

JeDi-BACH — towards exploring the interaction between climate and plant diversity

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Background

Earth system models often use a plant functional type (PFT) approach to describe global vegetation. This approach, designed for global application, has been criticized for neglecting intra-variation within a PFT and assigning fixed parameters without taking potential acclimation into account. Besides, paleo-modelling studies have to also **prescribe paleo-vegetation using present-day PFTs** due to limited reconstruction information on vegetation.

We implement a new vegetation model JeDi-BACH into the ICON-ESM taking over the idea from the JeDi model^{1,2}. It obtains an ecologically more reasonable representation of biodiversity based on the idea of environmental filtering.

In particular, JeDi-BACH has advantages for paleo-applications due to its plant representation theory. Being able to couple JeDi-BACH with the atmospheric model ICON-A, we attempt to investigate the interaction of climate and plant trait diversity under different climates.

Philosophy of JeDi-BACH

The aim of JeDi-BACH is to generate plants **as a result of environmental filtering**. To achieve this, JeDi-BACH applies two techniques:

1. Random generation of a large number of plant growth strategies, which all have a different functional capability.
2. Apply the hypothesis of environmental filtering: All species are allowed to grow everywhere, but only those that are able to maintain themselves at the given environment using their “born” functional abilities can survive.



In such a way, **a richer set of functional plants** is obtained with fewer diversity constraints but with more eco-physiological realisms via trade-offs.

Proof of concept

We performed a global simulation of the contemporary climate using JeDi-BACH with 250 random sampled plant species. We tested if JeDi-BACH can recover the observed gradient in root-shoot ratio (RSR) between humid and arid climates.

The ratio is defined as :

$$\text{Root-shoot ratio} = \frac{\text{Belowground biomass}}{\text{Aboveground biomass}}$$

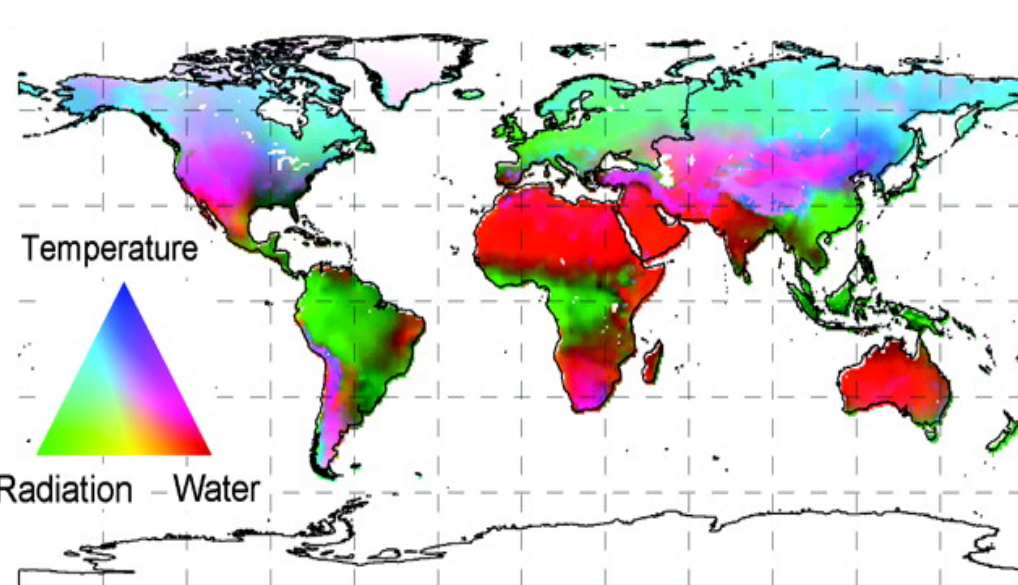
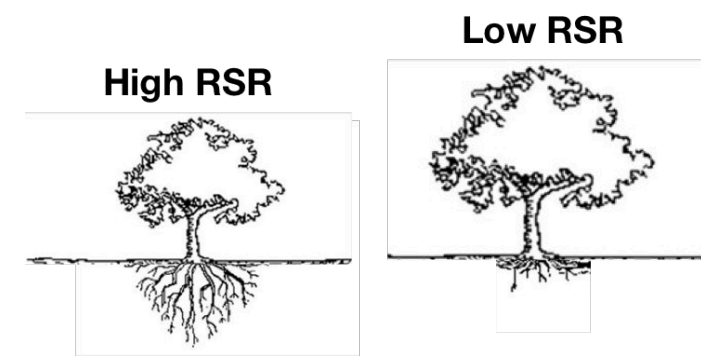


Fig. 1 Potential climatic constraints to plant growth determined from long term climatic and satellite data³. The considered climate attributes are: temperature (blue), radiation (green), and water (red).

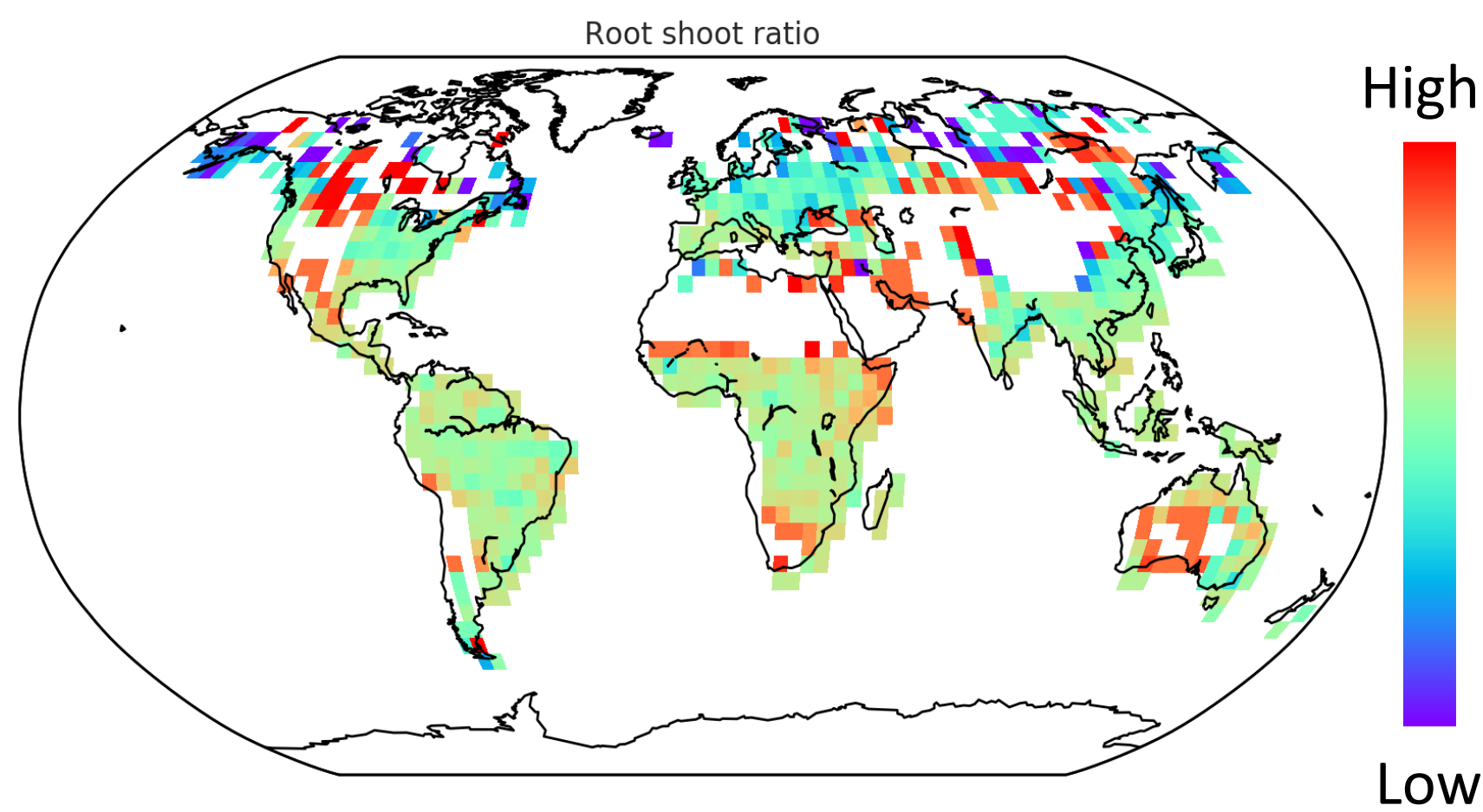


Fig. 2 Aggregated root-shoot ratio of surviving species after environmental selection. High RSR is shown in red and low in blue. Terrestrial blank regions indicate no species survived.

After environmental selection, the global distribution for aggregated RSR among the surviving species is shown in Fig. 2. In regions where water is considered to be the main constraint for plant growth (shown in red in Fig.1), only species with higher RSR (shown in red in Fig.2) survived.

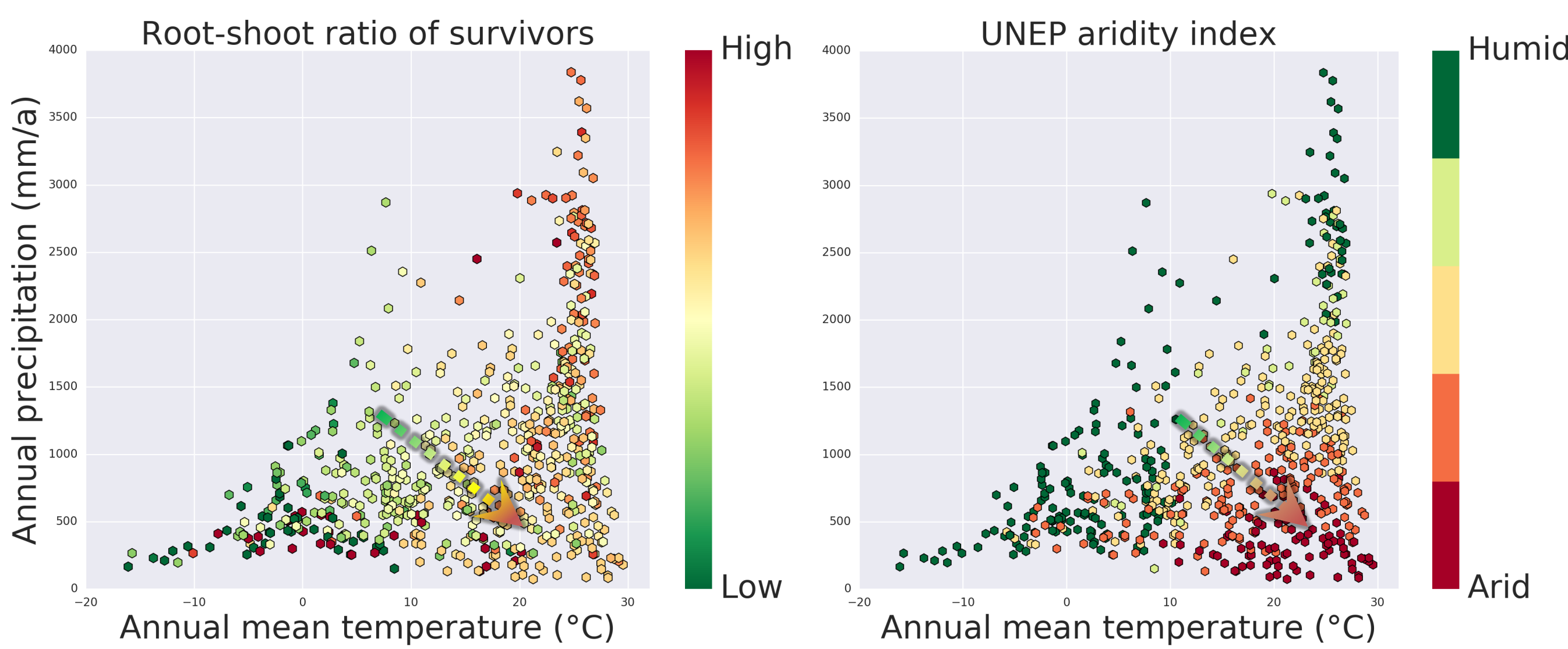


Fig. 3 Relation between root-shoot ratio of surviving species and environmental conditions: In the climate domain (dimensions mean annual mean temperature and precipitation) the gradient of the root-shoot ratio of the surviving species (left) follows the gradient of aridity (right).

As the climate becomes more arid, the RSR increases (Fig.3). This indicates that species that partition more carbon into roots survive better than those that don't. This tendency is consistent with the observational finding⁴ that plants with higher RSR are more likely to be found in arid regions.

Universal plant structure



In JeDi-BACH, each plant species is defined by a set of 15 plant trait parameters (see Table 1 below), which are linked with several functional tradeoffs. The parameters describe **how plants respond to environmental changes**, determine their **life history strategy**, and specify whether they have **a fast or slow growth strategy**. The values of these parameters are randomly sampled from the observational ranges known from global trait database. Hence, each parameter set realizes a plant species with a different growth strategy.

Plant trait parameters	Value
T01: Response time to soil moisture	Days to weeks
T02: Response time to temperature	Days to weeks
T03: Minimum temperature for plant growth	[-5-15°C]
T04: Temperature for terminating growing season	[10-15°C]
T05: Senescence response time to poor productivity	Days to weeks
T06: Germination fraction	[0-1]
T07: Allocation to reproduction	[0-1]
T08: Allocation to aboveground growth	[0-1]
T09: Allocation to belowground growth	[0-1]
T10: Allocation to storage	[0-1]
T11: Relative aboveground allocation to woody tissue	[0-1]
T12: Relative belowground allocation to woody tissue	[0-1]
T13: Woody tissue turnover time	1-80 years
T14: Fine tissue turnover time	1-100 months
T15: Plant nitrogen content	[0.6-3.6 gN/m ² (leaf)]

Table 1. Summary of plant trait parameters used in JeDi-BACH.

Summary & Outlook

With JeDi-BACH we have developed a unique tool capturing the adaptation of plant functional characteristics (e.g. RSR) to changes in the hydrological cycle and other environmental conditions under climate change.

Furthermore, from the given example, we demonstrate the ability of JeDi-BACH to obtain adaptive species under a given climate without much prescribed information about vegetation. This is particularly valuable for deep-time paleo-applications because the information on paleo-vegetation is often inadequate and sparse. JeDi-BACH could obtain better-suited species for modeling studies of no-analog paleo-climate.

Our next step is to perform coupled simulations with the atmospheric model ICON-A. We will thoroughly evaluate the model against a series of observations. Finally, we will study the interaction between plant trait diversity and climate in different climate states such as the Eocene climate.

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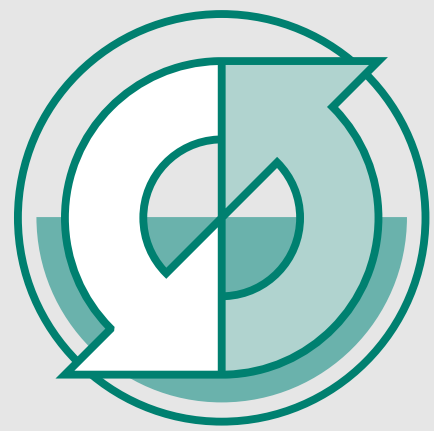
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