Titre :	**POLDER SCIENTIFIC OVERVIEW**
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The regular increase in greenhouse gases due to anthropogenic emissions in the atmosphere may have a major impact on the Earth's climate in the forthcoming decades. In order to reduce the uncertainties in forecasting climatic changes, it is necessary to better understand the processes involved in interactions between aerosols, clouds, radiation and atmospheric circulation. Such interactions are poorly represented by current numerical models and there is a need to quantify their role in phenomena involved in the evolution of the climate system.
Carbon dioxide uptake by the Upper ocean and continental biosphere also constitutes a large element of uncertainty in climate models. Space borne sensors will play a key role in climate research by providing global, long term observations of parameters describing the state of the atmosphere and Earth surfaces.

POLDER acquired data will be processed in order to:

- determine the physical and optical properties of aerosols so as to classify them and study their variability and cycle,
- improve the climatological description of certain physical, optical and radiative properties of clouds,
- precisely determine the influence of aerosols and clouds on the Earth's radiation budget,
- quantify the role of photosynthesis from the continental biosphere and oceans in the global carbon cycle.

1. Aerosols

Aerosols are liquid or solid particles of between 10^{-3} and 10 microns. They have various origins and are of different types. The major classes of aerosol are :

- stratospheric aerosols of sulfuric acid, mainly from volcanic eruptions,
- tropospheric marine aerosols from the oceans,
- desert aerosols of dust from desert or semi-desert areas,
- anthropogenic aerosols from urban pollution or fires,
- aerosols issued from chemical transformations.

An important topic in the Global Change program is the study of the biogeochemical cycle of tropospheric aerosols, and specifically the generation of aerosols from the surface, their uplift and transport as well as their interaction with other cycles.
Although minor constituents of the atmosphere, aerosols have both a direct and indirect impact on climate:

- direct through the diffusion and absorption of solar radiation, leading to a cooling effect,
- indirect, through their interaction with clouds.

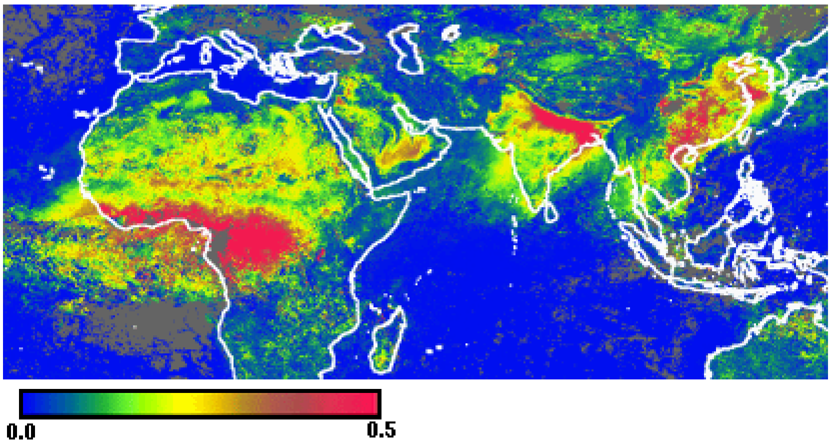
Aerosols act as condensation nuclei and affect the microphysical properties of clouds, which in turn drive the Earth's radiation budget (clouds formed in this way would reflect more solar radiation). The effect of aerosols might therefore counterbalance global warming due to greenhouse gases.

The extremely variable nature of their physical and chemical properties, together with their distribution over time and space, make the study of aerosols quite complex.

Furthermore, aerosols also affect satellite-based remote sensing of the Earth in the visible domain. An improved characterization of their optical properties is a key issue in improving the quality of products based on data from future space borne imaging instruments.
POLDER's original capabilities are such that new approaches may be proposed for the global mapping of aerosols (at a resolution of 20x20 km) above oceans and land.

The ocean is almost "black" in the near infrared and its contribution is quite constant at 565 nm wavelength (away from the glitter). The aerosol over ocean inversion scheme is based on the spectral dependence in the 565-865 nm range and on the directional information of the radiance and polarized radiance. The outputs are the Aerosols Optical Thickness and the bimodal aerosol size distribution. The coarse mode of aerosols is a mixture of spherical and non-spherical particles.

It is much more complicated to obtain the optical properties of aerosols over land, as their contribution to the top of the atmosphere signal is at most of the same order as the surface contribution. However, the contribution of aerosols outweighs any others in polarized light. The operational algorithm over land, therefore, only uses polarized channels at 443, 670 and 865 nm. Smallest particles (anthropogenic aerosols) can be detected.



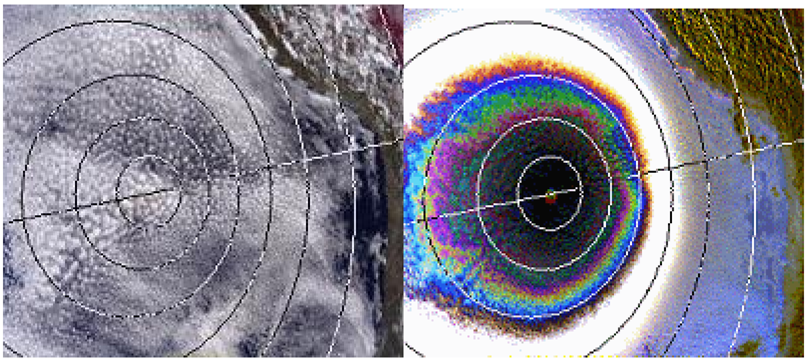
Aerosol index from POLDER 1 - December 1996 (Source: LOA)

2. Earth, radiation budget, water vapor & clouds

2.1. CLOUDS

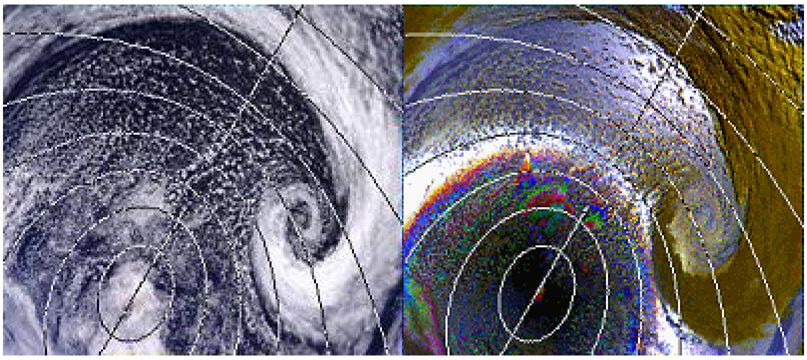
The models used to predict potential climate changes related to the increase in greenhouse gases and anthropogenic aerosols require a realistic description of global cloudiness and its associated properties. Polarized and bidirectional reflectance from the clouds are analyzed to improve the characterization of both their macro-physical properties (three-dimensional structure, validity of the plane-parallel hypothesis) and their microphysical properties (phase - water or ice - particle shape and size).
The POLDER derived cloud properties, such as cloudiness, cloud phase, cloud optical thickness, cloud pressure (computed with two different methods) intend to contribute to a better cloud climatology on a global scale.

Composite of total reflectance at 443, 670 and 865 nm | **Composite of polarized reflectance at 443, 670 and 865 nm**

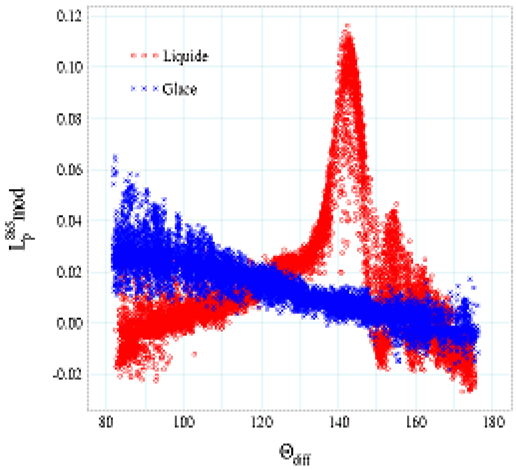


Stratocumulus banks off the Chile coast (1996 Nov. 12). On the polarized image, the iridescence inside the bright arch (140° scattering angle) may be used for high precision determination of cloud droplets size (source: LSCE).

Composite of total reflectance at 443, 670 and 865 nm **Composite of polarized reflectance at 443, 670 and 865 nm**



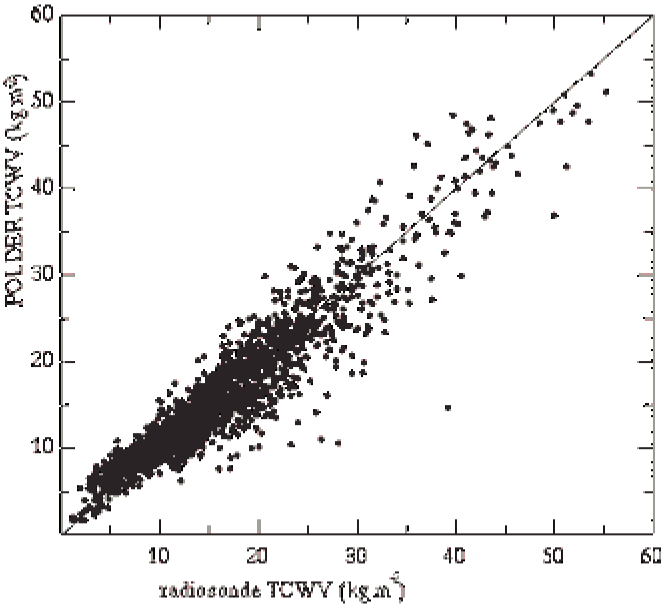
Depression over south Indian Ocean (1996 Nov. 28). High level icy cloud (right) masks the high polarization arch due to underlaying low level broken clouds (source: LSCE).



Modified polarized radiances observed by POLDER as a function of scattering angle. Polarization signatures of liquid (red) and ice (blue) clouds display significantly different features that allow for simple and direct cloud thermodynamic phase discrimination (source: LOA).

2.2. WATER VAPOR

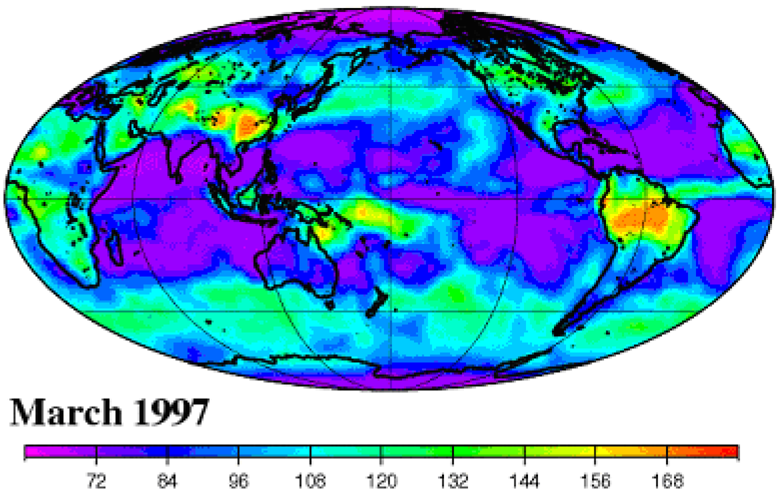
Atmospheric water vapor is a variable that fluctuates greatly over time and space. It is a vector of the energy exchanges at the surface/atmosphere interface and in the atmosphere by the liberation of latent heat. POLDER is able to estimate the integrated water vapor content in clear sky conditions, either above continents or oceans in glitter conditions, by means of differential absorption techniques using the 910 nm and 865 nm channels. These evaluations, with an expected accuracy of around 10 %, complement the existing measurements, especially over land, which suffers from sparse sounding sampling and the physical limitations of microwave and infrared techniques.



Comparison of TCWV (Total Column water Vapor) from ADEOS 1-POLDER measurements and TCWV from radio-sonde measurements for November 1996 and June 1997. The root mean square difference is 2.8 kg m^{-2} (source: LOA).

2.3. EARTH RADIATION BUDGET

The anisotropy of the radiation measured from space, together with diurnal variability and the calibration accuracy of the sensors, is one of the major sources of uncertainty in the determination of the Earth Radiation Budget. The conversion of the measured radiances into fluxes assumes a priori knowledge of the angular behavior.
POLDER performs near-simultaneous multidirectional measurements and consequently aids to the estimation of TOA (top of the atmosphere) shortwave reflected fluxes.



Shortwave flux density (Wm^{-2}) derived from ADEOS-1 POLDER observations for March 1997 (source: LMD)

3. Land surfaces

The global, systematic observation of land surfaces and continental biosphere characteristics is crucial to determine what fraction of carbon dioxide is absorbed by the vegetation. This is needed to analyze ecosystem response to climatic fluctuations and to derive the parameters of surface/atmosphere exchanges.

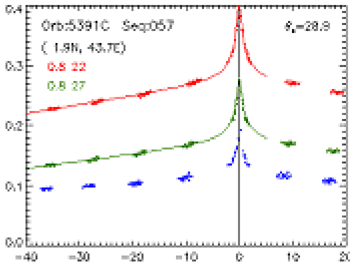
It is possible to determine vegetation cover indicators from the multispectral data acquired by the optical imaging sensors. The annual and inter-annual variation of these indicators may then be analyzed. It is also possible to derive parameters which describe vegetation cover (such as leaf area index) and primary production through statistical relationships.

Nevertheless, two major problems have to be overcome when using measurements from space :

- atmospheric effects (mainly due to aerosols), for which no global method of correction is currently available,
- surface directional effects, not usually taken into account in vegetation index computations.

POLDER, whose spectral channels are well suited to land surface observation, also has measurement specificities that should lead to some improvement with respect to the abovementioned problems.

Since the atmospheric molecules and aerosols polarize the scattered radiation, whereas the surface does not, the polarized reflectance measured by POLDER is essentially an atmospheric contribution. It is then possible to fit an aerosol model to the observations, derive the atmospheric optical thickness and thus satisfactorily correct for the atmospheric effect.



Hot-Spot directional signature measured from the POLDER instrument at 443 (blue), 670 (green) and 865 (red) nanometers. The reflectance is shown as a function of the phase angle, that is the angle between the sun and view directions. See details in Bréon et al., 2002, J. Geophys. Res., 107, 4282.

POLDER's multidirectional measurements may also be used to fit a directional model to the surface signature and derive a reflectance corrected for directional effects and normalized to a standard viewing geometry as well as a precise albedo, which is a crucial parameter in determining the radiation budget. Once normalized, the surface spectral signature may be used to derive various vegetation indices.

The bidirectional surface reflectance measurements constitute a specific signature that it should be possible to relate to certain structural parameters for vegetation cover (particularly the vegetation's interception and absorption of radiation), which should improve the quality of the surface cover classification on a global scale.

4. Ocean color

Free-floating photosynthetic organisms (phytoplankton), dissolved organic matter and sediments affect the spectral signature of the light reflected by the upper ocean by increasing absorption and scattering. "Ocean color" takes into account the spectral variations of light scattered by the sea surface upper-layer, and thus varies from deep blue in pure waters to dark green in phytoplankton-rich waters and "milky" green in sediment-rich waters.

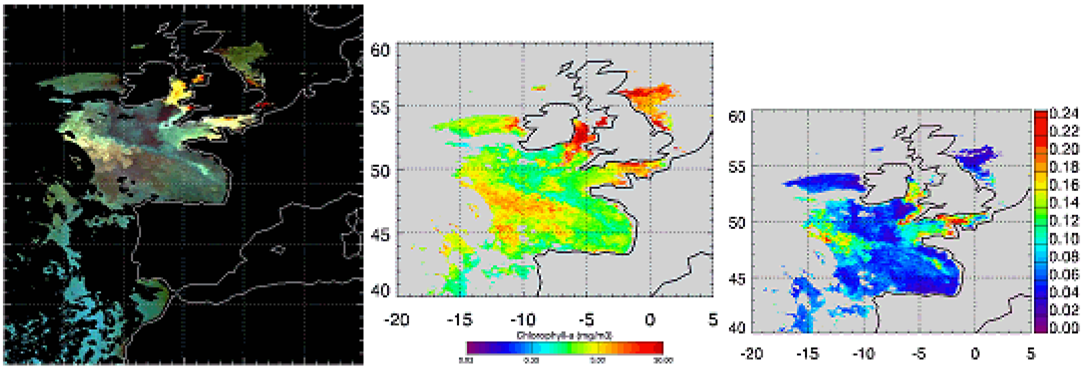
In the open ocean, where phytoplankton and associated biogenous materials are the prevailing components, the chlorophyll-a pigment concentration (Chl) is the index usually adopted to specify the bio-optical state of the water body. This pigment, which is contained in all photosynthesis-organisms, presents relatively strong and weak absorption in the blue and green part of the spectrum, respectively. This spectral property allows the retrieval of Chl from observation of ocean color.

By observing ocean color from space (IOCCG), the chlorophyll pigment concentration may be estimated and its spatial and temporal variability may be studied on both regional and global scales. This information is crucial to the understanding of marine ecosystems and the evaluation of energy fluxes affecting the food chains.

Phytoplankton also plays a geochemical role as a "biological CO_2 pump" due to its ability to take up atmospheric carbon dioxide through organic matter photosynthesis. International programs such as IGBP and JGOFS have emphasized the key role of oceans in the global carbon cycle. In order to quantify and model this process, satellite remote sensing pigment maps have to be translated into "primary production" maps (carbon uptake by surface or volume and time unit) via models.

Moreover, phytoplankton affects the heating rate of the upper ocean layers and consequently the oxygen and CO_2 fluxes at the ocean/atmosphere interface. In addition, because phytoplankton behaves like a passive tracer in certain cases, remote sensing of ocean color can be used to depict dynamic ocean features like eddies or the meanders of currents such as the Gulf Stream.

Besides Chl, the absorption, a, and the backscattering, b_b, coefficients are essential for satellite ocean color data applications, as b_b determines the amplitude of the remote sensed reflectance, and a modifies its spectral shape. These coefficients provide new additional biogeochemical information (a may be used to discriminate different phytoplankton species, and b_b is a proxy of the suspended particulate matter). Moreover, while the chlorophyll data as detected from space are now currently used to constraint models of oceanic carbon cycle, new generation of biological models now integrate explicitly two or more species of plankton, as well as dissolved and particulate organic carbon. The evaluation of such models by new (compared to Chl) bio-geophysical derived-satellite data is crucial as pointed out by members of IGBP & SCOR.



Pseudo-true color image (marine reflectance at 443, 490, and 565 nm), chlorophyll concentration and the backscattering to absorption ratio, b_b/a, as seen by POLDER the 10th of April 1997 (orbit 6508). b_b and a represent the backscattering by particles at 565 nm and the absorption by particles and dissolved matter at 443 nm, respectively. This ratio, whose patterns differ from the Chl ones, allows to distinguish different types of particles.

POLDER has the conventional capabilities of an imaging sensor for monitoring ocean color: a wide field of view, enabling global, repetitive observations, a resolution suited to the Open Ocean, and channels with well suited spectral and radiometric properties.

Furthermore, POLDER's original multidirectional and polarization capabilities will allow to:

- systematically avoid perturbations due to glitter.
- improve corrections for atmospheric effects (scattering by atmospheric molecules and aerosols) and other perturbations (such as reflection by foam). As the ocean contribution is generally less than 10% of the signal measured by the sensor, the accuracy of these corrections largely determines the accuracy of marine reflectance retrieved. The multidirectional and polarized measurements will lead to a better "pixel by pixel" understanding of the nature of atmospheric aerosols, which are highly variable over space and time.
- potentially distinguish between mineral particles and phytoplankton.

Source :
http://polder-mission.cnes.fr/
https://parasol.cnes.fr/