UNPOLARIZED INFRARED EMISSIVITY OF OIL FILMS ON SEA SURFACES

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1. INTRODUCTION

Remote sensing, by either radar or optical imagery, can be used to detect and monitor possible oil slicks on sea surfaces. For optical applications, in order to act quickly when marine oil pollutions occur, it is then essential to dispose of a means that can predict the emissivity, which quantifies the intrinsic radiation of the surface. Then, by calculating the contrast between a sea covered in oil (called contaminated sea) and a clean sea, it is possible to study the detectability of marine pollutions. For optical or infrared applications, at moderate angles, since the electromagnetic wavelength is much smaller than the sea surface mean curvature radius, the tangent plane approximation (usually called Kirchhoff approximation, KA) can be applied. Moreover, the electromagnetic wavelength being much smaller than the surface root mean square (RMS) height, the geometric optics approximation (GOA) can be applied. Indeed, at optical or infrared frequencies, the capillarity waves of sea surfaces also have a large mean curvature radius and a large RMS height comparatively to the wavelength. In what follows, the infrared emissivity of clean and contaminated seas is derived, starting from the hydrodynamic modeling of clean and contaminated sea surfaces.

2. HYDRODYNAMIC MODELING OF THE SURFACES OF CLEAN AND CONTAMINATED SEAS

The hydrodynamic modeling of the surfaces of clean and contaminated seas is based on the Elfouhaily et al. model [1] for the case of a clean sea. By comparison, for the case of a contaminated sea, a damping effect occurs, which has a maximum located in the gravity-capillarity region of the surface wave spectrum, around the surface wave frequency $\nu_s = 10$ Hz. This damping effect is expressed by an attenuation coefficient y [2], which is usually called the Marangoni viscous damping coefficient. For more details, one can refer to [3].

To describe this damping effect, we refer to two distinct hydrodynamic models of the literature. The first one, the Lombardini et al. damping model [2], is rather simple, as it depends on only 2 hydrodynamic parameters, but in return is independent of the film thickness H. The second one, the Jenkins and Jacobs damping model [4], is more sophisticated, as it depends on 9 hydrodynamic parameters and depends on the film thickness H, but is valid only for thin films. In this abstract, we concentrate on the first model, and represent in Fig. 1 the surface slope spectrum of clean and contaminated seas for a wind speed $u_{10} = 7$ m/s, with different values of the two parameters ω_D and E_0 of the Lombardini et al. model (ω_D being the oil characteristic pulsation, and E_0 the oil elasticity modulus). In the full version of the paper, both models will be studied.

Then, this hydrodynamic modeling is applied in section 3 to the infrared emissivity of clean and contaminated seas, in order to study the detectability of oil films. To do so, it must be noted that both the upper (air-oil) and lower (oil-sea) interfaces of the oil film obey the same hydrodynamic modeling, with identical parameters. Moreover, as dealing with thin oil films, it is assumed that the two interfaces of the oil film are strictly identical and parallel (see Fig. 5 of [3]). In what follows, the surface slope spectrum is used to calculate the surface RMS slopes, in the up-wind direction σ_{sx} and in the cross-wind direction σ_{sy}, for both clean and contaminated seas. Indeed, σ_{sx} and σ_{sy} are parameters of the slope probability density function which appears in the expression of the infrared emissivity under the GOA [5].

3. INFRARED EMISSIVITY OF CLEAN AND CONTAMINATED SEAS

In this paper, from an analytical approach based on the work of Bourlier [5], the unpolarized emissivity from a thin oil film over a two-dimensional anisotropic sea surface is derived by using the GOA. Under the GOA, which is based on the KA, the two interfaces of the oil film can be considered as locally flat. Consequently, for moderate emission angles and for thin films, the oil film can be considered as locally flat, and appears as a local Pérot-Fabry interferometer. Then, the multiple reflections between the upper and the lower interfaces of the oil film can be modeled in a simple way. Indeed, starting from the single

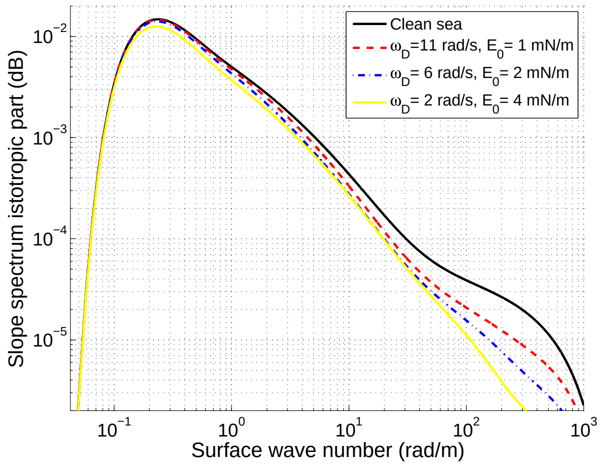

Fig. 1. Isotropic part of the surface slope spectrum of clean and contaminated seas (using the Lombardini et al. damping model) versus the surface wavenumber k_s. The wind speed is $u_{10} = 7$ m/s.

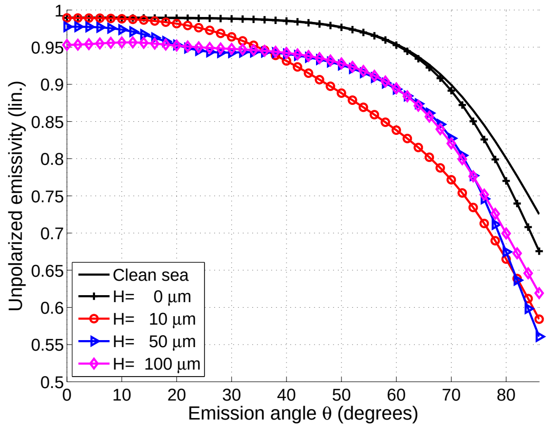

Fig. 2. Unpolarized emissivities of clean and contaminated (with $\omega_D = 11$ rad/s and $E_0 = 1$ mN/m) seas versus the emission angle θ, for $\lambda = 10$ μm, $u_{10} = 7$ m/s, $\phi = 0$. The oil film thicknesses are $H = \{0; 10; 50; 100\}$ μm.

(air/oil) interface case, under the GOA, the Fresnel reflection coefficient of a single interface can be substituted for the equivalent Fresnel reflection coefficient of the air/oil/sea film, calculated by considering an infinite number of reflections inside the film. Its expression is given by equation (9) of [3].

Then, the infrared emissivities of clean and contaminated seas can be computed. Fig. 2 represents the unpolarized infrared emissivities of clean and contaminated (with $\omega_D = 11$ rad/s and $E_0 = 1$ mN/m) seas with respect to the emission angle θ, for different oil film thicknesses $H = \{0; 10; 50; 100\}$ μm, at a wind speed $u_{10} = 7$ m/s and a wind direction $\phi = 0$. The case $H = 0$ is plotted to highlight the influence of the surface wave damping due to the presence of oil. The result of the contaminated sea for zero thickness $H = 0$ is very close to the one of the clean sea. Indeed, differences appear only for relatively high emission angles θ, owing to the damping of the capillarity waves in the surface wave slope spectrum due to the presence of oil. Then, for these typical wind speeds, the damping due to the presence of oil has an effect on the unpolarized emissivity only for high emission angles θ. By comparison, the results with various thicknesses highlight differences with the case $H = 0$ and, most important, with the clean sea case. The differences being significant, this makes the oil film detectable. Moreover, depending on the emission angle θ, it can be seen that the results with various thicknesses highlight significant differences between theses thicknesses, and a general different behavior with respect to θ. Then, from the knowledge of the emissivity of an oil film for a few values of θ, this makes it possible to evaluate the oil film thickness.

4. REFERENCES

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