



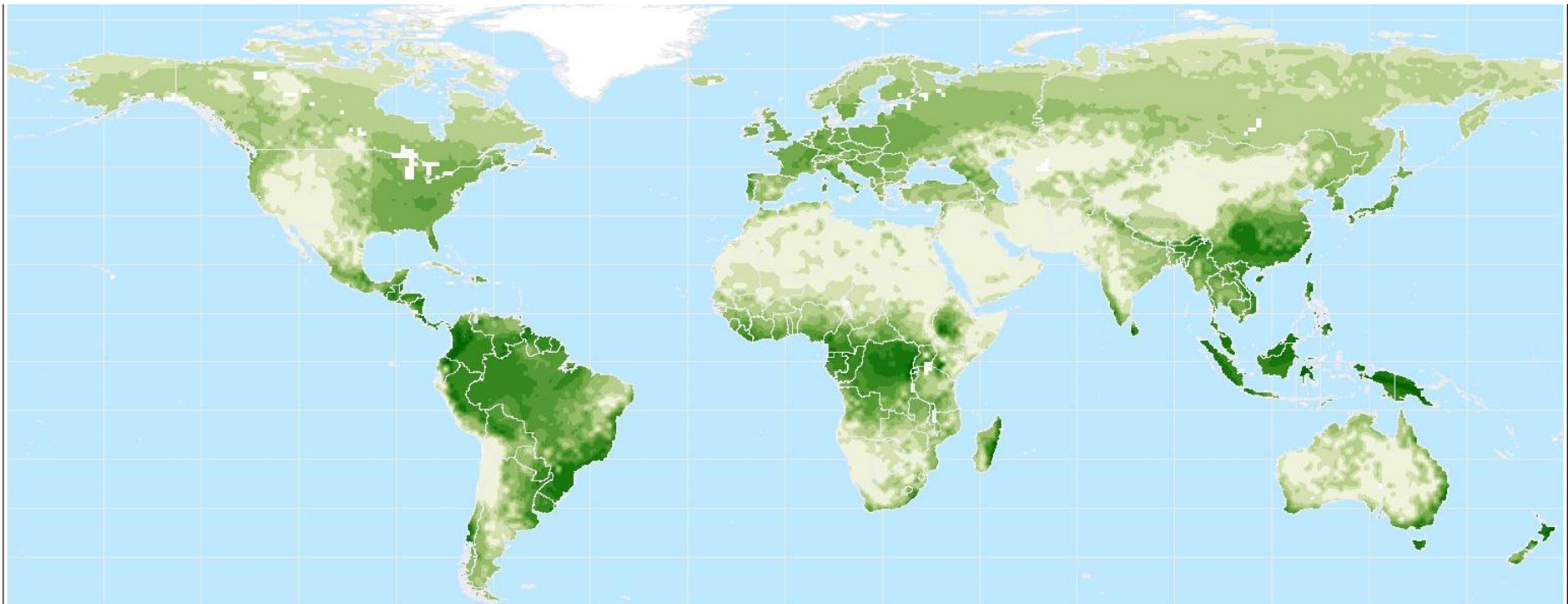
INVESTMENTS IN EDUCATION DEVELOPMENT

Mapping and modeling species distributions

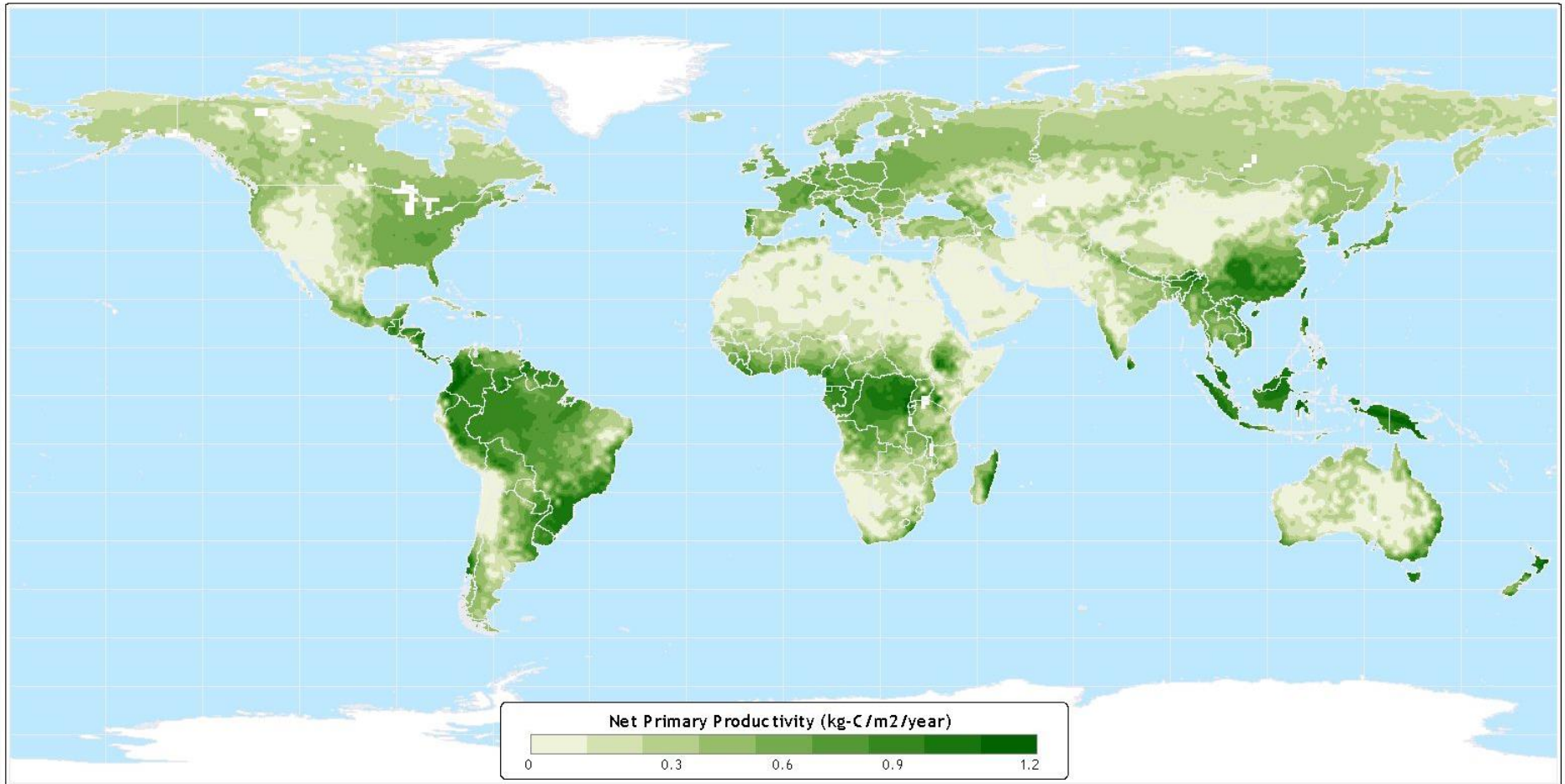
Department of Botany and Zoology, Masaryk University

Bi9661 Selected issues in Ecology, Autumn 2013

Borja Jiménez-Alfaro, PhD



Net Primary Productivity



Data taken from: IBIS Simulation
(Kucharik, et al. 2000)
(Foley, et al. 1996)

Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

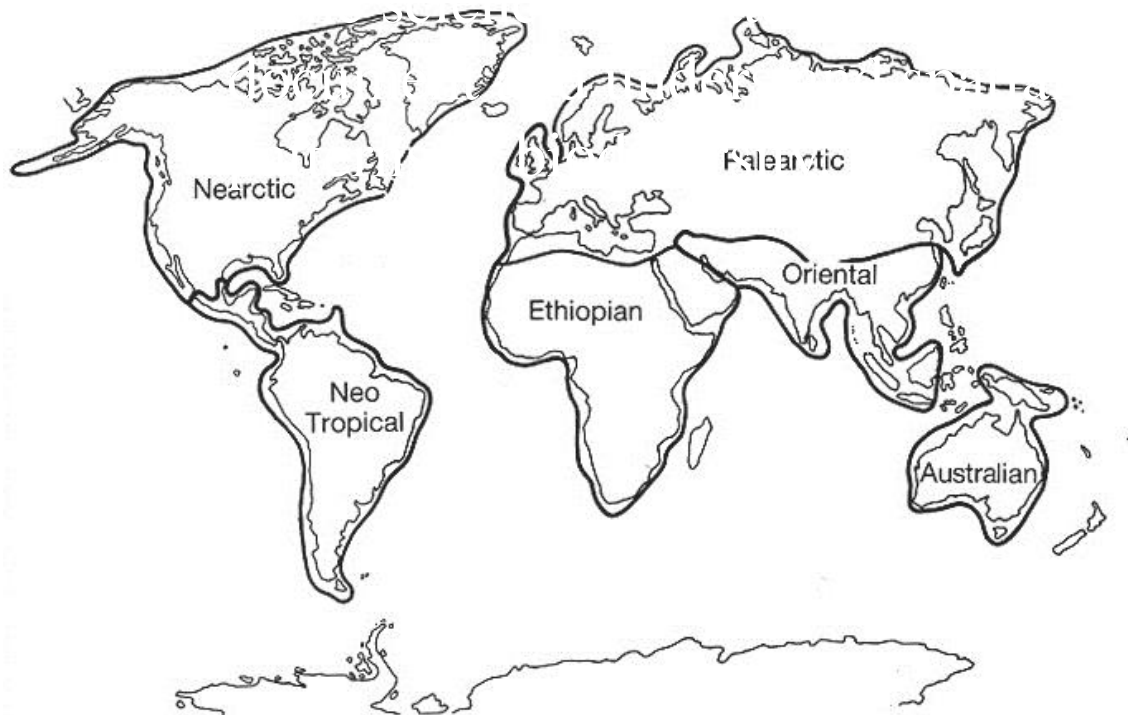
Introduction:

ASSESSING

SPECIES DISTRIBUTIONS

Biogeography

“attempts to explain why species and higher taxa are distributed as they are, and why the diversity and taxonomic composition of the biota vary from one region to another”



Philip Sclater
(1829-1913)

Historical biogeography

Reconstruct the origins, dispersal, and extinctions of taxa
Primarily focused on evolution, dispersal and vicariance

Ecological biogeography

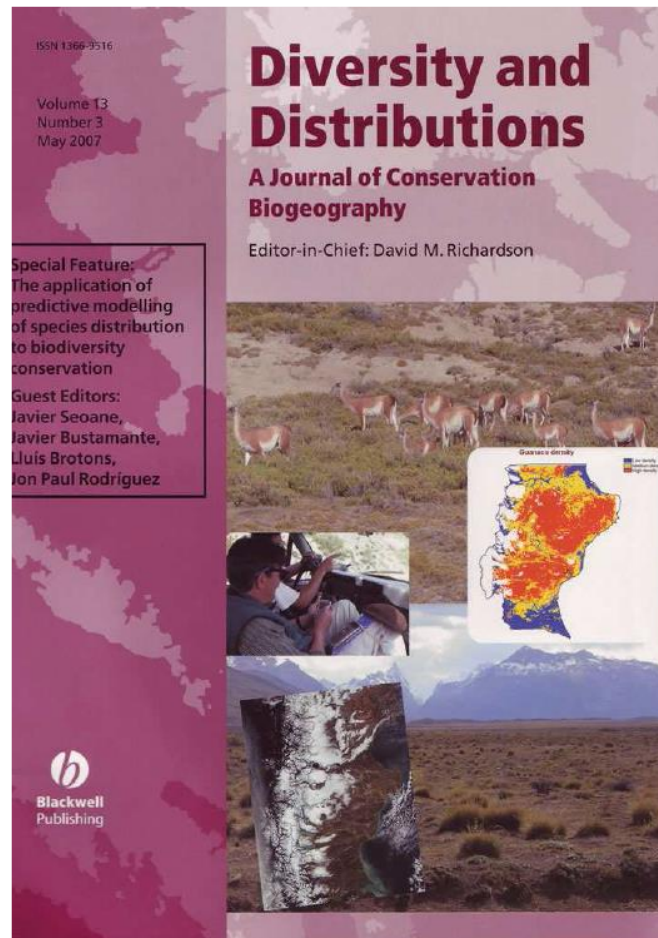
Primarily focused on present distributions, species responses to biotic environment and interactions with other organisms

Paleoecology

Combines historical and ecological biogeography, investigating the relationships between communities (abundance, distribution, and diversity of species) and abiotic conditions

Conservation biogeography

Work on the protection and restoration of natural environments



Special feature:
The application of
predictive modeling of
species distribution to
biodiversity conservation

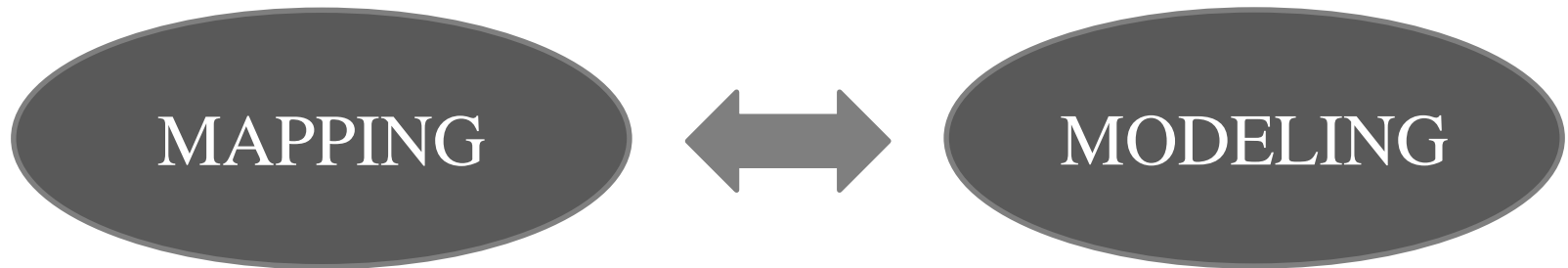
Special issue
Diversity and distributions
13 (3) 2006

Recent tools in biogeography

Computational power (computers)

Geographic Information Systems

Geostatistics



PREDICTING SPECIES OCCURRENCES

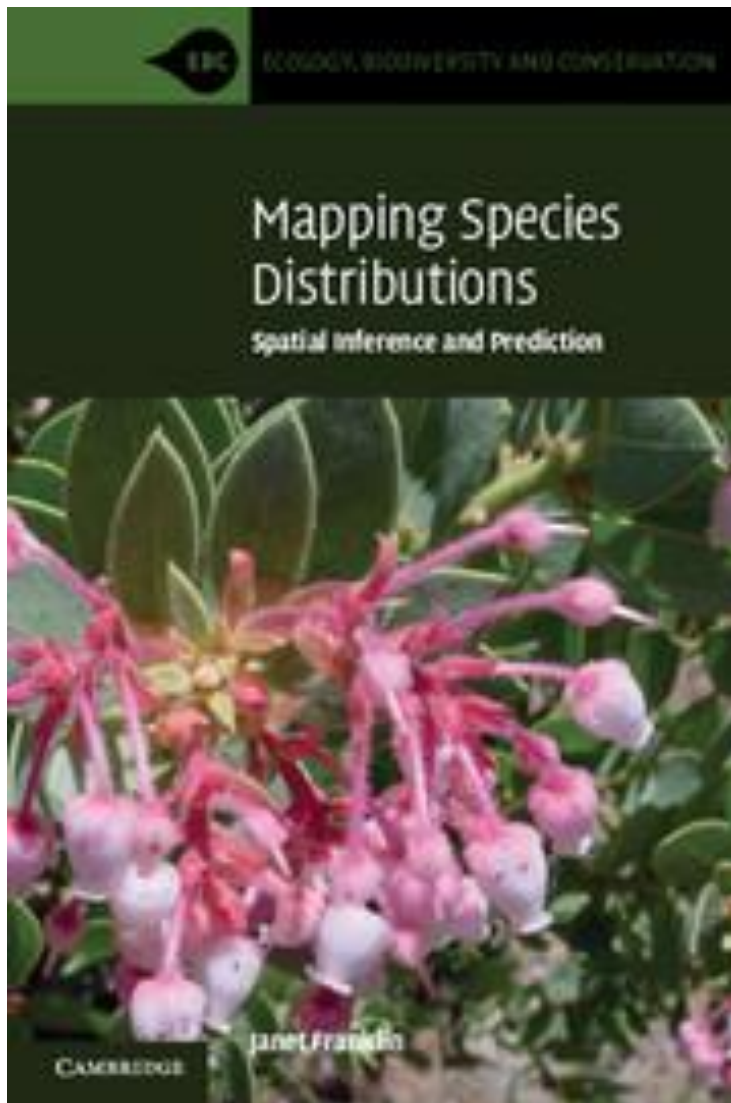
*Issues of Accuracy
and Scale*



Edited by
J. Michael Scott,
Patricia J. Heglund,
Michael L. Morrison et al.

2002

ASSESSING SPECIES DISTRIBUTIONS



2010

Ecological Niches and
Geographic Distributions

A. Townsend Peterson, Jorge Soberón,
Richard G. Pearson, Robert P. Anderson,
Enrique Martínez-Meyer, Miguel Nakamura,
and Miguel Bastos Araújo

MONOGRAPHS IN POPULATION BIOLOGY • 49

2011

Species distribution models (ecological niche models) are used for:

Predicting species occurrences and estimating ranges

Modeling ecological spatial responses

Reconstructing past distributions

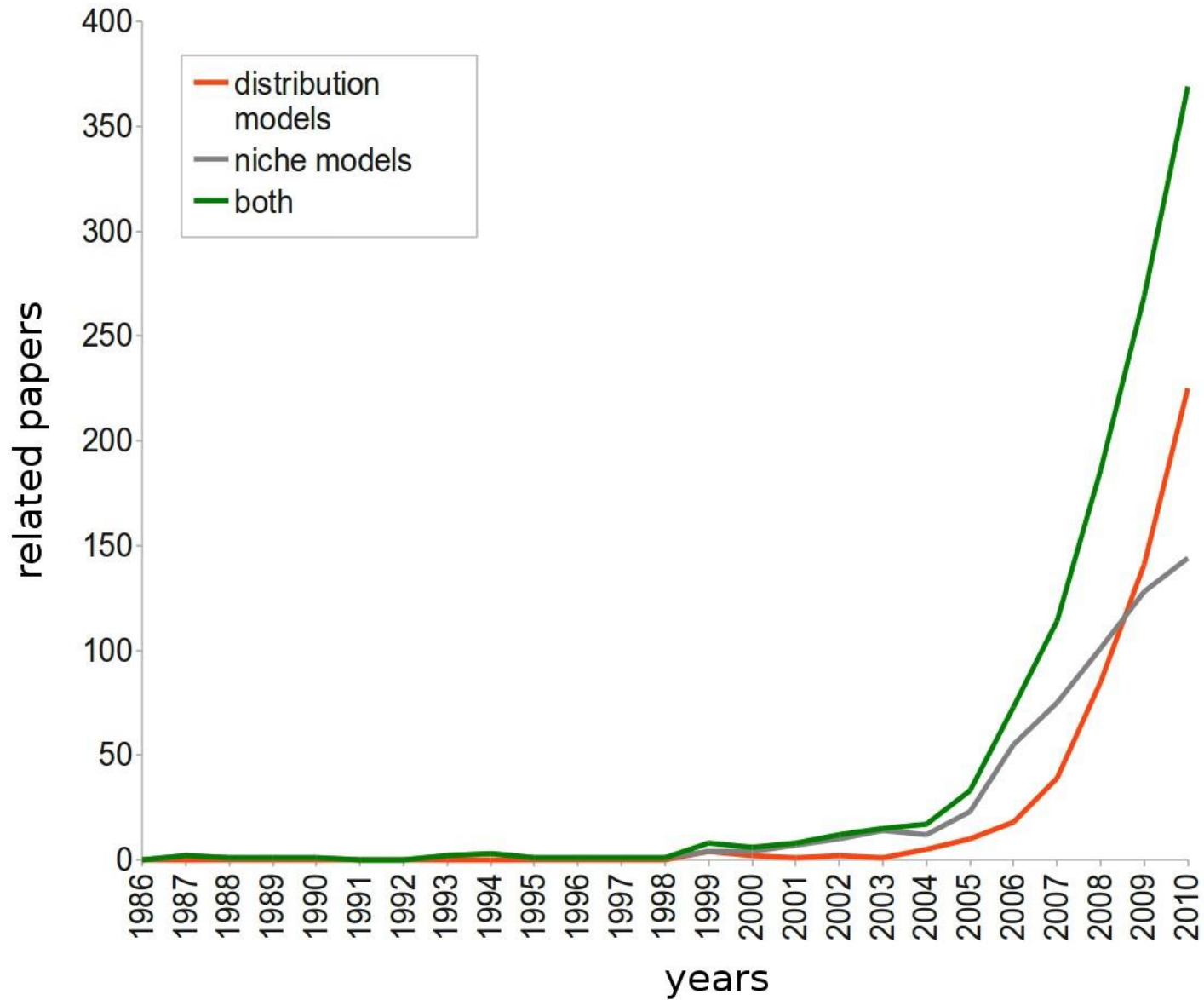
Biogeography of genetic and physiological data

Assessing responses to climate changes

Establishing diversity patterns (endemicity, richness)

and much more...

ASSESSING SPECIES DISTRIBUTIONS



ASSESSING SPECIES DISTRIBUTIONS

www.natureserve.org/prodServices/predictiveDistModeling.jsp

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Products & Services

- » NatureServe Web Services
- » NatureServe Vista Software
- » Biotics 4 Software
- » Conservation Planning Services
- » Confronting Climate Change
- » Forest Program
- » Ecosystem Mapping
- » Predictive Distribution Modeling
- » Expert Consultation
- » Information Technology & Tools

Products & Services

Predictive Distribution Modeling

Predictive Distribution Modeling (PDM) is an innovative GIS-based method used to produce predictive maps of where elements (i.e., species, ecological community type) are likely to occur and likely not to occur. The probability of occurrence is quantified and is directly related to underlying environmental variables and the locations of known occurrences. There are several advantages to using PDM (also known as "element distribution modeling") for inventory and conservation planning:

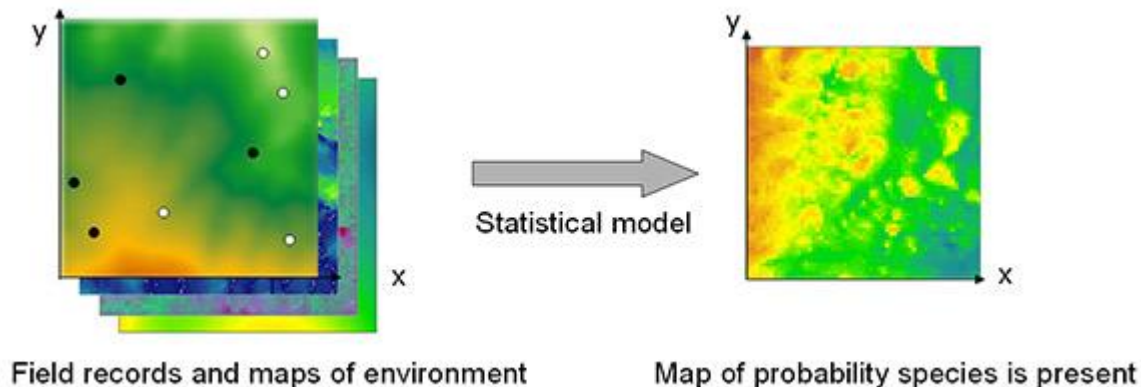
- Maps of documented occurrences ("dot maps") convey no information on likelihood of element occurrence in areas that have not been surveyed. Range maps from field guides and similar treatments are too coarse to inform on-the-ground action or study.
- Good predictive distribution maps make field inventories more efficient and effective. They show where to commit limited inventory resources for the highest likelihood of documenting a target element.
- Predictive distribution maps are crucial to state comprehensive wildlife conservation strategies and other agency planning efforts (e.g., USFS Regional and Forest Plans

Learn More

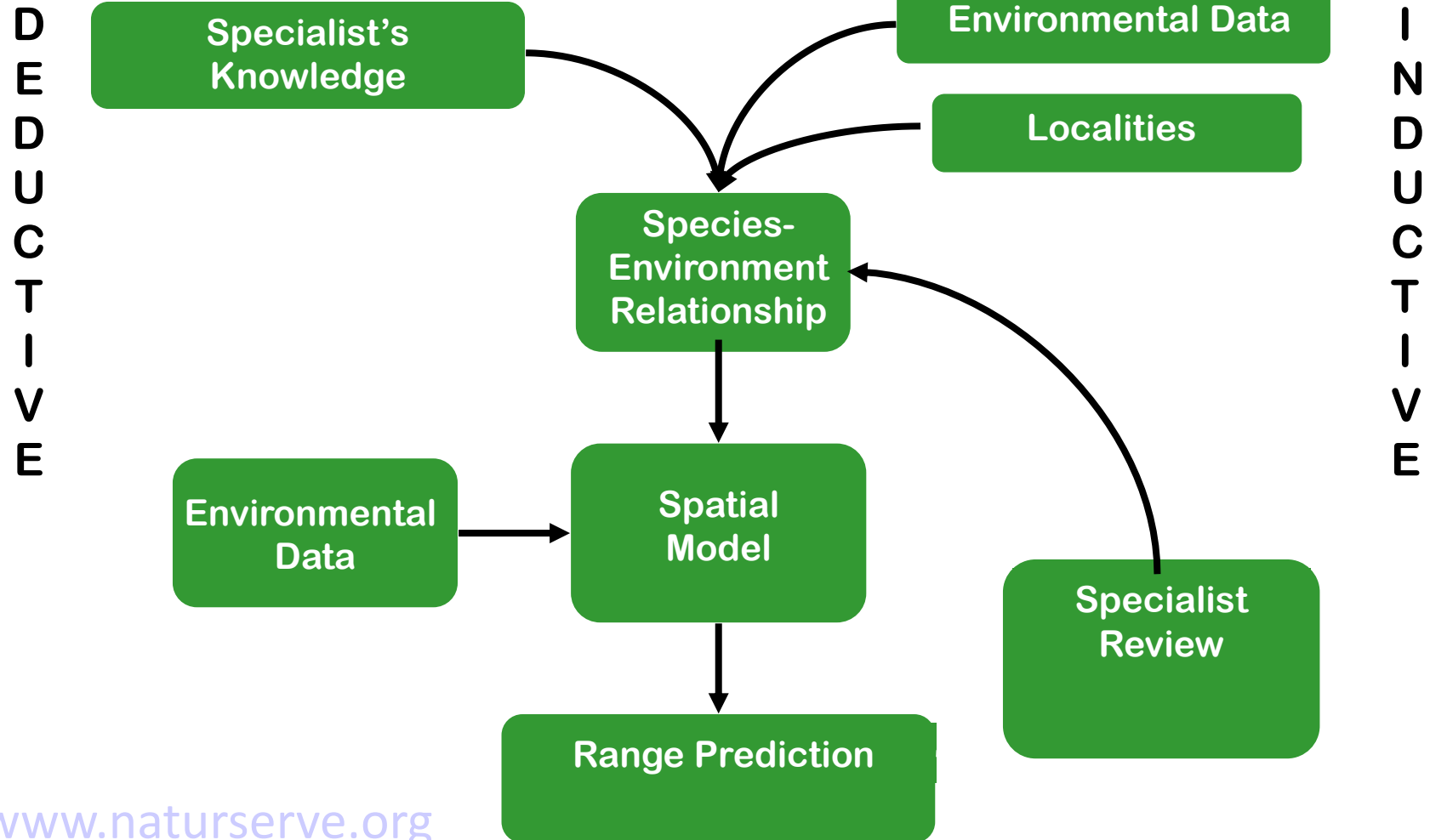
- **Learn** more on how NatureServe has used PDM to map species in Latin America
- For more information on PDM, **download** the white paper "Element Distribution Modeling: A Primer". (PDF, 328 KB)
- **Download** fact sheet on PDM. (PDF, 675 KB)

Three main steps:

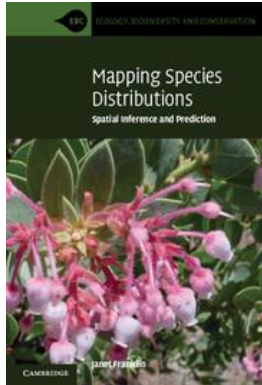
1. compile **spatial data** associated with the target element and **environmental data** for the area of interest
2. build a **statistical model** based on the association of the element to environmental variables at sites of known occurrence
3. Map the **model via GIS** across the area of interest



Distribution Modeling



ASSESSING SPECIES DISTRIBUTIONS



Franklin
2009

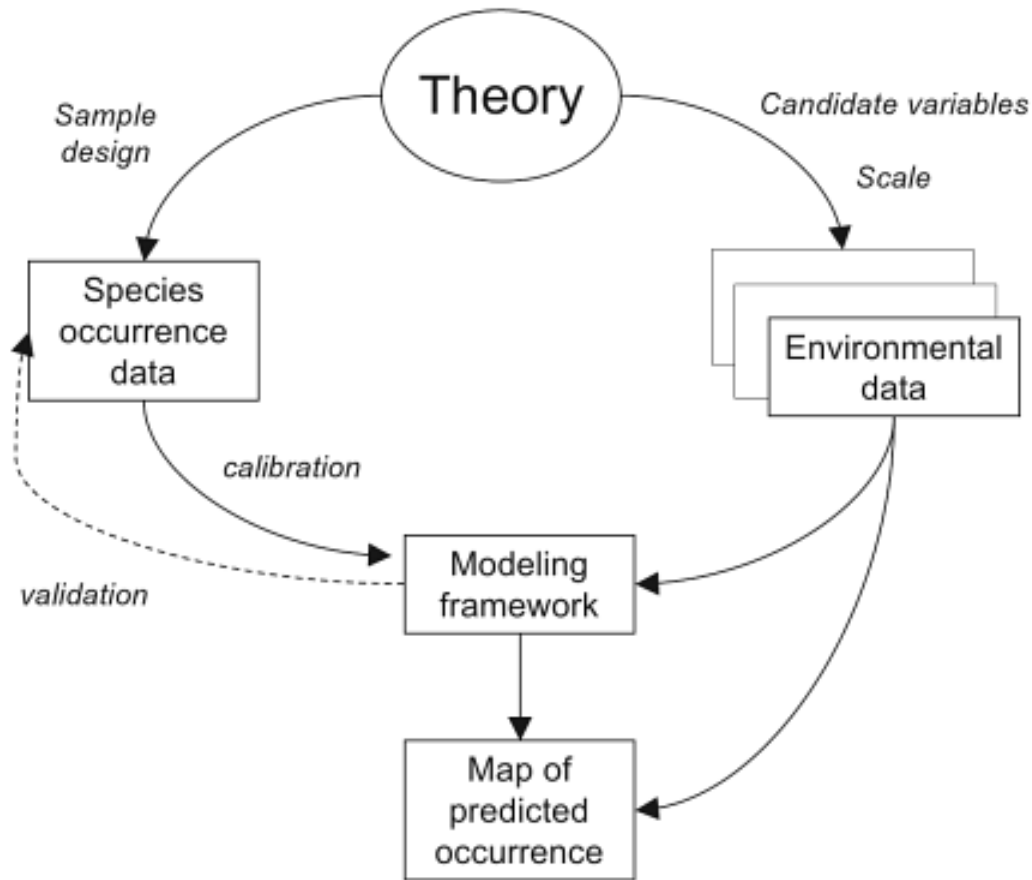
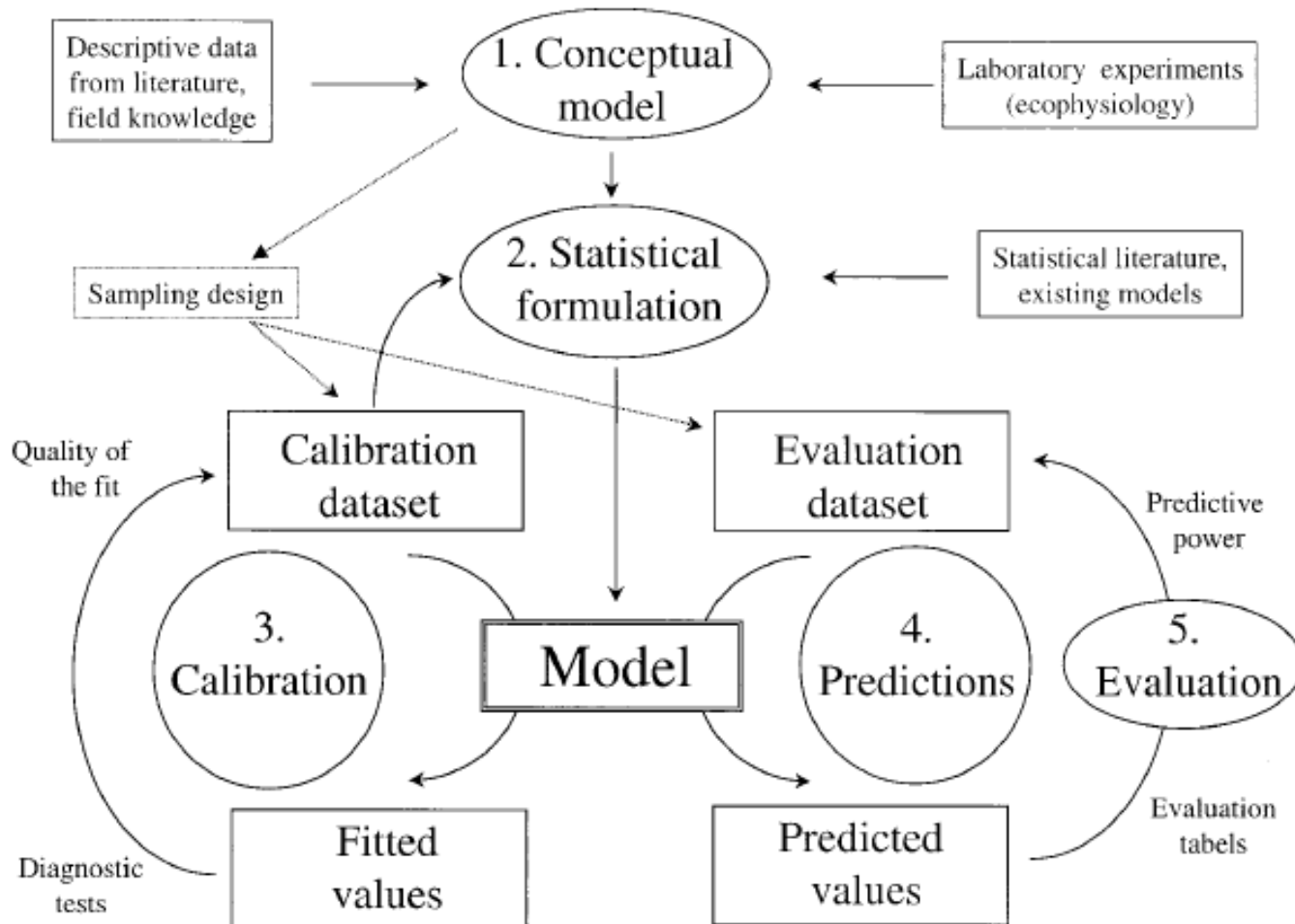


Fig. 1.2. Diagram showing the components of species distribution modeling. Biogeographical and ecological theory and concepts frame the problem, and identify the characteristics of the species and environmental data required to calibrate an appropriate empirical SDM and apply it to produce a map of predicted species occurrence or suitable habitat.

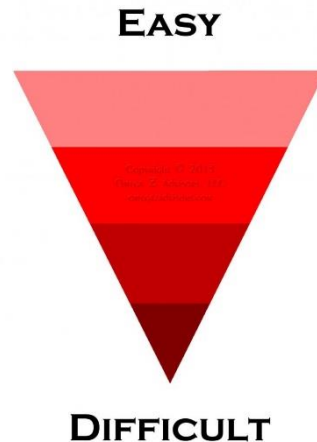
Model building process (from Guisan and Zimmerman 2000)



Distribution modeling (per se) is EASY

Just some technical skills are required

Anyone can compute it with user-friendly software



Applying distribution modeling is more TRICKY

You need a good purpose to do it

(research question, conservation goal)

You must know how to do it properly

About this course:

Part 1 – Mapping

Dealing with occurrence data
Environmental variables
Spatial terms and PRACTICE with GIS

Part 2 – Modeling

Background theory (niche concept)
Modeling methods
Maximum Entropy and PRACTICE with MaxEnt

Part 3 – Mapping and Modeling

Model implementation and evaluation
Applications and future challenges
Using your **OWN DATA** and **GROUP PRACTICE**

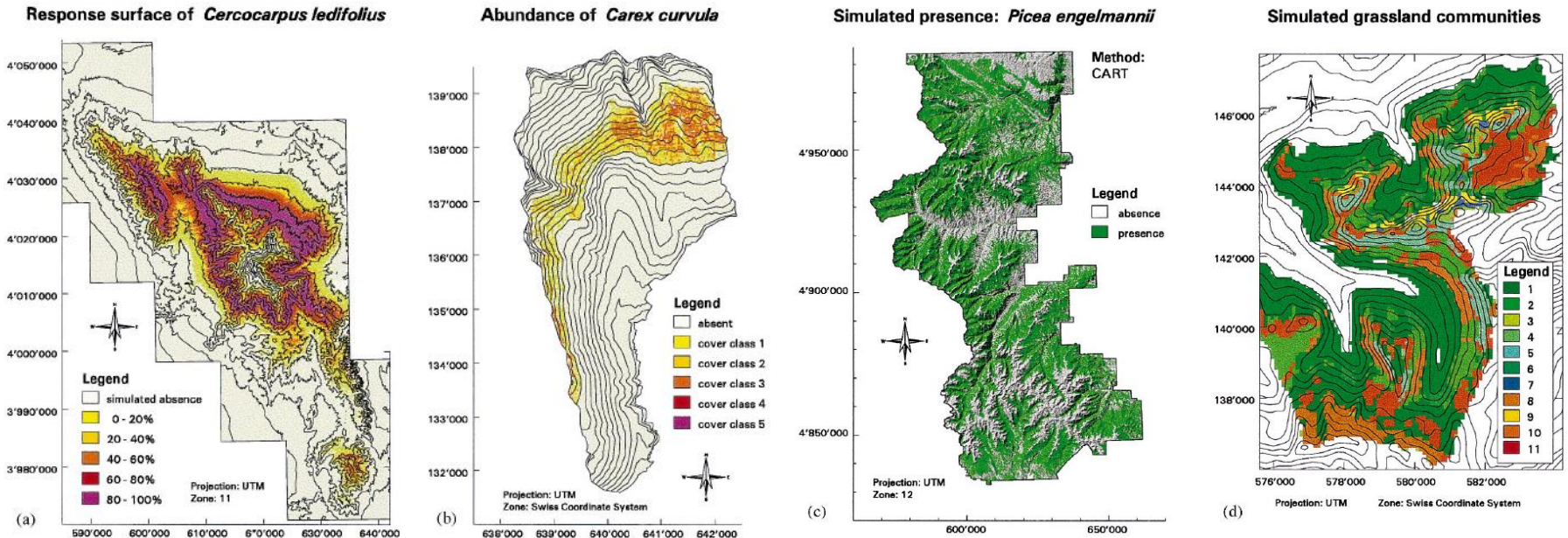
Part 1:

MAPPING

OCCURRENCE DATA

What is occurrence data?

A **record** for one species/organism/community in one **locality**
Presences (and **absences**) are the MAIN dependent variable for
 Species Distribution Modeling (but there are more)



Where to obtain occurrence data?

Two main options:

1. Designing your own field sampling

Pro: you have control on your data

Con: many times you have not time or money

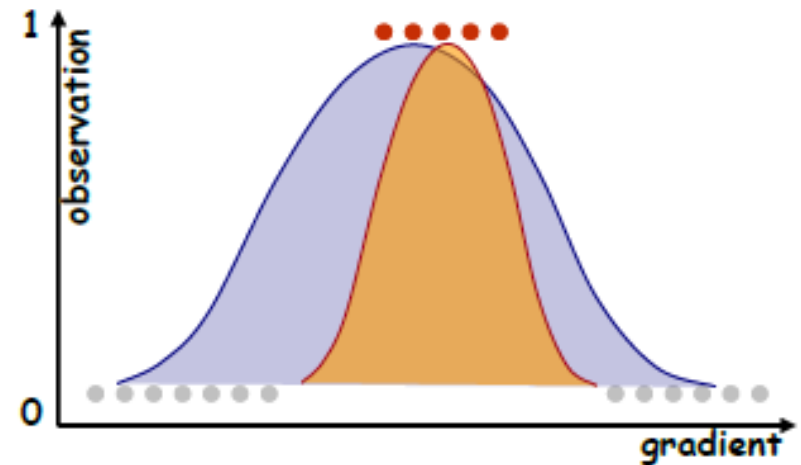
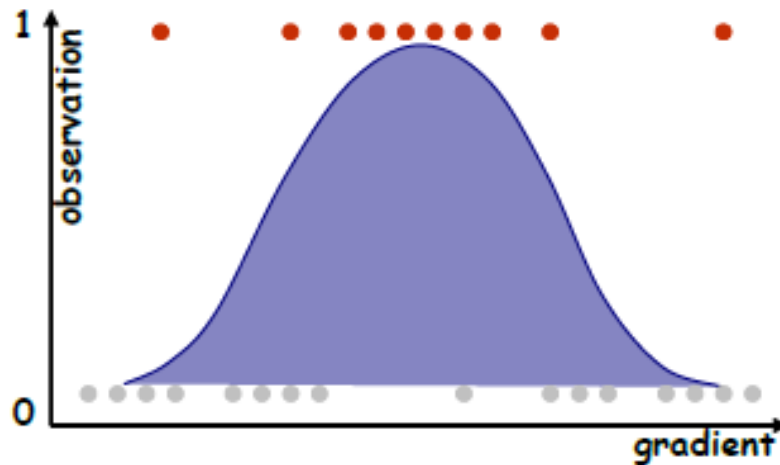
2. Using existing data (e.g. biodiversity databases)

Pro: huge amount of data around the world

Con: uncertainties on sampling, accuracy, etc.

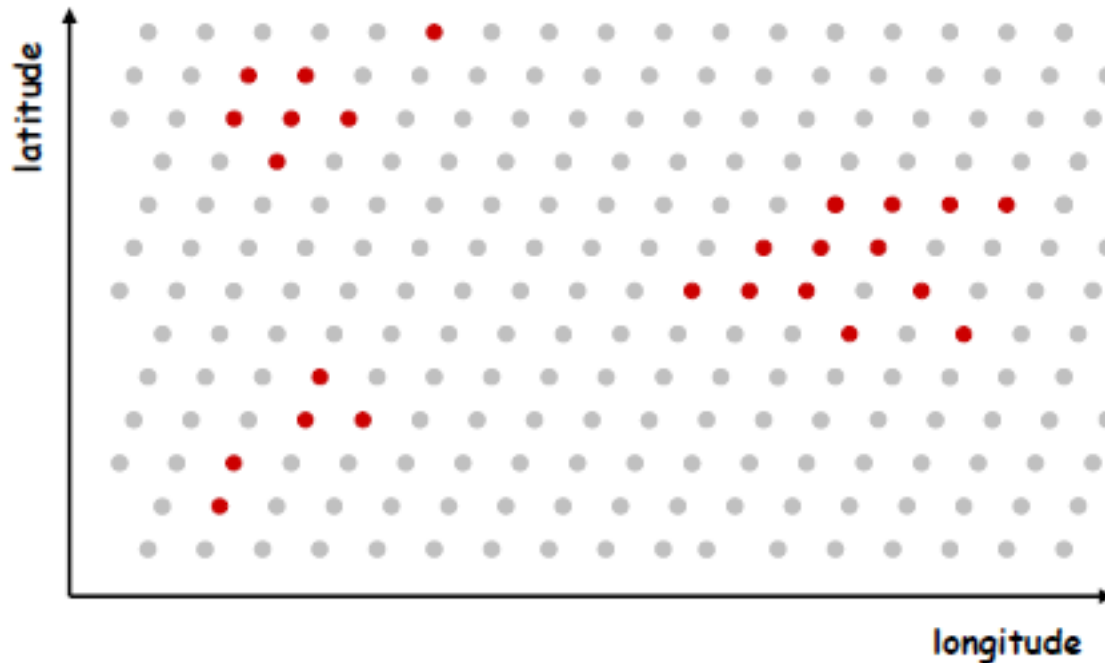
1. Sampling design

Probabilistic design is required to quantify the species responses along gradients, in order to consider the edges of environmental distribution



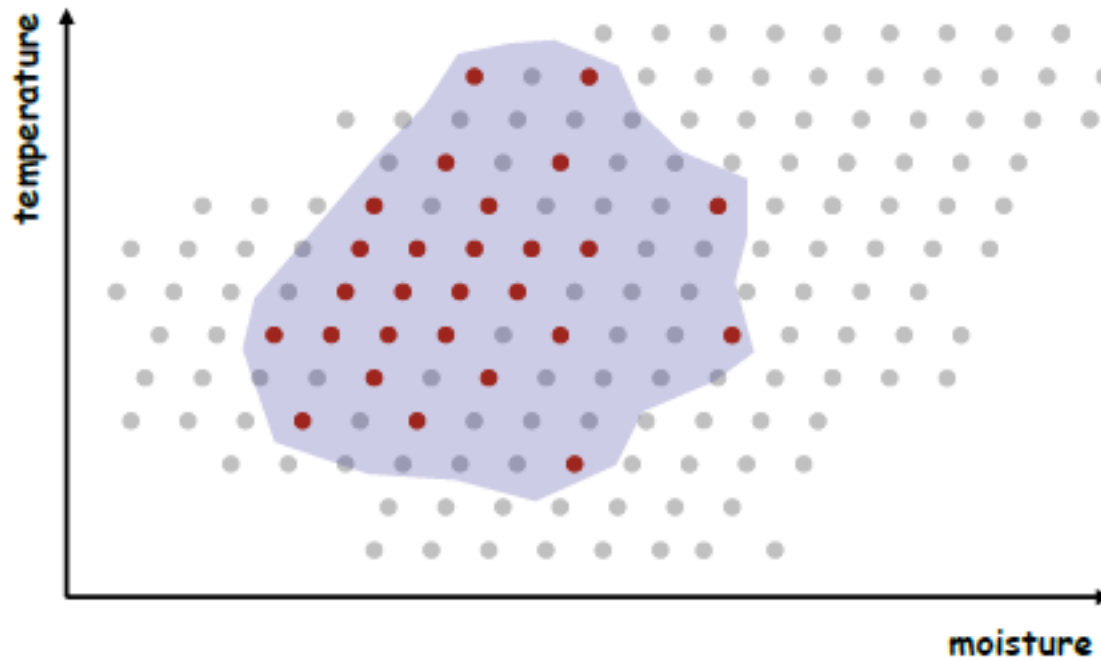
Geographic distribution of a species

Species are often distributed in a patchy manner at the scale of the landscape (non-random structure of L).



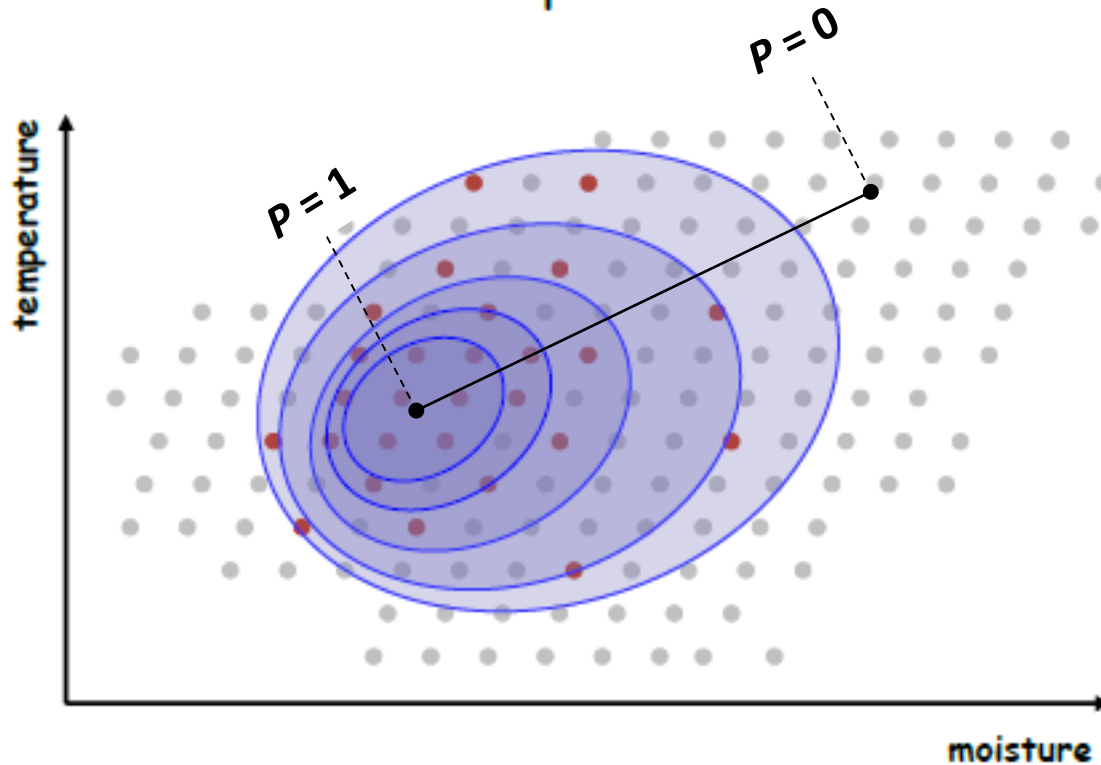
Distribution in the environmental space

If we translate this distribution into env. space, then the distribution often looks quite different



Distribution in the environmental space is different!

Our goal is then to quantify the density distribution or the likelihood to find a species in the environm. space



There is no universal design for all questions, but...

Simple random design is used for relatively homogeneous spaces (when the probabilities of occurrences are equal) but it is not a good option if you have to sample organisms which are rare or disjunctly distributed

Regular, systematic, clustered or stratified designs are preferred to sample occurrence data if the organism is clearly influenced by geographical, environmental or topographical gradients

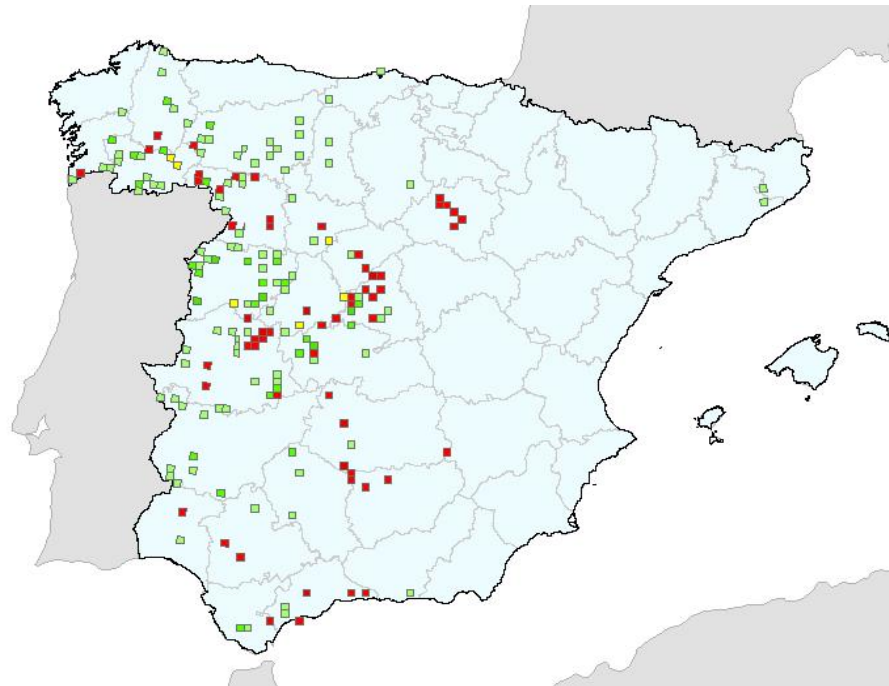
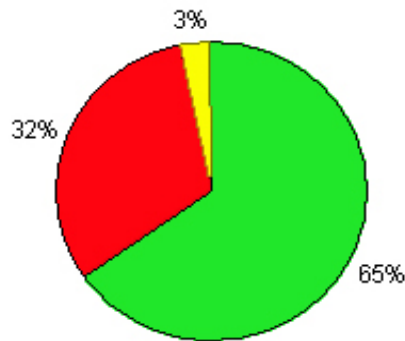
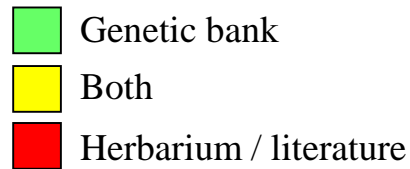
Even better can be mixed designs, e.g **random stratified sampling**

You “should” avoid **bias** survey sampling

-> Geographic bias: along roads, near the cities,...

-> Taxonomic bias: wrong identification of species

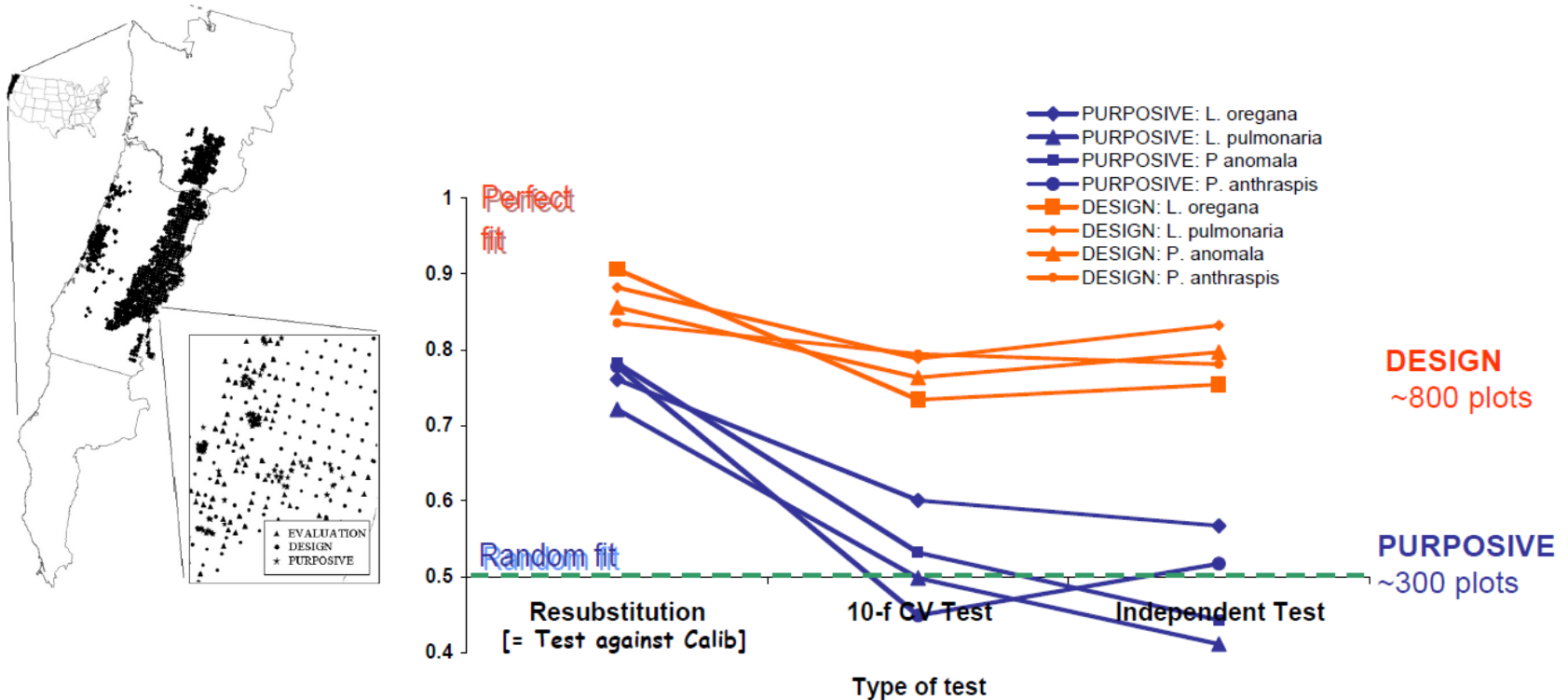
E.g.: identification of bias in biological collections of *Lupinus hispanicus* (Parra-Quijano et al.): different geographic cover



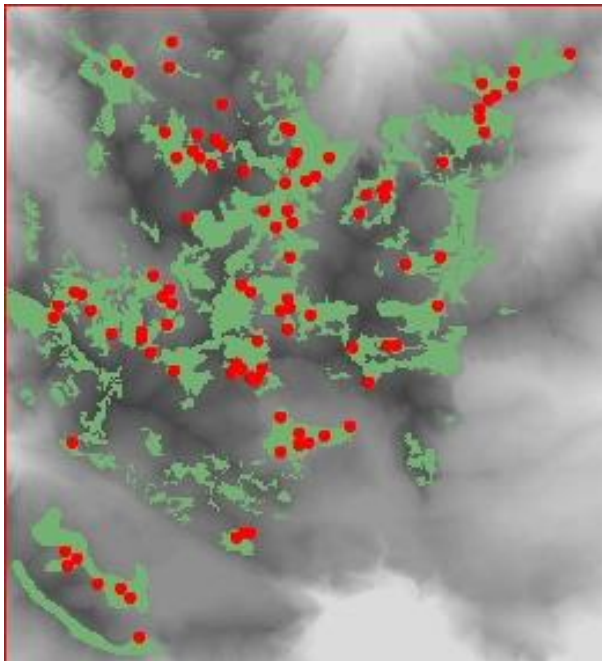
You “should” avoid **purposive** sampling

- > non-probabilistic, based on aprioristic knowledge
- > usually produces undersampling of the study subject

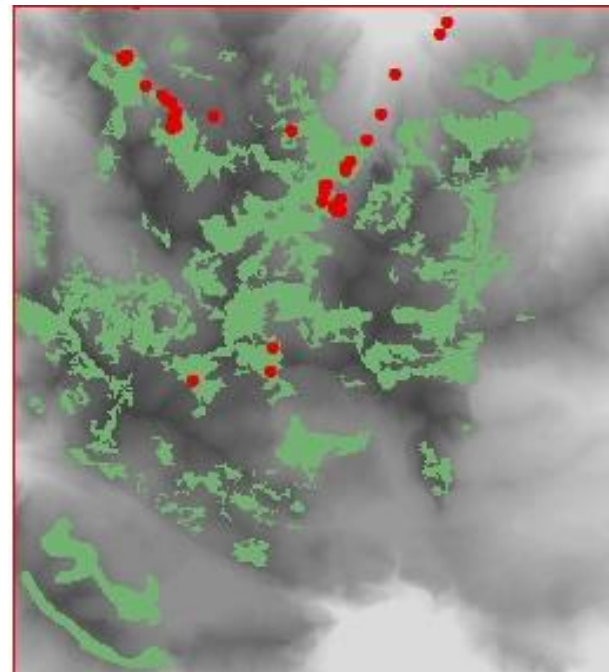
E.g.: Comparison of sampling survey desings for predicting lichen species in USA (Edwards et al. 2006)



A visual example of **designed** versus **purposive** sampling
(vegetation plots in Picos de Europa, Spain)



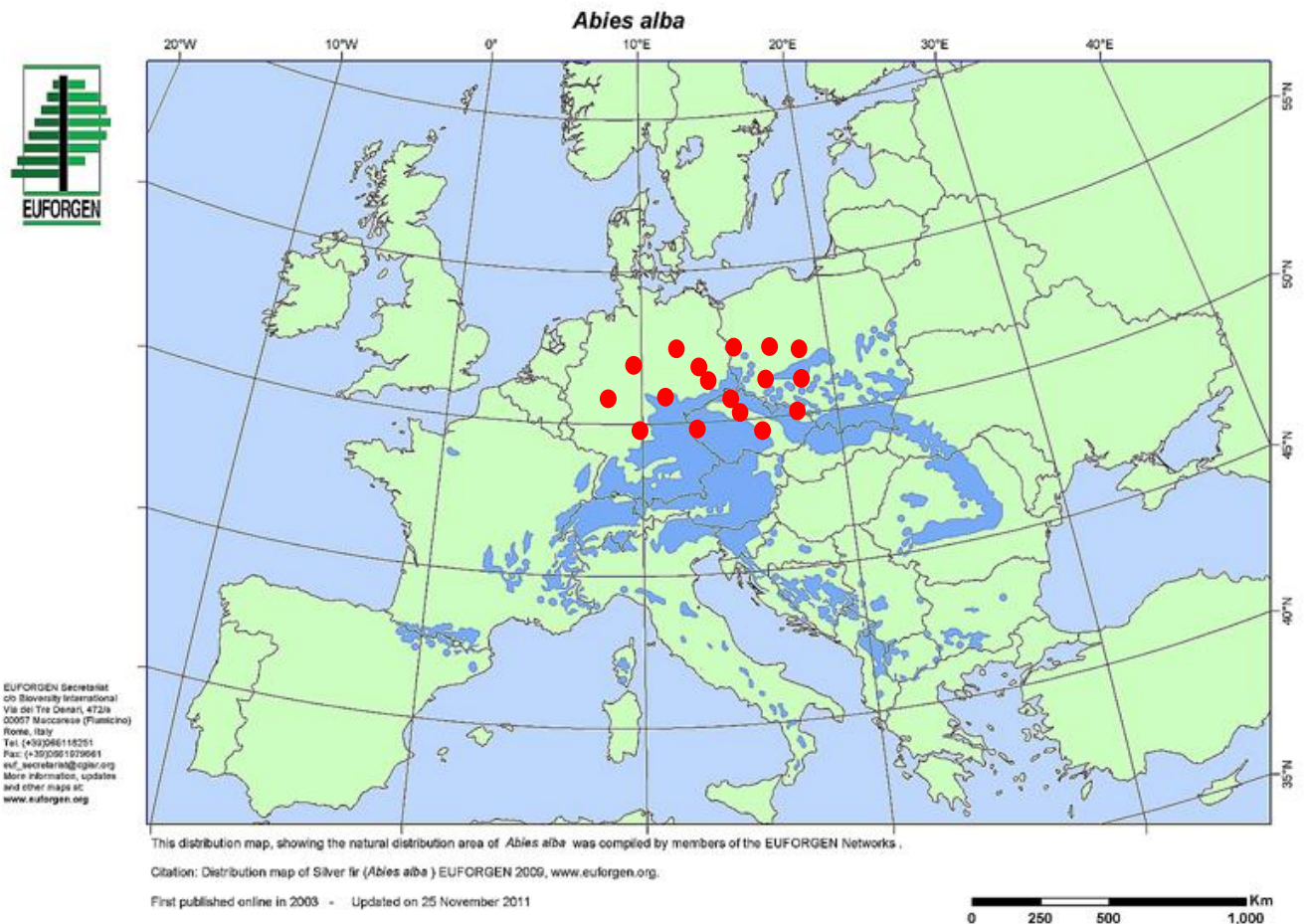
Designed (systematic)
(N = 80)



Purposive (biased)
(N = 100)

OCCURRENCE DATA

More important that the number of observations is the degree to which the range of the environmental space occupied by the species are covered in the sample (= **COMPLETENESS**) and the frequency of events (records of species presences) from the sample (= **PREVALENCE**)



EUFORGEN Secretariat
c/o Biodiversity International
Via dei Tre Cerri, 472/a
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Rome, Italy
Tel: (+39)066118251
Fax: (+39)0661079661
euf_secretariat@cgiar.org
More information, updates
and other maps at
www.euforgen.org

How many samples?

Or, a better question,

What is the **mínimum sample** size for my study?

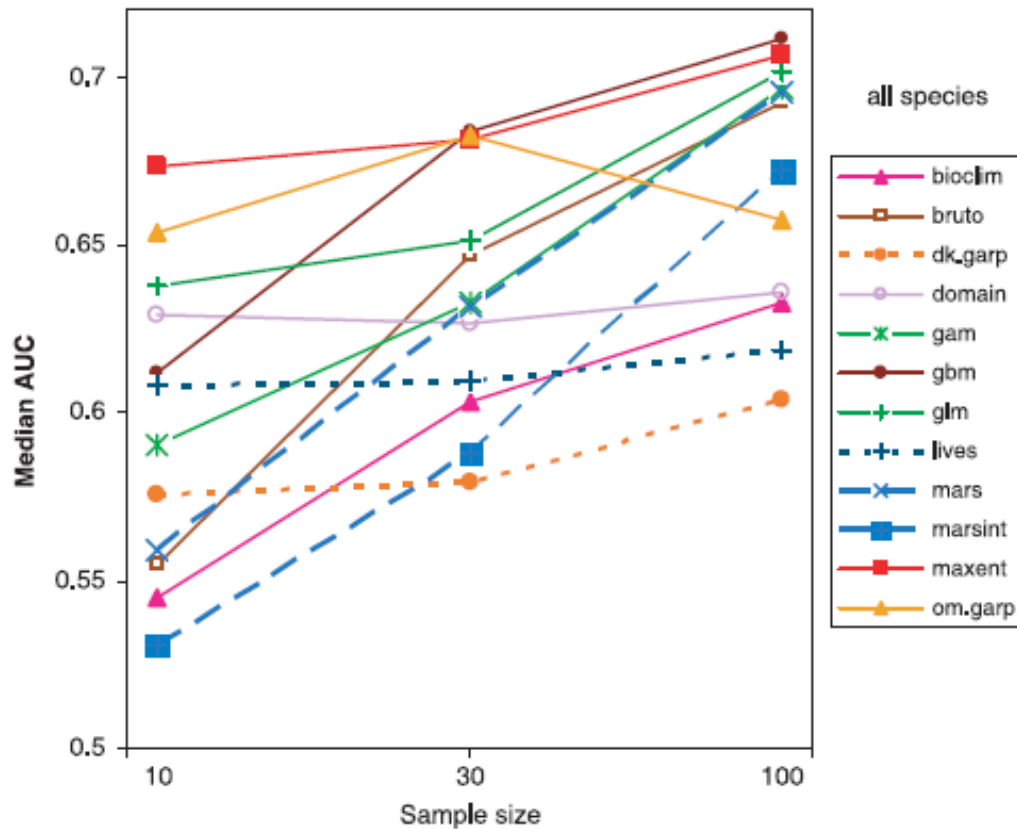
For SDMs, there are some rules:

→ A mínimum of 50 observations can be fine

→ 20-40 times as many observations as predictors

→ For rare species and some algorithms, 20 occurrences can be enough...!

Very few samples can be valid for rare organisms ... but it depends on the method



Wisz et al. 2008. Effect of sample size on the performance of species distribution models.
Diversity and Distributions 14: 763

In summary, the quality of our data for modeling distributions will depend on many factors:

- > **EXTENT** of the study area and **ACCURACY** of occurrences
- > The **ECOLOGY** of the species
- > How we sample the **ENVIRONMENTAL SPACE**
- > How many **PRESENCES** and **ABSENCES** are sampled
- > The **PREDICTORS** and the modeling **METHOD**

2. Using existing data (e.g. biodiversity databases)

-> SDMs are mainly used to map unknown species distributions

-> Species mapping has however a long history using known distributions from many different sources

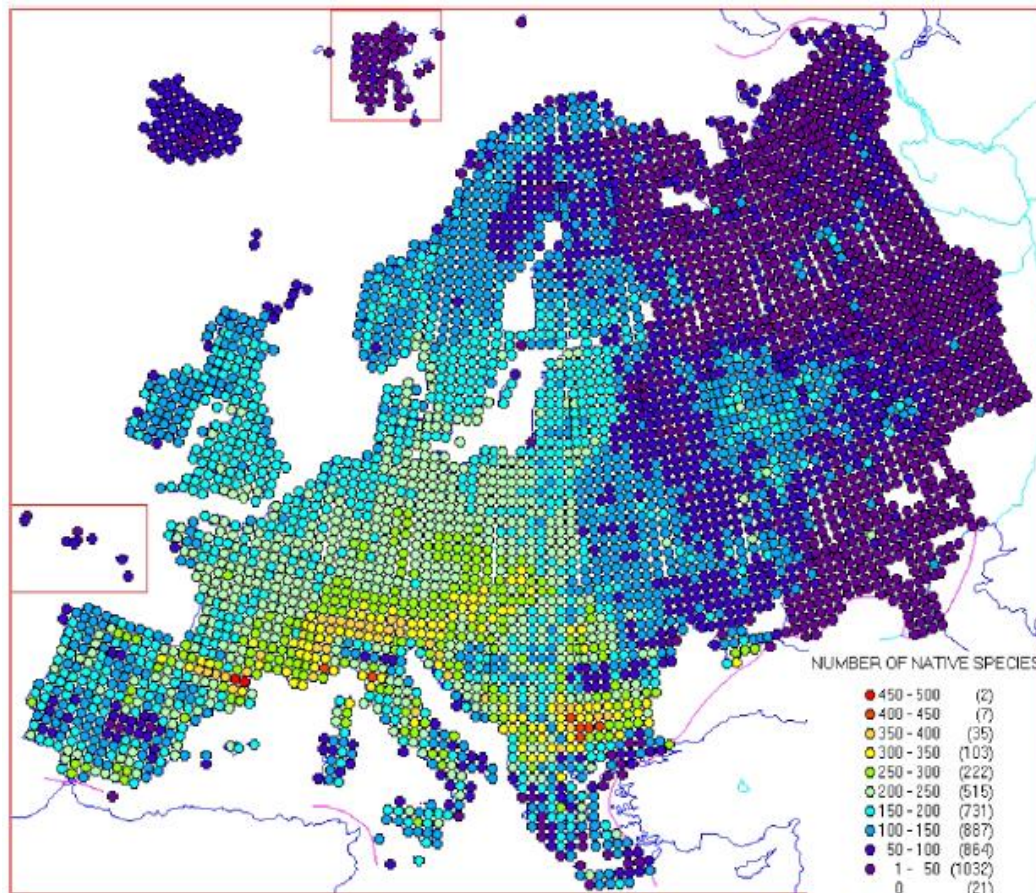
Main types of sources:

- **Grid-based atlases** (compilation of information)
- **Natural history collections** (museums, botanic gardens)
- **Surveys** (conservation, vegetation or faunistic surveys)

Grid-based Atlases

Pro: Cover large territories and represent distribution ranges well

Con: Coarse grain (10 km, 50 km) and small spatial accuracy



ATLAS FLORAE EUROPAEAE

50km x 50 km

2559 species

(20% of European flora)

Natural history collections

Pro: Large amount of data for all the world

Con: Low spatial resolution and high uncertainty

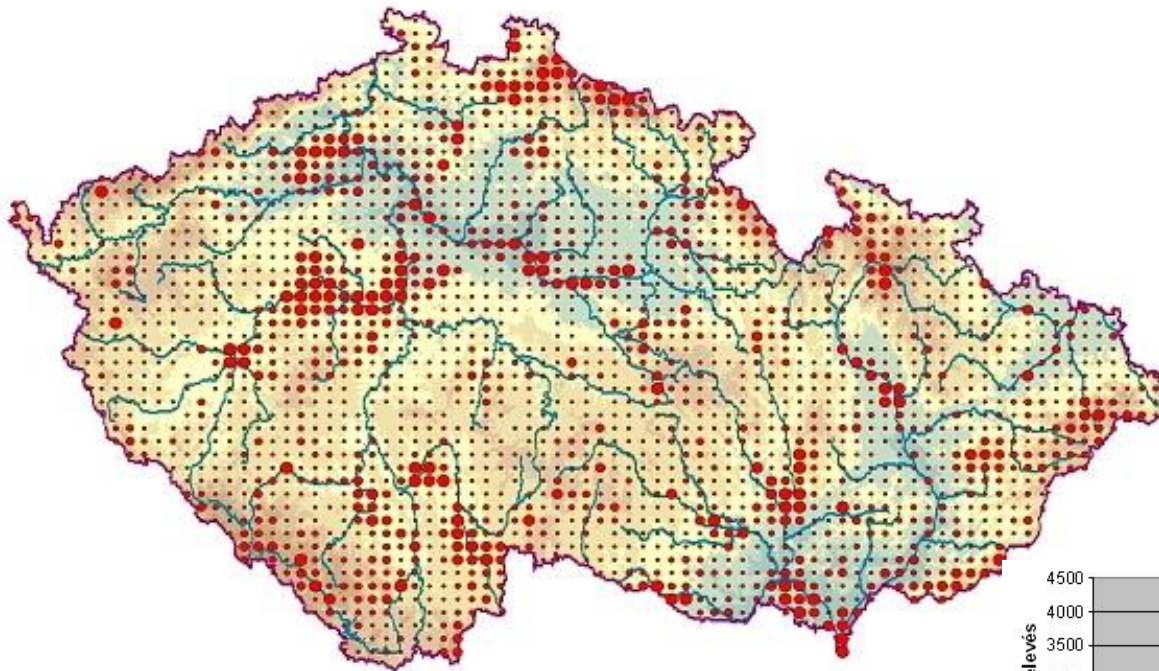
The screenshot shows the GBIF website homepage. At the top left is the GBIF logo. The main heading is 'Global Biodiversity Information Facility' with the tagline 'Free and open access to biodiversity data'. A navigation menu includes 'Data', 'News', 'Community', and 'About'. A 'Login or Create a new account' link is in the top right. The central statistics section displays: 417,165,184 OCCURRENCES, 1,426,888 SPECIES, 11,976 DATASETS, and 578 DATA PUBLISHERS. Below this are three columns of content: 'Sharing biodiversity data for re-use' (with links for 'Learn about GBIF', 'Publish your data through GBIF', and 'Technical infrastructure'), 'Providing evidence for research and decisions' (with links for 'Using data through GBIF', 'Enabling biodiversity science', and 'Supporting global targets'), and 'Collaborating as a global community' (with links for 'Current Participants', 'How GBIF is funded', and 'Enhancing capacity'). At the bottom is a search bar with the placeholder text 'Search news items and information pages...' and a 'Search' button.

| Category | Value |
|-----------------|-------------|
| OCCURRENCES | 417,165,184 |
| SPECIES | 1,426,888 |
| DATASETS | 11,976 |
| DATA PUBLISHERS | 578 |

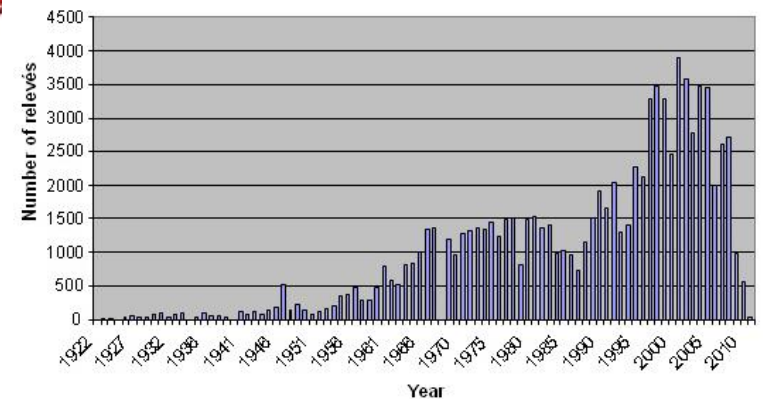
Biodiversity Surveys

Pro: Spatial accuracy is heterogeneous, although can be good

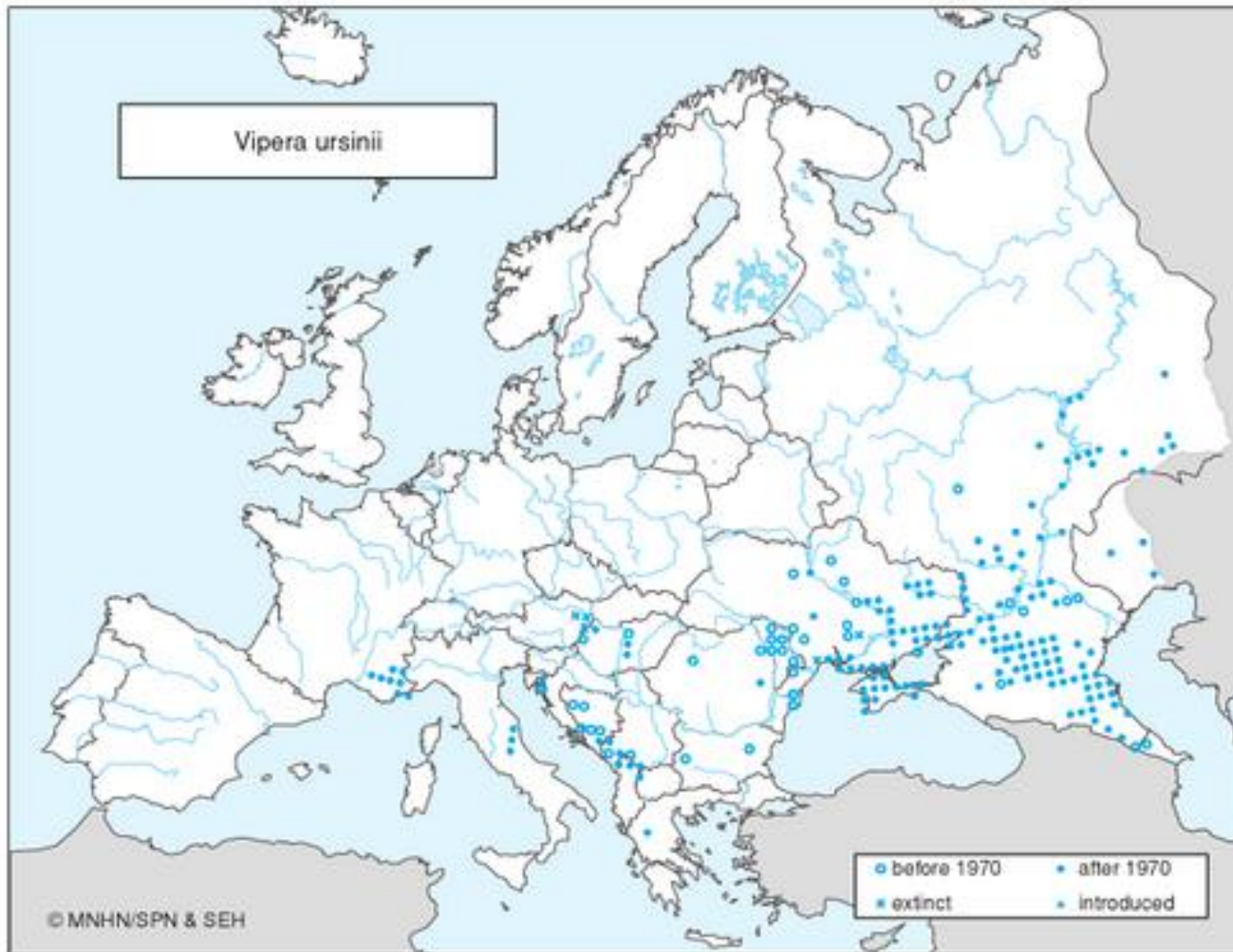
Con: Generally biased or purposive sampling



**Czech national
Phytosociological
Database**



OCCURRENCE DATA



There is some
sampling design
behind this?
PROBABLY NOT

Is the data valid?
PROBABLY YES

From
Franklin 2009

Fig. 2.3. Example of "dot map" for *Vipera ursinii* from *The Atlas of Amphibians and Reptiles in Europe* (Gasc *et al.* 1997) (<http://www.seh-herpetology.org/>). Each dot represents a 50 × 50 km UTM grid square. Copyright © Muséum National d'Histoire Naturelle & Service du Patrimoine Naturel and Societas Europaea Herpetologica. Used with permission.

Problems associated with biodiversity databases

1. **Low spatial accuracy:** location and coordinates (if existing) are generally imprecise
2. **Unknown sampling design:** generally biased or purposive, but in general not reported

How this affects our data:

- Incomplete distributions (bias)
- Undersampling
- Pseudo-replication
- Spatial autocorrelation of samples
- Low spatial accuracy of the analyses

Next week we will
go back to the
spatial issues

How to solve these limitations?

Georeferencing: it takes time but it allow us to measure spatial uncertainty

Resampling: to have some control of the data (e.g. analyzing subsets separately)

Adaptative sampling: resampling after a first assessment

Evaluating bias: using spatial information

Measuring spatial autocorrelation

Georeferencing

The main challenge of biological collections is the assignment of geographic coordinates to millions of historical records (Baker & al., 1998)

Home | Web Application | Standalone App | Collaborative Georeferencing | Developer Resources | Workshops | Support and Contacts



GEOLocate

A Platform for Georeferencing Natural History Collections Data

For Users:


- Overview
- GEOLocate Web Application
- Collaborative Georeferencing
- GEOLocate 3.xx (standalone)
 - Global Expansion
- Education & Outreach

For Developers:

- SOAP Services
- JSON/GeoJSON
- Embeddable Web Client

Brief overview (video) of the GEOLocate Project.






Web Application

Georeference collections data using



Web Services

Integrate georeferencing into your own databases and applications using GEOLocate webservices.



Desktop Application

The original standalone desktop application.

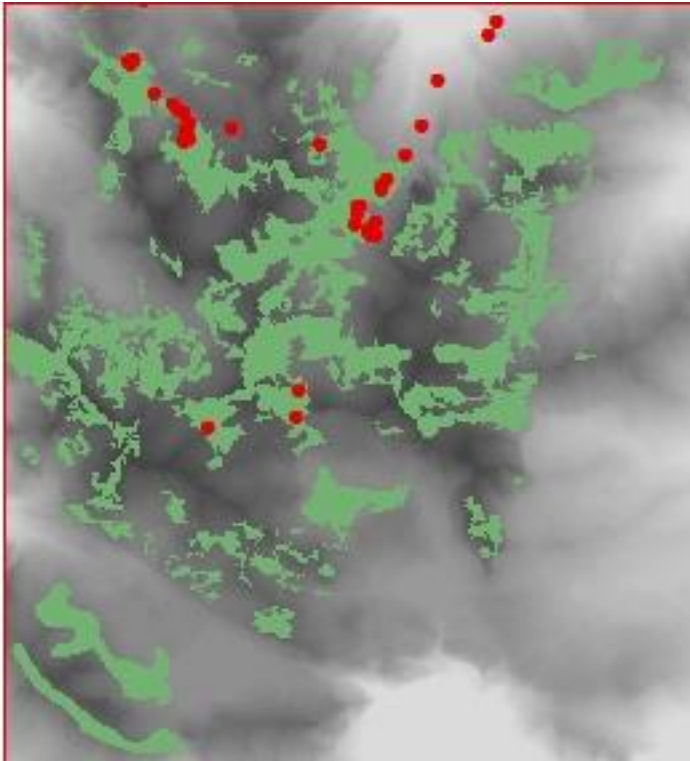


Collaborative Georeferencing

Build communities, share data, relate records across collections and improve verification efficiency.

Spatial autocorrelation

Oversampling of areas produces pseudo-replication and further overfitting of the models.



What to do?

Sampling (or resampling) according to spatial criteria

Assessing spatial autocorrelation (e.g. Moran's I) after modeling

Part 1:

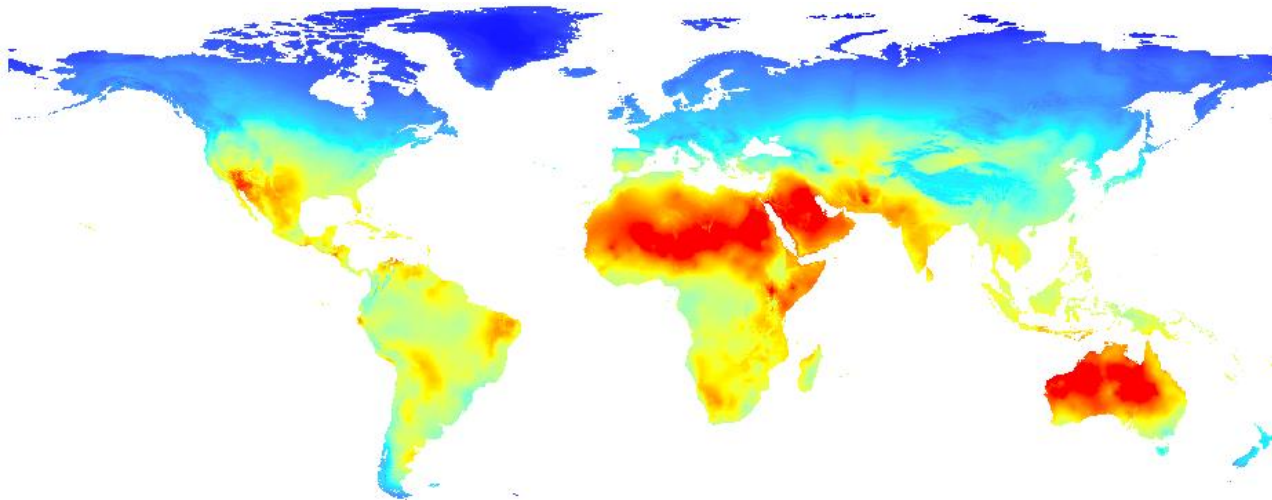
MAPPING

ENVIRONMENTAL VARIABLES

In the ecological space, what factors are important for the distribution of species?

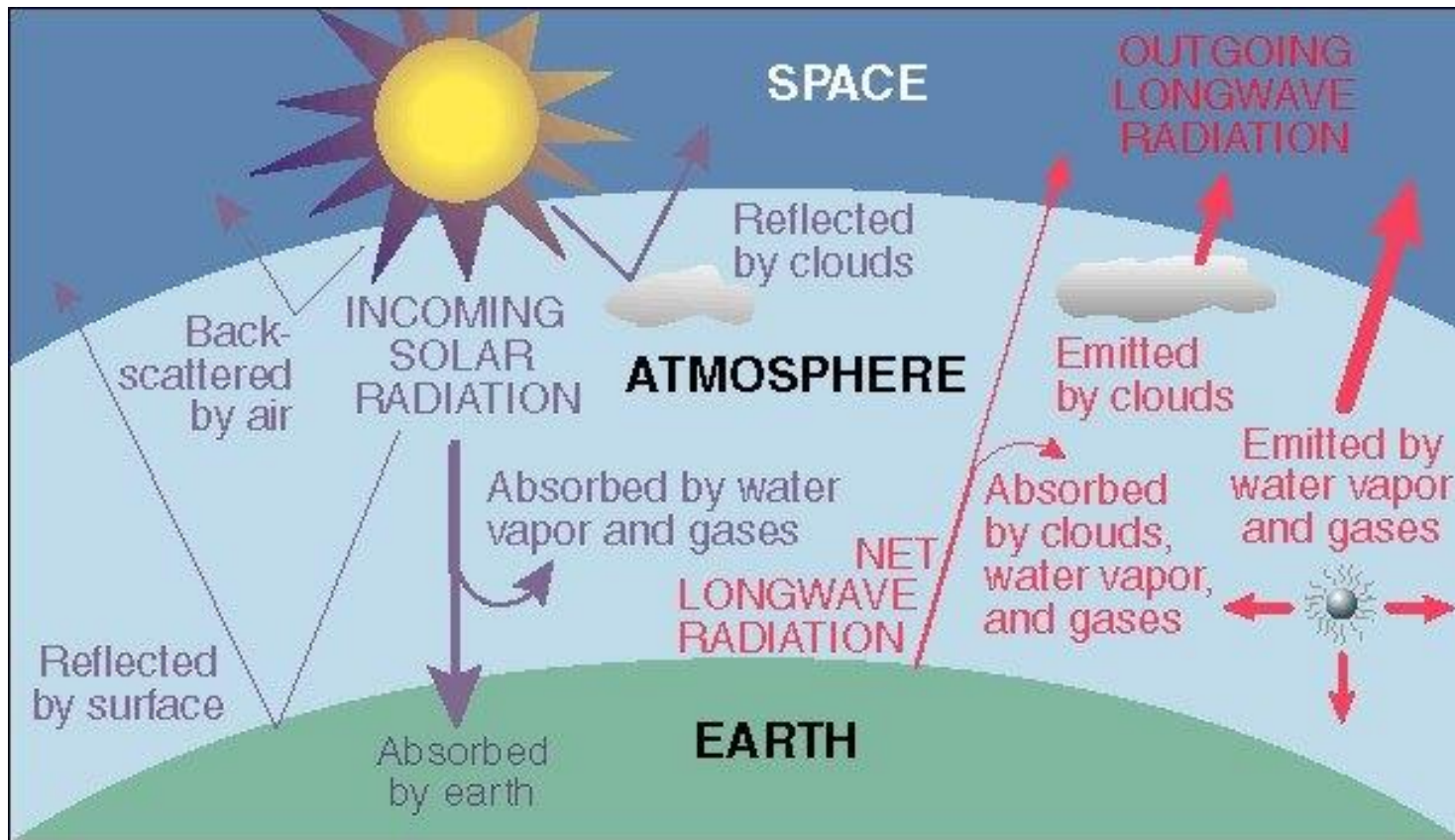
At the **macro-distributional** scale, ultimate controlling factors have to do with energy requirements of species.

Energy requirements are, in turn, determined by physiology and morphology

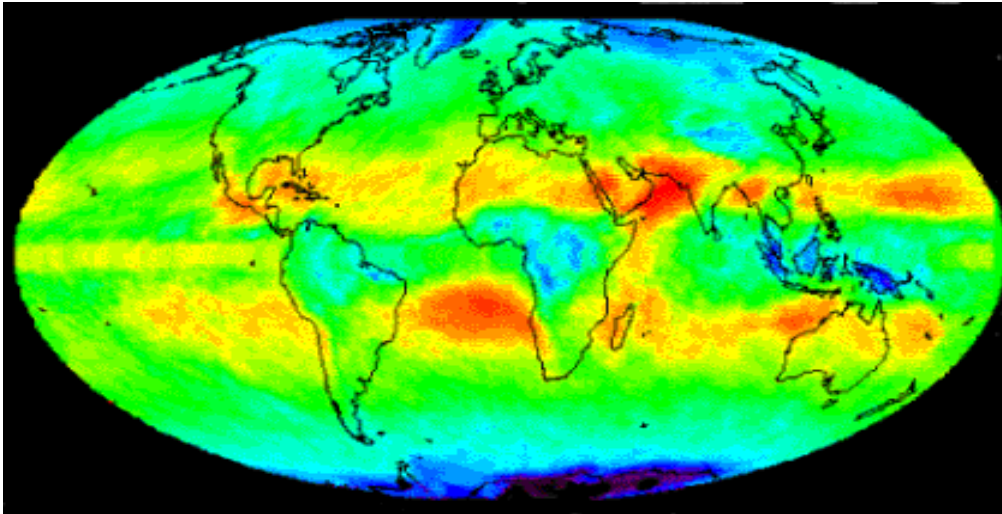


World Potential
Evapotranspiration

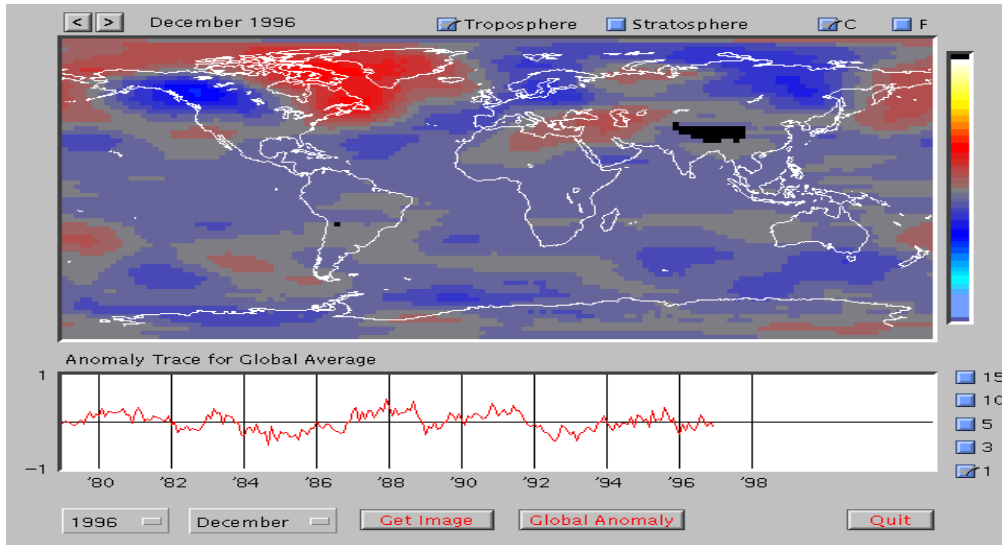
And... what is the primary source of energy for the Earth?



Solar energy brings

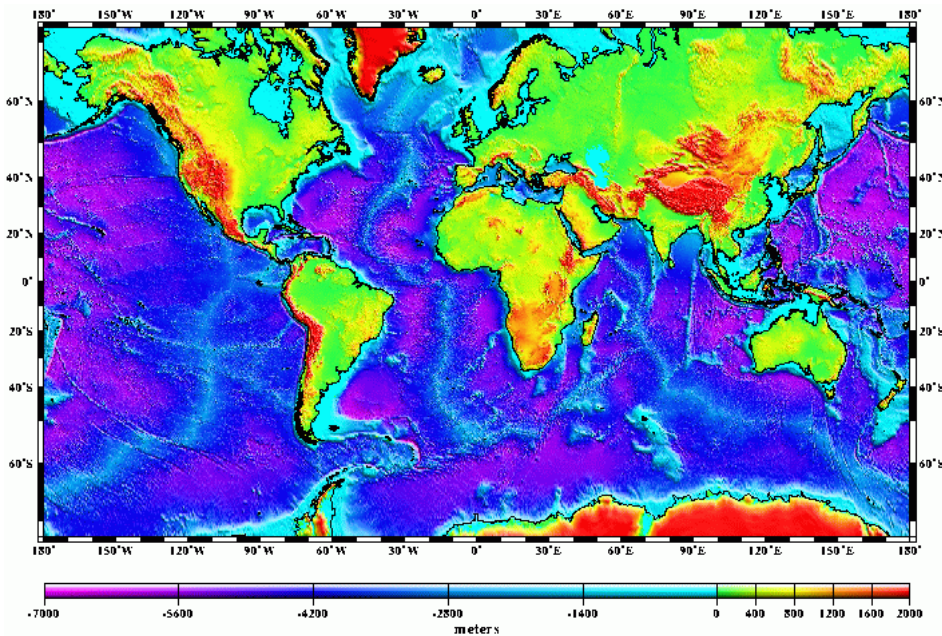
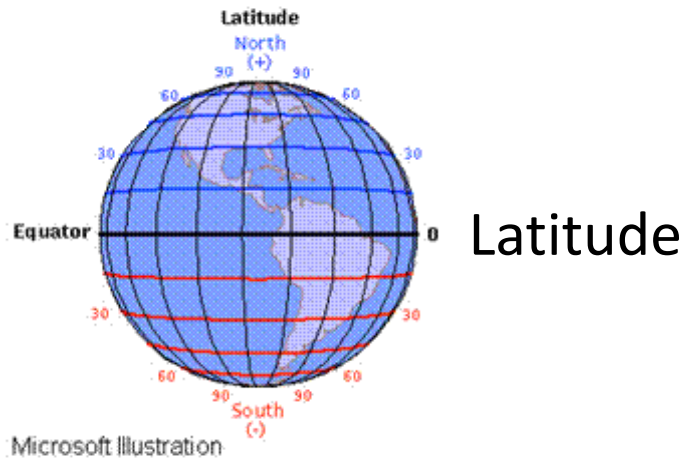


Light
(quantity and quality)



Heat

What factors affect solar radiation and temperature?



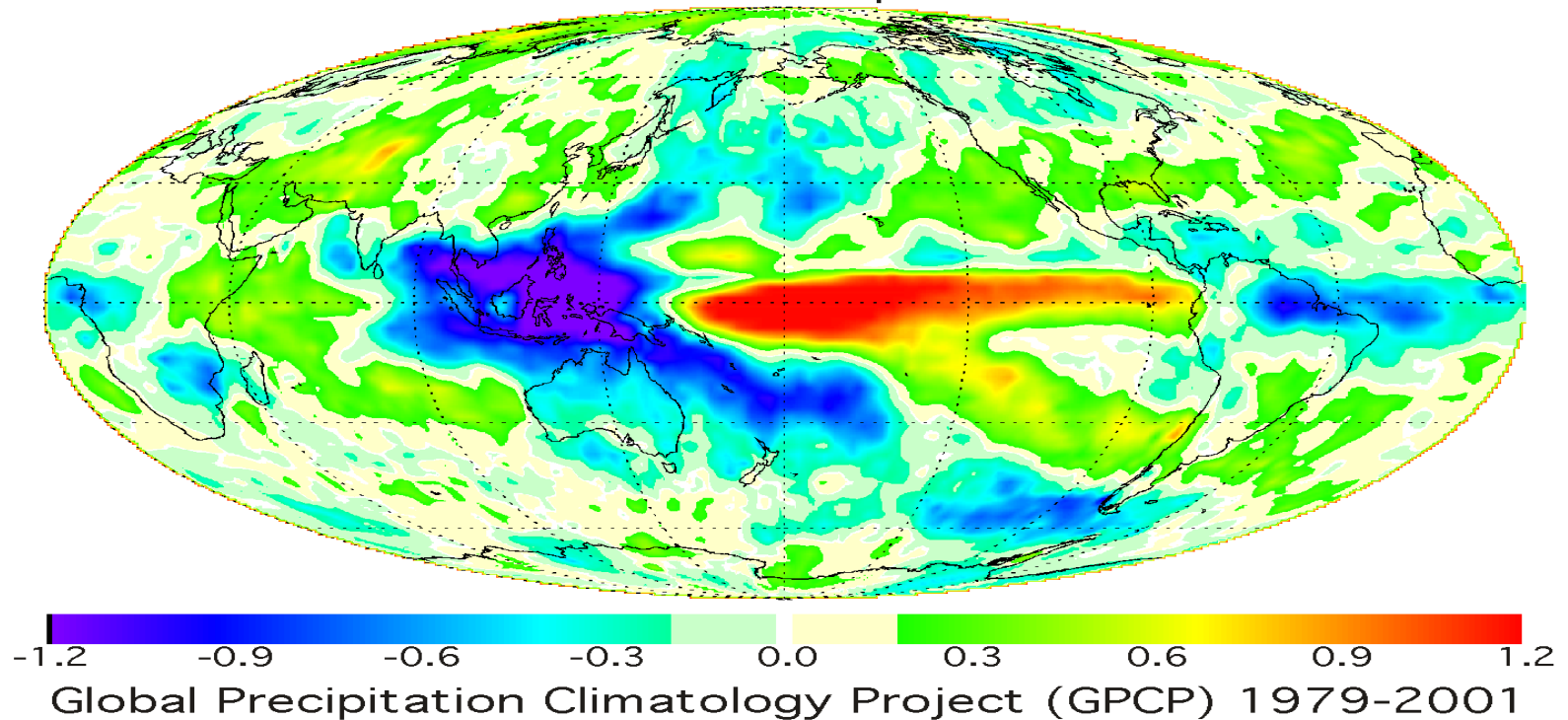
Topography:

- Elevation
- Slopes
- Exposure

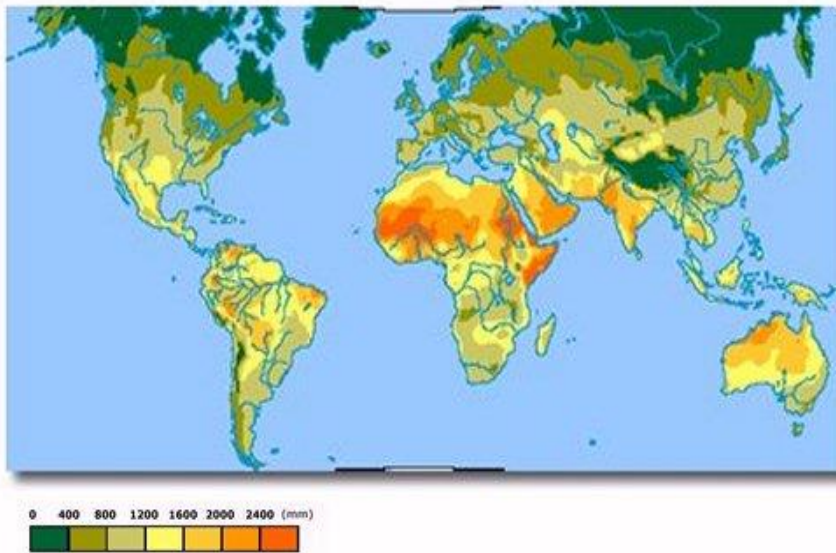
But the factory of primary production (vegetation)

... also needs WATER

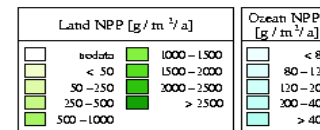
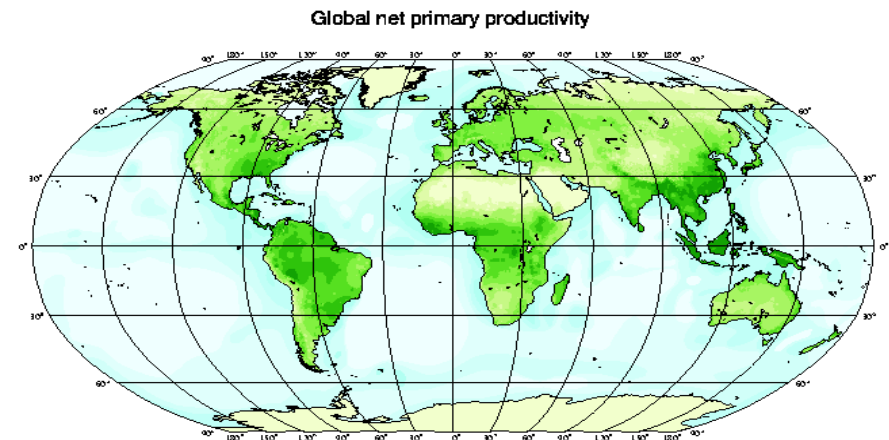
El Niño minus La Niña Composites
of Global Normalized Precipitation Anomalies



There are also functional manifestations of the interplay of all these factors



evapotranspiration



NPP patterns on land calculated from temperature and precipitation averages with the equations of the MIAMI-MODELL (LIEBH 1973) and corrected for soil fertility by a table fraction based on the FAO/UNESCO-world soil map from S. Stegmann.
NPP patterns on the ocean adapted from KOBLENZ-MISHKE, VOLKOVINSKI and KABANOVA (1970).

Map source: <http://www.ufz.uni-erlangen.de/DE/~lieth>

J. Beierkuhnlein
S. Stegmann
H. Lieth
Institute of Environmental
Systems Research
Universität Osnabrück
D-49069 Osnabrück
Germany

productivity

In sum

There are distal factors that determine directly or indirectly the distribution of all species (at broad spatial scales):

- > Amount of light
- > Amount of heat
- > Amount of water
- > Topography

NOTE: Energy and water income is dynamic in time. For some questions regarding the eco-geographic distribution of species, the time dimension is crucial

Implications

When modelling individual species, more proximal variables become relevant:

- > **Soil types**
- > **Evapotranspiration**
- > **Primary productivity**
- > **Light quality**
- > **Number of frost days**

NOTE: A necessary field of research is needed to achieve a better understanding of the inclusion of different types of variables in the modelling process, as well as the effect of redundancy on model quality.

But EACH organism has its own requirements

E.g.: interactions, parasitisms.....

Global Change Biology

Global Change Biology (2013), doi: 10.1111/gcb.12226

Finding the appropriate variables to model the distribution of vector-borne parasites with different environmental preferences: climate is not enough

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*Departamento de Zoología y Antropología Física, Universidad Complutense de Madrid, Madrid, E-28040, Spain, †Departamento de Zoología y Biología Celular Animal, Universidad del País Vasco (UPV/EHU), Vitoria-Gasteiz, E-01006, Spain

Abstract

Understanding how environmental variation influences the distribution of parasite diversity is critical if we are to anticipate disease emergence risks associated with global change. However, choosing the relevant variables for modelling current and future parasite distributions may be difficult: candidate predictors are many, and they seldom are statistically independent. This problem often leads to simplistic models of current and projected future parasite distributions, with climatic variables prioritized over potentially important landscape features or host population attributes. We studied avian blood parasites of the genera *Plasmodium*, *Haemoproteus* and *Leucocytozoon* (which are viewed as potential emergent pathogens) in 27 Iberian blackcap *Sylvia atricapilla* populations. We used Partial Least Squares

Types of environmental variables

In statistical terms, there are two main variables:

QUANTITATIVE

elevation, temperature, precipitation, etc.

QUALITATIVE (CATEGORICAL)

Soil type, land cover, vegetation

->They will be used differently in the modeling process

Types of environmental variables

In practice, we should distinguish the most appropriate variables for our study case, and especially the **SCALE**

Broad scale studies:

More focused on **DIRECT** variables, mostly climatic:

Temperature, precipitation, solar radiation, evapotranspiration

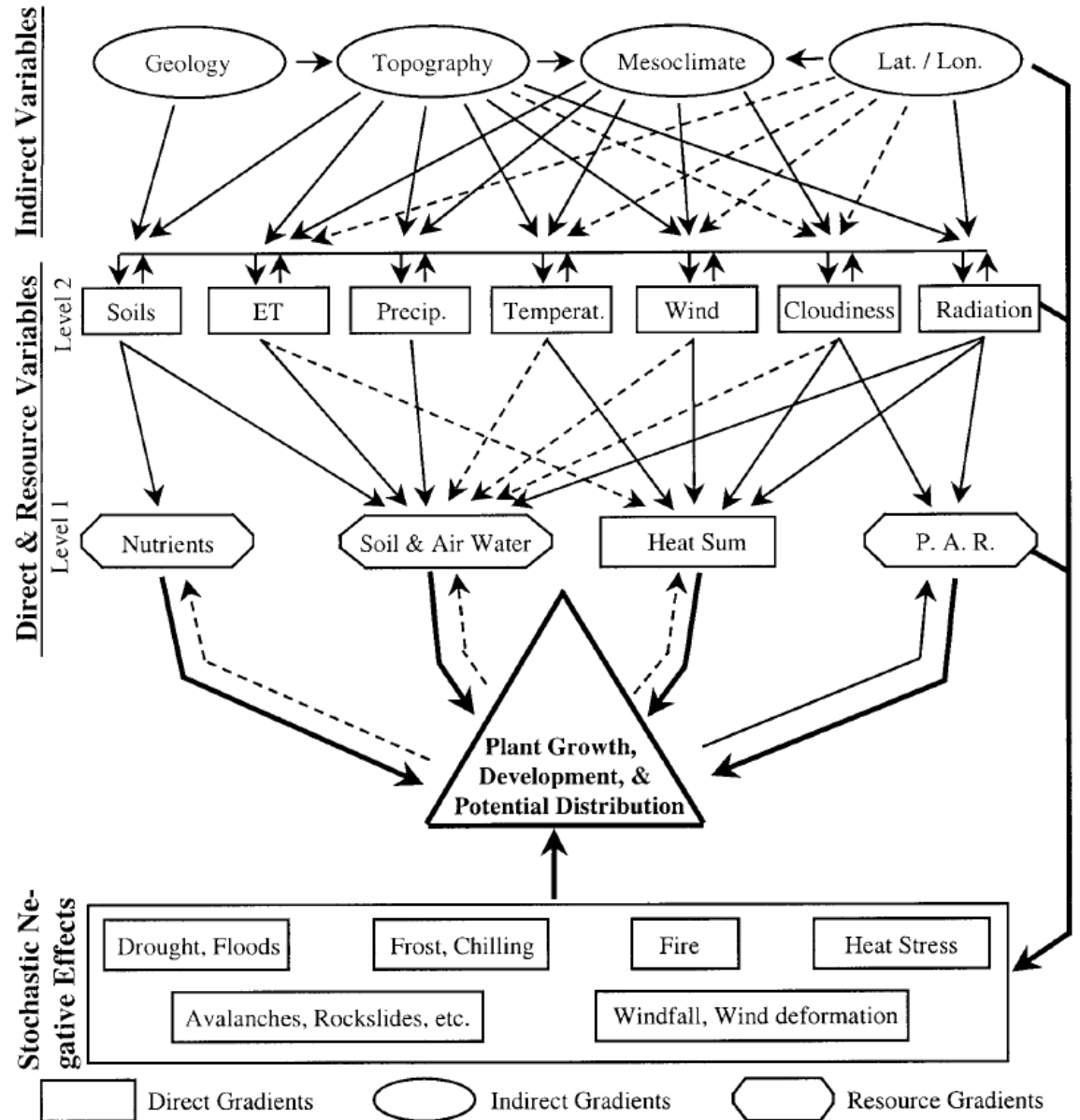
Local scale studies:

More focused on **INDIRECT** variables, mostly topographic:

Elevation, slope aspect, exposition, topographical indices, etc.

ENVIRONMENTAL VARIABLES

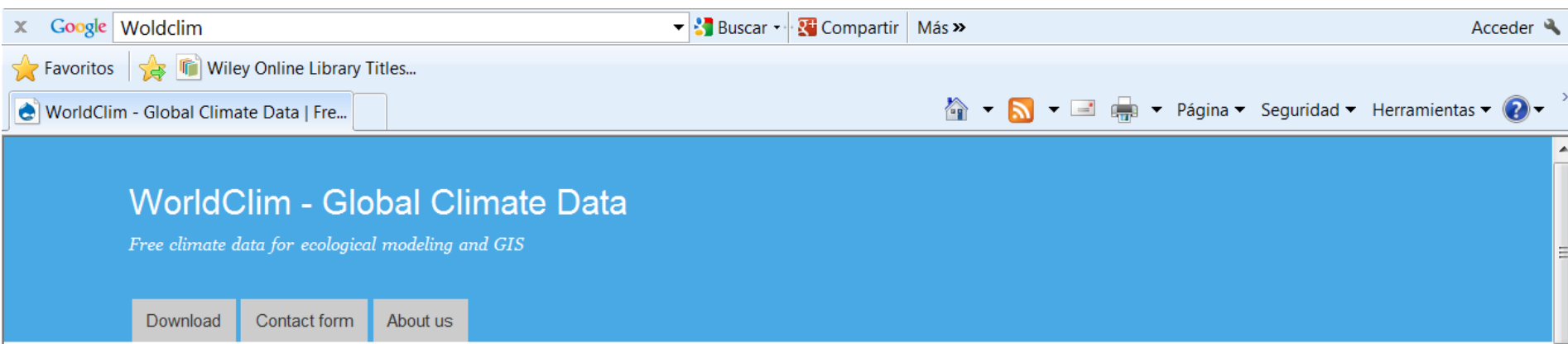
Conceptual model of relationships between resources, direct and indirect variables, and their influence on plant performance (from Guisan & Zimmerman 2000)



WORLDCLIM

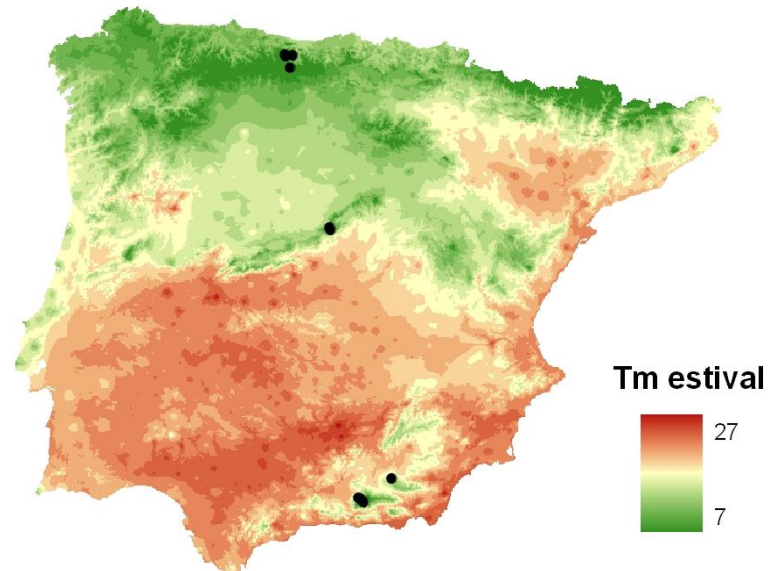
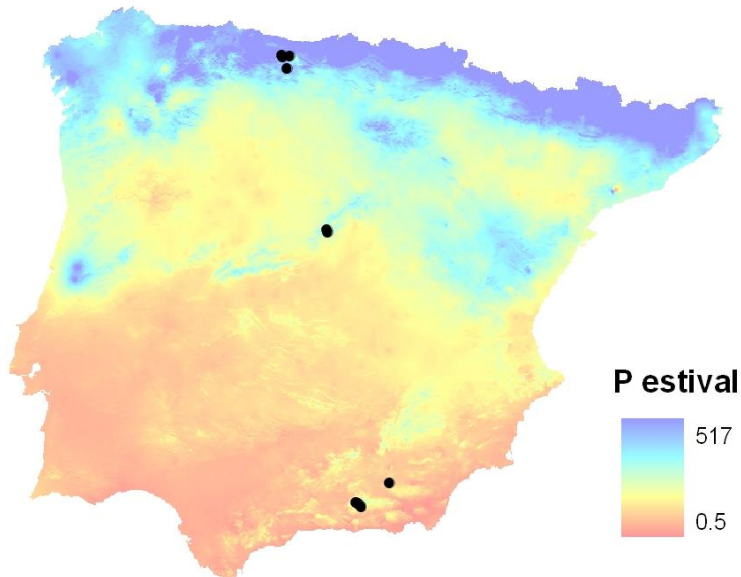
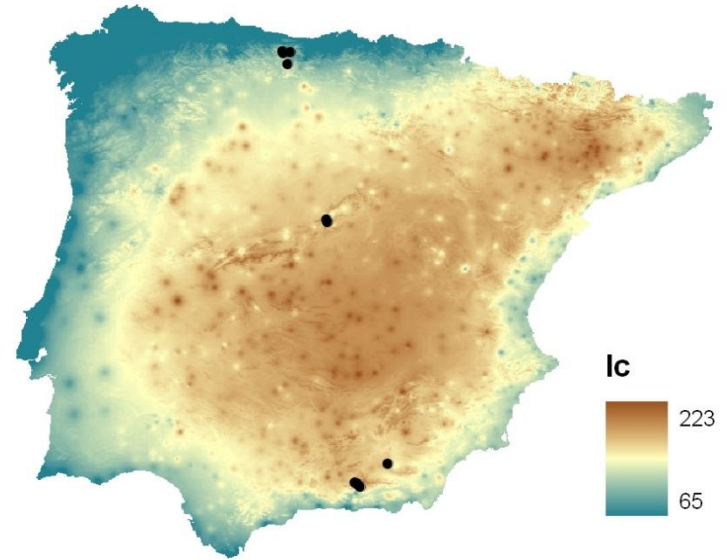
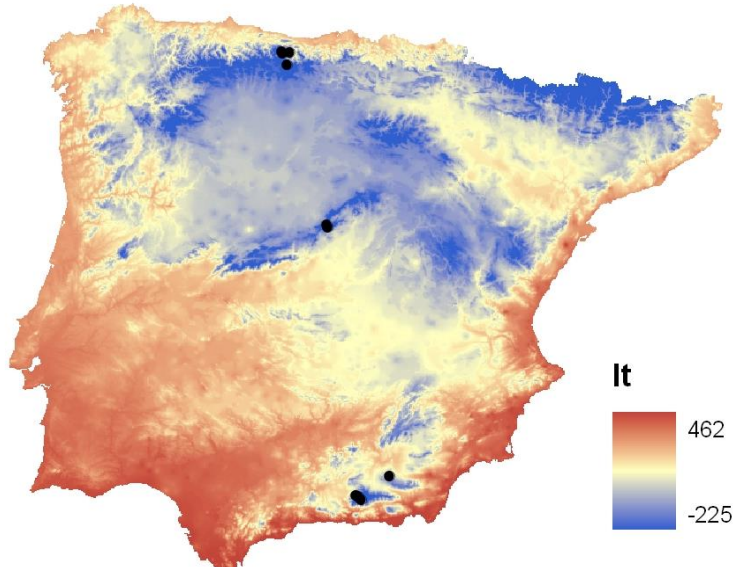
Averaged from long-term (30yr) series of Temp and Prec

BIOCLIM: “Bioclimatic variables are derived from the **monthly temperature** and **rainfall values** in order to generate more **biologically meaningful** variables. These are often used in ecological niche modeling (e.g., BIOCLIM, GARP). The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is a period of three months (1/4 of the year)”



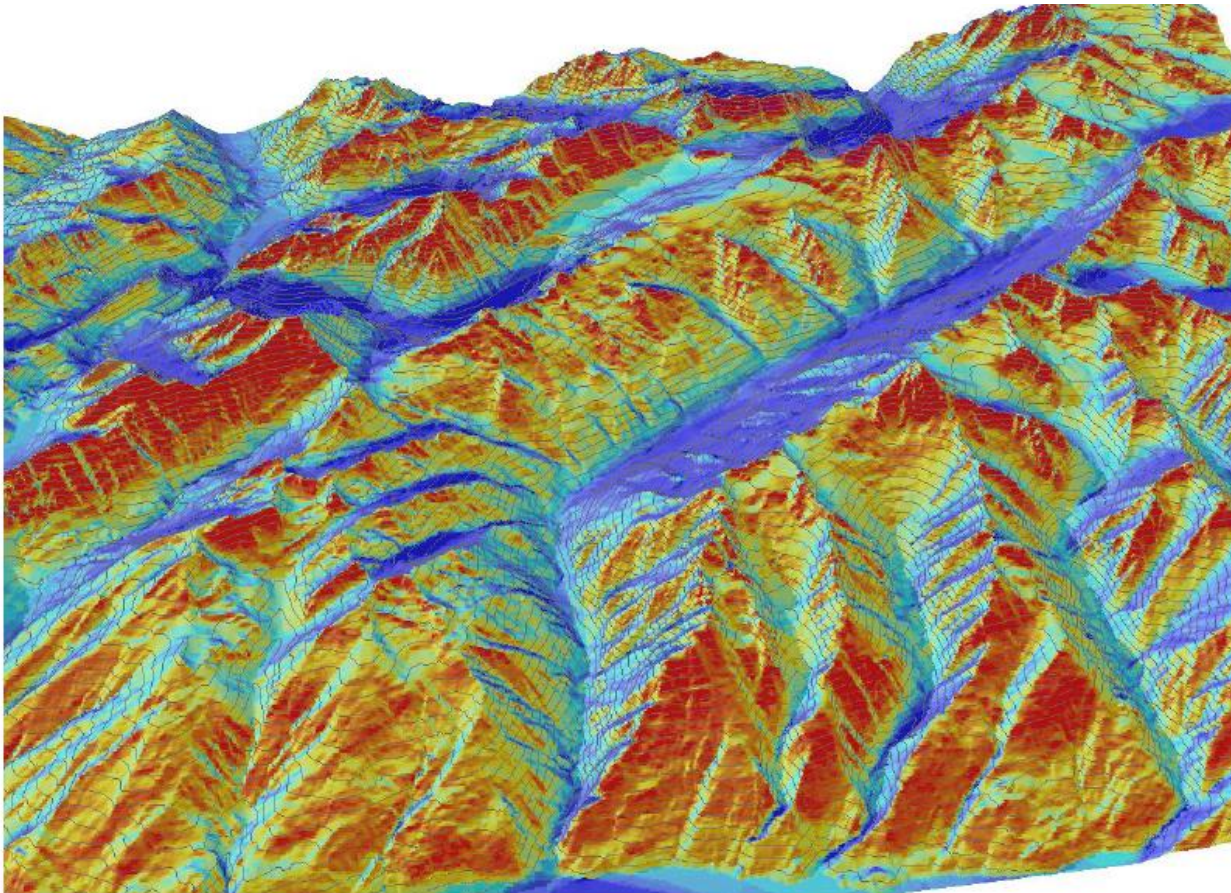
The screenshot shows a web browser window with the address bar displaying "WorldClim - Global Climate Data | Fre...". The page content includes the title "WorldClim - Global Climate Data" and the subtitle "Free climate data for ecological modeling and GIS". Below the title, there are three buttons: "Download", "Contact form", and "About us". The browser's address bar also shows "Woldclim" and "Google". The browser's toolbar includes icons for "Buscar", "Compartir", "Más >>", "Acceder", "Favoritos", "Wiley Online Library Titles...", "Home", "RSS", "Email", "Print", "Página", "Seguridad", and "Herramientas".

National data at higher resolution (e.g. Spain, 200m x 200m)



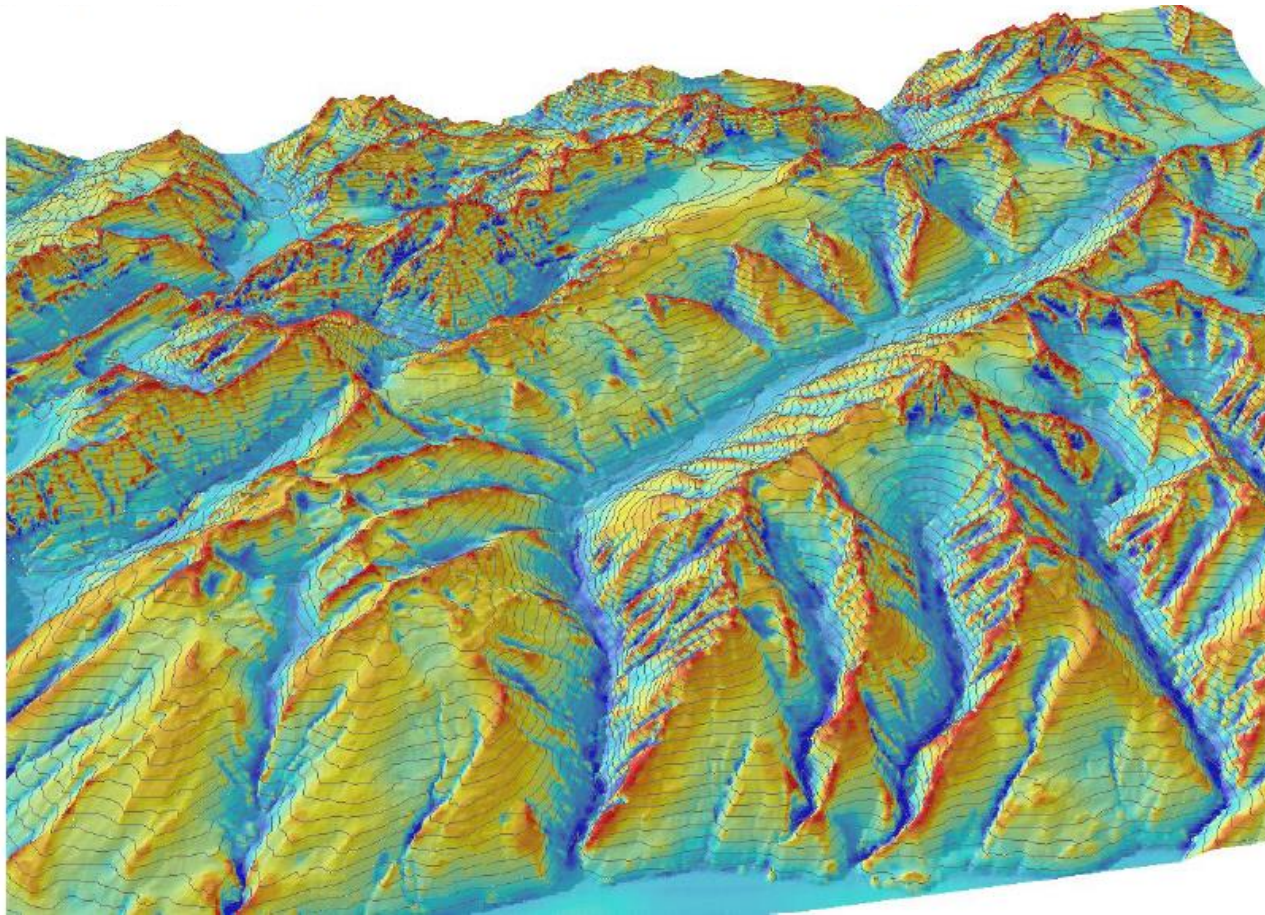
TOPOGRAPHY

Potential solar radiation (from the Digital Elevation Model)
Indirect variable reflecting heat accumulation



TOPOGRAPHY

Topographic Position Index (from the Digital Elevation Model)
Indirect variable reflecting moisture and wind exposure



MORE VARIABLES (AT DIFFERENT SCALES)

WorldGrids.org

Article Discussion

Worldgrids — a public repository and a WPS for global environmental layers
 Created and maintained by: T. Hengl and H.I. Reuter, ISRIC — World Soil Information
 Contributions by: M. Kilibarda

Project overview
 WorldGrids.org hosts 1 km environmental layers in a standardized format. Find more about the WorldGrids.org project:

- Basic design of the WorldGrids.org and how to find things;
- List of available layers and their properties;
- Instructions to submit new data to WorldGrids.org;
- Overview of Publicly available global data sets;
- Install and use pyWPS on your machine;
- Download visitor statistics by country (XML)

Access WorldGrids WPS from R
 Linking to the WorldGrids Web Processing Service (WPS) is possible via the WPS class implemented in the GSIF package for R. This is based on the pyWPS extension, running on a Debian system with 2GB RAM. For a list of examples see this tutorial:

- WPS overlay — Get values per location;
- WPS subset — Subset and download WorldGrids in various GDAL formats;
- WPS aggregate — Aggregate values per zonal grid;

Recent news
 This website is currently under construction. It is expected to be fully functional by mid-2012. In the meanwhile, read more about the project and how you can contribute. Try installing the GSIF package and running some simple analysis.

Preview and download maps

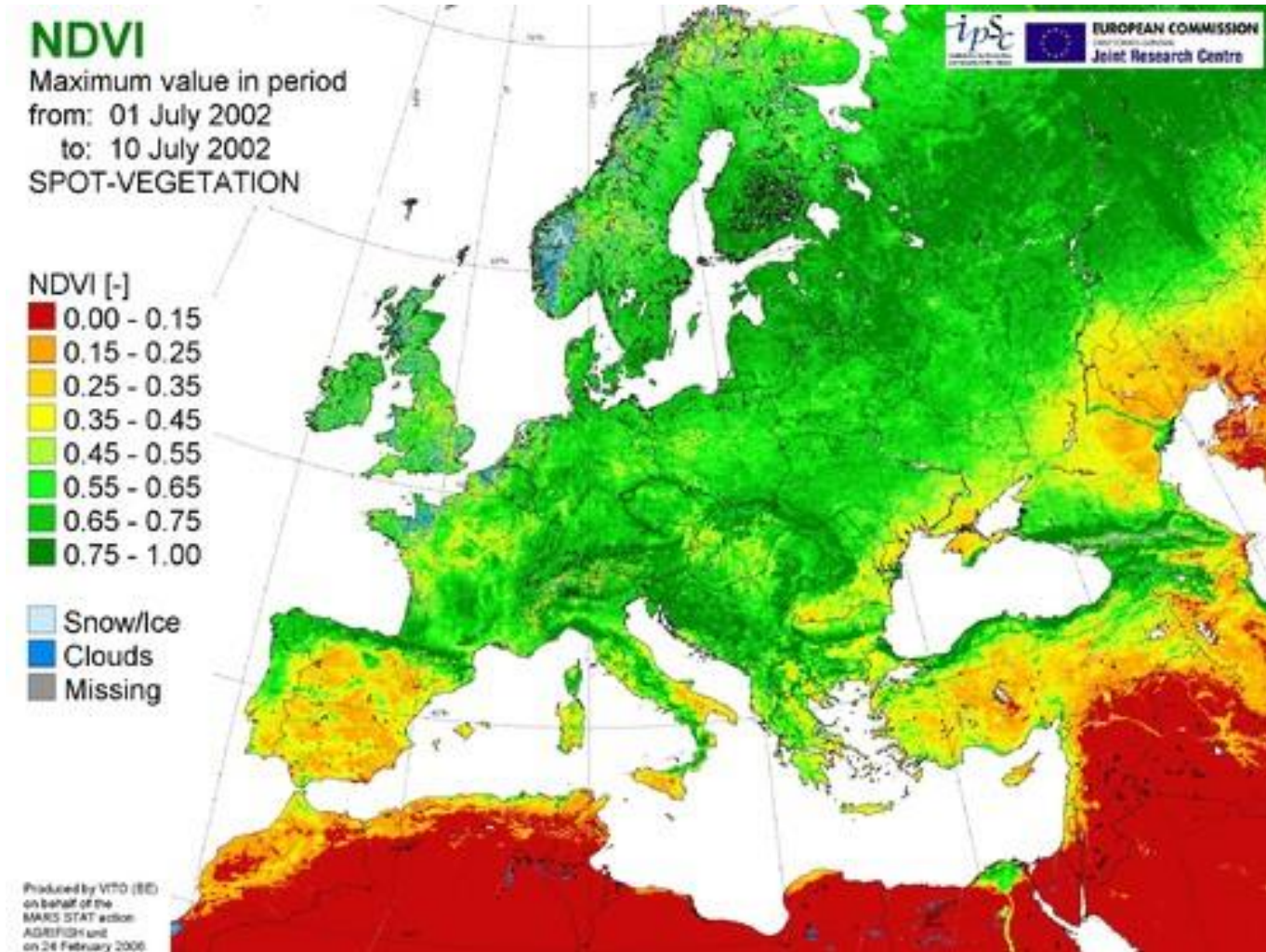
| Climatic and meteorological images | MODIS products | Land cover / land use | Soil polygon maps, eco-regions | DEM-derived parameters |
|------------------------------------|----------------|-----------------------|--------------------------------|------------------------|
| | | | | |

News and updates

- July 2012: (TH/HIR): added sample metadata to ISRIC metadata server (geonetwork instance for worldgrids);
- June 2012: (HIR/TH): added timeseries data (e.g. MODIS LST) to allow for more applications;
- June 2012: (HIR): developed functionality to allow external data input as an input parameter for wps processes;
- January 2012: (HIR) ArcGIS frontend - Implemented in the ArcGIS GSIF toolbox as of January 2012;

ISRIC World Soil Information

MORE VARIABLES (AT DIFFERENT SCALES)



MORE VARIABLES (AT DIFFERENT SCALES)

A map of **land use** in Europe. Yellow: cropland and arable, light green: grassland and pasture, dark green: forest, light brown: tundra or bogs, unshaded areas: other (including towns and cities).



Paleoclimatic models

Last inter-glacial (LIG; ~120,000 - 140,000 years BP)

Mid-Holocene (~6000 BP)

The image shows a screenshot of a web browser displaying the PMIP 2 Project Home Page. The browser's address bar shows the URL "PMIP 2 Project Home Page". The page features a navigation menu on the left with the following items: Home, What's New? (highlighted in cyan), Overview, Events, Experimental Design, Data Synthesis (highlighted in cyan), Database, Synthesis Maps (highlighted in cyan), and Proposed Analyses. The main content area has a yellow background and contains a blue banner with the text "Welcome to the PMIP 2 Web Site !". Below this banner is a link: "[PMIP 1] - [You are on the main PMIP 2 site] - [PMIP 3]". Another blue banner below that reads "Paleoclimate Modelling Intercomparison Project Phase II". At the bottom, there is a large logo for "Paleoclimate Modelling PMIP Intercomparison Project Phase II". The logo consists of the letters "PMIP" where each letter is filled with a different landscape image: 'P' shows a snowy mountain, 'M' shows a sunset over water, 'I' shows a tropical beach, and 'P' shows a cloudy sky. Below the logo, the text "Intercomparison Project Phase II" is written in bold black font.

Paleoclimatic models

Last glacial maximum (LGM; ~21,000 years BP)

The screenshot shows the Science journal website interface. At the top, there is a navigation bar with the Science logo, AAAS.ORG, FEEDBACK, HELP, LIBRARIANS, a search box for Science Magazine, and a SEARCH button. Below this is a secondary navigation bar with links for GUEST, ALERTS, ACCESS RIGHTS, MY ACCOUNT, and SIGN IN. A third navigation bar contains links for NEWS, SCIENCE JOURNALS, CAREERS, BLOGS & COMMUNITIES, MULTIMEDIA, and COLLECTIONS, along with a JOIN / SUBSCRIBE button. The main header area features the Science logo and the tagline 'The World's Leading Journal of Original Scientific Research, Global News, and Commentary.' Below this is a navigation bar with links for Science Home, Current Issue, Previous Issues, Science Express, Science Products, My Science, and About the Journal. The breadcrumb trail reads: Home > Science Magazine > 24 March 2006 > Otto-Bliesner *et al.*, 311 (5768): 1751-1753. The article title is 'Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation' by Bette L. Otto-Bliesner^{1,*}, Shawn J. Marshall², Jonathan T. Overpeck³, Gifford H. Miller⁴, Aixue Hu¹, and CAPE Last Interglacial Project members. The article is from Science, 24 March 2006, Vol. 311 no. 5768 pp. 1751-1753, DOI: 10.1126/science.1120808. The page includes a left sidebar with 'Article Views' (Abstract, Full Text, Full Text (PDF), Figures Only, Supporting Online Material) and 'Article Tools'. A right sidebar features an 'ADVERTISEMENT' for the 'Science Video Portal' with a play button icon and the text 'Featuring original content produced by the journal Science and its contributors'. Another 'ADVERTISEMENT' is located at the bottom right.

Science Magazine

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Home > Science Magazine > 24 March 2006 > Otto-Bliesner *et al.*, 311 (5768): 1751-1753

Article Views

Abstract

Full Text

Full Text (PDF)

Figures Only

Supporting Online Material

Article Tools

Science 24 March 2006:
Vol. 311 no. 5768 pp. 1751-1753
DOI: 10.1126/science.1120808

REPORT

Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation

Bette L. Otto-Bliesner^{1,*}, Shawn J. Marshall², Jonathan T. Overpeck³, Gifford H. Miller⁴, Aixue Hu¹, CAPE Last Interglacial Project members

< Prev | Table of Contents | Next >

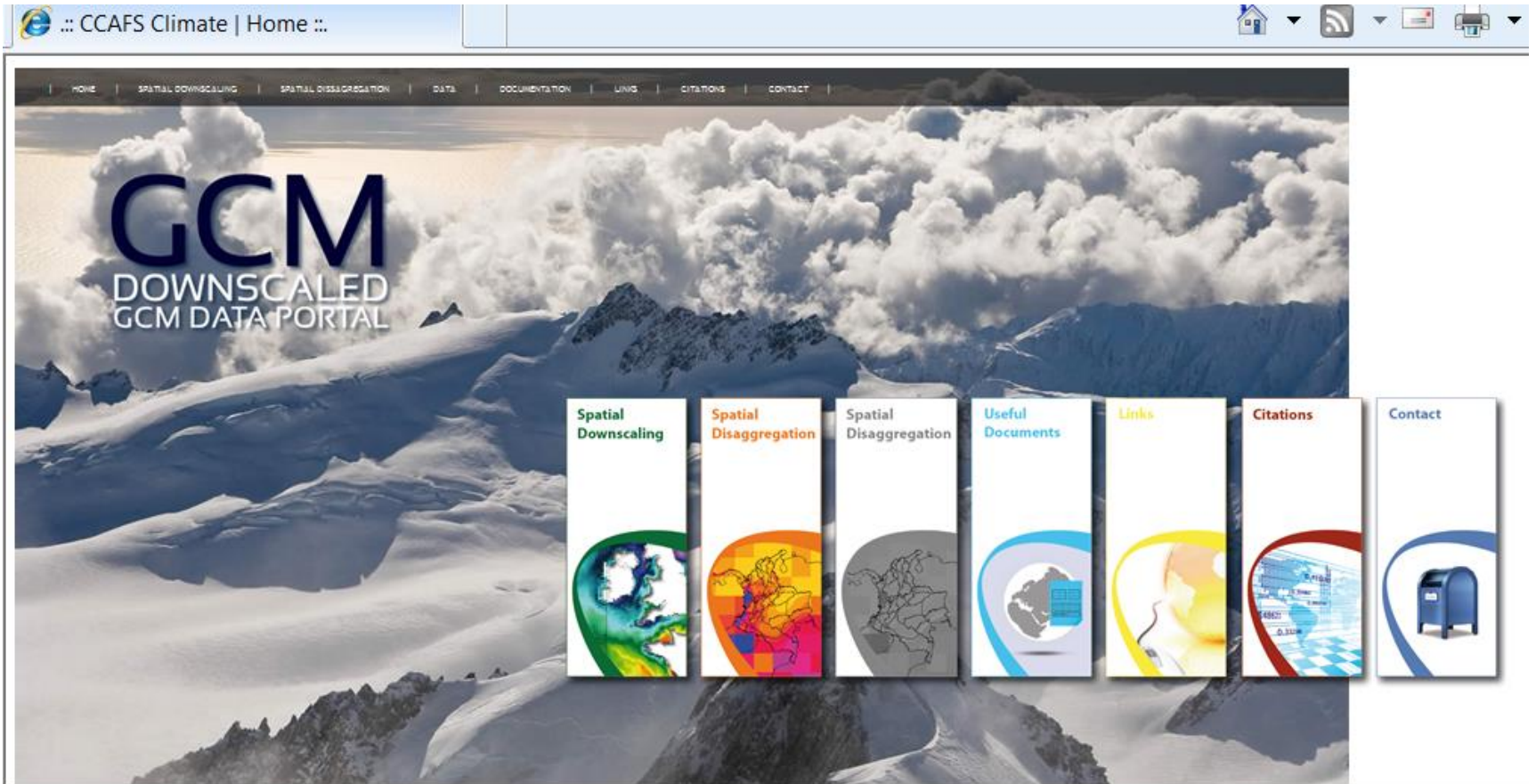
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Climate future projections



NEXT WEEK

Part 1 – Mapping

Dealing with occurrence data

Environmental variables

Spatial issues and PRACTICE with GIS (October 18)

Part 2 – Modeling

Background theory (niche concept)

Modeling methods

Maximum Entropy and PRACTICE with MaxEnt

Part 3 – Mapping and Modeling

Model implementation and evaluation

Applications and future challenges

Using your own data and GROUP PRACTICE