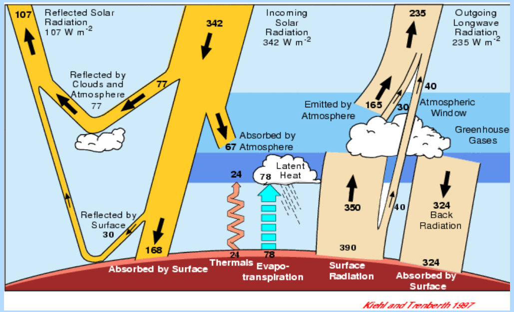
INDIRECT IMPACT OF ATMOSPHERIC AEROSOLS IN IDEALIZED SIMULATIONS OF CONVECTIVE-RADIATIVE QUASI-EQUILIBRIUM: DOUBLE-MOMENT MICROPHYSICS

Wojciech W. Grabowski and Hugh Morrison

National Center for Atmospheric Research

NCAR is sponsored by the National Science Foundation



Overview

This investigation is an extension of the previous cloud-resolving modeling study (Grabowski 2006) concerning the impact of cloud microphysics on convective-radiative quasi-equilibrium over a surface with fixed characteristics and prescribed solar input, both mimicking the mean conditions on Earth as shown in the figure above. The current study applies sophisticated double-moment warm-rain and ice microphysics schemes (Morrison and Grabowski 2007, 2008a, 2008b) which allow for a significantly more realistic representation of the impact of aerosols on precipitation processes and on the coupling between clouds and radiative transfer. Two contrasting CCN characteristics are assumed, representing pristine and polluted conditions, as well as contrasting representations of the effects of entrainment and mixing on the mean cloud droplet size. Detailed discussion of results is presented in Grabowski and Morrison (2010; submitted to *J. Climate)* available from the authors.

References:

Grabowski, W. W., 2006: Indirect impact of atmospheric aerosols in idealized simulations of convective-radiative quasi-equilibrium. *J. Climate*, 19, 4664-4682.

Grabowski, W. W., and H. Morrison, 2010: Indirect impact of atmospheric aerosols in idealized simulations of convective-radiative quasi-equilibrium. Part II: Double-moment microphysics. *J. Climate* (submitted).

Morrison, H., and W. W. Grabowski, 2007: Comparison of bulk and bin warm rain microphysics models using a kinematic framework. *J. Atmos. Sci.*, 64, 2839-2861.

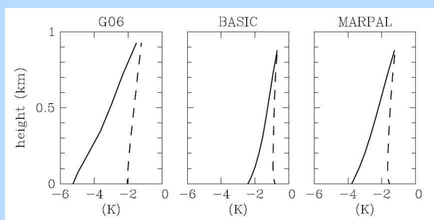
Morrison, H., and W. W. Grabowski, 2008a: Modeling supersaturation and subgrid-scale mixing with two-moment bulk warm microphysics. J. *Atmos. Sci.*, 65, 792-812.

Morrison, H., and W. W. Grabowski, 2008b: A novel approach for representing ice microphysics in models: description and tests using a kinematic framework. *J. Atmos.* Sci., 65, 1528-1548.

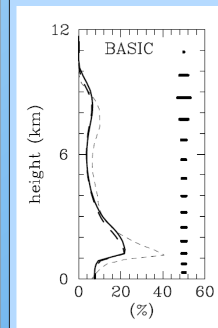
Summary of model results

The table below provides summary of model results and compares the new results to those of Grabowski (2006; G06) and to estimates in Kiehl and Trenberth (1997; KT97). The numbers in the brackets represent standard deviation of the temporal evolution. PRISTINE and POLLUTED refer to contrasting CCN characteristics; “h” and “ei” concern the impact of various entrainment/mixing characteristics (homogeneous and extremely inhomogeneous mixing, respectively).

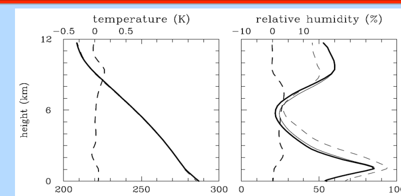
	PRISTINE	PRISTINE	POLLUTED	POLLUTED	KT97
	h	ei	h	ei	
Net TOA shortwave flux (W m^{-2})	256 (3)	257 (3)	247 (4)	248 (5)	235
G06 results	*225 (12)*	*245 (6)*	*201 (10)*	*225 (9)*	
TOA albedo	0.25 (0.01)	0.25 (0.01)	0.28 (0.01)	0.27 (0.01)	0.31
G06 results	*0.34 (0.03)*	*0.28 (0.03)*	*0.41 (0.03)*	*0.34 (0.03)*	
OLR (W m^{-2})	251 (4)	252 (4)	247 (8)	246 (12)	235
G06 results	*242 (3)*	*243 (3)*	*240 (3)*	*242 (3)*	
Radiative cooling of troposphere (W m^{-2})	-94 (4)	-94 (4)	-93 (8)	-91 (12)	-102
G06 results	*-101 (4)*	*-100 (5)*	*-101 (4)*	*-99 (4)*	
Solar flux absorbed at surface (W m^{-2})	202 (4)	204 (3)	193 (5)	194 (6)	168
G06 results	*163 (11)*	*184 (8)*	*141 (12)*	*164 (10)*	
Surface net longwave (W m^{-2})	96 (2)	96 (2)	93 (3)	93 (3)	66
G06 results	*73 (5)*	*73 (6)*	*70 (5)*	*73 (5)*	
Surface sensible heat flux (W m^{-2})	10 (1)	10 (1)	9 (1)	9 (1)	24
G06 results	*20 (2)*	*20 (1)*	*19 (1)*	*18 (2)*	
Surface latent heat flux (W m^{-2})	84 (1)	84 (1)	82 (1)	81 (1)	78
G06 results	*73 (2)*	*73 (2)*	*75 (2)*	*74 (2)*	
Surface precipitation (W m^{-2})	83 (19)	83 (21)	82 (20)	81 (20)	78
G06 results	*69 (33)*	*70 (29)*	*72 (28)*	*70 (32)*	
Surface energy budget (W m^{-2})	13 (3)	15 (3)	9 (4)	11 (5)	0
G06 results	*-2 (7)*	*17 (5)*	*-23 (9)*	*-2 (7)*	



Comparison of the lower-tropospheric temperature profiles (shown as a deviation from the surface temperature) between current simulations (BASIC), G06, and sensitivity simulation (MARPAL) in which the intercept parameter in the rain distribution was fixed. MARPAL’s Bowen ratio was similar to G06. Dashed lines are for mean (horizontally-averaged) profiles and solid lines are for gridpoints with significant rain. The main point is that the near-surface temperature in regions with rain (i.e., the cold-pool temperature) is significantly lower in G06 than in BASIC. As suggested by MARPAL, this is because the double-moment rain scheme predicts significantly lower rain evaporation rates than the single-moment rain scheme used in G06. This leads to the observed changes in the Bowen ratio between BASIC and G06 simulations.



Comparison of the cloud fraction profiles between current simulations (thick lines; PRISTINE – dashed; POLLUTED – solid) and G06 results (thin dashed line). Smaller cloud fraction, in the lower troposphere in particular, explains lower albedo in current simulations. The differences in albedo between PRISTINE and POLLUTED are smaller then in G06 (2-3% vs 6-7%).



Comparison of the temperature and relative humidity profiles between current simulations (solid lines; PRISTINE – thick; POLLUTED – thin) and G06 results (thin dashed lines). The difference profiles are shown in the left side of the panels (with scales above). Slightly smaller precipitable water in current simulations explains differences in radiative cooling and OLR.

Conclusions

New results are similar to G06, but there are some differences. These are consistent with the lower water vapor content in the troposphere and reduced lower-tropospheric cloud fraction in the new simulations. There is a significant reduction of the difference between pristine and polluted cases, from about 20 to about 4 Wm^{-2}, with the difference between homogeneous and extremely inhomogeneous mixing reduced to about 2 Wm^{-2}. An unexpected difference between previous and current simulations is the lower Bowen ratio of the surface heat flux. The change comes from the difference in the representation of rain evaporation in the sub-cloud layer between the single-moment parameterization applied in Grabowski (2006) and the double-moment scheme used here. The differences in cloud properties between polluted and pristine conditions are relatively small.

This work was supported by ARM DOE **DE-FG02-08ER64574 and Center for Multiscale Modeling of Atmospheric Processes under cooperative agreement ATM-0425247**