Comparison of cloud types observed from SEVIRI and POLDER2

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ABSTRACT/RESUME

A promising way of improving cloud property retrieval, is the combined use of new ensemble of data based on different measurement techniques. As a first step, a comparative study of cloudiness observed by SEVIRI on board Meteosat-8 and POLDER2 (POLarization and Directionality of the Earth's Reflectances) is performed. POLDER-2 cloud products are available only from April to October, 23rd 2003, the end of service of the ADEOS-2 platform. Several days in June 2003 are analyzed. The SEVIRI radiance data and the SAFNWC (Satellite Application Facility in support to NoW Casting) cloud products have been provided by the "Centre de Météorologie Spatiale" in Lannion (France). The SEVIRI cloud type and cloud top pressure products are checked against cloud top pressure and thermodynamic phase retrieved from POLDER. A cloud classification based on a Dynamical Clustering Method (DCM) is applied to SEVIRI data for an other interpretation. Late 2004, PARASOL will be launch in the frame of the A-train. The study engaged between POLDER2 and SEVIRI will then go further.

1. INTRODUCTION

Clouds form an essential component of the radiation balance of the Earth atmosphere. Consequently, a good knowledge of the role of clouds in the global climate system is necessary. Satellites can directly observe not only the spatial and temporal variabilities of clouds but also their effects on Earth's radiation balance at the top of the atmosphere. Such projects as ISCCP (International Satellite Cloud Climatology Project, [1] and ERBE (Earth Radiation Budget Experiment, [2]) have provided essential datasets allowing improving our understanding of the cloud-radiation-climate system. Among the new generation of Earth-orbiting instruments designed for Earth's observation, the SEVIRI radiometer onboard Meteosat-8 provides high quality data with 3 km spatial resolution, 15 mn temporal sampling and 12 narrow spectral bands. On the other hand, the recent POLDER radiometer launched on ADEOS-2 in December 2002 presents the particularity of having multispectral (8 solar spectral bands), multi-polarization and multi-directional (up to 14 different viewing angles) capabilities [3].

The POLDER level 1 products routinely processed by the French Space Centre (CNES) consist of calibrated radiances at 6.2 km resolution. An overview of algorithms and level-2 and -3 products of the "Earth Radiation Budget, water vapor and clouds" line (hereafter "ERB & clouds") is presented in [4] and [5]. Unfortunately, POLDER2 "ERB & clouds" products are only available from April 2003 to October 2003, the end of service of the ADEOS-2 platform. For 20 POLDER2 orbits in June 2003, preliminary output data of the SAFNWC (Satellite Application Facility in support to NoW Casting) cloud algorithm have been provided by the Centre de Météorologie Spatiale (CMS) in Lannion [6]. On the other hand, a cloud classification based on a dynamical clustering method [7] is applied as an alternative method to SEVIRI radiance data provided by the CMS.

Section 2 briefly presents how are derived the various cloud parameters compared in this study : cloud amount and cloud types defined by cloud pressure and cloud thermodynamic phase. As a preliminary step of the comparison of cloud types and cloud properties derived from SEVIRI and POLDER2, cloud amounts are compared in section 3. The analysis of SEVIRI cloud types as function of POLDER cloud phase is discussed in section 4. SEVIRI and POLDER cloud pressures are compared in section 5. Preliminary conclusion and perspectives are presented in section 6.

2. BRIEF DESCRIPTION OF THE CLOUD PROPERTY RETRIEVALS.

2.1 The POLDER cloud property retrievals

The "ERB & clouds" thematic interest takes advantage of the multi-spectral, multi-directional and multi-polarisation capabilities of POLDER to derive useful information on clouds and their effects on short-wave radiation [8]. The first stage of the "ERB & clouds" line is the recognition of cloud-contaminated pixels. This step is crucial since it controls further processing and it has a major impact on the determination of other products.

The cloud amount is determined by applying a cloud detection algorithm to each full-resolution pixel (6.2 km x 6.2 km) and for every viewing direction. The cloud detection scheme consists of threshold tests based on (i) the ratio of 763- and 765-nm channel reflectances, (ii) the reflectance at λ = 865 nm over ocean and λ = 443 nm over land, (iii) the polarized reflectance at 443nm for scattering angles less than 140°, (iv) the polarized radiance at 865 nm and, (v) the ratio of 865- and 443-nm channel reflectances.

If a POLDER pixel fails all of the tests, it is labelled as clear or cloudy depending on the classification of the neighbouring pixels and the spatial variability of the reflectance at 670 nm. Finally, the cloud cover is computed at the super-pixel scale (~ 3 x 3 pixels) and a quality index is defined from concurrent responses to the different tests.

Two different methods were developed to retrieve cloud pressure from ADEOS-POLDER data. The first one is derived from absorption measurements in the oxygen A-band and the second one is derived from spectral polarization measurements.
The derivation of the "Oxygen pressure" P_{oxy} is based on a differential absorption technique using the radiances measured in the POLDER narrowband and wideband channels centred on the oxygen A-band. Reference [9] have shown that P_{oxy} is found to be close to the mean pressure of clouds when compared to ARM/MMCR cloud boundary pressures.
Another retrieved cloud pressure is the so-called "Rayleigh cloud pressure", P_{Ray}, derived from polarization measurements at 443 nm. At this wavelength, the polarized reflectance is mainly related to the atmospheric molecular optical thickness above the observed cloud, at least for scattering angles ranging from 80° to 120° and outside the sunglint direction. That pressure is thus expected to be close to the cloud top pressure.

An improved algorithm for remotely determining the cloud-top thermodynamic phase is applied to the POLDER measurements. The algorithm utilizes near-infrared polarized reflectance over a large range of scattering angles in order to discriminate between ice and liquid water phases. Indeed, theoretical as well as experimental studies have shown that polarized signatures of water droplets and ice particles are quite different.

2.2. The SAFWC SEVIRI cloud type and cloud top pressure retrievals

Presently, the SAFNWC provides cloud mask, cloud type and cloud top temperature/pressure/height maps, by using the multi-spectral capabilities of the SEVIRI radiometer. In the future, cloud top phase maps will be added to the cloud products [10]. The first stage in the SAFNWC cloud product derivation is the separation between cloud free and cloud contaminated pixels. It is based on a series of sequential threshold tests; the process is stopped if one test is successful. The tests that allowed the cloud detection are stored and a quality flag is computed.

The main objective of the cloud type product developed within the SAFNWC context is to provide a detailed cloud analysis to support nowcasting applications.

The cloud top pressure is retrieved from the 10.8 µm brightness temperature for low, medium and thick clouds. For high thin clouds, a correction for semi-transparency is applied using two infrared channels, a window (10.8 µm) and a sounding (13.4 µm, 7.3 µm or 6.2 µm) channel.

2.3. The DCM cloud classification method applied to SEVIRI data

The Dynamical Clustering Method (DCM) [11] developed for METEOSAT cloud field analysis has been adapted taking advantage of the new multi-spectral capabilities of the SEVIRI data. The METEOSAT version of DCM makes use of two spectral parameters, the infrared and visible radiances and, two structural parameters, the local spatial standard deviation of the visible and infrared radiances (computed from 3*3 neighbouring pixels). For SEVIRI application, the detection of cloudy pixels has been improved over land by adding the $R_{0.6}$µm /$R_{0.8}$µm ratio as a supplementary parameter. For discrimination between high and middle/low cloud types, supplementary IR channels (6.2 µm and 12.0 µm) have been used.

2.4 Selected data set

POLDER "ERB & Clouds" products are available for the April to October 2003 period. June 2003 was chosen as key period for the POLDER "ERB & Clouds" product validation. The SAFNWC provided the SEVIRI radiance fields and a preliminary version of its cloud products for several days in June 2003 (11, 12, 21, 23, 25 and, 28). At that time, MSG satellite was not at its nominal position and the SEVIRI calibration was not final.

POLDER "ERB & Clouds" products are available at the 18.5 km x 18.5 km resolution but calculations are performed at the full resolution (6.2 km x 6.2 km). The SAFNWC cloud type and cloud pressure products available at the SEVIRI IR pixel scale (3 km x 3 km at sub-satellite point) have thus been projected on the full resolution POLDER grid (6.2 km x 6.2 km scale). In the same way, SEVIRI radiances and spatial standard deviations have been projected on this POLDER full resolution grid before applying the DCM algorithm.

The temporal sampling of the SEVIRI data set allows any ADEOS-POLDER2 path in the SEVIRI field-of-view be simulated with a time lag of ± 7.5 minutes.

3. CLOUD TYPES AND CLOUD AMOUNT

3.1 SEVIRI cloud type maps

Similar synoptic features appear on SAFNWC and on DCM cloud type maps. Example is given for June 25 on Fig.1. Thirteen cloud type classes are defined in the DCM classification, but only eleven in the SAFNWC cloud type product. In the Fig. 1 colorscale, the labels of common classes are written in black and those of classes only defined in SAFNWC (DCM) are written in red (blue).

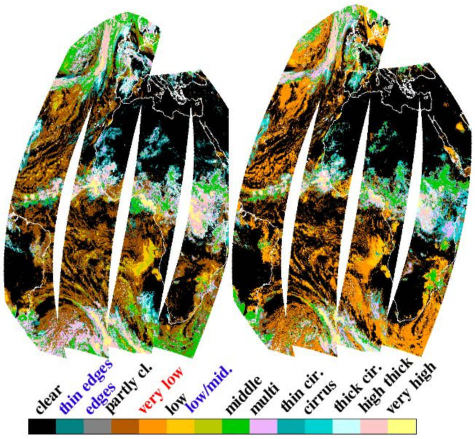

Fig. 1. The SEVIRI cloud types maps for June 25. The DCM map on the left, the SAFNWC map on the right. See text for color scale explaination.

3.2 Comparison of cloud amounts

Cloud amount estimates are derived from the SEVIRI cloud type maps. A cloud cover percentage is fixed for each class: 0% for clear, 25% for cloud edges, 50% for partial cloud cover and thin cirrus, 100% for the remaining classes. These percentages are averaged over 3 by 3 pixels to build maps comparable to the POLDER cloud cover product.

The average cloud amount given by DCM, SAFNWC and POLDER is respectively 81%, 76% and 74% over ocean. Over land, these percentages are 52%, 44% and 51%. In the DCM map (Fig.2-left), the frequency of partly cloudy pixels is high over ocean but the frequency of clear sky is lower than in the POLDER and SAFNWC map. Note that the term "partly cloudy" has not the same meaning for SEVIRI and POLDER at the pixel scale. In the former, it is used for pixels that are expected to be partially covered by clouds. In the later, it corresponds to POLDER pixels that are declared as cloudy in some viewing directions and clear in the others.

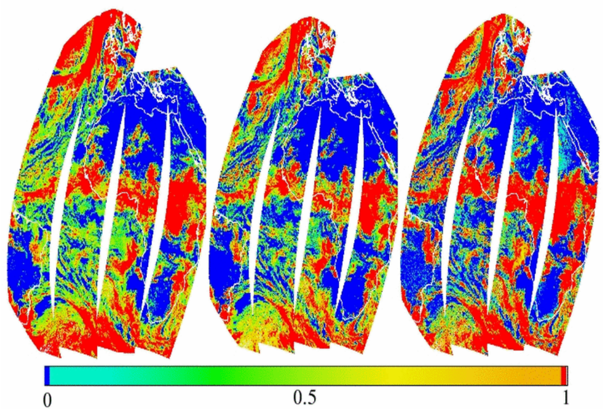

Fig. 2 DCM(left), SAFNWC(center), POLDER(right) cloud amount maps.

The co-occurrence matrix obtained from the pixel-to-pixel comparison of the POLDER and SEVIRI SAFNWC cloud amount maps is reported on Table 1. Over ocean (land), 76% (74%) of the pixels belong to the same class. Only 0.2% (1.1%) of the pixels belong to opposite classes. Close percentages are obtained by comparing POLDER to SEVIRI DCM (instead of SAFNWC). The agreement between the two SEVIRI cloud amount maps reaches 83% (82%). Pixels classified in opposite classes are almost absent (under 0.1%).

Table 1 Comparison of the SAFNWC and POLDER cloud amounts over ocean (land).

SEVIRI	POLDER		
SAFNWC	Clear	Partly	Overcast
Clear	20.6%(45.4)	3.6%(9.6%)	0.1%(1.0%)
Partly	5.4%(3.6%)	35.5%(14.2)	12.1%(10.3)
Overcast	0.1%(0.1%)	2.6%(1.4%)	20.1%(14.4)

4. SEVIRI CLOUD TYPE AND POLDER CLOUD PHASE

POLDER cloudy superpixels are classified in four cloud phase classes: liquid, ice, mixed and undetermined. A visual comparison of SAFNWC cloud type and POLDER cloud phase maps for June 25 (Fig. 3) shows a rather satisfactory agreement.
To quantify this level of agreement we report the SAFNWC cloud type distribution inside the POLDER cloud phase classes (Fig. 4). Using the POLDER phase quality index, the liquid and ice classes are split into five

classes : liquid and ice with a good quality index, liquid and ice with a poor quality index, and mixed phase. The reported cloud type is the more frequent SAFNWC cloud type inside the POLDER superpixel. Only the POLDER overcast superpixels are considered (respectively 41 % and 48 % of the cloudy superpixels over ocean and land).

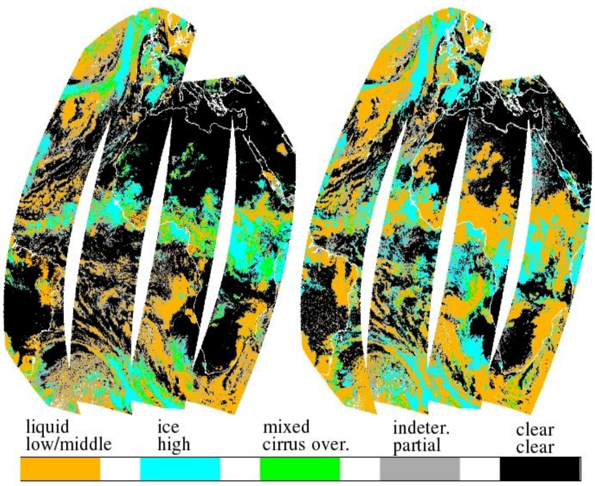

Fig. 3 SAFNWC cloud type (left) and POLDER cloud phase (right) maps.

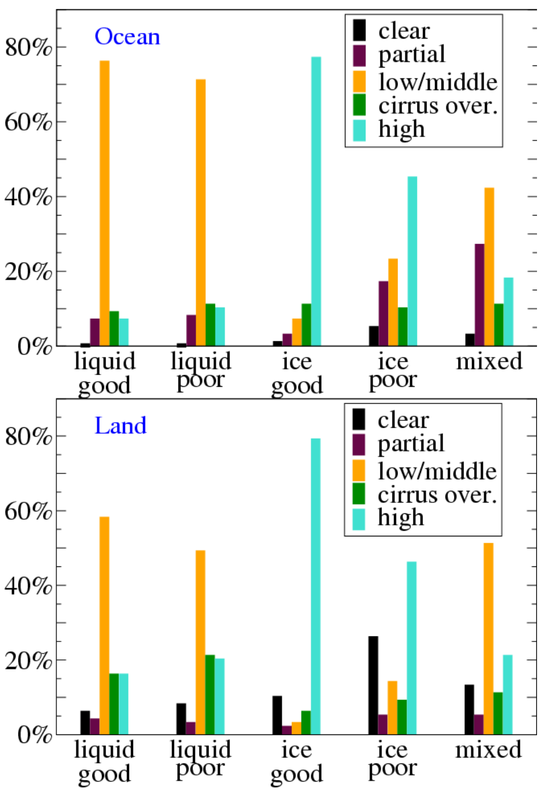

Fig. 4 SAFNWC cloud type distribution for each POLDER cloud phase

80 % of POLDER ice clouds are 'high clouds' or 'high clouds above other clouds' in the SAFNWC cloud classification. The POLDER liquid water clouds are 'low clouds' or 'middle clouds' in 76 % (59 %) of the cases over ocean (land). From the distribution of POLDER cloud phase classes inside each SAFNWC cloud type (not shown), we infer that almost 90 % of SAFNWC low-middle clouds correspond to POLDER liquid phase. SAFNWC high clouds correspond to POLDER ice phase in 70 % (53 %) of the cases over ocean (land). This low percentage of ice phase, particularly over land, can be explained in part because thin ice clouds overlapping thick liquid water clouds are generally classified as liquid by the POLDER algorithm. When selecting only high clouds, the percentage of ice phase reaches respectively 90 % (80 %) over ocean (land). Similar results are obtained from the DCM cloud type and POLDER cloud phase comparison.

5. SAFNWC CLOUD PRESSURE, POLDER CLOUD PRESSURES AND PHASE

The three cloud pressure maps, SAFNWC cloud top pressure, POLDER Rayleigh cloud top pressure, and POLDER Oxygen cloud middle pressure (Fig. 5) are in agreement with what is expected. The main characteristics of the two cloud top pressure maps are coherent with that found in the analysis of the cloud type and cloud phase maps: high clouds in the ITCZ, low clouds in the subsidence regions over ocean, etc.... As expected, the POLDER oxygen cloud middle pressure is overall higher than the cloud top pressures.

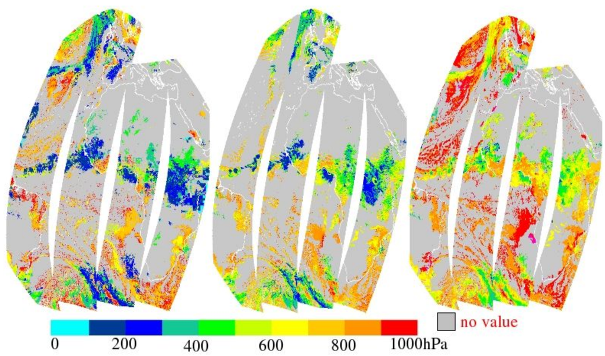

Fig. 5 SAFNWC (left) and Rayleigh (center) cloud top pressure and Oxygen cloud middle (right).

The distribution of the three cloud pressures is reported in Fig. 6 for water liquid and for ice clouds over ocean. The average pressure values are reported in Table 2.

For liquid water clouds over ocean (land), the mean difference between POLDER Rayleigh and SAFNWC cloud top pressure is 15 (-10) hPa and the root mean square difference (RMSD) is 145 (180) hPa. For ice clouds, the mean difference is 55 (50) hPa and the RMSD 140 (165) hPa. Graphs (not shown) of the SAFNWC and POLDER Rayleigh pressure differences show that in the upper part of the atmosphere (under

300hPa), the SAFNWC pressure is generally weaker than the POLDER Rayleigh pressure. Lower in the atmosphere (above 700 hPa) the POLDER Rayleigh pressure is often lower than the SAFNWC one over land. That is not observed over ocean.

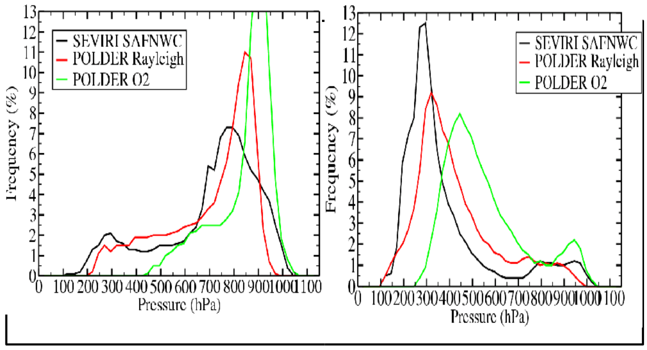

Fig 6. Cloud pressure distributions over ocean for liquid clouds (left) and for ice clouds (right).

Table 2 Average pressures in function of POLDER cloud phase.

	Pr. SAF	Pr. Rayleigh	Pr. Oxygen
Liquid	680hPa(557hPa)	695hPa(547hPa)	830hPa(714hPa)
Ice	362hPa(330hPa)	418hPa(378hPa)	542hpa(532hpa)

6. CONCLUSION AND PERSPECTIVES

First comparisons of POLDER and SEVIRI cloud products have been performed. Results are presented at the POLDER "ERB & clouds" product resolution (18.5 km x 18.5 km).

In general, POLDER, SAFNWC and DCM cloud amount are in good agreement. Only one percent of the cases are in total discrepancy (clear instead of overcast). However, DCM classification finds more partial clouds over ocean and SAFNWC algorithm finds less clouds (by 7-8%) over land than the two others methods.

The cloud phase derived from POLDER polarization measurements corresponds generally to that expected from the SAFNWC and DCM cloud types: over ocean (land) almost 90 % (90%) of homogeneous low/middle cloud scenes are liquid water clouds and 90 % (80 %) of homogeneous high cloud scenes (excluding the 'high above other clouds' class) are ice clouds.

The SAFNWC cloud top pressure is on average smaller than the POLDER Rayleigh cloud top pressure in the upper part of the atmosphere. The opposite tendency is observed in the lower part of the atmosphere over land.

As a part of the A-train satellite constellation, PARASOL will be launched in December 2004. First PARASOL-POLDER data will be available in January 2005. More comparisons including the operational SEVIRI cloud products will be performed.

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