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The optical properties of aerosols

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by
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The topics investigated under the present Contract can be summarized as follows:
1. Analysis by nondestructive means of the degree of cleanliness of a metallic or dielectric surface.
2. Determination of the contribution to the greenhouse effect from the ice crystal that are present in the high atmosphere (namely in cirrus clouds).
3. Discrimination of the shape and backscattering properties of atmospheric ice crystals in the millimeter wave range.
The results of the above mentioned investigations were exponded in several papers that were already published or are at present in the press. The list of these papers is reported at the end of the present report.

1. Analysis by nondestructive means of the degree of cleanliness of a dielectric surface.
The problem of the determination of the degree of cleanliness of a plane surface is known to be of importance both in basic reasearch and in technological applications. The preparation of clean substrates and the check of their cleanliness is, in fact a critical factor in several experiments as the presence of unwanted particles may influence both the electrical and optical properties of the substrate. It is therefore not surprising that the literature report many studies, both theoretical and axperimental on this subject.
Our contribution to the field is in a sense final because we were able to solve in a quite general way the problem of the determination of the optical properties of both isotropic and anisotropic particles deposited on a dielectric substrate. We stress that unlike the previous studies the method devised by our group does not require any approximation and in particular that the particles be small in comparison to the wavelenght. As a consequence our calculation show a distinctive feature that is missed by the approximate methods. We refer to the fact that, as required by the boundary conditions, a non vanishing field is allowed to propagate along the surface. This feature is present only in the methods that are based on a finite element integration of the Maxwell equations. Nevertheless we stress that the method that we devised requires only a fraction ot he CPU time requested by the finite element methods. In any case, the presence of the surface field allows for the determination of the anisotropy of the particles deposited on the substrate by grazing rays observations.
Our method is based on the expansion of the electromagnetic field in terms of spherical multipole fields and on a general reflection rule for spherical multipole fields that our group devised a few years ago. As a result we were able to get

the field scatterd by the particles on the surface as well as a general expression for the transition matrix of a particle in the presence of the surface. Of course the definition of the transition matrix allows, when necessary, for the calculation of the orientational averages over the distribution of the particles with little computational effort. The specific results and techniques are described in full detatil in the papers listed at the end of the present report.

2. Contribution to the greenhouse effect from the atmospheric ice crystals.
It is today widely accepted that the atmospheric ice crystals that are one of the components of the cirrus clouds may give a noticeable contribution to the greenhouse effect. Due to the presence of the atmosphere and of its water vapor content, the actual amount of this contribution is not easily determined by experimental measurements, because turbulence and selective absorption heavily influence the interpretation of the observative data. To this it shoud be added that the ice crystals occur in several highly anisotropic shapes with overall sizes that go from 0.5 micrometers to a few millimeters. The theoretical evaluation of the backscattering from atmospheric ice crystals in the infrared as a function of their orientational distribution may be therefore of help in the interpretation of the observative data. In this respect we stress that, in spite of all the studies on the subject, a reliable orientational distribution function for the orientation of the atmospheric ice crystal has not been determined up today. In fact, the observative data and the laboratory experiments suggest that, even in calm air, the orientational distribution function may depend on the size of the crystals.
With this in mind our investigation was, preliminarly directed to the study of the possible orientational distribution functions that are more likely to occur, and in the determination of general formulas that give the dependence of the backscatterd intensity on the orientational distribution. The, these formulas were applied to the study of the backscattered intensity from the ice crystals shaped as hexagonal platelets in the wavelenght range from 10 to 100 micrometers. As a byproduct be also obtained the depolarization ratio that is known to be of paramount importance for a reliable interpretation of the observative data. Although our calculations were actually restricted to crystals with an overall size of 15 micrometers, we got strong indication that for whatever choice of the orientational distribution, there is a strong backscattering at about 18 micrometrs. The exact amount of the backscattered intensity depends on the orientational distribution and thus ultimately on the air turbulence. Comparison of our results with those form the equal volume sphere, show that in some instances substitution of the actual crystals with such equivalent sphere may be not to bad an approximation in some wavelenght ranges. In particular, in the resonance region, that in the present case occurs at about 8 micrometrs, comparison with the results from the equivalent sphere suggest that the resonance peaks may be safely ignored because the underlieing curve turns out to be quite regular, so that it is to be expected that the main features of the backscattering spectrum are not appreciably affected in actual observations.

F. Borghese, P. Denti, M. A. Iatì and R. Saija, " Backscattering from model atmo spheric ice crystals," in Nucl. and Cond. Matter Phys. A. Messina, ed. (AIP, New York, 2000)

I cannot conclude this report without noticing that the experience that we gained in studying the properties of atmosphereic ice crystals can be used to get information on seamingly different systems. I refer to biological particles that can be found in the atmosphere as a result of industrial processes or of natural processes of oxydation of plants and algae. In view of the importance of these systems for the general ecology of wide regions of Earth, we are at present performing a preliminary study of this kind of particles, in collaboration with the Institute of Marine Biology of the University of Messina.