VERIFICATION OF STATISTICAL CLOUDINESS ESTIMATIONS FOR EUROPE

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ABSTRACT. Verification of statistical cloudiness estimations for Europe. The climate forcing induced by cloud cover consists one of the main doubtful aspect of climate change predictions. In the case of cloudiness even the sign of the trends are not cohesive in a given region. In this sense further investigation regarding the behavior of cloudiness are indicated. In this study a statistical estimation of total cloudiness is elaborated using the method of instrumental variables. For this analyze surface-observed monthly mean cloudiness data was applied for the period of 1973-1996. In the second part of the study the verification of results is established using an independent satellite retrieved data series for the period of 2005-2011. Based on verification can be conclude that the applied statistical estimation is able to reproduce the measured values with an RMSE 7, 3%, the difference between the measured and predicted changes of cloudiness is 1.44%, found a stronger decrease of cloudiness in real data as the estimation had indicate. The main differences between the observed and predicted value is evident in the distribution of the frequencies showing a shifting towards the lower values in observed data but not recognized in the estimated values. In the geographical distribution of estimations errors sign a difference is detected between the water surfaces and continental regions.

Keywords: cloudiness, statistical estimation, verification, climate change

1. INTRODUCTION

Cloudiness is one of the main components of climate system but in the same time the changes in cloudiness is one of the most uncertain aspects in model predictions of climate sensitivity (IPCC, 2007). The complexity of the variation in cloudiness derives, on the one hand, from the fact that cloudiness is a local variable associated also with anthropogenic activities. On the other hand the formation of cloudiness is related to the weather situations and geographical factors.

Statistical methods are widely used in literature in order to estimate the changes of cloudiness regarding climate change, and we have to emphasize the importance of these type of methods parallel with physical modeling, namely because GCMs can still handle with low accuracy the hydrological cycles, thus the cloudiness formation as well (Moore, 2001). Synthetic report of both the global

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climate model (GCM) outputs (Mika et al., 2011) and those from the regional model (RCM) outputs (Linden et al., 2009) publish the temperature and precipitation changes, but they generally hide numerical details of the expected changes in cloudiness. Hence the empirical assessment of its changes parallel to the ongoing global warming is not outdated from scientific point of view, either.

As noted in the recent studies the changes in cloudiness have no uniform global trend but showing regional patterns. Surface observations suggest increased total cloudiness over many continental regions including the USA (Sun, 2003), the former USSR (Sun and Groisman, 2000), Western and Northern Europe (Bartók, 2010). However, decreasing cloudiness over this period has been reported over China (Kaiser, 1998), Italy (Maugeri et al., 2001) and over central Europe (Auer et al.,2007).

However surface-observed cloud datasets extend over a long-term period of time, studies investigating the variations and trends in cloudiness have not been fully validated due to lack of independent cloud data (Norris, 2005). In the last 1-2 decades comparing surface and satellite cloud data is solvable, which offer the possibility to validate the cloudiness estimations with recent satellite measurements.

In present study a verification of statistical cloudiness estimation is elaborated using SM SAF Cloud Fractional Cover dataset (Schulz, 2009) as independent data. The estimation is calculated based on the cloudiness variation obtained from the period of 1973-1996, the verification is done for the period of 2005-2011. The study area includes almost the whole European continent, the region between 10W and 35E longitudes, and 35N and 65N latitudes (Fig. 1.).

2. METHODS AND DATA

2.1. Visual cloudiness data

The surface-based cloudiness data are from the “Extended Edited Cloud Reports Archive” (EECRA: Hahn and Warren, 1999). The studied region is represented by 832 stations (Fig. 2.) over Europe, for the period of 1973-1996, where the monthly average amount of total cloud cover is given in percentage of the sky. In case of sporadic missing data gaps are filled by linear regression from another nearby station.

2.2. Satellite derived cloudiness data

The satellite cloudiness data are CMSAF dataset (Schulz, 2009), representing Fractional Cloud Cover (CFC) from polar orbiting satellites, monthly mean, converted from sinusoidal projection (15x15 km2) to geographical lat-long, 0.2 x 0.2 deg resolution (Fig. 1). These data were converted to ESRI grids with the help of Multidimension Tool of ArcGIS. All 84 datasets (7 years*12 months) were transformed. With the help of Raster Calculator the annual means were calculated, then the multi-annual mean also. The mean values for the 832 observation points were extracted from the grid with Extract values to Points tool of ArcGIS.

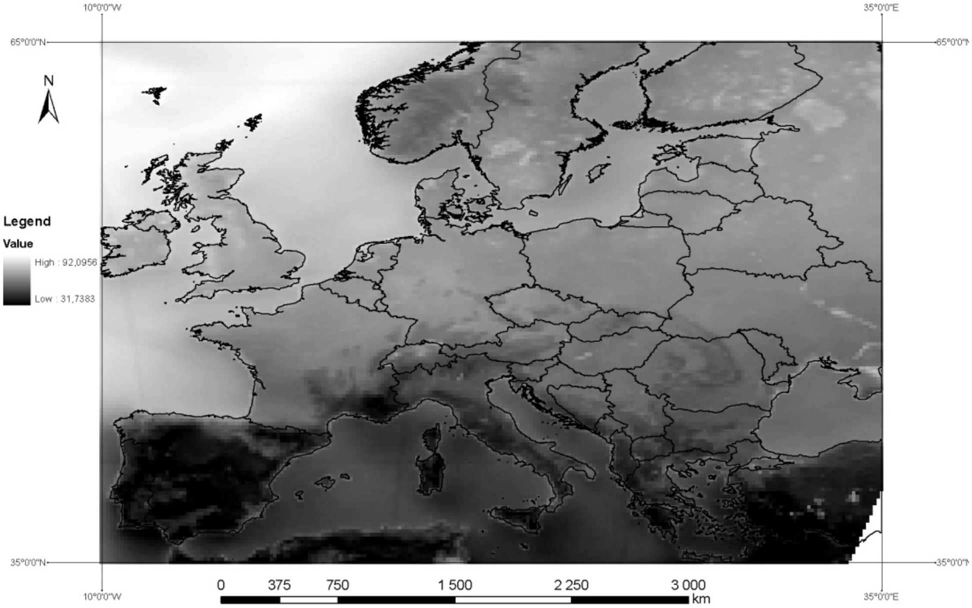

Fig. 1. ***Annual Fractional Cloud Cover in % representing the study area for the period of 2005-2011***

2.3. Method of instrumental variables

Let us have a dependent variable, Y, and an independent one, X. Let us further mark dY/dX as b, representing the regression coefficient of the linear stochastic connection, $Y = Y_0 + bX$. One possible way to estimate the regression coefficient, b, a linear stochastic connection, $Y = Y_0 + bX$, is the *method of instrumental variables*, first applied by Groisman and his colleagues (Vinnikov, 1986) in climatology. The criteria for an instrumental variable are:

- non-zero correlation with observed values of the independent variable,
- no correlation with the errors of the independent variable,
- no correlation with the residuals of regression in the dependent variable.

In case of an instrumental variable, Z, the linear regression coefficient should be estimated as the proportion of appropriate covariance values:

$$b = \frac{Cov\,(Y,Z)}{Cov\,(X,Z)} \tag{1}$$

For independent variable, *X*, the hemispherical mean temperature is selected (Jones, 1994). The instrumental variable for cloudiness is the sequence of years from the 24 years warming-up period, 1973-1996, exhibiting high (r = 0.796) correlation and strong (+0.021 K/ year) warming trend.

3. CHANGING OF CLOUDINESS OVER EUROPE

The past variation of local cloud cover indicators is calculated in function of hemispherical temperature by method of instrumental variables. By this method the changes of local variables in condition of 0.5 K hemispherical mean temperature increasing are calculated. Fig. 2. shows the behavior of annual cloudiness in the 1973-1996 period in function of temperature. The given period is characterized by a 0.21 K/decade warming trend. The cloudiness changes are given in absolute percentiles (100 % equal to total cloudiness). These changes, in condition of 0.5 K hemispherical mean temperatures increase, show temporal and spatial differences during the year: changes with both positive/increasing and negative/decreasing sign appear within the investigated area.

Some analyses have been elaborated in order to determine the reasons of geographical distribution of positive and negative changes. The results show that no significant correlation exists between cloudiness chances and geographical positions (altitude, longitude and latitude). This aspect can be explained by the fact that mesoscale total cloudiness is influenced mainly by the atmospheric circulations, and less by the geographical positions.

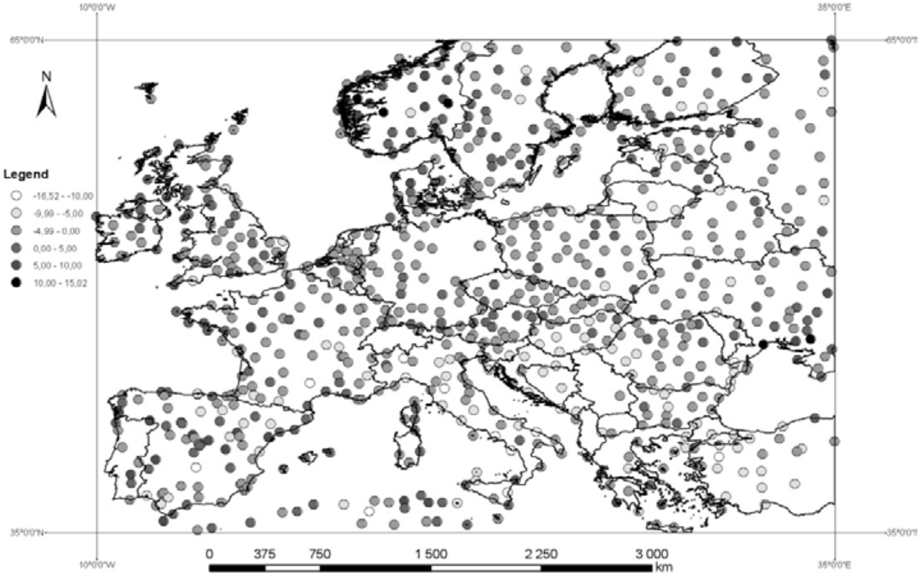

Fig. 2. ***The absolute total cloudiness changes (%) in Europe concerning 0.5K hemispherical warming***

4. VERIFICATION OF CLOUDINESS ESTIMATIONS

In this section the estimation of cloudiness is verified by independent time series, namely the CMSAF CFC data for the period of 2005-2011. This period exhibits an 0.5 K positive anomaly in temperature relative to the 1961-1990 mean (Jones et al. 1994) very close to that value what shows to the 1973-1996 period (the difference is 0.06 K). For this period high resolution satellite derived cloudiness dataset provide by the Satellite Application Facility on Climate Monitoring are available instead of visual observations.

In first step the two datasets are compared in order to detect the change in cloudiness indicated by the two datasets. The main statistics of the two periods is presented in the Table. 1. The results show a decrease in total cloudiness by 1.9**%.**

Table. 1. ***Statistics of total cloudiness for observed periods and estimation for Europe***

	1973-1996	2005-2011	Estimation for 2005-2011
Mean %	63.54	61.64	62.00
Max. %	81.29	89.60	85.08
Min. %	30.51	33.57	25.67
Stdev. %	9.98	9.01	11.2858

In the second step the results of statistical estimations are compared with the measured dataset in order to determine the error of cloudiness estimations. Choosing a period with the same warming tendency (0.5 K), the projected and measured data should be very similar. The estimated annual change in total cloudiness is -1.54, smaller than the measured one (Table 1.).

The difference between the estimated and measured values is quantified by the root mean square error showing a 7.30 % error in statistical estimation.

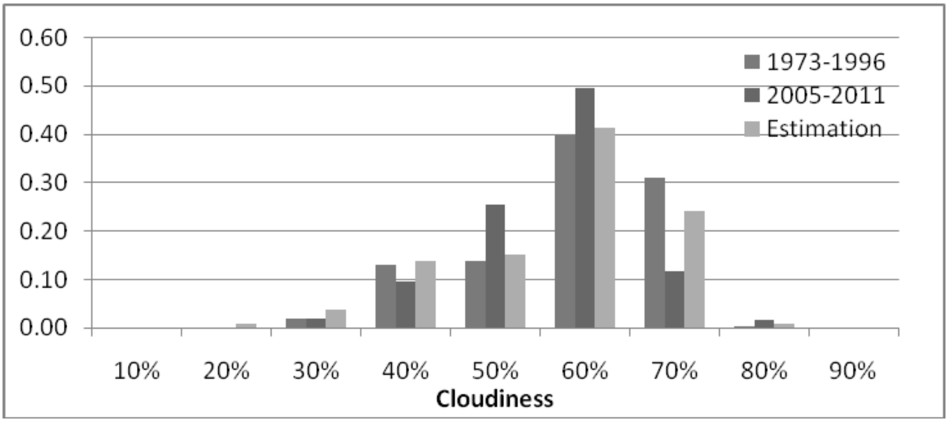

Fig. 3. ***Frequency distribution (histogram) for total cloudiness in Europe, representing observed periods and estimated values***

Fig. 3 shows the distribution of annual cloudiness in the period of 1973-1996, when more the 70% of the cases having annual mean cloudiness between 60% and 80%. In the period of 2005-2011 the distribution of cloudiness is shifted toward lowest values, 76% of the cases having values between 50% and 60%. In the case of estimations the modus is still the 60-70% category, but the relative frequency of the values is higher between 70-80% than between 50-60%. In the lower ranges (lower than 50%) an overestimated situation can be found, which suggest less decrease in the cloudiness compared to estimations.

A chi square test has been elaborated in order to determine if this shifting in distribution is statistically significant or not. The outputs of the analysis show that there is a significant shifting in the distribution of the measured multiannual data in the two different periods, namely between the period of 1973-1996 and 2005-2011. In the same time the distribution of the measured data in 1973-1996 and the estimation from these data do differ less. This points out the weakness of statistical estimation, namely that even the sign and the magnitude of changes are reflected in the results, but the shifting of the distribution is not reflected in the estimated values.

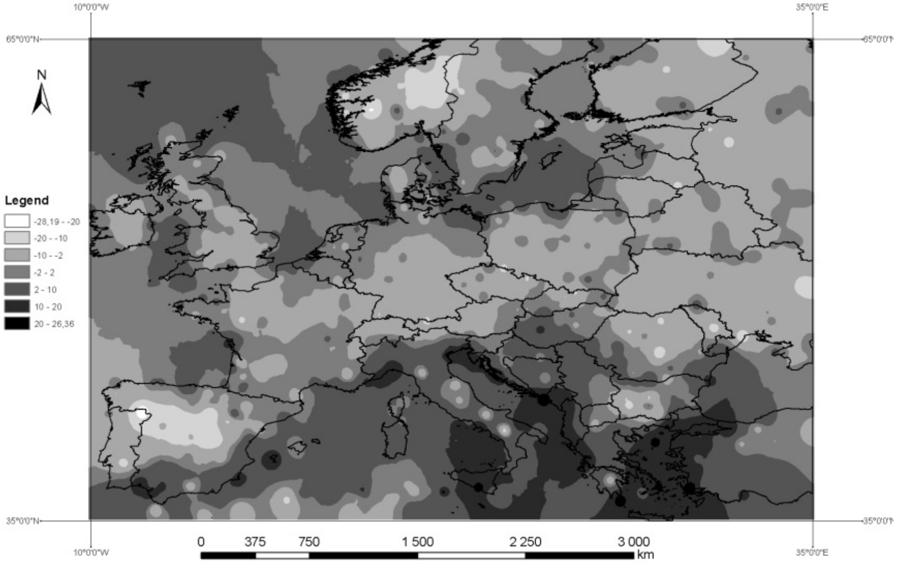

Fig. 4. ***The geographical distribution of estimation errors (%). Positive values representing higher value in observed cloudiness comparing with estimation, negative values representing lower value in observed cloudiness in cloudiness comparing with estimation***

The geographical distribution of errors between observed and estimated cloudiness data are presented in Fig. 4. created by interpolating the error values of the points using IDW (inverse distance weighted) method of Arc GIS tools. It can be observed a general difference between the continental regions and water surfaces. No correlation with altitude is detected. The values suggest that in the Southern and Northeastern part of Europe the observed changes in cloudiness are higher (more cloudiness) as the estimations would indicate (positive values), in the case of negative values the cloudiness decreases are more accentuated as the estimations would indicate. This decrease in observed total cloudiness compared to the estimations is characteristic mostly in the inner continental areas.

5. CONCLUSIONS

In this study a verification of statistical estimation using the method of instrumental variable is elaborated in order to quantify the changes in total cloudiness regarding 0.5 K hemispherical warming in Europe. The results in cloudiness changing estimated by this method show a good accordance with observed values in terms of sign and order of magnitude, establishing an RMSE of 7.3%. The weakness of this method consists in the fact that it can reproduces the situations, when the variable do not change linear, in our case the shifting in frequency distribution is not detected. The shifting in the frequency distribution is characteristic in the case of other climatologically parameters as well (e.g. extremes values of temperature), thus further methodological investigations are required in the case of cloudiness changes. The geographical distribution of errors in estimation indicates a difference between oceans and continental areas, in the case of oceans/sees the cloudiness amount having higher values as the estimated ones, in the case of continental areas the amount of observed cloudiness is lower as the estimated ones. This fact indicates a different response of cloudiness to climate change in the case of distinct surfaces.

Acknowledgment. The authors hereby thank Prof. Dr. Mika János for his methodological improvements applied in this article.

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