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An Improved Soil-Vegetation Physics for COAMPS™

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1. Introduction

The soil-vegetation model of Noilhan and Planton (1989) is efficient for operational uses, but it tends to overestimate the evaporation flux over wet soil and to underestimate the evaporation flux over dry soil (Nai et al. 2001). This problem can be partially corrected with a skin layer incorporated into the model (Viterbo and Beljaars 1995). This treatment was used to upgrade the simple soil-vegetation model installed in the Navy's Coupled System (COAMPS™) with a skin temperature computed diagnostically by an iterative algorithm from coupled nonlinear diagnostic equations (Nai et al. 2001). The upgraded model was tested with the measurements at the Oklahoma ARM central facilities and the results were encouraging. In this study, the following two physical processes are considered and parameterized to further improve the soil-vegetation model:

(i) Water vapor movement through the porous soil layer should enhance the evaporation flux over dry soil, especially when the soil water content is below the wilting point (Niu et al. 1997).

(ii) In the presence of runoff or rain, the soil water content should not jump to saturation instantly (as in the simple model) but the time scale of the saturation process should be controlled by soil water infiltration (Schaake et al. 1996).

2. Model equations

In the previous model, the skin temperature, T_s, was introduced into the equations for surface energy balance, but the above mentioned two physical processes were not considered in the formulation of latent heat flux [see (1)-(5) of Nai et al. 2001).

The above first physical process is parameterized and incorporated into the total evaporation flux, that is,

$$E = E\mathrm{g} + E\mathrm{tr} + E\mathrm{r} + E\mathrm{v}. \qquad (1)$$

Here, the first three terms are the evaporation fluxes from bare soil, foliage (transpiration) and intercepted water on foliage as in Noilhan and Planton (1989). The last term is the evaporation due to water vapor movement through the soil. This new term is given by

$$E\mathrm{v} = \rho U C_q\{A[Bq_{sat}(T_g) - q_a] + d\sin(\pi C)\}, \qquad (2)$$

where ρ is the air density, U the wind speed, C_q the coefficient for moisture flux, and $q_{sat}(T_g)$ the saturation specific humidity at the soil temperature T_g. Here,

$$A = (a/T_g)(w_{sat} - w_g)(w_{sat} - w_2),$$
$$B = b\sin(\pi A),$$
$$C = c(T_g - T_2)^2/T_s^2,$$

where w_{sat} is the saturation soil water content, w_g the soil water content, T_2 and w_2 the temperature and water content, respectively, for the deep soil layer, T_s the skin temperature, and a, b, c and d are constants estimated by fitting the model to ARM measurements.

The effect of soil water infiltration is parameterized by reducing the precipitation in the soil water equations (11)-(12) of Noilhan and Planton (1989) as in Chen et al. (2001). The reduction ratio is given by

$$[r/(s - P)]\exp[-t(w_g - w_{wil})/(w_{sat} - w_{wil})], \qquad (3)$$

where w_{wil} is the wilting soil water content, P the precipitation, and r, s and t are constants estimated by fitting the model to ARM measurements.

3. Data description

The Oklahoma ARM central facilities include Surface Meteorological Observation Station, Solar and Infrared Radiation Observation Station and Energy Balance Bowen Ratio Station. The observed wind speed, air temperature and humidity, precipitation, upward and downward shortwave radiative fluxes, and downward longwave radiative flux are used as input data to compute the boundary conditions and external forcing for a single-column version of the soil-vegetation model. The observed sensible heat flux H, *latent* heat flux λE, ground heat flux G, net radiative flux R_n, soil temperature T_g and water content w_g are used to verify the model's predictions (initialized by observed soil temperature and water content). The soil type is silt loam based on a Hybrid 16-category soil texture map, the vegetation type is pasture based on a USGS 24-category vegetation/land-use map, and the vegetation cover is 0.42 (for June and August) based on a NESDIS monthly climatology vegetation fraction map.

4. Results

For the dry period of 14-19 August 1999, the observed and predicted soil water contents are all below the wilting point (Fig. 1d), but the observed latent heat flux is not small and is captured only by the new model

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prediction (solid in Fig. 1b). The old and previously upgraded models overpredict sensible heat flux (Fig. 1a) and severely underpredict latent heat flux (nearly zero as shown by the gray solid and dashed in Fig. 1b). The parameterization in (2) is effective in enhancing the surface evaporation in this case. The predicted soil temperatures are for the top layer (shallower than the 0-0.05 m observation layer), so their diurnal variations are larger than the observed. The statistics are compared in Table 1 where RMS is the rms error and TCC is the time correlation coefficient with the observations.

The models are also tested for the wet period of 24-30 June 1999. The statistics are listed in Table 2 for the rainy day (June 30). The results indicate that the parameterization in (3) is effective in correcting the overpredicted soil water content and latent heat flux by the old and previously upgraded models.

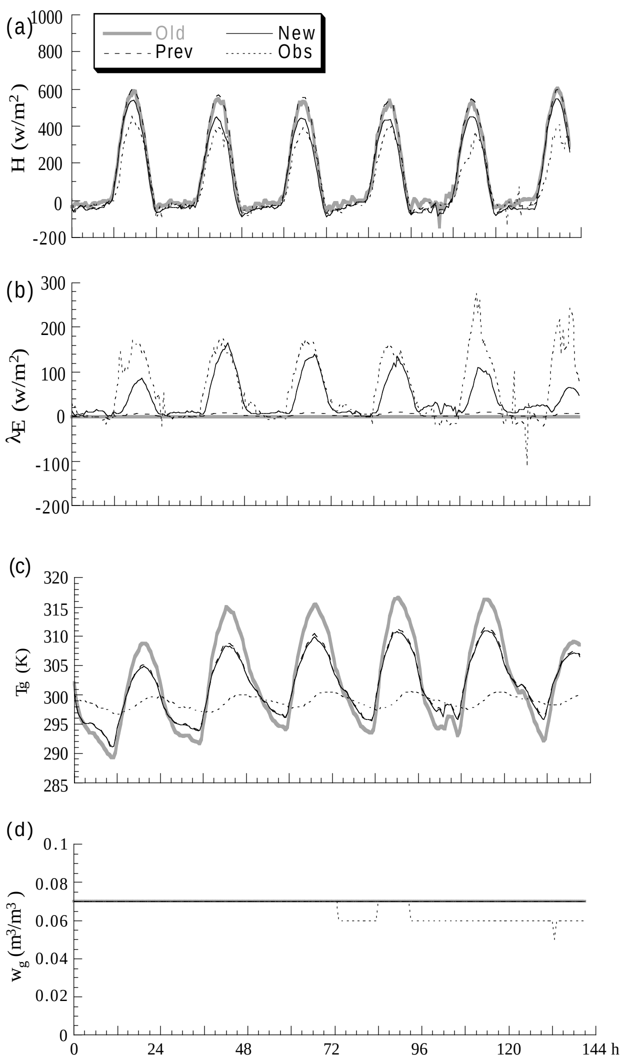

Fig. 1. Predicted (by the new, previous and old models) and observed (a) sensible and (b) latent heat fluxes, (c) soil temperatures, and (d) soil water contents for the dry period (August 14-19, 1999).

Table 1. Statistics for the dry period.

		H	λE	G	R_n	T_g	w_g
New	RMS	69.2	53.9	15.7	10.1	5.5	0.003
	TCC	0.96	0.76	0.80	1.00	0.49	0.90
Prev	RMS	98.4	90.7	15.9	8.8	5.7	0.004
	TCC	0.98	0.82	0.80	1.00	0.49	0.90
Old	RMS	88.5	95.3	24.8	13.2	8.1	0.005
	TCC	0.98	0.00	0.83	1.00	0.5	0.00

Units: w/m^2 for fluxes, ^0K for T_g, and m^3/m^3 for w_g.

Table 2. Statistics for the rainy day (30 June 1999)

		H	λE	G	R_n	T_g	w_g
New	RMS	104.7	74.8	20.0	30.4	2.35	0.029
	TCC	0.76	0.89	0.66	0.99	0.39	0.93
Prev	RMS	184.5	232.2	23.1	33.8	1.59	0.064
	TCC	-0.66	0.91	0.65	0.99	0.64	0.86
Old	RMS	198.0	231.2	28.1	45.4.2	1.72	0.062
	TCC	-0.60	0.93	0.56	0.98	0.62	0.93

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