Maya and Climate

Climate and the Collapse of Maya Civilization

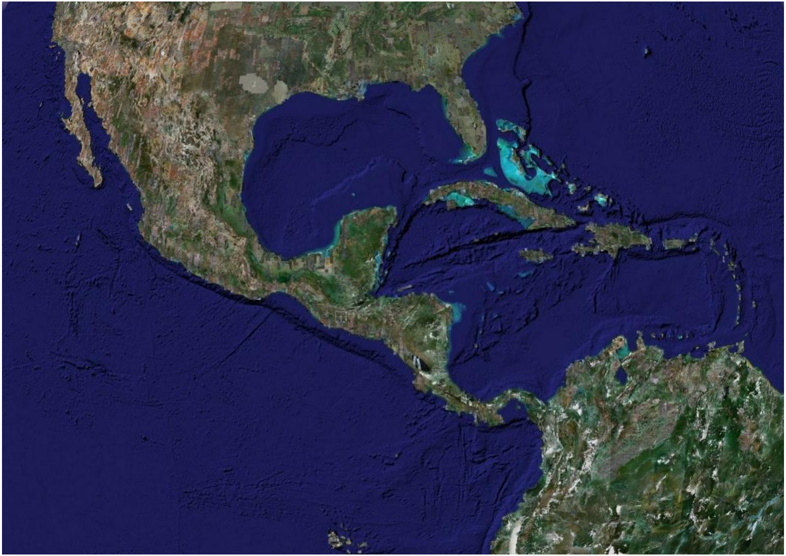
Peter Barmet, Thomas Kuster, André Welti

Department of Environmental Sciences
ETH Zürich

Climate History and Paleoclimatology, 24.11.2006

Outline

Geography (Middle America)



→ Lake Chichancanab

Geography (Yucatán Peninsula)

Areas

- north
- central
- south

Architecture

Buildings

- pyramids and temples
- observations
- ball courts

Architecture
Temple

Tikal

Architecture

Buildings

- pyramids and temples
- observations
- ball courts

Architecture
Ball Court

Monte Albán, in the Oaxaca region of Mexico

Ballgame

Ballgame

- resemble volleyball
- with ritual association (winners or losers are sacrificed)
- staked themselves (ending up as slaves)

Periods

Preclassic

- 2000 BC[a] to 250 AD[b]
- first settled villages along the Pacific coast
- ceremonial architecture (1000 BC)

[a] Before Christ
[b] Anno Domini, latin for "in the year of the lord"

Classic

- 250 to 900 AD
- city-centered empire consisting of independent city-states
- zenith of the civilisation (800 AD)

Postclassic Period

- 900 to 1511 AD (spanish colonial period began)

Collapse

Collapse

- estimated popullation before the collapse 3 – 13 million
- between classic an postclassic period, in 3 phases
  - 760 to 810 AD
  - to 860 AD
  - to 910 AD
- different theories
  - limited farmland, soil degradation (Bodenverarmung)
  - disaster
  - war (invasion)
  - epidemic
  - climate (drought)

Collapse

Areas and Time of Collapse Time

- central: 810 AD
- south: 860 AD
- north: 910 AD

Collapse

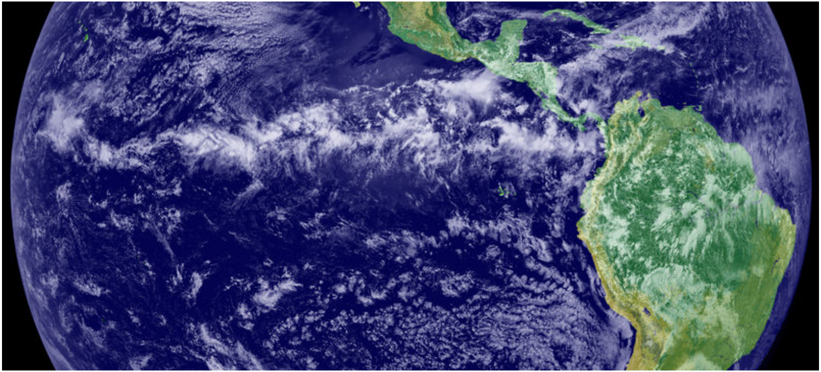
Collapse

- estimated popullation before the collapse 3 – 13 million
- between classic an postclassic period, in 3 phases
  - 760 to 810 AD
  - to 860 AD
  - to 910 AD
- different theories
  - limited farmland, soil degradation (Bodenverarmung)
  - disaster
  - war (invasion)
  - epidemic
  - climate (drought)

Inter Tropic Conversion (ITC)

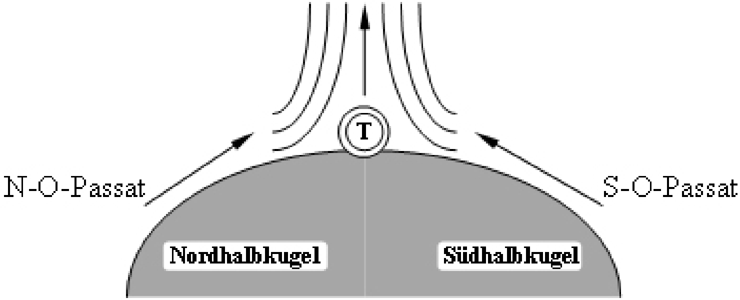
Abbreviations

- ITC: Inter Tropic Conversion
- ITCZ: Intertropical Convergence Zone

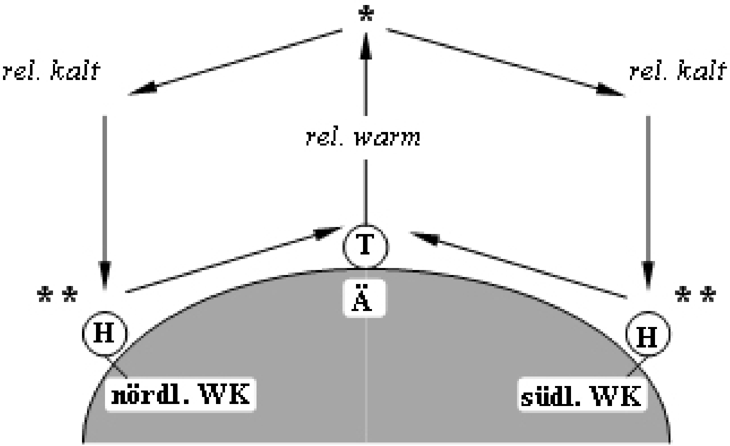


Functionality

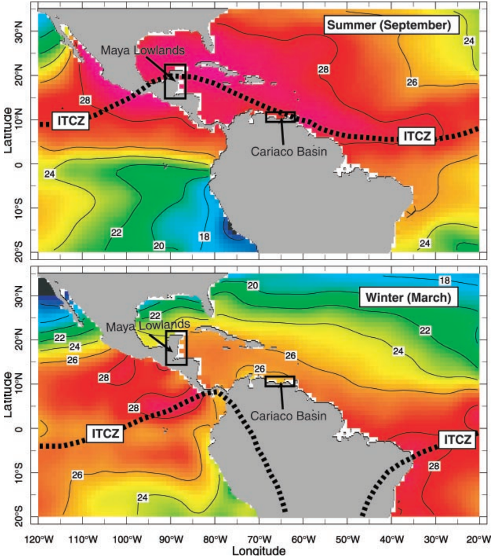
Inter Tropic Conversion (ITC)



Functionality
Hadley Cell



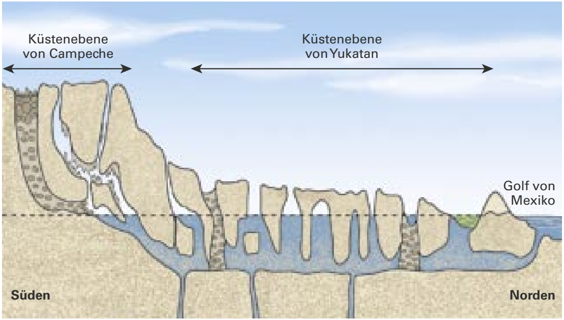
ITC over Middle America



Influence

- most of rain (90%) during summer
- dry winter
- southward displacement of the ITC → drought
- north–south precipitation gradient (Yucatán peninsula)
  - south: 4 000 mm
  - north: 500 mm

Sectional Drawing through the Yucatán Peninsula



Overview

- limestones rocks and mountains
- caves (as in the jura mountains)

Karst Cave with Groundwater

Groundwater

- access to groundwater is rare
- groundwater access is importend factor for a large population to survive

Methods

Sediment Core Analysis

- gypsum ($CaSO_4$) deposition
- oxygen isotops ($\delta^{18}O$)
- titanium content

Gypsum ($CaSO_4$) Deposition

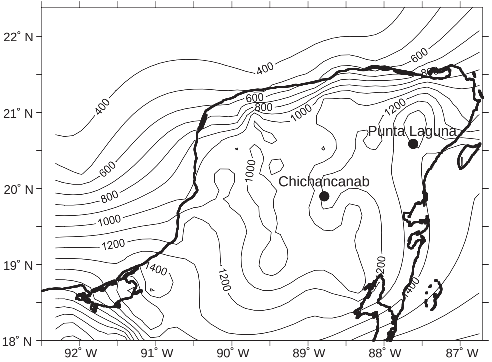
Where?

Cores from Lake Chichancanab

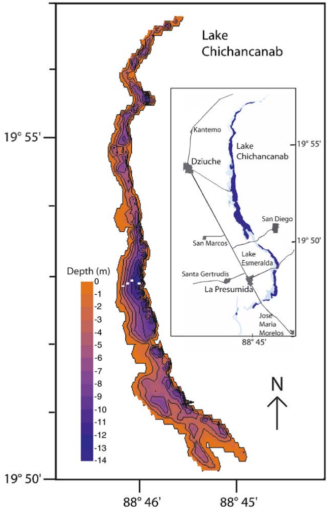
Why are Sediments from Lake Chichancanaba good Archives?

- closed basin that loses a large fraction of its water by evaporation
- $CaSO_{4(aq)}$ concentration near saturation
- fallout of $CaSO_4$ if saturation is reached trought height water evaporation during droughts

Lake Chichancanab



Location of Lakes Chichancanab and Punta Laguna on the Yucatán Peninsula



Positon of the depth transect of cores (white squares)

Gypsum ($CaSO_4$) Deposition

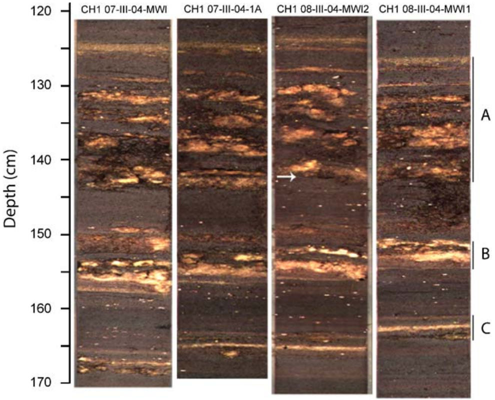
Where?

Cores from Lake Chichancanab

Why are Sediments from Lake Chichancanaba good Archives?

- closed basin that loses a large fraction of its water by evaporation
- $CaSO_{4(aq)}$ concentration near saturation
- fallout of $CaSO_4$ if saturation is reached trought height water evaporation during droughts

Gypsum ($CaSO_4$) Deposition



Gypsum Deposition

Series of lightcolored gypsum layers interbedded with organic-rich sediments containing shells

Method

- radiocarbon date (^{14}C) of shell material and wood
- digital color linescan camera

Oxygen Isotops (δ^{18}O)

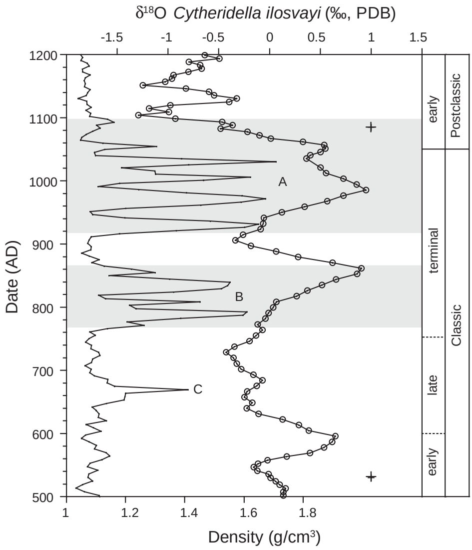
Where?

Cores from Lake Chichancanab

Detection of Drought Periods with δ^{18}O

- δ^{18}O is a proxy for evaporation
- enrichment of ^{18}O during droughts, because ^{16}O evaporates easier
- isotopic signal is conserved in shells

Oxygen Isotops ($\delta^{18}O$)



Analysis of $\delta^{18}O$

- high evaporation rates are indicated by high $\delta^{18}O$
- drought periods (shaded in figure)
- dated by radiocarbon (^{14}C)
- density meassurements to correlate different sediment cores

Titanium Content

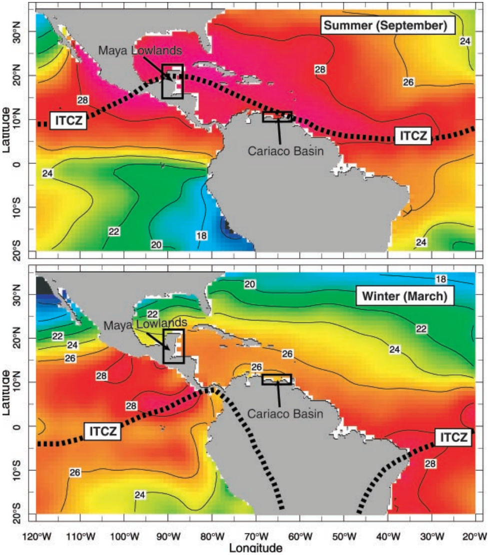
Where?

Cores from Cariaco Basin

Why is Cariaco Sediment a good Proxy for Precipitation?

- anoxic
- undisturbed sediment
- reflects variations in riverine input and the hydrological cycle over northern tropical South America

Cariaco Basin



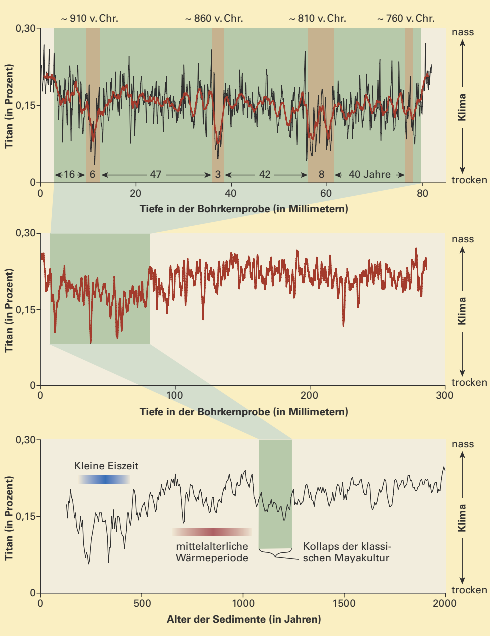
Titanium Content

Where?

Cores from Cariaco Basin

Why is Cariaco Sediment a good Proxy for Precipitation?

- anoxic
- undisturbed sediment
- reflects variations in riverine input and the hydrological cycle over northern tropical South America



Titanium Content

- titanium content is a proxy for precipitation
- less titanium → less precipitation
- corresponds to the collaps of maya civilisation

Method

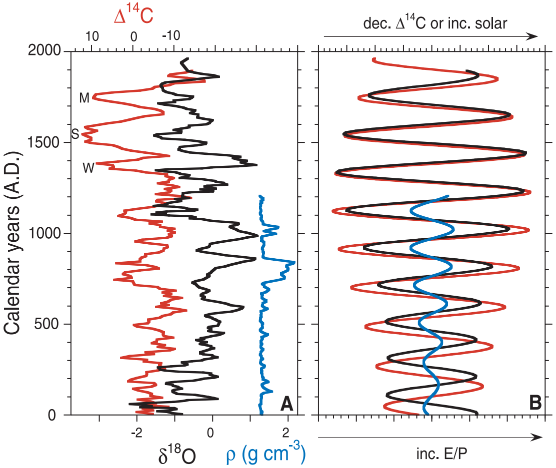
If titanium is irradiated with X-ray, it emits at specific wavelenght.

Results

5 500 BC	–	500 BC	relative wet
475 BC	–	250 BC	drought period (before the rise of Maya civiliation)
250 BC	–	150 BC	wet
150 BC	–	250 AD	drier period
250 AD	–	600 AD	good climate conditions
600 AD			begin of a long dry period
760 AD	–	850 AD	begin of the TCD, worst drought since the last 7 000 years
800 AD			zenith of the drought and collapse of the civilization
910 AD	–	990 AD	second drought period
1 060 AD	–	1 100 AD	third drought period

$\Rightarrow$ period 800 to 1 000 AD was the driest of the middle to late Holocene. This matches the period when the classic Maya civilisation collapsed.

Results



Cycle

Droughts cycle shows a periodicity of 206 years which could be forced by the solar cycle (solar cycle 208 years).

- drought (δ^{18}O)
- solar cycle (Δ^{14}C)

Discussion

Questions

- between the very dry periods there were about 50 years of less dry times, put Maya civilisation couldn't regenerate during them.
- last drought didn't correspond to the last collapse period
- solar radiation differs only a little during the solar cycle (1‰). How can the big impact on the precipitation be understood.

List of figures I

List of figures II

Bibliography I

G. H. Haug et. al.
Climate and the Collapse of Maya Civilization.
Science, 299:1731–1735, 2003.

D. A. Hodell et. al.
Terminal Classic drought in the northern Maya lowlands inferred from multiple sediment cores in Lake Chichancanab (Mexico).
Quanternary Science Reviews, 24:1413–1427, 2005.

D. A. Hodell et. al.
Solar Forcing of Drought Frequency in the Maya Lowlands.
Science, 292:1367–1370, 2001.

Bibliography II

- L. C. Peterson and G. H. Haug.
  150 Jahre Trockenheit.
  Spektrum der Wissenschaft, Januar 2006.
- Wikipedia in Spanish
  Cultura maya
  http://es.wikipedia.org/wiki/Antiguos_mayas
- Wikipedia in German
  Cultura maya
  http://de.wikipedia.org/wiki/Maya
- Wikipedia in English
  Cultura maya
  http://en.wikipedia.org/wiki/Maya_civilization