



## Anthropogenic Water Augmentation in Major American River Basins through Cloud Seeding to Enhance Snowpack

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Recent rapid depletions of glaciers and intense droughts throughout the world have created a need to reexamine modern water augmentation technologies for enhancing snowpack in mountainous regions. Today's reliance on clean efficient hydroelectric power in the Alps from France to Hungary poses a critical need for sustainable snow packs and high elevation water supplies through out the year. Hence, the need to make natural cloud systems more efficient precipitators during the cold season through anthropogenic weather modification techniques.

The Bureau of Reclamation, US Department of the Interior, has spent over \$39M in research from 1963 to 1990 to develop the scientific basis for snowpack augmentation in the headwaters of the Colorado, American, and Columbia River Basins in the western United States, and through USAID in Morocco. This paper presents a brief summary of the research findings and shows that even during drought conditions potential exists for significant, cost-effective enhancement of water supplies. Examples of ground based propane and AgI seeding generators, cloud physics studies of supercooled cloud droplets and ice crystal characteristics that indicate seeding potential will be shown. Hypothetical analyses of seeding potential in 17 western states from Montana to California will be presented based on observed SNOTEL snow water equivalent measurements, elevation and observed winter precipitation. Early studies indicated from 5 to 20% increases in snow pack were possible, if winter storm systems were seeded effectively. If this potential was realized in drought conditions observed in 2003, over 1.08 million acre feet ( $1.33 \times 10^9 \text{ m}^3$ ) of additional water could be captured by seeding efficiently and effectively in just 10 storms.

Results from recent projects sponsored by the National Science Foundation, NOAA, and the States of Wyoming, Utah and Nevada, and conducted by the National Center for Atmospheric Research will be discussed briefly. Examples of conditions in extreme droughts of the Western United States will be presented that show potential to mitigate droughts in these regions through cloud seeding. Implications for European hydropower generation and sustainable water supplies will be discussed.