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A two-step combination of top-down and bottom-up fire emission estimates at regional and global scales: strengths and main uncertainties

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Top-down emission estimation via inverse dispersion modelling is used for various problems, where bottom-up approaches are difficult or highly uncertain. One of such areas is the estimation of emission from wild-land fires. In combination with dispersion modelling, satellite and/or in-situ observations can, in principle, be used to efficiently constrain the emission values. This is the main strength of the approach: the a-priori values of the emission factors (based on laboratory studies) are refined for real-life situations using the inverse-modelling technique.
However, the approach also has major uncertainties, which are illustrated here with a few examples of the Integrated System for wild-land Fires (IS4FIRES). IS4FIRES generates the smoke emission and injection profile from MODIS and SEVIRI active-fire radiative energy observations. The emission calculation includes two steps: (i) initial top-down calibration of emission factors via inverse dispersion problem solution that is made once using training dataset from the past, (ii) application of the obtained emission coefficients to individual-fire radiative energy observations, thus leading to bottom-up emission compilation. For such a procedure, the major classes of uncertainties include: (i) imperfect information on fires, (ii) simplifications in the fire description, (iii) inaccuracies in the smoke observations and modelling, (iv) inaccuracies of the inverse problem solution. Using examples of the fire seasons 2010 in Russia, 2012 in Eurasia, 2007 in Australia, etc, it is pointed out that the top-down system calibration performed for a limited number of comparatively moderate cases (often the best-observed ones) may lead to errors in application to extreme events. For instance, the total emission of 2010 Russian fires is likely to be over-estimated by up to 50% if the calibration is based on the season 2006 and fire description is simplified. Longer calibration period and more sophisticated parameterization (including the smoke injection model and distinguishing all relevant vegetation types) can improve the predictions.
The other significant parameter, so far weakly addressed in fire emission inventories, is the size spectrum of the emitted aerosols. Direct size-resolving measurements showed, for instance, that smoke from smouldering fires has smaller particles as compares with smoke from flaming fires. Due to dependence of the smoke optical thickness on the size distribution, such variability can lead to significant changes in the top-down calibration step. Experiments with IS4FIRES-SILAM system manifested up to a factor of two difference in AOD, depending on the assumption on particle spectrum.