

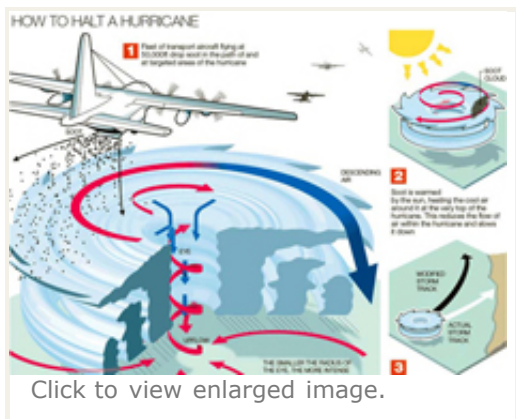


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## WHAT MATTERS: JUNE 2009

### My Journey to Engineer the Weather

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I arrived at MIT in 1996, and after two years of a frustrating search, I heard that Professor [Bob Langer](#) ScD '74 had been pondering how to modify hurricanes. Langer is one of the most prolific inventors at MIT with more than 700 patents, some of which became the cornerstone of \$100 billion industries. Although he is not an atmospheric scientist, he became my advisor and paid my way into my first hurricane modification initiative. Langer turned out to be just the right kind of advisor for me.

The National Oceanic and Atmospheric Administration ([NOAA](#)) conducted a hurricane modification project called [STORMFURY](#) that went on for more than 20 years until the mid-80s, doing experiments by seeding the clouds of hurricanes with freezing nuclei: silver iodide that promotes the freezing of super-cooled

water in the clouds of the eye wall. [Freezing nuclei](#) are made of a material whose crystalline properties resemble that of ice. (You might not believe it, but a hormone such as [testosterone is one of the best freezing nuclei](#)—but I cannot spare any.) [Silver iodide](#), which is not a very friendly chemical, was used in Stormfury in small quantities. My idea was that ice, after all, is the best freezing nucleus since its crystals are exactly the same as that of—ice! So I suggested carrying water in large transport airplanes equipped with heat exchangers that would be exposed to the high-speed cold air in high altitudes. The enhanced heat transfer would cause the water to freeze into snow or ice, and after grinding it in mid-flight, the small crystals could be used as freezing nuclei to replace silver iodide.

We contacted Joan and Robert Simpson, who initiated Stormfury, as well as other veterans at NOAA, and we were told that radar already showed that the hurricane's clouds [contain ice and that, therefore, adding artificial snow or ice would not make a difference](#) (pdf). Nevertheless, this work led to the development of a new snowmaking technology as a potential method for storing water and cooling from winters to summers, with recreational applications and more. This became my thesis topic at MIT's Department of Mechanical Engineering. Licensing of the new ice technology to [Boyd Technologies, LLC](#) is currently being discussed.

My second hurricane adventure was actually initiated by Professor [Kerry Emanuel](#), a brilliant atmospheric scientist from the Department of Earth, Atmospheric, and Planetary Sciences (EAPS), who never tires of explaining and simplifying complex scientific issues. Emanuel suggested retarding evaporation from the surface of the ocean, which contributes to the storm's intensity. For that, I constructed the [MIT Air-Sea Interaction Lab](#), where [evaporation retardation experiments were conducted using monolayer films](#). The monolayer is a one-molecule-thick film made of fatty alcohol that produces highly packed molecules that retard evaporation through the film, leading theoretically to a reduction of the hurricane's intensity when the material is spread in front of the storm. Unfortunately, our experiments showed that at high wind speeds the monolayer film is torn, becomes immersed in water waves, and is therefore not effective but

that at wind speeds of up to 25 mph, the monolayer retards evaporation by 70–80 percent, so it could be effective for use on water reservoirs, especially in dry, hot regions. Licensing of the new evaporation retardation technology to Boyd Technologies, LLC is currently being discussed. This work was the topic of my master's thesis in atmospheric sciences under Emanuel with material and assistance provided by the Langer Lab.

My third hurricane adventure was quite stormy, to say the least. I found 40-year-old Soviet literature reporting on a classified weather-modification project conducted in the Baltics in which an array of jet engines directed upward was used to form a "free jet." The jet formed by the engines entrains surrounding air and additional air is entrained in the entrained air and so forth, leading eventually to a huge mass of ascending air. The Soviet experiments successfully produced thunderstorms even in a stable atmosphere.

Remember the [butterfly effect](#)? According to it, a butterfly flapping its wings in Brazil may cause, in the chaotic weather system, a thunderstorm in Texas two weeks later. Well, I reasoned that one jet engine might be equivalent probably to about  $10^6$ – $10^7$  butterfly power. I suggested using an array or cluster of [jet engines mounted on a barge](#) (pdf) in the ocean to replace the butterflies.

This has become another hurricane-busting scheme that at least suggests, in my humble opinion, an effective physical means for perturbing the weather system—although we don't yet know how, where, and when to implement any hurricane-modification scheme. Nevertheless, I am now developing a new start-up to commercialize decommissioned jet engines directed upward in order to reverse a weather pattern called [atmospheric inversion](#) that causes frost and freezing damage to agricultural cash crops. There are extensive potential applications for this new technology.

My current hurricane modification adventure involves [Ross Hoffman](#), a brilliant, genial atmospheric scientist, and [Baruch Fischhoff](#), a thoughtful expert in decision-making and public risk perception. This time, we suggest seeding the divergent upper flow of the hurricane with carbon black (soot) nanoparticles, a suggestion made in the past—with some variations—by [W.M. Gray](#). The carbon black has optical properties that allow it to absorb solar energy that is imparted to the surrounding air, potentially altering the thermodynamics of the hurricane. Hoffman conducted simulations that showed that a hurricane's track is not "robust," meaning that, through relatively small perturbations, it might be possible to divert it from its track. (*Scientific American*, Oct. 2004). Fischhoff is covering the [public perception of risk, ethical, political, and policy issues](#) (pdf). My role is to cover the engineering challenges. We wrote a far-reaching NSF proposal that was rejected once. We hope to revise it soon. We focus on carbon black both in its own right and also with expectations that even if it is not successful, it may lead to potentially successful technology solutions.

The fundamental problem of weather modification is that reproducible controlled experiments are difficult if not impossible. There is always uncertainty whether the outcome of the modification, such as enhancing rainfall, is due to the modification or the natural variability of weather. Even if a well-supported theory of hurricane modification existed, the legal ramifications of weather modification on this scale are daunting. A few of the many possibilities:

1. The storm is not modified at all, but some people perceive that it is, suffer personal damage or injury, and file lawsuits.
2. The storm is modified according to theory, but still does significant damage and some people blame the modifiers on the damage, even though the modification actually reduced overall damage and impact.
3. The modified storm produced winners and losers and the perceived losers sue. For example, what if the hurricane abruptly changed course? The people affected by the new course might well blame the modification effort and sue. Imagine what would happen on the international scene if a

