Thunderstorm formation:
What do the GNSS Precipitable Water Vapor (PWV) data say?

By: Fadwa Alshawaf

For the TRYAT project

Link to the YouTube video: https://youtu.be/rOQ7cKIZJDY

How often do you watch a thunderstorms?

Do you question what they are and how they form?

In this video, we will talk about thunderstorms and their relation to the PWV, precipitable water vapor.

A thunderstorm is a short-lived weather condition that includes rain shower accompanied with thunder, lightning, and strong, gusty wind. Globally, there are an estimated 16 million thunderstorms each year, and at any given moment, there are roughly 2,000 thunderstorms in progress. In Germany, the statistics show between 20 and 35 thunderstorm days per year.

Thunderstorm normally happen in the summer, and most likely in the afternoons, but they can also arise in the winter.

For a thunderstorm to form, these three conditions are required: moisture, namely water and water vapor, atmospheric-***instability***, and ***lifting***.

Thunderstorms develop under different circumstances. A possible condition is the following: On a sunny day, evaporation conveys abundance of water into the troposphere. This ***moisture*** is needed to get precipitation. Atmospheric instability indicates a continuous rising of warm, light air. The motion of warm air upwards is called lifting or convection and it happens because of rising temperatures, weather fronts or presence of mountains.

Let's take the first condition. When it is very warm near the surface and cold in the upper layers of the troposphere, this temperature gradient cause the warm humid air to raise so fast. This constant air supply to the upper tropospheric layers condenses forming cumulus clouds that grow rapidly to larger sizes until they are so heavy. These can also be thunderclouds that hold electricity due to the continuous collision of moving ice particles that show lighting sparks and thunder. When the clouds can pull no more moisture, they start to precipitate.

How does the PWV look like before and after a thunderstorm? Let's see what the data say:

In this figure, the left axis shows the PWV values for six days in June 2019, estimated from GNSS data at 15 minutes temporal resolution, close to Berlin, Germany. The right axis shows the hourly precipitation values. Provided by the German Weather Service (DWD).

From the weather service, we know there was a heavy thunderstorm on June 11th started after 20:00 hours UTC. The precipitation values are shown by the pink bars. We see here before the storm hits, the PWV starts to increase rapidly in a short time until it reaches a maximum. When the conditions are right and the clouds are adequately heavy, precipitation starts. Research shows that a sharp increase in PWV appears before a heavy rain event. It often happens that the peak of PWV coincides with the beginning of the rainfall. In the figure, we see this happen twice, on June 11th and 12th.

Although we see high PWV values in this time window, there was no precipitation. That can be explained as follows:

Water or water vapor stays in the atmosphere for just around eight days, on average. So, rain might fall later or the vapor and the clouds might move with the wind and precipitate somewhere else.

Although thunderstorm are familiar and seemingly non-threatening, severe thunderstorms are dangerous and my cause, among other things, losses of billions of dollars per year in terms of property and agriculture. How these severe thunderstorms respond to a warming climate is a growing cause for concern and research.

That’s it for today’s video. Thank you for watching!