MEOPAR

MARINE ENVIRONMENTAL OBSERVATION
PREDICTION & RESPONSE NETWORK

Improved Sea Ice Forecasts through Classification and Assimilation of SAR imagery

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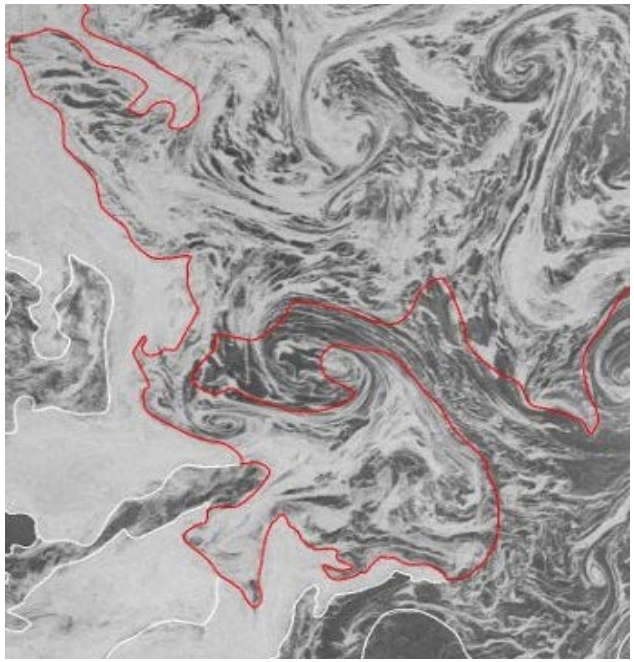
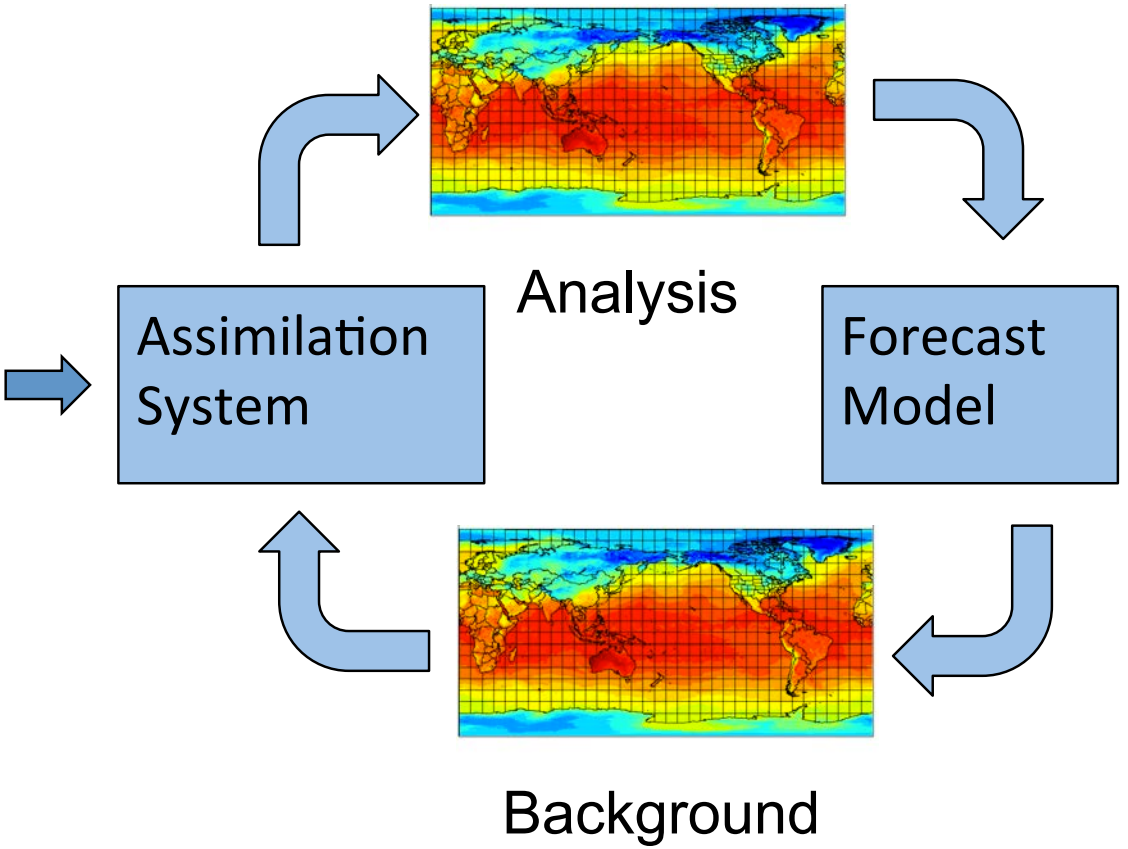
Collaborators: T. Carrieres, M. Buehner and M. Arkett at Environment Canada

MEETING THE CHALLENGES OF OUR CHANGING OCEAN

Project objective

- Combine computer vision with data assimilation to enable assimilation of high resolution information from SAR imagery



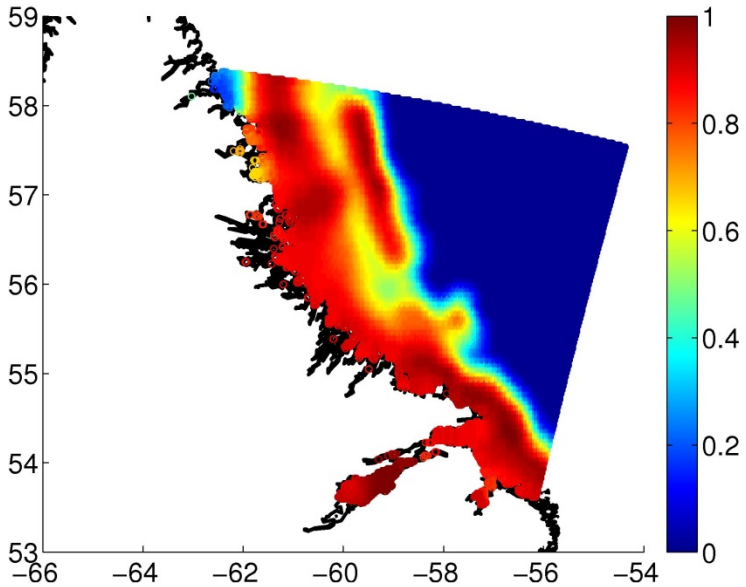


Personnel

- Data assimilation
  - Andrea Scott (Assistant Professor, UW)
  - Lei Wang (PhD student, UW)
  - Yang Chen (Undergrad Student, UW)
  - Mark Buehner (Research Scientist, EC)
  - Tom Carrieres (Modeling Manager, EC)
- Computer vision
  - David Clausi (Professor, UW)
  - Steven Leigh (Research Assistant, UW)
  - Matt Arkett (EC)

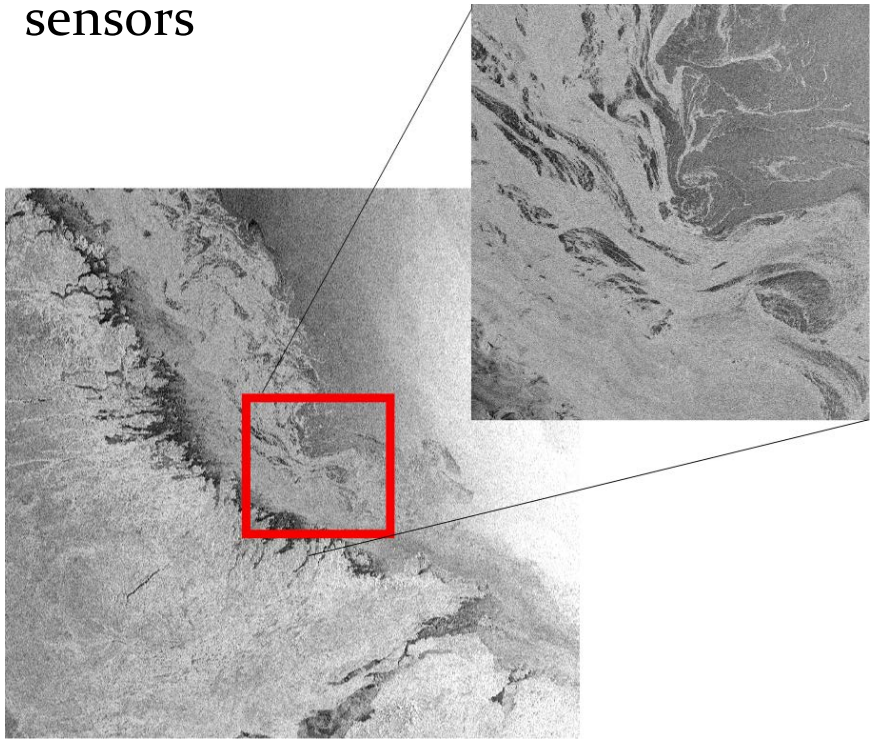
High and low resolution satellite data

Many sea ice forecasting systems rely heavily on data from passive microwave sensors



Resolution may be sufficient for weather forecasting – not for shipping or other operations in ice-infested waters

Higher resolution can be obtained from synthetic aperture radar (SAR) sensors



How can we assimilate this information?

Project overview

Objectives

Develop **automated** methods to assimilate ice/water data from SAR imagery in operational sea-ice forecasting system (robust and efficient)

Challenges

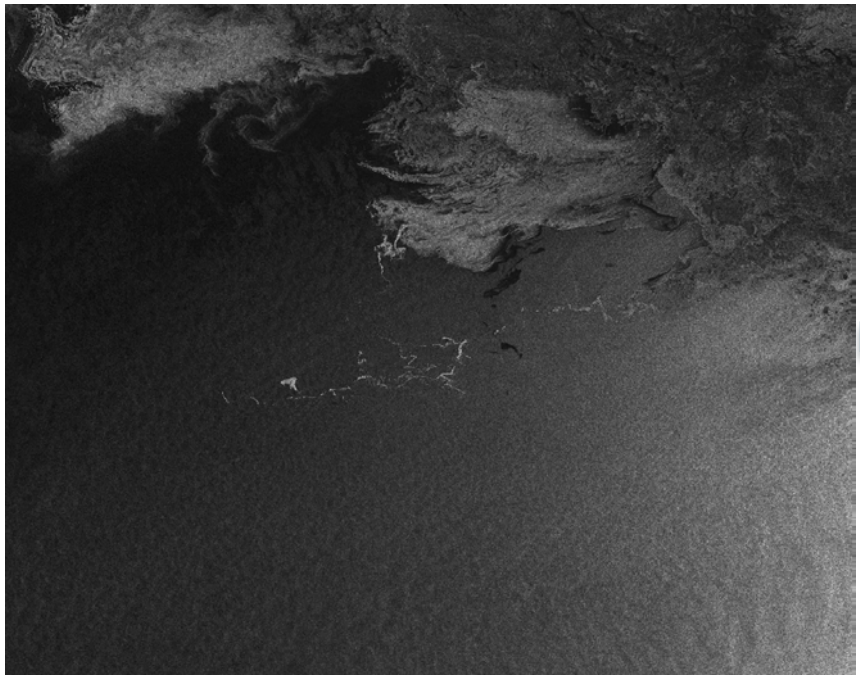
There is no direct mapping from a SAR image to parameters of interest (ice concentration, ice thickness, ice deformation)

Strategy

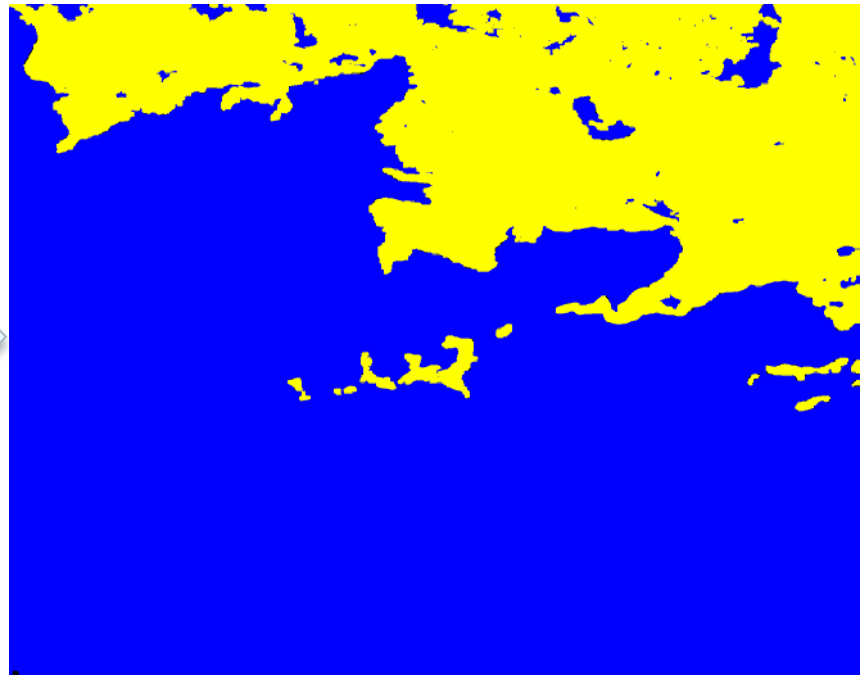
Start with an established computer vision method that can separate ice from water and assimilate these **binary** observations

Observations from image classification system

- MAGIC software system: IRGS + SVM (Leigh et al. 2014)
- Dual-pol RADARSAT-2 SAR -> Ice and water



HH image



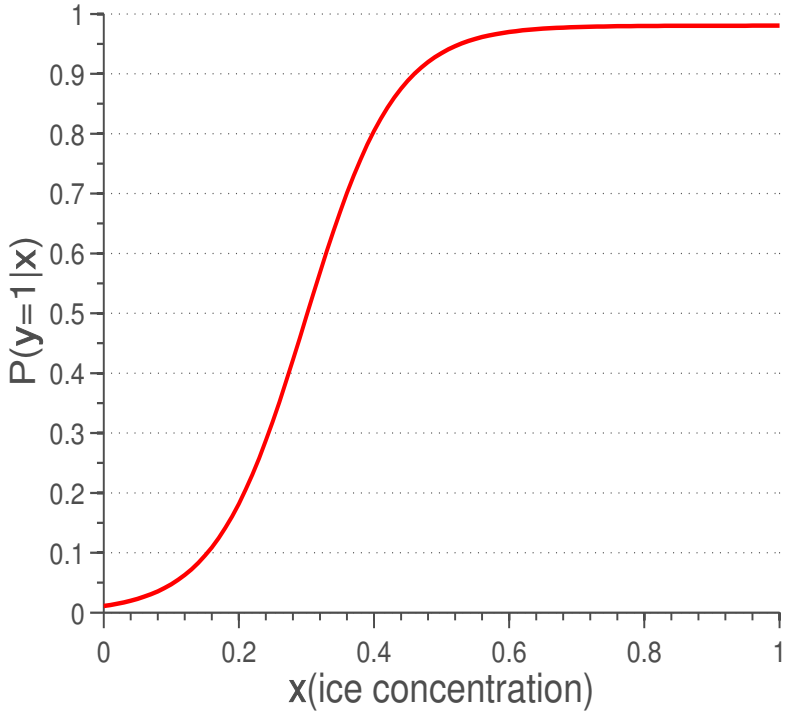
Classified image: Ice/water

Method to assimilate binary observations

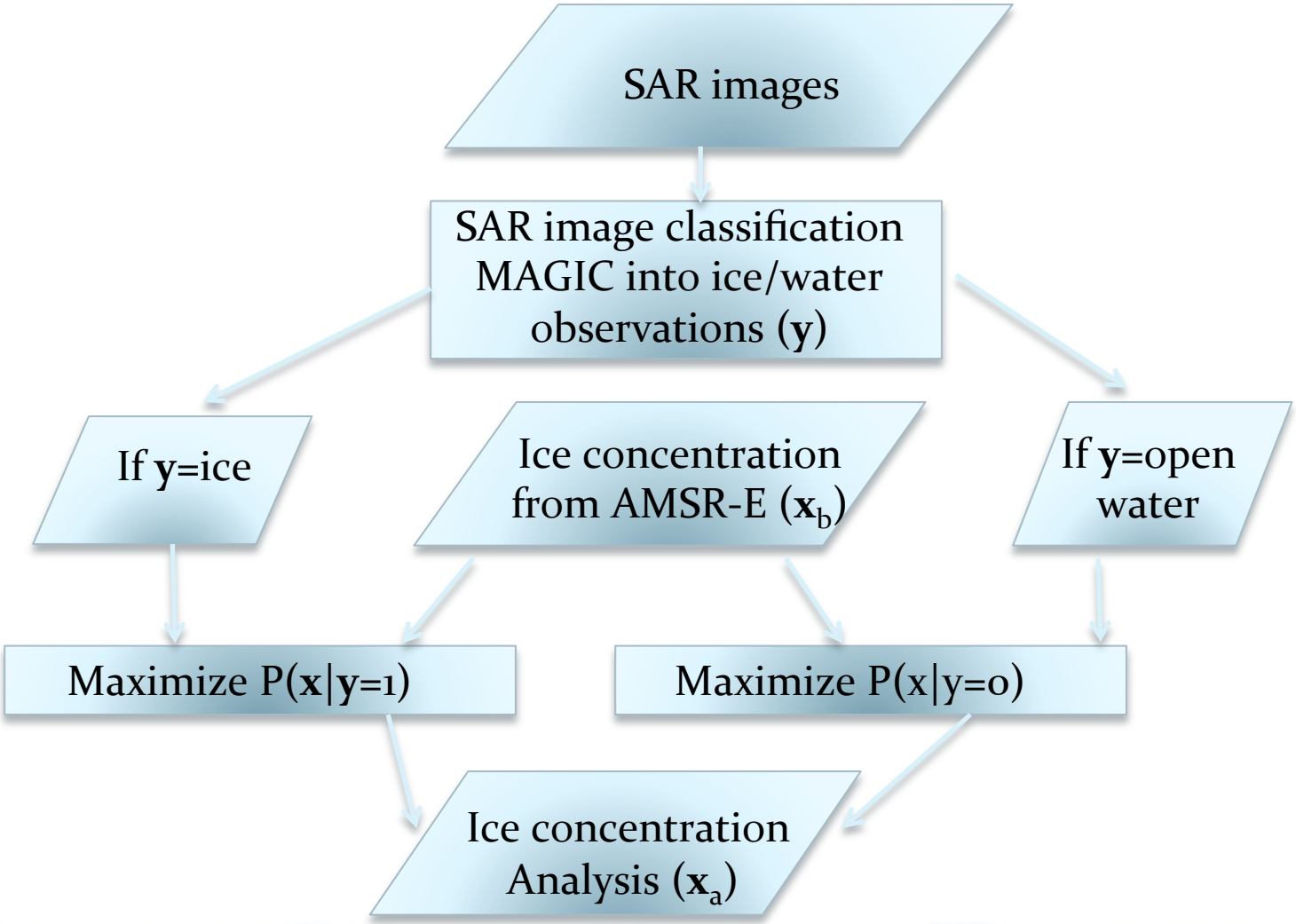
- Idea is to maximize the probability of the state, **x**, given the observations, **y**

$$P(\mathbf{x} \mid \mathbf{y}) \propto P(\mathbf{y} \mid \mathbf{x}) P(\mathbf{x})$$

- $P(\mathbf{x})$ is modeled as Gaussian distribution
- $P(\mathbf{y}|\mathbf{x})$ is modeled empirically

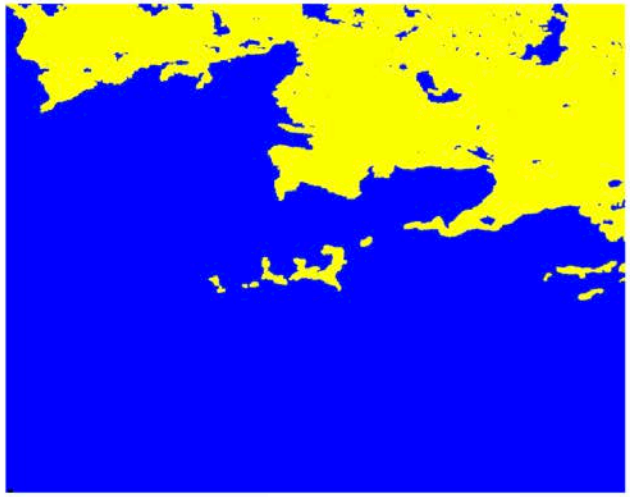


Methodology

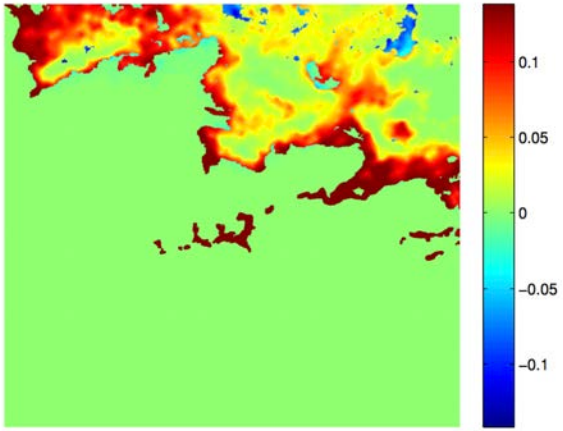


Results, Oct 6th, 2010

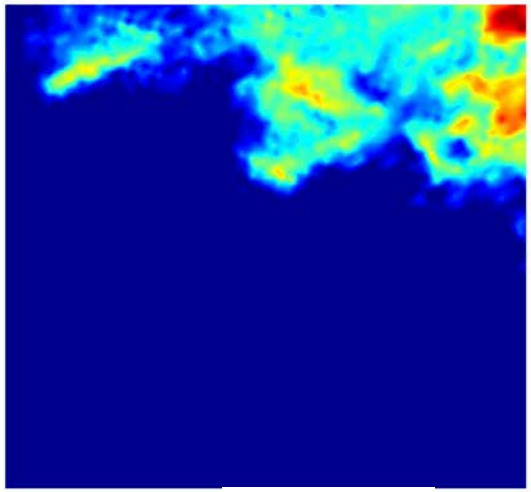
HH



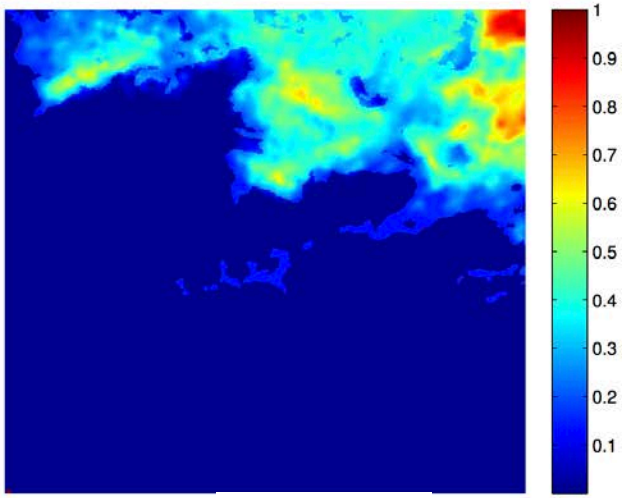
Ice/water



Increment



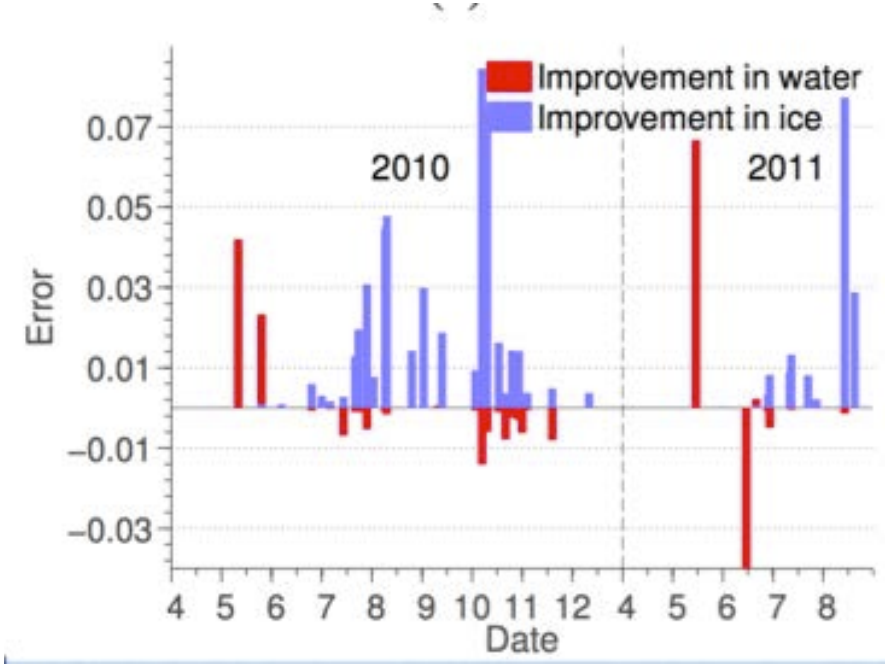
AMSR-E

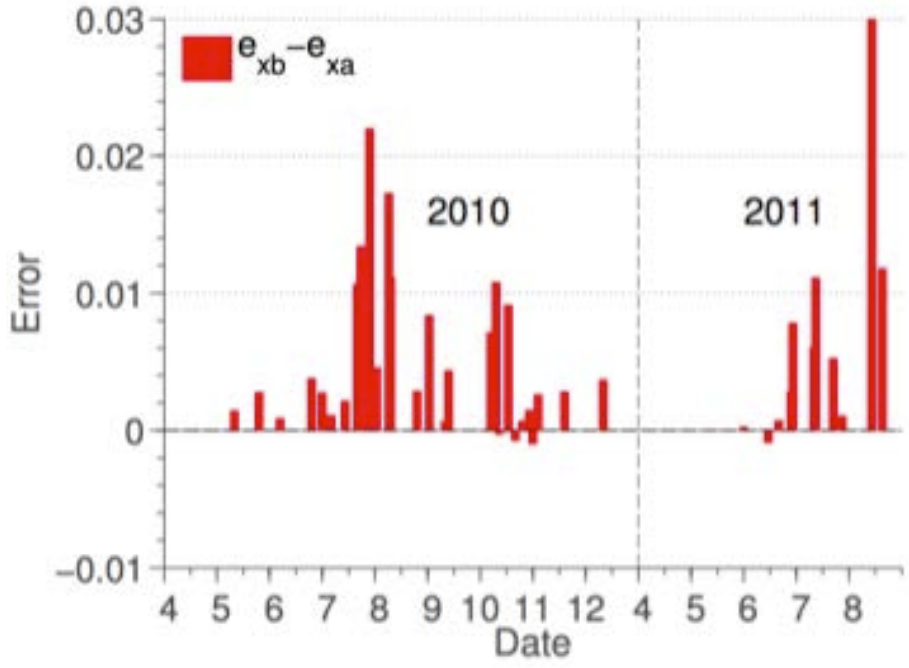


Analysis

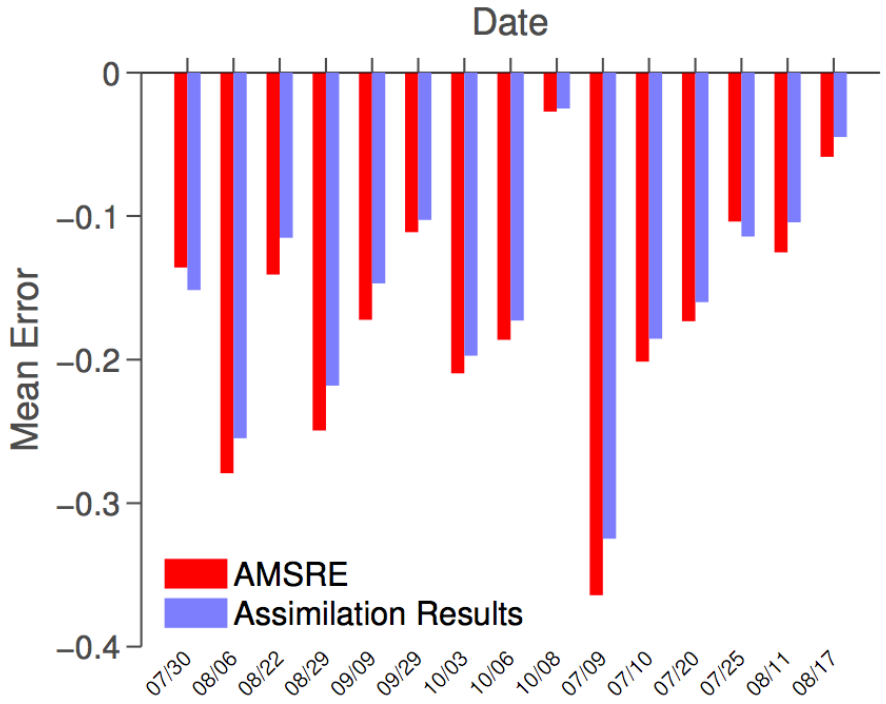
Comparison of assimilation output vs. independent data

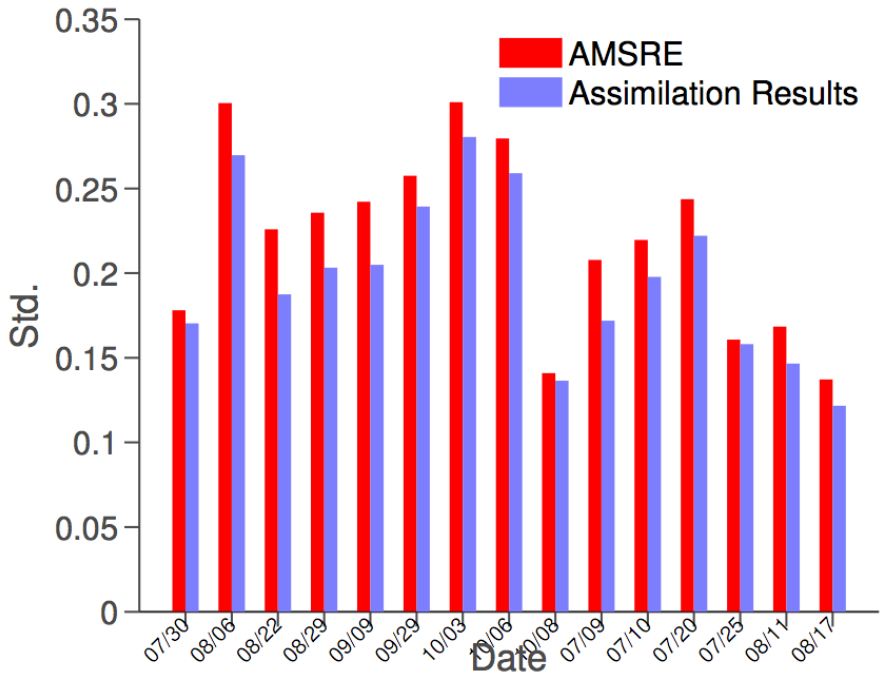
- Comparison is against ice/water analyses from IMS
- Error from assimilation output lower than background state





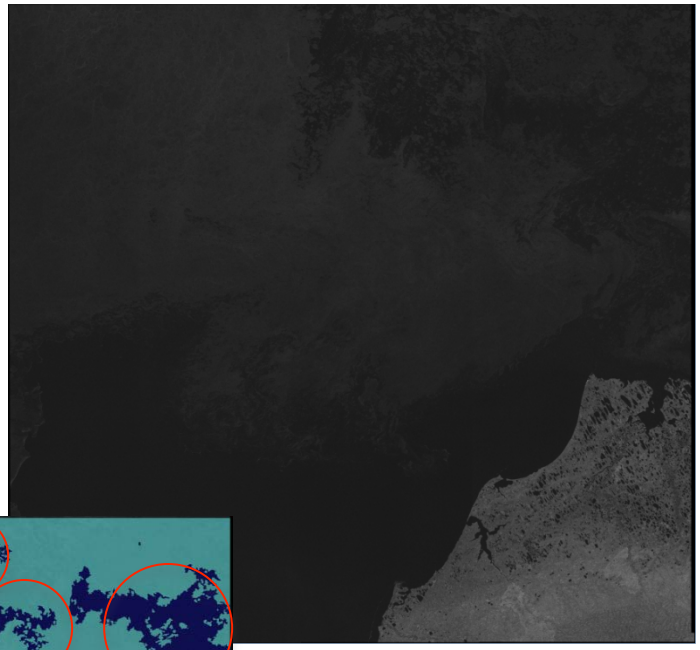
Verification against image analyses



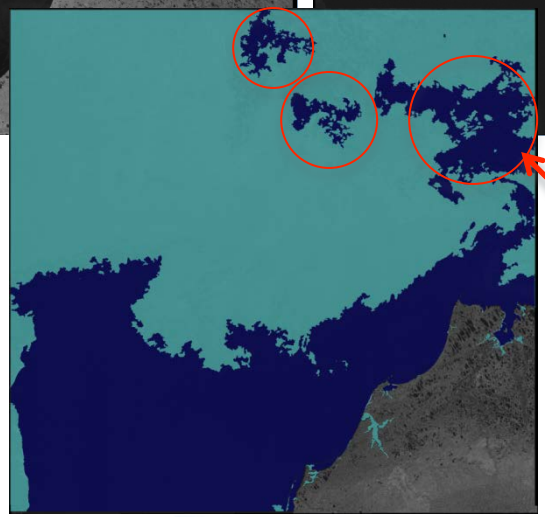


Accounting for misclassified pixels

HH image



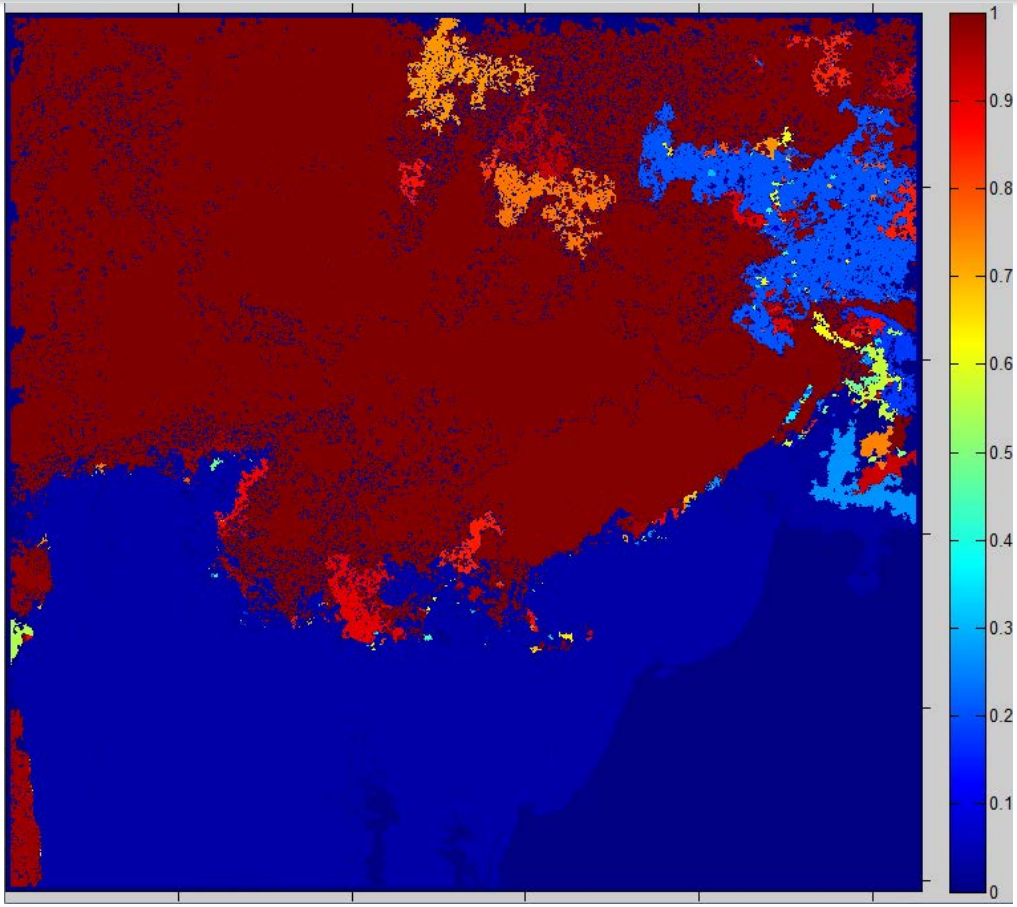
HV image



Misclassified

Ice/water image

Confidence map



0 – high confidence of water
1 – high confidence of ice

- Confidence in ice is the total probability of ice over a region
- Confidence in water is the total probability of ice over a region
- Use in quality control

Milestones and Lessons Learned so Far..

- Positive impact of assimilating ice water observations over the Beaufort sea (Wang, Scott and Clausi, submitted to IEEE TGRS)
- Information content of binary observations may be limited – a question of scale?
- Testing another method to calculate ice concentration from SAR imagery (Wang, Scott and Clausi, IGARSS 2014)
- Obtaining test sets of images with other coincident data can be challenging (due to variability of ice season, revisit time of SAR sensor and loss of AMSR-E)

Upcoming milestones

- To compare this assimilation strategy with one that uses an explicit forward model (CMOS presentation) in a realistic experiment (e.g., GSL 2014)
- To incorporate a realistic observation error estimate or quality control procedure such that erroneous observations are not assimilated
- To incorporate the assimilation of SAR data into the RIPS system (requires careful evaluation and implementation)
- To continue development of a method to automatically classify a SAR image into ice types

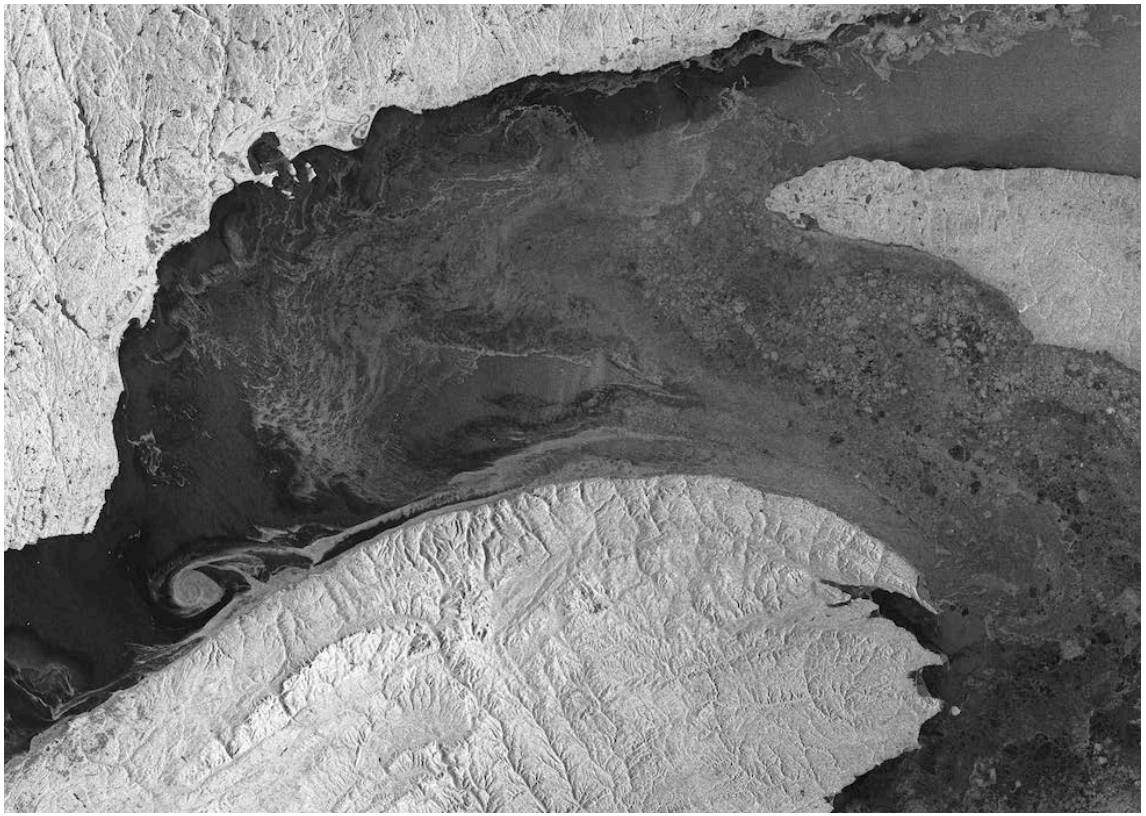
Future Outlook (2017)

- To assimilate SAR data
  - in the RIPS system
  - in a ***coupled ice-ocean model***
- What method? How to deal with dense observations?

- To assess the benefit of assimilating SAR data
  - to operations?
  - to science?

- Transition toward the use of data from RCM (Radarsat Constellation Mission)

Thank you!



Questions?

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Observation operator

- $\mathcal{H}$: $\begin{cases} P(\boldsymbol{y}=1|\boldsymbol{x}) = \dfrac{1}{1+e^{-r\boldsymbol{x}+rq}}, \\ P(\boldsymbol{y}=0|\boldsymbol{x}) = 1 - P(\boldsymbol{y}=1|\boldsymbol{x}) \end{cases}$ $\quad r, q \in \mathbb{R} \quad r > 0\ , q > 0$

- r = 15
- q = 0.3 (ice concentration threshold for ice classification)