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Near-surface turbulent wind flow over single terrain changes in tropical cyclones

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INTRODUCTION

Using wind observations from three tropical cyclone field campaigns, an analysis of near-surface turbulence is undertaken. With towers deployed in a variety of terrain exposures, preliminary results show turbulent parameters to be highly dependent on upstream terrain conditions. 'Memory' of these conditions can remain in the flow for many kilometres downwind a surface adjustment.

INFLUENCE OF UNDERLYING SURFACE ROUGHNESS

Historically, researchers have sought to utilise field campaign measurements to assess near-surface wind turbulence characteristics (e.g., gust factors, turbulence intensity) during landfalling tropical cyclones. A common assumption is that flow properties at any given location are in equilibrium with the underlying terrain. However, considering the largely inhomogeneous surface of the Earth, this is not generally the case. Changes in upstream roughness lead to the growth of internal boundary layers (IBL), which control how the mean and turbulent flow characteristics adjust to the new underlying surface (Figure 1). It is unclear whether current models that describe this adjustment are appropriate for tropical cyclones.

METHODOLOGY

To evaluate how changes in terrain influence measured turbulence, data from two tropical cyclone field campaigns in the USA (StickNet – TTU, FCMP – Univ. Florida) and our own campaign here in Australia (SWIRLnet – with JCU) were aggregated and analysed. For each measurement tower, wind speed data were binned into 10-minute intervals and 10° segments. Underlying and upwind terrain was determined through a mix of automated identification using the C-CAP Land Cover Database and visual analysis with Google Earth. The distance to the first change in terrain (e.g. sand to ocean in Figure 2), *fetch*, was measured so the influence of this variable on measured statistics could be determined. The Engineering Science Data Units (ESDU) procedure, commonly used by engineers to model this problem, was assessed for its efficacy during tropical cyclones.

PRELIMINARY RESULTS

Figure 3 shows the measured turbulence intensity ($Ti = \sigma/U$) for measurements taken at StickNet tower 103A during Hurricane Sandy (2012) where the mean wind speeds U >10 m/s. Winds were measured from a range of different directions, with each having a different associated *fetch* of sand after coming off the ocean. Theoretical turbulence intensities for water (blue line) and sand (red line), based on the ESDU model, are also shown. The transition from low Ti over the ocean to higher values as the fetch of sand increases is evident. This suggests that the wind sees the sand as rougher than the ocean. Inspecting the transition predicted by the ESDU model, it seems to follow the same trend. Similar analyses are currently being undertaken for more than 100 tower sites and 17 storms with results being aggregated.

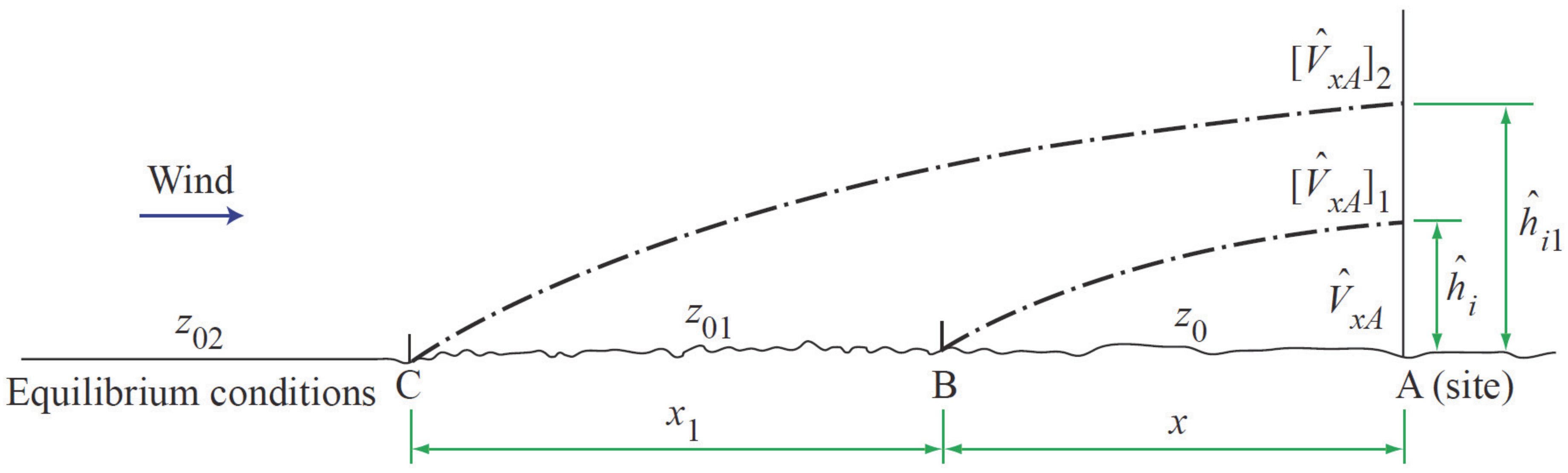

Figure 1: Two step changes in terrain roughness (ESDU 83045, 1983)

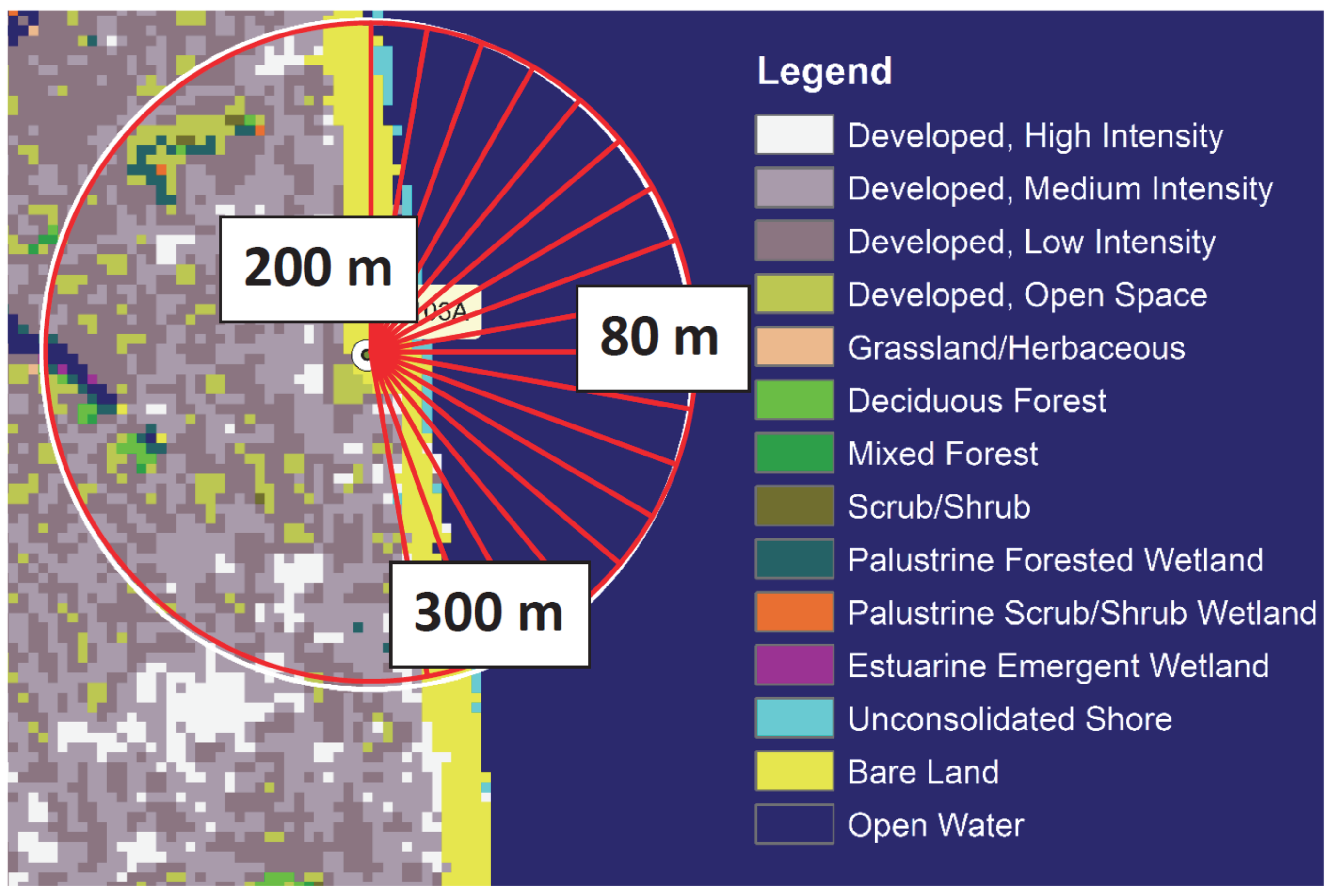

Figure 2: StickNet tower 103A deployed at the beach for Hurricane Sandy (2012). Coastal Change Analysis Program (C-CAP) land cover information on top including 10 degree fetch cones and distances.

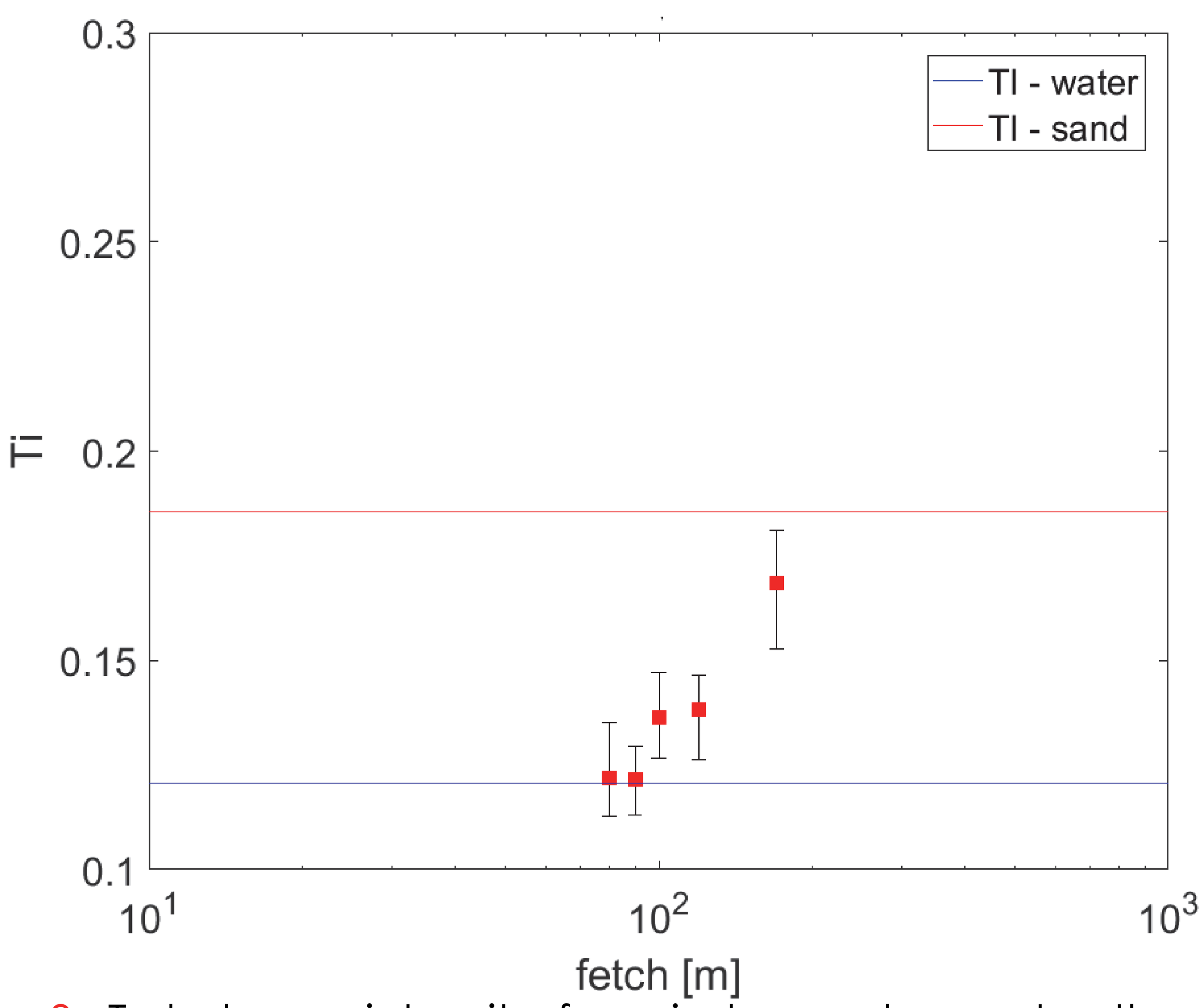

Figure 3: Turbulence intensity for wind speeds greater than 10 m/s measured at Hurricane Sandy (2012) StickNet tower 103A

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