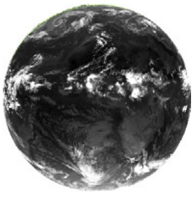
6 Conclusions

The presence or absence of clouds has a significant impact on the earth radiation budget. Consequently, cloud coverage statistics based on a reliable cloud detection are important for long-term monitoring of climate change as well as for validating climate models. As the cloud mask (generated from the cloud detection output) is generally the first link of a chain in the retrieval of atmospheric, surface, and cloud parameters, the quality of the cloud detection algorithm directly affects the quality of every depending product.

In the context of this dissertation, a cloud detection algorithm for the use within SEVIRI's whole field of view has been established as one of the first SEVIRI level2 products developed at the *Institut für Weltraumwissenschaften*, *Freie Universität Berlin*. The developed cloud detection algorithm is based on the analysis of spectral and temporal information from SEVIRI observations by artificial neural networks.

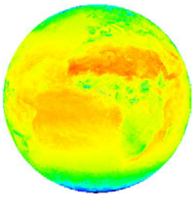
In particular, the assumed clear sky brightness temperature in the $10.8\mu m$ channel estimated from analyses of its temporal evolution is a central input parameter of the utilized neural networks. The estimation method is self-organizing and not dependent on any auxiliary data. It is based on assumptions regarding the smoothness of the surface temperature diurnal cycles, their possibility to change in time and that clouds generally appear colder in this channel than the underlying surface. The ranges of validity of these assumptions have been evaluated and discussed as possible sources of error. The accuracy



of the brightness temperature values calculated by the ACSBTE algorithm has been estimated with $3.3K$. First results of a cloud top pressure retrieval algorithm developed at the *Institut für Weltraumwissenschaften* show that the usage of BT_{ACSBTE} is valuable not only for cloud detection but also for the retrieval of cloud top pressure from SEVIRI data. A BT_{ACSBTE} level2 product processor has been integrated in the SEVIRI near real time processing at the *Institut für Weltraumwissenschaften*. The universal design of the ACSBTE algorithm makes it adaptable also for the estimation of assumed clear sky reflectances.

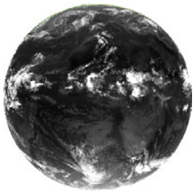
Other input parameters for the neural networks is data from the SEVIRI channels at $13.4\mu m$, $12.0\mu m$, $10.8\mu m$, $8.7\mu m$, $3.9\mu m$, $1.6\mu m$, $0.8\mu m$, and $0.6\mu m$. The training dataset has been created by manual classifications. Simulations with the radiative transfer program XTRA have been utilized to prove the physical relevance of the neural network input parameters and to determine the theoretical sensitivity of the developed algorithm to clouds of different types. For all trained networks, a multilayer perceptron architecture has been chosen, holding one hidden layer with 20 and 25 neurons, respectively, depending on the input complexity. The output of the recall function is converted to cloud covered probabilities according to the test and training dataset. This makes the cloud detection output physically interpretable. In average the trained ACSBTE networks classified 95.8% and the non-ACSBTE networks classified 91.3% of the training and test data with a confidence level greater than 0.95. A fundamental characteristic of neural network approaches is that they are not based on a physical model but on data that implicitly describes the underlying physical relations. For this reason, errors caused by incorrect assumptions on the model are impossible, but the disadvantage is that changes of the sensor or adapting the recall functions to a different sensor generally necessitates a new training process.

The cloud mask has been validated against more than one million European synoptical observations within a long-term validation period from July, 1st 2004 to December, 31st 2004. In a short-term validation period from June, 3rd 2004 to June, 8th 2004, the cloud mask has additionally been compared to the operational



EUMETSAT cloud mask included in the EUMETSAT cloud analysis product. The suitability for different applications has been evaluated by different statistical benchmarks. The overall bias which is especially important for cloud coverage statistics amounts to -0.0100±0.0003 within the long-term validation period. Within the short-term validation period, the corresponding values for the developed FUB and the EUMETSAT cloud mask are -0.026±0.002 and -0.075±0.002, respectively.

The degree of conservative cloud free and conservative cloud covered detection can be adjusted by a confidence threshold that also affects the amount of undecided cases. When choosing 0.5 as confidence threshold all SEVIRI pixels will be classified as either cloud free or cloud covered. This confidence threshold value has been chosen for the calculation of all following benchmark results describing the cloud mask quality. Within the long-term validation period, the overall probability of the cloud mask agreeing with the corresponding synop classification amounts to 83.50±0.06% for the cloud free case and to 88.94±0.04% for the cloud covered case. For the same period, the overall probability of a synop report confirming the cloud mask amounts to 81.18±0.06% for the cloud free case and to 90.42±0.04% for the cloud covered case. As overall benchmark, the Kuipers skill score and the proportion correct have been chosen, whereby the former is less intuitively interpretable but more meaningful. Within the long-term validation phase, the overall performance can be quantified with a Kuipers skill score of 0.724±0.001 and a proportion correct of 86.96±0.04%. The overall Kuipers skill score within the short-term validation phase amounts to 0.807±0.004 for the FUB and 0.747±0.005 for the EUMETSAT algorithm. The corresponding proportion correct values are 90.6±0.2 and 86.9±0.2 for the FUB and the EUMETSAT algorithm, respectively. These values prove the high quality of the developed cloud detection algorithm. The influence of cloud height, regional/surface aspects, the sensitivity to cloud integrated water content, the sensitivity to sub pixel cloud fraction and day/twilight/night effects have also been analyzed. Additionally, it has been analyzed in how far the usage of BT_{ACSBTE} effects the quality of cloud detection and masking. In summary, the usage of BT_{ACSBTE} increased the quality at nighttime and twilight but decreased the quality at daytime. This fact can be



expressed in terms of the Kuipers skill score: Within the long-term validation phase the Kuipers skill score increased from 0.634±0.001 to 0.658±0.001 under nighttime conditions and from 0.655±0.002 to 0.699±0.002 under twilight conditions but decreased from 0.858±0.001 to 0.811±0.001 under daytime conditions when using BT_{ACSBTE}. For this reason, the FUB algorithm for routine operation uses BT_{ACSBTE} only at nighttime and twilight but not at daytime. An over-interpretation of BT_{ACSBTE} when creating the training dataset has been suggested as possible reason for this behavior.

In conclusion, a brief outlook on two future tasks will be given: 1) As mentioned in the latter chapter, it was announced on the EUMETSAT website that the scene classification scheme was updated on August, 23rd 2004 with the effect that “more pixels are now classified as cloud during daytime” [*EUMETSAT*, 2004c]. A comparison to the updated cloud mask, particularly with regard to the overall bias and the detection probability of low clouds would be an interesting future task. 2) In order to prevent possible “edge effects”, the developed FUB algorithm in the present version merely analyzes spectral and temporal information but no spatial information. In future versions, the *HRV* channel could be used to provide valuable information on sub pixel properties, even though this would only affect the cloud detection quality at daytime which is already superior to the quality at nighttime and twilight.