

Importance of urban meteorological stations - the example of Freiburg, Germany

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Abstract

For more than two decades modern data collection systems have been used. The internet and the development of networks have significantly reduced the temporal delay between meteorological measurements and the visualization of measured variables. However, not only the free of charge, current information of the public on the meteorological conditions is of interest. The use of data from meteorological stations is also extremely valuable for research and education. The urban meteorological station Freiburg, which is run since May 1999 by the Meteorological Institute, Albert-Ludwigs-University of Freiburg, Germany represents an example for multiple uses. Meteorological information is provided by the station as current 10-min mean values and 10-min totals of precipitation, respectively.

Bedeutung von meteorologischen Stadtstationen - das Beispiel Freiburg, Deutschland

Zusammenfassung

Moderne Datenerfassungssysteme, die schon seit mehr als zwei Jahrzehnten im Einsatz sind, sowie das Internet und die Entwicklung von Netzwerken haben es ermöglicht, die Visualisierung und Präsentation von meteorologischen Variablen fast zeitgleich mit ihren Messungen durchzuführen. Aber nicht nur die freie, aktuelle Information der Öffentlichkeit über die meteorologischen Bedingungen ist von Interesse und Bedeutung. Der Einsatz von meteorologischen Stationen ist auch für Forschung und Lehre sehr hilfreich. Die Meteorologische Stadtstation Freiburg, die das Meteorologische Institut der Albert-Ludwigs-Universität Freiburg seit Mai 1999 betreibt, ist ein derartiges Beispiel. Die dort gemessenen meteorologischen Daten werden als aktuelle 10-Minuten Mittelwerte bzw. 10-Minuten Summen beim Niederschlag im Internet bereitgestellt.

1. Introduction and aim

The demand of the public for meteorological information is very high. Beside this, the demand for meteorological information is also of interest in different applications, e.g. in applied urban climatology (MATZARAKIS, 2001). Due to their objectives, synoptic and climate stations of national and other weather services are mostly located in areas, which usually do not represent the conditions characteristics of urban conditions. Despite of urban heat island and urban moisture excess, air temperature and air humidity are the meteorological variables showing a relatively reduced spatial variability at screen level. In contrast, the spatial pattern of radiation flux densities and wind conditions strongly responds to the three-dimensional urban structure. Therefore, measurements of radiation flux densities and wind speed are conducted within urban structures only for specific purposes (e.g. human-biometeorological assessments), while they are monitored above the urban roof level in the usual case. As a consequence, reference stations for the urban meteorological conditions are mostly set up on the top of build-

ings, which are higher than the mean roof level of a city, i.e. the meteorological measurements are conducted above the urban canopy layer (OKE, 2007).

The setup and representative location of an urban meteorological station is one important question. The processing of the data is a technical one and the presentation of the current data might be most important. For the latter, the existence and use of the internet make it easy to visualize current meteorological data and information, which allows everyone to be informed about the current meteorological conditions. The technical part including the processing and visualization of the data can be solved by use of commercial software packages offered by meteorological instrument manufacturers or data logger companies. The other possibility is to use program languages and to develop software and html packages for data processing and internet visualization. Also, an urban meteorological station has to be planned and run in a long-term continuous way, which requires permanent service, update and calibration of meteorological instruments.

Keeping all these requirements and problems in mind, the Meteorological Institute, Albert-Ludwigs-University of Freiburg (Germany), established an urban meteorological station Freiburg on the top of the chemistry building, which is one of the tallest buildings in Freiburg (Fig. 1). The meteorological measurements started in May 1999 for testing purposes and in September 1999 with full data processing and analyses.

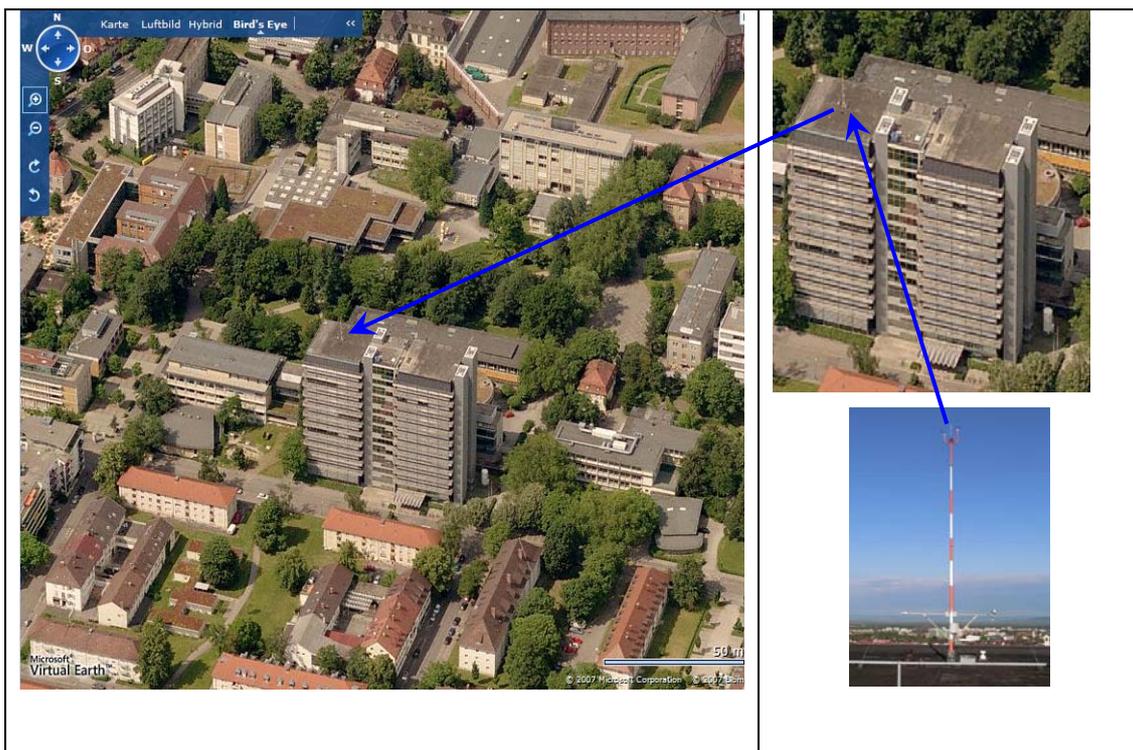


Fig. 1: Location of the urban meteorological station Freiburg, run by the Meteorological Institute, Albert-Ludwigs-University of Freiburg (source: Microsoft Virtual Earth)

The idea behind the installation of an urban meteorological station was:

- provision of current meteorological information of Freiburg in a clear way for the public and administration,

- provision of meteorological data for the education of students in meteorology and climatology,
- provision of meteorological data for scientific studies in meteorology and climatology,
- use as an urban meteorological anchor station.

2. Instrumentation and data processing

Located in the northern part of the city centre of Freiburg (272 m a.s.l.), the urban meteorological station Freiburg was installed on the roof of the chemistry building (51 m a.g.l.) of the Albert-Ludwigs-University of Freiburg. The website of the station is available under <http://www.mif.uni-freiburg.de> up to now. The horizon is only limited in the east by the Black Forest.

Currently, the following meteorological parameters are continuously measured:

- incoming short-wave radiation in 2 m a.g.l. (pyranometer, type CM21 by Kipp & Zonen Company),
- air temperature in 2 m a.g.l. (electrically ventilated Pt100 probe according to Frankenberger, self construction and production of the Meteorological Institute, Albert-Ludwigs-University of Freiburg),
- air humidity in 2 m a.g.l. (principle: electrically ventilated psychrometer according to Fankenberger, self construction and production of the Meteorological Institute, Albert-Ludwigs-University of Freiburg),
- horizontal wind speed and wind direction in 10 m a.g.l. using a combined measurement system (Lambrecht Company),
- precipitation (tipping-bucket rain gauge, Vaisala Company),
- air pressure at roof level (aneroid, Vaisala Company).

The meteorological measurements on the roof of the tall building are conducted in the transition area between the urban canopy layer and the urban boundary layer.

All sensors are scanned every 30 s. A data logger (Campbell 21X) aggregates 10-min mean and 10-min totals (precipitation), respectively. The transfer of the data from the station to a server of the Meteorological Institute takes place every 10 minutes via the network of the Albert-Ludwigs-University of Freiburg. The data are controlled and further meteorological parameters (e.g. vapour pressure or relative humidity) are calculated. The files are stored as daily files and are available also as raw files. After storage, the meteorological data are prepared for the online visualisation, which is performed by own written Delphi programs. The results are available on the website of the station. The temporal delay between data collection or aggregation and visualization takes approximately 2 minutes.

The website of the urban meteorological station Freiburg presents the results in different forms:

- current meteorological data as 10-min mean values and 10-min totals for precipitation, respectively, in form of a table (Fig. 2),

- meteorological data as 10-min mean values and 10-min totals for precipitation, respectively, during the past 48 hours (in CET) in form of diagrams (Figs. 3 and 4).

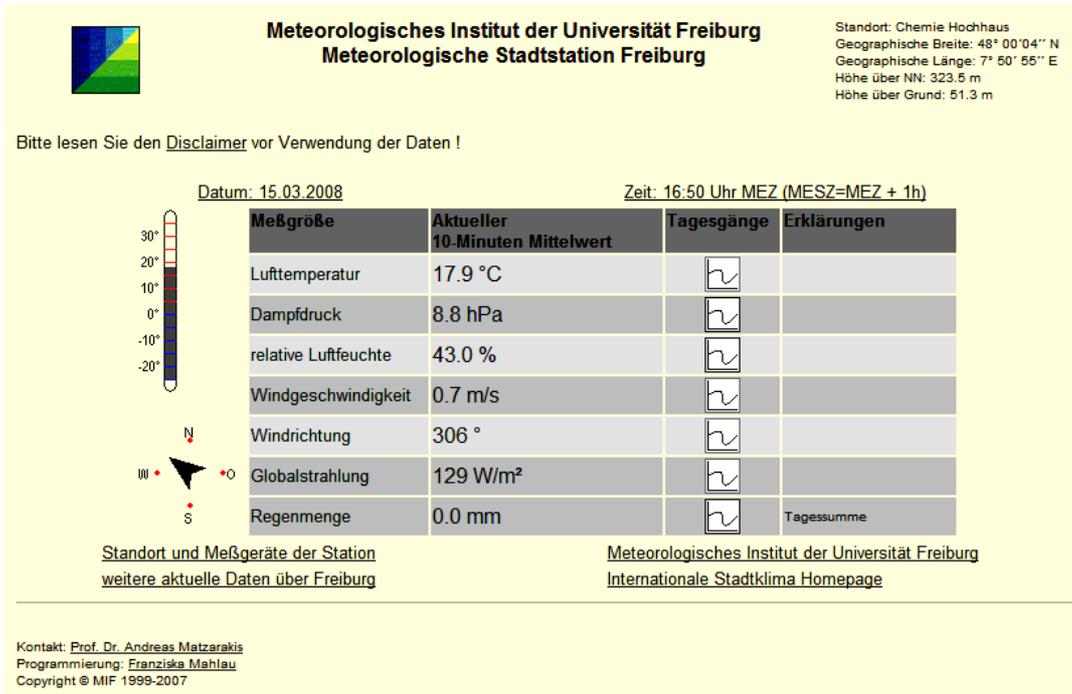


Fig. 2: Introducing website of the urban meteorological station Freiburg, run by the Meteorological Institute, Albert-Ludwigs-University of Freiburg, Germany (<http://www.mif.uni-freiburg.de>)

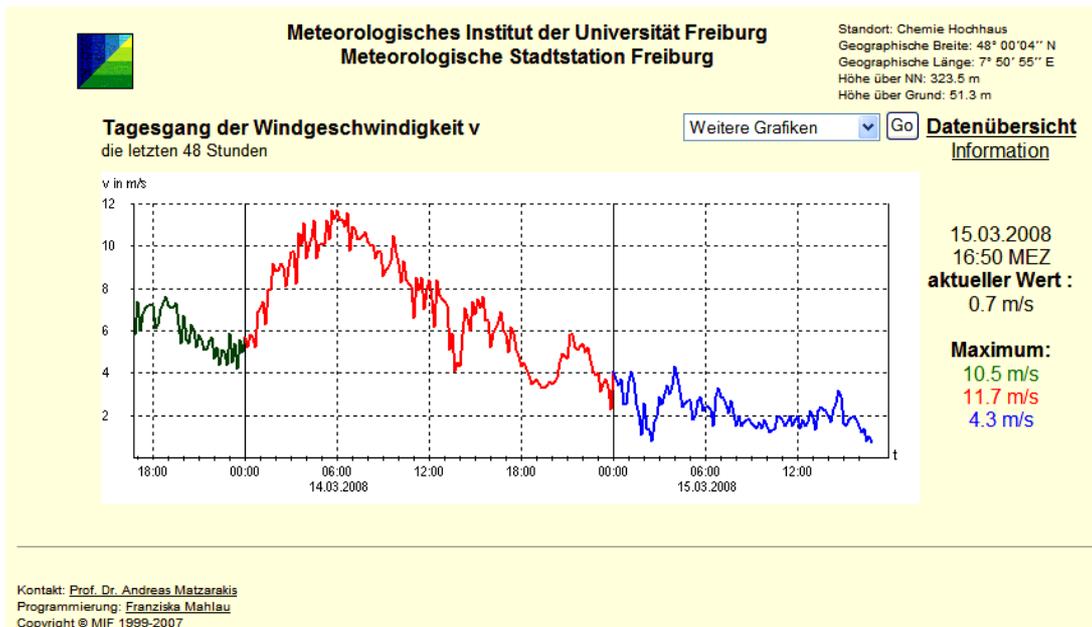


Fig. 3: Example for the visualization of the horizontal wind speed v measured during the past 48 hours at the website of the urban meteorological station Freiburg

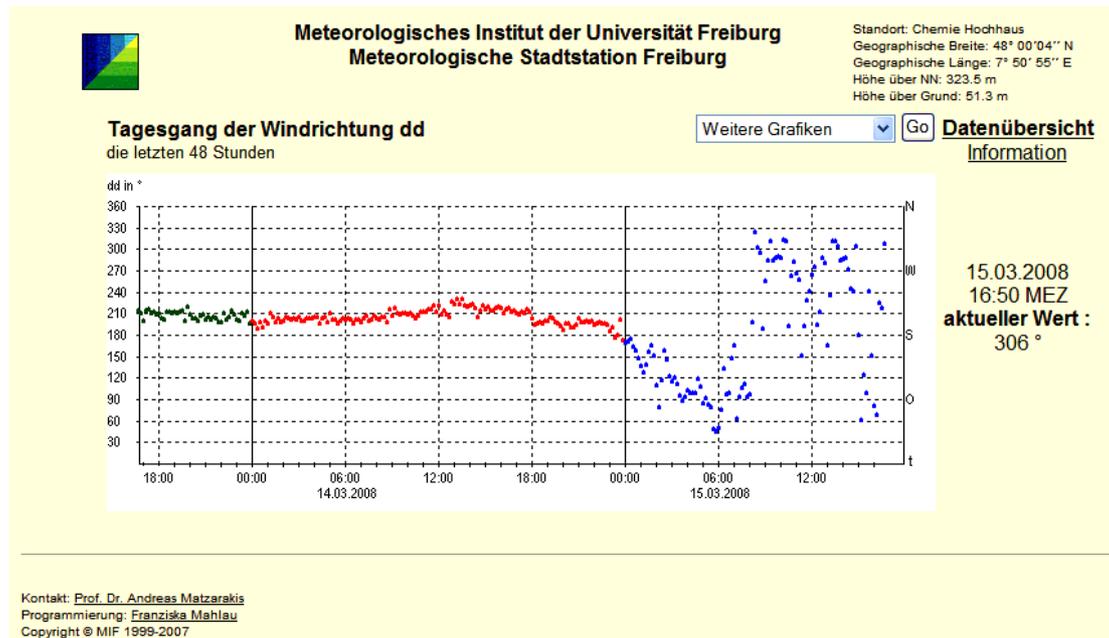


Fig. 4: Example for the visualization of the wind direction dd measured during the past 48 hours at the website of the urban meteorological station Freiburg

3. Applications

3.1 Research

The data of the urban meteorological station Freiburg can be used as basic information on extreme weather. For example, Figs. 5 to 8 contain the patterns for horizontal wind speed, gust speed, wind direction and precipitation during the severe storm “Emma”, which passed Freiburg on 1 March 2008. An almost constant wind direction (around 210° , i.e. around SW), a peak 10-min mean wind speed of approximately 18 m/s and peak gust speed of approximately 24 m/s characterized “Emma” in Freiburg. Precipitation was recorded in the period with high wind speed (Fig. 8).

The visualization of meteorological variables during hot summer weather on 15 July 2007 represents another example (Figs. 9 to 15) for the application of the meteorological data measured at the urban meteorological station Freiburg to describe extreme weather. The pattern of the incoming short-wave radiation reflects the cloudless conditions. Peak 10-min mean air temperature reached 35°C . The patterns for vapour pressure and relative humidity show that the humidity conditions were not in a stress range for people. The course of the wind direction above the mean roof level of Freiburg exhibits two major directions: between 240° and 330° during the daylight hours and around 120° in the night from 9 pm to 6am CET. This wind direction pattern, which is characteristic of the regional circulation system “Höllentäler”, can be clearly seen in the wind rose. The katabatic wind “Höllentäler” does not occur in each night, as distinct differences of the surface temperature between the elevated Black Forest and the lower Freiburg area caused mainly by high pressure weather are the necessary requirement for its formation. As indicated by the course of the horizontal wind speed, air flow during the “Höllentäler” situation is enhanced, but in a discontinuous way.

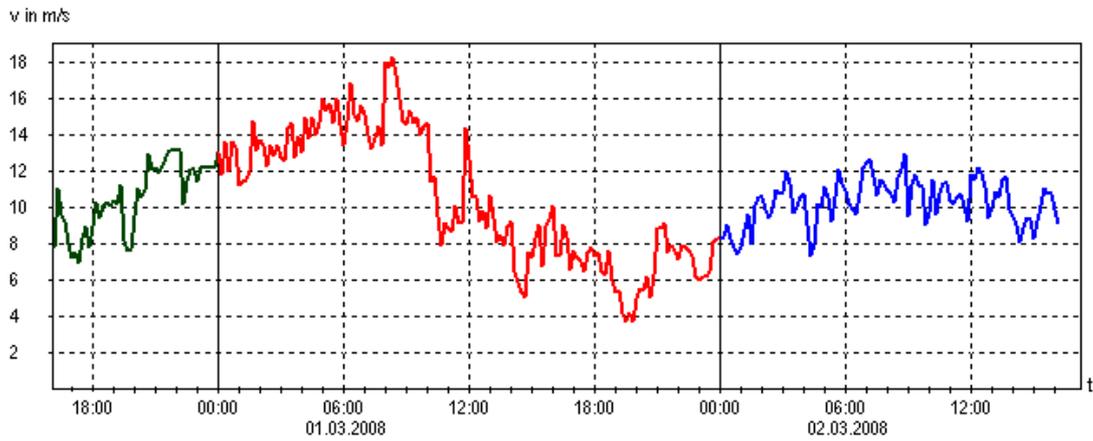


Fig. 5: Horizontal wind speed v during the severe storm “Emma” on 1 March 2008 measured at the urban meteorological station Freiburg

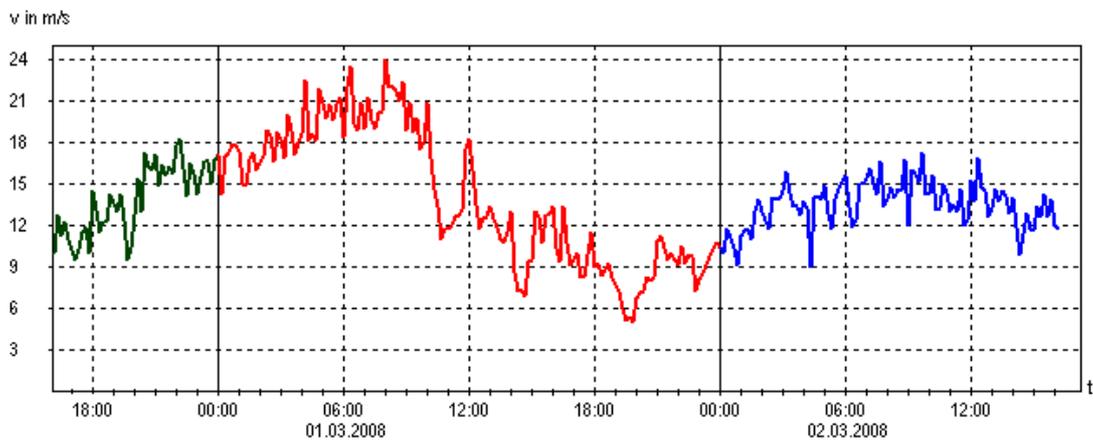


Fig. 6: Horizontal gust speed v during the severe storm “Emma” on 1 March 2008 measured at the urban meteorological station Freiburg

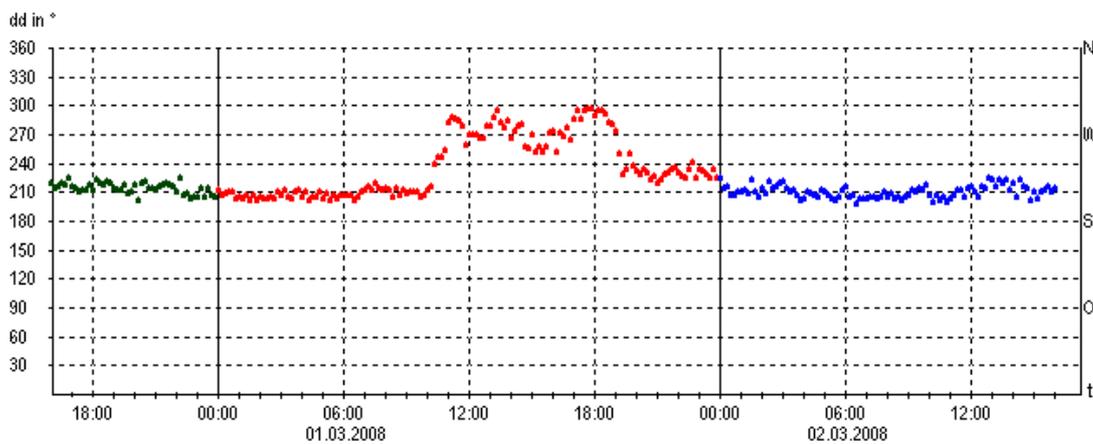


Fig. 7: Wind direction dd during the severe storm “Emma” on 1 March 2008 measured at the urban meteorological station Freiburg

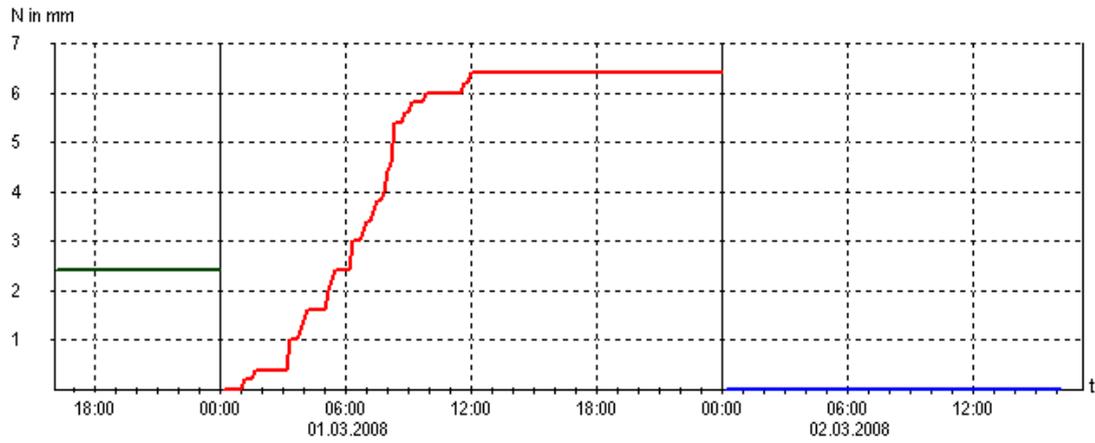


Fig. 8: Precipitation N during the severe storm “Emma” on 1 March 2008 measured at the urban meteorological station Freiburg

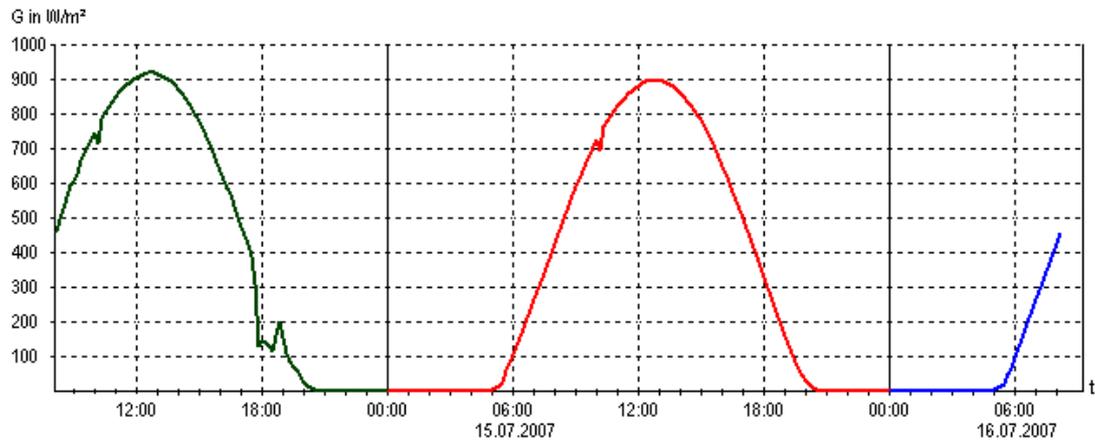


Fig. 9: Incoming short-wave radiation G during hot summer weather on 15 July 2007 measured at the urban meteorological station Freiburg

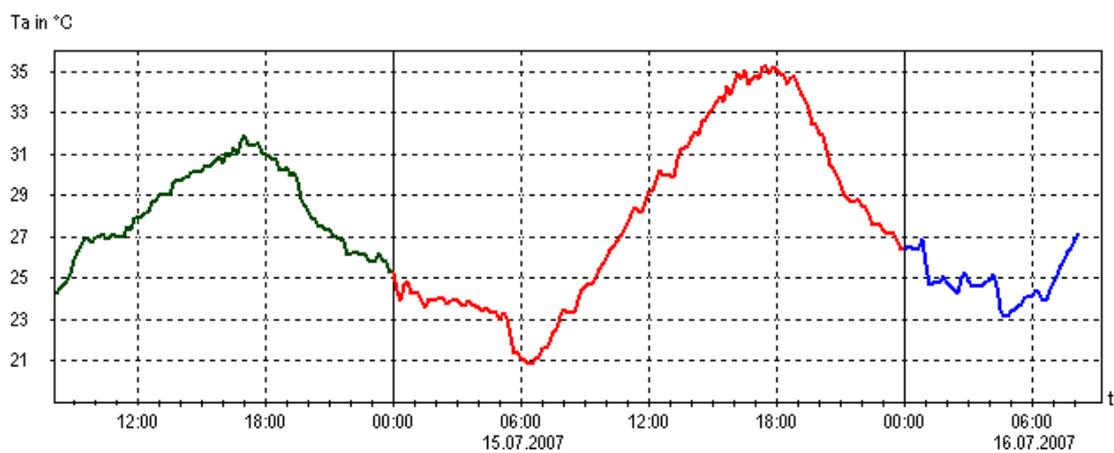


Fig. 10: Air temperature T_a during hot summer weather on 15 July 2007 measured at the urban meteorological station Freiburg

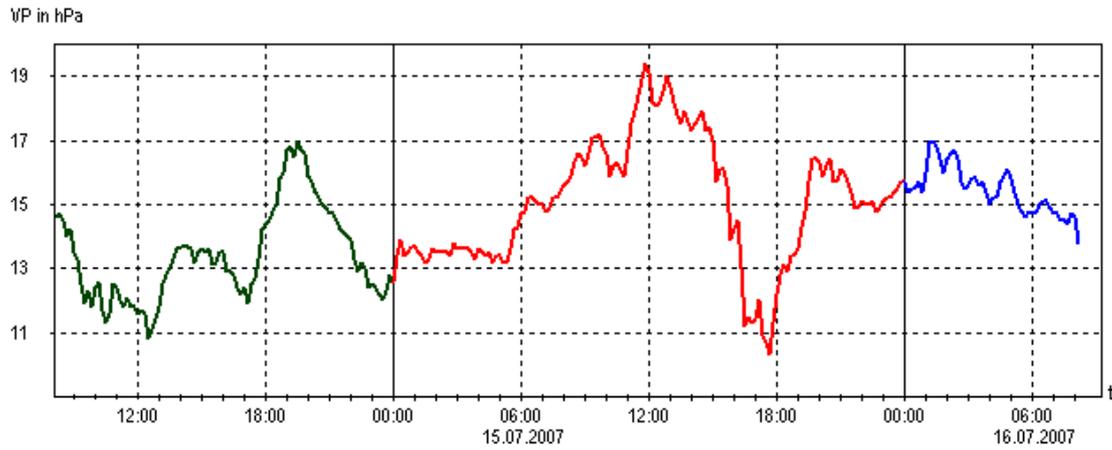


Fig. 11: Vapour pressure VP during hot summer weather on 15 July 2007 measured at the urban meteorological station Freiburg

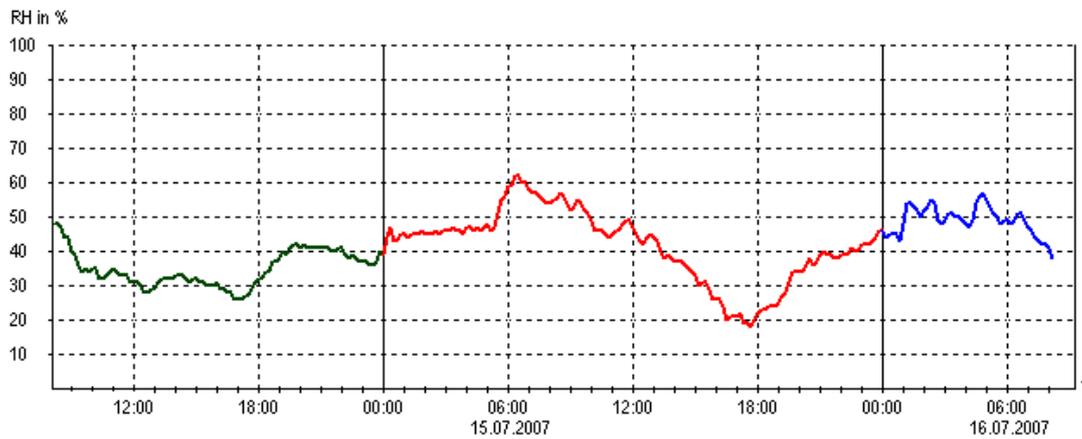


Fig. 12: Relative humidity RH during hot summer weather on 15 July 2007 measured at the urban meteorological station Freiburg

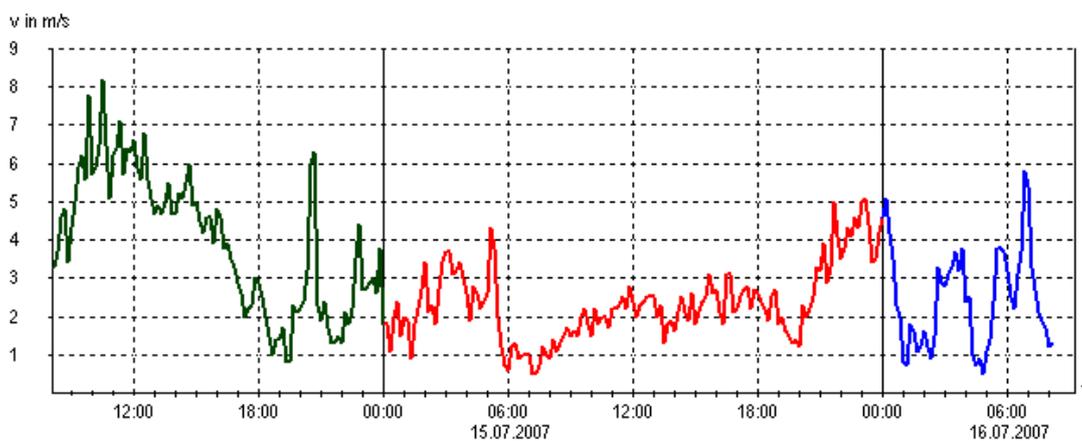


Fig. 13: Horizontal wind speed v during hot summer weather on 15 July 2007 measured at the urban meteorological station Freiburg

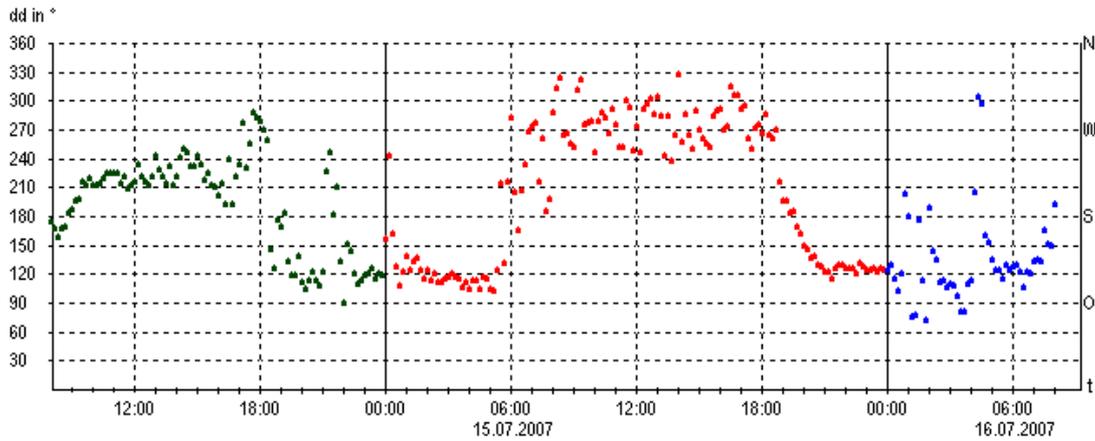


Fig. 14: Wind direction dd during hot summer weather on 15 July 2007 measured at the urban meteorological station Freiburg

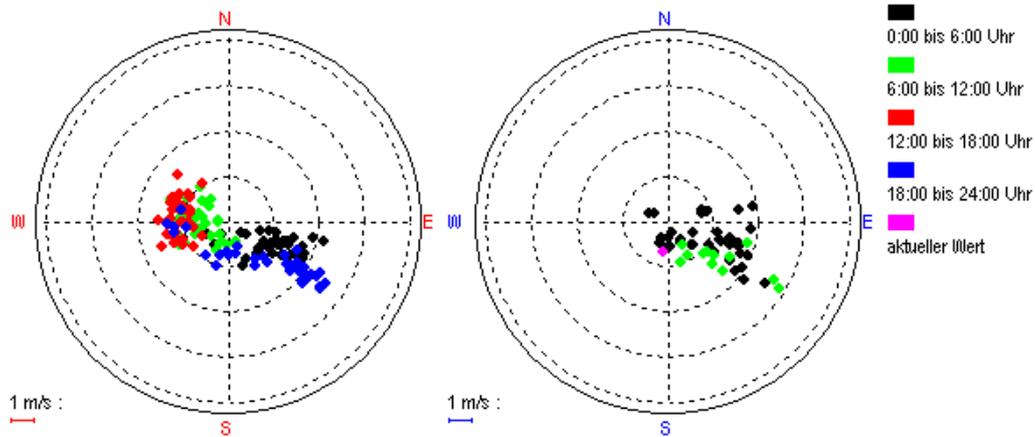


Fig. 15: Wind rose during hot summer weather on 15 July 2007 measured at the urban meteorological station Freiburg and coloured according to different 6-h periods

The urban meteorological station Freiburg has the character of an anchor station for the city of Freiburg. Therefore, the collected meteorological data can also be used for different applications in urban meteorological modelling (MATZARAKIS et al., 2007; ALI-TOUDERT and MAYER, 2007). In addition, the meteorological data from the urban meteorological station Freiburg are used for quality controls of meteorological data recorded at other adjacent stations (IMBERY, 2005). Institutions of the Albert-Ludwigs-University Freiburg also use the data from the urban meteorological station Freiburg, e.g. for the calibration of meteorological sensors or climate impacts analyses.

3.2 Education

In terms of education, the students in Freiburg are in close contact with the actual meteorological situation and are asked to discuss and explain weather conditions or specific phenomena like strong change of wind direction or air temperature drops from the starting semester. The students have the possibility not only to see and learn the way how meteorological measurement systems operate but they can also use the collected data.

The data are processed and analysed by the students in order to learn how to work with data files. The students calculate monthly averages, analyse the different meteorological variables statistically, draw figures and use this data for other purposes where meteorological data are necessary. The meteorological data of the urban meteorological station Freiburg are also available for scientific studies of students, e.g. bachelor or master thesis.

3.3 Administration and other demands

The meteorological data of the urban meteorological station Freiburg are also demanded for administrative purposes, e.g. by the technical office of the Albert-Ludwigs-University of Freiburg in order to calculate the heating conditions for the university buildings based on the outdoor air temperature. Finally, for the urban climate analysis of the municipality of Freiburg (for the master plan 2020), the data of the urban meteorological station Freiburg were used to characterize the meteorological background situation in Freiburg (RÖCKLE et al., 2003), e.g. to obtain results on human thermal comfort.

4. Conclusions

The free availability of quality controlled meteorological data is of significant importance due to different reasons, e.g. for scientific research, the education of students or the information of the public in the internet. The urban meteorological station Freiburg, run by the Meteorological Institute, Albert-Ludwigs-University of Freiburg, since May 1999, meets these requirements in an excellent way.

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