

Supplementary Table S1. Description of image object levels, segmentation and classification methods.

Level	Purpose	Segmentation	Classification	
			Criteria	eCognition Functions
I	Separate lake from lake shore	<ul style="list-style-type: none"> Multiresolution segmentation on red, green, blue, PC 1, and PC 2 on the whole image 	<ul style="list-style-type: none"> Threshold on PC 2 to label image objects Size of image objects to remove misclassified small lake image objects in the shore area. Spatial relationship to lake and lake shore objects Merge image objects of same class 	<ul style="list-style-type: none"> Assign Merge Enclosed by
II	Identify sub-regions of lake: Lake ice with shadow, lake ice without shadow, and vegetation in lake	<ul style="list-style-type: none"> Chessboard segmentation of lake object class Multiresolution segmentation on red, green, blue, PC 1, and PC 2 to segment lake object class 	<ul style="list-style-type: none"> Threshold on PC 2 to label image objects Size of image objects to remove misclassified lake ice types: Lake Ice with shadow and without shadow Spatial relationship of lake ice with shadow and lake ice without shadow Merge image objects of same class 	<ul style="list-style-type: none"> Assign Merge Enclosed by
III	Identify dark and white ice within lake ice with shadow and without shadow	<ul style="list-style-type: none"> Chessboard segmentation of sub-regions of lake ice Multiresolution segmentation on red, green, blue, PC 1, and PC 2 to segment sub-regions of lake ice 	<ul style="list-style-type: none"> Threshold on PC 1 to label image objects Merge image objects of same class 	<ul style="list-style-type: none"> Assign Merge
IV	Identify bubble patches in different regions of lake ice classified in level III.	<ul style="list-style-type: none"> Chessboard segmentation of dark and white lake ice image objects Multiresolution segmentation on red, green, blue, PC 1, and PC 2 to segment dark and bright lake ice objects Contrast split segmentation algorithm on PC 1 to split cluster of fused bubble patches into individual bubble patch 	<ul style="list-style-type: none"> Canny edge detection algorithm on PC 1 band to label bubble patch edge area Spatial relationship of image objects with bubble patch to remove misclassified bubble patch objects or re-classify any missing bubble patch objects. Opening morphological filter to shape bubble patch Merge image objects of same class 	<ul style="list-style-type: none"> Canny Edge Algorithm Assign Merge Enclosed by Relationship to neighbours: 'Border to' Morphological Filter: Opening

Supplementary Table S2. Bubble patch classification error matrix for year 2011.

		Ground Truth		Total	Commission Error
		Bubbles	No Bubbles		
Classification	n=122				
	Bubbles	45	2	47	4.3%
	No Bubbles	4	71	75	5.3%
	Total	49	73		
	Omission Error	8.2%	2.7%		
	Overall Accuracy	95.1%			

Supplementary Table S3. Bubble patch classification error matrix for year 2012.

		Ground Truth		Total	Commission Error
		Bubbles	No Bubbles		
Classification	n=151				
	Bubbles	51	2	53	3.8%
	No Bubbles	1	97	98	1.0%
	Total	52	99		
	Omission Error	1.9%	2.0%		
	Overall Accuracy	98%			