Responses to Editor and Referee's comments

First of all, we would like to thank Prof. Shao for his comments, which improved greatly the presentations and interpretations in our revised manuscript. In the revised article, we have addressed all comments from Prof. Shao. Our point-by-point responses to the Referee's comments are outlined below. The Referee's original comments are shown in italics and our responses are given in normal fonts.

Referee #3

Comments:

Can you provide a copy of your WRF-Chem namelist?

Response: The following presents the WRF-Chem namelist configuration used in this study.

```
 &time_control
 run_days                            = 92,
 run_hours                           = 0,
 run_minutes                         = 0,
 run_seconds                         = 0,
 start_year                          = 2017, 2000, 2000,
 start_month                         = 06,   01,   01,
 start_day                           = 01,   01,   24,
 start_hour                          = 00,   00,   12,
 start_minute                        = 00,   00,   00,
 start_second                        = 00,   00,   00,
 end_year                            = 2017, 2000, 2000,
 end_month                           = 08,   01,   01,
 end_day                             = 31,   31,   25,
 end_hour                            = 18,   18,   12,
 end_minute                          = 00,   00,   00,
 end_second                          = 00,   00,   00,
 interval_seconds                    = 21600,
 input_from_file                     = .true.,.true.,.false.,
 history_interval                    = 360,  60,   60,
 frames_per_outfile                  = 1000, 1000, 1000,
 restart                             = .false.,
 restart_interval                    = 1440,
 io_form_history                     = 2,
 io_form_restart                     = 2,
 io_form_input                       = 2,
 io_form_boundary                    = 2,
 auxinput6_inname                    = 'wrfbiochemi_d01',
```

```
 auxinput7_inname                    = 'wrffirechemi_d<domain>',
 auxinput8_inname                    = 'wrfchemi_gocart_bg_d<domain>',
 auxinput12_inname                   = 'wrf_chem_input',
 auxinput13_inname                   = 'wrfchemv_d<domain>',
 auxinput5_interval_m                = 1440, 1440, 60,
 auxinput7_interval_m                = 1440, 1440, 60,
 auxinput8_interval_m                = 1440, 1440, 60,
 auxinput13_interval_m               = 1440, 1440, 60,
 io_form_auxinput2                   = 2,
 io_form_auxinput5                   = 2,
 io_form_auxinput6                   = 0,
 io_form_auxinput7                   = 0,
 io_form_auxinput8                   = 0,
 io_form_auxinput12                  = 0,
 io_form_auxinput13                  = 0,
 debug_level                         = 0,
 auxinput1_inname                    = "met_em.d<domain>.<date>",
/

 &dfi_control
/

 &domains
 time_step                           = 30,
 time_step_fract_num                 = 0,
 time_step_fract_den                 = 1,
 max_dom                             = 1,
 s_we                                = 1,     1,     1,
 e_we                                = 280,   109,   94,
 s_sn                                = 1,     1,     1,
 e_sn                                = 230,   109,   91,
 e_vert                              = 30,    30,    28,
 num_metgrid_levels                  = 38,
 num_metgrid_soil_levels             = 4,
 dx                                  = 20000, 10000, 3333.33,
 dy                                  = 20000, 10000, 3333.33,
 grid_id                             = 1,     2,     3,
 parent_id                           = 0,     1,     2,
 i_parent_start                      = 1,     39,    30,
 j_parent_start                      = 1,     28,    30,
 parent_grid_ratio                   = 1,     3,     3,
 parent_time_step_ratio              = 1,     3,     3,
 p_top_requested                     = 5000,
 feedback                            = 1,
```

```
 smooth_option                       = 0
 p_top_requested                     = 5000
 zap_close_levels                    = 50
 interp_type                         = 1
 t_extrap_type                       = 2
 force_sfc_in_vinterp                = 0
 use_levels_below_ground             = .true.
 use_surface                         = .true.
 lagrange_order                      = 1
 /
 sfcp_to_sfcp                        = .true.

 &physics
 mp_physics                          = 2,     2,     2,
 progn                               = 1,     1,     1,
 ra_lw_physics                       = 1,     1,     1,
 ra_sw_physics                       = 2,     2,     1,
 radt                                = 10,    10,    30,
 sf_sfclay_physics                   = 2,     2,     1,
 sf_surface_physics                  = 2,     2,     1,
 bl_pbl_physics                      = 2,     2,     1,
 bldt                                = 0,     0,     0,
 cu_physics                          = 5,     5,     0,
 cu_diag                             = 1,     1,     0,
 cudt                                = 0,     0,     0,
 ishallow                            = 0,
 isfflx                              = 1,
 ifsnow                              = 1,
 icloud                              = 1,
 surface_input_source                = 1,
 num_soil_layers                     = 4,
 sf_urban_physics                    = 0,     0,     0,
 mp_zero_out                         = 2,
 mp_zero_out_thresh                  = 1.e-12
 maxiens                             = 1,
 maxens                              = 3,
 maxens2                             = 3,
 maxens3                             = 16,
 ensdim                              = 144,
 cu_rad_feedback                     = .true.,
 /

 &fdda
grid_fdda                            =1,
```

```
gfdda_inname                        = 'wrffdda_d<domain>',
gfdda_interval_m                     =360,
fgdt                                  =0,
if_no_pbl_nudging_uv                  =0,
if_no_pbl_nudging_t                   =0,
if_no_pbl_nudging_q                    =0,
if_zfac_uv                            =0,
k_zfac_uv                            =10,
if_zfac_t                             =0,
k_zfac_t                             =10,
if_zfac_q                            =0,
k_zfac_q                              =10,
guv                                 =0.0003,
gt                                  =0.0003,
gq                                   =0.0003,
if _ramping                           =1,
dtramp_min                            =60.0,
iso_form_gfdda                         =2,
 /

 &dynamics
 rk_ord                                = 3,
 w_damping                              = 1,
 diff_opt                              = 1,
 km_opt                                 = 4,
 diff_6th_opt                         = 0,           0
 diff_6th_factor                      = 0.12,      0.12
 base_temp                             = 290.
 damp_opt                               = 0,
 zdamp                                  = 5000.,    5000.,    5000.,
 dampcoef                               = 0.01,      0.01,      0.01
 khdif                                 = 0,           0,           0,
 kvdif                                 = 0,           0,           0,
 non_hydrostatic                      = .true., .true., .true.,
 moist_adv_opt                         = 2,           2,           0,
 scalar_adv_opt                       = 2,           2,           0,
 chem_adv_opt                          = 2,           2,           0,
 tke_adv_opt                           = 2,           2,           0,
 time_step_sound                       = 4,           4,           4,
 h_mom_adv_order                        = 5,           5,           5,
 v_mom_adv_order                        = 3,           3,           3,
 h_sca_adv_order                       = 5,           5,           5,
 v_sca_adv_order                       = 3,           3,           3,
 /
```

```
&bdy_control
spec_bdy_width                      = 5,
spec_zone                           = 1,
relax_zone                          = 4,
specified                           = .true., .false., .false.,
nested                              = .false., .true., .false.,
/

&grib2
/

&namelist_quilt
nio_tasks_per_group = 0,
nio_groups = 1,
/

&chem
kemit                               = 1,
chem_opt                            = 11,           11,
bioemdt                             = 30,           30,
photdt                              = 30,           30,
chemdt                              = 5,            5,
io_style_emissions                  = 1,
emiss_opt                           = 5,            5,
emiss_opt_vol                       = 0,            0,
emiss_ash_hgt                       = 20000.,
chem_in_opt                         = 0,            0,
phot_opt                            = 2,            2,
gas_drydep_opt                      = 1,            1,
aer_drydep_opt                      = 1,            1,
bio_emiss_opt                       = 3,            3,
ne_area                             = 104
dust_opt                            = 2,
dmsemis_opt                         = 1,
seas_opt                            = 2,
depo_fact                           = 0.25
gas_bc_opt                          = 1,            1,
gas_ic_opt                          = 1,            1,
aer_bc_opt                          = 1,            1,
aer_ic_opt                          = 1,            1,
gaschem_onoff                       = 1,            1,
aerchem_onoff                       = 1,            1,
wetscav_onoff                       = 0,            0,
```

```
cldchem_onoff                       = 0,              0,
vertmix_onoff                       = 1,              1,
chem_conv_tr                        = 1,              1,
conv_tr_wetscav                     = 0,              0,
conv_tr_aqchem                      = 0,              0,
biomass_burn_opt                    = 1,              1,
plumerisefire_frq                   = 120,            120,
have_bcs_chem                       = .false., .false., .false.,
have_bcs_upper                      = .false
aer_ra_feedback                     = 1,
aer_op_opt                          = 1,
opt_pars_out                        = 1,
diagnostic_chem                     = 0,
/
```

Why only those 8 cities are selected?

Response: The selection of the 8 cities for model validation was based on spatial representativeness, data availability, and coverage of diverse environmental conditions in Northwestern China.

- Arid regions: Turpan, Karamay (low rainfall, high solar radiation)
- Semi-arid regions: Lanzhou, Shizuishan (moderate industrial/urban emissions)
- High-altitude regions: Qinghai (Tibetan Plateau influence)
- Eastern transitional zones: Tongchuan, Jinan, Zhengzhou (monsoon-affected, higher anthropogenic emissions)

These cities span a latitudinal gradient (30°N–50°N) and cover key ozone-forming environments, ensuring robust evaluation of model performance across heterogeneous landscapes.

How did you fix SAT and RH from 1998? It seems there are large differences between Fig. S8b and Fig. S8c, can you please provide some statistical results?

Response: In the fixed scenario S4, only SAT and RH were replaced with 1998 values from ERA-Interim, while all other meteorological variables (e.g., wind, pressure, cloud cover) retained their original annual values from 1998 to 2017. This partial fixation isolates the impacts of SAT/RH trends but introduces discrepancies with other dynamic variables (e.g., wind-driven transport), leading to differences between scenarios (Fig. S8b vs. S8c). Such approache has been widely used in attribution studies (e.g., Li et al., 2020; Ding et al., 2023).

We conducted T-test between two data series for Figs.S8b and S8c. The two tails T-test of 0.1065 suggests no significant difference of O_3 concentrations under the two model scenarios over entire model domian. Large differences seem visible in the Northern China Plain (NCP) where ozone concentrations under fixed SAT and RH in 1998 seemed higher than fixed all meteorology in 1998 (S3 scenario). We further calculated the differences of the planetary boundary layer heights (PBLH) between the two scenarios (fixed RH and SAT scenario minus scenario S3). The results are illustrated new Fig. S9. Negative PBLH differences can be seen in many areas across China, including the NCP, indicating that fixed SAT and RH scenario reduced PBLH, which often associates with stronger pollution.

Corresponding discussions and new Fig. S9 have been added to revised paper (section 2.6) and SI following the Referee's comment.