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Fog Detection at the Cabauw Experimental Site for Atmospheric Research by Means of Sensor Synergy

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At the Cabauw Experimental Site for Atmospheric Research (CESAR, Netherlands) the onset and evolution of fog layers is observed using a set of remote sensing and in-situ measurement systems. These instruments include: lidar, radar, microwave radiometer, visibility sensors, and SMPS aerosol data obtained at an altitude of 60 m at the CESAR tower. The onset of fog goes through a number of phases that are dependent on the atmospheric cooling rate, the aerosol size distribution parameters, the aerosol hygroscopicity and difference between atmospheric saturation vapor pressure and the saturation vapor pressure at the surface of individual aerosol particles. Each instrument is sensitive to detect fog, mist or haze in different ways. During the first development phase of the fog when the relative humidity (RH) is below 100%, visibilities can already be restricted to distances of less than 1 km. During this phase lidar signals penetrate the fog by detecting the swelling of aerosol particles, but neither the radar nor the microwave radiometer can detect the haze / mist particles as they are too small to be ‘seen’. In the second development phase when RH>100% a portion of the haze particles activate to fog droplets and grow to large sizes. Then the lidar signal is quickly extinguished as the larger fog droplets are an efficient scattering medium of laser light. However, under these saturated conditions the radar is the instrument best equipped to detect the fog droplets.

The onset of fog and its nocturnal evolution were observed during the night of 23 March 2011. Here we will describe the observations in detail emphasizing the difference in detection capability between the various instruments. For the purpose of this experiment, the CESAR cloud radar (35 GHz) was modified using an aluminium reflector plate to deflect the radar signal path from the vertical to the horizontal direction so that the fog layer could be observed over the surface. Also we model the phase changes using a microphysical / thermodynamic model in order to explain the observed variations in remote sensing signals . For RH < 100% we will simulate the lidar / radar backscatter / extinction characteristics of the wetted aerosols using the 60 m SMPS aerosol size spectra with a number of different values for the hygroscopicity to match the visibility and RH observations made at the tower. Using the observed atmospheric cooling rates we will then employ a microphysical cloud droplet activation model to simulate the transition from wetted aerosols to water droplets in order to explain the signal transitions of the radar / lidar between RH < 100 to RH > 100%.

Preliminary conclusion of this work is that for a complete detection of fog layers, it is necessary to employ simultaneously a lidar (most sensitive for RH < 100%) and a radar (most sensitive for RH > 100%), as the classical meteorological definition of fog includes atmospheric conditions with RH < 100%. This result thus may impact plans to develop remote sensing visibility detection systems for airport and traffic management.