

THE ANALYSIS OF THE DAILY WIND CHILL INDEX OF PEAK OMU STATION, ROMANIA BY MEANS OF POWER SPECTRA AND WAVELET TRANSFORM

G. Najjar¹, B.S. David²

ABSTRACT

Le concept de la température ressentie au vent, a été d'abord quantifiée des expériences exécutées sur le mesurage du rate de refroidissement d'eau dans un récipient quitté à l'extérieur. Une fois créée le concept de la température ressentie au vent a apprécié l'utilisation étendue dans la description de la sévérité combinée de vent et de température aérienne basse sur les humains. Le présent article propose une application innovatrice de l'index de la température ressentie au vent en utilisant des méthodes modernes de résolution spectrale et la transformée en ondelettes. Le moment de transition de cirulations plus chaud vers les cirulations plus zonales et polaires manifestées à travers le temps sur la Roumanie est identifié par l'utilisation d'un Index WTC historique.

Key words: Windchill index (WTC), time series, spectral analysis, wavelet.

1. INTRODUCTION

One of the principal modes of heat transfer from an object is convection to the surrounding air. Convective heat transfer increases significantly with increasing air velocity. Thus a person is cooled at a faster rate under windy conditions than under calm conditions, given equal air temperature. Wind chill is a concept that relates the rate of heat loss from humans under windy conditions to an equivalent air temperature for calm conditions. The wind chill temperature (WCT) is an equivalent air temperature equal to the air temperature needed to produce the same cooling effect under calm conditions. Thus, it is not actually a temperature, but rather an index that helps relate the cooling effect of the wind to the air temperature under calm air conditions. It is important to remember that the wind will not cause an exposed object to become colder than the ambient air. Higher wind speeds will only cause the object to cool to the ambient temperature more quickly.

The concept of a wind chill temperature was first quantified from experiments performed in 1941 by U.S. Army Major Paul Siple and geographer Charles Passel while wintering over in Antarctica. They measured the cooling rate of water in a container left hanging outside and developed a temperature index for wind chill based on this data. After the publication of their results (Siple and Passel 1945), the wind chill concept has enjoyed widespread use in describing the combined severity of wind and low air temperature on humans. In 1973, NWS meteorologists began using WCT to describe human comfort level and, more significantly, to warn of the risk to human safety with regard to expected cold weather conditions.

These wind chill forecasts and warnings were expressed in equivalent temperatures (EF). Shortly thereafter, MSC also began using the Siple and Passel Index by including wind chill information in their public weather forecasts as a cooling rate in watts

1 Louis Pasteur University, Faculty of Geography, 67070 Strasbourg, France

2 „Babeş-Bolyai” University, Faculty of Geography, 400006 Cluj-Napoca, Romania.

per square meter ($W m^{-2}$). A table of WCT values was created as a public health tool to reduce the number of cases of hypothermia, frostbite, and other cold-related injuries. It warned people who had to be outdoors of the need to dress more warmly than the temperature alone might indicate.

In 2001, NWS implemented an updated Windchill Temperature (WCT) index. The change improves upon the former WCT Index used by the NWS and the Meteorological Services of Canada, which was based on the 1945 Siple and Passel Index.

2. METHODS AND DATA

The aim of the present investigation is to analyze the WCT as a tool of revealing information of the more general atmospheric processes which have affected the Romanian climate over the last two decades. For these purposes daily historical data concerning the wind speed and the mean daily temperatures from the highest mountain station in Romania (Vf Omu 2506 m) were used for a time span ranging from 1990 01 01 up to 2007 12 01 in order to construct the index. The data are continuous and homogenous thus providing a basis for in-depth analysis.

The formula for calculating the index is presented below:

$$\text{- Wind Chill (}^{\circ}\text{F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T (V^{0.16})$$

* The formula is usually computed in Fahrenheit and then a conversion to Celsius is applied

-Where, T = Air Temperature ($^{\circ}\text{F}$)

-V = Wind Speed (mph)

Notes:

- Uses calculated wind speed at an average height of five feet (typical height of a human face) based on readings from the national standard height of 33 feet (typical height of an anemometer);

- is based on the latest heat transfer theory, i.e., heat loss from the body to its surroundings, during cold and breezy/windy days;

- uses a standard factor for skin tissue and assumes a no sunlight scenario.

After the WTC was constructed for the historical period indicated above methods of multitaper spectral analysis and continuous wavelet transform were applied to the data (after subtracting the fit and the mean and dividing to the standard deviation.).

The *wavelet transform* can be used to analyze time series that contain nonstationary power at many different frequencies (Daubechies 1990). Assume that one has a time series, x_n , with equal time spacing dt and $n = 0 \dots N - 1$. Also assume that one has a *wavelet function*, $y_0(h)$ that depends on a nondimensional "time" parameter h . To be "admissible" as a wavelet, this function must have zero mean and be localized in both time and frequency space (Farge 1992). In this approach the Morlet wavelet, consisting of a:

$$\psi_0(\eta) = \pi^{-1/4} e^{i\omega_0\eta} e^{-\eta^2/2},$$

was used.

Where ω_0 is the nondimensional frequency, here taken to be 6 to satisfy the admissibility condition (Farge 1992). This wavelet is shown in Fig 1.

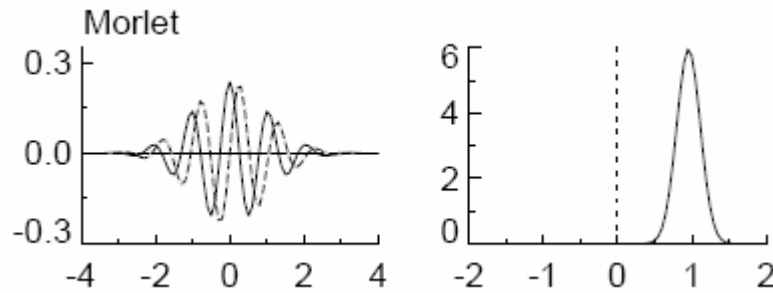


Fig. 1. The Morlet wavelet.

A multitaper spectrum is produced by averaging multiple windowed FFTs generated with a set of orthogonal data tapering windows known as discrete prolate spheroidal sequences (DPSS), Slepian functions, or eigentapers. Since each of the windows in a specific sequence is uncorrelated, an unbiased average spectrum can be produced and an F-ratio test is offered for determining the significance of any given peak in the spectrum.

A multitaper spectrum offers no greater frequency resolution than a single tapered spectrum. In fact, the spectral peaks resulting from the algorithm have a flat-topped envelope shape which makes the central frequency determination more difficult. What is gained is a reduced-variance spectral estimator that retains a high dynamic range and which utilizes all of the data in the record.

The Slepian data tapers are sometimes called eigentapers since they are generated using an eigenvector routine. There are two primary parameters, one that controls the frequency width of the window ($n\pi$) and the other controls the number of windows in the sequence (N_{win}). There are limits to the number of windows that can be used as spectral leakage increases as the sequence progresses. For a width of 2, up to 3 sequences are permitted. For a width of 3, up to 5 sequences are allowed, and for a width of 4, up to 7 sequences

3. RESULTS AND DISCUSSION

The multitapers have been used on the normalized index, which means that the mean value for the entire interval has been subtracted from each annual value and then the residual divided by the standard deviation.

Figure 2 shows the spectrum of the Omu WTC Index series, over 17 years of records, at daily resolution. Three significant peaks can be noticed at a level of 99% significance, although other relevant more numerous peaks appear at lower levels of significance.

For localization in the time domain also, the continuous wavelet transform was applied. Wavelet spectra can be used to obtain fractures in frequency (Mateescu 2006). The most sudden jumps were identified with great accuracy around the following dates: 1996/12/11; 2002/02/26 and 2007/10/08. The fractures in frequency are clearly visible in the time domain and their significance comes evident after analyzing the climatic diagrams for that period (Figure 3). The synoptic situation on two of the dates records weak ridges while the third situation can be described by zonal circulation. In all the three cases there are low altitude anticyclonic areas with a tendency of dissolution.

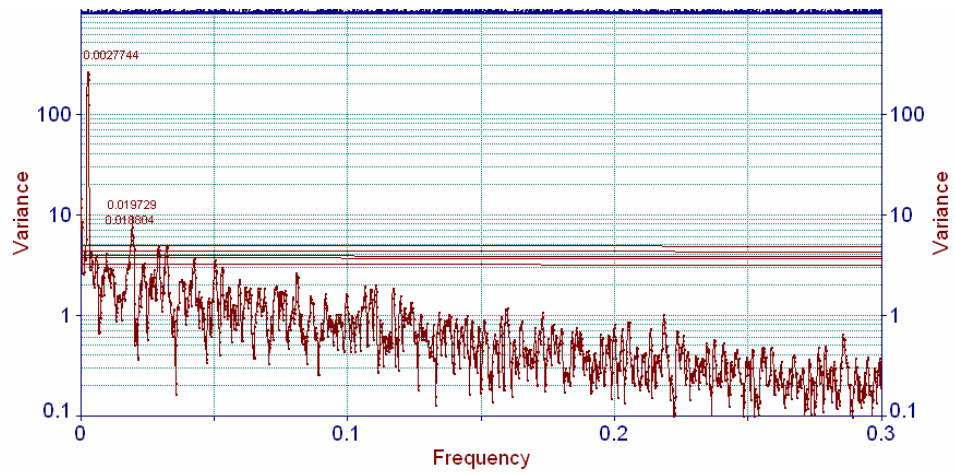


Fig. 2. The multitaper spectral resolution of the WTC index for the Omu station.

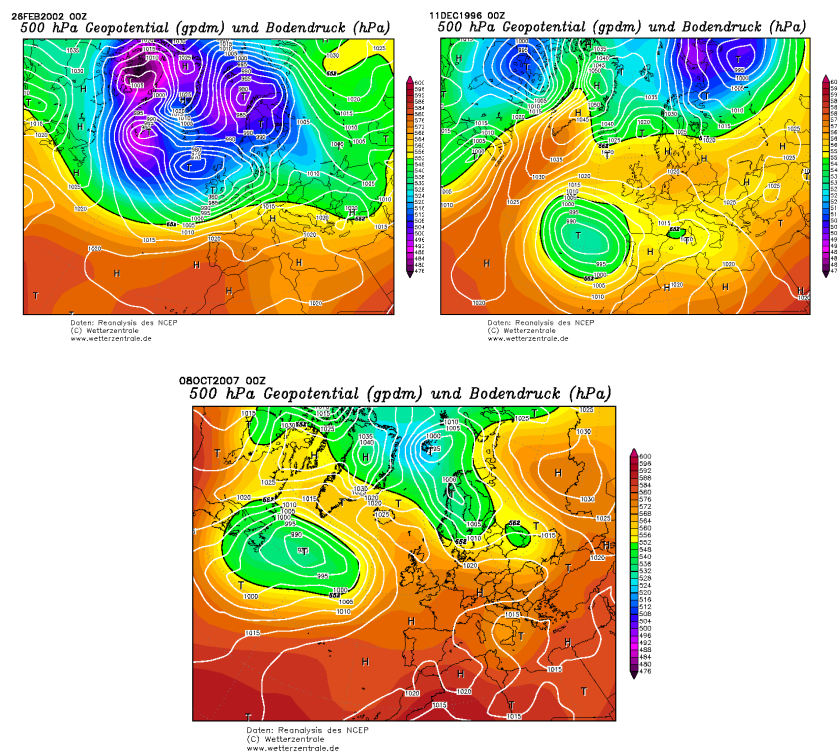


Fig. 3. The synoptic situation for the time-frequency domain fractures observed by analyzing the WTC index of the Vf. Omu station..

The date 18.12.2006 marks the transition from a SW circulation to a NW circulation over the general background of an advancing thalweg. In 8.10.2007 the Western or WSW circulation is present with elevated temperatures in altitude. 26.02.2002, the most evident of the discontinuities is rather a more “delicate” situation, namely a slight altitudinal confluence of a post – thalweg nature. However the ridge is still present.

The common element for all these synoptic situations is the warm air infiltration which corresponds to a transition between the predominant types of circulation that affect the Romanian territory. Most precisely the moment of transition from the southern or western circulation towards the colder zonal or polar circulations is recorded.

However in order to confirm the accuracy of analysis we needed confirmation from a less obvious fracture. Such a “lesser” fracture was recorded in 29.11.1999. On this date the synoptic situation recorded a strong high ridge combined with a strong pressure land anticyclone (1035mba) centered over Romania. The date of 29.11.1999 marks the precise day when the circulation gets “disoluted”.

4. CONCLUSIONS

The article proposes an innovative use of the WTC Index for identifying the moments of transition from one major type of circulation to another. This is a modern approach of the use of the WTC index, an index which was traditionally used in describing the combined severity of wind and low air temperature on humans.

The use of modern spectral analysis methods and of the wavelet spectrum transform in analyzing the WTC Index proves to be a high resolution method allowing for the identification of the most significant atmospheric changes. Further exploration must be undertaken to fully establish the proposed method by expanding the number of stations taken into account.

Acknowledgements: The authors wish to thank to the following: CNCSIS grant no 244/2007;

REFERENCE

1. <http://www.wetterzentrale.de/> archive
2. Daubechies, I., (1990): The wavelet transforms time-frequency localization and signal analysis. *IEEE Trans. Inform. Theory*, 36, 961–1004.
3. Farge, M., (1992): Wavelet transforms and their applications to turbulence. *Annu. Rev. Fluid Mech.*, 24, 395–457.
4. Mateescu M., Haidu I., La methode ondelettes comme outil de test d'homogeneité. Actes de XX Colloque de l'Association Internationale de Climatologie, Tunis 2007, pp.369-374, ISBN 9789973619075
5. Siple, P.A., Passel, C.F. (1945). Measurements of dry atmospheric cooling in subfreezing temperatures. *Proc. Amer. Phil. Soc.*, 89: 177-99.
6. Thom, E. C. (1959), The discomfort index, *Weatherwise*, 12, 57-60
7. Torrence C. Compo G.P. A (1998) Practical Guide to Wavelet Analysis *Bulletin of the American Meteorological Society*: Vol. 79, No. 1, pp. 61–78.
8. U.S. Department of Commerce. "NWS Wind Chill Temperature Index". February 26, 2004. National Oceanic & Atmospheric Administration (NOAA). Office of Climate, Water, and Weather Services. September 12, 2005. <http://www.nws.noaa.gov/om/windchill/index.shtml>
9. <http://www.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html>