# 3 Climatology of the Model

Several standard integrations of the model are performed. They include integrations with two different horizontal resolutions, namely T21 (triangular truncation up to wavenumber 21, $\sim$ 600km transform grid) and T42 (triangular 42, $\sim$ 300km transform grid), and integrations with two different vertical resolutions, 11 layers and 20 layers. The also include integrations with climatological SST, integrations with 10-year observed SST based on AMIP datasets. In the followings, the results of a 26-year integration with climatological SST in T21 11 layer resolution are described as an example. 26-year average value of DJF (December-January-February) and JJA (June-July-August) are shown.

The zonally averaged temperature and its deviation from climatology of objective analysis data (JMA-GANAL) are shown in Fig.1 and Fig.2 for DJF and JJA, respectively. The deviation is generally within ±2.5K in the troposphere except for a cold bias in the southern hemisphere midlatitude. There is a rather large cold bias in the stratosphere, especially in the summer-hemisphere high-latitude region.

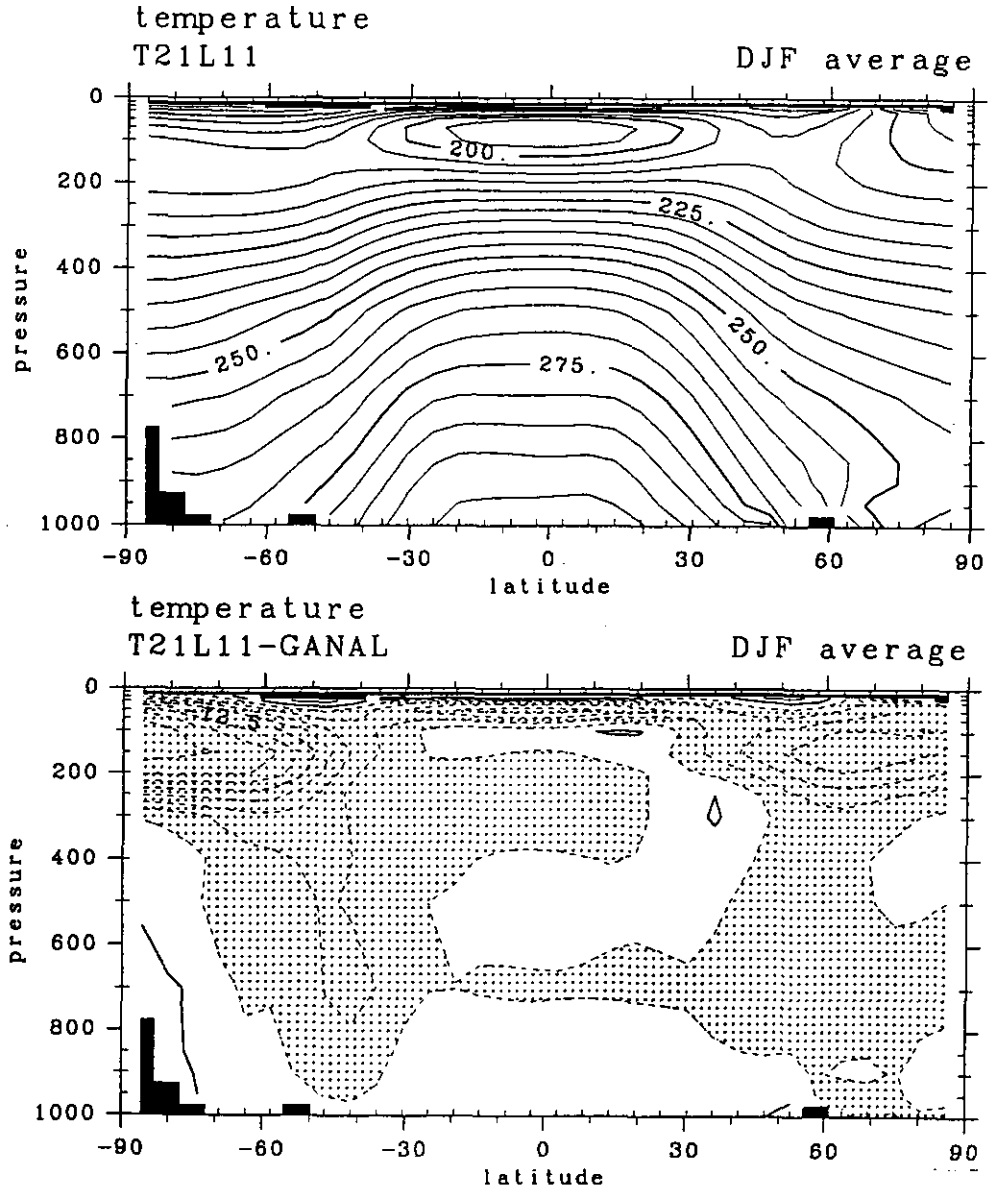


Figure 1: Zonally averaged temperature in DJF. Upper: model result. Contour interval is 5K. Lower: deviation from GANAL climatology. Contour interval is 2.5K. Areas of less than -2.5K are shaded.

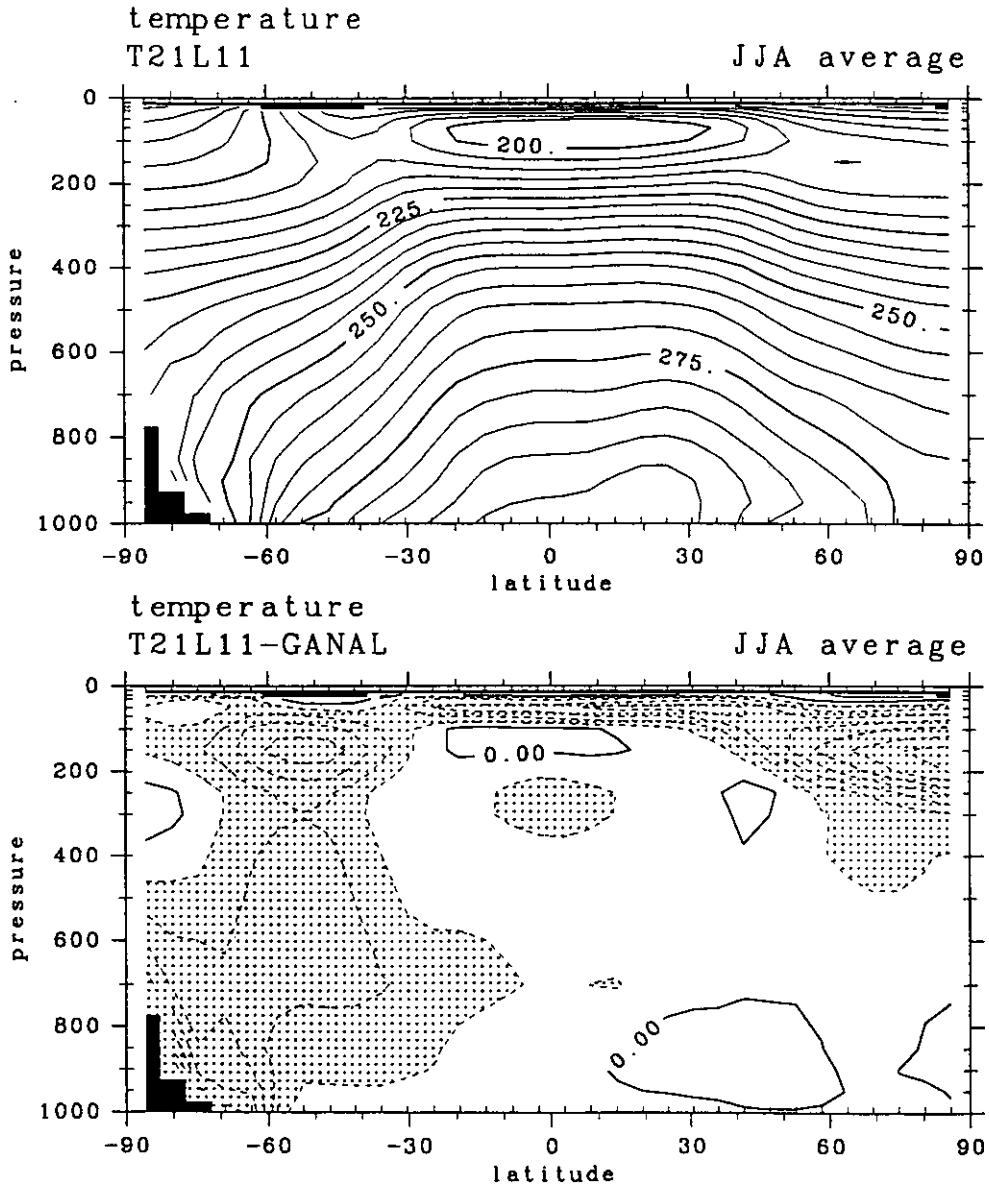


Figure 2: Zonally averaged temperature in JJA. Upper: model result. Contour interval is 10K. Lower: deviation from GANAL climatology. Contour interval is 2.5K. Areas of less than -2.5K are shaded.

The zonally averaged zonal wind and corresponding observed climatology are shown in Figs.3 and 4. The overall distribution is realistic, but the width of the jet is generally narrower in the model. Further, the center of the souther hemisphere jet is rather equatorward in DJF and the splitting of the subtropical jet and polar jet is weak in southern hemisphere in JJA. The easterly wind in the summer hemispheric stratosphere is rather weak.

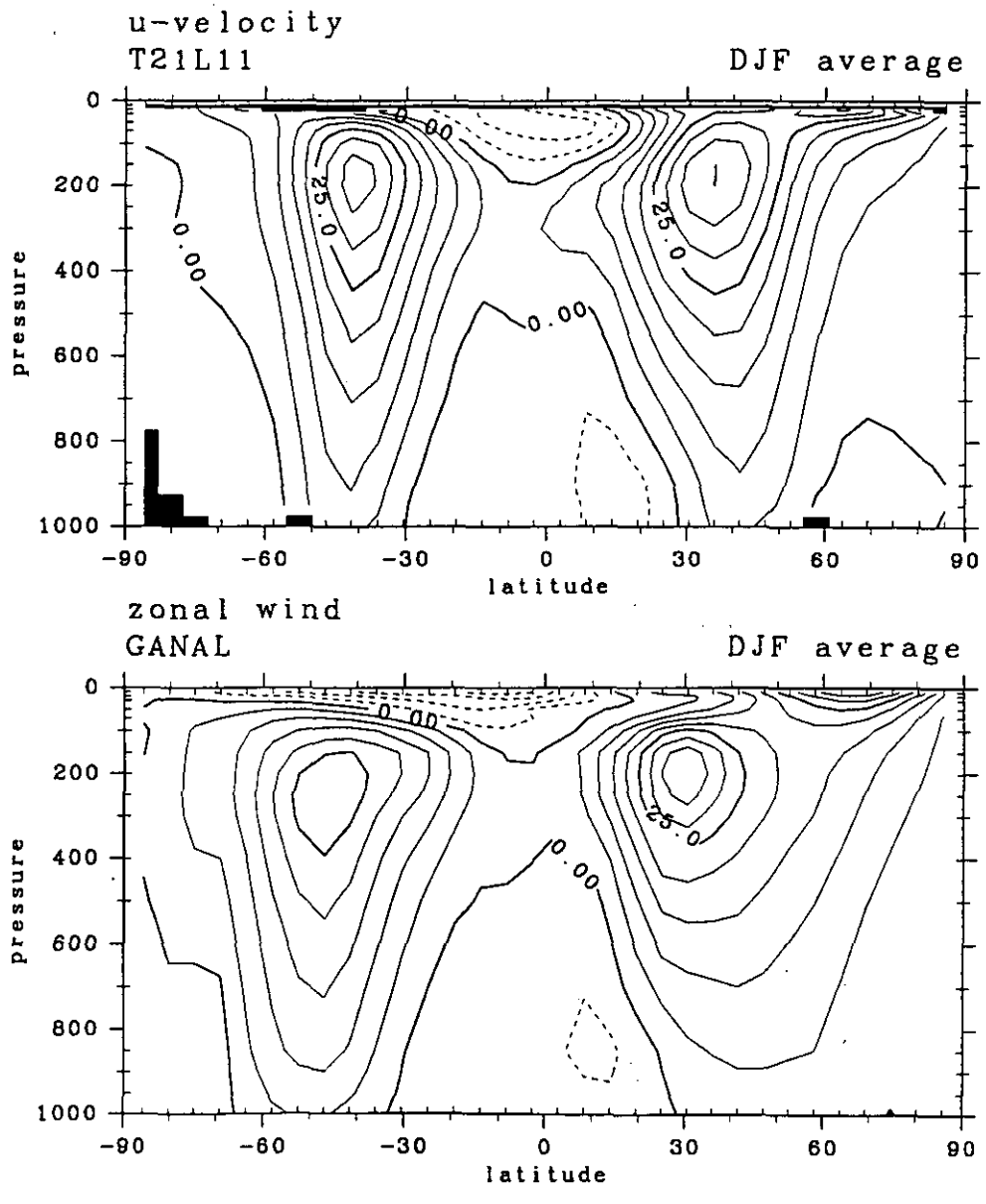


Figure 3: Zonally averaged zonal wind in DJF. Upper: model result. Lower: GANAL climatology. Contour intervals are 10m/s.

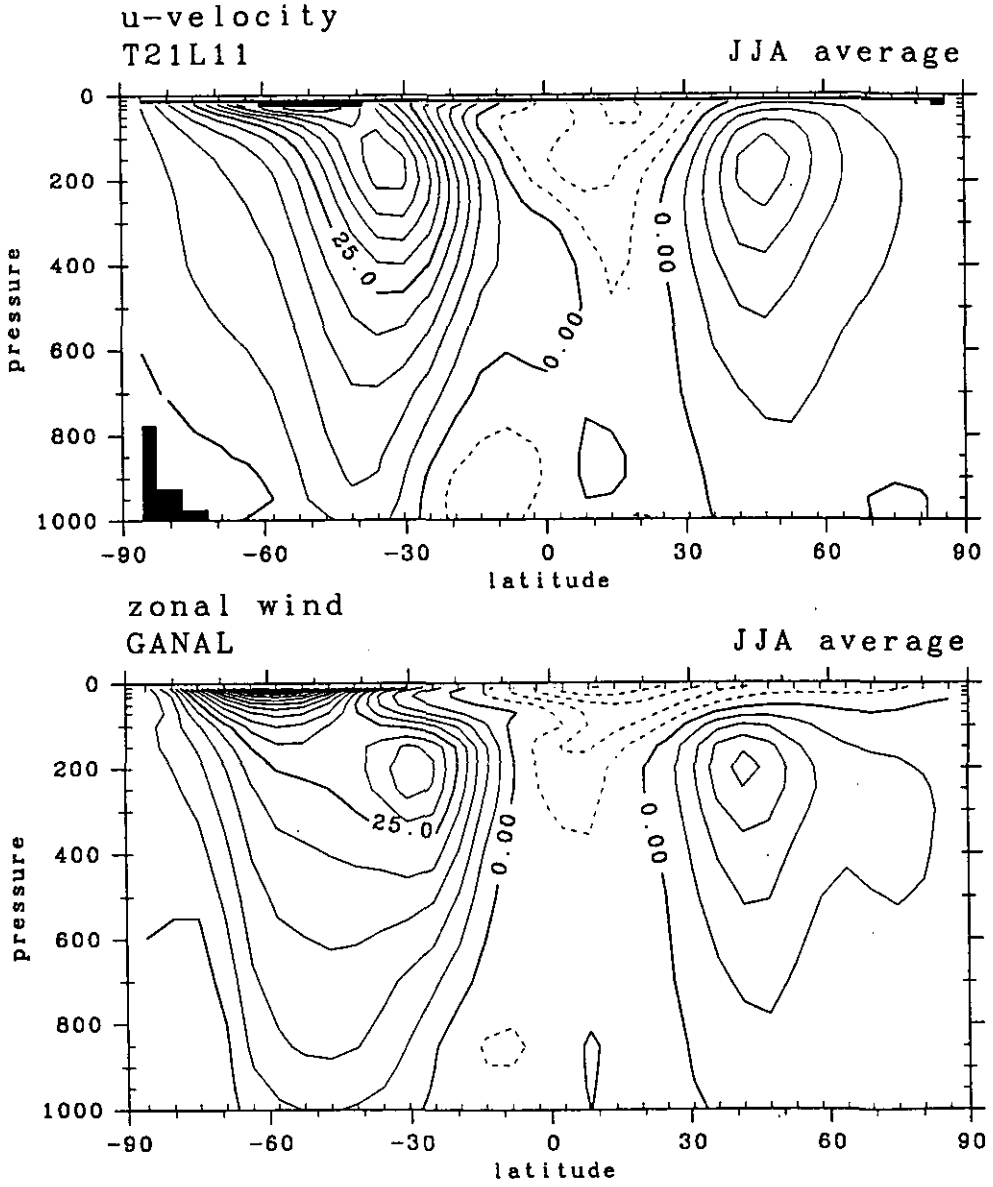


Figure 4: Zonally averaged zonal wind in JJA. Upper: model result. Lower: GANAL climatology. Contour intervals are 10m/s.

The relative humidity is generally lower than the GANAL climatology in the low-latitude lower troposphere and rather high in the baroclinic zone (Figs.5 and 6). Among others, dryness of the lower troposphere in the summer hemispheric subtropics is one of the most severe weakness of the model. The tropical upper tropospheric air is rather moist, which is created by the detrainment of the cumulus cloud.

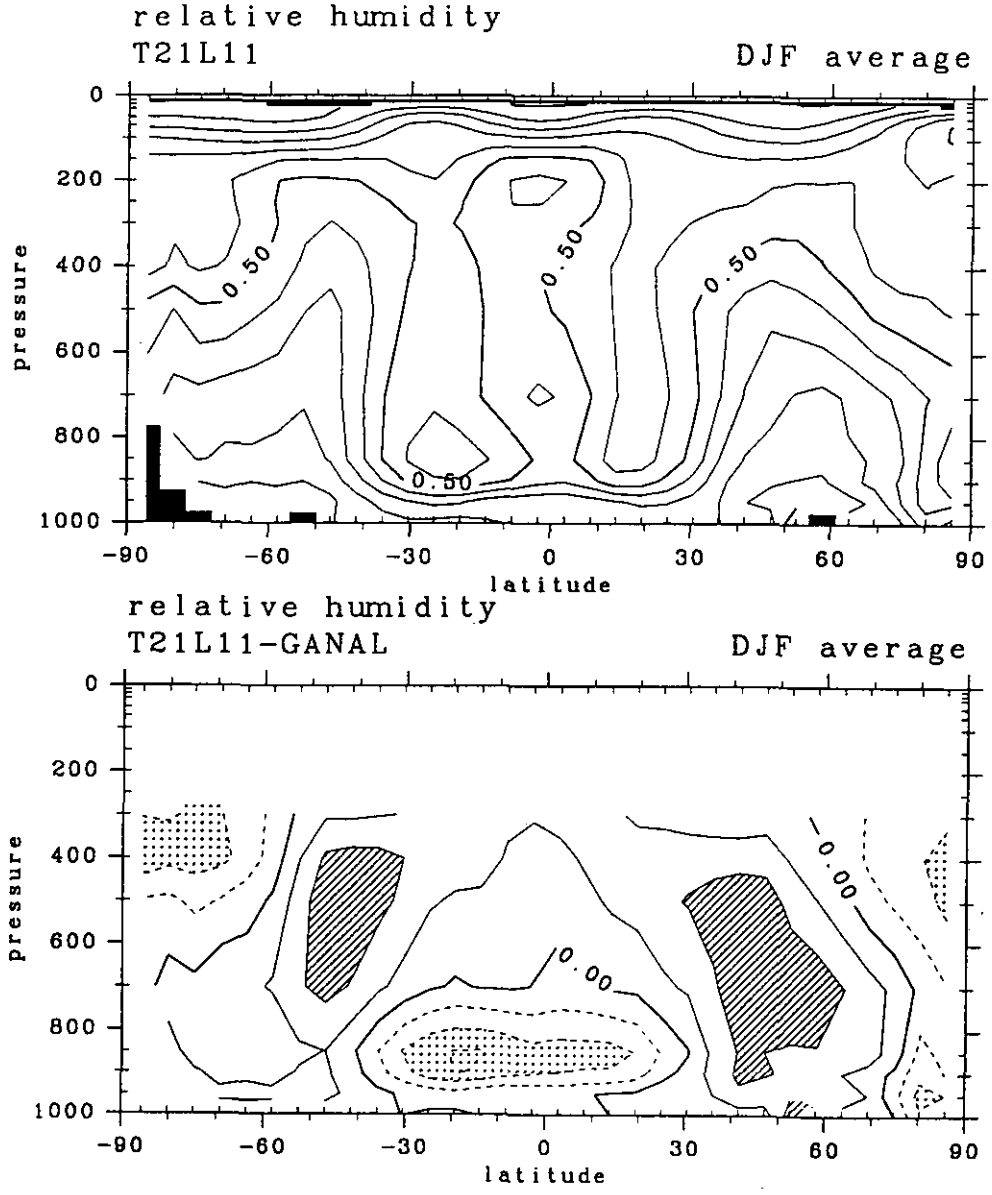


Figure 5: Zonally averaged relative humidity in DJF. Upper: model result. Lower: deviation from GANAL climatology. Contour intervals are 0.1. Areas of less than -0.2 are shaded.

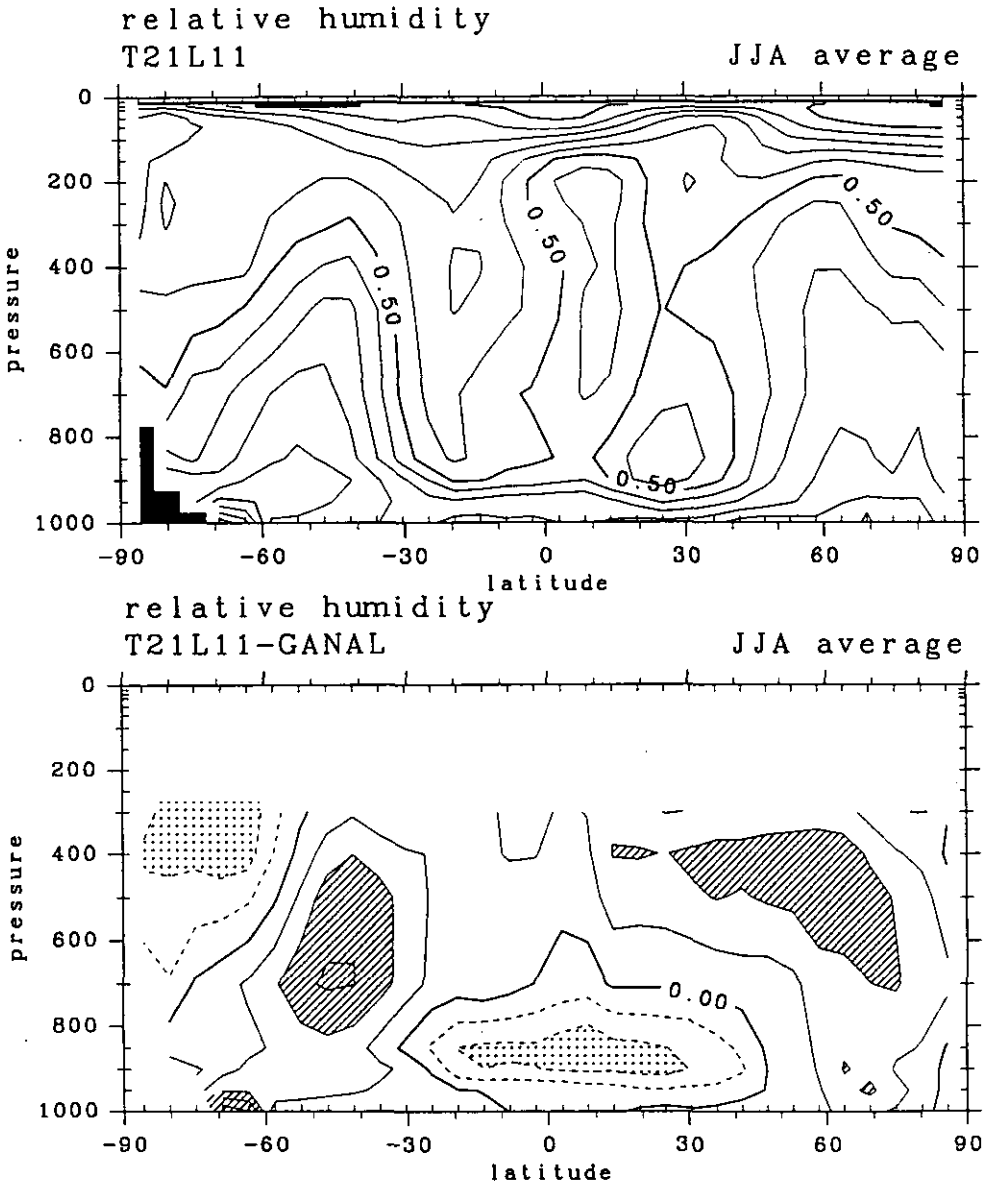


Figure 6: Zonally averaged relative humidity in JJA. Upper: model result. Lower: deviation from GANAL climatology. Contour intervals are 0.1. Areas of less than -0.2 are shaded.

The precipitation (Figs.7 and 8) reproduce the climatology rather well. However, there are several regions of insufficient precipitation, eastern Pacific ITCZ, SPCZ, the northern-hemispheric storm track in JJA, equatorial Africa in JJA, and the maritime continent in JJA. In these latter two regions, the land surface and the atmospheric boundary layer is too dry. It is considered that there are some problems in the feedback between the land-surface wetness and the cumulus convection.

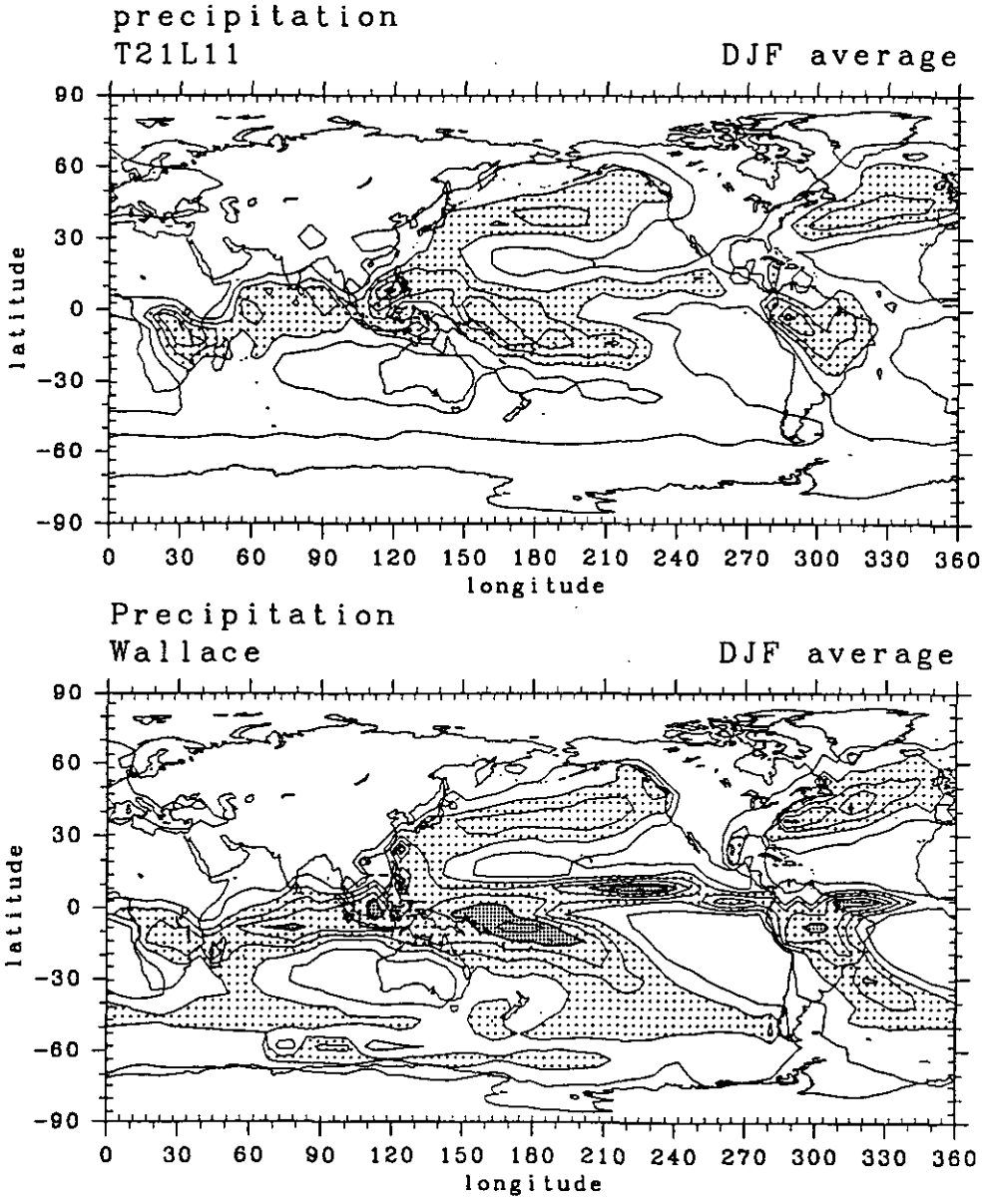


Figure 7: Precipitation in DJF. Upper: model result. Lower: Wallace-Legates climatology. Contour intervals are 60mm/month. Areas of larger than 120mm/month are shaded and areas of larger than 300mm/month are heavily shaded

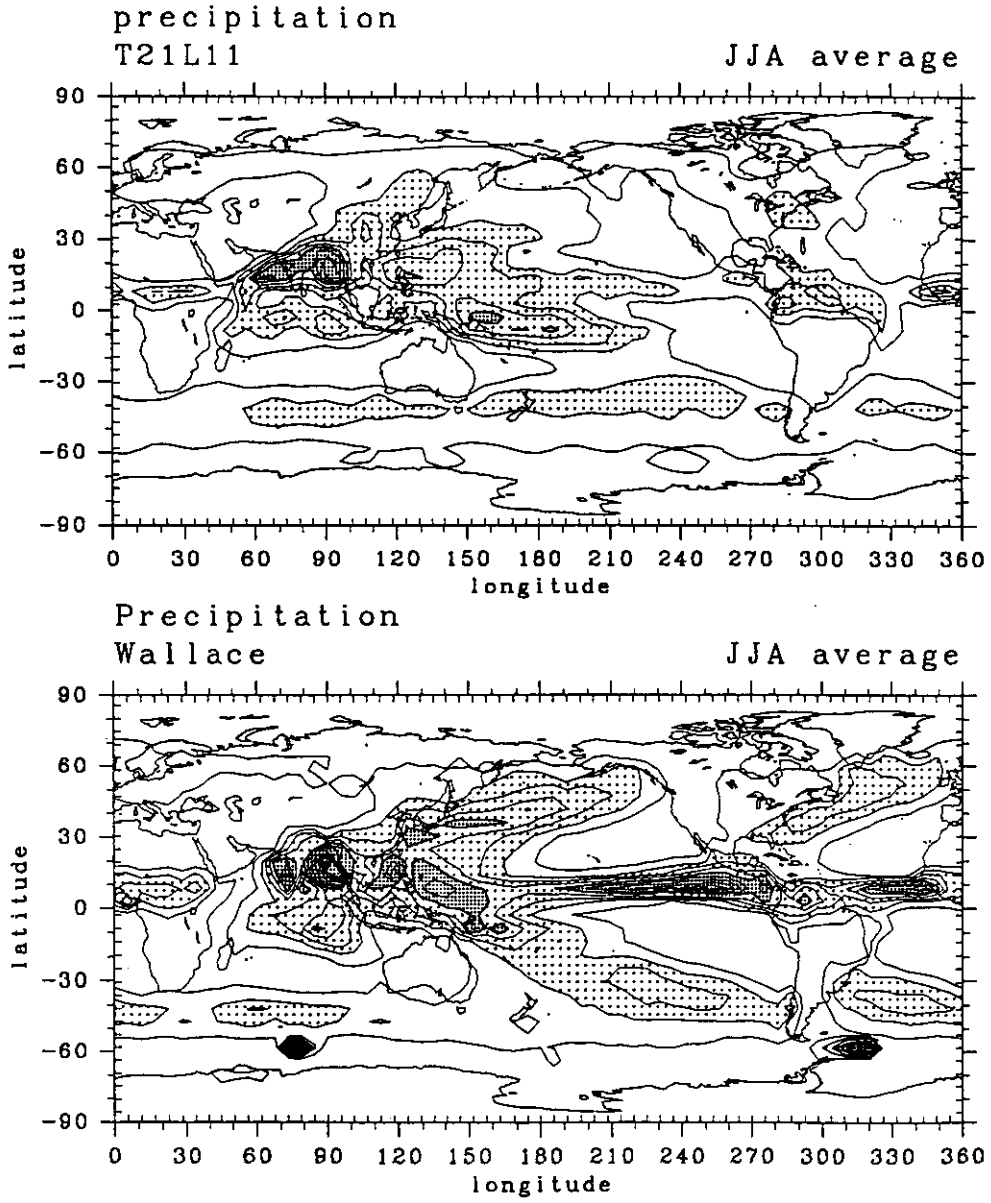


Figure 8: Precipitation in JJA. Upper: model result. Lower: Wallace-Legates climatology. Contour intervals are 60mm/month. Areas of larger than 120mm/month are shaded and areas of larger than 300mm/month are heavily shaded

The deviation of the surface air temperature from climatology is generally within ± 6 degrees (Fig.9). There are high temperature bias in the summer hemispheric subtropical continents, suggesting too dry land surface there. The deviation in the winter high latitude is rather large and generally have negative sign (cold bias).

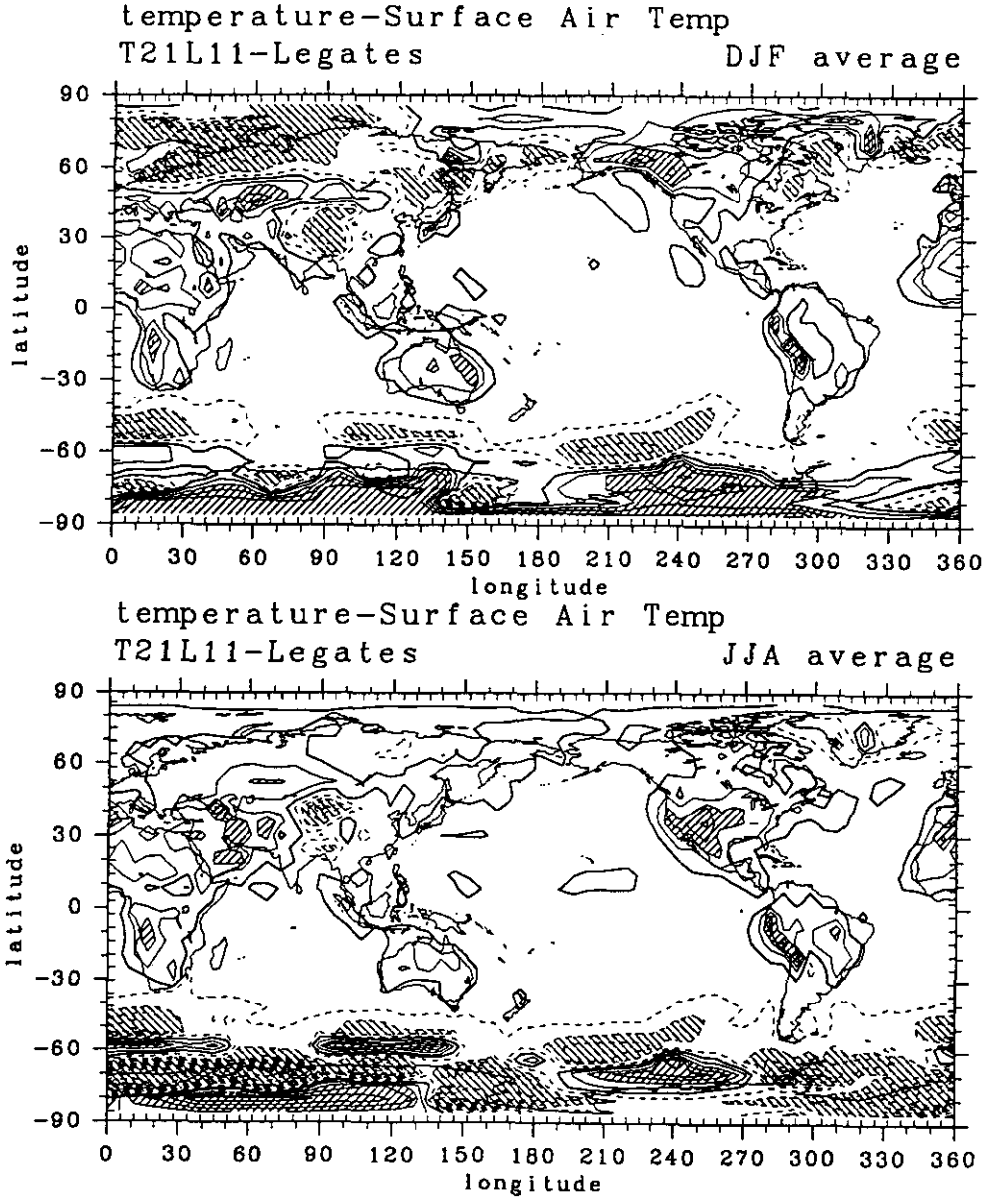


Figure 9: Deviation of surface air temperature from Legates climatology. Upper: DJF. Lower: JJA. Contour intervals are 3K. Areas of larger than 6K deviation are shaded.

The snow amount on the surface is shown in (Fig.10). The seasonal cycle of the snow cover is well simulated. The large snow amount in the eastern Europe may be related with the low temperature bias there.

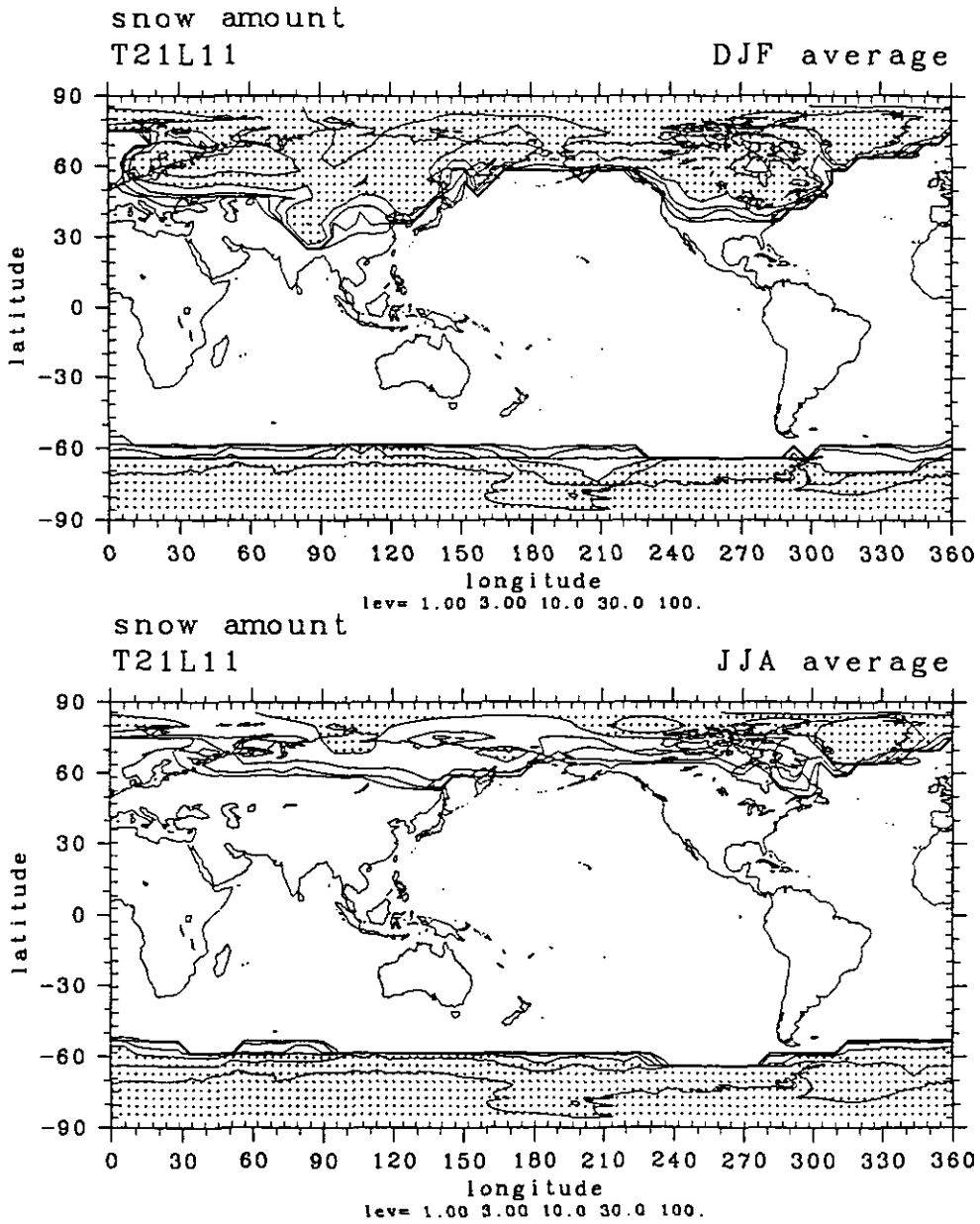


Figure 10: Snow amount. Upper: DJF. Lower: JJA. Contour levels are 1,3,10,30,100 kg/m$^2$. Areas of larger than 30kg/m$^2$ are shaded.

The zonally averaged radiative fluxes are shown in Fig.11. The longwave and shortwave fluxes have good correspondences to the observed values, except for the summer high-latitude where the net downward shortwave fluxes are rather smaller compared from the observed climatology.

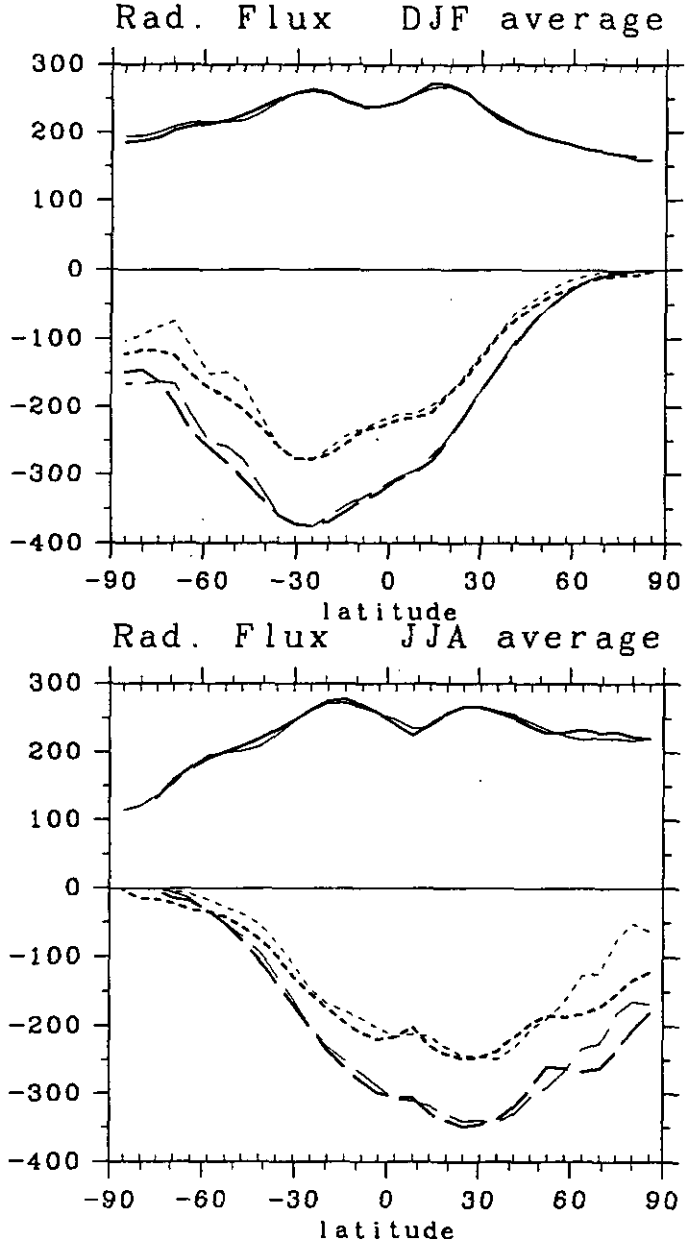


Figure 11: Zonal averaged radiative fluxes at top of atmosphere and surface. Solid line: longwave at top (OLR), broken line: shortwave at top, dotted line: shortwave at surface. Thick lines are observation (ERBE,ISCCP)and thin lines are model results. Upper: DJF. Lower: JJA. Unit is W/m$^2$.

The cloud radiative forcing, which is the difference of cloudy and clear sky radiative flux at the top of the atmosphere is shown in Fig.12. The shortwave forcing in the subtropical region is rather too strong. In DJF, the location of the maximum shortwave forcing is rather equatorward of that of observed maximum, reflecting the equatorward shift of the baroclinic zone (Figs.1 and 3).

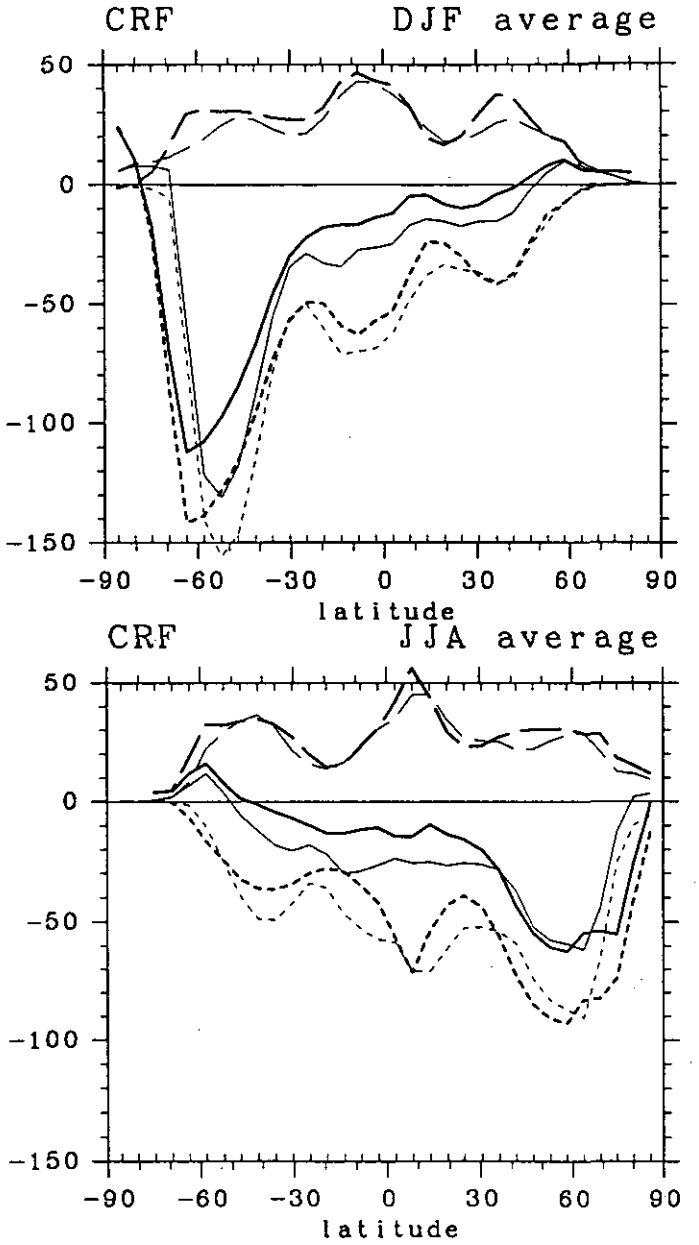


Figure 12: Zonal averaged cloud radiative forcing. Solid line: net forcing, broken line: longwave forcing, dotted line: shortwave forcing. Thick lines are observation (ERBE) and thin lines are model results. Upper: DJF. Lower: JJA. Unit is W/m$^2$.

The horizontal distributions of the longwave radiative fluxes (outgoing longwave radiation; OLR) are shown in Figs.13 and 14. The field in DJF is very realistic. In JJA, however, there is a region of too small OLR in the western Pacific subtropics.

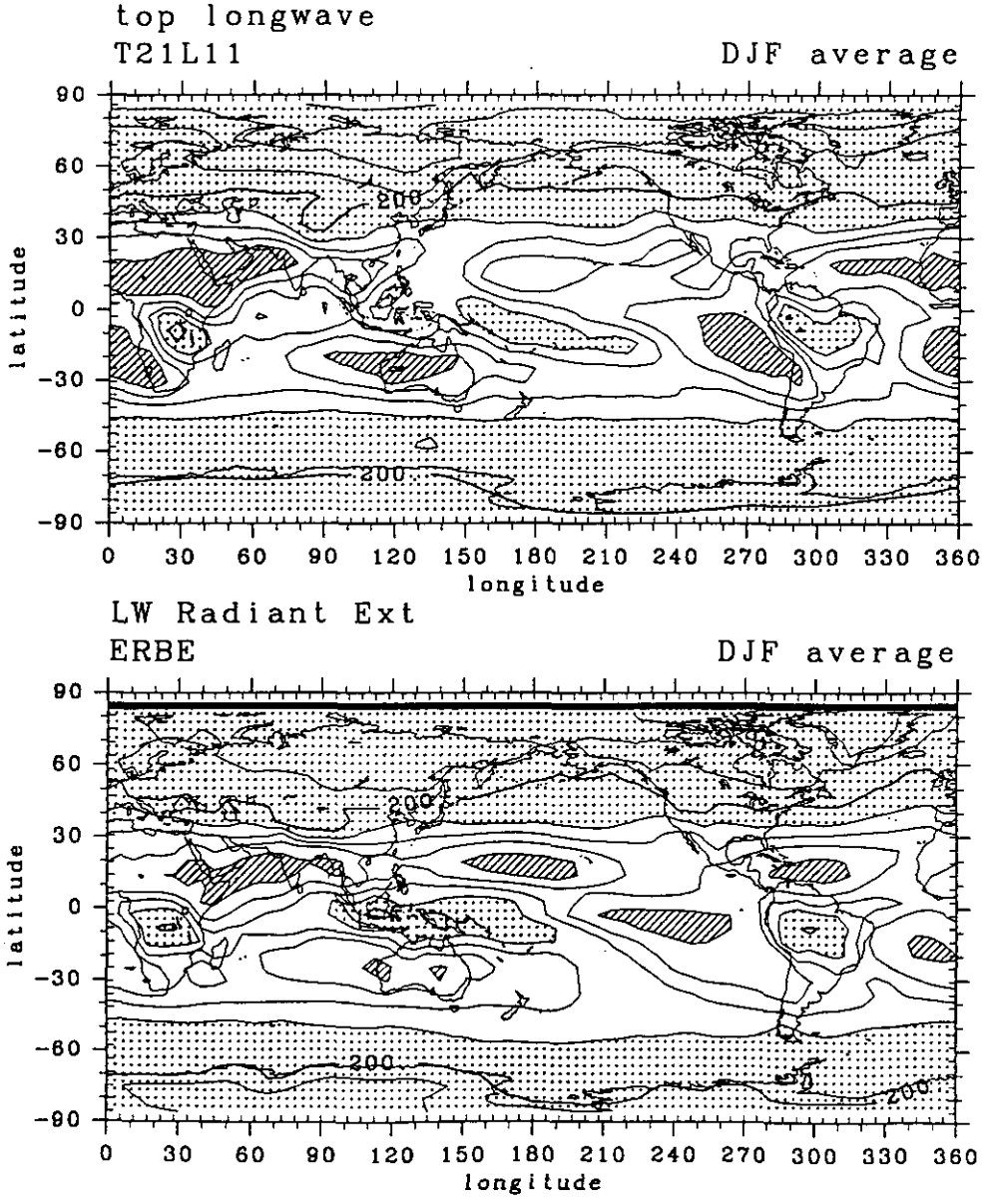


Figure 13: Outgoing longwave radiation (OLR) in DJF. Upper: model result. Lower: ERBE climatology. Contour intervals are 20W/m$^2$. Areas of less than 220W/m$^2$ are stippled and areas of larger than 280W/m$^2$ are shaded.

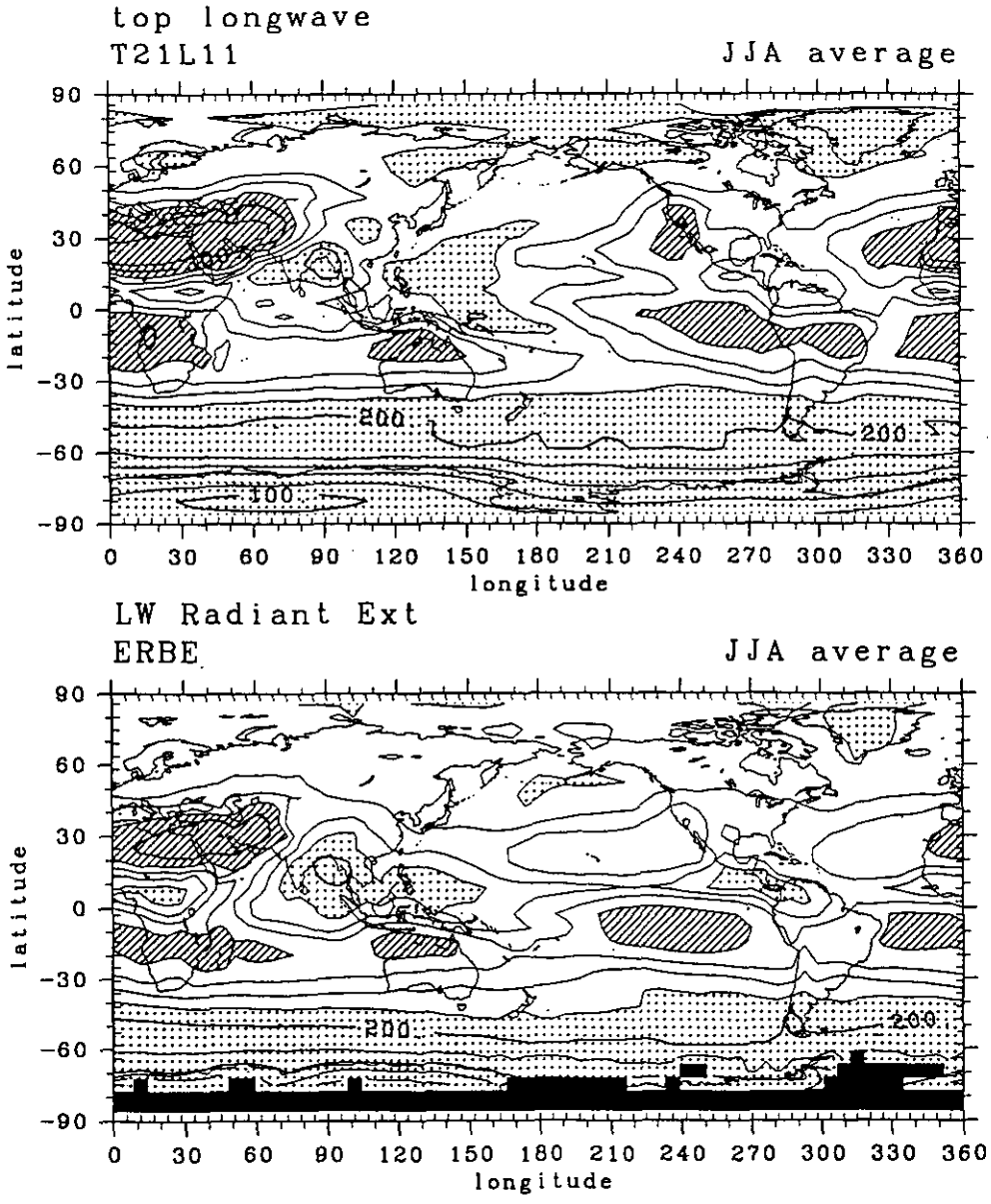


Figure 14: Outgoing longwave radiation (OLR) in JJA. Upper: model result. Lower: ERBE climatology. Contour intervals are 20W/m$^2$. Areas of less than 220W/m$^2$ are stippled and areas of larger than 280W/m$^2$ are shaded.

The horizontal distributions of the shortwave radiative forcing are shown in Figs.15 and 16. A significant overestimate appears in the subtropical western Pacific in JJA. Regions of unrealistic minimum forcing (stippled) exist along the west coasts of South America in DJF and North America in JJA.

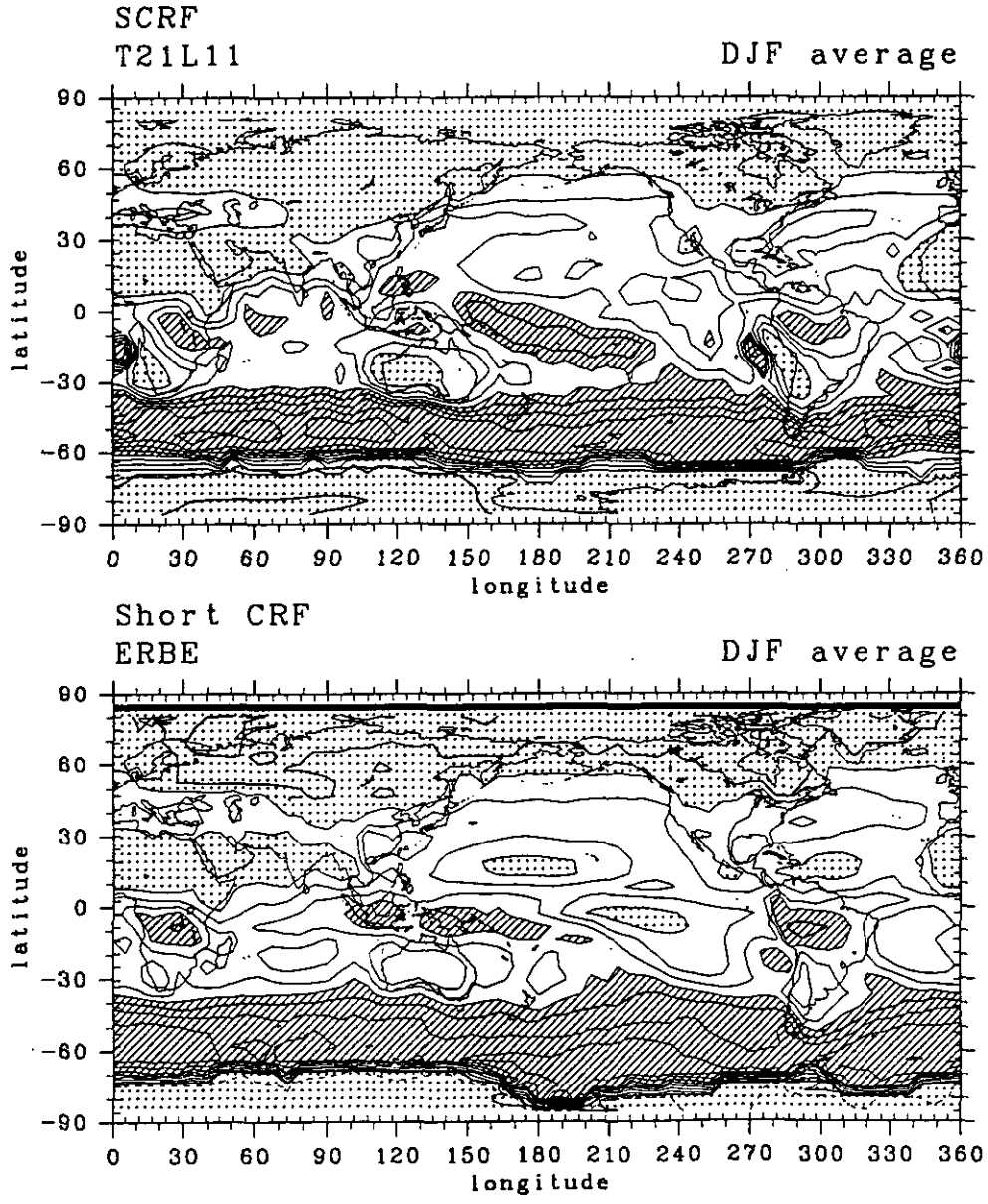


Figure 15: Shortwave radiative forcing in DJF. Upper: model result. Lower: ERBE climatology. Contour intervals are 20W/m$^2$. Areas of less than -80W/m$^2$ are shaded and areas of larger than -20W/m$^2$ are stippled.

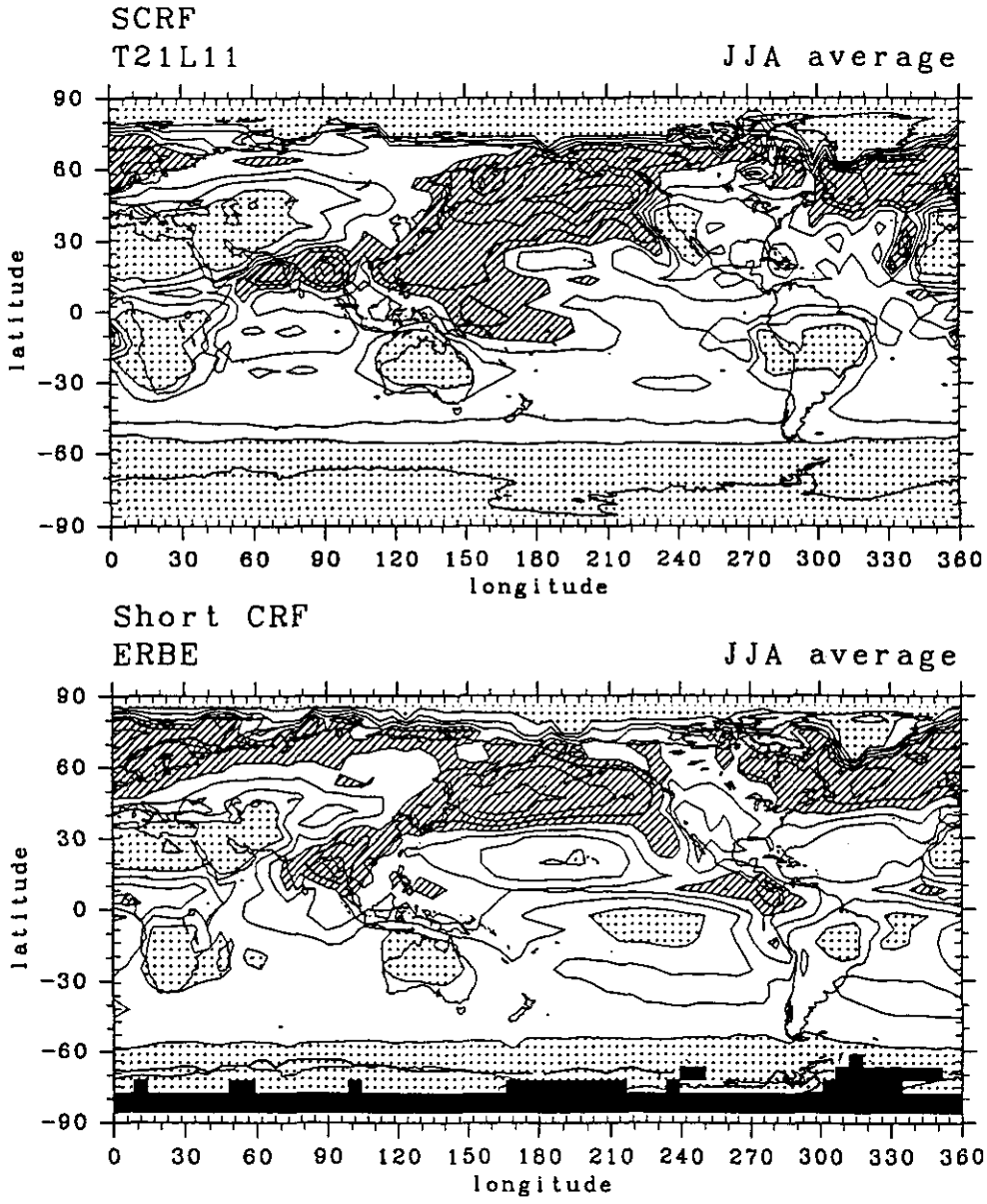


Figure 16: Shortwave radiative forcing in DJF. Upper: model result. Lower: ERBE climatology. Contour intervals are 20W/m$^2$. Areas of less than -80W/m$^2$ are shaded and areas of larger than -20W/m$^2$ are stippled.

The high level cloudiness is found to be excessive, especially in the region of too small OLR in the western Pacific subtropics (Fig.17). The low-level cloudiness field (Fig.18) is rather too small compared from the observed climatology and the high cloudiness over the subtropical ocean just west of the continents are reproduced but in a reduced magnitude.

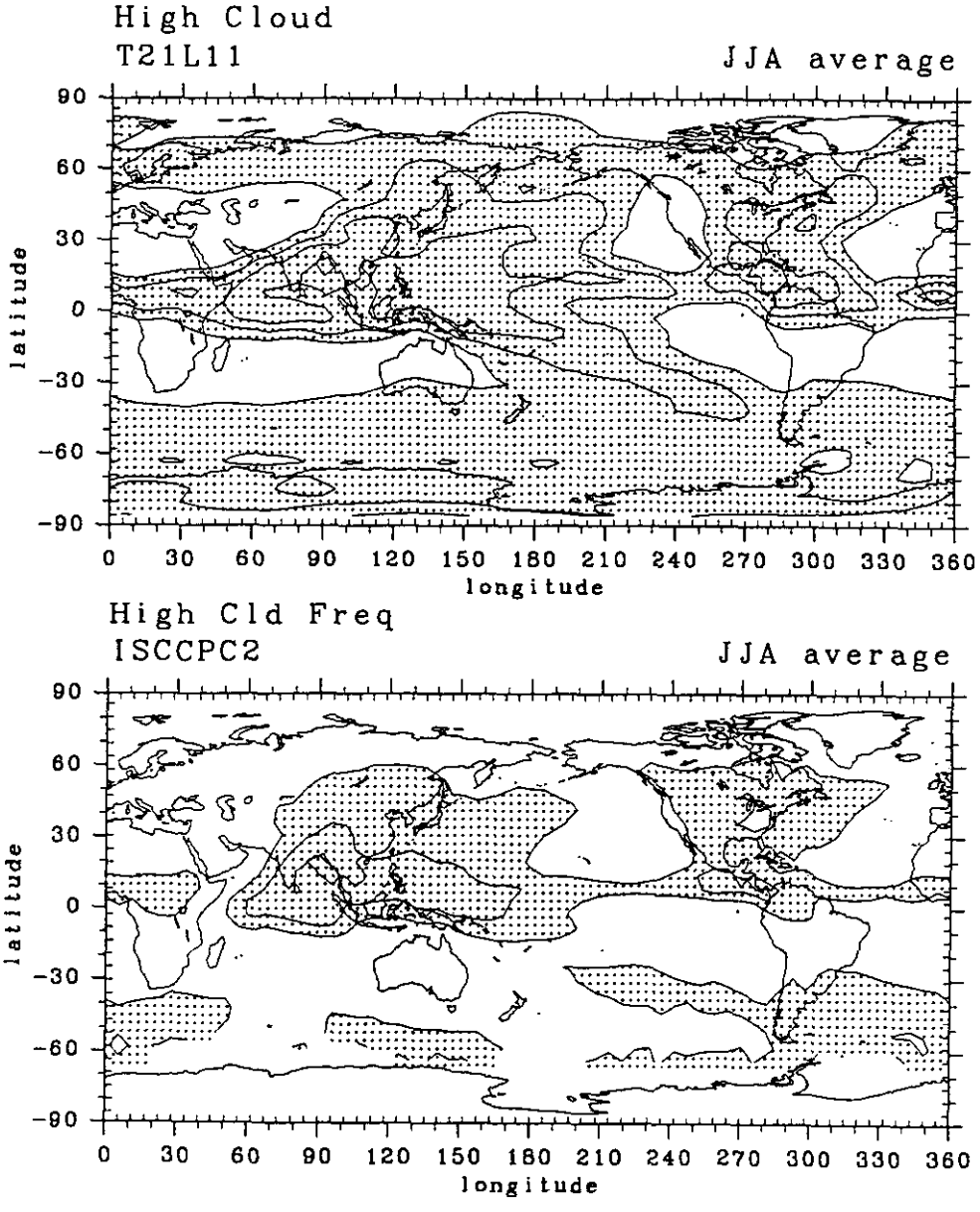


Figure 17: High cloud amount in JJA. Upper: model result. Lower: ISCCP climatology. Contour intervals are 0.2. Areas of larger than 0.2 are shaded.

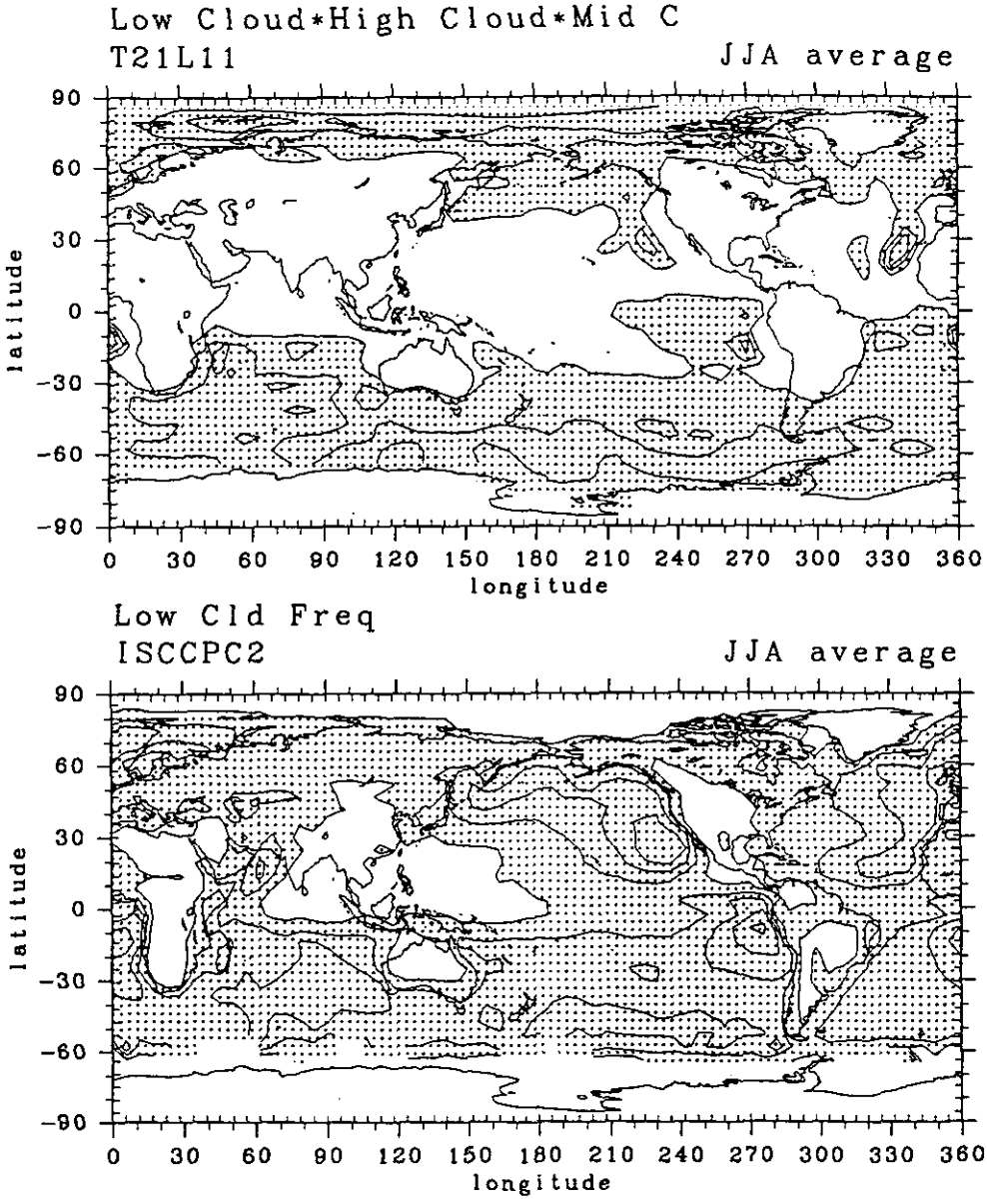


Figure 18: Low cloud amount in JJA. Upper: model result. Lower: ISCCP climatology. Contour intervals are 0.15. Areas of larger than 0.15 are shaded.