Comparison of surface models CLASS and ISBA over North America

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Context

The Canadian land-surface model CLASS and the French model ISBA were run in parallel from 1 May 2002 to 31 March 2003 over North America at a resolution of 10 km. Both models were forced by the same meteorological input (downward radiative fluxes, precipitation, and temperature, wind and humidity at ~ 40 m) from a series of 24 hour forecasts from the operational model at the Canadian Meteorological Centre (CMC). The surface fluxes produced by each model did not feed back on the atmospheric model (off-line mode).

Similarity and differences between the models

The ISBA model is the version present in the operational forecast model at CMC, while CLASS is version 3.0 but without the mosaic capability, the new sloping terrain runoff parameterization and without organic soils. A maximum number of common parameters were given to both models to minimize the differences between them. Vegetation and soil types, vegetation roughnesses and albedos as well as the thicknesses of permeable soil were identical. Leaf area indices, vegetation fractions and initial values of temperature and soil moisture were very close.

Despite the efforts to make both models share the same parameters, structural and formulation differences remained. The principal differences are listed here.

Surface temperature and energy budget: CLASS makes distinct calculations for vegetation and bare ground, and for snow covered and snow free portions of each grid point; ISBA makes a single calculation.

Heat and moisture vertical transfers in the soil: CLASS uses a diffusion equation and Darcian equations with three soil layers while ISBA uses a 'force-restore' approach with the diurnal time scale for both variables.

Stomatal resistance: ISBA uses a linear function of soil moisture content between the wilting point and the field capacity for modeling the effect of soil water while CLASS uses an exponential function, giving less resistance to transpiration for low and moderate soil moisture contents.

Infiltration and runoff: ISBA uses the VIC (Variable Infiltration Capacity) model while CLASS uses the Green-Ampt approach with surface ponding. Frozen soil impedes infiltration in CLASS but not in ISBA.

Thawing and freezing of ground water: This process is not handled conservatively in ISBA, underestimating its impact on soil temperature.

Water reservoirs: ISBA has a liquid water reservoir on the canopy while CLASS holds both rain water and snow. CLASS has a liquid water reservoir at the surface (ponding), three liquid and three solid ground water reservoirs while ISBA has two liquid and one solid water reservoirs in the ground. On the other hand, ISBA has a liquid water reservoir in the snow, which CLASS does not have yet.

Results

Results indicate larger runoff in ISBA, except that due to snow melting over frozen soil. This is due in part to the large value of the form parameter (b=1.0) used by ISBA in its infiltration model. This larger runoff resulted in generally smaller soil water contents in ISBA and hence smaller evapotranspiration rates. The difference in the formulation of the stomatal resistance (see above) also contributes to larger evapotranspiration in CLASS. There are areas, however, where ISBA evaporates more than CLASS. These are over warm and wet grounds, where it was found that bare soil evaporation is considerably larger in ISBA due to the large roughness length that it shares with the rest of the grid tile; in CLASS a separate (smaller) value of roughness is assigned to bare soil and the corresponding evaporation is smaller.

Snowmelt is slower in ISBA, partly because ISBA retains liquid water in the snow, which can refreeze at night, but also because it allows more sublimation than CLASS. This extra sublimation (which takes much more energy than melting and thus reduces snowmelt) is due to larger than zero Celsius temperature in ISBA in the snow, an unrealistic feature of the model.

Differences are also found in nighttime surface temperature during fall due to a combination of two factors. The force-restore scheme in ISBA handles reasonably correctly the diurnal cycle but completely ignores the annual (or seasonal) cycle. In particular, the upward ground heat flux during the fall coming from a warmer deep layer is missing and this contributes to cooler temperatures at the surface than with CLASS. The other factor is the underestimation in ISBA of the heat released by the freezing of ground water, which also contributes to lower the temperature at the surface during ground freezing episodes. The reverse effect should be found during spring but limitations in our experimental setup did not allow us to see it.

Conclusions

ISBA and CLASS generally gave similar results but differences in structure and in formulation are reflected in the results. While the latter can easily be modified (for example the stomatal resistance formulation), structural features such as the internal mosaic of CLASS or the 'force-restore' of ISBA keep each model different from the other.

Reference

Labadie, C. and É. Mallet, 2003: ``Comparaisons des modèles de surface ISBA et CLASS du 1er mai 2002 au 1er mars 2003 au-dessus de l`Amérique du Nord``, Rapport de stage, Recherche en prévision numérique, Service Météorologique du Canada, Dorval, Québec.

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