Classification of Ice Types from Convair-580 Data of Northumberland Strait, PEI

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ABSTRACT / RESUME

The discrimination between open water and sea ice, and/or between sub -classes of sea ice are challenges for SAR remote sensing. Compared to single channel SAR data, fully polarimetric data contain more physical information about the scattering processes, which can be used to increase the discrimination accuracy.
Unsupervised polarimetric classification or segmentation approaches allow the discrimination between sea ice and open water, as well as between several classes of sea ice. However, the main problem lies in the physical interpretation of the obtained classes. Airborne polarimetric SAR data acquired with the Environment Canada CV-580 C-band SAR is classified using an automated Wishart classifier and class mean information is investigated.

1. INTRODUCTION

Spaceborne SAR sensors represent the single most important information source for operational sea ice monitoring. The classification of sea ice types and the subsequent production of ice charts is an important task for ice centres around the world. The availability of multi polarization and fully polarimetric SAR data from spaceborne sensors like ENVISAT, RADARSAT-2 ALOS-PALSAR and TERRASAR-X will provide an opportunity to implement new classification methods based on the increased information available. Polarimetric SAR data is known to have a higher information content compared to single polarization data. A number of classification methods has been developed to utilize the information available for a scene. One of these methods is the Bayesian Wishart classifier.

In this paper a fully polarimetric data set of sea ice acquired in the Northumberland Straight on the Canadian East Coast is classified using the Wishart classifier. In an effort for class interpretation, the polarimetric signatures of the classes are analysed.

2. CV-580 DATA

On March 8, 2001 the Environment Canada CV-580 airborne SAR acquired fully polarimetric SAR data in the Northumberland Strait off the Coast of New Brunswick. The acquisition campaign was part of an ongoing effort by the Canadian Ice Service to study the benefits of multi-polarization and fully polarimetric SAR data of sea ice for their operational needs. Fig. 1 shows part of a RADARSAT-1 ScanSAR wide image acquired on the same day over the Canadian East Coast, overlaid with a magnified RGB colour composite using the CV-580 channel information HH, HV and VV. The airborne image covers 6.4 km in slant range and approximately 8 km in azimuth. SLC data with a pixel size of 4 m in slant range and 0.43 m in azimuth are available. Because of the high resolution and to reduce the effect of speckle noise, the data is multi-looked (40 looks in azimuth and 4 looks in range) resulting in a pixel size of approximately 17 m in azimuth and 16 m in slant range.

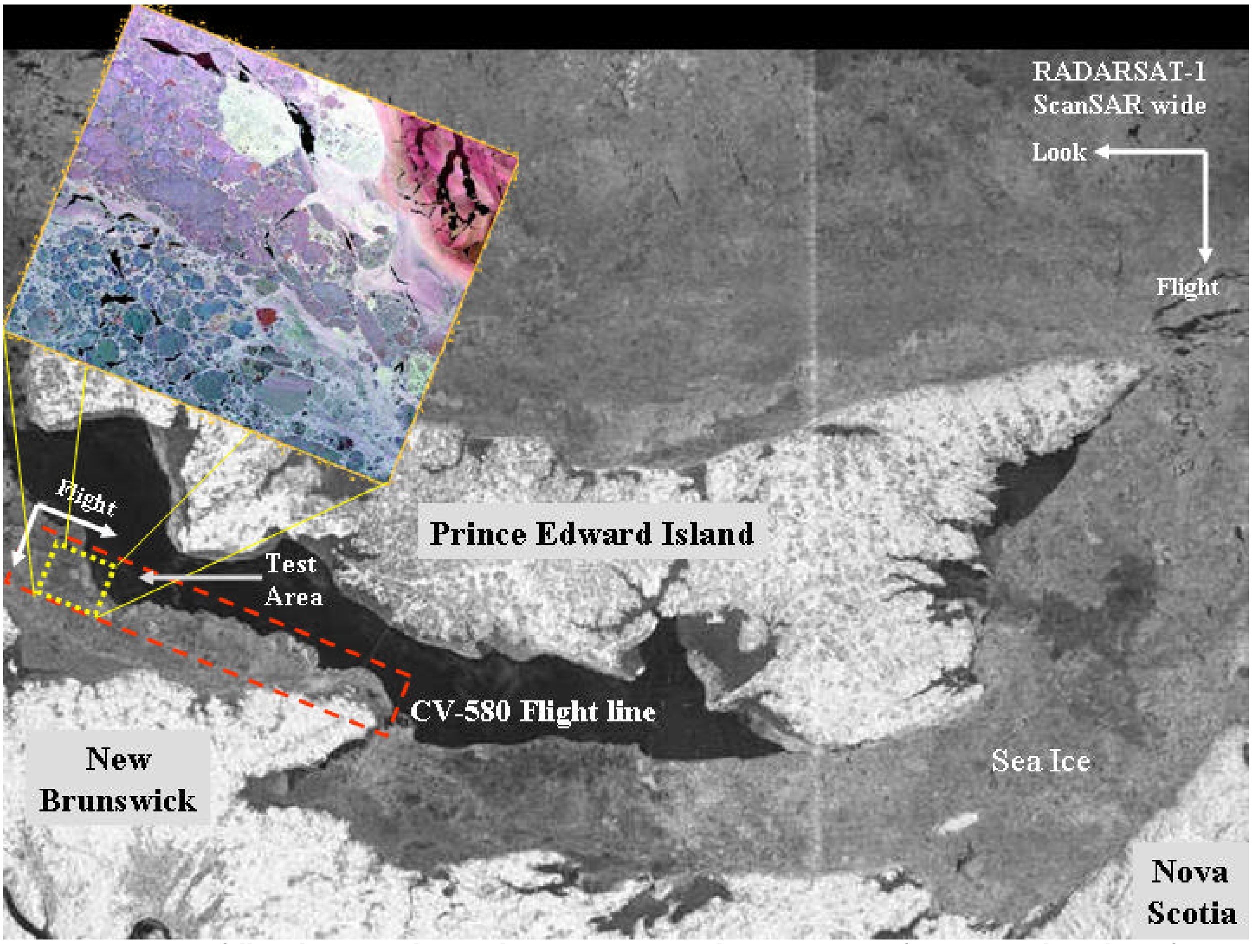

Fig. 1. CV-580 fully polarimetric data (Red: VV; Green: HV; Blue: HH) on top of a 150 x 210 km subset of a RADARSAT-1 ScanSAR image. Flight line and test area (approx. 6.4 x 8 km) of the CV-580 data are shown in red and yellow respectively. Both images were acquired on March 8, 2001 over the Canadian East Coast. The bright areas in the ScanSAR image are landmasses; the black areas are open water. The rest of the image shows sea ice coverage. The vertical streak is the nadir return that is unavoidable in some ScanSAR configurations.

Both images were acquired in freezing conditions. Climate reports for Moncton (New Brunswick) and Charlottetown (Prince Edward Island) from March 7, 8, and 9, 2001 indicate an average temperature in the area of approximately –4.2 degrees Celsius. Temperature records also indicate an extended melt-free period prior to data acquisition. Analysis of the SAR data by the Canadian Ice Service shows an ice concentration >90% for the area of the airborne acquisition. The ice is generally classified as medium First Year Ice (FYI) (70-120 cm thick) with floe sizes between 500 m and 2000 m (as observed from RADARSAT data). Using additional information like NOAA data, ice breaker and coastal observation, the more detailed ice analysis chart shows a mix of ice types in the area of interest [40% grey ice (10-15 cm thick), 40% medium FYI (70-120 cm thick), 20% thin FYI (30-70 cm thick)]. Based on the more detailed information floe sizes between 20 m and 500 m are reported.

From Fig. 1 it can be seen that the airborne scene covers much less area than the ScanSAR scene. The RGB colour composite image reveals rich information content, partly due to the availability of 3(4) channels and partly due to the much higher resolution.

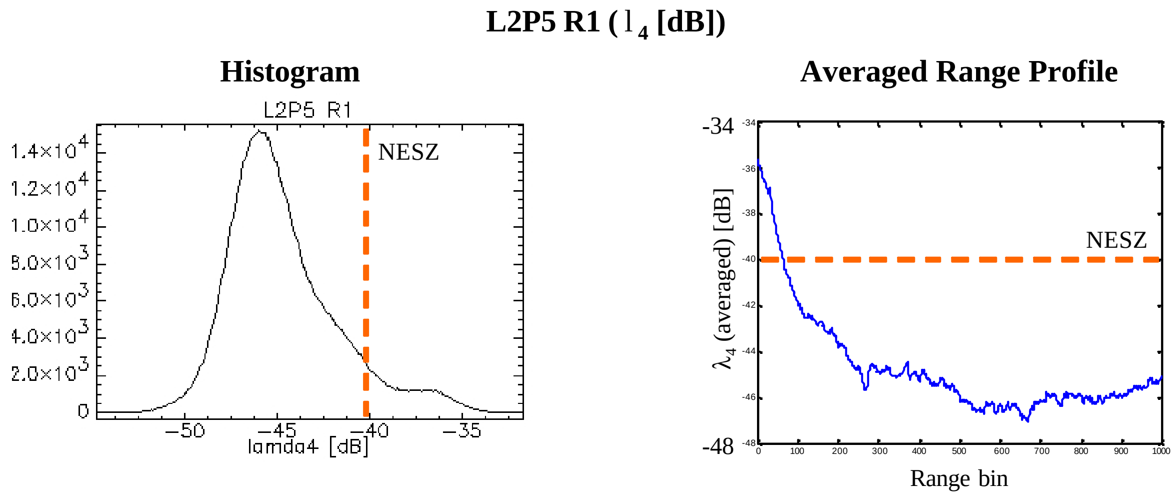

Fig. 2. Example results for a λ_4 analysis indicating that scene L2P5-R1 shows an increase in the λ_4 in near range above the specified sensor noise level NESZ. The near range section of the image was subsequently excluded from analysis.

3. DATA CALIBRATION

The CV-580 acquisition campaign included a number of flight lines in the area. Due to the high resolution of the data (4 m in range and 0.4 m in azimuth) images of roughly 8 km x 8 km were made available in single look complex format. The test area for this investigation was selected by CIS experts because of its interesting mix of ice signatures. No corner reflectors are available for the test site. Initial tests raised some concern about noise in the data. An analysis of the fourth eigenvalue (λ_4) of the coherency or the covariance matrix (histogram and range profile) was conducted to estimate the noise level in the image.

The covariance and the coherency matrices are common representations of polarimetric SAR data. Both matrices share the same eigenvalues and can be expressed as 3x3 or 4x4 matrices. In the latter case, the fourth eigenvalue represents a measure for the amount of noise in the image. If no noise is present and reciprocity is assumed (i.e. HV=VH), the matrices would be rank three and λ_4 would be zero.

Example results for a λ_4 analysis shown in Fig.2 indicate that the NESZ of the system (-40 dB) is exceeded in near range, otherwise, the analysis indicated a noise level of approximately –45 dB. The near range section of the image was subsequently excluded from analysis reducing the test area to about 6.4 km x 8 km and the incidence angle range to 41° to 64° (originally 22° to 64°).

While the test conducted is not fully conclusive on the quality of the polarimetric data it is possible to exclude data that do not meet these quality criteria from further analysis.

4. CLASSIFICATION

Visual analysis of the polarimetric RGB composite image reveals six different ice types in the image, four of which are FYI. Leads and new forming ice are also present in the scene (see Table 1). Expert ice analysts from the Canadian Ice Service aided in the interpretation of the data. Unfortunately, no additional validation information is available for the acquisition; an assessment of the ice types is therefore only possible based on the CV-580 data available.

The scene was classified using the Wishart classifier with a H/α segmentation used as initialization [1]. Due to the high level of pixel averaging, no additional filtering of the data needed to be applied before classification. As only six classes are desired, the H/α segmentation was modified in that way that H=0.9 was not used as a threshold [2]. Fig. 3 shows the classification result; the corresponding colour assignment is described in Table 1.

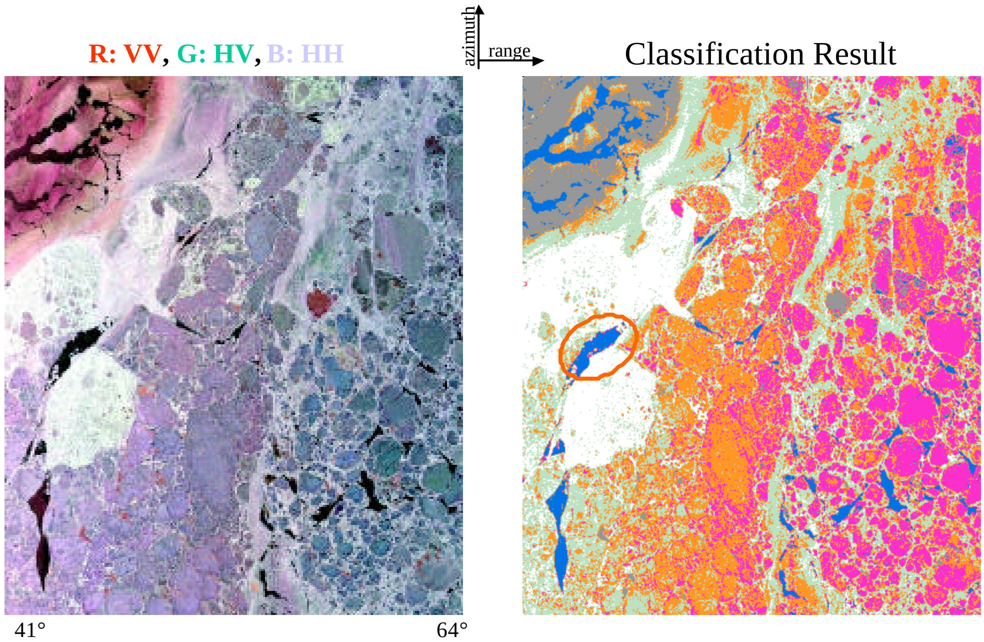

Fig. 3. CV-580 polarimetric RGB composite (left) and classification result (right).
Test site: Northumberland Strait. (Data set L2P5 R1). The colour assignment is shown in Table 1).
The red ellipse in the right image indicates one floe assumed to be covered in thin ice (see Section 5 for details).

Table 1. Colour assignment for CV-580 classification result (see Fig. 3).
The class number is arbitrary and used only in the classification process.

Class #	Colour	Ice Type
1	Grey	Young Ice
2	Magenta	FYI (floes, far range)
3	White	rough FYI (strong HV)
4	Green	ridged FYI
5	Blue	Leads
6	orange	FYI (floes, near range)

All classes show good agreement with the ice types derived by the expert analyst, which are described in Table 1. Leads, openings in the ice, are classified. There is reason to believe that some leads are open water while others are covered in thin ice. This is discussed in more detail in Section 5.

5. ANALYSIS OF CLASSES

The polarimetric data were analysed based on the classification discussed in Section 4.

Fig. 4 shows the histograms for the polarimetric channels as well as the total power divided by classes. The FYI classes (see Table 1) are partially divided by the reflected power. Simple thresholds for FYI type separation would not work for either one of the channels in this case given the remaining overlap and how well the classification result corresponds to the visual appearance of the RGB colour composite image (see Fig. 3). The young ice class has significantly different levels for HH and VV. Using one co-polarized channel only, young ice could not be uniquely identified and would be confused with a FYI type, although with different FYI types for HH and VV. Young ice is well classified using the algorithm described in Section 4. The signature of leads is generally weakest and also shows a significant difference in HH and VV. The HV signature is close to –45 dB, the measured noise level for the scene (see Section 3).

Generally, the HV response is below about –20 dB. This would pose a problem if the NESZ of the sensor is of about the same order which is the case for current and near future spaceborne missions capable of providing HV data. Classifying the data to the level of detail presented in this paper may not be possible if a sensor with a higher noise level is used for data acquisition.

In addition to channel information, classes were investigated for other polarimetric parameters. For this purpose class mean information was determined. Fig.5. shows class mean information for two selected classes, one FYI class and Leads. Information includes the covariance matrix, selected polarimetric parameters, H/A/α scatter plots (colouring indicates the density of the plot) as well as polarization response plots.

Table 2. Class average values for polarimetric parameters
(TP: Total Power; $|\rho_{HHVV}|$: magnitude of the complex correlation of HH and VV
Ps,Pv: Freeman-Durden scattering components for surface and volume
H,A,a: Cloude-Pottier decomposition parameters)

	TP	**HH/VV**	**Ps/Pv**	$|r_{HHVV}|$	**H**	**A**	a
Ice Type	**[dB]**	**[dB]**	**[dB]**	**[1]**	**[1]**	**[1]**	**[°]**
Leads	-24.5	-5.7	8.4	0.70	0.40	0.51	29.0
Young Ice	-16.1	-5.7	10.0	0.84	0.28	0.41	25.7
FYI (floes, far range)	-17.8	-0.2	5.3	0.65	0.58	0.54	25.1
FYI (floes, near range)	-15.0	-0.5	5.6	0.69	0.54	0.50	23.8
ridged FYI	-12.9	-0.4	4.9	0.68	0.57	0.46	22.9
rough FYI (strong HV)	-10.3	-0.5	3.0	0.70	0.60	0.27	22.2

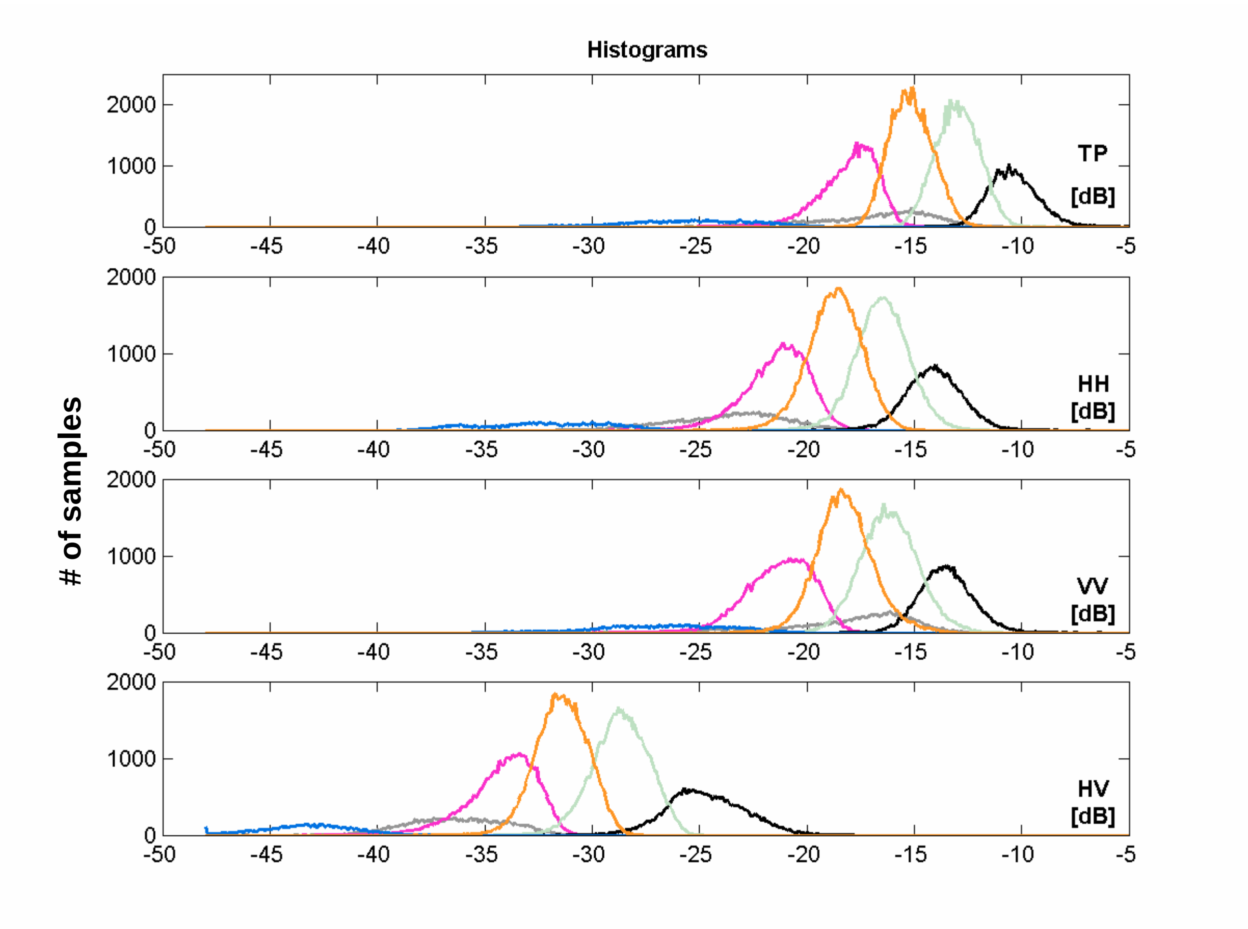

Fig. 4. Backscatter strength histograms of the polarimetric channels and the total power. The colour assignment is given in Table 1 (The rough FYI class is shown in black).

Some of the parameters are summarized in Table 2. A number of parameters show differences in the classes rather well, while others have only subtle differences. The signatures of Leads and young ice are similar. In particular HH/VV (< -5 dB) as well as the ratio between the Freeman-Durden [3] surface and volume scattering components (> 7 dB) separate the two from FYI classes. The polarimetric Entropy (<0.5) also provides a clear separation. Not as conclusive is the magnitude of the complex correlation, the Anisotropy and the α angle. An entropy value of < 0.5 in combination with a low α-angle (<40°) indicates dominant surface scattering, which is supported by the surface to volume ratio of the Freeman-Durden components. An increased contribution of volume scattering can be noted for the FYI classes, this contribution is relatively small compared to the surface scattering component except for the rough FYI class, where Ps/Pv reaches 3dB. Values in this order were experienced in AIRSAR dataset for Multi Year Ice (MYI).

The scatter plots shown in Fig. 5 (ii) indicate that the leads show a broad range of signatures. One lead in particular is thought to be covered in thin, new forming ice (see Fig. 3). This is an assumption based on the SAR data only, no ground measurements are available to confirm this. There is however a difference in signature between the various leads which is the subject of ongoing work. The separation of thin, new forming ice and open water, which is of interest for CIS, cannot be fully resolved using current operational spaceborne SAR sensors. In calm wind conditions, both thin ice and open water show low backscatter (potentially at or below noise level) and cannot easily be distinguished using single polarization SAR data.

6. CONCLUSIONS

The availability of fully polarimetric SAR data for sea ice classification allows the use of classification algorithms utilizing the increased information content. The Wishart classifier appears promising for ice type classification, the classification result described in this paper corresponds well to the expert analyst interpretation of the data. In addition the multitude of parameters available provides a significant help for class interpretation. The co-polarized channel ratio, the ratio between surface and volume scattering component as well as the polarimetric Entropy show significant differences between FYI and young ice or leads. Leads were successfully classified; a more detailed investigation of the lead signature reveals the presence of open leads as well as leads covered in thin new forming ice. A separation of the two would require post processing of the data. In an operational environment, however, this vast amount of information may not be as beneficial. A careful selection of important parameters is recommended based on classification requirements, classification potential and operational needs. This selection would require a substantial database containing ice data in different areas over a full ice season.

The data used in this case are high resolution (compared to data currently used operationally) and spatial averaging was applied to reduce the amount of speckle. For lower resolution spaceborne data spatial averaging will not be available to this extent as the loss of spatial information will outweigh the smoothing effect. The use of polarimetric filters is recommended in this case [4].

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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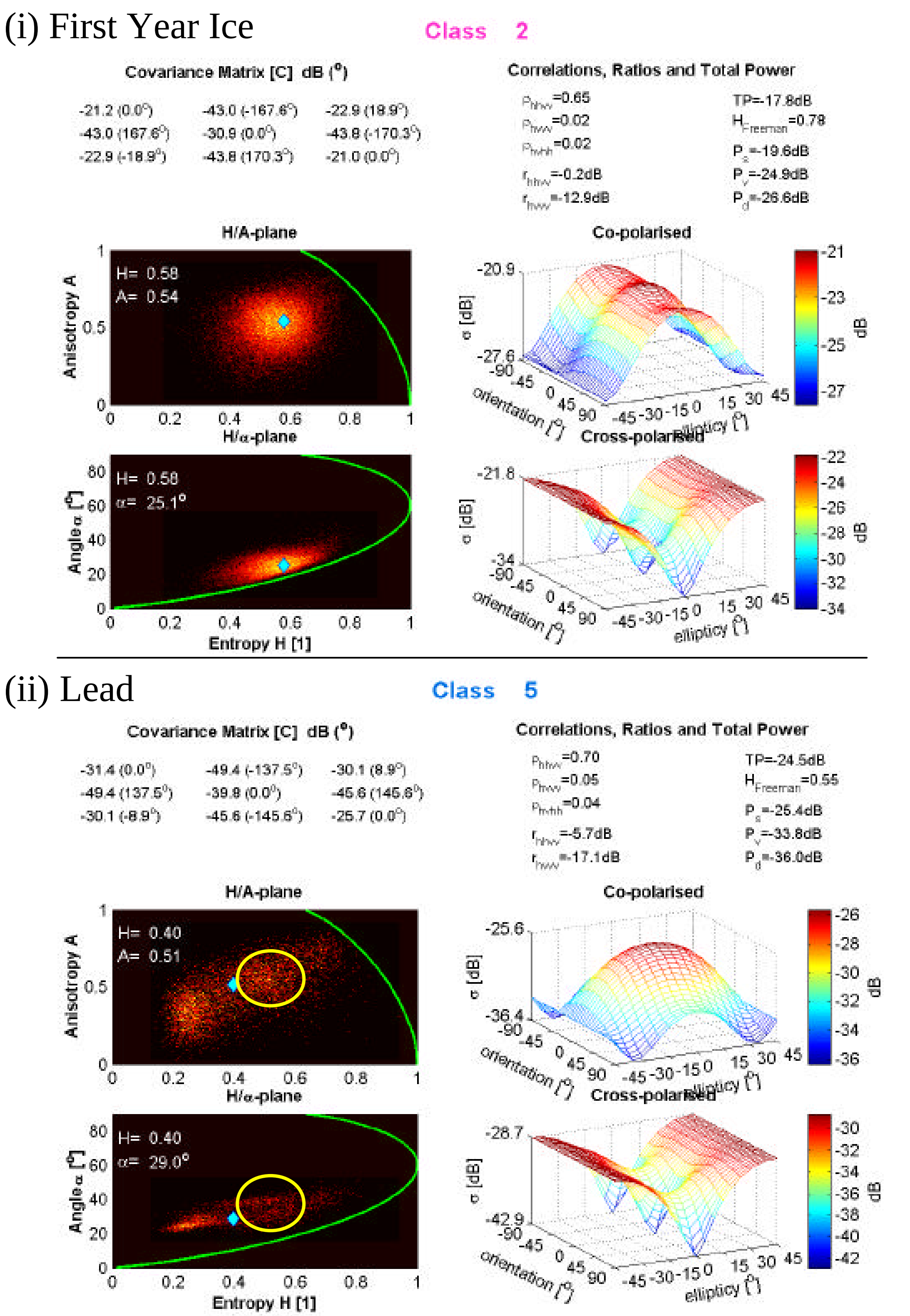

Fig. 5. Class mean information for a FYI class and leads. The yellow ellipses in (ii) indicate the signature of leads assumed to be covered in thin, new forming ice (see Fig. 4 for example).