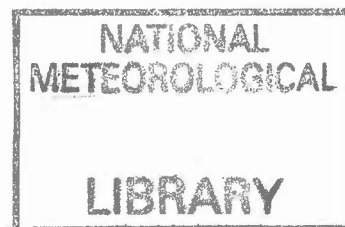


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**ANNUAL MEAN UKMO NWP SURFACE FLUXES FOR 1995 AND 1994
COMPARED WITH DA SILVA CLIMATOLOGICAL FLUXES.**

by

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Annual Mean UKMO NWP Surface Fluxes for 1995 and 1994 compared with da Silva Climatological Fluxes.

1. INTRODUCTION

Ocean circulation is driven by the fluxes of heat, fresh water and momentum through the ocean surface. Therefore accurate data sets of surface fluxes are needed to successfully model the oceans. FOAM, the Forecasting Ocean Atmosphere Model (Foreman, 1992) is one such model that requires information on surface fluxes to provide detailed forecasts of the ocean.

Surface fluxes are calculated by Numerical Weather Prediction (NWP) models as part of their forecast process. These fluxes are archived and then used by ocean modellers. Previous work, (Foreman *et al*, 1994), has shown that monitoring the surface fluxes over the years can help to identify errors in the NWP models.

Earlier work, Jones (1995), made comparisons between the UKMO NWP (U.K. Met. Office NWP Suite) surface fluxes for 1993 and 1994. The main conclusion drawn from this work is that the UKMO NWP fluxes differed from the climatologies used. Also, changes made to the NWP model during the study period modified the fluxes between the years. A subsequent study (Foreman and Jones, 1996) commented on marked differences in the northward heat transport calculated from the NWP heat fluxes for 1993, 1994 and 1995. These studies will be followed up and discussed in this work.

Jones (1995), used heat fluxes from Oberhuber (1988) and wind stresses from Hellerman and Rosenstein (1983) (H&R) for comparison with the NWP surface fluxes. In this study the da Silva *et al*, (1994) climatology is used. This data set is derived from individual observations between January 1945 and December 1989 in the Comprehensive Ocean - Atmosphere Data Set (COADS). Corrections were made to reduce wind speed bias associated with a more recent Beaufort equivalent scale, to quality control night time fractional cloud cover observations according to the brightness of the sky, and to correct certain present weather observations which were recorded as missing when there was actually clear weather.

This report compares the heat and momentum fluxes from the UKMO NWP Suite for 1995 with the fluxes from 1994 to establish the accuracy of the fluxes that go into FOAM. It is intended to build on the work done by Foreman and Jones (1996) which compared the heat fluxes for the same years. In particular the momentum fluxes, the total heat flux and the implied heat transport are studied and reasons for differences in the fluxes between the years are discussed. The accuracy of the fluxes is determined by comparing them with the da Silva climatological fluxes (da Silva *et al*, 1994). The reliability of this climatology is also addressed.

The paper is divided up into five sections, the first being the introduction. The second section of this paper explains the origin of the fluxes and indicates how they are calculated. This is followed by a look at the change in the wind stress magnitude between the years. The fourth section examines the differences in the total heat flux between 1994 and 1995 which is made up of the individual heat flux components. Influences on these fluxes resulting from NWP model changes is considered. The variation in the implied heat transport between the two

years is discussed in section 5. Finally the main conclusions are summarised.

2. NWP SURFACE FLUXES

To obtain a forecast from an NWP model several stages have to be undertaken. Firstly the observations from around the world are collected off the GTS (Global Telecommunications System) and checked for inconsistencies. The next stage is the analysis, during which the observations are assimilated into the model by merging them with the fields produced by the forecast model. Then a forecast is made by the NWP model. The surface fluxes are calculated as part of the "physics" component of the model, which represents the small scale processes and external factors such as radiation in the model. Further detail on the stages involved in calculating the surface fluxes is given by Foreman *et al* (1994).

Surface fluxes are archived by the UKMO NWP suite. In the global model used for this study, fluxes are output as 6h averages (or accumulations), allowing the full diurnal cycle to be captured. This study uses fluxes from the first 12h of each forecast to avoid physical inconsistencies that might arise as a result of data insertion during the analysis stage. The fluxes examined are the annual mean solar radiation, long wave radiation, latent heat flux, sensible heat flux and both components of the wind stress. From these the annual mean total heat flux, the northward heat transport and the wind stress magnitude are calculated.

NWP models undergo a process of continual improvement. It is therefore difficult to distinguish between inter-annual variability in the real atmosphere and variability that results from changes in the model. This is one reason for the 're-analysis' projects at NCEP and ECMWF (Gentson & Braun, 1995). In particular two major changes were introduced in the UKMO model in 1995. Firstly the modifications to gravity wave drag and introduction of orographic roughness in January 1995, (Milton *et al*, 1995) and secondly the decision in June 1995 to switch off horizontal diffusion over steep orography (Wilson *et al*, 1995). The latter change was seen to improve the forecast of marine stratus and stratocumulus decks and was expected to affect the heat fluxes.

Problems in assessing surface fluxes can also arise if there are areas of missing data in the original observations or there are significant operational problems when the fluxes are being archived. Neither was a problem in the two years 1995 and 1994.

3. WIND STRESS MAGNITUDE

3.1 ZONAL MEAN.

Zonal averages of the annual mean wind stress magnitude for the UKMO NWP 1995, 1994 and the da Silva climatology wind stresses are shown in fig. 1. The NWP wind stress magnitude in 1995 and in 1994 follows a similar pattern in the southern hemisphere with 1995 being marginally stronger. In the northern hemisphere there is a larger difference, especially in the region 30N-60N, between the two years. Northern mid latitude variation in the wind stress magnitude is thought to be due to different synoptic weather patterns between the years. This is supported in fig. 2 which shows the zonal average of the annual mean sea level pressure for 1994 and 1995. Here the gradient of these fields give an indication of the

wind speed in this area. It can be easily seen that there is a stronger meridional gradient in 1994. This is consistent with the wind stress being stronger by approximately 0.03 N m^{-2} in this region in 1994 compared to 1995. The important differences in the wind stress magnitude result mainly from changes in the zonal component of wind stress (fig. 3) rather than the meridional component (fig. 4). The changing synoptic situation can be seen again in fig. 3.

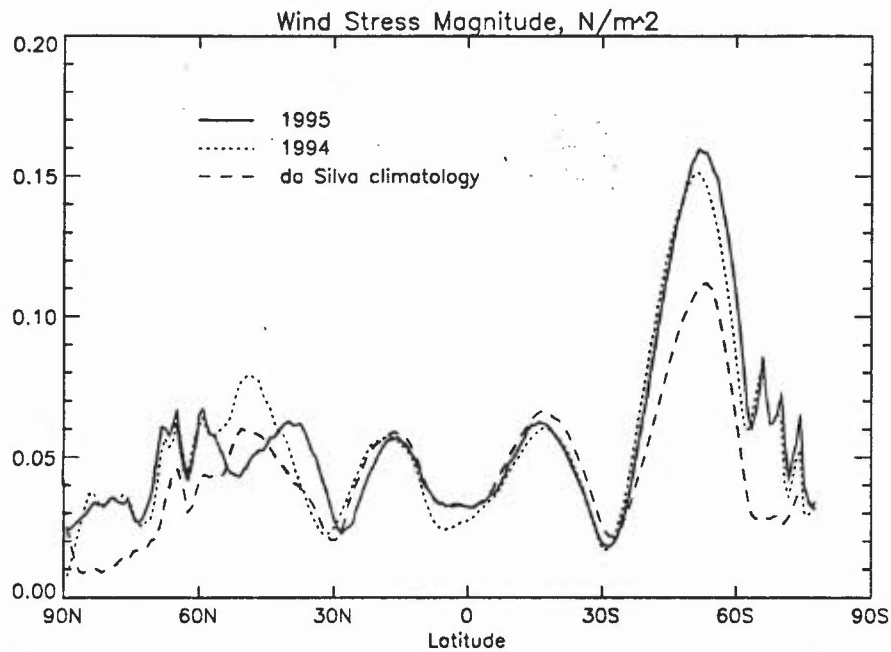


Figure 1. Zonal average of the annual mean wind stress magnitude for 1994, 1995 and da Silva climatology.

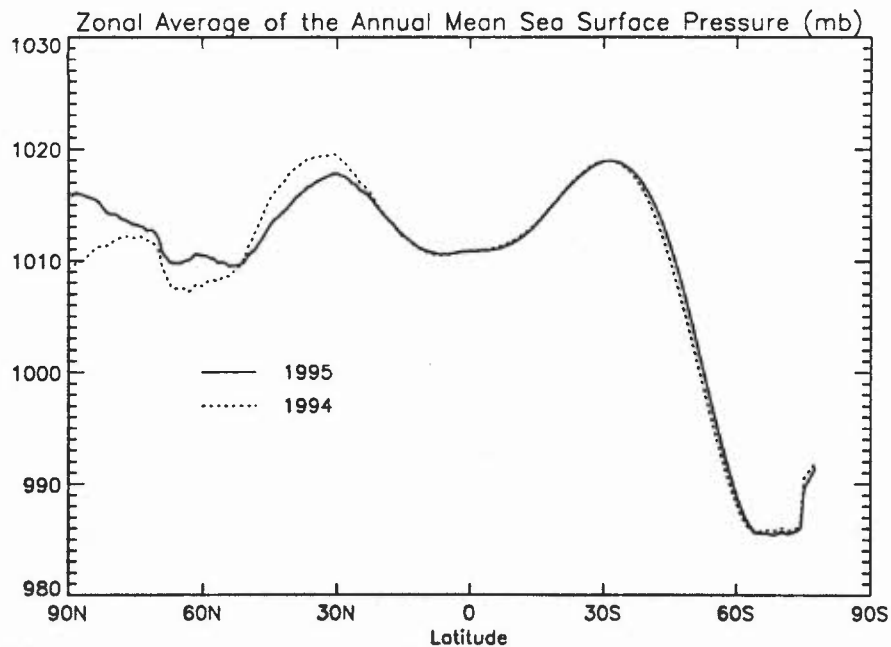


Figure 2. Zonal average of the annual mean sea surface pressure for 1994 and 1995.

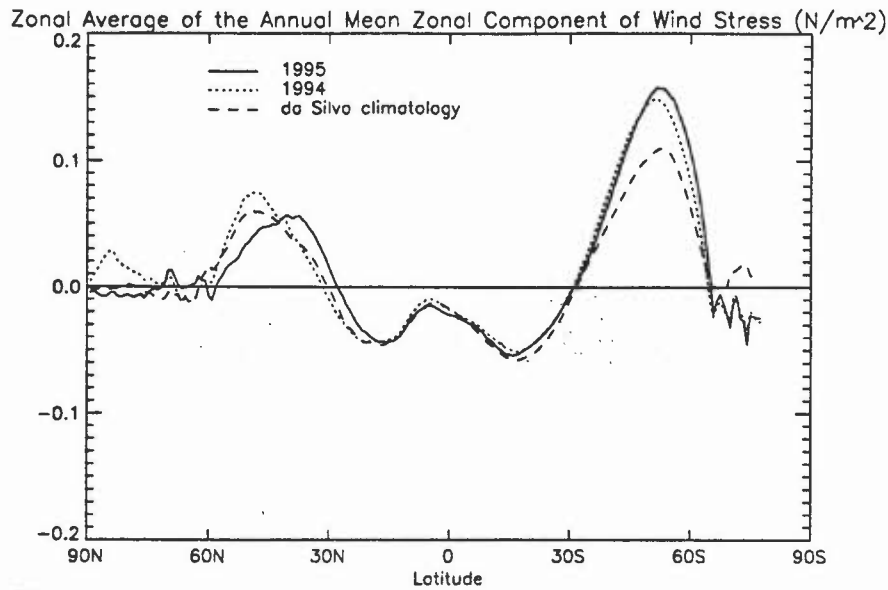


Figure 3. Zonal average of the annual mean zonal component of wind stress for 1994, 1995 and da Silva climatology.

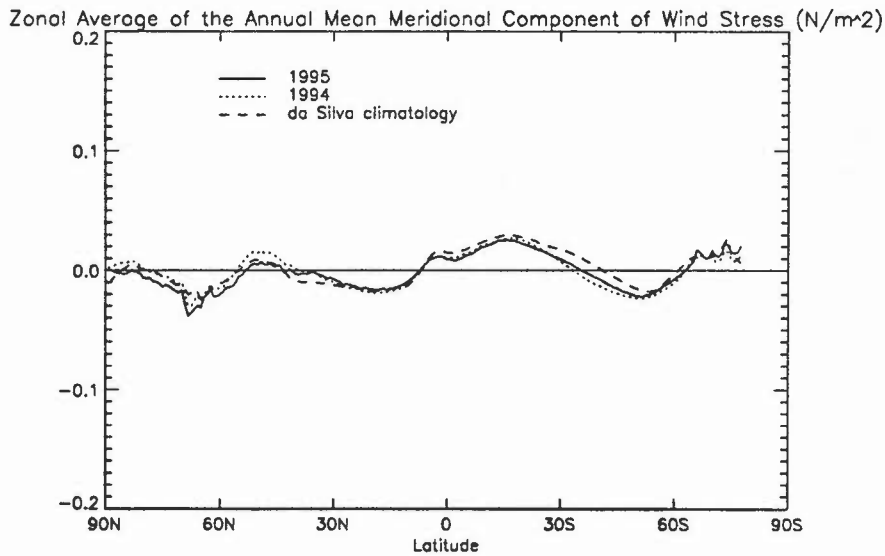


Figure 4. Zonal average of the annual mean meridional component of wind stress for 1994, 1995 and da Silva climatology.

3.2 DA SILVA CLIMATOLOGY WIND STRESSES.

The estimates made by the da Silva climatology of the wind stress magnitude largely agree with the NWP model, especially in 1995 in the equatorial regions (fig.1). It should be noted that this climatology is closer to the NWP wind stress magnitude in this region than the H&R climatological estimate of wind stress magnitude used in Jones (1995). In the southern ocean the NWP model still over estimates the wind stress magnitude compared with the da Silva climatology and the H&R climatology wind stress magnitudes.

In the U.K. Met. Office monthly monitoring results for ERS-1 winds, March 1996 (Data Assimilation Group, 1996) the wind speeds from the NWP model have been compared with ERS-1 altimeter observations of wind speed by latitude bands. This graph can be seen at fig. 5 where O-B (Observation - Background) represents the observations taken by the altimeter on ERS-1 minus the forecast of the wind speed from the NWP model. Interestingly, the NWP winds were weaker in the Southern Hemisphere compared to the winds observed by the satellite altimeter. Thus, whereas da Silva suggests the stresses, (and therefore winds), are too strong in the NWP model, ERS-1 suggests the opposite.

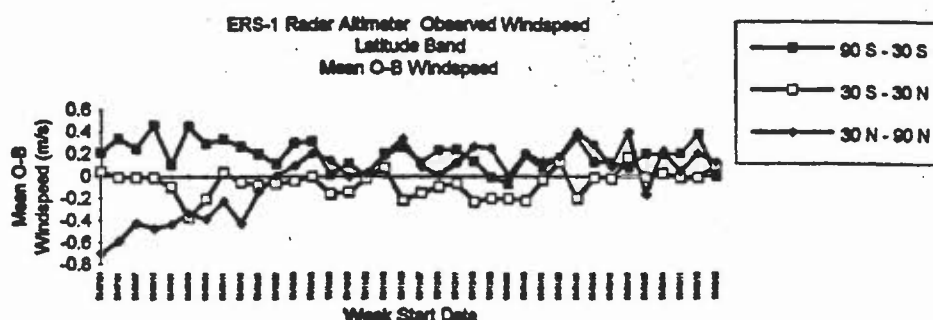


Figure 5. Mean ERS-1 altimeter observed wind speed (O) minus NWP wind speeds (B) for 24/7/95 to 25/3/96 in weekly intervals.

Reasons for the low wind stress in the southern ocean in the da Silva climatology could be due to lack of observations and poor sampling in this region. There is also a global fair weather bias, in the data, which is greater in the southern hemisphere, determined by the unwillingness of ship captains to go out in storms. The number of observations is particularly low in the southern hemisphere winter months. Also, as previously mentioned, the da Silva climatology uses a new Beaufort wind scale which should improve the accuracy of observations. Corrections are made to the old Beaufort wind scale data as it was under-estimating high wind speeds and over-estimating low wind speeds. The old scheme is still used on many ships. Another reason for a lower wind stress magnitude in the southern ocean could be to the introduction in the 1980's of a large number of drifting buoys which were placed in the southern ocean. Their wind speeds are taken as being at 20m but the height of the buoy permits only a 5m wind speed. The climatology didn't correct for this hence lighter wind speeds are recorded. Also Large *et al*, (1995) have seen an increase of 40% to the wind stress when the influence of high waves in ocean storms is considered. This could be another reason why the climatology's estimate of the wind stress is lower than that from the NWP model.

4. TOTAL HEAT FLUX

4.1 INDIVIDUAL HEAT FLUXES.

There are four individual heat fluxes saved by the NWP suite. These are the short wave radiation flux (Q_s), the long wave radiation flux (Q_B), the latent heat flux (Q_E) and the sensible heat flux (Q_H). The zonal averages of the annual mean of these heat fluxes are illustrated in fig. 6 - 9. Figure 6 shows the zonal average of the annual mean short wave

radiation flux in 1995 and 1994. From this diagram it can be seen that in 1995 there was slightly less shortwave radiation across the globe. The only exception to this is in the region 0-20S. Here there was a slight increase at the equator in 1995 with a decrease of about 10Wm^{-2} further south. The da Silva climatology estimate of short wave radiation flux is close to the estimates made by the NWP model with only small differences in the magnitude of the short wave radiation in the tropics and the high latitudes. From Jones, (1995) it can be seen that the da Silva climatology estimates of short wave radiation is closer to the NWP estimates than the Oberhuber (1988) climatology estimates.

In 1995, compared to 1994, there was a general decrease in the loss from the ocean to the atmosphere over the whole earth by the long wave radiation flux (fig. 7). Again there is one area where this statement is not applicable and that is on the equator where there is a greater loss in 1995 compared to 1994. The NWP model estimates a loss of nearly 20Wm^{-2} greater in the equatorial region and the tropics than the estimate of the long wave radiation flux from the da Silva climatology.

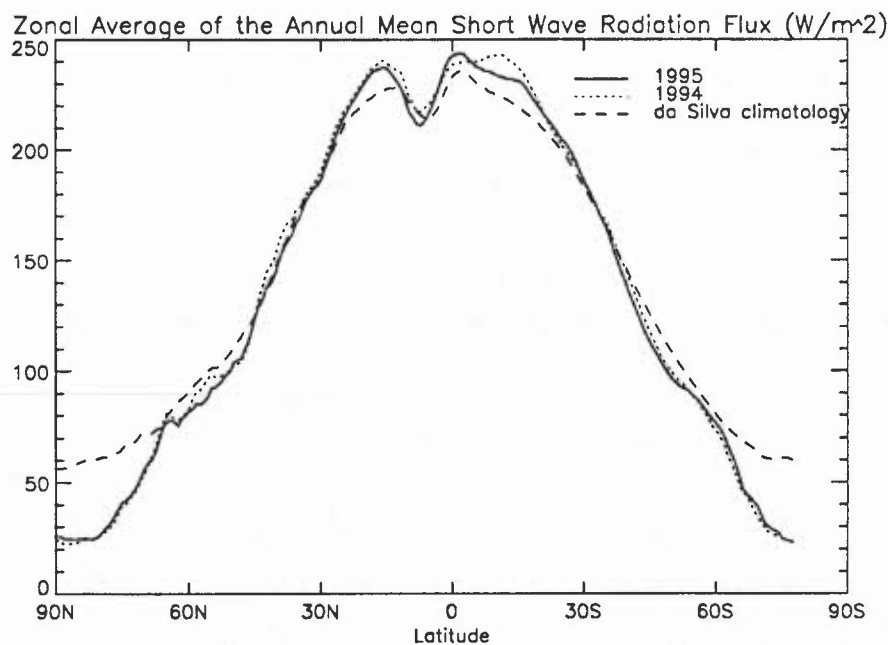


Figure 6. Zonal average of the annual mean short wave radiation flux for 1994, 1995 and da Silva climatology.

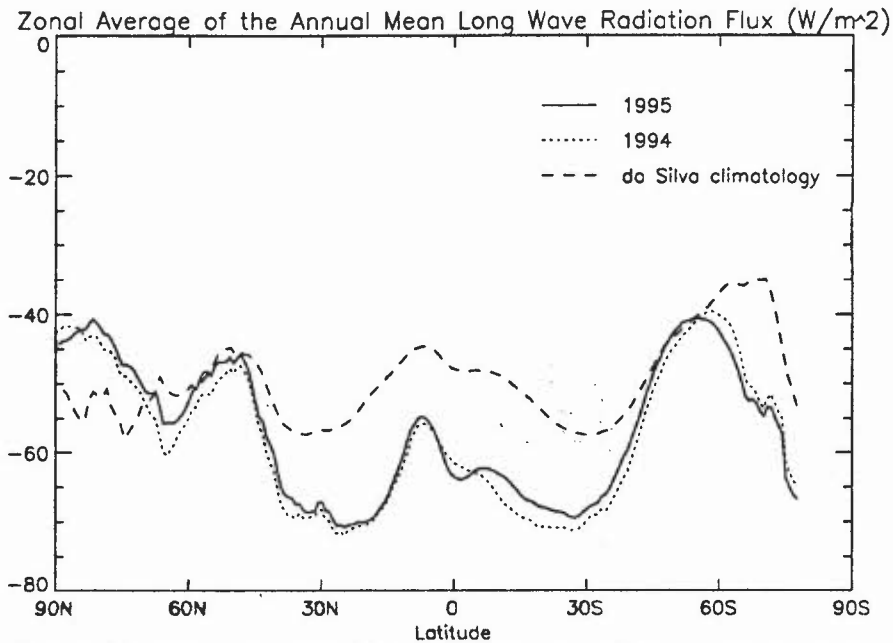


Figure 7. Zonal average of the annual mean long wave radiation flux for 1994, 1995 and da Silva climatology.

Figure 8 shows the zonal average of the annual mean latent heat flux. In 1995 there was a slight increase in the loss from the ocean to the atmosphere of heat by evaporation across the globe. At about 20S the loss was greater in 1994 and the difference is about 5Wm^{-2} . The estimate by the da Silva climatology is again less than the NWP model by up to 30Wm^{-2} in the tropics.

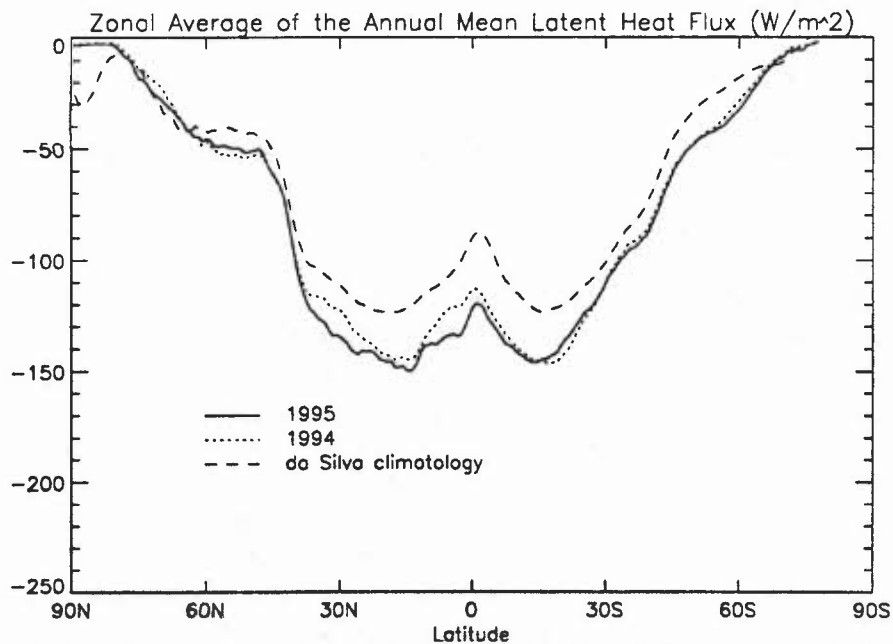


Figure 8. Zonal average of the annual mean latent heat flux for 1994, 1995 and da Silva climatology.

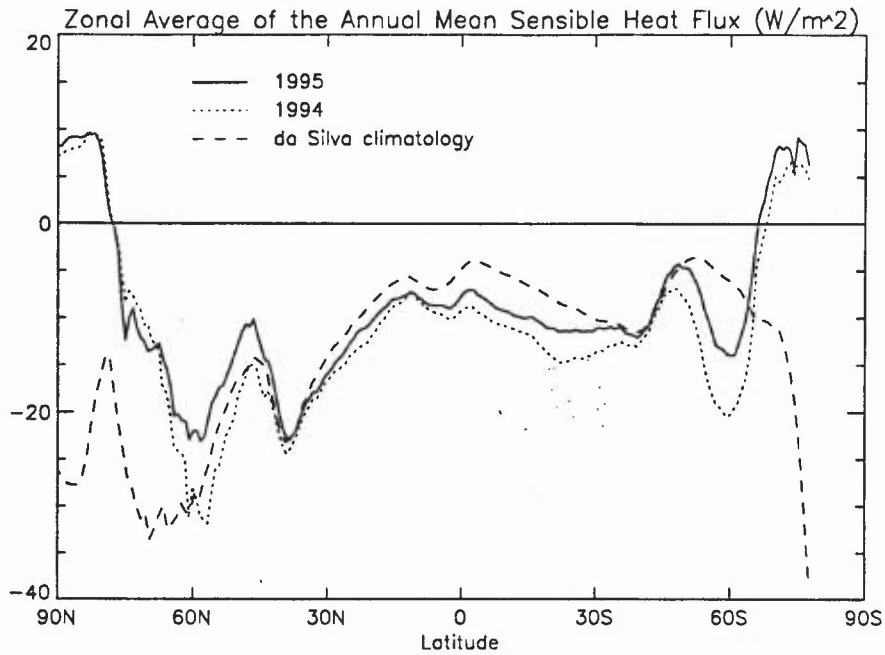


Figure 9. Zonal average of the annual mean sensible heat flux for 1994, 1995 and da Silva climatology.

The final individual heat flux is that of the sensible heat flux (fig.9). Over the whole globe there was a decrease in the loss from the ocean to the atmosphere in 1995 through the sensible heat flux. This is particularly so in the mid latitudes where the maximum difference is about 10 Wm^{-2} . Interestingly the da Silva climatology estimate of sensible heat flux is closer to the NWP model fluxes for 1995 compared to 1994. NWP sensible heat flux is closer to da Silva than to Oberhuber.

4.2 TOTAL HEAT FLUX.

The total heat flux is calculated from the archived individual heat fluxes in the following way:

$$Q_T = Q_S + Q_B - Q_E - Q_H \quad (1)$$

The zonal average of the annual mean total heat flux can be seen at fig.10. The geographical distribution of the change in the annual mean total heat flux between 1994 and 1995 is shown in fig.11. At 20S-30S there is a difference of about 10 Wm^{-2} between 1994 and 1995. If the total heat flux is broken down into the individual components, (table 1), it can be seen that the largest contributor to this difference is the latent heat flux, with an increase in 1995 of 5.6 Wm^{-2} in this region. An important point to make here is that there is an increase in all of the four heat fluxes in 1995. Generally, the total heat flux in 1995 shows a decrease around the equator in total heat entering the ocean and an increase in total heat leaving the ocean in the extra tropics. The exception here is at 45N-60N where there is a decrease in 1995 in heat loss from the ocean. This region can be seen in fig.11 off the west coast of North America.

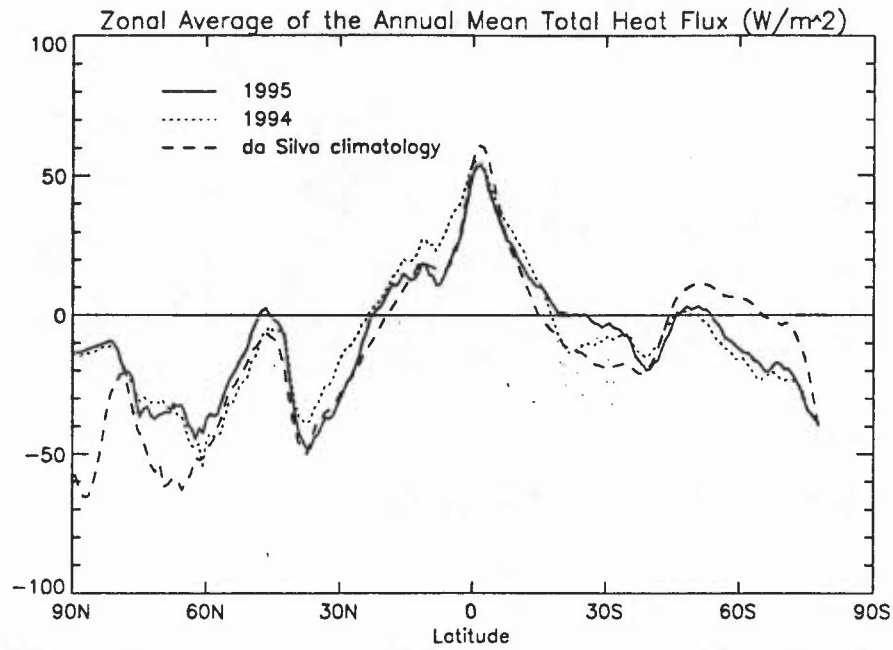


Figure 10. Zonal average of the annual mean total heat flux for 1994, 1995 and da Silva climatology.

Table 1. Zonal mean heat flux components at 22.5 S for 1994 and 1995. Sign convention is positive into the ocean. The difference between 1994 and 1995 for each heat flux component is of the same sign. The latent heat flux dominates.

Flux Component	1995 (Wm^{-2})	1994 (Wm^{-2})	Difference (Wm^{-2})
Total Heat Flux	0.17	-13.37	-13.54
Short Wave Radiation Flux	211.34	209.44	-2.09
Long Wave Radiation Flux	-68.32	-70.84	-2.52
Latent Heat Flux	-131.71	-137.30	-5.59
Sensible Heat Flux	-11.33	-14.67	-3.34

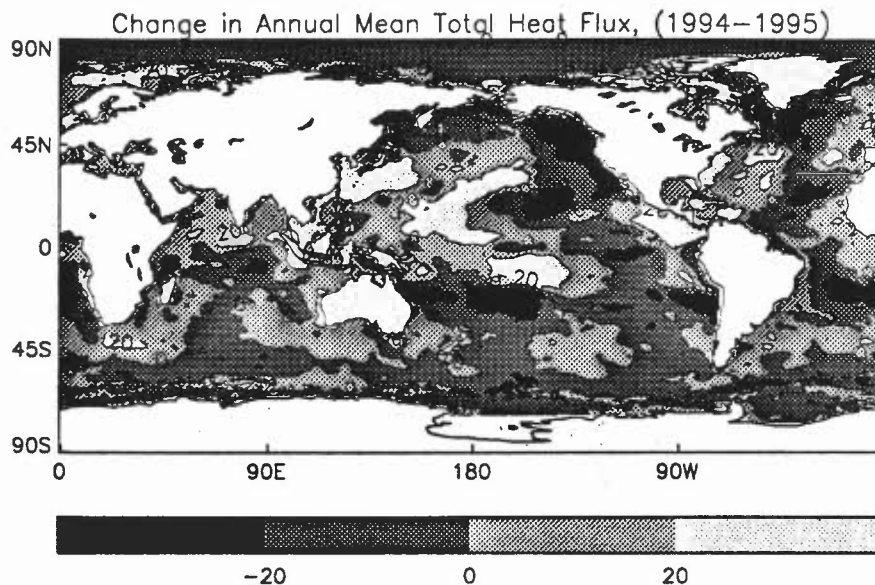


Figure 11. Difference between the annual mean total heat flux at the ocean surface in 1994 and 1995.

4.3 SEA SURFACE TEMPERATURE.

To account for some of the differences in the heat fluxes the annual mean sea surface temperature analyses from the NWP model for 1995 is compared with 1994. The change in the annual mean sea surface temperature can be seen in fig.12. Figure 13 shows the zonal average of the annual mean difference between 1995 and 1994. From both of these figures a small increase in the sea surface temperature in 1995 can be seen. This results from areas of warmer and colder sea surface temperatures. The global mean increase is 0.07°C which is large enough to have an effect on the heat fluxes for this year. Using a Haney (1971) argument, to estimate how a change in temperature can change the total heat flux, a mean increase in temperature of 0.07°C could result in an increase of 3Wm^{-2} in all but the shortwave radiation heat fluxes. In fig 7-9 this magnitude of increase can be seen. To verify this sea surface temperature increase between 1995 and 1994 the NWP sea surface temperatures were compared with an observational data set of sea surface temperature, MOHSST (Met. Office Historical Sea Surface Temperature), from the Hadley Centre. The mean increase in this case from 1994 to 1995 was only 0.03°C (N. Rayner, personal communication). One reason for the small difference between the NWP estimate of sea surface temperature and the MOHSST data set could be that a different set of observations was used in the NWP model in 1995 compared to 1994. This could have included more or different satellite observations. Thus SST changes could directly account for about half the differences between fluxes for 1994 and 1995.

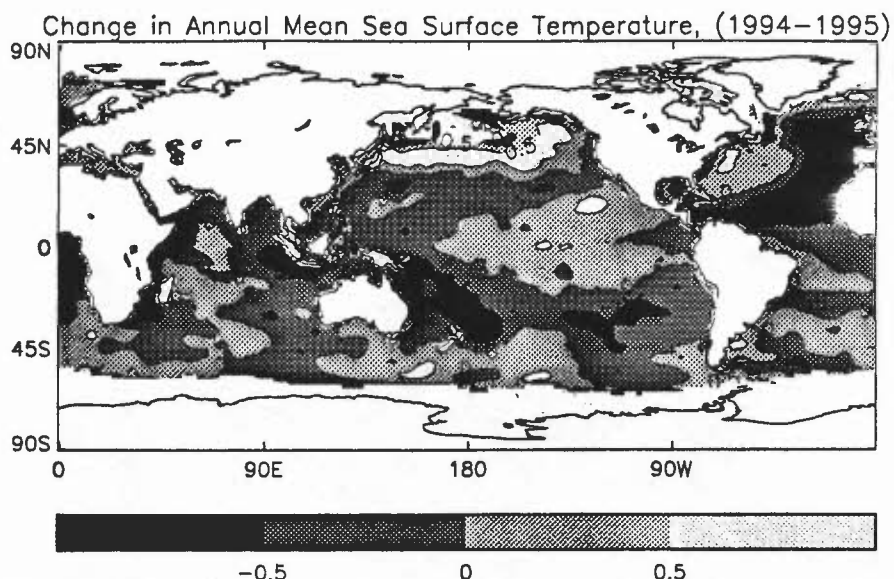


Figure 12. Difference between the annual mean sea surface temperature in 1994 and 1995.

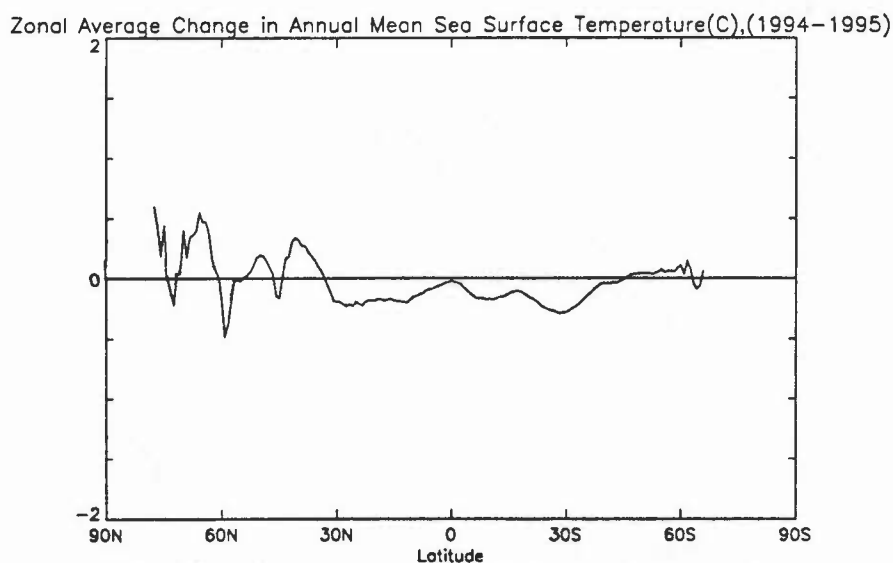


Figure 13. Zonal average of the difference between the annual mean sea surface temperature in 1994 and 1995.

4.4 MODEL CHANGES

Because of the differences in the NWP sea surface temperature between 1994 and 1995 the effect to the heat fluxes by the various model changes is difficult to detect. Firstly the new gravity wave drag and orographic roughness scheme which was introduced in January 1995 was expected to improve the forecast of low cloud and humidity. This was generally because the low level winds were lighter due to the increased drag at low levels over land and with a warmer, drier boundary layer low cloud was also reduced (Milton *et al*, 1994). Figure 14

shows the annual mean change in low cloud amount between 1994 and 1995. From this it is obvious that there was a reduction in low cloud in 1995 off the west coast of South America, the west coast of southern Africa and parts of the southern ocean but elsewhere the effect of this change is not so apparent. These correspond to areas of net heat differences in fig.11.

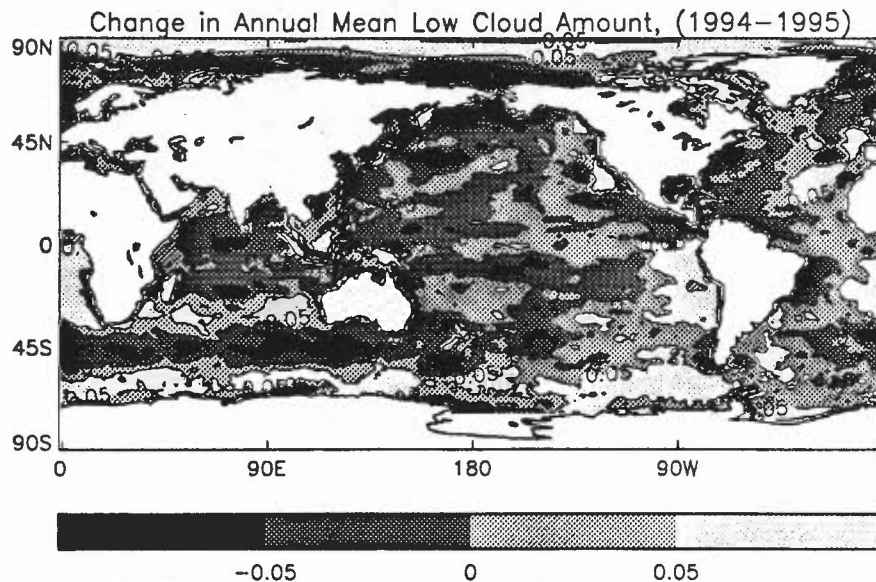


Figure 14. Difference between the annual mean low cloud amount in 1994 and 1995.

Fig 15 shows a Hovmöller diagram of the difference between the forecasts $T+72$ and $T+0$ of high cloud from January 1992 to February 1996. Introduction of the gravity wave drag scheme in January 1995 can be clearly seen here as a definite discontinuity at this point. The change in annual mean high cloud amount between 1994 and 1995 can be seen at fig. 16. Except for some equatorial regions there is an increase in high cloud amount everywhere in 1995, even over the southern ocean, suggesting that the gravity wave drag change resulted in large scale circulation changes.

The second model change, the decision to switch off horizontal diffusion over steep orography, went into the NWP model in June 1995 (Wilson *et al*, 1995). This change acted to improve the forecast of stratocumulus next to western coasts. It is well known that previous to this change the model was over-estimating the stratocumulus decks. Therefore in 1995 a reduction in this form of low cloud was expected. Figure 14 shows the impact of this change near the Andes Mountains. There was less low cloud in 1995 off the west coast of South America. Figure 17-18 shows the low cloud zonal average for March - May for the two years before the change and the corresponding plot for June - August after the change. There is no clear evidence that the change had an impact on global scale marine clouds, but this analysis does not produce local changes.

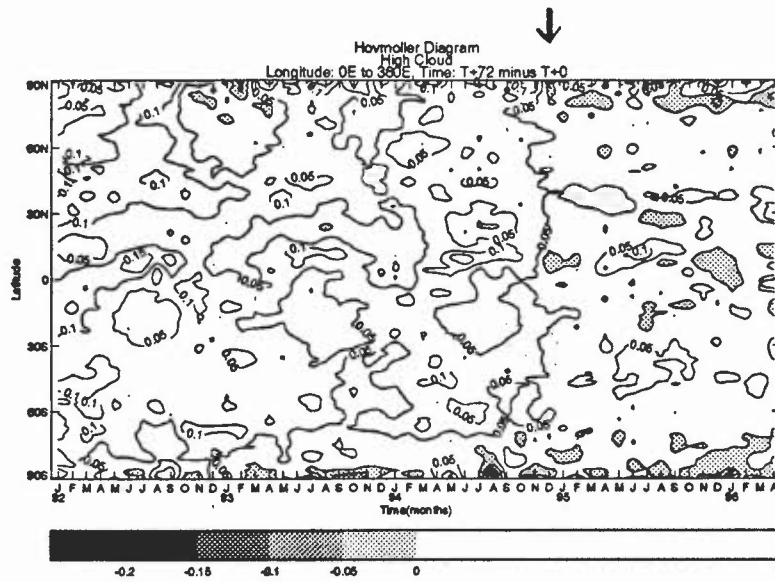


Figure 15. Hovmoller diagram showing the difference between T+72 and T+0 for high cloud amount from June 1992 to February 1996. A discontinuity can be seen in January 1995.

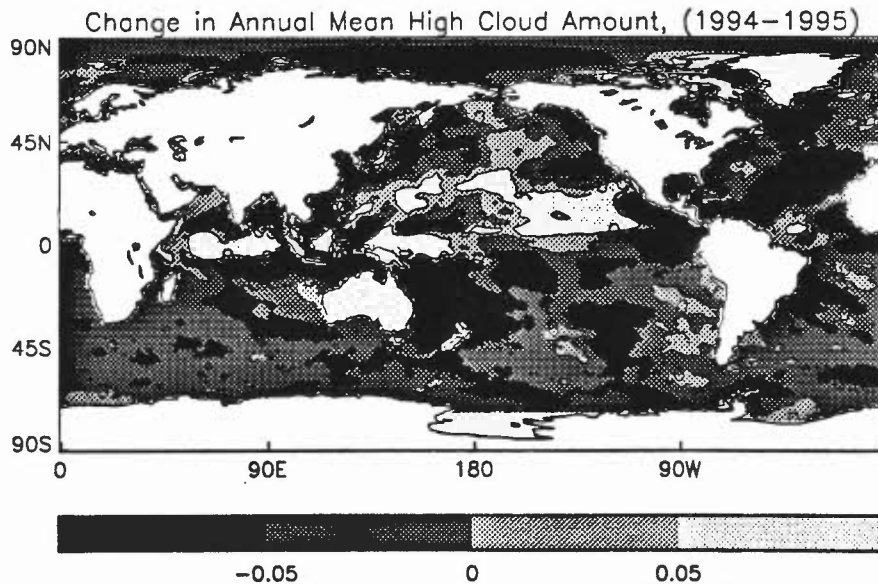


Figure 16. Difference between the annual mean high cloud amount in 1994 and 1995.

In a situation where there are less clouds than in previous years in an area one would expect an increase in the shortwave radiation reaching the earth and an increase in the long wave radiation loss from the ocean back to the atmosphere. This increase can not be seen in fig.

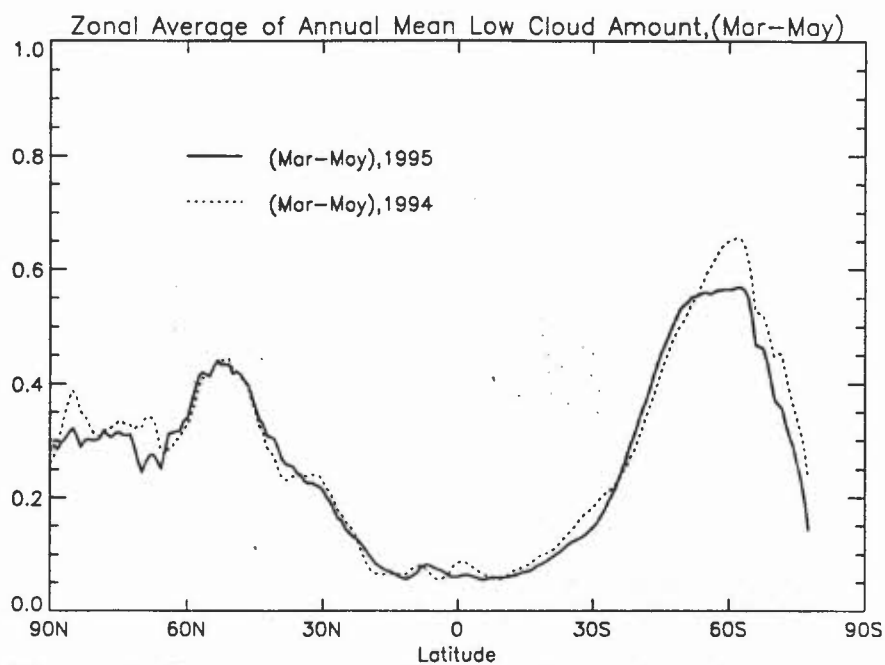


Figure 17. Zonal average of the seasonal mean low cloud amount for March to May, 1994 and 1995.

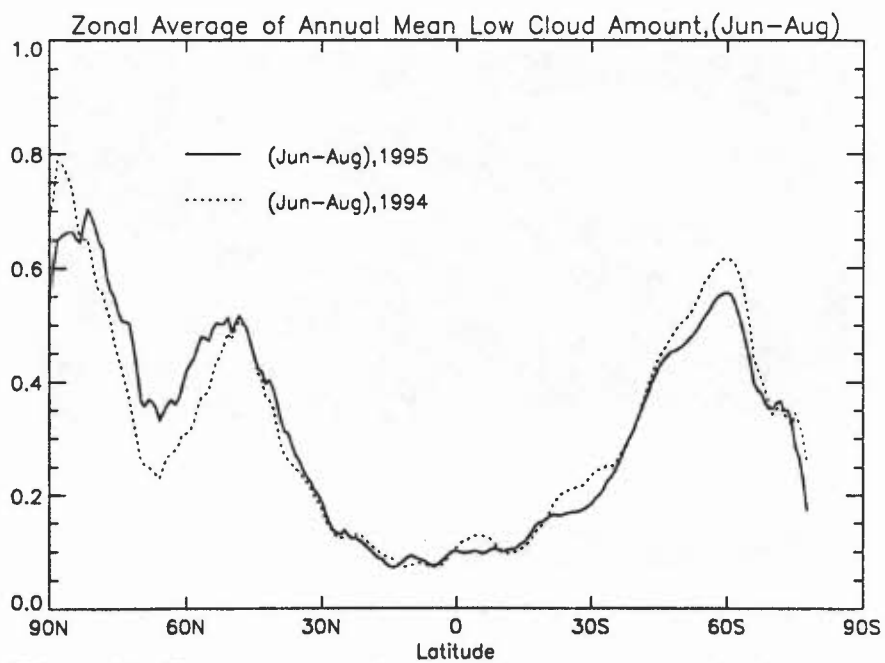


Figure 18. Zonal average of the seasonal mean low cloud amount for June to August, 1994 and 1995.

6 or 7, the annual mean short wave radiation flux and the annual mean long wave radiation radiation flux and the long wave radiation flux instead of increases. Any other features of the influence the two model changes had on the heat fluxes is masked out by the increase in the sea surface temperature. Finally, fig 10 indicates that the da Silva climatological estimate of the total heat flux is closer to the NWP total heat flux in 1995 compared to 1994 except in the region 10S - 30S. This observation could indicate that the improvements to the NWP model or the apparent increase in sea surface temperature are bringing the NWP surface fluxes closer to the estimates made by da Silva (1994).

5. IMPLIED HEAT TRANSPORT

The northward heat transport implied by the NWP heat fluxes for 1995 and 1994 can be seen in fig. 19. To obtain this result the heat fluxes are integrated northwards from the North Pole. The magnitude of the transport at the South Pole is a measure of the imbalance in the ocean heat budget in the model. Along with the implied northward transport for 1995 and 1994 the estimate of the northward heat transport by the da Silva climatology is also plotted. Each plot of the implied heat transport for 1995, 1994 and da Silva climatology follows the same pattern with a maximum northward heat transport in the northern hemisphere at about 20N and a minimum or negative northward heat transport at 20S. The major difference between the two years is that in 1994 there is an imbalance of 0.4 PW at the South Pole. A difference of this magnitude was noted in the work by Jones (1995) where an imbalance of 0.4 PW was seen in 1994 and which differed from the heat transport in 1993. There is no *a priori* reason that global heat fluxes should be in balance for a single year, but the NWP imbalance is comparable to that of da Silva.

Interestingly the heat transport in 1995 is closer to the climatological estimate than that in 1994. This could be due to improvements to the model bringing all the heat fluxes in 1995 closer to the climatological estimates. There are still discrepancies with the da Silva climatology heat transport in the southern hemisphere due to the constrain on the calculations in the southern ocean due to the lack of observations in this region. From fig. 19 it can be seen that the da Silva estimate of heat transport suggests that there is only a small amount of heat transported southwards in the southern hemisphere.

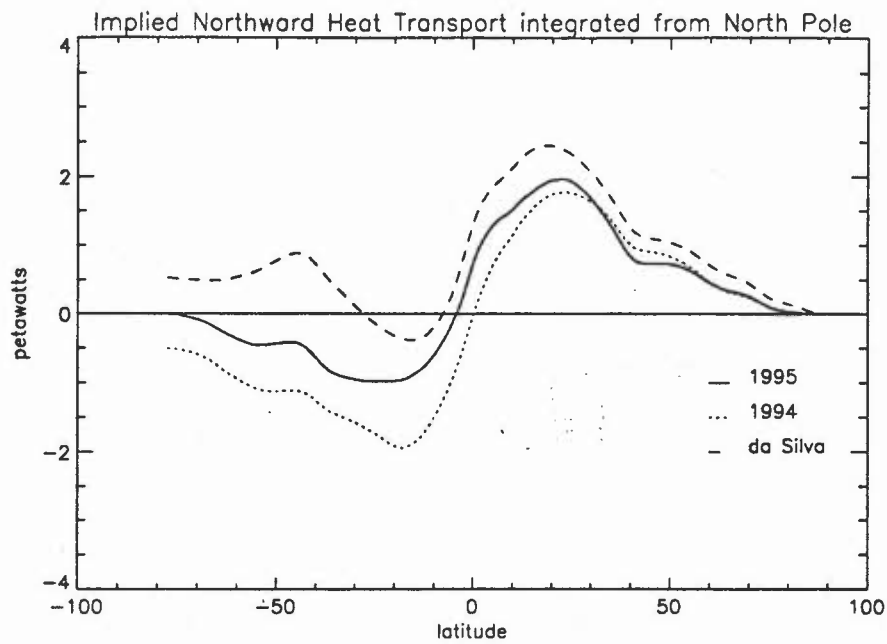


Figure 19. Zonal average of the implied northward heat transport integrated from the North Pole for 1994, 1995 and da Silva climatology.

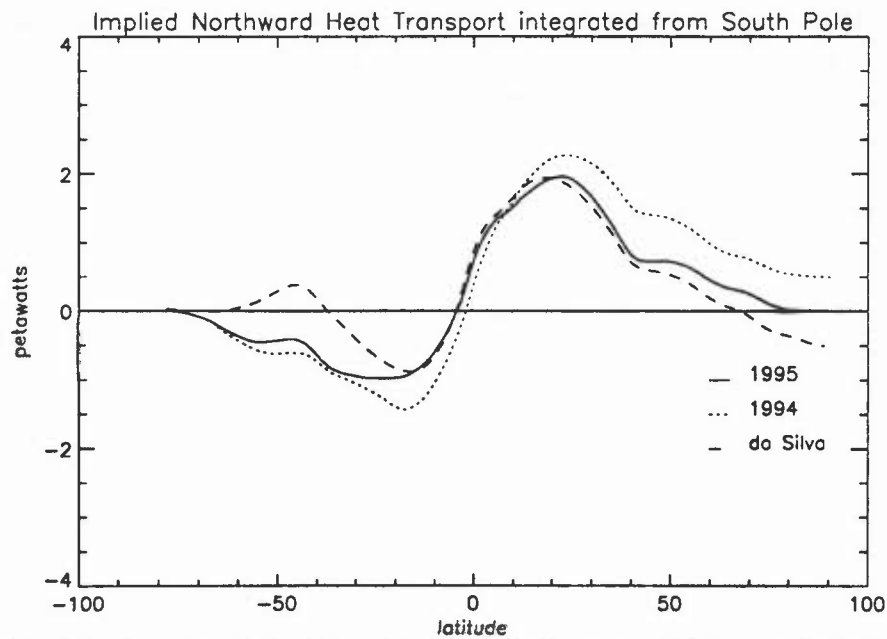


Figure 20. Zonal average of the implied northward heat transport integrated from the South Pole for 1994, 1995 and da Silva climatology.

Integrating the heat fluxes northward from the South Pole gives a different view of the heat transports. This can be seen in fig. 20 where the point of the divergence is between 10N and 20S. This divergence is seen in approximately the same place in Jones (1995). In the tropics the three heat transports are roughly aligned.

Finally a further comparison, fig.21, can be made between the da Silva climatological estimate of an implied heat transport and other climatological estimates of heat transports by Hastenrath, (1982) and Hsiung, (1985). Here the two older climatologies, which both have restrictions in high latitudes, estimate a greater transport than da Silva in the southern hemisphere. Both the Hastenrath and Hsiung climatologies are closer to the implied heat transport in the northern hemisphere from the NWP model in 1995 than they are to the da Silva climatology. The variations in these implied heat transports could be due to different cloud assumptions made in formulating the climatologies.

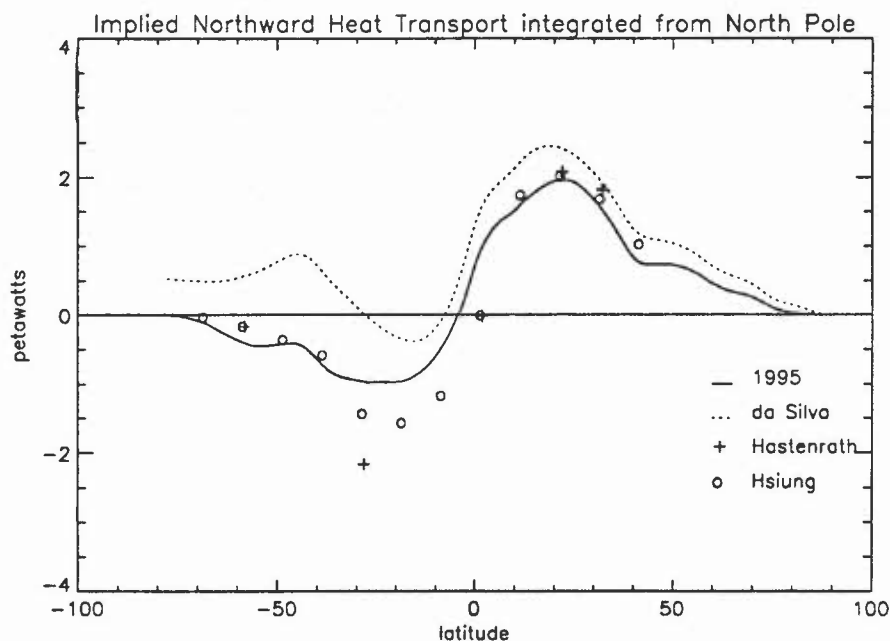


Figure 21. Zonal average of the implied northward transport integrated from the North Pole for 1995 and da Silva, Hastenrath and Hsiung climatologies.

6. CONCLUSION

From this work it can be seen that the differences in the surface fluxes between 1994 and 1995 can be mainly explained by the geographical variation in the NWP model's sea surface temperature in 1995. Changes to the NWP model such as the new gravity wave drag scheme and the switching off of the horizontal diffusion in 1995 were also thought to have had an effect on the surface fluxes, mainly through changes to cloudiness, but actual features were difficult to pinpoint due to the more dominant effect of the mean increase in the sea surface temperature.

Differences in the NWP wind stresses between 1994 and 1995 are thought to be due to natural variability.

In nearly all cases the surface fluxes in 1995, compared to those in 1994, are closer to the estimates by the da Silva climatology. Although both years are comparable with this climatology. From this study it can be seen that the model still over estimates the wind stress magnitude in the southern ocean compared to the da Silva climatology. This is probably due to lack of observations from the southern ocean in the climatology. The ERS-1 altimeter winds in the southern ocean are stronger than the model winds. The discrepancy between the climatologies, the NWP model and ERS-1 observations warrant further investigation.

The model also tends to over-estimate the long wave radiation flux, the latent heat flux and the short wave radiation flux in the tropical regions compared to the da Silva climatology.

There was a small imbalance in the implied heat transport in 1994 but this is comparable to the imbalance in the da Silva climatology.

When comparing this climatology with the older ones, (Oberhuber, H&R, Hastenrath and Hsiung) it seems that the da Silva climatological estimates of the surface fluxes are closer to the NWP fluxes. There are still restrictions with all climatologies at high latitudes.

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Figure Captions

- Figure 1 Zonal average of the annual mean wind stress magnitude for 1994, 1995 and da Silva climatology (1994).
- Figure 2 Zonal average of the annual mean sea surface pressure for 1994 and 1995.
- Figure 3 Zonal average of the annual mean zonal component of wind stress for 1994, 1995 and da Silva climatology (1994).
- Figure 4 Zonal average of the annual mean meridional component of wind stress for 1994, 1995 and da Silva climatology (1994).
- Figure 5 Mean ERS-1 altimeter observed wind speed (O) minus NWO wind speeds (B) for 24/7/95 to 25/3/96 in weekly intervals.
- Figure 6 Zonal average of the annual mean short wave radiation flux at the ocean surface for 1994, 1995 and da Silva climatology (1994).
- Figure 7 Zonal average of the annual mean long wave radiation flux at the ocean surface for 1994, 1995 and da Silva climatology (1994).
- Figure 8 Zonal average of the annual mean latent heat flux at the ocean surface for 1994, 1995 and da Silva climatology (1994).
- Figure 9 Zonal average of the annual mean sensible heat flux at the ocean surface for 1994, 1995 and da Silva climatology (1994).
- Figure 10 Zonal average of the annual mean total heat flux at the ocean surface for 1994, 1995 and da Silva climatology (1994).
- Figure 11 Difference between the annual mean total heat flux at the ocean surface in 1994 and 1995.
- Figure 12 Difference between the annual mean sea surface temperature in 1994 and 1995.
- Figure 13 Zonal average of the difference between the annual mean sea surface temperature in 1994 and 1995.
- Figure 14 Difference between the annual mean low cloud amount in 1994 and 1995.
- Figure 15 Hovmoller diagram showing the difference between T+72 and T+0 for high cloud amount from June 1992 to February 1996.
- Figure 16 Difference between the annual mean high cloud amount in 1994 and 1995.
- Figure 17 Zonal average of the seasonal mean low cloud amount for March to May, 1994 and 1995.

- Figure 18 Zonal average of the seasonal mean low cloud amount for June to August, 1994 and 1995.
- Figure 19 Zonal average of the implied northward heat transport integrated from the North Pole for 1994, 1995 and da Silva climatology (1994).
- Figure 20 Zonal average of the implied northward heat transport integrated from the South Pole for 1994, 1995 and da Silva climatology (1994).
- Figure 21 Zonal average of the implied northward heat transport integrated from the North Pole for 1995 and da Silva (1994), Hastenrath (1982) and Hsiung (1985) climatologies.