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Discussion

Reply to comments on "Variation of cosmic ray flux and global cloud coverage — a missing link in solar–climate relationships" ☆

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Svensmark and Friis-Christensen (1997) [henceforth SF-C] have presented a striking correlation between the cosmic ray flux and the cloud cover over a significant part of the Earth. They further suggested that this might point to a long-searched link between solar activity variations and global climate.

Jørgensen and Hansen (1999) [henceforth JH] claim that an observed change in cloud cover can be attributed to a change in the flux of cosmic particles only if (1) there is a significant correlation between the flux of cosmic ray particles and the observed impact on cloud cover, (2) the impact has a physical basis, and (3) other explanations can be ruled out. They claim that they have shown that none of these requirements are fulfilled and, accordingly, that evidence supporting the mechanism of cosmic rays affecting the cloud cover and hence climate does not exist.

It is unclear whether the objective of their comment is just to demonstrate that the mechanism proposed in SF-C has not yet been proven. In that case the statement is consistent with SF-C. If JH, on the other hand, mean that the mechanism proposed by SF-C can be ruled out, the material they present is neither new nor original and cannot support their conclusion.

1. The significance of the correlation

The significance of any correlation is difficult to assess as long as the physical mechanism has not been understood and formulated, however there is no reason not to use the existence of a correlation as a basis for a search of a relationship. One can of course discuss whether the global satellite data are "global" in the strict sense of the word. In this context, however, the discussion is not really relevant. SF-C restricted the observations to cloud cover from the geostationary satellites used in the ISCCP-C2 data set, due to their superior temporal and spatial resolution. Including the polar orbiting satellites would not imply a better representation of the global cloud cover, since these satellites had calibration problems during most of the period (Klein and Hartmann, 1993). In addition, spatial correlations map of cloudiness and cosmic rays show a sharp contrast **degrading** of the correlation over areas covered by polar satellites, a contrast that is created by the observational system and not of physical origin (Svensmark, unpublished). An inclusion of such data would therefore most likely serve to obscure any physical signal that might be present. Furthermore, JH do not present evidence that a "true" global coverage based on observations with the same spatial and temporal resolution as the geostationary satellites, would change the "global" cloud cover found by SF-C, significantly. The report on a missing correlation when dealing with the individual cloud types (Kernthaler et al., 1999) is irrelevant since that report used an

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old data set, ISCCP-C2, which was derived by means of an algorithm that was abandoned in 1990 due to its bad performance (Klein and Hartmann, 1993). A reanalysis of all the data was therefore performed based on an improved algorithm (Rossow et al., 1996). The resulting ISCCP-D2 data set differs considerably from the C2 data set with the categorization into the individual cloud types, and we could not reproduce the results of Kernthaler et al. (1999) using this new and improved data set (Marsh and Svensmark, unpublished).

2. The physical basis for the mechanism

It is clear from the literature that cloud condensation processes are not well understood. Obviously the claim of JH that the strongest impact on clouds should be near the height of maximum ionisation of the cosmic rays is not based on any experimental or observational data and ignores the properties of the atmosphere and the height profile of all other parameters of importance for the condensation processes. But absence of knowledge is not sufficient to claim that a physical basis is absent.

3. Other possible influences on cloud cover

It is certainly possible that other atmospheric processes may also have an effect on cloud cover. This is particularly the case in the tropics as stated by SF-C. But we can only agree with the statement of JH that there is no proof that the observed changes in cloud cover are caused by ENSO and/or volcanic activity. Hence a possible effect of the cosmic ray flux cannot be ruled out.

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