GENERAL CHARACTERISTICS AND METEOROLOGY OF WIND

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Summary

This Article presents an overview of the nature of wind and the methods of assessing the wind energy potential of promising wind power sites. Eolian features and biological indicators of wind speed are presented also as Bofort's rating of wind and its influence on the wind mills and their operation. The basic information on the techniques used to measure mean hourly, monthly and annual wind speeds, peak wind gusts, mean wind power, year-to-year and vertical wind variations is given. The characteristics of different kind of anemometers are identified. Some important expressions of energy and power of wind are given. The influence of icing, abrasive and corrosive particles and electrical effects of the atmosphere are shown.

1. Wind Distribution

Air in motion is what we call wind. The horizontal wind speed is usually much greater than the vertical wind speed. The total energy in the atmosphere is the result of conversion of potential energy of the atmosphere into kinetic energy. The ultimate energy source is of course the Sun.

Since the Earth shape is a sphere the amount of solar energy reaching a horizontal Earth surface decreases towards the poles. Other factors affecting the energy absorbed by the Earth's surface are cloudiness, albedo of the surface (i.e. the fraction of incoming energy reflected by a surface). Absorption by aerosols and scattering are also reducing factors.

Ever since the days of sailing ships, it has been recognized that some areas of the Earth's surface have higher wind speed than others. Terms such as doldrums, horse latitudes and trade winds are well established in literature. A very general picture of prevailing winds over the Earth surface is shown in Figure 1.

In some large areas or at some seasons, the actual pattern differs strongly from this idealized picture. These variations are due primarily to the irregular heating of the earth's surface in both time and position.

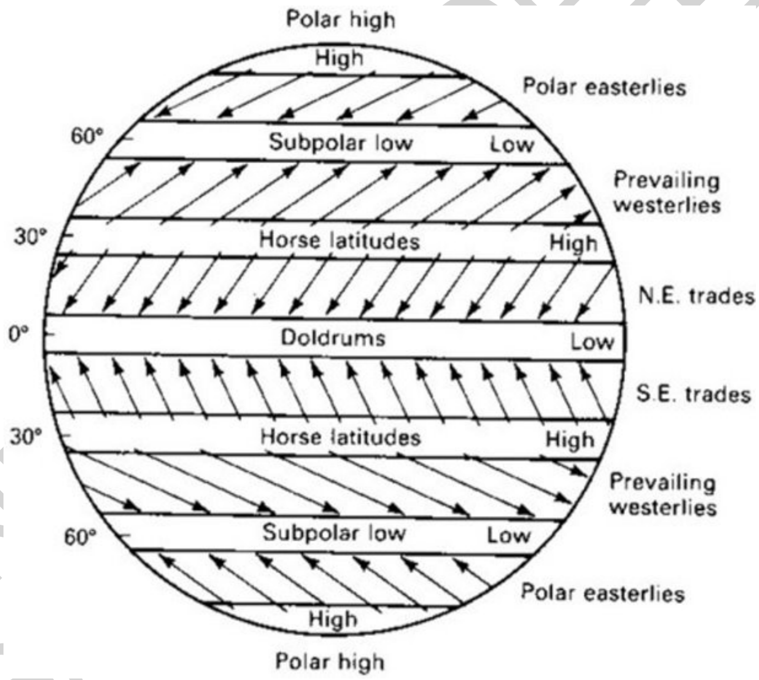

Figure 1. Ideal terrestrial pressure and wind systems.

The doldrums are due to a belt of low pressure, which surrounds the Earth in the equatorial zone as a result of the average overheating of the earth surface in this region. The air here is involved in strong convection flows. Late afternoon showers are common from the resulting adiabatic cooling, which is most pronounced at the time of highest daily temperature. These showers keep the humidity very high without providing much surface cooling. The atmosphere tends to be oppressive, hot, and sticky, with calm winds and slick glassy seas. Unless prominent land features change the weather patterns, regions near the equator will not be very good for wind-power applications.

There are two belts of high pressure and relatively light winds, which occur symmetrically around the equator at 30° N and 30° S latitude. These are called the subtropical calms, or subtropical highs, or horse latitudes. The latter name apparently dates back to the sailing vessel days, when horses were thrown overboard from becalmed ships to lighten the load and conserve water. The high-pressure pattern is maintained by vertically descending air inside the pattern. This air is warmed adiabatically and therefore develops a low relative humidity with clear skies. The dryness of this descending air is responsible for the bulk of the world's great deserts, which are located in the horse latitudes.

There are also two belts of low pressure, which occur at some 60° S and 60° N latitude, the subpolar lows. In the southern hemisphere, this low is fairly stable and does not change much from summer to winter. This would be expected because of the global encirclement by the southern oceans at these latitudes. In the northern hemisphere, however, there are large landmasses and strong temperature differences between land and water. These cause the lows to reverse and become highs over land in the winter (the Canadian and Siberian highs). At the same time the lows over the oceans, called the Iceland Low and the Aleutian low, become especially intense and stormy low-pressure areas over the relatively warm North Atlantic and North Pacific Oceans.

Finally, the polar regions tend to be high-pressure areas more than low pressure. The intensities and locations of these highs may vary widely, with the center of the high only rarely located at the geographic pole.

The combination of these high- and low-pressure areas with the Coriolis force produces the prevailing winds shown in Fig. 1. The northeast and southeast trade winds are among the most constant winds on earth, at least over the oceans. This causes some islands, such as Hawaii (20° N latitude) and Puerto Rico (18° N latitude), to have excellent wind resources. The westerlies are well defined over the southern hemisphere because of lack of landmasses. Wind speeds are quite steady and strong during the year, with an average speed of 8 to 14 m s^{-1}. The wind speeds tend to increase with increasing southerly latitude, leading to the descriptive terms *roaring forties*, *furious fifties*, and *screaming sixties*. This means that islands in these latitudes, such as New Zealand, should be prime candidates for wind-power sites.

In the northern hemisphere, the westerlies are quite variable and may be masked or completely reversed by more prominent circulation about moving low- and high-pressure areas. This is particularly true over the large landmasses.

The speed of the wind is continuously changing. Measurement of wind speed is very important to pilots, sailors, farmers, environmentalists and operators of wind energy systems. Accurate information about wind speed during some periods of time (month, year) is important in determining the best sites for wind turbines.

Wind direction, change of wind speed with height, influence of some obstacles are also important items of information. It is clear that buildings, groves and shelterbelts all have a great influence on the local flow even if the effects are damped fairly rapidly downstream. In some cases downstream effects can be felt 5-10 km after the passage of an obstacle - hills, forests. etc. Some of these effects on low level winds are due to a roughness change, e.g. from sea to land, others are due to changeable aerodynamic characteristics of different terrain features. A third category is the flow changes depending on changing thermal properties, e.g. sudden heating or cooling from below.

2. Eolian Features

The most obvious way of recording the wind is to install appropriate instruments and collect data for a period of time. This requires both money and time, which makes it desirable to use any information that may already be available at the earth surface level, at least for preliminary investigations. The earth surface itself is shaped by persistent strong winds, with the results called eolian features or eolian landforms. These landforms are present over much of the world; they emerge on any land surface where the climate is windy. The effects are most pronounced where the climate is most severe and the winds are the strongest. An important use of eolian features will be to pinpoint the very best wind energy sites, as based on very long term data.

Sand dunes are the best-known eolian features. Dunes tend to be elongated parallel to the dominant wind flow. The wind tends to pick up the fine materials where the wind speed is higher and deposit them where the wind speed is lower. The size distribution of sand at a given site thus gives an indication of average wind speed, with the coarser sands indicating higher wind speeds.

The movement of a sand dune over a period of several years is proportional to the average wind speed. Satellite or aerial photographs easily record this movement.

Another eolian feature is the playa lake. The wind scours out a depression in the ground that fills with water after a rain. When the water evaporates, the wind will scour out any sediment in the bottom. These lakes go through a maturing process and their stage of maturity gives a relative measure of the strength of the wind. Other eolian features include sediment plumes from dry lakes and streams, and wind scour, where airborne materials gouge out streaks in exposed rock surfaces.

Eolian features do not give precise estimates for the average wind speed at a given site, but can identify the best site in a given region for further study. They show that moving a few hundred meters can make a substantial difference in wind turbine output where one would normally think one spot was as good as another. We can expect to see substantial development of this measurement method over the next few decades.

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Biographical Sketch

Professor Vladimir A. Dobrovolski, Ph.D. was born in Moscow, Russia in 1936. He graduated from Moscow Aviation Institute in 1960 and Ph. D. Degree in 1968.

1960-1963 - test engineer, the USSR Civil Aviation

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