ARE SOME CLOUDS OBSCURED IN SATELLITE VIEW?*

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Many recent studies of the relation between cloud cover and cosmic rays or other solar proxies, as UV irradiation, have been based on an analysis of the satellite-based cloud data from ISCCP. However, some authors suggested that there is a possibility that the relations may be result from instrumental problems as low clouds masking by higher clouds in the satellite view. This problem has been addressed also in a previous paper. We performed a thorough analysis of the ISCCP cloud data for the period 1984-2004 in order to find if the relation between different types of clouds (low, middle or high) it is based on real conditions rather or on a simple obscuring of low clouds. Our results favour the first assumption and this is supported also by the fact that the relation has a clear geographical pattern. We also find that, in turn, low clouds may affect the observation of higher clouds in some regions.

Key words: atmosphere; climate; solar-terrestrial relations; cloud cover.

1. INTRODUCTION

Although most of studies and reports show that the Earth is experiencing a period of global warming which is highly probably due to the increase of greenhouse gases. However, there are several studies that show that there are correlations between some solar proxies and climate indicators as temperature, sea surface temperature, cloud cover, precipitation. Some results support the idea that the low cloud amount (LCA) shows a high degree of correlation with the flux of galactic cosmic rays (CR) impinging on the Earth. In [1–3] the global average of LCA and CR recorded by a neutron monitor for the period 1984–1994 were used to show that here is a high LCA-CR correlation. The authors of [4] studied the latitudinal (zonally averaged) LCA as well as their geographical pattern and compared it with the geographical distribution of the modelled cosmic ray induced

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ionisation (CRII). They concluded that the two quantities are well related to each other. Later, [5] and [6] have shown that the relation between the cloud cover and solar proxies is complicated by the presence of other clouds and must be treated with caution. The results of [6] imply that the negative correlation between UV irradiation (UVI) and LCA is more consistent than the positive correlation between CRII and LCA (it is well-known that the two proxies are anticorrelated). They have also found that the high cloud amount (HCA) seems to be, on the other hand, influenced mostly by CRII.

Different mechanisms have been suggested to explain a link between solar activity and cloud formation, such as via CRII effect on condensation nuclei [7], electrofreezing by the vertical current system induced by solar wind interaction with the magnetosphere [8] or UV heating [9]. These mechanisms can dominate at different altitudes, leading to opposite correlations between different types of clouds and solar proxies. Note that correlation studies can hardly distinguish between particular mechanisms because of strong inter-relation between different solar indices such as, e.g., CR, geomagnetic activity or UV variations. However, using partial correlation [6] offered a picture of the possible relationships between clouds and CRII on one hand and clouds and UVI on the other. Because of scarcity of ground based cloud observations, satellite-based cloud data collected in the ISCCP database [10] are commonly used in such studies. Lately, doubts have been casted concerning the purity of LCA data in ISCCP, as they may be obscured by middle and high clouds in the satellite view (see, e.g., [11–13]) since multi-layer clouds are identified in ISCCP by their tops.

On the other hand, thick low clouds may in turn affect high clouds identification especially over different backgrounds [13]. Therefore, there are questions about the consistency of the earlier found LCA-CRII relation [12]. If the latter is true, it would have a strong impact on any analysis involving satellite cloud data regardless of the aim of the study. Here we try to clarify this question. Using a thorough analysis of the cloud data in ISCCP covering the period 1984–2004 we try to identify the possible problems that could arise from using satellite cloud data.

2. RELATION BETWEEN CLOUDS AT DIFFERENT ALTITUDES

Here we analyze the monthly and annual cloud amount (percentage of the area covered by clouds of a given type) for the period 1984–2004 as given by the ISCCP-D2 dataset (http://isccp.giss.nasa.gov) in the IR diapason, in geographical grid of 5x5 degrees. The ISCCP database distinguishes between three types of clouds depending on the cloud top pressure P: low ($P > 680$ mb), middle ($440 < P < 680$ mb) and high ($P < 440$ mb).

Here we study the annual data (in order to avoid the seasonal cycle) for the period 1984–2004, i.e. 21 temporal points, in 2592 grid cells. The correlations between cloud cover and solar proxies has been analysed in [5–6] and here we will only refer to their results. It has been shown in these papers as well as in [12] that low and high (or middle) clouds are strongly anticorrelated (see Fig. 1) while high and middle clouds are strongly correlated (Fig. 2). Such a correlation between clouds could affect the final results of correlation studies between cloud cover and solar proxies. Coexisting low, middle and high clouds could be identified as only high clouds (see [12–13] for details).

Using partial correlations, [5] and [6] have shown that the correlation between clouds and solar proxies might be spurious in certain areas. It was also shown in [5] that the negative correlation seen between low and middle plus high clouds is not induced by any solar proxy. However, such a correlation study cannot establish whether this relation is an artifact caused by an instrumental effect (e.g., obscuring of low clouds by higher clouds) or a fact due to a real physical mechanism. In order to clarify this question we produced scatter plots of different type clouds versus the other, using monthly values for all grid cells (approx 650,000 points).

A first look at Figs. 3 (middle clouds *versus* low clouds) and 4 (high cloud *versus* low clouds) gives an impression that there is “obscuration” of one type of clouds by the other ones. The dense concentration is elongated from left top to right bottom, there is a sharp upper boundary, and the sum of all types of clouds never exceeds 100%. This effect would devaluate correlation studies based on low clouds, if the overlapping of low and higher clouds would be random.

However, different types of clouds are not independent (see, e.g., [13]) and their coexistence is limited by physical mechanisms (meteorological conditions), which are different for different regions. Accordingly, the observed relations shown in Figs. 3 and 4 are not homogeneous (see colour contours in both figures). The fact that the four zones (tropical/mid-latitude and mainland/ocean) do not overlap in the high-low cloud relation as well as in the relation between middle and low clouds, suggests that this relation is dominated not by a simple obscuring due to the random overlap of different clouds, but rather by physical conditions preventing from the coexistence of different types of clouds (e.g., [13–14]). Also fig. 5 shows that the total distribution of low and high cloud cover over tropical areas is different from middle-high latitudes regardless of the nature of surface beneath the clouds.

The scatter plot of high cloud cover versus middle cloud cover presented in Fig. 6 has also a sharp boundary in the upper part, suggesting that, when the cloud cover exceeds 30%, middle clouds are obscured by high clouds. However, the two types of clouds are positively correlated almost everywhere. An interesting feature of this plot is the different relation between the two types of clouds at tropical latitudes compared to higher latitudes. This means that indeed the co-existence of certain types of clouds has a physical basis. Middle and high clouds coexist in tropical areas but this is less probable at higher latitudes. Finally, Fig. 7 suggests that, most likely, when the high and middle cloud coverage is high, some caution should be paid to the low cloud cover definition. However, the fact that different areas are totally different from the cloud cover point of view supports the idea that some clouds simply do not co-exist.

If higher clouds would obscure lower clouds, similar contours should be seen regardless of the nature of the area beyond clouds or of the latitudes where the clouds are observed. Moreover there is no reason for which high clouds would obscure only low clouds and not middle clouds in the satellite view. Our results suggest that the anticorrelation (or correlation, on that matter) between different types of clouds has mainly a physical reason. High and low clouds do coexist rarely, while middle and high clouds are seen most of the time together. This is also sustained by other results studies (e.g. [14] and references therein).

3. CONCLUSIONS

As shown by [5–6], the correlation between solar proxies (mainly cosmic ray induced ionisation) and low cloud cover could be induced by the relation between cosmic rays and high (middle) clouds in some geographical areas (e.g., South Pacific, north cost of Eurasia). On the other hand, there are large geographical regions where the correlation between low clouds and solar proxies is not affected by middle and high clouds. On the other hand the correlations between higher clouds and solar proxies are also affected by the presence of low clouds, especially for middle clouds. The relation between low and higher clouds does not depend on the solar activity signal, implying that this relation is direct (either physical or instrumental) and not related to a possible modulation of cloud amount by CRII.

Our results suggest that in such regions there is a strong physical link between low and higher clouds, i.e. meteorological conditions prevents the coexistence of the different types of clouds [13–14]. In other words, a high value of high and middle cloud cover implies the real absence of low clouds and not an instrumental masking (and vice versa). Hence, low cloud-solar proxy relation in these regions is real and not intervened by higher clouds. Conversely, in the regions where all types of clouds coexist, more or less independently, the real low cloud cover may differ from that observed by ISCCP because of the partial obscuring, resulting in high cloud cover intervening the solar proxy-low cloud relation. This is sustained mainly by the fact that the scatter-plots of different types of clouds are totally different when moving from one region to the other. If the some clouds would be obscured by others, the distribution of cross-correlations would not depend on the region.

We found in [5] and [6] two large regions where low clouds could affect the correlation between high clouds and cosmic ray induced ionisation: South Atlantic and North Atlantic/European regions, where detection of high clouds in ISCCP may be affected by thick low clouds over oceans. AS shown in [5], the results based on correlation between any solar index and a particular type of clouds from ISCCP database may be distorted when using global or latitudinal zonal averaged data. Instead, such studies should be limited to specific geographical areas (e.g., south Atlantic, west Indian oceans and European regions for LCA), where other types of clouds do not distort the amount of cloud determined in ISCCP.

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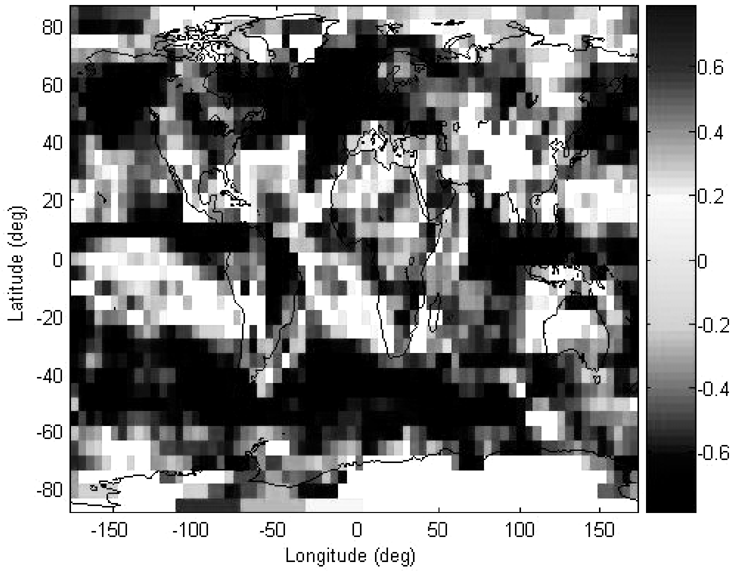

Fig. 1. – Global distribution of correlation between high and low clouds.

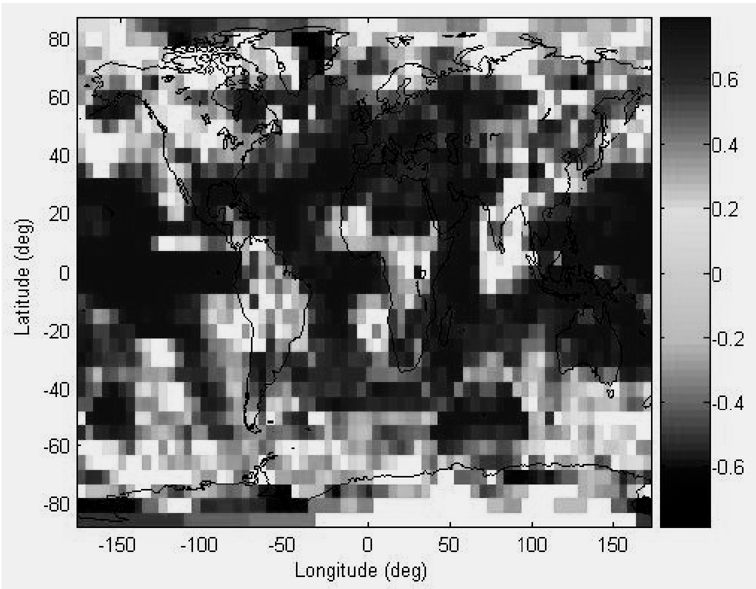

Fig. 2. – Global distribution of correlation between high and middle clouds.

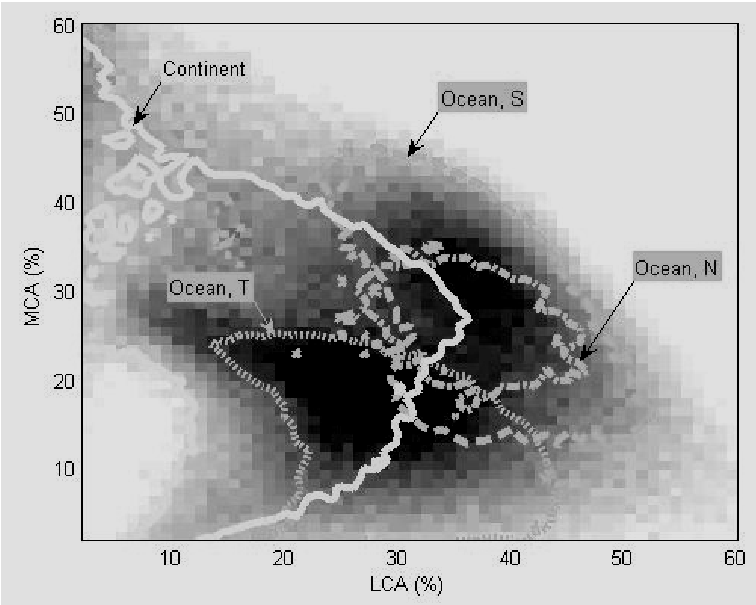

Fig. 3. – Scatter plot of middle cloud cover *versus* low cloud cover using monthly values for all grid cells. Colour contours correspond to different regions: Yellow (continuous line) corresponds to cloud cover above continental areas; different blue lines corresponds to oceans form southern (S, dash) and northern (N, dash-dot) hemisphere and tropical latitudes (T, dot).

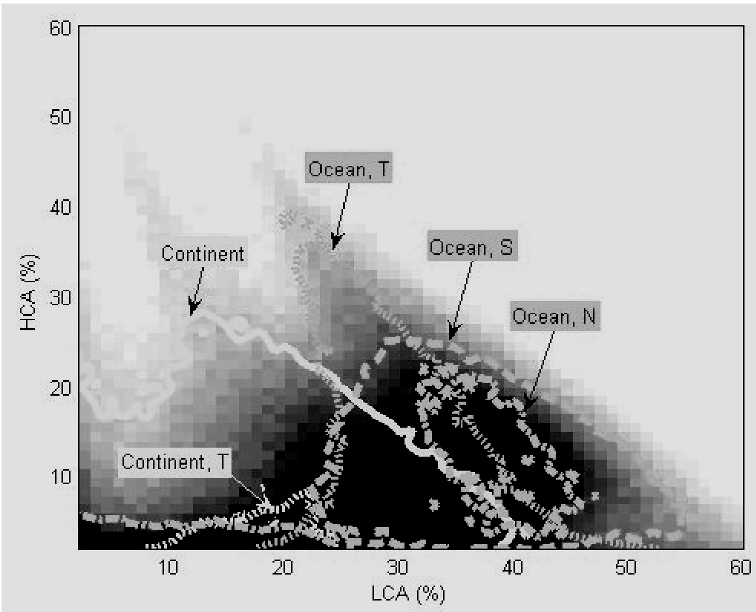

Fig. 4. – Scatter plot of high cloud cover *versus* low cloud cover using monthly values for all grid cells. Colour contours correspond to different regions. Yellow contours correspond to cloud cover over continental areas (T corresponding to tropical sites – dotted line) and blue lines are similar to Fig. 3.

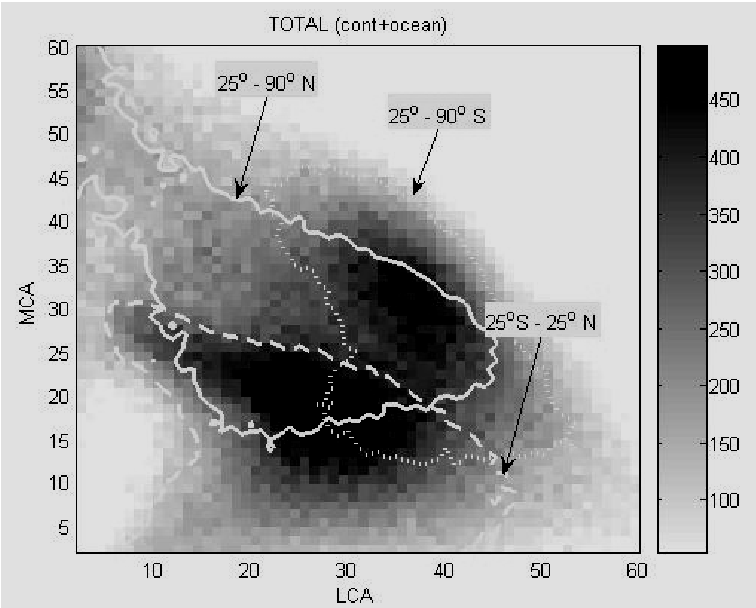

Fig. 5. – Same as previous, but for different ares. Yellow contours correspond to total cloud cover between 25°S and 25°N (dash line), between 25°N and pole (continuous line) and for similar latitudes in the opposite hemisphere (dotted line).

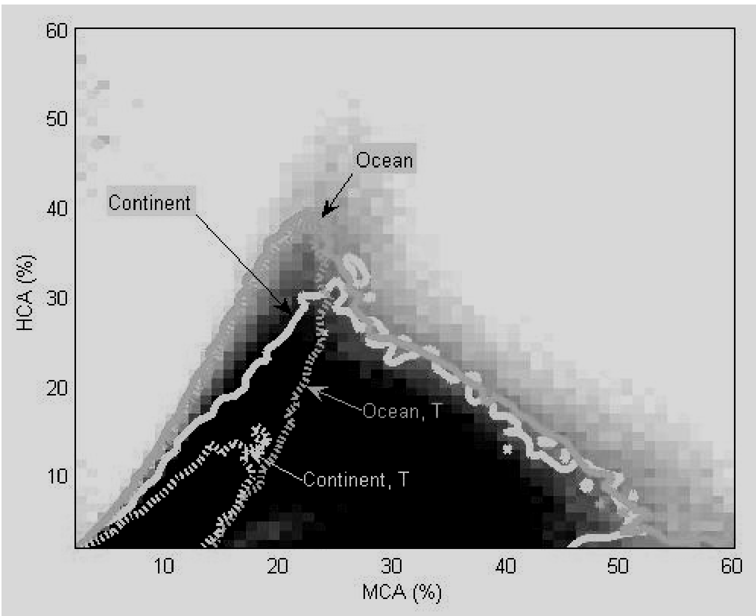

Fig. 6. – Scatter plot of high *versus* middle cloud cover, with similar contours as in Fig. 2.

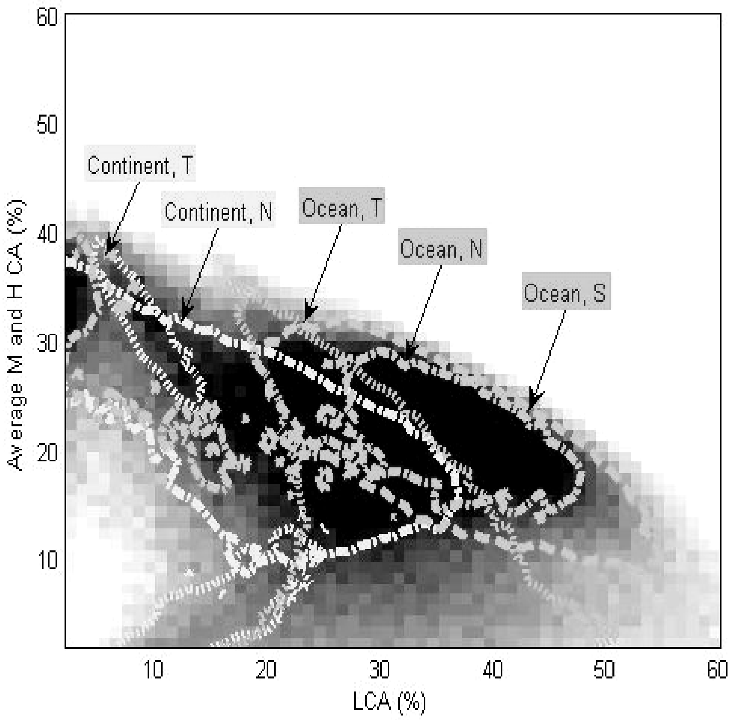

Fig. 7. – Scatter plot of high plus middle *versus* low cloud cover, with similar contours as in Fig. 2.