NASA Technical Memorandum 104538

A Simplified Treatment of SiB's Land Surface Albedo Parameterization

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April 1991

(NASA-TM-104538) A SIMPLIFIED TREATMENT OF SiB'S LAND SURFACE ALBEDO PARAMETERIZATION (NASA) 14 p CSCL 04B

N91-20598

Unclas

G3/47 0007616

NASA

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NASA
National Aeronautics and
Space Administration

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1991

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Abstract

The surface albedo parameterization presented by *Sellers* [1985] and *Sellers et al.* [1986] is simplified by assuming that the reflectance of direct solar radiation is a simple function of solar zenith angle. The function chosen contains three parameters that vary with vegetation type, greenness, and leaf area index. Tables of parameter values are presented. Using these tables, SiB's absorbances of direct solar radiation can be reproduced with an average relative error of less than 0.5%. Finally, the direct reflectance function is integrated over zenith angle to produce an equation for the surface reflectance of diffuse radiation.

1 Introduction

Koster and Suarez [1991] present a strategy for modeling land surface processes in general circulation models (GCMs) in which the surface of each grid box is assumed to consist of a "mosaic" of independent, homogeneous vegetation "tiles." Each tile within a grid box is covered by a specified type, amount, and state of vegetation (or by bare soil, permanent ice, or open water), and each tile maintains its own state variables and budgets of heat and moisture. The effects of vegetation within each tile are modeled using a simplified version of SiB, the parameterization proposed by *Sellers et al.* [1986].

The purpose of this report is to present the simplified version of SiB's albedo formulation used by *Koster and Suarez* [1991] in the "mosaic" model.

In SiB, each GCM grid box is assumed to be covered uniformly by a single biome consisting of a mixture of trees, ground cover, and bare soil. For each biome, one may specify the fraction of one "type" of tree (say, broadleaf deciduous, needleleaf, or some idealized mixed type), one "type" of ground cover (such as grass), and of course, the fraction of bare soil. The reflectance of the tree canopy is combined with that of the ground cover and soil (through areal-weighted averaging) to produce a net reflectance for the grid square.

In the "mosaic" model of *Koster and Suarez* [1991], each (non-ocean, non-ice) tile consists of a single vegetation cover or bare soil. The current version of the model selects the tile vegetation or soil type from the different tree, ground cover, and soil types used to build the SiB biomes. The present report concentrates on reproducing SiB's reflectance calculations for these constituent types. By reproducing the constituent reflectances, the net grid square reflectances calculated with either SiB or the mosaic strategy for a given vegetation mixture will be the same. (Small differences will occur for tree canopy and ground cover mixtures, because SiB allows the ground cover to lie below the canopy and thereby affect the canopy reflectance.)

We used SiB's algorithm to compute the reflectances of direct radiation for surfaces covered completely by each of six constituent vegetation types employed by SiB. We then used these calculations to parameterize the reflectances, as described in the next section. Tables of the relevant parameters are presented below.

2 Calculation of Surface Reflectances

The calculation of the net incoming solar radiation requires reflectance values for both the direct and diffuse components of both visible and near-infrared solar radiation. In SiB, these reflectances depend only on vegetation type, solar zenith angle, leaf area index (LAI), and the fraction g of leaves that are alive (the *greenness*). The mosaic model reproduces SiB's reflectances using the following parameterization of SiB's "two-stream approximation" reflectance calculation [*Sellers*, 1985].

We found that for a given vegetation type and over reasonable ranges of LAI and g, SiB's reflectances for the direct components of solar radiation can be approximated very closely by

$$\mathcal{R}(\mu) = \alpha(LAI, g) - \frac{\beta(LAI, g)\,\mu}{\gamma(LAI, g) + \mu}, \qquad (1)$$

where $\mathcal{R}(\mu)$ is the reflectance of the direct beam, μ is the cosine of the solar zenith angle, and α, β, and γ are fitted parameters. (The visible and near-infrared components of direct radiation require different sets of parameter values for (1).)

Reflectances $\overline{\mathcal{R}}$ for the diffuse components of the incident radiation, which are assumed in SiB to be independent of μ, may be obtained by integrating (1) over the hemisphere:

$$\overline{\mathcal{R}} = 2\int_0^{\frac{\pi}{2}} \mathcal{R}(\mu)\cos\theta\sin\theta d\theta. \tag{2}$$

Using (1), this gives

$$\overline{\mathcal{R}} = \alpha - \beta + 2\beta\gamma\,(1 - \gamma\ln\frac{1+\gamma}{\gamma}). \tag{3}$$

The parameters α, β, and γ for a vegetation type with given LAI and g can be obtained through linear interpolation on the values provided in Tables 1 through 6. Values are presented for six vegetation types: broadleaf evergreen trees, broadleaf deciduous trees, needleleaf trees, ground cover, broadleaf shrubs, and dwarf trees. The listed LAI values assume complete (100%) coverage of the surface by the vegetation. Values used for the reflectance of the ground beneath the canopy are listed in Table 7.

When tested over realistic ranges of LAI and g, (1) used in conjunction with Tables 1 through 6 reproduced SiB's direct radiation absorbances with an average relative error of less than 0.3% and never with an error higher than 10% for ground cover and 2% for the other vegetation types.

The diffuse reflectances computed with (3), however, do not match those of SiB. Although the hemispherical integration (2) is consistent with SiB's assumption of isotropic incident diffuse radiation, the diffuse reflectances produced with the two-stream calculation are somewhat higher than those produced with (3). This does not result from inaccuracy in (1); careful numerical integration of the two-stream direct reflectances from SiB reproduces the results of (3). We will use (3) in future GCM simulations and recommend that it be substituted for SiB's diffuse results.

References

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Sellers, P. J., 1985: Canopy reflectance, photosynthesis and transpiration, *Int. J. Rem. Sens.*, **6**, 1335-1372.

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Table 1: Reflectance parameters appearing in (1) and (3), for broadleaf trees. The three numbers in each box are α, β, and γ, in that order.

	Broadleaf Evergreen				*Broadleaf Deciduous*			
	Visible		*NIR*		*Visible*		*NIR*	
LAI	*g=.33*	*g=.67*	*.33*	*.67*	*.33*	*.67*	*.33*	*.67*
	0.0808	0.0788	0.2867	0.3564	0.0803	0.0782	0.2848	0.3544
.5	0.0153	0.0135	0.1291	0.1939	0.0148	0.0131	0.1217	0.1781
	0.0814	0.0760	0.1582	0.1934	0.0834	0.0789	0.1347	0.1440
	0.0796	0.0775	0.2840	0.3573	0.0790	0.0770	0.2819	0.3550
1.0	0.0372	0.0354	0.1707	0.2357	0.0357	0.0342	0.1522	0.2067
	0.1361	0.1336	0.2581	0.3141	0.1252	0.1235	0.1871	0.2217
	0.0792	0.0771	0.2828	0.3577	0.0785	0.0765	0.2804	0.3553
1.5	0.0506	0.0487	0.1969	0.2598	0.0462	0.0446	0.1713	0.2221
	0.2078	0.2034	0.3227	0.3818	0.1558	0.1531	0.2277	0.2629
	0.0790	0.0769	0.2822	0.3580	0.0784	0.0763	0.2798	0.3555
2.0	0.0587	0.0568	0.2125	0.2735	0.0524	0.0508	0.1820	0.2301
	0.2650	0.2622	0.3635	0.4200	0.1927	0.1912	0.2515	0.2839
	0.0789	0.0768	0.2819	0.3581	0.0783	0.0762	0.2795	0.3555
2.5	0.0630	0.0611	0.2216	0.2810	0.0554	0.0539	0.1879	0.2342
	0.2986	0.2969	0.3882	0.4415	0.2131	0.2122	0.2651	0.2947
	0.0789	0.0768	0.2818	0.3581	0.0783	0.0762	0.2793	0.3556
3.0	0.0652	0.0633	0.2267	0.2851	0.0569	0.0554	0.1910	0.2363
	0.3169	0.3159	0.4026	0.4533	0.2237	0.2232	0.2727	0.3003
	0.0789	0.0768	0.2817	0.3582	0.0783	0.0762	0.2793	0.3556
3.5	0.0663	0.0644	0.2295	0.2874	0.0576	0.0560	0.1926	0.2374
	0.3265	0.3259	0.4108	0.4598	0.2290	0.2286	0.2768	0.3031

Table 2: Continuation of Table 1.

	Broadleaf Evergreen				*Broadleaf Deciduous*			
	Visible		*NIR*		*Visible*		*NIR*	
LAI	*g=.33*	*g=.67*	*.33*	*.67*	*.33*	*.67*	*.33*	*.67*
4.0	0.0789 0.0668 0.3313	0.0768 0.0650 0.3309	0.2817 0.2311 0.4154	0.3582 0.2885 0.4633	0.0782 0.0579 0.2315	0.0762 0.0564 0.2312	0.2792 0.1935 0.2790	0.3556 0.2379 0.3046
4.5	0.0789 0.0671 0.3337	0.0768 0.0652 0.3333	0.2816 0.2319 0.4179	0.3582 0.2892 0.4651	0.0782 0.0580 0.2327	0.0762 0.0565 0.2324	0.2792 0.1939 0.2801	0.3556 0.2382 0.3054
5.0	0.0789 0.0672 0.3348	0.0768 0.0654 0.3346	0.2816 0.2323 0.4193	0.3582 0.2895 0.4662	0.0782 0.0581 0.2332	0.0762 0.0566 0.2330	0.2792 0.1942 0.2808	0.3556 0.2383 0.3058
5.5	0.0789 0.0673 0.3354	0.0768 0.0654 0.3352	0.2816 0.2326 0.4200	0.3582 0.2897 0.4667	0.0782 0.0581 0.2335	0.0762 0.0566 0.2333	0.2792 0.1943 0.2811	0.3556 0.2384 0.3060
6.0	0.0789 0.0673 0.3357	0.0768 0.0655 0.3354	0.2816 0.2327 0.4204	0.3582 0.2898 0.4671	0.0782 0.0582 0.2336	0.0762 0.0566 0.2334	0.2792 0.1943 0.2812	0.3556 0.2384 0.3061
6.5	0.0789 0.0673 0.3358	0.0768 0.0655 0.3356	0.2816 0.2327 0.4206	0.3582 0.2898 0.4672	0.0782 0.0582 0.2336	0.0762 0.0566 0.2335	0.2792 0.1944 0.2813	0.3556 0.2385 0.3061
7.0	0.0789 0.0673 0.3358	0.0768 0.0655 0.3356	0.2816 0.2328 0.4207	0.3582 0.2898 0.4672	0.0782 0.0582 0.2337	0.0762 0.0566 0.2335	0.2792 0.1944 0.2814	0.3556 0.2385 0.3062

Table 3: Same as Table 1, but for needleleaf trees and ground cover.

	Needleleaf				*Ground Cover*			
	Visible		*NIR*		*Visible*		*NIR*	
LAI	*g=.33*	*g=.67*	*.33*	*.67*	*.33*	*.67*	*.33*	*.67*
	0.0758	0.0683	0.2350	0.2474	0.2436	0.1637	0.5816	0.5489
.5	0.0108	0.0034	0.0846	0.0950	0.2050	0.1084	0.5256	0.4843
	0.0647	0.0258	0.1372	0.1435	0.3371	0.2634	0.4298	0.4167
	0.0746	0.0672	0.2311	0.2436	0.2470	0.1637	0.6157	0.5770
1.0	0.0334	0.0272	0.1299	0.1410	0.2524	0.1404	0.7444	0.6714
	0.1342	0.1227	0.2368	0.2524	0.5762	0.4375	0.9651	0.8974
	0.0742	0.0667	0.2293	0.2418	0.2486	0.1637	0.6391	0.5955
1.5	0.0478	0.0408	0.1614	0.1722	0.2799	0.1617	0.9908	0.8577
	0.2215	0.1999	0.3235	0.3370	0.7159	0.5532	1.6189	1.4160
	0.0740	0.0665	0.2285	0.2410	0.2494	0.1637	0.6556	0.6079
2.0	0.0571	0.0501	0.1814	0.1921	0.2947	0.1754	1.2700	1.0335
	0.2968	0.2825	0.3839	0.3955	0.7927	0.6291	2.4084	1.9414
	0.0739	0.0665	0.2281	0.2406	0.2498	0.1637	0.6673	0.6163
2.5	0.0624	0.0554	0.1935	0.2042	0.3022	0.1837	1.5680	1.1812
	0.3432	0.3339	0.4229	0.4332	0.8324	0.6763	3.2992	2.4147
	0.0739	0.0664	0.2280	0.2405	0.2500	0.1637	0.6758	0.6221
3.0	0.0652	0.0582	0.2004	0.2111	0.3059	0.1887	1.8505	1.2858
	0.3696	0.3634	0.4465	0.4563	0.8526	0.7048	4.1928	2.7803
	0.0739	0.0664	0.2279	0.2404	0.2501	0.1637	0.6820	0.6261
3.5	0.0666	0.0597	0.2043	0.2151	0.3076	0.1915	2.0767	1.3458
	0.3838	0.3794	0.4602	0.4697	0.8624	0.7213	4.9611	3.0202

Table 4: Continuation of Table 3.

	Needleleaf				*Ground Cover*			
	Visible		*NIR*		*Visible*		*NIR*	
LAI	*g=.33*	*g=.67*	*.33*	*.67*	*.33*	*.67*	*.33*	*.67*
4.0	0.0739 0.0673 0.3912	0.0664 0.0604 0.3877	0.2279 0.2064 0.4679	0.2404 0.2172 0.4773	0.2501 0.3085 0.8671	0.1637 0.1931 0.7310	0.6866 2.2211 5.5095	0.6288 1.3688 3.1468
4.5	0.0739 0.0677 0.3950	0.0664 0.0608 0.3919	0.2279 0.2076 0.4722	0.2404 0.2184 0.4815	0.2502 0.3088 0.8693	0.1637 0.1940 0.7363	0.6899 2.2808 5.8085	0.6308 1.3685 3.1954
5.0	0.0739 0.0679 0.3968	0.0664 0.0610 0.3940	0.2279 0.2082 0.4745	0.2403 0.2191 0.4839	0.2502 0.3090 0.8704	0.1637 0.1946 0.7395	0.6924 2.2774 5.9069	0.6321 1.3546 3.1932
5.5	0.0739 0.0680 0.3978	0.0664 0.0611 0.3950	0.2279 0.2085 0.4758	0.2403 0.2194 0.4851	0.2502 0.3091 0.8709	0.1637 0.1948 0.7411	0.6943 2.2362 5.8726	0.6330 1.3360 3.1676
6.0	0.0739 0.0680 0.3982	0.0664 0.0611 0.3956	0.2279 0.2087 0.4764	0.2403 0.2196 0.4858	0.2502 0.3091 0.8710	0.1637 0.1950 0.7420	0.6956 2.1779 5.7674	0.6337 1.3168 3.1328
6.5	0.0739 0.0680 0.3984	0.0664 0.0611 0.3958	0.2279 0.2087 0.4768	0.2403 0.2197 0.4861	0.2502 0.3091 0.8712	0.1637 0.1951 0.7426	0.6966 2.1160 5.6346	0.6341 1.2989 3.0958
7.0	0.0739 0.0680 0.3985	0.0664 0.0611 0.3959	0.2279 0.2088 0.4770	0.2403 0.2197 0.4863	0.2502 0.3091 0.8712	0.1637 0.1951 0.7428	0.6974 2.0564 5.4944	0.6344 1.2838 3.0625

Table 5: Same as Table 1, but for broadleaf shrubs and dwarf trees (tundra).

	Broadleaf Shrubs				*Dwarf Trees*			
	Visible		*NIR*		*Visible*		*NIR*	
LAI	*g=.33*	*g=.67*	*.33*	*.67*	*.33*	*.67*	*.33*	*.67*
	0.0807	0.0787	0.2845	0.3532	0.0802	0.0781	0.2825	0.3512
0.5	0.0203	0.0184	0.1498	0.2184	0.0199	0.0181	0.1369	0.1969
	0.0971	0.0924	0.1959	0.2328	0.0970	0.0934	0.1447	0.1643
	0.0798	0.0777	0.2837	0.3562	0.0791	0.0771	0.2812	0.3538
1.0	0.0406	0.0385	0.1930	0.2656	0.0388	0.0371	0.1681	0.2268
	0.1544	0.1470	0.3203	0.3859	0.1355	0.1337	0.2244	0.2624
	0.0794	0.0772	0.2832	0.3578	0.0787	0.0767	0.2806	0.3552
1.5	0.0548	0.0526	0.2201	0.2927	0.0494	0.0476	0.1860	0.2416
	0.2511	0.2458	0.3985	0.4734	0.1841	0.1812	0.2698	0.3110
	0.0792	0.0771	0.2831	0.3586	0.0786	0.0765	0.2803	0.3559
2.0	0.0632	0.0611	0.2364	0.3078	0.0554	0.0537	0.1958	0.2488
	0.3157	0.3123	0.4472	0.5227	0.2230	0.2213	0.2953	0.3347
	0.0792	0.0770	0.2830	0.3590	0.0785	0.0765	0.2802	0.3562
2.5	0.0679	0.0658	0.2460	0.3159	0.0584	0.0568	0.2010	0.2521
	0.3548	0.3527	0.4766	0.5498	0.2447	0.2437	0.3094	0.3461
	0.0791	0.0770	0.2829	0.3592	0.0785	0.0764	0.2801	0.3564
3.0	0.0703	0.0683	0.2514	0.3202	0.0599	0.0583	0.2038	0.2537
	0.3768	0.3756	0.4937	0.5644	0.2561	0.2554	0.3170	0.3517
	0.0791	0.0770	0.2829	0.3594	0.0785	0.0764	0.2801	0.3565
3.5	0.0716	0.0696	0.2544	0.3224	0.0606	0.0590	0.2053	0.2544
	0.3886	0.3877	0.5034	0.5720	0.2617	0.2613	0.3211	0.3543

Table 6: Continuation of Table 5.

	Broadleaf Shrubs				*Dwarf Trees*			
	Visible		*NIR*		*Visible*		*NIR*	
LAI	*g=.33*	*g=.67*	*.33*	*.67*	*.33*	*.67*	*.33*	*.67*
4.0	0.0791 0.0722 0.3948	0.0770 0.0702 0.3942	0.2829 0.2560 0.5088	0.3594 0.3235 0.5761	0.0785 0.0609 0.2645	0.0764 0.0593 0.2642	0.2801 0.2060 0.3233	0.3565 0.2547 0.3556
4.5	0.0791 0.0726 0.3978	0.0770 0.0705 0.3974	0.2829 0.2569 0.5117	0.3594 0.3241 0.5781	0.0785 0.0611 0.2658	0.0764 0.0595 0.2656	0.2801 0.2064 0.3244	0.3566 0.2548 0.3562
5.0	0.0791 0.0727 0.3994	0.0770 0.0707 0.3990	0.2829 0.2574 0.5134	0.3595 0.3244 0.5792	0.0785 0.0612 0.2664	0.0764 0.0595 0.2662	0.2801 0.2066 0.3250	0.3566 0.2549 0.3564
5.5	0.0791 0.0728 0.4001	0.0770 0.0708 0.3998	0.2829 0.2577 0.5143	0.3595 0.3245 0.5797	0.0785 0.0612 0.2667	0.0764 0.0596 0.2665	0.2801 0.2067 0.3253	0.3566 0.2549 0.3565
6.0	0.0791 0.0728 0.4006	0.0770 0.0708 0.4002	0.2829 0.2578 0.5147	0.3595 0.3246 0.5800	0.0785 0.0612 0.2669	0.0764 0.0596 0.2667	0.2801 0.2068 0.3255	0.3566 0.2549 0.3566
6.5	0.0791 0.0728 0.4007	0.0770 0.0708 0.4004	0.2829 0.2579 0.5150	0.3595 0.3246 0.5802	0.0785 0.0612 0.2669	0.0764 0.0596 0.2667	0.2801 0.2068 0.3256	0.3566 0.2549 0.3566
7.0	0.0791 0.0729 0.4008	0.0770 0.0708 0.4005	0.2829 0.2579 0.5152	0.3595 0.3246 0.5802	0.0785 0.0612 0.2669	0.0764 0.0596 0.2668	0.2801 0.2068 0.3256	0.3566 0.2549 0.3566

Table 7: Reflectances of the ground below the canopy.

	Visible	*NIR*
Ground cover, dwarf trees and broadleaf shrubs	0.100	0.200
All other vegetation types	0.110	0.225

Report Documentation Page

National Aeronautics and Space Administration

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-104538		

4. Title and Subtitle	5. Report Date
A Simplified Treatment of SiB's Land Surface Albedo Parameterization	April 1991
	6. Performing Organization Code: 911
7. Author(s)	8. Performing Organization Report No.
Randal D. Koster and Max J. Suarez	91A01312
	10. Work Unit No.
9. Performing Organization Name and Address	11. Contract or Grant No.
NASA/Goddard Space Flight Center Greenbelt, Md. 20771	
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Aeronautics and Space Administration Washington, D.C. 20546-0001	Technical Memorandum
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The surface albedo parameterization presented by Sellers (1985) and Sellers et al. (1986) is simplified by assuming that the reflectance of direct solar radiation is a simple function of solar zenith angle. The function chosen contains three parameters that vary with vegetation type, greenness, and leaf area index. Tables of parameter values are presented. Using these tables, SiB's absorbances of direct solar radiation can be reproduced with an average relative error of less than 0.5%. Finally, the direct reflectance function is integrated over zenith angle to produce an equation for the surface reflectance of diffuse radiation.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
GCM Parameterizations Surface albedos Vegetation effects	Unclassified - Unlimited Subject Category 47

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	11	

NASA FORM 1626 OCT 86