Effect of Ocean Surface Roughness on Radiative Transfer in Atmosphere and Ocean

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Monte Carlo or ray tracing technique is usually used to consider the ocean surface roughness for radiative transfer, which is *relatively easy to be implemented in code but is computationally expensive*.

We use an analytical technique (the discrete-ordinate method) for this problem. Analytical solution *is more efficient and has no statistical fluctuation as in Monte Carlo method, but is hard to be implemented in code*.

The analytical solution has been implemented into the Coupled DIScrete-Ordinate Radiative Transfer (***CDISORT***) code. Using CDISORT as the radiative transfer solver, a Coupled Ocean-Atmosphere Radiative Transfer (***COART***) has been developed.

Because CDISORT included the refractive index and now includes the surface roughness parameters, COART treats the ocean strata just as additional atmospheric layers with different optical properties.

COART is online at **http://www-cave.larc.nasa.gov/cave/**

Find it by searching "***COART model***" or "*Atmopshere-ocean radiative transfer model*".

COART can calculate the spectral and broadband radiances, including the water-leaving radiance, and fluxes at any levels in atmosphere and ocean, but we will show only some results closely related to ocean surface roughness here.

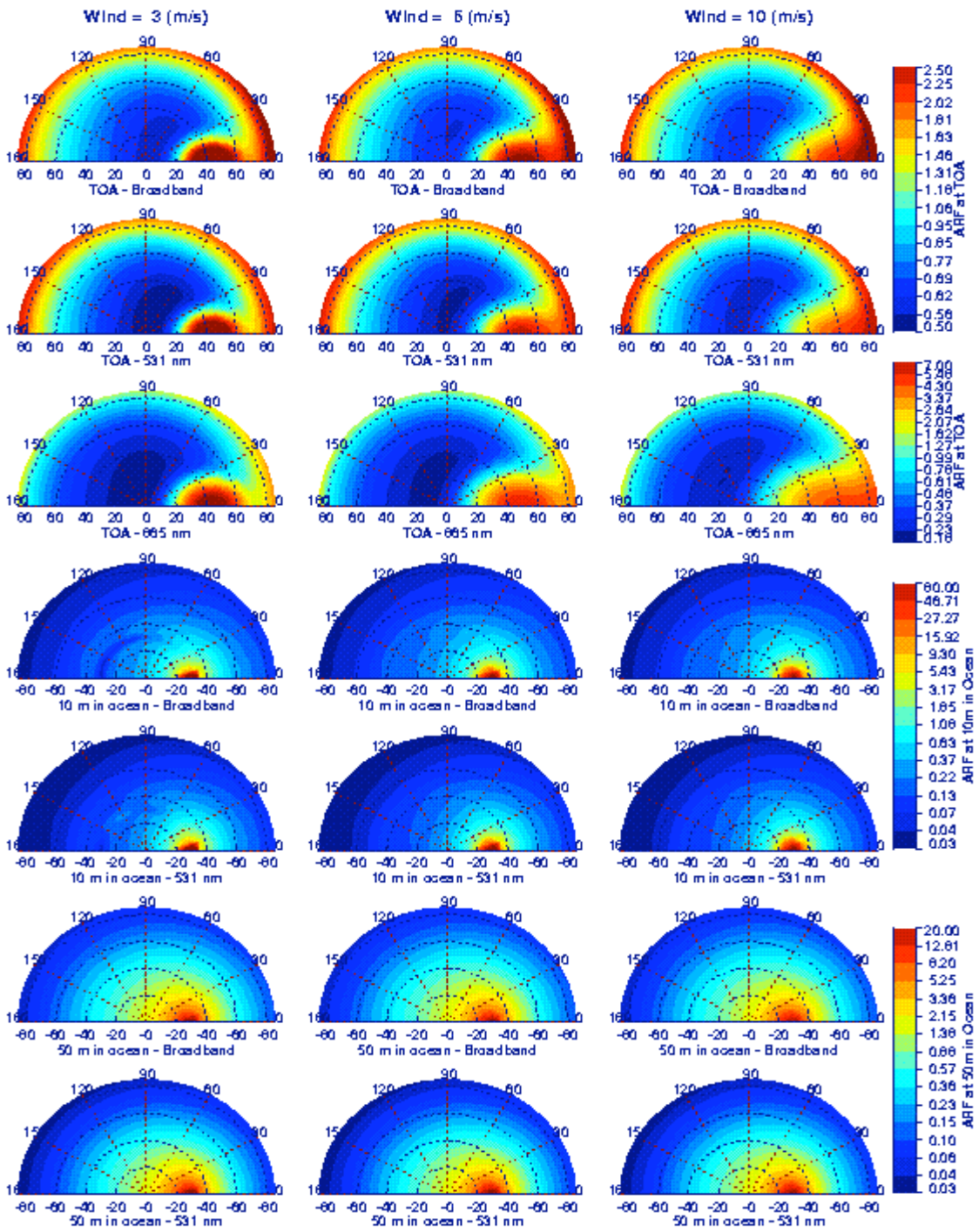

Figure 1. Model simulated upwelling radiance field at the top of atmosphere (TOA) and the downwelling radiance field at depths of 10 m and 50 m in the ocean for wind speeds of 3, 6 and 10 w/s and for three wavelength spectra, respectively.

SZA = 40°

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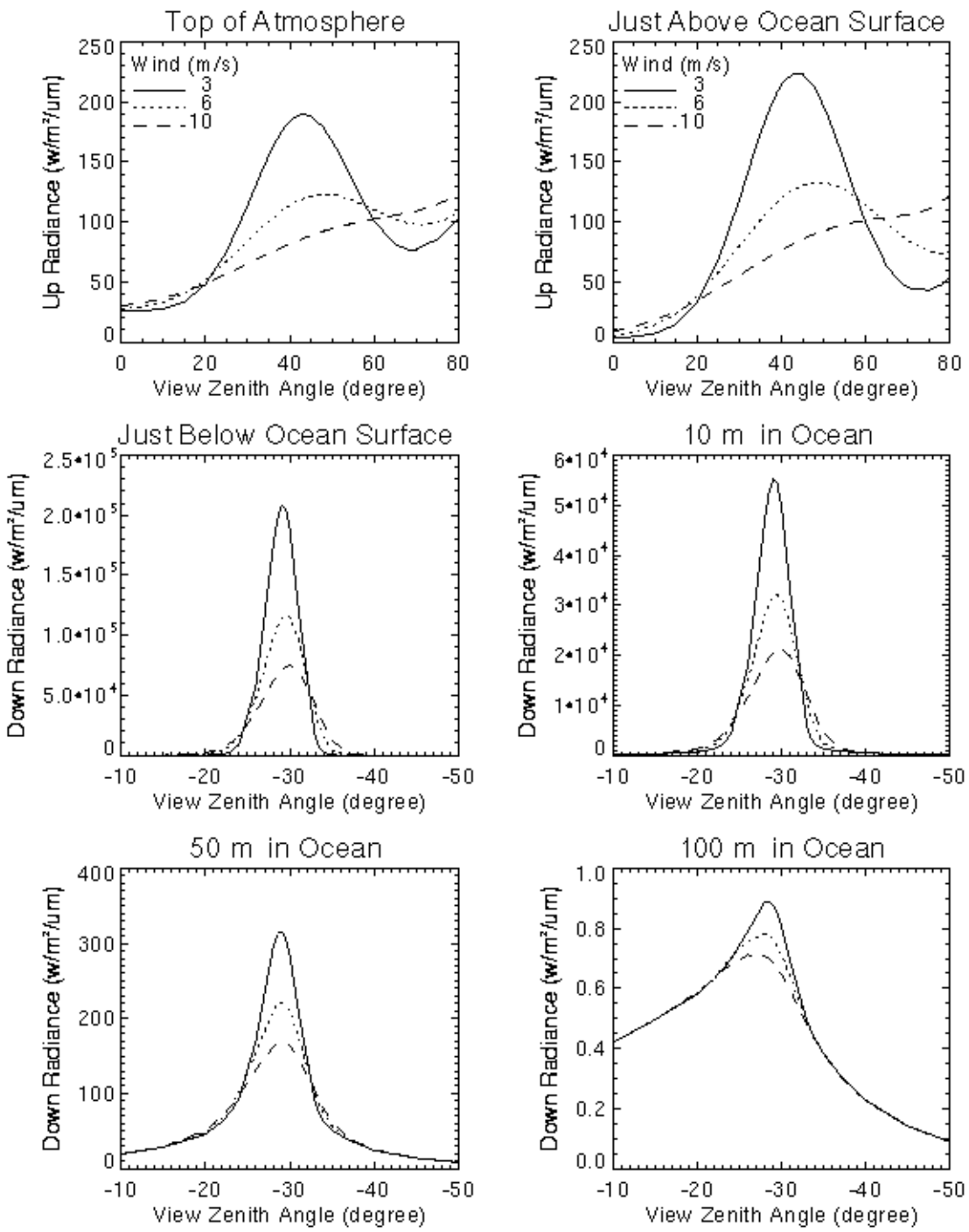

Figure 2. Effects of surface roughness on radiance distributions in principal plane around the reflected solar beam direction in atmosphere and the refracted solar direction in ocean.

SZA = 40°

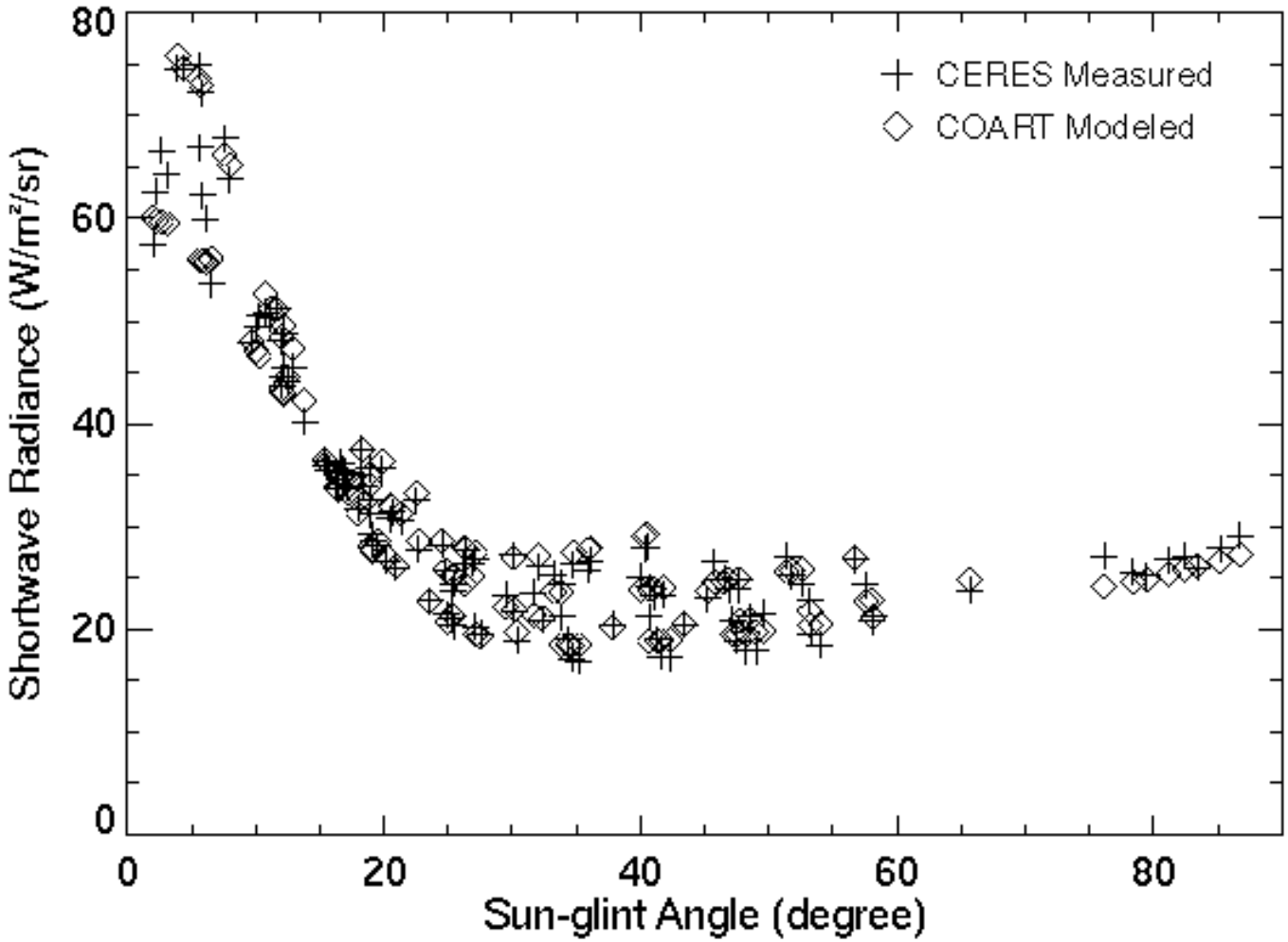

Figure 3. Comparison of modeled and measured radiances as a function of sun-glint angle.

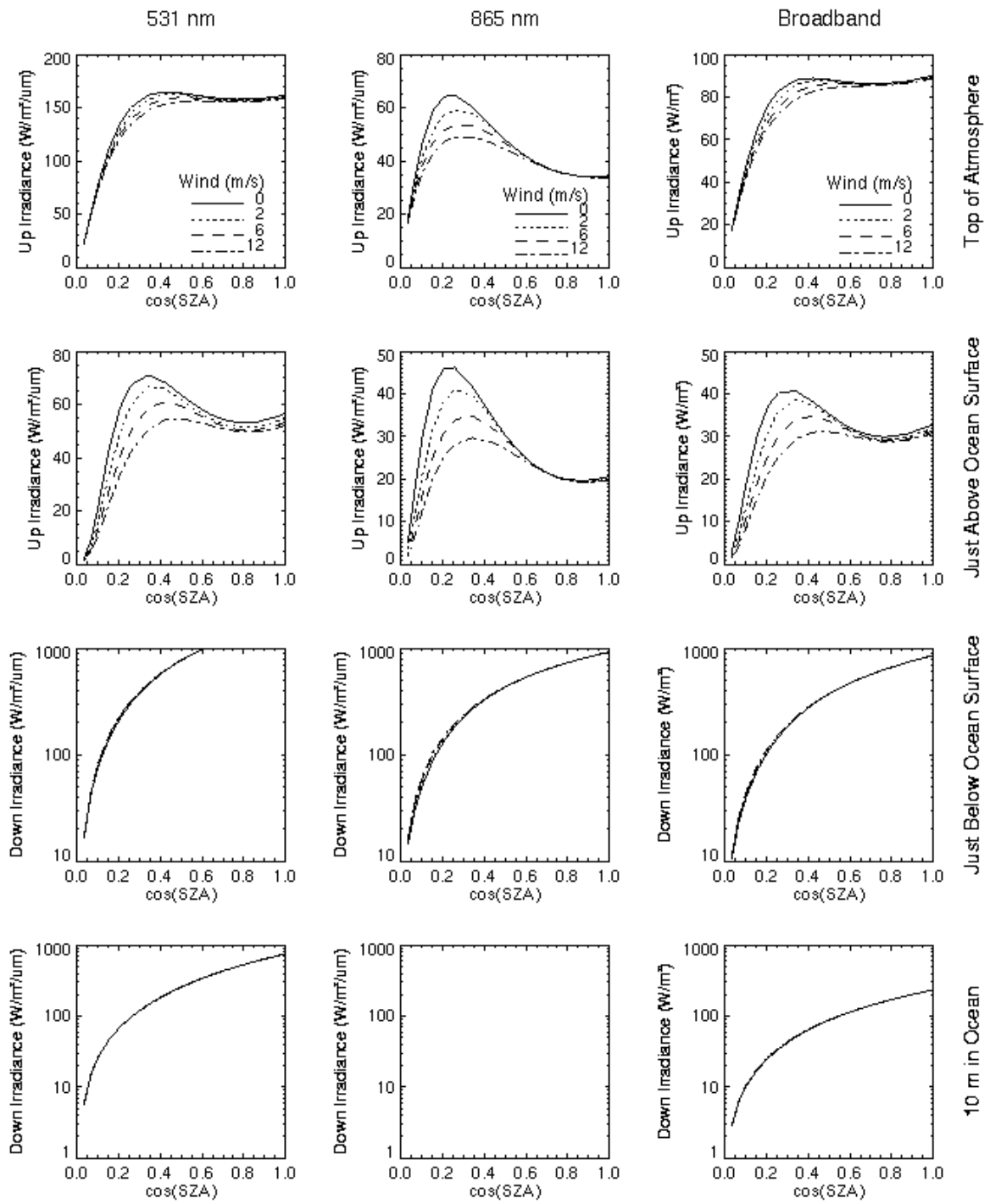

Figure 4. Modeled simulated upwelling irradiance in atmosphere and downwelling irradiance in the ocean for different wind speeds and different wavelengths.

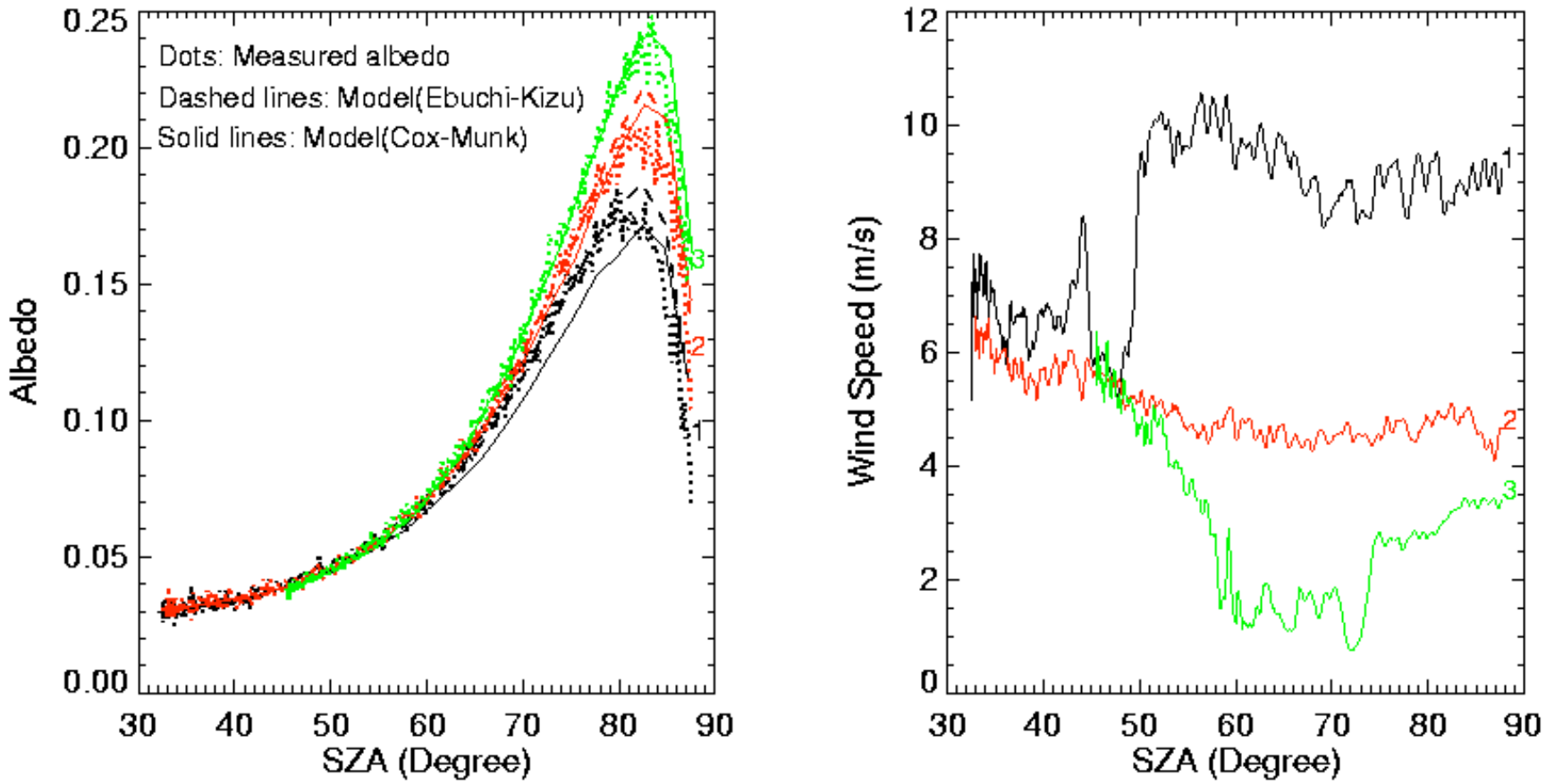

Figure 5. Effects of wind speed on ocean surface albedo. The left panel shows the modeled and measured surface albedo in three days. The right panel shows the corresponding wind speeds observed in these days. Different colors are for different days.

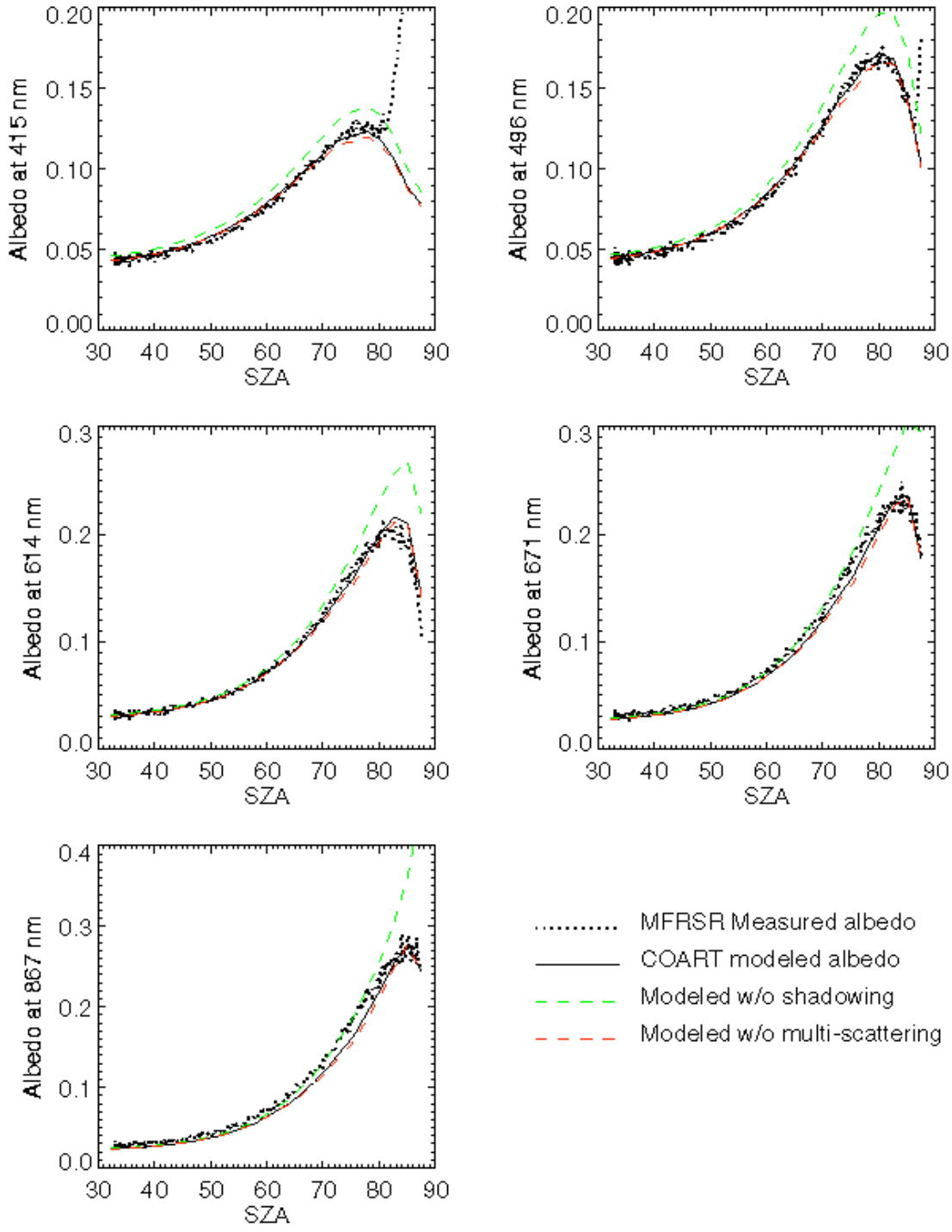

Figure 6. Effects of wave shadowing and multiple scattering between surface facets on the calculated surface albedo.

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Summary

- Ocean surface roughness effects, including wave shadowing and multiple scattering between surface facets, are treated analytically and accurately in radiative transfer solutions.
- Model simulations show that the ocean surface roughness has significant effects on the upward radiation field in atmosphere and downward radiation in ocean, particularly, the sunglint pattern and ocean surface albedo.
- As surface roughness or wind increases, the sunglint region broadens and the surface albedo decreases, but the transmission to ocean increases.

- The transmitted radiance field in ocean is highly anisotropic and this anisotropic feature rapidly decreases as surface wind increases and as depth in ocean increases.
- Down deeper into ocean, optical properties of ocean become more important than surface roughness to radiation field.
- The effects of surface roughness on radiation also greatly depend on wavelength and solar elevation. They are significantly smaller at high sun conditions for all spectrum.
- Model results are consistent with measurements.