Dear Anonymous Reviewer #1,
We thank you for taking the time to provide comments, and have revised the manuscript according to them. Our response to each comment is included in red text after each comment below.

1. *Use of air temperature data in the analysis*. The authors use air temperature data recorded on the R/V Lance vessel, which appears to have been at sailing within about 100 km of the area under investigation. At this time of year the sea ice cover will be very close to its freezing point and very sensitive to slight changes in its surface energy balance, so that air temperatures recorded at some distance away may not indicate whether or not the ice is freezing or melting at the time of a SAR acquisition. While it is understandable that measurements on the ice could not be made, assertions about the freezing/melting state of the ice cover made on the basis of these air temperature readings, and how this relates to the scattering behavior and classification performance, should be made with caution. The authors should use these ancillary data to guide their analysis and discussion points. Making concluding statements on the basis of these data, however, would not be appropriate.

We agree in this point, and the treatment of the meteorological measurements in the manuscript in was improved in two ways:

1. Strong statements on the relation between the results and temperature have been balanced:

   In the abstract, the last sentence was rewritten P4540L17-18:
   "Excluding temporally inconsistent SAR features improved the segmentation in one of the X-band scenes."

   In the new-written discussion-part:
   "During the week of data collection, the temperature was varying around zero degrees Celsius, introducing difficult conditions for sea ice information retrieval from SAR. The distance between the meteorological measurements retrieved from R/V Lance and the study site makes detailed analysis of SAR weather dependence difficult. Some general meteorological events observed in the meteorological data could however help explain our results."

   In the conclusion,
   P4560L12-13:
   "…performed poorly. The poor performance might be a result of air temperatures above zero degrees Celsius combined with low incidence angle and polarimetric channel combination (HH-VV). Reducing the…"

   P4560L17-18:
   "…,and our results indicate that an exclusion of temporally inconsistent features could improve the segmentation results in some cases. To confirm…"

2. We have included meteorological data from ECWMFs re-analysis (ERA-interim), both for the position of R/V Lance and the position of the satellite scenes. These data are included in Fig. 2, and in the following text (P4547L2):

"…until 2 September. To investigate how the distance between R/V Lance and the position of the satellite scenes influenced the meteorological information, 2 meter air temperature and surface pressure were extracted from the European Center for Medium-Range Weather Forecastes(ECMWF) re-analysis (ERA-Interim) (Dee et al., 2011). The parameters were extracted in 6-hours increments for both the position of R/V Lance and the satellite scenes (79.25° N 14.25° W). There was good agreement between ERA-interim air temperature and surface pressure at the two locations (Fig. 2). The re-analysis seemed to overestimate the air temperature during the start of the campaign."

2. *Selection of polarimetric features*. The authors draw a connection to a previous publication in order to justify the selection of polarimetric features in this study. This seems logical, however not enough information is provided in the current paper about the expected behavior of these features for the varying system and target parameters under consideration. The authors should follow on their descriptions of the expected behaviors of Relative Kurtosis and Geometric Brightness with appropriate background information relating to the other features. While some of the target behaviors are understandably novel, expected systembased behaviors should still be provided. For example, co-polarization ratio and copolarization correlation magnitude will vary as a function of incidence angle across the 10° range between R1 and R2. Variations in the co-polarization correlation magnitude between R1, R2, and R3 do appear to trace the variations in incidence angle, at least for ROIS 1-4, which somewhat contradicts the assertion made in lines 5-10 on page 4554.

To meet this request, we have added brief background information about all investigated features in the method section, P4549L25:
"…smaller eigenvalues. $R_{VH/VV}$ is known as a measure of depolarization (Drinkwater et al., 1992). In microwave scattering of sea ice, depolarization is expected related to multiple scattering within the sea ice volume or to surface roughness (Scharien et al., 2012, Moen et al., 2013). $R_{VV/HH}$ is only dependent on the relative permittivity for very smooth surfaces within the Brag regime (Hajnsek et al., 2003). For rougher surfaces, the feature is expected to increase with incidence angle and relative permittivity, and decrease with increasing surface roughness (Drinkwater et al., 1991, Fung, 1994). With volume scattering, $R_{VV/HH}$ (dB) tends toward zero (Scharien et al., 2012). $|\rho|$ is a measure of the proportion of polarised backscatter, reaching unity when the co-polarisation channels are perfectly correlated (Drinkwater et al., 1992). The feature is expected to decrease with incidence angle, at an increasing rate for high salinity ice (Drinkwater et al., 1992, Gill et al., 2012). $<\rho$ is the relative difference in phase between the co-polarisation channels, describing the sea ice scattering history (Drinkwater et al., 1992). The feature depends on both the sea ice relative permittivity and surface roughness."

Hajnsek et al., 2003, Drinkwater et al., 1991 and Gill et al., 2012 were added to the reference list.

We have reconsidered the assertions made in line P4554L5-10, and this part of the manuscript was reformulated:
"The incidence angle of the three RS-2 scenes varies between 38 and 48 degrees (see Table 1). $|\rho|$ varies linearly with incidence angle, according to Fig. 6, the same dependency cannot be seen for $R_{VV/HH}$."

The same topic has been commented on in the new-written discussion part:
"From Fig. 6, it seems like the influence of the changing incidence angle is small, except for |ρ|."

3. *Classification versus segmentation*. The term "segmentation" is used extensively, including the title. Segmentation typically refers to dividing an image into groups of connected pixels. What is being done here is an image classification, the labelling of pixels.

We agree that the term segmentation may need further explanation, and we used this term deliberately to distinguish it from the term classification. Classification commonly brings with it the understanding that you know what the "classes" represent. Although our segmentation algorithm (essentially a clustering algorithm) assigns a numeric label to each pixel, the value is a randomly chosen index for each group (cluster) holding no identification information (apart from that those pixels with the same label have similar statistical properties). This type of image segmentation is somewhere between a contiguous (connected) domain based segmentation, that the reviewer mentions, and an image classification to known classes. We have not found a better term to really convey this distinction.
Our work is a first step towards developing a true classification, where we now have to identify the uninformative labelled segments to assign meaningful class labels (i.e., ice types). Moen et al (2013) also used the term segmentation, and we think this term gives the most accurate description of our algorithm.

To make this clearer in the text, we made the following changes:

P4550L16-17: The sentence was rewritten and expanded
"In C-band, the algorithm produced a good late summer sea ice segmentation, separating the scenes into segments that could be associated with different sea ice types in the next step. The X-band performance was slightly poorer."

P4543L13-14: An extra sentence was added
"Secondly, the feature-based automatic segmentation algorithm is tested on our dataset. We investigate whether it groups the scenes into reasonable segments, possible to associate with distinct sea ice types. The algorithm…."

P4551L9-11: The sentence was rewritten
"The algorithm was set to segment the scenes into six different segments. The number was chosen to allow for the five sea ice types described by the ROIs, in addition to one extra segment to allow for detection of other sea ice types and to assure some flexibility for the algorithm."

P4551L13-15: was rewritten
"For each scene, the segmentation's performance is evaluated visually on its ability to separate the four main sea ice types represented in the ROIs (medium thick FYI, thin FYI, old ice and old deformed ice), and based on its ability to discriminate the pixels of the five ROIs into different segments."

P4556L16-17: The sentence was rewritten
"Figure 9 displays which segments the pixels of each of the ROIs are assigned to…"

P4557L13-14: The term “classes” was changed to “segments”
“Figure 11 displays which segments the pixels in each of the ROIs are assigned to in the segmentation of the two TS-X scenes.”

P4558L27: The term classes was changed to “segments”
“…size and number of segments are important…”

P4559L: The term class(es) was changed to “segment(s)”
“The number of segments was set in advance, based on visual inspection of the scenes and information retrieved from the helicopter-borne measurements. Choosing too few segments could force different ice types into a common segment, while increasing the number of segments could split an ice type into several segments.”

P4560L26-29
“Future studies should also focus on a better physical understanding of the relation between SAR polarimetric features and geophysical properties. This could improve the interpretation of the segmented sea ice scenes, and possibly lead to an automatically labeling the segments, a classification.”

Caption Fig. 8: The term classes was changed to segments
“Segmentations of the three Radarsat-2 scenes (R1, R2 and R3) into six segments.”

Caption Fig. 9: The term classes was changed to segments
“The segments assigned to the pixels in the five regions of interest by…”

Caption Fig. 10: The term classes was changed to segments
“Segmentations of the two TerraSAR-X scenes (T1 and T2) into six segments.”

Caption Fig. 11: The term classes was changed to segments
“The segments assigned to the pixels in the five regions of interest by”

4. *Organization and writing*. The results section includes long descriptions of methods and justifications for investigations that were either previously provided or belong elsewhere. For example see beginning of Section 3.13:the background information on sea ice permittivity is important, but would make sense if it were provided much earlier. As it is, the results section is cumbersome to read. It should be edited so that focus is on key results and discussion points. The paper should also be edited to make sure the correct tense is being used consistently (e.g. line 10 on page 4547, “(ROIs) were chosen” etc.).

We thank the reviewer for this opportunity to reconsider the results and discussion section. We have gone through the section with the reviewers comments in mind, and restructured it. In this work, we divided the section into a result and a discussion part. The use of tense was also edited. The new results and discussion sections are enclosed at the end of this document.

P4551L17-26 was rewritten
P4552L1-6 was removed
P4552L8-9 was rewritten

P4552L10-27 are unchanged
P4553L1-2 was rewritten
P4553L4-20 are unchanged
P4553L21-22 was moved to the introduction section, P4542L18.
P4553L23-P4554L15 was rewritten and moved to the discussion section.
P4554L16-21 are unchanged
P4554L23-P4555L2 was removed
P4555L3-16 was rewritten
P4555L18-24 was removed
P4556L1-15 was rewritten
P4556L16-28 are unchanged
P4557L1-22 was rewritten.
P4557L23-P4559L5 was moved to the discussion section, and rewritten.

Tense was also changed in the following sentences in the method section:
P4543L20-21: "…,five regions of interest (ROIs) with different sea ice types were defined…"

P4544L11-13:"The study site was situated in this area (Fig. 1). Both FYI and old sea ice in different stages of development were represented at the site"

P4547L6-8:"The area covered by the satellite scenes consisted of sea ice with different geophysical properties. Some regions were homogeneous and some contained mixtures of different sea ice types."

P4547L19-20:"ROI1 represents an area…"

P4547L21:"The sea ice in ROI1 was relatively smooth and had a moderate melt pond fraction."

P4547L23:"The sea ice in ROI2 was smooth…"

P4548L8:"The features studied were previously…"

P4550L9:"The probability density functions (PDFs) were estimated"

P4550L12-14:"As the ROIs investigated were small, resulting in small sample sizes, leave-one-out cross validation was used in training and testing the classifier. A 7x7 pixels neighbourhood, L=49, was used…"

P4550L17: "each individual feature were used"

P4551L12:"segmentation was confined"

5. *Sea ice in the Fram Strait*. More background information on sea ice conditions characteristic of the Fram Strait would significantly improve the quality of the paper. It would also make it easier for readers not familiar with the ice conditions in that region to assess the potential utility of the classification approach or individual polarimetric features for sea ice detection and discrimination studies elsewhere.

To meet this request, we have added a section about the Framstrait in the Method section:

2.1 Study site
Fram Strait is a dynamic region characterised by the outflow of sea ice from the central Arctic Ocean (e.g. Kwok, 2009b, Renner et al., 2014). The sea ice cover is therefore highly variable with both multiyear and first-year ice, and contains a large fraction of deformed ice. In late summer, the snow cover has usually melted completely, leading to melt ponds on top of the ice (e.g. Renner et al., 2013). While in most parts of Fram Strait, southward drift leads to fast movement of the sea ice, a region with iceberg-fast ice forms in some years in western Fram Strait (Hughes et al., 2011). In this region, the ice cover varies between rough ice due to deformation and very level ice where the ice is formed during winter and protected from impact (Beckers et al., 2015; unpublished data). The study site was situated in this area (Fig. 1). Both first-year sea ice (FYI) and old sea ice in different stages of development were represented at the site.

Hughes et al. (2011) and Kwok (2009b) was added to the reference list.

P4544L11-13 was removed.

Technical corrections:
P=Page, L=Line
P4540L6: These remotely sensed data are not *in situ*.
"In situ" was removed:
"Sea ice thickness, surface roughness and aerial photographs were collected during a helicopter flight at the site."

P4540L9: 'temporal'
The misspelling was corrected.

P4541L7: give the dual polarization combination used by ice services (HH + HV or VH + VV)
The combinations were added:
"…dual polarimetric SAR images (HH + HV or VH + VV) in sea ice monitoring…"
Also in P4541L10:
"…full polarimetric SAR imagery (HH + HV + VV)."

P4541L8: swath 'widths'
The misspelling was corrected.

P4541L14: State the C-band frequency in GHz, as done below for X-band.
The frequency was added:
"C-band (5.4 GHz) is considered…"

P4541L16: 'to investigate' instead of 'in investigating'.
The wording was changed:

"…new opportunities to investigate the potential…"

P4541L19: 'platforms'
The misspelling was corrected.

P4542L9: 'derived from' instead of 'based on'
The sentence was rephrased.

P4542L20-27: This could be split up into two sentences to improve readability.
The sentence was split up and rephrased:
"Newer studies include examination of backscatter signatures of multiyear sea ice with ship-based scatterometer (Isleifson et al., 2009) and investigation of the use of a supplementary frequency of either X- or Ku-band in addition to C-band in late summer sea ice classification with an airborne scatterometer (Brath et al., 2013). Satellite based studies include separation of MYI and FYI by dual polarisation intensity from Radarsat-2 (Warner et al., 2013), classification potential of polarimetric features from Radarsat-2 (Gill et al., 2013) and investigations of melt pond fraction retrieval from co-polarisation ratio data acquired by Radarsat-2 (Scharien et al., 2012, 2014b)."

P4543L10: 'individual'
The misspelling was corrected.

P4543L24: delete 'detailed'
"detailed" was removed.

P4544L2: '… ship, helicopter, and satellite platforms…'
"platforms" was added.

P4544L6: '…from the scientific vessel R/V Lance provided information …' (delete 'are also available')
The sentence was rephrased.

P4544L9: delete 'ground based'
"Ground based" was deleted.

P4544L18: '… and the positions…'
The misspelling was corrected.

P4544L19: ' … scenes were acquired during ascending orbits.'
The sentence was rephrased.

P4544L22: 'Air- and ship-borne measurements' or 'Airborne and shipborne measurements'
The title is rephrased to "Airborne measurements", and the following subtitles "Sea ice thickness", "Surface roughness" and "Melt pond fraction" are removed.

P4545L8: 'From this device …'
The sentence was rephrased.

P4545L13: How is it known that there is very little or no snow cover? More detail is needed to back up this observation.
Information about the snow cover is retrieved from the downward-looking helicopter photos and from scientists onboard the helicopter. The sentence was expanded:
"At the time of the acquisition there was very little or no snow on top of the sea ice, confirmed by the aerial photos and observations from scientists onboard the helicopter."

P4546L5-18: How reliable are the classified images? Was an accuracy assessment performed?
An accuracy assessment was performed by Renner et al. (2013). A sentence was added to specify this:
"as described in Pedersen et al. (2009) and Renner et al. (2013). In an accuracy assessment of the method performed in Renner et al. (2013), 76 % of the melt pond pixels were correctly classified."

P4546L22: Provide information regarding the meteorological instrumentation and measurement height.
The height of the automatic weather station was about 22 above sea level. The instruments consist of an air temperature sensor 3455, an air pressure sensor 2810 and a relative humidity sensor 3445, all from Aanderaa data instruments. This information was included in the manuscript:

P4546L22-23: The sentence was expanded
"An automatic weather station at R/V Lance consisting of an air temperature sensor (3455), an air pressure sensor (2810) and a relative humidity sensor (3445), all from Aanderaa, were recording metorological information during the campaign (Fig. 2). The height of the station was 22 meters above sea level."

P4547L10: '…(ROIs) were chosen …'
The misspelling was corrected.

P4547L19: It would be more appropriate to indicate that the ice types were labelled according the WMO sea ice nomenclature, in addition to providing the reference.
The sentence was rephrased:
"Table 2 presents helicopter measurements for each ROI, including mean and modal sea ice thickness, mean melt pond fraction, surface roughness, and sea ice class labels according to WMO sea ice nomenclature (World Meteorological Organisation, 1989)."

P4547L23-25: '…is smooth with a high melt pond …' ; 'ROI3 and ROI4 represent areas of weathered and deformed old ice …' ; 'ROI3 represents thinner ice with a higher melt …'
The sentences were changed.

P4548L4: delete different
"different" was deleted.

P4548L6: Sentence 'This study investigates … ' should be deleted (stated already).
The sentence was deleted.

P4548L18: 'Assuming reciprocity …'
The misspelling was corrected.

P4550L5: 'Bayes' decision rule'
The misspelling was corrected.

P4550L12: delete hence
"Hence" was deleted.

P4551L1: pdf should be PDF
P4552L21: PDF
pdf was changed to capital letters.

P4552L26: '… is not necessarily a result…'
The misspelling was corrected.

P4553L4-5: '…evolution of feature means from each ROI are displayed in …'
The sentence was corrected.

P4553L13: '…searching for temporally consistent'
The misspelling was corrected.

P4554L3-9: Did you try subtracting the additive noise from the RS-2 scenes before calculating RVV/HH? These data are found in the RS-2 header files. This method has been shown to improve
RVV/HH estimates of ocean and ice at the high incidences analyzed here.
We did not try to subtract the additive noise in this study, but will keep it in mind in future investigations.

P4554L10-15: Did Gill et al. (2013) look at the late summer period? Please clarify.
The study of Gill et al. was performed in late winter/spring, as stated in P4554L10. The study was mentioned as it investigated polarimetric features temporal consistency when temperatures were varying from below to zero degrees Celsius. The last sentence in the paragraph was changed to emphasise that the season was different in their and our study:
"The differences in results may be explained by different incidence angles, sea ice types, snow conditions and season."

P4555L8: '…could solely discriminate all ROIs…' (delete 'between')
"between" was deleted.

P4556L5: '…helicopter flight…'
The misspelling was corrected.

P4556L14: '… scenes are small.' (delete 'in general')
"in general" was deleted.

P4556L18: '… with the full feature set give …'
The misspelling was corrected.

P4557L3-4: Here the parameters are given in text form when the symbols were previously given. Best to stick with using the symbols.
The text was replaced with symbols.

P4557L13-15: This sentence should be re-written for clarity. The rest is very well described.
The sentence was changed to:
"Figure 11 displays which segments the pixels in each of the ROIs are assigned to in the segmentation of the two TS-X scenes. For T1 both for the full achievable (left) and the reduced (right) feature set."

P4558L3: 'acquisition'
The misspelling was corrected.

P4558L5-6: As given it is not clear how both of these processes (formation of rime, refreezing of the ice) would lead to a lower contrast between sea ice types. The occurrence of either is plausible and worthy of mention, as per the conditions. However the authors should be cautious attributing these processes to reduced ice type discrimination. Could a refreezing of the sea ice lead to increased microwave penetration depth and enhanced ice type discrimination on the basis of volume scattering differences between ice types?
This is an important aspect to bring in, and the sentence was rephrased to include it:
"Both of which could cause a lower contrast between different sea ice types, and hence hamper the segmentation results. A refreeze of the sea ice could however also possibly result in the opposite, enhanced volume scattering could lead to increased sea ice type discrimination."

P4558L20: add a period to the end of the sentence
A period was added.

P4558L24: '… at the time of acquisitions could all contribute to poorer segmentations.'
The misspelling was corrected.

P4559L3: *in situ* data were not used
This is very correct, the term "in situ" was removed and the sentence rewritten:
"The number of segments was set in advance, based on visual inspection of the scenes and information retrieved from the helicopter-borne measurements."

P4559L24: Another possible reason would be a higher sensitivity to incidence angle.
We agree in this, and changed the sentence to:
"Possible reasons for the two features inconsistency could be a higher sensitivity to changes in relative permittivity or incidence angles."

P4560L4: '… evaluated visually for its ability …'
The sentence was changed to:
"…and evaluated for its ability to…"

P4560L6-7: ‘The segmentation in general performed well …’
The sentence was changed.

P4560L16: ‘temporally’
The misspelling was corrected.

Figure 9 caption: ‘assigned’
Figure 11 caption: ‘assigned’
The misspellings were corrected.

3 Results

This section consists of three parts. The first two parts examine the individual sea ice type discrimination ability and the temporal consistency of six polarimetric SAR features. In the third part, an automatic segmentation algorithm based on the investigated features is tested on the data set. Results for C- and X-band are presented separately, as differences in incidence angle, resolution and polarimetric channel combinations make a direct comparison inappropriate (see Table 1). The features in C-band are based on the full covariance matrix, while those in X-band are based on reduced covariance matrices as the TS-X scenes are dual polarisation scenes (see Table 3). Note that ROI5 is only present in the RS-2 scenes.

3.1 Individual features' discrimination ability

The polarimetric features' individual capacity of classifying the investigated ROIs into separate classes are presented in Table 4 and 5, for RS-2 and TS-X respectively. The presented values represent the diagonal values of the confusion matrices, i.e., the percentage of true classification. The best result for each ROI is highlighted in bold. All pixels from the five ROIs were included in the classification, and the experiment was performed separately for each of the scenes included in the study. From the two tables we note that none of the features individually were able to classify all the five ROIs in a single scene with high accuracy. All features do however give satisfying classification results for some of the sea ice types represented by the ROIs, in some of the scenes. Hence, by combining the features, all features could add value to a feature-based sea ice type segmentation algorithm. The best feature for discriminating a given ROI varies from scene to scene. In all scenes except T1, ROI4 seems to be the most challenging to separate from the others. ROI4 consists of old ice, as does ROI3. An overlap between the PDFs of these two ROIs could be a reason for the poor discrimination result of ROI4.

In general, the result of the MAP classification for C- and X-band does not show large differences. The best classification accuracies in the C-band scenes are slightly higher than those in the X-band scenes, indicating a larger discrimination potential in C-band. This difference is not necessarily a result of different frequency. RK and B are calculated from a reduced covariance matrix in the X-band scenes, and therefore contain less information. The lower incidence angles of the TS-X scenes could also contribute to the observed differences.

3.2 Temporal consistency of features

The temporal evolution of the feature means from each ROI are displayed in Fig. 6 and 7 for RS-2 and TS-X, respectively. The variances of the features within each ROI are displayed as error bars equivalent to two standard deviations. Due to different polarisation channel combinations (see Table 1), different features are displayed for T1 and T2 in Fig. 7. This also limits a temporal investigation in X-band, and we will in the following focus on the results in C-band.

As weather conditions and incidence angles are different for the RS-2 scenes in the dataset (see Table1), the mean ROI values of the features are expected to vary between the scenes even if sea ice conditions are the same or very similar. Hence, when searching for temporally consistent features, we look at the evolution of the ranking of the mean ROI values of each feature. For instance, studying RK in Fig. 6, the mean value within each ROI varies between the scenes. However, the relative relationship between the different mean values is almost constant. The RK of ROI5 does for instance take values between 1.05 and 1.15, but the RK value is always highest in this ROI. The same between-ROI-consistency during the investigated period can also be found for B, $R_{VH/VV}$ and $\angle\rho$ (Fig. 6). The relative relationship of the mean ROI value of $R_{VV/HH}$ and $|\rho|$ change from scene to scene, hence no temporal consistency can be observed.

T2 shows similar relationships between the mean ROI values of the features as the RS-2 scenes for all three features extracted (Fig. 6 and 7). The same between-ROI relationship cannot be found for T1. The error bars in the TS-X ROIs are in general larger than in the RS-2 ROIs, which may indicate slightly poorer discrimination ability of the TS-X scenes.

A feature-based sea ice segmentation algorithm is dependent on features with good discrimination ability and temporal consistency to give consistent results during changing geophysical conditions. This is especially important as in situ information is often not available in the Arctic. Excluding temporally inconsistent features could help achieve a more temporally stable segmentation during changing conditions. We therefore suggest a reduced feature set, consisting of RK, B, $R_{VH/VV}$ and $\angle\rho$ for late summer sea ice segmentation. A reduction of features in the feature set could of course also imply loss of important information and hence degradation in the segmentation performance. The following subsection will further explore the use of a reduced feature set.

3.3 Segmentation

From Fig. 8, the segmentations of R1 and R2 look reasonable compared to the information from the helicopter fligth, both for the full (right) and reduced (left) feature set. The different segments seem to be associated with distinct sea ice types. One can recognise the thin FYI ice area in the middle of the scenes (violet), the heavily deformed old ice areas in the diagonal bottom-left part of the scenes (blue and turquoise), and two different sea ice types north (medium thick FYI, orange) and south (old ice, yellow) of the middle region. The segmentation of R3 (Fig. 8e) has a more granular appearance, and the areas with medium thick FYI are confused with the areas consisting of old ice (yellow, orange, grey). The differences between the segmentations with full and reduced feature sets for the three RS-2 scenes are small. The segmentation of R3 becomes slightly noisier with the reduced feature set.

Figure 9 displays which segments the pixels of each of the ROIs were assigned to in all three RS-2 scenes, both for the full (left) and the reduced (right) feature sets. In general, the segmentations with the full feature set give good distinction between the different ROIs included in this study. In particular, the thin FYI in ROI2 and the deformed old ice in ROI5 were separated with an accuracy above 71% from the other ROIs in all of the three scenes. In R1 and R2 the segmentation was not able to separate ROI3 and ROI4 clearly (Fig. 9a and 9c). These ROIs do both contain old ice, with different thicknesses and melt pond fractions, hence the ice types in the ROIs were quite similar. In R3 the medium thick FYI in ROI1 was segmented to three different segments. Reducing the feature set by exluding the temporally inconsistent features does not affect the results for R1 and R2 (Fig. 9b and 9d). In R3, it improves the separation of medium thick FYI in ROI1, and reduces the discrimination between the thin FYI in ROI2 and the old ice in ROI3 (Fig. 9f).

The segmentations of the two TS-X scenes, based on the achievable features limited by their polarisation channels (see Table 3), are presented to the left in Fig. 10. In addition, T1 was segmented with a reduced feature set presented to the right in the same Fig. The segmentation of T1 with a full achievable feature set gives a poor and granular impression. The area of thin FYI in the middle of the scene was not discriminated from the rest of the scene, and the deformed sea ice areas in the low left diagonal were not fully segmented (sea green). The segmentation of T2 also gives a slightly granular impression, but the areas of thin FYI in the middle of the scene (violet), and areas of deformed ice in the diagonal bottom-left part of the scene (blue and turquoise) were well segmented. Reducing the feature set in the segmentation of T1 improves the segmentation of the area with thin first year ice in the middle of the scene (violet), even if granular noise is still present.

Figure 11 displays which segments the pixels in each of the ROIs were assigned to in the segmentation of the two TS-X scenes. For T1 both for the full achievable (left) and the reduced (right) feature set. Fig. 11a confirm the poor impression of the segmentation of T1 with full achievable feature set, giving minimal discrimination between the four ROIs. In the segmented image of T2, the thin FYI in ROI2 can be separated from the other ROIs, but the rest of the ROIs were mainly segmented into the same segment. Reducing the feature set in the segmentation of T1 (see Fig. 11b) does not improve the segmentation performance, even if the visual inspection of Fig. 10b gave a slight improvement for the whole scene.

4 Discussion

Among the six investigated features, $R_{VV/HH}$ and $|\rho|$ were found temporal inconcistent during the study. The temporal inconsistency could have several reasons. These features might have a stronger sensitivity to sea ice relative permittivity than the others. As stated in the introduction, relative permittivity will vary largely with temperature during warm conditions (Vant, 1974; Barber et al., 1998), and small temperature differences between the scenes could cause large differences in relative permittivity. In Bragg-scattering theory $R_{VV/HH}$ is only dependent on the relative permittivity of the surface for a smooth surfaces (Fung, 1994). Another possible reason for the inconsistency of these two features is a stronger sensitivity to changes in incidence angles than for the rest of the features. The incidence angle of the three RS-2 scenes varies between 38 and 48 degrees (see Table 1). $|\rho|$ varies linearly with incidence angle, according to Fig. 6, but the same dependency cannot be seen for $R_{VV/HH}$. Gill et al. (2013) did a study on feature temporal consistency in C-band between a winter and a spring scene on FYI north of Canada. They found, similar to this study, that $\angle\rho$ showed high consistency during changing temperature conditions. In contradiction to our findings, they also found $R_{VV/HH}$ to have high temporal consistency. RK and B were not included in their study. The differences in results may be explained by different incidence angles, sea ice types, snow conditions and season.

Choice of features and their temporal consistency is not the only factor affecting the results of the segmentation algorithm. Differences in incidence angle and resolution between the scenes, changing meteorological conditions and choice of segmentation parameters do all affect the outcome of our study. The incidence angles in our study vary between 26° (T2) and 48° (R2). As the backscatter signature from a sea ice surface depends on incidence angle, this is expected to affect the results. Between the RS-2 scenes, the incidence angle variation is small with a 10 °difference. From Fig. 6, it seems like the influence of the changing incidence angle is limited, except for $|\rho|$. The pronounced difference in incidence angle between the RS-2 and TS-X scenes could contribute to the poorer performance of the segmentation algorithm in X-band, but a larger number of scenes with overlapping incidence angle is needed to confirm this. To gain equal sample sizes in our study, the same neighbourhood size was used in filtering all scenes even if the scenes resolution differed. The scenes with highest resolution would therefore have smaller spatial filter sizes. This difference in scale possibly influences the signature of physical properties of the surface, like surface roughness variation. We did, however, during our investigations, also try to use filter sizes adjusted to the resolution, but this made little difference to the results.

During the week of data collection, the air temperature was varying around zero degrees Celsius, introducing difficult conditions for sea ice information retrieval from SAR. The distance between the meteorological measurements retrieved from R/V Lance and the study site makes detailed analysis of SAR weather dependence difficult. Some general meteorological events observed in the meteorological data could however help explain our results. Both T1 and R2 were acquired during a period with air temperatures close to or above zero degrees Celsius, conditions which is on the limit of suitable for sea ice type discrimination by SAR. As reported by Scharien et al. (2010), moisture in the upper sea ice layer could mask out volume scattering and hence lower the backscatter contrast between different sea ice types. The difficult conditions could explain the poor segmentation performance of T1. However, R2 was acquired during similar meteorological conditions with good segmentation results. Lower frequency, higher incidence angle and extra information contained in the cross-pol channel (lacking for T1) could all have contributed to a better segmentation of R2. The segmentation of R3 was poorer than those of the two other RS-2 scenes. Prior to the acquisition of R3, a drop in temperature and relative humidity could have caused rime on the sea ice surface (Drinkwater, 1995) or draining and refreezing of freshwater in the upper layers of the sea ice (Scharien et al., 2010). Both of which could cause a lower contrast between different sea ice types, and hence hamper the segmentation results. A refreeze of the sea ice could however also possibly result in the opposite, enhanced volume scattering could lead to increased sea ice type discrimination.

Choice of sliding window size and number of segments are important for the segmentation results. The use of window size of 21×21 pixels or larger showed the best results in our dataset. The size of the window was in our case a trade-off between resolution details (small window) and segmentation with little speckle and larger continuous regions (large window). The choice of window size will also determine which kind of information one retrieve about the sea ice surface. If information about small-scale structure like ridges, melt ponds and small leads are important, this requires a small window. For more general information for instance about sea ice age, larger window sizes could be more appropriate. Choice of sensor would set restrictions on how high resolution it is possible to achieve, and high resolution is at the moment coupled to small swath width. The number of segments was set in advance, based on visual inspection of the scenes and information retrieved from the helicopter-borne measurements. Choosing too few segments could force different sea ice types into a common segment, while increasing the number of segments could split an ice type into several segments.