Corals and Climate Research

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atmospheric CO2 measurements show that CO2 has been increasing since at least the mid 1950’s
The ‘instrumental’ record of climate shows a ~1°C warming over the last century.
Why do 99.999% of climate scientists believe that anthropogenic CO₂ is warming the planet?

1. Theory predicts that increasing atmospheric CO₂ should warm the planet.

2. Geologic evidence links CO₂ and temperature in the past.

3. The warming is unprecedented in the most recent centuries (dwarfs natural variability).

4. Climate models show that rising CO₂ is necessary to simulate 20th century temperature trends (solar and volcanic minor players).
Atmospheric CO$_2$ and temperature over the past 650 thousand years

CO$_2$ and temperature are closely linked on geologic timescales

80ppm CO$_2$ ~5°C
To understand how climate has changed in the past, we need to use records of climate preserved in ice cores, ancient tree rings, coral bands, and other “paleoclimatic” sources:

key is to CALIBRATE to temperature records
The “Hockey Stick”

Key Points:
- Error bars increase as you go back in time.
- Natural variability accounts for <0.5°C over the last millennium.
- Late 20th century temperature trend is unprecedented.

Mann et al., 1999
Simulated annual global mean surface temperatures

(a) Natural
(b) Anthropogenic
(c) All forcings

Intergovernmental Panel on Climate Change (IPCC) 2001

solar & volcanic only
anthropogenic only
solar & volcanic & anthro
The uncertain climate future

Scientific Focus: no longer ‘if’
but ‘how much?’, ‘when?’, ‘where?’
→ regional climate responses?
→ precipitation responses?

Modelled global temperature rise

Modelled sea level rise
Satellite measurements (GRACE) confirm that Greenland is melting (negative mass balance)

-contributing 0.54mm/yr to global sea level rise
One regional concern: Are hurricanes gaining strength as the tropical oceans warm?

- total # not increasing
- intensity of Category 4, 5 storms increasing

**Comments:**
1) this work does not prove GW-hurricane causal link
2) weak 2006 season does not disprove GW-hurricane link

NEW modeling results published Sep 10, 2006 support GW-hurricane hypothesis!
My Research Goal:
To reconstruct tropical Pacific climate change of the recent past, so that we might better predict REGIONAL temperature and precipitation changes as climate warms.

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NOAA
NSF

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NCL
The Nature Conservancy
Prince Khaled Bin Sultan Bin Abdulaziz
El Niño-Southern Oscillation
An ocean-atmosphere phenomenon that originates in the tropical Pacific but affects global climate patterns

Why study tropical Pacific climate?
- ENSO extremes carry serious economic and social costs
- Improved ENSO forecasts minimize the costs

The impacts are not confined to the tropical Pacific
- ENSO extremes carry serious economic and social costs
- Improved ENSO forecasts minimize the costs

December 1997 SST Anomalies

El Niño impacts

Sea Surface Temperature Anomaly (°C)

Palmyra, Fanning, Christmas Islands
Are severe El Niño events becoming more frequent as global temperatures increase?
The 1990-1995 El Niño-Southern Oscillation event: Longest on record

Kevin E. Trenberth and Timothy J. Hoar
National Center for Atmospheric Research, Boulder, Colorado

Increased El Niño frequency in a climate model forced by future greenhouse warming

A. Timmermann, J. Oberhuber*, A. Bacher, M. Esch, M. Latif & E. Roeckner
Max-Planck-Institut für Meteorologie and *Deutsches Klimarechenzentrum, Bundesstrasse 55, D-20146 Hamburg, Germany

Weakening of tropical Pacific atmospheric circulation due to anthropogenic forcing

Gabriel A. Vecchi¹, Brian J. Soden², Andrew T. Wittenberg¹, Isaac M. Held¹, Ants Leetmaa¹ & Matthew J. Harrison¹
The instrumental record of El Niño’s is too short to answer some key questions:

1. Are late 20th century El Niño events more frequent and more severe than those of the recent past?

2. Is there a correlation between average global temperature and El Niño activity?

3. How much and how fast has ENSO changed in the past?

A well-placed rope swing in the Palmyra lagoon
Corals: The geologic record of El Niño

Living *Porites* corals provide records for the last 200 years

CORALS from the tropical Pacific record El Niño’s in the geochemistry of their skeletons

Fossil *Porites* corals enable us to extend the record back many centuries
Palmyra Island Results
research 1997 to present
published 2003
Generating climate reconstructions from the Palmyra corals:

1) Recover the corals, both modern (~10) and fossil (~100).

2) Prove that the coral geochemistry tracks large-scale climate. 
   ie. *Calibrate the modern coral geochemical record against the instrumental record of climate.*

3) Apply geochemistry to fossil corals and date them (U/Th dating).

*Aerial view of Palmyra*
The Palmyra Island Coral Collection

Medieval Warm Period (MWP)

Greenland green

Little Ice Age (LIA)

canals frozen in Europe

Date (A.D.)
How well do Palmyra corals record El Niños?

Red = instrumental record of El Niños
Black = modern coral $\delta^{18}O$

Less smoothed

More smoothed

$R = -0.66$

$R = -0.84$
What does this coral reconstruction of tropical Pacific climate tell us?

You tell me!
Fanning Island Expedition, May 2005:

Planning phase: 1 year

Duration: 2 weeks

Accomodations: NCL ‘compound’

Results published: 2007, 2008

Expedition goals:
1. Drill as many long fossil corals as possible.
2. Find large living corals for future underwater drilling.
3. Sample rainwater and seawater for chemical analysis.
4. Install temperature loggers on coral reef.
NCL compound

Aontela Village
“Big Rock”,
Primary drill site

The “Death March”
5km trek in search
of fossil corals

Secondary Drill site

Snorkeling sites
surveying modern reef health
Expedition Results:

~20m fossil coral drilled

Temperature loggers installed, good for 3yrs

~40 seawater samples

~10 rainwater samples
Line Islands Expedition, August 2005:

Planning phase: 2 years

Research Platform: R.V. White Holly

Duration: 1 month

Islands visited: Christmas Fanning Palmyra

Expedition goals:
1. Drill as many long fossil corals as possible.
2. Find and drill large living coral record (~1m) at Fanning.
2005 Line Islands Expedition:
http://sio.ucsd.edu/lineislands/

ABOUT THE EXPEDITION

There are almost no pristine/nearly pristine coral reefs in the world. Former reefs full of sharks, large fishes, sea turtles, and healthy corals are all but gone. Impacts such as chronic over-fishing, pollution, climate change, and disease have deteriorated reefs. One of the major problems for the conservation of coral reefs is that we seldom have ecological baselines against which to compare present reefs. Such quantitative baselines can reveal the ecological characteristics that have been lost and potentially can guide us toward strategies to restore degraded reefs. To supply the ecological baseline, we are conducting a thorough study of the ecosystems of two of the most pristine coral reefs remaining, those surrounding Palmyra atoll and Kingman reef in the Line Islands.

With a diverse team of reef ecologists, we will describe the diversity and structure of the reef communities, sampling all major taxonomic groups, including the microbes, algae, corals, other invertebrates, and fish. In order to quantify the effects of human disturbance on coral reef ecosystems, we will conduct comparable surveys on three inhabited islands of the Line Islands archipelago, Teraina, Tabuaeran, and Kiritimati. This survey will offer a unique view into the groups of organisms that are lost, the species interactions that are altered, and the trophic dynamics that are changed as humans disturb a reef. This study will be the...
Results thus far for the Line Islands coral collection

New dates go back to 6000 years before present!

- Palmyra:
  - 40 cores U/Th dated
  - 28 cores undated

- Christmas:
  - 18 cores U/Th dated
  - 63 cores undated

- Fanning:
  - 33 cores undated
**Strategy:**

1) use rare long cores (40-100 years) to reconstruct El Niño variability

2) use many short cores to reconstruct “average” climate
Future Research in the Line Islands

1) Date the rest of the Line Island fossil corals. (*next 2 years; NSF funding pending*)

2) Select long sequences for climate reconstruction via isotopic analysis (*next 1 year*)

3) Analyze modern coral from Fanning and Christmas for calibration (*next 6 months*)

4) Analyze results using statistical techniques, compare to other paleoclimate records, publish results (*ongoing*).

“Sounds great! What’s the hold up?”
1 year coral = 20 samples
100 yrs coral = 2000 samples
2000 samples = 50 days mass spectrometer

we need 150-200 U/Th dates
20 U/Th dates = 3 weeks continuous work
Conclusions

Much work to be done!

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