Column Collapse

I have wanted to write something about column collapse for a while but have not had the time to collect my thoughts enough for it to make sense.

We hear a lot of warnings about “Column Collapse” on incidents and the dangers that are associated with a sudden collapse of a thunderstorm or smoke column. These are transmitted on weather briefings and even read out over command net during large incidents. You will also hear many instances where firefighters will relay instances where they have witnessed or been involved on an incident where a column has collapsed.

I am not sure(actually I am sure) that I do not necessarily fall into the category of people who feel that columnar collapse is all that common. In fact, I would submit to all of you that if collapsing columns were a common occurrence, we would actually have 19 situations which “Shout Watch Out”(I am old enough to remember when we had 13 situations which Shouted Watchout).

I do not want to be misunderstood that I do not believe that pyrocumulous columns, Plume Dominated Fires or thunderstorm cells are not dangerous and cannot have significant impacts on fires. I just do not believe that the “collapse” of the column is really possible in the sense of something collapsing- like a building or a dam..

To understand how a pyroculululous cloud or thundercell is formed, requires some basic meteorology and math.

I will try to keep this on track, and not go too far into the math and science behind the formation of the clouds.

First, we have to understand the Adibatic Lapse Rate. This is the rate at which a parcel of air warms or cools based on its ascent or decent through the atmosphere. You know that if you leave the valley floor and travel to Butte Meadows that you can feel the temperature change. This is due to the Adiabatic Lapse Rate. For every 1000 feet you gain in altitude, your air temperature will drop by 5.5 degrees F. Conversely, for every 1000 feet you lose in altitude, your air temperature will gain 5.5 degrees F.

This holds true until you reach the expected Dew Point for that day. The DP is the temperature at which a parcel of air becomes saturated enough to allow condensation to form.

For air to condense and a water droplet to form, there needs to be a dust particle or other carbon substance for the water vapor to adhere to and create a water droplet. Clouds are the formation of condensation and represent the DP- at a given elevation.

If we pick a 95 degree day on the valley floor, we can project what the temperatures will be at a given altitude. We also need to know the DP. Once the DP is reached the lapse rate changes over to 3 degrees for every 1000 feet(Wet Adiabatic Lapse Rate).

In our scenario, we see that we will have a 95 degree day in Chico and our DP is 45 degrees. Based on that math, at 11,000 feet we would expect the temperature to be 45 degrees F and at the elecation we could expect dew to form based on our given DP of 45 degrees.We can then figure out that at 20,000 feet the air temperature would be below freezing, at 18 degrees F.

The Troposphere is lowest of the five levels of the atmosphere. It exists from sea level to 30,000 feet. If we continue to the edge of the Troposphere we can project an air temperature of -12 degrees F.

Why is this important? How do clouds form at elevations where water vapor would exist as ice? *As air rises it cools and becomes denser. As air descends it warms and becomes more buoyant.*

It is this process that allows towering clouds to form. Air ascends and once it reachs DP it begins to get heavier and condenses and becomes a droplet of water and potentially an ice crystal or hail.

This is where I have to ask that you accept some meteorology principles without a lengthy explanation.. otherwise this would be a much longer document.

If the existing atmospheric conditions are capped(stable)and do not allow more vertical growth, the cloud will stop building and the cloud will move in the general steering winds and dissipate or lose energy. If the atmosphere is more unstable, the cloud will continue to rise and develop vertically.

As air molecules are bounced around in the vertical development(updrafts), friction occurs and heat is released. As the heat releases it allows the air molecules to continue to rise. This process can change the DP and allow the moisture molecules to continue to rise- forming denser clusters of ice or hail. Once these air molecules reach a given altitude, perhaps around 25,000 feet, they become too heavy to be supported and fall out of the column. As they fall, they create friction as they descend through the warming column of air. It is this friction that causes negative and positive ions to form and can generate lightning strikes.

As the molecules descend, several things begin to happen. They warm, releasing energy around them, they transition from ice to water to air and they displace air around them as they fall. Imagine the force of millions of these water droplets falling.

This is the process where air is entrained into the column, rises through the core, cools and falls outside the core and then proceeds to the lower atmosphere where it is warmed again- rises and repeats the cycle.

If we build a large fire under this column, it can cause several things to occur; it is releasing mass amounts of heat- allowing the column to rapidly expand and attain higher elevations than perhaps the atmosphere was primed for that day. As the fuel is consumed energy is released in the form of mass amounts of smoke, soot and carbon- and moisture. This allows the water molecules to form and begin their maturation process into hail or ice. The release of moisture from the burning vegetation also injects more moisture into the column, changing its formation and encouraging more vertical growth.

The existence of the fire is the difference between a Cumulonimbus Cloud and a Pyrocumulous Cloud. In a PC cloud we have the smoke interacting with the atmosphere- these can form and dissipate rapidly based on how much heat the fire is generating.

We know that the formation of any towering cloud will have wind associated with it. Most often in the form of outflow winds. These are a function of energy displacement and air molecules moving around. These wind currents can be enhanced by terrain or general steering winds. We can also see “gust fronts” form. A gust front is a short lived(relatively) parcel of air that moves out from a storm complex and travels laterally across the terrain. These are common with thunderstorms and are directly related to the storm’s strength. The storms strength is directly related to its maximum elevation- how much moisture it has, or the general steering winds. Powerful gust fronts can occur and actually cause structural damage. It is not uncommon to see winds in excess of 35-40mph come out of mature thunderstorms-remember those molecules are falling 25,000 plus feet to meet the ground- that is a lot of air moving.

A gust front will move out from the storm and lose energy the further it gets from the storm cloud, however, they may travel 15-20 miles or more before completely dissipating. The strength of the gust front may also have a lot to do with the effects of terrain. Think of air like water.. the more mountainous the terrain.. the more friction and disturbance to the air column- the shorter the duration of the gust front.

Now to the point of this paper… Column Collapse…

You will undoubtedly hear people talk about it and many believe they have been involved in an occurrence. There have been occurrences of column collapse- but I think some very certain circumstances need to exist to overcome the physics of the lapse rates and the movements of parcels of air. I am not sure that science supports the idea of a parcel of air falling 30,000 feet to the earth..

As we have just discussed, air warms as it falls- as it warms it becomes less dense and more buoyant. This is the very reason that air would not come crashing down in a collapse. I just do not feel that the fundamental principles of lapse rates allow air to move like that.

What circumstances could initiate a column collapse?

High Moisture Content

I believe a very moist sub layer of the atmosphere(area below 10,000 feet) would allow the dew point to be higher and the lapse rate to remain at 3 degrees for every 1000 feet. In that scenario moisture in the form of rain or hail could fall to lower elevations. The lower the moisture fell, the more air it will displace and drag with it and cause a larger portion of the column to reach the ground or near the ground. This displacement would most likely be evidenced by straight line winds leaving the base of the column and moving out laterally- potentially in all directions. A strong rain core in a column could cause a collapse.

Strong Directional Wind

If a fire becomes Plume Dominated and then a strong wind pushes the top of the column off, there is an opportunity for the column to be pushed down to the lower elevations. This would be caused by the mixing of the air at the top of the plume with the influx of the wind. The directional wind can also aid in column rotation. This rotation can draw larger quantities of air into the column and aid in the plume development. Rapid plume development can allow the influx of air and rapid ascent. If we have mixing taking place at the upper elevations from a gradient styled wind, we can see that column shear off and its impacts may be seen out in front of the fire. This could be a cause for a column collapse.

Sharp Change in Topography

Any substantial change in topography where a plume is built on a fire near a rapid ascent or descent in topography, there is a chance for the column to change its structure and collapse. This would be most evident as a fire moves closer to the terrain change. I would expect to see this occur where the terrain transitions off a bench or rapidly gives way from a slope to flatter terrain. This could occur in places like the Sierra Escarpment or where steep slopes transition into the desert. A rapid change, especially descent in terrain could cause a column collapse.

Fire Adjacent to a Water Source

A plume dominated fire which occurs near a water source can draw in cooler moist air and inject that air into the column. This would change the DP and the lapse rates. This would allow the fire to build a large plume with the additional moisture laden air. As the fire moves away from the moisture source, there could be a scenario where the column encounters much drier air and this changes the lifting mechanisms within the fire. This could cause the denser, cooler air to fall through the warm column and drag wind with it. This could be a cause of a column collapse.

Rapid Change in Fuel Type

If a fire builds a plume on it as it grows over a dense fuel bed such as heavy brush or timber, and then the fire transitions over a dramatic fuel type change to lighter fuels, this could cause a loss of heating and lift and cause the column to collapse. This is the least likely scenarios, because the fire would slowly lose energy.

Any combination of the above situations could lead to a collapse.

What explains what firefighters have experienced?

The downdrafts and wind currents associated with a thunderstorm or plume dominated fire are chaotic at best and can have some dramatic effects on a fire.

The outflows from large plume dominated fires can mimic thunderstorm outflows, but are usually not as strong or long lived.

The greatest threat is when a fire becomes plume dominated with associated thunderstorms in the area. This usually implies higher DP's and greater opportunity for vertical growth of storms and pyro clouds. This is where we can have columns develop high enough(greater than 30,000 feet) and have them produce hail and even lightning. In these scenarios we can have very strong downdrafts and straight line winds come out of the column. These winds can have dramatic effects on fires and cause erratic fire behavior.

The greatest indicator of outflow winds will be column rotation while you are on a fire. If you are in an area where Haines Index is forecast a Haines of 5 or 6 is a sign that your fire may develop a Pyrocumulous and could cause some strong outflow winds.