Biogeography and Ecology of *Nothofagus* forests

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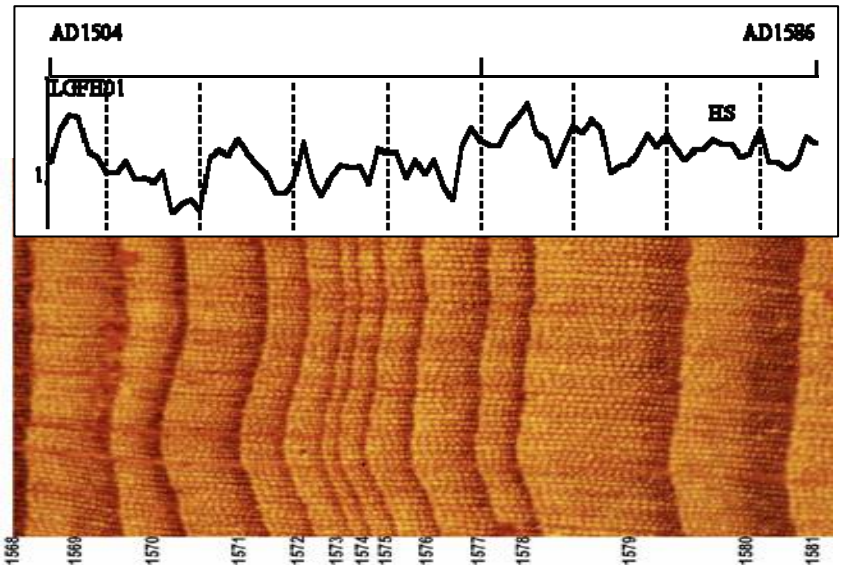
Fundación CEQUA

Outline

- Introduction.
- Geologic scale: history and paleoecology of *Nothofagus* forests.
- Recent scale: Ecology of *Nothofagus* forests.
- *Nothofagus* as a paleoclimatic proxy.

Introduction

- Temporal and spatial scales of *Nothofagus* forests dynamics.



Introduction

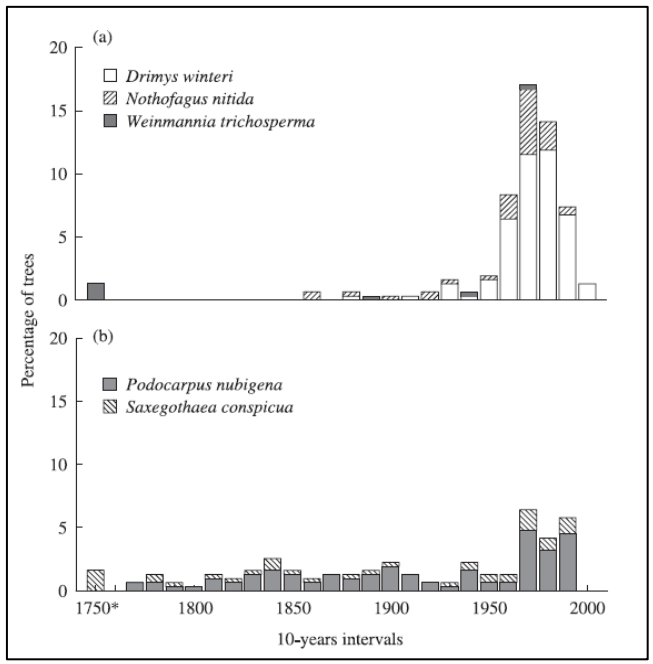
- Paleoecologists examine vegetation change through composition and physiognomy.
- Temporal scales: one to many millenia or periods of millions of years.
- Spatial scales > tens of squared kilometers.
- <u>Inferences</u> on incomplete record of micro- and macrofossils.

Introduction

- Ecologists study structural changes of the plant comunity.
- Temporal scales: few years to a millenium
- Spatial scales of a few square meters to a few square kilometers.

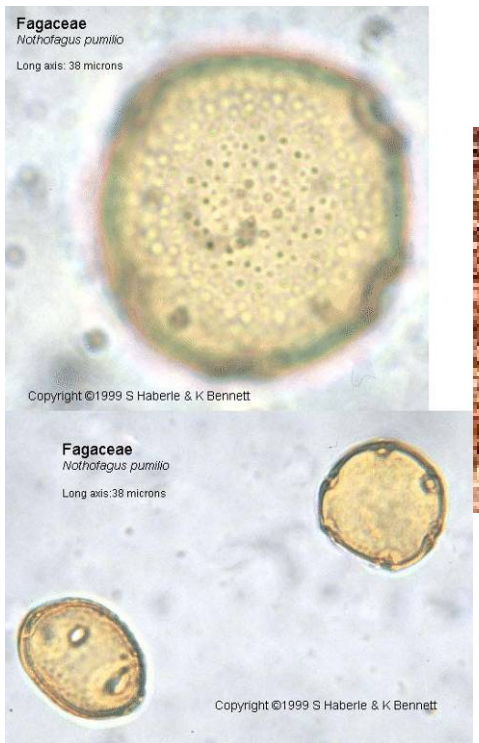
Introduction

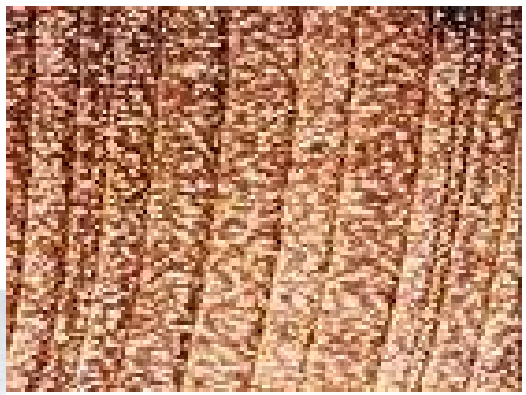
- Direct observation of permanent plots, draw inferences from population structures, substituting space for time in chronosequences.

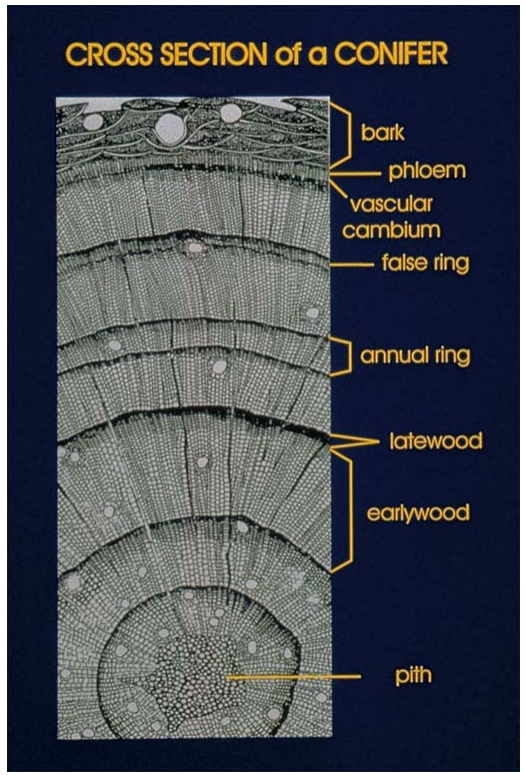


Introduction

- High resolution pollen and tree-ring studies help to link the temporal scales of paleoecologists and ecologists.







<u>Geologic scale</u>

History and Paleoecology of South American *Nothofagus* forests.

Macro and megascale vegetation change

Four major sources of environmental change for the last 65 million years:

- Climate change,
- changes in photoperiod,
- changes in carbon dioxide levels,
- changes in the positions of the southern landmasses.

Macro and megascale vegetation change

- Climate change: a major temperature drop at about the Eocene-Oligocene boundary associated with the initiation of the circum-Antarctic current.
- Steep increase in the equator-to-pole temperature gradient and rapid cooling at high latitudes, decline in rainfall, with a shift to more seasonal rainfall.

Macro and megascale vegetation change

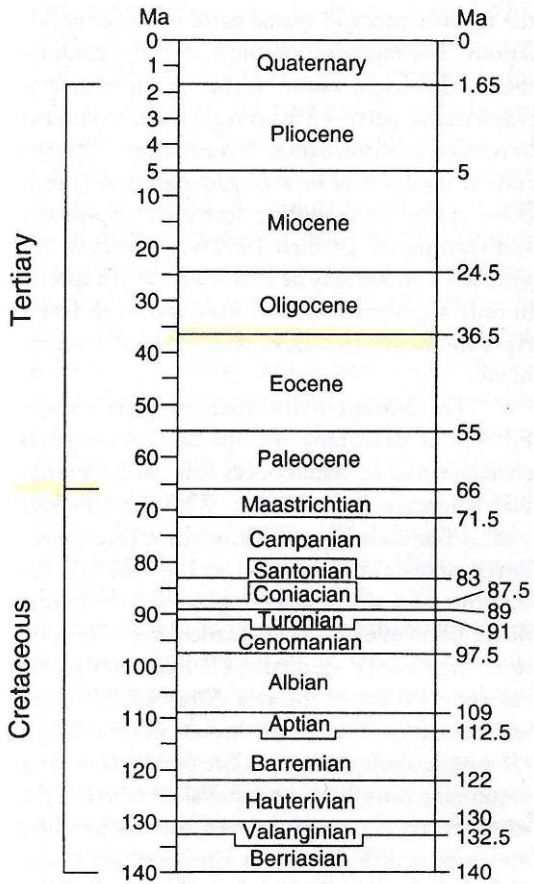
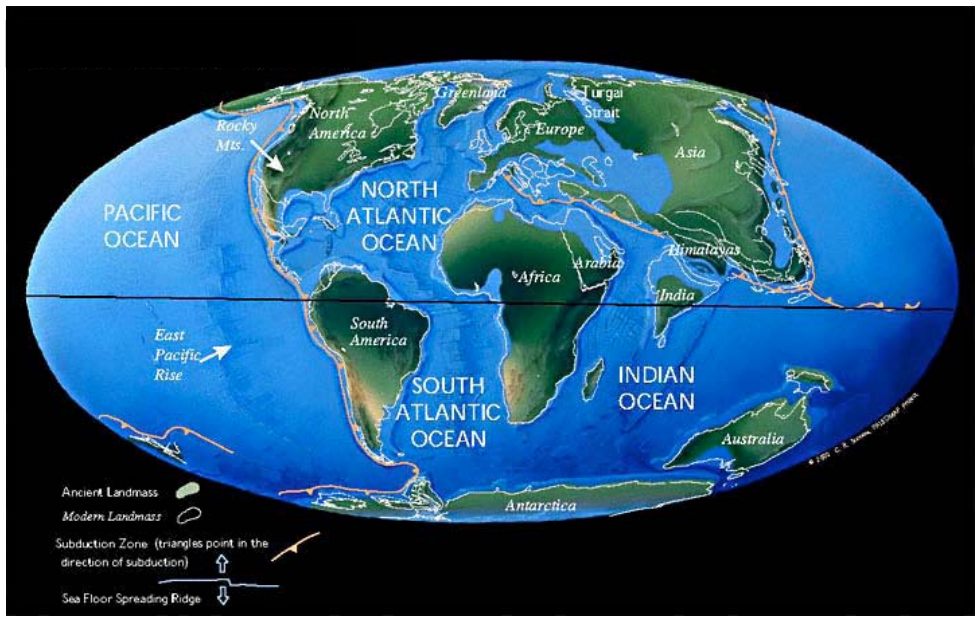
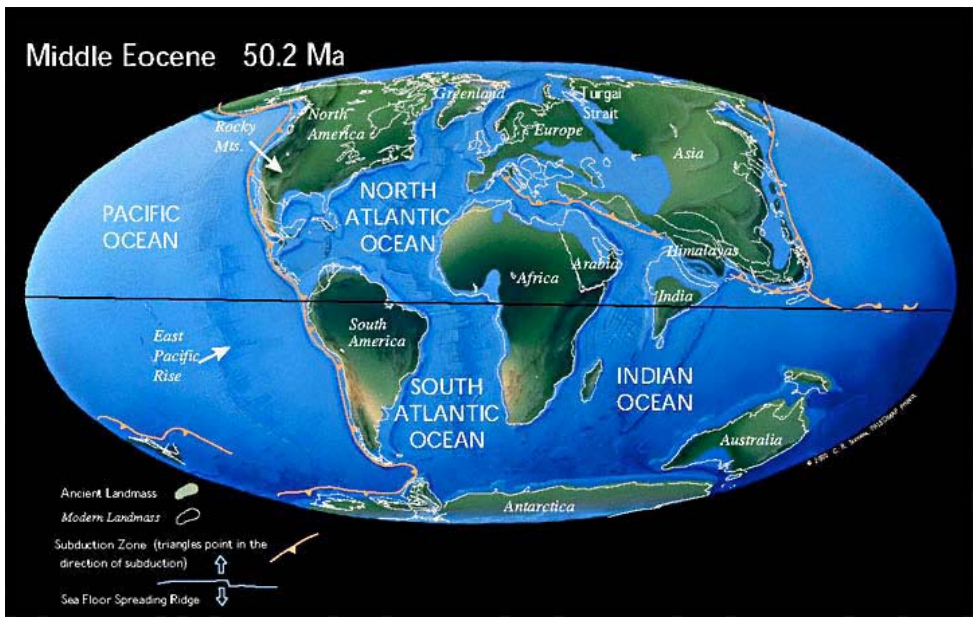


Figure 1.2. Geological timetable for post-Jurassic time (after Haq and Eysinga 1987).



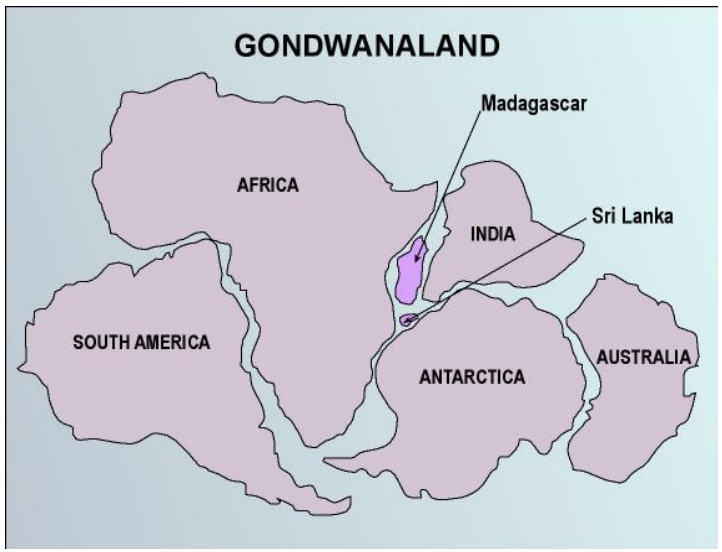
Macro and megascale vegetation change

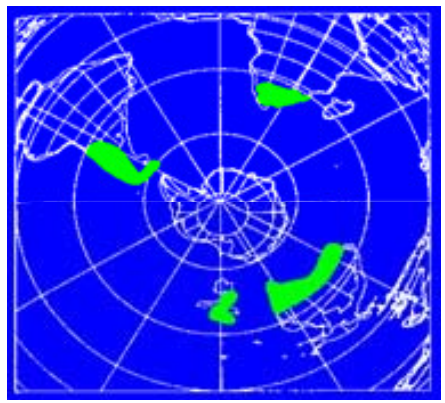
- Steep increase in the equator-to-pole temperature gradient and rapid cooling at high latitudes, decline in rainfall, with a shift to more seasonal rainfall.



Macro and megascale vegetation change

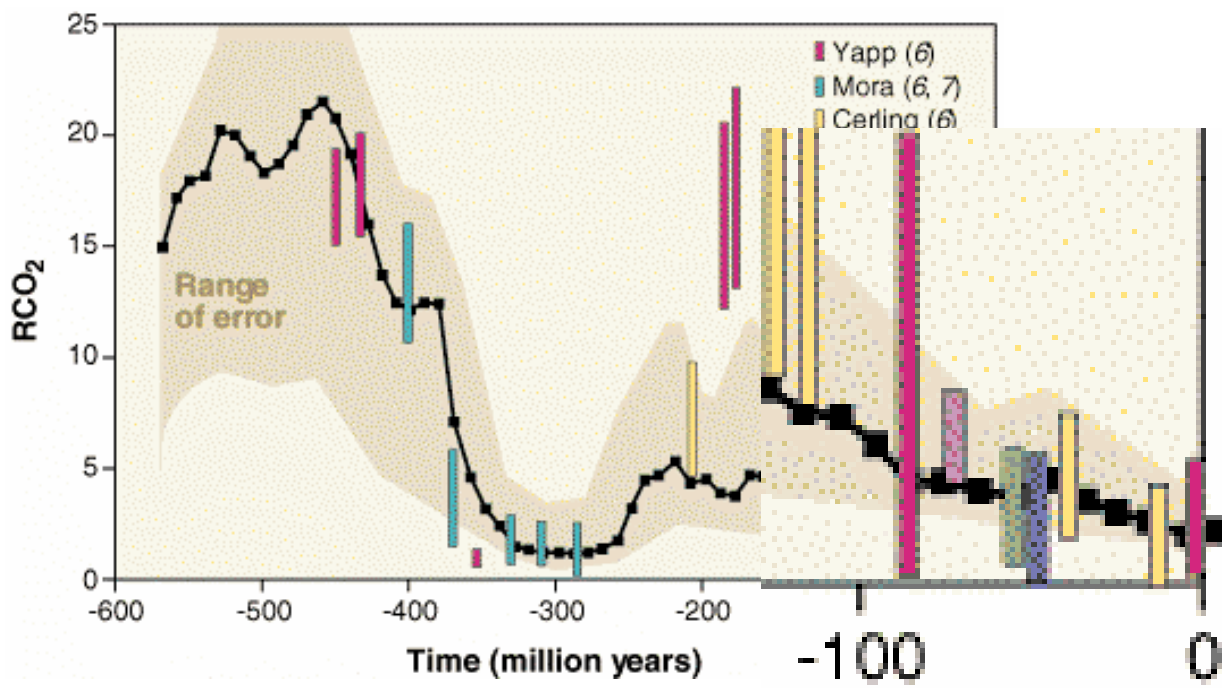
- <u>Photoperiod</u>: Land drift from polar to mid latitude photoperiods would have required major evolutionary changes in the photoperiodic responses of *Nothofagus*.





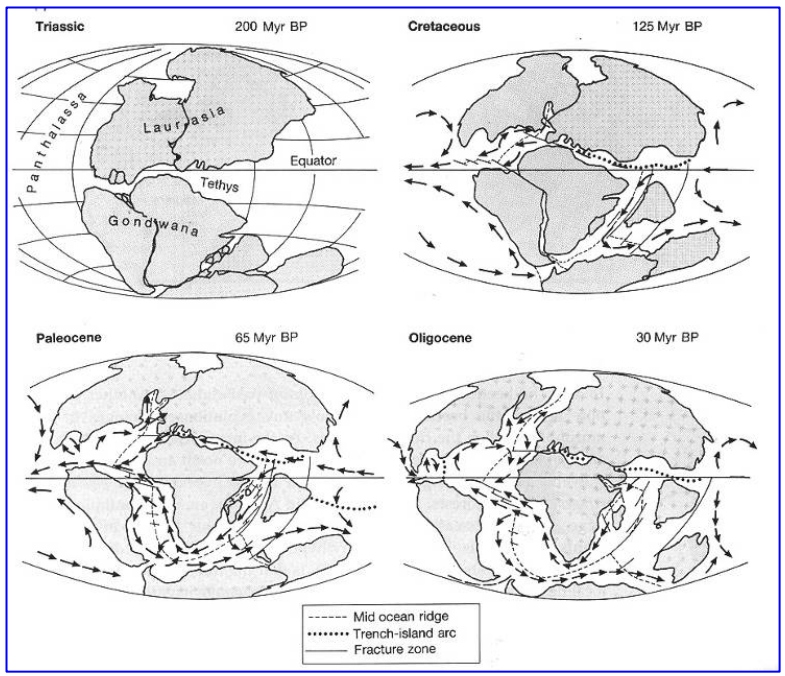
Macro and megascale vegetation change

- <u>Carbon dioxide levels</u>: CO2 levels were higher than present during the early Tertiary and then declined.



Macro and megascale vegetation change

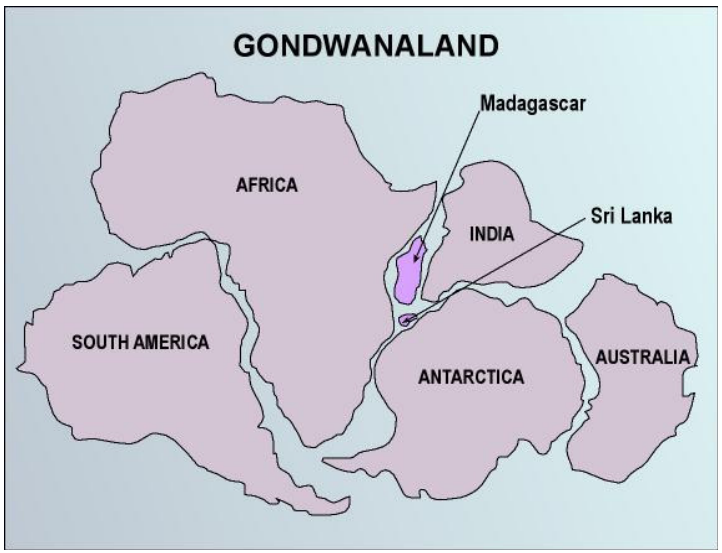
- <u>Changes in landmass position</u>: theory of plate tectonics has played a large role in explaining land-based dispersal as the major force in living plant distribution.

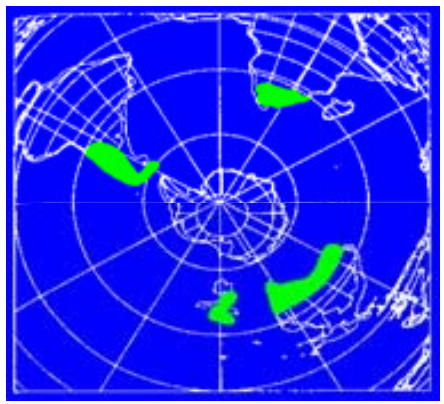


Origin and diversification of the genus *Nothofagus.*

Nothofagus is a key genus for biogeographic studies because:

- includes prominent trees in different land masses of southern hemisphere





Torres del Paine, Patagonia, Chile

Nothofagus pumilio and *Nothofagus betuloides*

South Island, New Zealand

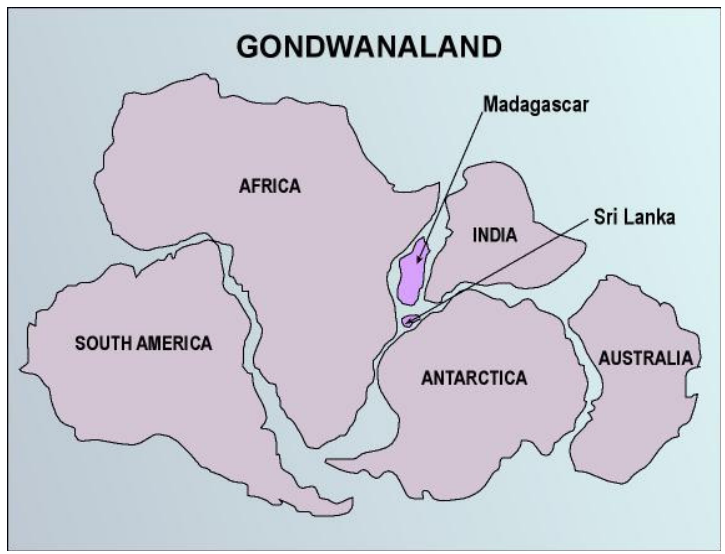
Nothofagus fusca

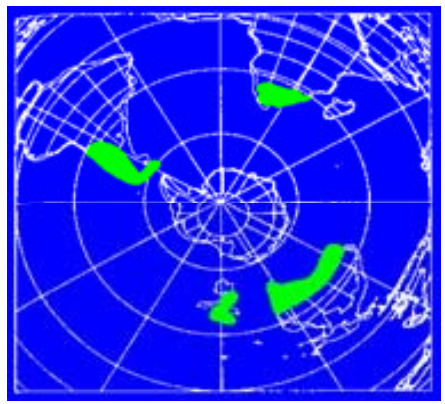
80 MYA: Both part of Gondwana

Origin and diversification of the genus *Nothofagus.*

Nothofagus is a key genus for biogeographic studies because:

- seeds poorly dispersed

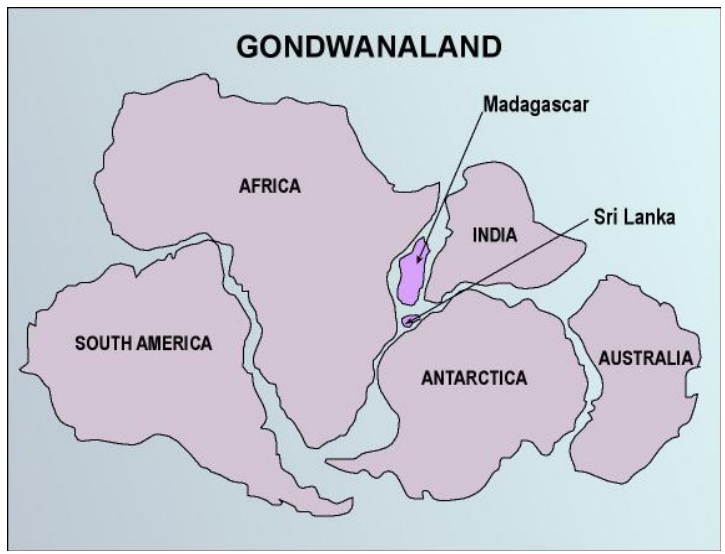


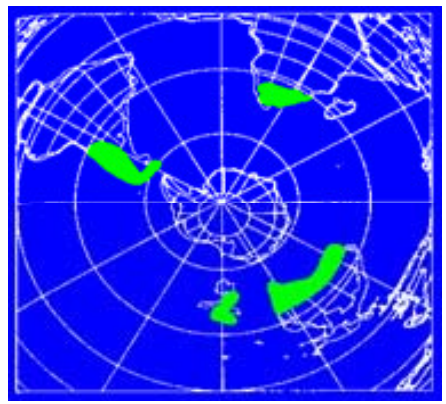


Origin and diversification of the genus *Nothofagus.*

Nothofagus is a key genus for biogeographic studies because:

- extensive fossil pollen record.

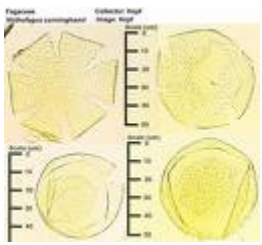
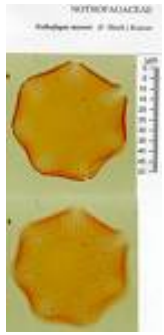


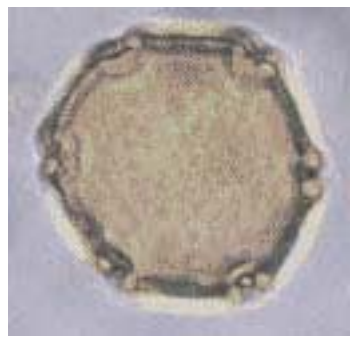


Origin and diversification of the genus *Nothofagus.*

Subgenera

- Brassospora (N. brassi type, no southamerican examples)
- Fucospora (N. fusca type a; only N. alessandri)
- Lophozonia (N. menziesii type; N. alpina, N. glauca, N. obliqua)
- Nothofagus (N. fusca type b; N. antarctica, N. betuloides, N. dombeyi, N. nitida, N. pumilio).



Origin and diversification of the genus *Nothofagus.*

Possible origins:

- southern South America-Antarctic Peninsula (Weddellian province).
- Cretaceous complex north of the equator in the Southeast Asian region.

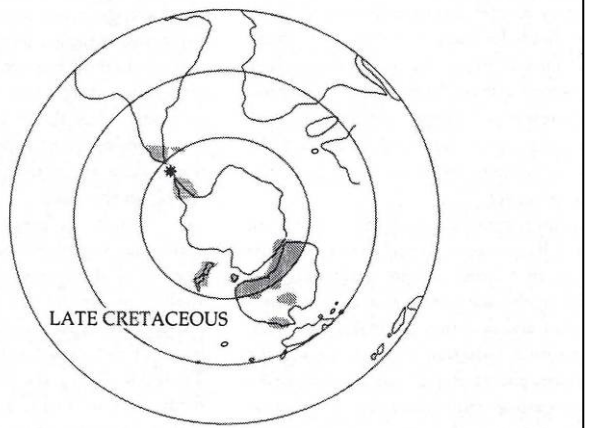
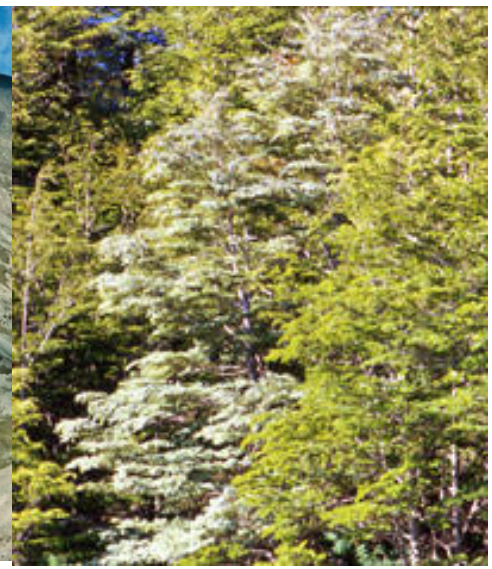


Figure 2.5. Distribution of *Nothofagidites* plotted on south polar projections. * = diversification center. Modified from Dettmann et al. (1990).

Quaternary (2 MYA to present).

- Marine sediment from off shore Argentina indicate interglacial dominated by Poaceae and Nothofagus, while glacial times show Podocarpus dominance with arid steppe-scrub vegetation.





Quaternary (2 MYA to present).

- Chilean side interglacial shows Nothofagus dominance with higher diversity of tree species, while glacial times Podocarpus dominates accompanied by Nothofagus, cooler rain forest species and moorland.

Late Quaternary (last 50,000 years)

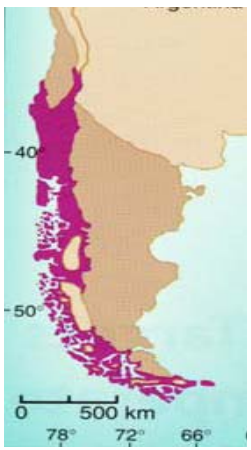
<u>South of 51ºS:</u>

- *Nothofagus* forests began during early Holocene by 9ka at the west side and about 8 ka in the rainshadow of the southern Andes.

Late Quaternary (last 50,000 years)

<u>South of 51ºS:</u>

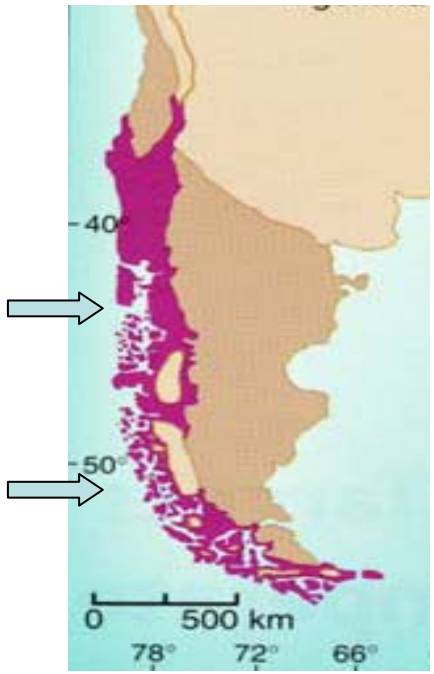
- During the mid-Holocene, 6-5 ka, Nothofagus forest declined as non arboreal taxa increased or *N betuloides* was replaced by *N pumilio*.
- After 5 ka *N betuloides* return to decline again by 3 ka.



Late Quaternary (last 50,000 years)

<u>43º-51ºS:</u>

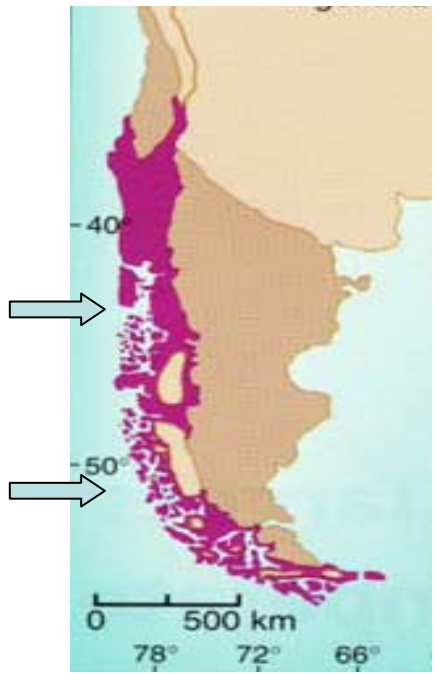
- *Nothofagus* forests appear after 13 ka on the west side and not until 10 ka at the east side of the Andes.



Late Quaternary (last 50,000 years)

43º-51ºS:

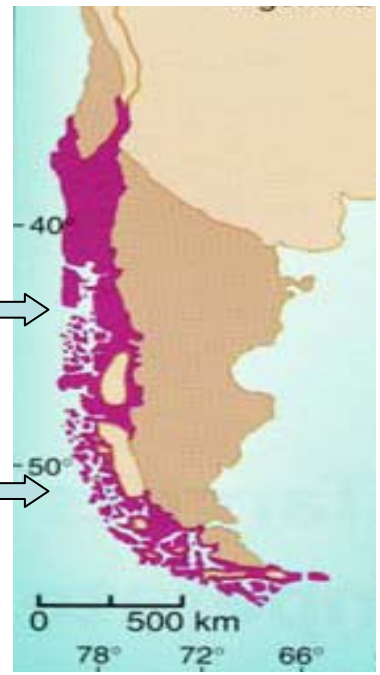
- *Pilgerodendron* increased at 12 ka at Taitao but only at 9 ka at Puerto Eden. *Podocarpus* appeared at 11 ka at Taitao but only at 3 ka at Pto Eden.



Late Quaternary (last 50,000 years)

43º-51ºS:

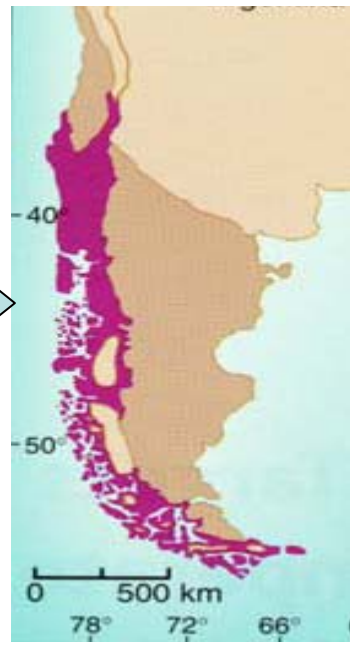
- *Pseudopanax, Weinmannia, Hydrangea, Drymis* begin to appear after 10 ka.



Late Quaternary (last 50,000 years)

<u>North of 43ºS:</u>

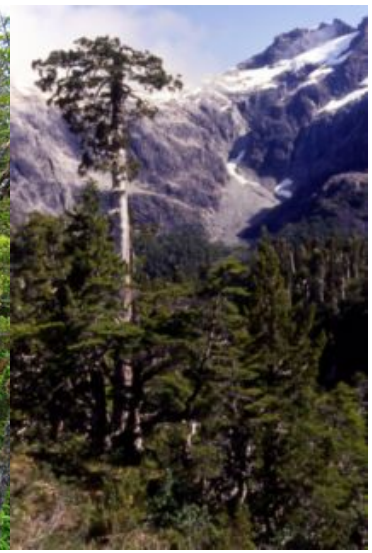
- Full and late glacial environments prior to 12.5 ka in the lake district west of the Andes were characterized by *Nothofagus* woodland.

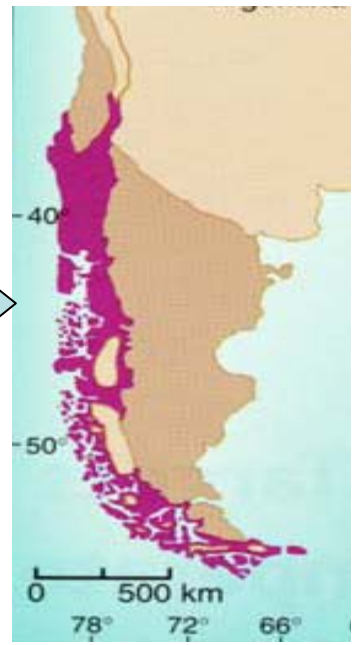


Late Quaternary (last 50,000 years)

<u>North of 43ºS:</u>

- *Nothofagus dombeyi* type and other arboreal taxa including Podocarpus, Fitzroya, Saxegothaea, and Myrtaceae were present prior 14 ka. Magellanic moorland taxa expanded to lower elevations.

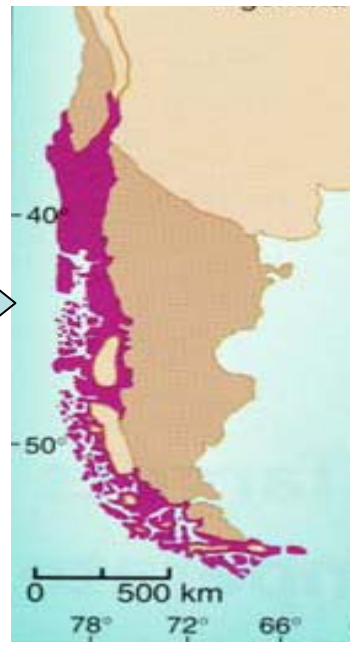




Late Quaternary (last 50,000 years)

<u>North of 43ºS:</u>

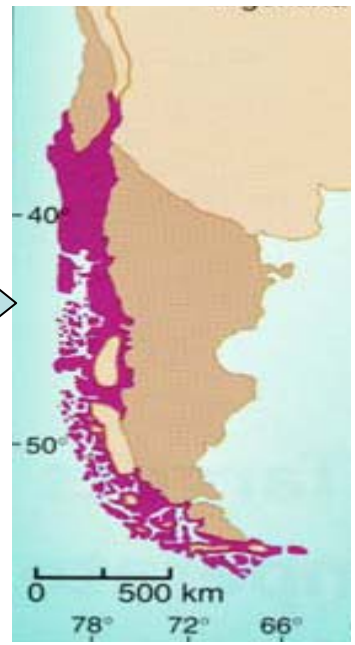
- After about 10 ka Weinmannia increased markedly replacing in part *Nothofagus dombeyi*. *Weinmannia* was replaced after 8 ka by *Eucryphia-Caldcluvia* type, Laurelia and *Nothofagus obliqua* type.



Late Quaternary (last 50,000 years)

<u>North of 43ºS:</u>

- Beginning at 5 ka and fully developed by 3 ka the Nothofagus dombeyi type forests mixed with Fitzroya-Pilgerodendron, Lomatia, Drymis, Poaceae,Asteraceae and Austrocedrus.



Late Quaternary (last 50,000 years)

North of 43ºS:

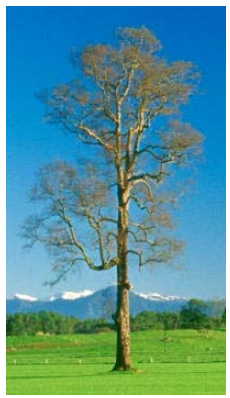
- Charcoal increase together with the ecologically diverse taxa suggests that climate variability was high indicating that ENSO began to play a major role during this period.

<u>Recent Scales</u>:
Ecology of southern Chilean and Argentinean Nothofagus forests.

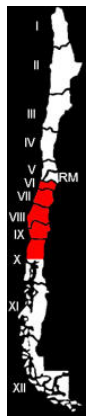
Ecology of southern Chilean and Argentinean Nothofagus forests

- Nothofagus extends from around 33º to 56ºS.

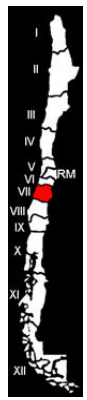
Warm temperate deciduous Nothofagus forests



N. obliqua



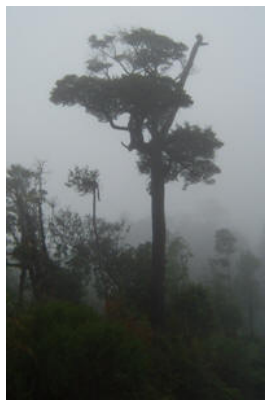
N. alpina



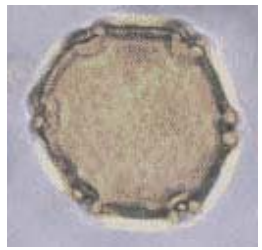
N. alessandrii
N. glauca

Evergreen *Nothofagus*

N. betuloides



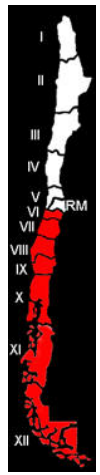
N. nitida



N. dombeyi

Cool temperate deciduous Nothofagus forests

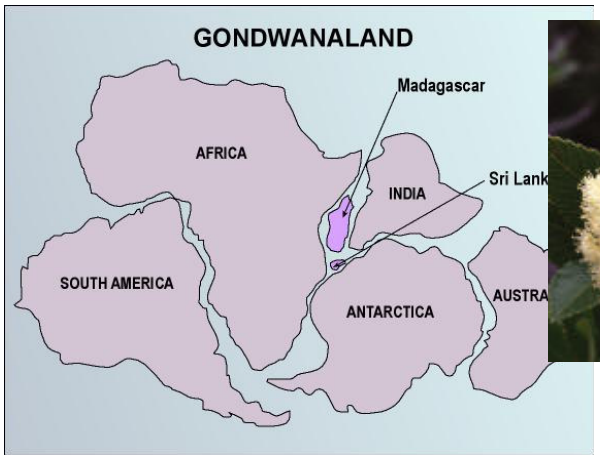
N. pumilio



N. antarctica

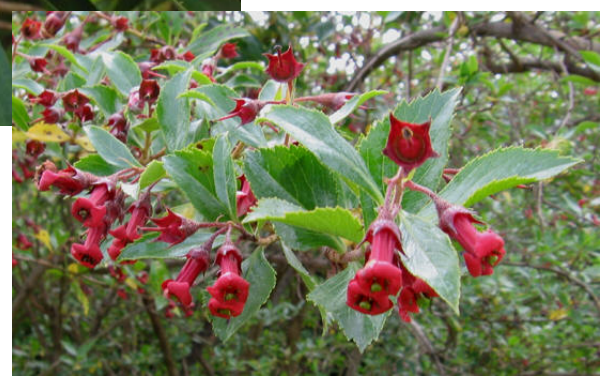
Ecology of southern Chilean and Argentinean Nothofagus forests.

- Many genera in South American Nothofagus forests have Gondwanaland distribution: *Araucaria, Aristotelia, Blechnum, Caldcluvia, Eucryphia, Gevuina, Griselinia, Laurelia, Lomatia, Luzuriaga, Podocarpus, Pseudopanax*.



Ecology of southern Chilean and Argentinean Nothofagus forests.

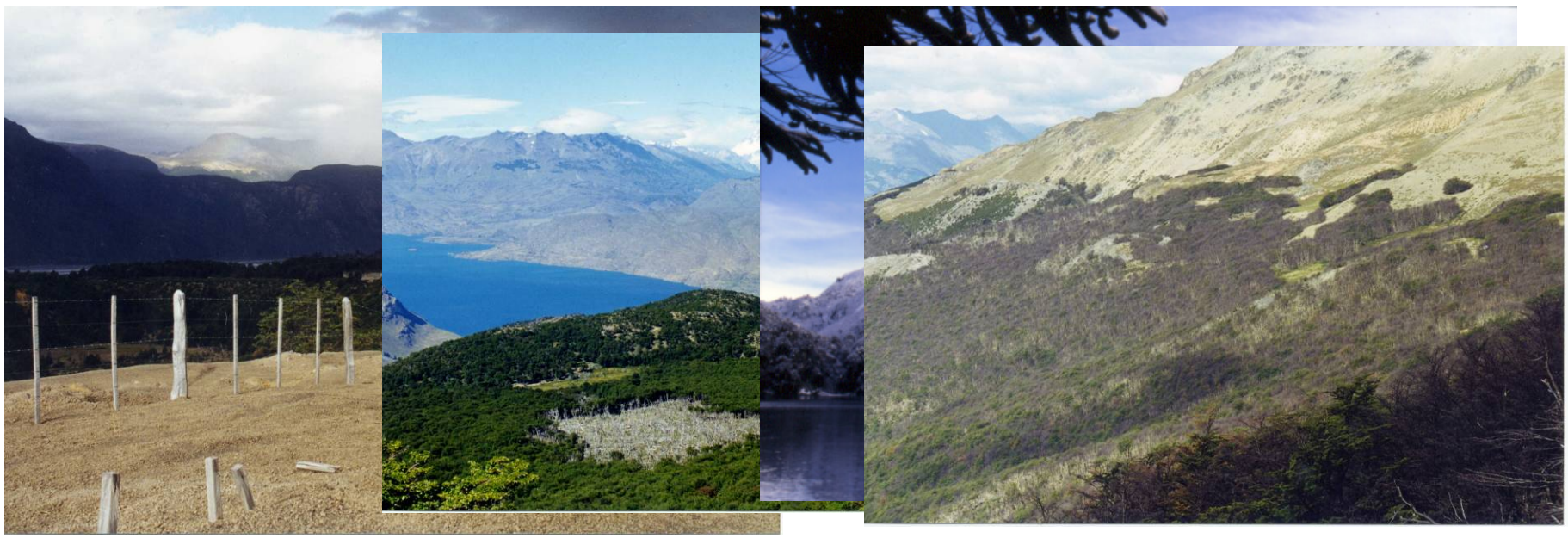
- Other several genera indicate a neotropical origin: *Azara, Chusquea, Crinodendron, Dasyphyllum, Desfontainea, Drimys, Escallonia, Myrceugenia, Raphithamnus, Schinus, and Ugni*.



Ecology of southern Chilean and Argentinean Nothofagus forests.

Forest dynamics:

- Coarse-scale natural disturbances: tectonism, glacial processes, blowdown, snow avalanches, fire,dieback.



Ecology of southern Chilean and Argentinean Nothofagus forests.

Forest dynamics:

- Fine-scale treefall gap.

Ecology of southern Chilean and Argentinean Nothofagus forests

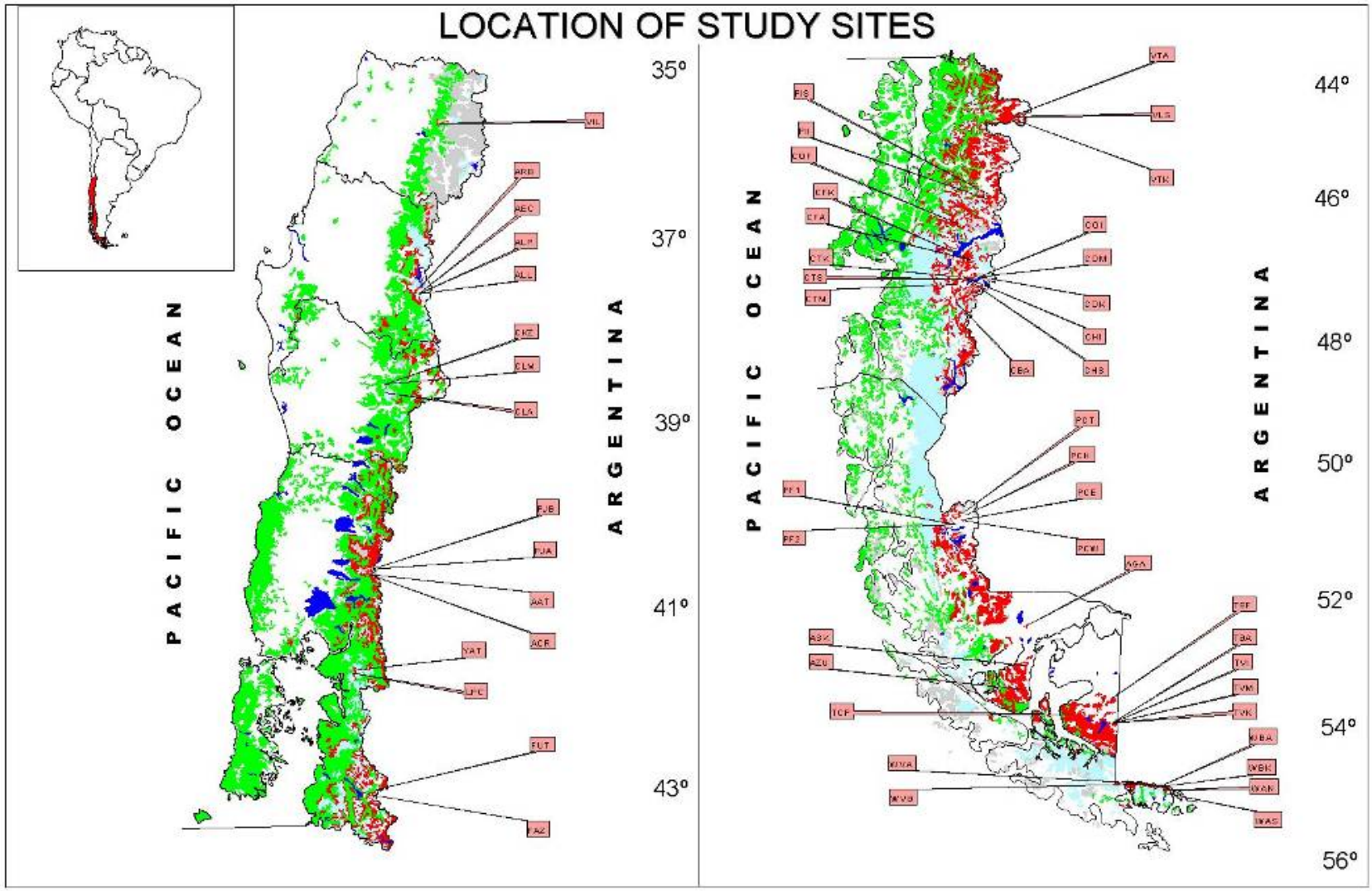
- ecological effects of anthropogenic climate change
- climatic influences on vegetation dynamics will be mediated through altered disturbance regimes.

Nothofagus forests in paleoclimatic research

Nothofagus forests in paleoclimatic research.

- Nothofagus pumilio radial growth has been used over its entire latitudinal in Chile and Argentina to find out how its spatial and temporal patterns relate to temperature and precipitation variation from instrumental records.

LOCATION OF STUDY SITES

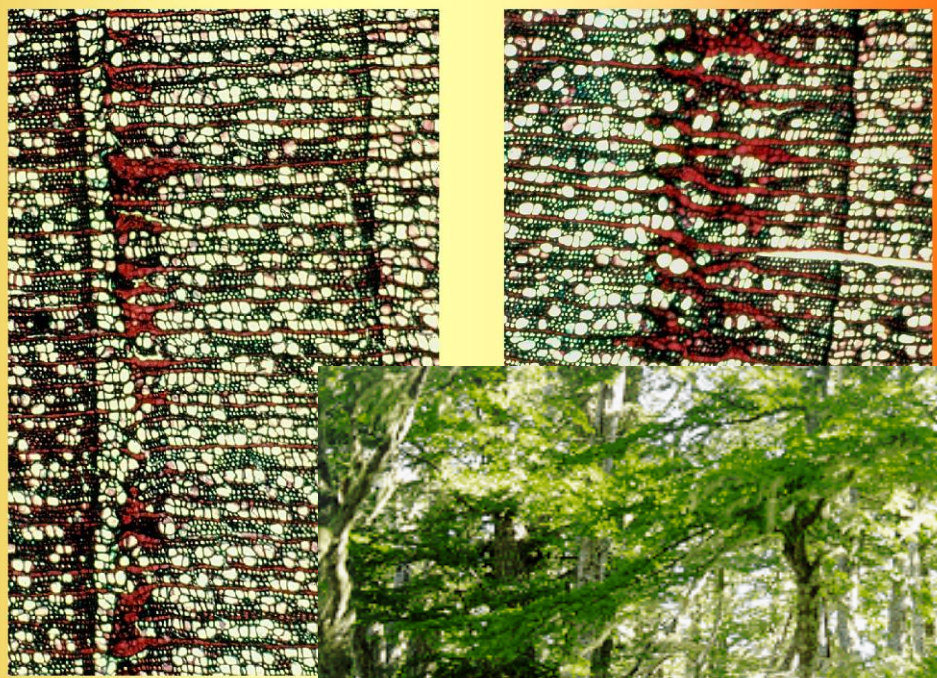


Frost Rings

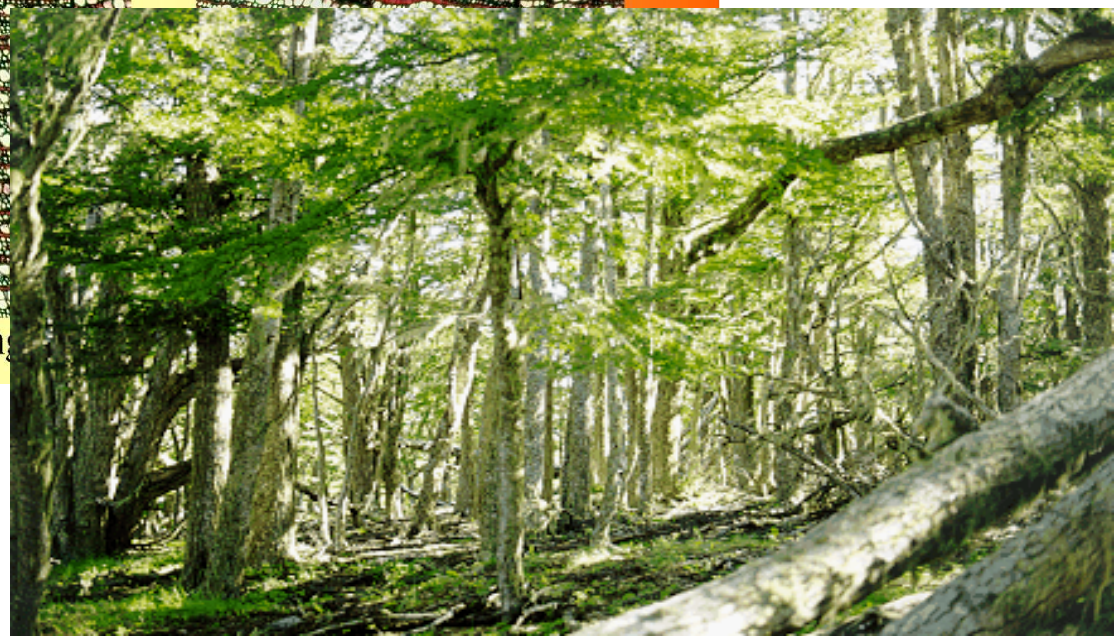
Nothofagus pumilio

Late frost

Early frost



|← Annual ring

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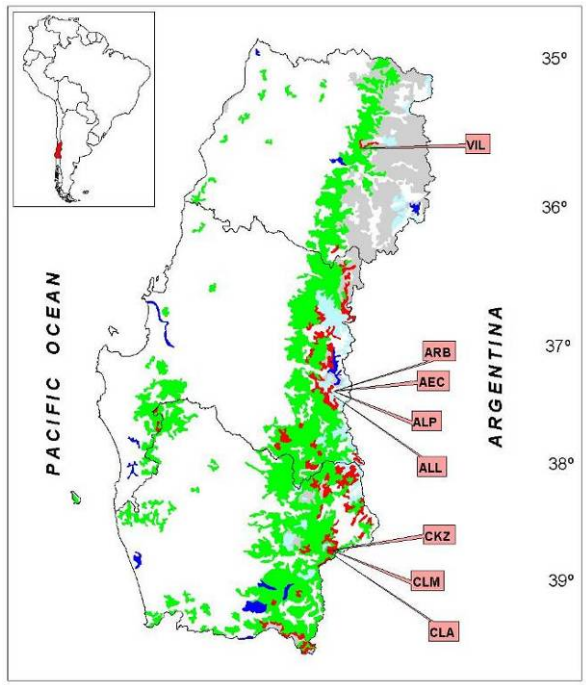
Nothofagus forests in paleoclimatic research.

- Tree growth at the northernmost regions shows a positive correlation with annual precipitation and negative correlation with mean annual temperature, under a Mediterranean-type climate



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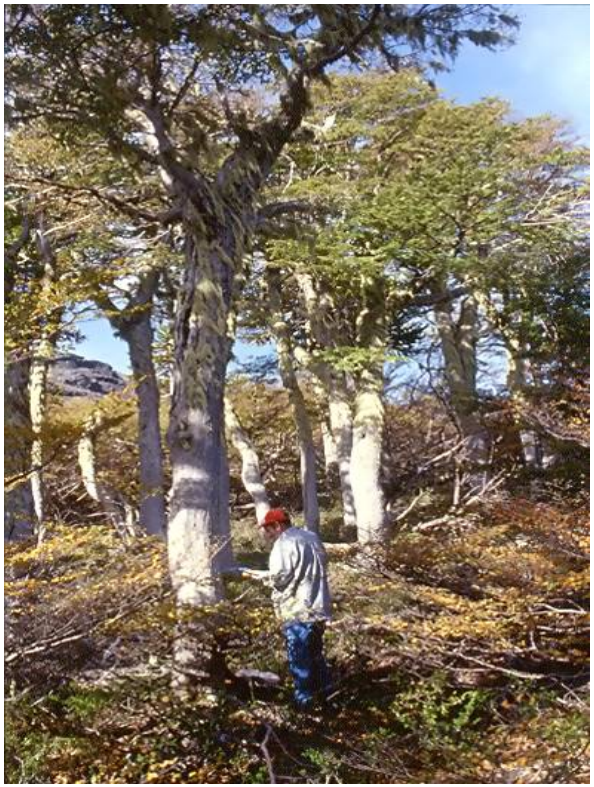
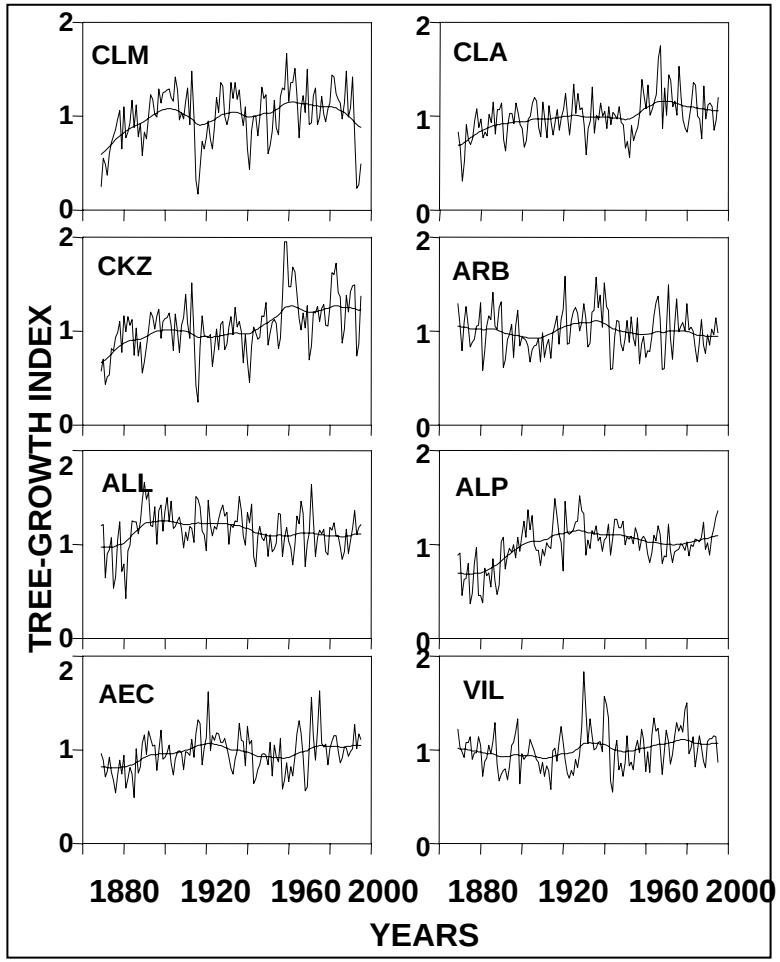
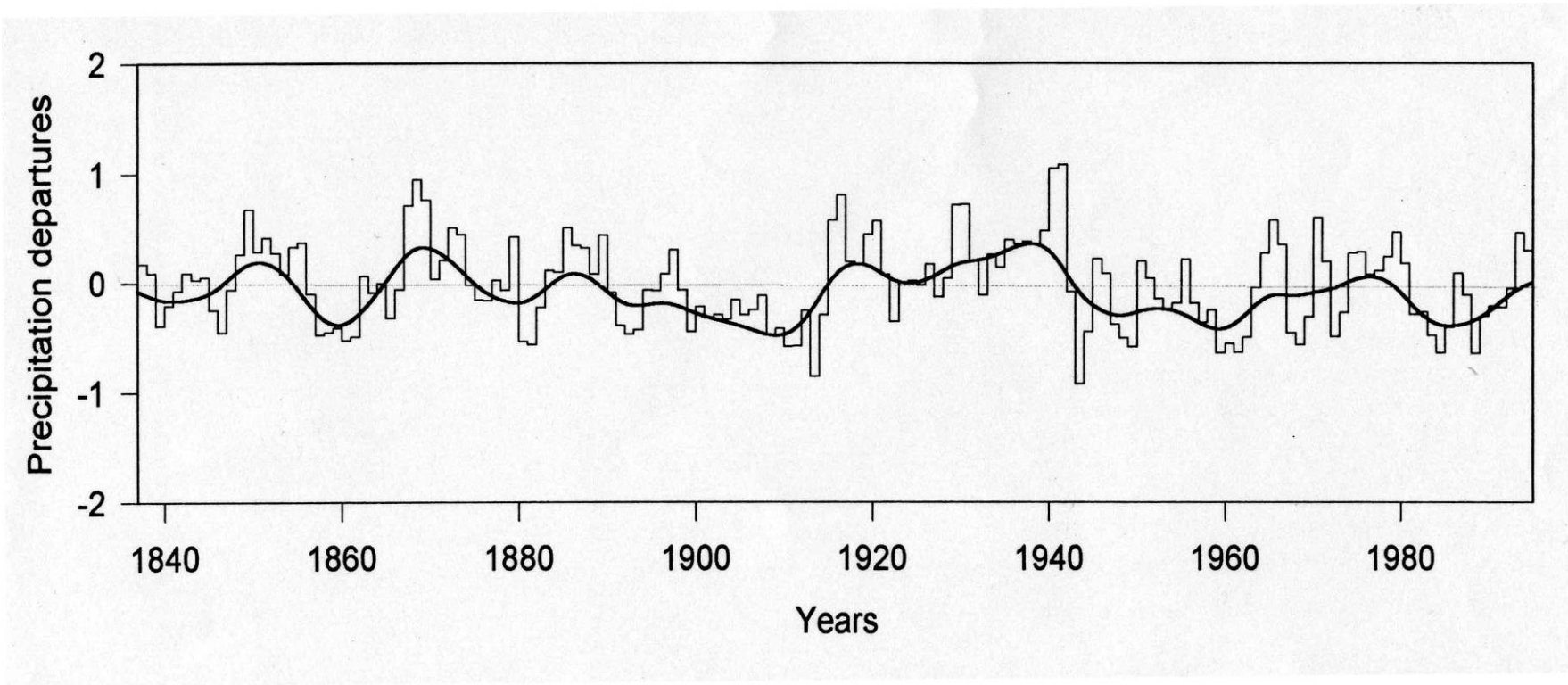



CLM
CLA
CKZ
ARB
ALL
ALP
AEC
VIL
TREE-GROWTH INDEX
0
1
2
1880
1920
1960
2000
YEARS

Reconstructed variations in November-December precipitation for the Central Andes (35º - 39º)



adjusted
r^2 = 0.37

Nothofagus forests in paleoclimatic research.

- Conversely, tree growth is positively correlated with mean annual temperature in the southern portion of the species distribution.

Aravena, J.C, Lara, A., Wolodarsky, A., Cuq, E

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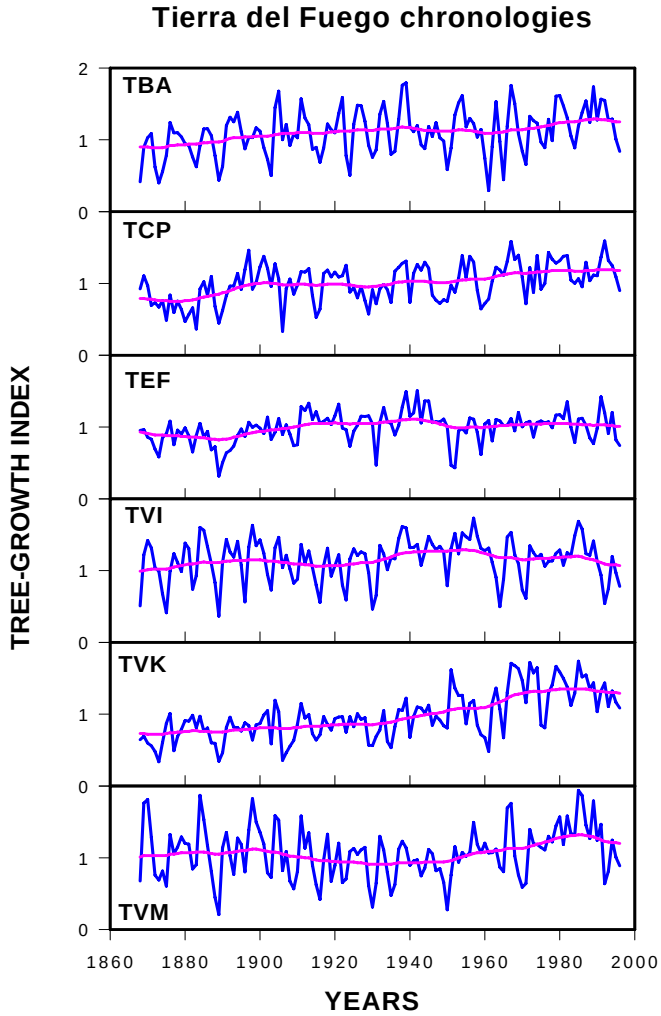

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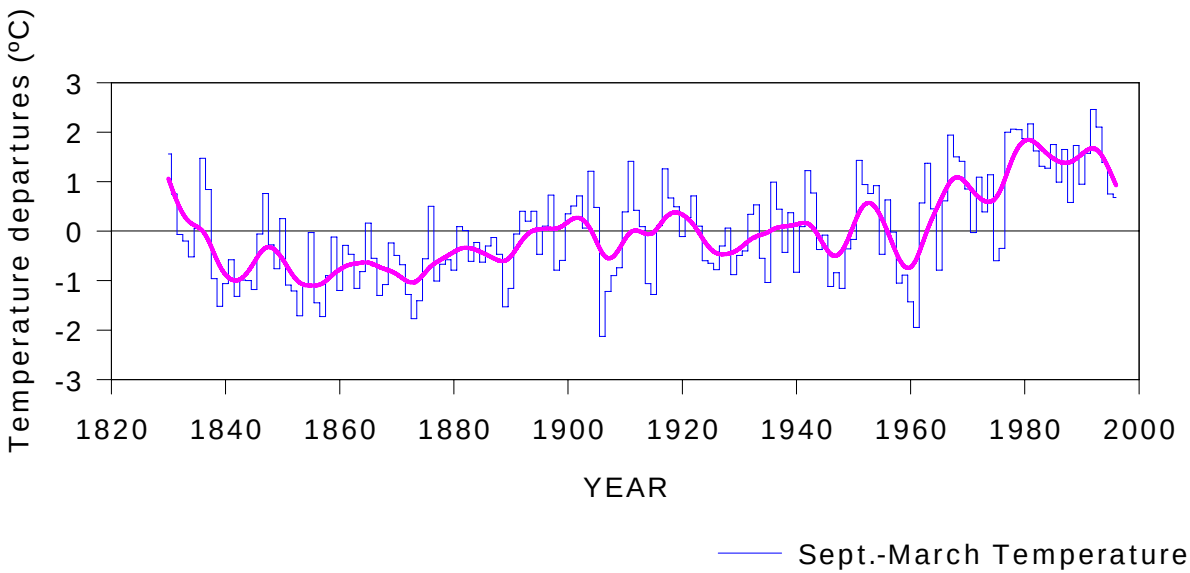
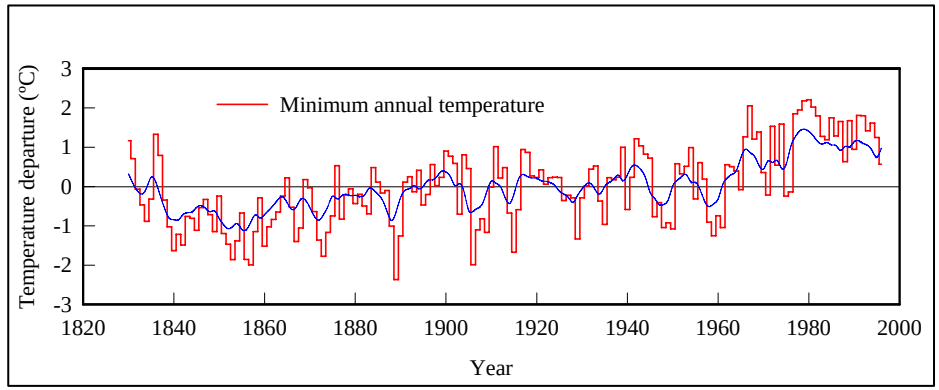


Nothofagus forests in paleoclimatic research.

- Temperature has a spatially larger control of *N. pumilio* growth than precipitation.
- Temporal patterns of *N. pumilio* tree growth indicate an increasing trend with above the mean values after 1960s.




Thanks