Geophysical Research Letters

Supporting Information for

Climatology of cloud-top radiative cooling in marine shallow clouds

Youtong Zheng[1,4], Yannian Zhu[2], Daniel Rosenfeld[2,3], and Zhanqing Li[1]

Affiliations:
[1]Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland, 20742, USA.
[2]Nanjing University, Nanjing, China
[3]Herew University of Jerusalem, Jerusalem, Israel

[4]Now at GFDL/AOS program, Princeton University, Princeton, New Jersey

Contents of this file

1. Text S1~S2
2. Figures S1~S5
3. Table S1

Text S1: Radiative transfer model

The radiative transfer model we use is the Santa Barbara DISORT Atmospheric Radiative Transfer model (Ricchiazzi et al., 1998). We specify the vertical grids with resolutions of 50 m from the surface to 2.25 km and the grid spacing increases with the altitude until the top of the atmosphere, leading to a total of ~ 60 grids in the vertical. The ozone profile and greenhouse gas concentrations are set to default values. The cloud optical depth is uniformly distributed throughout the cloud layer. The wavelength ranges of longwave and shortwave are set as 5 ~ 40 µm and 0.1 ~ 5 µm, respectively. The wavelength increment is 0.1 µm for shortwave and 0.2 µm for longwave.

Text S2: Configuration of the neural network model

Our NN has a total of four layers. The input and output layers have 25 and 5 nodes respectively, which matches the number of input and output variables. Between them are two fully connected hidden layers with 256 nodes. This adds up to a total of 73733 learnable parameters. We use the Rectified Linear Unit (ReLU) for activation function and the Adam optimizer with a mean squared error loss function. Given the large number of training samples, the specific choices of the hyper-parameters make little difference to the performance. The input data are normalized and shuffled before the training. The total training time was about 7 minutes on a single graphics processing unit.

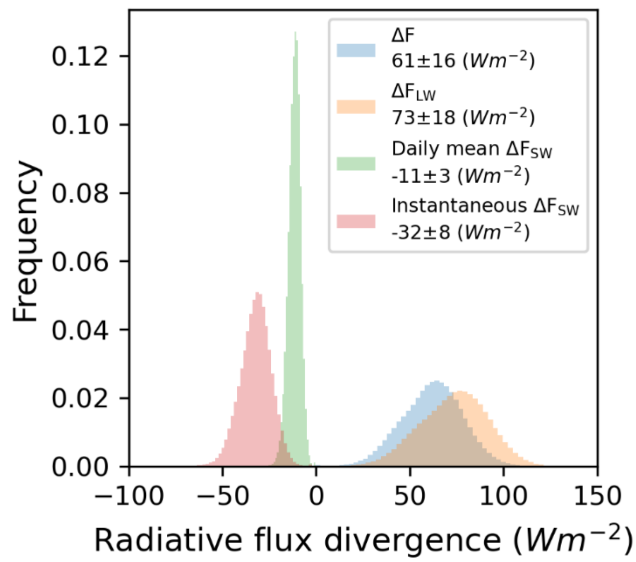

Figure S1: Probability density functions of cloud-top radiative flux divergences.

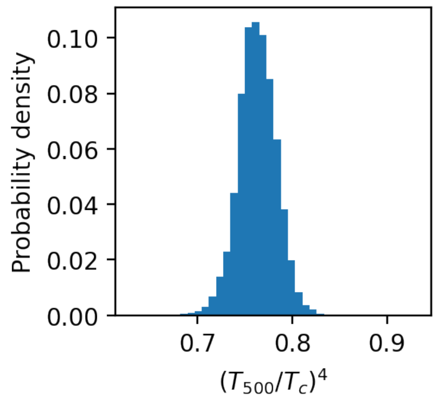

Figure S2: Probability density functions of the ratio between the temperature at 500 hPa (as an approximation for T_a in Eq. 2) and cloud-top temperature.

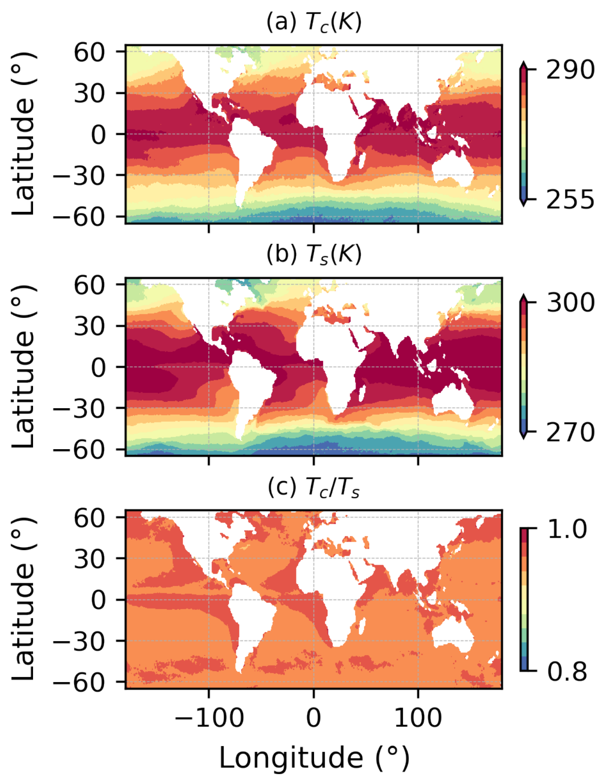

Figure S3: Annual-mean cloud-top temperature (a), sea surface temperature (b), and their ratio (c).

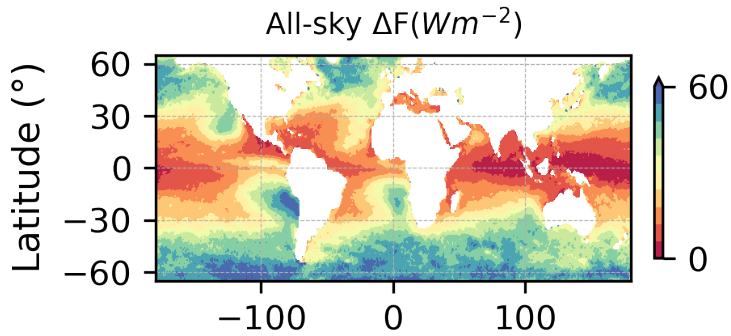

Figure S4: Annual-mean all-sky cloud-top radiative cooling.

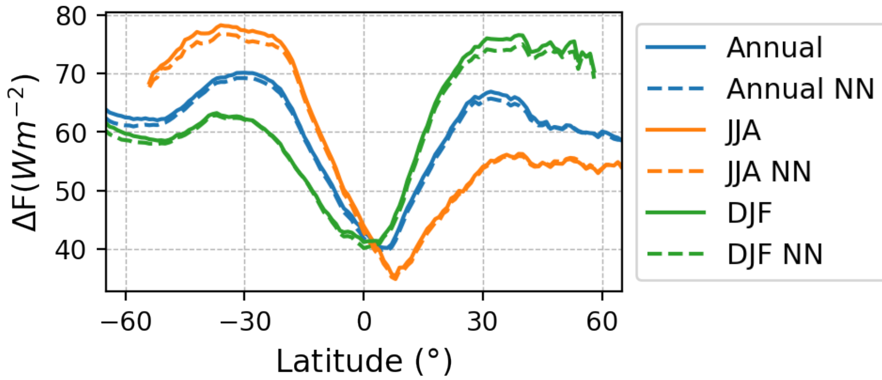

Figure S5: Zonal-mean meridional variations of cloud-top radiative cooling computed from the radiative transfer model (solid) and the neural network (dashed) for boreal summer (orange) and winter (green).

Input variables	Unit	Output variables	Unit
Cloud optical depth	Unitless	**Cloud top radiative cooling, ΔF**	W m^{-2}
Cloud droplet effective radius	μm	**Cloud top longwave cooling, ΔF_{LW}**	W m^{-2}
Cloud top temperature	K	**Cloud top shortwave heating, ΔF_{SW}**	W m^{-2}
Solar zenith angle	degree	Cloud base longwave heating	W m^{-2}
Sea surface temperature	K	Cloud longwave radiative effect	W m^{-2}
Absolute temperature from 1000 hPa to 100 hPa with 100 hPa interval	K		
Relative humidity from 1000 hPa to 100 hPa with 100 hPa interval	%		

Table 1: Input and output variables for the Neural Network. The CTRC variables used in this study are highlighted in bold.

Reference

Ricchiazzi, P., Yang, S., Gautier, C., & Sowle, D. (1998). SBDART: A research and teaching software tool for plane-parallel radiative transfer in the Earth's atmosphere. *Bulletin of the American Meteorological Society, 79*(10), 2101-2114.