Integrating Ecology into Models

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REPORT

Increasing the spatial and temporal impact of ecological research: A roadmap for integrating a novel terrestrial process into an Earth system model

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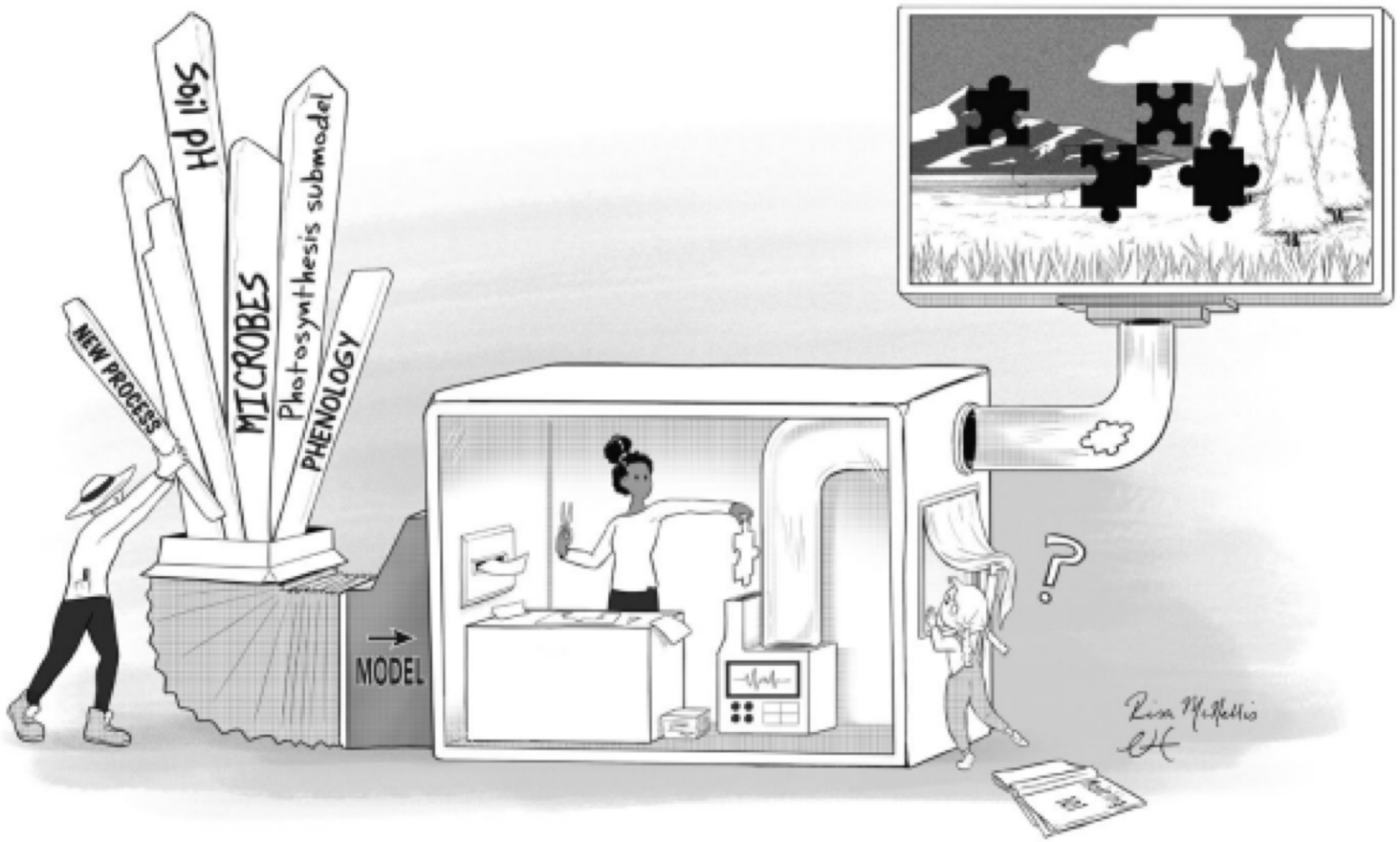
Abstract

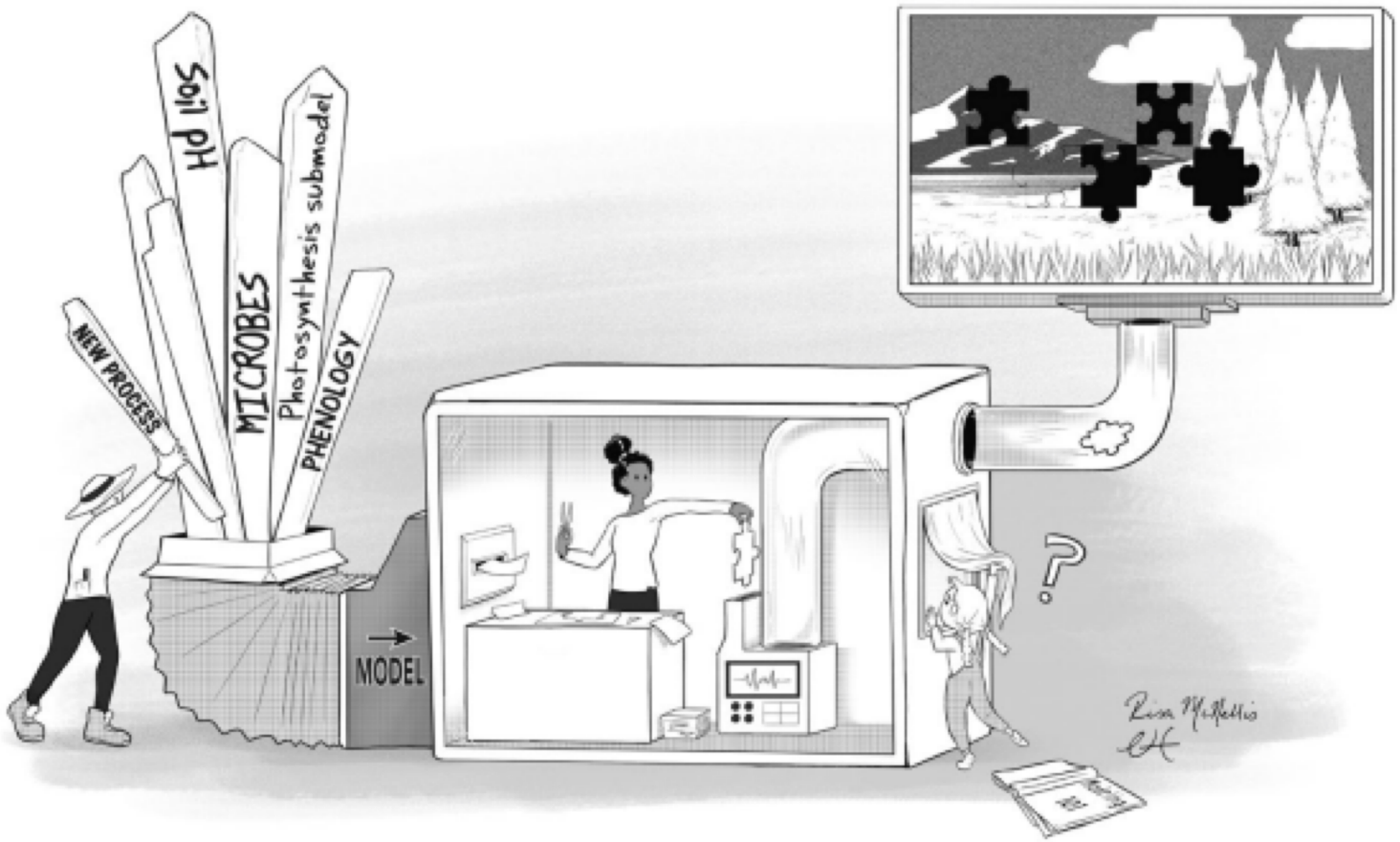
Terrestrial ecosystems regulate Earth's climate through water, energy, and biogeochemical transformations. Despite a key role in regulating the Earth system, terrestrial ecology has historically been underrepresented in the Earth system models (ESMs)

First, a historical perspective…



Dorothy pulled back the curtain to find that the model wasn't magic after all...

FIGURE 1 Historically, the process of integrating ecology in Earth System models (ESMs) has often separated tasks along disciplinary lines, with empirical ecologists feeding data into a mysterious "modeling" process and modelers modifying and using data without a thorough understanding of data collection procedures and caveats. The newest generation of scientists has the opportunity to pull back the curtain by developing cross-disciplinary skill sets and building stronger, more collaborative bridges between empirical and modeling communities, with the goal of accelerating the integration of ecological concepts into ESMs



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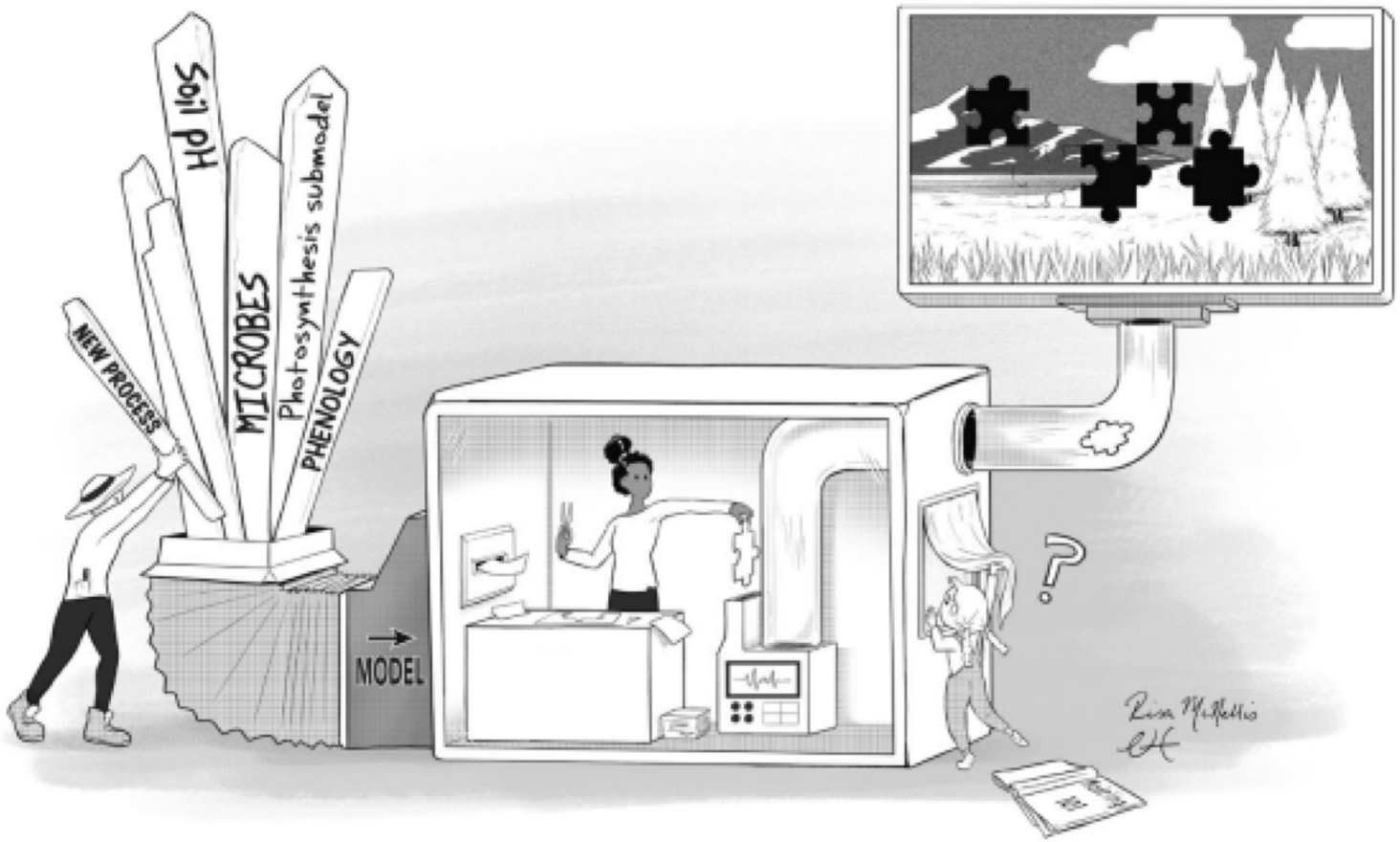

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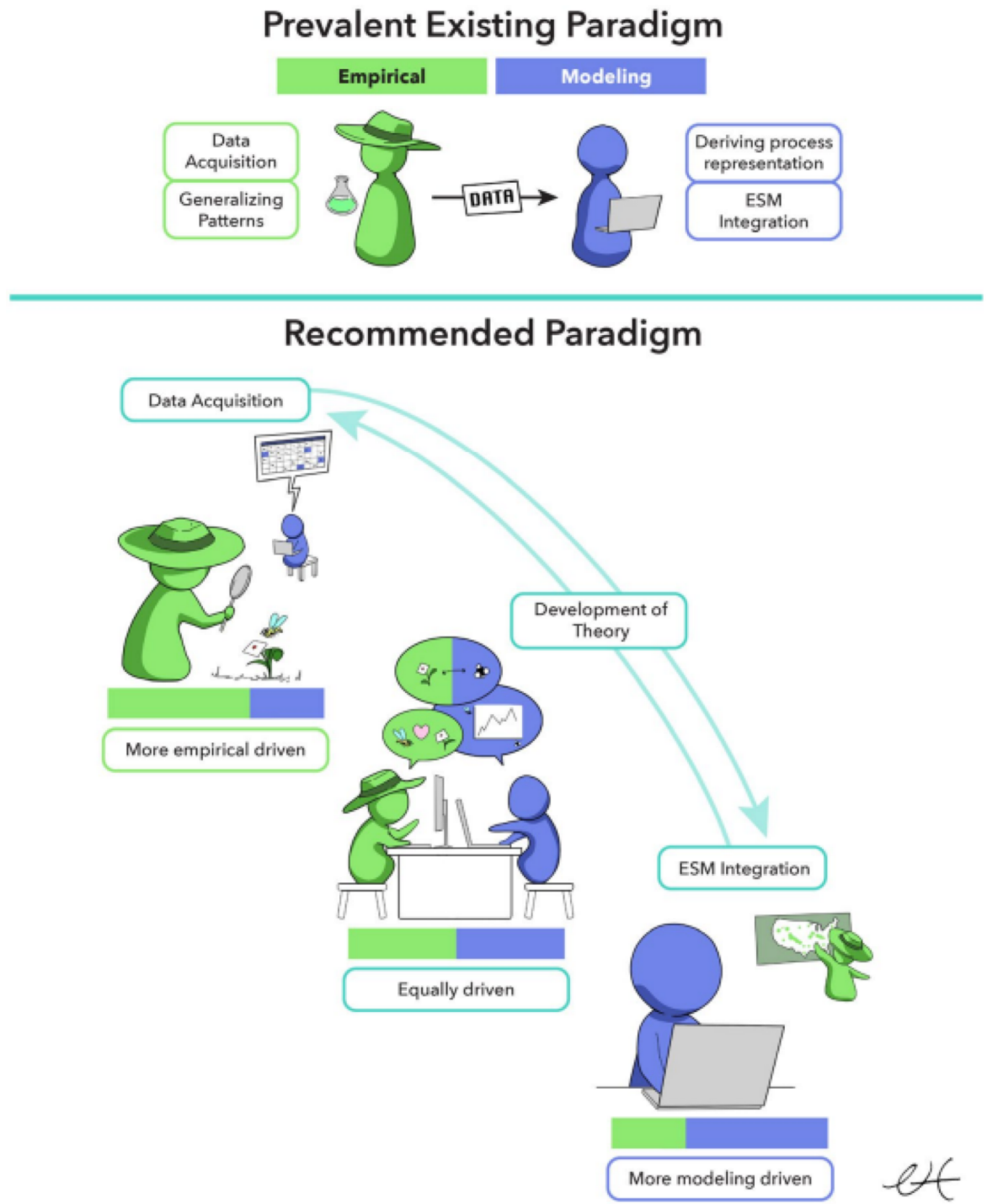
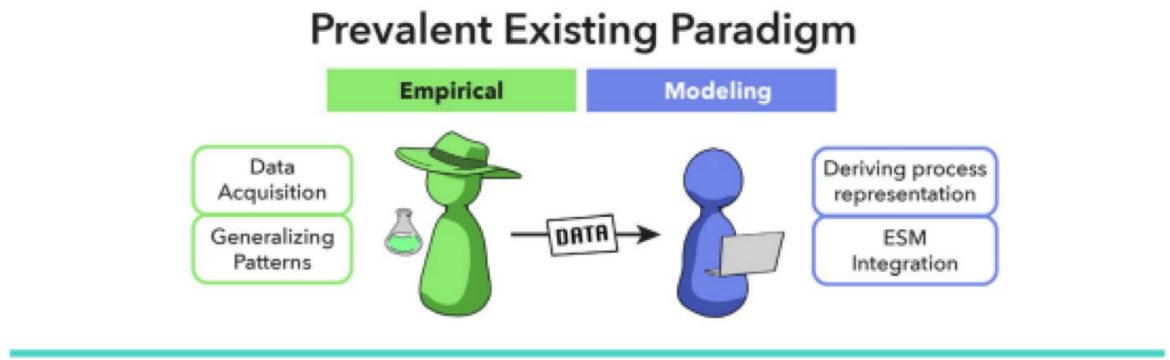


FIGURE 2 The prevalent existing paradigm in ecology–Earth system model (ESM) integration separates tasks along disciplinary lines, with empirical scientists giving data and generalized patterns to modelers who then develop quantitative models and work with ESMs. We recommend a shift away from this historical paradigm toward a more collaborative one in which empiricists and modelers are involved in co-producing knowledge (with differing degrees of contribution) at every stage of data collection, theory development, and model integration. We also emphasize the two-way exchange of ideas, insights, and data between empirical- and modeling-driven activities



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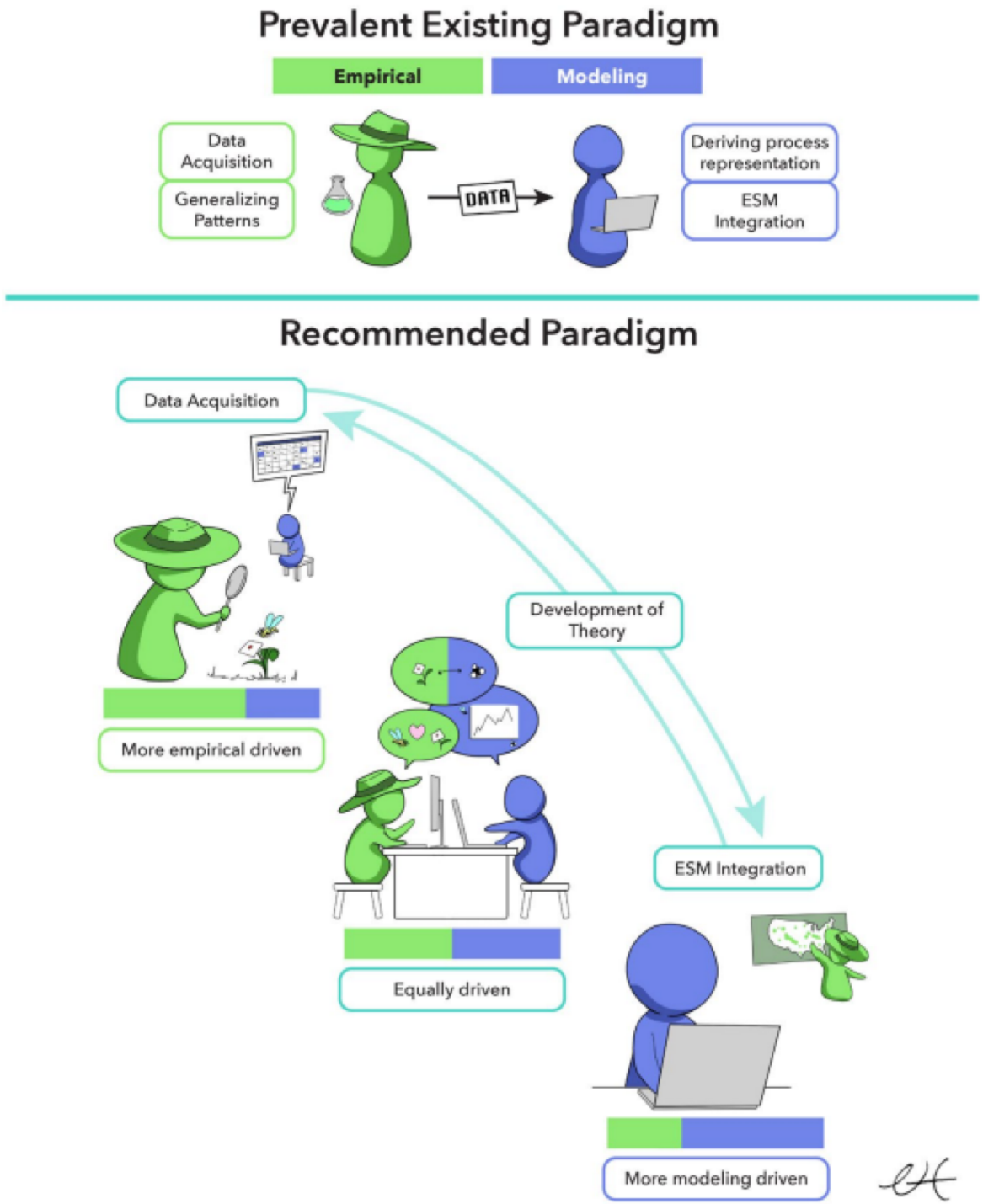


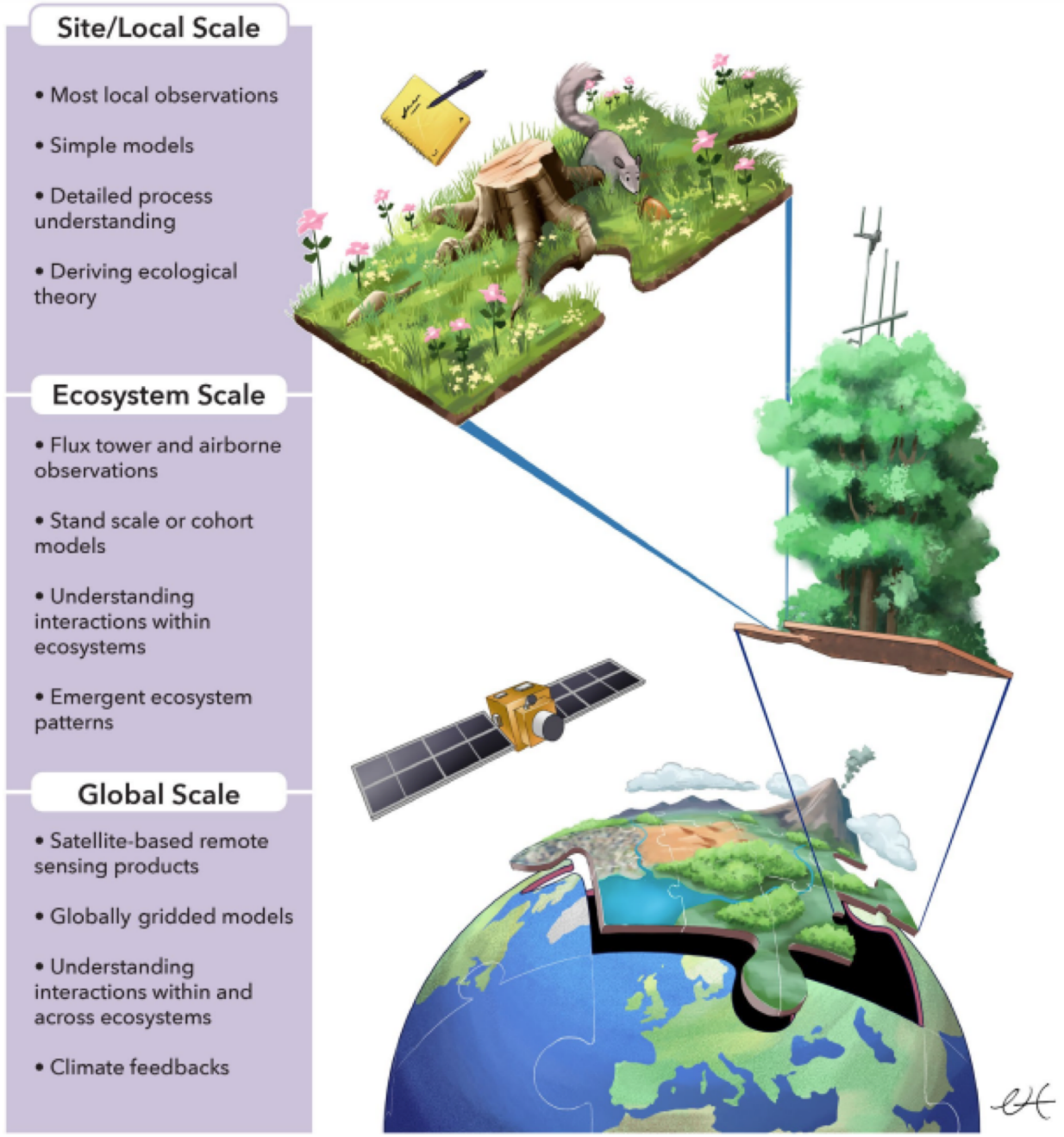


FIGURE 3 In the hierarchy of model development, simple models of individual processes, classes of organisms, and inorganic components (site/local scale) are often pieced together to form larger models of ecosystems and regions (ecosystem scale) and ultimately combined to form Earth system models (global scale). Data gathered at each of these scales can be used to inform model development at the same scale

Piecing together model components can both refine and expand the scale of models

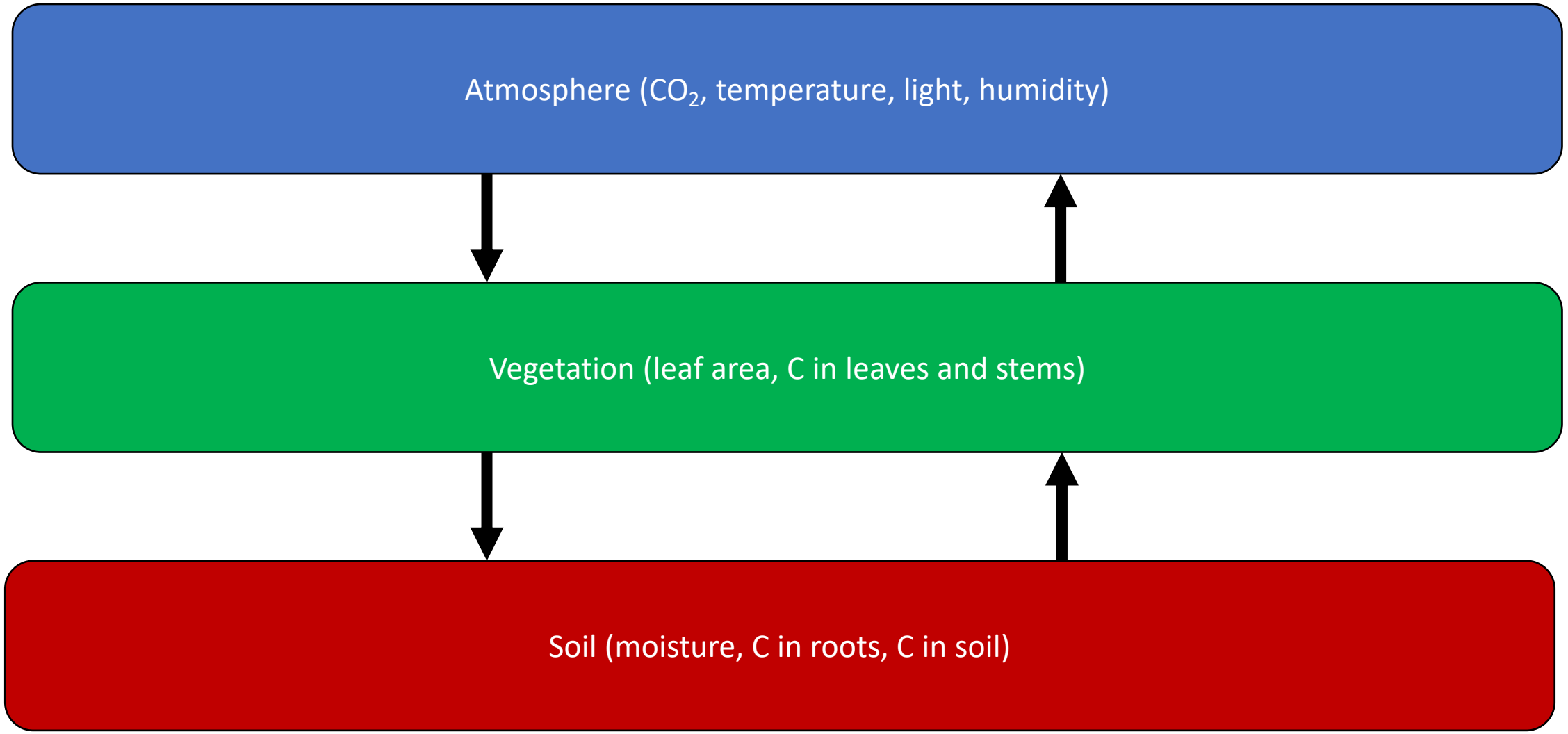
New processes enter an ESM if…

- The process influences climate on large scales
- The process can be reasonably incorporated into present infrastructure
- Process understanding and data are available to model the process globally
- Mathematics of the process are tractable
- There is a community of researchers dedicated to developing, testing, and maintaining the process

Roadmap

Let’s answer these questions in the R script you created for the homework assignment due today

For the purpose of this exercise, let's consider our future "base model"



1. Identifying and understanding the process

Do you expect your process to respond consistently to environmental drivers, enabling scaling across space and time?

1. Identifying and understanding the process

Is your process already in or related to an existing process in the model?

1. Identifying and understanding the process

Is the process likely to influence climate?

2. Beginning to work with simple models

What would a simple model of your process look like?

2. Beginning to work with simple models

Are there data to parameterize and test your simple model?

3. Integrating processes into ESMs

Something still far away on the horizon…

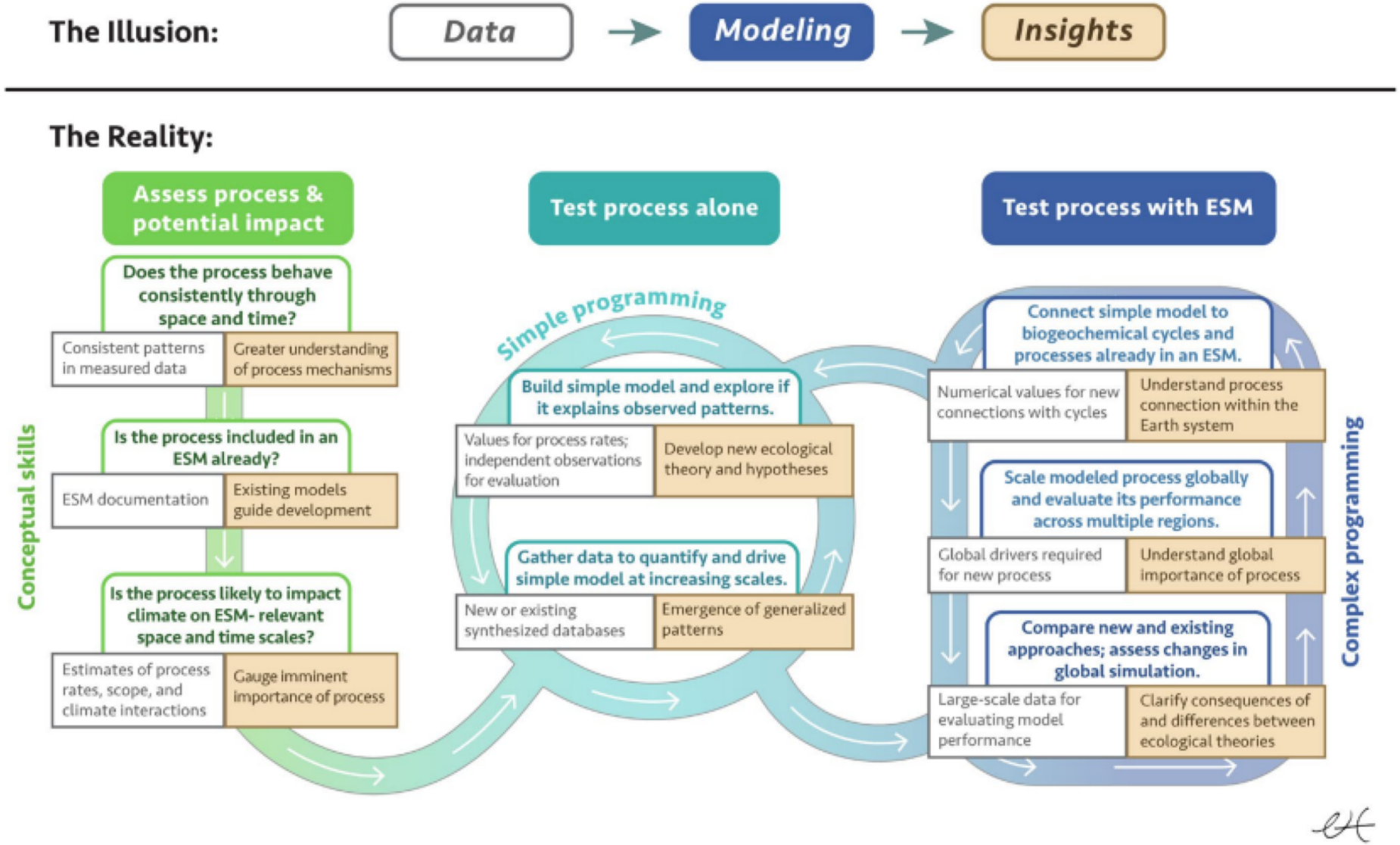


FIGURE 4 Although scientists sometimes think "The Illusion" (top panel) is the way that ecological concepts are integrated into Earth system models (ESMs), the reality is more like a complex metabolic cycle or eddy-filled stream, with different data inputs (gray boxes) and valuable insights (tan boxes) throughout the workflow. We identify three key phases in integrating a new process into an ESM, namely, "Assess process & potential impact," which emphasizes conceptual skills (green boxes), "Test process alone," which involves simple programming (teal), and "Test process with ESM," which involves more complex programming (blue). Within each phase, we offer specific questions to guide empiricists and modelers along the way