Verification of the numerous objective forecast techniques and the NHC official forecast has been completed for the 1972 season. (Tracy, Sherrill)

Probability ellipses based on the official forecast direction of motion are being accomplished.

A paper entitled, "Changes of the Maximum Winds as Deducted from Central Pressure Changes," is being prepared for the ERL Technical Report series. (Michaels)

During the past quarter, data processing personnel participated in STORMFURY Dry Run, 2 calibration flights, Hurricane Dawn flights, Project Cloudline radar evaluation flight, flux studies flight, hydrophilic powder seeding study flights and navigation evaluation flights. (Lewis, Pearce, Michaels)

Mr. Billy Lewis was appointed Project Leader for the installation and operation of a Univac 1108 computer in Miami, Florida. (Lewis)

A graphics program designed to display hurricane tracks with latitude, longitude, and speed as a function of time as well as the presentation of the storm track on a geographical map has been completed. (Foltz)

G. Contractors and Grantees

University of Miami, Professor Harry V. Senn

During the past quarter several RML personnel have participated in the Project STORMFURY dry run and cloudline experiments out of Jacksonville NAS and Barbados, B. W. I. In addition, a test flight was made using 39C and 40C to determine the efficiency of the RML-supplied iso-echo contouring units on the AVQ-30 and APS-20 radars as well as to run other tests on the radars. In general, the flights were successful in proving the applicability of the IEC units in providing quasi-quantitative radar meteorological data, in overcoming some of the misconceptions which might have been limiting the use and usefulness of these devices, and in comparing the AVQ-30 and APS-20 radars in a flight-weather situation. Recommendations for improvement of the RFF radars and radar data based on these flights, are being drawn up.

These recommendations, along with an improved three-dimensional model of hurricane precipitation based on the three-storm data under study for the past year, are being completed and incorporated into the final report which is presently under preparation.

Massachusetts Institute of Technology, Professor Fred Sanders

Professor Sanders and John Gaertner worked on further development of the SANBAR model for prediction of hurricane tracks. We completed a series of 72-hour forecasts for the Atlantic-Gulf-Caribbean area for initial times at 1200 GMT September 7 through 0000 GMT September 13, 1971, these twelve times

AN EXPERIMENT TO TEST THE MODIFYING EFFECTS OF HYDROPHILIC POWDER ON MARITIME CUMULUS CLOUDS

Billy M. Lewis and Harry F. Hawkins

National Hurricane Research Laboratory
National Oceanic and Atmospheric Administration
Miami, Florida

1. INTRODUCTION

For several years, USSR scientists have conducted weather modification experiments designed to reduce or eliminate hail damage to agricultural crops (Gaivoronskii, et al, 1968; Gayvoronskiy, et al, 1970). One of these efforts was directed towards developing techniques for dissipating cumulus congestus and cumulonimbus clouds. If the natural dissipation rate of the cloud could be accelerated, it was believed that there would not be sufficient time for the cloud to produce hail which could reach the ground in sizes or amounts large enough to damage agricultural crops.

A basic hypothesis was developed by the Soviet scientists to account for dissipating these convective type clouds. When the apex of an unstable cloud is seeded by dispersing hydrophilic powders in the region of both maximum updraft and liquid water, hydrophilic scavenging of small water droplets would lead to the formation of large water drops. As these combined hydrophilic-water particles reach the level of zero buoyancy and load the top of the cloud with larger drops at an earlier time in the cloud cycle than would naturally occur, these larger drops would begin to fall and to entrain air. The development of these processes could, it was argued, lead to the formation of a downdraft in the unstable cloud. Vaporization of rain in the dry air beneath the cloud would tend to weaken the vertical velocity field in the cloud. Thus, once the downdraft equaled or exceeded the updraft, the main portion of the cloud would dissipate rapidly. The anvil or crystalline portion of the cloud, if present, would not be affected by the process and should remain for a considerable time after the active portion of the cloud had dissipated. The seeding agent to be used should range in size from 5 to 50 microns and be dispersed at a rate of 1 to 2 kg per km of cloud.

Portland cement was selected as the hydrophilic agent to be used in Soviet field experiments. The cement was injected into cumulus congestus clouds of 3000 to 4000 meters average thickness, and thunderstorms of 10 km in vertical development. The Soviet scientists found that the clouds dissipated in every case, and they reported dissipation of thunderstorms of frontal and airmass origin was completed in 7 to 20 minutes after seeding in 54 out of 55 cases (Gayvoronskiy, et al, 1970).

The dissipation effects on these thunderstorms were described by Gayvoronskiy (1970) as "becoming fibrous in structure and began to split up into small portions which vaporized without significant precipitation." The clouds dissipated in 7 to 20 minutes; the period of dissipation depending on cloud size and stage of development. Gayvoronskiy (1970) has stated that radar echoes of seeded clouds showed perceptible reduction in size and subsequently disappeared.

Experiments at the Naval Weapons Center duplicated the USSR experiments in 1971 in conjunction with the Naval Weapons Center's Project Q. Field operations, conducted over the western Gulf of Mexico, led to the conclusion that the use of hydrophilic powders in a coarsely dispersed aerosol greatly affected growth rates of clouds 3 to 6 km thick. Observers noted that 9 out of 13 clouds dissipated in 5 to 20 minutes. Two additional clouds appeared to be adversely affected by the seeding experiments.

2. CURRENT INTEREST

A possible use of this form of weather modification might be to reduce convective activity in hurricanes. If the convective growth in the "feeder" rainbands could be reduced, the hurricane's structure might be materially altered. In order to evaluate the possible utility of hydrophilic powders in dissipating or reducing convective activity the National Hurricane Research Laboratory conducted several seeding experiments in 1972 on maritime tropical cumulus clouds in relatively undisturbed conditions.

3. PHYSICAL CHARACTERISTICS OF SEEDING AGENT

The seeding agent used in these experiments was portland cement. The chemical formula for this was: SiO_2 - 22.6%, AL_2O_3 - 4.0%, Fe_2O_3 - 3.7%, CAO - 64.3%, SO_3 - 2.2%, MGO - 0.9%. The physical composition was 2070 Wagner surface area with a mesh screen size of 12 micron.

4. DISPERSAL EQUIPMENT

The NOAA C-130 was equipped with a modified dropsonde chute used for dispersing the cement. The modification consisted of installing a set of blades attached to a crank in the center of the chute. Several steel bars were set into the chute wall in such a fashion that the rotating blades would cut open a plastic bag of portland cement resting on them. The outer and inner doors of the chute remained intact in order that the chute could be reloaded when the aircraft was airborne. A pressure relief valve was installed to equalize the air pressure in the chute with the aircraft cabin pressure so the chute could be opened when the aircraft operated at altitude. The plastic bags placed in the chute contained approximately 18 kg of portland cement, and the contents of the bag were released into the air stream when the crank handle was turned. The release rate was about 3 kg/km.

The dispersal system was tested on October 6, 1972, and worked satisfactorily. Two thunderstorms were each seeded twice during two penetrations during the test flight. Visually, the clouds appeared to alter their characteristics by the formation of a rain shower about 3 minutes after the first seeding. However, there was no filming of these clouds by a chase plane.

5. THE SEEDING EXPERIMENT

The seeding experiment was designed to use the visual and radar observational capabilities of the NOAA aircraft. As stated previously, the NOAA C-130 was used as the seeder aircraft. A NOAA DC-6 aircraft equipped with cloud and radar time-lapse 35 mm cameras was selected to monitor the seeded clouds.

The monitor aircraft flew an elongated oval pattern at a short distance from the seeded cloud. Since the monitor aircraft was equipped with a cloud camera facing outward on each side, and an RHI vertical scanning radar which scans at right angle to the aircraft heading, the cloud should be under almost continuous recorded observation during each cloud experiment.

The seeder aircraft was assigned command responsibility, and a meteorologist stationed on the flight deck selected target clouds. Once the monitor aircraft was in its orbit at an altitude of about 5 km, the seeder aircraft would penetrate the active cloud tower at an altitude of 5 to 6 km and an airspeed of 180 kts. The dispersal of cement began just after the entry into the cloud and continued until the 18 kgs were exhausted. Thus, it was assured that the cement was being released as the aircraft passed through the active updraft of the cloud.

In an effort to obtain unbiased results, a randomization table of seeding versus non seeding of the clouds selected was tabulated prior to flight days. Four clouds per day on two days, October 11 and 13, 1972 were selected for the "seeding runs." To insure that only those persons actually turning the crank and tabulating the seeding or no seed of the cloud had knowledge of which clouds were actually seeded, a large curtain was suspended about the dropsonde area. Two clouds were seeded on the first day and three clouds on the second day. Therefore, there were data from five seeded clouds and three unseeded control clouds for evaluation.

6. EVALUATION OF THE EXPERIMENT

The cloud camera films for each cloud were subjected to detailed examination. These cloud films strongly indicated that the life cycles of the first and fourth clouds on October 11, 1972 were similar. These two clouds were well organized and had active towers forming on the up-wind portion of the cloud. However, neither cloud developed towers which reached above 6 km. during the period the clouds were being observed.

Cloud 1 maintained its organization and continued to produce active towers after 35 minutes of observation. Even though cloud 1 was penetrated by the seeder aircraft 10 minutes after the observation period began, the cloud was not seeded.

Height finding 3 cm radar (RDR) film was used to construct plan view graphs of the width of the isoecho each time the chase plane scanned the cloud while following its race track pattern. The maximum and minimum heights of the isoecho tops were plotted along the axis of the cloud. Unfortunately, the radar camera malfunctioned half way through the cloud 2 monitoring period on October 11, 1972, and did not function again for the remainder of the flight.

The radar data for cloud 1 on October 11, 1972 are shown in figure 1 and indicate that the radar isoecho area varied in width by at least 20% as the cloud drifted along. Towers

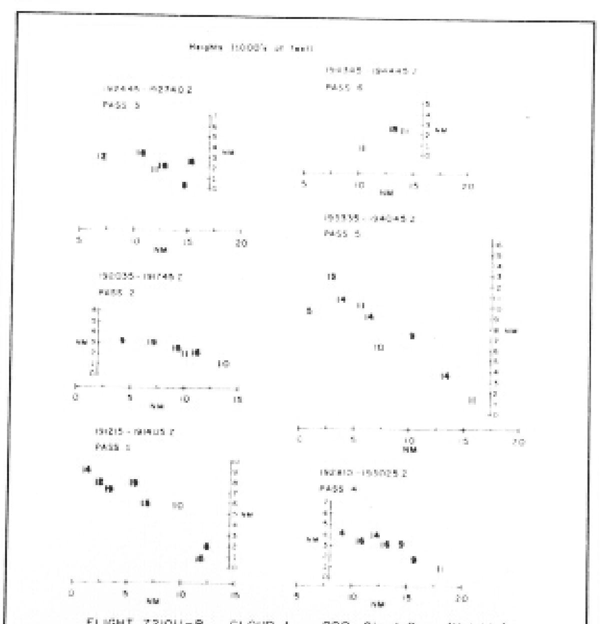

Figure 1. Maximum width of RHI 3cm radar isoechos depicted in plan view with heights of the tops of isoechos in 1000's of feet for cloud 1, October 11, 1972. The base line extends over the range for which RHI data are available for each pass.

remained below 20,000 ft. (6 km) and renewed activity became apparent upwind of the older echoes by approximately 1930Z. The reason the resurgent activity does not appear in passes 3, 4 and 6 is that the flight track ovals terminated short of the newer activity. The original remaining cloud mass (in the radar isoecho sense) had almost dissipated by 1945Z. The active towers in cloud 1 which were produced 35 minutes after observations began (as seen in the cloud films) were being produced by the resurgent cloud mass and were not part of the original portion of the cloud.

Cloud 4 on October 11, 1972 behaved similarly to cloud 1 according to visual evaluation of the cloud film. The cloud towers appeared to be very active at 2135Z. Little if any change was observed in the cloud prior to an actual seeding run at 2140Z. The cloud continued to produce incipient towers but shortly thereafter stopped growing at 2144Z. Very little of the cloud mass remained at 2147Z, and observation of the cloud was terminated because of lack of activity possibly associated with the seeding. In neither case (i.e. clouds 1 or 4) was an anvil produced or visible rain shower seen.

Clouds 2 and 3 on October 11, 1972 behaved quite differently from clouds 1 and 4. Both clouds 2 and 3 were in the cumulus congestus stage when "seeding" operations began, ie., active towers reached 5 km in height, and the two clouds developed incipient anvils after 25 minutes of observation.

Cloud 2 RDR data in figure 2 shows that the cloud isoecho reached 8 or 9 km with growth rates of at least 300 meters/min. The width of these echos varied as in cloud 1. Cloud 2 was seeded at 2010Z and 2028Z. Neither the visual nor radar film showed any decrease in cloud activity after the first seeding. No visual effects became evident after the second seeding (when the radar record terminated).

Cloud 3 was not seeded, and the cloud film depicts an almost identical sequence of events to those that have been described for cloud 2.

On October 13, 1972, four target clouds were selected for randomized experimentation. The RDR plan plots for these four clouds are depicted in figures 3, 4 and 5. The towers of cloud 1 grew from heights of approximately 5 km to 8 km in about 12 minutes. The resurgence of cumulus towers seemed to occur about every 12 to 15 minutes during the 45 minutes the cloud was being observed. The cloud was not seeded during this period, and an examination of the visual film did not reveal any events of unusual significance.

Cloud 2 was seeded on traverses through the length of the cloud at 2008Z and again at 2018Z. The center portion of the cloud developed rapidly at an approximate rate of 400 m/min. This rate of growth seemed faster than that observed in cloud 1 on the 13 October. Within 12 minutes after the first seeding and 2 minutes after the second seeding, the radar isoecho tops had subsided from 8 km to 5 km. The radar isoecho had diminished in both width and length.

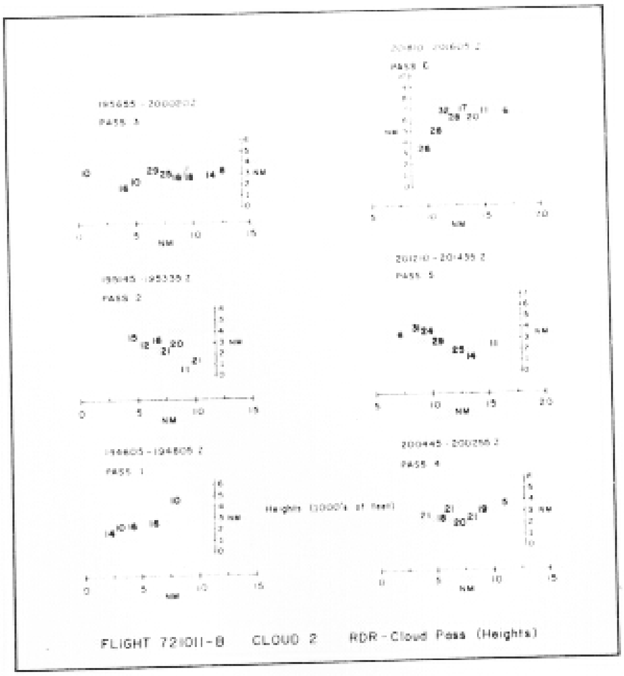

Figure 2. Same as figure 1 for cloud 2, October 11, 1972

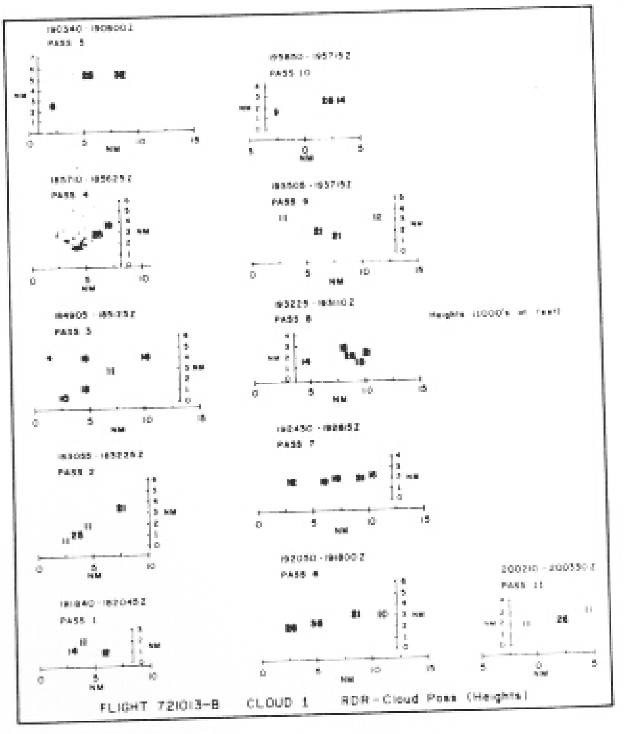

Figure 3. Same as figure 1 for cloud 1, October 13, 1972.

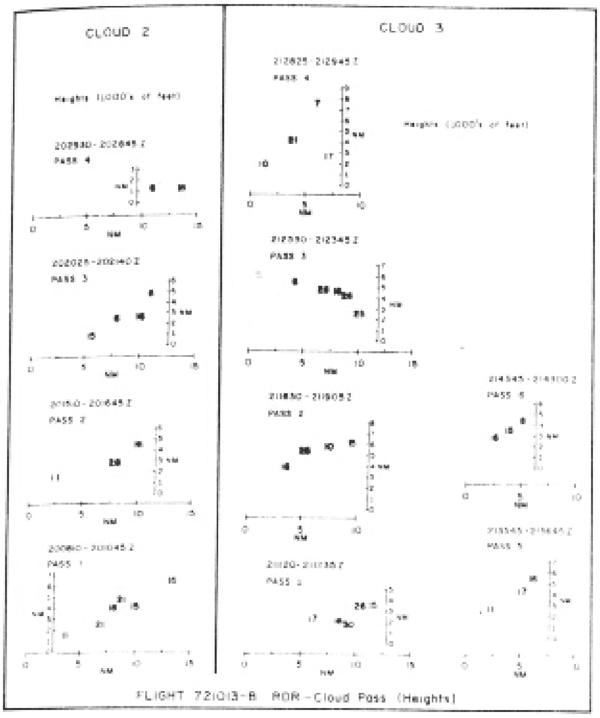

Figure 4. Same as figure 1 for clouds 2 and 3, October 13, 1972.

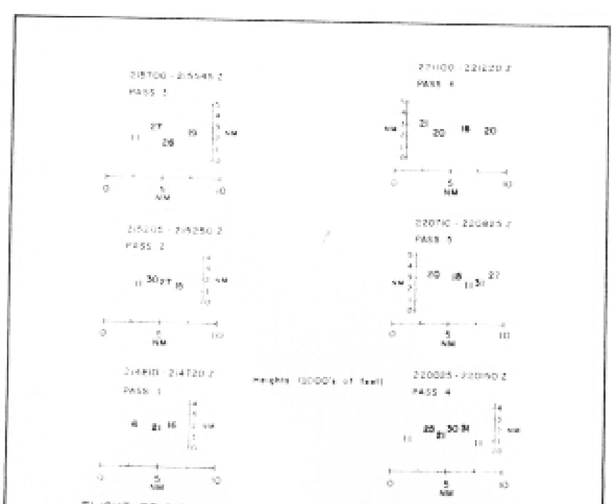

Figure 5. Same as figure 1 for cloud 4, October 13, 1972.

Cloud 3 was seeded at 2118Z and 2130Z and had a radar history very similar to cloud 2.

Cloud 4 was seeded at 2152Z. The seeded tower appeared on radar to be thicker and higher than those of clouds 1, 2 or 3. Within 16 minutes the seeded tower on cloud 4 had subsided from its maximum height by 30%, and the cloud did not resume any significant further growth. The decrease in intensity of the large single tower in cloud 4 after seeding was quite evident to the eye and was recorded on the side cameras.

7. CONCLUSIONS

The problem of measuring the effects of modification efforts remains much the same: namely, how does the sequence of events differ in the presence of modification agents from those in a natural sequence. From descriptions of earlier experiments it was considered possible that the course of events would be so drastically and manifestly changed that no subtlety would be required. In retrospect it is clear that in the shearing environment of these experiments over the tropical ocean nothing very startling became overpoweringly evident. Hence, it seems reasonable to conclude that this is not an infallible, overpowering technique that will quench cumulus activity in all situations - at least not when deployed on the scale and approach used in this experiment.

On the other hand there were suggestions in the data and definite impressions by some of the observers on board, that on some of the actual seeding runs visible effects were achieved. These were not adequately documented by the means at hand under the conditions that prevailed, and the impressions of participants are notoriously unreliable. The possibility remains, that under the proper conditions, this technique may prove to be quite effective. Adequately documented evidence of the efficacy of this technique should be made available.

8. RECOMMENDATIONS

The experiments should be repeated with tropical maritime cumulus under conditions where the vertical shear in the wind is quite weak and the production of swelling cumulus and cumulus congestus is more isolated. The equipment should include calibrated PPI and RHI radars, side cameras, flares for marking cloud entrances and, if possible, cloud physics instruments for measuring changes occurring in the cloud along with the necessary equipment for measuring vertical velocities.

REFERENCES

Gaivoronskii (Gayvoronskiy), I. I., Jr., A. Seregin, L. P. Zatsepina and B. I. Zimin, 1968: Modification experiments on thunderstorms. *Proceedings of the International Conference on Cloud Physics*, August 26-30, 1968, Toronto, Canada, 815-817.

Gayvoronskiy, I.I., L.P. Zatsepina and Y. A. Seregin, 1970: Results of modification experiments on convective clouds. *English Edition of Izvestira*, Academy of Sciences, USSR, Atmospheric and Ocean Physics, Vol. 6, No. 3, 141-144, UDC551.509.616.