USE OF MULTIPLE IR SENSORS DEVICE FOR AN IMPROVED ASOS CLOUD COVER ALGORITHM

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Abstract:
New scientific challenges in the field of atmospheric physics bring more innovative instruments for accurate day and night monitoring of the cloud cover. The instrument we present could be deployed and operated in remote locations. It allows for improving the available ASOS cloud cover algorithm. We will show algorithm simulations, illustrate optimal features and orientation of the static IR probes orthogonally positioned and compare experimental results with other techniques and instruments such as human observer, TSI, CIR13, and Ceilometer.

I-Introduction

Over the last few years several experiments showed a significant interest in cloud observations using thermal radiations in the window spectral range 9-14 µm (Long at al. 2003, Gaumet et al. 1998, Berger et al. 2003, Shaw et al. 2001). These instruments provide cloud cover intensity, cloud ceiling height and sky dome imagery. Some examples are the cloud infrared radiometer - CIR-13 and the Infrared Cloud Imager. The deployment of such systems in remote locations is somewhat problematic mainly due to the unavailability of power supply, external PC for data collection and processing, but also due to the level of operational maintenance needed.

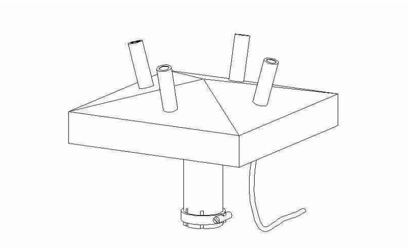

Figure 1: CIR-4 - initial schematic view

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Based on these considerations, we decided to develop a system, which will potentially solve the difficulties mentioned above. Figure 1 shows the schematic view of the instrument we envisioned – CIR-4.

II- Instrument description.

The system is called CIR-4 by analogy with Atmos Sarl's previous instruments CIR-7 and CIR-13. It is equipped with four pyrometers set at the same zenith angle and pointing in the four main directions of the geographic referential (North, East, South, and West). In the first stage of instrument development we will not treat the effect of the water vapour along the optical path between the detector and the cloud base.

In terms of data processing, the first approach is to determine cloud cover from the recorded brightness temperature (BT) time series, and cloud ceiling average height from the ten highest BT values during the sampling period. Instruments like CIR-4 should be self sufficient to allow deployment at any location. That is the reason to choose the MSISE-90 atmospheric model to provide us with temperature atmospheric profile. The validity of this model has been discussed by several authors (Besnard et al. 2001, 2003; Genkova et al., 2004), however it is the most generic solution for such a device. Figure 2 shows a temperature profile comparison between MSISE-90, the Reading Meteorological European Centre Model and a radio-sounding.

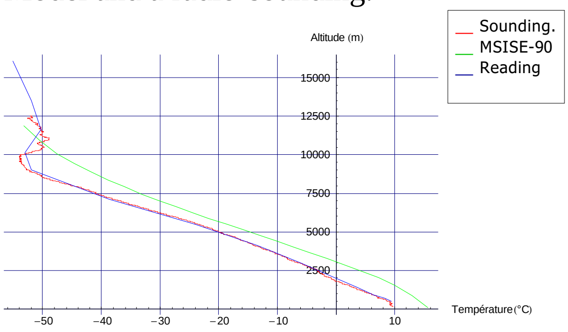

Figure 2: Temperature profile comparison.

The orthogonal positioning of the IR detectors will provide a unique way to approach the cloud dynamics problem as we will describe later in this paper.

To define properly the FOV and the zenith angle of the detectors, we decided to use numerical simulations based on the system previously described by Berger, Besnard and Gillotay.

III Numerical simulation

This two-dimensional plane-parallel simulation is based on a Monte Carlo simulation. The cloud is described by an ellipse set at a well defined height with a temperature defined by a vertical atmospheric profile, like MSISE-90, and moving with a constant speed along the main axis of the ellipse. Measurement ellipses are calculated at the same height level. The principle of the thermal surface integration of pyrometers has been known and applied in this field for a long time. The background temperature is set to
-57°C, in accordance with the features of our currently used pyrometers. The Monte Carlo simulation allows the calculation of intersection surface between measurement ellipses and virtual cloud.

It is necessary to be cautious analysing the simulation results indeed because the temperature threshold will be far different from the experimentally derived one. This effect could be due to various reasons like multiple cloud layers and lack of dynamics in the low part of the sensor range.

After several investigations, we found a compromise between cloud height, size and detection threshold. The field of view of each sensor is 12° and the view zenith angle is 15°. Considering previous studies (Besnard, 2004, Gaumet, 1998), the brightness temperature measured by the pyrometer includes minimal effect from the intervening atmosphere below cloud base at this zenith angle.

One simulation example is shown in figure 2. The black ellipses show the measurement areas and blue ellipses represent the virtual cloud position versus time. It is obvious in this illustration that these sample "clouds" do not completely fill the FOV of the sensor, and thus are offset from the vertical threshold that would be correct for these clouds.

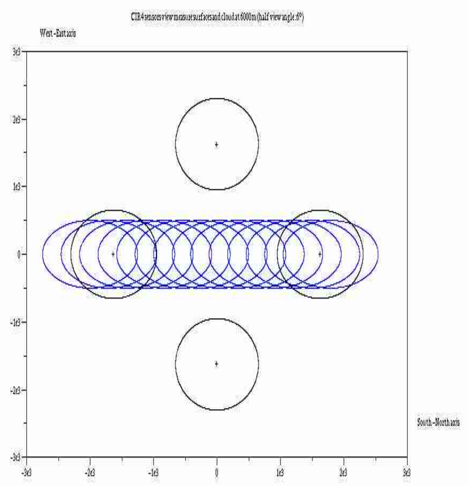

Figure 3: CIR-4 simulation example.

Multiple simulations with various cloud sizes and motion speeds have been performed. It is necessary to mention that the calculation power needed by the Monte Carlo process does not allow calculating the overlap between measurements ellipses and the virtual cloud as fast as once per second with our available equipment. That is why our model output temperature data have been interpolated to achieve this goal. An example of temperature curve is shown in figure 4.

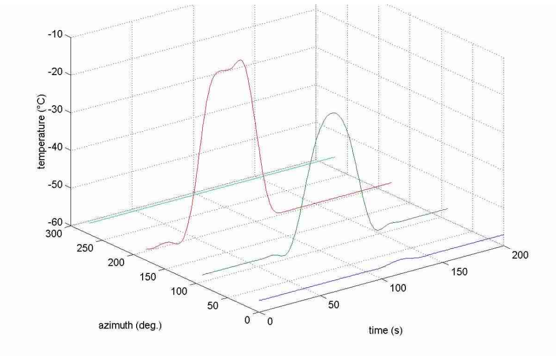

Figure 4: Temperature curve interpolation for each sensor.

In previous studies we showed that the thermal IR technique was mainly suited for clouds up to 8000 m high, hence we chose again to set the binarization threshold temperature at 8000 m high.

The cloud fraction obtained by this method is the average nebulosity over the four sampling areas and should not be

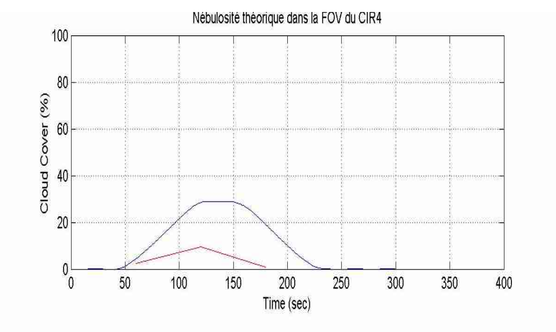

Figure 5: Comparison of nebulosity in measurement area (read curve) and in surrounding circle (blue curve).

assimilated in the nebulosity in the circle surrounding the sampling areas. An example is shown on figure 5. The nebulosity for each sensor has been obtained with time series binarized versus the 8000 m temperature threshold.

We performed different trials for time series durations. The shortest reasonable duration with a 1 Hz sampling frequency is one minute. Some faster sampling frequencies, up to 5 Hz, have been tested but are not of interest for cloud motions speeds below 200 km/h

Previous studies (Gillotay and al., 2001, Besnard et al,. 2002, Berger et al., 2003) have shown a temperature averaging phenomenon in case of multiple cloud layer overlapping each other vertically. This aspect has not been investigated through modelling yet. But based on the other theoretical considerations we have discussed, we have conducted some experiments.

IV- Experiments

Two CIR-4 systems have been deployed already - one in Le Mans for comparison with data provided by human observers in terms of cloud fraction and ceiling. The second one has been deployed in Brussels for comparison with a rotating CIR system and with a TSI440 from Yankee Environmental Systems. In the coming weeks another system will be deployed at the Meteo France testing facility in Trappes for comparison with ceilometric data.

In order to produce more accurate data, we include post processing. For each day, we recorded the temperature diagram, ceiling diagram and nebulosity curve. The plots shown in figures 6, 7, and 8 represent data recorded on 09/24/04 in Le Mans.

On the temperature diagram hereafter, the red colour represents the North sensor, the light brown – the East sensor, the south sensor is shown with blue and the west sensor into green.

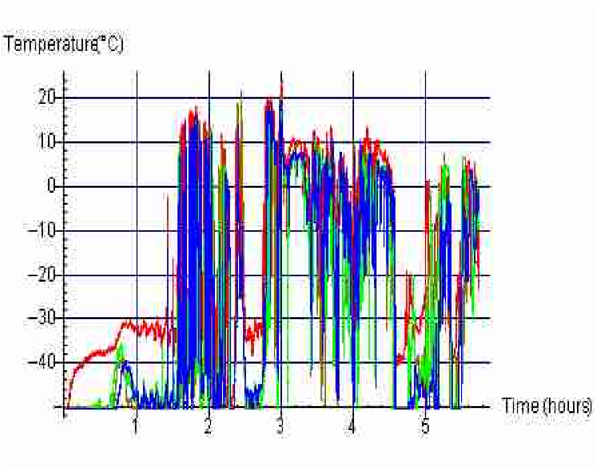

Figure 6: CIR-4 temperature diagram for 09/24/04.

Figure 6 shows relatively clearly the broken clouds conditions and the total anisotropy of the sky dome. This fact confirms that the ASOS algorithm can not be used with a single ceilometer to describe properly the cloud fraction on time scales such as hourly.

For the above diagram (Figure 6), it is necessary to mention that we perform an emissivity correction (ϵ=0.9) onto the data provided by pyrometers.

Figures 7 and 8 show data collected the same day, 09/24/04, but compared with human observations from the local facility of Meteo France.

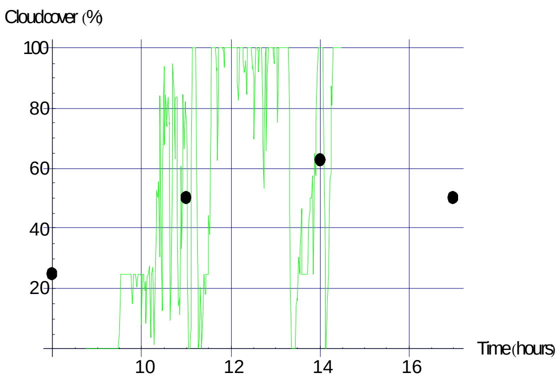

Figure 7: Cloud fraction comparison between human observer and CIR4 (9/24/04

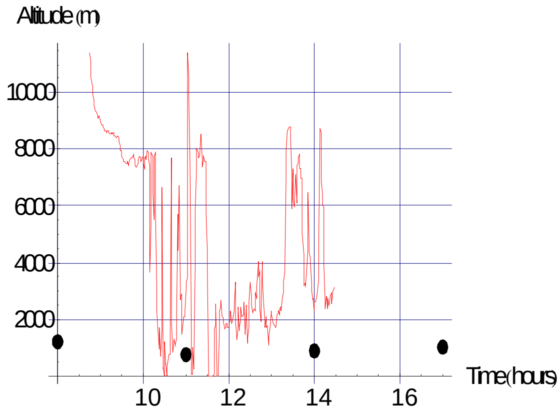

Figure 8: Ceiling comparison between human observer and CIR4 (9/24/04

Considering that there is a distance of 15 km between the data collection site and the Meteo France facility, the agreement between both techniques is encouraging.

As previously mentioned (Gillotay et al. 2001) the sampling interval of human observer data (every three hours) creates data gaps, hence is not appropriate for an accurate description of cloud cover. This fact is confirmed again by the previous figures.

V- Cloud dynamic

The cloud dynamic is an important factor for weather forecasts and for cloud cover trends for short term and local forecasts.

The principle of this process is to determine for each sampling of the four detectors the angle providing a maximal value of the signal (Warren, 1999). The angle value is followed up to an angular transition which will be close to 90° if the observed cloud motion does not follow a circle diameter belonging to the instrument FOV and around 180° in the opposite case. One example through simulations is shown in figure 9.

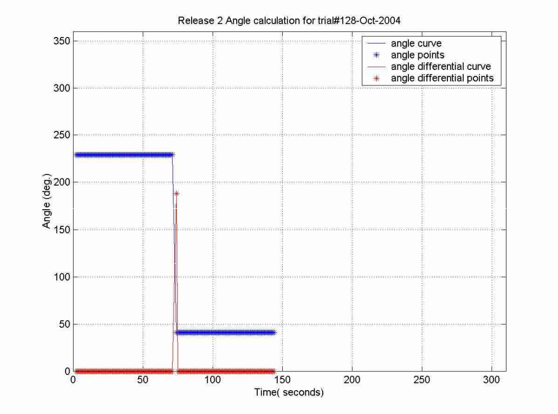

Figure 9: Angular variation of maximal temperature in simulations

It is important to mention that the cloud direction information will not be updated to an interval defined by the user, instead it will be defined by the cloud motion itself.

The speed is obtained by dividing the distance between the ellipses of interest by the time between successive transitions on two captors.

Figure 10 shows an example of experimental data.

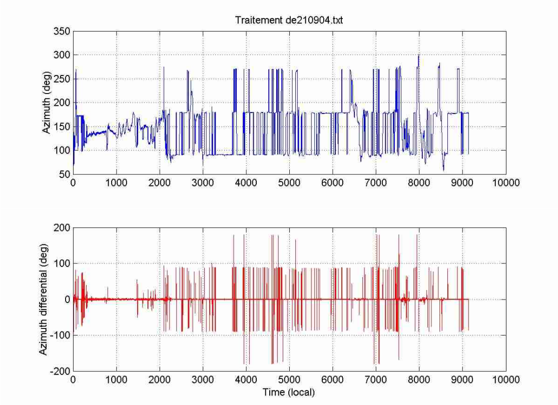

Figure 10: Angular variation of maximal temperature for 09/21/04.

VI-Conclusions and perspectives

This new instrument, CIR-4, shows a significant potential for cloud observation purposes and its integration into automatic systems. The four sensors allow to take into account the anisotropy of the cloud cover and to provide a description far more accurate than a single ceilometer. The MSISE-90 profiles will induce ceiling height data only as an evaluation. The possibility of automatic entering the Reading Forecast Centre temperature profile as an input into the instrument running software could increase significantly the accuracy of this measurement.

Combining this instrument to work simultaneously with an albedo measuring system, would create a useful tool to study the energy balance in the earth atmosphere.

VII-Acknowledgements

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