VALIDATION OF MODEL CLOUDS USING SATELLITE DATA

R Rizzi
European Centre for Medium-Range Weather Forecasts,
Shinfield Park, Reading, UK

An initial comparison of TOVS (Tiros-N Operational Vertical Sounder) radiances against simulations was reported in *Rizzi* (1994). The simulations were based on fields of temperature, humidity, skin temperature, cloud fraction and cloud liquid water, obtained form the early (step 21 to 45) stages of forecasts, both using the operational suite and a version of the Prognostic Cloud Scheme (PCS) available at the time. An estimate of Outgoing longwave flux at the top of the atmosphere (OLR) was also obtained from the measured (OLRTOV) and simulated (OLRSIM) radiances, and these estimates were compared with the instantaneous OLR computed during the forecast (OLRMOD). Although some of the results were instrumental in triggering changes to the PCS scheme, there still remained technical difficulties that did not allow to draw firm conclusions from some of the results obtained.

A database of 40 days of global level-1B TOVS data of both NOAA-11 and NOAA-12 was collected from 26 October 1994. It has been processed using the ITPP package to produce brightness temperatures in all TOVS channels and OLRTOV. The brightness temperatures and OLRTOV were filtered using the same technique described in *Rizzi* (1994) to reduce the resolution to the forecast model's.

A set of 11 3-day forecasts was run from 26 October using the updated version of the PCS. Using the fields of temperature, humidity, skin temperature, cloud fraction, cloud liquid content and ice content, for forecast steps between 21 and 42 hours, simulated radiances were computed, collocated in time (using First Guess at Appropriate Time mode of Presat) and space with the global satellite measurements.

In the following a first set of results is presented from the comparison of all the OLR estimates.

A. ESTIMATING OLR FROM RADIANCE

I have used two methods to estimate OLR from radiance measurements:

- the statistical regression part of the ITPP processing, described in *Rizzi* (1994);
- the statistical regression developed by B Ellingson and co-workers (*Ellingson et al*, 1994), referred as BE in the text and in the naming convention as well.

Both techniques rely on the availability of limb corrected HIRS/2 and MSU data. The correction was applied to obtain an estimate of OLR from the measured data (OLRTOV, OLRTBE) while the simulated nadir radiances were used to compute the simulated OLR (OLRSIM, OLRSBE).

When examining the different estimates from the two methods, I noticed that the limb correction was producing wrong results in HIRS channel 2 of NOAA-11, which is unfortunately used in the ITPP regression. So the ITPP regression could not be used for NOAA-11. The global, 10-day comparison between the two estimates for NOAA-12 is given in Table 1.

	NOAA-12 no.	OLRTBE-OLRTOV bias	stdev
global	6790055	4.87	14.21
land	2410597	5.63	11.59
sea	4379458	4.45	15.33

Table 1: Bias and standard deviation of OLRTBE-OLRTOV Period: 271094(12UT) -061194(18UT)

Although the estimates from the two techniques have a global bias below 5 W/m2, this is about half the bias between simulated and measured values over the same ten day period. The same is true for the global standard deviation. OLRTOV is systematically smaller than OLRTBE, the difference being largest for large OLR values and very small at low OLR. I have used the line by line HARTCODE (*Miskolczi et al*, 1988; *Miskolczi*, 1994) to compute fluxes at TOA for selected atmospheric profiles, in regions free of clouds, where the OLRSIM and OLRSBE estimates were particularly different. Details on the geographical distribution of the computations are given in Table 2 while the results are shown in Table 3. Except for case 12, OLRSIM is worse than OLRSBE; in case 2 it is in fact quite bad. The values of OLRSB are always smaller than the LBL results, the underestimation being generally larger for profiles yielding large OLR values, possibly because we are approaching the limits of validity of the statistical regression. In any case the results of the LBL computations clearly show the good quality of the BE regression. Since no OLRSIM estimate could be derived for NOAA-11 and the SBE estimate compares very favourably with LBL computations, it is the one that was used for the comparison.

In all results presented in Table 3 the model layering is used with seven extra layers being added at the top to reach a height of 50 km. The effect of atmospheric layering was also investigated for the first 3 profiles, the atmosphere being divided into 50 layers, with layer depth exponentially increasing with height, so that more layers were used in the lower troposphere. Largest differences of the order of 1 W/m2 were found, a result which shows (to me) that model layering is adequate for flux computation purposes. In all three cases the improved estimate was slightly lower than the one given in Table 3.

id	location	lat	lon	IE	ID	DAY
1	Off North-west coast of Australia	-18.12	111.55	29	12	27/10
2	Southern China (land)	22.38	106.28	43	12	27.10
3	Mid Indian Ocean south of Sri L	06.46	83.45	27	11	27/10
4	Gulf of Mexico off Texas Coast	29.40	-86.88	53	11	27/10
5	Tropical Africa (land)	-2.66	16.60	32	12	01/11
6	Off southern Alaskan Coast	45.81	-157.30	40	12	01/11
7	Southern Sahara (land)	17.77	11.76	31	11	30/10
8	Off coast of South Africa	-35.83	25.66	32	11	30/10
9	Off North-East Australian Coast	-19.01	150.30	37	11	30/10
10	Off Antarctica, Atlantic-Indian Basin	-65.51	107.26	53	11	30/10
11	Off NE Siberia	72.20	176.89	40	12	30/10
12	Mare Tirreno	41.05	10.26	48	12	30/10
13	Off Gulf of Cadiz	36.54	-7.32	22	12	30/10
14	Off Graham Land, Weddell Sea	-63.94	-49.38	42	12	30/10
15	Tropical Pacific Ocean	-5.24	-133.68	29	12	30/10

Table 2: Locations used for LBL computations

id	location	ORLSIM	OLRSBE	LBL	SBE-LBL
1	Off North-west coast of Australia	272.20	287.35	292.47	-5.12
2	Southern China (land)	234.84	261.59	265.24	-3.65
5	Tropical Africa (land)	285.31	272.57	275.95	-3.38
6	Off southern Alaskan Coast	250.63	258.10	258.82	-0.72
7	Southern Sahara (land)	261.04	280.02	284.36	-4.34
11	Off NE Siberia	188.53	199.98	201.90	-1.92
12	Mare Tirreno	272.84	271.68	274.85	-3.17
13	Off Gulf of Cadiz	266.35	279.86	287.21	-7.35
14	Off Graham Land, Weddell Sea	213.38	196.89	198.41	-1.52
15	Tropical Pacific Ocean	269.67	307.58	312.81	-5.23

Table 3: Results of LBL computations and corresponding OLRSIM and OLRSBE values

B. COMPARISON OF MEASURED AND SIMULATED OLR

Table 4 shows the bias and standard deviation between OLRSBE and OLRTBE for the whole 10-day period and for the two platform. The simulated value is warmer then the measured OLR, on a global basis and for an extended period, by about 10 Wm-2.

	NOAA-11			NOAA-12		
	No.	bias	stdev	No.	bias	stdev
global	6965074	11.46	26.41	6790055	9.43	26.27
land	2495372	9.54	24.68	2410597	7.71	23.95
sea	4469702	12.54	27.14	4379458	10.38	27.25

Table 4: Bias and standard deviation of OLRSBE-OLRTBE Period: 271094(12UT) -061194(18UT)

Fig 1 shows the zonal mean bias and standard deviation of OLRSBE-OLRTBE respectively for NOAA-12. Very similar curves are obtained for NOAA-11. The geographical distribution of the 10-day mean OLRTBE is shown in Fig 2a (top -colour scale from deep blue 50 W/m2 to purple 400 W/m2). The difference between the mean OLRSBE and OLRTBE in shown in Fig 2b (blue denotes -100 W/m2 and purple 100 W/m2). Image 2a shows that most of the tropical convection is found between the equator and 10N over the oceans, while it extends to 20S in the main landmasses.

The salient features that can be extracted from the 10-day mean differences and from the geographical distribution of differences for every six-hour period are:

1. The results are very similar for the two satellites.

2. Model convection in oceanic tropical areas appears organized in a band whose latitudinal extent is smaller that in real atmosphere.

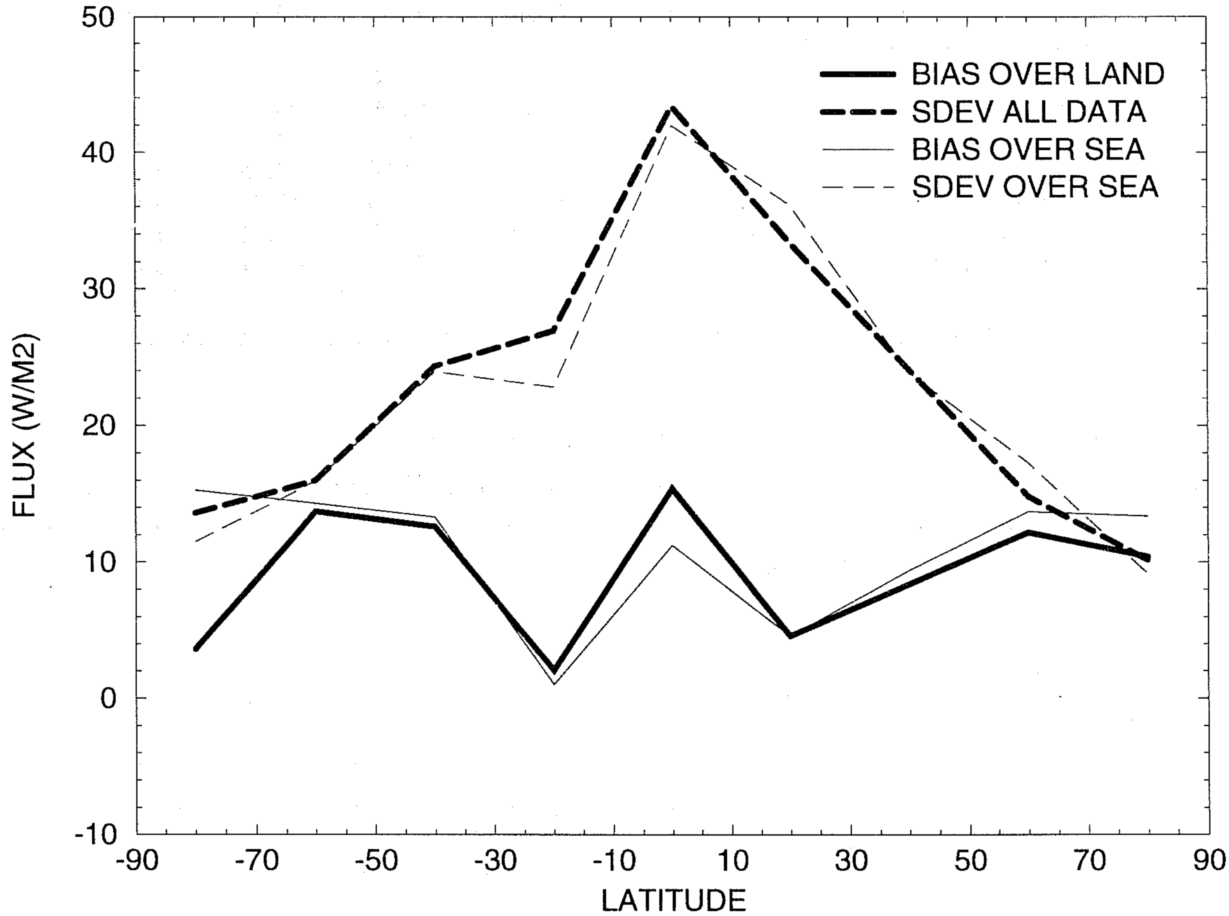

Fig 1 10-day mean bias (solid line) and standard deviation (long dashed) of the difference between simulated and measured longwave flux at TOA obtained from NOAA-12 radiances. The two sets of curves are for all data (thick lines) and for data over sea only (thin lines).

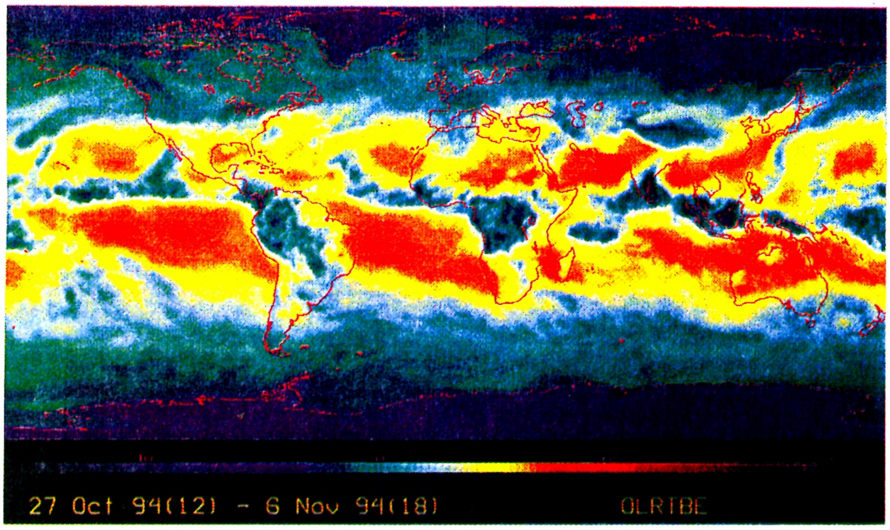

Fig 2a Geographical distribution of 10-day mean longwave flux at TOA obtained from NOAA-11 and NOAA-12 radiances (OLRTBE).

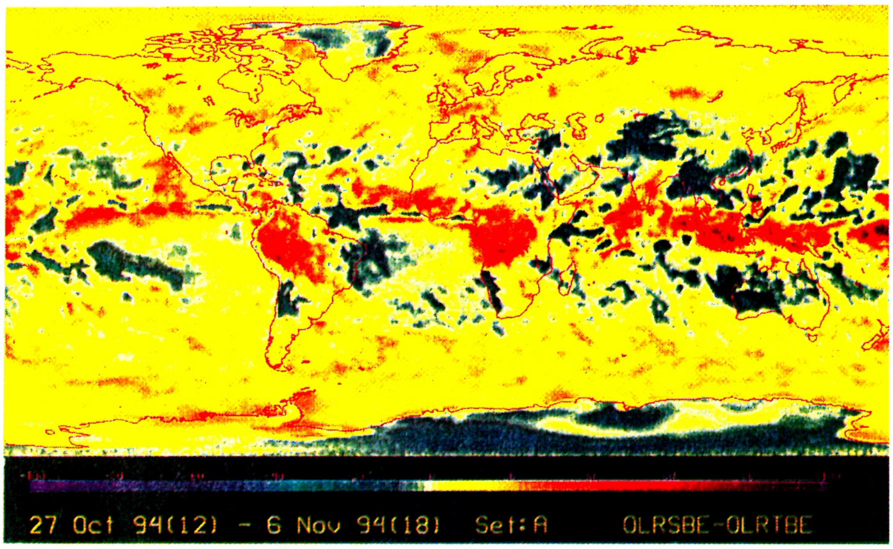

Fig 2b Geographical distribution of 10-day mean difference between simulated longwave flux at TOA (OLRSBE) and the one obtained from NOAA-11 and NOAA-12 radiances (OLRTBE).

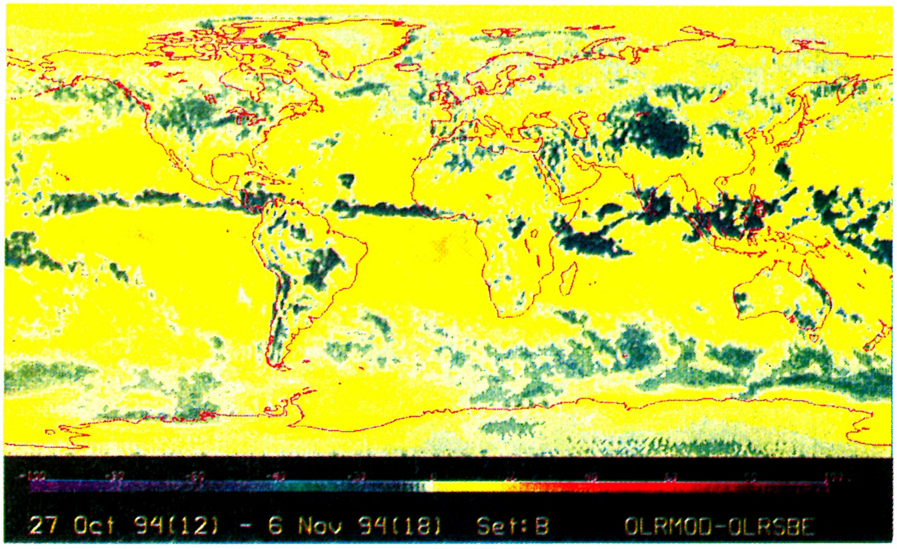

Fig 2c Geographical distribution of 10-day mean difference between model generated instantaneous flux at TOA (OLRMOD) and the simulated value (OLRSBE).

3. Largest positive bias and largest standard deviation are seen over land between latitudes 20S and 10N; the impact of model convection on OLR still does not match the effect observed on measured data, especially over land areas. At the same time, in large oceanic and continental subtropical areas, a cold bias is evident which, when considered together with the OLR overestimation in tropical convective areas, could indicate a model underestimation also of the strength of large scale subtropical descent.

4. Frontal cloud structures at polar and midlatitude regions over both hemispheres are generally located correctly. The OLR emitted by the highest clouds is generally higher than the measured values and also the geographical extent of the cloud system seems underestimated. Also the OLR is overestimated in regions behind cold fronts, possibly because the extent of post frontal cloudiness is underestimated and/or the model atmosphere is too dry in comparison to the real atmosphere. All these effects combine to produce the warm bias observed over the oceans at polar and mid latitudes over both hemispheres.

C. COMPARISON OF MODEL OLR AND SIMULATED OLR

In the present exercise the instantaneous OLR (OLRMOD) is also postprocessed, immediately before the call to the physics routine. OLRMOD is computed at the radiation time step using updated temperature, humidity and cloud fields. At time steps between the radiation time steps, only the temperature profile is updated while layer emissivity, computed using humidity and cloud fields, is held constant.

For the purpose of comparing OLR simulations (OLRSBE) to measurements (OLRTBE), forecast fields are needed at the time of the measurement. When computing OLRSBE to be compared to the model flux (OLRMOD), cloud and humidity fields at time=T and temperature at almost time=T+3 hours (Set B) have been used to eliminate the effect of the 3-hour lag in the temperature profile.

On a global basis, the effect of the 3-hour lag, averaged over the 10-day period is (for NOAA-12) a 1 W/m2 reduction in bias, caused by a 2.8 W/m2 bias decrease over land areas. For NOAA-11 the bias reduction is about 0.1 W/m2 (0.3 W/m2 over land).

The mean global statistics of the difference between OLRMOD and OLRSBE are shown in Table 5. The zonal statistics are shown in Fig 3 for NOAA-12. Results for NOAA-11 are again very similar. Fig 2c displays the geographical distribution of the mean difference using data from both satellites.

	NOAA-11			NOAA-12		
	no.	bias	stdev	no.	bias	stdev
global	6551682	3.60	13.25	6783030	1.96	12.56
land	2349264	3.58	13.74	2427999	-0.31	11.48
sea	4202418	3.61	12.69	4355031	3.24	12.77

Table 5: Bias and standard deviation of OLRMOD-OLRSBE(Set B) Period: 271094(12UT) -061194(18UT)

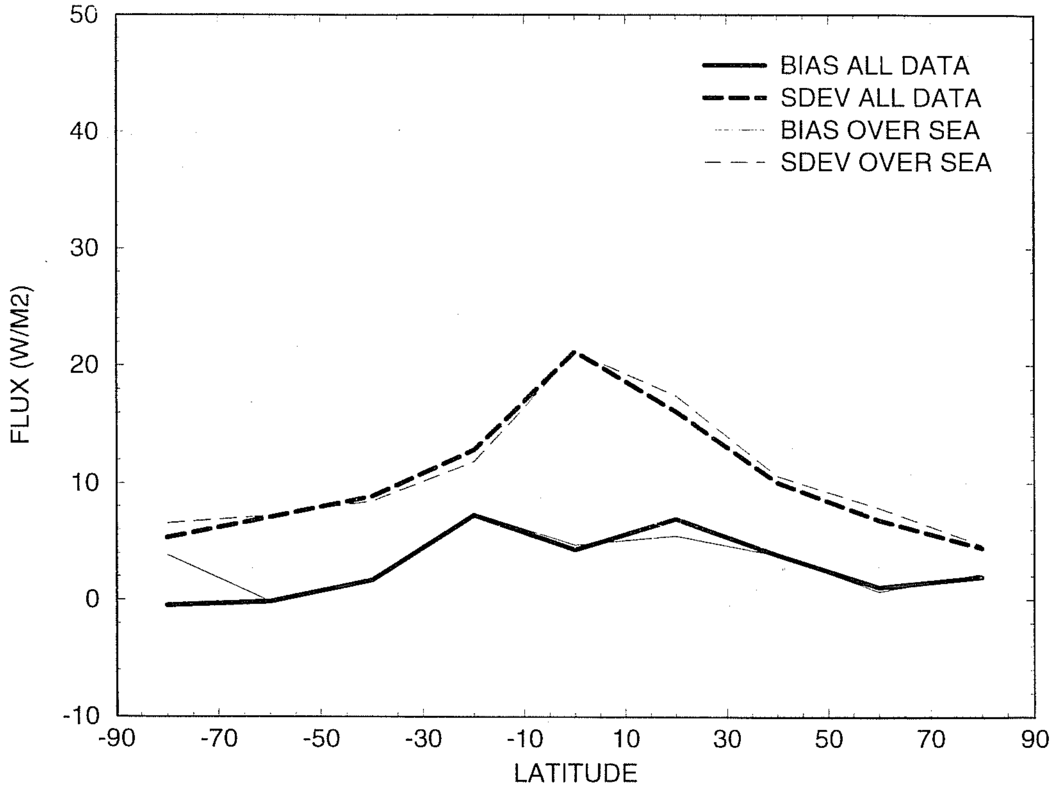

Fig 3 10-day mean bias (solid line) and standard deviation (long dashed) of the difference between model and simulated longwave flux at TOA. The two sets of curves are for all data (thick lines) and for data over sea only (thin lines).

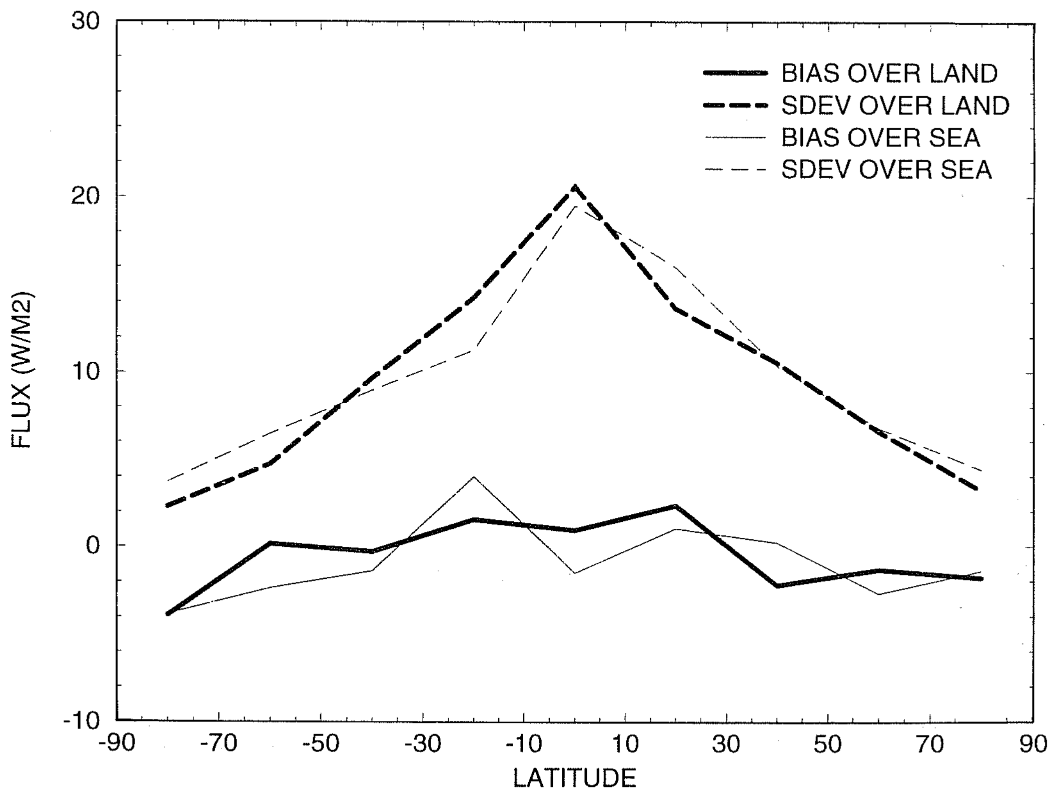

Fig 4 10-day mean bias (solid line) and standard deviation (long dashed) of the difference between model and simulated longwave flux at TOA for overcast conditions. The two sets of curves are for data over land (thick lines) and for data over sea (thin lines).

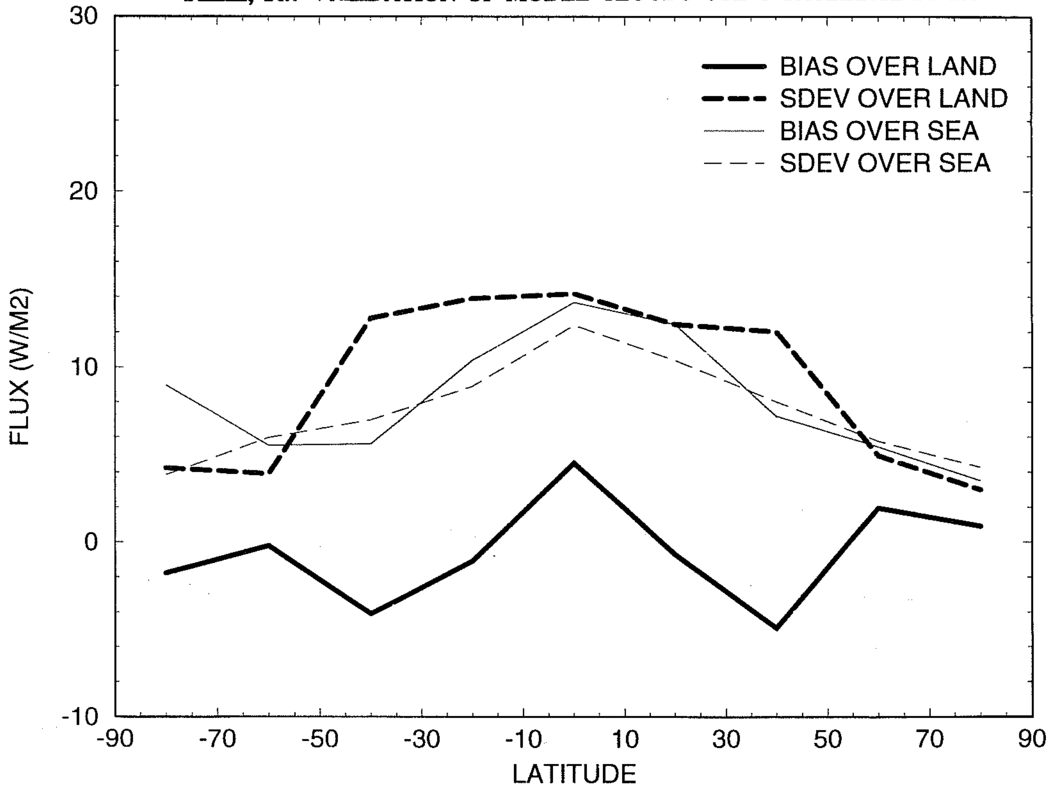

Fig 5 Same as Fig 4 but for clear conditions.

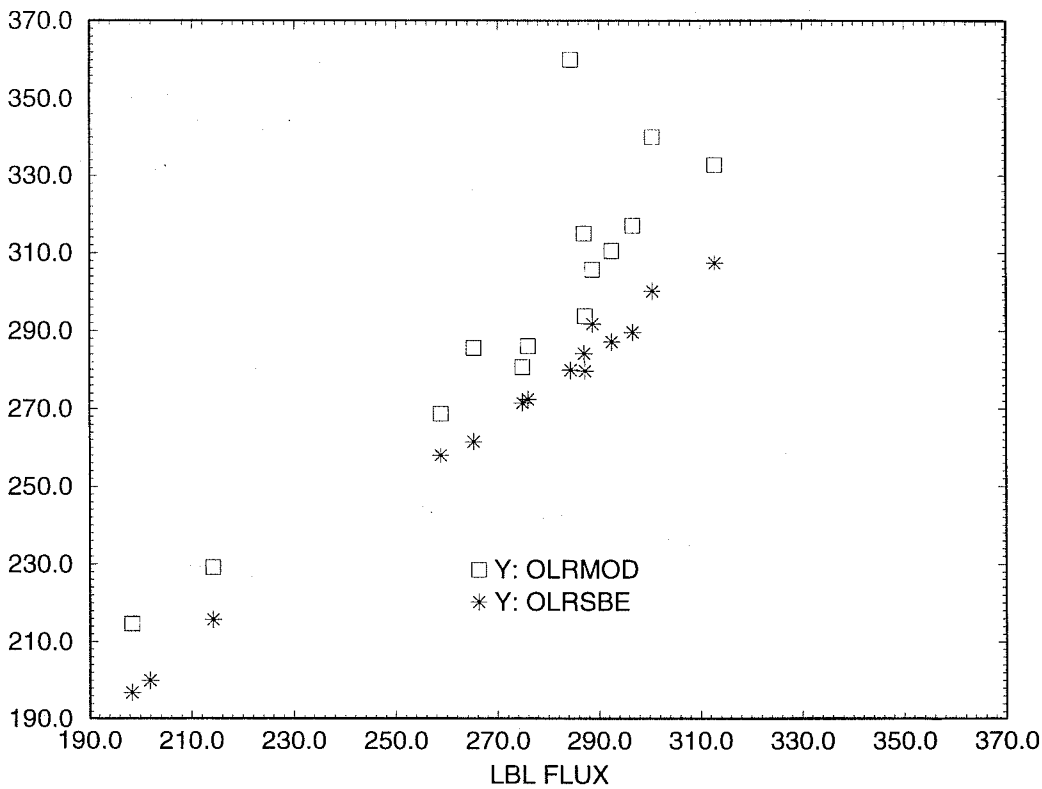

Fig 6 Scatter plot of OLRMOD (ordinate, squares) and OLRSBE (ordinate, stars) versus LBL on the abscissa.

The global difference is very small, of the order of 2.8 W/m2. The standard deviation, and to a lesser extent the bias, increase toward the tropical region. If the differences are computed for different values of (model) cloud cover one notices that bias (and to a lesser extent the standard deviation) increase with decreasing cloud cover, and attain maximum values in clear sky conditions. The results for overcast and clear conditions are shown in Figs 4 and 5, for NOAA-12. The bias for overcast conditions is small over sea and over land, while in clear areas the bias over sea is larger and increases toward the tropical region.

The pattern of standard deviation which emerges from the results in Figs 4 and 5 is more difficult to explain. It is similar for land and sea areas and for clear and overcast conditions. Images of the geographical distribution of OLRMOD and OLRSBE indicate that OLRMOD is smaller than OLRSBE in coldest overcast areas and therefore draws closer to OLRTBE. Cold (and also warm) OLRMOD features are more latitudinally elongated since flux computations are performed every 4 grid points. Another cause of difference is that, although cloud emissivity is computed identically, the two radiative schemes are very different in nature, OLRMOD being computed using a simplified flux scheme while OLRSBE is computed using a statistical regression from simulated radiances.

HARTCODE has been used to compute flux in clear sky conditions for the complete set of atmospheric profiles (Set B) in Table 2. Fig 6 is a scatter plot of OLRMOD (Y:squares) and OLRSBE (Y:stars) versus LBL (X axis. OLRMOD overestimates the LBL results in the whole range, the amount increasing with increasing OLR. Largest discrepancies arise in tropical areas (1, 3, 4, 7, 9 and 15) but excess flux is also apparent in Polar (6, 10 and 14) conditions. It seems that largest discrepancies are associated to situation in which a temperature inversion is present at or near the ground, while the flux is only slightly overestimated (compared to the LBL results) when the lower troposphere is neutral or nearly unstable (temperate profiles 12 and 13). The set of 15 cases produces an average difference of 19.5 W/m2 and a standard deviation of 18.6 W/m2 for OLRMOD, and an average difference -2.8 W/m2 and standard deviation 2.9 for OLRSBE.

CONCLUSIONS

A database of 40 days of measured TOVS radiances and fluxes of longwave radiation at TOA, and of 10 days of simulated radiances and longwave flux has been generated. Although there is still a lot to dig, the comparison of the first 10 days of flux estimate has revealed that

- the prognostic cloud scheme overestimates the global emission to space by about 10 W/m2;
- largest positive biases and standard deviations are seen over land in tropical convective areas;
- a positive bias is observed over sea at all latitudes except in large subtropical areas.

The flux computed during the forecast (OLRMOD) has been compared to the value (OLRSBE) derived from a statistical regression using simulated radiances. The global bias of the difference OLRMOD-OLRSBE is about 2.8 W/m2; zonal bias and standard deviation increase toward the equator and increase with decreasing model cloudiness. LBL flux computations, performed in various locations in clear sky conditions, over land and over sea, indicate that OLRMOD has a decisive tendency to overestimate the clear sky OLR flux, while the regression estimate lies on the coolish side.

REFERENCES

Ellingson, R G, Hai-Tien Lee and D Yanuk, 1994: Validation of a technique for estimating outgoing longwave radiation from HIRS radiance observations, JAOT 11, 357-365.

Miskolczi, F, R Rizzi, R Guzzi and M M Bonzagni, 1988: A New High Resolution Atmospheric Transmittance Code and its Application in the Field of Remote Sensing, Proc of IRS'88: Current Problems in Atmospheric Radiation, Lille 18-24 August, 388-391.

Miskolczi, F, 1994: Modelling of Downward Surface Longwave Flux Density for Global Change Applications and Comparisons with Pyrgeometer Measurements, Journal of Atmospheric and Oceanic Technology, Vol 11, No. 2, 608-612.

Rizzi, R, 1994: Raw HIRS/2 radiances and model simulations in the presence of clouds, ECMWF TR 73, September.