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Multi-instrumental analysis of space-borne data in the chemical weather studies: resolution kernels, linear characterization and biases

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Paper presents outlook on combining space-borne retrievals such as carbon monoxide (MOPITT, TES, AIRS, and MLS) and ozone (SBUV/2, TES, MLS, and HIRDLS) in the chemical weather studies. To optimally assimilate observations with different vertical resolutions and error characterizations the numerical aspects of resolution-dependent analysis of measured radiances or characterized retrievals (a priori and averaging kernels) are emphasized. The limits of linear characterization of CO data by resolution (averaging) kernels are examined for highly polluted scenes. The non-linear characterizations of retrieved CO indicate needs for correction of a priori information and use of the "today" CO forecast to recover the linear characterization of retrievals. If a priori is represented by chemical forecast then the diagnosed systematic model errors (uncertainties of model physics and boundary emissions) should be properly identified and corrected. The sequential multi-step source-state estimation schemes for assimilation of the mid-troposphere CO is outlined to achieve unbiased CO analysis (or multi-year re-analysis) and diminish the forecast errors related to misspecification of surface emissions. Application of this strategy is illustrated with four years of MOPITT data assimilated in the chemistry transport model. In practice, the space-borne data can be also biased (radiance biases and errors in algorithms). In addition to conventional validation and quality control algorithms the property of reported retrieval errors and resolution kernels (symmetry, positive elements, singular values) should be used as criteria for data acceptance by assimilation schemes. Across the tropopause, the sharp changes of vertical gradients of ozone and CO demand adequate inserting smoothed constituent profiles (with degrees of freedom for signal < 2-3) in the chemical analysis. Potential errors associated with the trial analysis of layer-averaged ozone profiles as the point-wise data can introduce smoothing of vertical gradients of simulated ozone. This aspect is especially important for scenes when intrusions of air masses across the tropopause form thin vertical laminar structures. Numerical aspects of resolution-dependent assimilation for combining nadir- and limb-viewing ozone retrievals in the upper troposphere and lower stratosphere are discussed using ozone data (SBUV/2, TES, MLS, and HIRDLS).