EPSC Abstracts
Vol. 6, EPSC-DPS2011-631-2, 2011
EPSC-DPS Joint Meeting 2011

Ray Tracing Simulation of Spectral Bio-Signatures with Integrated Earth BRDF Model

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Abstract

This study presents a new 3D Earth BRDF model. Each component, (i.e. land, ocean and atmosphere) BRDF characteristics was integrate into a 3D earth BRDF model in real scale. It was then combined with the Sun model and a hypothetical instrument in ray tracing computation. The disk averaged spectra (DAS) and associated spectral bio-signatures of the Earth were then simulated for annual variation of earth phase and different viewing orientations. They are compared with those of other studies.

1. Introduction

One of the key technical challenges to characterization of the spectral signals from potential "earth-like" exoplanets is accurate deconvolution of the collapsed (i.e. temporally and spatially) spectral signals from the target exoplanets. The earth Disk averaged spectra (DAS) provides the community with useful reference spectral datum of the known habitable planet today. Earlier studies on the earth DAS include simulation and modeling (Ford et al.(2001)[1], Tinttie et al.(2006)[2], Fujii et al.(2010)[3]) and observation from both ground (Woolf et al.(2002)[4], Montañés-Rodríguez et al.(2006)[5]) and space(Hearty et al(2009)[6]). In this study, we report a new versatile computational technique, capable of simulating the earth DAS and its associated spectral bio-signatures as well as the instrument performances.

2. Computational Technique

The computational model has 3 components i.e. the Sun model, an integrated earth BRDF model (Atmosphere, Land and Ocean) and instrument model combined in ray tracing computation (Fig.1). A set of rays defined by their power and direction vectors are created from inside the Sun and scattered outward from the Sun surface layer. They are then traced to the earth where they pass through the atmosphere, hit the land or ocean surface and then pass back to the space and to the instrument in orbit. The ray characteristics such as power and direction are altered as they experience reflection, refraction, transmission, absorption and scattering from encountering with atmosphere, land and ocean surfaces.

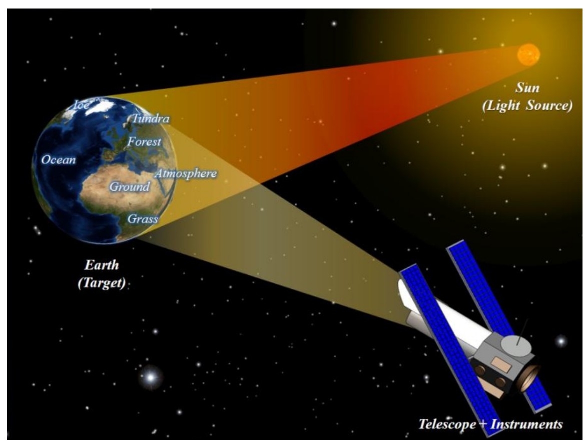

Figure 1: Concept of Integrated Ray Tracing(IRT) method[7]

The Sun is defined as a real scale Lambert scattering sphere and has the spectral radiant power data defined by Gueymard(2000)[8]. A single layer earth atmosphere consists of 16 distributed latitudinal facets with appropriate BSDF obtained from the 6SV radiative transfer code. The land surface is defined with Global Ecological Zone Map[9] data and 5 different kinds of vegetation distribution are used to define land albedo. The land scattering characteristics is defined by the semi-empirical "parametric kernel method" used for MODIS(NASA) and POLDER(CNES) missions. The ocean BRDF is defined for sea ice cap structure and for the sea water optical model, considering sun-glint scattering. The input Earth model and their key characteristics are shown in Fig 2.

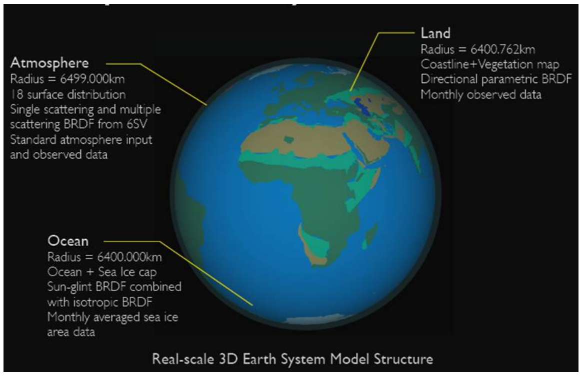

Figure 2: Input earth system model

A hypothetical spectrograph is added to the existing imager and bolometer instrument of the proposed EARTHSHINE[10] mission. It was then imported into the ray tracing computation for the measurement simulation of the Earth image and DAS from the Lagrange-1 point between the Sun and the Earth.

3. Results and Remarks

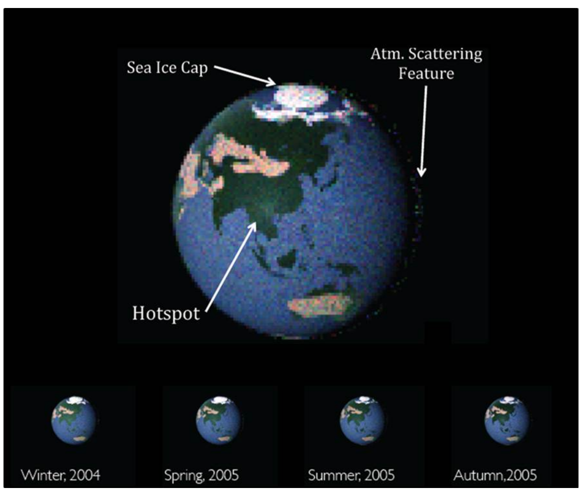

Figure 3: Ray-traced true color image at the instrument detector[11]

The trial ray tracing computation resulted in an imaging performance, representing changes in the earth image over 4 seasons as shown in Fig. 3. We note a hot spot feature near the center of the globe and atmospheric scattering at around the earth limb. We then calculated the disk averaged spectra of the Earth and compared with the results from previous study[2]. The details of computation model and simulation results are presented together with implications.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology (2011-0003958). We acknowledge the support of Breault Research Organization through the user licenses for Advanced System analysis Program (ASAP™) for ray tracing computation.

References

[1] E. B. Ford, S. Seager and E.L. Turner : Characterization of Extrasolar Terrestrial Planets from Diurnal Photometric Variability, Nature, 412, 885-887, 2001

[2] G. Tinetti, V.S. Meadows, D. Crisp, W. Fong, E. Fishbein, M. Turnbull, and JP. Bibring : Detectability of Planetary Characteristics in Disk-Averaged Spectra. I: The Earth Model, Astrobiology, 6(1), 34-47, 2006

[3] Y. Fujii, H. Kawahara, Y. Suto, A. Tarura, S. Fukuda, T. Nakajima and E.L. Turner : Colors of a Second Earth : Estimation the Fractional Areas of Ocean, Land, and Vegetation of Earth-like Exoplanets, ApJ, 715, 866-880, 2010

[4] N.J. Woolf, P.S. Smith, W.A. Traub and K.W. Jucks : The Spectrum of Earthshine: A Pale Blue Dot Observed from the Ground, ApJ, 574, 430-433, 2002

[5] P. Montañés-Rodríguez, E. Pallé, P.R. Goode and F.J. Martín-Torres : Vegetation Signature in the Observed Globally Integrated Spectrum of Earth Considering Simulatneous Cloud Data : Applications for Extrasolar Planets, ApJ, 651, 544-552, 2006

[6] T. Hearty, I. Song, S. Kim and G. Tinetti : Mid-infrared Properties of Disk Averaged Observations of Earth with AIRS, ApJ, 693, 1763-1774, 2009

[7] D. Ryu, S. Seong, JM. Lee, J. Hong, S. Jeong, Y. Jeong and SW. Kim : Integrated Ray Tracing Simulation of Spectral Bio-signatures from Full 3-D Earth Model, Proc. SPIE, 7441, pp. 74410A-1-11, 2009

[8] C.A. Gueymard : SMARTS2, A Simple Model of the Atmospheric Radiative Transfer of Sunshine : Algorithms and Performance Assessment, Florida Solar Energy Center, FSEC-PF-270-95, 1-88, 1995

[9] Global Ecological Zoning for the Global Forest Resources Assessment 2000 Final Report, Forest Resources Assessment, 1-211, 2001

[10] JM. Lee : Integrated ray tracing model for end-to-end performance verification Amon-Ra instrument, Yonsei University Graduate School, 28-31, 2006

[11] D. Ryu, SW. Kim, DW. Kim, JM. Lee, H. Lee, WH. Park, S. Seong, SJ. Ham : Integrated ray tracing simulation of annual variation of spectral bio-signatures from cloud free 3-D optical earth model, Proc. SPIE, 7819, pp. 78190E-1-14, 2010