JULES-RED simulations of forest demography and resilience in Brazil and RED version 2

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A quick introduction

• The Robust Ecosystem Demography (RED) dynamic vegetation model is being introduced into JULES (target is 6.2!) to introduce plant size as a new dimension:

\[ \frac{\partial n}{\partial t} + \frac{\partial}{\partial m} [ng] = -\gamma n \]

\( n \) = number density, \( m \) = plant mass, \( g \) = plant growth and \( \gamma \) = plant mortality

In RED version 1, competition for PFT \( l \) is conducted only on the seedling level:

\[ n_0 g_0 \bigg|_l = \frac{\alpha P}{m_0} \bigg|_l s_l, \quad s_l = 1 - \sum_k c_{l,k} v_k \]

\( \alpha \) = assimilate for reproduction, \( P \) = total plant grid-box assimilate, \( s \) = shading and \( c \) = competition coefficients.

Size-dependent Dynamics

An illustration of RED functionality

a) Forest Carbon Density

- Ecosystem Total
- Early-Successional
- Mid-Successional
- Late-Successional

b) Forest Size-Structure (yr: 0)

- Number Density (m⁻²kgC⁻¹)
- Plant Mass (kgC)
- Mortality (yr⁻¹)
Size-dependent Dynamics

Here we assume a simple power-law for a disturbance:

$$\gamma_d = \gamma_{d,0} \left( \frac{h}{h_0} \right)^{\phi_\gamma}$$

A positive power could be relating to a disturbance such as drought.

A negative power could be representative of fire.

TropForC-db contains carbon density and site age from pan-tropical locations (Anderson-Teixeira et al. 2016)
JULES gives RED the Grid-Box total assimilate (NPP – Local Litterfall), and any disturbance mortality.

RED updates the plant number density through mass classes and therefore the vegetation carbon, height and other important parameters.

Additional modules (Fire & Drought) can be developed for the RED framework allowing for important size-dependent processes.
JULES-RED spin-ups

• Current testing of the JULES-RED branch has been done with a copy of u-al752 for the LBA sites.

• Figure on the right we have assumed a mortality rate of $\gamma_b = 0.05 \text{ yr}^{-1}$ for BET-Tr and an arbitrary initial number density distribution.

• We have a target submission for JULES 6.2 into the trunk, there will be a switch between TRIFFID and RED.

• For CSSP-Brazil we would like to do resilience runs (N216 resilience runs) for South America, with other JULES components (INFERNO, SOX and SUGAR).
RED version 1 issues.

- There are currently two principal issues with RED version 1. Firstly, there is a dependence on regrowth time-scales on arbitrary parameters such as the minimum vegetation fraction, $\nu_{\text{min}}$ and the choice of seedling mass $m_0$.

- Secondly, achieving diversity among PFTs in the same competitive tier (i.e. tree vs tree or shrub vs shrub).
RED version 2  Seed Pool

• RED version 2 removes now includes an explicit seed pool, $N_s$ at a seed mass $m_s$. Seeds germinate into plants of the same mass $m_s \rightarrow m_0$ and enter the size structure at a rate of $\frac{g_s}{m} s$, ($s$ being the shading). The recruitment flux now becomes:

$$\frac{\partial N_s}{\partial t} = \frac{\alpha P}{m_s} - \gamma_s N_s - \frac{g_s}{m_s} N_s s$$

Seeds do not contribute to the shading competition. Therefore, this allows us to set a minimum seed density without arbitrarily compromising regrowth time-scales.
RED version 2  Diversity

• We assume a new competitive matrix for Grasses, Shrubs and Tree PFTs with a shared inter-group coefficient $c$, having $c < 1$ allows for PFT overlap in space.

• The new fraction JULES sees is the “top-down” coverage, which is simply $\nu_{TD} = cv$. 
RED version 2  Diversity

• We assume a new competitive matrix for Grasses, Shrubs and Tree PFTs with a shared inter-group coefficient $c$, having $c < 1$ allows for PFT overlap in space.

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RED version 2 Diversity

To mimic the Maximum Entropy Theory of Ecology (Harte, 2011), we pick a $c$ value to maximise our diversity function:

$$H_c = -c \sum_i \left( \frac{Z_i}{Z_{\text{tot}}} \right) \ln \left( \frac{Z_i}{Z_{\text{tot}}} \right),$$

$$Z_{\text{tot}} = \sum_i Z_i$$

$Z_i$ is an ecosystem PFT property such as coverage or carbon density.
RED version 1 versus version 2.

Here we have selected 6 Arbitrary PFTs meant to represent a distribution of mortality and growth rates.
Any Questions?