Current Issue Outline 79-1

Sea-Surface Temperature And Climate

Washington, D.C.
June 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Environmental Data and Information Service

Current Issue Outline 79-1

Sea-Surface Temperature And Climate

Washington, D.C.
June 1979

Reprinted June 1980

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

Environmental Data and Information Service
Thomas S. Austin, Director

CURRENT ISSUE OUTLINE 79-1

SEA-SURFACE TEMPERATURE AND CLIMATE

Current Issue Outlines have been developed by the Library and Information Services Division, Environmental Science Information Center, to provide objective background reviews on current topics of high general interest in marine or atmospheric science. Bibliographies of selected material are added so that the reader who wishes can pursue the subject in greater depth. Questions or comments should be directed to:

User Services Branch, D822
Library and Information Services Division
NOAA
Rockville, MD 20852

Telephone number is (301) 443-8358.

PREVIOUS TITLES IN THE SERIES

CIO 78-1 Icebergs For Use As Freshwater
CIO 78-2 Harnessing Tidal Energy

SEA-SURFACE TEMPERATURE AND CLIMATE

Issue Definition

Climatic variations are likely to arise from complex interactions among the atmosphere, the oceans, and the Earth's surface. Empirical observations as well as studies using climate models have suggested that variation of oceanic conditions, especially variation in sea-surface temperatures, may be the key to understanding monthly and seasonal climatic anomaly patterns.

When air passes over the surface of the ocean, its temperature and humidity levels change. For example, cool, dry air blowing over warmer water will gain heat and moisture; the rate of gain depends on the temperature difference. The additional moisture may be released some distance away, modifying the atmospheric conditions at that point.

Thus, sea-surface temperature has the potential for producing short-term weather variations as well as long-term climatic changes.

Scientists have recorded and monitored sea-surface temperatures for many years, and their studies have linked these temperatures to subsequent weather states in an attempt to improve long-range forecasting. They have cited sea-surface temperatures (SST's) and unexpected sea-surface temperature variations (SST anomalies) as contributing factors in hurricanes, monsoons, rainfall, typhoons, length of seasons, wind patterns, and severity of winter weather.

What factors determine large-scale variations in sea-surface temperature? Several conditions are believed to be responsible:

(1) amount of solar radiation absorbed in the sea, which varies with the amount of cloud cover.

(2) evaporation and cooling, which are related to vapor pressure, temperature, and wind speed over the sea surface.

(3) depth of the mixed ocean layer affected by factors (1) and (2).

(4) heat transfer in the oceans, both horizontally in currents, and vertically through upwelling or downwelling.

Because climatic changes have such obvious and far-reaching economic, social, and political effects, any refinement in long-range forecasting capability is desirable. If we can predict climatic change on the basis of sea-surface temperature or air-sea interaction data, it becomes possible to plan the stockpiling of heating fuels well in advance of an unusually severe winter, or to plan on planting crops (such as tomatoes and certain grains) that would be economically worthwhile only if it were known well in advance that the summer temperature and rainfall conditions would be suitable.

Research on SST and Climate

SST anomalies ranging from 1^{o} to 2^{o} above or below normal (with extremes to 4.5^{o} above or below normal) have been found in patches of water that may exceed 100 meters in depth and 1,000 kilometers in breadth. These unusually warm or cold patches have been observed to change rapidly in spring and fall (April - May/October - November) and often to persist throughout the winter and summer.

The specific processes by which these abnormal patches of water influence climate over the years are still not completely understood. Also, it is not yet certain whether SST anomalies initiate atmospheric changes or whether they are formed in response to such changes. The investigation of temperature and pressure relations at the air-sea boundary is a priority among oceanographers and meteorologists, who have been monitoring SST and relating the data to weather patterns in all parts of the world and to possible global climatic trends. Findings suggest an association between SST and atmospheric factors and the resulting conditions in areas located downwind or downstream.

For example, correlations have been found between SST anomalies near Newfoundland and the atmospheric conditions over Great Britain and Europe, between SST in the North Pacific and weather in Europe and the North America, between SST's in the equatorial Pacific and rainfall patterns in Australia, and between SST's in the Bering Sea and the Okhotsk high-pressure system that brings cool, cloudy weather to northern Japan.

Jerome Namias of the Scripps Institution of Oceanography of the University of California (San Diego) has done extensive research in his studies of the relation between sea-surface temperatures in the Pacific Ocean and the climate throughout the United States since the 1950's. His analysis of 26 years of SST data suggests a relationship between SST and the winter season weather patterns over the United States. He has uncovered a tendency for unusually cold SST's in the mid-Pacific, together with warm SST's off the California coast, to be associated with colder than normal winters in the eastern half of the United States and warmer than normal winters in the western half. The opposite pattern has also been observed: anomalously warm SST's in the mid-Pacific and unusually mild winters in the eastern half of the country, with correspondingly cold weather in the west. Winters were colder than normal in the east and warmer than normal in the west during 1958-71, and Namias associated marked SST anomalies with the temperature pattern change in 1958 and again in 1971, the beginning and the end of a period of unusual winter weather.

Namias has attempted to clarify the relationship between SST and climate by studying wind patterns. SST data for 26 years indicate that summer

SST's in the area of the Aleutian Islands influenced the strength, each autumn, of that vicinity's semipermanent low-pressure area known as the Aleutian low. The behavior and wind pattern of the Aleutian low have been associated with climatic conditions over North America.

Jeffery Rogers, in work done at NOAA's Great Lakes Environmental Research Laboratories at Ann Arbor, Mich., analyzed monthly SST data for the eastern portion of the North Pacific Ocean from National Marine Fisheries Service charts for January 1960 through September 1973. Statistical treatment of the data revealed three large regions of SST variability in the Pacific from 1960 to 1970. A subsequent change producing a new region coincided with the reversal in the trend toward unusually cold winters in the eastern portion of the United States (noted above). These SST areas were found to be related to fluctuations in atmospheric pressure over North America.

SST variations have been related to specific air-sea interactive weather systems such as hurricanes. C. Sergio Serra at the Institute of Geophysics in Mexico City documented the relation in the Gulf of Mexico and the northeastern Pacific Ocean between a higher SST and the resulting decrease in surface pressure, causing an increase in a hurricane's maximum winds. When hurricanes passed over a Gulf of Mexico area containing an anomalously high SST, they were seen to intensify. Conversely, when hurricanes in the northeastern Pacific passed over the cooler waters west of the Lower California peninsula, their intensity was observed to diminish. SST anomalies in the equatorial Pacific have been related to tropical cyclonic activity; to the recurrence of the El Niño phenomenon off the coast of northern Peru, which affects fish stocks and weather patterns; and to the intensity of the rainy season in northeastern Brazil, allowing a warning of potential drought or flood conditions.

The studies cited here suggest a relation between long-term, large-scale SST anomalies and atmospheric changes, which influence weather and climate. Do these results suggest that changes in SST can be used in weather forecasting or to predict global climatic events?

A 2-week experiment using the GISS (Goddard Institute for Space Studies, NASA) model of global atmospheric circulation was performed by Jerome Spar and Robert Atlas of the University Institute of Oceanography, City University of New York. They found that using observed SST's in place of expected average temperatures in the model did not lead to any general improvement in forecasting. However, these findings are preliminary only, and they serve to highlight the need for additional research on SST's, air-sea interactions, and their relation to both short-term weather patterns and long-term climatic change.

Unanswered Questions

Current work by oceanographers and meteorologists is focused on the following questions:

(1) How can current technology be applied to allow more accurate and efficient sampling of SST and SST fluctuations?

(2) How are anomalous SST patches formed and later broken up, and what are their characteristic motion and longevity?

(3) How do SST anomalies interact with the atmosphere at the air-sea boundary? What is the nature of the heat transfer mechanism at the air-sea boundary? What are the space and time scales of the interaction?

(4) To what extent can SST be used to predict unusual weather phenomena, seasonal abnormalities, and longer term climatic anomalies? In what parts of the world might this means of prediction be found useful?

Large-Scale Research Projects

Three major research efforts in the United States are investigating these issues. NORPAX (North Pacific Experiment), based at the Scripps Institution of Oceanography, is a combined effort of research, academic, and government agencies to study ocean temperatures. FGGE (First GARP Global Experiment--GARP is Global Atmospheric Research Program) is an international project to provide a 1-year examination of the global weather system. EPOCS (Equatorial Pacific Ocean Climate Study) is a new NOAA program to study SST fluctuations in the equatorial Pacific Ocean.

Bibliography

ARNOLD, J. E., and A. H. THOMPSON.
1974. On the relations between sea-surface temperature gradients and the structure of cloud systems associated with tropical disturbances. College Station, Tex., Texas A & M Research Foundation, TAMRF, Project 688, Final Report, 59 p.

ASAKURA, T.
1974. Role of the Bering Sea in long-range weather forecasting in Japan. In: Oceanography of the Bering Sea: with emphasis on renewable resources. International Symposium for Bering Sea Study, Hakodate, Japan, January 31 - February 4, 1972. Fairbanks, Institute of Marine Science Occasional Publication No. 2, p. 467-473.

BJERKNES, J.
1961. El Nino study based on analysis of ocean surface temperatures, 1935-1957. Inter-American Tropical Tuna Commission Bulletin 5(3): 217-234.
1966. Survey of El Nino 1957-1958 in its relation to tropical Pacific meteorology. Inter-American Tropical Tuna Commission Bulletin 12(2):25-86.
1966. A possible response of the atmospheric Hadley circulation to equatorial anomalies of ocean temperature. Tellus 18:820-829.
1969. Atmospheric teleconnections from the equatorial Pacific. Monthly Weather Review 97:163-172.
1970. Studies in climate dynamics for environmental security: large-scale ocean atmosphere interaction resulting from variable heat transfer at the equator. Rand Corp., RM-63530ARPA, 28 p.
1972. Large-scale atmospheric response to the 1964-65 Pacific equatorial warming. Journal of Physical Oceanography 2:212-217.

CAVIEDES, C. N.
1975. El Nino 1972: its climatic, ecological, human, and economic implications. Geographical Review 65:493-509.

DICKSON, R. R., H. H. LAMB, S. A. MALMBERG, and J. M. COLEBROOK.
1975. Climatic reversal in northern North Atlantic. Nature 256: 479-481.

EGGER, J.
1977. On the linear theory of the atmospheric response to sea surface anomalies. Journal of the Atmospheric Sciences 34:603-614.

FAVORITE, F., and D. R. McLAIN.
1973. Coherence in transpacific movements of positive and negative anomalies of sea-surface temperature, 1953-60. Nature 244:139-143.

FIÉUX, M., and H. STOMMEL.
1975. Preliminary look at feasibility of using marine reports of sea-surface temperature for documenting climatic change in the Western North Atlantic. Journal of Marine Research 33:83-95 (suppl.).

HAMMOND, A. L.
1974. Long-range weather forecasting: sea temperature anomalies. Science 184:1064-1065.

HASTENRATH, S.
1976. On mechanisms of tropical climate anomalies. In: Proceedings of the NOAA Climate Diagnostics Workshop, Washington, D.C., November 4-5, 1976, p. 19-1 to 19-14.

HOUGHTON, D. D., J. E. KUTZBACH, M. McCLINTOCK, and D. SUCHMAN.
1974. Response of a general circulation model to a sea temperature perturbation. Journal of the Atmospheric Sciences 31:857-868.

HUANG, J. C. K.
1975. Mid-latitude sea-surface temperature anomaly experiments with NCAR general circulation model. In: Proceedings of the WMO/IAMAP Symposium on Long-term Climate Fluctuations, Norwich, England, August 18-23, 1975, WMO Publication No. 421, p. 399-406.

JONES, J. J.
1975. Large-scale ocean and atmospheric patterns relative to the 1957-58 temperature anomaly in the North Pacific Ocean. Marine Science Communications 1:27-28.

KRUEGER, A. F.
1976. Circulation over the tropics and ocean warming in the eastern Pacific during 1976. In: Proceedings of the NOAA Climate Diagnostics Workshop, Washington, D.C., November 4-5, 1976, p. 11-1 to 11-8.

LAEVASTU, T., and W. E. HUBERT.
1970. The nature of sea-surface temperature anomalies and their possible effects on weather. Monterey, California, Fleet Numerical Weather Central Technical Note No. 55, 21 p.

McLAIN, D. R.
1976. Historical and recent changes of sea-surface temperature along the U.S. east and west coast. In: Proceedings of the NOAA Climate Diagnostics Workshop, Washington, D.C., November 4-5, 1976, p. 12-1 to 12-17.

MARKHAM, C. G., and D. R. McLAIN.
1977. Sea-surface temperature related to rain in Ceara, northeastern Brazil. Nature 265:320-323.

MILLER, F. R.

1977. The El Nino of 1976-77 in the southeast Pacific. In: Proceedings of the Second Annual NOAA Climate Diagnostics Workshop, La Jolla, California, October 18-20, 1977, p. 20-1 to 20-14.

MONIN, A. S., V. M. KAMENKOVICH, and V. G. KORT.

1977. Variability of the oceans. New York, John Wiley & Sons, Inc., 241 p.

NAMIAS, J.

1966. Large-scale air-sea interactions as primary causes of fluctuations in prevailing weather. New York Academy of Sciences Transactions 29: 183-191.

1969. Seasonal interaction between the North Pacific Ocean and the atmosphere during the 1960's. Monthly Weather Review 97:173-192.

1970. Macroscale variations in sea-surface temperatures in the North Pacific. Journal of Geophysical Research 75:565-582.

1971. The 1968-69 winter as an outgrowth of sea and air coupling during antecedent seasons. Journal of Physical Oceanography 1:65-81.

1972. Influence of northern hemisphere general circulation on drought in northeast Brazil. Tellus 24:336-343.

1972. Experiments in objectively predicting some atmospheric and oceanic variables for the winter of 1971-72. Journal of Applied Meteorology 11:1164-1174.

1973. Thermal communication between the sea surface and the lower troposphere. Journal of Physical Oceanography 3:373-378.

1974. Longevity of a coupled air-sea-continent system. Monthly Weather Review 102:638-648.

1975. The sea as a primary generator of short-term climatic anomalies. In: Proceedings of the WMO/IAMAP Symposium on Long-term Climate Fluctuations, Norwich, England, August 18-23, 1975, WMO Publication No. 421, p. 331-340.

1975. Stabilization of atmospheric circulation patterns by sea-surface temperatures. Journal of Marine Research 33:53-60 (suppl.).

1976. Negative ocean-air feedback systems over the North Pacific in the transition from warm to cold seasons. Monthly Weather Review 104: 1107-1121.

1976. Causes of the great California and Western Europe droughts of 1976. In: Proceedings of the NOAA Climate Diagnostics Workshop, Washington, D.C., November 4-5, 1976, p. 20-1 to 20-27.

OKAWA, T.

1974. Intensification of the Okhotsk high due to cold sea surface. In: Oceanography of the Bering Sea: with emphasis on renewable resources. International Symposium for Bering Sea Study, Hakodate, Japan, January 31 - February 4, 1972. Fairbanks, Institution of Marine Science Occasional Publication No. 2, p. 451-465.

OLIVIER, M. G., and H. W. BRANDLI.
1975. Cloud dissipation off the west coast of Florida. American Meteorological Society Bulletin 56:60-62.

PERLROTH, I.
1967. Hurricane behavior as related to oceanographic environmental conditions. Tellus 19:258-268.

PITTOCK, A. N., et al., (eds.).
1978. Climatic change and variability. London and New York, Cambridge University Press., 455 p.

QUINN, W. H.
1976. An improved approach for following and predicting equatorial Pacific changes and El Nino. In: Proceedings of the NOAA Climate Diagnostics Workshop, Washington, D.C., November 4-5, 1976, p. 21-1 to 21-15.
1977. Diagnosis of the 1976-77 El Nino. In: Proceedings of the Second Annual NOAA Climate Diagnostics Workshop, La Jolla, California, October 18-20, 1977, p. 21-1 to 21-14.

RAMAGE, C. S.
1974. Monsoonal influences on the annual variation of tropical cyclone development over the Indian and Pacific oceans. Monthly Weather Review 102:745-753.
1977. Sea-surface temperature and local weather. Monthly Weather Review 105:540-544.

RATCLIFFE, R. A. S.
1973. Recent work on sea-surface temperature anomalies related to long-range weather forecasting. Weather 28:106-117.

RATCLIFFE, R. A. S., and R. MURRAY.
1970. New lag associations between North Atlantic sea temperature and European pressure applied to long-range weather forecasting. Quarterly Journal of the Royal Meteorological Society 96:226-246.

ROGERS, J. C.
1976. Sea-surface temperature anomalies in the eastern North Pacific and associated wintertime atmospheric fluctuations over North America, 1960-73. Monthly Weather Review 104:985-993.

ROWNTREE, P. R.
1972. The influence of tropical east Pacific ocean temperatures on the atmosphere. Quarterly Journal of the Royal Meteorological Society 98:290-321.
1976. Response of the atmosphere to a tropical Atlantic ocean temperature anomaly. Quarterly Journal of the Royal Meteorological Society 102:607-625.

ROYER, T. C.
1975. On climatic control by the waters of the Gulf of Alaska. In: Climate of the Arctic, Proceedings of the 24th Alaska Science Conference, Fairbanks, August 15-17, 1973, p. 120-124.

SALMON, R., and M.C. HENDERSHOTT.
1976. Large-scale air-sea interactions with a simple general circulation model. Tellus 28:228-242.

SERRA, C. S.
1975. On the importance of the sea-surface temperature on hurricane development, numerical experiments. Geofisica Internacional 15:65-78.

SHUKLA, J.
1975. Effect of Arabian sea-surface temperature anomaly on Indian summer monsoon: a numerical experiment with the GFDL model. Journal of the Atmospheric Sciences 32:503-511.

SPAR, J.
1973. Transequatorial effects of sea-surface temperature anomalies in a global general circulation model. Monthly Weather Review 101: 554-563.
1973. Supplementary notes on sea-surface temperature anomalies and model generated meteorological histories. Monthly Weather Review 101: 767-773.

SPAR, J. and R. ATLAS.
1975. Atmospheric response to variations in sea-surface temperature. Journal of Applied Meteorology 14:1235-1245.

SWANN, C. L., and L. MADDOCK.
1977. A statistical analysis of some trends in sea temperature and climate in the Plymouth area in the last 70 years. Journal of the Marine Biological Association of the UK 57:317-338.

TABATA, S.
1976. General circulation of the Pacific Ocean and a brief account of the oceanographic structure of the North Pacific Ocean, Pt. 2, Thermal regime and influence on the climate. Atmosphere 14:1-27.

WEARE, B. C., A. R. NAVATO, and R. E. NEWELL.
1975. Empirical orthogonal analysis of Pacific sea-surface temperatures. In: Proceedings of the WMO/IAMAP Symposium on Long-term Climate Fluctuations, Norwich, England, August 18-23, 1975, WMO Publication No. 421, p. 167-174.

WRIGHT, P. B.
1977. Sea-surface temperature and climate. Nature 265:291.