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Validation of a radiation parameterization scheme using LASPEX data

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ABSTRACT

NCMRWF operational model forecasted surface radiation fluxes have been compared with LASPEX IOP observations of May, July, September and December, 1997. Some of the discrepancies in the model forecast are identified. A few modifications in the NCMRWF operational model radiation parameterization scheme are tried to reduce the disagreement. Presence of dust aerosols in the short wave radiation scheme reduces the errors seen in the net shortwave flux. A new weighting function for diurnal variation of downward longwave flux is also proposed.

Key words : Radiation parameterization, Short wave flux, Long wave flux, NCMRWF model.

Solar energy absorbed at the surface is the most important source of energy to the earth-atmospheric system. To keep this system in equilibrium, the surface loses some energy through longwave emissions. Rest of the energy exchange between surface and atmosphere occurs through sensible and latent heat fluxes. In the atmospheric models, accurate computation of radiation fluxes at the surface is important both for realistic representation of the surface energy balance and for an accurate computation of atmospheric processes. Here we try to compare the LASPEX-97 (Land Surface Process Experiment-1997) IOP (Intensive Observation Period) surface radiation flux observations at Anand with NCMRWF (National Centre for medium Range Weather Forecasting) operational model (hereafter, Control model) five-day forecast fluxes. Some modification to the shortwave (SW) and longwave (LW) parameterization is proposed for removing the discrepancies in the model forecast identified during the comparison of the control model fluxes with the observations.

MATERIALS AND METHODS

The surface radiation flux data collected from Anand observation point (22°35'N, 72°55'E) during the IOP of May, July, September and December 1997 of LASPEX is used in this study. Four five-day integrations were made with NCMRWF operational global model (Kanamitsu, 1989), which has GFDL radiation scheme (Lacis and Hansen, 1974; Schwarkopf and Fels, 1991). A brief description of NCMRWF operational global model is given in the Table 1. NCMRWF analysis for 13 May, 13 July, 14 September and 14 December, 1997 are used as the initial conditions for these integrations. Temperature and fluxes are picked up from the nearest grid point (23°18' N, 73°21' E). In the control model both SW (solar) and LW (terrestrial) radiation computations are

Table 1 : Brief description of NCMRWF global model

Model Elements	Components	Specifications
GRID	HORIZONTAL	Global Spectral-T80 (256X128; 256 points in a latitude circle, 128 points S. pole to N. pole)
	VERTICAL	18 Sigma (Pressure/Surface pressure) Layers [.995, .981, .960, .920, .856, .777, .688, .594, .497, .425, .375, .325, .275, .225, .175, .124, .074, .021]
	TOPOGRAPHY	MEAN
DYNAMIC	PROGNOSTIC VARIABLES	Rel. Vorticity, Divergence, Virtual Temp., Log of Surface Pressure, Water Vapour mixing ratio
	HORIZONTAL TRANSFORM	Orszag's Technique
	VERTICAL DIFFERENCING	Arakawa's energy conserving scheme
	TIME DIFFERENCING	Semi-implicit with 900 seconds of time step
	TIME FILTERING	Robert's method
	HORIZONTAL DIFFUSION	Second order over quasi-pressure surfaces, scale selective
PHYSICS	SURFACE FLUXES	Monin - Obukhov Similarity
	TURBULENT DIFFUSION	K-Theory
	RADIATION	Short Wave-Lacis & Hansen Long Wave- Fels and Schwarzkopf
	DEEP CONVECTION	Kuo scheme modified
	SHALLOW CONVECTION	Tiedtke method
	LARGE SCALE	Manabe-modified Scheme based on
	CONDENSATION	saturation
	CLOUD GENERATION	Slingo scheme
	RAINFALL EVAPORATION	Kessler's scheme
	LAND SURFACE PROCESSES	Pan Scheme having 3-layer soil model for soil temperature and bucket hydrology of Manabe for soil moisture prediction
	AIR-SEA INTERACTION	Roughness length over sea computed by Charnock's relation. Climatological SST, bulk formulae for sensible and latent heat fluxes
	GRAVITY WAVE DRAG	Lindzen and Pierrehumbert Scheme

done at 12 hr interval. To get the diurnal variation of fluxes at surface a diurnal cycle weight is applied on net SW and downward LW. Since SW computations are done with 12 hr average zenith angle at every point, the weight at any time step, t, is given by

$$SW\_W(t) = \frac{\text{zenith angle at the time t}}{\text{12 hr average zenith angle}}$$

Since LW radiation calls at 12 hr intervals (because radiation calls are computationally very expensive), in the operational model a weight (T4) is applied to the LW down at surface to account for the diurnal changes. At any time step t,

$$T4 = \left(\frac{T}{T_o}\right)^4$$

where T is the first model level temperature at t and T_o is the first model level (approximately 50 meter height from the surface) temprature at the time of radiation computation.

LW up from the surface is computed in the model using Stefan-Baltzmann's law ($\varepsilon\sigma T^4$) with surface emissivity (ε) value of one. Net LW flux is computed from the observation as the balance of net radiation flux and net SW flux (net LW flux = net radiation flux - net SW flux).

RESULTS AND DISCUSSION

Operational model SW fluxes

Comparison of operational model five-day forecast based on 13 May 1997 over Anand with the observation (Fig-1a) shows that the net SW at surface (Incoming SW at surface - reflected SW by the surface) is overestimated in the model forecast. Maximum difference in the flux is noted when the zenith angle is at the minimum. The small difference noted in the surface albedo value of the model and the observation point (less than 5% difference) has a definite role in the difference seen in the net SW. Apart from that, the presence of aerosols in the atmosphere also may have a contribution. The forecast based on 13 July, 1997 shows that (Fig-1b) model-forecasted net SW flux is more smooth compared to observation. This may be because, in the model, cloud computations are made only once in 12 hours. So the changes occurring in SW fluxes due to the variability of cloud amounts with 12 hr period are not accounted for in the model. Comparison between observations and model results during 14-19 September, 1997 period also shows that the model is not able to reproduce the high variability in Net SW (Fig-1c). This may be again due to deficiencies of the representation of clouds in the model. In the model clouds are generated purely based on the relative humidity distribution at each grid point. Even though we have compared the observation and model results from 14-19 December 1997 (Fig-1d), the quality of SW flux observationsduring this period seems to be not good.

Operational model LW fluxes

Comparison of observation during 13-18 May with operational model forecasted net LW at surface (LW down-LW up) shows that even though the model is able to follow the trend seen in the observations(Fig-2a), magnitude is out by around 50 Wm^{-2}. But during 13-18 July, 14-19 September and 14-19 December, the model shows diurnal variation (Fig-2b,2c and 2d) whereas the observations show very little diurnal

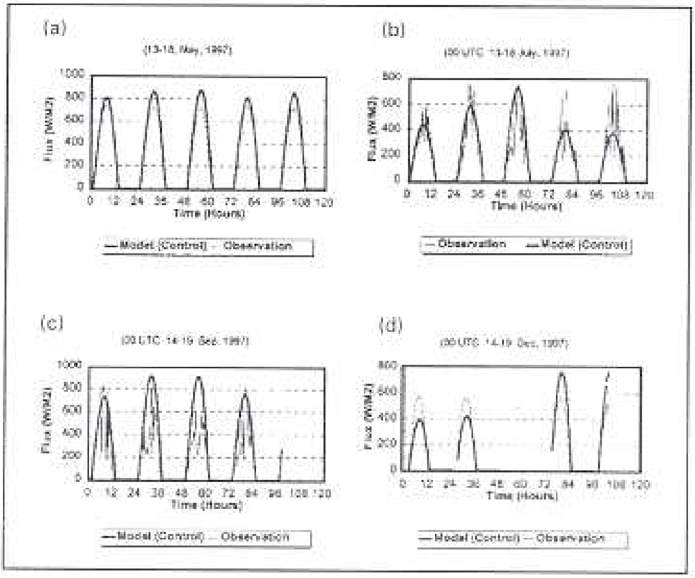

Fig. 1 : Net short wave at surface by control model and observation (a) May, (b) July, (c) September, (d) December

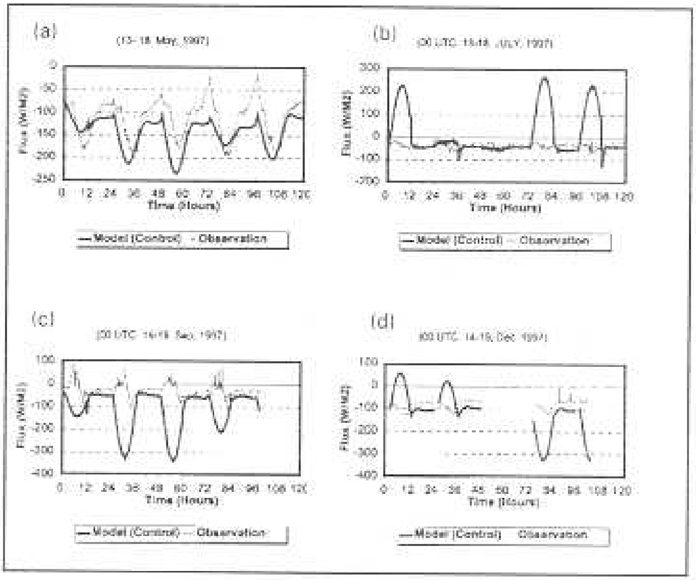

Fig. 2 : Net long wave at surface by control model and observation (a) May, (b) July, (c) September, (d) December

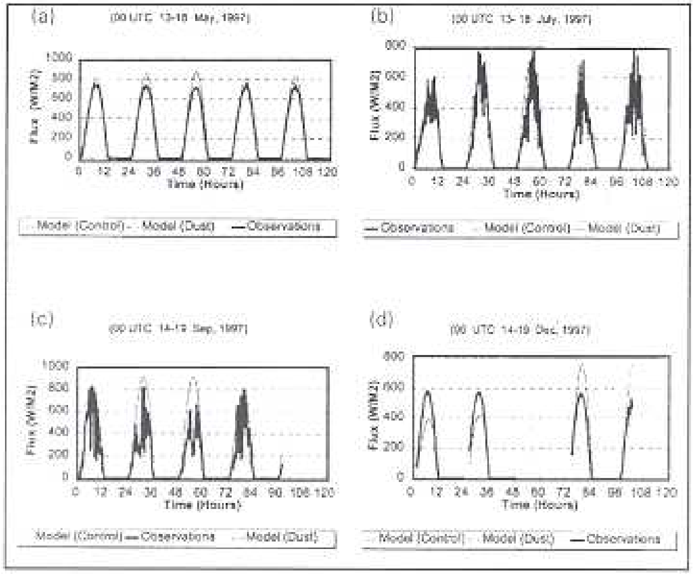

Fig. 3 : Net short wave at surface by control model, dust aerosol model and observation (a) May, (b) July, (c) September, (d) December

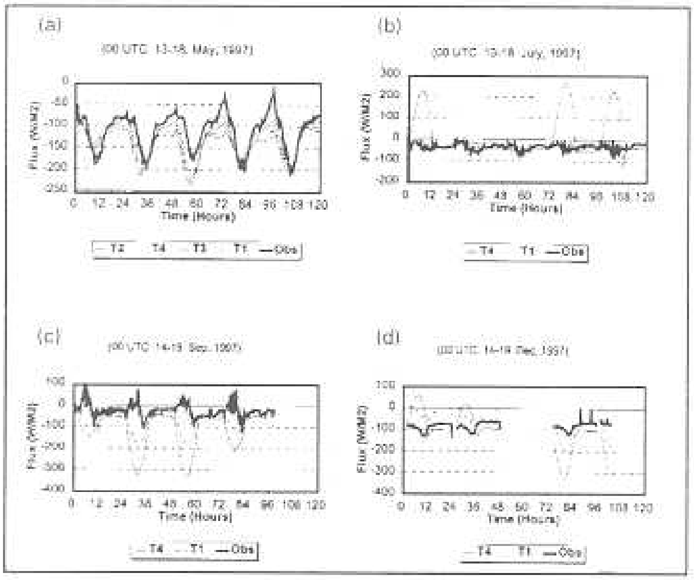

Fig. 4 : Net long wave at surface after applying weighting functions for diurnal cycle approximation (a) May, (b) July, (c) September, (d)December

variation.

SW experiment

Comparison of model SW fluxes with the observation clearly shows that in May radiation fluxes forecasted by the model are about 50-100 Wm^{-2} higher at the peak time (Fig-1a). So we tried to identify the reason for the difference between observation and model results. One reason may be the presence of dust aerosols in the atmosphere, which scatters and absorbs solar radiation. To see the effects of dust aerosol over Anand observation point, dust aerosol effects are computed using a dust aerosol model (Coakely *et al.* 1983 , Begum and George, 1999). In this model dust layer is assumed to be close to surface. Even though the aerosol optical thickness is highly variable, for simplicity, we have assumed light dust (Mohalifi, 1995) in all the four periods (Optical thickness = 0.4, Single scattering Albedo = 0.791, Asymmetry factor = 0.773) at Anand. In May (Fig-3a), the net SW at surface by dust aerosol model is less and close to observation, compared to operational model results. In other months also (Fig-3b, 3c, 3d) magnitude of net SW by dust model is less compared to operational model and most of the time dust model results are close to observations.

LW experiment

Comparison of model forecasts of net LW at surface with observation shows a large difference in magnitude. One possible reason for this difference may be the function used for diurnal approximation. In the operational model a 4th order temperature function is being used. So we tried other weighting functions for the diurnal approximations. They are

$$T1 = (T/T0);$$

$$T2 = (T/T0)^2;$$

$$T3 = (T/T0)^3$$

We applied all these weighting functions for all the four periods. In all cases, diurnal approximation with first order weight (T1) was closer to the observations (Fig-4).

CONCLUSION

Comparison of results of control model with observations show that forecasted surface flux trends, in general, are similar to what is observed in both SW and LW. But the magnitudes of model produced LW and SW fluxes are different compared to observation. The presence of dust aerosol in the model marginally reduces the SW peak and hence it is close to observations. In the LW diurnal cycle approximation, performance of first order weight is found to be better than the control model with fourth order weight.

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