Ticket 333: Adjusting the masks in the albedo code (@r8868)

CABLE evaluates a number of working variables, including the effective albedo/effective surface reflectances (4-band), differently according to whether the surface is vegetated or not, and/or sunlit or not. In ACCESS and JAC there has been a long-standing issue that the downwelling shortwave (i.e. whether the surface is sunlit or not) is not known until after the albedo is required. In ACCESS1.3, ESM1.5 and CM2 this issue was bypassed by substituting JULES albedos for CABLE's on the first time step. This method will not be possible/accepted by UMST for inclusion in JAC. Additionally this method fails the important test that a run comprising two model time steps is equivalent to running two separate model runs of one time step (with a restart in between).

A deeper assessment of the source code (for ACCESS and CABLE) indicates that 4 variables are problematic. These variables are evaluated in the init_radiation() and albedo() subroutines under the cable_radiation_driver interface routine between the UM/JULES and CABLE. They are - in init_radiation()

- EffExtCoeff_beam [formerly rad%extbm]

and in albedo()

- CanopyRefl_beam [rad%rhocbm]
- CanopyTransmit_beam [rad%cepkbm]
- EffSurfRefl_beam [rad%reffbm]

These variables are calculated differently if the local surface is both vegetated (LAI > threshold) and sunlit (downwelling shortwave > threshold) to when they are not. Typically they take a fixed constant value if the surface is not vegetated or not sunlit – usually the value for bare soil - and vary with (the cosine of) zenith angle and the properties of the vegetation if 'sunlit and vegetation'.

Of these variables – only EffSurfRefl_beam is used within the UM. This variable equates to the direct beam components of the 4-band surface reflectances – UM variables ALB_TILE and LAND_ALBEDO_CABLE[1]

Inside CABLE these variables are used within the radiation() subroutine. At this point within ACCESS the downwelling shortwave is available and the sunlit masks can be determined. Importantly ALL instances of the use of these 4 variables are restricted inside radiation() to be inside an equivalent condition on the surface being both vegetated and sunlit. There are no other uses of these four variables outside of the radiation() module – though there are downstream dependencies on variables which depend on them. This property implies that CABLE could evaluate these 4 variables beyond the 'sunlit and vegetation' condition without consequence, since the later restriction prevents the use (of bogus values) outside of the valid range.

Proposed solution

The underlying proposed change to the model can be expressed mathematically as changing

$$X = \begin{cases} f(\text{veg}, \cos\theta) & \text{if vegetated and sunlit} \\ \text{default} & \text{otherwise} \end{cases}$$

where *X* is any one of the 4 problematic variables and veg is a set of parameters, to

[1] In the ongoing development of JAC we need to check whether LAND_ALB_CABLE – the grid-cell averaged, beam-diffuse weighted albedo - is required as part of surf_couple_radiation. This variable was evaluated in CM2 and ESM1.5 in the corresponding part of the model but appears to have been superfluous. Unlike the other two variables which are passed directly to the UM, LAND_ALB_CABLE is passed into a DATA module.

$$X = \begin{cases} f(\text{veg}, \cos\theta) & \text{if vegetated} \\ \text{default} & \text{otherwise} \end{cases}$$

Importantly while *X* takes a different value if the surface is vegetated but not sunlit, only the values of *X* when both vegetated and sunlit are to be used.

The relaxation retains the restriction on whether the location is vegetated or not, as the problematic variables do depend on vegetation parameters and variables such as snow free leaf area. Since, we can expect that all vegetated surfaces will be sunlit at some point during a simulation we do not expect that this relaxation will cause problems – whereas attempting to evaluate these variables for non-vegetated surfaces will likely cause problems since necessary parameters may not have sensible values.

Implementation

In practice the change has been implemented by replacing the sunlit_veg_mask and sunlit_mask LOGICAL variables by the corresponding veg_mask LOGICAL variable in the calls to init_radiation() and albedo(). In the offline trunk these routines are called from cbl_offline_model_driver(). In the CM/ESM these calls are from cable_radiation_driver() and cable_cbm() – though this has not been implemented in order to preserve backwards compatibility (see below).

Importantly the call to the radiation() subroutine retains the distinction between the three masks.

Results at r8868

A set of serial offline CABLE runs have been completed using the benchcab system (170 FLUXNET sites, 4 science configurations). These runs demonstrate that the change in the use of the masks as described above produces no change (at the bit level) across 16 variables (fluxes and state variables).

Global offline CABLE runs using the mpi option have not been completed yet – but are not expected to result in any differences.

The change has been devised in such a way that backwards compatibility with the existing approach in the ESM is preserved. However, if the equivalent changes to the calls to init_radiation() and albedo() were implemented within the coupled model (CM or ESM) then we should expect changes. This is because the EffSurfRefl_beam variable takes a different value under some conditions (vegetated non-sunlit conditions) and this may become relevant within the UM[2]. Since the changes implemented here will be necessary for JAC – and hence ACCESS-CM3/ESM3 – some short runs using the different masks in the coupled model are worthwhile.

[2] Specifically, the UM only evaluates the surface reflectances as part of the UM"s radiation subroutines and this does not happen every model time step. During dusk or dawn periods some of the model time steps will be sunlit and some not. Consider, for example, the case where the radiation scheme evaluates the surface reflectances as if the surface were not sunlit but then the sunrises. These values of the surface reflectances are used to evaluate the downwelling shortwave at the surface once the sun rises - and so if they take different values then this can propagate into CABLE later on.

In practice the current CM/ESM implementation is a bug - the natural value for the reflectances when vegetated and not sunlit should be close to/equal the reflectances when vegetated and a very low sun angle (not a default, bare soil value). Additional work on the functional forms of the f functions maybe needed to ensure the transition is smooth but is a separate issue to the technical problem at the heart of Ticket 333..