PROBLEMS AND LIMITATIONS IN ECOLOGICAL NICHE MODELS: ASSUMPTIONS AND UNCERTAINTIES

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- Correlations
- Equilibrium and Habitat Saturation
- Dispersal and Landscapes
- Biotic Interactions
- Adaptation and Evolution

Niches, models, and climate change: Assessing the assumptions and uncertainties

John A. Wiens[a,1], Diana Stralberg[a], Dennis Jongsomjit[a], Christine A. Howell[a], and Mark A. Snyder[b]

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Correlations

Correlative niche models are based on analyses that relate the occurrence of a species in places to features of those places.

→ you are assuming that the variables included in the model do in fact reflect the niche requirements of a species.

It is necessary to have **spatial autocorrelation** among variables and species' records.

Without spatial autocorrelation, there is **not any relationship between the species distribution and the variable**.

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Equilibrium and Habitat Saturation

→ current distribution is in equilibrium
→ suitable habitats are fully occupied or ‘‘saturated’’

Suitable places may be unoccupied:

- if recent disturbances have eradicated a species from an area
- if a species is expanding into recently suitable areas
- if regional population density is inadequate to support colonisation of suitable areas

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Environmental equilibrium

- The species must be in equilibrium with the environment
- The species must occupied all suitable habitats

There are historical and dispersal reasons that hamper species to occupy all suitable habitats

Pseudo-equilibrium

→ The species must occupied all suitable habitats where it is able to disperse

Dispersal and Landscapes

→ individuals will be able to disperse to suitable locations

If environmental conditions shift more rapidly than individuals can disperse → the species may be relegated to persist only in isolated habitat refugia that meet their niche requirements.

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Biotic Interactions

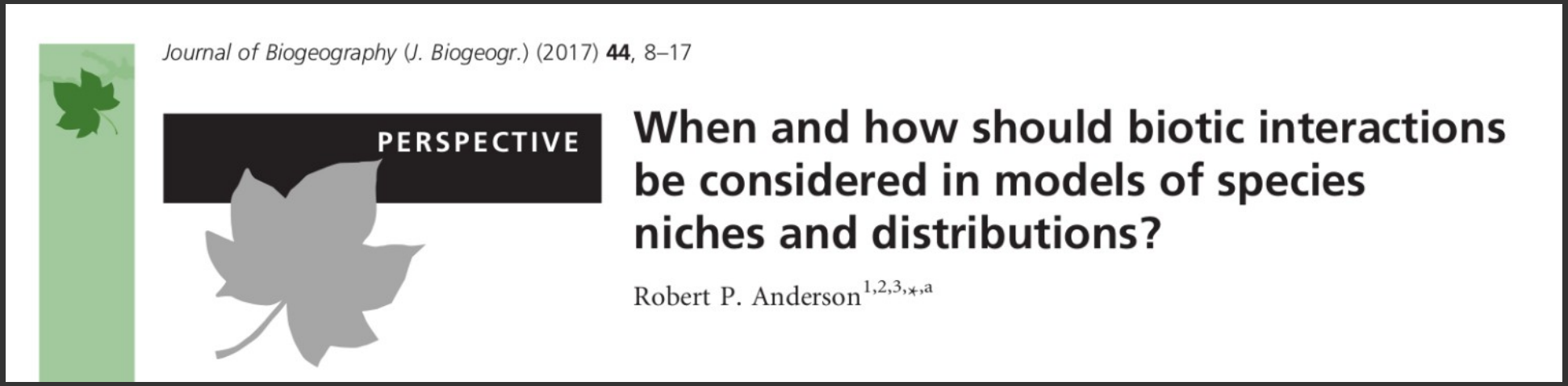
→ each species respond independently to the environmental factors that determine its niche space

→ species interactions are generally not included in niche models, even though the effects of biotic interactions may sometimes supersede those of climate.

Wiens et al 2009

Biotic Interactions

- Incorporate a species model as independent variable
- Gap analyses after the model
- ENM plus Abundance model



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Adaptation and Evolution → niche conservatism

→ niche envelope is a fixed and immutable characteristic of a species, unchanging over space and time

→ we can use correlative niche models for a species from some locations to extrapolate its distribution to other locations that have not been surveyed.

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Review

CellPress

Unifying niche shift studies: insights from biological invasions

Antoine Guisan[1,2*], Blaise Petitpierre[1*], Olivier Broennimann[1*], Curtis Daehler[3*], and Christoph Kueffer[4*]

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[4] Institute of Integrative Biology, ETH Zürich, Universitätstrasse 16, 8092 Zürich, Switzerland

Review about niche conservatism in invasive species

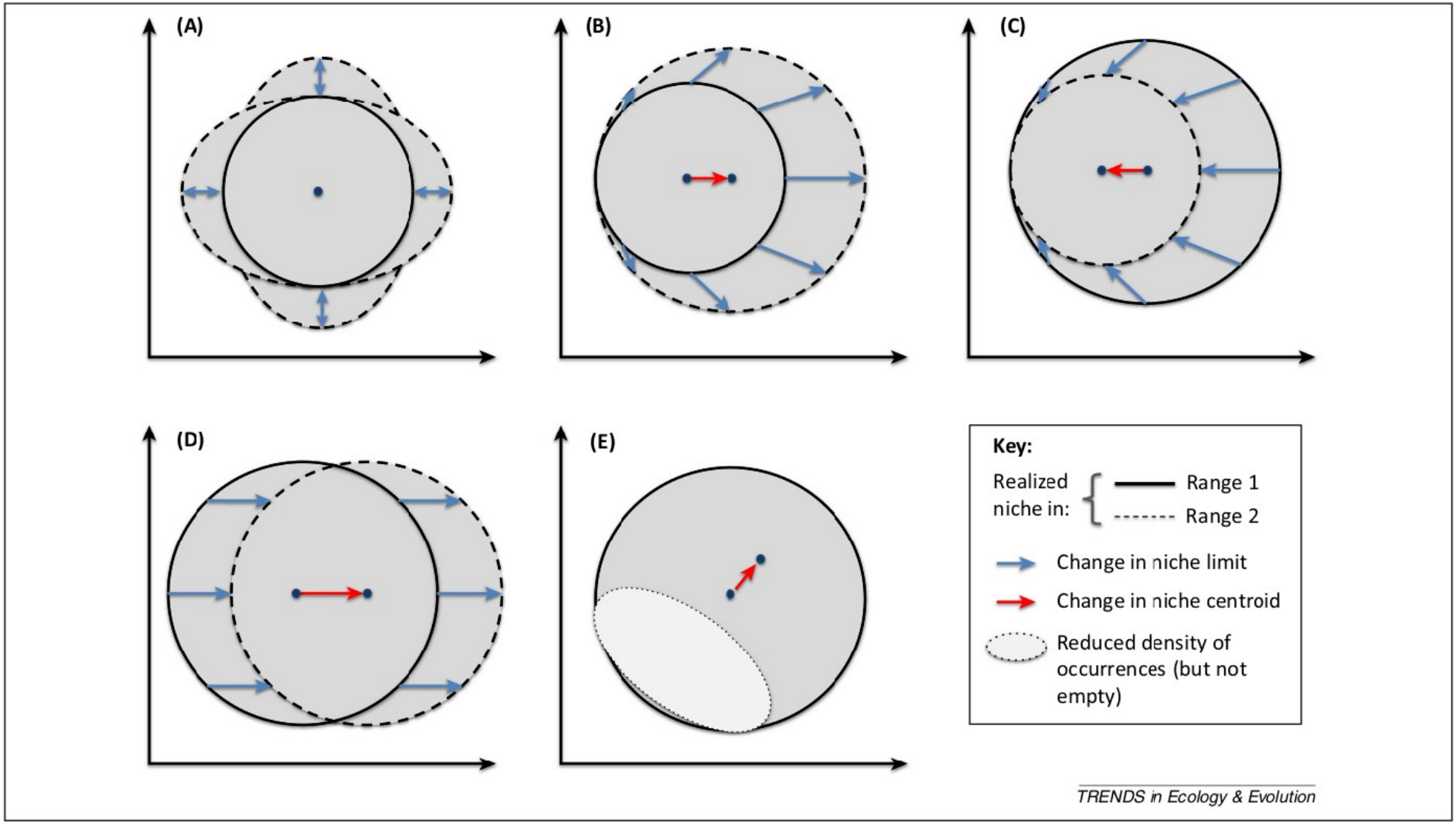
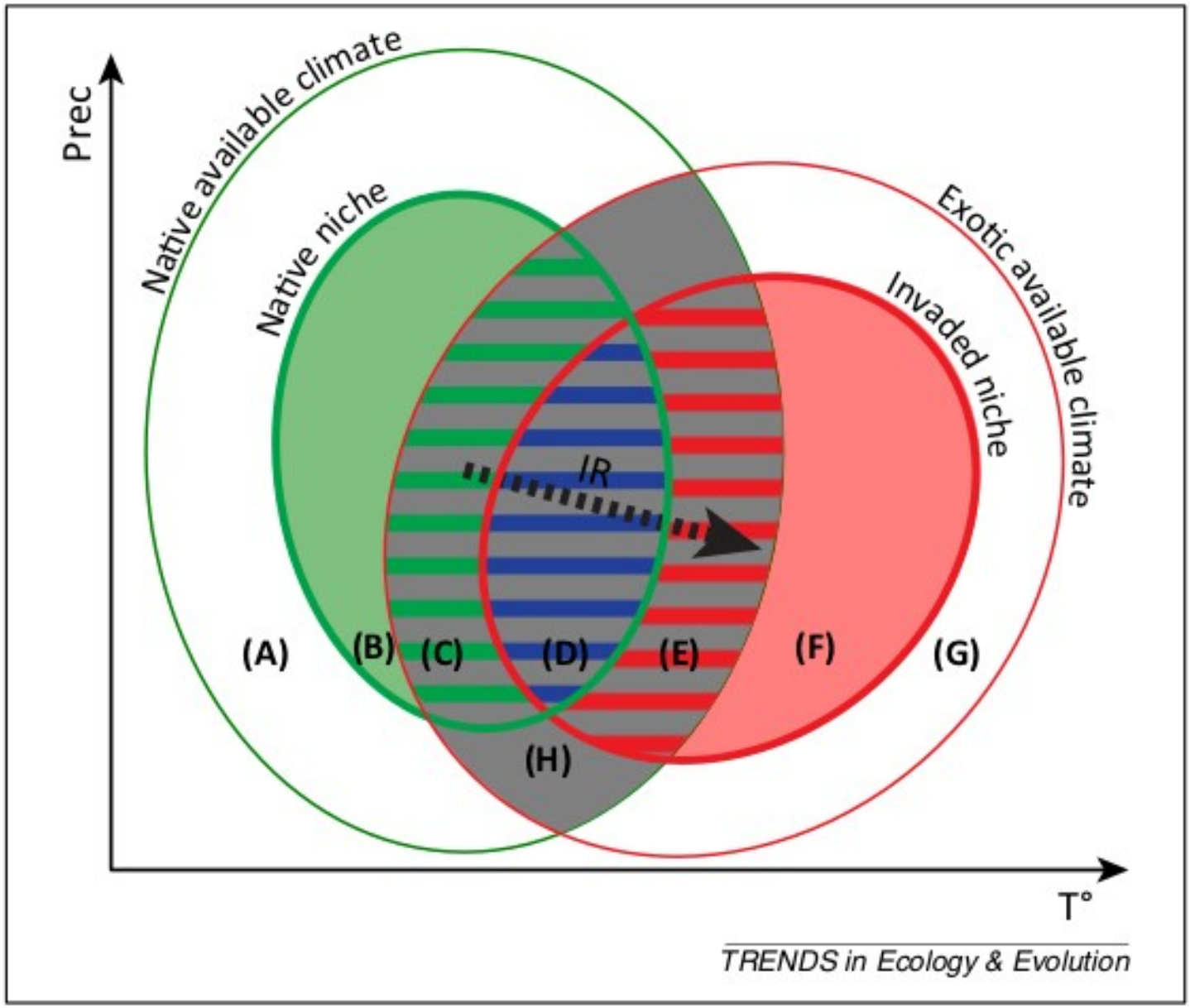


Figure 1. Theoretical scenarios of realized niche changes in space (e.g., following invasions) or time (e.g., under climate change). Change of: (i) the niche envelope (expansion or contraction) without change of the niche centroid, due to symmetric niche change, that is, in two opposite **(A)** or all directions in climatic space; (ii) the niche centroid with expansion **(B, C)** or displacement **(D)** of part of or the whole niche envelope; or (iii) the niche centroid only, due to a change of the density of occurrences within the same niche envelope in climatic space **(E)**. The latter case would result in stability (no change) in Figure 2. Observed changes are likely to be combinations of these cases.


Prec
Native available climate
Native niche
Exotic available climate
Invaded niche
IR
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
T°
TRENDS in Ecology & Evolution

MORE ASSUMPTIONS

1. **Niche Space Assumption**: The study contains the full range of conditions that the species can inhabit (for the examined abiotic variables).

2. **Dispersal/demographic Noise Assumption**: Factors related to dispersal, establishment, and persistence do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.

3. **Biotic Noise Assumption**: Biotic interactions do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.

4. **Human Noise Assumption**: Human modifications of the environment do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas.

Anderson 2013

- Distribution Model Algorithm Uncertainties
- Data Uncertainties
- Climate Model Projection Uncertainties
- Scale Uncertainties

Niches, models, and climate change: Assessing the assumptions and uncertainties

John A. Wiens[a,1], Diana Stralberg[a], Dennis Jongsomjit[a], Christine A. Howell[a], and Mark A. Snyder[b]

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Distribution Model Algorithm Uncertainties

Each algorithms have different characteristics and properties.

Absence (or pseudo-absence) and presence records:

- Generalised linear models (GLMs)
- Generalised additive models (GAMs)
- Artificial neural networks
- Genetic algorithms (GARP)

Presence-only data

- DOMAIN
- BIOCLIM
- Mahalanobis distance
- Maxent
- ENFA

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Data Uncertainties

ENMs are sensitive to the quality and quantity of data

Climate data:

→ spatial and temporal resolution (e.g., spatial distribution and duration of weather records) affect the downscaling of general circulation models (GCMs)

→ differences in the broad climatic variables used to drive GCMs can result in different projections, increasing model uncertainty

Occurrence records:

- comprehensiveness of survey coverage
- potential biases in recording presence or absence
- observer skill at identification

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Adaptation and Evolution → niche conservatism

→ niche envelope is a fixed and immutable characteristic of a species, unchanging over space and time

WHAT HAPPENS WHEN WE PROJECT A MODEL TO THE FUTURE OR TO THE PAST?

WHAT IS A MODEL?

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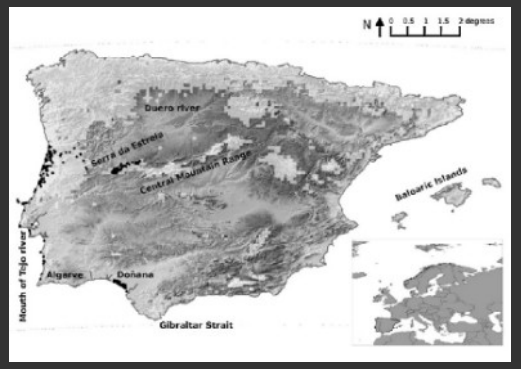
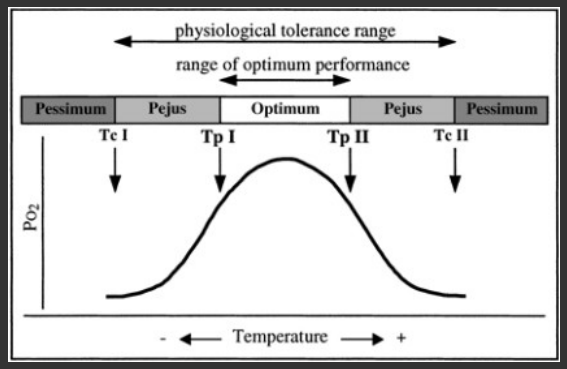
WHAT IS AN ECOLOGICAL NICHE MODEL?

Data about species' distribution

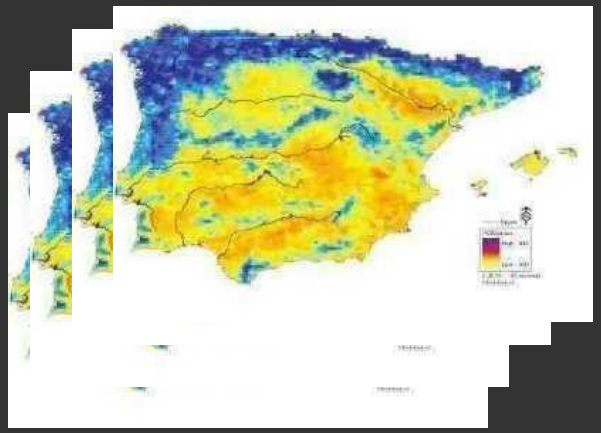


GPS points



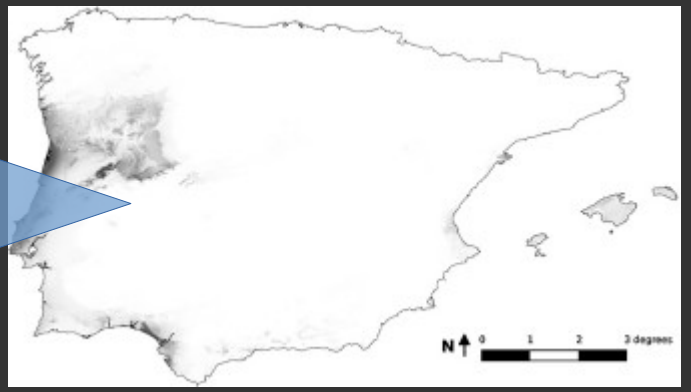
Physiological limits

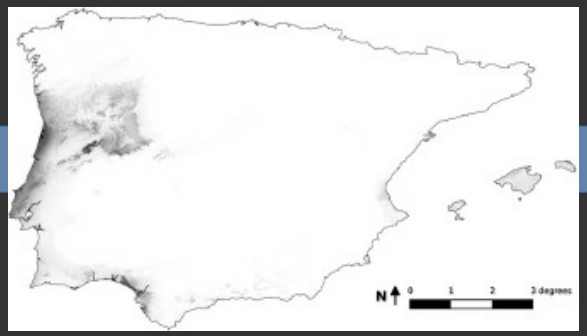
Climatic variables



Algorithm

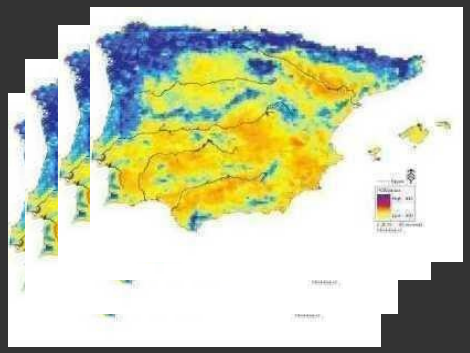
Model



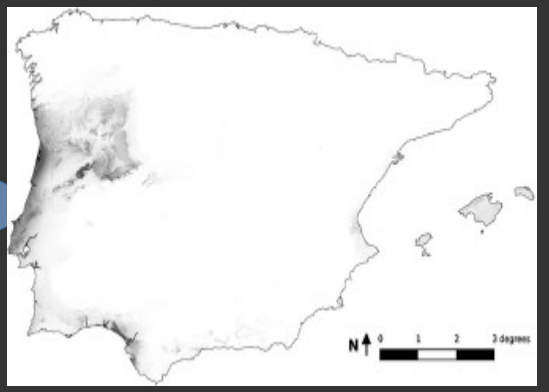


$$Y = B0 + B1X1 + \ldots + BnXn$$

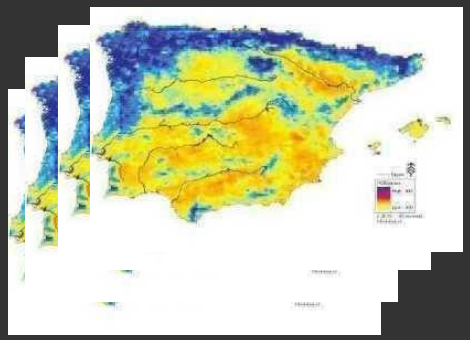
Current climatic variables



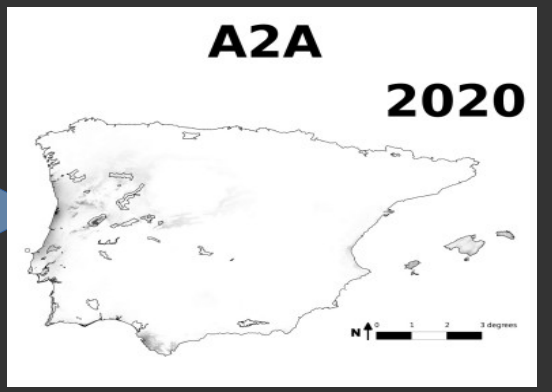
$$SP = 46 + 123*BIO7 - 32*BIO12$$



Future climatic variables



$$SP = 46 + 123*BIO7 - 32*BIO12$$



Climate Model Projection Uncertainties

ENM can be projected to future climate scenarios using general circulation models (GCMs) that describe potential future conditions at a coarse scale of resolution (typically 156–313 km).

→ GCMs rely on different parameters and functions to portray the dynamics of atmospheric circulation, ocean effects, or feedbacks between the land surface and the atmosphere

→ GCMs may project different consequences for the same level of greenhouse gas emissions

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2050

GCM	code	rcp26	rcp45	rcp60	rcp85
ACCESS1-0 (#)	AC		tn, tx, pr, bi		tn, tx, pr, bi
BCC-CSM1-1	BC	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
CCSM4	CC	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
CESM1-CAM5-1-FV2	CE		tn, tx, pr, bi		
CNRM-CM5 (#)	CN	tn, tx, pr, bi	tn, tx, pr, bi		tn, tx, pr, bi
GFDL-CM3	GF	tn, tx, pr, bi	tn, tx, pr, bi		tn, tx, pr, bi
GFDL-ESM2G	GD	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	
GISS-E2-R	GS	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
HadGEM2-AO	HD	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
HadGEM2-CC	HG		tn, tx, pr, bi		tn, tx, pr, bi
HadGEM2-ES	HE	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
INMCM4	IN		tn, tx, pr, bi		tn, tx, pr, bi
IPSL-CM5A-LR	IP	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
MIROC-ESM-CHEM (#)	MI	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
MIROC-ESM (#)	MR	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
MIROC5 (#)	MC	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
MPI-ESM-LR	MP	tn, tx, pr, bi	tn, tx, pr, bi		tn, tx, pr, bi
MRI-CGCM3	MG	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
NorESM1-M	NO	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi

- Rejected: RCP MIROC-ESM, MIROC- ESM-CHEM, and IPSL-CM5B-LR.
- Worst models for Europe: MIROC-ESM, MIROC-ESM-CHEM, FGOALS-g2, BNU-ESM and bcc-cms1-1 (IP).
- Table 6 presents results per GCM.
- Good models for Europe: ACCESS1-0, bcc-csm1-1-m, CCSM4, CMCC-CM, CNRM-CM5, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, HadGEM2-CC, HadGEM2-ES, inmcm4, MPI-ESM-LR, MPI-ESM-MR, and MRI-CGCM3.

Clim Dyn (2015) 44:3237–3260
DOI 10.1007/s00382-014-2418-8

CrossMark

Selecting CMIP5 GCMs for downscaling over multiple regions

C. F. McSweeney · R. G. Jones · R. W. Lee · D. P. Rowell

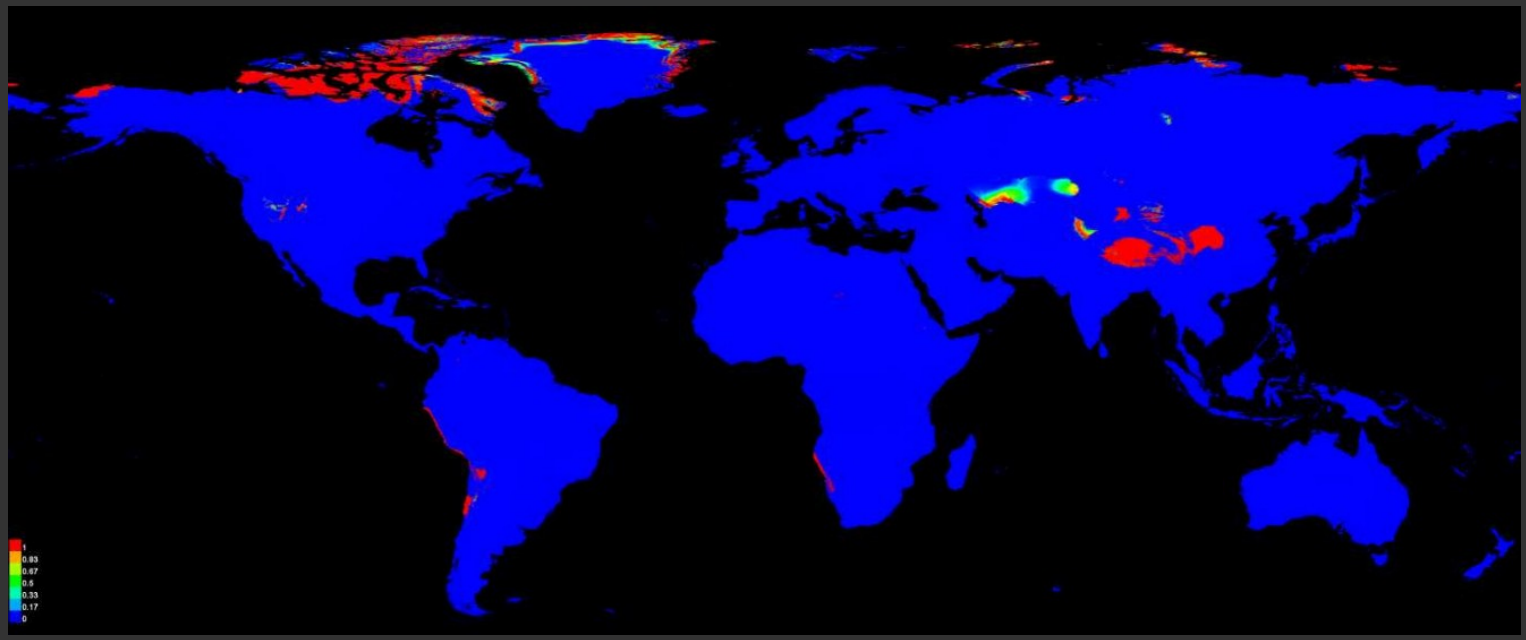
Models can be projected to

→ scenarios in different time periods

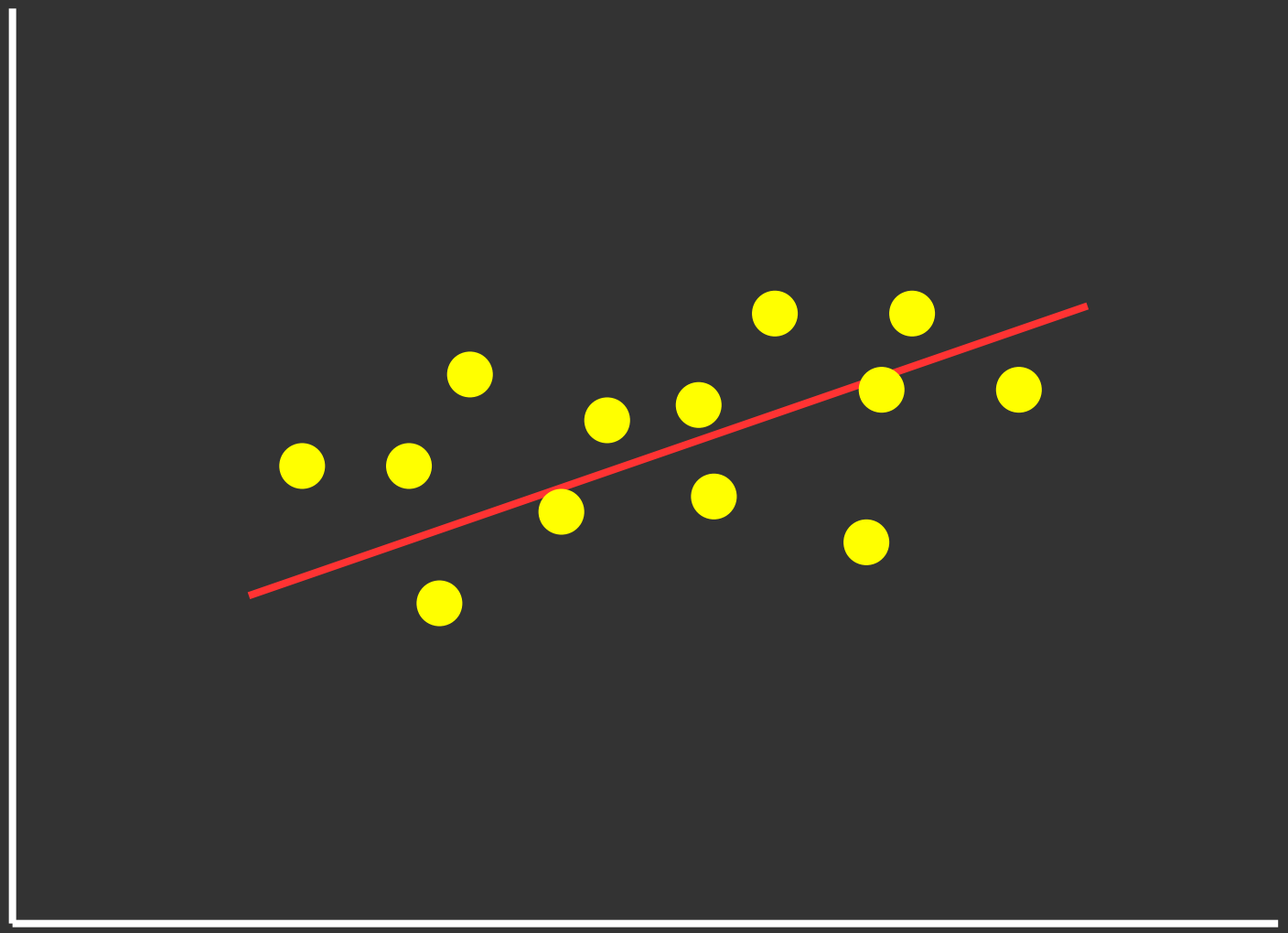
→ scenarios in different study areas

The study area contains the full range of conditions that the species can inhabit (for the examined abiotic variables).

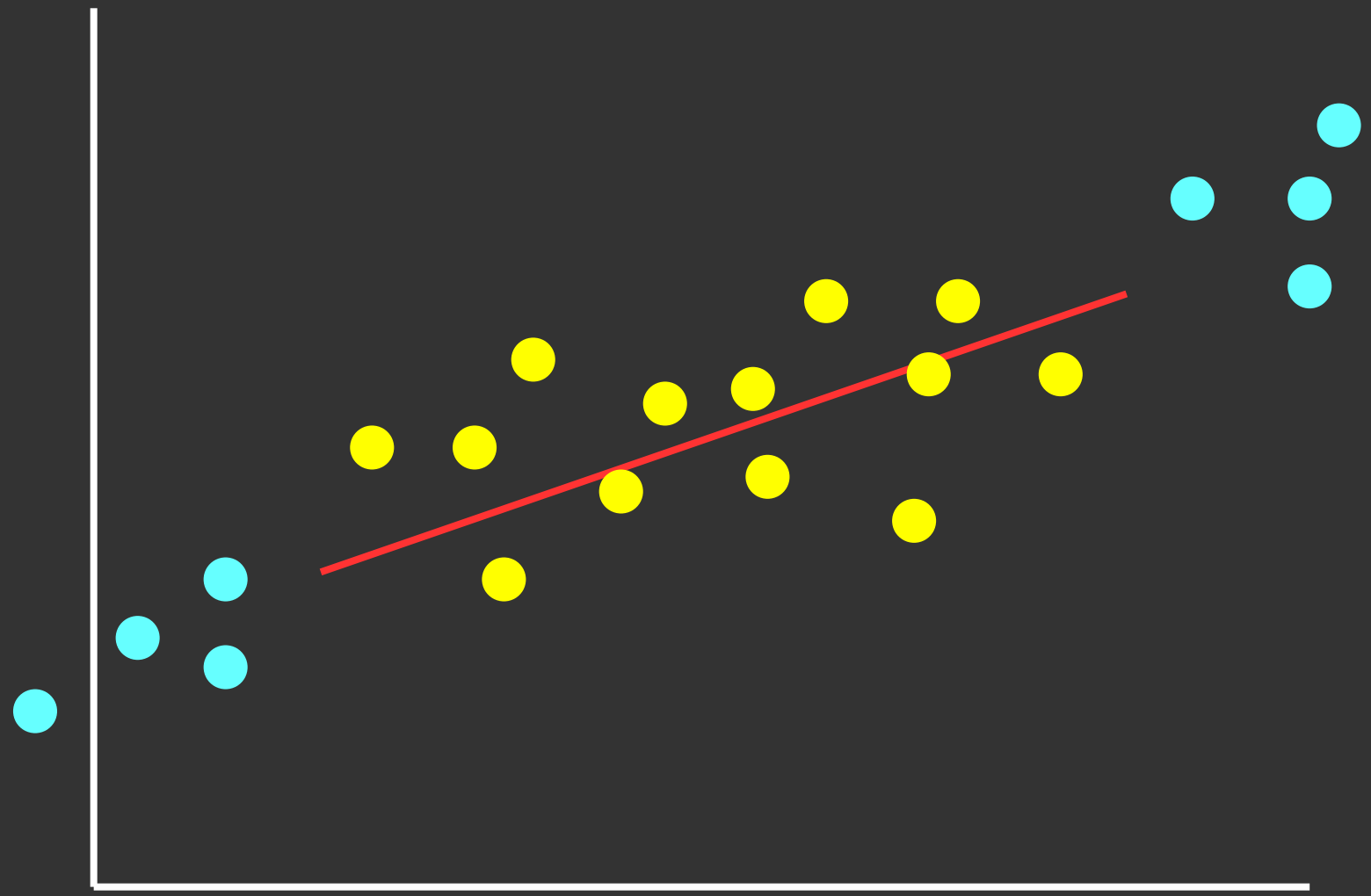
- Check Clamping maps if available.
- Calculate MESS: Multivariate Environmental Similarity Surface.



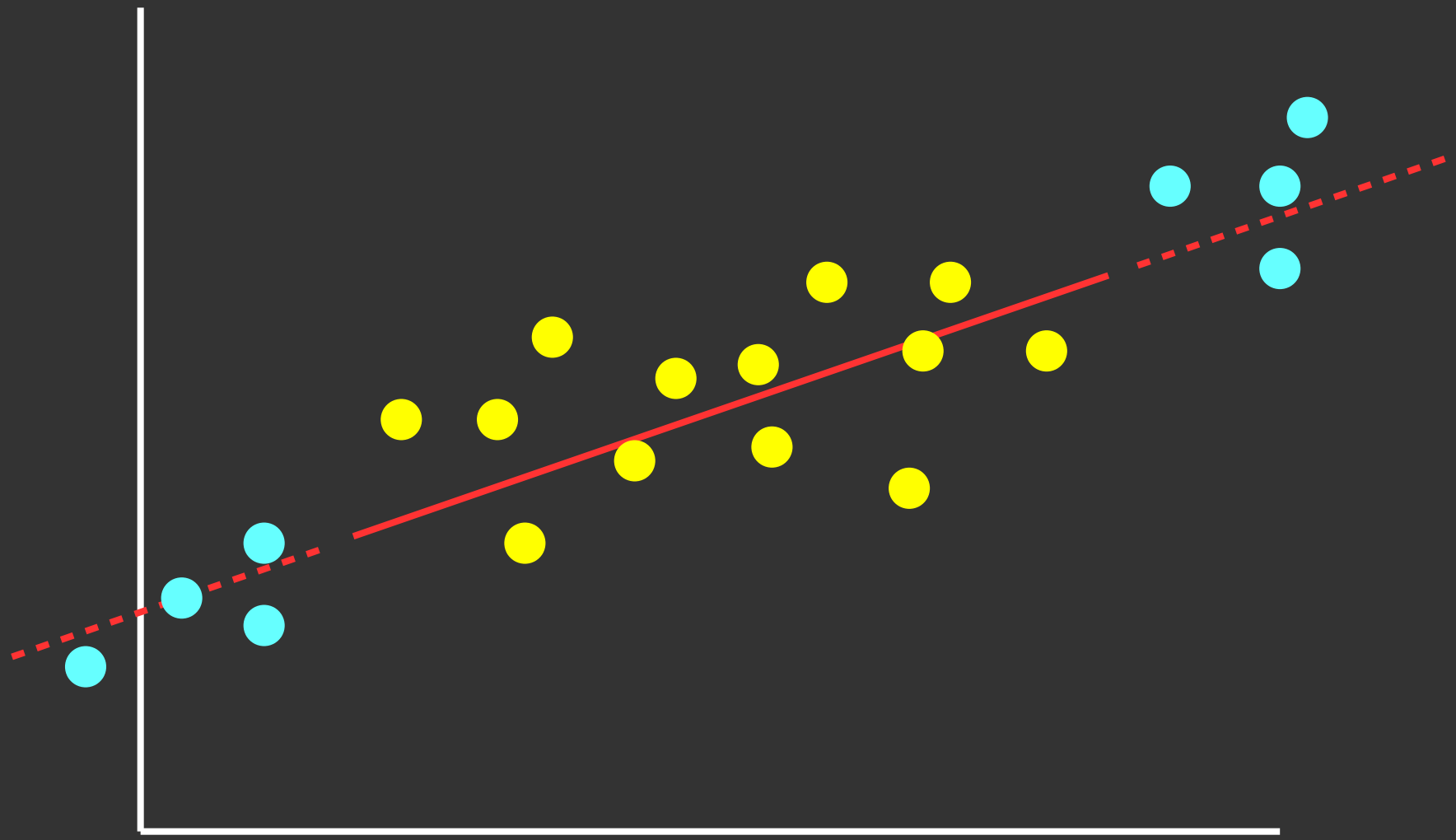
MODEL PROJECTIONS IN TIME AND SPACE



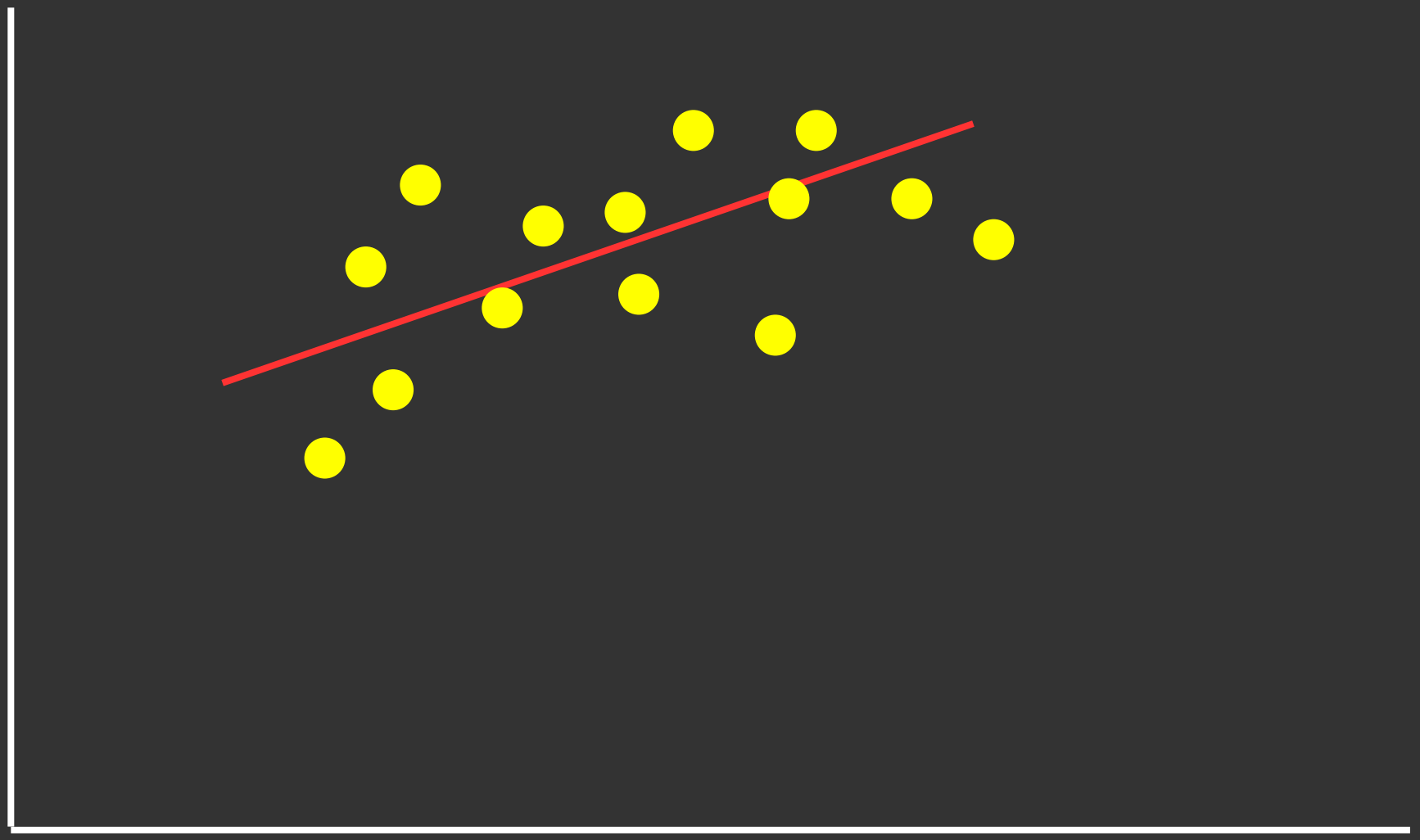
MODEL PROJECTIONS IN TIME AND SPACE



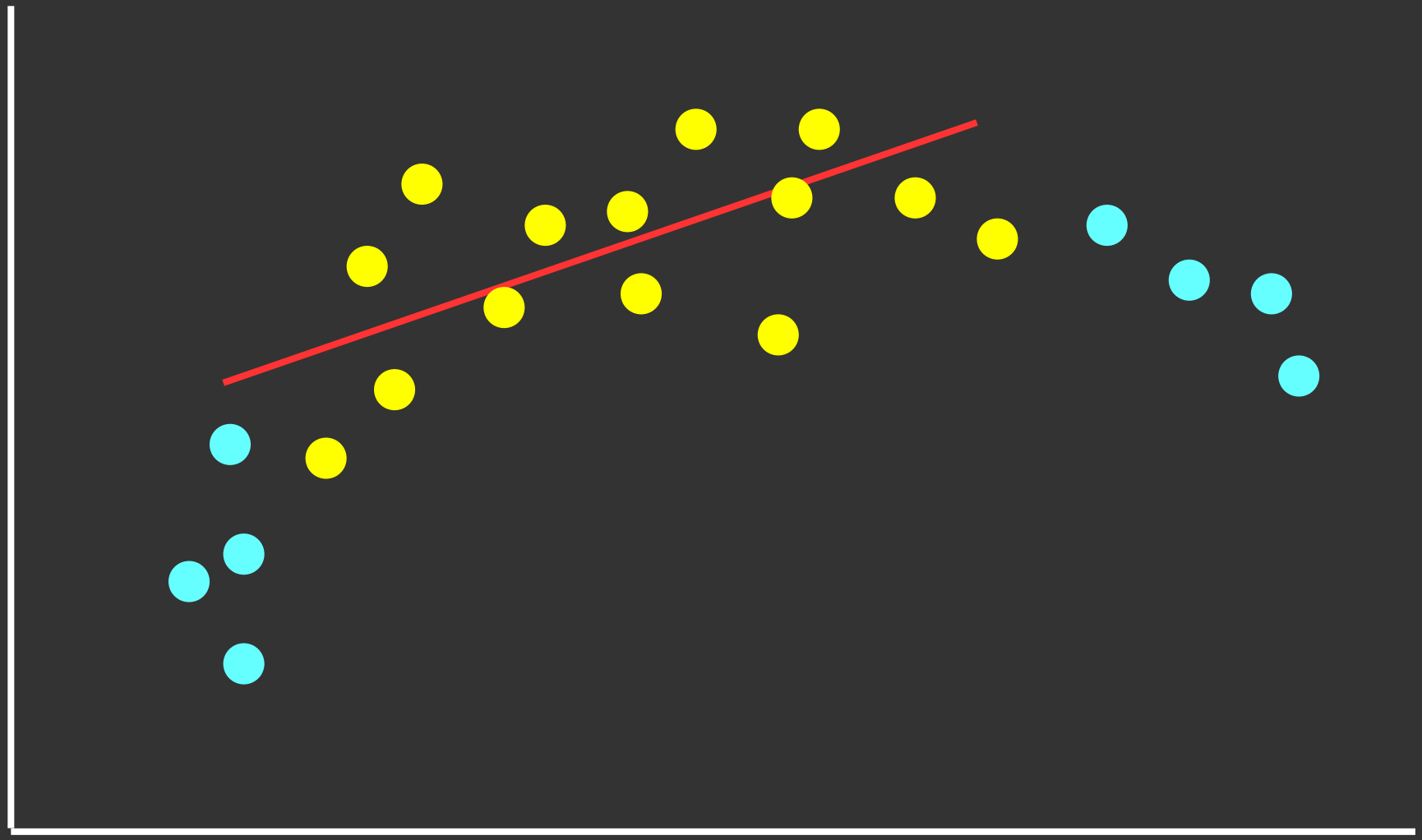
MODEL PROJECTIONS IN TIME AND SPACE



MODEL PROJECTIONS IN TIME AND SPACE



MODEL PROJECTIONS IN TIME AND SPACE



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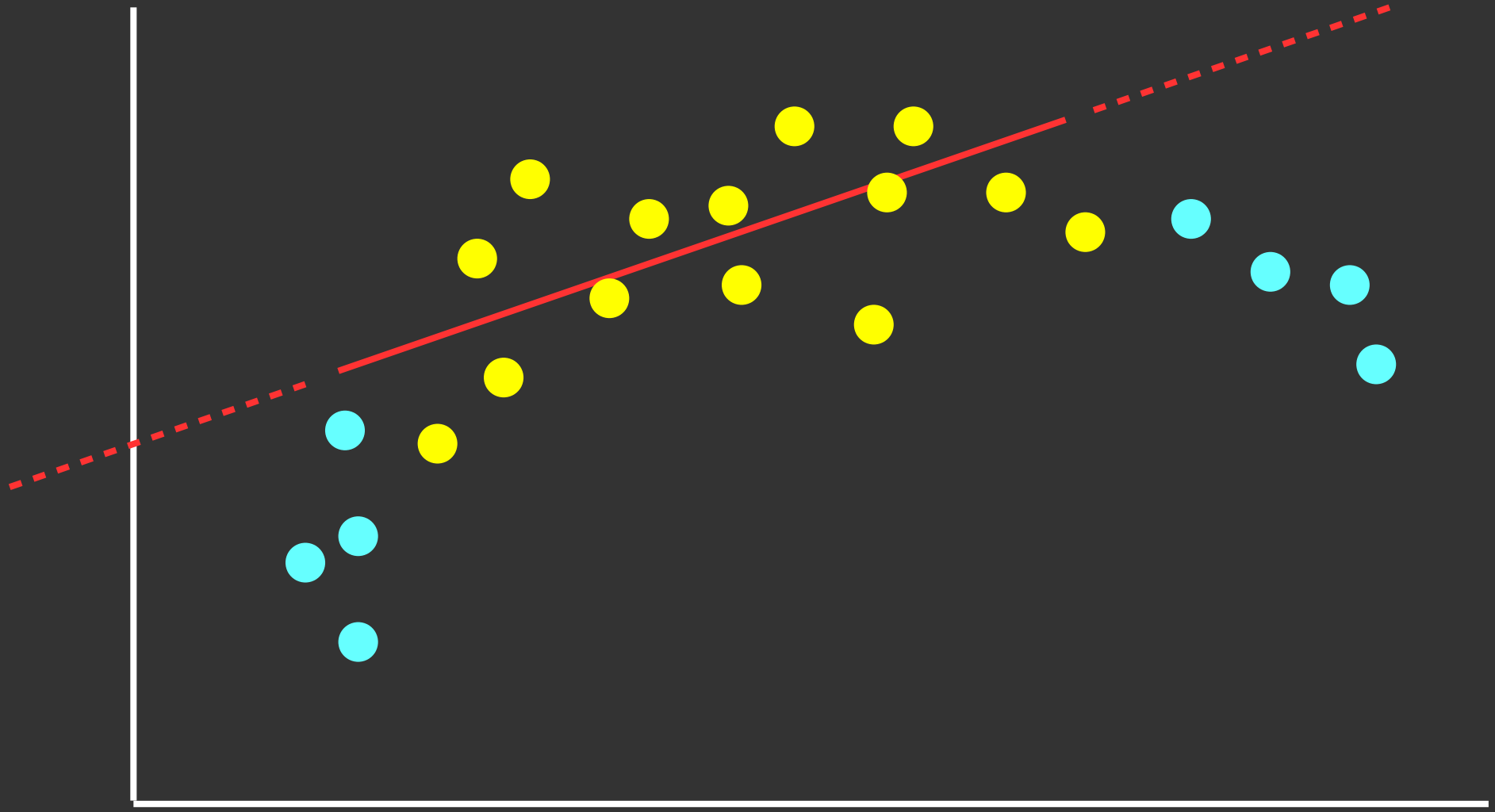
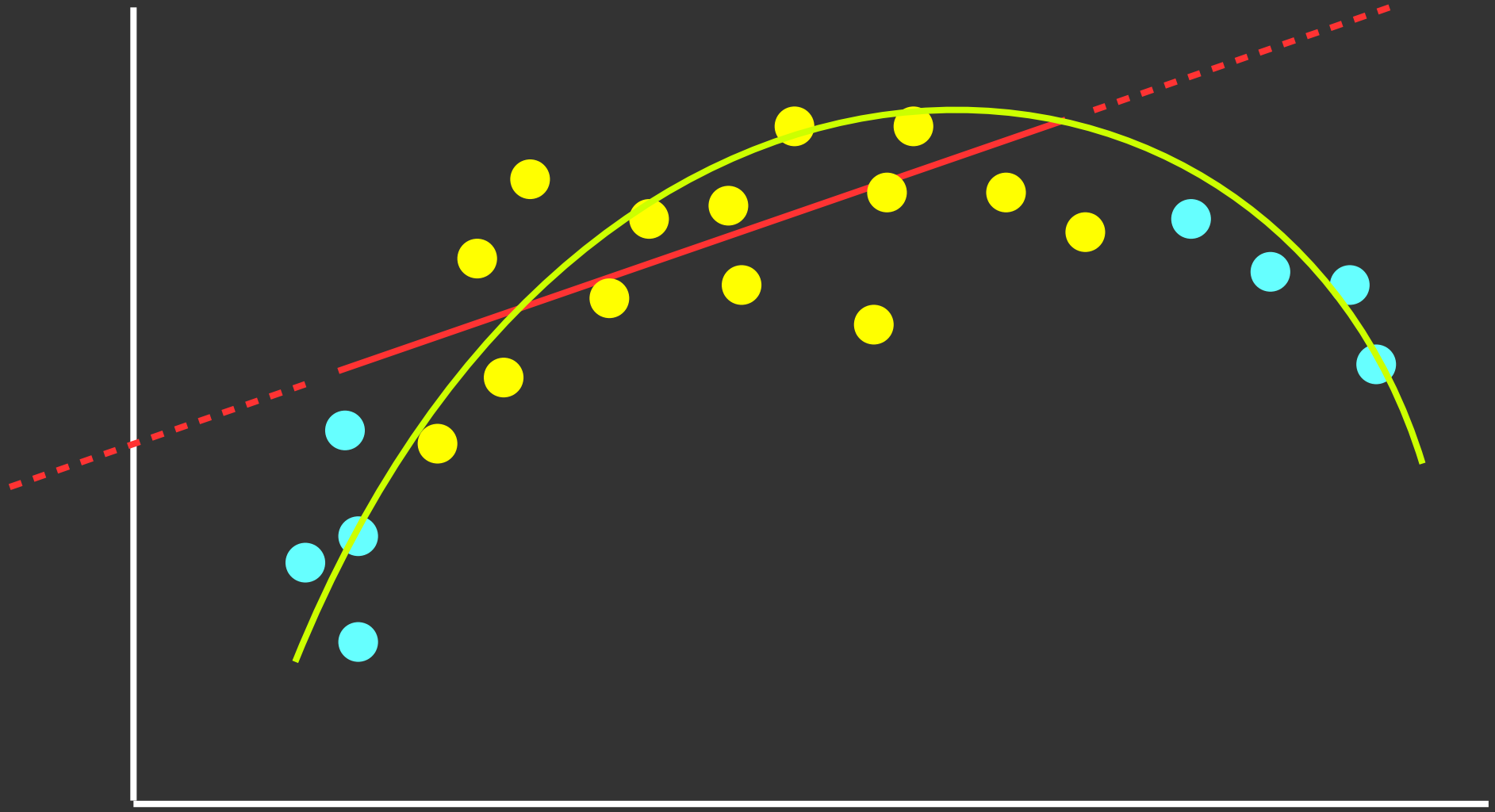


MODEL PROJECTIONS IN TIME AND SPACE



- **Exclude variables Bio 3, Bio14, Bio 15**
- **Low correlation between current and future variables**

PLOS ONE

RESEARCH ARTICLE

A Short Guide to the Climatic Variables of the Last Glacial Maximum for Biogeographers

Sara Varela[1,2]*, Matheus S. Lima-Ribeiro[3], Levi Carina Terribile[3]

Global and Planetary Change 107 (2013) 1–12

Contents lists available at SciVerse ScienceDirect

Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

Dangers of using global bioclimatic datasets for ecological niche modeling. Limitations for future climate projections

Joaquín Bedia [a,*], Sixto Herrera [b], José Manuel Gutiérrez [a]

Scale Uncertainties

The choice of the spatial scale depends on
→ scale of the available environmental data
→ scale of the current species distributional data

- At a very fine resolution: species distributions may not match environmental factors closely because behavioural interactions (territoriality, social attraction) can override habitat selection.

- At a coarse resolution: only the most general environmental relations may emerge in correlative analyses.

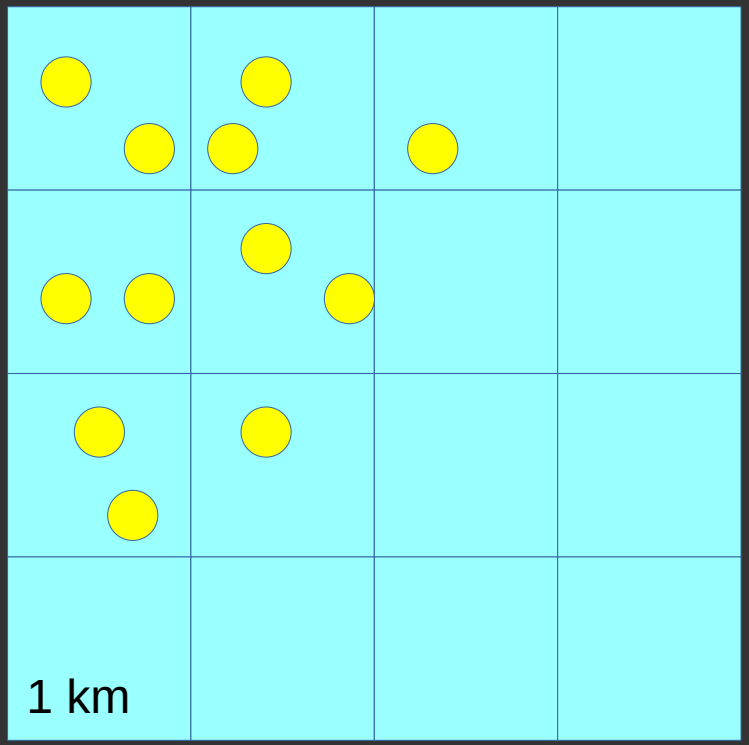
Correlative models using large grid-cell sizes may overestimate potentially suitable areas in relation to those predicted by using a finer grid-cell size.

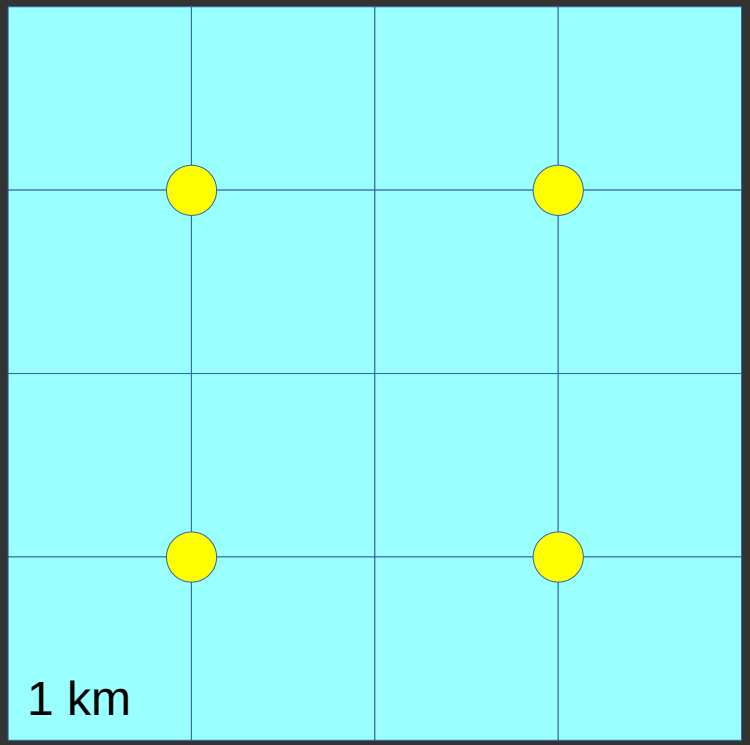
Wiens et al 2009

SPATIAL RESOLUTION OF VARIABLES

The spatial resolution of the variables must be similar or lower to the spatial resolution of the species' records.

You cannot use variables with a pixel larger than the accuracy of the species' coordinates.





The solution is to model the species at a coarse resolution and to project it to a set of variables with higher spatial resolution.

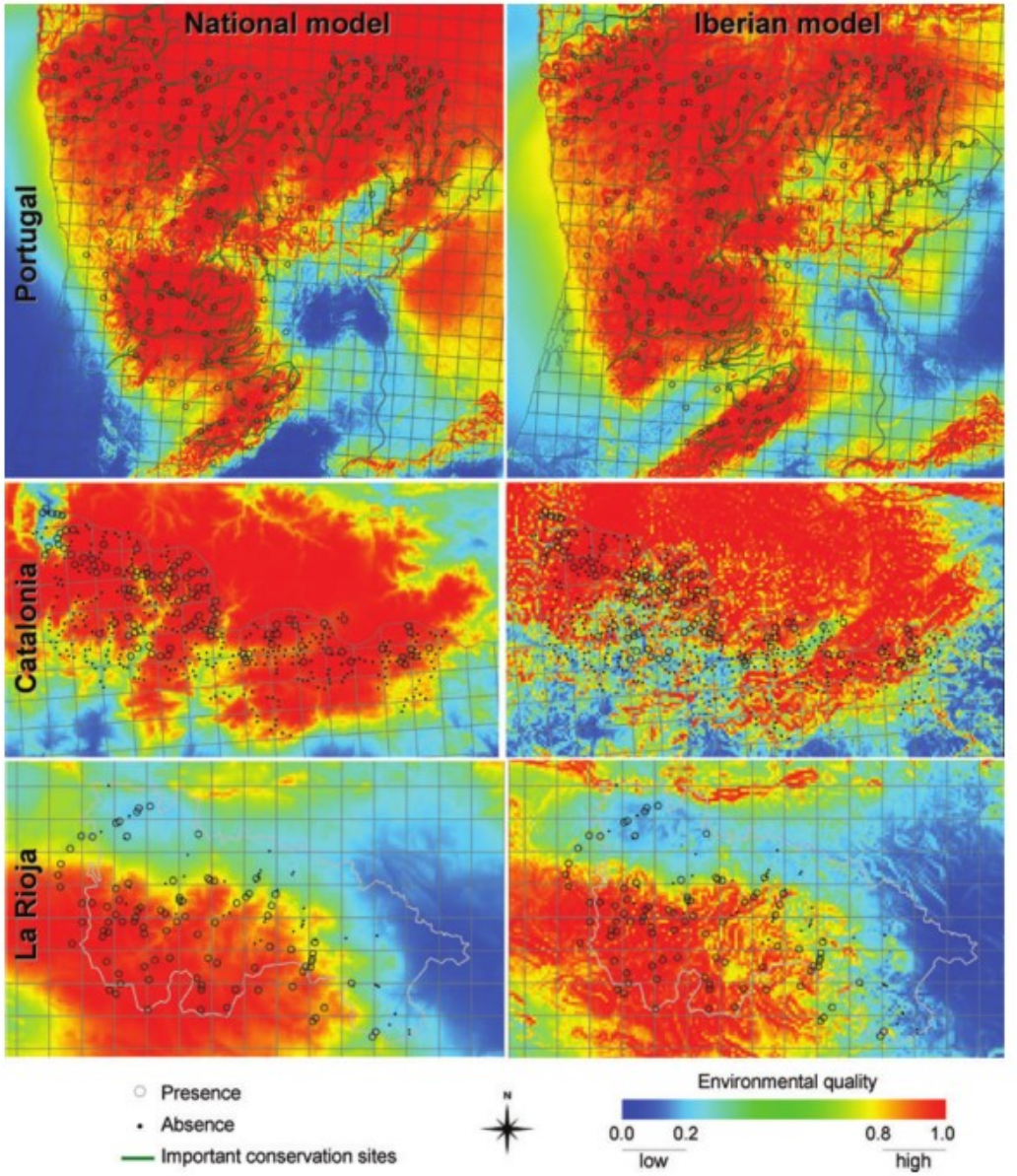


Figure 2. Environmental quality for Iberian desmans according to the national (Portuguese for Portugal and Spanish for Catalonia and La Rioja) and Iberian models of distribution compared with actual fine-resolution presence and absence data (Queiroz et al. 1998; Aymerich et al. 2001; Aguirre-Mendi 2004) and with important conservation sites for this species in Portugal (Queiroz et al. 1998). Environmental quality values are at the 1 × 1 km resolution and were derived from 10 × 10 km modeled data. The limits of countries or regions and the 10 × 10 km squares are displayed for reference.

Barbosa et al 2010

QUESTIONS?