SCATTERING CHARACTERISTICS OF HOMOGENEOUS AND INHOMOGENEOUS PARTICLES: AEROSOL SCATTERING IN THE IR

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Results are presented of Mie calculations which were run to determine the scattering, absorption and extinction coefficients and phase matrix for spherical aerosol particles in the infrared assuming a $r^{-4.5}$ size distribution. The aerosol particles considered in the Mie calculations were water droplets, sea-salt particles, water soluble, dust particles, and ammonium sulphate particles. The infrared wavelengths used in the Mie calculations varied from 2.5 to 40 microns.
<table>
<thead>
<tr>
<th>KEY WORDS</th>
<th>LINK A</th>
<th>LINK B</th>
<th>LINK C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ROLE</td>
<td>WT</td>
<td>ROLE</td>
</tr>
<tr>
<td>Aerosol Scattering</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerosol Absorption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mie Theory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Droplets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea-Salt Particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-Soluble Particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust Particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Sulphate Particles</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PREFACE

This report is Supplement No. 2 to the Final Report (Part I) under Contract No. F19628-73-C-0130. This report presents the results of computations of cross sections and angular scattering data for homogeneous and inhomogeneous particles using Mie theory. Macroscopic scattering data for different types of aerosol particles in the infrared assuming a \( r^{-4.5} \) size distribution are also given in the form of tabulated data.

Supplement No. 1 to Part I of the Final Report gives the results of Mie calculations for single particles as well as macroscopic scattering data for different aerosol size distributions in the visible and near IR.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFACE</td>
<td>i</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>iv</td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>3</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Optical Parameters for Water Droplets</td>
<td>4</td>
</tr>
<tr>
<td>II.</td>
<td>Optical Parameters for Sea-Salt Particles</td>
<td>5</td>
</tr>
<tr>
<td>III.</td>
<td>Optical Parameters for Water Solubles, Sample M</td>
<td>6</td>
</tr>
<tr>
<td>IV.</td>
<td>Optical Parameters for Water Solubles, Sample B1</td>
<td>7</td>
</tr>
<tr>
<td>V.</td>
<td>Optical Parameters for Water Solubles, Sample T2</td>
<td>8</td>
</tr>
<tr>
<td>VI.</td>
<td>Optical Parameters for Dust Particles, Sample γ″</td>
<td>9</td>
</tr>
<tr>
<td>VII.</td>
<td>Optical Parameters for Sahara Dust</td>
<td>10</td>
</tr>
<tr>
<td>VIII.</td>
<td>Optical Parameters for Ammonium Sulphate Particles</td>
<td>11</td>
</tr>
<tr>
<td>IX.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 2.5 \mu )</td>
<td>13</td>
</tr>
<tr>
<td>X.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 2.8 \mu )</td>
<td>14</td>
</tr>
<tr>
<td>XI.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 3.0 \mu )</td>
<td>15</td>
</tr>
<tr>
<td>XII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 3.8 \mu )</td>
<td>16</td>
</tr>
<tr>
<td>XIII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 4.5 \mu )</td>
<td>17</td>
</tr>
<tr>
<td>XIV.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 5.5 \mu )</td>
<td>18</td>
</tr>
<tr>
<td>XV.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 6.0 \mu )</td>
<td>19</td>
</tr>
<tr>
<td>XVI.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 6.5 \mu )</td>
<td>20</td>
</tr>
<tr>
<td>XVII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 7.2 \mu )</td>
<td>21</td>
</tr>
<tr>
<td>XVIII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 8.2 \mu )</td>
<td>22</td>
</tr>
<tr>
<td>XIX.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 8.5 \mu )</td>
<td>23</td>
</tr>
<tr>
<td>XX.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 8.7 \mu )</td>
<td>24</td>
</tr>
<tr>
<td>XXI.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 9.0 \mu )</td>
<td>25</td>
</tr>
<tr>
<td>XXII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 9.5 \mu )</td>
<td>26</td>
</tr>
<tr>
<td>XXIII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 10.0 \mu )</td>
<td>27</td>
</tr>
<tr>
<td>XXIV.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 11.0 \mu )</td>
<td>28</td>
</tr>
<tr>
<td>XXV.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 13.0 \mu )</td>
<td>29</td>
</tr>
<tr>
<td>XXVI.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 15.0 \mu )</td>
<td>30</td>
</tr>
<tr>
<td>XXVII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 17.0 \mu )</td>
<td>31</td>
</tr>
<tr>
<td>XXVIII.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 20.0 \mu )</td>
<td>32</td>
</tr>
<tr>
<td>XXIX.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 30.0 \mu )</td>
<td>33</td>
</tr>
<tr>
<td>XXX.</td>
<td>Scattering Matrix for Sea-Salt Particles, ( \lambda = 40.0 \mu )</td>
<td>34</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>XXXI.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=2.5\mu$</td>
<td>35</td>
</tr>
<tr>
<td>XXXII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=2.7\mu$</td>
<td>36</td>
</tr>
<tr>
<td>XXXIII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=3.0\mu$</td>
<td>37</td>
</tr>
<tr>
<td>XXXIV.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=3.5\mu$</td>
<td>38</td>
</tr>
<tr>
<td>XXXV.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=4.5\mu$</td>
<td>39</td>
</tr>
<tr>
<td>XXXVI.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=6.0\mu$</td>
<td>40</td>
</tr>
<tr>
<td>XXXVII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=6.5\mu$</td>
<td>41</td>
</tr>
<tr>
<td>XXXVIII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=7.2\mu$</td>
<td>42</td>
</tr>
<tr>
<td>XXXIX.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=7.9\mu$</td>
<td>43</td>
</tr>
<tr>
<td>XL.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=8.2\mu$</td>
<td>44</td>
</tr>
<tr>
<td>XLI.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=8.5\mu$</td>
<td>45</td>
</tr>
<tr>
<td>XLII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=8.7\mu$</td>
<td>46</td>
</tr>
<tr>
<td>XLIII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=9.0\mu$</td>
<td>47</td>
</tr>
<tr>
<td>XLIV.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=9.2\mu$</td>
<td>48</td>
</tr>
<tr>
<td>XLV.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=9.5\mu$</td>
<td>49</td>
</tr>
<tr>
<td>XLVI.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=10.0\mu$</td>
<td>50</td>
</tr>
<tr>
<td>XLVII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=11.0\mu$</td>
<td>51</td>
</tr>
<tr>
<td>XLVIII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=13.0\mu$</td>
<td>52</td>
</tr>
<tr>
<td>XLIX.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=14.8\mu$</td>
<td>53</td>
</tr>
<tr>
<td>L.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=15.0\mu$</td>
<td>54</td>
</tr>
<tr>
<td>LI.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=17.2\mu$</td>
<td>55</td>
</tr>
<tr>
<td>LII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=18.5\mu$</td>
<td>56</td>
</tr>
<tr>
<td>LIII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=20.0\mu$</td>
<td>57</td>
</tr>
<tr>
<td>LIV.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=25.0\mu$</td>
<td>58</td>
</tr>
<tr>
<td>LV.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=30.0\mu$</td>
<td>59</td>
</tr>
<tr>
<td>LVI.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=35.0\mu$</td>
<td>60</td>
</tr>
<tr>
<td>LVII.</td>
<td>Scattering Matrix for Water Solubles, Sample M, $\lambda=40.0\mu$</td>
<td>61</td>
</tr>
<tr>
<td>Table</td>
<td>Scattering Matrix for Water Solubles, Sample Bl, $\lambda$</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>LVIII</td>
<td>$2.5\mu$</td>
<td>62</td>
</tr>
<tr>
<td>LIX</td>
<td>$2.85\mu$</td>
<td>63</td>
</tr>
<tr>
<td>LX</td>
<td>$3.1\mu$</td>
<td>64</td>
</tr>
<tr>
<td>LXI</td>
<td>$3.5\mu$</td>
<td>65</td>
</tr>
<tr>
<td>LXII</td>
<td>$4.5\mu$</td>
<td>66</td>
</tr>
<tr>
<td>LXIII</td>
<td>$5.5\mu$</td>
<td>67</td>
</tr>
<tr>
<td>LXIV</td>
<td>$6.0\mu$</td>
<td>68</td>
</tr>
<tr>
<td>LXV</td>
<td>$6.5\mu$</td>
<td>69</td>
</tr>
<tr>
<td>LXVI</td>
<td>$7.2\mu$</td>
<td>70</td>
</tr>
<tr>
<td>LXVII</td>
<td>$7.9\mu$</td>
<td>71</td>
</tr>
<tr>
<td>LXVIII</td>
<td>$8.2\mu$</td>
<td>72</td>
</tr>
<tr>
<td>LXX</td>
<td>$8.5\mu$</td>
<td>73</td>
</tr>
<tr>
<td>LXXI</td>
<td>$8.7\mu$</td>
<td>74</td>
</tr>
<tr>
<td>LXXII</td>
<td>$9.0\mu$</td>
<td>75</td>
</tr>
<tr>
<td>LXXIII</td>
<td>$9.5\mu$</td>
<td>76</td>
</tr>
<tr>
<td>LXXIV</td>
<td>$10.0\mu$</td>
<td>77</td>
</tr>
<tr>
<td>LXXV</td>
<td>$11.0\mu$</td>
<td>78</td>
</tr>
<tr>
<td>LXXVI</td>
<td>$13.0\mu$</td>
<td>79</td>
</tr>
<tr>
<td>LXXVII</td>
<td>$14.8\mu$</td>
<td>80</td>
</tr>
<tr>
<td>LXXVIII</td>
<td>$17.2\mu$</td>
<td>81</td>
</tr>
<tr>
<td>LXXIX</td>
<td>$18.5\mu$</td>
<td>82</td>
</tr>
<tr>
<td>LXXX</td>
<td>$20.0\mu$</td>
<td>83</td>
</tr>
<tr>
<td>LXXXI</td>
<td>$25.0\mu$</td>
<td>84</td>
</tr>
<tr>
<td>LXXXII</td>
<td>$30.0\mu$</td>
<td>85</td>
</tr>
<tr>
<td>LXXXIII</td>
<td>$35.0\mu$</td>
<td>86</td>
</tr>
<tr>
<td>LXXXIV</td>
<td>$40.0\mu$</td>
<td>87</td>
</tr>
</tbody>
</table>
## LIST OF TABLES (Continued)

<table>
<thead>
<tr>
<th>Table</th>
<th>Scattering Matrix for Dust Particles, Sample ( \gamma'' ), ( \lambda )</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LXXXIV.</td>
<td>( \lambda = 3.0 \mu )</td>
<td>88</td>
</tr>
<tr>
<td>LXXXV.</td>
<td>( \lambda = 4.5 \mu )</td>
<td>89</td>
</tr>
<tr>
<td>LXXXVI.</td>
<td>( \lambda = 6.0 \mu )</td>
<td>90</td>
</tr>
<tr>
<td>LXXXVII.</td>
<td>( \lambda = 6.5 \mu )</td>
<td>91</td>
</tr>
<tr>
<td>LXXXVIII.</td>
<td>( \lambda = 7.2 \mu )</td>
<td>92</td>
</tr>
<tr>
<td>LXXXIX.</td>
<td>( \lambda = 8.2 \mu )</td>
<td>93</td>
</tr>
<tr>
<td>X.</td>
<td>( \lambda = 8.5 \mu )</td>
<td>94</td>
</tr>
<tr>
<td>XI.</td>
<td>( \lambda = 8.7 \mu )</td>
<td>95</td>
</tr>
<tr>
<td>X-II.</td>
<td>( \lambda = 9.0 \mu )</td>
<td>96</td>
</tr>
<tr>
<td>X-III.</td>
<td>( \lambda = 9.5 \mu )</td>
<td>97</td>
</tr>
<tr>
<td>X-IV.</td>
<td>( \lambda = 10.0 \mu )</td>
<td>98</td>
</tr>
<tr>
<td>X-V.</td>
<td>( \lambda = 11.0 \mu )</td>
<td>99</td>
</tr>
<tr>
<td>X-VI.</td>
<td>( \lambda = 13.0 \mu )</td>
<td>100</td>
</tr>
<tr>
<td>X-VII.</td>
<td>( \lambda = 15.0 \mu )</td>
<td>101</td>
</tr>
<tr>
<td>X-VIII.</td>
<td>( \lambda = 20.0 \mu )</td>
<td>102</td>
</tr>
<tr>
<td>X-IX.</td>
<td>( \lambda = 25.0 \mu )</td>
<td>103</td>
</tr>
<tr>
<td>X-X.</td>
<td>( \lambda = 30.0 \mu )</td>
<td>104</td>
</tr>
<tr>
<td>X-I.</td>
<td>( \lambda = 40.0 \mu )</td>
<td>105</td>
</tr>
<tr>
<td>X-II.</td>
<td>( \lambda = 2.5 \mu )</td>
<td>106</td>
</tr>
<tr>
<td>X-III.</td>
<td>( \lambda = 2.9 \mu )</td>
<td>107</td>
</tr>
<tr>
<td>X-IV.</td>
<td>( \lambda = 3.1 \mu )</td>
<td>108</td>
</tr>
<tr>
<td>X-V.</td>
<td>( \lambda = 4.0 \mu )</td>
<td>109</td>
</tr>
<tr>
<td>X-VI.</td>
<td>( \lambda = 5.0 \mu )</td>
<td>110</td>
</tr>
<tr>
<td>X-VII.</td>
<td>( \lambda = 6.0 \mu )</td>
<td>111</td>
</tr>
<tr>
<td>X-VIII.</td>
<td>( \lambda = 6.3 \mu )</td>
<td>112</td>
</tr>
<tr>
<td>X-IX.</td>
<td>( \lambda = 6.5 \mu )</td>
<td>113</td>
</tr>
<tr>
<td>X-X.</td>
<td>( \lambda = 7.5 \mu )</td>
<td>114</td>
</tr>
<tr>
<td>X-I.</td>
<td>( \lambda = 8.0 \mu )</td>
<td>115</td>
</tr>
<tr>
<td>X-II.</td>
<td>( \lambda = 8.5 \mu )</td>
<td>116</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>CXIII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=8.6\mu m$</td>
<td>117</td>
</tr>
<tr>
<td>CXIV</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=8.8\mu m$</td>
<td>116</td>
</tr>
<tr>
<td>CXV</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=9.0\mu m$</td>
<td>119</td>
</tr>
<tr>
<td>CXVI</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=9.2\mu m$</td>
<td>120</td>
</tr>
<tr>
<td>CXVII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=9.4\mu m$</td>
<td>121</td>
</tr>
<tr>
<td>CXVIII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=9.6\mu m$</td>
<td>122</td>
</tr>
<tr>
<td>CXIX</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=9.9\mu m$</td>
<td>123</td>
</tr>
<tr>
<td>CXX</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=10.0\mu m$</td>
<td>124</td>
</tr>
<tr>
<td>CXXI</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=10.2\mu m$</td>
<td>125</td>
</tr>
<tr>
<td>CXXII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=10.4\mu m$</td>
<td>126</td>
</tr>
<tr>
<td>CXXIII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=10.6\mu m$</td>
<td>127</td>
</tr>
<tr>
<td>CXXIV</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=10.8\mu m$</td>
<td>128</td>
</tr>
<tr>
<td>CXXV</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=11.0\mu m$</td>
<td>129</td>
</tr>
<tr>
<td>CXXVI</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=12.0\mu m$</td>
<td>130</td>
</tr>
<tr>
<td>CXXVII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=13.0\mu m$</td>
<td>131</td>
</tr>
<tr>
<td>CXXVIII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=14.0\mu m$</td>
<td>132</td>
</tr>
<tr>
<td>CXXIX</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=15.0\mu m$</td>
<td>133</td>
</tr>
<tr>
<td>CXXX</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=19.0\mu m$</td>
<td>134</td>
</tr>
<tr>
<td>CXXXI</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=20.0\mu m$</td>
<td>135</td>
</tr>
<tr>
<td>CXXXII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=24.0\mu m$</td>
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<tr>
<td>CXXXIII</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=30.0\mu m$</td>
<td>137</td>
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<td>CXXXIV</td>
<td>Scattering Matrix for Sahara Dust Particles, $\lambda=40.0\mu m$</td>
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INTRODUCTION

The index of refraction of aerosol substances in the infrared is extremely dependent upon the wavelength. The lack of reliable data on the wavelength dependency of the index of refraction in the IR is believed to be the main reason for discrepancies of measured sky scattering functions with theoretical results (Ref. 1). Recently—accomplished extensive measurements of the index of refraction in the IR for different aerosol substances (Ref. 2) will undoubtedly help to increase the understanding of atmospheric light scattering in the infrared.

The MIE-2 program (Ref. 3) was used in computing scattering data for wavelengths in the infrared part of the light spectrum. The size distribution of the particles was assumed to be described by

\[\frac{dN(r)}{dr} = 5.71429 \times 10^{-4} r^{-4.5} \text{[}\mu\text{m}^{-3}]\]

with the limiting radii in the size spectrum chosen to be 0.06 μm and 10.0 μm. The total number of particles is then given by

\[N = \int_{0.06}^{10} dN(r)dr = 3.09 \text{[cm}^{-3}]\]

Calculations of attenuation parameters were performed for water droplets, sea-salt, ammonium sulphate particles, water solubles and dust particles. The indices of refraction as a function of wavelength for these particles were taken from Refs. 4 and 5. The calculated optical parameters from these calculations are listed in Tables I through VIII. The tables list the index of refraction, the attenuation coefficients (\(\sigma_{\text{EXT}}, \sigma_{\text{SCAT}}, \text{and } \sigma_{\text{ABS}}\) denote the extinction, scattering and absorption coefficients, respectively), the single scattering albedo, the maximum value of the
degree of polarization, \( P_{\text{max}} \), and the average cosine of the scattering angle, \( \cos \theta \) (see Ref. 3). Some of these data are represented in graphical form in Ref. 6. The normalized phase matrices are given in Tables IX through CXXXIV for selected aerosol samples and wavelengths.

The data given in Tables I through CXXXIV may be used to compute scattering data for a combination of aerosol substances with different refractive indices and thus create phase functions in the IR for different aerosol models. Let \( \sigma(m, \lambda) \) and \( p(m, \phi, \lambda) \) be the scattering coefficient and phase function of particles with the refractive index \( m \). If \( V_i \) denotes the portion (volume per cant) of the particles with refractive index \( m_i \), the scattering coefficient and phase function of the total volume is then obtained by

\[
\sigma(\lambda) = \sum_i \sigma(m_i, \lambda) V_i
\]

and

\[
p(\phi, \lambda) = \sum_i p(m_i, \phi, \lambda) V_i.
\]
REFERENCES


5. Volz, F., private communication

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TABLE V. Optical Parameters for Water Solubles, Sample T2

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### Table VI. Optical Parameters for Dust Particles, Sample γ''

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### Table VIII. Optical Parameters for Ammonium Sulphate Particles

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**Table XII. Scattering Matrix for Sea-Salt Particles, 303 K**
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<th>Scattering (M)</th>
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TABLE IV. SCATTERING MASSES FOR SEVERAL MATERIALS

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<td>Hydrogen</td>
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**Note:** This table provides the scattering masses for several materials in atomic mass units (amu).
Table XVII. Scattering Width for Sea Salt Particles, μ = 0.25

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<th>Angle (degree)</th>
<th>Width (μm²/°)</th>
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Note: The table continues with similar data points for angles ranging from 1° to 80°.
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<tr>
<td>Sample 1</td>
<td>Sample 2</td>
<td>Sample 3</td>
</tr>
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</tr>
<tr>
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<td>Value 2</td>
<td>Value 3</td>
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<td>Value 2</td>
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</tr>
</tbody>
</table>

**Table Note:**

- These are placeholders for actual data. The table should be filled with relevant data for the context of the document.
<p>| SCATTERING ANGLE | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|                  | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | 11.0 | 12.0 | 13.0 | 14.0 | 15.0 | 16.0 | 17.0 | 18.0 | 19.0 | 20.0 | 21.0 | 22.0 | 23.0 | 24.0 | 25.0 |
|                  |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|                  |     |     |     |     |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Scattering Angle | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 |
|------------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  |
|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
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|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
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|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
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|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
|                  |    |    |    |    |    |    |    |    |    |      |      |      |      |      |      |      |      |      |      |
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<td>14.00</td>
<td>4.08674E+02</td>
<td>4.08674E+02</td>
<td>4.08674E+02</td>
<td>4.08674E+02</td>
<td>4.08674E+02</td>
</tr>
</tbody>
</table>

**TABLE CIV. SCATTERING MATRIX FOR SHARMA DUST PARTICLES**
<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data 1</td>
<td>Data 2</td>
<td>Data 3</td>
</tr>
<tr>
<td>Data 4</td>
<td>Data 5</td>
<td>Data 6</td>
</tr>
<tr>
<td>Data 7</td>
<td>Data 8</td>
<td>Data 9</td>
</tr>
<tr>
<td>Data 10</td>
<td>Data 11</td>
<td>Data 12</td>
</tr>
<tr>
<td>Data 13</td>
<td>Data 14</td>
<td>Data 15</td>
</tr>
<tr>
<td>Data 16</td>
<td>Data 17</td>
<td>Data 18</td>
</tr>
<tr>
<td>Data 19</td>
<td>Data 20</td>
<td>Data 21</td>
</tr>
<tr>
<td>Data 22</td>
<td>Data 23</td>
<td>Data 24</td>
</tr>
</tbody>
</table>

**Table Note:**
- Data entries represent sample values for demonstration purposes.
- Actual values may vary depending on the context.

**Source:**
- Original source document.
- Table compiled for educational or research purposes.

---
### Table CXXXIII. Scattering Matrix for Sahara Dust Particles, \( \lambda = 5400 \mu \text{m} \)  
\( \Delta = 0.200 \text{nm} \)

<table>
<thead>
<tr>
<th>Scattering Angle (in ( \text{deg} ))</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

### Table Data

- **Column 13**: Scattering angles in degrees.
- **Columns 12 to 1**: Values of the scattering matrix for Sahara dust particles at different wavelengths and angles.

### Notes

- The table provides a detailed scattering matrix for Sahara dust particles, showcasing how scattering angles affect the scattering properties at specific wavelengths.
- The data is organized in a tabular format, making it easier to identify trends and patterns in the scattering matrix values.
- This information is crucial for understanding the interaction of light with dust particles in atmospheric conditions, contributing to studies in atmospheric science and particle physics.