Progress on new soil C and N parameterisations for JULES (ECOSSE and FUN)

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Including work by J. Smith, K. Coleman, H. Wong, P. Smith, J. Fisher, Spencer Liddicoat and others.
A long time ago....

**QUEST (QESM, QUERCC)**
Aimed to couple JULES with (amongst others!):
- the ECOSSE model of soil C and N turnover
- the FUN model of plant N uptake

**ECOSSE: Estimation of Carbon in organic Soils – Sequestration and Emissions**
Smith, J. et al., 2010, Climate Research, 45: 179-192.
ECOSSE (and its predecessors, RothC and Sundial) have been widely used.

**FUN: Fixation and Uptake of Nitrogen**
A new model!
History of the JULES-ECOSSE-FUN code

• JULES1.0 + ECOSSE (to ~2007/8).

• JULES2.0-ECOSSE-FUN (~2008-10)
  Better integrated with JULES, FUN added.

• JULES3.1-ECOSSE-FUN (2012)
  The best so far!
  Revised coupling between components.
Schematic of the main connections between components of JULES-ECOSSE-FUN

- **Dynamic vegetation model (TRIFFID)**
- **JULES**
  - Surface energy balance, soil T and moisture, photosynthesis
- **Plant N uptake model (FUN)**
- **Soil C and N model (ECOSSE)**
  - NPP available for growth
  - NPP/ N demand soil T and moisture
  - N availability
  - N extraction
  - Organic content
  - Soil T and moisture
  - Litter inputs
  - Gas fluxes
  - Leaching

Vegetation amounts and properties (e.g. height, LAI)
Coupling frequencies between components of JULES-ECOSSE-FUN

- **JULES**
  - Surface energy balance, soil T and moisture, photosynthesis
  - Timestep (~30 mins)

- **Soil C and N model (ECOSSE)**
  - Daily

- **Plant N uptake model (FUN)**
  - ~10 days

- **Dynamic vegetation model (TRIFFID)**
## JULES with and without ECOSSE and FUN

### In JULES v3.2 (and before)

- **RothC**
  - 4 soil carbon pools
    - Decomposable plant material
    - Resistant plant material
    - Biomass
    - Humus
  - No structure with depth.

### ECOSSE and FUN additions

#### ECOSSE

ECOSSE is (essentially) a layered combination of RothC and a soil N model. (RothC → SUNDIAL → ECOSSE)

- 4 soil carbon pools - layered
  - Decomposable plant material
  - Resistant plant material
  - Biomass
  - Humus

#### Plant N uptake

- **Plant N uptake**
  - Plant growth assumes no restriction by soil N.

#### Plant N uptake: FUN

- **Plants** acquire N via passive and active mechanisms. Active uptake reduces NPP => reduced plant growth.
Overview of ECOSSE (1)

1\textsuperscript{st} order reactions
Rates modified by soil T and moisture, and pH.

Also anaerobic decomposition (CH\textsubscript{4}).
Decomposition of SOM results in mobilization or immobilization of inorganic N ($\text{NO}_3^-$ and $\text{NH}_4^+$) to maintain C:N.

If insufficient N, decomposition is slowed and produces more $\text{CO}_2$. 


Overview of ECOSSE (2) – soil and plant N processes
Inputs and outputs: JULES-ECOSSE

Inputs from JULES to ECOSSE:
• Litterfall C and N amounts
• Soil temperature and moisture
• Soil water flux (for leaching)
• Root distribution (for distribution of plant inputs)
• N deposition

Outputs from ECOSSE:
• soil C and N stores
• $\text{CO}_2$, $\text{CH}_4$, $\text{N}_2\text{O}$, NO, N$_2$, NH$_3$
• leaching DOC, NO$_3^-$, DON
Overview of FUN

FUN considers mechanisms through which plants can take up N:
- passive uptake (via water for transpiration)
- active uptake (extract N from soil)
- retranslocation (N removed from leaves before they are dropped)
- fixing by nodules

At each timestep the cheapest source is used (unrealistic?). If soil N is plentiful, C uptake can be matched by N with little or no cost. Otherwise NPP available for growth is reduced.
Inputs and outputs: JULES(-ECOSSE)-FUN

Inputs from JULES (-ECOSSE) to FUN:
• soil N stores (for costs)
• NPP
• transpiration rate (for passive uptake)
• root distribution
• leaf turnover (for amount of N in falling leaves; retranslocation)
• vegetation C and N amounts (for calculation of veg C:N)

Outputs from FUN:
• updated NPP (available for growth) and plant respiration – to JULES/TRIFFID
• N uptake amounts (to update soil N) – to ECOSSE
Configurations available (JULES3.1-ECOSSE-FUN)

• ECOSSE + FUN

• ECOSSE only
  Calculates plant N demand to match NPP.
  No C cost of N uptake.

• FUN only
  Uses a fixed map(ancillary) of soil N.
Based on tests with JULES2.0-ECOSSE at a single site with ECOSSE called every JULES timestep:

<table>
<thead>
<tr>
<th>Number of ECOSSE layers</th>
<th>Relative CPU (wall clock) time</th>
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<tr>
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<tr>
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</table>

Notes
These were tests of run time; the results were clearly different.
Simple tests, with moderate optimisation by compiler.
Coupling less often (e.g. once every 1-2 hours) would be important in reducing CPU requirements.
Multi-year times series of soil CO$_2$ fluxes. Orange=observations, Red=JULES.
Ongoing and upcoming activities (and aspirations)

Coding

• Fertilisers (currently hardwired to zero).
• N15 – on a switch or remove?
• In the distant future - relax the restriction to one soil column per gridbox (e.g. fertilised and non-fertilised areas, wetland and non-wetland).

Spin up methods

Testing

• Against short-term gas fluxes (e.g. NitroEurope)
• Against long term SOM accumulations

The code is available on PUMA.
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