CLOUD SEEDING EXPERIMENT

3. Study Design

The following two questions about the study design are very important to answer the question about the effects of seeding on rainfall amounts: Does the study design in the experiment enable us to claim that seeding caused higher rainfall? How should any inferences be interpreted? The answers to the above questions will be discussed below.

3.1 Does the study design in the case study enable us to prove cause-and-effect relationship between cloud seeding and higher rainfall?

Let us analyze now the way the experiment was conducted. In any experiment it is necessary to define the experimental unit upon which a treatment may be applied and the appropriate measurement is to be taken.

The experimental units in the cloud seeding experiment are isolated cumulus clouds in south Florida on a day that was deemed suitable for seeding. The criteria under which a day is classified as suitable or unsuitable for seeding are complex. In south Florida, days that satisfy the conditions are days with generally fair weather conditions (no strong wind shear and no rain) and with adequate numbers of apparently similar isolated cumulus clouds growing. A cloud is selected as a suitable cloud for seeding if it is relatively isolated, has cauliflower-like appearance, its top is rising, is at a height between 5.5 and 8 km, and has a specific liquid water content. Only clouds satisfying the above conditions were considered in the experiment. The goal was to make the selected clouds as homogeneous as possible. As you can see, both subjective and objective criteria were used to determine whether a given cloud could be considered as suitable or unsuitable for seeding.

The aircraft surveyed the experimental area for clouds that might meet the pre-set criteria. The researchers selected one of suitable clouds. The random mechanism was not used in the phase of the experiment.

Once the target cloud was determined, a random mechanism was used to decide whether to seed the cloud on that day or to leave it unseeded as a control. The experimenters were unaware whether the flare rack in the aircraft was armed with silver iodide and therefore whether or not the cloud was undergoing seeding. The fact that the experiment was blind, that is the airplane crew was unaware of whether seeding was conducted or not, prevented the intentional or unintentional biases of the investigators from having a chance to make a difference in the results. Moreover, the flight pattern of the aircraft while approaching a cloud, and the way the chemical was introduced into the cloud top were the same for each selected cloud.

Notice that although the experimental units were not selected randomly, they were randomly assigned to two treatment groups: unseeded clouds (control group) and seeded clouds (experimental group). Thus the experiment is an example of a randomized experiment because the investigators controlled the assignment of experimental units (suitable clouds) to groups (seeded, unseeded), and used a chance mechanism to make the assignment. The study design enables us to draw causal inferences.

Observe that although the study design enables us to claim the causal relationship between higher rainfall and cloud seeding for the clouds selected in the experiment, it does not explain the physical and chemical processes causing higher rainfall due to cloud seeding.

The experimental design for the experiment is treated in detail by Simpson, Woodley, Miller and Cotton in the paper *Precipitation Results of Two Randomized Pyrotechnic Cumulus Seeding Experiments* published in *Journal of Applied Meteorology,* Vol. 10, 1971, pp. 526-544.

3.2 How should any inferences be interpreted?

The clouds (experimental units) subjected to the treatment (seeding) or left as a control are not members of any well-defined population. They are not even selected randomly. Although a random mechanism was used to decide whether to seed the target cloud on a given day or to leave it unseeded as a control, the mechanism used to select the target cloud was not random.

As the clouds were randomly allocated to the two treatment groups (seeded and unseeded), cause-and-effect conclusions can be drawn regarding the effect on the particular clouds selected. However, the observed pattern cannot be inferred to hold in some general population.

As we don't have any population here and there is no random sampling involved, it makes no sense to test hypotheses about a population parameter or to obtain a confidence interval for the difference between population means. Any inferences in this case should be stated in terms of treatment effects and causation, rather than differences in population means and association.