- Preliminary LBA runs with SAM using CAM radiation and M2005 microphysics showed a near surface cold bias possibly related with high condensate/fog within the first 200m of the atmosphere. A realistically deep enough boundary layer could not develop in the simulations even during the day. (slides 2 and 3, the prescribed sounding has no diurnal cycle)

- I double checked that the initial sounding profiles and the ones that the model relaxes to are not saturated near the surface. So the fog is a CAM model response.

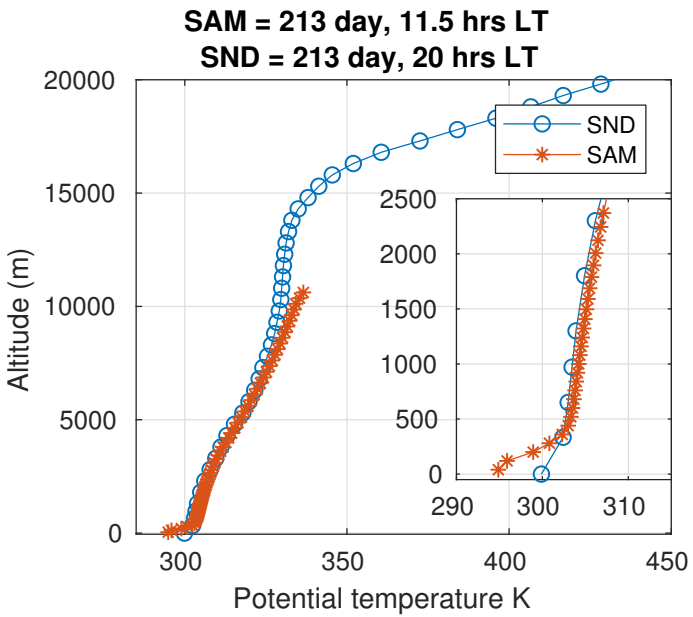
- The saturation happens because the near surface air is too cool and not because it is too humid.

- TOGA simulation using CAM and M2005 does not show this problem.

- We found that at least one other published study (Patricola et al 2012) also report similar strong near-surface cooling over Amazonia when WRF with CAM radiation is used. So the cool bias might be an issue with this radiation scheme over Amazonia/tropical land.

- The LBA CAM simulation has a diurnal cycle in surface temperature, precipitation, condensate. But relative humidity does not have a diurnal cycle and stays near saturation at all times. (slide 4)

Patricola, C. M., M. K. Li, Z. Xu, P. Chang, R. Saravanan, and J. S. Hsieh, 2012: An investigation of tropical Atlantic bias in a high-resolution coupled regional climate model. *Climate Dynamics*, **39,** 2443-2463.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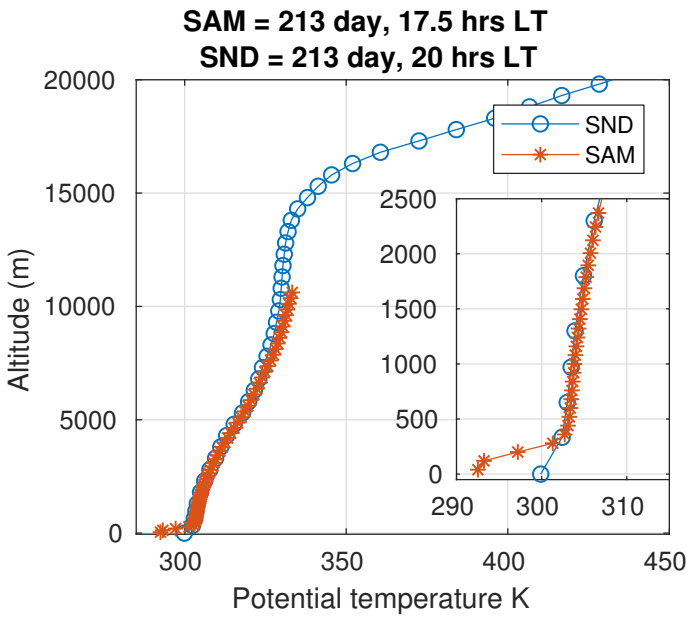
SND
SAM
Altitude (m)
Potential temperature K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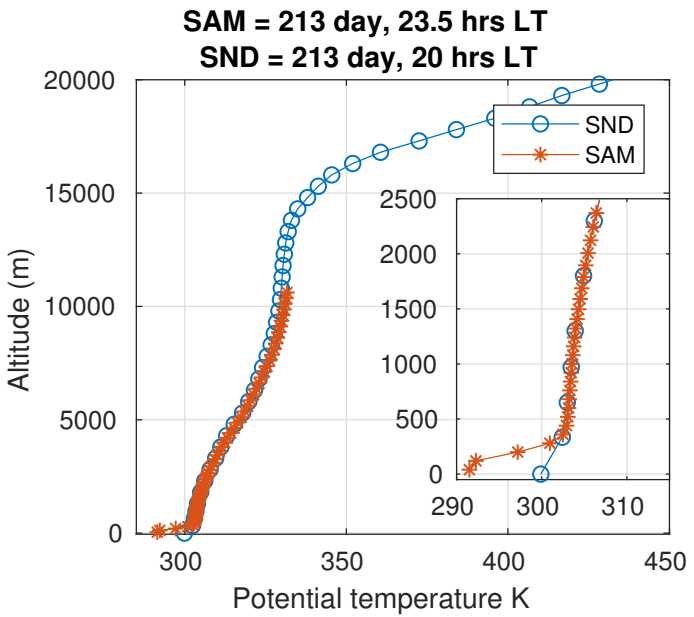
SAM
Altitude (m)
Potential temperature K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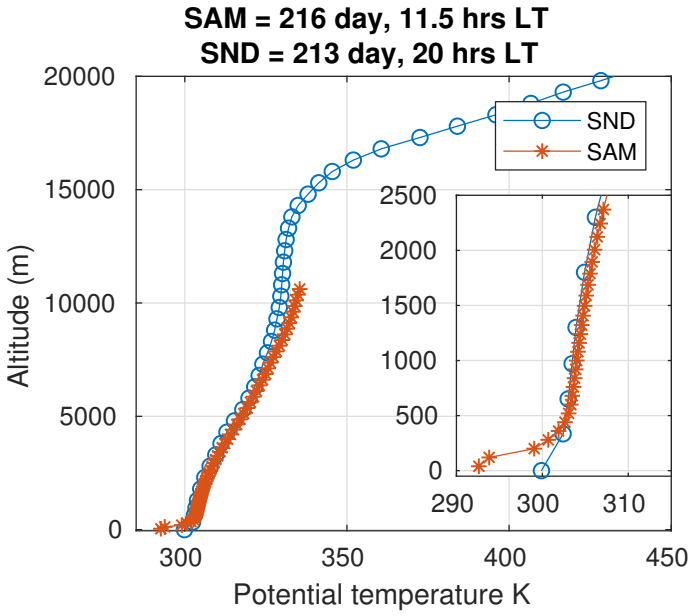
SND
SAM
Altitude (m)
Potential temperature K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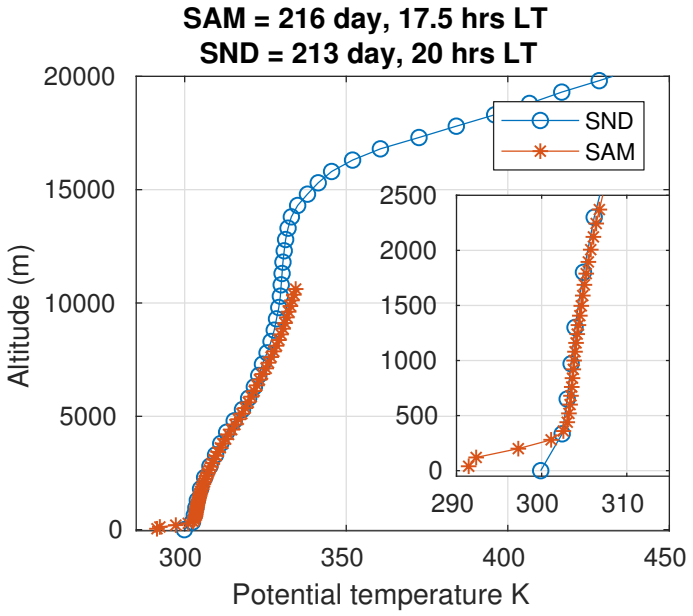
SAM
Altitude (m)
Potential temperature K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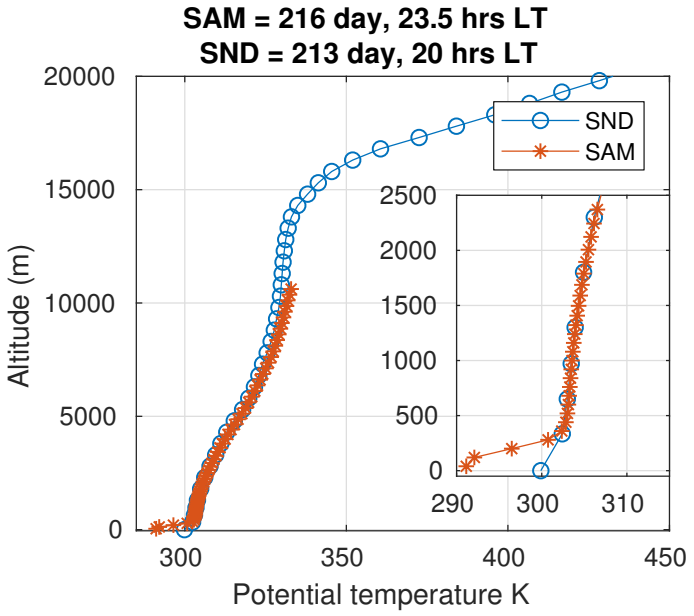
SND
SAM
Altitude (m)
Potential temperature K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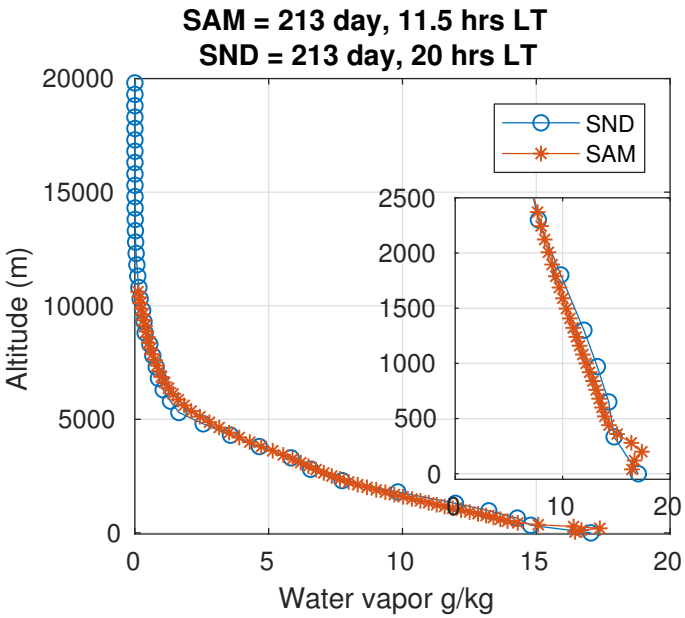
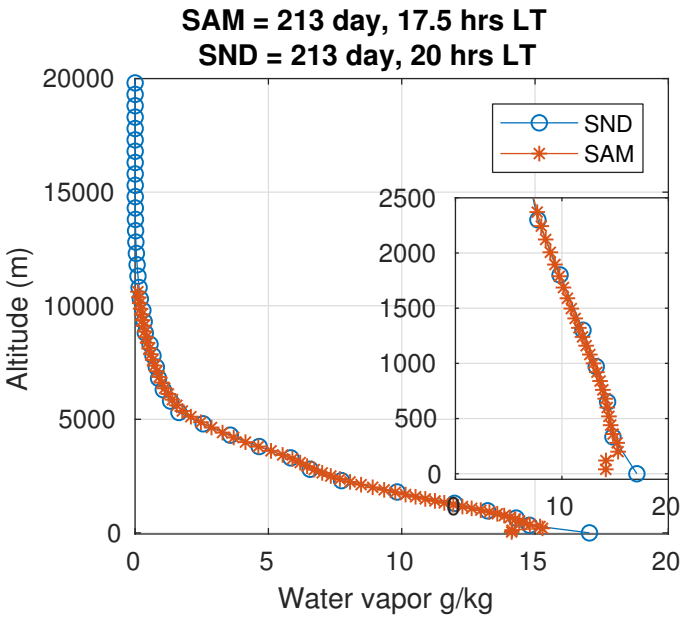
SND = 213 day, 20 hrs LT
SND
SAM
Altitude (m)
Potential temperature K


SAM = 213 day, 11.5 hrs LT
SND = 213 day, 20 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg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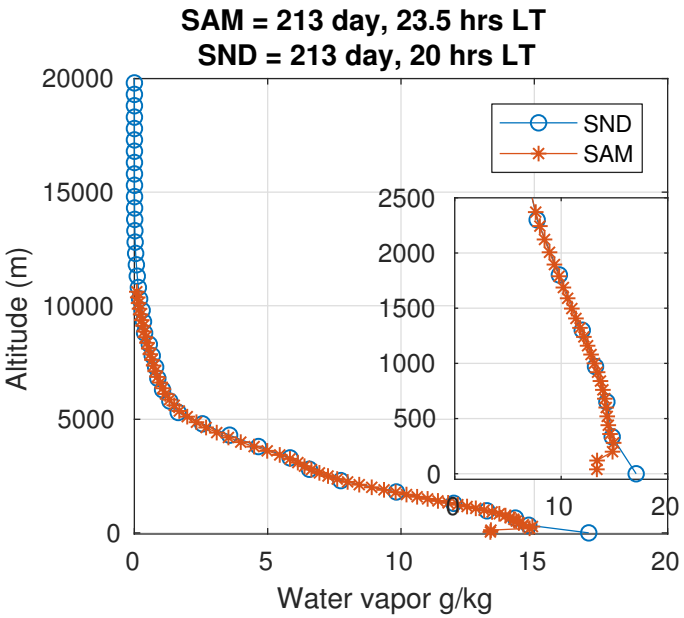
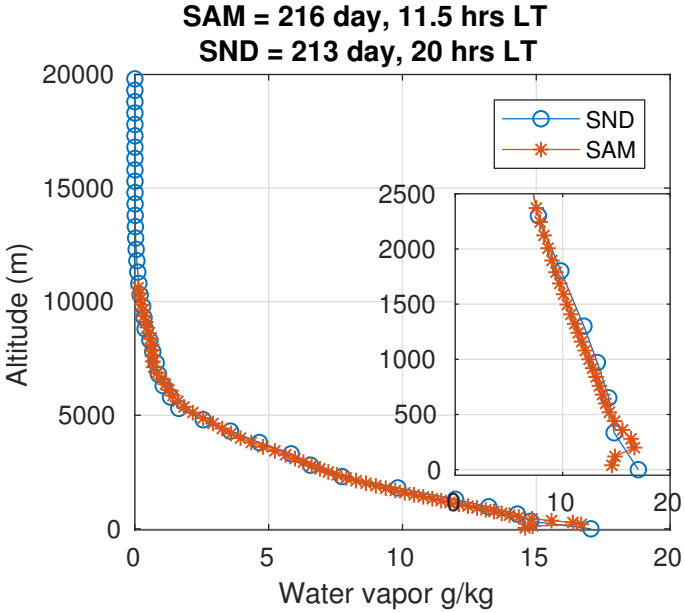
SND = 213 day, 20 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 213 day, 23.5 hrs LT
SND = 213 day, 20 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg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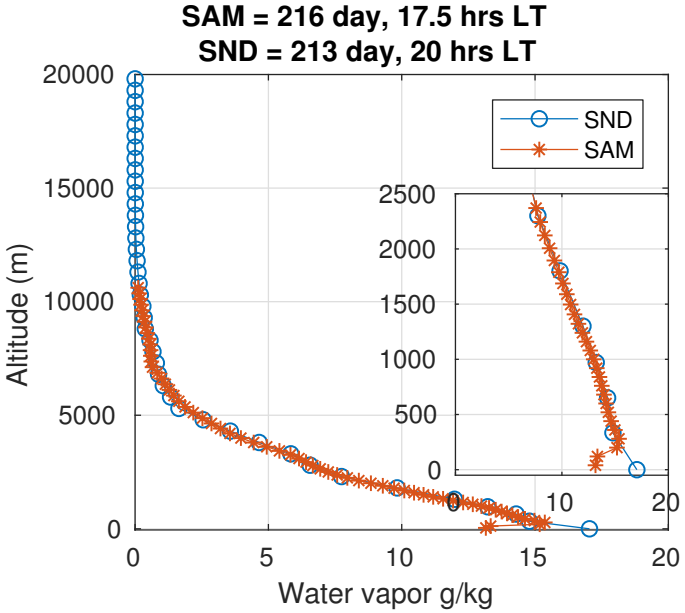
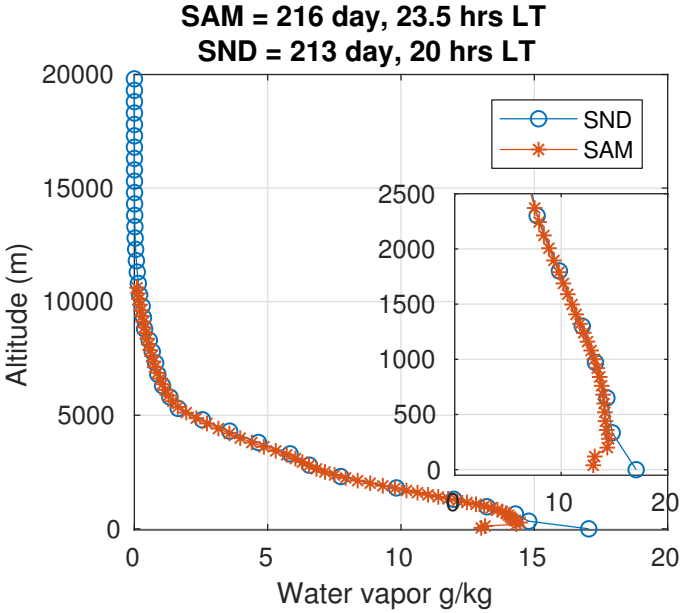
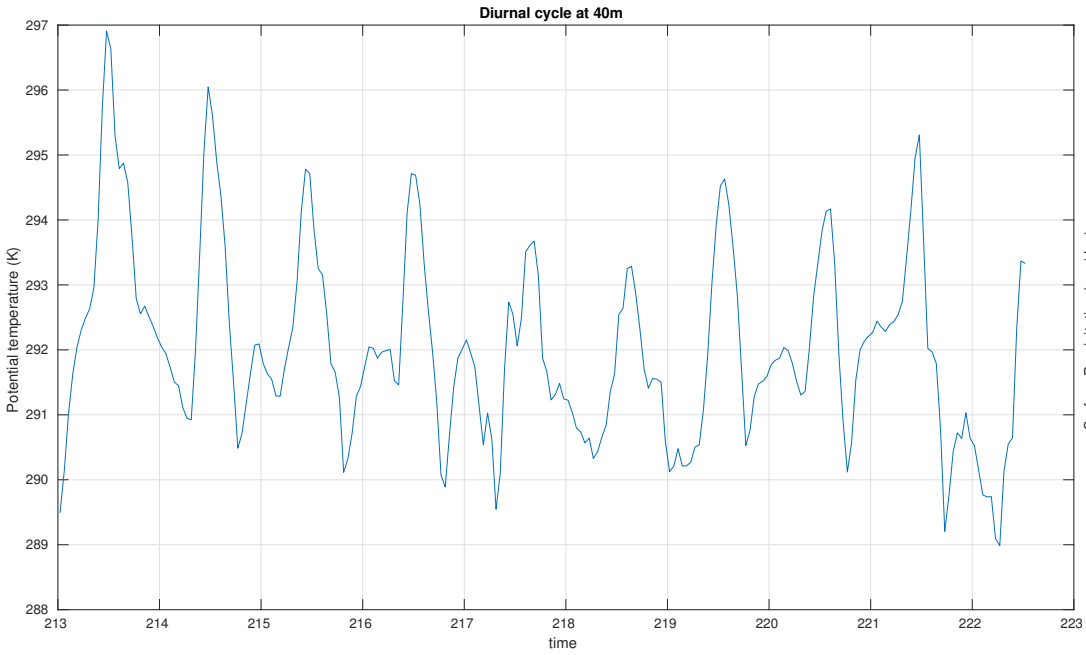
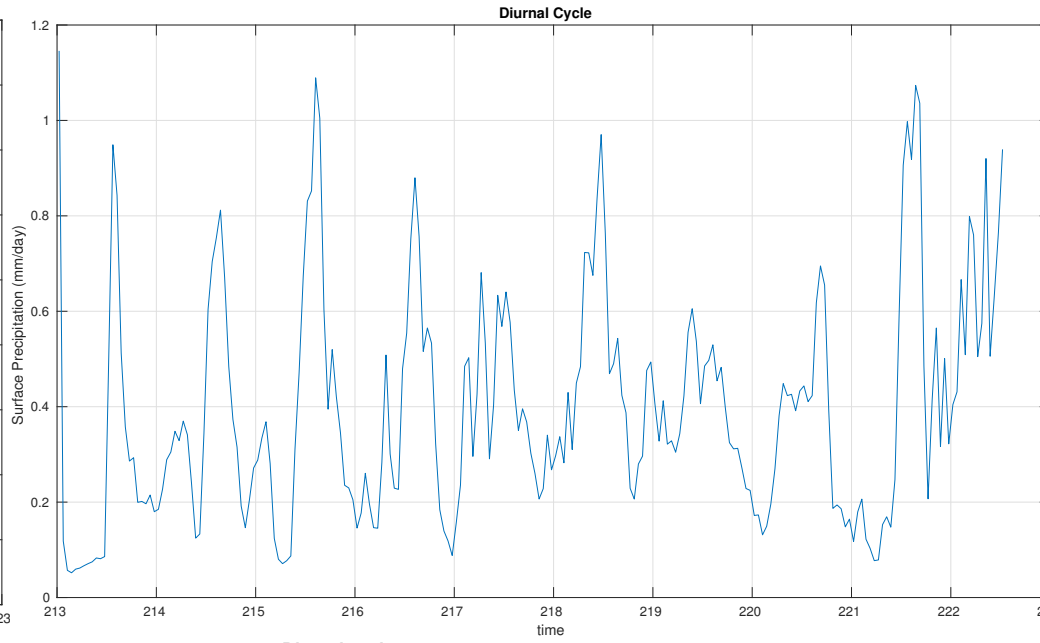
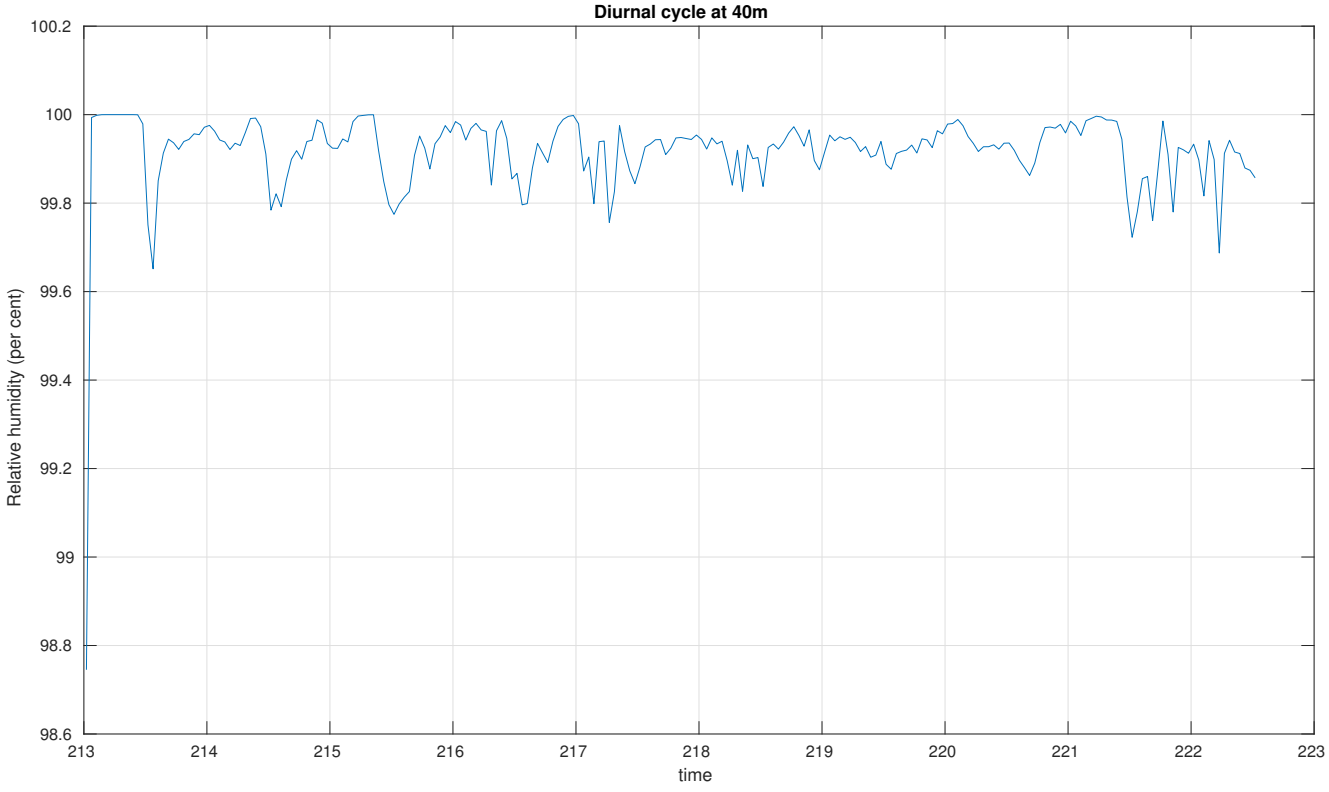
SND = 213 day, 20 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 216 day, 17.5 hrs LT
SND = 213 day, 20 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 216 day, 23.5 hrs LT
SND = 213 day, 20 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

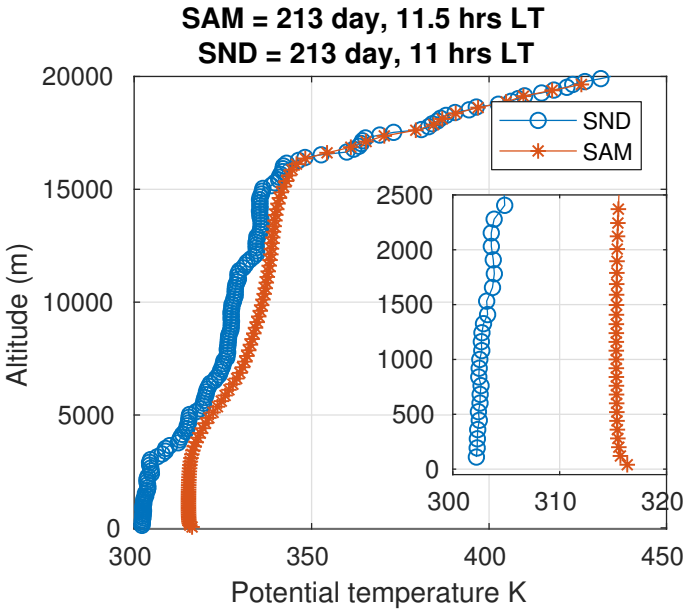

Diurnal cycle at 40m
Potential temperature (K)
297
296
295
294
293
292
291
290
289
288
213
214
215
216
217
218
219
220
221
222
223
time

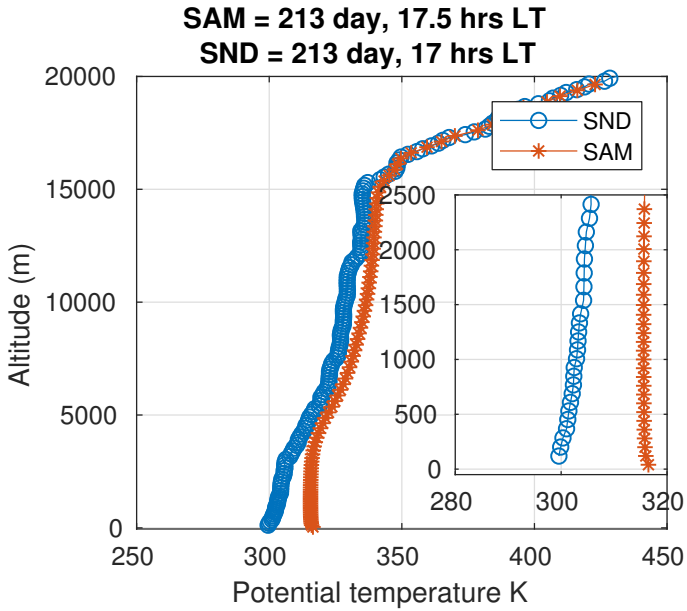

Diurnal Cycle
Surface Precipitation (mm/day)
1.2
1
0.8
0.6
0.4
0.2
0
213
214
215
216
217
218
219
220
221
222
time

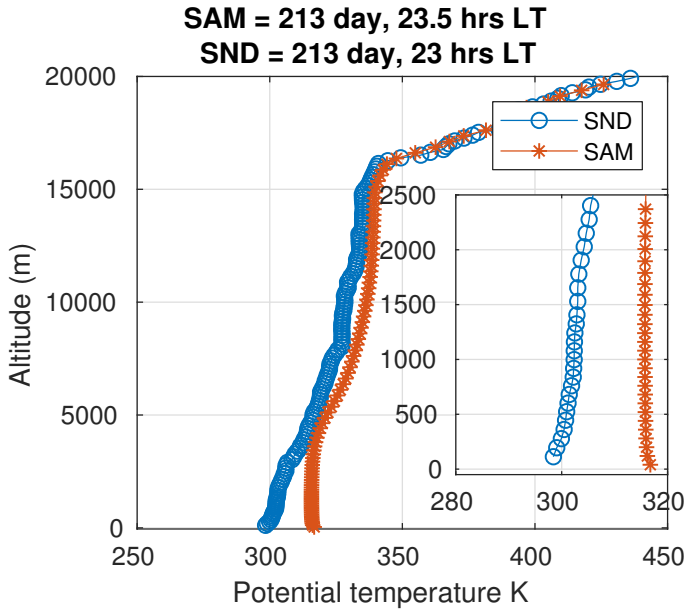

Diurnal cycle at 40m
Relative humidity (per cent)
100.2
100
99.8
99.6
99.4
99.2
99
98.8
98.6
213
214
215
216
217
218
219
220
221
222
223
time

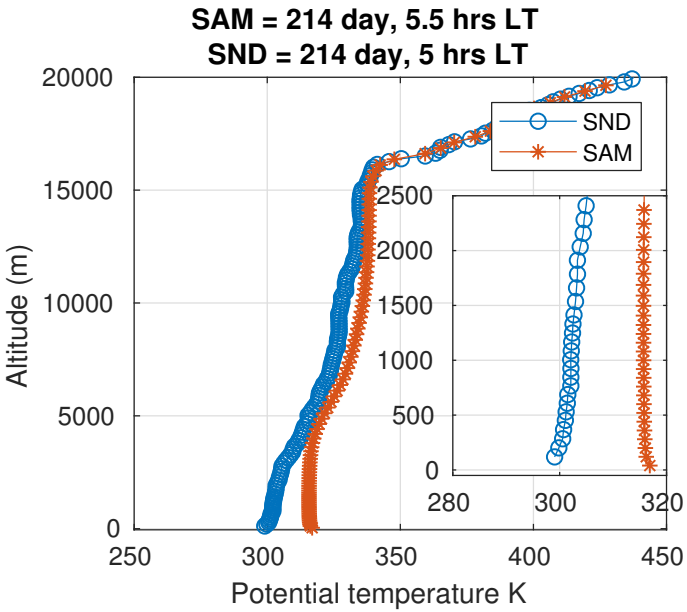
- I tested the microphysics and radiative transfer parametrization to find if they can explain the cold bias.
- I repeated the LBA-CAM experiment with Thomson microphysics but that had no impact on the fog layer. I did some other experiments switching between M2005 and Thomson microphysics and found no substantial impact of the microphysics scheme.

- Then I did sensitivity tests with the two radiative transfer schemes available in SAM - CAM vs RRTM. I found the simulated atmospheric profiles are very different between the two radiation schemes.
- RRTM simulates a warm bias throughout the atmosphere and a dry bias near the surface (slides 6 and 7). RRTM does not have a diurnal cycle (Slide 8)


SAM = 213 day, 11.5 hrs LT
SND = 213 day, 11 hrs LT
SND
SAM
Altitude (m)
Potential temperature K


SAM = 213 day, 17.5 hrs LT
SND = 213 day, 17 hrs LT
SND
SAM
Altitude (m)
Potential temperature K


SAM = 213 day, 23.5 hrs LT
SND = 213 day, 23 hrs LT
SND
SAM
Altitude (m)
Potential temperature K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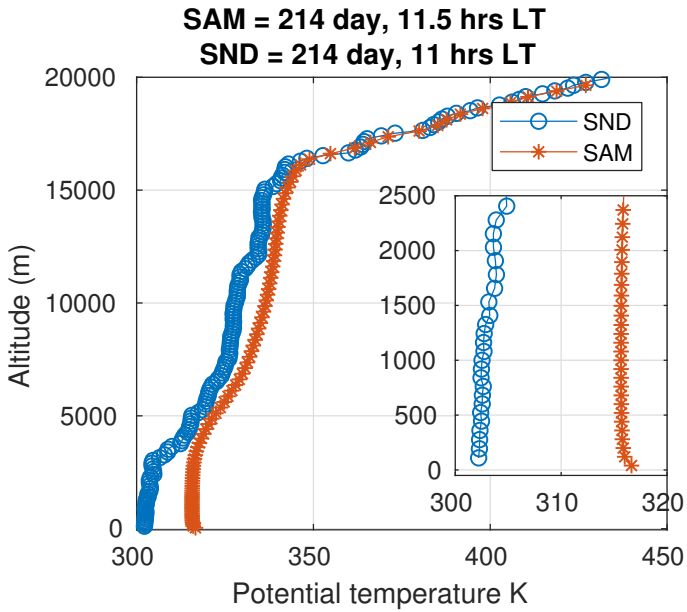
SND = 214 day, 5 hrs LT
SND
SAM
Altitude (m)
Potential temperature K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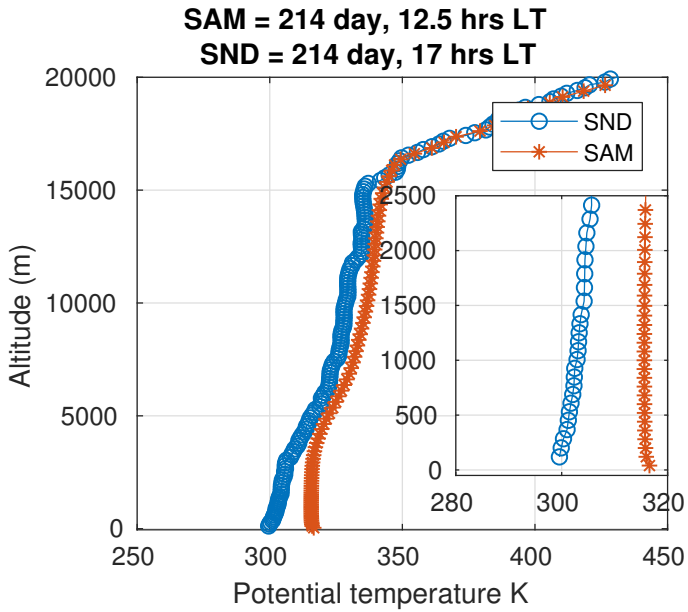
SND = 214 day, 11 hrs LT
SND
SAM
Altitude (m)
Potential temperature K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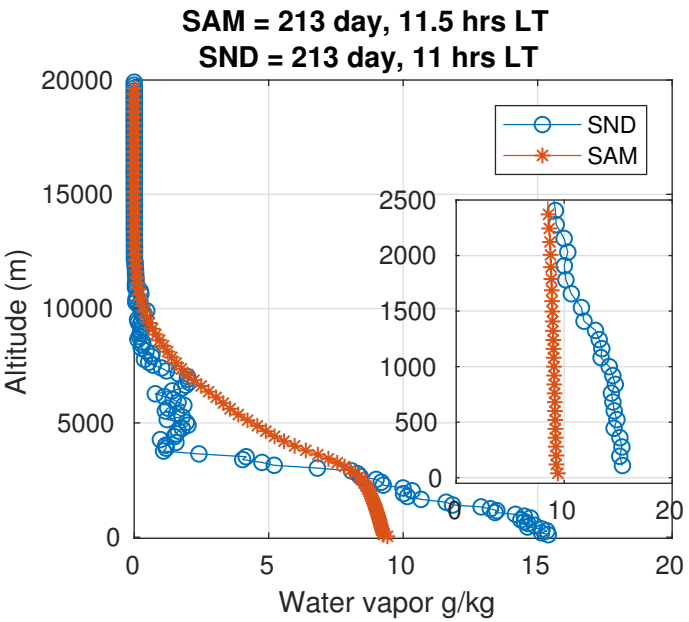
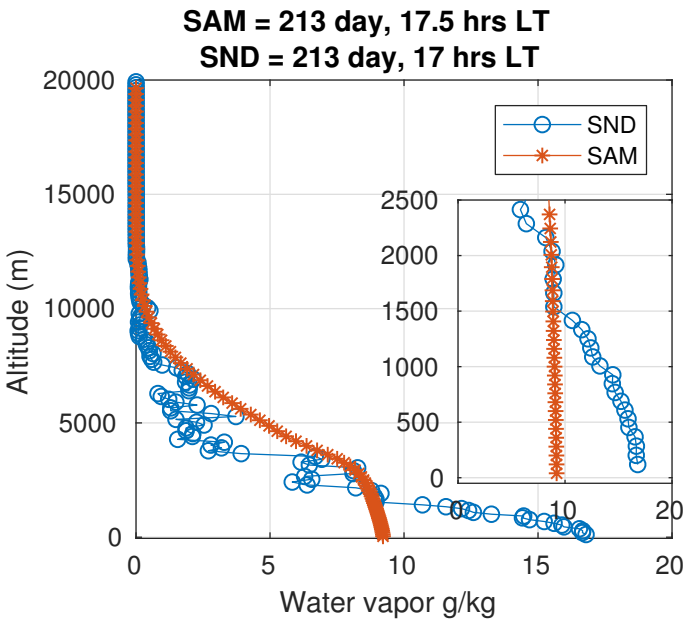
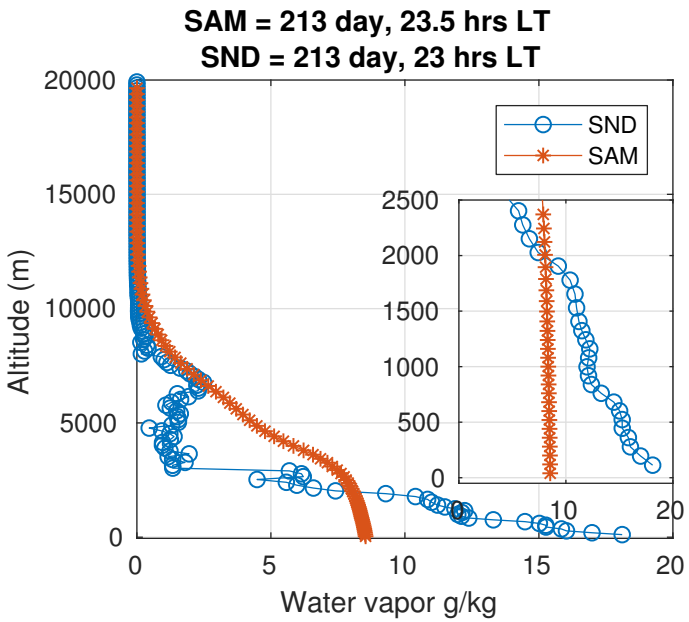
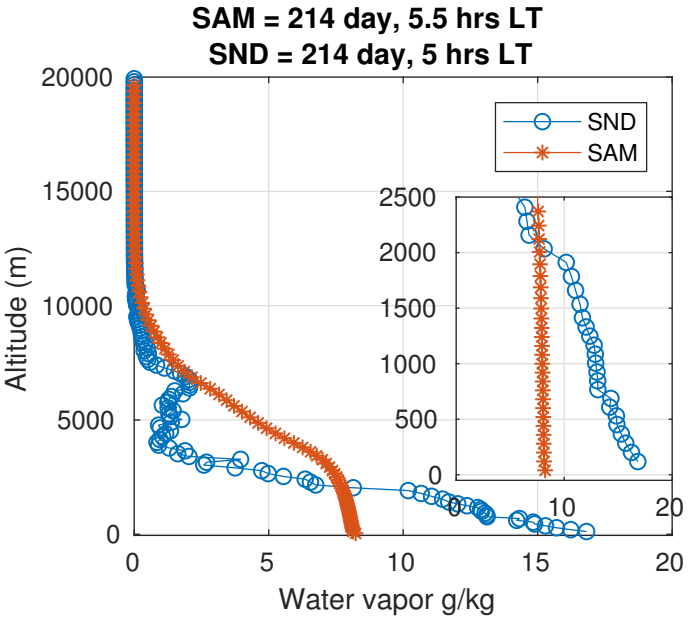
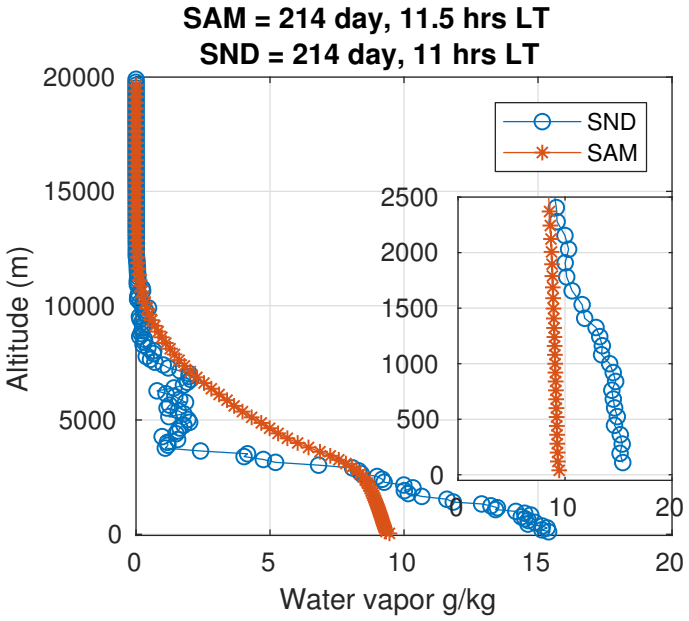
SND
SAM
Altitude (m)
Potential temperature K

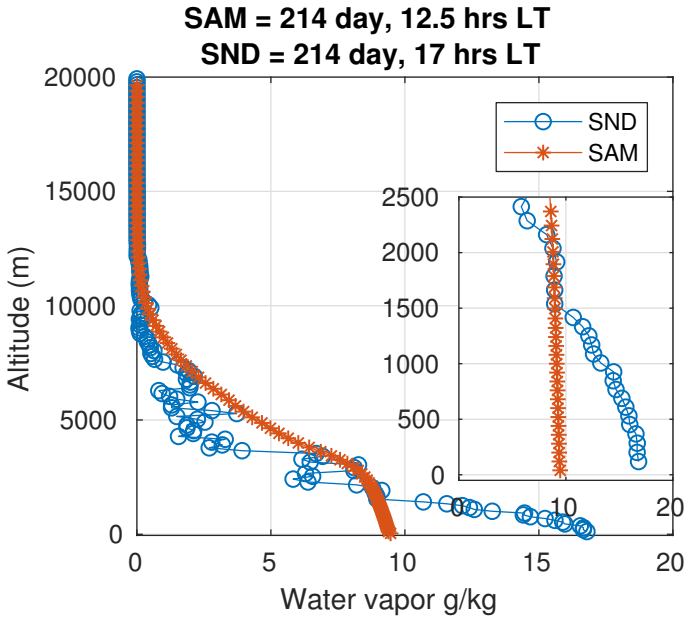

SAM = 213 day, 11.5 hrs LT
SND = 213 day, 11 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

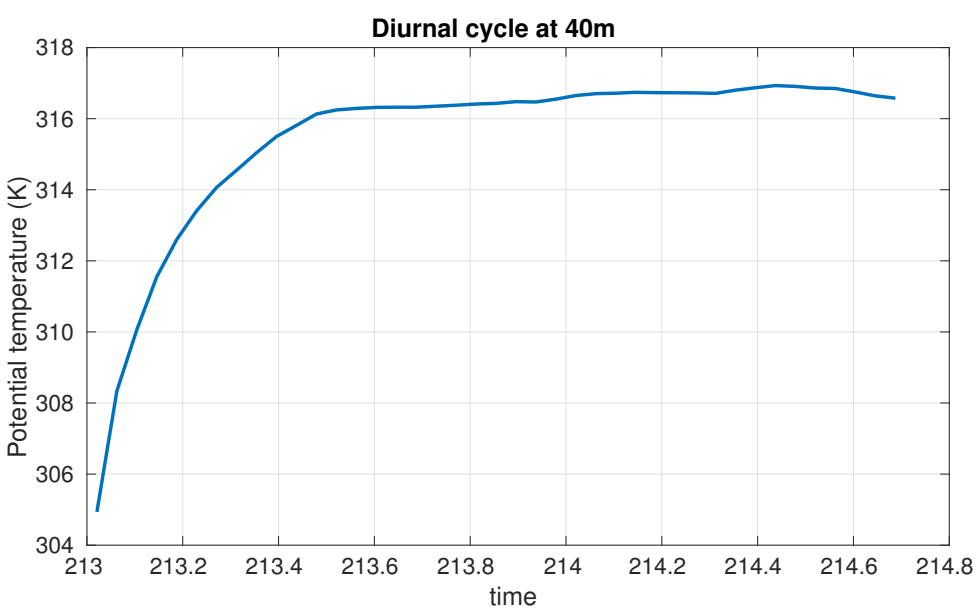

SAM = 213 day, 17.5 hrs LT
SND = 213 day, 17 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

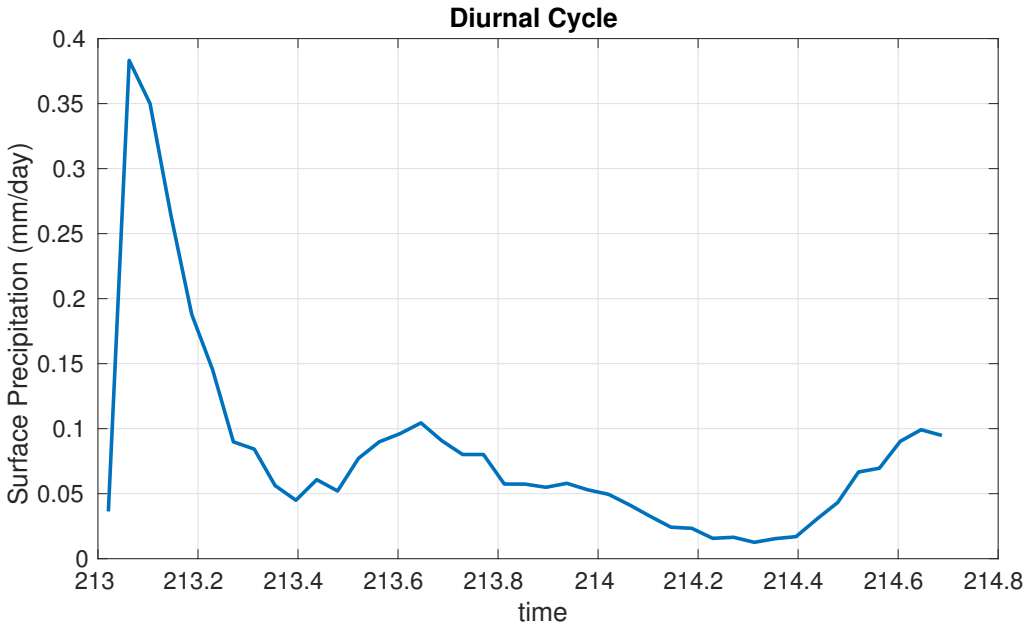

SAM = 213 day, 23.5 hrs LT
SND = 213 day, 23 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

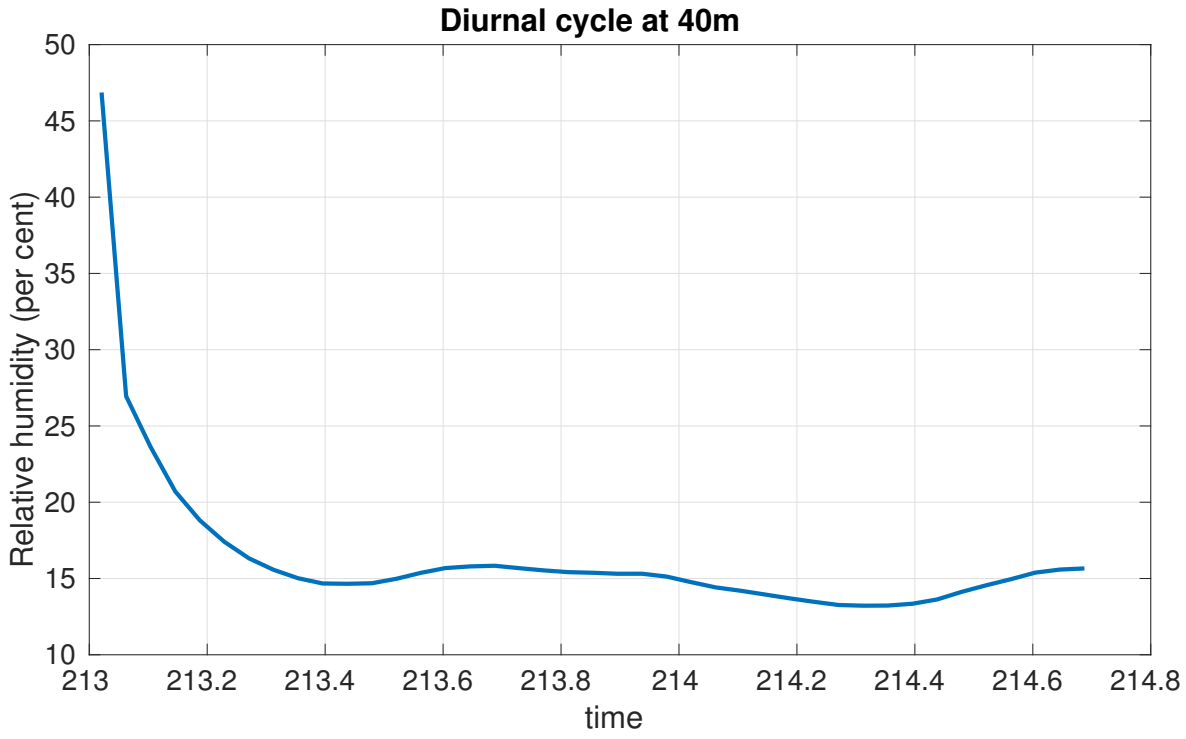

SAM = 214 day, 5.5 hrs LT
SND = 214 day, 5 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 214 day, 11.5 hrs LT
SND = 214 day, 11 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 214 day, 12.5 hrs LT
SND = 214 day, 17 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


Diurnal cycle at 40m
Potential temperature (K)
318
316
314
312
310
308
306
304
213
213.2
213.4
213.6
213.8
214
214.2
214.4
214.6
214.8
time

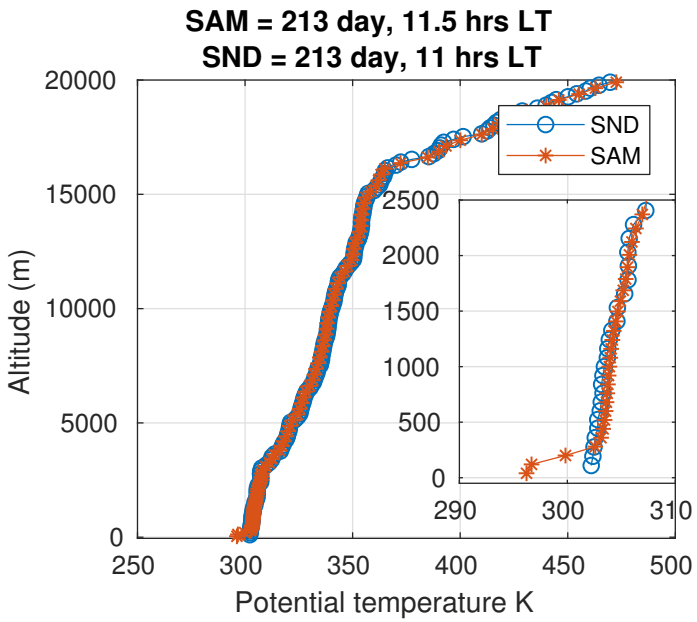

Diurnal Cycle
Surface Precipitation (mm/day)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
213
213.2
213.4
213.6
213.8
214
214.2
214.4
214.6
214.8
time

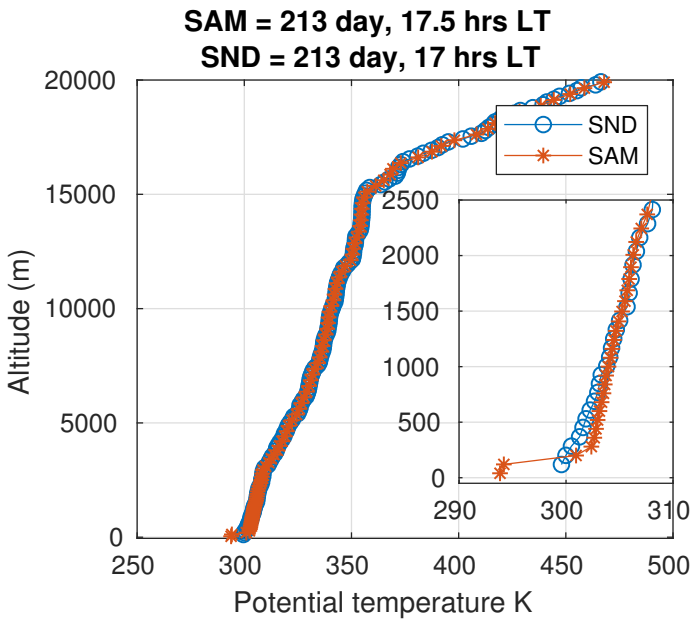

Diurnal cycle at 40m
Relative humidity (per cent)
50
45
40
35
30
25
20
15
10
213
213.2
213.4
213.6
213.8
214
214.2
214.4
214.6
214.8
time

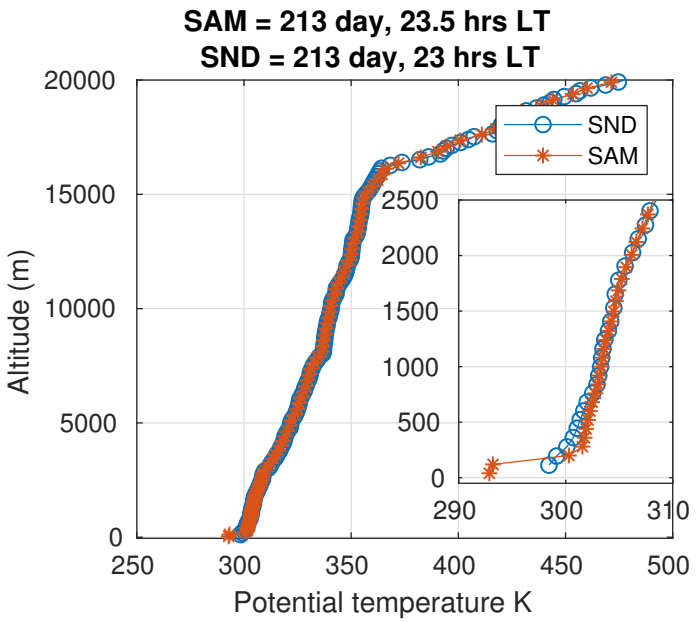
- Focussing on LBA-CAM, I repeated the experiment with higher sensible heat fluxes (highSHF), higher boundary layer temperature (highSHF_highBLT) and low boundary layer specific humidity (highSHF_highBLT_lowQ)
- highSHF (slides 10, 11), increased SHF from ~150 to ~200W/m2 at noon and corresponding increase during day time.
- highSHF_highBLT (slides 12, 13), increased BL temperature by ~8K between 9am and 5pm.
- highSHF_highBLT_lowQ (slides 14, 15), lowered near surface specific humidity from ~16g/kg to ~12g/kg
- These experiments used 4hr relaxation time

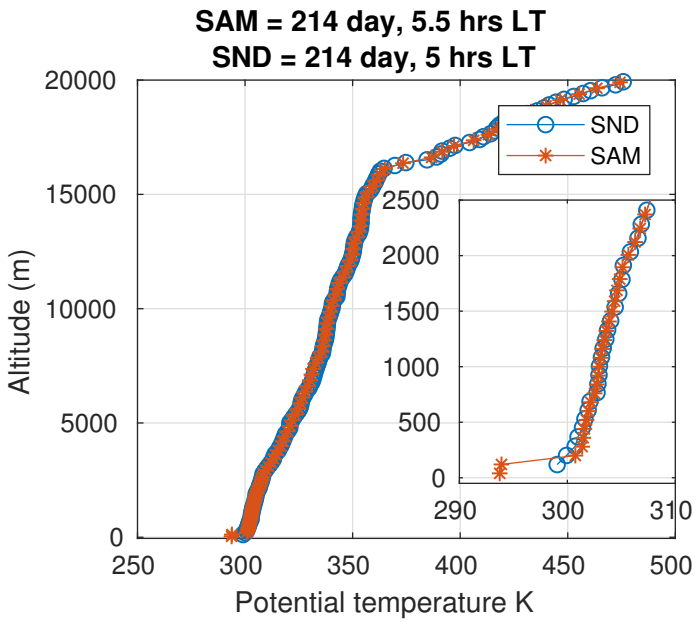
- None of these three experiments showed improvements over the original SAM-CAM experiments.

highSHF


SAM = 213 day, 11.5 hrs LT
SND = 213 day, 11 hrs LT
SND
SAM
Altitude (m)
Potential temperature K


SAM = 213 day, 17.5 hrs LT
SND = 213 day, 17 hrs LT
SND
SAM
Altitude (m)
Potential temperature K


SAM = 213 day, 23.5 hrs LT
SND = 213 day, 23 hrs LT
SND
SAM
Altitude (m)
Potential temperature K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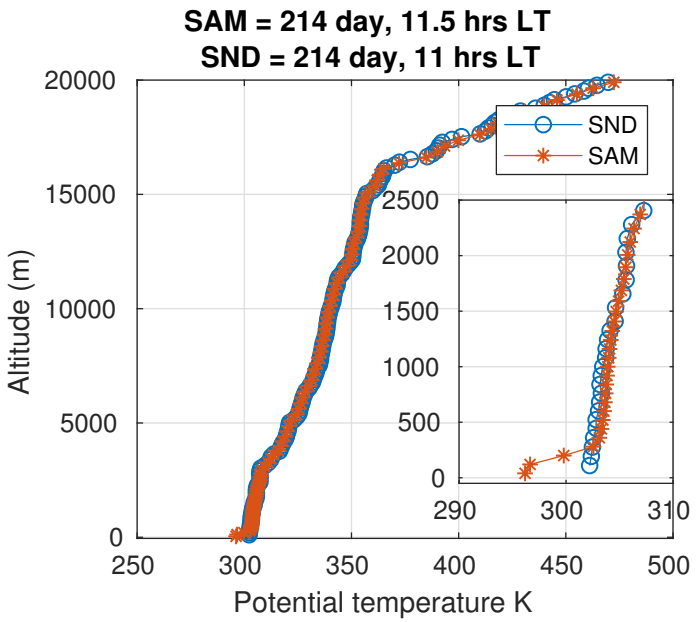
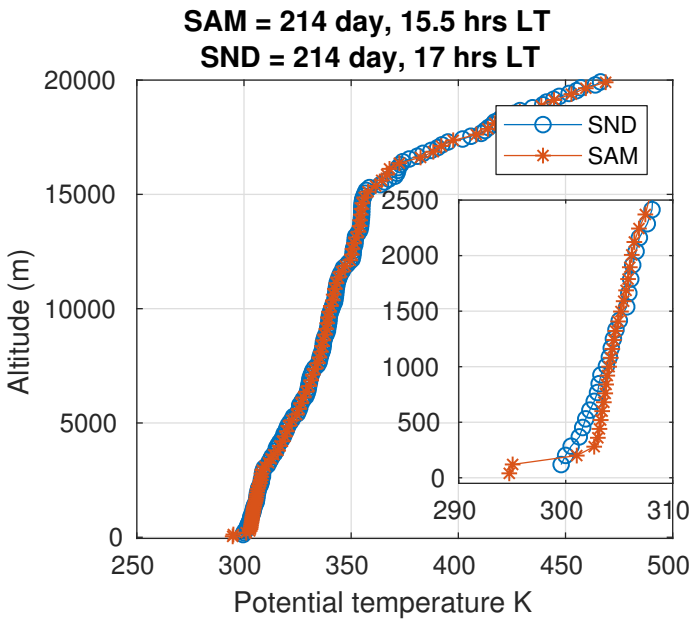
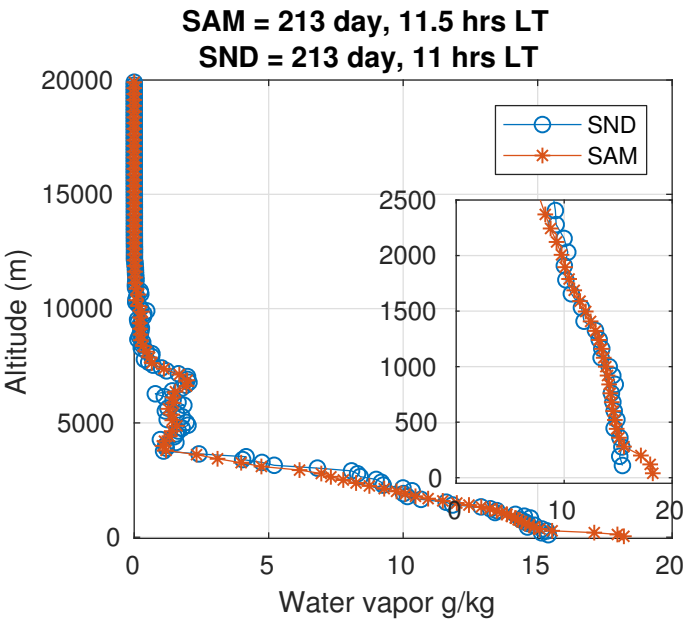
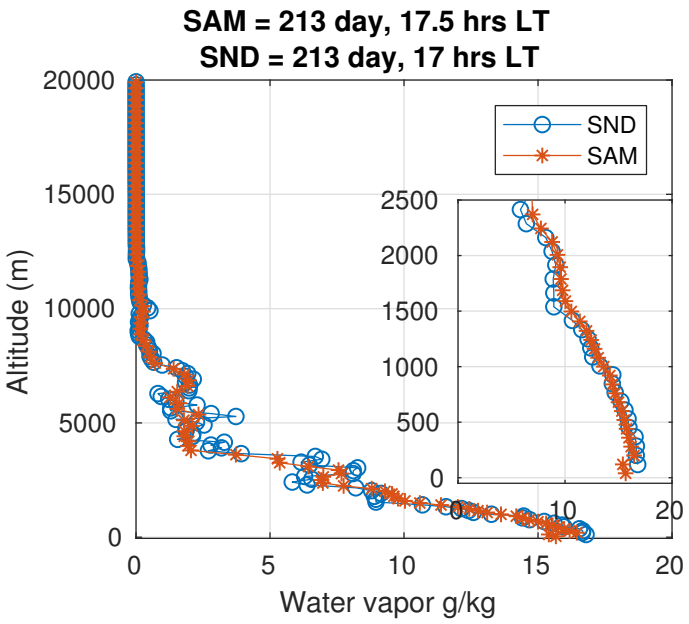
SND = 214 day, 5 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

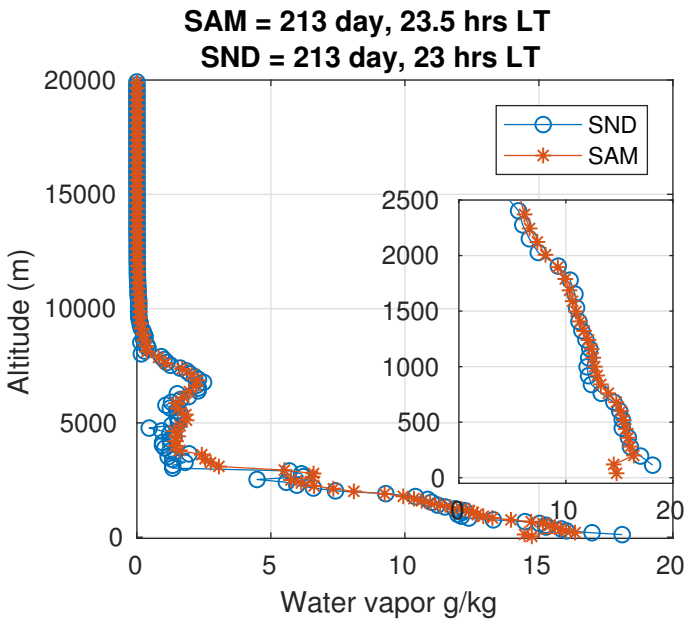

SAM = 214 day, 11.5 hrs LT
SND = 214 day, 11 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

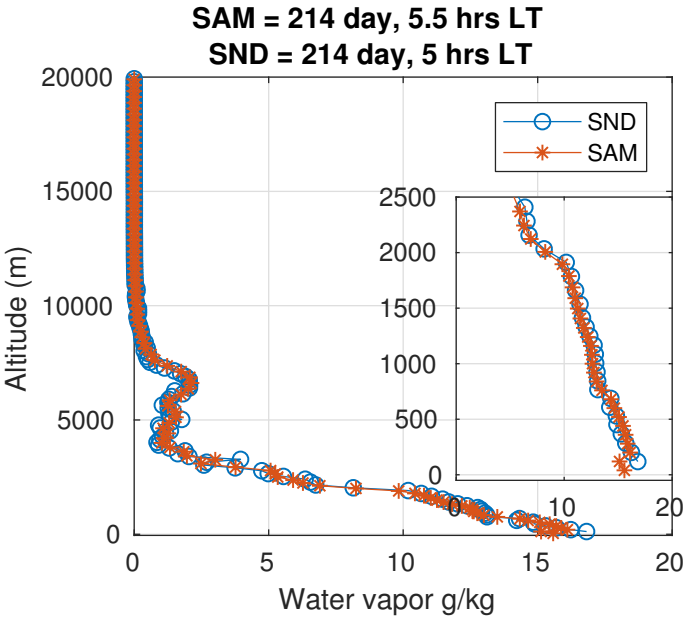

SAM = 214 day, 15.5 hrs LT
SND = 214 day, 17 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

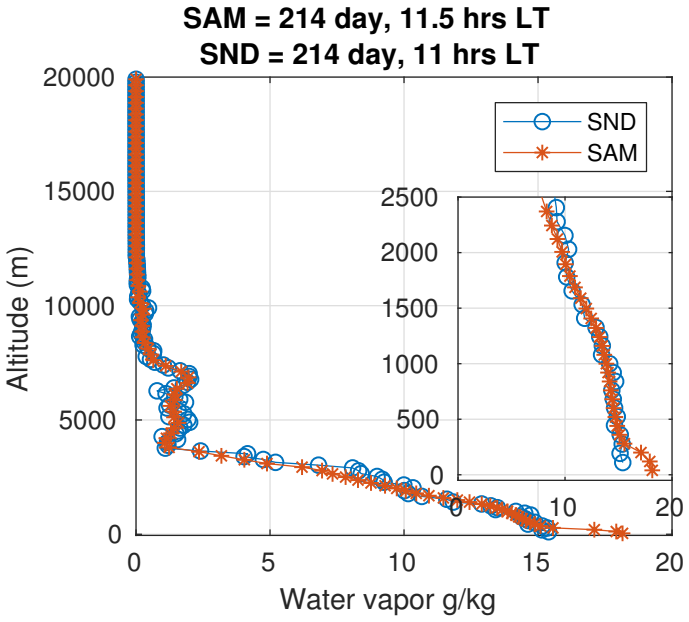
highSHF

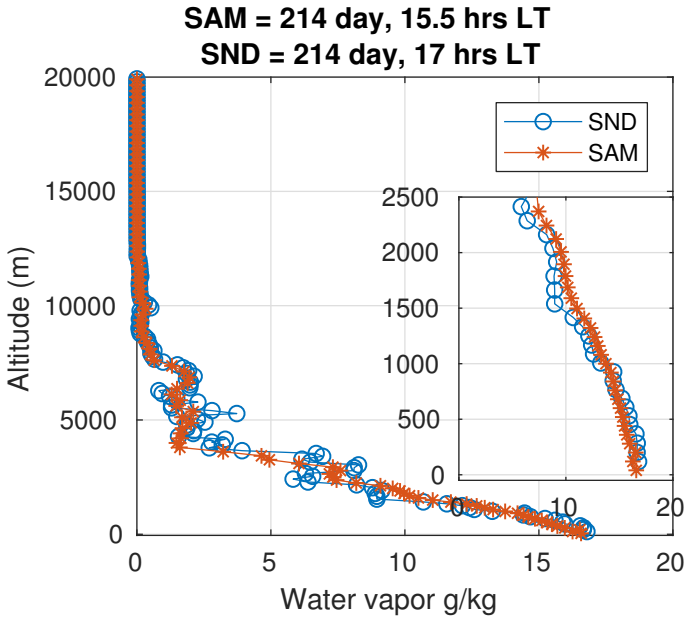

SAM = 213 day, 11.5 hrs LT
SND = 213 day, 11 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 213 day, 17.5 hrs LT
SND = 213 day, 17 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

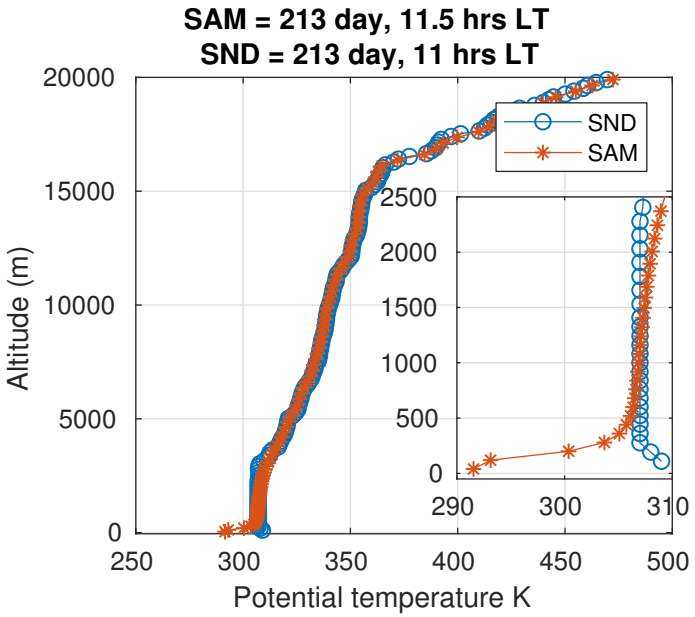

SAM = 213 day, 23.5 hrs LT
SND = 213 day, 23 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

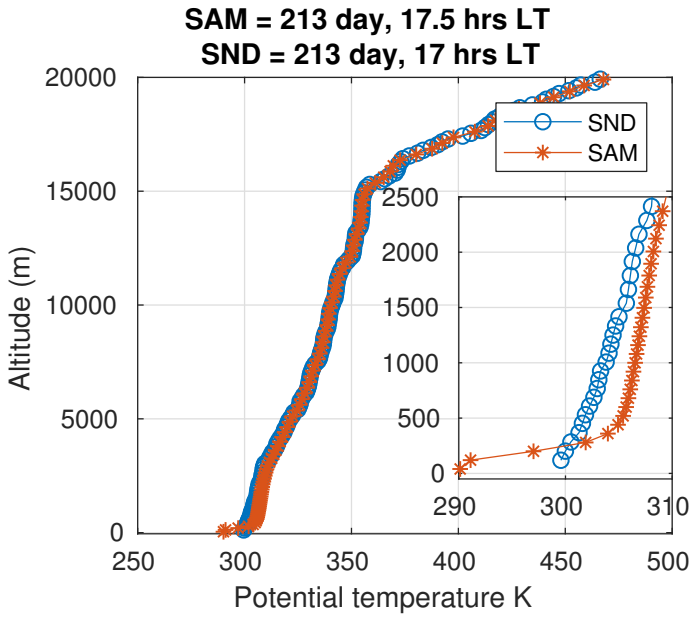

SAM = 214 day, 5.5 hrs LT
SND = 214 day, 5 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

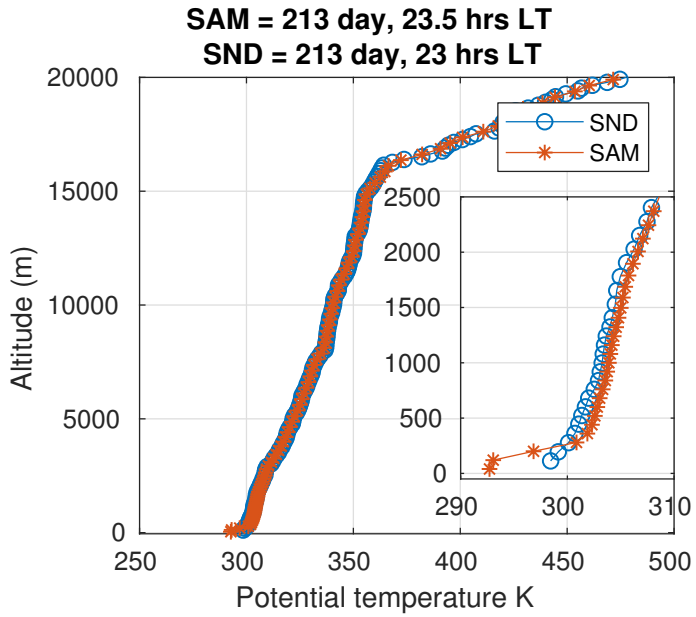

SAM = 214 day, 11.5 hrs LT
SND = 214 day, 11 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

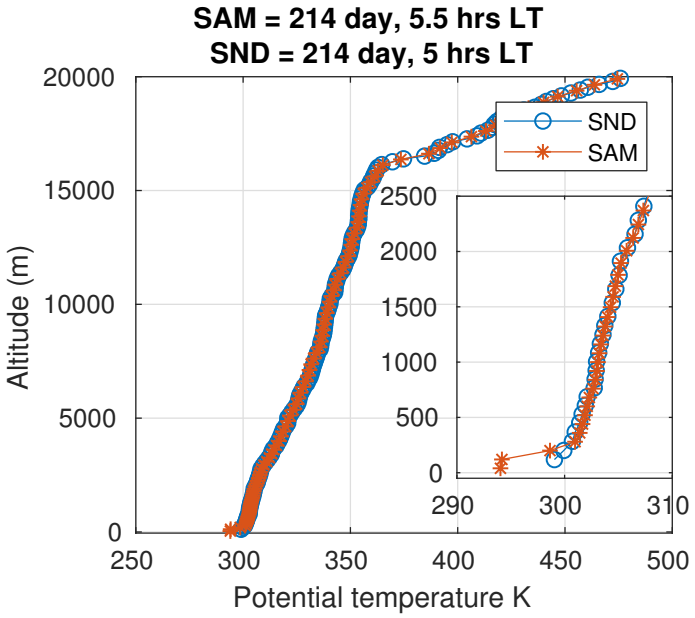

SAM = 214 day, 15.5 hrs LT
SND = 214 day, 17 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

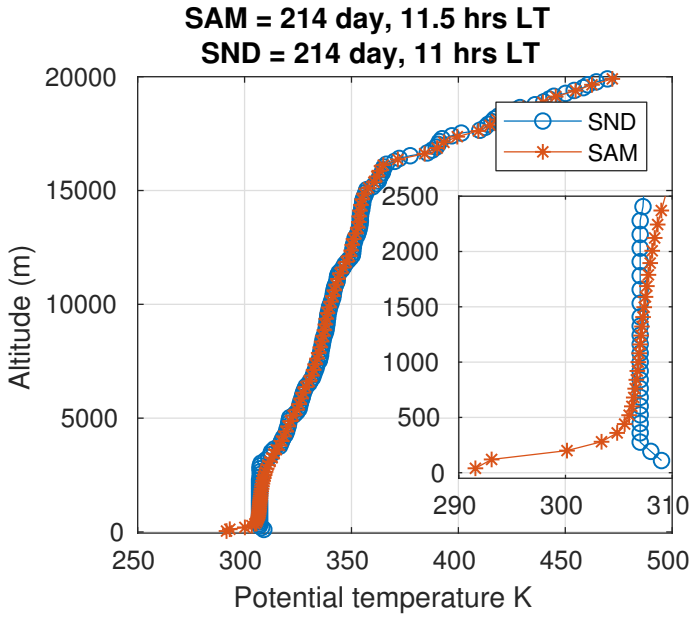
highSHF_highBLT

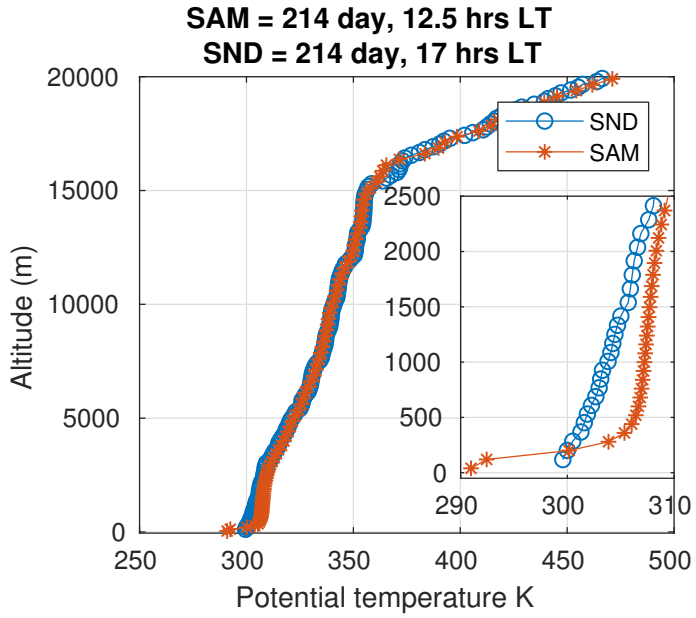




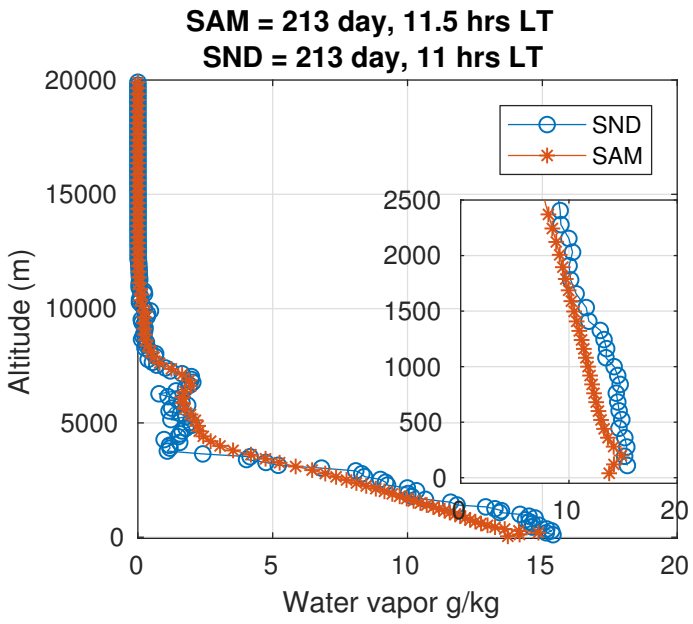


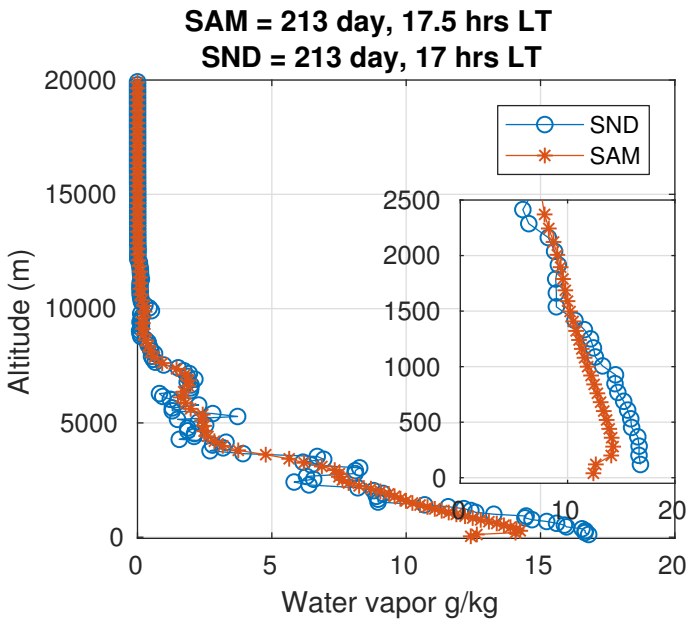


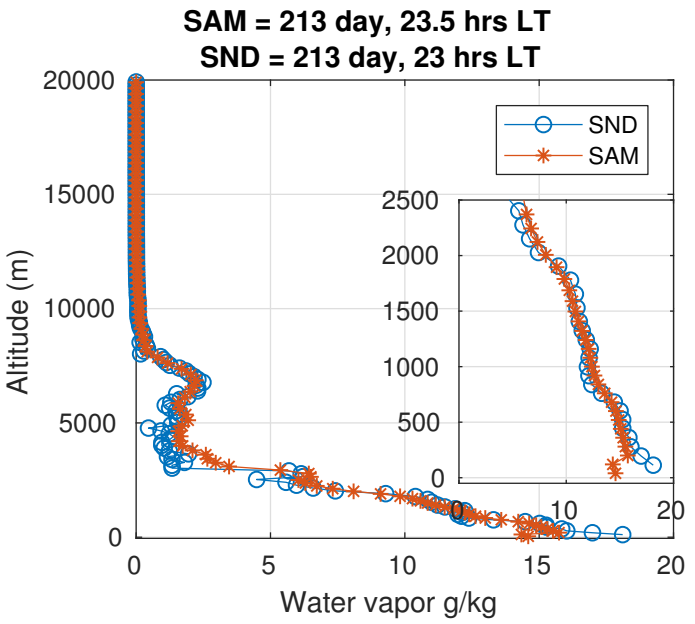


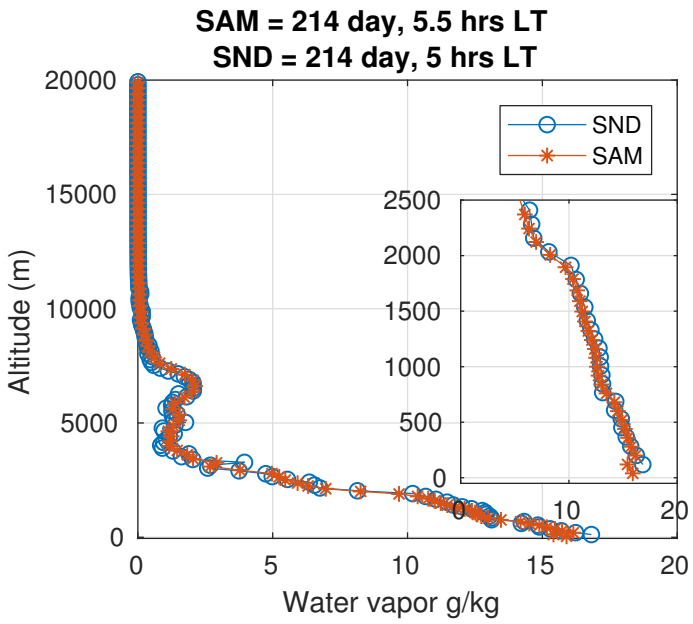


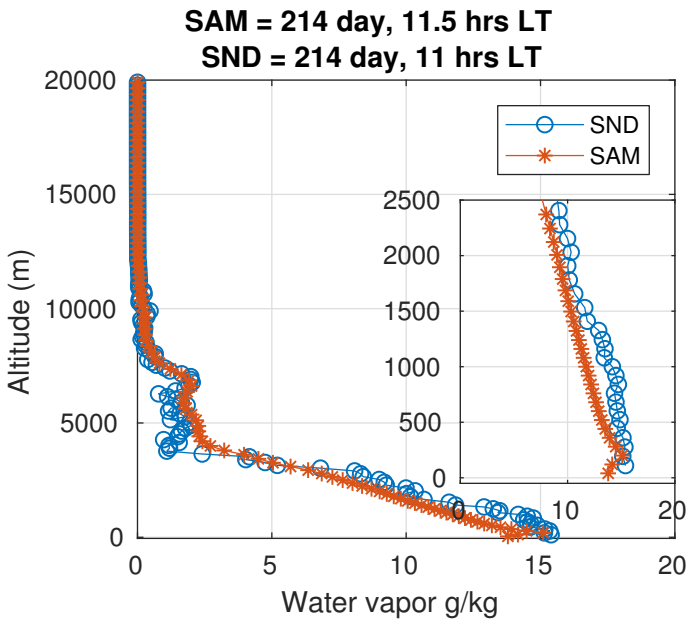
highSHF_highBLT

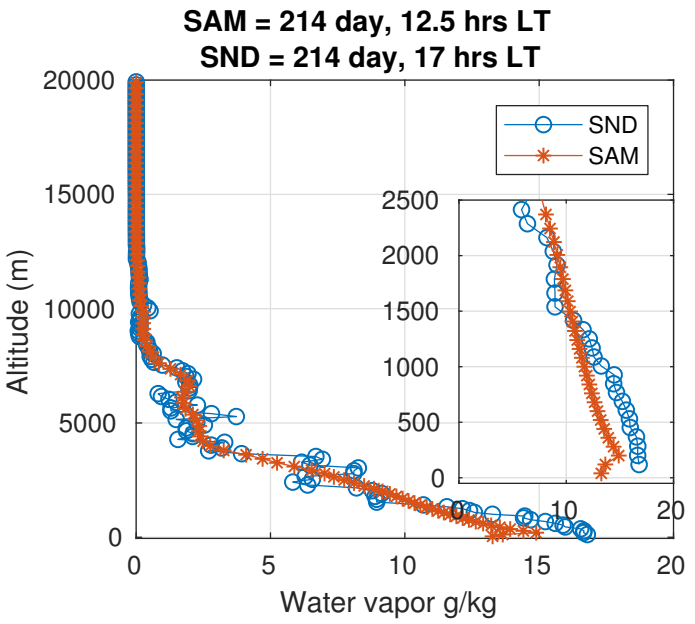




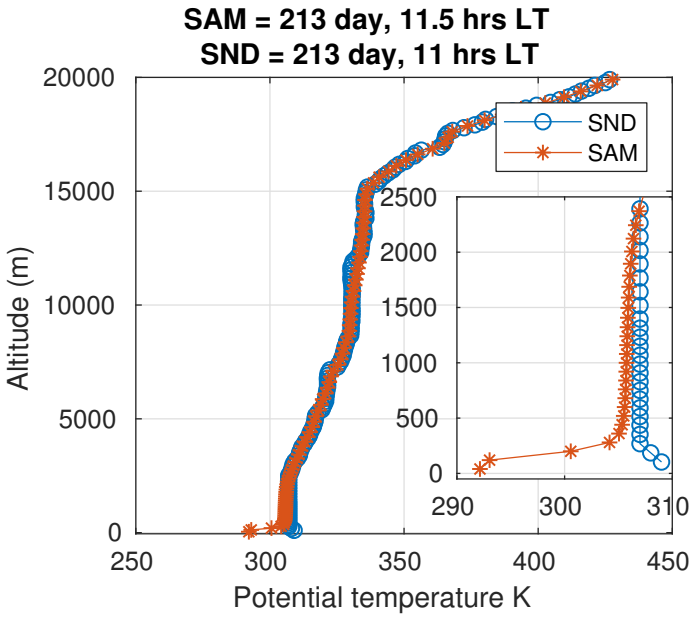


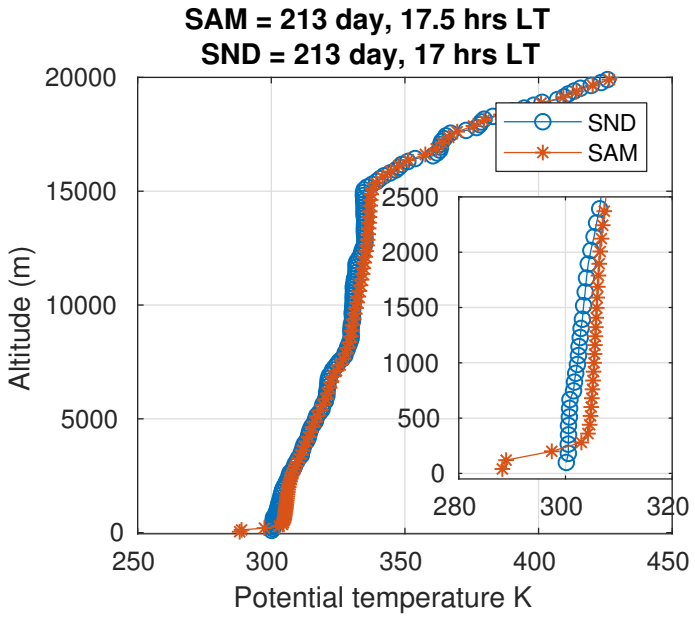


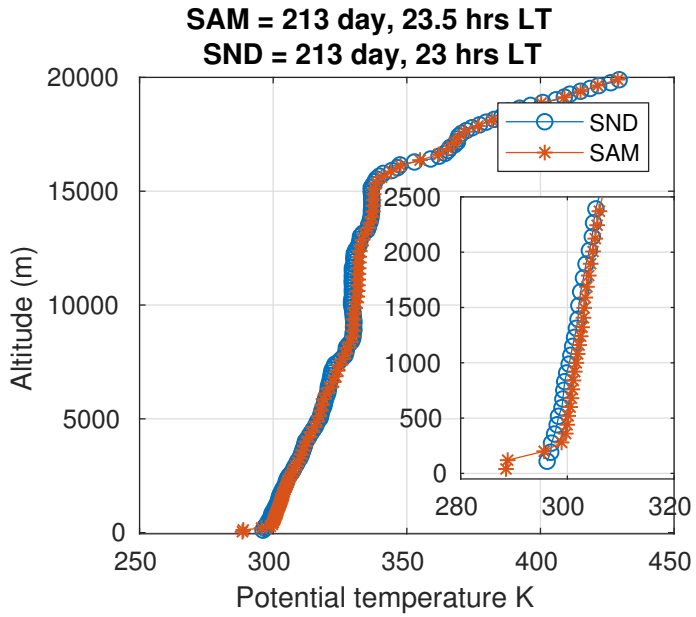


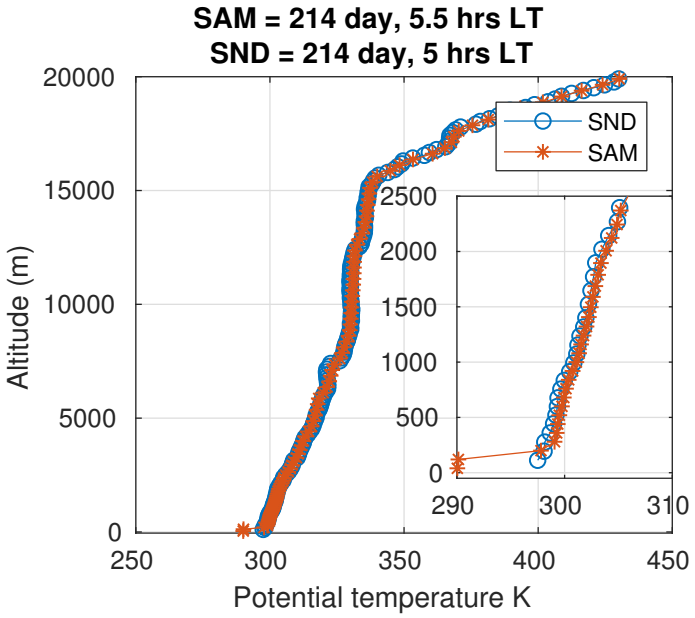


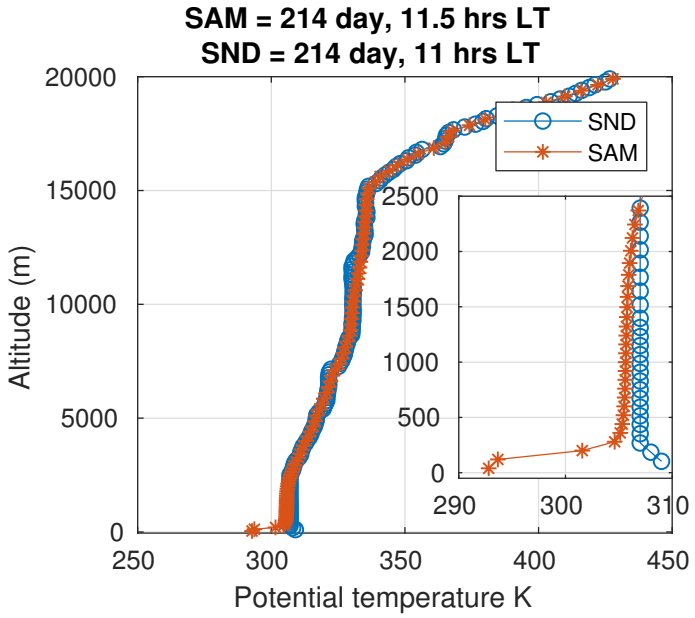
highSHF_highBLT_lowQ

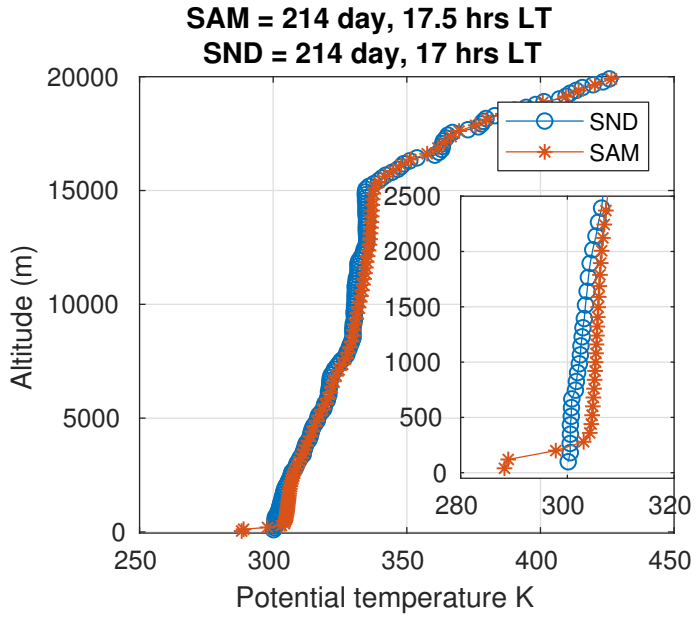




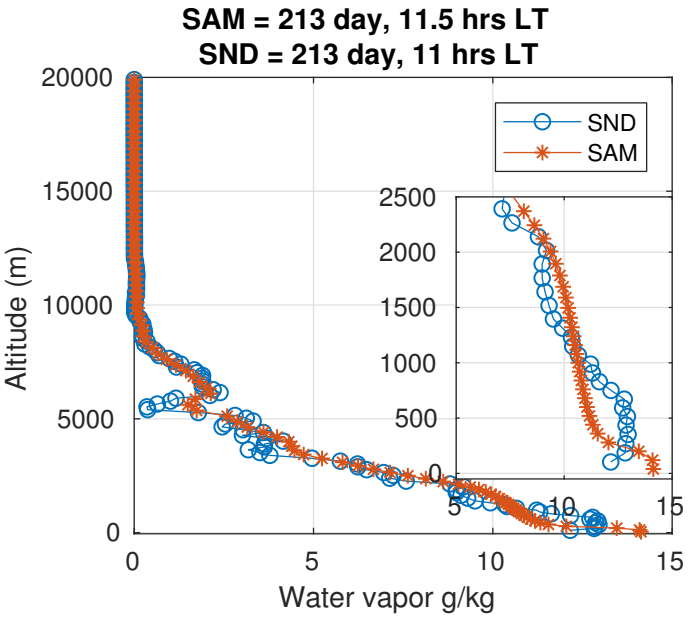


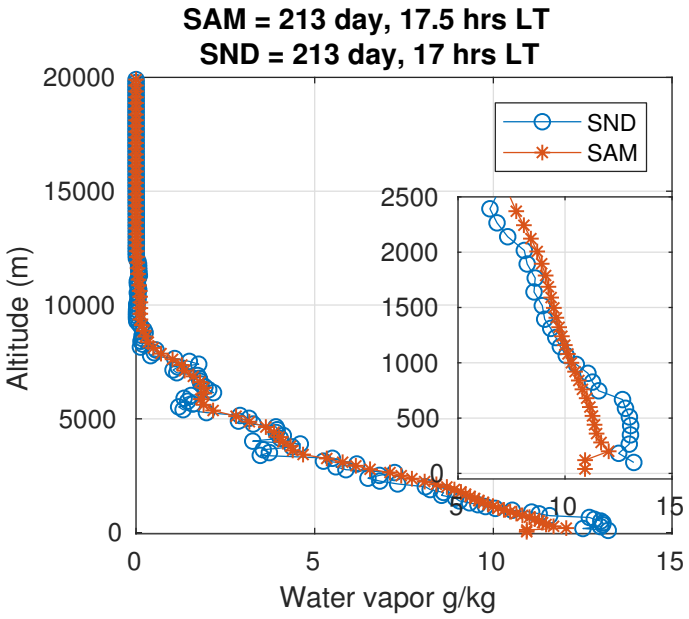


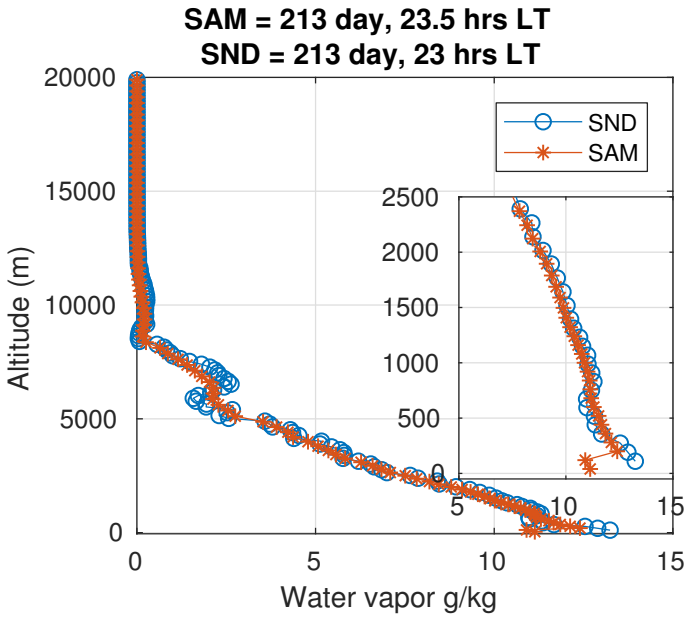


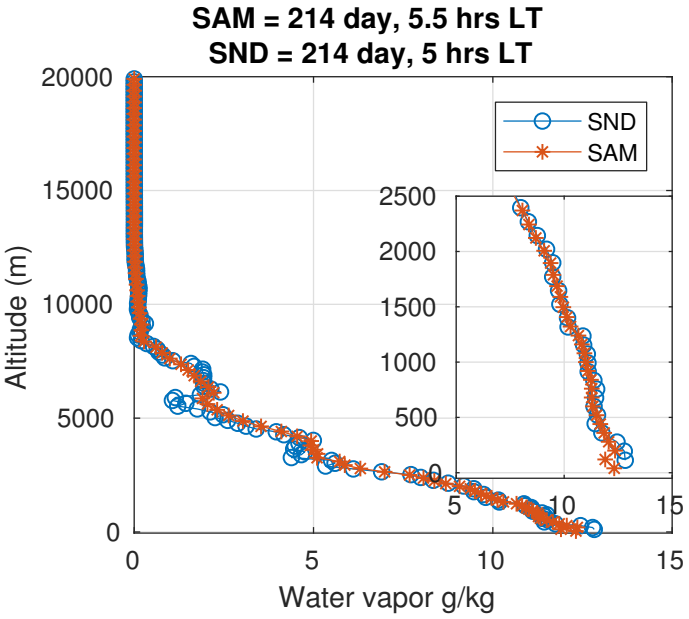


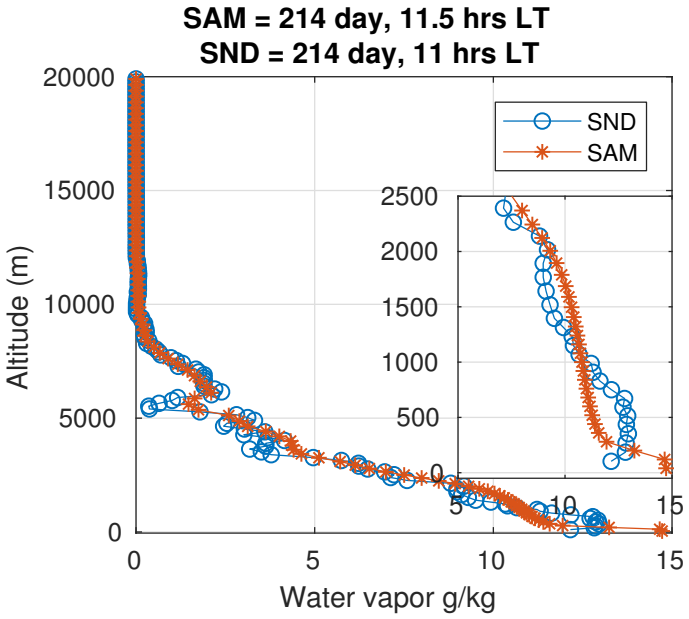
highSHF_highBLT_lowQ

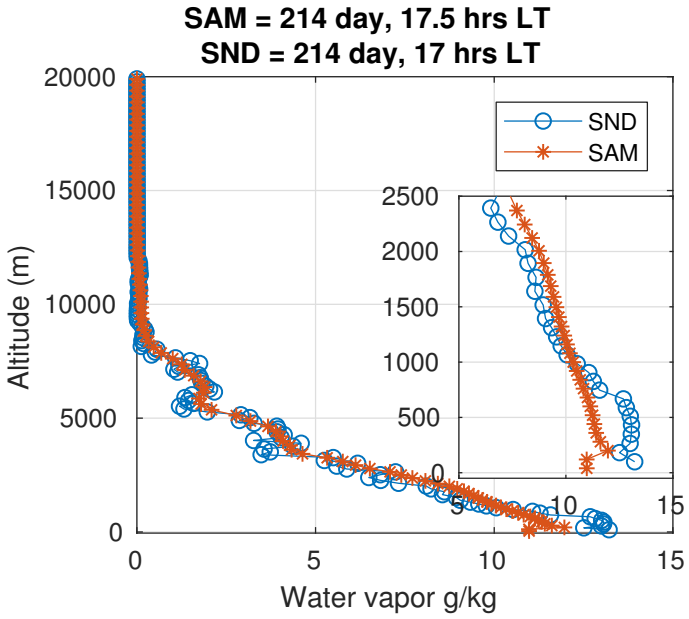








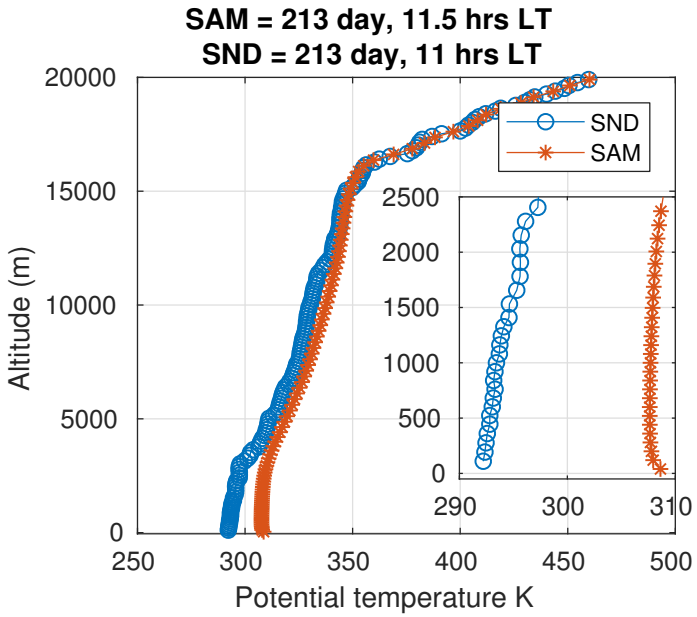


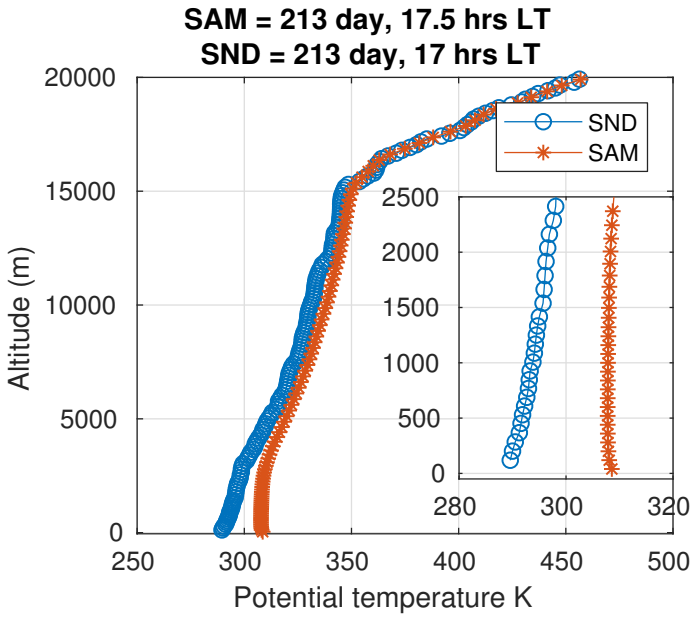


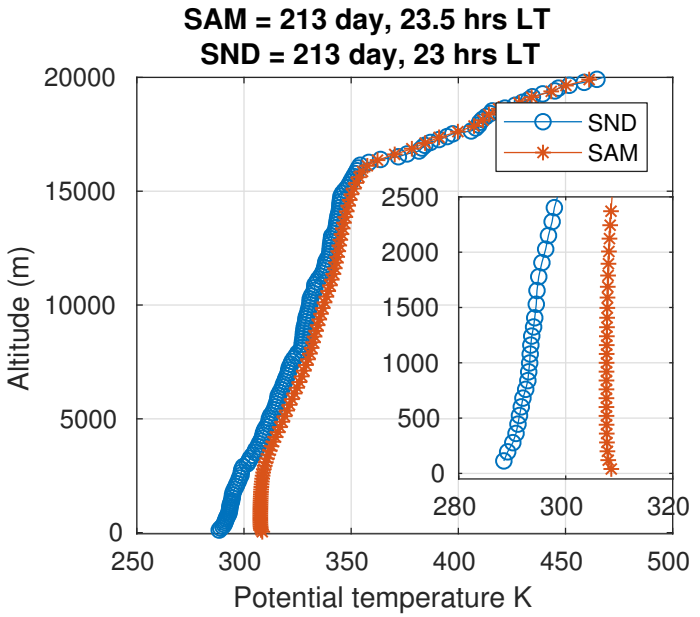
- I also performed a single day experiment with RRTM with boundary layer temperatures lowered by ~8K throughout the day (RRTM_lowBLT) (slides 17, 18, ignore the second row of figures)

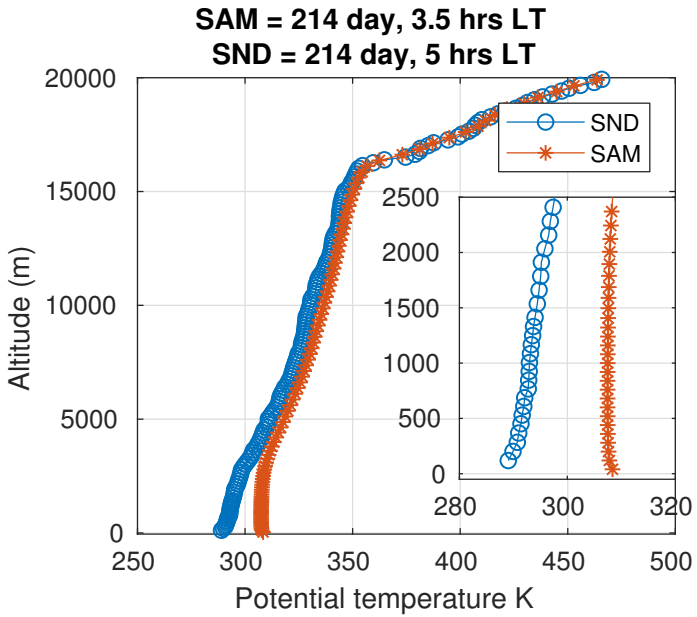
- The simulations are still warmer by the same amount (~15K) as the original RRTM experiment. The simulations are also drier by the same amount (8g/kg) as the original RRTM experiment.

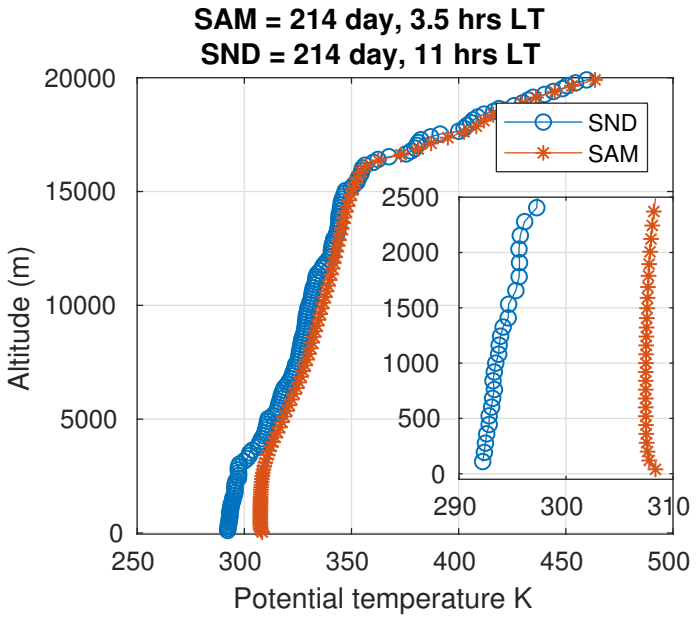
RRTM_lowBLT

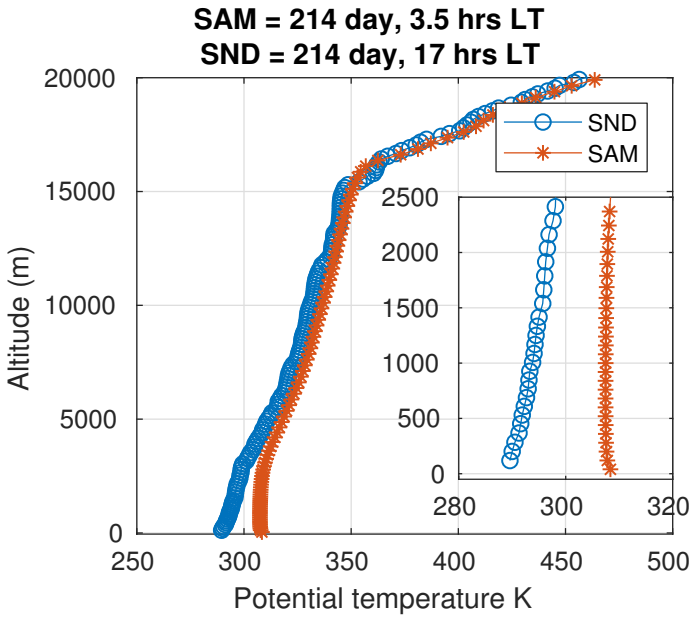

SAM = 213 day, 11.5 hrs LT
SND = 213 day, 11 hrs LT
SND
SAM
Altitude (m)
Potential temperature K


SAM = 213 day, 17.5 hrs LT
SND = 213 day, 17 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

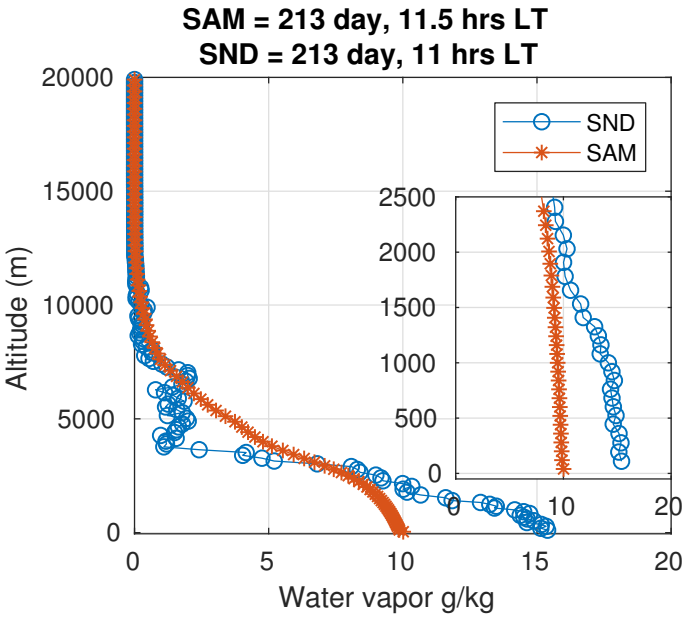

SAM = 213 day, 23.5 hrs LT
SND = 213 day, 23 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

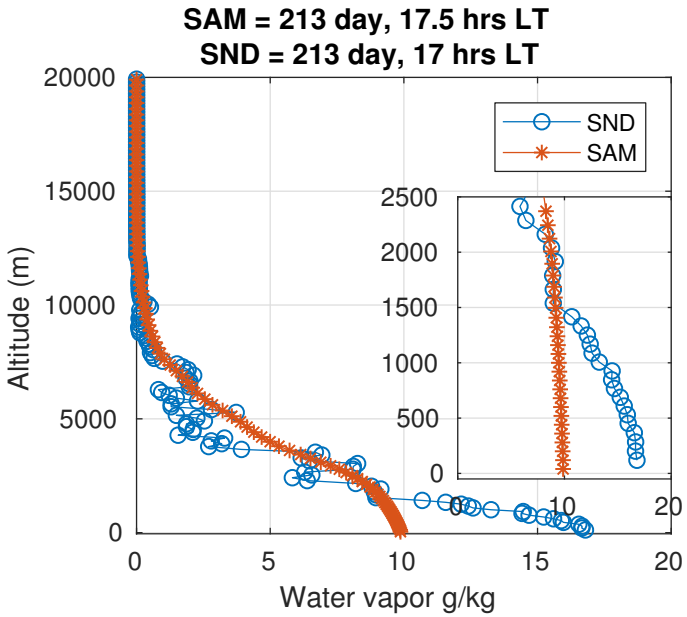

SAM = 214 day, 3.5 hrs LT
SND = 214 day, 5 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

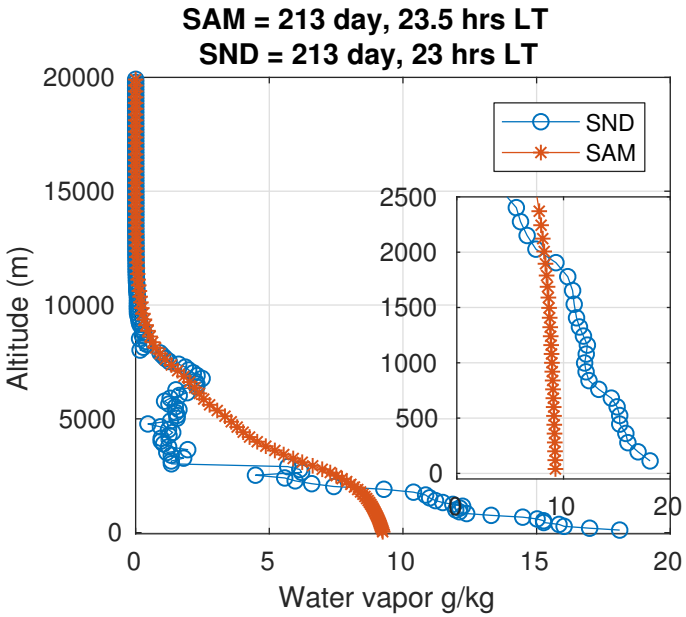

SAM = 214 day, 3.5 hrs LT
SND = 214 day, 11 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

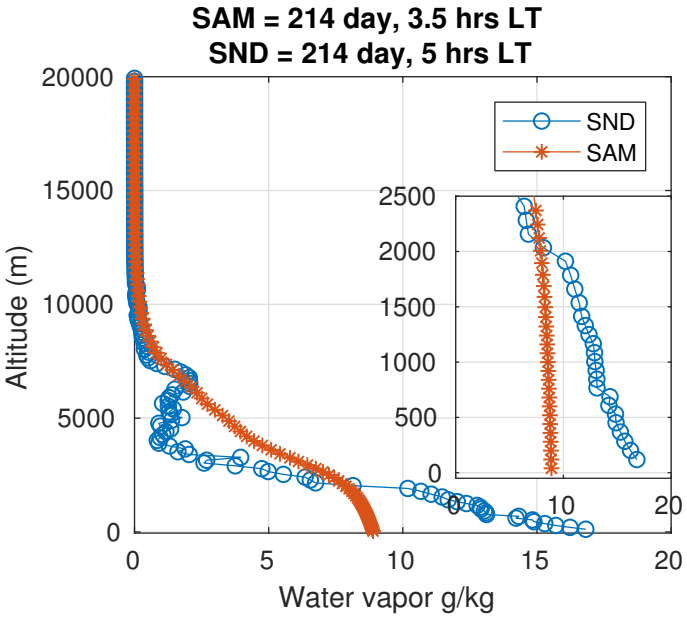

SAM = 214 day, 3.5 hrs LT
SND = 214 day, 17 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

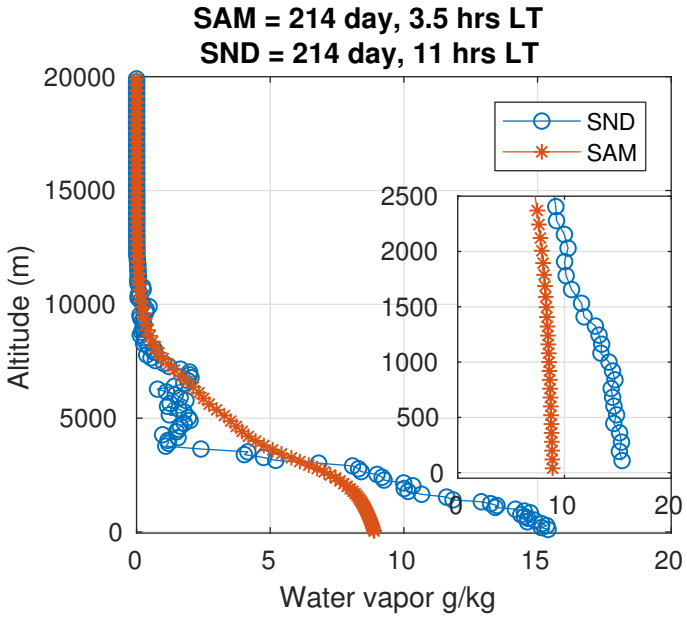
RRTM_lowBLT

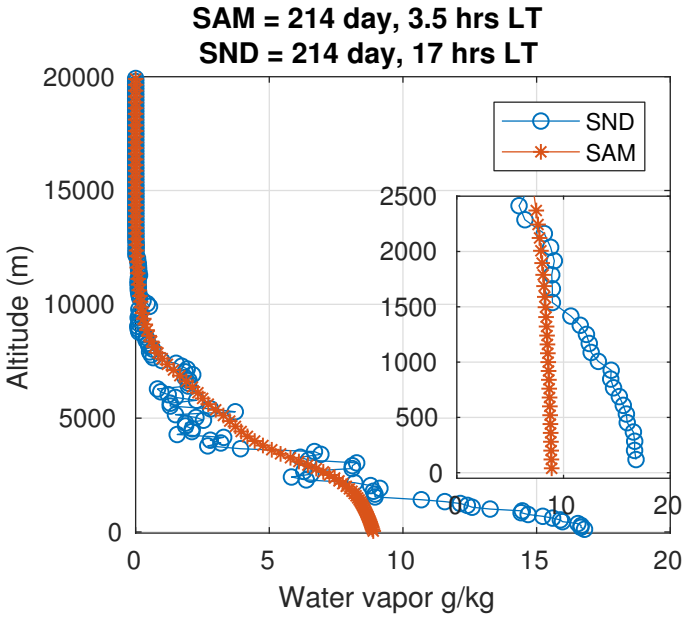

SAM = 213 day, 11.5 hrs LT
SND = 213 day, 11 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 213 day, 17.5 hrs LT
SND = 213 day, 17 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 213 day, 23.5 hrs LT
SND = 213 day, 23 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 214 day, 3.5 hrs LT
SND = 214 day, 5 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 214 day, 3.5 hrs LT
SND = 214 day, 11 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

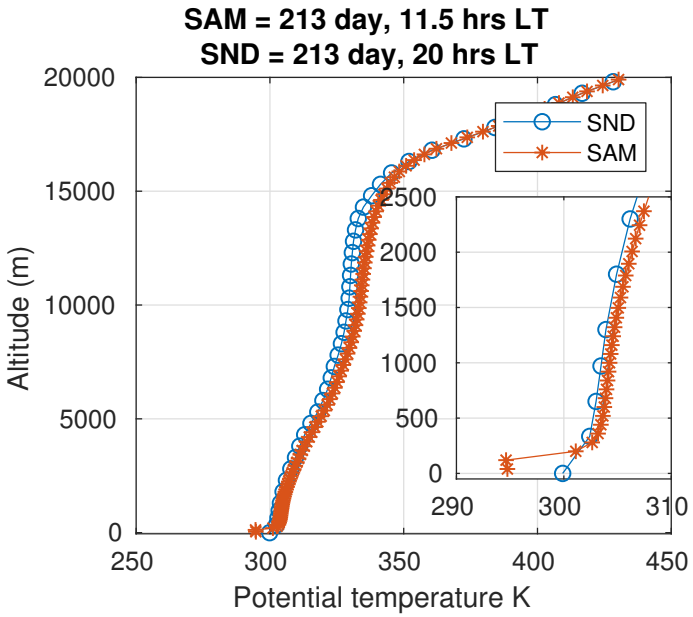

SAM = 214 day, 3.5 hrs LT
SND = 214 day, 17 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

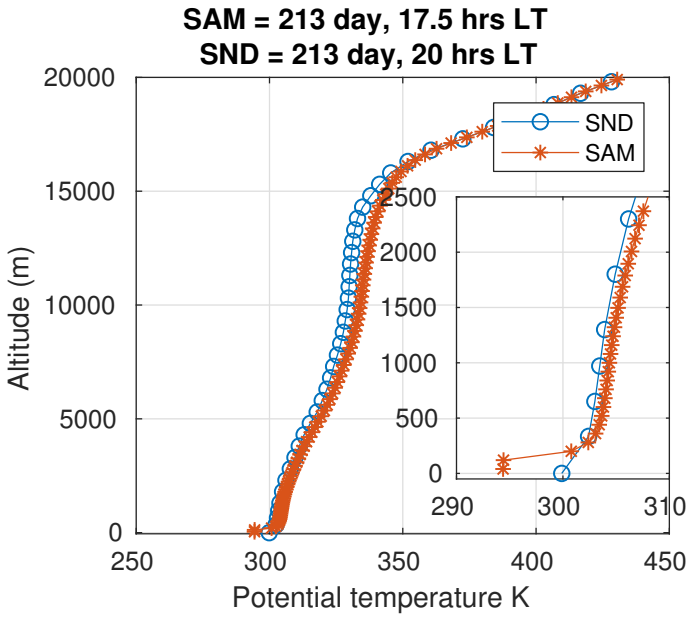
- In the meantime I also found a couple mistakes in the application of initial and boundary conditions. For example, the specific heat capacity used to calculate the sounding potential temperature profiles was higher (1120 J/kg/K) than the known value of 1004 J/kg/K. Correcting this did not change the fog layer in CAM or the excessive warming in RRTM.

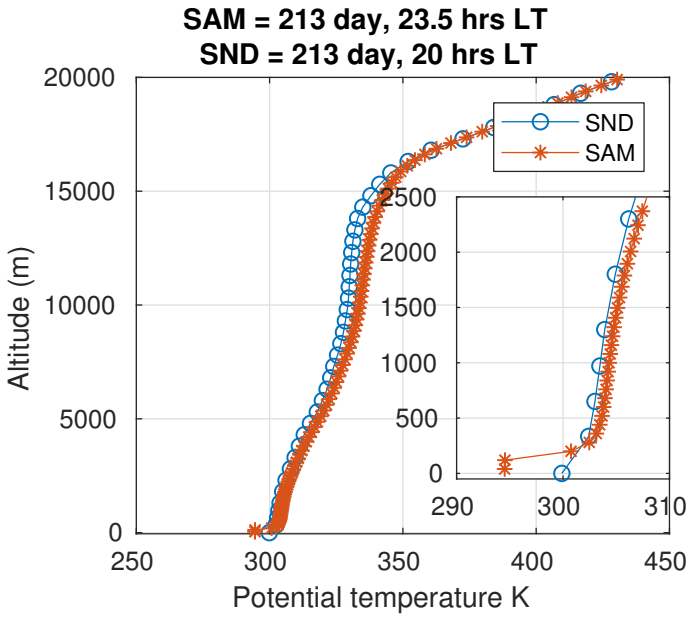
- The IC/BC supplied in the original version of the LBA experiments was provided in LTC. I found that model time was in UTC. However, correcting this a-synchronization did not improve the simulations either.

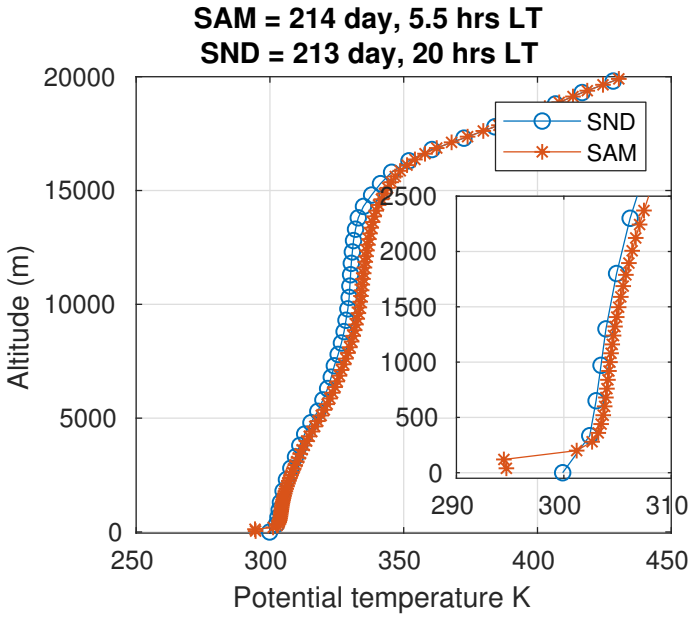
- Next I experimented with the relaxation time tautqls. I repeated the original LBA-CAM experiment with tautqls = 1day, 4hrs, 3hrs, 1hrs and 10min.
- The fog layer that is colder and drier than the applied sounding is present in all simulations. The near surface differences of potential temperature and specific humidity are also nearly the same in all experiments.
- CAM_15mintau (slides 21, 22) was performed with a sounding profile that does not have a diurnal cycle.

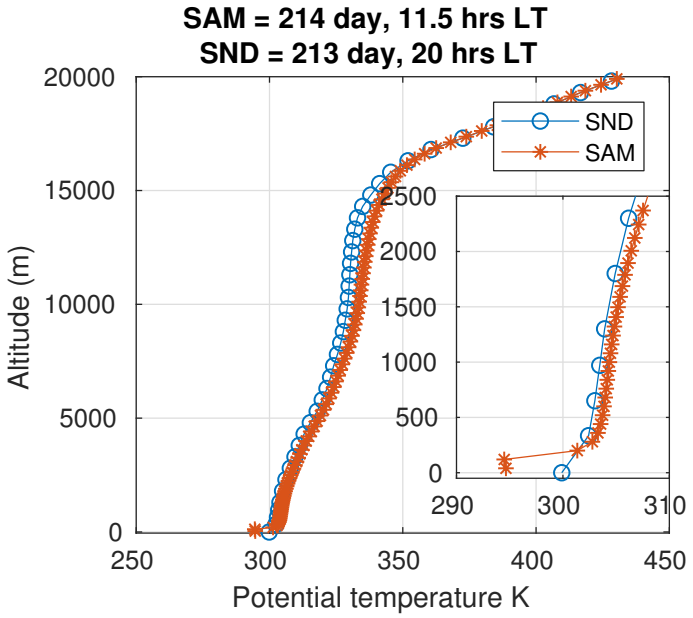
CAM_15mintau

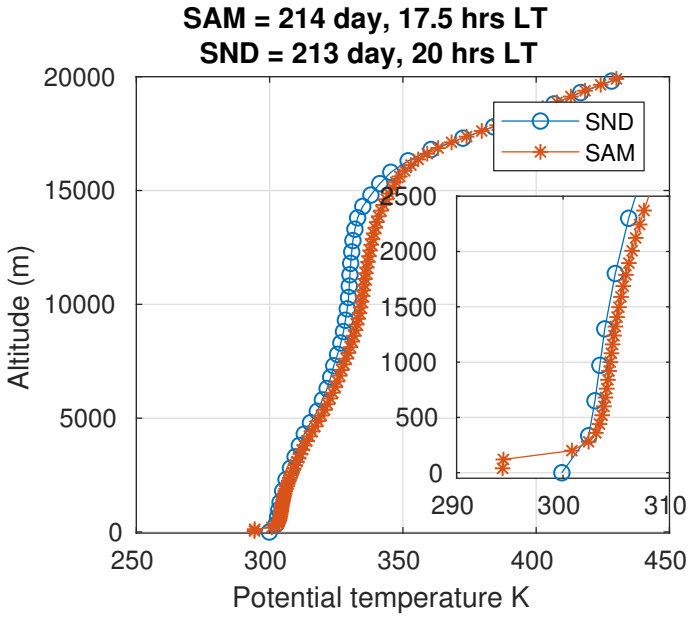




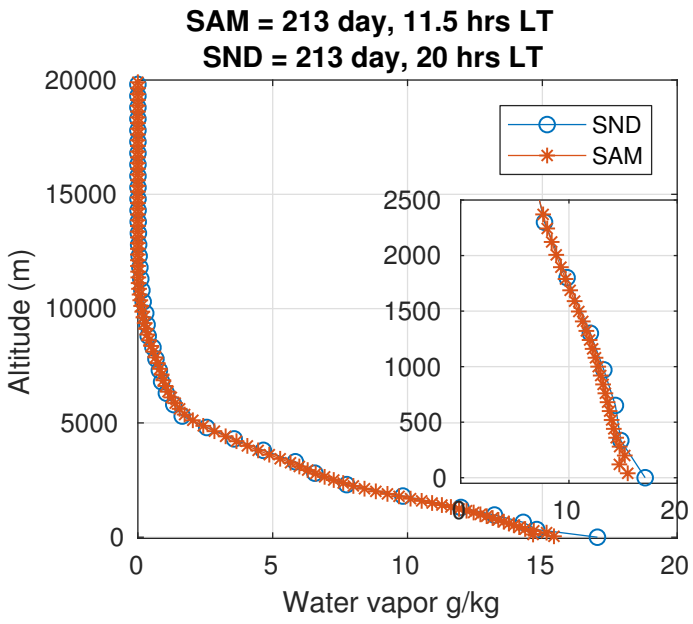


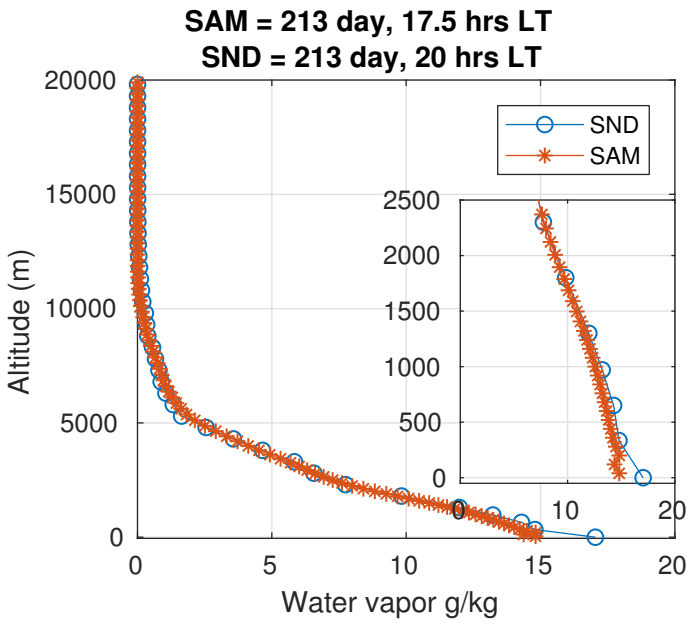


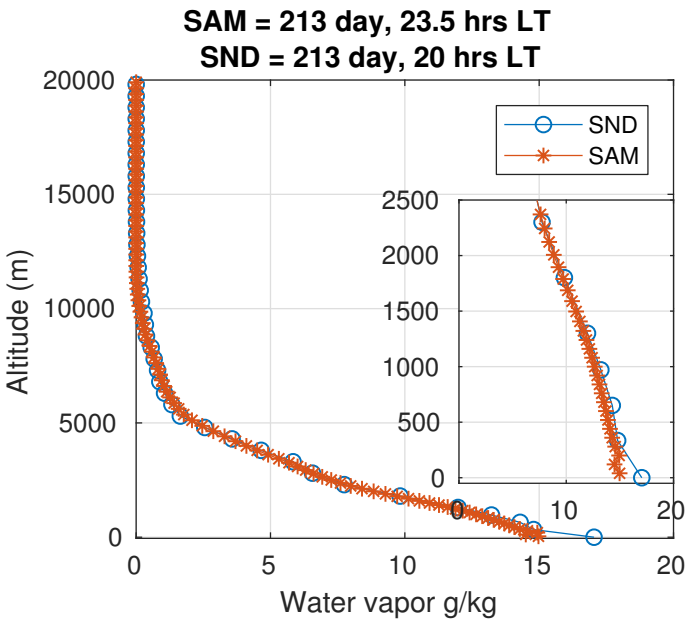


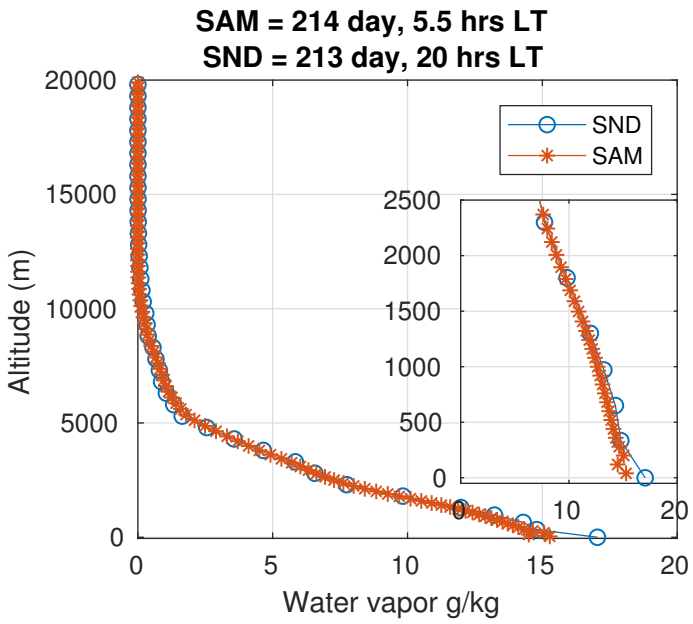


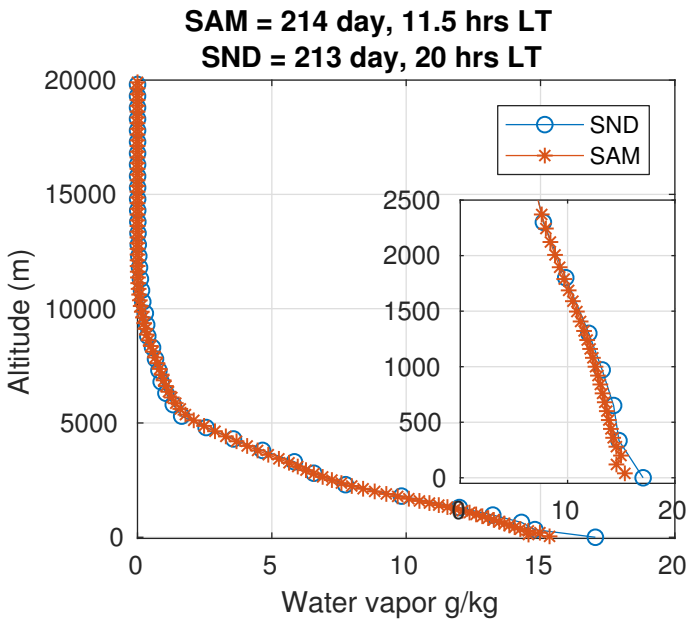
CAM_15mintau

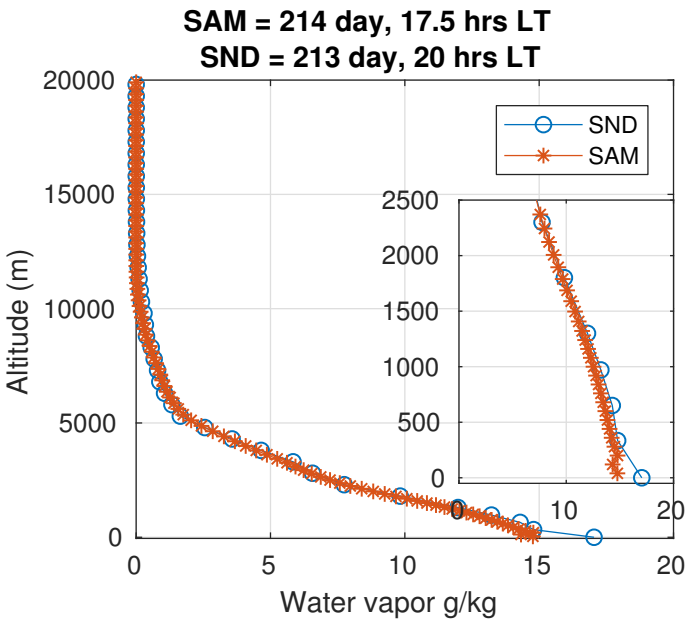






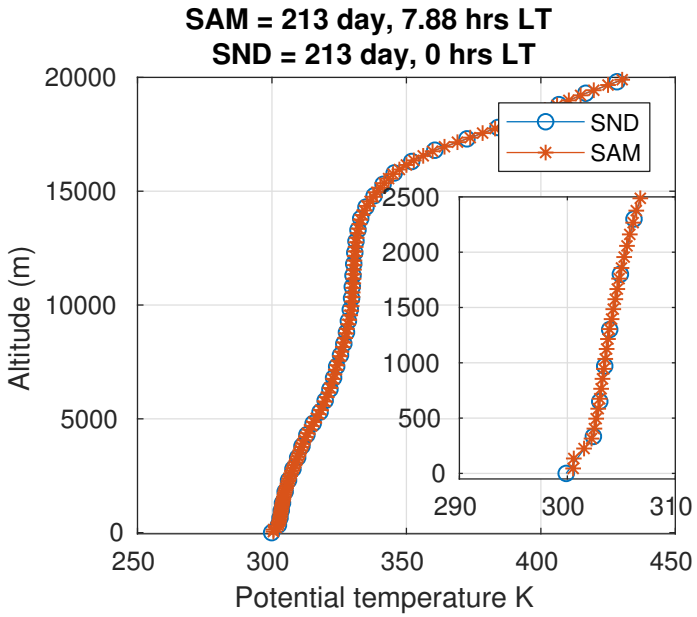


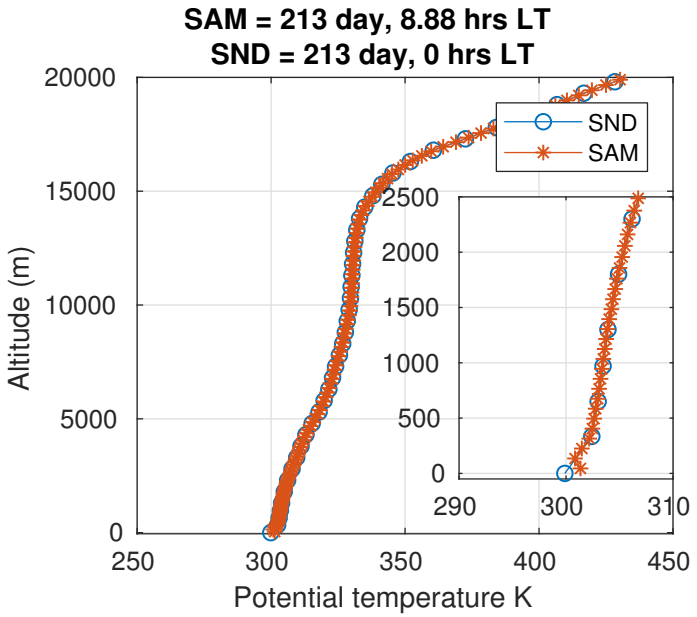


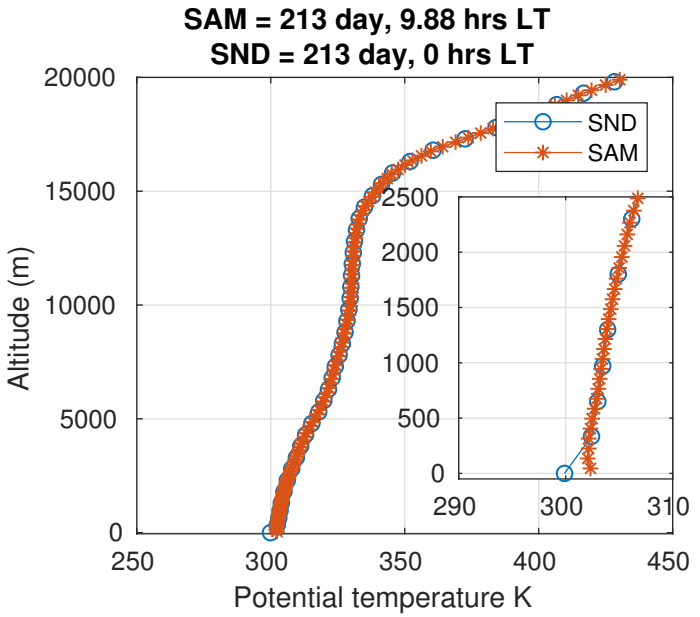


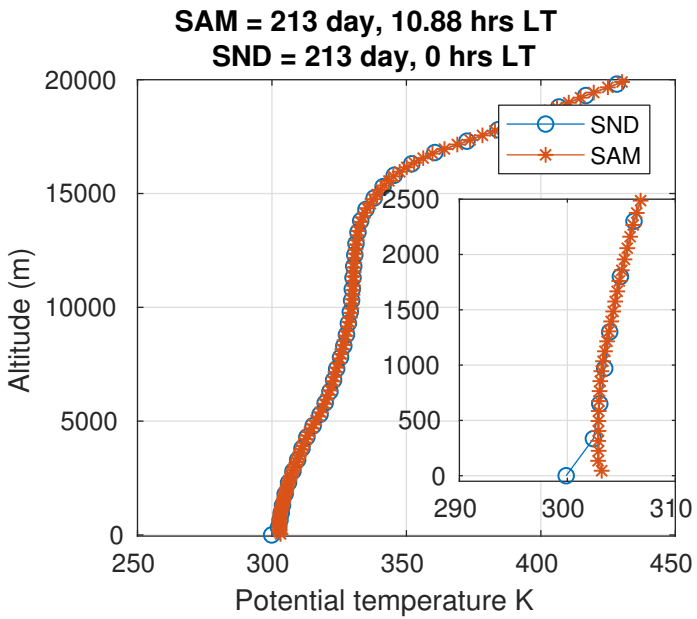
- Lastly, I repeated the experiment with prescribed radiative heating rates. This was a six hour experiment from 7:30am to 1:30pm.
- A study by Marat (Khairoutdinov, M., and D. Randall, 2006) where they simulate the LBA case also uses this strategy of prescribing radiative heating rates.
- This simulation has a very reasonable development of the boundary layer, precipitation and clouds, although the prescribed sounding profile did not have a diurnal cycle and it had a small inversion near the surface. (slides 24, 25, 26,27)

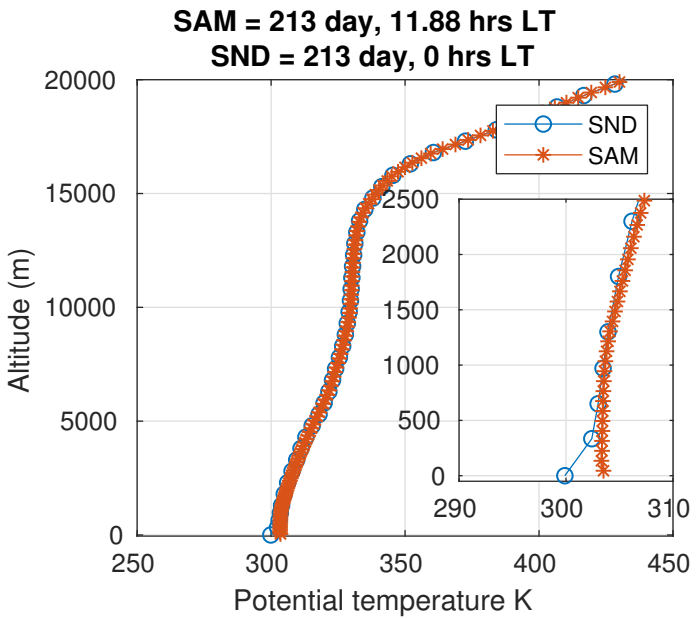
Khairoutdinov, M., and D. Randall, 2006: High-Resolution Simulation of Shallow-to-Deep Convection Transition over Land. *Journal of the Atmospheric Sciences*, **63,** 3421-3436.

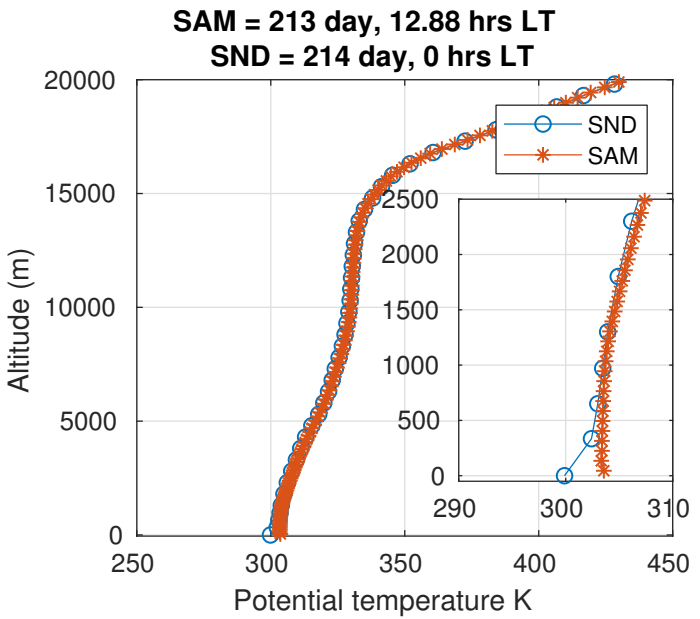

SAM = 213 day, 7.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

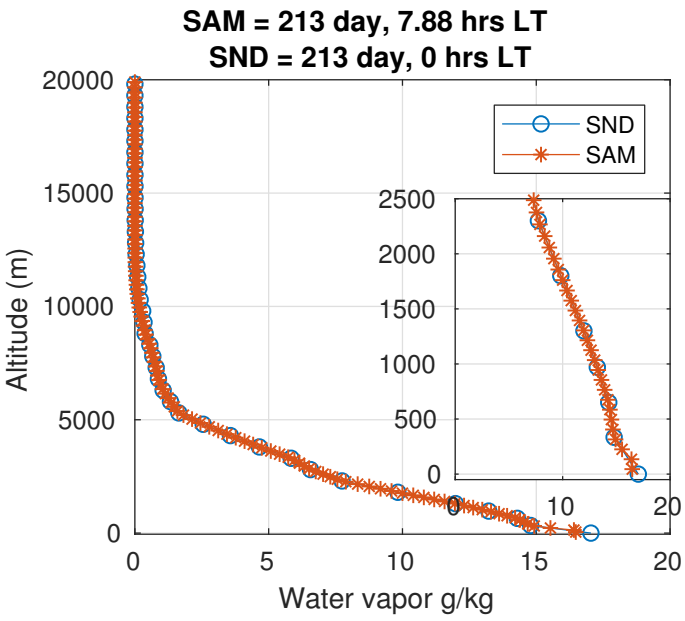

SAM = 213 day, 8.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

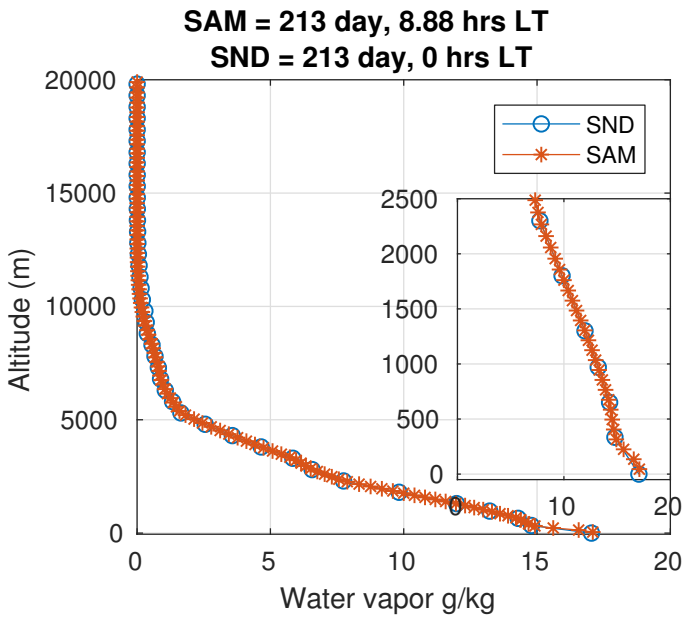

SAM = 213 day, 9.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

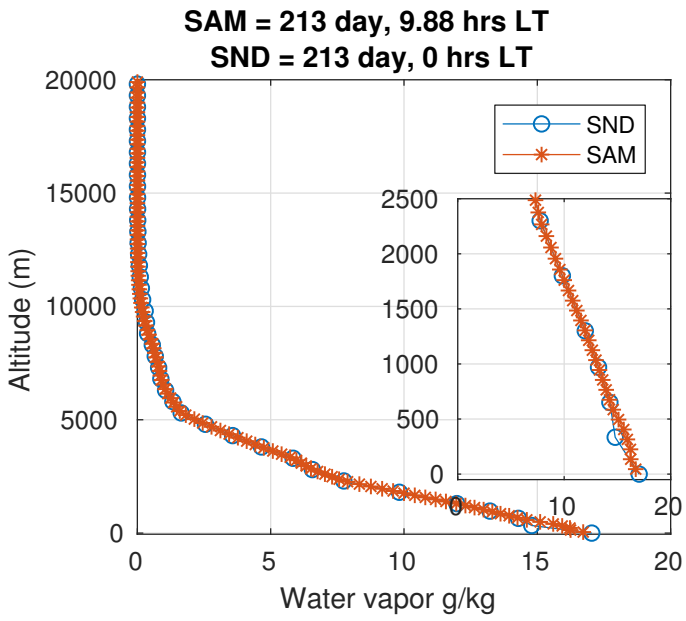

SAM = 213 day, 10.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

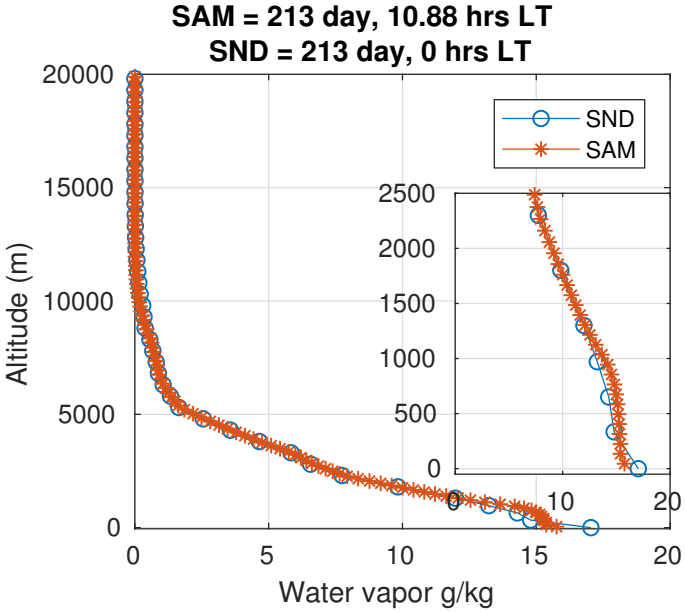

SAM = 213 day, 11.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

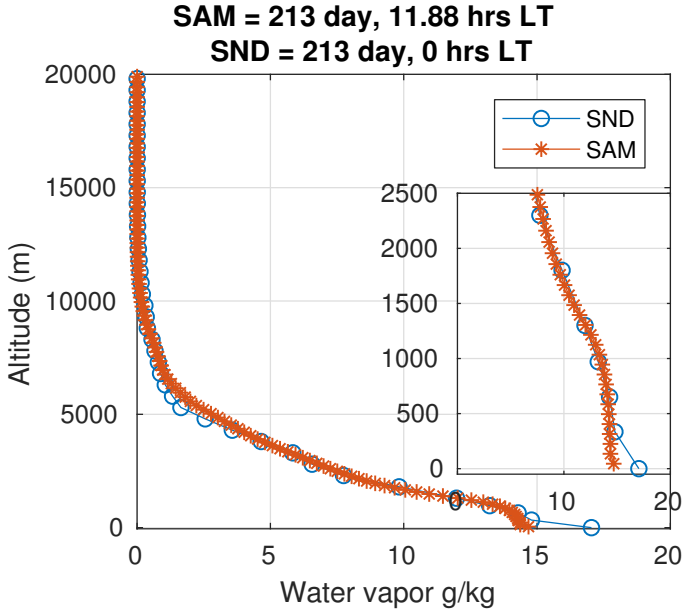

SAM = 213 day, 12.88 hrs LT
SND = 214 day, 0 hrs LT
SND
SAM
Altitude (m)
Potential temperature K

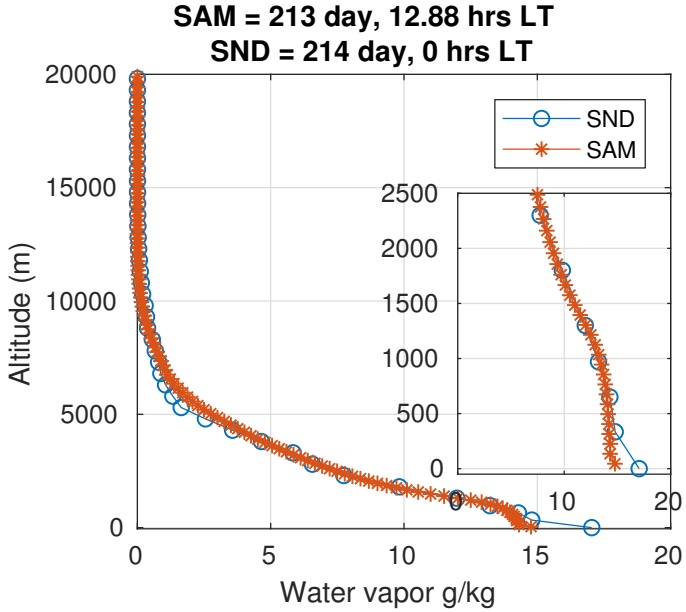

SAM = 213 day, 7.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

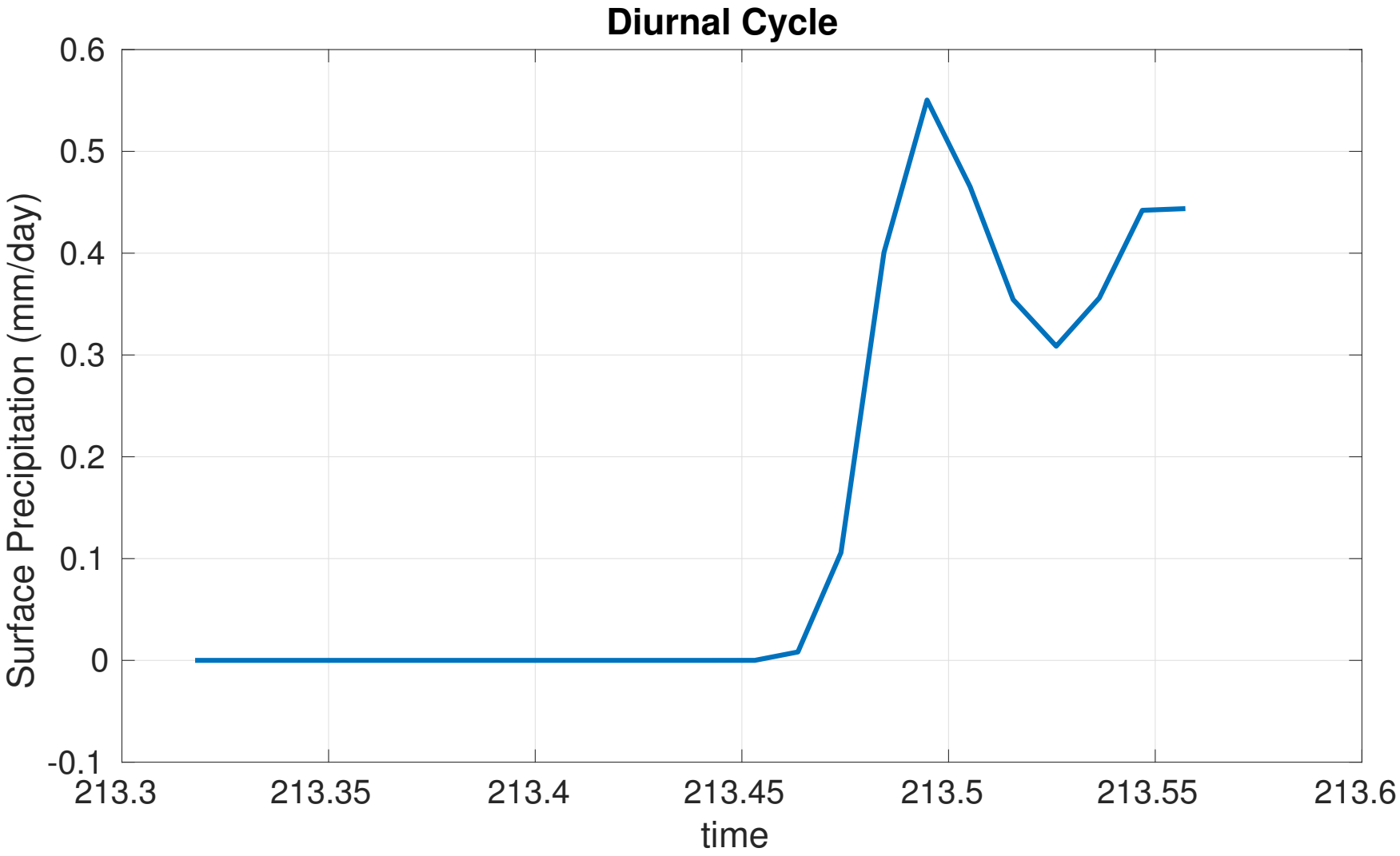

SAM = 213 day, 8.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg

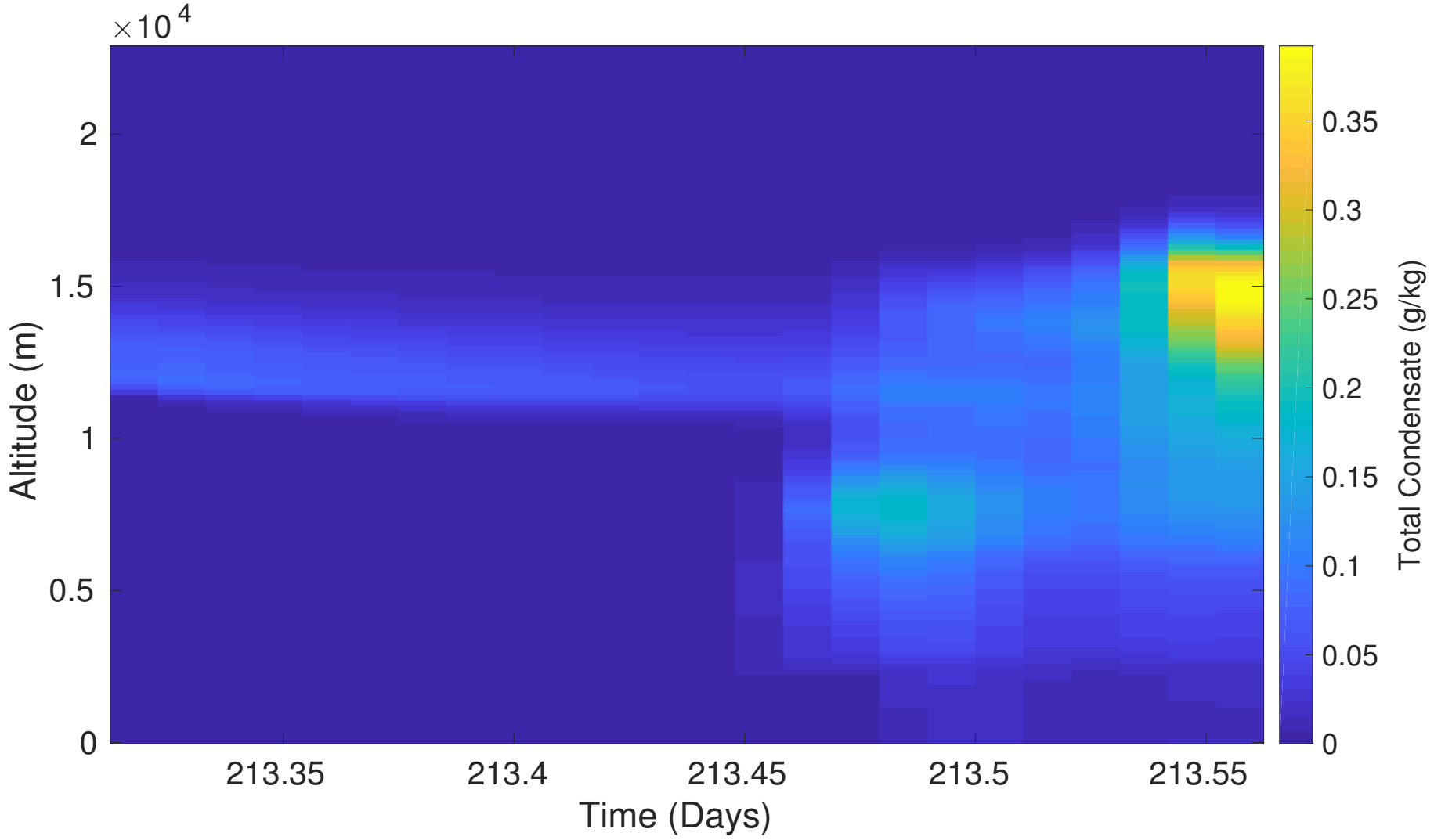

SAM = 213 day, 9.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 213 day, 10.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 213 day, 11.88 hrs LT
SND = 213 day, 0 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


SAM = 213 day, 12.88 hrs LT
SND = 214 day, 0 hrs LT
SND
SAM
Altitude (m)
Water vapor g/kg


Diurnal Cycle
Surface Precipitation (mm/day)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
213.3
213.35
213.4
213.45
213.5
213.55
213.6
time


×10 4
2
1.5
1
0.5
0
Altitude (m)
213.35
213.4
213.45
213.5
213.55
Time (Days)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Total Condensate (g/kg)