Terrestrial Ecosystem Models

JAMES | Journal of Advances in Modeling Earth Systems®

Commissioned Manuscript | Open Access

Perspectives on the Future of Land Surface Models and the Challenges of Representing Complex Terrestrial Systems

Rosie A. Fisher, Charles D. Koven

First published: 10 March 2020 | https://doi.org/10.1029/2018MS001453 | Citations: 262

R. A. Fisher and C. D. Koven contributed equally to this manuscript.

Different types of models

- Land surface models
- Terrestrial biosphere models
- Terrestrial ecosystem models
- Dynamic vegetation models
- General circulation models
- Earth system models

Different types of models

- Land surface models
- Terrestrial biosphere models
- Terrestrial ecosystem models
- Dynamic vegetation models
- General circulation models
- Earth system models

Generally thought of to be the same thing:
"numerical models that solve the coupled fluxes of water, energy, and carbon between the land surface and atmosphere, within a context of direct and indirect human forcings and ecological dynamics" (Fisher and Koven, 2020)

Different types of models

- Land surface models
- Terrestrial biosphere models
- Terrestrial ecosystem models
- Dynamic vegetation models
- General circulation models
- Earth system models

A type of land surface model where the type of vegetation in a given location can change

Different types of models

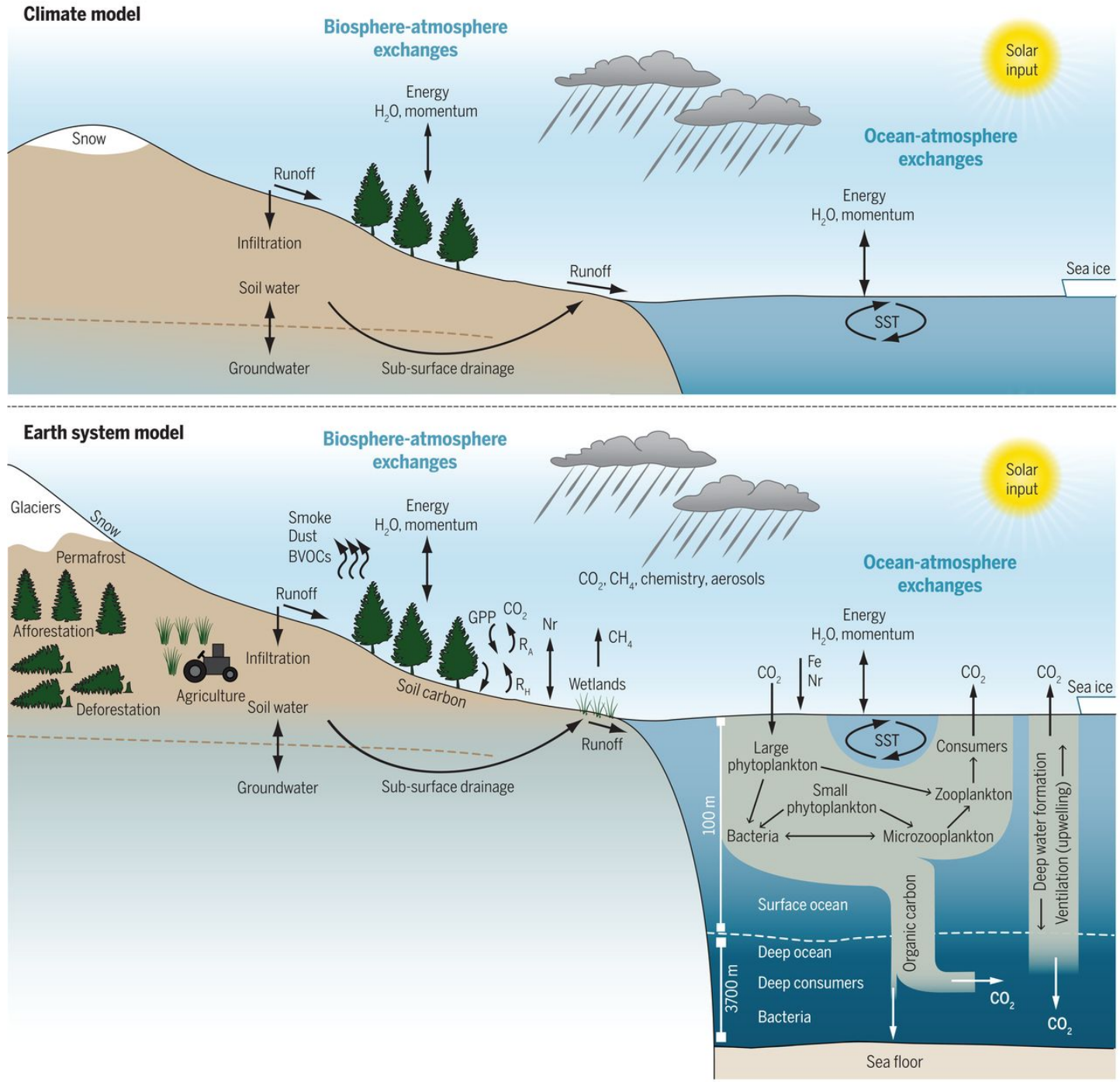
- Land surface models
- Terrestrial biosphere models
- Terrestrial ecosystem models
- Dynamic vegetation models
- General circulation models
- Earth system models

Models of atmospheric pools and fluxes used to predict climate dynamics

Different types of models

- Land surface models
- Terrestrial biosphere models
- Terrestrial ecosystem models
- Dynamic vegetation models
- General circulation models
- Earth system models

A model that couples together models of different components of the Earth system (e.g., land, ocean, atmosphere, sea ice, etc.)



Bonan and Doney (2018)

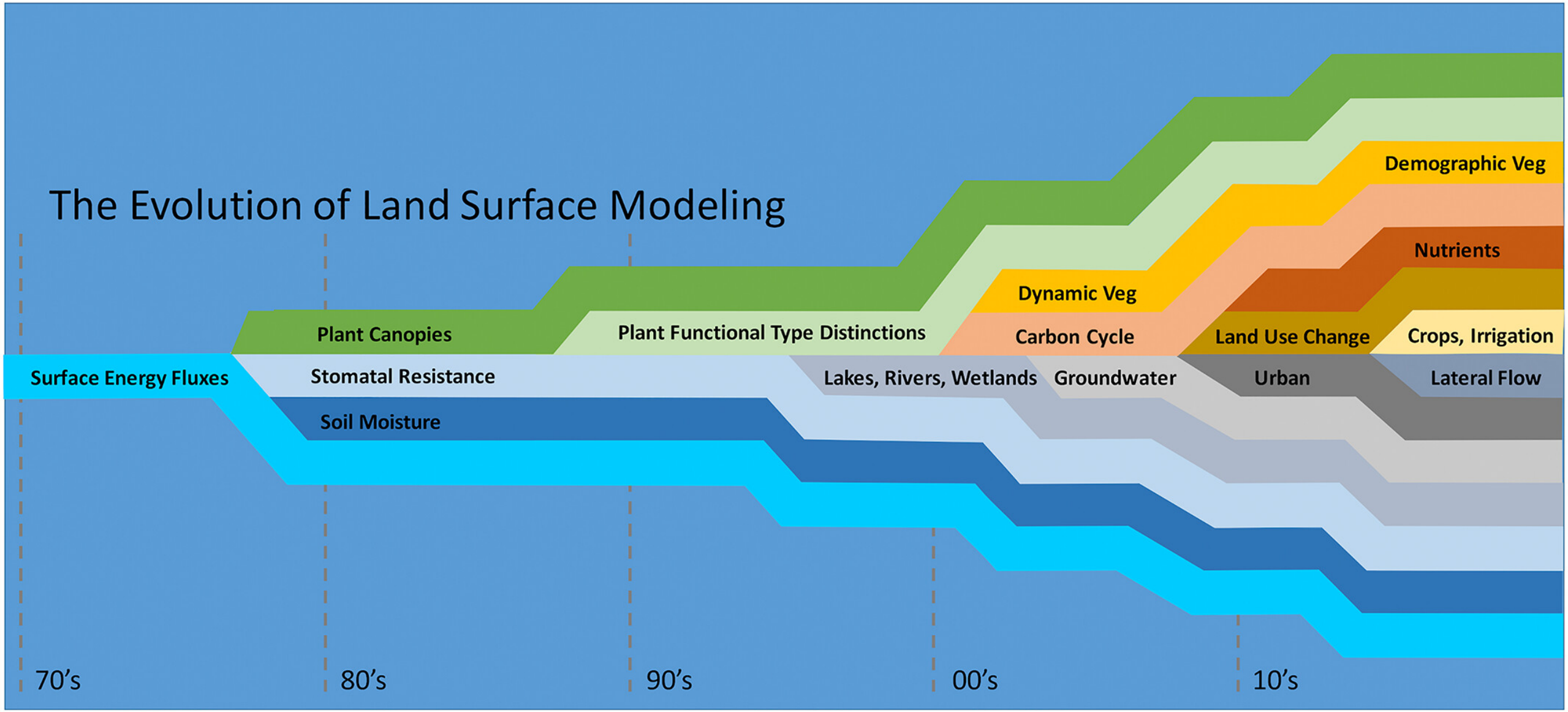
This class will focus on land surface/terrestrial biosphere/terrestrial ecosystem models

- Land surface models
- Terrestrial biosphere models
- Terrestrial ecosystem models
- Dynamic vegetation models
- General circulation models
- Earth system models

"numerical models that solve the coupled fluxes of water, energy, and carbon between the land surface and atmosphere, within a context of direct and indirect human forcings and ecological dynamics" (Fisher and Koven, 2020)

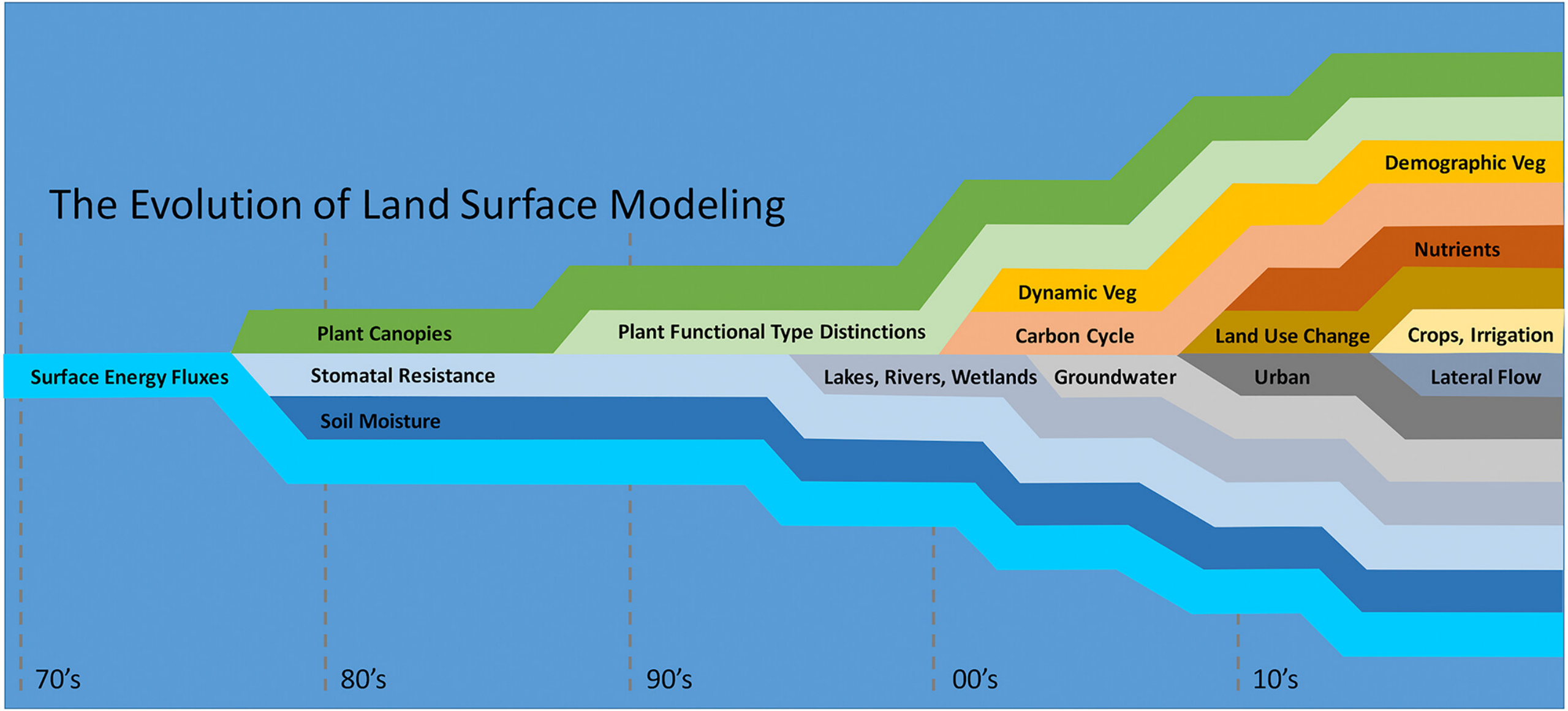
Why were these models originally developed?

1. Plant biophysical responses have an appreciable effect on climate
2. Terrestrial biogeochemical responses have an appreciable effect on climate through their impact on the carbon cycle



Fisher and Koven (2020)

How do these influence biophysical and biogeochemical processes?



Fisher and Koven (2020)

Table 1. Planetary stresses faced by terrestrial and marine ecosystems.

Stress	Reference
Terrestrial ecosystems	
Greening of the biosphere	
Earlier springtime and longer growing season	(*101*)
Higher leaf area index	(*55*)
Greater productivity	(*56*, *91*)
Higher water-use efficiency	(*102*)
Increased nitrogen deposition	(*5*, *26*, *28*)
Diffuse radiation	(*103*)
Browning of the biosphere	
Tree mortality	(*104*)
Extreme events	(*105*)
Wildfire and insects outbreaks	(*36*, *106*)
Ozone damage	(*29*, *30*)
Community assemblages	(*107*)
Land-use and land-cover change	(*4*, *40*)
Human appropriation of net primary production	(*108*)

Bonan and Doney (2018)

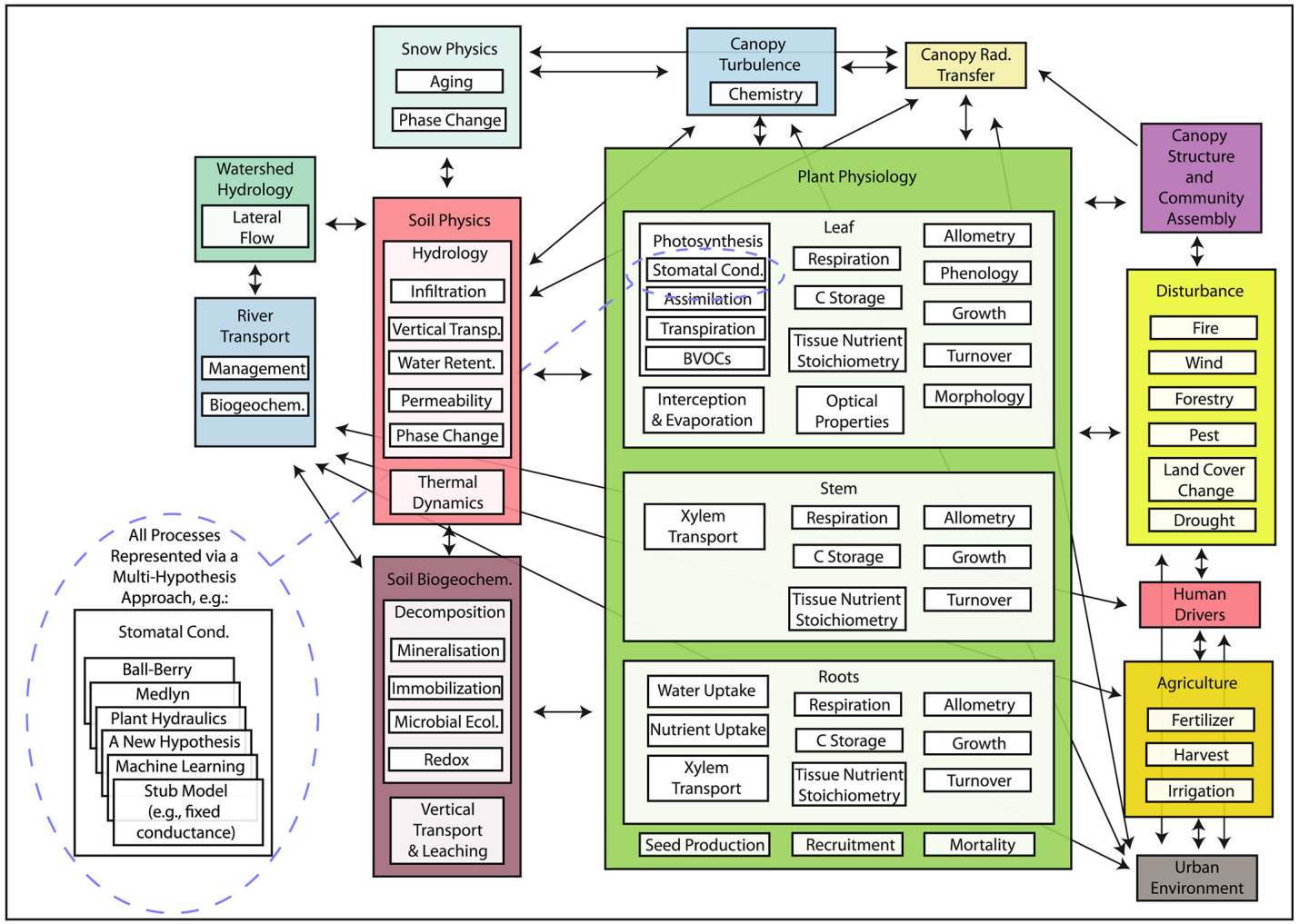
Fisher and Koven's 3 grand challenges

1. Managing and understanding process complexity
2. Heterogeneity and the dimensionality of the land surface
3. Projecting the temporal and spatial dynamics of model parameters

Fisher and Koven's 3 grand challenges

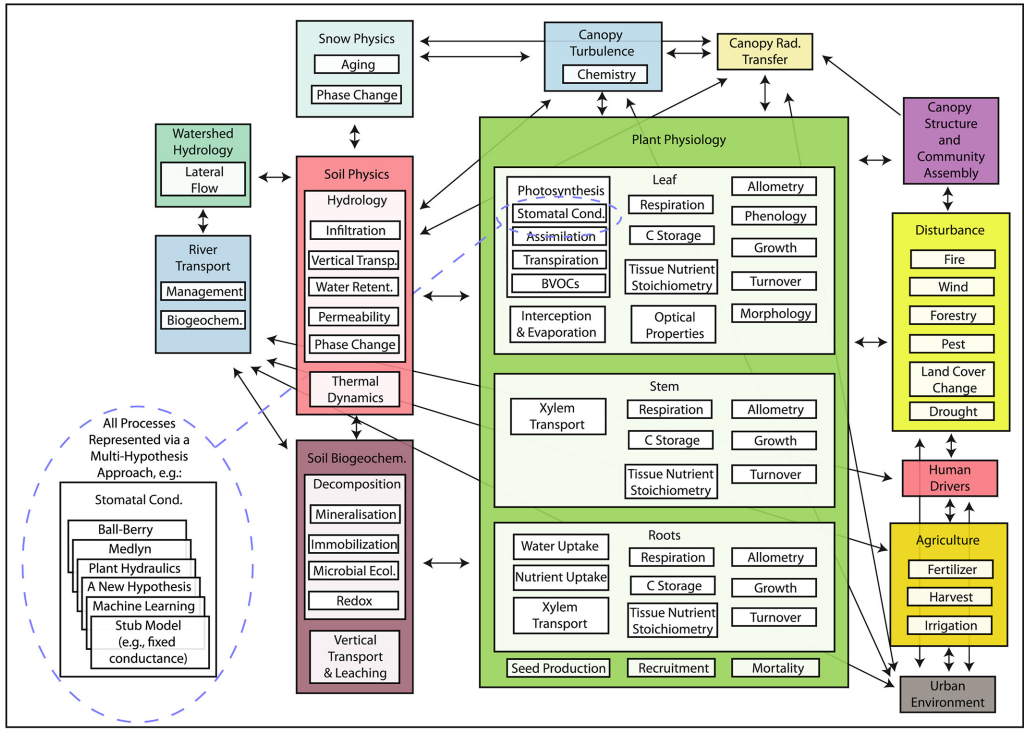
1. Managing and understanding process complexity
2. Heterogeneity and the dimensionality of the land surface
3. Projecting the temporal and spatial dynamics of model parameters

“the scope and complexity of land surface models have reached the point that no individuals are able to comprehensively understand all facets of any one model”

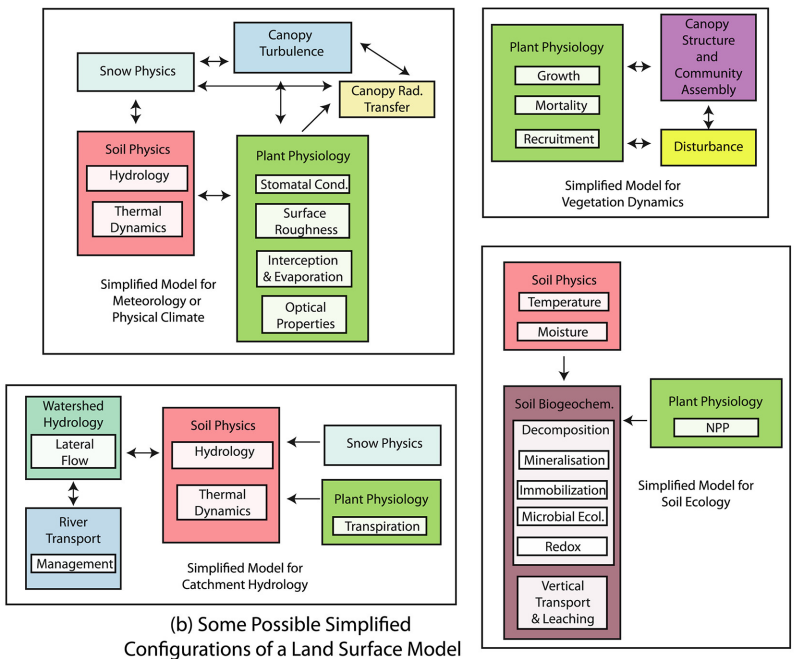


Land surface models can be super complex

Fisher and Koven (2020)



(a) Process Schematic of a Possible Full-Complexity Configuration of a Land Surface Model

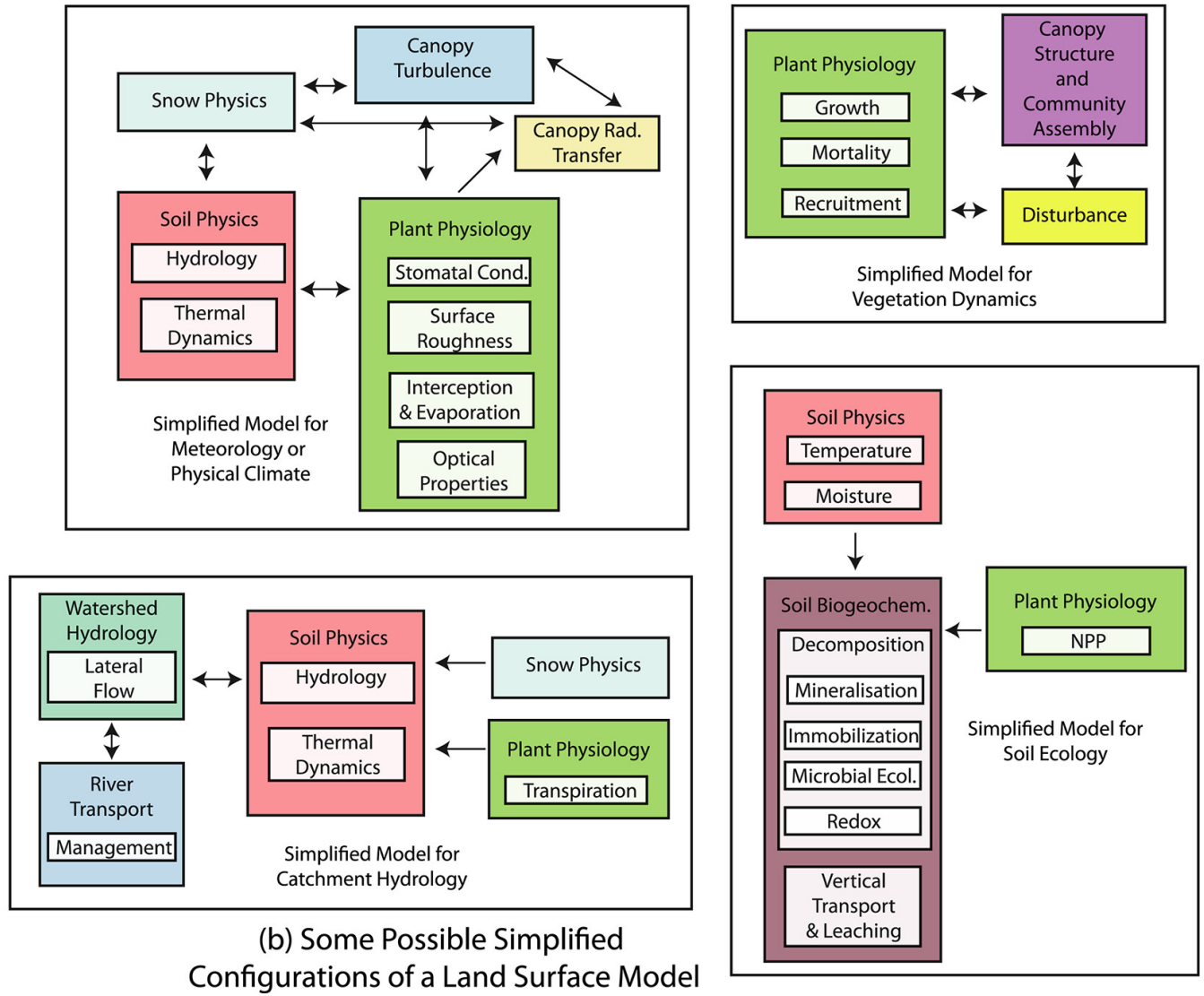


(b) Some Possible Simplified Configurations of a Land Surface Model

Modular complexity as a strategy for understanding models

Fisher and Koven (2020)

(a) Process Schematic of a Possible Full-Complexity Configuration of a Land Surface Model

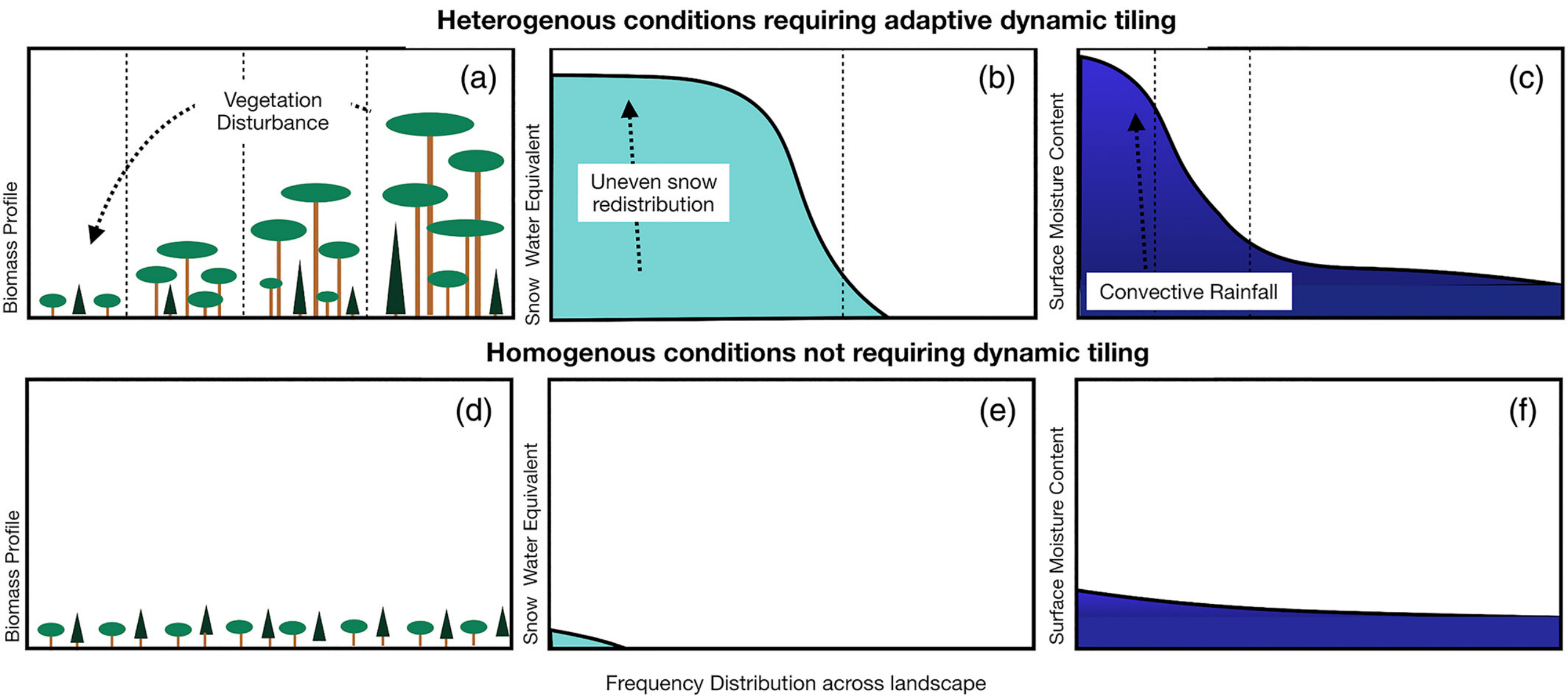


(b) Some Possible Simplified Configurations of a Land Surface Model

Fisher and Koven (2020)

Fisher and Koven's 3 grand challenges

1. Managing and understanding process complexity
2. Heterogeneity and the dimensionality of the land surface
3. Projecting the temporal and spatial dynamics of model parameters



Fisher and Koven (2020)

Fisher and Koven's 3 grand challenges

1. Managing and understanding process complexity
2. Heterogeneity and the dimensionality of the land surface
3. Projecting the temporal and spatial dynamics of model parameters

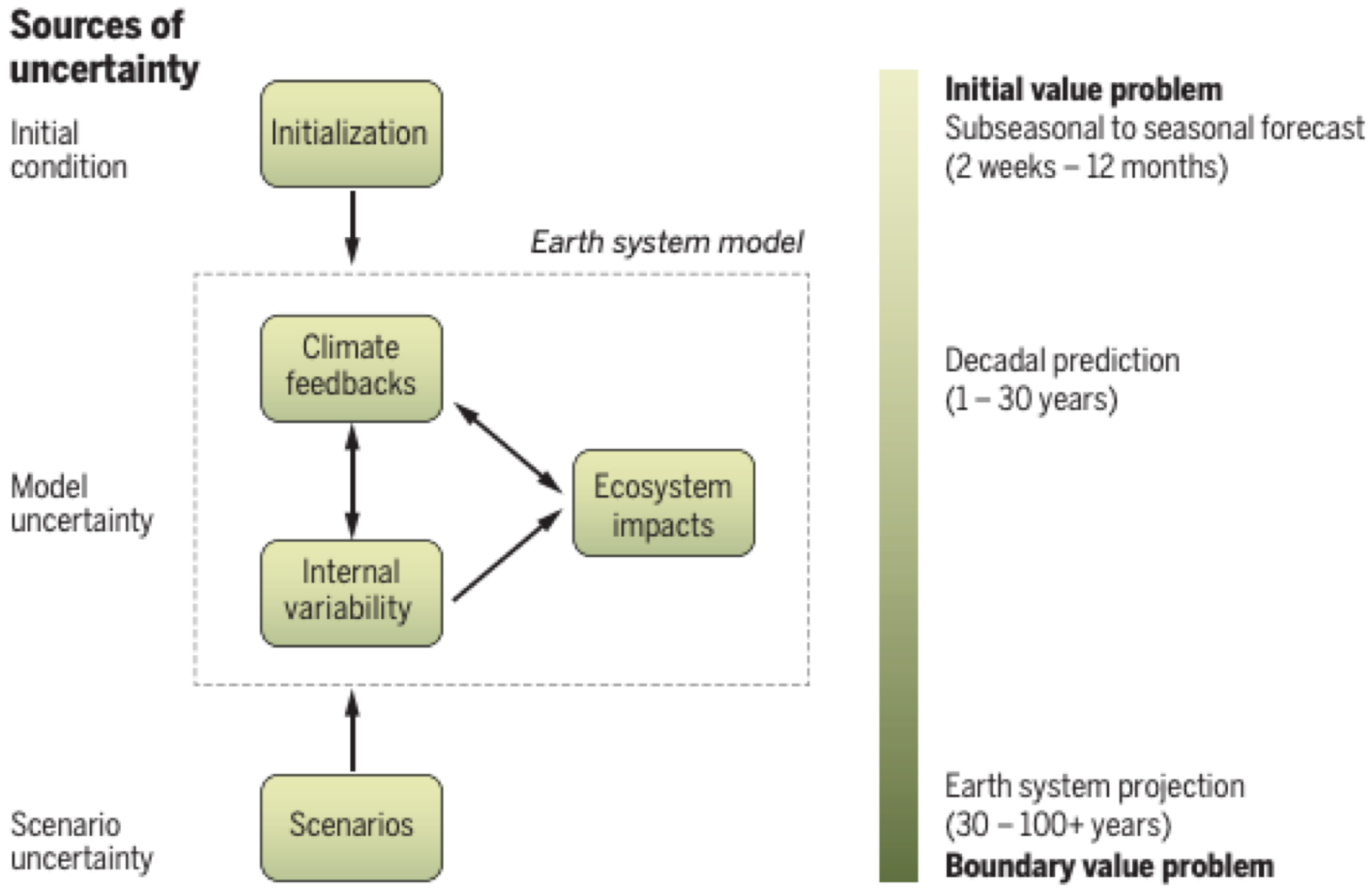
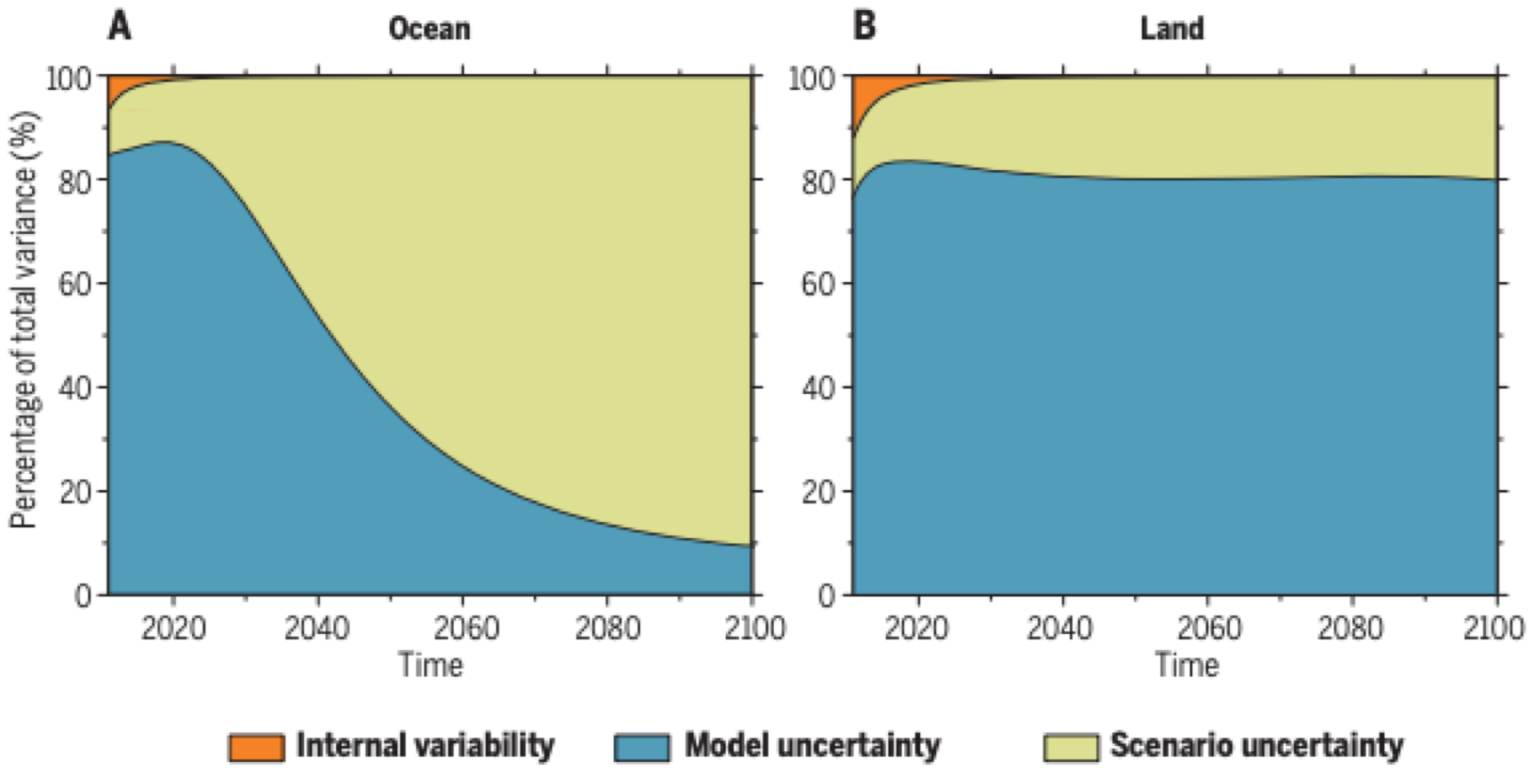
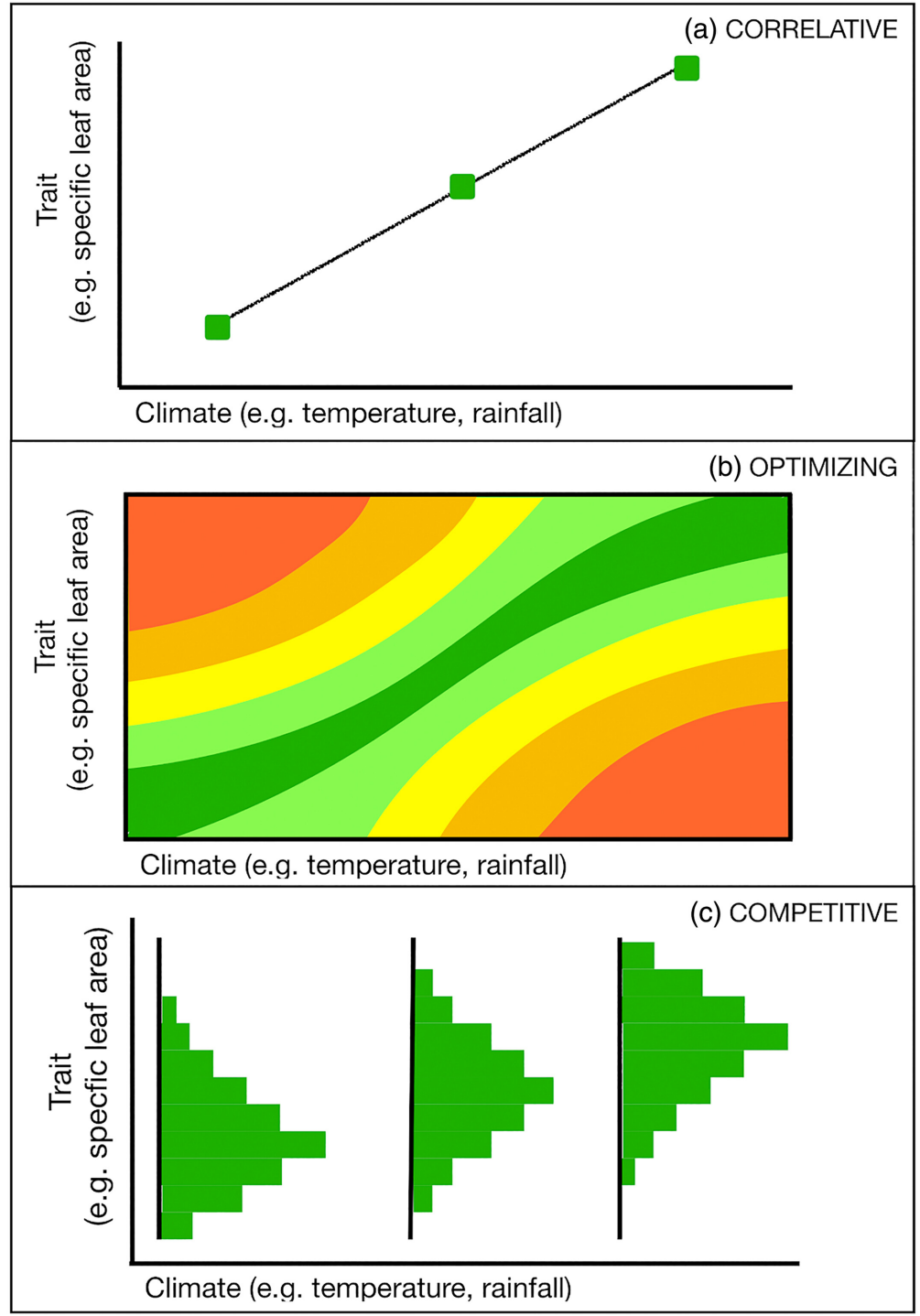


Fig. 2. Schematic depiction of Earth system prediction of the biosphere. The synergies between climate feedback processes, internal climate variability, and ecosystem impacts determine model outcomes. Subseasonal to seasonal forecasts and decadal climate prediction are initial value problems Earth system projections are a boundary value problem driven by anthropogenic forcing scenarios. Uncertainty arises from inexactness of initial conditions, model imperfections, and scenarios.

Bonan and Doney (2018)



Bonan and Doney (2018)



Fisher and Koven (2020)

In this class, we're taking a slightly different approach than "typical modelers"

- We're starting from scratch to build a model from the beginning
- Not using a pre-developed model
- What are the positives/negatives of this approach?