Assessment of Refractive Index and Microphysical Parameters of Spherical Aerosols from Data of Dual-Polarization Polar Nephelometer

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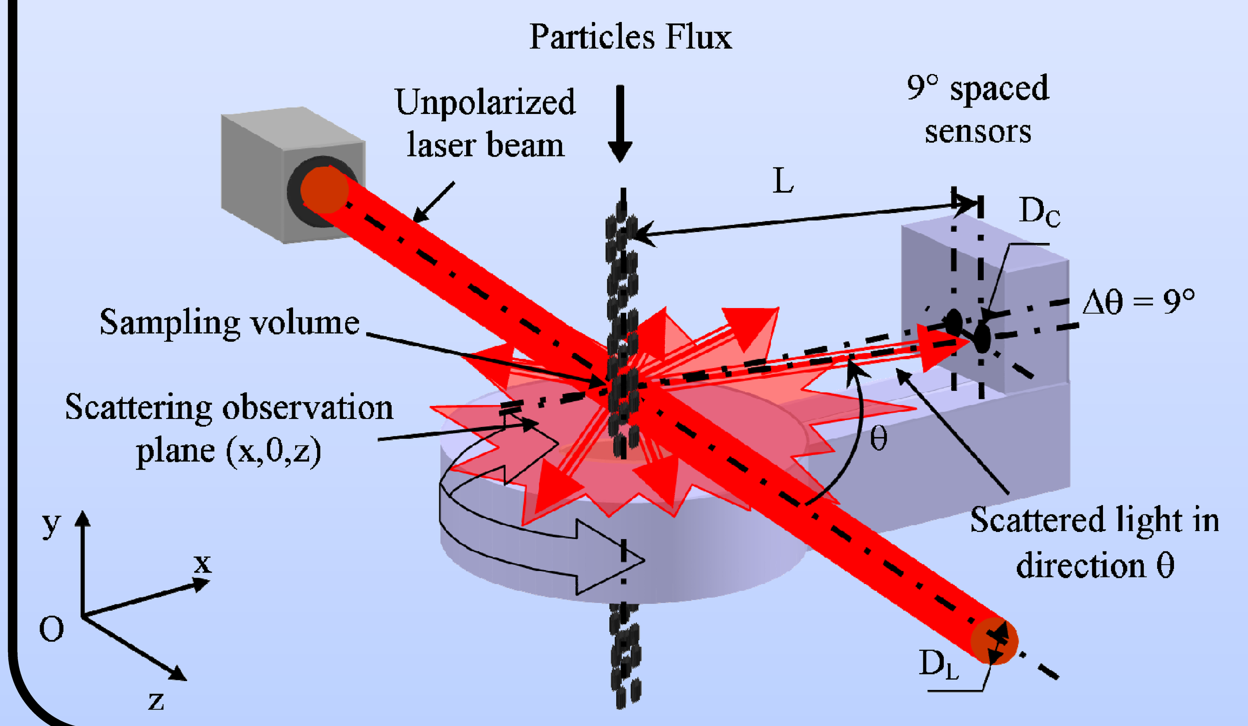
Abstract

The knowledge of both the size distribution and the composition (refractive index) of atmospheric particles is important for the understanding of the radiative balance of the Earth and the cloud life cycle. These parameters modify the phase function and the polarization characteristics of the scattered light. The laboratory nephelometer (designed by LaMP) makes possible to characterize the optical properties of a population of aerosols. It was performed sensitivity tests of dual-polarization polar nephelometer (D2PN) data to optical and microphysical parameters of population of spherical aerosol particles. Measurement errors were modeled as Gaussian random variables with zero mean and a standard deviation of 10%. It is shown that data of the D2PN enable to retrieve microphysical parameters along with the assessment of the refractive index.

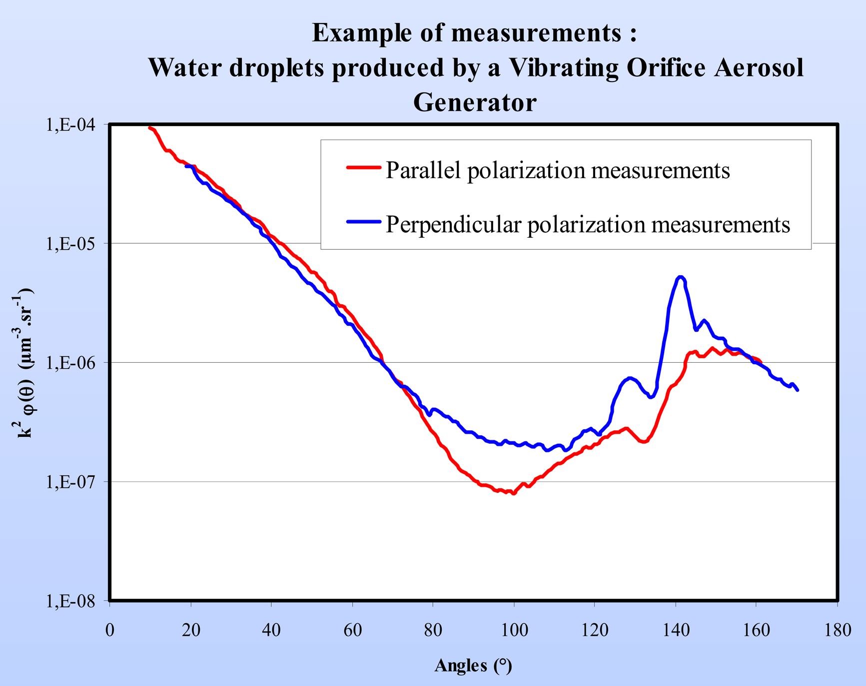
Introduction

Aerosols can affect weather and climate and have complex properties. Depending upon their shapes, sizes and composition they can reflect sunlight back to space and cool the atmosphere, they can also absorb sunlight and warm the atmosphere. The long term objective of the D2PN designed at LaMP is to develop a database (like the light scattering facility in Amsterdam) of optical and microphysical characteristics of aerosols and to test inverse codes against it. The aim of this work is to present results of sensitivity tests of D2PN data to optical and microphysical parameters of populations of spherical aerosol particles.

Dual-Polarization Polar Nephelometer (D2PN)



From an unpolarized laser beam (800 nm wavelength—1 W), the instrument measures the direct scattered energy (without mirror) in two perpendicular directions of the polarization. The scattered light is measured for light power ranging from 10pW to 3μW and with an angular resolution of 1° from 10° to 169°. The curves are quasi-continuous as function of angle according to the two directions of polarization, so degree of polarization is also measured. The accuracy of the measurements is estimated to better than 5%.



Sensitivity tests

Sensitivity tests were performed for the case of populations of spherical aerosol particles. Special attention was paid to the sensitivity of the data of the D2PN to simultaneous variations of the refractive index and microphysical parameters. In the following, the results are analyzed in terms of root mean squared relative errors:

$$RMS = \frac{1}{n}\sqrt{\sum_{i=1}^{n}\frac{\left(\varphi_i(m)-\varphi_{i,meas}\right)^2}{\varphi_{i,meas}^2}}$$

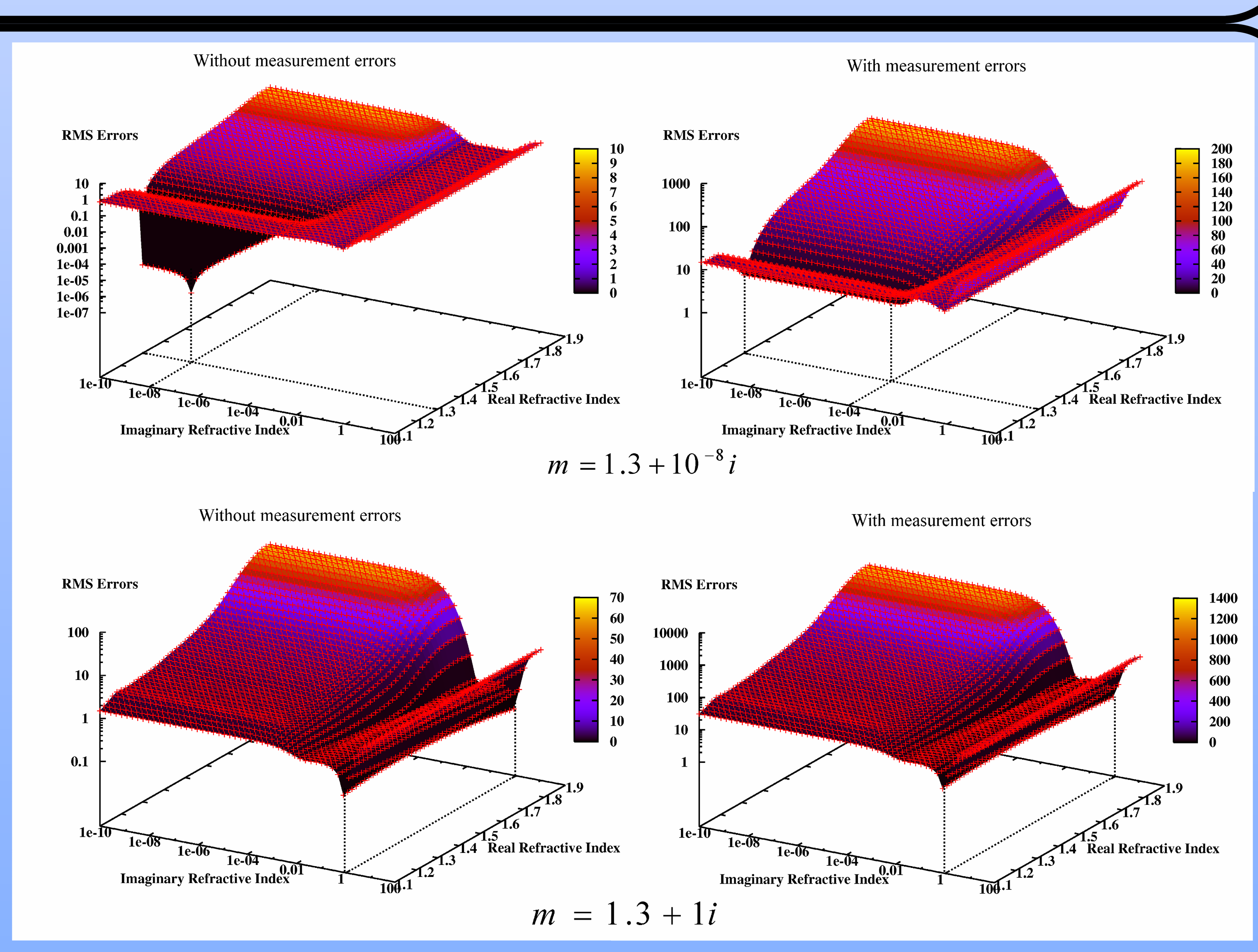
where n is the number of angles, φ is the phase function and m complex refractive index, φ_{meas} corresponds to a synthetic measurement, φ(m) is the phase function for the variable refractive index .

When measurement errors were considered, they were modeled as Gaussian random variables ε with zero mean and a standard deviation of 0.1, i.e., of 10%:

$$\varphi_{meas} = \varphi_{comp}(1+\varepsilon)$$

The RMS values were computed as the average over 20 realizations.

Size distributions of particles were modeled by a monomodal lognormal function.



The D2PN is able to retrieve the complex refractive index, and, at the same time, the size distribution. Measurement errors reduce the ability to estimate the actual value of the refractive index. The example with non absorbing particles shows that with measurement noise, a range of imaginary part of the refractive index can be derived instead of the discrete value found in the case without noise. Whereas with strong absorbing particles, noise don't change the value of imaginary part, real part cannot be retrieve.

Table 1 resume for other case of refractive index.

m = n + χ i		χ ≤ 10^{-4}	10^{-4} ≤ χ ≤ 5.10^{-3}	5.10^{-3} ≤ χ ≤ 5.10^{-1}	5.10^{-1} ≤ χ
Without noise	n	Exact value	1.xxx ± 0.01	1.xx ± 0.05	Impossible
	χ	Exact value	x.x 10^x ± 10 %	x.x 10^x ± 10 %	x.x 10^x ± 10 %
With noise	n	1.xxx ± 0.005	1.xxx ± 0.01	1.xx ± 0.05	Impossible
	χ	χ ≤ 10^{-4}	x.x 10^x ± 10 %	x.x 10^x ± 10 %	x.x 10^x ± 10 %

Table 1. Possible value and uncertainty function χ imaginary part of refractive index and noise. Values do not change with n real part.

Conclusion and discussions

- The size distribution and the complex refractive index can be determined by D2PN measurements.
- In the case when the absorption of particles is very high, the data of the D2PN are not sensitive to the real part of the refractive index. The imaginary part can be retrieved with good accuracy.
- Measurement errors substantially reduce the sensitivity to the imaginary part in the case of non absorbing particles.
- This nephelometer can also characterize optical properties of non spherical particles.

References

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