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Unsupervised Classification of Sea-Ice using SAR via an Adaptive Texture Sparsifying Transform

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Motivation

- Identification of sea-ice in polar regions
  - Navigation
  - Ship routing
- Manual process is unscalable
- SAR for ice identification
  - Good:
    - not affected by cloud/snow cover
  - Bad:
    - complex/noisy data

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Outline

- Background (compressive sensing)
- Proposed Method
- Experimental Results
- Conclusions/Future Work

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Background: Sparsifying Transform

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- Borrowed from compressive sensing
  - Efficient signal acquisition
- Sparsifying transform
  - Projection of data for accurate acquisition using low number of points

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Method Outline

1. Image representation
2. Sparsifying projection
3. Unsupervised classification

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Step 1: Representation

- "Signature" of the data
- Incorporate texture and spatial information
  - Realistic water/ice patterns

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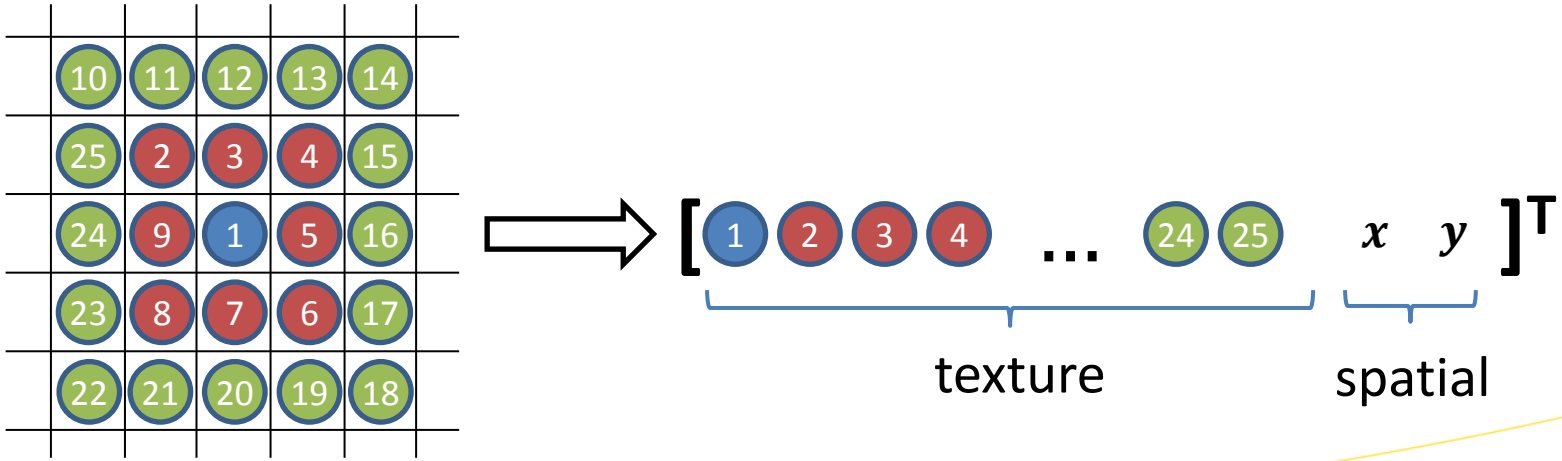

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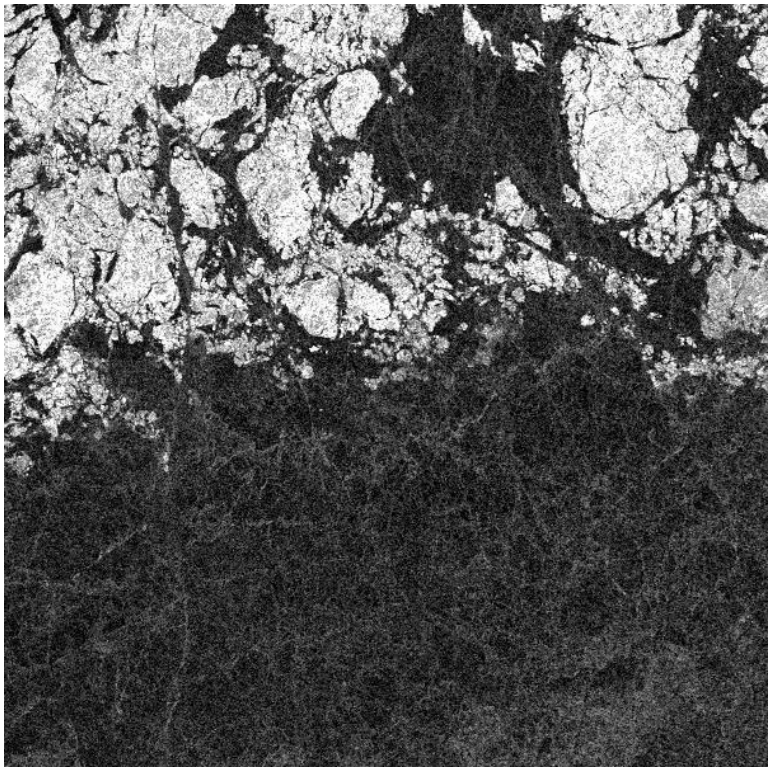
Step 1: Example



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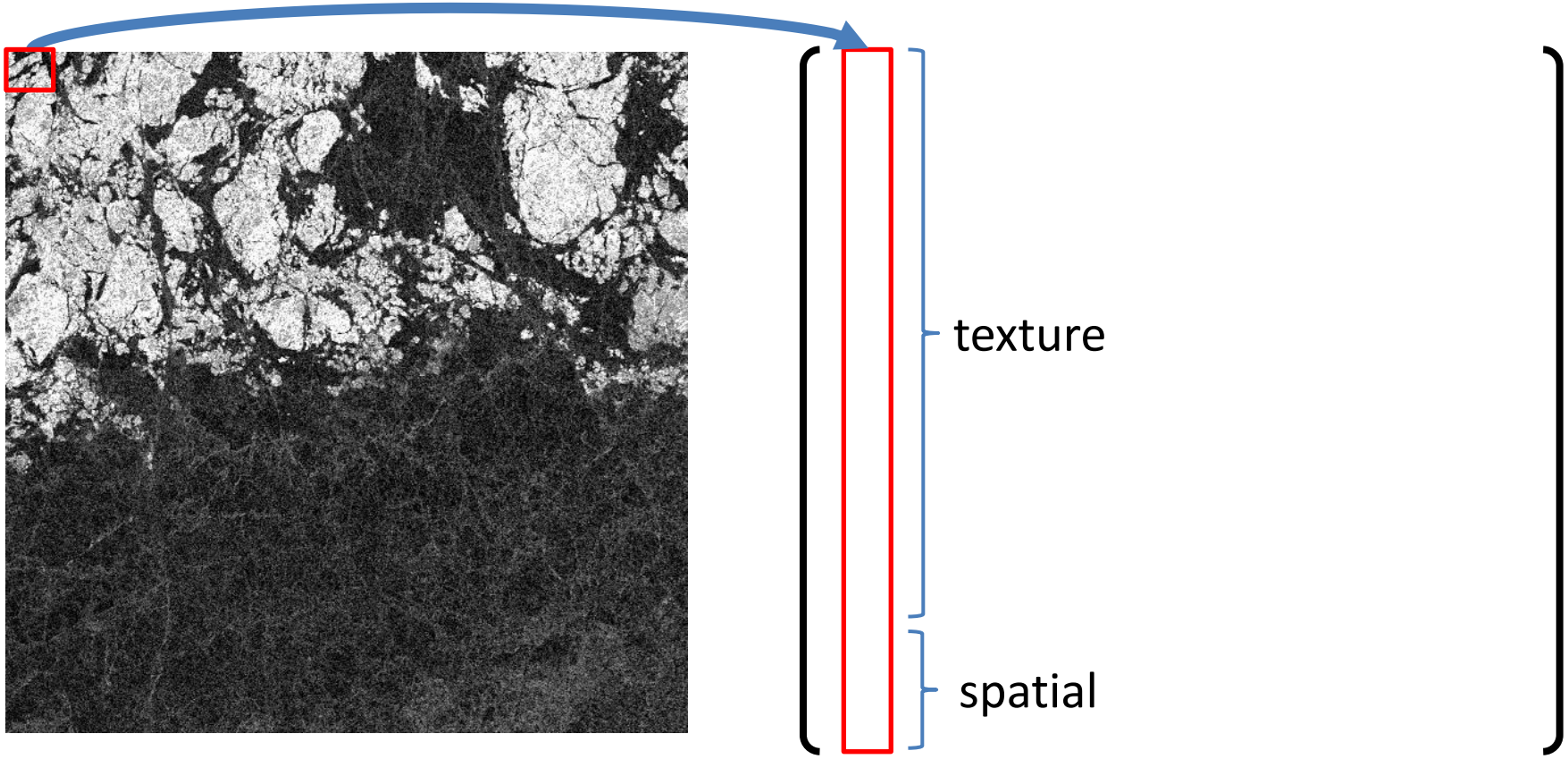

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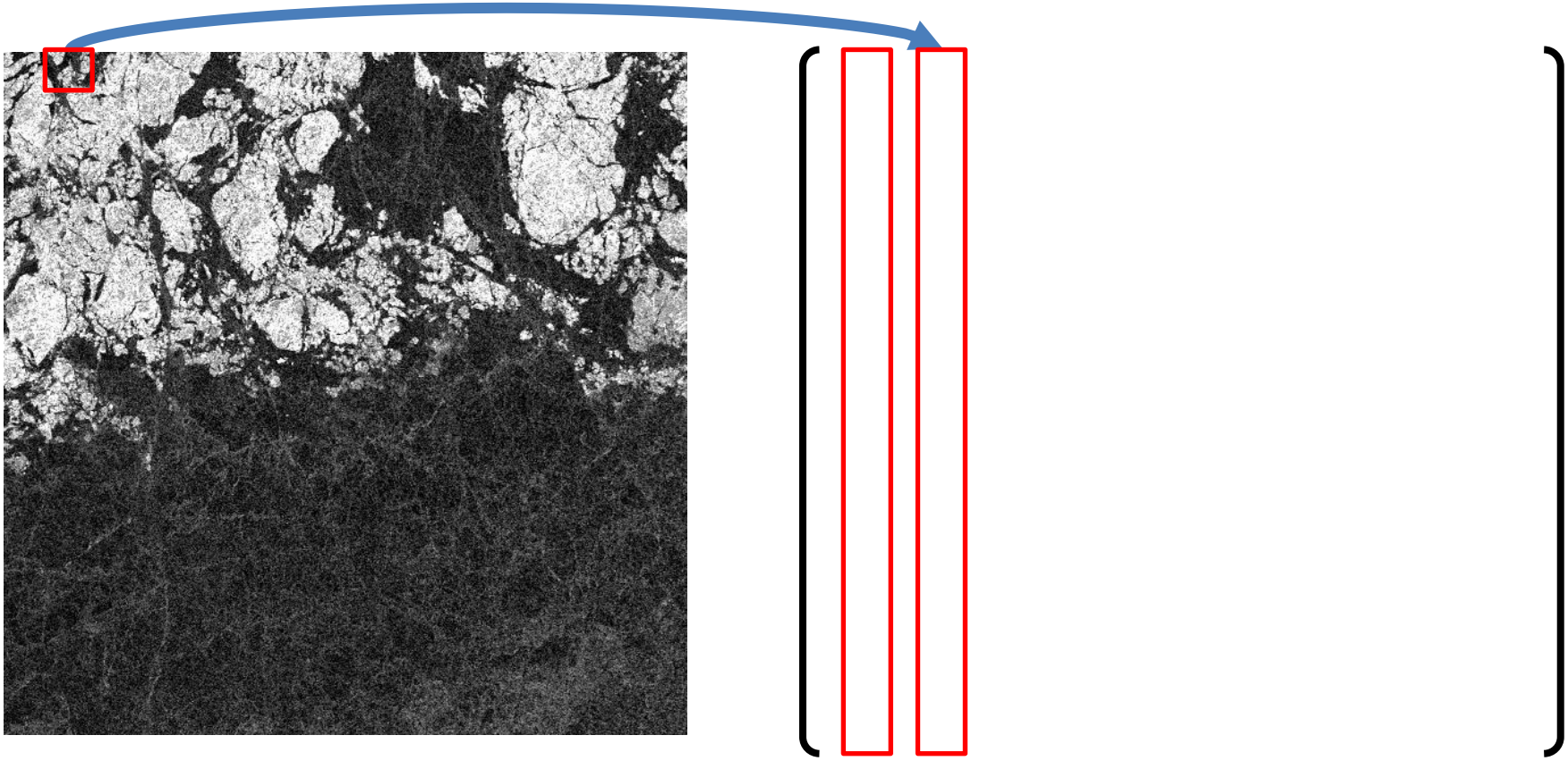

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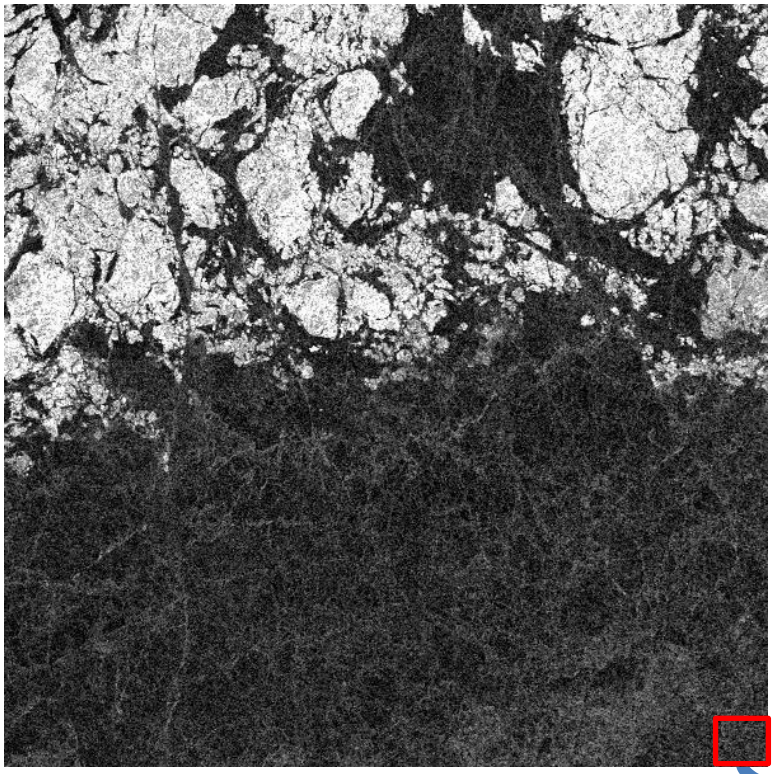

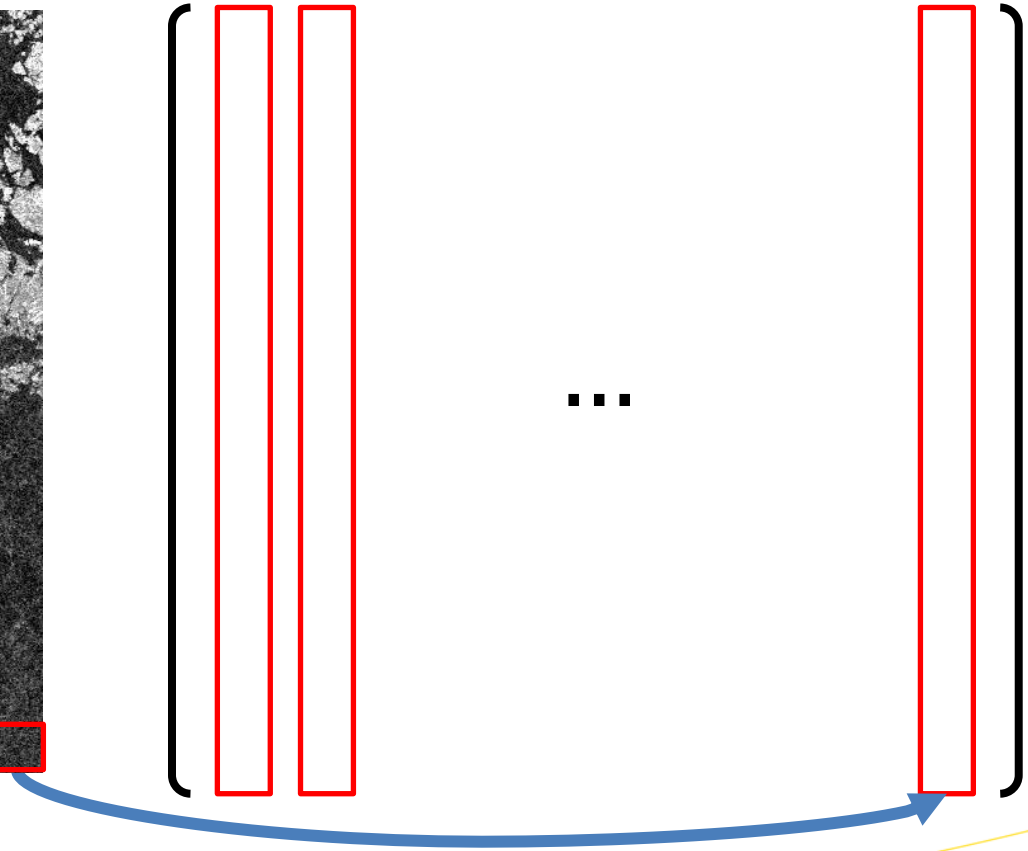

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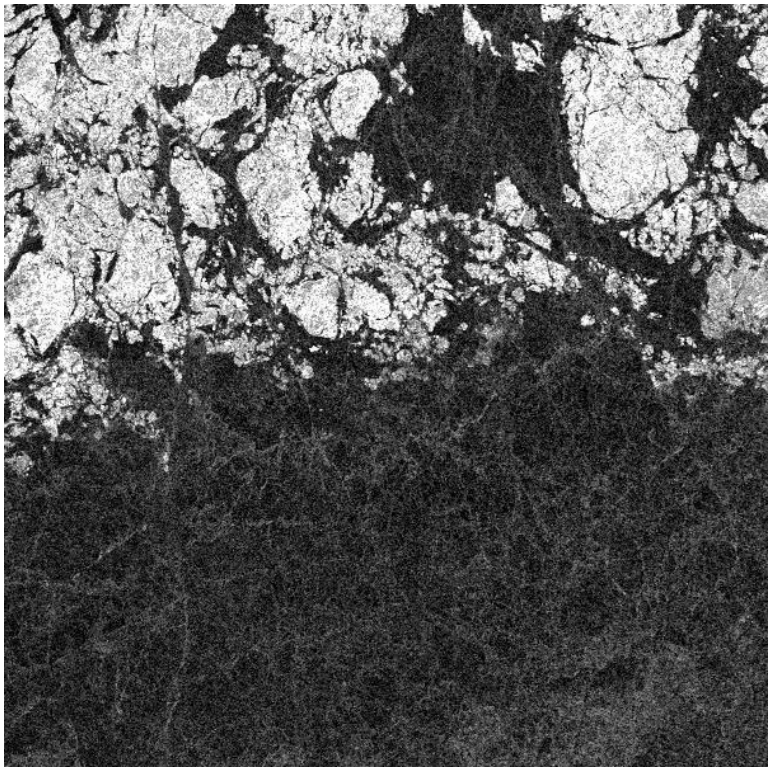

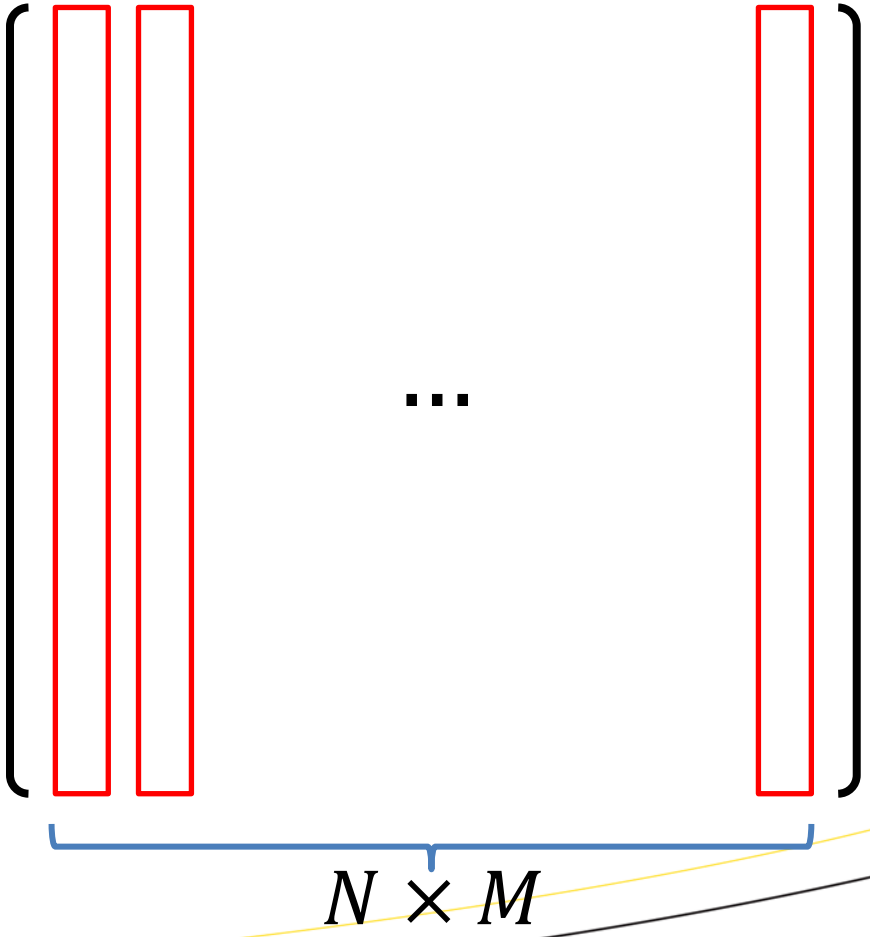

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Step 2: Sparsifying Projection

- Efficiently and compactly represent data
- Project signatures into sparse feature space
  - Reduce effect of noise
- Effectively "simplifies" data
- Solved using modified k-means
  - Relative texture/spatial weighting
  - $\sum\sum[\alpha \cdot \ell_2^t + \beta \cdot \ell_2^s]$

Texture similarity

Spatial coherence

Step 3: Unsupervised Classification

- Learn classifier in sparse feature space
  - **Assumption**: Sparsification resulted in well-separated classes
- Learns inherent patterns in data
  - No human bias!
- k-means with n_c classes
  - Ice/water: 2 classes
  - Types of ice: 2+ classes

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Experimental Setup – Data

- RADARSAT-2 SAR imagery
  - C-band, HV polarization, 50m spatial resolution
  - Chukchi and Beaufort Seas, Apr–Jun 2010
- Chosen because data contains:
  - Much noise (SAR, banding effects)
  - Low SNR (HV)
  - Different classes

Experimental Setup

- Parameter values
  - $\alpha = 1, \beta = 10$ (texture/spatial weight)
  - $n_b = 1000$ (number of salient points)
  - 2-layer neighbourhood
- Compared with:
  - Pixel-based methods
    - Gaussian mixture models, k-means
  - Region-based method
    - Iterative Region Growing using Semantics (IRGS) [1,2]

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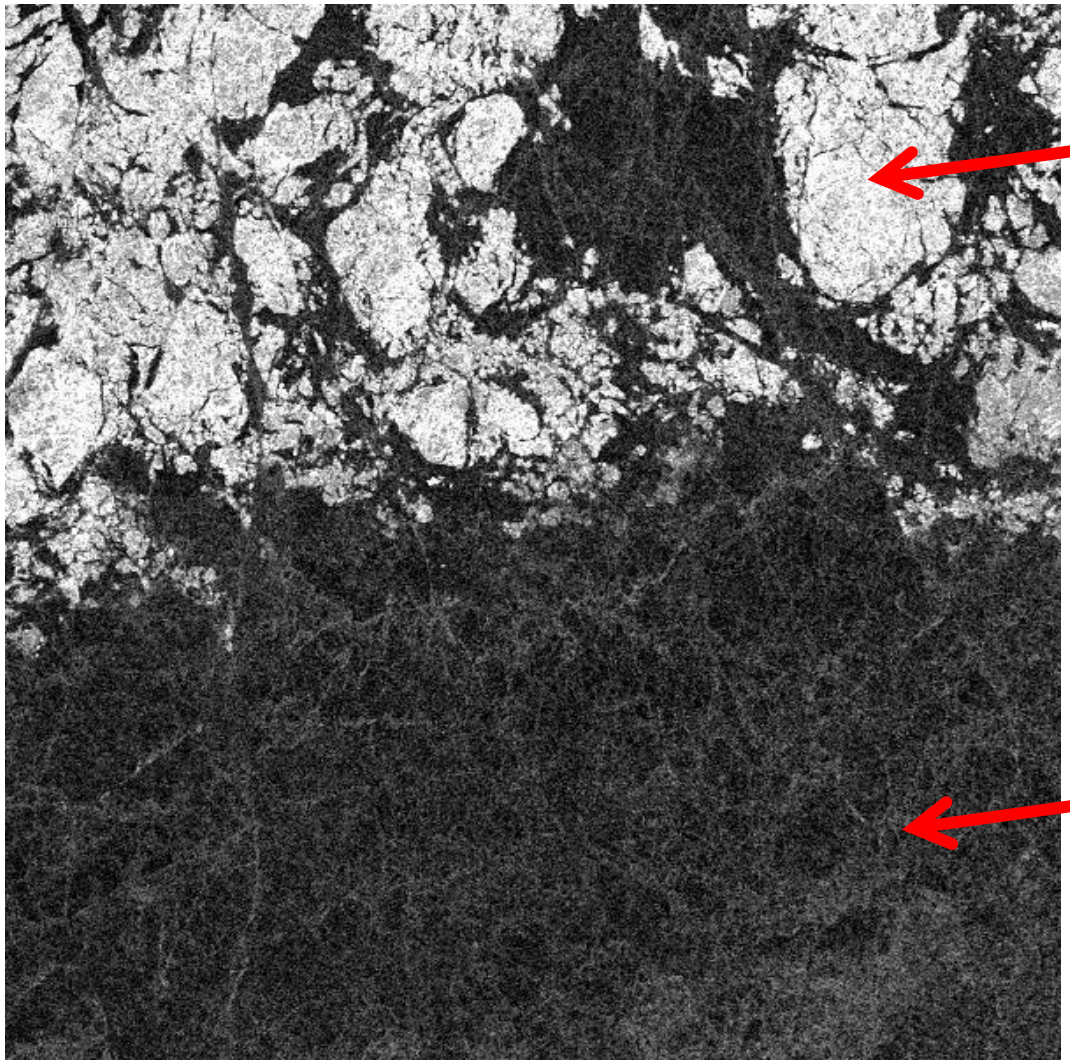
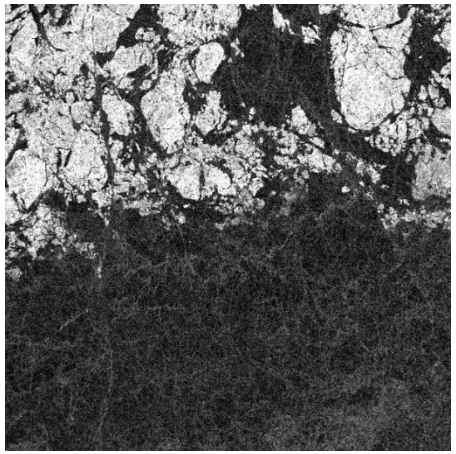
Results





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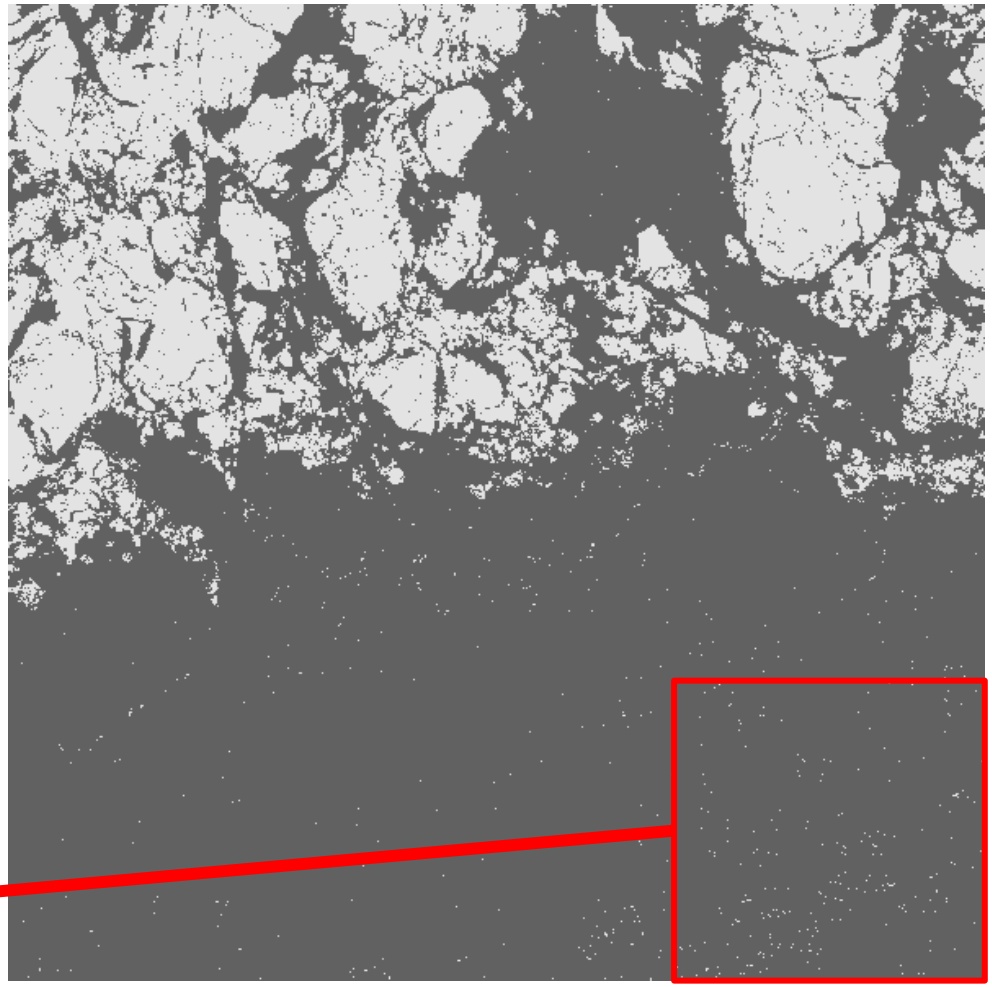
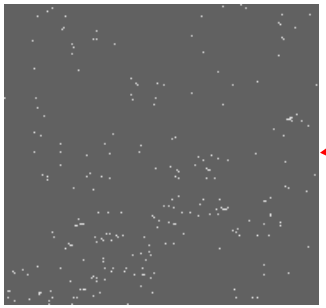
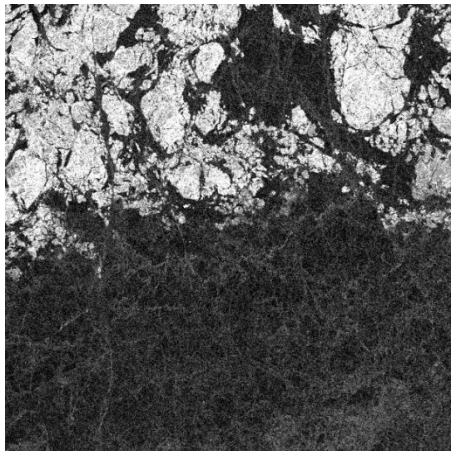


Erroneous localized ice types!



k-means



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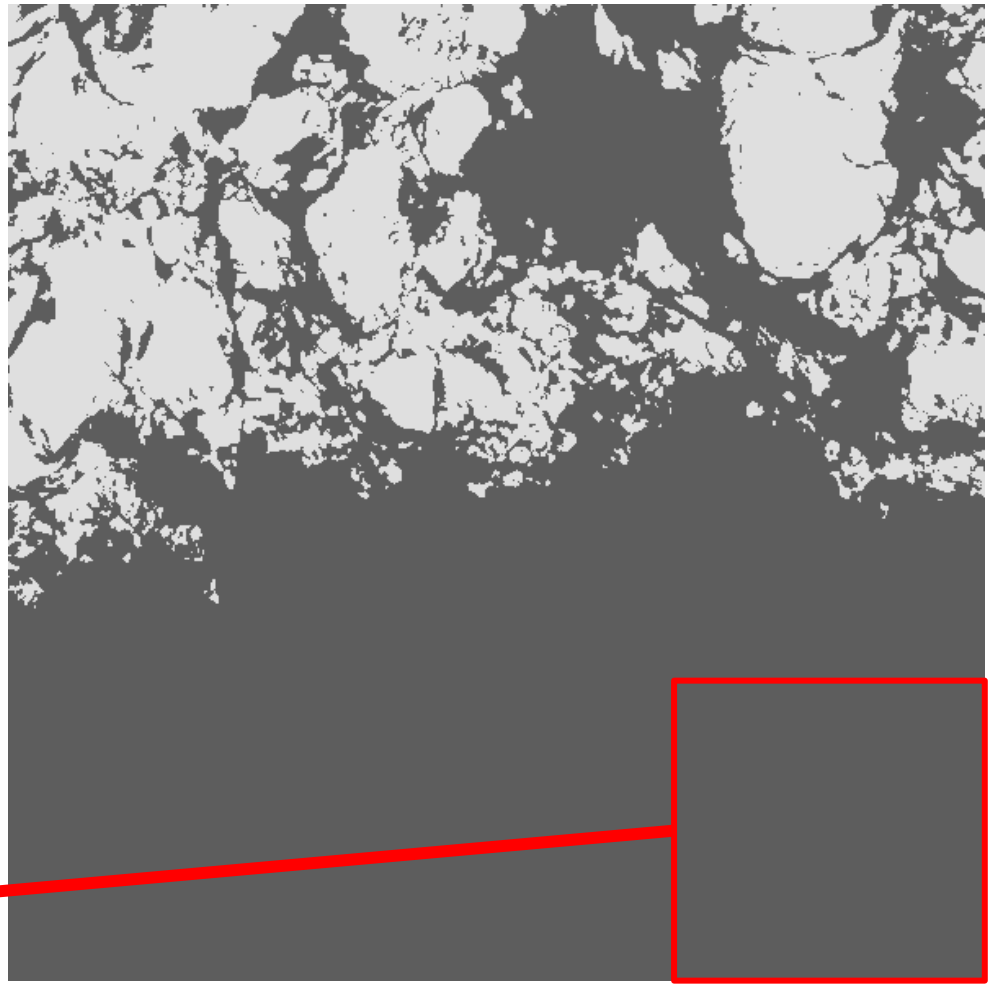
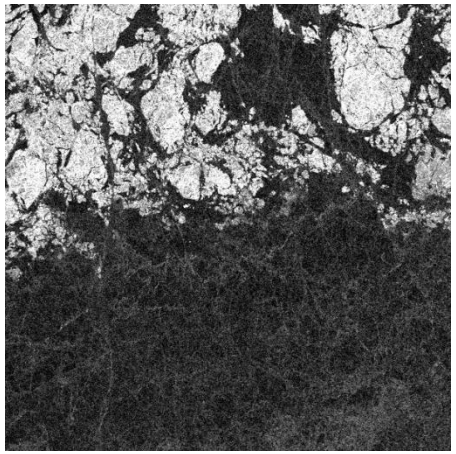
Results



Cohesive!

Proposed method



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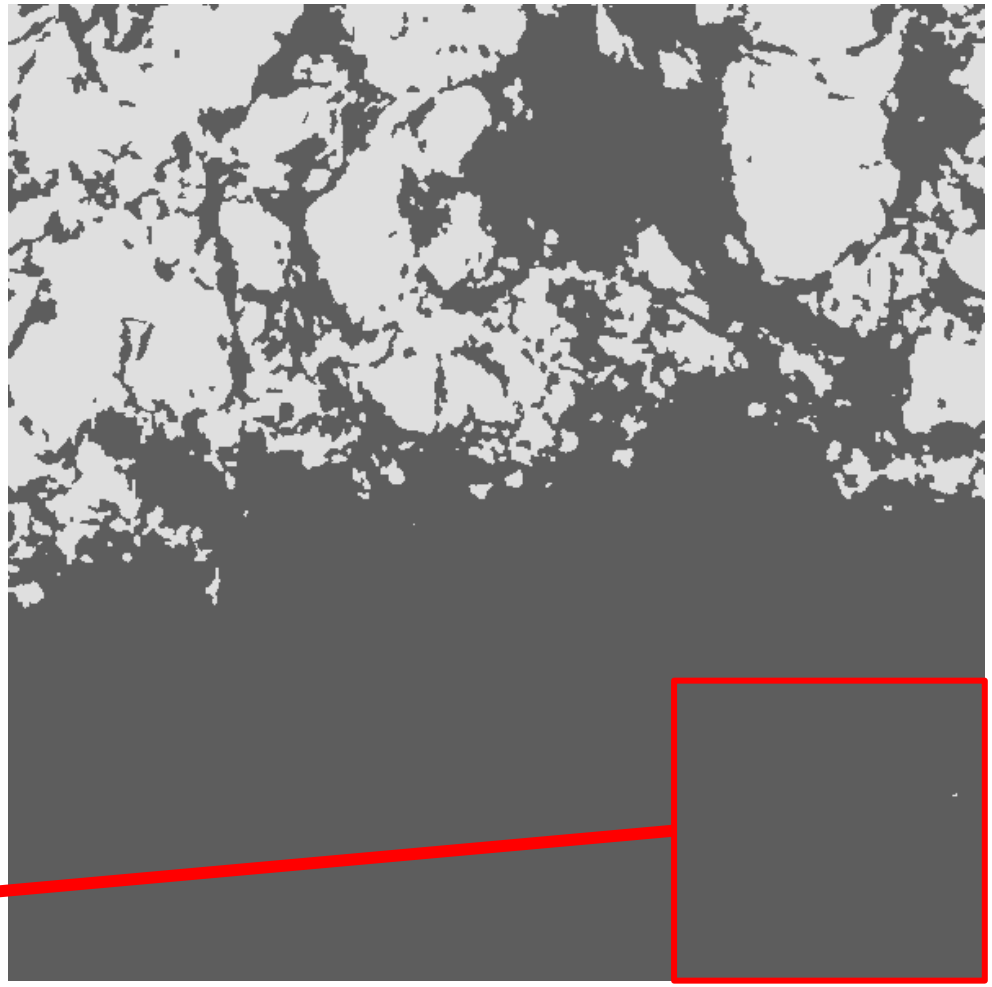

Comparable!

IRGS

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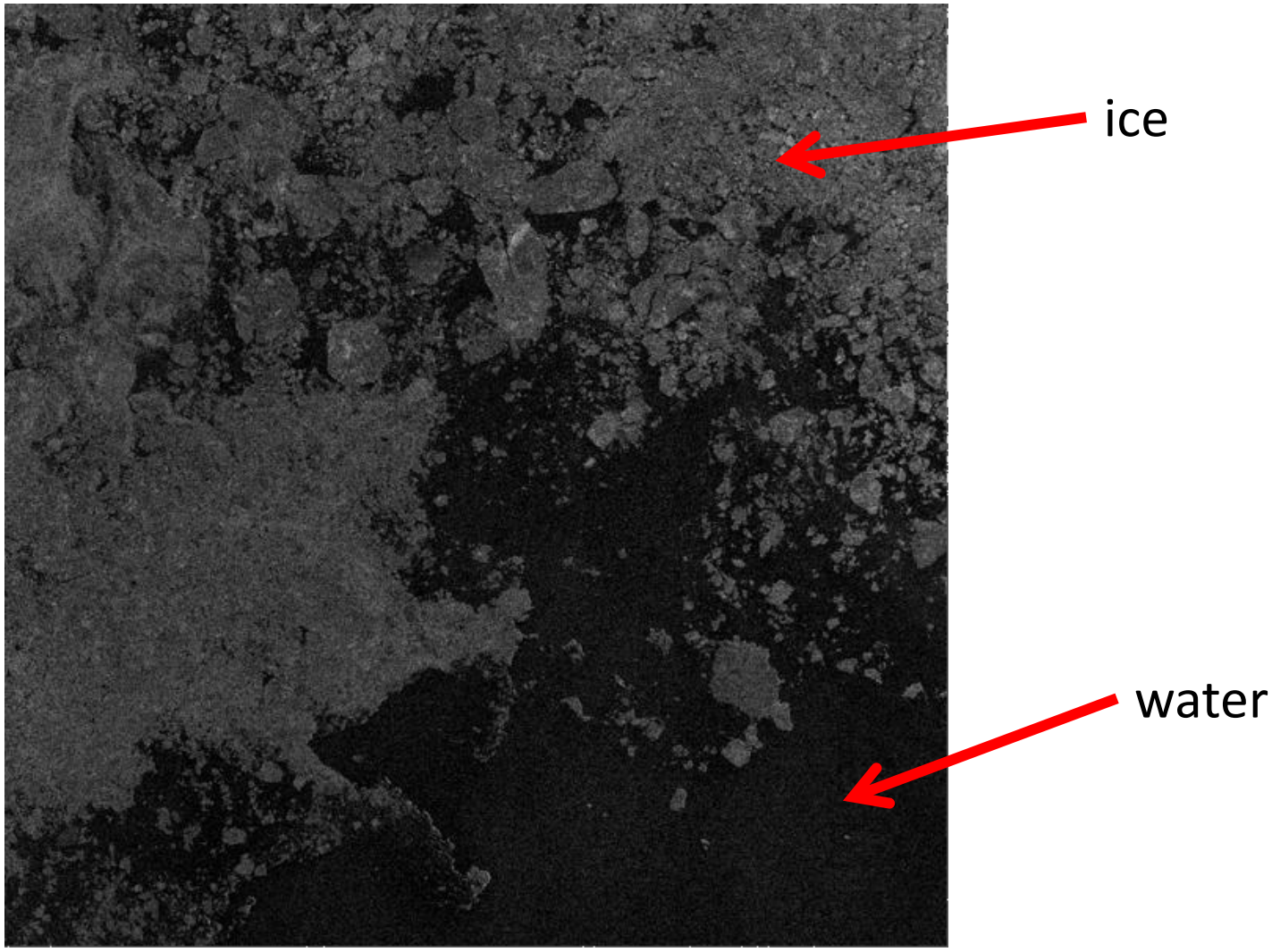
Results



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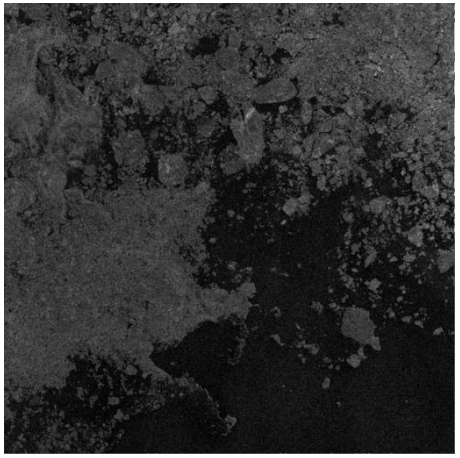
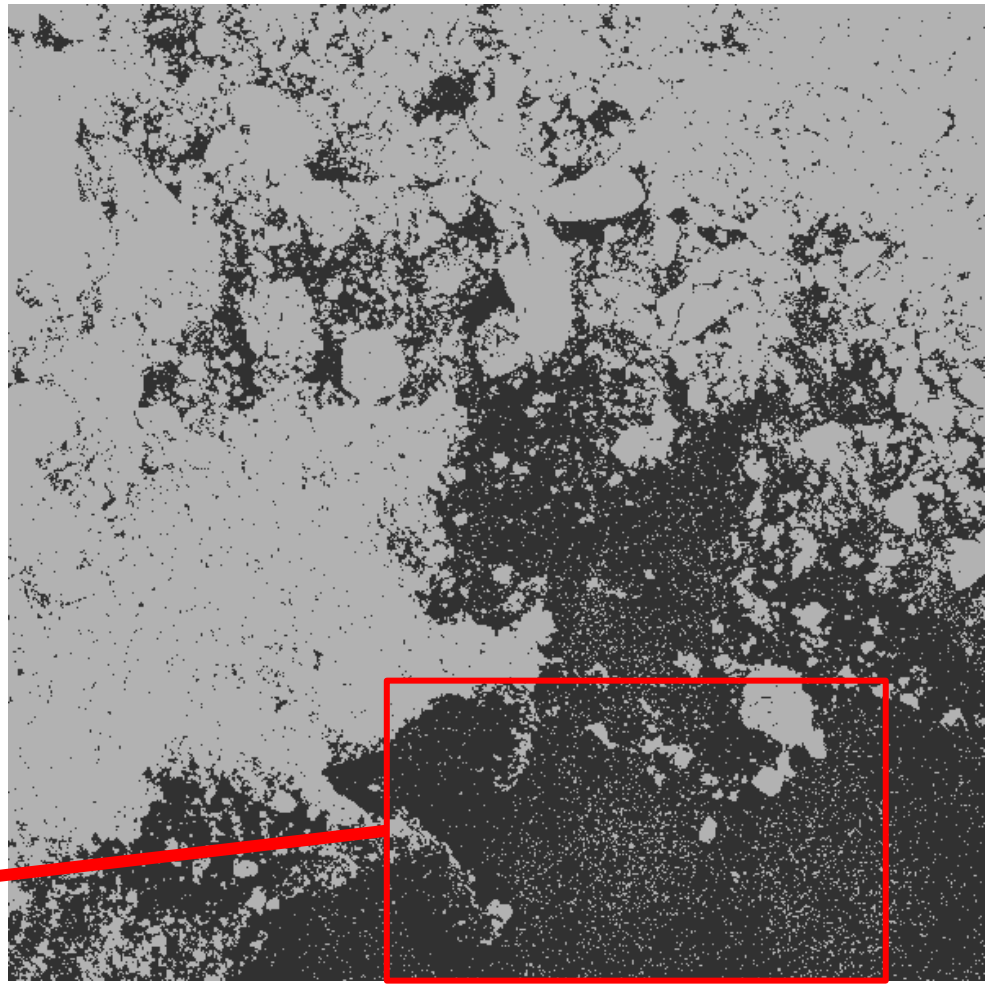
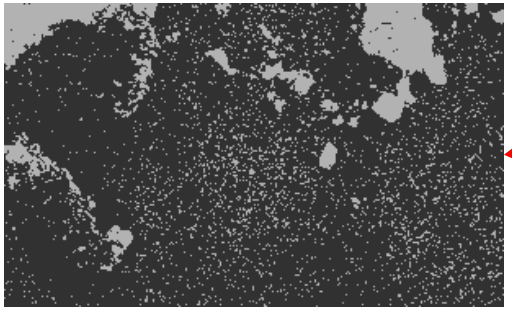


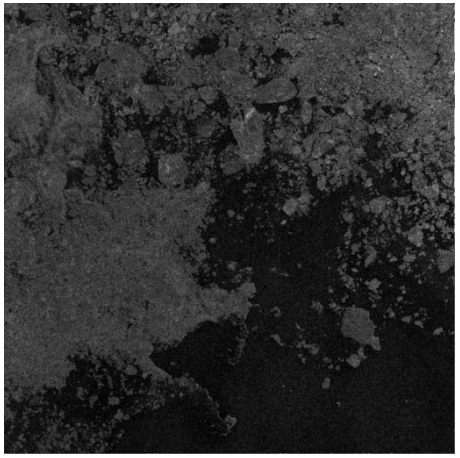


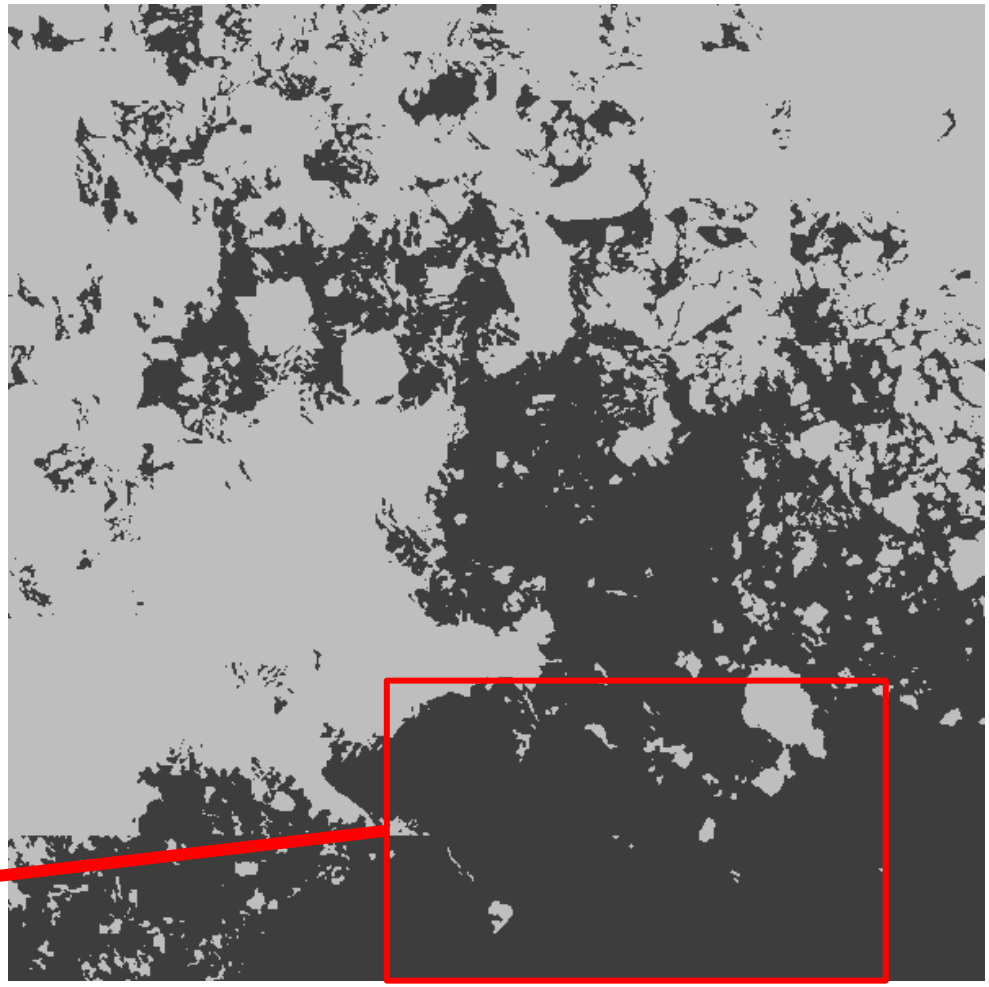
Banding effect!



GMM

Results





No banding effect!

Proposed method

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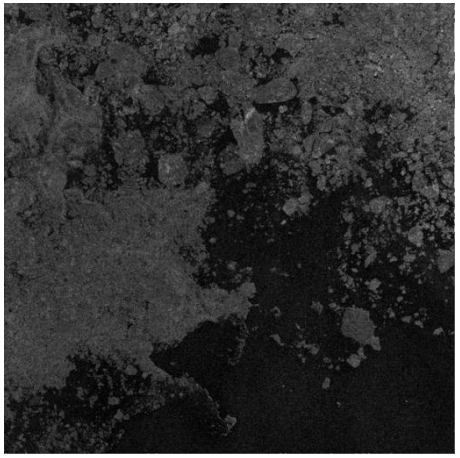
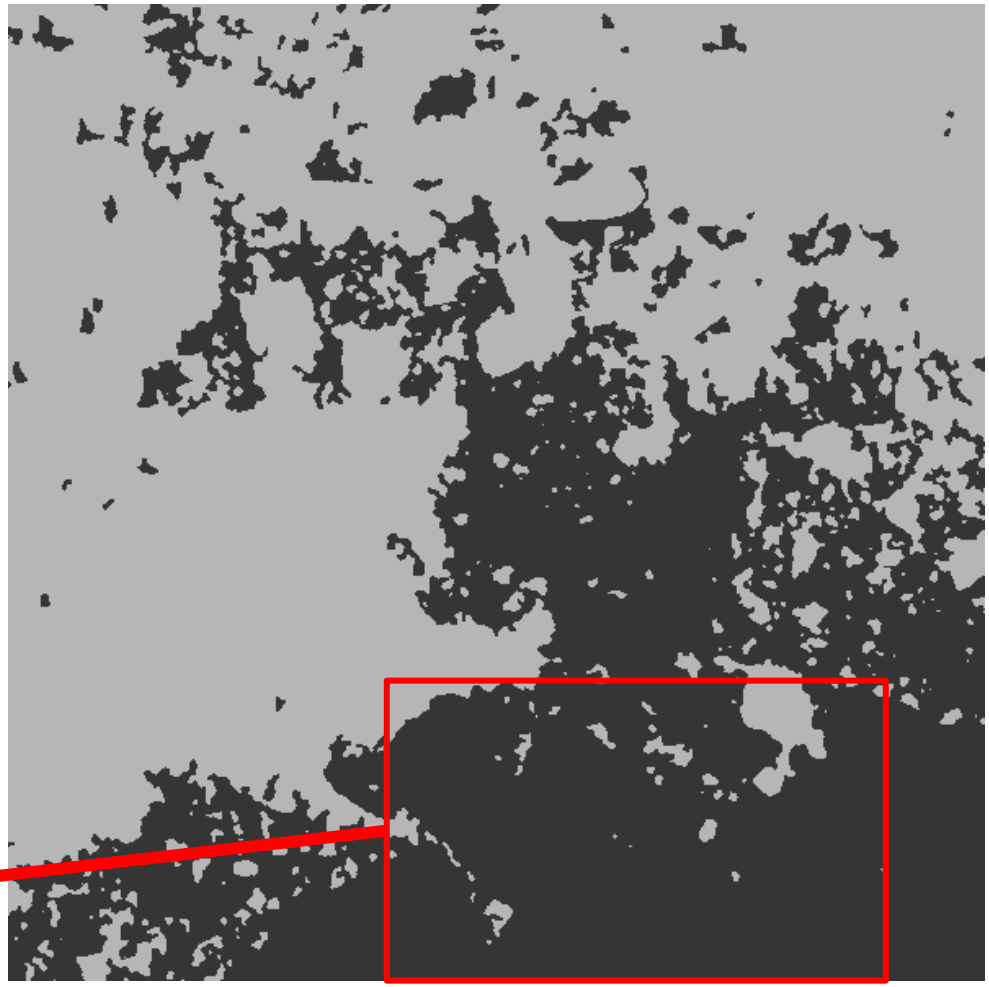
Results





Comparable!

IRGS

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Conclusions & Future Work

- Sparsifying transform for sea/ice classification
  - Simple 3-stage implementation
    - Representation, Projection, Classification
  - Represents noisy/complex data well
  - Promising results with HV RADARSAT data
- Future work
  - Rotation, scale invariance
  - Automatic parameter selection
  - Ground-truth comparison

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References

[1] Q. Yu and David A. Clausi, “SAR sea-ice image analysis based on iterative region growing using semantics,” IEEE Trans. Geosci. Remote Sens., vol. 45, no. 12, pp. 3919–3931, 2007.

[2] Q. Yu and David A. Clausi, “IRGS: Image segmentation using edge penalties and region growing,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 30, no. 12, pp. 2126–2139, 2008.

Download these slides!

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Thank You!

Comments/Questions/Feedback:

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