

Maya and Climate

Climate and the Collapse of Maya Civilization

Peter Barmet, Thomas Kuster, André Welti

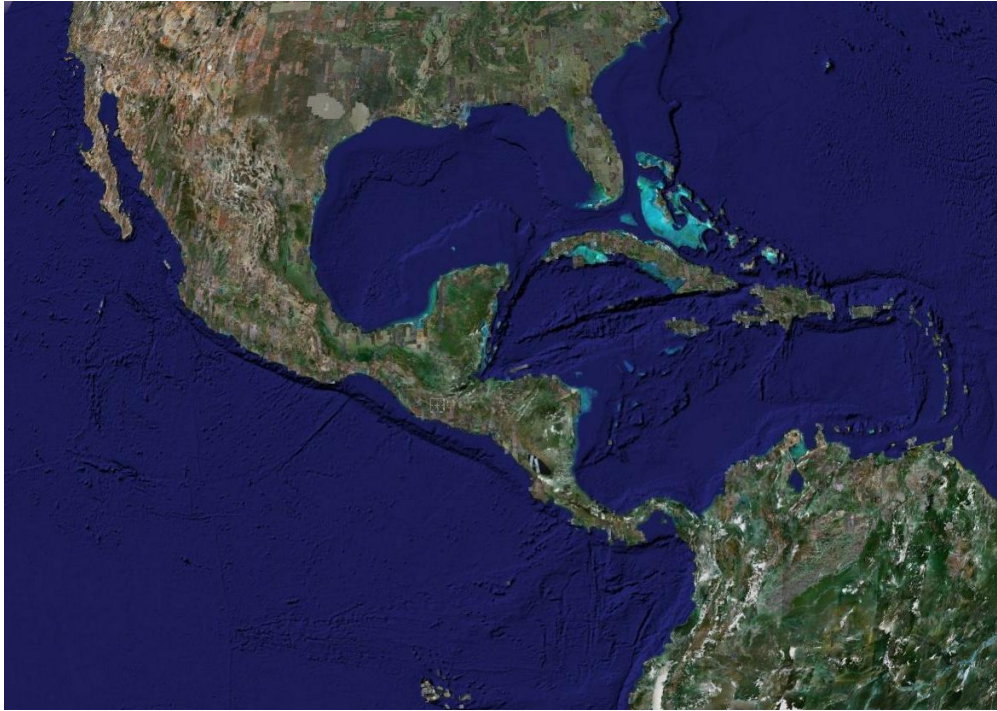
Department of Environmental Sciences
ETH Zürich

Climate History and Paleoclimatology, 24.11.2006

Outline

- 1 Maya civilization
 - Geography
 - Culture
 - History
- 2 Climate
 - ITC
- 3 Geology / Hydrology
- 4 Methods
 - Gypsum (CaSO_4) Deposition
 - Oxygen Isotopes ($\delta^{18}\text{O}$)
 - Titanium Content
- 5 Results
- 6 Discussion

Geography (Middle America)



→ Lake Chichancanab

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Maya and Climate

Geography (Yucatán Peninsula)



Areas

- north
- central
- south

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Maya and Climate

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)

^aBefore Christ

^bAnno 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 population before the collapse 3 – 13 million
- between classic and 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

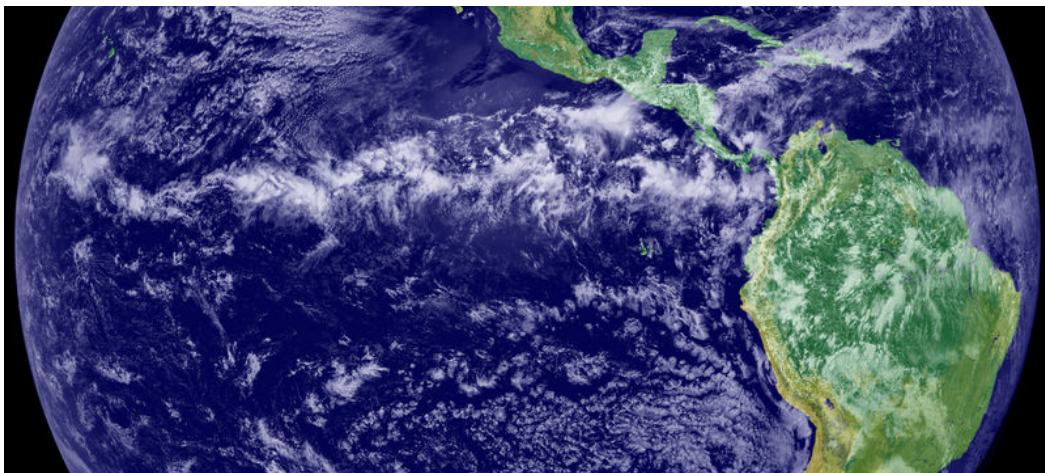
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Inter Tropic Conversion (ITC)

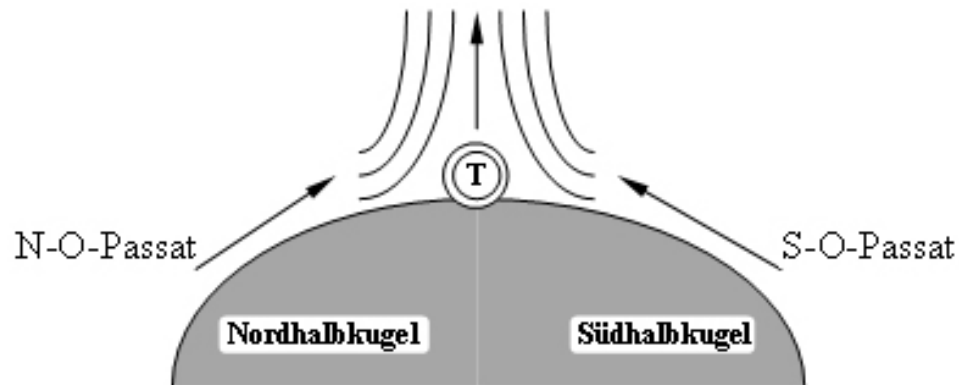
Abbreviations

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



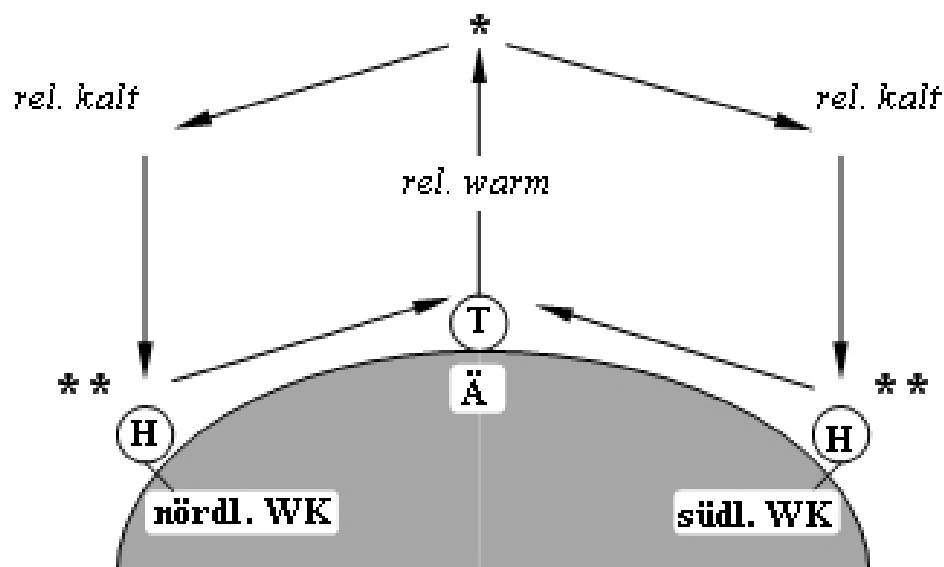
Functionality

Inter Tropic Conversion (ITC)

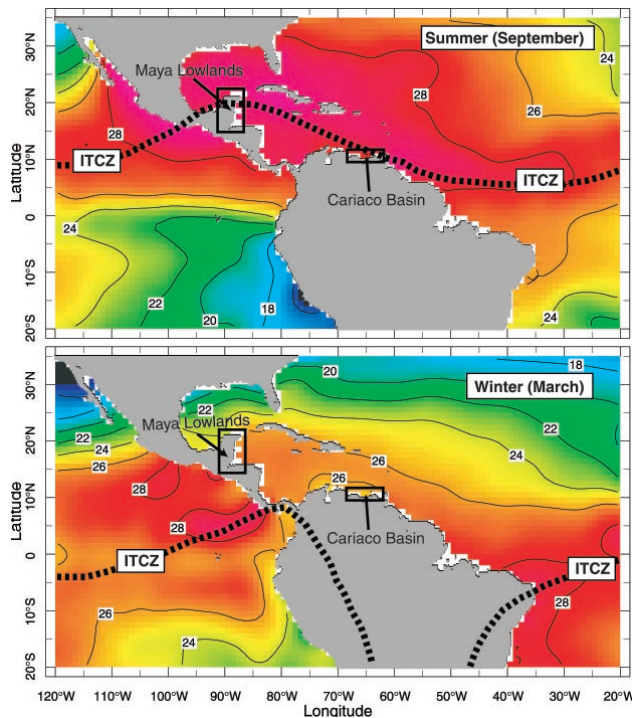


Functionality

Hadley Cell



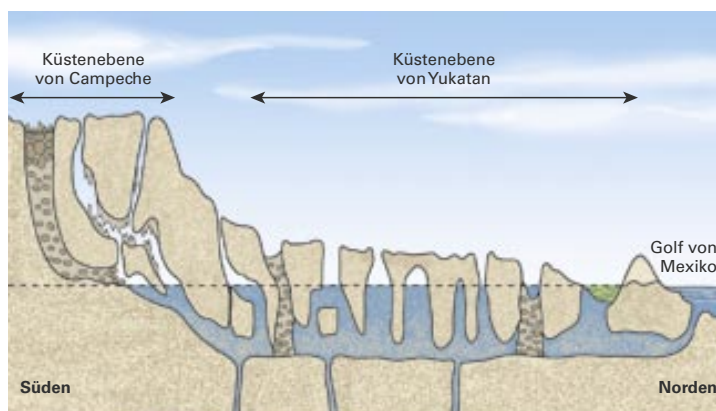
ITC over Middle America



Influence

- most of rain (90%) during summer
- dry winter
- southward displacement of the ITCZ → 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 important factor for a large population to survive

Methods

Sediment Core Analysis

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

Gypsum (CaSO_4) Deposition

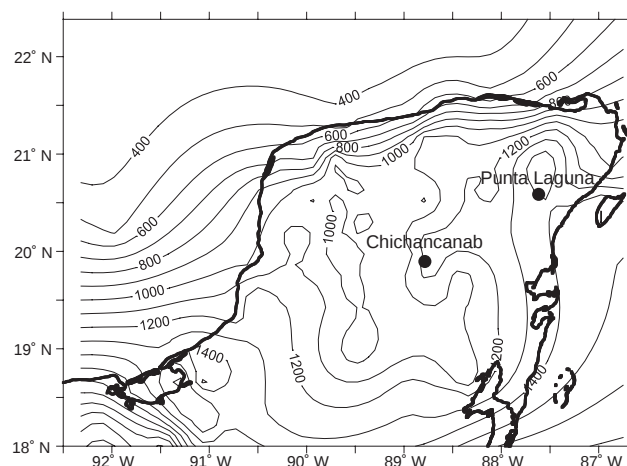
Where?

Cores from Lake Chichancanab

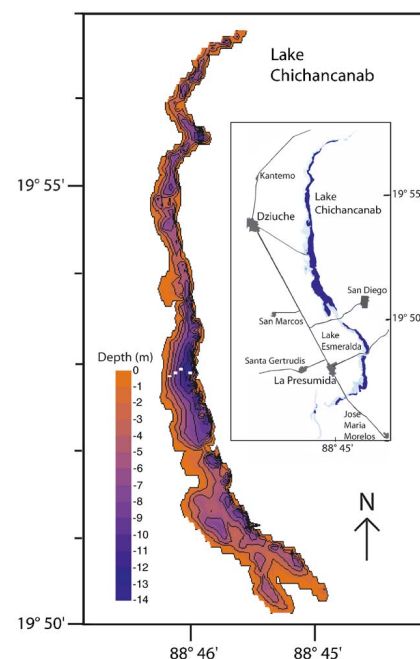
Why are Sediments from Lake Chichancanaba good Archives?

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

Lake Chichancanab



Location of Lakes Chichancanab and Punta Laguna on the [Yucatán Peninsula](#)



Position of the depth transect of cores (white squares)

Gypsum (CaSO_4) Deposition

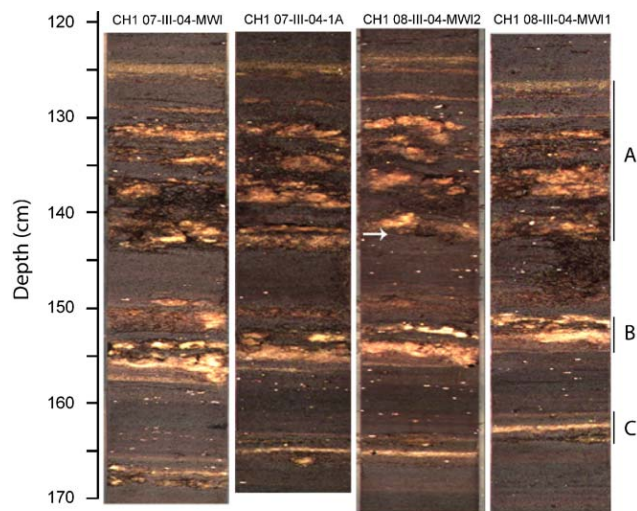
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Gypsum (CaSO_4) Deposition



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 ($\delta^{18}\text{O}$)

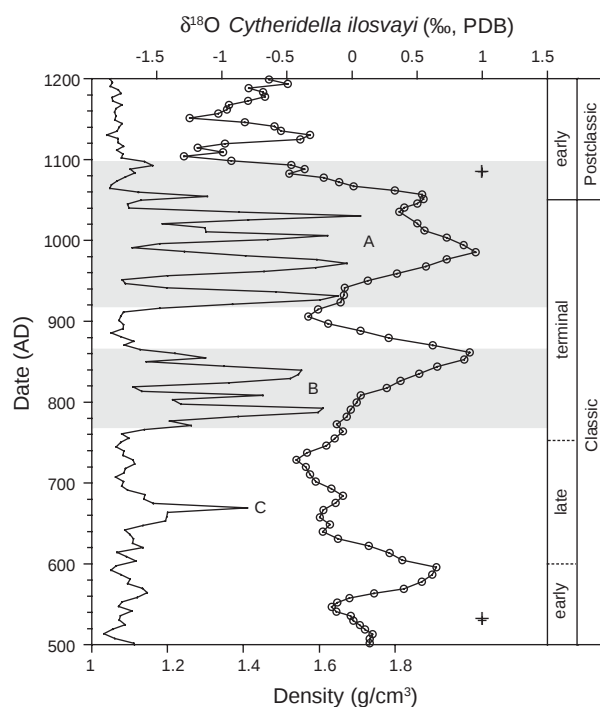
Where?

Cores from Lake Chichancanab

Detection of Drought Periods with $\delta^{18}\text{O}$

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

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



Analysis of $\delta^{18}\text{O}$

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

Titanium Content

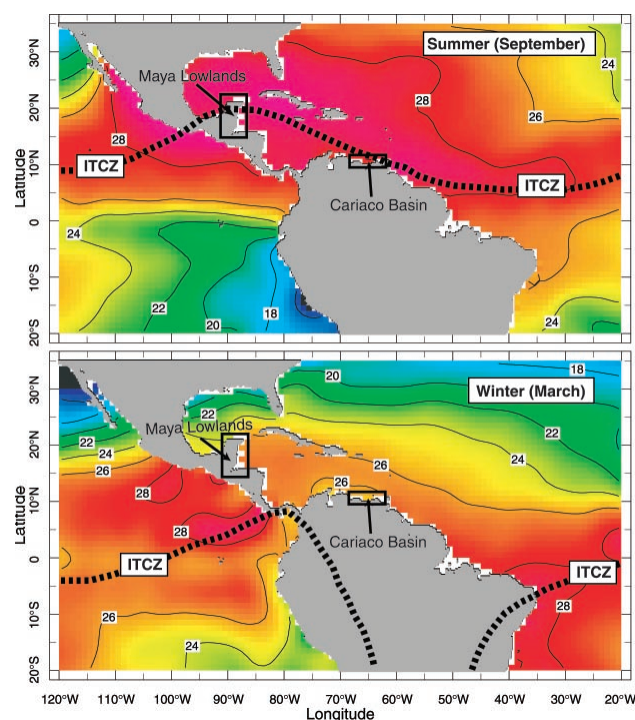
Where?

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



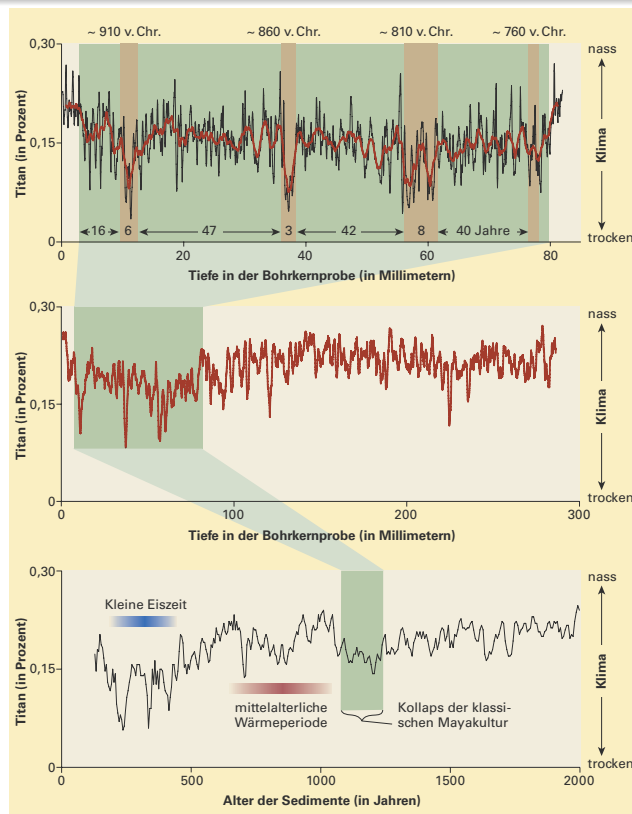
Titanium Content

Where?

Cores from Cariaco Basin

Why is Cariaco Sediment a good Proxy for Precipitation?

- anoxic
- undisturbed sediment
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Titanium Content

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

Method

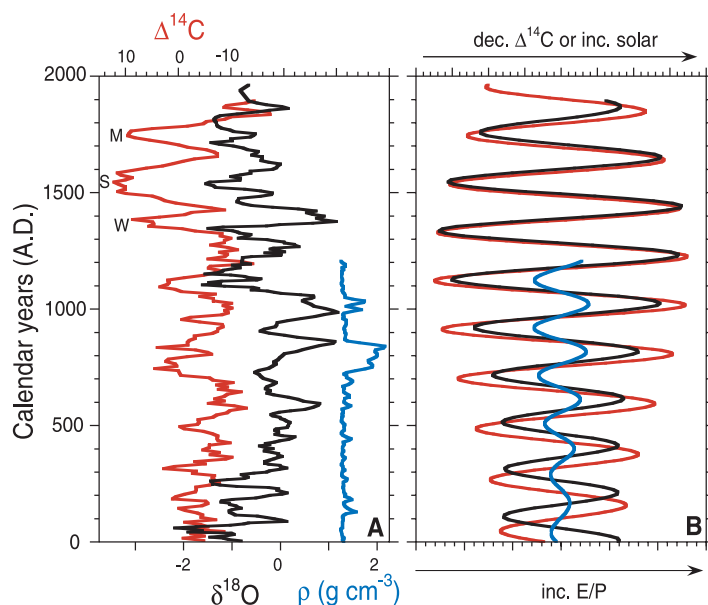
If titanium is irradiated with X-ray, it emits at specific wavelength.

Results

5 500 BC	–	500 BC	relative wet
475 BC	–	250 BC	drought period (before the rise of Maya civilisation)
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

⇒ 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 ($\delta^{18}\text{O}$)
- solar cycle ($\Delta^{14}\text{C}$)

Discussion

Questions

- between the very dry periods there were about 50 years of less dry times, but 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



Yucatan Peninsula

Google Earth



Map showing the extent of the Maya civilization

<http://en.wikipedia.org/wiki/Image:Mayamap.png>



Temple

<http://en.wikipedia.org/wiki/Image:Tikal6.jpg>



Ballcourt

<http://en.wikipedia.org/wiki/Image:12-05oaxaca024.jpg>

List of figures II



Satellite Image of the ITC

<http://de.wikipedia.org/wiki/Bild:Inter tropicalConvergenceZone-E0.jpg>



Inter Tropic Conversion

<http://de.wikipedia.org/wiki/Bild:ITC.jpg>



Hadley Cell

<http://de.wikipedia.org/wiki/Bild:Tropenklima.jpg>

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Cultura maya

http://es.wikipedia.org/wiki/Antiguos_mayas



Wikipedia in German

Cultura maya

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Wikipedia in English

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