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Nowcasting nocturnal cloudiness with surface-near temperature measurements

## Abstract

Cloudiness has an important influence on the near-surface temperatures. During daytime solar irradiation is shaded by clouds. Due to radiation in clear nights, the grass temperature  $T_{0m}$  (the air temperature at surface level) decreases more rapidly than the air temperature  $T_{2m}$  in 2 meter above ground. If there are clouds, this effect is reduced by long-wave counter-radiation.

Thus, the knowledge of cloud conditions is of central relevance for the prediction of near-surface temperatures and of associated risks like ground frost or road slipperiness. Especially within the nowcasting range up to three hours, it would be desirable to predict changes of the grass temperature (e.g. by post-frontal clearing or the formation of high fog) as accurately as possible. This requires detailed knowledge about the two-dimensional structure of the cloud field, which is information normally extracted from satellite data. But especially in winter nights and in orographically structured areas, the temperatures of cloud top and surface often are in the same range and their infra-red signals are not easily distinguishable. Therefore, other ways should be considered to provide two-dimensional cloud informations. This thesis introduces a model to deduce cloudiness from the temperature difference  $T_{diff} = T_{2m} - T_{0m}$ . It is initialized and tested with data from one station and then applied to a dense network to yield a two-dimensional cloud map by interpolation. With help of a tracking algorithm, the displacement of cloud patterns is nowcasted. The results could be used to predict changes of  $T_{diff}$  and thus, for instance, hazardous road conditions.

Since most of the risks mentioned above are connected with a temperature decrease below freezing level, this thesis concentrates on night time (sunset to sunrise) and winter months (November to April). Depending on the particular cloud situation, different temperature gradients in time and space are occurring. Their effect depends on the magnitude of the atmospheric counter-radiation, and thus on the height as well as on the amount of the clouds. Suitably, a height-adjusted cloud amount is introduced. A functional relation exists between the temperature difference  $T_{diff} = T_{2m} - T_{0m}$  and the height-adjusted cloud amount. Another indicator for cloudiness is precipitation: When it is raining or snowing, the sky is usually broken or overcast.

At the ANETZ station in Payerne, grass and air temperature, precipitation rate and further meteorological parameters are measured every 10 minutes. Every three hours cloud amount and cloud height are observed. Therefore, this station is suitable for initialization and testing of a diagnostic model basing on the data of the winters 1995/96 to 2001/02. Here, the connection between height-adjusted cloud amount and temperature difference is described by an exponential equation. The free parameters of the equation are determined by regression for five

wind speed and four temperature ranges separately. With increasing wind speed and at warmer temperatures, the quality of the model results decreases. If one assumes the observation of the height-adjusted cloud amount to be accurate to 0.9 Octa, the resulting model error is 1.22 Octa.

For obtaining a two-dimensional cloud map by interpolation, a measuring network as dense as possible is necessary. In northern and central Switzerland 13 stations of the automatic measurement network of MeteoSwiss (ANETZ), 5 stations of the meteomedia ag and 52 road weather stations of the road inspection office of the canton of Lucerne are operated in a study area of 100 × 100 km<sup>2</sup>. At all stations similar parameters are measured as in Payerne, but only few stations have observations of cloud height and amount. Further stations of the ANETZ and the meteomedia ag can be considered for interpolation, though they are situated outside the study area.

The model developed for Payerne is applied to all ANETZ and meteomedia stations without changing the regression parameters. For the road weather stations of the canton of Lucerne the different soil of the stations (road instead of grass) has to be considered. By additionally measuring the road surface conditions, the results can be corrected for effects of evaporation and hoar frost. The model error at the road weather stations is approximately 1.5 Octa.

By suitable interpolation of the data of all stations, one receives a cloud map every quarter of an hour. The interpolated cloudiness is divided into five classes (from clear to overcast sky) and supplemented by five precipitation classes out of weather radar measurements. For several case studies cloud maps were created, generally correctly showing substantial structures of precipitation and cloudiness, formation of clouds and clearing tendency. Frontal cloudiness and post-frontal clearing are recognised reliably. The formation of high fog can be identified. At the road weather stations the connection between post frontal clearing and slippery roads in view of the freezing of resting rainwater is shown in several cases.

With the radar tracking algorithm COTREC / RainCast, a pattern recognition technique, nowcasting of radar precipitation images is possible (Schmid et al. 2000). This algorithm is successfully applied to the cloud maps. Especially slow advective changes like post-frontal clearing are well forecasted. Rapidly moving structures restrict the possibilities of the nowcasting: the 15 minutes time interval between two cloud maps is large, the study area is small. Local changes of cloudiness like the formation of high fog can just be observed but not predicted. The cloud forecasts are not only successful in special situations (e.g. post-frontal clearing), but also on the average of all nights in January 2004. The reliable forecast range is 60 to maximally 90 minutes. Particularly, when clear sky or few clouds are predicted, the forecast is superior to assuming persistence. With regard to the risks of road slipperiness and ground frost, these cases are the really critical ones.

Altogether, the (height-adjusted) cloud amount of each station can be determined out of near-surface temperature measurements and precipitation information only. Within the interpolated two-dimensional cloud maps the advection of clouds and cloudless sky can be identified. Normally, the extrapolation of the cloud maps works successfully. These forecasts of the cloud field enables to anticipate a change in near-surface temperatures (e.g. in cases with changing cloudiness), and thus allows to nowcast ice formation or the risk of ground frost.