1.3°C. Dark blue and violet values in the tropical ocean indicate areas of negative MCSST skin/SST temperature differences where the skin is apparently warmer than the bulk temperature just below it. In these regions of strong solar insolation and associated skin layer heating it is feasible to have a skin layer that is warmer than the corresponding bulk temperature just below it. Added to this effect, the persistently high atmospheric water vapor content in the tropics works to lessen the cooling of the skin by restricting the outgoing long-wave radiative and turbulent heat fluxes from the sea surface. These are the processes that create the generally cooler skin temperatures at the sea surface.

This complex coupling of atmospheric conditions, solar insolation, and air-sea heat exchange is the reason that bulk-skin temperature differences must be explicitly taken into account in the calibration of satellite SST computations. In their study of meteorological measurements, collected along with skin bulk temperatures, P. Schluessel et al. (unpublished manuscript, 1989) also demonstrated, however, that over long time (> 12 hours) and space scales (> 50 km), these effects average out to yield skin and bulk temperatures that are much more coherent in their variations. Thus calibrations of satellite SST against bulk temperatures should utilize averages (in time and space) of bulk measurements rather than the most adjacent buoy SSTs in time and space. The satellite data should be averaged in space before the calibration is carried out.

Histograms of Bulk Skin Temperature Differences

The statistical distribution of the MCSST skin-/SST-calibrated temperature differences (in the cover figure) is shown here in the histograms of Figure 1. The overall mean difference is well represented by the mean value of 0.6°C for the nearly Gaussian histogram. Differences range from 2.0° to 1.8°C, with a standard deviation of 0.45°C. The histogram is shifted toward positive values, reflecting the predominantly cooler skin of the ocean's surface.

Separated into 20° latitude bands, these MCSST skin/SST differences (Figure 2) reveal some significant meridional changes. The largest offsets and widest ranges are in the tropical regions, with the greatest mean value (0.8°C) being in the southern hemisphere. The histogram of southern tropical differences deviates markedly from a Gaussian curve, with a strong bias to positive differences. The northern tropical histogram appears much more Gaussian, peaking at a value of about 0.35°C. The mid-latitude histograms are both more Gaussian in shape, with the southern hemisphere having a smaller standard deviation and a slightly higher mean value (0.75°C for the south versus 0.6°C for the north). The high-latitude histograms are both quite Gaussian in appearance, with mean values of about 0.5°C. This shift from lower to higher latitudes, in both the shapes of the histograms and in their mean differences, reflects the influence of the different climatological zones on the relationship between surface skin/SST and MCSST values.

Summary and Conclusion

Fourteen days of global infrared satellite data have been analyzed to determine the differences between sea surface temperatures calibrated against in situ buoy temperatures and those calibrated with in situ skin temperature measurements. Global differences (buoy-derived MCSST minus skin/SST) have a generally Gaussian distribution that ranges from -2.0° to 1.8°C with an overall mean difference of 0.6°C. Differences exceeding 1.0°C strongly recommend the calibration of satellite infrared measurements against in situ skin temperatures [*Schluessel et al.*, 1987] as a method of improving their absolute accuracy. An alternative suggested by the detailed analysis of P. Schluessel et al. (unpublished manuscript, 1989) is to calibrate spatially averaged satellite SSTs against temporally averaged buoy-measured SST values.

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News & Announcements

Research Ships Upgraded

PAGE 211

Two research vessels, operated by the Scripps Institution of Oceanography, University of California, San Diego, and Woods Hole Oceanographic Institution, Woods Hole, Mass., are undergoing scientific upgrading and engineering modifications costing $15 million each. The improvements will prepare them to take lead roles in major future ocean research efforts.

Research vessel *Knorr* (operated by WHOI) entered the McDermott Shipyard in Amelia, LA., on February 15. It will receive new engines and a propulsion system, and its length will be increased from 245 to 279 feet. The R/V *Melville* (operated by SIO) is scheduled for the same 10-month remodeling to begin in mid-November.

Both ships are owned by the U.S. Navy and operated by the oceanographic institutions under charter from the Office of Naval Research. They were built in the late 1960s by the Defoe Shipbuilding Corporation in Bay City, Mich., under the direction of the Naval Ship Systems Command. At the time, their design, which featured a unique cycloidal propulsion system, was considered innovative. However, along with exceptional maneuverability, came numerous mechanical failures, resulting in time-consuming and costly repairs.

After refitting, the ships will be quieter and more dependable, with an additional 20% main deck work area, 50% more lab space, and room for 10 more scientists. Also, they will feature increased fuel capacities and cruising ranges, new propulsion systems, and new antiroll systems. Other modifications will be large over-the-side handling arrangements, a new ventilation system and improved air conditioning, and a generally higher-quality working and living environment.

Upgrading of the two ships will prepare them for major research programs such as the World Ocean Circulation Experiment and the Global Ocean Flux Study. Currently, no U.S. research ships are capable of these efforts.

Meeting Report

Marine Diaries of Past Climate

PAGES 211-212

Report on the GICME Workshop

The determination of past climate from annually banded corals and other integrators of marine processes was the topic of the Geological Indicators of Climate From Marine Environments (GICME) Workshop held at the Woods Hole Oceanographic Institution, Woods Hole, Mass., May 25–26, 1988. This event, sponsored by the National Oceanic and Atmospheric Administration and U.S. Geological Survey, was attended by 22 scientists from geological, chemical, biological, and modeling backgrounds. Their primary goal was to present state-of-the-art observations made from marine organisms (i.e., corals, mollusks) and varved sediments, which record some aspect of their environment for the past few decades or centuries. It is projected that these indicators, when used in conjunction with global oceanographic models, will be useful in decadal or interdecadal climatic predictions.

As most scientists now agree that we are at the dawn of a significant greenhouse warming caused primarily by an increase in CO_2 from the burning of fossil fuels, it is crucial that we have valid integrators of past climate to assist prediction of future climate. Although paleoceanographers have identified the forcing functions that cause the glacial-interglacial cycles (external orbital changes, 10^4- to 10^6-year time scales), far less is known about the forcing mechanisms of climate changes observed on shorter time scales (> 1–10^4 years). Two climatic phenomena of general scientific importance are El Niño/Southern Oscillation (ENSO) and the "Little Ice Age," which spanned 1300–1800 A.D.

Corals provide continuous records as long as 10^3 years (and potentially longer), with resolution on the scale of months or seasons, whereas mollusks reveal shorter-term records (< 150 years) with a much higher level of resolution. The longevity of reef corals and the wide latitudinal and environmental distribution of many mollusks allow for collection of environmental data on both temporal and spatial scales that can provide realistic constraints for global models as they are developed and tested.

Table 1 summarizes some of the proxy indicators obtained from corals and mollusks and the resolution of these records. The main emphasis by members of the workshop was on corals. J. Harold Hudson earmarked the existence of occasional "stress bands" in Florida corals, which occurred simultaneously with cold fronts that passed through the area over the past 150 years (see Figure 1). Richard Dodge used skeletal extension growth rates of reefs off the southeastern coast of Florida to monitor anthropogenic impacts such as excessive sedimentation on the reefs.

Climatic information can be extracted from variations in the stable isotopes of carbon (^{13}C and ^{12}C) and oxygen (^{18}O and ^{16}O) in the aragonite (calcium carbonate) matrix. Gerard Wellington and coworkers reported long-lived temperature excursions in the eastern tropical Pacific from 1583 to 1910 A.D. from the $^{18}O/^{16}O$ stratigraphy of a large colony of *Pavona clavus* from the Urvina Bay uplift. Peter Swart analyzed a 6000-year-old coral from the Dominican Republic and concluded that a trend toward lower ^{18}O values was caused by either an increase in water temperature or evidence of increased freshwater runoff.

Julie Cole and Rick Fairbanks demonstrated that the ^{18}O record from a western equatorial Pacific coral primarily reflects the intense rainfall associated with ENSO events. The influx of isotopically depleted rainwater produced ^{18}O anomalies about $-1‰$ during ENSO years and suggested the ability to retrieve a long record of ENSO variability from this little-studied region.

TABLE 1. Proxy Indicators Obtained From Corals and Mollusks

Proxy (References in Parentheses)	Parameter	Resolution
	Chemical Parameters	
$\delta^{13}C$ (1)	light	monthly
$\delta^{18}O$ (1)	temperature/salinity	monthly
$\Delta^{14}C$ (2)	circulation, CO_2	monthly
^{90}Sr (3)	bomb fallout, circulation	seasonally
Cd/Ca (4)	nutrients, (PO_4)	seasonally
fluorescence (5)	humic materials from freshwater runoff	biweekly
	Growth Parameters	
extension (6)	various (temperature, light nutrients)	monthly
density		
mass		

Maximum length of records for corals is $>10^3$, and for mollusks it is about 150 years.

Suggested references: (1) *Fairbanks and Dodge* [1979], *McConnaughey* [1988]; (2) *Druffel* [1987]; (3) *Toggweiler and Trumbore* [1985]; (4) *Shen et al.* [1987]; (5) Isdale [1984]; and (6) *Wellington and Glynn* [1983], *Dodge and Brass* [1984].

Compelling evidence of changing oceanographic and climatic processes is found in Cd/Ca ratios in corals. Glen Shen reported that levels of Cd, a nutrient proxy, increased in Galapagos coral bands from 1600 to 1850 A.D., which would require dramatic changes in wind stress to enhance equatorial divergence.

Ellen Druffel presented high-precision radiocarbon analyses in a coral from the southern Great Barrier Reef that imply substantial shifts in circulation on decade time scales during the last stage of the Little Ice Age (1690–1760 A.D.). The Cd/Ca data and $\Delta^{14}C$ measurements suggest that higher-frequency climate variability (e.g., ENSO) may be modulated by the longer-term occurrence of the Little Ice Age. Longer-scale perturbations of the CO_2 cycle would be expected during this period, in contrast to the short-time-scale CO transients observed during recent ENSO events [*Bacastow*, 1980]. Glenn Jones illustrated how development of accelerator mass spectrometry (AMS) is making it easier to obtain radiocarbon results quickly on samples of milligram size.

Another climate proxy is obtained from analyzing the timing and intensity of fluorescent bands, caused by fulvic and humic compounds from terrestrial runoff, in long coral cores. Peter Isdale (Australian Institute of Marine Sciences, Townsville, Queensland) showed long-term trends in annual rainfall/runoff from 1735 A.D. for an area of Northern Australia whose climatic characteristics are presently correlated with the Southern Oscillation Index and ENSO. Thomas J. Smith, University of Florida, Gainsville, noted that the intensity of fluorescent banding in a coral colony from Petersen Key in Florida Bay had decreased from 1912 to 1931 A.D., corresponding with the construction of drainage canals that diverted runoff from the bay.

Douglas Jones presented evidence showing that the $^{18}O/^{16}O$ profiles in modern bivalves track yearly temperature cycles, while $^{13}C/^{12}C$ reflects the seasonal cycling of nutrients on the eastern coast of the U.S. From fossil mollusk isotope records, David Krantz showed that the Atlantic Shelf was mild temperate during the early Pliocene, shifting to warm temperate during the middle and late Pliocene transgressions, and once again mild temperate by the early Pleistocene. Lawrence Peterson discussed anoxic sediment records from the Cariaco Trench and the usefulness of various parameters, such as sedimentation rate, foram abundances, and lamination development, as recorders of climate change during the last deglacial period.

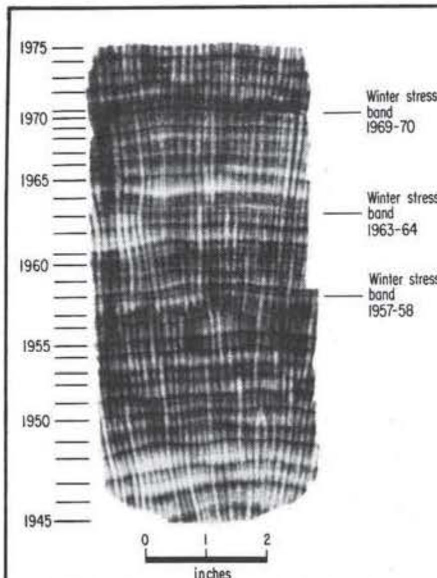

Fig. 1. X ray positive of a slab (4 mm thick) of *Montastrea Annularis* coral collected from The Rocks reef off the Florida Keys in 1975. High-density (dark) bands represent coral accretion during June–September, low-density bands during October–May, and additional dark bands or "stress bands" accrete during unusually cold winters [*Hudson et al.*, 1976]. These stress bands are apparent for the winters of 1957–1958, 1963–1964, and 1969–1970, and less pronounced for the winter of 1960–1961.

The availability of long coral cores, precise chronologies, and numerous tracers is providing the most detailed look at surface ocean history yet assembled. Questions concerning interactions between the atmospheric record, for which good data bases exist (e.g., northern hemisphere temperatures, ice-core data, tree-ring data), and the world oceans, for which long-term proxy data are now becoming available from both temperate and tropical oceans, provide an area of focus between the modeling community and the rapidly expanding group collecting information on oceanic conditions over a scale of tens to thousands of years.

A major consensus among the workshop participants was that it would be most fruitful to pursue two aspects of the climate record: ENSO and the Little Ice Age. Extending these capabilities further into the Holocene and back through the last glacial period is now possible using mass spectrometric methods for determining ^{230}Th abundances in corals [*Edwards et al.*, 1987].

Participants of the GICME Workshop were Julie Cole, Lamont-Doherty Geological Observatory, Palisades, N.Y.; Bill Curry, Woods Hole Oceanographic Institution, Woods Hole, Mass.; Richard Dodge, Nova University, Dania, Fla.; Ellen Druffel, Woods Hole Oceanographic Institution; Rick Fairbanks, Lamont-Doherty Geological Observatory; Bill Graham, National Oceanic and Atmospheric Administration, Rockville, Md.; Bob Halley, U.S. Geological Survey, Woods Hole, Mass.; Kirby Hanson, NOAA, Miami, Fla.; Dennis Hubbard, Fairleigh Dickinson University, West Indies Laboratory, St. Croix; J. Harold Hudson, USGS, Miami, Fla.; Peter Isdale, Australian Institute of Marine Science, Townsville, Queensland, Australia; Douglas Jones, University of Florida, Gainsville; Glenn Jones, Woods Hole Oceanographic Institution; Lloyd Keigwin, Woods Hole Oceanographic Institution; David Kranstz, University of South Carolina, Columbia; Larry Peterson, Rosenstiel School of Marine and Atmospheric Science, Miami, Fla.; Glen Shen, Lamont-Doherty Geological Observatory; Tom Smith, University of Florida, Gainsville; Bill Sprigg, NOAA, Rockville, Md.; Peter Swart, Rosenstiel School of Marine and Atmospheric Science; and Gerard Wellington, University of Houston, Tex. Copies of the GICME Workshop report are available from Hartley Hoskins, Woods Hole Oceanographic Institution, Woods Hole, MA 02543.

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This report was contributed by Ellen Druffel, Woods Hole Oceanographic Institution, Mass.

Meetings

Snowbird II: Global Catastrophes

PAGES 217-218

Introduction

Recently, on a National Public Radio retrospective on American life a quarter-century ago, a commentator remarked that 1963 was one of the last years when we knew that the dinosaurs died out "because they were stupid, just plain too stupid," and not due to some exotic mechanism. In 1989, catastrophic causes still reign supreme. Yet, in the public's mind, the controversy has not yet been settled: was it an asteroid, explosive volcanism, or a comet shower? Technical debates have raged since the late Luis Alvarez, his son Walter, and their Berkeley coworkers distributed preprints nearly a decade ago of their seminal paper [*Alvarez et al.*, 1980] on the extraterrestrial cause for mass extinctions at the end of the Cretaceous Period. A recent conference, Global Catastrophes in Earth History, has shown that the debate is now mainly over. The meeting was held October 20–22, 1988, at Snowbird, Utah, and hereafter I refer to it as the "Snowbird II meeting."

An earlier (October 1981), smaller meeting, also held at Snowbird, first brought together scientists from diverse disciplines to discuss possible causes for the Cretaceous-Tertiary (K-T) extinctions. At that pivotal "Snowbird I" meeting, I witnessed the remarkable interplay between radiochemists and paleontologists, between palynologists and planetary scientists. Everyone could see and evaluate the disparate evidence that argued for, or against, the Alvarez hypothesis. The asteroid-impact hypothesis emerged from Snowbird I as a substantial challenger to more conventional ideas, or so it seemed to me with my background of research on planetary cratering and on asteroids. Certainly everyone left chastened by new perspectives from the cross-disciplinary interactions. After seven years of new data, new twists, and continued debate in the literature, the time was ripe for the Lunar and Planetary Institute to reconvene all the players.

Since Snowbird I, there have been studies of more K-T sites, of other major extinctions, and of new ideas about the environmental responses to impacts and their biological consequences, beyond the original concept of a year of darkness and starvation. An impressive array of evidence has added credence to the impact hypothesis, as summarized by *Walter Alvarez* [1986] in these pages and by Luis Alvarez the year before he died [*Alvarez, L.W.*, 1987]. But, during the interim, there have also been some hold-outs who have disputed the data and interpretations of the majority and who have argued that the K-T extinctions were due mainly to some other terrestrial cause, probably volcanism [cf. *Officer and Drake*, 1985].

Snowbird II was structured to provide an opportunity for opponents to the tentative conclusions of Snowbird I to plead their case for volcanism and against impact. The mainstream scientific community, however, has moved beyond that debate to address the fascinating and fundamental questions of how the impact affected the ecosystem, and just where was the impact, and how big was the role of impacts in other mass extinctions since the Cambrian. For them, Snowbird II provided the chance for a detailed assessment of the data and calculations from the past several years of research about just what happened 65 m.y. ago. Few totally new results were presented at Snowbird II, but much seemed new to attendees who had not kept abreast of the literature in all the disciplines. Most of the 200 registrants were transfixed in their seats throughout the three-day program, some later calling it one of the best meetings they had ever attended. The participants overruled the program committee by insisting on almost unlimited discussion, which carried sessions into the evenings and elucidated many disputed issues.

Snowbird II began on an open-minded note. Karl Flessa (University of Arizona,Tucson, and National Science Foundation) presented three separate, contrasting introductions, one arguing dogmatically for impact-driven extinctions, the second for gradual extinctions induced by volcanism and other continuous processes, and a third for stepwise extinctions due to a comet shower or other complex causes. The meeting was structured to provide opportunities for all perspectives to be presented, including the volcanic alternative to the impact theory.