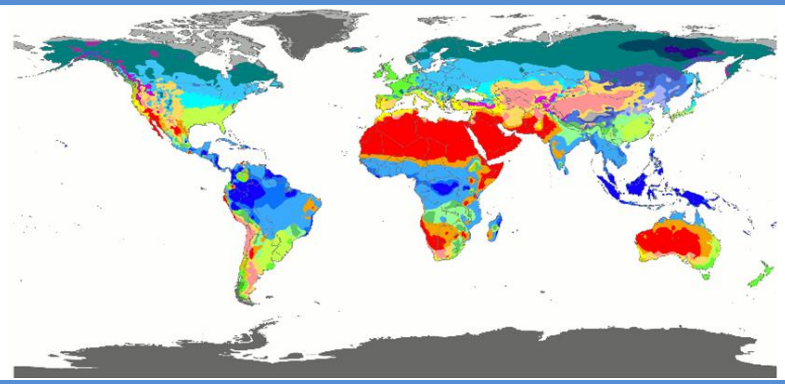
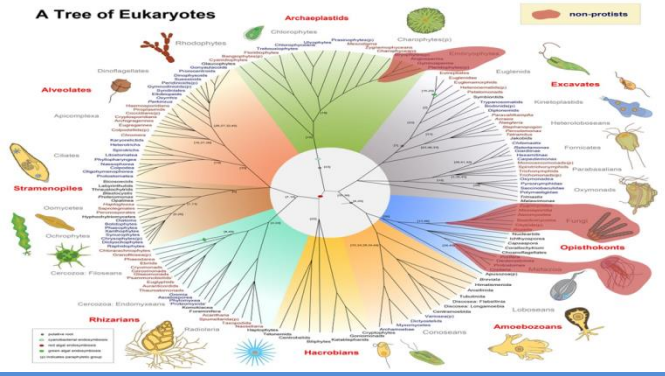


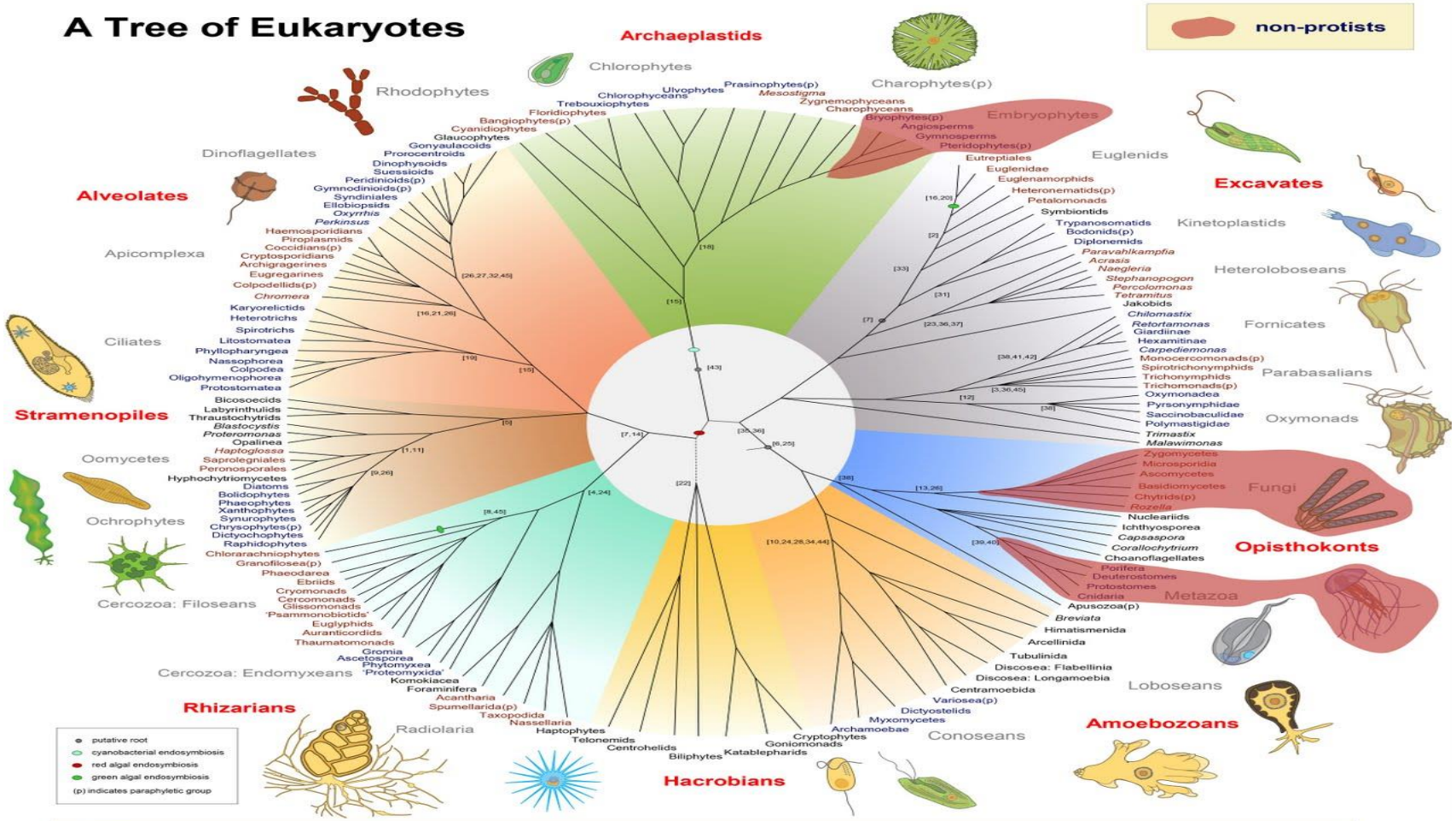

Climate and biodiversity: what modelling and data analysis can tell us

Lisbon, EGI Forum – EUBrazilCloudConnect – May 18th, 2005

Alain Franc
INRA, BioGeCo
INRIA Pleiade
Bordeaux

A Tree of Eukaryotes



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Ecology Letters, (2004) **7**: 1–15 doi: 10.1046/j.1461-0248.2003.00554.x

IDEAS AND PERSPECTIVES

A comprehensive framework for global patterns in biodiversity

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Abstract

The present study proposes to reconcile the different spatial and temporal scales of regional species production and local constraint on species richness. Although interactions between populations rapidly achieve equilibrium and limit membership in ecological communities locally, these interactions occur over heterogeneous environments within large regions, where the populations of species are stably regulated through competition and habitat selection. Consequently, exclusion of species from a region depends on long-term regional-scale environmental change or evolutionary change among interacting populations, bringing species production and extinction onto the same scale and establishing a link between local and regional processes.

Keywords

Beta diversity, community, competition, diversity, extinction, habitat breadth, local processes, regional processes, speciation, species richness.

Ecological Niche Modelling

Profile Techniques: BIOCLIM; DOMAIN; Ecological Niche Factor Analysis (ENFA); Mahalanobis distance

Regression-based Techniques: Generalized linear model (GLM); Generalized Additive Model (GAM); Multivariate Adaptive Regression Splines (MARS)

Machine Learning Techniques: MAXENT; Artificial Neural Networks (ANN); Genetic Algorithm for Rule Set Production (GARP); Boosted Regression Trees (BRT)/Gradient Boosting Machines (GBM); Random Forest (RF); Support Vector Machines (SVM)

Most niche modelling algorithms are available in the R packages 'dismo' and 'biomod2'.

The Collaboratory for Adaptation to Climate Change adapt.nd.edu has implemented an online version of openModeller that allows users to design and run openModeller in a high-performance, browser-based environment to allow for multiple parallel experiments without the limitations of local processor power.

From http://en.wikipedia.org/wiki/Environmental_niche_modelling

Usefulness of Bioclimatic Models for Studying Climate Change and Invasive Species

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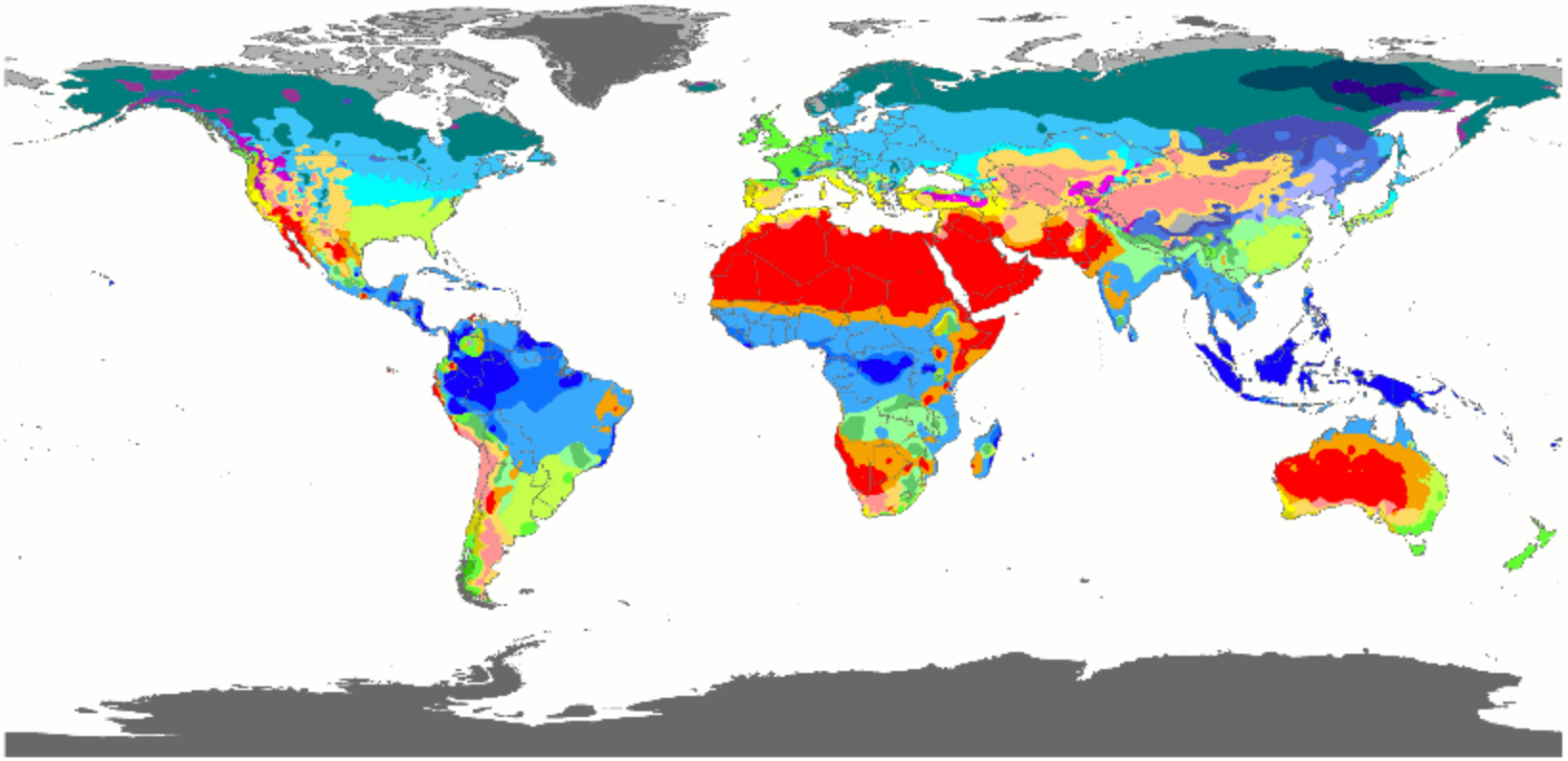
BOX 1. Key assumptions of bioclimatic models

- Biotic interactions are unimportant in determining geographic ranges or are constant over space and time.
- The genetic and phenotypic composition of species is constant over space and time.
- No dispersal limitation: species occur at all locations where climate is favorable and nowhere else.

BOX 2. Statistical methods often used for empirical bioclimatic models

- Logistic regression, generalized linear model (GLM)
- Generalized additive model (GAM)
- Climate envelope (e.g., BIOCLIM)
- Classification and regression tree (CART)
- Neural network (NN), genetic algorithm (e.g., GARP)

World map of Köppen-Geiger climate classification



Af	BWh	Csa	Cwa	Cfa	Dsa	Dwa	Dfa	ET
Am	BWk	Csb	Cwb	Cfb	Dsb	Dwb	Dfb	EF
Aw	BSh		Cwc	Cfc	Dsc	Dwc	Dfc	
	BSk				Dsd	Dwd	Dfd	

Contact : Murray C. Peel (mpeel@unimelb.edu.au) for further information

DATA SOURCE : GHCN v2.0 station data Temperature (N = 4,844) and Precipitation (N = 12,396)

PERIOD OF RECORD : All available

MIN LENGTH : ≥30 for each month.

RESOLUTION : 0.1 degree lat/long

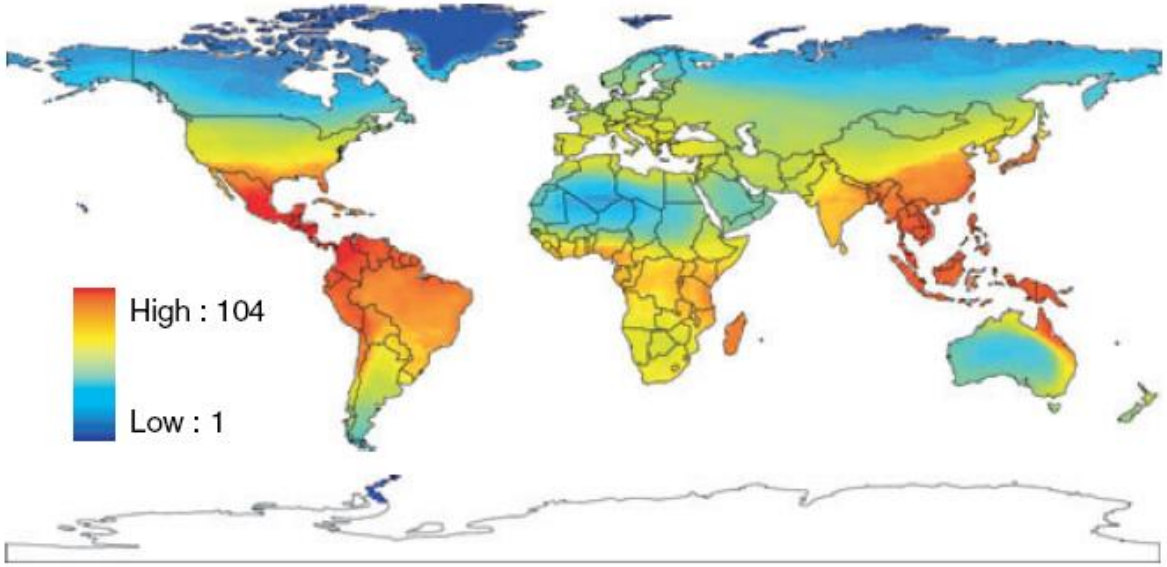


Figure 1 Global pattern in richness of 172 flowering plant families. Family richness per grid cell was calculated by summing the number of families represented in each grid cell. Richness increases going from blue to red. Relative richness values correspond closely to those estimated by Francis & Currie (2003) based upon a wider sample of angiosperm families, indicating that the subset of families used in the present analysis provide a good surrogate for total angiosperm diversity.

Jansson & Davies
Ecol. Let., 2008

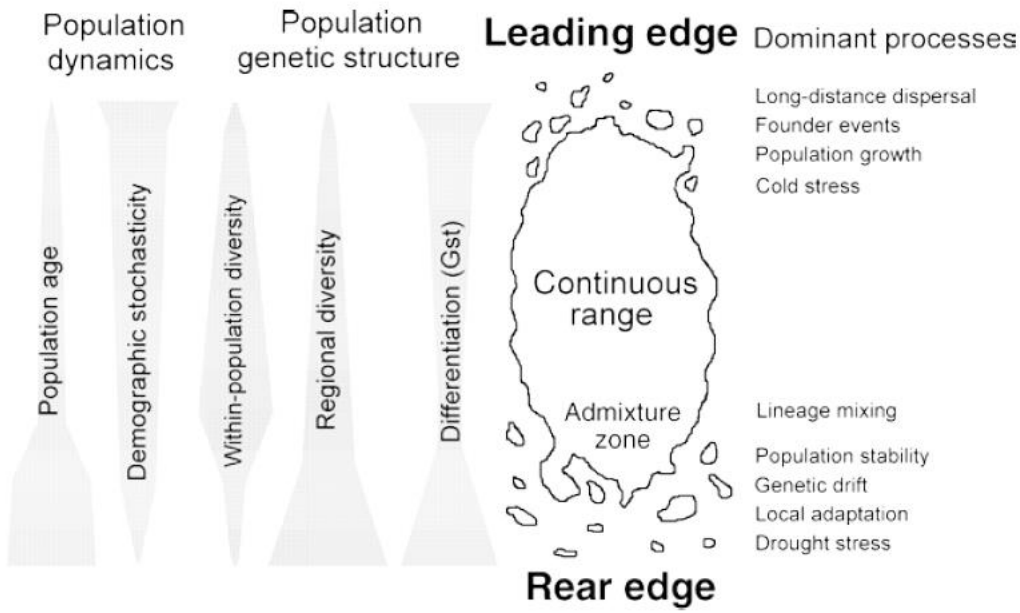


Figure 1 Population features and relevant processes at the leading and the rear edge of species ranges. The width of grey bars shown on the left hand indicates the quantity of features at the corresponding position within the range.

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IDEAS AND PERSPECTIVES

Conserving biodiversity under climate change: the rear edge matters

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Abstract
Modern climate change is producing poleward range shifts of numerous taxa, communities and ecosystems worldwide. The response of species to changing environments is likely to be determined largely by population responses at range margins. In contrast to the expanding edge, the low-latitude limit (rear edge) of species ranges remains understudied, and the critical importance of rear edge populations as long-term stores of species' genetic diversity and foci of speciation has been little acknowledged. We review recent findings from the fossil record, phylogeography and ecology to illustrate that rear edge populations are often disproportionately important for the survival and evolution of biota. Their ecological features, dynamics and conservation requirements differ from those of populations in other parts of the range, and some commonly recommended conservation practices might therefore be of little use or even counterproductive for rear edge populations.

Figure 3. Legend accompanying the maps.

Legend

1. Tropical rainforest
2. Monsoon or dry forest
3. Tropical woodland
4. Tropical thorn scrub and scrub woodland
5. Tropical semi-desert
6. Tropical grassland
7. Tropical extreme desert
8. Savanna
9. Broadleaved temperate evergreen forest
10. Montane tropical forest
11. Open boreal woodlands
12. Semi-arid temperate woodland or scrub
13. Tundra
14. Steppe-tundra
15. Polar and alpine desert
16. Temperate desert
17. Temperate semi-desert
18. Forest steppe
19. Montane mosaic
20. Alpine toundra
21. Subalpine parkland
22. Dry steppe
23. Temperate steppe grassland
24. Main taiga
25. Lakes and open water
26. Ice sheet and other permaner

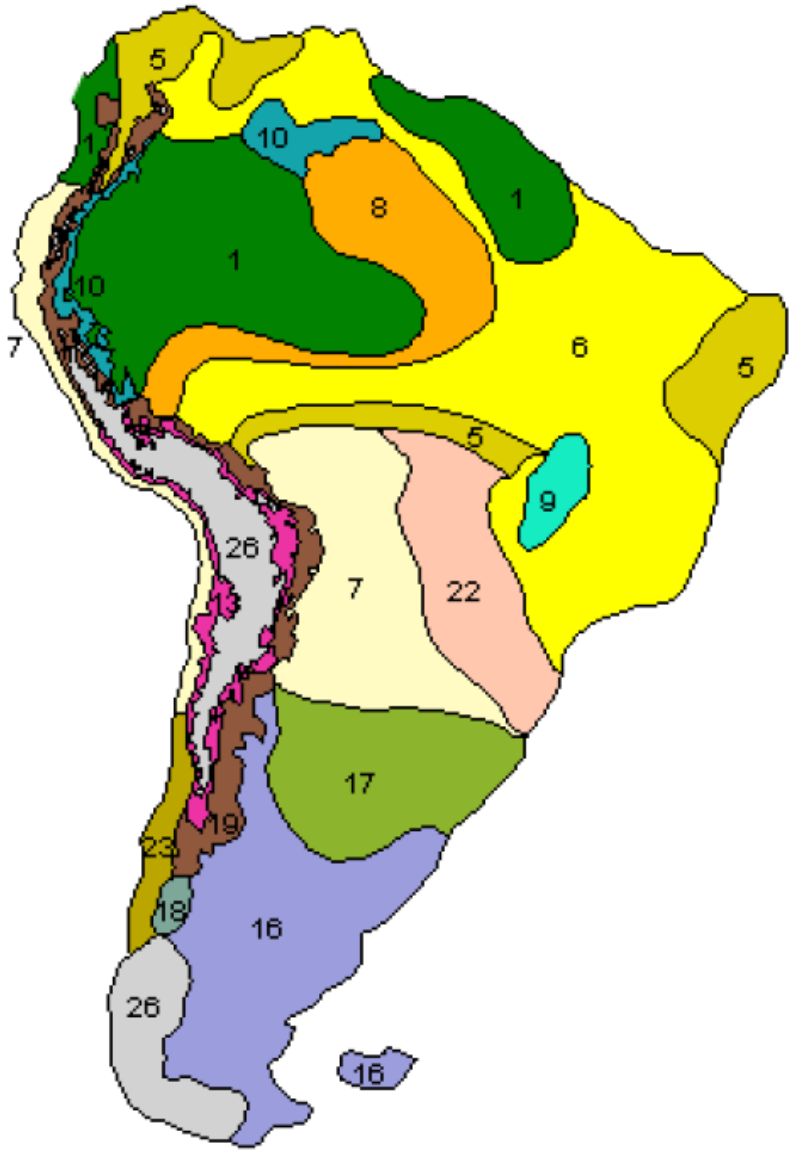

Figure 1. LGM extended coastlines (sea-level drop of 120m) computed from bathymetry (Smith and Sandwell, 1997).

Ray, N. and J. M. Adams. 2001. *Internet Archaeology* 11 (http://intarch.ac.uk/journal/issue11/rayad

A GIS-based Vegetation Map of the World at the Last Glacial Maximum (25,000-15,000 BP).

Amazonia Through Time: Andean Uplift, Climate Change, Landscape Evolution, and Biodiversity

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The Amazonian rainforest is arguably the most species-rich terrestrial ecosystem in the world, yet the timing of the origin and evolutionary causes of this diversity are a matter of debate. We review the geologic and phylogenetic evidence from Amazonia and compare it with uplift records from the Andes. This uplift and its effect on regional climate fundamentally changed the Amazonian landscape by reconfiguring drainage patterns and creating a vast influx of sediments into the basin. On this "Andean" substrate, a region-wide edaphic mosaic developed that became extremely rich in species, particularly in Western Amazonia. We show that Andean uplift was crucial for the evolution of Amazonian landscapes and ecosystems, and that current biodiversity patterns are rooted deep in the pre-Quaternary.

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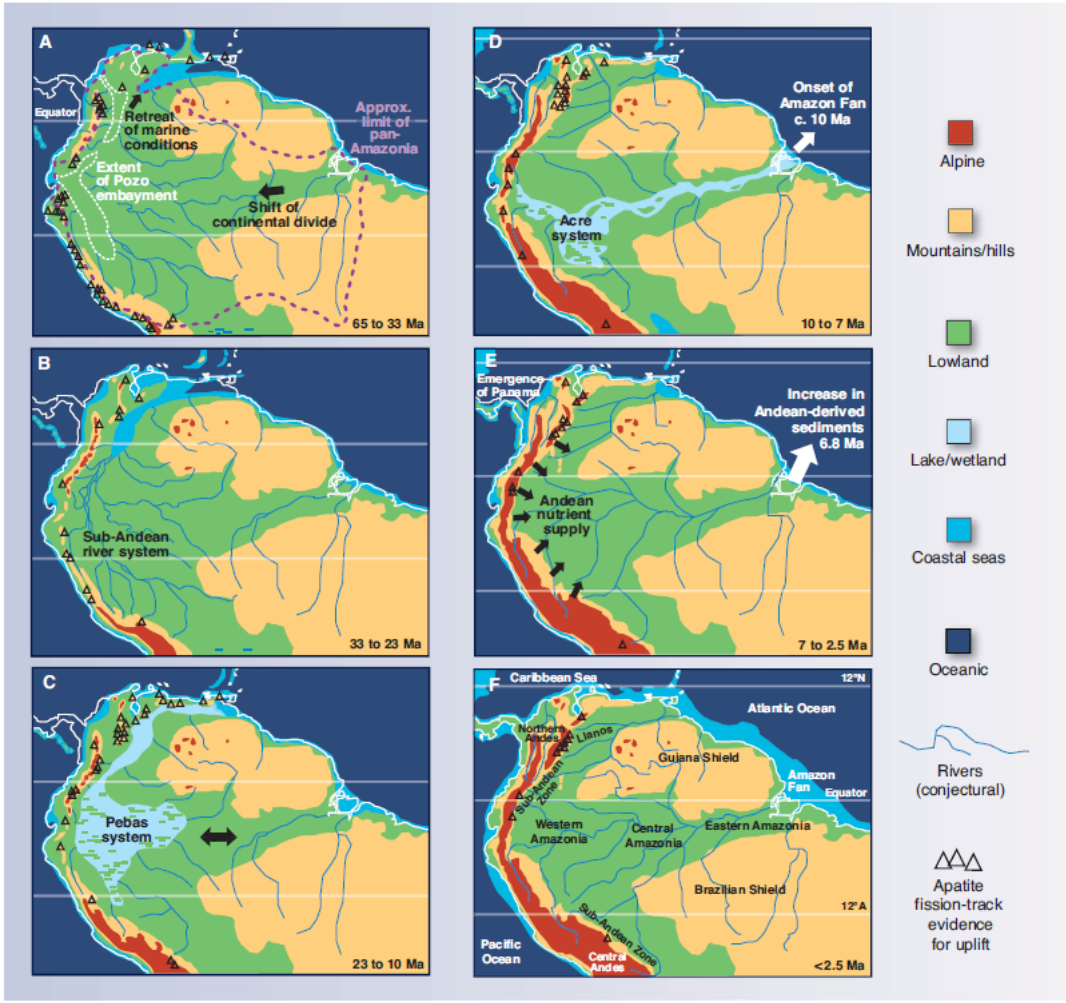
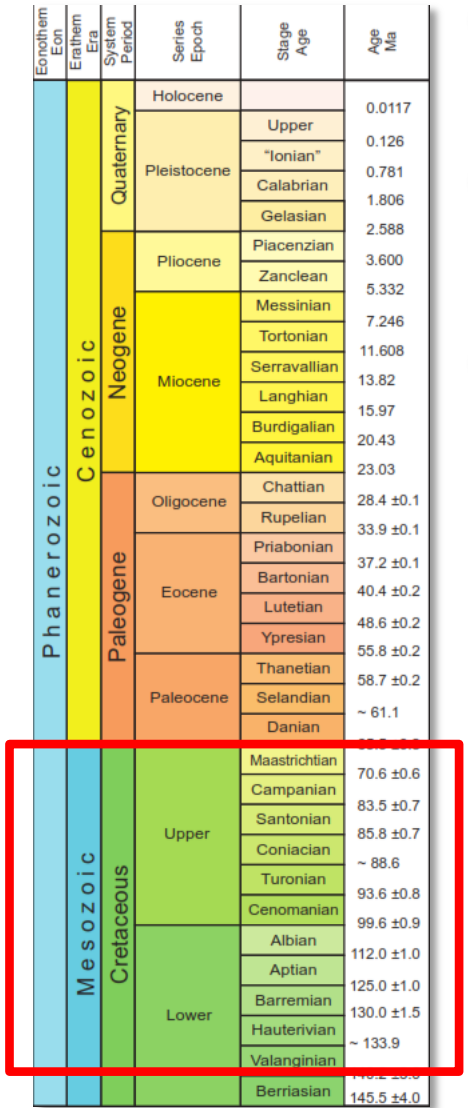


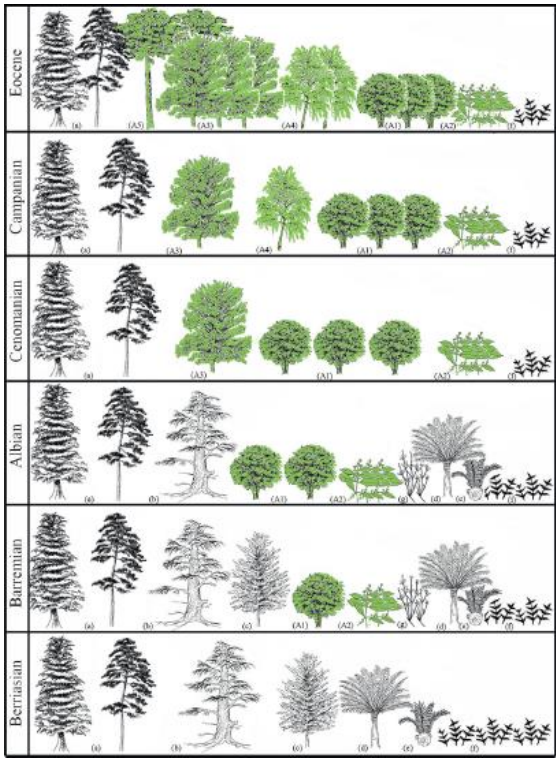
Fig. 1. Paleogeographic maps of the transition from "cratonic" (**A** and **B**) to "Andean"-dominated landscapes (**C** to **F**). (**A**) Amazonia once extended over most of northern South America. Breakup of the Pacific plates changed the geography and the Andes started uplifting. (**B**) The Andes continued to rise with the main drainage toward the northwest. (**C**) Mountain building in the Central and Northern Andes (~12 Ma) and wetland progradation into Western Amazonia. (**D**) Uplift of the Northern Andes restricted "pan-Amazonia" and facilitated allopatric speciation and extirpation [e.g., (*21*)]. (**E**) The megawetland disappeared and *terra firme* rainforests expanded; closing of Panama Isthmus and start of GABI. (**F**) Quaternary. Note that South America migrated northward during the course of the Paleogene.

- **Angiosperms: lower Cretaceous**
- **First Angiosperm fossil : China, Barremian (Yixian Fm)**
- **Major biotic evolution**
  Transition in the Mesozoic floras.
- **350 000 Angiosperm species**



Angiosperms

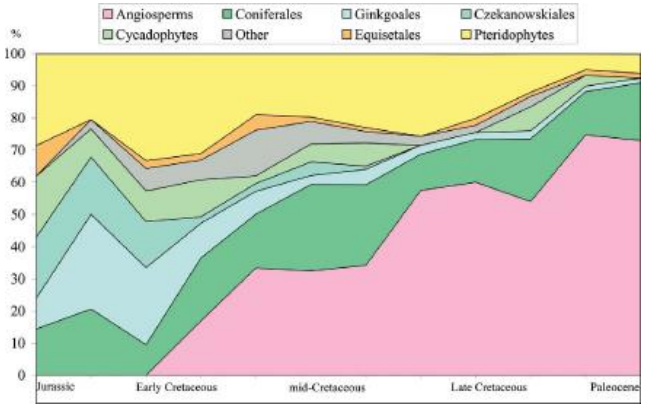
Conifers, ferns, cycads

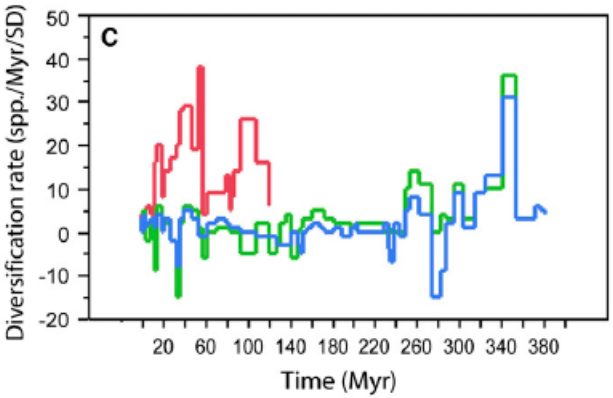


Why their radiation is so surprising ?

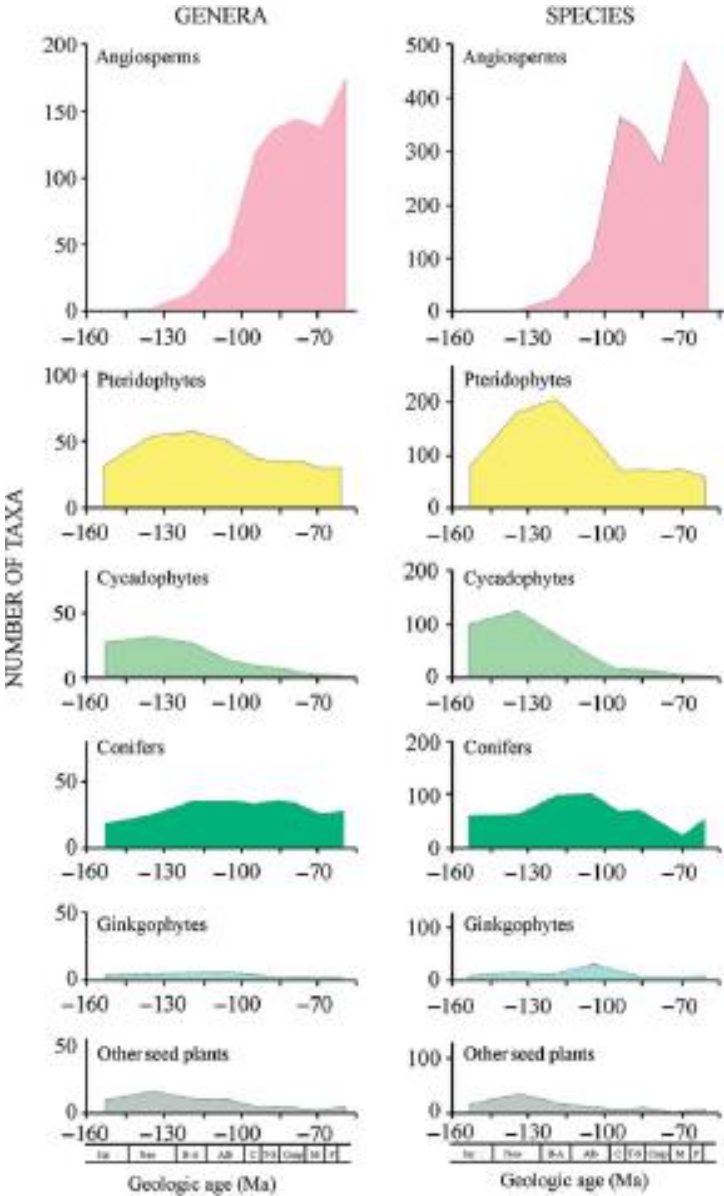
- **High** and **rapid** diversification (350 000 species)
- Sustained tempo of speciation
- Dramatic rise to ecological dominance (in 30 Ma)

Friis & Crane 2011

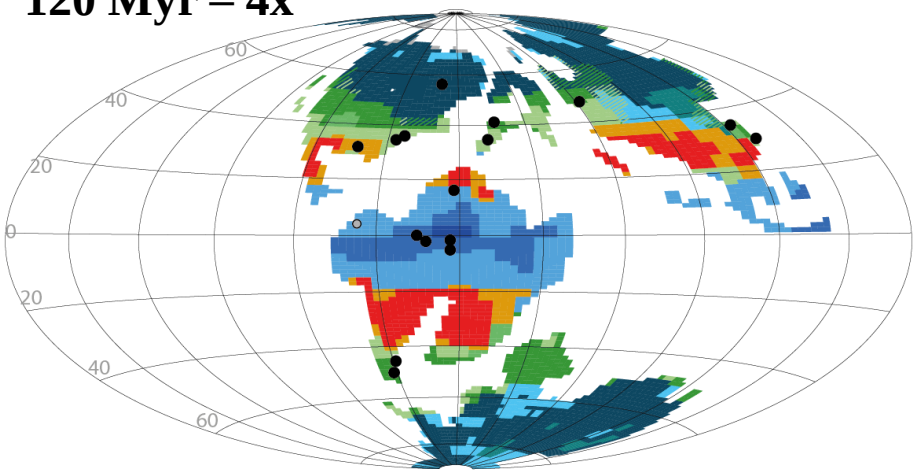




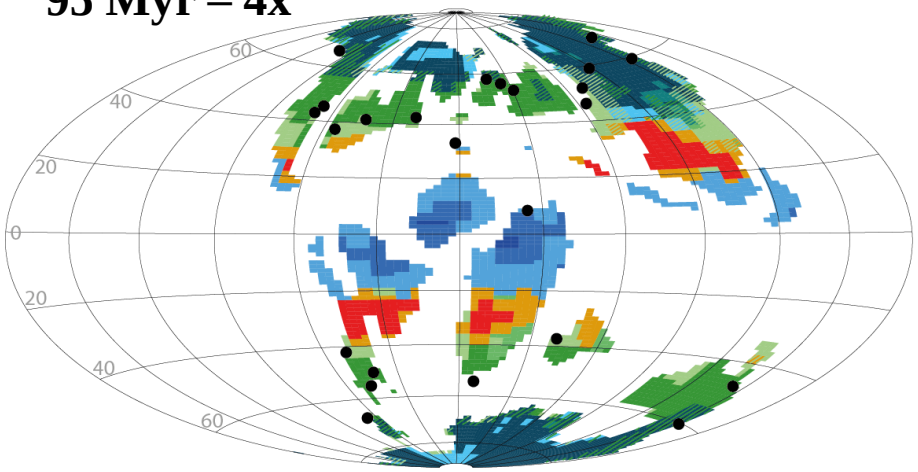
Crepet & Niklas, 2009 »



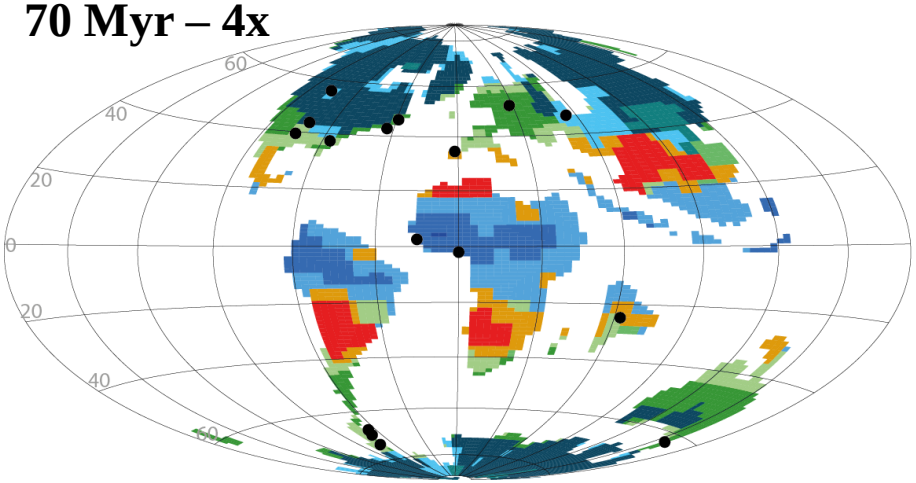
120 Myr – 4x

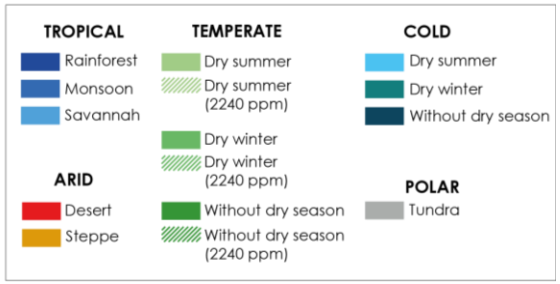


95 Myr – 4x



70 Myr – 4x

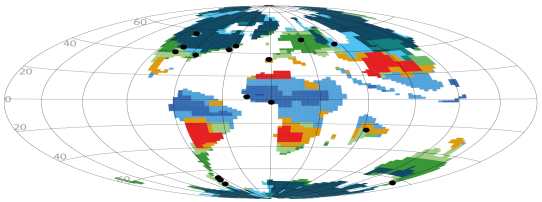




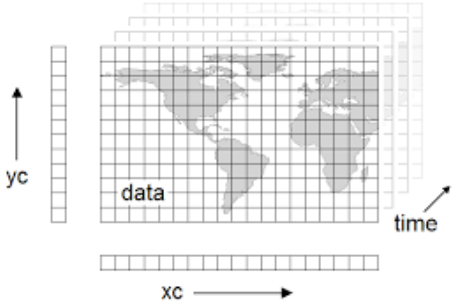
● Angiosperms localities

- 120 My : Low diversification
- 95 Myr – 70 My : high diversification and migration to higher latitudes

A tool for linking paleoclimate with paleoniches



NetCDF files
- Temperatures
- Precipitations

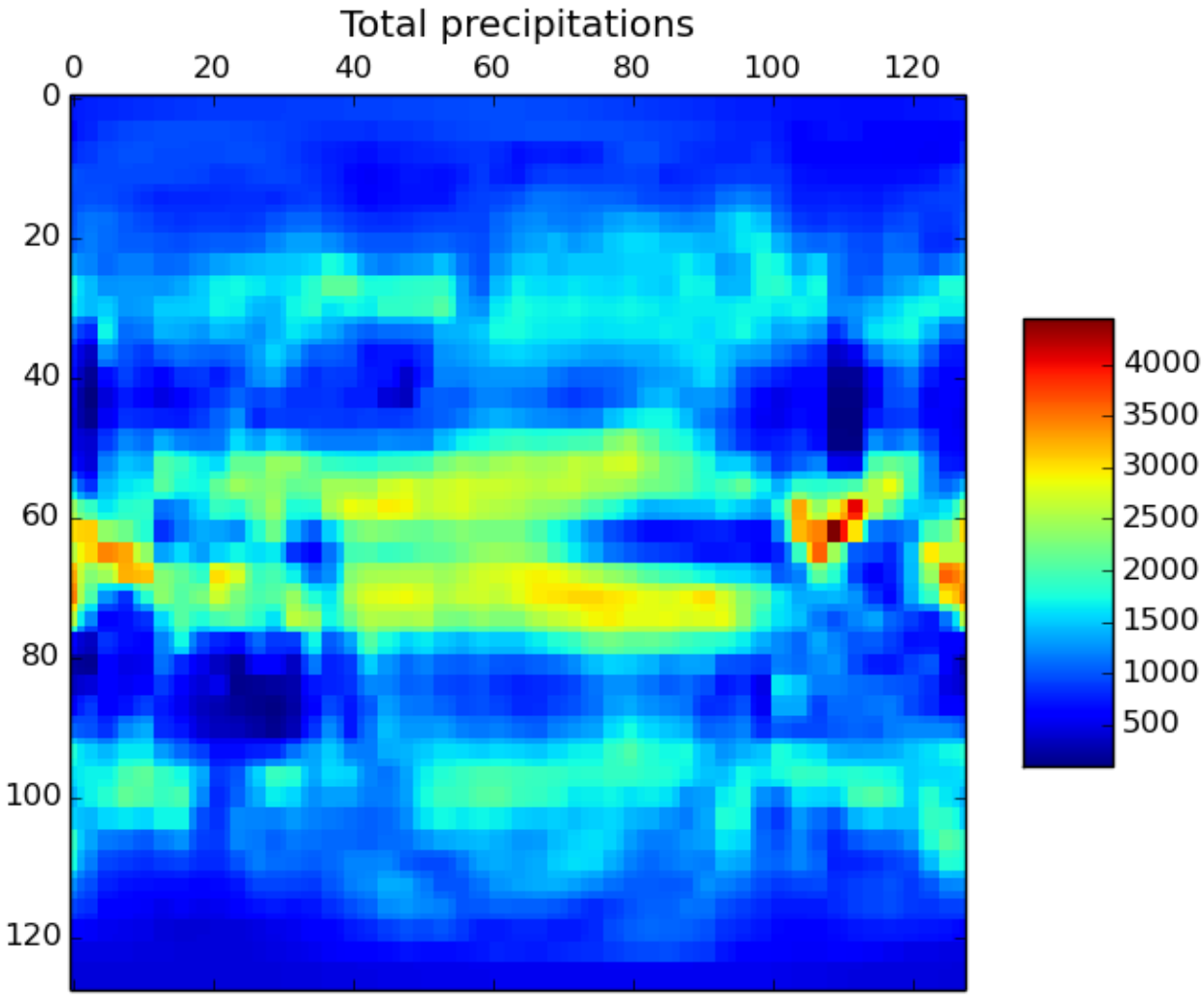



```
import netCDF4 as nc
dataset4test = '../netcdf_data/70Ma_8x.nc'
data = nc.Dataset(dataset4test, 'r', format='NETCDF4')
[…]
```

```
$ ./python-prg -i xxx -args […]
```

Project team

Galaxy server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1500
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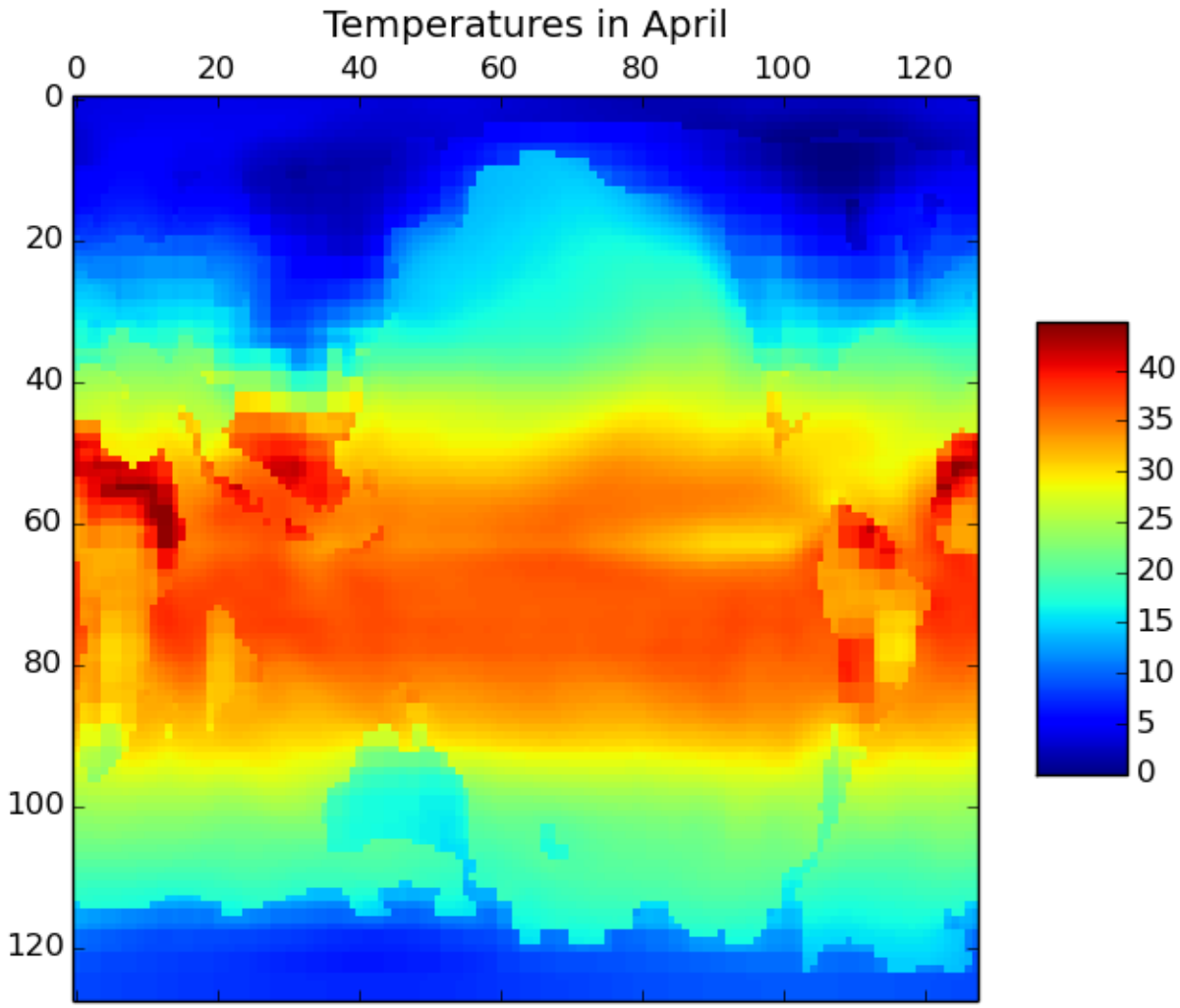
Temperatures in April
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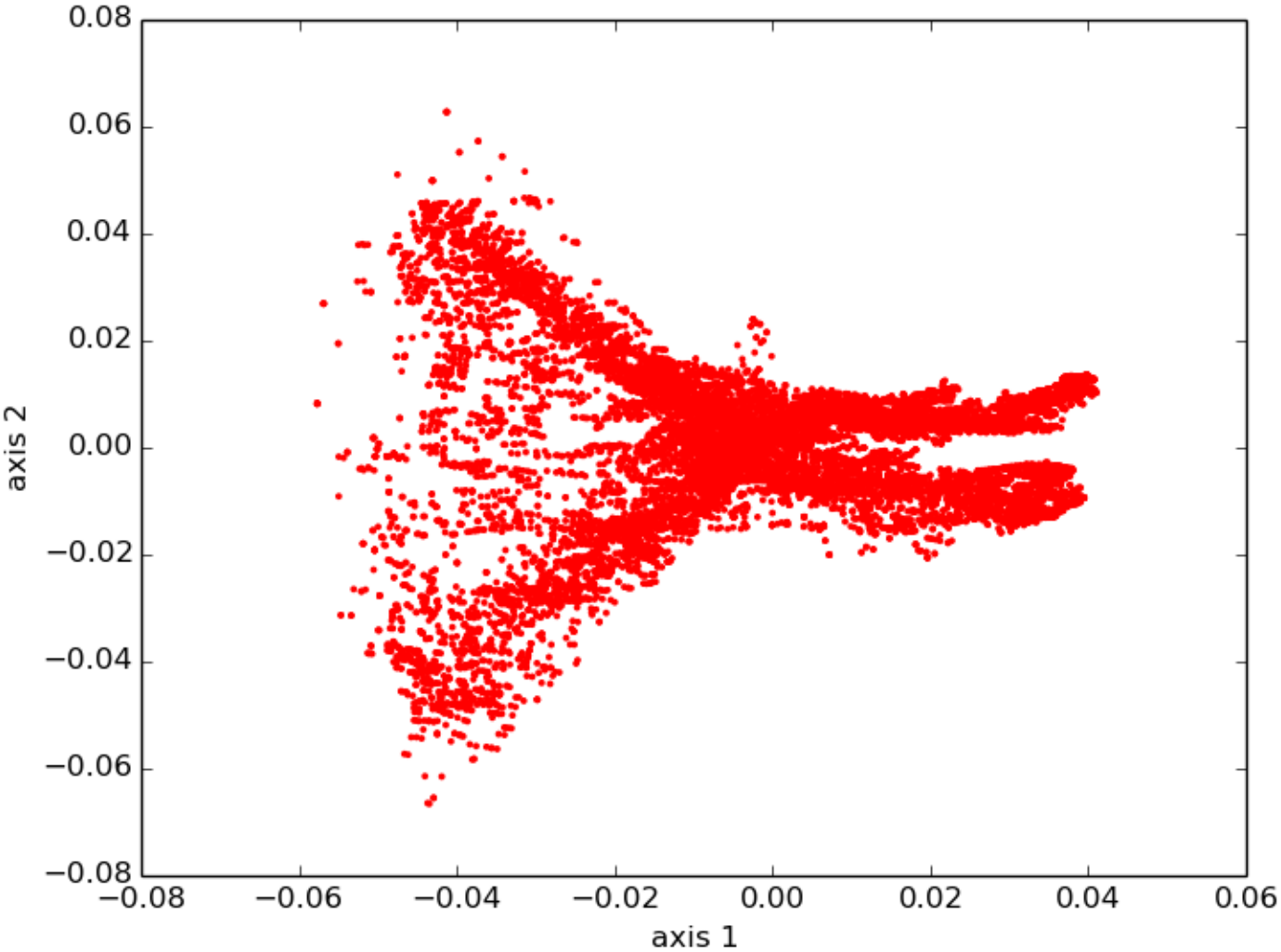
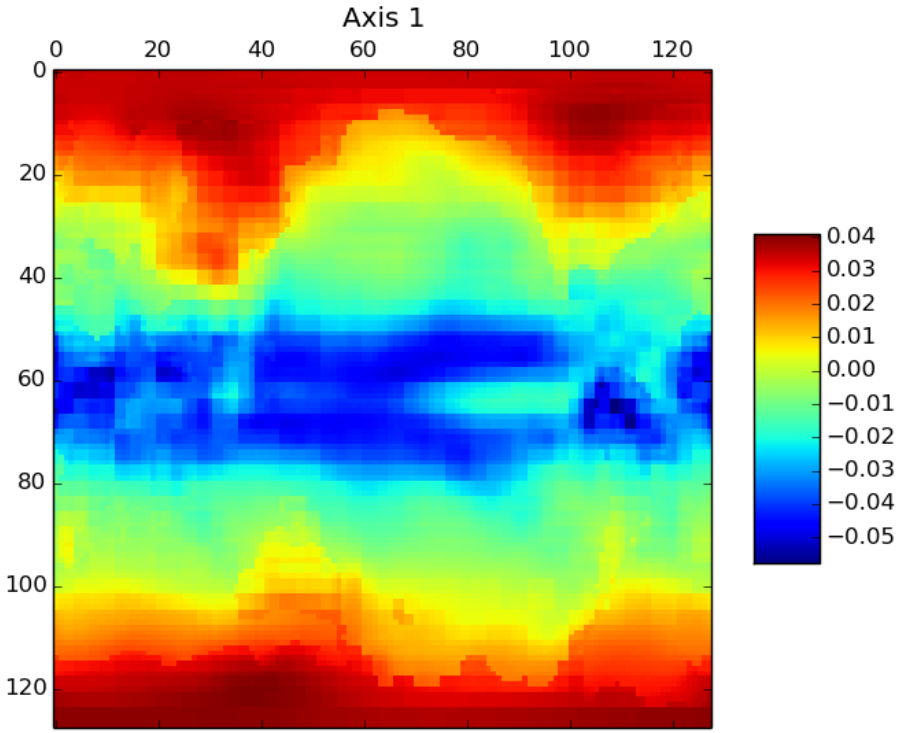
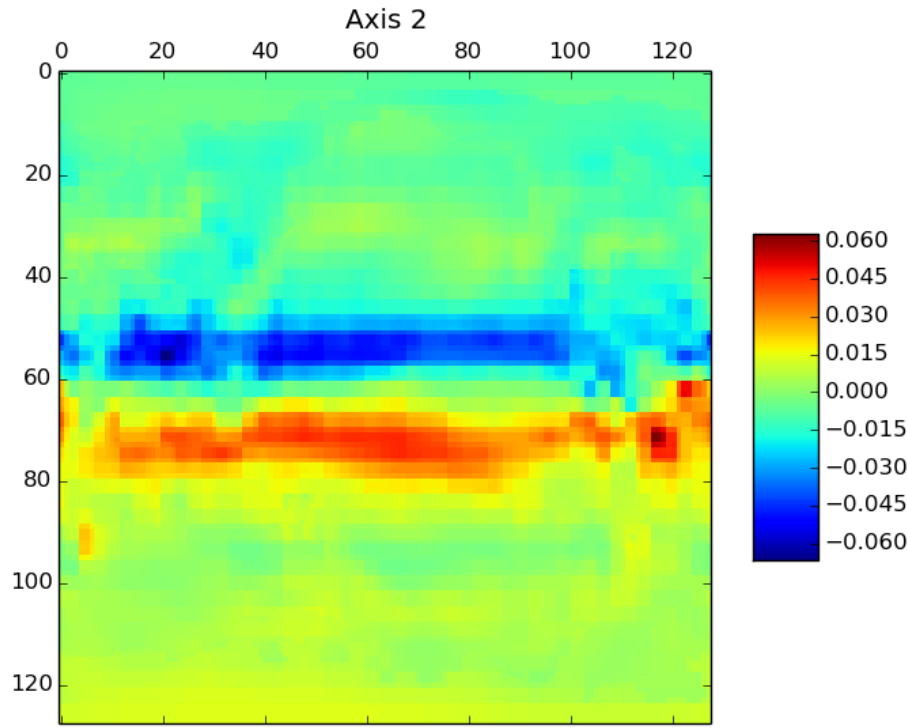
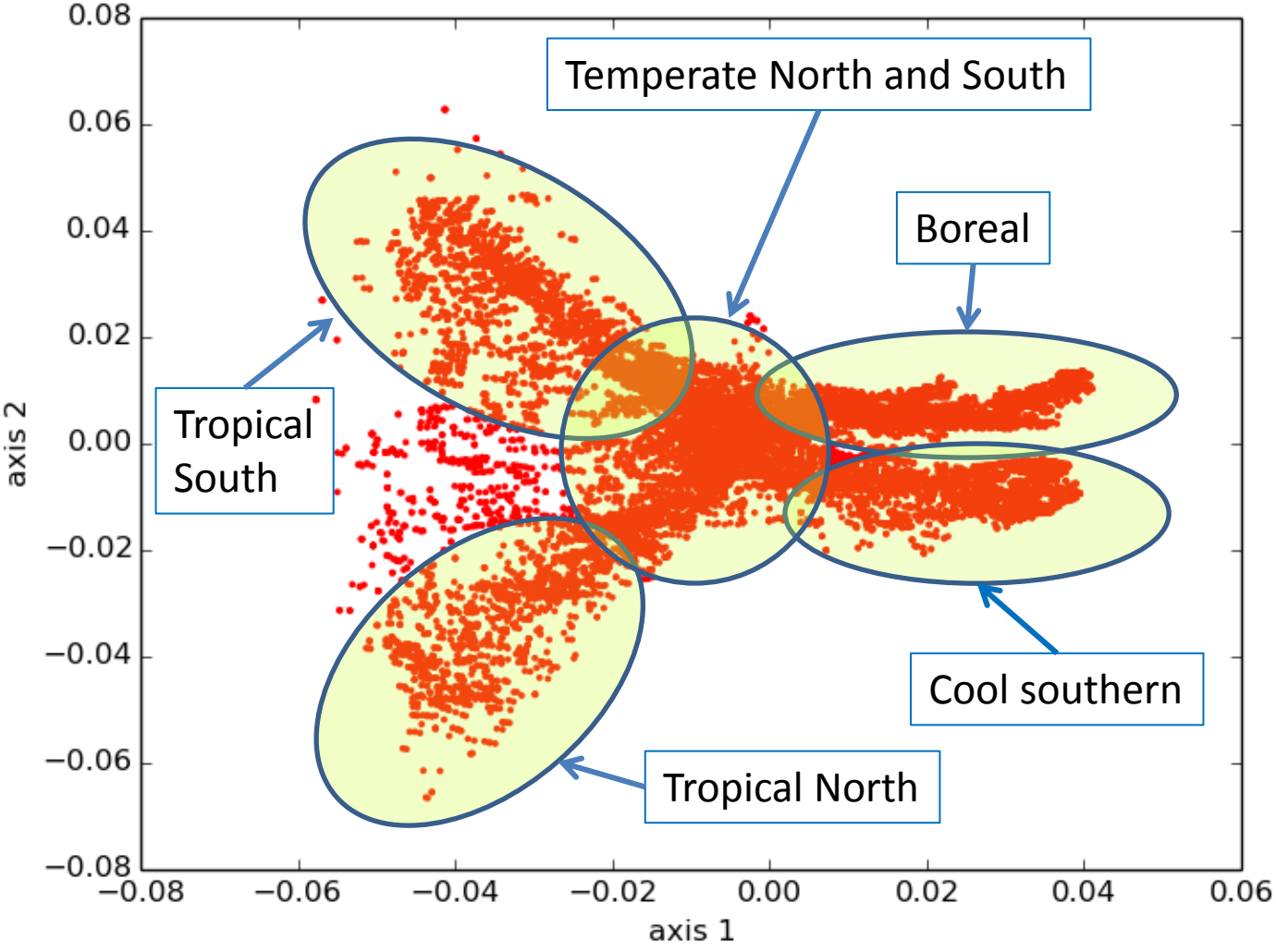
A PCA on temperature and precipitation data



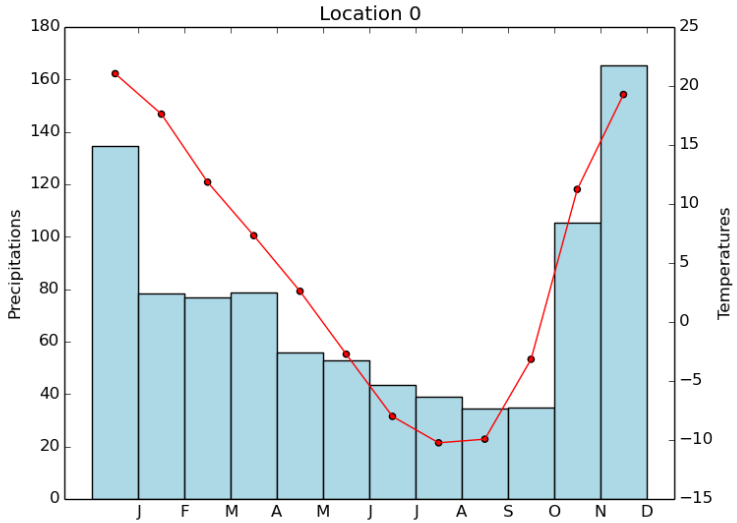
Mapping first two axis of PCA

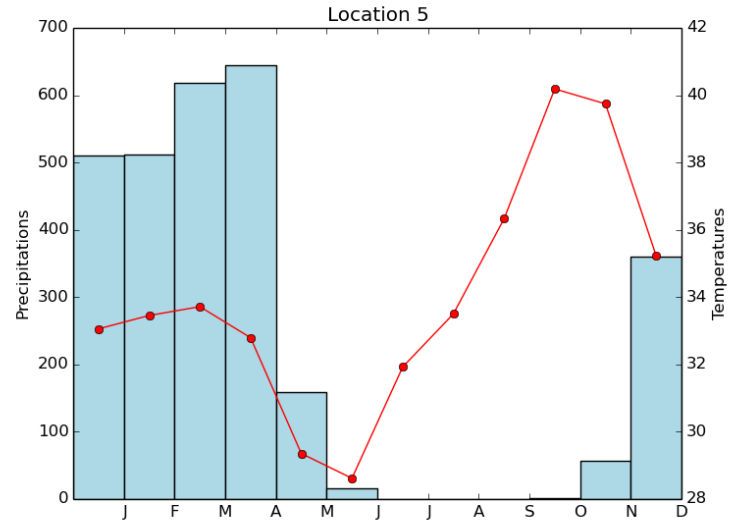


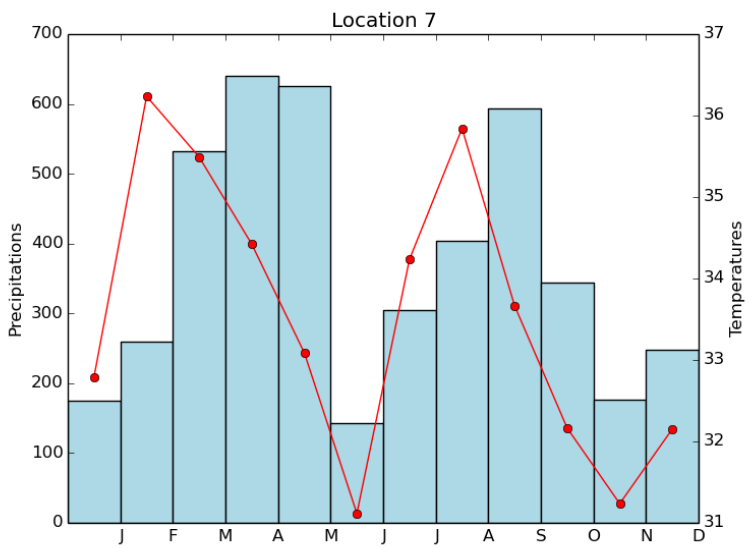


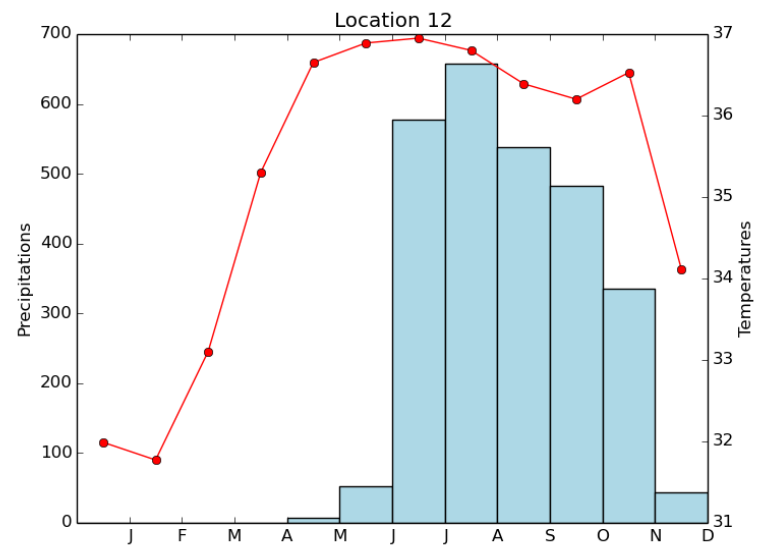

Temperate North and South
Boreal
Tropical South
Cool southern
Tropical North
axis 2
axis 1
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.08
−0.06
−0.04
−0.02
0.00
0.02
0.04
0.06

Climatic regimes in Maastrichtian, -70 My ?









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