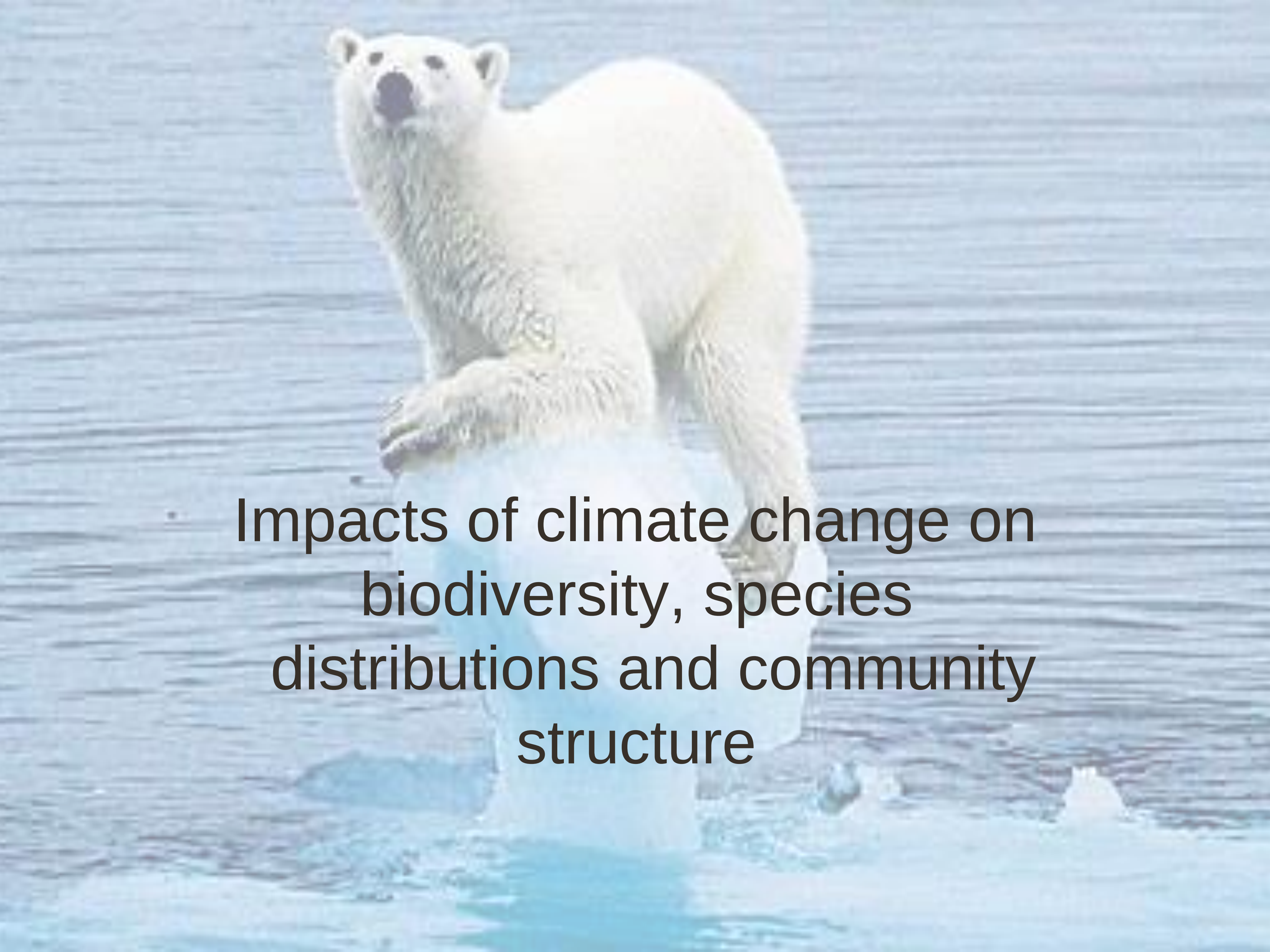
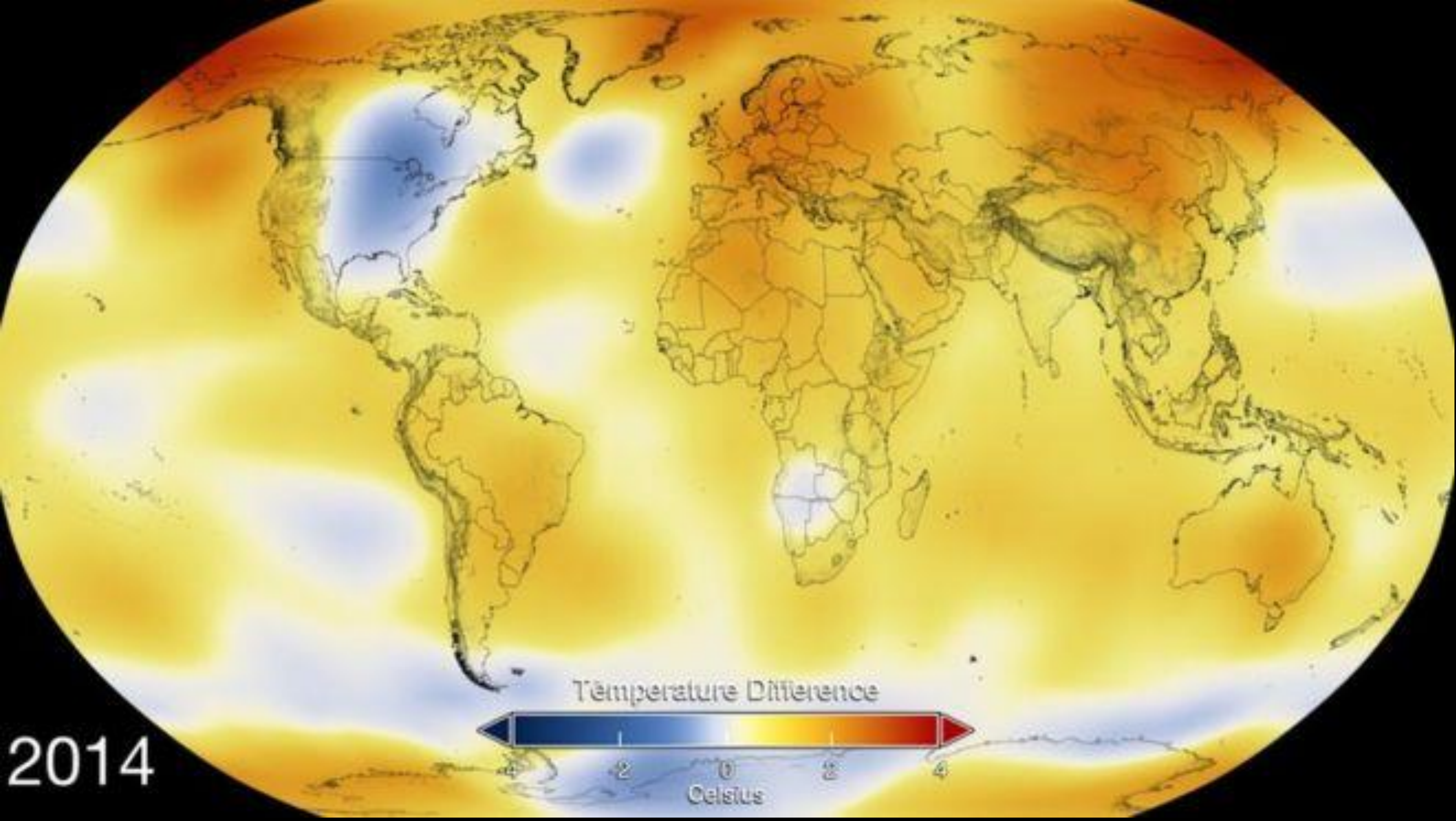
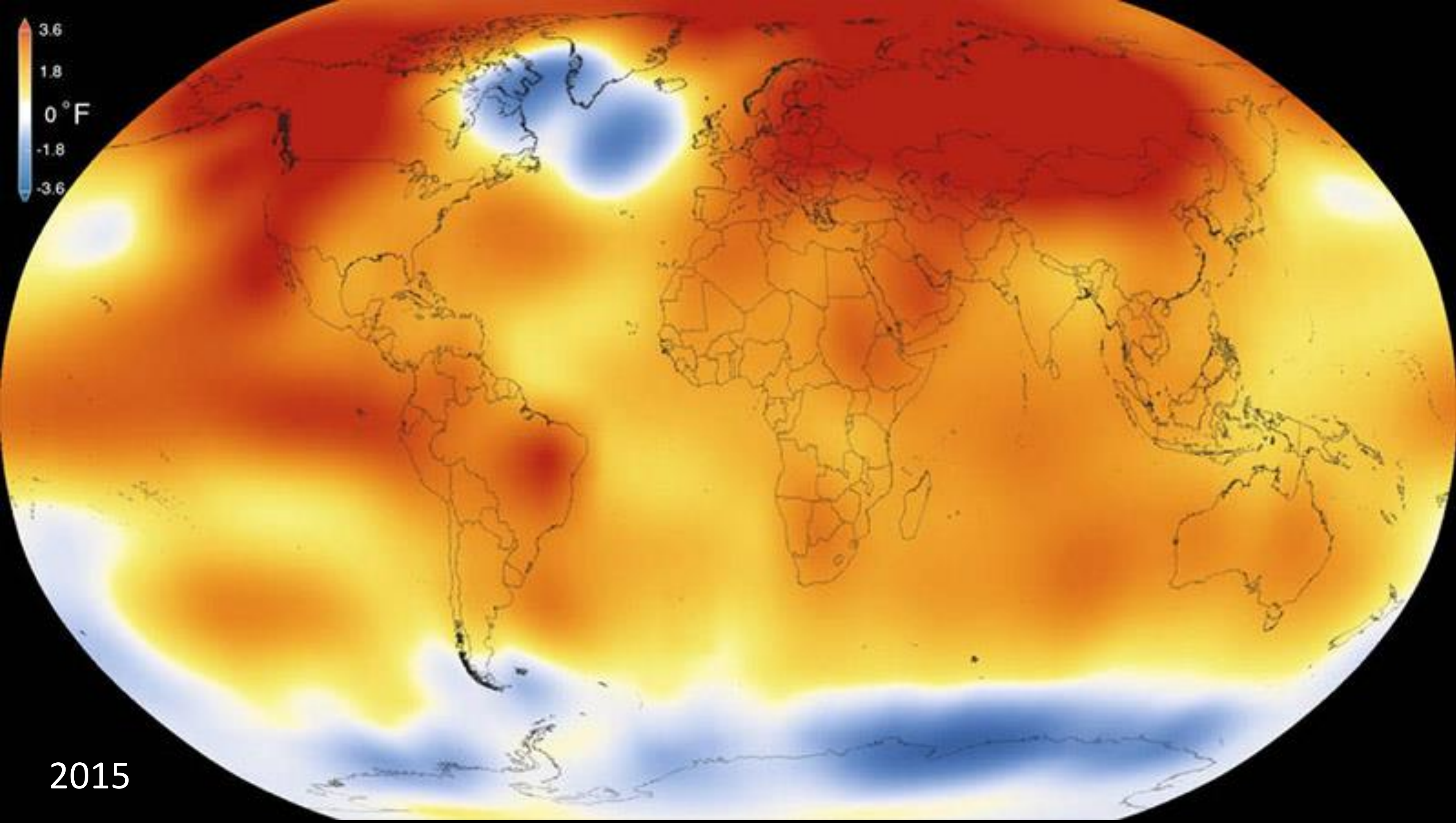


Impacts of climate change on biodiversity, species distributions and community structure

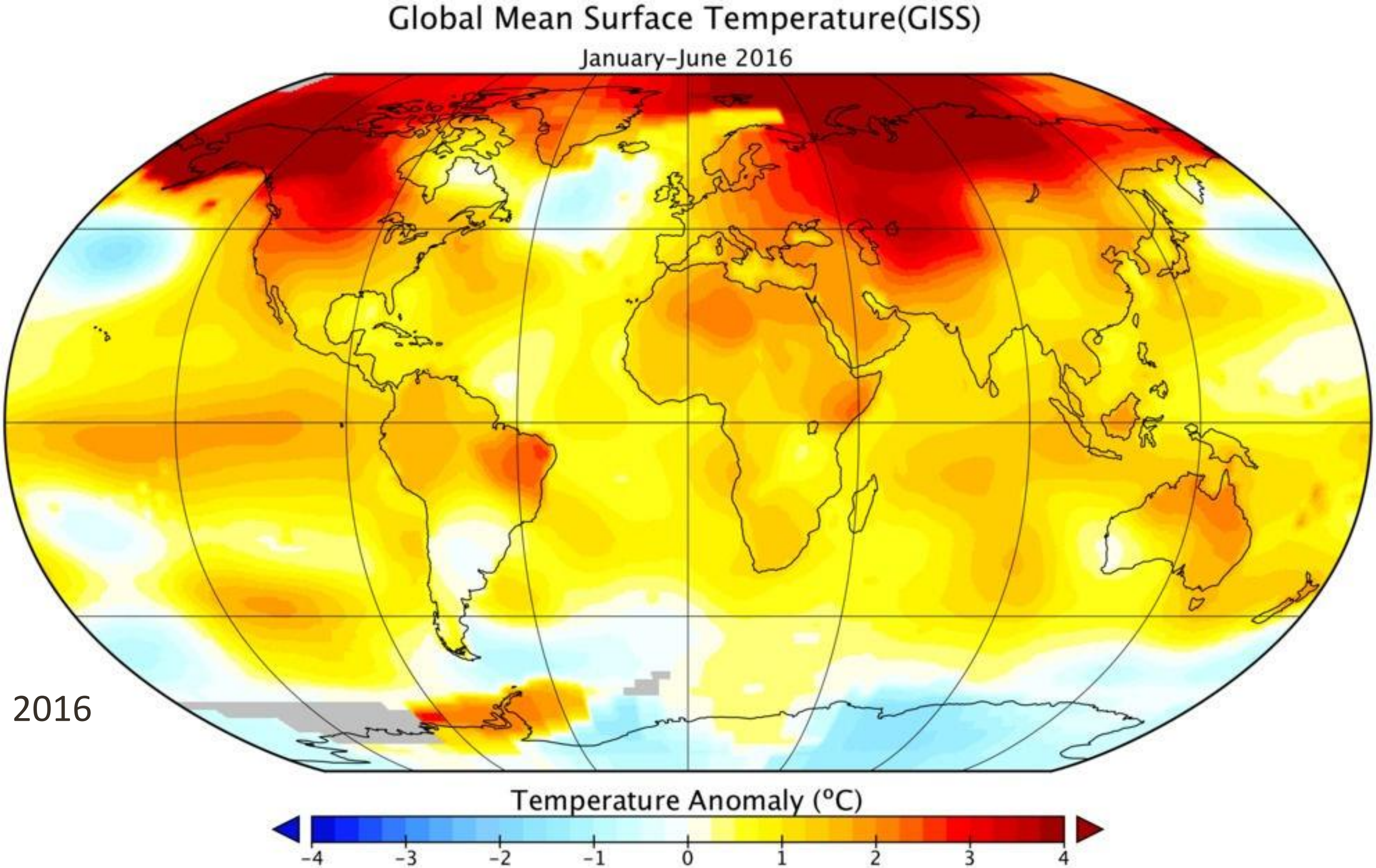


- UK Met Office
- Differences compared to the mean of 1850-1900
- 2014 -> 1,02°C warmer



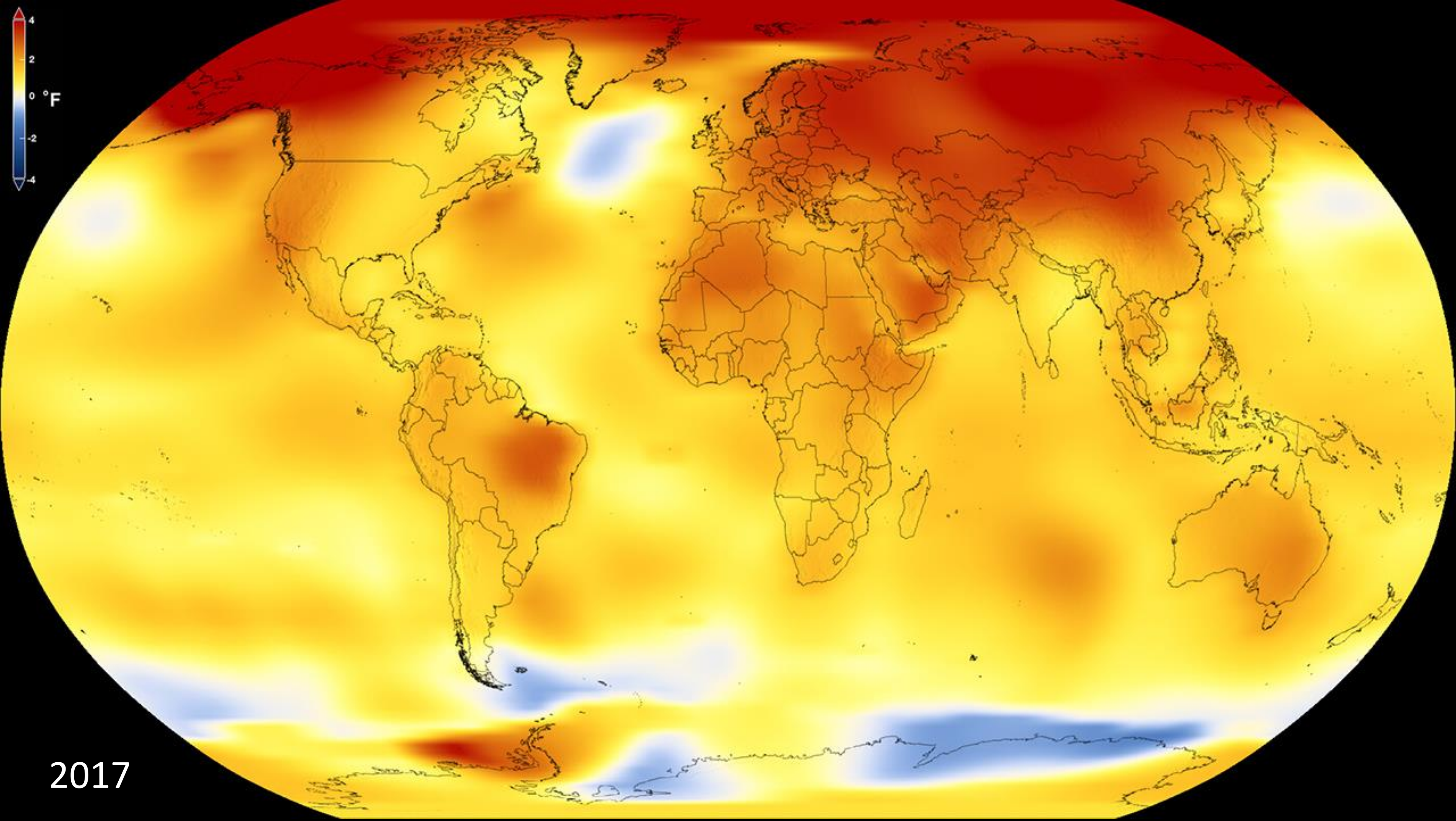
2015

- UK Met Office
- Differences compared to the mean of 1850-1900
- 2015 > 1°C warmer

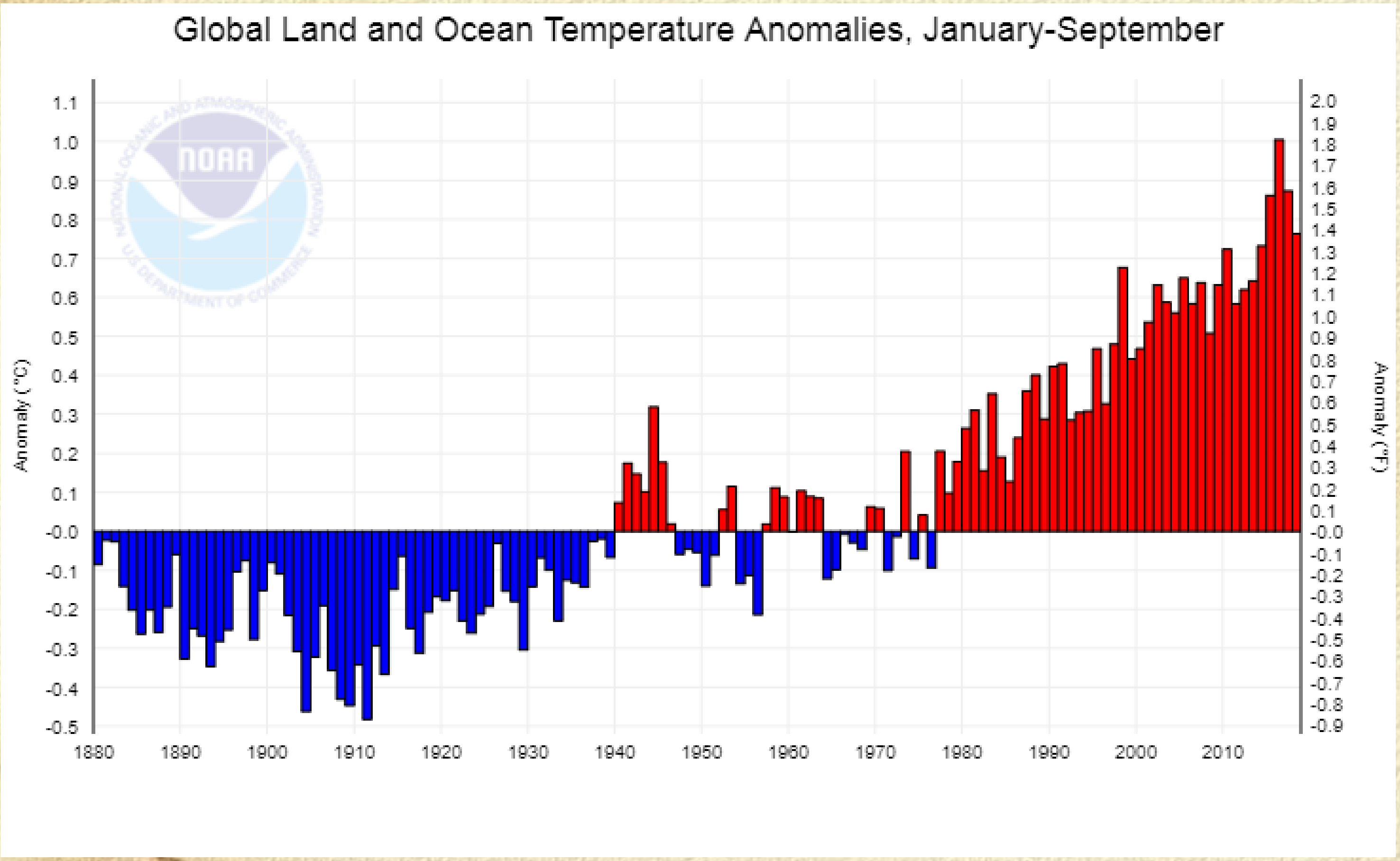


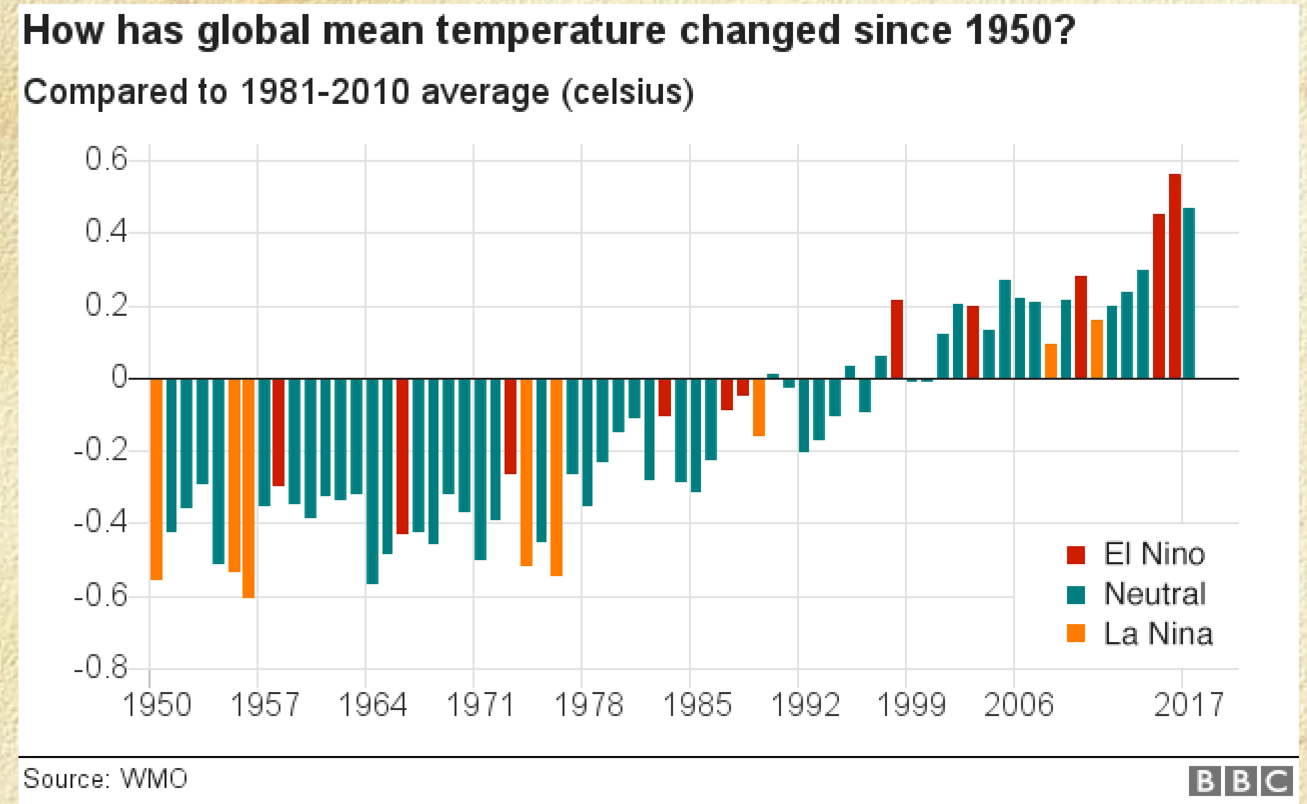
2016

- Differences compared to the mean of 1850-1900
- 1,3°C warmer



- UK Met Office
- Differences compared to the mean of 1850-1900
- 2017 > 1°C warmer


Global Land and Ocean Temperature Anomalies, January-September
Anomaly (°C)
Anomaly (°F)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010


How has global mean temperature changed since 1950?
Compared to 1981-2010 average (celsius)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1950
1957
1964
1971
1978
1985
1992
1999
2006
2017
El Nino
Neutral
La Nina
Source: WMO
BBC

Potential Impacts

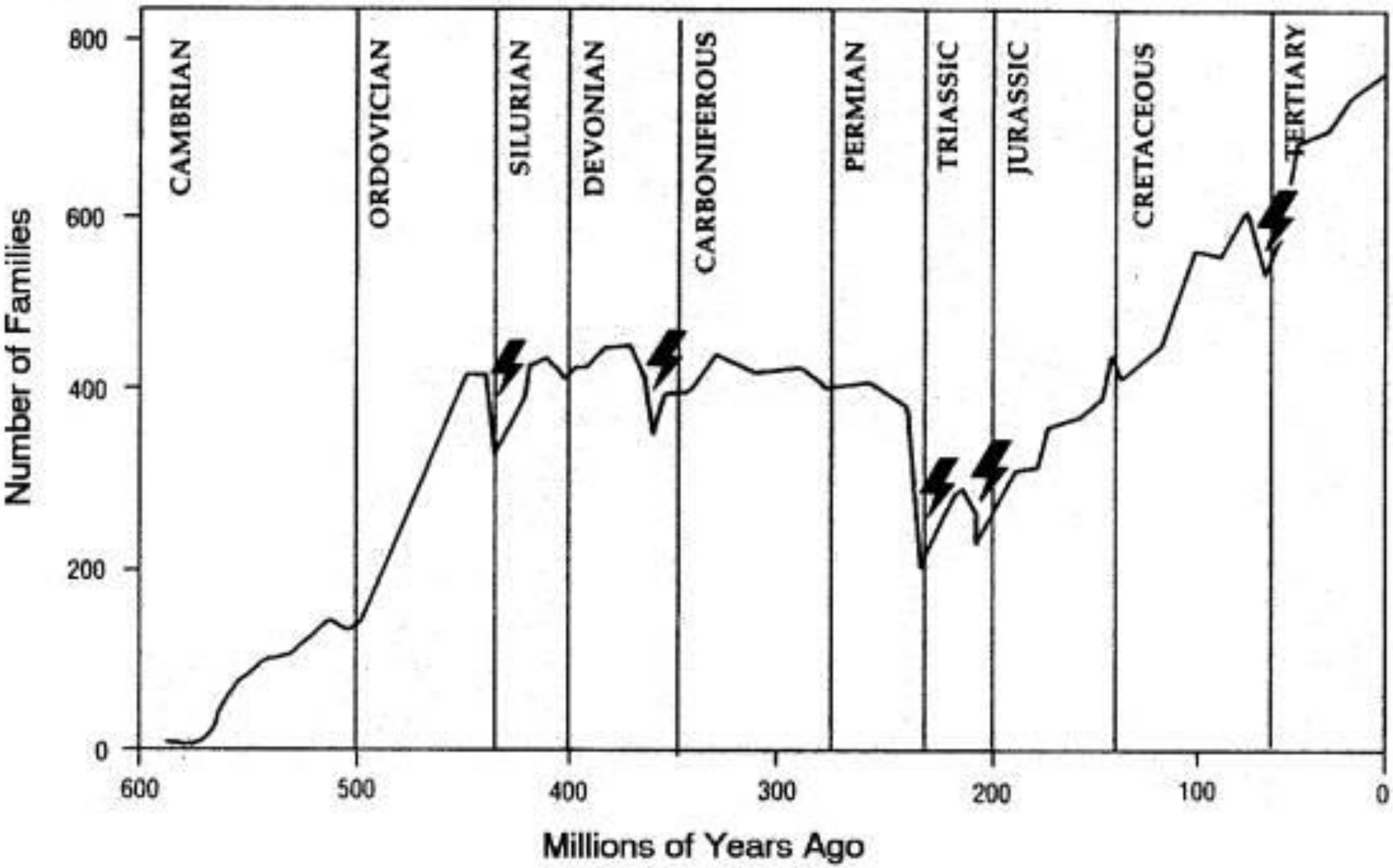
- Local or global extinction of species
  - Species with a narrow climate range
- Local adaptation of species
  - Species with a large climate range
  - Species with a short generation cycle
- Species distribution changes
  - Species with dispersal ability and large competition ability
- Changes in phenology and reproduction patterns
- Changes in community structure
- Changes in ecosystem service provision and ecosystem service functioning
- Invasion of exotic species

Biodiversity

- 5-100 million species of plants, animals and microorganisms
- Less than 2 million have been determined and described
- Many more species existed in prehistoric times and have since gone extinct (some of those were found as fossils)
- What distributions do and did these species have?

Biodiversity

- Today's biodiversity is the result of 3.5 billion years of evolution
- Five global catastrophes lead to the mass extinction of many species (the last one 65 million years ago)
- Today's biodiversity is the largest in the history of the planet



CAMBRIAN
ORDOVICIAN
SILURIAN
DEVONIAN
CARBONIFEROUS
PERMIAN
TRIASSIC
JURASSIC
CRETACEOUS
TERTIARY
Number of Families
800
600
400
200
0
600
500
400
300
200
100
0
Millions of Years Ago

Speciation and Extinction

- All species descend from ancestors
  - Thus, every species that exists today is based on a continuous line of ancestral species
- Some species go extinct
- Some species evolve into one or more species of a different form
- Most species that go extinct do so without leaving behind any descendant species but still many genealogical lines have managed to survive through time

Extinctions

- Extinctions happen, continuously and steadily throughout the planet's history
- Fossil records show, however, times of mass extinctions due to rapid and drastic environmental changes
- A species must always adapt to the everchanging conditions on earth
- Those species unable to adapt on time go extinct and other species which are better adapted expand and produce new forms

Recent extinctions

- During the last 200 years humanity have caused the extinction of thousands of species
- We don’t know how many microorganisms and small animals have gone extinct, but we have a better picture of the loss of some larger and more impressive species

Recent extinctions and threats

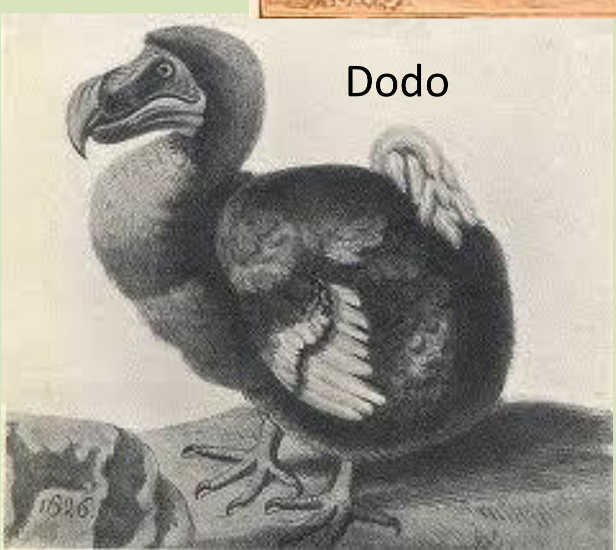
- Many species are endangered by the introduction of exotic/alien species, which either act as strong competitors or as natural enemies
- Climate change
- Habitat loss
- Pollution
- Deforestation
- Hunting
- Overexploitation
- And others

Extinction of the Tasmanian Wolf (*Thylacinus cynocephalus*)

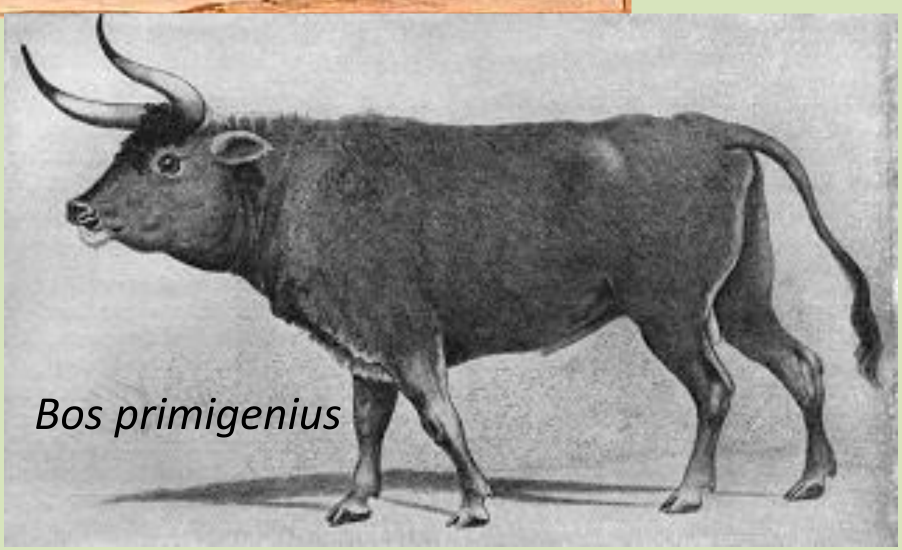
The Migratory Pigeon - *Ectopistes migratorius*

- North America
- Population in 1750 several billion
- In 1870 every day 3000 individuals were caught
- In 1890 they were almost extinct in the wild
- The last pair died in a zoological garden in 1914
- The fate of many other species was similar

Quagga



Dodo



Bos primigenius

Extinctions and the fossil record

- The fossil record provides many proofs of extinctions
- In many cases different groups of species went extinct simultaneously, within very short periods in geological times
- Such mass extinctions were triggered by drastic and global environmental changes

Extinctions and the fossil record

- Some 65 million years ago the composition of the fauna and flora of the earth changed drastically
- Mass extinctions took place
  - Dinosaurs on land and ammonites in the sea
  - Drastic changes in the abundance of other species (bird and mammal numbers increased, while in the sea fish increased while cephalopods decreased)

Extinctions and the fossil record

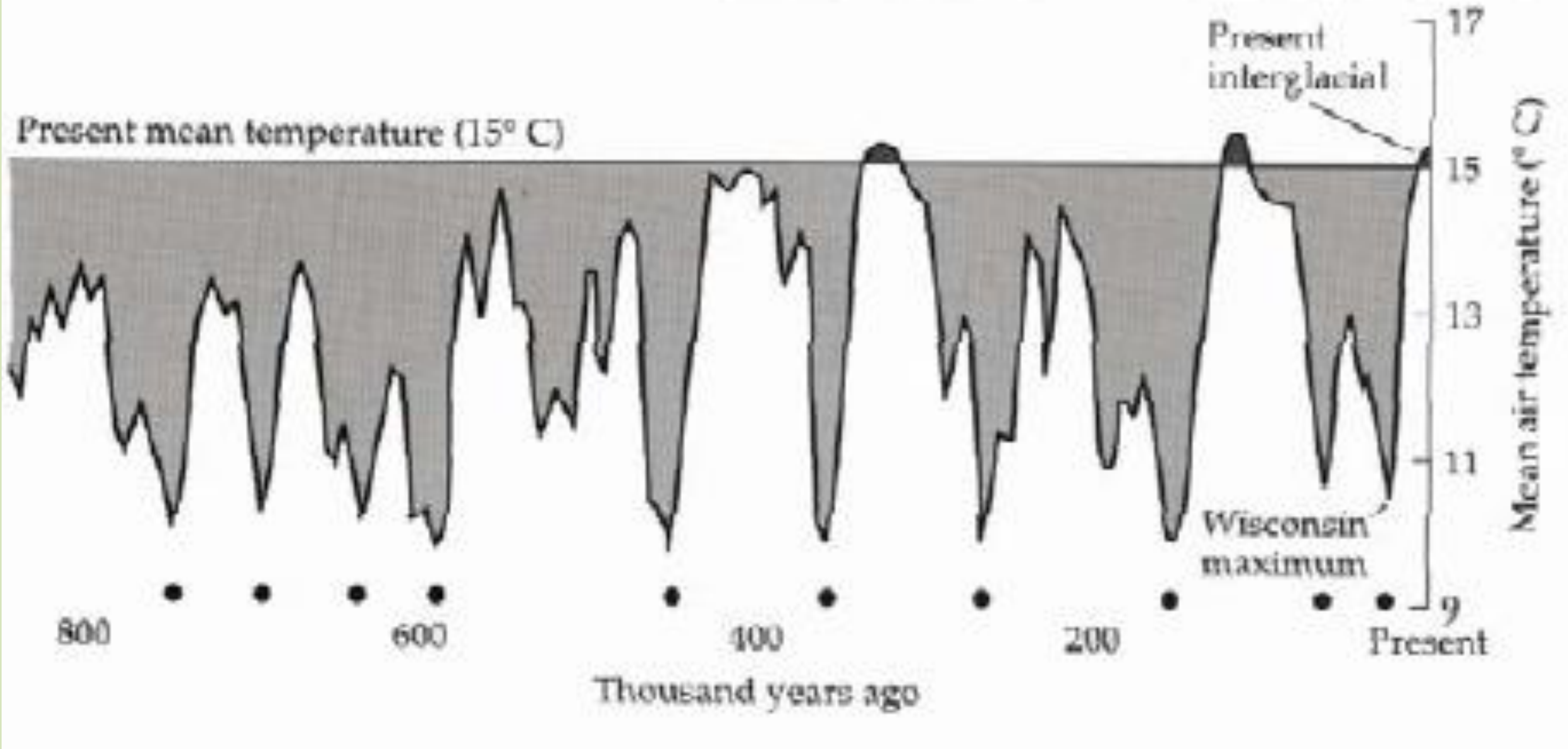
- Not all but only selected species went extinct
- Why did mainly the dinosaurs disappear?
  - The limiting parameter seems to have acted only on specific ecological needs and life strategies
  - Warm-blooded organisms (actively regulate their body temperature) mostly survived
  - Species resistant to short but extreme heat conditions mostly survived
    - (e.g. plants in seeds banks, many insects, invertebrates in fresh water)

The ever-changing planet

- The surface of the Earth and its climate have changed many times during the history of the planet
  - Conintents have shifted
  - Seas have increased and decreased
  - Mountain ranges have risen and eroded
  - Islands have appeared and disappeared
  - Ice ages have come and gone

Ice Ages and the biogeographical dynamics

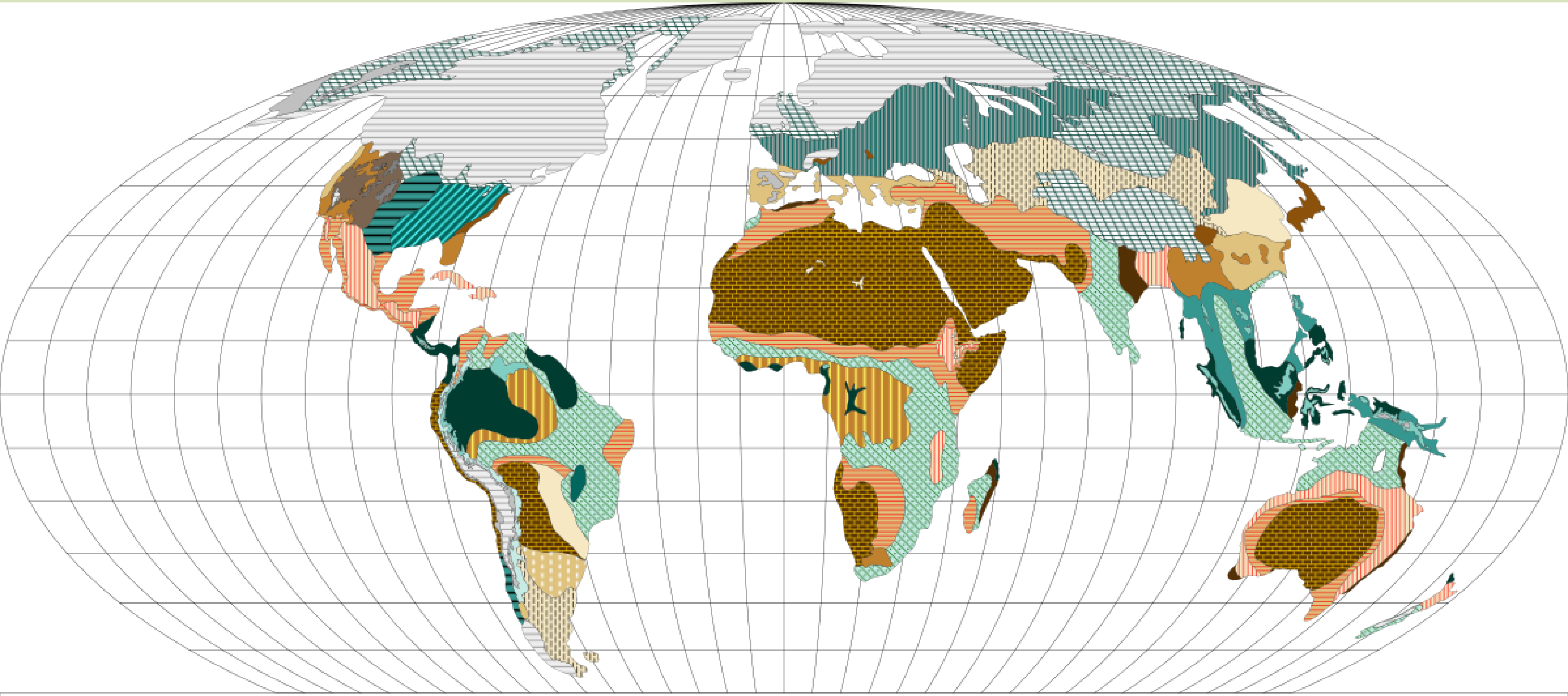
- In the history of the planet many ice ages have come and gone
- During the Pleistocene several glacial and interglacial cycles occurred
- The ice sheets were huge and had a thickness of 2-4km. Due to their weight they shaped the lithosphere beneath
- During their largest extend the ice sheets covered 1/3 of the planet's surface



- Estimated changes in temperature during the last 850,000 years.
- Note that the periods between the ice ages were relatively short and that the current interglacial period is one of the warmest
- The next ice agge? Expected to be in 100,000 years instead of 50,000 years, due to human activity

Changes in water levels during Pleistocene

- The ice sheets during Pleistocene lowered the water levels between 100- 160 m compared to today's levels and up to 230 m compared to other periods
- Thus, although there was relatively little continental drift during the Pleistocene the geographical profile of the Earth changed considerably



Last Glacial Maximum Vegetation

Mollweide projection map generated by @locoluis from shapefile published by Ray, N. and J. M. Adams. 2001
" A GIS-based Vegetation Map of the World at the Last Glacial Maximum (25,000-15,000 BP). Internet Archaeology 11.

Tropical rainforest	**Tropical grassland**	**Open boreal woodlands**	**Temperate desert**	**Subalpine parkland**
Monsoon or dry forest	**Tropical extreme desert**	**Semi-arid temperate woodland or scrub**	**Temperate semi-desert**	**Dry steppe**
Tropical woodland	**Savanna**	**Tundra**	**Forest steppe**	**Temperate steppe grassland**
Tropical thorn scrub and scrub woodland	**Broadleaved temperate evergreen forest**	**Steppe-tundra**	**Montane Mosaic**	**Main Taiga**
Tropical semi-desert	**Montane tropical forest**	**Polar and alpine desert**	**Alpine tundra**	**Ice sheet and other permanent ice**

Source: http://intarch.ac.uk/journal/issue11/rayadams_toc.html

Biogeographical responses to the glacial periods

The biogeographical dynamics of the Pleistocene fauna and flora was influenced by three elementary environmental changes :

- Changes in the location, extend and αλλαγές στη θέση, έκταση και configuration of the initial habitats
- Changes in the climatic and environmental zones
- Generation and destruction of dispersal routes

Responses of the fauna and flora:

- Some species were able to disperse along with their habitat, which moved with geographical latitude and altitude
- Some species remained and adapted to the new environmental conditions
- Some species' populations decreased and finally went extinct

Arctic fox

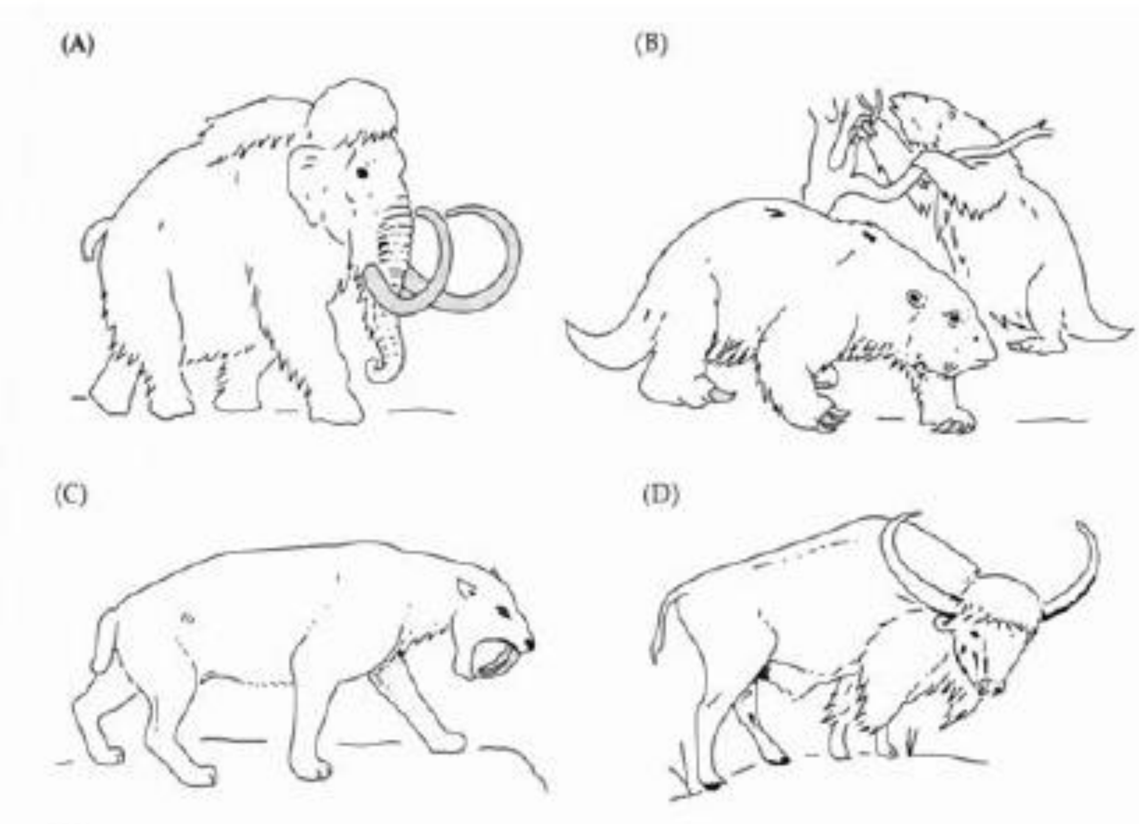
Vulpes lagopus

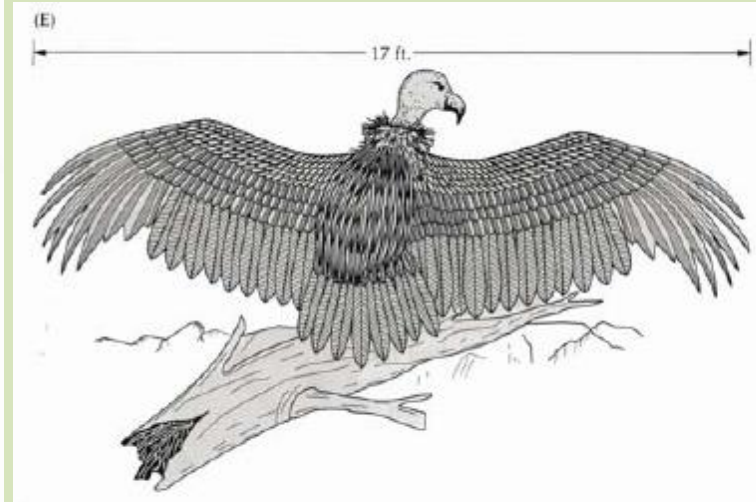
Fennek

Vulpes zerda

Polar Bear
Ursus maritimus

Asian Black Bear
Ursus thibetanus



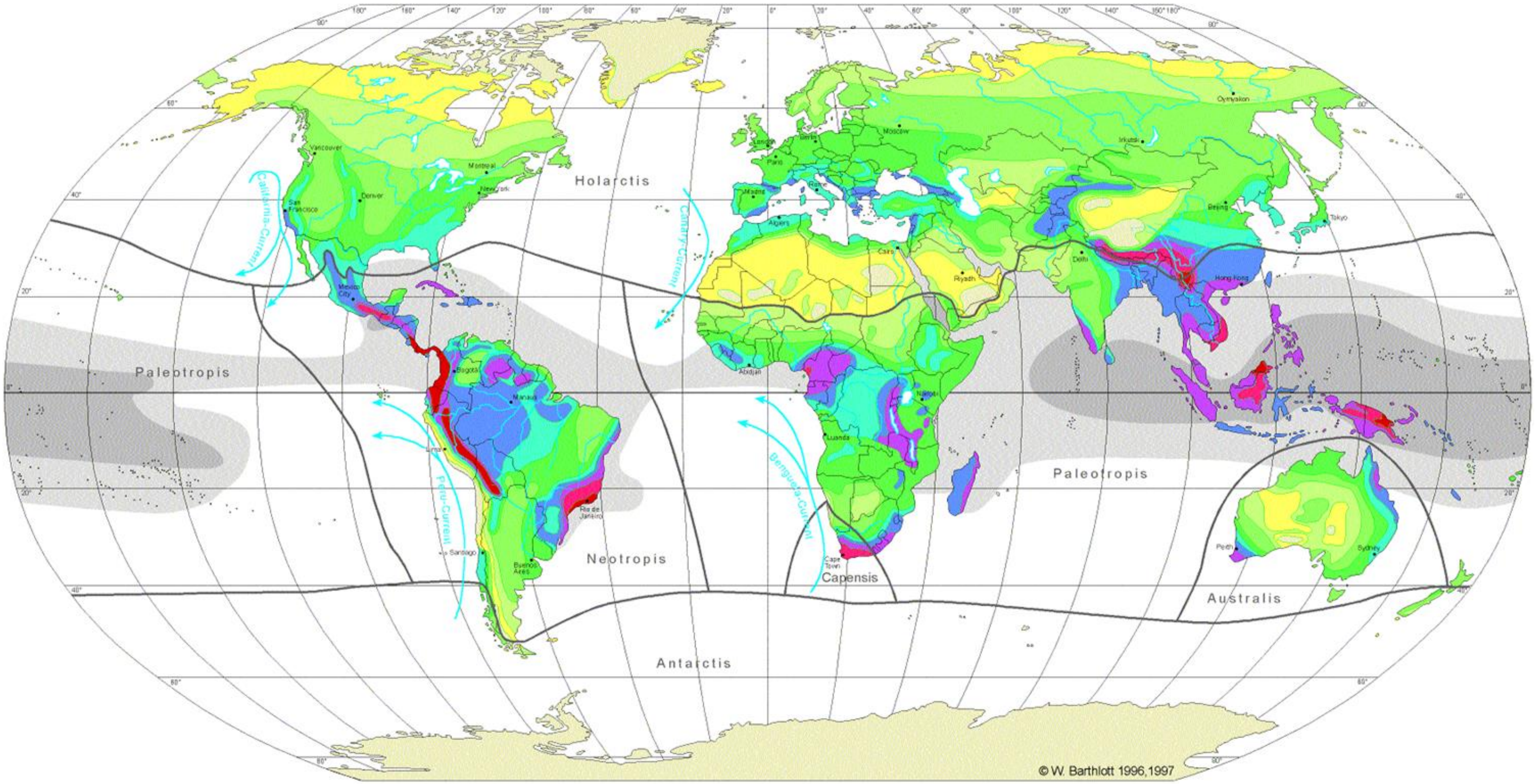


The mass extinctions of terrestrial vertebrates in North America towards the ned of the Pleistocene and the : (a) mammoth, b) ground-dwelling sloths c) sabretooth tigers δ) Giant Bison, ε) large species of predatory birds. The present-day species, which have replaced these are all of much smaller size.

The natural environment

- Living organisms live almost everywhere on the surface of the Earth. From the highest peaks to the depths of the sea.
- But not all species live everywhere
- The distribution of species depends e.g. on the climate and the geology in terrestrial systems and the temperature, salinity, light and pressure in marine systems.
- There is a plethora of environmental conditions on Earth (e.g. cold around the poles, salty in the sea, ice on mountain peaks etc.)

GLOBAL BIODIVERSITY: SPECIES NUMBERS OF VASCULAR PLANTS



Robinson Projection
Standard Parallels 38°N und 38°S
Scale 1: 130000000

Diversity Zones (DZ): Number of species per 10.000km^2

- DZ 1 (<100)
- DZ 2 (100 - 200)
- DZ 3 (200 - 500)
- DZ 4 (500 - 1000)
- DZ 5 (1000 - 1500)
- DZ 6 (1500 - 2000)
- DZ 7 (2000 - 3000)
- DZ 8 (3000 - 4000)
- DZ 9 (4000 - 5000)
- DZ 10 (≥5000)

Capensis floristic regions

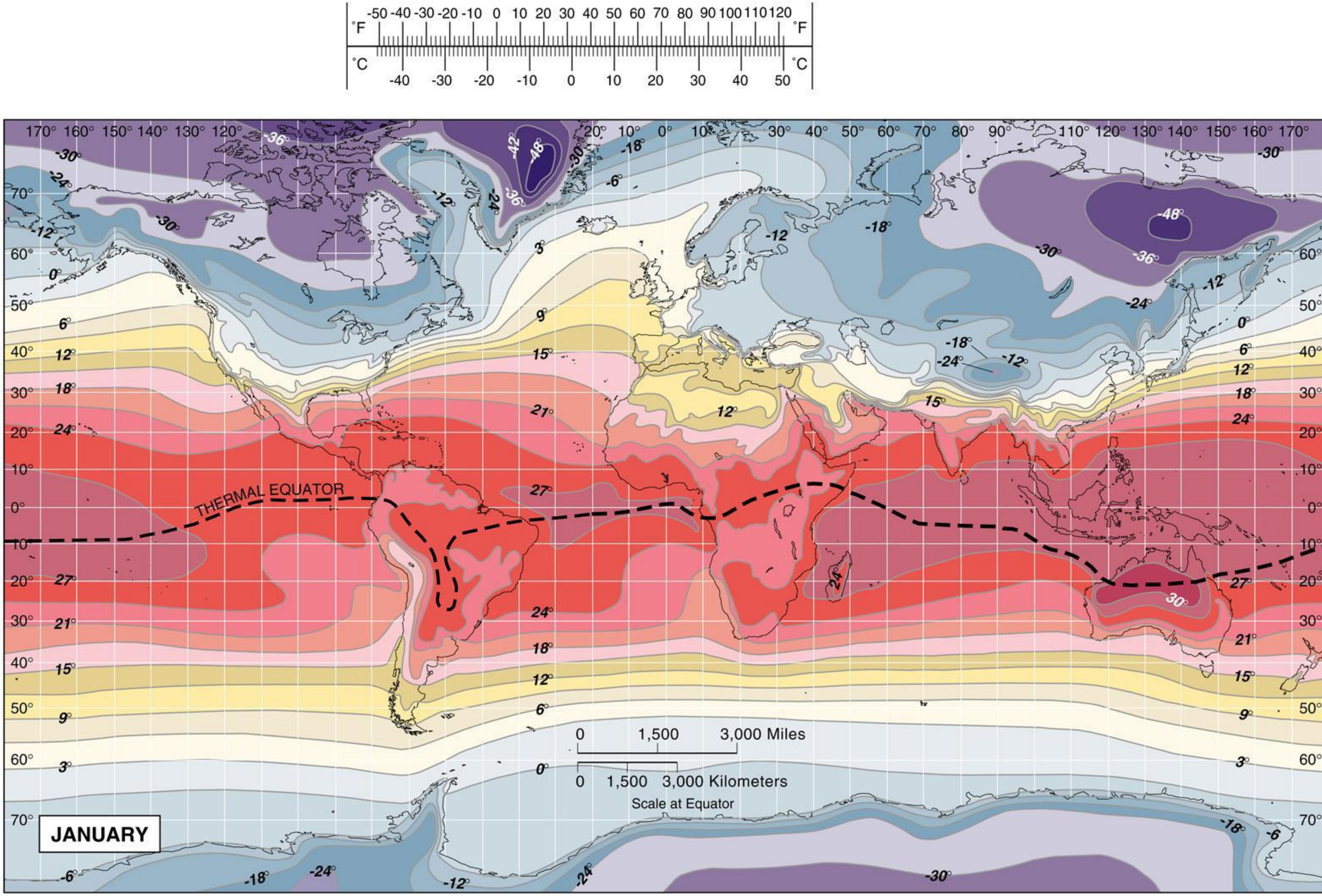
sea surface temperature

- >29°C
- >27°C

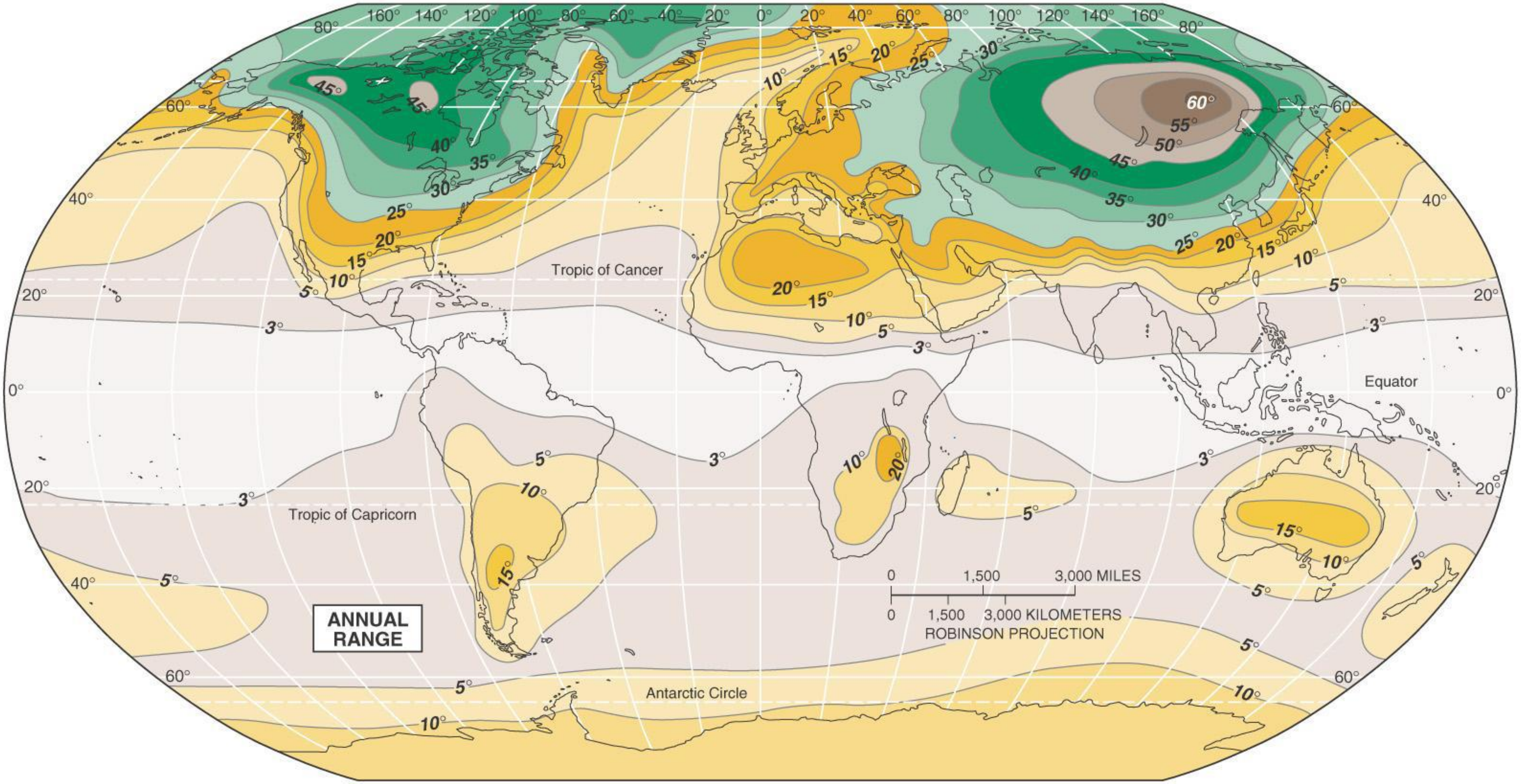
cold currents

W. Barthlott, N. Biedinger, G. Braun
F. Feig, G.Kier, W. Lauer & J. Mutke 1997
modified after
W. Barthlott, W. Lauer & A. Placke1996
Department of Botany and Geography
University of Bonn
German Aerospace Research Establishment, Cologne

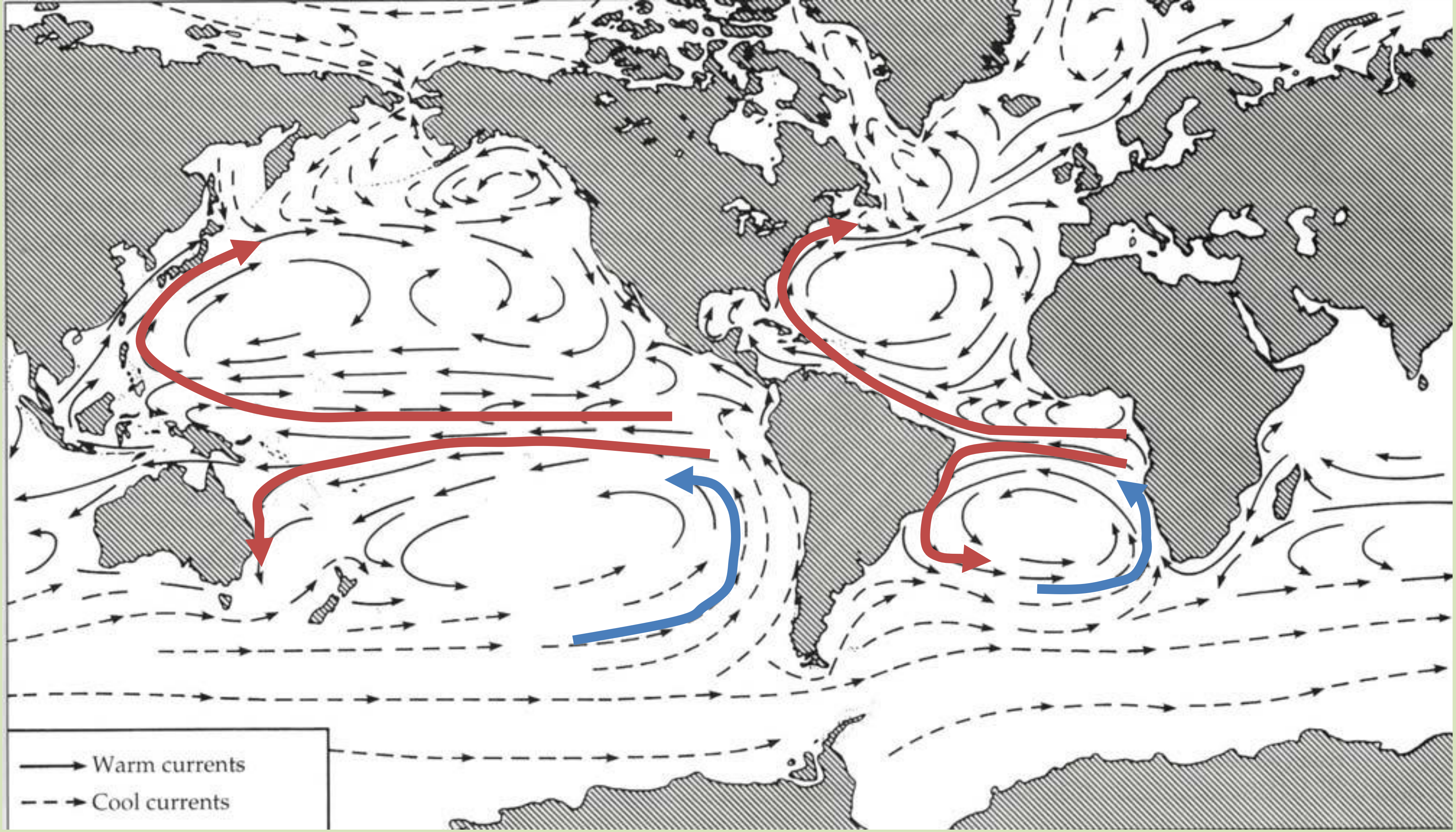
Cartography: M. Gref
Department of Geography
University of Bonn


°F -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 °F
°C -40 -30 -20 -10 0 10 20 30 40 50 °C
170° 160° 150° 140° 130° 120° 20° 10° 0° 10° 30° 40° 50° 60° 70° 80° 90° 110° 120° 130° 140° 150° 160° 170°
70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70°
THERMAL EQUATOR
-48° -42° -36° -30° -24° -18° -12° -6° 0° 3° 6° 9° 12° 15° 18° 21° 24° 27° 30°
0 1,500 3,000 Miles
0 1,500 3,000 Kilometers
Scale at Equator
JANUARY
(a)

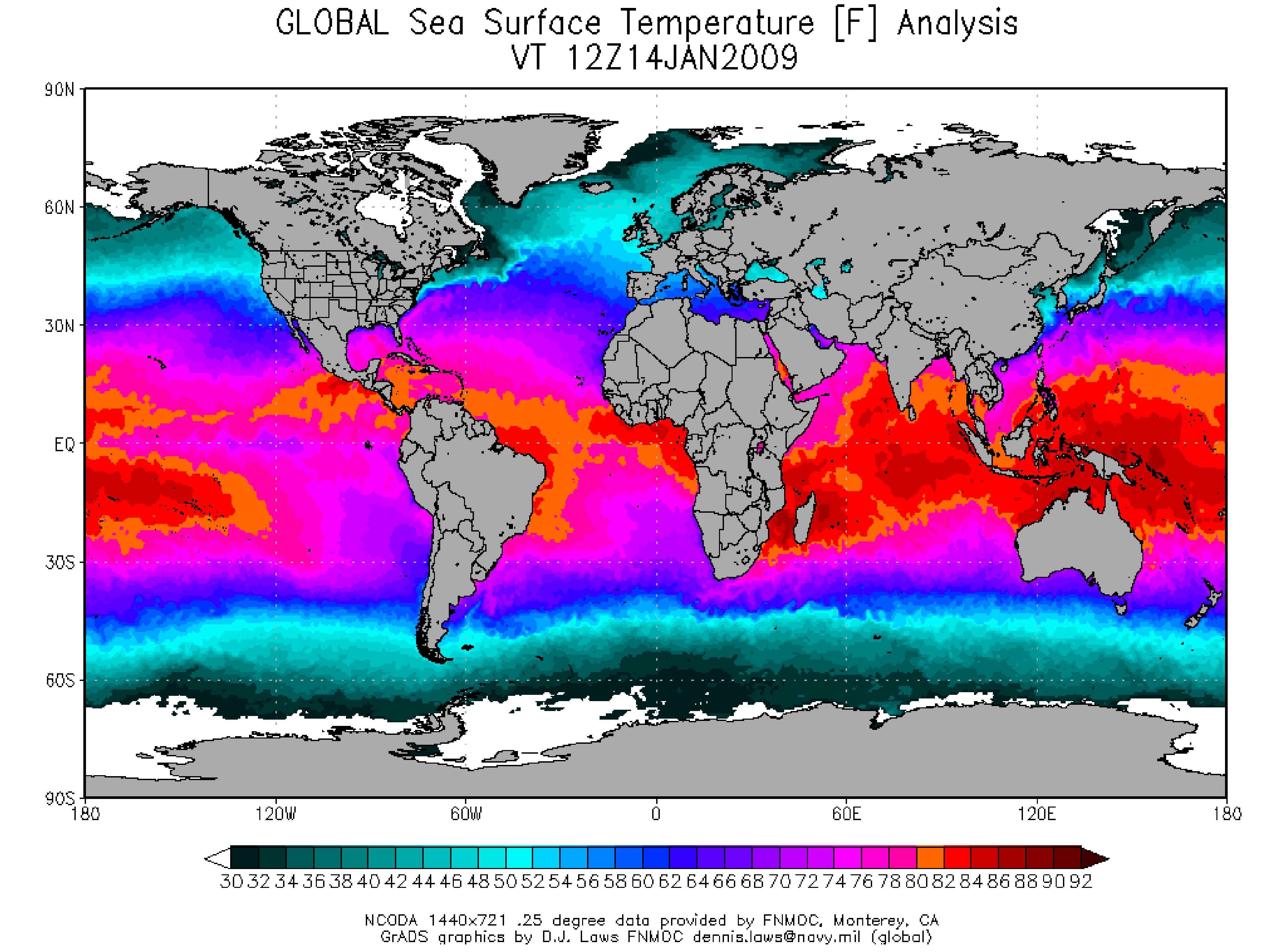
Θερμοκρασιακό εύρος



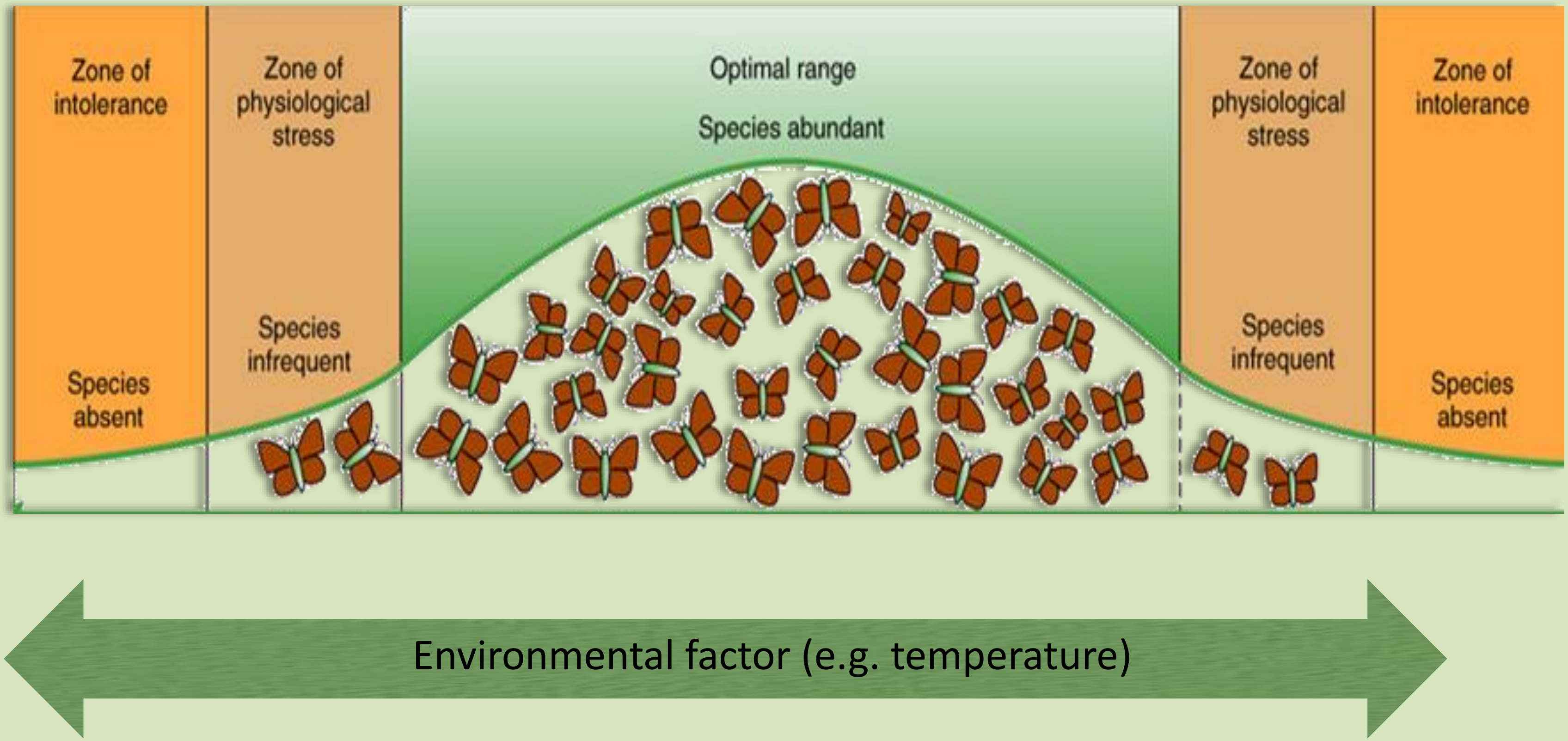
F°	5	9	18	27	36	45	54	63	72	81	90	99	108	F°
C°	3	5	10	15	20	25	30	35	40	45	50	55	60	C°



- Warm and cold currents

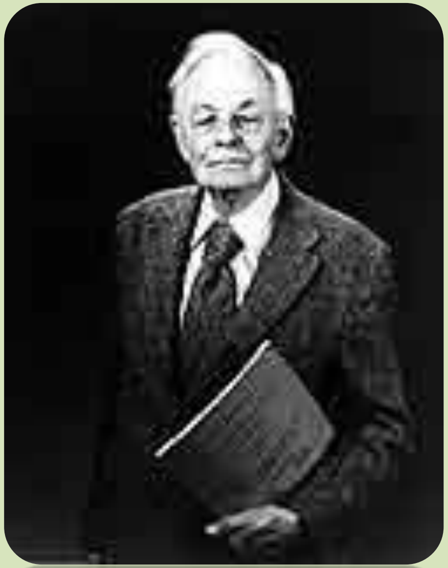

GLOBAL Sea Surface Temperature [F] Analysis
VT 12Z14JAN2009
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92
NCODA 1440x721 .25 degree data provided by FNMOC, Monterey, CA
GrADS graphics by D.J. Laws FNMOC dennis.laws@navy.mil (global)

- The distribution of a species is limited. Why?
- For a population to exist in an area all biotic and abiotic conditions, including the availability of food and other resources, must be within a certain range.



Ecological Niche

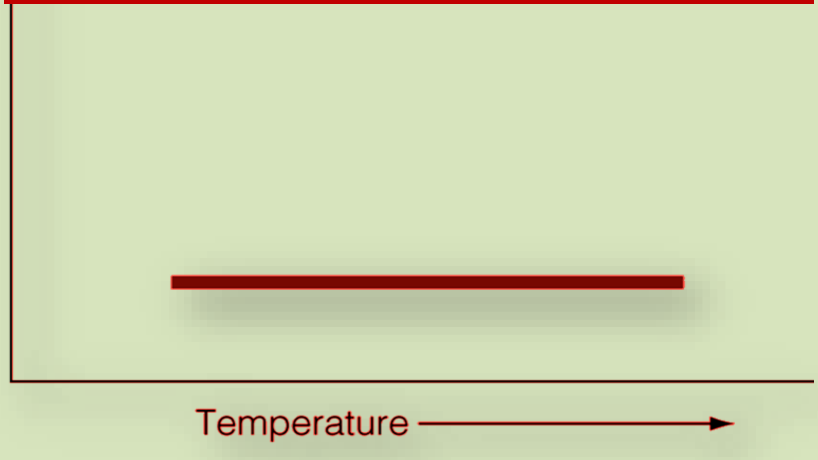
- Describes the limits of biotic and abiotic conditions under which a certain species can survive and reproduce
- The ecological niche
  - Has many dimensions
  - Can be distinguished between **fundamental** and **realized** niche



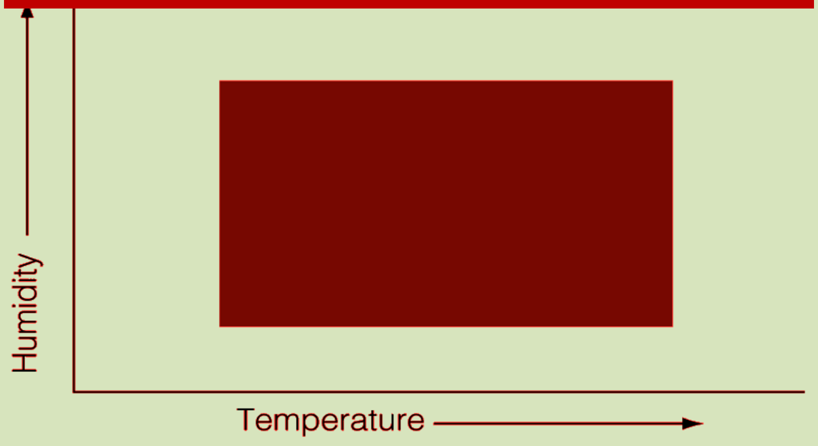
G.E. Hutchinson

Ecological niche and its dimensions

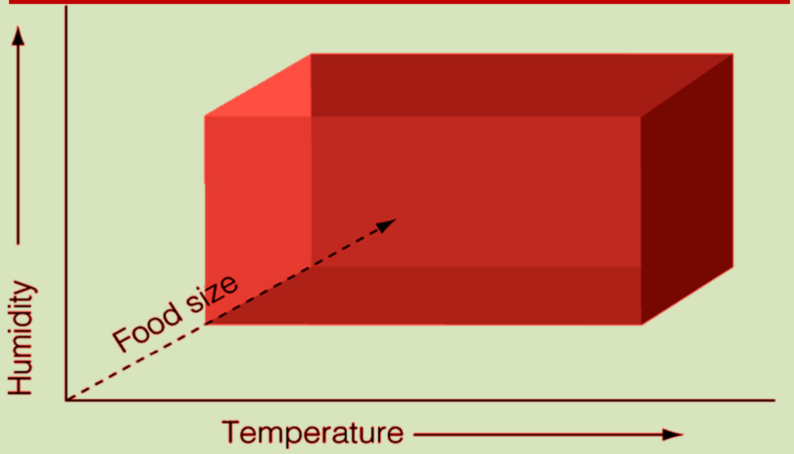
One dimension



Two dimensions

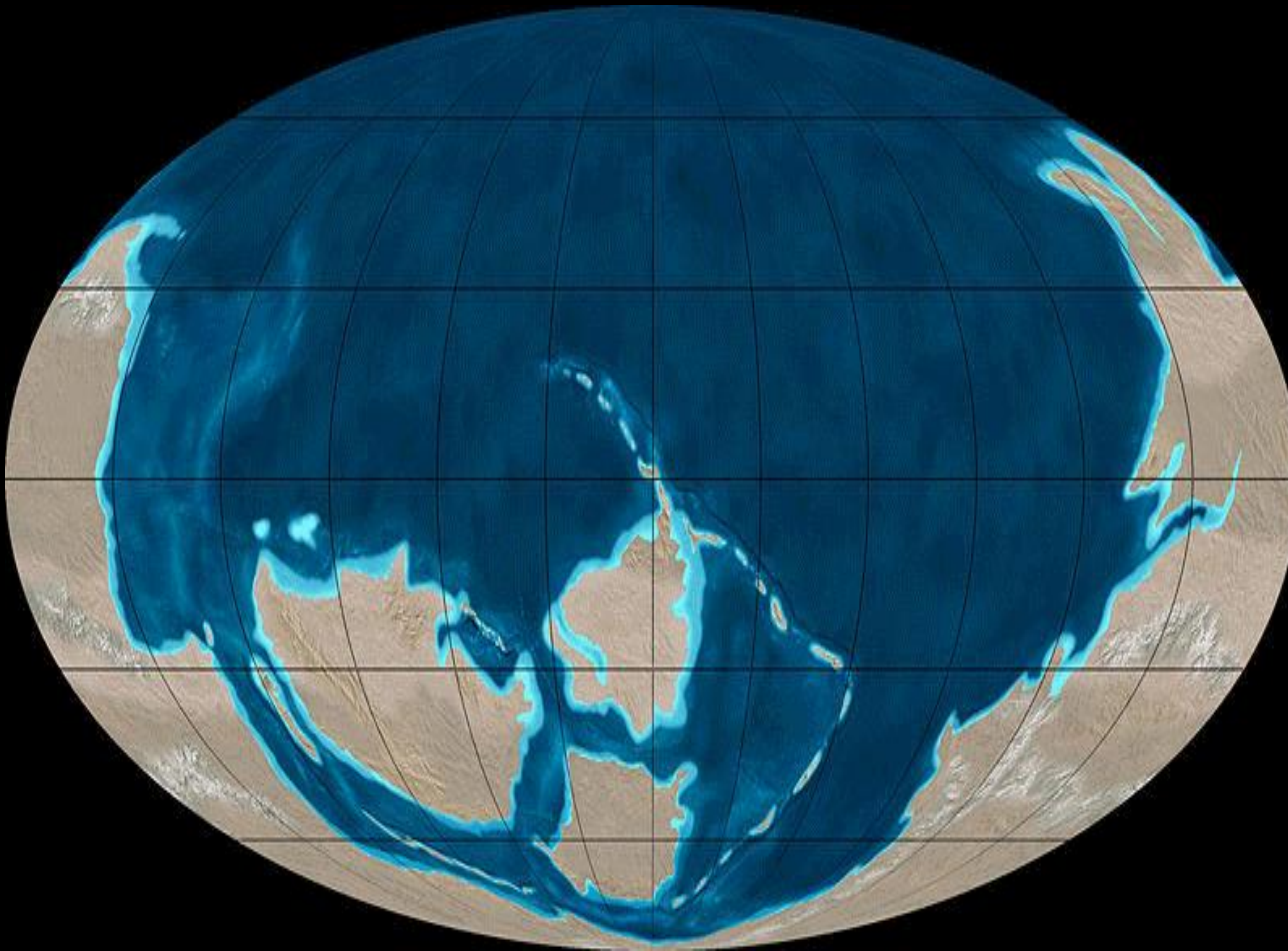


Three dimensions



- **Ecological niche=** body with many dimensions
- Potential dimensions:
  - temperature
  - humidity
  - Salinity
  - pH
  - Food size
  - …

Messinian Salinity Crisis



Messinian Salinity Crisis

- **5.9 million years ago**
- **Tectonic movements (African plate – European plate)**
- **The Mediterranean Sea gets cut off from the Atlantic**
- **Desiccation of the Mediterranean Sea**
- **Extinction of almost all marine life in the Mediterranean**

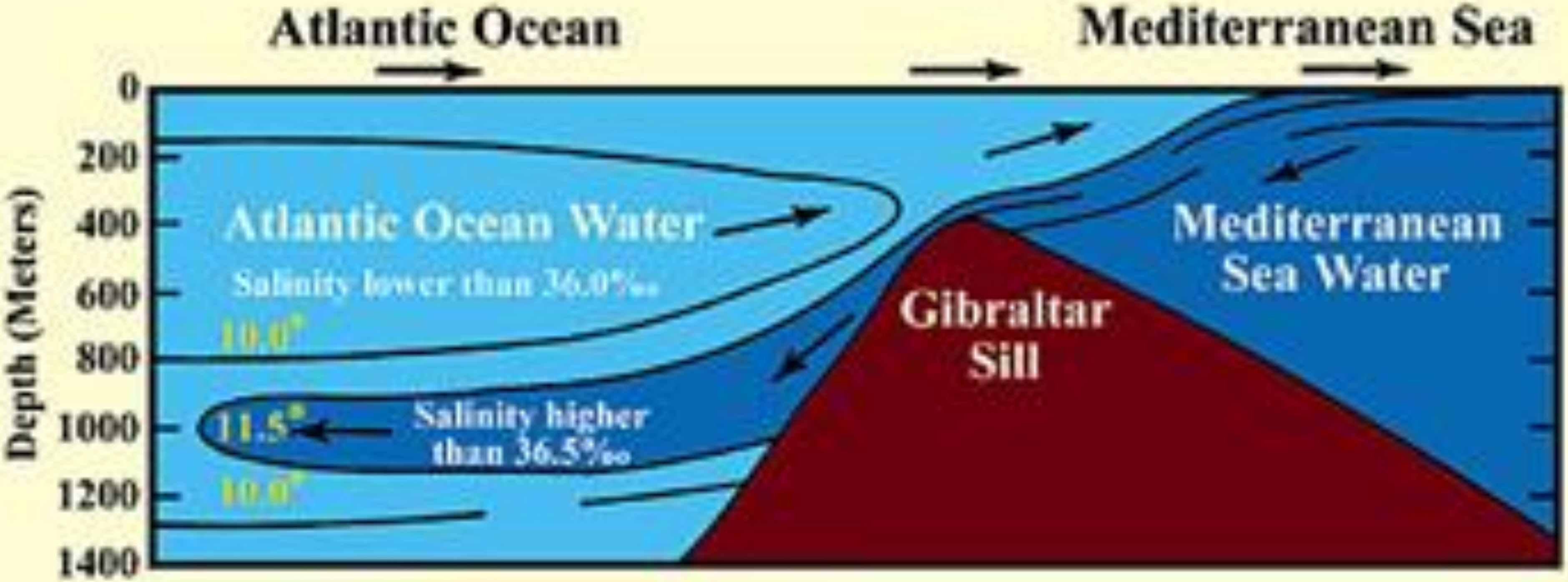
Messinian Salinity Crisis

- **Sea levels in the oceans rise by 10m**
- **Overflow at the present-day Straight of Gibraltar**
- **Colonization of the Mediterranean Sea by the Atlantic marine fauna and flora**

Hydrology - Today

- Limited water exchange between the Meidterranean and the Atlantic
- Limited fresh water run-off Χαμηλή εισροή γλυκού νερού
- Agriculture, dams (e.g. Aswan)
- High evaporation levels

=> Negative water balance



Atlantic Ocean
Mediterranean Sea
Depth (Meters)
0
200
400
600
800
1000
1200
1400
Atlantic Ocean Water
Salinity lower than 36.0‰
10.0°
11.5°
Salinity higher than 36.5‰
10.0°
Gibraltar Sill
Mediterranean Sea Water

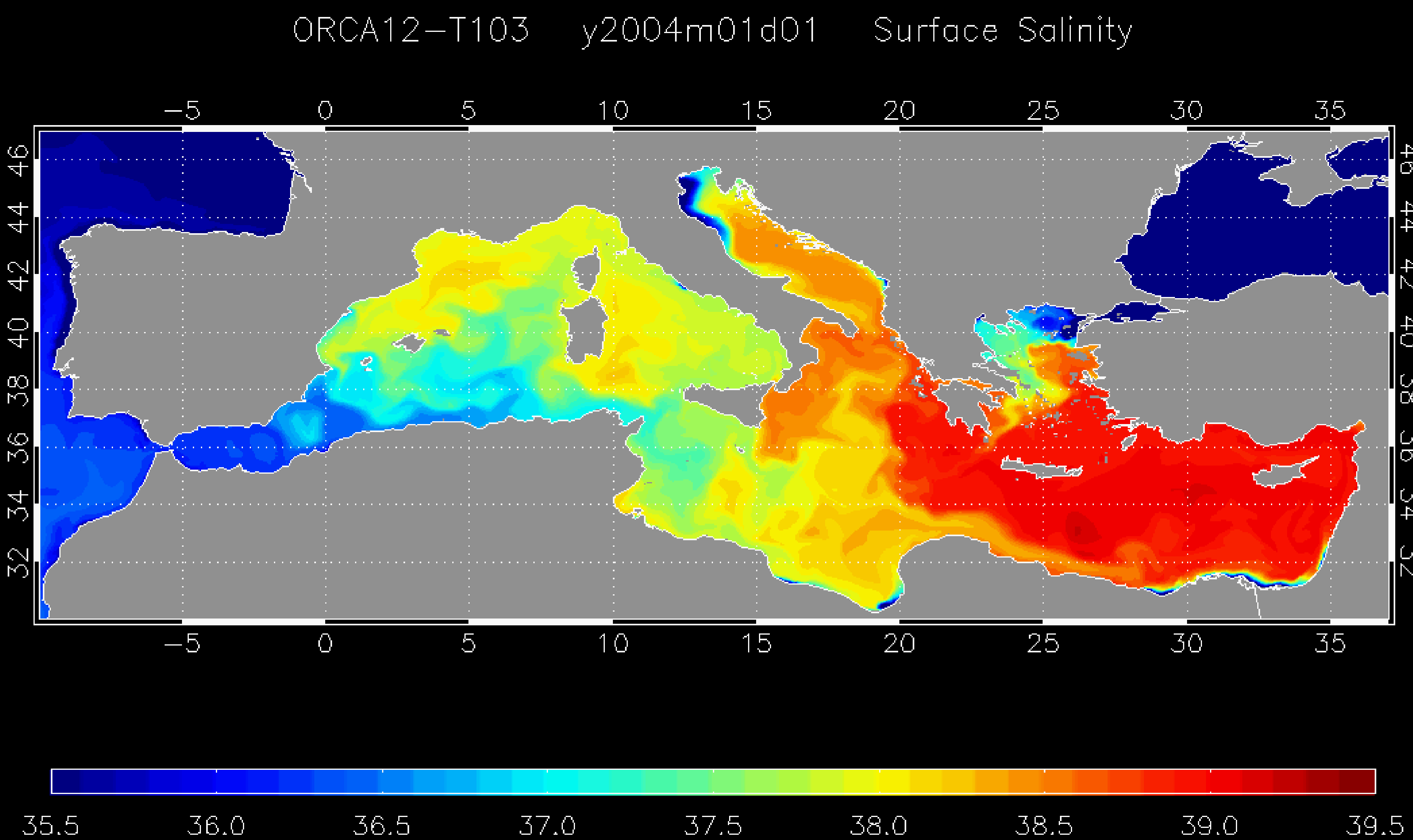
The Aswan Dam

Impacts

- Reduction of the fertilization along the Nile
- Reduction of the productivity along the Nile
- Reduction of the Nile Delta
- Reduction of the sardine fishing industry in the southeastern Mediterranean
- Illnesses (e.g. *Schistosoma mansoni*)

1902: the first dam (Aswan Low Dam)
1970: the second dam (Aswan High Dam)

Salinity


ORCA12–T103 y2004m01d01 Surface Salinity
–5
0
5
10
15
20
25
30
35
46
44
42
40
38
36
34
32
35.5
36.0
36.5
37.0
37.5
38.0
38.5
39.0
39.5

The fauna and flora of the Mediterranean Sea

- Atlantic origins
- Are well adapted to cooler waters, rich in nutrients and lower salinity levels
- According to scientific studies the conditions for marine organisms in the Mediterranean Sea will soon exceed the tolerable limits of salinity and temperature

Lessepsian Migration

The Suez Canal

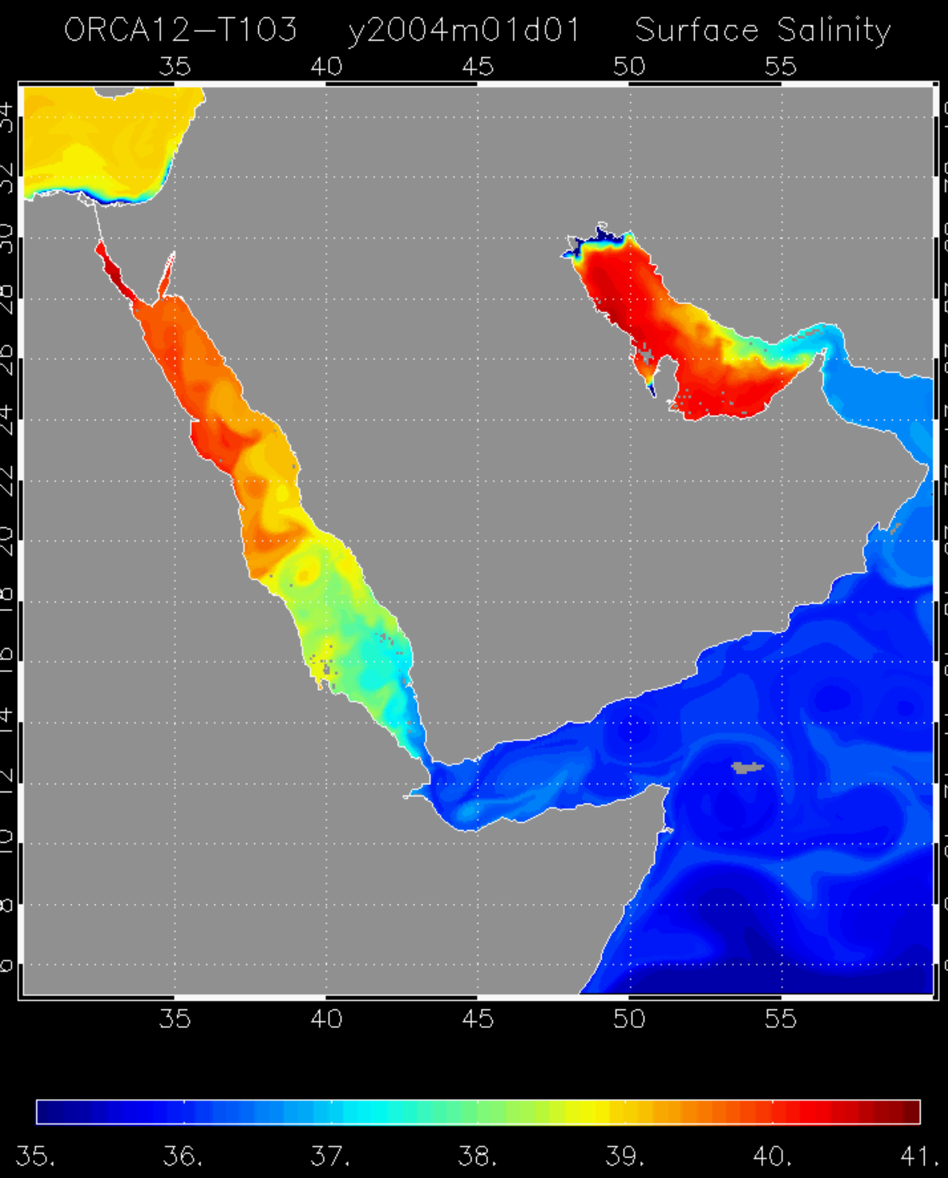
- 1869 Ferdinand Lesseps (French architect responsible for building the canal)

- 190 km length 12 m depth

- 14% of the world's trade

The fauna and flora of the Red Sea

- The fauna and flora originates in the Indo-Pacific Ocean
- Is well-adapted to high temperatures, high salinity and less nutrients in the water



ORCA12–T103 y2004m01d01 Surface Salinity
35 40 45 50 55
34 32 30 28 26 24 22 20 18 16 14 12 10 8 6
35. 36. 37. 38. 39. 40. 41.

The migration

- Mainly from the Read Sea to the Mediterranean
- Until today 300 macroscopic animal species from the Red Sea have been recorded in the Mediterranean
- Mainly mollusks and fish but also many crustaceans

Greece

- In 1934 the first exotic species of fish were recorded in Greek waters
- In 1946 the first mollusks
- Until 2005 128 exotic marine species had entered Greek waters

FISHES OF THE EASTERN MEDITERRANEAN

Daniel Golani | Bayram Öztürk | Nuri Başusta

Photographs: David Darom

The future?

- The Egyptian government is widening the Suez canal to allow for bigger ships to pass
- Climate Change

Modelling the species distribution of the genus *Merodon* (Diptera: Syrphidae) under different climate scenarios

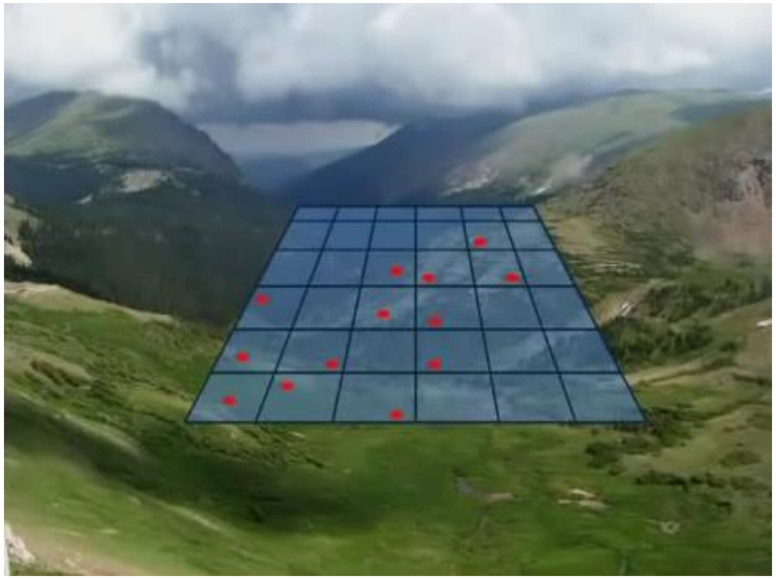
Αγγελική Καλοβελώνη[1], Thomas Tscheulin[1], Ante Vujic[2], Θεοδώρα Πετανίδου[1]

[1] Εργαστήριο Βιογεωγραφίας και Οικολογίας, Τμήμα Γεωγραφίας, Πανεπιστήμιο Αιγαίου.
[2] Department of Biology and Ecology, University of Novi Sad, Serbia

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

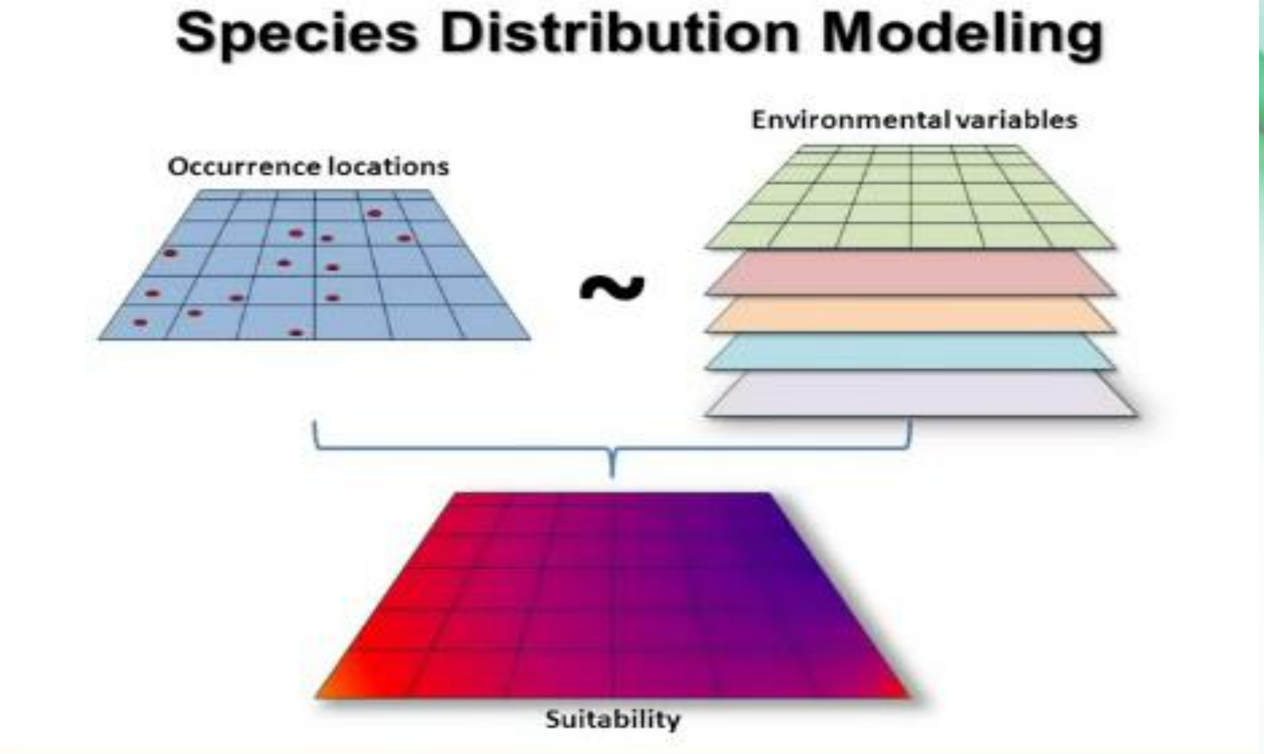
Species distribution modelling

Important tool: Species distribution models



Statistical models using species occurrence data and environmental data

Species distribution models



- **Definition of suitability**

Hoverflies and their importance

- 6000 species – 188 genera
- important pollinators (natural vegetation - crops)
- feed on pollen and nectar
- not well studied

Merodon clavipes

Merodon species on the Balkans (data – University of Novi Sad, Melissotheque of the Aegean)

1) **Generalists** (*M. armipes*, *M. aberrans*, *M. clavipes* και *M. nigritarsis*),
2) **Mountain species** (*M. cinereus* και *M. moenium*),
3) **Mediterranean species** (*M. albifrons, M. avidus*, *M. erivanicus* και *M. funestus*)
4) **Eastern Mediterranean species** (*M. spinitarsis* και *M. velox*)

Modelling

Occurrence points
(>30)

Bioclimatoic data
(WorldClim)

x 2 pseudo-absence sampling

Regression methods

- Generalised Linear Models (GLM)
- Multivariate Adaptive Regression Splines (MARS)

Classification methods

- Classification Tree Analysis (CTA)
- Flexible Discriminate Analysis (FDA)

Machine learning methods

- Generalized Boosting Model (GBM)
- Random Forests (RF)
- Maximum Entropy (MaxEnt)

Cross validation
80 / 20

Μετατροπή σε παρουσία / απουσία:

⇓

Επιλογή καλύτερων μοντέλων
(TSS)

⇓

Ensemble modelling

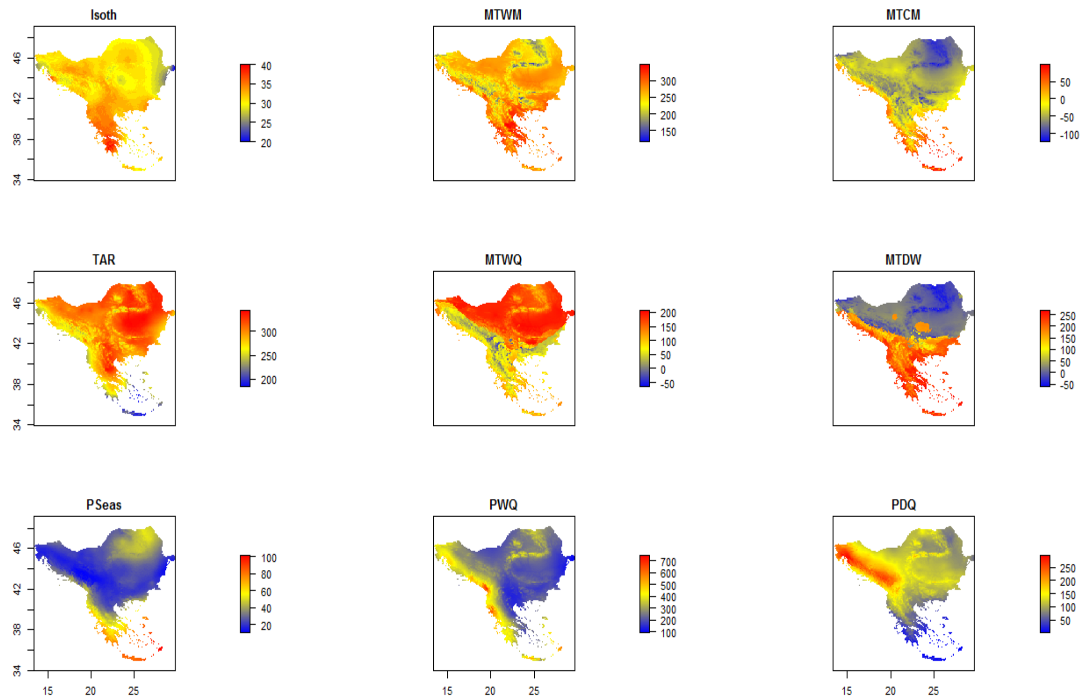
⇓

Consensus outcome

V=Bioclimatic variables

Bioclimatic variables used for modeling.

Variable	Description
Isoth	Isothermality
MTWM	Max Temperature of Warmest month
MTCM	Min Temperature of Coldest month
TAR	Temperature Annual Range
MTWQ	Mean Temperature of Wettest Quarter
MTDQ	Mean Temperature of Driest Quarter
PSeas	Precipitation Seasonality
PWQ	Precipitation of Wettest Quarter
PDQ	Precipitation of Driest Quarter



Pearson's correlation coefficient between selected predictors.

	Isoth	MaxTWM	MinTWM	TAR	MTWQ	MTDW	PSeas	PWQ
Isoth								
MTWM	0.4064							
MTCM	0.3142	0.6689						
TAR	0.0545	0.2691	-0.5359					
MTWQ	-0.2991	0.1870	-0.2319	0.5129				
MTDW	0.4754	0.4944	0.7456	-0.4045	-0.5920			
PSeas	0.2905	0.2627	0.5077	-0.3595	-0.0901	0.3494		
PWQ	0.2907	-0.1398	0.3010	-0.5487	-0.4248	0.2769	0.4679	
PDQ	-0.1604	-0.4745	-0.3910	0.0323	-0.2006	-0.2544	-0.6904	0.2410

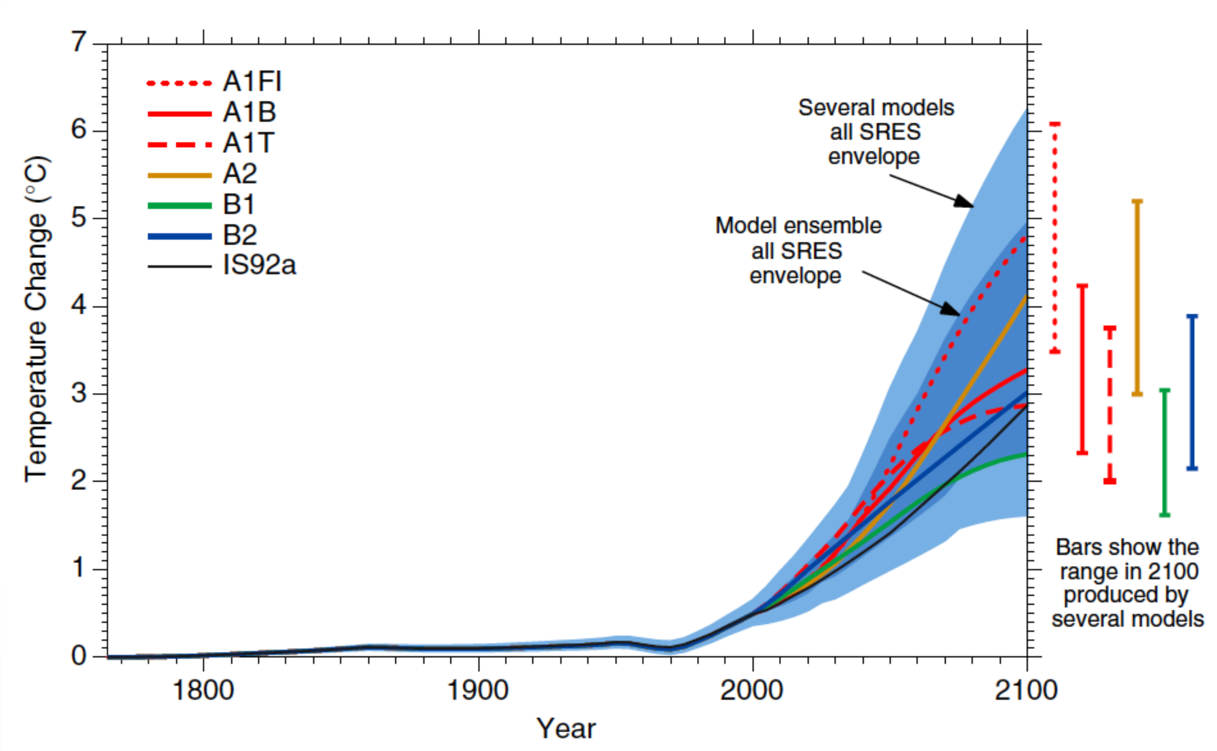
Modelling future distributions

Bioclimatic variables: 4th evaluation report of the Intergovernmental Panel on Climate Change (IPCC). Available from the Climate Change, Agriculture and Food Security research program (CCAFS, http://ccafs-climate.org)

Time frames:

α) 2040-2069 (2050),

β) 2070-2099 (2080)



Climatic scenaria:

a) A1B

b) A2

c) B1

Climatic models: mpi echam5, ukmo hadcm3

Calculations of variables:

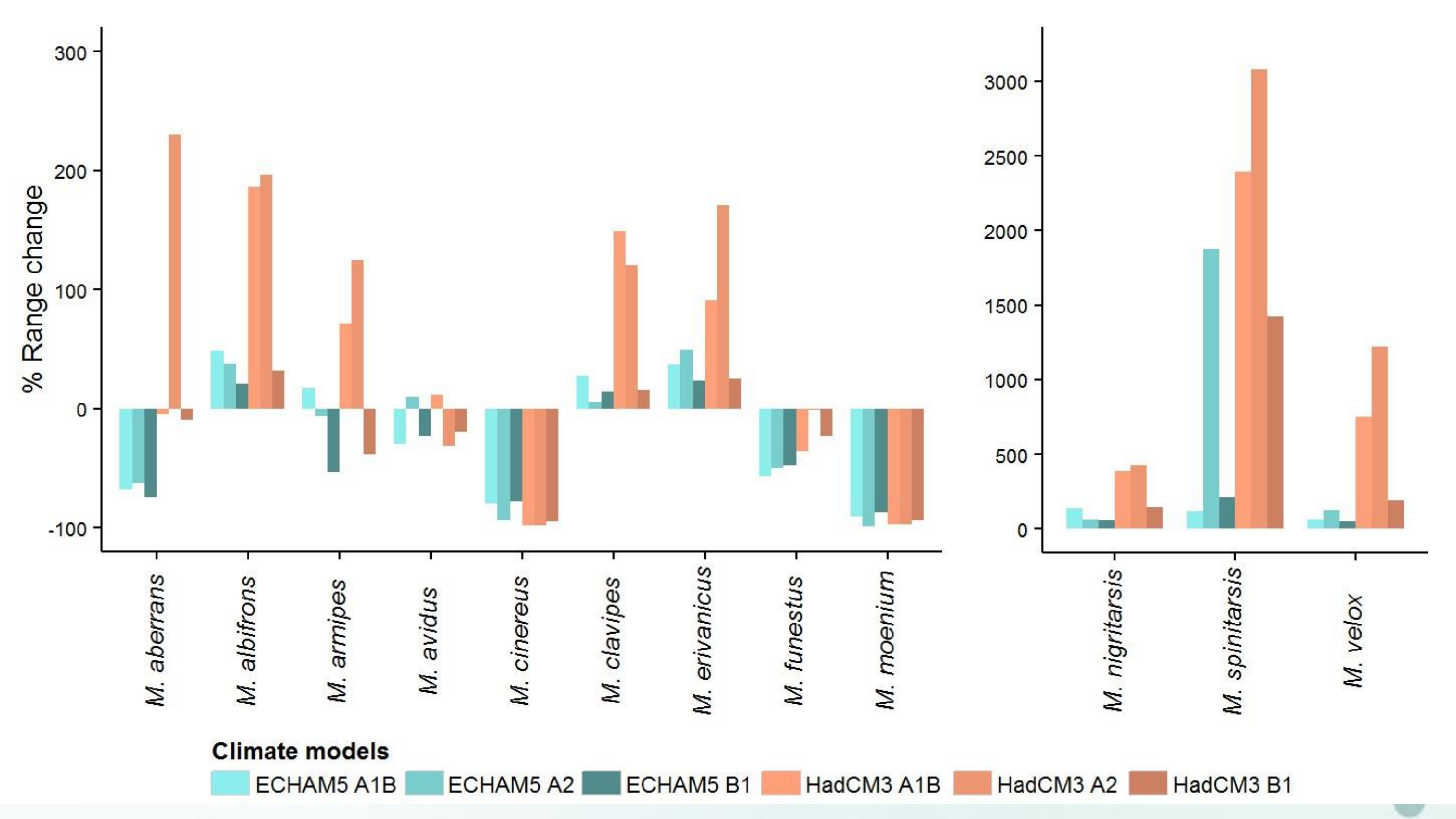
a) Percentage reduction/increase
b) Range change: percentage increase - percentage decrease
c) Overlap: percentage of common cells between current and future possible distribution
d) Species richness and species turnover for two dispersal scenarios (unrestricted dispersal, no dispersal)

Range change

The percentage gain, loss and overlap between the current and the future predicted area under the HadCM3 climate model in 2080.

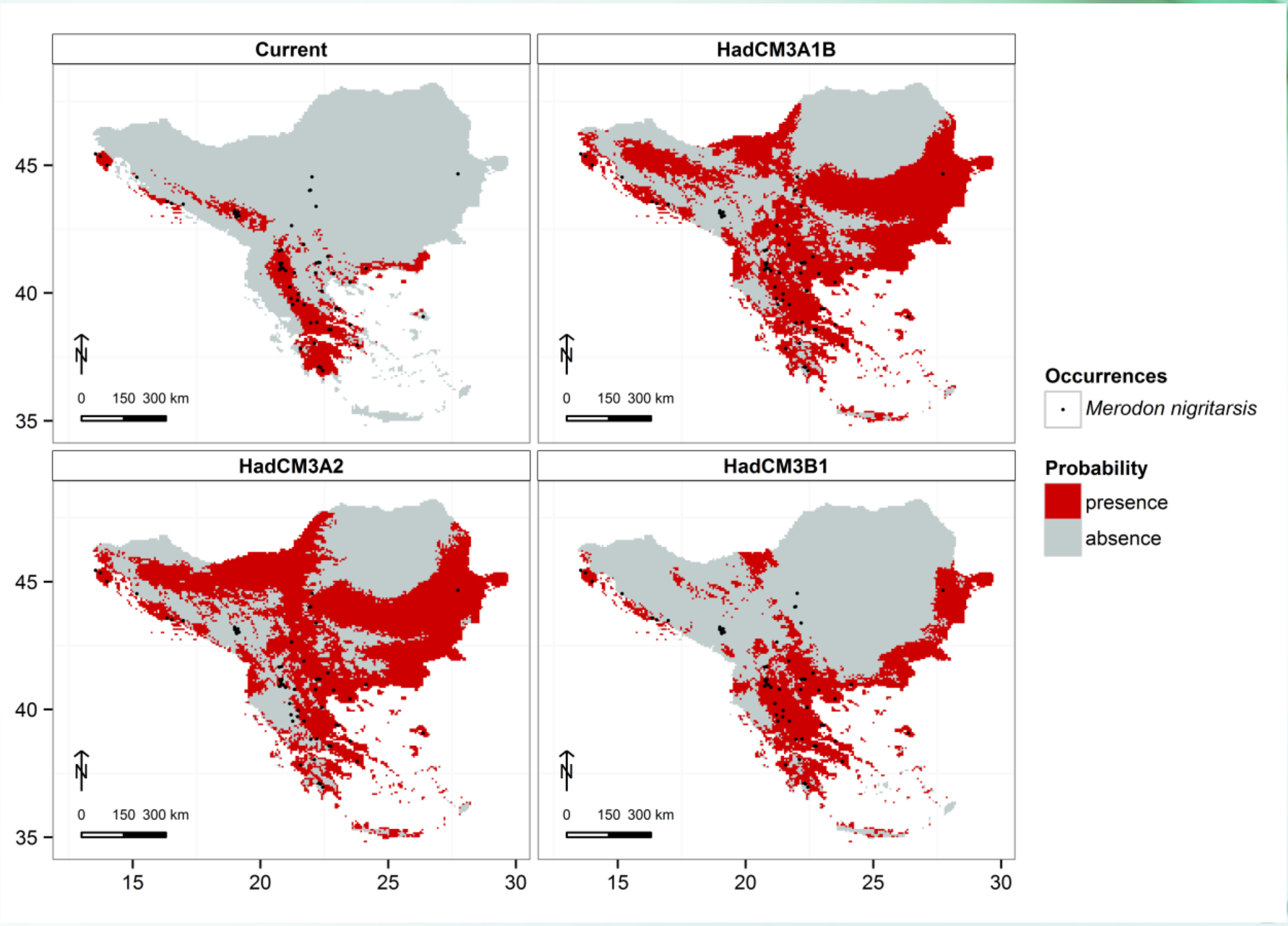
Species	HadCM3 A1B			HadCM3 A2			HadCM3 B1		
	gain (%)	loss (%)	overlap (%)	gain (%)	loss (%)	overlap(%)	gain (%)	loss (%)	overlap(%)
M. aberrans	18.58	**86.23**	9.61	29.58	**91.89**	7.75	7.83	**82.08**	14.52
M. albifrons	63.62	14.73	22.63	51.02	13.61	21.68	32.75	12.23	35.65
M. armipes	63.09	45.78	10.93	51.61	57.73	11.12	16.74	69.87	12.38
M. avidus	14.86	44.21	32.22	17.65	40.85	33.20	9.74	41.27	35.50
M. cinereus	0.21	**79.85**	2.13	0.00	**94.25**	1.83	0.00	**77.68**	5.29
M. clavipes	45.55	17.85	22.65	29.55	23.43	24.45	39.38	25.57	30.96
M. erivanicus	54.17	17.58	31.17	62.29	12.96	24.95	44.66	20.86	36.65
M. funestus	3.78	60.43	32.42	4.21	53.84	34.31	5.46	53.29	30.81
M. moenium	2.21	**92.42**	0.73	0.08	**99.01**	0.51	0.97	**87.68**	2.99
M. nigritarsis	163.11	25.95	11.71	102.64	37.27	9.03	77.64	24.84	21.05
M. spinitarsis	130.74	15.87	3.59	1885.14	7.36	3.03	225.25	14.29	5.43
M. velox	66.63	2.80	10.42	126.25	1.17	7.00	53.44	1.28	25.10

Range change



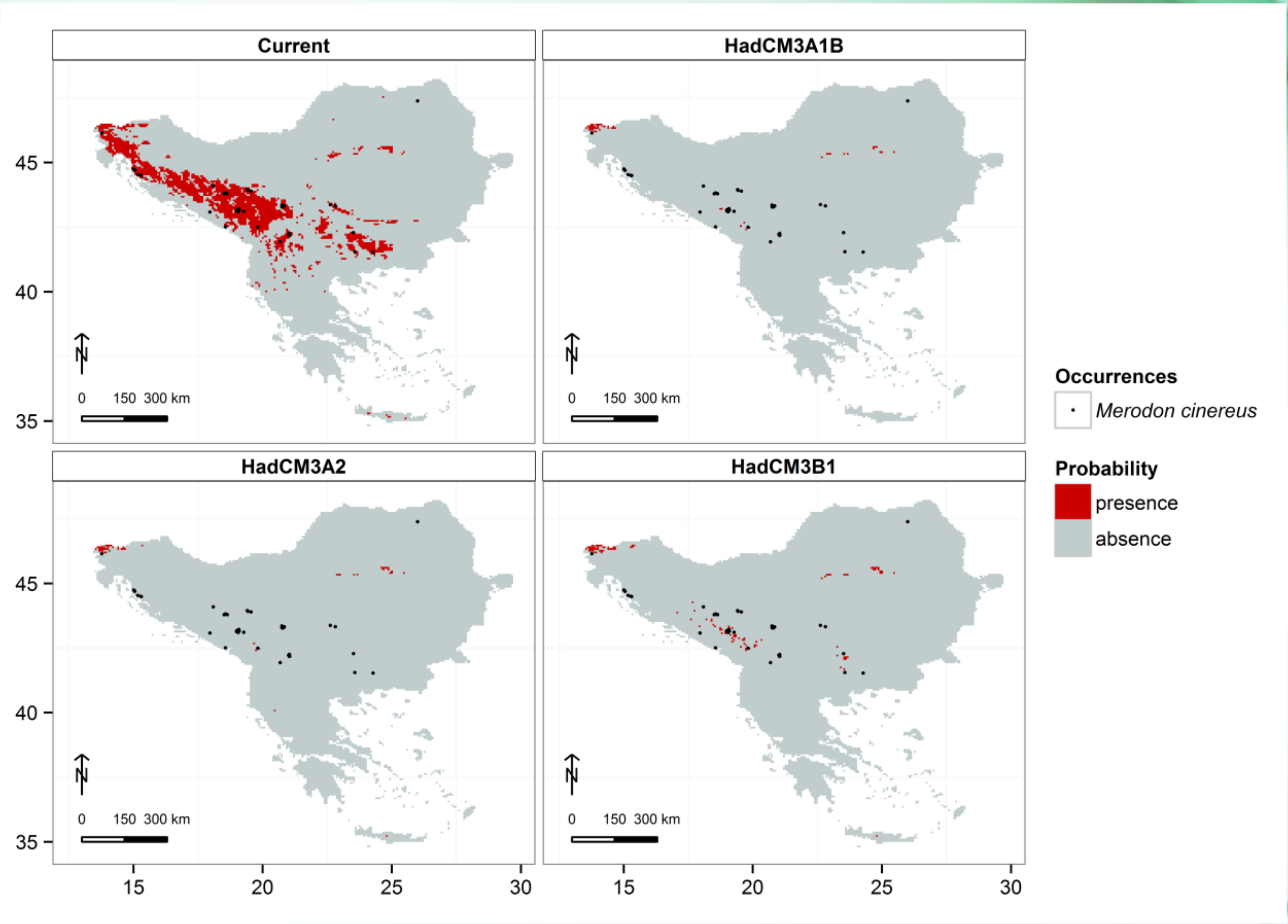
Estimation of species response

Generalist: *Merodon nigritarsis* – HadCM3 2080



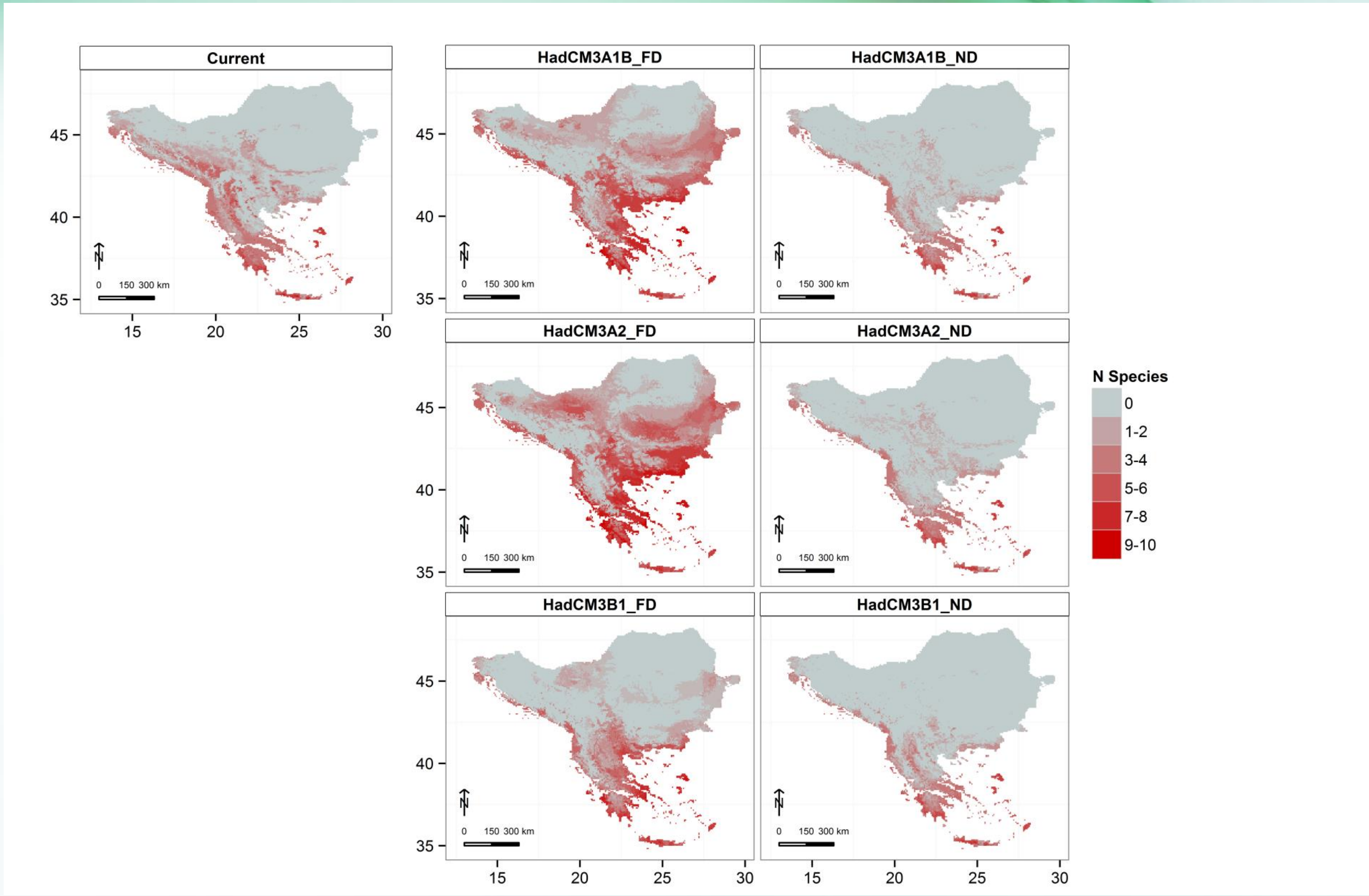
Estimation of species response

Mountain species: *Merodon cinereus* – HadCM3 2080



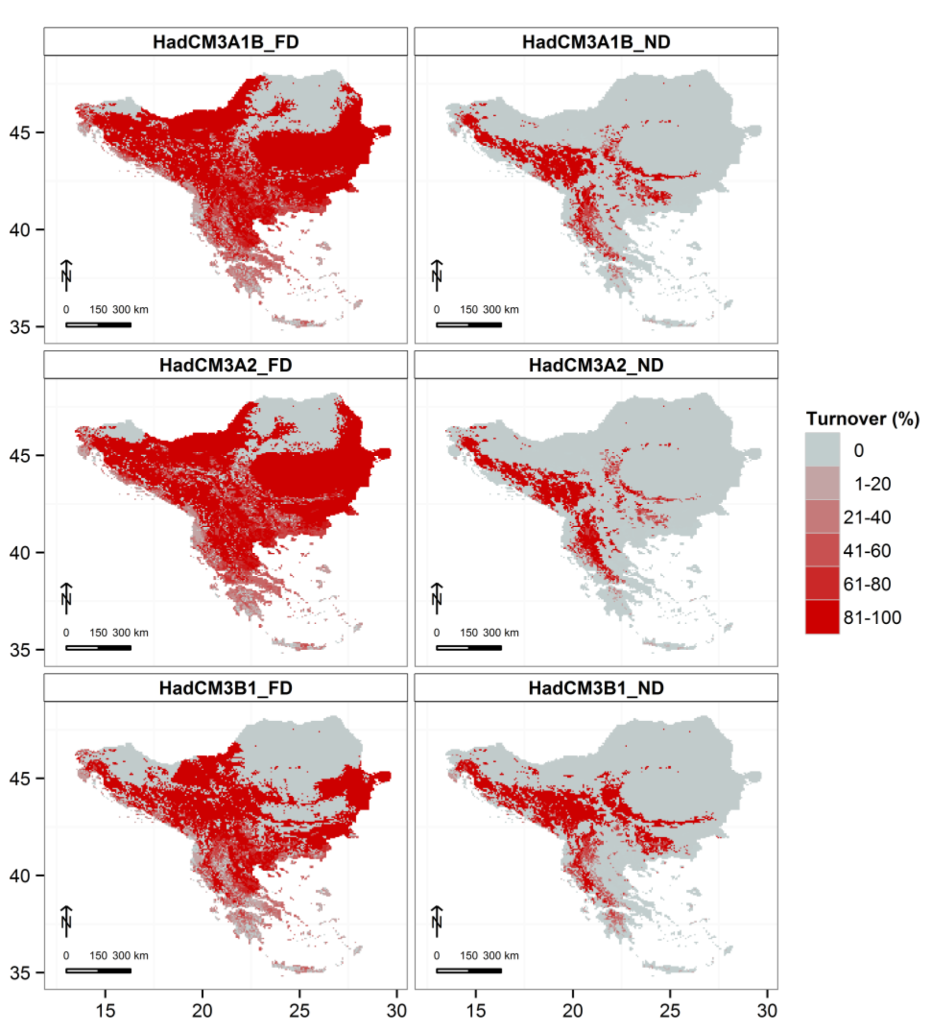
Species richness

HadCM3 – 2080



Species replacement (turnover)

HadCM3 – 2080



Conclusions

- Increased extinction probability for mountain species and species adapted to higher latitudes
- Increased expansion probability for generalist and Mediterranean species
- Increased species replacement (turnover) in the central and northwestern parts of the Balkans and retention of species compostions in the southern parts

Effect of elevated temperatures on the nectar production of four Mediterranean plants

Krista Takkis, Theodora Petanidou,
Thomas Tscheulin, Panagiotis Tsalkatis

European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
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NSRF
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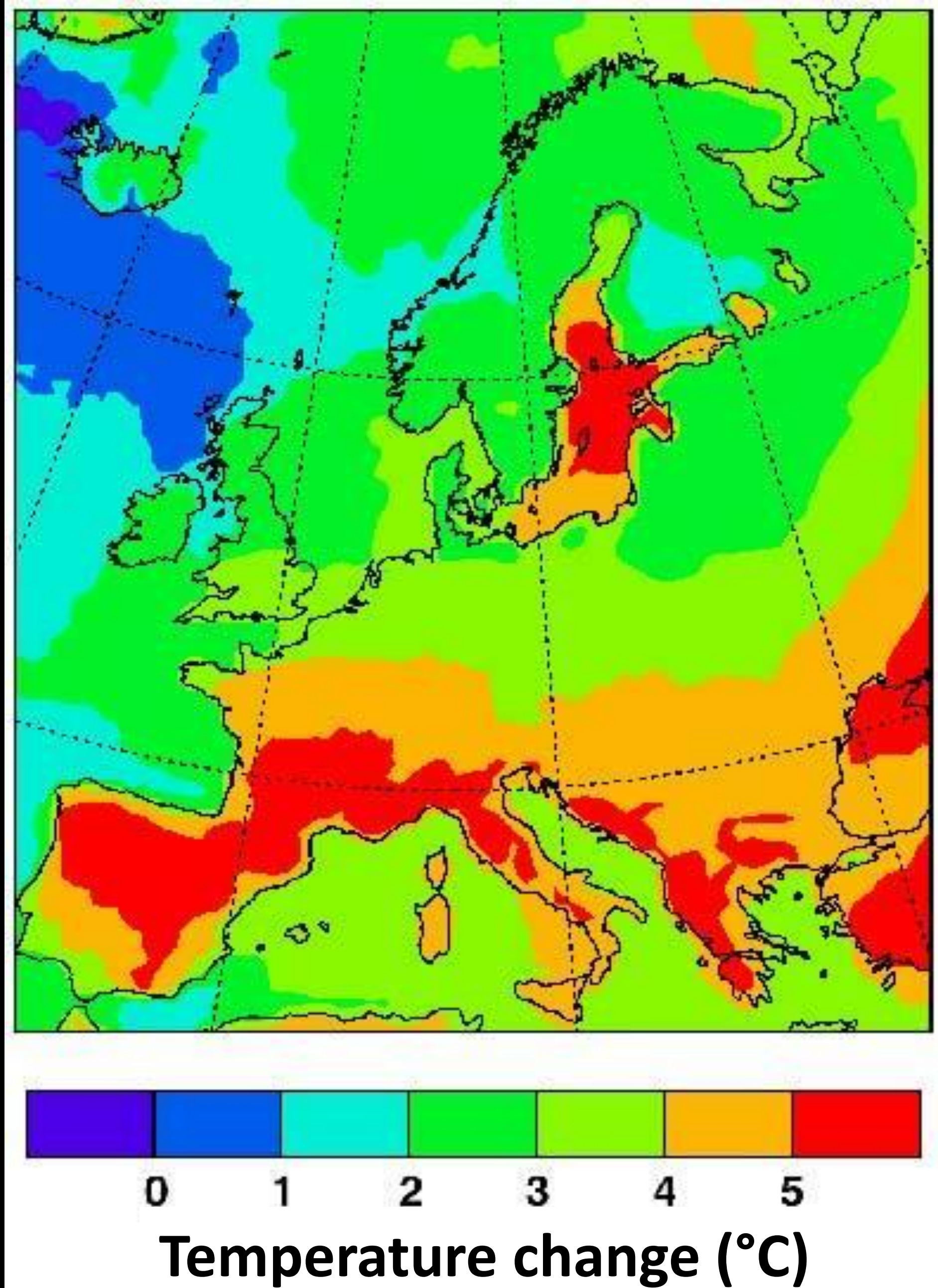
programme for development
EUROPEAN SOCIAL FUND

Climate change in the Mediterranean

Predicted effects on
- physiology
- phenology
- species interactions



Schär et al. 2004, Nature 427, 332-336

Four species of the phrygana

Asphodelus ramosus

Lavandula stoechas

Teucrium divaricatu m

Ballota acetabulosa

Experimental design

- Increasing temperature in **2–3 °C** steps every **3 days**
- Temperature range around the natural average

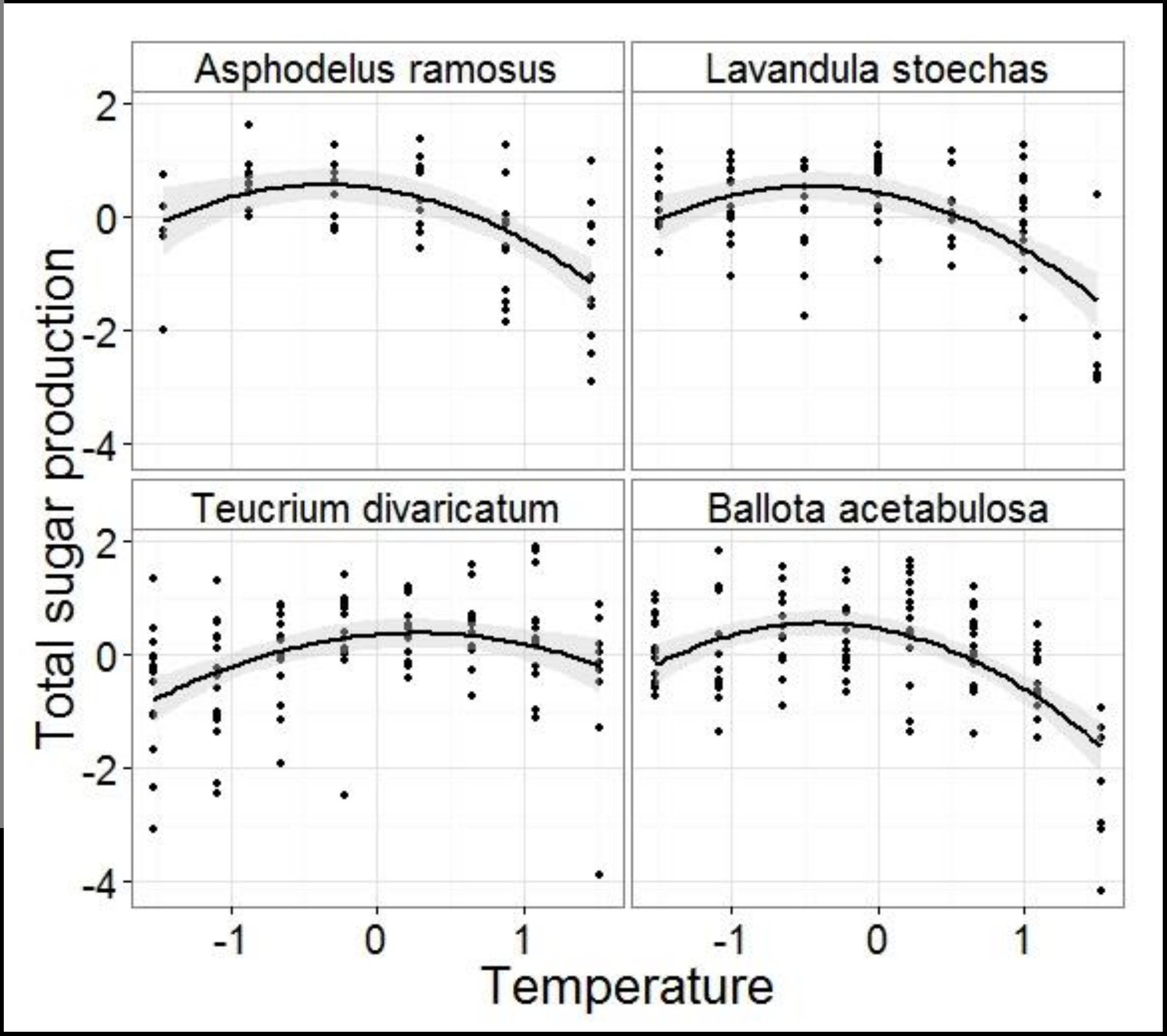
Control treatment outdoors

- For ***Teucrium divaricatum*** and ***Ballota acetabulosa***
- Near-natural conditions

Results – unimodal patterns in nectar volume and total sugar production

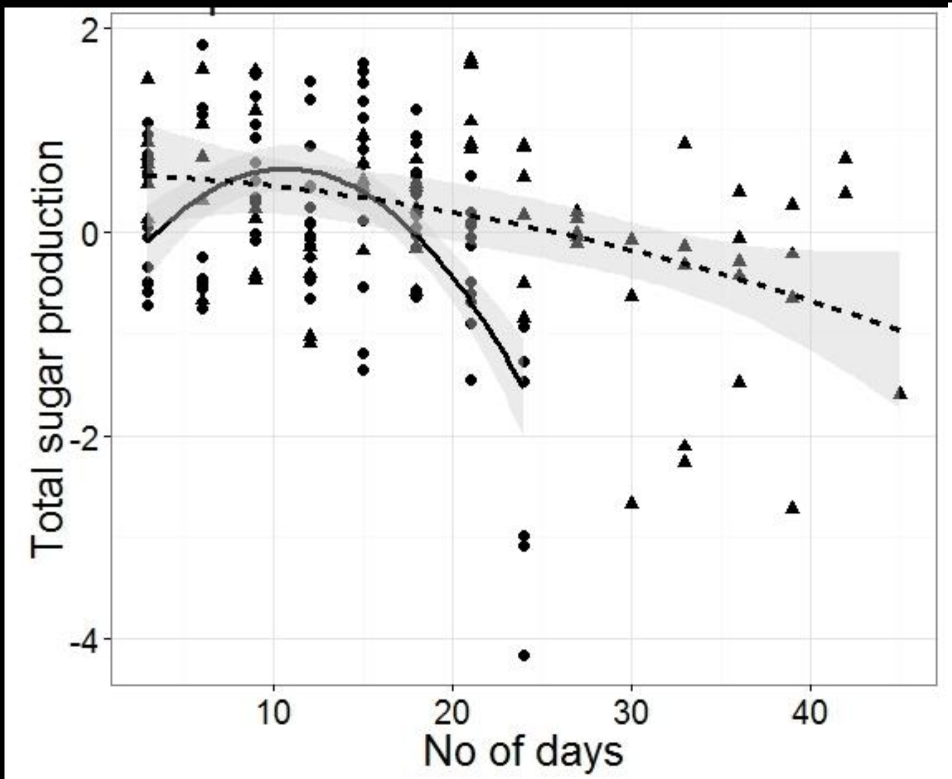
Optima:

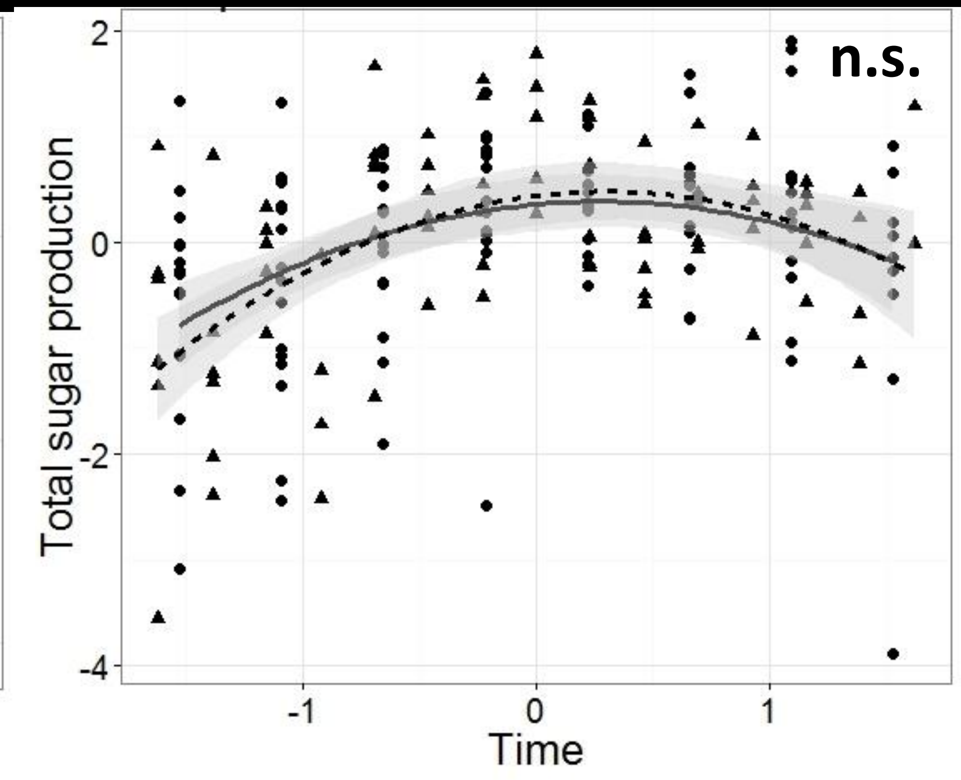
- *Asphodelus* ca 16°C
- *Lavandula* ca 20°C
- *Teucrium* ca 32°C
- *Ballota* ca 26–29°C



Effect of time: experiment vs control

Ballota acetabulosa *Teucrium divaricatum*





Conclusions

- Optimal conditions are close to natural avarage temperatures
- Stongly elevated temperatures can have negative effects on nectar production
- Species characteristics and the microhabitat can cause differences in plant response