

Two-Direction Retrieval for Satellite Observation in VNIR

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Two-Direction Retrieval for Satellite Observation in VNIR

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Prof. Tasuku Tanaka
Dr. Sisir Kumar Dash
Yasuhiro Yoshinaga

Yamaguchi University
Graduate School of Science and Engineering

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1. Background and theoretical basis

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1. We retrieve several physical quantities by satellite observing data.
2. We have 1 observing data, for 1 pixel, in 1 band, in general.
3. If spectral relationship among bands is well known, we can retrieve more than 1 physical quantity from 1 observing data.
But this is not the case for aerosol optical thickness in atmosphere.
4. The primary goal in VNIR satellite observation is to retrieve both surface reflectance (r) and aerosol optical thickness(τ).
5. The retrieving scheme for “ r and τ ” is successful for ocean but not for land.
6. Universal scheme for “ r and τ ” both on ocean and on land is required.

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Retrieval of “ r and τ ”

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1. Spectral Extrapolation Method (Current Method)
Linear equation and extrapolation
- “ r ” is assumed 0 and “ τ ” is retrieved in NIR.
- “ τ ” in V band is extrapolated from NIR.
- “ r ” is retrieved.
2. Two Directional Method
Quadratic equation
3. Merit of Two Directional Method
No Spectral extrapolation of “ τ ” needed
Universal retrieval algorithm for Ocean and Land

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Universal Retrieve

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Radiative transfer Process

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Plane Parallel Atmospheric Model

Observing Equation

$F(i_s)$ $I(0, i_1)$
 τ r (Lambert Surface)

$$\rho(\tau, r : \vec{i}_1, \vec{i}_s) = \frac{S(\tau, \vec{i}_1, \vec{i}_s)}{4\mu_1\mu_s} + \frac{r}{1 - r\bar{s}} \left[\frac{t(\mu_s)}{\mu_s} + \exp(-\frac{\tau}{\mu_s}) \right] \left[\frac{t(\mu_1)}{\mu_1} + \exp(-\frac{\tau}{\mu_1}) \right]$$

μ_n : cosine of the zenith angle of the direction \vec{i}_n

$$\rho(\tau, i_1, i_s) = \frac{\pi I(0, i_1)}{\mu_1 F_0}, \quad I(0, i_1) = \frac{S(\tau, i_1, i_s)}{4\pi\mu_1} F_0$$

$$t(\mu_1) = \int \frac{T(\tau, i_1, i_4)}{4\pi} d\Omega_4, \quad s(\mu_1) = \int \frac{S(\tau, i_1, i_4)}{4\pi} d\Omega_4, \quad \bar{s} = \frac{1}{\pi} \int s(\mu_1) d\mu_1$$

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Retrieval of Radiative Transfer

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1st order approximation

$$\rho(0, i_1) = P(i_1, i_s)\tau + r$$

2nd order approximation

$$\rho(0, i_1) = P(i_1, i_s)\tau + r + s_{00}(i_1, i_s)\tau^2 + s_{21}(i_1, i_s)(\log \tau)\tau^2 - \left(\frac{(1 - a(i_s))}{\mu_s} + \frac{(1 - b(i_1))}{\mu_1} \right) \tau^2$$

-No easy analytic form of the 2nd approximation for function “S”
-We employ “6 S” code for calculating function “S”
-Try and error approach by “6 S” is employed to retrieve it is noted “ τ ” and other terms include both Rayleigh and Mie scattering

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2. GLI Data

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Date of Launch	14, December 2002
Spectral range	0.375 - 12.5μm
No. of Spectral Bands	36
Instantaneous Field of View (IFOV)	10nm(VNIR/1km)
Scanning angle	45° (Ground Surface 1600km)
S/N, NEAT	800, 0.1K(1.25mrad IFOV bands)
Quantization	12 bits
MTF	0.35
Polarization sensitivity	Under 2%
Tilting angle	-20°, 0°, +20°
Coarse Data Transmission (DTL:Direct Transmission for Local user)	(443nm, 555nm, 667nm, 11.95mm)
Builder	NASDA, Japan

GLI Wave length

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Band Number	Central wavelength (nm)	Rayleigh Optical Thickness
1	380	0.44881
2	400	0.36092
3	412	0.31927
4	443	0.23887
5	460	0.20378
6	490	0.15699
7	520	0.12312
8	545	0.10165
9	565	0.08778
10	625	0.06823
11	666	0.04827
12	678	0.04199
13	680	0.04137
14	710	0.03474
15	710	0.03474
16	749	0.02784
17	763	0.02687
18	865	0.01665
19	865	0.01665

Table 4 Rayleigh optical thickness showing for GLI bands (1-19)

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GLI, Oct. 3, '03, Arabian Sea

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R(678nm):G(545nm):B(460nm)



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Chlorophyll Concentration by GLI

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-Chlorophyll Concentration (Nadir Viewing)



-Chlorophyll Concentration (+20°)

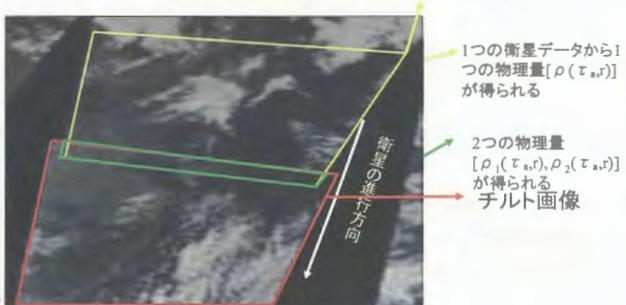


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2方向観測データ

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直下画像

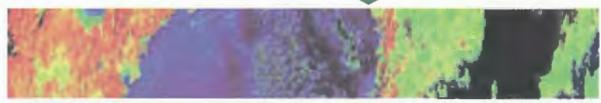


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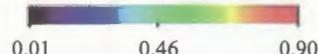
ρ 画像

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直下画像



チルト画像

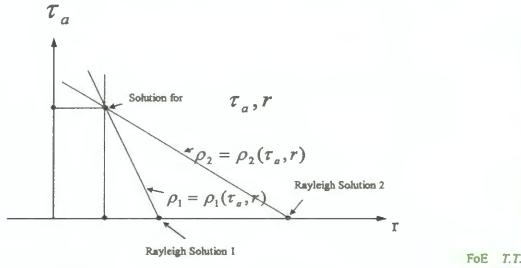


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3. Retrieval Scheme

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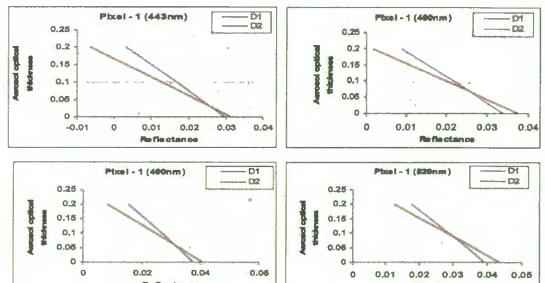
- Select the corresponding pairs of the identical pixel from the two different looking directions data
- Obtain the normalized reflectance "ρ" from observed data
- Assuming "τ", evaluate the surface reflectance, r1, r2, by "6S"
- Crossing Point of "ρ" of 2 direction is the solution for "r" and "τ"



4. Result

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Ocean



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Generalized Reflectance for Ocean

Wavelength (nm)	Viewing	Pixel-1	Pixel-81
443	D1	0.139649	0.136116
	D2	0.152415	0.162036
460	D1	0.126284	0.124583
	D2	0.158919	0.138368
490	D1	0.108381	0.107156
	D2	0.119284	0.120565
520	D1	0.092834	0.088368
	D2	0.103061	0.099988
545	D1	0.061668	0.077175
	D2	0.091107	0.088823
565	D1	0.071033	0.064170
	D2	0.078318	0.073721

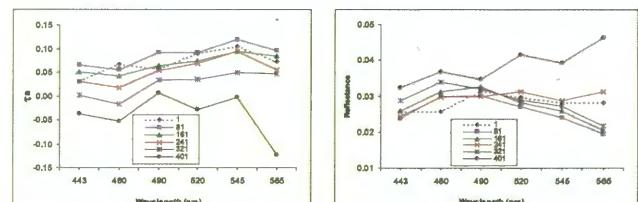
Table 5 GLI Generalised Reflectance (ρ) for six bands in D1 and D2

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Retrieved r and τ

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Pixel No	Wavelength	1	81	161	241	321	401
443		0.0257	0.0310	0.0238	0.0083	0.0259	0.0508
460		0.0257	0.0670	0.0269	0.0557	0.0312	0.0426
480		0.0314	0.0570	0.0301	0.0914	0.0325	0.0436
520		0.0287	0.0600	0.0271	0.0927	0.0283	0.0748
545		0.0283	0.1055	0.0240	0.1198	0.0258	0.0851
565		0.0261	0.0738	0.0198	0.0869	0.0205	0.0850



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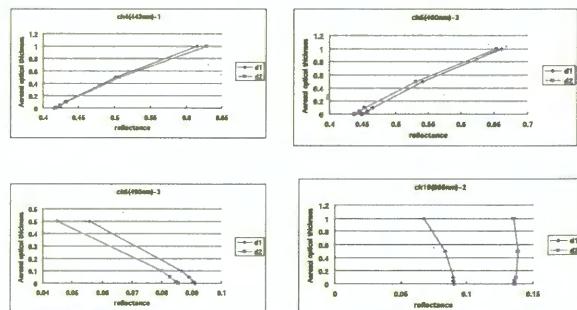
Chlorophyll Concentration

Pixel No	Chl-a (D1)	Chl-a (D2)	Estimated Chlorophyll
1	2.43	2.98	3.19
81	0.41	1.11	0.95
161	0.37	0.58	0.58
241	2.93	3.92	3.86
321	0.36	0.59	0.57
401	3.41	3.74	NA

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Land



陸域における τ_a と r の関係

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5. Conclusion

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1. We can retrieve both optical thickness and surface reflectance from two direction data on the ocean.
2. We can not retrieve optical thickness and surface reflectance from two direction data on the land.
3. For land retrieval, we may need to take into consideration the difference between surface reflectance on the spot and those around the spot.
4. We have to solve cubic equations, if we take into consideration the circumference effect of surface reflectance.
5. The problem is different signs of slope of iso-generalized-reflectance around "0", between on ocean and on land.

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