Response to Referee #2

We are very appreciative of the reviewer's thorough review of the paper and encouraging comments. His/her suggestions and comments are helpful in improving the paper. We hope that the revised version of the paper has addressed much of the reviewer's concerns and is now acceptable for publication. The following are our point-by-point responses to the reviewer's comments:

Major comments：

1. When the authors analyzed POM-01 sky radiometer data, it was assumed that surface pressure was 1 atm. The observation site is located at the altitude 1965.8 m (about 2000 m); surface pressure is about 800 hPa. Therefore, the scattering by air molecule (Rayleigh scattering) is overestimated. If it was assumed that surface pressure is 1 atm in this manuscript, all calculation should be made again. The reviewer cannot make an accurate judgment.

Response:

Reviewer is right. We should not set 1atm but 0.78 atm (real pressure at SACOL). We have recalculated and replaced all the results to those at 0.78 atm. Compared with the result at 0.78 atm, we underestimated AOD and SSA. The following figure compared the difference between two results at different atmospheric pressure for the example on 7 April.

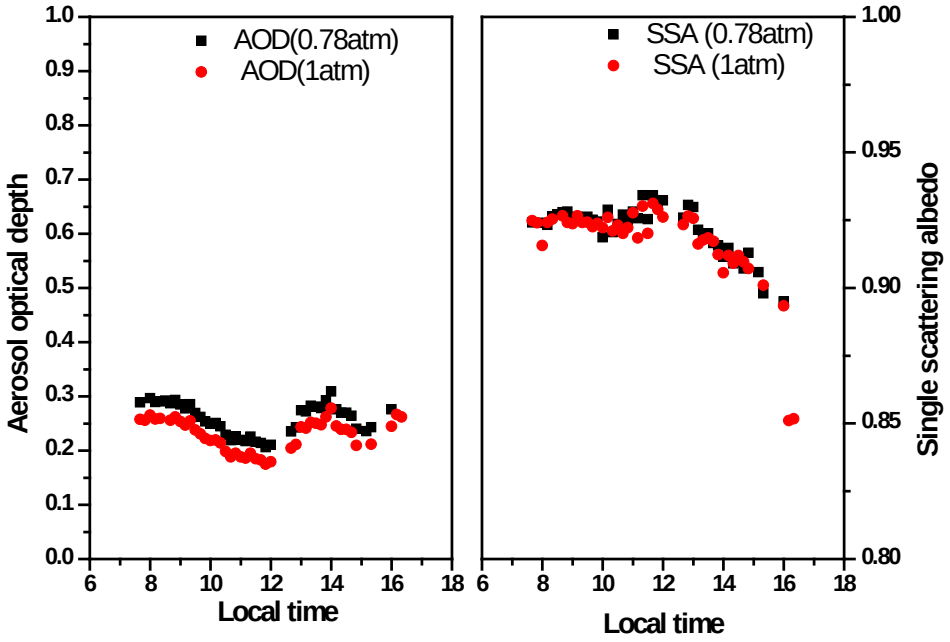
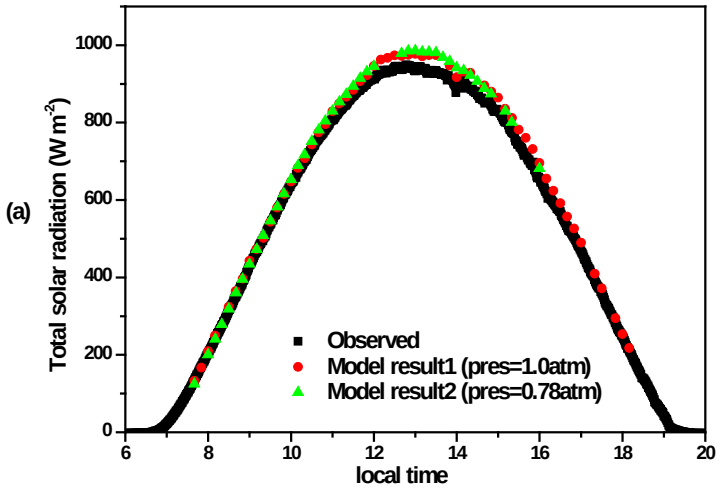


Fig. 1. AOD and SSA on 7 April at 0.78 atm and 1 atm, respectively.

If we use 1 atm at SACOL on 7 April, then the AOD is underestimated about a mean value of 0.02, SSA is underestimated about a mean value of 0.025. The comparison of radiative flux (total, direct, and diffuse) at different atmospheric pressure is shown in Fig. 2.



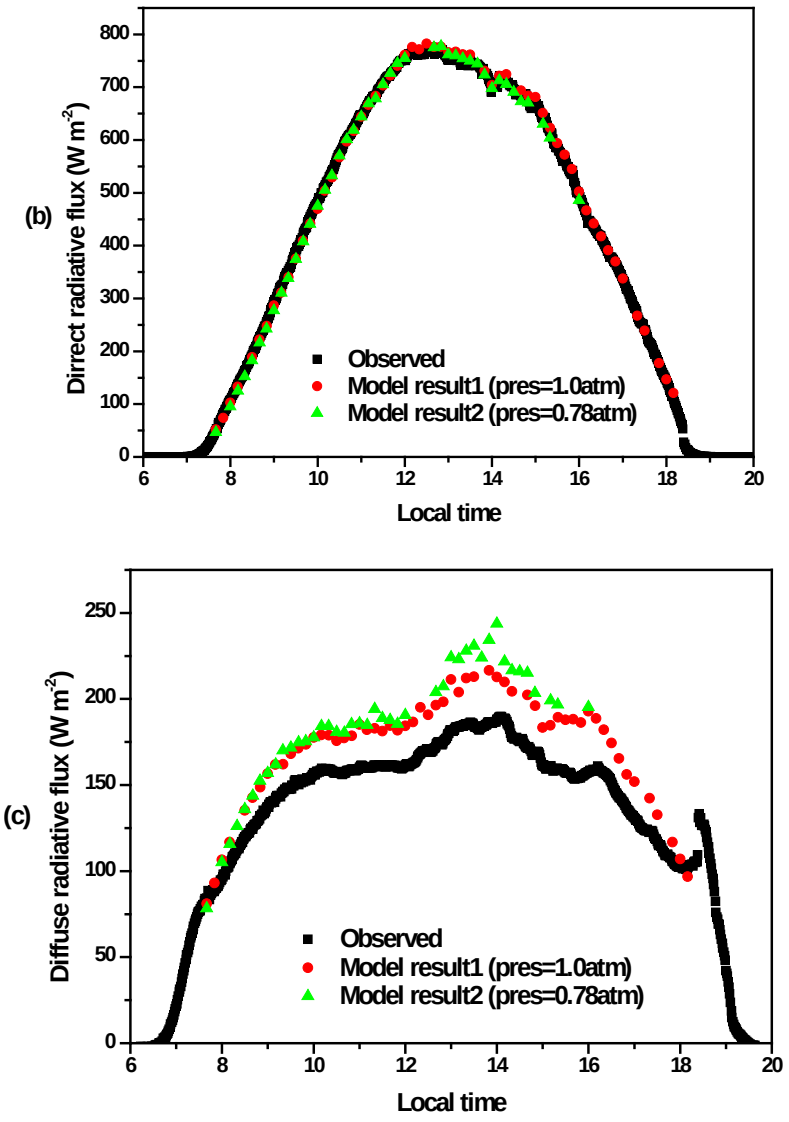


Fig. 2. Observed and modeled radiative flux (total, direct, and diffuse) at 1 atm and 0.78 atm.

2. The authors compared between aerosol optical thickness (AOD) observed by CIMEL sunphotometer and POM-01 sky-radiometer. Why SSA is not compared? Che et al. (2008) have already made a comparison and showed that there was tendency that SSA derived from sky-radiometer was larger than that derived from CIMEL sunphotometer.

Response：
Yes, we can also derive SSA from CIMEL measurements. However, the retrieval and comparable data points of SSA are quiet few (SSA will not be calculated if AOD is less than about 0.3). In this case, we couldn't give the comparison of SSA.

3. The authors described that the relative difference in the AOD between POM-01 and CIMEL was about 4%. I think that 4% is not small (see comment (5)).

Response:

Now, the relative difference in the AOD between POM-01 and CIMEL was about 1% under the pressure of 0.78 atm.

4. There is no description about SBDART. More explanation is necessary. If it is assumed that the surface pressure is 1 atm, the authors should make all calculation for broadband irradiance, again.

Response：

According to the average humidity profile derived from microwave radiometer, we chose atmospheric profile as sub-arctic winter atmosphere (water vapor is 0.418 g/cm2) in SBDART model simulation. We chose LOWTRAN_7 solar spectrum and set spectral variation of aerosol optical properties from 0.305 to 2.8.

We re-calculate all results, including the calculation for broadband irradiance.

5. According to the authors, relative difference of broadband direct irradiances between observation and calculation was 1.8%. If AOD by

CIMEL sunphotometer is accurate, AOD by POM-01 sky-radiometer is small by 4%. The error of direct irradiance is estimated following equation,

F0*exp(-m*(tau+delta_tau)/(F0*exp(-m*(tau))=exp(-m*tau*(delta_tau/tau)), where F0 is the solar irradiance at the top of atmosphere, m is path length, tau is AOD, and delta_tau is difference. Substituting typical values at the wavelength 500nm,; tau=0.4, m=1.5, and delta_tau/tau=0.04, we can get the following value,

exp(-m*tau*(delta_tau/tau))=exp(-1.5*0.4*0.04)=exp(-0.024)=0.024

2.4% error is nearly same magnitude as direct irradiance error. There is possibility that the error of direct irradiance is caused by error of AOD.

Response：

The error of direct irradiance is almost caused by error of AOD. However, in our simulation, the relative difference of broadband direct irradiances between observation and calculation is very small, so we considered that the AOD derived from sky-radiometer was relatively accurate and reliable. In the case, AOD was not adjusted during calculate the radiarive effect due to aerosols.

6. According to the authors, when optical properties derived from POM-01 skyradiometer were used, the calculated diffused irradiance was larger than the measured one. If it is assumed that the surface pressure was 1 atm, there is a possibility that the calculated irradiances become large due to the overestimate of air molecule scattering (Rayleigh scattering). If the scattered radiances (sky radiances) are reconstructed within the designated limit in the analysis of POM-01 sky-radiometer data, I think that 12.16% is too large. Anyway, if 1 atm is used as surface pressure, all

calculation should be made again. The accurate review cannot be done.

Response：

Yes, the 12.16% is really large. We have adjusted the SSA during the calculation of ARF because of such difference between calculated and observed diffuse radiative flux. The relative difference of diffuse irradiance between observation and calculation is even large at 0.78 atm than 1 atm.

7. On the assumption that CM21 measured scattered irradiance accurately, the authors adjusted SSA and ASY. There are uncertainties for measurement by CM21 such as thermal offset, cosine response error and so on. The authors should pay more attention to the measurement error by CM21.

Response：

Yes, we considered the uncertainties during analyzing and retrieving now. The temperature dependence of the response of the CM21 to radiation was investigated by examining the data for the 30-min periods before sunrise and after sunset. The output of CM21 showed the maximum negative value about -2.0 W/m2. The negative values depend on the atmospheric conditions during complete nighttimes and show a gradual increase with an increasing solar elevation.

8. SSA and ASY are simultaneously adjusted. There is no description about this method. More explanation is necessary.

Response:

Based on the irradiance observed from CM21 (measurement error is considered), if the simulated values of diffuse irradiance were larger than

observed ones, we decreased SSAs and increased ASYs simultaneously until the relative difference between observed and calculated diffuse flux could be less than about 3%. Of course, for the days in which the difference between observed and simulated diffuse flux is less than 3%, we considered the SSAs and ASYs are reliable.

Minor comments：

1. In Section 4.2 Fabs(t) ->Fobs(t)

It was modified in the revision.

2. eq. (4) RF->ARF

It was modified in the revision.