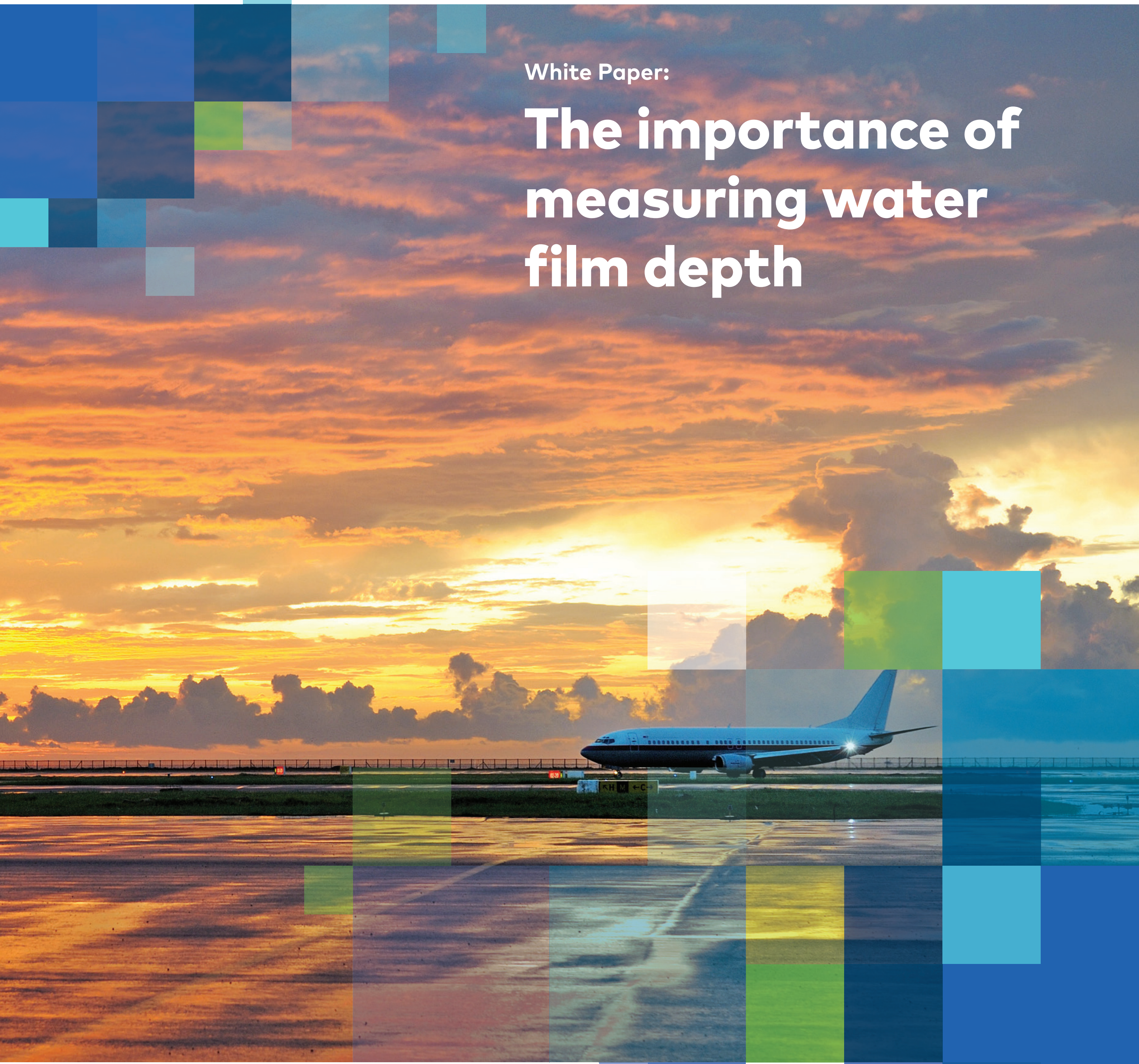
White Paper:

The importance of measuring water film depth



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As water accumulates on a runway due to intense rainfall or other factors, aircraft are at risk for aquaplaning (also known as hydroplaning). This leads to a loss of traction and, depending on the severity of conditions, can cause the pilot to lose control of the aircraft.

If you have ever driven a car on a rainy day, you know what aquaplaning is. Now think of the possible consequences of losing control of a 400-ton aircraft landing on a wet runway. The worst thing is: this situation is not rare at all. For airports with very high-intensity rain episodes (such as those in tropical areas) the hazard is often a reality.

The water film depth (WFD) is defined as the thickness of the water layer accumulated on the runway. It changes from one surface point to another, and also depends on time.

The DTN WFD algorithm can be leveraged by air traffic controllers to minimize the risk of aircraft aquaplaning during the critical times of takeoffs and landings.

The aquaplaning risk on runway operations depends on many factors, including runway slope, pavement texture, and some aircraft characteristics such as weight and tire inflation pressure.

According to ICAO Annex 14, a runway is contaminated by standing water when more than 25 percent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by water more than 3mm deep. By complying with minimum values of the longitudinal and transversal slopes, runways are built to drain water. However, water drainage is not an instantaneous process, and the depth of a water layer can grow as the runoff occurs.

Therefore, an estimate of the water film depth (WFD) may be used as a key element for assessing the aquaplaning risk during rainfall conditions. Indeed, an accurate estimation of the accumulated water on critical areas such as the runway touchdown zone (TDZ) can be directly related to the severity of the risk.

For both ATC and pilots, this knowledge represents valuable information that leads to safer and more efficient management of operations.

A new way of calculating WFD

The WFD Module developed by DTN integrates real-time measured rainfall intensity data to achieve continuous water height estimations at any point of the pavement.

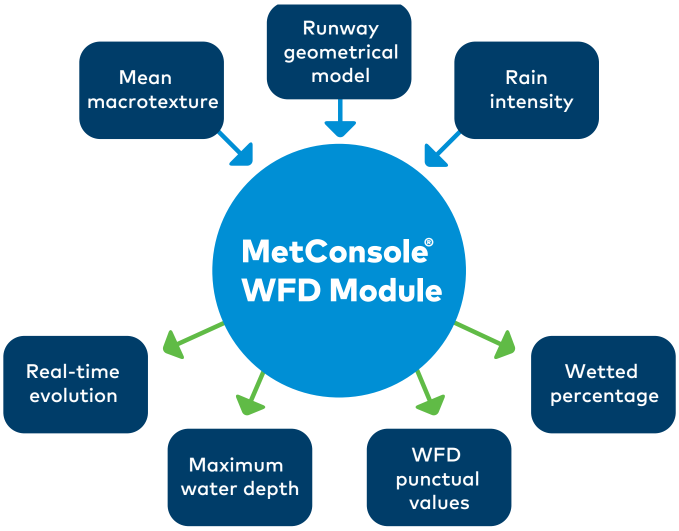
Unlike many other similar algorithms, the WFD Module is designed using both stationary and transitory approaches, which means that a continuous evolution of the WFD can be tracked while applying the well-known empirical models (such as those used in road design).

The WFD Module has been implemented in DTN MetConsole® AWOS and is available for deployment. The Module uses as inputs:

- The rain intensity, ideally in one-minute intervals. The algorithm accepts any sources of measurement, including pluviometers, present weather sensors, and external networks. More inputs will bring more precise estimations. All kinds of low- and high-intensity rainfalls, for short or long periods, are suitable.
- The longitudinal profile of the runway and the mean cross slope, as found in the official airport diagrams. A simplified 3-D model of the surface is internally built in order to calculate the different drainage lengths, paying attention to those areas where the flow paths converge and water may accumulate. Indeed, the algorithm can work with much more complex models, if there is available information.
- The mean macrotexture, related with pavement's resistance to the runoff.

The low number of necessary inputs results in an easy, immediate implementation for those customers that use MetConsole AWOS, with no effects on airport normal activity. The method continuously reports:

- Values of the WFD at a defined set of point locations "x, y" of the runway surface, such as the TDZ. The points are configured as part of the installation and they are chosen by the customer.
- The percentage of WFD exceeding the recommended height in a certain area (usually per thirds of runway) according to ICAO guidelines.



WFD Module Diagram. Estimation of runway water film depth from rainfall intensity instruments is accurate enough to provide decision support capabilities.

- The maximum overall estimated water height.
- The evolution in time of the previous three magnitudes.

Also, the WFD Module can be used in conjunction with pavement sensors to enable the self-calibration feature. Pavement sensors give precise, punctual measurements of the water layer, but they lack information for the rest of the runway. MetConsole combines them and the WFD Module to ensure the best performance of both.

When stationary meets transitory

- Historically, applying the equations of overland flow is a difficult problem to solve. The well-known Gallaway equation offers an empirical formula based on certain relationships and measurements of drainage lengths, rainfall intensities, slopes and other factors. Authorities around the world view this long-standing formula as reliable and use it.

Figure 1. Estimations vs. empirical model

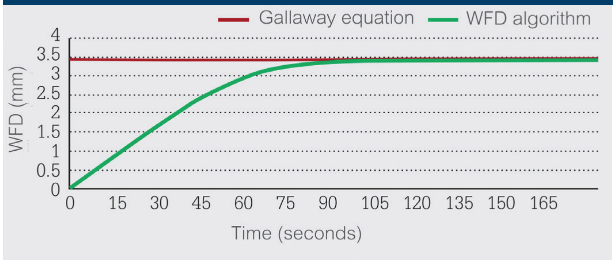


Figure 2. Rain event

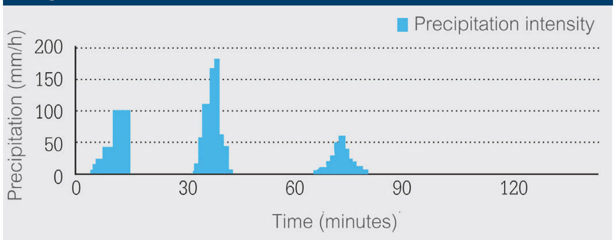


Figure 3. Estimations vs. measurements

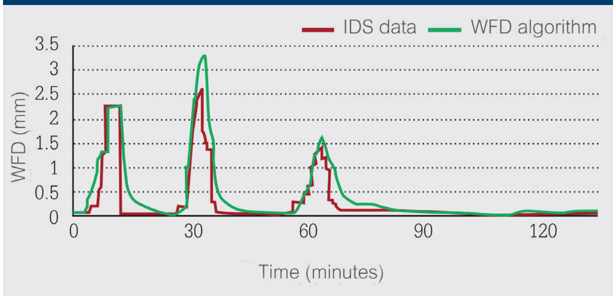
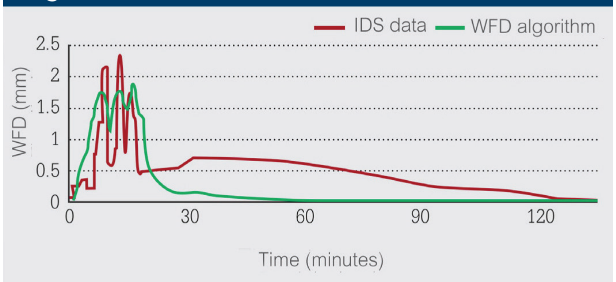


Figure 4. Estimations vs. measurements



Figures 1-4. Be aware of the risk — when the risk begins. The equations of the Fluid Mechanics that govern the growth of the water layer are internally solved by the WFD Module to provide runway real-time status.

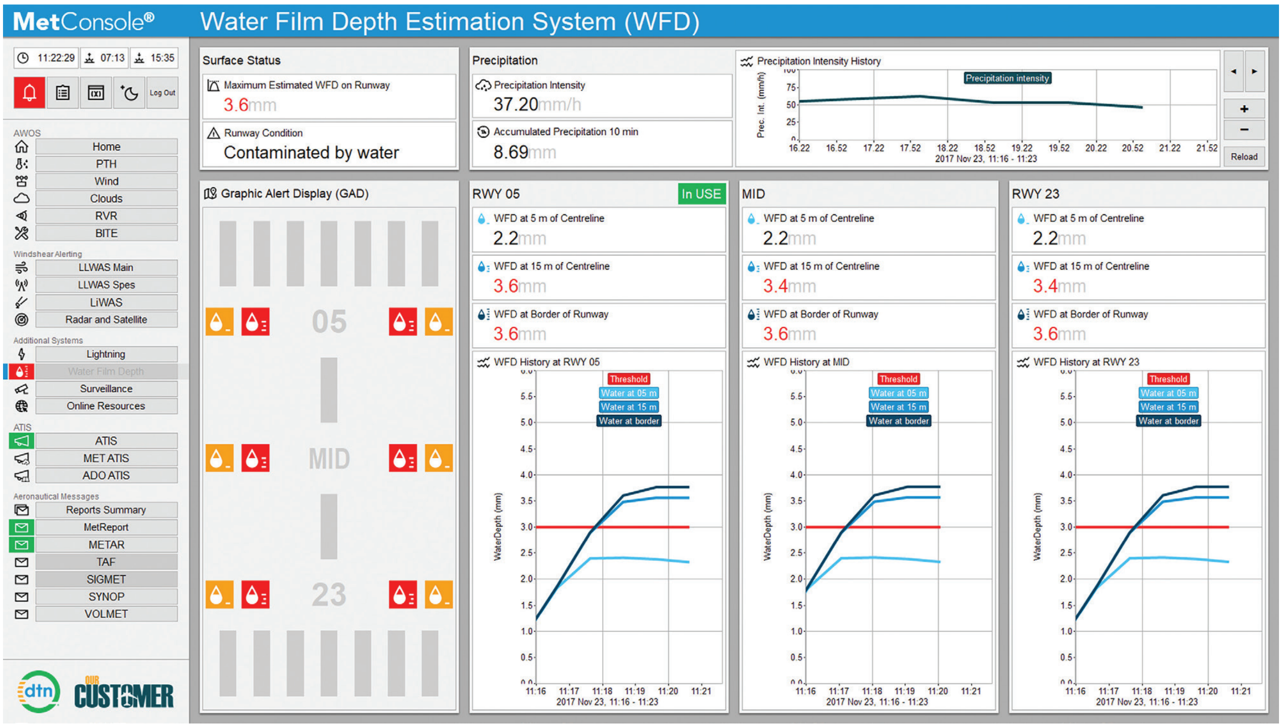


Figure 5. Full integration with MetConsole, including alert management and graphical visualization of the runway status.

The DTN WFD Module is compared to the empirical model in a simulated rain event of constant intensity of 200 mm/h, for a drainage length of five meters (see *Figure 1*). Green line (transitory model) represents the water depth estimation given by the algorithm. After the stationary conditions are reached, its value equals the one predicted by the Gallaway equation (red line). In this sense, the water film depth estimation algorithm is an extension of the Gallaway method, accepted worldwide, to transitory periods.

As soon as a rain data intensity is taken, the algorithm begins to compute the water film depth. The runway geometrical model is divided in parts and the flow lines corresponding to each drainage plane are analyzed. The macrotexture is used to take into account the pavement storage and the fact that the runoff occurs after a certain water height.

To test its performance, the WFD algorithm results were confronted with historical data from pavement sensors, in total more than 4.7 million real measurements that were taken over a nine-month period, by 12 different sensors in five airports. Rainfall intensity data was also provided. The most important data for the WFD algorithm test was the water film.

Throughout this and the rest of the tests, the mean absolute percentage deviation (MAPD) was computed, as an indicator of the accuracy. The estimations provided by the algorithm were perfectly acceptable.

Because of the geometrical model that averages the conditions on the runway, the comparison between the estimations and the punctual measurements of the pavement sensors turns out to be a careful problem (*Figure 4*). Slight changes of the geometry and the formation of puddles explain the differences that may be encountered when comparing external sensors and the WFD Module, and they can be used to fine-tune the internal working of the algorithm.

Features of the main systems are compared in the table below:

Features	Systems based on pavement sensors	Systems based on empirical estimation of the runoff properties	MetConsole WFD Module
Low-cost, easy implementation	⊗	⊗	✔
Real-time transitory evolution tracking of the water layer growth	✔	⊗	✔
Full-length runway WFD values	⊗	✔	✔
Installation does not require work on runway, nor its closing	⊗	⊗	✔
Self-calibration feature using external measurements	⊗	⊗	✔
No out-of-range values, or unlimited range	⊗	✔	✔
High customization of displayed information	⊗	⊗	✔
Hardware independent: it suits almost any number and brand of sensors	✔	⊗	✔

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Conclusion

The DTN WFD Module is a pioneering algorithm for estimating water accumulation on runways with a low number of measurements, capable of being deployed with no effect on an airport's normal operation. MetConsole's alerting capabilities support real-time decision making for Air Traffic Controllers and pilots during rainfall events.

About us

DTN has been in the Weather Systems business for more than 35 years, providing high value products to comply with the most rigorous standards of its customers.

In particular, DTN's Aviation Weather Solutions have been installed and integrated in more than 350 airports worldwide already.

Get to know the DTN WFD Module and the rest of DTN Weather Solutions at www.dtn.com or contact us at +31 345 544 080.

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