Daily integration of irregularly time spaced surface shortwave irradiance estimates using AVHRR data[1]

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(June 27, 2002)

1 Introduction

As part of the EUMETSAT Ocean and Sea Ice SAF project the Norwegian Meteorological Institute (DNMI) is supposed to produce daily estimates of downward surface solar irradiance (SSI) from NOAA POES and EPS METOP AVHRR data. The problem of estimating hourly SSI using these data is covered in e.g. Godøy and Eastwood (2002a) and further references on this subject within the Ocean and sea Ice SAF concept can be found in that report. This report address the problem of creating daily products from irregularly time spaced input data as the NOAA POES and EPS METOP platforms are sun synchronous platforms.

2 Background

Creating daily products using geo-stationary satellite data is merely a matter of averaging hourly values. Polar orbiting satellites gives hourly estimates of SSI irregularly covering the diurnal cycle. For some periods of the day several estimates might be available, while for other periods no estimates are available. The daily averaging process then becomes a matter of representation. Straightforward averaging of available SSI estimates will not be a representative daily average.

Figure 1 illustrates the diurnal variation in solar irradiance at top of the atmosphere (TOA). Basically solar irradiance is received in the atmosphere when the sun is above the horizon. The formulas necessary to estimate this (solar declination, zenith angle, hour angle etc) is taken from Paltridge and Platt (1976). Along the abscissa, hours of the day are plotted (0-23 UTC), along the ordinate the estimated TOA irradiance as function of time is plotted. The TOA irradiance is basically found using EQ 1 where E_0 is the solar constant (1367 used herein) and θ_0 is the solar zenith angle.

$$E = E_0 \cos(\theta_0) \quad \text{(EQ 1)}$$

In Figure 1 the square points on the solid line represents observations performed by a polar orbiting satellite. As can be seen, these are irregularly spaced in time. In this special situation a straightforward averaging of the estimated irradiance would create

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a too high daily irradiance. This can be seen as the horisontal thin line in middle of the illustration reflects the daily mean value as found when all hourly values are found. This would normally be the case using a geo-stationary satellite for estimation.

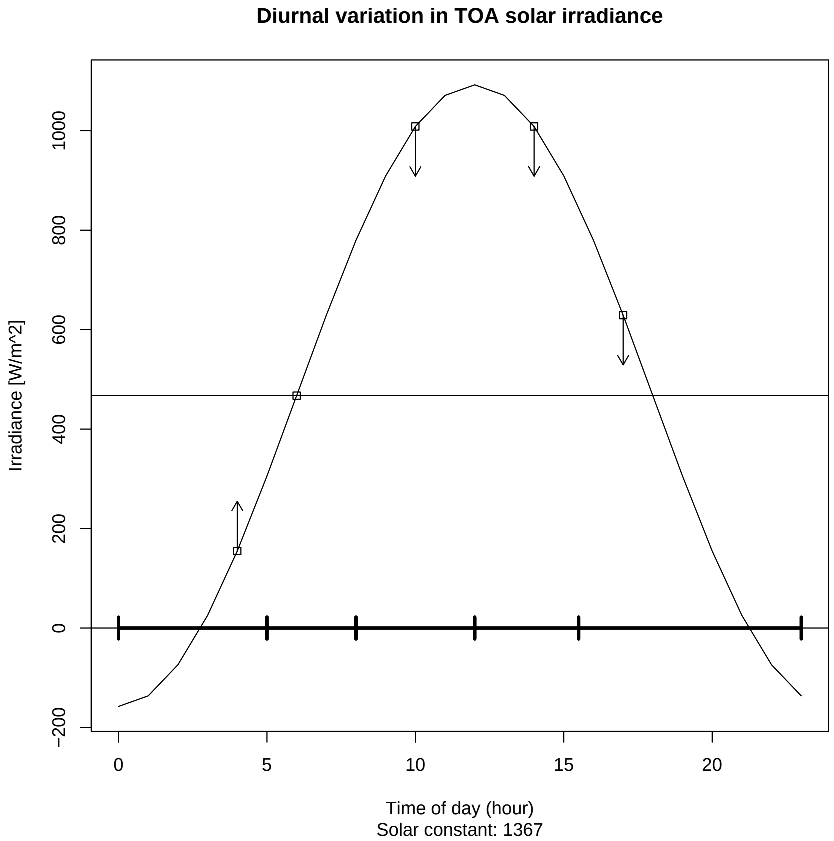

Figure 1 Diurnal variation in solar irradiance at top of the atmosphere as estimated using a solar constant of 1367, latitude 60.17°N and Julian Day 182 (June/July change).

The illustration in Figure 1 represent the irradiance at TOA and does not handle the effects of the atmosphere.

3 Method

The method selected for initial testing within the Ocean and Sea Ice SAF project at DNMI is basically a two step model:

1. First each “observation” is “normalized” to the daily mean value given no clouds.
2. Second each “normalized observation” is given a time weight which should reflect the representative period of that specific observation.

The first step, the “normalization”, is performed by applying weights to each “observation”. This is done by estimating the mean daily irradiance by averaging TOA fluxes (as these can be estimated at the time resolution required) giving the daily mean *(f_m)*. The normalization weight *(w_n)* is then found by combining the estimated

TOA irradiance for the specific time and location *(f_a)* with the daily mean value as described in EQ 2.

$$w_n = \frac{f_m}{f_a} \quad \text{(EQ 2)}$$

where f_m is the mean daily TOA irradiance for the specific location and f_a the actual TOA irradiance for the specific location and time.

The effect of this normalization is illustrated by arrows on the boxes representing observations in Figure 1. After weights have been applied to the "estimates" these would be representative for the effect of cloud cover on the SSI.

In a similar way, weights are estimated to assign a representative time period for each "observation" as well. One could let each "observation" have the same influence on the end result. But since polar orbiters sometimes pass over an area frequently (various platforms) and at other times of the day, no data are available, the cloud cover of this specific time would have a higher influence on the total cloud cover than other observations. In order to circumvent this, the 24 hour period compromising a day is divided into segments as illustrated by the heavy line with vertical bars in the bottom of Figure 1. The segments represents the valid time period for each "observation" and the time weight *(w_t)* is estimated by the ratio of the segment length in second to the total seconds in a full day as described in EQ 3.

$$w_t = \frac{s_i}{\sum_{i=1}^{N} s_i} \quad \text{(EQ 3)}$$

where the length of a time segment is estimated using UNIX time specifications for start and end time of the segment. Basically the denominator of EQ 3 would also be estimated using start and end time in UNIX specification of the day being studied, not by summing the segments which would be a more CPU consuming way to do the same task.

In the end, applying the two corrections indicated above should give a more representative estimate from irregularly time spaced "observations" from polar orbiters.

4 Discussion

The major drawback of the method proposed is the assumption that the cloud cover at the time of "observation" is the cloud cover experienced throughout the representative time period of the "observation". Everyone that have observed the sky knows the rapid changes in cloud cover. This affects the solar irradiance significantly.

The "normalization" weights are estimated using TOA fluxes as basis. This is not expected to create any trouble as the ratio which is the weight is supposed be rather consistent throughtout the atmosphere. By using TOA values, the CPU performance is drastically increased compared to weight estimation based upon e.g. cloud factor or likewise, not to mention the reduction of the I/O load.

The normalization weights proposed above have been used on daily SSI estimates during the spring of 2002 (results are presented in Figure 2). Time weighs has not been implemented yet. Results so far indicates an underestimation of daily fluxes in the order of 40W/m^2. This is too large and further examination of the method is required. However, results are getting better by time (Figure 2) indicating that snow on ground might be affecting the result. Further discussion on this topic is found in the first validation report on the Ocean and Sea Ice SAF High Latitude SSI (Godøy and Eastwood, 2002b).

The validation should be tested using daily validation data estimated using the same method as for the daily estimates (the weighting process).

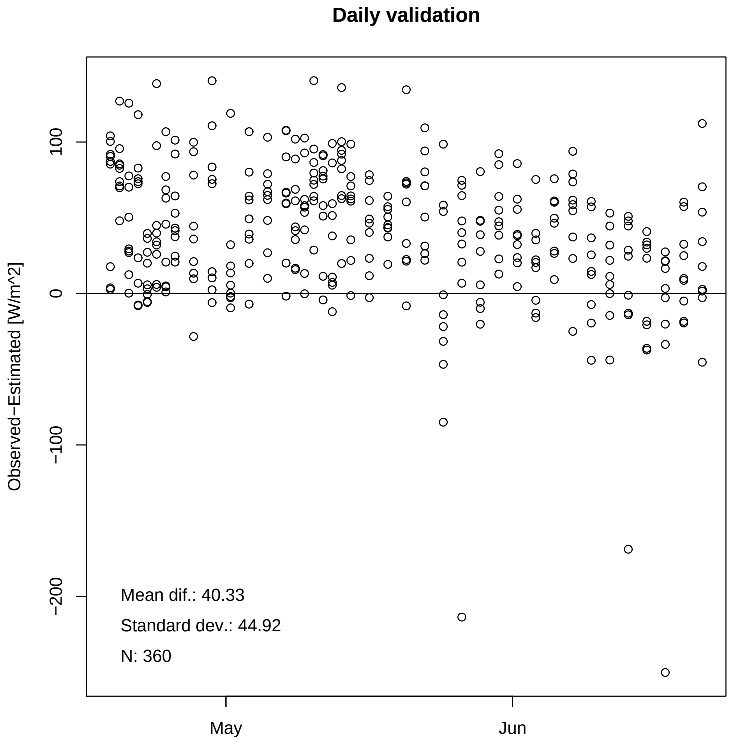

Figure 2 Temporal evloution of the difference - observed minus estimated SSI at various stations in Norway. See Godøy and Eastwood (2002b) for further details.Time period spans 18 April to 23 June 2002.

5 Summary

The method have been used in daily production during the spring. Results are not good so a further testing of the method using the same method for daily estimation of “observed” as estimated irradiance, that is for validation as well as estimated fluxes, is now required to check whether the method is the main problem.

Further testing will include use of the weighting technique on validation data as well as estimates.

References

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