

The Impetus of Firenado

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Abstract

For the vortex formation of fire whirl, the mechanism or physics behind is discussed. If the driving force for the updraft of fire whirl is just buoyancy of heated-air and flame inside the vortex, the vortex of firenado reaching up to a few kilometers, even more, above the ground surface cannot be explained. There should be an additional driving force for the updraft. The driving force for the vortex formation of firenado is supposed to be the electric interaction of electric charges in the vortex of firenado with the induced electric charges in a crustal conducting body underground.

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Introduction

It has been known that fire whirls, “vertically oriented, intensely rotating columns of gas found in or near fires” (Paul A. Werth 2011), usually last no more than a few minutes in a small size; however, in rare cases, if fire whirl has a tornado-like strong vortex, it is called firenado or fire tornado, which occurs on a large scale fire or firestorm, such as bushfire, wildfire, forest fire, etc. (Countryman 1971, Goens 1978) Because fire whirl is similar to dust devil apparently in the respect of vortex formation and its dynamics, it is also called as fire devil or dust devil over burning ground.

The vortex strength of dust devil and fire whirl should be dependent on the temperature inside vortex because the updraft for both cases is supposed to be made from thermal convection. Also, the height of vortex should be dependent on the strength of vortex; then, the weakness of dust devil can be understood because the hot air near the surface is getting cold on uprising and then losing the driving force. Fire whirl is also expected to have a limit in the height and the strength of vortex. Then, it is wonder how so strong and such tall vortex of firenado can be possible.

First of all, in the vortex formation process, the effect of Coriolis force is reviewed for large-scale wind systems such as hurricane, typhoon, etc. and for small-scale wind systems, especially for fire whirl and dust devil. Then, it is suggested that vortex of firenado, even fire whirl, should be cyclonic² as long as the vortex itself has the driving force for updraft (fire and flame in the core of vortex). For the question, how firenado can have such strong tornado-like vortex, the electric interaction as in the vortex of tornado (Kim 2010) is suggested.

Vortex of Fire Whirl and Coriolis Force

The updraft of fire whirl is generated by a strong thermal convection (buoyancy of heated-air and flame) produced by centered fire inside the vortex of fire whirl. At the beginning of vortex formation, the swirling of air can be made by wind shear, viscosity, Coriolis force, geographical effect, etc. In which the Coriolis force is a fictitious force appeared on a moving object in a rotating frame of reference as the inertial force that is appeared in non-inertial frame of references.

In Fig. (1), a mass object is moving under the influence of Coriolis force, $\vec{F}_c = -2\vec{\omega} \times m\vec{v}$, in which angular velocity, $\omega = \frac{2\pi}{T} \approx 7.272 \times 10^{-5} \text{ rad} \cdot \text{s}^{-1}$ (T : period of earth rotation). The mass object is in

² viewing from above, it is counterclockwise in northern hemisphere and clockwise in southern hemisphere.

motion with velocity \bar{v}_0 at time, $t = t_0$; \bar{v}_1 , at $t = t_1$; \bar{v}_2 , at $t = t_2$, in which the velocity of moving object is changed in direction but not in magnitude because Coriolis force doesn't work on the moving object. As shown in Fig. (1), the effect of Coriolis force is directly proportional to the time elapsed or the distance the object traveled because the deviation angle, θ , is directly proportional to the time, t as $\Delta\theta \propto \Delta t$.

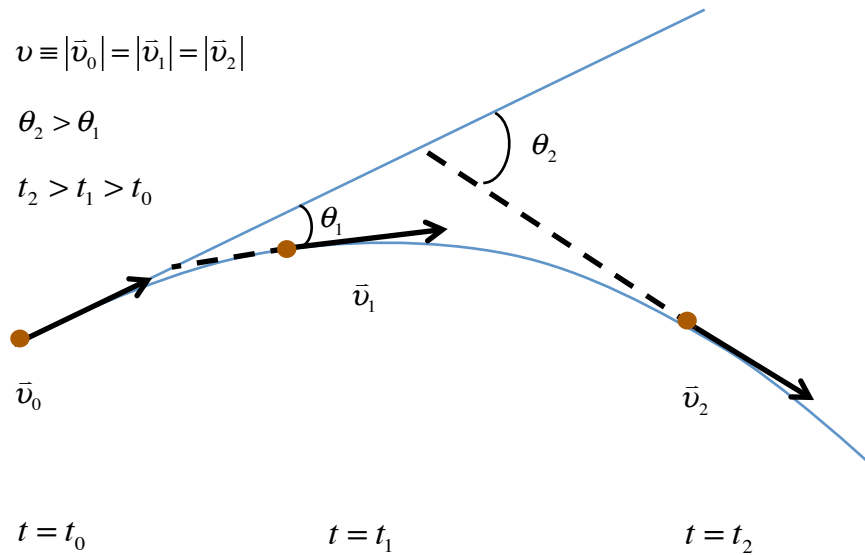


Fig. 1

In meteorology, to see the Coriolis effect on an air mass moving from high-pressure area to low-pressure area, the criterion of Rossby number³ is relevant (Ro), which says that the air mass has to travel a long distance since Coriolis force is so weak. Naturally, the criterion is applied to a large system, such as hurricane, typhoon, etc. of which the vortex is built up with all the air masses traveled such a long distance. However, according to the criterion of Rossby number, the Coriolis effect is negligibly small on a small system such as fire whirl, dust devil, waterspout, tornado, etc.

Nevertheless, the formation of vortex can be initiated from nearby updraft itself.⁴ For instance, if the updraft is formed from a strong thermal convection by fire, which produces an intensely localized low-pressure hot air columns, and if there is no dominant local effect against Coriolis force nearby the updraft for the incoming air flow that is feeding in the low-pressure updraft region, Coriolis force can be converged and strengthened nearby the updraft to initiate the vortex

³ $R_o = \frac{U}{fL}$, where U is speed scale; L , length scale; $f = 2\omega \cdot \sin\phi$ (ϕ : latitude)

⁴ It is not from a conventional theory in meteorology.

formation; hence, cyclonic vortex is created from nearby the updraft; then, angular momentum of the vortex is diffused out. The stronger updraft fire whirl has, the more likely the vortex of fire whirl is cyclonic because the intensity of Coriolis force is proportional to the velocity of mass object. Once the vortex of fire whirl is formed, the vortex is maintained with cyclostrophic balance.

As long as the driving force for updraft is included in the vortex itself as the flame in the vortex of fire whirl for a strong thermal convection and the Townsend avalanche process generating electric charges in the vortex of tornado for the electric interaction with a crustal conducting body underground (Kim 2010), and if Coriolis force can be converged and intensified nearby the updraft, it is natural to expect more cyclonic than anticyclonic rotation in the formation of vortex.

Even though firenado is similar to tornado in its strength and the damage it makes, the vortex of firenado is not connected to the base of a storm cloud, while the vortex of tornado is. Since dust devil also has no cloud connection, it might be valuable to review dust devil in its vortex formation and working mechanism briefly. The updraft of dust devil is made of locally hot air packet heated near a hot surface on the ground, but the ground surface maybe has an irregular shape and ununiformed temperature distribution; hence, airflow into the low-pressure region of updraft should not be uniform and also cannot be centered, from which a wind shear should be generated in a random direction to initiate the vortex formation; therefore, the vortex of dust devil should be equally possible for cyclonic or anticyclonic direction of rotation as shown in its statistics. (Goens 1978)

Electric Interaction

Although tornado is apparently a conventional meteorological phenomenon dealing with air pressure and pressure gradient force (PGF) in the atmosphere, the vortex of tornado is supposed to be initiated and maintained by the electric interaction between a storm cloud and a crustal conducting body underground, in which the electric interaction is electrostatic discharging process but much slower than in lightning discharges in atmosphere. (Kim 2010) Tornado is a process to get an electrical equilibrium between the storm cloud and the crustal conducting body such as the process of cloud-to-ground (CG) lightning discharges between a thundercloud and the ground.

Similarly, there is another interesting phenomenon in meteorology, although it is rare, so-called firenado or fire tornado, of which the name is given for a fire whirl (FireWhirl) that forms a tornado-like strong vortex and/or makes the damage like from a tornado. In historical firestorms (Daley 2018) (Hissong 1926) (Grazulis 2001) and recent wildfires in 2017 and 2018 (California, USA), the phenomenological descriptions of firenado are so bizarre and appalling; however, a

fundamental question is followed as how such strong vortex of firenado can be made and where the energy come from, in any way.

To create the vortex of fire whirl there should be an updraft. If the updraft is made only by the buoyancy of heated air and combustible gas (thermal convection) produced by fire, the driving force for the updraft of fire whirl is buoyancy of heated air inside vortex in which the air temperature can be maintained by flame that is also rising up to a certain height in the core of vortex. Then, the vortex of fire whirl is self-sustaining as long as fuels, burning debris and combustible gases, are being supplied. However, the driving force has a limit because the driving force for the updraft of fire whirl, that is, buoyancy of air inside the vortex depends on the temperature of air inside the vortex; the air temperature inside the vortex depends on the temperature of flame that can be reached up to $1800^{\circ} \sim 2000^{\circ} F$ (Garbert 2016). Since the strength of vortex in fire whirl, such as the wind speed inside vortex and the height of vortex, is supposed to be proportional to the driving force of fire whirl, there should be a limit such as how tall the vortex of fire whirl can be. Nevertheless, there have been many exceptional cases, those of which are called firenado or fire tornado. In the description of firenado, the height of vortex is frequently said to be tall and skinny reaching up to a few kilometers or even more above the ground. (Paul A. Werth 2011) Then, besides the internal thermal convection, there should be another driving force to raise the vortex up to such high altitude.

Although dust devil has no cloud connection and its driving force is the thermal convection as fire whirl, we've never heard the word such as dustnado or dust tornado. The clue to find the additional impetus for firenado should be in firenado itself as in the case of tornado (Kim 2010). What is unique of fire whirl? It is the fire that generates a strong thermal convection and the flame that is following up through the core of vortex. Not only does the fire of fire whirl make the thermal convection inside the vortex, but it also generates ionized particles and electrons from the burning process of combustible anything fed into the vortex; hence, the flame in the core of vortex is supposed to have lots of ionized particles and electrons, although it is not in a state of perfect plasma, and the ionized particles are mainly positive ions (T.S. CALL 1993). Instead of Townsend avalanche process to generate electrically charged particles in the vortex of tornado, fire whirl or firenado already has the electrically charged particles in the fire.

Now, it is supposed that there should be an electric interaction of the ionized particles and electrons inside the vortex of fire whirl with electric charges induced at the ground surface (fire whirl) or a crustal conducting body underground (firenado), which can be described with a schematic drawing as shown in Fig. (2-a) and Fig. (2-b), respectively.

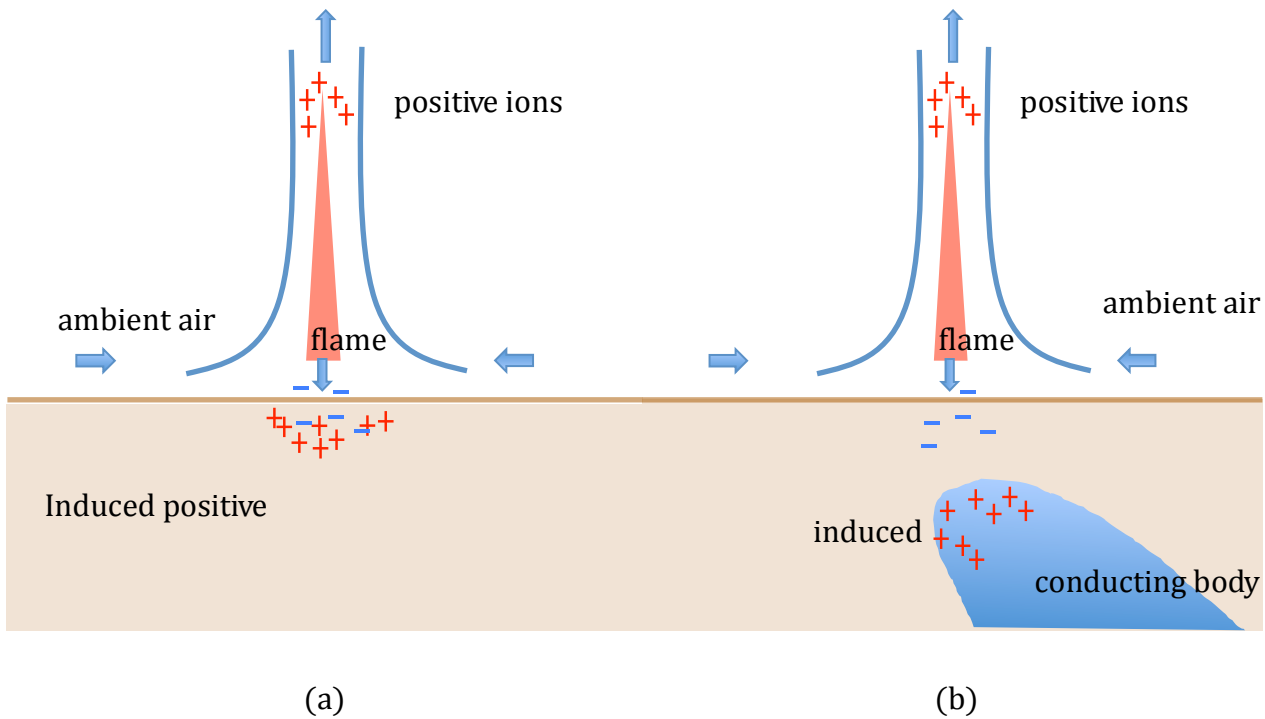


Fig. 2

In Fig. (2), the vortex of fire whirl contains lots of ions and electrons near the ground surface; since the mass of electron can be ignored if compared with the mass of ions, electrons are almost free from the buoyancy in the thermal convection inside the vortex of fire whirl and easily subjected to an external electric field. Then, more likely, some positive charges can be induced at the surface as shown in Fig. (2-a); electrons and negative charges, if any, are going down to discharge with the induced positive charges; positive ions in the vortex are being pushed upward, which should be the additional driving force to create the vortex of fire whirl. If the induced positive charges are locally isolated and small amount at the ground surface, the vortex of fire whirl might be transient such as the swirling of vortex appears momentarily and disappears. However, if a crustal conducting body underground is interacting with the fire whirl as shown in Fig. (2-b), the flame in the core of vortex is growing up tall since the flame itself is a kind of electrical conducting medium and the vortex of fire whirl is intensified; the fire whirl is self-sustaining as long as the fuel for fire such as burning debris and combustible gases keeps being sucked into the vortex and the electric interaction with the crustal conducting body is maintained. Although it is rare, fire whirl can be developed to firenado or fire tornado, so called, of which the vortex is as strong as the vortex of tornado and a spiraling flame is enclosed in the core of vortex.

Sometimes, firenado doesn't stay at one place but follows the electric field appeared on the ground surface right above the crustal conducting body because the upward electric field from the

conducting body pushes up positive ions in the air near the ground surface, which makes a low pressure area; thus, the firenado is pulled to the area, which depends on the electric charge distribution of the conducting body underground.

Discussion

Firenado and tornado, they look like different but behave like close relatives, of which the name is given just because it behaves like a tornado in the respect of the strength of its vortex and the damage it makes. Then, it is questionable how much we know about firenado and even tornado.

It is inferred that for the tornado-like strong vortex, firenado should have an additional driving force that is the electric interaction of electric charges of the flame inside the vortex of firenado with the electric charges induced at a crustal conducting body underground; also the vortex of firenado should be cyclonic as the vortex of tornado although it doesn't have to be such high percentile as the vortex of tornado. Moreover, it will be interesting if the statistics is reviewed for the cyclonic vortex of tornado, firenado, fire whirl, landspout, waterspout, etc., respectively.

There is an interesting comment by *Incident Behavior Analyst* as following (Kreider 2018); *"We have a concern as fire moves towards large bodies of water. Historically, there are five tragedy fires including this one to where we saw very rapid and abrupt changes to fire behavior as the fire gets closer to these cold bodies of water," Boursier said.*"

"We could have what we call blowup conditions. Cool air will be introduced to the fire area and that fire will get the air it needs to combust very rapidly. Other things that may happen include a channel of cold air topographically that could create those fire whirls and vortices, which is what we call them in scientific terms," said Boursier.

In which Mr. Boursier explained for the reason why the blowup⁵ conditions occur, which is partially agreeable because the cool air might speed up the burning process; however, as mentioned before, just with the cool air, the vortex of fire whirl cannot be strengthened enough to be tornado-like strong vortex. Instead, we can think about the electrical conductivity in freshwater or wet soil nearby the cold bodies of water⁶ that makes the electric interaction with the crustal conducting body underground get stronger, which makes the vortex of fire whirl intense; then, firenado can appear.

⁵ Blow-up: A sudden increase in fire intensity or rate of spread strong enough to prevent direct control or to upset control plans. Blow-ups are often accompanied by violent convection and may have other characteristics of a fire storm. (National Park Service | USDA Forest Service)

⁶ The electrical conductivity in wet soil should be much higher than in dry soil.

Recently, some weird phenomena in wildfires (California, USA in 2017 and 2018), such as “tree burns from the inside out”, “guardrail burning”, “metal melt “, and so on, have been revealed in YouTube website. Although an authorized agent did not report it, it is enough for us to bring up a reasonable suspicion whether an electric interaction is involved or not. Especially, one of them is interesting in that house fire started from the inside. (mental_boost) It can be considered as a puzzle; however, if the electric interaction is considered with a crustal conducting body underground, it might be a similar one as the lightning strikes in the atmosphere but from underground.

In fact, it is drastic idea, but it might be a new concept to be considered in wildfires from now on. Anyhow, to avoid the possibility of house fire in a similar situation, we should disconnect home electrical power line from outside including the disconnection from home electrical grounding system. Also, the weird phenomena, “California Wild Fires; Far From Normal” (EarthtoSpiritWarrior 2017), “Man Finds Tree Burning From Inside In California” (Philly 2017), etc. can be considered in the similar way.

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