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A newsletter for non-scientists (and scientists) interested in MAGIC

The last update discussed how an upward-pointing radar can utilize the Doppler effect to determine the downdraft (or updraft) velocity under conditions of light rain (drizzle), which allows determination of the terminal velocities of the drizzle drops and thus their sizes. The key element in that situation is that cloud drops are essentially standing still with respect to the surrounding air, and thus their velocities as measured by the radar are equal to the speed of the downdraft (or updraft). This approach won't work for heavy rain as the radar signal is dominated by the larger drops, and it is also attenuated by the falling rain. Under these situations a different technique is required, one that makes use of how radar signals are scattered by small water drops.

Most vertically-pointing radars have their receiver near their transmitter such that the signal received from cloud drops and raindrops is a wave that has been scattered straight back toward the radar, at 180 degrees. This backscatter signal depends on the size of the drop: it is small for small drops and initially increases rapidly with increasing drop size. At a certain size, depending on the radar frequency, the strength of this signal reaches a maximum value and then decreases to zero, after which it again increases to a value greater than the previous maximum. This behavior is not obvious, and not easy to explain, but is well known, and a graph of backscatter signal vs. drop size shows a distinct notch at this minimum. For a W-band radar, this notch occurs at drop diameter near 1.7 mm, medium-sized raindrops, which fall in still air (at sea level) at about 6 meters per second.

With this information the Doppler signal from a vertically pointing radar can be used to determine sizes and numbers of raindrops when there are downdrafts (or updrafts) under conditions of heavy rain. As discussed last time, the frequency shifts in the Doppler signal corresponds directly to speeds of the drops relative to the ground. Because there is a range of raindrop sizes, there will be a range of values. With increasing Doppler shift, the amplitude of this Doppler signal will exhibit a maximum, corresponding to the first maximum of the backscatter signal, then a minimum, corresponding to the minimum (i.e., notch) of the backscatter signal, and then will again increase. As the minimum corresponds to raindrops with diameter near 1.7 mm (for W-band radars), the corresponding value of the speed determined by the Doppler signal is equal to the speed such a drop would have in still air (near 6 meters per second) *plus* the speed of the downdraft (or *minus* the speed of the updraft). Thus the downdraft (or updraft) speed can be calculated by subtracting 6 meters per second from the measured speed at this minimum. Once the downdraft (or updraft) speed is known, the Doppler shifts can be converted to the raindrop fall speeds relative to the surrounding air, which are their terminal velocities. From these the raindrop sizes can be determined, and as the backscatter signal is known as a function of drop size, the total backscatter signal that is measured will allow determination of the number of drops of that size that are in the volume of air that is sampled.

This argument boils down to the following. The distinct notch in the backscatter signal will also occur in the Doppler signal, and we know the speed where this notch is supposed to occur. The amount by which we have to shift the curve to line it up to where it is supposed to be is the speed of the downdraft (or updraft). This shifted signal then gives all the information required to find drop sizes and numbers, and thus the drop size distribution, or DSD, that was discussed in the last update. This DSD can be used to calculated the rainfall rate, and this calculated value should equal the rate measured by disdrometers (as discussed in the MAGIC update of 2012-04-26).

A simple analogy that might clarify this topic is the following. Imagine a conveyor belt like those walkways at the airport, and imagine that at one end there is someone with a radar gun trying to determine how fast people are walking (i.e., their terminal velocities). The speed that is measured by the radar is the speed people are traveling relative to the ground, which is equal to their walking speeds PLUS the speed at which the conveyer belt is moving (this latter is analogous to the downdraft velocity). If the speed of the conveyor belt could be determined, then the walking speeds could be found. If everyone followed the rules (stand to the right, walk to the left), then the radar signal from those standing to the right would give the speed of the conveyor belt. Likewise, if the speed at which a given person walks is known, that speed can be used to determine how fast the conveyor belt is moving, and from that how fast everyone is walking (this is analogous to the situation with the backscatter notch discussed above). So, next time you’re on a conveyer belt you can think about whether you’re a cloud drop (stand to the right) or a raindrop (walk to the left).

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Please address any questions or comments to elewis@bnl.gov.
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