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An analytical model for the diurnal temperature cycle at the earth surface

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A precise determination of the temperature cycle typically occurring at specific places, under various weather and seasons conditions, is a very useful piece of information for a wide range of applications including agriculture, renewable energy use planning, buildings conditioning.

To this purpose it is highly desirable that the essential information are concentrated in few parameters defining a standard curve, as for instance it is usually made for the statistical analysis of wind intensity, where a Weibull distribution is commonly adopted which includes two design parameters.

We propose a new algorithm to obtain a curve reproducing the whole daily temperature cycles at surface level. Differently from other methods previously proposed in the literature, the present one introduces the great simplification of covering both diurnal and nocturnal temperature evolution by means of one single analytical expression, without loosing in accuracy.

The formulation of the method stems from the algorithm developed to reproduce the diurnal evolution of a convective boundary layer under clear sky and calm-wind conditions. The incoming solar radiation, which determines the sensible heat flux at ground, is reproduced by means of a sine curve of time, where the time scale τ_d is set by the external conditions (season, orography shading, etc.).

Instead the nocturnal phase is reproduced taking into account the formulation proposed by Reuten (1951) and leading to a temperature drop increasing with the square root of time elapsed after sunset, whereas the time scale τ_n is set by a combination of the physical properties of soil (conductivity, emissivity, water content, etc.) and atmosphere (lapse rate, relative humidity, etc.) close to the ground.

The expression obtained for the diurnal evolution of surface temperature is extended to cover also the nocturnal phase by switching at sunset to the more appropriate time scale valid for cooling process.

A smooth blending between the two scales is provided by using a hyperbola curve displaying as asymptotes the linear behavior typical of the diurnal and nocturnal phase respectively.

The adjustable parameters required to define the curve can be divided into two categories: 1. parameters which cannot be a-priory estimated from physical reasoning; 2. parameters depending on physical processes which can be either estimated or left free and obtained from the procedure of best fit to data available from measurements.

In the first category two adjustable parameters are included that control respectively the smoothness of the turning from the late nocturnal phase and the early diurnal one around sunrise when typically temperature minima occur, and the other one controlling the smoothness of the transition around sunset. Whereas in the second category the time scales τ_d and τ_n appear.

The application of the method is tested on a dataset of temperature daily cycles collected in Verona (Italy) in the time period 2001-2006. The method performs surprisingly well not only when working on data referred to fair weather conditions, but also for cloudy and rainy days.