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Another Wintertime Cloud Seeding Case Study with Strong Evidence of Seeding Effects

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Abstract. In the 1990s numerous winter orographic cloud seeding experiments were conducted over Utah's Wasatch Plateau. Several previously published case studies suc-cessfully documented the physical response in clouds and precipitation to ground-based seeding with silver iodide and liquid propane. A previously unpublished case study that shows additional evidence of positive seeding effects is presented here. Careful docu-mentation of seeding plume transport and dispersion coupled with aircraft and ground-based measurements within and outside the seeding plume are used to verify the steps in the conceptual model for orographic cloud seeding. It is shown that seeding produced significant increases in ice crystal concentrations (well above 10 times the natural back-ground at aircraft level) and strong indications of increased precipitation at the surface (> 3 times the precipitation rate measured outside the seeding plume). Compared to other Utah results, the most unique aspect of this case study was the apparent detection of the seeding effect in the data from the project Ka-band radar. The radar seeding signa-ture documented the areal extent and duration of the seeding effect in a way that was not previously possible using the more intermittent aircraft measurements and the lower spa-tial resolution precipitation data. The physical evidence of seeding effects documented in this and several other Utah/NOAA experiments supports the development of a larger scale randomized experiment to satisfy the call for proof of cloud seeding effectiveness in a recent National Academies of Science report.

New Developments in the Regional Atmospheric Modeling System Suitable for Simulations of Snowpack Augmentation over Complex Terrain

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Abstract: The Colorado State University Regional Atmospheric Modeling System (RAMS) has been used to emulate cloud seeding operations in the Colorado Rocky Mountains for the winter of 2003-2004 in a previous study (Cotton et al. 2006). This paper documents new developments in RAMS since that study using a winter storm simulation that occurred in Colorado from 3-4 November 2003 as an illustration. The authors reported the advantages and disadvantages in the precipitation prediction of the innermost grid (dx=3 km) by using the Kain-Fritsch convective parameterization scheme (CPS) in the outer grids in order to reduce the excessive precipitation in the innermost grid. Also, we examined the impacts of the bin-emulation approach to riming on supercooled liquid water prediction and precipitation. The bin-emulation approach alleviated a negative bias in the prediction of cloud liquid water content that occurred in the older microphysics package without this feature. With this new feature, there should be improvements in emulating cloud seeding operations in RAMS.

On the Use of Ratio Statistics for the Evaluation of Operational Cloud Seeding Programs

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Abstract. The purpose of this study is to describe and demonstrate the capability and merits of using ratio statistics in evaluating the effectiveness of operational (non-randomized) cloud seeding programs. The application of the ratio statistics methodology is illustrated by an independent statistical evaluation of the Kings River operational cloud seeding program over its entire period of operations from water years 1955 to 2004. The effect of seeding in terms of confidence limits was emphasized because they provide information on the strength of the seeding effect whereas null hypothesis significance tests indicate only whether there is any seeding effect at all. The effect of seeding on the Kings River-Pine Flat Dam streamflow station, the primary seeding target in the Kings River Basin, was evaluated using the control that gives the most precise evaluation results possible with the available data. The results of this evaluation study indicate that (i) for the data involved in this study, ratio statistics was found to be a more precise and more reliable evaluation methodology than the traditional historical regression methodology, (ii) evidence for positive, statistically significant and cost effective seeding effects was found at the target site in the Kings River Basin with an estimated increase in streamflow due to seeding of +5.1% with 90% confidence that the true effect of seeding is somewhere between +1.5 and +8.8%, and (iii) it was found that there was a marked improvement in seeding effectiveness that started around 1978, the physical cause (s) of which is worthy of further study.

New insights to cloud seeding for enhancing precipitation and for hail suppression

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ABSTRACT Satellite synoptic microphysical observations of the impacts of aerosols on cloud microstructure and precipitation forming processes provide us with the extent and scale of inadvertent weather modifica-tion. Intended seeding signatures are detectable at much smaller scale by the same satellite technology. Inadvertent and intended weather modification have been regarded until now mostly as independent is-sues. In this brief review the two are contrasted and presented as different manifestations of the same sensitivity of precipitation- forming processes to the role of aerosols in the rate of conversion of cloud droplets into precipitation and the dynamic response of the clouds, which result in changes of the amount and distribution of precipitation. These considerations are applied here separately to orographic and con-vective clouds. It is shown that we can learn much on the potential of cloud seeding for precipitation en-hancement by observing the opposite response of the clouds to inadvertent effects due to air pollution.

Should We Consider Polluting Hurricanes to Reduce Their Intensity?

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Abstract: An overview of simulations of hurricane response to African dust is presented. Those simulations suggest that under some conditions storm intensity might be reduced if large concentrations of small hygroscopic particles are present at the time the storms develop. Based on those results, it is proposed that seeding hurricanes with small hygroscopic particles can reduce hurricane intensity and damage, but future research is needed to determine the range of conditions under which such seeding may be effective and to determine whether such seeding is practically viable. Recommendations for a research program to further investigate the feasibility of such a procedure are provided.

A SPECIFIC EVIDENCE OF HAIL SUPPRESSION EFFECTIVENESS IN SERBIA

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Abstract: In 40 years period (1967-2006) of continuous hail suppression operations in Serbia only in 1999 it was interrupted due to NATO bombing. In that year the hail-swept agricultural area was 3.5 times larger then in other ten years in the period 1992-2002 when the hail suppression system was operating under similar conditions.

A LEVEL II WEATHER MODIFICATION FEASIBILITY STUDY FOR WINTER SNOWPACK AUGMENTATION IN THE SALT RIVER AND WYOMING RANGES IN WYOMING

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Abstract: North American Weather Consultants performed a feasibility/preliminary design study for a potential operational winter cloud seeding program for the Salt River/Wyoming Ranges in Wyoming, under contract to the Wyoming Water Development Commission. The Desert Research Institute (DRI) conducted atmospheric modeling as part of this study. The primary project goal is to increase winter snowpack in the target area through operational cloud seeding. An average increase of 10% in November through March precipitation via cloud seeding was calculated, using results from the Climax I and II re-search programs. Simulations using empirically derived snowpack-streamflow relations yielded increases in streamflow from three seeding modes totaling approximately 109,500 acre feet (1.35 x 108 m^3) on average. The costs per acre foot for the estimated increases in streamflow range from $1.91 to $7.13 per acre foot of additional water and associated benefit/cost ratios range from 5.8/1 to 1.6/1, depending on the seeding mode(s). A preliminary design for an operational winter cloud seeding program is de-scribed. One preliminary winter season of supercooled liquid water and lower-level tem-perature and wind observations is recommended, to determine the frequency of low-level temperature inversions during seedable periods. The DRI case study modeling results indicated that such inversions could inhibit the effectiveness of low elevation ground based seeding releases.

The Role of Weather Modification in the Colorado River Basin States Process

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No Abstract available

PRELIMINARY RESULTS OF SITE SELECTION STUDY FOR CLOUD SEEDING IN ORDER FOR PRECIPITATION ENHANCEMENT IN I. R. OF IRAN

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Abstract: Weather modification activities in I. R. of Iran includes site selection study as well as numerical cloud seeding modeling and field experiments for fog dispersion and rain enhancement. In this paper the primary results of site selection study for cloud seeding in order for precipitation enhancement in I. R. of Iran has been presented. The procedure is according to Precipitation Enhancement Project (PEP) Report No. 3 of the World Meteorological Organization (WMO). The results procedure has shown that the cloud seeding feasibility is highest at the northwest, north and northeast of Iran and it decreases from north to center, south and east of center. The results are very important for design of operational projects over Iran to classify capability for cloud seeding.