Electronic Supplementary Material (ESI) for Energy & Environmental Science.

Supplementary information: Post-Combustion Emissions Control in Aero-Gas Turbine Engines

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This supplementary information provides details and supporting material to the main text.

Aviation contribution to atmospheric NO_x mixing ratios

This section quantifies the aviation attributable NO_x mixing ratio for the baseline aviation (Figure 1) as well as the post-combustion emissions control (PCEC) with ultra-low sulfur (ULS) fuel scenario (Figure 2). The aviation contribution to cruise altitude (10 – 12 km) NO_x mixing ratio in the northern hemisphere is approximately 34%, while the use of PCEC with ULS fuel reduces this to approximately 0.25% (the change in burden is based on zonally mass weighted average of NO_x mixing ratios across the Northern Hemisphere at the typical cruise altitudes).

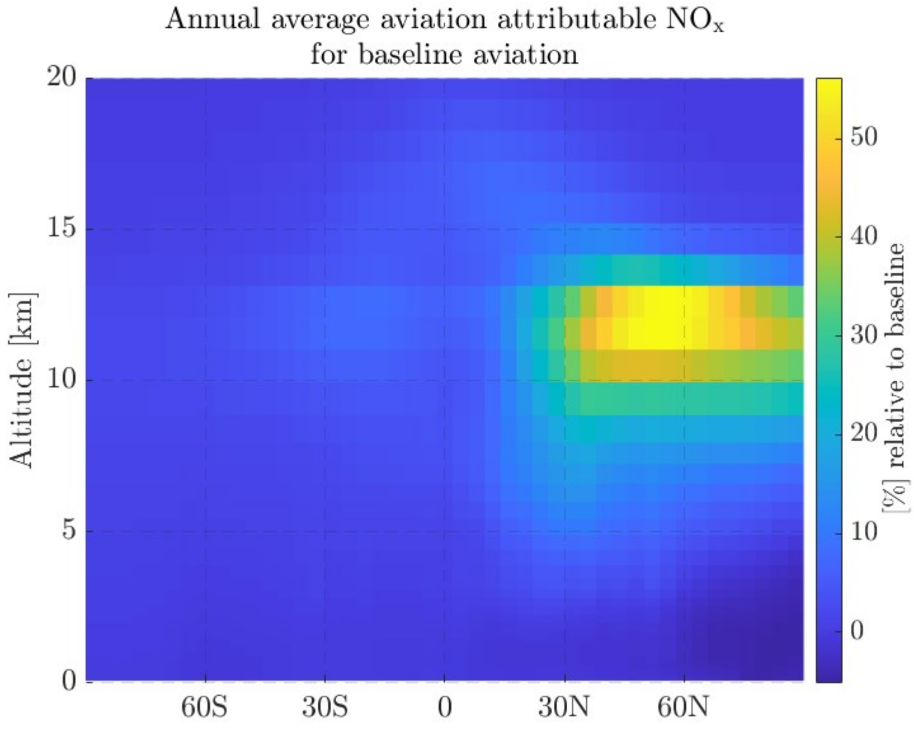

Figure 1: Zonal plot of aviation attributable NOx mixing ratio on an annual average basis

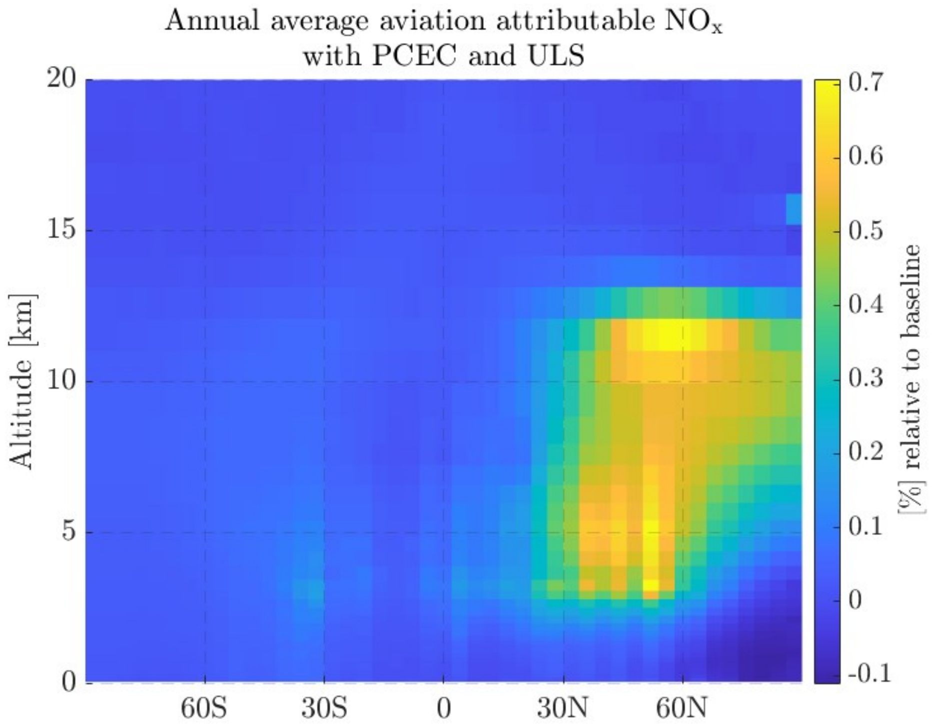

Figure 2: Zonal plot of aviation attributable NOx mixing ratios with the use of PCEC along with ULS fuel

Modified Breguet Range Equation

This section provides a detailed derivation of Eq 2, of section 2.4 in the main text. The rate of change of an aircraft's mass is,

$$\frac{dM_{a/c}}{dt} = -T \times SFC\left(1 + \frac{\dot{m}_{Red}}{\dot{m}_f}\right),$$

where $M_{a/c}$ is the aircraft mass, $\dot{m}_f$ is the mass flow rate of the fuel, $\dot{m}_{Red}$ is the mass flow rate of the reductant, SFC is the thrust specific fuel consumption, and T is the thrust provided by the engine. Using the lift to drag ratio (L/D) of the aircraft we can express the thrust as a function of aircraft mass, $T = \frac{gM_{a/c}}{L/D}$. Integrating the above equation gives,

$$M_f = \frac{MLW}{\left(1 + {}^{\dot{m}_{Red}}\!/_{\dot{m}_f}\right)}\left[\exp\left(gR\frac{SFC\left(1 + {}^{\dot{m}_{Red}}\!/_{\dot{m}_f}\right)}{V \times \frac{L}{D}}\right) - 1\right].$$

Surface area of pleated geometry

This section provides the derivation of Eq 3 in the main text. A schematic of a single pleat of a pleated catalyst geometry is shown below. The total flow through area (A) of the exhaust flow to be treated is given by,

$$A = 2NL \times s,$$

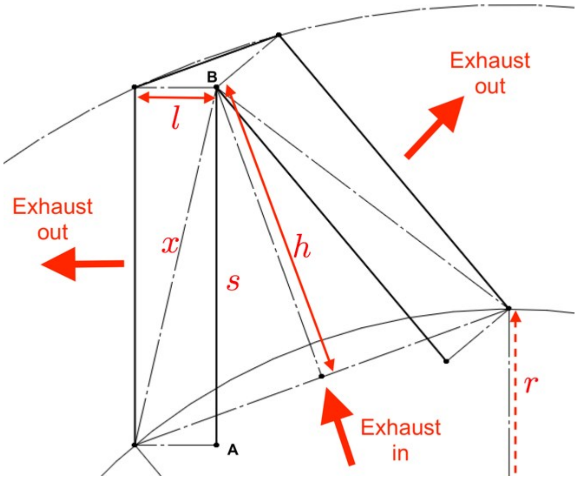

Figure 3: Geometry of pleated catalyst design. A single pleat is shown here. The reacting length and the pleat depth are l and h respectively. The radius of the inner circle is r and the length of the line segment AB is s, this represents the actual flow area per unit length perpendicular to the paper

where N is the number of pleats, L is the total length of the catalyst and s is the length of line segment shown in Figure 1. The length s is given by,

$$s = \sqrt{x^2 - l^2}$$

and

$$x^2 = h^2 + \frac{r^2}{2}\left(1 - \cos\left(\frac{2\pi}{N}\right)\right),$$

where r is the internal radius as shown in Figure 1. The total flow area is given by,

$$A = 2NL\sqrt{h^2 + \frac{r^2}{2}\left(1 - \cos\left(\frac{2\pi}{N}\right)\right) - l^2}.$$