

## Briefing Note

A briefing on research from the Climate Science for Service Partnership (CSSP) Brazil for decision-makers

# A guide to developments in land surface models, essential for climate projections in Brazil

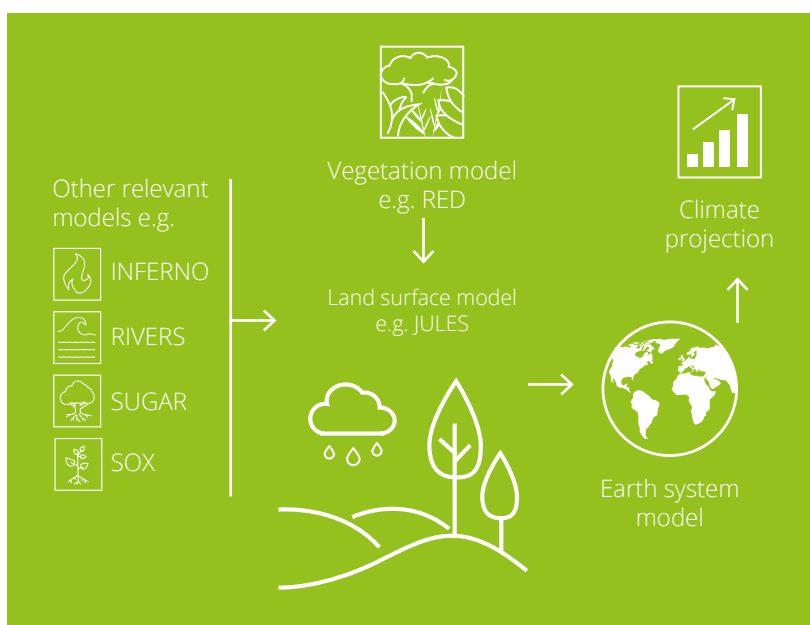
With global warming predicted to have major impacts across the planet, understanding how the Earth's land surface will respond to changes in weather and climate has never been more important (Fisher and Koven 2020). Improvements to land surface models used in climate projections must therefore be a priority for scientists and policy-makers alike. CSSP Brazil has supported collaboration with other projects to improve land surface models. This note covers some of the recent land surface model developments.

### The Joint UK Land Environment Simulator (JULES)

Land surface models simulate the Earth's surface, including: the reflection of sunlight back into space; the balance of energy between the surface and the atmosphere; rainfall and whether the rain runs across a surface or is absorbed; the dynamics of soils; and vegetation, including photosynthesis, carbon content and the life cycle of trees (Best et al. 2011, Clark et al. 2011).

One of the most widely used land surface models, JULES, was created by the Met Office and the Centre for Ecology and Hydrology in the UK. JULES can be coupled with an Earth system model to run climate projections, allowing robust assessments of the impact of climate change (JULES 2022, Met Office 2022). JULES can also be run as a standalone model.

### Models used to create a climate projection



### The JULES model in Brazil

While created in the UK, JULES is a global model, used in research across the planet. Through CSSP Brazil and other projects, research using JULES has revealed some interesting scientific results:

- Zeri et al. (2021) used JULES to simulate soil water content in the semi-arid region of Northeast Brazil, studying the variability of soil moisture to successfully identify the likely occurrence of drought.
- Parker et al. (2018) evaluated simulated methane emissions from six models including JULES for wetlands, including the Pantanal in Brazil, finding that all land surface models needed to represent river inundation events better.
- Caen et al. (2021) investigated how well the JULES model simulated carbon cycling across different biomes in Brazil, finding that the model performs better in areas with consistent vegetation, and worse in the transitions between biomes.
- Marthews et al. (2021) examined model predictions of river inundation events from the JULES-CaMa-Flood model, finding that although the model performs well, differences between the model and data imply that further improvements are needed.
- Rosan et al. (2021) looked at the projections of land use and land cover change over Brazil between 2000 and 2019 using a variety of models, including JULES. The authors found that projections from the models have improved since Earth observation data has been included.

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# Models created through CSSP Brazil to improve land surface models, such as JULES

### Representing human intervention in rivers (RIVERS)

The current version of JULES ignores many aspects of water resource management, such as the effect of building dams and reservoirs or removing water for human activities (Baron et al. 2021). Representing these activities in JULES is important for Brazil, being one of the biggest investors in hydropower: in 2020, 65.2% of electricity generated in Brazil came from dams and hydraulic sources (EPE 2021). RIVERS will address these shortcomings, improving forecasts of water availability, river flows and floods in Brazil.

### Interactive fire and emission algorithm for natural environments (INFERNO)

Wildfires are difficult to represent in Earth system models, due to the complex interactions between fires, vegetation and climate. To address this issue, Mangeon et al. (2016) created INFERNO, which estimates global burned area better than traditional fire indices such as the McArthur Forest Fire Index. Coupling INFERNO with JULES improved estimates of global vegetation cover by 35% (Burton et al. 2019). When used in climate projections, JULES-INFERNO showed significant future changes, decreasing projections of the amount of carbon stored in vegetation in Brazil by up to 25% (Burton et al. 2021).

### Robust ecosystem demography (RED)

Accurately representing vegetation cover in land surface models can be computationally expensive, and models often require many free parameters to describe the vegetation, increasing the uncertainty. RED uses a new, simple but accurate approach, assuming: the density of each plant type (broadleaf trees, needleleaf trees, C3 or temperate grass, C4 or tropical grass, shrubs) is proportional to its mass; that plant growth rates vary as a power of plant mass; and that competition between plants is only relevant for seedlings (Argles et al. 2020). RED will soon become the default dynamic global vegetation model used in JULES.

### Substrate utilisation by growth and autotrophic respiration (SUGAR)

Many land surface models do not represent plant respiration and growth accurately, assuming the amount of carbon that plants accumulate is always equal to the amount of carbon the plant uses in respiration and growth. SUGAR improves the representation of carbon storage in plants, allowing plant respiration and growth to vary independently of photosynthesis (Jones et al. 2020). SUGAR has already been shown to estimate carbon fluxes during a simulated drought in the Amazon more accurately than existing models.

### Stomatal optimisation model based on xylem hydraulics (SOX)

The SOX model simulates the opening and closing of stomata (tiny openings found in leaves and needles which allow gases to enter and leave a plant) and the water that passes through xylem (tissues that transport water through a plant). Current vegetation models represent vegetation responses to soil drought poorly: the SOX model can be coupled to these vegetation models to address these issues (Eller et al. 2018).

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