SORD: A New Open Source Vector RT Code

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INTRODUCTION = CONCLUSION

- New vector RT code SORD for atmospheric and terrestrial applications
- Method used: successive orders [1]
- Polarization: I, Q, U (no V – negligible error)
- Distribution: open source
- Language: FORTRAN 90/95
- Accuracy: high (**validation: 50 published benchmarks**)
- Run-time: see numbers below
- Support and further development: sergey.v.korkin@nasa.gov
- ftp://maiac.gsfc.nasa.gov/pub/skorkin/SORD_IP_16B/

VALIDATION

In [2] we have tested the code against 44 benchmarks >>>

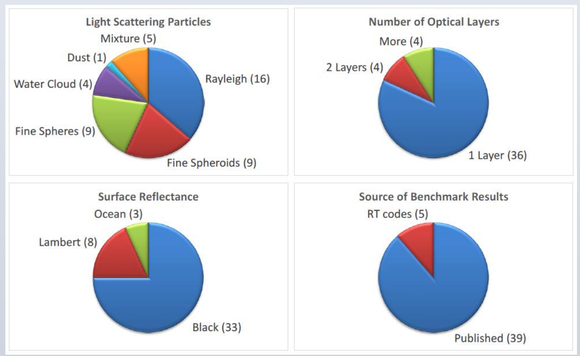


Figure 1. Itemized list of scenarios. (X) is the number of scenarios with a particular feature. E.g., 39 scenarios are published in literature (bottom-right).

ACCURACY PARAMETERS

Intensity, *I*: as usual (B – benchmark, S - SORD) $\delta I = 100\% \left| I_B - I_S \right| / I_B$

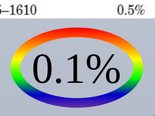
DoLP, *P* (DoLP omits the sign of *Q* and *U*): $0 \le P = \sqrt{Q^2 + U^2} / I \le 1$

✗ $\delta P = 100\% \left| P_B - P_S \right| / P_B$ ✓ $\delta P = 100\% \left| P_B - P_S \right|$

Accuracy requirement from instrument [3] and retrieval algorithm [4] developers, **and our targeted accuracy – SAME FOR *dI%* AND *dP%***

Instrument	Spatial Resolution (km)	Along-Track Angular Range	Spectral Range (nm)	Polarimetric Uncertainty
POLDER	6–7	60° fore–60° aft	443–910	2%
APS	6–20	60° fore–60° aft	412–2250	0.2%
MSPI	0.275–1.1	70° fore–70° aft	355–1610	0.5%

this purpose, the errors (in addition to shot noise) on the intensity need to be ≤1% and the errors on the relative Stokes parameters *q* and *u* need to be ≤0.002. These requirements can be relaxed if the



RESULTS FOR ACCURACY

"*Point*" – [SZA VZA AZA] in each particular scenario. E.g., a test with 1SZA x 10VZA x 5AZA = 50 different points. **The total number of points is 16888 [1].**

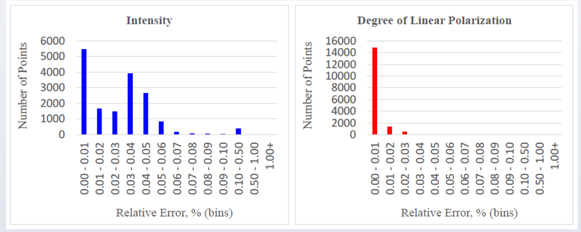
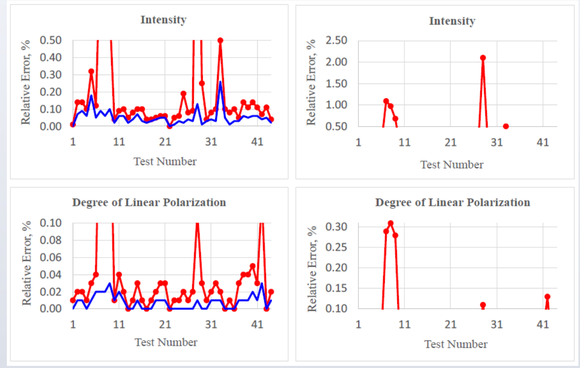


Figure 2 (above). Distribution of number of points over bins of relative error, in %, for *I* (left) and DoLP (right). **Note DoLP converges faster.**

Figure 3 (right). Maximum (red) and average (blue) absolute values of relative errors for *I* (top row) and DoLP (bottom row) in each test. Right column shows a few points with higher errors *I* (cloud cases, at horizon).



RESULTS FOR RUN-TIME (NOTATION ON X-AXIS: TEST_ORDINATES_MICROLAYERS)

Machine 1 (laptop): Intel i7-2720QM CPU, 2.2GHz, Windows 7 64 bit; Intel Visual Fortran Compiler 11.0.072 integrated with Microsoft Visual Studio 2008. In Visual Studio, we enabled the "Maximize Speed" option located under Configuration Properties\Fortran\Optimization. Further, we refer to this machine by the compiler name, "**ifort**".

Machine 2 (1 CPU on the AERONET server): Intel Xeon E7-4890 v2 CPU, 2.8 GHz, Linux 2.6 64 bit; The Portland Group Fortran 90/95 compiler 7.1-4 with the following compiler keys: -O3 –Mipa=fast, inline = Msmartalloc. We refer to this machine as "**pgf 90**".

Figure 4. Run time, in seconds, measured for all 44 benchmarks on the ifort-machine. Blue (left for each pair of bars) and red bars correspond to `SUM(A*B)` and `DDOT`, respectively. Smaller bar means faster computation.

ifort, sum(A*B) vs blas/lapack ddot(A, B)

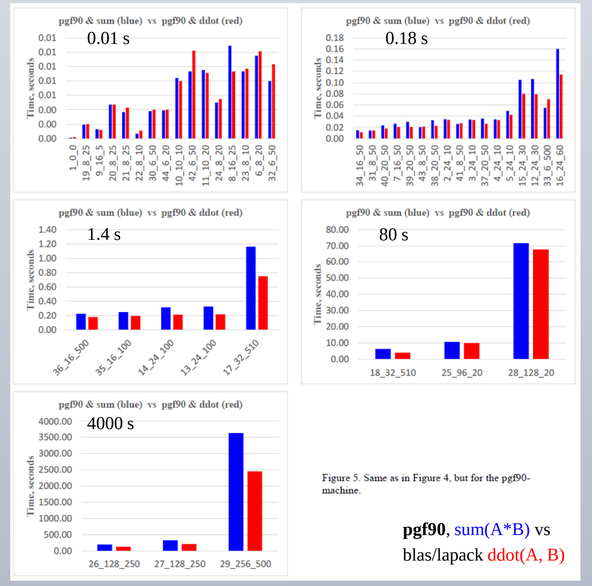
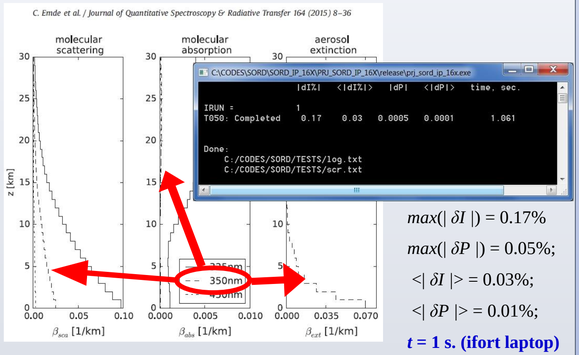


Figure 5. Same as in Figure 4, but for the pgf90-machine.

pgf90, sum(A*B) vs blas/lapack ddot(A, B)

NOT YET PUBLISHED RESULTS

IPRT tests [5] with dust + gas absorption + Rayleigh profiles: **Test #50 – 30 layers**



$max(|\delta I|) = 0.17\%$

$max(|\delta P|) = 0.05\%$;

$<|\delta I|> = 0.03\%$;

$<|\delta P|> = 0.01\%$;

***t* = 1 s. (ifort laptop)**

REFERENCES

1. van de Hulst, H. C., [Multiple light scattering. Tables, formulas, and applications], Academic Press, New York (1980). Volume 1, Section 4.3, p.46;
2. Korkin S, Lyapustin A, Sinyuk A, and Holben B, A new code SORD for simulation of polarized light scattering in the Earth atmosphere, Proc. SPIE, Vol.9853, 985305;
3. Diner, D. J., Davis, A., Hancock, B., Gutt, G., Chipman, R. A., and Cairns, B., "Dual-photoelastic-modulator-based polarimetric imaging concept for aerosol remote sensing", Appl. Opt. 46(35), 8428-8445 (2007) – See Table 1;
4. Hasekamp, O. P., and Landgraf, J., "Retrieval of aerosol properties over land surfaces: capabilities of multiple-viewing-angle intensity and polarization measurements", Appl. Opt. 46(16), 3332-3344 (2007) – See Conclusion;
5. Emde, C., Barlakas, V., Cornet, C., Evans, F., Korkin, S., Ota, Y., C.-Labonnote, L., Lyapustin, A., Macke, A., Mayer, B., and Wendisch, M., "IPRT polarized radiative transfer model intercomparison project – Phase A", J. Quant. Spect. Rad. Trans. 164, 8-36 (2015);
6. Lenoble, J., Herman, M., Deuzé, J L., Lafrance, B., Santer, R., and Tanré, D., "A successive order of scattering code for solving the vector equation of transfer in the earth's atmosphere with aerosols", J. Quant. Spect. Rad. Trans. 107, 479-507 (2007).
7. Dubovik, O., Herman, M., Holdak, A., Lapyonok, T., Tanré, D., Deuzé, J. L., Ducos, F., Sinyuk, A., Lopatin, A., "Statistically optimized inversion algorithm for enhanced retrieval of aerosol properties from spectral multi-angle polarimetric satellite observations", Atmos. Meas. Tech. 4, 975–1018 (2011).
8. Dubovik, O., Lapyonok, T., Litvinov, P., Herman, M., Fuertes, D., Ducos, F., Lopatin, A., Chaikovsky, A., Torres, B., Derimian, Y., Huang, X., Aspetsberger, M., and Federspiel, C., "GRASP: a versatile algorithm for characterizing the atmosphere", SPIE: Newsroom, DOI:10.1117/2.1201408.005558, Published Online: September 19, 2014. http://spie.org/x109993.xml (16 March 2016).

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