FREEZING ALARM SYSTEM BASED ON TIME SERIES ANALISYS

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Abstract: The aim of this work is to design an alarm system that allows protecting and preventing crop-freezing damages taking decisions with enough time to react. A first step was to obtain a temperature forecast mode. In this line an hourly temperature series was analyzed with Box-Jenkins methodology (ARIMA models). An alarm system is designed based on these forecast, at each 12 hours, in the air temperatures obtained each hour at real time and in the average errors between real and forecast each hour and each 12 hours. This system generates an index alarm that is related with the risk intensity that over a certain value will activate several sensors. This system is applicable to any area adjusting conveniently the parameters and the ARIMA model.

1 INTRODUCTION

Temperatures are one of the most important variable in the climatic influence, for this reason its forecast add a privilege information in agriculture to select the crops and to avoid crop damages, specially low temperatures and freezing. Studies done by Cao and Moss (1989), Jamieson et al. (1995) and Landau et al. (2000), point out the relevance of temperature in crops growth through regression functions. Several temperature models have been developed in order to simulate it through the daily maximums and minimums of one specific region (Jamieson et al, 1995), or with less accuracy such as monthly temperatures (Castellanos, 1997) or annual oscillations (Fernández, 1992).

The design of an alarm system based in forecast and real temperatures permit to reduce the freezing risk knowing that there is a high probability that this event will occur in the short future. These alarms varies with a crop threshold temperature (Ta) and a security margin (Tu) that protect and give enough time to have a positive sensors action avoiding freezing crop damage or a reduction in final crop production. This system could be used for greenhouse crops as well as for tree fruit and extensive crops.

Air temperature is a temporal serie that can be modeled using different techniques, one of them autoregressive (AR) integrated (I) moving averaging (MA) (Box and Jenkins, 1970; McMichael and Hunter, 1972; Kantz and Schreiber, 1997; Montgomery and Zarnowitz, 1998). The aim of this modeling approach is to express the current time series values as a linear function of past time series values (the autoregressive component) and current and lagged values of a white noise process (moving average component) it means to separate the observed elements into two components: the first is related to the organized part (including tendency, seasonality and cycles) and the second is the random residuals or white noise.

This work pretends to use a stochastic model to forecast hourly temperature to be included in an alarm system based on ARIMA technique. The alarm system design is in function of a freezing risk index (RI) for a certain crop. This RI is evaluated through forecasted temperature (Tf) and means error (ME).

2 MATERIAL AND METHODS

Hourly temperature series have been obtained from meteorological station at Comunidad de Madrid (Spain) located at 40ª 26’ 36’’ N; 3ª 44’ 18’’ W and an altitude of 595 m.

To modeling this time series Box-Jenkins algorithm and methodology have been used (Box and Jenkins, 1970). This ARIMA models have in account the probabilistic behavior of the studied variable to forecast the future values in a confidence interval.

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Mathematically speaking a time series are discrete observations over the dynamic stage of a variable, in this case is hourly temperature (W_t). It's structure could be described as a non stationary process. Box-Jenkins methodology should be applied on stationary series, consequently several transformations should be done to obtain new variables (Z_t) that obey to the same probability density function and a variance with independent from time. The first step to be done is to get a stationary series. Commonly this is obtained differentiated the original series W_t seasonally, $Z_t = W_t - W_{t-24}$. Once that an stationary series is obtained, three steps are essential in this methodology (Bowerman y O'Connell, 1987):

-Identification of possible models: based on the behavior the simple autocorrelation function and partial autocorrelation function, the parameters that express the influence of the preceding values or white noises in each one are calculated. (Matalas, 1967).

-Estimation of the parameters'model: the models obtained in the previous step are adjusted to the series through parameters estimation (Carlson 1970).

-Contrast of forecast versus data: a residual analysis for each model is done to choose the best one. This model is going to be used to forecast the values (Noakes, 1985). If the series was differentiated to obtain stationary, then the inverse process should be done with the forecast values.

Temperature time series used in this work are hourly and the seasonal period is 24. However, it has been checked that different forecast intervals give better results. A forecast interval of 12 hours has been applied (Castellanos et al., 2005).

Hourly temperature forecast has been made during the coldest months (november to april) at the meteorological station location and the hourly error and mean error (ME) have been calculated to obtain a minimum threshold value (E = -1.5).

$$e_t = \mathrm{Tr} - \mathrm{Tf}$$

$$\mathrm{ME} = \sum_{t=1}^{T} \frac{e_t}{T}$$

where Tr is the real temperature; Tf the estimated temperature and T the number of forecasted temperatures.

It has studied the cases where the temperatures are closed or under zero and the real temperature is lower than the forecast one. These are the cases where the risk of freezing hours begin to increase and at this situation the alarm system has its meaning.

A decision algorithm is designed to detect the freezing risk hours and then to turn on the alarm with a risk index depending on the probability of the event. The risk index will varies through time mean while the real temperature is know each hour. The initial parameters established are: the alarm temperature (Ta), the security threshold (Tu) and the ME threshold. Ta is specific of each crop and directly related to the base temperature. Tu is added to Ta depending on topographic characteristics, crop market value and, in general, the risk assumed for crops' protection.

The mechanism is as follow:

Initialization of the paramenters Ta, Tu, E. The alarm will begin based on the forecast temperatures or with temperatures taking by a sensor in real time each hour.

In the first case, the forecast temperatures for the next 12 hours is calculated and their values are compared with Ta+Tu. If they are under this value, the risk index (RI) will have intensity equal to the number of hours that this happens, so the maximum value of RI is 12. In the case that RI is zero, the alarm will not be active.

In the second case, a sensor is registering the real temperature each hour and it is compared with Ta+Tu, if it is lower then the alarm is active and RI will increase in one each hour it happens. At the same time, ME is calculated and compared with its threshold (E), doing a similar decision: if ME is under E (remember that it has a negative value), RI will increase in one unit if not, RI=0.

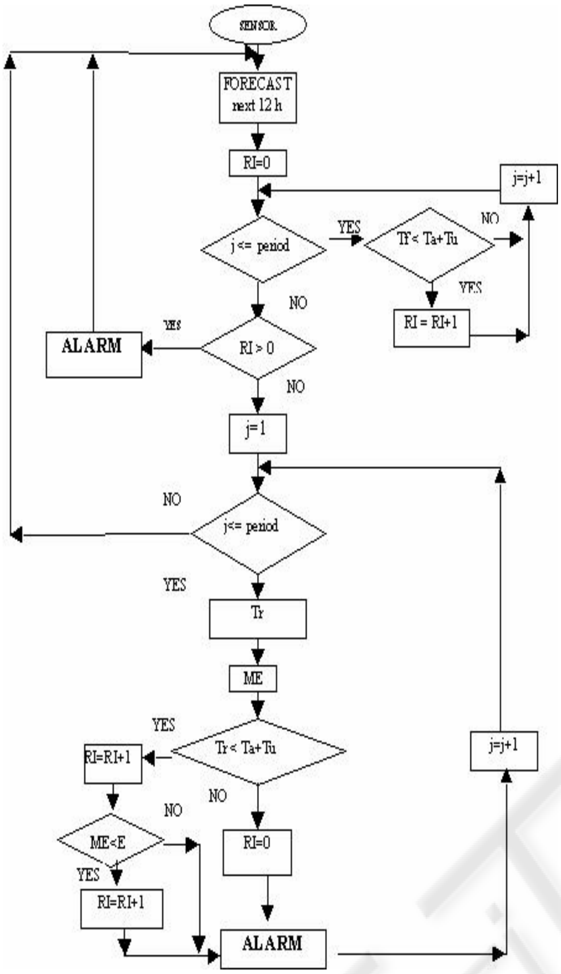

Figure 1: Alarm system flow chart

3 RESULTS AND CONCLUSIONS

The hourly temperature series from November to April are analyzed and the forecast calculated each 12 hours. Box-Jenkins methodology gives a useful model to forecast each interval with a good result. The confidence interval selected was 95% and the selected model for all the series was (1,1,1), $(1,1,1)_{24}$. This model is autoregressive and with a moving average, differentiated in the seasonal as in the non-seasonal part. This indicates a dependency of the recent temperatures and noise, as well as the temperatures and noise from the last day (Carlson et al, 1970).

As an example, two last weak in March have been showed (336 data points). This month has been selected due to its high risk and crop damage that normally are registered. Beside it, this month shows all the possible cases to test the design of the system alarm.

The hours that present a higher freezing risk are the first hours of the interval time. Studying the ME (figure 2) for these days we can see that the value corresponding to –1.5 is the correct one to be selected as a threshold (E). This value is obtained in all the scenarios studied (data not showed) at this meteorological station.

The alarm index (RI) is showed in figure 3. Its value varies between 0 and 12, depending on the Tr and Tf in each forecasted interval. The first case explained by the algorithm corresponds to isolated points (horizontal dimension 1), which begins with an index of 1 or 2 and it can be increased with this pattern. The second case corresponds to alarm indexes of high value can achieve 12 and its horizontal dimension is bigger than 1. This dimension indicates the consecutive number of hours with a freezing risk and this information is important in the possible crop damage and its consequences in crop yield and quality.

In the same figure (figure 3) real temperatures are showed to compare the alarm efficiency to detect the high-risk intervals.

The control system of the alarm is useful. It allows to detect with enough time periods where the probabilities of freezing temperatures are high.

For all the months studied the alarm is activated normally by the forecasted temperature, and in a few cases by the real temperature without using Tf. Further research is necessary to improve this alarm system, but nor days reduce the freezing situations without a previous risk notification so a prevention can be applied.

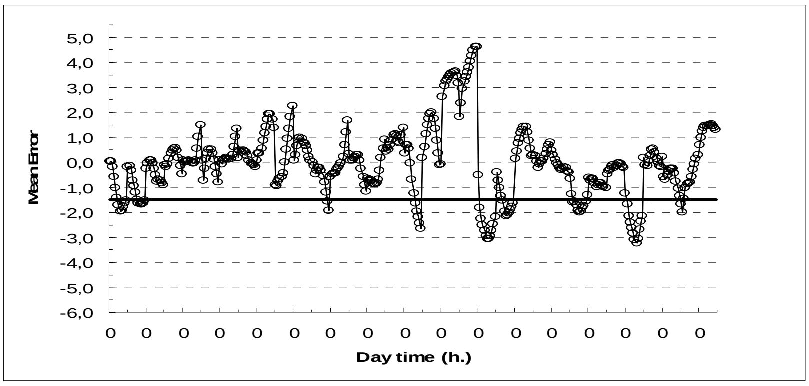

Figure 2: Mean error values (ME) corresponding to the third and fourth week of March of 1996. Bold line corresponds to the threshold mean error

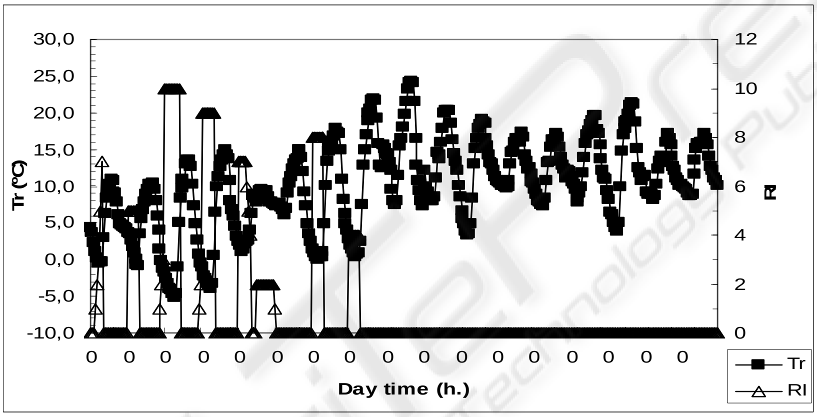

Figure 3: Real temperature (Tr) and Risk index (RI) during third and fourth weak in March 1996

REFERENCES

Bowerman, B.L., O'Connell, R.T.; 1.987. Time Series Forecasting. United Conceps and Computer Implementation. Duxbury Press. Boxton. 2nd edition

Box, G.E.P., Jenkins, G.M. , 1970. *Times series Analysis:Forecasting and control.* San Francisco: Holden Day

Cao, W., and D.N. Moss. 1989. Temperature effect on leaf and phyllochron in wheat and barley. Crop Science. 29(4):1018-1021.

Carlson, R.F.; Maccormick, J.A.; Watts, D.G., 1.970. Application of Linear Random Models to four Annual Steamflow Series. Water Resources Research. v.6, No.4, pp 1070-1078.

Castellanos, M.T., 1997. Estudio y predicción de temperaturas mediante análisis de series temporales en la Comunidad de Madrid. Ph.D. Dissertation, Polytechnic University of Madrid (UPM), Spain.

Fernandez, C.J., 1992. Simulation of normal annual and diurnal temperature oscillation in non-mountainous mainland Unites States. Agron. J. 84(2):244-251.

Jamieson , P.D. I.R. Brooking, J.R. Porter, and D.R. Wilson. 1995. Prediction of leaf appearance in wheat: a question of temperature. Field Crops Research 41:35-44.

Kantz, H., and T. Schreiber. 1997. Nonlinear time series analysis. Cambridge: Cambridge University Press.

Landau, S.; Mitchell, R.A.C.; Barnett, V.; Colls, J.J.; Craigon, J. and Payne, R.W. 2000. A parsimonious, multiple-regression model of wheat yield response to environment. Agric.For. Meteorol., 101, 151-166.

Matalas, N.C.; 1.967. Times Series Analysis. Water Resources Research. v.3, No.3, pp 817-829.

McMichael, F., and J. Hunter. 1972. Stochastic modeling of temperature and flow in rivers. Water Resources Research. 8, No.1,87-98.

Montgomery, A.L., and V. Zarnowitz.. 1998 . Time series analysis: Unemployment-United States – forescasting. Hornal of the American Statistical Association, 93,478-492.

Noakes, D.J.; McLeod, A.I.; Hipel, K.W.; 1.985. Forecasting Monthly Riverflow Times Series. International Journal of Forecasting. v.1, pp 179-190.