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Remote Sensing Classification Uncertainty: Validating Probabilistic Pixel Level Classification

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There already exists an extensive literature on classification of remotely sensed imagery, and indeed classification more widely, that considers a wide range of probabilistic and non-probabilistic classification methodologies. Although for many probabilistic classification methodologies posterior class probabilities are produced per pixel (observation) these are often not communicated at the pixel level, and typically not validated at the pixel level. Most often the probabilistic classification in converted into a hard classification (of the most probable class) and the accuracy of the resulting classification is reported in terms of a global confusion matrix, or some score derived from this. For applications where classification accuracy is spatially variable and where pixel level estimates of uncertainty can be meaningfully exploited in workflows that propagate uncertainty validating and communicating the pixel level uncertainty opens opportunities for more refined and accountable modelling.

In this work we describe our recent work applying and validation of a range of probabilistic classifiers. Using a multi-temporal Landsat data set of the Ebro Delta in Catalonia, which has been carefully radiometrically and geometrically corrected, we present a range of Bayesian classifiers from simple Bayesian linear discriminant analysis to a complex variational Gaussian process based classifier. Field study derived labelled data, classified into 8 classes, which primarily consider land use and the degree of flooding in what is a rice growing region, are used to train the pixel level classifiers. Our focus is not so much on the classification accuracy, but rather the validation of the probabilistic classification made by all methods.

We present a range of validation plots and scores, many of which are used for probabilistic weather forecast verification, but are new to remote sensing classification including of course the standard measures of misclassification, but also plotting reliability diagrams and computing Brier Skill Scores. We show that a combination of the various classifiers provides the most reliable probabilistic predictions (and also the best deterministic predictions). We show that the classification uncertainty is very spatially variable and reliably estimated statistically, and discuss possible summary measures for representing the overall uncertainty to users. We show how probabilistic classification results can be encoded using the recently developed GeoViQua Quality Model and UncertML.

We discuss the importance of the results in terms of classification in general and consider the relation between probabilistic classification and the issue of mixed pixels, consisting of more than one class. We also describe how the probabilistic classification results can be propagated through a complex workflow that considers the payment of farmers in the region based on the degree to which their fields are flooded from a given time period.