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Validation of land surface parameters in NCMRWF model with LASPEX dataset

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ABSTRACT

In the first part of this study the LASPEX data for the IOP of May, July, September and December 1997 was used for validation of LSP parameters in the NCMRWF global model. In general, global model's predicted patterns of temperatures, fluxes and wind speeds are similar to be observed. The maximas and minimas are not predicted well. In the second part of this study, an attempt was made to run a single column LSP model of NCMRWF in a stand-alone mode with available surface parameters in LASPEX dataset. The results of 1-d model simulation are encouraging.

Key words: NCMRWF model, LASPEX data, 1-d model

Since the early development of General Circulation Models (GCMs) at the end of the 1960s, the major role played by the land surface parameters has been widely recognized. Correct specification of surface parameters in NWP models is as important as the initial state of the atmosphere. Some of the important land surface parameters which have impact on model predictions are land surface temperature, soil moisture, albedo, snow depth, roughness length and soil temperatures. The main purpose of any land surface processes (LSP) scheme is to provide the atmosphere with surface fluxes of momentum, heat and moisture.

In the first part of this study the LASPEX data for the IOP of May, July, September and December 1997 are used for validation of LSP parameters in the NCMWRF model. In the second part, an attempt was made to run a single column LSP model of NCMRWF in a stand-alone mode with available surface parameters in LASPEX dataset.

NCMRWF MODEL

The land surface processes in the operational model at NCMRWF (Rajagopal, 1999) have the following features [A detailed description can be found in the Manual of the E- Physics (Miyakoda and Sirutis, 1986].

1. The exchange coefficients for momentm, heat and moisture are computed based on Monin- Obukhov similarity theory with similarity functions of Businger *et al.* (1971) and Hicks (1976) as modified by Carson and Richards (1978).

2. Evaporation over land is based on the potential evapotranspiration of Pan (1990) where the effect of vegetation is taken into account through stomatal/plant resistance (r_s) and is given by

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$$LE_p = \frac{\Delta\ H + (1-\gamma)\ LE_a}{\Delta + (1+\gamma)(1 + C_h |V| r_s)}$$

where,

$$H = [(1-\alpha)\ SW_{dn}) + LW_{dn} - \sigma T_a^4 - G]$$

$(1-\alpha)SW_{dn}$ = downward short wave radiative flux

α = albedo

LW_{dn} = downward long wave radiative flux

σT_a^4 = upward long wave radiative flux at air temperature T_a

G = ground heat flux

LE_a = $L \rho C_h |V| (q_s(T_s) - q_a)$

Δ = Slope of the saturation vapour pressure curve.

= $L / c_p\ dq_s/dT |_{Ta}$

γ = Psychrometer constant

= $4 \sigma T_a^3 / \rho c_p C_h$

3. The ground heat flux (G) is computed based on Bhumralkar (1975) as

$$G = \frac{K_s C_s \rho_s}{Z_{g1} - d_s/2} (T_s - T_{g1})$$

where, K_s is the soil thermal diffusivity, C_s is the soil specific heat, ρ_s is the bulk soil density, Z_{g1} is depth of first subsurface soil layer (=10 cm), d_s is the thickness of surface soil layer (=5 cm) and T_{g1} is the soil temperature at depth Z_{g1}.

4. The subsurface three-layer model of Delsol *et al.* (1971) having levels at depths of 10, 50 and 500 cm is used.

5. The surface temperature over land is computed using the time dependent prognostic equation [Arakawa (1972), Corby *et al.* (1972]

$$\partial(C_s \rho_s d_s T_s)/\partial t = (1-\alpha)SW_{dn} + LW_{dn} - \sigma T_s^4 - H_o - LE_o - G - L_f E_x$$

where,

H_o = $-\rho c_p C_h (\theta(Z) - \theta(Z_o))$

LE_o = βLE_p

where, β = availability of soil moisture

$\beta = 1$ if $W > W_c$

$\beta = W/W_c$, if $W < W_c$

where W is the available soil moisture

$W_c = 0.75\ W_{fc}$

W_{fc} is the field capacity (=150 mm)

$L_f E_x$ = heat used for melting snow/ice.

6. Soil temperatures T_{g1} and T_{g2} are predicted using the soil heat conduction equation of Bhumralkar (1975)

$$C_s \rho_s \partial T_{gi} / \partial t = \lambda\ \partial^2 T_{gi} / \partial Z^2$$

where λ = thermal conductivity ($C_s \rho_s K_s$)

7. Interactive bucket hydrology of Manabe (1969) is used for updating soil moisture

$$\partial W/\partial t = R - E_o + S_m$$

where R is the rainfall, E_o is the surface evaporation, and S_m is the snowmelt rate.

Correct specification of initial surface boundary fields in a GCM is as important as the initial state of the atmosphere. Table 1 shows the initial surface boundary fields required for the NCMRWF model and their specification in the model.

Table 1: Specification of initial surface boundary fields in NCMRWF model.

Fields	Land	Ocean
Land/sea surface temperature	Forecast	Climatology (M)
Soil moisture	Forecast	-
Soil temperatures (T_{g1}, T_{g2})	Forecast	-
Snow depth	Forecast	Forecast
Roughness length	Climatology (S)	Forecast
Albedo	Climatology (S)	Climatology (S)
Plant resistance	Climatology (S)	-
Deep soil temperature	Climatology (A)	

A = Annual mean S = Seasonal mean M = Monthly mean

MATERIALS AND METHODS

Ten metre tower data of Anand for IOPs of May, July, September and December has been used in the study. Data at every 15-minute interval were extracted from the LASPEX dataset for the 4 months. In the first study four 5-day forecast runs were made with NCMRWF global model starting with initial global analyses of 13 May, 13 July, 14 September and 14 December. The model predicted surface parameters at the grid point closest to Anand station were extracted at 15-minute interval and compared with the corresponding observations.

In the second part of this study, an attempt was made to run a single column LSP model of NCMRWF in a stand-alone mode with the usable surface parameters in LASPEX dataset. The observed variables used in this simulation are:

1. Wind, temperature at 8 m, net short wave radiation at surface and downward long wave radiation at surface (Input at all model time steps at 15-minute interval).
2. Soil temperatures at 0, 10, 40 and 100 cm (Input at the initial time only).
3. For humidity at 8 m and soil moisture model extracted values were used at all model time steps.

The single column LSP model was run for 5 days with data starting from 13th of May and July corresponding to IOPs.

RESULTS AND DISCUSSION

The flow pattern at 850 hPa for all the four initial conditions used in this study are shown in Fig. 1. It can be seen that there are no major synoptic scale disturbances over Indian region on all the four days. In the following sections global model validation at Anand and results of single column LSP model will be discussed.

Global model validation

It can be seen from Fig.2 that the global model (referred to as T80 in all figures) for all the cases underpredicts the skin temperature and that model is not able to match the observed sharp rise and fall of skin temperature. It can be seen that model's diurnal temperature range is much lower than the observed, which could be due to errors in radiative forcing terms. In the case of air

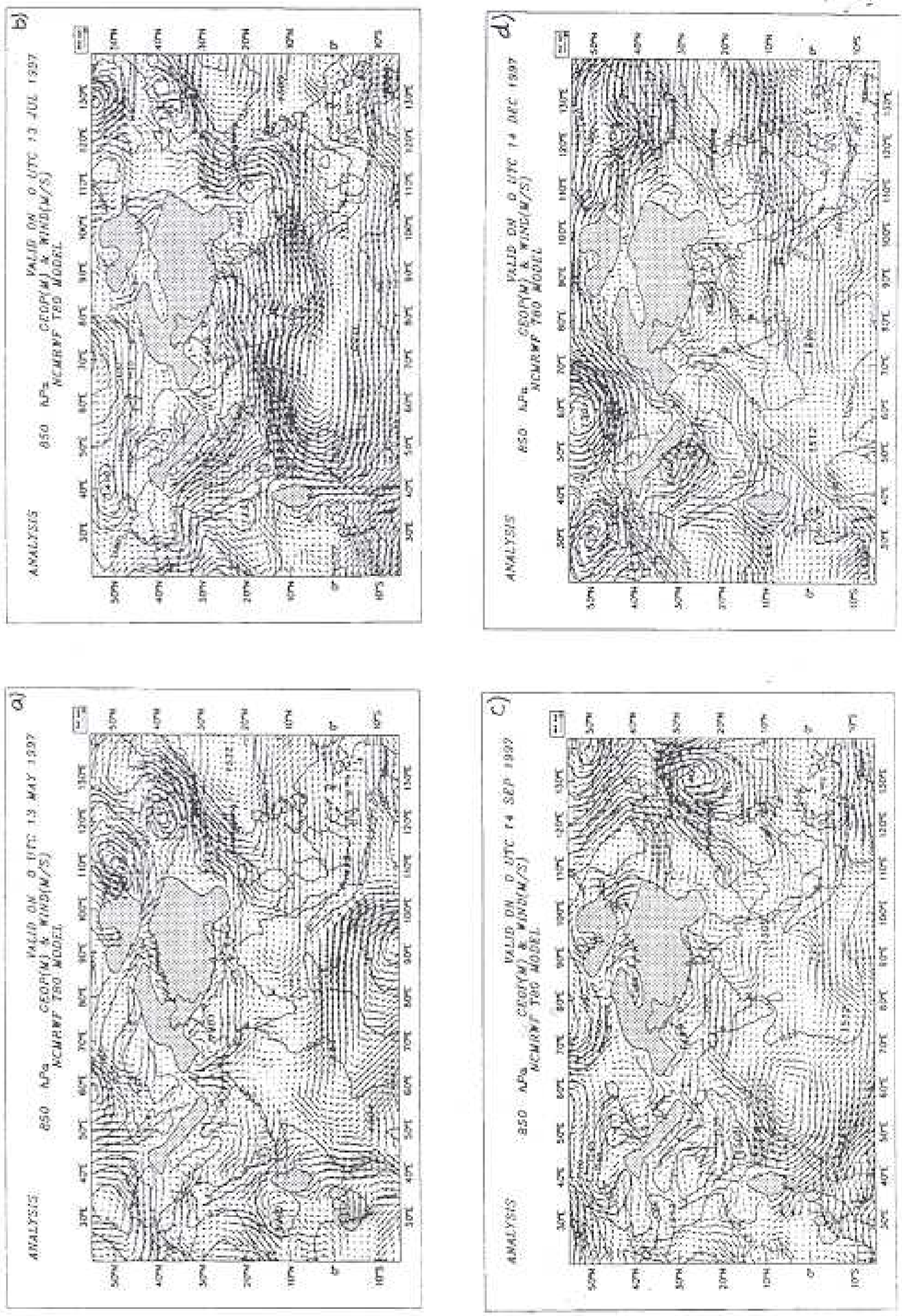

Fig. 1: 850 hPa Wind and Geopotential analysis valid for 00Z: (a) 13 May 1997, (b) 13 July 1997, (c) 14 Sept. 1997, (d) 14 Dec. 1997.

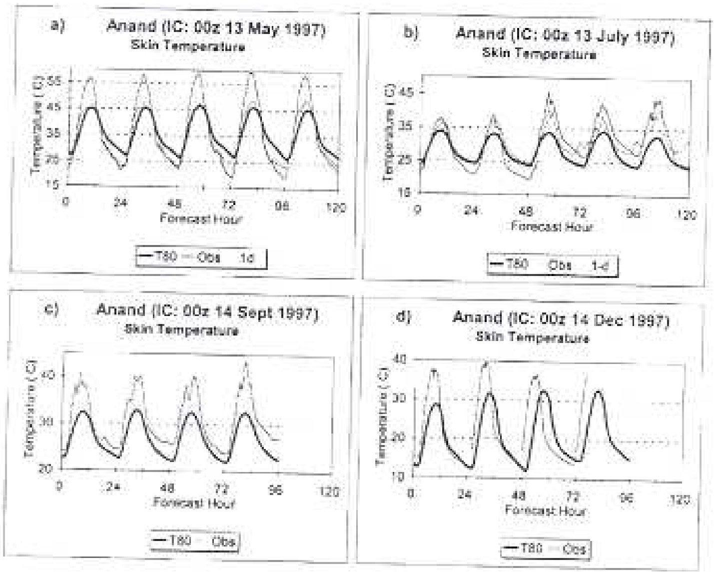

Fig. 2: Observed and predicted skin temperature (°C)

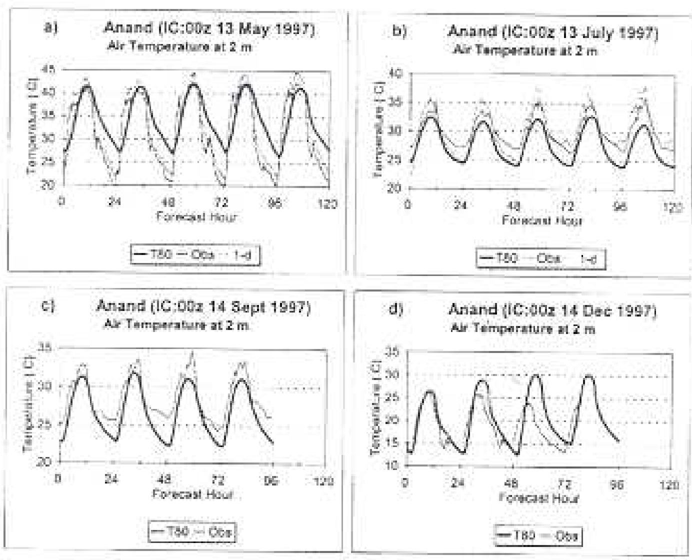

Fig. 3: Observed and predicted air temperature (°C) at 2 m

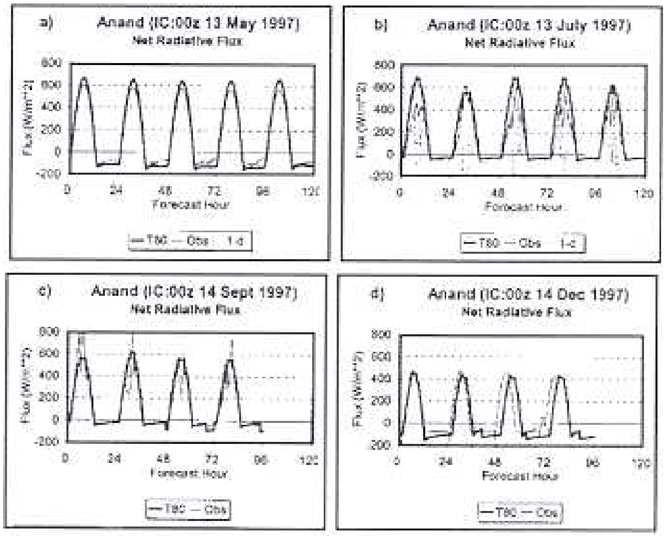

Fig. 4: Observed and predicted net radiative flux (Wm^{-2}) at surface

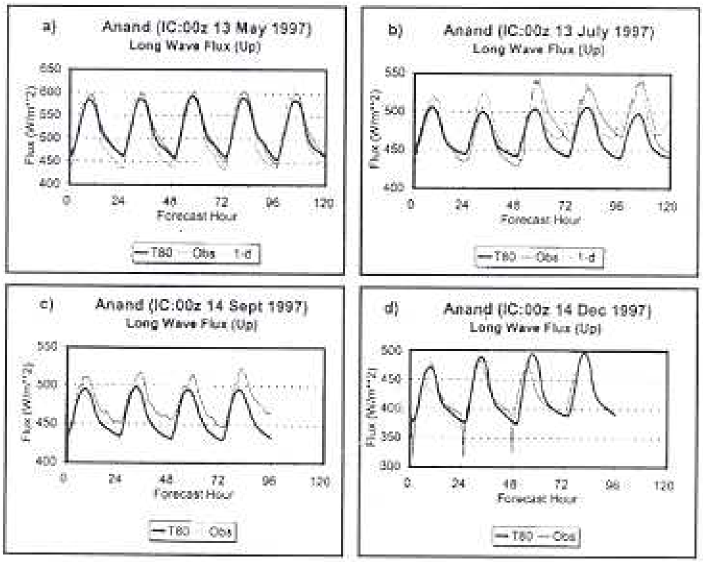

Fig. 5: Observed and predicted upward longwave flux (Wm^{-2}) at Surface

temperature at 2 m level (Fig.3a) model predicted minima are very high compared to the observed for the May case. For the July and September cases model predicted maxima and minima are lower than the observed, while for December case model maxima are higher. The reason for this type of behaviour of model's air temperature (which is quite similar to the skin temperature (Fig. 2)) could be the fact that this variable in the model is obtained by interpolation between skin and model's lowest level temperatures.

The surface net radiative flux, upward longwave flux at surface and the soil heat flux at 5 cm depth are shown in Figs. 4, 5 and 6 respectively. It can be seen that in general, the model's net radiative flux maximas are higher in all cases except in December. The observed kinks in the net radiative flux could be related to the monsoon clouds over the region. It should be noted that the model's flux also has small kinks, suggesting the presence of clouds in the model forecasts. The model's upward longwave flux is in general lower than that observed and the differences are larger for July and September months. The larger errors for the monsoon months could be due to errors in model cloud prediction. Fig.6 shows that the model predicts the general pattern of soil heat flux reasonably well, however it under predicts maxima and minima. This under prediction could be due to the negative feedback of the prediction errors in model's skin temperature and soil temperature at 10 cm (mentioned below).

Soil temperatures at 10 and 50 cm depths are shown in Figs. 7 and 8. Both temperatures are highly underpredicted by the model, which seems to highlight the deficiencies of the soil temperature prediction scheme used in the model. The model's 50 cm temperature has no diurnal variation at all while the 10 cm temperature shows a small diurnal variation, which is much small, compared to the observations. The model predicted wind speeds at 4 m level (Fig.9) are in general overpredicted, however, there is a good agreement with the observed trend. Predicted wind field is closest to the observed one in September and December and the largest errors are in May and July.

Single column LSP model results

It can be seen from Fig.2a that the single column LSP model's (hereafter referred to as 1-d model) predicted skin temperature maxima are still much lower than the observed values in May, however the predicted minimas are much closer. For July the predicted skin temperature is very close to that observed (Fig.2b). The large disagreement in May is to be investigated further by fine tuning some of the soil parameters used in the model.

There is in general a very good agreement in the case of air temperature at 2m level in both the months (Figs.3a-b), with a slight overprediction of the temperature maximas by the 1-d model. The net radiative flux was predicted reasonably well (Figs. 4a-b), with the exception of sharp fluctuations in the model simulated flux around noontime in the July case. These fluctuations could be due to presence/absence of clouds at those times in the 1-d model simulation. The upward longwave flux and soil heat flux at 5 cm (Figs.5-6) are simulated reasonably well by the 1-d model, with the predicted maxima and minima being slightly higher.

The 1-d model's soil temperature at 10 cm (Fig.7) is slightly better than the global model, however, the maxima are highly

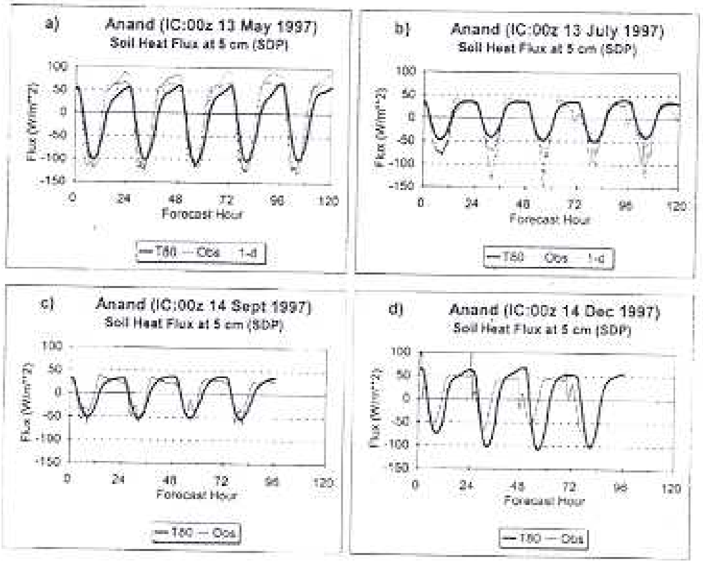

Fig. 6 : Observed and predicted soil heat flux (Wm^{-2}) at 5 cm

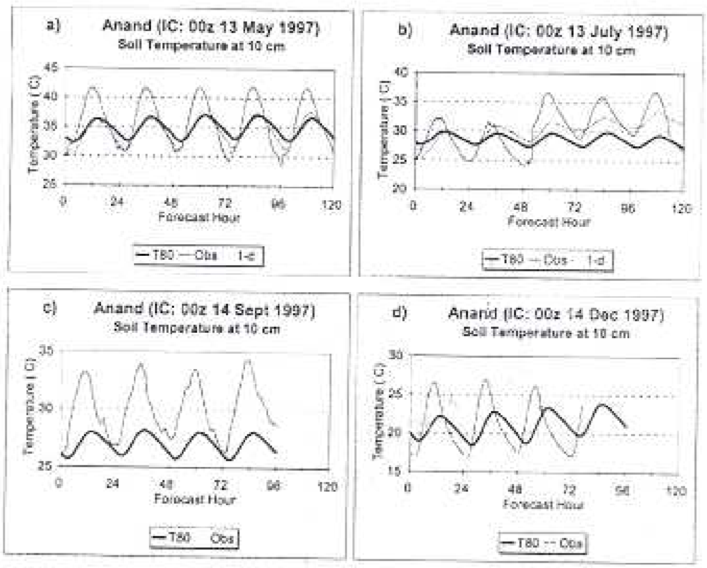

Fig. 7: Observed and predicted soil temperature (°C) at 10 cm

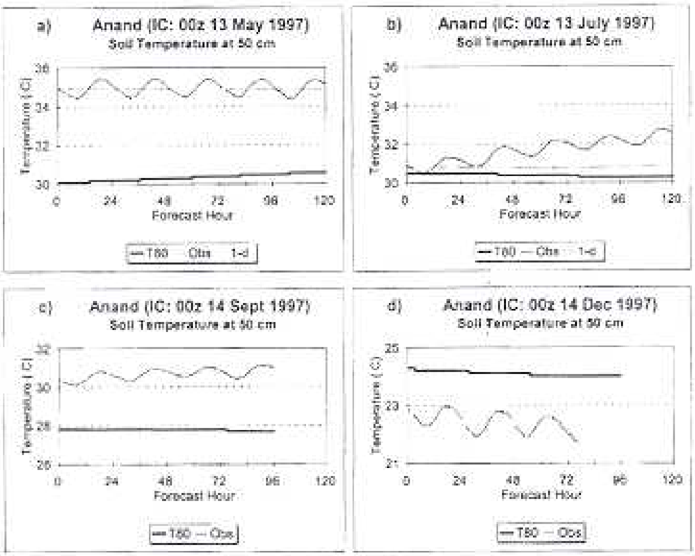

Fig. 8: Observed and predicted soil temperature (°C) at 50 cm

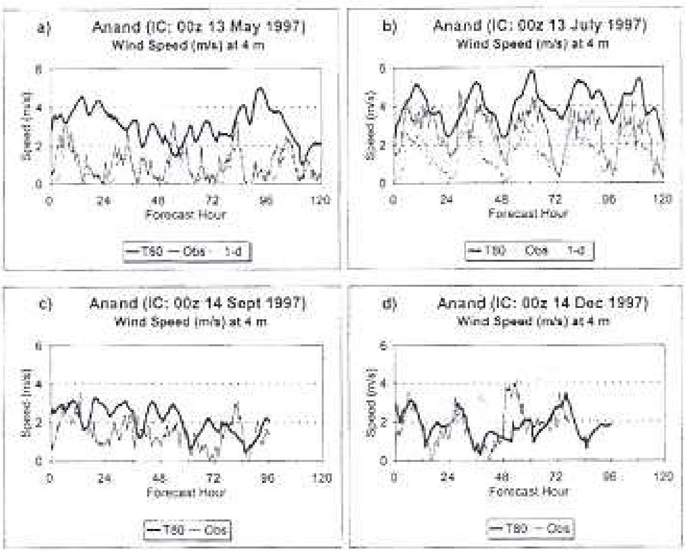

Fig. 9: Observed and predicted wind speed (ms^{-1}) at 4 m

underpredicted. It can be seen that 1-d model has been able to capture the observed increasing trend of the soil temperature in July. The 1-d model's soil temperature at 50 cm (Fig.8) just like the global model shows no diurnal variation. It appears that the initial input value is not getting modified during the whole simulation. The 1-d model's wind speeds at 4 m level (Fig.9) almost exactly match observed trend. However, wind speeds are always underpredicted by 1-d model and the differences are large in July.

CONCLUSIONS

In general, global model's predicted patterns of temperatures are similar to be observed. The maximas and minimas are underpredicted. The soil temperature at 40 cm depth showed very little diurnal variation in model forecasts. The global model's soil heat flux, longwave radiative flux and net radiative flux are quite comparable with observed values. Wind speed at 4 m level is in general overpredicted by the model in May, July and September cases.

The results of 1-d model simulation are quite encouraging. It will be a good tool to fine-tune some of the parameters used in the model's radiation and LSP schemes. Further work in this direction is to be attempted.

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