Quantification of the Errors Associated with the Representation of Surface Emissivity in the RRTMG_LW

Hongze Cheng, Xiuhong Chen, Xianglei Huang^{*}

Department of Climate and Space Sciences and Engineering, the University of Michigan,
Ann Arbor, Michigan, USA

^{*}Corresponding author: Prof. Xianglei Huang, Department of Climate and Space Sciences and Engineering, the University of Michigan, Ann Arbor, MI 48109-2143, USA. Tel.: +734 936 0491.

Email: xianglei@umich.edu

Abstract

Recent studies have shown that representation of surface spectral emissivity has a non-negligible impact on the polar radiation budget and on simulated climate. This fact motivates the inclusion of surface spectral emissivity into the radiative transfer scheme employed in the climate models. Using a line-by-line radiative transfer model, LBLRTM, as a benchmark, we quantify the errors due to the approximation of surface spectral emissivity in the RRTMG_LW, a radiation scheme widely used by climate models and

numerical forecast models. Error quantifications are done using representative sounding profiles in the tropics, mid-latitude summer, sub-arctic winter and Sahara desert interfaced with either ocean or desert spectral emissivities. Though including surface emissivity causes little difference in broadband outgoing longwave radiation, it can cause noticeable differences in longwave radiative cooling rate from surface to 700 hPa. Compared to the benchmark, the largest deviation in radiative cooling rate usually happens at the lowest atmospheric layers next to the surface, ranging from -0.23 K/day to 0.19 K/day with the largest fractional difference being -16.22%. The discrepancies caused solely by the representation of surface emissivity are confined at the lowest atmospheric layer. Using the emissivity at the diffusive angle or the hemispherically averaged emissivity can affect the calculation accuracy, especially for strongly anisotropic surface emission. The band-by-band contribution to the discrepancies between the RRTMG_LW and benchmark reveals compensating errors among the bands used in the RRTMG_LW.

Keywords

Surface spectral emissivity; longwave radiative cooling rate; radiation budget; LBLRTM; RRTMG_LW; climate models

1. Introduction

Surface emissivity is a key parameter for modeling the longwave (LW) radiative coupling between the surface and the atmosphere: it is an intrinsic optical property of the surface yet it decides the amount of upward longwave flux (or radiances) that enters the atmosphere. Moreover, emissivities of different surface types usually exhibit different

spectral dependence [1], which has been used widely in remote sensing to distinguish surface compositions, e.g., the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) using such spectral emissivity information to monitor land surface compositions and the change of the surface compositions [2].

In spite of the spectrally dependent nature of the surface emissivities, the atmospheric radiation schemes in state-of-the-art global climate models (GCMs) and numerical weather prediction (NWP) models still assume blackbody surface or a constant surface emissivity with no spectral dependence, usually termed as broadband surface emissivity [3-5]. Recent studies by Chen et al. [6] and Feldman et al. [7] showed discernible difference in the calculated radiation budget and simulated climate when blackbody surface assumption is replaced by a more realistic treatment of the surface spectral emissivity, especially over the Polar regions. These studies suggest that, in order to have a better simulated climate and a better understanding of the radiation budget at both the surface and the top of the atmosphere (TOA), spectral dependence of surface emissivity should be taken into account in the numerical models. Therefore, a question that must to be asked is: how accurately can the current longwave radiation schemes in the numerical models compute the radiative cooling rate profiles when such schemes take the surface spectral emissivity into account?

In principle, surface emissivity is a function of both frequency and solid viewing angle, i.e., surface emissivity can be spectrally dependent as well as angularly dependent. An example is shown in Figure 1a, which identifies noticeable changes of the emissivity of calm ocean water with viewing zenith angle (VZA) from 24° to 77°. The emissivity of desert, shown in Figure 1b, also exhibits angular dependence at all frequencies but the

variation with respect to the VZA is not as large as that of ocean surface emissivity. In the LW, the dependence on azimuthal angle is usually small. Therefore, the most important dependence is with respect to the VZA. For example, the upward LW flux at surface can be written as

$$F_s^\uparrow = 2\rho \int_{\Delta\nu} d\nu \int_0^{\frac{\pi}{2}} \left[\epsilon(q, \nu) B_\nu(T_s) + (1 - \epsilon(q, \nu)) I^\downarrow(q, \nu) \right] \cos q \sin q dq \quad (1),$$

where $B_\nu(T_s)$ is the Planck function at surface temperature T_s , $I^\downarrow$ is the downward radiance at the surface, θ is the zenith angle, ϵ is the emissivity, and $\Delta\nu$ is the LW spectrum range. Current LW radiation schemes in the GCMs cannot afford such rigorous evaluation over the VZA and over frequency. As a result, they usually can only perform calculations at one zenith angle. In most cases, the diffusive angle ($\cos\theta = 1/1.67$; [8]) is used for this purpose. Rather than performing time-consuming line-by-line calculation, the schemes divide the LW into a number of bands and calculate radiometric quantities for each band. As a result, band-averaged surface emissivity is used as input to the radiation schemes instead of the emissivity at high spectral resolution.

To summarize, the possible error sources when the surface spectral emissivity is included in the GCM radiation scheme are:

(1) Ignoring the angular dependence of surface emissivity. For example, the surface emissivity at the diffusive angle or the surface emissivity averaged over upper hemispherical zenith angles are used instead of the true angularly dependent surface emissivity. For example, Ham et al. [9] found negative bias in surface upward longwave

irradiance when hemispherical spectral reflectivity of ocean surface is used instead of angularly dependent surface emissivity.

(2) Approximating spectrally varying surface emissivity with band-averaged surface emissivity.

(3) Using an approximate method in the radiation scheme for solving the radiative transfer equation. This error contribution normally has been extensively studied when the radiation scheme is formulated and compared against line-by-line benchmark calculation.

Using a benchmark model such as Line-by-Line Radiative Transfer Model (LBLRTM) [10], the error contributions from the three sources above can be rigorously quantified. This study uses the RRTMG_LW [11], a radiation scheme used in a few climate and weather numerical modeling centers, as a case study to quantify the errors mentioned above. The rest of this paper is arranged as follows. Section 2 describes the radiative transfer models and methodology used in this study. Section 3 presents and explains the results. Conclusions and discussion are given in Section 4.

2. Model and methodology

2.1 LBLRTM and RRTMG_LW

LBLRTM version 12.2 is used in this study. It is a radiative transfer model developed by Atmospheric and Environmental Research, Inc. (AER) [10] and has been widely used as a benchmark model in atmospheric radiation parameterizations. It employs the HITRAN 2008 [12] spectroscopy database and MT_CKD version 2.5.2 for water vapor

continuum. The model has been extensively validated against both ground- and satellite-based observations [13-17]. The LBLRTM code package provides the capability to compute flux and radiative cooling rate profiles. We use 3-point Gaussian quadrature in the LBLRTM package to compute the flux and radiative cooling rate. The angularly and spectrally dependent surface emissivity is used in the LBLRTM package for the calculation. We use such LBLRTM results as the benchmarks in this study.

The Rapid Radiative Transfer Model for the LongWave (RRTMG_LW) was also developed by the AER. It utilizes the correlated-k approach to efficiently calculate longwave fluxes and heating rates [11]. It uses 16 bands from 10 cm^{-1} to 3250 cm^{-1} . As in other radiation schemes, diffusive approximation (i.e. one-angle calculation instead of multi-angle integration) is used and the surface emissivity is assumed constant within each band. RRTMG_LW is a widely used radiation scheme and has been incorporated into models developed by NCAR, NCEP, ECWMF and other institutes. Therefore, we will use the RRTMG_LW as a representative radiation scheme in the GCMs. By comparing results from the LBLRTM and RRTMG_LW, we will quantify the errors associated with the treatment of surface spectral emissivity in the RRTMG_LW model.

2.2 Methodology

We choose two typical types of surfaces in our study: calm ocean surface and desert surface. The spectral emissivity of ocean surface is computed using the Fresnel equations with the index of refraction of liquid water by Hale and Querry [18]. The spectral

emissivity of desert is estimated using the Fresnel equations with the index of refraction of Quartz O-Ray [19]. The emissivities are the same as those used in Feldman et al. [7].

We define Case 0, the benchmark case, as the case using the LBLRTM with 3-node Gaussian quadrature to compute the spectral flux and radiative cooling rates. The angularly dependent surface emissivity with full spectral resolution (dashed lines in Fig. 1) is used in Case 0. Then we define Cases 1-5 as follows:

Case 1: LBLRTM with diffusive approximation. The spectrally varying surface emissivity at the diffusive angle ($\sim 53^\circ$ zenith angle) (black lines in Fig. 1) is used in the calculation.

Case 2: LBLRTM with diffusive approximation and band-averaged surface emissivity. Surface emissivity at the diffusive angle is further averaged onto the RRTMG_LW bandwidths (red lines in Fig. 1).

Case 3: LBLRTM with diffusive approximation. Surface emissivity is averaged over the upper hemisphere and then is averaged onto the RRTMG_LW bandwidths (blue lines in Fig. 1). Note Case 2 and Case 3 would yield identical results if the surface emission is perfectly isotropic.

Case 4: Same as Case 2 but using RRTMG_LW instead of LBLRTM.

Case 5: Same as Case 3 but using RRTMG_LW instead of LBLRTM.

A summary of the definitions of cases is given in Table 1. Compared to Case 0, Case 1 approximates only the treatment of angular integration in the calculation, and Case 2 and Case 3 have approximations on both the angular integration and the spectral

resolution of surface spectral emissivity. Case 4 and Case 5 then evaluate how the method used to solve the radiative transfer equation. By comparing results from these cases, we can quantify errors due to different approximations.

In order to make the studies representative for different climates, we use four sets of atmospheric profiles: sounding profiles representative for the mid-latitude summer (hereafter, MLS), the subarctic winter (SAW), and the tropics (TROP) compiled by [20] and a desert profile. For the latter, we average the temperature and humidity profiles over Sahara desert region from December 2007 to February 2008 in the ECMWF ERA-Interim [21] to generate a representative profile for the Sahara desert (SAHARA). With four sets of atmospheric sounding profiles and two types of surface, there are eight atmosphere and surface configurations in total. For each configuration, we will use the LBLRTM and RRTMG_LW to compute fluxes and cooling rates of Case 0 and Cases 1-5 as described above. For all configurations and calculations, the LBLRTM and RRTMG_LW employ the same vertical height grid.

3. Results

3.1 LBLRTM vs. RRTMG_LW for the blackbody surface

It is instructive to examine the differences between the LBLRTM and RRTMG_LW calculations before the treatment of surface emissivity is incorporated into the two models. These differences are solely due to the way that the atmospheric radiative transfer equations by the two models are solved. Figure 2 shows the differences in clear-sky radiative cooling rates between LBLRTM and RRTMG_LW for a blackbody

surface. As far as the radiative cooling rates from surface to 300 hPa are concerned, the absolute differences in the cooling rates between the LBLRTM and RRTMG_LW results are only ~ 0.1 K/day or less. The largest fractional difference can be found at the levels near the surface, which is $\sim \pm 5\%$ for the MLS, SAW, and TROP profiles and only $\sim 2\%$ for the SAHARA profile. Between 700hPa and 300 hPa, the difference is generally within $\pm 3\%$. The findings above are consistent with the benchmark results of the RRTM_LW by [11].

3.2 Differences in the outgoing longwave spectral radiation

Figure 3a shows the benchmark (Case 0) outgoing longwave spectral flux at 1cm^{-1} interval for the MLS ocean configuration. The differences as calculated by Cases 1-5 are shown in Figure 3b. For Cases 4-5 computed by the RRTMG_LW, the difference of flux in each band is divided by the bandwidth and then shown on the plot so that it has the same unit as the other differences. Due to the amount of water vapor and CO_2 in the MLS profile, the surface emissivity contributes little to the TOA flux in the H_2O bands ($0\text{--}560\text{cm}^{-1}$ and $1200\text{--}1800\text{cm}^{-1}$) and CO_2 band ($560\text{--}800\text{cm}^{-1}$). This is why the differences between Cases 1-3 and Case 0 (blue, green, and red lines in Fig 3b) overlap with each other to a large extent in these bands. Note that Case 0 uses 3-point Gaussian quadrature to compute the flux while Cases 1-3 employ the diffusive approximation. The non-zero differences for Cases 1-3 in the H_2O and CO_2 bands are due to the different ways of treating angular integration. The different ways of treating surface emissivity affect the differences in the window bands ($800\text{--}990\text{cm}^{-1}$ and $1080\text{--}1200\text{cm}^{-1}$) and ozone band

(990-1080 cm^{-1}). Figure 3a and 3b show that the differences caused by the treatments of surface spectral emissivity is comparable to the differences caused by the treatments of angular integration, both being small and only accounting for 1-2% of the actual spectral flux in any part of the LW spectrum.

Table 2 shows the fractional difference of OLR in Cases 1-5 with respect to Case 0 for all eight configurations. The differences are all less than 1%. Comparing Case 2 to Case 3 (or Case 4 to Case 5), larger discrepancies can be seen for the ocean configuration than for the desert configuration. This is because the desert spectral emissivity (Fig. 1b) is more isotropic (i.e. has less angular dependence) than the ocean spectral emissivity (Fig. 1a). As a result, the hemispherical mean surface emissivity of desert is closer to its surface emissivity at the diffusive angle than the case of ocean.

3.3 Differences in the longwave radiative cooling rates

Figure 4 shows the benchmark (Case 0) calculation of radiative cooling rates of the aforementioned eight configurations. They are grouped according to the ocean surface (Fig. 4a) and desert surface (Fig. 4b). As expected, the cooling rates in the lower troposphere have a positive correlation with the amount of water vapor and, thus, the TROP configuration exhibits the largest radiative cooling from surface to 700 hPa while the SAW configuration has the smallest. For Cases 1-5, their differences from Case 0 are negligible for radiative cooling rates above 700 hPa. Therefore, in the following discussion we will only focus on the differences between surface and 700 hPa only.

Figure 5 shows the percentage differences of Cases 1-5 with respect to Case 0 for all configurations with ocean surface. The largest difference is always found at the surface or the layer right above the surface. Results from Case 1 and Case 2 are almost identical, which indicate that, under diffusive approximation, using the surface spectral emissivity at its original spectral resolution or at RRTMG_LW band resolution alone causes little difference in the LBLRTM calculation. For all panels shown in Fig. 5, noticeable differences between Case 2 and Case 3 exist because of the different ways of approximating the angular dependence of surface emissivity for the ocean surface, as explained in subsection 3.2. When the RRTMG_LW is used (Cases 4 and 5), the differences are comparable to their counterparts using the LBLRTM for the cases of MLS and TROP. For the cases of SAHARA and SAW, RRTMG_LW results show larger differences than the LBLRTM results, but in opposite directions for the layer nearest to the surface and all layers above it. As shown in Fig. 5b and 5d, Cases 4 and 5 underestimate the cooling rates at the surface by ~10-15% and overestimate it above surface by about 1% to 5%. The absolute differences between Case 4 (or Case 5) with respect to benchmark Case 0 are no more than ~0.17 K/day at the surface and no more than 0.20 K/day above the surface.

Figure 6 shows the results when the desert surface is used instead of ocean surface. Unlike in Fig. 5, the differences between Case 1 and Case 2 in Fig. 6 are large, which is related to the sharp change of desert emissivity with wavelength. The largest difference, ~-8%, can be seen at the SAHARA surface. As the surface emissivity of desert has less dependence on zenith angle than the ocean, the differences between Case 2 and Case 3 are much smaller than those shown in Fig. 5. For the same reasons, there is little

difference between Case 4 and Case 5 results for all configurations. Except for the differences above, the remaining conclusions obtained from Fig.5 are largely applicable to Fig. 6

The RRTMG_LW vs. LBLRTM differences for the case of blackbody surface in Fig. 2, hereafter termed as *diff1*, are the errors caused solely by the different methods used to solve the radiative transfer equation. The differences between Case 4 (or Case5) with Case 0 for the ocean and desert surfaces shown in Figs. 5 and 6, hereafter termed as *diff2*, are caused by approximations in the radiative transfer solver as well as approximations in representing surface spectral emissivity in the RRTMG_LW. Therefore, a double difference (*diff1-diff2*) can be formed and the result can be deemed as, at least to the first order, the difference solely due to the representation of surface spectral emissivity in the RRTMG_LW. This judgment is made because any other difference caused by the rest part of RRTMG_LW is already included in the results shown on Fig. 2. The double differences are shown in Figure 7. They are non-positive for all configurations. As expected, the largest differences are seen in the lowest layer for all configurations and, above the lowest layer, the differences are essentially zero. One fact to note is that, even the fractional differences for the SAW and SAHARA configurations are larger than those for the MLS and TROP configurations, the absolute radiative cooling rates for the SAW and SAHARA configurations are smaller than those for the MLS and TROP configurations (Fig. 4). As a result, the absolute differences due to the representation of surface emissivity for all configurations are around -0.2 to -0.07K/day. We also examine the cooling rate difference contributed by each spectral band in the RRTMG_LW. Figure 8a shows the Case 0 benchmark spectral cooling rate integrated for

each RRTMG_LW band for the lowest layer. For the MLS and TROP configurations, the window bands contribute most to the LW cooling rate. Both the MLS and TROP have abundant water vapor, thus the far-IR water vapor band is opaque, leading to little flux divergence near the surface. The water vapor continuum absorption and emission in the window band, as a result becomes the largest contributor to the flux divergence (i.e. radiative cooling). The SAW and SAHARA profiles have less water vapor than the MLS and TROP. Therefore, far-IR is less opaque and it contributes to the total cooling rate as much as the window bands do.

The band-by-band differences (Case 4 – Case 0) in radiative cooling rate at the lowest layer are shown in Fig. 8b. Every configuration has compensating positive and negative differences from different spectral bands. Even within the mid-IR window regions, the offset among bands is evident for all configurations. Note that even the absolute band-integrated radiative cooling rate is only ~ 0.3 K/day or even much less for each of the three bands in the far-IR, the difference between the RRTMG_LW and LBLRTM can be as large as ± 0.05 K/day.

4. Conclusions and discussion

Motivated by recent studies that illustrate the need of incorporating surface emissivity into the radiation scheme of climate models, we quantify the errors due to the representation of surface emissivity in the RRTMG_LW by comparing them with the LBLRTM benchmark calculation. In general, using the spectral emissivity at the diffusive angle is a better choice than the hemispherical mean spectral emissivity. This

conclusion is based on the fact that both treatments cause comparable errors when surface emissivity is nearly isotropic but the former one has smaller errors when surface emissivity behaves more anisotropically. Using surface emissivity at high spectral resolution or the RRTMG_LW band resolution causes little difference in the calculated radiative cooling rate when the diffusive approximation is used. Including surface emissivity in the RRTMG_LW causes little differences in radiative cooling rates above 700 hPa. Compared to the benchmark cases, the largest deviations are always seen in the lowest layers next to the surface. The fractional difference is larger for the arid configuration (SAHARA or SAW) than for the humid configuration (TROP or MLS) (Fig. 7). However, because the absolute near-surface radiative cooling for the arid configurations is smaller than that for the humid configurations (Fig. 4), the absolute differences in near-surface radiative cooling rate are ~ -0.1 K/day for all configurations examined here. The contribution to these differences from each RRTMG_LW band can be either positive or negative, with the far-IR bands and window bands contributing more than the rest bands.

The radiative cooling rate examined here is the layer-averaged cooling rate. Therefore, it is imaginable that the error associated with the RRTMG_LW calculation would be dependent on the vertical thickness of each layer. From a modeling perspective, high vertical resolution in the planetary boundary layer (PBL) is desired in order to better resolve turbulent motions in the PBL. Our study shows that most errors caused by incorporating surface emissivity into the radiation scheme also reside in the PBL, especially the layer just next to the surface.

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Figure Captions

Figure 1. (a) Spectral emissivity for calm ocean surface over the entire LW spectrum. Colored dash lines are the emissivities at different viewing zenith angles while black line is the emissivity at the diffusive angle. The emissivities at the diffusive angle averaged onto the RRTMG_LW bandwidth are shown as red step-wise line. The blue line is the hemispherical mean emissivity averaged onto the RRTMG_LW bandwidth. The abscissa is labeled according to the band ranges defined in the RRTMG_LW. (b) Same as (a) except for the desert surface.

Figure 2. (a) Left panel shows the radiative cooling rates profile as computed by the LBLRTM (black line) and by the RRTMG_LW (blue line) for the MLS atmospheric profile with a blackbody surface. Right panel shows the RRTMG_LW – LBLRTM

difference in percentage. (b) Same as (a) but for the SAW profile. (c) Same as (a) but for the TROP profile. (d) Same as (a) but for SAHARA profile.

Figure 3. (a) The spectral OLR at 1cm^{-1} resolution for the MLS+ocean case as computed by the benchmark Case 0. (b) The spectral OLR difference of Cases 1-5 from the benchmark. The spectral band ranges used in RRTMG_LW are labeled. Cases 4 and 5 are from the RRTMG_LW calculation thus the difference is constant for each RRTMG_LW band.

Figure 4. The radiative cooling rates from surface to 700hPa as computed by the benchmark Case0 for the ocean surface configuration (left panel) and for the desert surface configuration (right panel). Results for different atmospheric profiles are shown in different colors.

Figure 5. Percentage difference of radiative cooling rates between Cases 1-5 and Case 0 for the configurations with ocean surface. Results of Cases 1-5 are shown in different colors. (a) MLS (b) SAW (c) TROP and (d) SAHARA.

Figure 6. Percentage difference of radiative cooling rates between Cases 1-5 and Case 0 for the configurations with desert surface. Results of Cases 1-5 are shown in different colors. (a) MLS (b) SAW (c) TROP and (d) SAHARA.

Figure 7. Percentage differences in the radiative cooling rates caused solely by the approximation of surface spectral emissivity in the RRTMG_LW. Further details can be found in subsection 3.3.

Figure 8. (a) Radiative cooling rate at the lowest atmospheric layer from each RRTMG_LW band as computed from Case 0, the benchmark case for all four

configurations with desert surface. (b) Radiative cooling rate differences between Case 4 and Case 0 shown in (a).

Figure 1. (a) Spectral emissivity for calm ocean surface over the entire LW spectrum. Colored dash lines are the emissivities at different viewing zenith angles while black line is the emissivity at the diffusive angle. The emissivities at the diffusive angle averaged onto the RRTMG_LW bandwidth are shown as red step-wise line. The blue line is the hemispherical mean emissivity averaged onto the RRTMG_LW bandwidth. The abscissa is labeled according to the spectral bands used in the RRTMG_LW. (b) Same as (a) except for the desert surface.

Figure 2. (a) Left panel shows the radiative cooling rate profile as computed by the LBLRTM (black line) and by the RRTMG_LW (blue line) for the MLS atmospheric profile with a blackbody surface. Right panel shows the RRTMG_LW - LBLRTM difference in percentage. (b)-(d) Same as (a) but for the SAW, TROP, and SAHARA profiles, respectively.

Figure 3. (a) The spectral OLR at 1cm⁻¹ resolution for the MLS+ocean case as computed by the benchmark Case 0. (b) The spectral OLR differences of Cases 1-5 from Case 0. The spectral band ranges used in RRTMG_LW are labeled. Cases 4 and 5 are from the RRTMG_LW calculation thus the difference is constant for each RRTMG_LW band.

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Figure 6. Percentage difference of radiative cooling rates between Cases 1-5 and Case 0 for the configurations with desert surface. Results of Cases 1-5 are shown in different colors. (a) MLS (b) SAW (c) TROP and (d) SAHARA.

Figure 7. Percentage differences in the radiative cooling rates caused solely by the approximation of surface spectral emissivity in the RRTMG_LW. Further details can be found in subsection 3.3.

Figure 8. (a) Radiative cooling rate at the lowest atmospheric layer from each RRTMG_LW band as computed from Case 0, the benchmark case for all four configurations with desert surface. (b) Radiative cooling rate differences between Case 4 and Case 0 shown in (a).

Tables

Table 1. Definitions of cases used in the study.

	3-node Gaussian quadrature; spectrally and angularly varying emissivity	Diffusive approximation; spectrally varying emissivity at the diffusive angle (53°)	Diffusive approximation; band-averaged emissivity at the diffusive angle (53°)	Diffusive approximation; band-averaged and hemispherically averaged emissivity
LBLRTM	Case0	Case1	Case2	Case3
RRTMG_LW	N/A	N/A	Case4	Case5

Table 2. Fractional differences of OLR between Cases 1-5 and the benchmark Case 0 for eight configurations of atmosphere and surface conditions.

	MLS Ocean	SAW Ocean	TROP Ocean	SAHARA Ocean	MLS Desert	SAW Desert	TROP Desert	SAHARA Desert
Case1	-0.14%	0.39%	-0.17%	0.29%	-0.08%	0.01%	-0.06%	-0.09%
Case2	-0.16%	0.34%	-0.18%	0.26%	0.06%	0.29%	-0.02%	0.07%
Case3	-0.46%	-0.40%	-0.36%	-0.56%	-0.01%	0.09%	-0.06%	-0.16%
Case4	-0.05%	0.22%	0.00%	0.23%	0.12%	0.08%	0.06%	-0.20%
Case5	-0.40%	-0.59%	-0.20%	-0.72%	-0.20%	-0.13%	0.01%	-0.44%