Technical University of Denmark

Comparison between Multitemporal and Polarimetric SAR Data for Land Cover Classification

Skriver, Henning

DTU Library
Technical Information Center of Denmark

COMPARISON BETWEEN MULTITEMPORAL AND POLARIMETRIC SAR DATA FOR LAND COVER CLASSIFICATION

Henning Skriver

DTU Space
Technical University of Denmark
Ørsteds Plads, Building 348, DK-2800 Lyngby, Denmark
Ph.: +45 4525 3792, fax: +45 4593 1634, e-mail: hs@space.dtu.dk

ABSTRACT

The investigation focuses on the determination of the land cover type using SAR data, including single polarisation, dual polarisation and fully polarimetric data, at L-band. The analysed data set was acquired during the AgriSAR 2006 campaign by the airborne ESAR system over the Gormin agricultural site (Northeast Germany). The multitemporal acquisitions significantly improve the classification results for single and dual polarization configurations. The best results for the single and dual polarization configurations are better than for the polarimetric mode. Overall, the cross-polarisation configuration provides the best results.

Index Terms— Synthetic aperture radar, land cover, classification, polarization, agriculture

1. INTRODUCTION

Land process models (i.e. SVAT/Hydrological models), which simulate energy and mass exchanges between soil, vegetation, and atmosphere, can in principle calculate vertical soil moisture profiles and energy fluxes at adequate spatial and temporal scales. Information that is crucial for a number of applications such as flood and drought prediction, crop irrigation scheduling, and meteorology. However, their accuracy is usually limited by the scarce knowledge of input data. Remote sensing has the potential to provide estimates of some of the model inputs, such as for instance the land cover type, the soil moisture and the LAI.

Also, land cover maps provide fundamental information to many aspects of land use planning and policy development, as a prerequisite for monitoring and modelling land use and environmental change, and as a basis for land use statistics at all levels. It is well known that remote sensing may provide important and valuable information about crops and other land cover classes. This is true for both optical/infrared and radar data, where radar data is especially important for regions where cloud cover is a problem. In this paper, the investigation focus on the determination of the land covers type using SAR data, including single polarisation, dual polarisation and fully polarimetric data, at L-band. The analysed data set was acquired during the AgriSAR 2006 campaign. From April to July, approximately every week there were acquisitions of the ESAR system at C and L bands. Ground surveys to obtain detailed land cover maps were performed during two periods of intensive in situ measurements.

Different approaches have been used to extract land cover and crop information from polarimetric SAR data, i.e. statistical methods based on the Wishart distribution [1] or covariance matrix elements transformed into backscatter coefficients [2], methods based on scattering mechanisms [3-4], and knowledge-based methods [5-7]. In this paper, the focus is on the statistically-based methods using single-polarisation data, dual-polarisation data, and fully polarimetric data - in all cases using multitemporal data. Results for L-band only are presented, whereas results for both C- and L-band can be found in [8].

2. DATA SETS

The AgriSAR campaign was carried out over the Demmin site, in the Mecklenburg-Western Pomerania (Nothern Germany) from April to August 2006. The campaign was funded by ESA, coordinated by DLR and included the participation of 16 European institutions. The campaign encompassed multi-temporal airborne and spaceborne SAR and optical acquisitions together with extensive in-situ measurements of bio-physical parameters. The principal objective of the campaign was to assess the impact of the future ESA GMES Sentinel-1 and -2 missions for land applications and to provide a well-documented database to investigate the bio-physical parameter retrieval.

The Demmin test site is an agricultural area characterized by an almost flat topography (altitude variations within ±60m), and average yearly rainfall of approximately 489 mm and an average temperature ranging between 18° in July and 1° in January. The main cultivated crops are winter wheat, winter rape, winter barley, maize and sugar beet. The acquisitions dates are listed in Table 1.

ACQ. DATE	JULIAN DAY	DATA	DATA
APRIL 19	109	L-QUAD	C-HH+HV, C-VV+VH
MAY 3	123	L-QUAD	C-HH+HV, C-VV+VH
MAY 11	131	L-QUAD	C-HH+HV, C-VV+VH
MAY 16	136	L-QUAD	C-HH+HV, C-VV+VH
MAY 24	144	L-QUAD	C-HH+HV, C-VV+VH
JUNE 7	158	L-QUAD	C-HH+HV, C-VV+VH
JUNE 13	164	L-QUAD	C-HH+HV, C-VV+VH
JUNE 21	172	L-QUAD	C-HH+HV, C-VV+VH
JULY 5	186	L-QUAD	C-HH+HV, C-VV+VH
JULY 12	193	L-QUAD	C-HH+HV, C-VV+VH
JULY 26	207	L-QUAD	C-HH+HV, C-VV+VH

Table 1. ESAR acquisitions in the East-West track

The scattering matrix data in the form of SLC products were coregistered, converted to covariance matrix format and multilooked with a pixel spacing of 3 m and an equivalent number of looks of approximately 10.

3. METHODOLOGY

The statistical, data-driven methods have been studied for single, dual, and full-polarisation data. As data are 10-look the Gaussian assumption for the probability density function for the backscatter coefficients for individual polarisations is valid. Hence, the classification method used for the single and dual polarisation cases is the standard Baysian classification method for multivariate Gaussian statistics.

For the full-polarimetric cases, the standard ML Wishart classifier originally proposed by Lee et al. (1994) is used [1]. Also, the method proposed by Hoekman and Vissers (2003) using a new reversible transform of the covariance matrix into backscatter intensities has been applied [2].

In single, dual and full-polarisation cases, the multi-temporal information will be important for the classification, and therefore both single date and multi-temporal results will be reported. An example of classification results is shown in Fig. 1, where the results from using the cross-polarized channel at L-band are shown. The classification error is the average classification error for all the classes involved in the classification. The numbers on the x-axis refer to the acquisition time, i.e. the Julian day (cf. Table 1).

Many classification results reported in the literature are based on a too optimistic approach, where the same class polygons (training set) are used both for the training of the classifier and the evaluation of the results. In a more realistic approach, an independent test set is used for the evaluation. An example of the difference between these two approaches is shown in Fig. 1, where the estimated results based on these two approaches are shown. It is clearly seen, that the approach where the same set is used for training and testing underestimates the classification error. In this paper, all results are based on an independent test set.
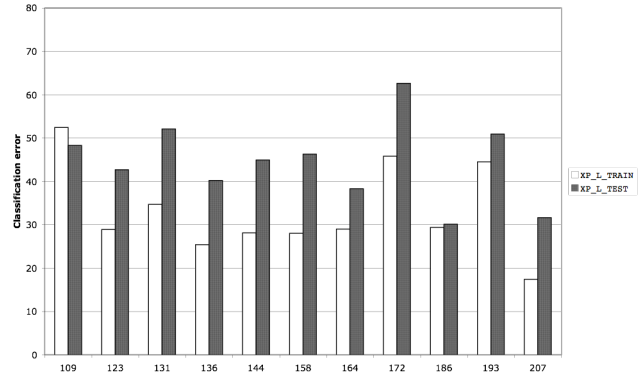

Fig. 1. Classification errors for the training and the test set for the cross-polarised channel at L-band.

4. CLASSIFICATION RESULTS FOR SINGLE AND DUAL POLARISATION

For a number of present and planned SAR missions, the main or only operation modes are single and/or dual polarization modes. Therefore, it is important to assess the classification potential of such modes. The classification potential for the different polarizations, frequencies, and acquisition times is evaluated by computing the average classification error for each case. The number of wrongly classified pixels is determined for each class, and an average error is computed.

Figs. 2-4 show the classification errors for the single polarisation HH and XP backscatter coefficients, and the dual-polarisation backscatter coefficients (HH, XP) for L-band. For each of the backscatter coefficients, three sets of classification errors are shown, i.e. single-acquisitions errors, and two cases of multi-temporal errors, i.e. using all acquisitions, and using only monthly acquisitions. The left columns show the classification error if only a single acquisition is used, the middle columns show the classification error if all acquisitions up to and including the one indicated with the Julian day is used, and the right columns show the error for monthly acqusitions.

It is very clear from all the Figs. 2-4 that the multitemporal information improves the performance of the classification. The single acquisition results show the same level of classification performance for all acquisition dates, whereas the multitemporal results show a decreasing trend in the classification error when more and more acquisitions are combined. The improvement, for instance, for the L-XP backscatter coefficient is between the worst day, Julian day 172: 63%, and the best performance when all acquisitions are combined: 3%. It is clear from these results that single acquisitions with single/dual-polarisation do not produce sufficient classification performance, hence multitemporal data are necessary. It is also seen that monthly acquisitions perform almost as well as all acquisitions.

For the multitemporal single polarisation results, the HH and VV results are comparable and the HH-polarisation is slightly better. The XP-polarisation is significantly better than the two co-polarised results.

For the multitemporal dual-polarisation results, the classification results where the XP-polarisation is included are better than the results, where the two co-polarised channels are used. Comparing with the single polarisation results, it can be seen that the use of two polarisations does not improve the results significantly.

The classification errors using all the multitemporal acquisitions are shown in Table 2. As indicated above, the best results are obtained using the XP-polarisation alone both for L- and C-band. In conclusion, the multitemporal acquisitions improves significantly the classification performance for both the single polarisation case and the dual-polarisation case. One thing that may bias the results, however, is the relatively small number of classes present in the AGRISAR 2006 data set. Therefore, the actual results obtained may be too optimistic.
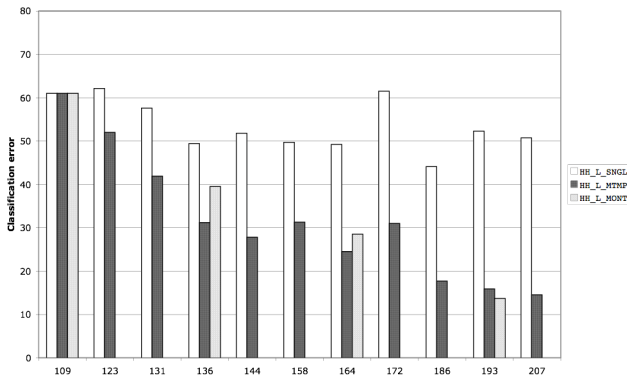

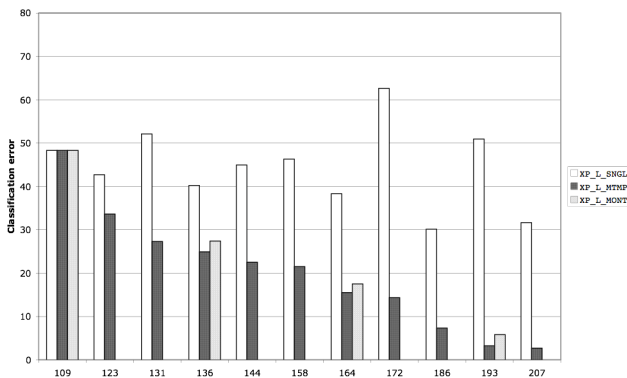Fig. 2. Classification errors for HH backscatter at L-band

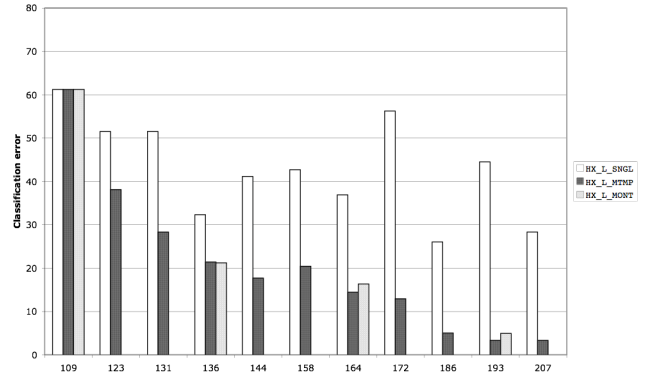Fig. 3. Classification errors for XP backscatter at L-band

Fig. 4. Classification errors for HH and XP backscatter at L-band

	L	C
HH	14,5	22,8
VV	21,1	18,5
XP	**2,7**	**6**
HHVV	11,3	16,1
HHXP	**3,3**	10,5
VVXP	5,0	**9,5**

Table 2 Classification accuracies for the single and dual polarization results for multitemporal combinations

5. CLASSIFICATION RESULTS FOR FULLY POLARIMETRIC DATA

A number of present and planned satellite SAR missions will provide polarimetric SAR data, and hence it is important to assess the potential improvement of classification accuracies using full polarimetric data.

5.1. Complex Wishart Classifier

The average classification accuracies for applying the Complex Wishart classifier [1] to the AGRISAR 2006 data set are shown in Fig. 5. A number of interesting observations can be made. It is clear that the difference between the single acquisition and the multitemporal case is much smaller than for the single and dual-polarisation cases reported in the previous section. Also, it is clearly seen that the multitemporal acquisitions do not cause any significant improvement of the results except for the first two acquisitions. The classification error using all multitemporal acquisitions is shown in Table 3. It is seen that this result is significantly worse than the results obtained for the single and dual-polarisation modes. In conclusion, there is a trade-off between the polarimetric information and the multitemporal information, where the best overall results are obtained using the multitemporal information. Also, the multitemporal single polarisation mode performs better than the Complex Wishart classifier.
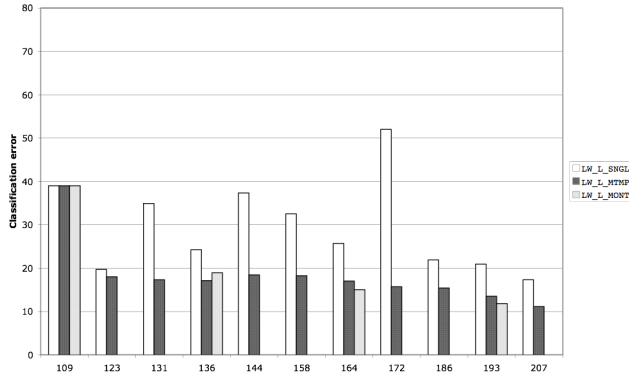
Fig. 5. Classification errors for the Wishart classifier

Complex Wishart	11,1

Table 3. Classification accuracy for the complex Wishart classifier using the multitemporal acquisitions

5.2. Hoekman and Vissers Classifier

Hoekman and Vissers (2003) introduced a new reversible transform of the covariance matrix into backscatter intensities [2]. The advantage is that the full polarimetric information can be described by backscatter intensities alone. This description will for instance better than the Wishart distribution describe the statistics of a collection of homogeneous areas for the same class but with some variability of the mean parameters due to e.g. slightly different development stages for crops. The method is applied using 5, 7, and 9 backscatter intensities, respectively.
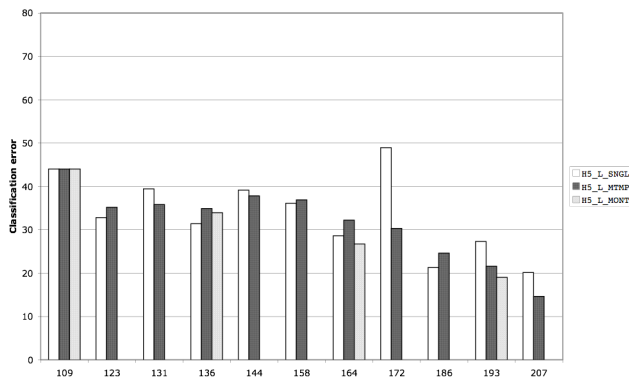

Fig. 6. Classification errors for the Hoekman and Vissers classifier with 5 backscatter coefficients.

5 backscatter intensities	14,6
7 backscatter intensities	26,8
9 baskcatter intensities	21,3

Table 4. Classification accuracy for the Hoekman and Vissers classifier using the multitemporal acquisitions

Fig. 6 shows the classification error for 5 backscatter intensities. The difference between single acquisition and multitemporal acquisition is very small, and also, in some cases the single acquisition case performs better than the corresponding multitemporal case. The classification errors using all the multitemporal acquisitions are shown in Table 4. We observe that the set with 5 backscatter intensities performs better than the two other sets. Also, we can see that this classifier performs worse than the Complex Wishart classifier reported in the previous section.

6. CONCLUSIONS

The best single polarisation is the cross-polarisation When all the large number of multitemporal acquisitions is used, the average classification error for all the classes for the cross-polarisation is about 3% at L-band. Dual polarisations do not improve the best classification result further. For both the single and dual polarisation modes the multitemporal acquisitions improves clearly the classification accuracy. Monthly acquisitions have the same error level as the more frequent acquisition modes. The results may be biased by the relatively small number of classes present, and the actual results may be somewhat too optimistic.

There is a trade-off between the polarimetric and the multitemporal information, where the best overall results are obtained using the multitemporal information. Both the Complex Wishart classifier and the Hoekman and Vissers classifier performed worse than the single polarisation case. The best multitemporal classification error for the first classifier was 11% and for the latter 15%.

7. REFERENCES

[1] Lee, J.S., M.R. Grunes, and R. Kwok, "Classification of multi-look polarimetric SAR imagery based on complex Wishart distribution", *International Journal of Remote Sensing*, vol. 15, pp. 2299-2311, 1994.

[2] Hoekman, D.H., and M.A.M. Vissers, "A new polarimetric classification approach evaluated for agricultural crops", *IEEE Trans. Geosci. Rem. Sens*., vol. 41, pp. 2881-2889, 2003.

[3] Cloude, S.R., and E. Pottier, "An entropy based classification scheme for land applications of polarimetric SAR", *IEEE Trans. Geosci. Rem. Sens*., vol. 35, 68-78, 1997.

[4] Freeman, A., and S.L. Durden, "A three-component scattering model for polarimetric SAR data", *IEEE Trans. Geosci. Rem. Sens*., vol. 36, pp. 963-973, 1998.

[5] Pierce, L.E., F.T. Ulaby, K. Sarabandi, and M.C. Dobson," Knowledge-based classification of polarimetric SAR images", *IEEE Trans. Geosci. Rem. Sens*., vol. 32, pp. 1081-1086, 1994.

[6] Skriver, H., "Land-cover map information from polarimetric SAR using knowledge-based techniques", 3rd Int. Symp. on Retrieval of Bio- and Geophysical Parameters from SAR data for Land Applications, 2001.

[7] Ferrazzoli, P., L. Guerriero, and G. Schiavon, "Experimental and model investigation on radar classification capability", *IEEE Trans. Geosci. Rem. Sens*., vol. 37, pp. 960-968, 1999.

[8] Skriver, H., F. Mattia, G. Satalino, A. Balenzano, V. Pauwels, N. Verhoest, and M. Davidson, "Land-Cover Classification from AgriSAR SAR Data", AgriSAR Final Workshop, ESA, 2007.