

The Role of Midlatitude Cyclones in the Emission, Transport, Production, and Removal of Aerosols in the Northern Hemisphere

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Text S1.

The equation below describes the relationship between aerosol extinction (Ext), dry mass (M_d), and extinction efficiency (β). To first order, enhancements in extinction (ΔExt) are equal to the sum of enhancements in dry aerosol mass (ΔM_d) and mass extinction efficiency ($\Delta \beta$). Starting with the definition of extinction:

$$Ext = \beta \times M_d$$

Expressing ΔExt relative to background conditions, where prime denotes background, then simplifying:

$$\begin{aligned} \Delta Ext &= \frac{Ext - Ext'}{Ext'} = \frac{Ext}{Ext'} - 1 = \frac{\beta \times M_d}{\beta' \times M_d'} - 1 = \frac{M_d}{\frac{M_d' \times \beta}{\beta'}} - 1 = \\ &(\Delta M_d + 1)(\Delta \beta + 1) - 1 = \Delta M_d \Delta \beta + \Delta M_d + \Delta \beta \end{aligned}$$

Neglecting the term of order two, $\Delta M_d \Delta \beta$, yields:

$$\Delta Ext \approx \Delta M_d + \Delta \beta$$

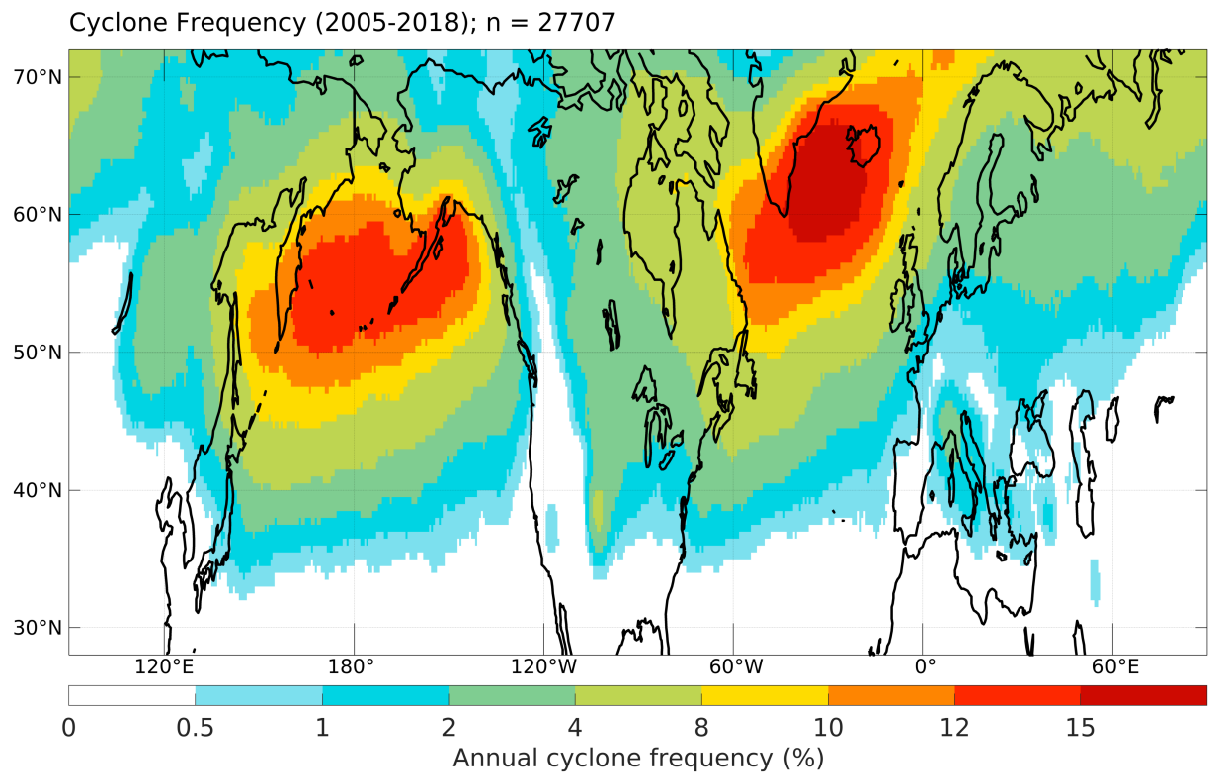
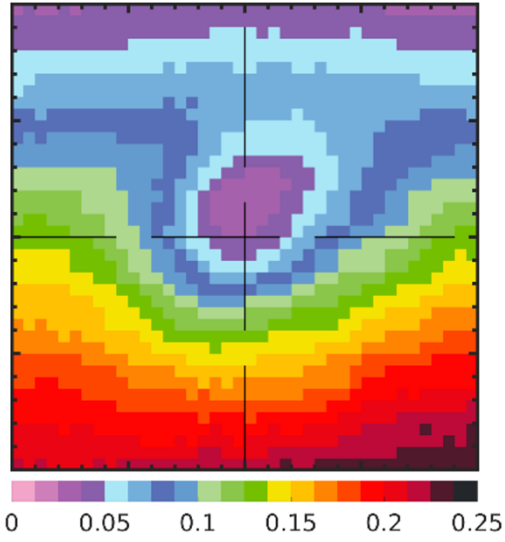
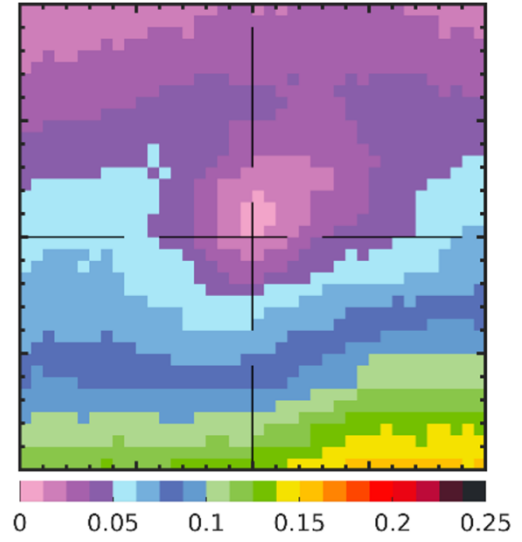


Figure S1. Annual mean NH midlatitude cyclone occurrence frequency for 2005-2018.

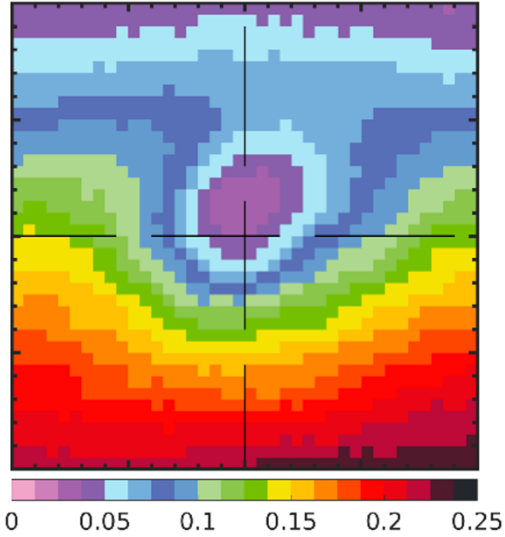
(a) MODIS Aqua Total



(b) MODIS Aqua Fine



(c) MODIS Terra Total



(d) MODIS Terra Fine

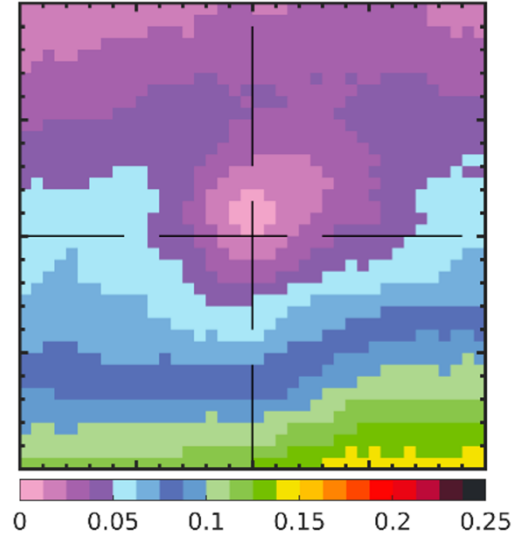


Figure S2. The fraction of 27,707 northern hemisphere midlatitude cyclones with valid data in the MODIS observations. (a) Fraction of cyclones with valid data for MODIS Aqua total AOD. (b) Same as (a) but for MODIS Aqua fine/coarse AOD. (c) Same as (a) but for MODIS Terra total AOD. (d) Same as (a) but for MODIS Terra fine/coarse AOD.

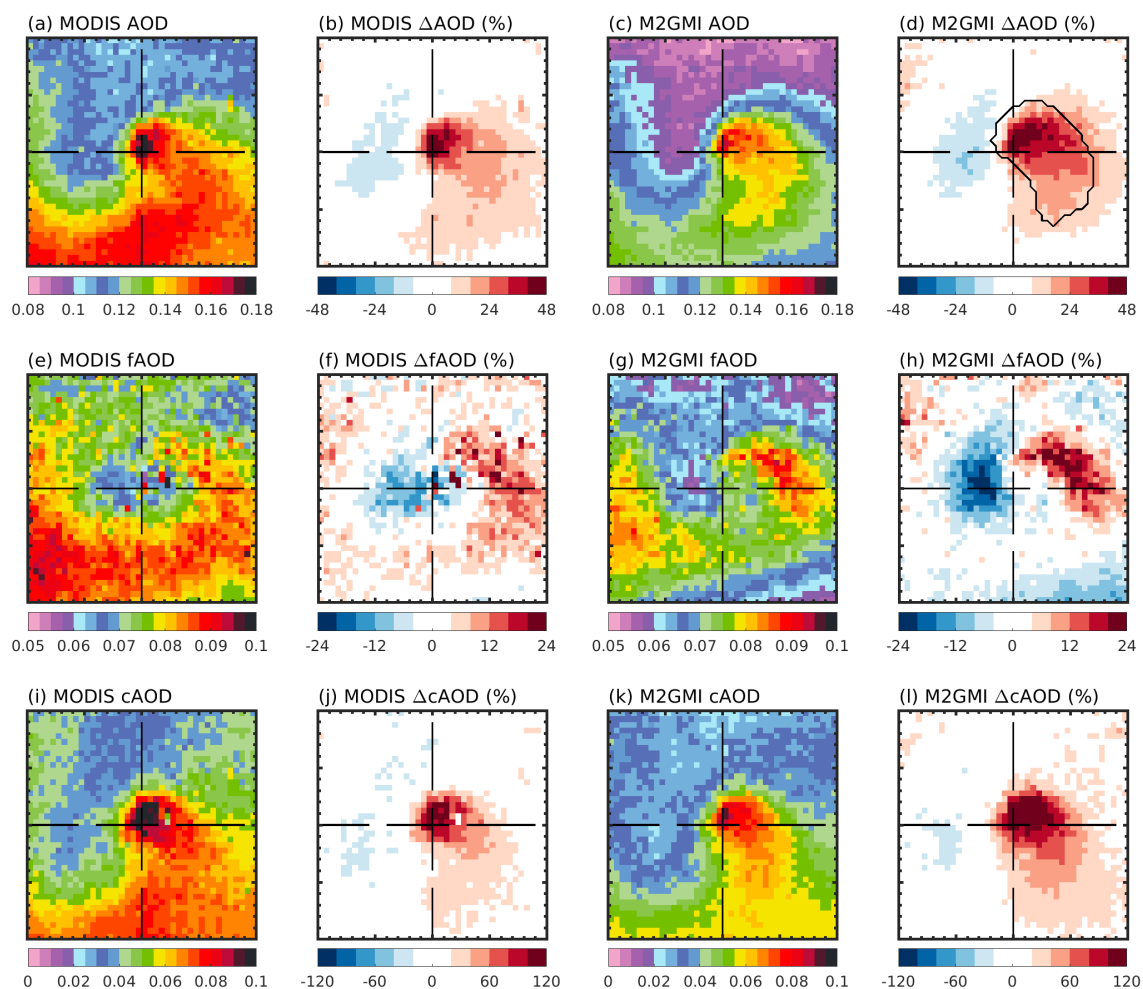


Figure S3. Same as Figure 2 of the main text but for MODIS Terra and the M2GMI model sampled at the Terra overpass time.

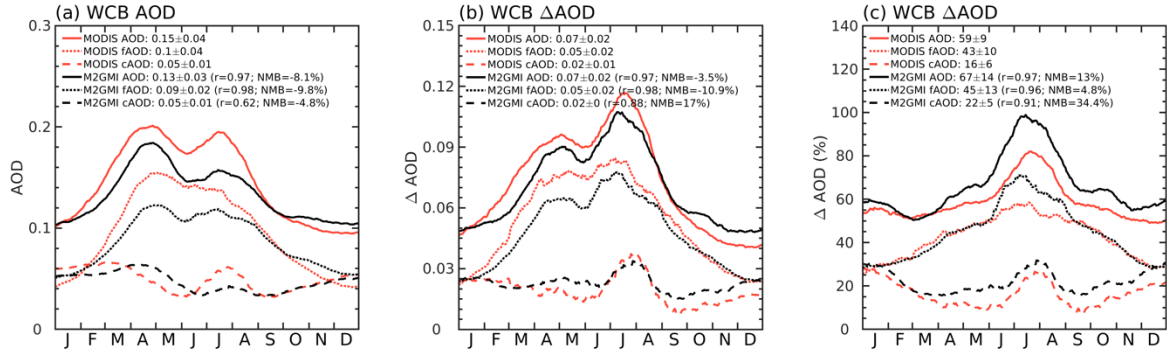


Figure S4. Same as Figure 3 of the main text but for MODIS Terra and the M2GMI model sampled at the Terra overpass time.

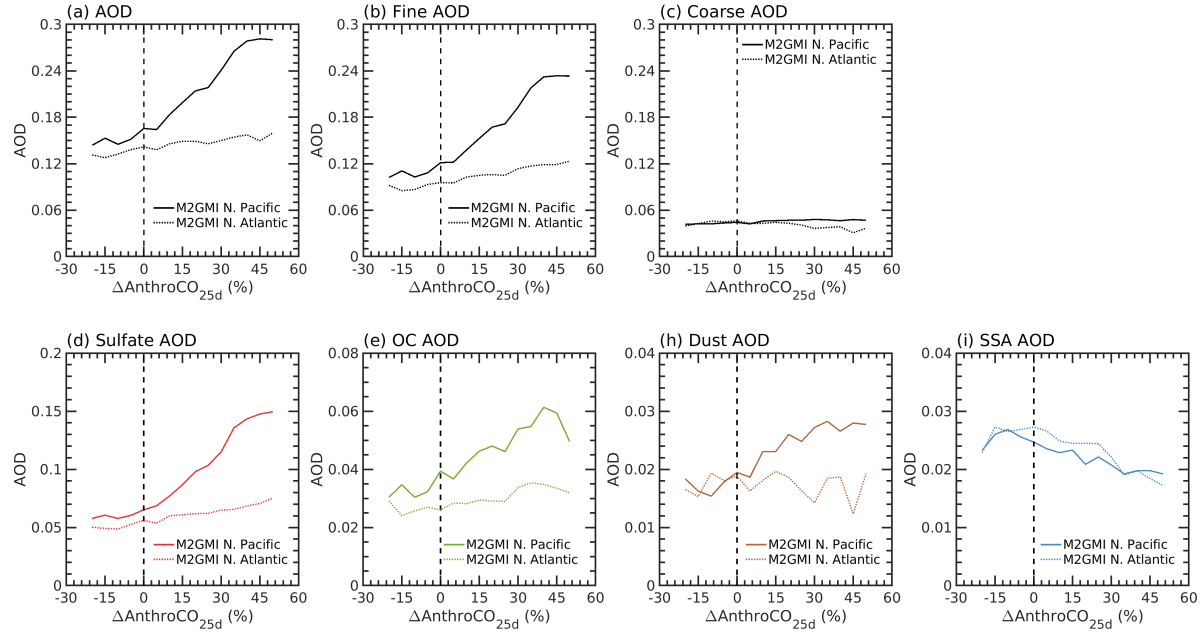


Figure S5. (a-c) Same as Figure 6 in the main text but for the full, daily-averaged M2GMI simulation. (d) Same as (a) but for sulfate AOD. (e) Same as (a) but for organic carbon AOD. (f) same as (a) but for dust AOD. (g) same as (a) but for sea salt AOD.

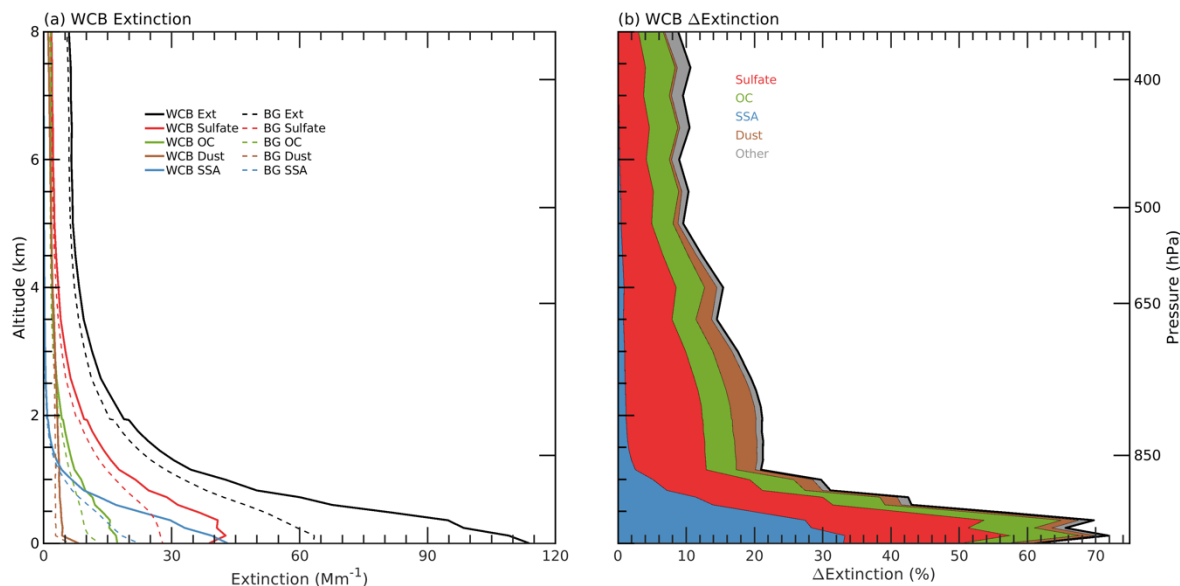


Figure S6. Annual mean vertical profiles of M2GMI aerosol extinction (units of Mm^{-1}) in the WCB of midlatitude cyclones. (a) Absolute extinction values (solid lines), and background extinction values (dashed lines). Resulting column AOD values for the cyclone profiles are given in the legend. (b) Extinction enhancement given as a percent relative to the total background. The individual component (colored) lines add together to the total extinction enhancement (black line).

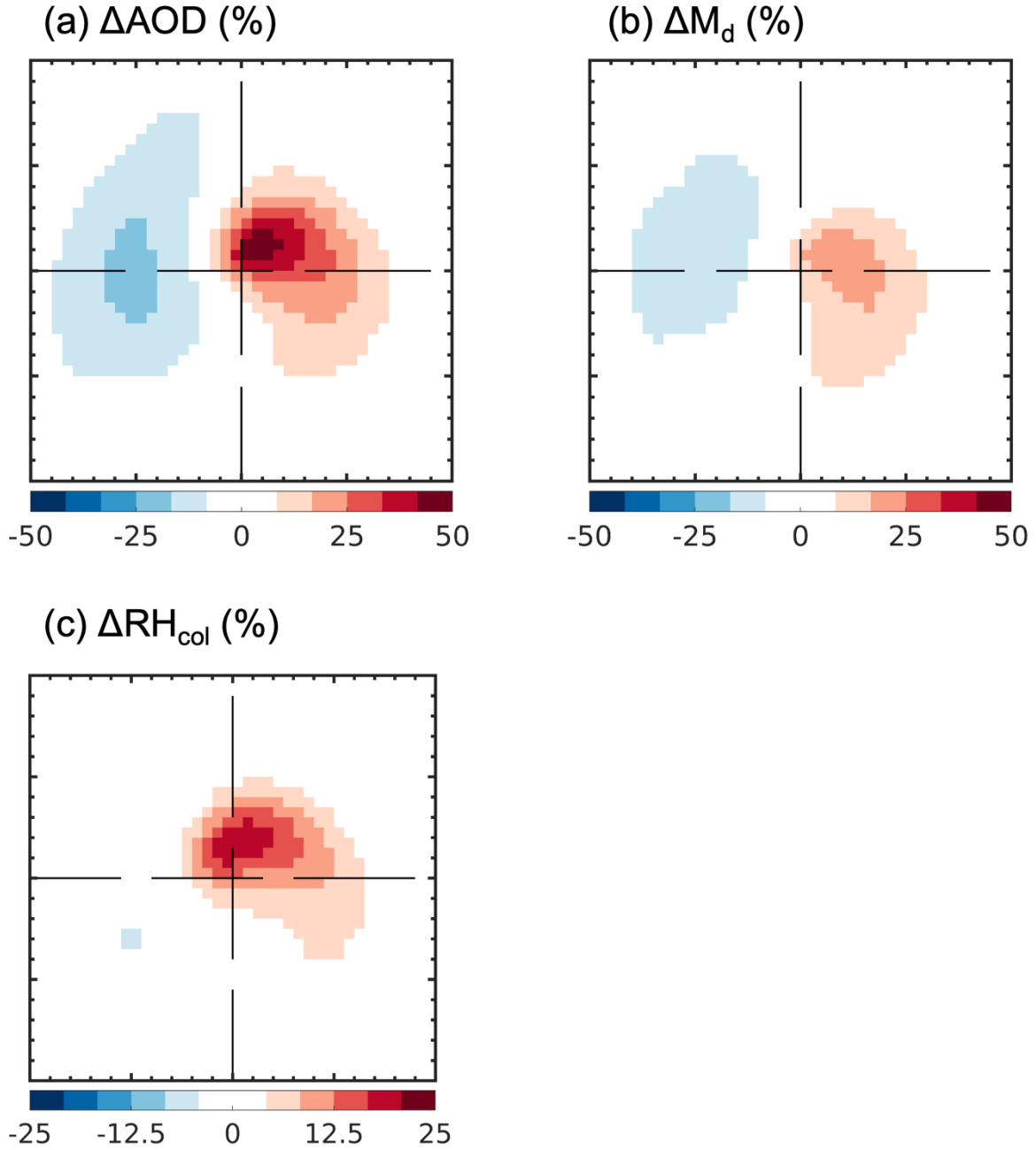


Figure S7. Annual mean composites of 27,707 midlatitude cyclones from M2GMI (2005-2018). (a) Total AOD anomaly (%; same as Figure 5f of the main text). (b) Total dry mass anomaly (%). Each aerosol component's dry mass has been weighted by its contribution to the background AOD (section 5 of the main text). (c) Column average relative humidity anomaly (%).

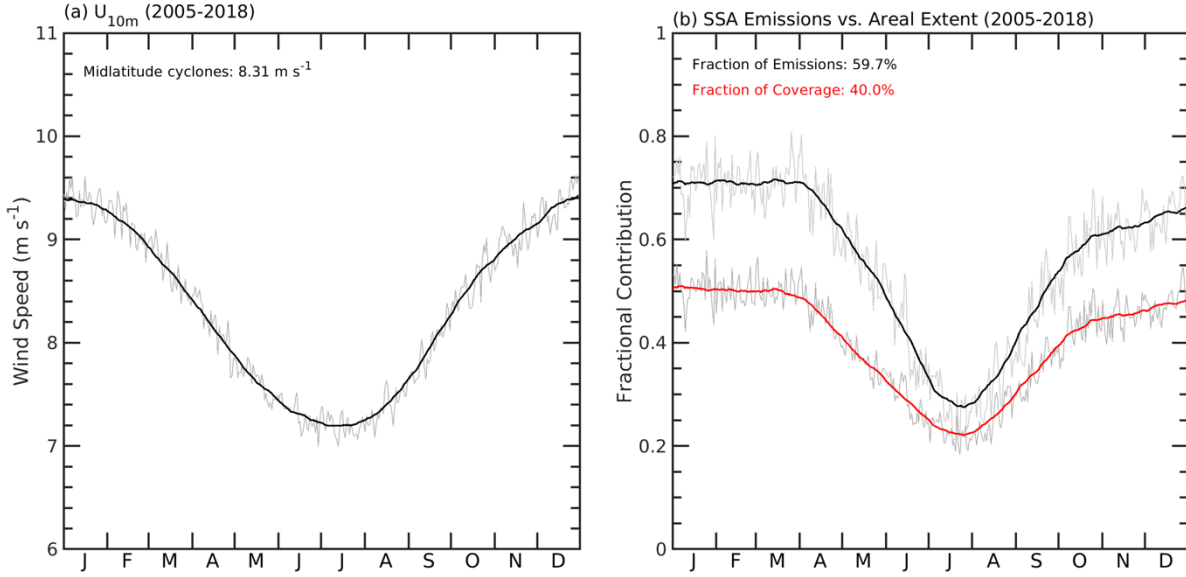


Figure S8. (a) Annual cycle of NH midlatitude cyclone 10 m wind speed (daily values are in gray while the black line shows wind speeds smoothed with a 40-day boxcar average). (b) Annual cycle of fraction of sea salt aerosol emissions due to midlatitude cyclones (daily values in gray with the black line showing the contribution smoothed with a 40-day boxcar average). Also shown is the fraction of NH ocean area covered by the strong wind speed regions of midlatitude cyclones (daily values in gray with the red line showing the area coverage smoothed with a 40-day boxcar average).