Title
Torrey Pine and Climate Change

Author
Berger, Wolfgang H

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TORREY PINE AND CLIMATE CHANGE

W. H. BERGER

SCRIPPS INSTITUTION OF OCEANOGRAPHY, UCSD, LA JOLLA

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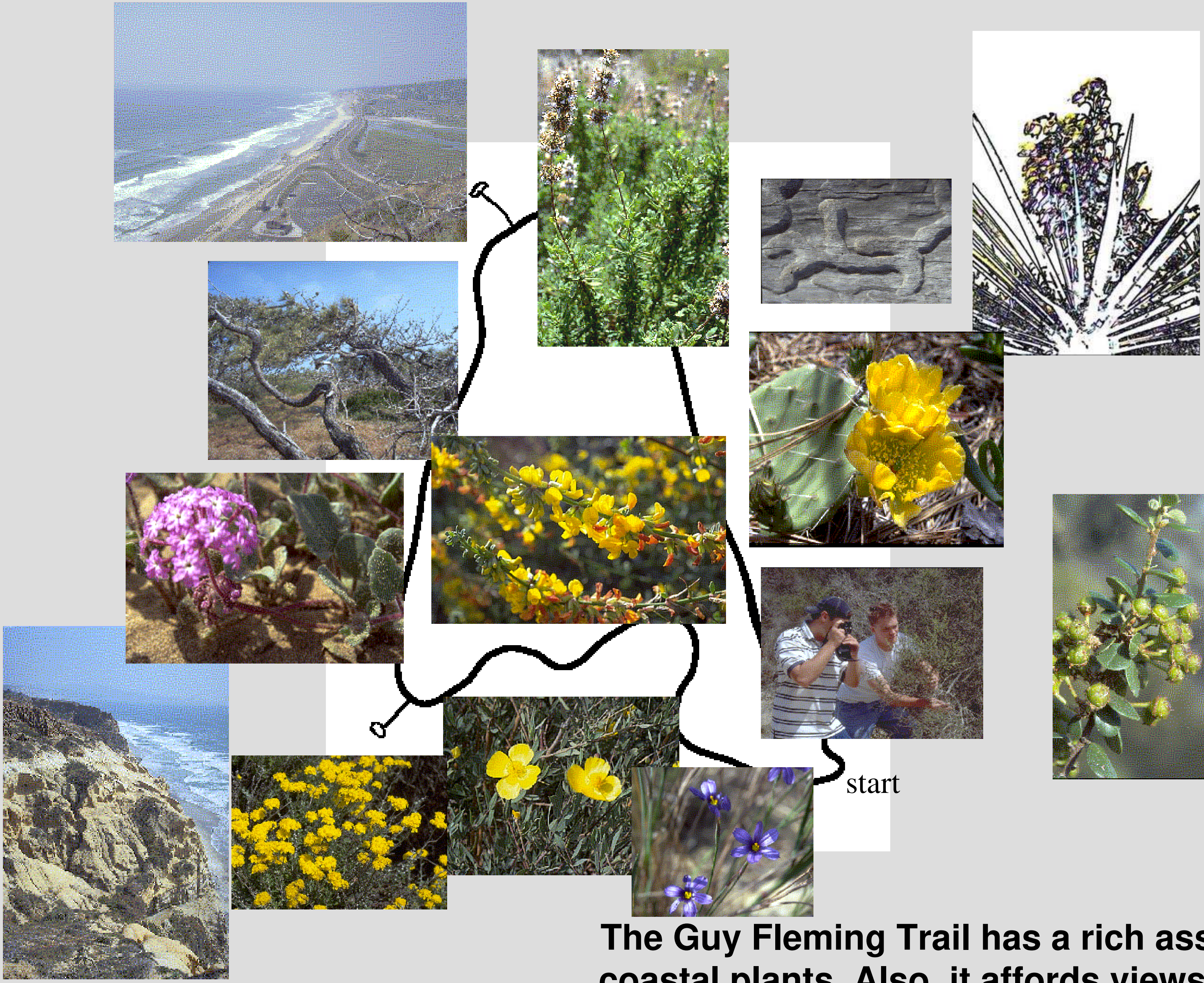
Pinus torreyana in North San Diego County grows in a limited region along the coast near Del Mar; the oldest trees are somewhat over a century old. **The history of its rate of growth is contained in its tree rings**, which tell an interesting story about patterns of climate change; that is, the history of precipitation in the region.

The Torrey Pine is known for its unusually long needles and its heavy cones. Its closest relative is the Coulter Pine, whose cones are so heavy they can be dangerous when loosened by squirrels in search of pine nuts.

There are only two locations where this species makes forests: the State Park south of Del Mar, California, and Santa Rosa Island offshore from Santa Barbara.

View from Guy Fleming Trail southward. In the distance Mt. Soledad.

The western boundary of the Torrey Pines State Park is along the Pacific Ocean. **The boundary is marked by high cliffs made of marine sediments of Tertiary age, with Quaternary deposits on top.**



The Guy Fleming Trail has a rich assortment of coastal plants. Also, it affords views northward along the shore and into the lagoon.

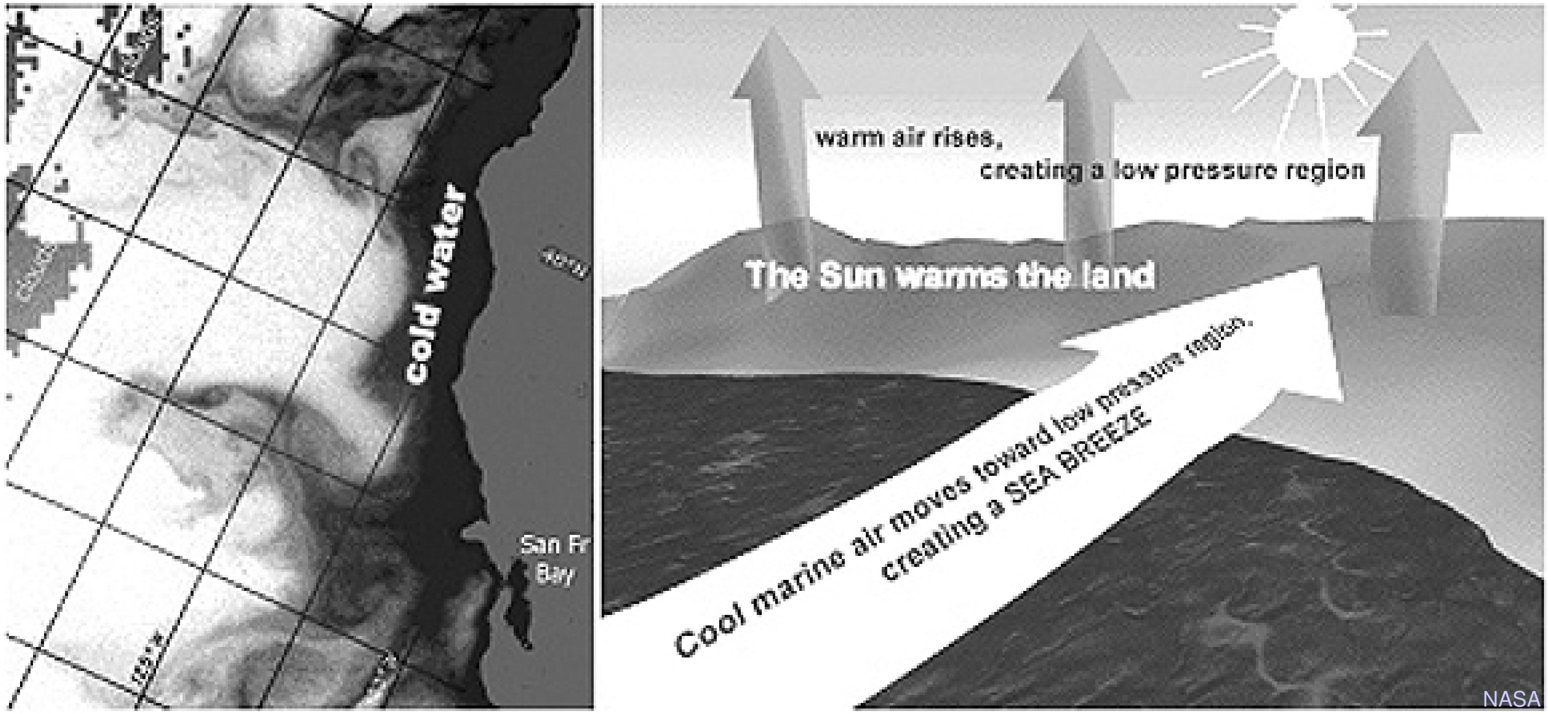
From the ocean viewpoint on the Guy Fleming trail, we can enjoy vistas of marine species -- birds most of the time, but also marine mammals occasionally. (Gray whales and dolphins, mostly.)

Winds connect ocean and coastal ecology.

One important type of wind is the

sea breeze.

Like many of the birds, hang gliders take advantage of the upwinds along the cliffs that are generated by the sea breeze climbing the obstacles posed by the cliffs.



Another important wind is the northwesterly wind moving parallel to the coast and joining the ***trade wind*** farther south. This wind is responsible for driving the California Current, and for ***upwelling*** of cold water along the shore (left graph).

Birds and mammals are abundant because of the rich food sources in the coastal waters of the California Current. The upwelling brings nutrients to the surface and stimulates growth of kelp and algae, at the base of the food chain.

The ***sea breeze*** is cool because it runs across the cold strip of water resulting from ***upwelling***. Cooling of marine air can result in the formation of fog in the coastal region, at times right up to the mountains.

Low cloud ceiling over marine air, coastal San Diego County (May, 2002)

Influx of cool air with the sea breeze, on the whole, keeps the coastal region rather dry. The Torrey Pine is drought adapted. Possibly the long needles can trap some moisture from fog, on occasion, thus wetting the ground under the tree, which benefits the growth of seedlings.

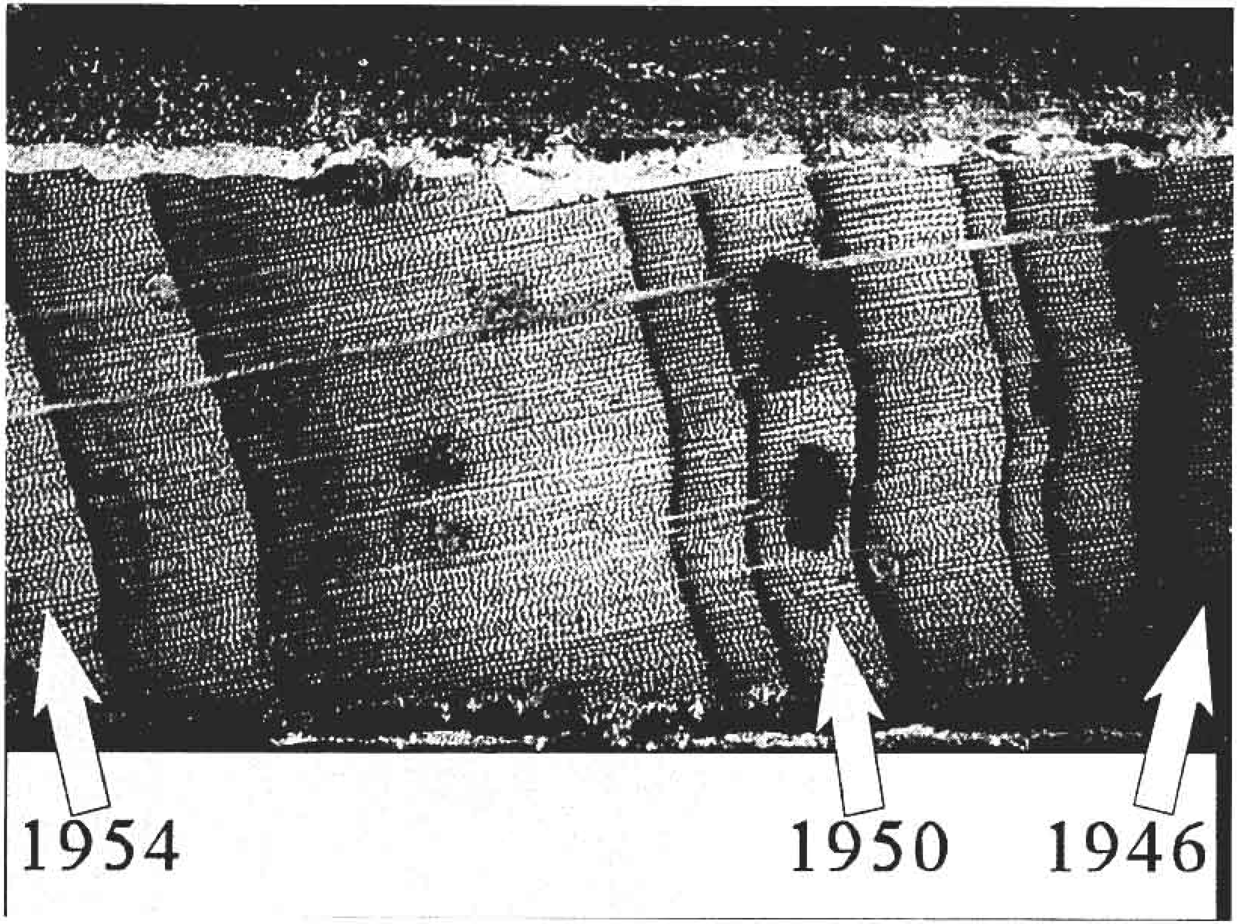
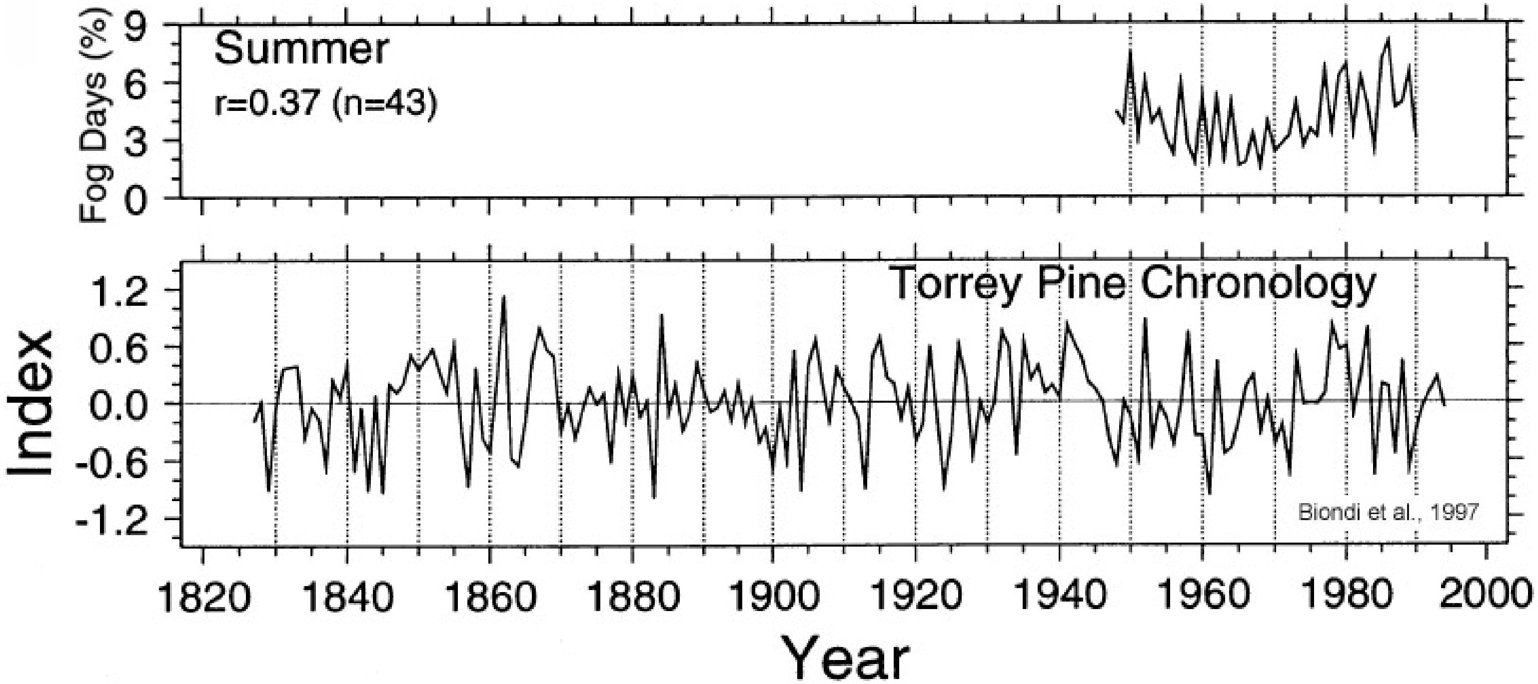


FIG. 3.—Annual xylem rings of Torrey pine as seen under a binocular microscope after specimen preparation and surfacing

original photo by F. Biondi, SIO

To find the response of the Torrey Pine to climate change, we turn to the growth record documented in the tree rings. Wide rings, in principle, signify rapid growth (a happy tree). Narrow rings signify stress. The chief source of stress is drought in this region.

Do the long pine needles trap moisture from fog? Perhaps.
But there is no evidence that growth responds to abundance of fog days.



First, a quick check on the idea that long needles might trap moisture from fog.

If they do, it is not recorded in the growth rings. It may affect recruitment of seedlings to the population of subadult trees, but this remains to be demonstrated.

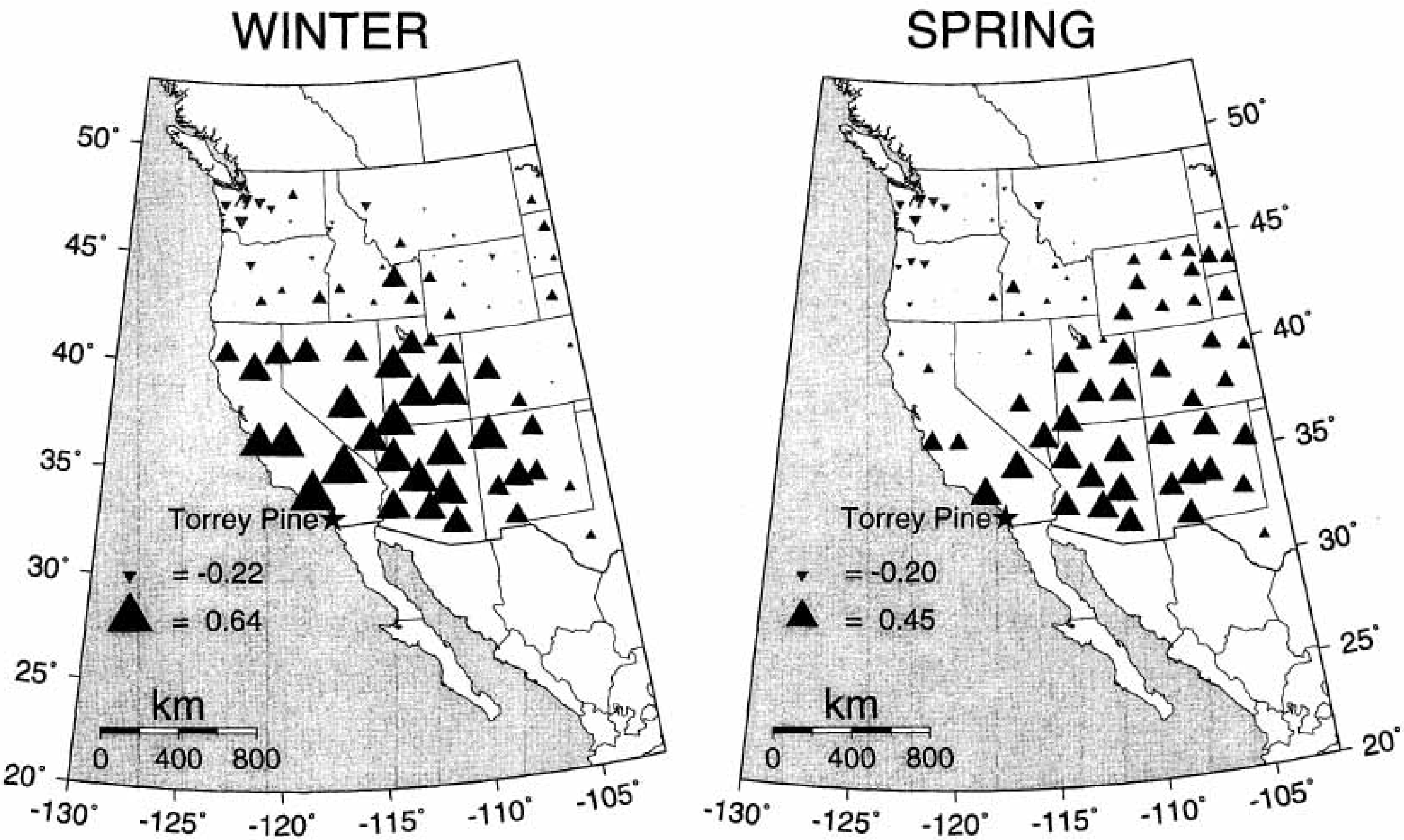
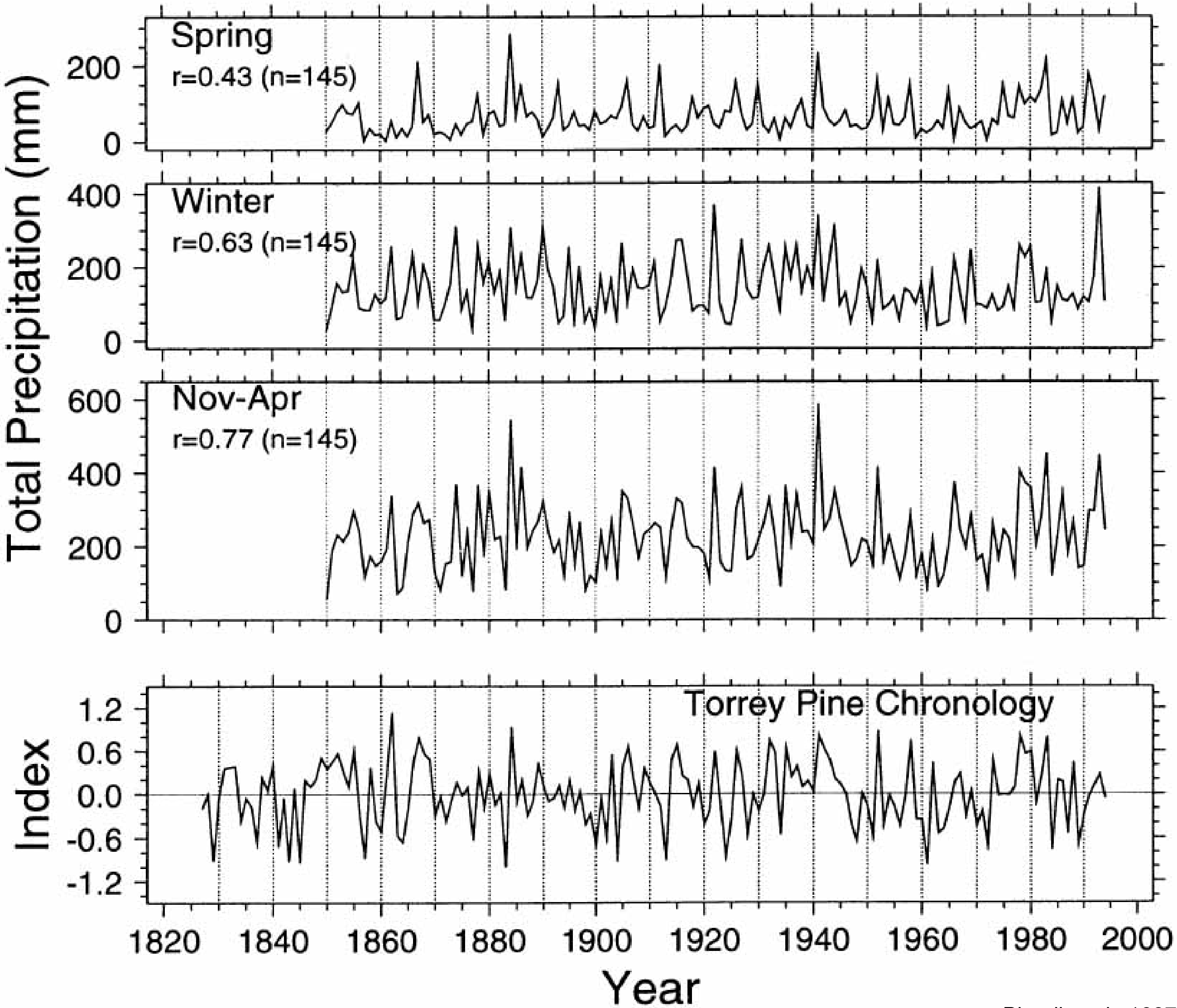


FIG. 6.—Linear correlation (r) between the Torrey pine tree-ring chronology and seasonal precipitation (WINTER and SPRING, 1895–1994) over NOAA/NCDC Climate Divisions for the western U.S. Symbol size for positive (▲) and negative (▼) correlations is directly proportional to the absolute value of r

The tree-ring record correlates well with the winter precipitation in Southern California, and to a lesser extent with spring precipitation (of which there is less).

Thus: **rainfall determines the growth rates of the pine**. (No surprise!)



Biondi et al., 1997

In fact, rainfall in Nov-Apr looks sufficiently like the tree-ring width record, so that the **history of rainfall can be reconstructed from the width of tree rings**, in principle.

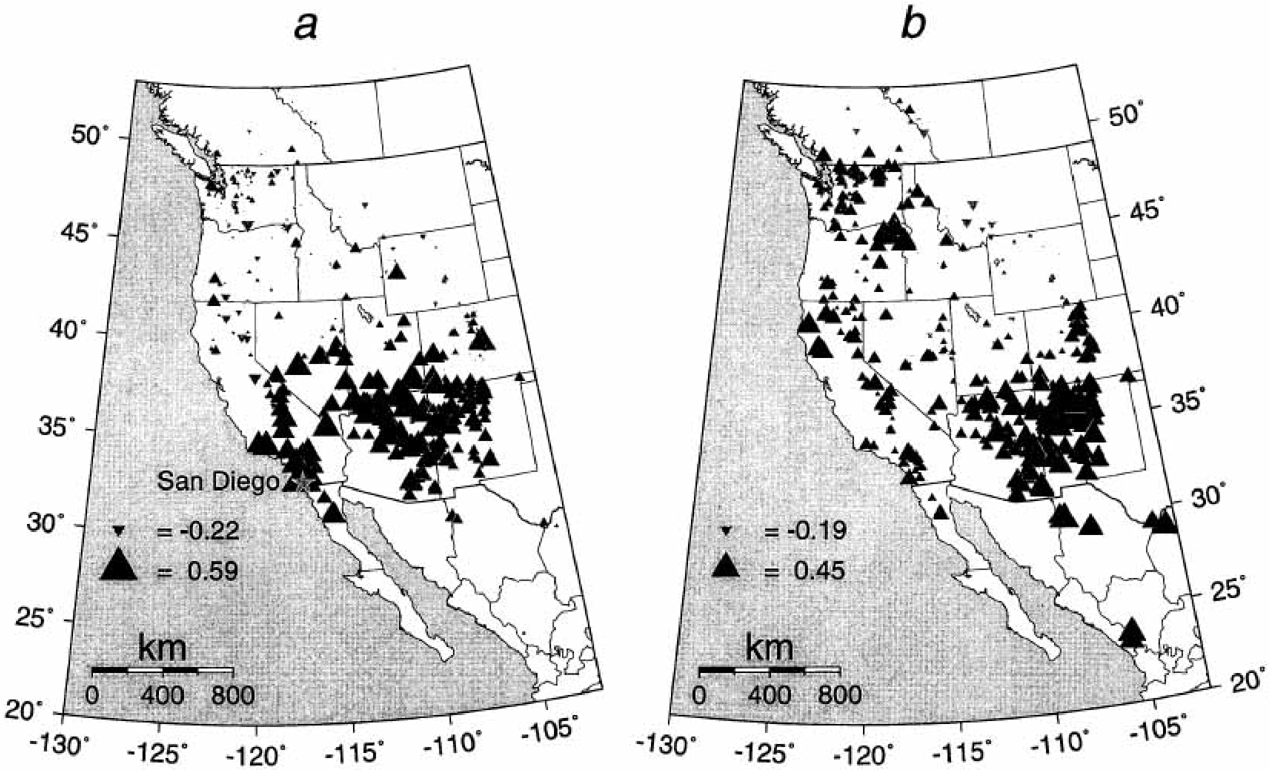


FIG. 9.—Linear correlation (r) between tree-ring chronologies and winter climatic variables. Symbol size for positive (▲) and negative (▼) correlations is directly proportional to the absolute value of r. (a) Total DJF precipitation in San Diego (1850–1994). (b) Southern Oscillation Index (SOI, 1882–1993; the sign was reversed to make El Niño years positive)

Biondi et al., 1997

The record of tree-ring width correlates well with the ENSO index ("Southern Oscillation"), that is with intensity of El-Ninyo type conditions; although the correlation is not quite as good as with precipitation in the cool seasons.

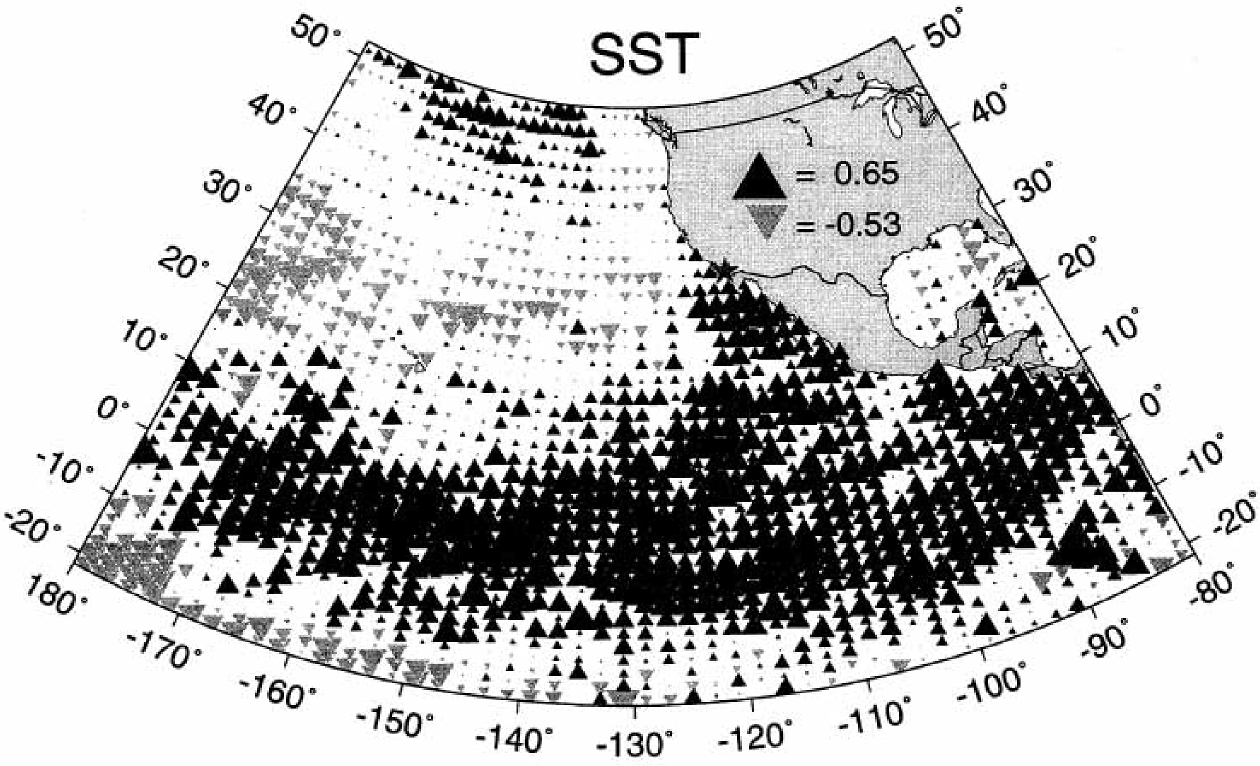
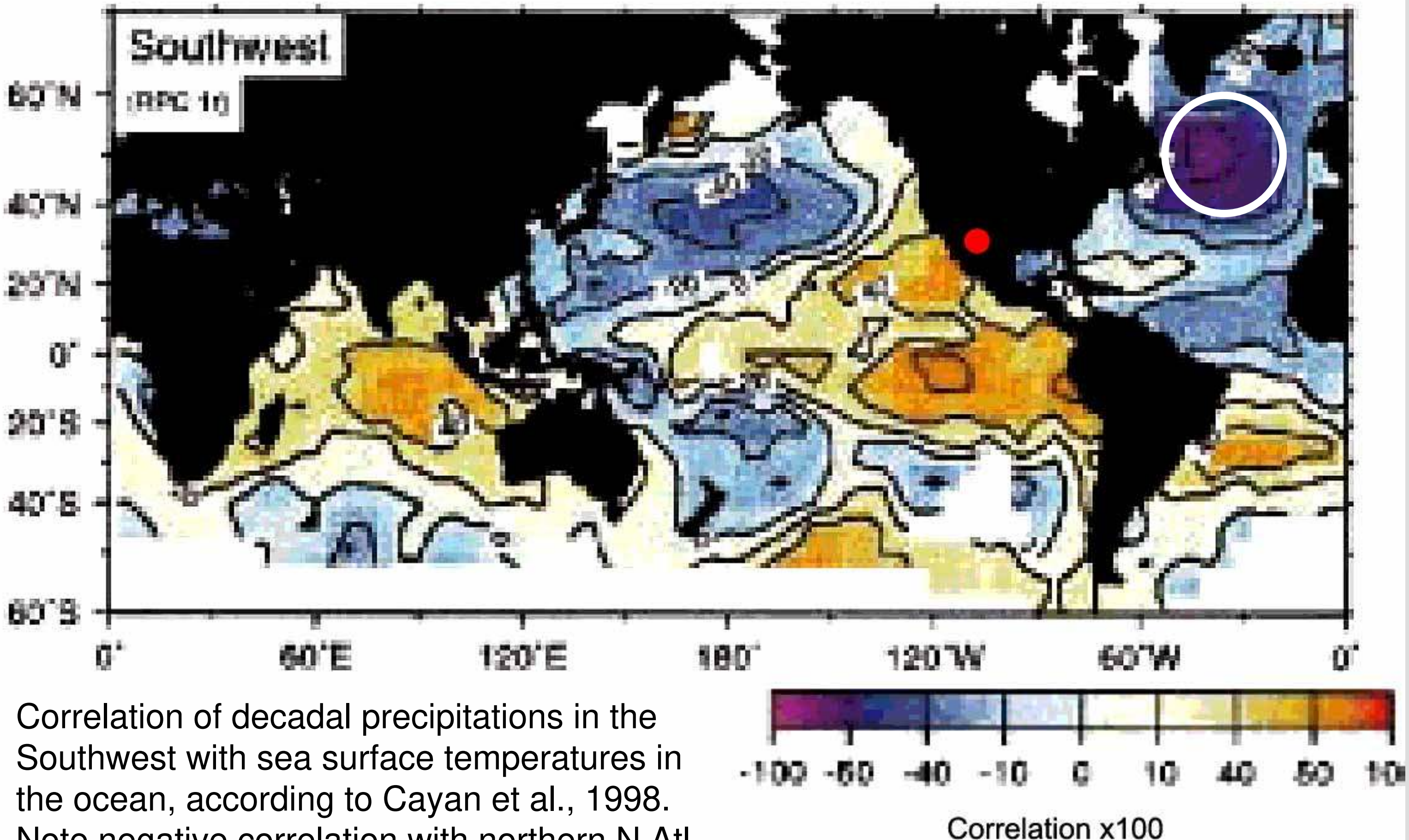


FIG. 7.—Linear correlation (r) between the Torrey pine tree-ring chronology (★) and gridded December to February mean sea surface temperature (SST) in the eastern tropical and subtropical Pacific during 1948–1992. Climate data were obtained from the Comprehensive Ocean-Atmosphere Data Set (COADS). Symbol size for positive (▲) and negative (▼) correlations is directly proportional to the absolute value of r

Biondi et al., 1997

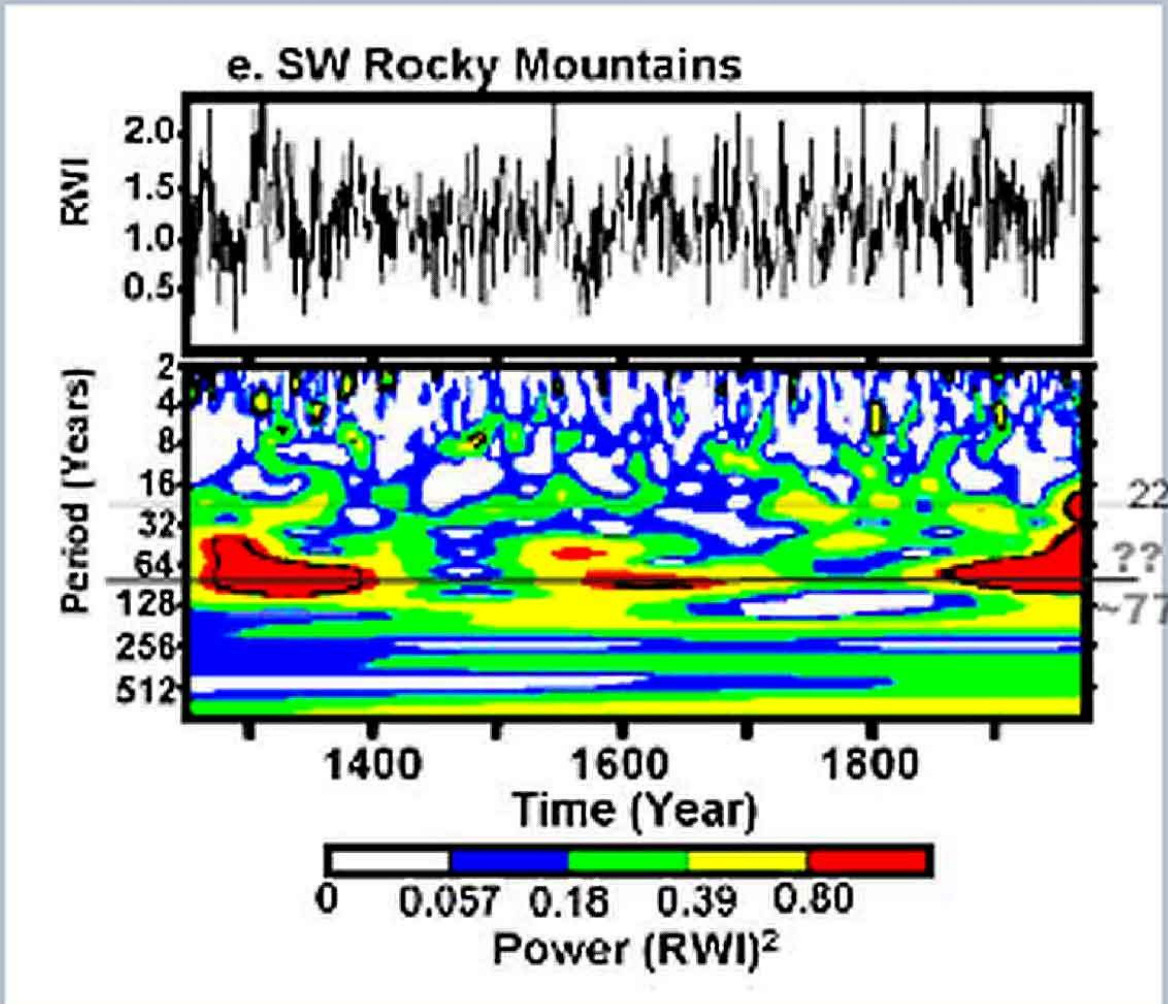
Another way of making this same point (correlating with strength of ENSO) is to look at the correlation of tree growth with the winter surface temperature in the eastern equatorial Pacific. When this region has relatively warm water, rainfall is increased and growth is strong. **Thus, the Torrey Pine records conditions in the tropical Pacific, which express themselves in rainfall in our region.**



Correlation of decadal precipitations in the Southwest with sea surface temperatures in the ocean, according to Cayan et al., 1998. Note negative correlation with northern N.Atl.

So, precipitation in our region is correlated with surface temperatures in the eastern tropical Pacific. Surprise is but modest. But: the biggest correlation of precip. in the Southwest is with the surface temperatures south of Greenland!! **We get more rain when it is cold there. Big surprise!** No one really understands why this is so.

Gray et al 2003



Tree ring width from 1250, SW Rockies
upper: straight data
lower: wavelet spectrum through time

One very intriguing aspect of these correlations between southwest precipitation and surface temperature variations in the northern North Atlantic is the **appearance of preferred periods within the records**, periods that are similar over much of the northern hemi-sphere.

The origin or origins of the preferred periodicities of variation are poorly studied and essentially unknown. One such period, near 22 y, has been noted. It looks a bit like twice the solar cycle. Or five times a tidal cycle (4.425).

Or it could be a preferred internal oscillation. **The matter is unresolved.**

What might the future hold for the Torrey Pine?

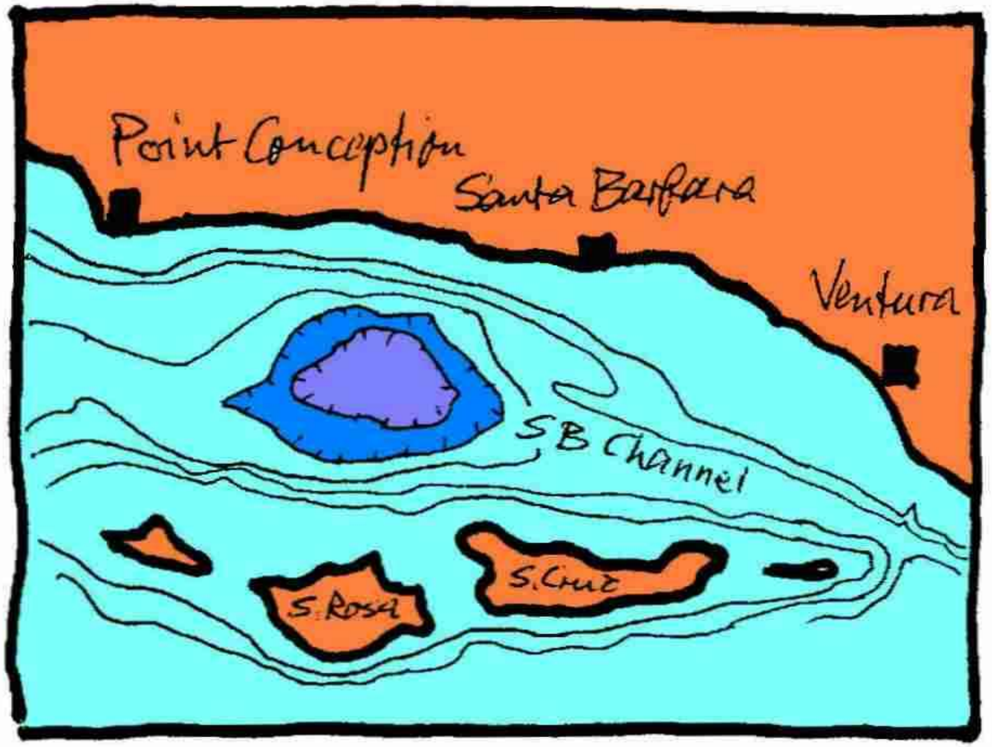
How will it respond to the local changes brought by global warming?

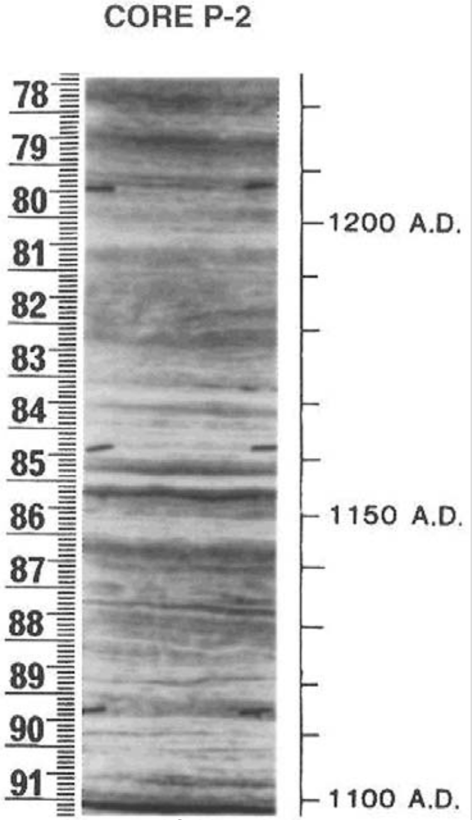
Receding glacier tongue, Columbia Ice Field, Banff/Jasper, Canada 06

Global warming is real: witness the removal of glaciers in the Rocky Mountains.

What we would like to know: how will the Torrey Pine fare with global warming. More generally, what will the Torrey Pines State Park look like, a hundred years from now?

The answer is not known, but we can make some guesses.



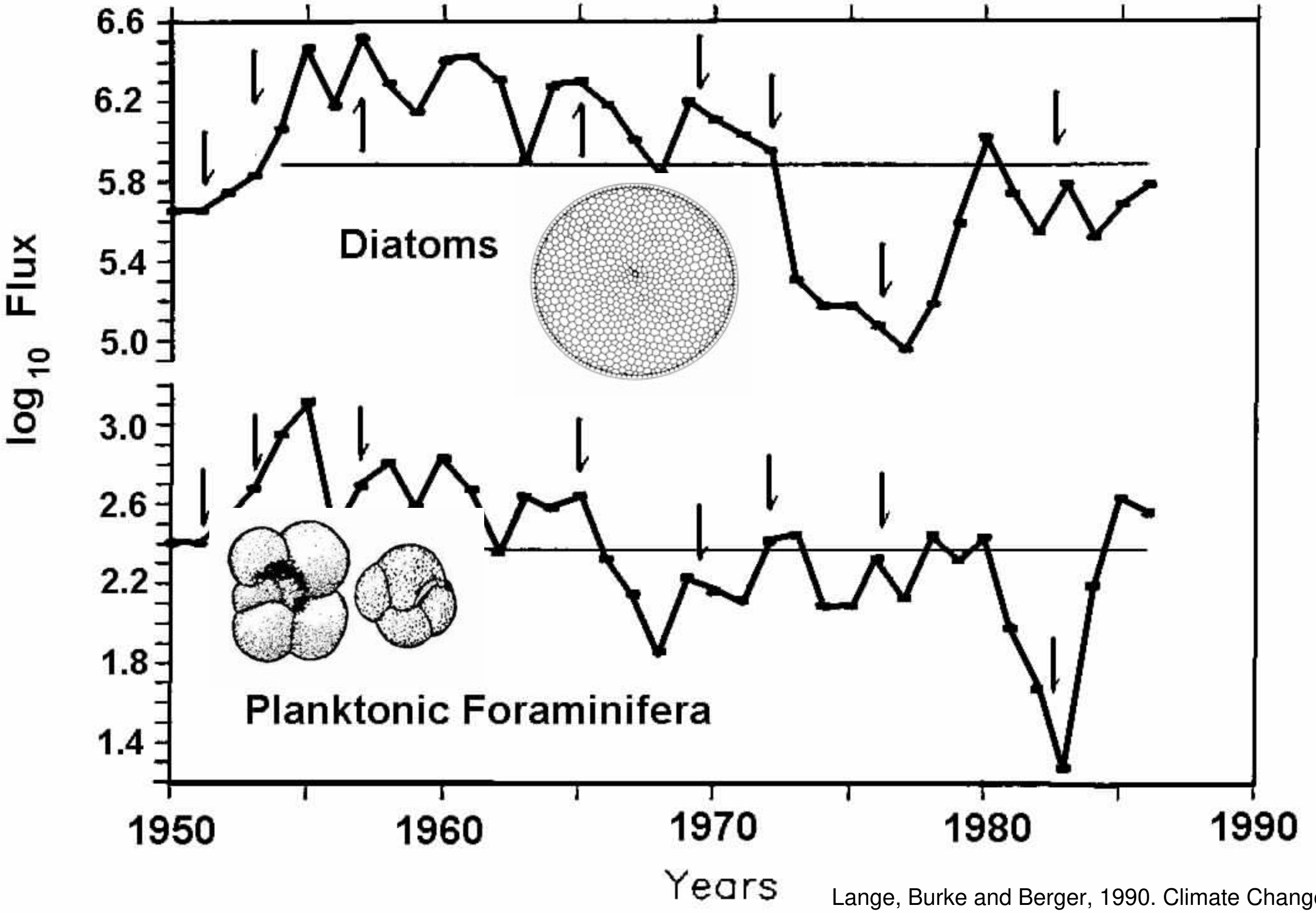


Lange and Schimmelmann, 1995

X-radiograph of a core from ODP Site 893, Santa Barbara Basin, showing fine sediment layers ("varves").

The first item is some idea of whether upwelling offshore will get stronger or weaker. If weaker, we should get more rain. This would be good for the Torrey Pine (but not so good for the seabirds and marine mammals).

There is a detailed record of thousands of years of history of the California Current not far away, in Santa Barbara Basin. The lack of oxygen prevents the stirring of the sediments, so that they are finely laminated. They contain information about the strength of upwelling in the shape of diatom content. **The diatom content has been decreasing since the middle 1970s, overall. Also, from direct temperature measurements, we know that the Current has been getting warmer, and slower.**



Lange, Burke and Berger, 1990. Climate Change.

The big drop in productivity in the (southern) California Current as seen in the sediments of Santa Barbara Basin. The system has not recovered since, so this appears to have been a regime change. (Markers denote position of El Ninyo events.)

Note the logarithmic scale: a change in 0.3 translates to a change of a factor of 2.

There is evidence that the California Current is slowing in response to general warming, and that upwelling has diminished over the last quarter century.

The associated drop in productivity is unfavorable for seabirds and marine mammals. The warming of the sea offshore should, in principle, favor the trees with more precipitation. However, warming on land also increases evaporation.

A related question is how the Park will be affected by the ongoing and continuing rise of sea level. This matters mostly in terms of the water budget in the lagoon. But it is also of great interest to the fate of the parking lot near sea level, the highway, and the future of the beach.

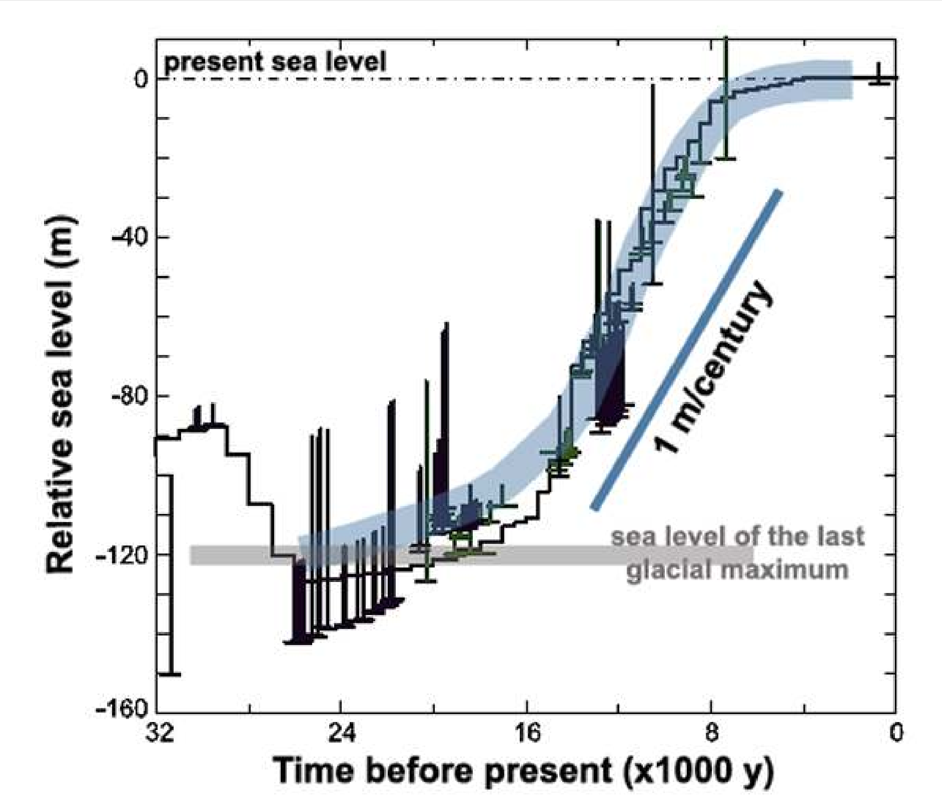
The Park extends into the lagoon to the north (Peñasquitos Lagoon).

With the continuing rise in sea level, the wetlands will expand and the tidal action will be reenforced. Also, a higher sea level will presumably lead to increased erosion along the shore. The beach will become narrower with time.

What will be the rate of sealevel rise in this century and the ones to come?

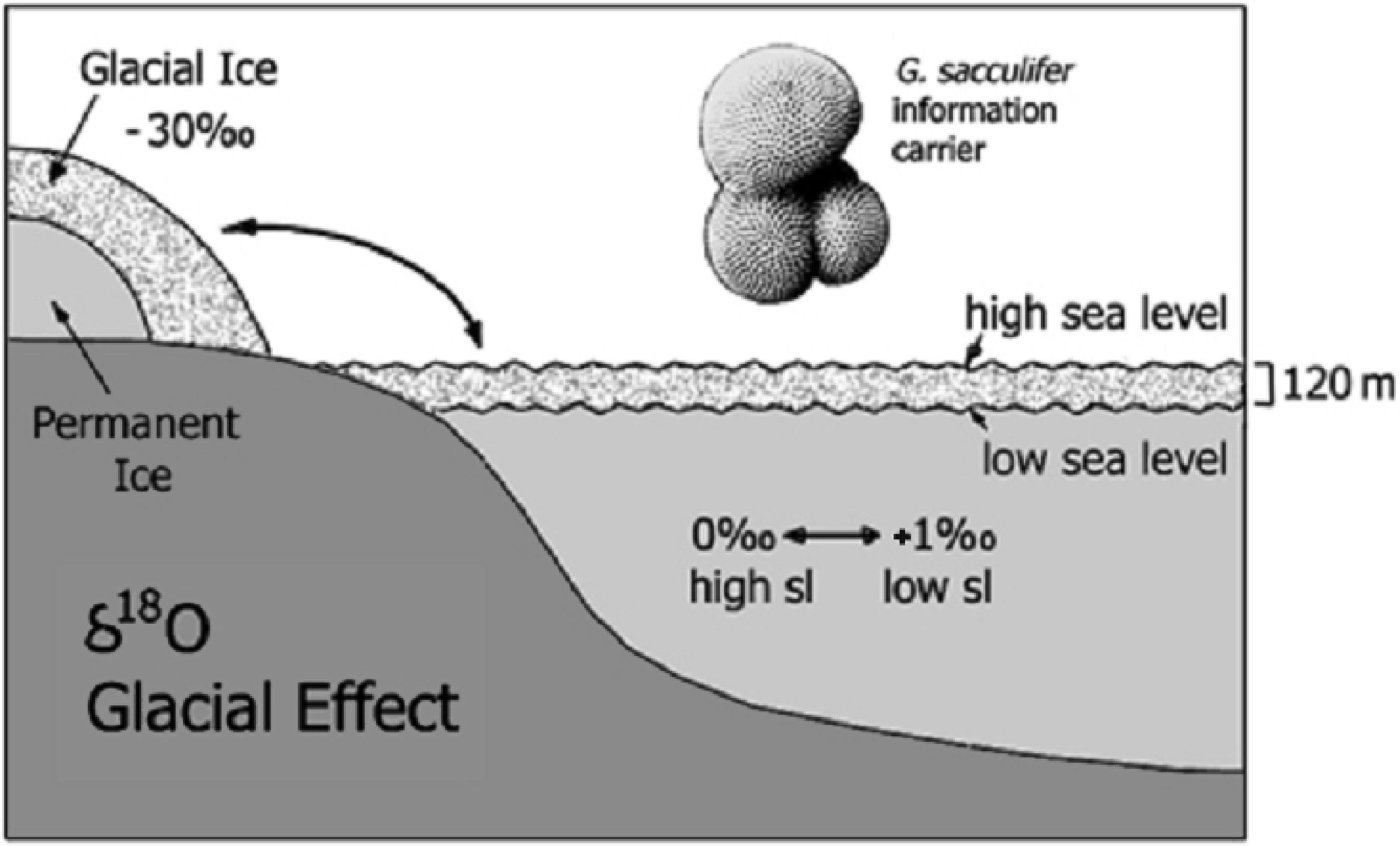
No one knows for sure. But we can obtain some clues from past behavior of polar ice.

In the past, when conditions were favorable for the melting of polar ice, sea level typically rose by 1 m per century or thereabouts. So this is a reasonable estimate for the rate to be expected, once polar ice starts melting in a serious manner. (As it has begun to do, according to some observers, in Greenland.)



Thus, we should not be surprised if sea level rises three feet or more within our century, and keeps rising over the next several centuries at a similar or somewhat higher rate.

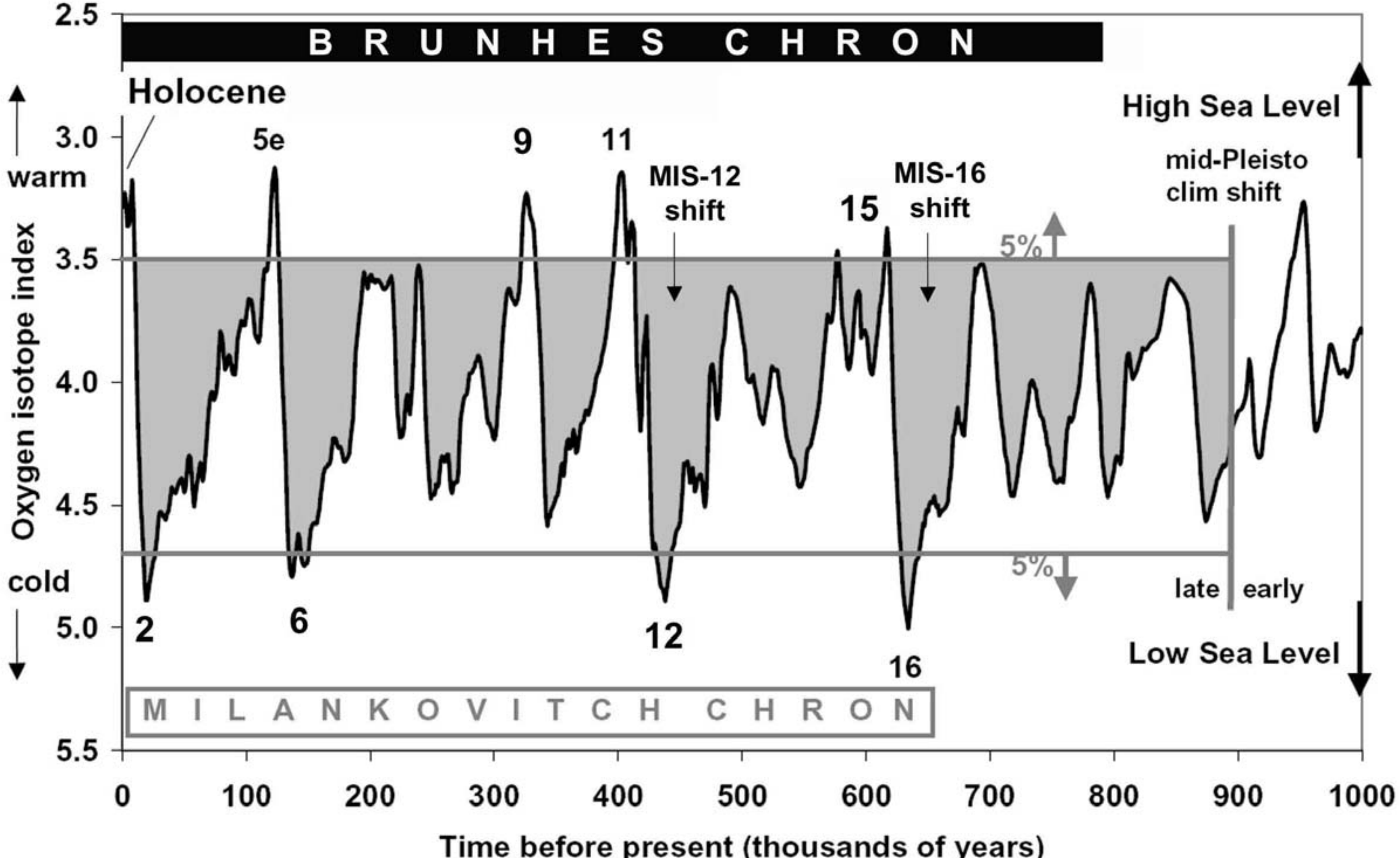
Sealevel change over the last 24,000 years according to Peltier and Fairbanks, 2006 (black lines). The typical rise during deglaciation is 1 m/century, indicating the rate at which polar ice tends to collapse when disappearing. In any one century, rates may be somewhat greater or smaller.



Seibold & Berger, 96

To confirm or reject these guesses about future sealevel rise, we can use the oxygen isotope record in the deep sea. It is based on the chemical analysis of the shells of foraminifers, such as *Globigerinoides sacculifer* (shown), a planktonic species, or others, including benthic species.

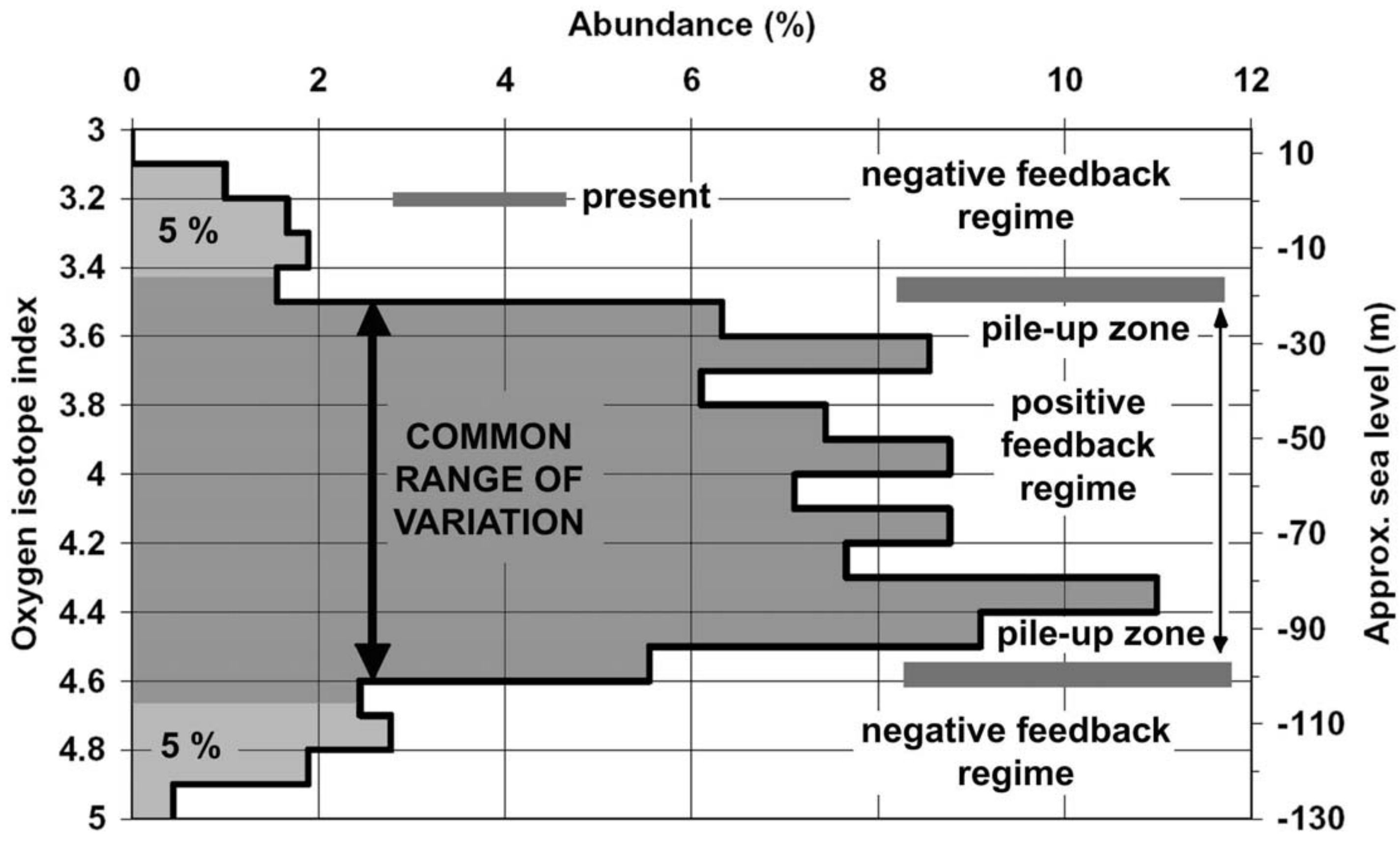
The basic idea is that glacial ice preferentially contains water (H-O-H) with the lighter isotope of oxygen (weight 16), leaving the heavier one (weight 18) to be enriched in seawater. The enrichment is seen in the shells. From this one can calculate the amount of ice, and hence the position of the sea level.



Data Zachos et al., 2001

When plotting the record of isotope change in the deep ocean (based on the analysis of benthic foraminifers) we note large fluctuations, with a period near 100,000 years.

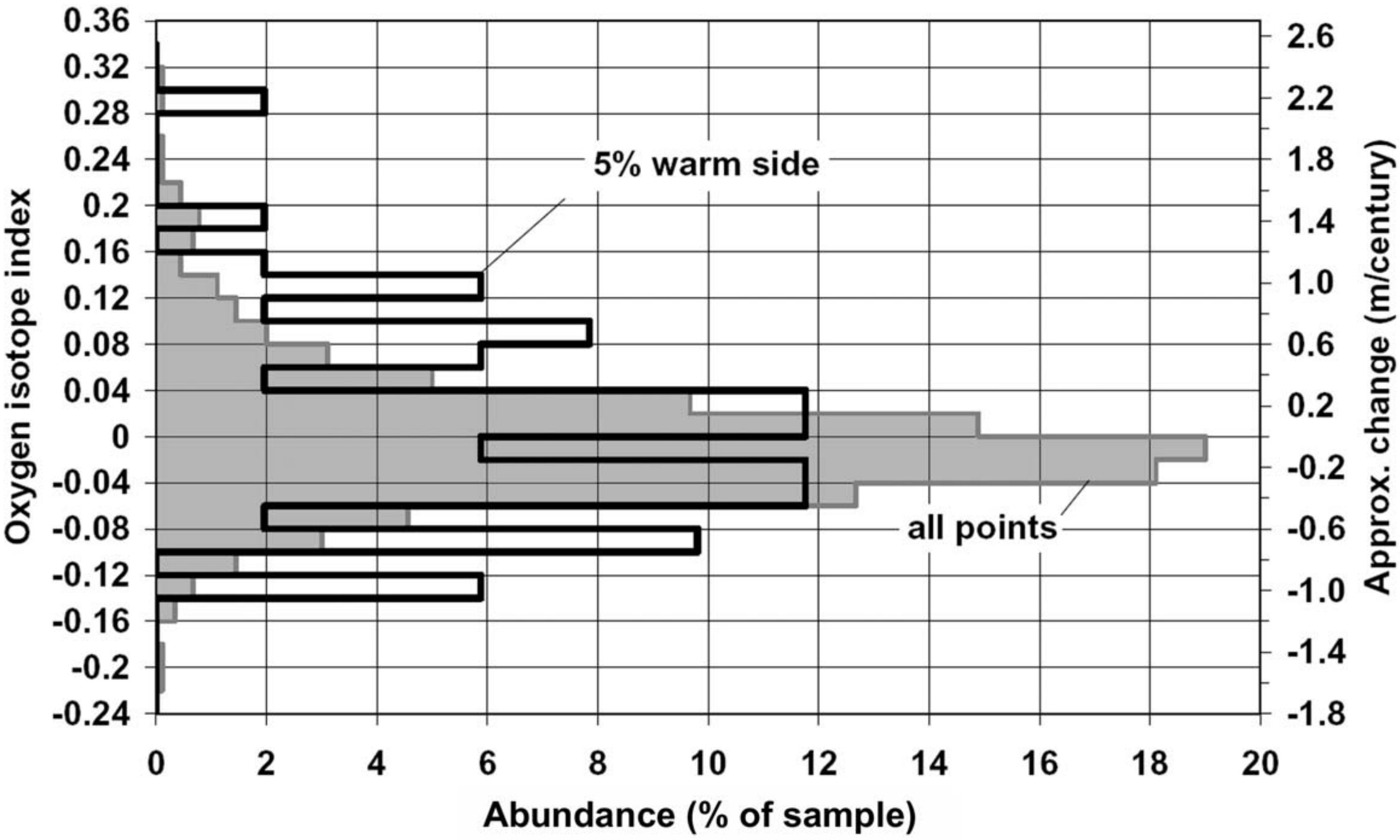
Also, we note that the sea level was as high as at present for less than 5% of the time, for the last 900,000 years. (That is, the time the climate system shifted into the present mode of operation, with severe ice ages and short warm periods.)



When converting the data for the last 900,000 years to a histogram of abundances, we note that there is a common range of variation between about -100 m and -15 m in the sealevel positions.

As the sea level rarely goes outside this range, we assume that there is one or more mechanisms trying to prevent that, which we label "negative feedback" (without specifying the nature of the mechanisms involved).

Also note that the system contains no values that would indicate a sealevel rise above the level of + 10 m. **This suggests great stability of the eastern Antarctic Ice Sheet.**



When plotting the corresponding *rates* as a histogram of abundances (axis to right), we note that a rise in sea level of more than 0.6 m/century (2 feet) is relatively rare, but that **1 m/century and somewhat greater is not *unusually* rare**. Thus, with sufficient forcing (warming, that is) we should expect such values. Interestingly, the distribution of abundances for warm times (5% of the data, pertaining to high stand of sea level) roughly follow this same distribution. In particular, high rates do not get less common during times of high sea level, as one might expect (as vulnerable ice on Greenland and in West Antarctica is used up). Instead, rates remain high till melting ends.

Antarctic shoreline in summer, Bransfield Strait, Jan 2006

Returning to the observation that sea level did apparently not rise above a level of + 10 m or thereabouts, in the last million years:

It suggests that while ice on Greenland and on the western Antarctic continent is vulnerable to melting (yielding about +10 m), the rest of the ice (the huge masses on the eastern Antarctic continent) are quite stable.

The great stability of the eastern Antarctic ice mass holds the promise that a thoroughly cold environment will persist in much of the Antarctic, for a very long time, if the addition of greenhouse gases can be curbed.

This bodes well for the survival of seabirds and marine mammals all around the Antarctic, where strong winds bring nutrients to the surface of the sea by mixing the ocean to great depth. The winds are so strong because of the presence of the ice on the southern continent.

If this analysis is correct (and it is just a guess), the Antarctic will provide a haven for seabirds and marine mammals for a long time to come, despite the overall warming.

Such are the thoughts of one geologist when looking out over the ocean, from the viewpoint of the Guy Fleming Trail, Torrey Pines State Park, San Diego County.

Enjoy the Torrey Pines Park -- there is nothing like it anywhere else!

References:

Biondi, F., D.R. Cayan, and W.H. Berger, 1997. Dendroclimatology of Torrey Pine (*Pinus torreyana* Parry ex Carr.). American Midland Naturalist, 138:237-251.

Cayan, D.R., M.D. Dettinger, H.F. Diaz, N.E. Graham, 1998. Decadal variability of precipitation over western North America. Journal of Climate, 11, 3148-3166.

Gray, S.T., J.L. Betancourt, C.L. Fastie, S.T. Jackson, 2003. Patterns and sources of multidecadal oscillations in drought-sensitive tree-ring records from the central and southern Rocky Mountains. Geophysical Research Letters, v. 30, doi:10.1029/2002GL016154.

Lange, C.B., and A. Schimmelmann, 1995. Data Report: X-radiography of selected, predominantly varved intervals at Hole 893A. Proc. Ocean Drilling Program, Scientific Results, 146 (pt.2) 333-346.

Lange, C.B., S.K. Burke, and W.H. Berger, 1990. Biological production off Southern California is linked to climatic change. Climatic Change, 16, 319-329.

Lanner, R.M., 1999. Conifers of California. Cahuma Press, Los Olivos, Ca., 274pp.

Nicol, Hank, 1981. Notes From The Naturalist. Torrey Pines Docent Society, Torrey Pines State Reserve, San Diego, Ca., 165pp.

Nicol, D.W. (Hank), 1985. Torrey Pines: Beyond The Trees. Torrey Pines Docent Society, Torrey Pines State Reserve, San Diego, Ca., 98pp.

Peltier, W.R., and R.G. Fairbanks, 2006. Global glacial ice volume and Last Glacial Maximum duration from an extended Barbados sea level record. Quaternary Science Reviews, in press.

Schoenherr, A.A., 1992. A Natural History of California. University of California Press, Berkeley, 772pp.

Seibold, E., and W.H. Berger, 1996. The Sea Floor. 3rd ed. Springer, Berlin Heidelberg, 356pp.

Zachos, J.C., Pagani, M., Sloan, L., Thomas, E., Billups, K., 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. Science 292, 686-693.