THE INTEGRATION OF REMOTE SENSING DATA INTO GLOBAL WEATHER PREDICTION, WAVE FORECASTING, AND OCEAN CIRCULATION COMPUTER BASED SYSTEMS

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ABSTRACT

Data from space from infrared imaging systems and SIRS are already providing information of great value in determining sea surface temperature and the atmospheric structure in cloudless areas over the oceans. Although some interpretations differ, it is clear that simultaneous measurements of radar sea return and passive microwave temperature will provide estimates of the wind speed, and perhaps wind direction, over the oceans, especially in cloudless areas, for a wide range of wind speeds. This report is concerned with the problem of integrating the data that would be obtained by a spacecraft, especially one with a combination radar-radiometer, into global analysis procedures for meteorological, wave and oceanographic predictions.

A computer based procedure that defines the mean vector wind as a function of elevation from the sea surface to the gradient wind level using an adequate theory of the structure of the planetary boundary layer has been developed. This procedure employs conventional ship reports, both those transmitted synoptically and those collected climatologically. Examples of the different fields that are produced are given.

A global wave forecasting procedure has been developed. Improved meteorological predictions obtained from the system to be described below would provide high accuracy wave forecasts in the two to four day time frame. Examples of the wave specifications produced for the North Pacific are shown. Data from space can in principle verify the wave heights given by this model as of a given time of observation.

So as to study areas of poor conventional data coverage, the wind analyses have been used to generate data on wind speeds such as would be obtained from a spacecraft. A small fraction of the available ship reports for the North Pacific Ocean have been used to simulate the data density for the South Pacific Ocean. A combined knowledge of low center positions from cloud patterns, coastal and island surface pressures, a few scattered ship reports, and the simulated spacecraft data permit the recovery of the vector wind field over the oceans and the surface atmospheric pressure patterns. The surface pressure pattern is in turn an important parameter in the interpretation of SIRS data. A combined analysis of the surface pressure field and the SIRS data would yield information for the entire atmospheric structure in the initial value problem for a global weather forecast.

The conditions in the interior of the oceans, that is, currents, temperatures, and salinities, are controlled by what happens at the coasts and at the air-sea interface. Fluxes of radiation, heat, momentum and water across the air-sea interface and river runoff and ground water discharge at the coasts can be used as inputs to an ocean circulation model. Presently available data from space and the data that could be obtained by future spacecraft should make it possible both to specify and predict conditions inside the oceans in much the same way as the weather is predicted at present. Efforts to develop such systems are described.

PRESENTLY AVAILABLE DATA FROM SPACE

Quantities of importance to both meteorology and oceanography are presently being sensed from space. Examples are SIRS data, infrared sea surface temperature data, and clouds and cloud patterns. These measurements provide atmospheric soundings, sea surface temperature fields, in which temperature fronts in the oceanic structure can be detected, and information on the location of low centers and fronts.

McClain (1970) has described how sea surface temperature fields can be obtained for four to five day average conditions over both hemispheres, using presently available infrared imagery. The motion of the clouds reveals most of the ocean surface during this period of time, so that realistic fields can be constructed. The sea surface temperature does not vary rapidly so that four or five day averages are permissible for some applications.

The ATS and NOAA imagery of clouds, such as shown in the ATS photograph in Fig. 1, show how fronts and low centers can be located. The surface low pressure centers are undoubtedly located a little to the east and equatorward of the tips of the spiraling cloud patterns shown in this image. Low centers over the ocean are often missed completely or located poorly on the basis of conventional data, and such images already clearly locate lows as accurately or more accurately, depending on their location, than ship reports. The long arching bands locate fronts. Cold fronts are often carried forward by extrapolation for many days over the ocean on the basis of very poor data in conventional analyses.

SIRS data as described by Wark and Hilleary (1969) can be used to define the constant pressure surfaces for the multi-layer numerical weather prediction models currently in use, as for example described by Shuman and Hovermale (1968). It is important to note that a better definition of the pressure at the surface of the ocean would make the SIRS data even more valuable because it would reduce the error in the specification of the heights of constant pressure surfaces for numerical prediction procedures.

RADAR AND MICROWAVE RESULTS

Results on radar sea return for five different frequencies and on passive microwave emission over a wide range of frequencies lend further support to the concept of using a combination, active radar passive microwave instrument to learn about the winds and waves over the oceans. Ross et al. (1970) have shown that passive microwave emission is sensitive to the presence of whitecaps and that the microwave temperature is related to the foam on the sea surface for high winds and waves. Hollinger (1970) in this third annual review, shows that passive microwave emission at low winds is sensitive both to the structure of the sea surface for high wave numbers and to whitecaps, with the whitecaps being of lesser importance than the sea surface structure for low winds.

The report by Guinard (1970), also in this annual review, indicates that radar sea return is weakly dependent on winds (and waves) for high winds, and that 13.3 gigahertz seems to be a good frequency to study radar sea return. The results of Guinard are not in agreement with the results of Moore and Pierson (1970) for 13.3 gigahertz, where a stronger dependence of radar sea return on wind at higher winds was found, based on a revised analysis of the available radar sea return data from several NASA missions. It is important to note that recent work by Valenzuela et al. (1970), using some of the same radar sea return data reported by Guinard (1970), can be interpreted to indicate a wind speed dependence even for higher winds. Pierson and Moore (1970) have discussed these matters in considerable detail.

The report by Krishen (1970), shows that the problems of calibrating and correcting the 13.3 gigahertz scatterometer of NASA MSC have been solved and that the Mission 119 data and the data from previous missions will form a consistent set of $\sigma^{\circ}(\theta)$ curves for a wide variety of wind speeds that will be good to $\pm\frac{1}{2}$ db. Some data for Mission 119 has already been prepared and released. A preliminary analysis of these data shows that the value of $\sigma^{\circ}(\theta)$ agree with previously obtained data, as described by Moore and Pierson (1969), for both the upwind-downwind condition and for the crosswind condition.

One important point about radar sea return is that it is direction dependent with all workers reporting a substantial difference between upwind-downwind and crosswind measurements. In contrast, the passive microwave data do not appear to be sensitive to direction, either the direction of the waves on the sea surface or the direction of the wind that generated the waves. For cloudless conditions, it may be possible to combine sea surface temperature measurements with the infrared, passive microwave emission measurements and radar sea return measurements to obtain both information on the wind speed and partial information on the wind direction.

Radar sea return varies from a maximum in either the upwind or downwind direction to a minimum at the crosswind direction. If the wind speed could be determined from the passive microwave measurements, then if the radar is looking in the upwind or downwind direction, the radar sea return will be a maximum and the wind direction will be known as either the direction χ or the direction $\chi + 180^{\circ}$. Similarly if the radar sea return is a minimum for the given velocity, then the wind direction is again known with an indeterminacy of 180°. If the radar sea return value lies between the maximum for upwind-downwind and the minimum for crosswind, this implies some angle, say ϕ, between the upwind-downwind direction of the wind and the radar beam. In turn, this implies that there are four possible wind directions that would be given by $\chi \pm \phi$ and $\chi \pm \phi + 180^{\circ}$. The overall pattern of winds around low centers and a few scattered ship reports should then provide a high quality analysis of the vector wind and the pressures in the planetary boundary layer.

For other conditions such as viewing through stratus clouds with a high liquid water content or rain, the passive microwave signal will be needed to calibrate the radar signal, but it should still be possible to obtain data on the wind speed over the sea surface under these conditions.

COMPUTER BASED PROCEDURES FOR THE USE OF DATA FROM SPACECRAFT

Once the winds and the pressures in the planetary boundary layer have been determined, they provide the information needed for the planetary boundary layer in numerical weather prediction models. If the pressure field can be determined accurately at the sea surface, it provides a basic input to the SIRS data that then makes it possible to describe the elevations of the constant pressure surfaces throughout the entire troposphere as described by Smith and Fritz (1969). Thus a combination of SIRS data and data from an active radar, passive microwave instrument could almost by itself, along with infrared sea surface temperature data, define the initial value problem for a numerical weather prediction for the entire southern hemisphere, given a few scattered ship reports and cloud imagery. For the northern hemisphere, the spacecraft data will improve the specification of the initial value problem compared to presently available data. This implies improved forecasts of the weather and improved wave forecasts.

It is, however, necessary to develop the computer procedures for utilizing the data that would become available from a combination passive microwave active radar instrument on a spacecraft in a polar orbit. This has been a major effort of our group during the past few years and has resulted in new techniques for analyzing the wind and pressure fields in the planetary boundary layer by means of conventional data. This work has also resulted in the development of a highly superior numerical wave specification and wave forecasting procedure and in the development of a system that simulates the data one might get from a radar radiometer and shows how it can be incorporated into a conventional analysis so as to provide an analysis of the planetary boundary layer in areas of low conventional data coverage. Finally, all of these developments point toward the possibility of computing what occurs and will occur in the interior of the oceans, just as is now done for the atmosphere so as to obtain true oceanographic predictions.

ANALYSIS OF THE PLANETARY BOUNDARY LAYER

If the meteorological and oceanographic data are not obtained in real time, the data density is substantially increased because many ships send in their logs of the weather a month or so late to the National

Weather Records Center. This data base is thus quite complete for most of the Northern Hemisphere, with the amount of ships available, being approximately twice the number that are available on the day-to-day real time teletype services. With this augmented data base, Cardone (1969) has developed a computer based procedure for defining the winds over the surface of the oceans. By means of this analysis, the winds as a function of height from the surface to the gradient wind level can be defined over the Northern Hemisphere oceans. The analysis produces the vector wind at twenty meters, the Monin-Obukov mixing length, the vector friction velocity at the sea surface, which in turn can easily be transformed to the vector wind stress, and the wind at the gradient wind level since the thermal wind is known. Part of the intermediary data needed consists of the air-sea temperature difference field. Examples of the various fields produced by this computer-based procedure are shown in Figs. 2 through 8. Fields such as these are available for the Northern Hemisphere every six hours for more than one year. The printouts are distorted and they should be mentally stretched so that the decimal points would lie on the sides of squares. The title on each figure describes it. The grid is four times the density of the conventional NWP analysis. The analysis has not been smoothed to the same extent as is usual for hemispherical analyses.

The air-sea temperature field as shown in Fig. 6 is an important field for describing the variation of the wind with height in the first meters above the sea surface. This field was obtained from conventional sources. Infrared imagery can supplement the present data sources for determining this field, and SIRS data could give a few data points along the subsatellite track for the air temperature near the sea surface. Above line 105, which is toward the equator, there is not enough information available to specify this field but the values are generally small and have been assumed to be zero.

The field for the inverse Monin-Obukov stability length shown in Fig. 7 provides the required parameter for the computation of the wind profile over the water. If it is zero, the wind profile is logarithmic. Positive values mean a stable atmospheric stratification and a weaker wind stress on the surface for the same wind at anemometer height along with a different variation of the wind with height. Conversely negative values mean an unstable stratification and a greater stress on the sea surface for the same wind at anemometer height.

Fig. 8 shows the magnitude of the friction velocity on the sea surface. The directionof the friction velocity is the same as in Fig. 5 for the wind at 19.5 meters. This stress field, which is directly obtained from this field, is an important field for numerical models of the wind driven ocean circulation.

One of the major purposes of the work by Cardone was to produce wind fields that would yield more accurate wave specifications; that is, a computation given the observed winds for all past times of what the waves are at a particular time, and more accurate wave forecasts, that is, a computation of what the waves will be, given the winds and waves up to a certain time, and forecasts of the winds for a day or so into the future. The growth of the wave spectrum in a given frequency range depends on the wind speed, the atmospheric stability, the fetch, the duration of the wind, and on spectral components that have propagated into an area from other areas. Each of these factors varies from point to point over the ocean. All of these factors are properly included in the wave specification and wave forecasting procedures to be discussed next in this paper in terms of the theories of Phillips (1957), Miles (1957), and Phillips (1966).

There is, however, a part of the wave spectrum that is saturated over a given frequency band. Further input from the wind in adding energy to the wave spectrum for these bands, only causes the production of whitecaps and breakers, so that this energy is eventually dissipated in turbulence. Cardone (1969) developed a way to compute the amount of energy dissipated in this way and called this quantity, the whitecap production index. This whitecap production index was then compared with the measurements of Monahan (1969) and with the measurements in the North Sea described by Ross et al. (1970). The theory for the computation of the whitecap production index is shown in Fig. 9. The computation of this index is a straightforward extension of present results in wave forecasting and specification. There should eventually be a strong interrelationship between the whitecap production index and the work of Austin (1970) as described at this Third Annual Earth Resources Review.

Given the specifications and forecasting procedures to be described in the next section of this paper, and given the sea surface temperature fields as described by McClain, it should not be difficult to remove the effects of fetch, duration, atmospheric stability and sea surface temperature, so as to determine the wind speed simultaneously with radar measurements. This would provide one of the quantities discussed above for obtaining information on the vector wind.

WAVES

Numerical wave specification and numerical wave prediction techniques have been developed. The report by Pierson, Tick and Baer (1966) discusses some of the theory that is used. Bunting (1970) has shown how well the predictions can be expected to verify.

Fig. 10 shows the land-sea table for the North Pacific and Fig. 11 shows the land-sea table for the North Atlantic Ocean that will be used as a basis of printing out such quantities as wave height and wave direction for the hindcasts (and eventually forecasts) that will be produced with this computer program.

The first successful run of this improved and highly sophisticated wave specification and wave forecasting system for the North Pacific was achieved during the week of December 7th, and the weekend of December 12 and 13, 1970. The results, as given in Fig. 12, show what the waves over the North Pacific would have been like if the sea surface had been flat calm and then the winds had started to act on the sea surface and had blown for six hours. After seven more days, or so, the waves over the North Pacific will be quite realistic since the observed winds are used to compute what the waves were like.

The waves are not very high, and the values shown illustrate the problem of start-up time in numerical wave specification models. It is impossible to measure the two dimensional wave spectrum over the while North Pacific so as to obtain the equivalent of the conditions for a more classical initial value problem. The wave spectra specified by these procedures, after a week or so, given good wind fields, yield significant heights and frequency spectra that verify well against actually measured waves.

It is quite possible that the data from the radar altimeter part of S193 on Skylab A will provide information on wave height that can be compared with the heights predicted by this model. The results of Yaplee et al. (1970) are quite encouraging in this connection as they lend strong support to the assumptions made by Pierson and Mehr (1970) in deriving the theoretical form for an average altimeter pulse being scattered back from the sea surface.

These wave forecasting and wave specification procedures were developed for deep water. Waves near coasts are modified by the effects of refraction over irregular submarine topography. It is important to note here the work of Chao (1970) in which the theory of wave refraction at a caustic was solved and of Chao and Pierson (1970) in which the theory was verified in a wave tank. It should now be possible to predict wave conditions at all important coasts as well as in deep water.

INTEGRATION OF THE DATA FROM A RADAR RADIOMETER INTO A PLANETARY BOUNDARY LAYER ANALYSIS

It is also necessary to develop ways that the data from a radar radiometer can be integrated into conventional data so as to produce useful analyses of the wind and pressure fields in the planetary boundary layer. To study this problem, the data given by the work of Cardone has been assumed to provide an accurate description of the winds over the North Pacific ocean for a particular synoptic map time. Simulated passes of a polar orbiting spacecraft are made over the North Pacific, and it is assumed that the magnitude of the vector wind at 19.5 meters can be determined from the combined radar radiometer data on a grid of points corresponding to repeated cross track scans. This provides a dense field of wind speeds. It is further assumed that the location of low centers can be determined from space photographs of clouds as described above, that conventional coastal data and island data will be available and that a few scattered ship reports will also be available, along with a field of the air-sea temperature difference from, say, SIRS and infrared sea-surface temperature fields. The assumptions simulate what will be available from a combination of spacecraft mounted sensors and conventional data for the Southern Hemisphere, for example, over the South Pacific ocean. Only about twenty or thirty ships from the as many as three hundred to five hundred that actually report for the North Pacific are selected at random from the total list of ships to simulate the Southern Hemisphere conditions.

The results of a computer based procedure developed at New York University by Mr. Leonard Druyan that uses these isolated ships, simulated radar radiometer data reduced to wind magnitudes alone as each grid point, island and coastal data, and cloud data are shown in Fig. 13. The recovery of the pressure field for the limited number of ships used is quite good. Since this figure was prepared added modifications of the computer procedure have led to even better results.

It is planned, once the computer based procedures have been further improved, to compute the pressure fields for a year of data, once per day, so as to produce statistics on how well the system can be expected to operate. The data produced by Cardone, as described above, will also be used to obtain information on the relative frequency of different wind speeds over the Northern Hemisphere oceans, for a further evaluation of the potential accuracies of the proposed radar radiometer system.

Also, the concept that some information on the wind direction can be inferred from the space data has yet to be evaluated in terms of the use of limited ship data and spacecraft data in the Southern Hemisphere. Limitation of the possible wind directions to either two or four directions at a given point from combined radar radiometer data, can provide enough information when combined with information on the global circulation to define the pressure pattern even more accurately. The simulation described above that uses only wind speed may actually be an overrestriction on the potential system. The root mean square error of the pressure field in Fig. 13 is already low enough to make the pressure field obtained by this method useful in applying SIRS data to the determination of the heights of constant pressure surfaces over the ocean.

PREDICTION OF THE OCEAN CIRCULATION

The time may soon be upon us when it will be necessary to predict conditions inside the ocean, just as weather conditions are now predicted for the atmosphere. The quantities to be predicted at a minimum would be the current speed and direction and the temperature and salinity at a number of levels inside the ocean. The conditions in the interior of the ocean are however, controlled by effects at the ocean atmosphere interface and by runoff at the coasts. Models of the oceans, such as those of Bryan (1969), show clearly that if the fluxes of heat, water, radiation and momentum across the air-sea boundary could be defined over the oceans, and if river runoff could be computed, the motions and conditions in the interior of the ocean would respond realistically to these forcing functions. It would not be necessary to measure the currents, temperatures and salinities in the interior of the ocean in order to predict what goes on in the interior of the ocean, if the conditions at the boundaries are correctly specified throughout past time.

Work toward this goal is also underway. Ways to use space data to compute the solar radiation absorbed at the sea surface are under development and are being correlated with XERB-1 data. The XERB-1 buoy is an experimental buoy located off our east coast that is a prototype of the buoys that may be deployed by the National Data Buoy System of NOAA. There may be many of these buoys deployed in the Northern Hemisphere. They could be the surface truth sites for an eventual combination spacecraft-buoy system. Ways to compute the infrared loss from the sea surface have been developed. The SIRS soundings would be used to define the atmospheric structure over the oceanic points for which the infrared loss would be computed. However, the data density may not be great enough since the method works only along the subsatellite track. The stress fields are known from the work of Cardone, as described above. Other work should make it possible to apply real time forcing boundary conditions to the finite difference equations of motion for the oceans as given by Friedrich (1970) and Okubo (1970), that will cause a realistic ocean circulation throughout the ocean interior. The motions and conditions in the ocean will then vary in response to the actual weather as it occurred over the ocean surface.

CONCLUSIONS

It seems, therefore, that data from space could play an important role in producing weather forecasts for the Southern Hemisphere of at least the quality now available for the Northern Hemisphere, in producing improved weather forecasts for the Northern Hemisphere bu augmenting the data base for the initial value problem in the Northern Hemisphere, in producing forecasts of waves on the global ocean, and in producing forecasts of what is occurring, and will occur in the ocean interior. Some of the necessary computer based procedures for accomplishing these goals have been developed and others are now being developed in our present program.

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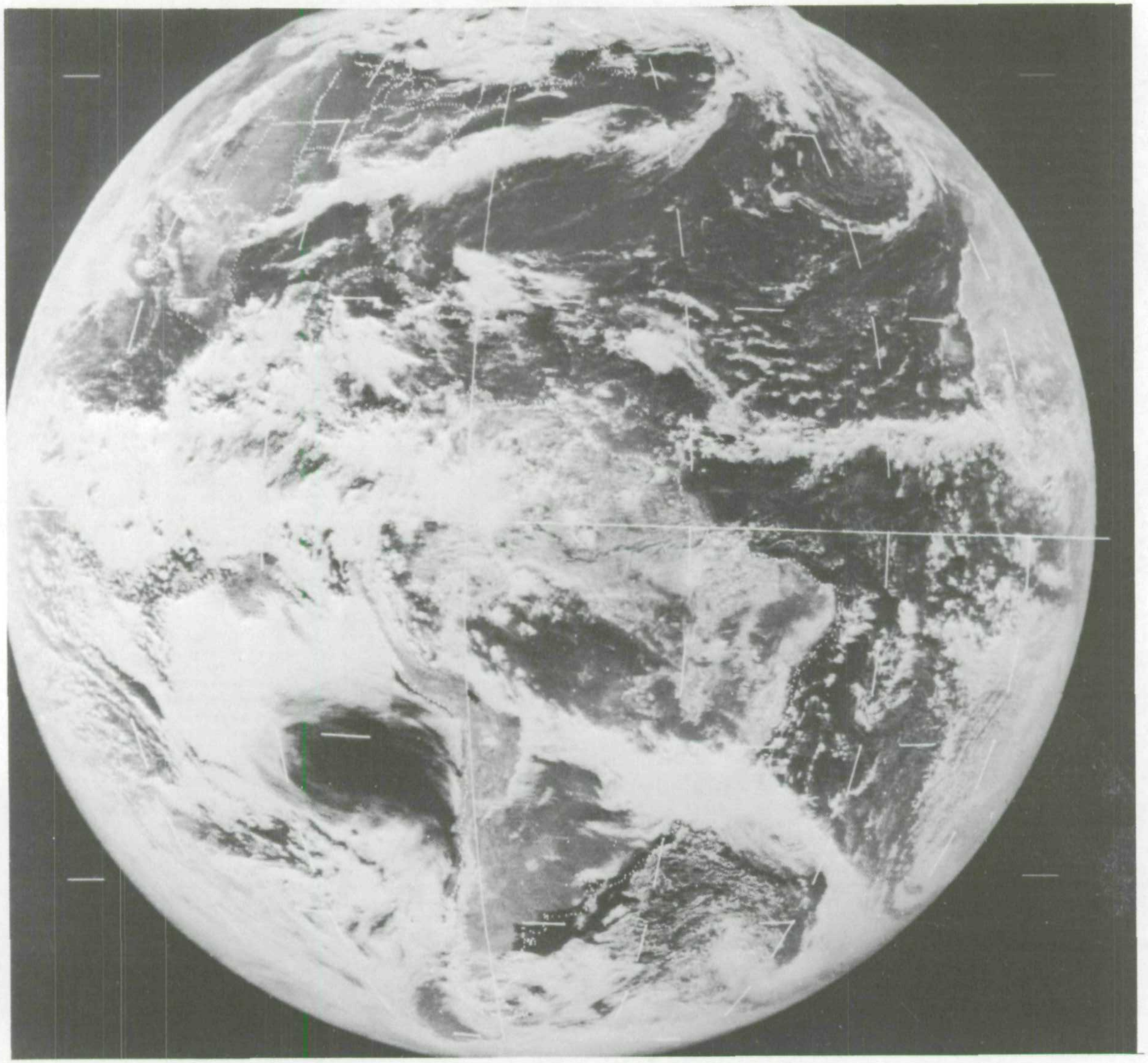

Figure 1. ATS image showing fronts and low centers near spiral cloud bands over the North Atlantic and South Atlantic Oceans.

Wind speed at 19.5 meters in knots for the portion of the expanded (125 x 125) NWP grid system covering the North Atlantic Ocean.
Asterisks represent land.
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43************************************  6.  9.  9.  4.  2.  6. 12.  9.  6. 10. 13.  8.  4.  5.  7.  6.  5.  0. 15. 12.  5. 11.
42********************************************  8.  6.  5.  6.  8.  9. 11.  9.  7.  6.  6.  3.  3.  4.  6.  8. 10. 13. 16. 14.
41********************  8. 13.**************** 12.  8.  8.  8.  9. 10.  9.  9.  6.  5.  3.  2.  3.  6.  8. 11. 18. 15. 14. 15.
40************************ 13. 19. 20. 25. 19. 15.  9.  9. 11. 12. 11. 12.  9.  7.  4.  2.  3.  5.  8. 10. 13. 16. 17. 18. 17.
39******************************** 23. 36. 22. 17. 13. 14. 12. 11. 11.  8.  7.  4.  1.  2.  5.  8. 10. 13. 15. 17. 18. 18. 17.
38**************************** 16. 18. 24. 20. 17. 16. 14. 14. 14. 12. 10.  6.  4.  4.  6.  8. 11. 13. 16. 17. 19. 18. 18. 16.
37********************  8. 14. 11. 15. 21. 17. 15. 14. 15. 13. 10. 10.  9.  6.  5.  6.  8. 10. 15. 14. 15. 16. 15. 16. 15. 14.
36********************  8.  8.  9. 13. 19. 18. 14. 14. 16. 13. 11. 12. 11.  9.  7.  9. 11. 11. 11. 14. 18. 16. 15. 15. 15. 12.
35**************** 23.  8.  9. 14. 14. 15. 29. 25. 17. 22. 14. 17. 17.  7. 13. 16. 12.  8. 14. 21. 16.  9. 17. 25. 16.  9. 11.
34************ 10. 15. 14. 10. 10. 15. 32. 21. 14. 12. 15. 11.  9. 11. 13. 11. 10. 14. 21. 19. 14. 16. 19. 18. 22. 17. 22. 12.
33************ 14. 17. 16. 13. 11. 14. 16. 15. 12. 14. 13. 11. 10. 11. 13. 12. 12. 14. 18. 19. 16. 17. 17. 17. 16. 14. 14. 12.
32******** 19. 18. 31. 23. 16. 15. 14. 15. 15. 15. 14. 13. 12. 11. 13. 20. 14. 15. 17. 20. 30. 21. 19. 19. 18. 17. 15. 14. 12.
31******** 26. 17. 17. 14. 14. 12. 12. 12. 13. 12. 13. 12. 12. 12. 15. 21. 10. 15. 19. 19. 21. 19. 18. 18. 17. 16. 15. 13. 12.
30**** 12. 14. 10. 11. 13. 11. 11. 10.  9. 10. 12. 11. 12. 11. 12. 14. 17. 16. 20. 24. 19. 18. 17. 17. 16. 16. 15. 14. 14. 12.
29 12. 16. 14. 13.  9.  9.  9.  8.  7.  7.  8. 13. 10.  9. 10. 11. 13. 14. 16. 23. 18. 17. 15. 14. 14. 14. 13. 13. 12. 10. 10.
28 17. 18. 20. 18. 11. 17. 11.  6.  4.  4.  5.  6.  7. 10.  9. 10. 13. 17. 15. 14. 15. 16. 13. 11. 13. 14. 12. 10. 10. 11.  9.
27 10. 15. 11. 10.  7.  9. 21.  8.  3.  1.  3.  4.  8. 13. 10. 16. 13.  7. 14. 20. 12.  5. 11. 17. 10.  4.  0. 13.  9.  5.  8.
26  6.  8.  6.  5.  4.  4.  6.  2.  1.  2.  3.  4.  6.  9.  9.  9. 12. 14. 11.  9. 10. 10.  8.  6.  7.  9.  7.  6.  9.  9.  8.
25  5.  4.  4.  4.  3.  3.  2.  1.  2.  3.  5.  7.  8.  9. 11. 11. 12. 10.  8.  6.  6.  6.  4.  2.  4.  6.  7. 10. 17. 10.  9.
24  5.  5.  5.  4.  4.  4.  3.  3.  3.  5.  7.  9. 10. 11. 13. 14. 13. 15.  7.  5.  5.  6.  3.  1.  4.  7.  7.  8. 11. 11. 11.
23  7.  6.  6.  6.  5.  5.  5.  5.  5.  6.  8.  9. 10. 10. 11. 11. 11.  7.  3.  1.  6.  4.  4.  1.  4.  4.  7.  9. 10. 10. 11.
22 11.  9.  9.  8.  8.  8.  7.  8. 10.  8.  9. 11. 12. 13. 12. 12.  9.  7.  3.  6.  8. 11.  6.  5.  5.  8.  8.  9. 10. 11. 11.
21******** 13.  9.  7.  7.  7. 10. 22.  9.  8.  9. 11. 10. 11.  7.  7.  4.  1.  5.  8.  3.  6.  4.  4.  6.  8.  8.  9. 10. 10.
20 10.****************  8.****  5.  9.  7.  7.  8. 14. 13. 13.  8.  5.  3.  2.  5.  8. 11.  5.  1.  3.  7.  7.  7.  8. 10.  9.
19 11.  4.  8. 11.********************  5.  8. 12. 10.  7. 12. 14.  8.  3.  7. 14. 10.  3.  5.  6.  4.  3.  8. 12.  8.  5.  9.
18  8.  9.  7.  6.  6.  8.  7.  6.  8.  9.  9.  9. 10. 12. 11. 10. 11. 12. 12. 13. 12. 11.  8.  8.  7.  8.  7.  7.  8.  9.  8.
17  6.  6.  6.  6.  7.  9.  9.  9. 11. 12. 12. 11. 12. 13. 11. 10. 11. 13. 12.  8. 10. 11. 10. 20. 10.  8.  8.  8.  8.  8.  8.
16  6.  6.  6.  7.  8.  9. 11. 13. 14. 14. 14. 15. 14. 14. 13. 13. 12. 13. 14. 15. 10.  7.  7. 10.  8.  8.  8.  8.  8.  8.  8.
15  6.  6.  6.  7.  8.  9. 11. 12. 13. 13. 13. 13. 13. 12. 11. 10. 10. 11. 13. 10.  8.  7.  5.  6.  6.  7.  7.  7.  7.  7.  7.
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Figure 2.

Wind speed at 19.5 meters in knots for the portion of the expanded (125 x 125) NWP grid system covering the eastern half of the North Pacific Ocean. Asterisks represent land.
Date: 12/1/66 Time: 0000 GMT

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71  5.  8. 14. 17. 17. 18. 18. 17. 22. 19. 18. 15. 18. 20. 20.**************************************** 19. 16. 14.************
70  5.  9. 16. 21. 22. 24. 26. 20. 19. 17. 16. 16. 16. 17. 18.************************************ 19. 18. 17. 15. 16. 12. 10.
69 24. 17. 21. 30. 28. 33. 25. 18. 18. 16. 15. 14. 15. 15.******************************** 15. 17. 19. 18. 16. 17. 29. 15. 10.
68 14. 15. 19. 24. 27. 30. 22. 20. 17. 15. 12. 13. 14. 13. 13.************************ 12. 12. 15. 17. 15. 12. 12. 14. 10.  8.
67 13. 16. 19. 23. 25. 24. 21. 24. 18. 18. 12. 13. 13. 12. 10.******************** 14. 13. 11. 14. 16. 13.  8.  9. 11.  8.  4.
66 19. 25. 30. 27. 26. 24. 26. 21. 15. 14. 13. 14. 15. 13. 11.******************** 20. 20. 19. 20. 20. 16. 12. 12. 12. 10.  6.
65 26. 41. 34. 28. 24. 25. 24. 25.  8. 13. 15. 16. 15. 14. 13.  7.  3.******** 21. 26. 29. 29. 27. 24. 20. 16. 14. 13. 10.  7.
64 26. 32. 30. 28. 24. 20. 17. 15. 13. 12.  7. 14. 15. 12.  7.  1.******** 18. 23. 28. 31. 31. 30. 26. 21. 16. 13. 10.  7.  6.
63 26. 29. 25. 24. 20. 16. 14. 14. 15. 15. 1 . 16. 13. 14. 11.  7.  8. 13. 20. 24. 27. 31. 29. 29. 23. 19. 13.  8.  6.  2.  4.
62 30. 28. 27. 20. 15. 13. 13. 15. 19. 17. 1 . 17. 21. 20. 18. 13.************ 25. 29. 30. 31. 28. 24. 16. 10.  4.  4.  2.  6.
61 23. 24. 19. 15. 13. 1   13. 15. 16. 15. 13. 14. 19.******************************** 25. 22. 23. 18. 14.  6.  1.  4.  5.  4.
60 26. 20. 16. 12. 13. 1   13. 15. 18. 15.  9. 14. 23.******************************** 21. 18. 19. 20. 11.  3.  5. 11.  9.  7.
59 13. 15. 15. 13.  9. 16. 24. 17. 11. 17. 11. 13.************************************ 24. 33. 20.  7. 12. 13.  8.  6.********
58 18. 15. 14. 17. 20. 18. 16. 18. 21. 19. 1 . 18. 23. 17. 12.************************ 17. 16. 18. 20. 13. 10. 13. 17.********
57 15. 17. 18. 21. 23. 21. 19. 19. 20. 20. 19. 21. 20. 19.**************************** 18. 16. 19. 17. 16. 16. 16. 18. 19. 18.
56 20. 21. 26. 26. 33. 25. 23. 22. 23. 21. 23. 23. 22. 21. 17.******************************************** 10. 20. 23. 22. 22.
55 14. 21. 23. 27. 27. 26. 24. 25. 29. 18. 20. 23. 22. 26. 19.******************************** 20.******** 20. 22.************
54 18. 19. 25. 33. 31. 29. 26. 32. 22. 21. 22. 22. 24. 22. 17.****************************************************************
53 23. 13. 17. 22. 21. 21. 21. 20. 18. 28. 19. 21. 19. 22. 16.****************************************************************
52 14. 14. 14. 19. 24. 2   30. 18. 13. 17. 15. 21. 25. 31. 15.******************************************** 10.****************
51 28. 20. 27. 25. 26. 2   22. 11.  6. 19.  7. 27. 14. 19.****************************************************************  8.
50 21. 21. 19. 35. 29. 30. 13.  7.  3.  5.  9. 14. 19. 20.********************************************************************
49 20. 38. 23. 26. 21. 20. 13. 11.  8. 10. 24. 14. 13. 21.********************************************************************
48 19. 24. 26. 35. 26. 22. 20. 16. 15. 15. 20. 22. 18.************************************************************ 18. 17. 19.
47 18. 20. 24. 26. 23. 23. 22. 19. 19. 18. 17. 19. 20.******************************************************** 18. 16. 14. 13.
46 15. 22. 32. 24. 24. 26. 30. 22. 22. 22. 23. 20. 19.******************************************************** 18. 16. 13. 11.
45 15. 29. 22. 19. 20. 29. 22. 18. 16. 19. 16. 17.**************************************************************** 14. 11.  7.
44 10. 19. 19. 16. 18. 17. 13. 14. 10. 15. 12.************************************************************************ 11.  6.
43  6. 11. 17. 14.  9. 15. 22. 15.  6. 13.************************************************************************************
42 15. 10.  9. 12. 16. 14. 17. 21. 19. 21.************************************************************************************
41 22. 11. 10. 14.  3. 16. 14. 14. 19.****************************************************************************************
40 10. 10. 11. 13. 17. 19. 15. 12.  9.****************************************************************************************
39  7.  7.  7.  9. 10. 12.  9.  9.  7.****************************************************************************************
38  7.  6.  5.  5.  8.  9. 12.  9.********************************************************************************************
37  6.  5.  3.  1.  3.  5.  4.  8.  6.****************************************************************************************
36  7.  7. 11.  6.  5.  5.  7.  9. 11.****************************************************************************************
35  4.  6. 11.  7.  3.  8. 14. 10.  5.****************************************************************************************
34  5.  6.  6.  9. 11. 11. 11. 11. 13.****************************************************************************************
33  6.  5.  7.  9. 10. 12. 10. 12. 15.****************************************************************************************
32  5.  6.  7. 10. 13. 13. 14. 12.********************************************************************************************
31  9.  8.  8. 10. 11. 12. 11. 10.  8.****************************************************************************************
30 10. 12. 10. 10. 11. 11. 10.  8.  7.****************************************************************************************
29  6.  4.  5. 10. 11. 10.  9.  7.  8.****************************************************************************************
28 13. 10.  8.  9. 11.  9.  6.  6.  5.************************************************************************************  8.
27  6. 10. 13. 10.  5.  8. 10.  6.  3.  4.  3.************************************  4.  7.  3.  5.  4.  4.  6.************  9.
26 12. 10.  8.  9. 11.  8.  5.  5.  5.  4.  5.  3.********************************  9.  9.  8.  8.  8.  6.  5.  4.************
25 10.  9.  9.  9.  7.  6.  7.  6.  5.  7. 16.********************************  7.  9.  9.  7.  9.  8.  8.  7.  6.************
24  9.  9. 10.  9.  8.  1.  5.  6.  6.  6.  8.********************************  9.  8. 10. 11. 11. 11. 10.  9.  8.  7.********
23  8.  8.  9.  9.  9. 13.  8.  6.  6.  5.  4.**************************** 12. 11. 12. 10.  9.  8.  7.  8.  8.  9.  8.  8.  8.
22  6.  7.  7.  7.  8.  8.  6.  6.  6.  6.  5.  3.**************************** 11. 10.  9.  7.  6.  5.  7.  9.************ 10.
21  5.  5.  6.  6.  6.  6.  6.  5.  8.  6.  3.  1.  1.************************ 14. 12. 10.****************  6.  8.  8. 10.****
20  5.  4.  4.  5.  6.  5.  4.  5.  7. 13.  4.  1.  2.  3.******************** 15. 21. 12.****************  4.  7. 10. 10. 11.
19  4.  4.  6.  4.  3.  5.  6.  4.  4.  5.  3.  2.  2.  3.  5.****************************************  7. 10.  8.  5. 10. 16.
18  7.  4.  4.  4.  5.  4.  4.  4.  4.  3.  3.  3.  4.  4.  4.  4.************************************ 15. 10.  9.  9.  8.  8.
17  5.  4.  4.  4.  4.  4.  4.  4.  3.  3.  4.  3.  3.  4.  4.  4.  6.  6. 13.******************** 20. 16. 13.  9.  9.  8.  7.
16  5.  5.  4.  4.  5.  5.  5.  4.  4.  3.  3.  4.  5.  5.  5.  4.  4. 12. 15. 15.********************************  9.  8.  6.
 5  5.  5.  5.  4.  4.  4.  4.  4.  4.  3.  3.  4.  5.  4.  3.  3.  4.  5. 10. 10. 15.****************************  9.  7.  7.
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Figure 3.

Wind speed at 19.5 meters in knots for the portion of the expanded (125 x 125) NWP grid system covering the western half of North Pacific Ocean. Asterisks represent land.
Date: 12/1/66 Time: 0000 GMT

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     33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  61  62  63

125************************************************************************************  1.  5.  4.  5.  2.********************
124****************************************************************************************  3.  4.  3.************************
123****************************************************************************************  8.  5.  6.  2.********  5.********
122********************************  2.****  4.************************************  3.  3.  3.  3.  3.  3.  4.****************
121****************************  2.  9.****************************************  4. 13.  5. 18.  6. 11.  2.  5.************ 10.
120****************  5.  3.****************  1.****************************  4.  4.  4.  5.  7. 12.  6.  5.  5.************  5.
119********  5.  2.************  1.  2.  2.  3.  1.********************  1.  1.  3.  7.  8. 12. 12. 12.  7.  5.****************
118  2.****  2.  1.********  2.  1.  2.  2.  2.  2.****************  3.  3.  4.  4.  5.  7.  8. 11. 20.  9.  5.  5.  6.********
117  4.********  2.  3.  2.  2.  1.  2.  2.  3.  2.****************  4.  3.  3.  4.  5.  7. 10. 10. 22.  9.  6.  5.  6.  6.****
116  2.********  3.  2.  3.  2.  2.  1.  0.  1.  0.  1.************  2.  3.  4.  5.  7. 11. 23. 10.  8.********  4.  4.  5.****
115  4.      7.  6.  7.  6.  8.  5.  4.  3.  2.  2.  2.  1.  2.  2.  4.  5.  6.  7.  9. 15. 20.  9.************  6.  8.  6.  5.
114  3.  4.  5.  6.  5.  7.********  8.  7.  4.  4.  7.  4.****  4.  6.  6.  7.  8. 11. 24. 25.********************  5.  5.  4.
113 13.  2.  9.  4. 17.  6.********************  5.  1.**** 12.  6.  8.  8.  8. 13. 20. 14.****************************  6.****
112  3.  4.  5.  6.  5.****************  6.  2.  2.  3.****  2.  1.  6. 12. 21. 31. 37. 19.************************************
111  7.  6.  7.  6.  7.  6.********  4.********  2.  5.****  8.  5. 11. 20. 40. 41. 35. 28.************************************
110  4.  4.  4.  5.  4.  5.************************  3.  3.  3.  5. 16. 24. 33. 30. 30. 30. 28.********************************
109  4.  5.  5.  6.  7.  6.  6.************  3.  3.******** 16. 15. 30. 36. 33. 36. 33. 29. 27. 25.****************************
108  5.  5.  5.  6.  5.  6.  4.  4.  4.  3.******************** 17. 37. 29. 24. 28. 26. 26. 21. 23. 26.************************
107  5.  7. 11.  9. 10.  9.  6.  5.  4.  5.  9. 11. 14.******** 19. 25. 36. 20. 27. 29. 23.************************************
106  4.  4.  7.  7.  7. 15.  7.  3.  4.  5.  8. 13. 16.******** 34. 32. 25. 25. 34. 30. 30.******** 36.************************
105  6.  2.  1.  4. 10.  5.  8.  1.  9.  4.  9. 15. 25.******** 25. 21. 24. 32. 29. 36. 35. 37.********************************
104  8.  7.  8.  8.  6.  8.  8.  7.  8. 12. 19. 21. 23. 24. 26. 23. 23. 25. 31. 33. 38.****************************************
103 11. 11. 11. 11. 12. 14. 13. 12. 11. 19. 33. 28. 28. 20. 39. 30. 27. 27.****************************************************
102 10. 10.  9. 10. 11. 13. 12. 14. 11. 19. 25. 26. 29. 34. 32.****************************************************************
101  9.  9.  7. 11. 14. 16. 20. 19. 16. 31. 21. 24. 29. 40. 37.****************************************************************
100 10.  8.  6.  8.  8. 12. 14. 28. 24. 20. 19. 21. 25. 30. 38.****************************************************************
 99  7.  6.  4.  4.  0.  7. 13. 19. 36. 19. 15. 22. 44. 24. 24. 35. 27.********************************************************
 98  8.  7.  5.  4.  5.  8. 10. 14. 18. 16. 17. 21. 24. 21. 23. 27. 24.********************************************************
 97  5.  6.  8.  3.  5. 11. 18. 13. 13. 17. 25. 34. 21. 22. 26. 27.************************************************************
 96  8.  4.  2.  4.  9. 14. 17. 16. 18. 20. 24. 28. 25. 26. 28. 26. 20.********************************************************
 95  9.  3.  5.  8. 11. 20. 26. 21. 21. 24. 28. 30. 31. 31. 34. 27. 24.********************************************************
 94  5.  5.  9. 11. 14. 29. 24. 23. 26. 27. 29. 31. 30. 28. 29. 27. 22. 19. 16.************************************************
 93  8.  8.  9. 11. 12. 18. 19. 22. 25. 27. 27. 27. 25. 13. 24. 26. 27. 19. 15.************************************************
 92  4.  5.  7.  6.  9. 19. 14. 18. 24. 20. 19. 19.******** 14. 19. 28. 16.****************************************************
 91  7.  3.  6.  2.  2.  6.  8. 13. 16. 14. 11.************************  8.  5.  8.********************************************
 90  2.  1.  1.  3.  3.  6.  8. 11. 13. 13.****************  9.****************************************************************
 89  6.  2.  3.  2.  7.  8. 13. 11.  9. 14.******** 22. 25. 16. 12. 13.********************************************************
 88  9.  7.  7.  3.  3.  6.  9. 11. 11.**************** 24. 19. 16.************************************************************
 87 15. 14. 12.  8.  4.  5. 11. 14. 16.************ 22. 24. 18. 19.************************************************************
 86 17. 17. 15. 14.  6.  7. 13. 18. 27. 21.******** 12. 23. 22. 26.************************************************************
 85 19. 19. 20. 30. 13. 12. 13. 18. 23. 21.************ 24. 19.****************************************************************
 84 17. 18. 14. 15. 14. 26. 12. 19. 18. 17. 17. 17.****************************************************************************
 83 17. 23. 13. 11. 12. 12. 10. 30. 19. 12.  8.********************************************************************************
 82 15. 29. 15. 13. 10. 10. 10. 13. 13.  9. 11.************ 13.****************************************************************
 81  5. 13. 16. 25. 14. 11. 12. 14. 12.  9. 18. 14. 19.************************************************************************
 80  5. 11. 15. 17. 15. 17. 19. 18. 13.  7.  3.  8. 15. 16.********************************************************************
 79  7. 10. 14. 17. 19. 22. 25. 23. 19. 13.  7.  6.  9. 12. 13.****************************************************************
 78  7.  9. 10. 11. 15. 21. 30. 26. 23. 19. 15. 13. 14. 13. 13. 10.  6.  6.****************************************************
 77 17. 15. 18.  5.  9. 16. 29. 25. 25. 22. 18. 18. 20. 17. 12.  9.  6.  4.****************************************************
 76 19. 15. 10.  3.  3. 10. 23. 20. 20. 18. 16. 18. 25. 17. 14. 10.  9.  7.****************************************************
 75 22. 15.  9.  8.  9.  7.  9. 12. 14. 14. 14. 20. 33. 14. 14. 14. 12.  8.****************************************************
 74 30. 16. 13. 14. 14. 12.  9.  9. 12. 15. 17. 21.************ 20. 17.********************************************************
 73 14. 12. 16. 20. 18. 16. 15. 12. 14. 19. 23. 23.****************************************************************************
 72  8. 10. 17. 27. 18. 17. 24. 15. 18. 19. 18.  9. 21.************ 21.********************************************************
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Figure 4.

Wind direction in degrees for the portion of the expanded (125 x 125) NWP grid system covering the western North Pacific Ocean.
Asterisks represent land.
Date: 12/1/66 Time: 0000 GMT

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     33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  61  62  63

125************************************************************************************ 16. 74. 73. 77. 57.********************
124**************************************************************************************** 50. 56. 38.************************
123**************************************************************************************** 71. 76. 80. 62.********297.********
122******************************** 78.****149.************************************342. 18. 44. 32.350. 61. 52.****************
121**************************** 76.142.**************************************** 24. 81.324.291.334. 77. 25.265.************173.
120****************118.112.****************203.**************************** 72. 34.357. 30. 41. 48. 22. 54. 57.************ 81.
119********117.136.************235.233.240.246.275.******************** 58.175. 72. 62. 55. 59. 54. 54. 54. 65.****************
118324.****303. 42.********312.325.312.296.322.298.**************** 16.  6. 34. 28. 24. 34. 26. 38. 31. 45. 58. 60. 84.********
117170.******** 74. 66. 53. 61. 14.341.309.274.301.****************  6.  8.340. 15. 34. 25. 34. 46. 61. 59. 57. 62. 48. 72.****
116 50.******** 89. 82. 94. 96. 89. 83.  0.104.  0. 68.************ 63. 50. 66. 45. 28. 28. 19. 36. 51.******** 57. 77. 71.****
115 69. 85.101.105.111.116.116.114. 97.132.180.159.223.152.129. 83. 35. 61. 58. 52. 48. 29. 28. 41.************ 55. 53. 73. 94.
114 81. 90. 98.107.108.108.******** 98.102.104. 79. 76. 87.**** 76. 77. 55. 57. 55. 31. 21. 38.******************** 61. 73. 92.
113 96. 56.291.111.112.107.********* ********** 67.359.****101. 77.  7. 46. 67. 49. 45. 32.**************************** 72.****
112 81. 84. 92. 98. 99.**************** 92. 97. 58. 76.****258.333. 48. 28. 31. 42. 32. 17.************************************
111 92. 88. 88. 86. 83. 83.******** 91.********252.254.****248.293.340. 21. 22. 15. 47. 65.************************************
110 70. 73. 69. 68. 67. 71.************************199.195. 75. 32. 45. 31. 24. 32. 52. 73. 92.********************************
109 72. 62. 56. 57. 62. 62. 75.************ 73.119.******** 68. 50. 45. 42. 21. 20. 58. 76. 91. 95.****************************
108 68. 63. 57. 59. 61. 76. 81.101.116.107.******************** 46. 30. 47. 45. 41. 58. 76. 86. 81. 45.************************
107 59. 57. 44. 51. 72. 75. 93. 89. 68. 67. 56. 74. 87.******** 51. 45. 75. 50. 37. 61. 77.************************************
106 67. 59. 58. 66. 76. 78. 32. 49.119. 81. 72. 77. 82.******** 30. 39. 56. 54. 38. 49. 64.******** 71.************************
105 53. 59.218. 80. 76.107.197.123. 34.112.121. 78. 65.******** 54. 33. 58. 65. 52. 29. 52. 54.********************************
104 59. 58. 61. 71. 68. 71. 69. 66. 72. 58. 52. 59. 61. 54. 12. 45. 57. 51. 54. 52. 49.****************************************
103 54. 60. 67. 78. 62. 52. 60. 61. 58. 46. 38. 48. 53. 55. 23. 43. 44. 48.****************************************************
102 63. 59. 58. 5 . 50. 56. 82. 66. 92. 46. 45. 45. 36. 10. 38.****************************************************************
101 59. 58. 60. 49. 47. 49. 53. 39. 27. 24. 40. 39. 23. 13. 35.****************************************************************
100 69. 67. 64. 51. 54. 51. 36. 12. 25. 38. 45. 31.  4. 19. 18.****************************************************************
 99 72. 73. 61. 50.  0. 66. 70. 34. 22. 37. 40. 26. 10. 25. 26. 12. 50.********************************************************
 98 62. 65. 68. 49. 35. 27. 32. 37. 25. 37. 34. 24. 31. 37. 36. 34. 47.********************************************************
 97 41. 57. 56. 26.294.351.  0. 16. 51. 26. 15.  8. 18. 35. 38. 34.************************************************************
 96 41. 31.347.320.335.340.349.357.  0. 11. 11.  9. 16. 13. 11. 12. 15.********************************************************
 95 28.347.287.286.305.336.335.343.356.  0.  5.  3.  0.356.347.349.348.********************************************************
 94358.299.274.282.319.359.344.343.348.355.355.356.354.350.343.336.331.326.318.************************************************
 93338.286.266.277.301.334.335.342.343.350.355.351.348.358.332.329.328.321.317.************************************************
 92296.270.268.274.306.331.343.340.320.347.352.351.********340.335.340.328.****************************************************
 91262.212.132.125. 18.  2.  5.359.347.358. 17 ************************322.276.308.********************************************
 90118.205.172. 92. 31. 39. 33.  8.354.353.*** ************ 12.****************************************************************
 89212.212. 20. 81.104. 38.  9.  3.343.339.*** ****343.333. 13.358.314.********************************************************
 88161.186.185.170. 10. 15.  2.345.325.****************342.345.334.************************************************************
   176.188.201.196.194.333.340.330.321.************338.335.339.325.************************************************************
   175.186.189.192.230.295.313.315.309.316.********300.323.328.340.************************************************************
   176.185.188.183.214.257.299.307.306.308.************315.310.****************************************************************
 84179.181.185.192.215.229.270.299.301.302.309.315.****************************************************************************
 83176.175.176.190.205.219.273.298.283.289.304.********************************************************************************
 82168.180.183.184.194.205.226.254.216.271.312.************353.****************************************************************
 81188.187.184.178.189.198.206.220.228.271.311.340.358. ***********************************************************************
 80225.203.203.195.194.194.195.197.198.208.298. 13. 30. 16.********************************************************************
 79243.189.213.205.195.187.179.180.178.168.129. 82. 49. 39. 28.****************************************************************
 78266.262.251.214.189.172.154.167.168.161.145.115. 88. 73. 61. 44. 24. 17.****************************************************
 77311.305.308.251.177.155.134.158.165.160.146.123. 99. 92. 84. 74. 36. 70.****************************************************
  6321.317.318.332.109.137.145.156.162.158.144.120. 88. 99.103.108.118.106.****************************************************
 75321.326.340.  5. 24. 56.114.143.154.152.140.130.130.110.123.129.130.130.****************************************************
   313.332.354.  8. 19. 30. 57.102.122.126.126.127.************138.139.********************************************************
 73318.353. 13. 10. 14. 28. 40. 72. 99.109.114.124.****************************************************************************
   321.  3. 12.  6. 28. 36. 24. 66. 90. 99.106.115.124.************145.********************************************************
```

Figure 5.

Air-sea temperature in degrees Celsius for the portion of the expanded (125 x 125) NWP grid covering the western North Pacific Ocean.
Asterisks represent land.
Date: 12/1/66   Time: 0000 GMT

```
     33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  61  62  63
125************************************************************************************  .0  .0  .0  .0  .0********************
124****************************************************************************************  .0  .0  .0************************
123****************************************************************************************  .0  .0  .0  .0********  .0********
122********************************  .0****  .0************************************  .0  .0  .0  .0  .0  .0  .0****************
121****************************  .0  .0****************************************  .0  .0  .0  .0  .0  .0  .0  .0************  .0
120****************  .0  .0****************  .0****************************  .0  .0  .0  .0  .0  .0  .0  .0  .0************  .0
119********  .0  .0************  .0  .0  .0  .0  .0********************  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0****************
118  .0****  .0  .0********  .0  .0  .0  .0  .0  .0****************  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0********
117  .0********  .0  .0  .0  .0  .0  .0  .0  .0  .0****************  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0****
116  .0********  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0************  .0  .0  .0  .0  .0  .0  .0  .0  .0********  .0  .0  .0****
115  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0************  .0  .0  .0  .0
114  .0  .0  .0  .0  .0  .0********  .0  .0  .0  .0  .0  .0****  .0  .0  .0  .0  .0  .0  .0  .0********************  .0  .0  .0
113  .0  .0  .0  .0  .0  .0********************  .0  .0****  .0  .0  .0  .0  .0  .0  .0  .0****************************  .0****
112  .0  .0  .0  .0  .0****************  .0  .0  .0  .0****  .0  .0  .0  .0  .0  .0  .0  .0************************************
111  .0  .0  .0  .0  .0  .0********  .0********  .0  .0****  .0  .0  .0  .0  .0  .0  .0  .0************************************
110  .0  .0  .0  .0  .0  .0************************  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0********************************
109  .0  .0  .0  .0  .0  .0  .0************  .0  .0********  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0****************************
108  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0********************  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0************************
107  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0********  .0  .0  .0  .0  .0  .0  .0************************************
106  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0********  .0  .0  .0  .0  .0  .0  .0********  .0************************
105  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0  .0********  .0  .0  .0  .0  .0  .0  .0  .0********************************
104 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.5 -.3 -.2 -.1  .0  .0  .0  .0****************************************
103-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0-1.0 -.5  .0  .0****************************************************
102-1.4-1.6-1.6-1.6-1.5-1.3-1.2-1.0-1.2-1.3-1.6-1.9-1.8-1.7-1.1****************************************************************
101-1.9-2.2-2.5-2.3-2.2-1.7-1.2-1.1 -.9-1.7-2.5-2.8-3.1-2.4-1.6****************************************************************
100-1.8-2.1-2.1-2.1-1.9-1.6-1.7-1.7-2.3-2.9-3.4-3.9-3.4-3.0-2.0****************************************************************
 99-1.8-2.0-2.2-1.9-1.6-1.5-1.4-2.4-3.4-4.2-4.9-5.0-5.1-3.7-2.3-1.1  .0********************************************************
 98-1.0-1.0 -.9 -.7 -.8 -.9-1.6-2.3-3.0-3.8-4.1-4.4-3.8-3.2-2.1 -.9 -.4********************************************************
 97 -.3  .0  .3  .3  .3 -.2 -.8-2.1-3.4-3.4-3.5-3.8-4.1-2.8-1.5 -.7************************************************************
 96  .0  .3  .3  .3  .0 -.4-1.2-2.0-2.3-2.6-2.6-2.5-2.2-1.9-1.2 -.4 -.2********************************************************
 95  .4  .7 1.1  .4 -.2 -.6-1.1-1.8-2.5-1.7-1.0-1.3-1.6-1.0 -.3 -.1  .0********************************************************
 94  .1  .5  .3  .2 -.2 -.7-1.4-2.0-2.2-2.3-1.9-1.5-1.1 -.7 -.4  .0  .0  .0  .0************************************************
 93  .0  .2  .4  .0 -.4 -.8-1.2-2.3-3.4-2.8-2.2-1.7-1.1 -.5  .0  .0  .0  .0  .0************************************************
 92 -.2 -.1 -.2 -.3 -.8-1.3-2.2-3.2-3.5-3.9-3.1-2.2******** -.3  .0  .0  .0****************************************************
 91 -.4 -.4 -.3 -.6 -.9-1.7-2.6-4.0-5.5-5.0-4.5************************  .0  .0  .0********************************************
 90 -.4 -.5 -.5 -.6-1.0-1.5-2.6-3.6-4.2-4.7**************** -.3****************************************************************
 89 -.6 -.6 -.6 -.5 -.4-1.3-2.2-3.3-4.3-4.5********-1.5 -.7  .0  .0  .0********************************************************
 88 -.6 -.7 -.6 -.5 -.7-1.0-1.6-2.2-2.6**************** -.5 -.2  .0************************************************************
 87 -.8 -.9-1.0 -.5  .0 -.7-1.4-1.2 -.9************ -.7 -.3  .0  .0************************************************************
 86 -.8-1.2-1.0 -.9 -.8 -.6 -.5 -.4 -.3 -.2******** -.3 -.1  .0  .0************************************************************
 85 -.7-1.4-2.2-1.3 -.4 -.6 -.7  .4 1.5 1.0************  .0  .0****************************************************************
 84 -.6 -.9-1.0-1.1 -.9 -.8 -.4  .0  .3  .7  .5  .3****************************************************************************
 83  .3 -.4-1.2 -.9 -.5-1.0-1.5 -.5  .4  .3  .3********************************************************************************
 82 -.4 -.4 -.5 -.5 -.5 -.5 -.2  .0  .4  .8  .6************  .0****************************************************************
 81 -.3 -.5 -.6 -.2  .2  .0 -.2  .6 1.5 1.2  .9  .6  .2************************************************************************
 80-1.3-1.2-1.1 -.9 -.5 -.1  .4  .9 1.2 1.4 1.0  .6  .2 -.2********************************************************************
 79-1.6-2.0-2.4-1.7-1.0 -.3  .3 1.3 2.2 1.7 1.1  .6  .2 -.1 -.4****************************************************************
 78-2.4-2.6-2.5-2.4-1.5 -.7  .3 1.3 1.6 1.9 1.3  .8  .4  .0  .0 -.1  .0  .0****************************************************
 77-2.6-3.3-3.9-3.1-2.3-1.1  .1 1.3 2.6 2.1 1.6 1.0  .4  .2  .0  .0  .0  .0****************************************************
 76-2.3-2.5-2.7-2.8-2.1-1.3 -.3  .7 1.0 1.4 1.8  .6  .4  .1  .0  .0  .0  .0****************************************************
 75-1.1-1.8-2.5-2.5-2.4-1.6 -.7  .0  .9  .7  .5  .3  .1  .0  .0  .0  .0  .0****************************************************
 74-1.7-1.4-1.6-1.8-1.5-1.2 -.6  .0  .3  .5  .3  .2************  .0  .0********************************************************
 73-1.1 -.9 -.7-1.1-1.4 -.9 -.3  .0  .4  .3  .2  .1****************************************************************************
 72-1.6 -.8 -.7 -.6 -.4 -.3  .0  .3  .3  .4  .2  .1  .0************  .0********************************************************
```

Figure 6.

NOT REPRODUCIBLE

Inverse Monin-Obukov stability length (feet^{-1}) for the portion of the expanded (125 x 125) NWP grid systems covering the western North Pacific Ocean. Asterisks represent land.
Date: 12/1/66 Time: 0000 GMT

```
          32       33       34       35       36       37       38       39       40       41       42       43       44       45       46

125*******************************************************************************************************************************************
124*******************************************************************************************************************************************
123*************************************************************************** ***************************************************************
122*********************************************************************************    .0000*********    .0000***************************
121************************************************************************    .0000    .0000*********************************************
120*********************************************    .0000    .0000************************************    .0000***************************
119***************************    .0000    .0000***************************    .0000    .0000    .0000    .0000    .0000******************
118*********    .0000*********    .0000    .0000******************    .0000    .0000    .0000    .0000    .0000    .0000******************
117    .0000    .0000******************    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000******************
116    .0000    .0000******************    .0000    .0000    .0000    .0000    .0000    .0000    .0000      000    .0000    .0000*********
115    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000
114    .0000    .0000    .0000    .0000    .0000    .0000    .0000******************    .0000    .0000    .0000    .0000    .0000    .0000
113    .0000    .0000    .0000    .0000    .0000    .0000    .0000*********************************************    .0000    .0000*********
112    .0000    .0000    .0000    .0000    .0000    .0000************************************    .0000    .0000    .0000    .0000*********
111    .0000    .0000    .0000    .0000    .0000    .0000    .0000******************    .0000*********    .0000    .0000*********
110    .0000    .0000    .0000    .0000    .0000    .0000    .0000******************************************************    .0000    .0000
109    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000***************************    .0000    .0000******************
108    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000*** ************************************
107    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000*********
106    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000*********
105    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000*********
104    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000
103   -.0039   -.0038   -.0040   -.0038   -.0038   -.0037   -.0025   -.0032   -.0036   -.0039   -.0013   -.0003   -.0005   -.0005   -.0011
102   -.0069   -.0072   -.0083   -.0090   -.0079   -.0066   -.0038   -.0043   -.0028   -.0049   -.0017   -.0011   -.0011   -.0009   -.0005
101   -.0087   -.0109   -.0121   -.0210   -.0095   -.0053   -.0032   -.0014   -.0014   -.0019   -.0007   -.0025   -.0021   -.0015   -.0005
100   -.0085   -.0092   -.0132   -.0145   -.0146   -.0132   -.0059   -.0040   -.0010   -.0018   -.0030   -.0040   -.0037   -.0023   -.0013
 99   -.0105   -.0154   -.0216   -.0458   -.0428    .0000   -.0146   -.0043   -.0031   -.0010   -.0052   -  098   -.0042   -.0009   -.0026
 98   -.0065   -.0073   -.0106   -.0131    .0000    .0000   -.0074   -.0081   -.0060   -.0043   -.0071   -.0065   -.0041   -.0029   -.0033
 97    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000   -.0057   -.0104   -.0054   -.0023   -.0013   -.0042   -.0025
 96    .0000    .0000    .0000    .0000    .0000    .0000    .0000   -.0020   -.0035   -.0033   -.0028   -.0019   -.0013   -.0015   -.0012
 95    .0000    .0000    .0000   2.2563    .0000    .0000    .0000   -.0007   -.0018   -.0024   -.0013   -.0005   -.0006   -.0007   -.0004
 94    .0000    .0000    .0000    .0000    .0000    .0000     0000   -.0010   -.0017   -.0014   -.0013   -.0009   -.0006   -.0005    .0000
 93    .0000    .0000    .0000    .0000    .0000    .0000    .0000   -.0016   -.0020   -.0022   -.0017   -.0013   -.0009   -.0008    .0000
 92    .0000    .0000    .0000    .0000    .0000    .0000   -.0016   -.0051   -.0046   -.0025   -.0043   -.0038   -.0029******************
 91    .0000    .0000    .0000    .0000    .0000   -.0617   -.0206   -.0171   -.0119   -.0098   -.0121   -.0181***************************
 90    .0000    .0000    .0000    .0000    .0000   -.0322   -.0191   -.0194   -.0152   -.0120   -.0138************************************
 89    .0000    .0000    .0000    .0000    .0000    .0000   - 0095   -.0063   -.0133   -.0222   -.0100******************   -.0014    .0000
 88    .0000    .0000    .0000    .0000    .0000    .0000   -.0116   -.0097   -.0088   -.0099************************************    .0000
 87    .0000    .0000   -.0025   -.0040    .0000    .0000    .0000   -.0056   -.0031   -.0017***************************    .0000    .0000
 86    .0000    .0000   -.0020   -.0023   -.0025    .0000    .0000    .0000    .0000    .0000    .0000******************    .0000    .0000
 85    .0000    .0000   -.0018   -.0025   -.0006    .0000    .0000    .0000    .0000    .0015    .0011***************************    .0000
 84    .0000    .0000   -.0014   -.0026   -.0023   -.0023    .0000    .0000    .0000    .0000    .0000    .0000    .0000******************
 83    .0000    .0000    .0000   -.0041   -.0039    .0000   -.0036   -.0078    .0000    .0000    .0000    .0000***************************
 82    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000***************************
 81    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0090    .0183    .0017    .0000    .0000*********
 80   -.0675   -.0193   -.0056   -.0023   -.0014    .0000    .0000    .0000    .0018    .0051    .2923    .7445    .0000    .0000    .0000
 79   -.0124   -.0138   -.0089   -.0061   -.0029   -.0013    .0000    .0000    .0012    .0040    .0095    .2282    .0000    .0000    .0000
 78   -.0055   -.0206   -.0156   -.0112   -.0089   -.0032    .0000    .0000    .0009    .0016    .0034    .0045    .0000    .0000    .0000
 77   -.0026   -.0043   -.0066   -.0055   -.0428   -.0134   -.0019    .0000    .0010    .0023    .0026    .0029    .0019    .0000    .0000
 76   -.0022   -.0028   -.0057   -.0128   -.0939   -.0981   -.0070    .0000    .0000    .0015    .0028    .0027    .0000    .0000    .0000
 75   -.0017   -.0010   -.0041   -.0138   -.0159   -.0141   -.0144    .0000    .0000    .0030    .0000    .0000    .0000    .0000    .0000
 74   -.0030   -.0007   -.0027   -.0045   -.0043   -.0037   -.0045    .0000    .0000    .0000    .0000    .0000    .0000******************
 73   -.0083   -.0029   -.0033    .0000   -.0012   -.0022   -.0018    .0000    .0000    .0000    .0000    .0000    .0000******************
 72   -.0069   -.0120    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000*********
```

Figure 7.

Friction velocity ($\sqrt{\tau/\rho}$ where τ is surface stress and ρ is density) for the portion of the expanded (125 x 125) NWP grid system covering the western North Pacific Ocean. Asterisks represent land.
Date: 12/1/66 Time: 0000 GMT

```
     33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  61  62  63
125************************************************************************************  .1  .2  .2  .2  .1********************
124****************************************************************************************  .1  .1  .1************************
123****************************************************************************************  .2  .2  .2  .1********  .2********
122********************************  .1****  .1************************************  .1  .1  .1  .1  .1  .1  .1****************
121****************************  .1  .3****************************************  .2  .4  .2  .7  .2  .4  .1  .2************  .3
120****************  .2  .1****************  .0****************************  .2  .2  .1  .2  .2  .4  .2  .2  .2************  .2
119********  .2  .1************  .0  .1  .1  .1  .0********************  .0  .0  .1  .2  .3  .4  .4  .4  .2  .2****************
118  .1****  .1  .0********  .1  .0  .1  .1  .1  .1****************  .1  .1  .1  .2  .2  .2  .3  .3  .7  .3  .2  .2  .2********
117  .2********  .1  .1  .1  .1  .0  .1  .1  .1  .1****************  .1  .1  .1  .1  .2  .2  .3  .3  .8  .3  .2  .2  .2  .2****
116  .1********  .1  .1  .1  .1  .1  .0  .0  .0  .0  .0************  .1  .1  .1  .2  .2  .4  .9  .3  .3********  .2  .2  .2****
115  .1  .2  .2  .2  .2  .2  .3  .2  .1  .1  .1  .1  .1  .0  .1  .1  .1  .2  .2  .2  .3  .5  .7  .3************  .2  .3  .2  .2
114  .1  .1  .2  .2  .2  .2********  .3  .2  .1  .1  .2  .2****  .2  .2  .2  .2  .3  .3  .9 1.0********************  .2  .2  .1
113  .4  .1  .3  .1  .6  .2********************  .2  .0****  .4  .2  .3  .3  .3  .4  .8  .5****************************  .2****
112  .1  .2  .2  .2  .2****************  .2  .1  .1  .1****  .1  .0  .2  .4  .8 1.3 1.6  .7************************************
111  .2  .2  .2  .2  .2  .2********  .2********  .1  .2****  .3  .2  .3  .8 1.8 1.9 1.6 1.1************************************
110  .1  .2  .2  .2  .2  .2************************  .1  .1  .1  .2  .6  .9 1.4 1.3 1.3 1.3 1.1********************************
109  .2  .2  .2  .2  .2  .2  .2************  .1  .1********  .5  .5 1.3 1.6 1.4 1.6 1.4 1.2 1.1 1.0****************************
108  .2  .2  .2  .2  .2  .2  .2  .1  .1  .1********************  .6 1.6 1.2 1.0 1.1 1.0 1.0  .8  .9 1.1************************
107  .2  .2  .4  .3  .3  .3  .2  .2  .2  .2  .3  .3  .5********  .7 1.0 1.6  .8 1.1 1.2  .9************************************
106  .2  .2  .2  .2  .2  .5  .2  .1  .1  .2  .3  .4  .5******** 1.4 1.3 1.0 1.0 1.5 1.3 1.2******** 1.6************************
105  .2  .1  .0  .2  .3  .2  .3  .1  .3  .2  .3  .5 1.0******** 1.0  .8 1.0 1.3 1.2 1.6 1.5 1.7********************************
104  .3  .2  .3  .3  .2  .3  .2  .2  .3  .4  .7  .8  .9 1.0 1.1  .9  .9 1.0 1.3 1.4 1.7****************************************
103  .4  .4  .4  .4  .4  .5  .4  .4  .4  .7 1.4 1.2 1.2  .8 1.8 1.2 1.1 1.1****************************************************
102  .3  .3  .3  .3  .4  .5  .4  .5  .4  .7 1.0 1.1 1.2 1.5 1.4****************************************************************
101  .3  .3  .3  .4  .5  .6  .8  .7  .6 1.3  .8 1.0 1.2 1.9 1.7****************************************************************
100  .3  .3  .3  .3  .3  .4  .5 1.1  .9  .8  .8  .8 1.0 1.3 1.7****************************************************************
 99  .3  .3  .2  .2  .0  .3  .4  .8 1.7  .8  .6  .9 2.2 1.0  .9 1.6 1.1********************************************************
 98  .3  .3  .2  .2  .2  .3  .3  .5  .7  .6  .7  .9 1.0  .8  .9 1.1 1.0*****  *************************************************
 97  .2  .2  .3  .1  .2  .4  .7  .5  .4  .7 1.0 1.6  .8  .9 1.1 1.1*********  *************************************************
 96  .3  .2  .1  .2  .3  .5  .6  .6  .7  .8 1.0 1.2 1.0 1.1 1.2 1.0  .8********************************************************
 95  .3  .1  .0  .3  .4  .8 1.0  .8  .9 1.0 1.1 1.3 1.3 1.3 1.4 1.1 1.0*****  *************************************************
 94  .2  .2  .3  .3  .5 1.2 1.0  .9 1.1 1.1 1.2 1.3 1.3 1.1 1.2 1.1  .8  .7  .5************************************************
 93  .3  .2  .3  .4  .4  .7  .7  .9 1.0 1.1 1.1 1.1 1.0  .4 1.0 1.0 1.1  .7  .5************************************************
 92  .1  .2  .2  .2  .3  .7  .5  .7 1.0  .8  .8  .7********  .5  .7 1.1  .5****************************************************
 91  .2  .1  .2  .1  .1  .2  .3  .5  .6  .5  .4************************  .3  .2  .3********************************************
 90  .1  .0  .0  .1  .1  .2  .3  .4  .5  .5****************  .3****************************************************************
 89  .2  .1  .1  .1  .2  .3  .5  .4  .3  .5********  .9 1.0  .6  .4  .4********************************************************
 88  .3  .2  .2  .1  .1  .3  .3  .4  .4****************  .9  .7  .6************************************************************
 87  .5  .5  .4  .3  .1  .2  .4  .5  .6************  .9 1.0  .7  .7************************************************************
 86  .6  .6  .5  .5  .2  .2  .4  .7 1.1  .8********  .4  .9  .8 1.0************************************************************
 85  .7  .7  .8 1.3  .4  .4  .4  .7  .8  .8************ 1.0  .7****************************************************************
 84  .6  .7  .5  .5  .5 1.0  .4  .7  .7  .6  .6  .6****************************************************************************
 83  .6  .9  .4  .4  .4  .4  .3 1.3  .7  .4  .3********************************************************************************
 82  .5 1.2  .5  .4  .3  .3  .3  .4  .4  .3  .3************  .4****************************************************************
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 80  .2  .3  .5  .6  .5  .6  .7  .6  .4  .0  .0  .3  .5  .6********************************************************************
 79  .3  .4  .5  .6  .7  .8 1.0  .8  .6  .3  .0  .2  .3  .4  .4****************************************************************
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 77  .6  .6  .7  .2  .3  .6 1.2 1.0  .9  .7  .6  .6  .7  .6  .4  .3  .2  .2****************************************************
 76  .8  .5  .3  .2  .1  .3  .9  .7  .7  .5  .5  .6 1.0  .6  .5  .3  .3  .2****************************************************
 75  .9  .5  .3  .3  .3  .3  .3  .4  .4  .4  .5  .7 1.4  .5  .5  .5  .4  .3****************************************************
 74 1.3  .6  .5  .5  .5  .4  .3  .3  .4  .5  .6  .8************  .7  .6********************************************************
 73  .5  .4  .5  .8  .7  .6  .5  .4  .5  .7  .9  .9****************************************************************************
 72  .3  .3  .6 1.1  .7  .6 1.0  .5  .6  .7  .6  .3  .8************  .8********************************************************
```

Figure 8.

SPECTRAL GROWTH MODEL (INOUE-CARDONE)

$$\frac{dS(f)}{dt} = \left[A\ (f, U_{19.5}) + B(f, U_*) \cdot S(f) \right] \left[1 - \left(\frac{S(f)}{S_\infty} \right)^2 \right]$$

where $S(f)$ = spectral intensity at frequency f

A = Phillips Resonance Growth Parameterization

B = Miles-Phillips Instability Growth Parameterization

S_∞ = Pierson-Moskowitz Fully Developed Spectrum

ENERGY DISSIPATED IN BREAKING WAVES

$$E = \rho_w \cdot g \cdot \int_0^\infty B \cdot S \cdot \delta \cdot df$$

where $\delta = 1 \qquad S = S_\infty$

$\delta = 0 \qquad S < S_\infty$

FOAM COVER FRESH WATER

$$W_F = -.0185 + .893 \times 10^{-3} \cdot E\ (\mathrm{ergs/cm^2/sec})$$

SALT WATER EFFECTS

$$W_S = 1.5 \cdot W_F$$

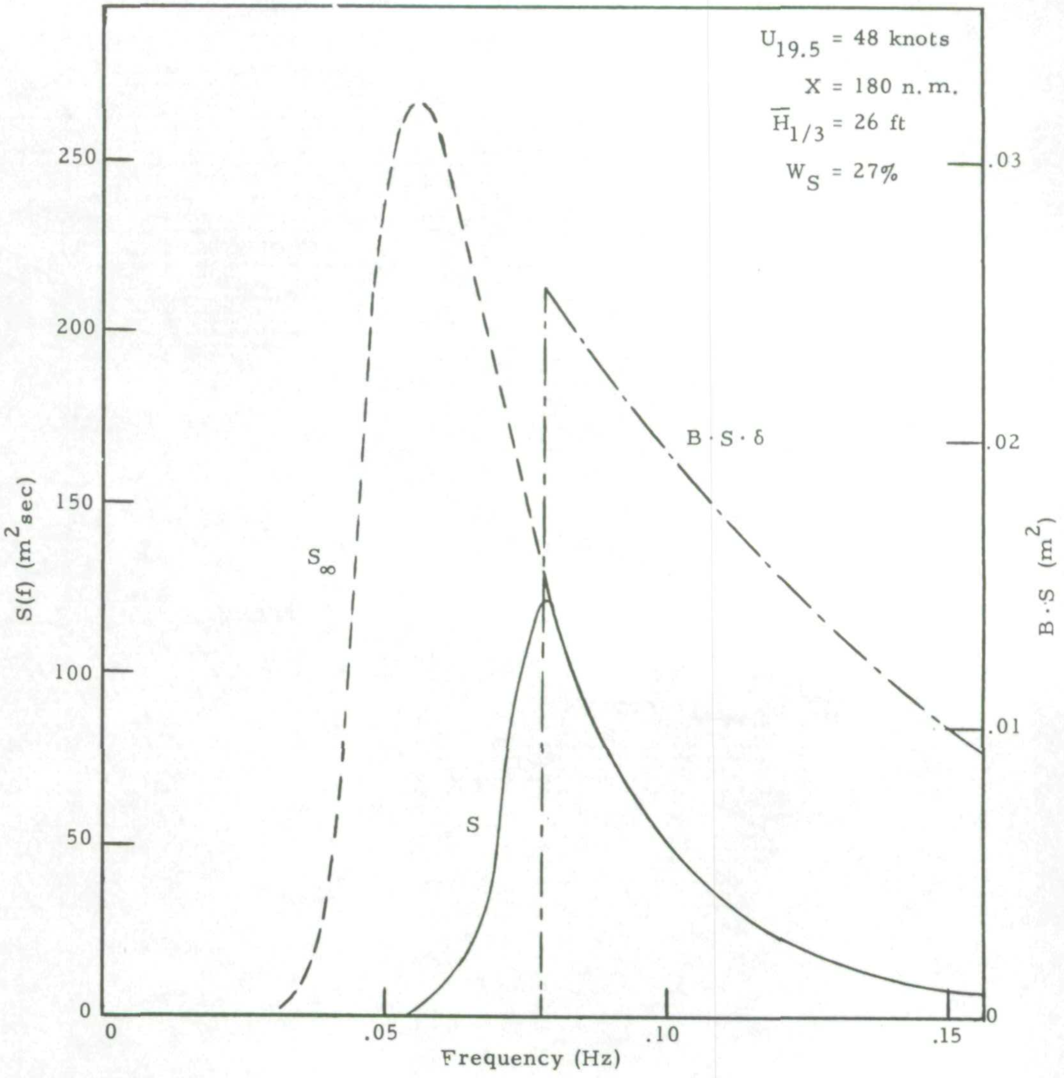

Figure 9. The computation of the whitecap production index.

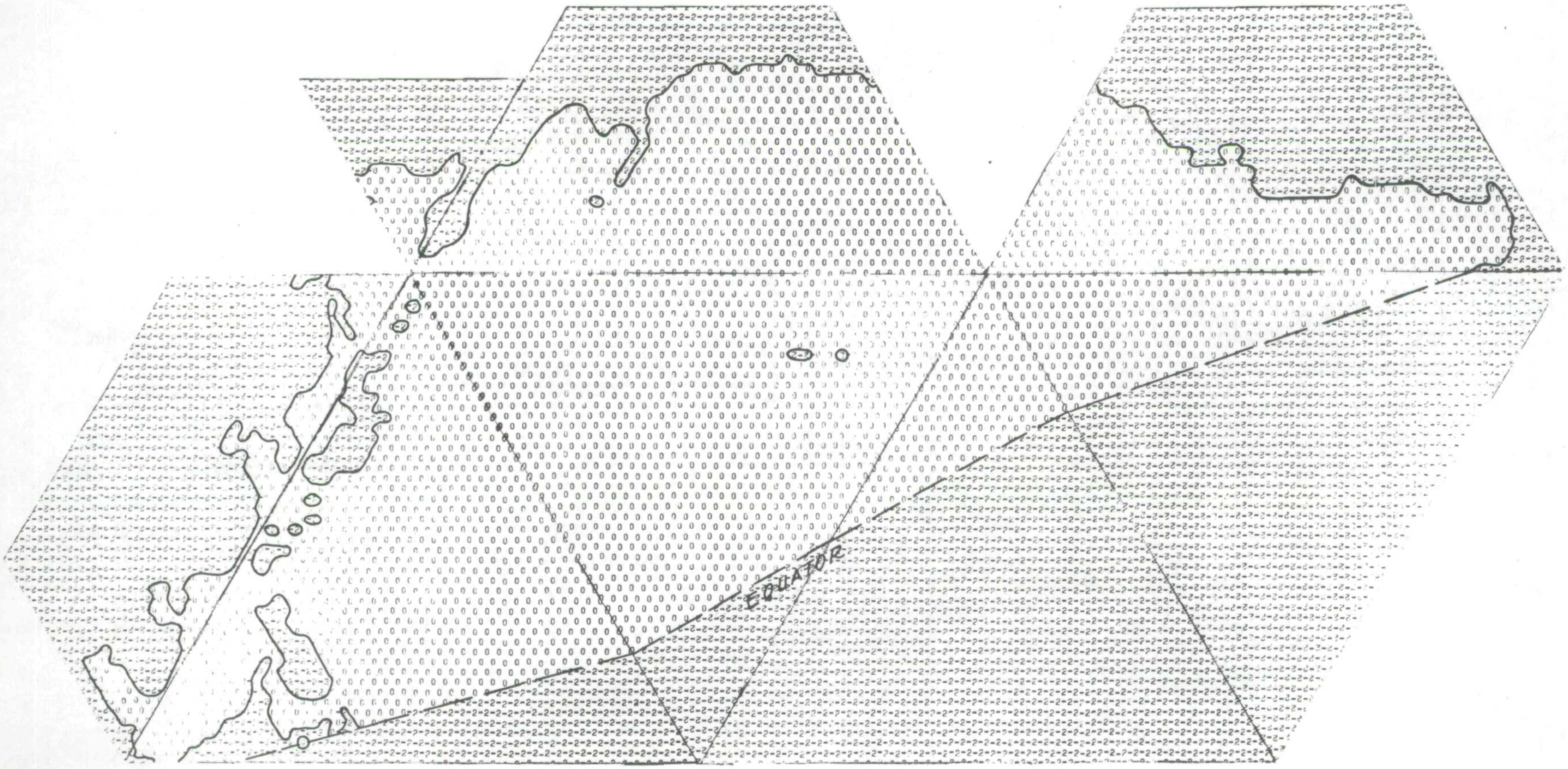

FIG. 10. LAND SEA TABLE FOR WAVE HINDCASTS AT EACH ZERO, 360 NUMBERS TO DESCRIBE THE WAVE SPECTRUM WILL BE COMPUTED

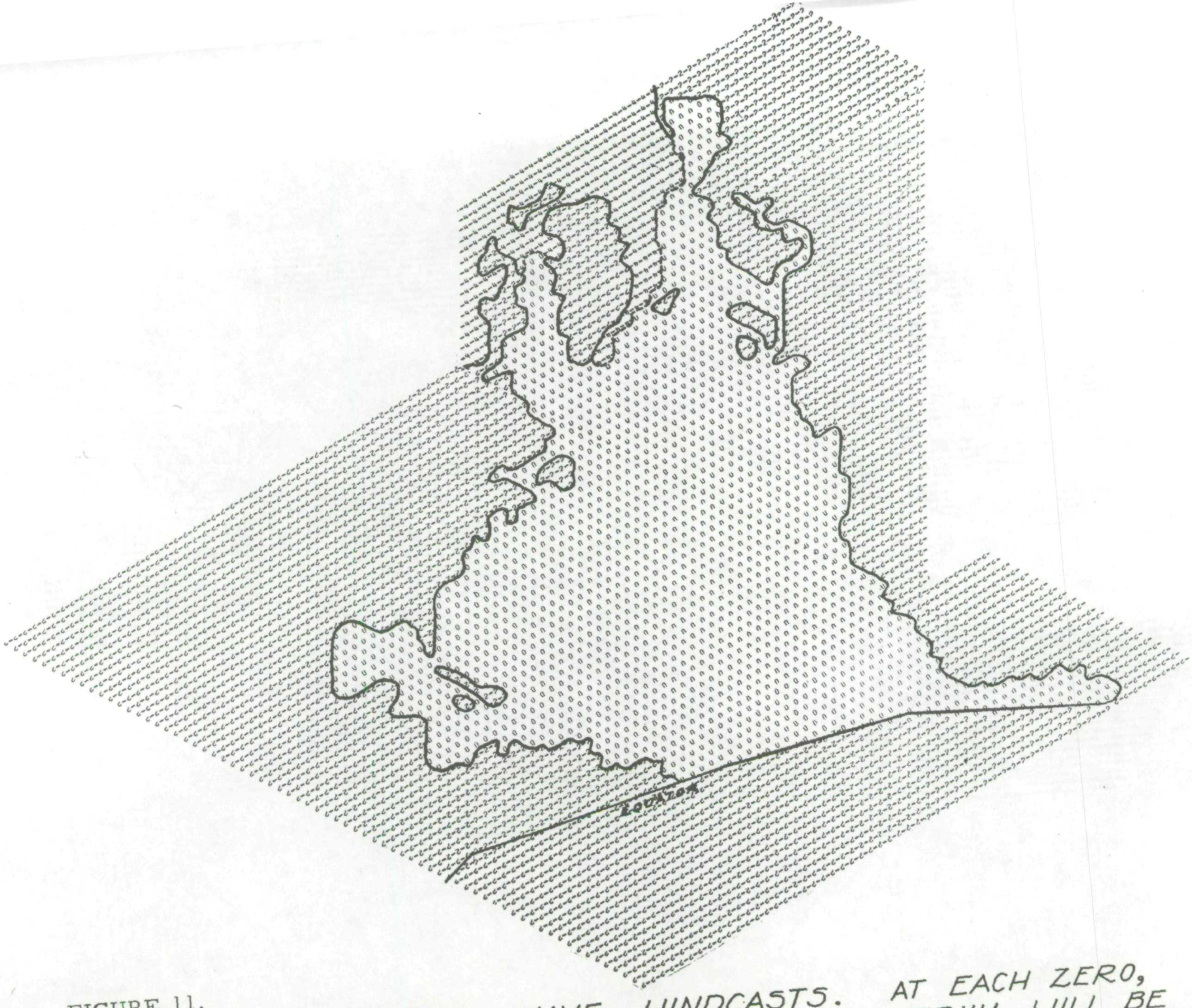

FIGURE 11.

LAND SEA TABLE FOR WAVE HINDCASTS. AT EACH ZERO, 360 NUMBERS TO DESCRIBE THE WAVE SPECTRUM WILL BE COMPUTED (NORTH ATLANTIC)

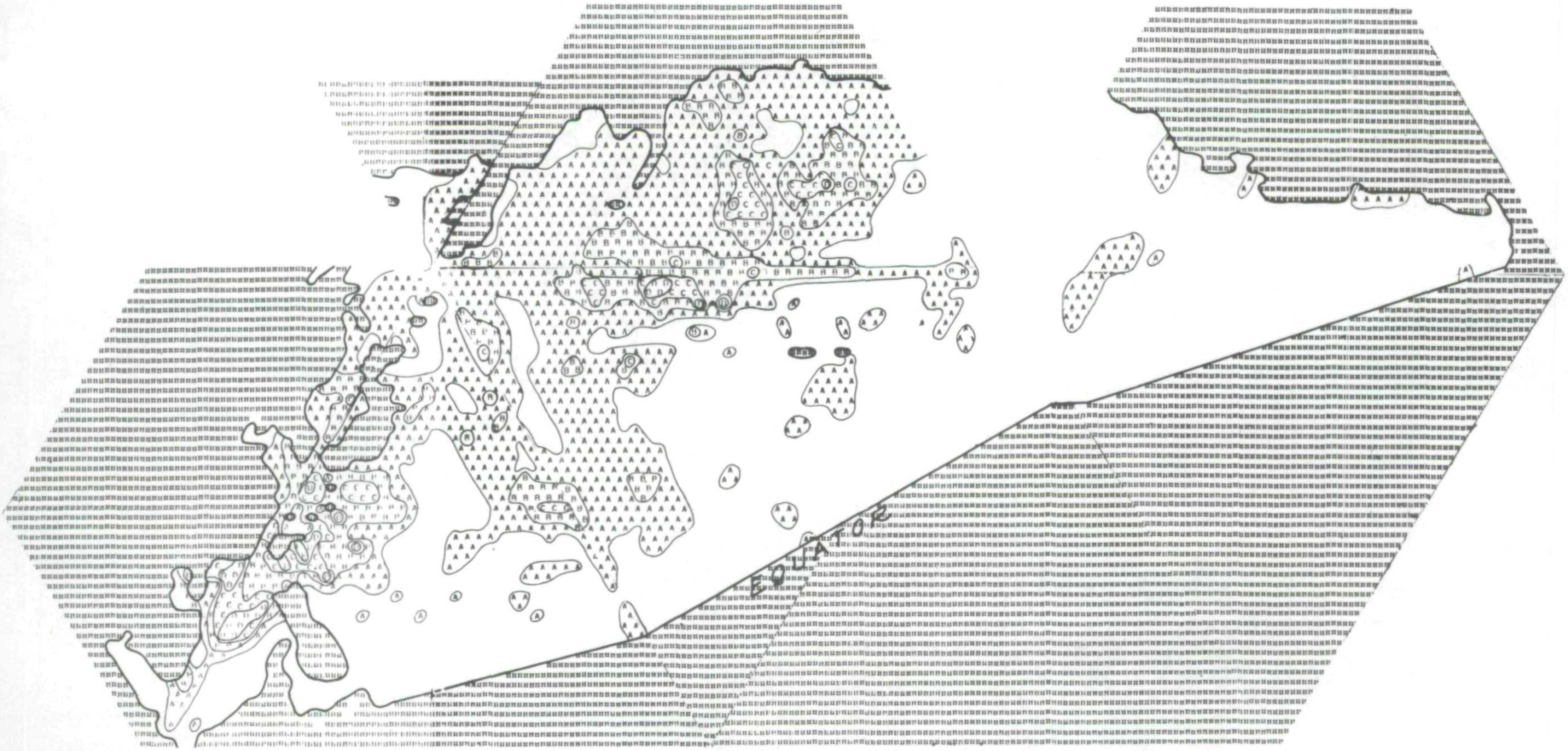

FIG. 12. INITIALIZATION SIGNIFICANT WAVE HEIGHTS FOR NORTH PACIFIC OCEAN. BLANK EQUALS 0 TO 2 FEET, A EQUALS 2 TO 4 FEET AND SO ON.

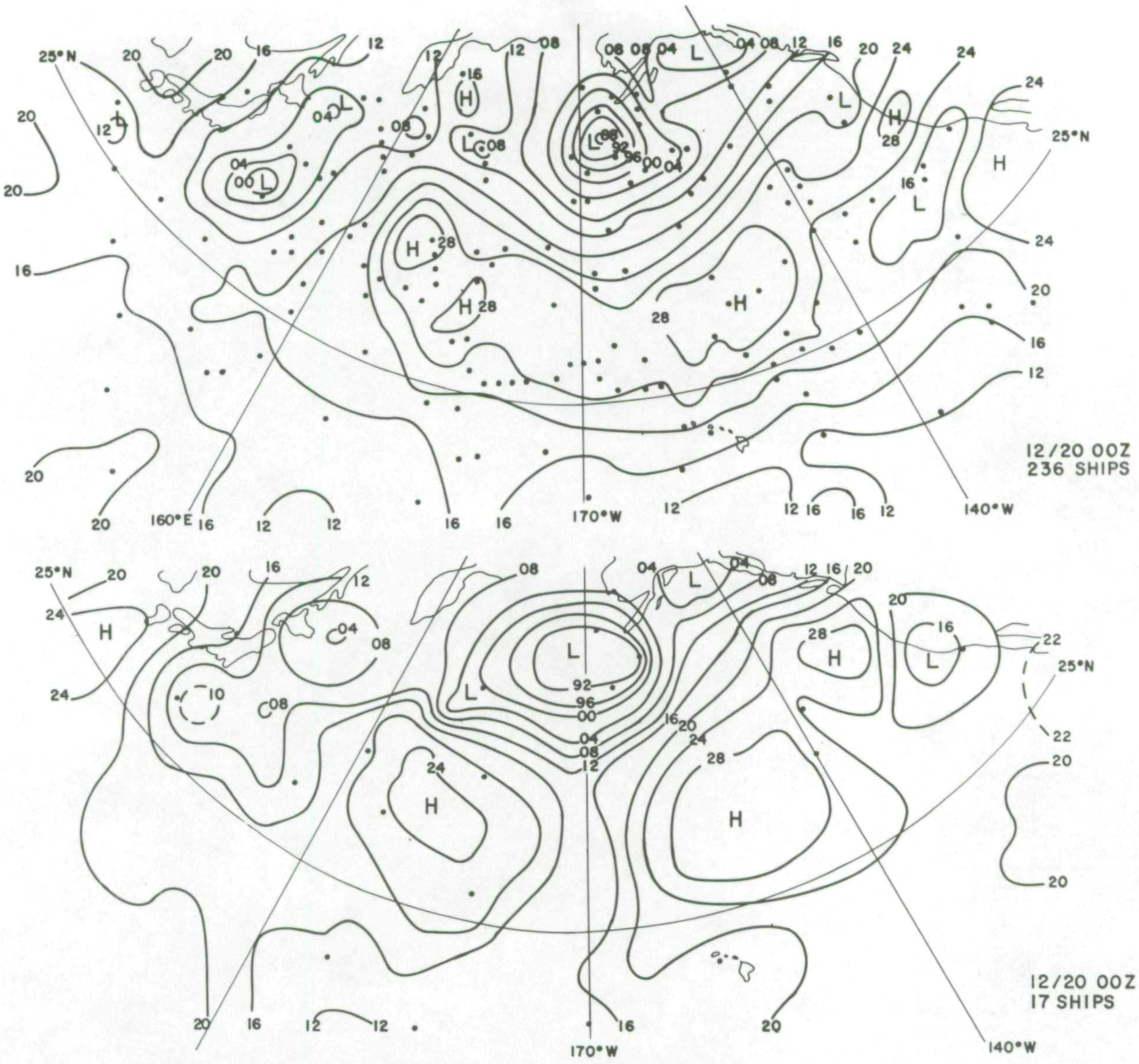

Fig. 13. Top: Pressure field analysis based on all available ships. Bottom: Pressure field analysis based on 17 ships and simulated wind speed information.