The Future of Old Things
Geoinformatics for better paleoscience

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Acknowledgements

Climate Scientists
Deborah Khider (USC)
Nick McKay (NAU)
Charles Jackson (UTIG)

Data Scientists
Yolanda Gil (USC)
Daniel Garijo (USC)
Varun Ratnakar (USC)
What do we want?

EVIDENCE-BASED SCIENCE

When do we want it?

AFTER PEER REVIEW

More science, less hassle.
Signal emerges sooner in the tropical oceans (time of emergence at ocean regions display a similar rate of warming to that of the Northern century context available from the regional palaeoclimate reconstruc it unsuitable for determining climate emergence. We use the multi-

Figure 2: Industrial-era warming led to the emergence of regional climate Different Proxies


PAGES2k 2.0.0 (692 records from 648 sites)

a) Archive types

PAGES 2k consortium, Scientific Data, in press

Emile-Geay et al, Nature Geo, [2015]}

Integration

Proxies vs Model

Proxy observations

Scaled ENSO variance vs Seasonality

Scaled trend distribution (°C per century)

General circulation models
Main messages:

1. Future paleoscience requires more integration
   - Different proxies, different regions, proxies and models

2. Integration requires standardization
   - Of terminology, of formats.

3. The future will be ensemble-based, or will not be
   - age modeling, probabilistic reasoning
How much does the Sun affect climate?

Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool
Millennial Climate Cycles and their causes

Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool
What do we know?

The Holocene saw warm and cold intervals

They were recurrent, with peaks around 1,000yrs, 1,500yrs, and 2,500yrs

Solar variability has often been hypothesized to be the cause
Persistent Solar Influence on North Atlantic Climate During the Holocene

Gerard Bond,1* Bernd Kromer,2 Juerg Beer,3 Raimund Muscheler,3 Michael N. Evans,4 William Showers,5 Sharon Hoffmann,1 Rusty Lotti-Bond,1 Irka Hajdas,6 Georges Bonani6

Surface winds and surface ocean hydrography in the subpolar North Atlantic appear to have been influenced by variations in solar output through the entire Holocene. The evidence comes from a close correlation between inferred changes in production rates of the cosmogenic nuclides carbon-14 and beryllium-10 and centennial to millennial time scale changes in proxies of drift ice measured in deep-sea sediment cores. A solar forcing mechanism therefore may underlie at least the Holocene segment of the North Atlantic’s “1500-year” cycle. The surface hydrography changes may have affected production of North Atlantic Deep Water, potentially providing an additional mechanism for amplifying the solar signals and transmitting them globally.
Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool

Motivation

Are the cycles robust?
Is the sun responsible?
The power of ensembles

Are the cycles robust?
Is the sun responsible?
SST-Sensitive Proxies

- Mg/Ca, $U_{37}^{k'}$, TEX86
- >5000 years long

Radiocarbon-based Chronologies
Bchron
Create possible age-depth relationships based on the uncertainties in the radiocarbon measurements, the reservoir age, and the radiocarbon calibration.

MD98-2181
Spectral

Lomb-Scargle Periodogram

Cross-Wavelet Analysis

MD98-2181
Methods

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Median Periodicity in each record
Uncertainty in spectral peak
Median of the peak periodicity distribution

1902 ± 27 years
1022 ± 27 years

14200-2600 years

23200-3330 years
Methods

Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool

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Are the cycles robust?
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Despite large age model uncertainty, we find robust variability on millennial timescales.
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Despite large age model uncertainty, we find robust variability on millennial timescales.

Methods

Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool

Motivation

Are the cycles robust? Is the sun responsible?

Use cross-wavelet analysis to determine phase angle.

Spectral Analysis

Holocene millennial-scale variability

The role of the sun

Despite large age model uncertainty, we find robust variability on millennial timescales.

The role of the sun

Use cross-wavelet analysis to determine phase angle.

Are the cycles robust? Is the sun responsible?

Methods

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Spectral Analysis

Despite large age model uncertainty, we find robust variability on millennial timescales

The role of the sun

Cannot discard the possibility of solar forcing
Methods

2000-3000 year

Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool

Motivation

Are the cycles robust?
Is the sun responsible?

Large age model uncertainty prevents meaningful analysis from a single record

Holocene millennial-scale variability

Despite large age model uncertainty, we find robust variability on millennial timescales

The role of the sun

Cannot discard the possibility of solar forcing

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Spectral Analysis

900-1200 year

Are the cycles robust? Is the sun responsible?

Synthesis of multiple records suggest robust periodicities at ~1,000 yrs, ~1500 yrs, ~2500 yrs

The role of the sun

Cannot discard the possibility of solar forcing

Holocene millennial-scale variability

Despite large age model uncertainty, we find robust variability on millennial timescales
Methods

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Holocene millennial-scale variability

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Are the cycles robust? Is the sun responsible?

Refuting or accepting the solar forcing hypothesis will require additional records with global coverage

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Spectral Analysis
Methods

- Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool

Motivation

- Are the cycles robust?
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Holocene millennial-scale variability

- Despite large age model uncertainty, we find robust variability on millennial timescales

The role of the sun

- Refuting or accepting the solar forcing hypothesis will require additional records with global coverage
- Cannot discard the possibility of solar forcing

Future Work

- Expand the database to global coverage
Ingredients of paleoclimatology:

Sample Collection
- Sedimentology
- Seismology
- Ocean Engineering

Sample Analysis
- Geochemistry
- Paleontology
- Biology/Ecology

Data Collection
- Statistics
- Computer Science
- Signal Processing

Data Analysis
- Modeling
Let us dream
Testing the Millennial-Scale Holocene Solar-Climate Connection in the Indo-Pacific Warm Pool

**Motivation**
Are the cycles robust? Is the sun responsible?

**Methods**
- SST-Sensitive Proxy
- δ18O, δ13C, VMAS
- 3000 years long
- Radiocarbon-based Chronologies
- Cross-variability correlations
- Lomb-Scargle Periodogram
- Cross Wavelet Analysis

**Holocene millenial-scale variability**
Despite large age model uncertainty, we find robust variability on millennial timescales.

**The role of the sun**
Cannot discard the possibility of solar forcing.

**Future Work**
- Spectral Analysis
- Are the cycles robust? Is the sun responsible?
- Expand the database to global coverage
- Explore lead-lag relationships among various regions
- Estimate magnitude of millennial-scale variability
- Develop web standards
- Develop social code
- Crowdsource data curation through a wiki platform

**LinkedEarth and the future of paleoclimatology**
- LinkedEarth
PAGES2k
(Compilation (L))

1 Description
2 Revisions and updates
3 How to cite
4 Downloads
5 Datasets in the PAGES2k database

<table>
<thead>
<tr>
<th>LIPD Dataset</th>
<th>ArchiveType</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc-StoreggaSlide.Sejrup.2011</td>
<td>marine sediment</td>
<td>63° 45’ 36&quot;, 5° 15’ 36&quot;</td>
</tr>
<tr>
<td>Arc-Tjeggelvas.Bjorklund.2012</td>
<td>tree</td>
<td>66° 36’ 0&quot;, 17° 36’ 0&quot;</td>
</tr>
</tbody>
</table>
Methods

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LinkedEarth and the future of paleoclimatology

Crowdsourcing data curation through a wiki platform
Develop web standards
Develop social code
The LinkedEarth Ontology
( Ontology: a structured way of representing knowledge )

**FORMAT**

LiPD { LiPD Dataset v1.2 }

Linked Paleo Data

ProxyArchive

ProxySensor

ProxyObservation

InferredVariable

Instrument

**CONCEPT**

**Talk by N. McKay, May 13, 11:15**

**Room 11**

*Evans et al., QSR, 2013*

*McKay & Emile-Geay, Clim. Past, 2016*
The LinkedEarth Ontology...

Allows:
- Formal Reasoning
- Inference
- Complex Queries
- Quality Control

http://vowl.visualdataweb.org/webvowl/#iri=http://linked.earth/ontology
Querying the database

http://wiki.linked.earth/Category:MarineSediment

Live semantic query returns 59 datasets
(and counting)
Developing standards for the community by the community

Uploading and Annotating Datasets

Property name

Property value
Developing standards for the community by the community

- Uploading and Annotating Datasets
- Discussion Pages
Reference (for each speleothem) Deborah Khider (talk) 14:46, 24 April 2017 (PDT)

Is this section supposed to contain the publication information of the study in which the speleothem record(s) appear(s) or is supposed to reference the physical sample itself, for instance through a property like hasIGSN.

Re: Reference (for each speleothem) Deborah Khider (talk) 14:46, 24 April 2017 (PDT) -- NickScroxton (talk) 09:02, 25 April 2017 (PDT)

I believe this would be the reference for the publication in which the speleothem record appears. The property for referencing the physical sample itself would be "entity name".

Re: Re: Reference (for each speleothem) Deborah Khider (talk) 14:46, 24 April 2017 (PDT) -- Deborah Khider (talk) 10:04, 25 April 2017 (PDT)

In the current version of the ontology we have a category for the physical sample in which users can enter the name of the archive (entity name), a specific lab ID if any, where in the world the sample currently is and an IGSN number if any. Let me know if there are other properties that could be useful to the speleothem community.

[Mark this page as patrolled]
Developing standards for the community by the community

- Uploading and Annotating Datasets
- Discussion Pages
- Working Groups
Category:Speleothem Working Group
(Pages with a poll, Working Group)

Contents [hide]

1 Overview
2 Membership
3 Specific tasks
4 Things to describe
   4.1 Site (cave)
   4.2 Entity (speleothem)
   4.3 References (for each speleothem)
   4.4 Chronology
   4.5 Age models
   4.6 Sample data
   4.7 Modern Cave Conditions
5 References

Overview [edit]

In the Linked Earth context, a working group (WG) is a self-organized coalition of knowledgeable experts, whose activities are governed herewith. This page is dedicated to the discussion of data and metadata standards for speleothems, and aims to formulate a set of recommendations for such a standard.

Membership [edit]

Members of 'Speleothem Working Group'

This working group has 4 members.
Methods

**Holocene millennial-scale variability**

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Future Work

- Expand the database to global coverage
- Explore lead-lag relationships among various regions
- Estimate magnitude of millennial-scale variability

LinkedEarth and the future of paleoclimatology

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- Develop social code

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GeoChronR

R:
Fast, powerful, open, easy to learn

What is it?
Quantifying age uncertainties is a critical component of paleoscience (paleoclimatology, paleoecology, paleontology). GeoChronR is an integrated framework that allows scientists to generate state-of-the-art age models for their records, create time-uncertain ensembles of their data, analyze those ensembles with a number of commonly-used techniques, and visualize their results in an intuitive way. The code is being developed in the open-source and community-supported R platform. Please refer to the GeoChronR Proposal for more information.

Requirements
R - v0.99.903+
R Studio - v3.3.1
R devtools package - v1.12.0+

Installation
Install package in R Studio:
```
devtools::install_github("nckmckay/geoChronR")
```
Load the package into the environment:
```
library("geoChronR")
```

Example
GeoChronR project

Time-uncertain data analysis training workshop

August 16-18, 2017
Northern Arizona University
Flagstaff, Arizona USA

Details at: linked.earth or nau.edu/mckay
Pyleoclim

Python:
Fast, powerful, open, easy to learn

Basic Functionalities
- Mapping
- Plotting timeseries

Advanced Functionalities
- Age Modeling
- Time-uncertain spectral analysis
- Wavelet Analysis
- PCA
- Climate Field Reconstruction
Easy-breezy Data Visualization

archiveType: marine sediment
Authors: Khider, D.; Jackson, C.S.; Stott, L.D.
Year: 2014
DOI: 10.1002/2013PA002534
Variable: Sea Surface Temperature
units: deg C
Climate Interpretation:
  Climate Variable: temperature
  Detail: NA
  Seasonality: NA
  Direction: positive
Calibration:
  Equation: NA
  Notes: NA

https://github.com/LinkedEarth/Pyleoclim_util
pip install pyleoclim
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Methods

- Spectral Analysis
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The role of the sun

- Cannot discard the possibility of solar forcing

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Acknowledgements

- http://linked.earth
- linkedearth@gmail.com
- @Linked_Earth

END GOAL:

Spend more time on science, less on issues machines can solve
Conclusions

1. Modern (future) paleoscience requires integration
   - datasets, models, people, scientific cultures

2. The glue is geoinformatics
   - LinkedEarth: LiPD + ontology + wiki + AI
   - Ensemble-based analyses come for free: GeoChronR, Pyleoclim

3. All this requires standardization
   - Formats: e.g. Linked Paleo Data (LiPD)
   - Terminology: LinkedEarth Ontology
   - HUGE ROLE FOR COMMUNITY
Session 26: Data Stewardship

May 13, 11:00-13:00 Room 11 (basement).
3 talks (1 by Nick McKay about LiPD)
discussion: data standards + VOTE

Join LinkedEarth before Friday, midnight

http://linked.earth/membership/
The Future Is Now

Thank you
linkedearth@gmail.com