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SENSIBLE AND LATENT HEATING OF THE ATMOSPHERE AS INFERRED FROM DST-6 DATA

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ABSTRACT

The average distribution of convective latent heating, boundary layer sensible heat flux, and vertical velocity are determined for the winter 1976 DST period from GLAS model diagnostics. Key features are the regions of intense latent heating over Brazil, Central Africa, and Indonesia; and the regions of strong sensible heating due to air mass modification over the North Atlantic and North Pacific Oceans.

1. INTRODUCTION

Radiative transfer, latent heat release, and sensible heating at the earth's surface are the principal sources of heating in the atmosphere. According to the zonally-averaged values of Newell et al. (1974), latent heating during the winter is a maximum in the mid-troposphere between 30N and 30S, with smaller maxima centered at 55N and 55S; radiation cools the troposphere everywhere except in the high latitudes of the Southern Hemisphere; and the transport of heat to the atmosphere from the underlying surface ("boundary layer fluxes") occurs everywhere outside of the polar regions, and is largest at 40° in the northern hemisphere, and 30° in the southern hemisphere. There have been numerous estimates of atmospheric radiative heating (cf. Hunt, 1977, for summary) but very little is known about the global distribution of either boundary layer heating or latent heating. Frequently boundary layer fluxes are deduced as a residual from the surface energy balance (e.g., Budyko, 1963), and average latent heating is estimated from precipitation measurements at the surface (e.g., Newell et al., loc cit).

We present here selected results from our diagnostic analysis of the winter 1976 Data Systems Test (DST) dataset which span the period 29 January to 4 March 1976. The analysis represents a synthesis of the comprehensive DST data with assimilation and forecast calculations carried out with the GLAS general circulation model. It will be demonstrated that GCM assimilations and forecasts for sufficiently short periods provide an internally consistent basis for estimating state variables in data sparse regions, and estimates of vertical fluxes and latent heat release-quantities that normally are impossible to measure in nature.

2. SUMMARY OF ANALYSIS

The GLAS assimilation without satellite data ("NOSAT-7578") formed the basic global dataset. At an interval of 6 h throughout the duration of the DST period, boundary layer fluxes, and convective heating and vertical velocity (ω) at each grid point in the vertical were computed and stored along with approximately 21 other diagnostic quantities that were routinely calculated during the model integration. Here boundary layer flux refers to the flux of sensible heat from the surface, which may have either fixed or variable temperature, into the bottom layer of the model as computed by an empirical surface drag law. Latent heating refers only to the latent heat release from the parameterization of moist convection; it does not include the latent heat released when supersaturation occurs as a result of non-convective processes. Vertical velocity is computed from model-generated state variables, and is fully consistent with the model's thermodynamic calculations.

Averages were constructed for the entire period 29 January to 4 March, excluding the period 3-6 February which was deleted because of missing data.

3. RESULTS AND DISCUSSION

Figure 1 illustrates the average distribution of convective latent heating at level 5 in the model. Virtually all heating occurs in a band between 20N and 20S, and the largest values are found over northeast Brazil, equatorial Africa, and over Indonesia, and the southwestern tropical Pacific. In an independent analysis of DST-6 wind data, Paegle et al. (unpublished manuscript) computed the mean upper level flow divergence, and areas of maximum divergence correlate very well with the regions of maximum latent heating computed here. This correlation between heating and divergence illustrates the strong coupling between the latent heating and large-scale dynamics of the tropics, and supports the hypothesis that the large-scale dynamics in the tropics are in fact forced by the latent heating that occurs over Brazil, Africa, and Indonesia. Evidently, the largest latent heating rates occur over land, where heating rates are 4-6°C per day, as compared with 1-3°C per day over oceanic regions.

The average boundary layer flux of sensible heat (watts per square meter) is illustrated in Figure 2. The largest fluxes over land occur over southern South America, South and Central Africa, India, and Australia. Still larger fluxes of sensible heat (in excess of 150 $\mathrm{Wm^{-2}}$) occur in the North Atlantic between Newfoundland and Iceland. Values in excess of 50 $\mathrm{Wm^{-2}}$ occur in the Barents Sea, the Sea of Okhotsk, and in the North Pacific

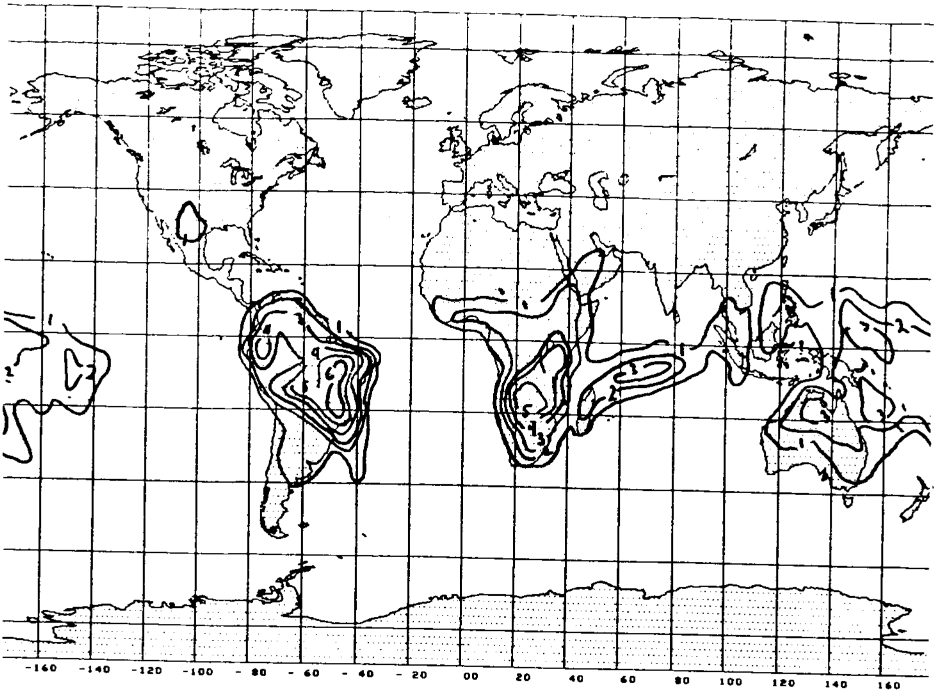

Fig. 1. Convective Latent Heating (^{0}C Day^{-1}).

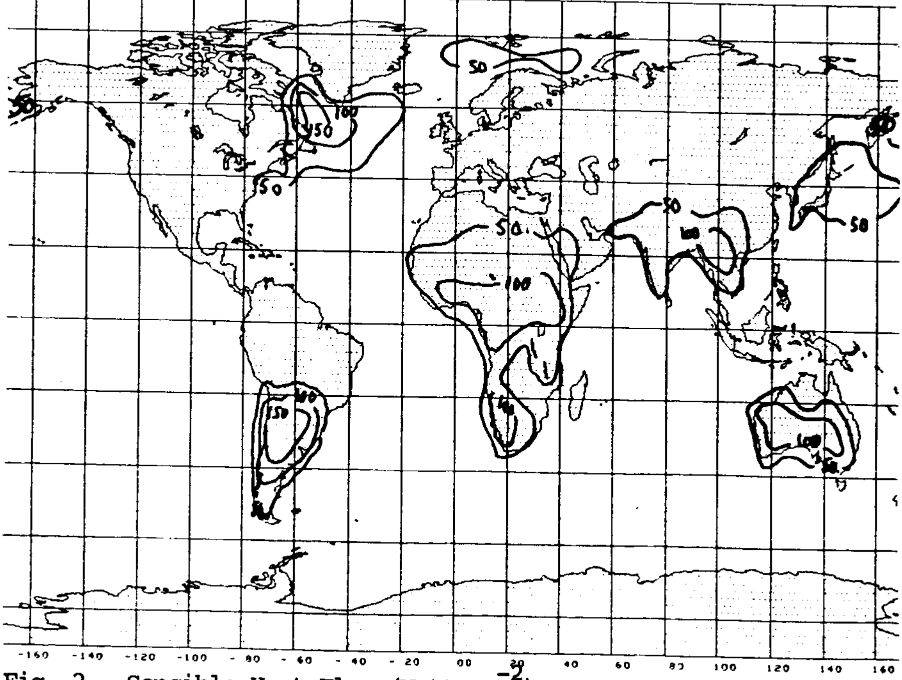

Fig. 2. Sensible Heat Flux (Watts m^{-2}).

between Siberia and the Aleutian Islands. These large fluxes in the high latitudes of the North Atlantic and North Pacific occur as a result of the strong and frequent air mass modification that occurs in these regions. During the winter cold Arctic air masses stream off the Canadian, Greenland, and Siberian continents over the relatively warmer waters of the Gulf Stream or Kuroshio. The large air sea temperature difference causes extensive convective heating in the lower layers of the air masses. (The simultaneous adjustment of ocean surface temperature is not calculated in the model at the present time.)

It has been recently demonstrated (Herman and Johnson, 1978) that the sea ice content of these same regions of the North Atlantic and North Pacific plays a key role in the wintertime climate of the northern hemisphere through its effect on sensible and latent heat fluxes. Sea ice extent and air mass modification obviously combine in a complicated way to determine the net diabatic heating in the high latitudes.

The average vertical velocity field at level 5 of the model (in microbars per second) is shown in Figure 3. The global field is, of course, very complicated. It is worth noting, however,

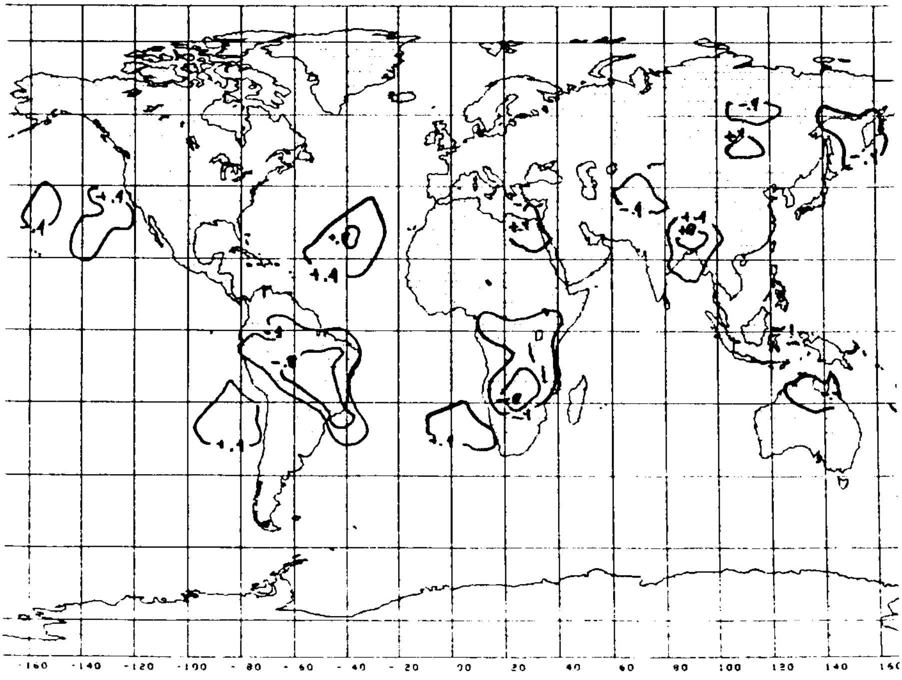

Fig. 3. Vertical Velocity (microbars sec^{-1}).

the strong and well defined regions of rising motion (ω negative) that occur in conjunction with the convective activity over Brazil and Africa; rising motion associated with air mass modification is found over the Sea of Okhotsk, and the regions of strong subsidence over the subtropical Atlantic and Pacific are also evident.

4. ACKNOWLEDGMENTS

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