

Supplementary materials for “Evaluation of preindustrial to present-day black carbon and its albedo forcing from Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP)”

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Five ACCMIP models show non-negligible imbalances between the emission and total deposition rates (see Table 3). Here we describe what we believe to be the source of discrepancy in each model. For GISS-E2-R and GISS-E2-R-TOMAS, the gap is due to a diagnostic error in wet deposition by large-scale clouds. One of the equations to determine tracer evaporation from cloud water was analytically correct, but the resulting value from the equation was slightly off due to inadequate numerical precision of equation terms (e.g., $A - B = A$ when $A \gg B$). In the case of GFDL-AM3, the wet deposition from large-scale clouds had an opposite sign to that for convective clouds. This was not accounted for when the total deposition was calculated so that in columns with both large-scale and convective clouds the terms tended to cancel. For HadGEM2, the discrepancy is very likely due to missing a minor process when compiling the wet and dry BC deposition fields for a separate biomass-burning tracer. Finally, the discrepancy in MIROC-CHEM is under investigation.

The deviation of the simulated BC surface mass concentrations from the observations is computed with the log-mean normalized bias (LMNB) and log-mean normalized error (LMNE), which are defined as follows:

$$LMNB = \frac{\sum_{i=1}^N \log_{10} \left(\frac{C_{mod,i}}{C_{obs,i}} \right)}{N} \quad LMNE = \frac{\sum_{i=1}^N abs \left[\log_{10} \left(\frac{C_{mod,i}}{C_{obs,i}} \right) \right]}{N} \quad (1)$$

where $C_{mod,i}$ is the modeled BC in month i , $C_{obs,i}$ is the observed BC in month i , and N is 12 for the total number of months in a year.

For BC snow concentrations, the LMNB and LMNE are computed using Eq (1), but, in this case, $C_{mod,i}$ or $C_{obs,i}$ are the modeled or observed data in a given region and “ N ” is the total number of observation data in that region.

If a model has LMNB of 0.3, it means that the model overpredicts, on average, within a factor of 2 ($=10^{0.3}$) of the observation.

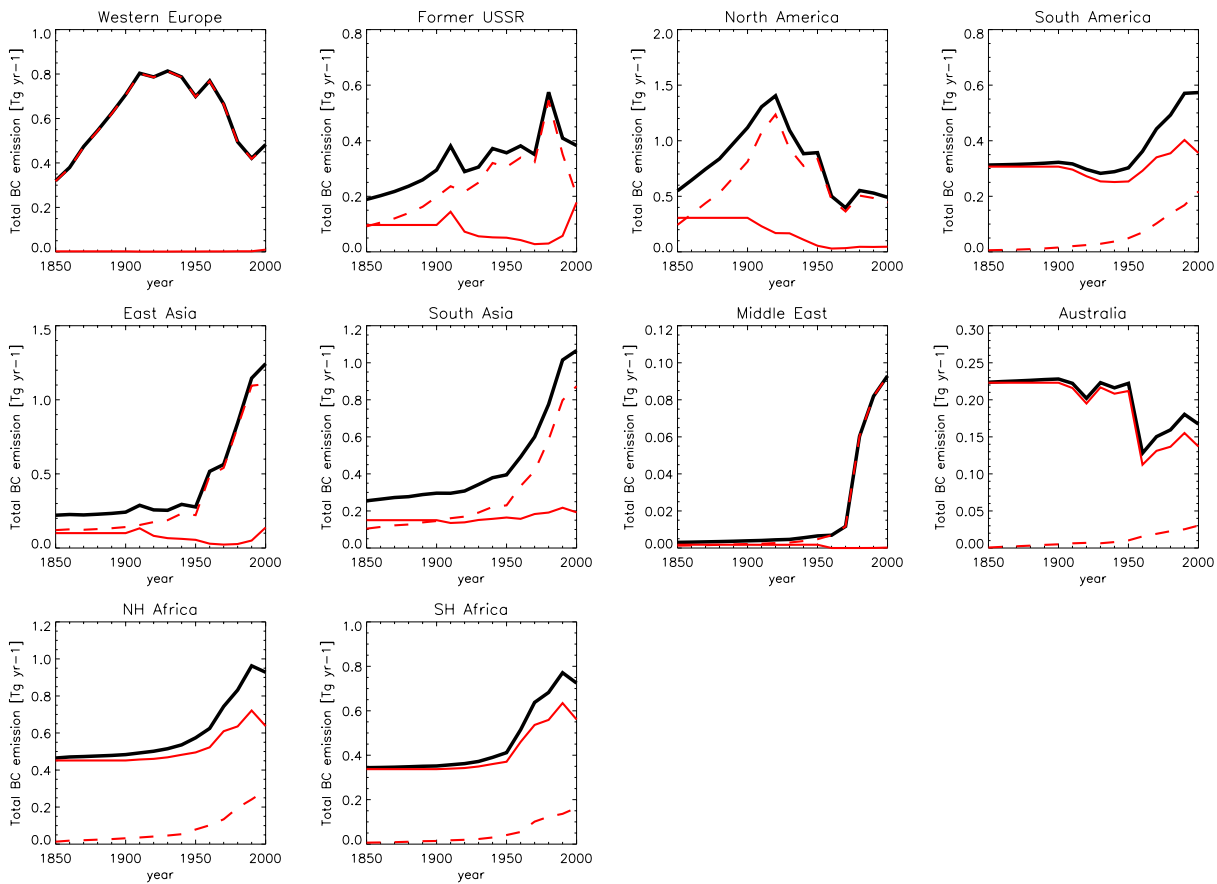
If a model has LMNB of -0.6, it means that the model underpredicts, on average, within a factor of 4 ($=1/10^{-0.6}$) of the observation.

If a model has LMNE of 0.6, it means that the model predictions are, on average, within a factor of 4 ($=10^{0.6}$) of the observation.

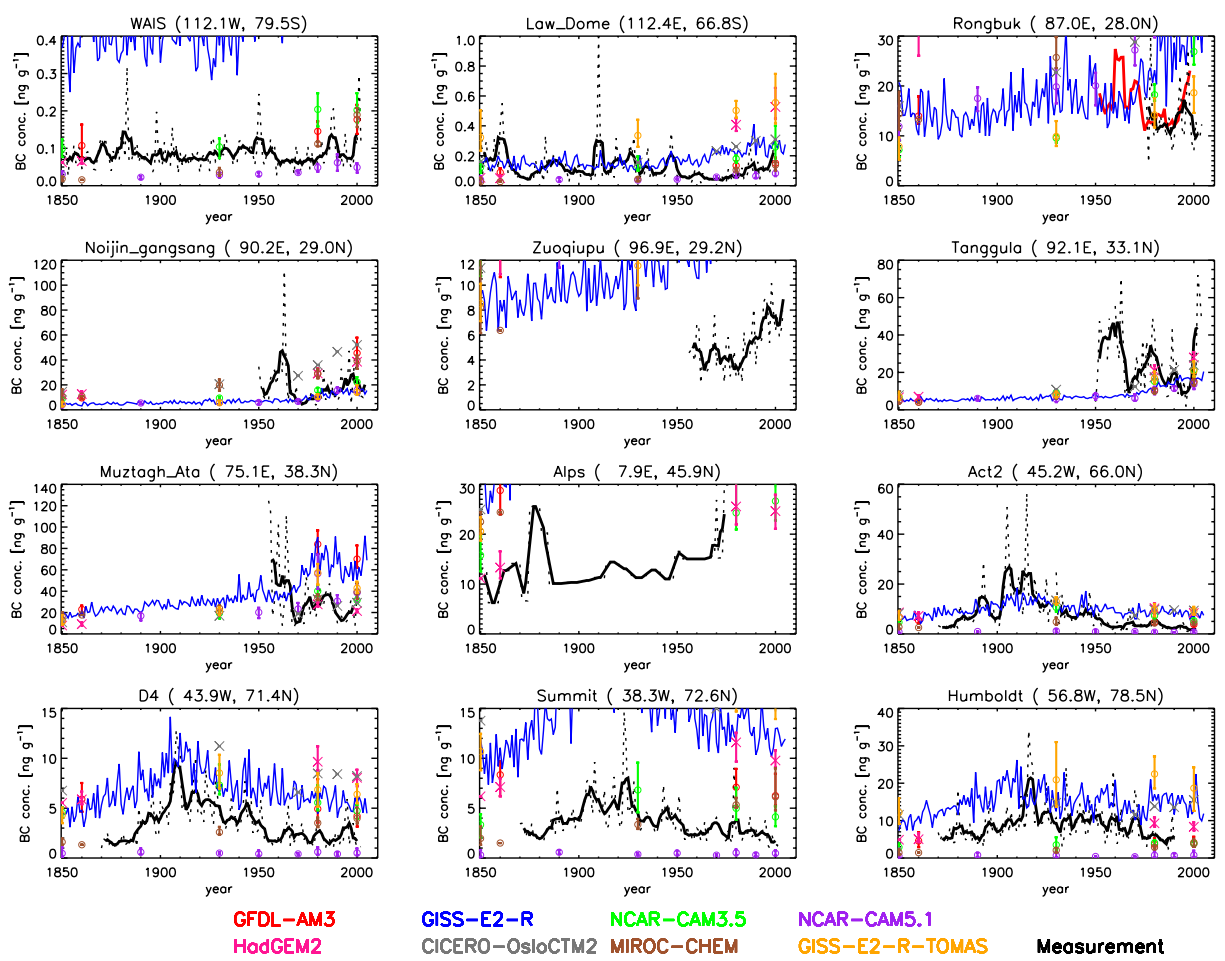
S-Table 1. Summary of statistical measures for BC mass concentration evaluation including correlation, log-mean normalized bias (LMNB) and log-mean normalized error (LMNE).

| | GFDL-AM3 | GISS-E2-R | NCAR-CAM3.5 | NCAR-CAM5.1 | HadGEM2 | CICERO-OsloCTM2 | MIROC-CHEM | GISS-E2-R-TOMAS | |
|-------------|------------------------|-----------|-------------|-------------|---------|-----------------|------------|-----------------|-------|
| Correlation | Alert | -0.59 | 0.83 | 0.50 | 0.60 | 0.78 | 0.70 | -0.61 | 0.78 |
| | Ny-Ålesund | 0.04 | 0.76 | 0.68 | -0.09 | 0.69 | 0.55 | 0.11 | 0.86 |
| | Barrow | -0.60 | -0.48 | -0.50 | -0.11 | 0.85 | -0.22 | -0.59 | -0.49 |
| | Pallas (Pallastunturi) | -0.13 | 0.40 | 0.53 | -0.30 | 0.44 | 0.26 | -0.03 | 0.73 |
| | Hyytiälä | 0.43 | 0.69 | 0.56 | -0.16 | 0.50 | 0.76 | 0.35 | 0.61 |
| | Preila | 0.24 | 0.63 | 0.31 | -0.30 | 0.75 | 0.43 | -0.57 | 0.61 |
| | Mace Head | 0.15 | 0.02 | -0.18 | -0.18 | 0.50 | 0.29 | -0.64 | -0.41 |
| | Jungfrauoch | 0.95 | 0.96 | 0.94 | 0.95 | 0.84 | 0.76 | 0.96 | 0.93 |
| | Ispra | -0.57 | 0.46 | -0.59 | -0.79 | 0.92 | 0.87 | -0.70 | 0.23 |
| | Sable Island | 0.17 | 0.08 | 0.09 | -0.50 | 0.04 | 0.14 | 0.26 | 0.10 |
| | Trinidad Head | 0.67 | 0.11 | 0.26 | 0.70 | 0.68 | 0.13 | -0.13 | 0.03 |
| | Bondville | 0.40 | -0.49 | -0.26 | 0.53 | -0.65 | 0.42 | 0.66 | -0.55 |
| | Southern Great Plains | 0.28 | 0.55 | 0.28 | -0.05 | -0.79 | -0.48 | 0.81 | 0.56 |
| Mauna Loa | -0.05 | 0.91 | -0.12 | -0.30 | 0.79 | 0.84 | -0.08 | 0.95 | |
| LMNB | Alert | -1.64 | -0.74 | -1.10 | -2.20 | 0.35 | -0.98 | -1.34 | -0.47 |
| | Ny-Alesund | -0.85 | -0.40 | -0.47 | -1.78 | 0.59 | -0.58 | -0.79 | -0.08 |
| | Barrow | -1.18 | -0.41 | -0.64 | -1.34 | 0.47 | -0.64 | -0.88 | -0.18 |
| | Pallas (Pallastunturi) | -0.34 | -0.04 | -0.15 | -0.72 | 0.42 | -0.14 | -0.27 | 0.09 |
| | Hyytiälä | -0.08 | 0.04 | -0.05 | -0.29 | 0.22 | -0.16 | -0.19 | 0.14 |
| | Preila | -0.15 | -0.04 | -0.24 | -0.46 | 0.06 | 0.07 | 0.01 | 0.03 |
| | Mace Head | -0.13 | -0.01 | -0.47 | -0.60 | 0.06 | -0.02 | -0.15 | 0.14 |
| | Jungfrauoch | 0.03 | -0.06 | -0.05 | -0.18 | 0.18 | 0.28 | -0.25 | -0.03 |
| | Ispra | -0.60 | -0.41 | -0.64 | -0.73 | -0.29 | -0.48 | -0.59 | -0.33 |
| | Sable Island | -0.18 | -0.05 | -0.02 | -0.41 | 0.23 | -0.19 | -0.08 | 0.07 |
| | Trinidad Head | -0.10 | 0.07 | -0.09 | -0.42 | 0.23 | -0.14 | -0.01 | 0.10 |
| | Bondville | 0.04 | 0.18 | 0.17 | 0.14 | 0.15 | 0.27 | 0.11 | 0.27 |
| | Southern Great Plains | -0.14 | -0.07 | -0.08 | -0.10 | 0.12 | -0.19 | -0.27 | 0.04 |
| Mauna Loa | -0.19 | -0.05 | -0.06 | -0.64 | 0.38 | 0.11 | -0.37 | -0.14 | |
| LMNE | Alert | 1.64 | 0.74 | 1.10 | 2.20 | 0.37 | 0.98 | 1.34 | 0.48 |
| | Ny-Alesund | 0.85 | 0.40 | 0.48 | 1.78 | 0.59 | 0.59 | 0.79 | 0.20 |
| | Barrow | 1.18 | 0.60 | 0.65 | 1.34 | 0.47 | 0.64 | 0.95 | 0.48 |
| | Pallas (Pallastunturi) | 0.34 | 0.19 | 0.22 | 0.72 | 0.42 | 0.22 | 0.28 | 0.16 |
| | Hyytiälä | 0.09 | 0.06 | 0.07 | 0.29 | 0.22 | 0.16 | 0.19 | 0.14 |
| | Preila | 0.20 | 0.16 | 0.24 | 0.46 | 0.12 | 0.16 | 0.24 | 0.16 |
| | Mace Head | 0.17 | 0.16 | 0.47 | 0.60 | 0.14 | 0.14 | 0.37 | 0.19 |
| | Jungfrauoch | 0.10 | 0.09 | 0.11 | 0.20 | 0.19 | 0.28 | 0.25 | 0.09 |
| | Ispra | 0.60 | 0.41 | 0.64 | 0.73 | 0.29 | 0.48 | 0.59 | 0.33 |
| | Sable Island | 0.18 | 0.09 | 0.06 | 0.41 | 0.23 | 0.19 | 0.10 | 0.10 |
| | Trinidad Head | 0.12 | 0.22 | 0.15 | 0.42 | 0.23 | 0.22 | 0.23 | 0.21 |
| | Bondville | 0.07 | 0.18 | 0.17 | 0.14 | 0.17 | 0.27 | 0.11 | 0.27 |
| | Southern Great Plains | 0.14 | 0.09 | 0.10 | 0.12 | 0.17 | 0.19 | 0.27 | 0.06 |
| Mauna Loa | 0.40 | 0.11 | 0.26 | 0.67 | 0.44 | 0.16 | 0.39 | 0.16 | |

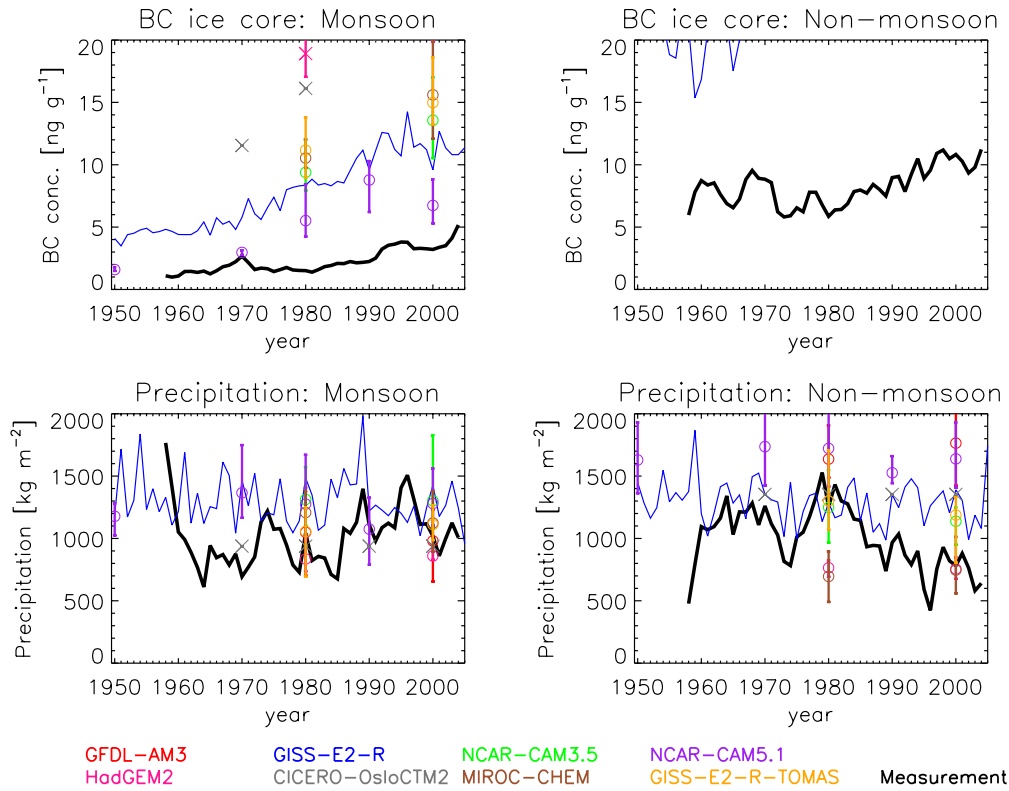
S - Figure1. Regional emission rate changes from 1850 to 2000. Black thick line is for total BC emissions, red solid line for biomass burning emissions and red dashed line for fossil fuel and biofuel emissions.



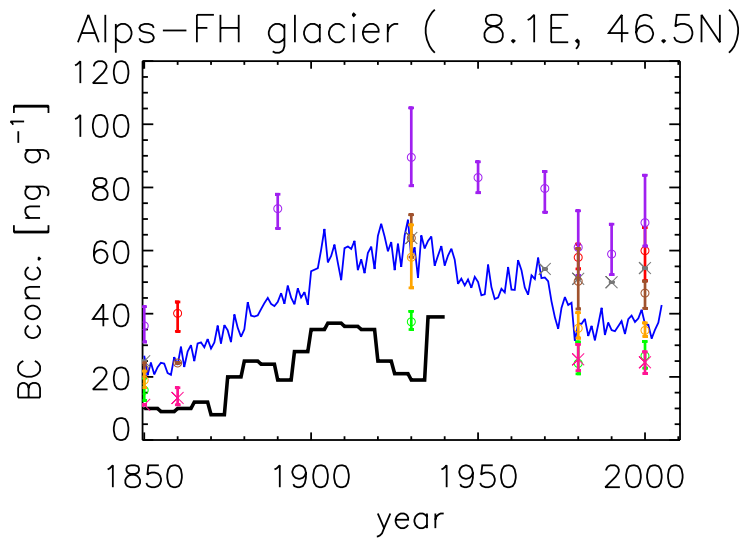
S- Figure 2. Same as Figure 12 but with Y-axis scale emphasizing observation values.



S- Figure 3. Same as Figure 14 but with Y-axis scale emphasizing observation values.



S-Figure 4. Comparison of the modeled BC concentrations with the Alps ice core from the Fiescherhorn (FH) glacier.



S- Figure 5. Spatial distribution of a ratio of BC emissions in 2000 to BC emissions in 1980.

