellite land/ocean differences more accurately, but not with accuracy sufficient for climate modeling purposes. Based upon the rms errors shown in Table 2 and the Δ differences in Fig. 4, indications are that the linear regression equations approximate the emitted LW radiation in a reasonably poor manner. The linear regression equation poorly approximates the Nimbus 6 emitted LW radiation when using the temperature and cloud data sets previously detailed.

A comparison of the regression coefficients developed by Cess (1976) and those defined for this study for annually-averaged, Northern Hemisphere conditions is shown in Table 3. The magnitude and sign of the coefficients agree reasonably well even though different climatological data sets representing sur-

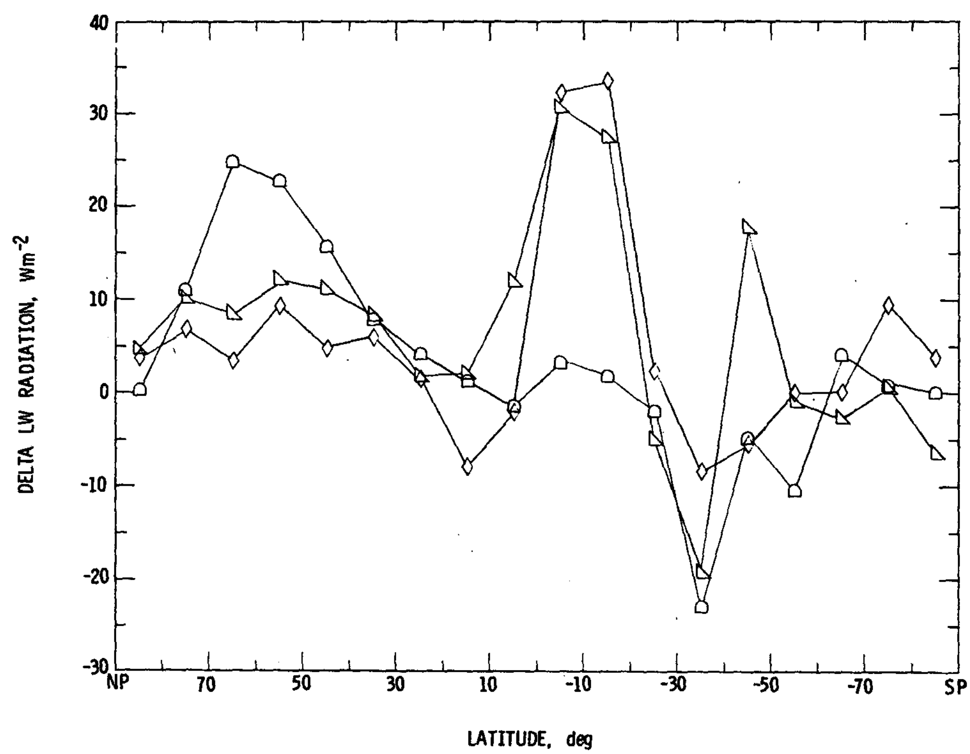


FIG. 4. Northern Hemisphere winter averaged water minus land differences in LW radiation profiles as calculated from the zonal regression equation (semicircles), Northern and Southern Hemisphere regression equations (triangles), and the Nimbus 6 satellite data (diamonds). Regression equations are as given in Table 2.

TABLE 3. Linear regression equation coefficients, Northern Hemisphere.

$$I(x, T, A_C) = A_0 + A_1T(x) + A_2A_C(x) + A_3T(x)A_C(x)$$

| Coefficients | $A_0$ | $A_1$ | $A_2$ | $A_3$ | rms error (W m$^{-2}$) |
|---|---|---|---|---|---|
| Cess | 257 | 1.63 | −91 | −0.11 | 1.5 |
| Nimbus 6 | 267 | 2.50 | −99 | −1.5 | 4.3 |

face temperature, cloud fraction and emitted LW radiation were used.

From this analysis, it is concluded that a linear, unweighted regression equation defined with the zonally averaged data sets used in this study is unable to characterize the intra-annual variation of the separate land and water features of emitted LW radiation shown to exist in the Nimbus 6 measurements. Further analysis concerning the effect that these differences produce when incorporated into energy balance climate models should be addressed.

The process of developing equations which fit different data sets is extremely dependent upon the data set used, the assumptions made in analyzing the data set, and the error inherent in the data. Because of this, the actual magnitude of the emitted LW radiation data profiles were not explicitly compared here, but only the magnitude and sign of the water minus land differences. It is again noted that the Nimbus 6 data set used in this analysis comprises a total of 12 months of wide-field-of-view Earth radiation budget data from the Nimbus 6 satellite deconvolved to an ~30 km top of the atmosphere. It is felt that the water minus land differences in emitted longwave radiation are significant and, as previously stated by Campbell and Vonder Haar (1980), should be included in even the simplest climate models.

## 5. Concluding remarks

This study has compared LW radiation profiles calculated with the use of forms of linear parameterizations currently being used in energy balance climate models with emitted LW radiation profiles derived from Nimbus 6 wide-field-of-view satellite data. An explicit comparison is made between differences in LW radiation profiles over water and over land surfaces for Northern Hemisphere winter. Results indicate that linear representations of emitted LW radiation over land and water surfaces which are primarily functions of surface temperature do not characterize the differences in the land and water profiles of the emitted LW radiation shown to exist in the Nimbus 6 ERB data. However, the incorporation of variable features of fractional cloud amount above these surfaces does improve the parameterizations when compared with the Nimbus 6 derived profiles of emitted LW radiation, but the magnitude and character of the land and water variation is still quite different than that shown to exist in the satellite data profiles.

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