Towards Better Evaluation of Design Wind Speed of Vietnam

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1. Introduction

The wind itself owns variations and indeterminists governed by global circulations, regional climates, and local topographies and so on. Customarily, extreme wind speeds are preferably defined in term of probability which is interested for engineering today. Thus, the well wind records, identified wind mechanisms, and suitable methods of extreme value analysis and so on, are always required to predict reliable design wind speeds that would be used for structural design. For the past three decades, there have been many valuable studies in developing basic design wind speed map. These knowledge-bases give an opportunity to put forward an appropriate procedure for extreme wind study of Vietnam.

Evidently, it is better first to pay attention to what researchers did for making wind speed map then to check up on Vietnamese situations to discuss on what should be adopted. In several major wind loading codes, explanation on the way to treat extreme winds are available, except a detail procedure for making wind map. Commentary for wind load of AIJ-RLB (2004) published in 2006 [1], generously offered a detail procedure for making wind speed map of Japan (abbreviated by Japan's procedure). In Japan's procedure, 5 steps were required including: Step 1: Collecting data: Records of wind speed and direction (for all meteorological stations from 1961 to 2000); Step 2: Evaluating of terrain category in considering to historical variation; Step 3: Reducing those data to common base (meteorological standards); Step 4: Analyzing extreme value probability for mixed wind climates with two sub-steps, Step 4a: Evaluating extreme wind probability distribution due to non-typhoon winds, and Step 4b: Evaluating extreme wind probability distribution due to typhoons (Typhoon simulation technique was employed); Step 5: Synthesizing extreme value distributions; and finally: making Basic Wind Speed Map. Basically, steps 1 to 3 were treatments of processing "raw" wind data to obtain reliable wind data; steps 4 and 5 dealing with extreme analysis of TC and NTC winds, then combining them in to one and design wind speeds could be predicted.

In this study, we shall discuss in turn following aspects: choosing and processing wind data for analysis, appropriate method for extreme wind analysis and appropriate procedure for evaluating design wind speed of Vietnam. Moreover, discussion on uncertainties in developing wind map of Vietnam and future works are also provided.

2. Choosing and processing wind data of Vietnam

Although 75 years data were available for all meteorological stations in Japan but only 40 years data were employed. This emphasizes the importance of "reliability" and "homogeneity" of wind data in analysis. In addition, the well identified wind climates and the appropriate methods of extreme wind analysis can assist for choosing record length. As explained elsewhere [2], wind data may be considered being reliable as: the anemometers used to obtain data are performed adequately and properly calibrated; the wind sensor was exposed in such a way that it was not influenced by local flow effects due to surrounding obstructions; and the atmospheric stratification being assumed to have been neutral. The homogeneity of data is judged based on several factors including averaging time used in records, the height above ground and the roughness of surrounding terrain. Incidentally, steps 1 to 3 of Japan's procedure showed how to obtain wind data to satisfy those requirements.

2.1. Outline on wind data and wind climate in Vietnam

Winds have been measured soon in Vietnam as the Phulien-Haiphong meteorological station operated since 1902. However, due to historical reasons measurements were not consecutive. Lien et al., 1990 [3] gave a good brief description on the situation of wind measurements before 1990. Table 1 outlines record length of official 108 stations (see Fig. 1) obtained from National Hydro-Meteorology Data Center; in which, 60 stations have daily maxima (called A1-A60) and other 48 stations with monthly maxima (called B1-B48). Basically, almost stations are located in open country, and the surface wind observations have to follow the regulations given by national standard [4]. However, in mountainous areas, stations historically located on the tops of hills or on flat sites in large valleys. As a result, local topographic effects probably caused significant distortions to records, and unfortunately, to date, there have been no studies on such matters.

Table 1. Summary of stations and recorded length

Type of data	Recorded length (year)			Number of station	Ratio	Notes
	Start –year	End-year	Length			
Daily maxima (60 stations)	1961	2000	40	10	10/60	Data in 2min-mean and at level of 10 m above ground
	1971>1976	2000	25>30	30	25/60	
	1977>1979	2000	22>24	20	20/60	
Monthly maxima (48 stations)	1971>1974	2000	27>30	41	41/48	
	1977>1980	2000	21>24	7	7/48	

Table 2. Wind anemometers and measuring ranges [4]

Anemometers	VILD	EL	TAVID	WRS-91	MUNRO
Measured rage (m/s)	0-40 (0-20)	2-40	0.5-60	1-60	0-50
Notes: VILD used popular before 1995; EL used popular after 1995; others in several stations					

Table 2 shows several types of anemometers/measuring ranges have been used. VILD anemometers (originally made in Russia) were commonly used up to the year of 1995. VILD operate mechanically and measurements are conducted outdoors. From 1995-2000, most stations adopted “automatic” anemometers, so wind data can now be obtained by checking indicators indoors and the measurements to be written on report sheets. However, almost these “automatic” anemometers can only measure wind speeds of over 40 m/s in several stations (Table 2). To date, there are no specifications for correction/calibration of values obtained from different anemometer. It is worthy to consider to the way used to obtain daily maxima. Maximum wind speed of present day is highest value obtained by checking consecutively in duration from 7pm of the previous day to 7pm of the present day. It is observed through site surveys that anemometers, e.g. EL-an “automatic” anemometer, often do operate for 4 times of a day (7am, 1pm, 7pm and 1am of next day) for making daily official report and whenever “strong wind” occurs, observer will soon operate indicator of anemometer to check speeds and directions [5, 6]. Whereas, few stations have been equipped anemographs and they worked inconsecutively [7]. Thus, wind events occurred during relatively long period such as monsoon, or even tropical cyclone, it is possible to obtain maxima of these events if anemometers were not failed due to very high wind speeds. However, questions on measures of thunderstorm winds are being subjected as they are transient and localized storms and do not often pass/hit to stations. As a result, it is reasonably to deduce that some extreme wind events in records probably are based on assessment by Beaufort scale, i.e. man-made data. This is important point in processing wind data.

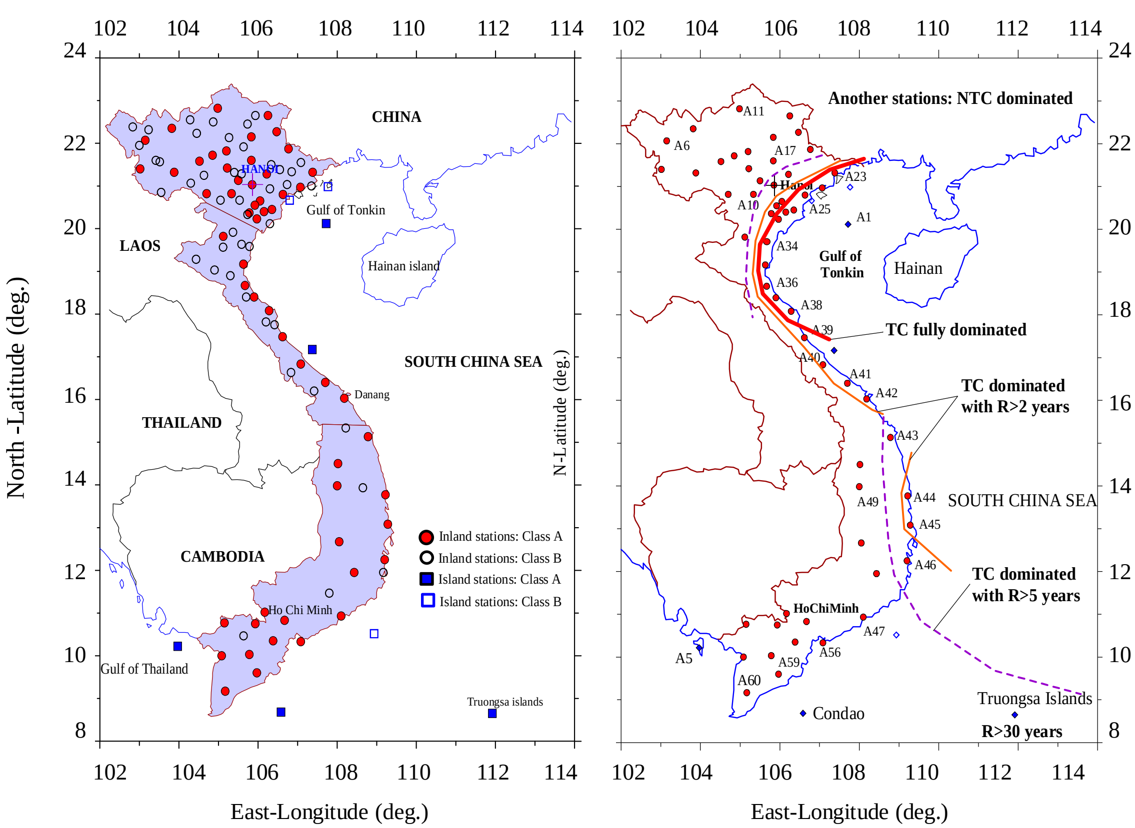

Fig.1. Distribution of meteorological stations with available data in Table 1

Fig. 2 Dominant wind mechanisms in term of return period (R-year) [8]

On the wind mechanism, Giang et al. [8] based on daily maxima of 60 stations and best track data of tropical cyclones (downloaded from the website of the Japan Weather Agency) have identified dominant wind for each station and dominant winds were clarified in relevant to return periods (years) as shown in Fig. 2. Basically, at sites near the coastline in the northern and central regions, TC winds are dominant, but for stations located in the southern regions, from latitudes of 8^0 N to 11^0 N, the effect of TC is negligible whereas NTC winds are completely dominant. Mixed climate regions were observed at stations near the coastline from latitudes 12.5^0 N to 14.5^0 N and stations up to 100 km of the coastline in the north of the country. Moreover, several sites given in the Vietnamese loading codes (draft version 1996 (VN06) [9] and valid version 1995 (VN95) [10]), for locations more than 120 km of the coastline (e.g. A17, see Fig 3), were judged to be strongly affected by TC, but Giang et al. [8] pointed out TC did not dominate at all in compare to NTC winds.

2.2. Appropriate data length for use in Vietnam

Absolutely, three main factors including local topogaphy, measurements by diffrerent anemometers and changing roughness lengths play the important role on the results of analysis. The first one is often treated as a case study of interest. Whereas, the two rest factors, on general, are most important in processing data. In order to evaluate historical variation of terrain category (step 2 of Japan's procudure) at a given station, surely, the real situation of obstacles such as aerial photos/photo of surrounding areas (for every years or so forth) is required. Another alternative method is to use "pseudo-gust factors" (deduced from real data) and gust factor (deduced from mean wind speed and turbulence profiles defined by codes for different terrains) as explained in [1]. Then, raw records could be divided in to several appropriate consecutive periods corresponding to different categories to convert wind speeds in to standard category. Tamura et al., 1989 [11] showed a "yearly variation" of annual maximum wind speed and total building volume (averaged in Japan overall) in duration of 1930 -1980 of Japan. As seen in Fig. 3, annual maxima were significantly reduced coincidentally to remarkable increase of total volume building after 1960. Another example of evaluation for terrain roughness in Fukuoka (Japan) meteorological station for WNW directions in period of 1961-2000 [1] is given in Fig. 4. Probably, two to three categories should be taken to correct wind data. Presently, it is hard to solve such kind of these works in Vietnam due to the lack of required information as mentioned above.

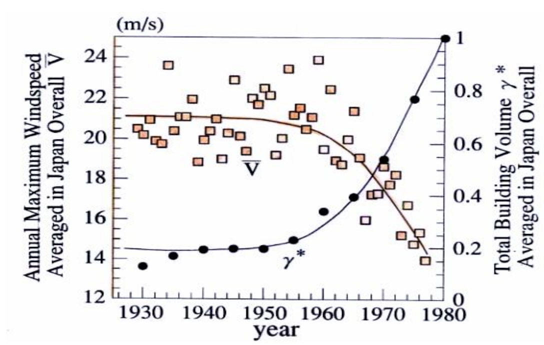

Fig. 3. Yearly variations of annual maximum wind speed and building volume in Japan (Tamura et al., 1989[11])

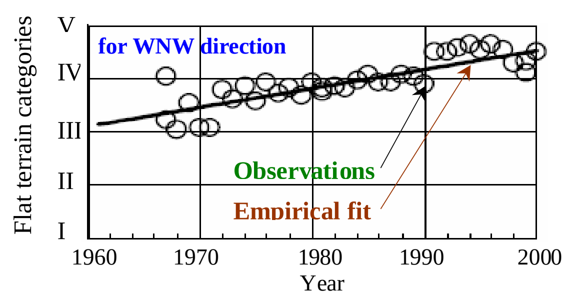

Fig. 4. Evaluation for terrain roughness in Fukuoka Meteor. stations (1961-2000) [1]

As wind data were in form of 2 min-mean and probably stations have been in different terrain categories, thus wind data are required to convert to the metrological standards, i.e. at 10 m above ground, 10 min-mean (Japan and European countries used 10 min-mean, 3s-gust speed used in US and others), in open flat country. Overseas experiences shown that, for stations located in urban areas, to avoid the direct influence of buildings/obstacles to the flow, it is common to change wind sensor's altitude to higher level. However, such a manner has not considered by Vietnamese authorities. In fact, almost stations located in populated areas, "minimum safety distance" of 20 times of wind sensor-level from anemometers (i.e. at least 200m) was strongly violated. Lang (Hanoi) station is good example as people do measure wind speed at 10 m above ground whilst several surrounding high-rise building were built since 2000.

Due to the fact of limited record lengths especially for stations located in southern area of country, previous works did use monthly maxima for Gumbel method to deal with these stations and more recent studies have used annual maxima up to the end of the year 2000 [12]. However, questions on the homogeneity of wind data and changing roughness length surrounding stations remain. These decisions are mainly based on VILD's measurements contributed to the wind data set. Incidentally, in a recent work done in 2005, Lien et al. [13] had noted that "considerable on reduces of measured wind speeds for last ten years of several stations such as Lang (Hanoi), Son Tay, Bac Giang and so on due to the changes of obstacles around stations or anemometers working without maintaining/calibrating". Obviously, at present stage, as calibration/correction for wind anemometers have not carried out yet and changes of site category due to urbanization have been addressed at many sites, especially since 1995, the use of record lengths to the end of the year of 2000 would make itself to be less reliable. It is therefore could be concluded that, in general, the record length by the end of 1994 is preferred for analysis.

3. Appropriate method of extreme wind study

As reliable and homogeneous wind data are obtained, obviously, the decision of method to be used for extreme winds mainly depends on data length. In literature, Palutikof et al., 2000 [14] gave a useful review of extreme wind methods and also more recent Holmes et al., 2003 [15] have outlined several aspects in relevant to codification for design wind speed. We shall review the practical applications of extreme wind method worldwide.

3.1. Design wind speed in mixed climare regions

Before 1970's, Gumbel method with annual maxima was common used for extreme wind regardless to wind mechanisms/types. At a given station, probably wind climates are contributed by several individual wind types and this implies that they kept different probability of recurrence/speed. The concept for evaluating design wind speed in mixed wind climate regions was first proposed by Gomes and Vickery (G&V), in 1978 [16]. Recently, G&V methodology has been reviewed and updated by Cook [17], in which, the methods of using sub-annual maxima are applied. G&V methodology was adopted to evaluate design wind speeds and resulted in several major wind load codes, such as AIJ-RBJ-2004 [1], AS/NZ 1170.2: 2002 [18], new wind map of Germany [19] and so on. Expression of G&V methodology applied in a specified epoch T, is as following equation [16]

$$P_{com}(V < u, T) = \prod_{i=1}^{n} P_i(V < u, T) \qquad (1)$$

where, V is maximum wind speed; $P_{com}(\ldots)$ and $P_i(\ldots)$ are respectively cumulative combined probability of maximum wind and cumulative probability of maximum wind of wind mechanism i ; u is wind speed state variable. In the case T=1, it is epoch of annual maxima.

3.2. Asymptotic distributions for use in analyzing extreme winds

To date, it seems that several distributions are interested for extreme wind; namely, three asymptotic types of Extreme value distribution; Generalized Extreme Value distribution, and Generalized Pareto Distribution. Detail explanation of them and fitting methods are out of scope of this context but it could be found in many text books, e.g. [2, 20, 21, 22]. However, it should be noted that the most appropriate distribution is still a research problem.

Three asymptotic types of Extreme value distribution, Gumbel (Type I), Frechet (Type II) and reverse Weilbul (Type III) were first introduced by Fisher and Tippett in 1928 for the largest values in a sample depending on the form of the tail of the parent distribution. And they were combined in to a single form by Von Mises, 1939 and introduced by Jenkinson, 1954 [referred in 14] and known as Generalized Extreme Value (GEV) distribution (see Eq. 2).

$$P(V) = \exp\left\{-\left[1 - k\left(V - u\right)/a\right]^{1/k}\right\} \qquad (2)$$

where k is the shape factor, a is the scale factor, and b is the location parameter. The value of the shape factor k specifies three special cases: k = 0 corresponds to Type I; k < 0: Type II; and k > 0: Type III. Fig. 5 shows a graphical illustration of GEV in different shape factors [22].

Type I was used popularly to fit observations, for instant, used for Non-Hurricane winds in US (see ASCE/ISE 7-05 [23]), for Non-Typhoon wind in Japan [1] and also for simulated TC wind obtained from tropical cyclone simulation, e.g. [2]. Whereas, Type II is not widely used in wind engineering as it often predict very high wind speeds (especially in high return period) which are questionable in practice. In contrast to Type I and Type II as they predict unlimited values, Type III shows an upper limit and predicts lower values than those done by Types I and III. Recently, several researchers in their works employed Type III for extreme winds, e.g. Kasperski, 2000 in developing new wind map of Germany [19] and so on. It is observed that (see Fig. 5), for special reasons as a limited value of wind speed are believable or expected, type III could be used, otherwise, Type I is preferred in the view of "safety" as addressed in almost wind loading codes.

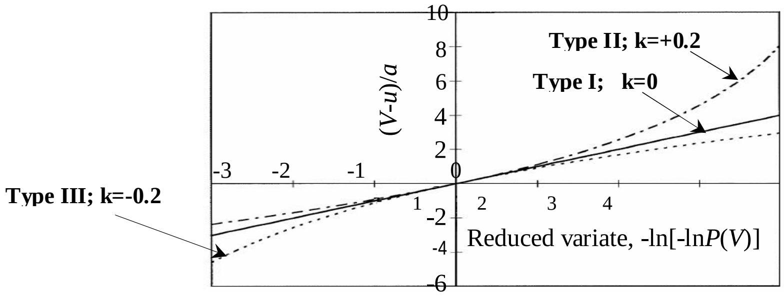

Fig. 5 GEV distribution in corresponding to shape factors k=0.2, 0 and -0.2 (Homles [23])

Generalized Pareto distribution (GPD) has been used recently in wind engineering after initial works of Pickands in 1975 [24] in which GPD was proved to be the limiting distribution. GPD were used deal with Non-hurricane winds in works of Lechner et al., 1992 [25], Simiu and Heckert, 1995 [26] in US, Homles and Moriaty, 1999 [27] for Australia downburst wind, and others. In addition, GPD also used for TC winds, e.g. Simiu et al., 1998 [28] done with simulated hurricane winds. Extreme method using GPD is known as Peak over Threshold method (POT). Cumulative distribution function of GPD is shown in Eq. 3

$$P(Y \le y) = 1 - [1 + cy/\sigma]^{-1/c} \qquad (3)$$

here, $Y=V-u_o \geq 0$, with u_o is the assigned threshold and u_o is sufficiently large; σ and c are scale and shape parameters respectively. Similar to GEV distribution, GPD with individual cases of c=0, c>0, c<0, are respectively corresponding to Type I, Type II and Type III of extreme value distributions. However, as GPD is applied for wind data, in almost cases lead to fit observation by Type III distribution [29, 30].

3.3. Methods using sub-annual maxima

Probably, as record length is long enough to overcome large sampling errors in analysis, and in well identified wind climate, probably Gumbel (G) method for annual maxima is useful because of it is easy to perform. Recent work done in 2000 by Sacré [31], where G-method is used to renew wind map of France, in which record lengths are of over 40 years and just frontal depression is dominant. However, the "reliable" record lengths what often met in practice in many countries are generally just less than 50 years. Consequently, questions on using "sub-annual" maxima for extreme wind analysis were raised since 1970's. Here, we briefly described two methods, Method of Independent Storms (MIS) and Peak Over Threshold (POT), which are preferred to overcome the weak point of short record length.

Method of Independent Storms (MIS)

Initial works done by Jensen and Franck in late 1960's and early 1970's, in Denmark were resulted in Jensen and Franck method. The Jensen and Franck's procedure [referred in 32] is as follows: 1) Measuring wind pressure continuously; 2) Identifying the independent storms based on a chosen threshold; 3) Using Gumbel distribution to fit pressure observations of 7 consecutive years; finally, 4) 50 year return period wind pressure (R=50 year, frequency f=0.2) is calculated based on conversion factor of $f_s=0.02/r$ (r: annual rate of independent storms). Relying on Jensen and Franck's idea, Cook, 1982 [32] proposed a method so-called "Modified Jensen and Franck method" known as Method of Independent Storms (MIS) today. MIS could be applicable for discontinuous data and each step in Jensen and Franck's method were improved sophisticatedly. Detail of MIS could be found in [21, 32]. The main point of MIS is that cumulative distribution of all independent storms, $P_S(V<v)$ was transferred to annual cumulative probability, $P(V<v)$ by using basic theory of extreme value and annual rate of independent storm, r; shown in the Eq. 4

$$P(V < v) = [P_S(V < v)]^r \qquad (4)$$

here, parameters of $P_S(V<v)$ are determined by fitting Gumbel distribution for all independent storms data. From Eq. 4, wind speeds in different return period could be predicted.

MIS was confirmed with its "stable" predicted results by several researchers, e.g. [33]. Cook [21] applied MIS to develop UK's wind map from 20 years ago. More recent used MIS are works of Miller et al., 2001 to revise UK wind map [e.g. 34], for evaluating Non-Typhoon wind in Japan [1], and also by Sacré et al. 2007 [35] to improve their works of French wind map given in 2000 [31] and so on.

Peak Over Threshold Method (POT) associated with GPD distribution

POT could be seen as new trend in extreme wind study. Procedure to evaluate wind speed in different return period could be found in [2, 22, 26, etc.]. However, debates on the applicability of this method still being open due to the difficulty in selecting an appropriate threshold associated with shape parameter of GPD as available data are limited, e.g. [37-41]. In wind loading code, POT has been applied for reanalyzing NTC-prone region in Australia [19, 23, 36]

4. Appropriate procedure for evaluating design wind speed of Vietnam

Discussions above leads to a most appropriate treatment for evaluating design wind speeds of Vietnam is as following steps: 1) The record length up to the end of the year of 1994 (end-year 1994) should be used as discussed in section 2.2 and, for convenience, data should be separated to TC and NTC winds. Pre-processing data to reject unreliable values is most important in this step; 2) As record lengths of all stations are basically short (10 stations having 34 data years, others 98 stations having 15-24 data years), methods using sub-annual maxima are preferred than traditional Gumbel method for annual maxima. As POT still to be subject for debating, MIS seem to be reasonable to deal with NTC data of stations A1-A60; 3) Analyzing TC and NTC winds for 60 stations (A1-A60) separately and dominant wind types could be clarified for each station; 4) Combining TC and NTC probabilities and therefore, combined wind speed could be obtained by Eq. 1; 5) Results obtained from above 60 stations could be referred to check the applicability of other 48 stations (B1-B48) having monthly maxima.

Here, we shall examine the applicability of MIS method to deal with sub-annual maxima and evaluating design wind speeds based on combining probabilities of TC and NTC winds. In addition, as present study has not generated TC winds by TC simulation yet, but the applicability of Poisson process for modeling to be examined to evaluating maximum TC wind based on TC observations.

4.1. Using sub-annual maxima for extreme wind analysis

4.1.1. MIS method for NTC wind MIS results for NTC winds from different thresholds

Figure 6a, b show parameters of three thresholds (TH1, TH2 and TH3) and corresponding annual rates of independent storms of 60 stations having daily maxima (A1 to A60) with record length up to the end-year 1994. Figure 6c and d compare MIS results for predicted NTC winds. Here thresholds are chosen around lowest value of annual maxima for each station. Stable results were observed almost stations, especial for return period R ≤ 100 years.

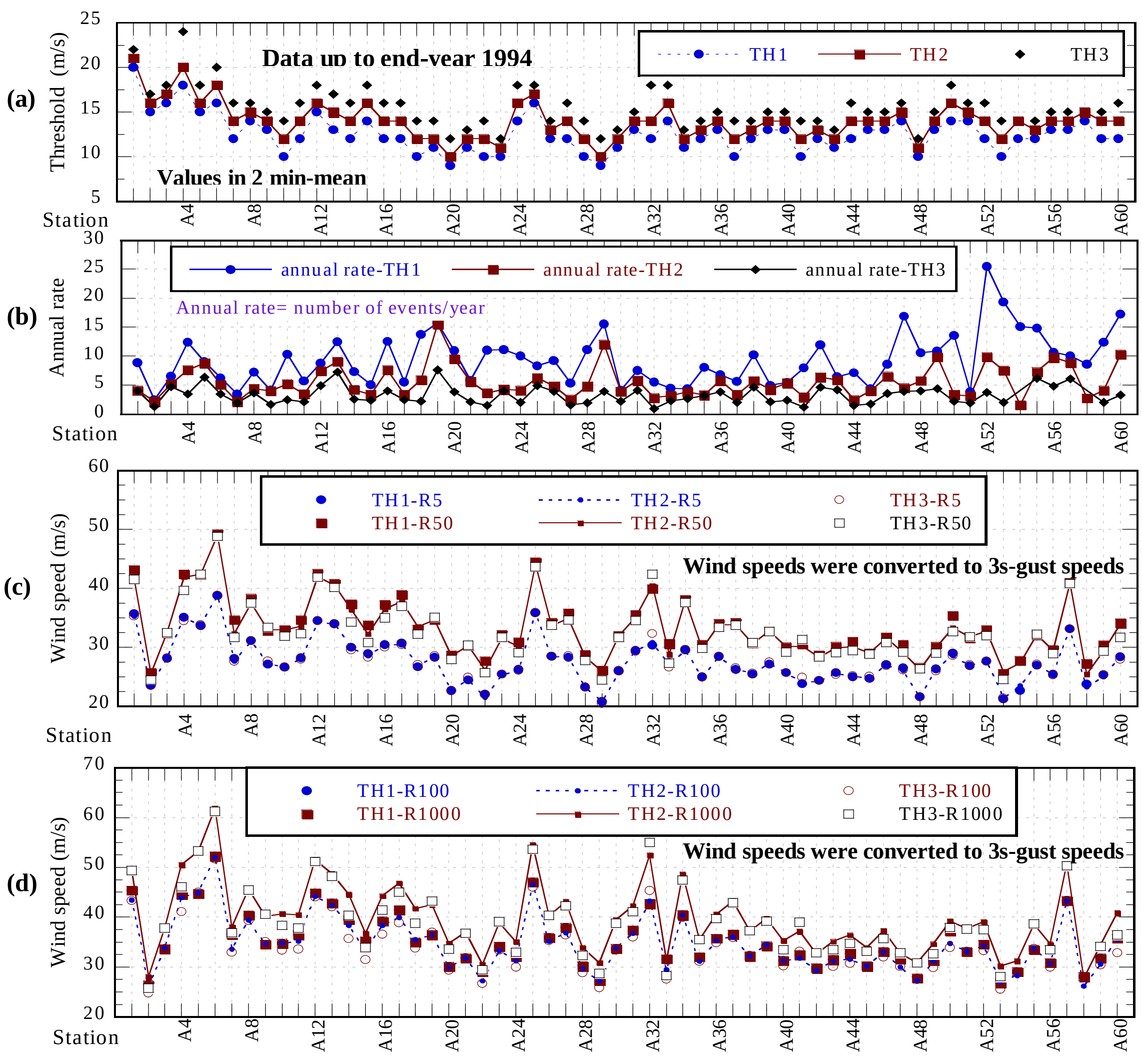

Fig. 6. MIS results from different thresholds for NTC winds of 60 stations (having daily maxima, A1 to A60)
a) Thresholds (2min-mean); b) Number data points corresponding to each threshold;

c) Annual rate of independent storms; d) Predicted values in corresponding to return periods R of 5 and 50 years; e) Predicted values in corresponding to return periods R of 100 and 1000

MIS results for NTC winds from different record lengths

Figure 7a-d show MIS results for 60 stations in which different record lengths up to the end of the years 1990, 1994 and 2000 were taken to account. Based on individual situation of each data set, threshold was chosen to be around the lowest values of annual maxima (see Fig. 7a). In general, stable results for almost stations could be seen in Fig. 7 c and d, especially for results used record length up to end-years of 1990 and 1994.

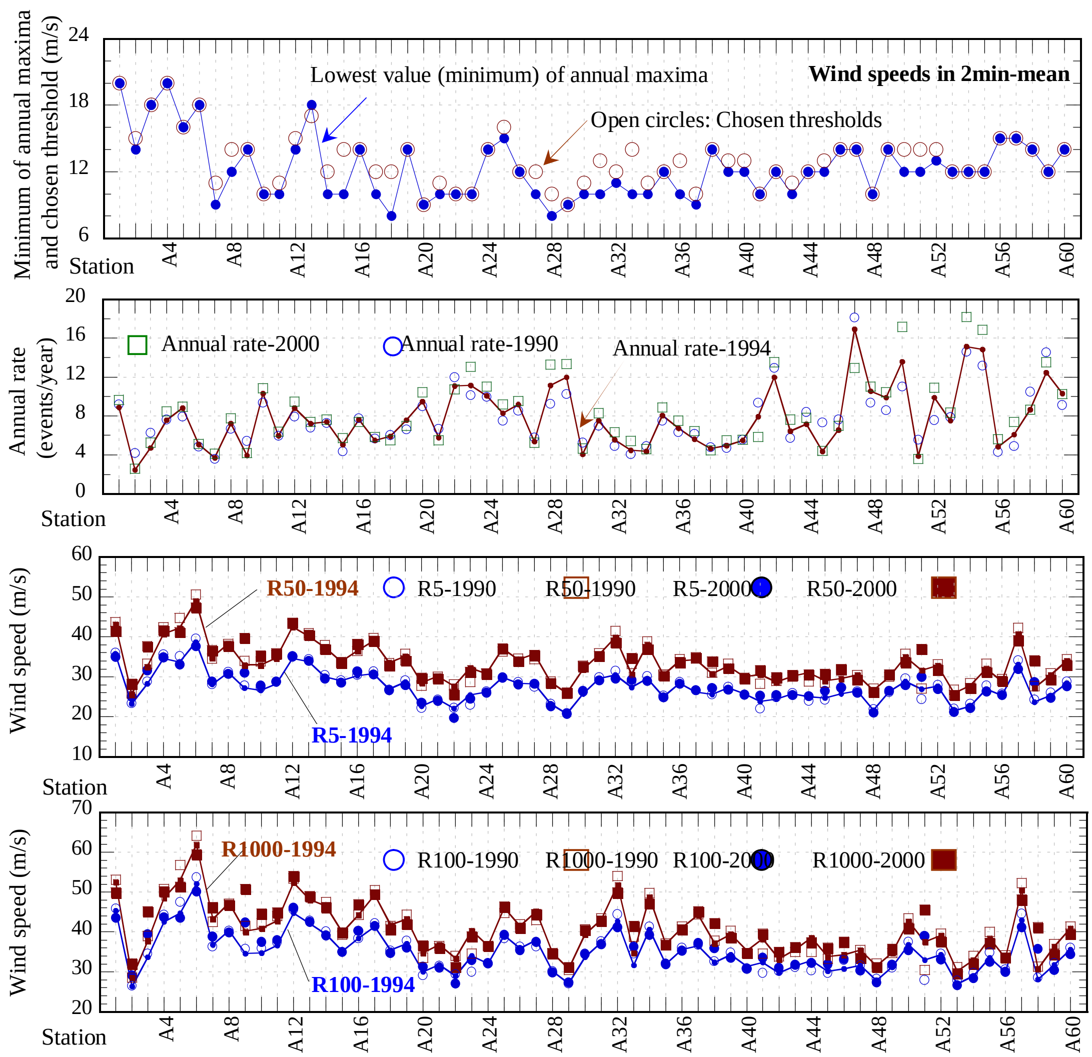

Fig. 7. MIS results from different record lengths for NTC winds of 60 stations (having daily maxima)
a) Lowest value of annual maxima and chosen thresholds; b) Annual rates of independent storms in corresponding to data up to end-years of 2000, 1994 and 1990; c) Predicted values in corresponding to return periods R of 5, 50 years; d) Predicted values in corresponding to return periods R of 100 and 1000

Comparisons of MIS results for NTC winds and Gumbel results for mixed data of stations have not affected by tropical cyclones

Figure 8 shows comparisons of wind speeds predicted by MIS for NTC wind and Gumbel results “mixed” data of 30 stations which have not affected by TC or the influence of TC are negligible (e.g. TC winds have contributed insignificantly to annual maxima). Record length up to end-years of 1994 and 2000 were used in these comparisons. It could be seen from Fig. 8 that, MIS results are slightly smaller than Gumbel results. Incidentally, results given appendix of VN06 (from mixed data) for design wind speeds VN06 [10] were shown and basically higher values are pronounced. Particularly, significant differences between Gumbel results by present study and VN06 of stations A6 (Laichau), A8 (Sonla) and A12 (Caobang) probably are due to the way of processing wind data. These stations located in northern mountainous areas had experienced several wind speeds of ≥40 m/s and as discussed before (section 2.1) on the way to obtain daily maxima in practice; to the author's knowledge, those suspected values should be rejected or kept one of them as looking for "safety" reason. At the other stations such as A7 (Dienbien), A9 (Mocchau), A18 (Vanchan) and A51 (Dalat), the difference between Gumbel results by present study and VN06 are questions on the length of data what they used may be different.

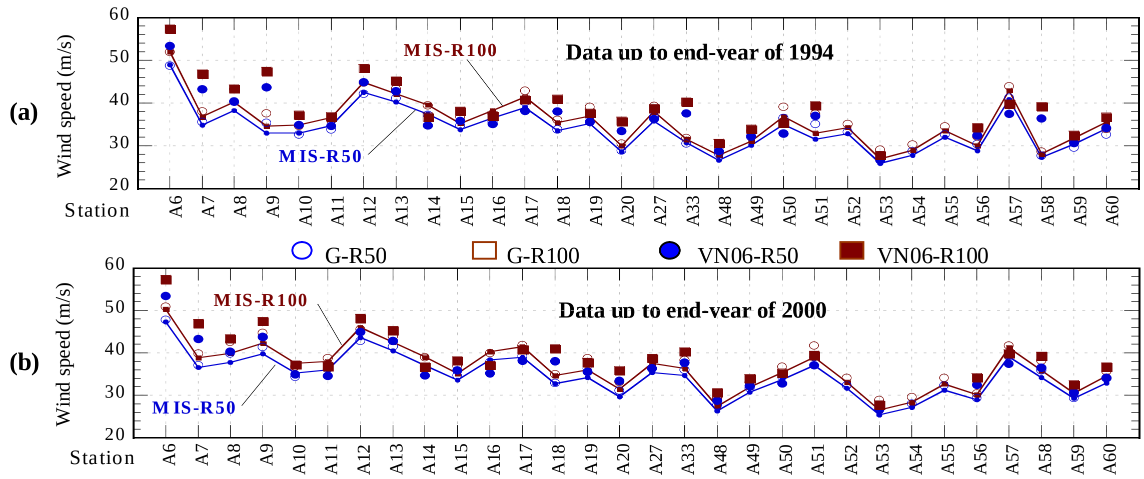

Fig. 8. Comparisons predicted wind speeds (with return periods, R of 50 and 100 years) by MIS results for NTC winds, Gumbel (G) for mixed data and results given in VN06 [10]

Winds speeds were converted to 3s-gust speeds and using data up to the end of the years of the years: a) 1994; b) 2000.

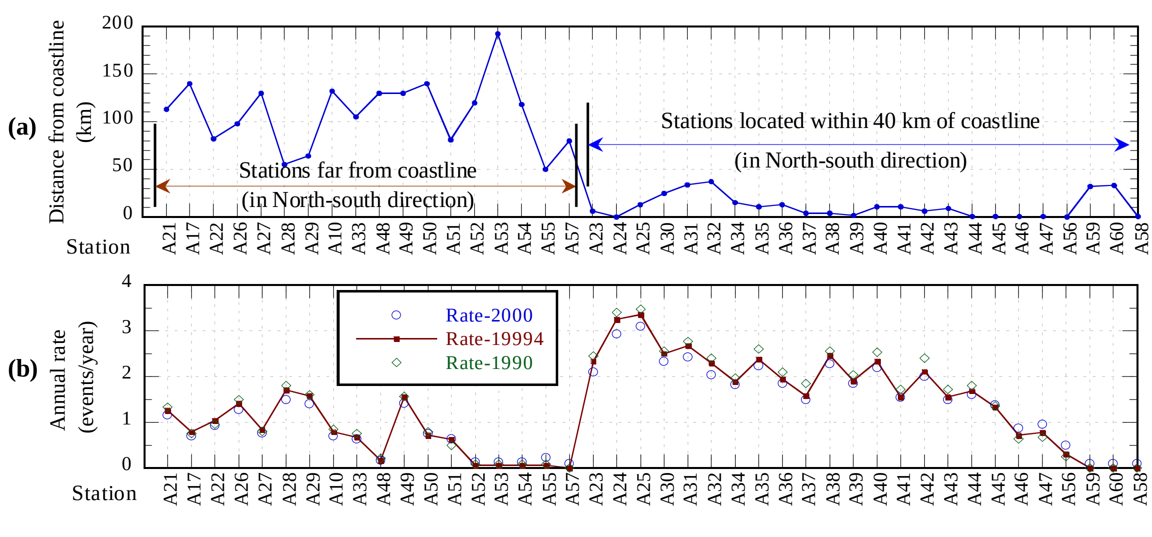

Fig. 9. Stations used for evaluating TC winds

a) Distance from stations to the coastline b) Annual rate of TC winds at stations

4.1.2. Poisson process for modeling TC recurrence and predicting TC winds

At present stage, as a sophisticated method called Tropical cyclone simulation has not been done yet due to the lack of cost and data. It is therefore, all TC winds for each station should be taken in to account for analysis. Fig. 9a and b show the annual rate of TC occurrence; in which 42 inland stations were considered in corresponding to their distances from coastline (just TC induced wind speeds of ≥10 m/s were taken [9]). There were no significant differences of annual rates in different record lengths. Surely, the sampling error is reduced as data points increased. For 37 stations having TC annual rates are over of unity, χ square test confirmed the applicability of Poisson distribution for modeling TC occurrence. Previous studies [3, 13] did evaluate TC wind speeds in which just annual maxima TC winds were used in Gumbel analysis and the poor results would be expected for stations having low annual rate [9]. In general, for all stations TC wind predicted by present study are slightly smaller than that obtained by method used in previous studies [3, 13] as seen in Figure 10 for 20 stations located within 40 km of coastline (see Fig.2 for their locations).

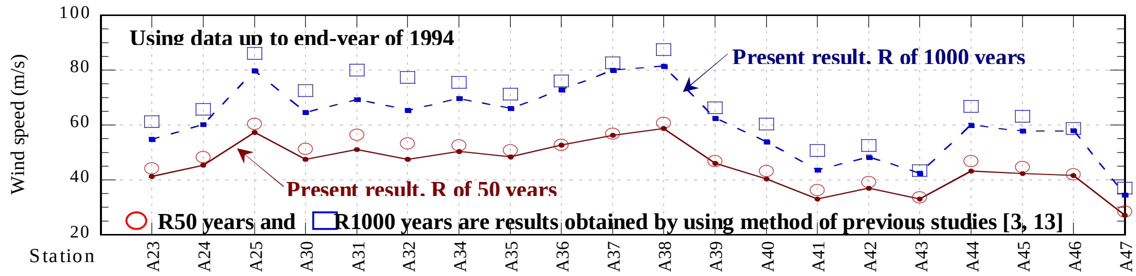

Fig. 10. Comparisons of predicted TC winds (converted to 3s speeds) of 20 stations located within 40 km of coastline by present study (using Poisson process) and results obtained by method used in previous studies

4.2. Evaluating design wind speed from combined probabilities of TC and NTC winds

Although 47 stations having TC data as noted in last section, but just 36 stations having sufficient data points for analysis. Figure 11 shows a comparative example of design wind speed values, for stations located along the coastline (see Fig. 2 for their locations).

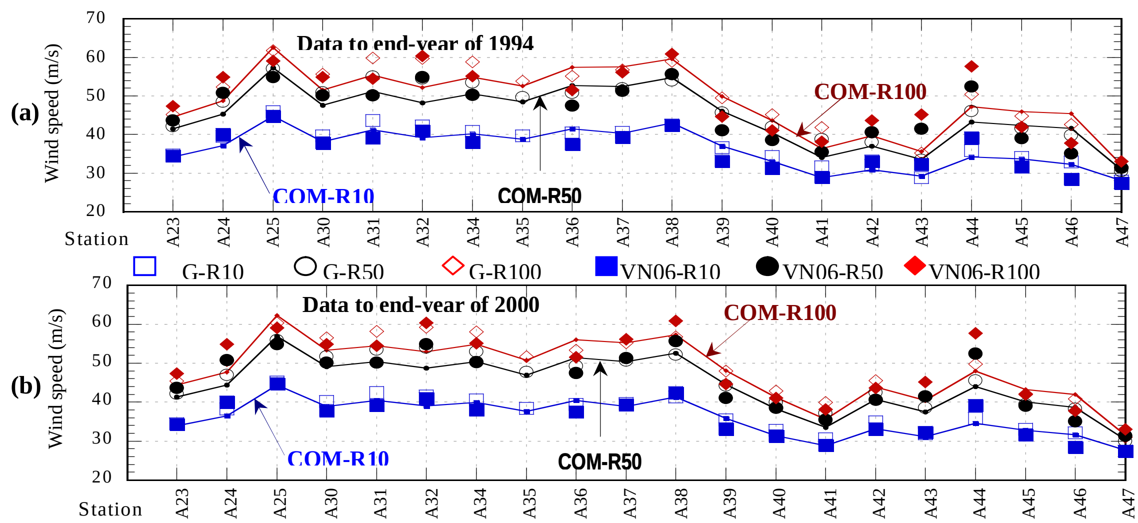

Fig. 11. Comparisons of wind speeds (converted to 3s speeds) corresponding to different return periods R of 10, 50 and 100 years of 20 stations located within 40 km of coastline by Gumbel with mixed data (G-R..), combined probabilities (COM-R..) and results given by VN06 (VN06-R..) [10]

It is observed that, for stations having one dominated wind mechanism, say, TC or NTC, i.e. it did contribute mainly to annual maxima, the difference between combined wind speeds and those given by Gumbel method are insignificant, though combined wind speeds are slightly smaller in almost cases. Whereas, it is not a case for stations as both two TC and NTC contributed relatively equally to annual maxima (e.g. stations A31 and A34 (see Fig. 3) which TC did contribute to annual maxima: 20/34 years and 23/30 years respectively). Similar to deal available data of station A33 (see Fig. 8a-b), stations A44 having two observations ≥40 m/s (2 min-mean) coincided to period what VILD anemometers were used and taking all those values associated with short record length (25 and 19 years, respectively to end-years of 2000 and 1994) for traditional Gumbel analysis probably would produce unbelievable results and direct to inaccurate decision.

5. Conclusions and further works

The paper reviewed several main points in evaluating design wind speeds and put forward a suitable procedure to deal with extreme wind in Vietnam. Generally, for almost stations, the record lengths up to the end of 1994 are recommended for use as it probably minimizes the uncertainties inherited from available data and reduce the influence of roughness changes due to urbanization. Method of independent storms for NTC winds was proved to be well applicable especially for stations having short record length of in south of Vietnam. Currently, as tropical cyclone simulation has not been carried out yet, the use of all records of TC winds with Poisson process for modeling TC recurrence is necessary to better evaluate TC wind maxima.

Except some special cases as shown in the main text, maximum winds predicted by present study are not significantly different to results given in appendix of draft version of Vietnam wind loading code 2006 and slightly smaller than value deduced from basic wind pressure map. Method using combination of probabilities from individual wind types can predict accurately deign wind speeds corresponding to very low/high return periods which are applied for different types of structures, depending on their important levels (required performances), for instant, in Japan, 1 year return period wind speed is used for examining habilitation, and values of ≥300 years for designing extremely important structures and their components.

Previous and also present studies have to use "correction factor" of Russian colleagues to correct predicted wind speed by VILD and also have to convert to 3-gust speeds or 10 min-mean for use in structural design. It may take time to get better anemometers and measurement works, the available wind data obtained by VILD anemometers still proves useful for at least 10 years. Thus, some fundamental studies are necessary to offer solutions for these matters.

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