The Surface and Atmospheric Radiation Budget and Aerosol Forcing With a New Formulation for Ocean Surface Albedo

T. P. Charlock and W. L. Smith, Jr.
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

Z. Jin, F. G. Rose, K. Rutledge, and D. A. Rutan
Analytical Services and Materials, Inc.,
Hampton, Virginia

Introduction

The ocean surface is the most ubiquitous boundary condition for shortwave (SW). To fully exploit the increased accuracy of Clouds and Earth's Radiant Energy System (CERES) (Wielicki et al. 1996) top of atmosphere (TOA) SW (when corrected for the effect of the earth's annulus), we require an improved a priori ocean albedo. Uncertainties in the computed surface and atmospheric radiation budget (SARB) and aerosol forcing due to ocean albedo (~0.005) are now as large as those due to observational error in TOA albedo (~0.005).

We compute ocean albedo with a coupled model (evolved from Jin and Stamnes 1994), explicitly accounting for radiative processes in both sea and air, and using measured wind speeds and aerosol optical depth (AOD). Look up tables (LUTs) are used to specify the ocean spectral albedo in appropriate bands of a highly modified Fu and Liou (1993) radiative transfer code. Tests of the modified code over land are described in Charlock et al. 2001. The new ocean albedo LUTs include an empirical, wind-speed-dependent adjustment for foam. Figure 1 shows that at low values of cosSZA (solar zenith angle), the sea albedo increases from the visible to the near infrared; the opposite is noted at high values of cosSZA.

The impact of the sea on TOA albedo is several times larger than the aerosol. This is critical because when aerosol forcing is inferred with satellite data, uncertainties in ocean albedo translate directly into uncertainties in the aerosol forcing. Satellites can infer aerosol forcing to TOA broadband SW by two routes (Figure 2). In the first route, a narrow band satellite radiometric observation and an assumed value for ocean spectral reflection can be used to retrieve the spectral AOD; the aerosol forcing to broadband is then computed with various assumptions over the spectrum. In the second route, broadband satellite data is used to retrieve the reflected SW at TOA, and aerosol forcing is produced by differencing this observation with a calculation assuming pristine (aerosol-free) sky over the sea. By either route, the optical properties of the ocean that one assumes are crucial; if they are wrong, the inferred TOA aerosol forcing is also wrong. How well do we know ocean albedo?

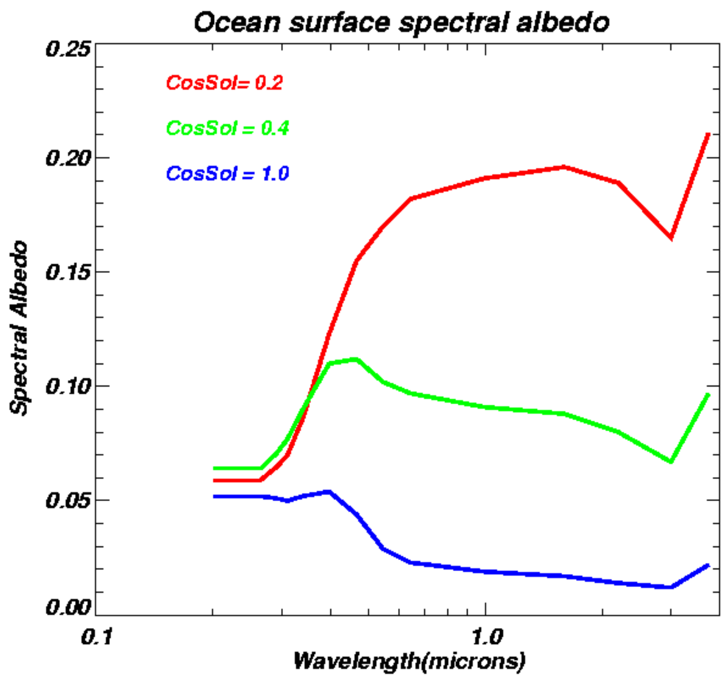

Figure 1. Ocean spectral albedo in the bands of the Fu-Liou code based on LUT to the coupled air-sea radiative transfer model of Jin.

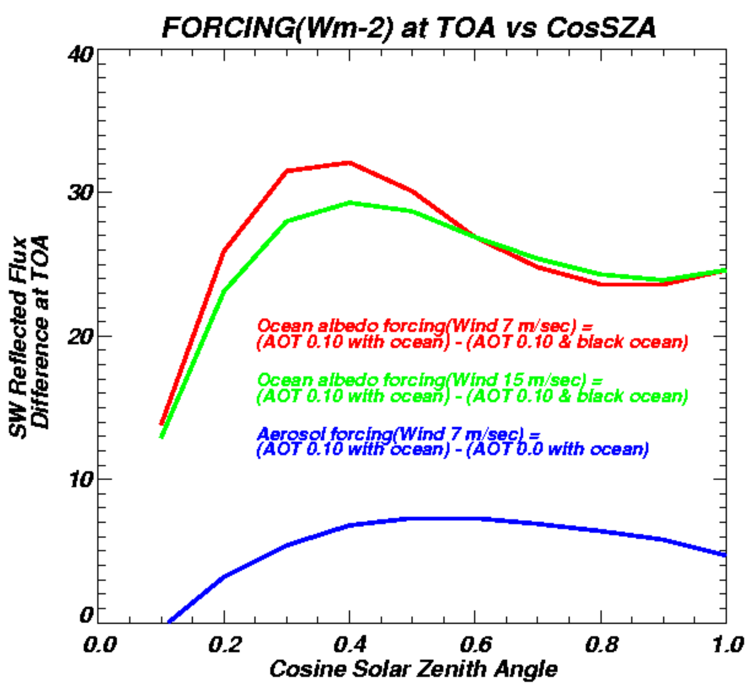

Figure 2. Contrasts the ocean surface albedo forcing to TOA reflected SW flux with the aerosol forcing due to continental AOD of 0.10.

Theory is compared with observations from the long-term CERES Ocean Validation Experiment (COVE) sea platform (25 km east of Virginia Beach). Figure 3 shows that for every season, observed albedos are slightly higher than computed albedos (Jin et al. 2001). The mean difference of –0.0075 is small–but not comforting if one's task is using computed sea optics and satellite data to infer the correspondingly small forcing of aerosol over the world's oceans. The comparison used clear-sky intervals, broadband radiometer observations that subscribed to the Baseline Surface Radiation Network (BSRN) protocol, AERONET Cimel observations spectral AOT, Cox-Munk ocean facets specified from observed wind speed, and chlorophyll from SeaWiFS. And in the subsequent July 2001 Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS) field campaign (i.e., Smith et al. 2001) we input dissolved organic matter, chlorophyll, bubbles, etc., and find again that ocean albedo is not a "solved problem."

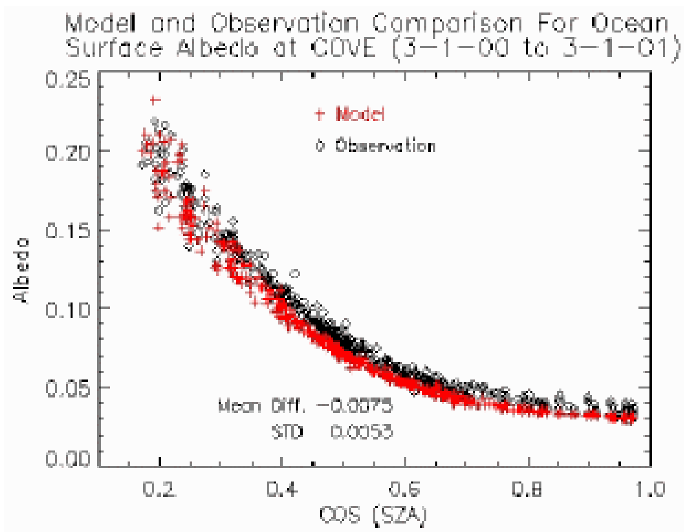

Figure 3. One year of clear-sky broadband ocean albedo from (a) coupled model (red) using observed wind speed and AOD, and from (b) COVE observations (black).

We show the results of May 1998 CERES Tropical Rainfall Measuring Mission (TRMM) processing over the tropical oceans for the surface and atmosphere radiation budget (SARB, i.e., Charlock and Alberta 1996, Rose et al. 1997, and Rutan and Charlock 1999) with the modified Fu-Liou code and the new ocean albedo parameterization. Inputs for the SARB calculation include cloud screening (Minnis CERES group) with the Visible Infrared Scanning Radiometer (VIRS) imager on TRMM, upgraded CERES broadband TOA observations (Loeb CERES group), and European Centre for Medium-Range Weather Forecasts. Aerosols are retrieved with VIRS (Stowe-Ignatov of CERES) over much of the ocean and otherwise taken from the MATCH assimilation (Collins et al. 2001). TOA fluxes are computed, and the initial SARB calculations are compared to CERES TOA observations for every footprint. The comparison results in the adjustment to AOD and other parameters. We do not tune to an exact match. The normalized sum of squares of adjustments to key parameters is minimized using a priori values for the uncertainty of each key parameter. The SARB is recomputed with the adjusted parameters and finally compared again to CERES observations at TOA (Figure 4). The output includes SW, LW, and infrared window fluxes (up and down) at the surface, 500 hPa, 200 hPa, 70 hPa, and TOA; adjustments to inputs; and computed pristine (aerosol-free) fluxes to estimate aerosol radiative forcing.

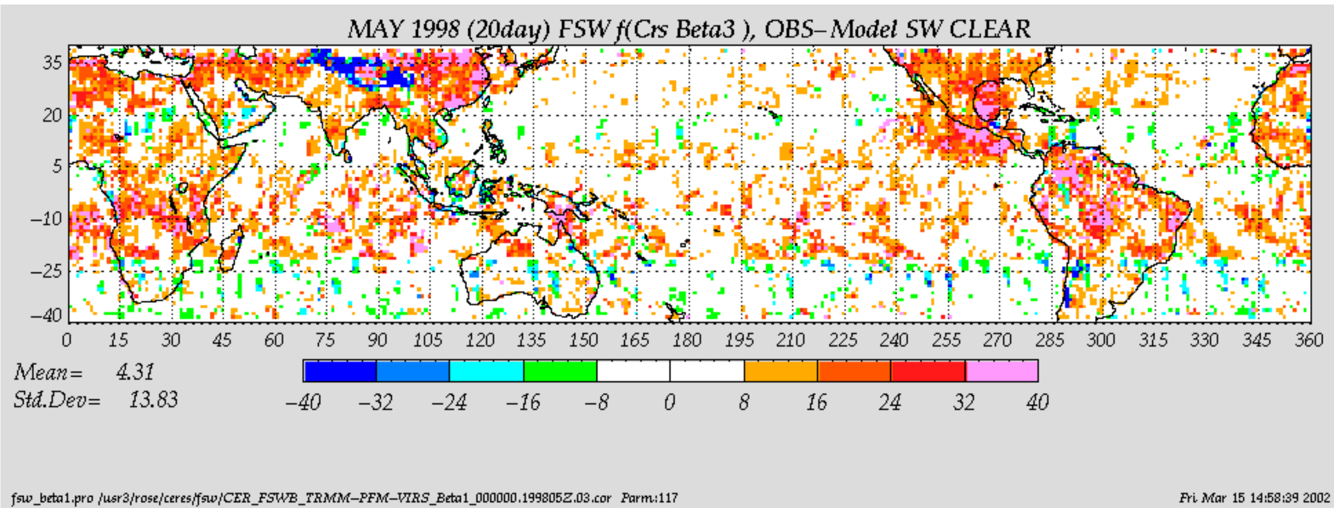

Figure 4. Difference of tuned, computed SARB and CERES observations of reflected SW at TOA for 20 days in May 1998. Preliminary results with simplified averaging.

Corresponding Author

T. P. Charlock, t.p.charlock@larc.nasa.gov, (757) 864-5687

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