## An Interesting Finding

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I have an idea of using converted helicopter rotors to push ground level humid air up to make rain. People tried to use jet engines to make clouds/rain. They made clouds but not rain (Vul'fson and Levin, 1987). There may be many reasons the jet engine failed to produce rain. To find out some differences between the jet engine method and the helicopter method, I made a simplified comparison between the two methods by using equation (8) in Alamaro, *et al.* (2006) and have some interesting findings.

The equation is

$$U_m(x) = 7.75(J/D(x))^{1/2}/x$$

where

$U_m(x)$ is the jet maximum average velocity at the center of the circular Gaussian velocity profile at the height x from the jet engine nozzle,
$J = D_0 A U_0^2$ is the momentum flux at the exit from the nozzle,
$D_0$ is the density of the gas at the nozzle,
$A$ is the cross sectional area of the nozzle,
$U_0$ is the speed at the exit from the engine which is approximated as uniform,
$D(x)$ is the air density as a function of height $x$.

Following the calculation in their Example B for the speed of a jet plume at $x$ = 1,000m due to a single engine, I use the same equation to calculate the $U_m(x)$ at $x$ = 5,000m from the same jet engine where $U_0$ is 460m/sec, $A$ has a diameter of 0.5m, and $D_0$ is 1.17kg/m$^3$. The $U_m$(5,000) from the jet engine is 0.446m/sec. The rate of gas sent up is 90m$^3$/sec.

The jet engine delivers a power of $D_0 A U_0^3/2$ at the nozzle. If a helicopter rotor delivers the same power at $U_0$ = 50m/sec, the area of the rotor will be equivalent to 153m$^2$. The rate of ground level humid air sent by the rotor is 7,650m$^3$/sec. The $U_m$(5,000) by the helicopter rotor is 1.35m/sec.

Likewise, when the air speed of a helicopter rotor is 25m/sec, the area of a rotor delivering the same power will be equivalent to 1,224m$^2$. The

rate of ground level humid air sent by the rotor is 30,600m$^3$/sec. The $U_m$(5,000) from the helicopter rotor is 1.92m/sec.

By assuming the gas sent up by the jet engine is the same as the ground level humid air, apparently, with the same power, the helicopter rotor can send much more ground level humid air up and with a higher air speed at the height of 5,000m. For the purpose of making rain, apparently, the helicopter rotor can do a better job. It is noted that the exhaust temperature plume effect is not considered in the $U_m(x)$ calculation. Nevertheless, to make rain, the consideration should be much more involved. While some people would like to do theoretical analyses, it may also be of interest to do some field tests by using helicopter rotors. With the controllable characteristics of the helicopter rotors, the helicopter rotors may also be used for some weather studies.

### References

Alamaro, M., Michele, J., Pudov, V., 2006: "A Preliminary Assessment of Inducing Anthropogenic Tropical Cyclones Using Compressible Free Jets and the Potential for Hurricane Mitigation," *Journal of Weather Modification*, **38**, 82-96.

Vul'fson, N. I., and L. M. Levin, 1987: The Meteotron as an Agent of Influence on the Atmosphere. A report of the E. K. Fedorov Institute of Applied Geophysics, Moscow. (Abstract and text in Russian, also with English abstract, available from the editor).