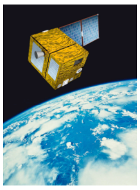
POLARIZATION &
ANISOTROPY of
REFLECTANCES for
ATMOSPHERIC
SCIENCES coupled with
OBSERVATIONS from a
LIDAR



PARASOL and the A-TRAIN

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CENTRE NATIONAL D'ETUDES SPATIALES

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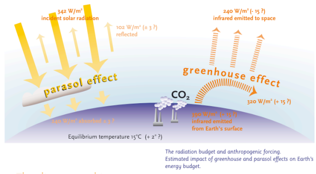
This poster is based on the PARASOL print press pack available at http://smsc.cnes.fr/PARASOL/

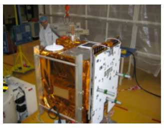
SCIENTIFIC GOALS

Greenhouse gases were long considered the only object worthy of study by scientists researching global warming. That was until work to model and measure the radiation budget, in particular at the LMD dynamic meteorology research laboratory in France, showed that natural or manmade aerosols play a crucial role in shaping climate. Indeed, according to the French science academy they could even be "the largest source of uncertainty in climate forcing calculations." The Parasol mission, decided in 1999, aims to measure polarization and directionality of reflectances, especially in regions covered by the lidar on the Calipso minisatellite. Solar radiation becomes polarized when scattered by certain particles like aerosols, water droplets or ice crystals. Parasol will measure light polarized in different directions to gain a more precise characterization of clouds and aerosols than can be obtained by more traditional methods that measure their spectral signature. Data collected by Parasol will allow us to establish the quantity and size distribution of aerosols over ocean regions, as well as their turbidity index over land surfaces, and to evaluate radiative forcing from solar radiation. They will also help to detect clouds, determine their thermodynamic phase and altitude, and estimate reflected solar flux. The integrated water vapour content will also be estimated.

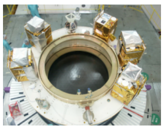


The radiation budget and anthropogenic forcing. Estimated impact of greenhouse and parasol effects on Earth's energy budget.

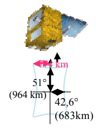
PARASOL LAUNCH

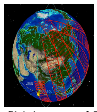


Parasol has been launched on December 18th as an auxiliary passenger on an Ariane 5G+ flight that will also be carrying Helios 2A, the first satellite in France's second-generation military surveillance system, the four Essaim microsatellites built around the Myriade bus, and a Spanish nanosatellite. Mounted on the ASAP5 platform (Ariane Structure for Auxiliary Payload) with its five co-passengers, it will be the last to separate from the launcher into a near-circular orbit at an altitude of 705 kilometres. CNES will be required to position six satellites—the Helios2A military satellite, to be positioned with respect to its predecessor Helios 1B; Parasol in the A-train; and the Essaim formation—almost simultaneously in an unprecedented, ultraprecise orbital dance choreographed by operations teams. CNES's Operational Orbit Determination Centre (CCO) will determine the orbit of each satellite using data from its network of 2-GHz tracking stations, the Prioranet network, and from Chinese stations for Parasol. The close sequence of positioning operations calls for special care to avoid radiofrequency signal interference and the risk of the satellites colliding.



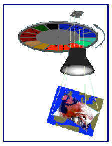
Ariane 5's fairing opens to insert Helios 2A and Parasol into orbit.





Global coverage: 2 Days / Cycle: 16 days

PARASOL INSTRUMENT BUILT ON POLDER HERITAGE



- **Two-dimensional CCD detector array:CCD : 242 * 274 pixels**
- **9 spectral bands (443, 490, 565, 670, 763, 765, 865, 910, 1020 nm), 3 are polarized (490, 670, 865 nm)**
- **Up to 14 ≠ viewing angles per pixel for a single satellite pass**
- **Pixel at nadir : 5.3km x 6.2 km (705km)**
- **POLDER was aboard the Japanese ADEOS-1 platform from August 1996 to June 1997 and ADEOS-2 from April to October 2003.**
- **Life Time: 2 years**

443	**20 nm**	Radiance	Cloud detection Drop of ocean color applications
490P	**20 nm**	polarization	Aerosol retrieval Cloud pressure
565	**20 nm**	Radiance	Lidar @ 532 nm
670P	**20 nm**	polarization	Aerosol retrieval Cloud properties
865P	**40 nm**	polarization	Aerosol retrieval Cloud properties
763	**10 nm**	Radiance	Cloud oxygen pressure by Differential absorption
765	**40 nm**	Radiance	in Oxygen A band
910	**20 nm**	Radiance	Water vapor retrieval
1020	**20 nm**	Radiance	Lidar @ 1064nm Aerosol retrieval

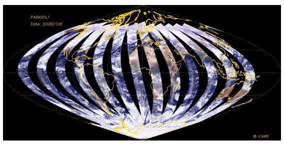
After the loss of the POLDER instruments on the Japanese satellites ADEOS I in June 1997 and ADEOS II in October 2003, Parasol offers a new opportunity for the climate change research community. The likenesses between the two instruments are undeniable, since the Parasol payload is based to a large extent on the POLDER instrument, which was designed by the LOA atmospheric optics laboratory (CNRS-USTL, Lille). However, its scientific objectives diverge somewhat from POLDER, since its main purpose is to acquire atmospheric measurements, although it can also observe ocean colour and vegetation. The Parasol payload consists of a digital camerawith a 274x242-pixel CCD detector array, wide-field telecentric optics and a rotating filter wheel enabling measurements at different wavelengths and in several polarization directions. Because it acquires a sequence of images every 20 seconds, the instrument can view ground targets from different angles. Compared to POLDER, the telecentric optics array has been turned 90 degrees to favour multidirectional viewing over daily global coverage. Likewise, a 1020-nm waveband has been added to conduct observations for comparison with data acquired by the lidar on Calipso, one of its companion satellites. Parasol also relies on the innovative techniques developed to calibrate the POLDER instruments, using in particular the Sun's reflection from the ocean surface, clouds and desert areas as targets to validate in-flight performance.

SCIENTIFIC PRODUCTS

PARASOL STANDART PRODUCTS:

The **level 1 product** shall account for 14 viewing directions per pixel.

- Calibrated radiances and polarized radiances in the 9 channels
- Browse product will be provided.
- A **track product** consisting of extractions of the full swath level 1 product over the CALIPSO-CENA/CloudSAT track (±10 pixels) shall also be provided.



PARASOL STANDART PRODUCTS:

Level 2 and level 3 products consist in (resolution ~20Kmx20km):

-Aerosols over ocean:
- Total aerosol optical depth
- Ratio of the Aerosol optical thicknesses of the accumulation and coarse modes
- Angström exponent
- Effective radius of the size distribution

-Aerosol over land:
- Aerosol optical thickness of the accumulation mode
- Angström exponent of the accumulation mode

-Cloud and ERB product
- Cloud Cover
- Cloud Optical Thickness
- Cloud Phase
- Cloud Top pressure (2 methods)
- Short-wave albedo.

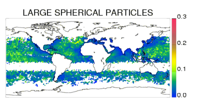
- Water vapor content

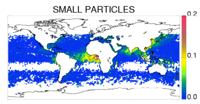
PARASOL RESEARCH PRODUCTS:

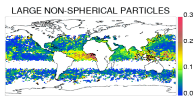
-Cloud product
- Ice cloud microphysics index (shape/size)

-Aerosols over ocean
- Aerosol refractive index of the accumulation mode
- Phase function (corrected for surface and multiple scattering contributions)
- Polarized Phase function (corrected for surface and multiple scattering contributions)

-Aerosols over land
- Polarized Phase function (corrected for surface and multiple scattering contributions)

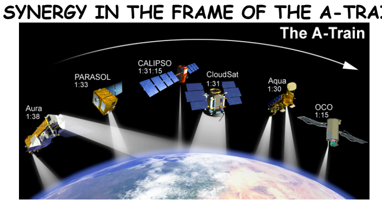






Example of aerosol products that will be derived from PARASOLThis example is derived from POLDER measurements in December 1996 and represents the maps of the monthly mean aerosol optical thicknesses of the 3 aerosol components.

SYNERGY IN THE FRAME OF THE A-TRAIN



The Parasol mission intends to characterize the radiative properties of clouds and aerosols by exploiting its complementarity with the other instruments in the A-Train formation, which include the CERES and MODIS radiometers on the Aqua satellite, the lidar on Calipso and the radar on CloudSat. The French-U.S. A-Train observatory is a world first. Until now, passive instruments measuring solar radiation reflected by the Earth's surface have operated independently. And the use of active lidar and radar instruments to measure clouds and aerosols is relatively recent. The A-Train will offer a unique opportunity to obtain reflectance data from Aqua in regions observed by Calipso and CloudSat across a very wide spectrum, combined with data on the polarization of reflected light from Parasol. The six satellites will cross the equator one at a time, a few minutes apart, at around 1.30 pm local time, hence the nickname "afternoon constellation". However, the A-Train's railway metaphor is not strictly accurate, as the satellites do not follow each other in single file like carriages or trucks. Rather, each one flies, collects data and carries out its mission independently of the other five.

AEROSOLS

√ high confidence level
√ low confidence level

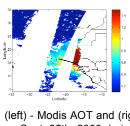
	MODIS	CALIPSO-CENA	PARASOL
• Refractive index			√ (ocean)
• Aerosol Size Distribution	√ (ocean, Angstrom)	√ (land/ocean)	√ (ocean, Angstrom*)
• Non sphericity		√ (land/ocean)	√ (ocean)
• Optical thickness	√ (land/ocean)	√ (land/ocean)	√ (land*/ocean)
• Phase function	√ (recomputed)		√ (ocean), √ (recomputed)
• Single scattering albedo	?	?	?
• Vertical distribution		√ (land/ocean)	

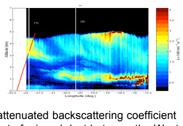
CLOUDS

		Resolution	Cloud Cover	Cloud Phase	Coud Optical Depth	Cloud Height	Ice cloud micro-physics (size/shape)	SW albedo	Water Vapor Content (Clear-sky)
PARASOL		20 km	X	X	X	X	X	X	X
MODIS		1-5 km	X	X	X	X	X		X
CERES		20 km						X	
CALIPSO-CENA	Lidar	TBD	X	X	(X)	X	X		
	IIR	1 km				X	X		
CLOUDSAT		1km			X	X	X		
AMSR-E		12 km 21km			X				X
SEVIRI/MSG		5 km	X	(X)	X	X			X
GERB/MSG		50 km						X	
ISCCP		30 km	X	(X)	X	X			

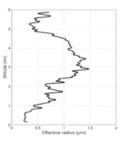
Aerosol remote sensing from Active and Passive

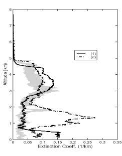
Retrieval of aerosol profiles of extinction (total and fine mode) from a synergy between CALIPSO lidar and PARASOL or MODIS has been tested during several field campaigns involving an airborne backscattering lidar, MODIS/TERRA, and Airborne POLDER. The following figures show an example of the retrieval of the aerosol vertical profile during a Saharan dust outbreak out of the African coast (the Saharan Dust Experiment, Sept. 2000, Léon et al., 2003).





(left) - Modis AOT and (right)- lidar attenuated backscattering coefficient on Sept. 25th, 2000 during a transport of mineral dust between the West African coast and the Cape Verde Islands

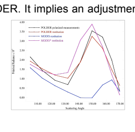




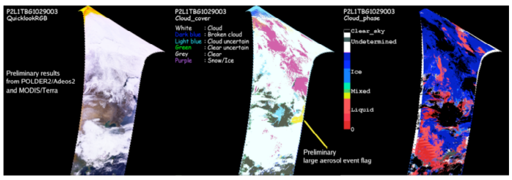
Average vertical profile of aerosol effective radius(left) on Sept. 25th, 2001 as retrieved by the proposed algorithm between Cape Verde and Dakar (Sénégal). Comparison (right) between (shaded area) in situ measured extinction coefficient obtained from C-130 and (solid and dashed line) lidar-retrieved extinction coefficient on 25 September close to locations (1) and (2).

PARASOL and MODIS synergy

Thanks to the POLDER-2 mission (April-October 2003) and MODIS aboard TERRA, it has been possible to test different approaches for coupled algorithms that will be apply to PARASOL-AQUA. The following figures show how the aerosol refractive index can be determined using polarization measurements. The MODIS* retrieval fits the polarized radiance measured by POLDER. It implies an adjustment on the refractive index (Gérard et al., 2005)



	POLDER	MODIS	MODIS*
_0.87	0,100	0,132	0,135
0.87-0.67	0,283	0,198	0,072
$c_{0.87}$ small	15,1 %	18,6 %	7,4 %
$c_{0.87}$ large S	84,9 %	81,4 %	92,6 %
$c_{0.87}$ large NS	0 %	-	0 %
r_{eff} small	0,22 _m	0,25 _m	0,22 _m
r_{eff} large S	3,29 _m	1,97 _m	3,29 _m
m_{small} (VIS)	1,35-0,0i	1,40-0,002i	1,35-0,0i
$m_{large\ S}$ (VIS)	1,35-0,0i	1,45-0,0035i	1,33-0,0i



A processing line is being developed at LOA to allow cloud retrievals from combination of POLDER and MODIS data. The processing software is able to ingest and relocate all L1B POLDER and MODIS type data on a common reference grid. It also provides all necessary ancillary data (METEO, surface albedo map, etc...) to perform cloud properties retrievals within the science packages.
The images above present preliminary results of the cloud detection and cloud thermodynamic phase retrieved from a combination of information selected from POLDER and MODIS "best of" capabilities (spatial resolution, spectral coverage, multiangle and polarization measurements). This approach is currently being further developed at LOA to better characterize cloud macrophysics (cloud top altitude, multilayer index, spatial variance), radiative heterogeneity, cloud particle size and cloud albedo. After preliminary investigations, the processing line will be implemented at the ICARE thematic center for production run and systematic processing of PARASOL/MODIS-Aqua data.

References :
- Data : POLDER2/ADEOS2 (CNES/NASDA) and MODIS/TERRA (NASA)
- Development/Processing : J. Riedi, C. Oudard and JM. Nicolas (LOA 2005)
- Image production : HDFLook Project (L. Gonzalez - C. Deroo)

DATA AVAILABLE AT :
PARASOL-POLDER products distribution center http://polder.cnes.fr/
ICARE Data Center http://www-icare.univ-lille1.fr