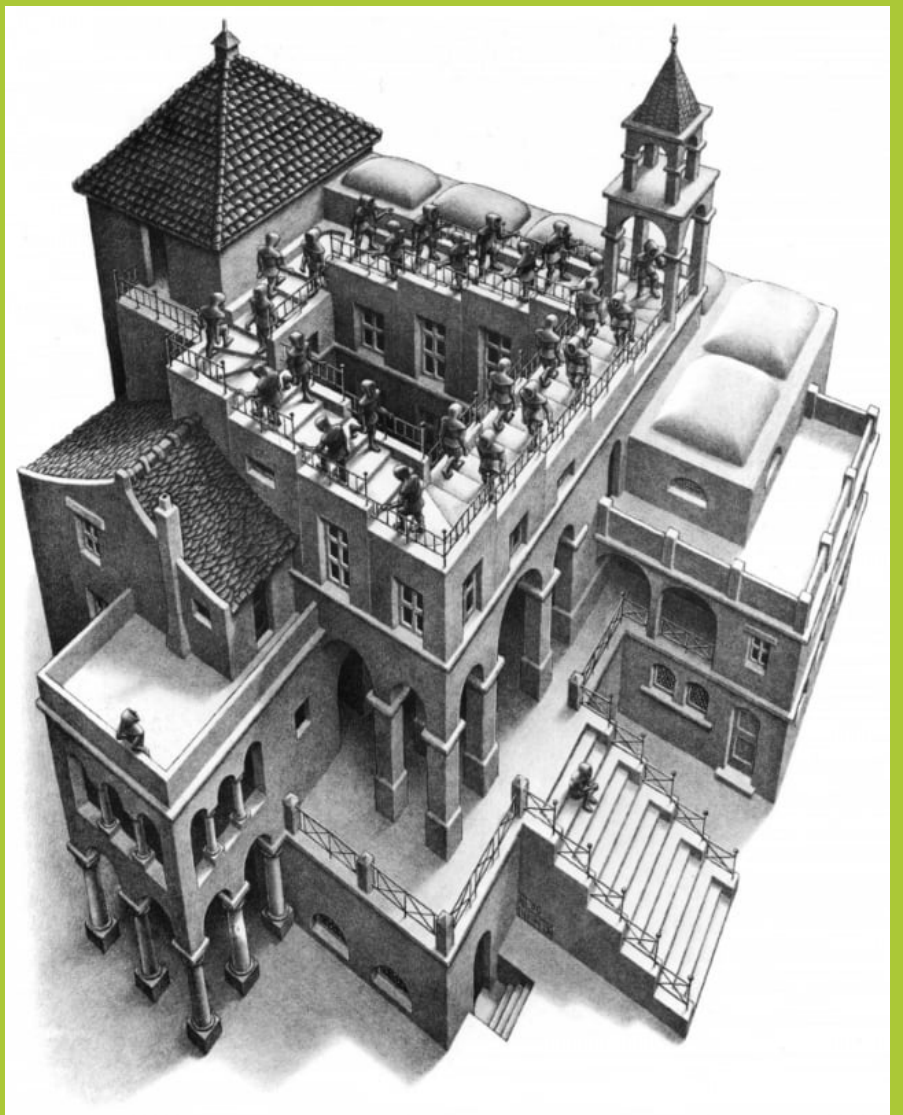
Introduction to process-based forest modelling

Miquel De Cáceres, Rodrigo Balaguer
Ecosystem Modelling Facility, CREAF

Outline

1. Fundamental concepts
2. Modelling cycle
3. Overview of process-based forest models



M.C. Escher - Ascending and Descending, 1960

1. Fundamental concepts

Models: What are they?

- *Model* - A **simplification of reality** constructed to gain insights into a set of attributes of a physical, biological, economic, or social system.
- *Conceptual model* - A **hypothesis** regarding the important factors that govern the behavior of an object or a process of interest.
- *Statistical model* - A numerical model **built using observations** within a probabilistic framework.
- *Mechanistic (or process-based) model* - A numerical model that explicitly **represents the understanding** of physical, chemical or biological processes.
- *Simulation model* - A numerical model that represents the development of a solution by **incremental steps** through the model domain.

Model components

- *Modules* or *sub-models* - An independent or self-contained component of a model (e.g. Farquhar's C3 photosynthesis model).
- *State variables* - The dependent variables calculated within a model, which often **change over the simulation** (e.g. soil moisture).
- *Parameters* - Terms in the model that are **fixed during a model run** but can be changed in different runs (e.g. soil texture).
- *Constants* - Terms that are **fixed values under all runs**, representing known physical, biological or ecological activities (e.g. the speed of light).

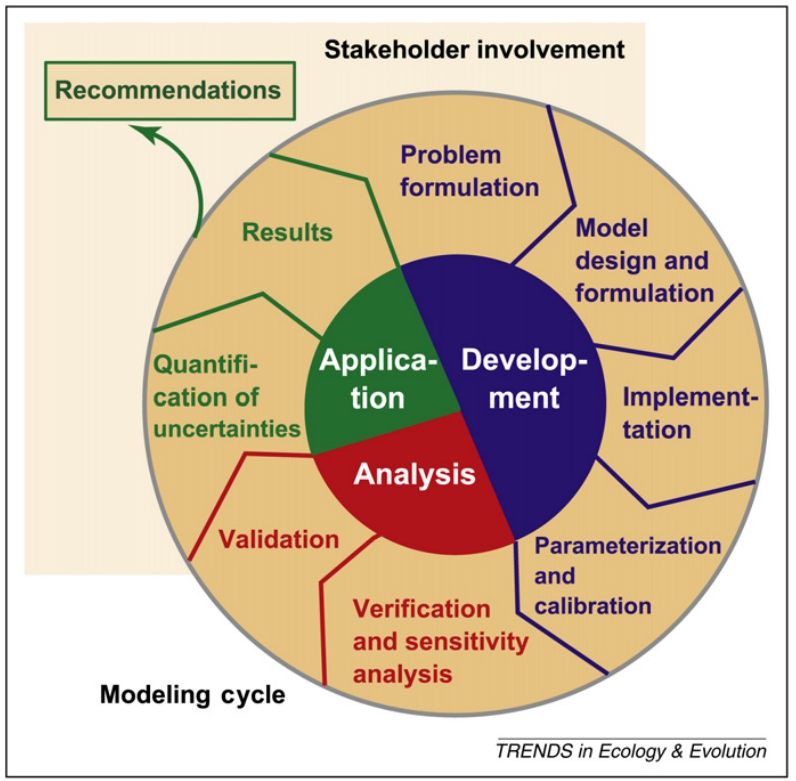
Model assessment

- *Verification* - Examination of the implementation to ascertain that they truly **represents the conceptual model** and there are no inherent numerical problems.
- *Qualitative assessment* - Uncertainty in model predictions that **cannot be quantified** (i.e. about the theory underlying the model or the model design).
- *Uncertainty analysis* - Investigation of the **effects** of lack of knowledge or potential errors of **inputs** (e.g. climate forcing) **on the model output**.
- *Robustness* - The capacity of a model to perform well **across the full range of conditions** for which it was designed.
- *Sensitivity* - The degree to which the model outputs are **affected by changes in input parameters**.
- *Transparency* - The clarity and completeness with which data, assumptions, and methods of analysis are **documented**.

2. Modelling cycle

Modelling tasks: Development (1)

1. *Problem formulation*
    - Definition of objectives
    - Definition of the spatio-temporal physical domain
2. *Model design and formulation*
    - Data availability
    - Conceptual model
    - Use of existing vs. new model formulation
    - Compatibility with other modules
3. *Implementation*
    - Algorithmic design
    - Model coding (e.g. Python, C++)
    - Profiling and code optimization



Modelling tasks: Development (2)

4. *Parameterization and calibration*

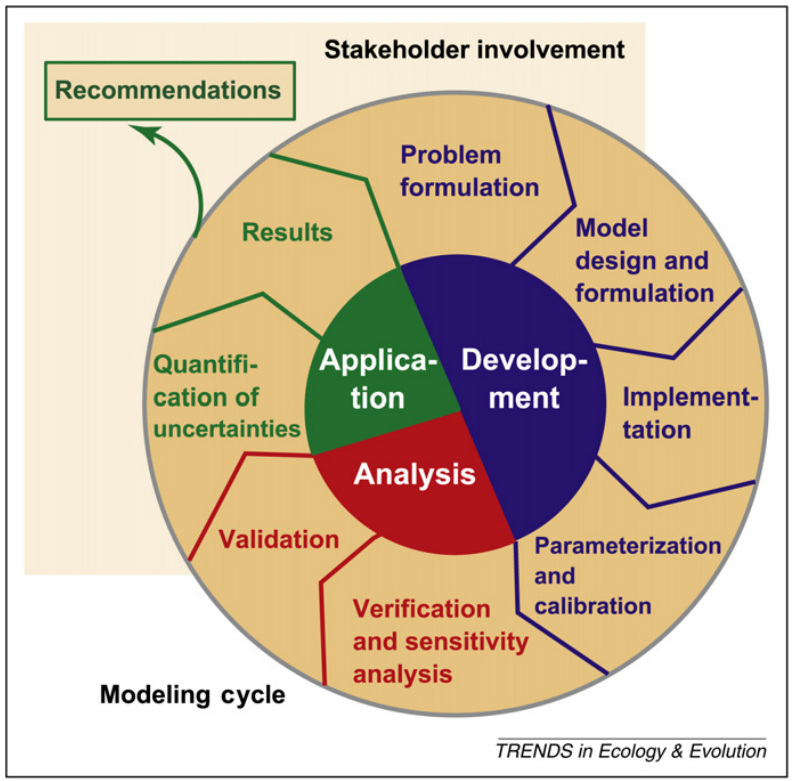
- Sources for direct parameter estimation
- Sources for parameter calibration
- Meta-modelling (estimation from the output of other models)

5. *Model analysis*

- Verification and qualitative assessment
- Sensitivity/uncertainty analysis
- Formal evaluation (validation)

6. *Model application*

- Simulation and documentation
- Quantifying uncertainty
- Evidence for decision



3. Overview of process-based forest models

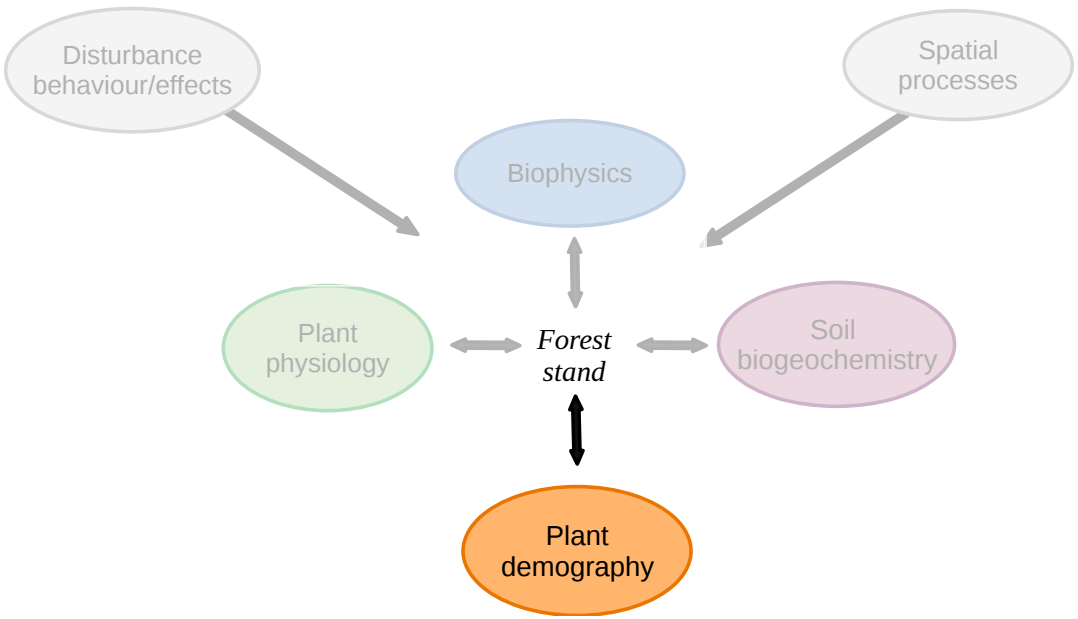
A typology of forest processes

Processes

A typology of forest processes

Forest gap models

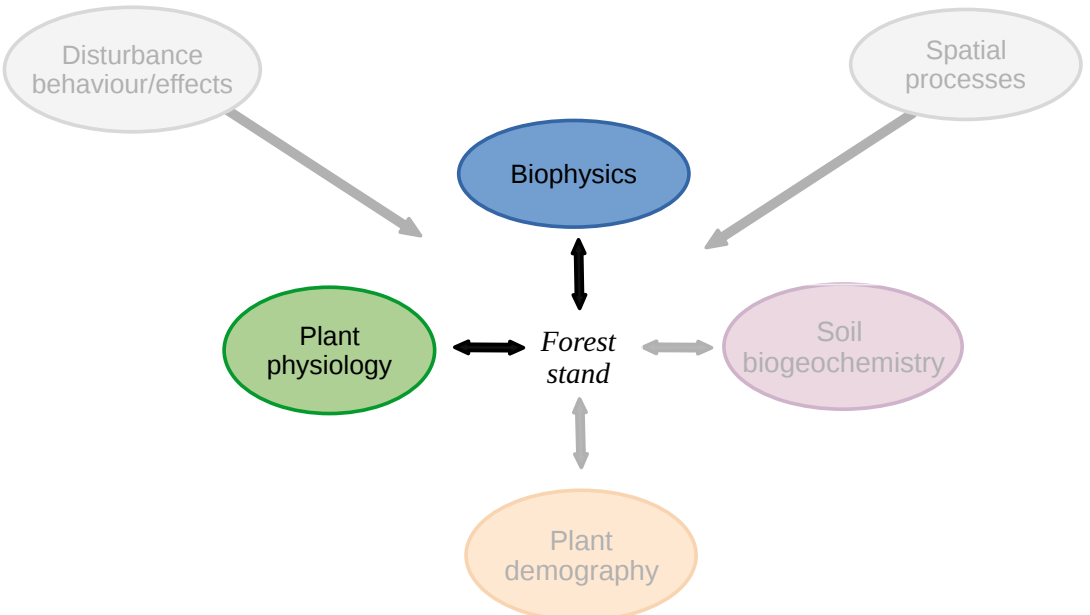
FORCLIM, FORCEEPS, GREFOS



A typology of forest processes

Soil-vegetation-atmosphere transfer model

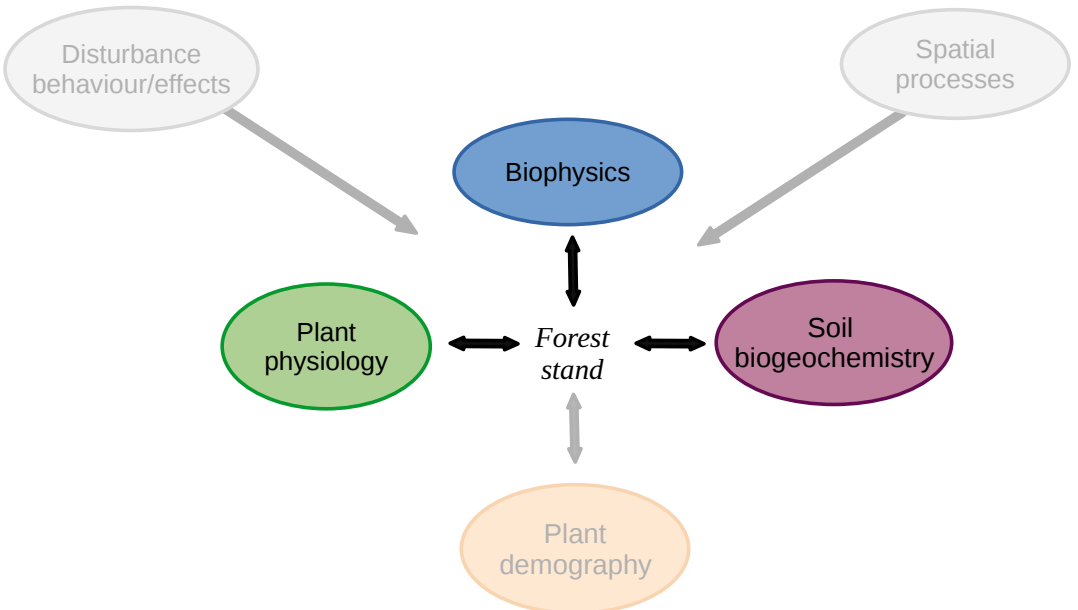
BILJOU, MuSICA, CANVEG



A typology of forest processes

Forest biochemical model

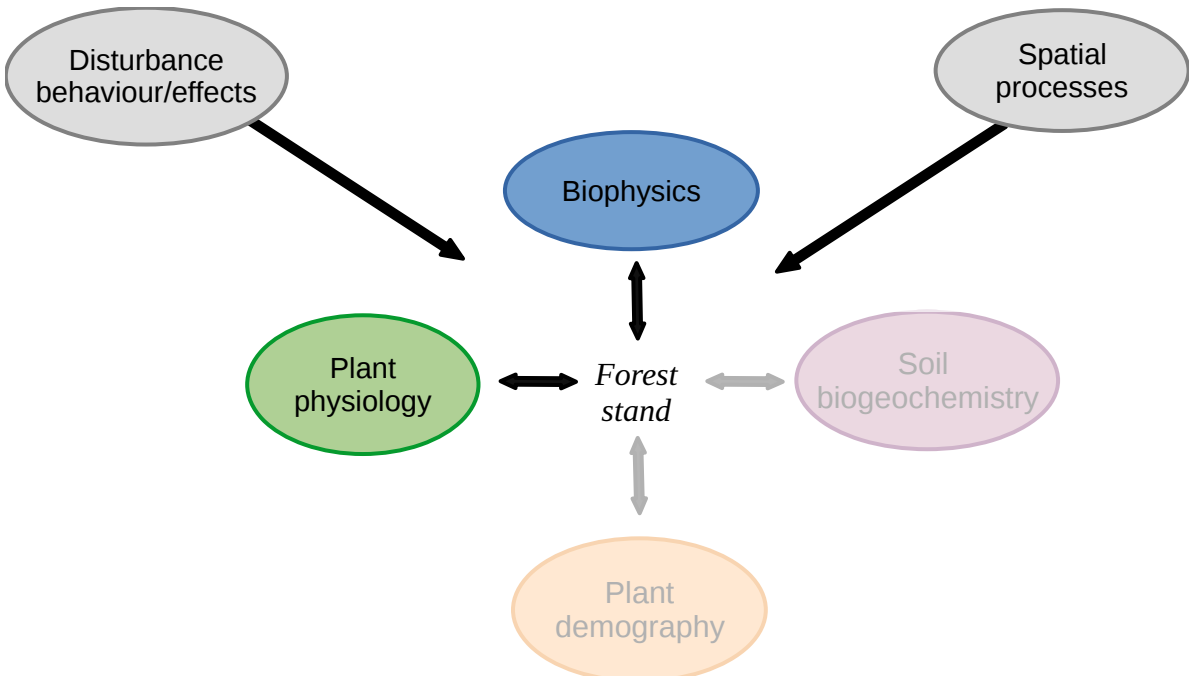
CASTANEA, GOTILWA+, FOREST-BGC

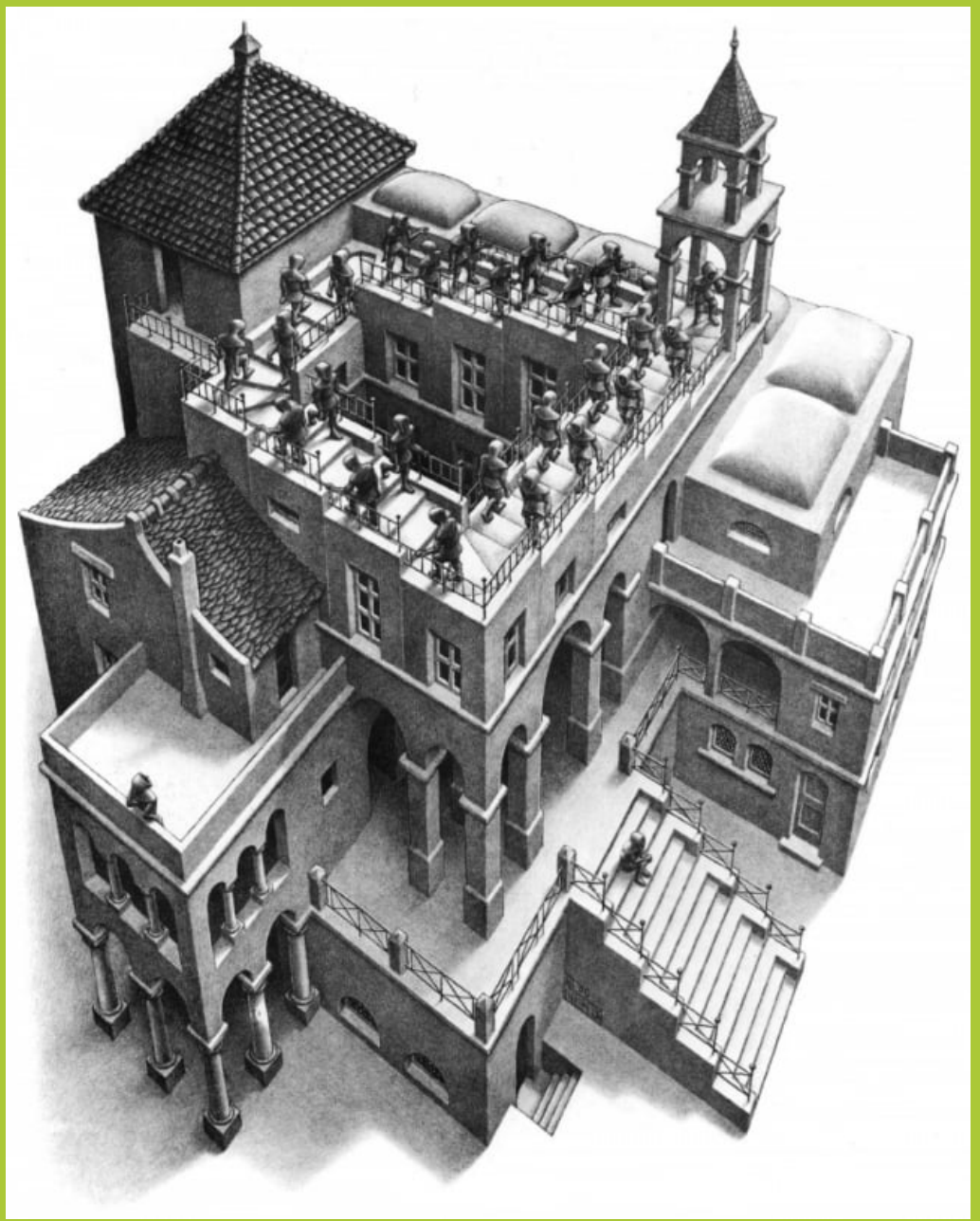


A typology of forest processes

Watershed ecohydrological model

RHESYS, ECH2O, Tethys-Chloris





M.C. Escher - Ascending and Descending, 1960