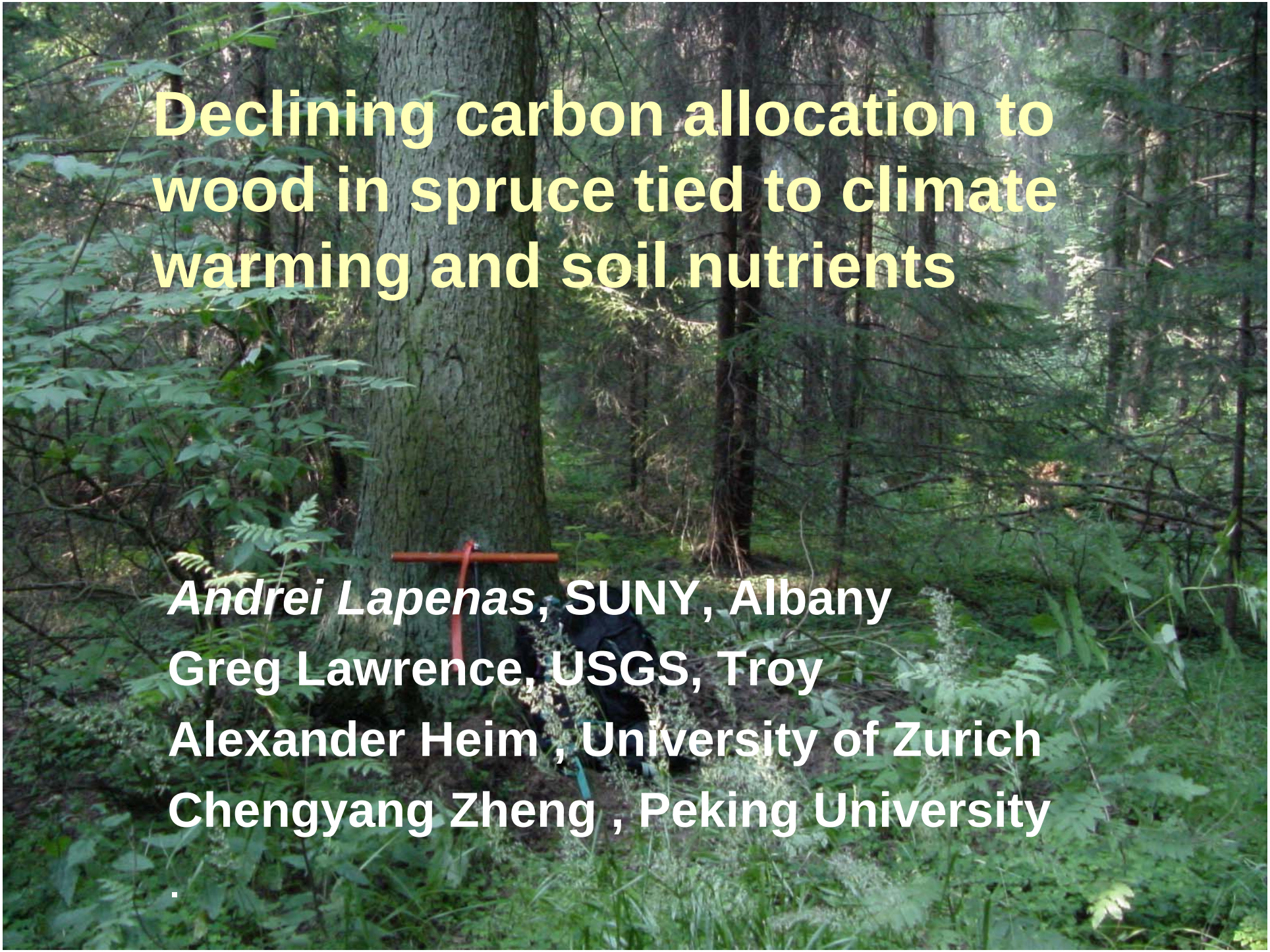

Declining carbon allocation to wood in spruce tied to climate warming and soil nutrients

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Greg Lawrence, USGS, Troy
Alexander Heim , University of Zurich
Chengyang Zheng , Peking University

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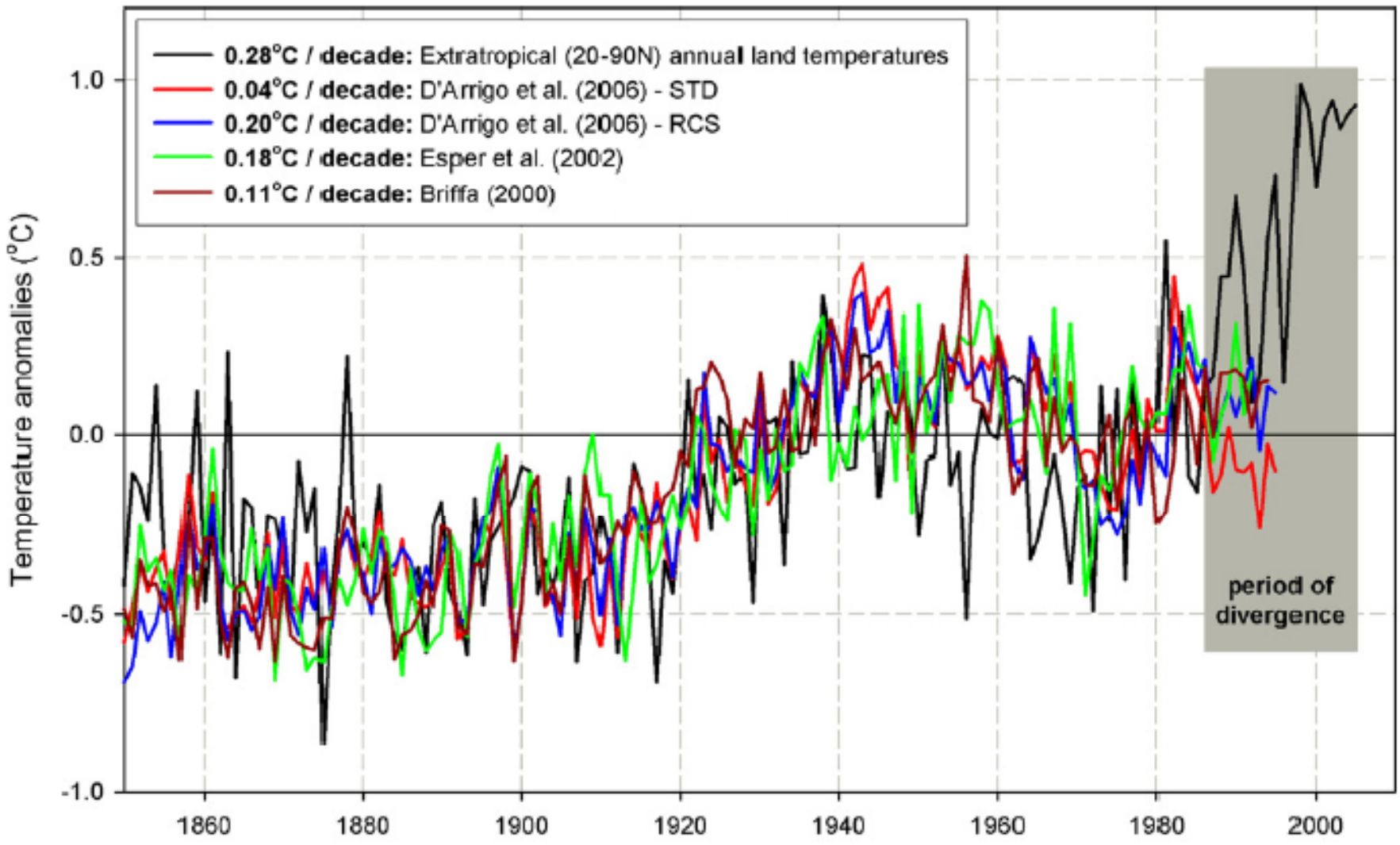
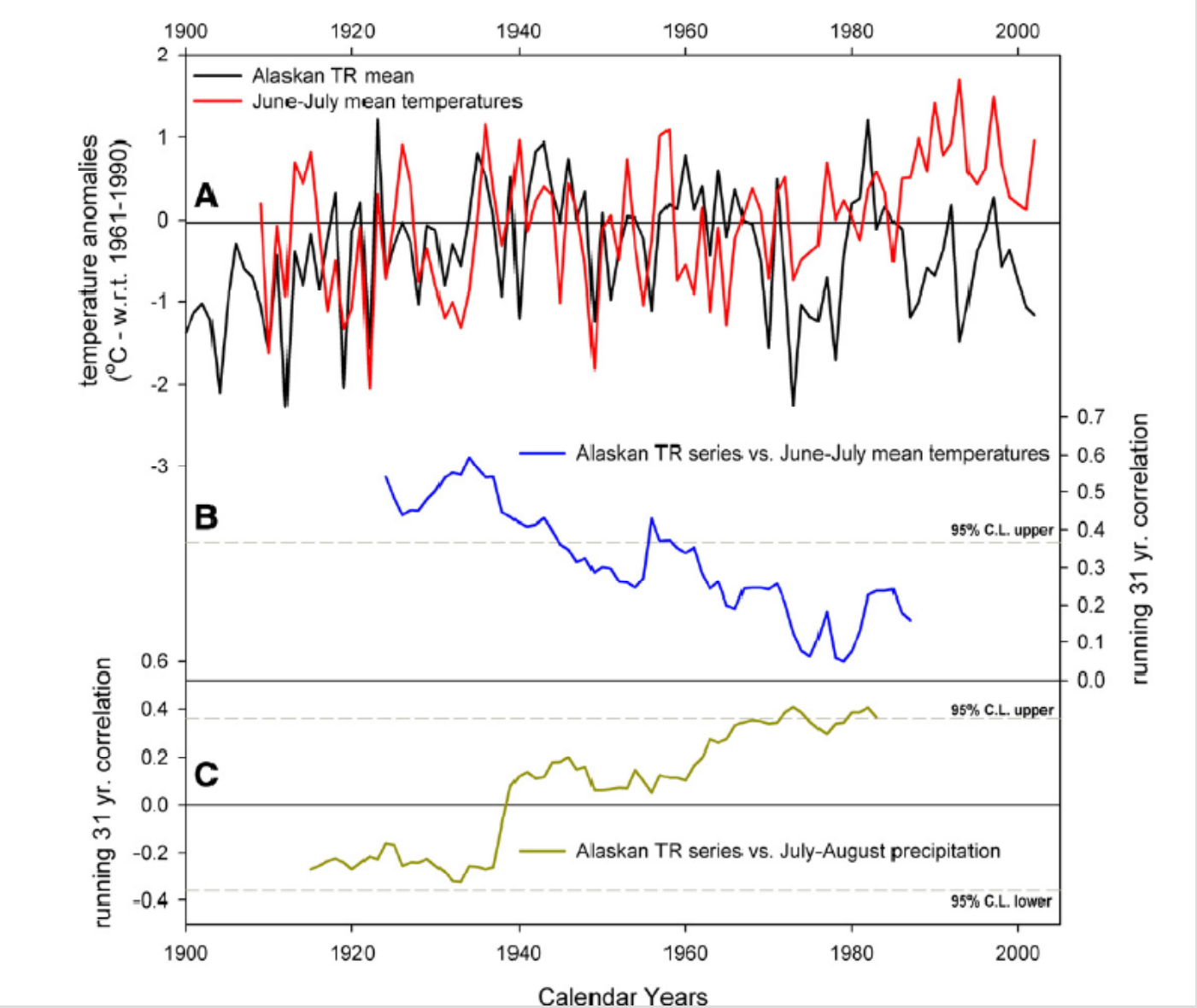
Outline

1. Divergence Problem (DP) in dendroclimatology
2. Existing hypothesis
3. Studies of two Norway Spruce (*Picea Abies*) stands with DP in Western Russia
4. Discussion and conclusions

Divergence Problem in Dendroclimatology

- During the last 30-40 years numerous studies revealed locations in boreal forests of Eurasia and North America where trees exhibit significant decline in their radial growth and temperature sensitivity
- This "***divergence problem***" in dendroclimatology was defined as offset between warmer instrumental temperatures and their underestimation in reconstruction models based on tree rings

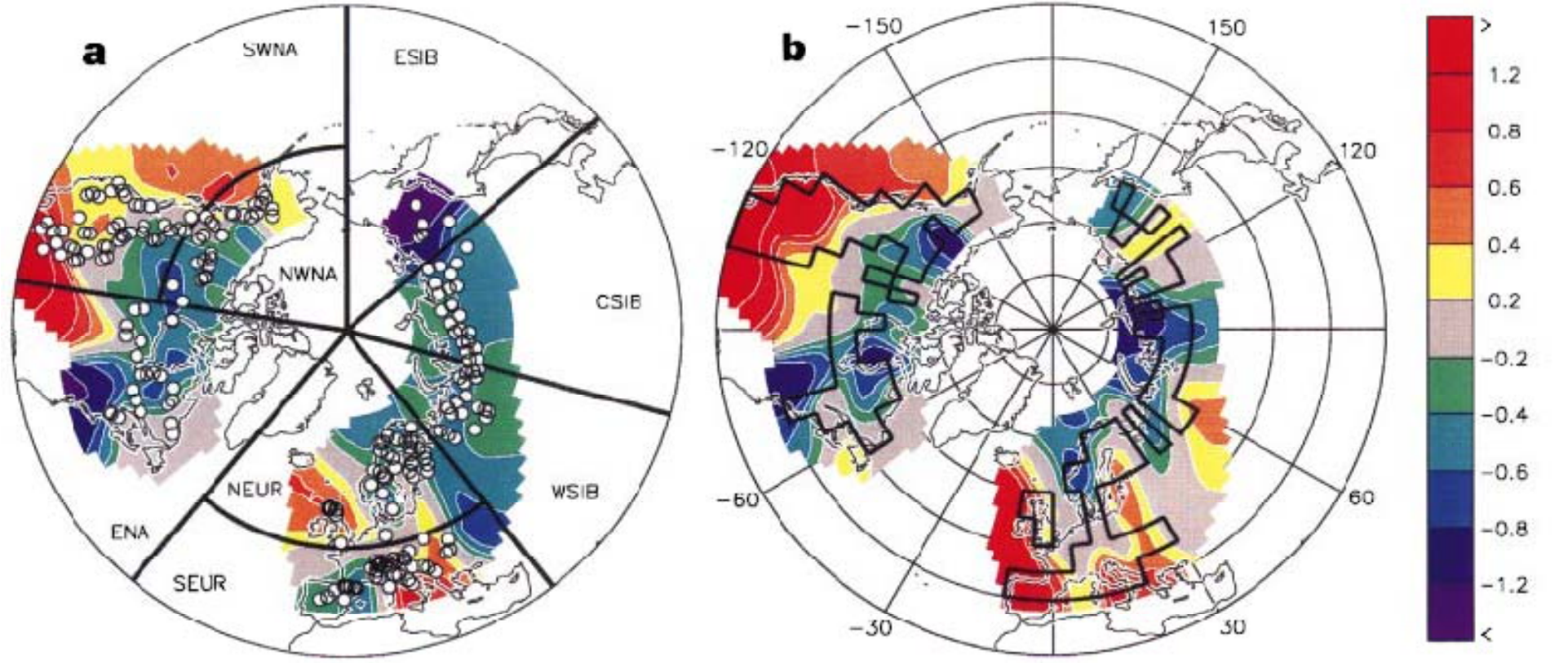

0.28°C / decade: Extratropical (20-90N) annual land temperatures
0.04°C / decade: D'Arrigo et al. (2006) - STD
0.20°C / decade: D'Arrigo et al. (2006) - RCS
0.18°C / decade: Esper et al. (2002)
0.11°C / decade: Briffa (2000)
Temperature anomalies (°C)
1.0
0.5
0.0
-0.5
-1.0
1860
1880
1900
1920
1940
1960
1980
2000
period of divergence



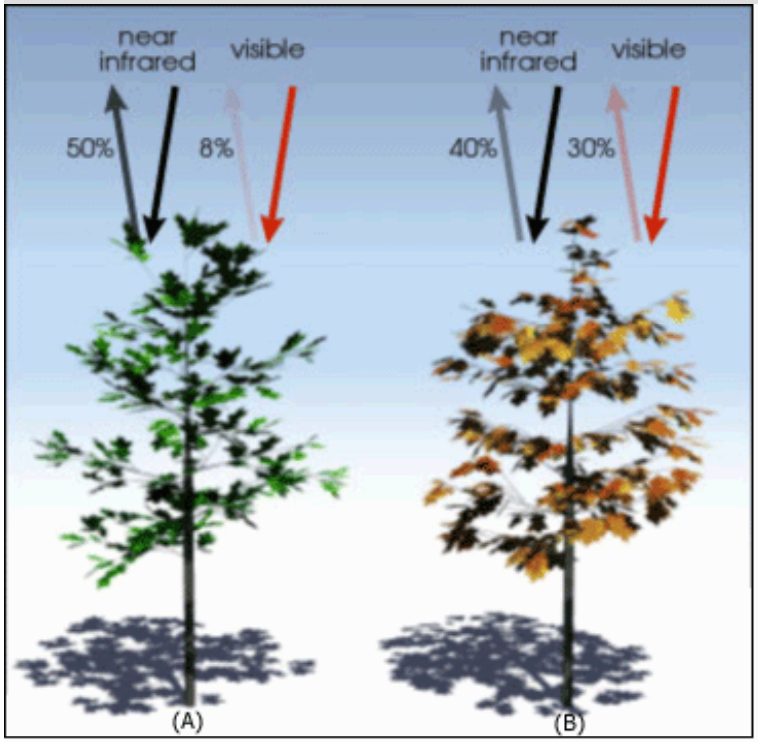
In some cases, however, trees lose sensitivity to temperature AND/BUT

increase sensitivity to precipitation (D'Arigo et al., 2009)

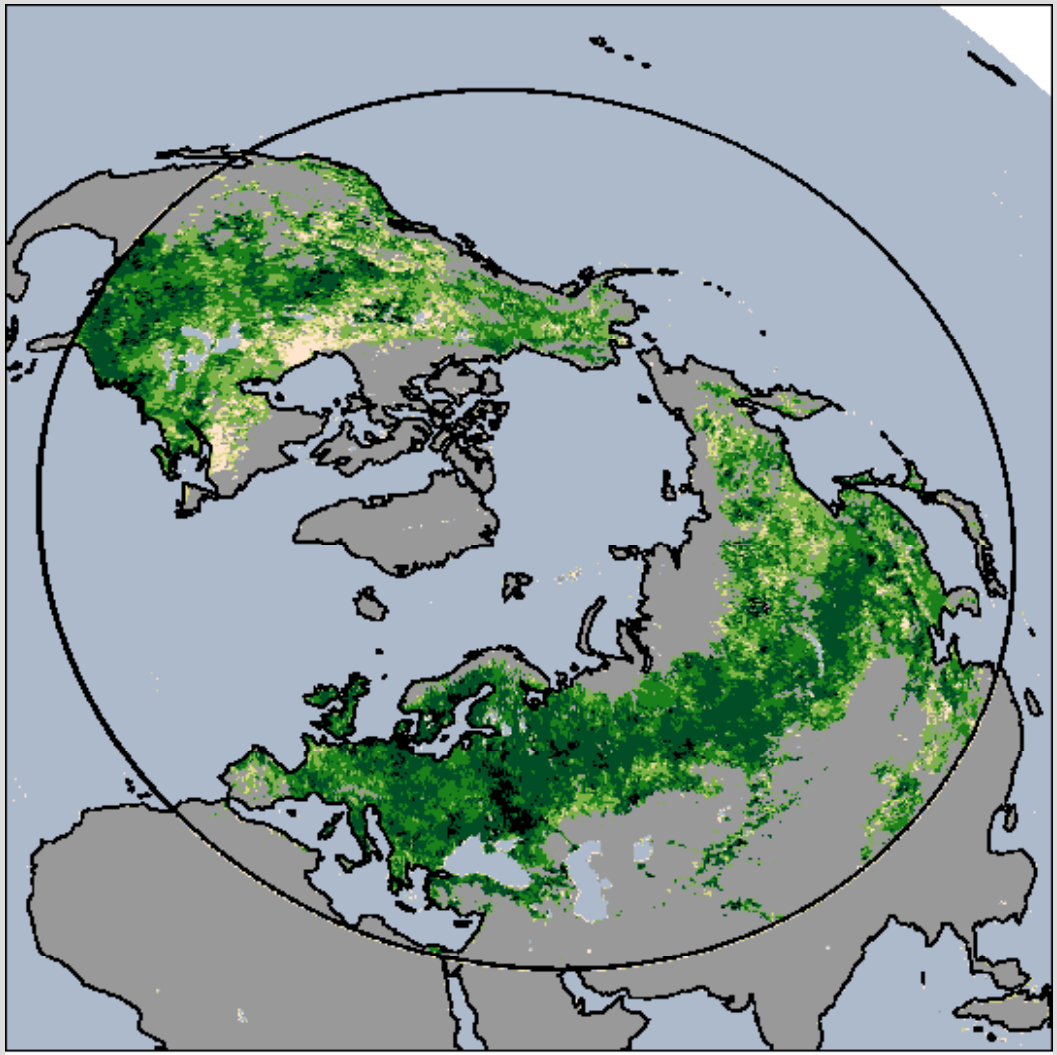
Divergence, however, is real (at least in high latitudes of Northern Hemisphere, D”Arigo et al 1992, Briffa et al, 1998, 2000, Lawrence, Lapenas 2005)



“Greening” of Northern Hemisphere = more carbon sink?



Normalized Difference Vegetation Index (NDVI) = (G-R)/(G+R)



Why is divergence bad ?

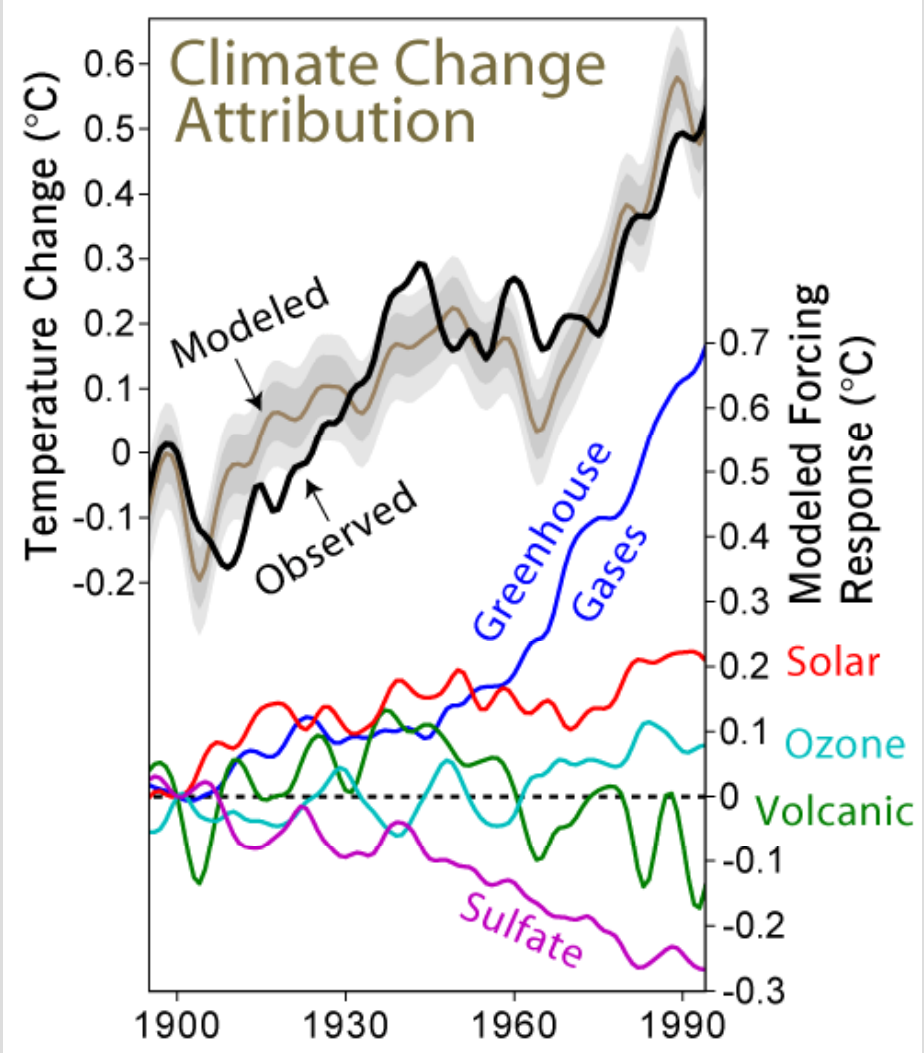
Compromises dendroclimatology as method of plaleoclimatological reconstructions

Leads to overestimate of modern carbon sink into boreal forest => no closure in carbon balance=> no good prediction for atmospheric CO_2 growth=> no good climate forecast.

Hypothesis (about 10 exist by now)

- Delay of snow melt relative atmospheric temperature (Vaganov, Briffa et al 2000)
- Methodological issues such as “end effect” in standardization of chronological records and age models (Cook and Peters, 1997)
- Possible effect of “global dimming” on summer photosynthesis especially in high latitudes (my favorite one☺)

Global dimming exists (see below)



Radiative forcing from dimming = 0.3 W/m2

Has to be divided by 4! (?)

Albedo of forest ~0.3

Absorption =forcingx(1-albedo)= (0.3/4)x0.7=0.054 W/m2

NPP and PAR are related

(Spruce, fore example, increases NPP on 10-30% with 30 -50 W/m2 increase in PAR absorption.....

One more hypothesis: soil acidification

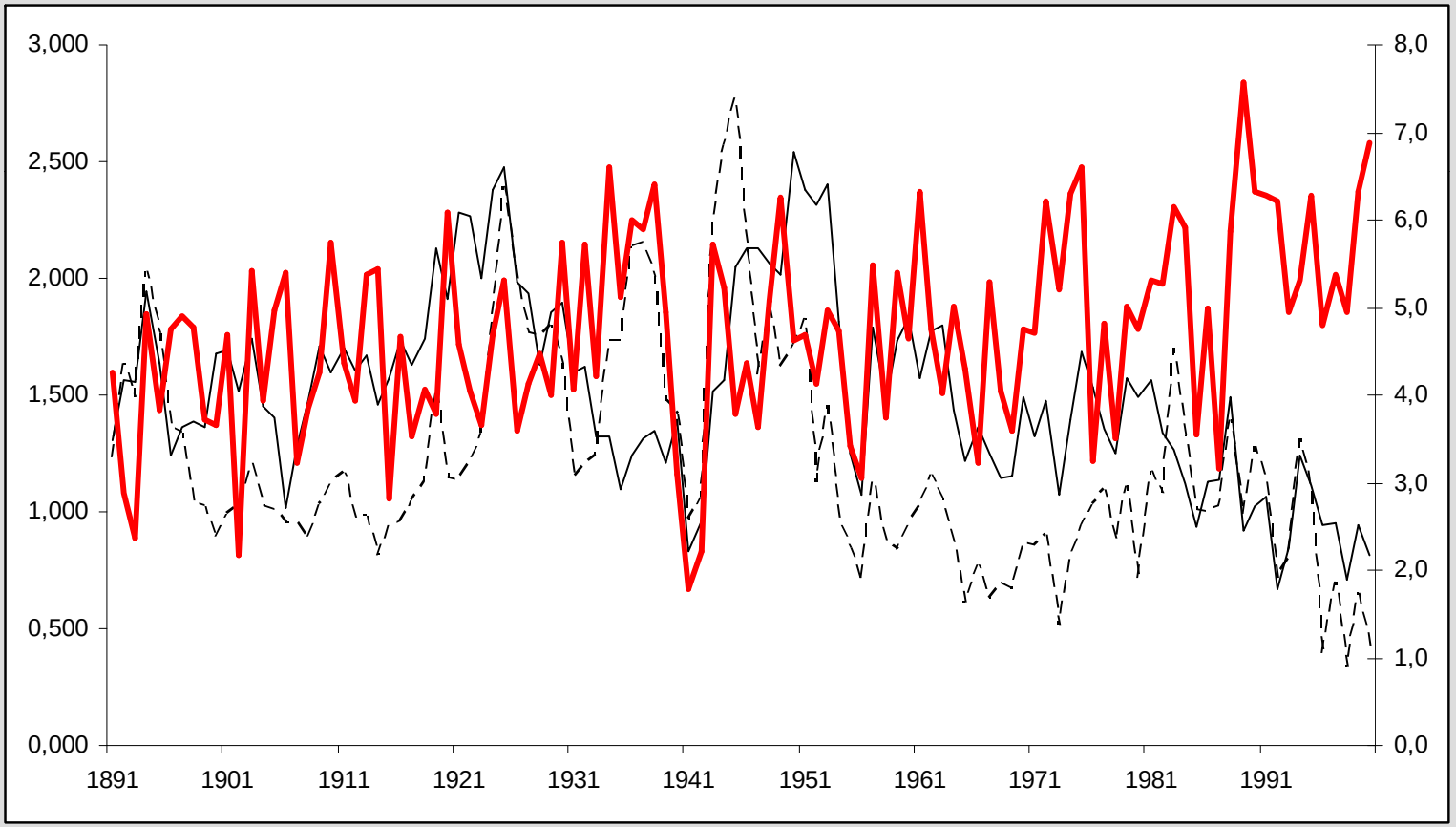
- Soil acidification leads to the loss of calcium and release of mineral aluminum into exchange phase
- Therefore, acidification often leads to increase in Al/Ca ratio in soil solutions
- It was shown, however, that increase in Al/Ca ratio above 1-2 leads to a greater environmental stress (at least in the case of Spruce) as visible through increase in such stress marker as putrescine (Shortle, Lawrence et al 2000)
- And...decline in radial growth and decrease in the sapwood area
- Therefore, in 2005 a group of scientists suggested that soil acidification might be responsible for divergence between spruce growth and temperature (Lawrence et al 2005)

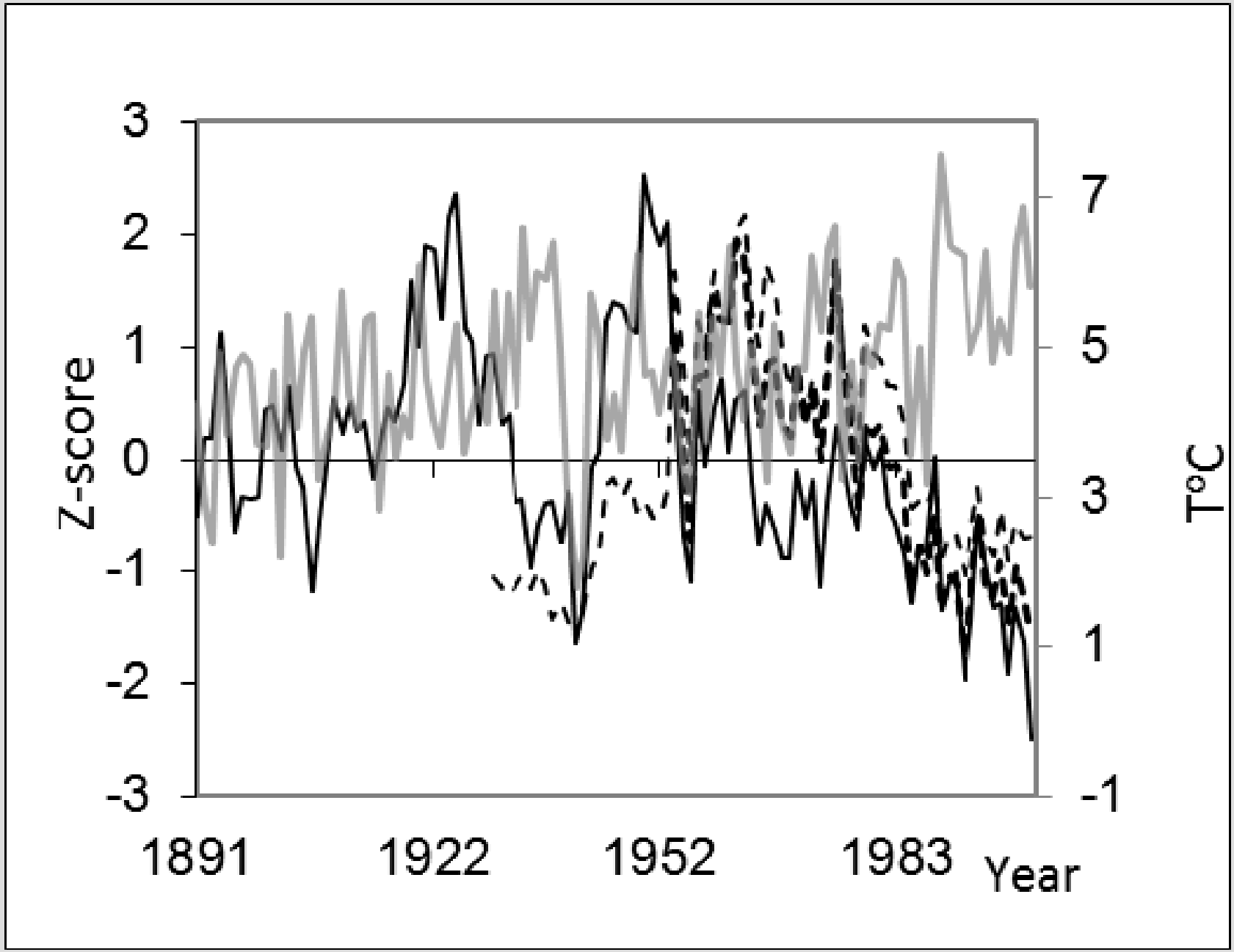
Studies of two Norway Spruce (*Picea Abies*) stands in Western Russia

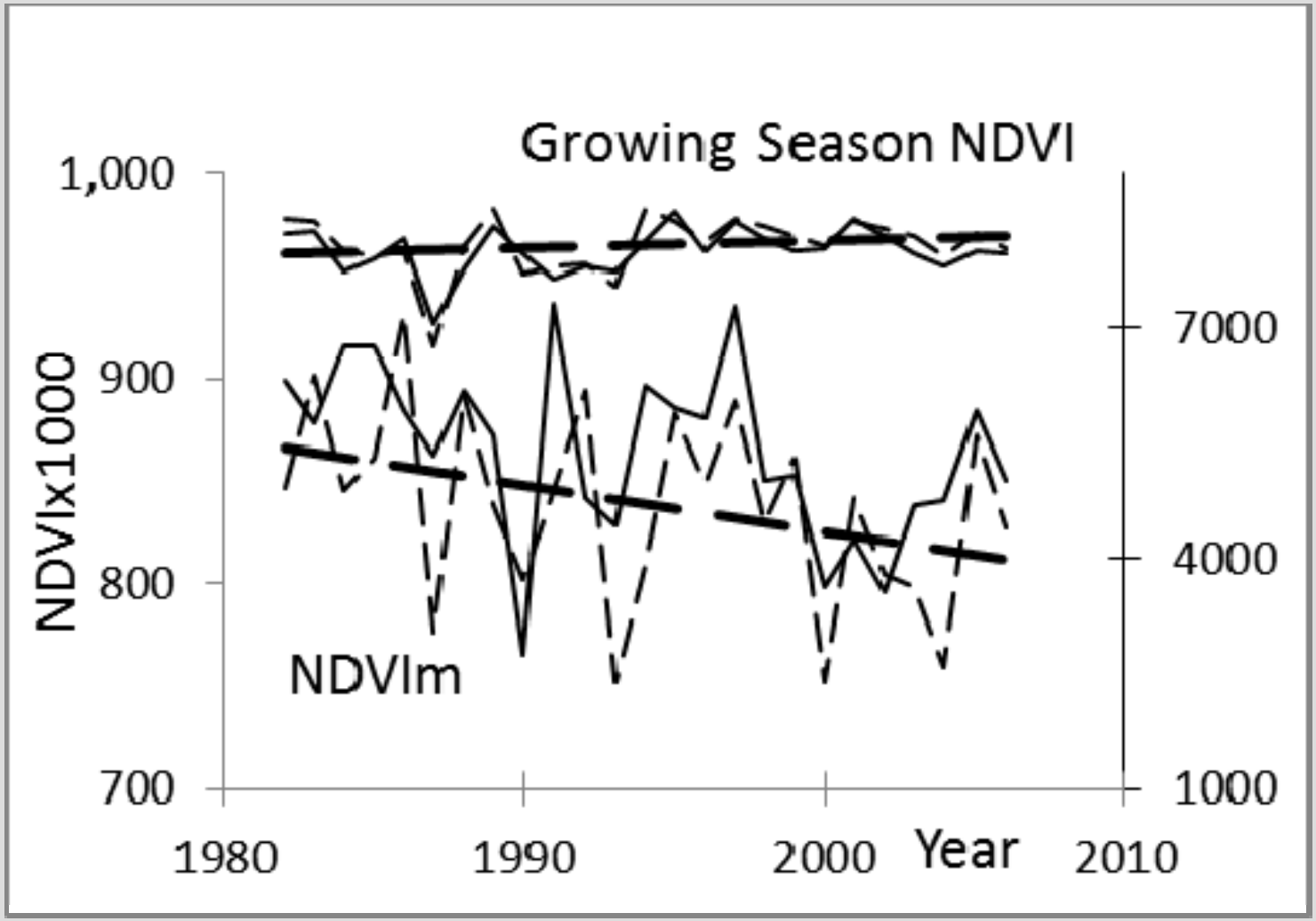
- A) tree ring records
- B) NDVI records
- C) archived soil samples

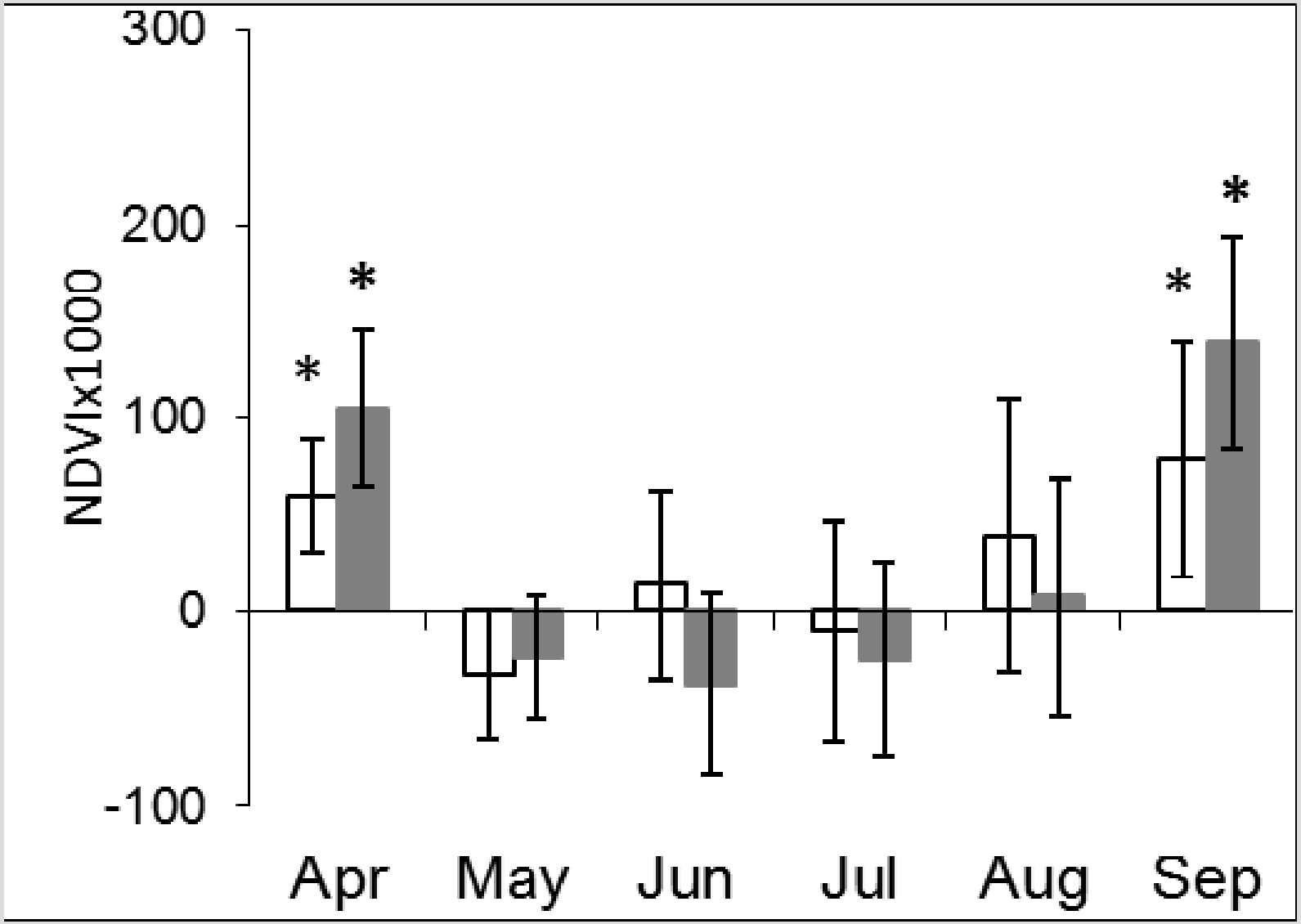

NORTH ATLANTIC OCEAN
ARCTIC OCEAN
SVALBARD (NORWAY)
FRANZ JOSEF LAND
NEW SIBERIAN ISLANDS
SEVERNAYA ZEMLYA
NOVAYA ZEMLYA
Norwegian Sea
Barents Sea
Kara Sea
Laptev Sea
North Sea
Baltic Sea
Black Sea
Gulf of Bothnia
Lake Ladoga
Lake Onega
Arctic Circle
UNITED KINGDOM
NORWAY
SWEDEN
FINLAND
DEN.
NETH.
GERMANY
POLAND
BELARUS
UKRAINE
RUSSIA
EST.
LITH.
LAT.
SLOV.
HUNG.
ROMANIA
MOLD.
TURKEY
GEO.
Amsterdam
Copenhagen
Oslo
Stockholm
Helsinki
Tallinn
Riga
Berlin
Prague
Warsaw
Vilnius
Minsk
Kiev
Lviv
Chisinău
Bucharest
Odesa
Constanța
Sevastopol'
Ankara
Murmansk
Belomorsk
Arkhangel'sk
St. Petersburg
Novgorod
Konosha
Smolensk
Tver'
Vologda
Kotlas
Yaroslavl'
Kostroma
Moscow
Bryansk
Orël
Ryazan'
Nizhniy Novgorod
Kirov
Kharkiv
Voronezh
Penza
Kazan'
Izhevsk
Perm'
Saratov
Samara
Ufa
Donets'k
Rostov
Volgograd
Novorossiysk
Tuapse
Cral
Orenburg
Orsk
Astrakhan'
Atyraŭ
Yekaterinburg
Chelyabinsk
Kurgan
Petropavl
Tobol'sk
Tyumen'
Khanty-Mansiysk
Surgut
Nizhnevartovsk
Nar'yan-Mar
Vorkuta
Pechora
Salekhard
Nadym
Novyy Urengoy
Dikson
Noril'sk
Igarka
Tiksi
Yakut
Vilyuysk
Lensk
Neryu
Ust'-Ilimsk
Ust'-Kut
Lesosibirsk
Nizhneangarsk
Bratsk
Tomsk
Kansk
Krasnoyarsk
Novosibirsk
Novokuznetsk
Abakan
Chita
Borzya
Pavlodar
Omsk
Dnipro
Don
Volga
Kama
Ob'
Irtysh
Yenisey
Angara
Lena
Vilyuy
Pechora

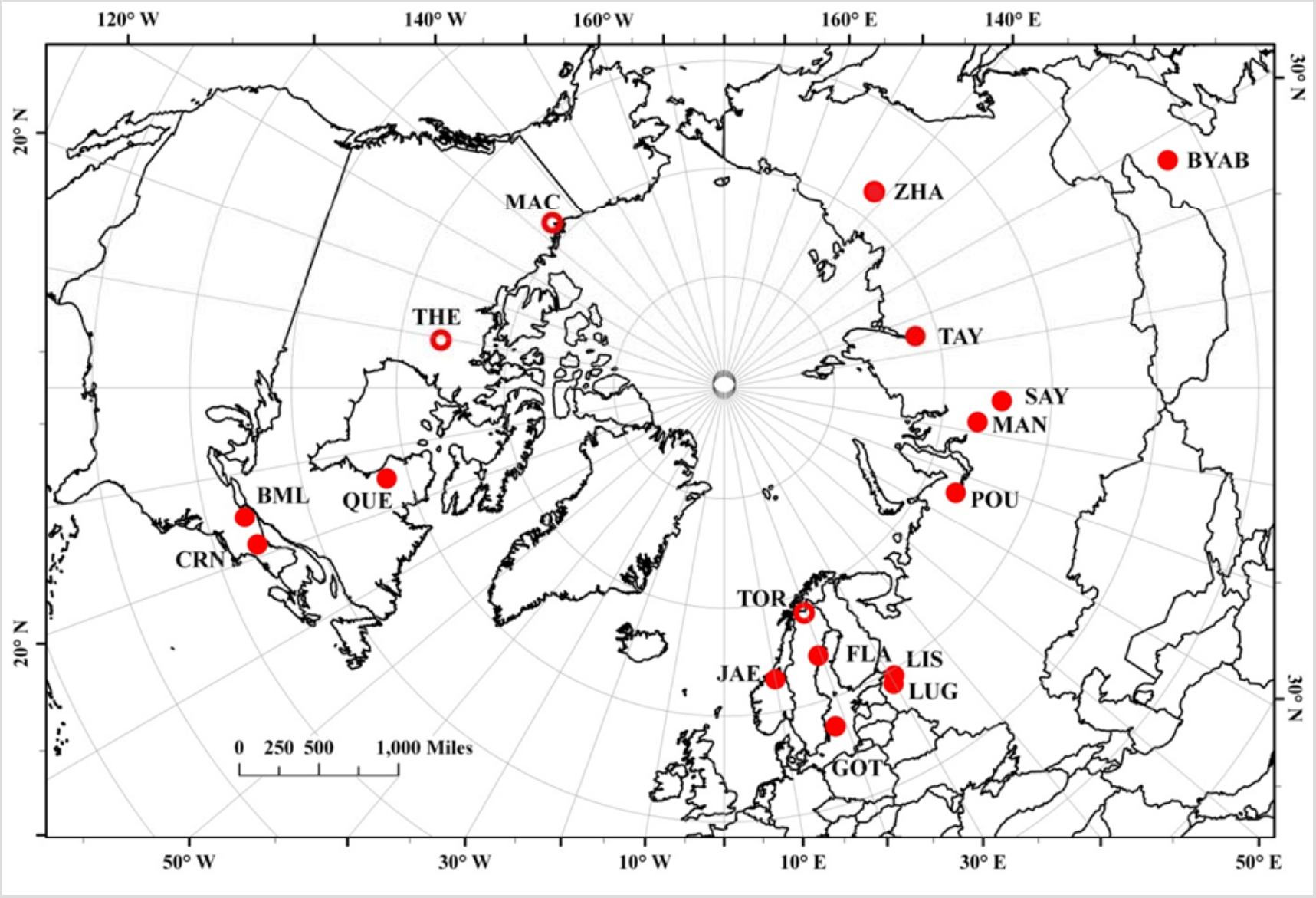
Lisino (solid), Luga (dashed), Mean Annual Temperature (red)



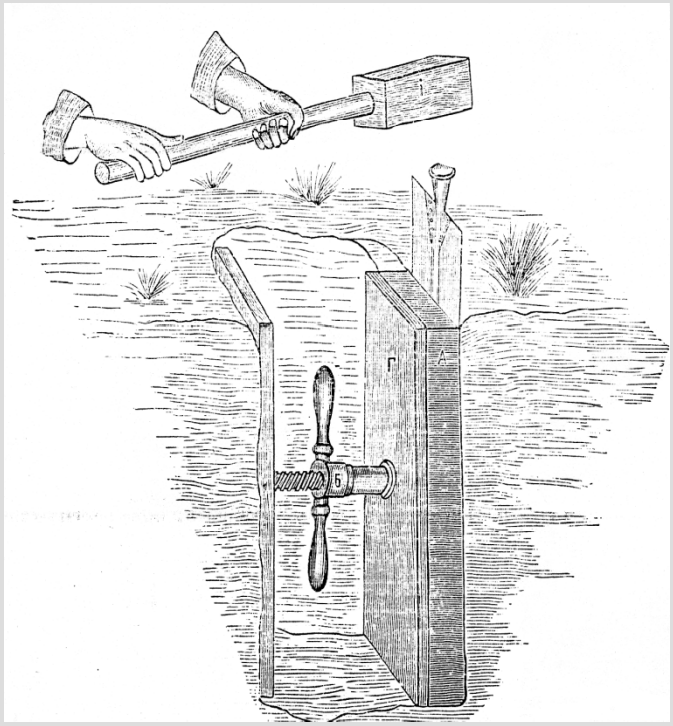

3
2
1
0
-1
-2
-3
Z-score
7
5
3
1
-1
T°C
1891
1922
1952
1983
Year


Growing Season NDVI
1,000
900
800
700
NDVIx1000
NDVIm
7000
4000
1000
1980
1990
2000
2010
Year

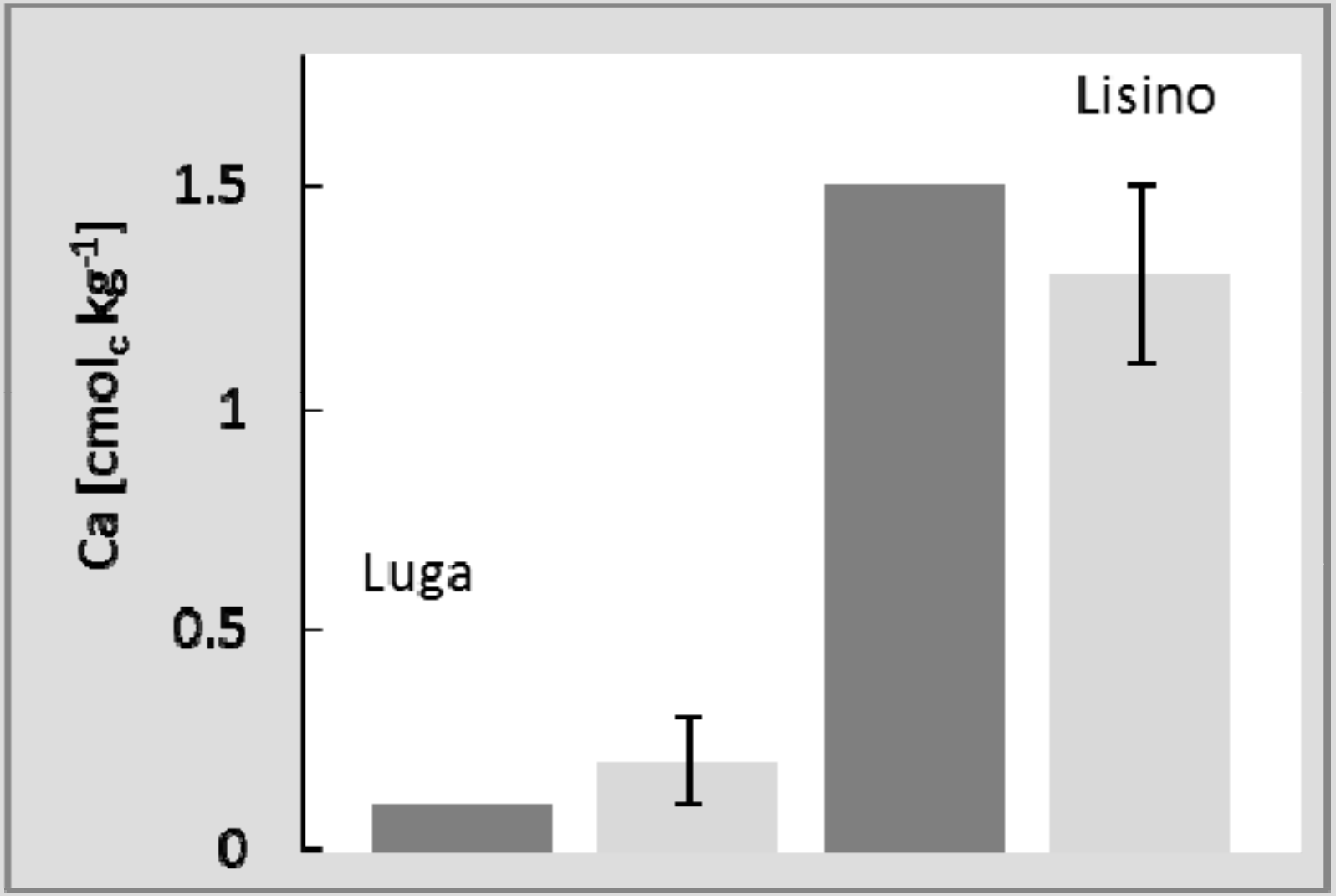

300
200
100
0
-100
NDVIx1000
*
*
*
*
Apr
May
Jun
Jul
Aug
Sep

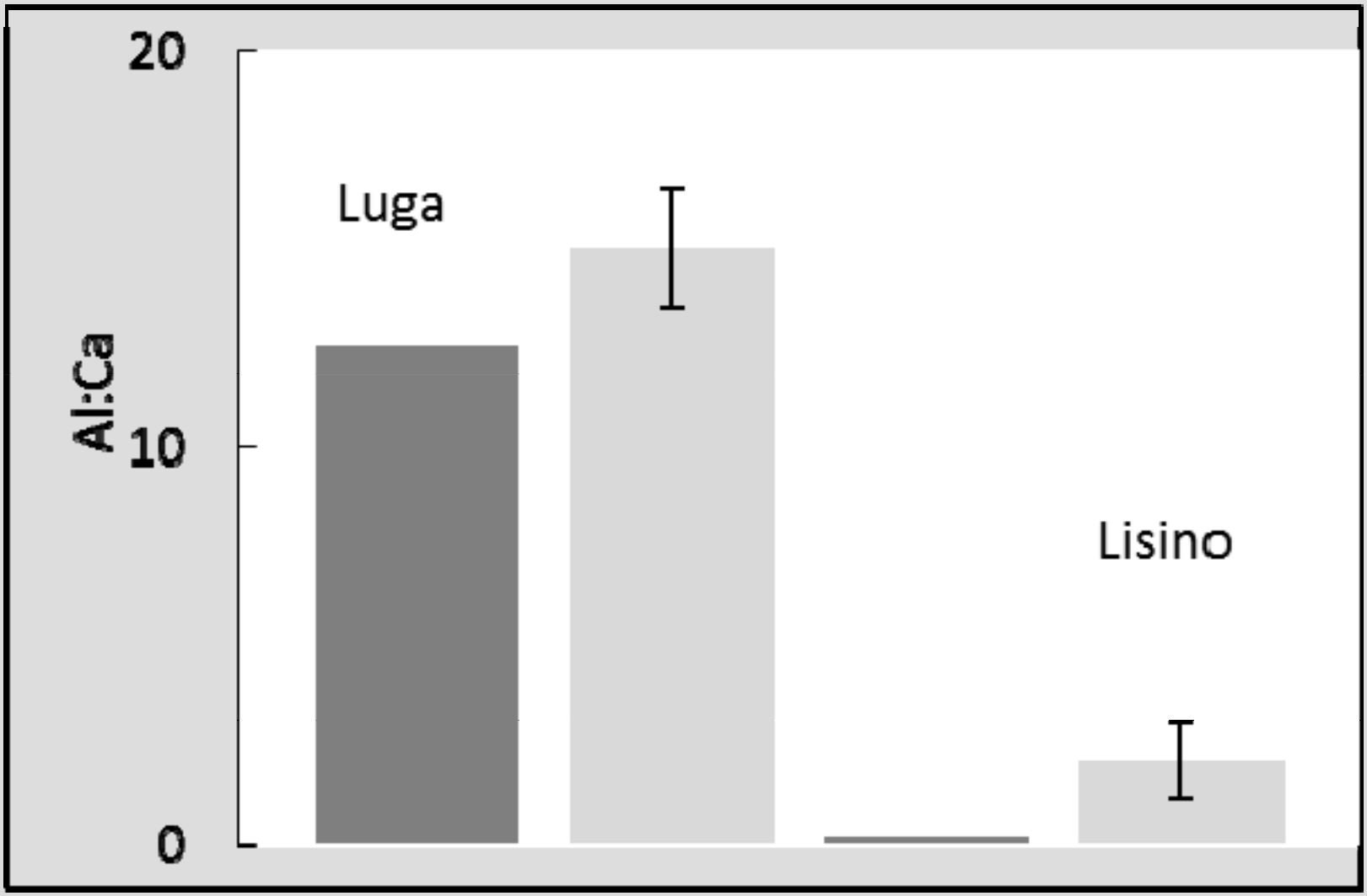

120° W
140° W
160° W
160° E
140° E
30° N
20° N
BYAB
ZHA
MAC
THE
TAY
SAY
MAN
POU
QUE
BML
CRN
TOR
FLA
LIS
LUG
JAE
GOT
0 250 500 1,000 Miles
50° W
30° W
10° W
10° E
30° E
50° E

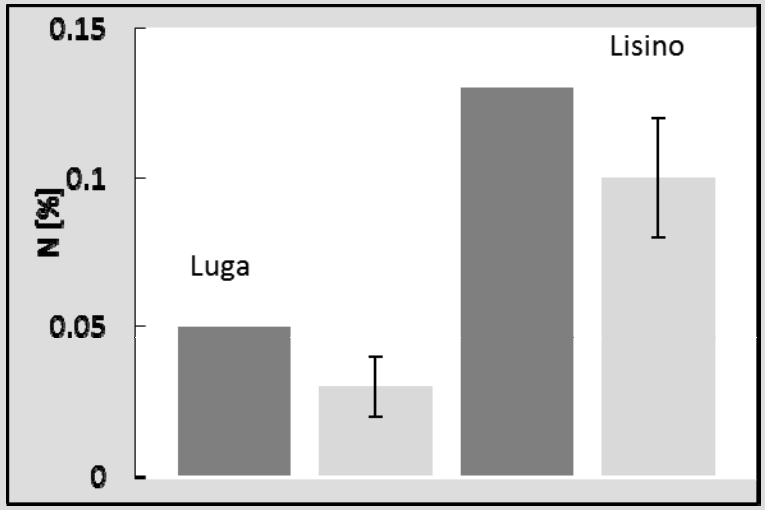
Central Dokuchaev's Soil Museum
St. Petersburg

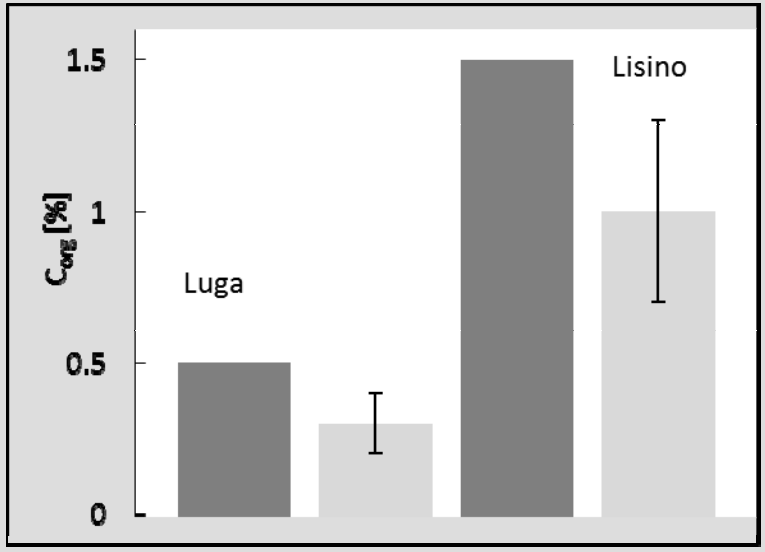


1930, 1960, 2001


Ca [cmol$_c$ kg^{-1}]
1.5
1
0.5
0
Luga
Lisino

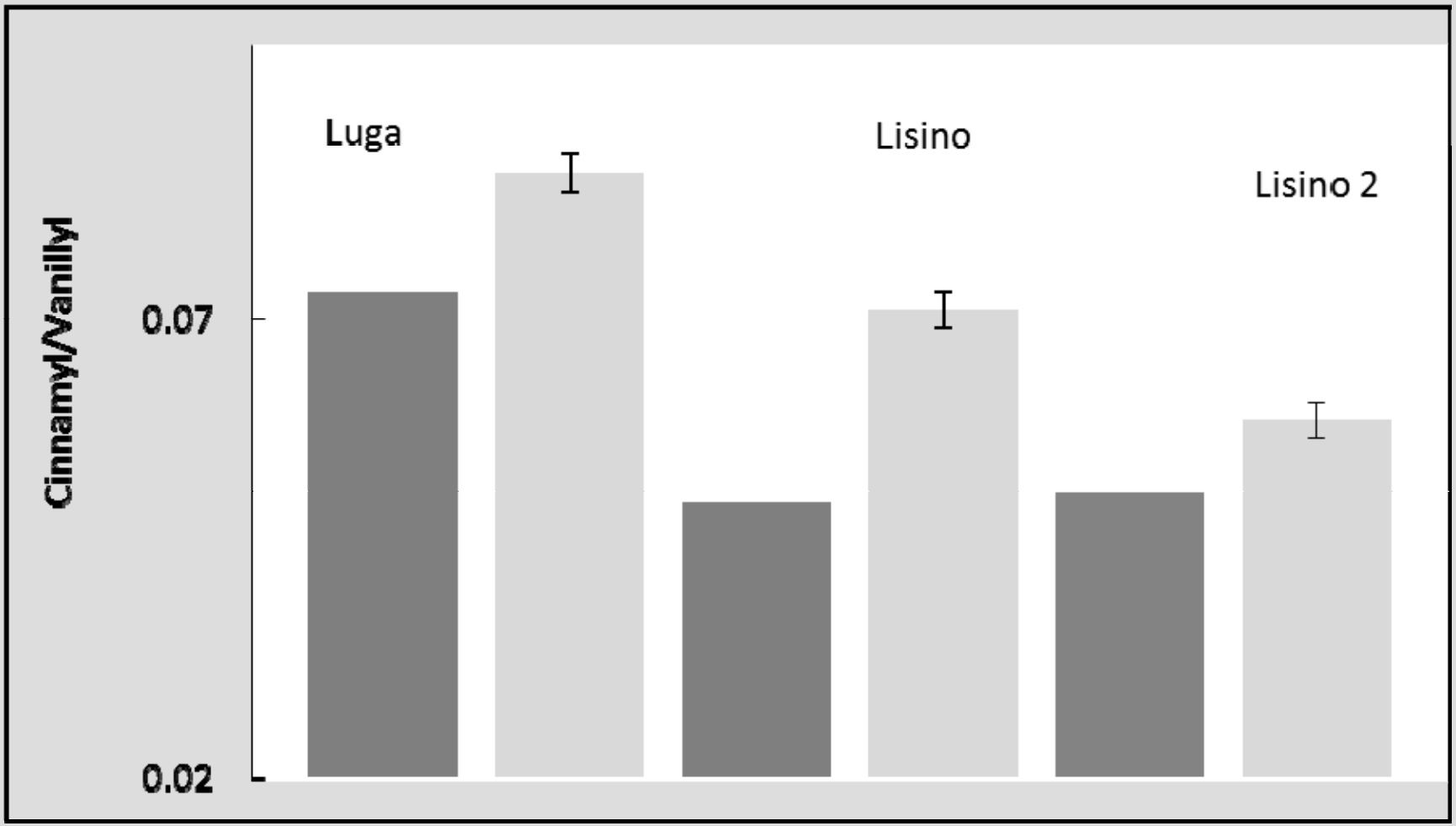

20
10
0
Al:Ca
Luga
Lisino


0.15
0.1
0.05
0
N [%]
Luga
Lisino


1.5
1
0.5
0
C_{org} [%]
Luga
Lisino

Lignin biomarkers

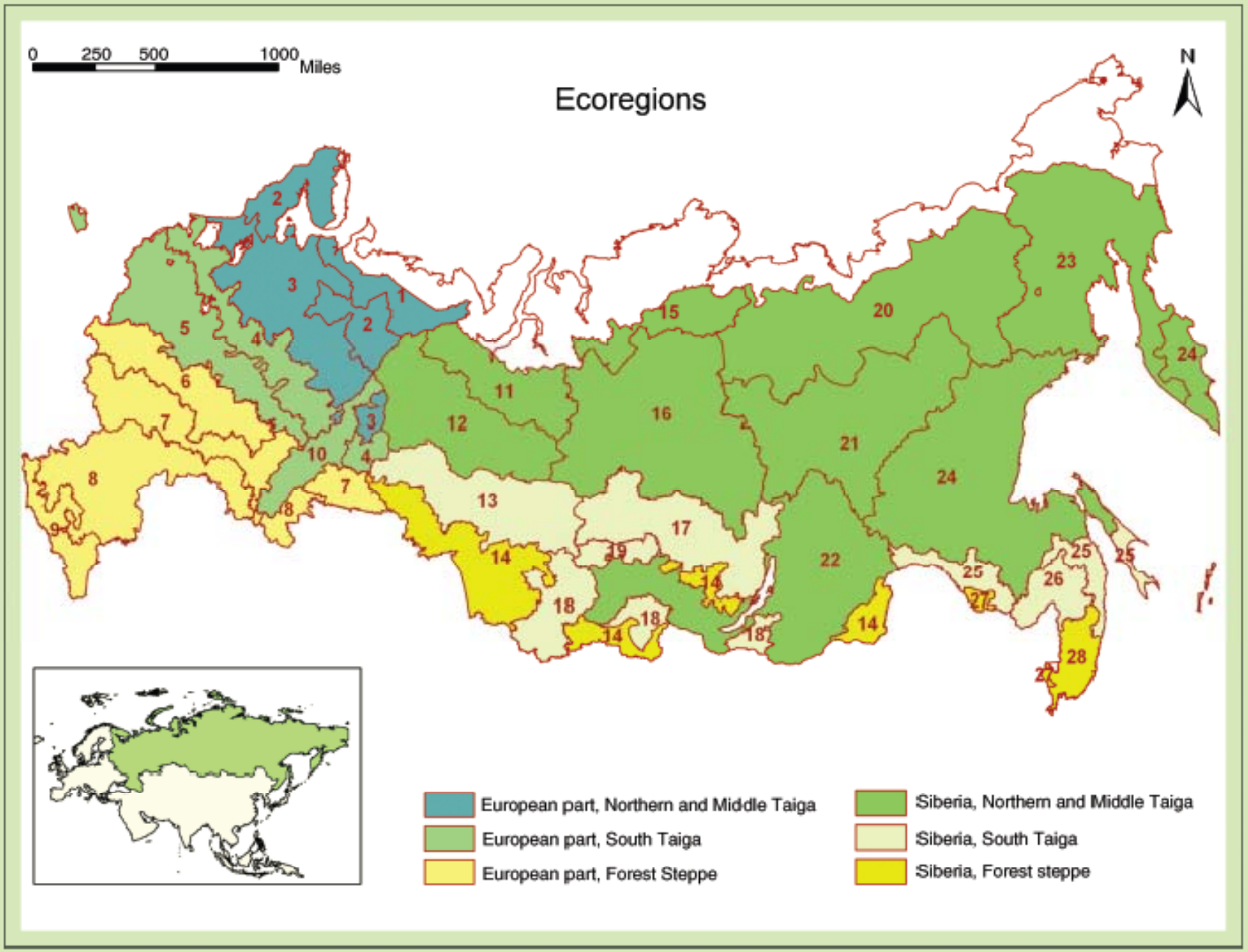
- Conifer wood is composed of vanillyl units only, while leaf tissue (and roots, and any potential understorey vegetation) contribute cinnamyl units. Thus a change from low to high C/V ratios in forest floor samples could be used as an indicator of more non-woody tissues.


Luga
Lisino
Lisino 2
Cinnamyl/Vanillyl
0.07
0.02

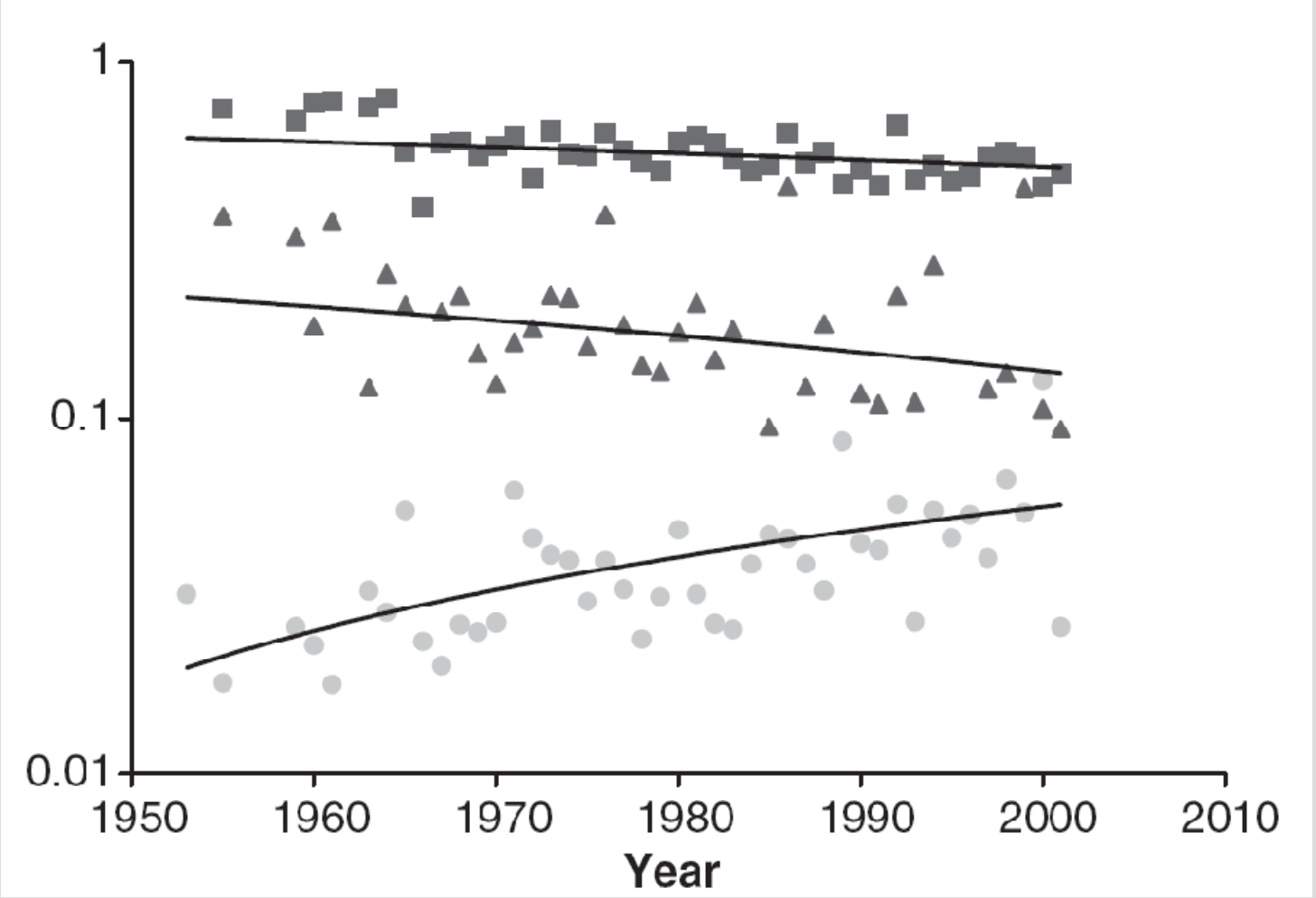
How to explain all these data?

Facts:

1. Decline in radial growth
2. No change or some increase in seasonal NDVI
3. Decline in mid-summer NDVI
4. Increase in non-woody sources of lignin


0 250 500 1000 Miles
N
Ecoregions
European part, Northern and Middle Taiga
European part, South Taiga
European part, Forest Steppe
Siberia, Northern and Middle Taiga
Siberia, South Taiga
Siberia, Forest steppe

Trends in stem wood (squares), roots (triangles) and green parts (circles) (Lapenis et al. 2006)



Phenotypic plasticity?

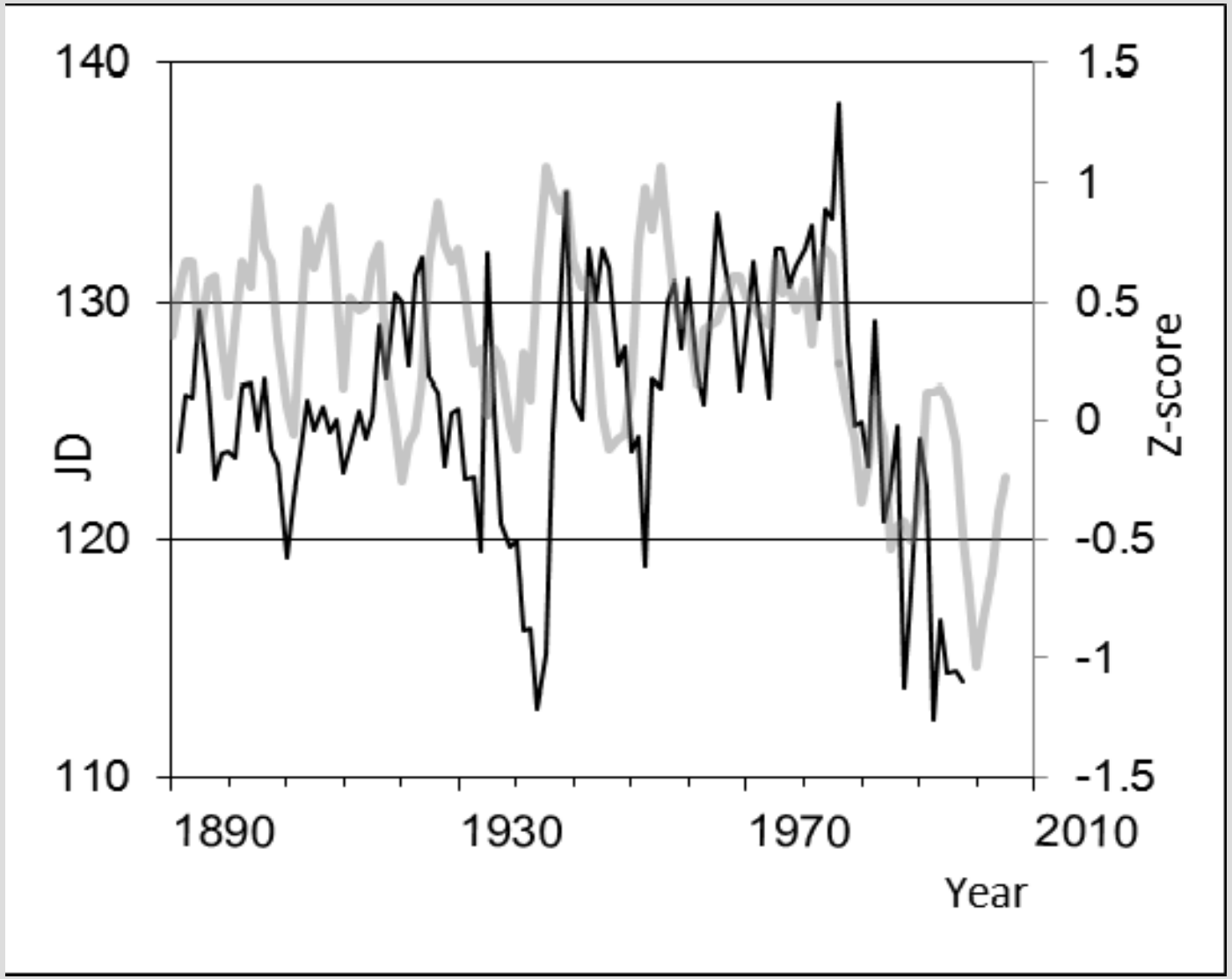
- Although the allometric relation between leaf area and the vascular system demands that xylem formation keep pace with shoot growth, there may be room for plasticity; furthermore, leaf turnover is relatively independent of turnover in stem tissue.

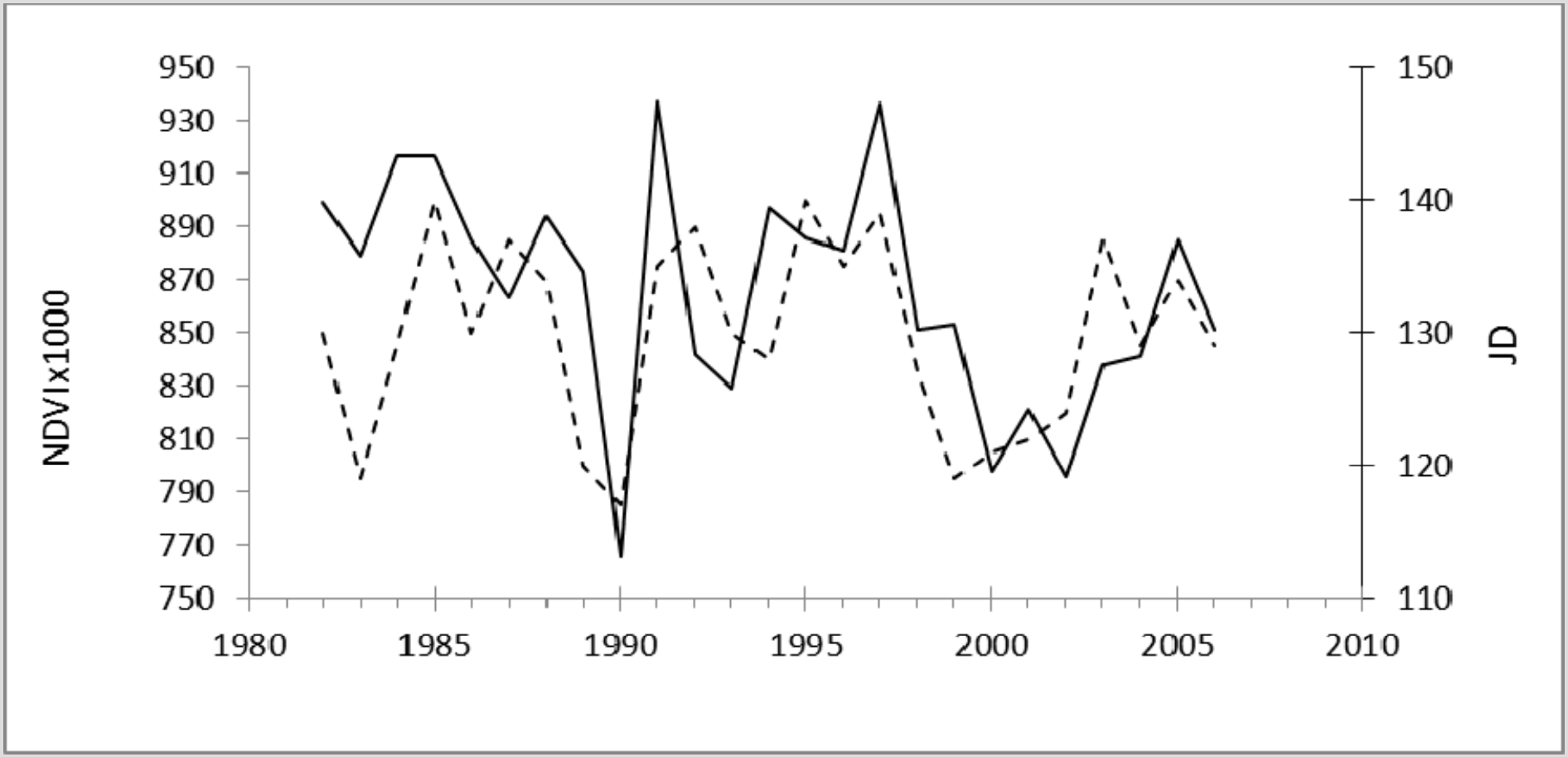
Climate change were very small!

- +1.5ºC warming of mean annual temperature
- + 10% icrease in precipitation

Large changes in phenology!

- Budbreak advance of + 10-15 days
- No change in time of snow melt, however!
- Therefore, the phase I of starch accumulation in spruce now is up to 30% shorter!


140
130
120
110
JD
1.5
1
0.5
0
-0.5
-1
-1.5
Z-score
1890
1930
1970
2010
Year


NDVIx1000
950
930
910
890
870
850
830
810
790
770
750
1980
1985
1990
1995
2000
2005
2010
150
140
130
120
110
JD

Conclusions

- Decline in radial growth was accompanied by shift in allocation of carbon towards non-woody parts
- The shift of carbon allocation is linked to changes in phenology of spruce and, thus, to small changes in climate
- The linkage between carbon shift and phenology was weak, however, at strongly acidified site