Why Injecting Fine Dust into a Tornado Is More Promising Than Injecting Coarse Dust: A Geometric Explanation

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Abstract

One of the promising ways to tame a tornado is to inject dust into it. Somewhat counter-intuitively, injecting coarse dust only makes the tornado stronger, while injecting fine dust can indeed help in the taming. This difference has been explained by a mathematical analysis of the corresponding equations, but (in contrast to the usual physics practice) this mathematical analysis has not yet been accompanied by a simple qualitative physical explanation. We show that such a simple explanation can be obtained if we analyze the problem of taming tornados from the geometric viewpoint.

1 Formulation of the Problem

How to tame a tornado: an idea. Blades in an empty blender rotate very fast. However, when we place some material into the blender, the blades slow down. The more material we place in a blender, the more the blades slow down. This known phenomenon leads to a natural idea that maybe we can slow down rotations in a tornado if we inject substance into it.

In general, this idea does not work well. An injection of heavy coarse material into a simulated flow has been tried; unfortunately, it turns out that such an injection only makes the flow stronger; see, e.g., [2, 9]. This is in line with how tornados usually evolve: a tornado starts small, and it power increases as it grabs more matter into its vortex.

This somewhat counter-intuitive experimental fact has been confirmed by a detailed theoretical analysis [4, 5, 6, 7, 8], according to which a insertion of coarse dust into a laminar flow indeed has a stabilizing effect on this flow.

There is still hope. Interestingly, the same theoretical analysis shows that insertion of *fine* dust into a flow destabilizes this flow. This fact provides a hope that an injection of fine dust can, in principle, tame the tornado [6, 7, 8].

Problem: we need a simple physical explanation. The above-mentioned theoretical explanation is too mathematical for the physicists' taste: it is mathematically correct but it lacks a simple qualitative physical explanation which usually accompanies mathematical analysis of physical phenomena.

What we do. In this paper, we show that a geometric analysis of the problem provides the desired simple qualitative explanation.

2 Analysis of the Problem

Describing tornados in geometric terms. From the geometric viewpoint, a tornado is a thick rotating volume of gas. Its 2-D projection is a circle.

This rotating mass also moves, but since the rotation is usually much faster than the linear motion, in the first approximation, we can ignore this linear movement and only concentrate on rotation. In this approximation, the tornado is symmetric with respect to rotations around its axis – and this is its only geometric symmetry.

The ideal state of the atmosphere: a geometric description. According to statistical physics (see, e.g., [1, 3]), all the processes, if undisturbed, eventually reach their most stable state – the state characterized by the maximal entropy.

For the atmosphere, this most stable state is (at least locally) a state with no linear or circular movement, a state in which the density depends only on the height. From the viewpoint of 2-D geometry, this state is invariant with respect to rotations, shifts, and scalings (dilations $\vec{x} \to \lambda \cdot \vec{x}$).

What we want to achieve when injecting dust. In geometric terms, taming a tornado means that we want to change from the state where the only symmetries are rotations to the state with more symmetries. Eventually, this happens – tornados do not last forever. What we want to do is to speed up this change. We want to achieve this speed-up by introducing a disturbance to the original process – e.g., by injecting dust.

How can we achieve that: a geometric idea. From the geometric viewpoint, if the disturbance has only the same symmetries as the original process, then the introduction of this disturbance does not change the symmetries of the process – and thus, does not lead to the desired objective.

In geometric terms, the only promising way to achieve the desired objective is to add disturbances which have *more* geometric symmetries. Hopefully, this will help the tornado process acquire more symmetries – and thus, speed up the transition to a more symmetric (and hence, less catastrophic) behavior.

The more symmetric the disturbance, the more promising is its influence on the tornado. Let us show that this explains the different effects of coarse and fine dust on tornado taming.

Case of coarse dust. Due to their friction, dust particles becomes smooth. In terms of a 2-D projection, a particle of coarse dust is a small circle.

Its symmetry group is the group of all rotations – exactly the same symmetries group as of the tornado itself. This explains why insertion of the coarse dust does not tame the tornado.

Case of fine dust. By definition, a fine dust consists of particles whose width can be ignored. In geometric terms, such a particle is represented by a point. In terms of the desired 2-D symmetries (rotations, shifts, and dilations), this point is invariant not only with respect to rotations, but also with respect to scalings.

In other words, fine dust has additional symmetries. In view of the above, this explains why injection of the fine dust can indeed destabilize the tornado process.

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