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On the significance of global greening trends with multiple testing – an application to five data products

José Cortés¹, Miguel Mahecha², Markus Reichstein², and Alexander Brenning¹

¹Department of Geography, Friedrich Schiller University, Jena, Germany (jose.cortes@uni-jena.de)

²Max Planck Institute for Biogeochemistry, Jena, Germany

The statistical analysis of environmental data from remote sensing and Earth system simulations often entails the analysis of gridded spatio-temporal data, where a hypothesis test is performed for each grid cell. When the whole image or set of grid cells is analyzed for a global effect, the problem of multiple testing arises – this applies to the study of global greening trends, which have been widely reported. Although there is a consensus on the greening patterns, there is still much debate about the attribution to CO₂ fertilization, temperature rise, and land use intensification. We argue that none of the studies uses a proper statistical methodology and hence fail to identify the hotspots of “real greening”. To perform statistical inference, we need to account for this multiplicity of hypothesis tests. In this work, we demonstrate how to address this issue with a permutation method based on clustering, which allows us to make robust inference on regions or patterns, using the Mann-Kendall Test as the basis. The method is illustrated by comparing global greening trends derived from five different data products which contain global data for Leaf Area Index and/or Fraction of Absorbed Photosynthetically Active Radiation: GIMMS 3g, NOAA CDR, Land Long Term Data Record, LTDR MOD15A2, and SPOT/PROBA-V data. We find that many greening trends detected in earlier studies do not withstand our rigorous significance testing. Yet we do find consistent greening trends in South East China. Our results show substantial differences in statistically significant patterns of greening and browning among the products used, but greatly reduce the focal areas of greening that should be investigated in detail with proper trend-attribution methods.