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Identification and description of fire emission plumes from Sentinel-5p observations

Daniel Kinalczyk[1], Matthias Forkel[1], and Jos de Laat[2]
[1]Technische Universität Dresden, Institute of Photogrammetry and Remote Sensing, Junior Professorship in Environmental Remote Sensing, Germany (daniel.kinalczyk@tu-dresden.de)
[2]Koninklijk Nederlands Meteorologisch Instituut (KNMI)

Understanding the dynamics and characteristics of emission plumes from wildfires is of paramount importance for environmental monitoring and policy decisions. These plumes, composed of various greenhouse gases and pollutants, can have far-reaching consequences on global climate, air quality and health. In this study, a data-driven approach to detect and characterise emission plumes from wildfires utilising TROPOMI (Tropospheric Monitoring Instrument) of the Sentinel-5p satellite observations of nitrogen oxides (NOx), carbon monoxide (CO) and aerosols. The analysis leverages VIIRS active fire data to identify locations of fire occurrence, laying the foundation for plume detection. The primary hypothesis states that a plume image consists of three components: a plume body or core, a transitional zone from plume to clear sky, and the clear sky itself. To realise this hypothesis, a data-driven unsupervised algorithm to identify and map plumes is developed, which is based on kernel functions to pre-process the Sentinel-5p images. These kernels effectively highlight plume-related features, allowing for more precise delineation. Subsequently, Gaussian Mixture Models (GMM) are utilised to classify the images into three components of the plume according to the main hypothesis. In instances where multiple plume candidates exist, a Gaussian distance weighting function to identify the likeliest plume is employed. Furthermore, the mapping of the plume-clean air transition zones is further evaluated by employing Monte Carlo simulations to validate and refine the transition zone assessments. To verify the detections, plumes of methane (CH4), carbon monoxide (CO), formaldehyde (HCHO), nitrogen dioxide (NO2) and aerosols for several plumes over the Amazon and Alberta are extracted and the plume properties are related to different landcover types. The findings of this study provide valuable insights into the development of an advanced methodology for plume detection, which has broad implications for the understanding and monitoring of fire emissions and atmospheric research.