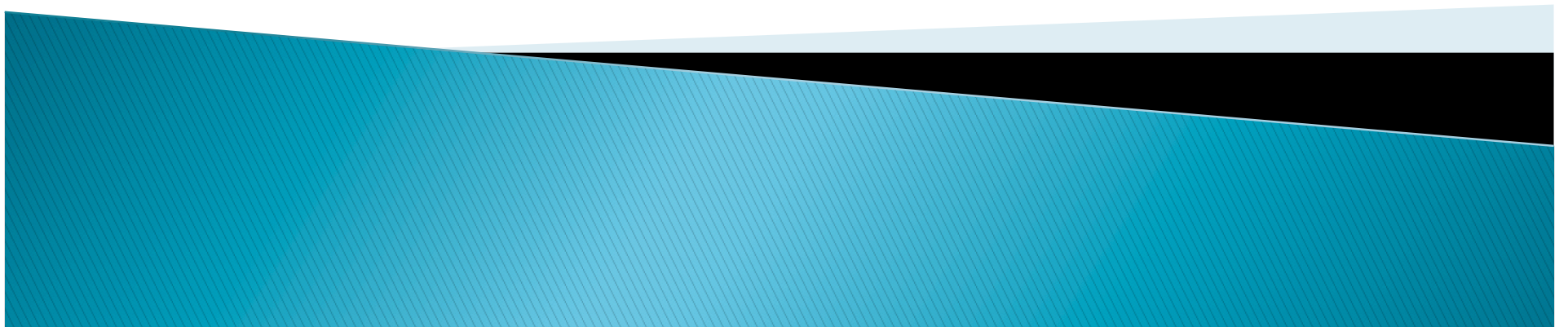
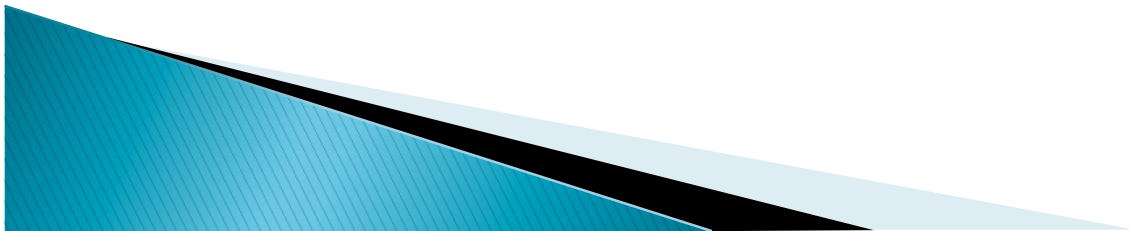


Narrowband to broadband conversions of land surface albedo I Algorithms

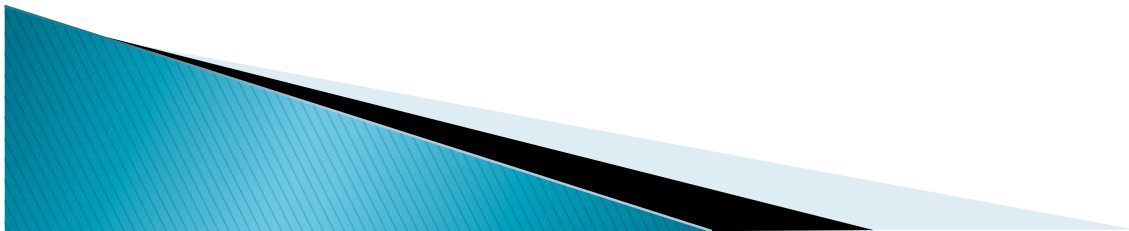
Shunlin Liang
2000



- ▶ High resolution, narrowband observation
- ▶ Broadband Albedo
 - Used to be estimated from broadband sensors
 - Accurate determination requires multispectral sensors (narrowband observation)

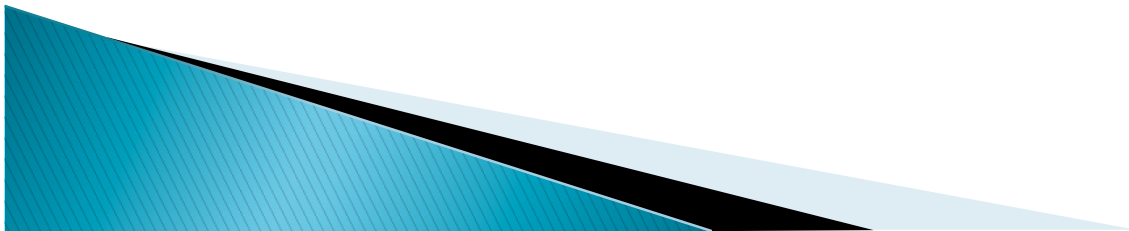


- ▶ The derivation of surface broadband albedos from narrowband observations requires:
 - A. Atmospheric correction
 - B. Angular model: directional reflectance to spectral albedo
 - C. Narrowband to broadband conversion



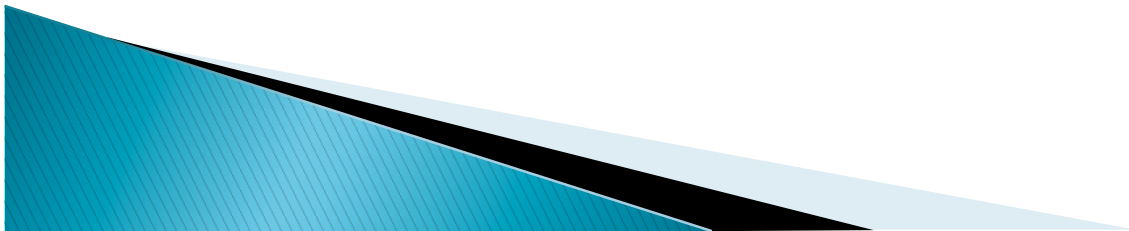
Broadband albedo

- ▶ Not only measure surface reflective properties
- ▶ But also, depend on atmospheric conditions
 - Downward distribution at the bottom of atmosphere is the weighting function for converting spectral albedos to broadband albedos



Objective

- ▶ Providing simple formulae for compute broadband albedos from narrowband sensors
 - Total shortwave albedo
 - Total visible
 - Direct visible
 - Diffuse visible
 - Total Near-IR
 - Direct Near-IR
 - Diffuse Near-IR



Methods

- ▶ Simulation: MODTRAN, SBDART

$$F = F_0 + \frac{r_s}{1 - r_s \bar{r}} \pi \mu_i E_0 \gamma(\mu_i) \bar{r} \quad (2)$$

$$\alpha(\theta_i; \Lambda) = \frac{F_u(\theta_i; \Lambda)}{F_d(\theta_i; \Lambda)} = \frac{\int_{\lambda_1}^{\lambda_2} F_u(\theta_i; \lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} F_d(\theta_i; \lambda) d\lambda}, \quad (3)$$

- ▶ Narrowband albedo: downward flux and sensor spectral reflectance
- ▶ Broadband albedo: ratio of upwelling flux to the downward flux
- ▶ Regression analyses to generate conversion formulae

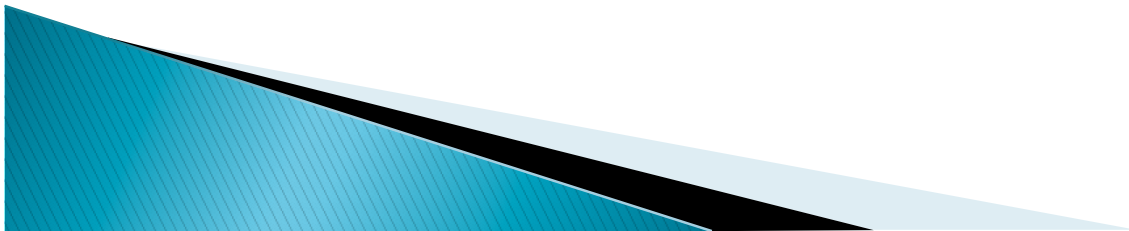


Table 1
Spectral bands of the narrowband sensors

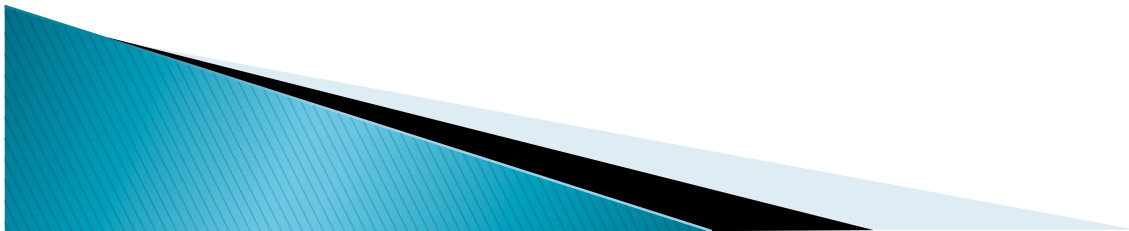
Sensors	Spectral bands and their wavelength ranges (μm)								
	1	2	3	4	5	6	7	8	9
ASTER	0.52–0.6	0.63–0.69	0.78–0.86	1.6–1.7	2.15–2.18	2.18–2.22	2.23–2.28	2.29–2.36	2.36–2.43
AVHRR-14	0.57–0.71	0.72–1.01	–	–	–	–	–	–	–
GOES-8	0.52–0.72	–	–	–	–	–	–	–	–
ETM+	0.45–0.51	0.52–0.6	0.63–0.69	0.75–0.9	1.55–1.75	–	2.09–2.35	–	–
MISR	0.42–0.45	0.54–0.55	0.66–0.67	0.85–0.87	–	–	–	–	–
MODIS	0.62–0.67	0.84–0.87	0.46–0.48	0.54–0.56	1.23–1.25	1.63–1.65	2.11–2.15	–	–
POLDER	0.43–0.46	0.66–0.68	0.74–0.79	0.84–0.88	–	–	–	–	–
VEGETATION	0.43–0.47	0.61–0.68	0.78–0.89	1.58–1.75	–	–	–	–	–



Conversion formulae_ASTER

$$\alpha_{\text{short}} = 0.484\alpha_1 + 0.335\alpha_3 - 0.324\alpha_5 + 0.551\alpha_6 \\ + 0.305\alpha_8 - 0.367\alpha_9 - 0.0015$$

$$\alpha_{\text{visible}} = 0.820\alpha_1 + 0.183\alpha_2 - 0.034\alpha_3 - 0.085\alpha_4 \\ - 0.298\alpha_5 + 0.352\alpha_6 + 0.239\alpha_7 - 0.240\alpha_9 \\ - 0.001$$



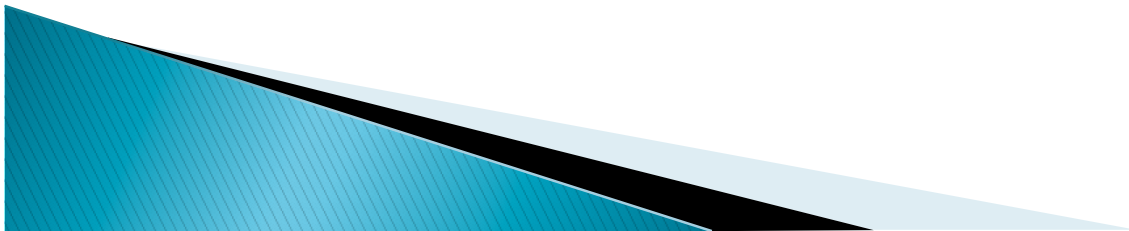
$$\begin{aligned}\alpha_{\text{diffuse-visible}} = & 0.911\alpha_1 + 0.089\alpha_2 - 0.040\alpha_3 - 0.109\alpha_4 \\ & - 0.388\alpha_5 + 0.441\alpha_6 + 0.316\alpha_7 \\ & - 0.303\alpha_9 - 0.002\end{aligned}$$

$$\begin{aligned}\alpha_{\text{direct-visible}} = & 0.781\alpha_1 + 0.224\alpha_2 - 0.032\alpha_3 - 0.070\alpha_4 \\ & - 0.257\alpha_5 + 0.308\alpha_6 + 0.200\alpha_7 - 0.208\alpha_9 \\ & - 0.001\end{aligned}$$

$$\alpha_{\text{NIR}} = 0.654\alpha_3 + 0.262\alpha_4 - 0.391\alpha_5 + 0.500\alpha_6 - 0.002$$

$$\begin{aligned}\alpha_{\text{diffuse-NIR}} = & 0.835\alpha_3 + 0.033\alpha_4 - 0.191\alpha_5 + 0.352\alpha_6 \\ & - 0.002\end{aligned}$$

$$\begin{aligned}\alpha_{\text{direct-NIR}} = & 0.629\alpha_3 + 0.295\alpha_4 - 0.418\alpha_5 \\ & + 0.517\alpha_6 - 0.001.\end{aligned}\tag{4}$$



Conversion Formulae_AVHRR

$$\begin{aligned}\alpha_{\text{short}} = & -0.3376\alpha_1^2 - 0.2707\alpha_2^2 + 0.7074\alpha_1\alpha_2 \\ & + 0.2915\alpha_1 + 0.5256\alpha_2 + 0.0035.\end{aligned}\quad (6)$$

$$\alpha_{\text{visible}} = 0.0074 + 0.5975\alpha_1 + 0.4410\alpha_1^2$$

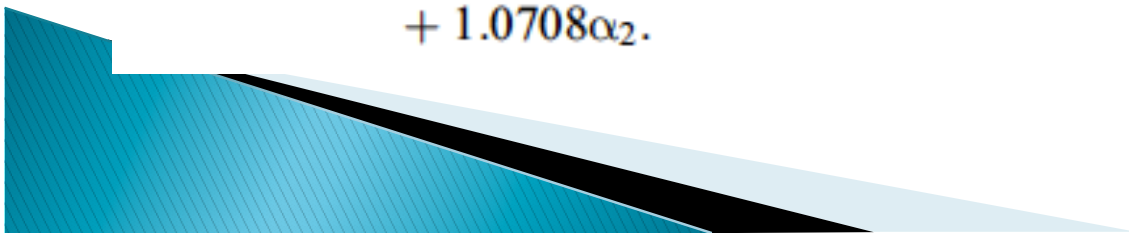
$$\alpha_{\text{diffuse-visible}} = 0.0093 + 0.5190\alpha_1 + 0.5257\alpha_1^2$$

$$\alpha_{\text{direct-visible}} = 0.0051 + 0.6685\alpha_1 + 0.3648\alpha_1^2$$

$$\alpha_{\text{NIR}} = -1.4759\alpha_1^2 - 0.6536\alpha_2^2 + 1.8591\alpha_1\alpha_2 + 1.063\alpha_2$$

$$\begin{aligned}\alpha_{\text{diffuse-NIR}} = & -0.628\alpha_1^2 - 0.3047\alpha_2^2 + 0.8476\alpha_1\alpha_2 \\ & + 1.0113\alpha_2 + 0.002\end{aligned}$$

$$\begin{aligned}\alpha_{\text{direct-NIR}} = & -1.5696\alpha_1^2 - 0.6961\alpha_2^2 + 1.9679\alpha_1\alpha_2 \\ & + 1.0708\alpha_2.\end{aligned}\quad (7)$$



Conversion Formulae_GOES

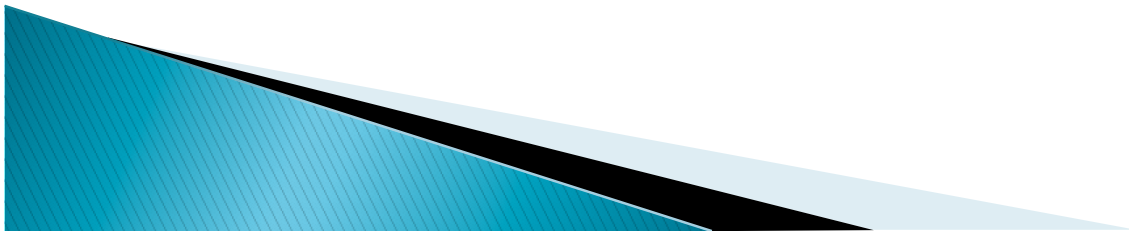
$$\alpha_{\text{short}} = 0.0759 + 0.7712\alpha. \quad (9)$$

For visible albedos, a 2nd-order polynomial function can produce good fits (Eq. (10)):

$$\alpha_{\text{visible}} = -0.0084 + 0.689\alpha + 0.3604\alpha^2$$

$$\alpha_{\text{diffuse-visible}} = -0.006 + 0.6119\alpha + 0.443\alpha^2$$

$$\alpha_{\text{direct-visible}} = -0.0111 + 0.7586\alpha + 0.2862\alpha^2. \quad (10)$$



Conversion Formulae_Landsat TM/ ETM+

$$\alpha_{\text{short}} = 0.356\alpha_1 + 0.130\alpha_3 + 0.373\alpha_4 + 0.085\alpha_5 \\ + 0.072\alpha_7 - 0.0018$$

$$\alpha_{\text{visible}} = 0.443\alpha_1 + 0.317\alpha_2 + 0.240\alpha_3$$

$$\alpha_{\text{diffuse-visible}} = 0.556\alpha_1 + 0.281\alpha_2 + 0.163\alpha_3 - 0.0014$$

$$\alpha_{\text{direct-visible}} = 0.390\alpha_1 + 0.337\alpha_2 + 0.274\alpha_3$$

$$\alpha_{\text{NIR}} = 0.693\alpha_4 + 0.212\alpha_5 + 0.116\alpha_7 - 0.003$$

$$\alpha_{\text{diffuse-NIR}} = 0.864\alpha_4 + 0.158\alpha_7 - 0.0043$$

$$\alpha_{\text{direct-NIR}} = 0.659\alpha_4 + 0.342\alpha_5 - 0.0033. \quad (11)$$

Conversion Formulae_MISR

$$\alpha_{\text{short}} = 0.126\alpha_2 + 0.343\alpha_3 + 0.415\alpha_4 + 0.0037$$

$$\alpha_{\text{visible}} = 0.381\alpha_1 + 0.334\alpha_2 + 0.287\alpha_3$$

$$\alpha_{\text{diffuse-visible}} = 0.478\alpha_1 + 0.306\alpha_2 + 0.219\alpha_3 - 0.001$$

$$\alpha_{\text{direct-visible}} = 0.335\alpha_1 + 0.349\alpha_2 + 0.317\alpha_3$$

$$\alpha_{\text{NIR}} = -0.387\alpha_1 - 0.196\alpha_2 + 0.504\alpha_3 + 0.830\alpha_4 + 0.011$$

$$\alpha_{\text{diffuse-NIR}} = -0.240\alpha_1 + 0.269\alpha_3 + 0.866\alpha_4 + 0.003$$

$$\alpha_{\text{direct-NIR}} = -0.407\alpha_1 - 0.226\alpha_2 + 0.536\alpha_3 + 0.826\alpha_4 + 0.012.$$

(14)



Conversion Formulae_MODIS

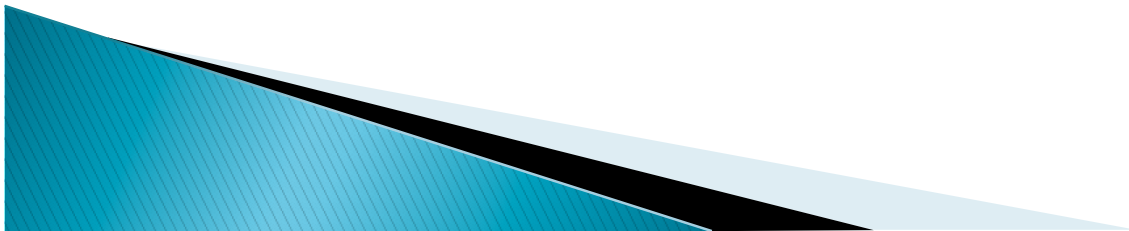
$$\alpha_{\text{short}} = 0.160\alpha_1 + 0.291\alpha_2 + 0.243\alpha_3 + 0.116\alpha_4 \\ + 0.112\alpha_5 + 0.081\alpha_7 - 0.0015$$

$$\alpha_{\text{visible}} = 0.331\alpha_1 + 0.424\alpha_3 + 0.246\alpha_4$$

$$\alpha_{\text{diffuse-visible}} = 0.246\alpha_1 + 0.528\alpha_3 + 0.226\alpha_4 - 0.0013$$

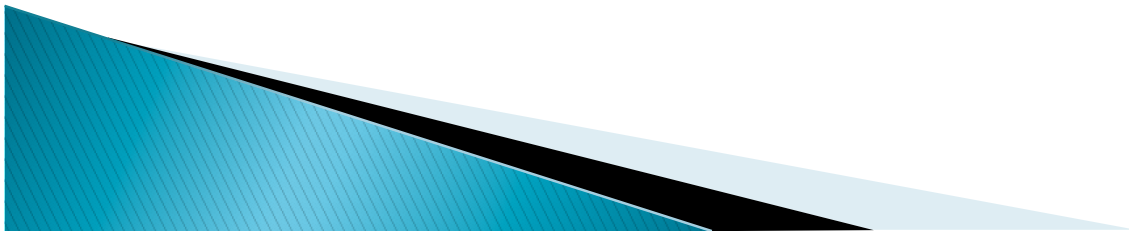
$$\alpha_{\text{direct-visible}} = 0.369\alpha_1 + 0.374\alpha_3 + 0.257\alpha_4$$

$$\alpha_{\text{NIR}} = 0.039\alpha_1 + 0.504\alpha_2 - 0.071\alpha_3 + 0.105\alpha_4 \\ + 0.252\alpha_5 + 0.069\alpha_6 + 0.101\alpha_7$$



$$\alpha_{\text{diffuse-NIR}} = 0.085\alpha_1 + 0.693\alpha_2 - 0.146\alpha_3 + 0.176\alpha_4 \\ + 0.146\alpha_5 + 0.043\alpha_7 - 0.0021$$

$$\alpha_{\text{direct-NIR}} = 0.037\alpha_1 + 0.479\alpha_2 - 0.068\alpha_3 \\ + 0.0976\alpha_4 + 0.266\alpha_5 + 0.0757\alpha_6 \\ + 0.107\alpha_7. \quad (15)$$



Conversion Formulae_POLDER

$$\alpha_{\text{short}} = 0.112\alpha_1 + 0.388\alpha_2 - 0.266\alpha_3 + 0.668\alpha_4 + 0.0019$$

$$\alpha_{\text{visible}} = 0.533\alpha_1 + 0.412\alpha_2 + 0.215\alpha_3 - 0.168\alpha_4 + 0.0046$$

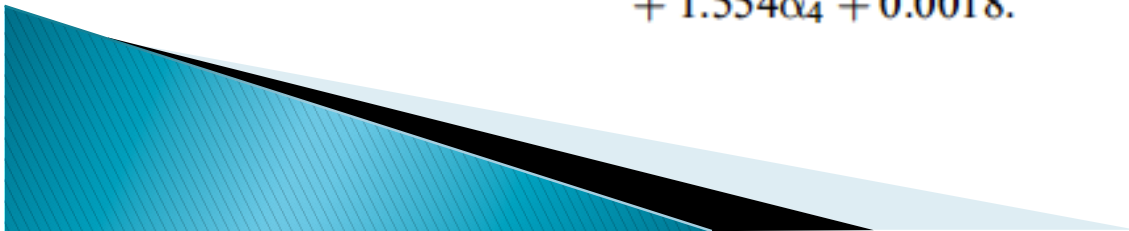
$$\alpha_{\text{diffuse-visible}} = 0.615\alpha_1 + 0.335\alpha_2 + 0.196\alpha_3 - 0.153\alpha_4 + 0.0036$$

$$\alpha_{\text{direct-visible}} = 0.495\alpha_1 + 0.447\alpha_2 + 0.223\alpha_3 - 0.175\alpha_4$$

$$\alpha_{\text{NIR}} = -0.397\alpha_1 + 0.451\alpha_2 - 0.756\alpha_3 + 1.498\alpha_4 + 0.0013$$

$$\alpha_{\text{diffuse-NIR}} = -0.209\alpha_1 + 0.279\alpha_2 - 0.210\alpha_3 + 1.045\alpha_4$$

$$\alpha_{\text{direct-NIR}} = -0.425\alpha_1 + 0.474\alpha_2 - 0.825\alpha_3 + 1.554\alpha_4 + 0.0018. \quad (16)$$



Conversion Formulae_VEGETATION

$$\alpha_{\text{short}} = -0.0022 + 0.3512\alpha_1 + 0.1629\alpha_2 + 0.3415\alpha_3 + 0.1651\alpha_4$$

$$\alpha_{\text{visible}} = 0.0033 + 0.5717\alpha_1 + 0.4277\alpha_2$$

$$\alpha_{\text{diffuse-visible}} = 0.0029 + 0.6601\alpha_1 + 0.3391\alpha_2$$

$$\alpha_{\text{direct-visible}} = 0.0034 + 0.5310\alpha_1 + 0.4684\alpha_2$$

$$\alpha_{\text{NIR}} = -0.0038 + 0.6799\alpha_3 + 0.3157\alpha_4$$

$$\alpha_{\text{diffuse-NIR}} = -0.0040 + 0.8495\alpha_3 + 0.1350\alpha_4$$

$$\alpha_{\text{direct-NIR}} = -0.0033 + 0.6567\alpha_3 + 0.3382\alpha_4. \quad (17)$$

