THE NEW VERSION OF THE WORLDWIDE CLIMATOLOGICAL DATABASE METEONORM

Jan Remund and Stefan Kunz
Applied meteorology, METEOTEST, Fabrikstrasse 14, CH-3012 Bern, Switzerland,
0041 (0)31 3072626, 0041 (0)31 3072610, e-mail remund@meteotest.ch

Abstract – This paper describes the principles and the new features of METEONORM version 5.0, which has been published in June 2003. METEONORM is a complete, worldwide climatological database. It contains monthly mean data of 7'400 stations and a set of 8 parameters. The software enables data generation of hourly values for any place in the world based on spatial interpolation and stochastic generation of time series. Aside radiation parameters like global, diffuse, beam and radiation on inclined planes many additional parameters are delivered like temperature, dewpoint, precipitation or wind speed. The chain of algorithms has been completely revised based on the knowledge of the EU FP5 project SoDa.

1. INTRODUCTION

Meteorological information is a very important factor for simulation of solar energy applications. Today generally hourly values are needed for simulation tools.

There are three main types of meteorological information available: measured values, typical meteorological years (TMY) or design reference years (DRY) and mathematically generated time series. Each of them have their advantages and disadvantages.

- Measured values (ground and satellite). They give the most precise information, but have several disadvantages: there are only few ground stations existing worldwide with the whole set of information, 10 years of data are needed and they are expensive. Satellite information can cover only the radiation information.
- TMY or DRY type of data include variations of several years in one year and so only a dataset of one year is needed for simulation. Depending on the application they are more or less adapted (Argiriou et al., 1999). They are site dependent. Generally 10 year distributions are achieved (extreme values of 10 year included).
- Mathematically generated time series. There are two subgroups: stochastically generated data (Markov chains, autoregressive processes) and such based on Fourier analyses. The big advantage of the mathematically generated time series is, that they are in principle site independent and can be used for any place. The distribution and the auto- and cross-correlations are designed to fit measured values as much as possible. One year includes information of several as in TMY's. Generally mean monthly distributions are achieved (mean extreme values).

METEONORM belongs to the third group of data. Data is stochastically generated and is based on measured long term monthly mean values. With interpolation of the monthly values time series for the whole globe can be calculated. This was also the main reason for choosing this type of generation method, because all other type (also Fourier time series) are site dependent.

It has been proofed as a worthwhile tool for many people dealing with solar energy since 18 years . In June 2003 the version 5.0 of the software has been published. The principle of the generation as well as the most important updates are shown in the following chapters.

2. PRINCIPLES OF GENERATION

2.1 Radiation parameters

METEONORM's orderly facade conceals not only numerous databases from all parts of the world but also a large number of computational models developed in international research programs.

METEONORM is primarily a method for the calculation of solar radiation on arbitrarily orientated surfaces at any desired location (Remund et al., 1998). The method is based on databases and algorithms coupled according to a predetermined scheme (chains of algorithms). It commences with the user specifying a particular location for which meteorological data are required, and terminates with the delivery of data of the desired structure and in the required format.

Depending on user requirements, the calculation procedure employs between two and ten computation models (Tab. 1).

2.2 Non radiation parameters

METEONORM endeavours to provide suitable interfaces for most design programs in common use in photovoltaics, solar thermal applications and building simulation. For this, a range of 19 output formats is provided (e.g TRNSYS, DOE, PVSYST or TMY2). Several of these programs require further meteorological parameters in addition to global radiation and temperature. To provide these formats, simple formulae are presented below for estimating the required parameters.

For a number of additional parameters, monthly values can only be obtained by first calculating hourly values.

The principal problem in simulating further parameters is to ensure their compatibility with the previously obtained parameters. The supplementary parameters are not of the same quality as the main parameters (global radiation and temperature) and were not validated in an equally comprehensive way.

METEONORM includes the following additional parameters on hourly basis:

- Temperature, surface temperature
- Humidity (dewpoint, wet bulb temperature, mixing ratio, rel. humidity)
- Precipitation, driving rain
- Wind speed and direction
- UVA, B and erythemal radiation (clear and all sky)
- Longwave radiation (up, down, vertical) and radiation balance
- Illuminance
- Cloud cover
- Air pressure (only altitude dependent)

The models (Tab. 1) for all parameters are mainly based on the chain of algorithms used and described in the SoDa project (see Paper "Chain of algorithms to calculate advanced radiation parameters" and Remund and Page., 2002). The models not described in this paper are listed in the following section.

Tab. 1: The table shows the sequence in which the computational models are coupled in generating hourly radiation data on an arbitrarily orientated surface at a site for which no measurements are available.

Interpolation with monthly average value model G_h, Ta, Td, RR, …	Space dependent interpolation of horizontal radiation, temperature and other parameters based on weather data taking altitude, topography, region, etc. into account.
Hourly value generator G_h, Ta	Stochastic generation of time dependent global horizontal radiation and temperature data having a quasi-natural distribution and an average monthly value equal to the average value over 10 years.
Radiation resolution $G_h \rightarrow D_h$, B_n	Resolution of global radiation into diffuse and direct components.
Radiation on inclined surface with skyline effect, hourly value model G_k	Calculation of hemispherical radiation on arbitrarily orientated surfaces taking the reduction due to skyline profile into account.
Additional parameters G_h, Ta $\rightarrow$ UV, RR, …	Calculation of temperature and additional parameters based on radiation and temperature time series and monthly mean values (if available).

2.3 Models for non radiation parameters not used in SoDa

METEONORM includes several parameters not used and described in SoDa:

- Precipitation, driving rain
- Wind speed and direction
- Illuminance

All models are described validated in the handbook of METEONORM (Remund and Kunz, 2003).

A new precipitation model has been derived. It's based on existing models based on WGEN (Richardson and Wrigth, 1980). For some intermediate steps and hourly values new functions and distributions have been found. Daily and hourly distribution are modelled with Weibull distributions (Selker and Haither, 1990). The amount of hours and days with precipitation are calculated well. For driving rain Straube's method (2001) is used.

Wind speed and direction are generated stochastically. The input of wind speed are monthly wind speed, climatic region and local terrain specifications. A Weibull distribution is assumed. A and k values are modified depending on climatic zone and terrain. A mean daily profile is added depending climatic zone, terrain and daily radiation sum.

Wind direction is modelled independently of wind speed and other parameters (too complicated and local effects). The main input are 100 typical stations worldwide with measured distributions of wind direction for July and January. Wind direction can only be viewed as a rough approximation, but main features of climatic zones are given.

For illuminance the model of Perez et al., 1990) is used.

3. NEW OR UPDATED FEATURES

3.1 The four main new or updated features

1. Extension of the climatological database. From 2'500 stations to 7'400 stations worldwide (mainly 61-90 climatological values). Additional radiation information from satellites.
2. Inclusion of current data (monthly means) for control of systems.

3. Automatic calculation of high horizons.
4. Adaption of the algorithms to the latest results found in the EU IST research project SoDa and addition of more parameters.

3.2 Climatological Database

The database has been extended to over 7'400 stations. For many areas a very high density of stations can be achieved (Fig. 1).

A complete set of 8 basic parameters (global radiation, temperature, dewpoint temperature, rain, days with rain, sunshine duration, wind speed and direction) is available. It contains mainly global radiation data of Global Energy Balance Archive GEBA (Gilgen et al., 1999) and other parameters of Climatological Normals of 1961-90 of WMO (1998).

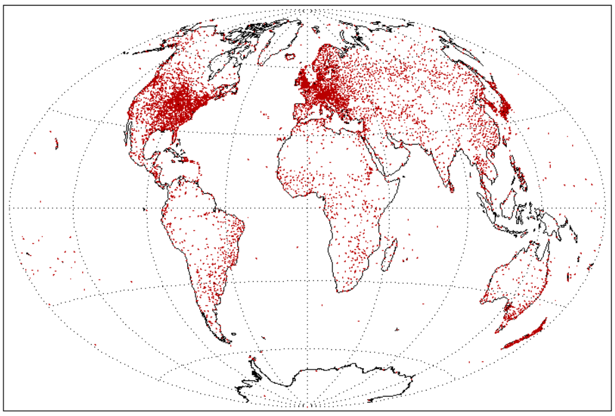

Fig. 1: Distribution of ground stations.

For version 5.0 two new sources have been added:

- Globalsod data (NCDC, 2002): Parameters temperature, wind speed and precipitation. The data was quality controlled, processed to 1994–01 means and adapted to 1961–90 standards.
- The Global Historical Climatology Network (Vose et al., 1992): Longterm monthly temperature, precipitation (NDP-041). The data was processed to mean values mainly for periods 1950–87.

With help of interpolation tools (Lefèvre et al., 2002) the ground data is usable for the whole globe. The intepolation of monthly means of global radiation has an rmse of 15%, the temperature interpolation a rmse of 1.3°C.

Because there are some areas with low density of radiation measurements, satellite has been included. This has been done with a simplified form of cloud indices method like Perez et al. (2003). Four satellite pictures are processed to daily means and summed up to monthly values. The 5 satellite pictures of Meteosat, Indoex, Japanese GMS, GOES-West and GOES-East are coupled to one worldwide map.

The difference between the ground measurements and satellite information is interpolated spatially with the inverse distance method (Lefèvre et al., 2002). The result of this procedure are maps following the long term values at the ground stations and the high frequency variations of the satellite pictures (Fig. 2).

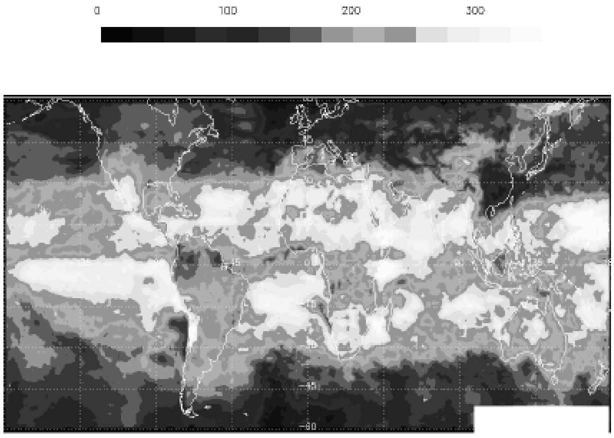

Fig. 2: Global irradiance map for March in W/m^2 based on satellite and ground information. Means adapted mainly to 1981–90.

3.3 Current data

As a big extension the import of current data is possible. Current monthly values of temperature and radiation are accessible on a web server via the METEONORM software. Data is always interpolated (for method see Lefèvre et al., 2002). The data exists from 1998 onwards and will be available in future approximately two weeks after the end of each month.

In Switzerland, interpolated data of the Automatic Network of MeteoSwiss with corrections for horizon and location influences are available since 2001. The following parameters are delivered:

- Temperature: Monthly mean, mean daily minimum and maximum, hourly minimum and maximum temperatures.
- global radiation
- Switzerland only: Precipitation and days with precipitation over 1 mm.

A quality flag shows the level of accuracy of the interpolation.

3.4 High horizons

High (far and near) horizons can be entered for any point on earth with help of an easy to use graphical interface. As a new feature in version 5 for any point in Switzerland the horizon is calculated automatically. This is done with the help of a digital terrain model. In areas like the Swiss alps the influence of the mountains on radiation is often large (in the magnitude of 10-20%). The measurement of the horizon line by hand or photography is normally time consuming, so a lot of time can be saved.

This feature could be added to regions outside of Switzerland if high resolution digital terrain models (at least 250 m resolution) will be available.

3.5 Adaption to latest scientific results

The algorithms have been adapted to results found in the EU IST research program SoDa (see section 2). The clear sky model of ESRA (Rigollier et al., 2000) is now used. Stochastic radiation and temperature generation has been updated and strongly enhanced. Temperature generation is now based on measured distributions of daily temperature values of 4'700 stations.

UVA, B and erythemal radiation is included as new generated parameters.

The Linke turbidity (see paper "Worldwide Linke turbidity information"), stratospheric ozone and water vapour information of SoDa is used internally in a 20' resolution.

4. CONCLUSIONS

The new version 5.0 of METEONORM is a complete climatological database and data generator for simulation tools.

The inclusion of new datasets of mean values of temperature and precipitation and of satellite information for global radiation makes it worldwide useable.

The possibility of import of current data makes it also a source for quality control of solar systems.

The inclusion of precipitation and UV enlarges the potential user community of METEONORM.

Acknowledgements - This work is supported partly the Swiss Federal Office of Energy, Bern (contract No. 87296).

REFERENCES

Argiriou, A., Lykoudis, S. Kontoyiannidis, C. A. Balaras, D. Asimakopoulos, M. Petrakis and P. Kassomenos, 1999. Comparison of methodologies for tmy generation using 20 years data for Athens, Greece. *Solar Energy*, Vol. 66 (1) (1999) pp. 33-45.

Gilgen H., M. Wild M., A. Ohmura, 1998. Means and trends of shortwave incoming radiation at the surface estimated from Global Energy Balance Archive data. *Journal of Climate*, 11, 2042-2061.

Lefèvre M., J. Remund, M. Albuisson, L. Wald, 2002. Study of effective distances for interpolation schemes in meteorology. Annual Assembly, European Geophysical Society, Nice, April 2002, Geophysical Research Abstracts, vol. 4, EGS02-A-03429.

NCDC, 2002. Globalsod. Global surface daily data: temperature, precipitation, winds, pressure, snow, etc. (http://ncdc.noaa.gov).

Perez, R., P. Ineichen, R. Seals, J. Michalsky and R. Stewart, 1990. Modeling daylight availability and irradiance components from direct and global irradiance. *Solar Energy*, Vol. 44, No.5, pp. 271-289.

Perez, R., P. Ineichen, K. Moore, M. Kmiecik, C. Chain, R. George and F. Vignola, 2003. A new operational model for satellite-derived irradiances: description and validation. *Solar Energy*, Vol. 73, No.5, pp. 307-317.

Remund, J., E. Salvisberg and S. Kunz, 1998. Generation of hourly shortwave radiation data on tilted surfaces at any desired location. *Solar Energy*. Vol. 62, Nr. 5.

Remund, J. and S. Kunz, 2003:METEONORM Version 5.0. Software and Handbook on CD-ROM. Meteotest, Fabrikstrasse 14, 3012 Bern Switzerland. www.meteonorm.com .

Remund, J. and J. Page, 2002. Chain of algorithms: short- and longwave radiation with associated temperature prediction resources. SoDa Deliverable D5-2-2/3. Internal document.

Richardson, C.W. and D.A. Wright, 1984. WGEN: A model for generating daily weather variables. U.S. Dept. Agric., Agric. Res. Svc. Pub. No. ARS-8, 83 pp.

Rigollier C., Bauer O., Wald L., 2000. On the clear sky model of the 4th European Solar Radiation Atlas with respect to the Heliosat method. *Solar Energy*, 68(1), 33-48.

Selker, J.S. and Haither, D.A., 1990. Development and Testing of Singe-Parameter Precipitation Distributions. *Water Resources Research 26(11):2733-2740.*

Straube, J., 2001. Driving Rain Measurement Contract - Final Report, MEWS, Institute for Research in Construction, National Research Council Canada, Ottawa, Canada K1A 0R6

Vose, R.S., R.L. Schmoyer, P.M. Steurer, T.C. Peterson, R. Heim, T.R. Karl and J.K. Eischeid, 1992. The Global Historical Climatology Network: long-Term Monthly Temperature, Precipitation, Sea Level Pressure and Station Pressure Data (NDP-041). Downloadable from Carbon dioxide information analysis center (http://cdiac.ornl.gov).

World Meteorological Organisation (WMO), 1998. 1961 – 90 Climatological Normals (Clino). Version 1.0 – November 1998. CD-ROM.