Meeting: “Strategy to integrate ORCHIDEE-CAN in/as the TRUNK ?”

8th September (following ORCHIDEE-team meeting)
Invited and present: Josefine Ghatas, Nicolas Vuichard, Philippe Peylin, Bertrand Guenet and Sebastiaan Luyssaert .

1. Which is the status of the branch? Developments, debugging, etc

ORCHIDEE-CAN currently includes (largely based on Naudts et al., 2015):

- Albedo. TRUNK: For each PFT the total albedo for the grid square is computed as a weighted average of the vegetation albedo, the soil albedo, and the snow albedo. The scheme overlooks the effect of vegetation shading bare soil for sparse canopies and gives the ground in all PFTs the same reflectance properties as bare soil. ORCHIDEE-CAN: multi-layer scheme calculating the absorbed, transmitted and reflected light (Pinty et al 2006) within vertical layers of the canopy while accounting for leaf and background reflective properties, zenith angle and a prognostic canopy structure (McGrath et al, in Prep).
- Energy budget. TRUNK: The coupled energy balance scheme, and its exchange with the atmosphere, is based on that of Dufresne and Ghattas (2009). The surface is described as a single layer that includes both the soil surface and any vegetation. A big leaf approach does not account for within canopy transport of carbon, water and energy. Further, it is inconsistent with the current multi-layer photosynthesis approach and the new multi-layer albedo approach. ORCHIDEE-CAN: multi-layer energy budget which accounts for within canopy turbulence as a function of prognostic canopy structure. The scheme makes use of the new layering for photosyntheisis and albedo. If the plant experioences water stress, the scheme calculates the stomatal conductance that satisfies the water stress and recalculates the associated photosynthesis and energy budget.
- Photosynthesis. TRUNK: C3 and C4 photosynthesis is calculated following Farquhar et al.(1980) and Collatz et al. (1992), respectively. Photosynthesis assigns artificial LAI levels to calculate the carbon assimilation of the canopy. These levels allow for a saturation of photosynthesis with LAI, but have no physical meaning. The scheme uses a simple Beer law transmission of light to each level, which is inconsistent with the new albedo scheme. ORCHIDEE-CAN: the layering system has changed and each canopy is divided in 10-layers. The same layers are used for photosynthesis, albedo, stomatal conductance and energy calculations. The analytical solution implemeneted by Nicolas Vuichard has been used.
- Autotrophic respiration. TRUNK: Autotrophic respiration distinguishes maintenance and growth respiration. Maintenance respiration occurs in living plant compartments and is a function of temperature, biomass and, the prescribed carbon/nitrogen ratio of each tissue (Ruimy et al., 1996). A prescribed fraction of 28 % of the photosynthates allocated to growth is used in growth respiration (McCree,1974). The remaining assimilates are distributed among the various plant organs using an allocation scheme based on resource limitations (see allocation). ORCHIDEE-CAN: the same principles are used but a labile carbon pool was introduced. Only part of the labile pool (depending on air temperature) is used for growth. Although not termed in this way, this approach strongly resembles the proposed sink/source approach by Körner et al.
- Carbon allocation. TRUNK: Carbon is allocated to the plant following resource limitations Friedlingstein et al. (1999). Plants allocate carbon to their different tissues in response to external limitations of water, light and nitrogen availability. When the ratios of these limitations are out of bounds, prescribed allocation factors are used. The resource limitation approach requires capping LAI at a predefined value. Due to this cap, the allocation rules are most often not applied, reducing the scheme to prescribing allocation. ORCHIDEE-CAN: a allometric based allocation scheme following Sitch et al., 2003 (thus LPJ) was introduced. This approach was adjusted to account for different diameter classes and at the same time make allocation a function of within-stand competition (Deleuze and Dhote, 2004, Bellassen et al 2010). The new allocation scheme calculates a 3-D stand and canopy structure assuming spherical crowns and a Poisson distribution of the individual trees.
- Phenology. TRUNK: At the end of each day, the model checks whether the conditions for leaf onset are satisfied. The PFT-specific conditions are based on long- and short-term warmth and/or moisture conditions (Botta et al., 2000). ORCHIDEE-CAN: grasslands were changed to evergreen PFT to make the new allocation scheme work.

- Mortality and turnover. TRUNK: All biomass pools have a turnover time. Living biomass is transferred to the litter pool; litter is decomposed or transferred to the soil pool. This approach is not capable of modelling stand dimensions. ORCHIDEE-CAN: forest management was introduced as one way of tree mortality. If forest management is absent then self-thinning is used as the main source of mortality. In addition to these sources some background mortality, here termed 'environmental' mortality was added. Mortality is now a function of the tree dimensions.
- Forest management An explicit distribution of individual trees (Bellassen et al., 2010) is the basis for a process-based simulation of mortality. The aboveground stand-scale wood increment is distributed on a yearly time step among individual trees according to the rule of (Deleuze et al.,2004): the basal area of each individual tree grows proportionally to its circumference. The concept of the original implementation were retained, however, the implementation was adjusted for consistency with the new allocation scheme and to have a larger diversity of management strategies.
- Land Use Change. TRUNK: the trunk combines the code of the product pools and land use changes. ORCHIDEE-CAN: the code between product use and land use change was separated increasing the transparency of both processes. The land use change code was extended to deal with age classes (which are implemented as diameter classes. Thus ORCHIDEE-CAN has diameter classes to deal with within-stand heterogeneity and diameter classes (termed age classes) to deal with landscape heterogeneity. The latter are coded as separate PFTs. Age classes may thus get different parameters to deal with for example secondary vegetation).
- Species change. TRUNK: dealt with in the DGVM. Natural species changes are simulated but species changes through management are not possible. ORCHIDEE-CAN: the DGVM was not adjusted but routines were added with human induced species and management changes.
- Snow. TRUNK: the multi-layer snow scheme. ORCHIDEE-CAN: the code includes the multi-layer snow code but this code still needs to be integrated with the multi-layer albedo and multi-layer energy budget scheme.
- Water stress. TRUNK: function based on soil water content. This approach ignores within-plant water transports and sees water stress as a control of Vcmax only. ORCHIDEE-CAN: water stress is calculated by considering the atmospheric demand and the max water supply through plant transport. The latter makes use of soil water potential and thus requires the use of the 11-layer hydrology. When water stress occurs only stomatal conductance (instead of Vcmax) is recalculated.
- Spin-up. ORCHIDEE-CAN: makes use of the analytical spin-up.

Known problems (some may also apply to the trunk – indicated by *):
- *The soil-root interface of the new water stress module required a substantial tuning factor (outside the observations).
- The DGVM is broken. There are no known scientific conflicts but the diameter classes and age classes should be implemented throughout the DGVM.
- The fire module is broken. There are no known scientific conflicts but the diameter classes and age classes should be implemented in the fire module.
- Very low soil water content – likely an accounting bug.
- *Land use does not deal with soil moisture columns between PFTs. Water balance closure is not guaranteed.
- *Land use does not deal with changes in no frac bio (urbanisation). Carbon and water balance closure are not guaranteed.
- *The approach of first substracting no frac bio and then rescaling to 1 causes serious problems with conserving surface area under land use change. Should we simply add a PFT no frac bio?
- The multi-layer snow scheme needs to be integrated with the new albedo and energy budget schemes.
- *The concept of the multi-layer energy budget scheme is closer to an ecosystem approach than the single layer scheme. Hence, it would be more consistent to give each PFT its own soil water and soil thermics column. Such an approach would also introduce some of the sub-grid heterogeneity (i.e., snow) that is now dealt with in an empirical way.
- The multi-layer energy budget will require a new interface to be used in coupled simulations. The vegetation now has dimensions which is in conflict with the assumptions made in the single-layer coupling. Note that the multi-layer scheme can be run as in a single-layer mode. The coupling works but not when we want to make use of the full functionality of the multi-layer scheme.

On going debugging:
- Species change: loss of veget_max possibly a precision problem with map reading (10^-8) (Sebastiaan)
- Multi-layer energy budget scheme: averaging from PFT to pixel (off-line only) and global, multi-proc, century long simulations (James)

On-going developments:
- Windfall: new modules, litlle feedback on existing code (Ferenc & Seb)
- Recruitment: new module (done), testing the feedback on existing code (Jonathan, & Seb)
- Improved soil-root interface: this could fix one of the know problems. I have no recent progress update (Annemiek, Robert V, Philipe C)
- New stand dynamics: the current implementation does not allow to follow an individual tree. Several data streams could be better used for model validation if individual trees could be followed through time. This requires working around sparse matrices (Philippe P)

2. Which are the developments on the TRUNK and MICT which are in conflict or need to be adapted to CAN?

Conflicts:
- No known scientific conflicts.

Required adaptations (AR6):
- Spitfire
- multi-layer snow (NIR snow albedo)
- DGVM (level of needed changes unknown ?)
- Tropical parameters (ongoing: Jonathan)
- VOC (if the changes include a radiation scheme)
- I don't know of all the ongoing work on land use change but the introduction of age classes in ORCHIDEE-CAN makes this process technically much more complex to deal with. Bookkeeping approaches of land use change would need to be adjusted.

Required adaptations (AR7):
- Revise the coupling to the atmosphere
- Revise the sub-grid heterogeneity
- Technical revision of PFTs and diameter classes per pixel.

3. ORCHIDEE-CAN into the TRUNK or vice versa?

- Although previously agreed to put the trunk into ORCHIDEE-CAN, that decision was more or less based on the fact that ORCHIDEE-CAN contained all changes of the TRUNK. Since 18 months this is no longer true (the DOFOCO team has no resources left). In those 18 months the trunk has evolved substantially.
- Many of the changes to the trunk are very technical and not easy to implement by a researcher. Most of the ORCHIDEE-CAN changes are scientfic and bugs resulting from its implementation should be within reach of researchers. Integrating ORCHIDEE-CAN in the trunk could partly shift the workload.
- The integration of ORCHIDEE-CAN into the TRUNK could go through 5 steps:
(1) merge stomate.f90, replace most of stomate, introduce sapiens. While developing the code we initially tried to introduce a flag that would allow to switch between both set-ups. This was too time consuming so we dropped the case. Many of the high-level call statements have changed so if we try this again it would more or less result in two different models in a single code. I still believe an abrupt change is adviceable but note that this would result in partly loosing the TRUNK for stomate.
(2) Intoduce new layering and albedo, merge photosynthesis. These routines make the link

between stomate and sechiba. They are essential to ORCHIDEE-CAN. ORCHIDEE-CAN does not work with the old layering (the energy budget requires physical layers rather than equal amounts of LAI). This is the most 'damaging step'.
(3) Merge energy budget and new water stress. The old single-layer code is replaced by the new multi-layer code but this code can be run with a single layer and reproduced the results from the old scheme (e.g. still makes use of a TOA albedo rather than a multi-layer albedo). There is a flag that activates the full functionality of the multi-layer energy budget. This functionality is still being debugged (later stage of debugging: spatio-temporal multi-proc test).
(4) Integrate multi-layer snow with new albedo and energy budget scheme.
(5) Integrate other modules (not yet available) in the ORCHIDEE-CAN structure, e.g., new fire, new VOC, ...

- In the current ORCHIDEE-CAN code we kept the TRUNK code but large parts are no longer used (in stomate this is apparent in the diagniostic and prognostic label of many subroutines). It would be easier, more transparent and a first major cleaning to decide not to copy the diagnostic code (as it is no longer used and the call arguments have changed). This would have a large impact on the constantes routines.

4. Proposition for integrating CAN functionality in the trunk: persons involved and planning in the context of CMIP6 developments

Note:

- The code itself has been rather well tested and applied globally (although zoomed) off-line and coupled. Therefore, only few obvious problems are to be expected (i.e. pulses, crashes, switches, etc …). New problems will most likely become apparent when validating the model results outside of Europe. Merging requires three tasks to be performed: (1) guiding the merge, (2) coding the merge and (3) testing the model.
- Integrating CAN functionality will lay the basis for CM6_version 2 as agree by the ORCHIDEE group in 2014.

Context: Preparation of CM6_v1

Figure 1: Construction of CM6v1

- Current Trunk will be improved with existing developments until early 2016
- After that (2016 onward), it will become a branch “CM6v1” that will be maintained during the whole CM6 exercise (up to 2018) with BUG corrections but no major developments from the “group”.

Schedule for CM6v1 up-coming and planned MERGES:

1. Inclusion of the merge of the soil Thermic/Hydrology vertical discretization (work of Fuxing): Ongoing merge led by Josefine up to early November 2015.
2. Update of the VOC (few days) early November; led by Josefine and Juliette
3. Update of the Albedo for soil and vegetation (new bare soil map and optimized coefficient for vegetation); led by Philippe P. and Josefine
4. Inclusion of Nitrogen Cycle code to start global coupled tests: Early November; Led by Nicolas Vuichard with help from Josefine. First tests with an option included by Nicolas to fix the C/N ratio, which allows turning off the impact of the N-cycle on the C/W/E cycles.
5. Update of the multi-layer snow scheme (fractional coverage an fully implicit); November (could be done before the N cycle); Led by Fuxing with contribution from Tao. Implication of Jan, Catherine, Philippe and Frederique; Josefine will help for

the merge.

6. Inclusion of SPITFIRE (work from Yue Chao; version not coupled with LUC); during late November-December; led by Patricia (in collaboration with Yue and Philippe C.) with the help of Josefine
7. Grassland and Crop Modules; Check early 2016 which module can be included: Grassland Management (GM) and CROP module are possible if the input data-set are available; Note that a simple split between winter and summer temperate crop (few phenology parameter change could be done also)

These MERGES, although tested separately will need to be tested/evaluated all-together in global-coupled mode. For the N-cycle, if the impact on the C and W cycles becomes too critic for CM6v1, we will be able to run with the option of fixed C/N ratio.

Preparation of a new TRUNK including ORC-CAN (CMIP6v2):

In parallel we will start the merge of ORCHIDEE-CAN into the TRUNK in order to maximize the contribution from everyone (see figure 1 below)

Constraints / background:

- James will leave in June 2016. Seb L. will have some spare time to code late 2015 and erarly 2016 and will be at Amsterdam starting January 1st 2016.
- We need to work in parallel to maximize the availability of people (i.e. cleaning of the code).
- Additional contributors (to be recruited for January 2016) will help for this version: an engineer (supervised partly by BG, NV, SL and partly JG); a scientist working on the N-C part with Nicolas/Bertrand/Sebastiaan; a scientist under Eraclim2 project to make global simulations with ORC-CAN

PHASE – 0:

Not strictly a phase but regroup some actions that can be in parallel of phase – 1 and phase – 2 described below and that will be done depending on the maturity of the proposed actions listed below:

- **New Driver** (update from Jan): It should be included in the TRUNK as soon as possible : November ? (either before or after the start of this new TRUNK-ORC-CAN merge)
- **Cleaning** of the code and retiring the Choisnel scheme for the hydrology and the one layer snow scheme;
- Specific work on **sub-grid scale variability**: For phase-2 below (the integration of the multi-layers canopy scheme) it would be beneficial to have more flexibility for the tiling and possibly an energy budget per tile. This is a MAJOR structural change that should be prepared and that involves some thinking/refinement for the coupling with the Atmosphere (implicit coupling is still possible with multiple energy budgets, as currently done for the sea-ice and ice free ocean pixels). First, we will iterate by email to agree on a scheme which should describe the flexibility as for the Number of energy budget, the Number of soil thermal/water budget,… Philippe P will start the discussion. The proposed changes (when agreed among the group) will be inserted into the agenda below.

PHASE – 1:

Mid-November 2015 – December 2015
Step 1: Merge of CAN-stomate into TRUNK:
Includes Tree diameter/age classes, C allocation (partially done for C allocation with the previous inclusion of the N-cycle), Forest management and recruitment
Guiding : Sebastiaan
Coding: Bertrand and Sebastiaan.
Testing and discussing: Bertrand, Nicolas Viovy, Nicolas Vuichard, Jonathan B. and ???.

Teleconf/meeting will be planned late November to discuss some “issues & CAN-choices

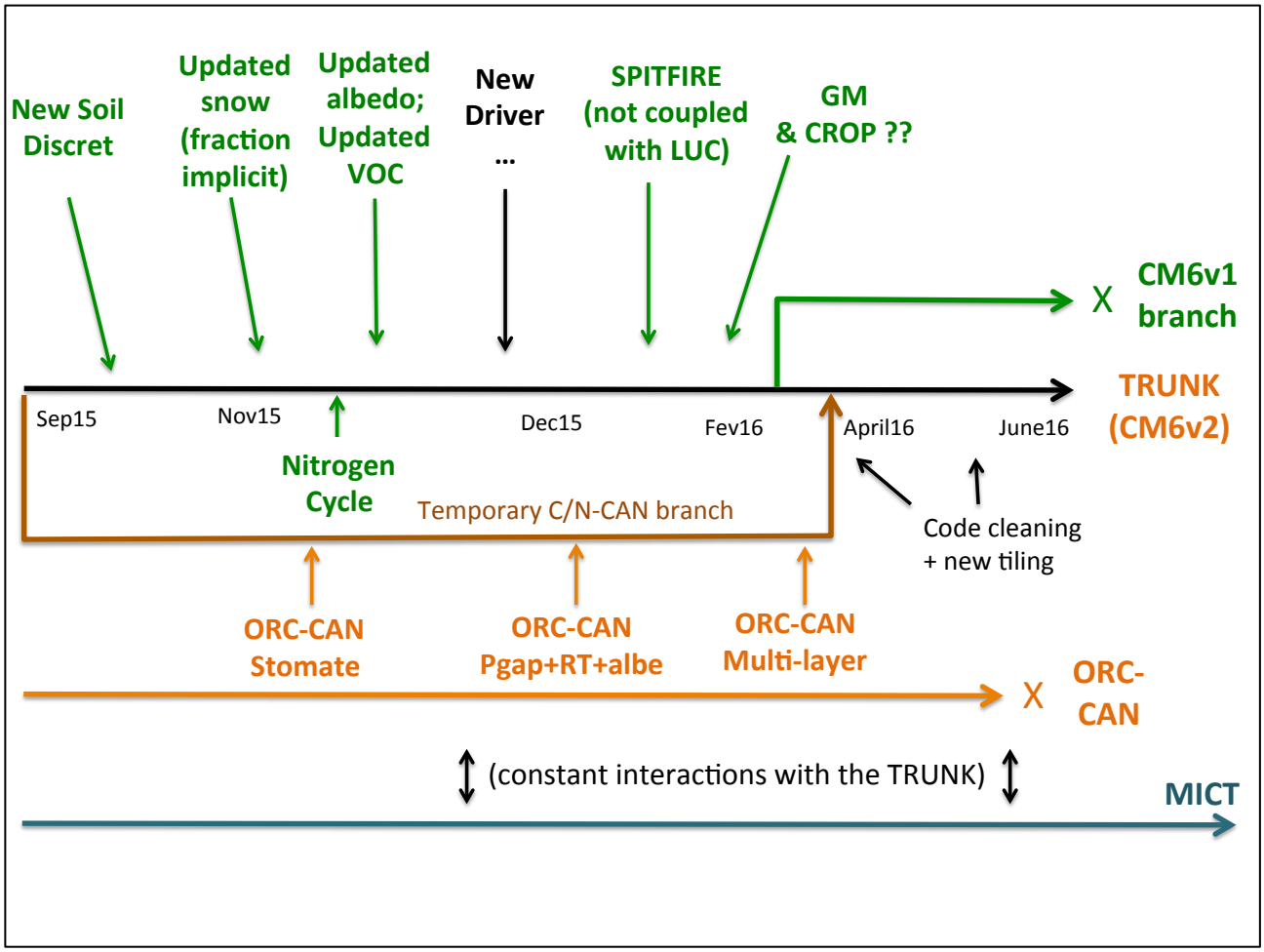
January 2016 – February 2016
Step 2: link between stomate and sechiba
Includes P_gap model for forest stand with 2-stream Radiative Transfert scheme from Pinty (including albedo, light penetration into canopy,…), change of layering for photosynthesis (from delta_lai to delta_thickness)
Guiding: Sebastiaan,
Coding: Philippe P (another volunteer ?).
Testing and discussing: Jan, Catherine, Frederique, others ???

Meeting plan late January to discuss some issues (interactions with the snow module in particular)

PHASE - 2:
1/ March 2016 – April 2016
Step 3 (sechiba)
Guiding: James
Coding: Jan or Catherine ? (or James if no-one can do it).
Testing and discussing: Jan, Catherine, Philippe, Agnes, Frederique, others ?

2/ November 2015 – April 2016
Step 4 (merge snow and multi-layer): The initial merge can be coded in ORCHIDEE-CAN but additional thinking for a better integration should be discussed.
Guiding by Chaterine and Jan.
Coding by James.
Testing: who wants ?

The scheme below could provide an overview of the different “team actions” as a road map for the TRUNK and the different branches:


New Soil Discret
Updated snow (fraction implicit)
Updated albedo; Updated VOC
New Driver ...
SPITFIRE (not coupled with LUC)
GM & CROP ??
X
CM6v1 branch
TRUNK (CM6v2)
Sep15
Nov15
Dec15
Fev16
April16
June16
Nitrogen Cycle
Temporary C/N-CAN branch
Code cleaning + new tiling
ORC-CAN Stomate
ORC-CAN Pgap+RT+albe
ORC-CAN Multi-layer
X
ORC-CAN
(constant interactions with the TRUNK)
MICT