INSTABILITY INDICES FOR ATMOSPHERIC CONVECTION

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ABSTRACT

Three instability indices based on differences between equivalent potential temperature values at 1000hPa - 850hPa, 1000hPa - 700hPa and 1000hPa - 500hPa pressure levels have been analyzed. Daily radiosonde measurements from 1986 to 1990 have been considered to determine a relationship amongst convective cloud types, cloud cover precipitable water and precipitation over Isparta in Central Anatolia. The reliability of model is tested by considering data between 1991 and 1995.

1. INTRODUCTION

Three instability indices have been discussed to develop more reliable and effective forecasting for dry and wet convection in the central part of Turkey. Variation of convection, cloud cover and precipitation have been analyzed for the last decade Schowalter (1), Ratcliff (2), Boyden (3), Jefferson (4), Afriyie and Adefolalu (5) have developed some empirical models for prediction of atmospheric instability. Monthly variations of two instability indices are based on the equivalent potential temperature values at 1000, 700 and 500hP pressure levels over the northern zone of West Africa for severe weather forecasting.

Knowledge of the total moisture present in the atmosphere is important not only to meteorological and hydrological studies, but also to satellite communication, remote sensing of the atmosphere, and radio astronomy. For instance, microwave attenuation depends on the water content of the atmosphere and hence requires a good assessment of water vapor in the path of signal propagation, Afriyie (6). Complex topography creates atmospheric structures of high complexity, not only effecting airflow as an obstacle but also forming special circulation. Upper air soundings of temperature, humidity and wind field play an important role on convective activity, Reinhardt et al. (7), Lindemann (8) and Beets (9).

Climate observing networks assist in long-term simulation of climate change and also in near-term seasonal to interannual forecasts WMO (10). Such forecasts can have major economic impacts by influencing daily activities as agricultural practices, air pollution studies and soaring activities. Training and experience activities of Turkish Air Association have been carried by the Gliding School in the Northwestern zone of Central Anatolia. An empirical model has been tested to forecast atmospheric convection and precipitable water in this paper.

2. MATERIAL AND METHODS

Upper air radiosonde data for Isparta (φ = 37° 45'N, λ =30° 33'E, h=997m) at 00:00GMT have been used to compute instability indices. Air temperature, dew-point temperature and relative humidity for the standard pressure levels at 1000, 850, 700 and 500hPa have been considered. Rainfall rate, cloud type and cover observed between 1986 and 1995 have been analyzed.

Daily values of specific humidity and vapor pressure at 1000, 850, 700 and 500hPa are computed for a station at Isparta. Potential temperature and equivalent potential temperature values have been defined by thermodynamic equations. Sample of daily upper layer data for 5 days interval in a month between 1986 and 1990 have been analyzed to define the threshold value of indices. The second period between 1991 and 1995 have been considered to test empirical equations.

To forecast precipitation and atmospheric convection, energetic of lower and upper layer should be taken into account.

Three potential instability indices (I_{850}, I_{700} and I_{500}) are defined as below:

$$I_{850} = \Theta_e(1000) - \Theta_e(850) \tag{1}$$

$$I_{700} = \Theta_e(1000) - \Theta_e(700) \tag{2}$$

$$I_{500} = \Theta_e(1000) - \Theta_e(500) \tag{3}$$

Where $\Theta_e(1000)$, $\Theta_e(850)$, $\Theta_e(700)$ and $\Theta_e(500)$ are equivalent temperature values at 1000, 850, 700 and 500hPa pressure levels respectively. In a situation of thermal instability (stability) these indices should be positive (negative).

Precipitable water, W, within a unit cross-sectional area of atmospheric column of pressure P_1(hPa) at the bottom and P_2(hPa) at the top and of mean mixing ratio m (kg/kg) is given in millimeters, by the approximate formula, Stull (11):

$$W = m(P_1 - P_2)/g \tag{4}$$

Where g is the gravitational acceleration.

Daily precipitable water content values are computed between 1000 - 850, 1000 - 700 and 1000- 500hPa levels. W850, W700 and W500 are respectively precipitable water between these levels.

Correlation coefficients and linear relation between dependent variables (W_{850}, W_{700} and W_{500}) and independent variables ($\Theta_e(850)$, $\Theta_e(700)$, $\Theta_e(500)$, I_{850}, I_{700} and I_{500}) are obtained. The Log - linear transformations of W and Θ_e are also considered.

3. RESULTS AND CONCLUSION

3.1. Analyses of Cloud Cover, Precipitation and Instability Indices

Figure 1 shows variation of cloud cover, precipitation and three stability indices for radiosonde data recorded in Isparta in 1986. Correlation coefficients between cloud cover, precipitation and I_{850} are higher than correlation coefficients between precipitation and other indices. Multiple correlation coefficient increases up to 0.82 amongst precipitation, I_{850} and $\Theta_e(850)$.

3.2 Relationship Between Precipitable Water, Equivalent Temperature and Instability Indices

Table 1 shows linear equations and values of regression coefficients.

Maximum correlation is obtained for log - linear relationships in Isparta.

Figures 2 (a - d) shows regression lines based on aerological data between 1986 and 1990 in Isparta.

3.3 Tests of Empirical Equations

Figure 3 (a - d) shows the graphs of calculated LnW_{850}, LnW_{700}, LnW_{500} by using the present model against actual values in Isparta. The linear correlation coefficients between precipitable water content values are respectively 0.91, 0.87, 0.76 and 0.71 for logarithmic values of precipitable water content between 1000 - 850, 1000 - 700 and 1000 500hPa levels and precipitable water content (W_{500}) between 1000 - 500hPa pressure levels.

The correlation coefficient (0.91) between logarithmic values of predicted and actual precipitable water content values for the atmospheric column of 1000 - 850hPa levels is higher that the other coefficients.

3.4 Conclusions

Daily equivalent potential temperature is a good predictor of the logarithmic precipitable water value over Isparta. Log - linear relation between precipitable water content and equivalent potential temperature shows a fairly strong positive correlation. Negative correlation does exist between precipitable water content and instability indexes for the atmospheric column of 1000 - 850hPa levels. The highest correlation coefficient between parameters at 850hPa shows thermodynamic parameters at this level had played an important role on convective structure and precipitable content of study area.

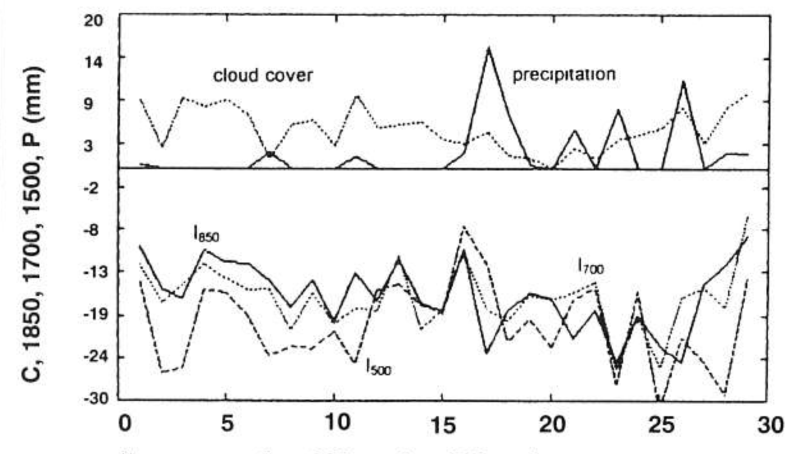

FIGURE 1. Variation of cloud cover, precipitation and stability indices for selected samples in 1986 in Isparta

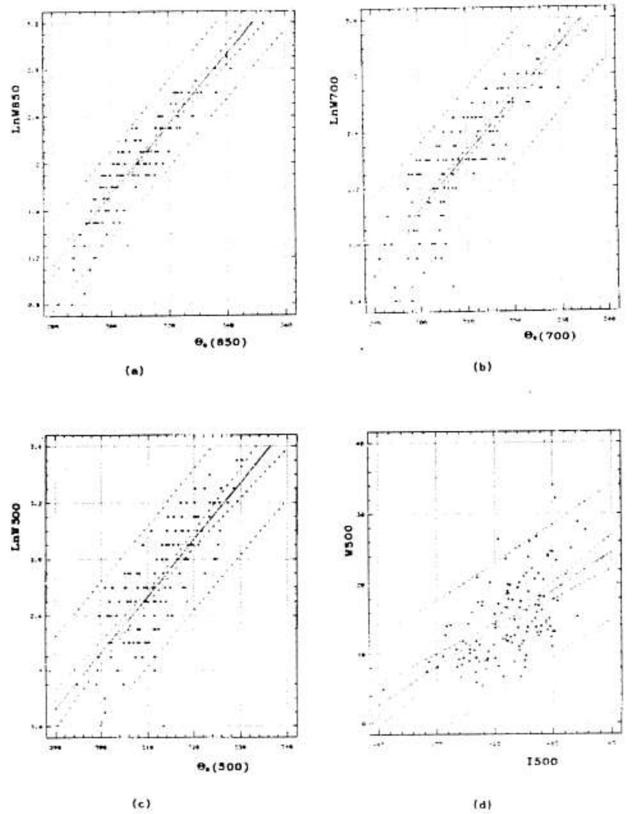

FIGURE 2. Regression lines based on aerological data between 1986 and 1990 in Isparta.

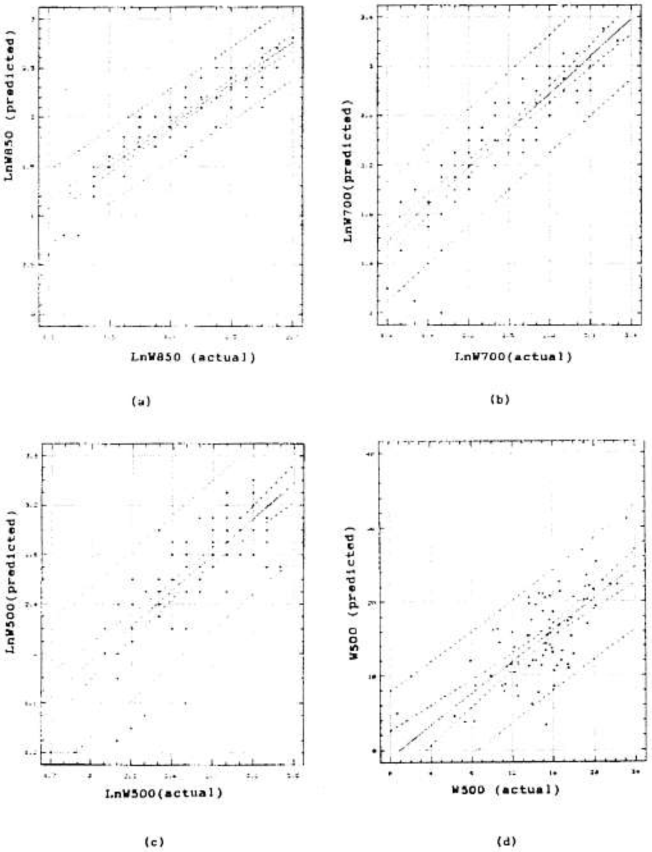

FIGURE 3. Actual and model values of LnW_{850}, LnW_{700}, LnW_{500} and W_{500} in Isparta.

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Table 1

Liner Equations and Regression Coefficients

Linear Equation	Regression Coefficient
$LnW_{850} = 0.0299\ \Theta_e\ (850) - 7.261$	0.88
$LnW_{700} = 0.0385\ \Theta e\ (700) - 9.504$	0.84
$LnW_{500} = 0.0404\ \Theta e\ (500) - 9.979$	0.76
$W_{850} = -0.198\ I_{850} + 4.663$	-0.35
$W_{700} = 0.119\ I_{700} + 14.268$	0.13
$W_{500} = 0.539\ I_{500} + 25.959$	0.57

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