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Aerosol Impacts on Circulation, Cloud Anvil and Radiation through a Mesoscale Convective System: Bin versus Bulk Results

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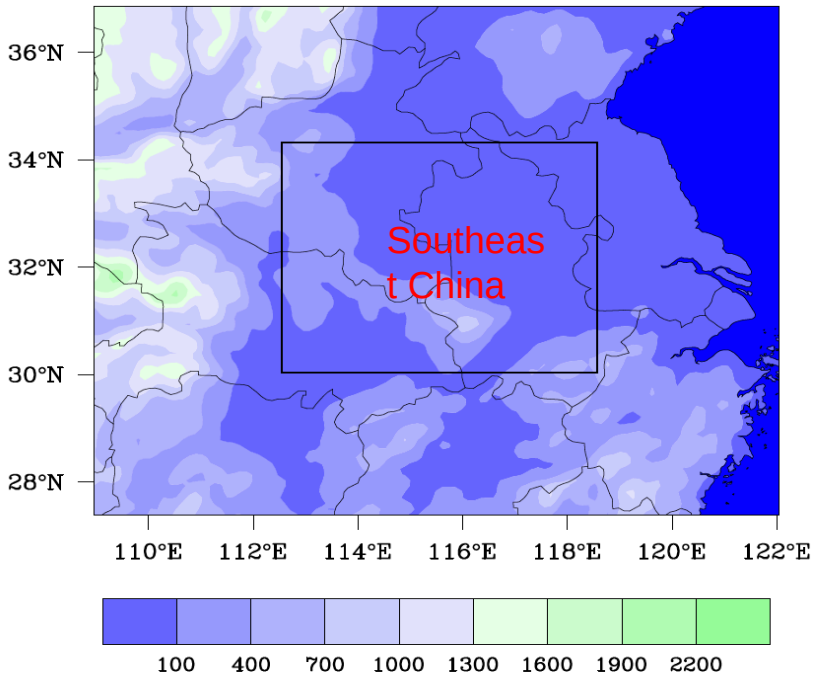
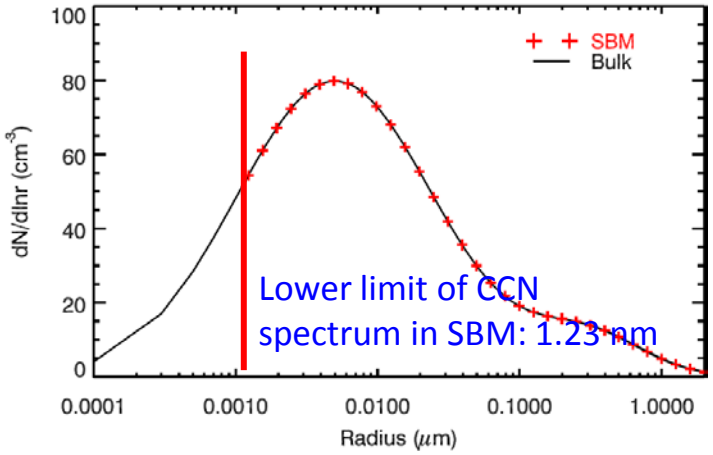
Introduction

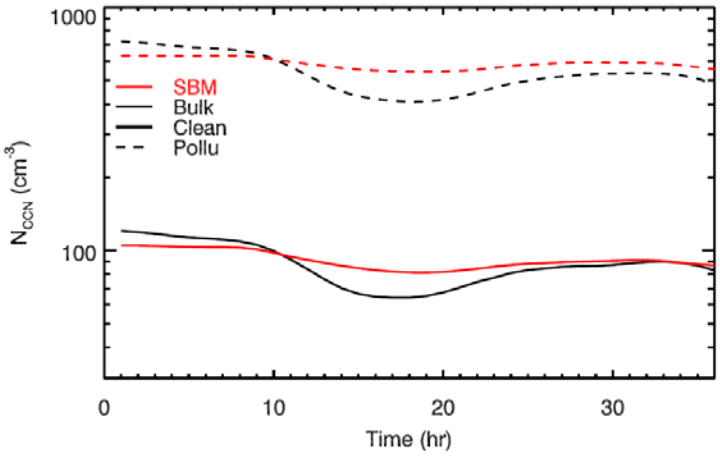
- Aerosol invigoration of convection has been frequently observed and simulated with bin microphysics.
- Following Li et al 2012 (Nature-Geo) and Fan et al 2012 (GRL) showing that enlarged cloud fraction, higher CTH, and strong atmospheric warming induced by aerosol invigoration, examine if the Morrison scheme considering aerosol budget is able to simulate the qualitatively consistent results.
- Past studies showed that bulk schemes gave inconsistent results with bin scheme in terms of aerosol effects on convection and precipitation. No studies focus on the impacts on stratiform/anvil regimes and their radiative effects.

Research Design

- Run the same MCS in Fan et al. 2012 (GRL)
- Run high-resolution simulations at CRM scale but over regional domains.
  - Real-case WRF3.2 simulations. Two-way nesting. The same microphysics were applied to both domains and CCN are increased by 6 times in both domain for the polluted case.
  - The Morrison scheme used here is modified by us (Fan et al. 2012).

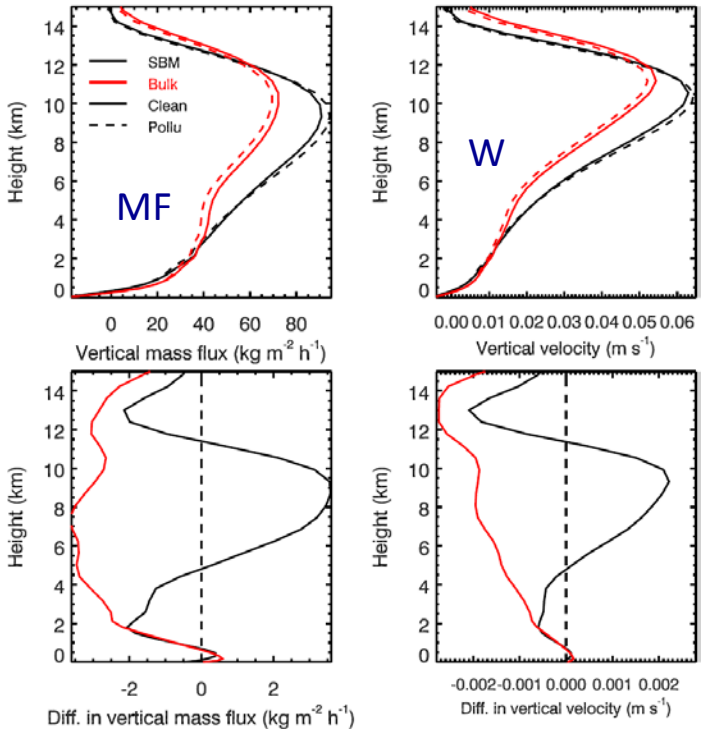




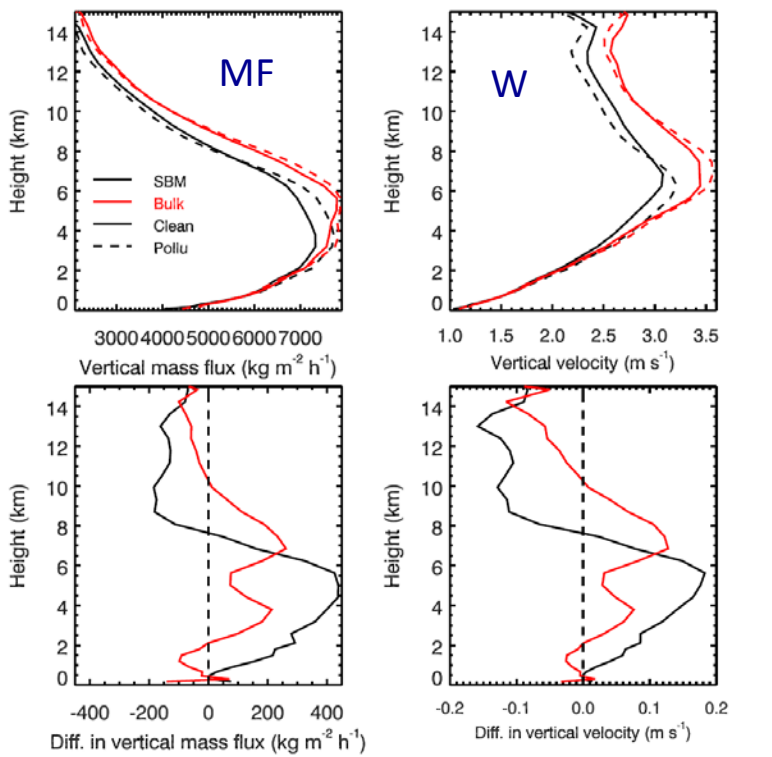


Vertical Mass Fluxes and Vertical Velocity

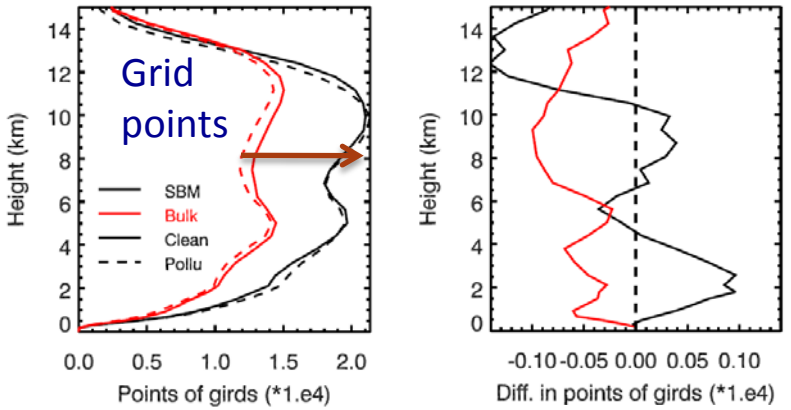
Domain-average



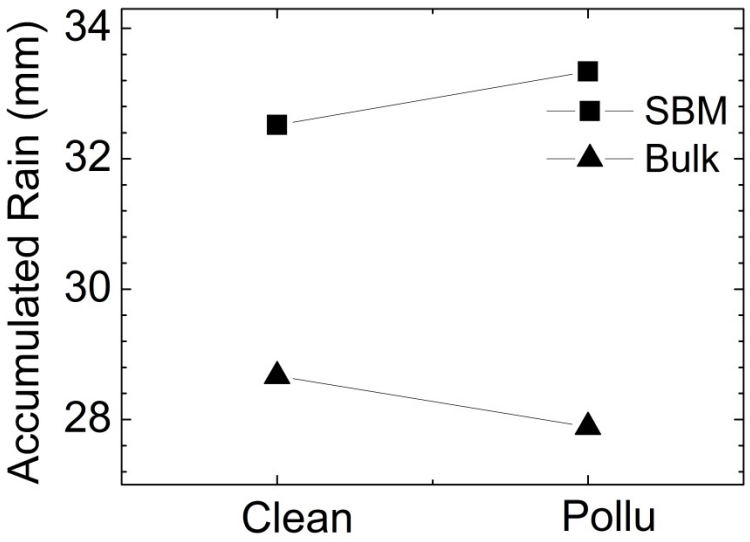
w>1m/s

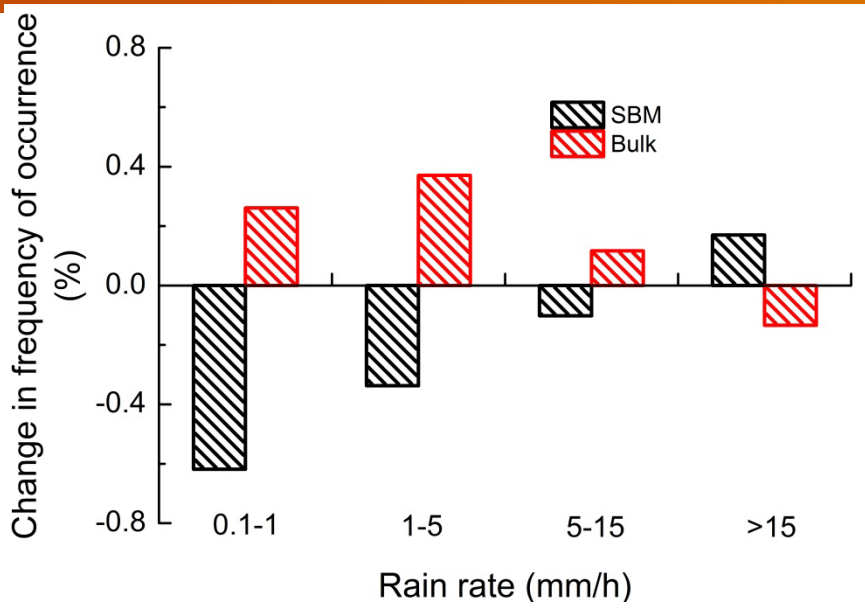


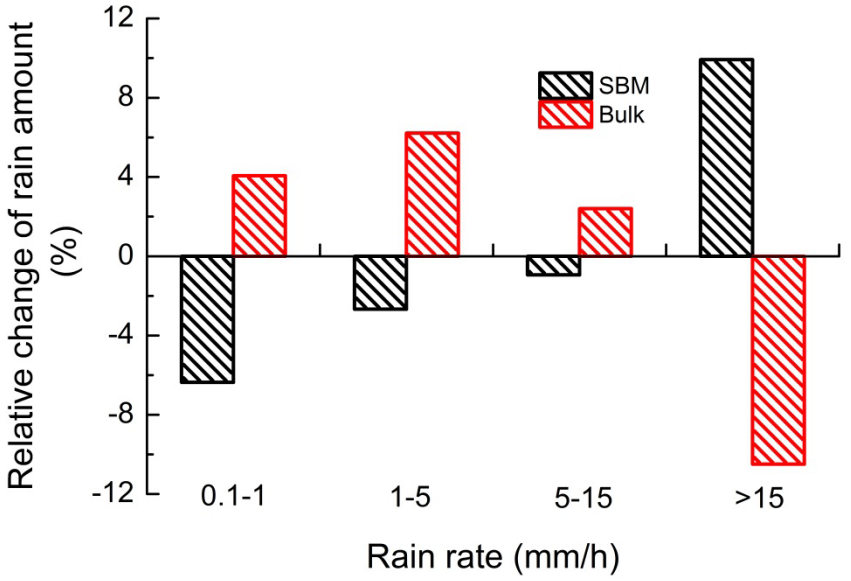
- Domain average, opposite results in MF and W between bin and bulk.
- Averaged over W> 1 m/s, qualitatively consistently results.
- Narrower but stronger convection in bulk compared with SBM. Further narrower and stronger in the polluted case.



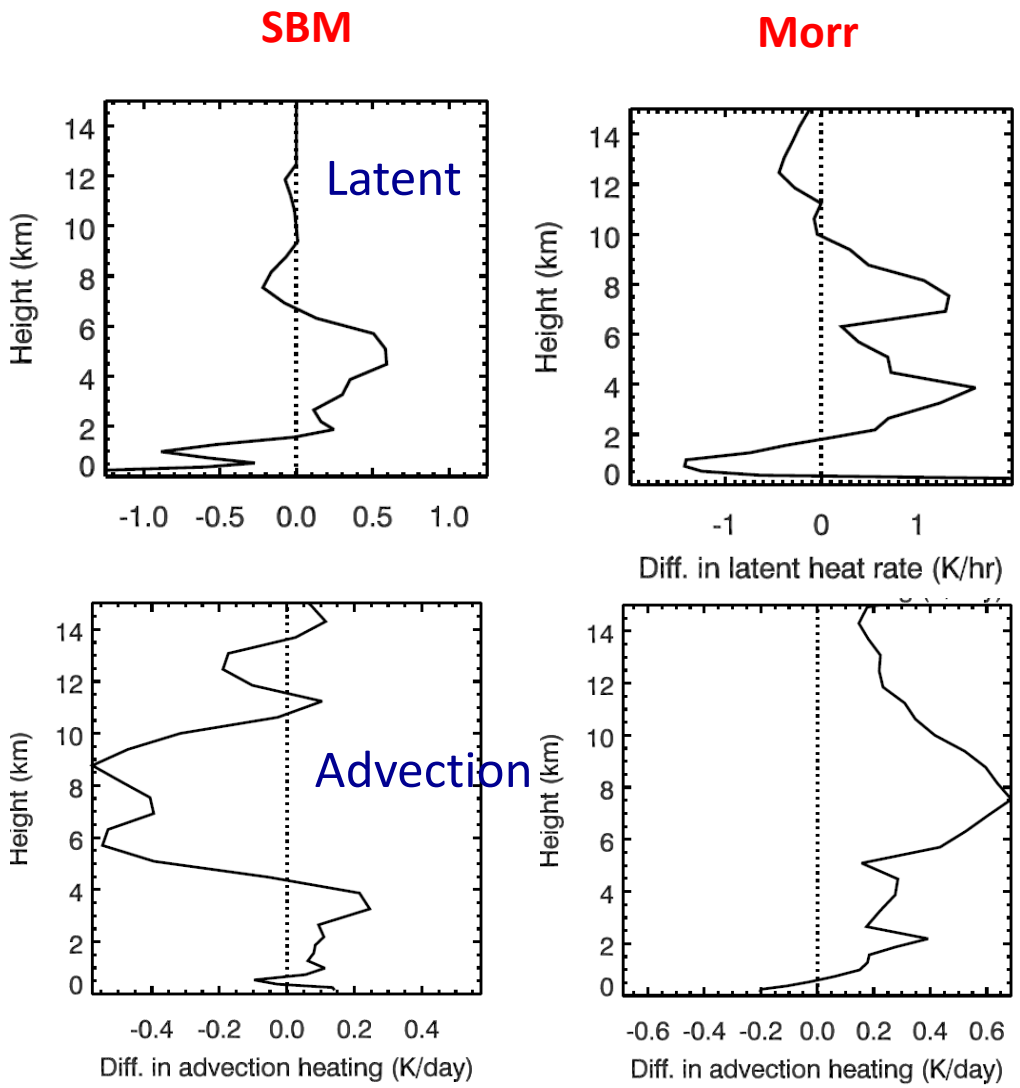
Precipitation





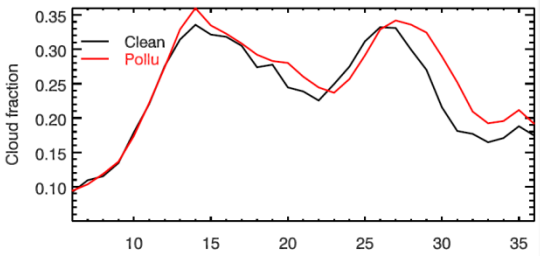
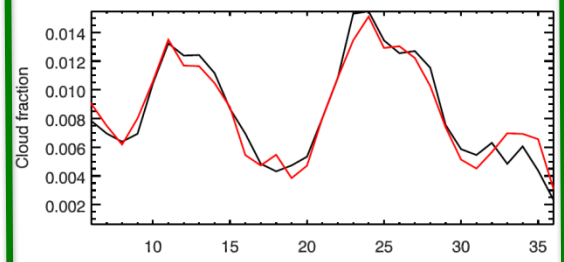
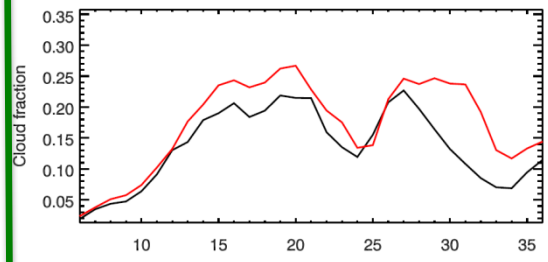
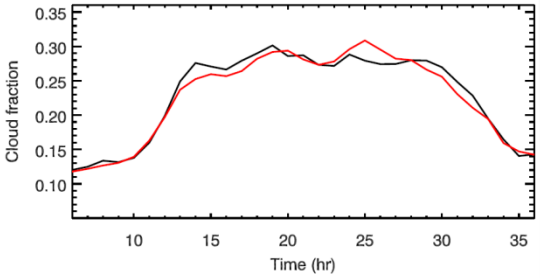
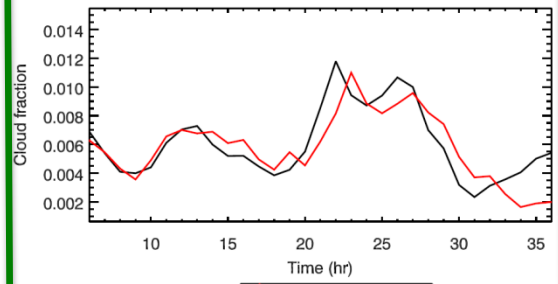
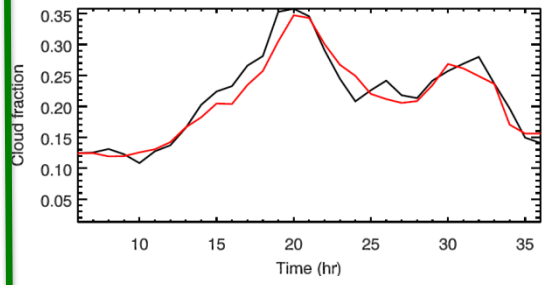
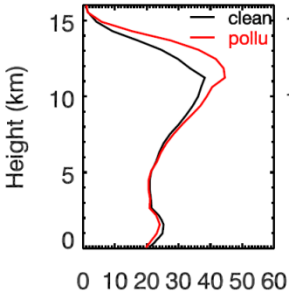
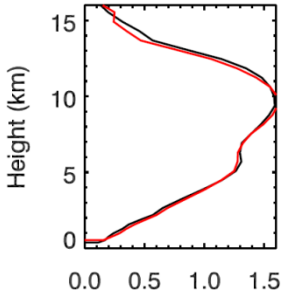
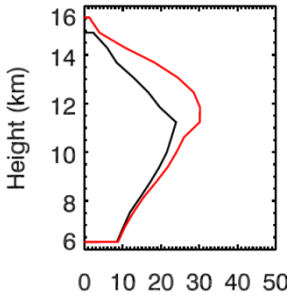
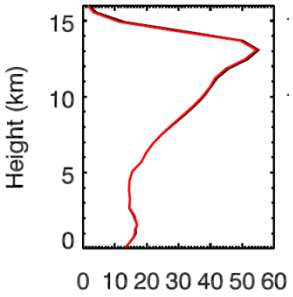
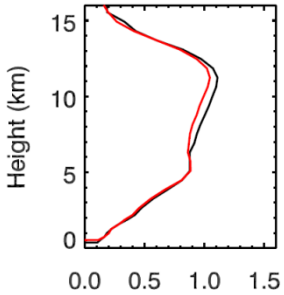
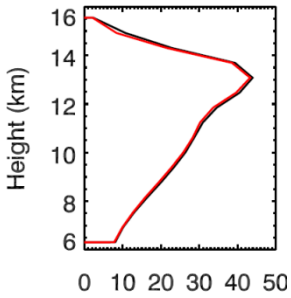


Latent and Advection Heat



- Both latent and advection heating are increased with Bulk in the polluted case, indicating there is a strong cooling effect from clouds.

Cloud Fraction

	Domain	Convective	Stratiform/anvil
SBM			
Morr			
SBM			
Morr			

Cloud Top Height

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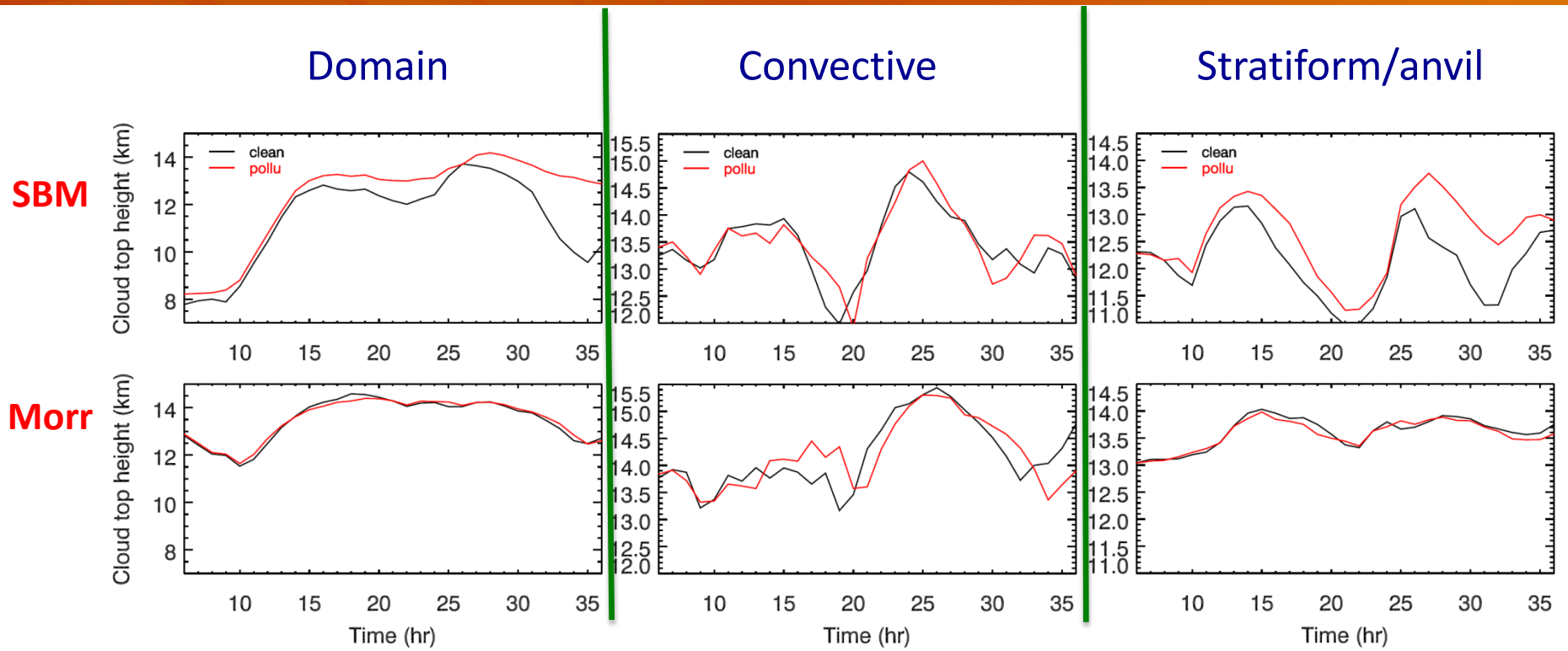
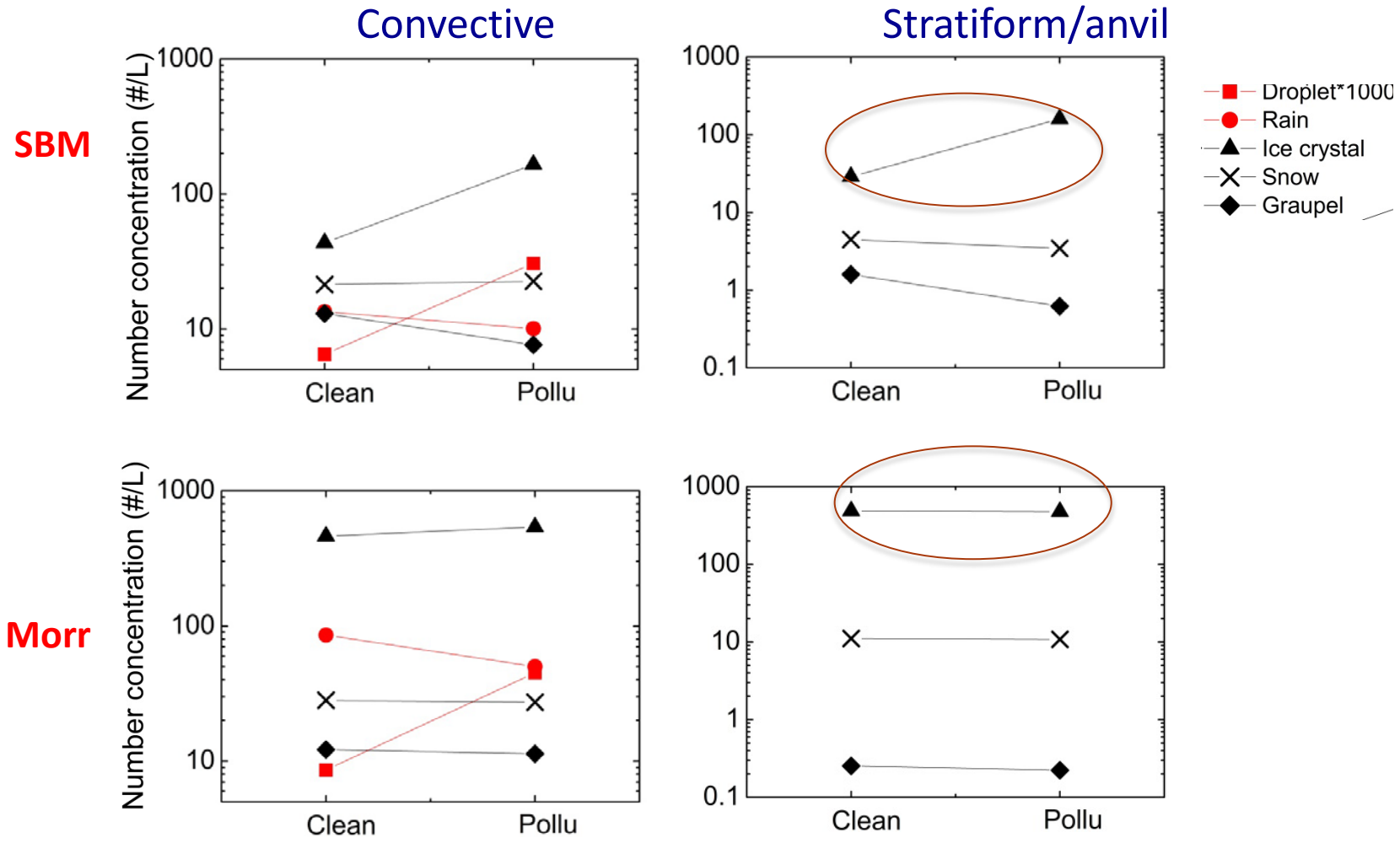


Cloud Microphysical Properties



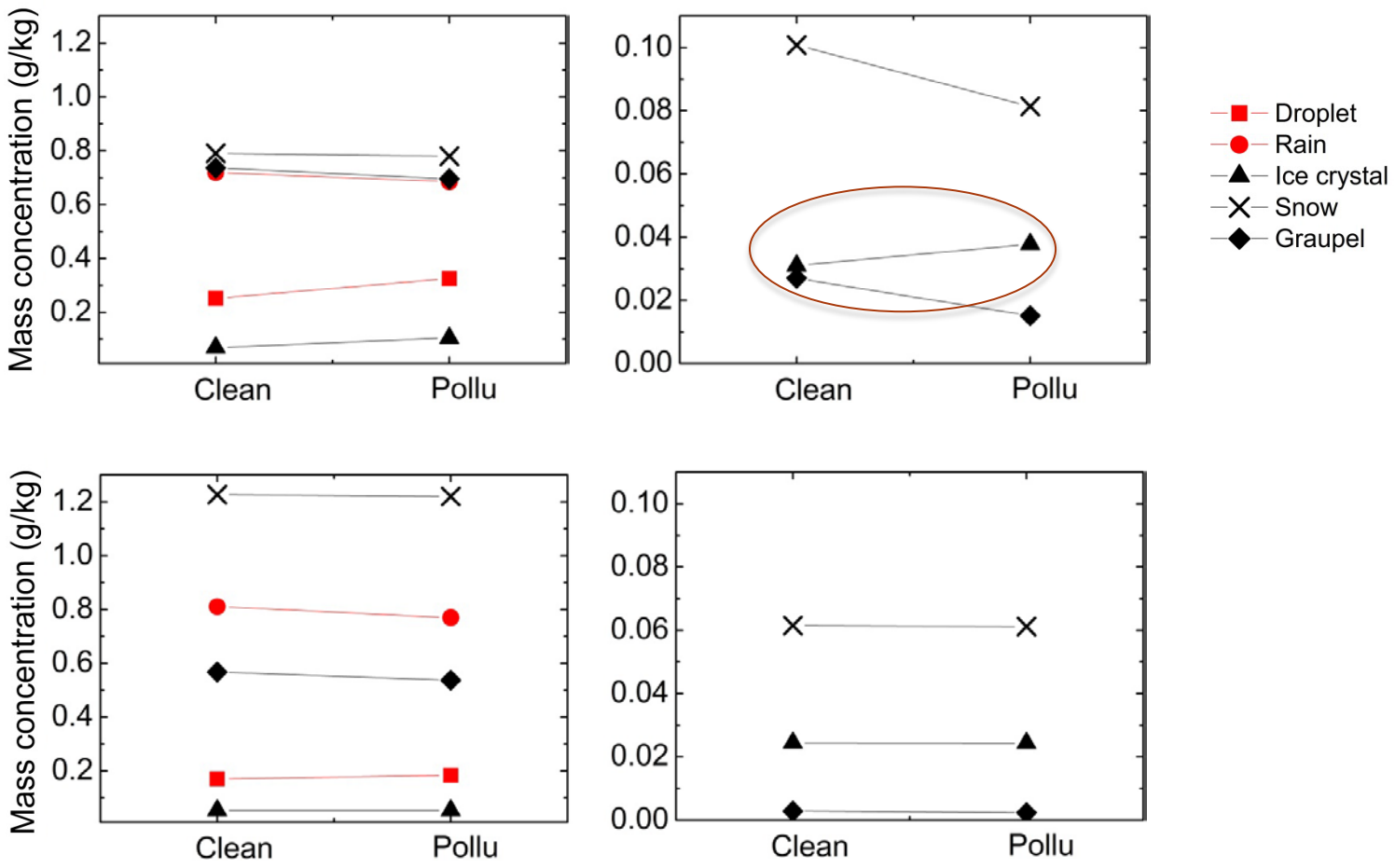
- Much higher Nr and Ni with bulk than SBM
- Significant increase of Ni in the polluted case is not seen in the stratiform with Bulk.

Convective

Stratiform/anvil

SBM

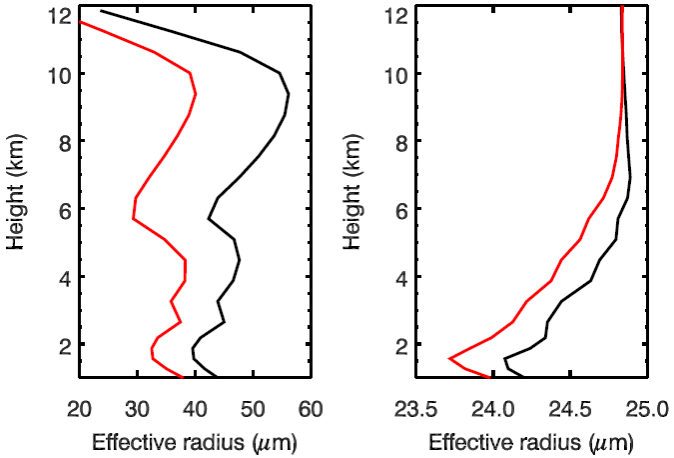
Morr



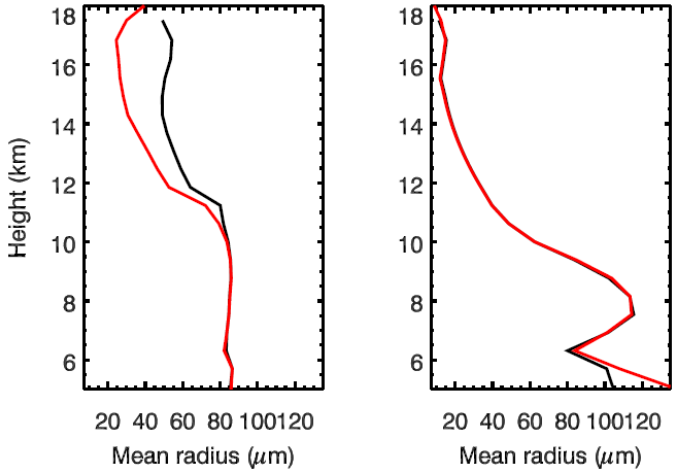
- Significantly more ice mass in SBM than Bulk in the polluted case.
- Increased ice mass and decreased snow mass by CCN with SBM. No changes with Bulk.

SBM **Morr**

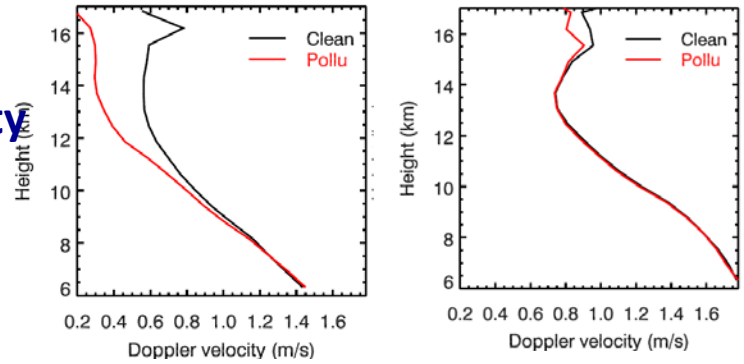
Drop

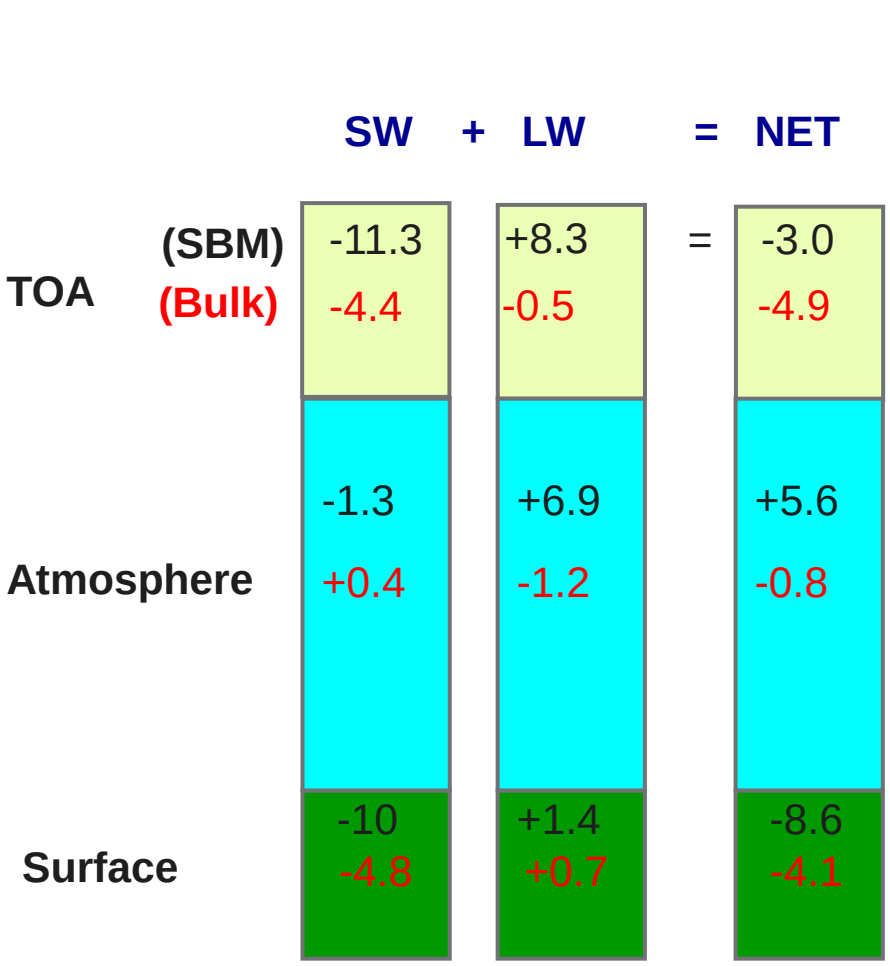


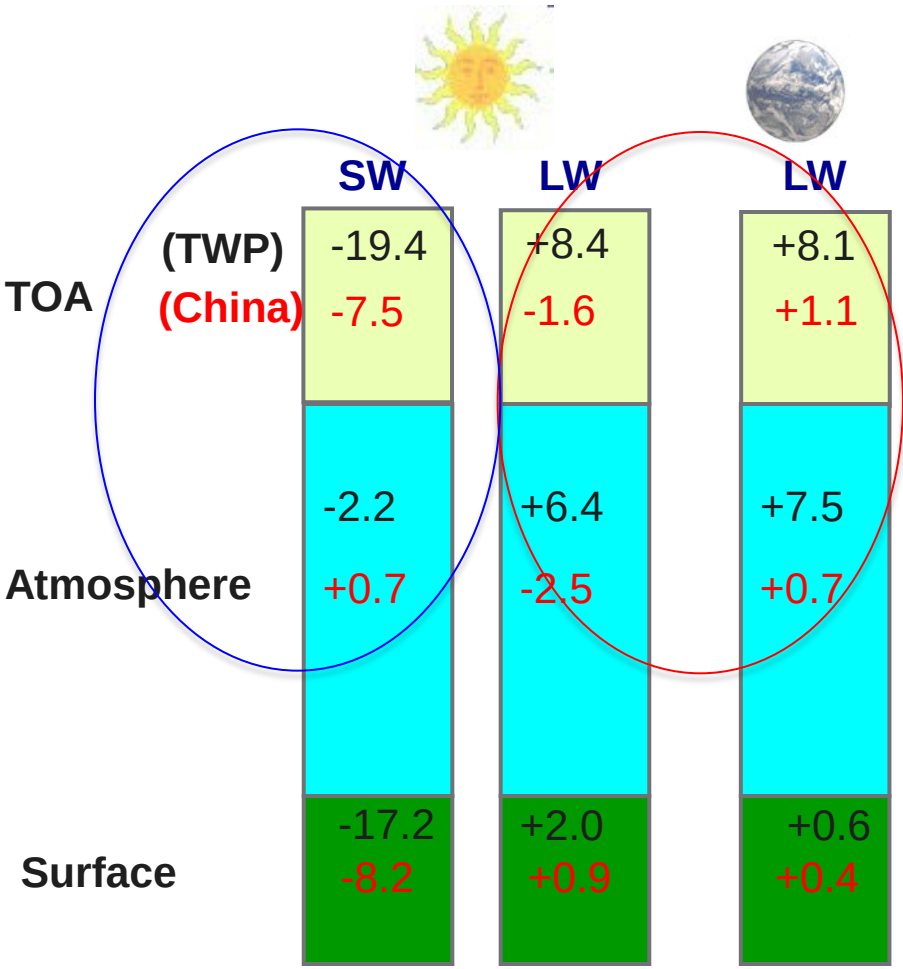
Ice

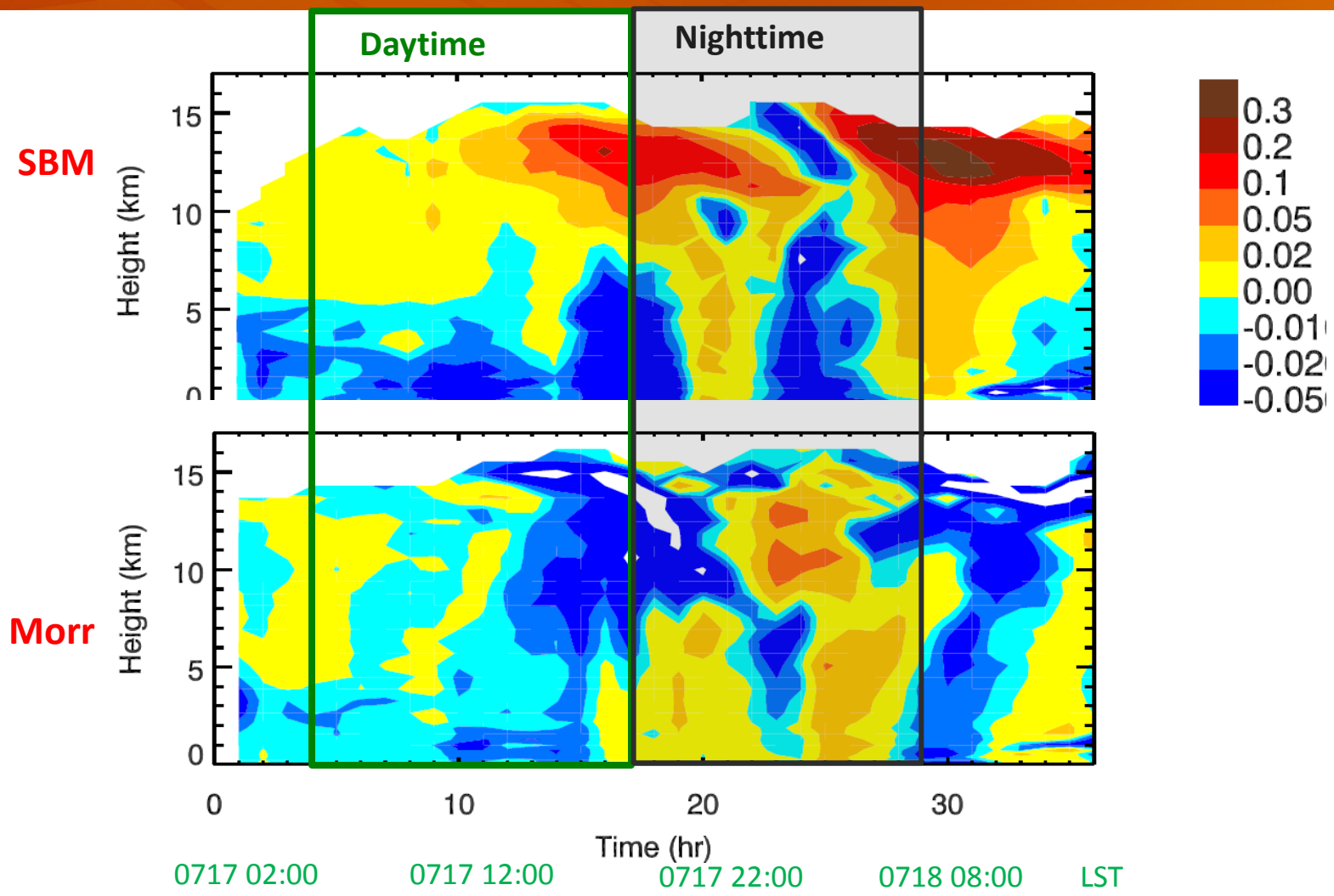


Fall velocity




SW + LW = NET
(SBM)
(Bulk)
TOA
-11.3
-4.4
+8.3
-0.5
=
-3.0
-4.9
-1.3
+0.4
+6.9
-1.2
+5.6
-0.8
Atmosphere
-10
-4.8
+1.4
+0.7
-8.6
-4.1
Surface


SW
LW
LW
(TWP)
(China)
TOA
-19.4
-7.5
+8.4
-1.6
+8.1
+1.1
-2.2
+0.7
+6.4
-2.5
+7.5
+0.7
Atmosphere
-17.2
-8.2
+2.0
+0.9
+0.6
+0.4
Surface


Daytime
Nighttime
SBM
Morr
Height (km)
15
10
5
0
0.3
0.2
0.1
0.05
0.02
0.00
-0.01
-0.02
-0.05
0
10
20
30
Time (hr)
0717 02:00
0717 12:00
0717 22:00
0718 08:00
LST

Conclusions

- SBM predicted aerosol invigoration effects: enhanced vertical mass fluxes and vertical velocity, increased heavy rain and suppressed light rain.
- Considering the CCN budget similar as SBM, the bulk scheme still predicted opposite aerosol effects on vertical mass fluxes, precipitation, and advection heating to SBM.
- With SBM, CCN significantly increase cloud fraction and CTH, which occurs mainly in the stratiform/anvil regimes. With Bulk, those effects are not seen since detrained cloud mass and ice particle size are not changed much.