"REVIEWED"

A NOTE ON THE POTENTIAL FOR SEEDING FIRE-INDUCED CONVECTIVE CLOUDS

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The recent outbreaks of widespread, drought-related forest and range fires in the Western United States have increased interest in reducing fire danger and damage. One possible approach that deserves serious assessment is the application of cloud seeding to convective clouds over the fire-prone areas. Such clouds may form naturally, especially over mountainous terrain, or may be produced or enhanced by the fires themselves. This note examines a September 1988 afternoon with fire-induced convective clouds as viewed with digital satellite data. It is recommended that similar studies be made of the entire 1988 fire season in the West to determine the frequency of clouds possibly suitable for seeding.

Towering cumulus or even cumulonimbus clouds may often be present during the summer months when the fire danger is greatest. In fact, thunderstorms often ignite the fires, and Project Skyfire of the 1950's was conducted to see if cloud seeding could reduce the lightning danger. Even during severe drought conditions in which there is little atmospheric water that is condensable into clouds, fires create water vapor as a product of combustion. The smoke from the fires should make the clouds extremely colloidally stable, with tiny cloud droplets. Thus, only the ice phase process should be able to make such clouds precipitate. Cloud seeding, with dry ice or AgI released from aircraft directly into the supercooled portions of fire-induced cumulus clouds, will initiate the precipitation process and might drop rain downwind of the fire, dampening the surface into which the fire is moving.

Fires which produce supercooled clouds may also create a circulation regime that could be exploited by setting AgI generators on the ground upwind of the fires. The AgI nuclei might then be drawn into the fire-induced cloud, seeding it when and if it becomes supercooled.

The idea of seeding convective clouds associated with forest fires is not new. For example, some exploratory work has been done in Alaska (Harpster and Douglas, 1971) and in Canada (Isaac et al., 1980). Perhaps a number of workers have even occasionally experimented with fire-induced cumulus. Such a cloud, labeled as Cloud 2 on 8 December 1972 in Holroyd et al. (1978), was seeded by the first author using an aircraft and dry ice pellets. It produced the second highest estimate of dry ice effectiveness of the reliable Australian experiments. This suggests that the ingested smoke did not radically alter the cloud microphysics so as to prevent seeding from starting the precipitation process.

The cover photograph of this volume shows two fire systems during the afternoon of 7 September 1988 as viewed by the NOAA-AVHRR polar orbiting satellite. The upper part is of the Yellowstone Park fires and the lower is of a fire on the south side of the Uinta Mountains of northeastern Utah. The state boundaries are shown in black. In the computer processing, fires were identified using the infrared band 3 (3.50 to 3.95 μm) with a threshold at 47 °C. They are colored in red on top of the Yellowstone smoke. A more orange tone is the fire area in the Uintas because a slightly different color processing was used to show the smoke emanating from the fire.

Of interest to weather modifiers are those parts of the clouds that were supercooled. Infrared band 4 (10.4 to 11.7 μm) was used to identify the 0 and -20 °C thresholds. Clouds between 0 and -20 °C are shown in green on top of the fires and smoke. Those clouds colder than -20 °C are shown in blue within the green ring. Five regions over the Yellowstone fires had supercooled clouds. One of them, and also the Uinta fire, had portions colder than -20 °C. A field of cumulus clouds with supercooled tops (green) was east of the Uinta fire.

Figure 1 shows cloud top temperature profiles with distance downwind of the fires. Surface temperatures adjacent to the fires and the fire locations are also indicated. The larger supercooled elements, labeled "TCU" for towering cumulus, are 5 to 7 km long, but most of the smoke is warmer than 0 °C.

The Yellowstone profile extends eastward from the large fire in the northwestern part of the park for a 29-km-wide swath through four of the supercooled cloud elements. The surface locations of the fires are marked by the broad lines at the bottom. The Uinta cloud was profiled within a similar swath in the direction of 123°. Scatter diagrams of temperatures within the swaths were prepared from which the general surface temperatures adjacent to the fires and

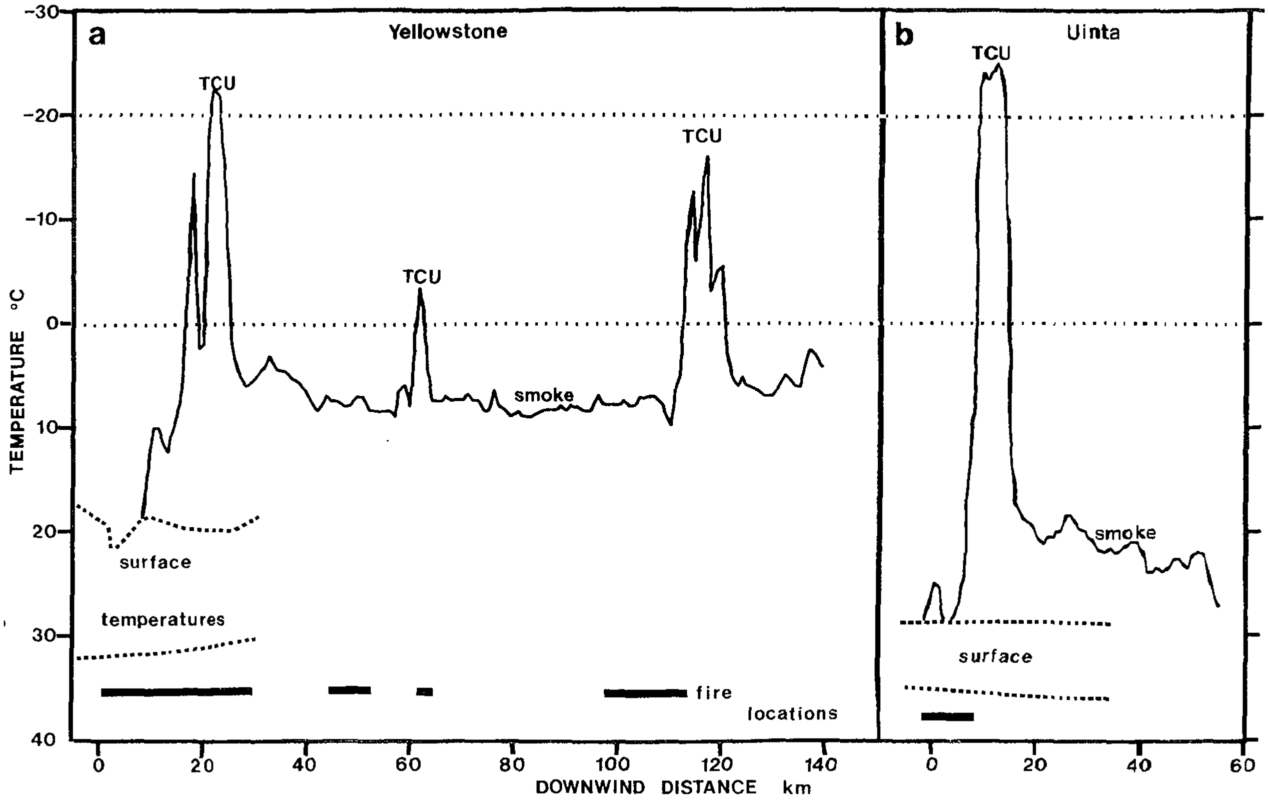

Figure 1. - Temperature profiles of the tops of clouds produced by (a) the Yellowstone fires and (b) the Uinta fire on 7 September 1988.

the coldest cloud temperatures were extracted. The larger supercooled cloud elements were 5 to 7 km long. Most of the smoke had tops at only about 7 °C for the Yellowstone fires and 21 °C for the Uinta fire, making such portions unsuitable for dry ice or AgI seeding technologies.

The ground release of AgI nuclei is perhaps the simplest strategy that can be carried out during an actual fire situation. The generators can be ignited upwind of a major fire whenever there is a possibility of the formation of supercooled fire-induced cumulus clouds. A more direct approach would be to use a high-performance aircraft to seed the developing turrets with dry ice as done in HIPLEX-1 (Smith et al., 1984). Not all large fires will produce clouds suitable for seeding, but the costs of seeding from either the ground or by aircraft are small compared to typical firefighting budgets. Minor fires are unlikely to produce fire-induced cumulus clouds that might become supercooled.

The rain from fire-induced clouds will be highly contaminated by the smoke. But those concerned with air pollution would most likely prefer to have rain wash the air rather than have the smoke travel across several states as it did from the 1988 Yellowstone fires. An ability to hinder the spread of large fires through cloud seeding could also be considered an air pollution reduction technique. The rain would reduce the smoke downwind by washing the air. The rain would reduce future smoke by hindering the future fire. Only in unusually calm air masses could the rain be expected to fall directly on the fire producing the fire-induced cumulus.

Rain from naturally occurring cumulus clouds might be initiated through cloud seeding to fall on the fire itself on some occasions. Several fires in northwestern Montana (not illustrated) had supercooled clouds near or over them on the afternoon of 7 September 1988.

This paper presents only a "snapshot" of fires during one afternoon. There were numerous other fires in the field of view of the satellite which produced only smoke and no fire-induced cumulus clouds. A study should be conducted to determine how frequently there were opportunities for seeding fire-induced clouds during the 1988 and perhaps earlier fire seasons. If the frequency was sufficient to justify it, exploratory seeding of convective clouds over fires should be carried out with state-of-the-art instrumentation systems used to physically evaluate the results in the manner of HIPLEX-1 (Cooper and Lawson, 1984). The potential benefit-cost ratio is too high to continue to ignore cloud seeding as one of the tools that might be used to fight range and forest fires.

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