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Longwave Radiation at the Cloud-Aerosol Transition Zone from Radiative Parameterizations in Weather Research and Forecasting Model (WRF)

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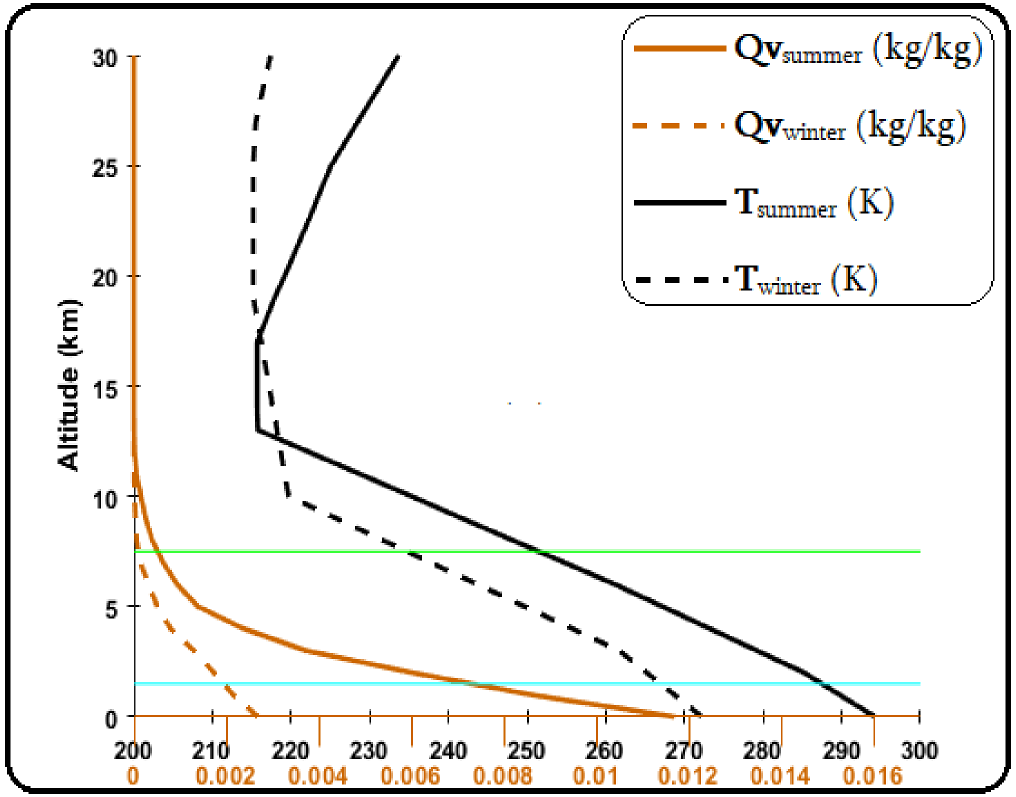
There are conditions between cloudy and cloud-free air at which it is hard to define the suspended particles in the atmosphere either as a cloud or an atmospheric aerosol; it is called twilight or transition zone. This occurs when characteristics of the suspended particles are between those corresponding to a pure cloud and those corresponding to a pure atmospheric aerosol. However, in most meteorological and climate studies the condition of sky is assumed to be either cloudy (fully developed cloud) or cloud-free (dry aerosol), neglecting the transition zone. The present communication aims to show the uncertainties introduced by this simplified assumption in modeling longwave radiation. For this purpose, the parameterizations RRTMG, NewGoddard and FLG included in the Weather Research and Forecasting Model (WRF) version 4.0 were isolated from the whole model. These parameterizations were then used to perform a number of simulations under ideal “cloud” and “aerosol” modes, for different values of (i) cloud optical thicknesses resulting from different sizes of ice crystals or liquid droplets, cloud height, mixing ratios; and (ii) different aerosol optical thicknesses combined with various aerosol types. The differences in the resulting longwave radiative effects (RE) at the top of the atmosphere and at the Earth surface were analyzed. The primary results show: (1) the parameterization RRTMG is not capable of simulating the REs of the aerosols in the longwave region, (2) different assumptions of a situation corresponding to the transition zone lead to a mean relative uncertainty of about 170% in the estimated longwave irradiance at both top of the atmosphere and surface, (3) the absolute uncertainties observed in the surface downwelling irradiances are substantially greater than those relating to the upwelling irradiances at top of the atmosphere when liquid clouds and aerosols are compared. Whereas, the opposite is true when ice clouds and aerosols are compared.

Methods: Reference Atmospheres

- Cloud-and aerosol-free (“clean”) Standard mid-latitude Summer and Winter atmospheres (Anderson et al., 1986).
- Surface Emissivity: 0.97



Anderson, G. P., Clough, S. A., Kneizys, F. X., Chetwynd, J. H., & Shettle, E. P. (1986). AFGL atmospheric constituent profiles (0.120 km). AIR FORCE GEOPHYSICS LAB HANSCOM AFB MA

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Methods: Cloud and Aerosol Comparison Cases

- Ice clouds and aerosols at high altitudes (I-a)
- Liquid Clouds and aerosols at low altitudes (L-a)

I-a	L-a
Cristal size: 10 – 120 μm	Droplet size: 2.5 – 15.0 μm
Altitude of the layer: ~ 7.5 km	Altitude of the layer: ~ 1.5 km
Aerosol type: Urban, Continental, Marine	
Cloud/aerosol optical depth at 550 nm (τ): 0.01 – 2.00	

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Methods: Radiative Effect

$$\mathbf{RE}^{\alpha}_{\mathrm{irr,par}}(\tau) = \mathbf{E}^{\alpha}_{\mathrm{irr,par}}(\tau) - \mathbf{E}^{0}_{\mathrm{irr}}$$

RE: Radiative Effect for the cloud/aerosol layer with optical depth at 550 nm equal to τ ($\mathrm{W\,m^{-2}}$)

E: Broadband Longwave Irradiance ($\mathrm{W\,m^{-2}}$)

irr: Upwelling or Downwelling Longwave Irradiances

par: Parameterization

α: Run case

0: Reference Case

Methods: Radiative Effect Uncertainty

$$\Delta\mathbf{RE}_{\text{irr,par}}(\tau) = \max(\mathbf{RE}_{\text{irr,par}}(\tau)) - \min(\mathbf{RE}_{\text{irr,par}}(\tau))$$

$$\overline{\mathbf{RE}}_{\text{irr,par}}(\tau) = 0.5[\max(\mathbf{RE}_{\text{irr,par}}(\tau)) + \min(\mathbf{RE}_{\text{irr,par}}(\tau))]$$

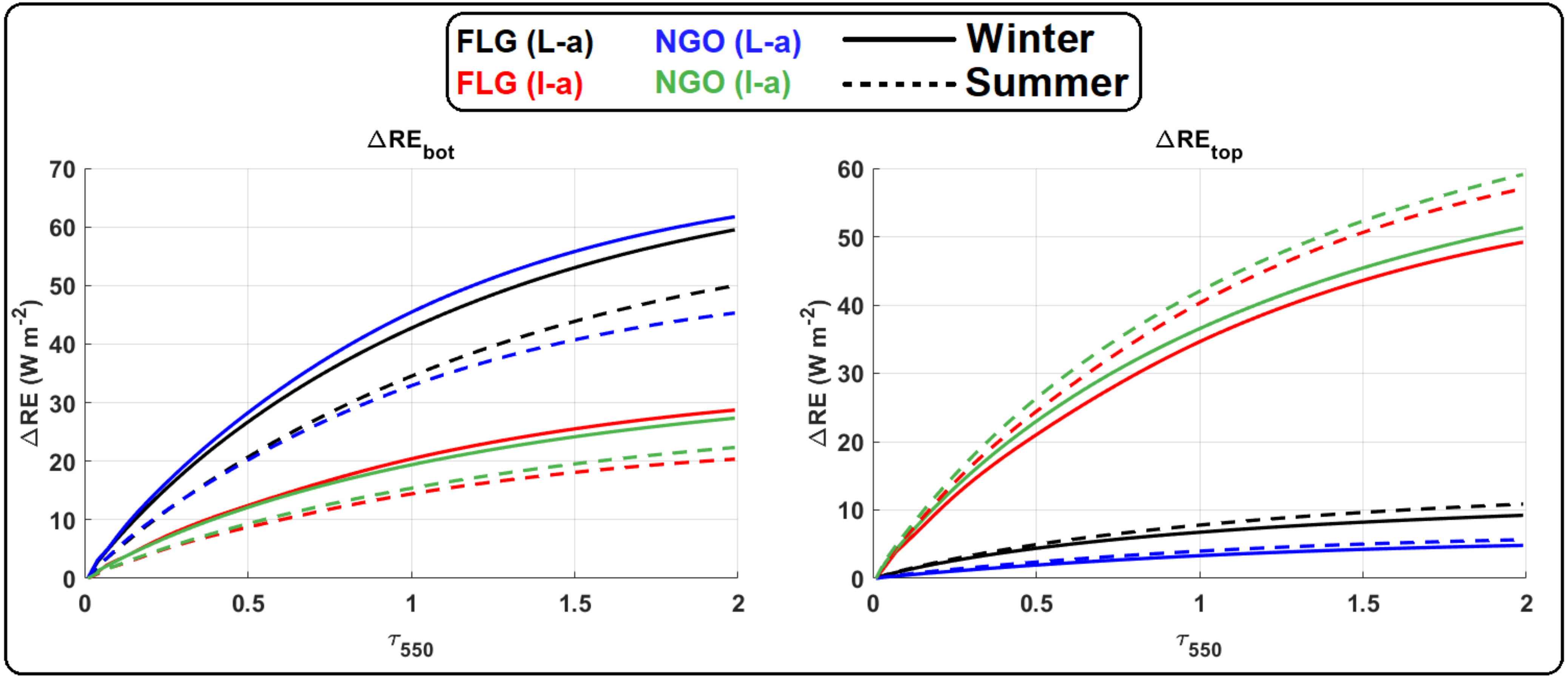
$$\mathbf{R\Delta RE}_{\text{irr,par}}(\tau) = \Delta\mathbf{RE}_{\text{irr,par}}(\tau)/\overline{\mathbf{RE}}_{\text{irr,par}}(\tau)$$

$$\overline{\mathbf{R\Delta RE}}_{\text{irr,par}} = \frac{100}{2-0.01}\int_{0.01}^{2} \mathbf{R\Delta RE}_{\text{irr,par}}(\tau)\, d\tau$$

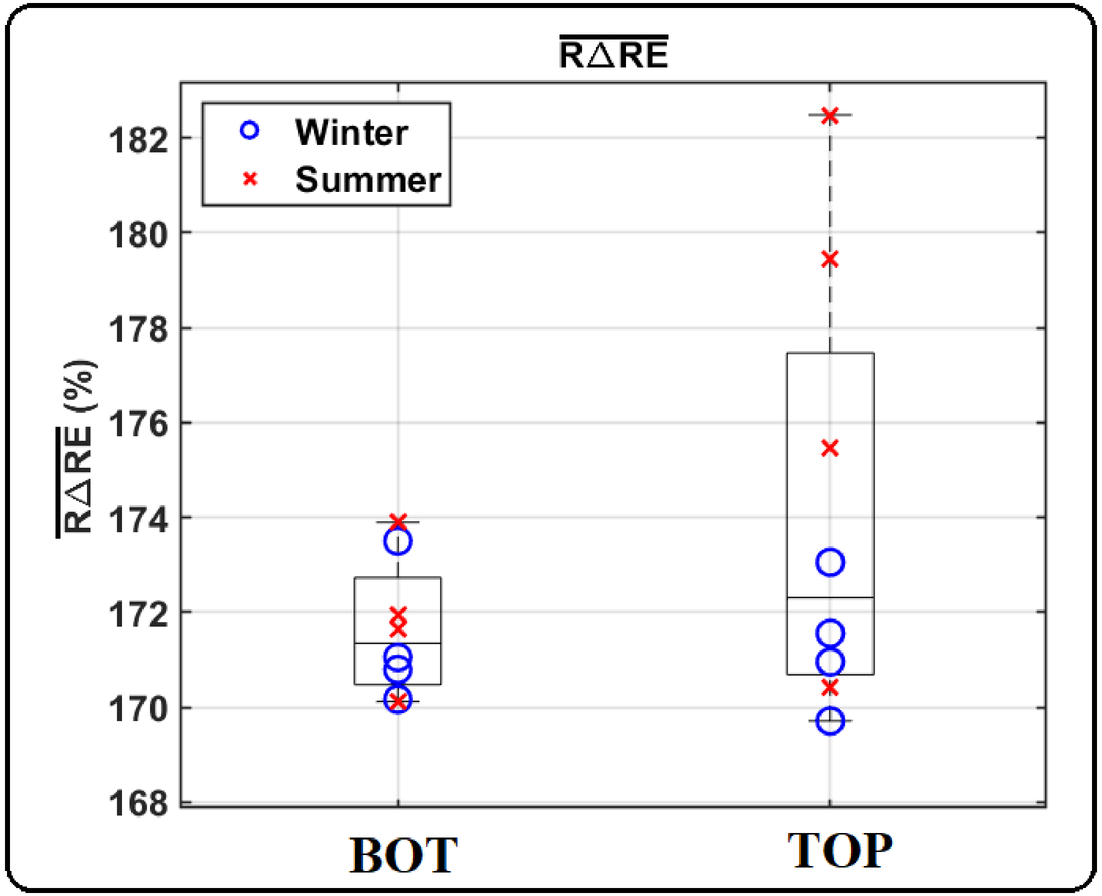
$\Delta\mathbf{RE}$**:** Radiative Effect Uncertainty ($\mathrm{W\ m^{-2}}$)

$\overline{\mathbf{R\Delta RE}}_{\text{irr,par}}$: Mean Relative Radiative Effect Uncertainty (%)

Results: ΔRE



Results: $\overline{\mathbf{R\Delta RE}}$



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