PACE: Radiative Transfer studies for Atmosphere-Ocean Systems

Summary

relevant for PACE instrument design

- PACE ST polarimeter document

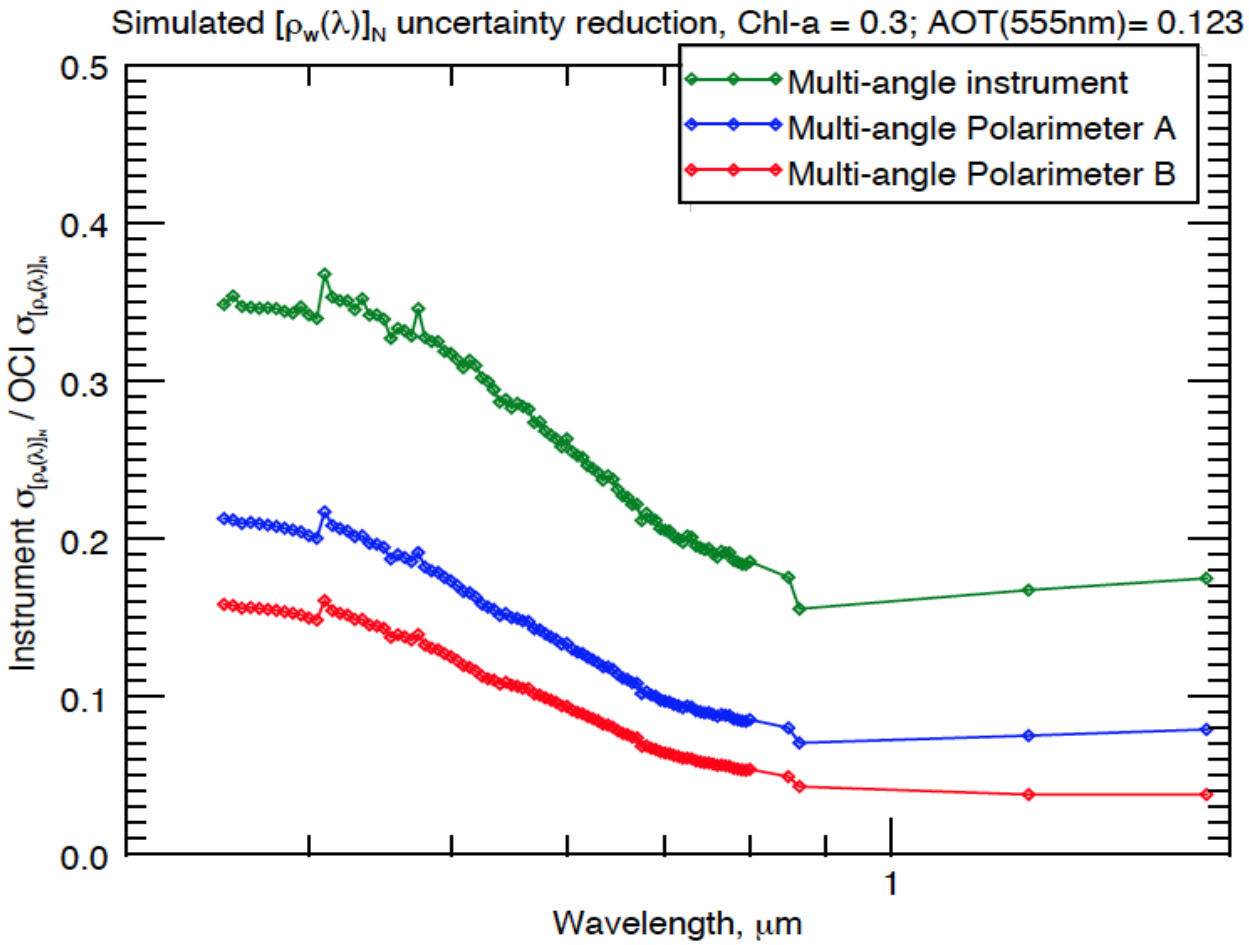
Project	What did we propose	What did we accomplish
ACROSS	➢ Perform sensitivity analyses for proposed PACE instrument options ○ OCI → *NUV-SWIR radiance* ○ OCI/OG → *O2-A band radiance* ○ OCI+ → *1378, 2250 radiance* ○ OCI-3M → *VIS-SWIR polarization*	➢ Proposed PACE instrument sensitivity studies: ○ OCI → *95 channels between 0.35 µm and 2.13 µm* ○ OCI-3M → *5 view angles between +/– 50 degrees* → *5 channels between 0.41 µm and 2.25 µm* → *1% polarization accuracy* ➢ Other satellite instrument sensitivity studies: ○ OCI-2M → *OCI-3M but without polarization* ○ OCI-3M+ → *OCI-3M but more views & better accuracy*
	➢ Write manuscript about sensitivity analyses results	
PACE '15	➢ Compare RT computations for various atmosphere-ocean systems (AOS) ○ 5 AOS models ○ 2 altitudes ○ 4 wavelengths ○ >100 scattering angles	➢ Computations with 3 different RT codes ○ AOS models I, II, III ○ all altitudes, wavelengths, angles ○ 3 Stokes parameters ○ error ~ 1e-6 → *ΔP < 0.1%* ➢ 90+ page draft manuscript *Discuss tomorrow*
	➢ Update hydrosol model ○ Involve input from PACE-IOP group	➢ Investigated 4 multi-parameter models ○ ACROSS-I & -II models, c-model, IOCCG5 ➢ 15+ page draft document
Other	➢ Study aerosol height retrievals from O2-A data	➢ Theoretical and actual aerosol height retrieval studies using blue/UV polarization ➢ manuscript in preperation

relevant for PACE instrument design

PACE: Radiative Transfer studies for Atmosphere-Ocean Systems

1. ACROSS → *Test increase in information in OCI+Polarimeter versus OCI alone*

Less improvement in atmospheric correction



More improvement in atmospheric correction

PACE: Radiative Transfer studies for Atmosphere-Ocean Systems

Motivation

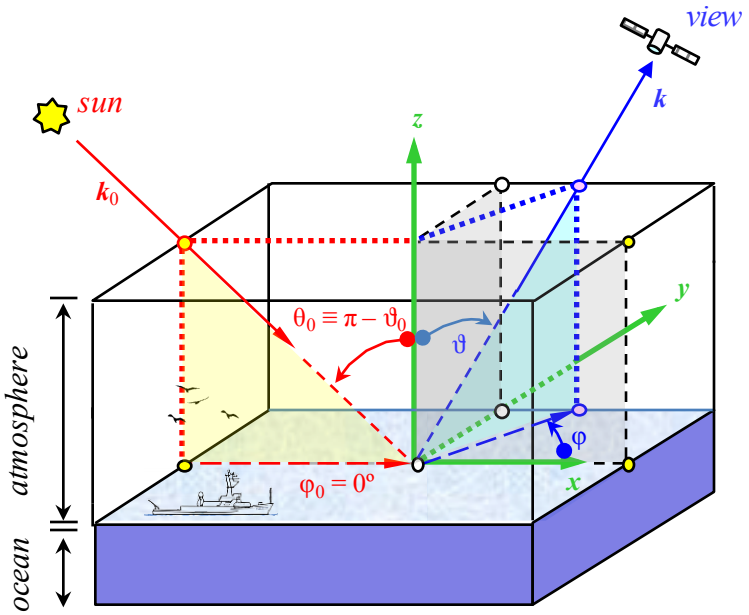
Polarization is an extremely useful tool to retrieve aerosol properties

- provided that it is measured with very high accuracies (0.2%–0.5%)

Simulated aerosol retrieval from space-borne observation over ocean at 865 nm

Synthetic TOA data of *I*, *Q*, & *U*:

- μ_0=0.8; μ=0.2, 0.4, 0.6, 0.8, 1.0
  Δφ=60° & 120°
- Fine mode aerosol, τ = 0.2
  (r_e = 0.4 μm; v_e=0.2; m=1.45
- Rough ocean surface
  (W = 7 m/s)
- Black water body



AOS system

Aerosol candidate models:

- Fine mode aerosol:
  τ = 0.01 – 0.4, Δτ = 0.01
  r_e = 0.01 – 0.8 μm, Δr_e = 0.01
  m = 1.3 – 1.7, Δm = 0.01
  ω = 0.78 – 1.00, Δω = 0.02
  v_e = 0.2

>350,000 aerosol candidate models

Source: *Mishchenko and Travis, JQSRT 102:13,543-13,553 (1997)*

Motivation

Polarization is an extremely useful tool to retrieve aerosol properties

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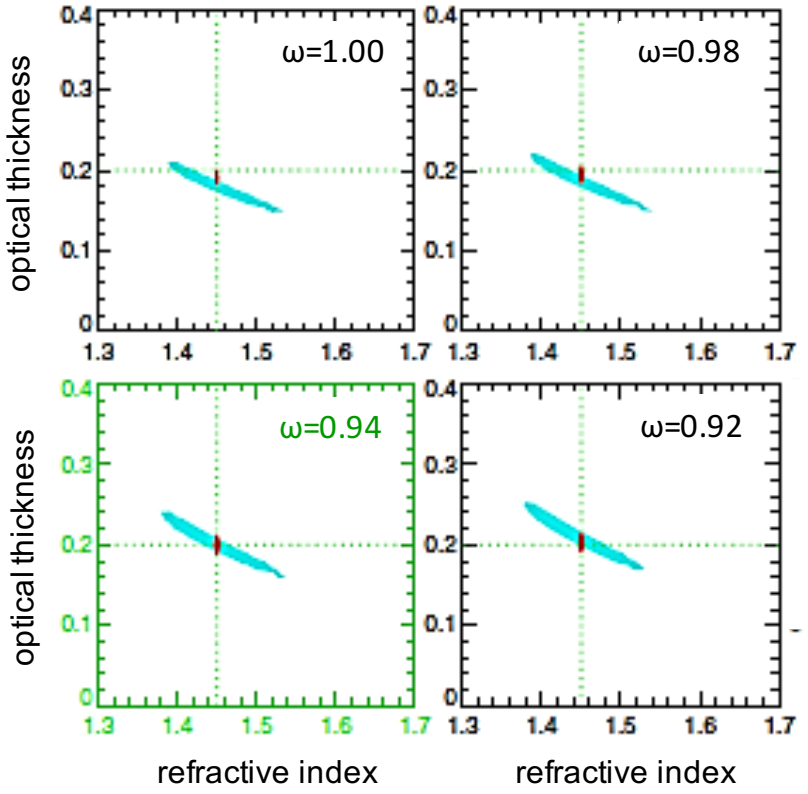
Simulated aerosol retrieval from space-borne observation over ocean at 865 nm

- radiance *I*,
- 9 viewing angles
- $\Delta I = 4\%$

- polarization Q/I and U/I,
- 9 viewing angles
- $\Delta P = 0.2\%$



Aerosol candidate models:

- Fine mode aerosol:

$\tau = 0.01 – 0.4$, $\Delta\tau = 0.01$
$r_e = 0.01 – 0.8$ μm, $\Delta r_e = 0.01$
$m = 1.3 – 1.7$, $\Delta m = 0.01$
$\omega = 0.78 – 1.00$, $\Delta\omega = 0.02$
$v_e = 0.2$

>350,000 aerosol candidate models

Source: *Mishchenko and Travis, JQSRT 102:13,543-13,553 (1997)*

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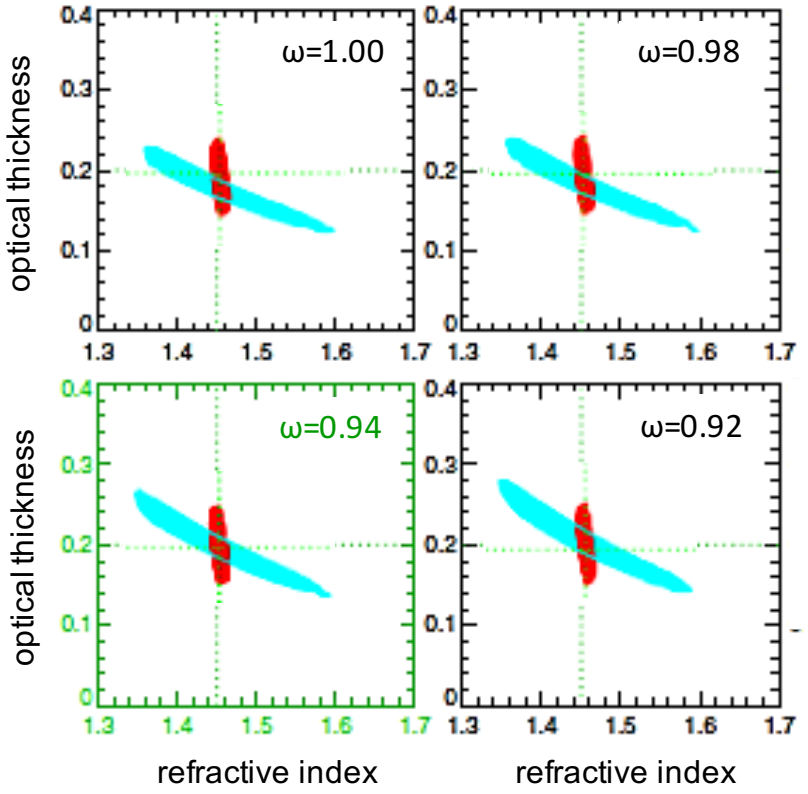
Simulated aerosol retrieval from space-borne observation over ocean at 865 nm

- radiance *I*,
- 9 viewing angles
- ΔI = 6%

- polarization Q/I and U/I,
- 9 viewing angles
- ΔP = 0.8%



Aerosol candidate models:

- Fine mode aerosol:

τ = 0.01 – 0.4, $\Delta\tau$ = 0.01
r_e = 0.01 – 0.8 μm, Δr_e = 0.01
m = 1.3 – 1.7, Δm = 0.01
ω = 0.78 – 1.00, $\Delta\omega$ = 0.02
v_e = 0.2

>350,000 aerosol candidate models

Source: *Mishchenko and Travis, JQSRT 102:13,543-13,553 (1997)*

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Motivation

Polarization is an extremely useful tool to retrieve aerosol properties

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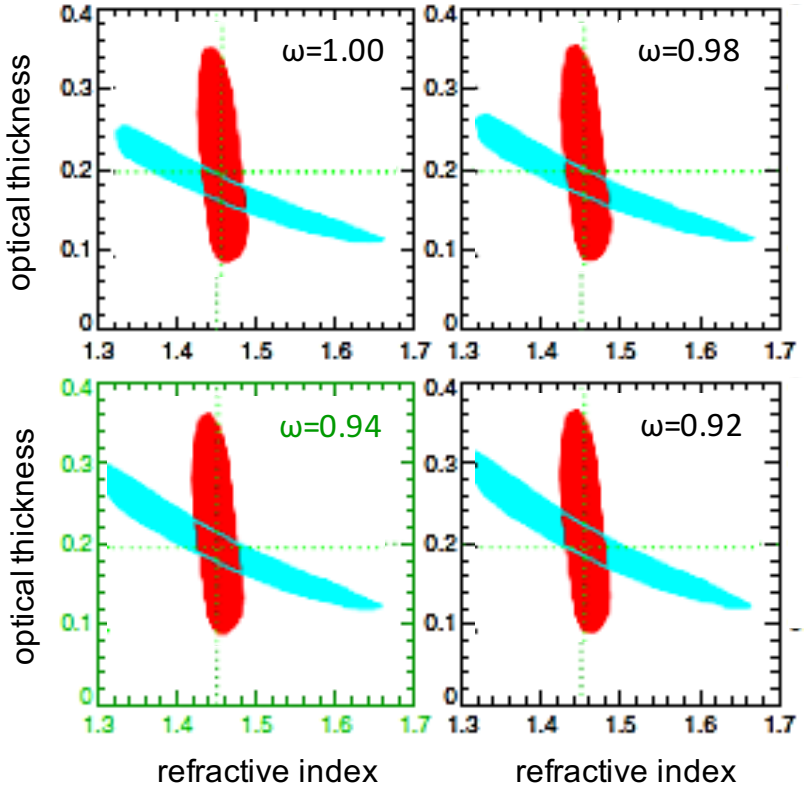
Simulated aerosol retrieval from space-borne observation over ocean at 865 nm

- radiance *I*,
- 9 viewing angles
- ΔI = 8%

- polarization Q/I and U/I,
- 9 viewing angles
- ΔP = 2.0%



Aerosol candidate models:

- Fine mode aerosol:

τ = 0.01 – 0.4, $\Delta\tau$ = 0.01
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ω = 0.78 – 1.00, $\Delta\omega$ = 0.02
v_e = 0.2

>350,000 aerosol candidate models

Source: *Mishchenko and Travis, JQSRT 102:13,543-13,553 (1997)*

Motivation

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- our forward RT computations need to match these accuracies!

2015:

Contents lists available at ScienceDirect

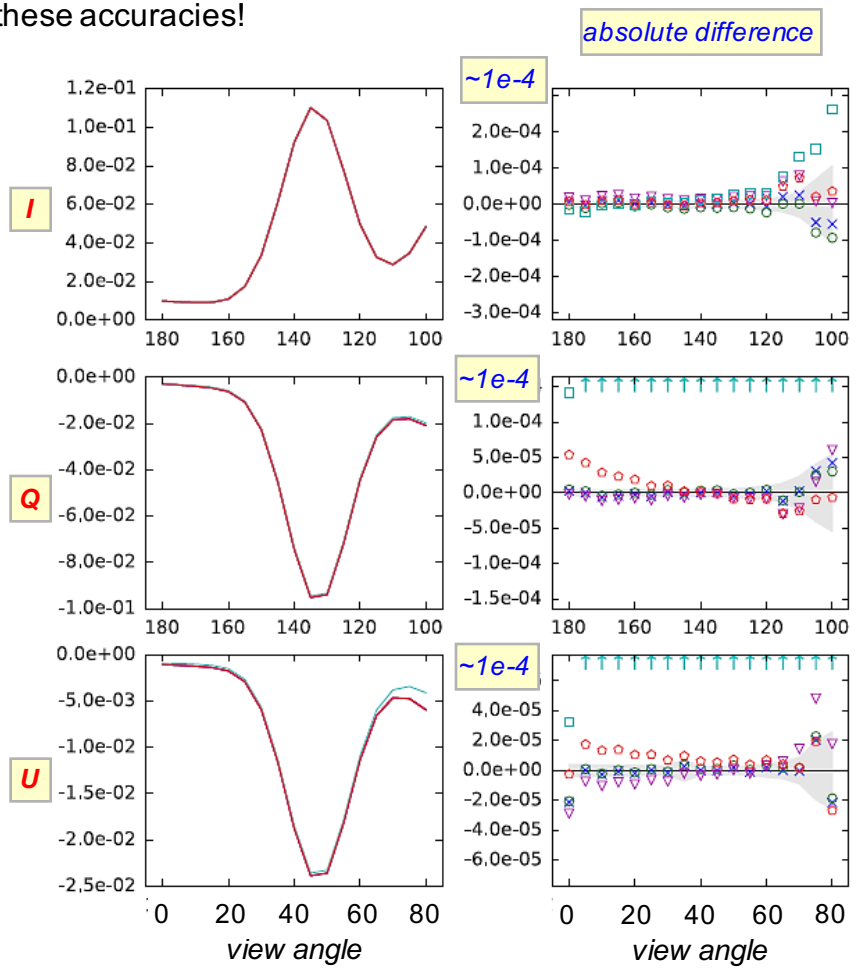
Journal of Quantitative Spectroscopy & Radiative Transfer

journal homepage: www.elsevier.com/locate/jqsrt

IPRT polarized radiative transfer model intercomparison project – Phase A

Claudia Emde [a,*], Vasileios Barlakas [b], Céline Cornet [c], Frank Evans [d], Sergey Korkin [e], Yoshifumi Ota [f], Laurent C. Labonnote [c], Alexei Lyapustin [g], Andreas Macke [h], Bernhard Mayer [a], Manfred Wendisch [b]

AOS system: molecular atmosphere above ocean surface

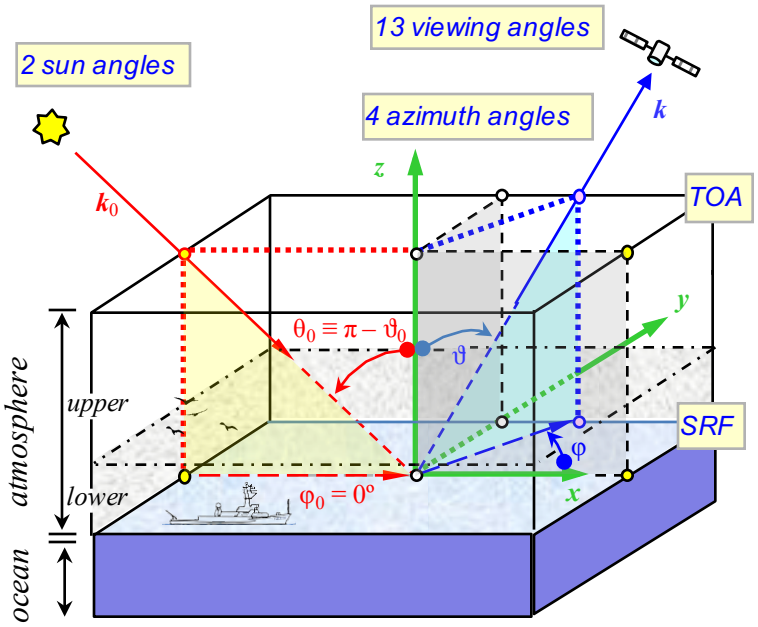


Results

Polarization is an extremely useful tool to retrieve aerosol properties

- provided that it is measured with very high accuracies (0.2%–0.5%)

- our forward RT computations need to match these accuracies!



AOS model	Ocean Body	Ocean Surface	Atmosphere
AOS-I, AOS-I*§	none	rough‡ • see Sec. 3.2 • see Table 5	molecular+ • see Sec. 3.3 • see Table 8
AOS-II	pure water+ • see Sec. 3.1 • see Table 2	rough‡ • see Sec. 3.2 • see Table 5	none
AOS-III	pure water+ • see Sec. 3.1 • see Table 2	rough‡ • see Sec. 3.2 • see Table 5	molecular+ • see Sec. 3.3 • see Table 8
AOS-IV	pure water+ & hydrosol • see Sec. 3.1 • see Table 2 & 3, 4	rough‡ • see Sec. 3.2 • see Table 5	molecular+ • see Sec. 3.3 • see Table 8
AOS-V	pure water+ & hydrosol • see Sec. 3.1 • see Table 2 & 3, 4	rough‡ • see Sec. 3.2 • see Table 5	molecular+ & aerosol • see Sec. 3.3 • see Table 6 & 7, 8

>100 scattering geometries x 2 altitudes

λ = 350 nm, 450 nm, 550 nm, 650 nm

I, Q, U → ΔP ≤ 0.1%

Results

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AOS model	Ocean Body	Ocean Surface	Atmosphere
AOS-I, AOS-I*§	none	rough‡ • see Sec. 3.2 • see Table 5	molecular+ • see Sec. 3.3 • see Table 8
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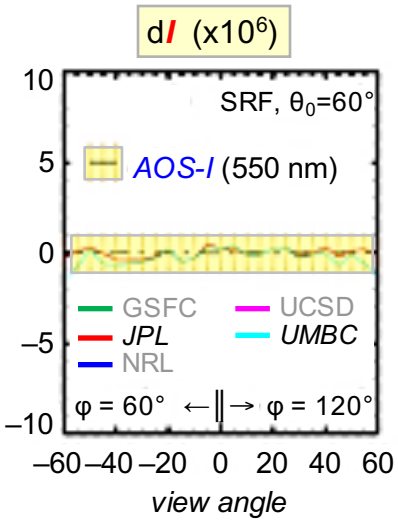

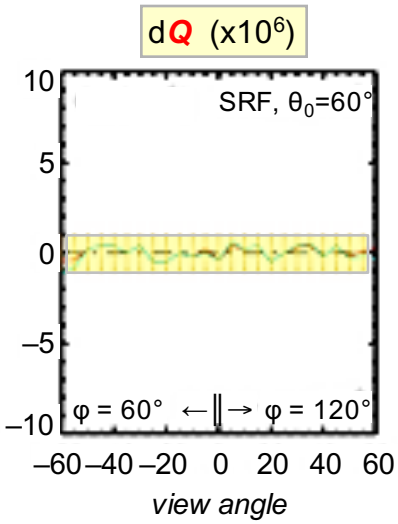

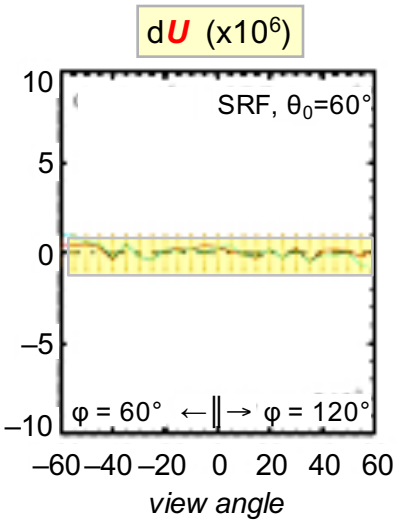

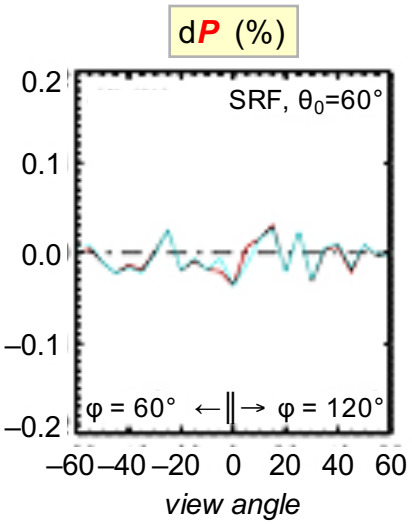

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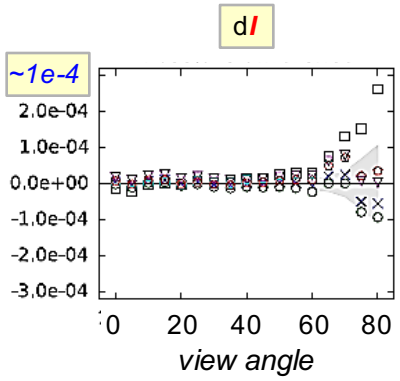
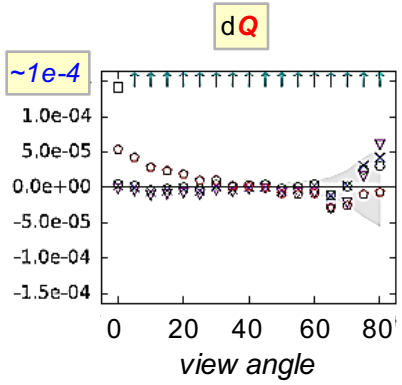
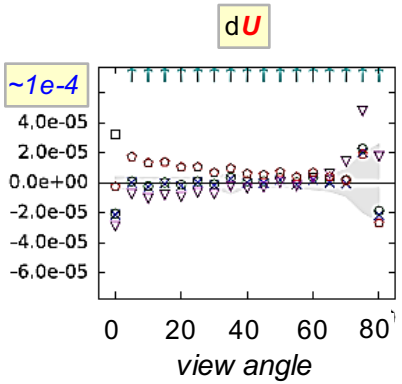
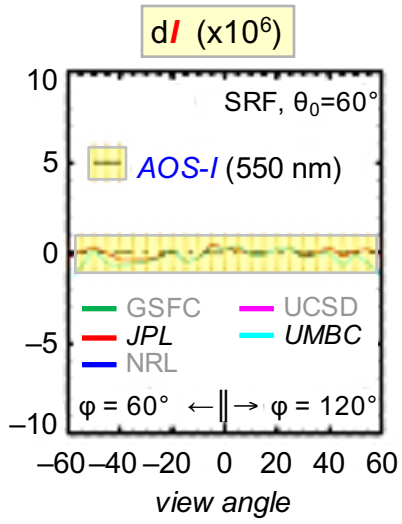
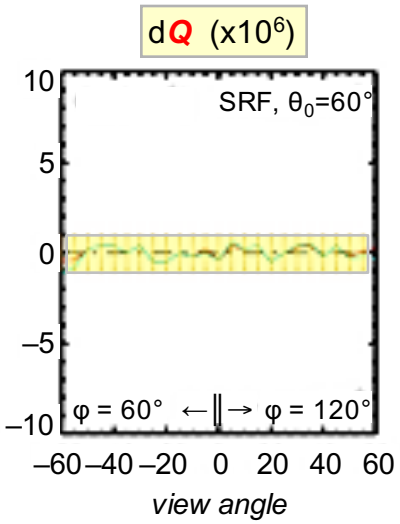


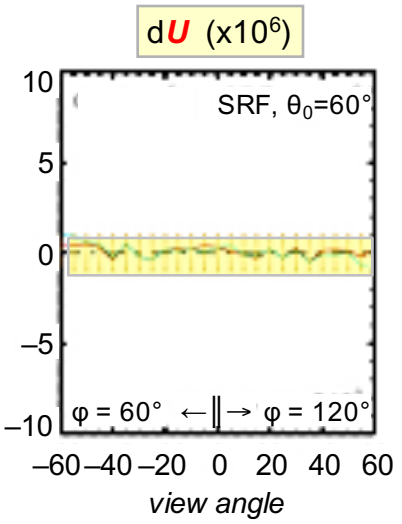


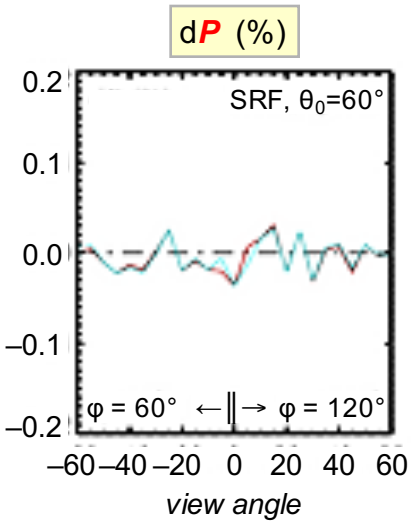


- Benchmarked >magnitude better
- Satisfies polarization accuracy



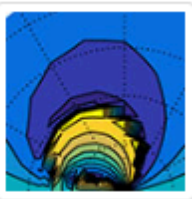






Backup Slides

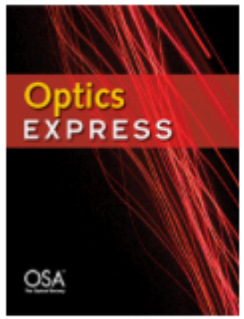
Raman scattering



Contribution of Raman scattering to polarized radiation field in ocean waters

Peng-Wang Zhai, Yongxiang Hu, David M. Winker, Bryan A. Franz, and Emmanuel Boss

Author Affiliations ▾ Find other works by these authors ▾



Optics Express Vol. 23, Issue 18, pp. 23582-23596 (2015) • doi: 10.1364/OE.23.023582

Accessible
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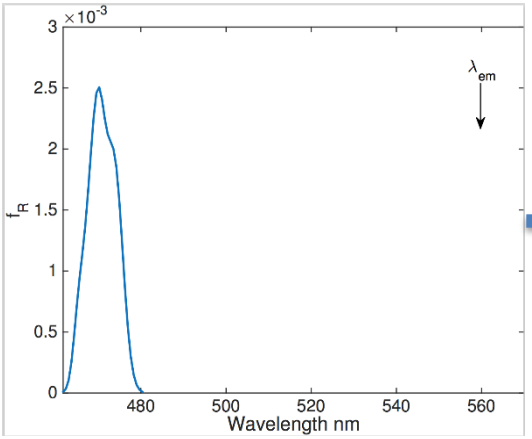
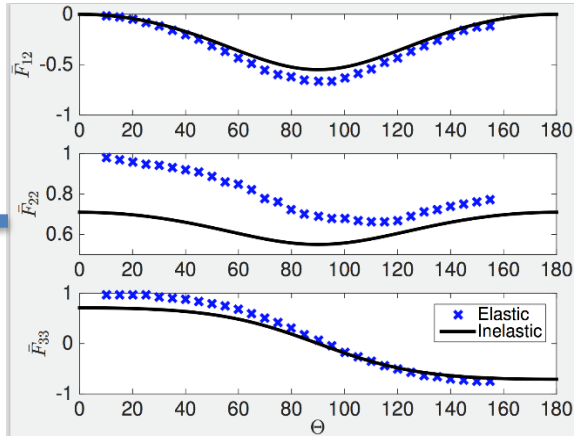
Abstract

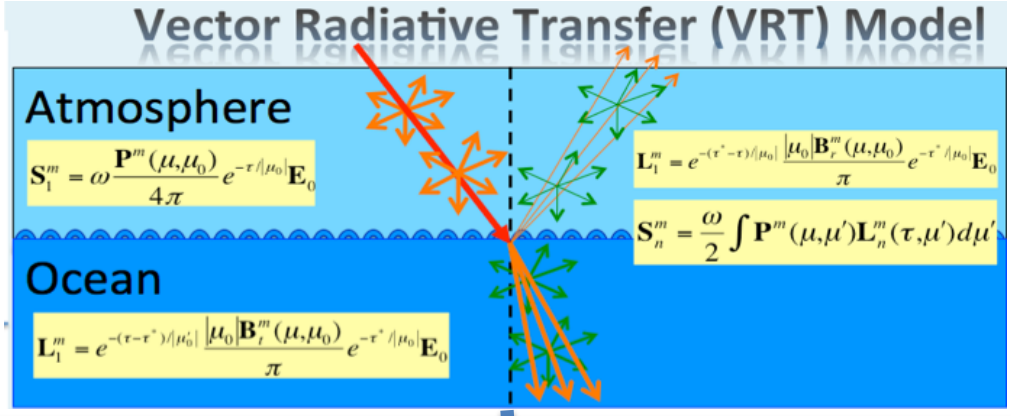
We have implemented Raman scattering in a vector radiative transfer model for coupled atmosphere and ocean systems. A sensitivity study shows that the Raman scattering contribution is greatest in clear waters and at longer wavelengths. The Raman scattering contribution may surpass the elastic scattering contribution by several orders of magnitude at depth. The degree of linear polarization in water is smaller when Raman scattering is included. The orientation of the polarization ellipse shows similar patterns for both elastic and inelastic scattering contributions. As polarimeters and multipolarization-state lidars are planned for future Earth observing missions, our model can serve as a valuable tool for the simulation and interpretation of these planned observations.

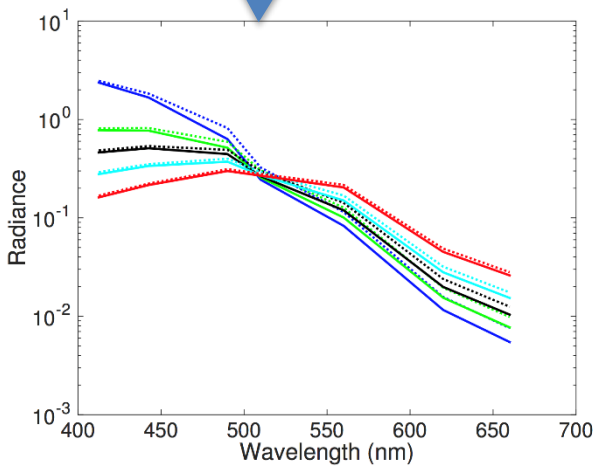
Full Article | PDF Article

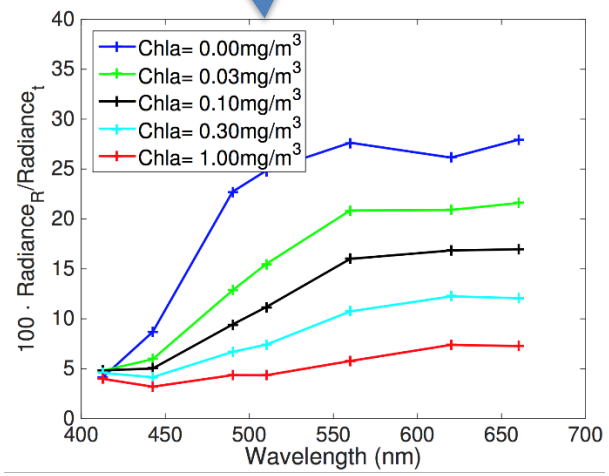


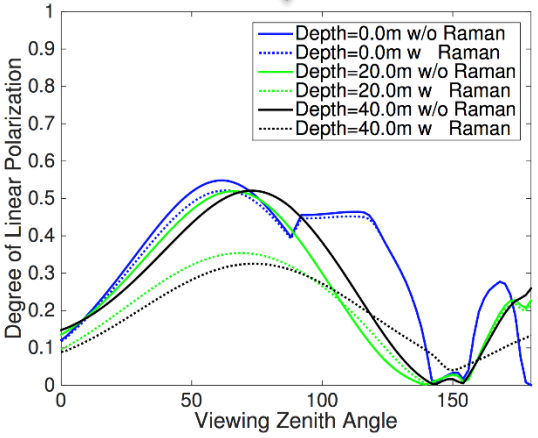


Vector Radiative Transfer (VRT) Model









Summary

- The polarized radiative transfer equation is solved with both elastic and inelastic (Raman) scattering included.
- The angular radiation field can be provided at arbitrary vertical locations in the coupled atmosphere and ocean systems.
- Raman scattering contribution is found to be significant in visible spectrum and clear waters.