Ocean Optics 2013: Reflectance Inversion Laboratory 19 July 2013

Goals of Laboratory

To experiment with reflectance model inversion by examining the output sensitivity to basis vectors, initialization, reflectance models.

Code Supplied

1. Main programs (run one at a time)

Rrs_inversion_comparison_MODIS.m (compares RP95, GSM, QAA at MODIS wavelengths)
Rrs_inversion_comparison_SeaWiFS.m (compares RP95 and QAA at SeaWiFS wavelengths)
Rrs_inversion_RP95.m (runs Roesler Perry 1995 with variable wavelengths, data sets)
Rrs_inversion_RB03.m (runs Roesler Boss 2003 with variable wavelengths, data sets)
Rrs_inversion_RPFG.m (runs Roesler Perry 1995 with variable wavelengths, data sets, 4 phytoplankton absorption spectra –functional groups)
GIOP (in folder GIOP, you will find the General IOP model inversion from Jeremy Werdell. See details below in #6 in assignments for more details AFTER you have run the programs above).
Linear Matrix Inversion with uncertainty (Boss and Roesler 2008, see #7 under assignments)

2. Inversion Model programs called by main programs

GSM01_invert and GSM01_cost [*Garver et al. 2002*]
QAA4_MODIS and QAA4_SeaWIFS [*Lee et al. 2002*]
RP95_invert and RP95_cost [*Roesler and Perry 1995*]
RB03_invert and RB03_cost [*Roesler and Boss 2003*]
RPFG_invert and RPFG_cost [*Roesler et al. 2004*]

3. eigenvector functions provided

water_iops_PF_TScorr (called by all inversions, does varying T/S matter?)

phyto_avg_abs (implemented in RP95)
phyto_species_abs (implemented in *Roesler et al. 2004* and *Roesler and Boss 2003*))
phyto_Lee (try using it)
Also, try Bricaud et al 1995 (see next page);

a_{CDOM} and a_{nap} separate with slopes of 0.018+/- 0.002 or 0.01+/- 0.002, respectively or combined a_{cdm} with combined slope of 0.0145+/-0.002

b_{bp} with variable spectral slope (+0.5 to -1.5)

4. Regression function

Fminsearch (not Levenberg-Marquardt, does have some differences)

5. Data files supplied for experimentation and then your data sets to be loaded by you

1. Subsurface irradiance reflectance from Roesler and Perry 1995 (JGR)
   Rrs_E_PugetSound.dat (11 spectra, Puget Sound)
   Rrs_E_GulfMaine (8 spectra, Gulf of Maine)

Rrs_E_DabobBay (8 spectra, Dabob Bay north of Puget Sound)
Rrs_E_WestCoast (8 spectra, transect off Oregon gyre waters to coast)

2. R_L_HL_simulation.dat Simulated hyperspectral reflectances that Curt provided from Hydrolight runs, see excel file for details of runs
3. *Your measured reflectance spectra from cruise (load in format of column 1 is wavelength, columns 2 to n are reflectance spectra 1 to (n-1)*
4. *Your reflectance spectra from Hydrolight simulation*

Assignment (this is an exploratory laboratory exercise, get as far as you can so you can ask questions)

1. Using the provided data sets (from Roesler and Perry 1995 and Curt's simulations), experiment by
    a. comparing the various models on the same data sets
    b. comparing retrieved IOPs as a function of wavelength resolution
    c. comparing retrieved IOPs with inputs from Hydrolight
    d. looking at sensitivity of retrievals to input parameters (a_{phyt}, S_{cdom}, S_{nap}, n_{bb}, Temperature and/or Salinity of water…)
2. Once you are comfortable running the models, load your data sets into the models:
    a. Various ways of determining reflectance
    b. Hydrolight simulations using IOPs from cruise
3. Run supplied inversion models to retrieve IOPs (a_{phytp}, a_{cdom}, b_{bp})
4. How do the retrieved IOPs depend upon
    a. the phytoplankton absorption eigenvector
    b. the slope of a_{cdm} (or the separation of the two)
    c. the slope of b_{bp}
    d. the number of wavelengths (try hyperspectral, then degrade to SeaWiFS, then MODIS wavelengths; what can be done with 3 wavelengths
    e. the model chosen
5. Test the QSSA. Using your IOPs from the cruise,
    a. compute $b_b/(b_b+a)$
    b. compute R = Lu(0-)/Ed(0+) from Hydrolight
    c. how do the spectral shapes of the two compare?
    d. Given $R_{QSSA} \cong (f/Q)\, b_b/(b_b+a)$ and $R_{HL} = Lu/Ed$, what is f/Q? Does it vary spectrally?
    e. People often approximate to $R_{QSSA} \cong (f/Q)\, b_b/a$, what do your results suggest?
6. The General IOP Model The purpose of this code is to allow the user to change both choice of eigen-functions for IOPs as well as relationship of Rrs to IOPs (using literature models) to invert a spectra or Rrs. This approach is similar to 'ensemble forcasting' in atmospheric science. Run many different models. The likely solution is somewhere in between.
    a. Run 'run_giop.m'.
    b. Look at 'giop.m' for the different option you could be using. Modify one of them to see how much impact it has on the inversion.
7. In the folder 'chapter_08_syn' you will invert ZP Lee's synthetic data set using the a code of Boss and Roesler (all can be downloaded from: http://ioccg.org/groups/lee.html). The advantage of this code is in that it provides for

error bars in inverted parameters, based on varying the eigen-functions in the range observed and finding all the solution within the uncertainty in Rrs.

a. run 'IOCGG_ZPL_data_inversion'
b. run the same code but on a field dataset at 'chapter_08_insitu'. There it is called 'IOCGG_in_situ_data_inversion.m'.
c. try to modify these codes to invert a reflectance spectra of your choice

Reference:

Boss, E., W. Peng and C. S. Roesler. 2005. Uncertainties of inherent optical properties obtained from semi-analytical inversions of ocean color. Applied Optics 44: 4074-4085.

Boss, E. and C. Roesler, 2006. Chapter 8, Over Constrained Linear Matrix Inversion with Statistical Selection. In: IOCCG (2006). Remote Sensing of Inherent Optical Properties: Fundamentals, Tests of Algorithms, and Applications. Lee, Z.-P. (ed.), Reports of the International Ocean-Colour Coordinating Group, No. 5, IOCCG, Dartmouth, Canada.

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Hoge, F. and P. Lyon. 1996. Satellite retrieval of inherent optical properties by linear matrix inversion of oceanic radiance models: An analysis of model and radiance measurement errors**.** J. Geophys Res, 101(C7): 16631–16648, DOI: 10.1029/96JC01414

Maritorena S, Siegel DA, Peterson AR. 2002. Optimization of a semianalytical ocean color model for global-scale applications. Appl Optics 41 (15):2705-2714

Lee ZP, Carder KL, Arnone RA. 2002. Deriving inherent optical properties from water color: A multiband quasi-analytical algorithm for optically deep waters. *APPLIED OPTICS*. 20 September 2002 _ Vol. 41, No. 27 _ 5755-5772

Lee, ZP and C. Hu. 2006. Global distribution of Case-1 waters: An analysis from SeaWiFS measurements. *Remote Sensing of Environment* 101 (2006) 270 – 276.

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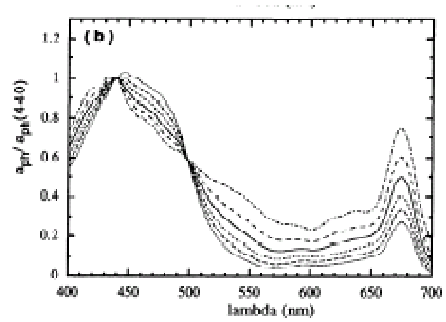
Werdell, P. J., B. A. Franz, S. W. Bailey, G. C. Feldman, E. Boss, V. E. Brando, M. Dowell, T. Hirata, S. J. Lavender, ZP Lee, H.Loisel, S. Maritorena, F. Mélin, T. S. Moore, T. J. Smyth, D. Antoine, E. Devred, O. H. Fanton d'Andon, and A. Mangin, 2013. Generalized ocean color inversion model for retrieving marine inherent optical properties. Appl. Opt. 52, No. 10, 2019-2037.

Phytoplankton absorption eigenvector from
Bricaud et a. 1995
Variable spectral shape in $a^*_{ph}(\lambda)$



$$a^*_{ph}(\lambda) = A(\lambda)\langle chl\rangle^{-B(\lambda)}$$

λ, nm	A	B	r^2	λ, nm	A	B	r^2
400	0.0263	0.282	0.702	402	0.0271	0.281	0.702
404	0.0280	0.282	0.706	406	0.0290	0.281	0.707
408	0.0301	0.282	0.710	410	0.0313	0.283	0.713
417	0.0323	0.286	0.718	414	0.0333	0.291	0.723
416	0.0342	0.293	0.725	418	0.0349	0.296	0.729
420	0.0356	0.299	0.733	422	0.0359	0.306	0.739
424	0.0362	0.313	0.746	426	0.0369	0.316	0.747
428	0.0376	0.317	0.749	430	0.0386	0.314	0.746
432	0.0391	0.318	0.750	434	0.0395	0.324	0.754
436	0.0399	0.328	0.757	438	0.0401	0.332	0.761
440	0.0403	0.332	0.762	442	0.0398	0.339	0.767
444	0.0390	0.348	0.774	446	0.0383	0.355	0.779
448	0.0375	0.360	0.783	450	0.0371	0.359	0.781
452	0.0365	0.362	0.783	454	0.0358	0.366	0.788
456	0.0354	0.367	0.789	458	0.0351	0.368	0.791
460	0.0350	0.365	0.789	462	0.0347	0.366	0.791
464	0.0343	0.368	0.792	466	0.0339	0.369	0.793
468	0.0333	0.369	0.793	470	0.0332	0.368	0.792
472	0.0325	0.371	0.792	474	0.0318	0.375	0.793
476	0.0312	0.378	0.793	478	0.0306	0.379	0.793
480	0.0301	0.377	0.791	482	0.0296	0.377	0.790
484	0.0290	0.376	0.788	486	0.0285	0.373	0.786
488	0.0279	0.369	0.783	490	0.0274	0.361	0.779
492	0.0267	0.356	0.774	494	0.0258	0.349	0.770
496	0.0249	0.341	0.763	498	0.0240	0.332	0.756
500	0.0230	0.321	0.747	502	0.0220	0.311	0.735
504	0.0209	0.300	0.722	506	0.0199	0.288	0.706
508	0.0189	0.275	0.686	510	0.0180	0.260	0.664
512	0.0171	0.249	0.641	514	0.0163	0.237	0.615
516	0.0156	0.224	0.578	518	0.0149	0.211	0.541
520	0.0143	0.196	0.498	522	0.0137	0.184	0.459
524	0.0131	0.173	0.417	526	0.0126	0.162	0.374
528	0.0121	0.151	0.332	530	0.0117	0.139	0.287
532	0.0113	0.129	0.248	534	0.0108	0.119	0.211
536	0.0104	0.109	0.176	538	0.0100	0.100	0.147
540	0.0097	0.090	0.116	542	0.0093	0.081	0.092
544	0.0090	0.073	0.074	546	0.0086	0.066	0.057
548	0.0083	0.059	0.044	550	0.0080	0.052	0.033
552	0.0076	0.044	0.023	554	0.0072	0.036	0.014
556	0.0068	0.027	0.007	558	0.0065	0.016	0.002
560	0.0062	0.016	0.002	562	0.0059	0.013	0.001
564	0.0057	0.010	0.001	566	0.0055	0.007	0.000
568	0.0054	0.007	0.000	570	0.0053	0.005	0.000
572	0.0053	0.011	0.001	574	0.0052	0.018	0.003
576	0.0052	0.022	0.004	578	0.0052	0.028	0.007
580	0.0053	0.035	0.013	582	0.0054	0.040	0.016
584	0.0055	0.050	0.028	586	0.0055	0.056	0.033
588	0.0056	0.065	0.043	590	0.0056	0.073	0.058
592	0.0057	0.081	0.072	594	0.0056	0.088	0.084
596	0.0056	0.093	0.097	598	0.0055	0.095	0.098
600	0.0054	0.092	0.086	602	0.0054	0.088	0.078
604	0.0055	0.086	0.083	606	0.0055	0.082	0.078
608	0.0056	0.076	0.067	610	0.0057	0.071	0.060
612	0.0059	0.069	0.063	614	0.0060	0.066	0.062
616	0.0062	0.063	0.056	618	0.0063	0.064	0.061
620	0.0065	0.064	0.063	622	0.0066	0.068	0.073
624	0.0067	0.071	0.083	626	0.0068	0.074	0.092
628	0.0069	0.076	0.099	630	0.0071	0.078	0.104
632	0.0073	0.080	0.109	634	0.0074	0.084	0.119
636	0.0075	0.088	0.128	638	0.0076	0.093	0.138
640	0.0077	0.098	0.149	642	0.0078	0.105	0.164
644	0.0079	0.113	0.177	646	0.0080	0.119	0.189
648	0.0081	0.123	0.195	650	0.0083	0.124	0.197
652	0.0085	0.125	0.200	654	0.0089	0.124	0.203
656	0.0095	0.122	0.206	658	0.0104	0.120	0.218
660	0.0115	0.121	0.235	662	0.0129	0.125	0.269
664	0.0144	0.131	0.308	666	0.0161	0.137	0.345
668	0.0176	0.143	0.377	670	0.0189	0.149	0.404
672	0.0197	0.153	0.424	674	0.0201	0.157	0.439
675	0.0201	0.158	0.445	676	0.0200	0.159	0.445
678	0.0193	0.158	0.444	680	0.0182	0.155	0.433
682	0.0166	0.148	0.406	684	0.0145	0.138	0.368
686	0.0124	0.124	0.315	688	0.0102	0.107	0.247
690	0.0083	0.086	0.164	692	0.0067	0.065	0.094
694	0.0054	0.042	0.036	696	0.0044	0.015	0.004
698	0.0036	−0.016	0.003	700	0.0030	−0.034	0.012