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## 1 Volume Size Distribution of Minerals at Tinfou, Morocco

The volume size distributions in Perlwitz et al. (2015, Fig.1) for the minerals were calculated from the volume fractions of the minerals (Kandler et al., 2009, Table 1) and the number size distribution for high dust (Kandler et al., 2009, Table 4) as follows:

The number density distribution is the sum over four size modes, as the best fit of measured data, each of them follows a log-normal density distribution:

$$\frac{dn}{d \log D} = \frac{\ln 10}{\sqrt{2\pi}} \sum_{i=1}^4 \frac{n_i}{\ln \zeta_i} \exp \left( -\frac{\ln^2(D \cdot m_i^{-1})}{2 \ln^2 \zeta_i} \right) \quad (\text{S1})$$

with  $i$  is the number of the mode,  $D$  is the particle diameter and  $n_i$ ,  $m_i$  and  $\zeta_i$ , the total number of particles, the number median diameter, and the geometric standard deviation of the  $i$ -th mode, respectively.

Using  $\log D = \log e \cdot \ln D$  and  $\ln 10 = \frac{\log 10}{\log e} = \frac{1}{\log e}$ , Eq. (S1) can be rewritten into:

$$\frac{dn}{d \ln D} = \frac{1}{\sqrt{2\pi}} \sum_{i=1}^4 \frac{n_i}{\ln \zeta_i} \exp \left( -\frac{\ln^2(D \cdot m_i^{-1})}{2 \ln^2 \zeta_i} \right) \quad (\text{S2})$$

When the number density distribution is log-normally distributed the volume density distribution will be log-normally distributed as well. Both distributions have the same geometric standard deviation. The volume median diameter  $m_{Vi}$  and the number median diameter obey to the relationship (Seinfeld and Pandis, 1998, p. 425f),

$$\ln m_{Vi} = \ln m_i + 3 \ln^2 \zeta_i \quad (\text{S3})$$

Thus, the density distribution of the particle volume  $V$  can be written with the parameters of the number density distribution,

$$\frac{dV}{d \ln D} = \frac{1}{\sqrt{2\pi}} \sum_{i=1}^4 \frac{n_i}{\ln \zeta_i} \exp(3 \ln m_i + \frac{9}{2} \ln^2 \zeta_i) \exp \left( -\frac{[\ln D - (\ln m_i + 3 \ln^2 \zeta_i)]^2}{2 \ln^2 \zeta_i} \right) \quad (\text{S4})$$

With

$$t = \frac{[\ln D - (\ln m_i + 3 \ln^2 \zeta_i)]}{\sqrt{2} \ln \zeta_i} \quad (\text{S5})$$

and

$$dt = \frac{1}{\sqrt{2} \ln \zeta_i} d \ln D \quad (\text{S6})$$

we obtain,

$$dV = \frac{1}{2} \sum_{i=1}^4 n_i \exp(3 \ln m_i + \frac{9}{2} \ln^2 \zeta_i) \frac{2}{\sqrt{\pi}} \exp(-t^2) d \ln t \quad (\text{S7})$$

The volume increment  $\Delta V^k$  of size bin  $k$  is the integral between the lower and  
55 upper boundary,  $D_1^k$  and  $D_2^k$ , of the size bin, respectively,

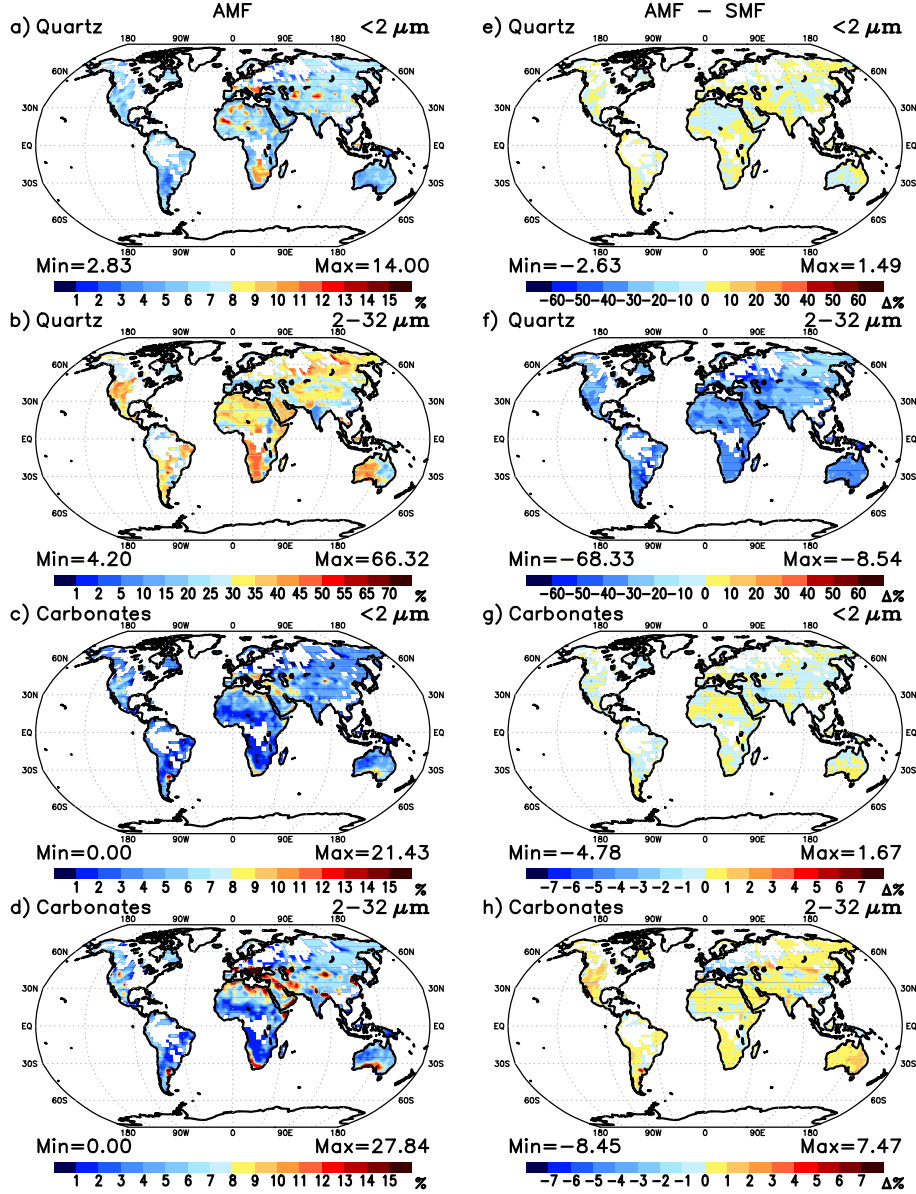
$$\Delta V^k = \frac{1}{2} \sum_{i=1}^4 n_i \exp(3 \ln m_i + \frac{9}{2} \ln^2 \zeta_i) (\text{erf}(t_2^k) - \text{erf}(t_1^k)) \quad (\text{S8})$$

where erf is the error function, and  $t_1^k$  and  $t_2^k$  are related to  $D_1^k$  and  $D_2^k$  through  
Eq. (S5).

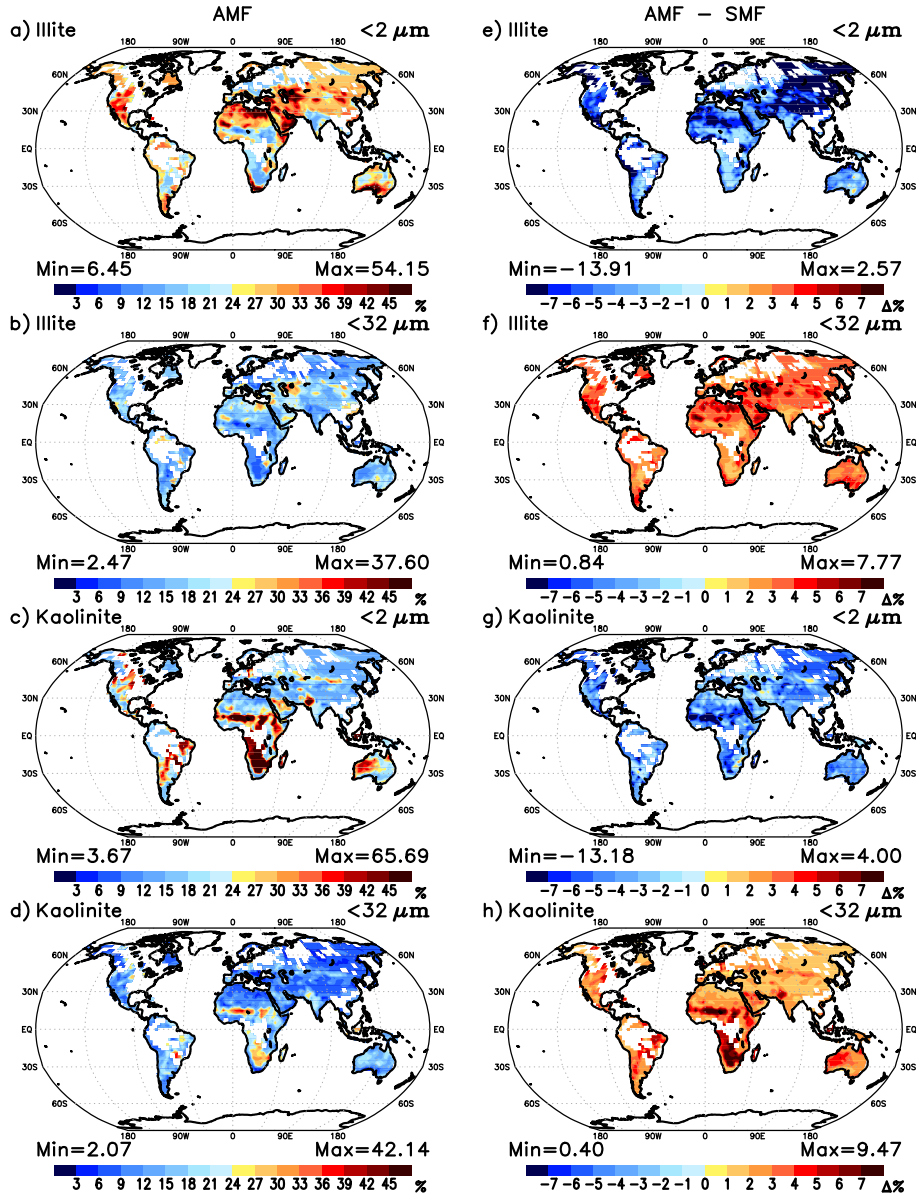
By multiplying Eq. (S8) with the relative volume fraction  $v_n^k$  and normalizing  
60 over the total volume of the mineral summed up to a particle size bin  $K$ , we obtain  
a normalized distribution of the volume fractions  $V_n^k$  of the mineral phases in dust  
aerosols over the particle size for each mineral phase  $n$ ,

$$\Delta V_n^k = \frac{v_n^k \Delta V^k}{\sum_{k=1}^K v_n^k \Delta V^k} \quad (\text{S9})$$

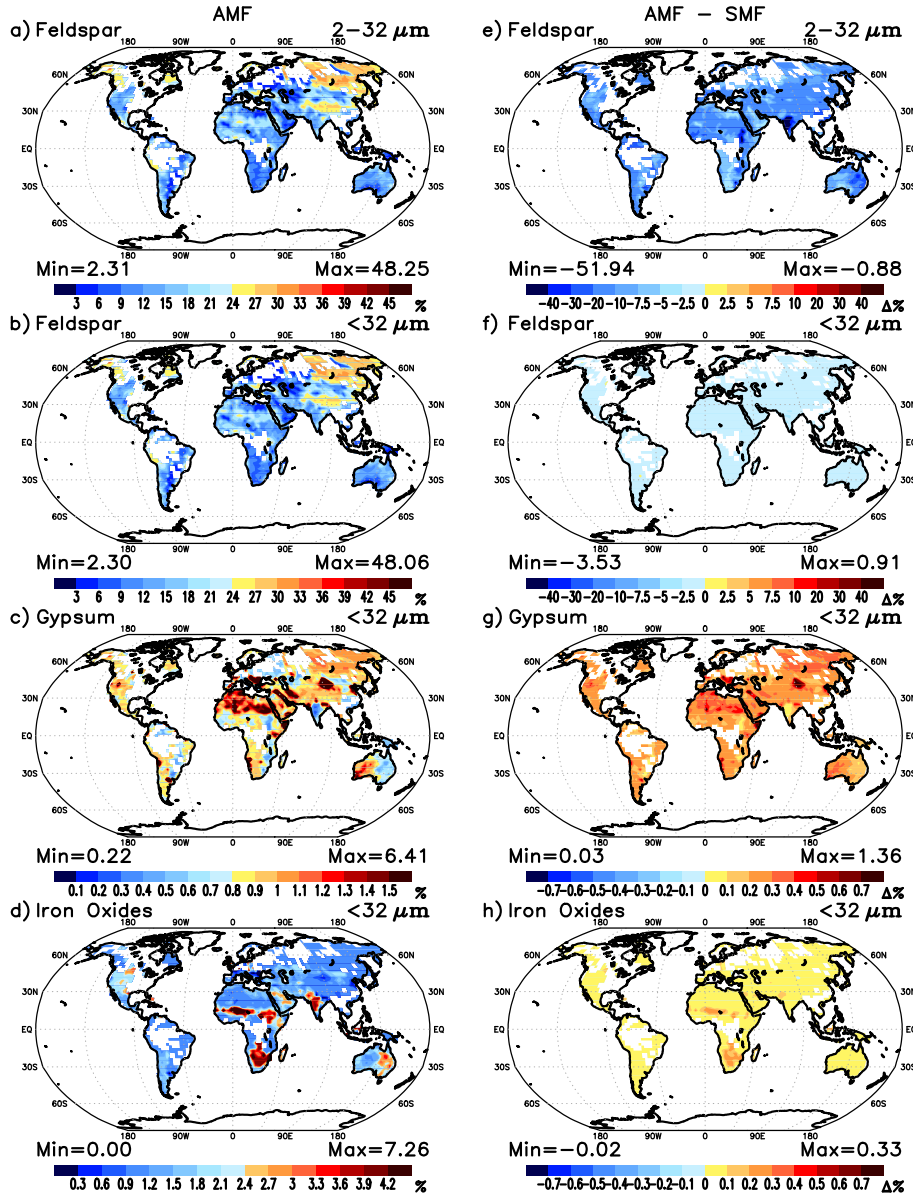
## 2 Supplementary Figures



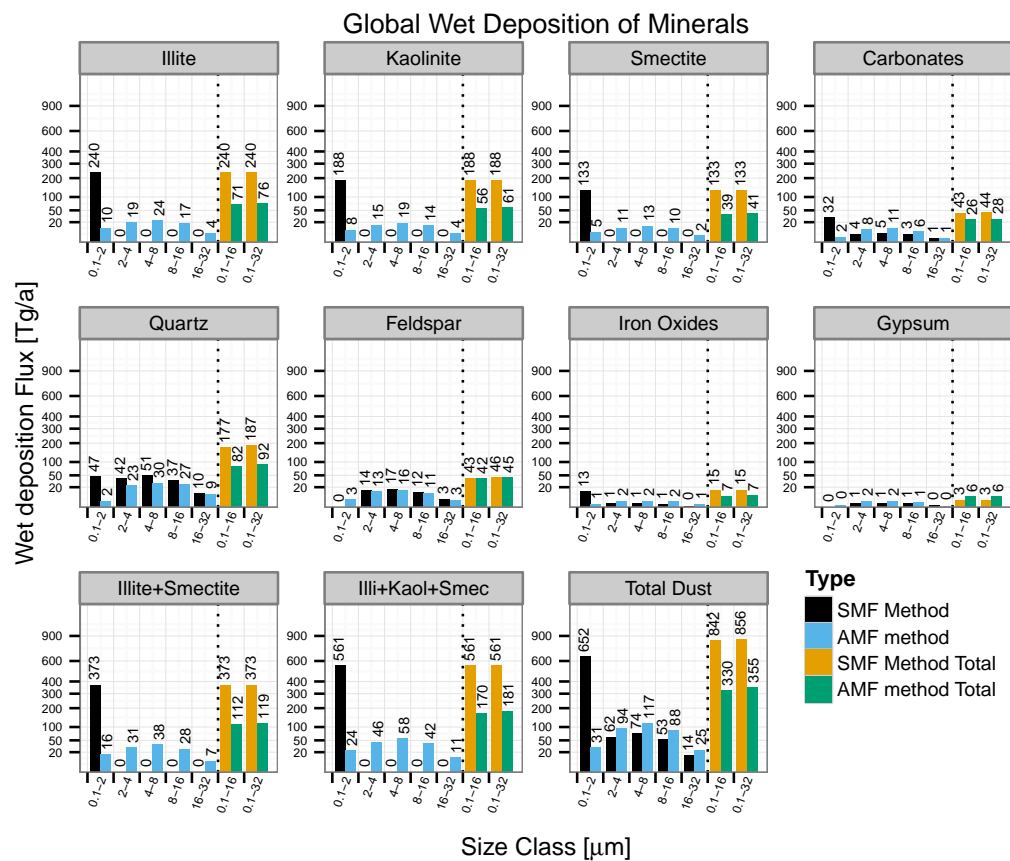
**Figure S1.** (Left panels) (a, b) Quartz and (c, d) carbonate fractions at emission after reaggregation and fragmentation for the aerosol fraction method (AMF) method, but without additional constraints on emission, for (a, c) the clay-size range and (b, d) the silt-size range at the model resolution of  $2^\circ \times 2.5^\circ$  latitude by longitude. (Right panels) Difference of the (e, f) quartz and (g, h) carbonate fractions between AMF method and soil mineral fraction (SMF) method for (e, g) the clay-size range and (f, h) the silt-size range.



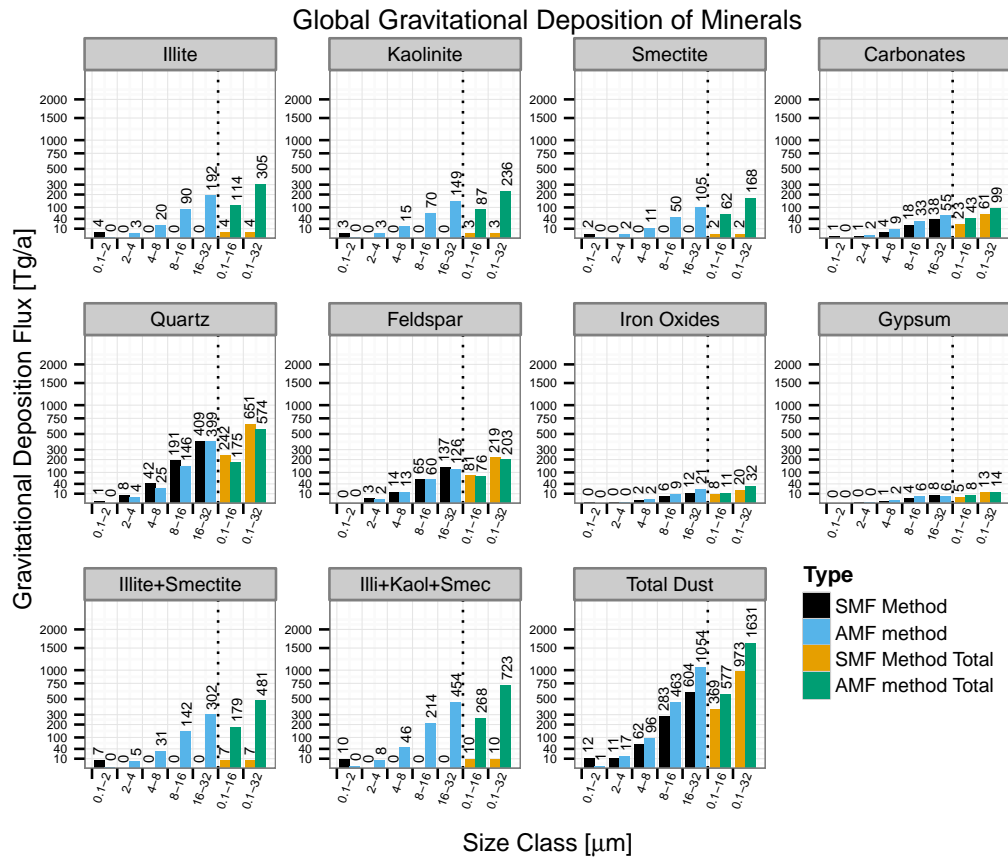
**Figure S2.** (Left panels) (a, b) Illite and (c, d) kaolinite fractions at emission after reaggregation and fragmentation for the aerosol fraction method (AMF) method, but without additional constraints on emission, for (a, c) the clay-size range and (b, d) the total size range at the model resolution of  $2^\circ \times 2.5^\circ$  latitude by longitude. (Right panels) Difference of the (e, f) illite and (g, h) kaolinite fractions between AMF method and soil mineral fraction (SMF) method for (e, g) the clay-size range and (f, h) the total size range.



**Figure S3.** (Left panels) (a, b) Feldspar, (c) gypsum, and (d) iron oxide fractions at emission after reaggregation and fragmentation for the aerosol fraction method (AMF) method, but without additional constraints on emission, for (a) the clay-size range and (b, c, d) the total size range at the model resolution of  $2^\circ \times 2.5^\circ$  latitude by longitude. (Right panels) Difference of the (e, f) feldspar, (g) gypsum, and (h) iron oxide fractions between AMF method and soil mineral fraction (SMF) method for (e) the clay-size range and (f, g, h) the total size range.

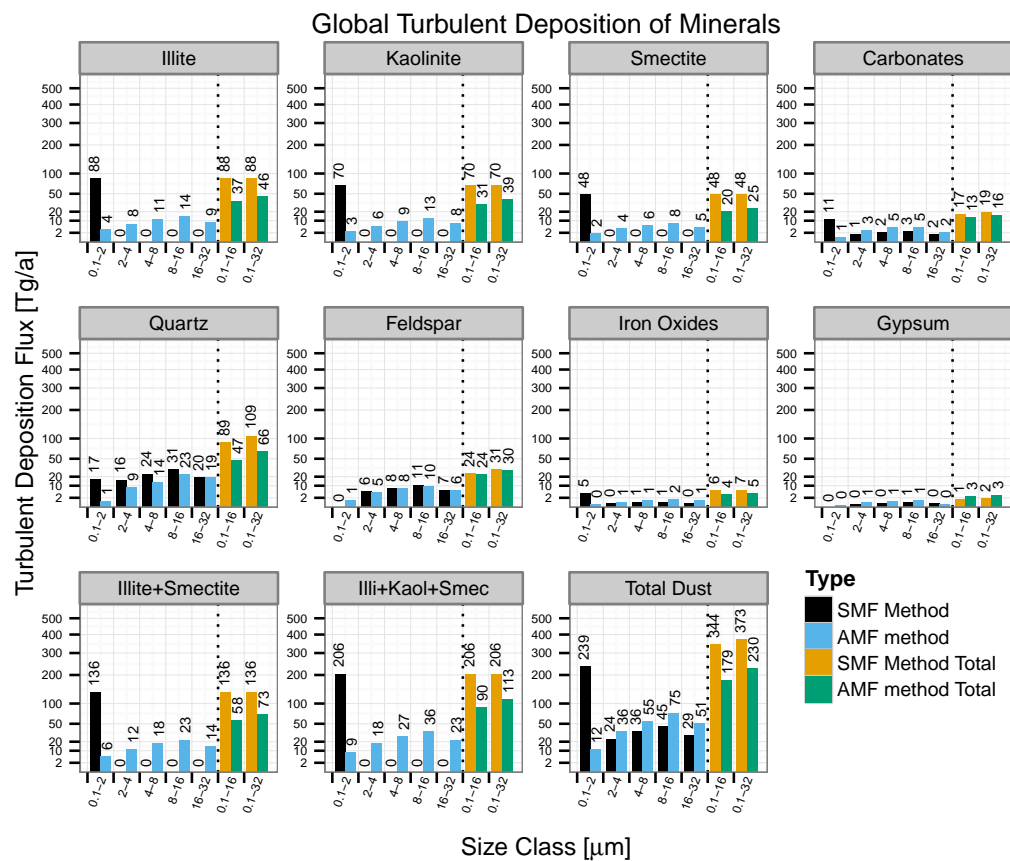


**Figure S4.** Global annual mineral wet deposition (Tg).

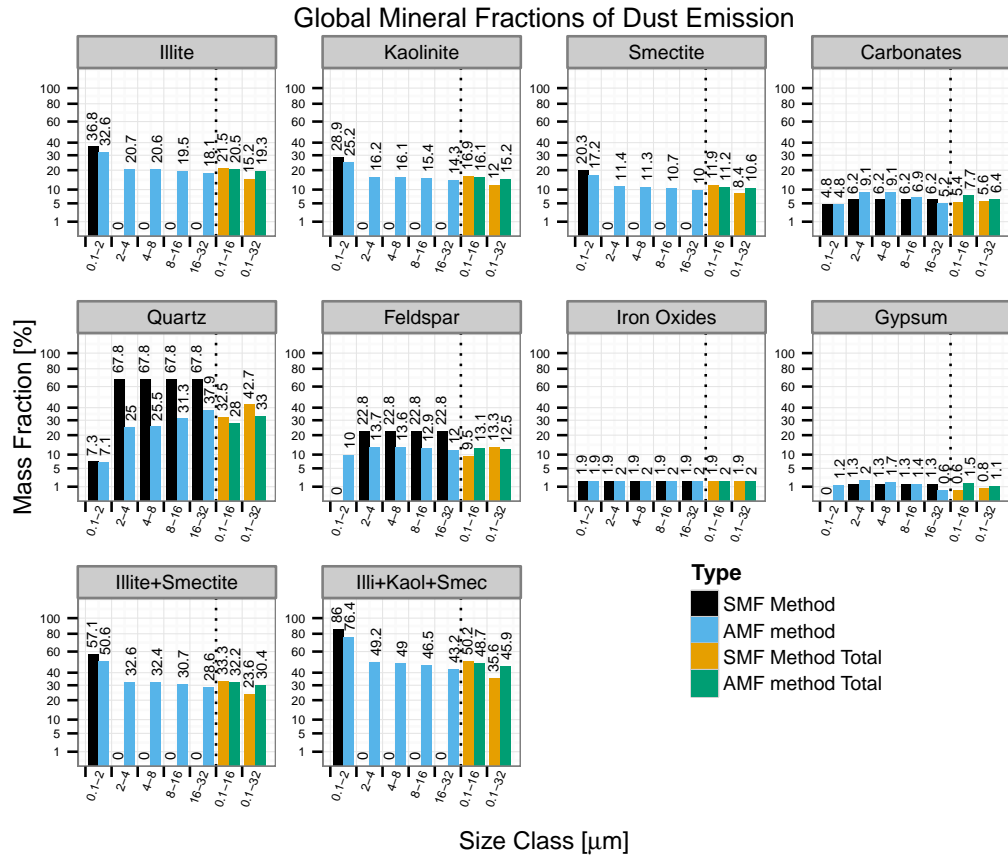


**Figure S5.** Global annual mineral gravitational deposition (Tg).

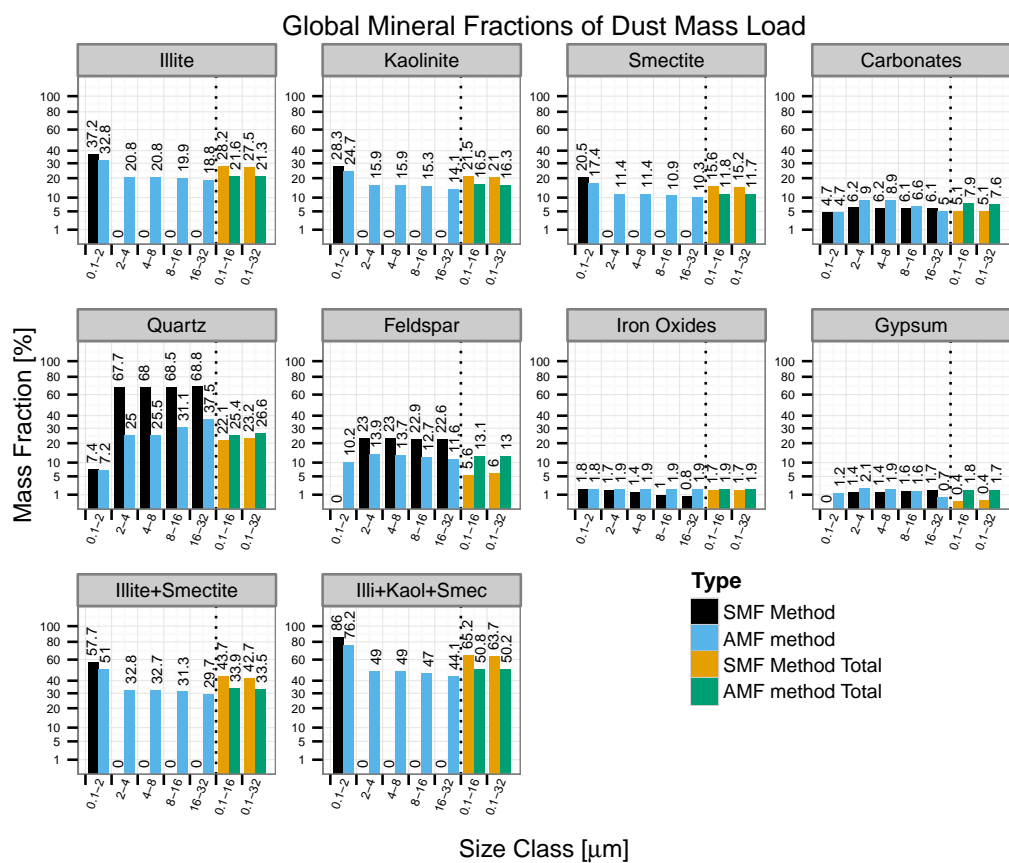




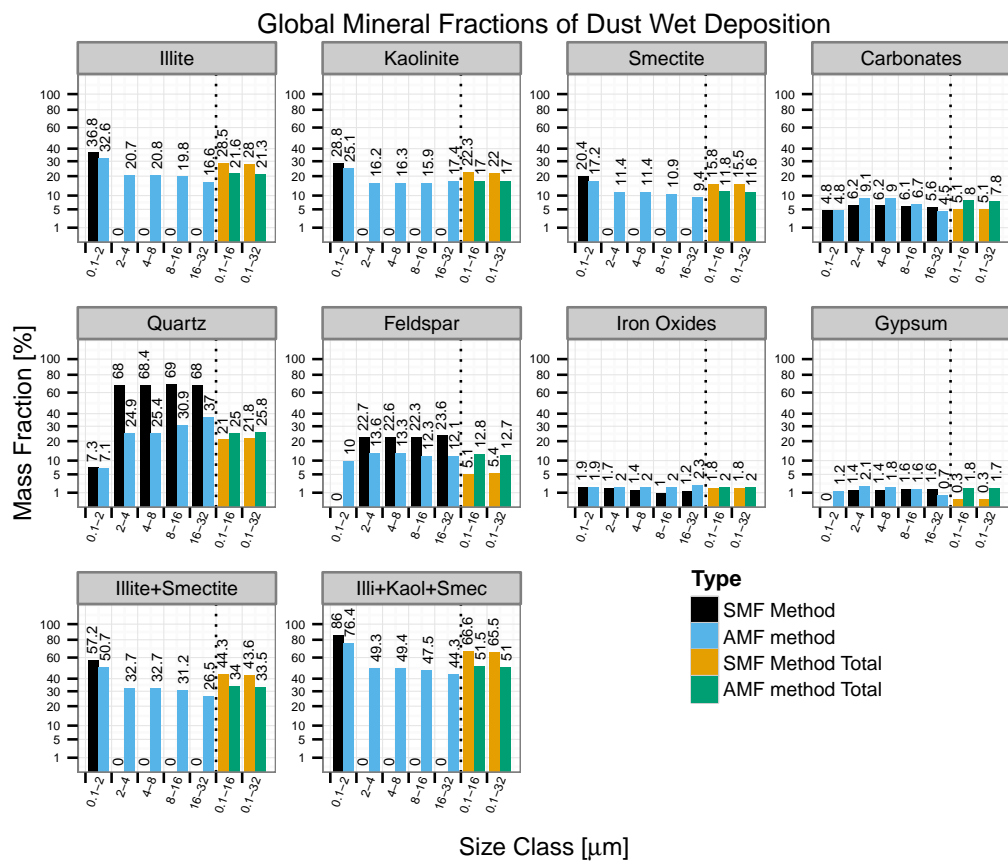
**Figure S6.** Global annual mineral dry turbulent deposition (Tg).



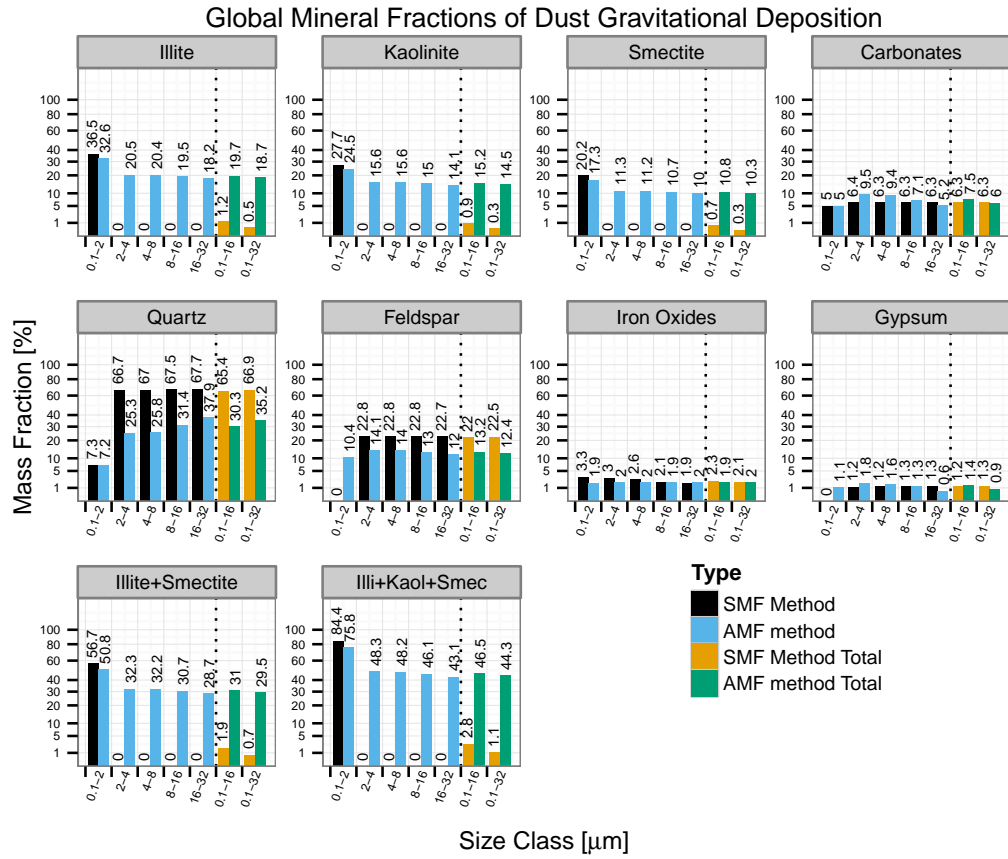
**Figure S7.** Global annual mineral emission fractions (%).



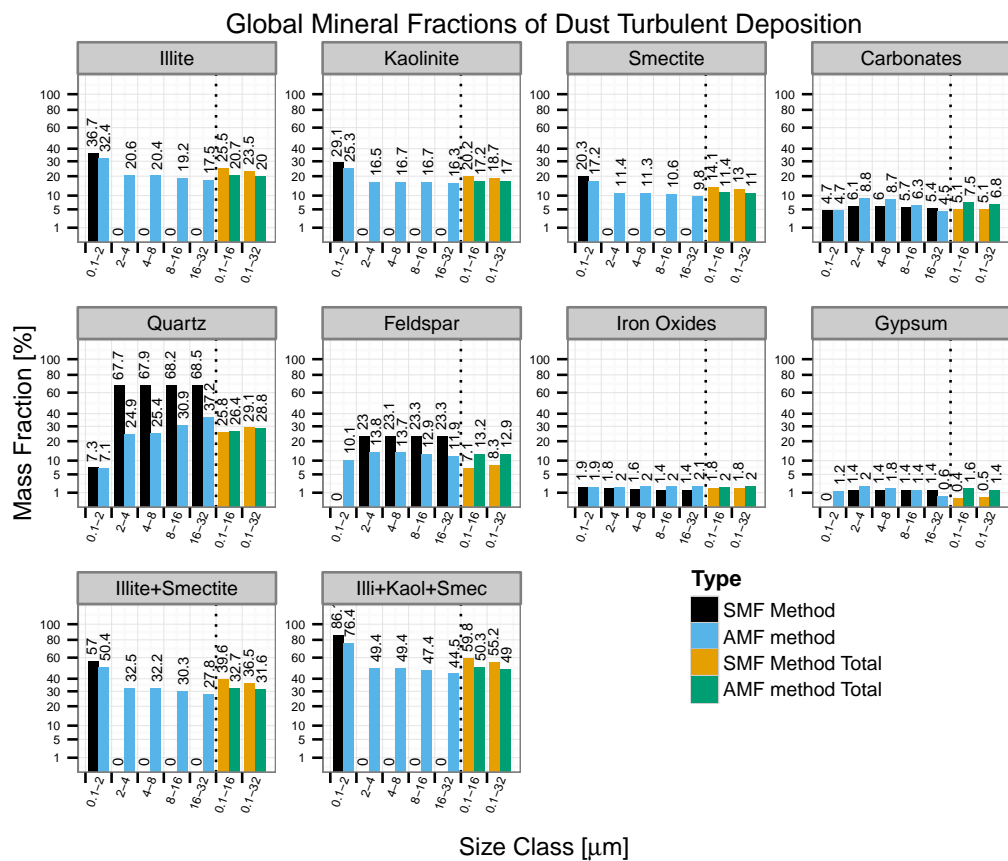
**Figure S8.** Global annual mineral mass load fractions (%).



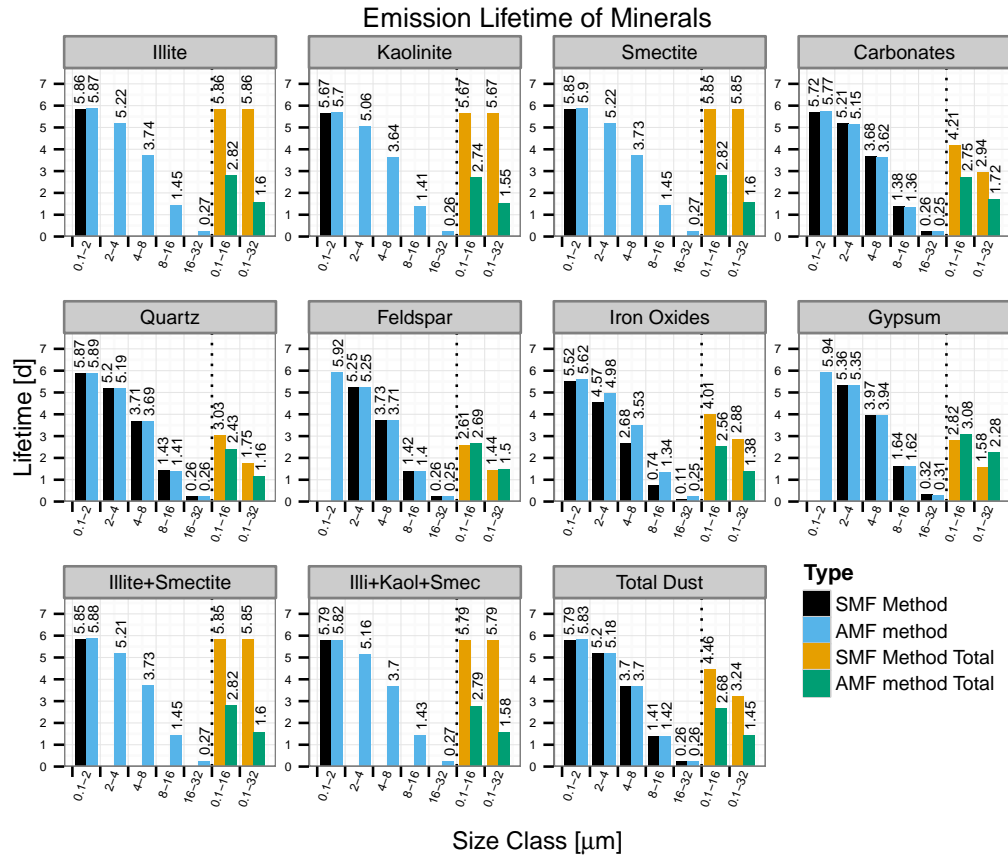
**Figure S9.** Global annual mineral wet deposition fractions (%).



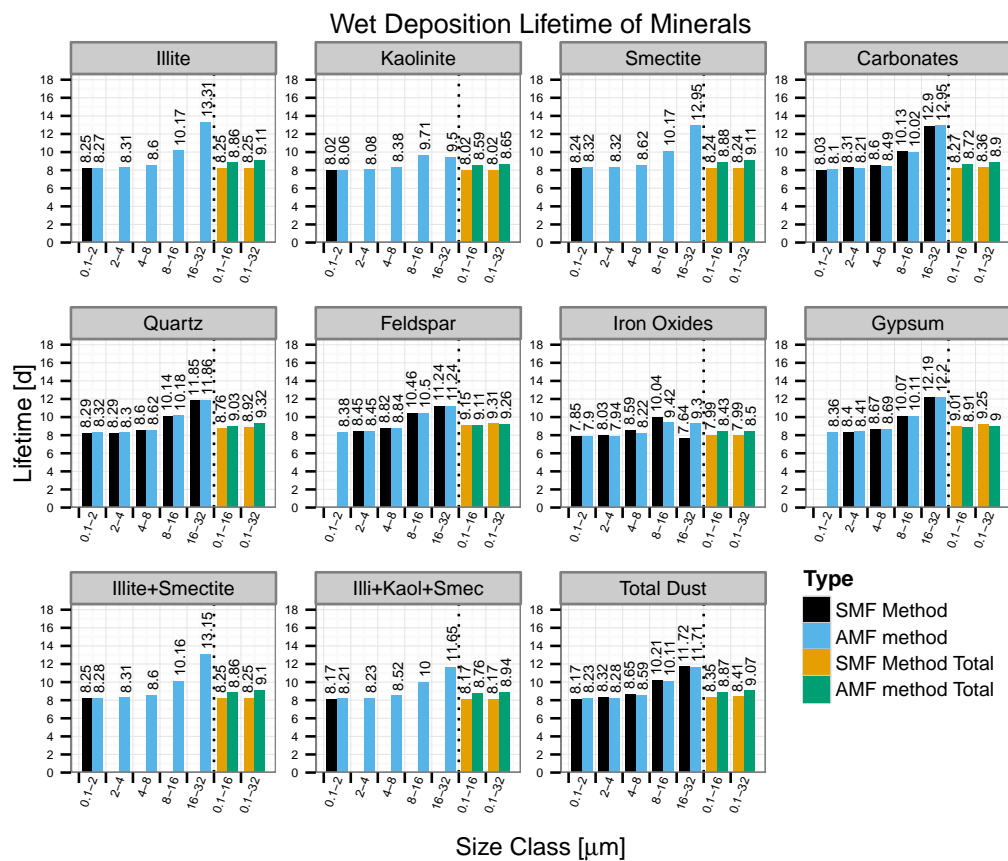
**Figure S10.** Global annual mineral gravitational deposition fractions (%).



**Figure S11.** Global annual mineral dry turbulent deposition fractions (%).

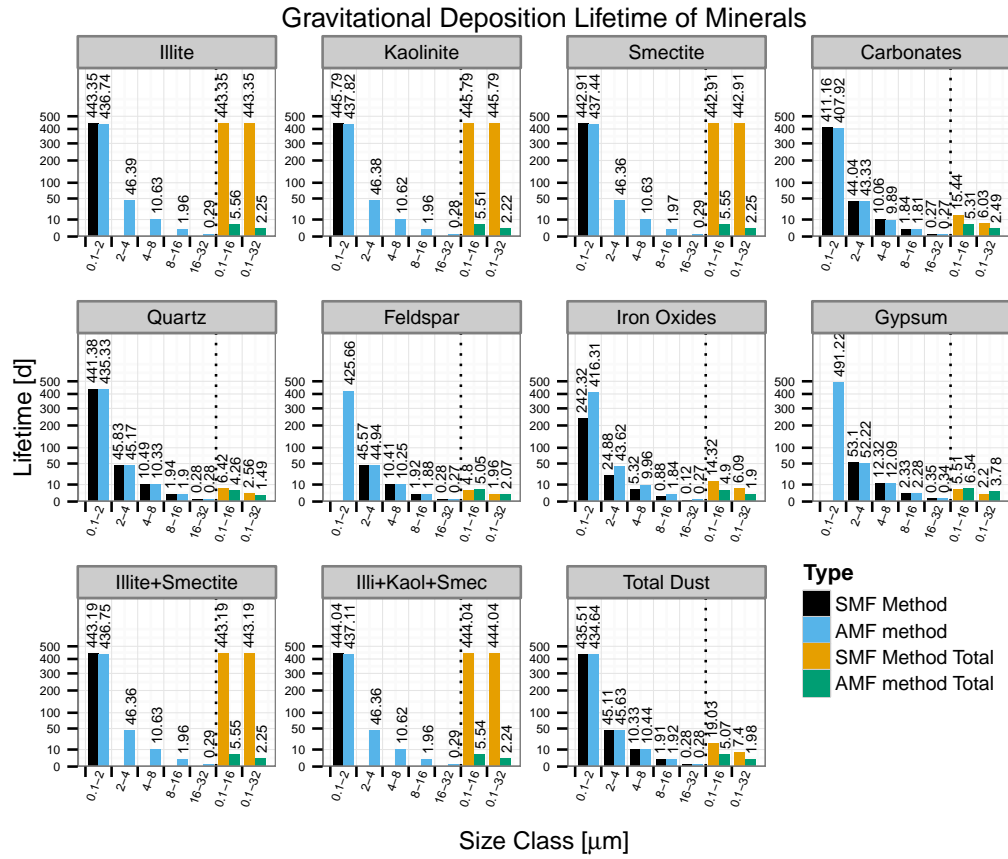


**Figure S12.** Total mineral life time (d).

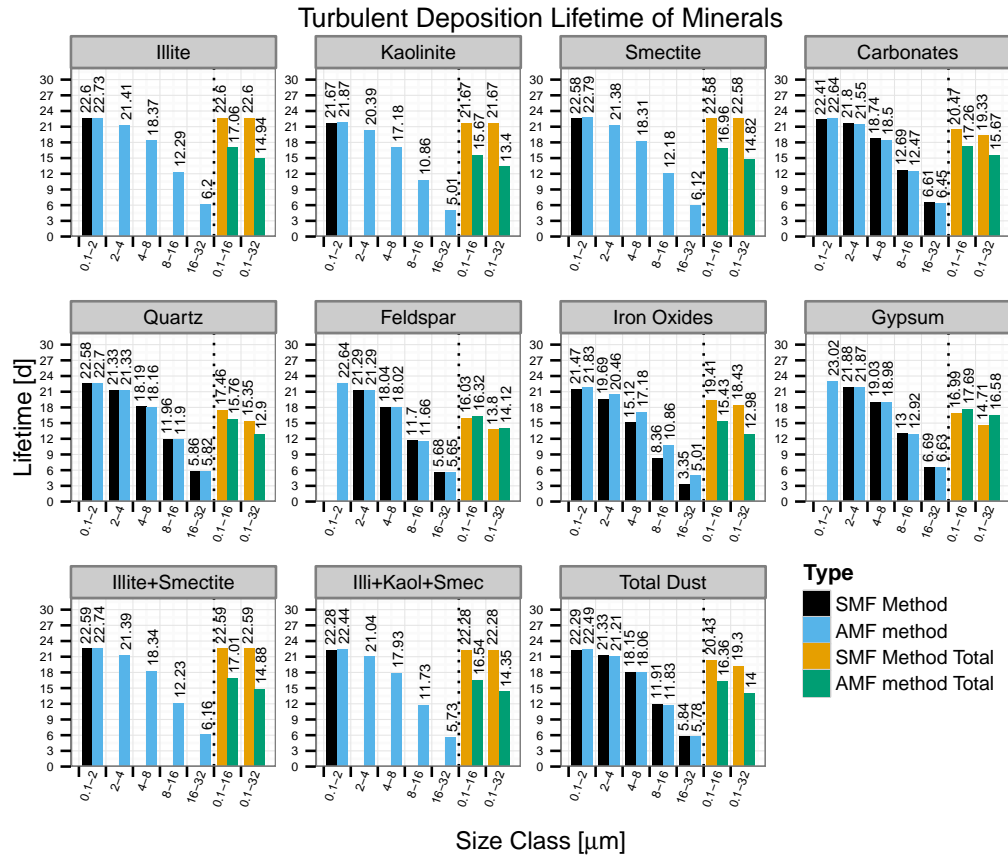


**Figure S13.** Mineral wet deposition life time (d).

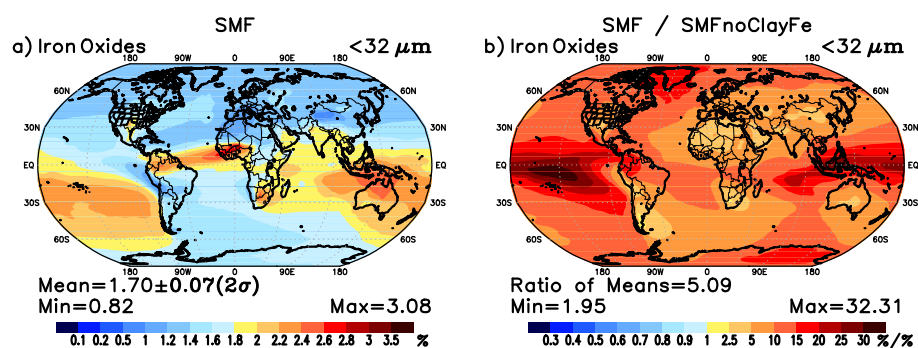




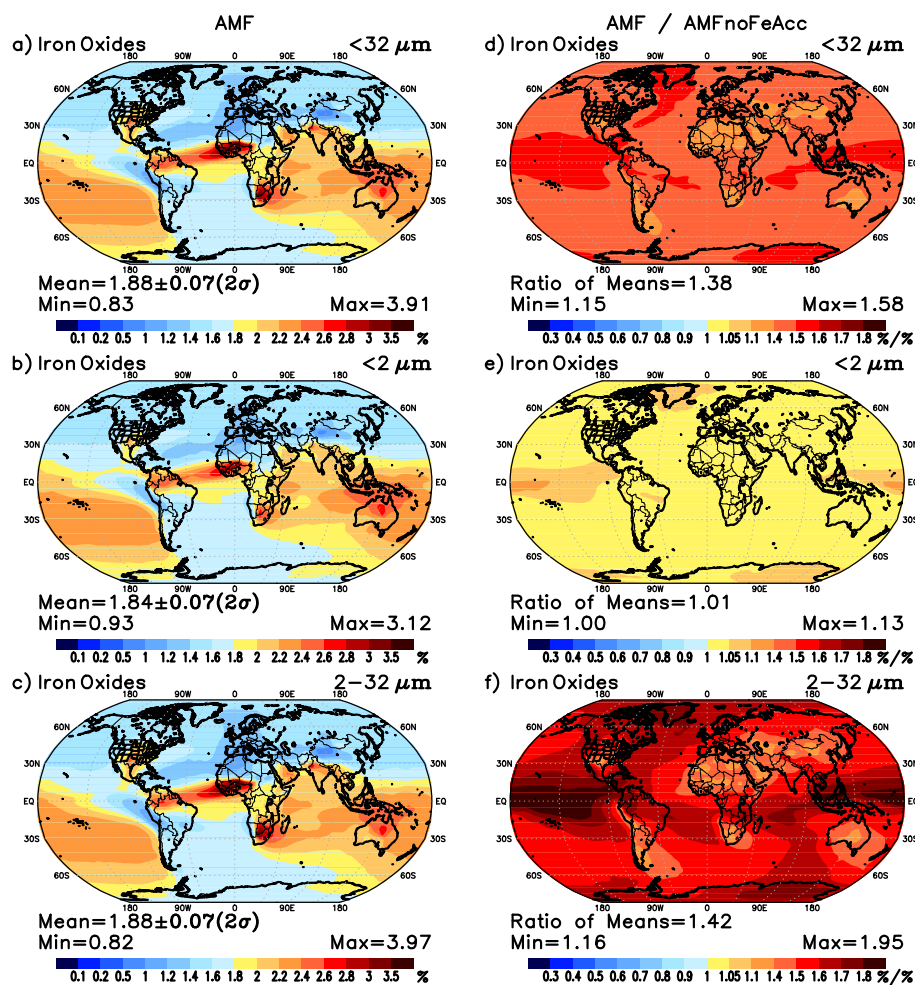
**Figure S14.** Mineral gravitational deposition life time (d).



**Figure S15.** Mineral turbulent deposition life time (d).



**Figure S16.** (a) Annual-average column mass fractions of iron oxides for the soil mineral fraction (SMF) method and (b) column mass fraction ratios between the SMF method and the SMF method without iron oxides (SMFnoClayFe) in the clay size range.



**Figure S17.** (Left panels) Annual-average column mass fraction of iron oxides for the aerosol mineral fraction (AMF) method and (right panels) ratio between the AMF method and the AMF method without iron oxide accretions (AMF-noFeAcc) for (a, d) total dust; (b, e) clay-sized dust, and (c, f) silt-sized dust.

**Table S1.** Annual mean and standard deviation of dust cycle for the SMF and AMF method.

Variable	Size range	SMF	AMF
Emission [ $\text{Tg a}^{-1}$ ]	<i>Clay</i> ( $< 2 \mu\text{m}$ )	$920 \pm 40$	$44 \pm 2$
	<i>Silt</i> ( $2 - 16 \mu\text{m}$ )	$657 \pm 30$	$1049 \pm 47$
	<i>Silt</i> ( $16 - 32 \mu\text{m}$ )	$647 \pm 30$	$1131 \pm 51$
	<i>Total</i> ( $< 16 \mu\text{m}$ )	$1577 \pm 70$	$1094 \pm 49$
	<i>Total</i> ( $< 32 \mu\text{m}$ )	$2224 \pm 100$	$2224 \pm 100$
Load [ $\text{Tg}$ ]	<i>Clay</i> ( $< 2 \mu\text{m}$ )	$14.60 \pm 0.56$	$0.71 \pm 0.03$
	<i>Silt</i> ( $2 - 16 \mu\text{m}$ )	$4.66 \pm 0.17$	$7.31 \pm 0.26$
	<i>Silt</i> ( $16 - 32 \mu\text{m}$ )	$0.46 \pm 0.01$	$0.81 \pm 0.02$
	<i>Total</i> ( $< 16 \mu\text{m}$ )	$19.26 \pm 0.73$	$8.02 \pm 0.29$
	<i>Total</i> ( $< 32 \mu\text{m}$ )	$19.72 \pm 0.74$	$8.83 \pm 0.31$
Wet deposition [ $\text{Tg a}^{-1}$ ]	<i>Clay</i> ( $< 2 \mu\text{m}$ )	$652 \pm 29$	$31 \pm 1$
	<i>Silt</i> ( $2 - 16 \mu\text{m}$ )	$190 \pm 9$	$298 \pm 14$
	<i>Silt</i> ( $16 - 32 \mu\text{m}$ )	$14 \pm 3$	$25 \pm 5$
	<i>Total</i> ( $< 16 \mu\text{m}$ )	$842 \pm 37$	$330 \pm 16$
	<i>Total</i> ( $< 32 \mu\text{m}$ )	$856 \pm 39$	$355 \pm 20$
Gravitational deposition [ $\text{Tg a}^{-1}$ ]	<i>Clay</i> ( $< 2 \mu\text{m}$ )	$12 \pm 1$	$1 \pm 0.04$
	<i>Silt</i> ( $2 - 16 \mu\text{m}$ )	$357 \pm 19$	$576 \pm 30$
	<i>Silt</i> ( $16 - 32 \mu\text{m}$ )	$604 \pm 28$	$1054 \pm 48$
	<i>Total</i> ( $< 16 \mu\text{m}$ )	$369 \pm 20$	$577 \pm 30$
	<i>Total</i> ( $< 32 \mu\text{m}$ )	$973 \pm 48$	$1631 \pm 78$
Turbulent deposition [ $\text{Tg a}^{-1}$ ]	<i>Clay</i> ( $< 2 \mu\text{m}$ )	$239 \pm 14$	$12 \pm 1$
	<i>Silt</i> ( $2 - 16 \mu\text{m}$ )	$105 \pm 6$	$167 \pm 10$
	<i>Silt</i> ( $16 - 32 \mu\text{m}$ )	$29 \pm 2$	$51 \pm 3$
	<i>Total</i> ( $< 16 \mu\text{m}$ )	$344 \pm 20$	$179 \pm 10$
	<i>Total</i> ( $< 32 \mu\text{m}$ )	$373 \pm 22$	$230 \pm 13$

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