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A Statistical Evaluation of the Kern River Operational Cloud Seeding Program

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Abstract: A target-control statistical evaluation of the Kern River Basin operational cloud seeding program was conducted using ratio statistics. The cumulative effect of seeding from water year 1977 through water year 2006 was calculated in terms of confidence intervals because they provide information on the strength of the seeding effect whereas null hypothesis significance tests infer only whether there is any seeding effect at all. The effect of seeding on several targets in the Kern River Basin was evaluated using the controls that give the most precise evaluation results possible with the available data. Evidence for positive, statistically significant and cost effective seeding effects were found at all 3 sites in the Kern River Basin that were evaluated with estimated increases in streamflow due to seeding ranging from +8.4% to +12.2%, depending on the target location. Physical studies that help explain the statistical results and that could lead to more cost-effective seeding operations are indicated.

Pooling of the estimates of the seeding effects for the Kern River, Kings River, and San Joaquin River Basin operational cloud seeding programs indicated that the common effect of seeding on the three River Basins is +6.4% with 90% confidence that the true effect of seeding is somewhere between +3.9% and +9.0%. The probability that the seeding effect is greater than 0% and 1% (threshold of cost-effectiveness) are both 100%. Thus, there is a strong statistical evidence in support of the hypothesis that cloud seeding in the watersheds of the Southern Sierra Nevada Mountains is a cost-effective technology for increasing streamflow by significant and societal important quantities

An Assessment of Impact of Cloud Seeding on Local Rainfall - A Case Study of First Part of the ISKI Rain Enhancement Program Conducted in Istanbul, Turkey During 1990-1991

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Abstract: Major metropolitan areas of Turkey suffered from extensive drought and associated water shortage during the late 1990s and early 1990s. Water levels at the major dam lakes dropped below their critical levels in Marmara, and Central and Western Anatolian regions. The impact of resulting water shortages was greatest especially on drinking water supplies during summer months when the temperatures peaked. A number of rainfall enhancement projects in response to the emerging water shortages problems developed and were put into implementation by the local authorities of Istanbul, Ankara, and Izmir. Nevertheless economic viability of the projects was not considered seriously. The efforts were directed to find immediate solution to supply water to the local communities who suffered from the shortage of water in the urban areas. Istanbul Municipality and Istanbul Water and Drainage Works (ISKI) launched "ISKI Rain Enhancement" project, to meet immediate water demand of the city of Istanbul. It was the first operational rainfall enhancement program in the country and included cloud seeding in a nearly 2100 km^2 area covering four main water catchments which supply drinking water to the Istanbul Metropolitan area. The first rainfall enhancement phase covered October 1990 through March 1992, and later extended to 1993 to 1994. This study presents an analysis of the first phase of the ISKI rainfall enhancement program, which covered October 1990 through May 1991 period The study focuses on rainfall data of target and control areas in and near the vicinity of the water basins where the cloud seeding was conducted in order to assess effectiveness of the seeding.

This study concludes that cloud seeding applications were effective to some extend in a limited geographical scale and above a certain rainfall threshold. Despite the fact that higher rainfall was observed in some target areas during the seeding days, the statistical analysis presented here raises questions about the proper assessment of such applications only by the "Double Ratio" method. The results indicated that the "Double Ratio" method alone is not adequate to assess the impact of the seeding, and other statistical tools should be developed and applied in order to make a better judgment of the cloud effects on the local rainfall. The analysis conducted in this study proved that the seeding had varying effect on the local rainfall and some of the seeding operations were more successful than others.

The Snowy Precipitation Enhancement Research Project; A Description and Preliminary Results

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Abstract: A gradual reduction in water from the snow-melt over the past century has motivated Snowy Hydro Ltd. to pursue a wintertime cloud seeding project in the Snowy Mountains of southeastern Australia. The Snowy Precipitation Enhancement Research Project is one of only a few cloud seeding experiments in the last two decades to employ a randomized design, and the first such randomized experiment to incorporate dual-trace chemistry analysis of snowfall as part of the project evaluation. The project design, seeding criteria, ground-seeding network, and measurement infrastructures are described, as are the general components of the statistical evaluation plan. Some initial results from analysis of physical and trace chemical measurements are presented for an extended storm period in 2006 that included five randomized experimental units. The trace chemistry results were found to validate several of the components of the seeding conceptual model, and a unique time series of tracer element concentrations appears to indicate when seeding and tracer materials were released. Progress during the first four seasons of the project is described, as are various findings that could affect the outcome of the project.

Comparison of Two Acoustic Ice Nucleus Counters

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Abstract: Two acoustical ice nucleus counters (a.k.a. "NCAR counters") were compared at the Weather Modification, Inc, facilities in Fargo, ND, 17-19 December 2007. One counter was one of three built by NCAR in 1976 based on the design of the inventor (and one of the authors, Langer), and is traceable to the Colorado State University Cloud Simulation and Aerosol Laboratory. The other counter was built for WMI in 2006 by the first author. The purpose of the comparison was to document the reliability and reproducibility of the devices under controlled conditions. Both counters were brought to operating specifications, then comparisons were run using two types of AgI aerosols sampled through a common source: AgI-NH_4I-aceteone and AgI-NH_4I-$C_6H_4Cl_2$-$NaClO_4$-acetone. The former was assumed to produce contact nuclei and the latter fact-acting condensation-freezing nuclei. The counters showed close agreement to within a factor of 1.04 to 1.66, depending on the type of AgI aerosol. Times to first indication of plume encounters were on the order of 20 to 30 s depending on the concentration of nuclei, and the instrument-induced smoothing of plume encounters were similar. The results indicated that these devices can provide similar quantitative measurements of different AgI ice nuclei, not merely yes/no indications of AgI presence.

Polarimetric Cloud Analysis and Seeding Test (POLCAST)

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Abstract: The Polarimetric Cloud Analysis and Seeding Text (POLCAST) was a cloud seeding research experiment that was conducted to help determine if hygroscopic seeding could be detected directly by polarimetric observation or through derived polarimetric parameters. The operational phase of the program, a cooperative study between the North Dakota Research Board (NDARB), University of North Dakota, Weather Modification Inc., and Ice Crystal Engineering, was conducted from 10 July - 5 August 2006. The study was centered on the measurements recorded by the University of North (UND) C-Band polarimetic Doppler Radar (NorthPol). Hygroscopic flares, deployed on a Weather Modification Incorporation (WMI) aircraft, were used in the study. Ice Crystal Engineering provided these flares.

From the polarmetric radar observations, liquid water content, rainfall rates and hydrometeor type were analyzed. The radar-estimated liquid water content retrievals indicated an increase in 7 of the 8 cases after hygroscopic seeding. In correspondence, the rainfall rates were also higher along with the durations of the cells in the seeded cases. The differential reflectivity decrease after seeding, which is an indication that rain drops were decreasing on average in size. The reflectivity also increased after seeding except at cloud base where there was a decrease in reflectivity after seeding. The hydrometeor identification results were in good agreement with the trends observed in reflectivity and differential reflectivity fields.

Study of Optimal Scheme in Cannon Precipitation Enhancement

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Abstract: One of the most important problems in precipitation enhancement by the use of cannon is to figure out operating parameters and affected area. Diffusion of a

catalyzer injected with multiple cannon-shots is studied in this paper. Effective seeding areas using different eddy diffusivity coefficients, azimuth, elevation and wind speeds are simulated. Based on these calculations an operation method is put forward, i.e. cannonballs are shot against the wind in a semicircle with multiple rounds. The method has been programmed in the Cannon Precipitation Enhancement Operation Command System which can automatically determine effective seeding areas to facilitate assessment of precipitation enhancement.