4B.1 WIND SPEED TIME AVERAGING CONVERSIONS FOR TROPICAL CYCLONE CONDITIONS

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1. INTRODUCTION

A progress report is presented on a WMO-supported project that aims to provide recommendations for converting between estimated or measured near-surface wind speeds having different time averaging periods under tropical cyclone (TC) conditions. The review was originally commissioned in response to a request arising from the Fourth Tropical Cyclone RSMC's Technical Coordination Meeting in Nadi (Fiji), November 2002. A draft set of recommendations was completed in 2004, discussed at IWTC-VI in 2006 and the final version is currently undergoing client and peer review. The recommendations are expected to update the present advice for forecasters in the WMO Global Guide to Tropical Cyclones (WMO 1993) in due course.

2. BACKGROUND TO THE REVIEW

Wind speed time averaging conversions are used to transfer between estimates of mean wind speeds and peak gust wind speeds within a given observation period. In the tropical cyclone context, the principally applied wind averaging conventions have been:

- The 10-min averaged mean wind (global);
- The 1-min "sustained" wind (USA), and
- The peak gust, nominally 2-sec or 3-sec.

In addition to these, some of the WMO Regional Associations recognize a 3-min average for visual readings (e.g. ESCAP NIO TC Panel and Typhoon Committee) and China also adopts a 2-min average in some situations. In addition to the direct role of these metrics being used in warnings to inform the public, they also underpin regional schemes for the naming and classification of TCs (e.g. the Saffir-Simpson Scale) and influence climatology statistics. The review of wind averaging methodologies is expected to help clarify the methods being applied within the different WMO regional associations, to better standardize and facilitate exchange of measured and estimated wind speeds and to update the Global Guide recommendations accordingly. In addition, the increasing amount of reliably measured wind speeds during TC conditions has provided an opportunity for comparing new data with accepted empirical wind turbulence models.

3. THE REVIEW PROCESS

The review firstly addresses the theoretical background to a simple statistical model of the near-surface wind environment. This provides a review of the fundamental issues needing consideration, leading then to the specific case of tropical cyclones. The development is supported by reference to numerous case studies and an example extreme tropical cyclone wind dataset (*Orson*, Western Australia, 1989) is included to assist in practical application. Only basic mathematical developments have been included and the interested reader is referred to relevant texts for further detail.

Using a variety of existing methods and data, recommendations are then made as to the appropriate method to be used for deriving wind averaging conversion factors for tropical cyclone conditions. The aim has been to provide a broad-brush guidance that will be most useful to the forecast environment rather than a detailed analytical methodology. Notwithstanding this, accurate wind prediction and measurement under all conditions (not just tropical cyclones) is a very difficult and challenging problem that requires careful consideration of a number of important matters such as local surface roughness, site exposure and topographic effects. Furthermore, instrument type and response can affect the interpretation of wind measurements.

4. THE NEAR-SURFACE WIND

Conventionally, it is assumed that the actual wind can be considered as the sum of a mean wind and some turbulent components. From the observational perspective, the aim is to process measurements of the wind so as to extract an estimate of the mean wind and its turbulence properties. From the forecasting viewpoint, the aim is, given a specific wind speed metric derived from a process or product, to usefully predict other metrics of the wind. Typically these needs revolve around the concept of the *mean* wind speed and an associated *gust* wind speed. The review has uncovered a tendency towards misuse of the term "mean" or "sustained" wind in the forecasting environment that can lead to confusion.

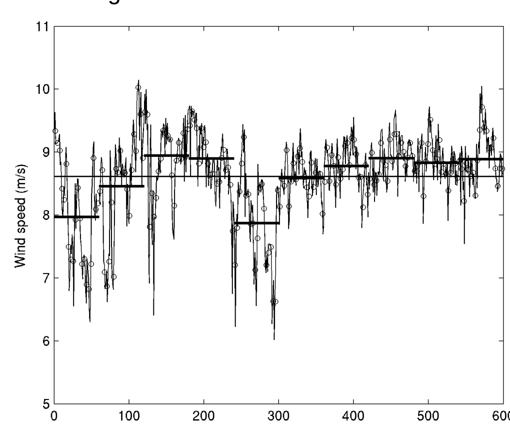

Figure 1 Example estimates of the mean wind speed.

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Figure 1 presents 10 minutes of sonic anemometer data measured at North West Cape, Western Australia, at 42 m height. The thin curve is the 1-s mean wind derived from sonic 10 Hz measurements, the open circles are the 3-s mean wind speeds. Thick horizontal bars show the 1-min mean wind speed and the thin horizontal line is the 10-min mean wind speed. Thus the difference between 1-s, 3-s, 1-min and 10-min observed means is solely that the longer averaging period leads to the sample mean being a more accurate estimate of the true mean. Provided that the sampling is random, the expected values for each averaging period are equal, and individual realizations will be both greater and less than the true mean. Note however that if a 10-min sample is subdivided into ten 1-min samples, the mean of each calculated, and the largest of these 1-min means is chosen, then this is no longer an unbiased estimate of the true mean, since the sampling is not random. Such a measurement is correctly termed a *gust*.

Wind averaging factors, or *gust* factors, are a convenient way to exploit the time-invariant statistical properties of the turbulent wind provided that (a) the flow is steady (or stationary in the statistical sense), (b) the boundary layer is in equilibrium with the surface roughness, and (c) the reference height is constant (+10m here). Converting between the mean and gust metrics can then proceed, but only on the basis of a single estimate of the mean wind. Hence, *mean* wind speeds *per se* cannot be converted; only the most likely *gust* wind speeds of a given *duration* (τ) within a specific *period* of observation (T_o) of the mean wind can be estimated.

5. DRAFT RECOMMENDATIONS

Because the forecasting of tropical cyclones is an already difficult task, a simplified approach is recommended that should lead at least to an increase in consistency of quoted and forecast winds. An existing mathematical model of wind over-land in extra-tropical conditions (ESDU 2002) was adapted for this purpose and nominally calibrated against a wide range of assembled tropical cyclone data applicable to four simplified surface roughness regimes of interest to forecasters. Figure 2 illustrates a step in the process, whereby the matching of theory (lines) and data (symbols) for an "off sea" roughness environment is shown (legend numbers refer to observation periods in seconds).

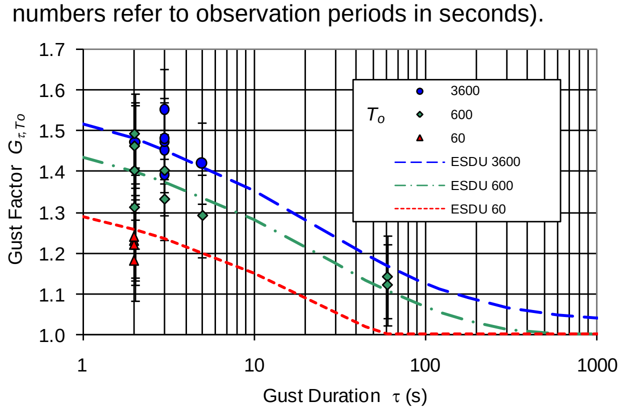

Figure 2 Calibration of the "Off Sea" exposure class.

The recommended procedure is seen as a practical interim solution until such time as increased data collection and analysis provides a more definitive description of the near-surface wind turbulent energy spectrum in various situations under tropical cyclone conditions. Table 1 summarizes the recommendations in this regard, noting that the "exposure class" must first be determined, then the reference (or observation) period. Choosing the gust duration then yields the indicated G factor that relates the gust wind speed to the estimated mean wind speed within that period of time.

Table 1 Draft Recommended +10m Conversion Factors

Exposure Class	Reference Period T_o (s)	Gust Factor $G_{\tau,To}$ Gust Duration τ (s)	
		3	60
In-Land - roughly open terrain	600	1.66	1.21
	180	1.58	1.15
	120	1.55	1.13
	60	1.49	1.00
Off-Land - offshore winds at a coastline	600	1.52	1.16
	180	1.44	1.10
	120	1.42	1.08
	60	1.36	1.00
Off-Sea - onshore winds at a coastline	600	1.38	1.11
	180	1.31	1.05
	120	1.28	1.03
	60	1.23	1.00
At-Sea - offshore > 20km	600	1.23	1.05
	180	1.17	1.00
	120	1.15	1.00
	60	1.11	1.00

6. CONCLUSIONS

The recommended conversion factors serve to provide a more comprehensive advice than currently available in the Global Guide. The associated report should assist in clarifying the situations where such factors can and cannot be applied and the need for clear definition of the various wind metrics in the WMO regional plans.

Considering the hitherto commonly used assumption that $G_{60,600}$ is 1.13, this lies between the "off land" and "off sea" exposure classes here and is much greater than the "at sea" recommendation, where the intensity of tropical cyclones is most commonly assessed. This has implications in the current conversion of so-called 1-min sustained winds deemed applicable to Dvorak-estimated maximum storm winds, to 10-min winds.

7. REFERENCES

WMO 1993: Global guide to tropical cyclone forecasting. Tropical Cyclone Programme Report No. TCP-31, *World Meteorological Organization*, WMO/TD – No. 560, Geneva.

ESDU 2002: Strong winds in the atmospheric boundary layer. II: Discrete gust speeds. Engineering Science Data Unit, Item No. 83045, London.