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Quantifications Of The Errors Associated With The Representation Of Surface Emissivity In The RRTMG_LW

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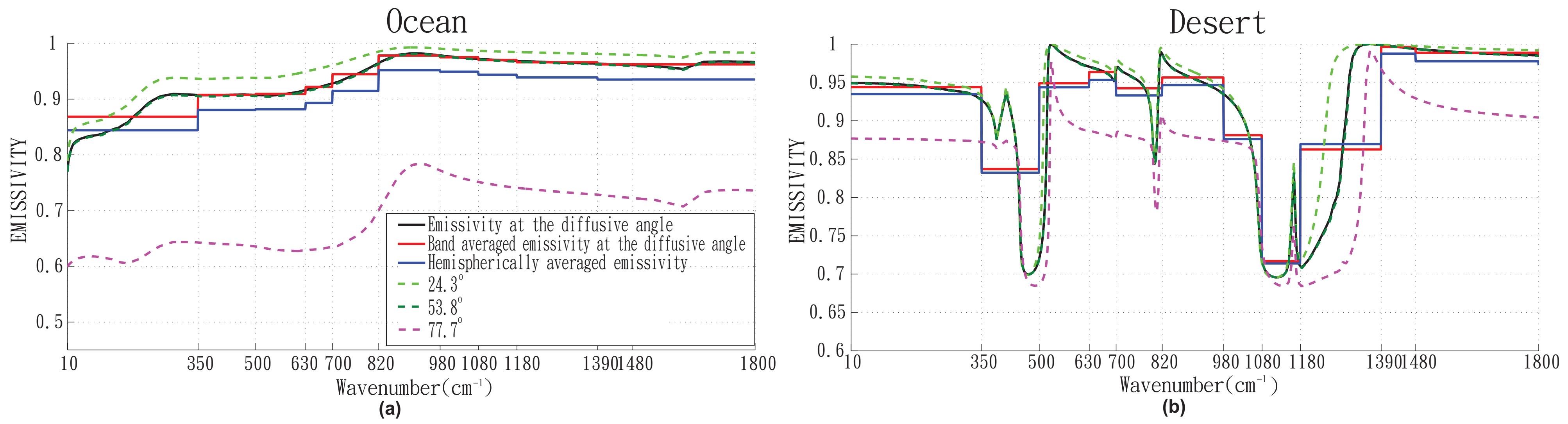
Motivations

1. Current climate models and numeric weather predictions (NWP) assume blackbody surface (ε=1) in the longwave radiation schemes.
2. In reality, the surface spectral emissivity, which is a function of both zenith angle θ and wavenumber ν, has non-negligible impact on the radiation budget, especially in Polar regions (Chen et al. 2014).
3. Quantify the errors due to the representation of surface emissivity in mainstream radiation schemes.

Emissivity



Different ways of the representations of the spectral emissivity for two types of surface.

LBLRTM and RRTMG_LW

1. A line-by-line radiative transfer model (LBLRTM) version 12.2 is used as benchmark.
2. The RRTMG_LW model utilizes the correlated-k approach to calculate fluxes and the radiative cooling rates .
3. The RRTMG_LW is one of the most widely used longwave radiation scheme in current weather and climate models.

Possible error sources of the RRTMG_LW

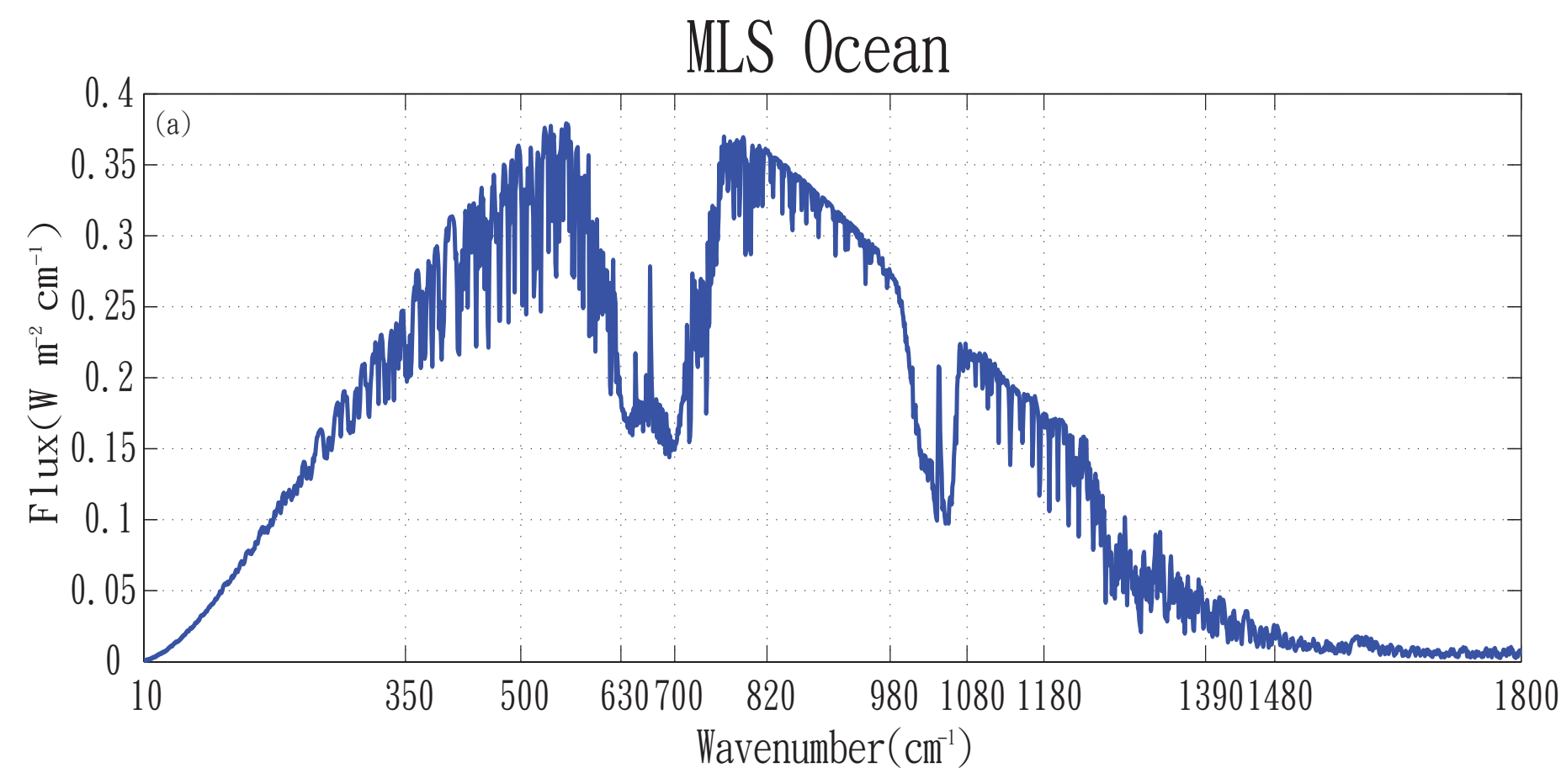
1. Ignoring the angular dependence of surface emissivity.
2. Approximating spectrally varying surface emissivity with band-averaged surface emissivity.
3. Approximate method for solving the radiative transfer equation.

Methodology

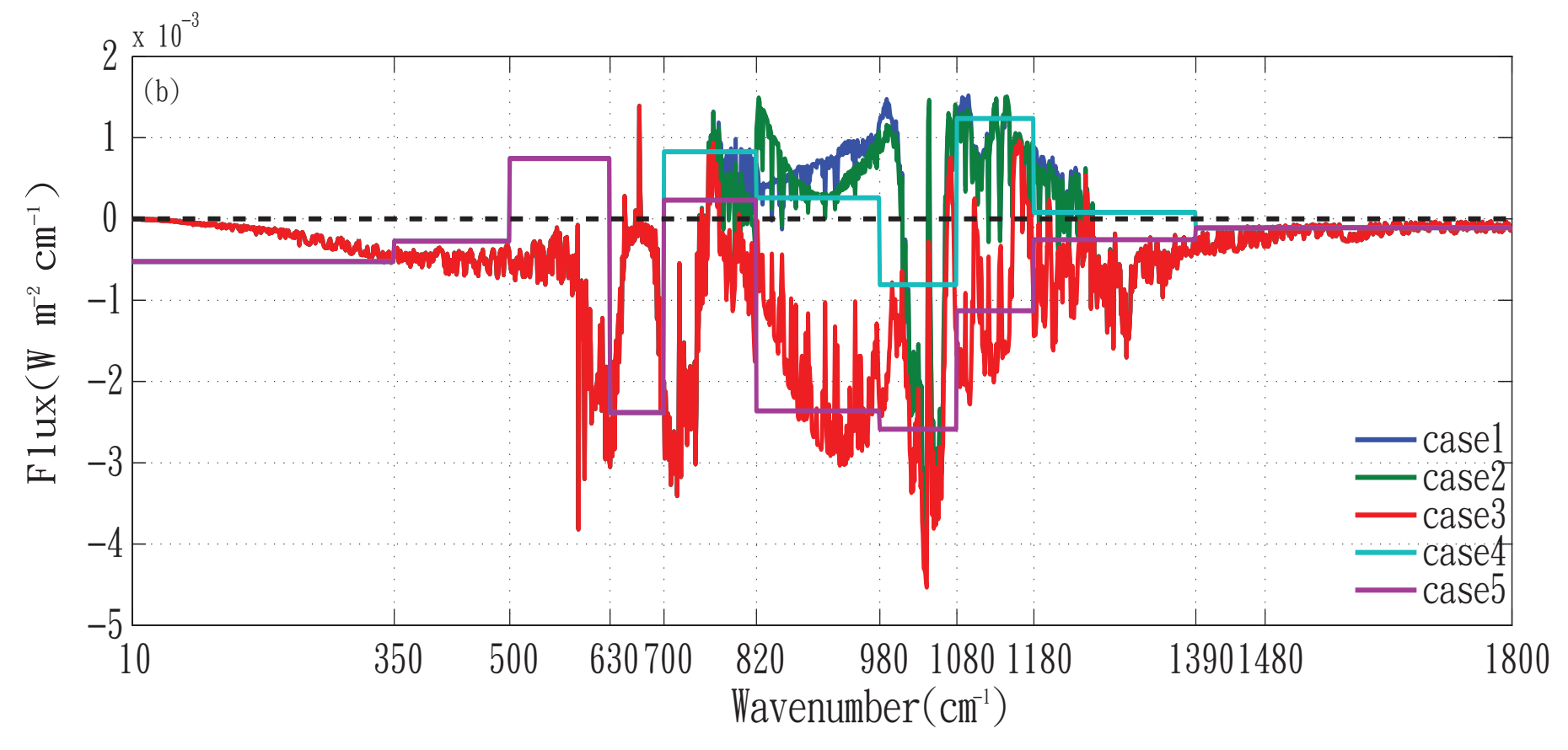
1. Compare the radiative cooling rates calculated by the LBLRTM using different representations of surface emissivity.
2. Compare the radiative cooling rates calculated by the RRTMG_LW and by the LBLRTM .
3. Four atmospheric profiles are used: mid-latitude summer (MLS), subarctic winter (SAW), tropical (TROP) and Sahara desert (SAHARA) profiles.
4. Two types of surface are applied: coean and desert.

Case definitions

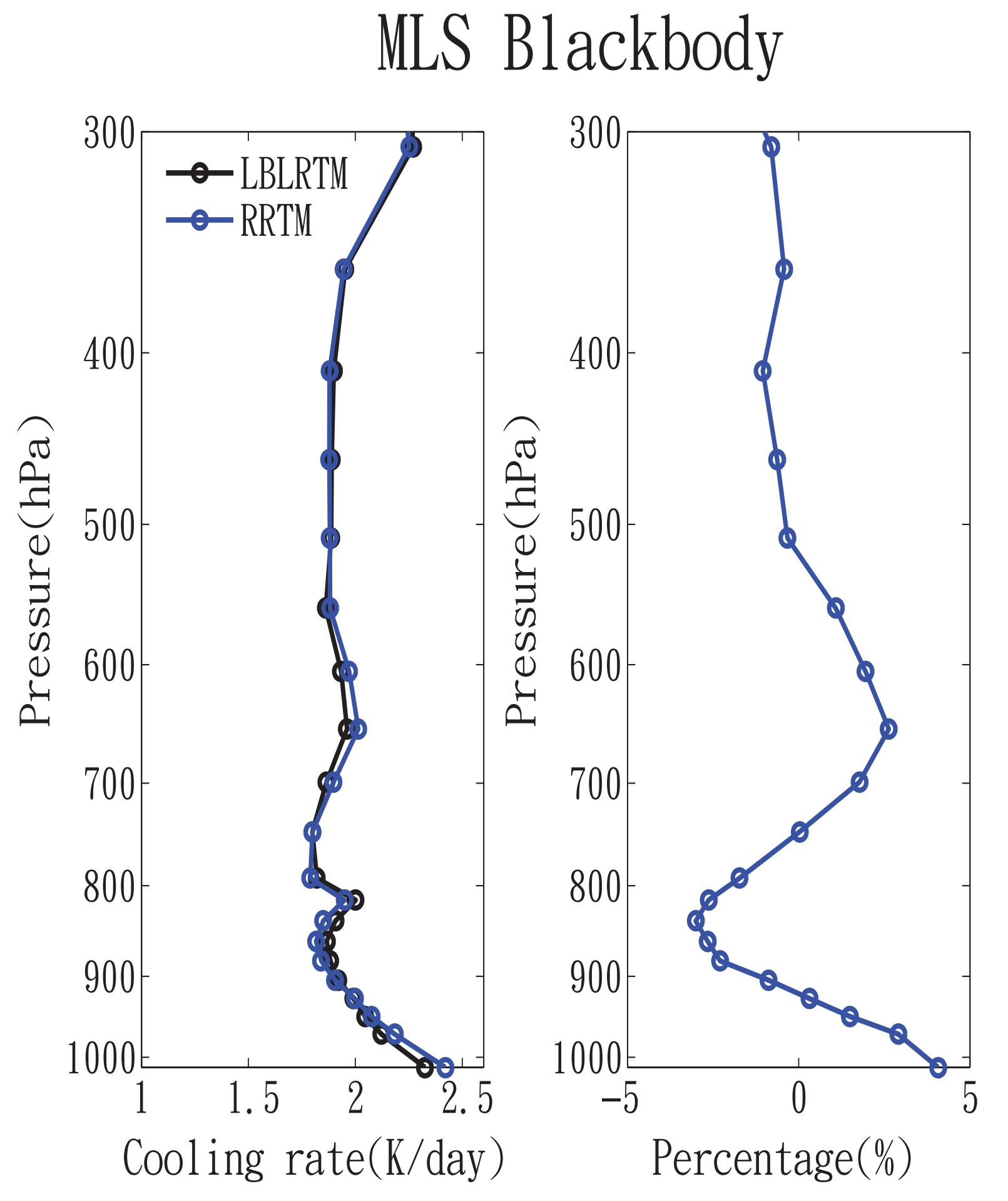
	3-node Gaussian quadrature; angularly-dependent emissivity	Diffusive approximation; spectrally varying emissivity at the diffusive angle (53°)	Diffusive approximation; band-averaged emissivity of diffusive angle (53°)	Diffusive approximation; band-averaged and hemispherically averaged emissivity
LBLRTM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



Spectral OLR at 1 cm⁻¹ resolution for the Mid-latitude Summer (MLS) + ocean surface emissivity computed by the benchmark Case0.

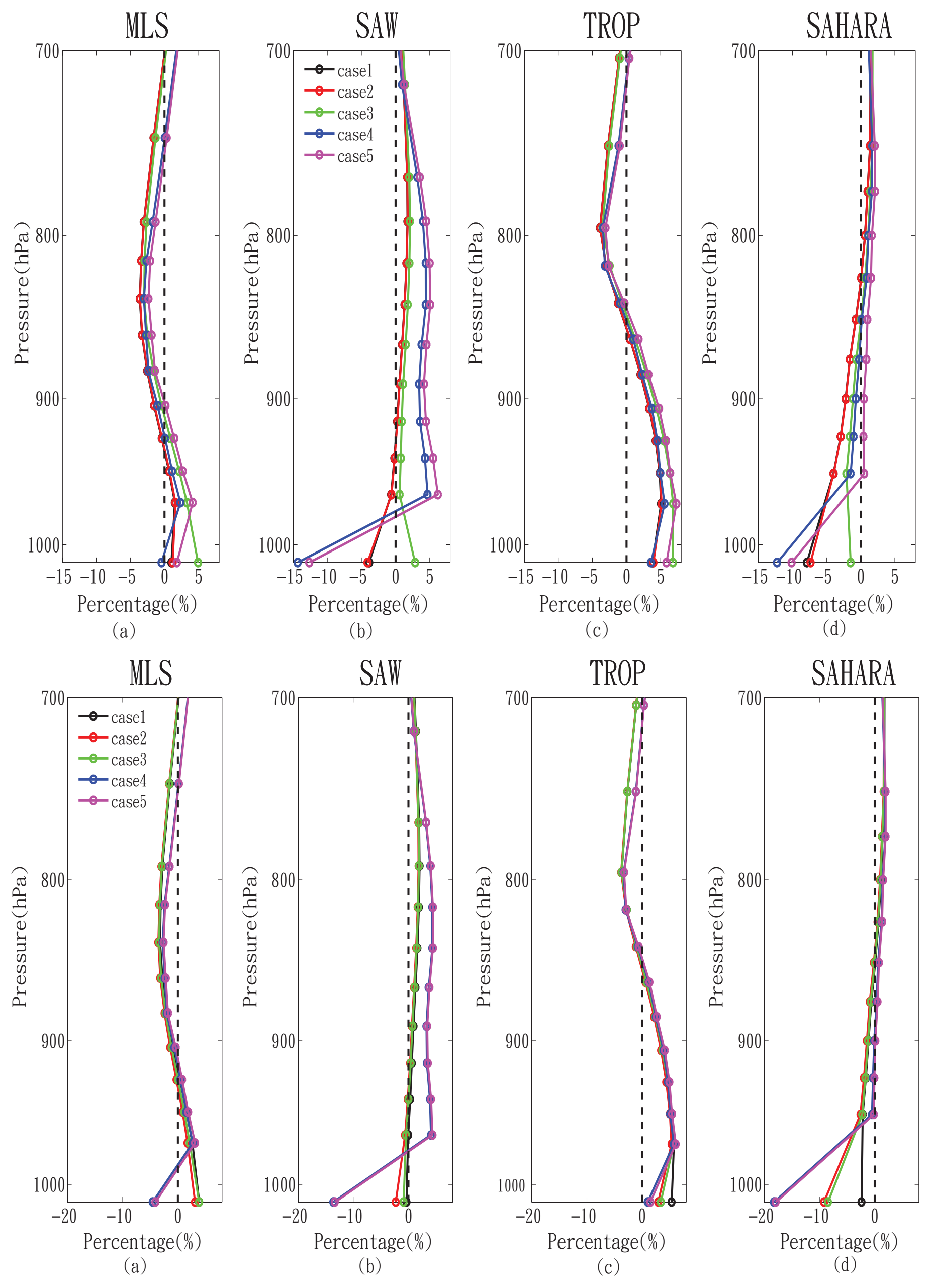


Spectral OLR difference of Case 1-5 from the benchmark.



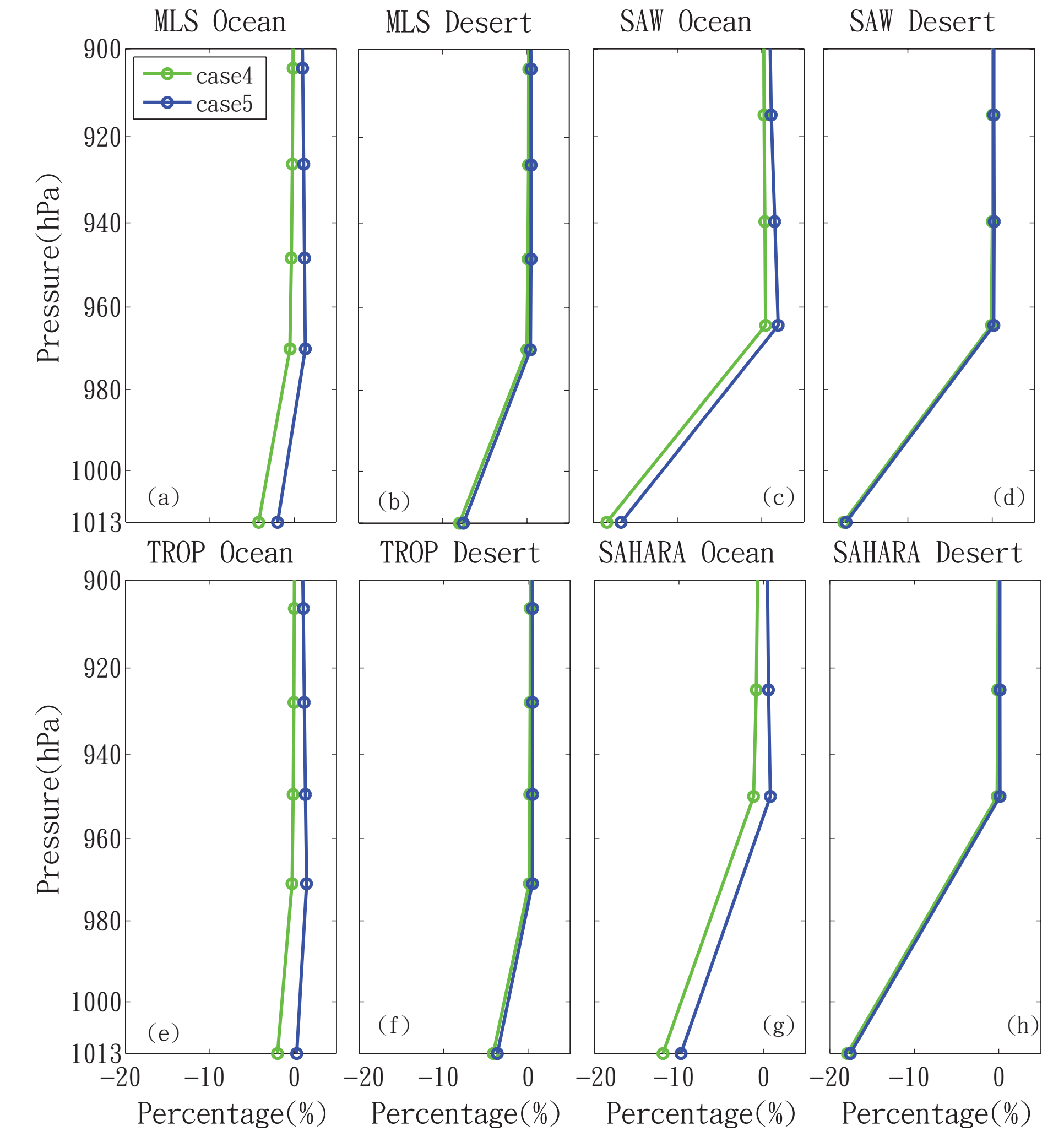
Radiative cooling rate computed by the LBLRTM and the RRTMG_LW with blackbody surface and their percentage difference.

*The longwave radiative cooling rates differences caused solely by the approximate method applied in the RTMG_LW are no more than ~±5% for all four profiles.

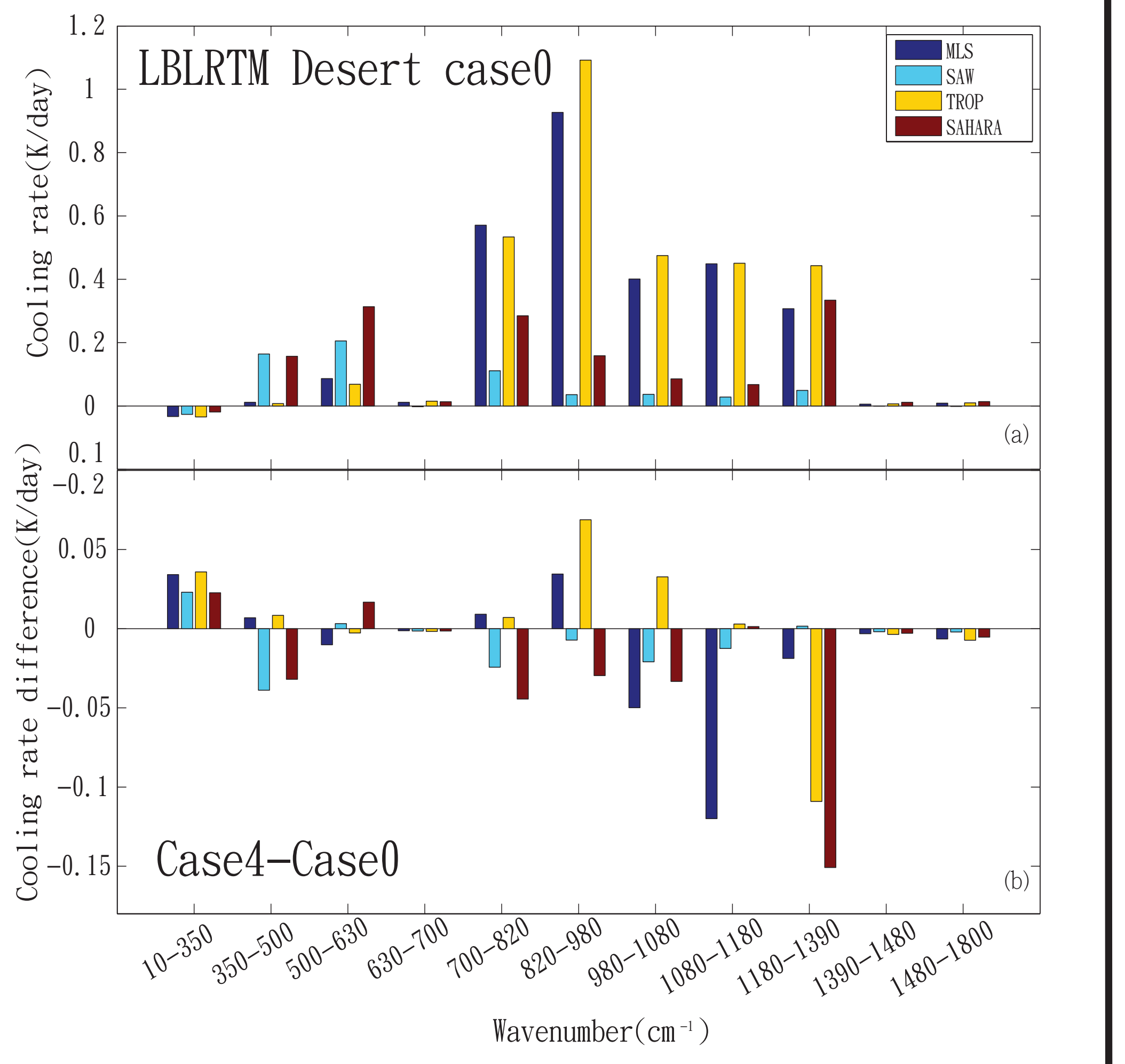


Percentage difference of radiative cooling rates between Case 1-5 and Case0 for the configuration with the ocean surface (upper row) and the desert surface (bottom row).

- The surface emissivity variation with respect to the viewing zenith angle is larger for the ocean than for the desert surface. This is the reason that the difference between Case2 and Case3 is larger for the ocean surface than for the desert surface.



Percentage difference in the radiative cooling rates caused solely by the approximation of the surface spectral emissivity in the RRTMG_LW



(a) Radiative cooling rates from each RRTMG_LW band as computed from Case0, the benchmark case for all four configurations with desert surface. (b) Radiative cooling rate differences between Case 4 and Case0.

Conclusion

- The representation of surface emissivity causes little difference in broadband outgoing longwave radiation.
- The representation of surface emissivity can cause noticeable differences in longwave radiative cooling rates from surface to 700 hPa.
- The largest discrepancy in radiative cooling rate is ~10-15%, which happens at the lowest atmospheric layer next to the surface for the subarctic winter and Sahara desert profiles.
- The discrepancies caused solely by the representation of surface emissivity are confined at the lowest atmospheric layer and the fractional difference is no more than 20%.

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