USING NUMERICAL WEATHER PREDICTION TO FORECAST WIND DIRECTION VARIABILITY

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Introduction

Broad fire fronts generally propagate more rapidly than narrower "linear" fires. They also create a wider damage swath, are more difficult to control, and fire-atmosphere coupling tends to be strongest for large fires.

Conditions with highly variable wind direction can help to broaden the fire front. This factor may be important both for established fires and for new ignitions, for example from spotting. Here, we aim to investigate structures in the atmospheric boundary layer which are conducive to high wind direction variability, and to recommend ways to improve forecasts of direction variability using ACCESS.

The variability of wind direction is neither routinely forecast nor routinely measured. The main application of wind direction variability is for forecasting pollution dispersion, when the most critical forecasts occur during periods of light winds and highly stable stratification, typically at night. Unfortunately this situation is of relatively low importance for fire behaviour, and there is a need to improve knowledge of wind direction variability in strong winds and high temperatures. Research into fluctuations in wind energy production has shown some promising results that may be relevant in this regard.

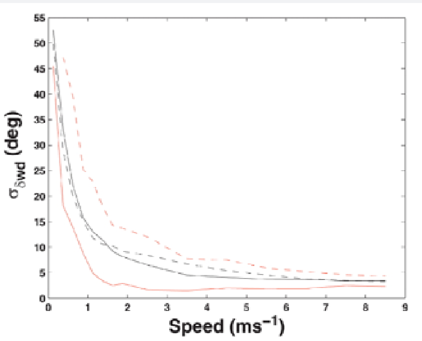

Fig 1. The standard deviation of the change in wind direction between consecutive one-minute averages from two different sites. Daytime: dashed curves. Night: solid curves. From Mahrt (2011).

Sources of direction variability

Direction variability can be divided into that due to turbulence, and that due to larger-scale motions.

Variability due to turbulence is relatively well-understood. Surface-layer similarity theory (Kaimal and Finnegan 1994) predicts the near-surface cross-stream velocity variance. Simplified turbulence closure models, such as the level 2 model of Mellor and Yamada (1982) give this quantity above the surface layer. The direction variance is then the cross-stream velocity variance divided by the wind speed squared. These estimates verify well against observations, and include the important stability dependence.

Larger-scale motions include boundary-layer rolls (Etling and Brown 1993), convective clouds (Vincent 2010), lateral plume meandering (Hanna 1983) and flows induced by topography (Mahrt 2011). These induce direction variability on time scales ranging from minutes or longer.

The direction variability is less for high wind speeds and at night (Fig 1).

The direction variability depends on the wind averaging period, and is less for longer averaging periods. It is not known what averaging period is most suitable for fire spread, but it is likely that this depends on the size of the fire.

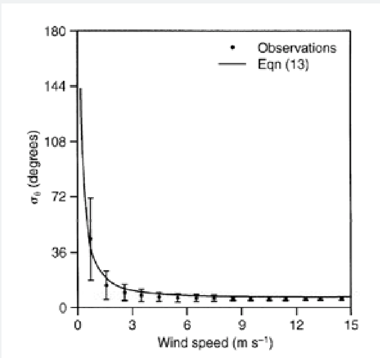

Fig 2. Observed (points) and predicted (curve) standard deviation of wind direction. From Davies and Thomson (1999).

Forecasting direction variability

Empirical parameterisations of direction variability show good agreement with observations (Fig 2). Caution is necessary, however, since the amount of verification data is small and the main focus has been on highly stable conditions, of less relevance to fire weather.

Numerical Weather Prediction systems are now of sufficiently high resolution to explicitly represent some of the larger-scale sources of variability. The main focus has been on forecasting wind speed variability for the wind energy industry. For example, Vincent (2011) showed that a 2-km grid model could represent wind variations with a time-scale of about an hour, associated with an open-cellular cumulus field over the North Sea.

The way forward

The available parameterisations will be implemented and tested using ACCESS data. Two challenges are anticipated: that most of the existing research focusses on stable conditions, and the paucity of verification data. A significant effort is planned to acquire suitable data from existing research field experiments.

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