Developments in the JULES land surface model for the QUEST Earth System Model

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We present an overview of new process models that are being added to the JULES land surface model for use in the QUEST Earth System Model (QESM). The new components address vegetation dynamics, plant nitrogen uptake, fire, soil carbon and nitrogen processes, and biogenic volatile organic compounds (BVOCs).

Background - QESM

Limits to computer power have traditionally meant that the component sub-models of an Earth System Model were less complicated than state-of-the-art standalone models. With modern computers, this restriction has eased. The aim of QESM is to provide a step-change in the complexity of the land surface model, so that the QESM will be able to simulate the key feedbacks between the land surface and the rest of the climate system. For QESM, the standard version of JULES is augmented by several new process models.

QESM will comprise of:

HadGEM3-A

NEMO (Nucleus for European Modelling of the Ocean)

CICE (Community Ice CodE)

QPFT (ocean biology)

UKCA (chemistry/aerosols)

JULES (Joint UK Land Environment Simulator) plus new components

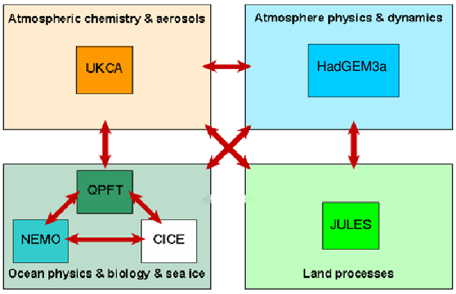
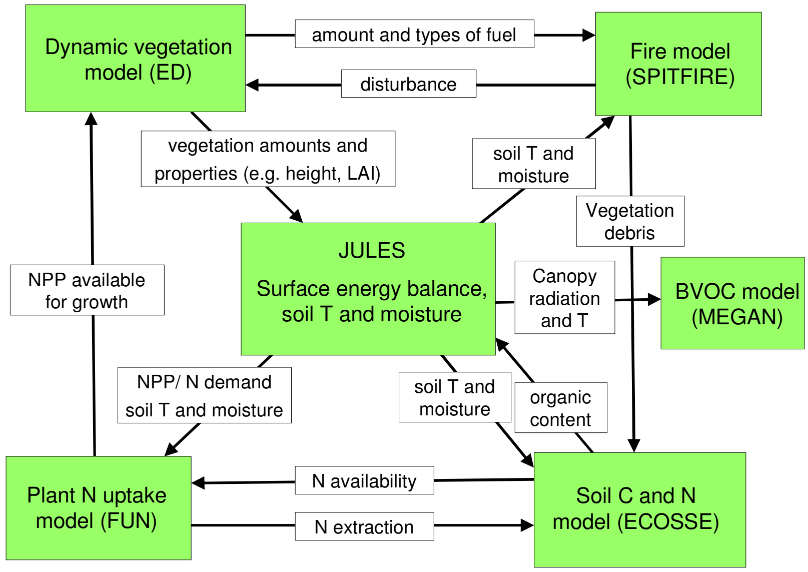


Figure adapted from Manoj Joshi.

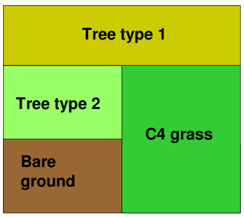
Schematic of the main connections between components of the land surface model



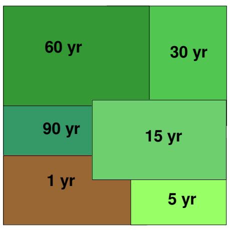
Dynamic vegetation model – ED (Ecosystem Dynamic Model)

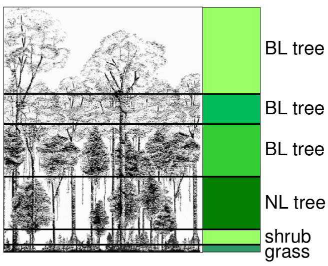
ED is quite different from other Dynamic Global vegetation Models and is based on the principles of "gap" models.

The patch structure used in most land surface models (including the TRIFFID component of JULES) is based on Plant Functional Types (PFTs).



The patch structure in ED is defined by time since disturbance by tree mortality or fire. Newly disturbed land is created every year, and patches represent stages of regrowth. Patches with sufficiently similar characteristics are merged.

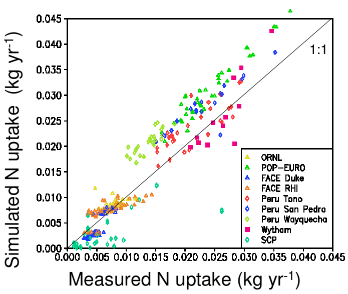




Within each ED patch, plants of a given PFT and similar height are grouped into "cohorts". Cohorts compete for resources (e.g. light). The profile of light through the canopy is used by the JULES photosynthesis calculations.

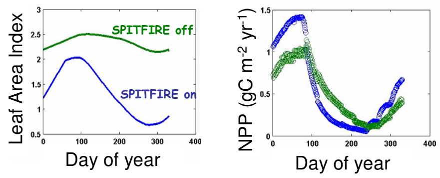
Nitrogen uptake by plants - FUN

Lack of Nitrogen generally limits plant growth. The FUN model first takes up N through advection in the transpiration stream. If further N is required, the C costs of active uptake from soil N, retranslocation from leaves, and biological fixation are compared, and the cheapest source is used. NPP is then allocated to acquire N, optimising growth while maintaining the plant's C:N ratio. Initial results, driving FUN with observed soil and plant conditions, are promising (see figure).



Fire model - SPITFIRE

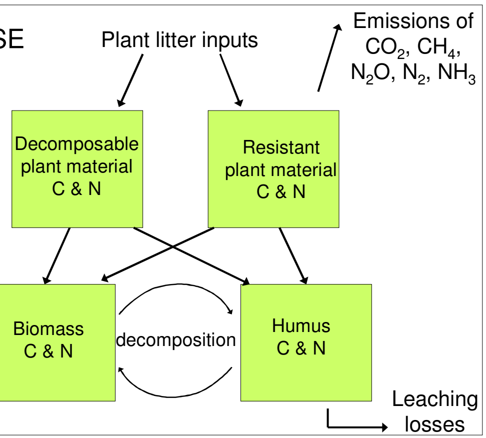
SPITFIRE explicitly simulates processes of climatic fire danger and wildfire lightning- and human-caused ignitions, fire spread (if conditions are sufficiently dry), fire intensity, fire-induced tree mortality (crown scorch and cambial death), and emissions of trace gases and aerosols from biomass burning. Figures show the effect of SPITFIRE in simulations with ED of a location in Northern Territory, Australia.



Fire substantially reduces LAI, particularly in the dry season. With fire, NPP is reduced in the dry season, but increased in the wet season - C4 grass has increased in abundance at the expense of less fire-tolerant trees.

Soil C and N model - ECOSSE

ECOSSE is derived from the SUNDIAL and RothC models. Plant inputs are divided into decomposable and resistant pools, depending on land use type. These decompose into biomass and humus according to soil temperature and moisture. Soil organic matter turnover between pools continues, resulting in mineralisation / immobilisation of N. Gaseous losses include CO_2, CH_4, N_2O, N_2 and NH_3. Leaching losses include NO_3^-, DON and DOC.



Plant emission of BVOCs – MEGAN (with N.Hewitt, D.Beerling, K.Ashworth and others)

MEGAN will be used to calculate biogenic emissions of isoprene in QESM. MEGAN estimates the net emission above the canopy as Emission = ε γ ρ.

ε is the emission factor for PFT under standard conditions. This varies by a factor ~1000 between plant groups, with highest values generally for broadleaf trees and shrubs, although large variations exist even within a single plant family.

γ Activity factor, accounting for deviation from standard conditions (e.g. temperature). ρ Factor accounting for loss within canopy.

Quantifying and Understanding the Earth System

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