The Development of Diurnally-Varying Sea-Surface Temperature Scheme. Part I. Preliminary numerical experiments.

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1. Introduction

We have developed a new scheme for precisely simulating a diurnally-varying sea-surface temperature (SST). The new scheme is developed to be incorporated into a nonhydrostatic atmosphere model coupled with a slab mixed-layer ocean model (hereafter, the coupled model is referred to as NCM). The new scheme for simulating diurnally-varying SST is formulated based on Schiller and Godfrey (2005) (hereafter referred to as SG). The short-wave absorption/penetration is, however, estimated for the formulation of Ohlmann and Siegel (2000) (hereafter referred to as OG).

2. New scheme

The concept of SG is as follows: A skin layer is formed in the uppermost layer when the short-wave radiation warms the sea surface. The depth of skin layer depends on total short-wave radiation and wind stress accumulated from the sunrise. When a skin layer is thin, the amplitude of diurnally-varying SST is large. After the sunset, the skin layer disappears and the depth of skin layer is equal to the depth at the first, uppermost layer in the ocean model. At that time, total values of short-wave radiation and wind stress have been sustained till the next sunrise.

The formulas associated with short-wave absorption/penetration in OS were derived from the multiple regression analysis. The formulas are functions of chlorophyll concentrations (mg m^{-3}), cloud indices under a cloudy condition and solar zenith angle under a clear-sky condition.

3. Experiment Design

Numerical experiments are performed by the NCM in order to check the performance of new scheme. The integration time is 63 hours. The time step is 10 seconds. The horizontal grid is 32 x 32 with a grid spacing of 2 km. The short-wave radiation is assumed that the maximum is 1000 W m^{-2} and it is varied with sinusoidal formulas of Danabasoglu et al. (2006). The net flux defined as the summation of upward (from the sea to the surface) long-wave radiation, sensible and latent heat fluxes is set to be 50 W m^{-2} and its value is assumed to be equal to that of latent heat flux. No resultant precipitation occurs during the integration in these experiments. The cloud index is assumed to zero for the numerical experiments. The value of chlorophyll concentration is assumed to be 0.1 and 1 mg m^{-3} and has not been changed during the integration. The depth of the first, uppermost layer (hereafter referred to as dz) is set to be 5 m. Wind stresses are derived from wind speeds at the first, lowermost layer in the atmospheric part of NCM and bulk formula of Kondo (1975) incorporated into the atmospheric part of NCM.

4. Results

Figure 1 indicates the evolution of skin layer depth ($zD_t(t)$) diagnosed by the new scheme. The time '0' indicates the initial time at 0000 UTC (0900 JST). When the numerical experiments are initiated to run, $zD_t(t)$ turns to be thin around 0100 UTC (1000JST). After that, $zD_t(t)$ becomes thicker. After the sunset, high wind speed leads to thick $zD_t(t)$, which is equal to dz at the maximum. Figure 1 also indicates that $zD_t(t)$ becomes thin as the wind speed is low. Low wind speed is also associated with the sustenance of thin depth of $zD_t(t)$ after the sunset.

Figure 2 indicates the evolution of SST simulated by the NCM with the new scheme. The chlorophyll concentration is 0.1 mg m^{-3}. The simulated SST shows diurnal variations. Without the new scheme, the amplitude of diurnally-varying SST is small, while the new scheme produces larger amplitude of diurnally-varying SST. An increase in the peak SST is nearly 0.5°C when the wind speed is 3.0 m s^{-1}.

Figure 3 indicates the evolution of SST simulated by the NCM with the new scheme except that the chlorophyll concentration is 1 mg m^{-3}. The peak amplitude of simulated SST increases by 0.1° compared with that shown in Fig. 2. This suggests that high chlorophyll concentration leads to large amplitude of diurnally-varying SST. This is due to high absorption of solar radiation near the sea surface.

Because this paper describes only the performance of new scheme in the ocean part of NCM, the impact of diurnally-varying SST on the atmosphere is beyond the scope of this paper. However, net flux is affected by the variation of SST. In addition, wind stress may be affected by the variation of SST, indicating that the variation of wind stress can affect the variation of SST in turn. This issue is reported by Wada and Kawai (2009) in this Blue Book (2009).

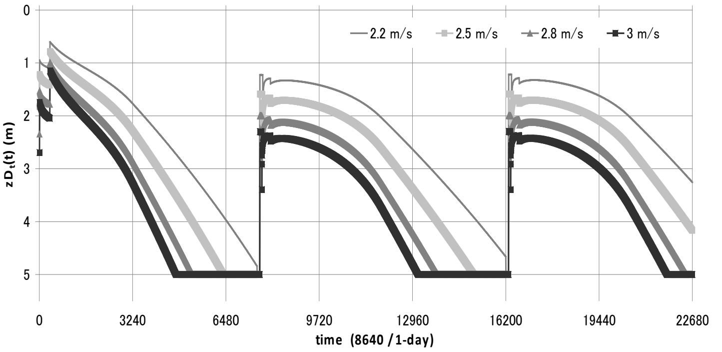

Figure 1 The evolution of skin layer depth ($zD_t(t)$) diagnosed by the new scheme

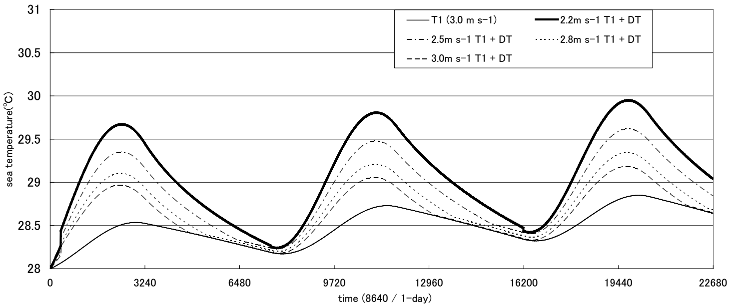

Figure 2 The evolution of SST simulated by the new scheme. A chlorophyll concentration is 0.1 mg m^{-3}.

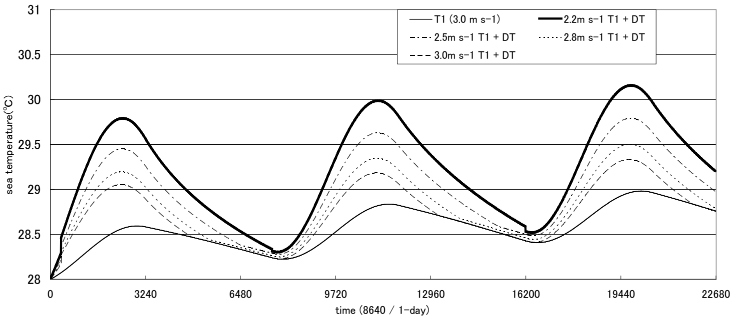

Figure 3 As in Fig. 2 except that a chlorophyll concentration is 1 mg m^{-3}.

References

Danabasoglu, G., W.G. Large, J.J. Tribbia, P.R. Gent, B.P. Briegleb, and J.C. McWilliams, 2006: Diurnal Coupling in the Tropical Oceans of CCSM3. J. Climate, 19, 2347–2365.

Kondo, J., 1975: Air-sea bulk transfer coefficients in diabatic con ditions. Bound.-Layer Meteor., 9, 91-112.

Ohlmann, J.C., and D.A. Siegel, 2000: Ocean Radiant Heating. Part II: Parameterizing Solar Radiation Transmission through the Upper Ocean. J. Phys. Oceanogr., 30, 1849–1865.

Schiller, A., and J. S. Godfrey, 2005: A diagnostic model of the diurnal cycle of sea surface temperature for use in coupled ocean-atmosphere models, J. Geophys. Res., 110, C11014, doi:10.1029/2005JC002975.

Wada, A., and Y. Kawai, 2009: The development of diurnally-varying sea-surface temperature scheme. Part II. Idealized numerical experiments. CAS/JSC WGNE Research Activities in Atmosphere and Oceanic Modelling, Submitted.

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