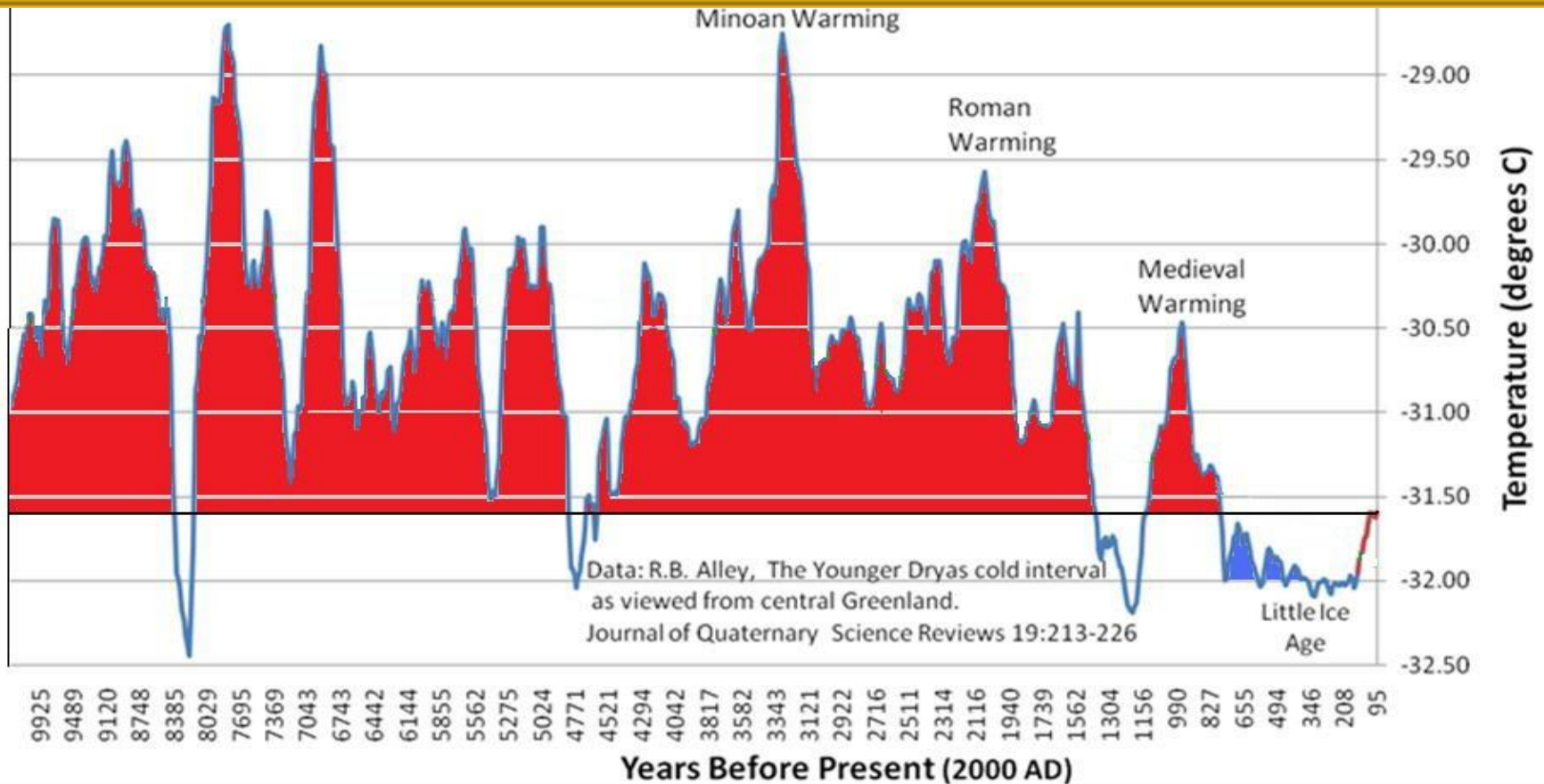


Weather, Climate, and Climate Change--What the Data Tell Us

Climate History and El Nino (ENSO)



Bob Endlich

bendlich@msn.com

30 Sep 2019

class web page: <https://casf.me/> Class Info

The following several slides are editorial in nature,
but begin with real stories taken from the “news”
pages of the Washington Post.

The first, from 17 Jan 2017

Scientists have a new way to calculate what global warming costs. Trump's team isn't going to like it.

By Chelsea Harvey

How we view the costs of future climate change, and more importantly how we quantify them, may soon be changing. A much-anticipated [new report](#), just released by the National Academy of Sciences, recommends major updates to a federal metric known as the “social cost of carbon” — and its suggestions could help address a growing scientific concern that we’re underestimating the damages global warming will cause.

The social cost of carbon is an Obama-era metric first addressed by a federal working group in 2009.

The basic premise is simple: Scientists agree that climate change will have all kinds of impacts on human societies, including natural disasters and effects on human health, productivity and agricultural output, all of which have economic consequences.

https://www.washingtonpost.com/news/energy-environment/wp/2017/01/12/scientists-have-a-new-way-to-calculate-what-global-warming-costs-trumps-team-isnt-going-to-like-it/?utm_term=.a6e0ad0f2

After Maria, the misery deepens

In isolated mountains of Puerto Rico, residents are running out of basics

The Washington Post 25 Sep 2017 [+6 more](#) BY SAMANTHA SCHMIDT AND JOEL ACHENBACH

Juncos, puerto rico — In the heat and humidity here in the central mountains, Meryanne Aldea fanned her bedridden mother with a piece of cardboard Sunday as the ailing woman lay on her side, relieving a large ulcer in her back.

The 63-year-old mother, Maria Dolores Hernandez, had cotton stuffed in her ears to keep flies out, since her now screenless windows were letting all sorts of bugs in. The gray-haired di-

abetic woman spoke with her daughter about her worries: that she would run out of prescription drugs, that they were almost out of generator fuel to keep her insulin refrigerated and to run the fans at night. With all the heat, she feared that her ulcer would become infected.

Editorial

The Washington Post is schizoid:

They approvingly proclaim that the **social costs of carbon** need to be attached to use of energy.

Yet, they whine when non-availability of electricity harms poor people.

Their solution is to use renewables:

Subsidized Wind and Solar

How did that work out in Puerto Rico?

The next slides have an answer:

I think this is from a storm chasing small business called Live Storms Media; they put this up on YouTube as *****NOT FOR BROADCAST***** hoping to be paid for the video by markets which can afford to pay the fees.

9-22-17 Puerto Rico Wind - Solar - Cellular Structures Destroyed ...



*****NOT FOR BROADCAST*****

MORE VIDEOS

FOR LICENSING CONTACT
brett@livesstorms.com

0:26 / 1:21



YouTube



Puerto Rico Wind/Solar Destroyed By Maria <https://youtu.be/1AAHJs-j3uw>

Posted on September 27, 2017 by tonyheller



<https://realclimatescience.com/2017/09/puerto-rico-windsolar-destroyed-by-maria/>

Green energy is worthless. If Puerto Rico had to depend on it, they would be back to the Dark Ages.

We have covered:

Daily and Weekly changes (so far) in the Annual Cycle

Controls on the Annual Cycle in the Tularosa Basin Area

Hurricane Harvey Data: Harvey was NOT CO₂-Enhanced
2016 Baton Rouge Floods: NOT CO₂-Enhanced

We Shift Gears Today: **Earth Climate History:**

Geological Time Scale, last 600 Million Years

Within the past 500,000 years (part of Pleistocene)

Within the past 10,000 years (Holocene)

Discussion of **El Nino, La Nina, ENSO Neutral**

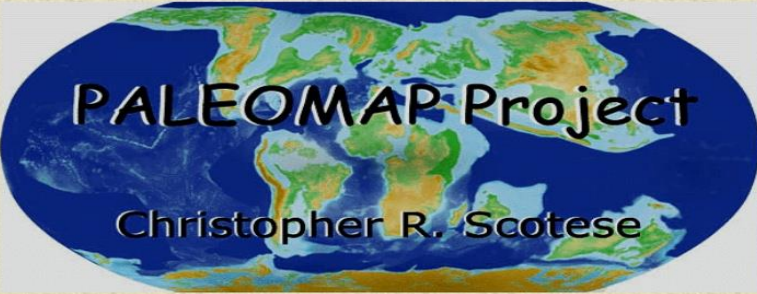
Time Domain: Last 600 million years

Since the Cambrian “explosion of life” across Ocean sea floors
-- when fossils became common.

References for Temperature and Carbon Dioxide data

<http://www.scotese.com/>

<http://ajsonline.org/content/301/2/182.abstract>



PALEOMAP Project
Christopher R. Scotese

Site Map
Earth History
Climate History
Research
Software
Order Form
Credits

Sci/Tech WebAwards 2001
SCIENTIFICAMERICAN.COM

Selected by Science Education
SCI LINKS
From NSTA

SCIENTIFIC AMERICAN
2002
SCI-TECH
WEB AWARDS

Goal of the PALEOMAP Project

✧ The goal of the PALEOMAP Project is to illustrate the plate tectonic development of the ocean basins and continents, as well as the changing distribution of land and sea during the past 1100 million years.

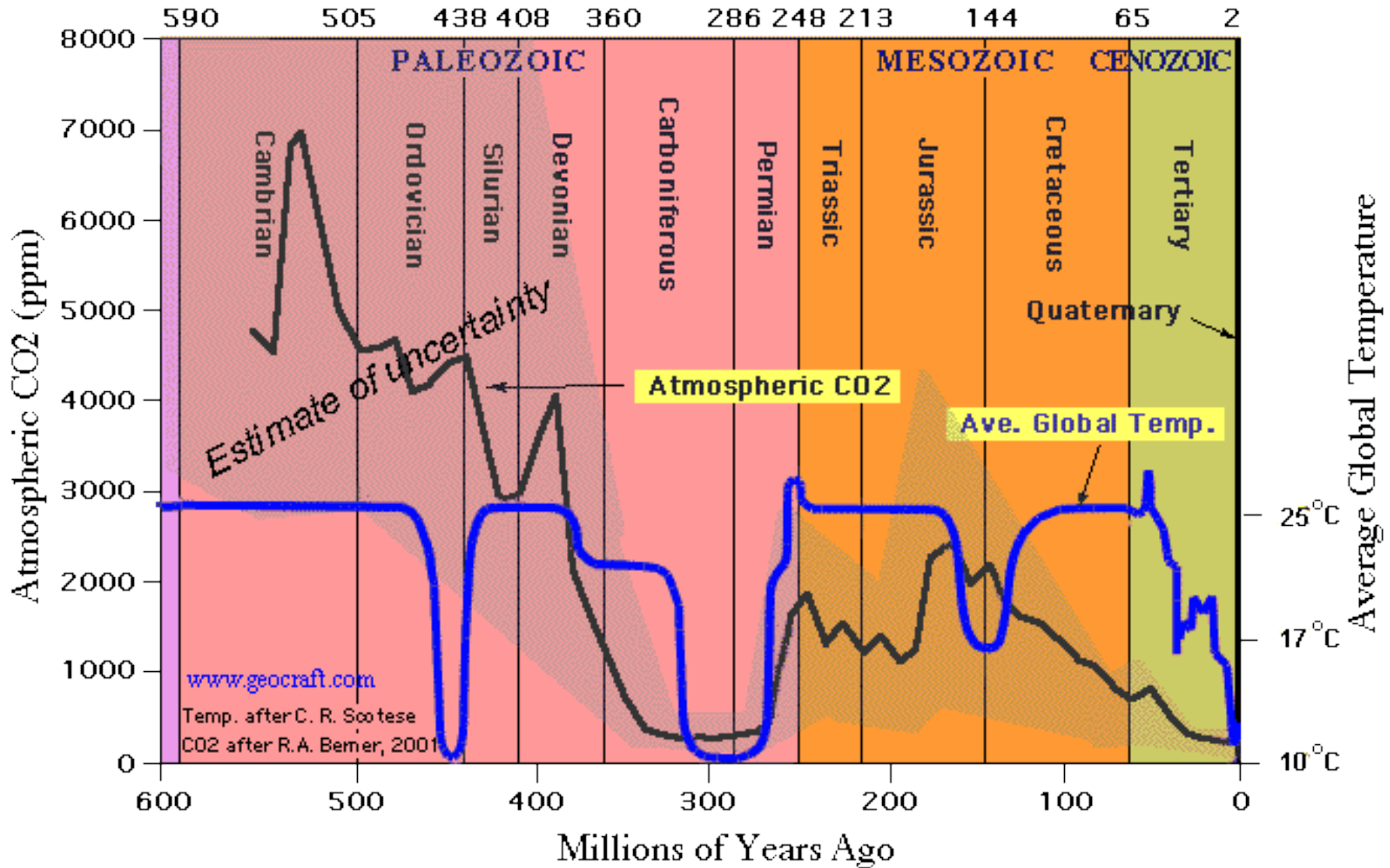
[AMERICAN JOURNAL OF SCIENCE, VOL. 301, FEBRUARY, 2001, P. 182-204]

GEOCARB III: A REVISED MODEL OF ATMOSPHERIC CO₂ OVER PHANEROZOIC TIME

ROBERT A. BERNER and ZAVARETH KOTHAVALA

Department of Geology and Geophysics, Yale University,
New Haven, Connecticut 06520-8109

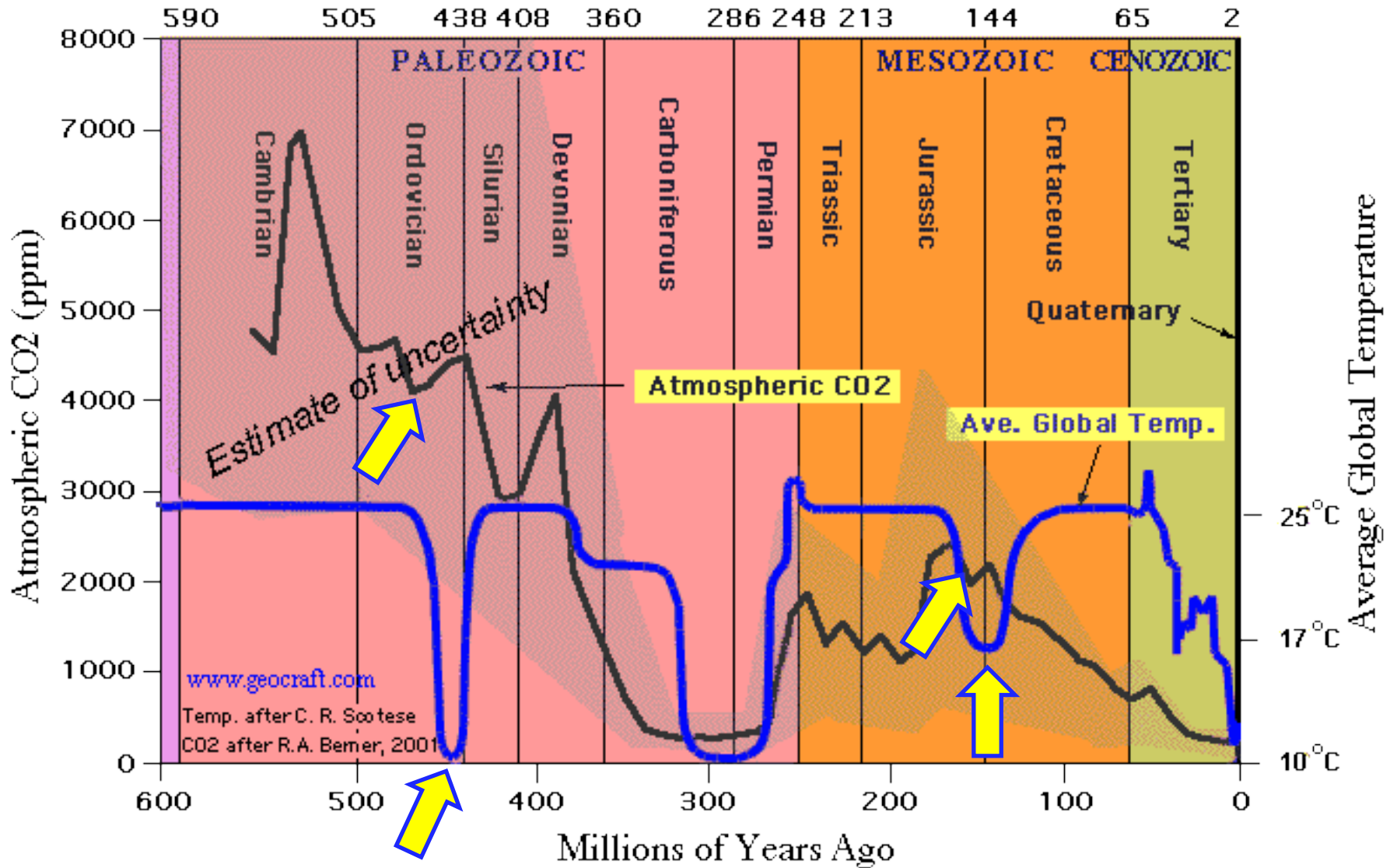
ABSTRACT. Revision of the GEOCARB model (Berner, 1991, 1994) for paleolevels of atmospheric CO₂, has been made with emphasis on factors affecting CO₂ uptake by continental weathering. This includes: (1) new GCM (general circulation model)



X-Axis Time: Cambrian 600 MY ago Left Present on Right

Y-Axis Blue Average Global Temperature, Scotese Paleomap Project [Climate](#) Tab

Y-Axis Black Atmospheric <CO₂> Berner & Kothavala, Am J. Sci., 2001, p 182-204



If atmospheric <CO₂> effect has such a great effect on Temperature and the feedbacks are so strong, why, at the end of the Ordovician, 450M years BP, did temperatures fall so precipitously, when <CO₂> INCREASED from 4100 to 4500 PPM.? Similar effect in at end of Jurassic. Yellow Arrows.

Proxies for Temperature

Liquid-in-glass thermometer record available, at best, since 1800s

Proxies for temperature: Objects in the physical record dependent on temperature during their creation -- used to determine temperature history.

Example: Ice Core Data.

Water consists of H₂O. Oxygen consists of isotopes of O₁₆ and O₁₈. The O₁₆/O₁₈ ratio can be used to determine temperature of the water substance which became snow... then ice after burial...hundreds...thousands of years.

“The heavier [isotope](#) (¹⁸O) condenses more readily as [temperatures](#) decrease and falls as [precipitation](#), while the lighter isotope (¹⁶O) can fall in even colder conditions. The farther [north](#) elevated levels of an ¹⁸O isotope are detected signals a warming over time.^[8]”

Often written in the technical literature as $\delta^{18}\text{O}$.

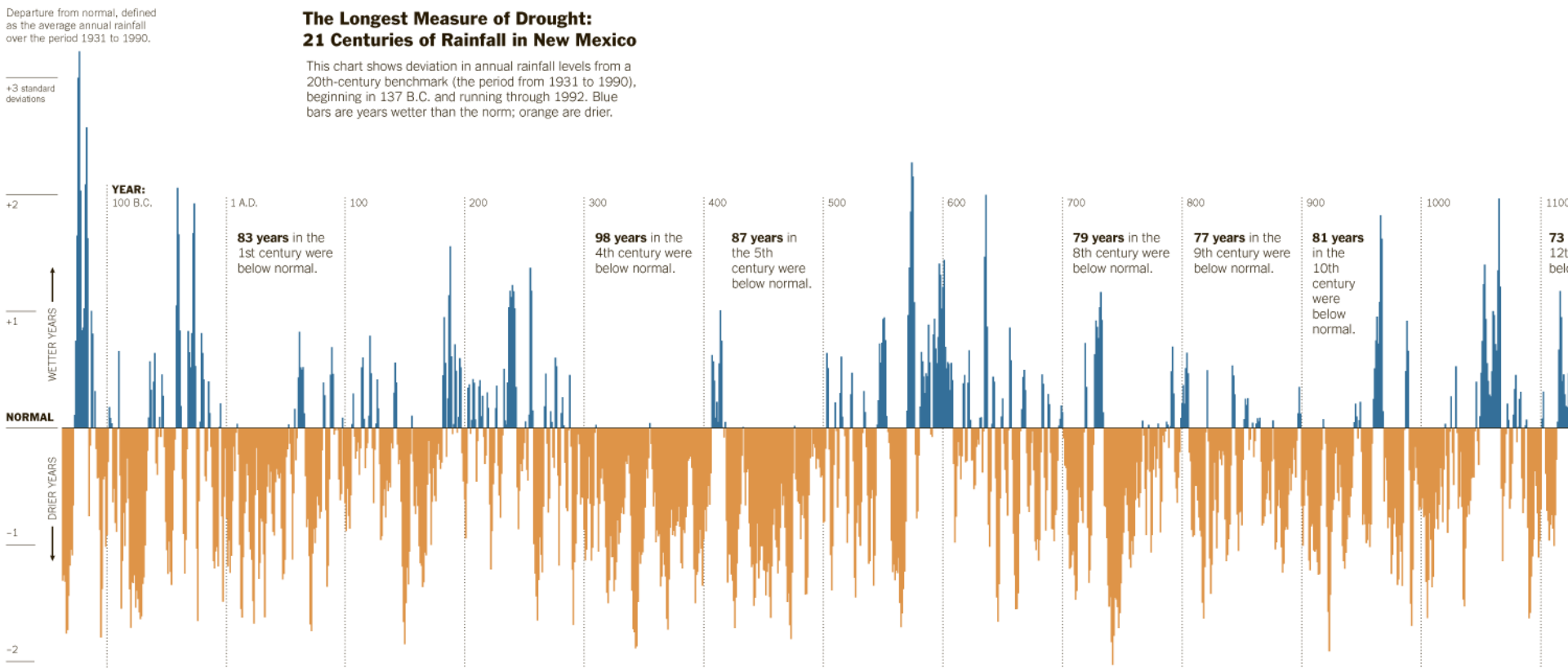
Typically used for Greenland Ice Cores

Proxies for Temperature, Rainfall

Tree Rings, pioneered by the University of Arizona Tree Ring Laboratory.

“Dendroclimatology is the science of determining past climates from trees, primarily from properties of the annual [tree rings](#).”

Tree rings...wider when conditions favor growth, narrower when times are difficult.”



Other Proxies for Temperatures

Boreholes:

"Boreholes have a great advantage over many other proxies in that no calibration is required: they are actual temperatures.

However, they record surface (ground) temperature not the near-surface temperature (1.5 meter) used for most "surface" weather observations."

"Central Greenland borehole temperatures show "a warming over the last 150 years of approximately $1^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ preceded by a few centuries of cool conditions.

Preceding this was a warm period centered around A.D. 1000, which was warmer than the late 20th century by approximately 1°C ."

A borehole in the Antarctica icecap shows that the "temperature at A.D. 1 [was] approximately 1°C warmer than the late 20th century".

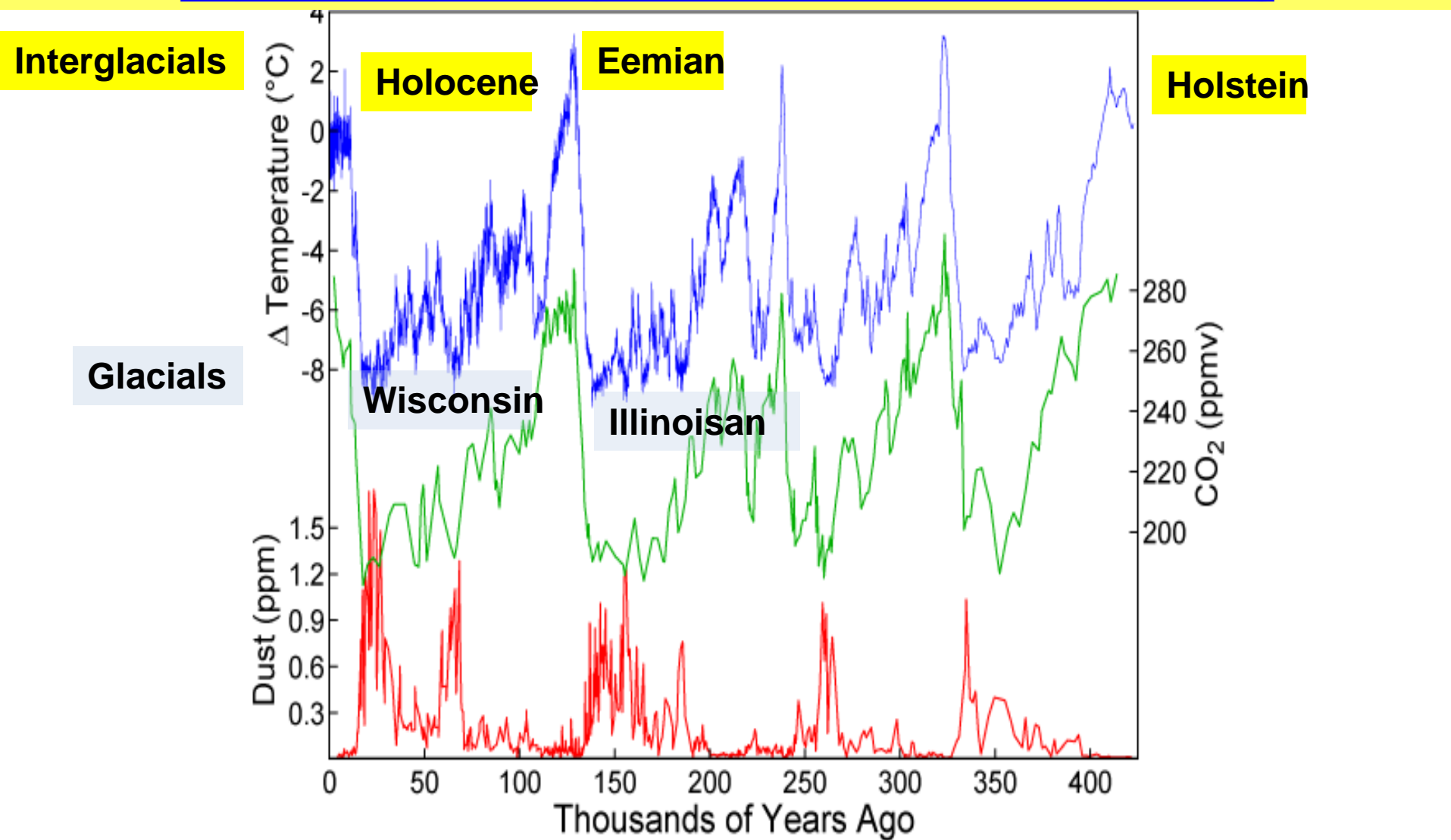
How did "Wikipedia's Climate Doctor" allow this one to escape deletion?

<https://casf.me/wikipedias-climate-doctor-by-lawrence-soloman/>

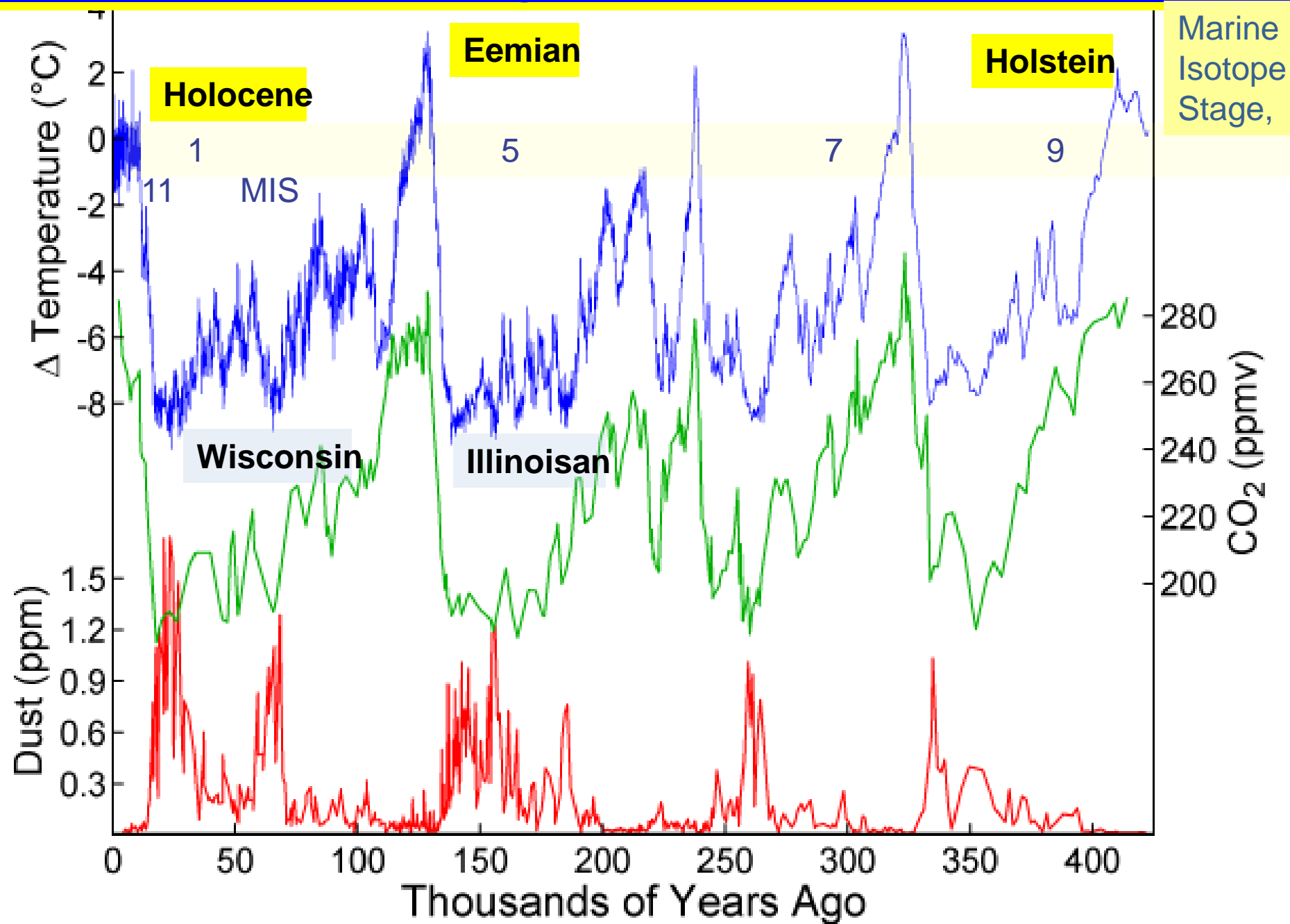
Time Domain:

last 450,000 years-- Vostok Ice Cores

Prominent 100,000-year Climate
Cycles



X-Axis Time Present Time, Left 450,000 years BP, Right
Y-Axis Blue Temperature difference “anomaly” from mean, last 10K yrs
Y-Axis Green, Scale on Right, atmospheric <CO₂>



Letter <http://www.nature.com/nature/journal/v462/n7271/abs/nature08564.htm>

Nature **462**, 342–345 (19 November 2009) | doi:10.1038/nature08564; Received 9 October 2008;
Accepted 5 October 2009

Evidence for warmer interglacials in East Antarctic ice cores

L. C. Sime¹, E. W. Wolff¹, K. I. C. Oliver^{2,4} & J. C. Tindall³

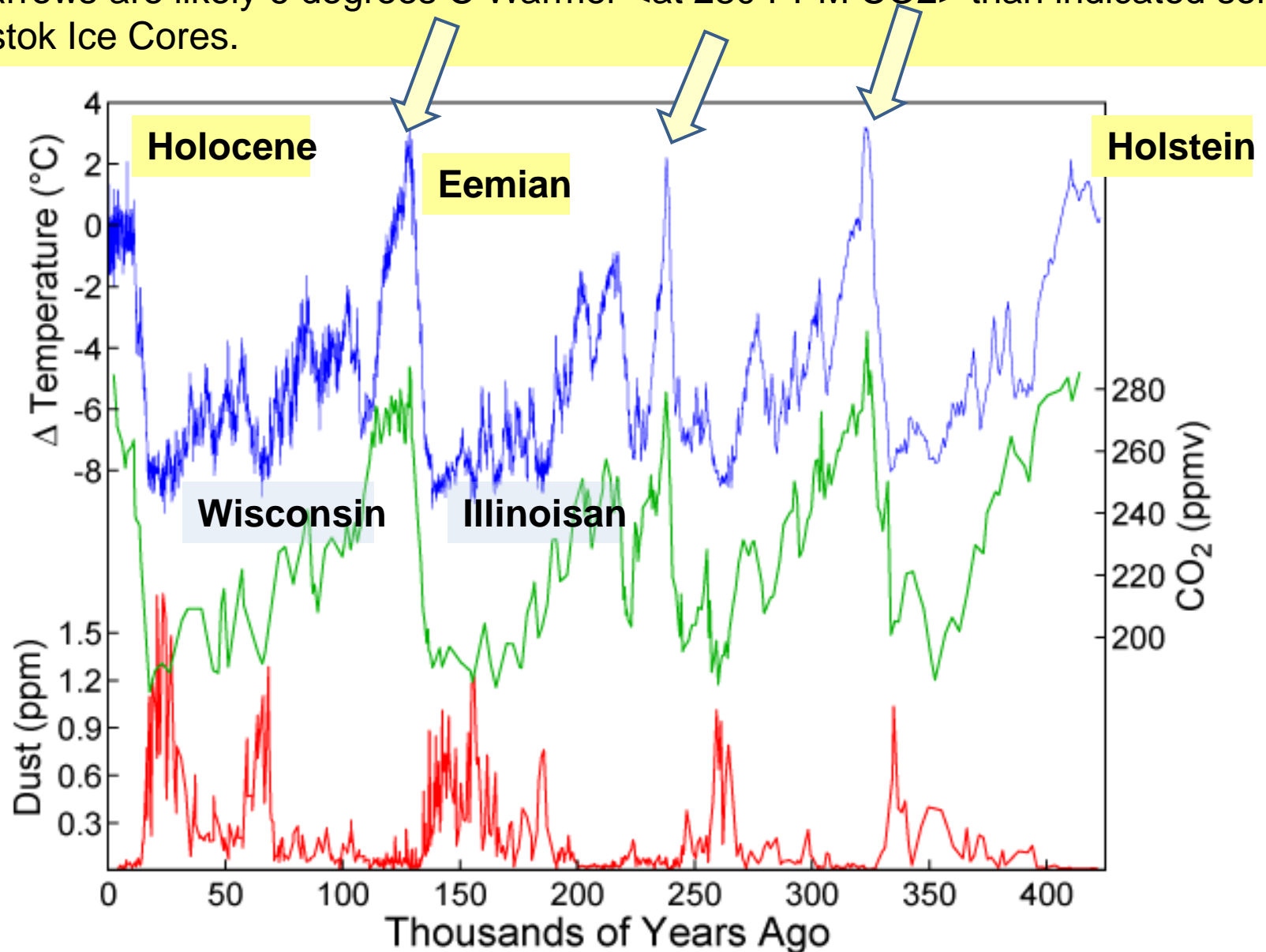
Three East Antarctica Ice Cores from the past 340,000 years.

“We conclude that previous temperature estimates from interglacial climates are likely to be too low.

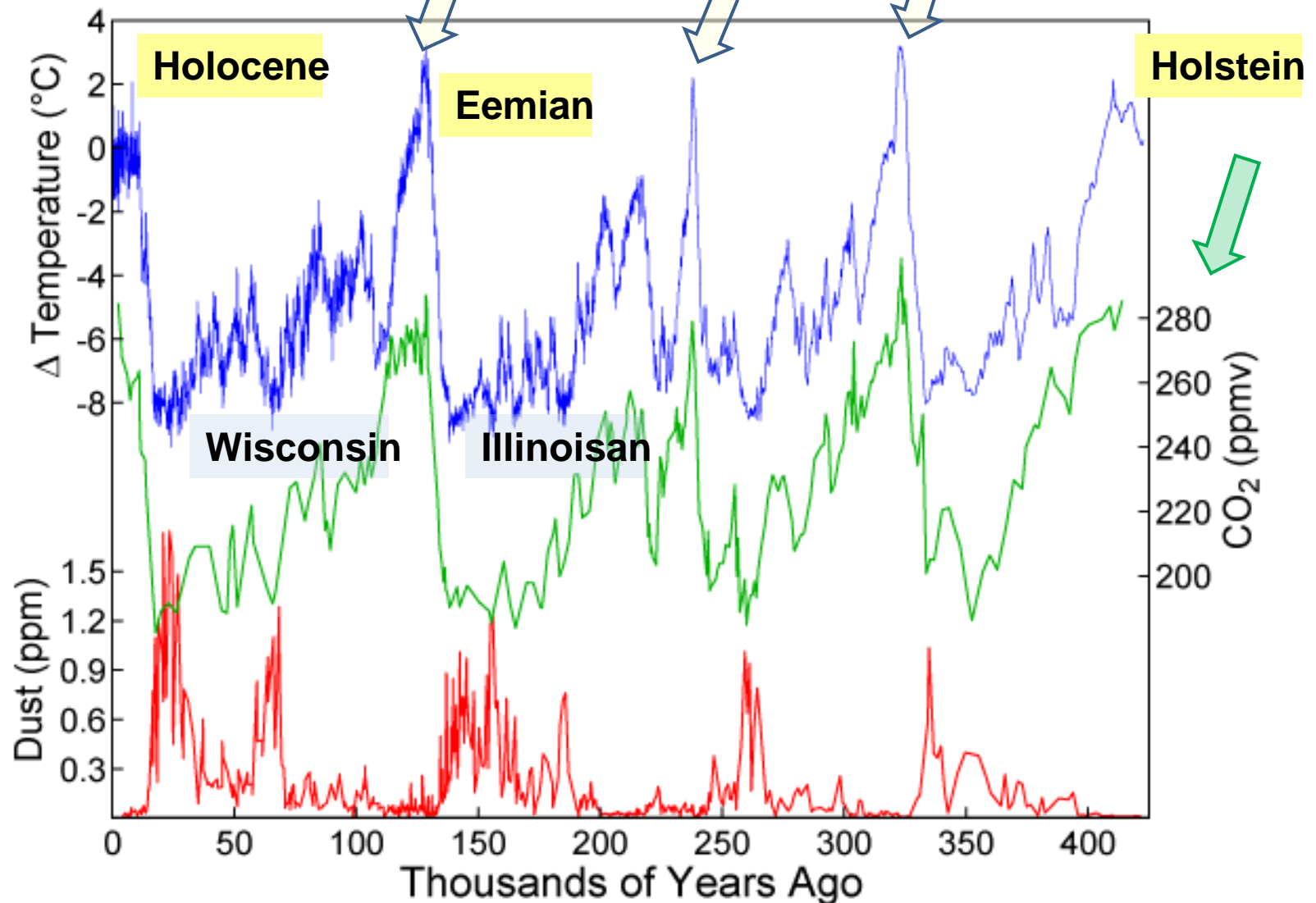
The available evidence is consistent with a peak Antarctic interglacial temperature that was at least 6 K higher than that of the present day

—approximately double the widely quoted 3–1.5 K (refs [5](#), [6](#)).”

Previous Nature Letter says there is evidence that the three interglacials shown with yellow arrows are likely 6 degrees C Warmer <at 280 PPM CO₂> than indicated solely by the Vostok Ice Cores.



Present $\langle \text{CO}_2 \rangle$ is ~415 PPM, which on the green CO_2 scale on the right would be **Off Scale High**. If CO_2 controlled temperature, then this would be the warmest of the five interglacials. It is the coldest. Therefore, CO_2 does not control temperature.





WIKIPEDIA
The Free Encyclopedia

Article

Talk

<http://en.wikipedia.org/wiki/Eemian>

Read

Edit

View history

Eemian Previous Interglacial, 130,000 years ago.

From Wikipedia, the free encyclopedia

Temperature: perhaps 6C (10F) warmer than mean of the Holocene

CO2: 280 PPM

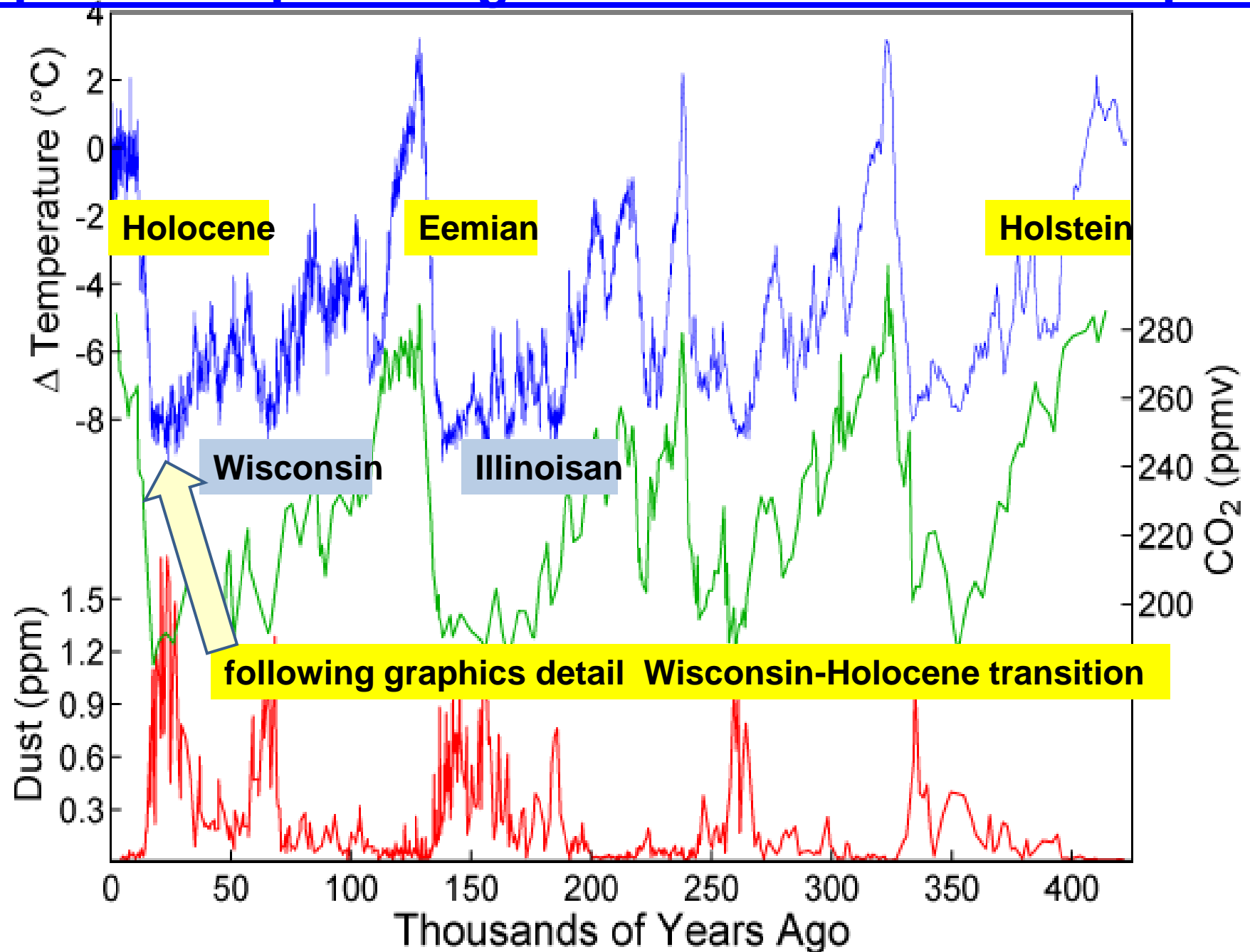
Sea Level 4 to 6 m higher than present Sea Level

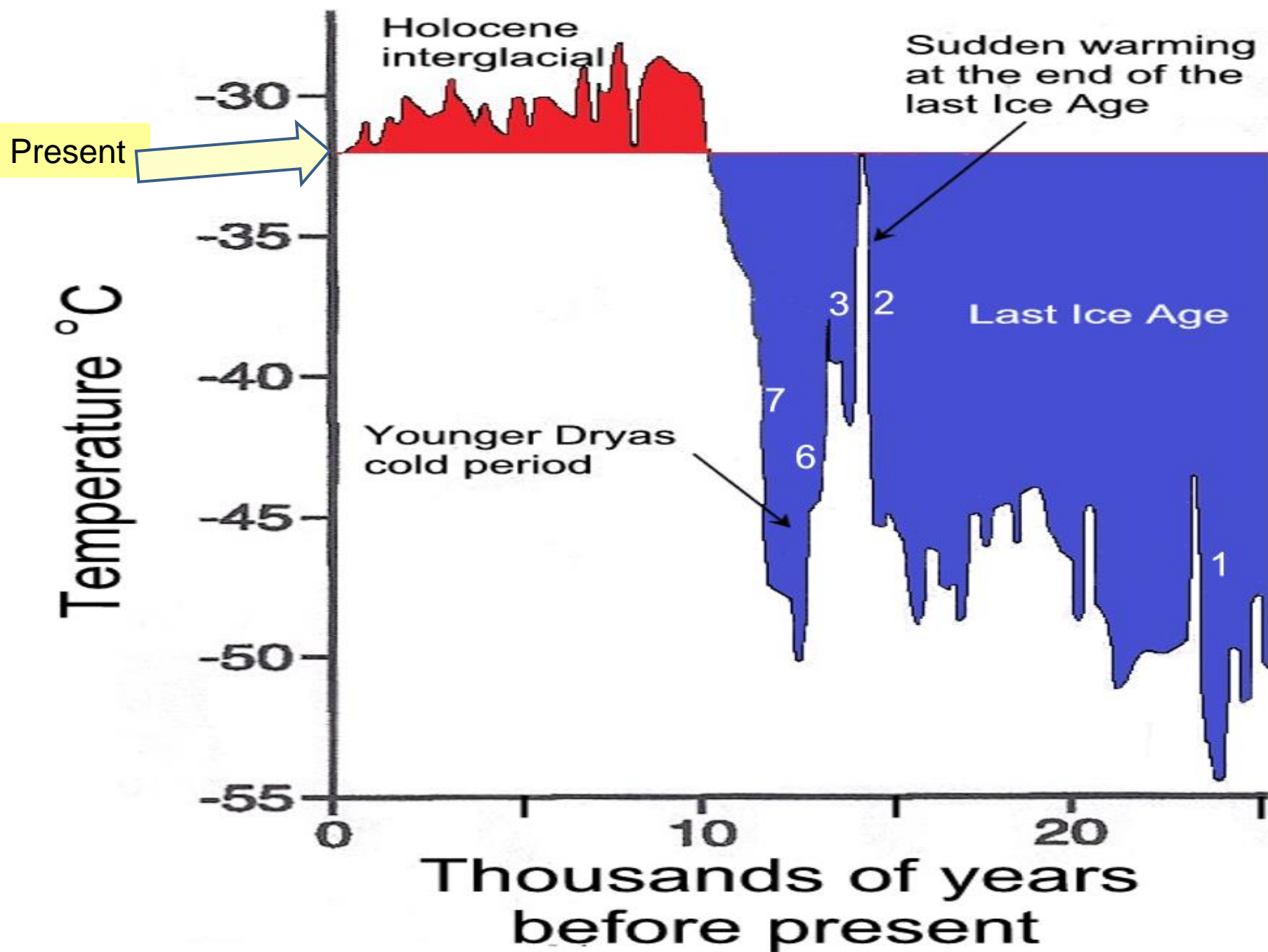
Features: The [hippopotamus](#) was distributed as far north as the rivers [Rhine](#) and [Thames](#)

Forests reached as far north as [North Cape, Norway](#) (which is now [tundra](#)) well above the Arctic Circle.

Greenland ice core site [Dye 3](#) was glaciated during the Eemian, implies Greenland could have contributed at most 2 m (6.6 ft) to [sea level rise](#).

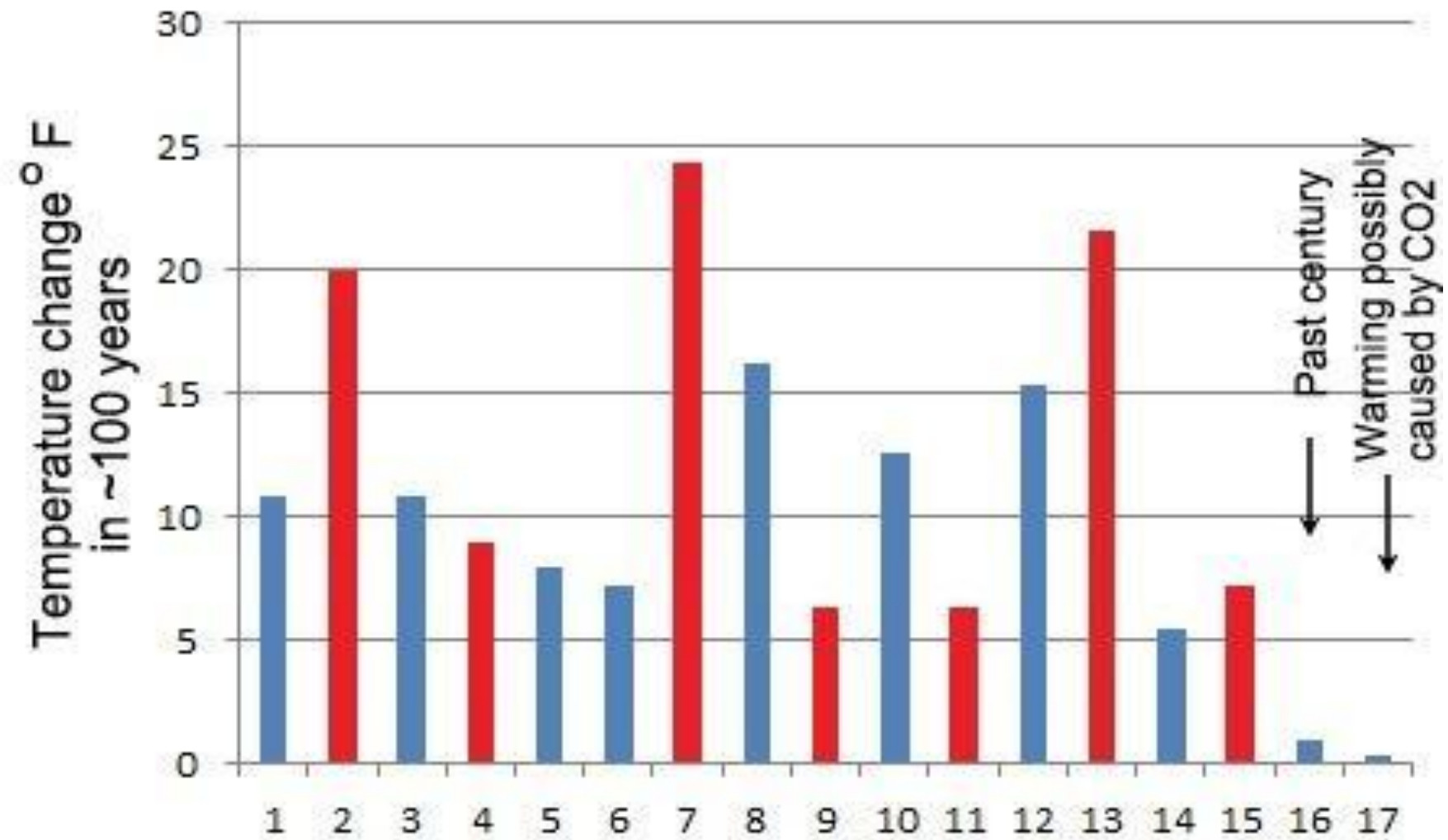
[Scandinavia](#) was an island due to the inundation of vast areas of [northern Europe](#) and the [West Siberian Plain](#).





Seventeen Sets positive (red), negative (blue) Temperature change Deg F / 100 years
Dr Don Easterbrook's analysis of GISP2 proxy temperatures.

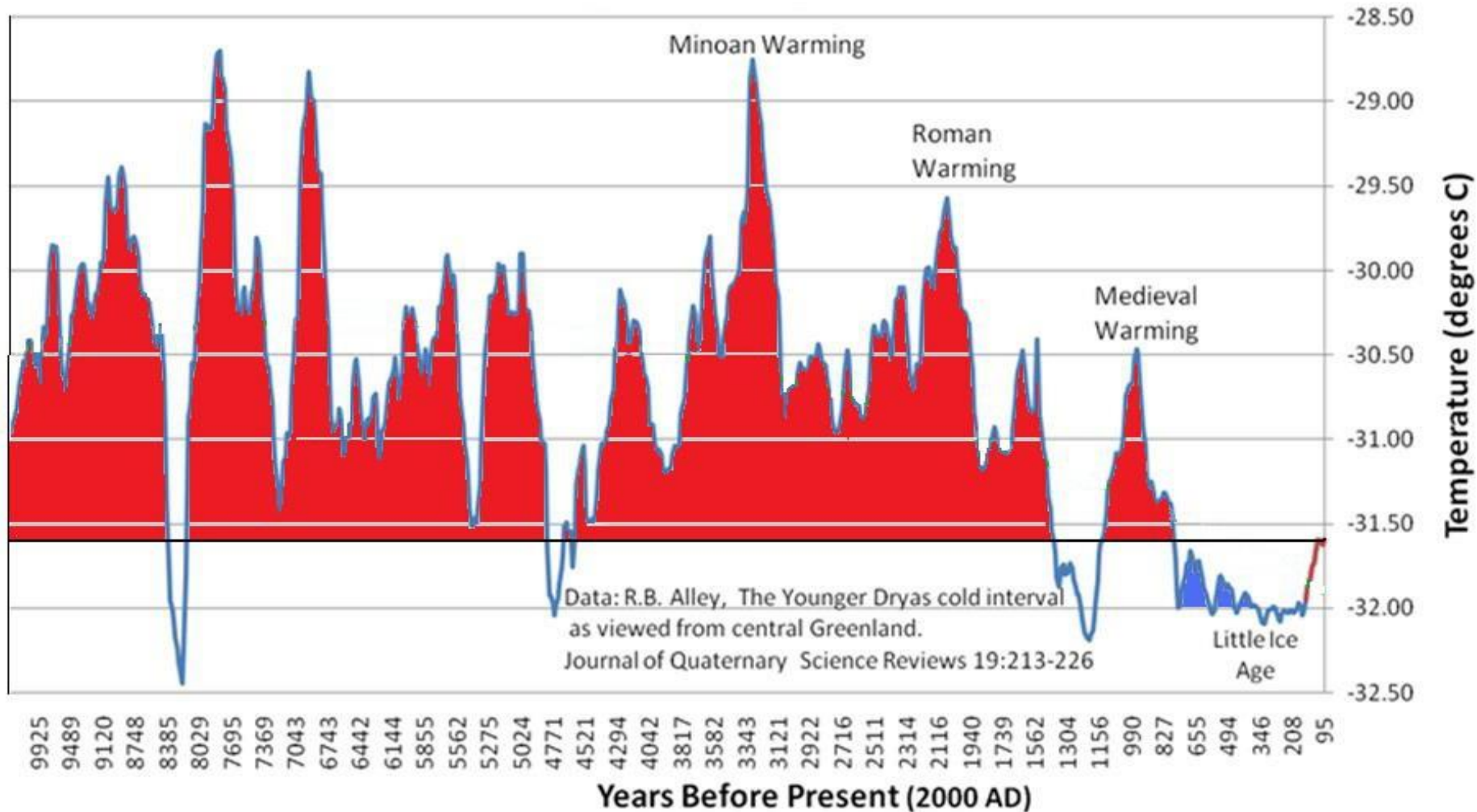
Highest rate: +14F in 40 years (younger Dryas)



Time Domain: Last 10,000 years,
the Holocene

More Climate Cycles 1000-1450
year periodicity

Greenland GISP2 Ice Core - Temperature Last 10,000 Years



X-Axis, Time

Oldest on Left,

Present on Right

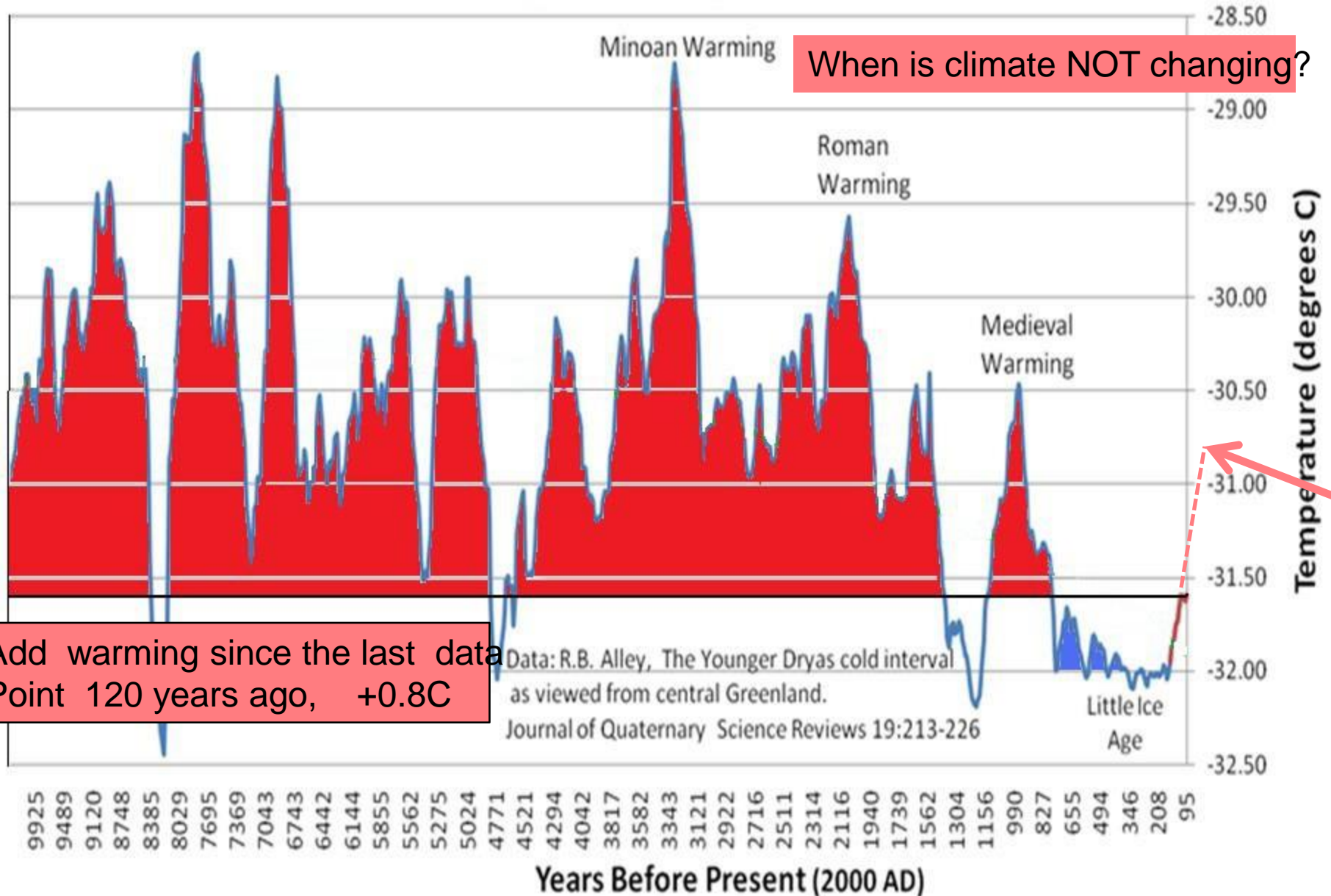
Y-Axis, Temperature

from the O16/O18 ratio , Greenland GISP2 Ice Core

Coldest Down, Warmer Up.

Greenland GISP2 Ice Core - Temperature Last 10,000 Years

<http://wattsupwiththat.files.wordpress.com/2013/03/gisp2-ice-core-temperatures.jpg?w=960&h=540>



Minoan, Roman, Medieval Warm Periods

The past 3500 years shows a distinct “1000-1500” year periodicity in temperatures

Show of hands

Have you heard of “Bond Cycles” of climate fluctuations?

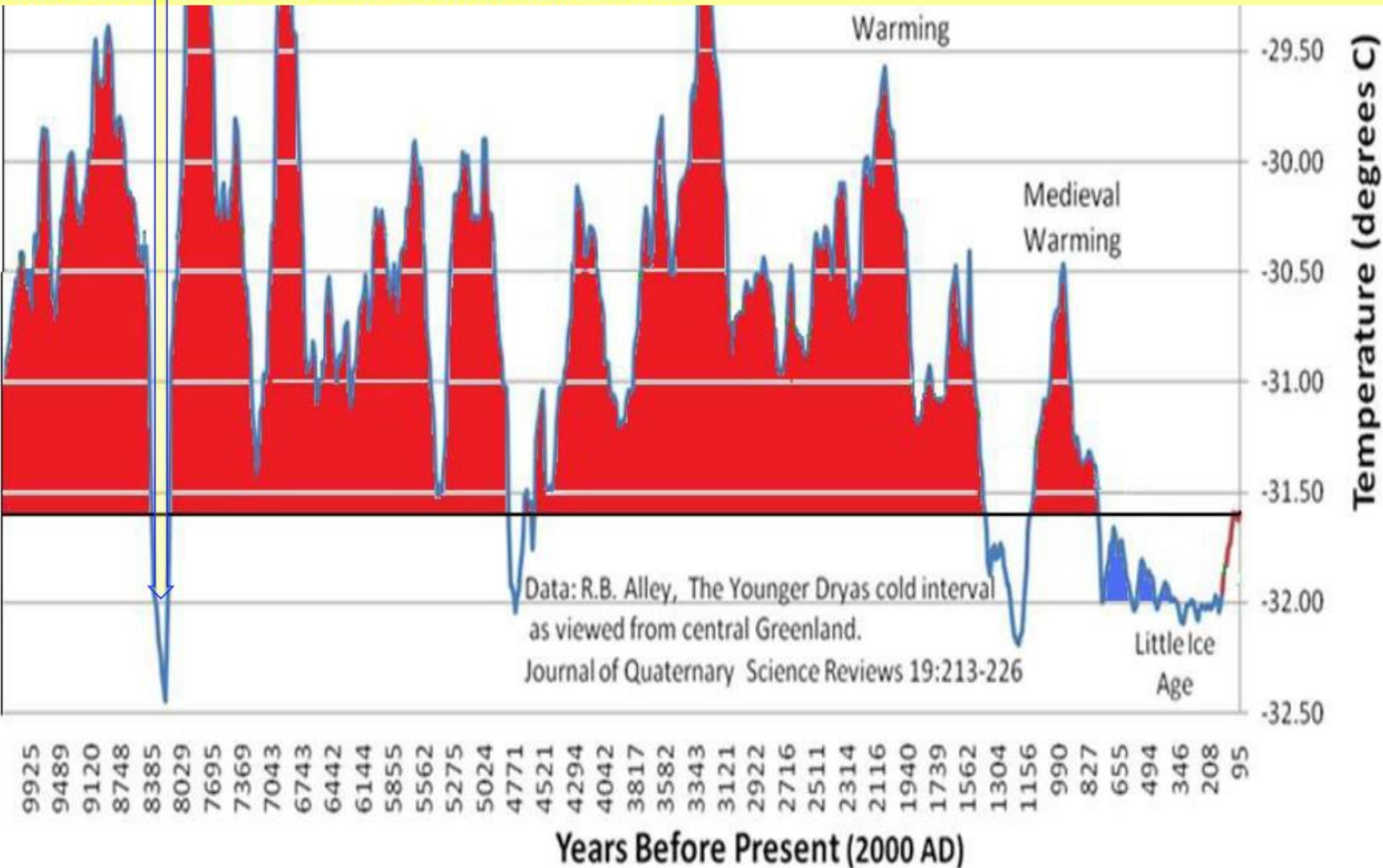
Have you heard of the 1000-1500 year periodicity of temperatures?

Have you heard that it was distinctly warmer 3500, 2000, and 1000 yrs ago?

If not, then, “Why not?”

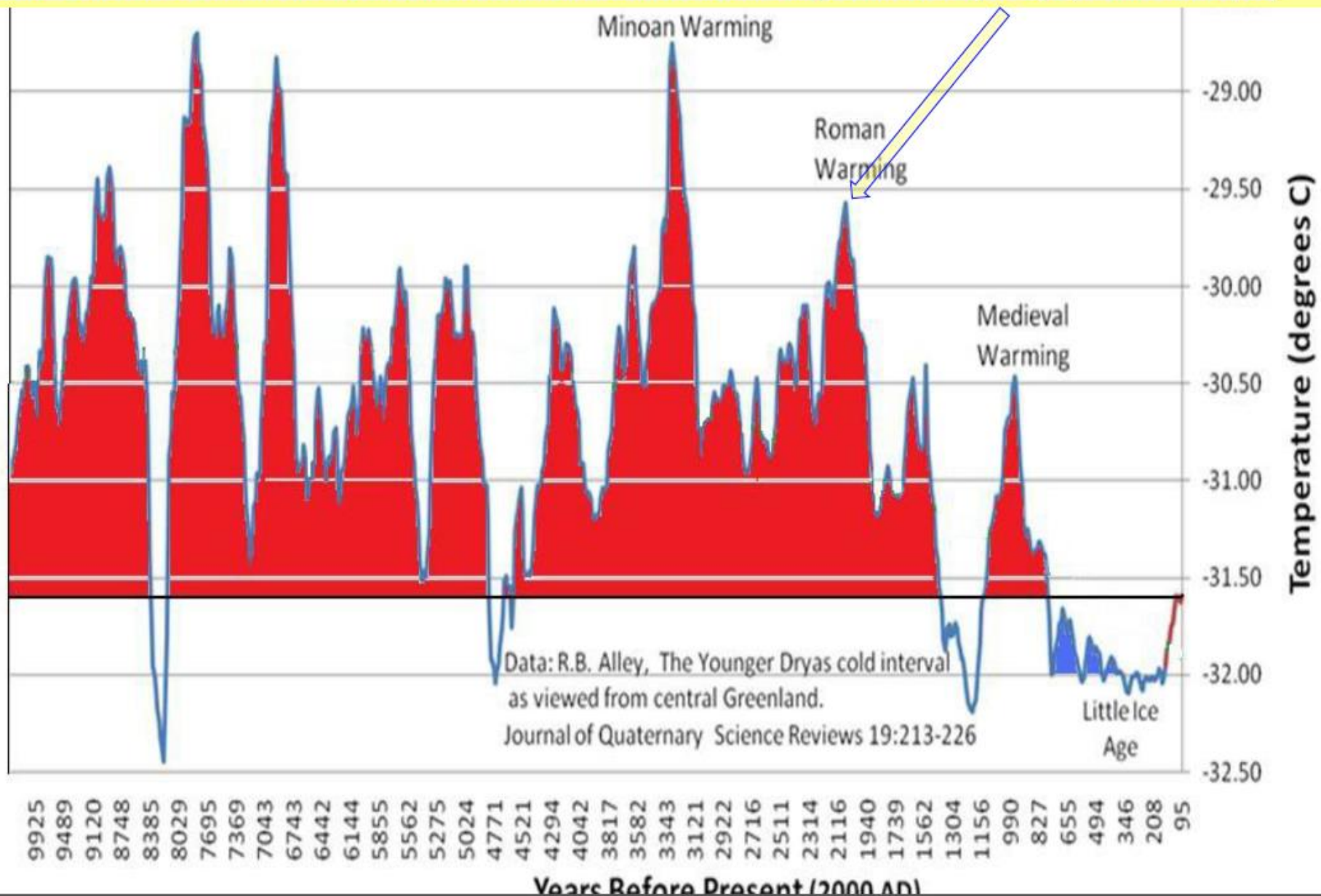
6181 BC: Sudden cooling kills numerous trees, trunks of which are found by Swiss Geologist Christian Schluchter at the base of the Mont Mine' Glacier, Switzerland, about 5 miles north of the Italian border and 10 miles west of Zermatt.

<http://notrickszone.com/2014/06/09/giant-of-geologyglaciology-christian-schluechter-refutes-co2-feature-interview-throws-climate-science-into-disarray/>

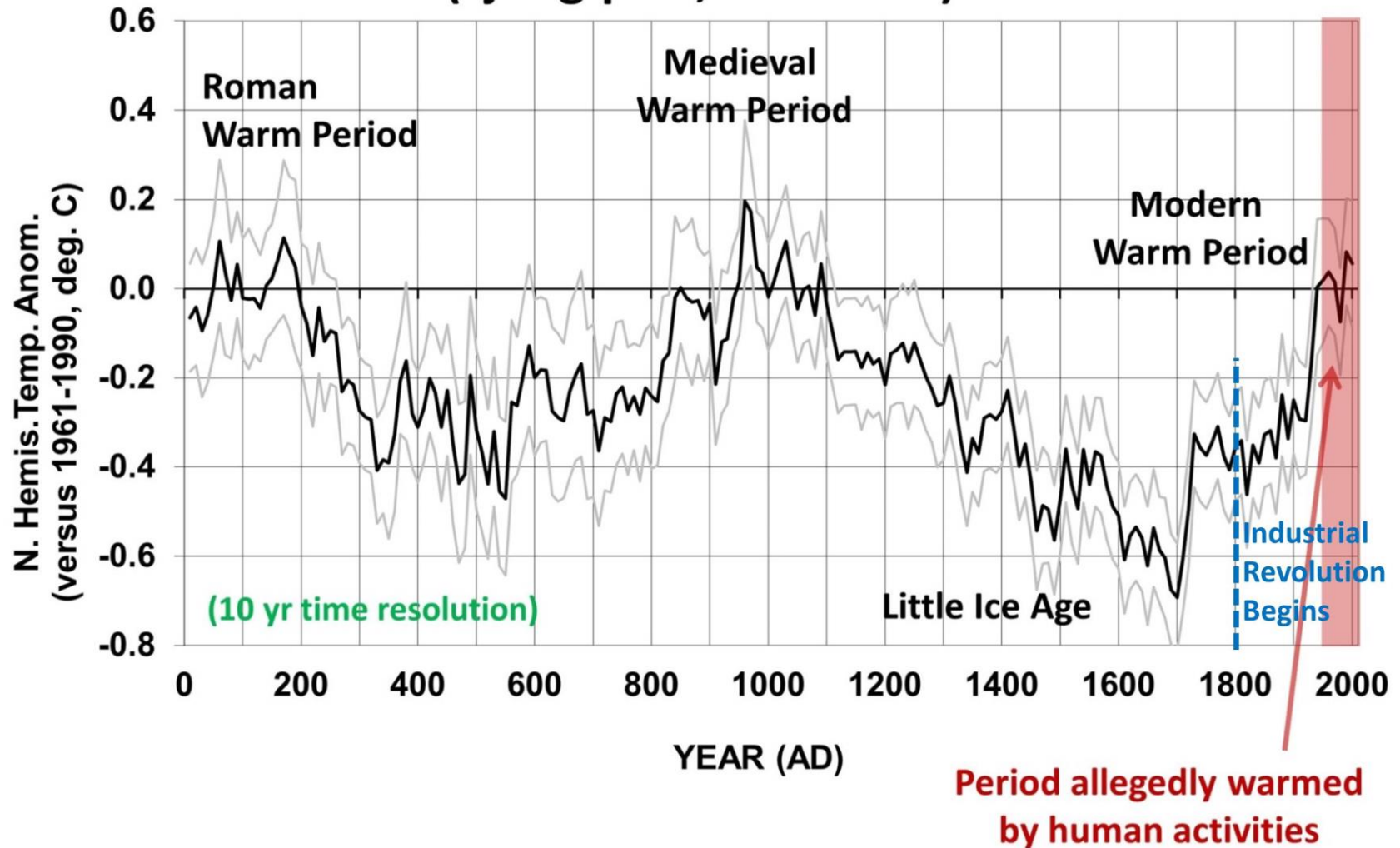


“the forest line was much higher than it is today; there were hardly any glaciers. Nowhere in the detailed travel accounts from Roman times are glaciers mentioned.”

<http://notrickszone.com/2014/06/09/giant-of-geologyglaciology-christian-schluechter-refutes-co2-feature-interview-throws-climate-science-into-disarray/#sthash.z6pKzqtQ.zWfPF60s.dpuf>



N. Hemisphere Temperature proxies (Ljungqvist, F.C. 2010)



Multi-proxy reconstruction also shows ~1000-year cycles in the Holocene

Persistent solar influence on North Atlantic climate during the holocene

Gerard Bond; Bernd Kromer; Juerg Beer; Raimund Muscheler; et al

Science; Dec 7, 2001; 294, 5549; Research Library Core

pg. 2130

Persistent Solar Influence on North Atlantic Climate During the Holocene

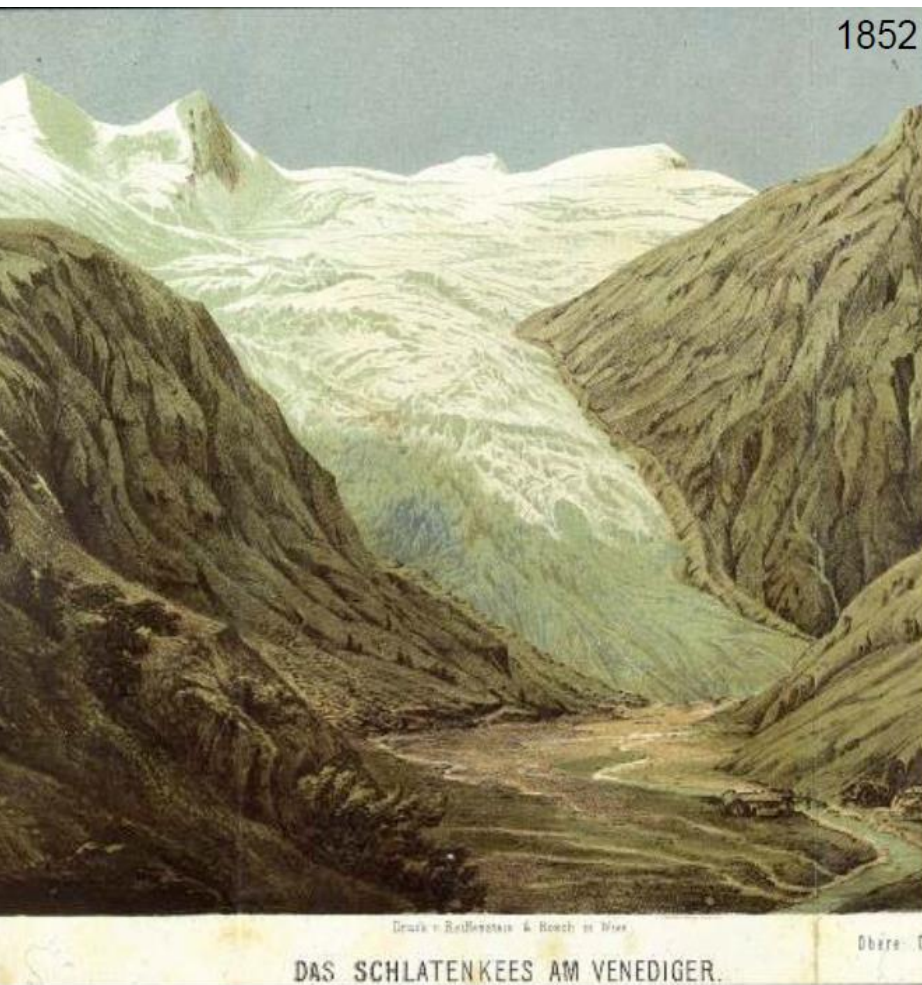
Paper on Bond Cycles

**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 hydrographic changes may have affected production of North Atlantic Deep Water, potentially providing an additional mechanism for amplifying the solar signals and transmitting them globally.

Glaciers as Climate Witness, Gletcher als Klimazeugen

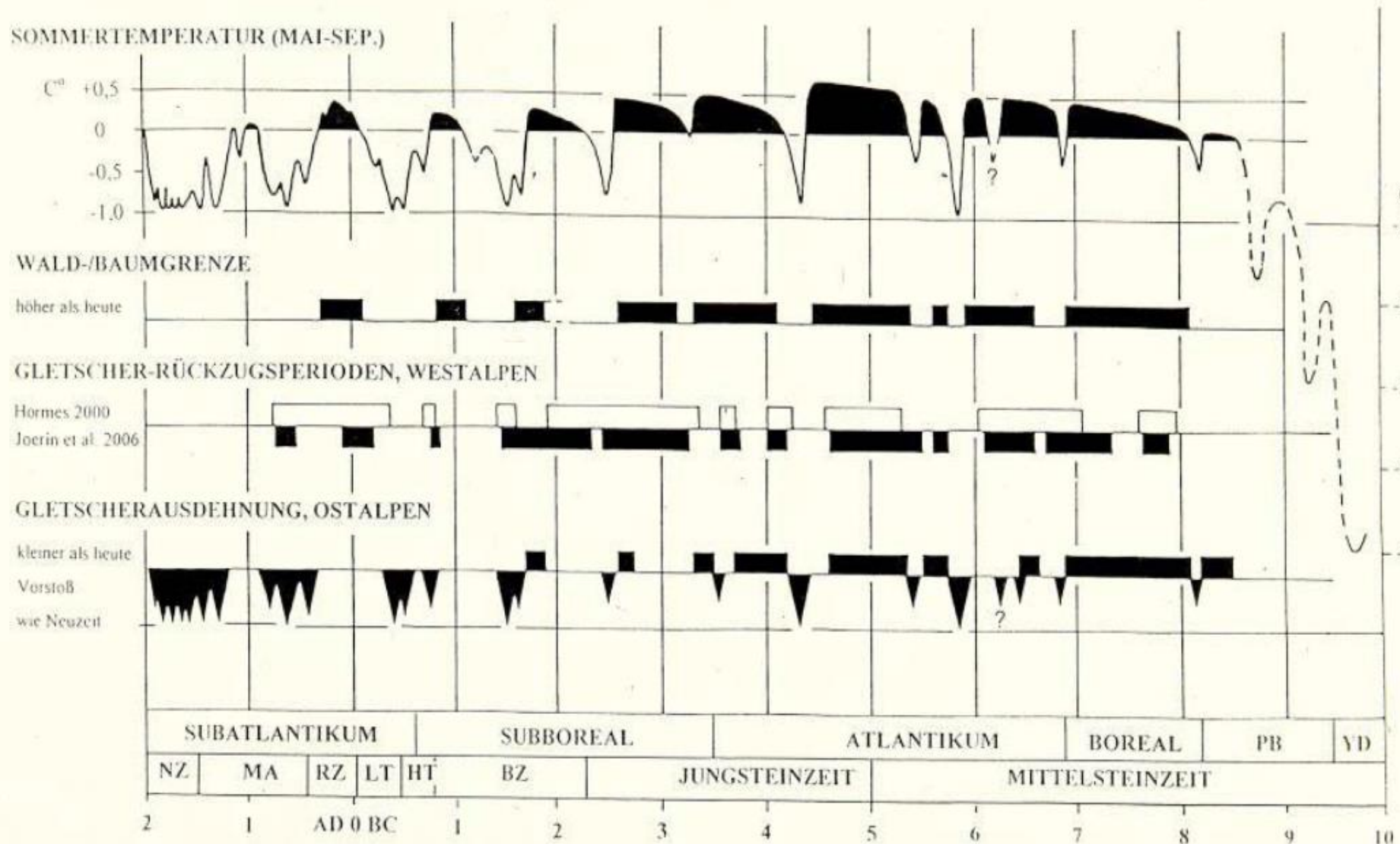
http://www.iuf-berlin.org/wm_files/wm_pdf/prof._patzelt_berlin_4.12.2009.pdf



These images in the Austrian Alps shows glacial retreat from 1852-1995. This is the sort of information that alarmists like to show as proof of man-caused Global Warming. Has this happened before?

Glaciers as Climate Witness, Gletscher als Klimazeugen

http://www.iuf-berlin.org/wm_files/wm_pdf/prof._patzelt_berlin_4.12.2009.pdf



Think of it:

Ice Cores from Greenland show ~12 warm periods last 10,000 years. <O16/O18 ratio>
Present Warm Period Notably Weaker than past such periods.

Ice Cores show dramatic cooling, “8.2 K year” event, https://en.wikipedia.org/wiki/8.2_kiloyear_event

Christian Schluchter shows same cooling event...jumble of trees Mt Mine' Switzerland

Ice cores match up with Roman Warm Period and Hannibal's crossing of Alps

Ice Cores match up with Medieval Warm Period

History of England and Europe

Ice Cores match up with borehole data set from Greenland.

Austrian Alps Dendrochronology also shows ~12 Warm Periods last 10,000 years

Present Warm Period Notably Weaker than past such events

Fundamentally Different Proxies show the same pattern, but separated by
Thousands of Kilometers.

Do the data send a distinct message?

El Nino, a basic description

Origins of the name, *El Niño*

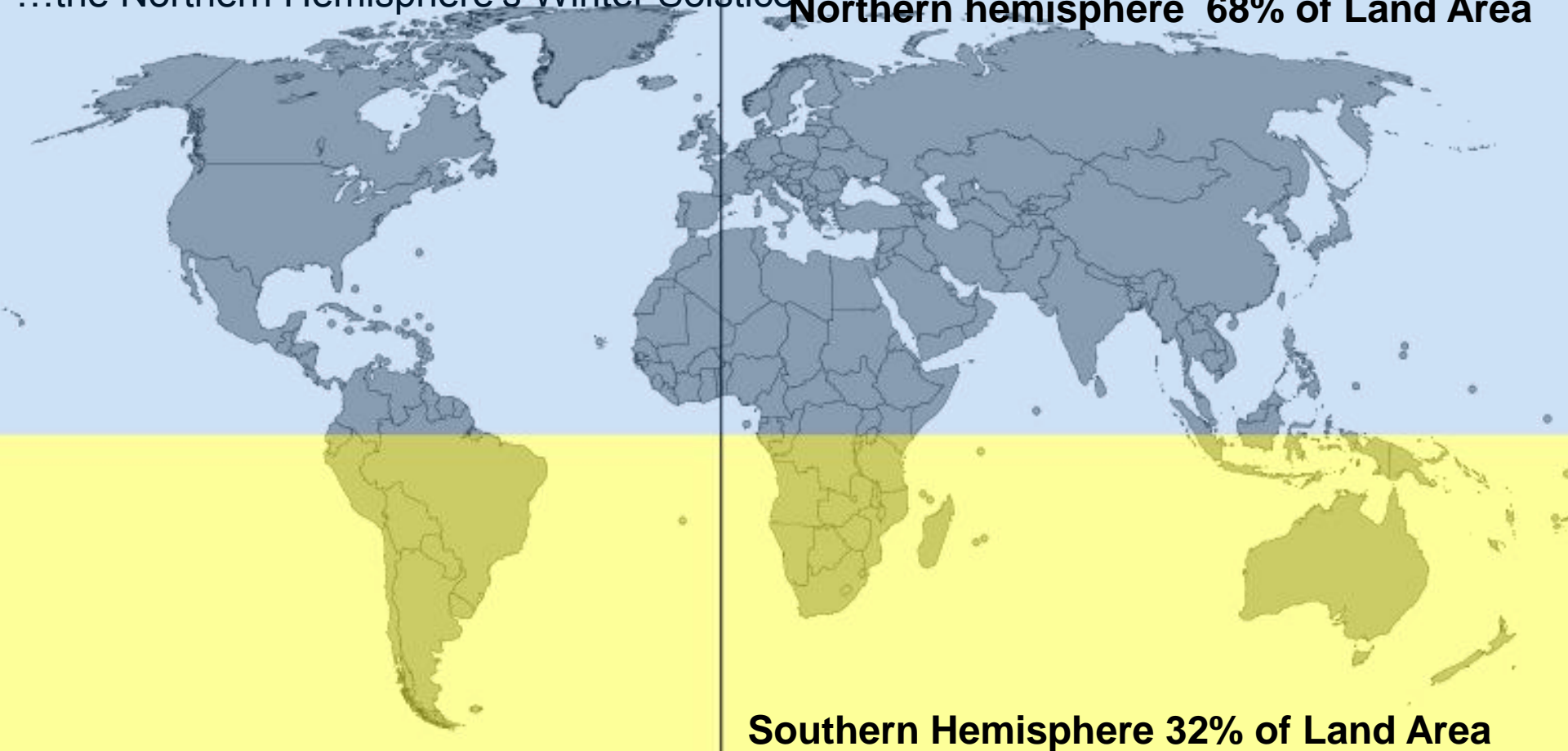
El Niño... originally recognized by fisherman off the coast of South America as appearance of **unusually warm water in the Pacific Ocean**, occurring ~beginning of the year.

El Niño means *The Little Boy* or *Christ child* in Spanish.

This name was used for the tendency of the phenomenon to arrive around Christmas...

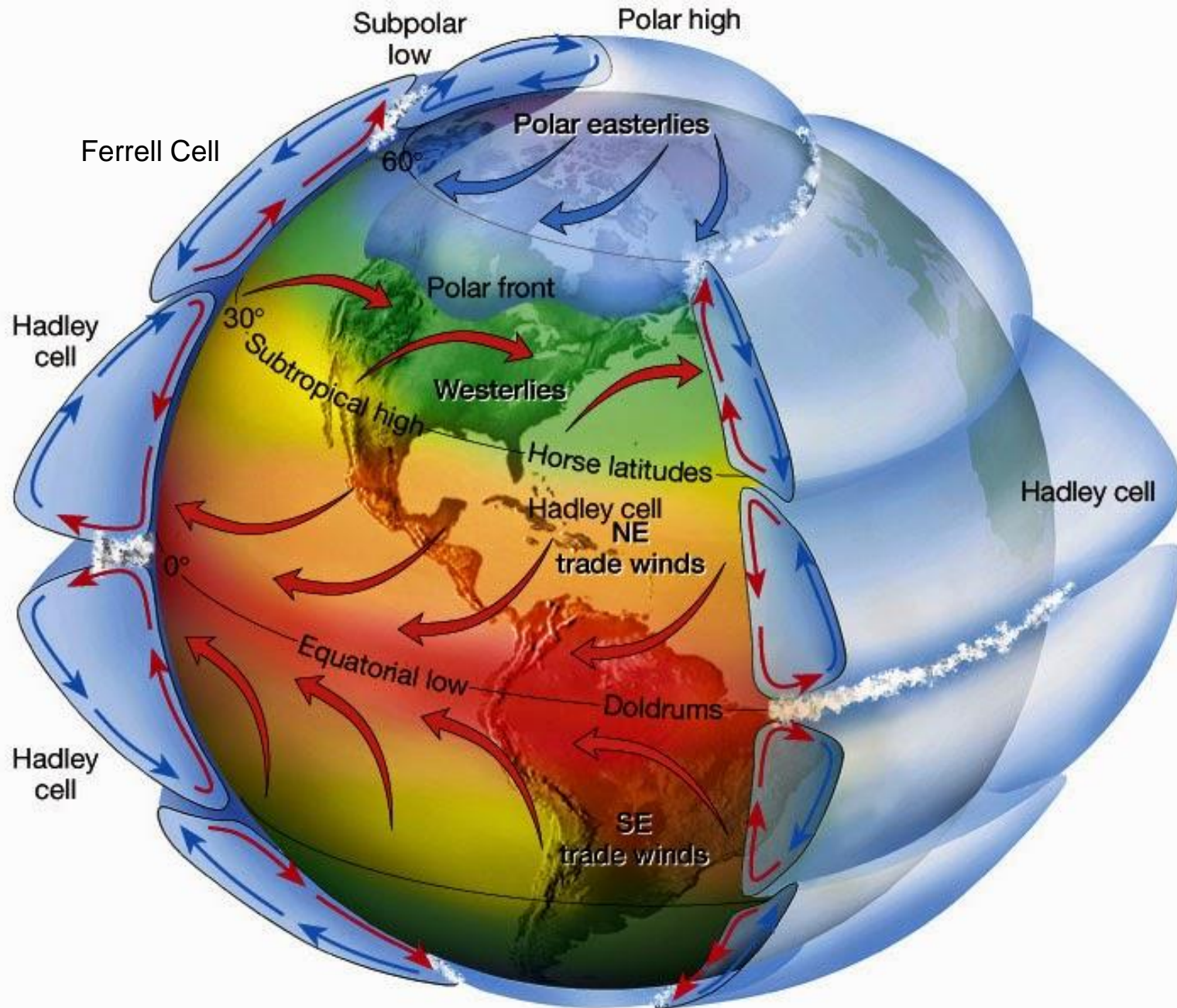
...the Northern Hemisphere's Winter Solstice

Northern hemisphere 68% of Land Area



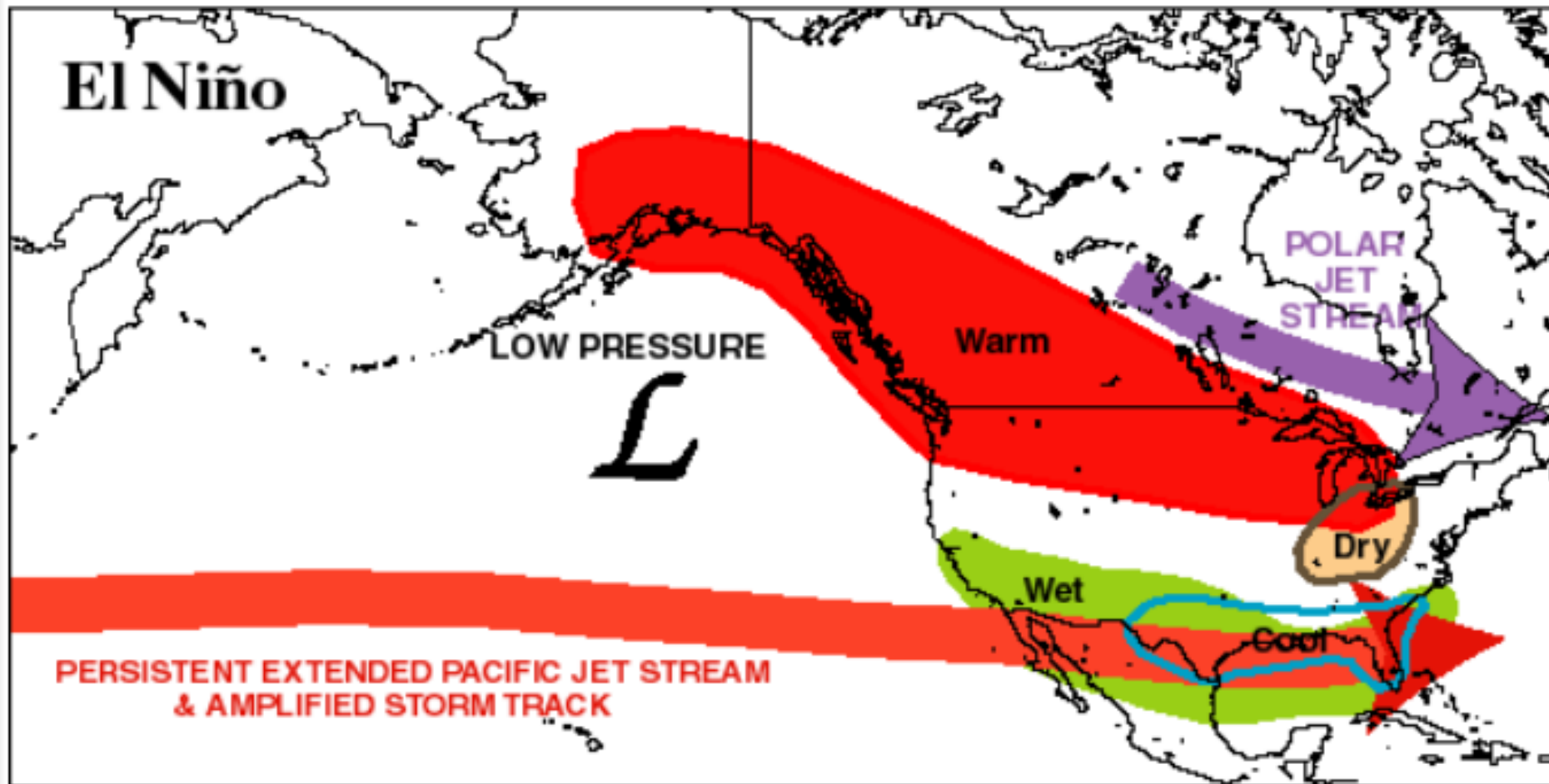
Southern Hemisphere 32% of Land Area

<http://1.bp.blogspot.com/-tDTpvWrModo/U2XoP6s57XI/AAAAAAAAA7o/r6lk0N5VHk8/s1600/Hadley+c>

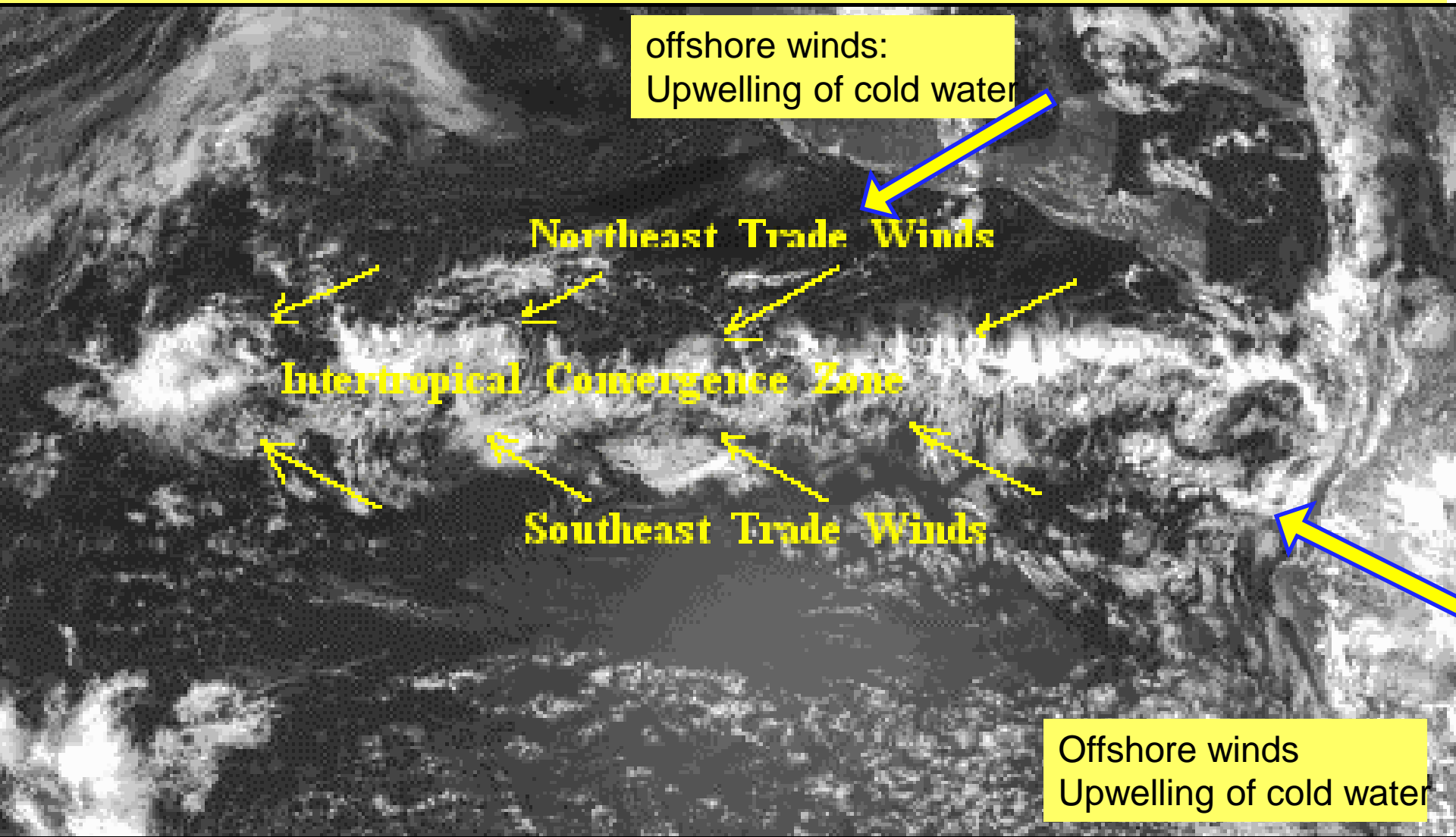


El Niño pattern: Brings wet from California to New Mexico to East Coast

Huge Warm Pattern from Gulf of Alaska all the way to Michigan!



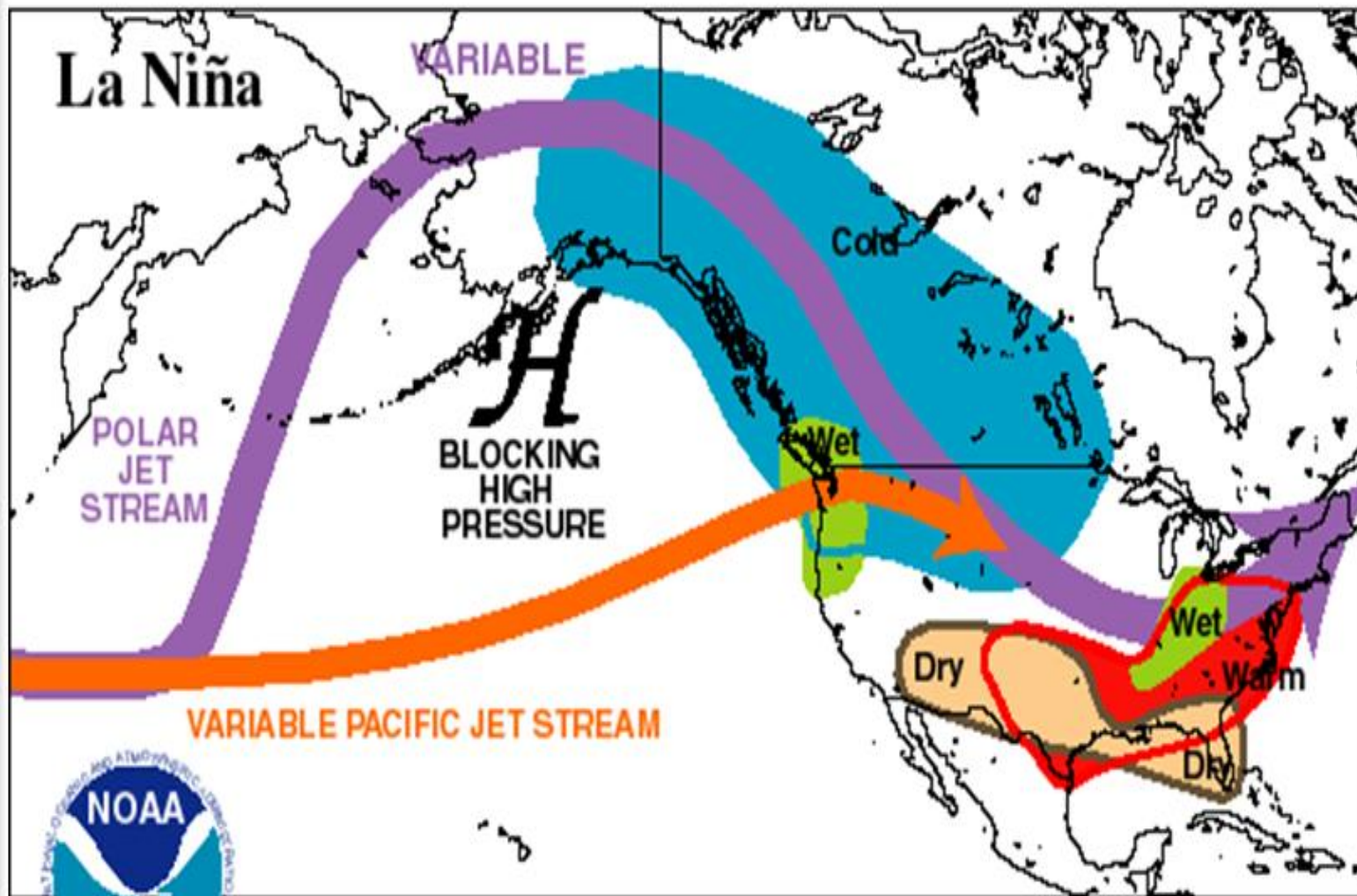
The Northeasterly Trade Winds are very prevalent, stronger in La Nina years. Visitors to Hawaii usually encounter the steady from the northeast Trade Winds



But EL NINO is caused by a disruption of this pattern, which allows warm water to flow from Indonesia/Western Pacific across the entire Pacific Ocean.

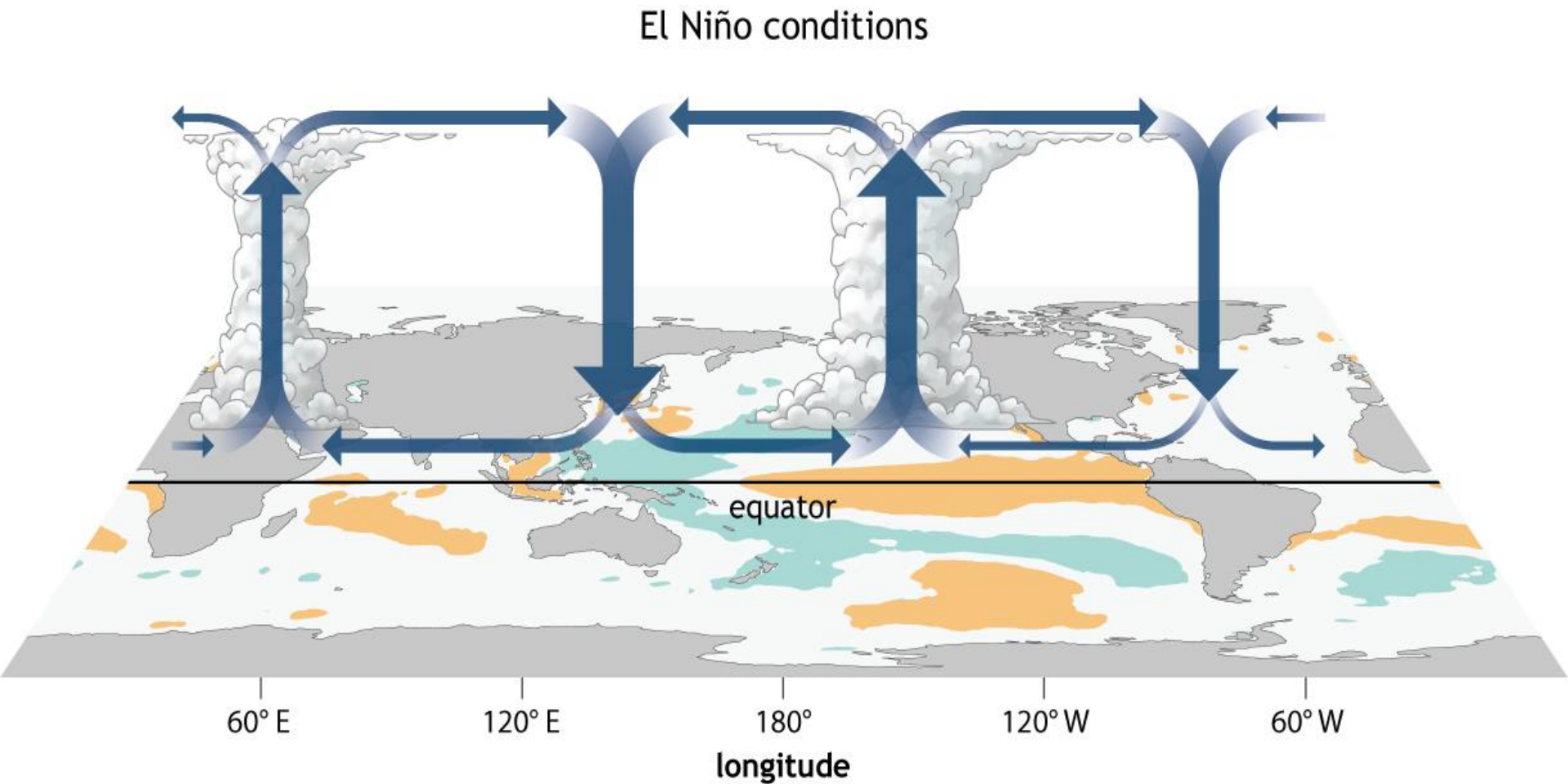
La Nina pattern, brings dry/drought from Arizona to Florida

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/nawinter

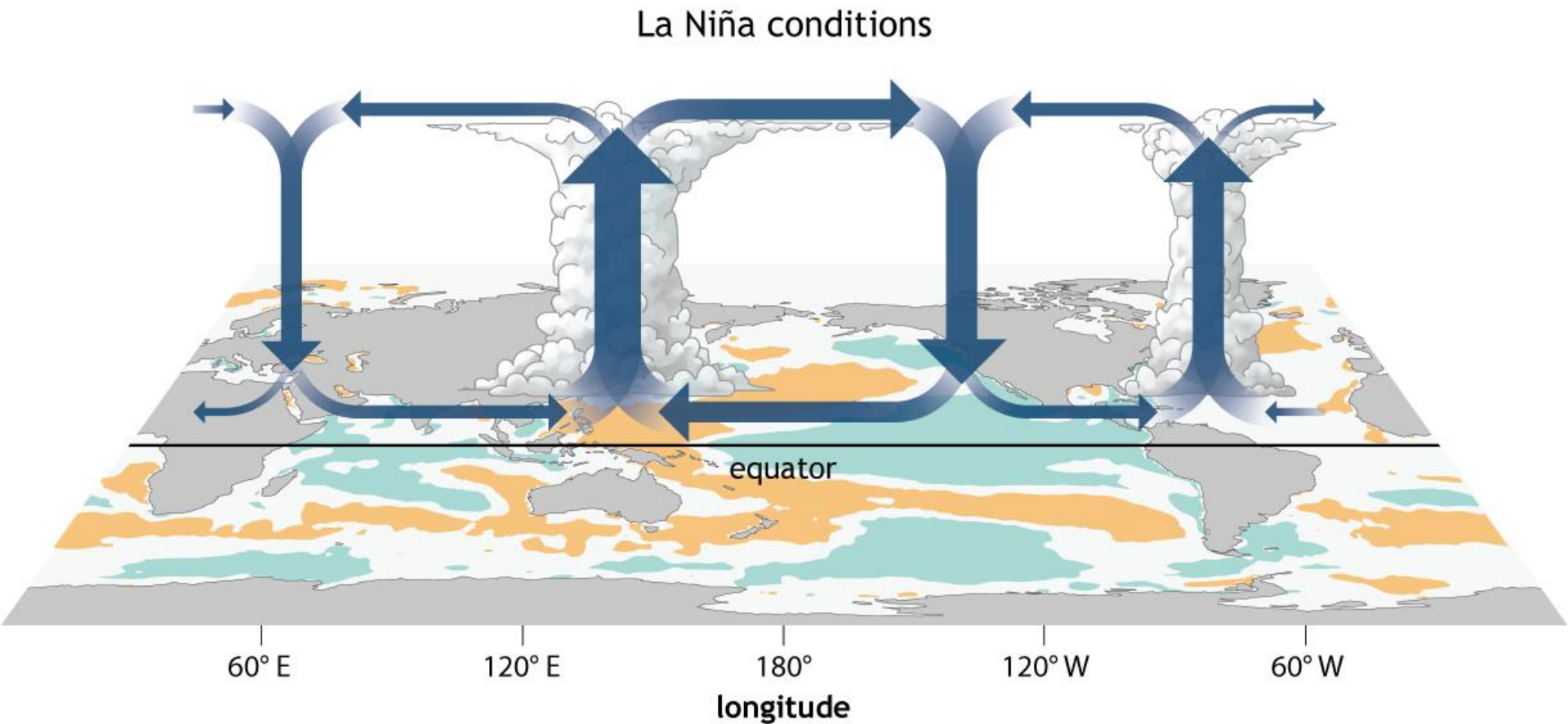


Climate Prediction Center/NCEP/NWS

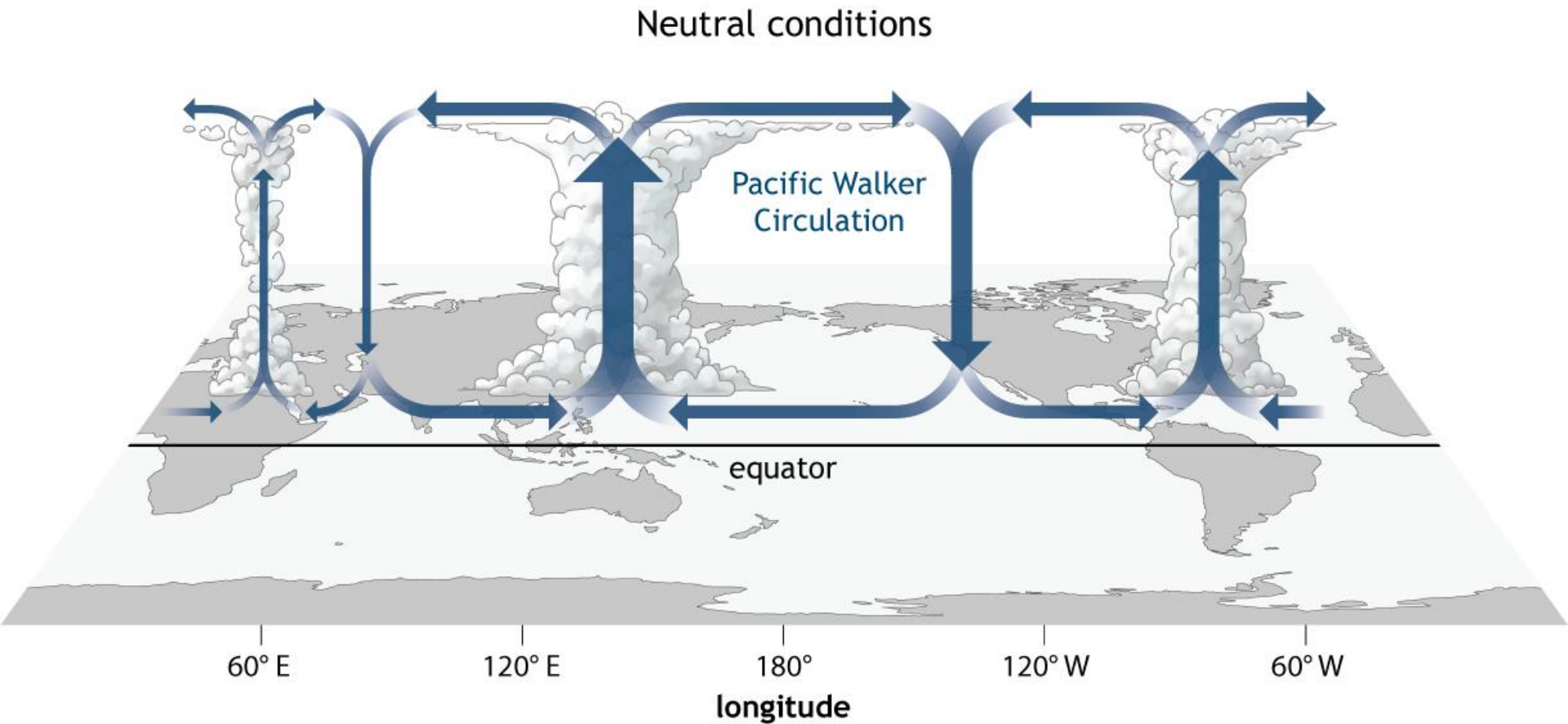
<http://www.climate.gov/news-features/blogs/enso/walker-circulation-ensos-atmospheric-buddy>



<http://www.climate.gov/news-features/blogs/enso/walker-circulation-ensos-atmospheric-buddy>



<http://www.climate.gov/news-features/blogs/enso/walker-circulation-enso-atmospheric-buddy>



Nino 3.4 region: area bounded from 5N to 5S and from 120W to 160E



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July Global Release: Thu, 20 Aug 2015, 11:00 AM EDT

Equatorial Pacific Sea Surface Temperatures

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[BAMS State of the Climate](#)

[Temp, Precip, and Drought](#)

[Climate at a Glance](#)

[Extremes](#)

[Societal Impacts](#)

[Snow and Ice](#)

[Teleconnections](#)

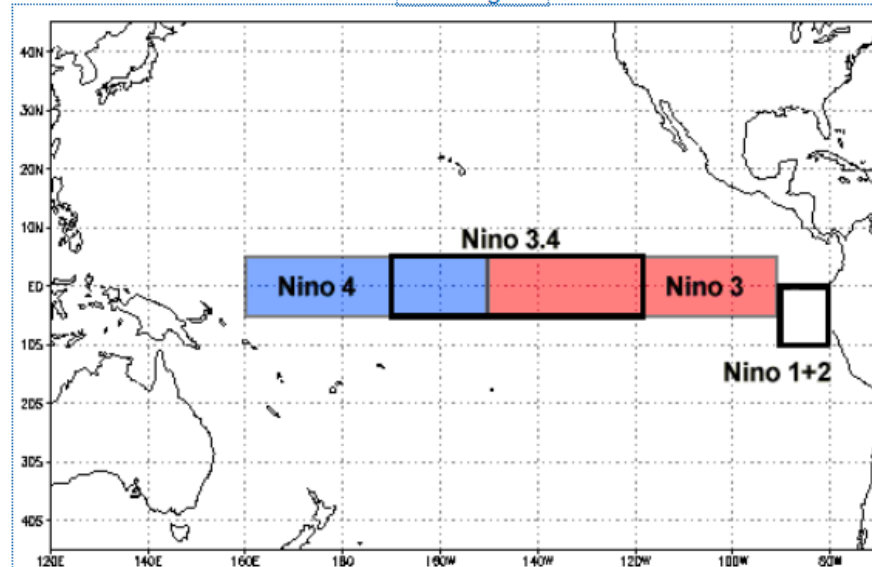
[GHCN Monthly](#)

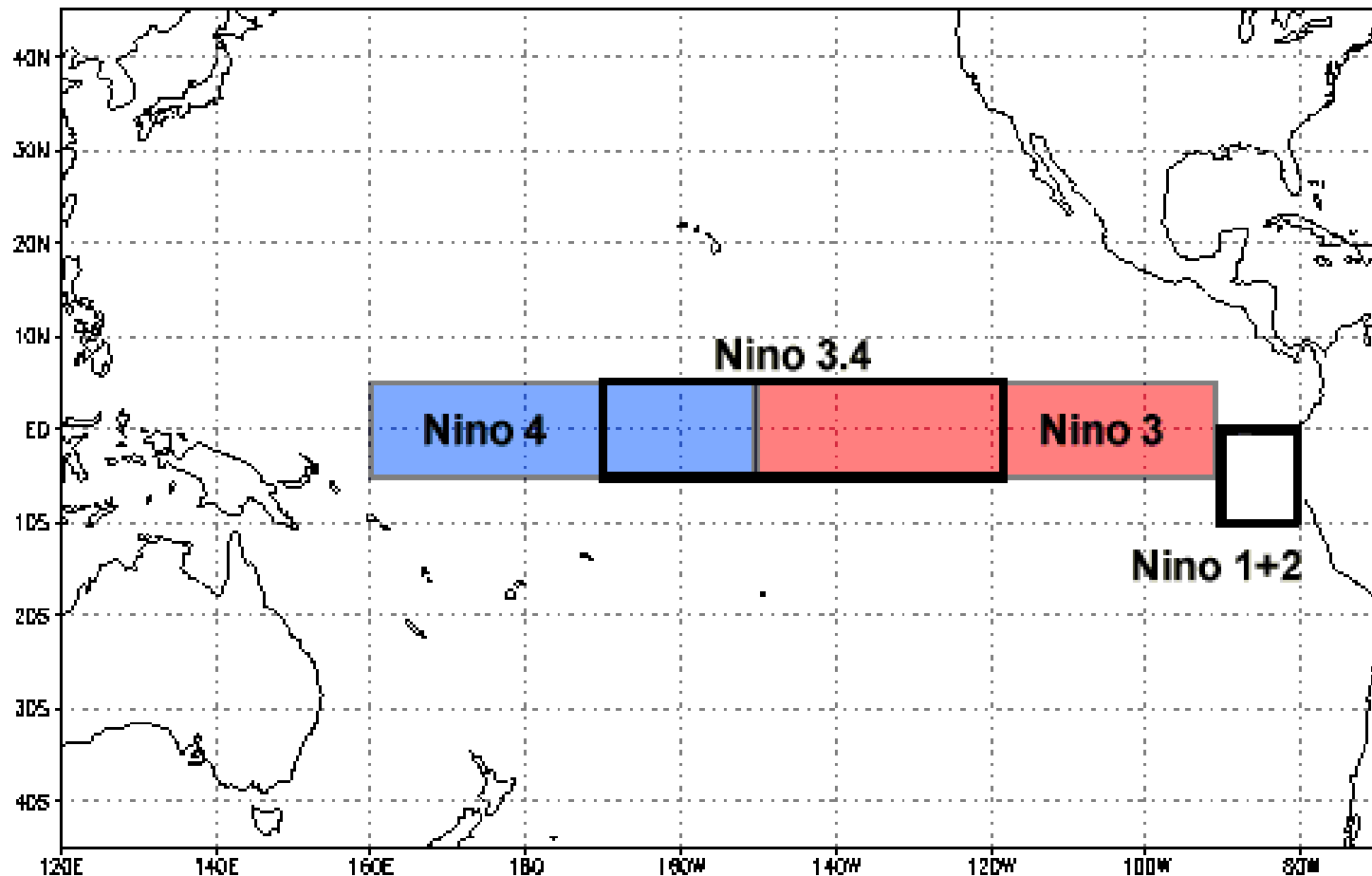
[Monitoring References](#)

[ENSO](#) | [Zonal Winds](#) | [SSTs](#) | [Sea Temps](#) | [SST Anomalies](#) | [OLR](#) | [SOI](#)

El Niño (La Niña) is a phenomenon in the equatorial Pacific Ocean characterized by a five consecutive 3-month running mean of sea surface temperature (SST) anomalies in the [Niño 3.4 region](#) that is above (below) the threshold of $+0.5^{\circ}\text{C}$ (-0.5°C). This standard of measure is known as the [Oceanic Niño Index \(ONI\)](#).

Niño Regions





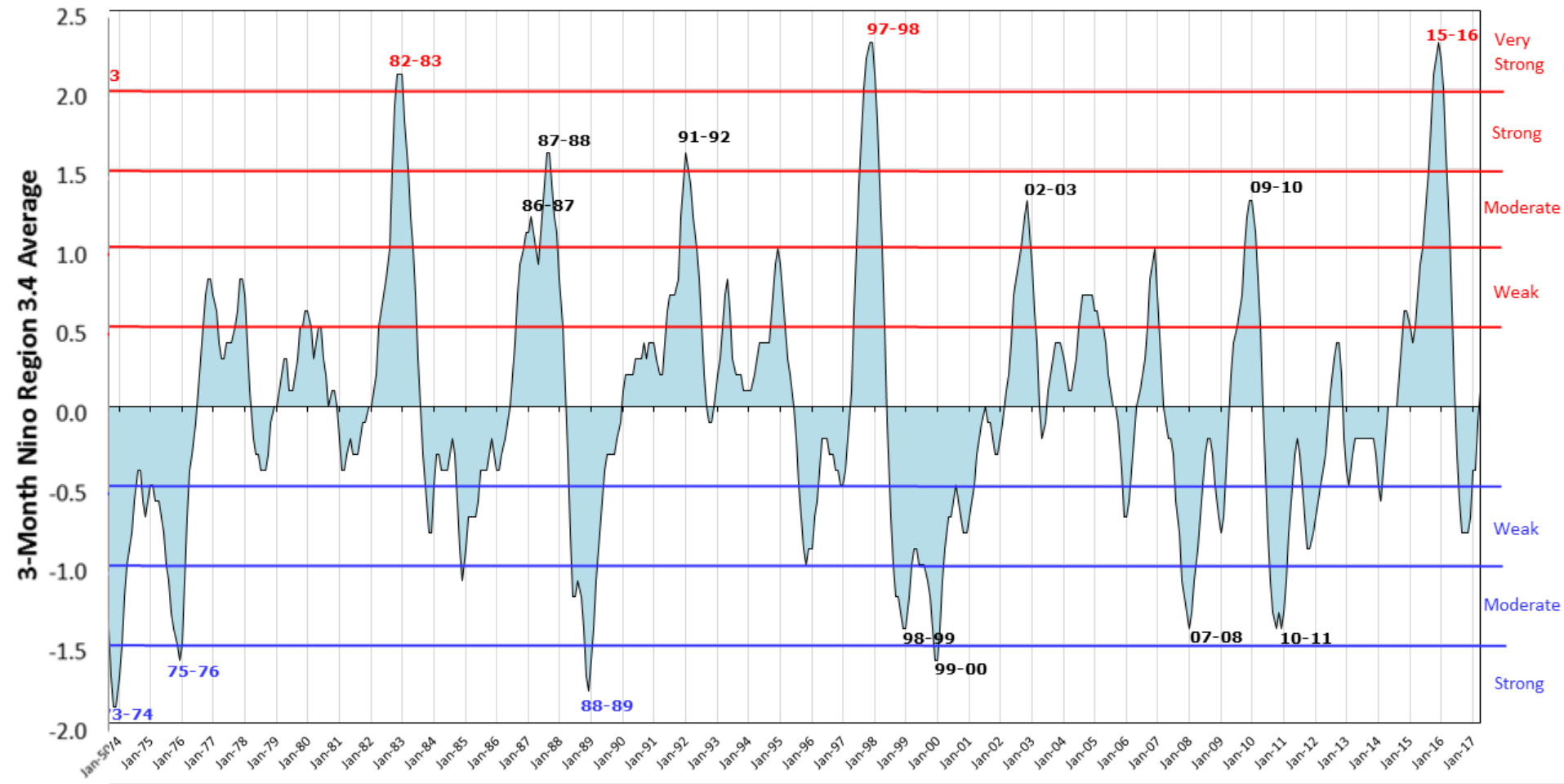
The **Oceanic Niño Index**: (ONI) is one of the primary **indices** used to monitor the El Niño-Southern Oscillation (ENSO). The ONI is calculated by averaging sea surface temperature anomalies in an area of the east-central equatorial Pacific **Ocean**, which is called the **Niño 3.4 region** (5S to 5N; 170W to 120W).

Golden Gate Weather Services, Jan Null, used with permission

Red = Strong El Niño
Blue = Strong La Niña
Black = Moderate (either)

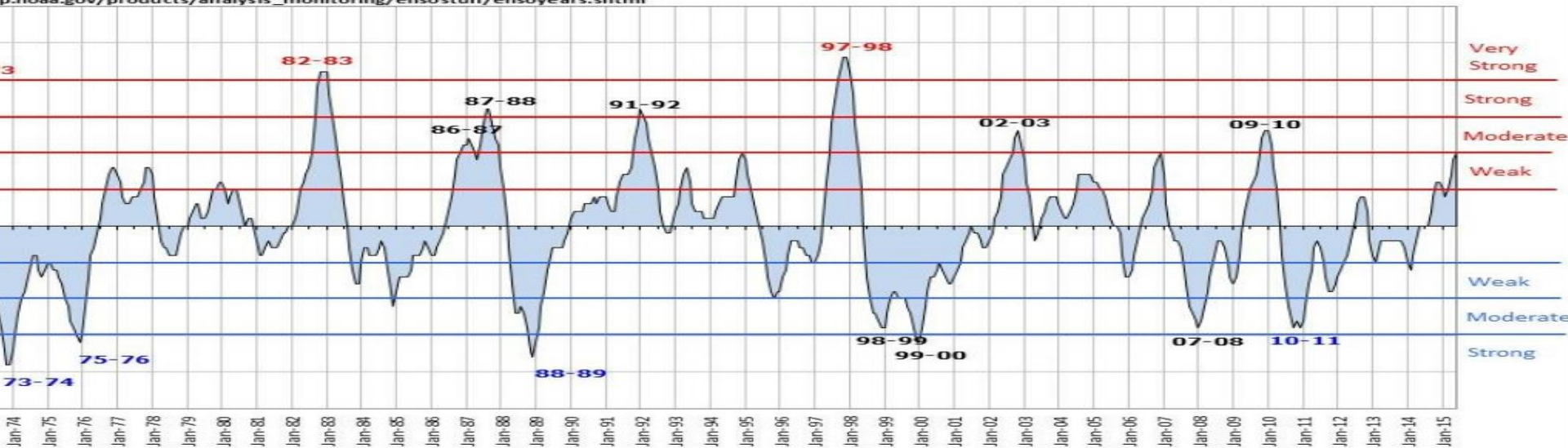
Oceanic Niño Index (ONI)

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_stuff/ensoyears.shtml



hnic Niño Index (ONI)

p.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

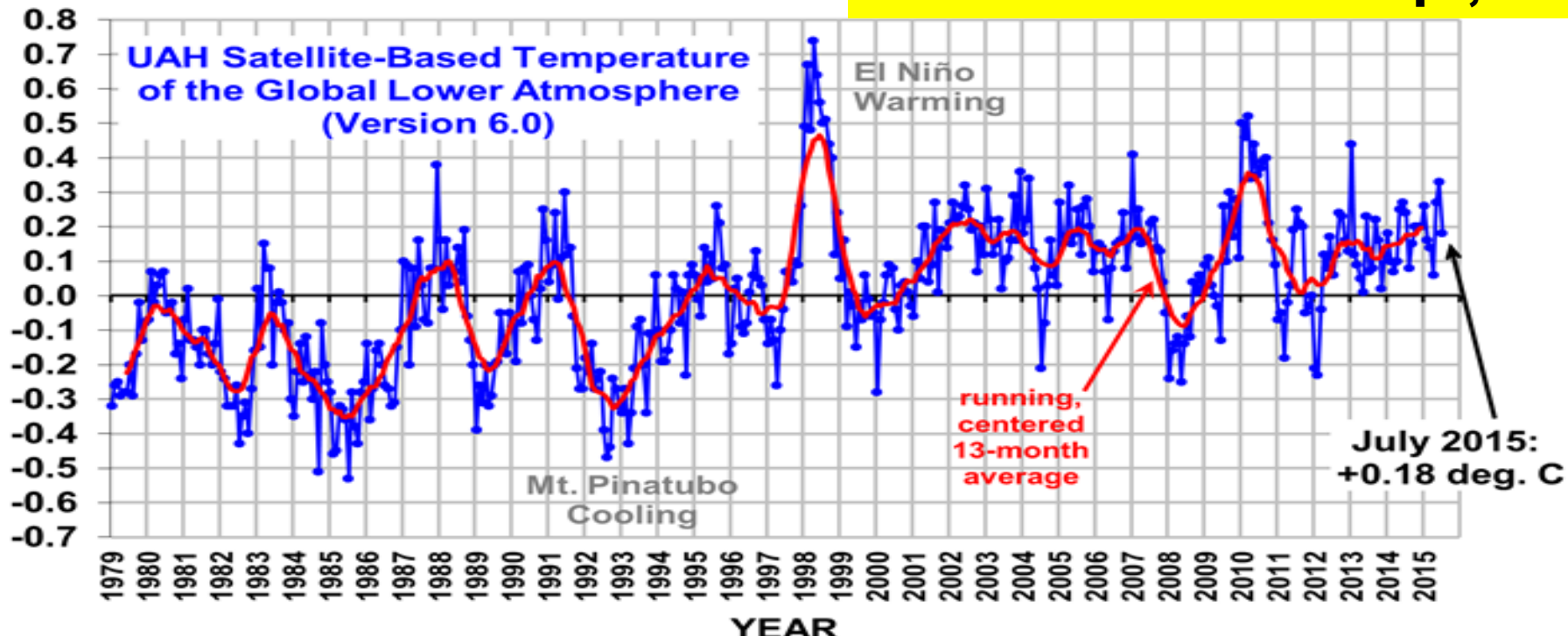


nnning 3-Month Mean ONI values

Nino 3.4 Temperatures, Ocean SST

Global Greenhouse Temps, TLT

T Departure from '81-'10 Avg. (deg. C.)



Nino 3.4 Temperatures, Ocean SST

Global Greenhouse Temps, TLT

UAH Satellite-Based Temperature of the Global Lower Atmosphere (Version 6.0)

Global Greenhouse Temps, TLT

Running, centered 13-month average

August, 2019: +0.38 deg. C

T Departure from '81-'10 Avg. (deg. C)

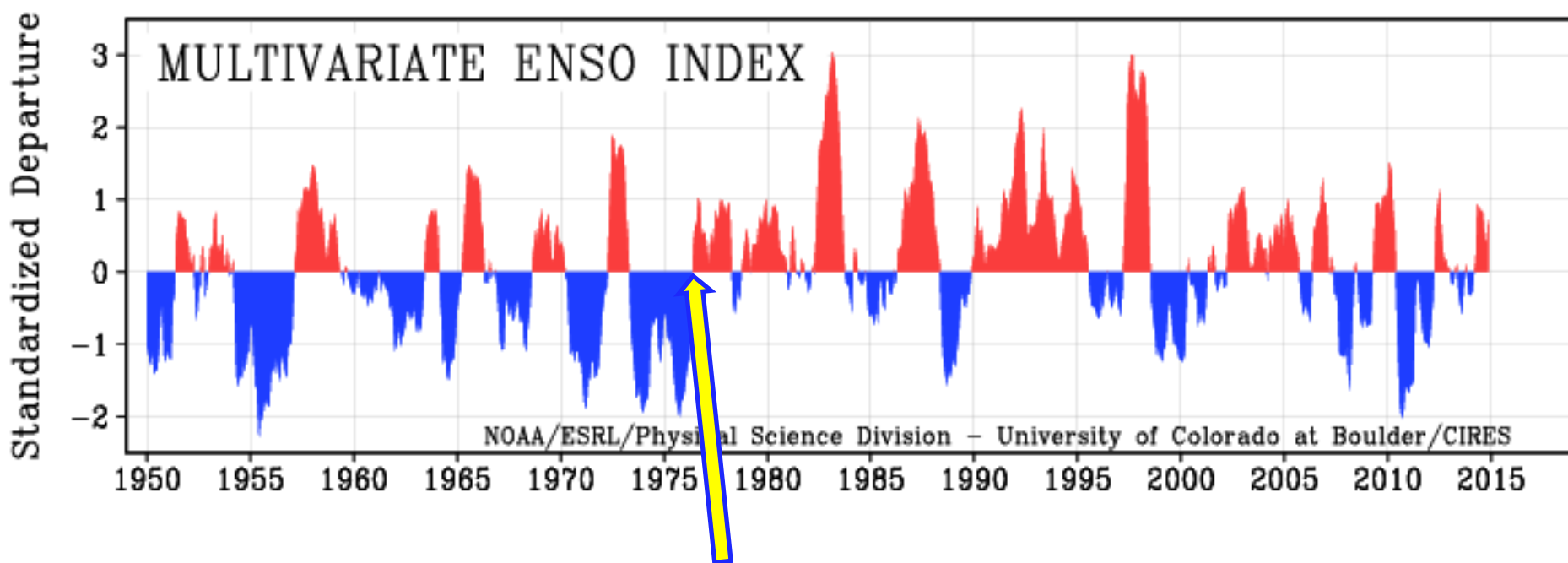
Dates: Feb 1979 - Aug 2019



Earth System Research Laboratory

Physical Sciences Division

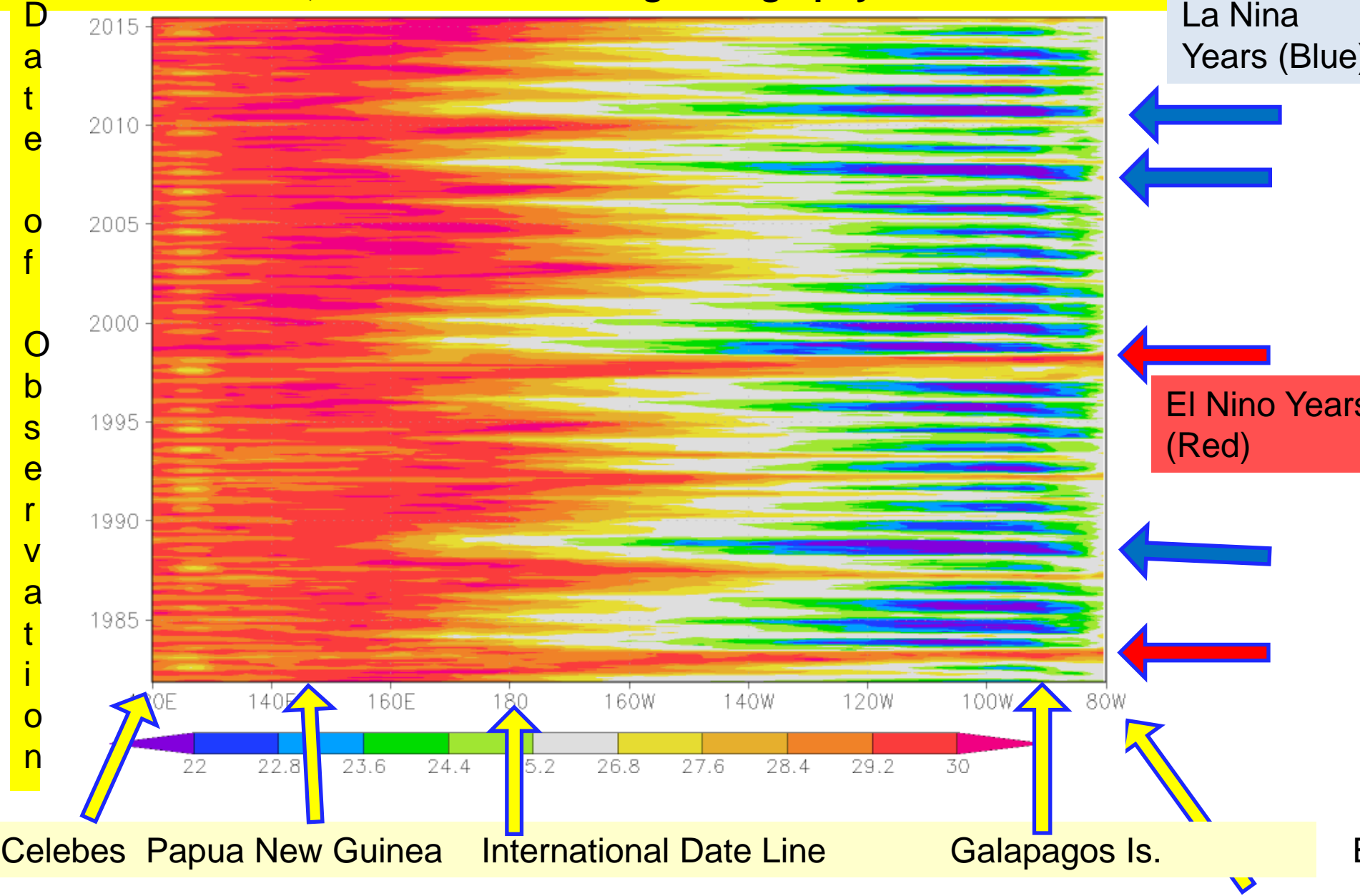
<http://www.esrl.noaa.gov/psd/enso/mei/>



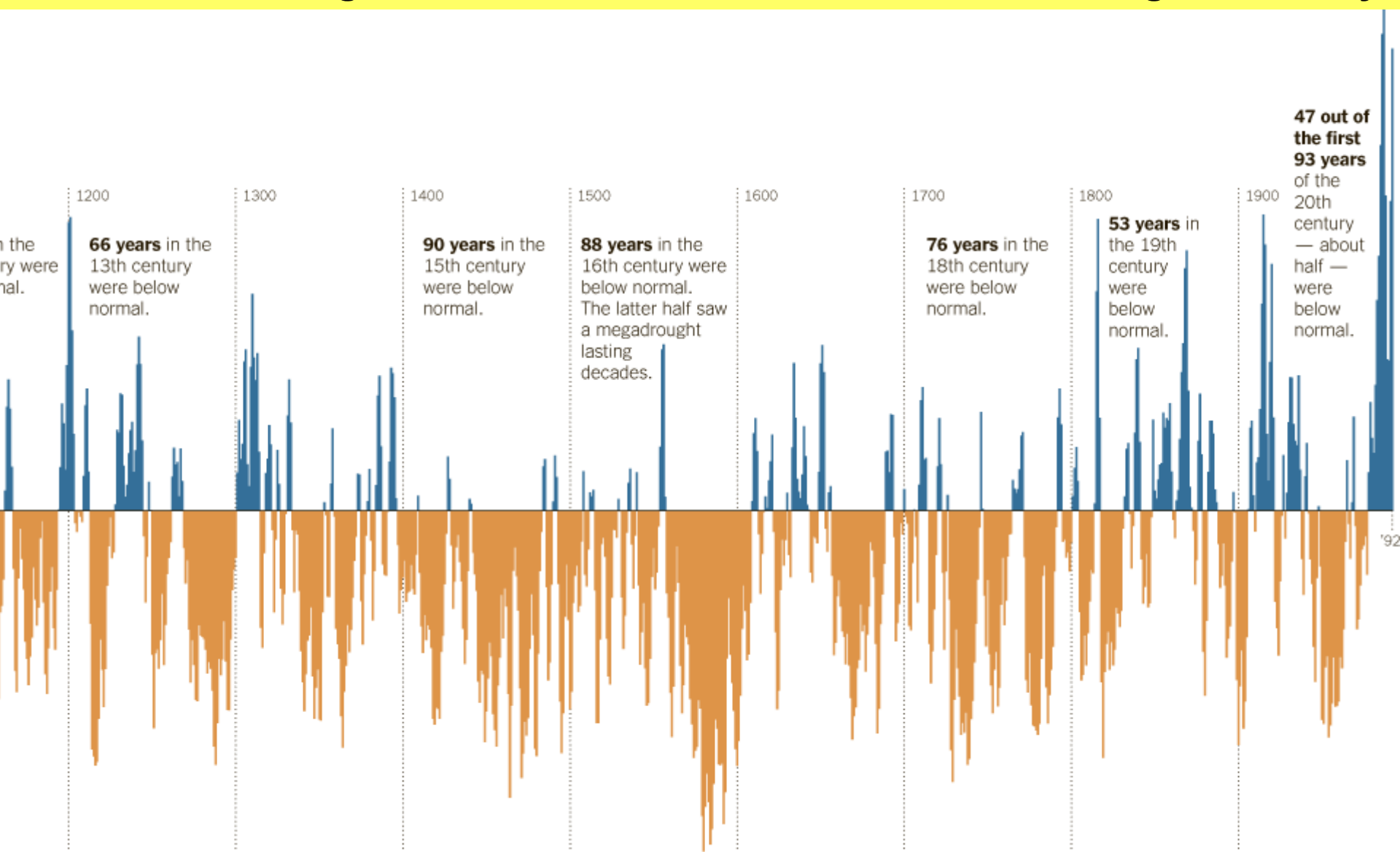
Notice the Great Climatic Shift of 1976, when the number of El Ninos per decade increased dramatically.

Bob Tisdale's Hovemuller diagram. Equator Sea Surface Temperature (Longitude)

SSTs , not anomalies. Rough Geography –Yellow arrows



Rainfall and Drought Chart: New York Times...U of A Tree Ring Laboratory



X-Axis Time: 1200s on LEFT -- present on RIGHT

Y-Axis: Rainfall (Blue, above Axis) Drought (Brown, Below Axis)

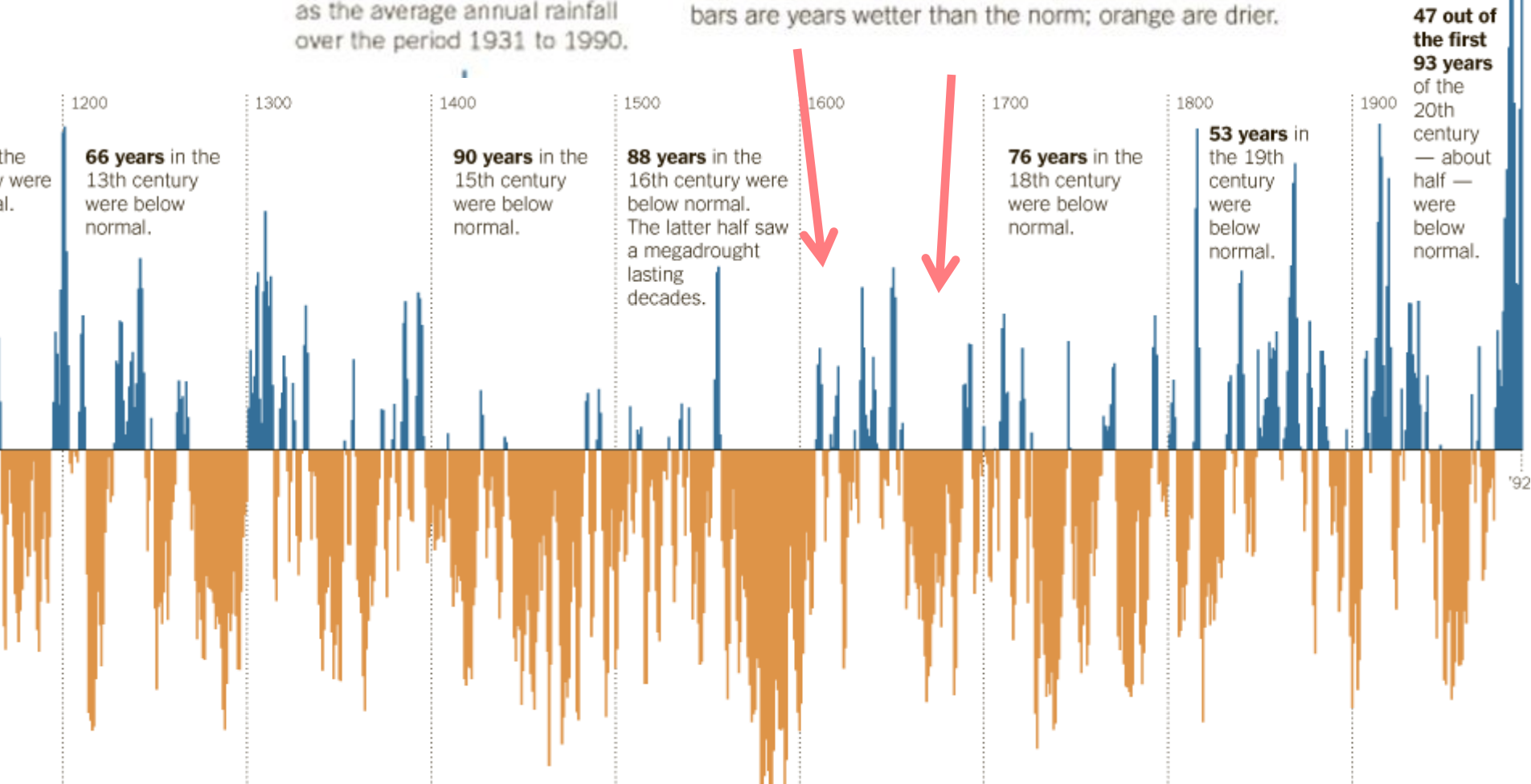
Axis = 20th Century Avg 1900-1993

The New York Times

The Longest Measure of Drought: 21 Centuries of Rainfall in New Mexico

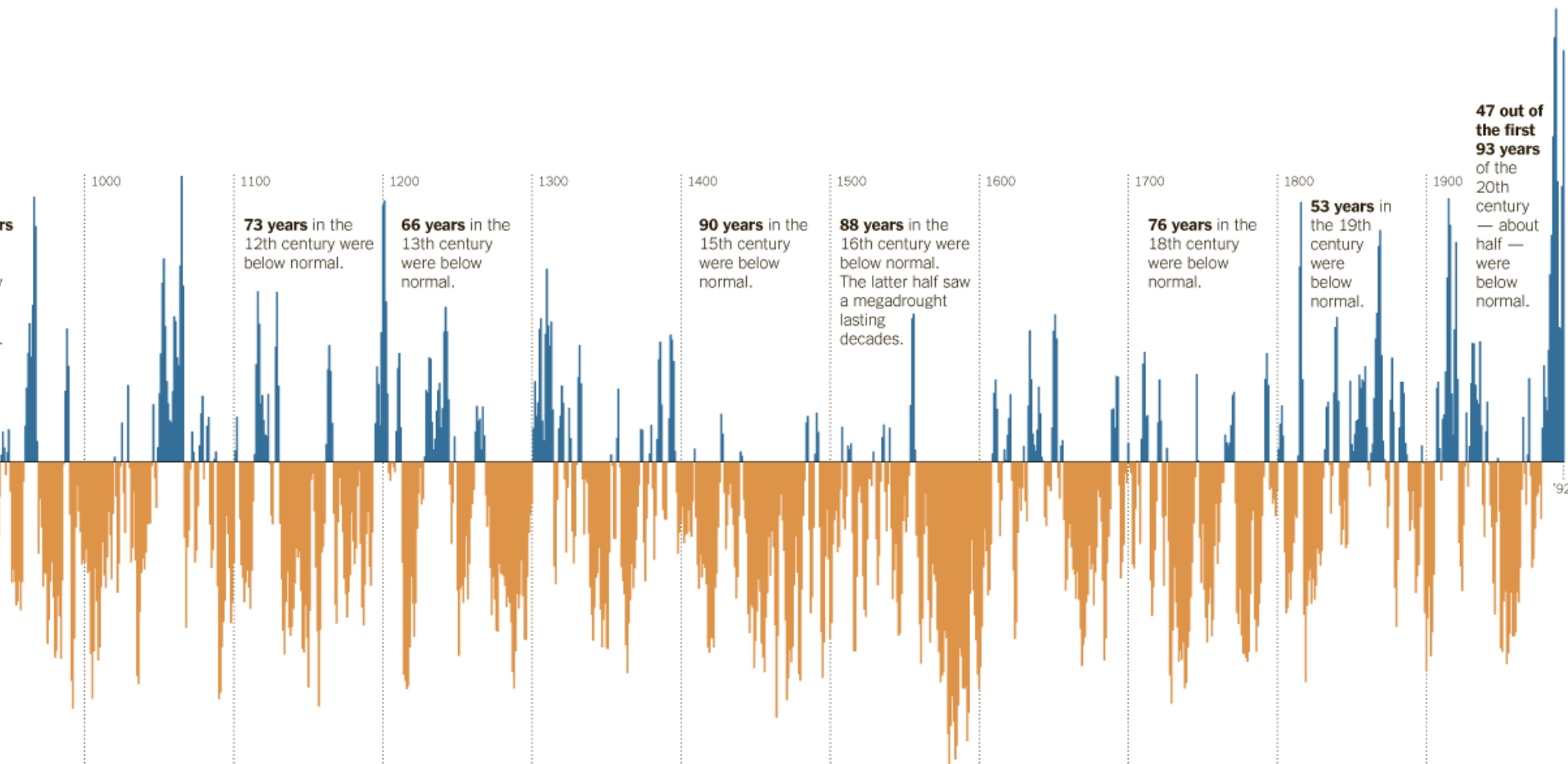
Departure from normal, defined as the average annual rainfall over the period 1931 to 1990.

This chart shows deviation in annual rainfall levels from a 20th-century benchmark (the period from 1931 to 1990), beginning in 137 B.C. and running through 1992. Blue bars are years wetter than the norm; orange are drier.



Late 20th Century wettest in 2000 years. Abo' Mission, Mountainair: founded 1620 re-roofed, 1640, abandoned because of drought ~1675.

El Nino/ENSO helps explain dramatic changes from Wet to Dry in New Mexico



Repeat of this IMPORTANT POINT!

WATER TEMPERATURE OF OCEAN OFFSHORE NORTH AMERICA
DETERMINES RAINFALL/DROUGHT in (especially) Western North America

What determines that water temperature?

The Multi-year weather pattern called EL NINO

El Nino Southern Oscillation “ENSO”

Later, we'll study a 60-year pattern

PACIFIC DECADEAL OSCILLATION or “PDO”

30 years MORE EL NINOS, and
30 years FEWER EL NINOS.

Now to discuss the variability of rainfall here based on weather records.

**It's not necessary to resort to human-caused CO2-fueled climate change,
only to understand the climate we have here naturally.**

The variability of the monsoon rainfall in Tucson is from driest, 1.59" to wettest, 13.84," or 12.25 inches.

In El Paso, the variability of the monsoon rainfall is from driest 0.23" to wettest, 15.28," or 15.05 inches.

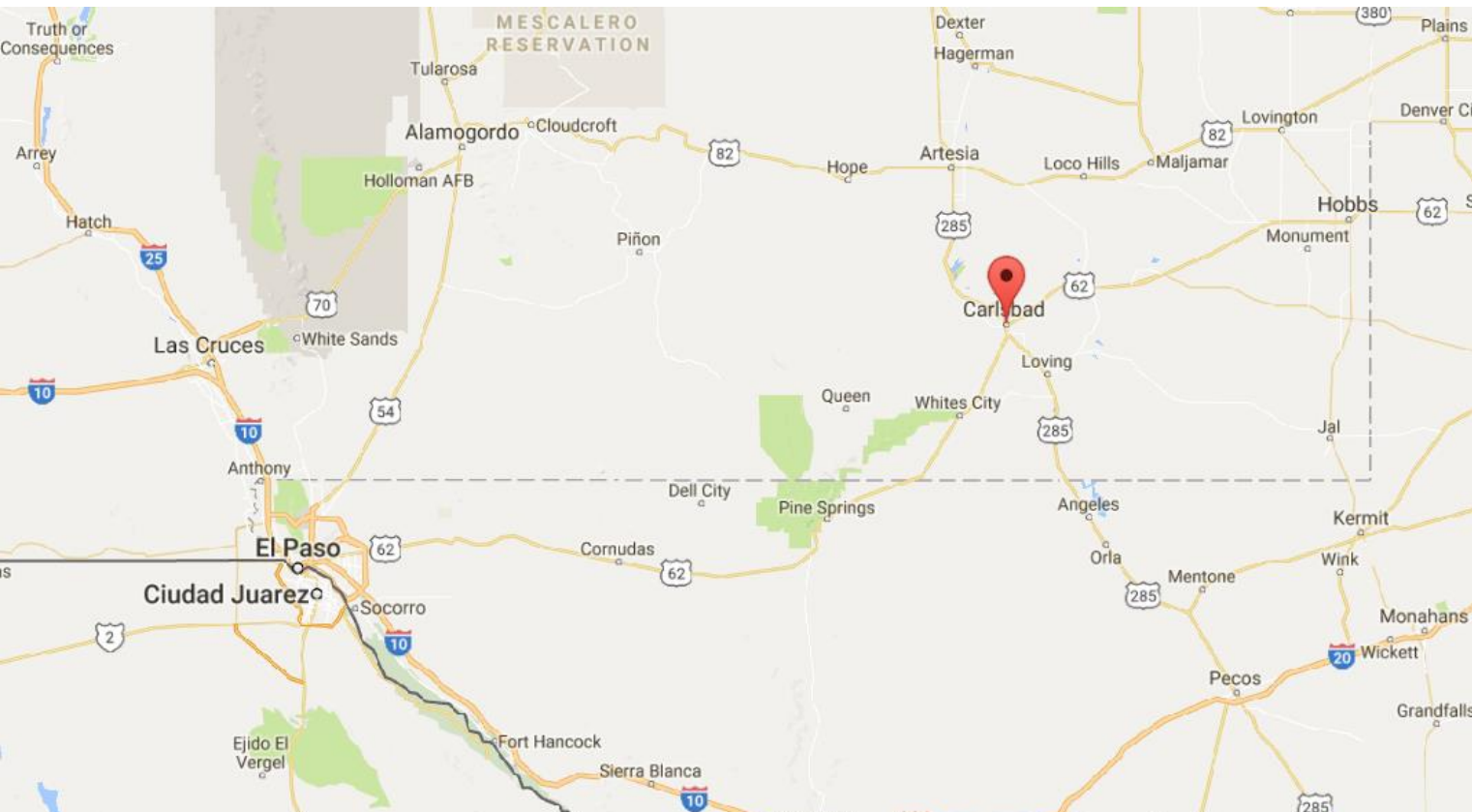
Extremes in precipitation, Carlsbad, New Mexico

1924: with 2.93 inches of Rain

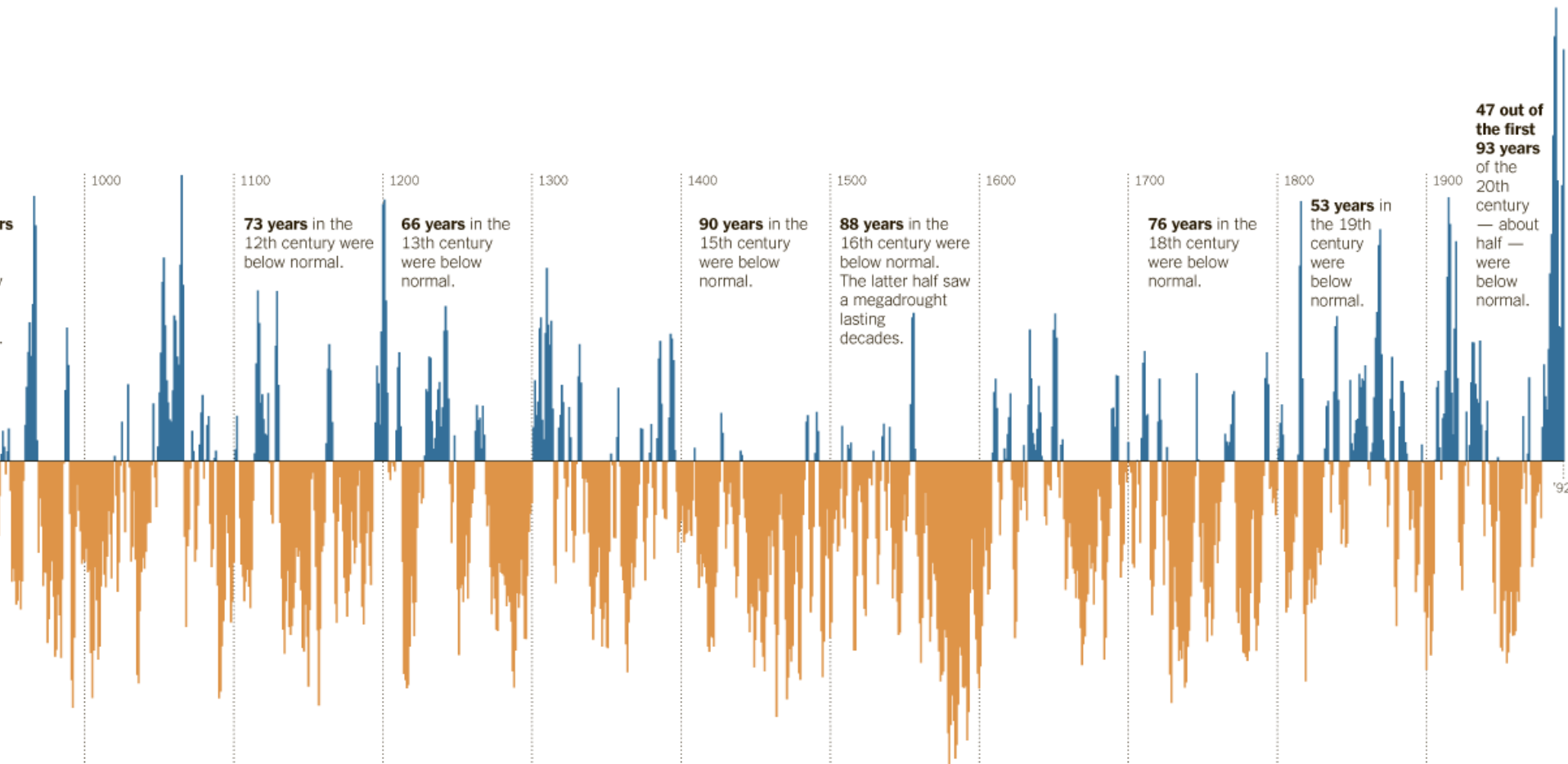
1941: with 33.94 inches of Rain

**Think of it: 30 inches difference between wettest and driest years
a factor of Ten Times—difference between the two.
And, 1941 stands out as the wettest year, by far.**

What about 1941 caused so much rain?



El Nino/ENSO helps explain dramatic changes from Wet to Dry in New Mexico

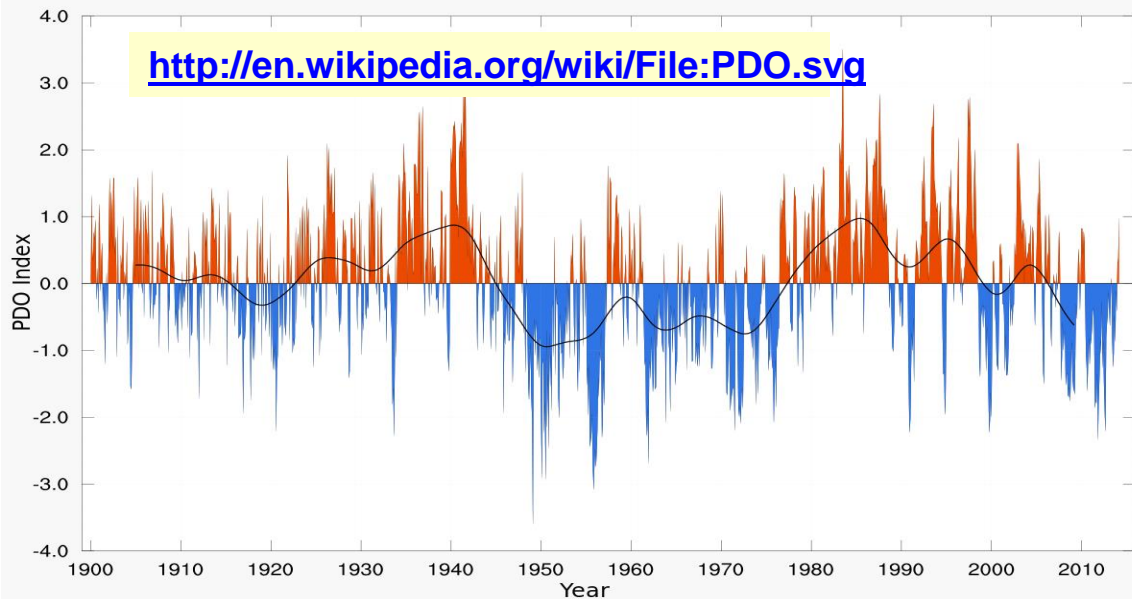


Pacific Decadal Oscillation

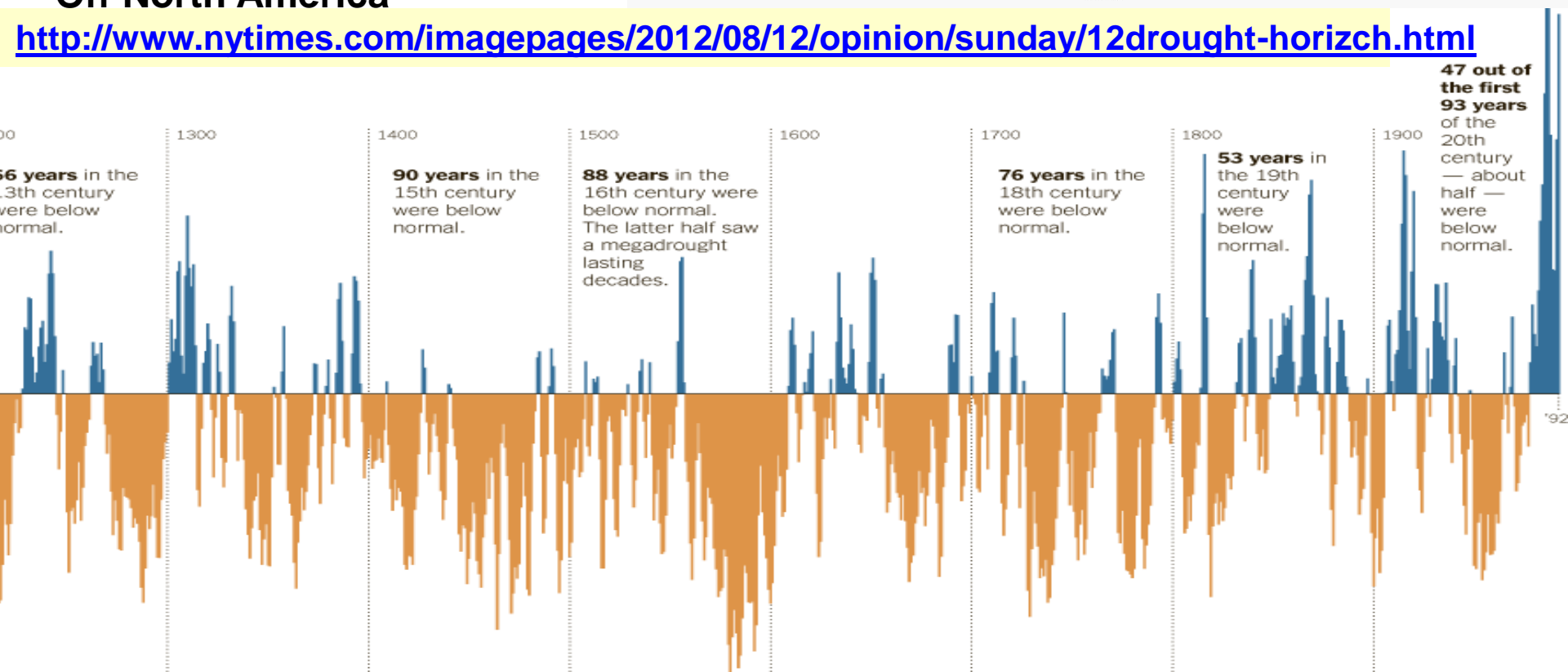
Natural change in offshore

Water Temperature Pattern

Off North America

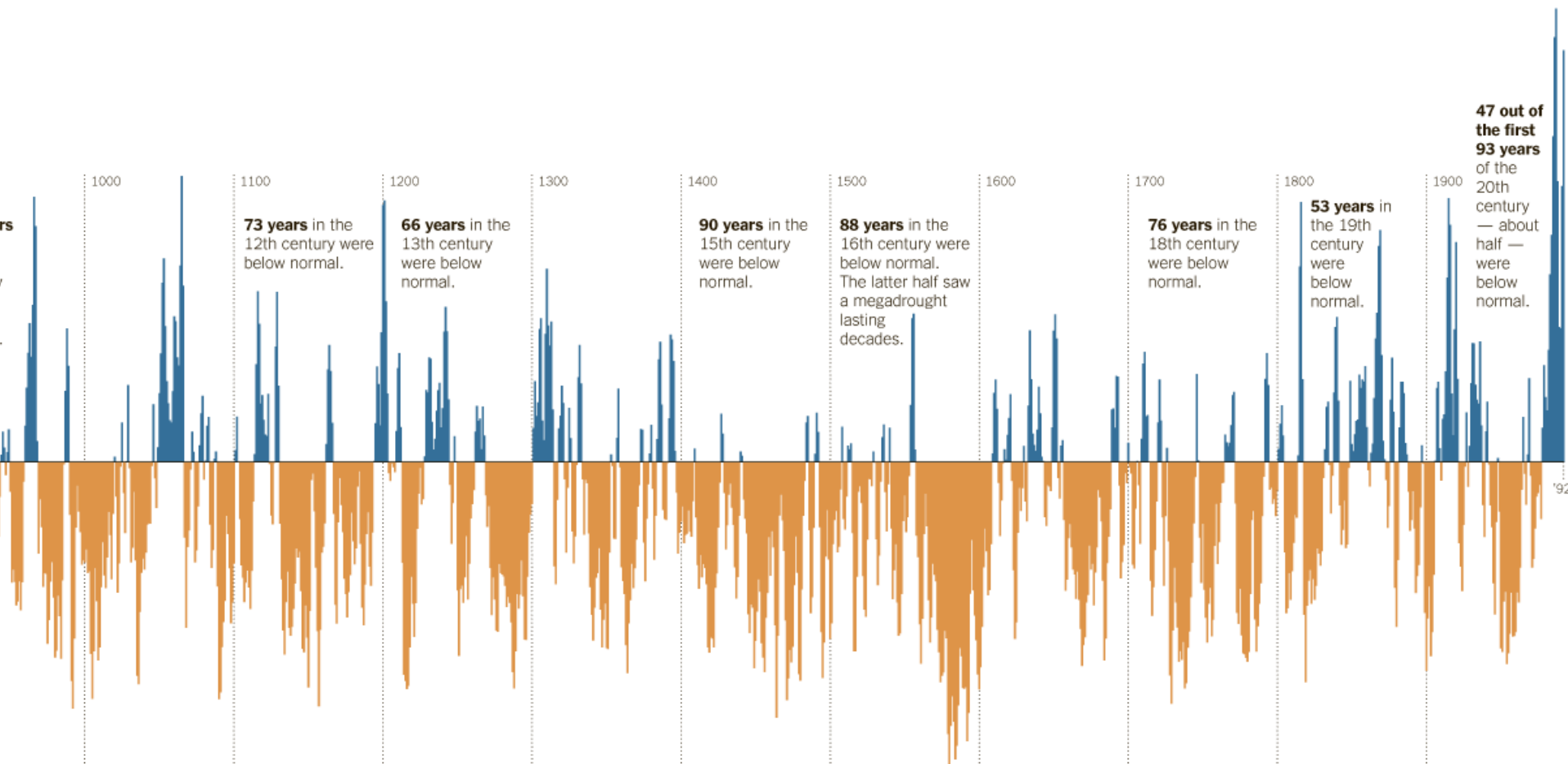


<http://www.nytimes.com/imagepages/2012/08/12/opinion/sunday/12drought-horizch.html>



El Nino/ENSO helps explain dramatic changes from Wet to Dry in New Mexico

60-year Pacific Decadal Oscillation helps explain Rainfall and Drought in NM



A highly-recommended
E-book.

This book is the source
for the excellent
graphics I used later
in this section.

WHO TURNED ON THE HEAT?

THE UNSUSPECTED GLOBAL
WARMING CULPRIT,
EL NIÑO-SOUTHERN OSCILLATION

BY BOB TISDALE

**El Nino, basics on how
it develops and works...**

**The entire phenomenon
is called**

**ENSO: El Nino Southern
Oscillation**

1.2 The ENSO Annotated Illustrations

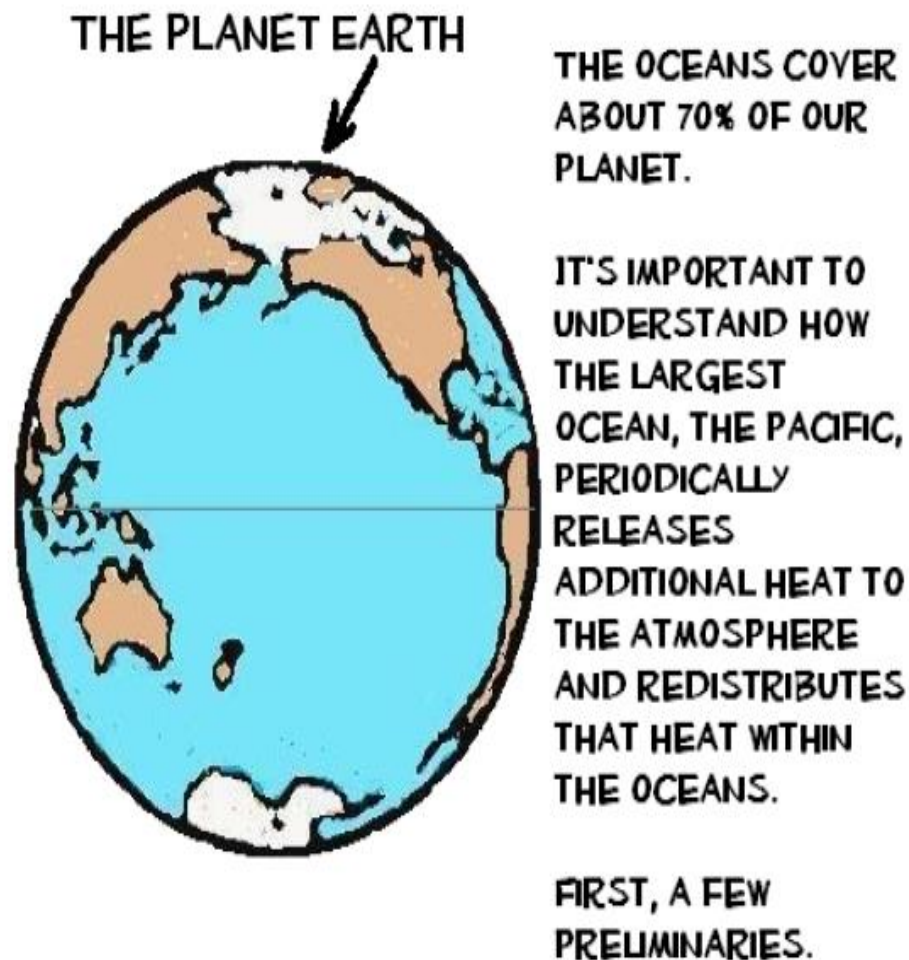
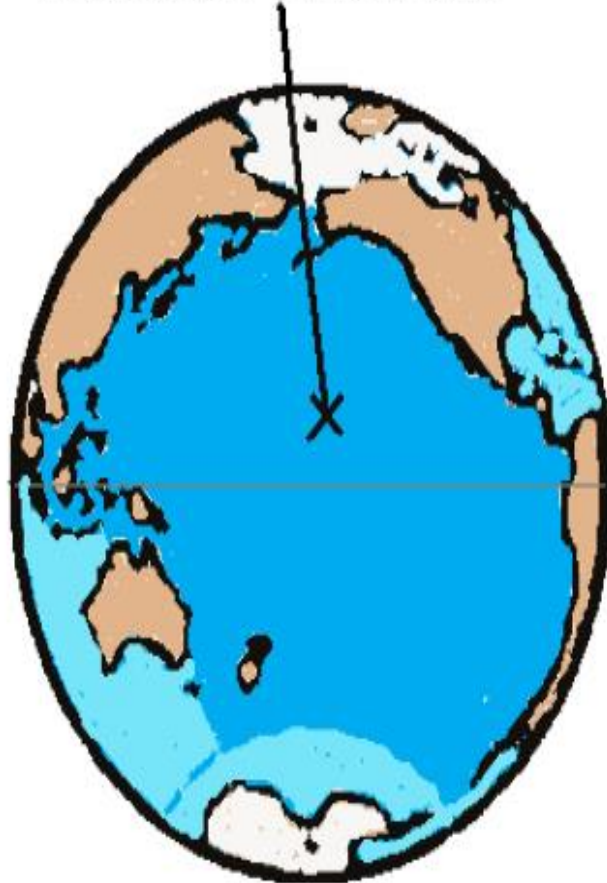


Figure 1-1

Bob Tisdale

HHH

THE PACIFIC OCEAN



THE PACIFIC OCEAN
STRETCHES ALMOST
HALFWAY AROUND THE
GLOBE AT THE EQUATOR.

IT COVERS THE SURFACE OF
THE PLANET FROM ASIA TO
NORTH AMERICA AND FROM
AUSTRALIA TO SOUTH
AMERICA.

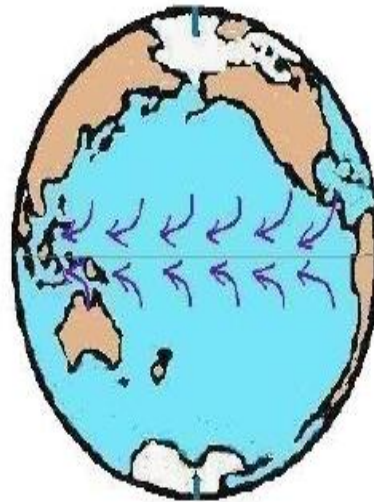
IT REACHES FROM THE
BERING STRAIT NEAR THE
ARCTIC OCEAN TO THE
IMAGINARY BORDER WITH
THE SOUTHERN OCEAN THAT
SURROUNDS ANTARCTICA.

Figure 1-2

Bob Tisdale

HHH

TRADE WINDS



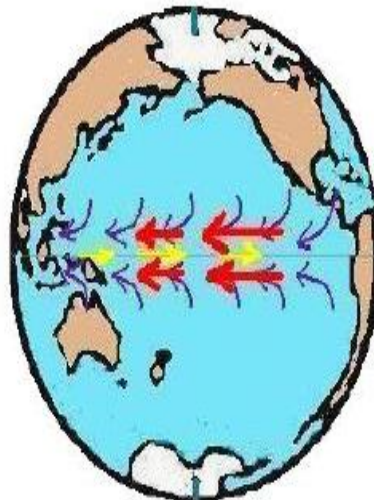
THE TRADE WINDS BLOW ACROSS THE SURFACE OF THE TROPICAL PACIFIC, FROM THE NORTHEAST TO THE SOUTHWEST IN THE NORTHERN HEMISPHERE AND FROM THE SOUTHEAST TO THE NORTHWEST IN THE SOUTHERN HEMISPHERE.

Figure 1.3

Bob Tisdale

HHH

OCEAN CURRENTS

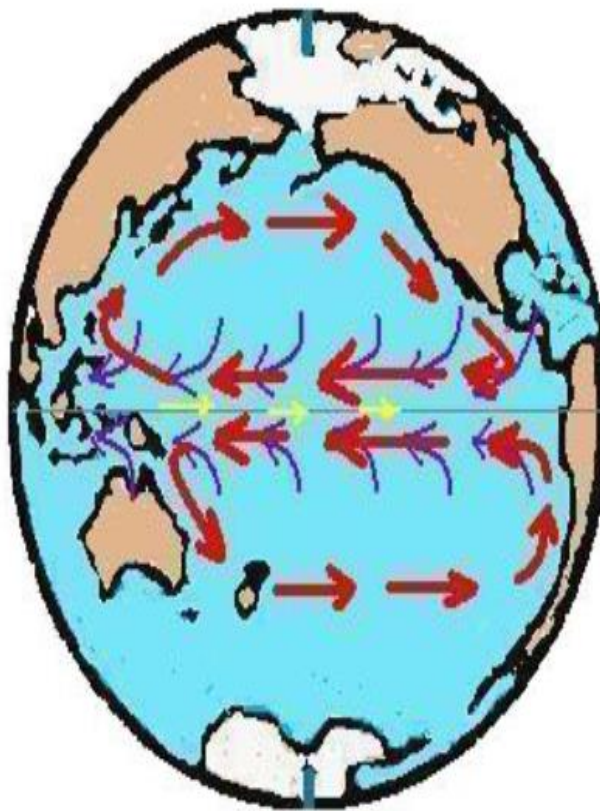


THE OCEAN CURRENTS IN THE TROPICAL PACIFIC ARE DRIVEN BY THE TRADE WINDS.

THE CURRENTS NEAR THE EQUATOR ARE CALLED THE NORTH AND SOUTH EQUATORIAL CURRENTS. THEY CARRY WATER FROM EAST TO WEST.

THERE'S ALSO A (NORMALLY) SMALLER CURRENT THAT RUNS BETWEEN THEM CALLED THE EQUATORIAL COUNTER CURRENT.

OCEAN CURRENTS

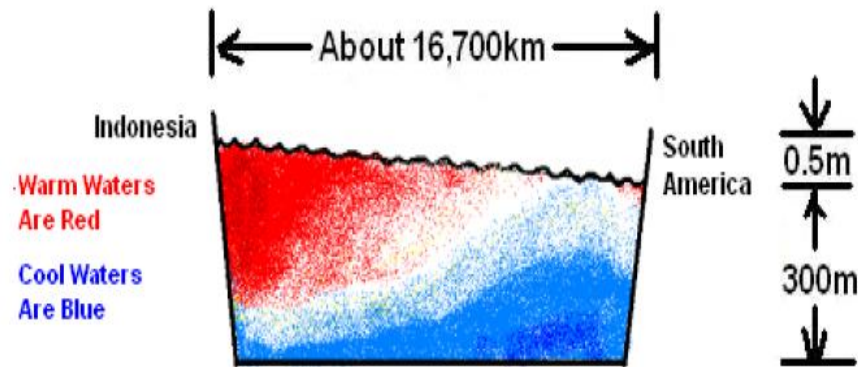


THE TRADE WIND-DRIVEN
WATERS COLLIDE WITH
LAND SO THEY ARE
FORCED TO HEAD TOWARD
THE POLES.

THEY THEN CIRCLE
AROUND AND FORM WHAT
ARE CALLED THE NORTH
AND SOUTH PACIFIC
GYRES.

Figure 1-5

INTRODUCTION TO THE CROSS SECTION OF THE
EQUATORIAL PACIFIC OCEAN
USED IN MANY OF THE GRAPHICS THAT FOLLOW



THE DIMENSIONS OF THE CROSS SECTION ARE SKEWED. BUT KNOWING THE SEA LEVEL IS ABOUT 0.5 METERS HIGHER IN THE WEST THAN IN THE EAST UNDER "NORMAL" CONDITIONS IS IMPORTANT.

THE VARIATIONS IN TEMPERATURES BELOW THE SURFACE ARE ALSO IMPORTANT, BUT THEY TAKE PLACE IN THE TOP 300 METERS.

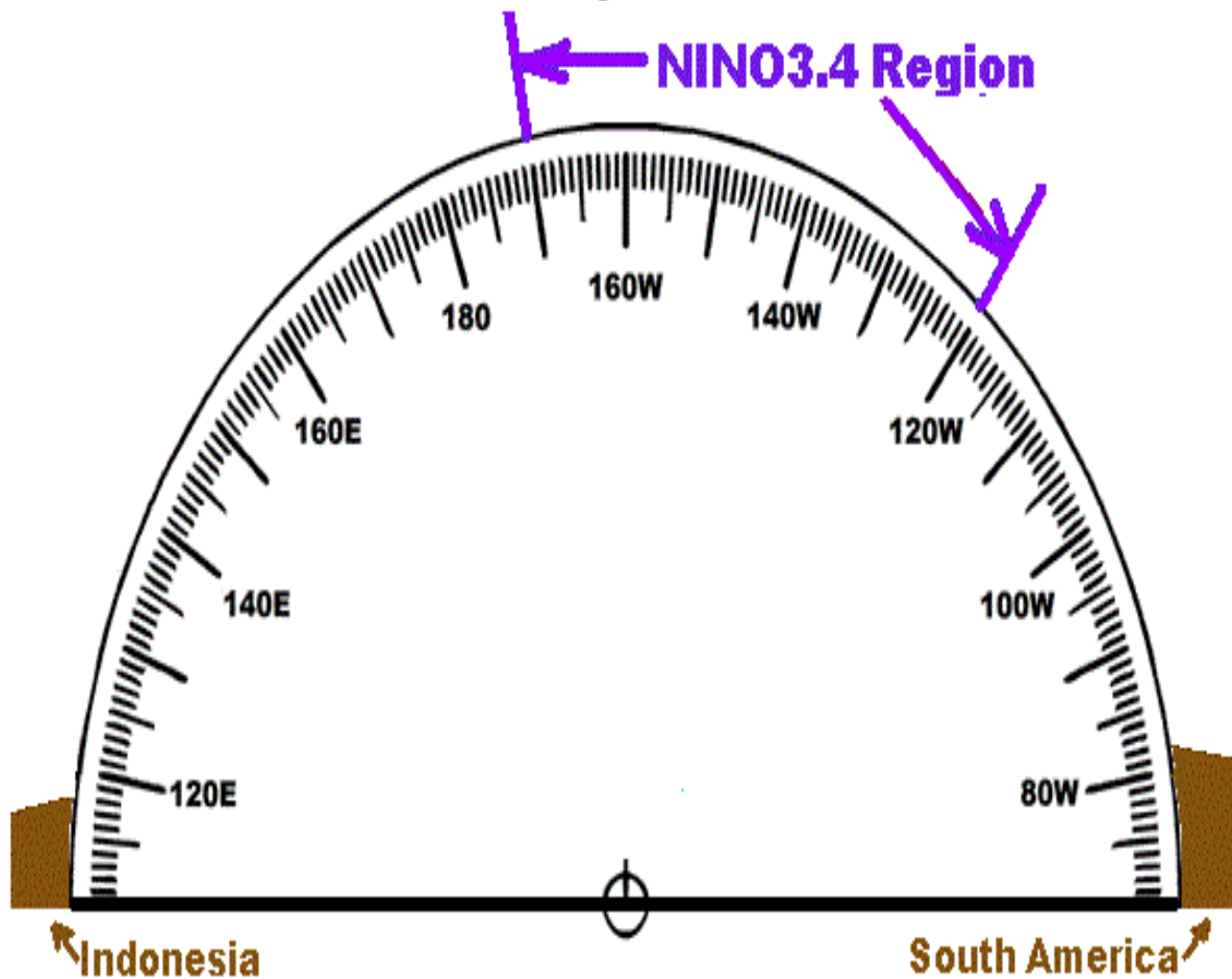
AND THE OVERALL WIDTH OF THE TROPICAL PACIFIC MUST BE KEPT IN MIND.--ALMOST HALFWAY AROUND THE GLOBE.

Figure 1-6

Bob Tisdale

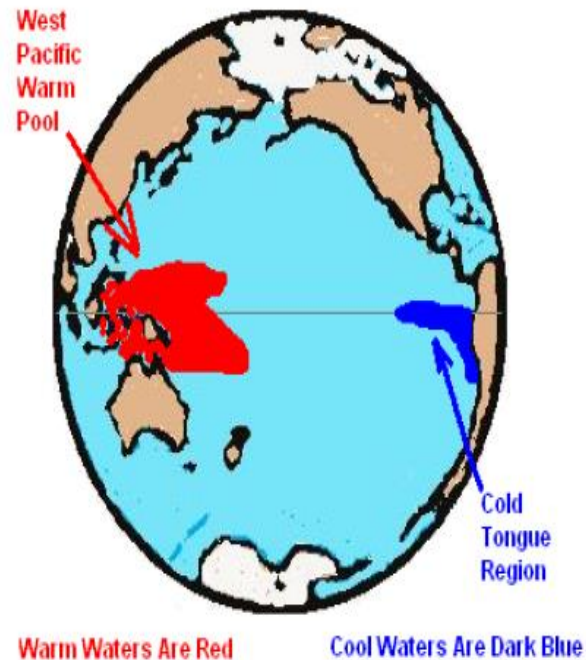
EQUATORIAL PACIFIC

A Different Perspective of Its Surface



NORMAL OR "ENSO-NEUTRAL" CONDITIONS (A)

(NOT AN EL NIÑO AND NOT A LA NIÑA)



THE TRADE WINDS PUSH THE SUN-WARMED WATER TO THE WEST AND IT ACCUMULATES IN AN AREA CALLED THE WEST PACIFIC WARM POOL, REACHING DEPTHS OF ALMOST 300 METERS.

THE TRADE WINDS ALSO DRAW COOL WATERS FROM BELOW THE SURFACE OF THE EASTERN EQUATORIAL PACIFIC IN A PROCESS KNOWN AS UPWELLING.

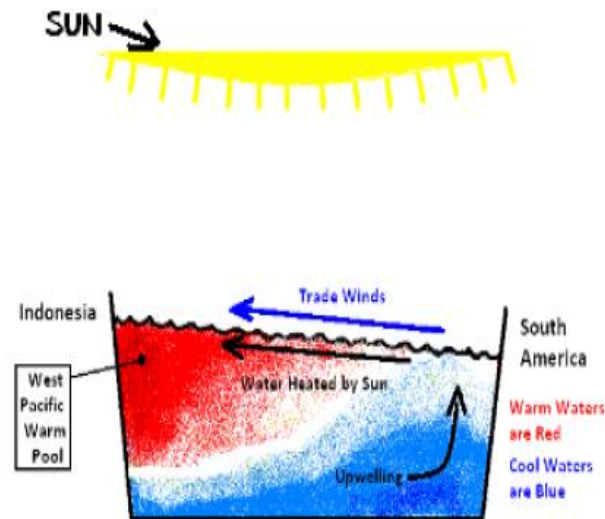
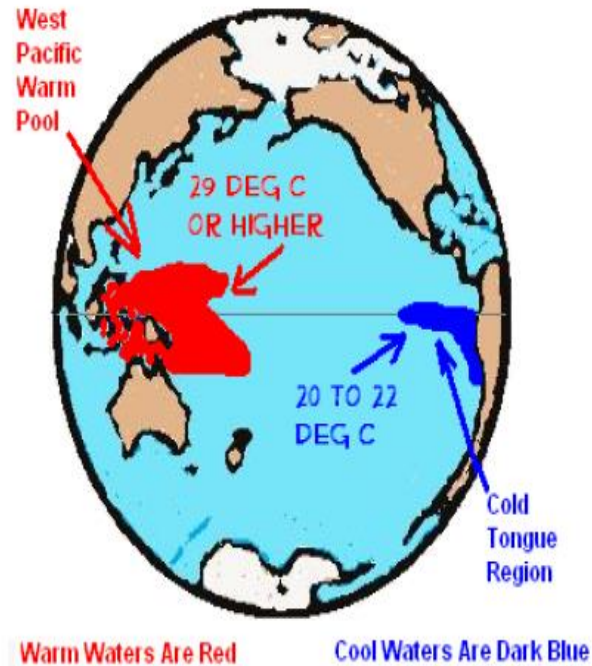


Figure 1-7

NORMAL OR 'ENSO-NEUTRAL' CONDITIONS (B)

(NOT AN EL NIÑO AND NOT A LA NIÑA)



AS A RESULT, THE SEA SURFACE TEMPERATURE IN THE WEST PACIFIC WARM POOL CAN BE 8 TO 10 DEG C WARMER THAN IN THE COLD TONGUE REGION IN THE EAST.

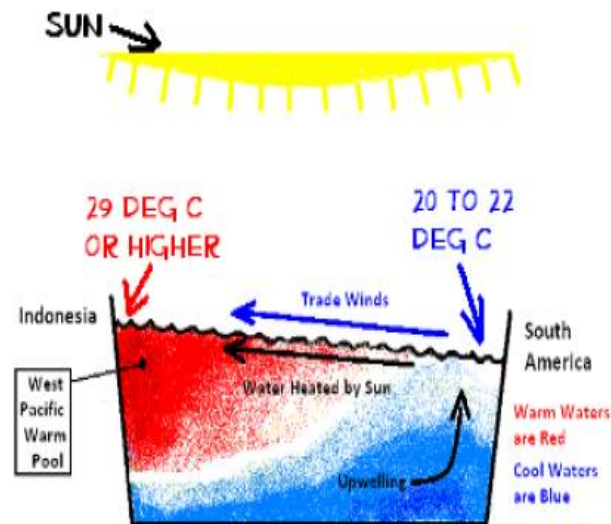
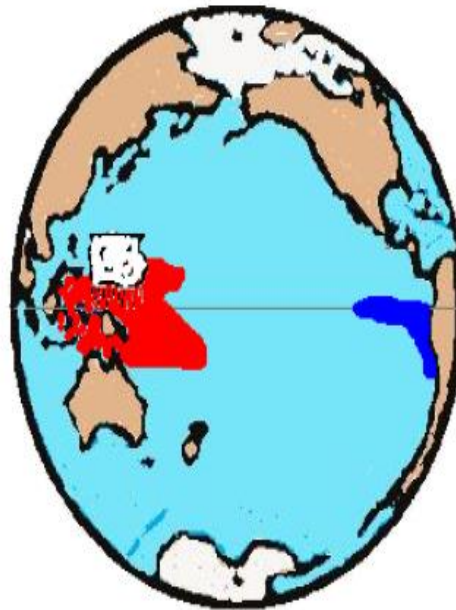


Figure 1-8

NORMAL OR "ENSO-NEUTRAL" CONDITIONS (C)

(NOT AN EL NIÑO AND NOT A LA NIÑA)



Warm Waters Are Red

Cool Waters Are Dark Blue

THE OCEANS RELEASE
HEAT PRIMARILY
THROUGH
EVAPORATION.

AS THE WARM, MOIST
AIR OVER THE PACIFIC
WARM POOL RISES, IT
COOLS.

AS IT CONTINUES TO
RISE AND COOL, THE
AIR CAN HOLD LESS
OF THE MOISTURE,
AND IT COMES OUT AS
RAIN.

IN DOING SO, IT
RELEASES THE HEAT
FROM THE SUN THAT
WAS USED TO
EVAPORATE IT.

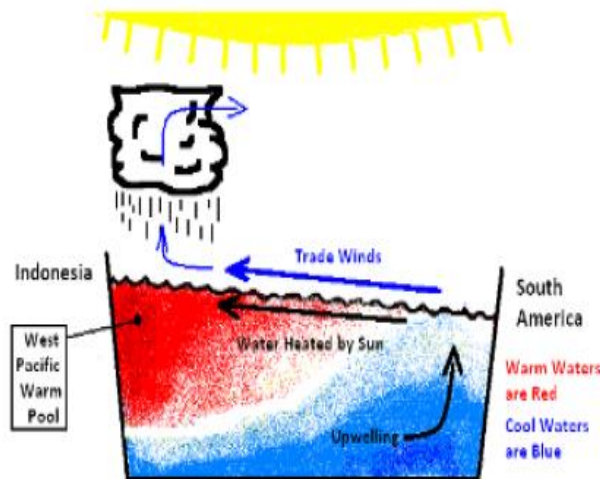
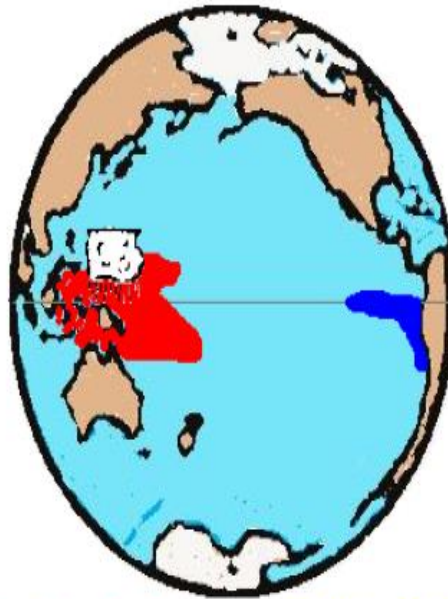


Figure 1-9

NORMAL OR "ENSO-NEUTRAL" CONDITIONS (D)

(NOT AN EL NIÑO AND NOT A LA NIÑA)



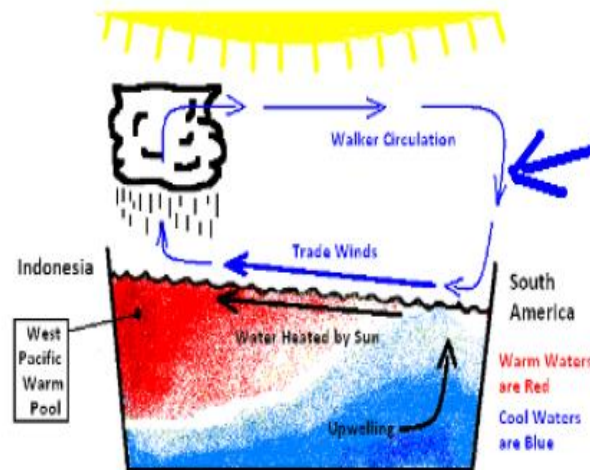
Warm Waters Are Red

Cool Waters Are Dark Blue

THE TRADE WINDS
REPLACE THE RISING
AIR IN THE WEST.

THE AIR SINKS IN THE
EAST.

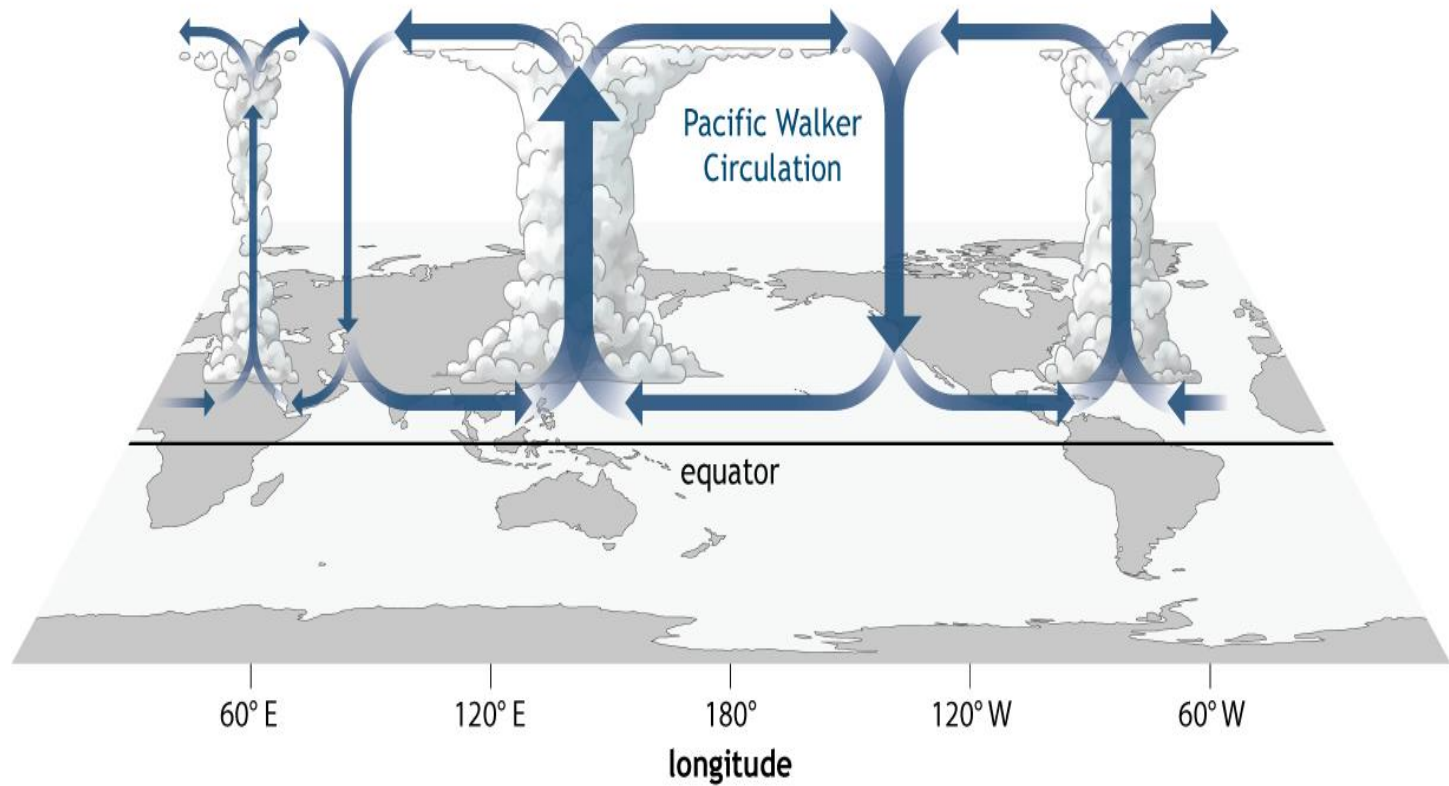
AND THE
EASTWARD UPPER
WINDS AND WESTWARD
TRADE WINDS
CONNECT THEM.



THIS IS KNOWN AS
WALKER CIRCULATION
OR A WALKER CELL,
JUST IN CASE YOU
WERE WONDERING.

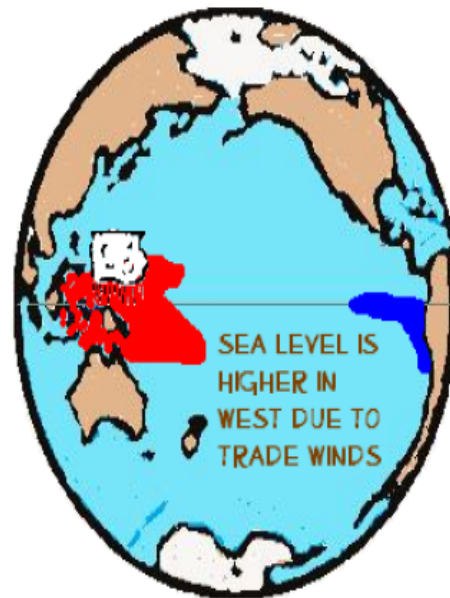
Figure 1-10

Neutral conditions



NORMAL OR "ENSO-NEUTRAL" CONDITIONS (E)

(NOT AN EL NIÑO AND NOT A LA NIÑA)

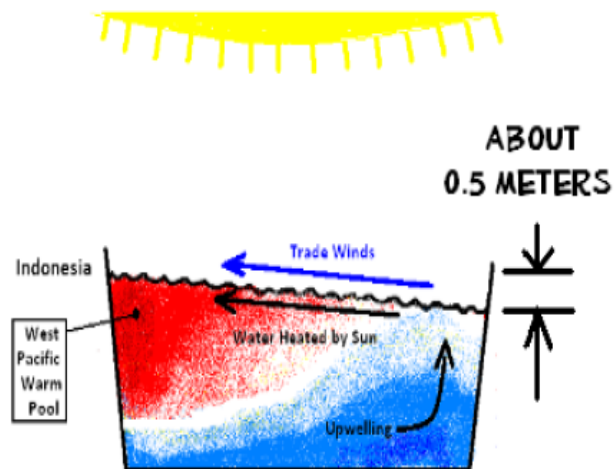


Warm Waters Are Red

Cool Waters Are Dark Blue

BECAUSE THE
TRADE WINDS ARE
PUSHING THE WATER
TO THE WEST, IT
PILES UP THERE.

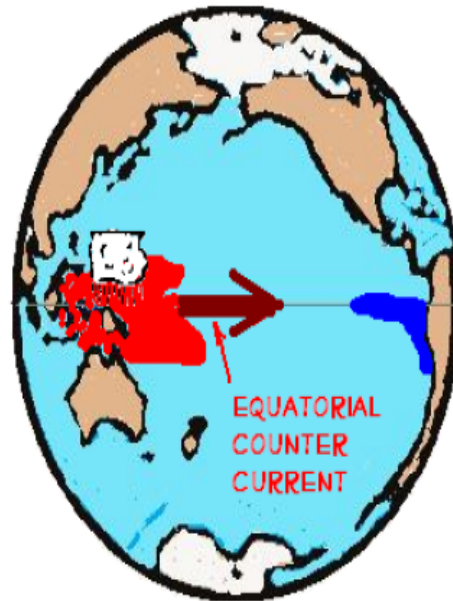
IT IS ABOUT 1/2
METER HIGHER IN
THE WEST PACIFIC
WARM POOL THAN IT
IS IN THE COLD
TONGUE REGION IN
THE EAST.



GRAVITY WOULD LIKE
IT TO BE LEVEL,
BUT THE TRADE
WINDS ARE HOLDING
THE WARM WATER IN
PLACE IN THE WEST.

Figure 1-11

WHAT DO YOU SUPPOSE HAPPENS WHEN THE TRADE WINDS DECIDE TO RELAX?



Warm Waters Are Red

Cool Waters Are Dark Blue

WHEN THE TRADE WINDS WEAKEN, GRAVITY TAKES OVER AND TRIES TO LEVEL THE SEA SURFACE HEIGHT OF THE EQUATORIAL PACIFIC.

THE EQUATORIAL COUNTER CURRENT GETS MUCH LARGER AND WARM WATER FROM THE PACIFIC WARM POOL SLOSHES TO THE EAST.



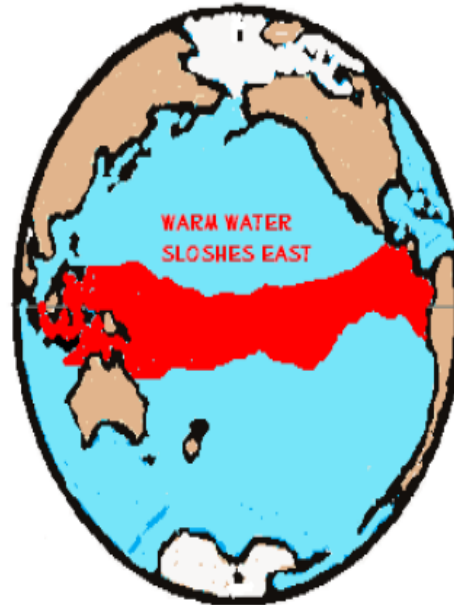
GRAVITY TAKES OVER WHEN THE TRADE WINDS WEAKEN AND TRIES TO LEVEL THE HEIGHT OF THE OCEAN



AND THAT'S
HOW AN EL NIÑO
STARTS!!!!

Figure 1-12

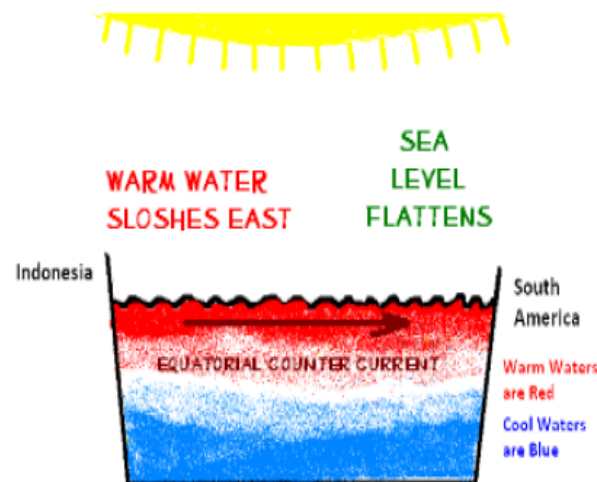
EL NIÑO CONDITIONS (A)



Warm Waters Are Red

Cool Waters Are Dark Blue

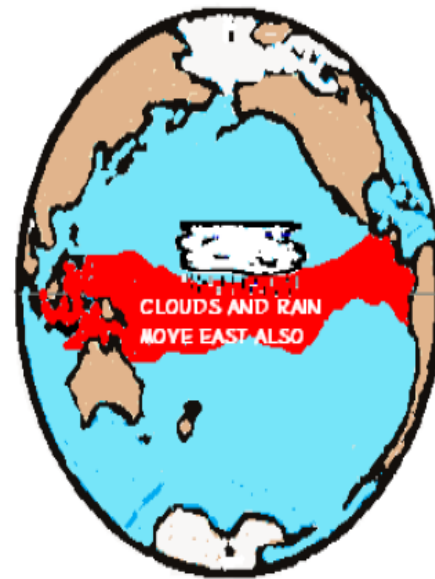
DURING AN EL NIÑO, WARM WATER FROM THE SURFACE AND BELOW THE SURFACE OF THE PACIFIC WARM POOL IS CARRIED EAST AND SPREAD ACROSS THE SURFACE OF THE CENTRAL AND EASTERN TROPICAL PACIFIC, SOMETIMES AS FAR AS THE AMERICAS.



THE WARMER WATER COVERS MORE OF THE SURFACE, AND THAT INCREASES THE SEA SURFACE TEMPERATURE OF THE TROPICAL PACIFIC.

Figure 1-13

EL NIÑO CONDITIONS (B)

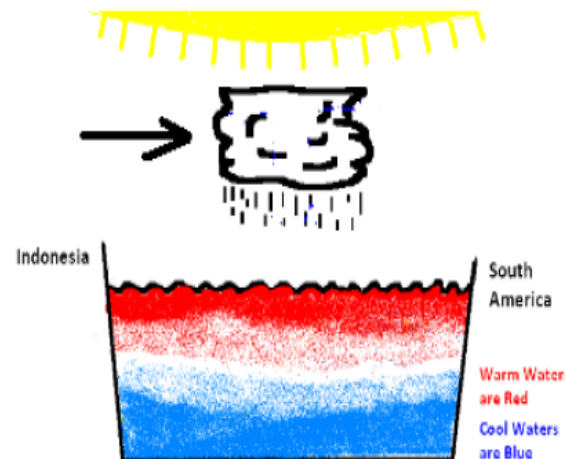


Warm Waters Are Red

Cool Waters Are Dark Blue

THE CLOUDS AND RAIN
ACCOMPANY THE WARM
WATER TO THE EAST.

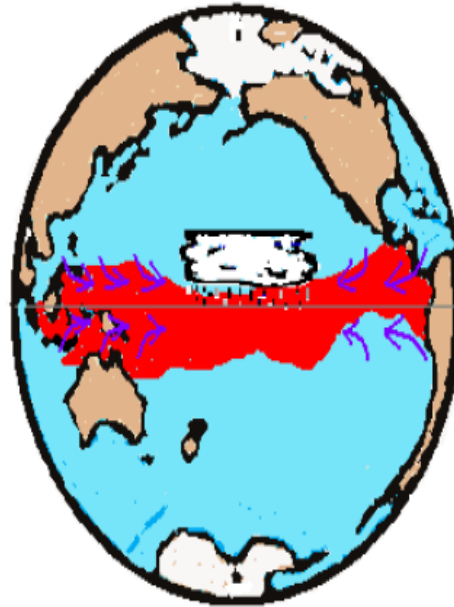
BECAUSE THE WARM
WATER COVERS A
GREATER SURFACE
AREA, THERE IS MORE
EVAPORATION, MORE
CLOUDS AND MORE
RAIN.



AS A RESULT, MORE
HEAT THAN NORMAL IS
DISCHARGED FROM
THE TROPICAL PACIFIC
OCEAN TO THE
ATMOSPHERE.

Figure 1-14

EL NIÑO CONDITIONS (c)



Warm Waters Are Red

Cool Waters Are Dark Blue

TO FEED THE RISING AIR THAT HAS NOW TRAVELED EAST, THE TRADE WINDS IN THE WESTERN TROPICAL PACIFIC REVERSE DIRECTION AND BECOME WESTERLIES.

THE TRADE WINDS IN THE EASTERN PACIFIC WEAKEN

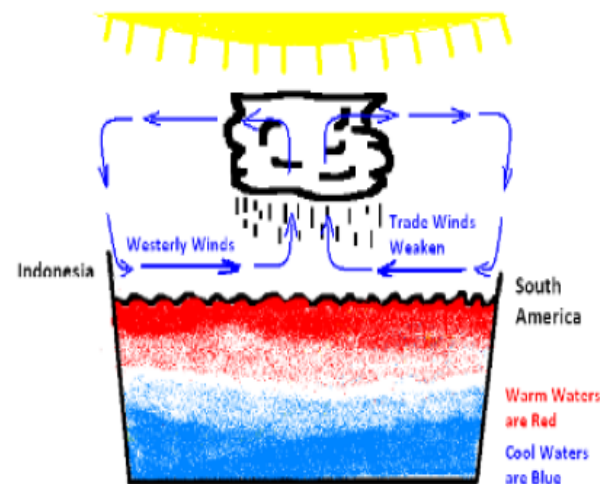


Figure 1-15

Some Lessons from Bob Tisdale's data set:

ENSO is not a true oscillations.

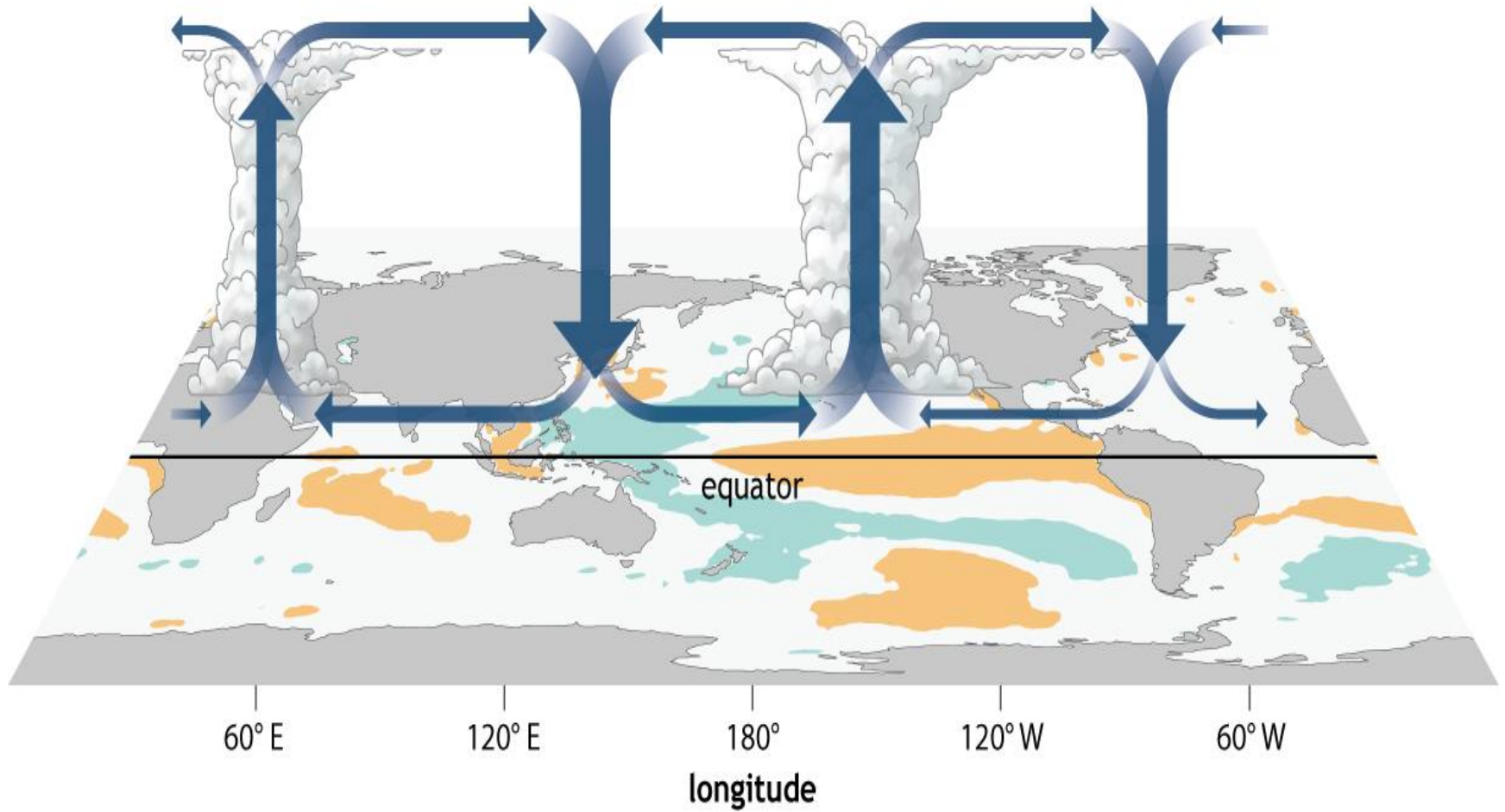
El Ninos are not regular occurrence.

Some El Ninos last a year, some two years, some, almost 3 years long.

La Nina is not the "Opposite" of El Nino

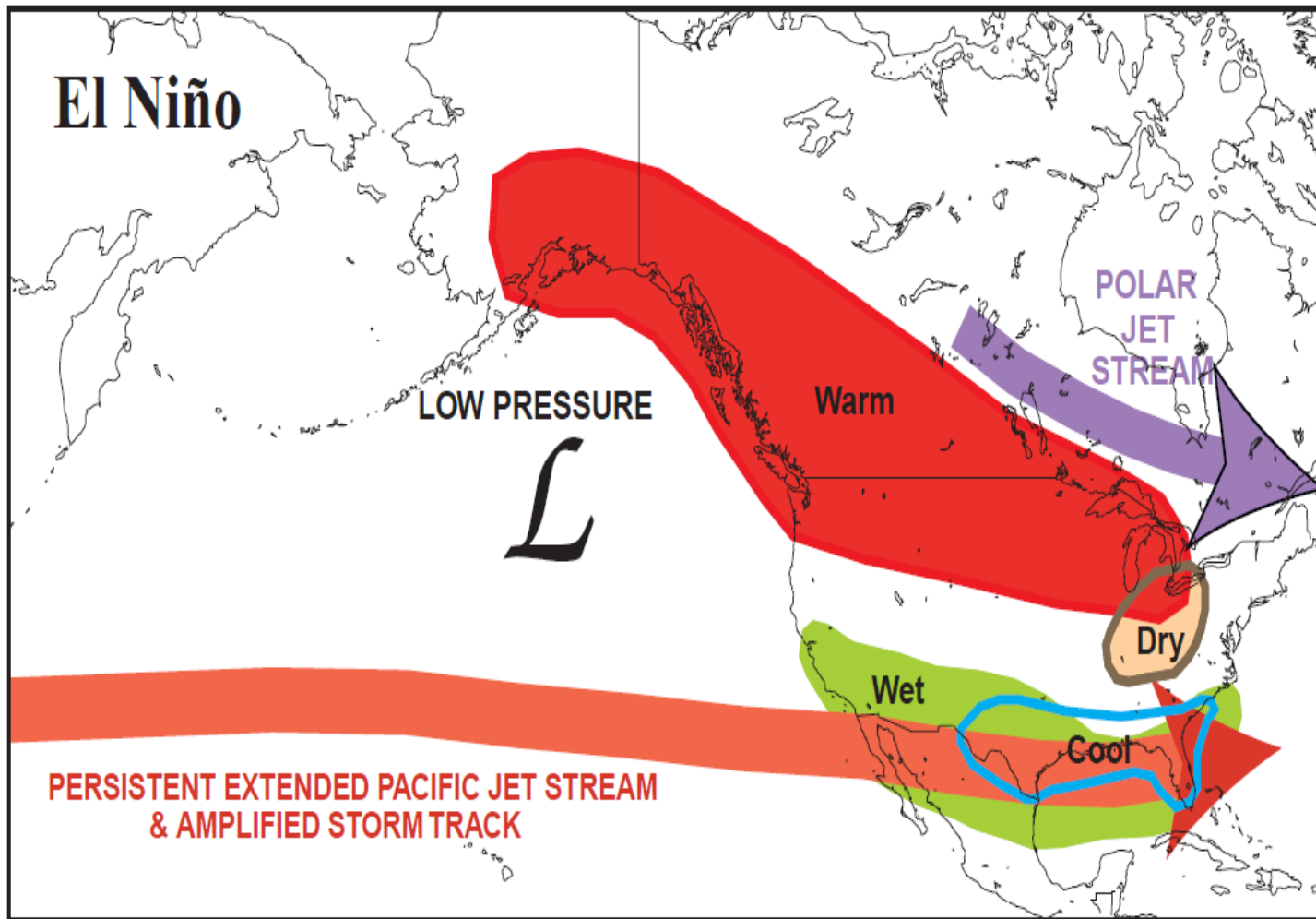
La Ninas are periods when there are strong trade winds and strong upwelling from the Americas' west coasts.

El Niño conditions



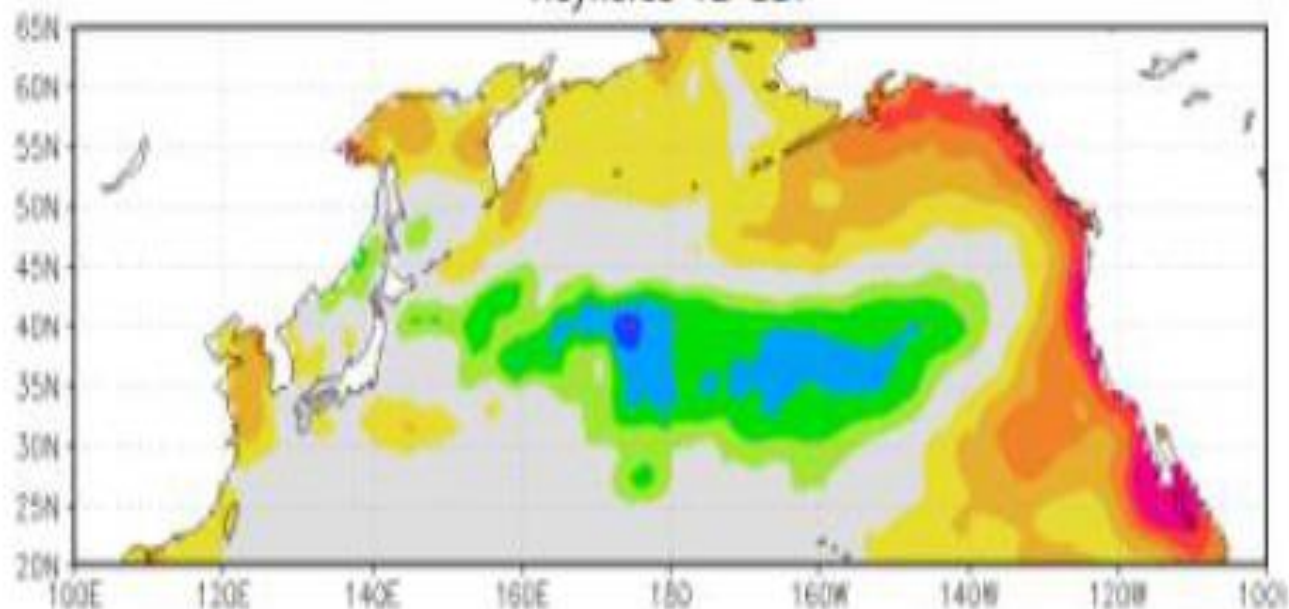
El Niño's effects on Northern Hemisphere Weather Patterns

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/naw



El Niño Sea Surface Temperature Anomaly Pattern In The North Pacific

sst-clim8209 May-Mar1998
Reynolds v2 SST



EAST PACIFIC EL NIÑO EVENTS

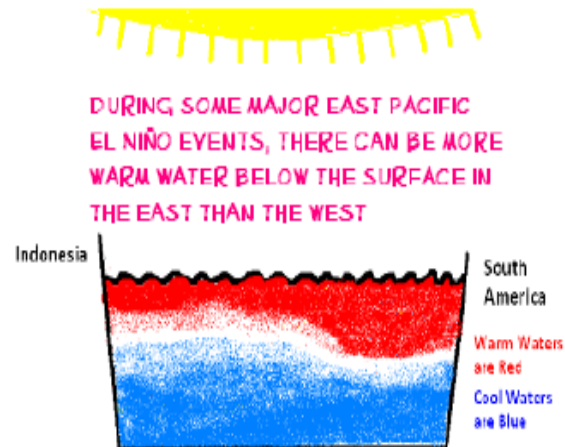


Warm Waters Are Red

Cool Waters Are Dark Blue

DURING EAST PACIFIC EL NIÑO EVENTS, THE WARM WATER REACHES THE COASTS OF THE AMERICAS.

EAST PACIFIC EL NIÑO EVENTS ARE TYPICALLY STRONGER THAN CENTRAL PACIFIC EL NIÑO—SO STRONG, THEY CAN RAISE EASTERN PACIFIC SEA SURFACE TEMPERATURES AS MUCH AS 5 DEG C (9 DEG F) IN SOME PLACES.



DURING A VERY STRONG EL NIÑO, THERE CAN BE MORE WARM WATER BELOW THE SURFACE IN THE EASTERN PACIFIC THAN IN THE WEST.

Figure 1-17

Bob Tisdale

TRANSITION FROM EL NIÑO TO ENSO-NEUTRAL (A)

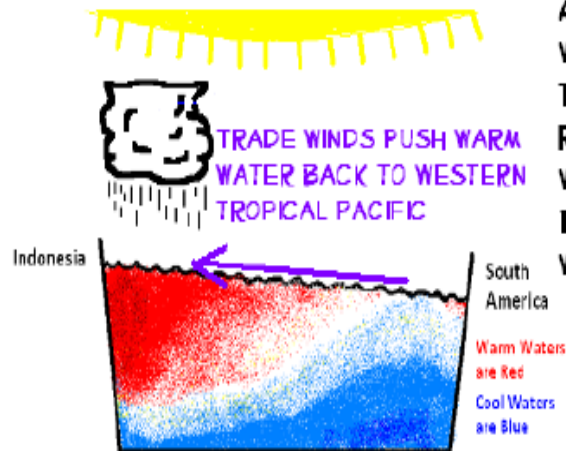


Warm Waters Are Red

Cool Waters Are Dark Blue

EL NIÑO EVENTS
TYPICALLY PEAK IN
DECEMBER AND
JANUARY.

AS THE TROPICAL PACIFIC
TRANSITIONS FROM EL
NIÑO TO ENSO-NEUTRAL
STATES, THE TRADE
WINDS RESUME THEIR
NORMAL EAST TO WEST
DIRECTION.



ANY WARM SURFACE
WATERS LEFT OVER FROM
THE EL NIÑO ARE
RETURNED TO THE
WESTERN TROPICAL
PACIFIC BY THE TRADE
WINDS.

Figure 1-18

Bob Tisdale

TRANSITION FROM EL NIÑO TO ENSO-NEUTRAL (C)



SOME OF THE WARM
WATER LEFT OVER FROM
THE EL NIÑO HELPS TO
RECHARGE THE PACIFIC
WARM POOL FOR THE
NEXT EL NIÑO.

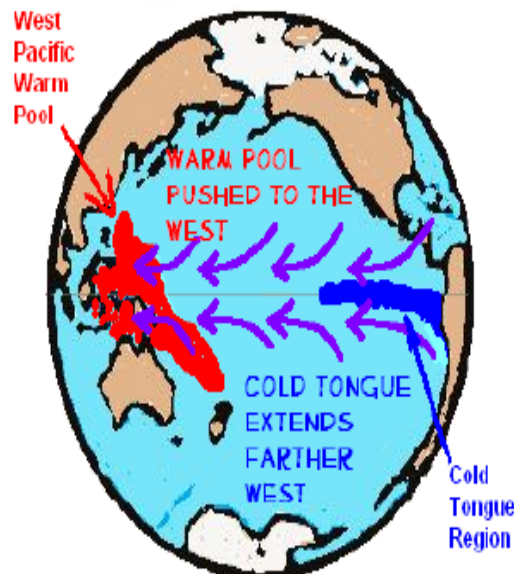
THE REMAINDER IS
CARRIED POLEWARD AND
INTO THE INDIAN OCEAN.

Figure 1-20

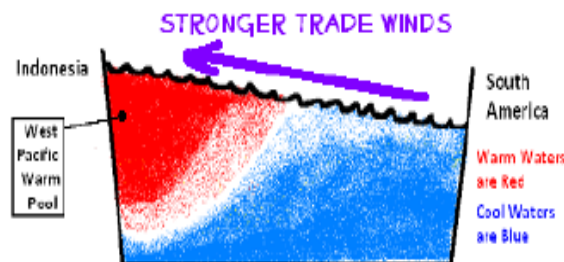
HHH

Bob Tisdale

LA NIÑA CONDITIONS (A)



Warm Waters Are Red Cool Waters Are Dark Blue



TRADE WINDS ARE STRONGER THAN NORMAL DURING A LA NIÑA.

THE STRONGER TRADE WINDS PUSH THE WARM WATERS FARTHER TO THE WEST IN THE TROPICAL PACIFIC.

AND THE COLD TONGUE IN THE EAST EXTENDS FARTHER TO THE WEST, TOO.

LA NIÑA EVENTS ARE BASICALLY AN EXAGGERATED ENSO-NEUTRAL STATE.

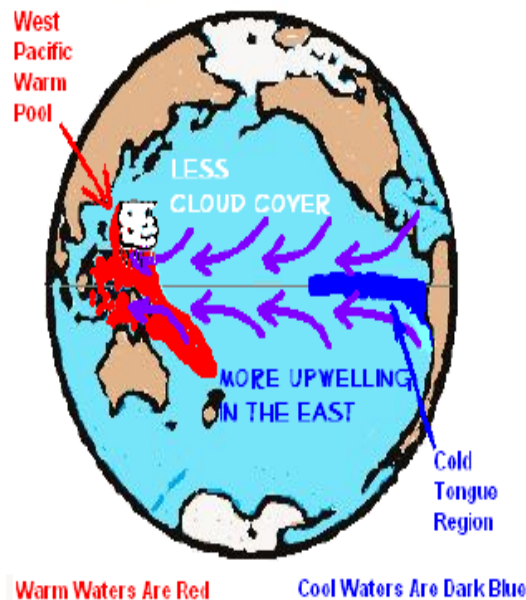
BUT THEY ARE IMPORTANT.

Figure 1-21

HHH

Bob Tisdale

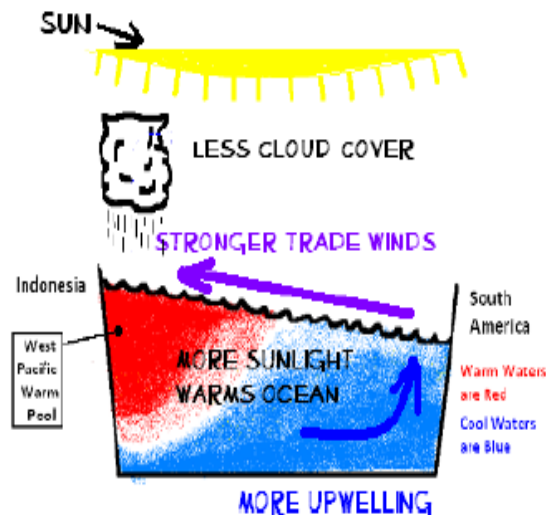
LA NIÑA CONDITIONS (3)



THE STRONGER TRADE WINDS CAUSE MORE COOL SUBSURFACE WATER TO BE DRAWN TO THE SURFACE IN THE EAST (MORE UPWELLING).

AND THE STRONGER TRADE WINDS RESULT IN LESS CLOUD COVER.

WITH LESS CLOUD COVER, MORE VISIBLE SUNLIGHT (DOWNWARD SHORTWAVE RADIATION) REACHES THE SURFACE OF THE TROPICAL PACIFIC. SUNLIGHT PENETRATES AS DEEP AS 100 METERS, DECREASING IN STRENGTH WITH DEPTH.



THE ADDITIONAL SUNLIGHT WARMS THE TROPICAL PACIFIC MORE THAN NORMAL.

You heard the words,
“Sunlight penetrates
the ocean water”
in the first lesson...

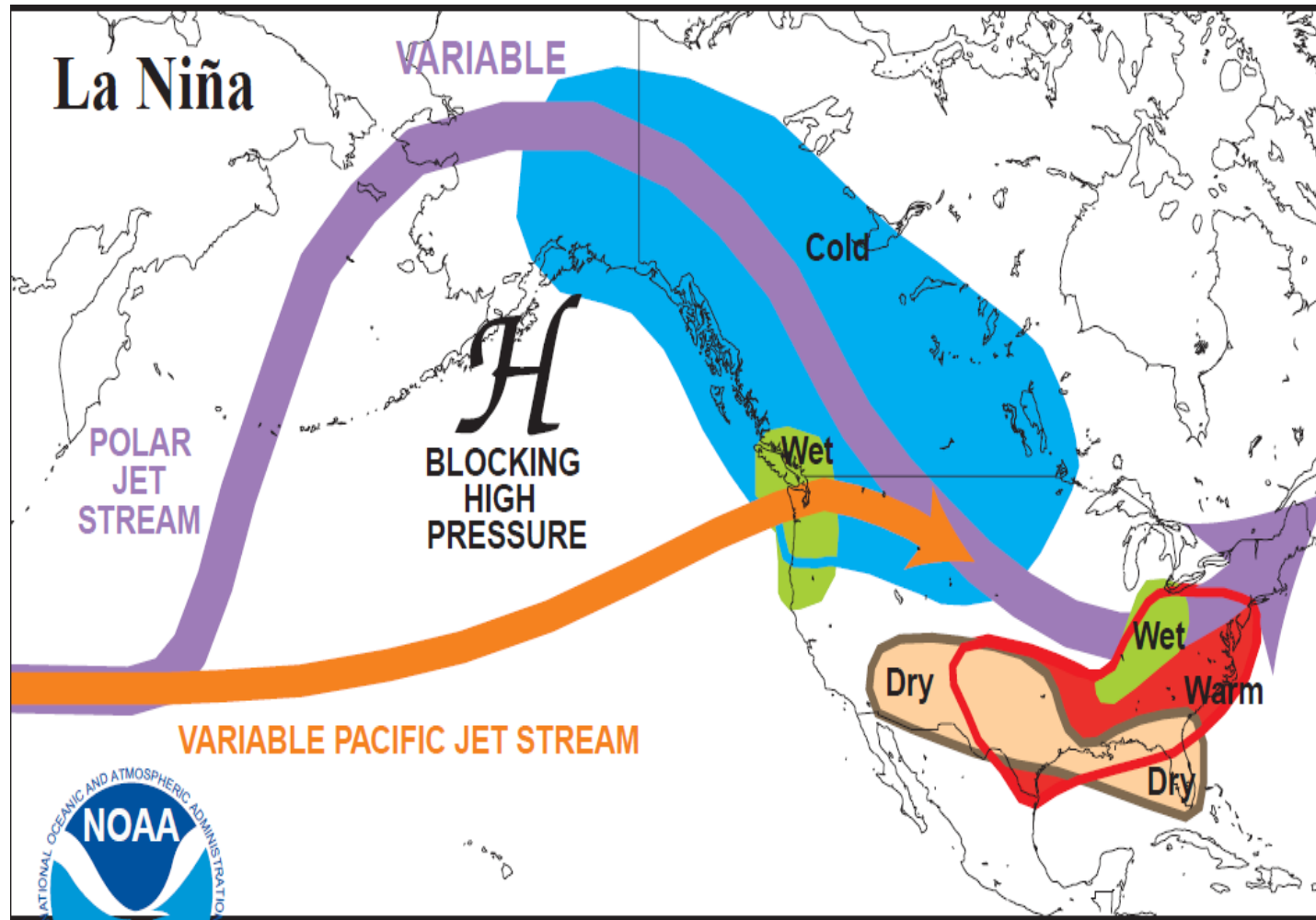
Figure 1-22

Bob Tisdale

El Nino's counterpart is La Nina.

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/naw

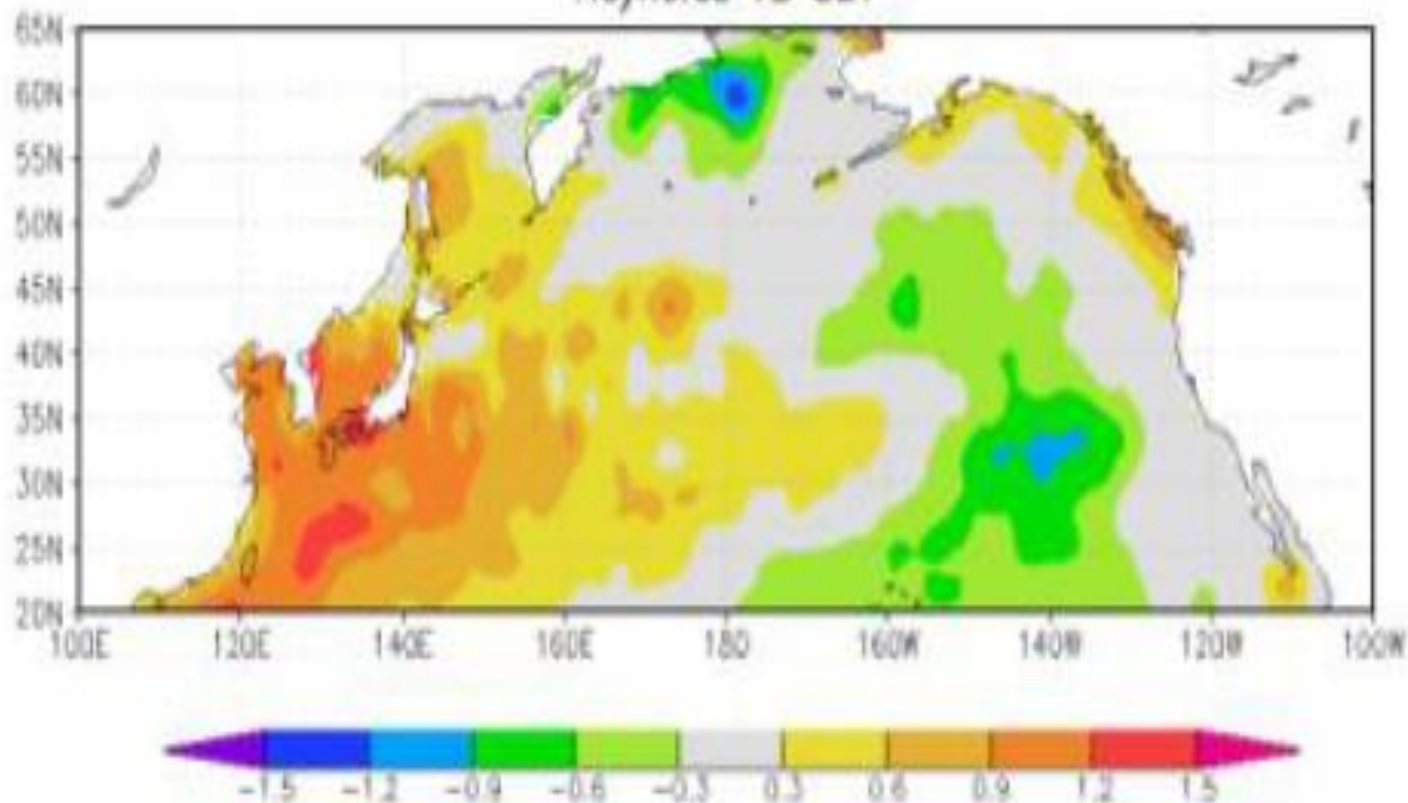
La Nina results in dry from Arizona to Florida



Climate Prediction Center/NCEP/NWS

La Niña Sea Surface Temperature Anomaly Pattern In The North Pacific

sst-clim8209 Mar-Jan1999
Reynolds v2 SST



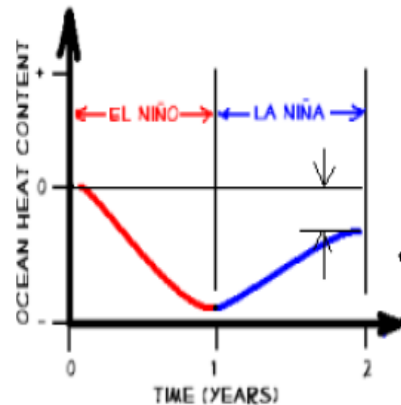
Maps Created at KIIIM Climate Explorer

Figure 4-73

Bob Tisdale

LA NIÑA RECHARGES THE HEAT DISCHARGED BY THE EL NIÑO

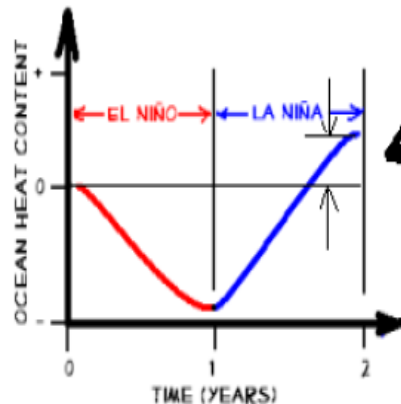
TROPICAL PACIFIC OCEAN HEAT CONTENT



BECAUSE MORE SUNLIGHT REACHES AND WARMS THE TROPICAL PACIFIC DURING THE LA NIÑA, OCEAN HEAT CONTENT THERE INCREASES, REPLACING THE HEAT GIVEN OFF DURING THE EL NIÑO.

MOST TIMES, LESS HEAT IS SUPPLIED DURING THE LA NIÑA THAN WAS DISCHARGED DURING THE EL NIÑO.

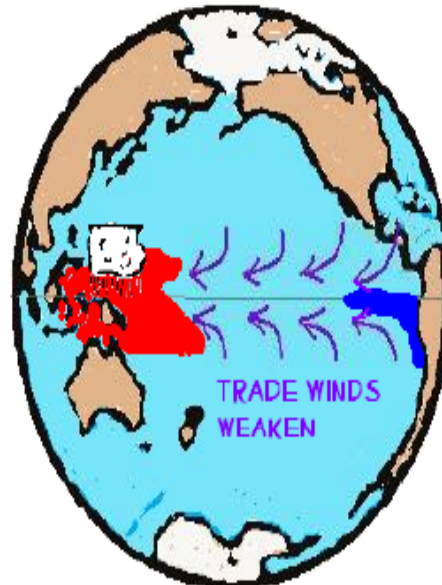
TROPICAL PACIFIC OCEAN HEAT CONTENT



OCCASIONALLY, THE LA NIÑA SUPPLIES MORE HEAT THAN WAS DISCHARGED BY THE EL NIÑO.

THAT 'OVERCHARGING' OCCURRED DURING THE 1973/74/75/76 AND 1995/96 LA NIÑA EVENTS!

TRANSITION FROM LA NIÑA TO ENSO-NEUTRAL

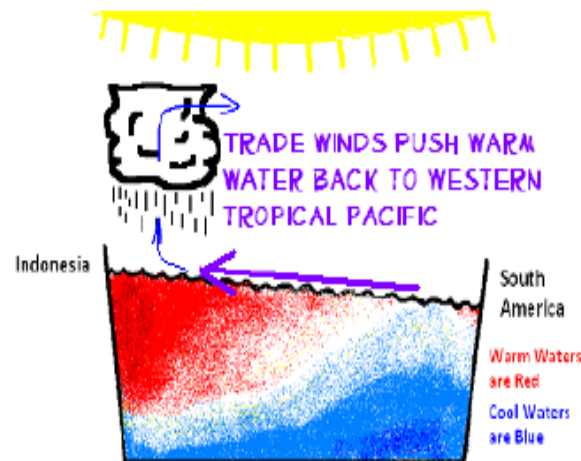


Warm Waters Are Red

Cool Waters Are Dark Blue

LA NIÑA EVENTS ALSO
TYPICALLY PEAK IN
DECEMBER AND
JANUARY.

AS THE TROPICAL PACIFIC
TRANSITIONS FROM LA
NIÑA TO ENSO-NEUTRAL
STATES, THE TRADE
WINDS WEAKEN TO THEIR
NORMAL STRENGTH.



UPWELLING IN THE EAST
DECREASES AND THE
SEA SURFACE
TEMPERATURES WARM IN
THE CENTRAL AND
EASTERN EQUATORIAL
PACIFIC, ALL RETURNING
TO NORMAL CONDITIONS.

Figure 1-24

HHH

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LA NIÑA IS NOT THE OPPOSITE OF EL NIÑO

BEFORE EL NIÑO



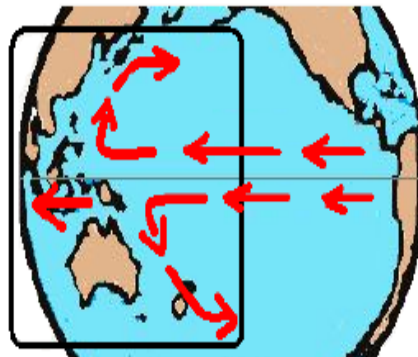
BEFORE THE EL NIÑO, MOST OF THE WARM WATER THAT WILL BE RELEASED BY THE EL NIÑO IS BELOW THE SURFACE AND EXCLUDED FROM SURFACE TEMPERATURE MEASUREMENTS.

DURING EL NIÑO



DURING THE EL NIÑO, THE WARM WATER FROM BELOW THE SURFACE OF THE PACIFIC WARM POOL THAT HAD BEEN EXCLUDED FROM THE SURFACE TEMPERATURE RECORD IS NOW SPREAD ACROSS THE SURFACE AND INCLUDED IN THE SURFACE TEMPERATURE RECORD.

AFTER EL NIÑO



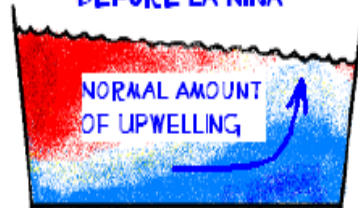
AFTER THE EL NIÑO, THE WARM WATER IS RETURNED TO THE WEST WHEN FLOW RETURNS TO ITS NORMAL DIRECTION. MUCH OF THE WARM WATER REMAINS ON THE SURFACE AND CONTINUES TO BE INCLUDED IN THE SURFACE TEMPERATURE RECORD.

Figure 1.25

Bob Tisdale

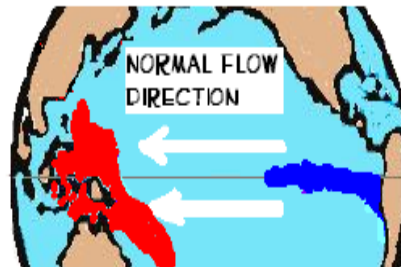
LA NIÑA IS NOT THE OPPOSITE OF EL NIÑO

BEFORE LA NIÑA



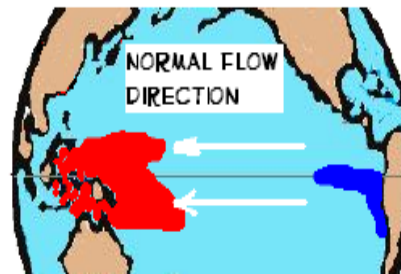
BEFORE THE LA NIÑA, THE SEA SURFACE TEMPERATURE IN THE EASTERN EQUATORIAL PACIFIC IS DICTATED BY THE TEMPERATURE OF THE UPWELLED WATERS.

DURING LA NIÑA



DURING THE LA NIÑA, STRONGER TRADE WINDS INCREASE THE AMOUNT OF UPWELLING, WHICH EXPANDS THE SURFACE AREA OF COOLER WATERS IN THE EAST. THE WARM POOL IS PUSHED TO THE WEST. THE FLOW IS IN THE NORMAL DIRECTION.

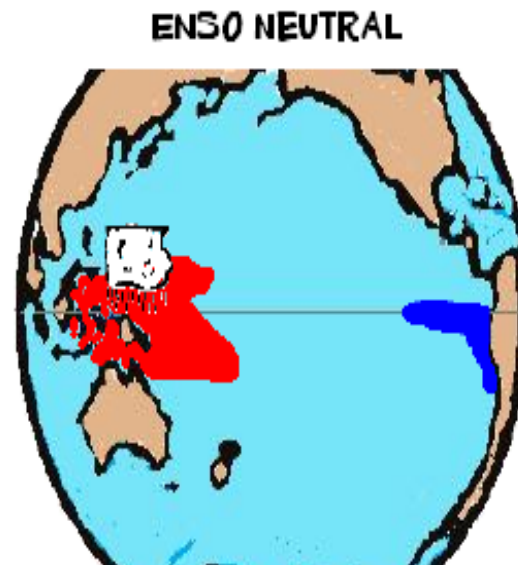
AFTER LA NIÑA



AFTER THE LA NIÑA, THE TRADE WINDS RELAX BACK TO THEIR NORMAL STRENGTH. THE UPWELLING OF COOL WATER SLOWS. THE WARM POOL EXPANDS EAST.

UNLIKE AN EL NIÑO, THERE ARE NO "LEFTOVER" COOL SURFACE WATERS IN THE EASTERN TROPICAL PACIFIC THAT NEED TO BE RETURNED TO THE WEST. THE TRADE WINDS HAVE BEEN PUSHING THE WATER FROM EAST TO WEST ALL ALONG, THROUGH THE ENSO-NEUTRAL AND LA NIÑA PHASES.

WHY GLOBAL SURFACE TEMPERATURES WARM DURING AN EL NIÑO (A)



AN EL NIÑO RELEASES
HEAT INTO THE
ATMOSPHERE. BUT THAT
IS NOT WHY GLOBAL
SURFACE TEMPERATURES
WARM IN RESPONSE TO
THE EL NIÑO.

BECAUSE THE PACIFIC
WARM POOL IS SO WARM, A
LOT OF MOISTURE IS
PUMPED INTO THE
ATMOSPHERE THERE.

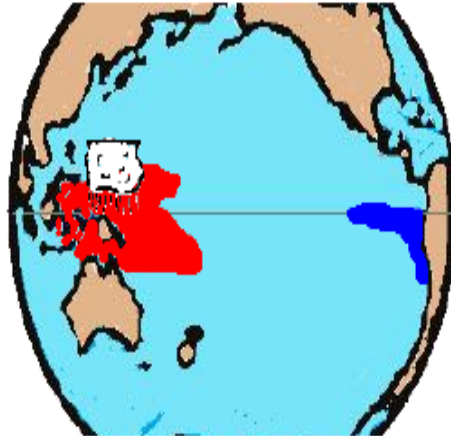
BECAUSE THE PACIFIC
WARM POOL IS ALSO SO
LARGE, IT IS ONE OF THE
DRIVING FORCES OF
GLOBAL CLIMATE.

Figure 1-27

Bob Tisdale

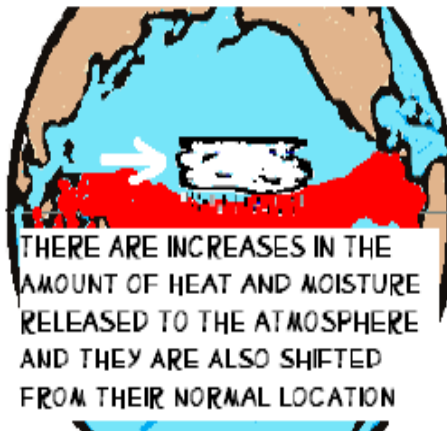
WHY GLOBAL SURFACE TEMPERATURES WARM DURING AN EL NIÑO

ENSO NEUTRAL



THE 'NORMAL' STATE OF GLOBAL CLIMATE IS IN PART DEPENDENT ON THE LOCATION OF ALL OF THE MOISTURE AND HEAT BEING RELEASED FROM THE WESTERN TROPICAL PACIFIC.

EL NIÑO



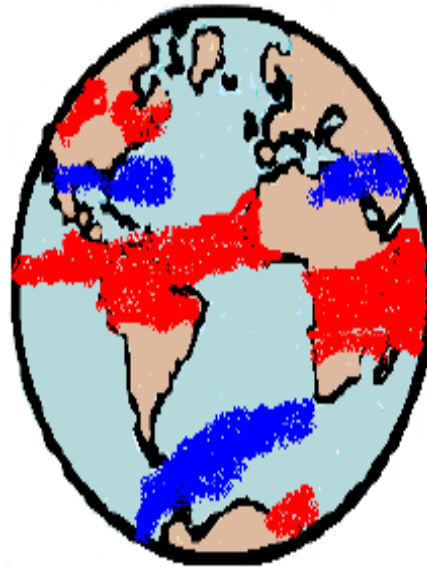
THEN, DURING THE EL NIÑO, NOT ONLY IS MORE HEAT AND MOISTURE BEING RELEASED TO THE ATMOSPHERE, BUT THAT RELEASE OF HEAT AND MOISTURE HAS BEEN SHIFTED ABOUT A QUARTER OF THE WAY (OR MORE) AROUND THE GLOBE.

Figure 1-28

Bob Tisdale

WHY GLOBAL SURFACE TEMPERATURES WARM DURING AN EL NIÑO

CORRELATION OF SURFACE
TEMPERATURE WITH ENSO INDEX
(3-MONTH LAG)



RESPONSE DURING EL NIÑO

RED --> AREAS THAT WARM

BLUE--> AREAS THAT COOL

THE INCREASED RELEASE OF
HEAT AND MOISTURE AND THEIR
RELOCATION DURING AN EL NIÑO
CAUSE CHANGES IN ATMOSPHERIC
CIRCULATION PATTERNS.

IT IS THOSE CHANGES IN
ATMOSPHERIC CIRCULATION
DURING AN EL NIÑO THAT CAUSE
SURFACE TEMPERATURES
OUTSIDE OF THE EASTERN
TROPICAL PACIFIC TO WARM IN
SOME PLACES AND TO COOL IN
OTHERS.

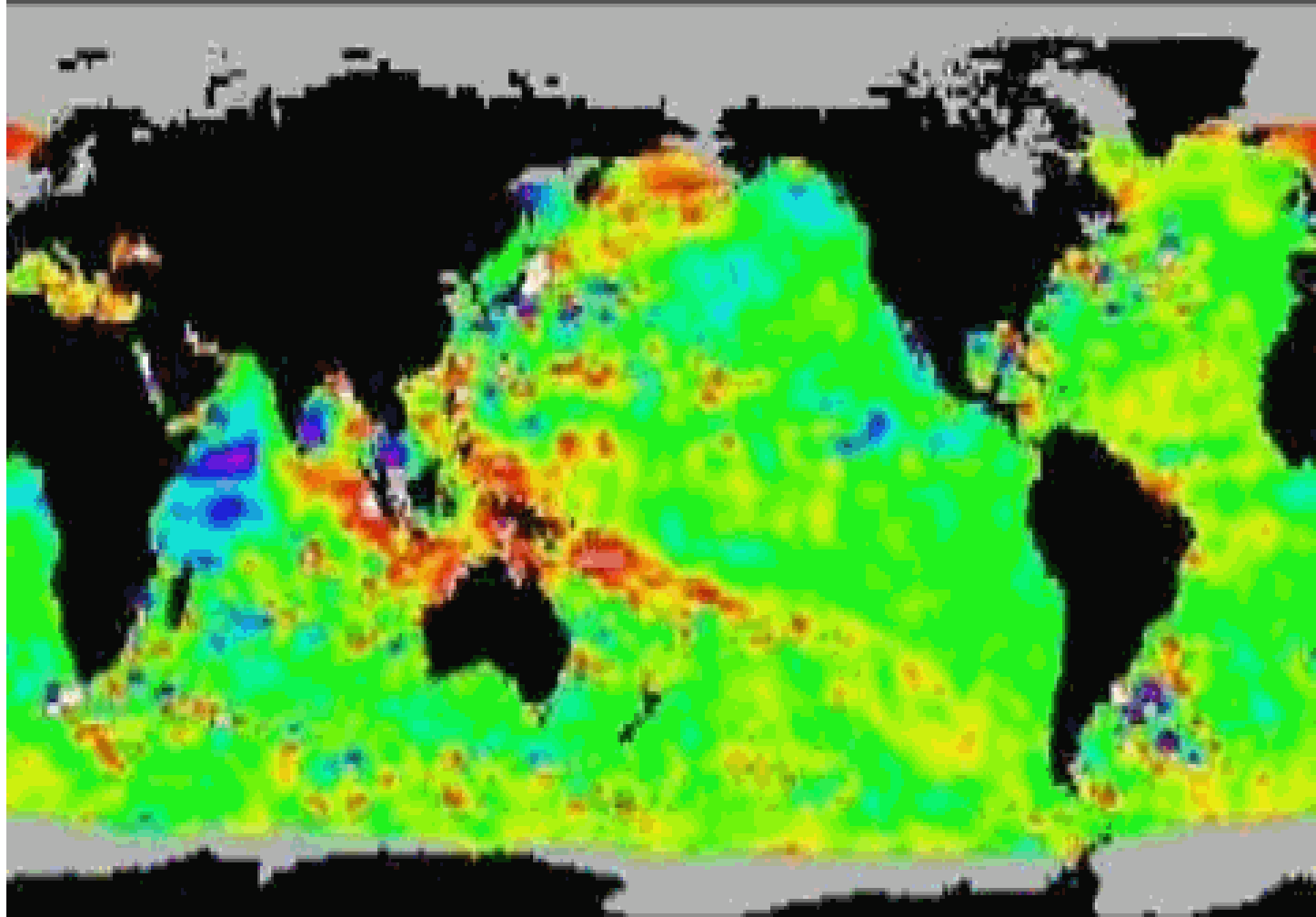
SINCE THE AREAS THAT WARM ARE
GREATER THAN THOSE THAT COOL,
GLOBAL SURFACE TEMPERATURES
RISE DURING AN EL NIÑO.

MORE AREAS AROUND THE
GLOBE COOL THAN WARM DURING
A LA NIÑA SO GLOBAL SURFACE
TEMPERATURES COOL.

Next graphics show animations of El Nino, and then La Nina

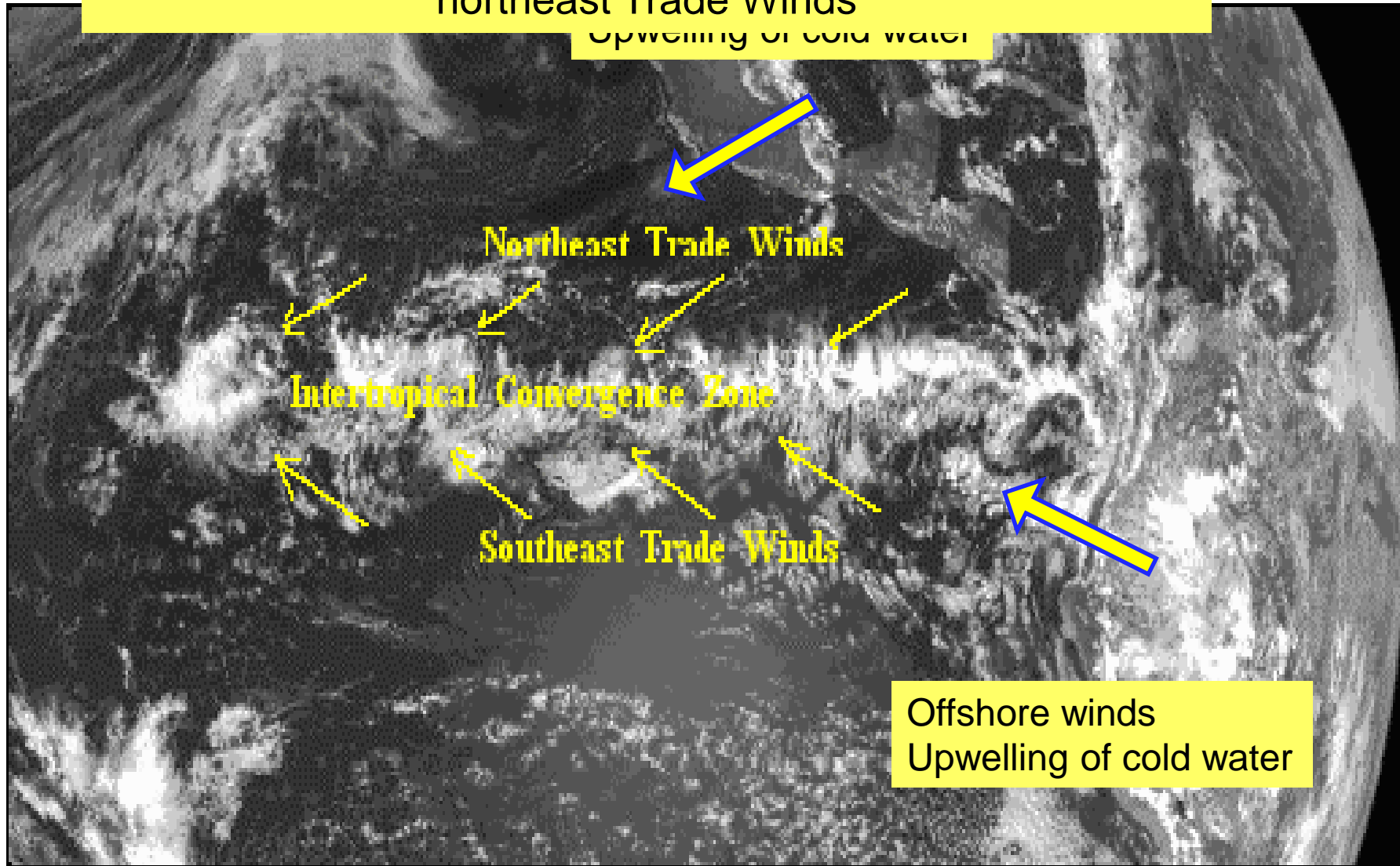
START

DEC 16 1996



The Northeasterly Trade Winds are very prevalent,
stronger in La Nina years.
Visitors to Hawaii usually encounter steady from the
northeast Trade Winds

Upwelling of cold water



Northeast Trade Winds

Intertropical Convergence Zone

Southeast Trade Winds

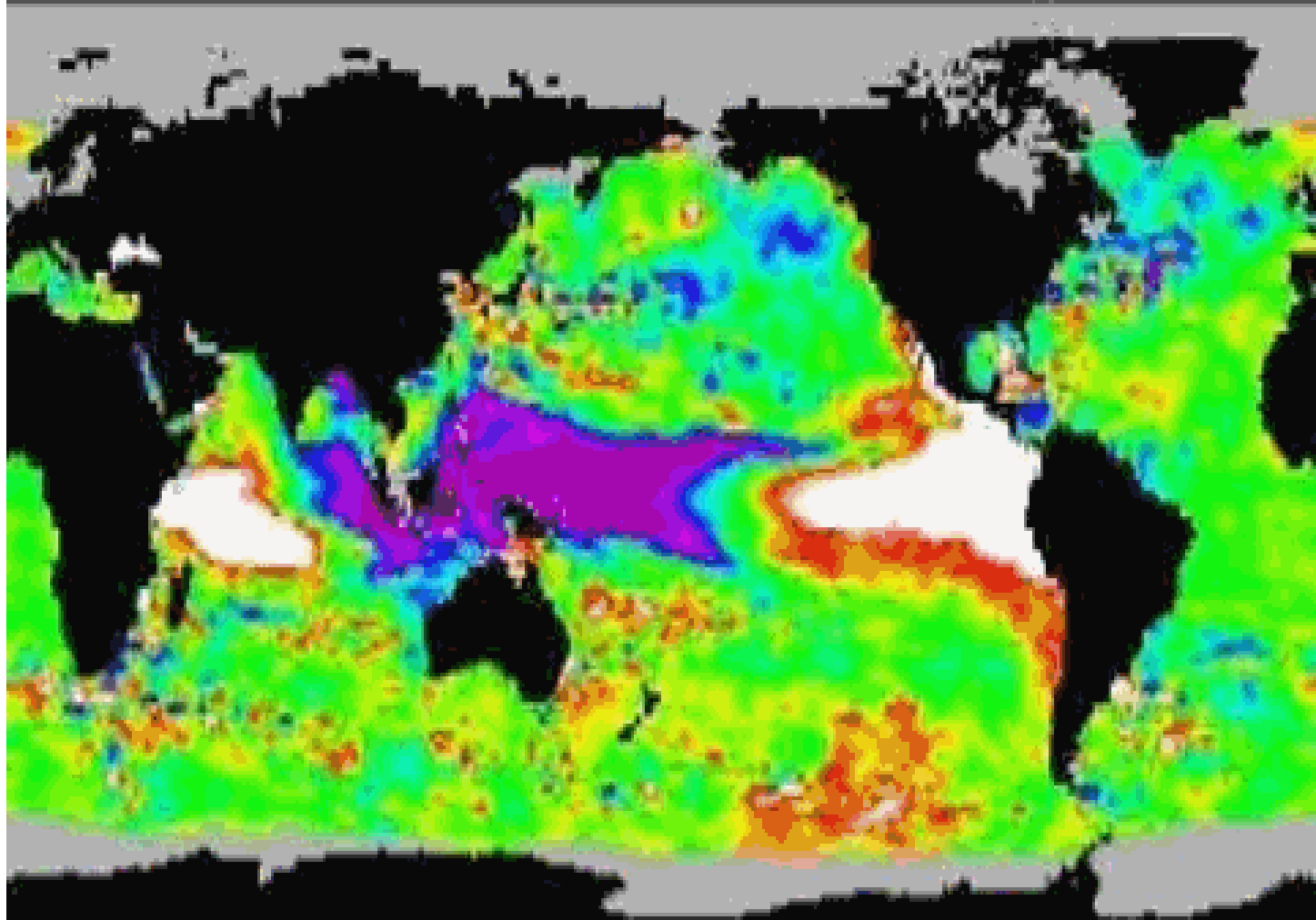
Offshore winds
Upwelling of cold water

Animation of La Nina beginning on 31 Jan 1998

<https://bobtisdale.files.wordpress.com/2012/06/animation-3-1.>

START

DEC 31 1997



IMPORTANT POINT!

WATER TEMPERATURE OF OCEAN OFFSHORE NORTH AMERICA
DETERMINES RAINFALL/DROUGHT in (especially) Western North America

What determines that water temperature?

That Multi-year weather pattern called EL NINO

also, El Nino-Southern Oscillation “ENSO”

Later, we’ll study a 60-year pattern

PACIFIC DECADEAL OSCILLATION or “PDO”

30 years MORE EL NINOS, and
30 years FEWER EL NINOS.

Why we use anomalies or departures from a mean to help describe weather and climate variations.

Global Sea Surface Temperatures (Reynolds OI.v2)

Nov 1981 to Nov 2011

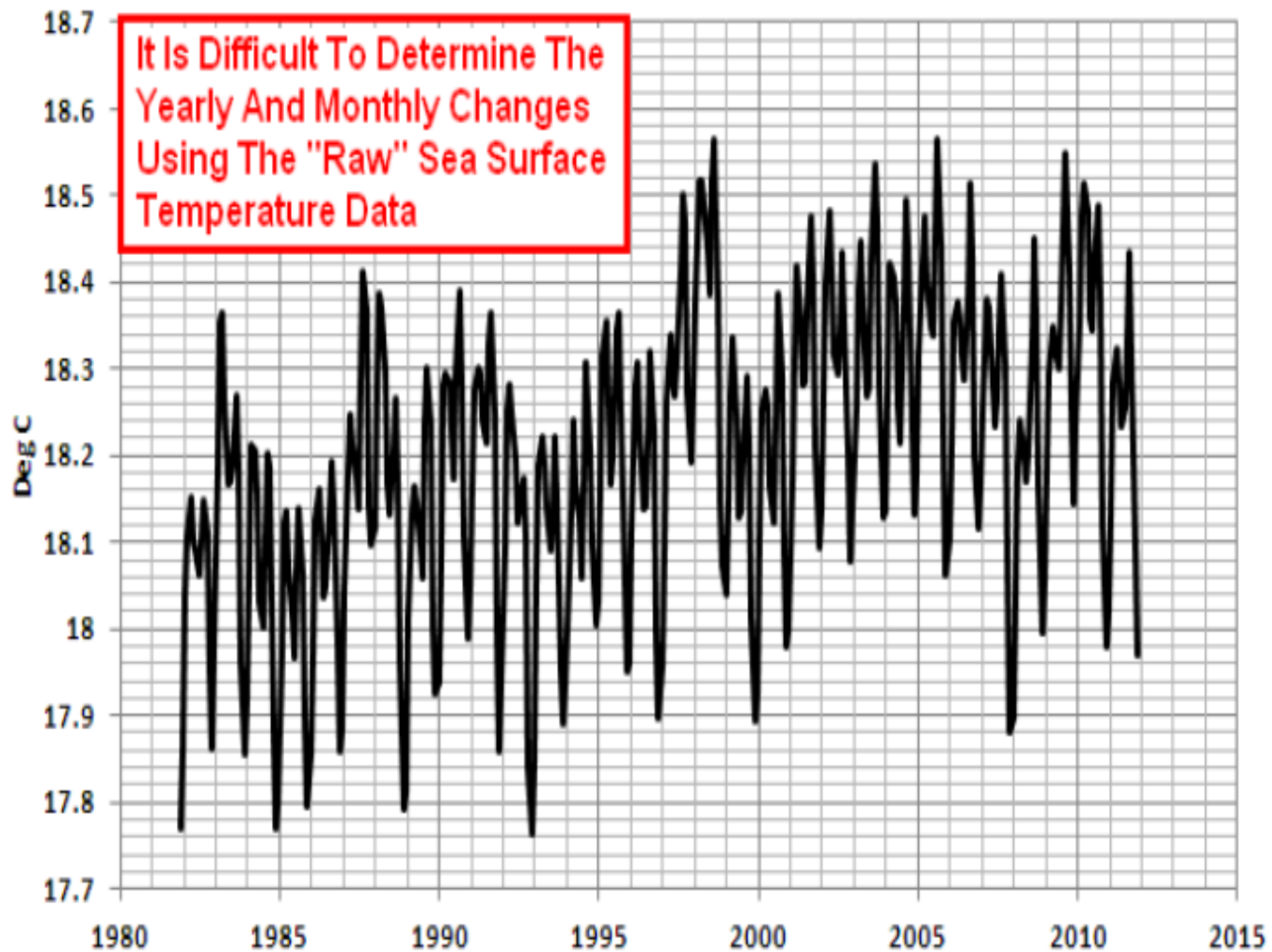


Figure 2-17

Bob Tisdale

Sea Surface Temperature Comparison (Reynolds OI.v2)

Northern Hemisphere, Southern Hemisphere

Nov 1982 to Nov 2011

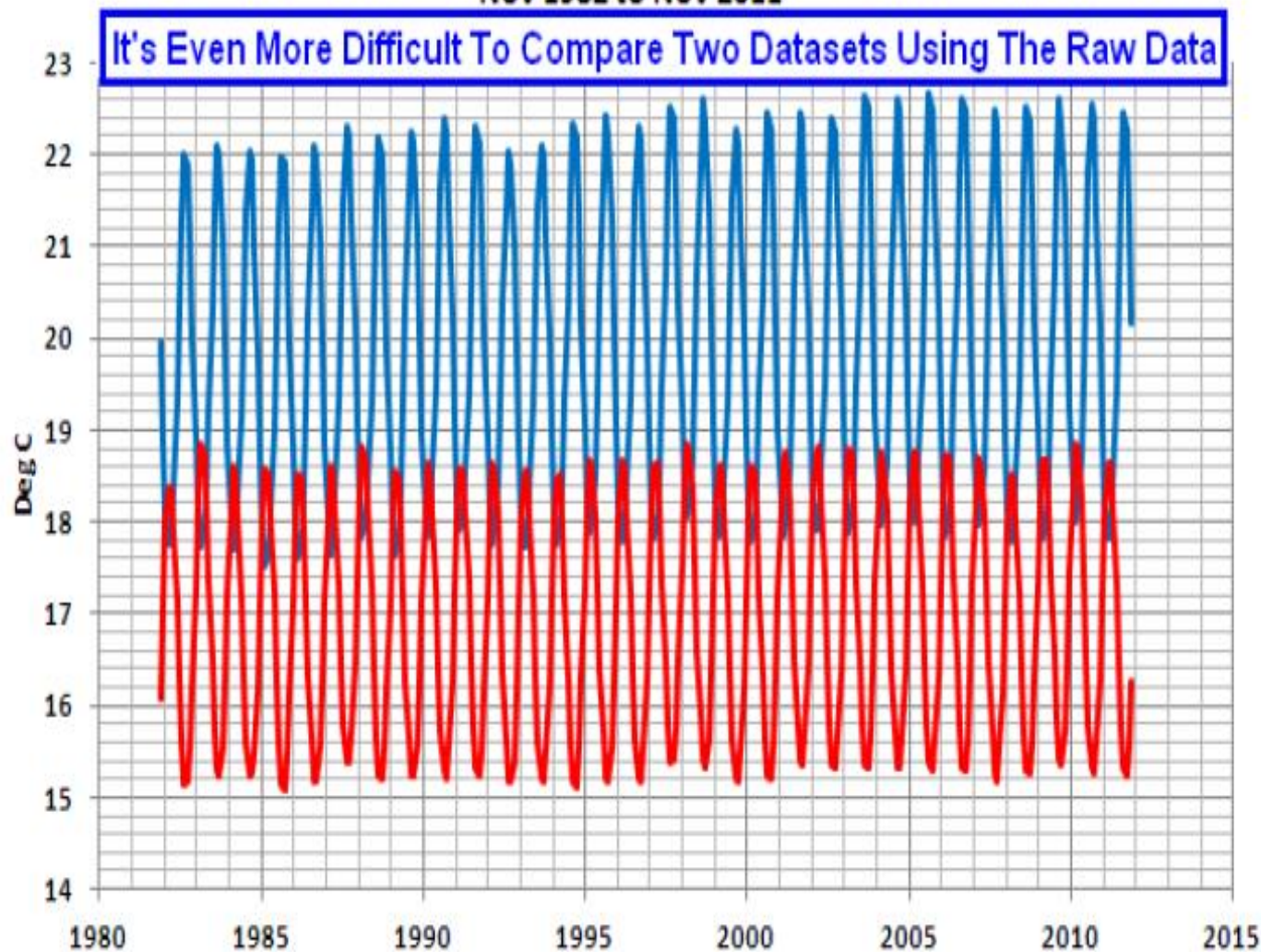


Figure 2-18

Bob Tisdale

Sea Surface Temperature Anomaly Comparison (Reynolds OI.v2)

Northern Hemisphere, Southern Hemisphere

Nov 1981 to Nov 2011

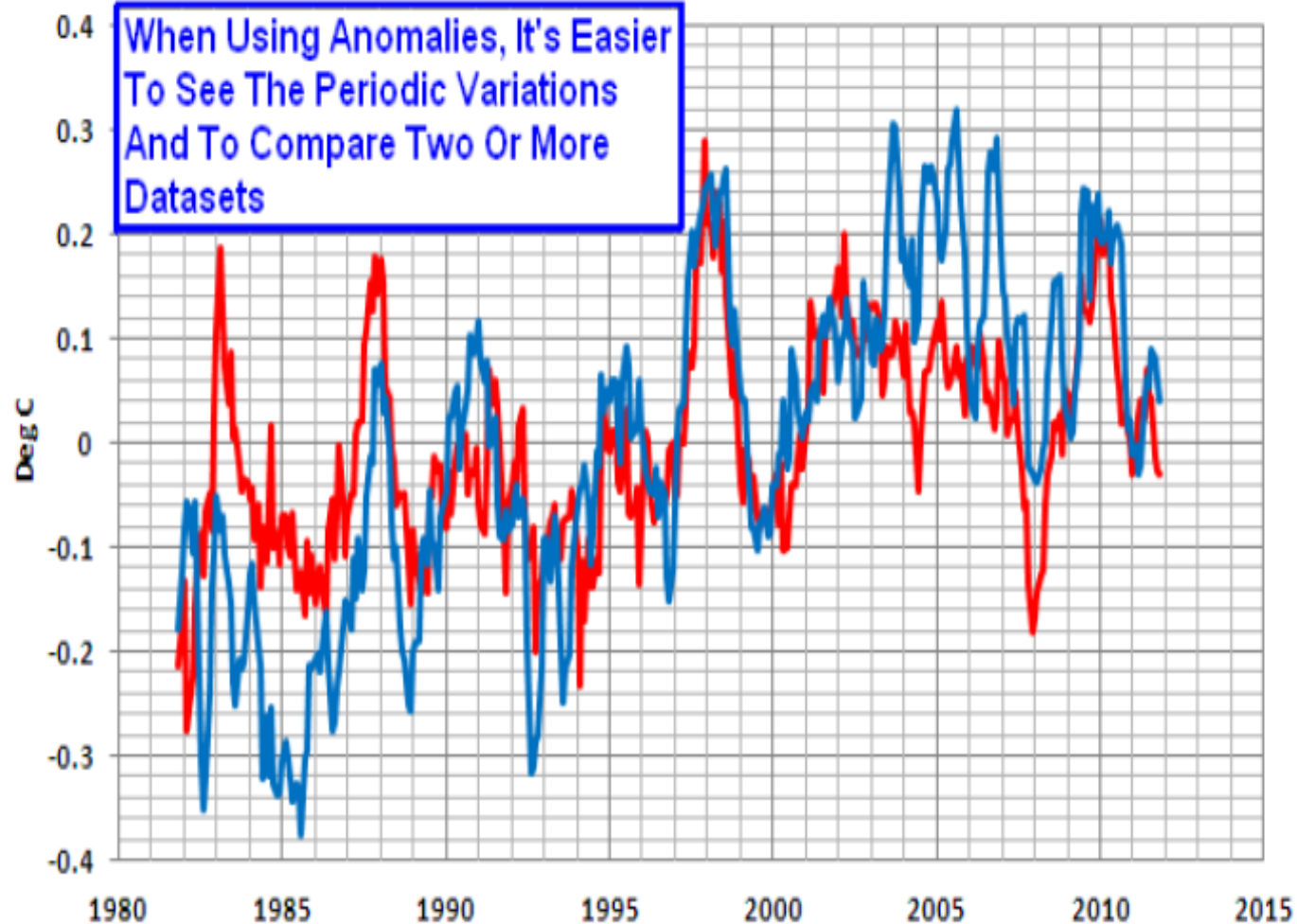


Figure 2-19

Bob Tisdale

Reynolds Ol.v2 NINO3.4 Region (5S-5N, 170W-120W)

Sea Surface Temperature & Base Period Average Sea Surface Temperature

Jan 1995 to Jan 2005

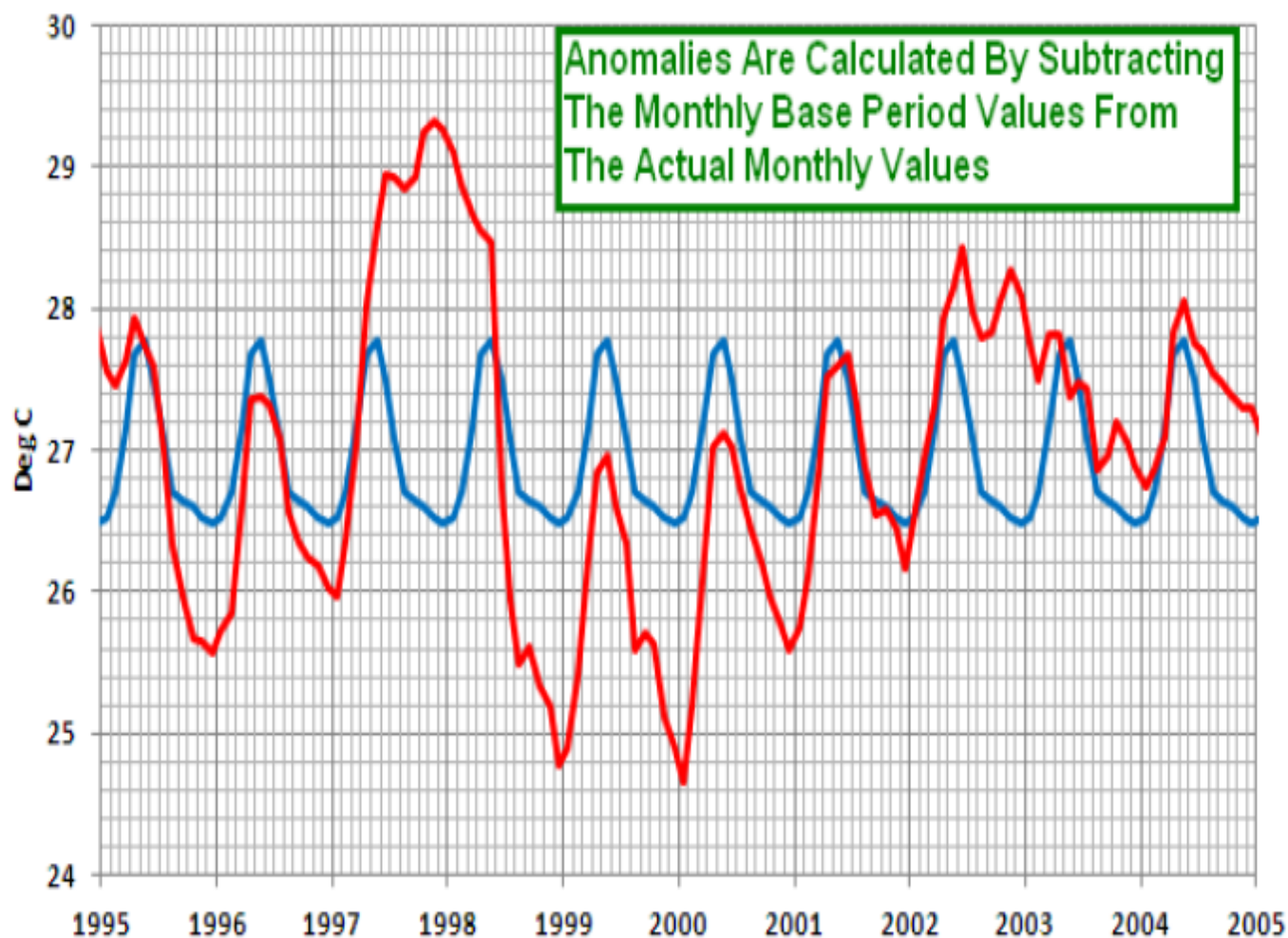


Figure 2-20

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NINO3.4 Sea Surface Temperature Anomalies
Jan 1995 to Jan 2005

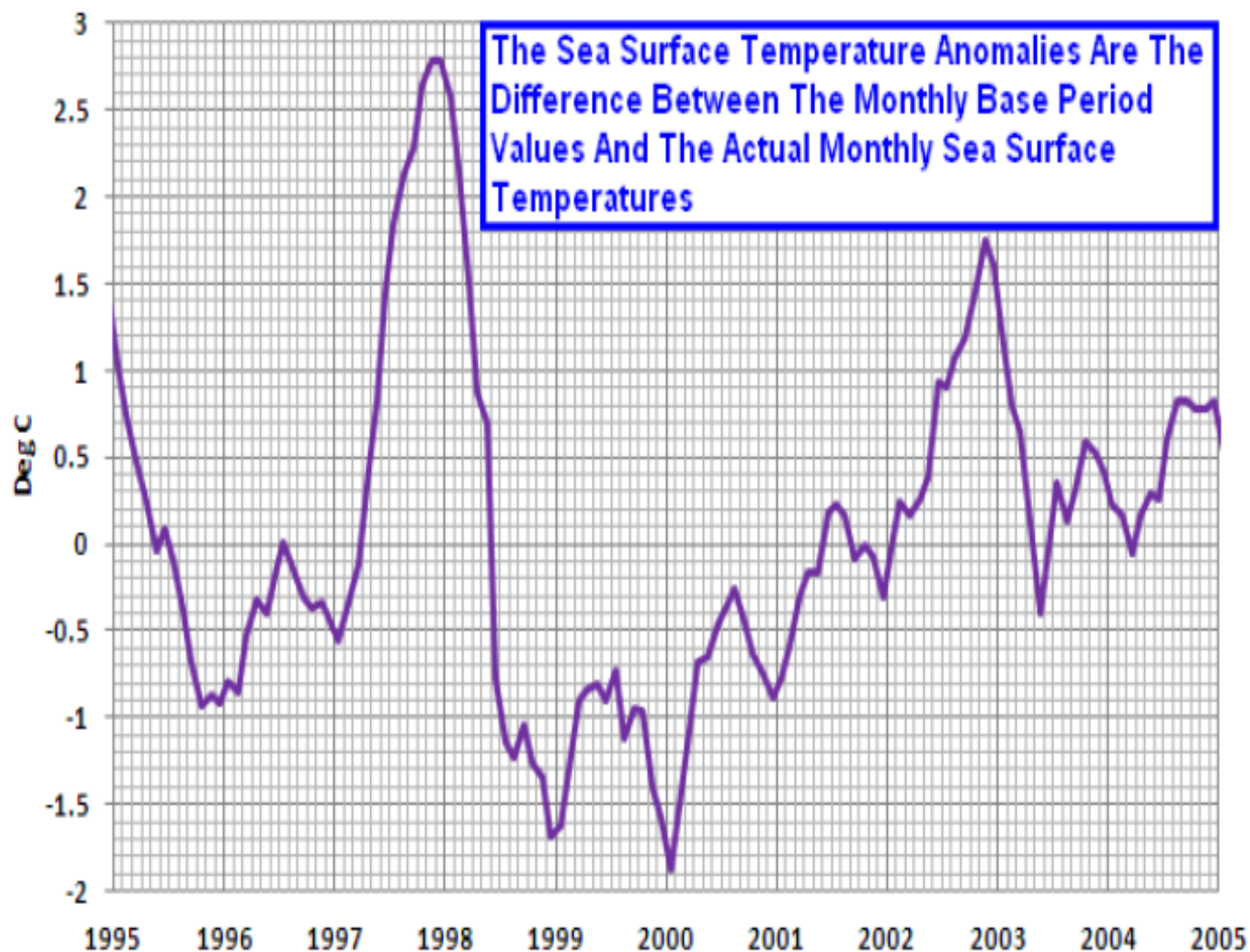


Figure 2-21

Bob Tisdale

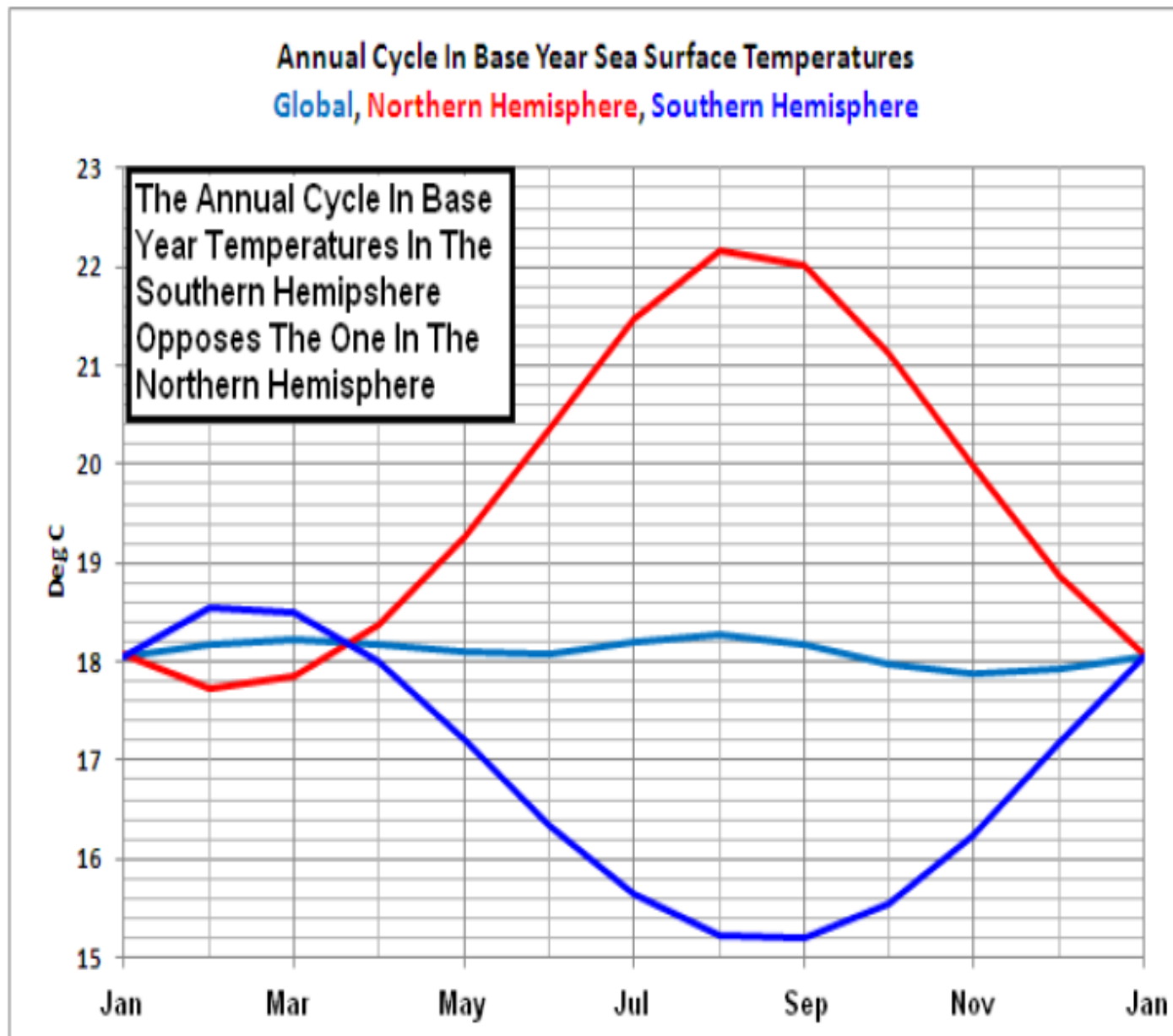


Figure 2-22

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Annual Cycle In Base Year Sea Surface Temperatures

NINO 3.4 Region (5S-5N, 170W-120W),

Pacific Warm Pool (20S-20N, 120E-180E)

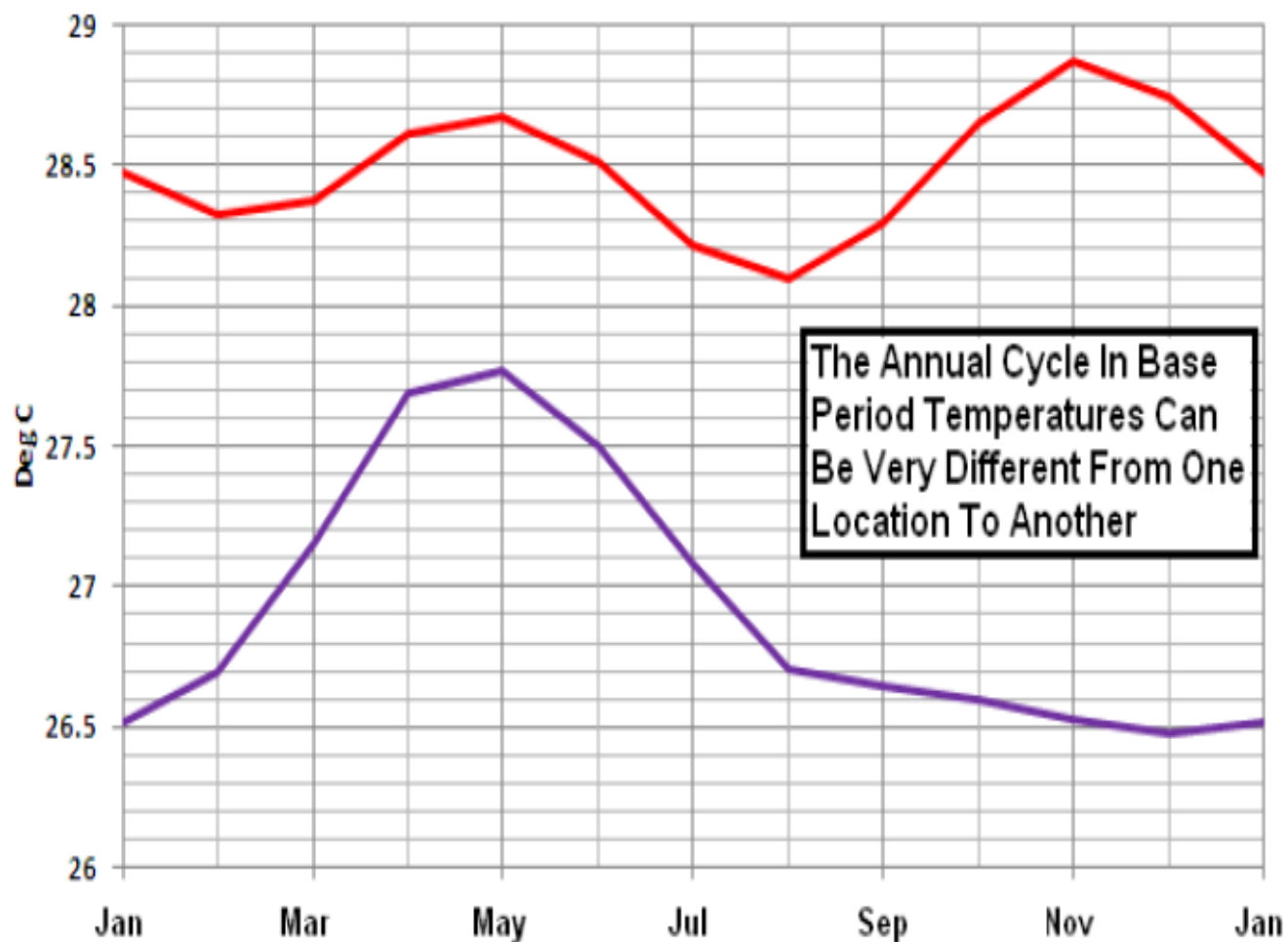


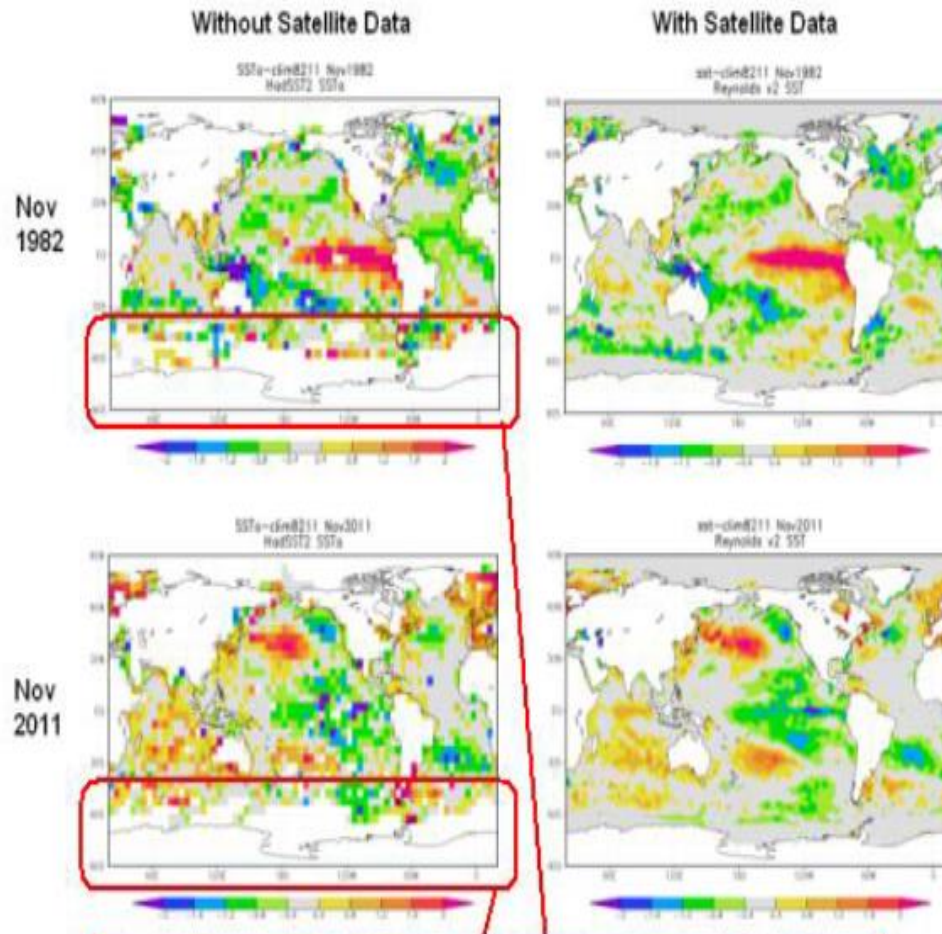
Figure 2-23

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Next Slide...

Why do they do this?

Global Sea Surface Temperature Coverage - Datasets With and Without Satellite-Based Measurements



Sea Surface Temperature Datasets Like HADSST2
And HADSST3 Exclude Major Portions Of The
Southern Ocean, Which Has Cooled Since 1982.
That Causes A Bias Toward Warming In Global Data.

Maps Created At KIMI Climate Explorer

Figure 2-25

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