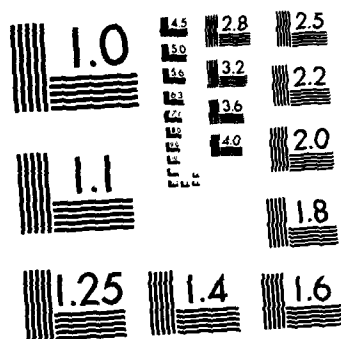END

FILMED

DTIC

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NPS68 - 82 - 006

AD A123732

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Model Simulations of Seventeen Years

of Mixed Layer Evolution at Ocean Station Papa

Roland W. Garwood

David Adamec

November 1982

Final Report for Period October 1981 - September 1982

Approved for public release; distribution unlimited.

Prepared for:

Naval Ocean Research and Development Activity (Code 320)

NSTL Station, Mississippi 39529

NAVAL POSTGRADUATE SCHOOL

Monterey, California 93940

Rear Admiral J.J. Ekelund   David A. Schrady
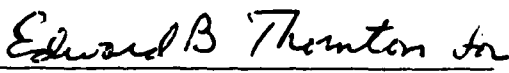Superintendent   Provost

    The work reported herein is a result of the research project "Modelling
Upper Ocean Thermal Structure" supported by the Naval Research and
Development Activity, NSTL Station, MS under program element 62759N.
Reproduction of all or part of this report is authorized.

This report was prepared by:

Roland W. Garwood   David Adamec

Assoc. Professor of Oceanography   Adj. Res. Instr. of Meteorology

Reviewed by:

C.N.K. Mooers, Chairman   R.J. Renard, Chairman

Department of Oceanography   Department of Meteorology

Released by:

William M. Tolles

Dean of Research

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NPS68-82-006	**2. GOVT ACCESSION NO.** AD-A123 782	**3. RECIPIENT'S CATALOG NUMBER**

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
Model Simulations of Seventeen Years of Mixed Layer Evolution at Ocean Station Papa	Report for October 1981 – September 1980
	6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Roland W. Garwood David Adamec	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Departments of Oceanography and Meteorology Naval Postgraduate School Monterey, California 93940	62759N N6846282WR20098

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Naval Ocean Researh & Development Activity NSTL Station, Mississippi 39529	November 1982
	13. NUMBER OF PAGES 37

14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)	15. SECURITY CLASS. (of this report)
	Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

—

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ocean thermal prediction
Mixed Layer Evolution
Atmospheric forcing of the ocean

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The bulk second order closure method of Garwood (1977) is used to predict the well-mixed layer depth and temperature evolution at Ocean Station Papa for the years 1953-1969. The time dependent boundary conditions are the specification of the surface buoyancy flux and wind stress derived from the 3-hourly atmospheric observations. Much of the variance of the well-mixed layer depth and temperature evolution is obviously associated with the annual

DD FORM 1473 1 JAN 73 **EDITION OF 1 NOV 65 IS OBSOLETE**
S/N 0102-014-6601 |

cycle. However, a closer inspection of the results reveals a variability related to the synoptic response of the sea-surface temperature and mixed layer depth to both strong and light wind events. The simulations are not intended to be a best fit, but rather a demonstration of the capability of a one-dimensional model to simmulate the interannual variability observed at OWS Papa.

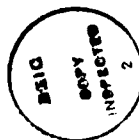MODEL SIMULATIONS OF SEVENTEEN YEARS

OF MIXED LAYER EVOLUTION AT OCEAN STATION PAPA

Roland W. Garwood[1] and David Adamec[2]

Naval Postgraduate School, Monterey, CA 93940 (U.S.A.)

1. Department of Oceanography

2. Department of Meteorology

ABSTRACT

The bulk second order closure method of Garwood (1977) is used to predict the well-mixed layer depth and temperature evolution at Ocean Station Papa for the years 1953-1969. The time dependent boundary conditions are the specification of the surface buoyancy flux and wind stress derived from the three-hourly atmospheric observations. Much of the variance of the well-mixed layer depth and temperature evolution is obviously associated with the annual cycle. However, a closer inspection of the results reveals a variability related to the synoptic response of sea-surface temperature and mixed layer depth to both strong and light wind events. The simulations are not intended to be a best fit, but rather a demonstration of the capability of a one-dimensional model to simulate the interannual variability observed at OWS Papa.

1. INTRODUCTION

Ocean Station Papa (50N,145W) in the eastern North Pacific Ocean has been the site of a number of one-dimensional model simulations of the oceanic planetary boundary layer or mixed layer. Using the bulk model of Kraus and Turner (1967) at this site, Denman and Miyake (1973) first simulated the mixed layer response to local atmospheric forcing during June 1970 for a twelve-day period. Mellor and Durbin (1975) applied a profile (rather than bulk) turbulence closure model to simulate a few weeks of upper ocean thermal structure evolution for the same time of the year (late spring but after the mixed layer had shallowed). Camp and Elsberry (1978) used three versions of the bulk mixed layer model (Elsberry et al, 1976; Kim, 1976; and Kraus and Turner, 1967) to study periods of fall and early winter deepening in response to strong atmospheric forcing at a number of locations, including Ocean Station Papa. The lengths of these model integrations were up to a month, and a number of different years were examined. The Mixed Layer Experiment (MILE) of August 18 to September 5, 1977 was also situated at Ocean Staion Papa. At least two different model simulations have been conducted of the MILE period; Garwood (1978) and Davis et al (1982). All of the above model simulations at Ocean Station Papa were of relatively short duration, and all were during the same half of the year, namely between the months of May and December after the seasonal thermocline had been set up.

3

For about 30 years, from the early 1950's until 1981, the Canadian Goverment sponsored a nearly continuous collection of meteorclogical and oceanographic data at Ocean Station Papa. The Canadian Goverment has recently terminated ship activities at Papa, thus interupting one of the few data sets available to oceanographers who wish to study long term variability in the upper ocean. Such cbservations have included BT drops, air temperature, humidity, wind measurements and sky cover.

The purpose of this study is to report the multi-year evclution of the ocean thermal structure predicted by a boundary layer entrainment model in response to forcing parameters calculated from observations taken at OWS Papa. In spite of the existence of this long time series of observations, until now no model simulaticns have been reported which are for more than a few weeks in duration, and no study has previously been conducted of the interannual variability in the ocean mixed layer response to the atmosphere. Also, no simulations have previously been conducted for the period of spring transition (usually between March and May at Ocean Station Papa) when the seasonal thermccline is set up. The purpose of this paper is to document the results of a series of seventeen consecutive model integrations (each of one year in duration) that for the first time take full advantage of the continuity of the data set.

2. METHOD

The bulk second order closure method of Garwood (1977) is employed as the OPBL model. The required time dependent surface boundary conditions is the specification of the surface bucyancy and momentum flux which are calculated using bulk aerodynamic formulae (Camp and Elsberry,1978). The forcing is calculated from the observations taken every three hours. Except for the parameterizaticn of the shear production of turbulence, there is no calculation of the momentum budget in this study. For each of the seventeen years, the model is initialized with a mixed layer depth, mixed layer temperature, a temperature jump at the base of the mixed layer and a bottom temperature (in this case 200 m) to which the temperature decreases linearly from that temperature just below the initial mixed layer depth (see Table I for these values). Each of the model runs is also initialized with a salinity profile that is a constant 34 ppt down to the mixed layer depth, decreases linearly to 35 ppt down to a depth of 150 m and remains a constnt 35 ppt below 150 m. This salinity profile contributes to the late winter mixed layer, but has no influence upon the evolution of the seasonal thermccline because the surface salinity flux is zero. This is equivalent to precipitation balancing evaporation.

Within the model there are essentially two degrees

5

of freedom which can be thought of as "tuning parameters". For all seventeen years of integration, only one set of tuning parameters is used. These tuning parameters were calibrated in such a way so that the maximum summer temperature predicted by the model for 1959 is in agreement with the maximum summer temperature observed at OWS Papa during that year. The year 1959 represents no special case but rather a random choice. This was not intended to be a best fit or optimal tuning in this study, but a demonstration of the relative interannual variability that can be simulated by a one dimensional model.

3. RESULTS

Each year at OWS Papa is represented by a set of seven figures labeled a-g. Those figures marked 'a' are the observed mixed layer depths from BT drops. The mixed layer depth was defined to be that depth where the water temperature first deviated by .2 C from the surface value. Figures marked 'b' are the model predicted time evolution of water temperature. The mixed layer depth can be inferred from the tight packing of isotherms. Figures marked c-g are a four day running mean of the time series of the observed sea-surface temperature, air temperature, dew point temperature, wind speed and percentage of cloudiness respectively.

For the most part, the seventeen figures are self evident. It is reccommended that the reader peruse them

6

consecutively, looking for interannual differences and similarities. This should be followed by a much closer inspection of each year, with particular attention paid to the synoptic response of sea-surface temperature and mixed layer depth to both strong and light wind events.

Most of the variances in the dew point, sea and air temperatures are obviously associated with the annual cycle. The air (dry bulb) temperature in all of these cases range from winter lows of about 4 C or 5 C to summer highs ranging near the 14 C or 15 C mark. On the average, the wind speeds are higher in the winter than they are in the summer, although the highest values are attained in the late fall. Oddly enough, the percentage of cloudiness is at a minimum when storm activity is at a peak, and maximum cloudiness occurs in the summer.

Since the model predicted values were only saved once a day, the diurnal signal is not evident here, and the annual cycle is the dominant signal. Initially, the mixed layers are deep and the sea-surface temperatures are low. Then, sometime in spring, the upper-ocean winter regime gives way to a summer regime during which the mixed layer is much shallower and the sea-surface temperatures are much higher. As fall approaches and the frequency of storms increase, the mixed layer becomes progressively deeper until once again the winter regime is restored. There is a limit to mixed layer deepening since the dissipation length scale

is limited by the planetary rotation scale , $U*/f$, where $U*$ is the model computed turbulent velocity scale. This prevents the mixed layer from becoming infinitely deep. The halocline prescribed as an initial condition, also may limit deep mixing for some years, as revealed by model integrations having no halocline (not shown here).

Perhaps the most striking feature in the year-to-year variability of the model hindcasts is the way the winter regime is transformed into a summer regime. This phenomenon is sometimes called 'spring transition'. During the spring, the winds are lighter and there is an increase in the net downward heat flux into the mixed layer. The combination of the lack of turbulent kinetic energy to maintain a deep mixed layer and the formation of a layer of buoyant water due to heating, allows a new mixed layer to reform at a shallower depth. In many cases, the transition has an almost sudden occurrence as is the case for 1959 (Fig. 7a), while with other cases, the change from a winter to a summer regime is more gradual and occurs in two or more steps as in 1957 (Fig. 5a). As suggested by Elsberry and Garwood (1978), the date of spring transition strongly influences summertime sea-surface temperatures. An early transition means that heat accumulates in a shallower boundary layer for a long period of time and hence increases summer sea-surface temperatures more than usual. Conversely, a late transition date will lead to relatively cooler summer temperatures. At OWS Papa, spring transition normally occurs

8

between Julian days 100 and 120.

In conclusion, the bulk method used here seems to be capable of simulating the seasonal and synoptic-scale variability observed at OWS Papa. Seventeen years of air-sea observations and model integrations provide an extensive test. Certainly other effects such as advection would be needed to provide a complete explanation of ocean variability at OWS Papa, but it is nevertheless encouraging that one dimensional mixing can account for a large part of the variance on time scales from the synoptic to more than a year.

ACKNOWLEDGMENTS

REFERENCES

Camp, N.T., and R.L. ELsberry, Oceanic thermal response to strong atmospheric forcing, 2, The role cf one dimensional processes, 'J. Phys. Oceanogr.', 8, 215-224, 1978.

Davis, R.E., R. DeSzoeke and P.P. Niiler, Variability in the upper ocean during MILE, 2, Modeling the mixed layer response, 'Deep Sea Research', 28, 1453-1476, 1982.

Denman, K.I. and M. Miyake, Upper layer modification at ocean station Papa: Observations and simulation. 'J. Phys. Oceanogr.',3, 185-196, 1973.

Elsberry, R.L., T. Fraim, and R. Trapnell Jr., A mixed layer model of the oceanic thermal response to hurricanes, 'J. Geophys. Res.', 81, 1153-1162, 1976.

Elsberry, R.L. and R.W. Garwood Jr., Sea-surface temperature anomaly generation in relation to atmospheric storms, 'Bull. Am. Meteorol. Soc.',59, 786-789, 1978.

Garwood, R.W., Jr., An oceanic mixed layer model capable of simulating cyclic states, 'J. Phys. Oceanogr.', 7, 455-468, 1977.

Garwood, R.W., Evidence of planetary-scale dissipation in the summertime oceanic boundary layer, 'Trans. Am. Geophys. Union', 58, 1156, 1978.

Kim, J.W., A generalized bulk method of the oceanic mixed layer, 'J. Phys. Oceanogr.', 6, 686-695, 1976.

Kraus, E.B. and J.S. Turner, A one dimensional model of the seasonal thermocline, 2, The general theory and its consequences, 'Tellus',19, 98-106, 1967

Mellor, G.L. and P.A. Durbin, The structure and dynamics cf the ocean surface mixed layer, 'J. Phys. Oceanogr.', 5, 718-728, 1975.

TABLE AND FIGURE CAPTIONS

Table I   Listing of initial sea-surface temperature, mixed
layer depth, temperature jump at the base of the mixed layer
and temperature at 200 meters for the years 1953-1969.

Fig. 1.   (a) Mixed Layer depths from BT drops, (b) depth
vs.   time   contours   of   temperature,   (c)   sea-surface
temperature, (d) air temperature (e) dew point temperature,
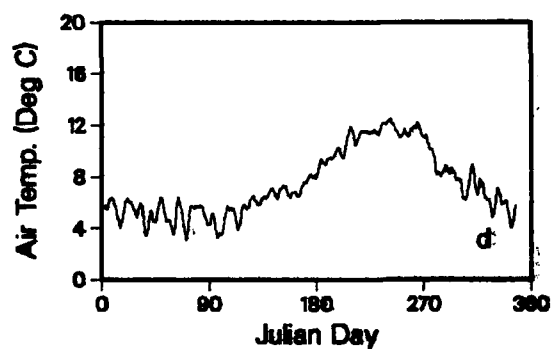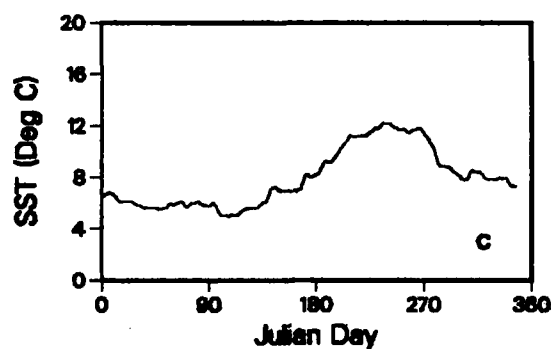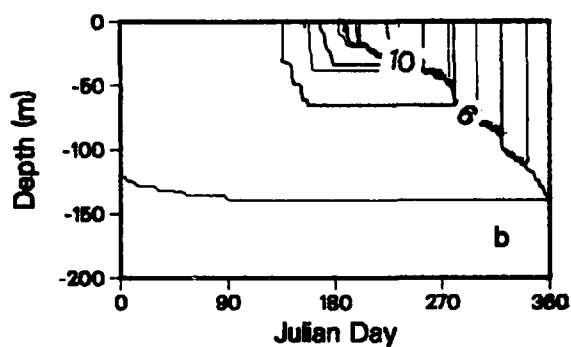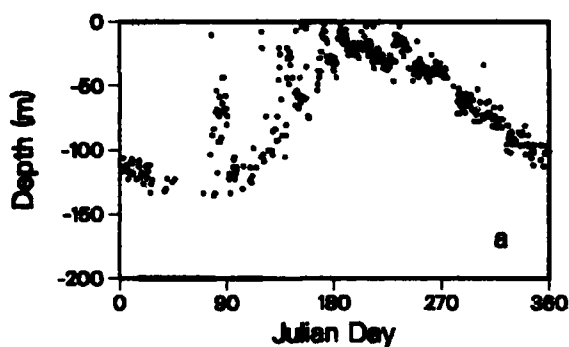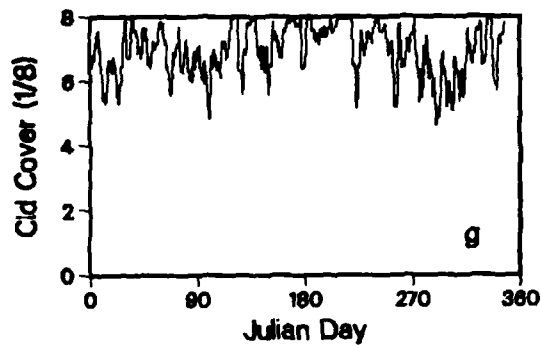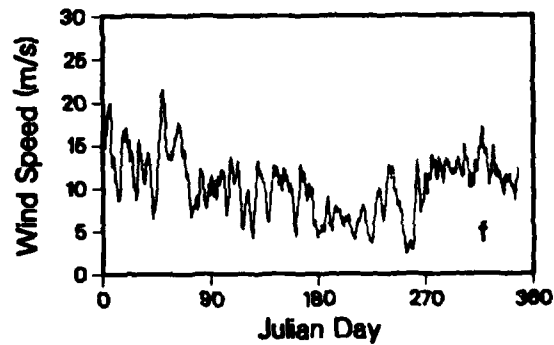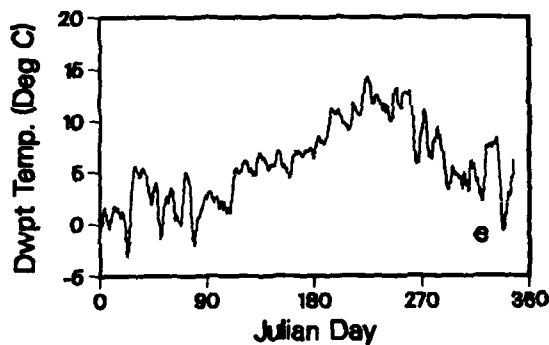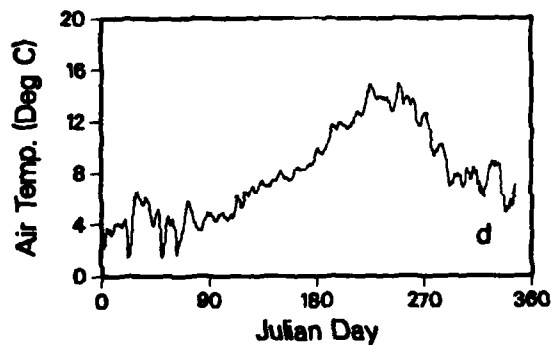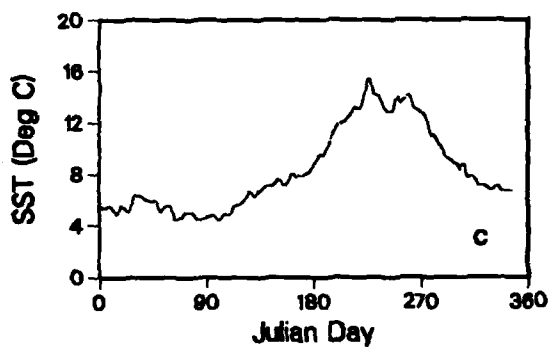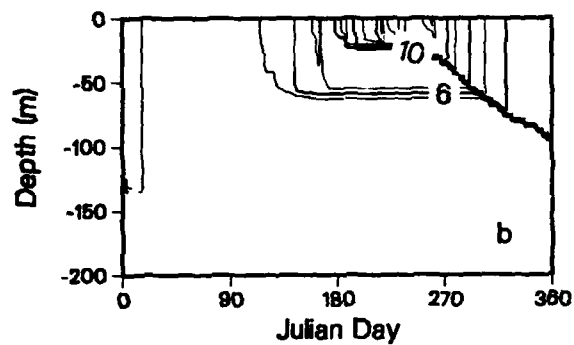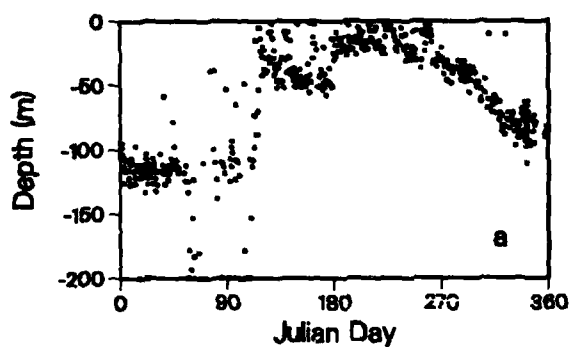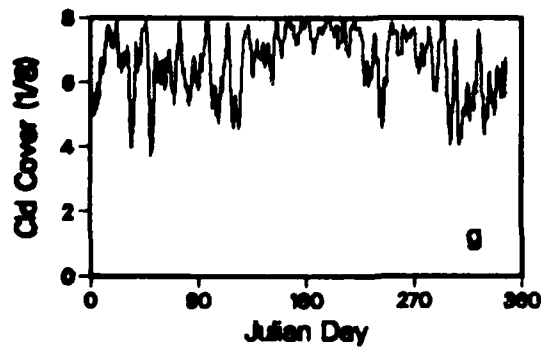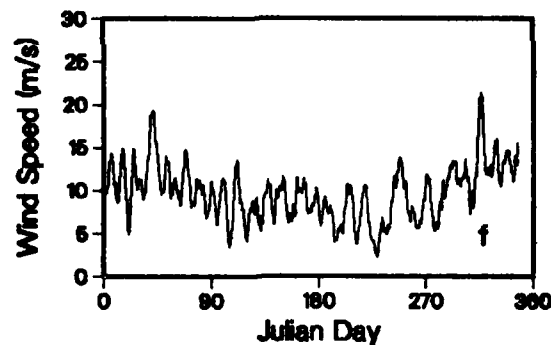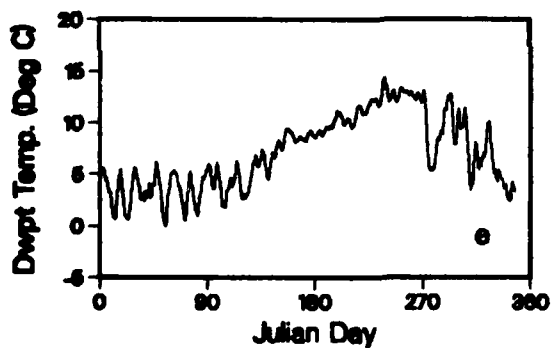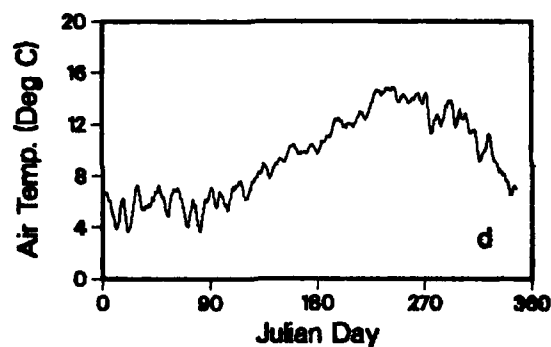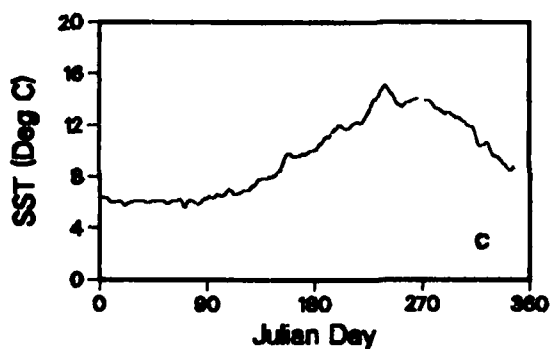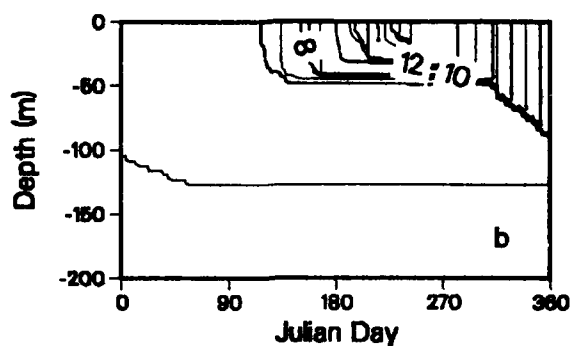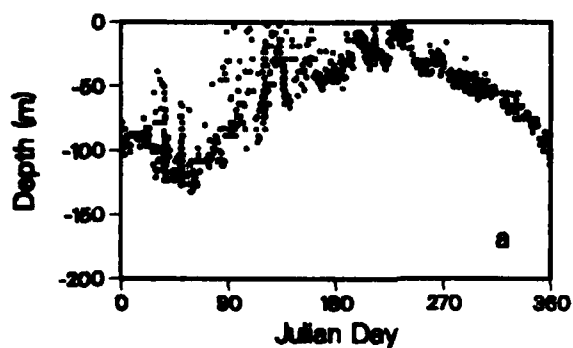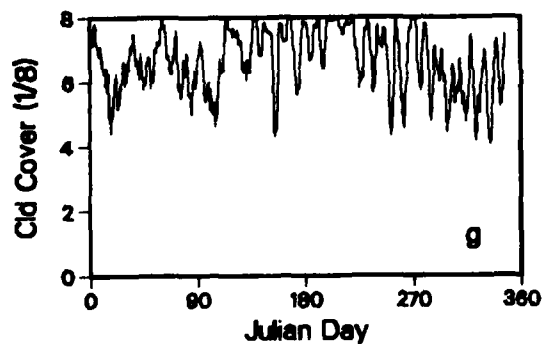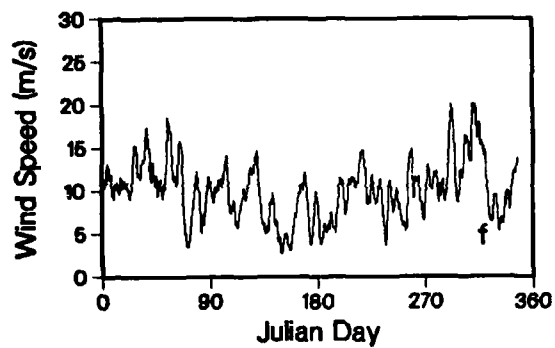(f) wind speed and (g) cloud cover for year 1953.

Fig. 2.   As in Figure 1 but for 1954.

Fig. 3.   As in Figure 1 but for 1955.

Fig. 4.   As in Figure 1 but for 1956.

Fig. 5.   As in Figure 1 but for 1957.

Fig. 6.   As in Figure 1 but for 1958.

Fig. 7.   As in Figure 1 but for 1959.

Fig. 8.   As in Figure 1 but for 1960.

Fig. 9.   As in Figure 1 but for 1961.

Fig. 10.   As in Figure 1 but for 1962.

Fig. 11.   As in Figure 1 but for 1963.

Fig. 12.   As in Figure 1 but for 1964.

Fig. 13.   As in Figure 1 but for 1965.

Fig. 14.   As in Figure 1 but for 1966.

Fig. 15.   As in Figure 1 but for 1967.

Fig. 16.   As in Figure 1 but for 1968.

Fig. 17.   As in Figure 1 but for 1969.

Table I

	Depth	Temp.	T jmp	T bot
1953	100.0	5.6	0.9	3.4
1954	120.0	5.4	0.7	3.4
1955	115.0	5.9	1.2	3.4
1956	120.0	5.5	1.4	3.0
1957	100.0	5.7	0.9	3.4
1958	120.0	7.0	0.9	3.2
1959	105.0	6.0	0.6	4.0
1960	110.0	6.5	1.5	4.0
1961	110.0	5.7	0.7	4.3
1962	100.0	6.0	1.5	3.8
1963	125.0	6.3	1.3	4.0
1964	100.0	5.7	1.3	2.8
1965	120.0	5.0	0.6	2.8
1966	130.0	5.9	1.0	3.6
1967	120.0	6.6	1.4	3.2
1968	130.0	5.3	0.5	3.2
1969	110.0	5.6	0.8	3.2
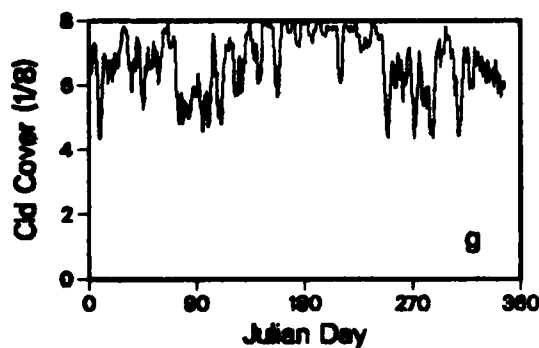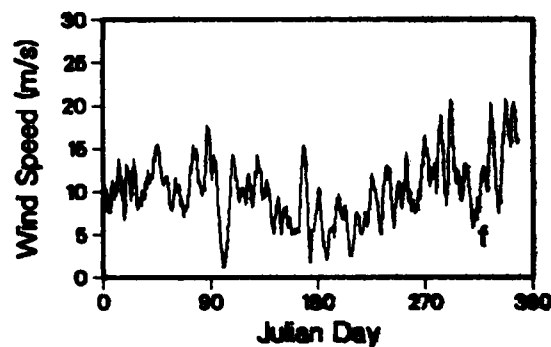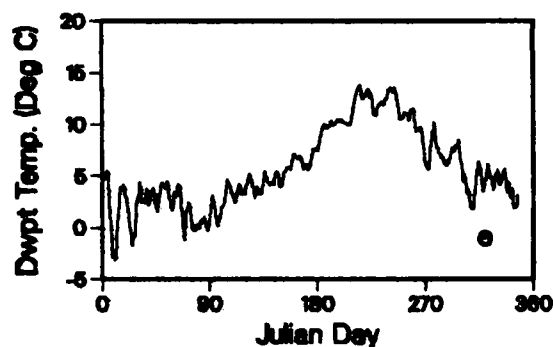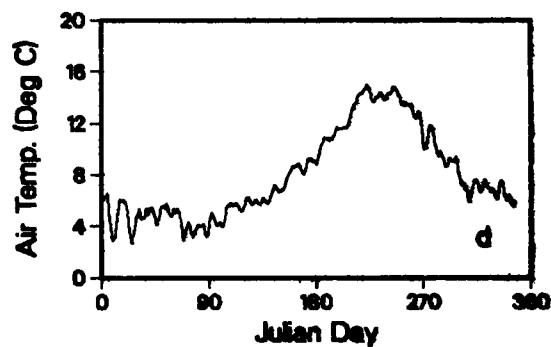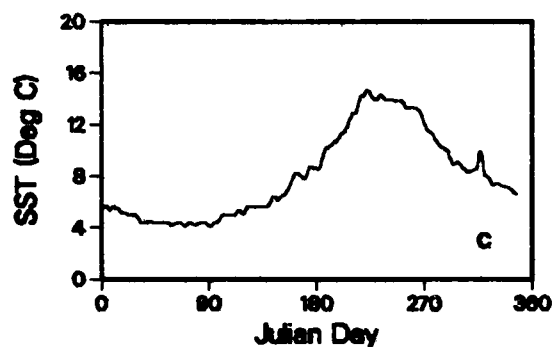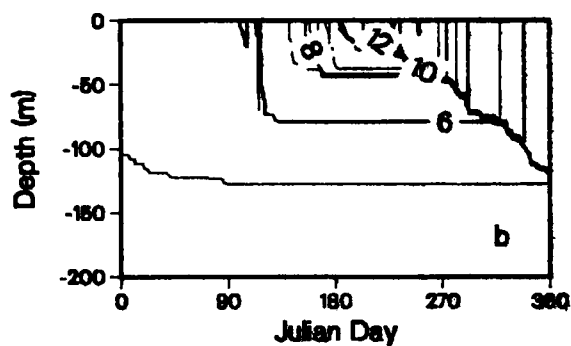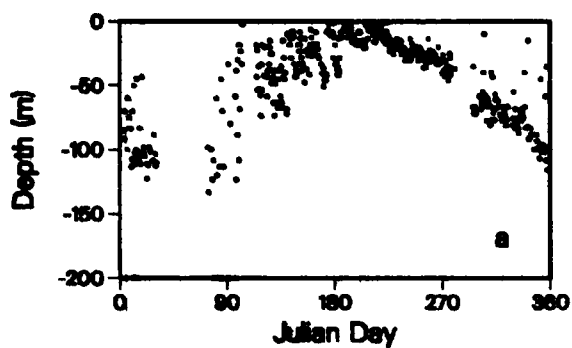
Figure 1. (a) Mixed layer depths from BT drops,
(b) depth vs. time contours of temperature,
(c) sea-surface temperature, (d) air temperature,
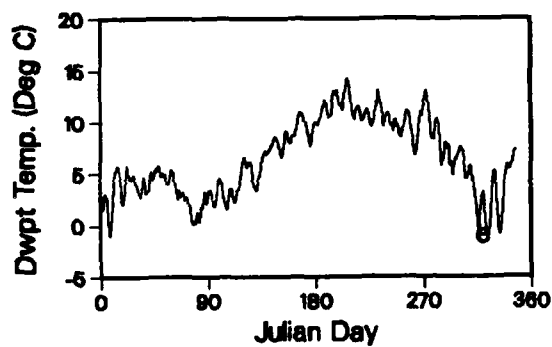(e) dew point temperature, (f) wind speed and
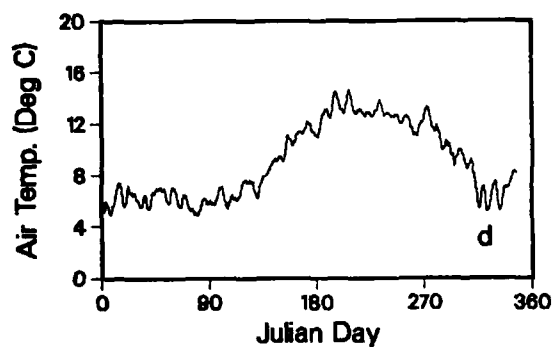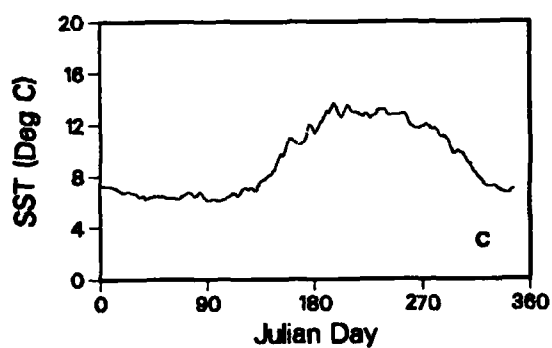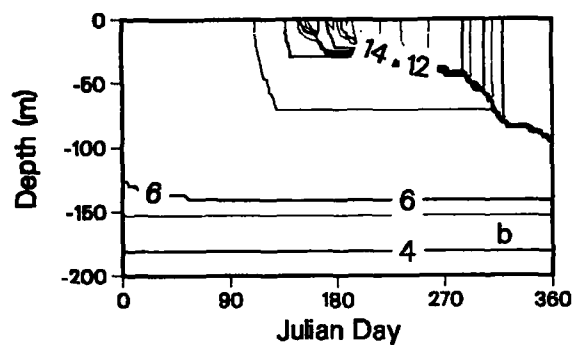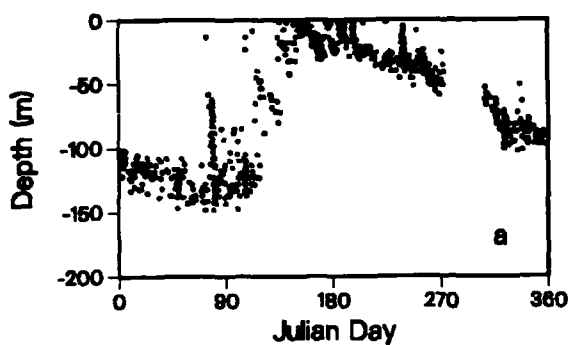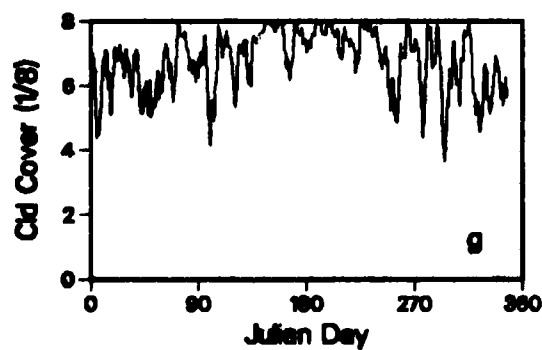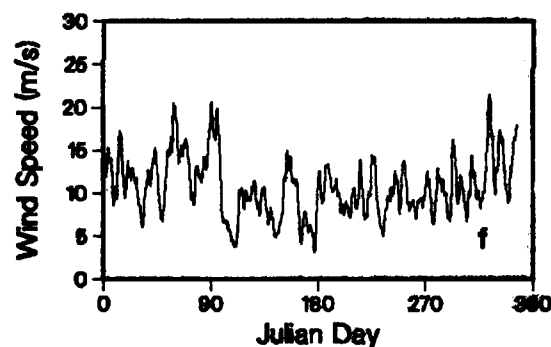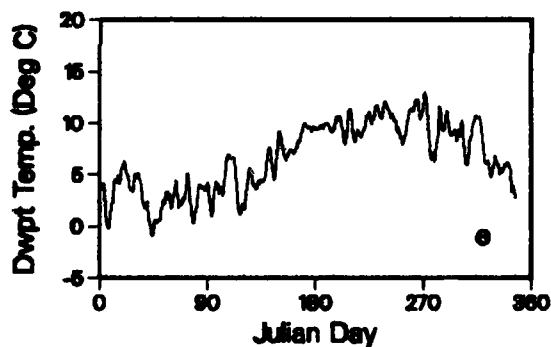(g) cloud cover for year 1953.

14
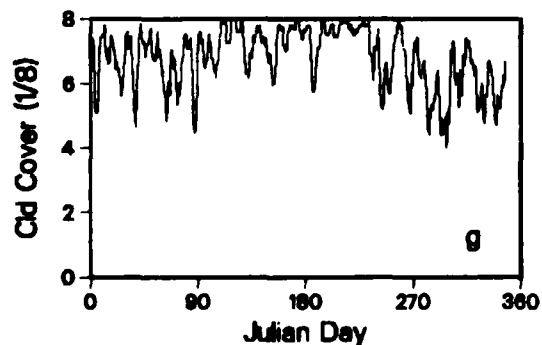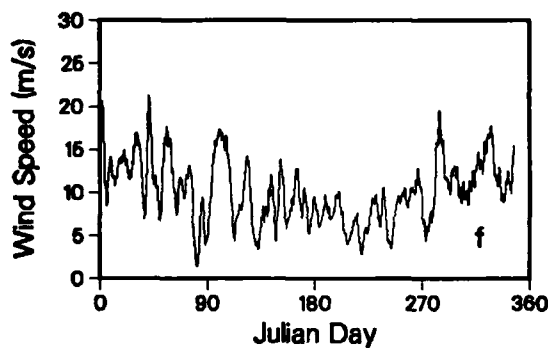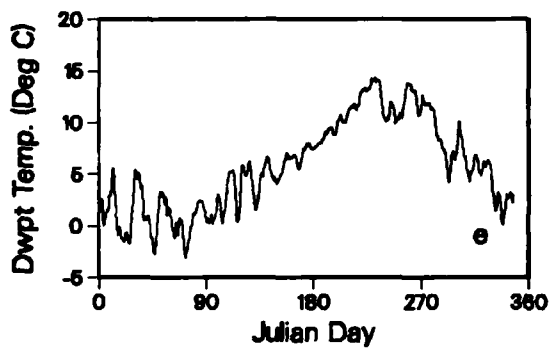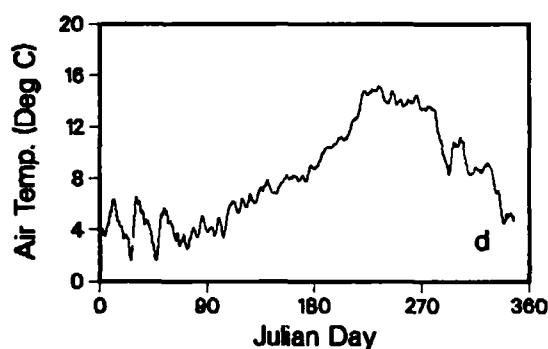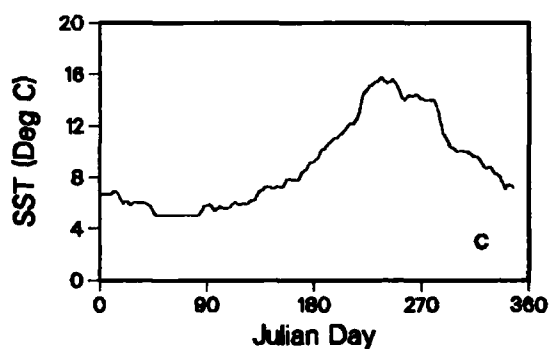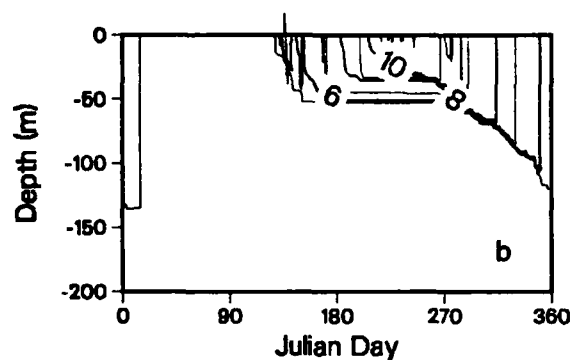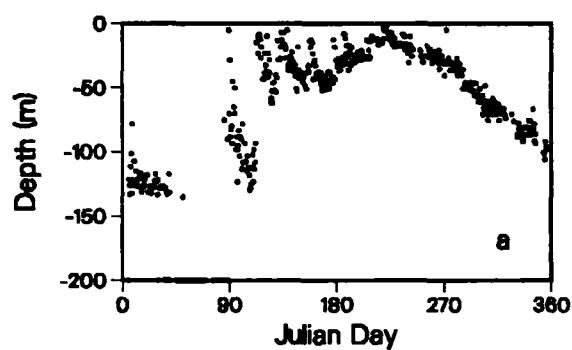
Figure 2. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1954.
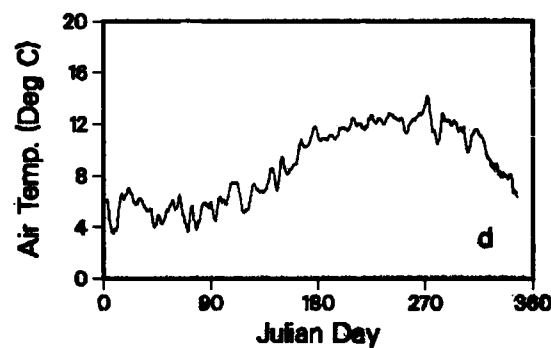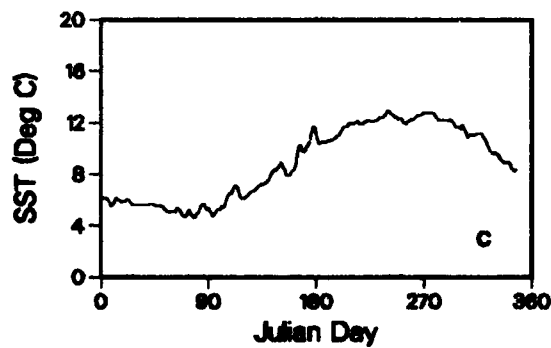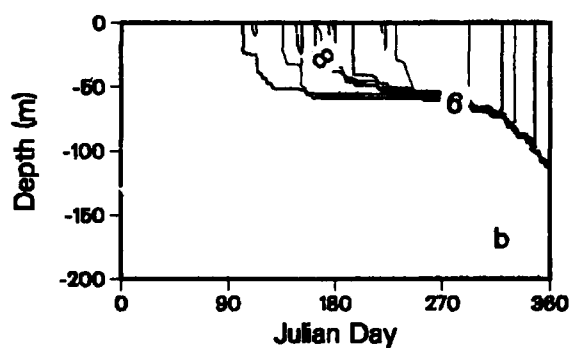
15
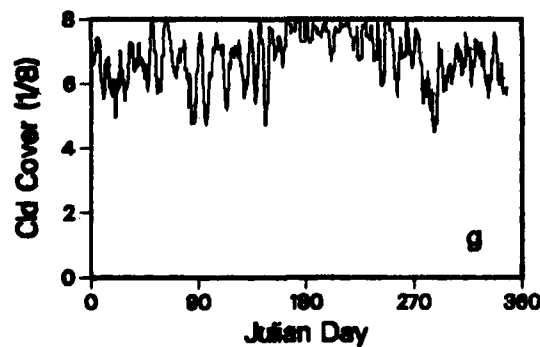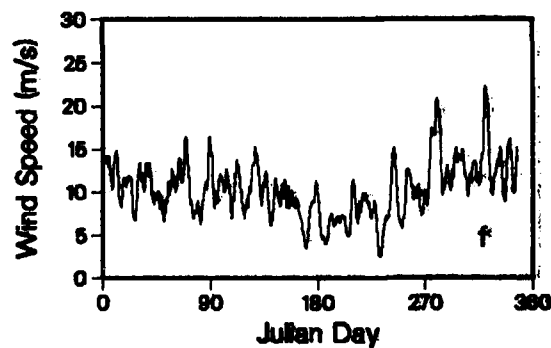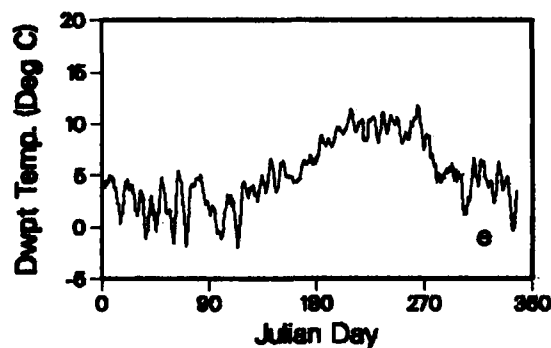
Figure 3. (a) Mixed layer depths from BT drops;
(b) depth vs. time contours of temperature,
(c) sea-surface temperature; (d) air temperature;
(e) dew point temperature, (f) wind speed and
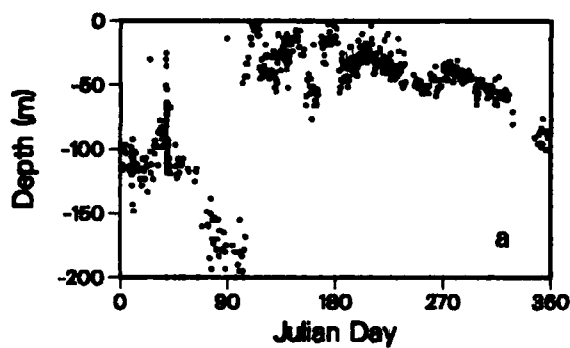(g) cloud cover for year 1955.

16

Figure 4. (a) Mixed layer depths from BT drops,
(b) depth vs. time contours of temperature,
(c) sea-surface temperature, (d) air temperature,
(e) dew point temperature, (f) wind speed and
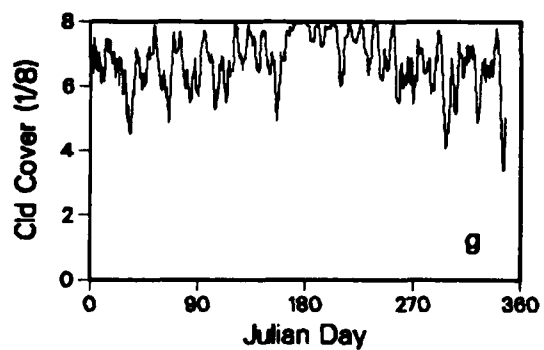(g) cloud cover for year 1956.

17

Figure 5. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1957.
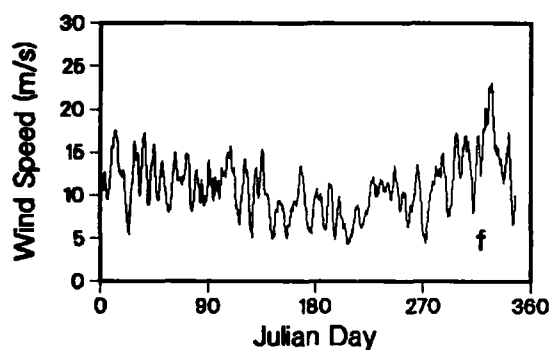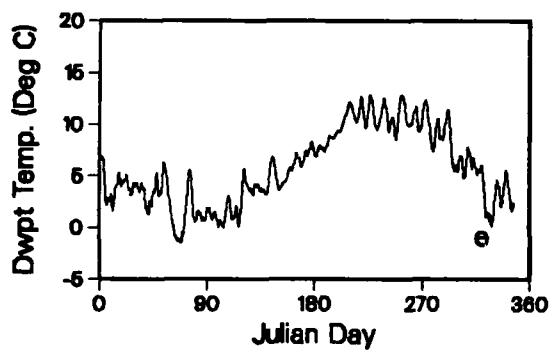
18

Figure 6. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1958.
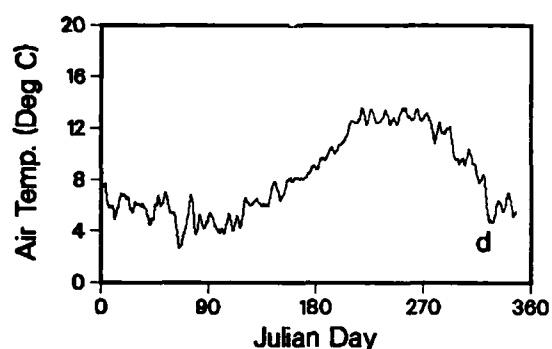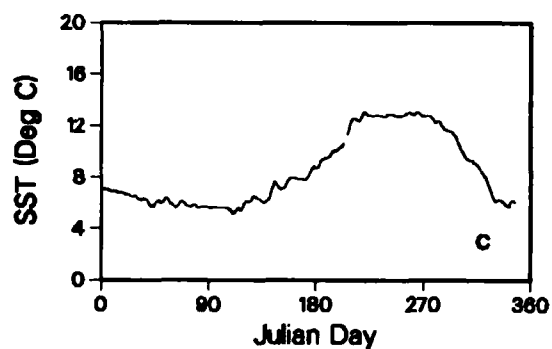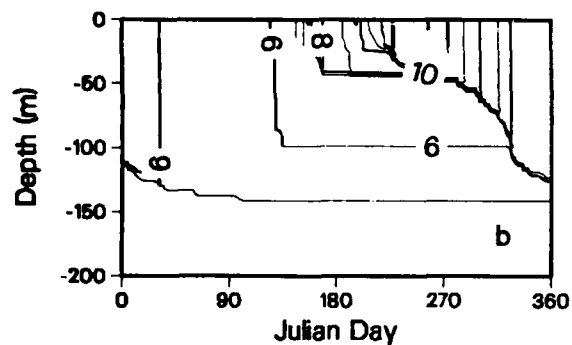
19

Figure 7. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1959.
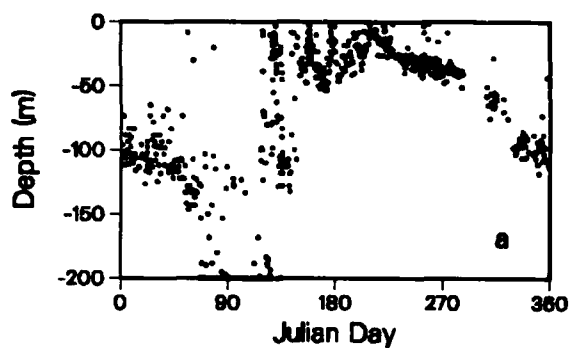
20

Figure 8. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1960.
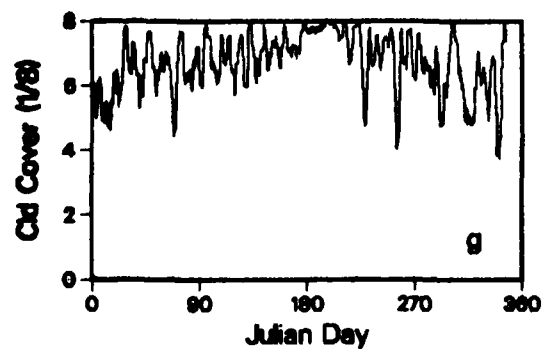
21

Figure 9. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1961.
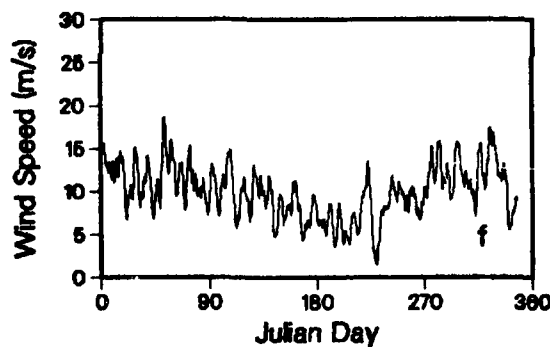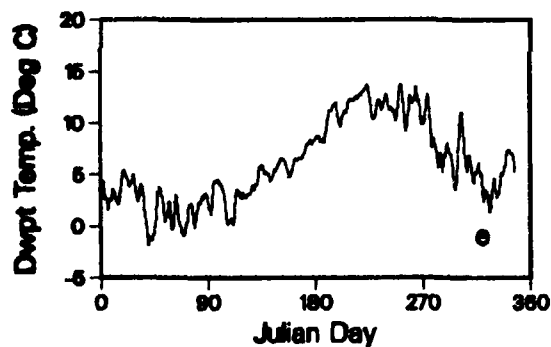
22

Figure 10. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1962.
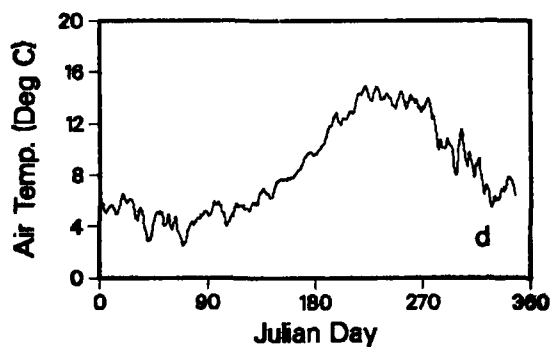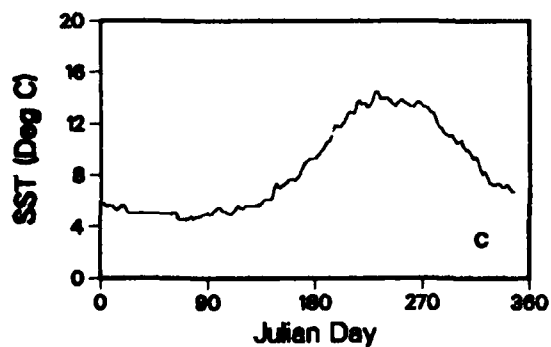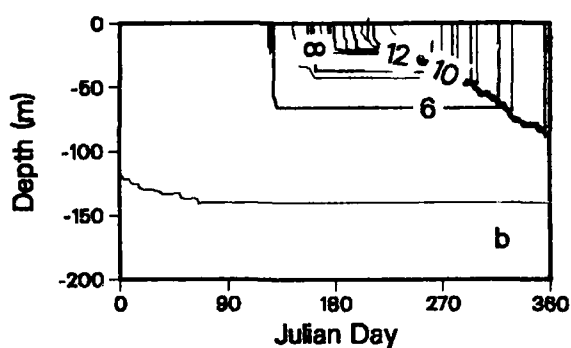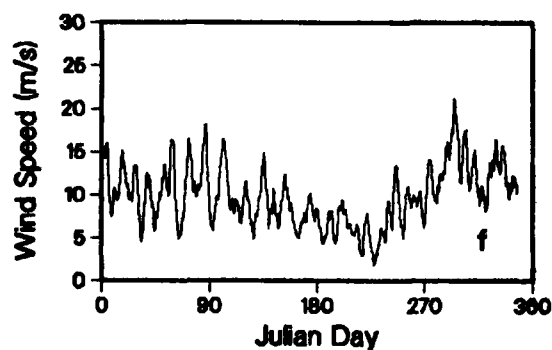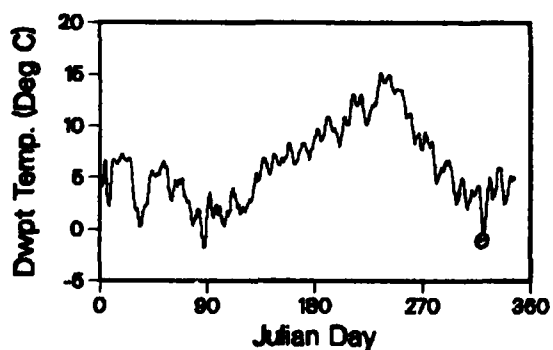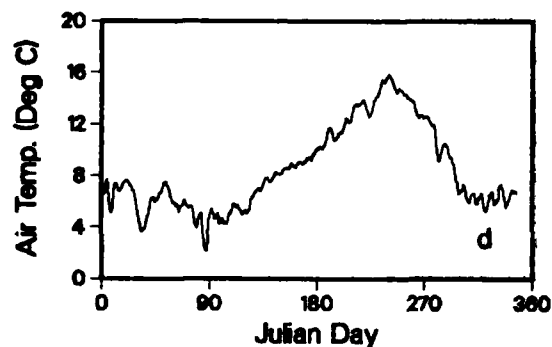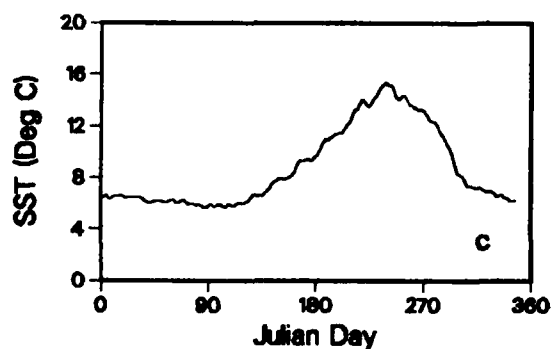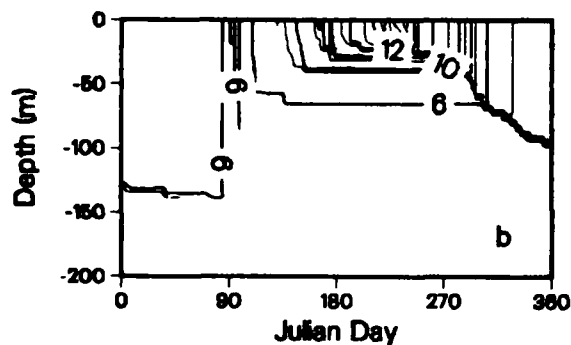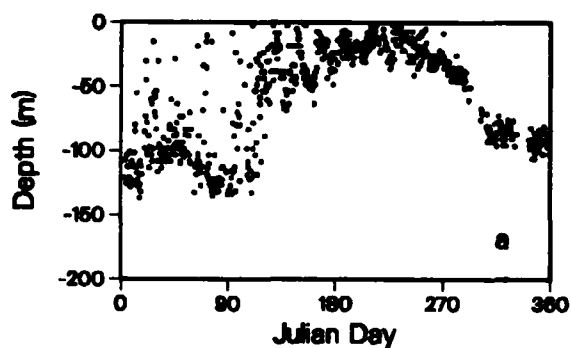
Figure 11. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1963.
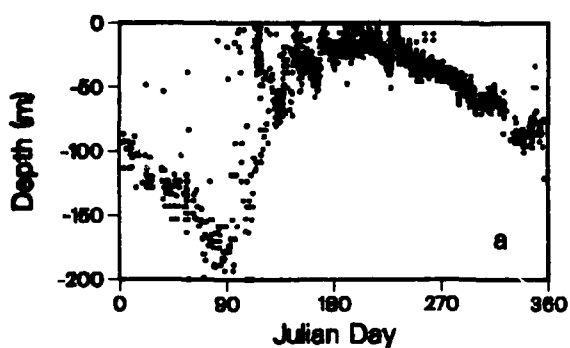
24
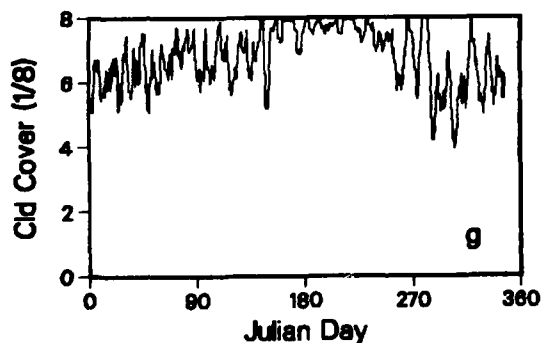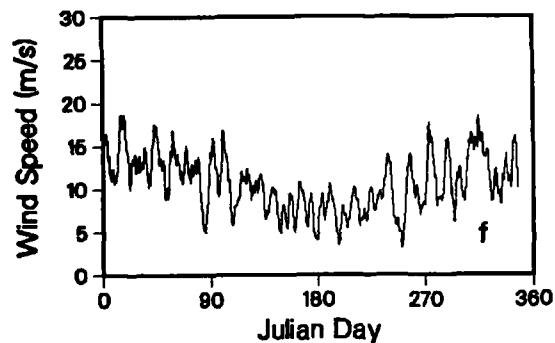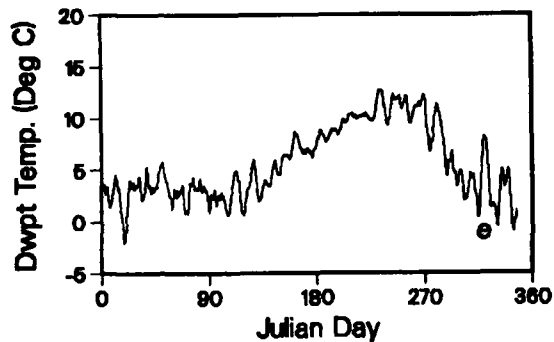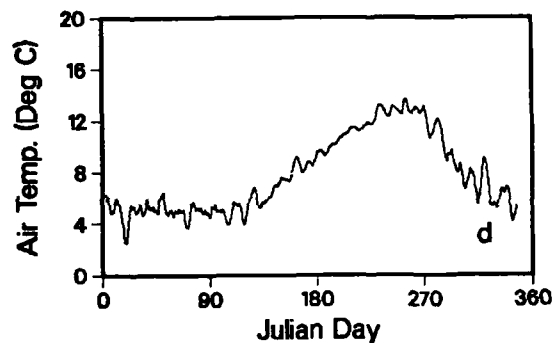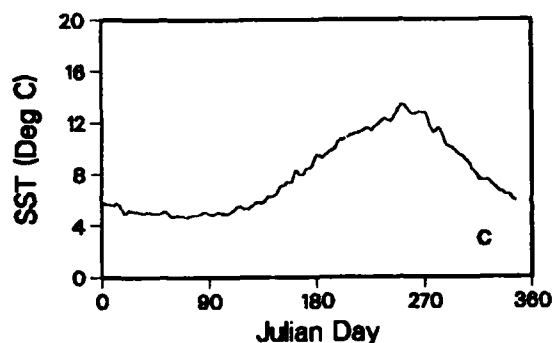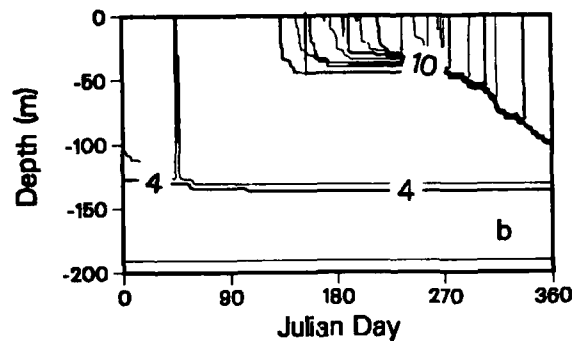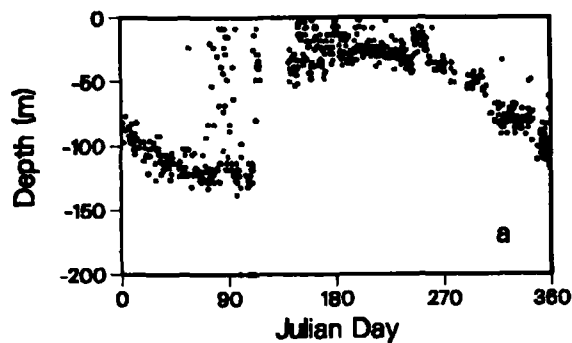
Figure 12. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1964.
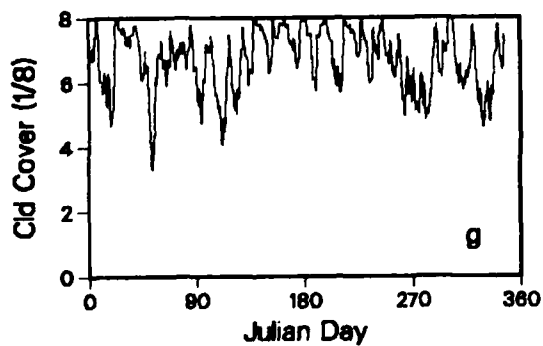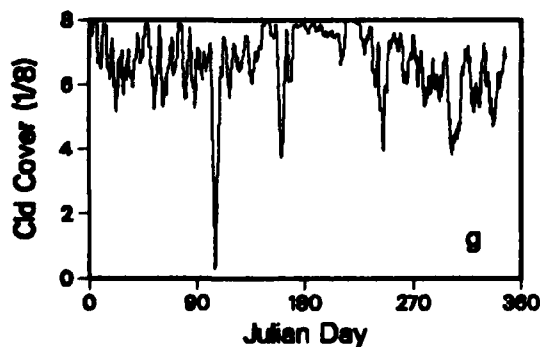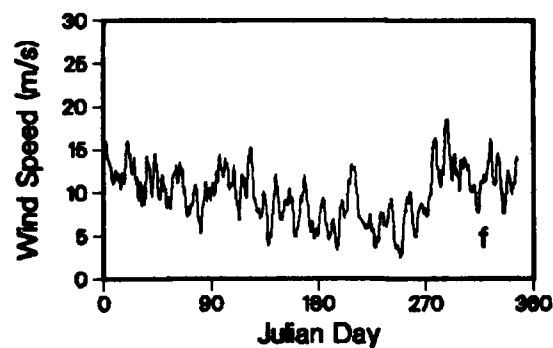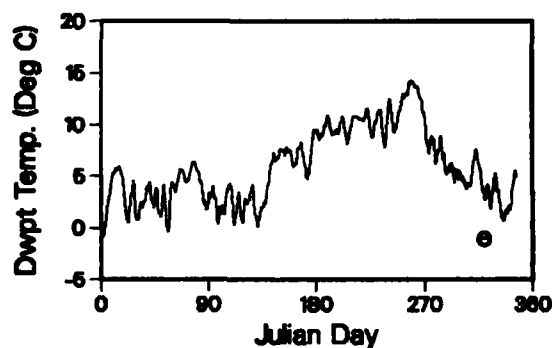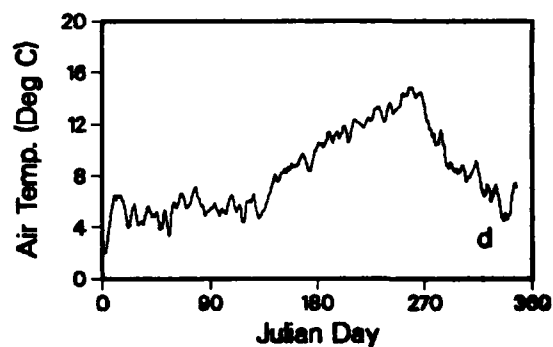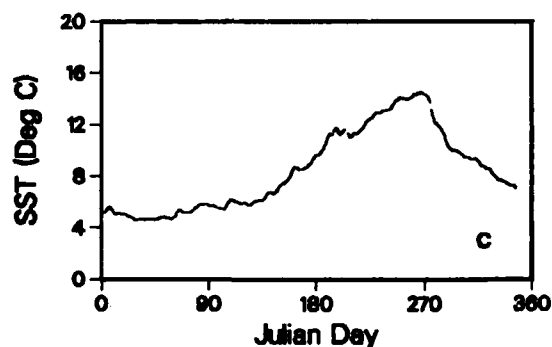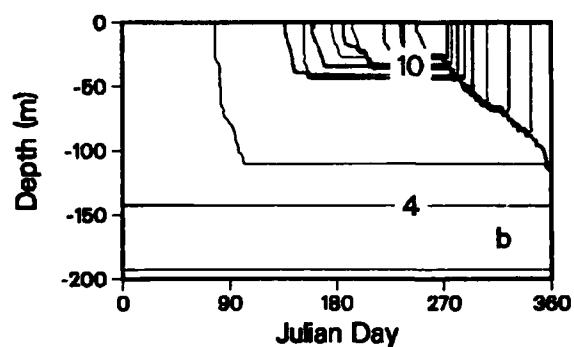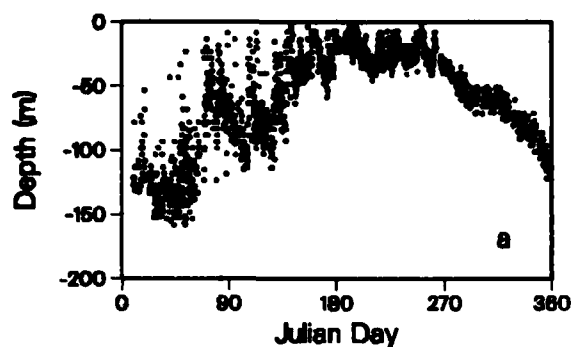
Figure 13. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1965.
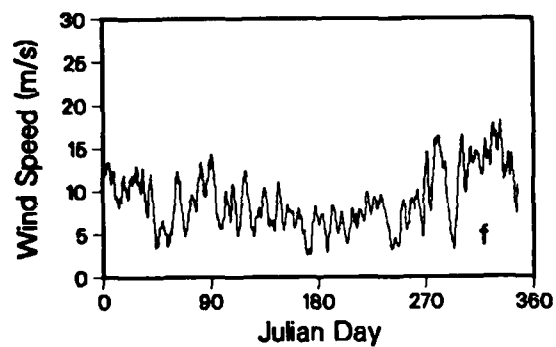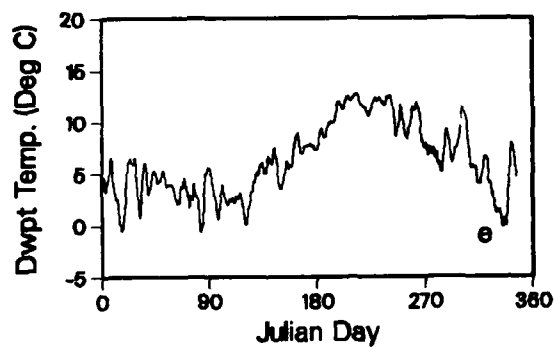
26
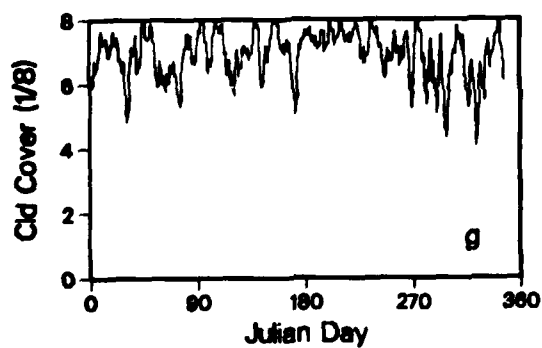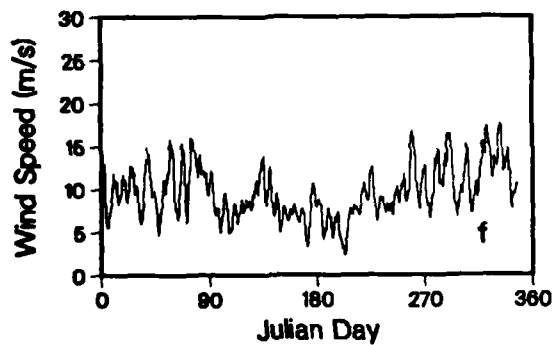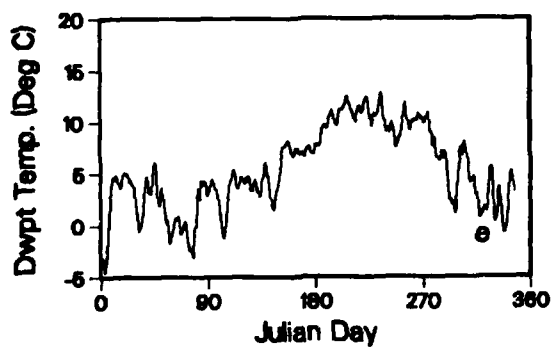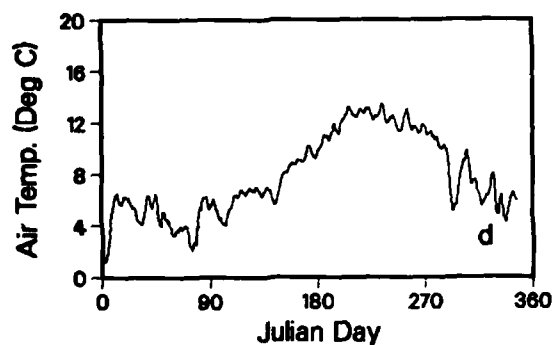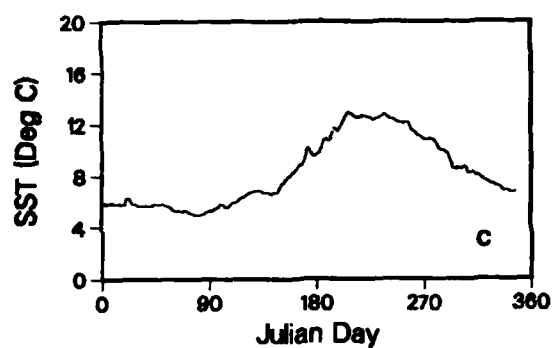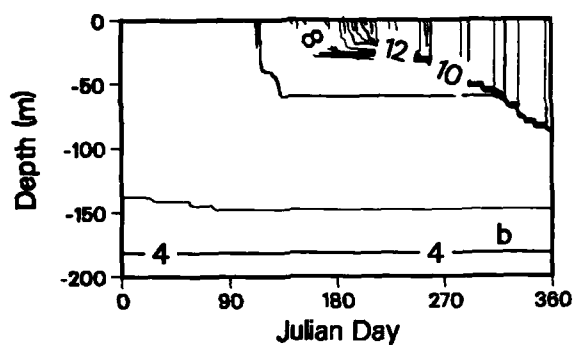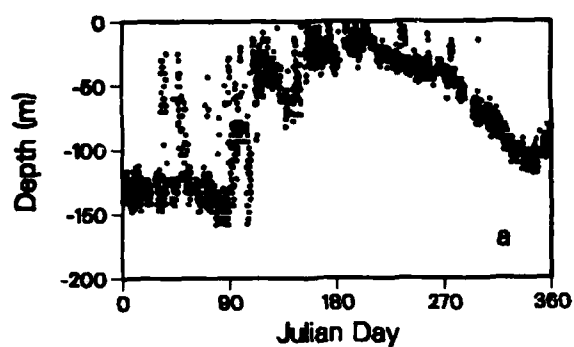
Figure 14. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1966.
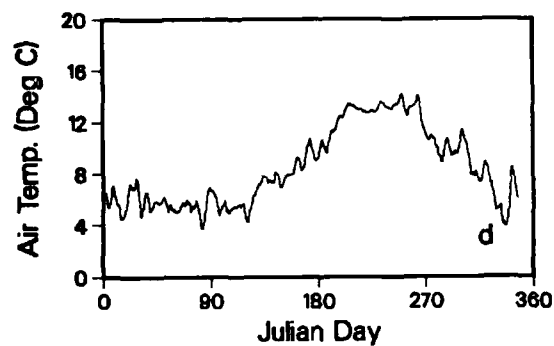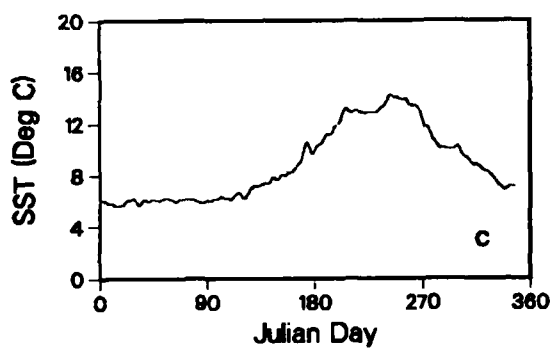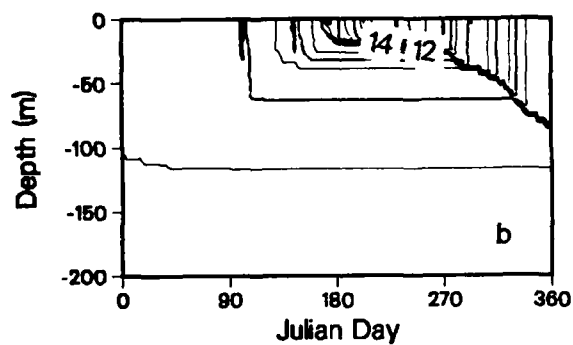
27
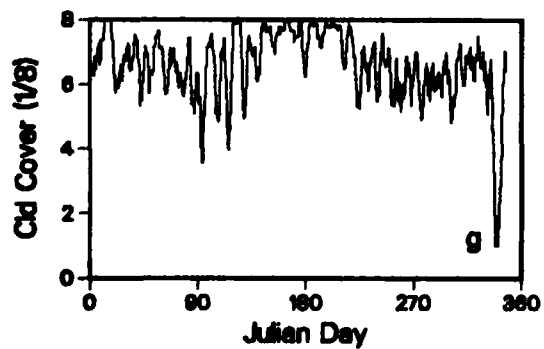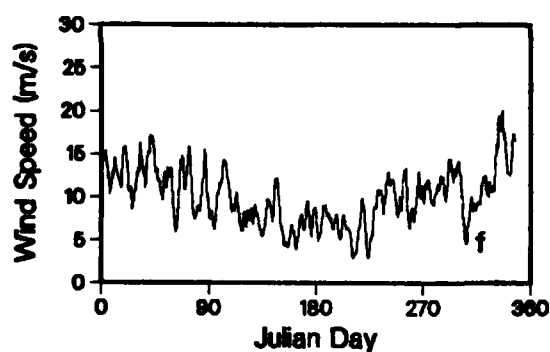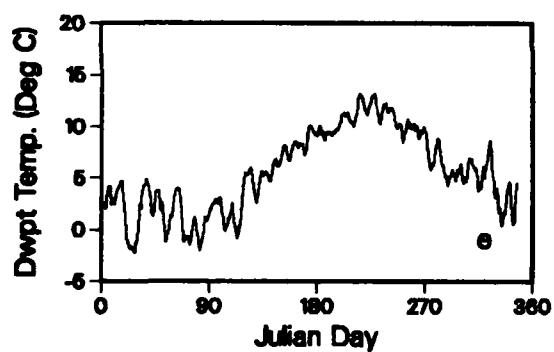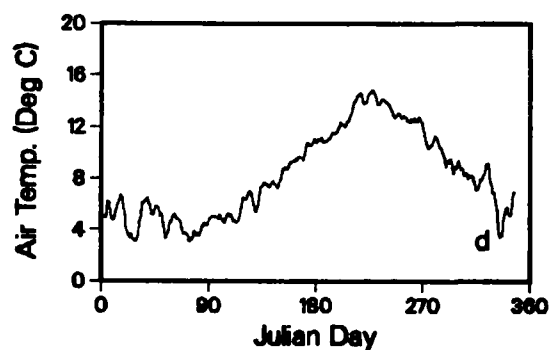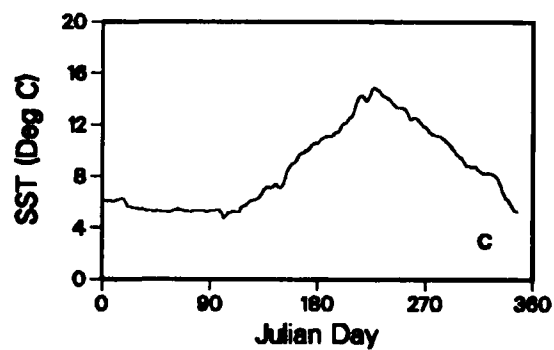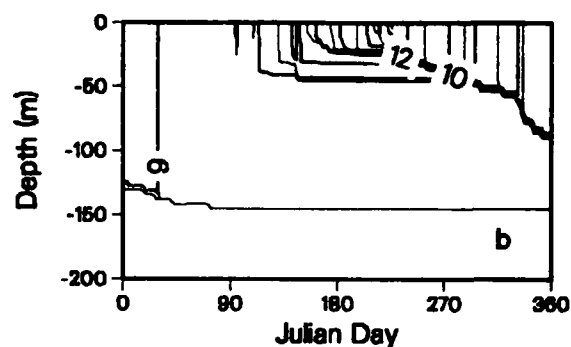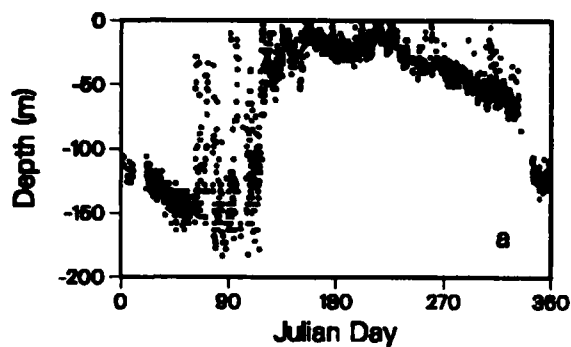
Figure 15. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1967.
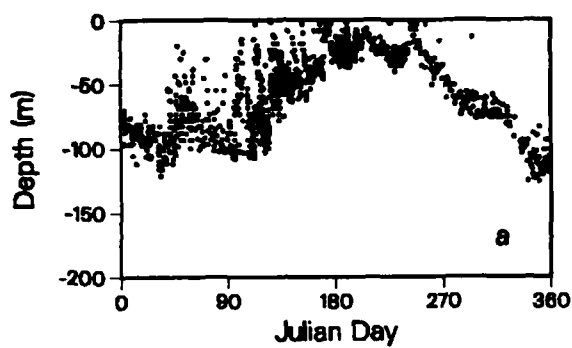
28
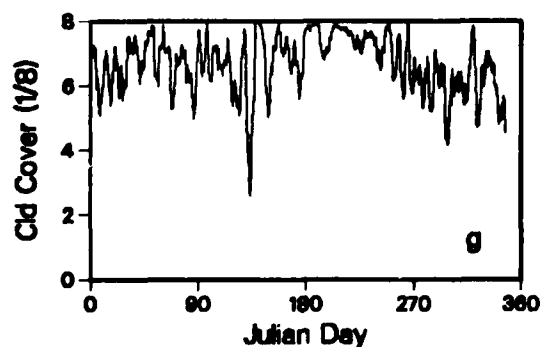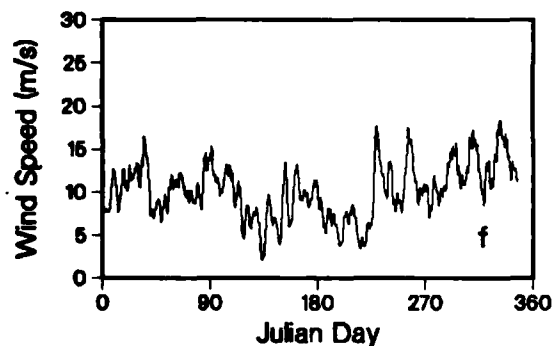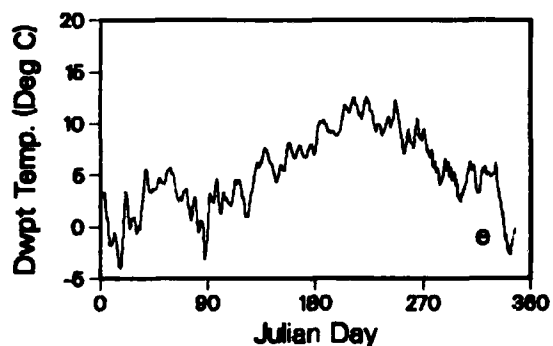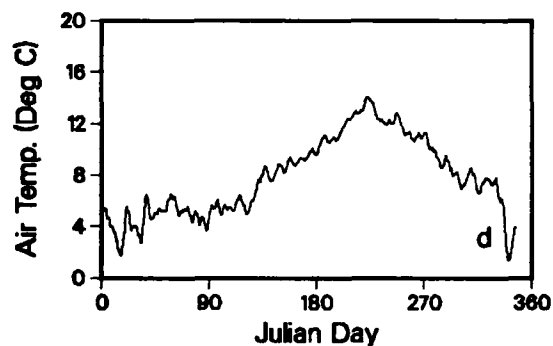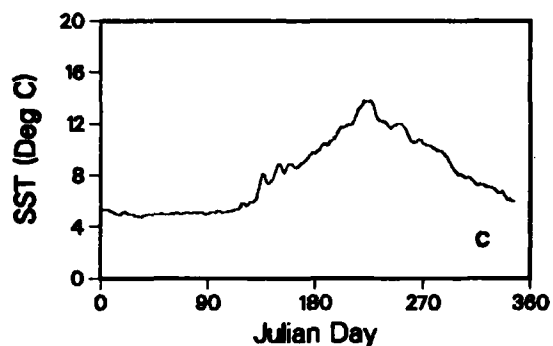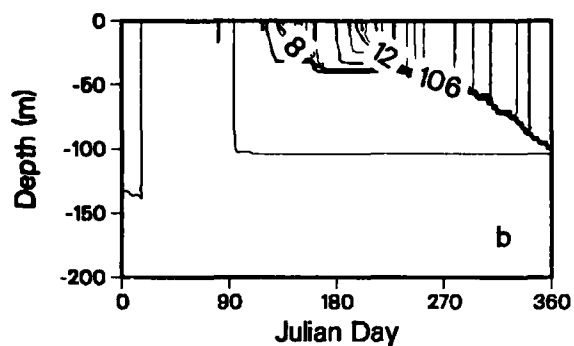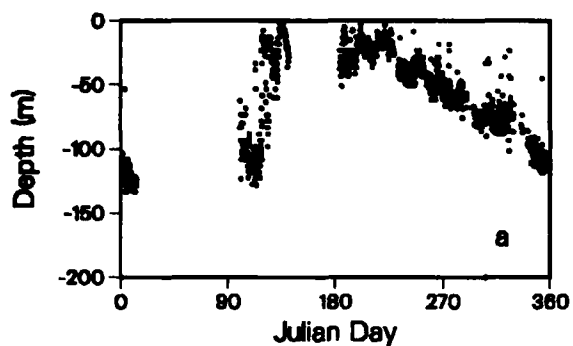
Figure 16. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1968.
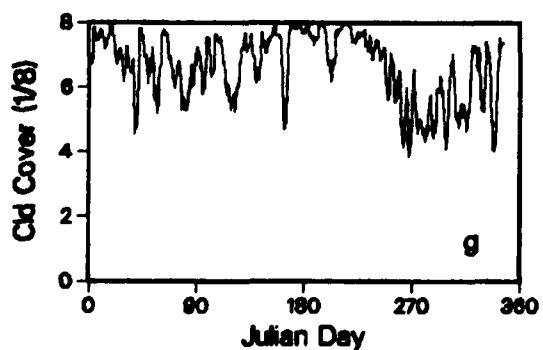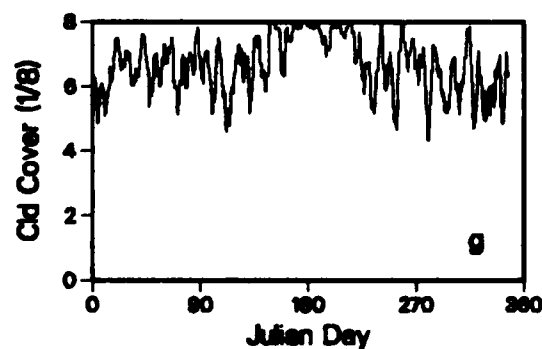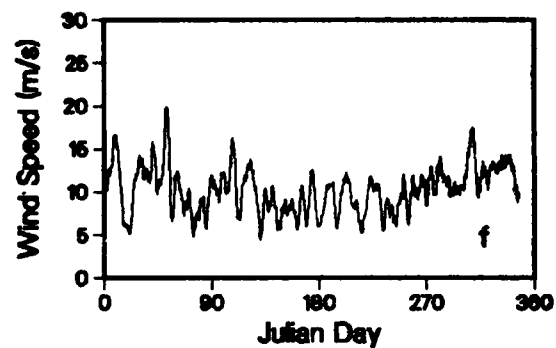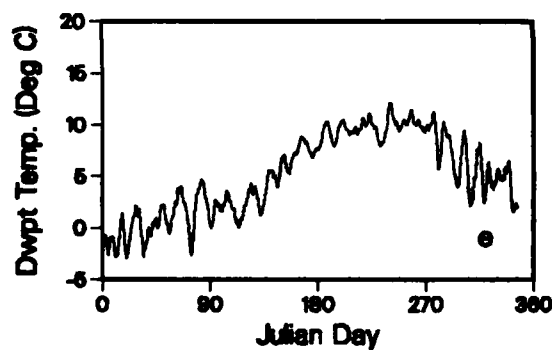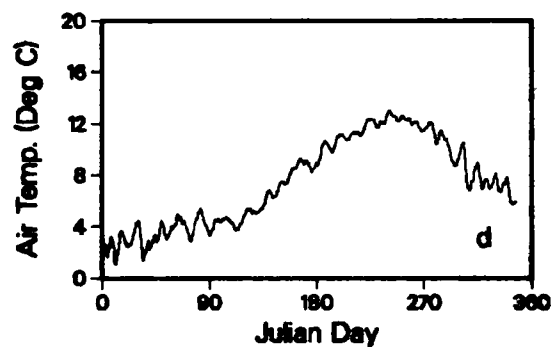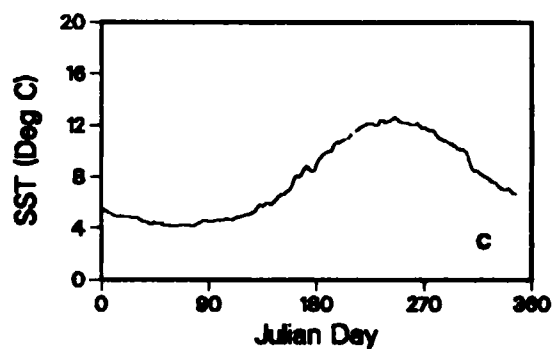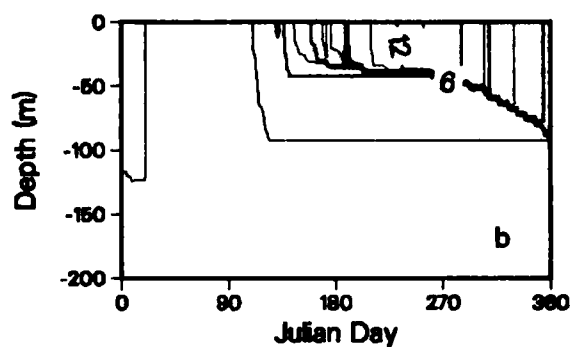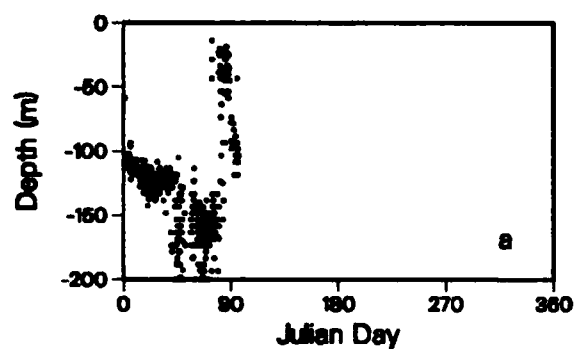
Figure 17. (a) Mixed layer depths from BT drops, (b) depth vs. time contours of temperature, (c) sea-surface temperature, (d) air temperature, (e) dew point temperature, (f) wind speed and (g) cloud cover for year 1969.

30

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center   2
    Cameron Station
    Alexandria, Virginia

2. Library, Code 0142   2
    Naval Postgraduate School
    Monterey, California   93940

3. Commanding Officer (Attn: S. Piacsek)   1
    Naval Ocean Research and Developmnt Agency
    NSTL Station, Missisippi   39529

4. Commander   1
    Naval Oceanography Command
    NSTL Station, Mississippi   39529

5. Commanding Officer   1
    Fleet Numerical Oceanography Center
    Monterey, California   93940

6. Officer-in-Charge   1
    Naval Environmental Prediction Research Facility
    Monterey, California   93940

7. Librarian   1
    Naval Environmental Prediction Research Facility
    Monterey, California   93940

8. Commander
    Attn: Code 8100   1
    Attn: Code 6000   1
    Attn: Code 3300   1
    Naval Oceanographic Office
    NSTL Station
    Bay St. Loius, Mississippi   39522

9. Office of Naval Research   1
    Code 481
    NSTL Station, Mississippi   39529

10. Dean of Research, Code 012   1
    Naval Postgraduate School
    Monterey, California   93940

11. Prof. R.L. Elsberry, Code 63Es   1
    Naval Postgraduate School
    Monterey, California   93940

12. Prof. R.W. Garwood, Jr., Code 68Gd   10
    Naval Postgraduate School
    Monterey, California   93940

31

13. Department of Meteorology, Code 63Mm   1
    Naval Postgraduate School
    Mcnterey, California   93940

14. Prof. R.L. Haney, Code 63Hy   1
    Naval Postgraduate School
    Mcnterey, California   93940

15. Prof. C.N.K. Mcoers, Code 68Mr   1
    Naval Postgraduate School
    Mcnterey, California   93940

16. Prcf. R.J. Renard, Code 63Rd   1
    Naval Postgraduate School
    Mcnterey, California   93940

17. Prcf. M. Rienecker, Code 68Rr   1
    Naval Postgraduate School
    Mcnterey, California   93940

18. Prcf. A. Willmott, Code 68Wt   1
    Naval Postgraduate School
    Mcnterey, California   93940

19. Mr. D. Adamec, Code 63Ac   5
    Naval Postgraduate School
    Mcnterey, California   93940

20. Mr. P.C. Gallacher, Code 63Ga   1
    Naval Postgraduate School
    Mcnterey, California   93940

21. Department of Oceanograpy, Ccde 68   1
    Naval Postgraduate School
    Monterey, California   93940

22. Ccmmanding Officer   1
    Naval Research Laboratory
    Attn: Library, Code 2627
    Washingtcn, D.C.   20375

23. Naval Research Laboratory   1
    Code 2627
    Washingtcn, D.C.   20375

24. Office of Naval Research
    Attn: Code 483   3
    Attn: Code 460   1
    Attn: Code 102B   2
    800 N. Quincy Street
    Arlington, Virginia   22217

25. Contracting Officer   1
    ONR Code 613C: JMD
    800 N. Quincy Street
    Arlington, Virginia 22217

26. Deputy Under Secretary of Defense   1
    Research and Advanced Technology
    Military Assistant for Environmental Science
    Room 3D120
    Washington, D.C. 20301

27. NODC/NOAA   1
    Code D781
    Wisconsin Avenue, N.W.
    Washington, D.C. 20235

28. Commanding Officer   1
    ONR Branch Officer
    Attn: Dr. R.L. Lau
    1030 E. Green Street
    Pasadena, California 91106

29. Dr. David Anderson   1
    DAMTP
    Silver Street
    Cambridge CB3 9EW
    United Kingdom

30. Dr. K. Bryan   1
    GFDL/NOAA
    Princeton University
    P.O. Box 308
    Princeton, New Jersey 08540

31. Dr. Curtis A. Collins   1
    Program Manager
    Environmental Prediction Office of IDOE
    National Science Foundation
    Washington, D.C. 20550

32. Dr. Claude Frankignoul   1
    Dept. of Meteorology, 54-1520
    Massachusetts Institute of Technology
    Cambridge, Massachusetts 02139

33. Dr. Jerry A. Galt   1
    NCAA Pacific Marine Environment Lab.
    University of Washington WB-10
    Seattle, Washington 98105

34. Prof. W.L. Gates, Chairman   1
    Dept. of Atmospheric Sciences
    Oregon State University
    Corvallis, Oregon 97331

35. Dr. Adrian Gill   1
    DAMTP
    Silver Street
    Cambridge CB3 9EW
    United Kingdom

36. Dr. Lou Goodman   1
    ONR Code 481
    c/c NUSC, Building 101-N
    Newport, Rhode Island 02840

37. Dr. David Halpern   1
    NOAA/PMEL
    3711 15th Avenue N.E.
    Seattle, Washington 98105

38. Dr. Dale B. Haidvogel   1
    Center for Earth and Planetary Sciences
    Harvard University
    Cambridge, Massachusetts 02138

39. Prof. Y.J. Han   1
    Dept. of Atmospheric Sciences
    Oregon State University
    Corvallis, Oregon 97331

40. Dr. Ed Harrison   1
    Dept. of Earth and Planetary Sciences
    Massachusetts Institute of Technology
    Cambridge, Massachusetts 02139

41. Dr. William Holland   1
    NCAR
    P.O. Box 3000
    Boulder, Colorado 80302

42. Cdr. Robert G. Kirk   1
    ONR Code 481
    NSTL Station, Mississippi 39529

43. Dr. Jeong-Woo Kim   1
    Dept. of Atmospheric Sciences
    Oregon State University
    Corvallis, Oregon 97331

44. Library   1
    Woods Hole Oceanographic Institution
    Woods Hole, Masschusetts 02543

34

45. Affonso da S. Mascarenhas, Jr.   1
    Dept of Meteorology and Physical Oceanography
    Room 54-1711
    Massachusetts Institute of Technology
    Cambridge, Massachusetts 02139

46. Ekki Mittelstredt   1
    Deutsches Hydrographisches Institut
    Bernhard-Nocht-Strabe 78 Postfach 2 20
    2000 Hamburg 4, F.R.G.

47. Dr. Bob Miller   1
    Harvard University
    Division of Applied Sciences
    Pierce Hall
    Cambridge, Massachusetts 02138

48. Dr. M. Miyake   1
    Institute of Ocean Sciences
    9860 W. Saanich Road
    P.O. Box 5000
    Sidney, B.C. V8L 4B2
    CANADA

49. Dr. Mike McPhaden   1
    NCAR
    P.O. Box 3000
    Boulder, Colorado 80302

50. Dr. J. Namias   1
    Scripps Institution of Oceanography A-030
    LaJolla, California 92093

51. Dr. Peter Niiler   1
    Scripps Institution of Oceanography A-030
    LaJolla, California 92093

52. Dr. J.J. O'Brien   1
    Meteorology Annex
    Florida State University
    Tallahassee, Florida 32306

53. Dr. C. Paul   1
    NOAA/AMCI/PLOL
    15 Rickerbacker Cswy
    Miami, Florida 33149

54. Prof. Allan R. Robinson   1
    Harvard University
    Pierce Hall
    Cambridge, Massachusetts 92073

55. Dr. P. Ripa   1
    CICESE
    P.O. Box 4844
    San Ysidro, California 92073

56. Lcdr. John Roeder   1
    ONR Code 481
    NSTL Station, Mississippi 39529

57. Dr. Tom Sanford   1
    Applied Physics Laboratory
    University of Washington
    1013 NE 40th Street
    Seattle, Washington 98105

58. Prof. Artem S. Sarkisyan   1
    Institute of Oceanol. USSR
    Academy cf Sciences
    Moscow, USSR

59. Dr. Robert E. Stevenson   1
    ONR Scientific Liaison Officer
    205 Mathews Campus, UCSD
    LaJolla, California 92093

60. Dr. Bert Semtner   1
    NCAR
    P.O. Box 3000
    Bculder, Colorado 80302

61. Dr. Kenzo Takano   1
    Rikagaku Kenkyusho
    Yamato-Machi, Saitama Prefecture
    JAPAN

62. Dr. Rory Thompson   1
    CSIRO Division of Fisheries and Oceanography
    Bcx 21, Cronulla, N.S.W.
    AUSTRALIA, 2230

63. Dr. J.D. Thompson   1
    JAYCOR
    205 S. Whiting Street
    Alexandria, Virginia 22304

64. Dr. Warren White   1
    NORPAX A-030
    Scripps Institution of Oceanography
    LaJolla, California 92093

65. Prof. Klaus Wyrtki   1
    University of Hawaii Institute of Geophysics
    2525 Correa Road
    Honolulu, Hawaii 96822

66. Dr. W. Washington   1
    NCAR
    P.O. Box 3000
    Bculder, Colorado 80302

67. Huseyin Yuce   1
    Yuk. Muh. Kd. Yzb.
    Sey. Hid. ve Osl. Da. Bsk. ligi
    Cobuklu/Istanbul
    TURKEY