Multibeam Echosounder System Optimization for Water Column Mapping of Undersea Gas Seeps

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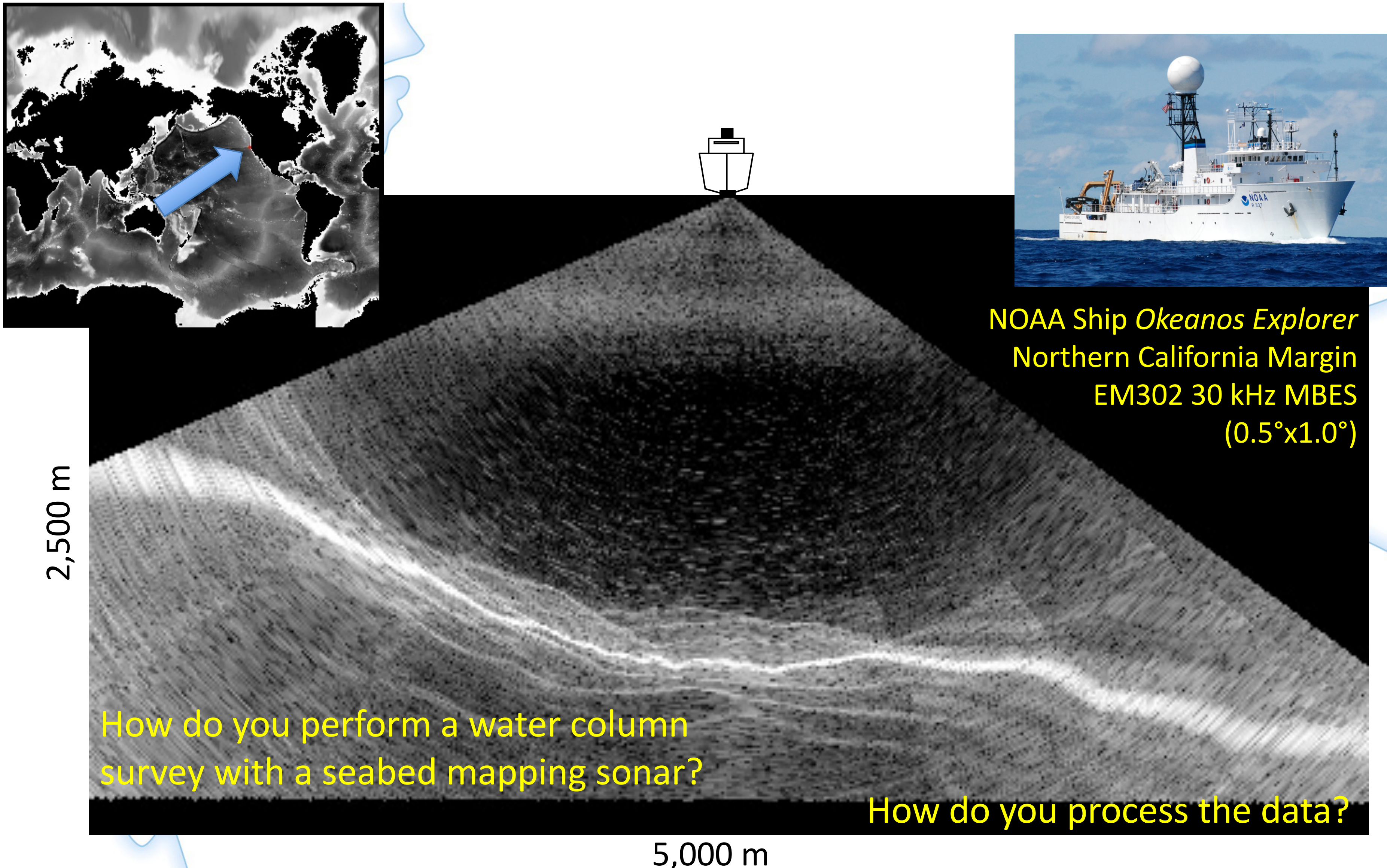
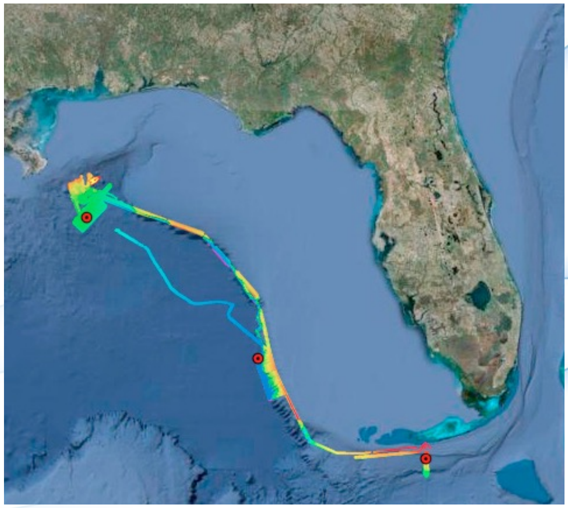
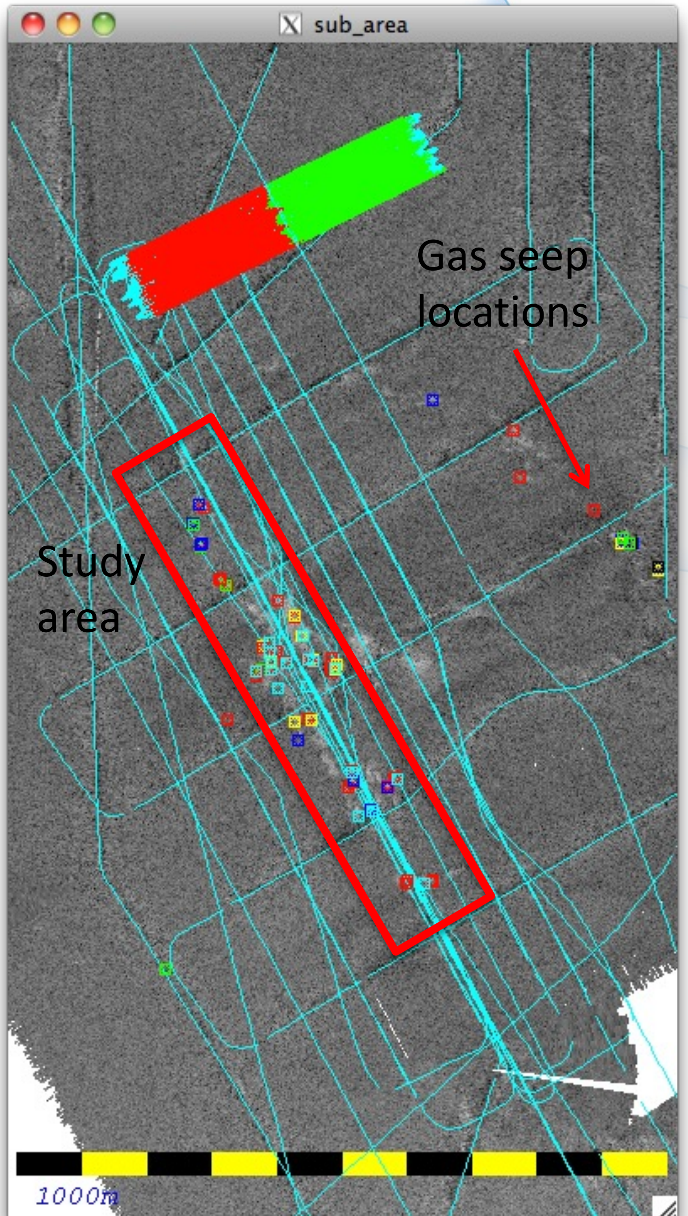


J. V. Gardner, M. Malik, and S. Walker. Plume 1400 Meters High Discovered at the Seafloor off the Northern California Margin. Eos Trans. AGU, 90(32), 2009

Introduction



- 2010: Deep Water Horizon disaster
  - Need for acoustic remote sensing of underwater oil plume, NOAA and CCOM/JHC assist in this effort
  - NOAA Ship *Pisces* observes natural gas seeps with EK60 while assisting with monitoring of DWH…**what would we have seen with multibeam?**
- 2011: Research partnership with NOAA OER and UNH/CCOM
  - Explore use of multibeam water column imagery for remote sensing of natural seeps
  - NOAA Ship *Okeanos Explorer* 30 kHz EM302
- Problems:
  - How to do a water column survey with a seabed mapping sonar?
  - How to process the data?



1. Survey Methods

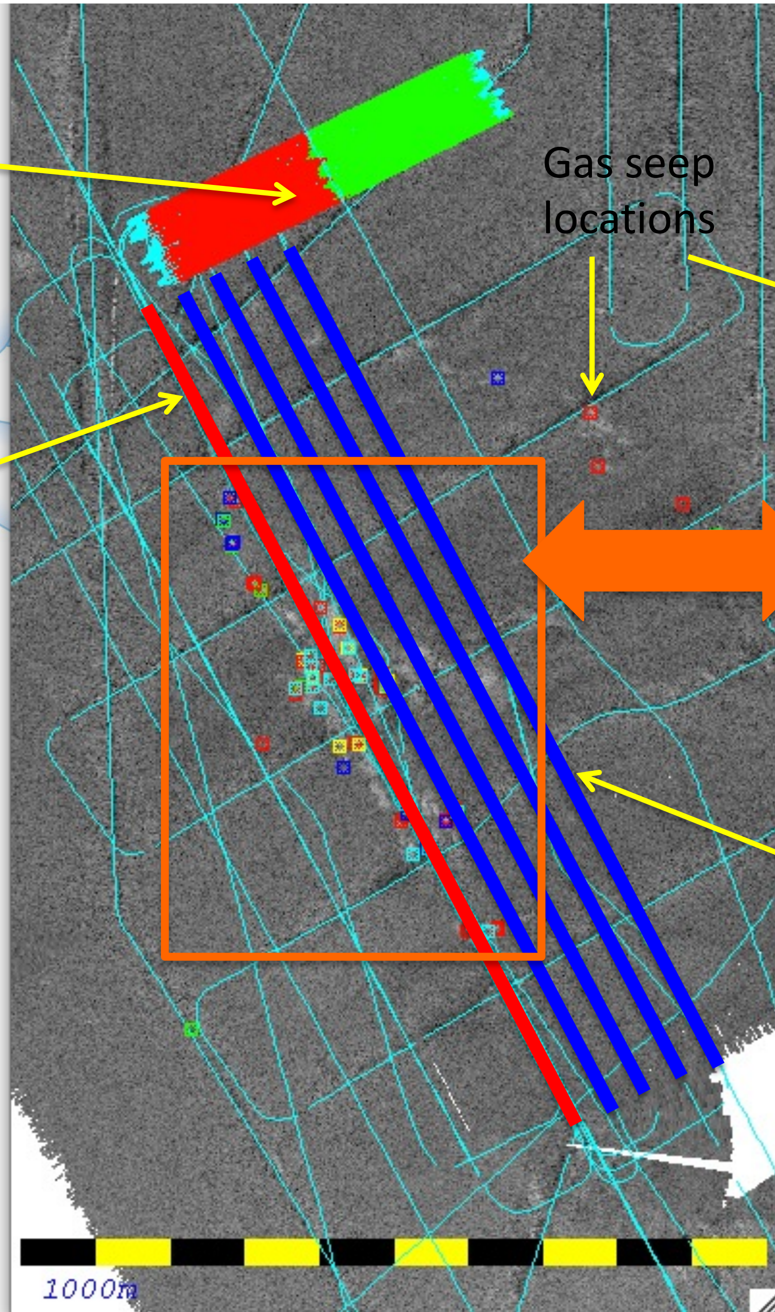
Two part problem:

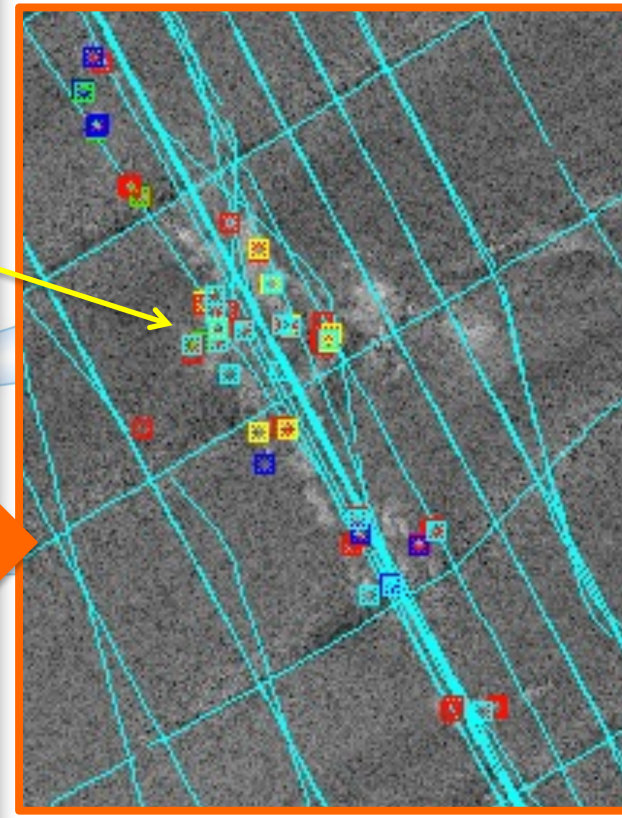
- How do we configure the mapping system?
- How do we configure the survey line plan?

24 Hour Optimization Exercise:

- Repeated test lines over area of known plumes (Biloxi Dome)
- Varied system parameters: what are optimal settings?
- Varied lateral offset from plumes: how far away can we confidently detect?

Typical coverage achieved, 100 pings

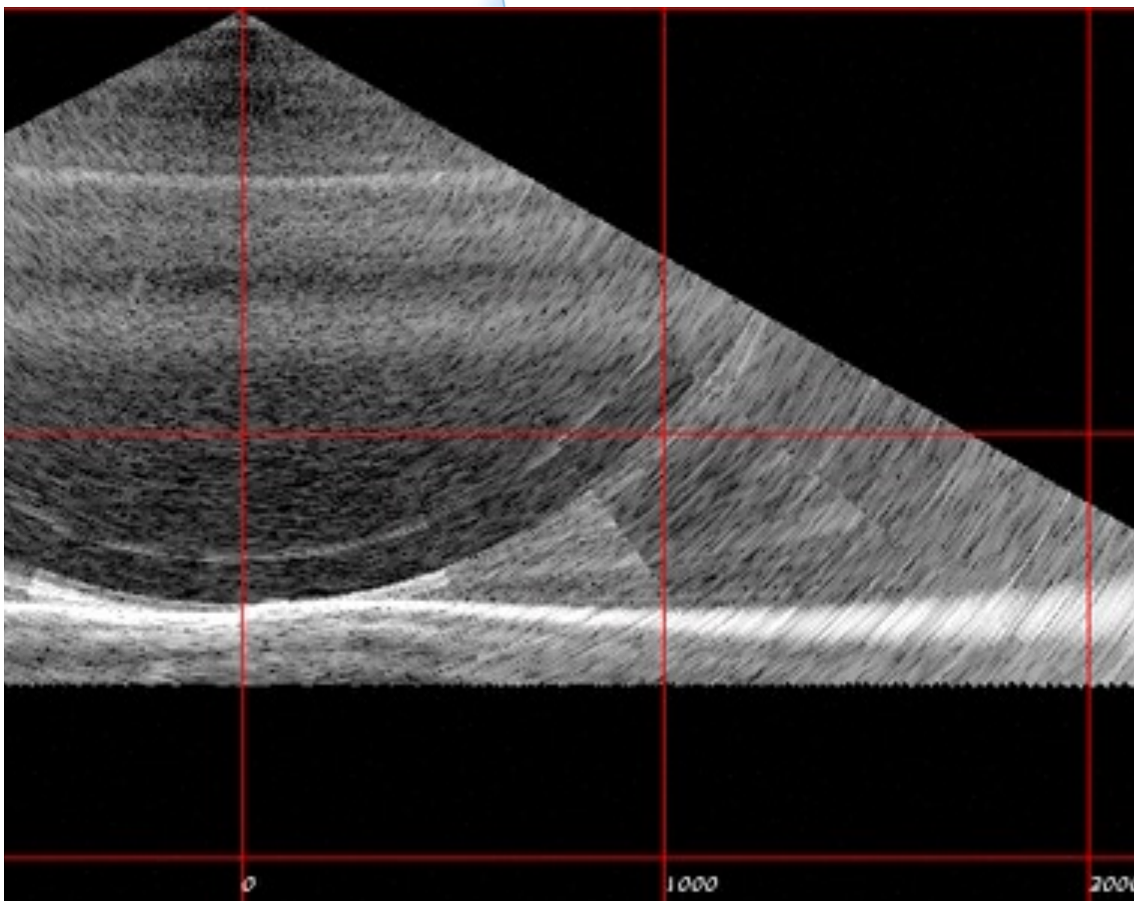




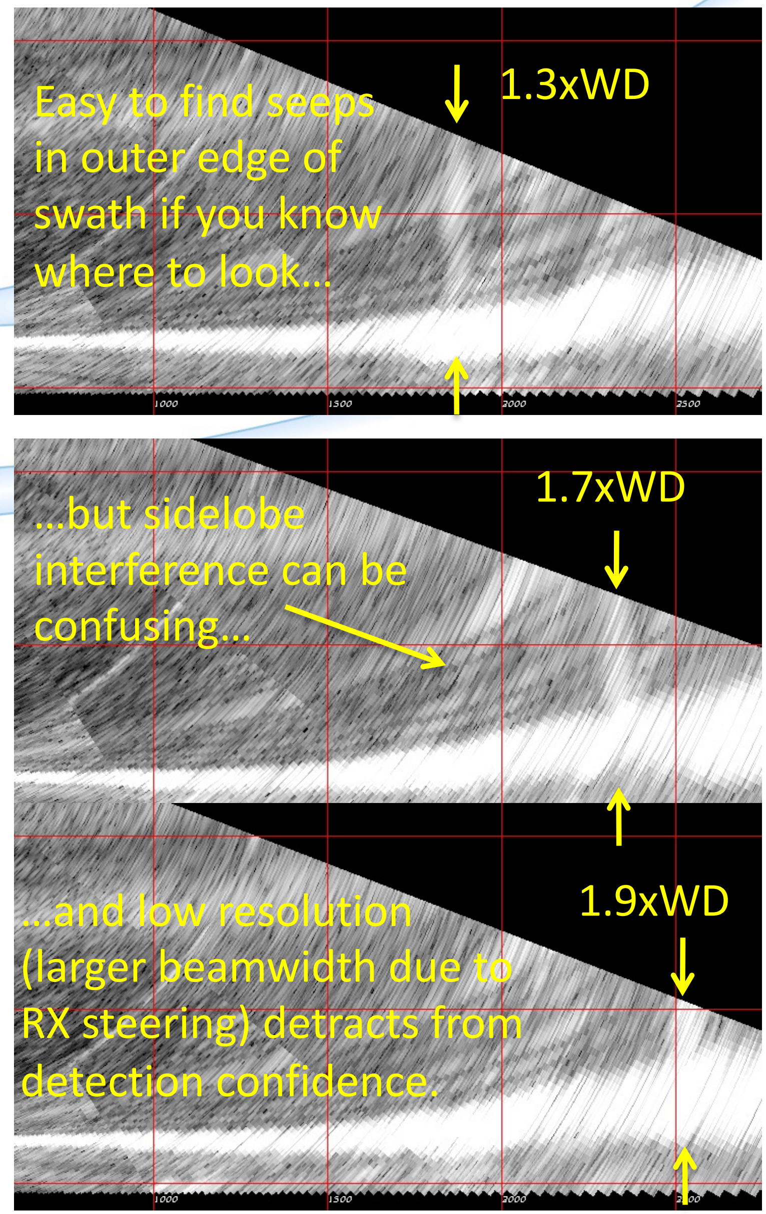
Main line:
Repeat passes in various configurations:
- Deep/Very Deep
- Single/Dual ping
- CW/FM

Offset lines:
Configured system with Deep/Dual ping/CW, ran parallel offset lines at spacing of:
- 500 m
- 1,000 m
- 1,500 m
- 2,000 m

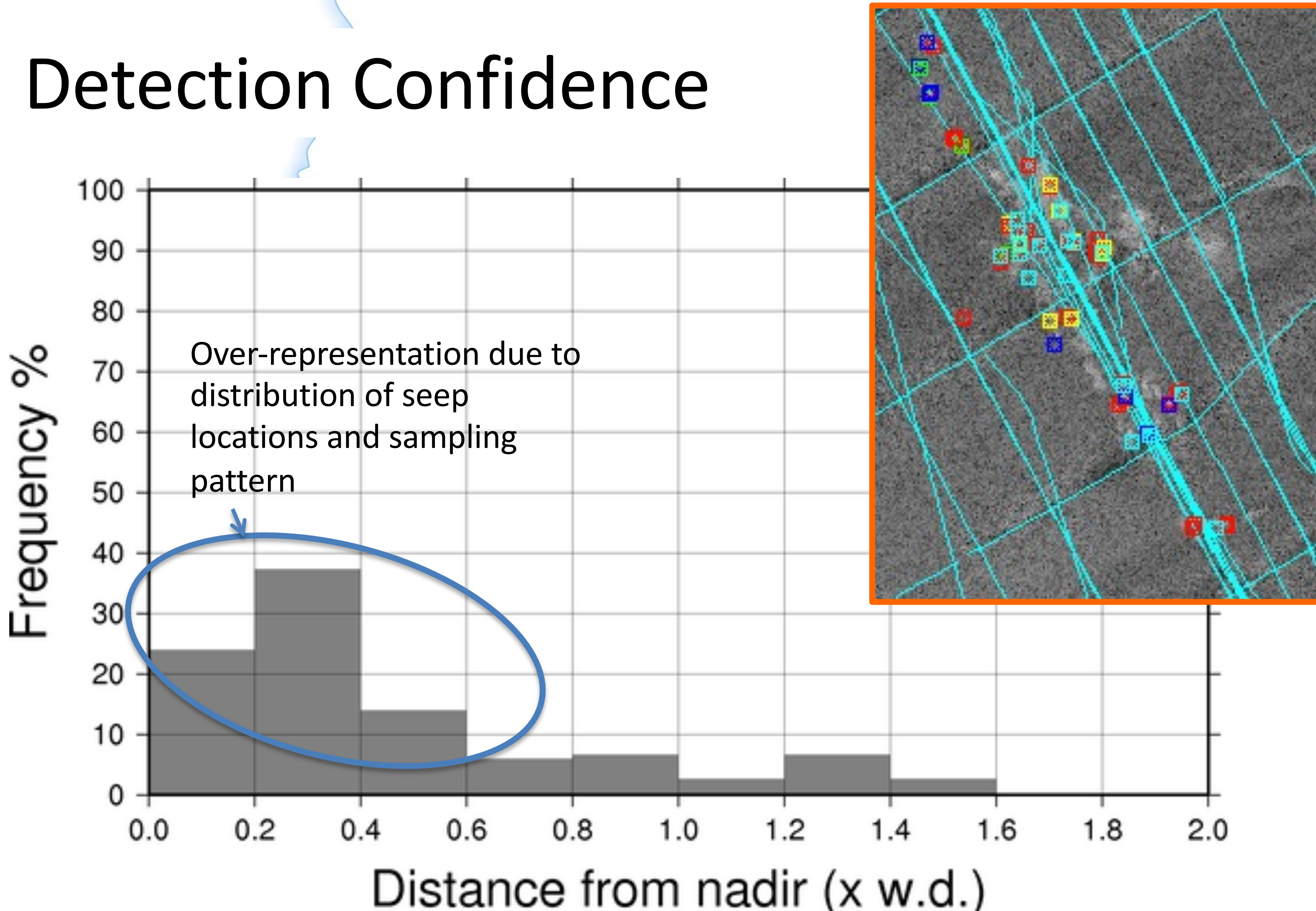
Detection Confidence



Frequency encoded transmit sectors allows for detections beyond minimum slant range



Detection Confidence

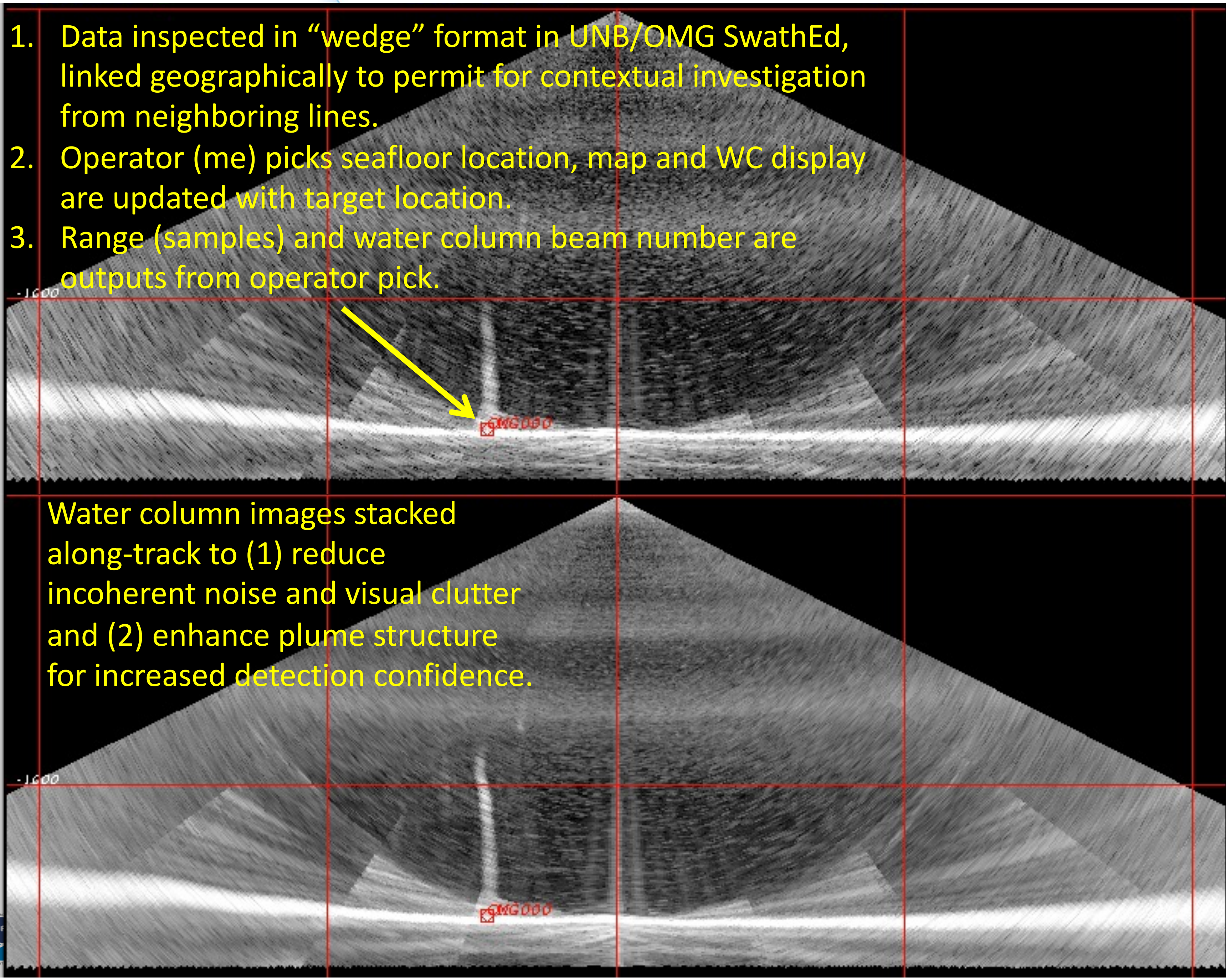


Survey Methods: Findings

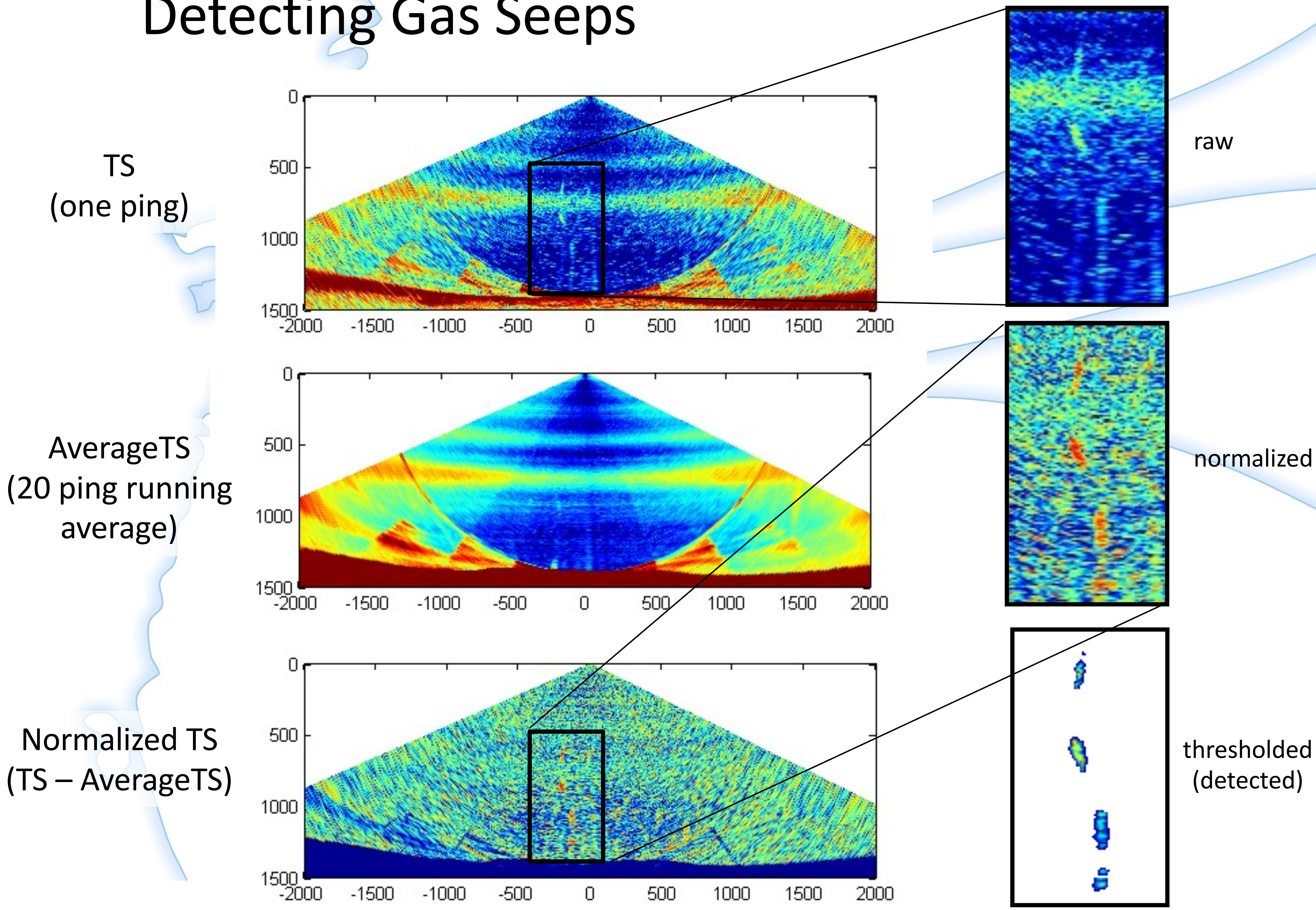
- Optimal system mode (for our project, your mileage may vary):
  - DEEP/CW mode (5 ms CW effective pulse length for all sectors)
  - Fixed angular sector (+/- 60°)
  - Dynamic dual swath
- Sidelobe interference not an issue, can confidently detect within +/-1x WD (+/-45°)
- Transmit control: pitch/yaw stabilization enabled, helps with limitations of COTS geo-referencing since ensonified volume approximates a vertical plane
- Roll stabilization critical for filtering in post-processing: non-issue with KM systems but very important for other systems

2. Processing Methods

- Commercial software available 2011 not adequate for our needs
- Home grown target detection:
  - **Where are the seep locations?** UNB/OMG SwathEd software modified for manual digitization of **seabed seep locations**
  - **How do the plumes behave?** Matlab scripts developed for automated extraction of **3D gas plume structure**
- Home grown georeferencing:
  - Modification of UNB/OMG multi-sector raytracing/georeferencing algorithms (Beaudoin et al., 2004)
  - Extends work of van der Werf (2010)
  - Applied to **seabed seep locations** and **3D gas plume structure**
- Target data structure and file format designed for common use between SwathEd and Matlab


1. Data inspected in “wedge” format in UNB/OMG SwathEd, linked geographically to permit for contextual investigation from neighboring lines.
2. Operator (me) picks seafloor location, map and WC display are updated with target location.
3. Range (samples) and water column beam number are outputs from operator pick.
-1600
OMG000
Water column images stacked along-track to (1) reduce incoherent noise and visual clutter and (2) enhance plume structure for increased detection confidence.
-1600
OMG000

Detecting Gas Seeps



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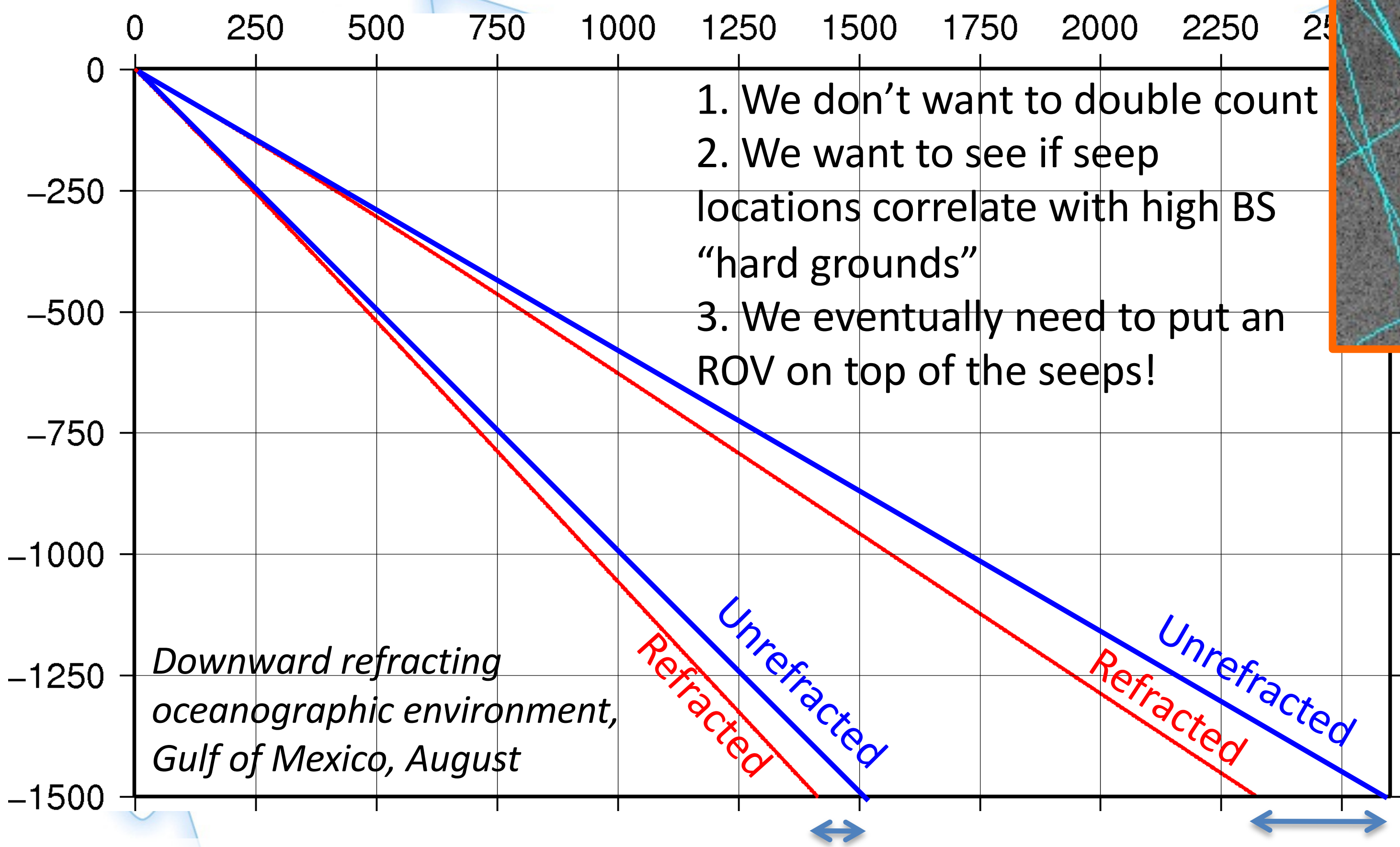
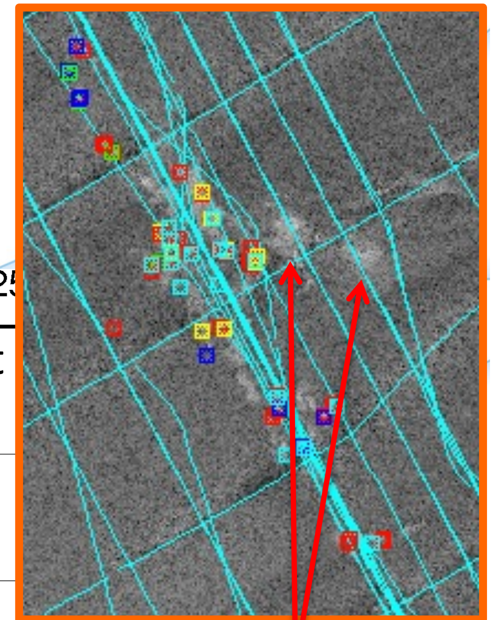
Georeferencing…
Why is it important?



1. We don’t want to double count
2. We want to see if seep locations correlate with high BS “hard grounds”
3. We eventually need to put an ROV on top of the seeps!



High BS
“hard grounds”

Horizontal displacement is non-negligible and grows non-linearly with beam angle

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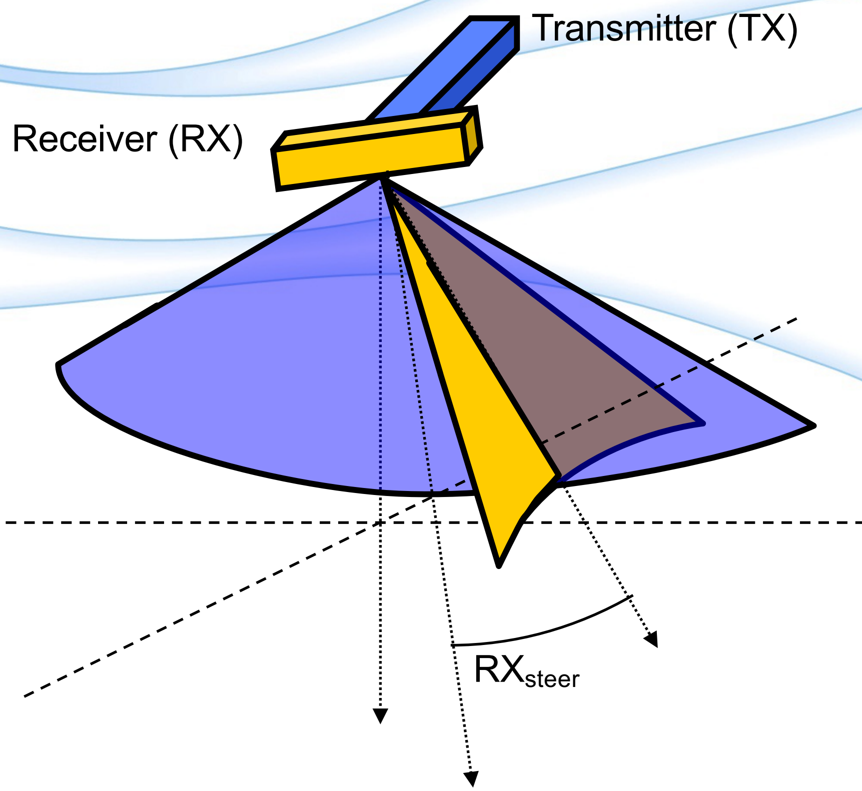
Georeferencing

Need to acknowledge that steered beams are conic and not planar…

Need to respect multi-sector nuances…(different TX time for each sector)

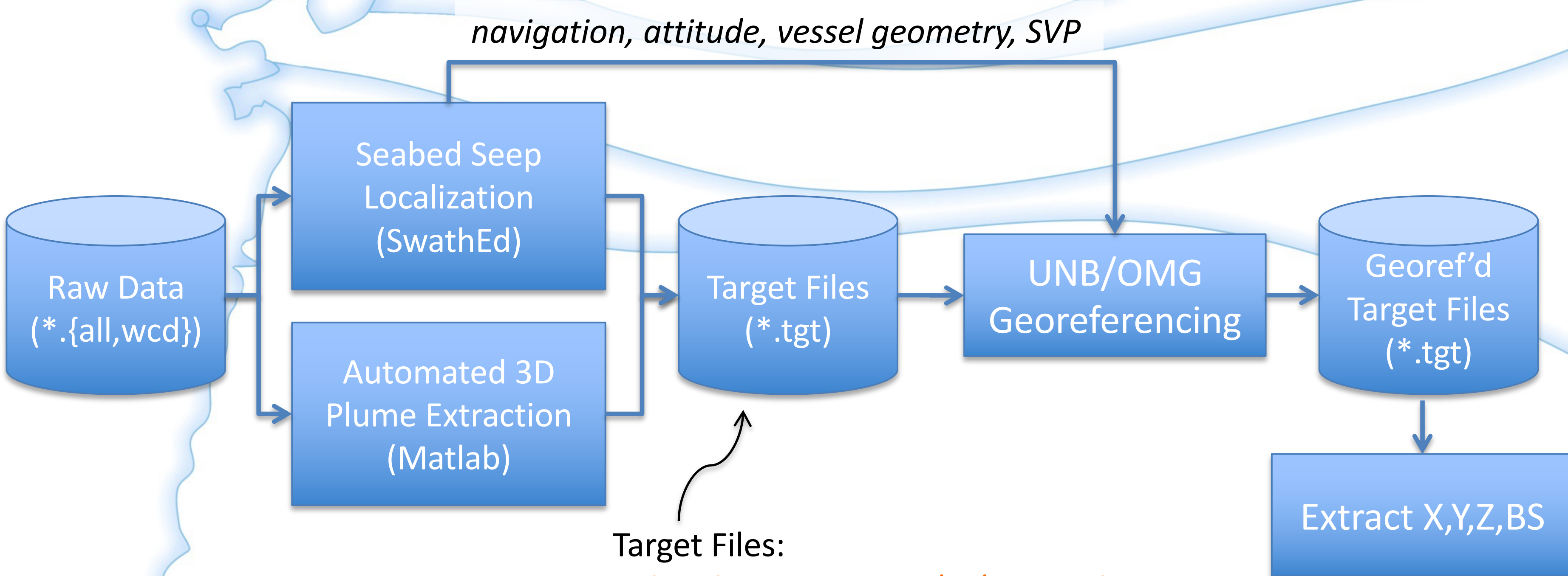
Need to recover orientation at reception time for sample of interest…

Water column reports roll stabilized angle. Need to recover RX steering angle at reception time for sample of interest.



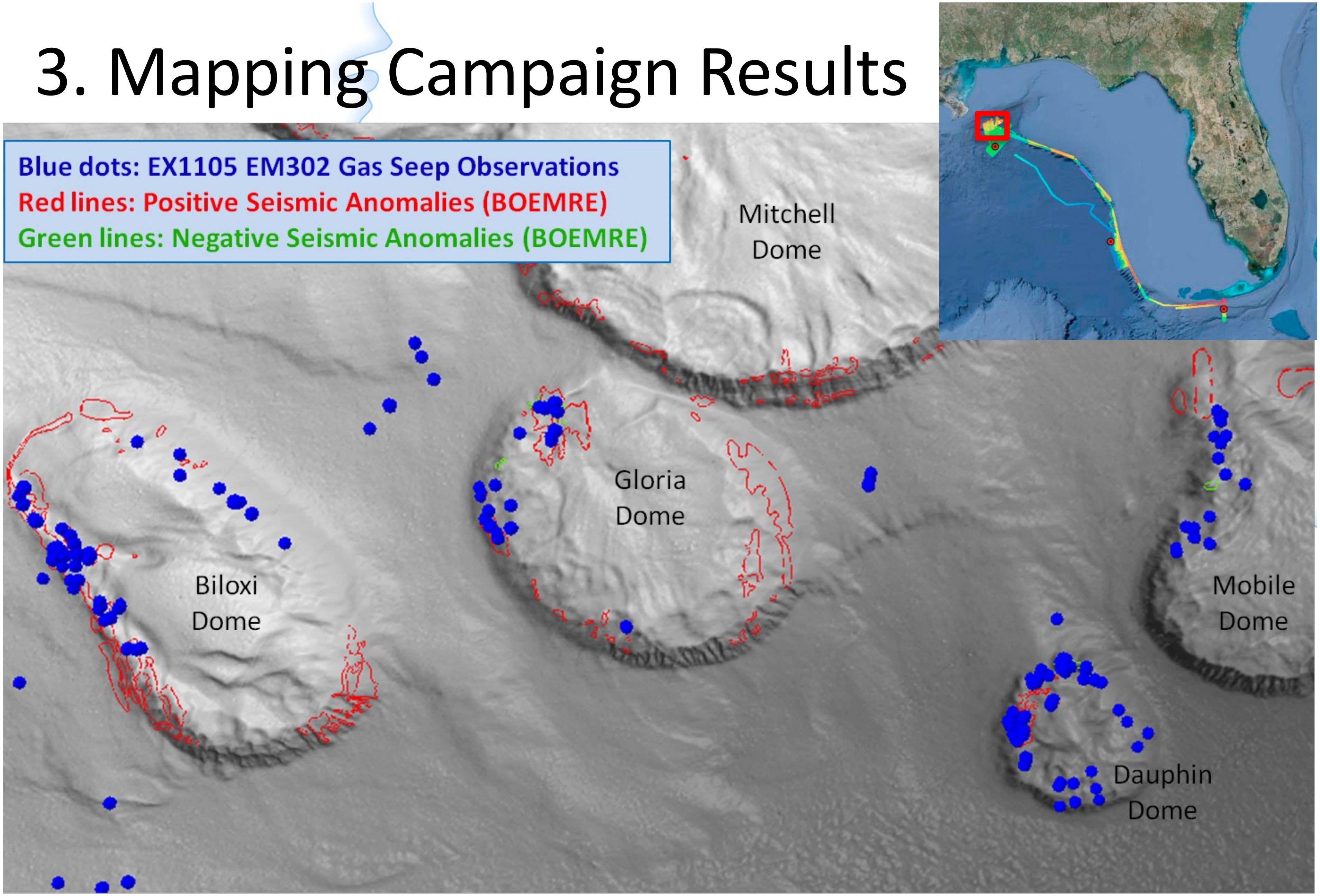
See Beaudoin et al. (2004) and van der Werf (2010)

Workflow



Target Files:
- Ping time, range, angle, beam, ping, raw depth, raw across, amplitude
- Reduced depth, reduced across, latitude, longitude,

3. Mapping Campaign Results



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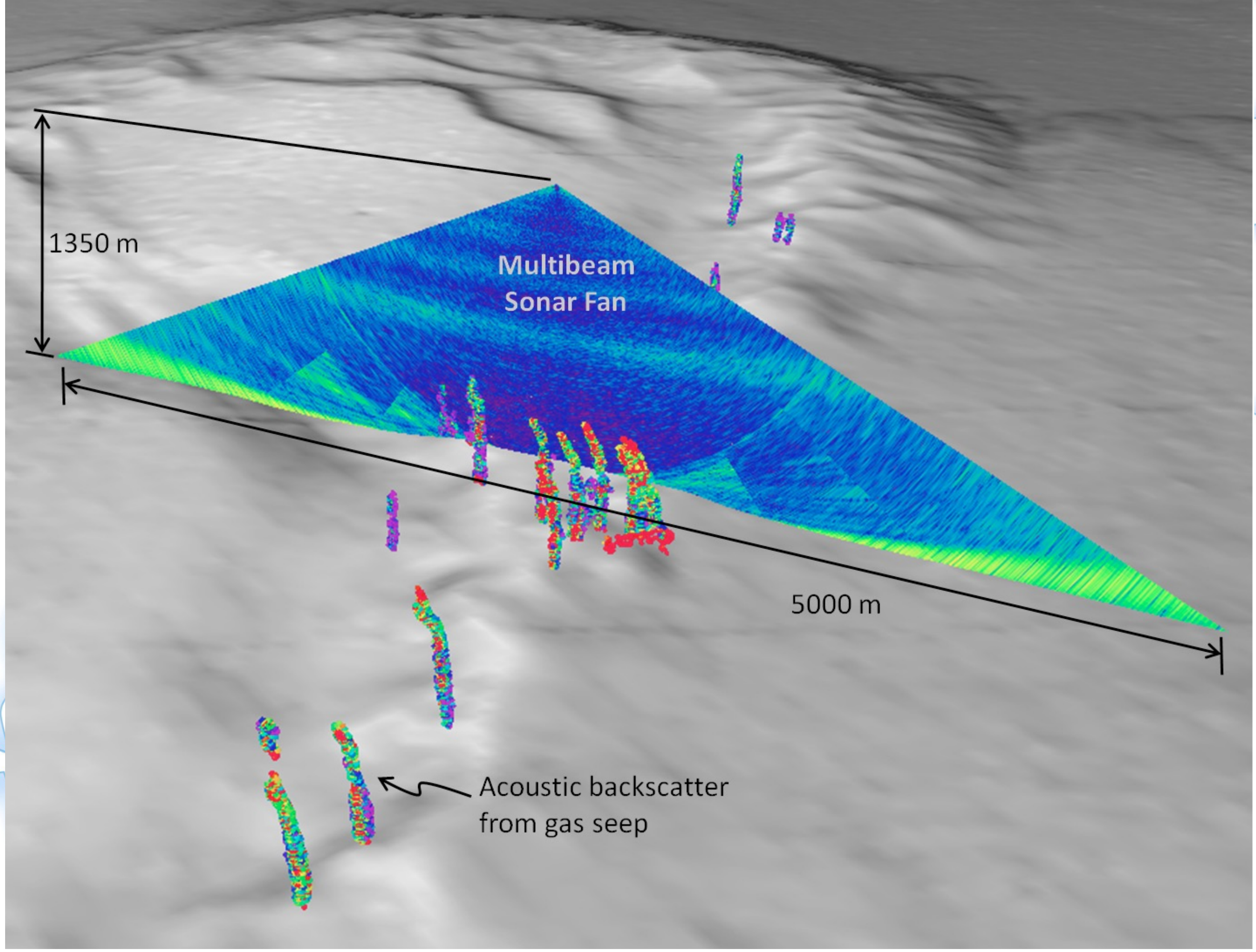
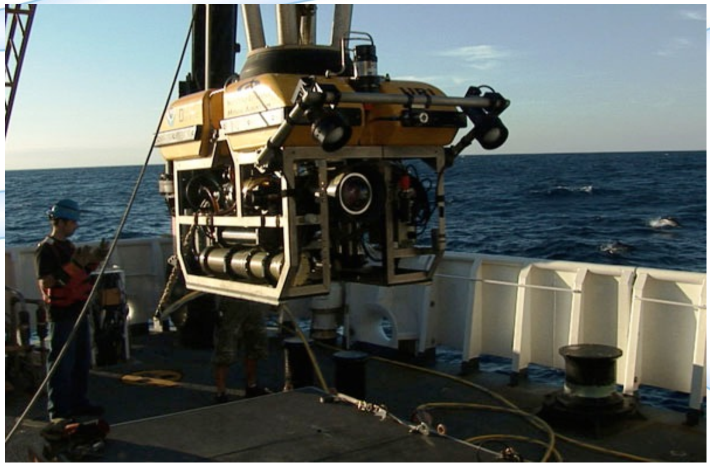
Mapping Campaign Results



Ongoing Work

- 2011 field season paved the way
  - established procedures and workflow
  - proved the EM302 can remotely sense presence/absence of gas plumes
- 2012 field season: Okeanos Explorer's ROV ground truthed acoustic measurements with video, gas capture
  - size of bubbles?
  - rate of flux?
  - one stream or multiple streams?
- Improved georeferencing:
  - Working with UNB to improve multi-sector georegistration algorithms (J. Hughes Clarke, T. Hamilton)



Summary and Conclusion

- Multibeam echosounder water column capabilities well suited for manifest mapping of gas seeps in the Gulf of Mexico:
  - 30 kHz works well, other frequencies?
  - Frequency encoded transmit sectors crucial to reduce sidelobe interference
- Important new tool for US regulatory mission and for science
- Methods and workflows established, have shared georeferencing findings with software vendors to improve post-processing abilities

Take Home Message

- If you're serious about water column, do your homework
  - Before the field work, assess your ability to process (cannot rely on real-time WC display)
  - Budget for system configuration testing time
  - Assess testing results in the field and adapt survey plan accordingly

Acknowledgements

- NOAA funding for CCOM/JHC
- Okeanos Explorer
  - Captain and crew
  - Mapping team
  - ROV team
- NOAA Office of Exploration and Research (OER)
- Bureau of Ocean Energy Management (BOEM)

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