Jetwash-induced vortices and climate change

Wesley Schouw

1Affiliation not available

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Abstract

A revised view of the factors causing climate change which has immediate implications for public policy directed at halting or slowing climate change, and at ameliorating its effects. Climate change is driven primarily by shifts in patterns of global atmospheric circulation driven by persistent, large-scale vortices caused by the wake turbulence left by commercial air traffic. Because this traffic is so densely concentrated along the most highly-traveled routes, the vortices become semi-permanent, and their effects on atmospheric circulation are causing widespread changes in how the atmosphere traps and releases heat.

1. Introduction: Cause and effect

Earth’s climate is in the midst of drastic changes. These include the warming of the atmosphere and upper oceans, an increase in average sea level, and the loss of mass in the Greenland and Antarctic ice sheets (IPCC, 2013). These changes have been more dramatic over the last four decades than they have been at any other time in the last several millennia, and they can be attributed to human activity with “virtual certainty” (IPCC, 2014).

Not all shifts in global climatic indicators over that period are causes of global warming, however. In particular, the increase in atmospheric CO2 (Petit et al., 1999; Steffen, et al., 2015) is typically described as one of the primary drivers of warming (Hallett et al., 2002). And while those increases are clear indicators of climate change, there are good reasons to think that they are as a result of climate change, rather than being the root cause, of recent shifts in climatic conditions.

More specifically, rising CO2 levels is likely to be a form of feedback from changes in global wind patterns and in the atmospheric circulation of water vapor. Those latter two factors—rather than CO2 increases themselves—are responsible for climate change, and both of them are affected by a common, and recent, shift in human activity. This shift is the increasing frequency of long-distance air travel in jet-propelled aircraft, whose jetwash creates long-lasting vortices that affect wind patterns and atmospheric circulation. For that reason, the vortices are key contributors to anthropogenic climate change. That is the position introduced and defended in the present article.

The outline of the argument is as follows. It is well established that large-scale vortices, such as those caused by solar wind or other major perturbations, affect global wind patterns (Keller et al., 2002). Vortices of this kind, especially twinned vortices that stretch for up to a thousand kilometers at a time, have been observed to collect particles from surrounding regions (Glassmeier, K. H., & Heppner, 1992; Schunk, Zhu, & Sojka, 1994). This accumulation of particles offers a rich concentration of condensation nuclei that produces an accumulation of water vapor within and around the vortices. This is relevant to climate change because it disrupts the normal movement of water vapor caused by default patterns of atmospheric circulation, and atmospheric water vapor is well understood as a contributor to global warming (Salomon et al., 2010). Against this background of established findings, this article will then suggest, on the basis of several sources
of evidence, that vortices from jet-propelled aircraft magnifies and modifies the effects of existing atmospheric vortices and wind patterns.

2. Vortices and global atmospheric circulation

Earth’s weather systems are highly irregular (Figure 1). It is characterized by bands of wind activity running across the north Pacific, North America, and the north Atlantic, as well as a series of similar bands connecting the southern edges of Earth’s continents (Mingalev, Mingalex, & Mingaleva, 2012; Wu & Kayava, 2013). This presents a sharp contrast with other planets in the solar system, such as Jupiter, which present highly active weather systems that are nonetheless much more consistent. Jupiter, for instance, has patterns of global atmospheric circulation that appear to be form of bands that run perpendicular to the axis of the planet (Porco et al., 2003; West, Friedson, & Appleby, 1992).

Figure 1: Global Winds. Image created by the GEOS-5 Nature Run William Putman/NASA Goddard Space Flight Center.

The major factors that determine any planet’s large-scale patterns of atmospheric circulation involve the layout of land and water. Land masses heat faster on the surface than bodies of water do, and store heat less efficiently, creating updrafts over land, especially near coastlines. There is another crucial element in how this plays out, however, which is typically omitted from this list, and this is the formation and effects of vortices. A vortex is in essence a three-dimensional conveyor belt of air, which can be caused by either a moving body (see Section 3) or by temperature changes, evaporation, and other atmospheric changes. They can persist for long periods of time as they are to come degree self-sustaining, thanks to their rotational movement that reduces interaction with surrounding fluids (Barengy, Donnelly, & Vinen, 1983).

Vortices have always been part of Earth’s weather systems. This is because solids conduct heat better than liquids and gases. This is both because the particles in solids are so closely packed together and because of their relative lack of movement. Fluids move easily, and as they flow, they allow heat to be moved from one point to another, making it easier for the heat to dissipate. This is why land is hotter than the ocean.

In particular, solar heat is trapped in the uppermost layers of Earth’s landmasses. This causes air to rise faster above land than it does over large bodies of water, resulting in the formation of vortices at land/water boundaries. These vortices are often very large, stretching for thousands of miles. Once formed, they are persistent, semi-stable weather systems, and can drift across the planet much as storm systems do. Their stability comes from the fact that they are thermodynamically closed systems (Kreith & Margolis, 1959), such that they compensate for disruptions in their circulation by closing the break on a less viscous medium.
The land masses on earth are highly porous due to their varied composition (i.e., they are composed of multiple soils, types of rock, and geological formations of different kinds). This porosity allows ocean water, and water from large bodies of fresh water, to percolate into landmasses. That water then evaporates as it nears the surface, due to the storage of heat in earth and rock, and that evaporation exacerbates the formation of vortices, feeding into them and filling them with water vapor.

3. Vortices and global warming

3.1. Vortices and atmospheric circulation

Recently, humans have created a novel means of forming large-scale vortices capable of affecting atmospheric circulation. This technology is jet-powered flight. Twin-engine aircraft, such as commercial passenger jets, create vortices as they fly. Wake turbulence is atmospheric disturbance that is formed by the passage of an aircraft through fluid (Figures 2 and 3); it has several components, of which the most noteworthy are vortices formed by wingtips and by jetwash. These vortices are sometimes visible in the form of contrails, and they can persist for long periods of time if undisturbed.

In fact, aircraft create vortices at every point where there is a difference in the speed at which air flows across one surface relative to another. This happens at wingtips, for instance, where the air flowing over different portions of the wingtip moves at different speeds, creating a circular pattern of air movement as the wind continues to move forward (Green, 2012).

![Figure 2: Vortices left by an aircraft. Images reproduced from publicly available video produced by NASA using a C-5A Airliner.](https://www.youtube.com/watch?v=RadGavdgKAk)

However, the major driving force behind the powerful vortices created by modern aircraft is from jet wash, or the high-speed winds created by exhaust propelled out of jet engines. Friction between these winds and surrounding air creates powerful and persistent vortices. All aircraft create two counter-rotating vortices, circulating in opposite directions and pulling in surrounding air; as these expand following the passage of the aircraft, they interact with existing wind patterns.

Wind also has the ability to change the speed and direction of a vortex depending on the direction the vortex is rotating and wind is blowing. And crucially, atmospheric circulation tends to flow in one direction due to Earth’s rotation. Thus, under the influence of existing wind patterns, one of the vortices left by an aircraft’s jet engines will tend to be disrupted and will disperse, while the other will persist and become stronger.
Twin-engine aircraft are thus a major new source of powerful, long-lasting atmospheric vortices. This is why, for instance, flocks of birds are able to fly in large V-formations while aircraft with multiple engines cannot.

3.2. Wake turbulence, water vapor, and global warming

The significance of aircraft-produced vortices is that they last long enough to accumulate. Specifically, along highly trafficked routes, the passage of many twin-engine aircraft results in hundreds of vortices being formed within just a few hours. These vortices can combine, creating massive vortices on the scale of those that form naturally at land-water boundaries. More importantly, as long as air traffic continues to flow along a given route, the vortex there will consistently be reinforced (Figure 4).

These long-lasting, large-scale vortices differ from naturally occurring ones in several key ways. The most important of these is atmospheric location: aircraft-produced vortices form at approximately 30,000 feet, which is the average cruising altitude of commercial airliners.

This is also the altitude at which atmospheric water vapor typically condenses. This condensation is exacerbated by the presence of large vortices, because they tend to be saturated with condensation nuclei such as CO2, pollen, and dust swept up from the Earth’s surface. Water vapor latches onto these, and is transported up and down the vortex lines, which extend from aircraft’s points of origin to their destinations. Because the temperature of the exhaust fumes is extremely high (Eckbreth, Dobbs, Stufflebeam, & Tellex, 1984), they tend to melt ice molecules from clouds as aircraft pass, increasing the vapor available for condensation. In fact, ice molecules can be seen entering but not exiting the vortex as they are vaporized.
Speaking generally, the atmosphere holds more water vapor suspended over a given square meter of the Earth’s surface at higher altitudes than it does at lower altitudes, just because the available volume of air increases exponentially as one travels upward. This is why aircraft-produced vortices affect weather patterns: they redistribute water vapor and condensation nuclei, concentrating them along high-traffic flight paths, producing a consequent concentration of condensation. This creates effects clearly visible around the world in the form of devastating floods or destructive hail (Hoeppe, 2016).

4. Evidence of the atmospheric effects of wake turbulence

4.1. “Fallstreak” or “hole-punch” clouds

The above model is supported by several key considerations. The first of these is the existence of fallstreak clouds, which represent a reduced-scale version of the same effect. Fallstreak clouds, also known as hole-punch clouds, are examples of vortices created by aircraft as they pass through the cloud layer (Figure 5). Surrounding clouds are drawn toward the vortices, and, because these both contain high concentrations of potential condensation nuclei and are at sufficiently high temperature to melt cloud-born ice molecules, they produce condensation that falls to Earth as rain, snow, or hail (Heymsfield et al., 2010; Heymsfield et al., 2011).

A related phenomenon involves the increasing number of cumulus clouds being reported and photographed by the general public. This is another clear sign that water vapor is being driven up to higher altitudes than normal, allowing the sun to illuminate them even after it has set from the observer’s perspective.

4.2. Atmospheric magnification effects

Another key source of evidence involves visible distortion caused by the increases in water vapor density in the upper atmosphere that are caused by aircraft-produced vortices. Water vapor at different altitudes...

Figure 4: Locations of sustained vortices created by air travel. Image reproduced from publicly available video produced by EUMETSAT. Retrieved from https://www.youtube.com/watch?v=wVRbeGc_6zM
creates atmospheric disturbances, and these can focus the sun in a manner similar to a magnifying glass or a Fresnel lens (Owens, 1967; Tang & Munkelwitz, 1994).

This has two observable consequences. First, the distortions are sometimes visible as parhelia in the upper atmosphere (Figure 6), due to the multilens effect caused by the presence of water vapor at higher-than-normal altitudes (McDowell, 1974). Second, it increases global surface temperatures in certain areas and decreases it in others.

Figure 6: Parhelia. Retrieved from https://commons.wikimedia.org/wiki/File:Fargo_Sundogs_2_18_09.jpg.
4.3. Sea ice carving and air traffic

Finally, patterns of “carving,” or gradual erosion, in the sea ice surrounding the Arctic Circle and the Antarctic ice shelf closely follow global air traffic routes. See Figure 7, in which circular carvings of sea ice are visible running parallel to the routes of the most southern commercial flights.

Figure 7: NASA Blue Marble: Land surface, ocean color and sea ice (top panel). Base image is NASA Blue Marble: Land surface, shallow water, and shaded topography with airports and major flight routes route data is from Airline Route Mapper - http://arm.64hosts.com/ (middle panel).

This effect, too, can be attributed to the action of vortices. When atmospheric vortices break—which happens naturally as they weaken over time, or are disrupted by other weather patterns—the broken “ends” of the vortex cylinder will reconnect themselves either to the rest of the vortex or to a solid surface, whichever is nearer (Brady & Szoke, 1989). When land is the closer of the two, vortices touch down (as happens in the formation of tornadoes), and the heat and water vapor they carry are delivered to nearby surfaces. When
those surfaces are ice, they melt.

5. Conclusion

Climate change is an increasingly urgent economic and social issue across the globe. It is imperative now more than ever that scientists identify possible contributions to global warming made by various technologies and human activities (Hoeppe, 2016). The present article has argued that commercial flights between major international airports are among the leading causes of observed changes in climatic indicators, due to their effects on the formation of particle-laden vortices that affect the atmospheric distribution of water vapor.

This contradicts some extant models of the causes of climate change, such as the suggestion that CO2 is primarily responsible for rising temperatures. This article suggests that, instead, climate change is driven primarily by shifts in patterns of global atmospheric circulation driven by persistent, large-scale vortices caused by the vortices left by commercial air traffic. Because this traffic is so densely concentrated along the most highly-traveled routes, the vortices become semi-permanent, and their effects on atmospheric circulation are causing widespread changes in how the atmosphere traps and releases heat.

This revised view of the factors causing climate change has immediate implications for public policy directed at halting or slowing climate change, and at ameliorating its effects. In particular, reducing commercial air travel, and shifting high-traffic routes to avoid bodies of sea ice and other vulnerable locations, should be primary goals of parties concerned about the effects of climate change.

6. References


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