

Temporally Averaged Reflected SW Flux

Algorithm for POLDER-2

Aim of the algorithm : Derivation of monthly average reflected shortwave (SW) flux from instantaneous SW albedos previously calculated for each orbit at the superpixel resolution.

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Author : M. Viollier
Laboratoire de Météorologie dynamique,
Ecole Polytechnique,
91128 Palaiseau Cedex (France)
e-mail : viollier@lmd.polytechnique.fr

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Development of the POLDER “Earth radiation budget, water vapor, and clouds” algorithms results from a joint effort of Laboratoire d’Optique Atmosphérique (LOA), Laboratoire des Sciences du Climat et de l’Environnement (LSCE) and Laboratoire de Météorologie dynamique (LMD). It has been supported by CNES (Centre National d’Etudes Spatiales), CNRS (Centre National de la Recherche Scientifique) and Région Nord-Pas de Calais.

1. INTRODUCTION

In the POLDER level-2 data processing, the instantaneous broadband or shortwave albedo A_{SW} (hereafter noted α) is derived as a function of narrow-band albedos (see Spectral Albedo Integration Algorithm for POLDER-2). However, this instantaneous albedo at the local time of the observation (around 10:30 am) is not equivalent to the daily average. It would be equivalent only if the changes in cloudiness during the day could be ignored and if the albedo of a constant scene did not vary with solar zenith angle. This is not the case: for a constant scene the daily averaged albedo is generally higher than the 10:30 instantaneous albedo, typically by 15%. There is however no simple relationship between them. For this reason, diurnal interpolation and extrapolation procedures (DIEP) have been developed for ERBE (Brooks et al., 1986) and for ScaRaB (Standfuss et al., 2001). These algorithms have been adjusted to POLDER in order to compute daily and monthly means of the SW reflected flux density and to compare with ERBE, ScaRaB and CERES determinations (Viollier et al., 2002).

2. DIURNAL EXTRAPOLATION

The purpose of the SW diurnal model is to extrapolate the instantaneous albedo α from observation time t_{obs} to the 24 local hour boxes centered on the local half hour t_h : 0030, 0130, ..., 2330. Assuming that the observed scene is constant along the day, equation (1) takes into account the predictable variation of the solar zenith angle (μ_s is the cosine of the solar zenith angle) and its influence on the albedo through the directional function α^{dir}

$$\alpha(t_h) = \alpha(t_{obs}) \frac{\alpha^{dir}(\mu_s(t_h))}{\alpha^{dir}(\mu_s(t_{obs}))} \quad (1)$$

If at least two SW observations are available, two series of extrapolated flux estimations are computed, and the albedo is linearly interpolated between the two observation hours. For each region, the daily and the monthly means of the diurnal albedos are then computed as well as the total incoming flux (based on 1368 Wm^{-2} for the annual mean solar irradiance); their product gives the regional reflected flux (Wm^{-2}) at the top of the atmosphere.

3. THE ERBE-TYPE ALGORITHM

In the ERBE algorithms (see Brooks et al., 1986), equation 1 is applied for the four cloud cover ranges according to the fraction f_j of scene types j present in the considered ERBE 2.5° region, using the directional albedos α_j^{dir} provided by Suttles et al. (1988) and the observed albedo α_j per scene type. Equation 1 is replaced by

$$\alpha(t_h) = \sum_j f_j(t_{obs}) \alpha_j(t_{obs}) \frac{\alpha_j^{dir}(\mu_s(t_h))}{\alpha_j^{dir}(\mu_s(t_{obs}))}. \quad (2)$$

The ERBE scene identification is based on the analysis of both SW and infrared radiances and thus cannot be applied to POLDER. However, the multi-spectral, multi-directional and

polarization analyses of POLDER provide a better description of cloud parameters (Parol et al., 1999). In order to benefit from this, a scene identification based on 20 types has been introduced. This new scene classification distinguishes four ranges of cloud fraction (clear sky < 5%, partly cloudy 5-50%, mostly cloudy 50-95%, and overcast > 95%) using the POLDER cloud cover, four intervals of cloud optical thickness at 670 nm and the cloud phase. The surface type (ocean, land, snow/ice, desert, land-ocean mix) is determined using the POLDER scene indicator. Details are shown in table 1. Based on 4 months of POLDER data (Nov 1996, Feb 1997, May 1997 and June 1997), for each of these 20 scene types, the directional albedo functions have been calculated by averaging the POLDER albedos in solar angle bins (0.02 of width in μ_s) and by fitting the results with a third-order polynomial function of μ_s to smooth for latitudinal variations of scene type occurrences. For desert scenes where the solar zenith angle sampling is too limited, the directional models of Capderou (1998) are adopted. With these directional albedo functions, equation 1 is applied to extrapolate the 10:30 albedo to the other hours of the day.

	scene type	geotype	cloud cover	cloud optical thickness	
1	c. s. ocean	ocean	[0.0,0.05[-	
2	c. s. land	land			
3	c. s. coast	coast			
4	c. s. desert, north hm	desert			
5	c. s. desert, south hm	desert			
6	ice / snow	any	[0.0,0.95]	any	
7	p.c. ocean	ocean	[0.05,0.5[
8	p.c. land	land or desert			
9	p.c. coast	coast			
10	m.c. ocean	ocean	[0.5,0.95]		
11	m.c. land	land or desert			
12	m.c. coast	coast			
13	o. very thick, liquid	any]0.95, 1.0]		[20, ∞ [
14	o. very thick, non-l.				
15	o. thick, ocean	ocean or coast			[10, 20[
16	o. thick, land	land or desert			
17	o. thin, ocean	ocean or coast			[4, 10[
18	o. thin, land	land or desert			
19	o. very thin, ocean	ocean or coast		[0, 4[
20	o. very thin, land	land or desert			

Table 1: Scene identification using POLDER level 2 parameters (c.s.=clear sky, p.c.=partly cloudy, m.c.= mostly cloudy, o.= overcast)

4. THE POLDER ALGORITHM: ERBE-TYPE AND CLIMATOLOGICAL CORRECTION

Except when several observations are available in the day, the ERBE-type method is based on the assumption of diurnally constant cloud conditions. Standfuss et al. (2001) have improved this approach by introducing adjustments based on a regional diurnal albedo climatology computed from the 5 years of ERBS scanner data (1985-1990). The new method uses the hourly climatological albedo instead of the ERBE directional albedo to extrapolate the SW

flux from the observation to each local hour independently of the scene type. Equation 1 is replaced by

$$\alpha(t_h) = \alpha(t_{\text{obs}}) \frac{\alpha^{\text{cli}}(t_h)}{\alpha^{\text{cli}}(t_{\text{obs}})} \quad (3)$$

where α^{cli} is the monthly climatological albedo defined for each $2.5^\circ \times 2.5^\circ$ ERBE region and for each local hour. The climatological albedo implicitly accounts for the θ_0 -dependent directional variations and the time-dependent meteorological variations. However, the extrapolation with equation 3 may lead to unrealistic values when the observed albedo deviates strongly from the 'climatological' albedo (e.g. in case of a climate anomaly). To avoid this problem, appropriate restrictions for the application of equation 3 have been defined. The ERBE-type (equation 2) and the 'climatological' (equation 3) extrapolation are applied concurrently giving $\alpha^{\text{E}}(t)$ and $\alpha^{\text{C}}(t)$. Separately for each hour, the middle value between the ERBE-like albedo $\alpha^{\text{E}}(t)$, the climatologically extrapolated albedo $\alpha^{\text{C}}(t)$ and the climatological mean $\alpha^{\text{cli}}(t)$ is chosen. Typically, the 'climatological' extrapolation is used in 60% of the cases. On the global scale, the regional monthly time sampling error (up to 40 Wm^{-2}) of the ERBE-type extrapolation is reduced by about 20% for single NOAA-AM and PM observations. This is due to a high efficiency of the climatological extrapolation in areas with a coherent diurnal cycle of cloudiness (morning oceanic low cloud and afternoon convection) and a neutral behavior elsewhere. Applied to POLDER, the differences between ERBE-type extrapolated and climatologically extrapolated monthly mean flux densities are significant but small ($\pm 5 \text{ Wm}^{-2}$ typically) as compared to the magnitude of El Nino inter-annual regional anomalies (20 Wm^{-2}).

5. OUTPUT PARAMETERS

The flux densities (expressed in W/m^2) which are provided in the level-3 POLDER “ERB, WV & clouds” product are :

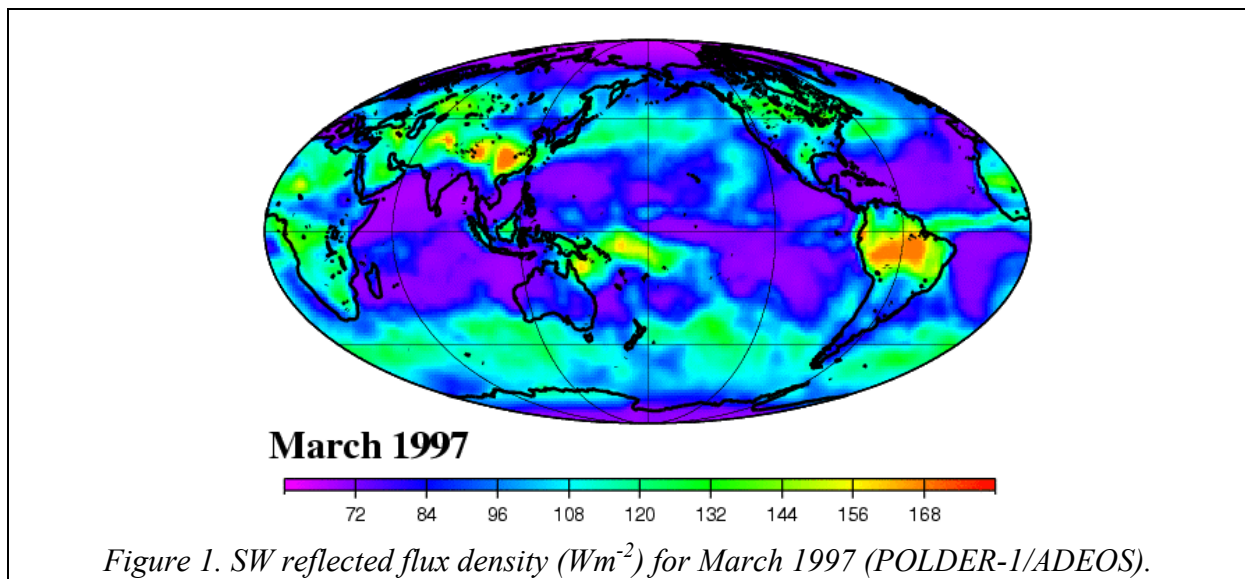
- the monthly average shortwave incident flux density,
- the monthly average shortwave reflected flux density,
- the monthly average clear-sky shortwave reflected flux density, i.e. the average over the only observations where the superpixel has been declared cloud-free by the cloud detection algorithm.

For practical reasons, the monthly means have been processed at the super pixel scale. However, due to the large cloud variability, the monthly means are significant only at low resolution (2.5°) like the monthly climatological albedo used in the computations.

The errors due to the narrow-to-broad band conversion and the radiance-to-flux conversion (about 10% for the instantaneous flux estimations) are expected to be reduced to the 2% level by the space and time averaging processes assuming large statistical independence of the error sources. Therefore the monthly mean uncertainty results from these errors in addition to the calibration (4-6%, Hagolle et al., 1999) and time sampling errors. For the tropical monthly means (about 90 W/m^2), the uncertainty may reach 7 W/m^2 .

6. EXAMPLES FROM POLDER-1

The eight monthly means of POLDER-1 have been processed¹ at the superpixel scale and averaged into the 2.5° x 2.5° ERBE grid. Monthly regional reflected fluxes are shown on Figure 1 for March 1997. Low fluxes (in purple) are found in cloud-free oceanic areas and in polar zones. Mid-latitude cloud regimes and the Atlantic ITCZ are characterized by fluxes above the global average (green). The highest fluxes (yellow and red) correspond to cloudy areas in South America and China but also to enhanced tropical convection over the western Pacific whereas large parts of Indonesia are cloud free. This unusual observation is the most important feature of our series. It corresponds to the beginning of the 1997-1998 ENSO warm event.



7. REFERENCES

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¹ The instantaneous albedos used for the calculation of the daily average were here derived by using the previous algorithms developed for POLDER (Buriez et al., 1997), not the new algorithms for POLDER-2.

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