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THE PRECIPITATION AND FORMATION MOVEMENT OF CLOUDS IN THE CENTRAL PACIFIC

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ABSTRACT

The report describes the cloud data and some of the research results of Project 4.5, Task Group 3.1, Task Force III. A rational classification of tropical clouds characteristic of the Central Pacific Ocean is attempted; fifty-two coloured photographs of oceanic clouds are reproduced as a foundation for a tropical cloud atlas; and the topic of cumulus precipitation is treated at some length. Then follows a discussion of the techniques necessary to any attempt to forecast the movement and transformation of atomic clouds in low latitudes, the chief attention being paid to events following the first six hours after the explosions. A method of computing vertical motions in the free atmosphere is described and applied. The report concludes with a chapter of recommendations.

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CHAPTER 4

DISCUSSION AND RECOMMENDATIONS

4.1 REVIEW

So far as future weapon testing in the Marshall Islands area is concerned, the only parts of this report that are of interest concern the meteorological conditions governing the motion of atomic clouds, and the possibility of forecasting cloud and precipitation immediately before and for some time after atomic explosions. The topics upon which recommendations can be made therefore are those connected with the observations, analysis and forecasting of the field of motion and those which bear on the detection and forecasting of extensive sheets of thick altostratus, accompanied by rain.

4.1.1 Comparison of the Artificial with the Natural Cloud

Experience during Greenhouse suggests that up to about six hours after the explosion the atomic cloud may be regarded as a large and long-lived cumulus. This means that the chief deformative fields lie in the vertical planes and that the most important part of those fields consist in the successive vertical profiles of the horizontal component of the wind which the cloud meets during its translation. As with the cumulus these fields result in a "shear" of the cloud. The translation of the cloud is at the same time sufficiently approximated by neglecting the vertical motions of the ambient and included air and computing the dis-

Fig. 3.24 Schematic Representation of Atomic Cloud (Easy Test) at H + 24

160° E 162° 164° 166° 168° 170° 172° 174° 176° 178° 180°

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29

placements of individual portions of the cloud, level by level.

After about six hours, however, the approximations are no longer valid. Diffusion of the cloud particles has led to the spread of the mass and the deformative twist and shear due to the field of strain have led to large relative displacements of the cloud elements. At this stage the separate cloud portions move in different parts of the total field of motion; their future positions therefore have to be computed one by one and the position of the whole cloud estimated through a synthesis of these separate calculations.

4.1.2 Precipitation and Convection of Radioactive Material by Natural Clouds

The general conclusion of Chapter 2, as far as the immediate purpose is concerned is that the most frequent rains in the Marshall Islands fall from cumuli whose effective cloud thickness exceeds 5000 ft. Most of the cumuli yield small amounts of rain, in showers lasting not more than a few minutes. As agents which could collect and precipitate material from a radioactive cloud in the second phase (over six hours after the explosion) therefore they would be ineffective. They would have to reach into upper regions of very high particle concentrations, so far not attained, in order to constitute hazardous natural collectors.

On the other hand, if high concentrations of radioactive material existed in the middle atmosphere (say, between 15,000 and 20,000 ft) and at the same time an upper flow similar to that after Easy test occurred, hazardous precipitation might occur. In the first place the upper horizontal deformation fields would concentrate the material along an axis of stretch, which also, analysis shows is a region in which altostratus is most likely to occur in thick widespread sheets (see Figs. 2.32-35) with rain, not only from the altostratus itself but also from tall cumuli and cumulonimbi penetrating it. The latter would be effective contaminators, since rain is much heavier from the cumulonimbus and cumulus congestus prevailing in these situations.

4.1.3 Forecasting Natural Cloud Cover

It becomes apparent from section 4.1.2 that the forecasting of natural cloud cover and precipitation might be important in future test programs. The difficulties of accurate forecasting have been sufficiently emphasized in Chapter 2. Fortunately the types of clouds likely to be important are those with which synoptic analysis can deal: that is, widespread sheets of altostratus-altocumulus associated with major disturbances in either the lower atmosphere (typhoons and tropical storms) or the upper (upper level cyclones and troughs in the westerlies). The attack on the forecast problem then is through the analysis of the field of motion.

4.1.4 Forecasting the Field of Motion

We finally arrive at the conclusion that the most important forecast in any future operation must be that of the changes in the field of motion at all levels in the troposphere over the Marshall Islands. From this forecast would be derived the prognoses of the successive positions and shapes of the atomic cloud, the concentration of material at various levels within those shapes, the transport upward or downward of previously detected nuclei of concentration through atmospheric motions and independently of fall-out, and finally the precipitation of the material on to the surface by natural clouds.

4.2 RECOMMENDATIONS

The following recommendations are made on the basis of the meteorological results of Project 4.5 alone. Since personnel on the project have only partial knowledge of variables which must seriously qualify the recommendations the latter are advanced in a very tentative manner indeed.

4.2.1 Forecasting Atomic Cloud Movement

During the first phase of the cloud movement (up to six hours after the explosion) the present Radex methods, based upon spot winds at the point of detonation, are as successful as may be expected. More refined methods would probably not improve the forecasting appreciably.

During the second phase, however, trajectory analysis using complete analyses of the field of motion at all levels up to 10,000 feet above the highest point to which the cloud is expected to attain is essential if the cloud is to be followed with any success. It is recommended that diagnostic and prognostic streamline maps together with the derived vertical motion maps be made the basis of any future trajectory analysis aiming at accurate tracking of the cloud during the second phase.

Since it is now known that vertical motions which in the mean may be as large as 4 cm/sec can occur over large areas of the Marshall Islands, the possibility of large vertical displacements of parts of the cloud during the second phase should always be considered. It is recommended that further work on vertical motion analysis be associated with any future program and that account be taken of this component of the motion in trajectory analysis. Advantage should be taken of the fact that the cloud material is an atmospheric tracer, to check the results of the vertical motion analysis and prognosis. This would be of inestimable value in meteorological research.

If possible, checks on dummy trajectory forecasts should be made before any actual test. This could be very simply effected by the release and tracking of a constant level balloon from the test island, say, every second day. Forecasting personnel would by this means have a longer series of checks on their trajectory analyses and forecasts than has been possible. On Greenhouse and previous tests, it seems, the only checking possible occurred during the most intense part of the Operation.

4.2.2 Operational Forecasting

In addition to the forecasts of movement and transformation of the cloud, which is the main preoccupation of this report, there would be on any future test, the need for normal operational forecasting, such as was carried on at Eniwetok during Operation Greenhouse. But facilities adequate to conduct trajectory forecasting would also be adequate for normal operational forecasting. It suffices, then, to treat the facilities that would be required to conduct the type of forecasting previously outlined.

It is clear that the results and methods described in this report depend on two factors: an adequate reporting network and sufficient knowledge of tropical meteorology to make accurate analyses and prognoses

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from the reports. Accurate analyses and prognoses ultimately depend on advances in knowledge obtained through research. The only data so far obtained from the Tropics that are of a caliber approaching those required for research are those derived from the weapon testing projects in the Marshall Islands. The routine reports from the tropical Pacific utilized by the Air Weather Service in day to day forecasting are not adequate for even simple forecasting for air transport operations in low latitudes. None of the methods of streamline analysis described in this report, for example, can be applied to current maps of the tropical Pacific - there is not enough data. The importance of Operation Greenhouse, therefore, from a meteorologist's point of view, far transcends its immediate object. Those responsible for the meteorological planning of the Operation were acutely aware of this and elaborate precautions at those levels were taken to preserve the data when it should be collected and to see that its accuracy and the frequency of observation attained to the highest standards. But, it must be noted, this ideal was not immediately present in the consciousness of all persons in ATU 3.4.5. The abrogations of the original program which were noted in Chapter 1 were in some cases made arbitrarily and without considering their effects not only on the research projects organized as units of Task Group 3.1 but on the very activities that ATU 3.4.5 was constituted to perform. It is strongly recommended that if future tests occur, control be exercised from above over lower operational echelons to see that the primary meteorological missions are not hamstrung by arbitrary decision and that the immense value for research of the meteorological data collected during the operation is kept in mind by all personnel at all times.

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It is impossible to make some of the computations described in this report using Crossroads or Sandstone data. For the type of forecasting described, the Greenhouse network represents a minimum. This sometimes failed - partly to the cumbersome communications system (see Chapter 1) and partly because the original plans for the frequency of observations were not carried out by Task Group 3.4. It is recommended that in future tests the full Greenhouse network, as originally planned and including reports from Truk and Ponape be regarded as a minimum requirement.

If a higher order of accuracy in the estimates and computations and consequently a "safe" margin for the forecasts is required, then a network slightly more extensive, though not more dense than the Greenhouse stations would be needed. The following would constitute a desirable net:

Bikar or Utrik	Ponape
Eniwetok	Truk
Wake	Manus
Kwajalein	Nanumea or Funafuti
Majuro	Canton Island
Bikati or Tarawa	Kapingimarangi
Nauru	Guam
Kusaie	Midway
Palmyra	French Frigate Shoals
Johnston	Nandi
Iwo Jima	Henderson Field or Munda
Honolulu	Rabaul

Some of these stations already have facilities for obtaining rawinsonde data; the others would have to be equipped, so that winds to maximum heights could be observed four times per day. The stations in the southern hemisphere are necessary, if it is desired to follow the complete perturbations that pass from east to west across the region; these perturbations

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do not cease abruptly at the equator; they overlap the equatorial easterlies in both hemispheres (11, 28, 30, 32).

In any future operation the same number of weather reconnaissance patrols would be required; however, the administrative procedures by means of which the flight plans would be set up would have to be more flexible than those that obtained on Greenhouse. It should be possible to vary the tracks to be flown at least twelve hours before take-off and to do this by the most direct channel between the responsible meteorologists and the Commander of the Reconnaissance Squadron. Cloud photography on flights, which lie entirely outside a previously defined operational area, should be permitted for research purposes.

Finally, the opportunity that an Operation of the Greenhouse type provides for research on tropical clouds and precipitation should be grasped. In particular, much more use should be made in the field of radar observations of cloud and precipitation. All stations should be equipped with radar and provision made for obtaining photographs or drawings of the scope at regular intervals and as a routine weather observation.

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39