Coupling CABLE into the UM: The REV_CORR package (Ticket 139)

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A previous examination of the CABLE model has revealed several structural differences depending on whether the model is used in surface-only mode or coupled to the UK Met Office's UM atmospheric model in ACCESS. Briefly these are that

1. CABLE is twice per time step when run in coupled mode. The first call only undertakes the diagnostic energy balance calculations; the second call undertakes both diagnostic energy balance and prognostic (e.g. soil temperature) calculations given (minor) adjustments to the atmospheric forcing.
2. CABLE is required to provide values for the fluxes at the end of the time step to the atmosphere; in surface-only mode the default is for the output fluxes to be at the beginning of the time step.
3. In recognition of 2 an assumed evolution of the surface energy balance of the soil column through the time step is incorporated into the output of CABLE in coupled mode. These are the 'correction terms'.

Aspect 1 has been addressed in a separate set of working documents/results. This note outlines concerns about the current (CABLE v3933) implementation of the correction terms, in particular their completeness, their formulation and how they interact with other components of CABLE. This note will comprise both mathematical manipulations and code discussions (for which some background knowledge of the code will be necessary).

Concerns with the correction terms

There are several interrelated concerns with the correction terms as currently implemented. The following is a brief list of concerns, further details on each are given after next:

1. They are incomplete in that while the turbulent fluxes of sensible and latent heat are corrected the other fluxes are not corrected. This must have consequences for the (diagnosed) energy balance closure and potentially for ACCESS performance.
2. They appear to be incomplete in that while the impacts of changes (over the time step) in surface soil temperature on the energy balance is incorporated into the correction terms there are no associated corrections due to changes in surface soil moisture content.
3. The functional form of the correction terms appears to be over sensitive, resulting in large values for the correction terms (which potential violates other assumptions in CABLE and ACCESS, including the formulation of the correction terms themselves).
4. The correction terms have only been written for one particular form of the soil latent heat flux whereas CABLE routinely carries at least two functional forms (Penman-Monteith and humidity deficit).
5. The uncorrected latent heat flux (as per the surface-only model) is restricted by physical limits. However the correction terms and, hence, the corrected latent heat flux is not restricted.
6. The correction terms have an associated implied correction to the soil moisture. In the current code this correction (necessary to conserve water) is applied but on the subsequent time step (i.e. conservation is not assured on a time step by time step basis).

The REV_CORR package introduced here addresses concerns 1, 3 and 4. In addition the package also covers code changes to address Ticket #67, a bug fix in the calculation of the friction velocity (Ticket #138), extensions to incorporate 'litter' resistances in the calculation of screen level temperature/humidity and permit their output (in offline simulations) and includes an alternate algorithm for the calculation of within canopy air temperature/humidity.

Origin of the correction terms

As noted above, ACCESS requires CABLE to provide surface fluxes of sensible and latent heat at the end of a time step. As the temperature and moisture within the soil column evolve through the time step, the surface fluxes also evolve. This evolution needs to be incorporated into the fluxes that are passed back to the UM. Within CABLE & ACCESS 1.4 the linearization approach of McGregor et al. (1993) was used – three considerations are particularly relevant for this discussion

1. The increments to the soil fluxes should be small in magnitude so as to be considered minor perturbations and thus conform to the linearization. The increments must also respect any physical limits on their value.
2. Increments to the soil fluxes imply changes to the conservation of energy and moisture within the soil column. The conservation requirements must be satisfied.
3. The McGregor et al. (1993) approach was applied to a model of simpler structure than CABLE.

Despite point 1 ACCESS simulations can be found (Ziehn pers. com.) where the correction terms to the surface fluxes can be substantial (100 Wm^{-2} in magnitude or greater).

Away from conditions involving the melting or freezing of soil moisture, CABLE soil temperature, T_s, evolves according to the heat conduction equation (Kowalczyk et al. 2006)

$$\frac{\partial \rho_s c_s T_s}{\partial t} = -\frac{\partial G}{\partial z} = \frac{\partial}{\partial z}\left(\kappa_s \frac{\partial T_s}{\partial z}\right) \tag{1}$$

where *G* is the flux of energy within the soil (positive downwards). The soil parameters, ρ_s, c_s and κ_s are themselves dependent on soil moisture, however over a time step these are held constant. The boundary conditions for (1) are a zero heat flux at the base of the soil column and the energy balance at the soil surface i.e.

$$-\kappa_s \frac{\partial T_s}{\partial z} = G = (1-\alpha_s)S + L^{\downarrow} - \varepsilon_s \sigma T_s^4 - \lambda E_s - H_s \tag{2}$$

where the symbols take their usual meaning. In (2) three terms directly depend on the surface temperature and hence co-evolve as the soil temperature varies over a time-step. Unfortunately as two of these terms are nonlinear it is problematic to combine (1) and (2) within one solvable system for the temperature (and fluxes) at the end of the time step.

The McGregor (1993) approach linearizes the energy balance (2) around the state at the start of the time step (indicated by subscript 0) to give

$$G = (1-\alpha_s)S + L^{\downarrow} - \varepsilon_s \sigma T_{s0}^4 - \lambda E_{s0} - H_{s0} - \left(4\varepsilon_s \sigma T_{s0}^3 + \lambda \frac{\partial E_{s0}}{\partial T_s} + \frac{\partial H_{s0}}{\partial T_s}\right) \partial T_s \tag{3}$$

Eqns (1) and (3) can be combined in a linear system. CABLE discretises the combined equation, in time and into soil layers, to form a single set of linear equations for the change in T_s over the time step – *this applies in all simulations including surface-only*. The second and third terms in the bracket are the 'correction' terms, specifically

$$H_{cor} = \Delta T_s \frac{\partial H_{s0}}{\partial T_s}, \qquad \lambda E_{cor} = \Delta T_s \lambda \frac{\partial E_{s0}}{\partial T_s} \tag{4}$$

are determined given the change over the time step in soil surface layer temperature, ΔT_s, after the soil temperature is evolved within ACCESS simulations.

This formulation is specific to the 'soil_snow' default soil scheme – and applies in both offline and coupled simulations. Consequently while identified through consideration of ACCESS, surface-only CABLE simulations are also effected by the concerns raised earlier.

Concern 1: Incompleteness of the energy balance (coupled simulation diagnostics).

As is evident from (3) if the correction terms are applied to the sensible and latent heat fluxes within the energy balance then the corresponding terms on the longwave radiation and ground heat flux should also be applied. In ACCESS these associated corrections are not applied. The correction term to the ground heat flux is (most likely) purely diagnostic. However the corrections to the outgoing longwave radiation should impact the determined surface radiative temperature and hence, potentially, feedback onto the radiation scheme of ACCESS. These two fluxes should be adjusted when CABLE is run within ACCESS so that

$$L^{\uparrow} = \varepsilon_s \sigma T_{s0}^4 + L_{cor}^{\uparrow} = \varepsilon_s \sigma T_{s0}^4 + 4\varepsilon_s \sigma T_{s0}^3 \Delta T_s \tag{5}$$

and

$$G = G_0 + G_{cor} = G_0 - L_{cor}^{\uparrow} - H_{cor} - \lambda E_{cor} \tag{6}$$

The algorithms determining the evolution of the soil column within CABLE are unchanged.

Concern 2: Incompleteness of the linearization

McGregor (1993) notes that for full applicability linearization around all the state variables involved in the energy balance should be considered. Within ACCESS an alternate approach to incorporate changes to the atmospheric forcing variables is adopted (and hence the double call) – however this leaves soil moisture as unconsidered.

Following on from (3) the corresponding linearization of the ground heat flux around surface layer soil moisture content, w_s, is

$$G = (1-\alpha_s)S + L^{\downarrow} - \varepsilon_s \sigma T_{s0}^4 - \lambda E_{s0} - H_{s0} - \lambda \frac{\partial E_{s0}}{\partial w_s} \partial w_s \tag{7}$$

i.e. there is a second component to the correction term for latent heat. The sensitivity term $\partial E_{s0}/\partial w_s$ has a non-trivial formulation – it depends on the functional form of the potential evaporation, the functional form of the soil wetness factor, β, whether there are puddles present and/or snow cover.

Implementation: This is a complicated issue to resolve and interacts with concerns 3-6. This correction was assessed by McGregor (1993) and found to be negligible on ground of magnitude. Hence while theoretically necessary for completeness addressing this concern has been deferred.

Concern 3: Functional form of the currently implemented correction terms.

The functional form of the correction terms, as currently implemented, assumes bulk aerodynamics forms are used for both turbulent fluxes. The sensible heat flux from the soil is

$$H_s = \rho c_p \,(T_s - T_{vair})/r_{tsoil} \tag{8}$$

with T_{vair} the within-canopy air temperature and r_{tsoil} the aerodynamic resistance to turbulent transfer of scalars form the soil surface. Consequently

$$\frac{\partial H_s}{\partial T_s} = \frac{\rho c_p}{r_{tsoil}} \tag{9}$$

Away from physical limits the humidity deficit method form for the soil latent heat flux gives

$$\lambda E_{s0} = \beta \lambda f_{cls} E_{pot} = \beta \lambda f_{cls} \rho \,(q_s(T_s) - q_{vair})/r_{tsoil} \tag{10}$$

where q is the mixing ratio of water, q_s is the value of q at saturation, β (the soil wetness factor) relates actual soil evaporation to potential evaporation, E_{pot}, and f_{cls} quantifies the difference between latent heat of evaporation and sublimation, i.e. is $f_{cls} = 1$ if the surface is above freezing and 1.1335 if below. The corresponding sensitivity term is given as

$$\frac{\partial \lambda E_s}{\partial T_s} = \frac{\mathrm{d}\Delta q}{\mathrm{d}T_s}\frac{\partial \lambda E_s}{\partial \Delta q} = \frac{\mathrm{d}q_s(T_s)}{\mathrm{d}T_s}\frac{\partial \lambda E_s}{\partial \Delta q} = \frac{\rho\beta\lambda f_{cls}}{r_{tsoil}}\frac{\mathrm{d}q_s(T_s)}{\mathrm{d}T_s} \tag{11}$$

where $\Delta q = q_s(T_s) - q_{vair}$. To obtain (11) it is evidently necessary to assume that q_{vair}, and hence Δq, is independent of T_s.

Note that the Penman-Monteith form for the soil latent heat flux is derived form an expression of mathematical equivalence to Eq (10) and consequently the same sensitivity term $\partial \lambda E_s / \partial T_s$ is valid.

However, both T_{vair} and q_{vair} are diagnostic variables – these depend on the balance between the fluxes from the soil and canopy and on the respective resistances. They are therefore not independent of T_s. By assuming that they are – as is the current implementation – risks obtaining the incorrect response in both the soil column and atmosphere.

Instead, return to the fundamental balance of fluxes within CABLE's single canopy layer. We have that

$$H = H_s + H_v \tag{12}$$

where the subscripts *s* and *v* denote the fluxes from the soil and vegetation respectively. Formally the two fluxes are co-dependent through T_{vair}. Discerning how sensitive H_v is to changes in T_s is a problem of substantially more complex nature than determining the sensitivity of H_s since this also brings in stomatal, radiative transfer and physiological responses. Hence (without justification) we assume that this component to the sensitivity can be neglected and H_v is constant (over the time step). We then have that

$$\frac{\rho c_p (T_{vair} - T_{air})}{r_{t1}} = H = H_s + H_v = \frac{\rho c_p (T_s - T_{vair})}{r_{tsoil}} + H_v \tag{13}$$

where r_{t1} is the aerodynamic resistance between the within canopy and reference level air. Eq (13) gives

$$T_{vair} = \left[\frac{H_v}{\rho c_p} + \frac{T_{air}}{r_{t1}} + \frac{T_s}{r_{tsoil}}\right]\frac{r_{t1} r_{tsoil}}{r_{t1} + r_{tsoil}} \tag{14}$$

whereby

$$H_s = \frac{\rho c_p}{r_{tsoil}}\left(T_s - \left[\frac{H_v}{\rho c_p} + \frac{T_{air}}{r_{t1}} + \frac{T_s}{r_{tsoil}}\right]\frac{r_{t1} r_{tsoil}}{r_{t1} + r_{tsoil}}\right) \tag{15}$$

and

$$\frac{\partial H_s}{\partial T_s} = \frac{\rho c_p}{r_{tsoil}}\left(1 - \frac{r_{t1}}{r_{t1} + r_{tsoil}}\right) = \frac{\rho c_p}{r_{t1} + r_{tsoil}} \tag{16}$$

where we have assumed that all covariance between T_s and other variables determining H_s can be neglected. Comparing (9) with (16) shows that the current implementation overestimates the sensitivity of H_s to changes in T_s. It should be noted that T_{vair} the above is not strictly equivalent to the CABLE variable met%tvair as that variable is calculated taking variations in H_v into account[1].

Note that r_{tsoil} in Eq (8-16) should include both the aerodynamic resistance and any litter resistance term.

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[1] It is possible to construct the sensitivity terms using the coefficients within the existing within_canopy routine. However this would require that the fluxes from the leaves are also adjusted after the soil column is evolved, with consequent impact on the carbon cycle and radiation calculations.
Alternatively the existing (diagnostic) cable variable %tvair can be set to equal T_{vair} – see routine within_canopy_SSEB.

The corresponding working for the latent heat flux is

$$\frac{\rho(q_{vair} - q_{air})}{r_{t1}} = E = E_s + E_v = \frac{\rho\beta(q_s(T_s) - q_{vair})}{r_{tsoil}} + E_v \tag{17}$$

leading to

$$\frac{\partial\lambda E_s}{\partial T_s} = \frac{\rho\lambda\beta f_{cls}}{r_{t1} + r_{tsoil}}\frac{\mathrm{d}q_s(T_s)}{\mathrm{d}T_s} \tag{18}$$

As before, q_{vair} above is not strictly equivalent to the CABLE variable met%qvair as that variable is calculated taking variations in E_v into account[1]. Again, note that r_{tsoil} in Eqs (17) and (18) should include the aerodynamic resistance term, any litter term and any soil porosity resistance.

For completeness: CABLE (v3933) only incorporates the soil wetness factor β in Eq (10) if the potential evaporation $E_{pot} > 0$. However β is included in the sensitivity term $\partial\lambda E_s/\partial\Delta q$ in all conditions, i.e. the code is internally inconsistent. For consistency the β should only be included in Eq (18) if $E_{pot} > 0$.

Finally, returning to Eq (11), note that some of the other factors setting the soil evaporation are potentially sensitive to changes in temperature, including λ directly and β indirectly (see concern 2). These issues have not been investigated further.

Concern 4: Functional form of soil evaporation term.

CABLE currently supports two parameterisations for the soil evaporation term – the humidity deficit method and the Penman-Monteith (PM) approach. While algorithmically different the Penman-Monteith form for the soil latent heat flux is derived from an expression of equivalent mathematical form to Eq (10) (i.e. proportional to $\Delta q = q_s(T_s) - q_{vair}$. Consequently the same sensitivity term $\partial\lambda E_s/\partial T_s$ is valid - though significant algebra is required to demonstrate this directly.

Concern 5: Application of physical limits on soil evaporation with the correction terms

Within the surface-only configuration of CABLE substantial effort is undertaken to ensure that soil moisture stocks are not depleted below physical and physiological limits throughout and over the course of the time step. In contrast no such limits are placed on the magnitudes of the correction terms. This has the potential, when interfacing with other parts of the model, to lead to a lack of moisture balance within the model (not just in the diagnostic outputs) as some variables are capped and others not. It should be noted that this issue also applies to surface-only configuration as, while the outputted fluxes do not have the correction terms applied, these terms do in effect exist as part of the solution of the soil temperature equation.

A substantive complication to this problem is that the limits apply both on conditions at instants in time (in the case of limits on the flux) and over the time step (in the case of limits on the water budget). Furthermore, as ΔT_s is not known until the soil temperature is evolved, it is impossible to formulate the sensitivity terms ahead of time to ensure that any limits are not crossed. To apply limits on the corrections terms therefore implies changing the solution methodology of the soil temperature equation and has been deferred.

Concern 6: Time stepping of the water balance with correction terms

There is a fundamental difference in how CABLE time steps its soil temperature and soil moisture variables. Both are governed by diffusive-like partial differential equations – the difference lies in the upper boundary conditions. Soil temperature, as discussed above, is evolved in partnership with the soil surface energy balance, i.e. the surface fluxes are assumed to vary during the time step in a linear (in T_s and time) manner. Soil moisture, in contrast, is evolved using specified, and assumed constant, values for the evaporation/infiltration (upper boundary conditions).

In ACCESS 1.3 it was recognised that if the latent heat flux passed to the atmosphere reflected the flux at the end of the time step and is assumed to be constant over the time step, then there is an impact on the water balance of the soil, i.e. $\Delta t\ \Delta T_s\ \partial E_s/\partial T_s$, not accounted for within CABLE's surface-only soil moisture calculations. The approach taken to address this conservation issue was to a) diagnose the water increment once ΔT_s (and the corresponding soil evaporation and snow melt terms) is known and apply this as a contribution to the infiltration/evaporation on the next time step. Water conservation is violated on the time step but conserved over longer runs.

However, sequentially the calculations of plant transpiration and the soil wetness factor, β, and many other components of CABLE occur prior to the application of the infiltration/evaporation within the soil moisture dynamics. Consequently evaporation, transpiration etc. on the next time step are set by an incorrect value for the soil moisture – with unknowable consequences. Furthermore - with the crossed time stepping - it is possible that a correction flux is quantified as a water flux from the energy balance but implemented as snow flux (or vice-versa), which leads to a loss of conservation. Ideally we require the evaporation and infiltration applied to reflect conditions on the correct time step (and with any appropriate limits).

Again, as the correction terms are not known before the soil temperature is evolved, as many of the snow/soil moisture equation coefficients are calculated *prior in sequence* to the evolution of the soil temperature, and as there are interactions between soil temperature and snow cover/soil moisture, placing these correction terms to the snow/soil moisture on the correct time step is non-trivial. Addressing this concern has also been deferred.

The REV_CORR package

The REV_CORR package is a set of code modifications that incorporate Eq (5), (6), (16) and (18) (with cases) into CABLE. The code changes are distributed through the biophysics parts of the code and activated via a cable_user logical switch (L_REV_CORR) in the CABLE namelist file (default is set to false). It is anticipated that the code changes will, in the future, be part of default CABLE removing the need for the logical switch. To facilitate the code changes new variables (both typed and temporary variables) have been introduced. The typed variables imply changes in other cable code. The full list of cable subroutine altered are

- biophysics: cable_canopy, cable_cbm, cable_soilsnow
- ancillary: cable_common, cable_define_types, cable_output, cable_checks
- MPI: cable_mpimaster, cable_mpiworker, cable_mpicommon

The code set sits in CABLE repository /branches/inh599/CABLE-2.0_rev_correction_terms2/

Some specific notes on the implementation: A) The science of the REV_CORR package is distributed across the three biophysics routines. The modified sensitivity terms are determined at the end of the main cable_canopy subroutine and the correction terms are quantified in both cable_soilsnow and cable_cbm.

B) CABLE partitions the total resistance from the soil to the reference level via a series of individual resistances. In Eq (13) r_{tsoil} is cable variable rt0 and r_{t1} is variable rough%rt1. However CABLE quantifies the sensitivity terms $\partial H_s/\partial T_s$ and $\partial \lambda E_s/\partial T_s$ using variable rough%rtsoil. This differs in form depending on the LAI of the surface. In particular for low LAI surfaces rough%rtsoil is already the sum of rt0 and rough%rt1 (as per the denominator in Eqs (16) and (18)). Care is then needed to avoid double counting of r_{t1} in the revised sensitivity terms. This necessitates the use of new temporary variable rttsoil

C) To facilitate legibility of code, provide flexibility and reduce the risk of errors in the future the correction term to the latent heat flux is recoded as single proportional factor i.e.

$$\lambda E_{cor} = \Delta T_s \lambda \frac{\partial E_{s0}}{\partial T_s} \qquad \text{with} \qquad \frac{\partial E_{s0}}{\partial T_s} = \frac{\mathrm{d}\Delta q}{\mathrm{d}T_s}\frac{\partial \lambda E_s}{\partial \Delta q}$$

D) The impacts of litter resistances are captured by new (temporary) variables relitt and rhlitt. As these are initialised to zero theoretically the same code could be used without an IF condition on whether the litter scheme is active (or not). For safety the IF condition has been retained. **It would be possible to use these same variables to simplify/improve the legibility of other parts of the cable_canopy subroutine – this has not been undertaken.**

E) In CABLE v3933 the total latent heat flux from the soil is %fes is corrected but the corresponding partitioned (soil vs puddle) fluxes are not corrected. The REV_CORR package assigns the correction term to the soil component (%fess).

F) To facilitate the running/testing of CABLE in an offline configuration that resembles CABLE as it operates within ACCESS, the energy balance diagnostic variable %Ebal and output variable %LWnet have been modified by including the correction to the net radiation (%fns_cor= $\pm 4\varepsilon_s \sigma T_{s0}^3 \Delta T_s$). As the canopy radiation fluxes are not recalculated after the correction terms are determined this increment is applied in its entirety (not by a factor of $(1-\tau)$, τ the canopy transmissivity, as might be expected) . These two diagnostics are usually only relevant for offline simulations so this inclusion is counter-intuitive. However for standard offline simulations the correction terms are set to zero and this change to the diagnostic outputs has (correctly) no impact.

G) It was noted above that addressing some aspects of the correction terms has been deferred. Nevertheless progress has been made on some of these areas. The REV_CORR package anticipates these developments somewhat and includes some new, but currently unused, variables (e.g. %fescor_upp). If the foreshadowed developments do not eventuate then it may be sensible to remove those variables for efficiency reasons.

H) Testing of the REV_CORR package has primarily occurred in single site and global, GSWP2-driven, offline simulations. No further code modifications are anticipated in order to utilise the package within ACCESS (not even within the CABLE-UM interface and initialisation routines). However this will need to be reviewed and tested before full acceptance.

Additional components to the REV_CORR package

There are six other sets of changes included within the REV_CORR code set. These are

1. Code required to implement bug fixes identified in the CLS package (Ticket #137 - concerning moisture conservation in both coupled and offline CABLE simulations). These code changes are not switchable.
2. A reordering of the operations when calculating the screen level temperature and humidity to avoid dividing by zero (Ticket #67).
3. A new subroutine that moves the screen level calculations out of the main cable_canopy calling sequence. This is primarily for code legibility but also extends the calculations to incorporate litter resistances.
4. CABLE screen level variables and momentum flux can now be output for offline simulations.
5. A new subroutine to replace within_canopy (within_canopy_SSEB). This provides an alternate/simpler algorithm, consistent with Eq (14) and its humidity equivalent. Unlike the existing routine this scheme formally applies over snow cover and with litter resistances.
6. A bug fix to address an issue of inconsistent use of reference heights when calculating the friction velocity u_* in routine comp_friction_velocity (Ticket #138). This bug only applies if the reference height for the wind, z_{ref_uv}, differs from that of the atmospheric scalars, z_{ref_Tq} (as in ACCESS).

In more detail on 5: In CABLE, u_* is determined via standard boundary-layer similarity theory as

$$u_* = U(z_{ref})\kappa \Big/ \left[\log\left(\frac{z_{ref}}{z_{0m}}\right) - \psi_m\left(\frac{z_{ref}}{L_{MO}}\right) + \psi_m\left(\frac{z_{0m}}{L_{MO}}\right)\right] \tag{19}$$

where z_{ref} is the height of the observed/lowest model layer wind speed *above* the displacement height, z_{0m} the roughness length, $\kappa = 0.4$ is the von Karman constant, L_{MO} the diagnosed Obukhov length and ψ_m are empirical/semi-theoretical functions quantifying the impact of buoyancy on the wind profile in the constant flux layer Eq (19). Within CABLE the argument of the first ψ_m term is %zetar= z_{ref_Tq}/L_{MO} whereas the argument of the log term uses (correctly) z_{ref_uv}/z_{0m}. If $z_{ref\_uv} \neq z_{ref\_Tq}$ then the code does not align with the theory. The argument of the second, typically much smaller, ψ_m term is currently %zetar $z_{0m}/z_{ref\_uv} = z_{0m}z_{ref\_Tq}/z_{ref\_uv}L_{MO}$ which compounds the issue.

To correct this issue the argument of the two ψ_m terms should be %zetar z_{ref_uv}/z_{ref_Tq} and %zetar z_{0m}/z_{ref_Tq} respectively.

Intersection with the SLI soil scheme

CABLE v3933 carries both the default soil scheme (soil_snow) as used in ACCESS and the Haverd Soil-Litter-Isotope enabled scheme (SLI). SLI is premised on different and separate soil energy balance and soil temperature/moisture algorithms. In particular SLI evolves the soil column through the use of multiple (smaller) time steps per CABLE time step – with the diagnosed energy balance being the average over the time step. This contrasts to CABLE soil_snow in both offline and coupled (i.e. ACCESS) configurations. **The need for, the mathematical form of and the numerical stability motivation for the correction terms will need to be revisited if/prior to SLI being used within ACCESS.** In practice the most likely modification required will be to switch off the correction terms if SLI is active and CABLE is coupled to the UM – this condition has not been implemented.