Stable oxygen isotopes in tree rings: a climate archive

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Process-oriented analysis

- High temporal resolution (seasonal)
- isotopes in many compartments
- Detailed microclimatic measurements
- Few sites
- isotope fractionation model

Climate reconstruction based on isotopes

- Low temporal resolution (annual)
- isotopes in tree-rings
- monthly climate data from distant weather station
- Many sites
- statistical analysis
Studies in Siberia

Institute of Forest, Krasnoyarsk

(1) Northeastern Yakutia (YAK) (Hughes et al., 1999; Sidorova et al. 2008)
(2) Eastern Taimyr (TAY) (Naurzbaev et al. 2002; Sidorova et al. 2009)
(3) Tura (Knorre et al. 2006; Sidorova et al. 2009)
(4) Eniseysk (Knorre et al. in preparation)

The photos of the studied sites made by M.M. Naurzbaev (1-2) and by A.V. Kirdyanov (3-5).
**Tura:** 64°N, 100°E; highly continental, mean annual air temperature of -9.2°C; annual precipitation of only 317 mm
Studies in Northern Eurasia

Saurer et al. GRL 2002
Comparison between species and sites

Picea abies
Pinus sylvestris
Abies alba
Fagus sylvatica
Fraxinus Excelsior
Quercus petraea

Saurer et al., JGR, 2008
Tree-ring $\delta^{18}O$ chronologies from different species and sites in Switzerland are quite similar in decadal scale variability.

Saurer et al. 2008
Alpine site
Lötschental, Switzerland
Larix decidua
**The problem/challenge:**
Correlations between trees from one site often very strong
-> indicates common forcing
BUT climatic signal still not so clear

Single tree chronologies from an Alpine site (*Kress et al. 2009*)

\[ r = 0.81 \]
Alpine site

Kress et al., GBC 2010
Spatial extension of $\delta^{18}O$ signal

Correlation coefficient ($r$) $p < 0.001$
Correlations to temperature are lower for δ\textsuperscript{18}O compared to δ\textsuperscript{13}C

Kress et al. 2009
What is the driving force for changes in $\delta^{18}O$?

- Temperature
- Rel. humidity

$\delta^{18}O$ in precipitation

$\delta^{18}O$ in tree-rings
What is the driving force for changes in \( \delta^{18}O \)?

- Atmospheric circulation
- Temperature
- Relative humidity

\( \delta^{18}O \) in precipitation

\( \delta^{18}O \) in tree-rings
Tree-ring and precipitation $\delta^{18}O$ from Swiss sites

North Alps South

Precipitation

Tree-rings

-25 -20 -15 -10 -5 0 5
$\delta^{18}O$ [%o]


-4 -2 0 2 4
$\delta^{18}O$ [%o]

Bern Grimsel Locarno

North Alps South
Temperature fields for classes of years with high or low $\delta^{18}O$ of precipitation
Geopotential height fields (500mbar) for years with high or low $\delta^{18}$O of precipitation.
Frequency of cyclonic conditions

\[ \delta^{18}O_{\text{tree-ring}} (\text{modelled}) = \delta^{18}O_{s} + f \left[ \varepsilon_{k} + \varepsilon_{e} + (\delta^{18}O_{v} - \delta^{18}O_{s} - \varepsilon_{k}) \cdot rH \right] + \varepsilon \]

Assumptions:
\[ \delta^{18}O_{v} = \delta^{18}O_{\text{soil}} \cdot \varepsilon \]

\( f, \varepsilon_{k}, \varepsilon_{e}, \varepsilon \) are known constants

Tree-ring \( \delta^{18}O \)

Saurer et al., JGR, 2012
Alpine site: Working with historic material

Lötschental, Switzerland
Larix decidua
Merging different chronologies
Methods to merge overlapping tree–ring isotope series to generate multi–centennial chronologies
Hangartner, Kress, Saurer, Frank and Leuenberger, Chemical Geology 2012
Methods to merge overlapping tree–ring isotope series to generate multi–centennial chronologies

Comparison of linking methods 3 (blue) and 4 (red)
Alpine site
Standardized chronology

\[ \delta^{18}O \text{ (‰)} \text{ (z-scores)} \]

Year AD

800 1000 1200 1400 1600 1800 2000

\[ Kress \text{ 2009} \]
Alpine site
Long-term variability of tree growth in a changing environment – identifying physiological mechanisms using stable C and O isotopes in tree

SNF iTree
Tree-ring network in Europe and $\delta^{13}$C-derived water-use efficiency (WUE)

Saurer et al., Global Change Biology, 2014
Model:

WUE from Bern LPX global dynamic vegetation model

Data:

WUE calculated from tree-ring carbon isotopes

**Model:**

WUE from Bern LPX global dynamic vegetation model

**Data:**

WUE calculated from tree-ring carbon isotopes
Conclusions

- $\delta^{18}\text{O}$ signal in tree-rings are regional-scale

- Generally not strongly dependent on species/site/local conditions

- $\delta^{18}\text{O}$ is not just temperature

- Models of different complexity are useful and necessary for the interpretation
Thank you for your attention!