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EARTH SYSTEM MONITOR

A guide to NOAA's data and information services

INSIDE

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

Marine animals as oceanographic data collectors

New electronic tags open further avenues to autonomous data collection

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The miniaturization of electronic components and sensors has improved technology for ocean and atmospheric sampling as well as in other related fields. Small, electronic tags, for example, have enabled research on the behavior and movements of oceanic animals, leading to remarkable new insights about their physiology, biology and use of the ocean environment (Costa, 1993). Electronic tags encompass a range of technologies, including simple transponder tags to identify individual animals, telemetering acoustic or radio tags to track or monitor animals directly or with remote recording stations, and archival tags, which record and store data from various sensors for retrieval when the animal is recaptured. Newer versions may also transmit these data via satellite.

If properly instrumented, calibrated and archived with suitable metadata, there is no reason that these data cannot be used for broader oceanographic purposes. Two issues have hindered the widespread use of such "biological autonomous" oceanographic data collection. First, unless data are telemetered by satellite, the animal must be recaptured in order to make use of the data contained in the tag. Adequate recapture rates require deployment either in large numbers

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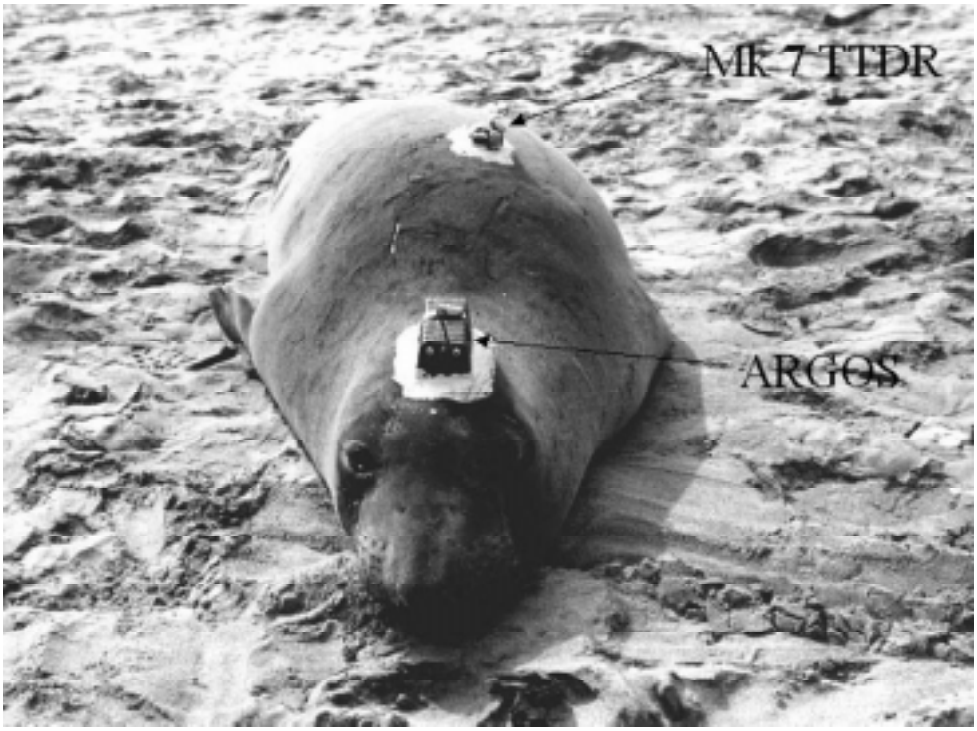

▲ **Figure 1.** Adult female elephant seal with ARGOS satellite transmitter and time-temperature-depth recorder attached. Observations of behavior at sea suggest that only the head is out of the water, so the location of the TDDR on the back means that it is submerged during surface behavior; thus, temperature measurements reflect ocean temperature.

Marine animals, *from page 1*

(with concomitant expense) or on animals with a high likelihood of return. Return rates have been relatively high for animals with homing behavior and low mortality rates, such as certain marine mammals or sea turtles.

Determination of the position where data were collected is the second problem that must be overcome; for many tags, geographic position is poor or lacking. Tags able to record geoposition are generally too large except for very robust animals. Data recording tags placed on many fish, for example, have had no mechanism to determine position with the exception of tagging and recovery locations. Archival tags with light sensors that estimate longitude (from time of sunrise or sunset) and latitude (from day length) have been applied to several species, but the locations typically have relatively large theoretical variances. A more recent development, which partially addresses both return rate and location information is the "pop-up" tag, programmed to release from the animal after a preset time and then to transmit its data to a satellite (Block et al., 1998). While the data volume transmitted by these tags is limited to a recent series of temperature-depth profiles, the technology is improving; moreover the tags can be programmed to continue transmitting SST data for 30 days (Lutcavage et al. 1999).

An excellent candidate for an animal to collect oceanographic information is the northern elephant seal (see Figure 1). From California rookeries, this species ranges widely over the northeastern Pacific on foraging trips that last from 2 to 9 months. Migration patterns differ between the sexes; females may migrate throughout the northeastern Pacific, while males migrate to destinations along the continental margin from coastal Oregon north to the Aleutian Islands. Females are at sea on average 3 months during the spring migration and 7 months during the summer-fall migration. Adult females increase their body mass during both migrations, the second of which includes gestation. Northern elephant seals dive continuously, exhibiting extremely long duration dives (mean = 22 min., max =120 min.) with short surface intervals (1-3 min). Dives are routinely to 600 m, with dives as deep as 1600 m (see Le Boeuf et al. 2000).

Research on northern elephant seals has been carried out to learn about the animal's ecology and how it uses the ocean environment. With additional funding from NOAA's ESDIM program, we evaluated data taken from sensors carried by northern elephant seals for inclusion in the World Ocean Database (WOD, Levitus et al. 1998). Between March 1998 and March 1999, 6 female and 3 male elephant seals were tagged in central California with time-temperature-depth recorders (TTDR) and ARGOS platform terminal transmitters set to collect data during subsequent foraging trips. Temperature and depth were measured and stored every 30 sec and retrieved after the animals returned to the rookery months later. Portions of the tracks where both ARGOS and TTDR data were available from these 9 animals averaged 4634 km over 67 days with 2.4 ARGOS positions per day. Mean dive duration was 20 min and mean dive depth was 428 m.

Temperature and depth profiles from the instruments were compared with CTD casts, and the results showed that accuracy is at least comparable to data from XBTs. Comparing seal-collected temperature profiles and surface temperature with other sources of in situ data likewise showed very good agreement. Data were quality controlled and entered into the World Ocean Database (WOD). A total of 75,665 autonomous pinniped bathythermograph (APBT) profiles over the 41,702 km of seal trackline were added to the WOD (see Figure 2). These results were recently published in the Journal of Atmospheric and Oceanic Technology (Boehlert et al. 2001) and data are now available in the latest version of the WOD (Conkright et al. 2002).

Autonomous samplers, such as the northern elephant seal, have immense

— continued on page 4

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EARTH SYSTEM MONITOR

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DMSP gas flares presentation

NGDC's Chris Elvidge provided a presentation on the monitoring of changes in gas flaring associated with oil and gas production. This was given on April 15, 2002 at the Global Gas Flaring Reduction Initiative Workshop held in Oslo, Norway.

The workshop was organized by the Oil, Gas and Chemicals Department of the World Bank and the Government of Norway. A number of countries have agreed to reduce the emissions of carbon dioxide from gas flaring as part of the Kyoto Protocol. The workshop brought industry and government together to review the reduction plans and discuss how to evaluate /confirm the reductions.

The Defense Meteorological Satellite (DMSP) presentation showed how gas flares can be detected in various arts of the world and how the size and brightness of the flares can be used as an indicator of changes in the quantity of gas flaring. Examples of DMSP gas flaring detection were given from Mexico, Brazil, China, Russia, Egypt, Syria, Algeria, and Nigeria.

Economic value of NESDIS products meeting

The first phase of a contractor-led effort to provide NESDIS with information on the economic value of its data and products was conducted at the National Climatic Data Center during April 10-12. Contractors from Centrec Consulting Group (CCG), conducted a site visit to become more knowledgeable about the NCDC data and information. They also discussed possible case studies to document the economic impacts of specific climate products. CCG will also visit the other data centers as part of this effort. A final report will be produced by Centrec in November of this year.

MODIS observes iceberg calving

Moderate Resolution Imaging Spectroradiometer (MODIS) imagery from February 10,2002, revealed a large crack in the Thwaites Ice Tongue, located in the Antarctic's Amundsen Sea. NSIDC scientist Ted Scambos alerted analysts at the Navy/NOAA/Coast Guard National Ice Center, who subsequently confirmed the calving of Iceberg B-22.

News briefs

Sunspots galore

Earth's environment could be affected by the current sunspot activity. Presently, there are a dozen active regions of which three have twisted delta-class magnetic fields. These harbor enough energy for X-class solar flares. A fourth region has a beta-gamma magnetic field that poses a threat for M-class flares. Holographic images showing the far side of the Sun revealed, in advance, a substantial sunspot group that rotated onto the visible solar disk a week later.

A partial halo coronal mass ejection occurred on 10 April 2002. While we are expecting to see solar activity begin its long decay to solar minimum by 2006, the Sun continues to surprise with bursts of extended activity.

NSIDC Director receives award

In March 2002, the Mountain Geography Specialty Group of the Association of American Geographers honored NSIDC Director Roger Barry with a Lifetime Achievement Award for 2002, the International Year of the Mountain. Dr. Barry's work with his book "Mountain Weather and Climate," dedication to the discipline, mentoring of dozens of students, and participation in international organizations and editorial boards around the world were the primary bases for his receiving of the award.

Press release on winter climate

In association with the National Climatic Data Center's December thru February 2001/02 State-of-the-Climate Report, a press release on U.S. and global seasonal climate statistics was issued by the National Oceanic and Atmospheric Administration on March 14, 2002. The December-February season was the 5th warmest on record in the U.S. and the 2nd warmest globally. A warmer and drier than normal winter season led to worsening drought conditions along much of the eastern seaboard from Maine to Georgia as well as a large part of the western U.S. The winter of 2001-02 was the warmest on record in ten states and three states recorded their driest winters since records began in 1895.

Antarctic ice shelf collapses in largest such event of last 30 years

On March 18, 2002, NSIDC and the University of Colorado, in conjunction with the British Antarctic Survey and the University of Innsbruck, issued a press release announcing the disintegration of the Larsen B Ice Shelf. Between January 31 and March 5, 2002, approximately 3,250 square kilometers of the ice shelf shattered, sending a plume of icebergs into the Weddell Sea. NSIDC scientist Ted Scambos monitored the breakup using satellite imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra Satellite.

Articles covering the breakup event appeared in The New York Times, The Los Angeles Times, The Washington Post, The London Daily Telegraph, and on the Reuters and Associated Press news services, where the news was picked up by regional newspapers around the world. Scambos gave several interviews, and appeared on ABC's Nightline and CNN Moneyline.

For the University of Colorado press release, see "Antarctic Ice Shelf Collapses in Largest Event of Last 30 Years" at *http://www.colorado.edu/PublicRelations/NewsReleases/2002/1683.html*. For the NSIDC news release, see "Antarctic Ice Shelf Collapses" at *http://www.nsidc.org/iceshelves/larsenb2002/index.html*.

USGCRP highlights Climate Time Line

The U.S. Global Change Research Program (USGCRP) website has linked to the Climate Time Line (CTL) through their "New Recent Internet Postings Related to USGCRP Focus Areas." The CTL is currently under development by science educators at the University of Colorado and NOAA as a tool for exploring the complex world of climate science and history. The CTL's basic design is an interactive matrix that uses the powers of ten approach to frame climate information at varying time scales.

For more on the USGCRP listing, see *http://www.usgcrp.gov/usgcrp/new.htm#paleo*. To visit the CTL development site, visit *http://www.ngdc.noaa.gov/paleo/ctl*.

Marine animals, *from page 2*

potential to contribute oceanographic data in a cost-effective manner; estimated cost per APBT, including personnel time to deploy and recover instruments, is less than a dollar (Boehlert et al. 2001). Research programs exist on an expanding variety of species, including southern elephant seals, tunas and billfish, sharks, seabirds, and whales. A major scientific undertaking called the "Census of Marine Life" (CoML; Ausubel 1999; see also *www.coml.org*) views electronic tags as an important new technology. Two current CoML pilot projects, called "Pacific Ocean Salmon Tracking" and "Tagging of Pacific Pelagics" are focused on use of electronic tags. With continued miniaturization, improvements in sensor technology, and geolocation techniques, more of these data will become appropriate for use in oceanographic studies.

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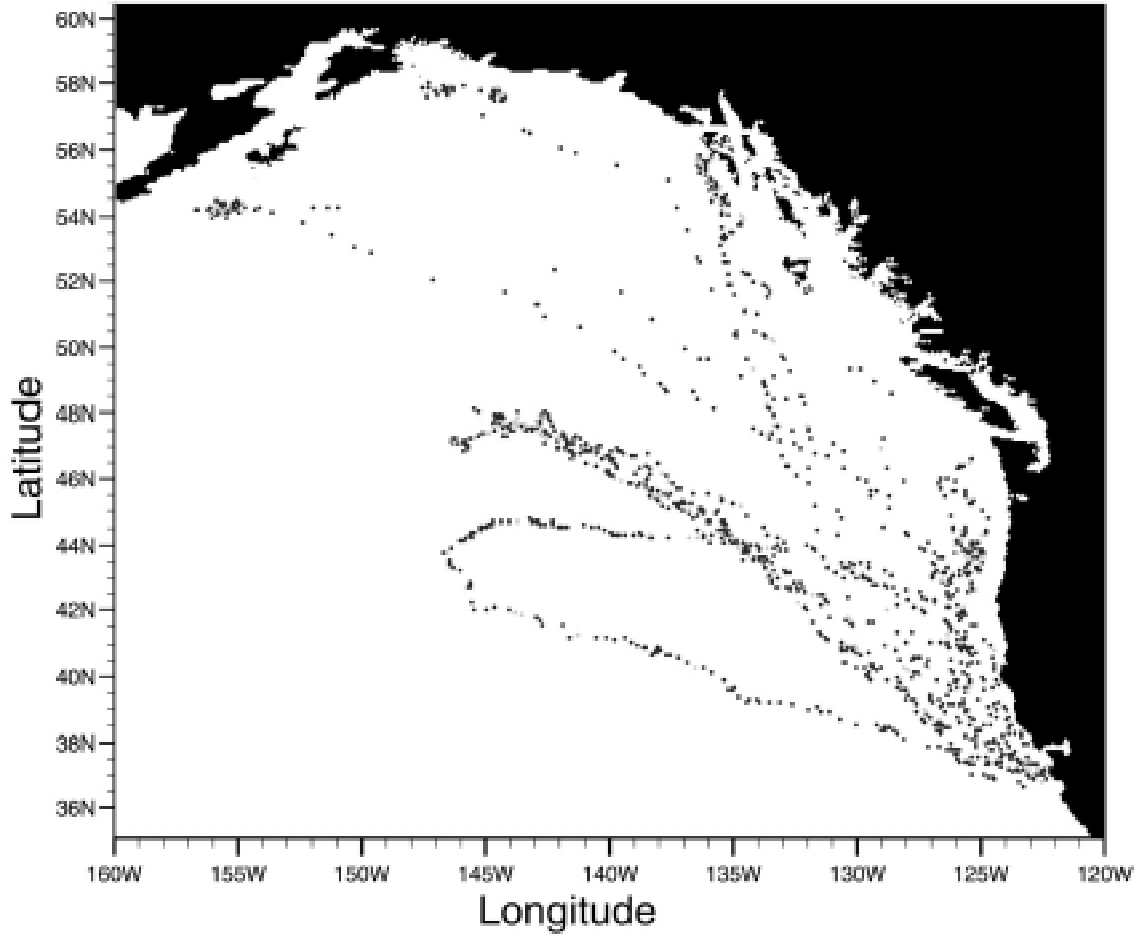

▲ **Figure 2.** Distribution of autonomous pinniped bathythermographs (APBT) added to the World Ocean Database. Shown are locations of those profiles with an associated ARGOS location, representing 1478 APBTs. The number of profiles added is 75,665.

Communities of bacteria

A metric for evaluating restoration of degraded coastal wetland habitat

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Wetlands are complex ecosystems that are often modified by navigation or dredging channels, filled for development, or drained for pasture land. Coastal wetlands are particularly vulnerable to loss because of their proximity to an estuary, lake or to the sea. Losses in the northwest are commonly between 50 and 90% in an individual estuary (Boule and Bierly 1987). These figures are troubling, especially if one considers that the economic value of services provided by wetlands was estimated at US $33 trillion per year (Costanza et al 1997).

The ultimate goal of habitat restoration is to return pre-disturbance ecosystem functions to an area that has been severely degraded or altered by anthropogenic activities (National Research Council, 1992). Restoration success has been evaluated by measuring any number of physical and biological parameters, or metrics. These have included depth of standing water, temperature, plant diversity, plant percent cover, width of drainage channels, salinity, fish abundance and growth rates. Inadequate information about site to site variability and natural population fluctuations of biological metrics can limit the predictive power of the parameter (Simenstad and Thom 1996, Zedler and Callaway 1999). My research, funded by NOAA's National Estuarine Research Reserve (NERR) Graduate Research Fellowship program, is intended to describe bacteria communities in estuarine sediment and compare communities from a restoration site with three adjacent reference sites.

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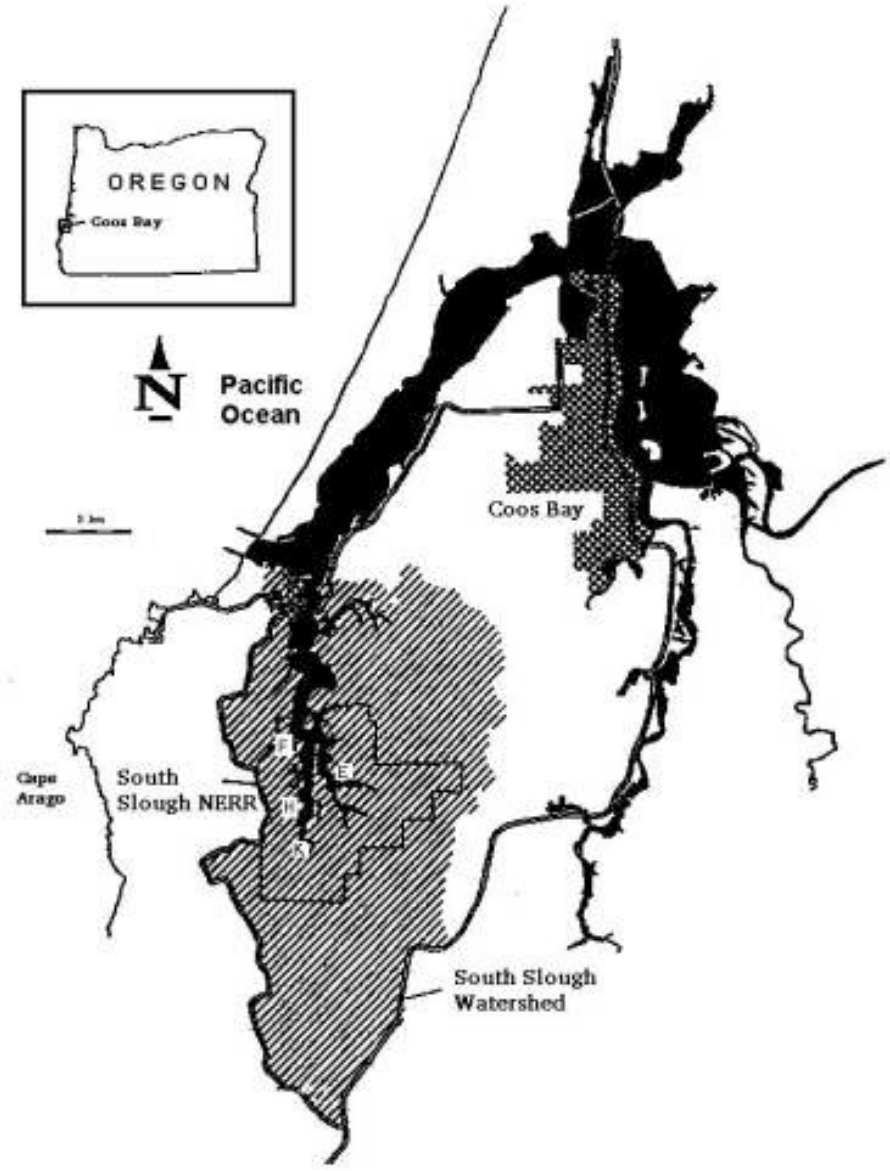

▲ **Figure 1.** Map of South Slough NERR and vicinity. Sampling sites are as follows: Ferrie Ranch (F), Elliott Creek (E), Hidden Creek (H), and Kunz Marsh (K). Kunz Marsh was restored in 1996; Elliott Creek and Ferrie Ranch were restored circa 1980.

Bacteria are microscopic and show few recognizable features in their physical appearance, therefore special tools are needed for identification (Pace 1997, Hugenholtz 1998). A revolution in identification tools in the late 1990's has given scientists the ability to describe multi-species bacteria assemblages and ask important questions about the organization of microbial communities in nature. The great naturalist, E.O. Wilson (1994) of Harvard University said, "If I could do it all over again, and relive my vision in the twenty-first century, I would be a microbial ecologist… Into that world I

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▲ **Figure 2a.** Sediment core sample.

▲ **Figure 2b.** Core sampling at Elliott Creek.

Communities of bacteria, *from page 5*

would go with the aid of modern microscopy and molecular analysis." The new tools to which E.O. Wilson alludes are DNA fingerprinting, sequencing, DNA-based fluorescent markers and three-dimensional microscopy. These tools have allowed me to ask the questions in my research. What are the species of bacteria present in a community and what are their patterns of distribution in wetland sediment? Answers to these questions will provide a foundation for understanding bacteria community organization in degraded habitats and their path toward recovery after a restoration project.

South Slough National Estuarine Research Reserve (SSNERR), part of the Coos Bay estuary, has an active program of wetland restoration of salt marshes in the reserve since 1996 (Rumrill and Cornu 1997). Using these restoration sites, I saw a perfect opportunity to evaluate the utility and limitations of using bacteria as a metric for evaluating restoration success.

Materials and methods

Sampling Design

Sediment bacteria were sampled within a 30m^2 area in each four sites (see Figure 1) within the South Slough NERR in August 2000. Kunz marsh (**K**) was passively restored in 1996, Elliott Creek (**E**) and Hidden Creek (**H**) were passively restored in the early 1980s

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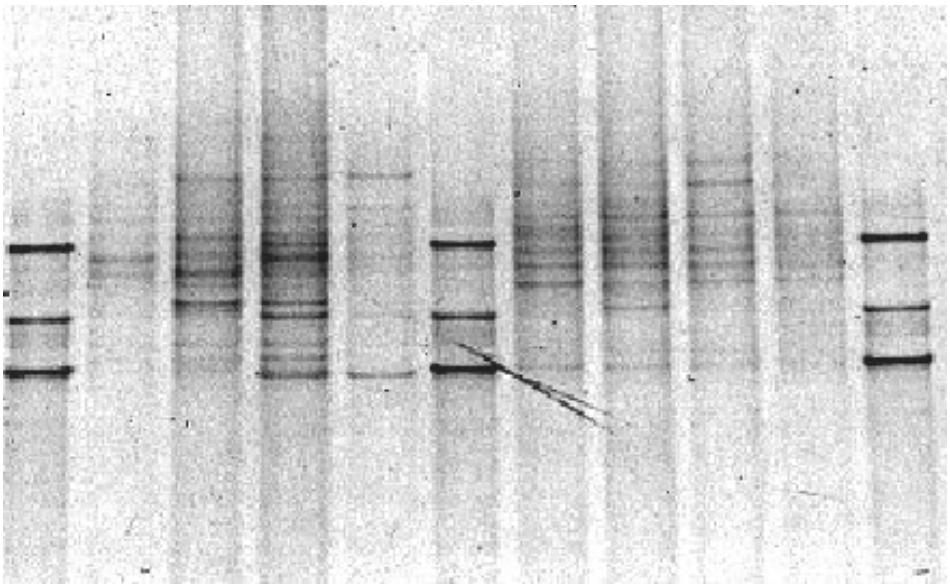
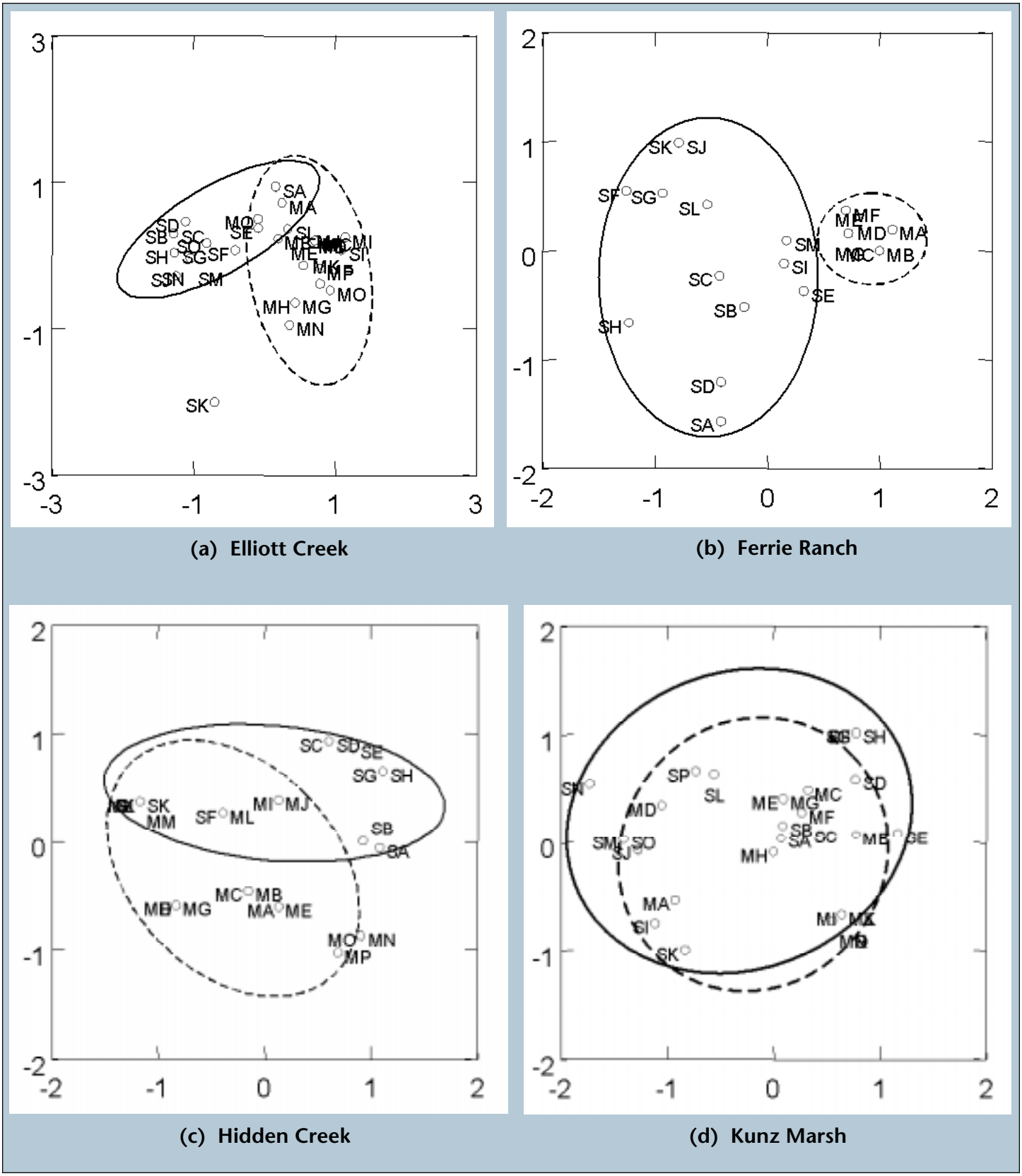


▲ **Figure 3**. Bacteria Community Profile
Denaturing Gradient Gel Electrophoresis (DGGE) was used to profile bacteria communities in South Slough NERR. Dark bands in lanes 1, 6, and 11 are known markers used to compare position of unknown bands on multiple gels. Lanes 2-5 and 7-10 are replicate cores from two depth fractions 0-1 cm and 1-2 cm respectively.



▲ **Figures 4 a, b, c, d. Estuarine sediment bacteria community profiles (DGGE) associated with algal mats (M) and without mats (S).** A unique community associated with algal mats was found in the three reference sites, but not in the restoration site. This suggests that there are interactions between the bacteria community and algal mats in pristine habitats that are not occurring in the restoration site.

Communities of bacteria, *from page 6*

and Hidden Creek **(H)** was never drained and diked. Eight sediment cores (Figure 2a) were collected; four cores from sediments with an overlying algal mat (*Vaucheria longicaulis, Anabaena sp., Oscillatoria sp., Microcoleus sp.*) and four from sediments with no overlying mat. Each core sample fractionated into 4- 1 cm depth increments to compare bacteria communities by depth. Upon returning to the lab, DNA was extracted from the sediments and the bacteria community was analyzed using molecular methods.

Small subunit ribosomal DNA from the community was amplified using the Polymerase Chain Reaction (PCR). The products were separated with Denaturing Gradient Gel Electrophoresis (DGGE), resulting in a community profile (Figure 3). Community profiles were assigned a Jaccard similarity value (Van Hannen et al 1999) and plotted on non-metric two dimensional axes (Warwick et al 1990, Clarke and Green 1988).

Results and discussion

The presence or absence of algal mats was shown to be important in determining what species of bacteria are found (Figure 4) in the reference sites but not in the restoration site. There are interactions between the bacteria community and algal mats in pristine habitats that are not occurring in the restored mudflat.

With regard to depth, the pattern at the restoration site was equivalent to those restoration site. Clearly the bacteria communities reacted more quickly to depth than to the presence of algal mats. The pattern of unique communities from each depth is not surprising, given the strong gradient of oxygen and sulfide in anoxic estuarine sediments. It was hypothesized that this gradient was established shortly after the restoration site was flooded with seawater in 1996. Since bacteria are a metabolically diverse group, they filled the gradient of niches along the depth gradient rapidly.

When communities from all sites are analyzed together, one might expect an estuary wide pattern of community composition in restoration sites that is recognizably different than reference sites. Unfortunately, the patterns of bacteria community composition are complex. There are a number of site specific processes that influence the community profile, which makes estuary wide generalizations impossible. Continuing analysis of the species composition should help resolve some these patterns. Ultimately, one would like to go to any estuary in the world and make predictions about sediment bacteria communities regarding recovery of a restored habitat and identify "indicator" species. At present, we cannot make these predictions because we don't understand why sediment bacteria communities are much more variable at a 1-3 km scale than at the m or cm scale. Differences in bacteria communities at the 1-3 km scale are hypothesized to be caused by a combination of local nutrient dynamics, salinity and allocthanous and autocthanous carbon pools.

In summary, four years following the return of tidal variation, there lacks a unique community of bacteria associated with algal mats in the restoration site. The period of recovery for development of unique community profiles in algal mats is unknown. It is hypothesized that the bacteria community responds more rapidly to depth-driven chemoxic gradient than to the presence of algal mats.

This research shows the potential and limitations of using bacteria communities as a metric for gauging habitat recovery. Community complexity is intriguing, but makes the establishment of useful benchmarks difficult. There are two potential benchmarks identified in this research, namely, plant/ algal mat associated bacteria communities may be a good long term benchmark while a unique depth associated community may be a short term benchmark to evaluate degradation and recovery of habitat following restoration.

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Characteristics of temperature and salinity fluctuations in a South Indian estuary

A study of Vembanad Lake, a monsoon-influenced estuary

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Estuaries, which are one of the most productive environments, provide feeding, spawning and rearing areas for a very large proportion of commercial fish and shellfish. Because of the intrusion of ocean waters by the tidal action, the estuarine conditions are greatly influenced by the coastal oceanic phenomena. Estuaries along the south west coast of India are influenced by the large freshet during southwest monsoon season, i.e. from June to September. During this season, the effect of fresh water can be seen close to the mouth, and salt-water intrusion will be limited to a short distance in the estuary from mouth. Vembanad Lake, which is the largest estuarine system in the west coast of India, has a length of about 80 km (Figure 1). This system lies parallel to the coastline and covers an area of about 300 km^2. This estuary consists of numerous islands that divide it into several arms. The estuary opens into Arabian Sea at Cochin. This opening which is popularly known as Cochin bar mouth lies between Puthuvypu and Fort Kochi. The rivers which discharge fresh water into this estuarine system are Periyar on the north, Pampa on the south and Muvattupuzha, mid way between the two. There exists another opening at Azhikode, located further north (not shown in the figure), through which a part of the discharge from Periyar flows into Arabian Sea. The lower reaches of the estuary near Kochi are also referred to as Cochin Backwaters.

In the southern part of the estuary, where the present study area is located, highly saline water intrudes as much as 26 km from the barmouth during the pre-monsoon period, both at surface and subsurface levels (Balchand and Nair, 1994). However, in monsoon season, saline water extends only to 5km at surface and about 20km at subsurface levels. In pre-monsoon months, when

— *continued on page 10*

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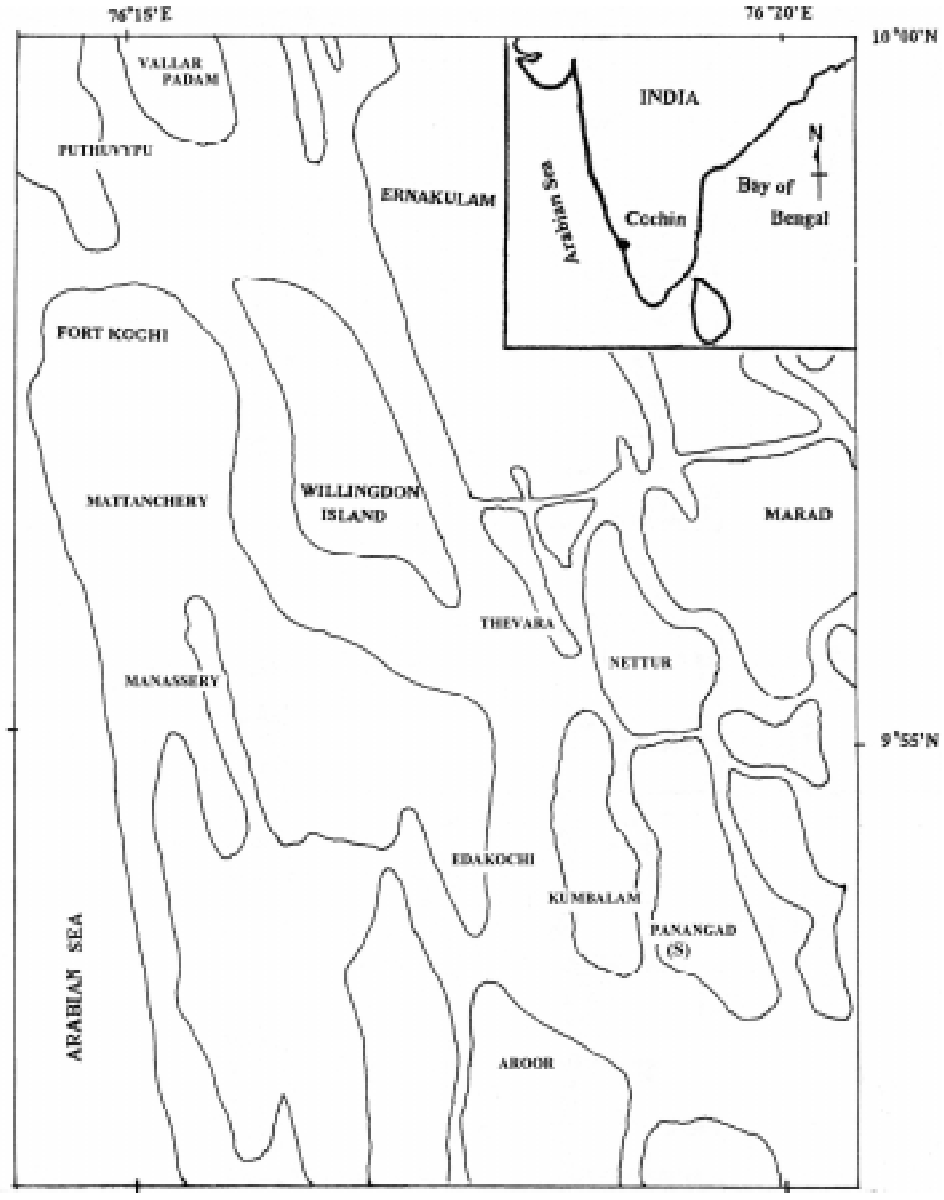


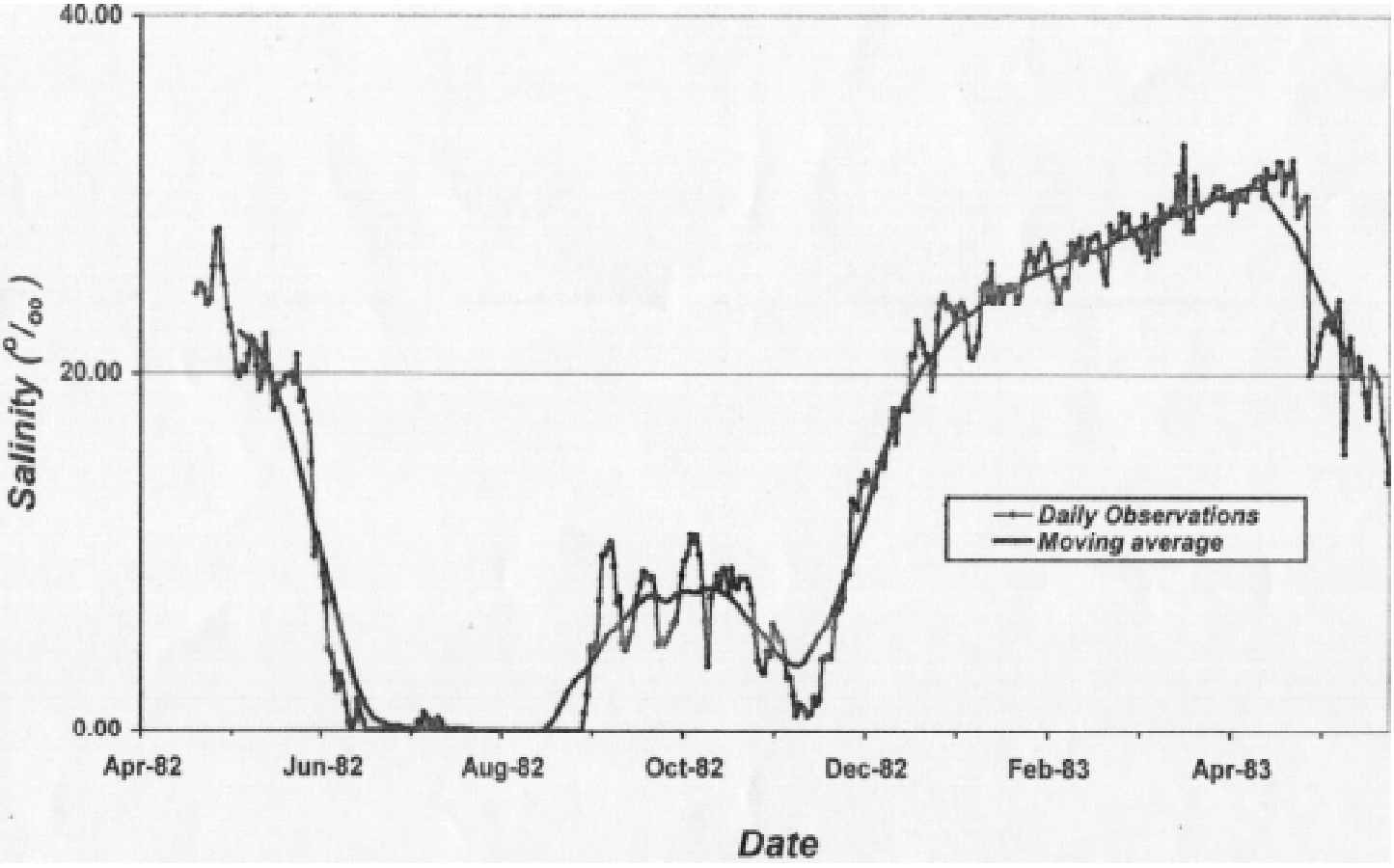
▲ **Figure 1.** Station Map.

Vembanad Lake, *from page 9*
the salinity is about its maximum, practically no salinity change is encountered from surface to bottom. However, in monsoon season, when there is generally a sharp decline in salinity, the bottom salinity still remains high. This wide variation in salinity can be attributed to the influx of fresh water, which is confined to the upper layers. Apart from the influence of monsoon rains and the considerable amount of evaporation during summer months, the effect of coastal upwelling and sinking in the Arabian Sea were considerable in Cochin Backwaters (Ramamirtham and Jayaraman, 1963). Stratification and distribution of salinity, in relation to tides and freshwater discharges, have been studied for May, July and January by Joseph and Kurup (1990).

Long-term data spanning for many years are an essential requirement for understanding and tracking the changes in estuaries and such data will contribute to better understanding of estuarine ecosystem functions and for improving management decisions (Powell and Rumrill, 2001). It has been reported by them that, based on this concept, the permanent observation facilities in the South Slough National Estuarine Research Reserve in USA had been established. The studies discussed earlier and many similar studies, from Vembanad Lake use, only data collected over tidal cycles or spot data during different seasons. Long-term data with close time interval, extending over a few years from Vembanad Lake have not been reported so far. In the present paper, long-term daily observations at a fixed locality in the Vembanad Lake, have been discussed.

Data and methods

After the establishment of the College of Fisheries (Kerala Agricultural University) at Panangad, Kochi, in the Kerala State, India, a programme to collect estuarine data on daily basis was started. Surface temperature and salinity were collected daily at 11.00 A.M. from Panangad Jetty, which is located in the arm of estuary that separates Panangad and Kumbalam islands (Figure 1). This arm of the estuary is about 200m wide and the jetty is situated about 12km from the Cochin barmouth. The sampling started on April 19, 1982 and extended to May 31, 1983. Salinity was estimated using APLAB model conductivity-salinity meter. The time series data on temperature and salinity were examined and a few unusual values in the series were edited. Occasional data gaps were filled by interpolation. The original series was



▲ **Figure 2.** Time series data of salinity.

smoothed using the 31-point moving average method. The departure from the moving average is determined to obtain the high pass filtered data.

The fluctuation series (high pass data), which consists of 378 data points, are analyzed for finding out the spectrum, using Fast Fourier Transform. Periodogram is a way of representing the variability in a time series in terms of harmonic components at various frequencies. Because of the constraints of data length while using FFT, the fluctuation series of both parameters have been divided into two series consisting of 256 points. Two spectra of both salinity and temperature have been estimated for the time series from May 3, 1982 to January 13, 1983 and September 3, 1982 to May 16, 1983. Another logic for this partition is that salinity data have zero values during southwest monsoon period and in case this feature has any predominant effect on the results, this can also be ascertained by obtaining spectra for series with and without this portion. Before applying FFT, series were mean corrected. Spectra are smoothed using the Hamming window. This is a weighted moving average transformation, used to smooth the periodogram values (Blackman and Tukey, 1958).

Results and discussion

The original and smoothed surface salinity curves are presented in Figure 2. Salinity at this location ranged between 0 and $32^0/_{00}$. In 1983, high salinity ($>30^0/_{00}$) is noticed in April. After mid April, salinity decreased in both the years. With the onset of southwest monsoon, rapid decrease in salinity is noticed and fresh water condition exists in the region. This is also in agreement with the earlier studies (Sankaranarayan and Qasim, 1967, and Menon *et.al.*, 2000). With the retreat of southwest monsoon, from mid August onwards, salinity gradually increased to reach $10\text{-}12^0/_{00}$ by October and then decreased to about $4^0/_{00}$ by December. This secondary fall is due to the effect of northeast monsoon rainfall. Subsequently a sharp increase of about $20^0/_{00}$ is noticed within a month, followed by a gradual increase to reach the maximum of about $30^0/_{00}$ by April. The surface salinity variation from fortnightly observations in the backwaters presented by Menon *et.al.* (2000) also shows bimodal variation around present study area. The rapid decrease in May, before southwest monsoon onset and the sharp increase after secondary minimum, seen in their study agree with present findings.

Surface temperature varies between 27°C and 35°C (Figure 3). High values

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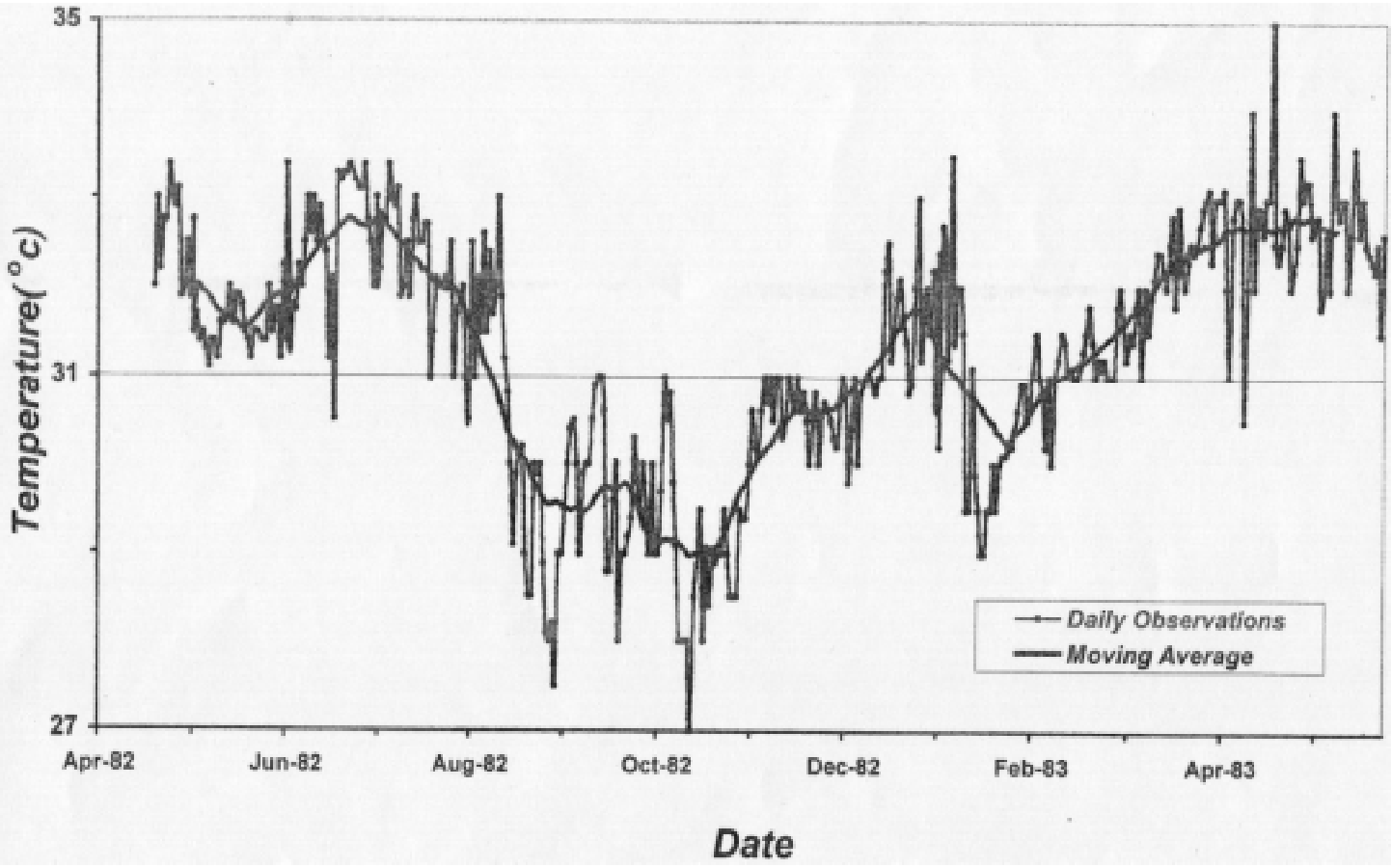
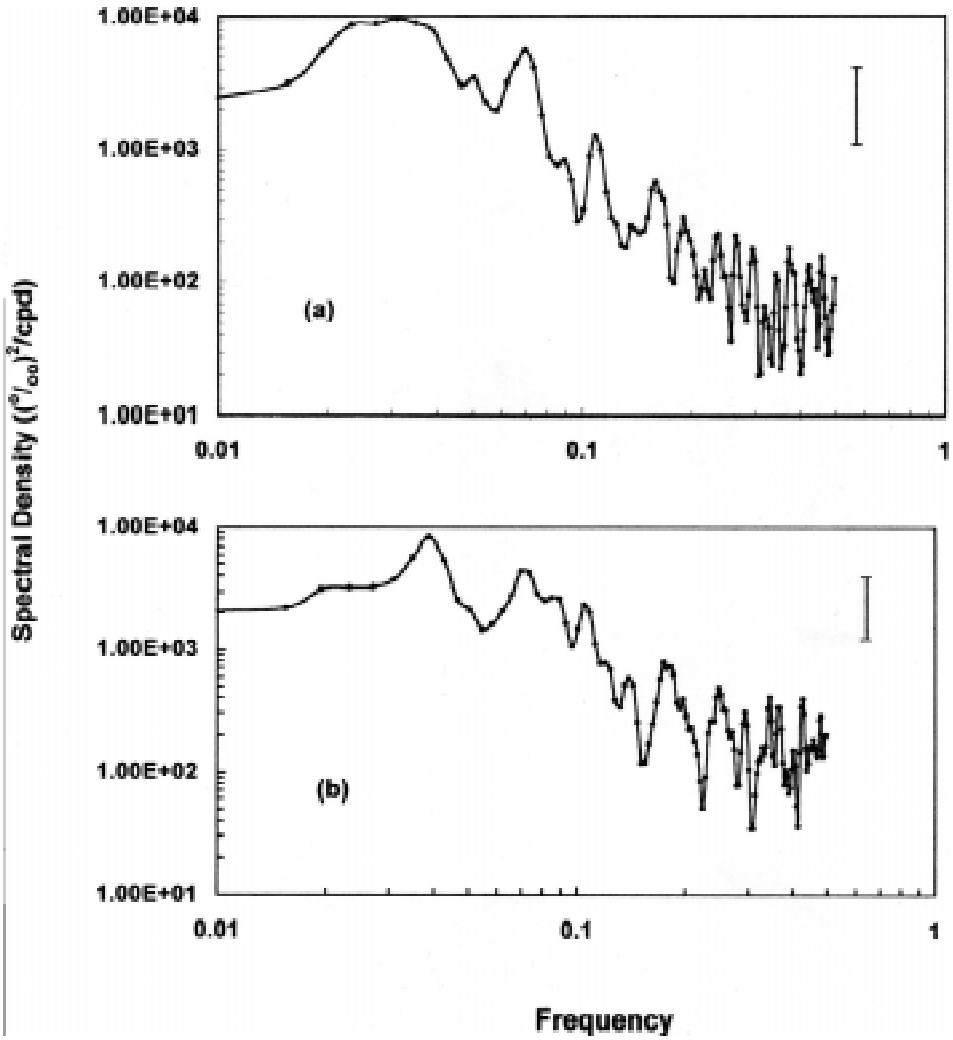


▲ **Figure 3.** Time series data of temperature.



▲ **Figure 4.** Salinity spectra. Vertical bar indicates 90% confidence limits.

Vembanad Lake, *from page 11*
are noticed during March-April, prior to southwest monsoon. In general, temperature variation is inverse to that of salinity, except when both increased during summer (Feb-April) and decreased prior to monsoon onset. Temperature series show more fluctuations compared to salinity variations (Menon *et.al,* 2000).

Spectral characteristics

Salinity spectra are presented in Figure 4. One prominent peak in the salinity spectra is seen at frequency of 0.07cpd. Apart from this, the series 1 shows a high plateau between 0.025 and 0.04cpd, while the series 2 shows a peak at 0.04cpd. In the case of temperature, higher energy with minor fluctuations is noticed between 0.02 and 0.06cpd (Figure 5). The peak at about 0.07cpd is present in temperature also. Temperature spectra are, in general, more noisy. The noise could also be brought in because of the impact of variation in exchange of heat at air - water interface, in response to variations in atmospheric characteristics. Nevertheless, the frequency of energy peaks seen in the lower frequency ranges matches with those in salinity spectra. Peaks at much higher frequencies in all spectra are generally an order of magnitude less. In addition, spectra at higher frequencies are also enhanced as an artifact of above high pass filter used. Thus, we are left with two peaks, one around 15 days and another around 30-42 days. The periods around 0.07cpd (15 days) are due to the effect of spring and neap tides. During the lunar cycle, the tide exhibits two springs and two neaps. The longer periodicity, which is not related to tides, needs some other explanation. It may be noted that these are seen consistently in all the spectra.

The periodicity of about 30-42 days could not have been caused by freshets of such periods, because the bulk of fresh water flow in South Indian rivers occurs during southwest monsoon with a secondary peak during northeast monsoon. The effect of these would show up at periods of around 180 days. The observed periods are much less than this. Further, it cannot be assumed that fresh water is released in large quantities at regular intervals of about 25-50 days from dams, so that estuarine characteristics are affected in such intervals, because this would negate the purpose of dams itself, which are meant for storing water for the lean season.

Coastal processes

We are, therefore, tempted to attribute these long periods to another source viz. coastal phenomena. As the entire north Indian Ocean responds to the reversing monsoons, their impact can be seen off south west coast of India. Most conspicuous of these is the seasonal upwelling. Based on thermohaline characteristics and low dissolved oxygen content of the water in Cochin Backwaters, Ramamirtham and Jayaraman (1963) pointed out that upwelled water from offshore region spreads in the backwaters. Banse (1968) concluded the presence of cool upwelled water on the entire shelf (up to 12° N) off the west coast of India during the southwest monsoon. He noted that upwelling off the south west coast of India started with the onset of monsoon, but attributed the large-scale upsloping of isolines on the shelf to seasonal changes of mass distribution and to currents in the Arabian Sea at large. Johannessen *et.al.* (1981) observed that the up sloping along coast started in March/April and seasonal variation was repetitive from year to year. They suggested that while wind was an important driving force from February onwards, upwelling was also associated with the southwest monsoonal conditions, which drive the anticyclonic gyre in the Arabian Sea.

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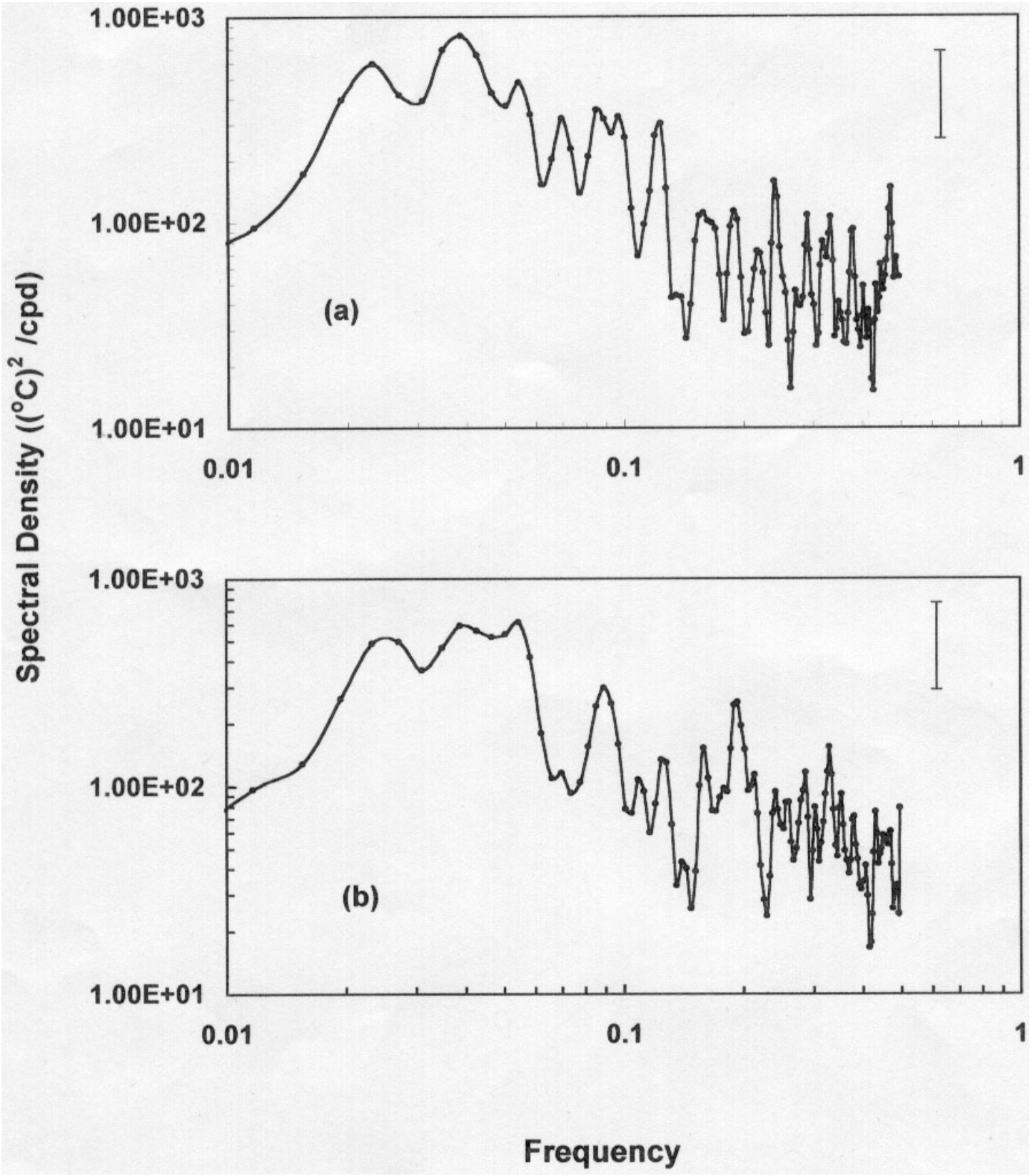

▲ **Figure 5.** Temperature spectra. Vertical bar indicates 90% confidence limits.

Vembanad Lake, *from page 12*

It is thus established that upwelling starts prior to the southwest monsoon. During this time *i.e.* the pre monsoon season, the fresh water flow through South Indian rivers that join the Arabian Sea diminishes and consequently the estuaries become well mixed and their lower reaches become totally influenced by coastal processes. At the same time upwelling off the west coast of peninsular India will bring up low saline subsurface water to nearshore regions. Shetye *et.al*.(1990) have observed a core of low saline water hugging to the inner continental slope off the southwest coast of India during early monsoon and also that the upwelled waters are of lesser salinity. According to them the low saline waters could be coming from the southwest corner of Bay of Bengal. Shenoi *et.al.* (1999) observed the penetration of low saline waters from Bay of Bengal and also the commencement of upwelling before the onset of monsoon. Therefore, the present finding of fall in salinity by May and similar earlier observations could be the result of intrusion of low saline waters into the estuary.

Having seen that estuarine conditions are closely related to the coastal dynamics, it would be worthwhile to examine the predominance of lower frequencies in salinity and temperature spectra mentioned earlier. Theoretical studies have indicated that the concept of Kelvin wave is important to the circulation off the west coast of India (Mc Creary *et.al.,* 1993). Numerical and analytical studies have established that the circulation off the south west coast of India is related to low frequency Kelvin waves, which come to the west coast of India from the Bay of Bengal, circumnavigating Sri Lanka (Shankar and Shetye, 1999). They also indicated that the commencement of upwelling before the onset of monsoon as mentioned earlier, might be due to this. Further, it is also pointed out that if the period of such waves is more than around 40 days, these turn west towards Lakshadweep Sea, while those with periods less than that propagate northwards along the coast. The spectral peaks/plateau in the range of 25-43 days seen in the present analysis could, therefore, be a manifestation of the effect of coastal dynamic regime consisting of coastally trapped Kelvin waves of similar periods which instead of turning west, move northward. This would therefore affect characteristics of estuarine waters also.

Though our study connects coastal dynamics to the data at a location inside the estuary, its impact on present data during southwest monsoon may perhaps be suspected because of the fresh water conditions in estuary during this season. However, our confidence is much increased by the persistence of spectral peaks at lower frequencies for both salinity sets, viz. 1) excluding southwest monsoon season and 2) including this season. Temperature spectra also indicate similar peaks. Also, since our data compare well with the gross features nearer to the barmouth studied by earlier workers, it can be considered that the low frequency coastally trapped waves do affect the characteristics in the estuary. It would however be worthwhile to generate long-term data from a chain of stations in the estuary covering environmental parameters in order to throw more light on these mechanisms.

Acknowledgements

The authors wish to thank Dr. M.J. Sebastian and Dr. D.M. Thampy, the former Deans, College of Fisheries for their interest. Thanks are also due to Dr. P.V. Joseph, the Visiting Professor, Dept. of Atmospheric Sciences, Cochin University of Science and Technology (Retd. Director, India Meteorological Department), for valuable suggestions.

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Climate Indicators Program

The National Climatic Data Center's Climate Indicators Program continues to provide support to the Nation's private sector. Aquila, Inc., a company that provides weather-risk management solutions, will soon begin providing a version of the NCDC's Residential Energy Temperature Demand Index to their customers via the Aquila web site. Aquila Corporation is pursuing the development of improved climate indices. We expect continued cooperation between the Center and Aquila as they work toward the creation of new indices that provide insight into the impact of weather and climate on the nation's economy.
Contact: NCDC

Caribbean sclerosponge data

The NOAA Paleoclimatology Program has archived a 600-year Carbon Isotope record derived from coralline sponge skeletons in the Caribbean Sea. Sclerosponges secrete aragonitic skeletons, which can be dated and sampled in the same manner as coral skeletons. The Carbon Isotope record clearly indicates the industrial 12C increase in atmospheric CO_2, as well as 13C/12C variations linked to the climate fluctuations of the Little Ice Age. Published by Bohm *et al.* in *Geochemistry Geophysics Geosystems* (2002), the data are available on the NOAA Paleoclimatology Program website at: *http://www.ngdc.noaa.gov/paleo/coral/caribbean.html*.
Contact: NGDC

T-REX Project

The National Climatic Data Center has been contacted by the Colorado Department of Transportation for climatic data to assist in their T-REX Project. This project is a citizen-endorsed solution to replace outdated, aging highways with modern, efficient highways and a light rail transit system. Funded without any new or increased taxes, the $1.67 billion project will increase mobility, enhance accessibility and transportation options, as well as improve safety to the traveling public in a heavily congested, growing business corridor. The project includes highway expansion and improvements, and the addition of light rail, along I-25 and I-225 to a newly configured I-25 interchange.
Contact: NCDC

Data products and services

NGDC Space Environment archive critical to cell phone study

A March 6, 2002 press release by the American Geophysical Union, entitled "Solar radio bursts affect cell phones," acknowledges the study was possible only because of an archive of solar radio bursts data which was assembled by the National Geophysical Data Center. Lucent Technologies' Bell Labs, along with scientists from the New Jersey Institute of Technology, studied the records covering 40 years. Radio bursts greater than 1000 solar flux units can potentially disrupt cell communications by covering conversation with noise or causing calls to be dropped. They find these large bursts occur on average 10-20 days per year, with higher rates during the solar maximum period. Their paper "Noise in Wireless Systems Produced by Solar Radio Bursts" appeared in *Radio Science*, March-April 2002 issue.
Contact: NGDC

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NSIDC to distribute Aqua instrument products

The Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) is one of a suite of instruments on board the NASA Earth Observing System Aqua Satellite. NGDC's affiliated National Snow and Ice Data Center (NSIDC) at the University of Colorado, Boulder, will archive and distribute the ASMR-E data products, as well as snow and ice products from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Aqua [NSIDC has archived and distributed snow and ice products from the MODIS on board *Terra* since shortly after *Terra* was launched in December 1999].

The AMSR-E measures passive microwave radiation, allowing for derivation of many parameters including cloud properties, radiative energy flux, precipitation, land surface wetness, sea surface temperatures, sea ice, snow cover, and sea surface wind fields.
Contact: NSIDC

New NGDC Paleoclimatology Program archivals

• Evolution of last millenium's climate

The NGDC Paleoclimatology Program has archived 1000-year reconstructions of global temperature, the North Atlantic Oscillation, and the Southern Oscillation Index. Published by Jones *et al.* in *Science* (2001), the paper compares several state of the art climate reconstructions and evaluates uncertainty in our current knowledge of climate variability. The data and research summary are available on the NOAA Paleontology Program website: *http://www.ngdc.noaa.gov/paleo/pubs/jones2001/jones2000.html*.

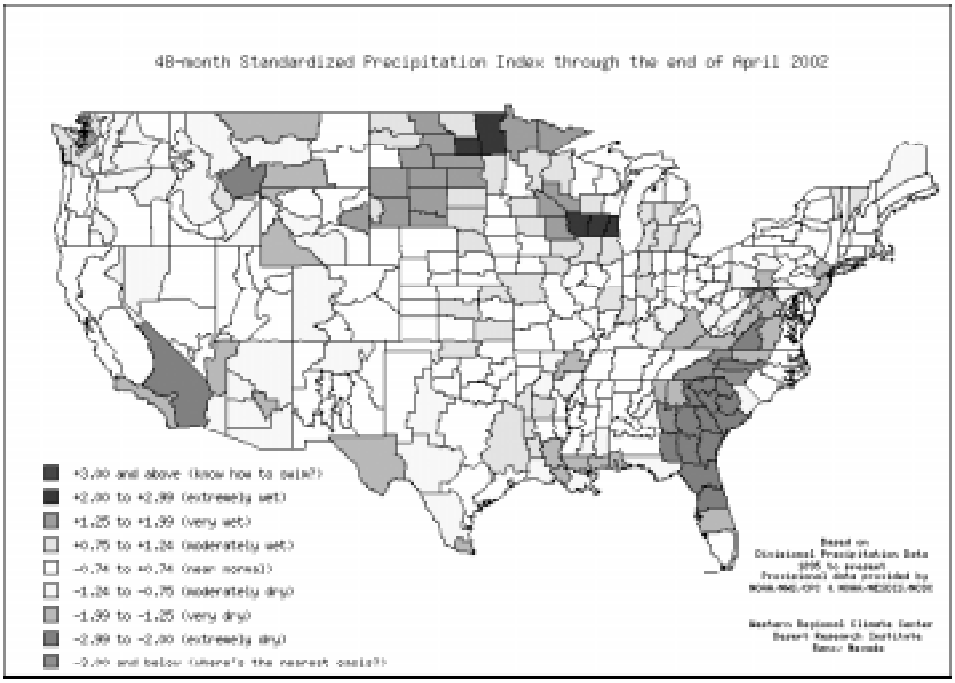
• Northern Hemisphere temperature

The NGDC Paleoclimatology Program has archived a 600-year reconstruction of Northern Hemisphere and Regional temperature. Published by Briffa *et al.* in *Journal of Geophysical Research* (2001), the 20th century is clearly shown by all of the paleoseries composites to be the warmest during this period. The data and research summary are available on the NGDC Paleoclimatology Program website at: *http://www.ngdc.noaa.gov/aleo/pubs/briffa2001/briffa2001.tml*.
Contact: NGDC

Drought persists in Eastern U.S.

Drought has developed over much of the eastern United States during the last four years, with the drought beginning in May 1998, at the end of the last El Nino cycle. Above average precipitation noted by climate divisions with green anomalies were associated with the main U.S. storm track which was from the south central states across the Mississippi and western Ohio Valleys and then across the central Great Lakes. States in these areas generally had average or above average precipitation.

In contrast, areas to the east of that region, along the east coast, especially in the southeast, were very dry with drought intensifying. Note the difference in rankings between North Carolina and Tennessee. The maps depicted show the Standardized Precipitation Index (SPI), which is a relatively new drought index based only on precipitation, and the precipitation percentiles for the 4-year period. The SPI can be used to monitor conditions on a variety of time scales. This temporal flexibility allows the SPI to be useful in both short-term agricultural and long-term hydrological applications. ■



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