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Enhancements in Deriving Smoke Emission Coefficients from Fire Radiative Power Measurements

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Abstract

Smoke emissions have long been quantified after-the-fact by simple multiplication of burned area, biomass density, fraction of above-ground biomass, and burn efficiency. A new algorithm has been suggested, as described in Ichoku & Kaufman (2005)(5), for use in calculating smoke emissions directly from fire radiative power (FRP) measurements such that the latency and uncertainty associated with the previously listed variables are avoided. Application of this new, simpler and more direct algorithm is automatic, based only on a fire's FRP measurement and a predetermined coefficient of smoke emission for a given location. Attaining accurate coefficients of smoke emission is therefore critical to the success of this algorithm. In the aforementioned paper, an initial effort was made to derive coefficients of smoke emission for different large regions of interest using calculations of smoke emission rates from MODIS FRP and aerosol optical depth (AOD) measurements. Further work had resulted in a first draft of a 1×1° resolution map of these coefficients. This poster will present the work done to refine this algorithm toward the first production of global smoke emission coefficients. Main updates in the algorithm include: 1) inclusion of wind vectors to help refine several parameters, 2) defining new methods for calculating the fire-emitted AOD fractions, and 3) calculating smoke emission rates on a per-pixel basis and aggregating to grid cells instead of doing so later on in the process. In addition to a presentation of the methodology used to derive this product, maps displaying preliminary results as well as an outline of the future application of such a product into specific research opportunities will be shown.

Methodology

The basic premise of the two algorithms used in this research is that smoke emission from a fire can be determined directly from its FRP(6) and a coefficient of emission, C_e, which can be determined from a linear relationship between FRP and the rate of smoke emission, R_{sa}. R_{sa} is calculated as the total smoke aerosol mass, M_{sa}, over the time, T, it takes the smoke to clear the designated area. M_{sa} is estimated from surrounding AOT_{550} values from the MODIS 10km MOD04_L2 product(7), and T is estimated using pixel geometry and 850mbar wind speed data from MERRA's 1.25×1.25° resolution "inst3_3d_asm_Cp" product(1)(8). The Ichoku & Ellison algorithm expands on it's predecessor by using wind direction as well to more accurately determine AOT associated with the plume, and to determine if the fire is infected by smoke induced elsewhere. Wind magnitudes are also used in conjunction with relative fire locations within an aerosol pixel to improve values of T. R_{sa} and preceding parameters are also calculated on a per-pixel basis and therefore theoretically eliminate the uncertainty in estimating these parameters on a much larger scale.

MISR Plume Inventory Case Studies

Figure 1 (above). MISR plume inventory data(2) from Siberia in May, 2003 is used to compare actual wind direction (blue) with MERRA wind directions at 925, 850 and 700mbar (greens). MODIS pixels are shown over the MISR visible image to help with analysis.

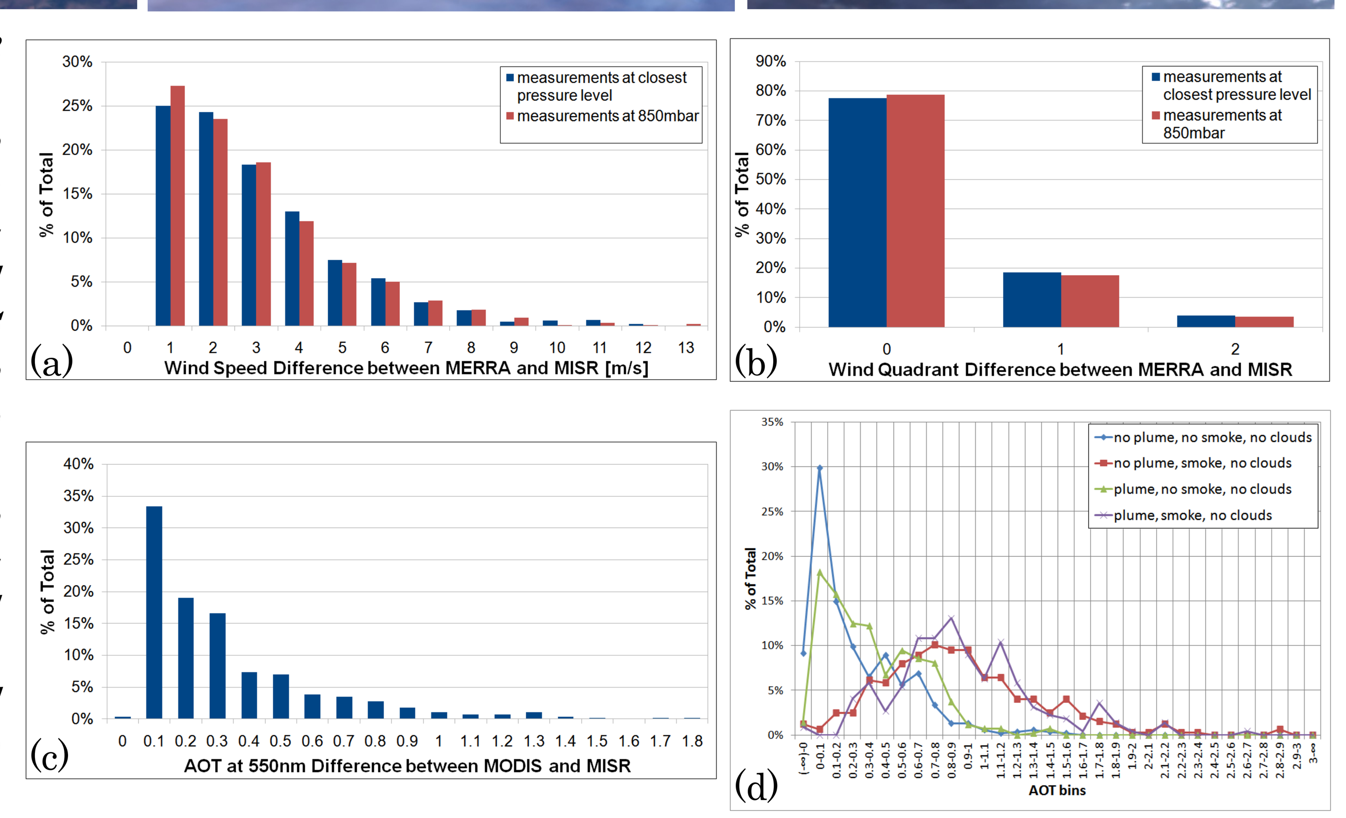

Figure 2 (right). Comparative charts between MISR digitalized plumes/images and MODIS and MERRA data used in this research (a-c) and MODIS AOT distributive analysis (d) are shown.

Global Emission Coefficient Maps

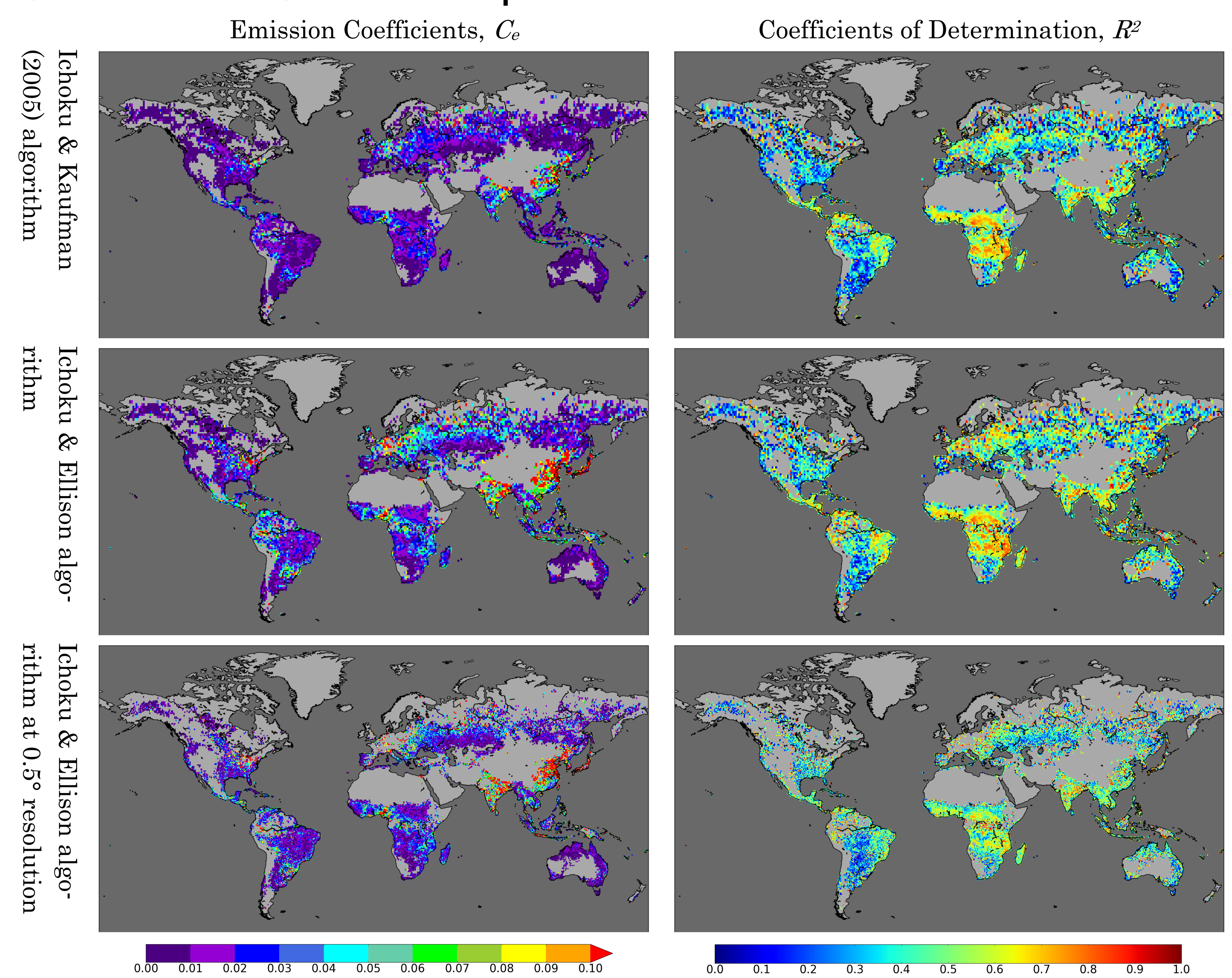

Figure 3. These maps depict coefficients of emission (C_e) and corresponding R^2 values (3). Unless otherwise stated, linear regression forced through the origin is used to calculate C_e using all available data between 2003-2010 at 1° resolution.

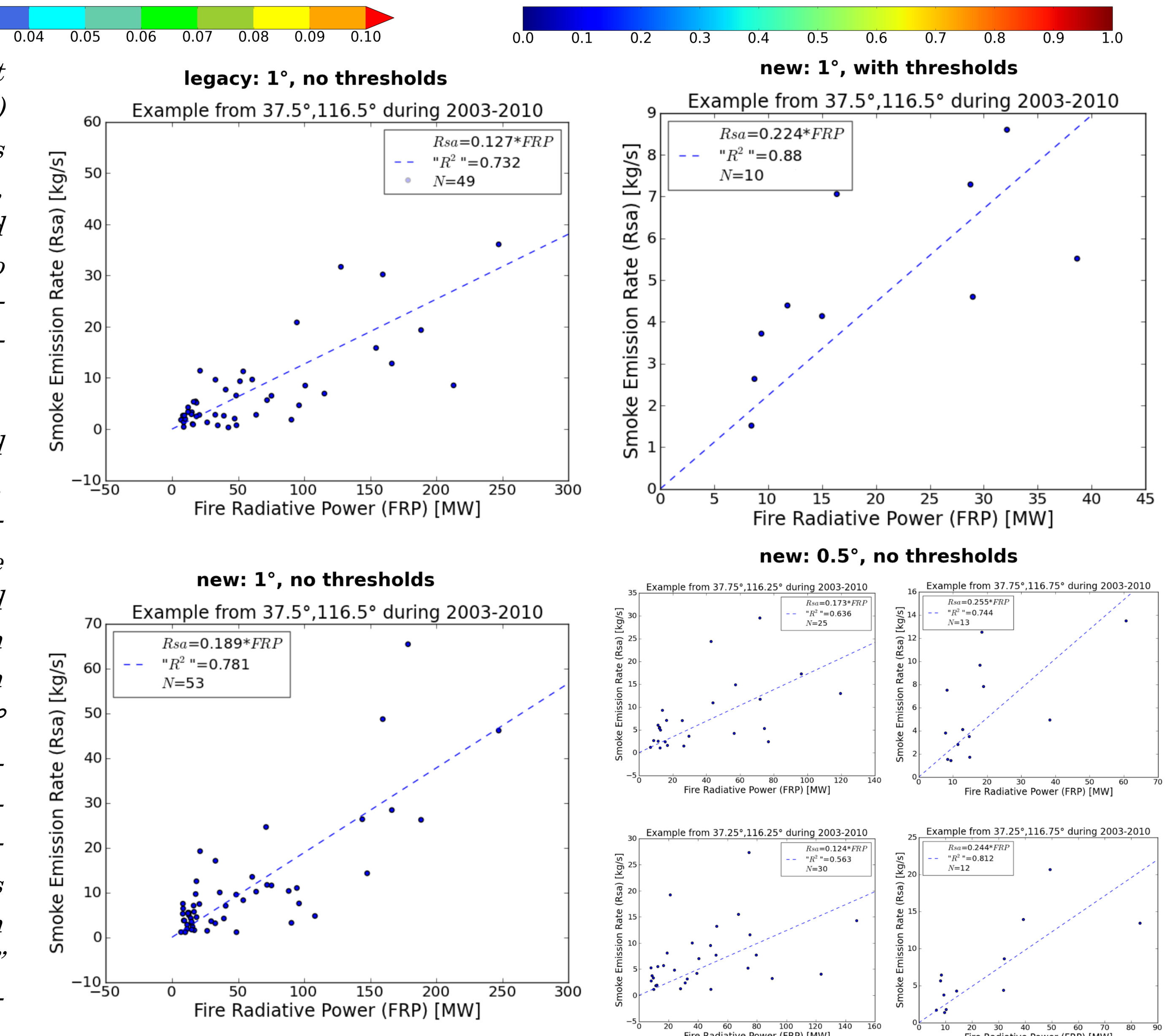

Figure 4. C_e is calculated from linear regression plots, where FRP is the independent variable and R_{sa} is the dependant variable, forced through the origin as shown for these examples taken in Northeast China at 37.5° latitude and 116.5° longitude using different configurations as described in Figure 3. "Legacy" indicates the Ichoku & Kaufman (2005) algorithm and "new" indicates the Ichoku & Ellison algorithm.

Northern Sub-Saharan Africa Smoke Emissions

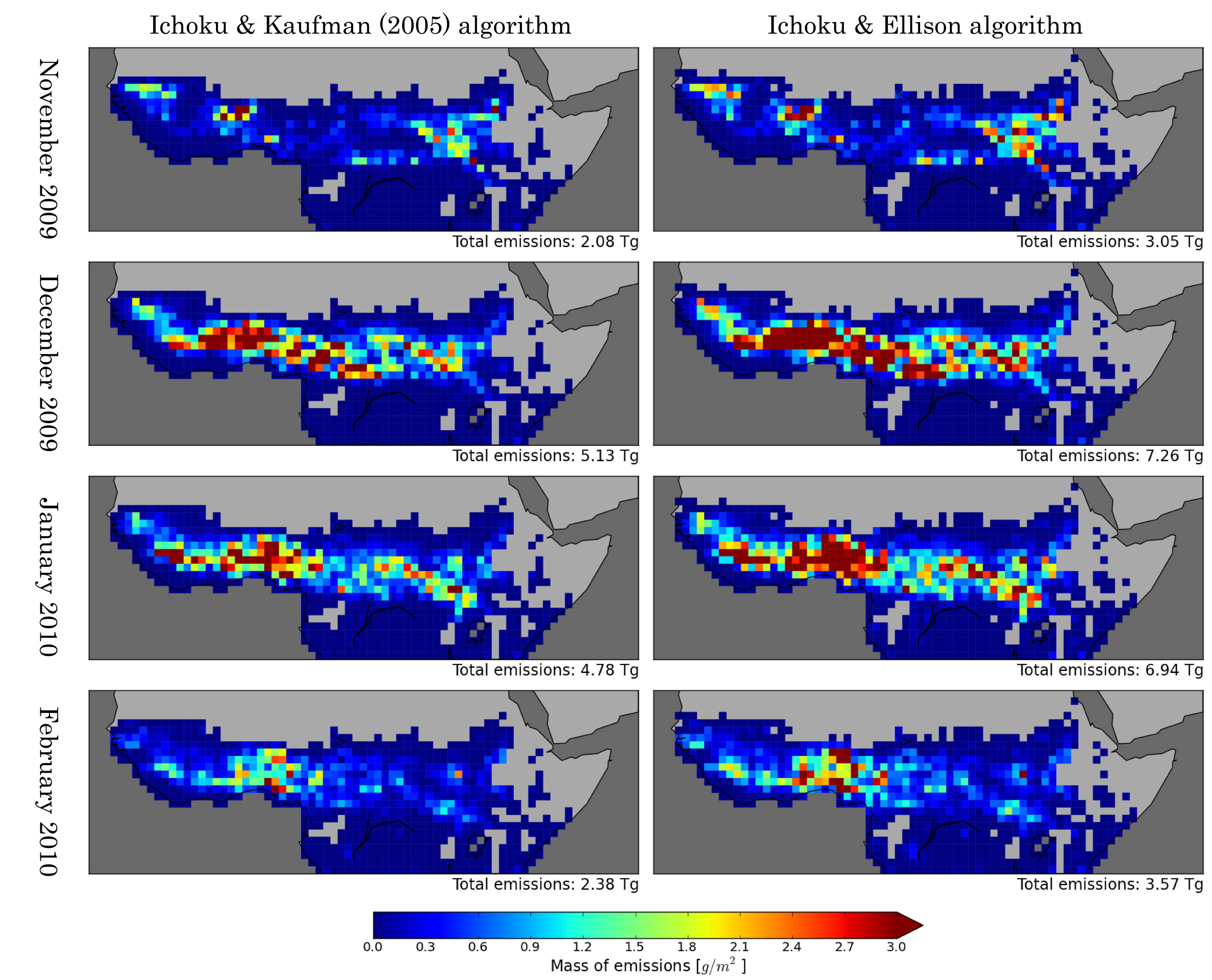

Figure 5. Coefficient of emission (C_e) maps as shown in Figure 3 are used along with SEVIRI hourly, 1° gridded (MODIS-corrected) FRP data(4) over northern sub-Sahara Africa to derive monthly smoke emissions.

Conclusion

Good progress has been made to obtain sufficient amounts of data to make initial estimations of emission coefficients, using both the Ichoku & Kaufman (2005) algorithm and the Ichoku & Ellison algorithm, which has also been used to easily and quickly derive emissions of total particulate matter over northern sub-Saharan Africa. The initial product will be made available soon, with subsequent versions following it to gain better correlation between FRP and R_{sa} by identifying and filtering out bad data.

References

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