AUV-Based Mapping and Monitoring

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Outline

- Technology Requirements
- Technology Background: SAS
- Technology Background: Self-Potential
- Exploration Examples
- Production Monitoring
- Conclusion

Requirements

Metrics for (early) Exploration:

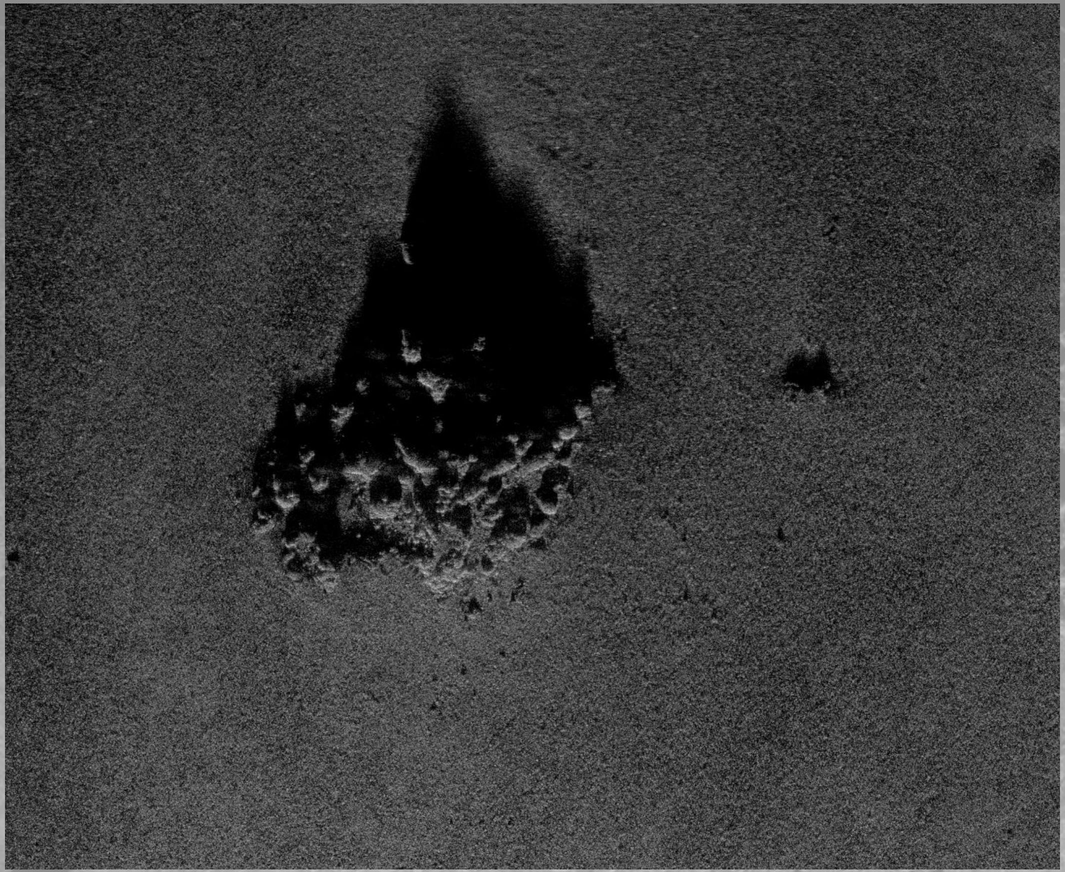
- Large Area Detection
  - Extinct Systems
  - Buried Systems

Metrics for Monitoring:

- Production Area Coverage
  - Change in Deposit
  - Sediment Deposition
- Plume Monitoring
  - Regional Benthic Observation

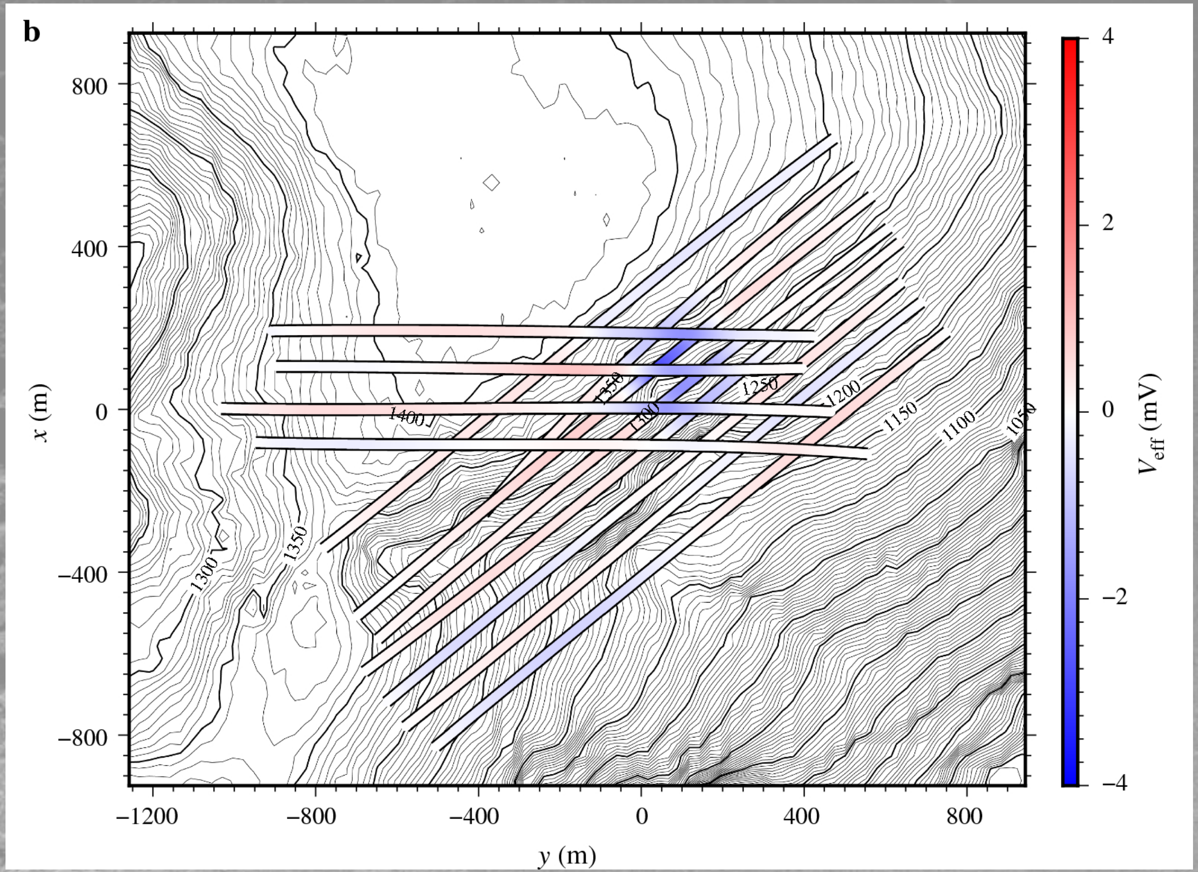
Technology Focus

Synthetic Aperture Sonar



Denny et al, in prep

Self-Potential

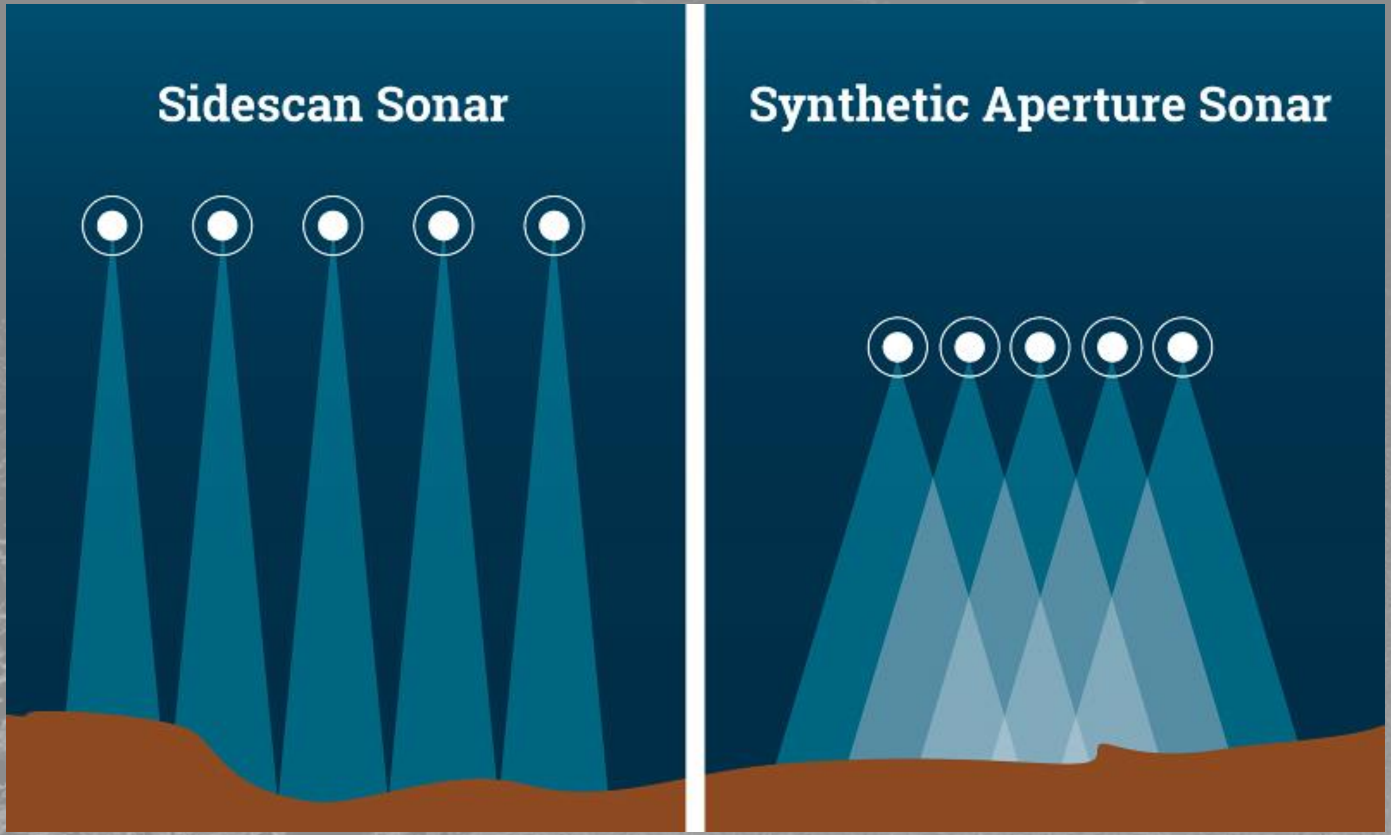


Adapted from Fig. 3, Kawada & Kasaya 2018

Background: SAS

Advantages:
- Wide area coverage
- Range-independent resolution (to 2x2cm)
- Ideal for high-resolution mapping

Disadvantages:
- Poor performance in rough terrain due to vehicle altitude and pitch errors
- High-cost platform
- No sub-surface information (yet)



… Old idea, SAS described by Cutrona (1975)
Similar technique (SAR) in wide use from space based and aerial platforms
https://doi.org/10.1121/1.380678

Image courtesy of NOAA
https://oceanexplorer.noaa.gov/technology/sonar/sas.html

Background: Self Potential

Advantages:

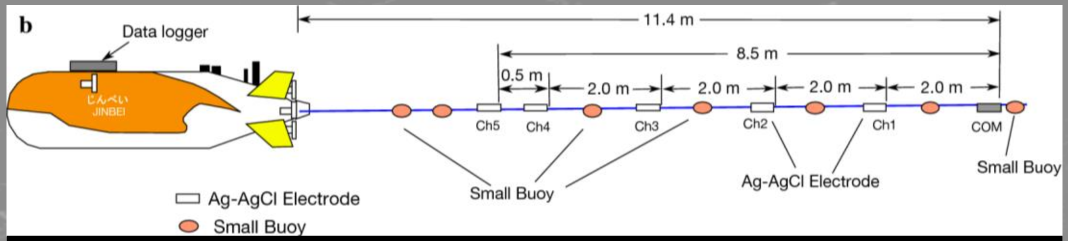
- Passive acquisition
- Deployable from small vehicle
- Detection of buried and dormant / extinct systems

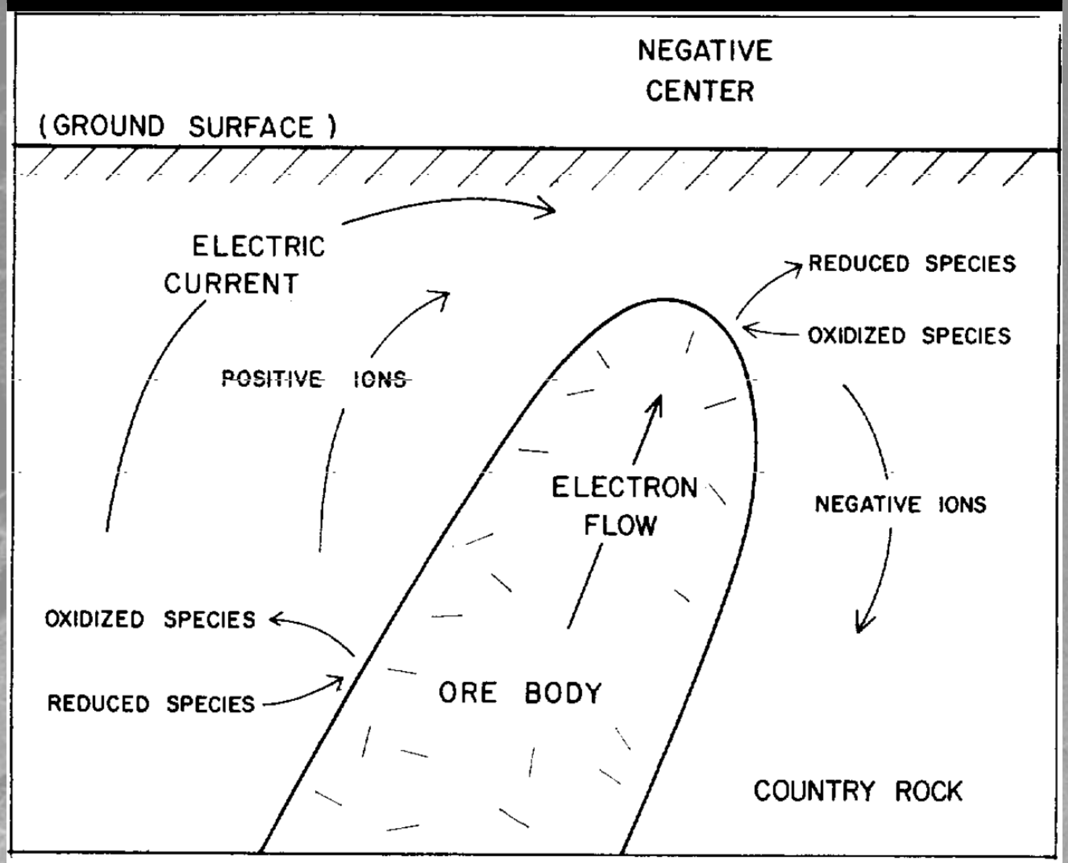
Disadvantages:

- Poor performance in rough terrain due to vehicle altitude and pitch errors
- Poorly constrained response
- Hydrothermal mineralization ≠ economic deposit

… Old idea, self-potential described by Sato and Mooney (1960)
Widely used in terrestrial environment, only recently used subsea

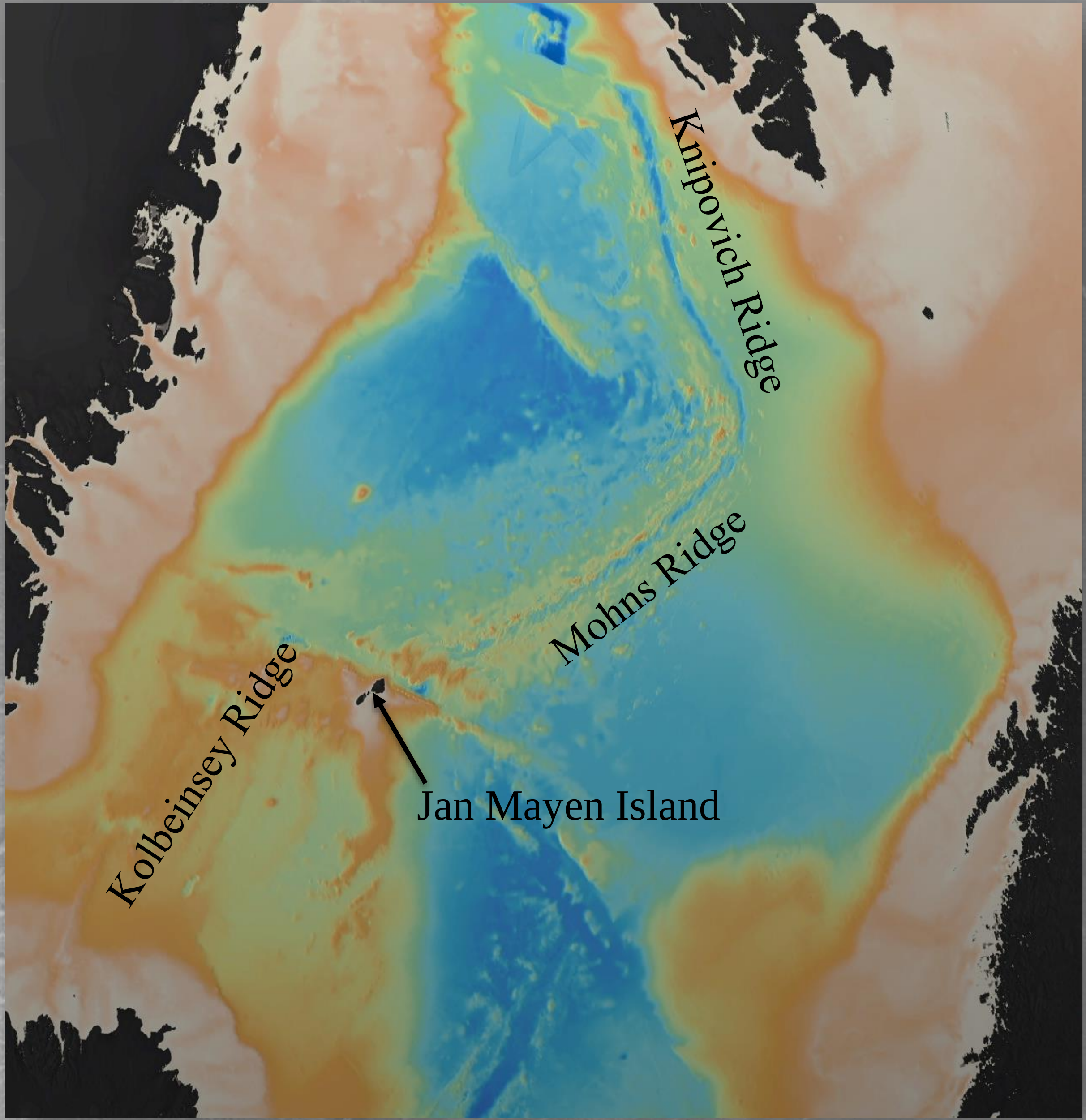
https://doi.org/10.1190/1.1438689



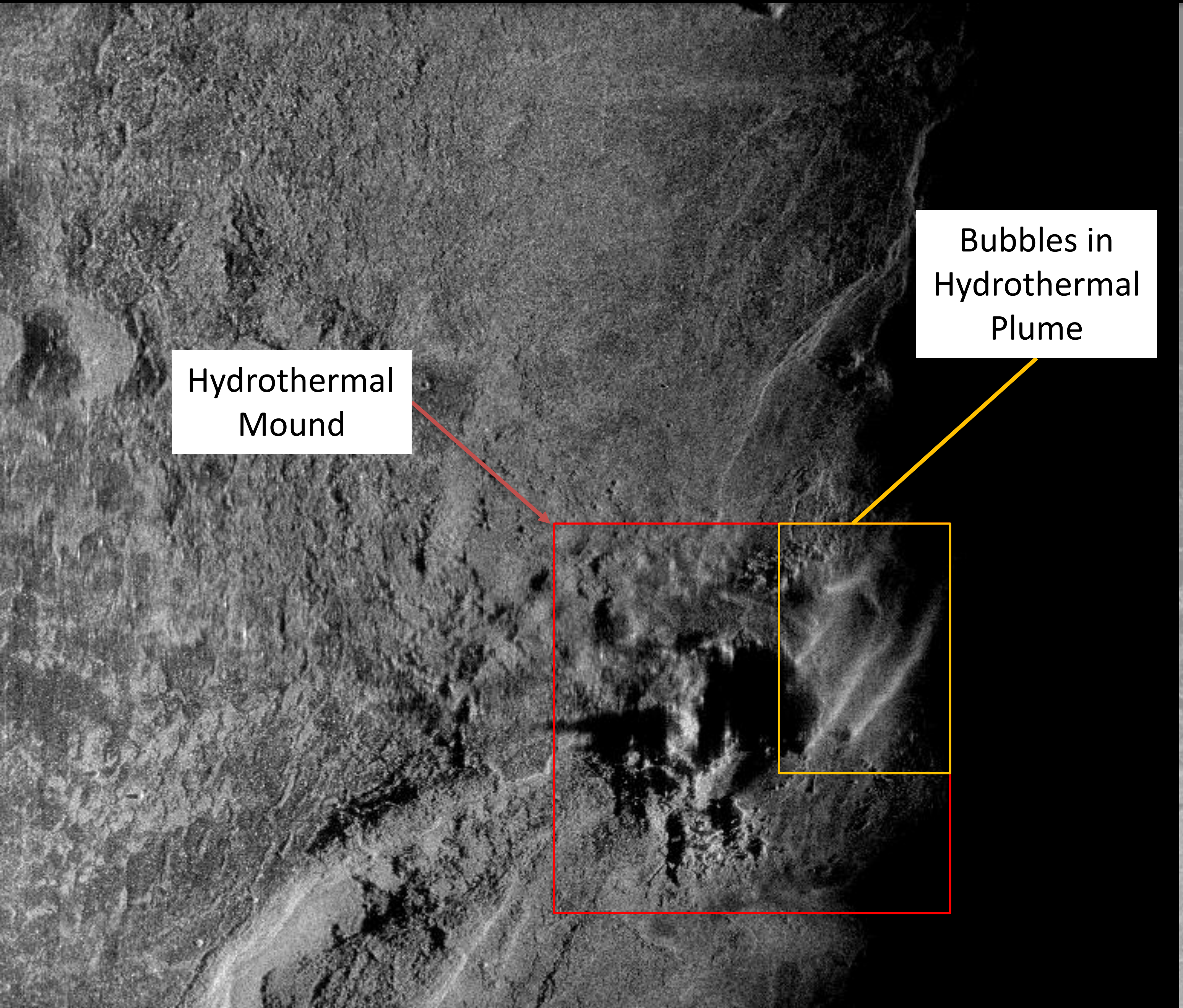


Top – Kawada and Kasaya 2018
Bottom – Sato and Mooney 1960

Example Area: Arctic Mid-Ocean Ridge



Active Field Imaging: SAS

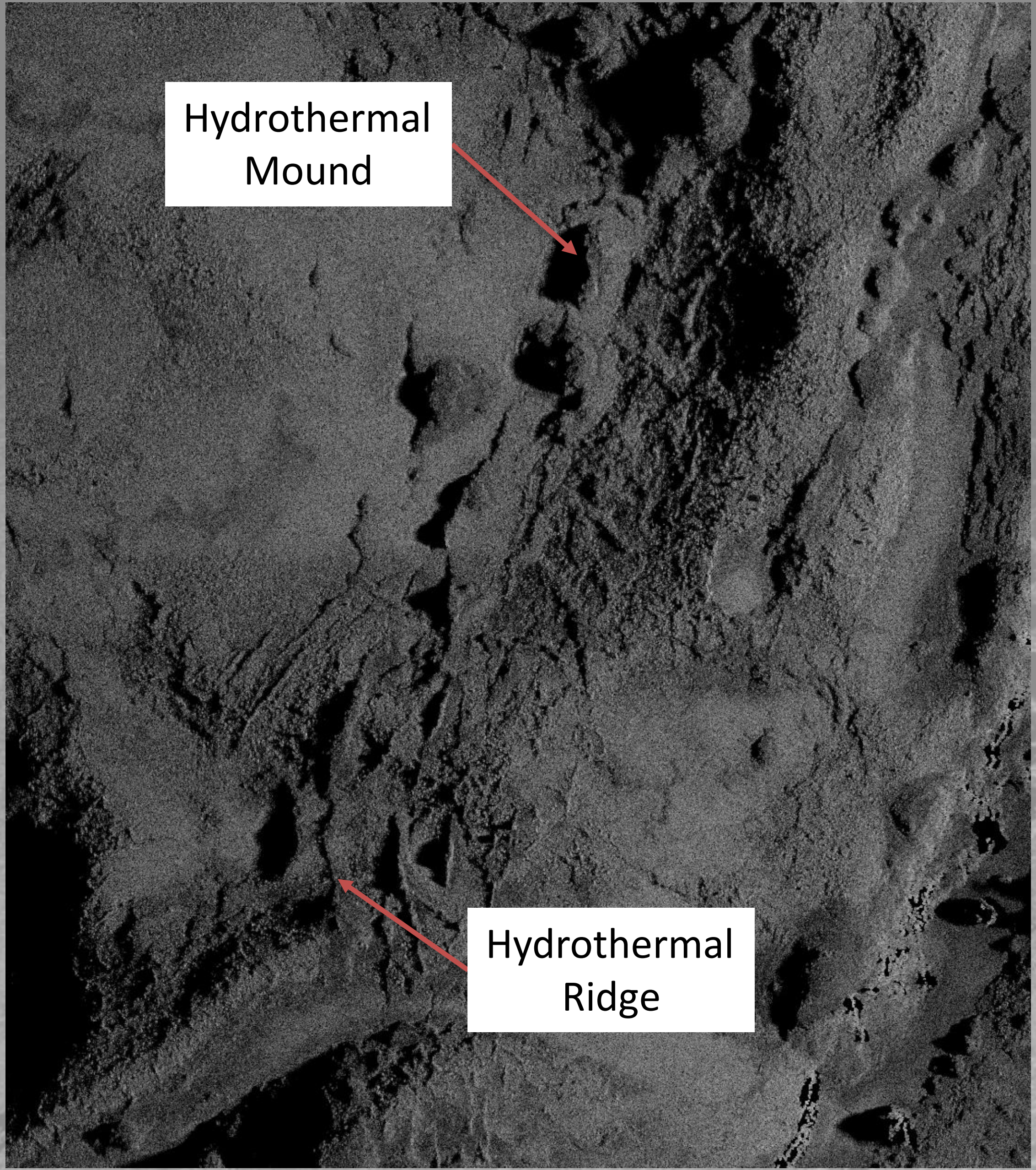


SAS can image:

- Complex hydrothermal chimneys
- Bubbles in buoyant plume
- Surface extent of mound
- Low-relief features

Denny et al, in prep

Dormant Field Imaging: SAS



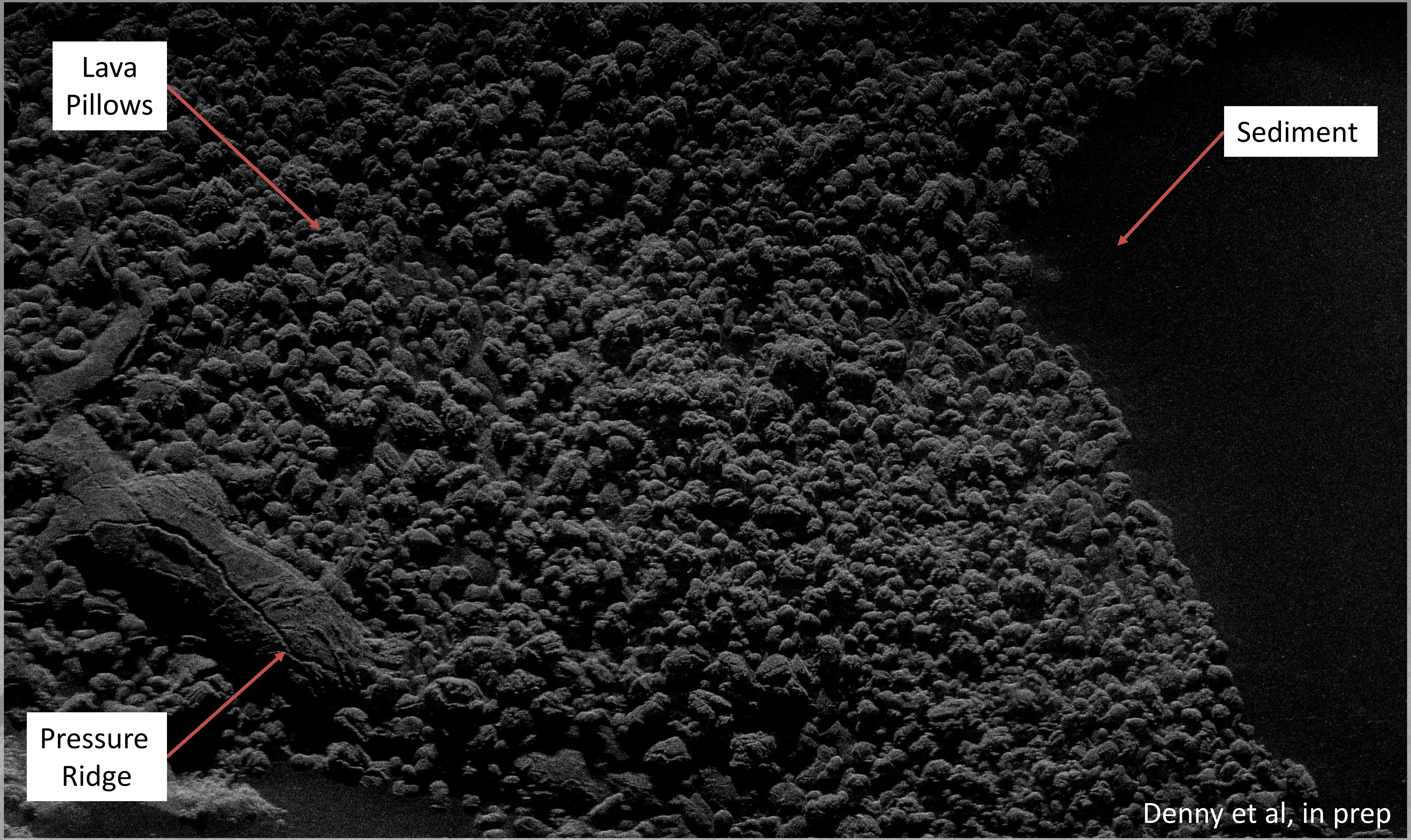
SAS can image hydrothermal:

- Inactive
- Dormant
- Weakly active

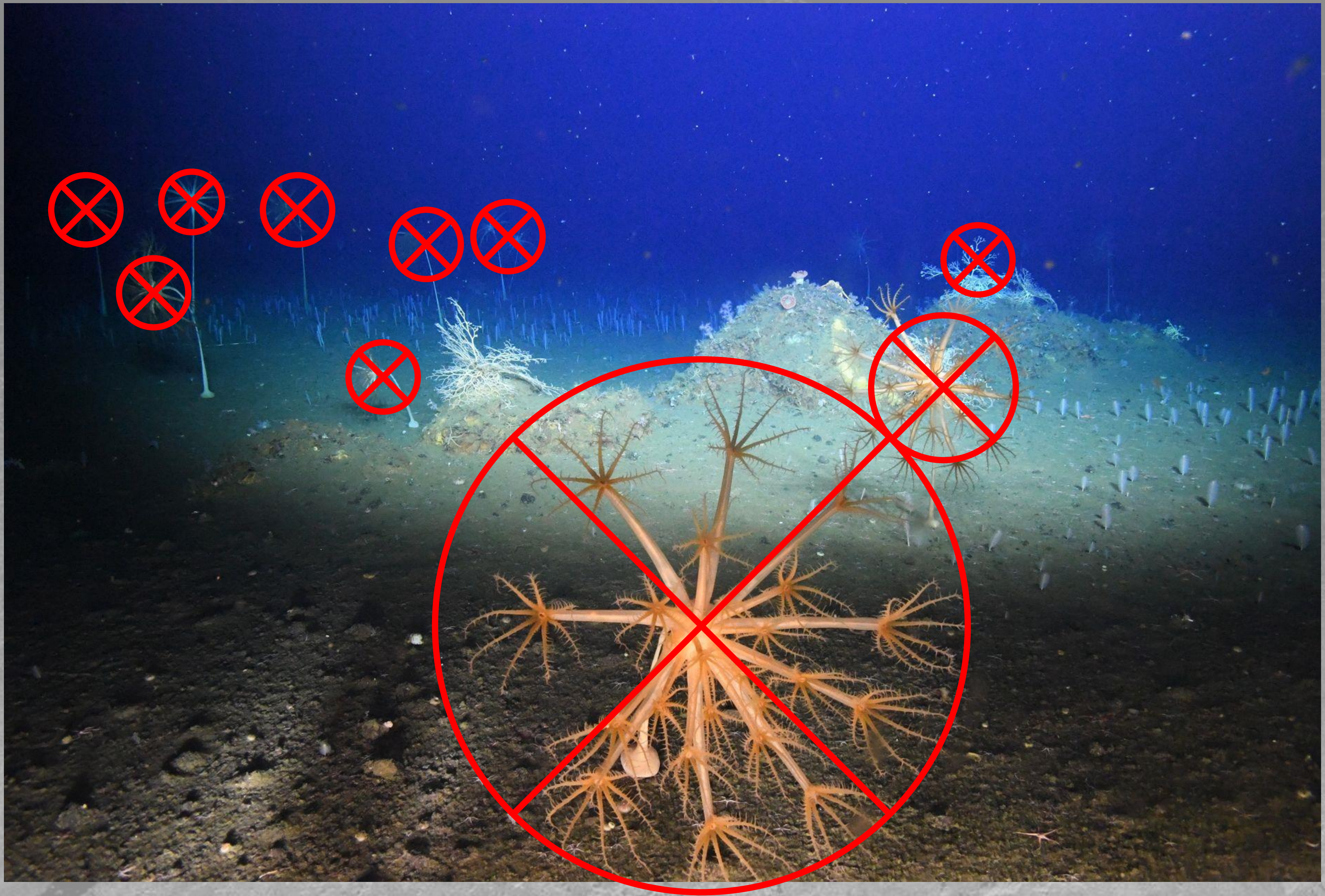
Independent of active flow indicators

Denny et al, in prep

Lava Flow: SAS



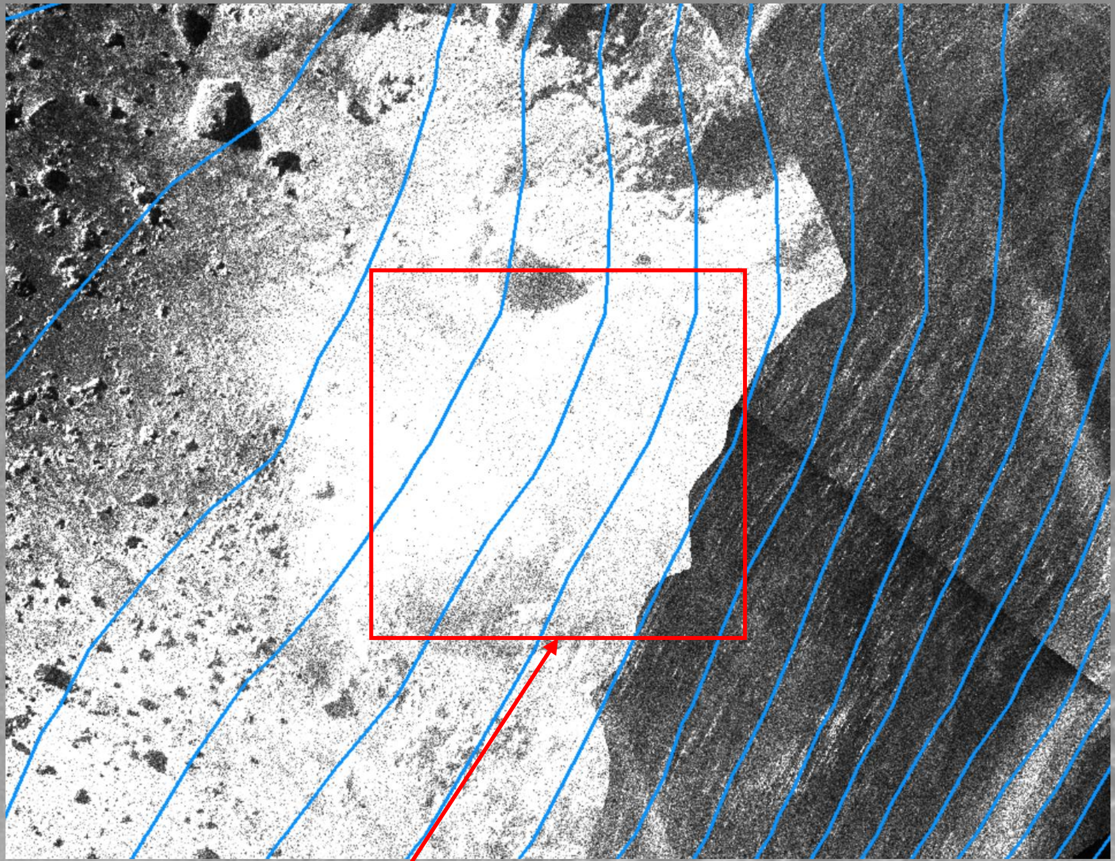
Limitations: SAS

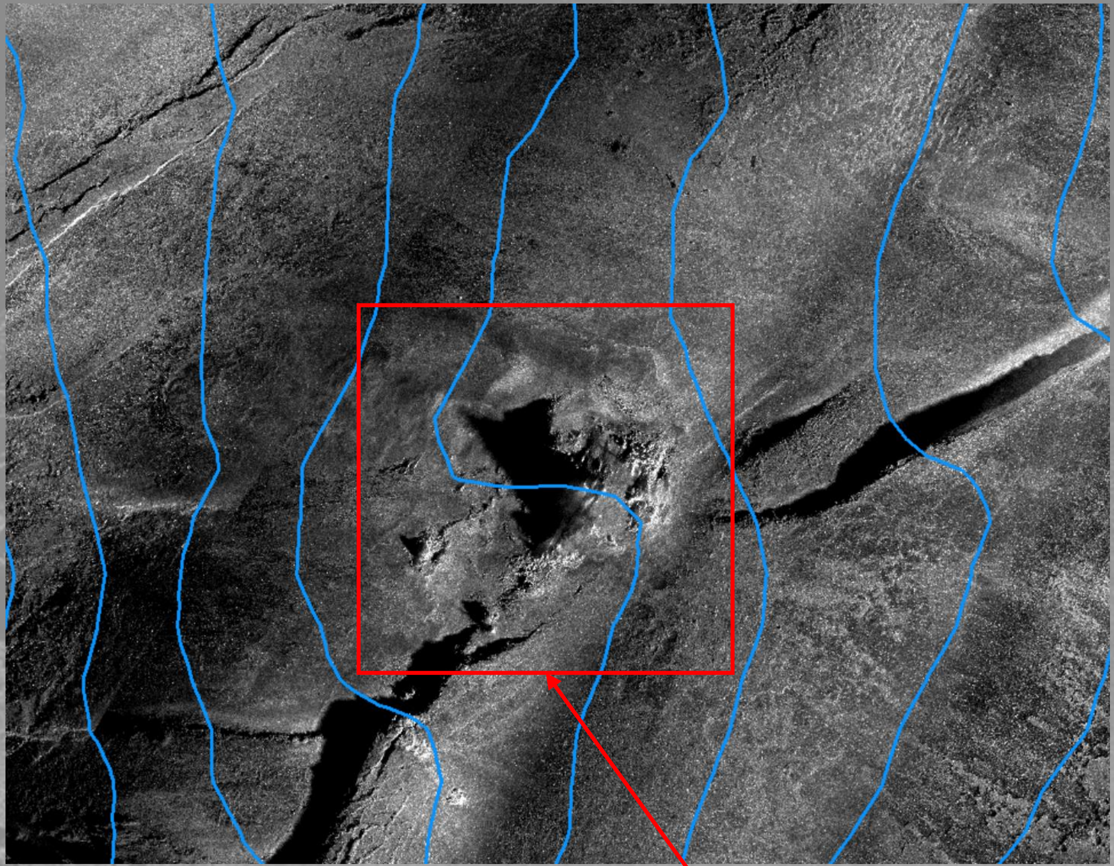


- Unable to image soft-bodied organisms
- Useful for habitat identification, but not able to image benthic fauna (yet)

Image courtesy of the Center for Deep Sea Research, UiB

Limitations: SAS



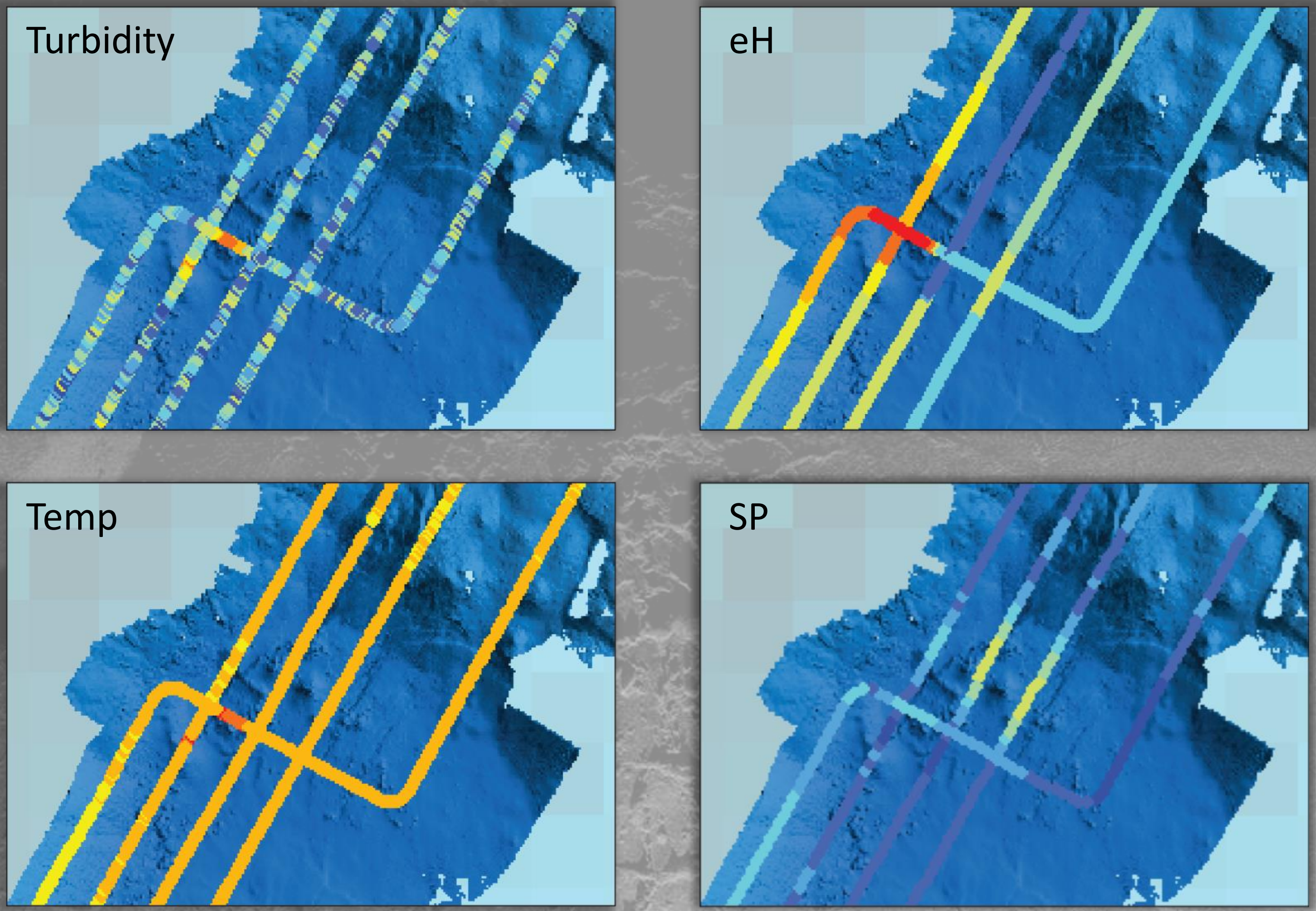


Troll Wall
Vent Field
Slope 28°

SAS is difficult to collect in steep or rough terrain
(contour interval 10m)

Bruse
Vent Field
Slope 6°

Active Field: Self-Potential



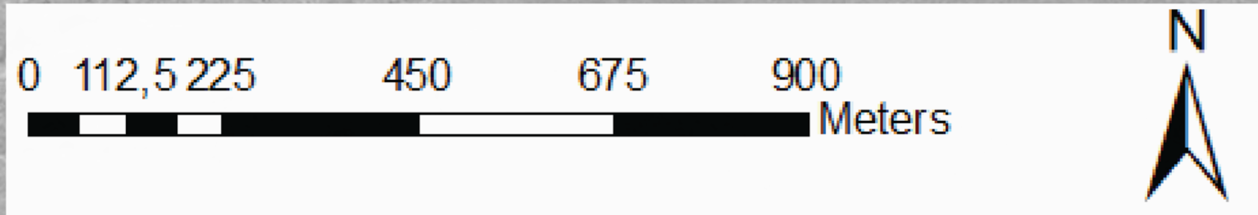


Image courtesy of NPD and Solveig Onstad, PhD Candidate, University of Bergen
Publication in prep

Inactive Field: Self-Potential

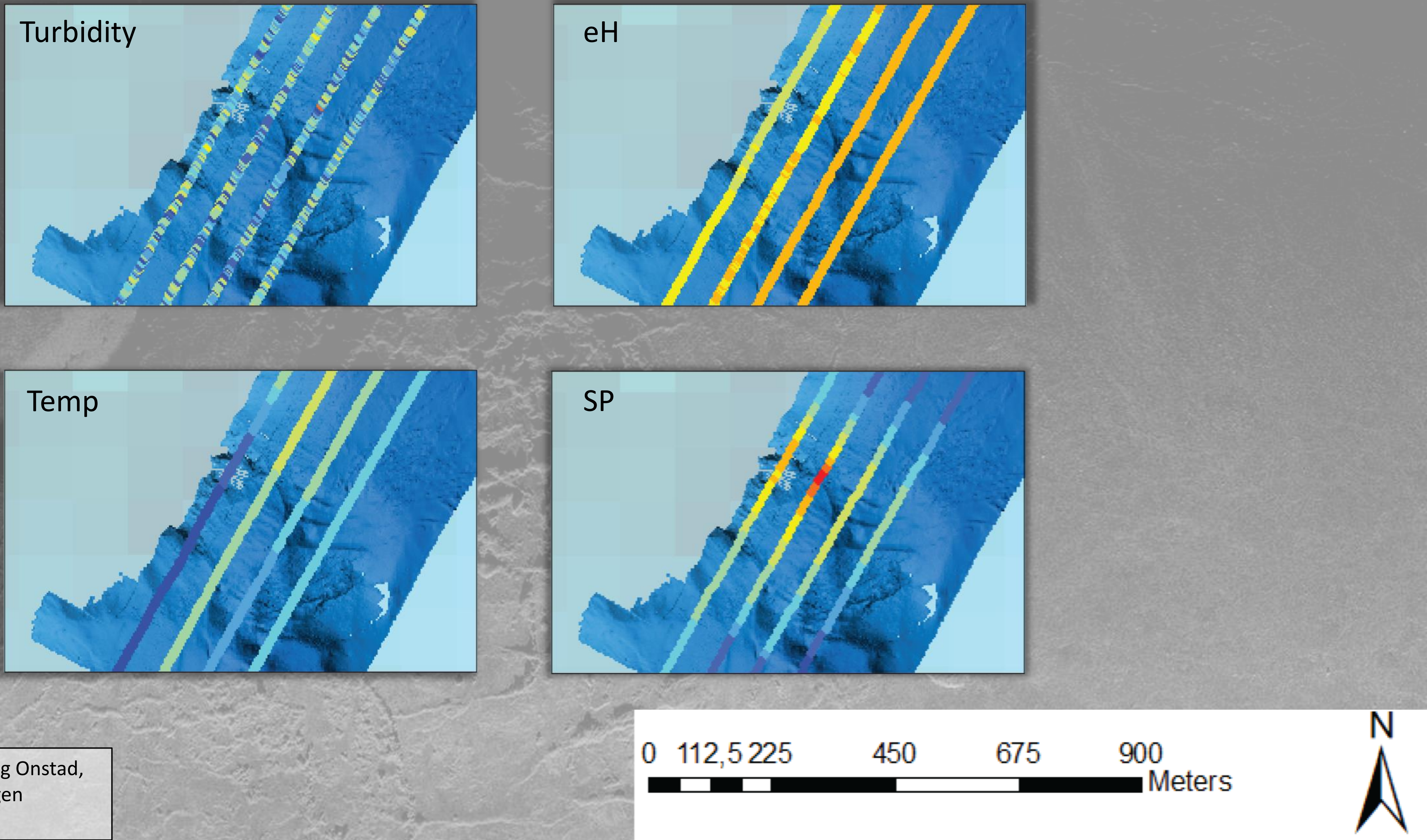
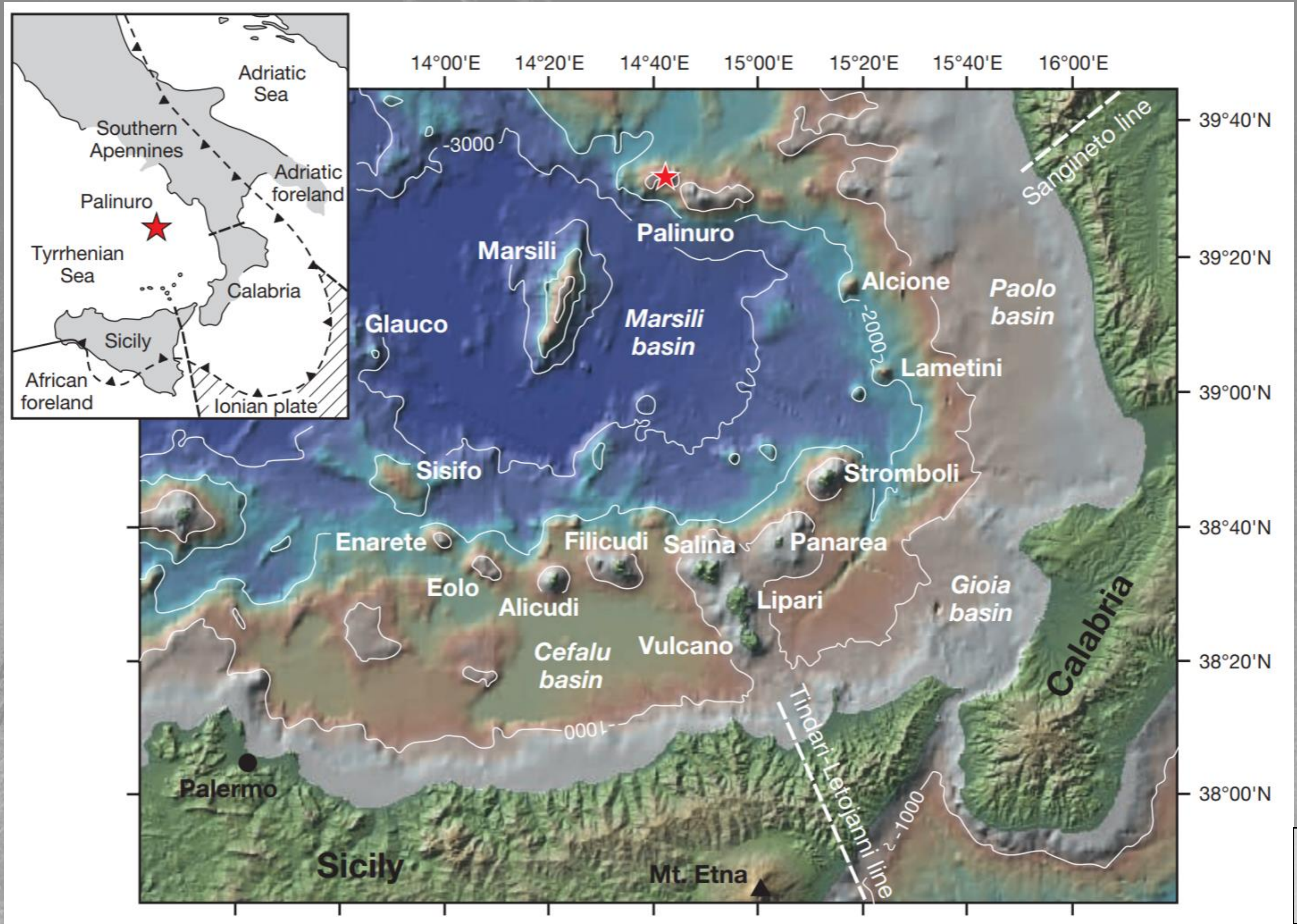


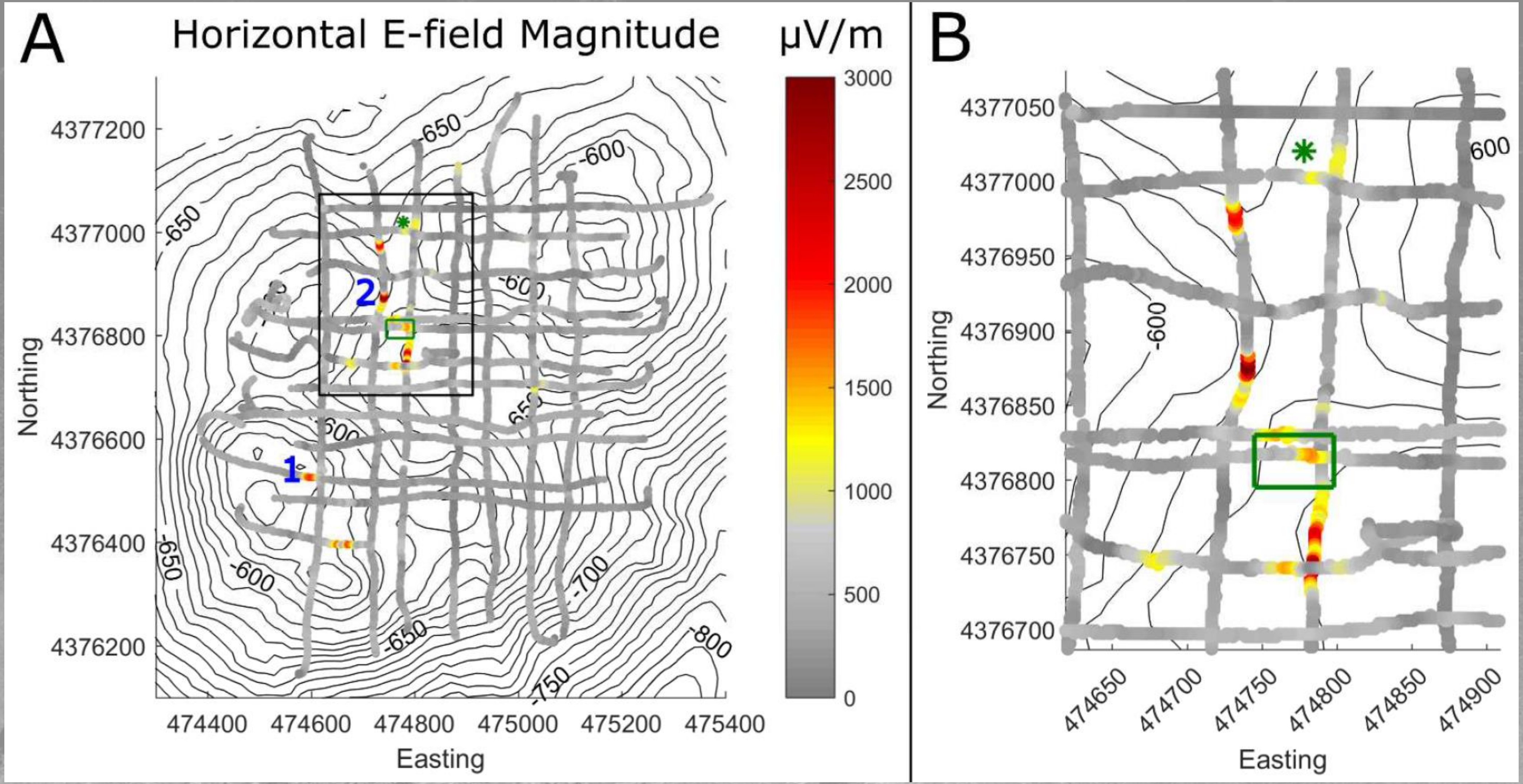
Image courtesy of NPD and Solveig Onstad, PhD Candidate, University of Bergen
Publication in prep

Example Area: Palinuro Seamount



Petersen et al, 2014
https://doi.org/10.2113/econgeo.109.8.2129

Surficial and Buried Field: Self-Potential

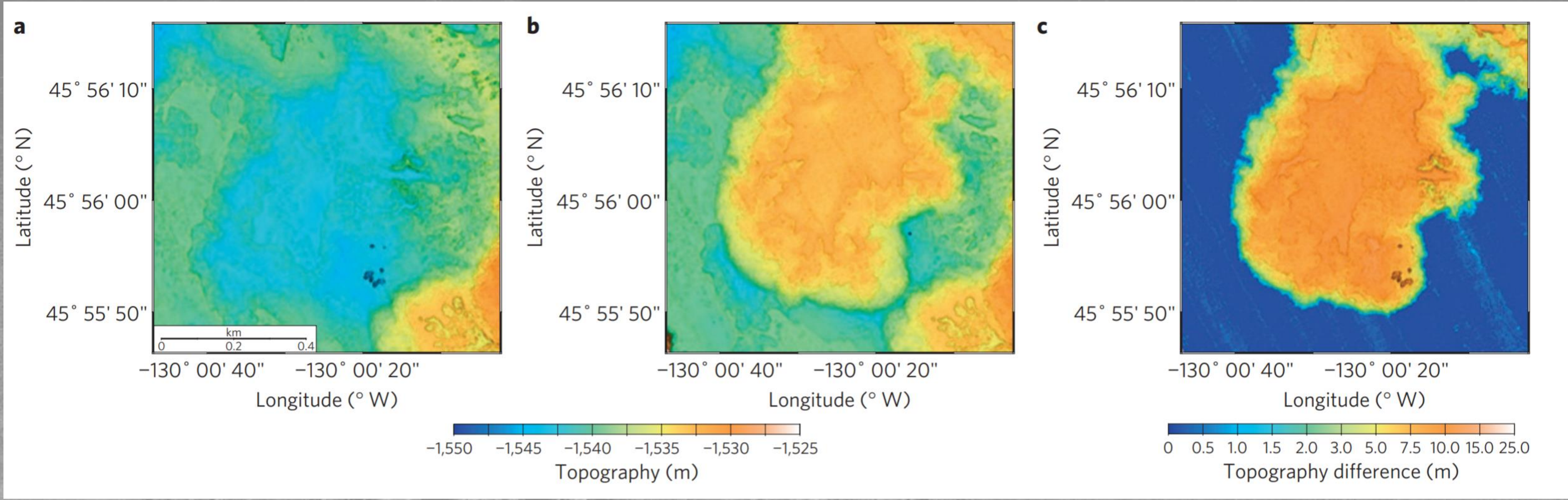


Limitation: Unknown detection limits / false negative

Safipour et al, 2017
doi: https://doi.org/10.1190/geo2017-0237.1

Production Monitoring: Extraction

- Option 1 – Repeat Bathymetric Survey

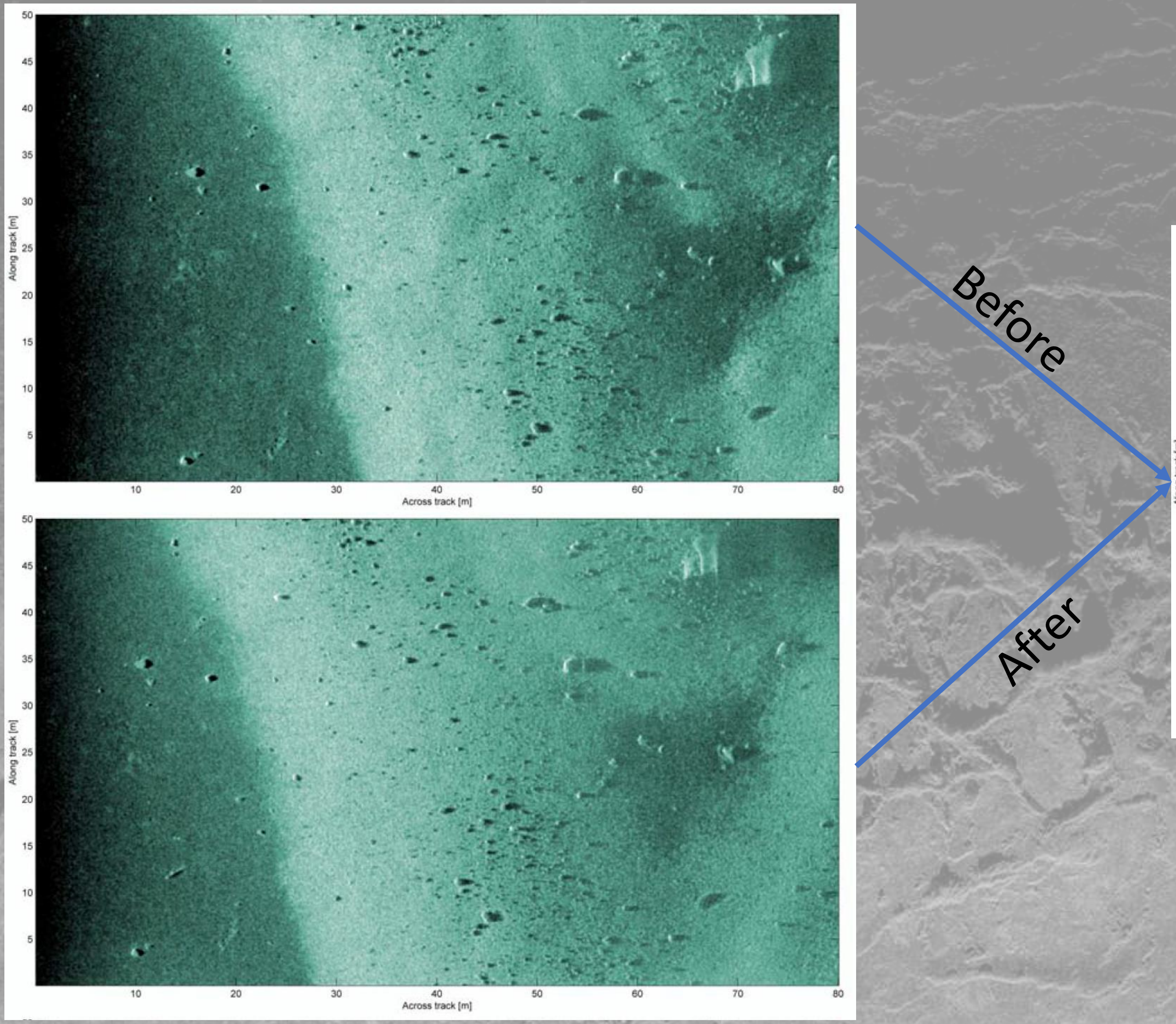


Caveats
- Hard to co-locate surveys (horizontal and vertical)
- Require bottom pressure measurement

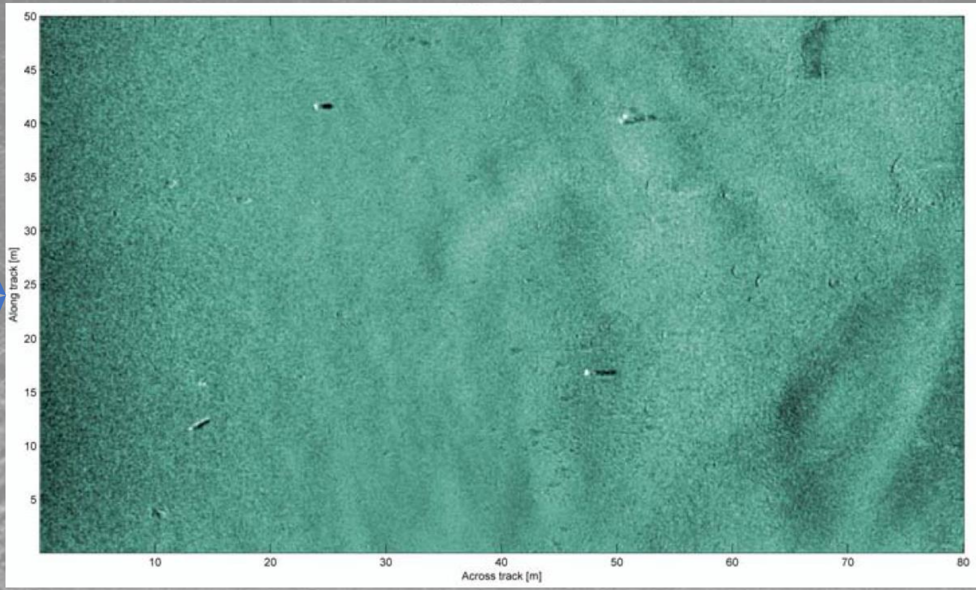
From Figure 4: Caress et al, 2012
https://doi.org/10.1038/ngeo1496

Production Monitoring: Extraction

- Option 2 – Repeat SAS Survey – sonar based navigation possible



SAS Difference Map



From Figure 15: Midtgaard et al, 2011
http://dx.doi.org/10.23919/OCEANS.2011.6107272

Production Monitoring: Plume

- Wide-area (100's km^2) observation required to determine cumulative impact
- Sonar-based or image based processing for change detection capable of cm-scale resolution

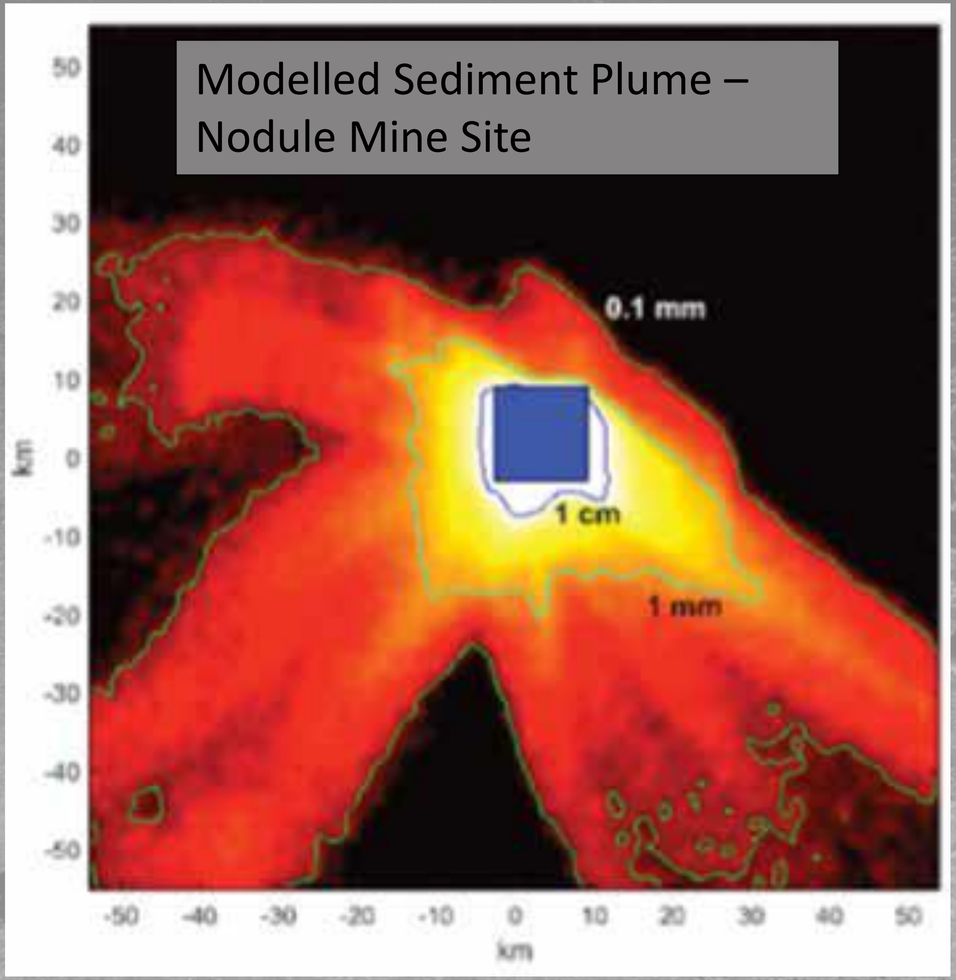


Figure 6 from MIDAS Research Highlights (2015)

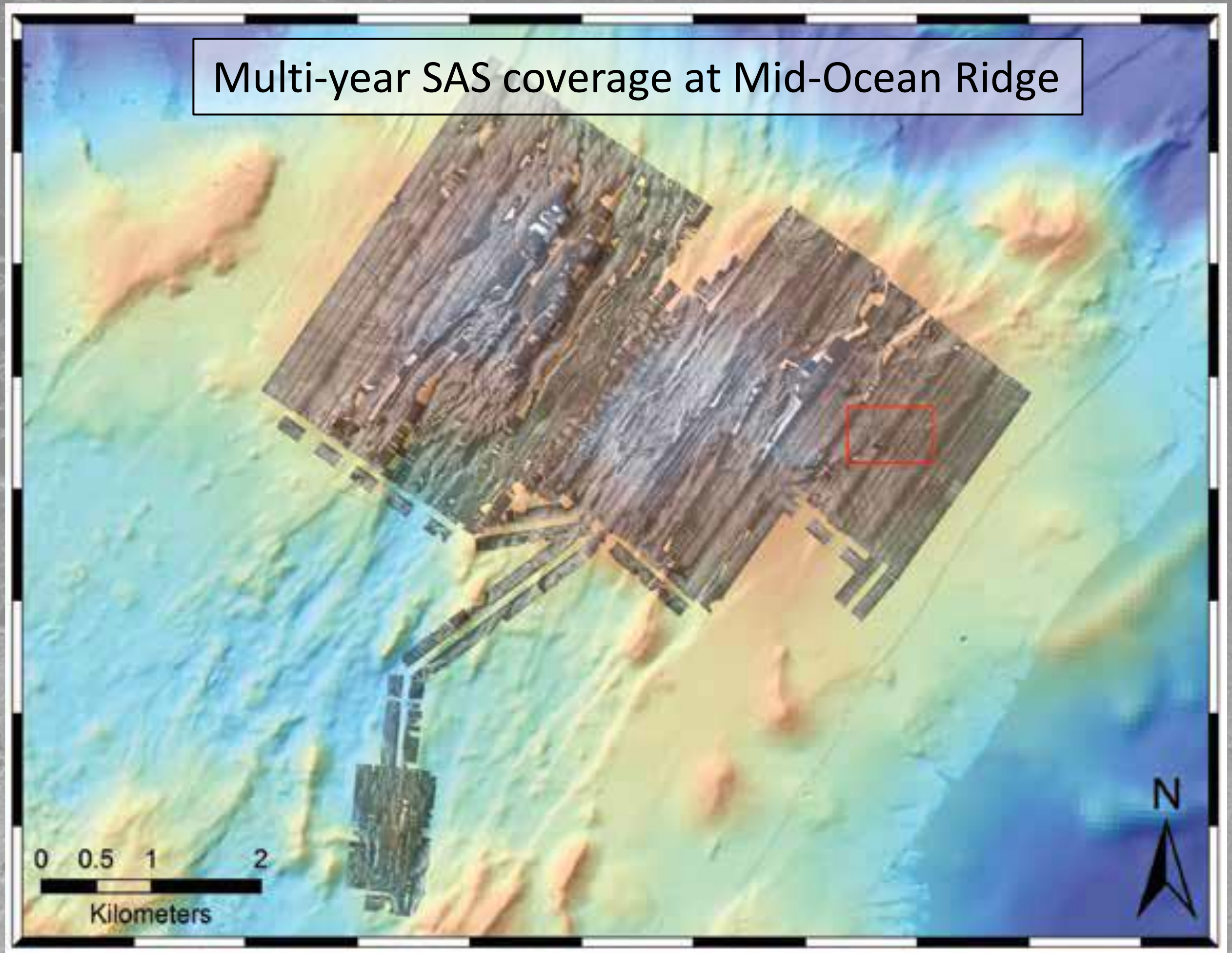


Figure 4 from Denny et al (2015)

Conclusion:

- No ‘silver bullet’ sensor for exploration to monitoring
- We can find extinct and buried systems, but false negative likely
- Wide area coverage (100’s km^2) needed in exploration and monitoring

Final Thought:

- Better exploration and monitoring possible with improved AUV terrain following