Cloud properties of arctic boundary-layer stratus: impacts on surface radiation

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Introduction

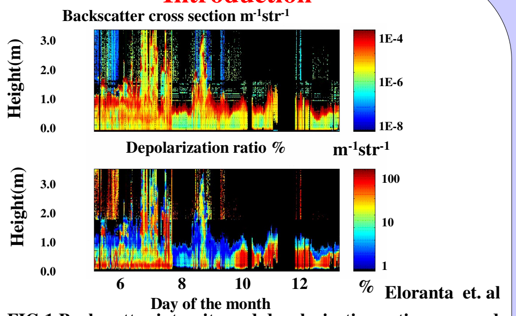

FIG 1 Backscatter intensity and depolarization ratio measured by Wisconsin HSRL lidar in Barrow, AK show optically thick boundary-layer stratus between 5 and 12 Oct. 2004.

Optically-thick boundary-layer stratus have a large impact on surface longwave radiation budget given their high cloud coverage. Here, the following are investigated:

1) Is radiative forcing calculated using the LBLRTM (Line-By-Line Radiative Transfer Model) initialized with observed microphysical & macrophysical characteristics of single-layer boundary layer stratus consistent with that observed by the AERI (Atmospheric Emitted Radiance Interferometer)?
2) What are relative roles of cloud microphysical and macrophysical properties in determining the longwave surface radiation budget?

Surface longwave radiation simulation

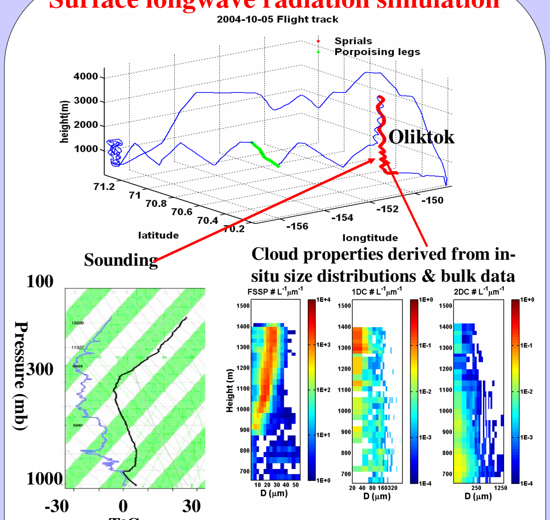

FIG 2 Inputs for LBLRTM simulation. In-situ data collected during spirals conducted by UND Citation over Oliktok (e.g., red line in profile). Time-averaged effective radius of ice crystals (Rei) and of water droplets (Rew), number concentrations of ice (Ni) and water (Nw) were derived as function of altitude (McFarquhar et al. 2007) and input to LBLRTM. Averages obtained for period UND Citation over Oliktok, and separate simulations conducted for each day. Other inputs summarized in Table 1.AERI observations, to which simulated results compared, were collected over oliktok point.

Inputs	Comments on the source
T(z), Td(z)	Closest sounding in time released at Oliktok
Aerosol number concentration	Use climatologically-averaged value
Surface albedo	Assumed as new snow covered ground (emissivity 0.985)
Ni and Nw	Derived from in-situ data
Rei and Rew	Derived from in-situ data

TABLE 1 Inputs to LBLRTM

Observed & Simulated long-wave radiance

a Comparison for 10 Oct 2004

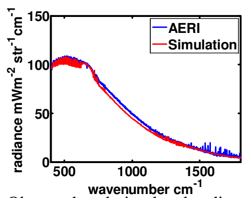

FIG 3 Simulated and observed surface longwave radiance as function of wavenumber; AERI observations and in-situ data averaged between 2130 and 2245 UTC on 10 Oct. 2004.

Observed and simulated radiance differ by 3.09 $Wm^{-2}str^{-1}$, which is less than 5% of the total integrated radiance over the range of 400-1800 cm^{-1}. The discrepancy is mainly caused by disagreement in the range of 700-1200 cm^{-1}.

b Comparisons for 9 and 12 Oct 2004

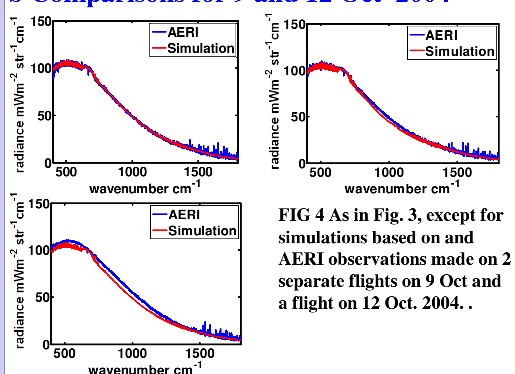

FIG 4 As in Fig. 3, except for simulations based on and AERI observations made on 2 separate flights on 9 Oct and a flight on 12 Oct. 2004. .

c Simulated/observed radiance comparison

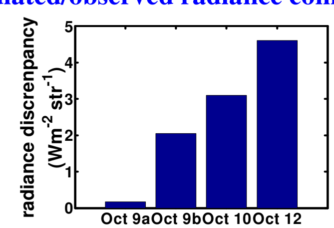

FIG 5 Summary of difference between observed AERI radiance integrated over wavenumber and that simulated by LBLRTM for 4 flights through optically thick boundary layer stratus. Simulated radiance is biased low compared to AERI observations. Note: on Oct 12, the discrepancy was the largest probably because the UND Citation did not reach the bottom of the cloud liquid layer.

Sensitivity tests

Sensitivity tests varying the LWP, Rew, and the location of clouds are performed to explain discrepancies between simulated and observed longwave radiance, and to examine the importance of cloud microphysical and macrophysical quantities in determining longwave surface radiation budget.

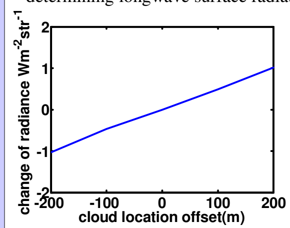

FIG 6 Variation of radiance as function of Cloud location. In the LBLRTM simulation, the location of clouds was shifted up or down compared to observed value**.** Shifting cloud location 100 m introduces 0.5 $Wm^{-2}str^{-1}$ change of the surface radiance.

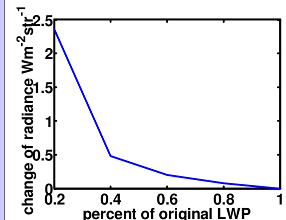

FIG 7 Variation of radiance as function of LWP. Changing LWP from 100 gm^{-2} to 80 gm^{-2} only introduces 0.08 $Wm^{-2}str^{-1}$ change of surface radiance but changing LWP from 40 gm^{-2} to 20 gm^{-2} introduces a 1.88 $Wm^{-2}str^{-1}$ change in surface radiance difference.

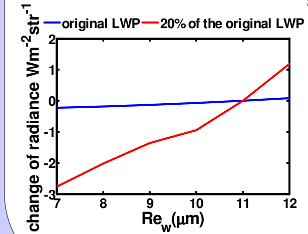

FIG 8 Variation of radiance as function of Rew (keeping LWP constant). Changing Rew from 7 µm to 12 µm introduces a 3.96 $Wm^{-2}str^{-1}$ radiance difference when LWP is 20 gm^{-2} but only a 0.31 $Wm^{-2}str^{-1}$ radiance difference when LWP is 100 gm^{-2} .

Conclusions

- **The longwave radiances simulated by the LBLRTM using in-situ observations obtained in optically-thick boundary layer stratus as input average 2.4 $Wm^{-2}str^{-1}$ lower than AERI observations.**
- **For optically thick clouds the longwave surface radiance changes by 0.5 $Wm^{-2}str^{-1}$ by shifting cloud height 100 m while changing LWP from 100 gm^{-2} to 80 gm^{-2} only introduces a 0.08 W m^{-2} str^{-1} change of surface radiance.**
- **The microphysical properties of thinner stratus (LWP 20 gm^{-2}) have more impacts on the surface longwave radiance than do those of thicker stratus (LWP 100 gm^{-2}).**

Acknowledgments

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Reference

McFarquhar, G., G. Zhang, M. Poellot, G. Kok, R. McCoy, T. Tooman, A. Fridlind and A. Heymsfield, 2007: Ice properties of single layer stratocumulus during the Mixed-Phase Arctic Cloud Experiment (M-PACE): Part I. Observations. *J. Geophys. Res.*