Supplementary Materials for

Stratospheric impact of the anomalous 2023 Canadian wildfires

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This PDF file includes:

Figs. S1 to S10

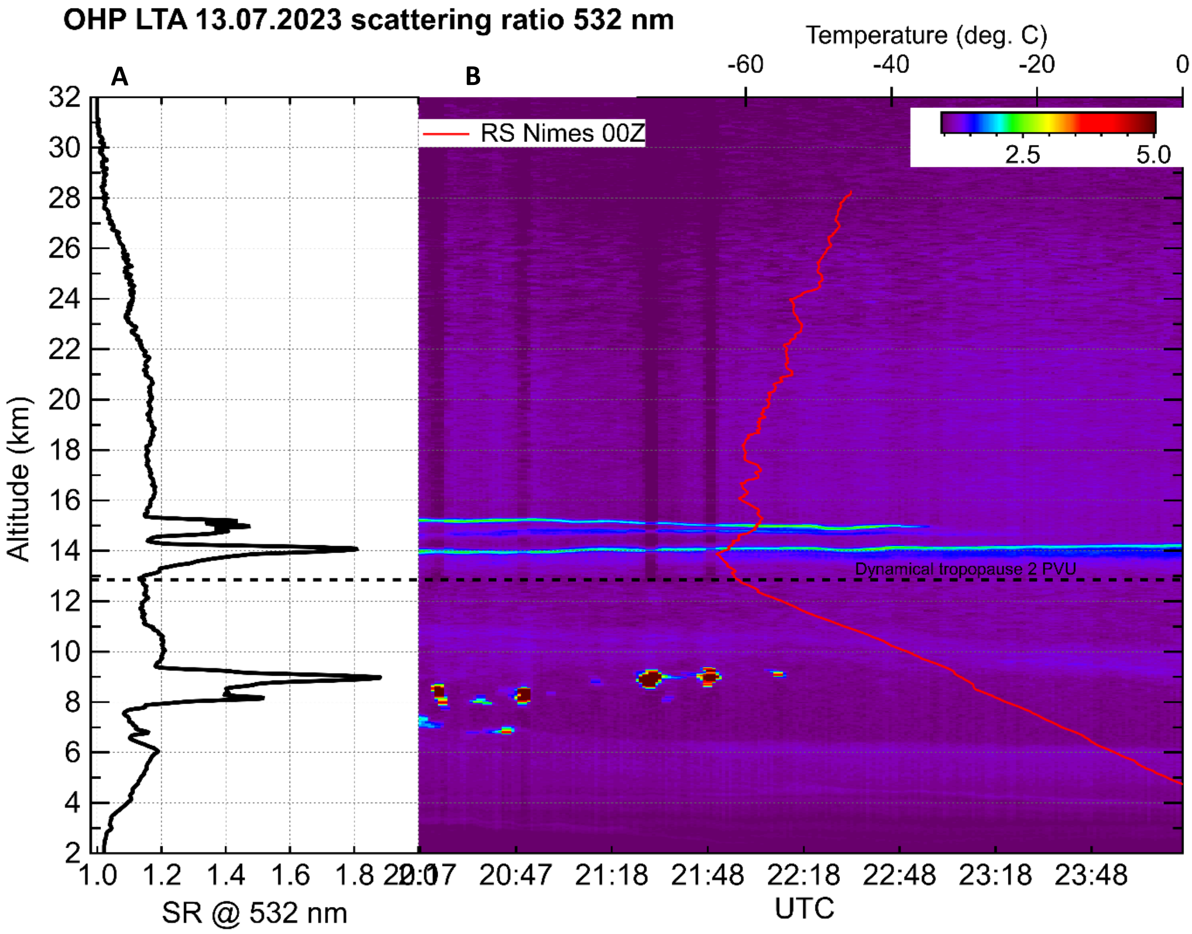

Figure S1. Detection of stratospheric smoke layers originating from a twin pyroCb event in Magadan (eastern Siberia, 30 June 2023) by LTA lidar at OHP (Observatoire de Haute Provence, 43.9 E, 5.7 E). (A) Vertical profile of scattering ratio at 532 nm for the entire duration of lidar acquisition. (B) Time curtain of scattering ratio, dynamical tropopause level (2 PVU, dashed line) and temperature profile from nearest radiosoundings at Nimes at 0 UT on 14 July 2023 (red curve, upper horizontal axis). The enhancements of scattering ratio at 14 and 15 km are associated with stratospheric smoke. A similar profile was acquired on the same date by LILAS lidar (not shown).

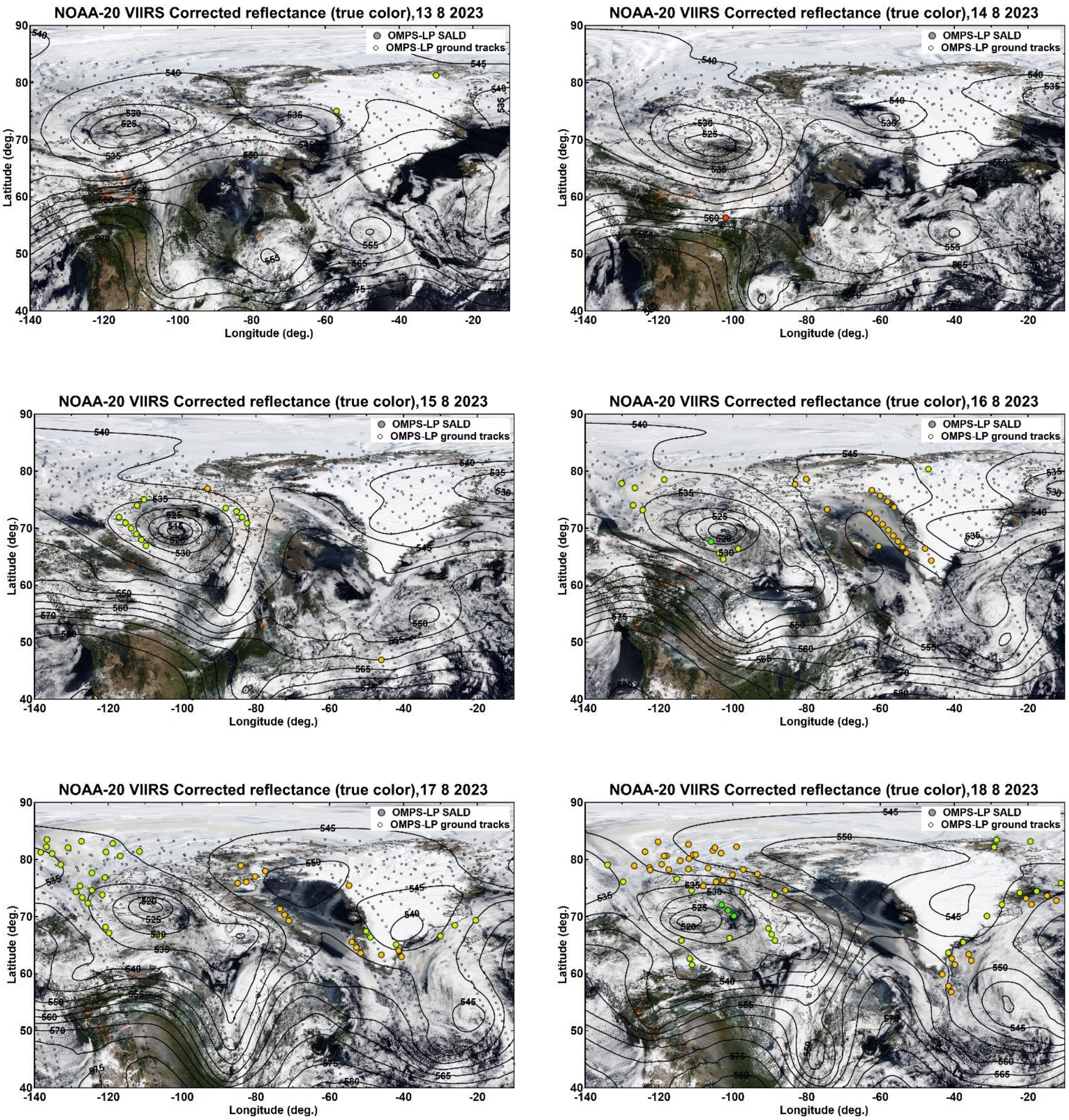

Figure S2. WCB-driven smoke uplift episode (event #3) illustrated as sequential geographical maps for the 13 - 18 August 2023 period. The panels include: true color images of NOAA-20 VIIRS corrected reflectance; ERA5 geopotential height at 500 hPa (contours, labels in dam); OMPS-LP ground track locations (open circles); OMPS-LP SALD locations (color-filled circles); GFAS fine anomalies (red dots). Smoke becomes visible above the cloud tops on 15 August, and matches the SALD locations.

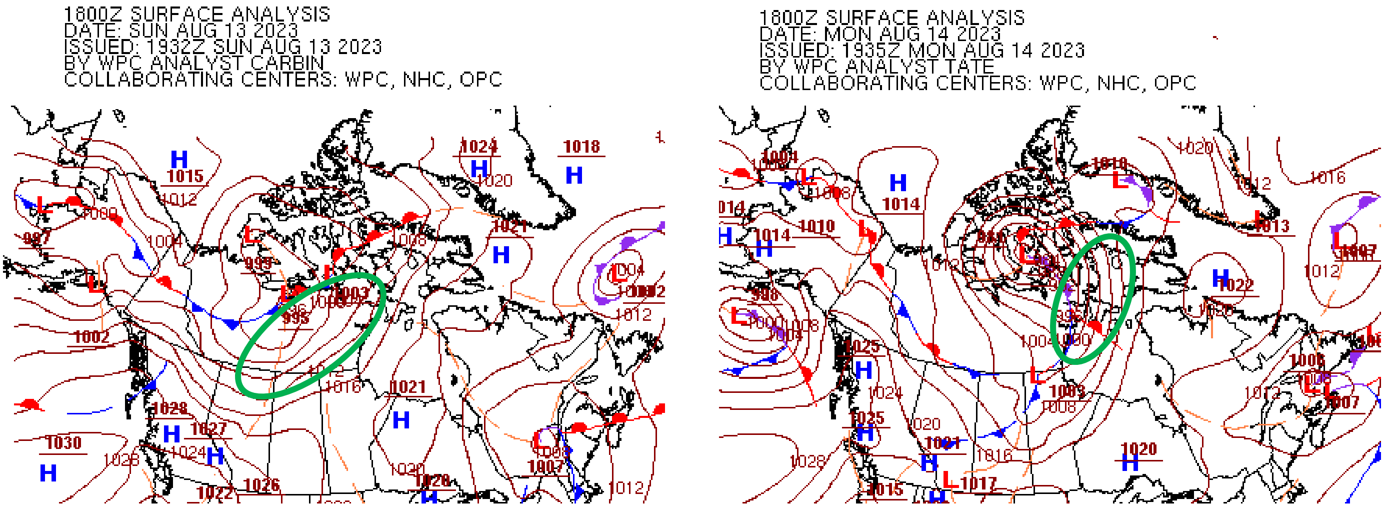

Figure S3. NOAA Weather Prediction Center (WPC) surface analysis maps for 13 and 14 August at 00 UTC corresponding to event #3. Green oval indicates the WCB uplift zone.

The maps are available from https://www.wpc.ncep.noaa.gov/archives/web_pages/sfc/sfc_archive.php

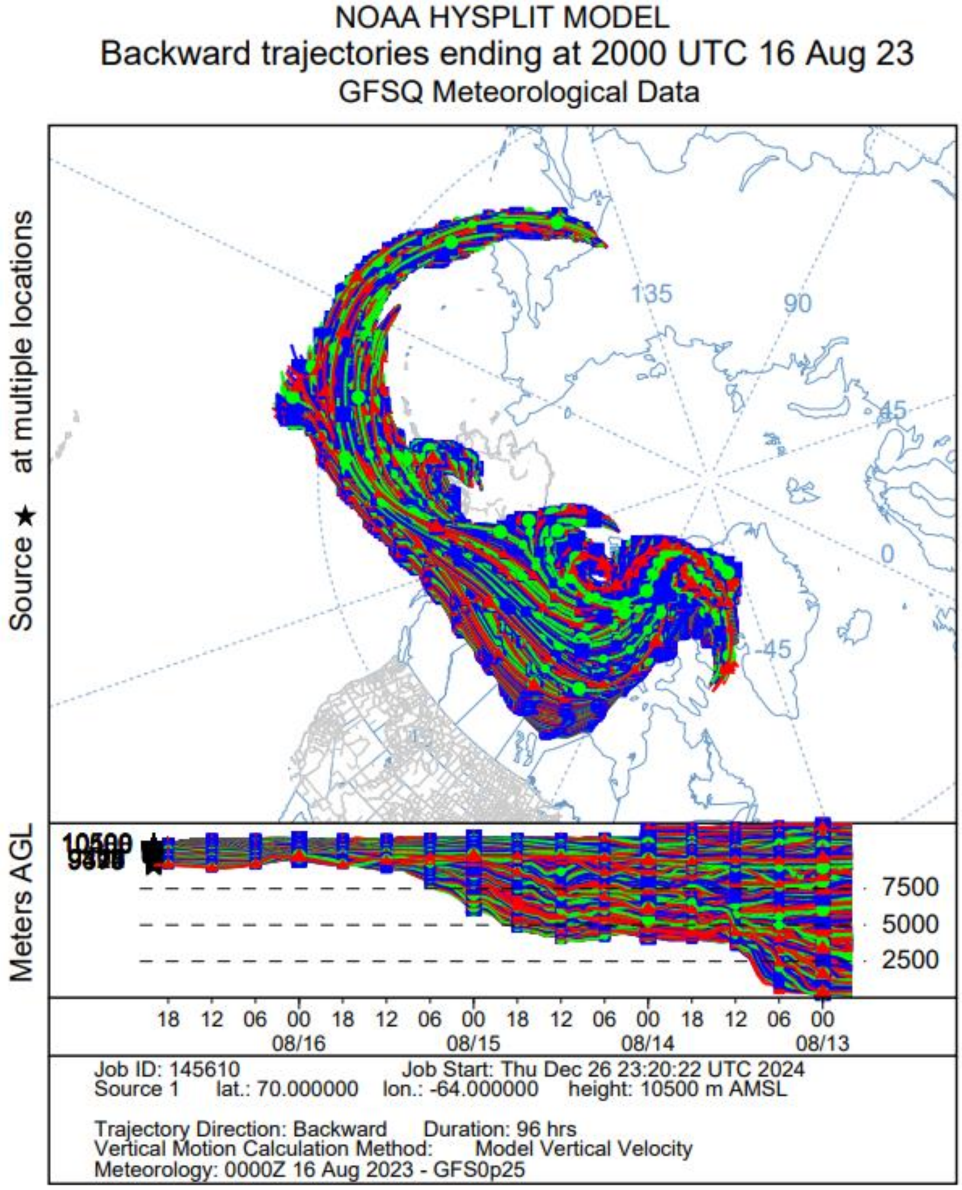

Figure S4. WCB uplift (event #3) from the backward trajectory analysis. HYSPLIT 96-hour backward trajectories (model vertical velocity) ending on 16 August 2023 20 UT. The trajectories were initialized in matrix mode with 0.1 deg. grid within a domain 70N – 74N, 54W – 64W corresponding to a cluster of SALDs on 16 August west of Greenland (Fig. 3D).

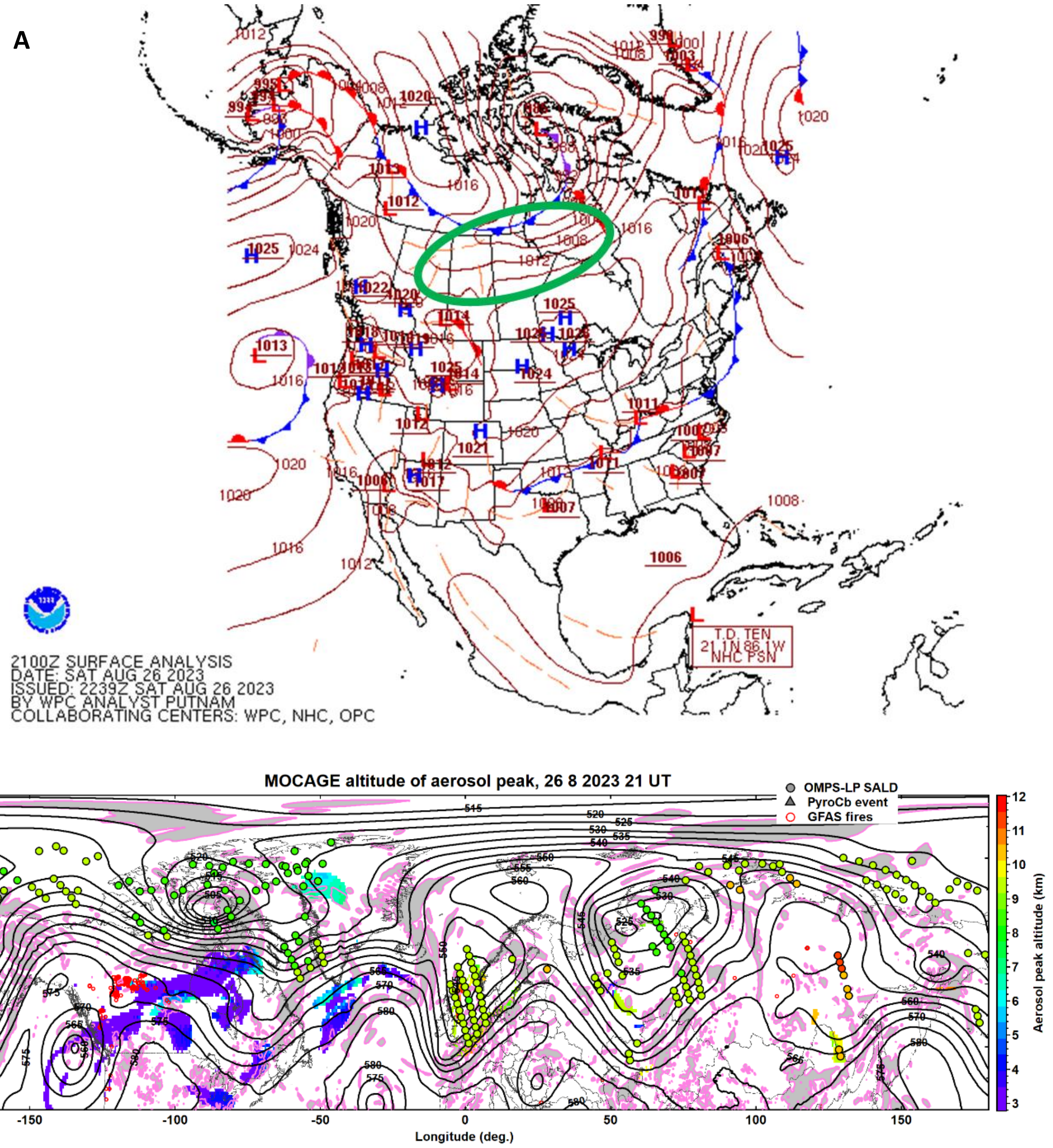

Figure S5. Meteorological analysis of WCB uplift episode (event #4) for 26 August at 21 UTC. (A) WPC surface analysis map. Green oval indicates the WCB uplift zone. (B) Color shading show MOCAGE-simulated altitude of maximum concentration of wildfire aerosols (km); black contours show ERA5 geopotential height at 500 hPa (labels in dam); pink contour with grey shading indicates areas with downward ERA5 500 hPa vertical velocity; open circles mark OMPS-LP ground track locations; color-filled circles indicate OMPS-LP SALD locations (same color map as for MOCAGE altitude). SALD altitude corresponds to the peak of the observed extinction ratio profile.

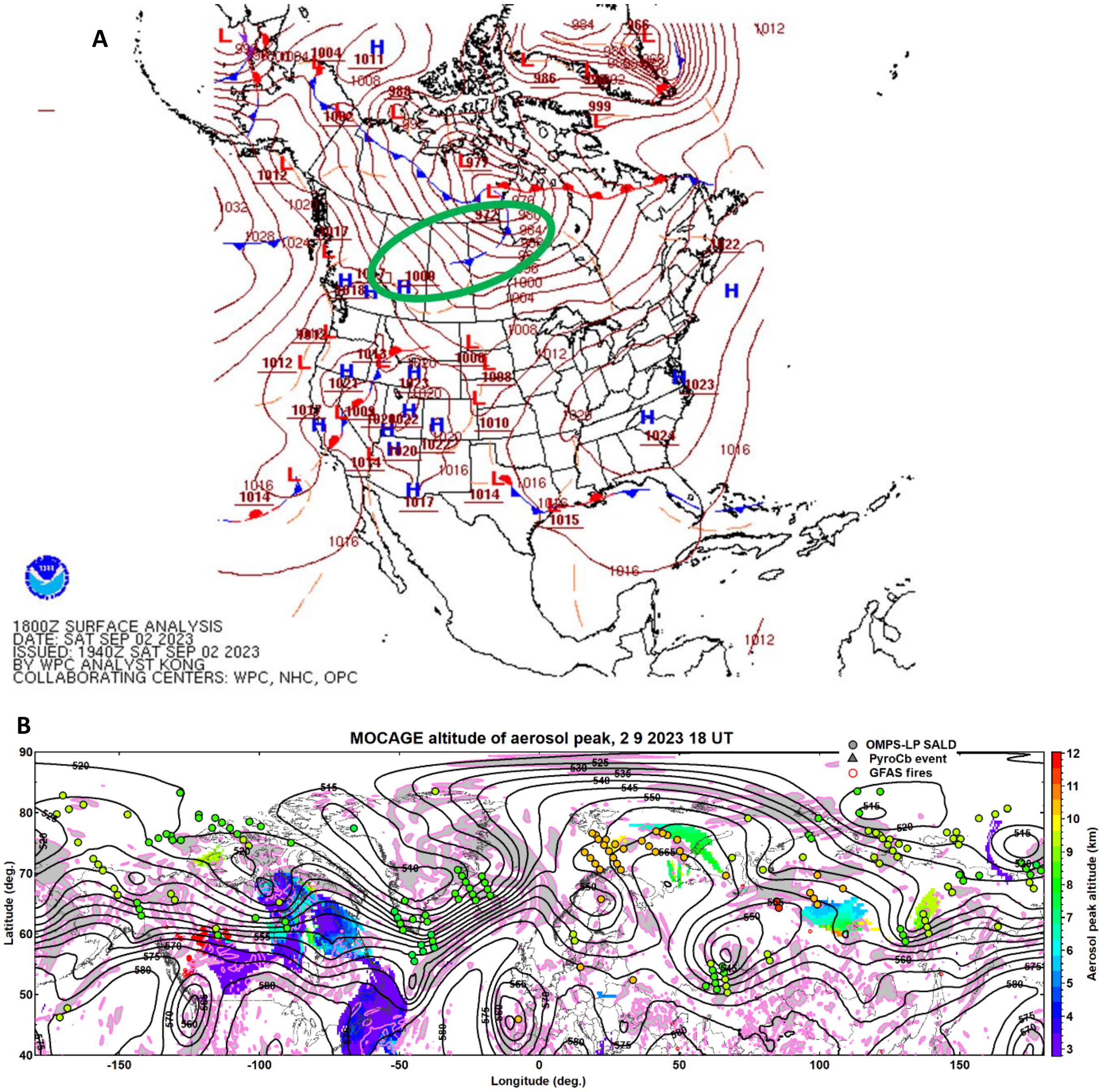

Figure S6. Meteorological analysis of WCB uplift episode (event #5) for 2 September at 18 UTC. (A) WPC surface analysis map. Green oval indicates the WCB uplift zone. (B) Color shading show MOCAGE-simulated altitude of maximum concentration of wildfire aerosols (km); black contours show ERA5 geopotential height at 500 hPa (labels in dam); pink contour with grey shading indicates areas with downward ERA5 500 hPa vertical velocity; open circles mark OMPS-LP ground track locations; color-filled circles indicate OMPS-LP SALD locations (same color map as for MOCAGE altitude). SALD altitude corresponds to the peak of the observed extinction ratio profile.

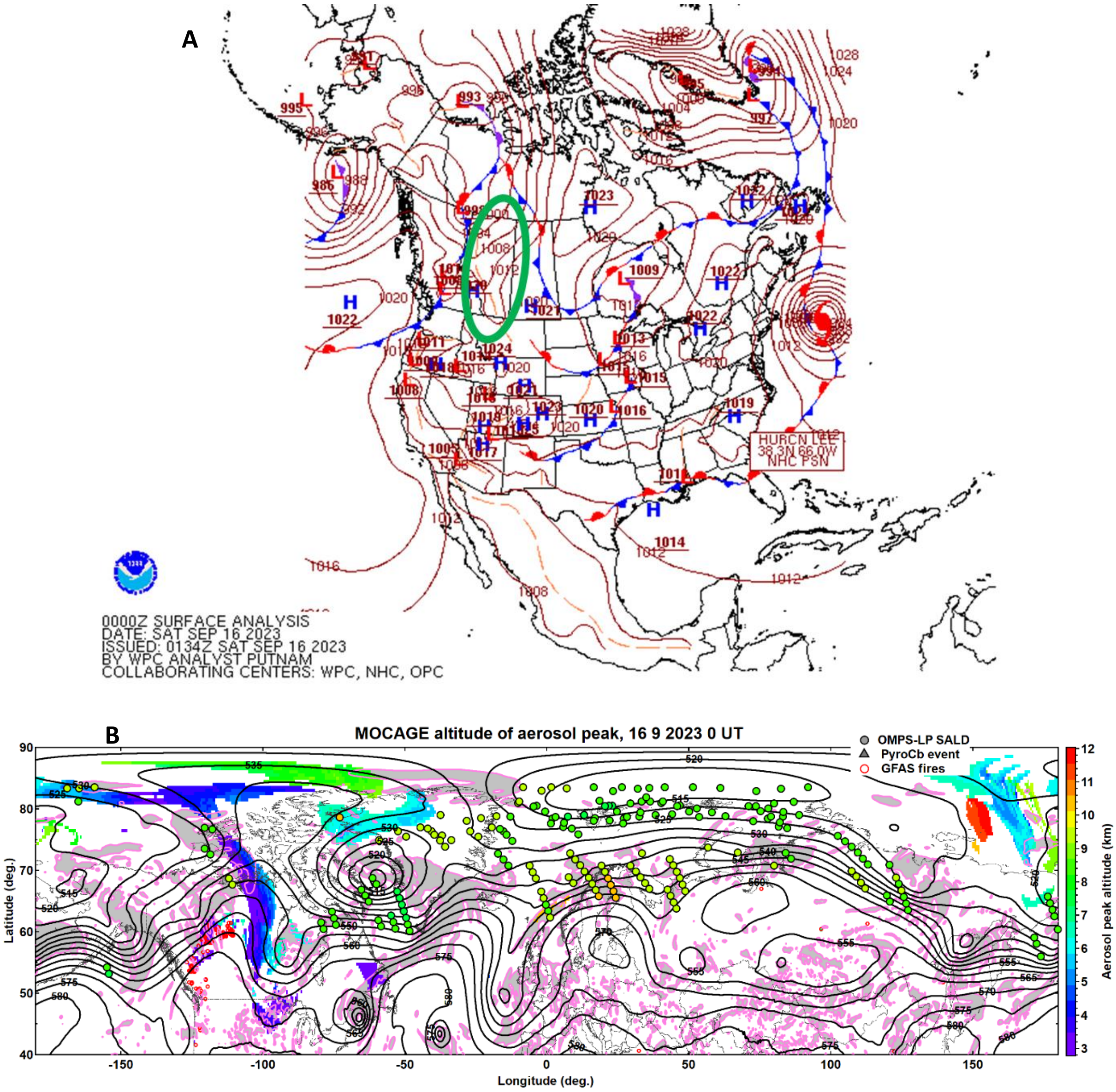

Figure S7. Meteorological analysis of WCB uplift episode (event #6) for 16 September at 00 UTC. (A) WPC surface analysis map. Green oval indicates the WCB uplift zone. (B) Color shading show MOCAGE-simulated altitude of maximum concentration of wildfire aerosols (km); black contours show ERA5 geopotential height at 500 hPa (labels in dam); pink contour with grey shading indicates areas with downward ERA5 500 hPa vertical velocity; open circles mark OMPS-LP ground track locations; color-filled circles indicate OMPS-LP SALD locations (same color map as for MOCAGE altitude). SALD altitude corresponds to the peak of the observed extinction ratio profile.

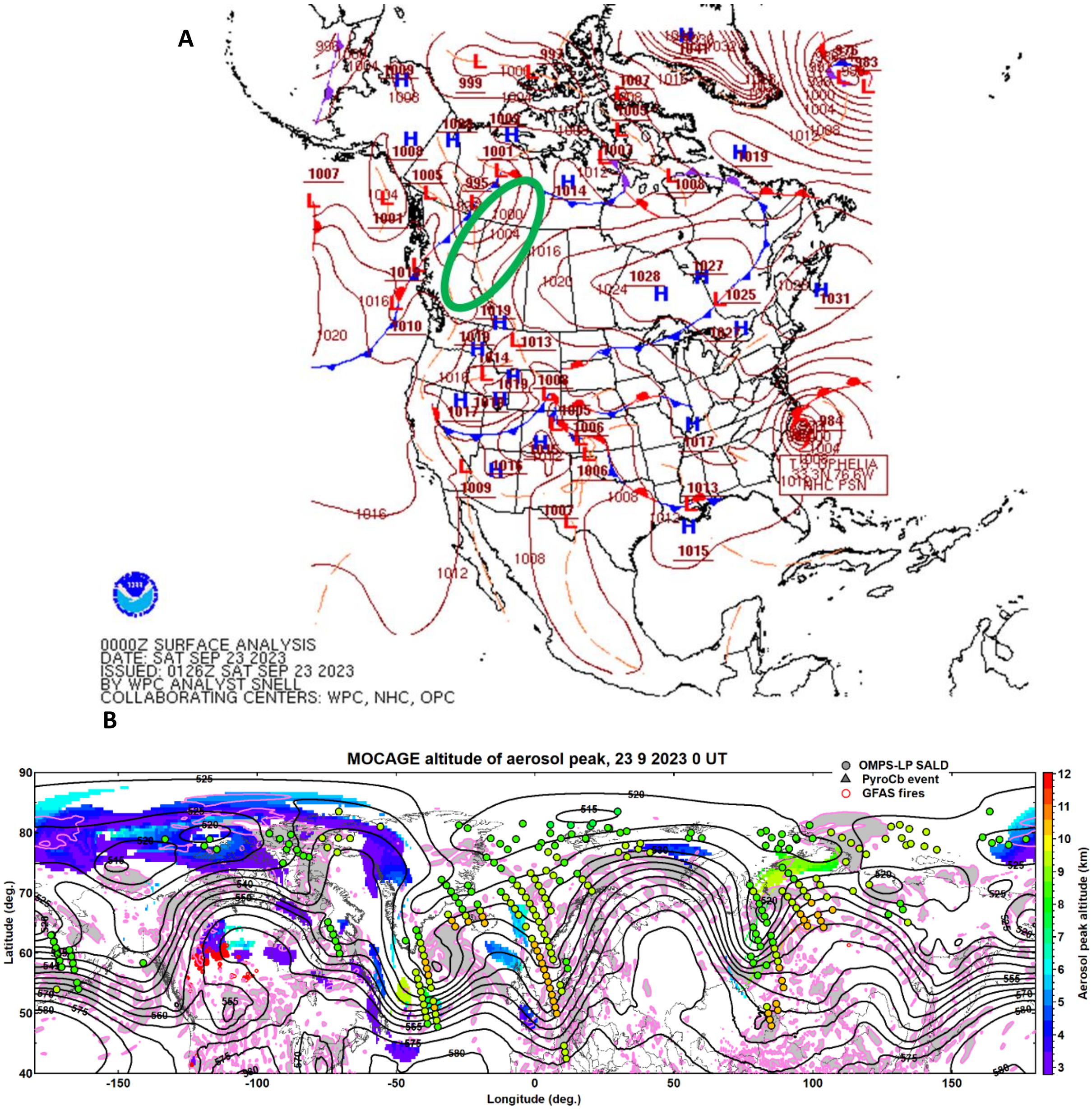

Figure S8. Meteorological analysis of WCB uplift episode (event #7) for 23 September at 00 UTC. (A) WPC surface analysis map. Green oval indicates the WCB uplift zone. (B) Color shading show MOCAGE-simulated altitude of maximum concentration of wildfire aerosols (km); black contours show ERA5 geopotential height at 500 hPa (labels in dam); pink contour with grey shading indicates areas with downward ERA5 500 hPa vertical velocity; open circles mark OMPS-LP ground track locations; color-filled circles indicate OMPS-LP SALD locations (same color map as for MOCAGE altitude). SALD altitude corresponds to the peak of the observed extinction ratio profile.

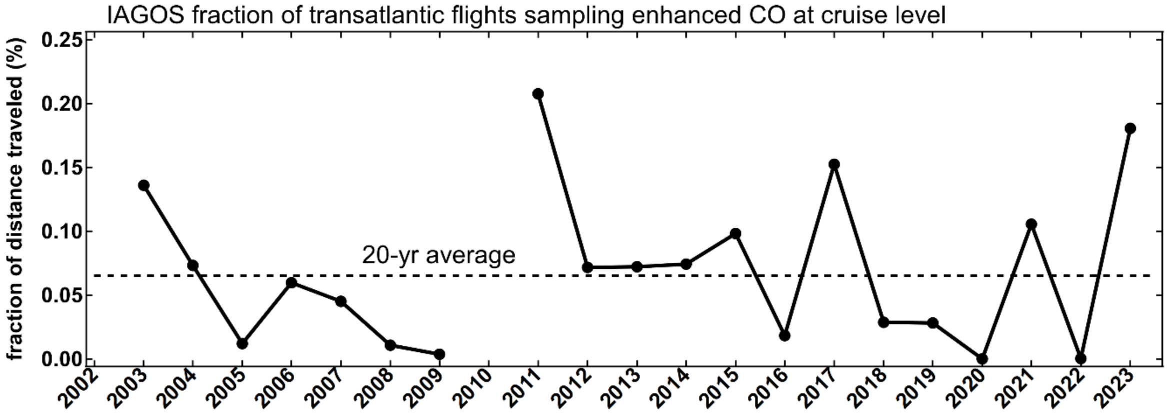

Figure S9. Time series of the percentage fraction of IAGOS transatlantic flights sampling enhanced CO i.e., mixing ratios exceeding +3 sigma limit or 195 ppbv, computed from the ensemble of cruise data from transatlantic flights since 2003. Dashed line marks the average fraction since 2003.

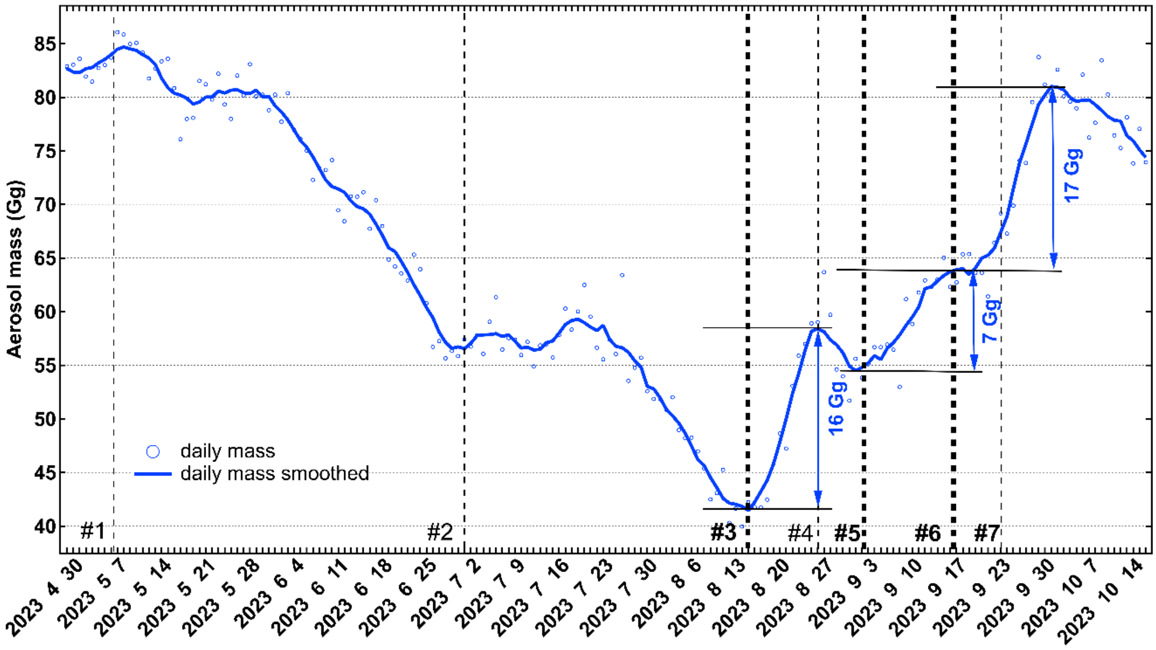

Figure S10. Variation of aerosol mass bounded within latitude range4 0° N – 82º N and vertical layer between the local thermal tropopause and 16 km.

Mass of smoke aerosols injected into the stratosphere was estimated using OMPS-LP extinction profiling data and the absolute mass difference method (*4*) with the assumed particle mass extinction coefficient of 4.5 m^2 g^{-1} (*13*). The daily mass of aerosols is computed by integrating the aerosol extinction in horizontal and vertical dimensions within the latitude band affected by wildfires (40° N – 82º N) and within the altitude layer where smoke aerosols were detected i.e., between the tropopause and 16 km (Fig. 2C). After converting the integrated extinction to mass, the resulting daily time series of aerosol mass are smoothed using 7-day boxcar. To compute the injected mass corresponding to specific event, the aerosol mass on the day before the event is compared with the local maximum of mass following the event.

The main limitation of this method is linked with the variability of stratospheric aerosol load modulated by volcanic eruptions and meridional transport of aerosols. In Summer 2023, the global was affected by the Hunga eruption in January 2022 (Tonga) whereas the northern extratropical stratosphere was affected by the eruption of Shiveluch volcano (Kamchatka peninsula) in April 2023 (*73*). A gradual removal of volcanic aerosols from the extratropical stratosphere by sedimentation and horizontal transport resulted in a progressive decay of its SAOD throughout the wildfire season, which reduced the difference between the pre-event and post-event stratospheric aerosol mass. The obtained injected masses represent thus a lower-bound estimate.