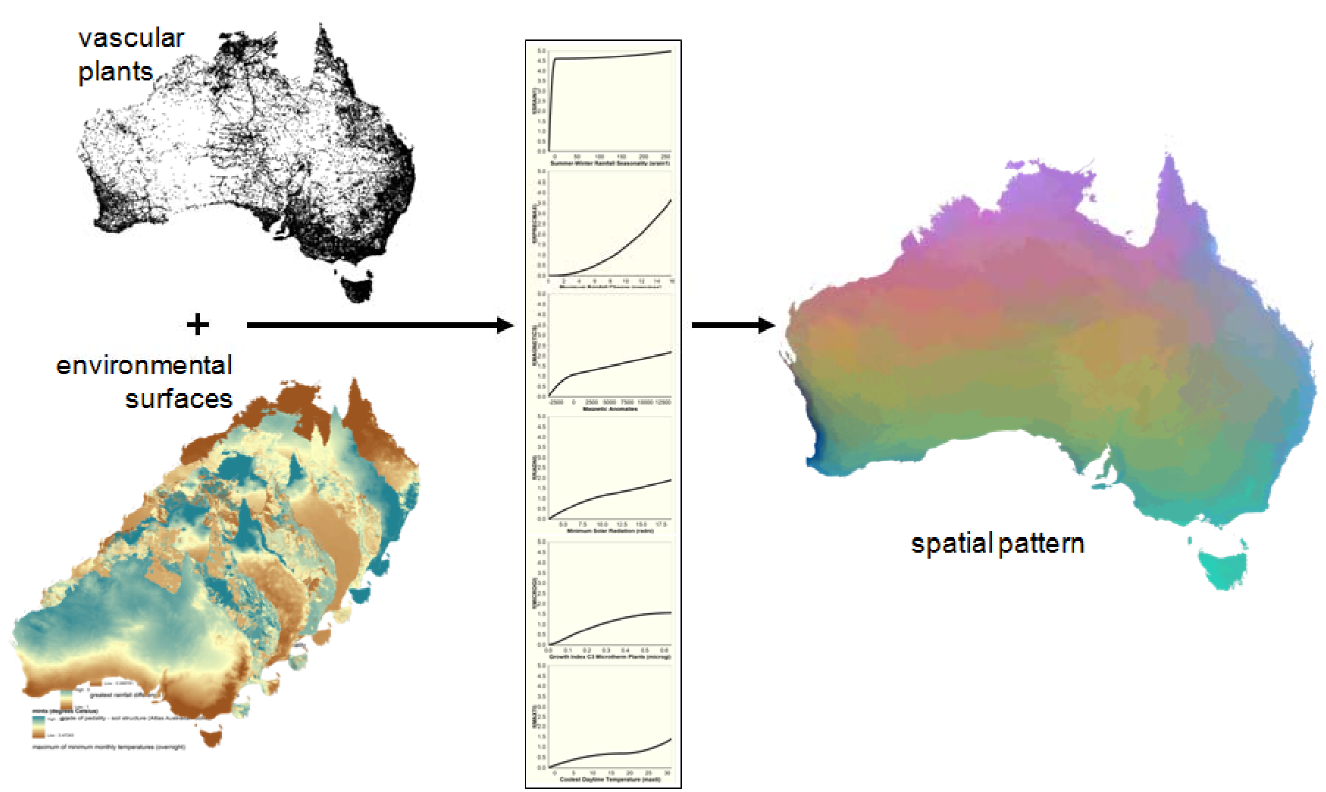

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Informing data models in ecology:
Which layers should I use in my biodiversity model?

Kristen J Williams[1,3], Michael P Austin[1], Simon Ferrier[1], Janet Stein[2], Lee Belbin[3]
[1]CSIRO Ecosystem Sciences, [2]ANU Fenner School, [3]Atlas of Living Australia

ESA2011 Hobart, 21 November 2011, 13:30-13:45

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Informing data models in ecology: outline

1
- Why we need to clarify which layers are useful

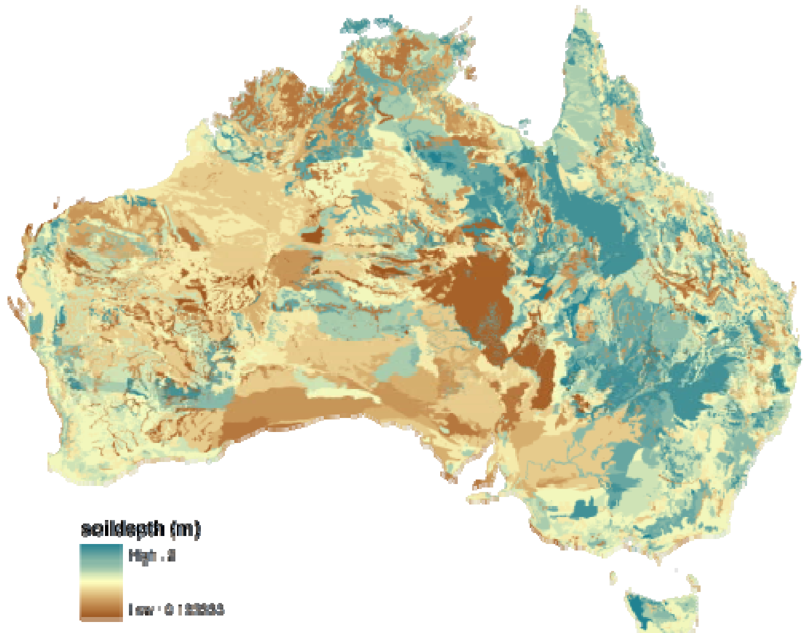
2
- Outlining the data model and case study

3
- Principles for selecting environmental layers

Why we need to clarify which layers are useful

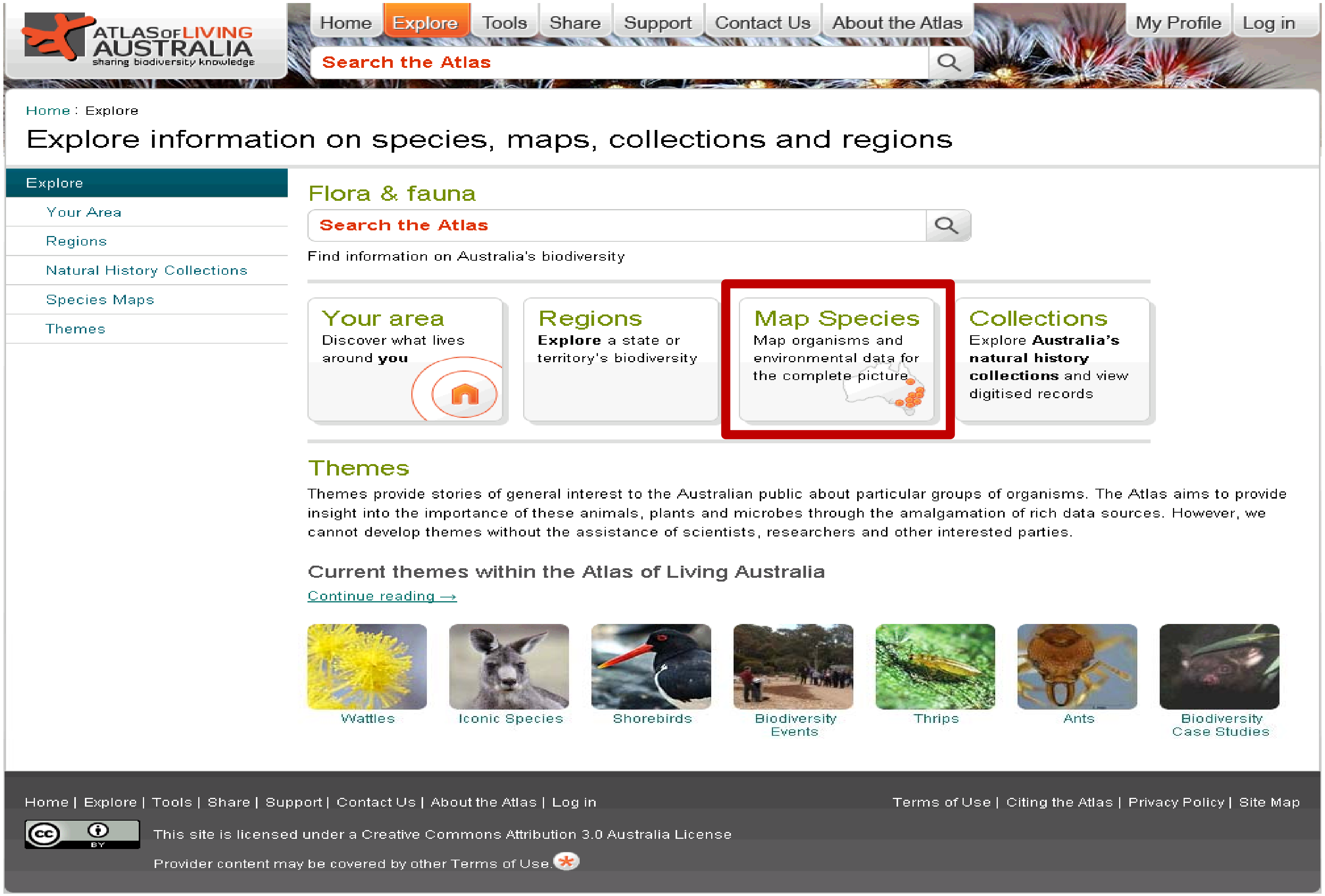
- Digital environmental data is a necessary input to a wide range of ecological modelling approaches
- Deciding on which layers to include is an ongoing challenge
- Open access to models and data, such as through the Atlas of Living Australia (www.ala.org.au), highlight the need for more general guidance on which layers to use for a given purpose

Eucalyptus delegatensis canopy



solum depth (Atlas Australian Soils)

Online data portals provide ready access to data for research and planning: http://www.ala.org.au/



ALA "Map Species" Spatial Analysis Tools: http://www.ala.org.au/explore/species-maps/

- **Sampling**: attribute species occurrence data with values of environmental and contextual data layers
- **Filtering**: use values of environmental or contextual layers to define an envelope and subset species occurrence data
- **Scatter plot**: view the species occurrence data in environmental space for any two variables and an area of interest
- **Prediction**: use MaxEnt to model the relationship between species occurrence data and selected environmental layers
- **Classification**: classify selected environmental layers into domains (the ALOC algorithm from PATN)

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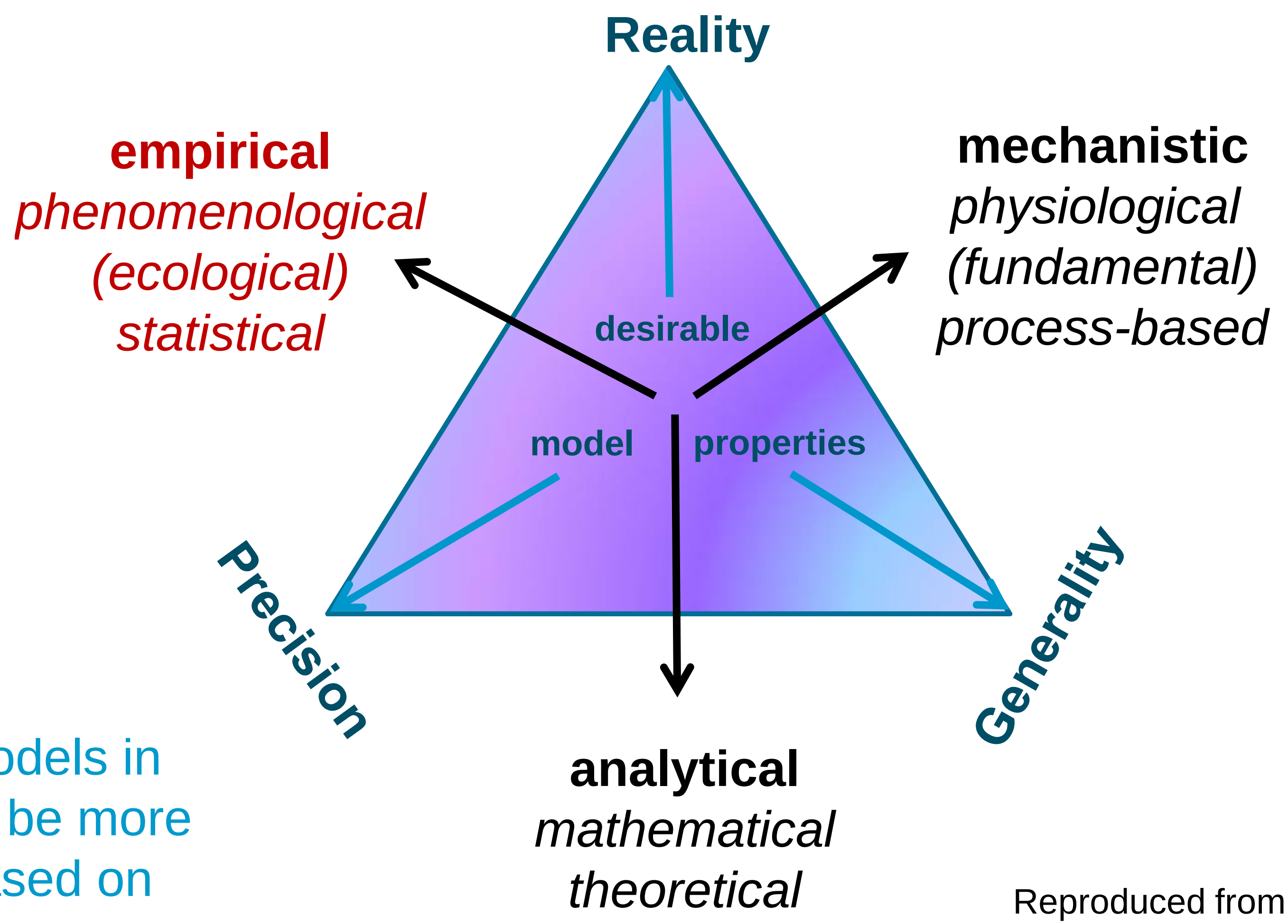
Desirable properties and types of models



Empirical models in ecology can be more general if based on meaningful parameters

Reproduced from Fig 2 in Guisan & Zimmermann (2000) *Ecological Modelling 135:147-186.*

Three components of a biodiversity model

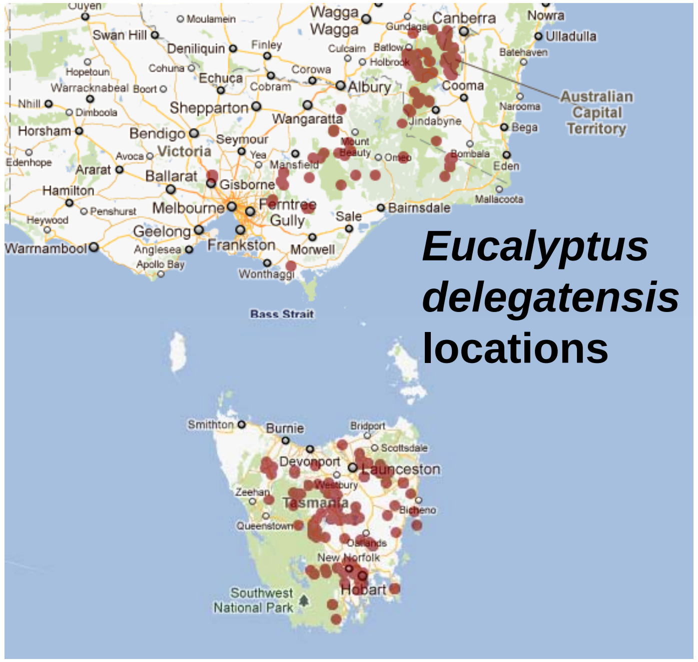
Ecological Model	• What ecological theory is assumed or tested?
Data Model	• Are there any limitations imposed by the nature of the data used?
Statistical Model	• Are the statistical procedures and methods used compatible with ecological theory?

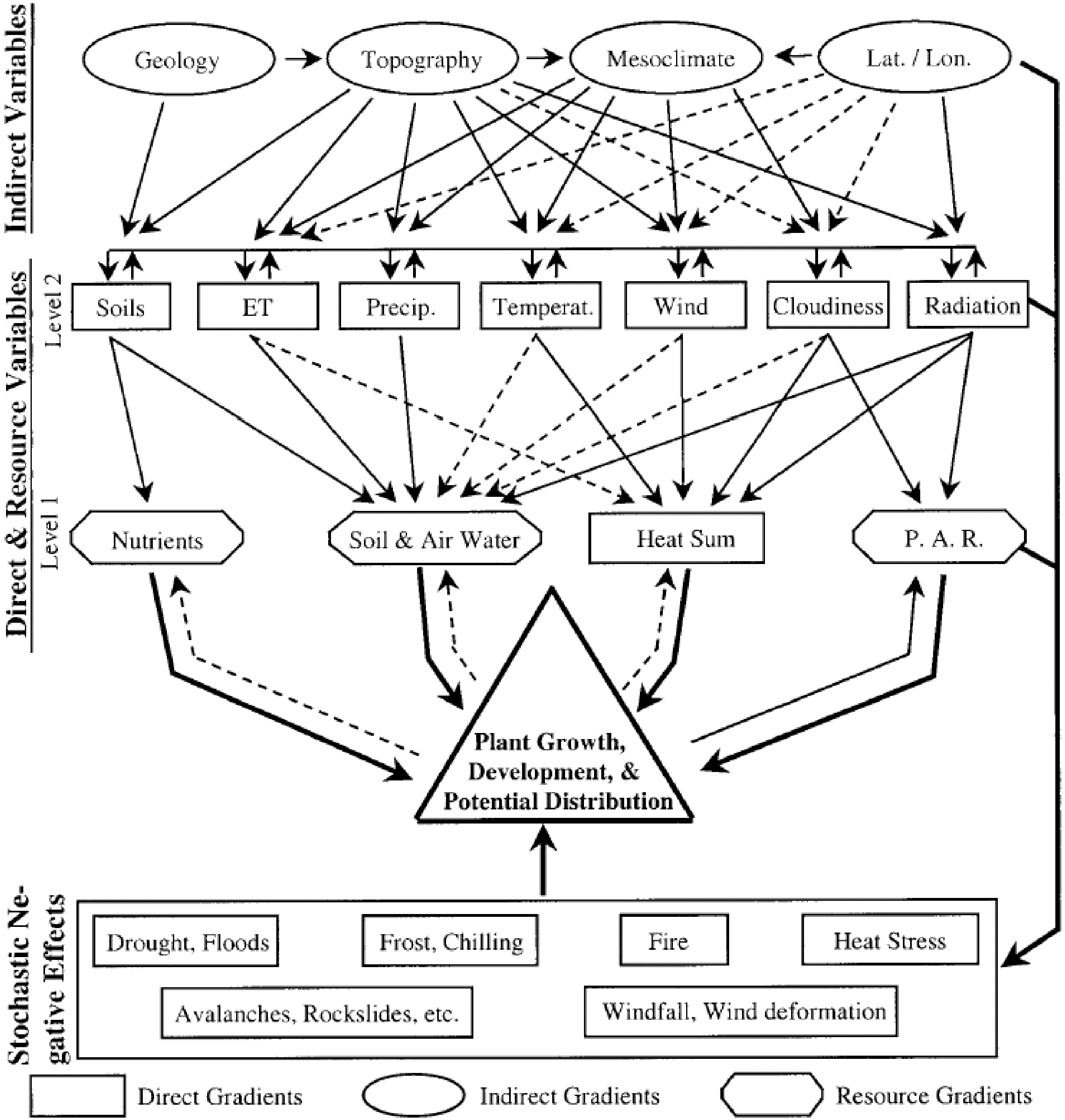
Austin, M. P. 2002. *Ecological Modelling, 157: 101-118.*
Austin, M. 2007. *Ecological Modelling, 200: 1-19.*

Basic components informing the choice of environmental layers for a data model

- Purpose (location, study species, response variable) – informs the extent and resolution of environmental layers to compile
- Applicable ecological theory – informs the scope and type of environmental layers to compile and evaluate
- Applicable statistical model – informs the format of layers and procedures for selecting environmental layers to include/test

Best demonstrated using a case study, plant species





Guisan & Zimmermann, *Ecological Modelling*, 135: 147 (2000), Fig. 3

An attempt to structure the problem for plants

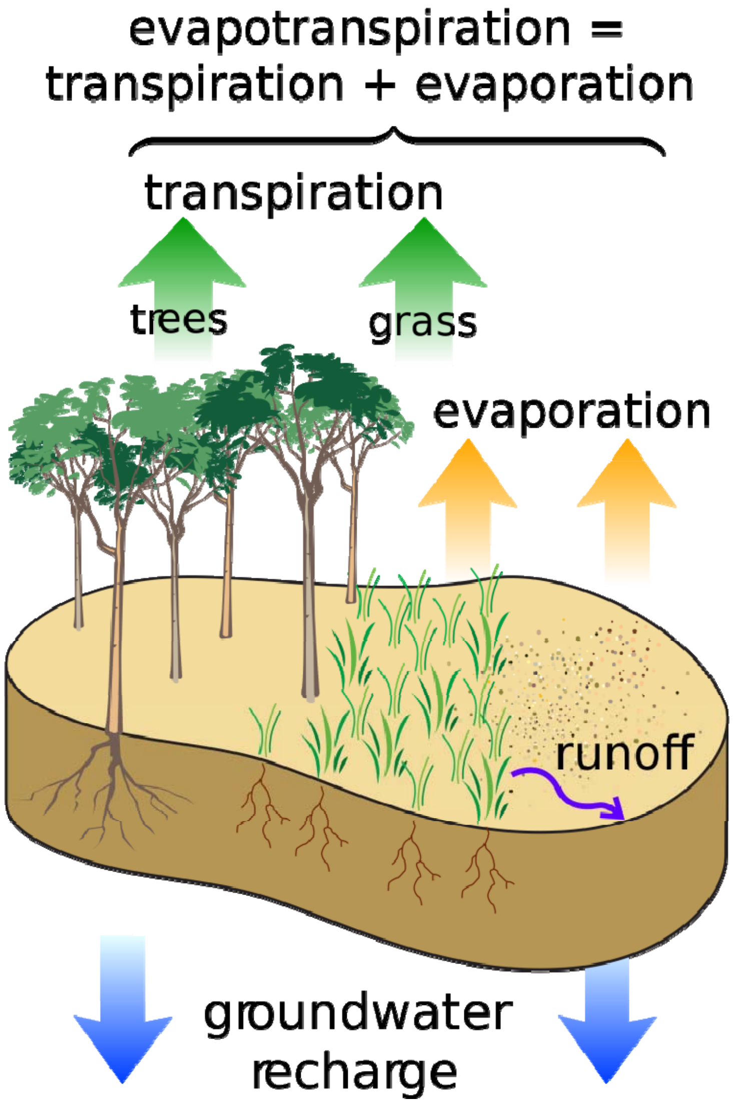
But lots of potential factors or their proxies to compile and consider in a model, including outputs from biophysical process models, with variable quality and correlations

Over 100 layers to choose from in the ALA

A wide range of National 1km gridded environmental variables in the ALA spatial portal

- Climate variables
  - Mean conditions of evaporation, precipitation, minimum and maximum temperature, wind, humidity, solar radiation (ANUCLIM derivatives)
- Disturbance regimes
  - Fire frequency and mean climatic extremes (proxies for drought, flood, frost, heat, etc)
- Soil variables
  - Soil depth, clay%, bulk density, hydraulic conductivity, structure, water holding capacity, calcrete, nutrient status, etc (derivatives of the Atlas of Australian soils)
- Geoscience variables
  - Geological age and inherent fertility (derivatives of the 1:1M National Geology), and geophysics - gravity and magnetics
- Terrain variables (DEM derivatives)
  - Slope, aspect, elevation diversity, topographic position, wetness indices, multi-resolution indices, etc

The role of biophysical process models: e.g., Environmental water predictors

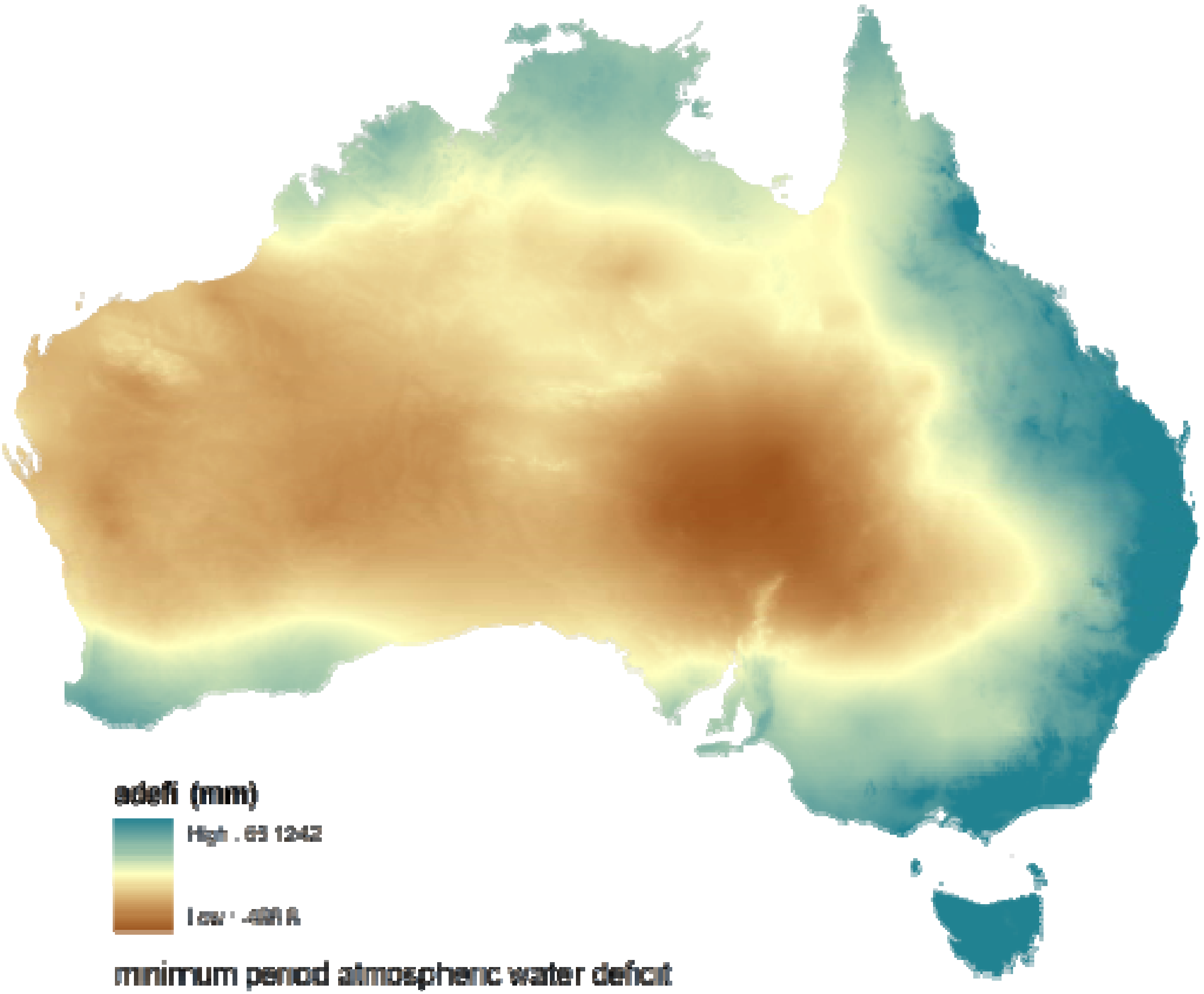


It is good practice to develop physiologically-relevant predictors

Water balance models potentially reduce a large number of predictors to just a few

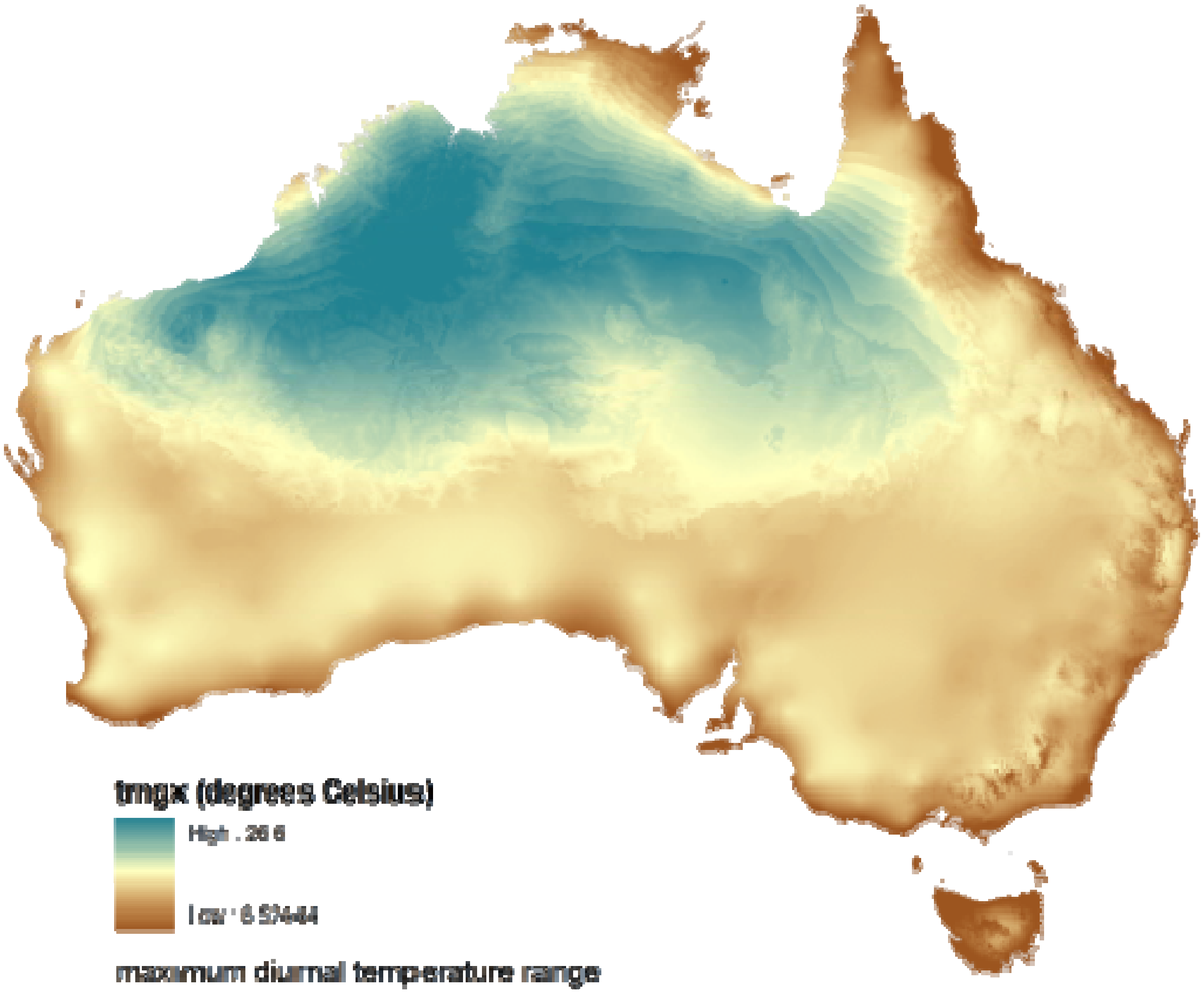
But the outputs can be confounded by poor resolution and inaccuracy of soil parameters

Example variables: water (P-E)

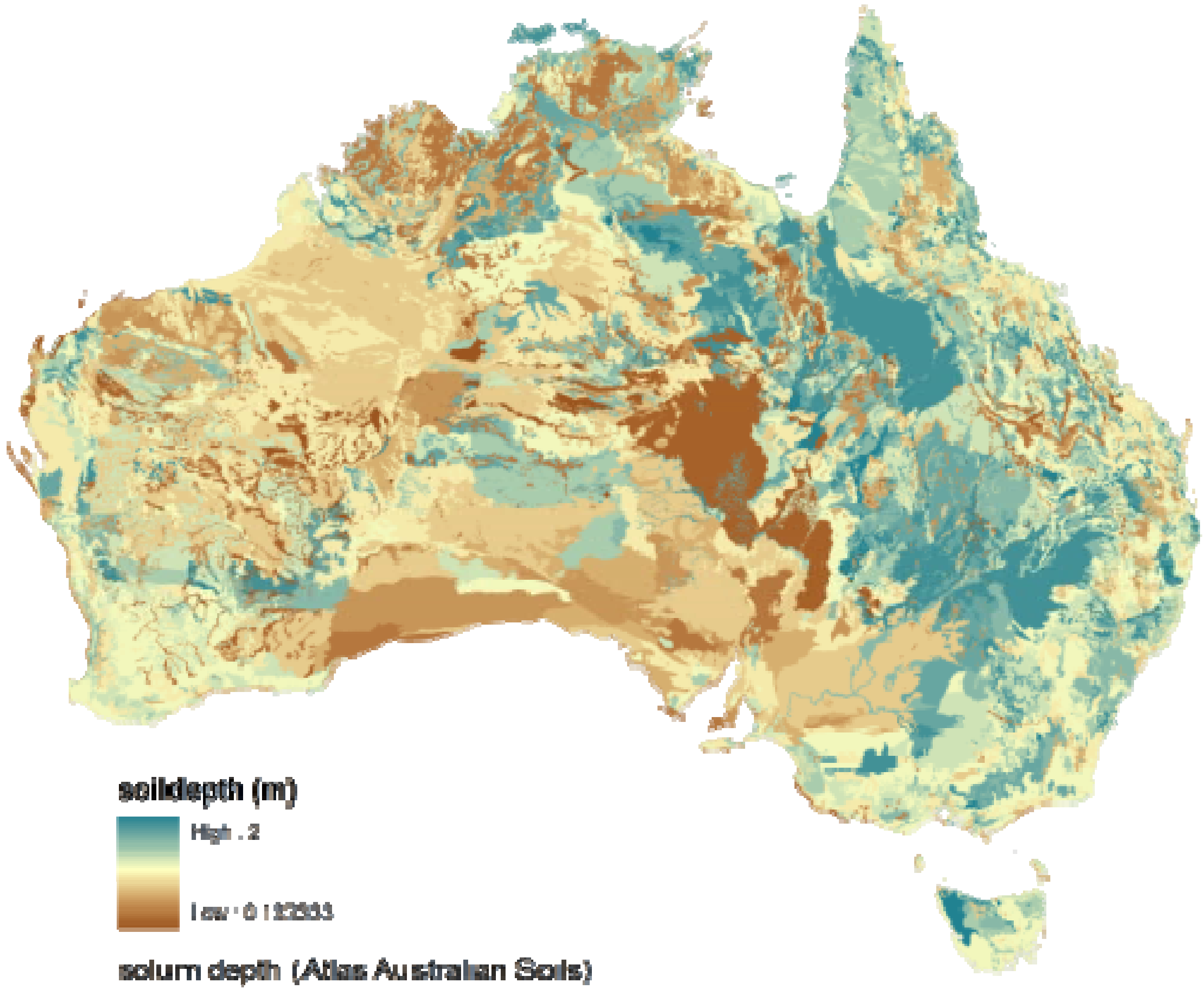


minimum period atmospheric water deficit

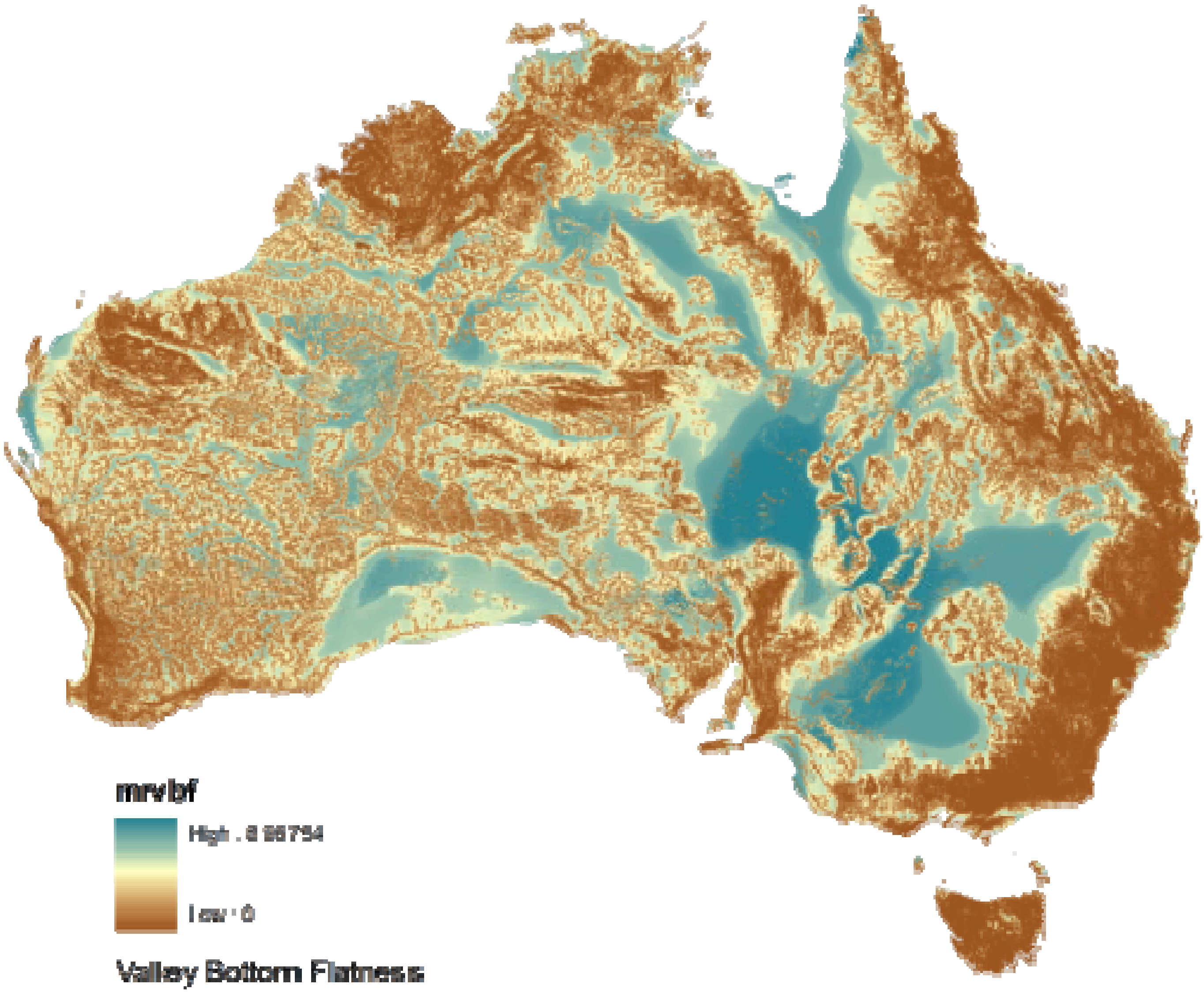
Example variables: diurnal temperature range



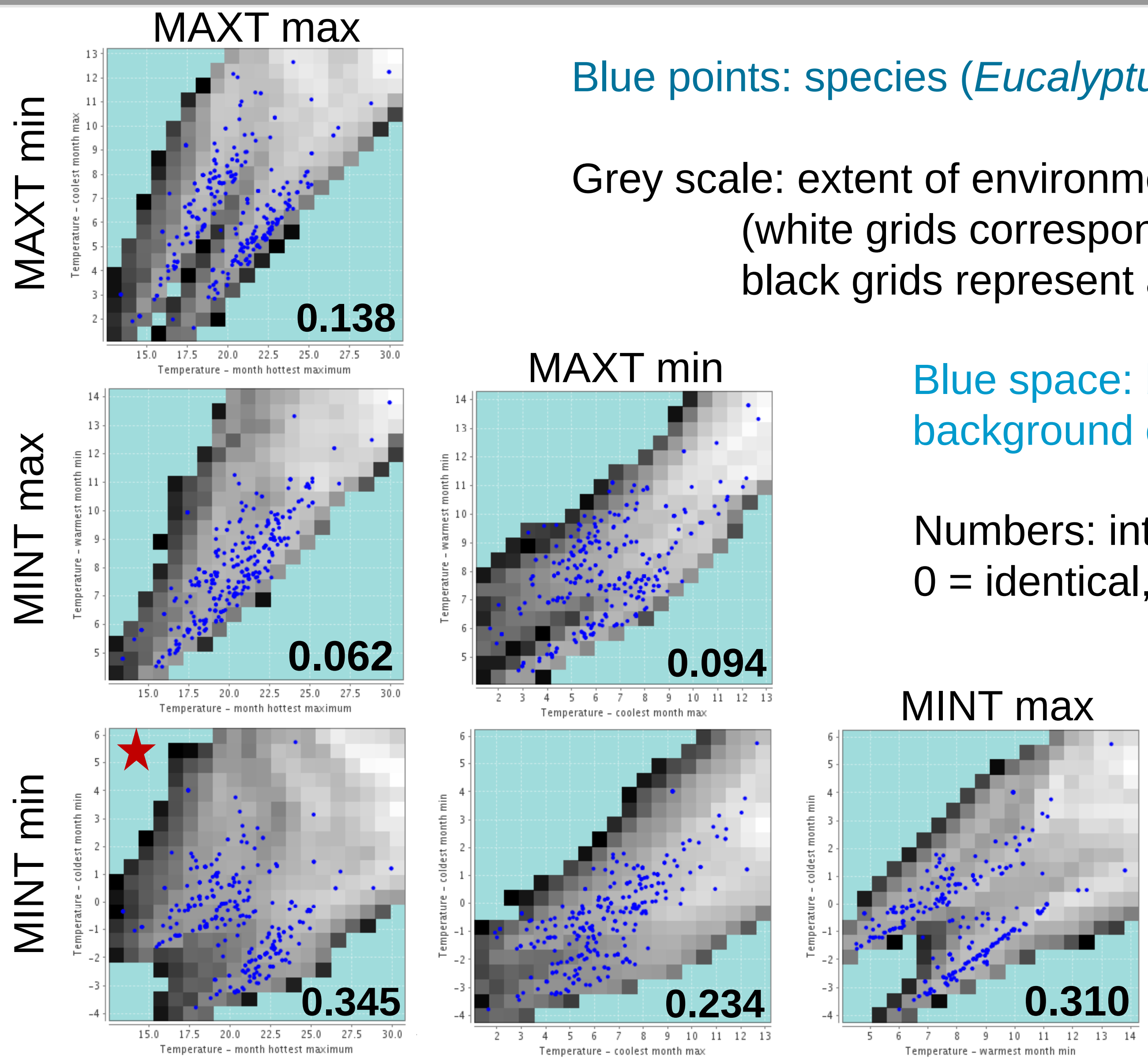
Example variables: soil depth



Example variables: DEM multi-resolution indices



Example scatter plots from ALA spatial portal – minimum and maximum temperatures



Blue points: species (*Eucalyptus delegatensis*)

Grey scale: extent of environment in Australia
(white grids correspond to a large area,
black grids represent a small area)

Blue space: beyond background environments

Numbers: inter-layer association
0 = identical, 1 = entirely different

* Extreme ends of the gradient are more independent

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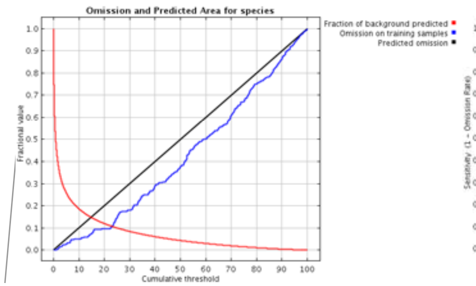
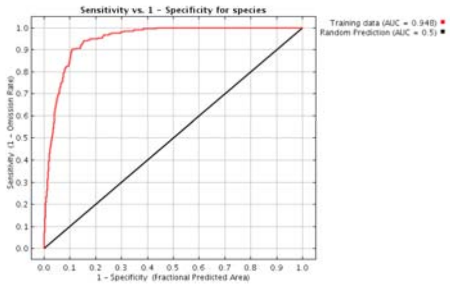
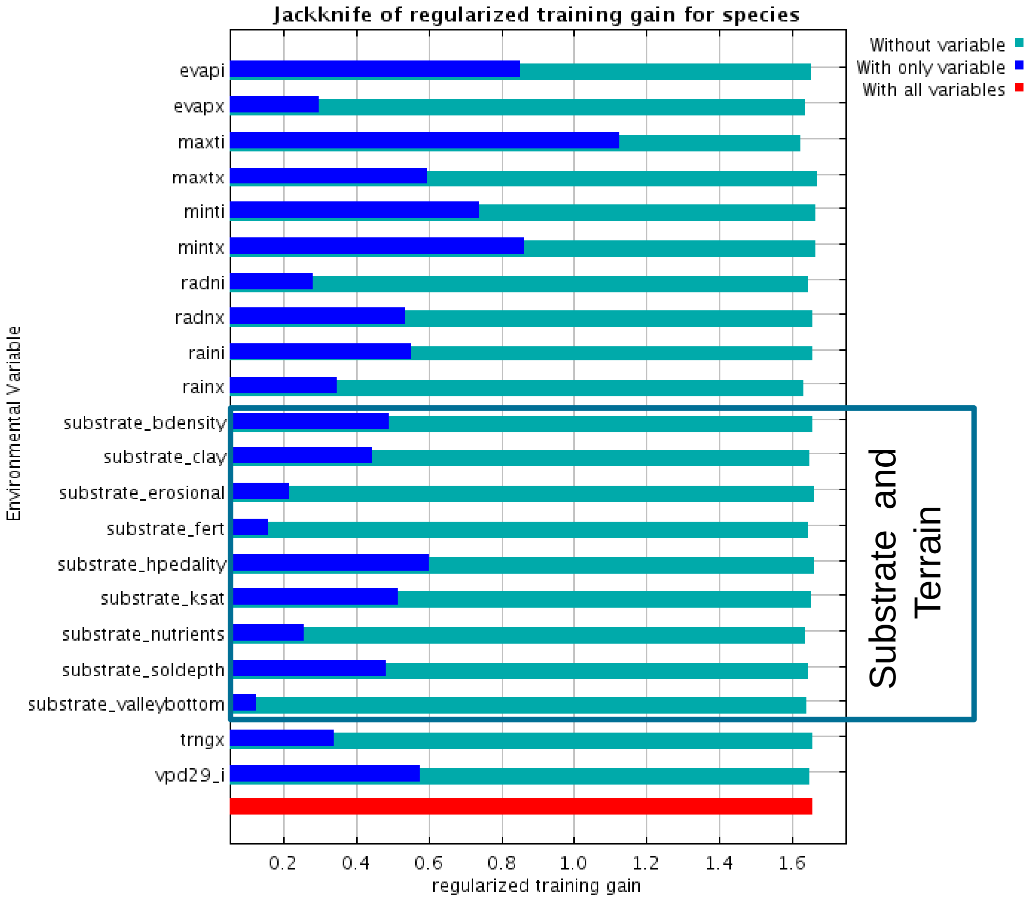
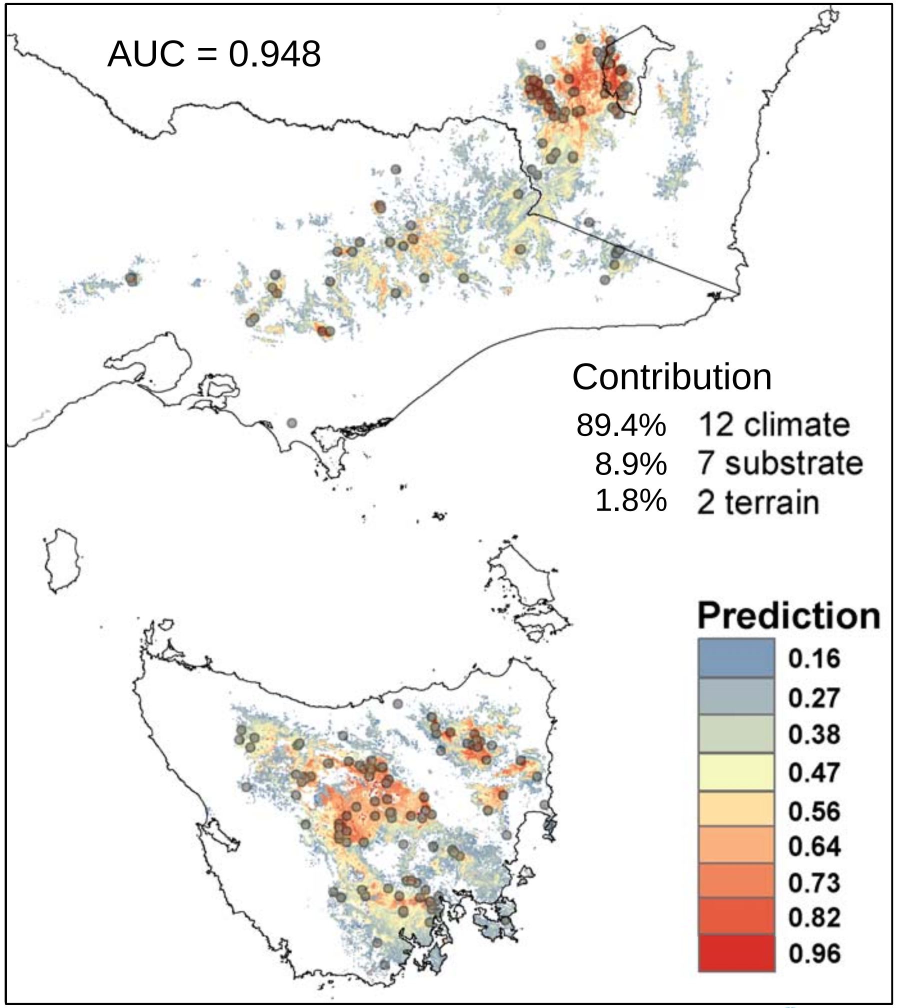
Example ALA output: MaxEnt model prediction







Maxent model: *E. delegatensis*



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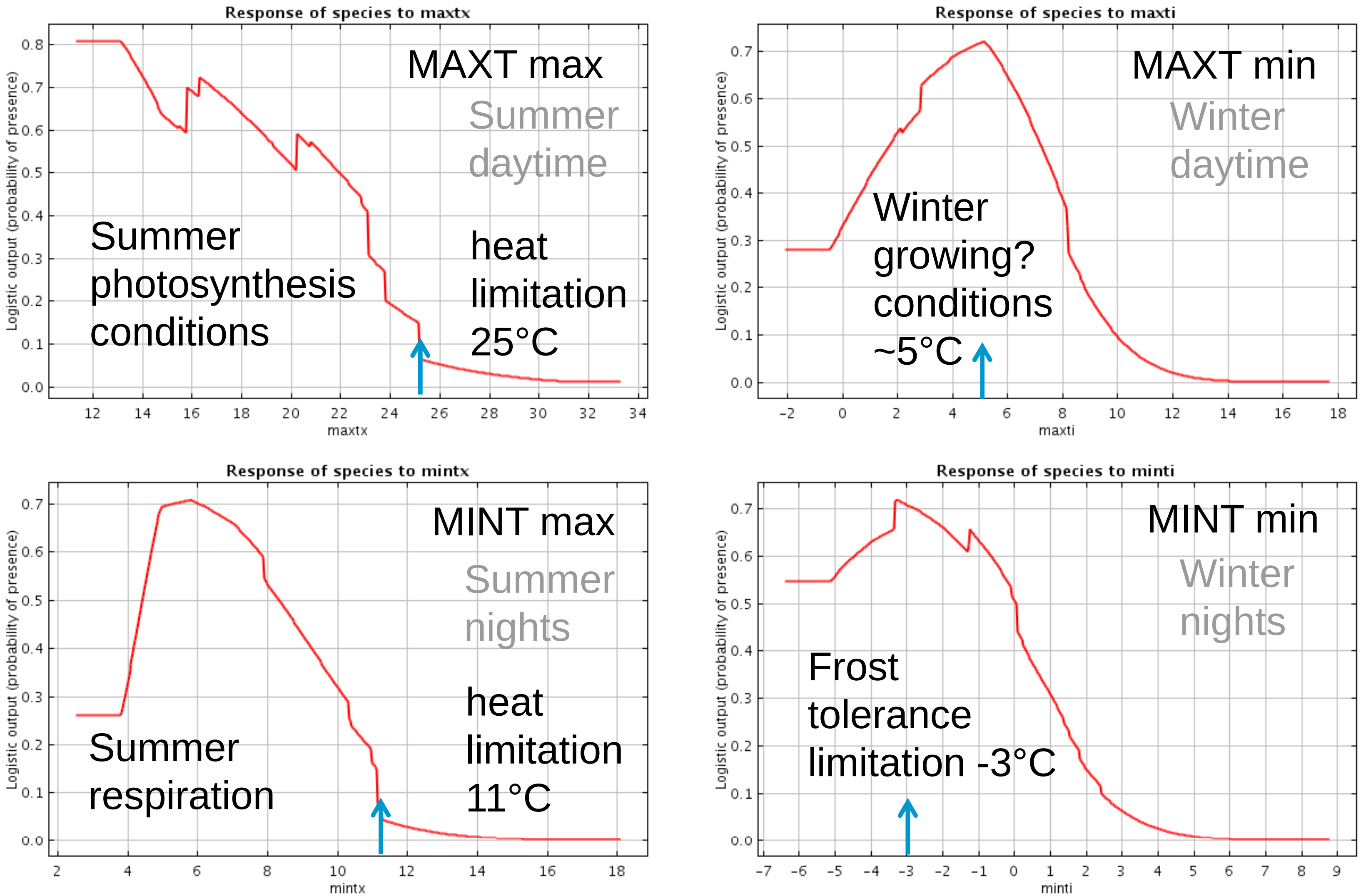
Indicative physiological parameters?



Maxent models created using only the corresponding variable

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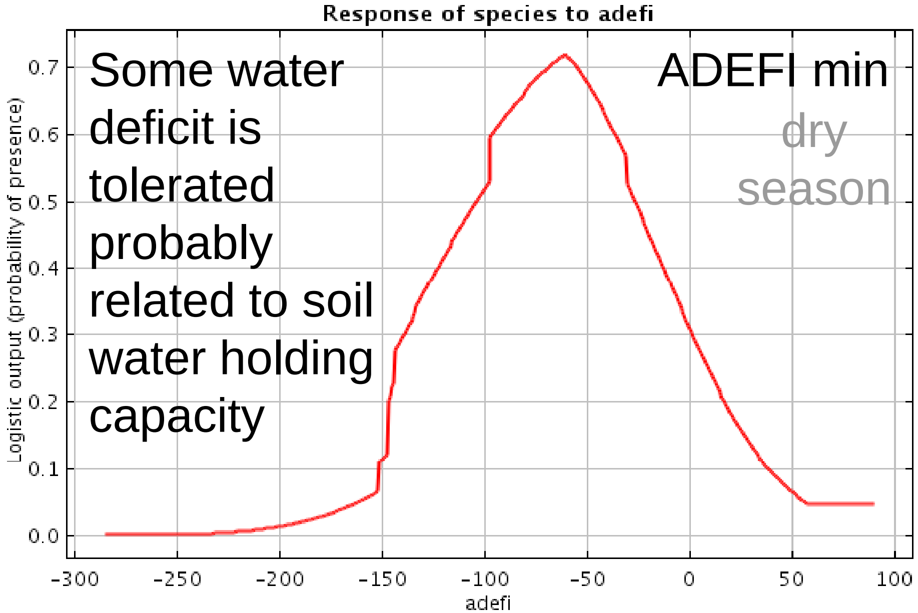
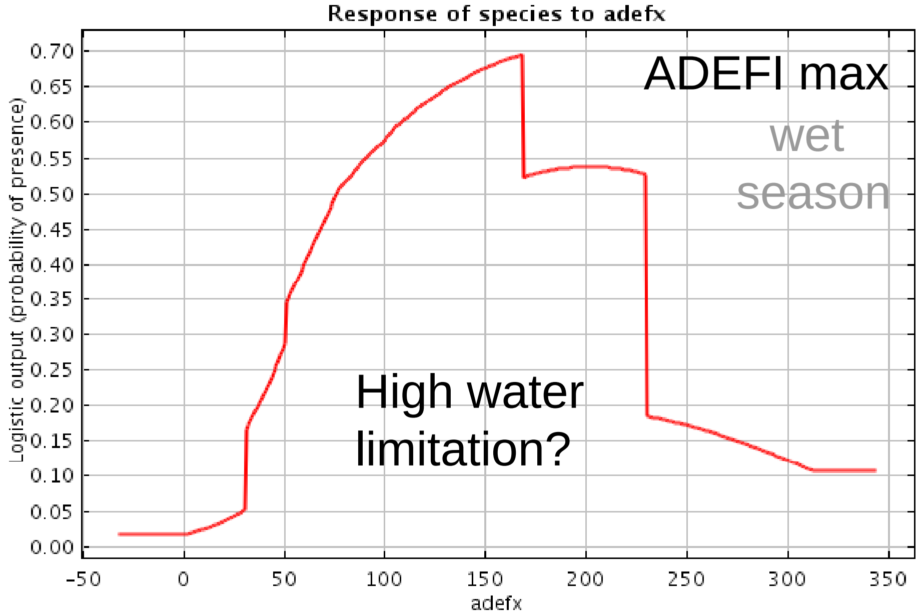
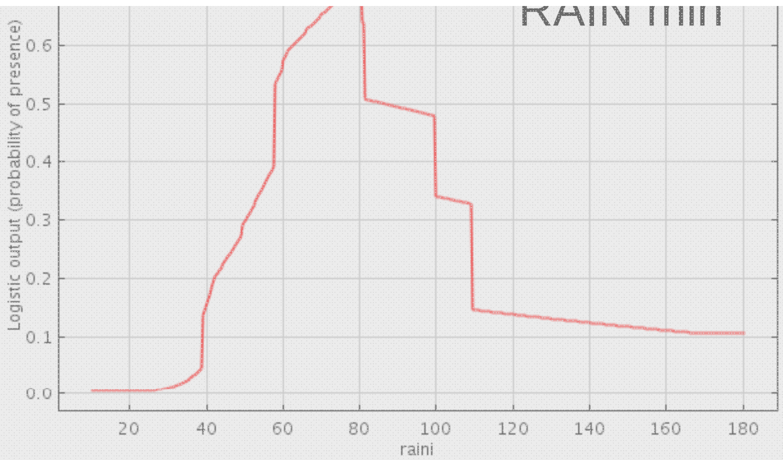
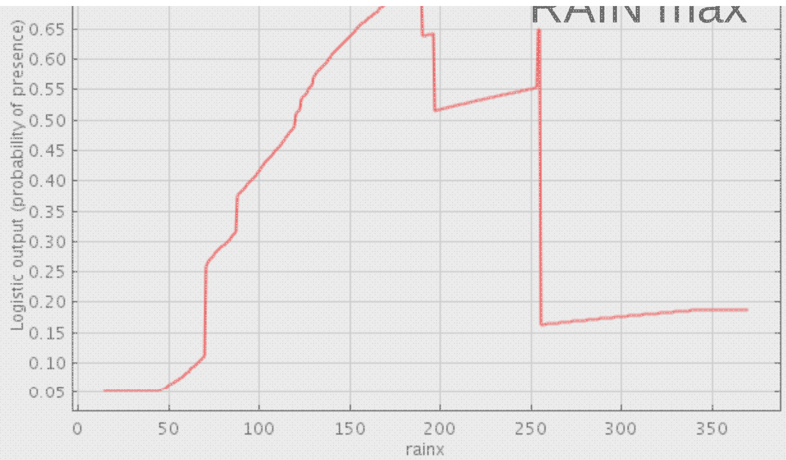
Rainfall and evaporation? Would atmospheric water deficit be more ecologically meaningful?









Maxent models created using only the corresponding variable

Principles for selecting environmental layers

- Adopt explicit ecological rationale based on theory (purpose)
- Note whether the variable is a direct or indirect driver of distribution patterns, proximal or distal to physiological process
- Use logic and scatter plots to explore correlation patterns between variables to understand origins and which are relatively independent
- Develop a hypothesis-driven framework for successively including variables in a model (initial set and supplementary to test residuals)
- Avoid combining variables that are self-excluding alternative sets (e.g. rainfall and evaporation, atmospheric water deficit)
- Iteratively revise your understanding of the environmental layers through the practice of model building, note effective combinations
- Visualise results in both environmental and geographic space and link to ecological rationale (potential physiological optima and limits)

Conclusions

- No simple solutions, but ecological theory adds structure to the process of identifying, evaluating and selecting layers
- Biophysical process models improve reality (more proximal predictors), but gains may be offset by inaccurate, incomplete or low resolution input parameters: use simple, interpretable variables
- Scatter plots and model testing with explicit subsets in a hierarchical or structured way, is an iterative learning process
- Above all – know how your layers were generated (metadata), critically evaluate their utility and encourage new developments
- This presentation has focused on terrestrial environments, but the same applies to other environments: marine and freshwater, etc

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Eucalyptus delegatensis canopy

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Thank you

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