

## **Lidar: Towards a new methodology for field measurement of spray drift**

By E GREGORIO<sup>1</sup>, X TORRENT<sup>1</sup>, F SOLANELLES<sup>2,4</sup>, R SANZ<sup>1</sup>, F ROCADENBOSCH<sup>3</sup>, J MASIP<sup>1</sup>, M RIBES-DASI<sup>1</sup>, S PLANAS DE MARTÍ<sup>1,2</sup> and J R ROSELL-POLO<sup>1</sup>

<sup>1</sup>*Departament d'Enginyeria Agroforestal, Research Group in AgroICT & Precision Agriculture, Universitat de Lleida-Agrotecnio Center, Lleida, Spain*

<sup>2</sup>*Departament d'Agricultura, Ramaderia, Pesca i Alimentació. Generalitat de Catalunya, Lleida, Spain*

<sup>3</sup>*Dept Teoria del Senyal i Comunicacions. Univ. Politècnica de Catalunya, Barcelona, Spain*

<sup>4</sup>*Research Group in AgroICT & Precision Agriculture, Spain*

Corresponding Author Email: [egregorio@eagrof.udl.cat](mailto:egregorio@eagrof.udl.cat)

### **Summary**

Lidar technology is becoming a promising alternative for spray drift measurement to the labour and time-expensive methodologies based on the ISO 22866 standard. This paper presents last advancements in an eye-safe lidar system specifically designed for drift monitoring. The lidar system was tested with an air-assisted sprayer in two cases: with standard hollow cone and air induction low-drift nozzles. The remaining variables (flow rate, environmental conditions,...) were similar. Lidar measurements allowed to know the time evolution of spray drift clouds and showed a much higher droplet concentration, dwelling time and dimensions for the cloud generated by standard nozzles. Also, the ability of the lidar system to distinguish different nozzle types according to their drift potential was proved. Finally, staring (laser beam stationary through the drift cloud) and 2D scanning measurements are discussed as starting points for an alternative spray drift measurement methodology.

**Key words:** Lidar system, spray drift, sprayer, nozzle type, drift measurement

### **Introduction**

Field measurement of pesticide spray drift is usually carried out by using passive collectors and tracers according to the ISO 22866:2005 standard. However, tests based on collectors are very expensive in terms of labour and time consumption. These factors limit the number of tests that can be carried out in practice. Furthermore, these methods only provide point measurements of the drift cloud, they are unable to monitor its temporal evolution, the collector efficiency depends on the prevailing weather conditions and subsequent chemical analyses are required (Gregorio *et al.*, 2014). Due to these limitations, there exists a great interest in developing new methodologies for measuring spray drift more efficiently.

Lidar (light detection and ranging) technology is an advantageous alternative to the use of collectors because it allows real-time monitoring of the spray drift, with high range-resolution and it requires only one person to operate the system. Furthermore, the experimental setup to perform the field tests only includes the sprayer and the lidar system itself. This is much more simple and faster to implement than the passive collectors setup based on the ISO 22866:2005. Other advantages

are related to the post-processing of experimental data. In passive collectors tests, huge human and time resources are required to carry out chemical analysis while the post-processing of lidar data is reduced to develop and apply computer algorithms which in addition, can be automated. Despite these advantages, most current lidar systems are designed to work emitting the laser beam in an upward vertical direction for atmospheric sounding purposes. Furthermore, their complex architecture, high cost and not eye-safe emission make them not appropriate for spray drift studies. Eye-safety is especially relevant because of the horizontal laser sounding in drift monitoring. The authors have recently developed a lidar system specifically designed for spray drift monitoring (Gregorio *et al.*, 2015). It is an affordable eye-safe system, easy to transport, with high range and temporal resolution.

The present study has three main objectives. First, to present the last improvements applied to the developed lidar system. Secondly, to verify that the lidar system is able to differentiate –by comparison- spray clouds generated by different nozzle types under similar test conditions. Finally, to propose ideas for a new methodology for field drift measurement using lidar systems as an alternative or complement to the ISO 22866:2005 standard.

## Materials & Methods

### *Experimental setup*

Two spray tests were carried out on 27 October 2015, in the School of Agrifood and Forestry Science and Engineering (Spanish initials: ETSEA) of Universitat de Lleida, in Lleida (Catalonia, Spain). An air-assisted orchard sprayer (Teyme Eolo-Star 1090, Teyme Tecnología Agrícola SL, Torre-Serona, Spain) with eight operating nozzles at each side (left/right) was used. Two nozzle types were tested: 1) standard hollow cone (Albuz ATR 80 Grey, Saint-Gobain, Evreux, France) and 2) air induction low-drift (Albuz TVI 80 03, Blue). At the working pressure (1 MPa), both nozzle flow rates are similar (2.08 and 2.19 L·min<sup>-1</sup> for the ATR and for TVI, respectively). As shown in Fig. 1, the lidar system was placed at 50 m from the sprayer to ensure full overlap between the laser beam and the telescope field-of-view. Distance between laser beam and sprayer was 5 m in order to obtain high values of the backscattered lidar signals. In both tests, the sprayer was kept in a static position while spraying during 16 s with tap water.

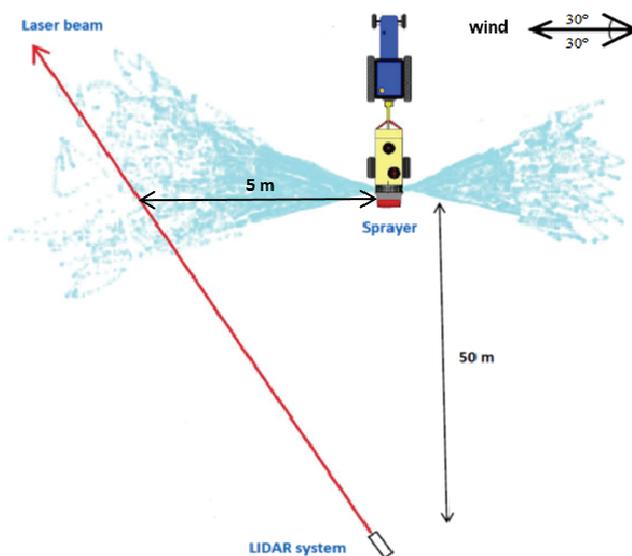


Fig 1. Relative position of the lidar system and the sprayer.

### *Lidar system*

The lidar system is based on a 1534-nm wavelength, 3-mJ pulse-energy erbium-glass laser and an 80-mm diameter telescope. A detailed description of this system can be found in Gregorio *et*

al. (2015). Recently, its scanning capability has been improved thanks to the implementation of a new pan & tilt unit (PT-2002, NB Security Systems, Roskilde, Denmark). This unit allows to scan at high speed, up to 25 and 12 degrees s<sup>-1</sup> in azimuth and elevation, respectively. Also, a flight-case (Fig. 2) has been designed to protect the electronic control components, including the industrial PC (digitiser) as well as the power supplies. From a practical point of view, it is noteworthy that all the system can be assembled by one operator in less than 5 mins.

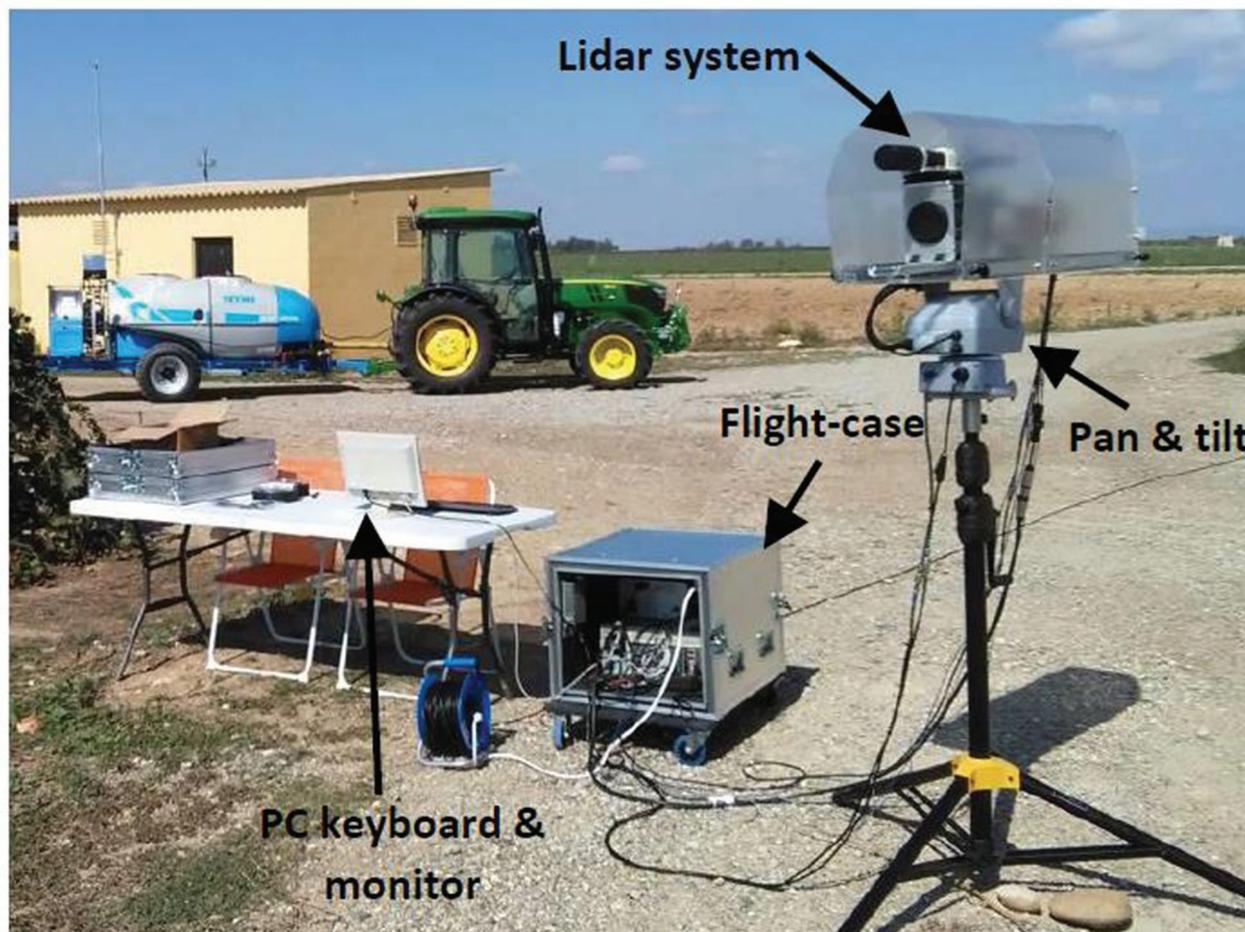


Fig. 2. The lidar operator is able to control the pointing (pan & tilt unit), the laser emission (included in the lidar system) and the digitiser (inside the flight-case) through the PC keyboard and the monitor.

The lidar system worked in staring mode (i.e. the laser beam was stationary through the drift cloud recording a line sample) with a pulse repetition frequency (PRF) of 5 Hz. It was observed that the signal backscattered by the spray cloud caused saturation on the photodetector. Due to this, a neutral density filter (10% of theoretical transmission) was placed at the laser output in order to reduce the emitted and received signals. This fact demonstrates the capacity of the lidar system to measure spray drift at distances much farther than the 50 m tested here.

#### *Data processing*

During the measurements, the digitiser acquires the backscattered signal corresponding to each emitted laser pulse. Each measurement was displayed in real-time by means of the GageScope<sup>®</sup> (DynamicSignals LLC, Lockport, IL, USA) oscilloscope software. As an example, Fig 3 presents several measurements (each curve is a measurement) where the range profiles of the signal intensity are shown. The digitiser saves each measurement in an ASCII file.

During the data processing, measurements were calibrated subtracting the background signal due to the atmospheric aerosols (Mie scattering) and the molecular (Rayleigh) scattering. In these tests, the background signal was calculated taking into account the measurements carried out along the 5 s previous to the start of the spraying. Since the lidar signal decreases with the square of the distance

(Collis & Russell, 1976), a distance (range) correction was applied to the calibrated measurement in order to allow their comparison. The range-corrected background-subtracted lidar measurements are used to generate range-time intensity (RTI) plots and time-integrated lidar signal following the procedure described in Gregorio *et al.* (2014). Numerical computer software (Matlab<sup>®</sup> versión 7.3, MathWorks Inc., Natick, Massachusetts, USA) was used for signal processing.

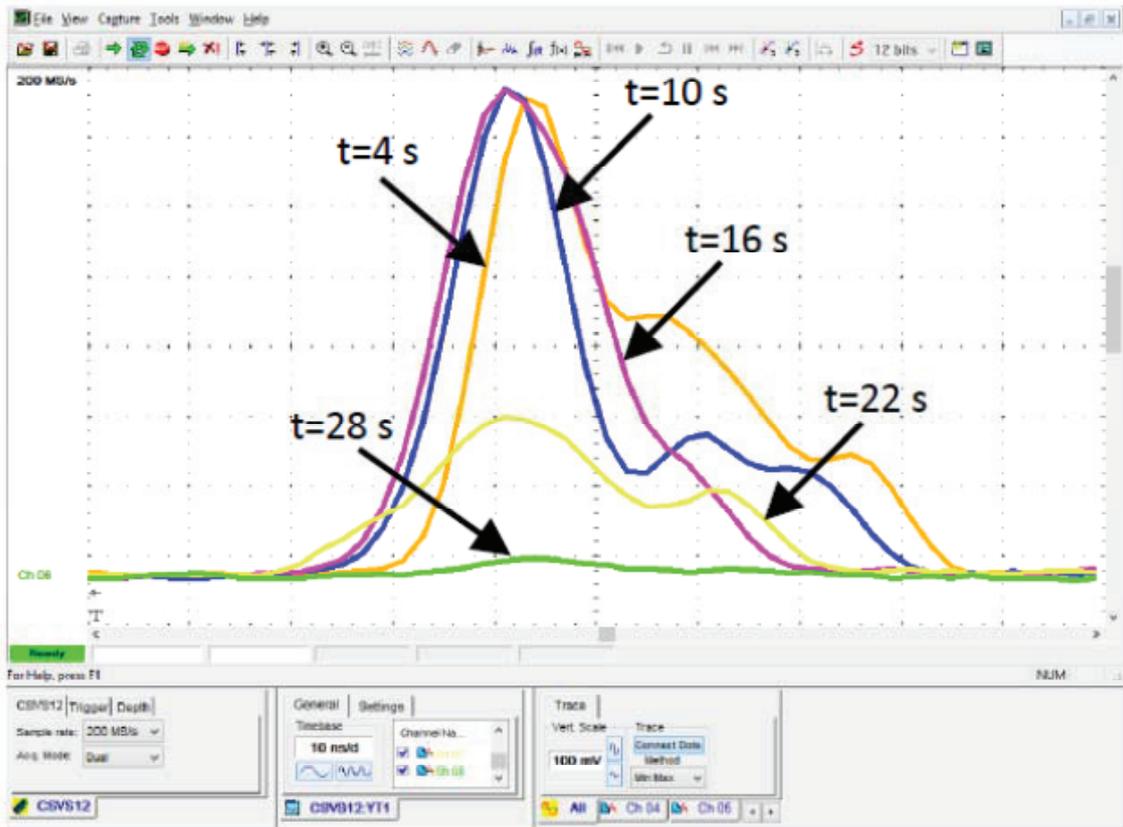


Fig. 3. Range profiles of the signal backscattered by the spray cloud at different times after the start of the spraying (standard nozzle). Vertical scale: 100 mV division<sup>-1</sup>; horizontal scale: 1.5 m division<sup>-1</sup>.

## Results

Figs 4 and 5 show RTI plots corresponding to the standard nozzle and low-drift nozzle tests, respectively. Both plots are represented at the same logarithmic scale for an easy comparison. In the case of the standard nozzle (Fig. 4), the airborne spray presents a high concentration up to 8 s ( $t=24$  s) after the end of the application (red line at  $t=16$  s) and is clearly visualised by the lidar system (not by the human eye) at least 16 s after the application ( $t=32$  s), moment at which ended the lidar measurement. For the low-drift nozzle test (Fig. 5), the spray remains suspended in the air for about 3 s ( $t=19$  s) after the end of the application. Moreover, residual spray is detected up to 10 s after the application ( $t=26$  s). In addition, the signal is an order of magnitude lower and the cloud reaches a width of 8 m, in comparison with the 15 m obtained with the standard nozzle.

Fig. 6 presents the range profiles of time-integrated lidar signals corresponding to both tests. While these curves do not provide information about the time-evolution of the spray drift, they give an easy comparison between signal intensity generated by each nozzle.

A drift reduction potential (DRP) value of 94% is estimated by comparing the area under the time-integrated lidar signal curve of the low-drift nozzle test with the area under the curve of the standard nozzle test (Fig. 6).

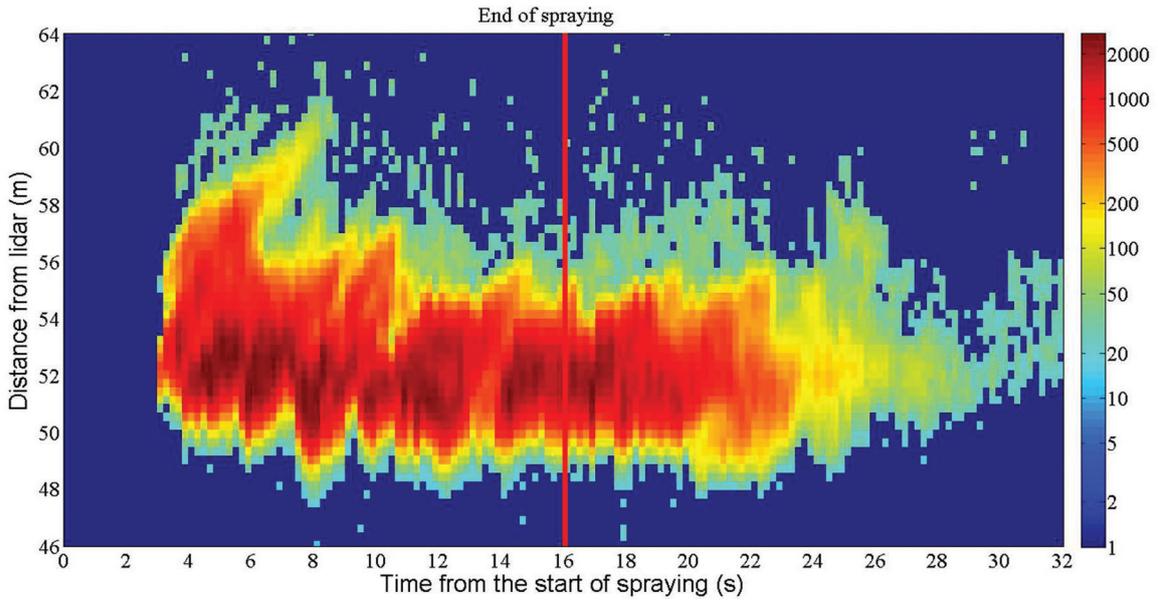


Fig 4. RTI plot corresponding to the standard nozzle test.

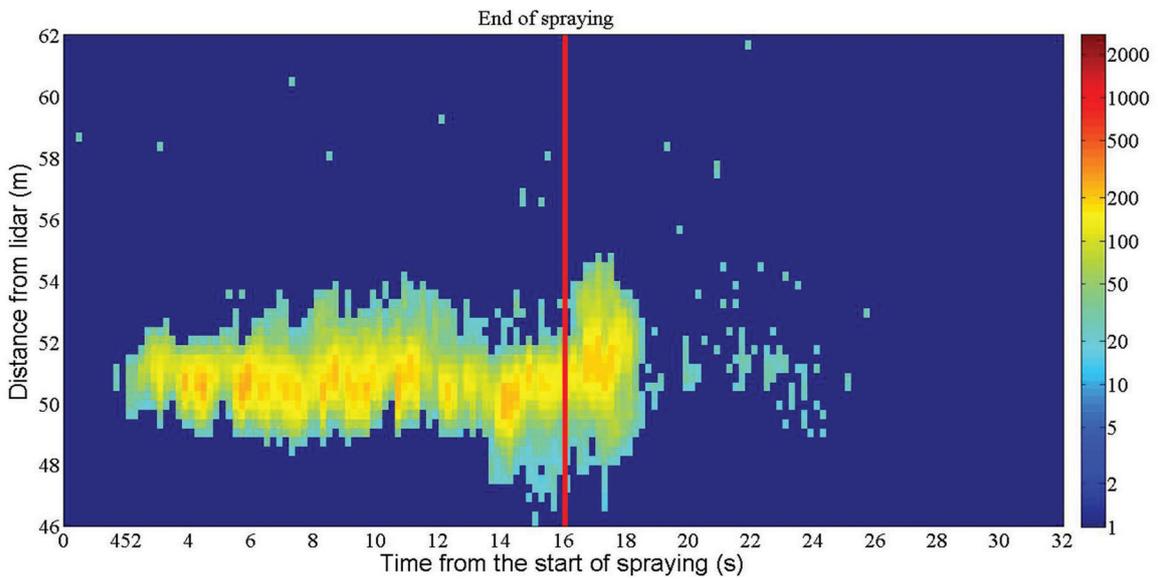


Fig 5. RTI plot corresponding to the low-drift nozzle test.

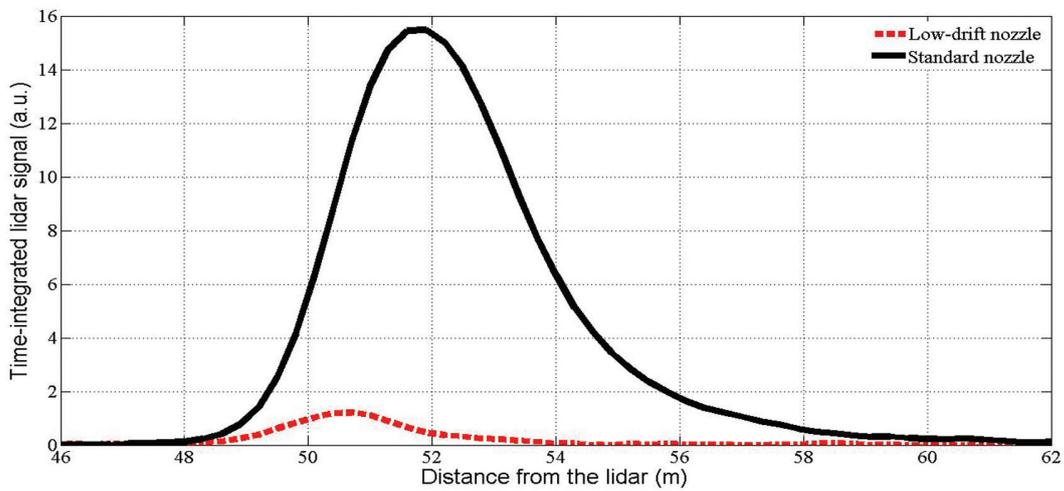


Fig. 6. Range profiles of time-integrated lidar signal corresponding to the low-drift nozzle (red) and the standard nozzle (black) tests.

## Discussion

Results presented in Figs. 4, 5 and 6 demonstrate that the lidar system is an appropriate tool to evaluate the drift potential of nozzles. Differences in lidar signal intensities between both nozzles are very significant, following a trend similar to the field test measurements carried out by Planas *et al.* (2013) in a fruit orchard. In this study, a DRP value of 91% was found for vertical depositions. It should be noted that these measurements were conducted according to ISO 22866:2005 and using different nozzle types. On the other hand, lidar results show that staring mode allows to study the time-evolution of the spray drift with high time-resolution (200 ms in these tests). In this sense, the time that the spray remains suspended in the air is related to the droplet size, among other parameters. It is known that the droplet size is one of the most influential spray application factors (Nuyttens *et al.*, 2011).

Furthermore, the implementation of a new pan & tilt unit opens the door to carry out quick 2D-scans. It should be noted that the scanning speed will be limited by the laser pulse frequency (maximum PRF equal to 10 Hz) and by the desired range-resolution. Higher speed implies a lower range-resolution (at a constant PRF). The choice between staring or scanning measurements depends whether high-time resolution information or bi-dimensional images (at lower time-resolution) are required. The presented advancements provide a good starting point for developing a new lidar-based methodology for the field measurement of spray drift in order to overcome the ISO 22866 labour and time requirements.

With respect to the prototype, the construction of a protective case for the lidar head (emission and reception subsystems) is planned. This case will reduce the exposure of the optoelectronic elements to dust or rain. Future works include the development of new software for an integrated control of the laser emitter, the digitiser and the pan & tilt unit. This will simplify the system operation and will allow an automatic storage of the azimuth and elevation angles at each measurement file.

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