Decadal record of monsoon dynamics in the High Himalayas-Tibetan plateau transition zone using tree ring data

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1 Why tree ring data?

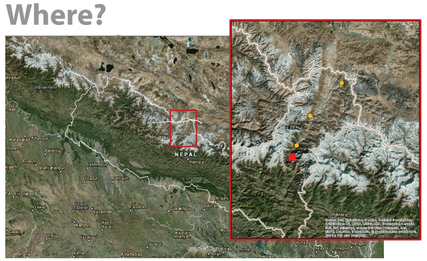
Tree ring data include physical (tree ring width and wood anatomy) and chemical (stable isotopes) parameters which represent a powerful tool to learn about past climate ans its year-to-year variability in space and time. But, what makes tree rings special compared to other climatic proxies?

- annual resolution
- dating control
- wide spatial distribution
- possibility of using rather simple transfer functions and robust isotope fractionation models
- calibration against instrumental data with statistically-defined confidence
- record high and low–frequency dynamics

What is the aim?

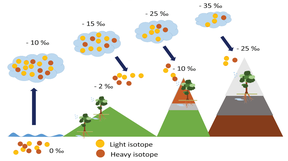
We strive to reconstruct a record of intense monsoon years based on tree-ring isotope chronologies along a latitudinal gradient, this will shed light on how often and how far the Indian monsoon penetrated into trans-Himalayan region over the last century.
Four experimental sites have been selected, hereafter the results from a key site on the nickpoint of the altitudinal profile of the valley are presented.

Where?



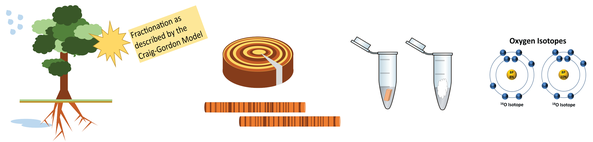
- Kali Gandaki river valley connects the very wet, monsoon dominated south Himalayan front with the arid trans-Himalayan region and the southern Tibetan Plateau
- It is a preferential corridor for the penetration of air masses through the orogeny as such it is highly sensitive to monsoon

How do oxygen isotopes record rain?



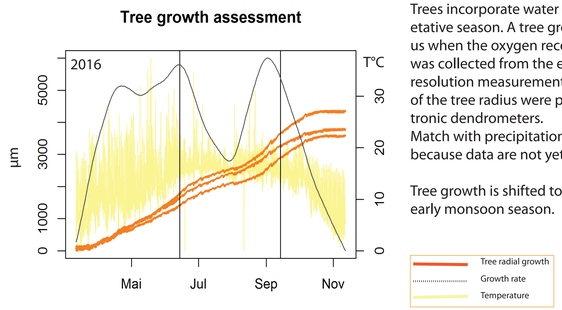
The preferential selection for heavy isotopes during condensation results in:
Strong monsoon -> more rain -> more negative values
Weak monsoon -> less rain -> less negative values

Schematic representation of an oceanic cloud moving along a continental and latitudinal gradient. This model is simplicistic and does not take in consideration evapotranspiration and recycling of continental water sources such as lakes and rivers.



Graphic illustration of the steps required to build an isotopic record from dendrochronological time series. Two main fractionation steps occurr in the tree : the uptaken water get enriched in the leaves as described by Craig and Gordon in 1965, additionally cellulose synthesis results in a biochemical fractionation factor of ~27‰. Due to these events cellulose $\delta^{18}O$ has tipically positive values.

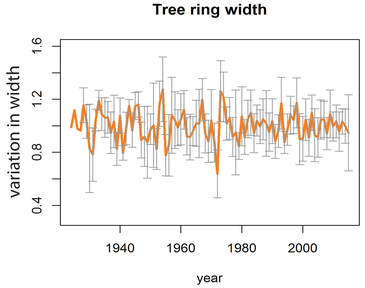
2 Incorporation of water over a growth year



Trees incorporate water only during the vegetative season. A tree growth assessment tells us when the oxygen recorded in the cellulose was collected from the environment. High resolution measurements (30 min frequency) of the tree radius were performed using electronic dendrometers.
Match with precipitation could not be tested because data are not yet available.

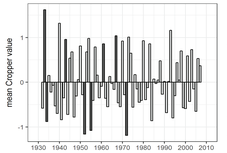
Tree growth is shifted to premonsoon and early monsoon season.

Limits of tree ring width

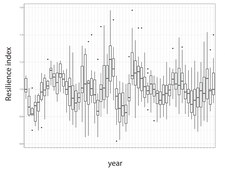


Tree ring width chronology from the average of 44 cores collected from 22 individual trees, shows a highly variable signal.
Although the variability of the signal is not constant along the time series and some extreme fluctuations (e.g. 1972) do correspond to outstanding past hydroclimatic conditions, no significant correlation was found with precipitation data.

The tree ring width chronology presents some extreme years which are supposed to be a mixed signal of climatic and ecological forcig factors. Due to this ambiguity tree ring width appears not to be an effective tool to investigate past hydroclimatic conditions in the trans-Himalayan region.



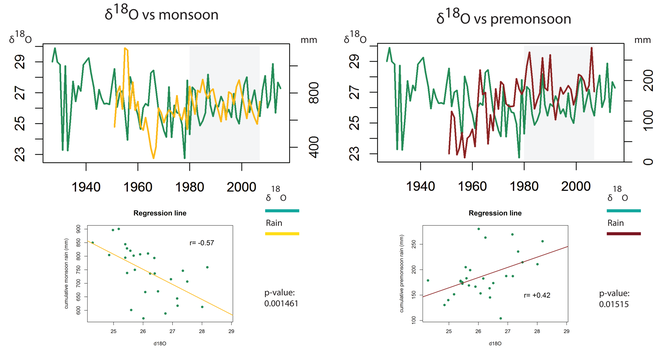
Analysis of pointer years performed with the "normalisation in a moving window" method proposed by Cropper in 1979 highlights some outstanding years. Their interpretation though is not clear.



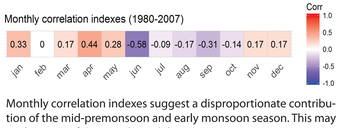
Resilience provides information on the ability of the trees to retain growth levels prior to disturbance.
Regular long term fluctuations may suggest a respons to a ecological forces rather than climatic.

3 Tree ring $\delta^{18}O$ correlates with monsoon strength

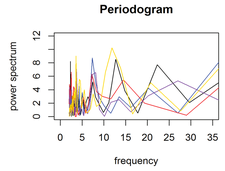
The isotope chronology results from the average of 5 indipendent isotope series extracted from 5 individual trees.
The precipitation data derives from the Aphrodite which is an integrated rain gauge network.
Aphrodite is less well constrained backwards in time (quality and number of rain gauges)



$\delta^{18}O$ cellulose significantly correlates negatively (r= - 0.57) with the June-October cumulative rain , while it shows a positive significant correlation (r= +0.42) with the premonsoon season (Mar-May).



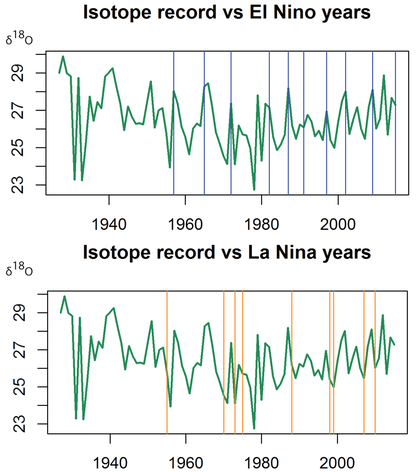
Monthly correlation indexes suggest a disproportionate contribution of the mid-premonsoon and early monsoon season. This may explain part of the signal variability.



A Fourier transform analysis highlights 7 years periodicity in all the individual isotopic series.

Tree ring $\delta^{18}O$ records ENSO

El Niño and La Niña are defined as opposite phases of the so called El Niño-Southern Oscillation Index which describes the fluctuations in temperature between ocean and atmosphere in the east-central Pacific.
El Niño years are usually related to a weakening in the indian monsoon circulation. In contrast, during La Niña, the monsoon is strengthened resulting in intensified rainfall events.

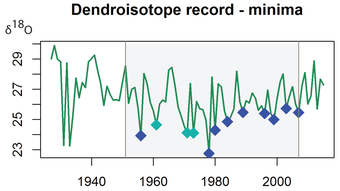


- All El Niño years correspond to a local maxima in the $\delta^{18}O$ record, as expected from the model of water moisture fractionation along a latitudinal gradient
- Not all the peaks in the isotopic time series are explained by ENSO events

- La Niña years partially correspond to local minima in the $\delta^{18}O$ record, althougth in some cases a one year offset is observed
- A hydrological rather than meteorological influence is suspected

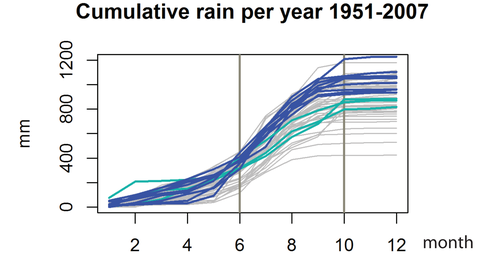
Tree ring $\delta^{18}O$ minima correspond to the most intense monsoons

Eleven minima have been identified in the tree ring $\delta^{18}O$ record.
Monthly resolution precipitation data were extracted to build a spaghetti plot of cumulative rain per each available year (1951-2007).



- The years identified through the isotopic record correspond to the most rainy years. A big consistency in the steepness of the cumulative curves during the monsoon season is observed

- In three cases , due to a drop in the data quality of the Aphrodite dataset, an underextimation of the precipitation amount is presumed



Take home message(s)

1. The incorporation of water oxygen isotopes in the tree rings occurr in the early phase of the vegetative season
2. Tree ring isotopic record shows a periodicty which correlates with major hydroclimatic patterns such as El Niño and La Niña
3. A decadal trend in the tree ring isotope record reflects the intensification of the premonsoon phase over the last 40 years