**2.7** **O3-NOX-VOC non-linear parametrisation (321)**

**Empirical O3 isopleth fitting.** The O3 isopleth is an intuitive tool for O3-NOX-VOC non-linear relationship exploration, widely adopted for local pollution control strategy research1. Qian et al. put forward an empirical approach that using the quadric function to fit the isopleth, based on the observed concentrations of O3 and emissions of precursors2. Certain linear combinations of the quadratic fitting coefficients can be of realistic implications as the first- and second-order precursor sensitivities to O3, which has been validated by Shen and Sun et al. through high-order decoupled direct method (HDDM)3. The empirical fitting method is applied in this study, but the isopleths are changed to the net accumulation rates of O3 so as to eliminate the budgets caused from fluxes (because for coupled ESMs with interactive chemistry-climate feedbacks, the atmospheric dynamics can be altered by greenhouse gases like O3, bringing in confounding effects), and the levels of precursors are modified into log10-transformed emission rates to fit into normal distribution (the raw values of the emission rates are right-skewed).

lgNet(O3) = *β* + *αN* lgNOX + *αV* lgVOC + *αNV* lgNOX·lgVOC + *αNN* lgNOX2 + *αVV* lgVOC2 (Equation 1)

**Precursor sensitivity estimation.** The precursor sensitivities are defined as the marginal change of the O3 net accumulation rates against the unit shift of log-transformed NOX (*SN*) or NMVOC (*SV*) emission rates, mathematically equal to the derivatives of the aforementioned fitted empirical equations, as shown in the beneath equations. Higher-order sensitivities are not considered in this study.

*SN* = *∂*lgNet(O3) / *∂*lgNOX = *αN* + *αNV* lgVOC + 2*αNN* lgNOX (Equation 2)

*SV* = *∂*lgNet(O3) / *∂*lgVOC = *αV* + *αNV* lgNOX + 2*αVV* lgVOC (Equation 3)

Considering the O3 precursor sensitivities are regional indicators which are of unneglectable geographical variability, all relevant analyses are conducted on region-clustered scale. For countries of vast territory (i.e. China and the United States in this study), representative provinces or regions (e.g. Jing-Jin-Ji of China) are selected out to ensure the area of the study regions to be comparable with other countries. Study regions are circumscribed from a central location covering no exceeding 5×5 cells (i.e. 10°×10°) inside the administrative area. The sensitivity estimations are carried out by Python package *scikit-learn* 1.1.1.

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