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# Global distribution of cloud top phase from POLDER/ADEOS I.

J. Riedi, M. Doutriaux-Boucher, P. Goloub

Laboratoire d'Optique Atmosphérique, Université des Sciences et Technologies de Lille, France

P. Couvert

Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur-Yvette, France

**Abstract.** The eight months of data acquired by the POLDER instrument have now been processed. This dataset provides daily information on the global distribution of cloud top phase. We present here the results of a statistical analysis of ice and liquid phase occurrence frequencies at the global scale. Temporal variation of these frequencies above land and ocean are analyzed. These results are compared with ISCCP data and the consistency of the POLDER phase product is demonstrated.

## Introduction

Clouds are well known to be crucial modulators of the Earth radiation budget. Their properties (cloud cover, optical thickness, altitude, *phase*, water vapor, microphysical properties) and their variations in space and time, need to be understood if we aim to predict climate change. The POLDER (POLarization and Directionality of the Earth Reflectances) instrument has proven capabilities in deriving key information needed to improve our knowledge of cloud, radiation and climate interactions. Particularly, the potential of polarization measurements of the upward shortwave radiation to derive cloud information has been demonstrated by both airborne and spaceborne data analysis [*Bréon and Goloub*, 1998]. From November 1996 to the end of June 1997, the satellite version of POLDER provided polarization measurements at the global scale. Thanks to its large field of view, a same location on the surface can be viewed from up to 14 directions. Cloud observations over a large range of scattering angles make possible the distinction between spherical and non spherical particles, in other words, between liquid and ice phase. At first, we will briefly discuss the principle of the cloud phase detection algorithm, and describe the POLDER phase product used in our studies. In a second part, we will expose the results of these analyses, which provide information on zonal and seasonal variation of cloud top phase. POLDER data are then compared with ISCCP data from the D1 dataset. In a last part, the results will be discussed and the quality of POLDER phase product investigated.

## Method

Considering a cloudy system observed from satellite, the polarized component of the upward radiance is mainly formed in the upper cloud layer. Around 80% of the single scattered radiation reflected from the cloud layer arises from the top 100 m of the layer. Calculations have shown that the polarized component, Lp, is saturated for cloud optical depth greater than 2.0. The important quantity for determining cloud phase is the polarized radiance Lp, that is less sensitive than the total radiance[1] L to multiple scattering effects. Thus, the polarization features, which correspond to *single scattering*, are preserved in Lp.

According to both theory and observations [*Chepfer et al.*, 1998], [*Goloub et al.*, 1999], the polarization features of clouds depend strongly on the particle shape. Within the range of scattering angles that can be observed by POLDER, clouds composed of liquid spherical particles, present a strong maximum about 140° from the incoming direction (primary rainbow). Also, a zero of polarization (neutral point) around 90°, and supernumary bows for angles greater than 145°, make possible the distinction with ice crystals clouds, which show an essentially positive polarization, decreasing as the scattering angle increases (Figure 1). Discrimination between ice crystals and liquid water droplets is made using these differences. In this way, the cloud top phase detection may be considered as a cloud particles shape detection, even if cirrus clouds are unlikely to be composed of spherical ice crystals. A complete description of the algorithm principle has been given by [*Parol et al.*, 1999] and [*Goloub et al., (submitted to J. Geophys. Res., )* 1999].

The data used in our present studies are the level 2 POLDER phase product, at the resolution of about 60km x 60km which corresponds to a zone of 9x9 full resolution POLDER pixels. All frequencies are calculated using cloudy pixels for which phase has been retrieved successfully. This criteria rejects 14% of the cloudy pixels. Pixels with mixed phase (14%) have also been rejected from the analysis. At this resolution level, they correspond to pixels containing separate ice and liquid clouds, and are not representative of multilayered clouds nor mixed phase single cloud. Hence, the sum of liquid and ice occurrence frequencies is always equal to 1. The next section presents the analysis of eight months of POLDER phase data.

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[1] Also, the polarization degree, defined as the ratio of Lp over L, is subject to multiple scattering effects since it depends on L.

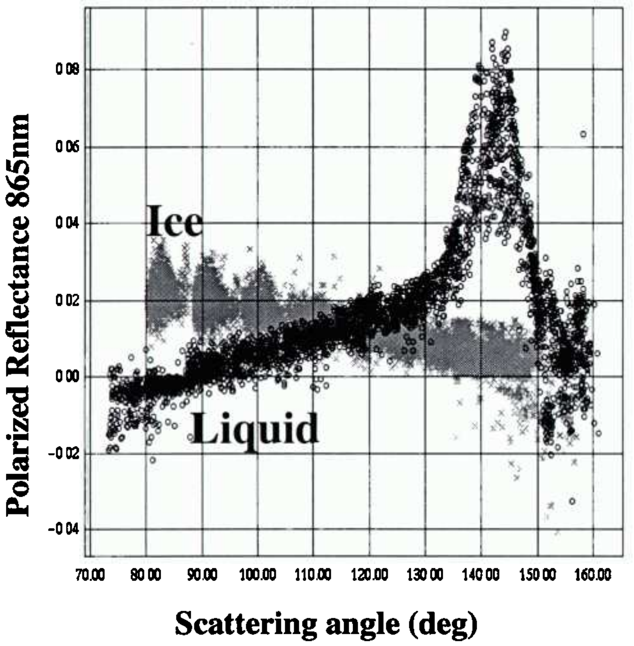

**Figure 1.** Polarized reflectances observed by POLDER over liquid (black) and ice (grey) clouds at 865 nm.

## Occurrence frequencies of liquid and ice phase

Only results for ice clouds are presented in this paper. They will be compared with ISCCP high clouds amounts in the next section. The comparisons are limited to the ± 60°latitude zone, due to difficulties in cloud detection over snow covered surfaces, using visible/near infrared radiometers. Figure 2 shows the occurrence frequencies of ice clouds obtained for the period of November 1996 to June 1997. As expected, the maximum occurrence of ice phase corresponds to the InterTropical Convergence Zone and its variation along the equator. Two minima occur in the tropics at ± 20°latitudes. The maximum of occurrence in the Northern hemisphere appears in February and the minimum during June, respectively associated with boreal winter and summer. Also, June is marked by a maximum of occurrence of ice phase in the Southern hemisphere.

**Table 1.** Frequency of occurrence (in %) of liquid and ice phase at global scale, over land, ocean, and both.

| | Liquid | | | Ice | | |
|---|---|---|---|---|---|---|
| | Land | Ocean | Both | Land | Ocean | Both |
| Nov | 60 | 75 | 71 | 40 | 25 | 29 |
| Dec | 59 | 75 | 71 | 41 | 25 | 29 |
| Jan | 60 | 76 | 72 | 40 | 24 | 28 |
| Feb | 61 | 73 | 70 | 39 | 27 | 30 |
| Mar | 55 | 74 | 69 | 45 | 26 | 31 |
| Apr | 57 | 72 | 68 | 43 | 28 | 32 |
| May | 64 | 73 | 70 | 36 | 27 | 30 |
| Jun | 68 | 72 | 71 | 32 | 28 | 29 |

Table 1 summarizes the results of statistics over land and ocean separately. We can observe that the distribution between ice and liquid clouds is rather constant at global scale, with about 30% of ice clouds versus 70% of liquid clouds. But if we look at repartition over land and ocean separately, we observe some differences between land and ocean, and also between the different months. At first, it should be noted that the ice phase is much more frequent over land than over ocean. It is also interesting to observe that liquid and ice phase frequencies of occurrence vary much more over land than over ocean (13% over land, against only 4% over ocean). This could be explained by the fact that ocean have a larger thermal capacity and that deep convection is easier to achieve over land. These variations are amplified in the Northern hemisphere over land, by the large variations of the atmosphere temperature, between local summer and winter.

ISCCP data matching the POLDER operational period are not available at present time. Thus, we have considered the ISCCP-D1 dataset ([*Rossow et al.*, 1996]) from April 1990 to March 1991 which have been analyzed and documented by [*M. Doutriaux-Boucher and G. Sèze*, 1998].

ISCCP high clouds are classified as clouds with associated pressure lower than 440 hPa. In fact, cloud thermodynamic phase is much more governed by temperature than pressure level. Temperature differences as important as 30K may be found at a given pressure level for different latitudes ranging from 60°N to 60°S. As an example, a temperature of 240 K can be found in June at a pressure level of 410hPa at 50°N, but one have to go down to 310 hPa to observe the same

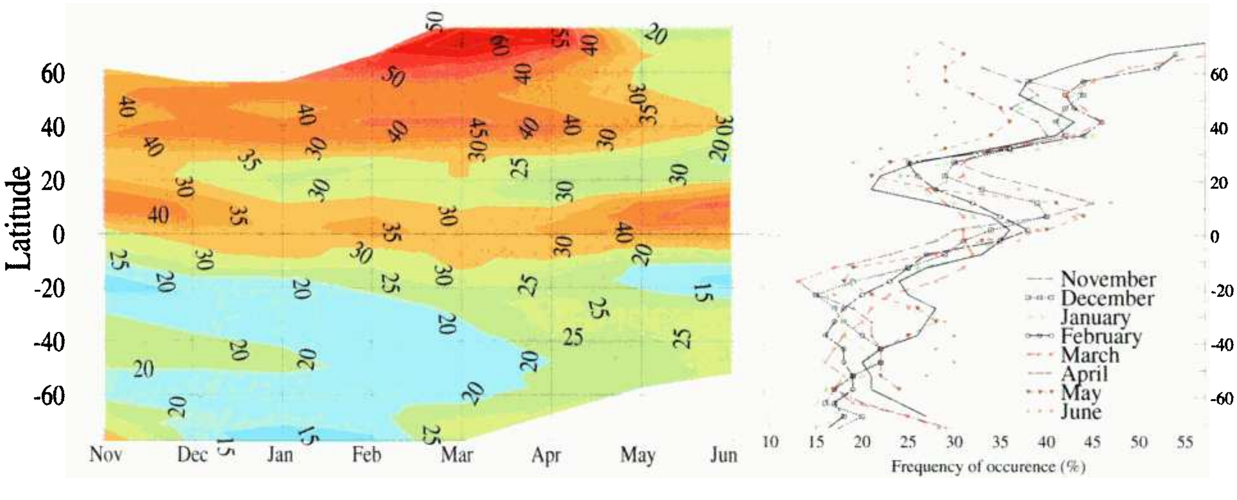

**Figure 2.** Seasonal variation of ice clouds occurrence frequencies during the POLDER operational period.

temperature at the equator. Frequencies of occurrence for clouds above 310hPa and 440hPa, have been derived from ISCCP dataset. In order to select ISCCP high clouds which were colder than 240K (threshold recognized by [*Hutchison et al.*, 1997]), we have used temperature profiles provided with the POLDER dataset. For each latitude Lx, the pressure Px associated to 240K can be retrieved (see Figure 3). Then, the occurrence frequency Fx of "cold" clouds is derived from the occurrence frequencies of the two classes of ISCCP high clouds($F_{310}$,$F_{440}$), and the previously obtained pressure, using a linear interpolation.

Figure 4 shows the comparisons of POLDER ice clouds with ISCCP "cold" clouds frequency of occurrence as a function of latitude. Clouds detection problems over snow covered surfaces appear clearly in the POLDER results poleward of 60°N for April and May. Very high frequencies occur in this region during winter season, and the frequency falls down suddenly between April and May. In fact this period corresponds to a rapid decrease of snow covered surfaces.

Despite the different periods considered in our studies for POLDER and ISCCP data, the general features are the same for the two datasets. Maxima and minima of occurrence appear at the same location except for December and February, for which the maxima along the equator are shifted. POLDER underestimates frequencies of occurrence in the Southern Hemisphere, particularly between 40°S and the Equator, whereas it tends to overestimate them in the Northern Hemisphere. Once again, the differences occur on the magnitude of the features, but not on the global latitudinal variations. May and June show a rather good agreement however.

Four hypotheses may be advanced to account for these differences between the two datasets. The first reason which could explain these results is that we, unfortunately, have not considered simultaneous ISCCP and POLDER data. This analysis would have to be done again, as the ISCCP data are made available.

The second one, is the different spatial resolution of instruments used to acquire data. According to [*Wylie*, 1998], both the sensitivity of the sensor and the size of its field of view, have an impact on the cloud amount retrieved using spaceborne radiometers. The bigger the FOV of the sensor is, the larger the total retrieved cloud amount. This is an advantage of the POLDER instrument upon ISCCP, but the spatial resolution of the sensor has also an impact on the detection of small or thin clouds. The POLDER sensor resolution is about 6 km against 2 km for the visible channels of radiometers used to produce the ISCCP cloud products. Preliminary comparisons performed against synoptic weather reports have shown that the relatively low resolution of POLDER level 2 products, reduces by 10% the occurrence of ice clouds when compared with cloud phase analysis done at full resolution.

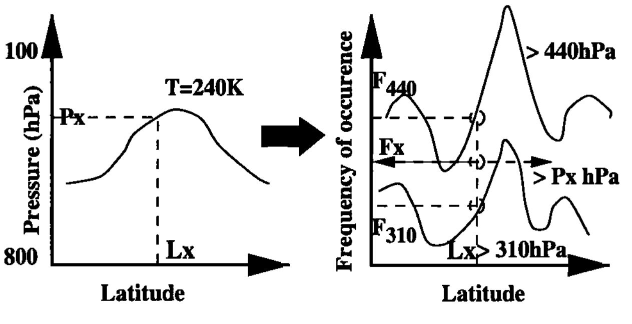

**Figure 3.** Schematic principle of the method used to select ISCCP "cold" clouds.

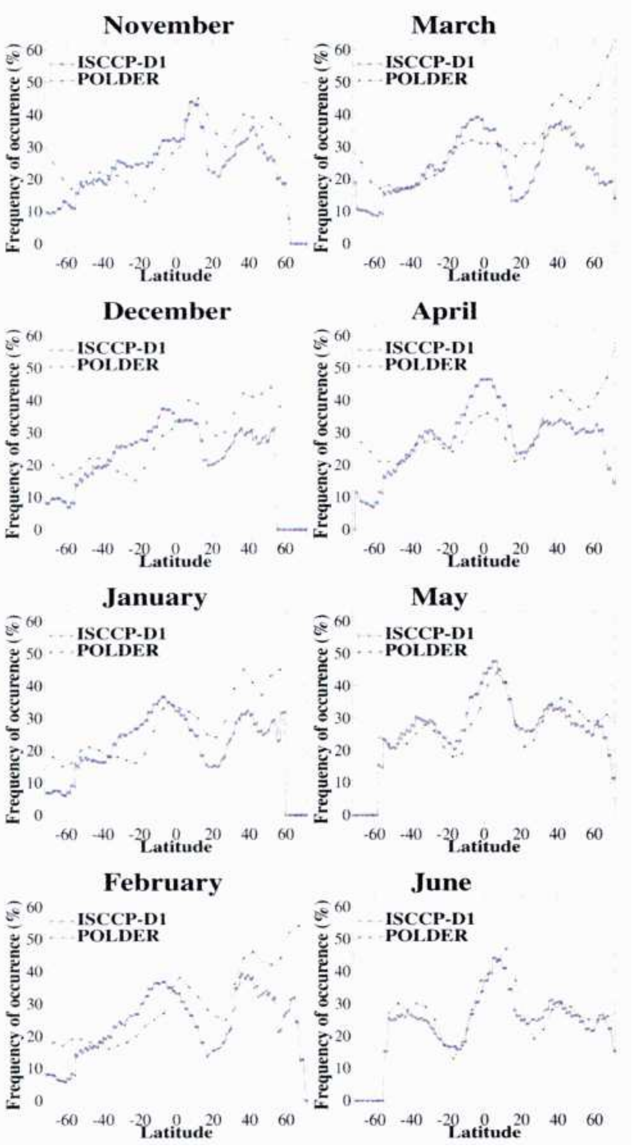

**Figure 4.** Comparison between ISCCP "cold" clouds fraction (relative to total clouds fraction) and POLDER ice phase frequency of occurrence.

Concerning the detection of thin cirrus, ISCCP has the advantage of using thermal infrared channels which are more sensitive to that particular type of clouds than visible/near-infrared channels used by POLDER. This could account for the higher occurrence frequencies found by ISCCP in some region.

The last point to consider is the method used for producing the two datasets. ISCCP cloud analysis uses both visible and infrared radiances in order to derive cloud pressure, optical thickness, temperature and cloud types. Our selection of "cold" clouds relies on pressure level and cloud temperature criteria which do not ensure that we are looking at ice clouds only. POLDER cloud analysis is conducted, basically using only visible/near infrared radiances, but the phase retrieval algorithm is based on polarization measurements. This method does not require any assumption about cloud temperature or pressure, and lead to informations about microphysical properties of the cloud which is thought to be more reliable for cloud thermodynamic phase analysis.

## Conclusions

Cloud phase derived from near-infrared photopolarimetric measurements is a very innovating result. Comparison with ISCCP-D1 dataset shows the global consistency of POLDER phase product, whenever the frequencies of occurrence are not always of same magnitude, very probably due to cloud detection weaknesses of POLDER [*Parol et al.*, 1999]. The analysis of the POLDER phase product is also conducted using comparison against synoptic weather reports, radar and lidar measurements. At the same time, POLDER level 1 data are reanalyzed to produce a phase index at full resolution. Finally, this results will be used to improve and define new algorithms for cloud analysis, for the future instrument POLDER on ADEOS II, which will be launched on the end of year 2000.

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## References

Bréon, F.M., and P. Goloub, Cloud droplet effective radius from spaceborne polarization measurements, *Geophys. Res. Lett., 25,* 1879-1882, 1998.

Chepfer, H., G. Brogniez, and Y. Fouquart, Cirrus clouds microphysical properties deduced from POLDER observations, *J. of Quant. Spectr. and Rad. Transfer, 30,* 375-390, 1998.

Doutriaux-Boucher, M., and G. Sèze, Significant changes between the ISCCP C and D cloud climatologies, *Geophys. Res. Lett., 25,* 4193-4196, 1998.

Goloub, P., J. Riedi, M. Doutriaux-Boucher, and P. Couvert, Cloud Thermodynamical Phase from POLDER/ADEOS. Preliminary results, *In Proceedings of the ALPS99 International Conference, WK2-O-04,* 1999.

Hutchison, K. D., B. J. Etherton, P. C. Topping, and H. L. Huang, Cloud top phase determination from the fusion of signatures in daytime AVHRR imagery and HIRS data, /it Int. J. Remote Sensing, 18, 3245-3262, 1997.

Parol, F., J. C. Buriez, C. Vanbauce, P. Couvert, G. Sèze, P. Goloub, and S. Cheinet, First results of the POLDER "Earth Radiation Budget and Clouds" operational algorithm. *IEEE/Tran. Geosc. Rem. Sens.*, 1999.

Rossow, W. B., A. W. Walker, D. E. Beuschel, and M. D. Roiter, International Satellite Cloud Climatology Project (ISCCP), World Climate Research Programme (ISCU and WMO), *Tech. Doc. WMO/TD 737,* 115 pp., World Meteorol. Org., Geneva, Switzerland, [Available from ISCCP Global Proceessing Center, NASA GISS, 2880 Broadway, New York, NY 10025], 1996.

Wylie, D. P., Cirrus and Weather: A satellite perspective, *in Cirrus, OSA Technical Diggest (Optical Society of America, Washington DC, 1998),* 66-69, 1998.

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M. Doutriaux-Boucher, P. Goloub, and J. Riedi, Laboratoire d'Optique Atmosphérique, Université des Sciences et Technologies de Lille, 59655 Villeneuve d'Ascq Cedex. France,
Phone: (33) 03 20 43 47 66, Fax: (33) 03 20 43 43 42, (e-mail: riedi@loaser.univ-lille1.fr; mdoutri@loaser.univ-lille1.fr; goloub@loaser.univ-lille1.fr)

P. Couvert, Laboratoire des Sciences du Climat et de l'Environnement, C.E.A, 91191 Gif-sur-Yvette. France (e-mail: couvert@lsce.saclay.cea.fr)

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