CONFERENCE PROCEEDINGS

ABSTRACTS AND BIOGRAPHICAL SKETCHES

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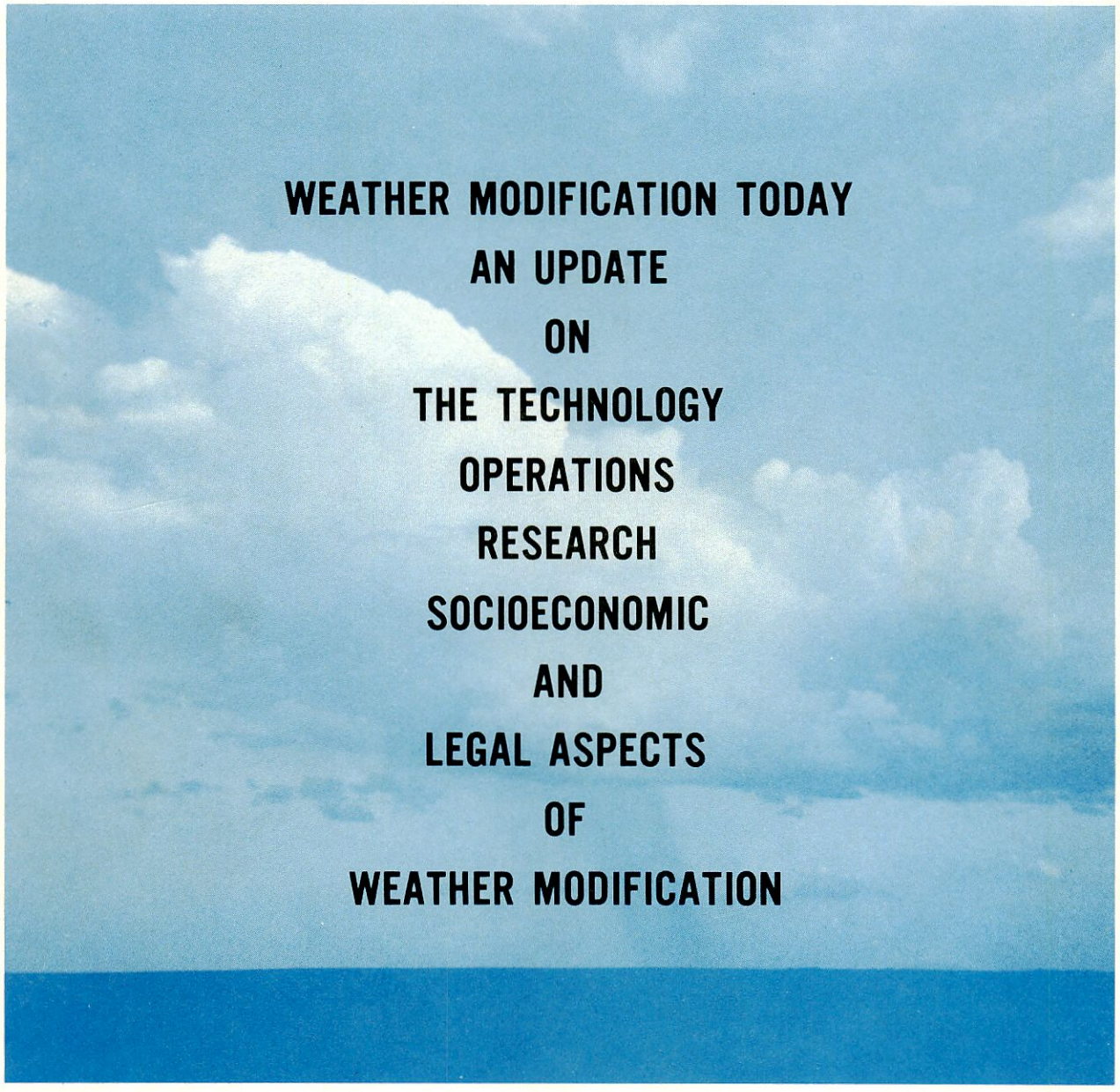

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AUSTIN, TEXAS
NOVEMBER 8, 1977

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CONFERENCE PROCEEDINGS

ABSTRACTS & BIOGRAPHICAL SKETCHES

FOR

WEATHER MODIFICATION TODAY

AN UPDATE

ON

THE TECHNOLOGY

OPERATIONS

RESEARCH

SOCIOECONOMIC

&

LEGAL ASPECTS

OF

WEATHER MODIFICATION

November 8, 1977

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Austin Hilton Inn
IH-35 & HWY 290
Austin, Texas

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November 8, 1977

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PROCEEDINGS OF THE

WEATHER MODIFICATION TODAY CONFERENCE

Foreword

The "Weather Modification Today" conference held in Austin, Texas on November 8, 1977 was designed to provide the latest information on the state of the art of weather modification with emphasis on the operational, research, socioeconomic, and legal aspects of the technology. In addition, the conference was structured to give project directors of all weather modification programs in Texas an opportunity to describe their respective programs. It covered a wide range of subject matter related to various types of weather modification activities including a comprehensive and cooperative research endeavor, known as the High Plains Cooperative Program (HIPLEX), and several commercial cloud-seeding programs to enhance rainfall and suppress hailfall. Speakers represented governmental entities, universities, research firms, water organizations, and farmers and ranchers. Since the conference was expected to consist of an essentially heterogeneous population, a format of many brief presentations rather than a few, more detailed presentations was used. This was done to expose the participants to the various expert speakers and give them a cursory introduction to the speakers' particular expertise. These proceedings consist of abstracts for each presentation, a brief biographical sketch of each speaker, and sources for further information for most subjects addressed at the conference. Publishing the proceedings prior to the conference served to provide the conference participants with valuable information necessary to assess the speakers' subject matter prior to the presentation.

Weather Modification Today

An Update

November 8, 1977

I. Commencement

Carl Riehn

Neville Clarke

A.L. Black

Carl W. Riehn

Executive Director, North Texas Municipal Water District

President, Texas Water Conservation Association

Mr. Riehn has worked in a governmental administrative capacity since completing his education; as an Administrative Intern for the City of Garland, Assistant City Manager in Arlington, Texas, City Manager of Sulphur Springs, Texas, for six years, City Manager of Mesquite, Texas, for three years and Executive Director of the North Texas Municipal Water District since 1969.

He was born in Dallas; grew up in Fort Worth and graduated from Polytechnic High School in 1951. After two years service with the United States Navy Reserve he went back to school and received a Bachelor of Business Administration Degree in Public Administration from Texas Technological University and then received a Graduate Fellowship in Governmental Administration at Southern Methodist University for one year. He has been active in many professional associations; International City Managers Association, Texas City Managers Association, Texas Municipal League, has served as President of the East Texas City Managers Association, and President of the North Texas Chapter of the American Society for Public Administration. Currently he is a Member of the Board of Directors and President of the Texas Water Conservation Association.

Neville P. Clarke

Texas Agricultural Experiment Station
College Station, Texas

Dr. Neville P. Clarke was appointed Acting Director of the Texas Agricultural Experiment Station by the Board of Regents, The Texas A&M University System on August 1, 1977. The Experiment Station is the state's agricultural research agency involved with work at the main campus of Texas A&M University and at outlying research centers and stations across Texas.

Dr. Clarke is Associate Dean for Research and Professor of Physiology at the College of Veterinary Medicine, Texas A&M University, a position he has held since retirement from the Air Force in August of 1975. In December, 1976, Dr. Clarke was given an additional appointment as Assistant Director, Texas Agricultural Experiment Station with responsibility of managing all animal health research activities of this organization including work conducted at the outlying research and extension centers across the State of Texas. Dr. Clarke plans and advocates a broad based program of research in animal health and integrates the research activities of seven academic departments and two research institutes within the College of Veterinary Medicine. The scope of research includes health of food and companion animals, foreign animal disease studies, conducted both at the University and overseas, and a program in comparative animal medicine carried out jointly between the College of Veterinary Medicine and the Baylor College of Medicine at the Texas Medical Center in Houston.

Since retirement from the Air Force, Dr. Clarke has been consultant to the Air Force Surgeon General on Biotechnology Research and Development and has continued to be a member of the Aerospace Medical Panel of the Advisory Group for Aerospace Research and Development of NATO, an appointment held prior

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A.L. Black

Chairman, Texas Water Development Board
Texas Department of Water Resources

Mr. Black, of Friona, a farmer and agribusiness leader on the Texas High Plains, was appointed to the Texas Water Development Board by Governor Dolph Briscoe in March, 1974, as the Board's farmer/rancher member. He was named Chairman of the Board by Governor Briscoe on January 16, 1976. Mr. Black's business interests include banking, farming, and cattle feeding. He is Chairman of the Board of the Friona State Bank and vice president of Friona Industries. A leader in the conservation of the soil and water resources of Texas and the nation, Mr. Black has served as director and president of the State Soil and Water Conservation District Association and as a director of the National Association of Soil and Water Conservation Association Districts.

Weather Modification Today

An Update

November 8, 1977

II. Morning Session

Pierre St. Amand

John Carr

Lloyd Stuebinger

T.B. Smith

J. Sonnenfeld

Ronald Lacewell

Merlin Williams

ABSTRACT

WEATHER MODIFICATION TODAY-- A CHALLENGE IN SOCIAL SCIENCE

"Hic ego barbarus sum, quid non intelligor illis"

Pierre St.-Amand
Naval Weapons Center

Now that some of the technical problems involved with the production of rain and the alleviation of hail have been identified, it appears that they will be solved in due course and that a technology of emmense benefit to the human race will evolve. The question is, what must we do in order to make it possible to use the technology?

The lack of understanding of the technical base upon which society depends, by a large portion of the population, presents a formidable obstacle to equipping and to furthering that same technology base. This, coupled with the infiltration into the democratic system of government of special interest groups who do not hesitate to take large risks with the population as a whole in order to secure small gains for themselves and their constituents make it difficult to carry out well-thought-out programs of technological innovation or even to do what is necessary to provide ordinary services in a routine manner.

Legal problems, so long as the law is observed and impartially carried out are not severe, although they do, at times, present a burden. The unenlightened involvement of special interest groups operating outside the proper legal framework that make it imperative that people in the weather modification business learn how to cope with this situation in order to be able to do what they must in order to provide water, and to protect crops.

(continued page 45)

BIOGRAPHICAL SKETCH

Pierre St.-Amand

Naval Weapons Center
China Lake, California
(714) 939-3195

Born in Tacoma, Washington, 4 February 1920. Moved to Alaska at age 10 months with parents, lived in Eskimo fishcamp on lower Yukon River for six years and then in the Fairbanks area where I attended the University of Alaska. Worked at prospecting, mining, and as aircraft mechanic, surveyor and radio operator. Served in the U.S. Army Airways Communications System during World War II. Worked at the University of Alaska in the Geophysical Institute and on seismologic, magnetic and ionospheric research. Obtained MS and PhD in Geophysics and Geology from California Institute of Technology. Fulbright Scholar to France in 1954-1955. Employed at Naval Ordinance Test Station, China Lake, California, as Physicist until 1958 when left to go to Chile with the International Cooperation Administration. Taught Geology, Geophysics and related subjects at University of Chile. Served as advisor to Chilean Geological Survey. Investigated Chilean earthquakes of 1960. In 1961, returned to U.S. Naval Ordnance Test Station where I became Head of the Earth and Planetary Sciences Division. The division works in all branches of geology, geophysics and notably in weather modification. Consultant to various state and foreign governments and to commercial interests in geology, seismology, weather modification and related material. Consultant to Organization of American States.

ABSTRACT

TEXAS PROGRAMS & THEIR OBJECTIVES

John T. Carr, Jr.
Texas Department of Water Resources

Since passage of the Weather Modification Act by the Texas Legislature in 1967, a number of weather modification research and operational projects have been carried out either wholly within Texas or partially within both Texas and Oklahoma and New Mexico. The research projects have been funded principally by the State of Texas and the U.S. Department of the Interior, Bureau of Reclamation, while the operational projects have been carried out principally by cloud-seeding firms using private funds. Typically with operational projects in Texas, an association of interested participants is formed and a contract is awarded to a weather modification firm. Two of the longest-running projects in Texas, however, have been carried out in-house with the sponsor's own airplanes, radar equipment, and professional meteorologists.

The first full scale operational project in Texas began in 1970 with hail-suppression as its goal. That project, which later was expanded in area and now has two sponsors, is the longest running hail-suppression project in the United States—eight years. The first rainfall stimulation/enhancement operational project began in 1971; in 1975, for the first time, the operator--the Colorado River Municipal Water District--was granted a four-year permit to operate. In 1977 there were seven permitted weather modification projects in Texas.

At the present time silver iodide is the cloud-seeding agent used in all weather modification operational projects in Texas. In past years, in addition to silver iodide, finely-milled salt was used as a seeding agent during portions of the San Angelo Cumulus Project experiment, and dry ice is being considered for use in the High Plains Cooperative Program (HIPLEX) in Texas in 1978.

(continued page 46)

BIOGRAPHICAL SKETCH

John T. Carr, Jr.

Department of Water Resources
Austin, Texas
(512)475-6318

Professional Experience: January 1962 - present; Director, Weather Modification and Technology Division, Texas Department of Water Resources, Austin, Texas; and Weather Modification Activities Coordinator, Hydrologist and Hydrometeorologist, Texas Water Development Board and Texas Water Commission. June 1947-January 1962; U.S. Air Force Meteorologist, and degree work at University of Texas at Austin. Education: The Engineer School, Fort Belvoir, Virginia, 1941; Parks Air College, East St. Louis, Illinois, 1942; U.S. Armed Forces Institute of Technology, Weather Observer, Weather Forecaster, and Modern Weather Techniques courses, 1947-59; University of Texas at Austin: degree work in meteorology, geology, mathematics, accounting, and economics -- 1961-62; a graduate course in hydrology 1963; a course titled, "Management of Human Resources," 1969-70. Professional Affiliations: Professional Member, American Meteorological Society (AMS); Certified Consulting Meteorologist No. 68; Past Chairman, AMS Water Resources Committee; Member, Legislative Committee of the Weather Modification Association; Board Member, National Water Supply Improvement Association; Vice-Chairman, North American Interstate Weather Modification Council; Member, Water Desalting Committee, American Water Works Association. Numerous publications and technical papers on meteorological, hydrological, and water desalting topics.

SUGGESTED SOURCES FOR FURTHER INFORMATION

"Design of the High Plains Experiment with Specific Focus on Phase 2, Single Cloud Experimentation" by B. Ackerman, et.al., Illinois State Water Survey, September, 1971.

"San Angelo Cumulus Project Final Report" by T.B. Smith, et.al., Meteorology Research, Inc., prepared for the Texas Water Development Board, October 1974.

"The Economic Effects of Weather Modification Activities, Part One - Crop Production," November 1975, and "Part Two - Range Production and Inter-industry Analysis, " August 1976. Prepared by the Texas Water Development Board.

"Radar Evaluation of Big Spring Weather Modification Program" by T.B. Smith, et. al., Meteorology Research, Inc., a technical report submitted to the Texas Water Development Board, July 1977.

"The Effects of Seeding Clouds from Ground-Based Generators Using the Sea Breeze as Seeding Agent Carrier," A Proposal to: Office of Water Resources Research, prepared by the Texas Water Development Board, January, 1974.

ABSTRACT

HIPLEX - AN OVERVIEW WITH EMPHASIS ON THE 1977 FIELD OPERATIONS

Lloyd A. Stuebinger
Bureau of Reclamation
Engineering and Research Center
Denver Federal Center
Denver, Colorado

A brief review of the High Plains Cooperative Program from its inception to present research efforts is given. The physical basis for the research being conducted to increase precipitation from summertime clouds characteristic of the region is discussed. References are made to background studies being made. These are expected to lead to selection of an evolving design and evaluation plan. The 1977 field operations centering on the Miles City, Montana site are presented. Principal equipment components consisting of radar, aircraft, rawinsondes, precipitation networks, and meteorological supporting elements are described. A typical operation is simulated for selection of an experimental day including air activities with ground support. Comparison is made with the Goodland-Colby, Kansas field site. Coexistent with field experimental work, social, economic, and environmental studies are being carried out. Results thus far are contingenet upon a much more thorough analysis of a great amount of field data now available. A deficit of ice crystal concentrations found in developing and mature isolated convective clouds and feeder cells of cumulonimbus systems suggests that seeding might be effective in these clouds. The value of jet aircraft as an on-top seeder and dry ice as a seeding agent for experimental projects is discussed. Future plans call for intensificiation of analysis of field data, increased cloud physics measurements at the Big Spring, Goodland-Colby sites, and selection of a design and evaluation plan.

BIOGRAPHICAL SKETCH

Lloyd A. Stuebinger

U.S. Department of Interior
Bureau of Reclamation
Engineering and Research Center (Code 1200)
Building 67, Denver Federal Center
Denver, Colorado 80225
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Native of Missouri; obtained B.S. in agricultural engineering at University of Missouri 1942; attended the Aviation Meteorological cadet training program Army Air Forces Technical Training School Grand Rapids, Michigan and was commissioned in 1943; served as a weather officer in the U.S. Army Air Corps 1943-1946 and USAF Weather Service 1950-1970; received M.S. (Research) St. Louis University 1955; served as weather forecaster in assignments in Nebraska, Colorado, Newfoundland, and Europe; assigned in Scientific Services, Offutt Global Weather Central 1958; advanced weather officer Tokyo Weather Central, Fuchu, Japan, 1965, and as Chief of Environmental Applications Branch, ETAC, Washington D.C., during last assignment 1968; joined Bureau of Reclamation as a research meteorologist in 1970; participated in the 1971 Texas and Oklahoma drought emergency cloud seeding programs; was project monitor for the Bureau on the winter Cascade Program (an orographic cloud seeding research program) conducted by the University of Washington 1972-1974 and summer research programs operated in Southern High Plains until present assignment; currently coordinator of the Texas High Plains program.

ABSTRACT

WEATHER MODIFICATION RESEARCH

T.B. Smith
Meteorology Research, Inc.

The history of weather modification research has extended over the past 30 years and has been characterized by a slow but significant rate of progress. Two major developments in the past few years have resulted in an accelerated rate of growth in the understanding of weather modification processes. These are 1) the increasing use and ability of computers to simulate the natural and seeded cloud developments and 2) the increasing sophistication of the measurement systems available for observational use. Both of these developments have been made possible by a trend toward more stable, long-term financial support for weather modification research, particularly through the efforts of the U.S. Bureau of Reclamation.

In view of the microphysical effects produced by the seeding events, it was inevitable that early attention would be paid to the details of these small-scale processes within the cloud systems. Subsequently, increased attention was devoted to the reaction of the entire cloud to the effects of seeding. During this phase, much discussion and attention was focused on "dynamic" seeding of cumulus clouds, i.e., the rapid, induced vertical growth of the seeded cloud in comparison to its environment.

The next area of interest in cumulus seeding has been attempts to induce "mergers" of clouds in which a larger organized system may be produced out of a combination of individual cloud elements. In nontropical regions this interest has been manifested in much greater attention to the treatment of mesoscale cloud systems which frequently organize into long-lasting lines or clusters of individual clouds.

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BIOGRAPHICAL SKETCH

Theodore B. Smith

Meteorology Research, Inc.
Altadena, California
(213) 791-1901

Educational background; B.A., Physics, Ohio State University, 1938; M.S., Physics, California Institute of Technology, 1940; Ph.D., Meteorology, California Institute of Technology, 1949. Professional experience; instructor in meteorology and conducted research in this subject at the California Institute of Technology in the period from 1942 to 1948; carried out meteorological research during the next six years for the American Institute of Aerological Research in Pasadena and in Denver, Colorado. Joined MRI in 1955; assumed the General Managership in February of 1977; played a leading role in a major share of this Company's research projects. Has been closely concerned with contrail formation, mesoscale weather studies, diffusion, and, particularly, weather modification; specifically, has directed studies of diffusion aspects of chemical and biological warfare for various agencies of the Armed Forces, contrail formation for the Air Force, and weather modification for the Advisory Committee on Weather Control. As an outgrowth of work in diffusion, has become a recognized authority on air pollution and toxic hazards; since 1965, has paid an increasing amount of attention to weather modification and has served as Principal Investigator in the major weather modification projects conducted by MRI for the Bureau of Reclamation; has authored and co-authored many papers and reports on a variety of meteorological subjects, principally concerned with diffusion and weather modification. Memberships; American Meteorological Society, Professional Member, President of Los Angeles Chapter, 1961-62, Member of Committee on Weather Modification; American Geophysical Union; American Nuclear Society Standards Committee.

ABSTRACT

COMMUNITY PERCEPTION OF WEATHER MODIFICATION

J. Sonnenfeld
Texas A&M University

Efforts by individuals and groups to modify or control the public environment commonly elicit a public reaction. It is difficult to make any modification of the environment which everyone will agree to be reasonable. Proponents of a project generally have little difficulty in justifying a decision to proceed: their motivations are positive -- to improve a situation or condition in the environment, either by enhancing a deficient quality, or by eliminating a deficiency or hazard. Reactions to such projects are more diverse, relating to conflicts in needs, or in values, or to a lack of confidence in those proposing or managing a project. In other words, while the reasons for support of an effort to modify the environment are generally simple and unambiguous -- the achievement of some goal whose value is apparent -- the reasons for rejection are more variable, given concerns which are both environmental and nonenvironmental in nature. Open conflicts may or may not develop; they may develop early or late, they may occur within as well as between communities. Any group concerned with improving the quality of some aspect of the environment needs to be sensitive to the latent dissatisfaction as well as to the sources of any active expression or resistance to project plans, if its members are to be able adequately to evaluate the costs as well as the benefits of their proposals; and social costs and community well-being may be as critical as economic costs and benefits in such decision-making. This paper will consider both the sources and indicators of community conflict over weather modification.

BIOGRAPHICAL SKETCH

J. Sonnenfeld

Department of Geography
Texas A&M University
College Station, Texas
(713) 845-7141

Obtained B.S. in Natural Resources at Oregon State College, 1952; and PhD in Geography from Johns Hopkins University, 1957. Studied economic change among native populations in Arctic Alaska in 1954, and returned in 1963 for additional research on the environmental perceptions of native and non-native populations. Taught at the University of Delaware for 13 years before coming to Texas A&M in 1968 as Professor of Geography. Among the early workers in the multidisciplinary field of environmental perception and behavior, emphasizing more recently the community dimensions of resource perception and decision-making such as relate to issues of environmental quality and quality-of-life.

SUGGESTED SOURCES OF FURTHER INFORMATION

"Public Participation on Water Resources Planning" by A. Bruce Bishop (Report by the U.S. Army Engineer Institute for Water Resources, IWR Report 70-7) December 1970.

"Attitudes of Potential Users of Weather Modification" by James Bohland, University of Oklahoma (paper presented at annual meetings of the Southern Division of the Association of American Geographers, Dallas, April 1974).

"The Impact of the Rapid City Flood on Public Opinion about Weather Modification" by Barbara C. Farhar, Bulletin of the American Meteorological Society Vol. 55 (7), July 1974.

"Weather Modification and the Decision Process" by J.E. Haas, K.S. Boggs, and E.J. Bonner, Environment and Behavior Vol. 3 (2), June 1971.

"Social Aspects of Weather Modification" by J. Eugene Haas, Bulletin of the American Meteorological Society Vol. 54 (7), July 1973.

ABSTRACT

ECONOMIC IMPLICATIONS OF WEATHER MODIFICATION

Ronald D. Lacewell
Texas A&M University

Weather modification has been carried out in many parts of the United States over about 30 years. In 1974, some 70,000 square miles were seeded for hail suppression over 14 projects in the United States and increased to 130,000 square miles in 1975. Weather modification activities have had little economic analysis. Primary focus has been on estimating changes in hail damages and rainfall. This report considers three principal types of weather modification evaluation: (1) change in hail damages or rainfall (2) economic implications of select projects and (3) economic implications for specified levels of hail suppression and rainfall change.

Of several estimates of the reduction in hail damages attributable to hail suppression, only one was statistically significantly different from zero. The study showed a reduction in hail damages of 48 percent on the Texas High Plains with no change in rainfall either in the target area or surrounding counties. Another study of the same area found a six percent reduction in damages but it was not statistically significant (i.e., not really different from zero). Again no effect on rainfall was discerned.

Of seven hail suppression projects reviewed, six showed reductions in hail damages ranging from six percent (Texas High Plains) to 60 percent (North Dakota). Associated with the same seven projects was no change in rainfall for three, an increase for three (from seven percent to 27 percent) and decrease for one (four percent in South Africa).

Applying economics to the six percent reduction in hail damages to cotton on the Texas High Plains indicates an average annual benefit of

(continued page 48)

BIOGRAPHICAL SKETCH

Ronald D. Lacewell

Texas A&M University
College Station, Texas
(713) 845-2333

Native of Texas, obtained a B.S. and M.S. in agricultural economics at Texas Tech University, 1963 and 1966; economist with U.S. Department of Agriculture three years; obtained Ph.D. in agricultural economics at Oklahoma State University in 1970. Worked with Bureau of the Census, Department of Commerce for 1964 Census of Agriculture; was instructor at Texas Tech University in 1966. Joined the Texas A&M University in 1970. Currently associate professor with primary research responsibilities related to water resources (irrigation, flood damage insurance, water utilization), energy issues, environmental issues (principally agricultural pesticides and analysis of new crop production systems).

SUGGESTED SOURCES OF FURTHER INFORMATION

"An Evaluation of Weather Modification Activities in the Texas High Plains," by James R. Scoggins, et. al., Texas Water Development Board Report 193, June 1975.

"Hail Suppression: Impacts and Issues," by Changnon, et. al., a report to the National Science Foundation available from Illinois State Water Survey, June 1977.

"Results from an Applications Program of Hail Suppression in Texas," by Henderson and Changnon, in Monthly Weather Review, 1972.

"Economics of Weather Modification: A Case Study in South Dakota," by Richard Rudel, in Agriculture in the Modern World, 1974 Biennial Conclave Proceedings, Gamma Sigma Delta Honor Society of Agriculture.

ABSTRACT

FEDERAL PROGRAMS AND WEATHER MODIFICATION POLICY

Merlin C. Williams
National Oceanic and Atmospheric Administration

Federal programs in weather modification since 1973 have not progressed at a pace commensurate with expressed needs of state and local groups. The factors contributing to the attitudes responsible for this situation are a complex combination of social conservatism regarding environmental change and an inability of the weather modification field to produce generally acceptable, positive results. Two recent developments provide optimism for the possibility of significant programmatic advances in the area of summer convective cloud modification. First, the promising results of the FACE program in 1976 provide a technical base for increased activity. Second, preliminary indications of support for increased activity in the field by the Department of Commerce, Weather Modification Advisory Board provide a policy base for future activities.

BIOGRAPHICAL SKETCH

Merlin C. Williams
National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Boulder, Colorado
(303) 499-1000 ext. 6455

Native of South Dakota; B.S. and M.S. in civil engineering in 1953 at South Dakota State University and 1962 at University of Wyoming, respectively. Principal work in weather modification research and operations and hydrometeorology. Since 1974, Deputy Program Manager for Weather Modification, NOAA-ERL; 1971-74, Director, South Dakota Weather Modification Program; 1966-71, Director, Atmospheric Water Resources Research, Fresno State College Foundation; 1961-66, Project Engineer, National Resources Research Institute, University of Wyoming; 1959-61, Hydrometeorologist, U.S. Bureau of Reclamation; 1957-59, Instructor, Civil Engineering, South Dakota University.

NOTES

Weather Modification Today

An Update

November 8, 1977

III. Afternoon Session

Edwin Kessler

Howard Taubenfeld

John Girdzus

James Scoggins

Donald Haragan

T.B. Smith

H. Robert Swart

Richard Jordison

Thomas Wehan

ABSTRACT

ON RECENT DUST STORMS CLOSELY RELATED TO AGRICULTURAL PRACTICE

Edwin Kessler[1], Dorothy Alexander[2], and Joseph Rarick[3]

During late winter 1976-1977, there were several severe dust storms on the High Plains. Photographs transmitted from geostationary satellites on February 23 and March 2 showed distributed sources in Texas and Colorado with the southwestern limit of dust raised by the wind coinciding remarkably with the Texas-New Mexico border(see figure).

Landsat photographs show that along much of the Texas-New Mexico border, there is a marked and abrupt change of agricultural practice. The New Mexico side is mainly rangeland and the Texas side is marked by quarter-section subdivisions with the familiar inscribed circles that indicate irrigated cropland.

The broad indications of the satellite photographs have been confirmed by a ground survey. The cropland is susceptible to wind erosion early in the season, before irrigation water is applied and when the preceding months have been unusually dry. Interviews disclose substantial hostility in the border area between the "sodbusters", mainly Texans, and the "cattlemen", mainly New Mexicans. Some cattlemen view the farmers with contempt, while some farmers indicate that they must plow or lose ownership of their land, there being insufficient profit in the cattle business. However, the transition in agricultural practice at the state border seems to be abetted by a transition in law governing the use of water: the surface owner in New Mexico without a state permit can apply subsurface water only for domestic use, while the surface owner in Texas has been much freer to use subsurface water for irrigation of cropland.

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[1]National Severe Storms Laboratory, NOAA, Norman, Oklahoma
[2]Attorney, Archer, Archer, and Alexander, Perryton, Texas
[3]University of Oklahoma, Norman, Oklahoma

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BIOGRAPHICAL SKETCH

Edwin Kessler

National Severe Storms Laboratory, N.O.A.A.
Norman, Oklahoma 73069
(405) 329-0388

Native of New York and Texas; obtained A.B. in general science and mathematics at Columbia College, New York City 1950; ScD in meteorology from M.I.T., Cambridge, Mass., 1957; during late 50's worked on radar meteorology at Air Force Cambridge Research Laboratories. From 1961 to 1964 he was Director of the Atmospheric Physics Division in the Travelers Research Center, Hartford, Conn. and since 1964 he has been Director of the National Severe Storms Laboratory. The NSSL investigates thunderstorm processes, develops and applies methods for storm observation and prediction, and examines possibilities for their beneficial modification. Dr. Kessler is a Fellow of the American Meteorological Society and of the American Association for the Advancement of Science, a past national councilor of the AMS, former associate editor of the Journal of Applied Meteorology and past chairman of the AMS Committee on Weather Radar. He is Adjunct Professor of Meteorology at the University of Oklahoma and during fall 1975 was a Visiting Professor at M.I.T. He has published extensively on radar meteorology and on relationships between air flow and distributions of water substance in the atmosphere.

SUGGESTED SOURCES OF FURTHER INFORMATION

Glantz, M., 1977: "The value of a long range weather forecast for the west-African Sabel"; Bull. Amer. Meteor. Soc., Vol. 58, No. 2, pp 150-158.

Rayner, F.A., 1970: "Apollo 9 eyes water management," The Cross Section, High Plains Underground Water District, Lubbock, Texas Vol. 16, pp 1 & 3.

Reeves, C.C., 1974: "An Apollo photo and the Texas-New Mexico line", Photogrammetric Engineering, pp 461-466.

ABSTRACT

THE LAW AND WEATHER MODIFICATION

Howard J. Taubenfeld
Southern Methodist University

An updating of the legal situation around the United States and some comments on possible federal legislation; cloud seeding and drought relief - the interests of the states (Washington/Idaho).

BIOGRAPHICAL SKETCH

Howard J. Taubenfeld

Southern Methodist University
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ABSTRACT

ANALYSES OF RAINFALL AND COTTON YIELD DATA WITHIN THE CRMWD OPERATIONAL AREA

John Girdzus
Colorado River Municipal Water District

The people residing in the Upper Colorado River Basin are keenly aware of the importance of water for their livelihood. This is particularly true in the semi-arid portion of the river basin located immediately east and west of the escarpment, commonly referred to as the Cap Rock. The plight of the people in this region is principally determined by water made available through ground and surface water reservoirs, and summer rains.

Impelled by the need to increase and replenish these water sources, the Colorado River Municipal Water District (CRMWD), in 1971, interested in the present and future demands of water, weighed the uncertainty of a prolonged need for supplemental water against the uncertainties of a rain enhancement program. It was decided that the likelihood of gain outweighed the risk of loss, and so in 1971, the District sponsored and initiated a rain stimulation program.

The primary purpose of the program was to supplement surface water run-off into those reservoirs located along the Colorado River north of Robert Lee, Texas. Additionally, rains received through cloud seeding would also improve crop production and pasture lands located within and downwind of the project area.

A study of a limited nature was conducted from rainfall data collected within and adjacent to the District's cloud seeding project area. This information, as well as cotton yield data, will be presented in assessing the possible effects of increased rainfall on cotton production departures from normal for seeded and unseeded areas. It might well be expected that increased

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BIOGRAPHICAL SKETCH

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B.S. in Meteorology, Belknap College, Center Harbor, New Hampshire; graduate studies at South Dakota School of Mines and Technology, Rapid City, South Dakota. Experience; 1971, Daily Prognostication Report, Belknap College; 1973, Great Plains Weather Modification Graduate Research Assistantship, Institute of Atmospheric Sciences; 1974, project meteorologist for the Atmospherics, Inc. hail suppression program, Littlefield, Texas; 1975 to present, project meteorologist for the Colorado River Municipal Water District rainfall stimulation program, Big Spring, Texas.

ABSTRACT

PARTICIPATION BY TEXAS A&M UNIVERSITY IN HIPLEX

James R. Scoggins
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Texas A&M University

During the summers of 1976 and 1977 Texas A&M University personnel participated in a mesoscale experiment in the Texas HIPLEX area. This experiment consisted of the collection of data from ten special surface stations and four rawinsonde sounding stations. These data were combined with precipitation data collected by the Colorado River Municipal Water District and radar data collected by Meteorology Research, Inc. to form the data base for the mesoscale experiment. Each summer data were collected from the special surface stations for the period June 1 - July 15, while sounding data were collected at three-hour intervals on 14 days during the summer of 1976, and 16 days during the summer of 1977. The experiment will be described showing the placement of all equipment and the nature and extent of the data collected.

Texas A&M has the primary responsibility for the processing and analysis of the mesoscale data. The methods of processing will be discussed and examples of the data shown. The analysis of the data collected during the summer of 1976 will be discussed and results presented to show how conditions in the surface layer and aloft are related to the formation and intensity of convective activity. Some aspects of the interaction between the convective activity and the environment, based on an energy budget, will be presented.

BIOGRAPHICAL SKETCH

James R. Scoggins

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Native of Georgia; obtained B.A. degree in Physics and Mathematics from Berry College, 1952, and B.S., M.S., and Ph.D. degrees in Meteorology from Pennsylvania State University in 1954, 1960, and 1966, respectively. Served in U.S. Air Force as Airman and Weather Officer from September 1952 until May 1957; was mathematician and computer programmer for Lockheed for one year; Graduate Assistant in Meteorology at Pennsylvania State University for one year; Meteorologist for Lockheed for one year; did research in atmospheric design criteria and its applications to aerospace vehicle design and operation for the National Aeronautics and Space Administration for seven years; served on the Texas A&M University faculty for ten years in the positions of Associate Professor and Professor of Meteorology, Assistant Dean for Operations, Assistant Dean for Research, and Associate Dean for Research in the College of Geosciences for five years, and Director of the Center for Applied Geosciences for three years. Courses taught at Texas A&M include graduate courses in mesometeorology, atmospheric turbulence, engineering meteorology, and severe weather; undergraduate courses taught include physical meteorology, synoptic meteorology, and dynamic meteorology. Research at Texas A&M has been in the areas of mesometeorology, atmospheric dynamics, atmospheric turbulence, design criteria for aerospace systems, and satellite meteorology. During the past ten years served as consultant to McDonald-Douglas Corporation, U.S. Army at White Sands Missile Range, New Mexico, the Texas Department of Water Resources, Antennas and Propagation Laboratory of the University of Texas, and TRW Systems, Inc. Served on numerous committees, both university and national, and presently serves on the Texas HIPLEX Advisory Committee, Texas Weather Modification Advisory Committee, as a Texas A&M UCAR Representative, and as Chairman of the American Meteorological Society's Committee on Meteorological Aspects of Aerospace Systems.

ABSTRACT

TEXAS TECH UNIVERSITY'S PARTICIPATION IN HIPLEX

Donald R. Haragan
Texas Tech University

The atmospheric science group at Texas Tech University has been involved in two areas of HIPLEX research, (1) Satellite Cloud Studies, and (2) Precipitation Climatology of the Texas HIPLEX site. The satellite investigation was modified in June 1976 and the precipitation analysis began in June 1977.

Satellite Cloud Studies. The meteorological satellite has provided a new perspective for observing clouds and is particularly useful in studying the formation, development and translation of clouds and cloud systems. Of particular value to this end is the Geostationary Operational Environmental Satellite (GOES) which provides continuous monitoring of a selected hemisphere of the globe. The spatial resolution of the GOES sensors in combination with its temporal characteristics permit the study of mesoscale processes such as convective cloud development.

The GOES system has been selected for the Texas-HIPLEX satellite cloud study to determine cloud properties in the Southern High Plains. The parameters of particular interest are the horizontal and vertical extent of convective cloud elements and the changes with time of these properties. It is expected that this study will demonstrate that valuable information is available from satellite data and that the satellite should become an integral part of a comprehensive observational program in conjunction with surface, upper-air and radar measurement platforms.

Visible and infrared radiance data from the GOES system have been acquired in support of the Texas-HIPLEX program. The data are in the form of one-half nautical mile resolution visible and four nautical mile resolution infrared

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BIOGRAPHICAL SKETCH

Donald R. Haragan

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Native of Texas; obtained B.S. in meteorology at University of Texas at Austin in 1959, M.S. in meteorology at Texas A&M University in 1960 and Ph.D. in atmospheric science at University of Texas at Austin in 1969. Was Research Meteorologist at UT Austin Balcones Research Center for five years and instructor of meteorology at UT Austin for four years; Assistant/Associate Professor of atmospheric science at Texas Tech since 1969; Chairman, Department of Geosciences, Texas Tech, 1972-1977. Registered Professional Engineer, Texas. Member of American Meteorological Society, American Geophysical Union, Texas Academy of Science, Society of Professional Engineers, Sigmi XI, Phi Kappa Phi, Chi Epsilon Pi, Omicron Delta Kappa. Primary research interests in water resources in arid and simi-arid environments, hydrometeorology and precipitation climatology, experimental weather modification.

ABSTRACT

MRI CONTRIBUTION TO HIPLEX IN TEXAS

T.B. Smith
Meteorology Research, Inc.

During the past several years MRI has operated an M-33 radar system at Snyder, Texas in cooperation with the remainder of the Texas HIPLEX program. Radar data from 10 cm and 3 cm radar sets are recorded on magnetic tape in quantitative fashion. With appropriate conversion techniques the radar reflectivity values can be transformed into estimates of rainfall amounts throughout the project area. Comparisons with ground raingages can further calibrate the radar-rainfall estimates to provide a more detailed observation of rainfall in the area than can be provided by raingages alone.

In addition, to the raingage network (operated by Colorado Municipal Water District) a surface network of 10 observational stations has been maintained during the past two summers to record variations in temperature and wind related to cloud and precipitation developments in the area. Further data are provided by a light aircraft which measures cloud base height and records variations in cloud updrafts within the area.

All of these data sources together with radiosonde data are being combined into the development of a better understanding of the natural and seeded cloud systems in the Big Spring area and their potential for modification.

BIOGRAPHICAL SKETCH

T.B. Smith, see page 17

Plains Weather Improvement Association, Incorporated

Rain Augmentation/Hail Suppression Program

Plainview, Texas

(Abstract not received by publication date)

BIOGRAPHICAL SKETCH

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B.S. in Meteorology, University of Oklahoma, 1972. Prior experience: Radar Technician, U.S. Navy; 1970-72, Meteorological Technician, National Severe Storms Laboratory; 1972, Meteorologist-in-charge, South Dakota District 2, Atmospherics Incorporated; 1972-74, Project Analyst, Division of Weather Modification, State of South Dakota; 1974-75, Head of Field Operations, Division of Weather Modification, State of South Dakota; 1975-present, Program Manager, Plains Weather Improvement Association, Incorporated, Texas. Professional memberships: Weather Modification Association, Certified; Weather Modification Association, Corporate representative for PWIA, Inc.; American Meteorological Society, Individual Professional member; American Association for the Advancement of Science, Individual Professional member; North American Interstate Weather Modification Council, Affiliate member representative for PWIA, Inc.

ABSTRACT

THE 1977 OPERATIONAL WEATHER MODIFICATION PROGRAM IN LITTLEFIELD, TEXAS

Richard R. Jordison
Atmospherics Incorporated

During the shortened operational season in the summer of 1977, there were 29 seeding days on which 68 seeding flights occurred with the dispersal of 49,650 grams of silver iodide.

In May, planned seeding was not done, and 200,000 acres within the target area was damaged by hail. By contrast, 550 acres damage was done in the target during the rest of the program, suggesting a highly effective season of hail suppression operations.

The program was ended prematurely when the Texas Water Development Board exercised its discretionary powers and terminated the permit for Atmospherics Incorporated following local elections on the subject.

BIOGRAPHICAL SKETCH

Richard R. Jordison

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Native of Illinois; obtained B.S. in meteorology at Parks College of St. Louis University in 1972. Forecaster and operational meteorologist for hail suppression field program in Northern Italy for two seasons. Forecaster for South Dakota State Weather Modification Program for two years. Chief forecaster for the North Dakota State Weather Modification Program in 1976. Project Supervisor for the Atmospherics Incorporated weather modification program in Littlefield, Texas in 1977.

ABSTRACT

GROUND BASED CLOUDSEEDING OPERATIONS IN TEXAS

Thomas J. Wehan
Irving P. Krick, Inc. of Texas

The Krick organizations have been involved in weather modification programs throughout Texas since the early 1950s. All of these operations have been conducted with ground-based equipment. The method evolved from basic studies of atmospheric diffusion processes funded by the U.S. Air Force in 1948. Field tests were carried out in Arizona in 1949 and throughout much of the United States and elsewhere in the early 1950s. These tests confirmed the viability of using ground-based equipment for orographic, frontal and convective weather situations anywhere throughout the world, when pursued by meteorological personnel trained and experienced in the unique techniques developed within our organizations.

To date, some eighteen projects have been conducted in the State using ground-based silver iodide dispensing units. The most recent of these programs are located in north central and in west Texas, and will be the main focus of this report. Both projects initiated operations in 1976. The north central counties of Stephens, Throckmorton, Shackelford and Young (T-17) operated for approximately a six month period beginning May 7th and ending October 26th. The 1977 program began on April 1st and was terminated in early November. The west Texas program (T-18) for the Red Bluff Water Power Control District began operations on September 20, 1976, and is still active.

These programs are controlled from the company's Palm Springs weather center, where weather data from all over the United States and the world are continuously being received. At the beginning of each day, surface and upper air data are analyzed to determine the potential for cloud development and the suitability of cloudseeding operations. Once an operational day has

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BIOGRAPHICAL SKETCH

Thomas J. Wehan

Irving P. Krick, Inc. of Texas
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Master of Science (Meteorology), California State University, San Jose, California - 1975; Bachelor of Science (Meteorology), Florida State University, Tallahassee, Florida, 1969; Bachelor of Arts (Geology), University of California, Riverside; Riverside, California - 1967. Experience: Atmospheric Water Resources, Fresno University Foundation, Fresno, California. Worked in cooperation with Atmospheric Water Resources Research in the collection and analyses of data for their State and Federally sponsored weather modification projects and for my thesis. Collected and analyzed all snow crystal data; collected and analyzed much of the synoptic data and related the data for an evaluation of the weather modification operations. Findings were included in reports to the State of California and Bureau of Reclamation. 1971-1973. Consultant to Desert Research Institute, University of Nevada; Reno, Nevada. Analyzed and interpreted ice crystal data from the Antarctic for Federally sponsored research. 1972. Associated with Irving P. Krick Associates, Inc. and affiliated companies since May, 1975. Responsibilities have included short range forecasting for various clients across the United States, analyses of weather modification programs operated in the United States; as well as analysis of the ground generator plume study program carried out in Alberta, Canada during the summer of 1975. Publications and papers: "Procedures and Techniques for Reducing Ice Crystal Data." Unpublished paper, Atmospheric Water Resources Research, Fresno University Foundation; "Synoptic and Mesoscale Influences on Ice Phase Microphysics in Sierra Nevada Snowstorms." Master's Thesis, San Jose State University; San Jose, California. Member: American Meteorological Society.

Continuation Pages

to retirement from the service. In August, 1976, Dr. Clarke was appointed to the Executive Council of the National Academy of Sciences National Research Council Committee on Hearing, Bioacoustics and Biomechanics. In June, 1977 Dr. Clarke was appointed a member of the USAF Scientific Advisory Board (To the Secretary of the Air Force).

Public relations must be developed. Recalcitrant groups must be met with and the matter talked out. Unanimity will never be achieved but the situation can be ameliorated. An informed public often reacts properly--an uniformed public can not.

Careful observance of the proprieties by members of the weather modification community are essential if the public is not to lose faith altogether in the profession. Mutual criticism must be confined to the professional community. Academic objections to the art are a common source of trouble, and although well meant, are often voiced before the speaker has had an opportunity too really understand the situation. Wanting to do more research is commendable; saying that we don't understand enough to do work is not.

In order to make the profession of weather modification an effective arm of society we must learn how to overcome this challenge, just as we have overcome some of the technical problems of our trade. The Chinese ideograph for "danger" is identical to that for "opportunity".

Silver iodide was dispensed in 1977 at sub-cloud level from an airborne platform in both hail-suppression projects and in the CRMWD rainfall stimulation/enhancement project. Silver iodide was dispensed from ground-based generators in the remaining four project areas. The Texas Department of Water Resources takes no official position with regard to the type of cloud-seeding material used or the method by which it is dispensed. However, all applications for weather modification permits are closely evaluated by the Department's Weather Modification Advisory Committee and the Department staff with respect to the type of cloud-seeding material and dispensing method proposed by the applicant, as well as the applicant's qualifications, before a recommendation is made to grant the permits. In this manner, the public's interest is protected during all weather modification operations in Texas.

While a considerable amount of evidence tends to support the production of increased rain from individual cumulus clouds, the total amount of rain produced from such clouds may be a very small fraction of the total rainfall occurring in the area. Most of the rain, it is now realized, occurs as a result of the "merged", or organized cloud systems. The increasing attention currently being devoted to the treatment of these systems, therefore, offers hope that more productive and economic amounts of fainfall can be generated in the near future through seeding techniques.

$929.5 thousand. Losses avoided in the target area was an annual average of 3.21 thousand bales of cotton ranging from 0.43 to 4.94 thousand. Annual benefits ranged from $124.4 to $1,428.9 thousand.

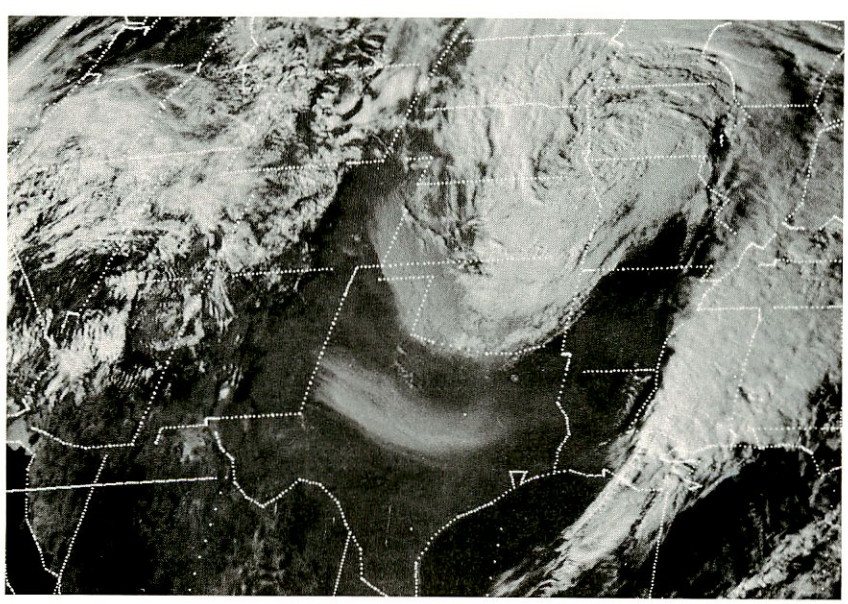
A last type of analysis on benefits of weather modification assumes a given level of hail suppression and change in rainfall. A study of nine counties in North Dakota assuming a one inch increase in rainfall during the growing season estimates an increase in farmer net returns of about $15 million. Similarly for cotton on the Texas High Plains, a program that reduced hail by 20 percent and changed rainfall by -10 percent, 0 and +10 percent is estimated to cause a 19 cent reduction, $1.69 and $3.54 increase in per acre profit, respectively. At all higher levels of hail suppression even with a 10 percent reduction in rainfall during the growing season, producer profit was increased.

A last study was on a national scale and assumed widespread adoption of hail suppression. Overall, with widespread adoption, a benefits to costs ratio of hail suppression was estimated to be about 15 to 1. Consumers and producers in target areas were the beneficiaries. Due to an increase in agricultural output, prices declined hence a consumer benefit and costs of production in target areas declined often improving these producers. Producers in non-target areas incurred a lower price for their corps, hence, a reduced profit position.

In summary, very little is known about the effect of weather modification on hail damages or rainfall. Thus, without the factors quantified, application of economics is futile.

We may ask how the costs and benefits of influencing state and federal policies and regulations are distributed. Those dealing with price and availability of water and of the energy required to apply it in agriculture are perhaps paramount. Also, much crop production relates closely to federally administered price supports; and both grain price-supports and beef import policies relate to farmers' choices between beef and crop production. There may be legal issues if damage to property and threats to health and safety in areas downwind from dust sources can be traced to knowing efforts at the sources.

A much larger study effort is required to develop understanding of the issues involved here commensurate with their importance, and adequate for assessment of relevant policies in agriculture, public works, economics, and law.



Photograph from geosynchronous satellite March 2, 1977 showing western limit of wind-raised dust along the Texas-New Mexico border. Also note dust over eastern Colorado, southwestern Kansas, and western Oklahoma. Brightest areas show clouds.

rainfall occurring at certain times of a crop's growing season would be beneficial and at other times detrimental to the crop's maturity. Consideration is also given to the economic effects of weather modification on agriculture.

digital computer tapes. Measurements for the period June 1 - July 15, 1976, over a 90,000 km^2 area centered at Big Spring, Texas, form the data set for the study; data for the same period in 1977 will be available soon. The period June 1 - July 15 has been selected to correspond to the Texas-HIPLEX mesoscale period during which an intensive data gathering effort was conducted by Texas A&M University.

Computer programs have been developed to objectively summarize the number, size, brightness and cloud-top temperature in the study area. Growth rates of the various cloud properties can be determined by comparison of successive data. Digital radiance data, from which quantitative results can be derived, are preferred over photographs, from which subjective estimates alone can be derived. Verification of satellite data results at each stage of the analysis is checked against surface and upper-air data (the Texas A&M University network) and radar data (National Weather Service at Midland and Meteorology Research, Inc. at Snyder). Presently, the study is being pursued on a case study basis, examples from the June 22-23, 1976, case will be shown.

Precipitation Climatology of the HIPLEX Southern Region. The problem of weather modification evaluation has been compounded by the lack of adequate statistical data to define quantitatively the natural variability characteristics. Evaluation of modest increases of decreases in surface precipitation from cloud seeding will be particularly difficult in the Texas-HIPLEX area because of the great natural variability of precipitation in space and time. As an aid in establishing an adequate experimental design for seeding activities and for properly evaluating the results, a climatology of precipitation events is being developed for the Texas HIPLEX region. Daily and monthly precipitation data have been collected for all National Weather Service

stations and cooperative observers in the area. Temporal variations (monthly and daily) are being computed using the entire period of record at several representative stations. Spatial variability in annual and monthly rainfall is based on data from more than 70 stations during the 27-year period from 1944 to 1970.

Results of a North Dakota experiment to increase precipitation by cloud seeding revealed a greater number of rainfall events during seeding periods. To test this hypothesis in Texas it is necessary to establish a climatology of rainfall events in the absence of seeding. Based on the total period of record at three stations, the percent frequency of various numbers of rainfall periods per month has been computed in addition to the number of rainfall periods with varying amounts of rain. Most of the rainfall periods brought less than ½-inch of rain. Larger rains (two inches or more) are much less common, occur in the warm season, are distinctive features of rainfall in the Texas HIPLEX area and have a considerable influence on the average precipitation.

In addition to computing the frequency of daily rainfall events, the diurnal variation of precipitation events has been tabulated for each month of the year. An analysis of meso-synoptic events associated with the occurrence of precipitation is underway. It is important to realize that the sequence of meteorological events leading to precipitation varies with the seasons during the year. Precipitation during April and May occurs from violent convective activity initiated by frontal or upper-air disturbances. Scattered shower developments which occur during summer result from daytime heating, low level moisture and an absence of subsidence aloft. Late autumn and early winter rains occur when warm, moist Gulf air overruns a shallow layer of continental polar air at the surface.

ABSTRACT, Donald R. Haragan

Further insight into the nature of the spatial distribution of rainfall is provided by correlation analysis. Correlation coefficients utilizing more than 2600 station-pairs have revealed the seasonal nature of precipitation in the Texas HIPLEX area. Correlation analysis provides information on the average sizes and paths of the storms through the area.

Storm size and intensity determine the extent of precipitation ground coverage. Late fall and winter storms, characterized by stable air converging toward a center of low pressure or by frontal waves with a continuous supply of moisture, result in correlations which are high along the path of the storm and do not vary rapidly with distance. In the summer precipitation situation, daytime heating and convective instability result in high precipitation gradients and, therefore, smaller correlations between stations. A special situation is apparent in May where the correlations fall off slowly with distance even beyond 160 miles. This is probably due to the organized nature of the rainfall-producing system and the fact that once vertical motion is provided, abundant precipitation results almost without exception over a wide area along the path of the storm.

With sufficiently high correlations, as in the month of May, it may be possible to use predictor equations to estimate the amount of rainfall expected in a weather modification target area during seeding operations. This possibility is presently being investigated. The prediction equations would be multiple regression equations of the form

$$P_e + A + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + \ldots$$

where P_e is the estimated precipitation in the target area,

X_j is the precipitation in area j,

B_j are the partial regression coefficients, and

A is the intercept.

A measure of the effectiveness of the cloud seeding operation is obtained by computing the difference, D, between the observed precipitation, P_o, and that expected, P_e, if no seeding had taken place.

been forecast, and prior to the development of seedable clouds in the target area, it must be determined which of the ground generators are to be operated. The rate of vertical rise of the seeding material is calculated from a study of airmass characteristics, and the pattern of transport and diffusion is obtained from the radisonde wind data. A "plume" is then constructed to represent the horizontal and vertical path that the seeding material will follow from its release at the ground to the levels where the particles will become effective as ice nuclei. An important element of this calculation is not only the time it will take for the material to reach cloud levels where it will become active, but also the additional interval for the attainment of precipitation fallout over the prescribed contract area.

Using the plume, a decision is made as to which ground based generators will be operated to treat the target area most effectively. Telephone calls are placed from the control center in Palm Springs to the individual generator operators selected. The changing weather and windflow patterns at all levels are monitored continuously, and as conditions alter, different generators may be activated. The monitoring of weather conditions also provides a safeguard against any adverse effects from these operations.

The 1976 results from the north central Texas project indicated a general area of wetness over the target, with the greatest positive departures from normal (over 160% of normal) extending from Throckmorton eastward into Young County. A large dry pocket (less than 80% of normal) was centered just south and northwest of the project area. The results for the west Texas region cover the period from 20 September 1976 through 30 June 1977. Data for the remaining months has not been received or analyzed. Results for this period indicate that the T-18 project area also fared better than its environs, with precipitation

well above normal (greater than 120% of normal). A large dry area (less than 80% of normal) was found to surround the target, with the exception of an area to the northeast.

Results for the 1977 project in north central Texas (T-17) are unavailable at this time as data collection is still under way. An analysis of this year's operation is expected sometime in early 1978.