DRY WINDS, DUST STORMS AND PREVENTION OF DAMAGE TO AGRICULTURAL LAND

A.N. Zolotokrylin
Institute of Geography, Russian Academy of Sciences, Moscow, Russia

Keywords: dry wind, drought, desertification, duststorm, sandstorm, wind erosion, airborne dust transport, land degradation.

Contents

Summary

Dry wind is a part of a greater natural phenomenon—drought. Typically dry winds occur in the arid temperate regions. Hot winds of arid tropical and subtropical areas, with different local names, are similar to dry winds. The criterion of dry wind is a combination of air temperature, relative humidity and wind velocity. Dry winds cause damage to agriculture in arid areas. If soil humidity is sufficient, dry winds do damage only when they occur within the meteorologically sensitive phases of plant growth.

Dust storms are an intermittent component of the global process of wind erosion. Arid and semi-arid areas are important sources of aerosol, which reach the atmosphere during dust storms. There are different mechanisms for emission of earth particles into the air, e.g. saltation with strong wind or thermo-convection without it. Among numerous classifications of dust storms, there is an original classification based on the color and composition of storm-carried dust. There are promising new methods for studying large-scale dust transport and new sources of dust storms in environmentally disastrous areas, using remote sensing. This technology has revealed that large-scale dust transport is an

important phenomenon at the global scale. In the twentieth century, the human factor has greatly increased the input of dust into the air and formed new centers of dust storms in areas of environmental crisis. Dust storms, which have become more frequent in arid agricultural lands, are an obvious symptom of break-down in the natural relative equilibrium between substrate and wind, prompting desertification processes. The solution must be to seek restoration of the equilibrium by various environmental actions, without abandoning agriculture.

1. Dry Winds

1.1. What is Dry Wind?

The phenomenon of dry wind should not be analysed outside the context of the whole complex of associated meteorological conditions and soil moisture. Dry winds, which may attain a considerable velocity of more than 10 m s^{-1}, have high temperature and low relative humidity (high air humidity deficit). The daily variation of temperature and air humidity is low because the insolation and nocturnal radiation are considerably reduced by the high content of dust in the air. The name dry wind is widely used in temperate countries. Hot winds of the same kind in tropical and subtropical areas have local names, e.g., sirocco in the Mediterranean, samum (simoom) in Algeria, or khamsin (khamseen or chamsin) in Egypt.

Dry wind causes high evaporation, disturbs the water balance of plants, damages plant organs, and decreases yields. If dry wind runs through a plantless area, it picks up finely powdered earth, frequently causing dust storms. Dry wind may blow for several days to several weeks at a time.

Dry winds do a lot of harm to farming in different countries. Their effect is more determined by soil phenomena rather than by atmospheric phenomena. If soil humidity is sufficient, damage only occurs when strong dry winds coincide within the meteorologically sensitive phases of plant growth. If plants are adequately supplied with water, the harmful effects of dry wind are much reduced.

The reverse situation holds if there is moisture shortage in the soil. In this case, dry wind can cause great damage to crops. Evaporation from leaves may be very high and the plants may be unable to replace the water lost from their tissue by absorbing moisture from soil through their roots. Hence, a plant may dry up and die even if soil humidity is sufficient. If dry wind occurs during grain ripening, a plant normally ceases to develope. Grains quickly shrivel and dry up, causing crop failure. It is known that a plant needs to absorb and transpire 200 to 500 kg of soil water to create 1 kg of dry matter. However, the transpiration must take place gradually throughout the whole vegetation period. This requirement is not met during conditions of dry wind. Transpiration becomes excessive and changes from a beneficial factor to a harmful one.

1.2. Criteria of Dry Winds

The criteria of dry winds have regional features. The attribute of dry wind which renders it a harmful phenomenon is evaporation, but as evaporation is not easy to measure, particular combinations of temperature, relative humidity, and wind velocity are used as criteria, bearing in mind that evaporation ultimately depends on these factors. The practice of classifying dry winds in Russia, Ukraine, and Kazakhstan uses the criterion as follows: simultaneous combination of relative humidity of 30% or lower, air temperature of 25 °C and higher, and wind velocity of 5 m s^{-1} and more at noon.

E.A. Tsuberbiller proposes to use the saturation deficit of 20 hPa as the criterion of originating dry wind in the grain belt of temperate Eurasia. The intensity of dry wind increases with growing saturation deficit (Table 1).

Dry Winds	**Evaporation, mm day^{-1}**	**Saturation Deficit (hPa) in Shelter at Noon at Wind Velocity:**	
		< 10 m s^{-1}	**> 10 m s^{-1}**
Light	3-5	20-32	13-27
Moderately intensive	5-6	33-39	28-32
Intensive	6-8	40-52	33-45
Very intensive	> 8	i 53	i 46

Source: E.A. Tsuberbiller. 1957. Agrometeorological Criteria of Dry Winds. In: *Dry Winds, Their Origination and Control*. ed. B.L. Dzerdzeevsky. Moscow, Nauka, pp. 71-80 (in Russian).

Table 1. Agro-meteorological values of dry winds

Wind is an intensifying factor in the dry wind complex because even moderate wind of 3 to 7 m s^{-1} continuously blows through vegetation cover and intensifies air exchange among plants and raises their water consumption. Very strong dry wind causes evapotranspiration of 8 mm day^{-1} which is equivalent to water consumption of 80 t ha^{-1}.

The consequences of plant exposure to dry wind also depend on the duration. Tsuberbiller determined that a plant in a temperate climate could endure light dry wind without any damage for five days and very intensive dry wind only for one or two days. Water loss reduces a plant’s internal pressure, exerted by the cell contents, and results in loss of turgor. In a temperate climate, leaf turgor begins to reduce when the saturation deficit drops to about 20 hPa. Table 2 shows Tsuberbiller’s data on critical values of saturation deficit causing damage to grain crops in the southern Russian plain.

Damage	**Critical Values of Saturation Deficit, hPa**	**Productive Water Content (mm) in Soil Horizons**	
		0-20 cm	**0-100 cm**
Slight reduction of turgor	20	< 20	< 100
Curling leaves	26	< 10	80-90
Considerably reducing turgor	33	10-15	70-80
Turning leaves yellow	33	< 10	< 50
Drying off leaves	40	0-5	< 50
Very high reducing turgor	40	0-5	< 35
Turning ear scales white and grasping grain	40	< 10	< 35

Source: Tsuberbiller, E. A. (1957). Agrometeorological Criteria of Dry Winds. In: *Dry Winds, Their*

Origination and Control. ed. B.L.Dzerdzeevsky. Moscow, Nauka, pp. 71-80 (in Russian)

Table 2. Critical values of saturation deficit (hPa) causing damage to grain crops (for given soil water content)

Table 2 shows that the effect of dry wind on crops differs depending on soil humidity. Moderately intensive dry wind, accompanied by productive water content of 10 to 15 mm in the root layer, causes reduction of leaf turgor in the daytime. If the productive water content is less than 10 mm, a plant wilts within the first hours, turns yellow, and does not recover its turgor at night. In this case, photosynthesis falls off to zero, decreasing yields sharply.
If the water content of the root layer is not less than 80% of the field moisture capacity, a plant does not usually suffer from dry wind. According to Tsuberbiller, the required productive water content of the 0-20 cm soil layer, depending on saturation deficit at noon, is 25-30 mm for a deficit of 27-40 hPa and 30-40 mm for a deficit of 40-52 hPa.

1.3. Distribution of Dry Winds

Dry winds are common in temperate Eurasia (the southern and south-eastern Russian Plain, the Caspian Sea area, Kazakhstan, and western Siberia) where they usually blow from the east, south-east, or south. The recurrence of dry wind ranges greatly. Very intensive dry winds with saturation deficit of more than 50 hPa occur in the steppe only in 15% to 40% of years. The northern boundary of the occurrence of such dry wind runs approximately along the border between steppe and forest-steppe. The number of days with dry winds, when the saturation deficit exceeds 40 hPa, averages 1 to 3 per year for the steppe zone, increasing to 15 to 25 in some years, and is 1- to 2 per decade for the forest zone. Light dry winds with saturation deficit of 20-32 hPa at noon occur in the forest zone two or three times a year on average. The mean annual number of days with light dry winds in the forest-steppe zone ranges from 14 in the west to 30 in the east, while the equivalent figures in the steppe zone are 30 to 60 days.

The distribution of days with dry winds during the vegetation period of temperate Eurasia is rather irregular. In the forest zone, dry winds are most likely occur in June, but in the forest-steppe, they are in April-June. In the steppe, there are two maxima: in May and in July-August. In the steppe, cold dry winds blow in spring, and sometimes in autumn. They are characterised by low relative humidity (8-15%) and cause strong to intensive drying of plants. Multi-day dry winds are more likely to occur in summer. In the Ukrainian steppe, dry winds blowing continuously for more than five days have a 20% chance of occurring in May, a 25-28% chance in June, and a 30% chance in July.

Wind called sirocco occurs in the Mediterranean. It is a hot, strong southern or south-eastern wind blowing from the interior desert areas of North Africa and the Arabian Peninsula. It is either humid or dry depending on air masses. While crossing the Mediterranean Sea, the sirocco is enriched in moisture, but, it still dries up plants in many areas of the European Mediterranean. Sirocco is well known in Italy and the Dalmatian coast, where it usually blows in spring. In the eastern Mediterranean, sirocco is very dry and carries a lot of sand dust. On lee mountain slopes, sirocco sometimes takes on the features of foehn. Hot sirocco blows in the northern Sahara early in summer. It comes from the central Sahara. This wind has different names in different countries, e.g. shergy in Morocco, gebly in Lybia, samum or khamsin in Egypt. It is accompanied by sharply increasing temperature and decreasing air humidity. This alone would cause damage to crops, but it also carries much sand and dust, which cause further damage. In the island mountains of the central Sahara, it takes on the features of local foehn.

Samum, or simoom, is a common local name for dry, hot wind usually blowing from the west or south-west in the deserts of North Africa and the Arabian Peninsula. It often takes a form of a strong, short-term squall carrying large amounts of sand or dust. It usually occurs in spring and summer.
Khamsin, or khamseen or chamsin, is a hot, dry wind blowing from the south in north-eastern Africa and the Red Sea. It is accompanied by high (up to 40 °C) temperature and sharply decreasing relative humidity. It blows for about two months a year from April to June. It occurs on the front side of a low-pressure center moving from the deserts of North Africa to the eastern Mediterranean. In the Negev desert, the khamsin (sharav) blows from the east-south-east, from the deserts of Arabia. While occurring, the relative humidity may decrease to 10%, and the temperature may reach above 45 °C. The khamsin often carries large amounts of sand and dust to decrease visibility and cause dust storms.

In the deserts of the Iranian plateau, hot winds blowing from the Arabian Gulf are most frequent in August. In the Sistan Depression located in Iran and Afghanistan, hot north-westerly wind blows in summer beginning from the second half of June. It is locally called *sadobistorus* meaning a "wind of 122 days." It sometimes abates, and sometimes storms. The wind brings to the depression scorching air with a lot of salt dust.

-
-
-

Bibliography

Grigoryev, A.A., Kondratyev, K.J. (1980). Atmospheric dust observed from space. *WMO Bulletin*, 3-9. [The work shows that large-scale dust transport is an important atmospheric phenomenon of the global scale.]

Golitsyn, G.S. et al. (1997). Study of emissions and transport of dust aerosol in Kalmykia Black Lands. *Journal of Aerosols Sciences*, Vol. 28, Suppl.1, S725-S726. [The work concerns the thermoconvection mechanism of emission and transport of dust aerosol at comparatively weak wind.]

Gouide, A. (1983). Dust storms in space and time. *Progress in the Physical Geography*, Vol.7(4), 502-530. [The work describes the seasonal dynamics of dust storm frequency in major global source areas for dust and summerises examples of long distance dust transport.]

Hastenrath, S. (1991). *Climate Dynamics of the Tropics. Updated Edition from Climate and Circulation of the Tropics*, 488 pp. Kluwer Academic Publishers. [The work analyses the weather conditions of dust storm generation in the dry tropics.]

Nalivkin, D.V. (1969). *Hurricanes, storms and whirlwinds. Geography and geological activity.* Nauka, Moscow. 487 pp. (in Russian). [It is the first work that systematises the data on the generation and properties of hurricanes, storms, and tornadoes, as well as their effect on different natural processes.]

Biographical Sketch

Alexander Nikolaevich Zolotokrylin was born on July 12, 1938. He is a leading scientist of the Climatology Laboratory at the Institute of Geography (IG), Russian Academy of Sciences (RAS).

His main objective is observation and study of spatial and temporal variability of energy cycle components and surface characteristics over inhomogeneous surfaces in different vegetation zones at a sub-grid scale for global climate models, diagnosis of inter-annual changes of atmospheric circulation and climate, forecasting impacts of climate change on selected components of the environment, and climate aspects of desertification.

He graduated in 1967 (MS, Geography-Climatology) in the Department of Geography, Moscow State University, and in 1975 obtained his doctorate (Ph.D.) in geography (climatology, meteorology, agrometeorology). His thesis was entitled Energy Balance of Forests.

Dr. Zolotokrylin has authored more than 90 research papers and sections of collective monographs in the field of climate and environment.

Other Positions: 1986–1996 – Head of Geosystem Climatology laboratory IG RAS; 1988–1994 – member of National Program on Hydrological and Atmospheric Processes for the project Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme. 1988–1991 – responsible for the climatological part of international experiments KUREX-88 and KUREX-91 under GEWEX. Since 1994 he has been a member of the Russian National Committee on GEWEX Asian Monsoon Experiment – Siberia (GAME – Siberia). Since 1988 he has been a full member of the Russian Geographical Society.