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DIRECTORATE OF
SCIENCE & TECHNOLOGY

Scientific and Technical Intelligence Report

Communist Chinese Cloud Physics and Weather Modification Research

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OSI-STIR/69-3
February 1969

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Scientific and Technical Intelligence Report

COMMUNIST CHINESE CLOUD PHYSICS AND WEATHER MODIFICATION RESEARCH

Project Officers

[redacted] (b)(3)

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February 1969

CENTRAL INTELLIGENCE AGENCY

DIRECTORATE OF SCIENCE AND TECHNOLOGY

OFFICE OF SCIENTIFIC INTELLIGENCE

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PREFACE

Cloud physics and weather modification research is being conducted on an increasingly large scale in at least 15 countries in addition to the United States and the USSR. Some ultimate objectives are to improve man's ability to augment precipitation in areas of little or no rainfall, to dissipate fog and low clouds, to prevent or reduce hail formation, and to control or dissipate large storm systems such as hurricanes and typhoons. In addition, weather modification experimentation has potential military applications.

This report is an evaluation of Communist Chinese research in cloud physics and weather modification, with special emphasis on basic theoretical research and cloud seeding programs. The effects of the Cultural Revolution upon Chinese research in these fields are unknown, but their programs probably have been affected to some degree. Little information on basic research has been received since the cessation of publication of the major scientific journals in mid-1966.

The present report updates an earlier report on the same subject, (b)(3)
and supplements a recent general study on Chinese meteorology. It was prepared by the Office of Scientific Intelligence and coordinated with the Directorate of Intelligence. It is based mainly on a study conducted for OSI (b)(3)
Information received through October 1968 is included.

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COMMUNIST CHINESE CLOUD PHYSICS AND WEATHER MODIFICATION RESEARCH

PROBLEM

To evaluate Chinese research in cloud physics and weather modification.

CONCLUSIONS

1. The Chinese are substantially behind the leading nations, whose work they have followed closely, in cloud physics and weather modification research. Organization of these efforts on a national scale is not apparent and no orderly, long-range program appears to be in progress. The Chinese have demonstrated little improvement in their weather modification experiments since the late 1950s. They have decreased the number of field experiments and have reported few quantitative measurements.

2. From the early 1960s to mid-1966, the Chinese emphasized basic theoretical studies in cloud physics in an effort to explain cloud dynamics and precipitation processes. Although this research exhibits a wide range of quality, only a limited number of investigators and organizations appear to be capable of producing high-quality theoretical analyses. The Chinese are strongest in the mathematical and analytical aspects of cloud physics and weakest in data collection techniques. This emphasis on a theoretical approach may eventually lead to more significant results than their hapazard experimental work.

3. Few Chinese laboratory experiments in cloud physics have been noted. Of those reported, most were crude and the concepts and instrumentation used were quite similar to those of earlier foreign experiments.

4. Chinese cloud physics and weather modification instrumentation development is far below the quality and quantity of that of the leading nations. The majority of instruments are of low quality or are prototypes, a major handicap to the Chinese. Ground-sampling techniques predominate. There is little indication that aircraft sampling techniques are used.

SUMMARY

Communist China has been conducting weather modification experiments since at least 1958. The initial activity, which was prompted by a major drought, consisted of several cloud seeding experiments to produce rain. The early experiments, as well as those noted since the late 1950s, were crude, with little or no apparent scientific control. In addition, little basic research was evident in the early stages of this effort.

In the early 1960s fewer experiments were noted and more emphasis was placed on theoretical research. Chinese literature at this time consisted mainly of reviews of the work being performed by foreign countries. Typical work of this period was a series of monographs published in 1965 which presented the state-of-the-art and results of Chinese studies. These were also intended to serve meteorological workers and educators as reference

texts and several were concerned with such aspects of physical meteorology as cloud structure, ice nuclei, and cloud and rain droplet size spectra. Papers were authored by relatively high-level meteorologists, such as Chao Chi-p'ing of the Institute of Geophysics and Meteorology, who reported in 1963 on the progress of research on cloud current dynamics.

Chinese scientific literature up to mid-1966 is characterized by a steady increase in papers on cloud physics research while the number of articles on experimentation has decreased. Most of the Chinese cloud physics research, conducted at the Institute of Geophysics and Meteorology by several of their leading meteorologists such as Ku Chen-ch'ao, has been published in *Acta Meteorologica Sinica*. The published papers show that the Chinese have improved somewhat their theoretical cloud physics research, but most of their work consists of repetitions or extensions of previous foreign experiments and has produced nothing outstanding. While their mathematical and analytical work is strong, particularly in stochastic treatment of warm cloud processes, the Chinese have not developed or made good use of radars, computers, aircraft samplers, and other instrumentation. However, some unsophisticated cloud physics instruments which are adequate for measurements not requiring high precision have been developed. The improvement in Chinese theoretical research in cloud physics will probably continue and may lead to more significant achievements in weather modification than the unorganized experimental approach of the early years.

There is no evidence of a well coordinated large-scale program in either weather modification or observation systems capable of greatly improving their understanding of the physical processes of clouds. Observational and other hardware limitations severely limit Chinese abilities to conduct effective field programs. More recent weather modification attempts also have shown the lack of scientific control that was evident in early experiments. Most of the experiments were conducted on a local scale by commune members, usually with the assistance of aircraft of the People's Liberation Army. In all cases noted, these activities were in support of local agricultural programs by attempting artificially to produce rain or disperse hail clouds. These experiments reportedly produced good results but their verification techniques have been questionable. Their true success, therefore, is doubtful. This is especially true in their use of "sky-high fireworks" to combat hail.

There is a possibility of a chance discovery due to their freedom to seed or otherwise modify clouds at will. They appear to be unaffected by the various political, sociological, and legal restrictions that often exist in other countries.

DISCUSSION

BACKGROUND

Weather modification studies in Communist China began in the late 1950s with a number of crude attempts to modify cloud and precipitation processes, mainly for the purpose of increasing precipitation in agricultural areas. Although these attempts were widespread, no quantitative measurements were reported and few attempts at controlling the experiments or of measuring their results were noted. Experimentation began because of a severe drought in northeast China. The Twelve Year Plan for Meteorology (formulated in 1956) included cloud physics research and weather modification. These programs were later affected by the Great Leap Forward, the Soviet withdrawal, and probably the Cultural Revolution.[1]

Through the early 1960s modification attempts diminished and more emphasis was placed on theoretical studies to examine and explain the basic cloud dynamics and precipitation processes. Relatively high-level personnel, such as Ku Chen-ch'ao (7457/7261/3390) and Chao Chi-p'ing (1560/4764/1627) were reported to be leading such atmospheric physics studies, illustrating their importance to the Chinese.[2,3] A selected list of organizations and key personnel is included as an appendix.

Work in the early 1960s centered around the collection of papers relating to Chinese cloud phys-

ics studies which resulted in a series of monographs published in 1965.[4 5] These monographs presented the results of selected Chinese studies and were intended to serve as a reference text for meteorologists and educators. While the overall quality of these papers was not high, their significance was in their value as a single-source reference for an introduction to some of the problems in cloud physics under investigation.

BASIC THEORETICAL RESEARCH

The main Chinese effort in cloud physics, subsequent to the diminished widespread modification experiments of the late 1950s, has been in basic theoretical research. Published Chinese literature on cloud physics research increased after 1959 while the number of articles on weather modification experiments declined. They rapidly increased their theoretical cloud physics research and this trend may have continued. Although no outstanding achievements have thus far resulted, their studies follow closely those of the USSR and the West, and their theoretical approach may lead to more significant achievements in weather modification than the earlier, more haphazard, field experiments. Their mathematical and analytical work is strong, particularly in stochastic treatment of warm cloud processes.[6] Three of a total of six cloud physics articles published in *Acta Meteorologica Sinica* in 1966 may be classified as theoretical or basic research. This proportion is roughly indicative of their interests and activity during 1963-1965 and is also typical of a series of monographs published in 1965.

One of these articles is related to the coalescence processes occurring in a large scale vertical motion field.[7] The second article is a mathematical treatment of the earth's electrical field potential and makes computations of the distribution of electrical potential in a vertical cross section of a thunderstorm and at the earth's surface in the vicinity of a thunderstorm.[8] The results are claimed to be better than those of Wilson (England) or of Frenkel (USSR) whose previous work is referenced. This claim, however, is not supported by the paper.

The last of the three articles is the latest in a long series of theoretical papers concerning the growth of cloud drops under conditions of small scale fluctuations. This subject and the Chinese emphasis upon warm cumulus cloud growth caused by "fluctuations" were first introduced in a paper by Ku Chen-ch'ao published in 1962. This paper was the first article relating to cloud physics to be published in *Acta Meteorologica Sinica*. Ku published four additional articles relating to this effect in *Acta Meteorologica Sinica* in 1962 and 1963. In his 1963 article he suggested that the concept of gravitational coalescence, which takes into account eddy fluctuations in the vertical currents, represented a more reasonable explanation of rain in warm clouds than other theories do.[9] Similar ideas had been suggested as early as 1947 in the literature of other nations to explain precipitation from nonfreezing clouds. The Chinese press, however, promoted this idea as a "new precipitation theory advanced by China's 'Young Weather Workers'." [10 11] Other Chinese meteorologists adopted Ku's concept of the effects of fluctuating environments of moisture and turbulence, resulting in the appearance of more articles on this topic than any other between 1964-1966. Ku's influence is clearly evident in Chinese investigations and published articles in the cloud physics area. While this would be expected owing to his position as head of the Atmospherics Physics Laboratory of the Institute of Geophysics and Meteorology, the extent of this follow-the-leader attitude is striking and may indicate a reluctance of other Chinese meteorologists to strike out on their own.

The latest example of the continuing Chinese interest in warm cloud precipitation theory is a mathematical treatment of the probability of continuous growth of cloud drops published in June 1966.[12] The authors' conclusions were that, while vertical motion fluctuations were dominant in condensation processes to about the 20 micron size, fluctuations in moisture content plays the principal role in stochastic growth of droplets beyond 20 microns by continuous coalescence. Ku Chen-ch'ao's guidance and encouragement are acknowledged.[12] The complexity of the mathematical treatment of the problem is more impressive than the conclusions which are simply more refined explanations of Ku's earlier conclusions.

An earlier article deserves mention because of its further indication that the Chinese have at least a few scientists working in the Institute of Geophysics under Ku who are capable of performing high-level theoretical research. This article, published in

1964, is excellent and concerns the development of a three-dimensional model for cumulus cloud growth.[13] It is noteworthy that calculations for the model were reportedly carried out on an unidentified computer. Computers available to Chinese meteorologists prior to this time appear to have been almost exclusively reserved for numerical weather prediction work. Although published Chinese work indicates a wide range of scientific quality, only a limited number of personnel and organizations appear capable of producing high-quality theoretical analyses.

LABORATORY EXPERIMENTS

Few Chinese laboratory experiments in cloud physics have been reported. Perhaps the most notable work reported recently (1966) was conducted at the Lan-chou Institute of Geophysics on the investigation of the growth of frost needles on the surface of frozen water drops in an electric field.[14] The instrument setup was relatively simple and utilized easily accessible items. The experiment was well conceived but the author admitted that it was an extension of a Soviet experiment conducted in 1962. The Soviet experiment showed that the growth of frost needles by deposition of supercooled fog droplets in the presence of an electric field is accompanied by electrification of the droplets, but quantitative measurements were not made.[15] The Chinese measurements of this electrification resulted in values an order of magnitude higher than those of British investigators published in 1963. The Chinese investigators suggest their results may offer a clue to a better understanding of the electrification mechanism in thunderstorms. The work would have been more significant if the concept and the instrumentation were original rather than similar to those used in previous foreign experiments.

A second article on laboratory experimentation published in 1966 was a report on chloride particle detection studies by Yeh Chia-tung (0673/1367/2639) of the Department of Meteorology, Nanking University.[16] Yeh discussed microscopic investigations of the reaction halo enlargement of chloride particles collected on gelatin films. These investigations resulted in an empirical relationship between the enlargement factor and the diameter of the chloride particle. Results of this experiment apparently were intended to correct size distributions of chloride particles collected via the film processes. The chloride particles were probably selected for study because of the use of salt or salt water in several Chinese cloud-seeding experiments and because of their importance as naturally occurring condensation nuclei.

INSTRUMENTATION DEVELOPMENT

Chinese cloud physics instrumentation is considerably inferior in quality and quantity to that of the United States, the USSR, and several other countries. The Chinese can make some relatively simple measurements, but their lack of sufficient quantities of sophisticated instruments is a major handicap in improving their knowledge of cloud physics processes and weather modification work. Minimal use has been made of radars, computers, airborne instrumentation or of other observation systems which could greatly improve their understanding.[6]

None of the articles in the last issues of *Acta Meteorologica Sinica* (first two volumes of 1966) pertain to cloud physics or weather modification instrumentation development. During 1965, however, four articles were noted, three of which described actual Chinese developments. In the other, Ku Chen-ch'ao discussed the problems associated with determining the location of "thunder-lightning" utilizing a single-station detector, but offered no solution to these problems.[17] No implication of actual instrument design or development activities in this general area can be inferred, but a review by Ku indicates the kind of high-level interest which sometimes precedes Chinese development.

One of the 1965 articles included a discussion on an improvement in the Chinese cloud-droplet sampler for utilization at ground level that extends the sampling period from 2 seconds to 2 minutes and has an adjustable exposure. In addition, the drums containing the sampling tapes are motor-driven rather than hand-driven. A prototype of this still rather crude instrument was built for field data collection in 1964.[18] This is typical of Chinese attempts to improve crude instruments. Admitted shortcomings of operational inconvenience, lack of a dehumidifying mechanism, and bulkiness probably have prevented its quantity production. The emphasis on ground observation equipment for cloud sampling in this and other articles probably indi-

cates only limited use of aircraft for sampling programs.

Another paper was concerned with the development of a special radiosonde for probing electric fields in thunderclouds.[19] The advantages over aircraft soundings, however, seem hardly worthwhile unless such measurements are to be made on a routine, high-density basis, and this again may illustrate aircraft restrictions for atmospheric research. In any event, only five soundings were reported, and this development as recently as 1965 appeared to be of a prototype nature.

The third cloud physics instrumentation development reported in 1965 is that of an atmospheric ice nuclei counter consisting of a cloud chamber. The chamber was reported to perform satisfactorily and to be under experimental production at the Shanghai Refrigerator Plant;[20] however, none of the field investigations described in Chinese articles are reported to have utilized this instrument.

An earlier (1964) development of a laboratory instrument for determining the electric charge of cloud droplets relied on the deposition of charged cloud droplets on a sampling plate and a subsequent determination of their deflection in an electric field.[21] The instrument was tested using a spray of water in a laboratory and is not suitable for field use. No subsequent mention of the instrument has been found.

A summary of known Chinese sampling techniques for determining size and/or concentration of precipitation elements and atmospheric nuclei appears in table 1.

FIELD ACTIVITIES

Weather modification

Weather modification in China began in the late 1950s with a number of crude attempts to modify clouds and precipitation. Through the early 1960s, modification attempts decreased and theoretical studies were given more attention. While some modification attempts have continued, they are usually isolated activities connected with agricultural activities. There is no evidence of any large-scale well-controlled field program. Although a large number of Chinese who are familiar with Western and Soviet modification techniques have been involved in the work, they have a limited ability to operate effective field programs.[6]

Table 1

A Summary of Chinese Sampling Techniques

Technique	Element Measured	Where Measured	Reference
Spot (Halo)	Chloride particles	Probably ground	AMS,* 36(2), 1966
Filter paper	Raindrops	Ground	CPIG,** 10, 1965
Blotting paper	Raindrops	Ground	CPIG, 10, 1965
Sugar solution	Atmospheric nuclei	Ground	AMS, 35(4), 1965
Aluminum foil	Ice and snow crystals	Aircraft	AMS, 35(4), 1965
Aluminum foil	Ice and snow crystals	Aircraft	AMS, 35(3), 1965
Aluminum oxide or soot film on movie film	Ice nuclei	Ground	AMS, 35(2), 1965
Photographic paper	Small raindrops	Probably ground	AMS, 33(4), 1965

* Acta Meteorologica Sinica

** Collected Papers of the Institute of Geophysics and Meteorology

The earliest attempts at producing rain from clouds were prompted by extreme periods of drought and took place mainly in Kirin and Kansu Provinces. Routine methods were employed in which various materials such as carbon dioxide, salt, quicklime water, salt solution, silver iodide, and sodium iodide were used as seeding materials. Military aircraft and ground-based and balloon-borne generators were utilized to dispense the materials. Positive results were reported but no scientific control of the experiments was indicated.[1 22]

Infrequent reports were noted during the 1960-1964 period. These included reviews of foreign weather modification attempts with different techniques and materials and contained several references to Chinese experiments in cloud seeding to produce rain. One activity in the Shanghai area in 1964 reportedly produced heavy rains.[23–26] The seeding of summer cumulus clouds in Hunan Province reportedly took place in 1963. A total of 62 attempts were made in which powdered salt was injected into thick cumulus clouds. Of these tests, 11 resulted in precipitation in the thick cumulus state, 25 in the incus (anvil shaped), six in only virga (evaporating rain), and six in cloud dispersal. Three tests showed no effects and the results in the rest could not be observed. These results, compared with earlier Chinese data, were claimed to be in agreement with US data.[27] The Nationalist Chinese reported in 1964 that rainmaking experiments had taken place over Hainan Island and several other areas but no details were given.[28]

The most recent reports of field weather modification were noted in widely separated publications. One, a New China News Agency article of September 1967, indicated that "man-made rain" had recently fallen on farming districts around Shanghai. The seeding was reported to have been accomplished by People's Liberation Army (PLA) aircraft in response to a threat to crops due to a dry spell.[29] No mention of seeding material, techniques, or numerical results was made, and it is important to note that the crew "worked around the clock to equip the plane with artificial precipitation devices." This indicates that planes equipped with such devices were not available on a standby, or operational, basis, but the implication of operational utilization of cloud seeding to produce precipitation is inherent.

On 28 December 1967 the Peking New China News Agency also reported on artificial seeding of rain clouds in Chekiang Province. Wen-chou, Li-shui and other areas in the hilly region of southern Chekiang suffered a 150-day drought and artificial seeding operations were carried out in the areas by the PLA Air Force for more than 20 days. Although no results of the experiment were reported, the report implied that a bumper harvest, achieved despite the worst drought in 100 years, was at least partially due to the cloud seeding activity.[30]

The next mention of cloud modification attempts was included in recent press accounts of a new Chinese hero, Men Ho. Men was publicized throughout China as a true supporter of Mao and a "brilliant example for all revolutionary cadres in the party, the country, and the Army to follow." Men was a deputy political instructor of an Army unit in Tsinghai Province. He reportedly lost his life while assisting in the preparation of explosives for rockets to be used for dispersing clouds to prevent the formation of crop-destroying hail. No other details of this experiment were reported except that native rockets were being readied for launch.[31–33]

Two earlier news releases from the Chengchow Domestic Service, 18 November 1966, reported on two rainmaking experiments in Honan.[34] These so-called experiments also appear to have an operational overtone since they were conducted to relieve drought in specific areas, in October and November of 1966, and since none of the detailed measurements normally associated with scientific experiment were mentioned. These operations, plus those previously mentioned, indicate that the Chinese experiments are mainly carried out in areas that are undergoing drought conditions. This attitude is in contrast to that of the US practice wherein broad experimentation is underway but with a slower, more scientific approach to operational utilization. It should be noted, however, that private concerns in the United States are operationally active in rainmaking activities on a much larger scale than the total of the reported Chinese activities. A listing of selected Chinese cloud seeding experiments is included in table 2.

A field operation similar to that in which Men Ho was involved was reported in a news release of 1966, and while apparently occurring in the summer of 1965, it is probably representative of 83 hail-

Table 2

Listing of Selected Field Cloud Seeding Experiments

WHERE-WHEN	REPORTED BY	WHERE REPORTED	REMARKS
Nanking area, Nov 58	Anhwei Province Artificial Precipitation Working Group	AMS,* 30 (1), Feb 59	Dry-ice at 5,600 meters to form clouds
Various areas in China, 58	Central Meteorological Observatory, Meteorological Bureau	AMS, 30 (3), Aug 59	Summary report
Peking area, 58	Hopeh Province	AMS, 30 (1), Feb 59	Dry-ice and salt solution (dispersal study)
Lesser We-tai Mountain, 58	Hopeh Provincial Weather Bureau	AMS, 30 (1), Feb 59	Silver iodide (fog dispersal)
Kansu Province	Kansu Provincial Artificial Precipitation Working Group	AMS, 30 (1), Feb 59	Artificial precipitation and cloud dispersal
Kirin Province, Aug-Sep 58	Kirin Province Artificial Precipitation Working Group	AMS, 30 (1), Feb 59	20 Aerial, dry-ice seedings to produce precipitation
Wu-han region 58	Wu-han	AMS, 30 (1), Feb 59	Salt solution dry-ice to produce precipitation
Hunan Province, Summer 63	Investigators of Central Meteorological Bureau and Hunan Provincial Weather Bureau	AMS, 35 (3), Aug 65	Salt-powder seeding of cumulus
Near Shanghai, Winter 63-64	Yeh Chia-tung	Science Pictorial, No 3, Mar 64	Seeding to produce artificial snow
Hainan Island, 64	Nationalist Chinese	Classified report	No details
Shanghai, 64(?)	Liu Tzu-chi	Aeronautical Knowledge, No 12, Dec 64	By PLA Air Force, resulted in heavy rain
Shang-chin and other cities, Honan Province	Chengchow Domestic (News) Service	FBIS, 22 Nov 66	By PLA Air Force, to produce rain in drought area
Chi County, Honan Province, 12 Nov 66	Chengchow Domestic (News) Service	FBIS, 22 Nov 66	By PLA Air Force, to produce rain in drought areas
Near Shanghai, Sep 67	NCNA, Peking	FBIS, 8 Sep 67	By PLA Air Force to produce rain in drought area
Southern Chekiang Province, 67	NCNA, Peking	FBIS, Dec 67	By PLA Air Force for more than 20 days to produce rain in drought area

* Acta Meteorologica Sinica

dispersal operations conducted from 1960 to 1965 in Mien-ning County, Szechwan Province. The use of locally-made rockets (actually fireworks) was noted to have been ineffective prior to 1959. Improved multistage "sky-high fireworks" capable of achieving heights of 2,000 meters (6,500 feet) before explosion have been in use since then. These improved rockets were reported to have dispersed hailclouds without hail formation in 78 of 83 attempts. A firing network was organized to launch a thousand rockets whenever a hailstorm was reported to be imminent.[35] Based on similar Western and Soviet work, such experiments have little effect on a hail-producing cloud. A similar, possibly related report appeared in a Hong Kong publication in 1966. The author discussed rockets used to combat hail in Wan-ning County, Szechwan Province. These were single and two-stage rockets weighing a little over an ounce and slightly over a pound respectively. The propellant chamber was made of strawboard and the launching pad of wood. The rocket reportedly produced a strong pulse wave upon exploding at altitudes of 1 to 2 km (see figure 1).[36] No mention of similar activities in other areas has been reported. Evaluation of the claims for this form of hail suppression is difficult to make, but the reported results are exceedingly doubtful since the rockets could not reach the freezing levels. The Chinese claimed, however, that dispersal was caused by the sound waves resulting from the explosions.

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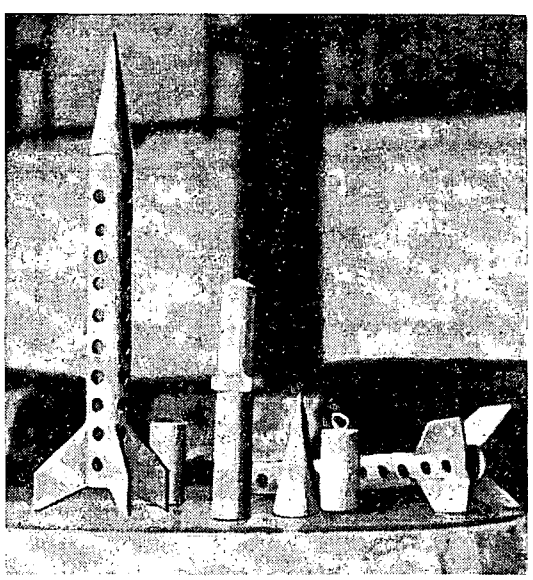

Figure 1. Hail prevention rockets used in China for hail-cloud control.

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The firing of so-called "National Guns" for modifying hail clouds also has been reported and evidently has been in use for some time. These guns consisted of iron tubes which were filled with black powder and packed with felt wadding. They were mounted on wooden supports, aimed in the direction of a cloud, and fired. The Chinese attributed control of a cloud by this means to the sound waves produced by the explosion (see figure 2).[36]

Other countries, such as the USSR, Italy, and other European countries, have tried explosive suppression, and some success has been claimed. The Soviet attempts, which utilize artillery firings of ice-producing nuclei into specified portions of a potential hailcloud, are reasonably well documented with data. In comparison, the Chinese techniques are crude, and their claims appear to be exaggerated. Furthermore, reported Chinese efforts in hail prevention are minor in comparison with those of the USSR.[36]

Other Chinese attempts at hail prevention more scientific in nature include the aircraft dispersal of silver iodide, pilot-balloon-lofted cartridges containing silver iodide, and jet aircraft burning silver and acetone. In the latter, the silver iodide and acetone are mixed in an airborne generator and the mixture fed into the aircraft's nozzle where it is sublimated (see figures 3 and 4).[36] It is not possible to evaluate the significance of this technique because of insufficient information.

No other recent Chinese field experiments have been noted. The final volume of *Acta Meteorologica Sinica* was largely devoted to cloud physics articles, and no mention was made of either an experimental or operational weather modification study or project. The last published seeding experiments which reported cloud measurements occurred during the winter of 1963-1964 near Shanghai. The objective of that experiment was to produce snow from stratiform clouds and it was reported to be successful on a small scale.[37]

The almost compete lack of scientific articles subsequent to the summer of 1966 makes a current evaluation of Chinese field operations and experi-

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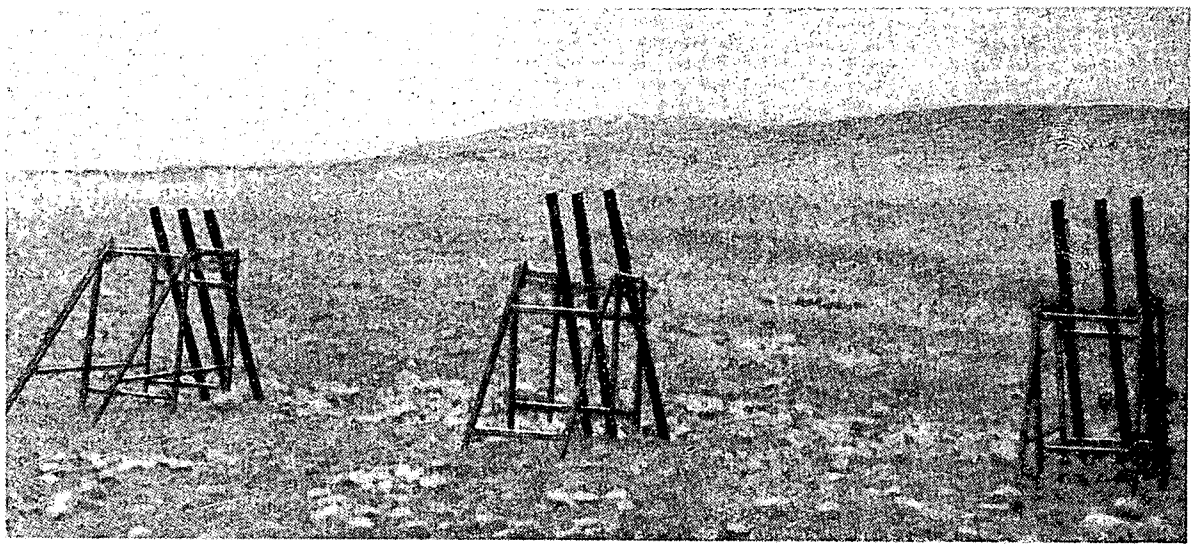

Figure 2. Chinese "National Guns" utilized in the modification of hail clouds.

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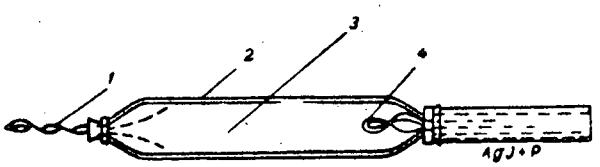

1. Ignition fuse
2. Case
3. Incendiary mixture
4. Cartridge primer

Figure 3. Cartridge with silver iodide and red phosphorus, delivered to the cloud by pilot balloon.

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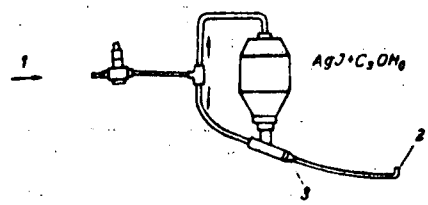

1. Compressed air
2. Jet plane nozzle
3. Atomization chamber

Figure 4. Generator for sublimating a mixture of silver iodide with acetone in the nozzle of a jet plane.

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ments difficult. It appears unlikely that the recently reported attempts to operationally increase rainfall in local areas are the only experiments conducted during the past few years. Despite the continuance of this type of activity, it is doubtful that the Chinese have made much improvement in their relatively low standing in field activities as compared with other nations. However, due to their ability to test without regard to the political, legal, and sociological constraints imposed in other countries, such as the United States, the possibility of a chance breakthrough does exist. Until their experimentation measurements are improved, it appears that only a major change in cloud and/or precipitation patterns resulting from their experiments would be detected by the Chinese.

No recent reports have been noted which would reflect Chinese work on the dispersal of clouds and fog. Some tests were indicated, however, by reports presented at the 1962 annual meeting of the Chinese Meteorological Society. Although no progress in this area is known, the Chinese would have little difficulty applying well-known techniques to supercooled clouds and fogs with

results similar to those achieved by other countries.[28]

Data Collection

The Chinese have concentrated their efforts in cloud physics data collection in the field on cloud and precipitation droplet size measurements, nuclei measurements, thunderstorm electrical fields data, and, to a very limited degree, radar analyses of hailstorms. Some cloud temperature and turbulence data have also been collected in conjunction with the above measurements.

Overall, the number of field data collection activities reported in the Chinese literature is small, and these data collections generally lack the scope and complexity typical of the programs in other countries. The lack of, or failure to assign, aircraft, sophisticated measurement devices, and computers for use in these activities to any significant degree is obvious in their efforts. This deficiency prevents the Chinese from being able to adequately verify their more extensive theoretical models or to properly evaluate their weather modification efforts. While this might be taken to indicate a low priority for the activities, it is more probably due to the lack of necessary equipment.

One reasonably complete field collection of cloud data utilizing aircraft occurred in the Kirin area of northeast China in the late spring and early summer of 1963. Fifteen flights were conducted to observe ice and snow crystals in precipitating cold stratus using an aluminum foil sampling device. The aircraft could not reach altitudes with temperatures lower than —15°C.[38] For the latitude of Kirin, 45°N, this temperature would result in an altitude limitation of approximately 15,000 feet during the late spring and early summer. Whether this limitation was due to aircraft ceiling, personnel limitation (lack of oxygen devices), or other causes is not known, but earlier seeding flights have mentioned the lack of oxygen supply for personnel.

Two other examples of field data collection reported in 1966 consisted of ground observations of electric field variations near thunderstorm clouds and analyses of radar echoes from hailstorms.[39] [40] The electric field observations were taken in the summer of 1963 in Kansu Province, and the radar echo analyses and associated surface observations were for ten hailstorms near Peking in 1964. Studies of radar echoes from thunderstorms in the Tai-shan area in the summer of 1962 were published in 1965.[41] Additional collections during this time period involved ground observations of nuclei[42] [43] and cloud-fog droplets or crystals.[44] Neither the instrumentation used nor the reported results would contribute significantly to a better understanding of cloud or precipitation processes. The majority of the Chinese data collection operations have been small in scope and duration, and very minor when compared to similar activities in the advanced nations.

APPENDIX

Selected list of organizations and key personnel publishing papers on cloud physics and weather modification between 1958 and 1966.[2-5 41]

Institute of Geophysics and Meteorology, Academy of Sciences, Peking

Ch'an Li-shan (6124/7787/3790)
Chang Kuang-kun (?)
Chao Chi-ping (1560/4764/1627)
Chao Yen-ts'eng (6392/3601/2582)
Ch'en Jui-jung (7115/3843/2837)
Chen Shui-yung (?)
Ch'en Wan-kuei (?)
Ch'en Yen-chuan (7115/3508/3197)
Cheng Ta-chou (6774/6671/1558)
Chiang Pen-t'ang (?)
Chou Hsiao-ping (0719/2556/1627)
Chou Hsiu-chi (0719/4423/7535)
Chou Shih-chien (0719/6108/1696)
Chu Chen-hua* (?)
Ho Chen-chen (0149/3791/3791)
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