



Project title:

**Energy-Specific Solar Radiation Data
from Meteosat Second Generation (MSG):
The Heliosat-3 Project**

Project Acronym:

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1 Data requirements for the new calculation schemes

1.1 Compilation of the data requirements

In table 1 the compilation of the data requirements for the new calculation schemes for surface solar irradiance is provided. The table describes the necessary atmospheric parameters and the specified accuracy and resolution of these parameters in relation to the solar irradiance cases. Afterwards the accuracy and resolution of each atmospheric parameter is discussed.

Case	Possible RTM	Requirements	WP	Mesurement/ Retrieval with	accuracy/ resolution	
Clearsky direct ↓ Clearsky diffus, global	- MODTRAN (pseudospherical)	- Water vapor content: columns	2030	MSG-SEVIRI infrared channels	< 15%	50x50 km, daily
	- SBDART (planparallel)	- vertical layers: lower, middle and upper tropospheric humidity		MSG, MPEF product "middle and upper tropospheric humidity"		
	- 6s, etc	- Ozone concentration maps: vert. columns	2050	basing on data from ERS-2 / GOME and SCIAMACHY (MSG)	< 5% (< 10%)	100 x 100 km, daily
		- Aerosols optical depth and Aerosols type/class: 8 types, mixtures from components based on OPAC classification	2040	Climatology from GOME / ATSR-2 + SCIAMACHY / AATR retrieval MSG	AOD < 0.1 Abs. as good as possible	seasonal spatial resolution see section 1.2.3
Homogeneous clouds diffus → global	- MODTRAN - SBDART, 6s, etc	+ Cloud optical depth + eff. cloud droplet radius + liquid water path + Cloud top temperature	2020	MSG - SEVIRI all channels using APOLLO scheme	all < 30 % see 1.2.4	temporal/spatial SEVIRI pixel resolution
Broken Clouds direct	- SHDOM (planparallel) - SBDART	+ Cloudmask (land/ocean) + Cloudtype classification	2020	Cloud detection with APOLLO scheme	as good as possible	temporal/spatial SEVIRI pixel resolution
Broken Clouds diffus + direkt → global	- SHDOM - Monte Carlo	+ Icewaterpath (Cirrus - Clouds)	2020	Cloud detection with APOLLO scheme	as good as possible	temporal/spatial SEVIRI pixel resolution

Glossary:

APOLLO=extended AVHRR Processing scheme for Over Land, cLouds and Ocean

AVHRR=Advanced Very High Resolution Radiometer

ATSR-2=Along Track Scanning Radiometer

AATSR=Advanced ATRS

GOME=Gloabal Ozone Monitoring Experiment

MSG=Meteosat Second Generation

SCIAMACHY= SCanning Imaging Absorption SpectroMeter for Atmospheric CHAtographY

SEVIRI=Spinning Enhanced Visible and Infrared Imager

SHDOM, SBDART, 6s, Monte Carlo, Modtran= radiative transfer programs, a short description is provided in section 5.

RTM=Radiative Transfer Program

- = basic requirement for clear sky conditions

+ = additional requirement for cloudy conditions

Table 1: Compilation of data requirements

1.2 Remarks to the data requirements

1.2.1 O₃, WP 2050

The effect of O₃ on the solar irradiance in the VIS/NIR is very low, beyond a wavelength of 330 nm an accuracy of 5 % leads to an insignificant error in the calculation of the solar irradiance (330-1100 nm).

1.2.2 H₂O, WP 2030

The direct effect of H₂O in the visible is low compared to that of the aerosols for the clear sky irradiance. Model simulations indicate that the direct effect of errors in the water columns in the limit of the provided accuracy should be in general less than 2-3 % for the calculated integrated radiation energy flux (calculated solar irradiance) in the VIS/NIR (330-1100 nm). But water vapour has also in indirect effect on the radiance in the VIS, because it effects the size distribution of the aerosols and hence the optical properties of the aerosols.

1.2.3 Aerosols, WP 2040

Aerosols are the dominant factor regarding the calculation of clear sky irradiance. The data requirement for the accuracy of the Aerosol Optical Depth (AOD) is pointed out to be less than 0.1 . The spatial resolution for the GOME/ATSR-2 climatology will be 5x5 degrees. The given accuracy and spatial resolution is based on a state of the art retrieval procedure and is restricted by the limitations of the satellite measurements. GOME has a high spectral but a rough spatial resolution. The GOME/ATSR-2 climatology is a good basis in order to yield a significant improvement in the estimated solar irradiances within the assumed accuracy.

Nevertheless, because the effect of aerosols is very important for the calculation of clear sky irradiances a higher accuracy than that of 0.1 and especially a higher spatial resolution is desirable from the viewpoint of the solar applications. Therefore within this project a higher accuracy of AOD is aimed for. In figure 1 the effect of the assumed error in AOD (0.1) on the transmitted intensity is diagrammed.

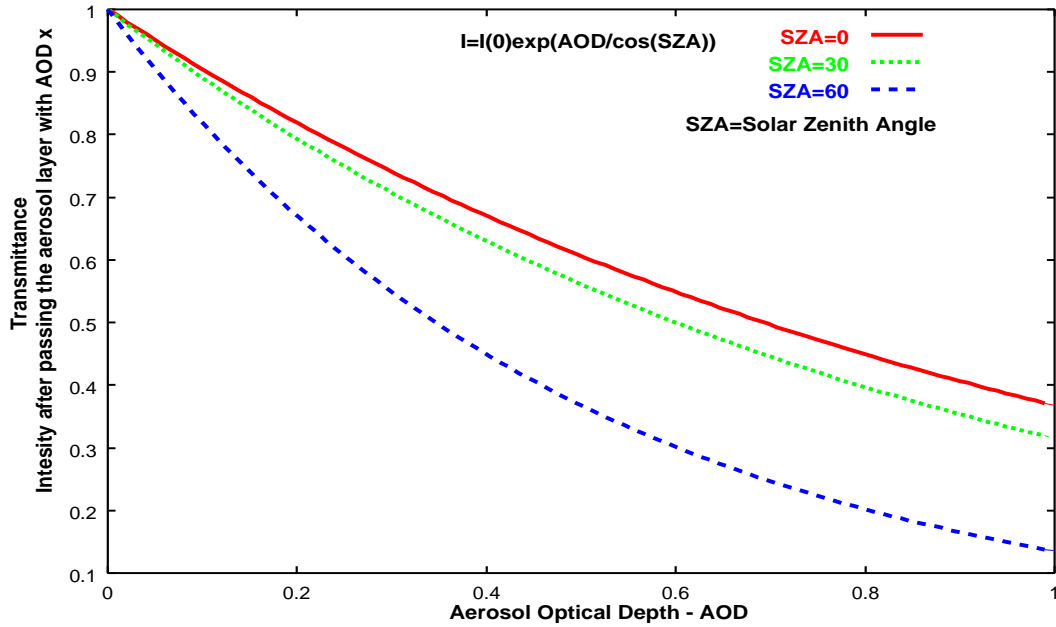
A higher spatial resolution can be achieved using SCIAMACHY/AATSR data, since the spatial resolution of SCIAMACHY is improved compared to the GOME instrument. With SCIAMACHY/AATSR it should be possible to enhance the resolution to approximately 100x100 km². But the SCIAMACHY launch will be to late (October 2001 ?) to yield a complete climatology from SCIAMACHY/AATSR within the Heliosat-3 project (not enough data). But it is possible to yield a set of test data for selected sites, that makes is possible to investigate the improvement of clear sky solar irradiance calculation schemes using aerosol parameters with a higher resolution than that of the GOME/ATSR-2 climatology.

Additionally the possibilities of MSG/SEVIRI to derive appropriate information about the aerosols in the atmosphere will be investigated.

1.2.4 Clouds, WP 2020

The effect of clouds play a major role in the current error (RMS) of the calculated monthly mean and daily mean irradiances. Within the specified accuracy and resolution for the cloud parameters it will be possible to yield a significant improvement in the estimation of solar irradiances. A relative error of 30% for cloud parameters seems to be very large. But contrarily to other data this should be given in MSG pixel resolution (15 min timesteps and approx. 3 km x 3 km horizontal resolution in nadir). After averaging in the spatial and/or temporal domain much better accuracy is expected.

Nevertheless, because of the very large effect of clouds on the solar irradiance, a higher accuracy of the cloud parameters is aimed for within this project.



The intensity $I(0)$, prior to the aerosol layer, is assumed to be 1. The y-axis describes the intensity after the light has passed the aerosol layer (=the transmittance, because $I(0)=1$). The x-axis is the Aerosol Optical Depth of the aerosol layer. The effect of the AOD on the intensity is diagrammed for three different SZA. Below the effect of the assumed errors in the AOD on the intensity is diagrammed as absolute value.

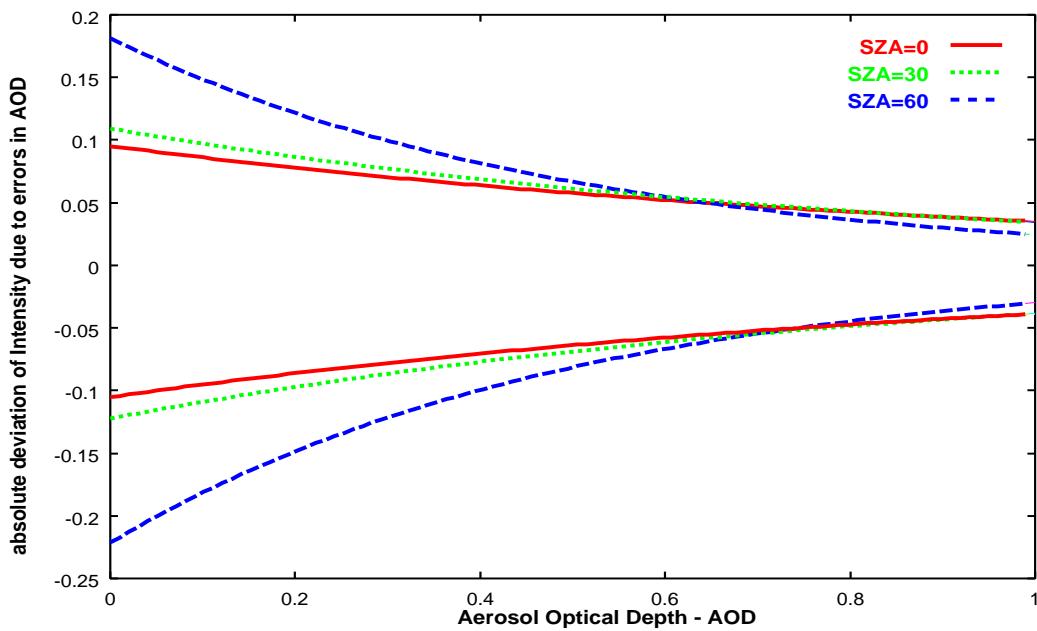


Figure 1: Effect of assumed error in AOD on the intensity.

1.3 Short description of the radiative transfer programs

The following description and characterization of the radiative transfer models is a mixture of information provided from the model developers or model contributors via Internet linked with our own knowledge and view.

1.3.1 MODTRAN - MODerate resolution TRANSmittance

The Moderate Resolution Transmittance (MODTRAN) Code calculates atmospheric transmittance and radiance for "frequencies" from 0 to 50,000 cm^{-1} at moderate spectral resolution, primarily 2 cm^{-1} (20 cm^{-1} in the UV). MODTRAN was driven by a need for higher spectral resolution than LOWTRAN. Except for its molecular band model parameterization, MODTRAN adopts all the LOWTRAN 7 capabilities, including spherical refractive geometry, solar and lunar source functions, and scattering (Rayleigh, Mie, single and multiple), and default profiles (gases, aerosols, clouds, fogs, and rain).

Major upgrade in Version 3.7 was the capability of users to easily defined cloud and rain descriptions. For example, clouds can be placed anywhere within the defined atmosphere, can co-exist with aerosols, and can have a mixed phase composition. A second major upgrade was the inclusion of molecular band model parameters based on the HITRAN96 spectroscopic database. MODTRAN 4.0 have a significantly improved multiple scattering model. Please note that the MODTRAN4 code is not free of charge.

Source code and documentation available via: <http://www.vsbm.plh.af.mil/soft/modtran.html>

1.3.2 6s:

The 6s model enables the simulation of effects of the atmosphere linked with the Sun-Target-Sensor path on the Remote Sensing Signal. The 6s (Second Simulation of the Satellite Signal in the Solar Spectrum) code is the improved version of the 5s code developed by the Laboratoire d'Optique Atmosphérique. It enables to simulate plan observations, to account for elevated targets and to take into account non lambertian surface conditions. New gases (CH_4 , N_2O , CO) have been integrated in the computation of the gaseous transmission. The step for spectral integration has been improved to 2.5 nanometers.

The documentation of the model is well organized and provides a lot of information, it seems that the code is very qualified for the correction of clear sky calculation of solar irradiance as well as for sensitivity studies of clear sky transmittance. Especially the handling of the code seems to be flexible and concomitant easy and transparent. Please note the 6s model has currently no capability to handle clouds.

Source code and documentation available via: <ftp://loaser.univ-lille1.fr/>

1.3.3 SHDOM:

Spherical Harmonic Discrete Ordinate Method (SHDOM) for Atmospheric Radiative Transfer. This program computes unpolarized monochromatic or spectral band radiative transfer in a one, two, or three-dimensional medium for either collimated solar and/or thermal emission sources of radiation. The properties of the medium can be specified completely generally, i.e. the extinction, single scattering albedo, Legendre coefficients of the scattering phase function, and temperature for the particular wavelength or spectral band may be specified at each input grid point. SHDOM is superior to Monte Carlo radiative transfer methods when many radiative quantities are desired, e.g. the radiance field across the domain top or the 3D distribution of heating. Radiances at any angle, hemispheric fluxes, net fluxes, mean radiances, and net flux convergence (related to heating rates) may be output anywhere in the domain. For highly peaked

phase functions the delta-M method may be chosen, in which case the radiance is computed with an untruncated phase function single scattering correction. A correlated k-distribution approach is used for the integration over a spectral band. There may be uniform or spatially variable Lambertian reflection and emission from the ground surface. Several types of bidirectional reflection distribution functions (BRDF) for the surface are implemented, and more may be added easily. The horizontal boundaries may be either periodic or open.

Source code and documentation available via: <http://nit.colorado.edu/~evans/shdom.html>

1.3.4 SBDART:

SBDART is a FORTRAN77 computer code which computes plane-parallel radiative transfer in clear and (homogenous) cloudy conditions within the earth's atmosphere. All important processes which contribute to the UV, visible and IR radiation fields are included. The code is a marriage of a sophisticated discrete ordinates radiative transfer module, low resolution atmospheric transmission models, and Mie scattering results for light scattering by cloud droplets. The code is well suited to handle a wide variety of problems in atmospheric radiative energy balance and remote sensing.

SBDART is a practical approach to solving plane-parallel radiative transfer problems within the earth's atmosphere. The code is designed for the analysis of a wide variety of radiative transfer problems encountered in satellite remote sensing and atmospheric radiation budget studies. The program is based on a collection of well tested and reliable physical models which have been developed by the atmospheric science community over the past few decades.

For a general description and review of the program please refer to Ricchiazzi et al 1998. (Bulletin of the American Meteorological Society, October 1998).

Source code and documentation available via: http://g.ices.ucsb.edu/esrg/pauls_dir

1.3.5 Monte-Carlo-Model - GRIMALDI:

GRIMALDI is a small set of programs to calculate for example monochromatic or broadband fluxes, radiances or photon path-lengths. GRIMALDI uses line by line programs to calculate gas-absorption coefficients and a Monte Carlo program to solve the radiative transfer problem. Simulation of each photon path including interactions (scattering and absorption) with molecules and other small particles allows to calculate radiance and flux fields, especially in connection with three dimensional inhomogeneities, with high accuracy.

All programs of this file-set, which contains four main programs and several data files, are guided by one control file.

Source code and documentation available via:

<http://hurricane.ifm.uni-kiel.de/GRIMALDI/manual.html>

1.3.6 LOWTRAN

LOWTRAN 7 is a low-resolution propagation model for calculating atmospheric transmittance and background radiance from 0 to 50,000 cm^{-1} at a resolution of 20 cm^{-1} with a minimum of 5 cm^{-1} sampling. The program calculates single scattered solar radiation. Multiple scattered radiation has added to the model as well as new molecular band model parameters and new or updated ozone and molecular oxygen absorption parameters for the UV. Other modifications include e.g. new cirrus cloud models. The model also includes updated aerosol models with options to replace them with user derived values.

Source code and documentation available via:

<http://www.ncdc.noaa.gov:80/pub/software/lowtran>

2 User requirements on solar data

2.1 Introduction

This document originates from the project SoDa, supported by the IST programme of the European Commission. The SoDa users requirements originate themselves from several sources. These sources are:

- Documentation and/or information on user requirements from solar energy data vendors: Ecole des Mines de Paris and Meteotest. These data and information constitute the baseline as well as the products developed by these vendors: European Solar Radiation Atlas (ESRA) and MeteoNorm, which are used by a qualified majority of solar energy data users in Europe,
- Outcome of informal oral consultation with key players in the solar energy field. All consultation took place during the year 2000. This consultation took place at fairs, conference, and via direct contacts through e-mail and telephone,
- The Satel-Light server, a follow-on of the project Satel-Light supported by the programme JOULE of the European Commission,
- Publicly available documentation, from diverse sources. This documentation includes the CIBSE User Guide (Chartered Institution of Building Services Engineers of United Kingdom)

The European Solar Radiation Atlas (ESRA) is commercialised by the Ecole des Mines de Paris. The number of users consulted for the definition of the ESRA user requirements is approximately 30. They were contacted through the administration of a closed questionnaire and further interviewed by phone. The ESRA benefits from the experience gained by the sales and realisation of the three previous editions. Reference: B. Bourges and L. Kadi: "European Solar Radiation Atlas: User needs and specifications. A report to the European Commission", Contract J0U2-CT94-0305, EMN/ESRA/Doc 6.95, 95 p., Ecole des Mines de Nantes, France, 1995.

The creation of the 4th edition of the European Solar Radiation Atlas, directed by the Commission, comprised a survey of the users requirements, taking into account the experience gained in the sales and use of the three previous editions. This document reports on this survey. The panel was composed of representatives of companies and institutes involved in solar systems R&D, sales and installation, since these are the major part of the customers targeted by the ESRA. Efforts have been made to survey the needs of companies and institutes dealing with the production of biomass for the production of energy and further to the needs in agriculture crop prediction and agro-meteorology. These users requirements played an important role in the collection of the meteorological data, creation of the databases and the design of the exploitation software. Among others, they led to the development of methods for the combination of satellite-derived estimates and ground-based measurements of solar irradiation, since it was the unique way to answer the customers requests. The requests depend upon the typology of the customer. However, there are convergences for requesting a complete geographical coverage (not only sparse measuring stations), time-series of daily global irradiances and of air temperatures, and also climatological means of several meteorological parameters.

METEONORM, produced and commercialised by Meteotest. The number of users consulted for the definition of the METEONORM user requirements are approximately 300 and were con-

tacted through the administration of a closed questionnaire and further interviewed by phone. The survey was performed by the company Polyquest AG, in Bern, Switzerland. Reference: Roman Scherrer: "Neukonzeption Meteororm - Bedürfnisanalyse", 1992, internal Meteororm report. (in German). *This document contains the user requirements and their analysis carried out for the definition of METEORNORM user requirements.*

SATEL-LIGHT, developed by ENTPE. The number of users consulted for the definition of the ENTPE user requirements are approximately 200 and were contacted through the administration of a closed questionnaire and meetings. Reference:

Beyer H.G., Dumortier D., Fontoynt M., Hammer A., Heinemann D., Ineichen P., Olseth J., Page J., Reise C., Roche L., Skartveit A., Wald L.: "SATEL-LIGHT: processing of Meteosat data for the production of high quality daylight and solar radiation data available on a World Wide Web Internet server". Final Report, European Commission, JOR3 CT95-0041, 1999. <http://www.satel-light.com>.

In this project, we looked at satellite images as a way to produce the information needed for the design of daylighting systems. We showed that Meteosat images could provide daylight data every half-hour with enough accuracy with a resolution (5 km by 7 km) which would be impossible to reach with a network of ground stations. We processed two years of satellite images and made the information available on an Internet web server. To insure the adequacy of the information to the needs of the building design community, we organised two workshops during which the objectives of the project and a prototype of the web server were presented. The feedback from the potential users was very positive. They recognised that the project was providing information that had been missing for years. They expressed their concern regarding the short-term period covered by the data and with the fact that other parameters such as temperature would be missing from the database. SoDa will provide an answer to these shortcomings. The workshops also helped us in defining the information most helpful to the users. Since 1999, the Satel-Light server is up and running, users are invited to comment on it and to check the progress of SoDa.

Daylighting Atlas

Asimakopoulos D., Carvalho L., Chauvel P., Czeplak G., Dumortier D., Fontoynt M., Kittler R., Littlefair P., Page J., Perraudon M., Petrakis M., Tregenza P.: "Availability of daylight in Europe and design of a daylighting atlas". Final Report, European Commission, JOU2 CT92-0144, 1995.

This project focused (1) on the analysis of the availability of daylight in Europe on the basis of ground measurements made by each partner; (2) on the design of an atlas geared toward designers of daylighting systems. The design of the atlas showed that long term (10 years) daylight availability information over Europe was non-existent. Therefore, we had to rely on more general solar radiation information (i.e. used for solar thermal systems). This was frustrating because hourly information (variability is extremely important for daylighting) was available only for a few sites in Europe and when available it was extremely expensive. The SODA IS would have been at that time extremely valuable. We ended up dividing Europe into 5 zones with one or two sites for each zone. We agreed on the basic climatic information needed for daylighting design.

Bücher, K., G. Kleiss, D. Bätzner, K. Reiche, R. Preu, P. Ragot and D. Heinemann: "Realistic PV Efficiency Map: European Wide Evaluation of PV-Modules", 14th European Photovoltaic Solar Energy Conference, 30 June - 4 July 1997, Barcelona, 268-271 (1997).

This paper reports on an EU-ALTENER project dealing with the definition of standardised reference conditions for the performance of photovoltaic solar cells. Solar radiation and ambient temperature are the most important factors identified by the project. In its realisation, the project suffered from the unavailability of combined radiation and air temperature data. The SoDa service would have been of great value for this task. This project is a good illustration of many other projects, where significant amounts of the project budget are spent only to provide the data which are necessary for the main work.

Brösamle, H., H. Mannstein, C. Schillings and F. Trieb: "Assessment of Solar Electricity Potentials in North Africa Based on Satellite Data and a Geographic Information System". *Solar Energy*, 70, 1-12 (2001).

A perfect example of what kind of information is necessary for comprehensive investigations of a new solar energy technology (here: solar thermal power plants). Different information have to be known at the same time; among them are meteorological data (radiation, air temperature) but also geographical, demographic and infrastructure information. The results are real economic figures (\$/kWh).

A similar work has been funded by the European Commission for the isolated sites: SolarGIS (DG XII, JOULE II, JOU2-CT94-0439, 1993-1996) "Integration of renewable energies for electricity production in rural areas".

The purpose of the SOLARGIS methodology is to lead at a regional scale comprehensive integration studies through the use of an adapted information environment, that includes: a Geographical Information System (GIS), which allows a proper management of the different geographical information layers and a set of technical and economical evaluation tools, linked to the GIS database. One of the major problems encountered for the application to Tunisia was the lack of data on the solar radiation. More information: <http://www-cenerg.cma.fr/%7Est/solargis/>

The project MORE-CARE is building upon the project SolarGIS. Its title is "more advanced control advice for secure operations of isolated power systems with increased renewable energy penetration and storage". It is financed by the EC: DG XII, JOULE III, ERK5-CT1999-00019, 2000-2003.

The co-ordinators recognised that the lack of meteorological data creates interference with the exploitation of the outcomes. This is true to many projects in the JOULE program. More information: <http://www-cenerg.cma.fr/more-care/>

Reise C. "Solar Radiation Data Requirements in the Solar Energy Business", internal SoDa document, March 2000.

Page J. "Contribution on SoDa User Issues in the Construction Industry", internal SoDa document, March 2001.

2.2 Solar Energy Engineering

2.2.1 Test Reference Years and Design Reference Years

Test Reference Years (TRY) and Design Reference Years (DRY) are special time-series of meteorological and radiation values extracted from continuous observations spanning several years (ten or more years). TRYs and DRYs are made up of several parameters (hourly values) from twelve months selected from different years. These reference years are typical years, which means that every month is selected, according to criteria based on the statistical distribution of

the parameters. They are useful for applications where daily data are sufficient for the simulation and studies. Many models use TRYs or DRYs as inputs. Formats of the data should be standardized in that respect.

The main reason for constructing a reference year for a particular site is to give industrial engineers, consultants, architects, and research institutions a standardised set of climate data to be used as input data for computer simulations of complicated systems needing more than one climate parameter, and normally also containing non-linearity. Reference years with hourly data are often used for calculations of indoor climate, building energy consumption or energy conservation measures, or performance of solar energy systems; however many other uses have been observed. Such reference years describe a typical year. They are not suitable for tasks in which weather extremes occurring with frequencies less than once per year are required.

As a minimum, a TRY should contain for each hour dry bulb temperature, a humidity parameter such as dewpoint temperature or relative humidity, global and diffuse irradiance, preferably also direct normal irradiance, wind velocity, all stored against the month, day and hour. Sunshine duration, sometimes only available as a daily value, or wind direction during the hour are often available and can be incorporated.

Preferred content of a test reference year

- Station WMO identifier
- Time indicator for irradiation measurements:
local standard time (L) or true solar time (T)
- Dry bulb temperature, in 0.1 C
- Mean hourly global irradiance, in $W m^{-2}$
- Mean hourly diffuse irradiance, in $W m^{-2}$
- Mean hourly direct beam normal irradiance, in $W m^{-2}$
- Sunshine duration, in minutes
- Relative humidity, in per cent
- Wind speed, in $0.1 m s^{-1}$
- (Year), month, day
- Hour, local standard time, 01-24
- Mean hourly long-wave irradiance, $W m^{-2}$
- Clearness index KTh, in per cent
- Wind direction, in degrees, clockwise from North
- Cloud-cover, daily value, 0-10

A design reference year DRY is produced from a TRY through an adjustment procedure which adjusts the most important parameters (temperature, radiation, wind speed) to accord with multi-year means and frequency distributions, using either to an input data sequence of 10-20 years, or 30-year means (Skartveit et al. 1994; Lund 1995). As in the case of a TRY, it is a dataset corresponding to a full year - 8760 hours - with hourly records.

The adjustment process gives to each month of a DRY a larger span in temperature than a single month would normally have, and also a larger daily temperature variation. DRYs are therefore badly suited for extraction of statistical values. Statistical values should be only extracted from multi-year sequences of data.

Design Reference Year (DRY). Frequency of measurement is 1 hour, unless otherwise specified. Note that precipitation (field number 21) is presented integrated over 6 hours for hours 1 and 13, and over 12 hours for hours 7 and 19. Hence the daily sum for precipitation is the sum of observations for hours 7 and 19. "Adjusted" means that a parameter has been adjusted in the production of the DRY.

Content	Note
Station name or number	
Time indicator for radiation measurements	
Dry bulb temperature, 0.1°C	Adjusted
Dew point temperature, 0.1°C	Adjusted, keeping the relative humidity almost unchanged
Global irradiance $W m^{-2}$ (mean value for the preceding hour)	Horizontal surface. Measured and adjusted
Diffuse irradiance $W m^{-2}$ (mean value for the preceding hour)	Horizontal surface. Measured with shadowband, corrected. Not adjusted
Direct beam normal irradiance $W m^{-2}$	Derived from global and diffuse.
Downward longwave irradiance $W m^{-2}$	
Illuminance, global, lux	Derived from the method of Perez et al. (1990)
Illuminance, diffuse, lux	id.
Illuminance, direct beam normal, lux	id.
Total cloud amount, observed	
Equivalent opaque cloud amount, every hour or 3-hours	
Sunshine duration in the hour, minutes	Given for day hours. Threshold is $120 W m^{-2}$
Wind direction, tens of degrees (0 for North, 9 for East, ...) 00 is calm, 99 unsteady, low speed	10 m above ground, values averaged over 10 minutes.
Wind speed, $0.1 m s^{-1}$	Adjusted
Indicator for special data (= 0)	
Maximum temperature, 0.1°C, only at 7 and 19 hours	Taken for the preceding 12 hours. Adjusted
Minimum temperature, 0.1°C, only at 7 and 19 hours	Taken for the preceding 12 hours. Adjusted
Pressure, hPa, every 3-hours	Station pressure, not reduced to sea surface
Precipitation, 0.1 mm, only at 1, 7, 13 and 19 hours	
Weather code, every 3-hours	
Weather since last observation W1 and W2, every 3-hours	
Empty	
Relative humidity in %	
Solar altitude, 0.1 degree of arc angle	Mean solar altitude for the hour. For sunrise and sunset hours mean altitude for that part of the hour when the sun (centre) is above the horizon, atmospheric refraction included.
(Year), month, day. (for DRY, year = 12)	
Hour, local standard time, 01-24	Always winter time
Continuation, 0 or 1	Indicates a following record, for direct irradiance

Table 2: The direct normal irradiance (beam irradiance) is derived from diffuse and adjusted global irradiance and solar altitude. It is given as a mean hourly value and, if greater than $5 W m^{-2}$, stored in a separate subsequent record, as computed 5-minute values. For Copenhagen this parameter is not adjusted. For most other DRYs the adjustment is applied to the direct beam normal irradiance, and not to the global irradiance. A special record format is used for 5-min. direct beam normal irradiance, estimated only if the hourly value for direct beam normal irradiation exceeds $5 Wh m^{-2}$.

2.2.2 Time-series of measurements (or satellite assessments)

Requests are various, depending on the usage. The following requests have been issued by customers.

- Time-series of hourly sums of sunshine duration, global, diffuse and beam irradiation on horizontal plane
- Time-series of daily sums of horizontal global irradiation, and of sunshine duration, daily mean air temperature, minimum and maximum air temperature, and daily precipitation.
- Monthly means of daily sums of sunshine duration, and of horizontal global irradiation.
- Ten-year averages of monthly means for daily sums of horizontal global irradiation and sunshine duration, daily minimum and maximum air temperatures, surface atmospheric pressure and water vapor pressure and monthly sums of precipitation.
- Monthly values of the Ångström coefficients.

Other resources requested: advanced parameters and applications modules

- Day by day estimated hourly irradiation values on inclined planes from daily observed global data using the concept of smoothed daily irradiance profiles.

- Illuminance values.
- Clear sky irradiation on inclined planes for any selected Linke turbidity factor.
- Incoming long wave radiation.
- Global spectral irradiation on horizontal planes.
- Cumulative frequency curves.
- Yearly energy output from solar water heater.
- Output from photo-voltaic grid connected system
- Photo-voltaic stand-alone system with batteries.
- Daily energy output from a solar water heater.
- Passive solar heating (direct gains)

2.3 Daylight

2.3.1 Which parameters?

Daylight is a field where all you need is the visible part of solar radiation (as opposed to other fields like thermal energy where you also need temperature, humidity, wind...).

However, you need this information with many more details. Diffuse and direct components of solar radiation (not just global) are absolute requirements. They should be available as fluxes available on the horizontal plane (to be compatible with simple design methods) and on the plane of the glazing. A description of the sky luminance distribution helps in understanding more clearly from which part of the sky vault, the light is coming from (this level of information is provided in the Satel-Light server).

These parameters should possibly take into account the urban environment in which the building is located. This is not something straightforward to do, however this is critical to get closer to reality (most of the existing products do not take into account obstructions or use very basic models).

2.3.2 What information?

Since light cannot be stored, users need to know what amount of light is available and when. Frequency information that can be suited to the building operating schedule is the most useful: e.g. how often given levels are exceeded from 8:00 to 14:00 ?, a school operating schedule. This means that the data available should have a temporal resolution sufficient enough to match the frequency distribution of reality (previous studies have shown that a 15 min resolution was good enough, the 30 min resolution used in satel-light is also adequate).

Mean monthly hourly values are more useful than mean daily values because they provide users with information on how daylight is changing throughout the day. Cumulated values during a time period (9:00 to 17:00, all year) are useful for users working for museums because most paintings should be exposed to only a maximum amount of visible light.

Information on the direct component of solar radiation should be coupled with some information on the solar position in the sky vault. Sunpath diagrams should of course be provided. However, a better information would be provided by showing with statistics, the strength of the direct component in various parts of the sky: how often the direct solar illuminance exceeds given levels, in a given zone of the sky ?

If the building is in the sketch phase, the information mentioned above may be enough. The information on the diffuse component of solar radiation will be combined with standard practice design method such as the daylight factor method, to obtain its daylight autonomy. However to

finalize the design, particularly if the daylight system is complex, the climatic information will have to be used in a software which can properly take into account the optical properties of all materials in the building. For this reason, users need hourly values of solar radiation in a format compatible with these programs.

2.3.3 What are the potential users in daylight ?

- Architects for building design in the sketch phase
- Engineering firms for building design in all stages.
- Glazing manufacturers for design and marketing.
- Store manufacturers (manual and automatic) for design and marketing.
- City planners to optimize street daylight and evaluate its electricity consumption.
- Lawyers to evaluate the impact of new buildings on access to daylight.
- Individuals for general information on the climate and assessment of shades.

2.3.4 Ancillary Data

All applications request ancillary data for supporting data processing, results presentation, data query, etc. Ancillary data are:

- terrain elevation
- water bodies and land masses
- borders of countries
- countries
- databases of major European cities