LATE FROST EVENTS IN AN ALPINE VALLEY: MEASUREMENTS AND CHARACTERISATION OF THE PROCESS

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Abstract: Under the research project GEPRI, aimed at investigating and characterizing late frost events potentially dangerous for cultivated areas, in the spring of 2004 an intensive meteorological field experiment has been made in the Adige River Valley in Trentino (Northern Italy). The project is aimed at a better characterization of the mechanism of late frost events in complex topography in order to improve the forecast of the occurrence of nocturnal temperature minima. In this work some preliminary results of the micrometeorological measurements performed at a target area within an apple-trees orchard are presented and discussed. Measurements allowed the determination of the complete energy balance, as well as the identification of specific local-scale circulations which appear to be relevant in characterizing the night-time cooling process. In case of fair weather conditions, the latter displays a sequence of at least four different phases which seem to alternate rather than superimpose advective- and radiative-effects.

Keyword - *Late frost, night-time cooling, energy balance.*

1. INTRODUCTION

Frost can cause severe destruction of fruit, vegetables and plants, and is therefore a relevant damage factor for crops. In general, younger vegetal tissues have a greater water content, and tend to freeze at higher temperature, hence shoot tips, emerging leaves and developing inflorescences tend to be most sensitive to frost. The project Ge.Pri. (Gelate Primaverili, Spring Frosts) started in 2002 aims at better characterizing the mechanism of late frost events in complex topography in order to improve the forecast of nocturnal temperature minima, both in their intensity as well as in their evolution. In this paper data measured during an intensive field experiment between February 20, and May 10, 2004, are presented. This has been the second field experiment of the project: the first took place in spring 2003 and data are discussed in de Franceschi et al. (2004).

2. SITE DESCRIPTION AND INSTRUMENTAL SET-UP

The measurements have been taken at the Agricultural Research Farm "Maso delle Part", in the Adige River Valley, near Mezzolombardo (46.22° N, 11.08° E), at an elevation of 203 m a.s.l.. The average height of the surrounding mountains reaches approximately 1200 m above the valley floor to the West and 600 m to the East: a map of the area close to the site based on a digital elevation model is shown in Figure 1. The vegetation of the area consists of about 2.5 m high apple orchard uniformly covering the valley floor. A standard meteorological station was installed in the middle of a cut-block to measure the atmospheric pressure, temperature, relative humidity (2 m a.g.l.) and wind velocity and direction (3 m a.g.l.). The height of the instruments was chosen so as to be comparable to that of an already operating weather station located in a wide clearing outside the cut-blocks. A series of thermocouples at 6 height levels was set up to measure temperature profiles from 0.3 m to 5.0 m a.g.l.. A radiation measurement system was installed 2 m a.g.l., between two rows of trees approx 1.5 m apart, composed of a CNR1 radiometer (Kipp & Zonen) intended for separately analysing the radiation balance of incoming and outgoing solar and infrared radiation. A soil heat flux sensor (L.S.I. Lastem DPE260) was installed 1 cm below the surface, near the radiometer for measuring the flux into the ground. Turbulent heat fluxes were measured by the eddy correlation technique (Kaimal and Finnigan, 1994) at height of 6.0 m a.g.l., about 3.5 m above the canopy roof. The three wind speed component and sonic temperature fluctuations were measured with a three-axis sonic anemometer (Gill Solent HS Research) and the water vapor and carbon dioxide fluctuations were measured with an infrared open path gas analyzer (LiCor LI-7500). Data were sampled at 20 Hz, the coordinate system of the sonic anemometer streamline aligned (Kaimal and Finnigan, 1994) and Webb correction was applied (Webb et al. 1980). Data collected by means of conventional instruments were stored as 10-min averages along with standard deviations. Turbulent quantities were evaluated on 30-min average windows partially overlapped in order to have time series comparable to all the other collected data.

Close to the cut-blocks, in a grass field, a Scintec MFAS-64 Sodar was installed in order to measure the vertical three-dimensional wind profile from the ground up to 500 m, with a spatial resolution of 10 m and a time averaging of 30 minutes.

Figure 1. Topographic map showing the location of the experimental site Maso delle Part.

3. RESULTS

During the 81 days of field experiment (20 Feb. - 10 May 2004) temperature minima were observed in a range between –5 °C and 11 °C, and maxima between 3 °C and 26 °C, and there have been 26 rainfall days. From early spring to late fall the area is characterized by valley circulations (de Franceschi, 2003) with thermally driven southerly up-valley winds occurring on most of the sunny afternoons. Night time wind is typically characterized by weak katabatic flows from North. One representative day (4 March) and one night (4-5 March) characterized by high pressure and clear sky conditions, have been chosen out of all the meteorological data collected during the experiment for a detailed description. These two days are representative of relatively general and frequent conditions under such a weather. The day-time period is characterized by buoyancy driven up-valley winds from South, displaying maximum intensity soon after noon: the 10-min averaged wind intensity measured by the anemometer at 6 m a.g.l. reaches 4.7 m s^{-1}, whereas inside the canopy at 3 m a.g.l. an average intensity of 4.0 m s^{-1} was observed. Night time flows are very weak, as the wind intensity usually does not exceed 1 m s^{-1}. The energy balance (Figure 2-a) shows that latent and sensible heat fluxes are of the same order of magnitude during the day (Bowen ratio B_0~1). Short after sunset the sensible heat flux displays a minimum due to the combined effect of site shadowing and persistence of up-valley winds. Later, when the wind drops, these fluxes almost vanish. The latent heat flux, on the contrary, becomes never negative but is almost zero during the whole night: this suggests that effects of water vapour deposition or condensation are negligible. During the day the heat flux into the ground is about 25 – 30 % of the net radiation, whereas during the night it is almost equal to the net radiation (the turbulent fluxes are negligible and only this two terms have to balance). The air temperature variation (Figure 2-b) is strictly correlated to the energy balance. At every height the air temperature quickly increases at sunrise, when net radiation becomes positive, reaching a maximum in the early afternoon (13:30) and then decreasing during all the night until the sunrise of the day after. Overall daily variation is about 20 °C, from 15 °C to –5 °C. As expected, during the day higher temperatures occur closer to the ground (instable stratification, sensible heat flux positive generating buoyancy), whereas lower temperatures occur close to the ground (stable stratification) at night.

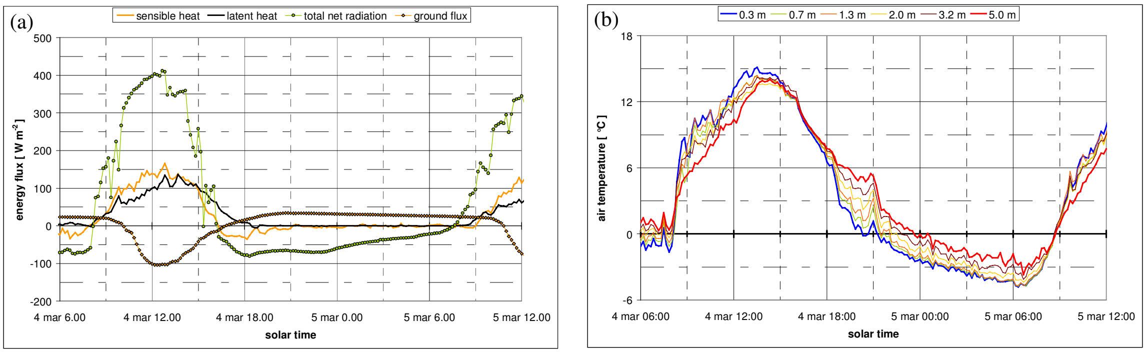

Figure 2. Energy balance (a) and temperature variation (b) during the 4th and 5th March 2004.

4. NIGHT TIME COOLING

The air temperature drop can be divided into 4 steps (Figure 3). The first step (approximately from 15:00, i.e. local sunset, to 18:40) is characterized by the persistence of the up-valley wind. The turbulent exchanges are high, but the two energy fluxes have a very different behavior, with a positive latent heat flux and a negative sensible heat flux (it reaches -35 W m^{-2} at 18:00, as soon as short-wave radiation becomes zero). The up-valley wind ends blowing (i.e. its intensity is less than 0.5 m s^{-1}) at 18:40, and consequently the turbulent fluxes become almost zero. The air temperatures display a large cooling rate, of about 2.5 °C per hour, the same at every height: during this period, the temperatures globally decrease from 14 °C to 6 °C. The cooling process is the result of both radiative and advective effects, and is relatively fast because of the large turbulent exchange due to the high wind intensity. The second step lasts from 18:40 until 20:50 and is characterized by a weak wind intensity from 250° N, i.e. from the slopes West of the site. The temperature decrease is slower in comparison to the previous phase, and the stratification becomes stronger, with the temperatures at lower height decreasing much more rapidly than those at higher one: the temperature difference between 0.3 m and 5 m above the ground is about 5 °C. The turbulent exchanges in this phase are very weak, with latent heat flux almost zero while the value of the sensible heat flux is about -15 W m^{-2}. The third step lasts only 30 minutes (from 21:00 to 21:30) and is characterized by a very fast decrease of the air temperature at every height. At 5 m the temperature decreases of about 3 °C and at 0.3 m of about 1.5 °C: the stratification is still present but its intensity is reduced to 4 °C along the 5 m height separating the uppermost and lowermost levels. During this phase, the temperature decrease is mainly caused by advection of cool air transported by a weak katabatic flow from the North. At 21:30 begins the fourth step (the last and the longest) that ends at 6:50 the day after. During this period the air temperatures decrease with the same cooling rate of 0.4 °C h^{-1} at every height, and the stratification intensity between the two most distant sensors remains approximately constant (3 °C). The wind is very weak, less then 0.5 m s^{-1}, and hence the turbulent heat fluxes are negligible: the cooling is exclusively a radiative one and long-wave net radiation balances the heat flux out of the ground.

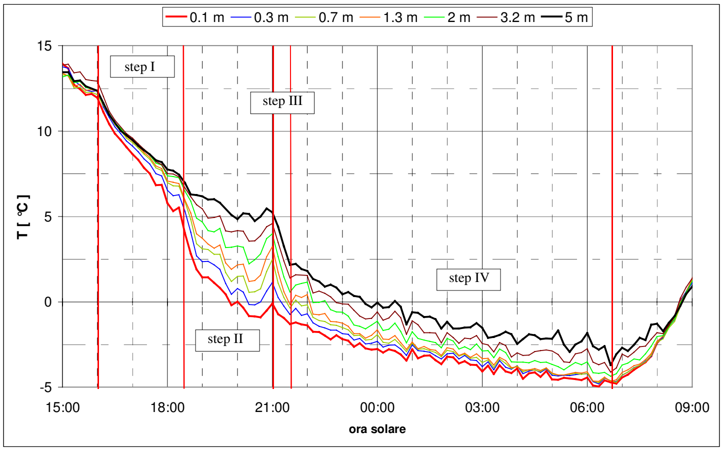

Figure 3. Temperatures variation during the night between 4th and 5th March 2004.

5. CONCLUSIONS

Data collected at an agricultural site during intensive measurements between February and May 2004 display some specific features of the nighttime cooling process. The presence of steep valley-slopes as well as of pronounced orographic inhomogeneities in the surroundings of the experimental site induces the air temperature decrease close to the ground as the sequence of 4 distinct steps. Data suggest that advective and radiative processes are acting alternatively instead of contributing together in a complicated manner. Further developments of this study will mainly focus on the reproduction of this phenomena by means of properly adapted and physically based numerical models, in order to improve the forecast of late-frost events.

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