

Permanent Monitoring systems for Seabed Leakage Detection



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Seabed leaks

Where do they come from?

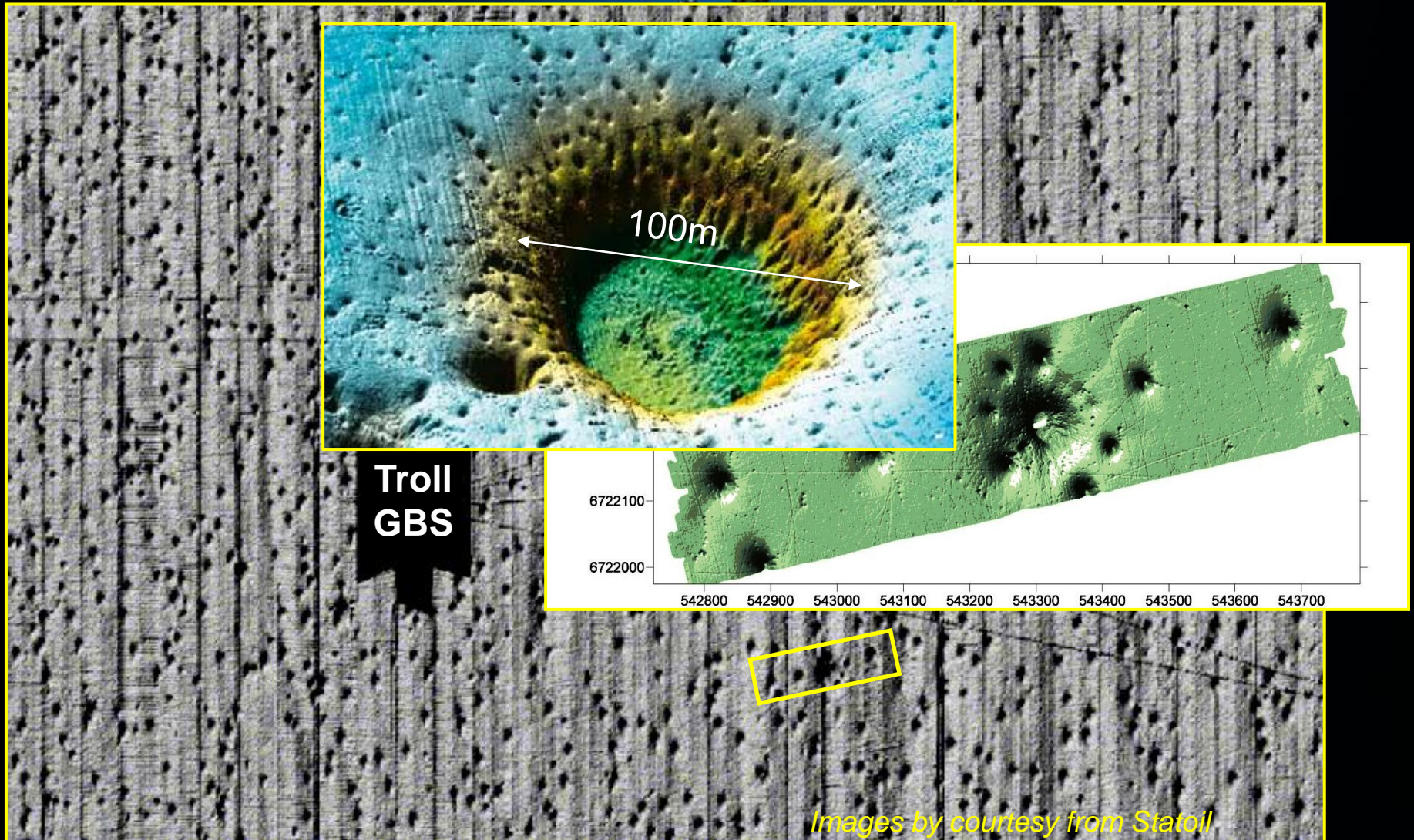


- **Natural vents:
Faults, Pockmarks,
and Chimneys**
- **Melting hydrates**
- **Shallow gas layers**
- **Long term leakage
along well casings
(cracked cement)**
- **Injection: fault re-
activation/fracturing**
- **Lost well control
and failing barriers**

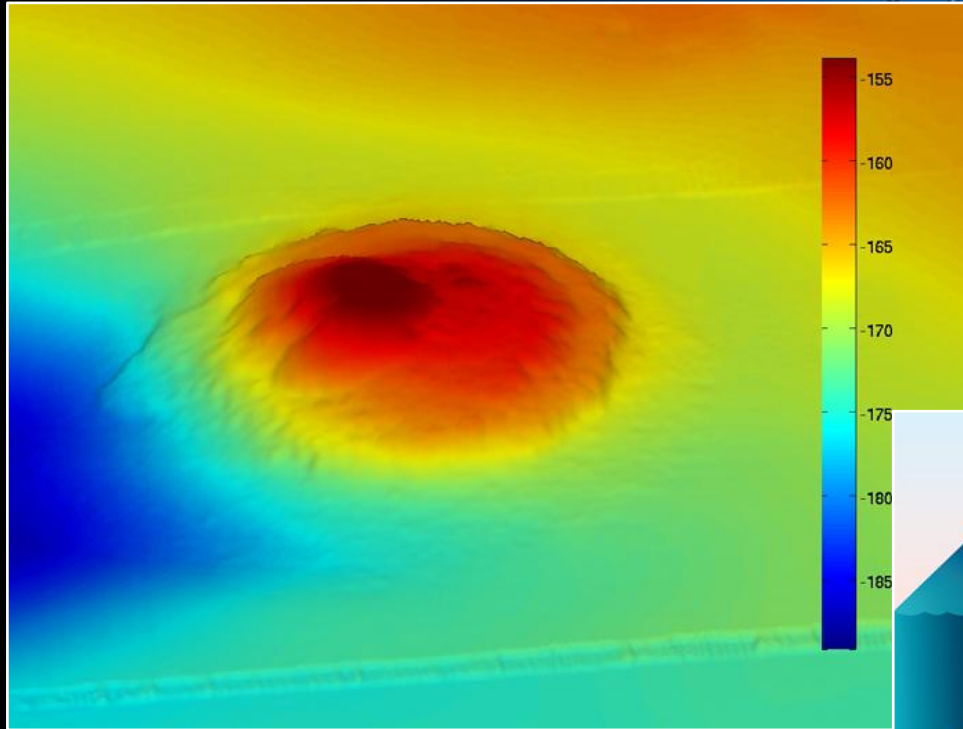
The mysterious pockmarks at the Troll field



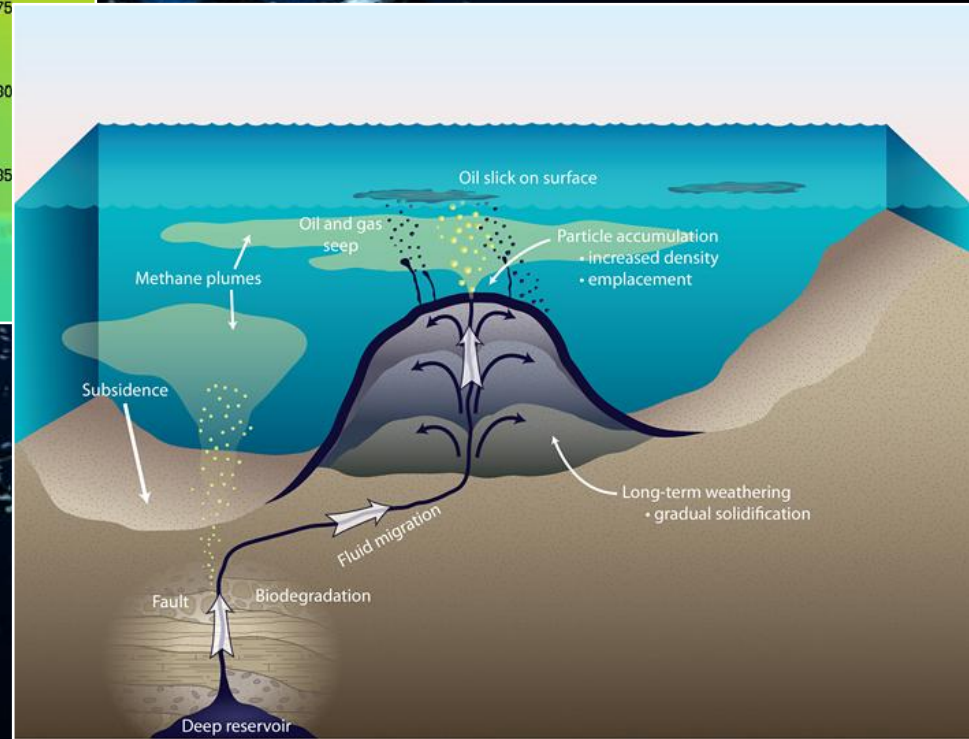
Footprints from melted hydrate lumps (after the last glacial period)



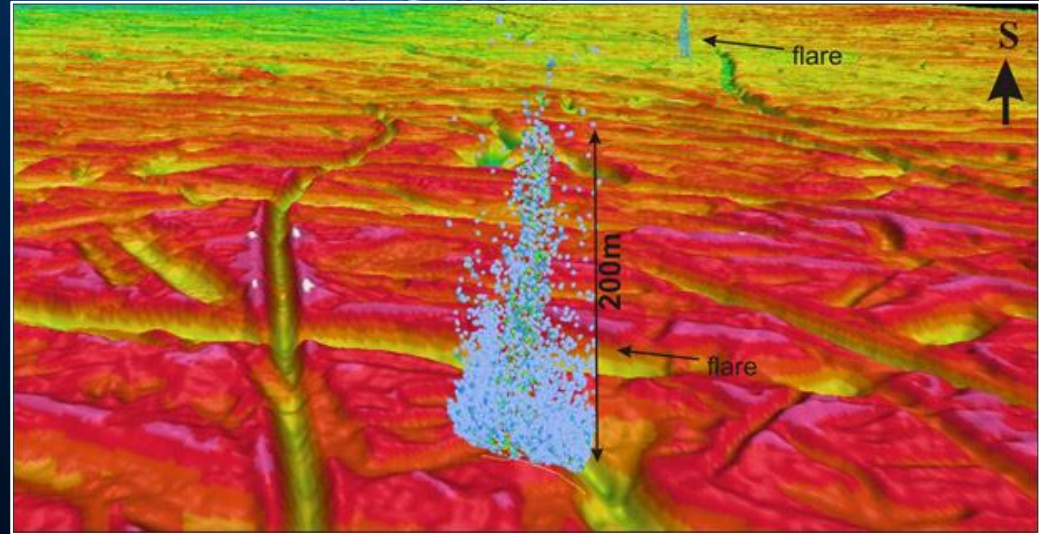
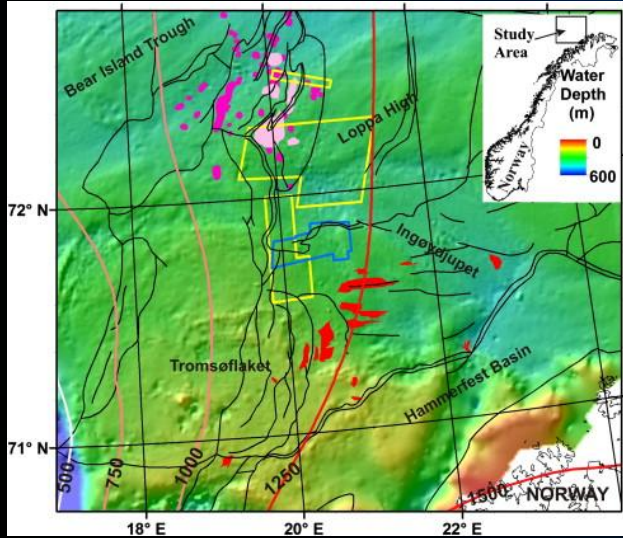
Santa Barbara Tar seeps



From Woods Hole Oceanographic Institution (www.whoi.edu)

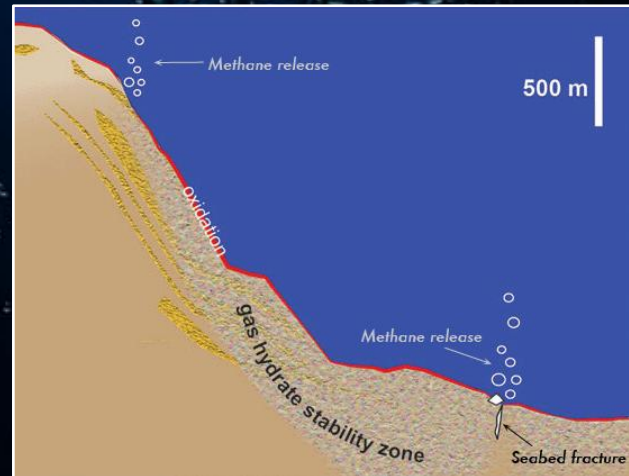
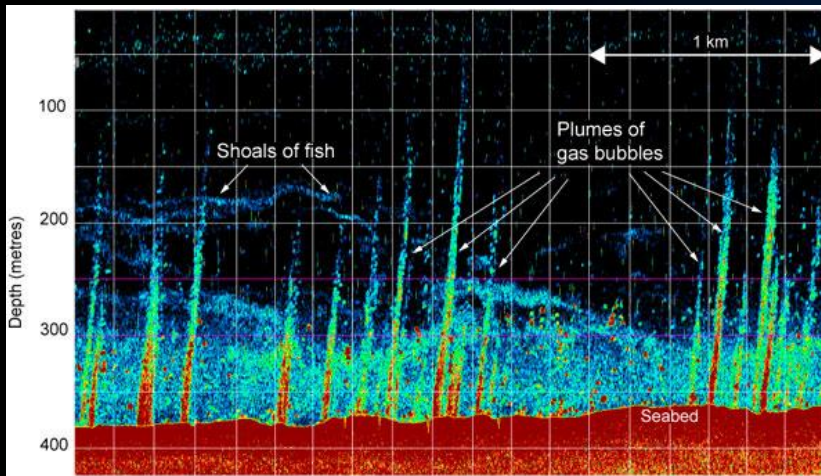


Barents Sea - Loppa High



from GEO365.no illustrations: NGU/Lundin Petroleum

Arctic Methane Flares

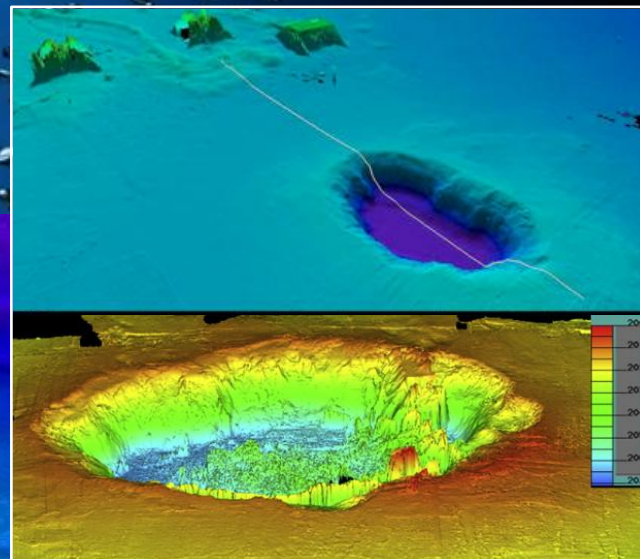


Seabed leakage

in conjunction with production

“An Operators Nightmare”

Tordis- 2008



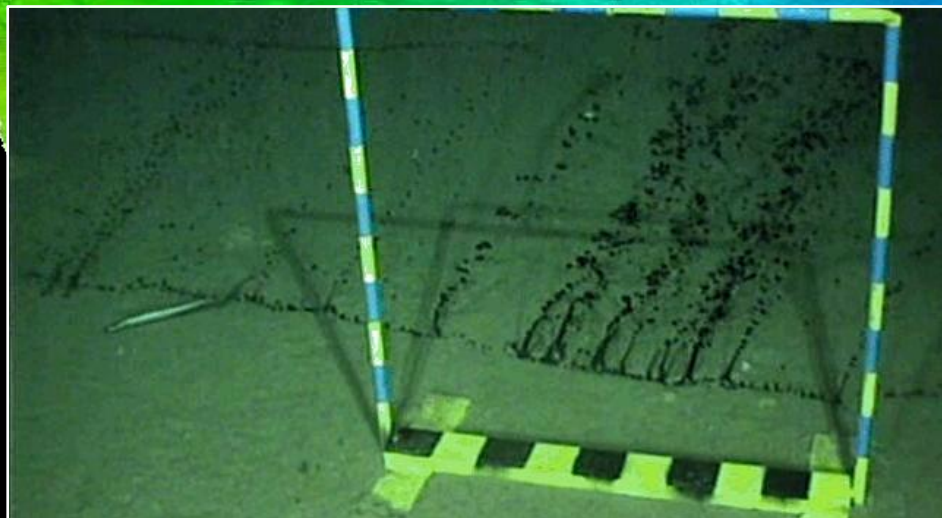
Water injection - fracturing

Snorre A - 2004



Lost well control/failing barriers

Frade/Roncador 2011 and 2012

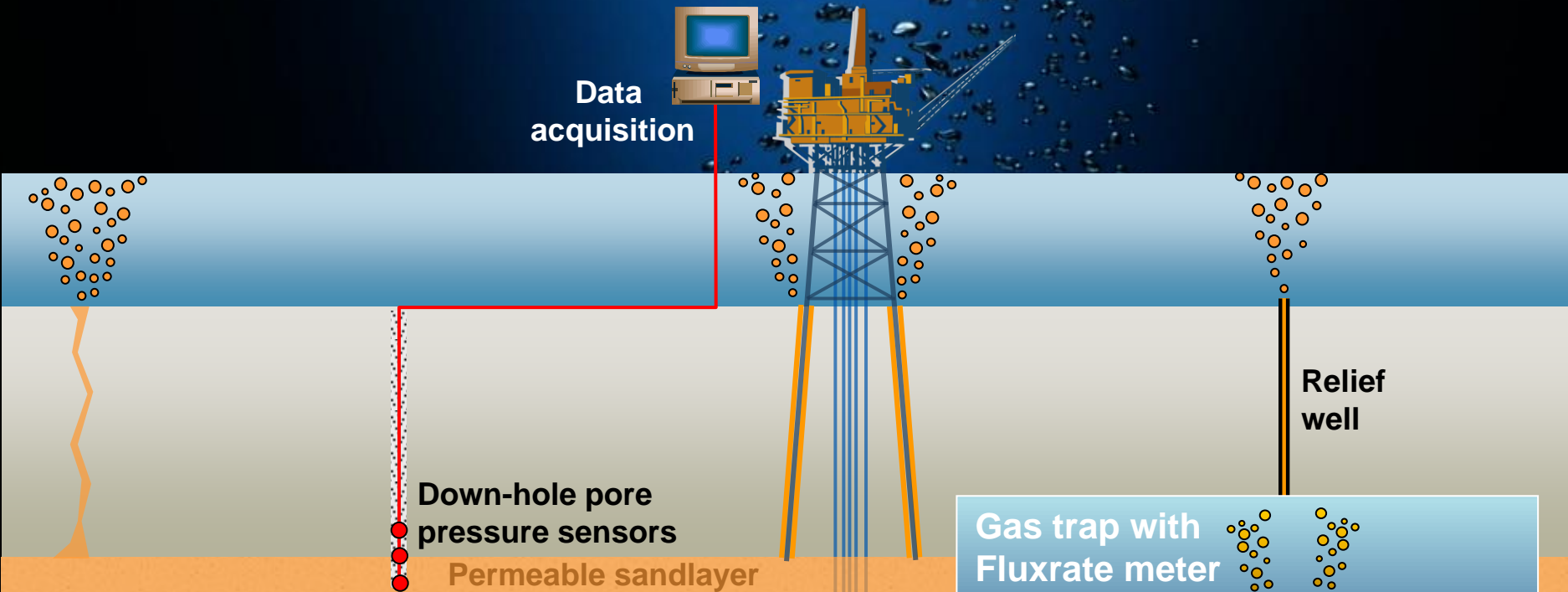


Reservoir “kick”/ Fault reactivation



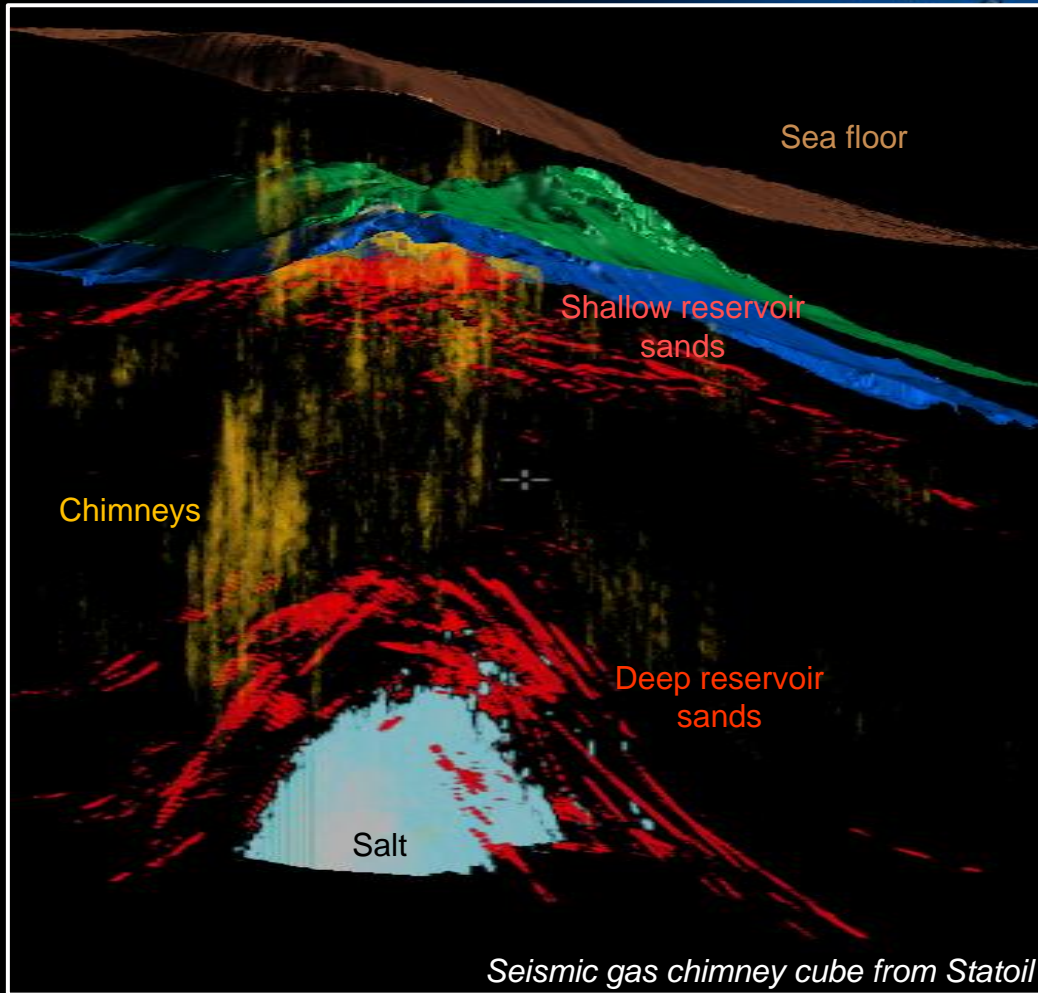
Leakage along casing

Charging shallow layers with gas

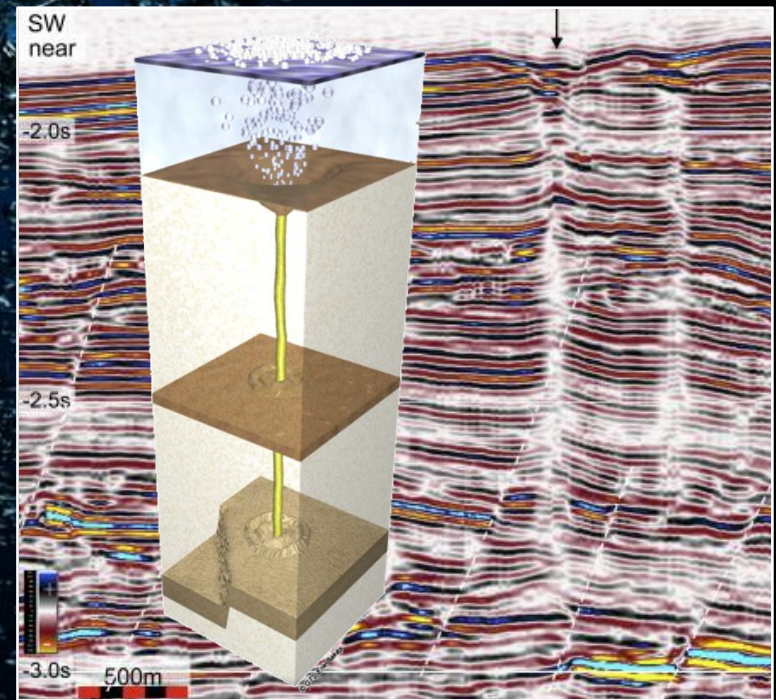


Seabed leaks

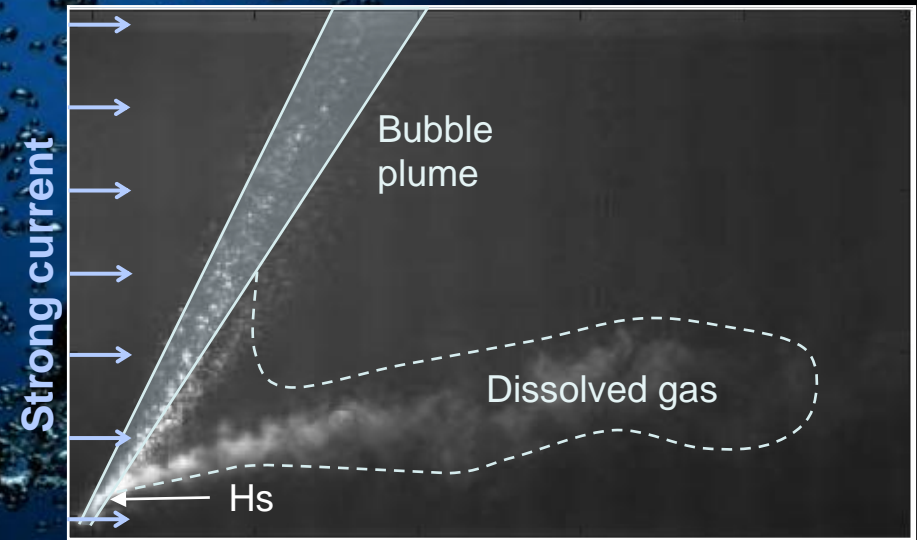
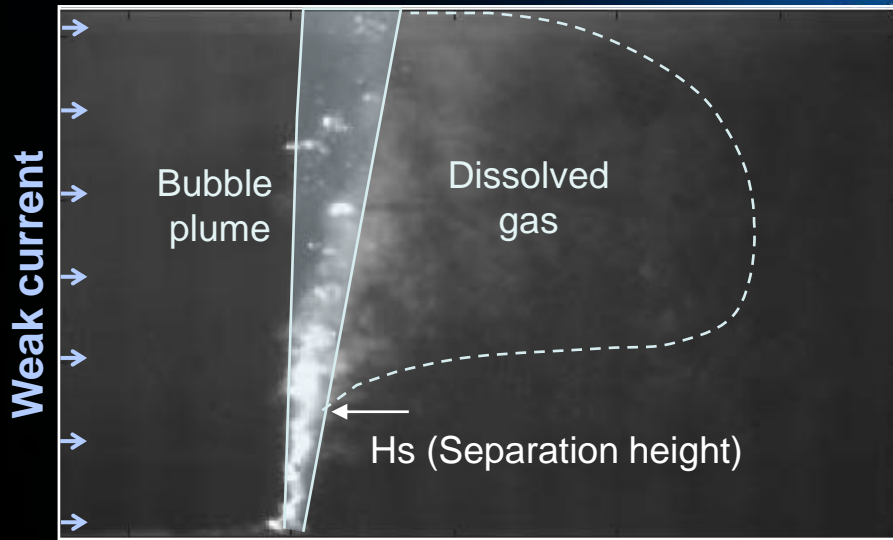
Natural or introduced by production?



Bubble seeps present before production?
Early long term monitoring may also be useful in order to establish the baseline before injection!



Characteristics of Seabed Gas Leaks



From SOCOLOFSKY et al "Multi-phase plumes in uniform and stratified crossflow" JOURNAL OF HYDRAULIC RESEARCH, VOL. 40, 2002, NO. 6

Monitoring solution for Permanent seabed leakage detection in the vicinity of production facilities:

Traces and Features:

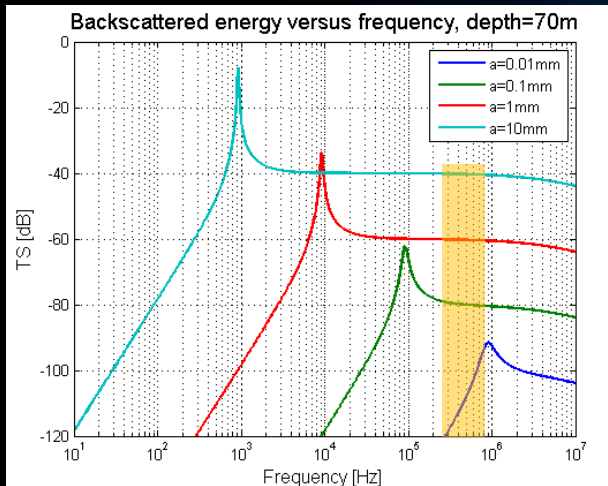
- Gas bubble trains or plumes
- Concentration of dissolved gas
- Seabed currents

Instrumentation:

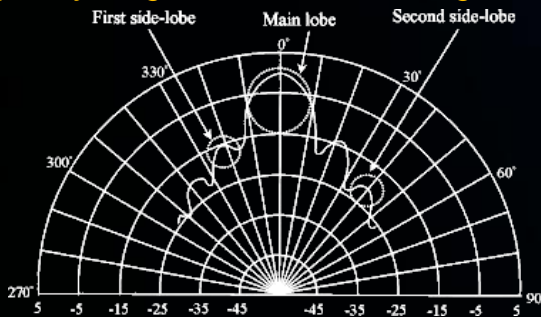
- Sonars
- Sniffers
- Current meters

Sonar gas leak detection

- Multibeam or Scanning sonar ?
- Aspect and detection capability
- Point of View, backscatter and acoustic shadows
- Automatic detection – Filtering and identification



Frequency range multibeam/scanning sonars



Cerberus diver detection sonar



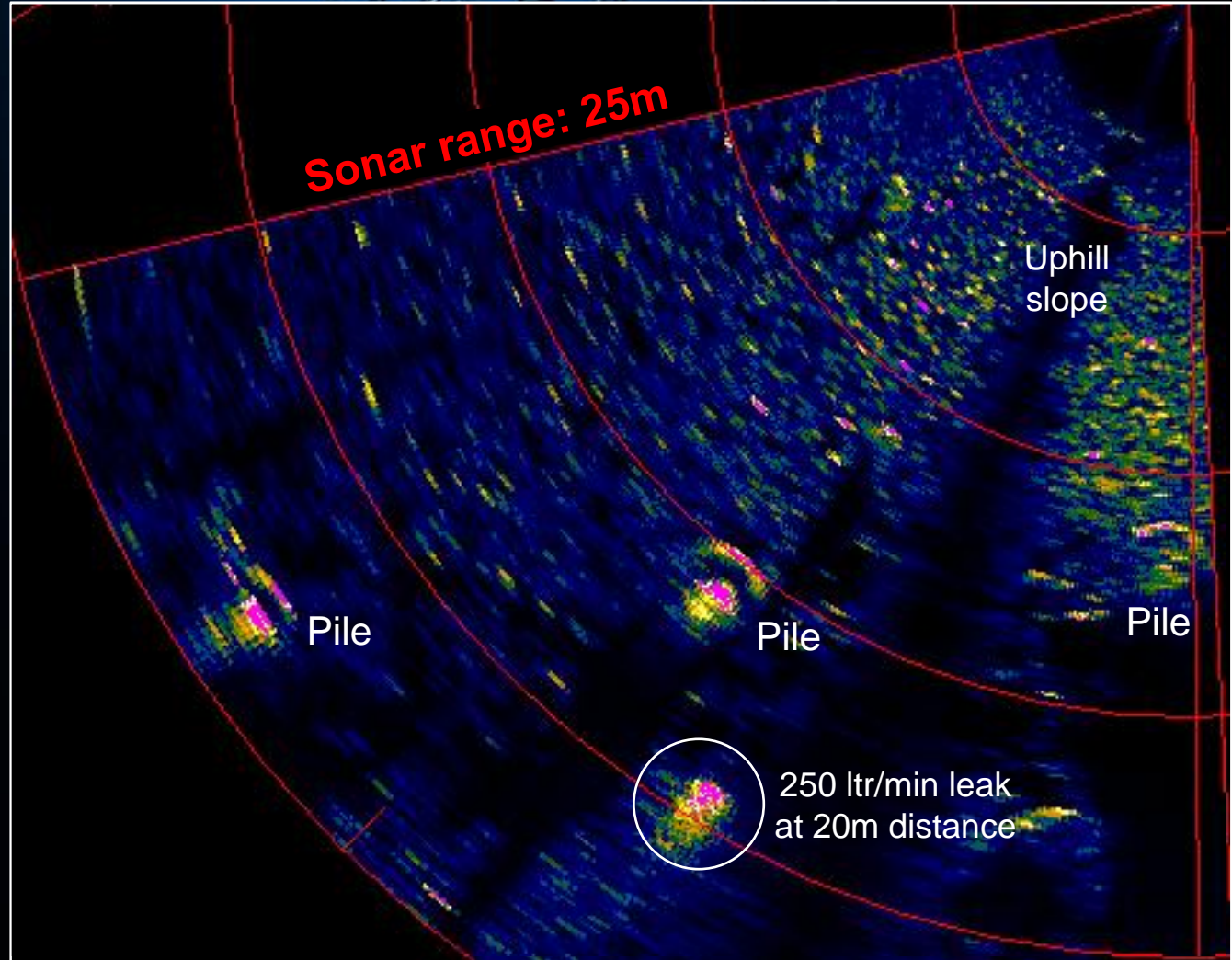
SLD monitoring head with MS1000 sonars

Sonar gas leak detection

Horizontal aspect and detection capability

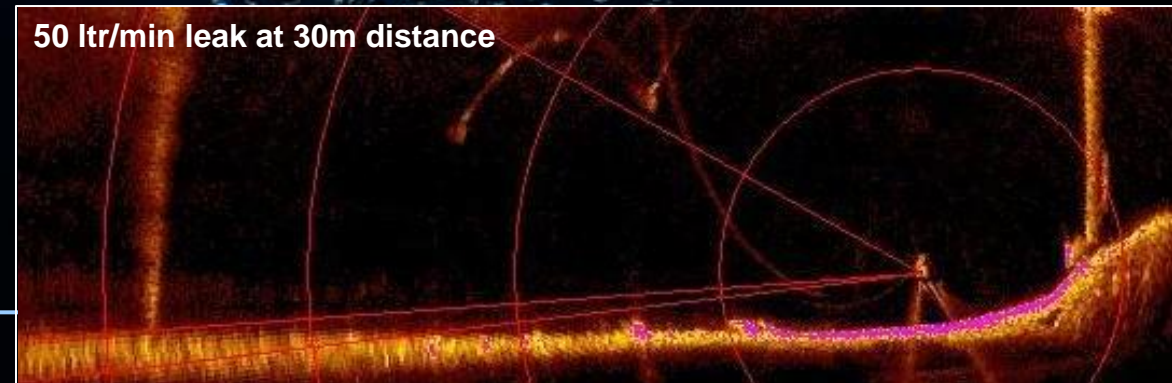
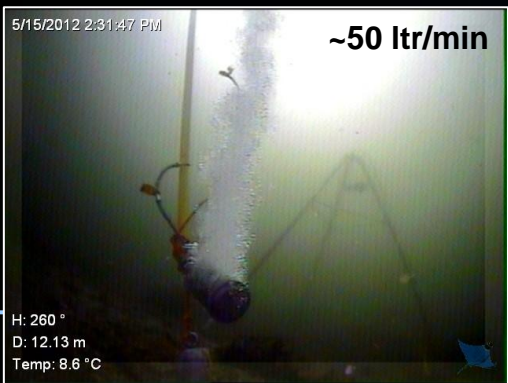
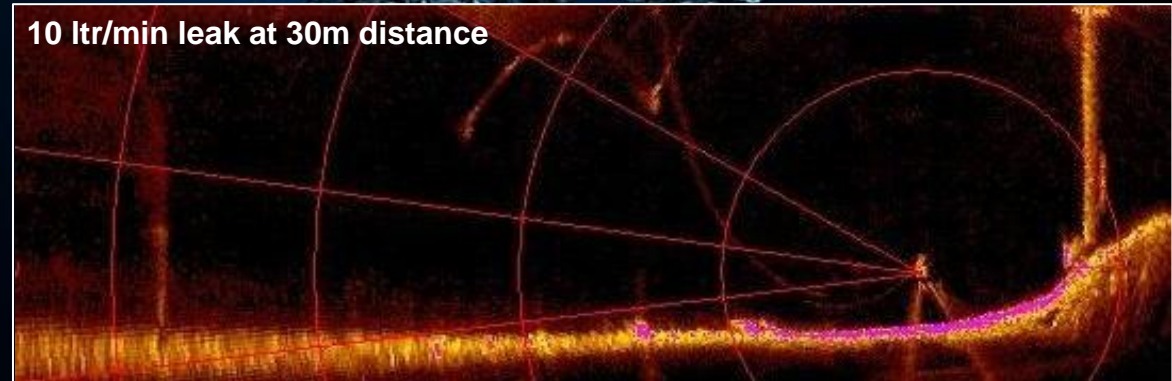
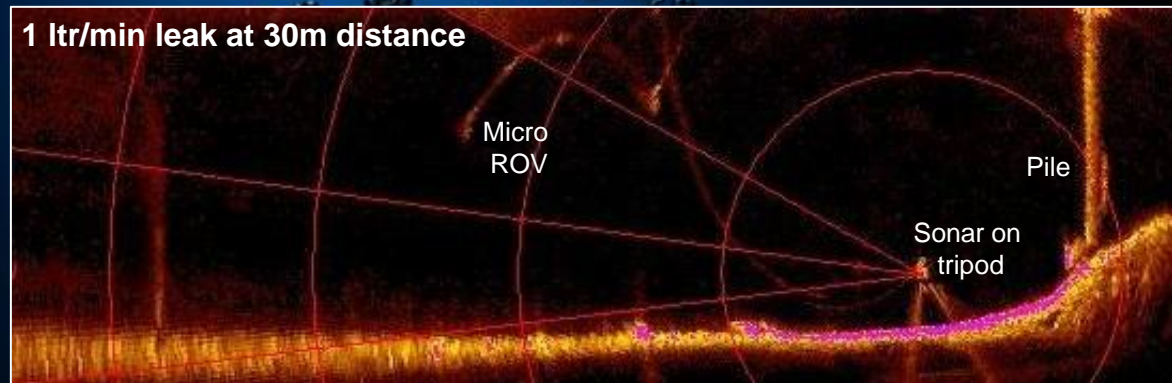


Sonar head



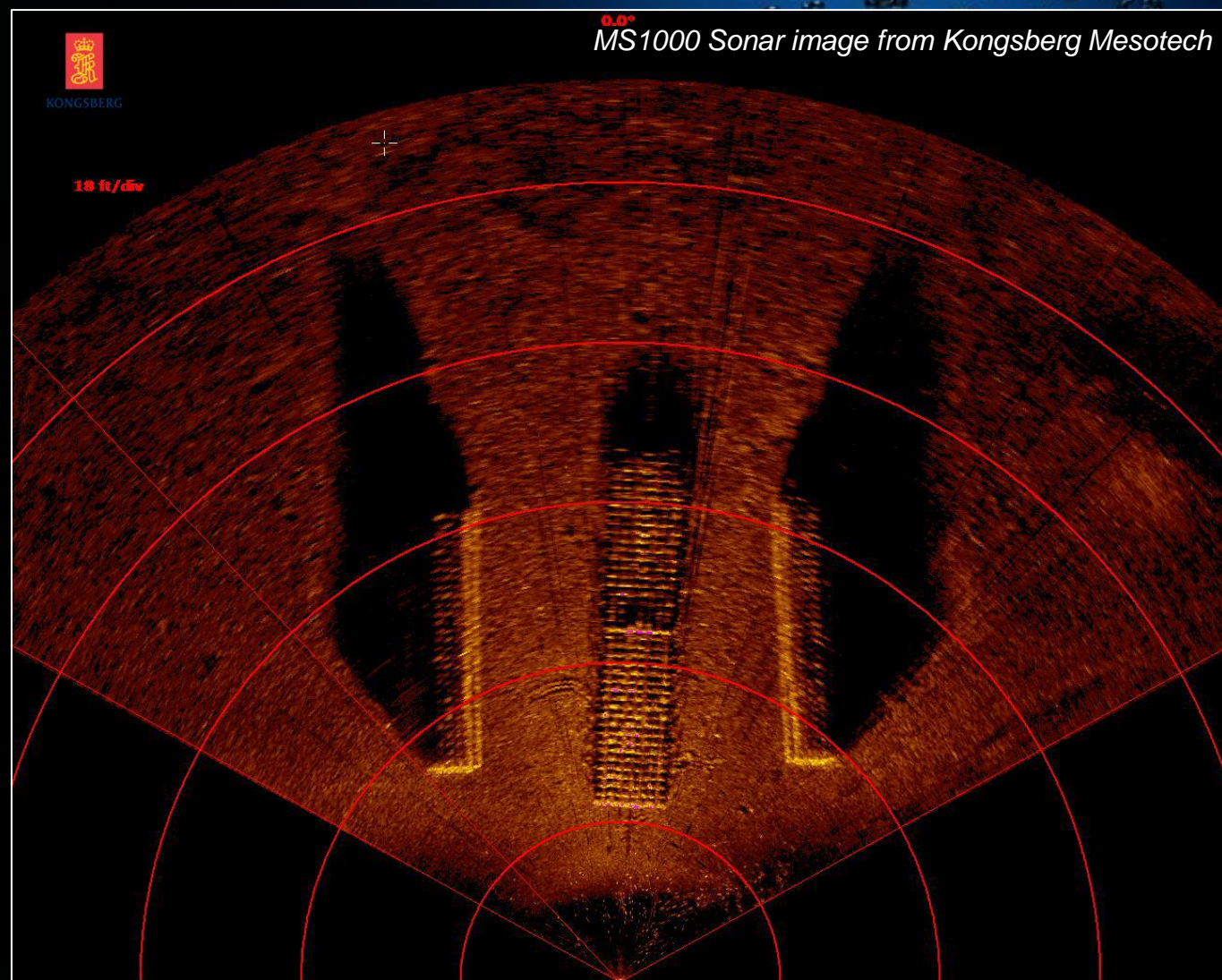
Sonar gas leak detection

Vertical aspect and detection capability



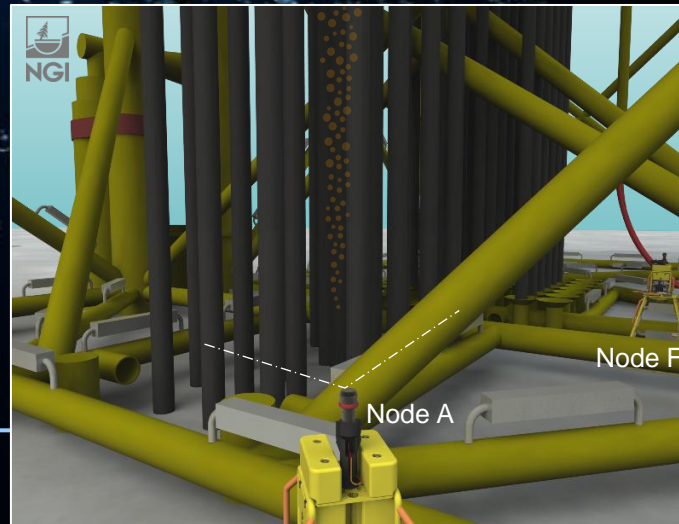
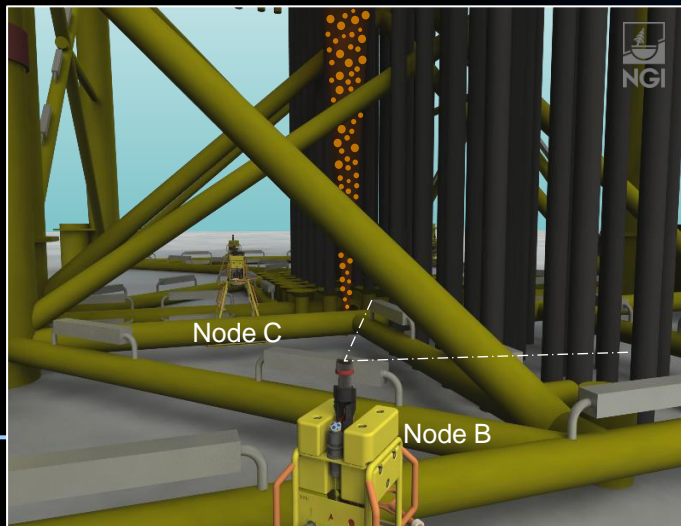
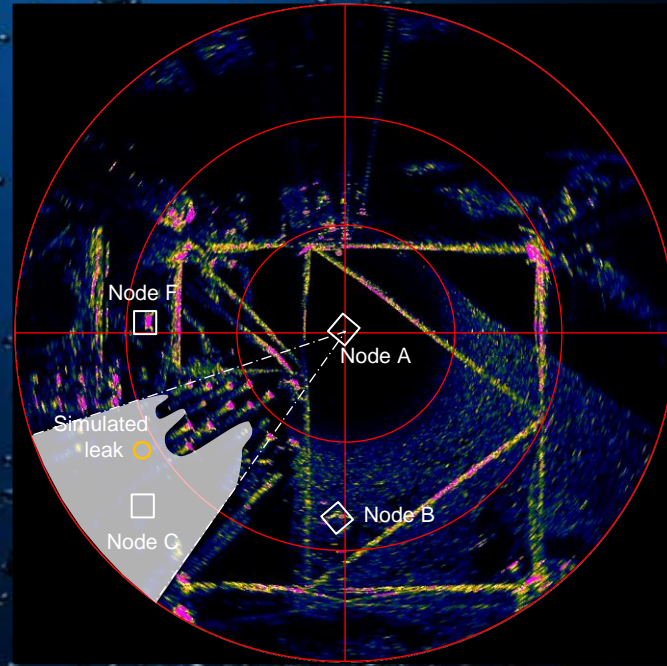
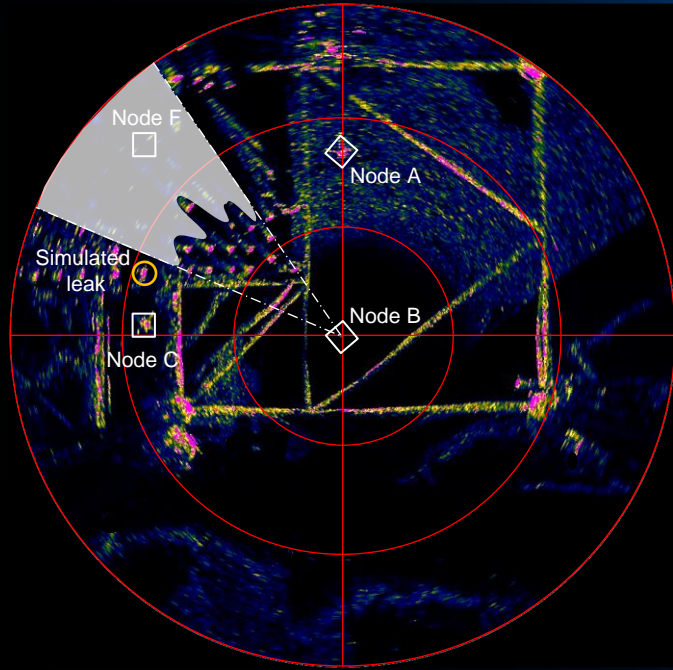
Sonar gas leak detection

Acoustic shadows and blind zones



Sonar gas leak detection

Point of view and "Blind" zones 30m sonar range



Automatic detection algorithms

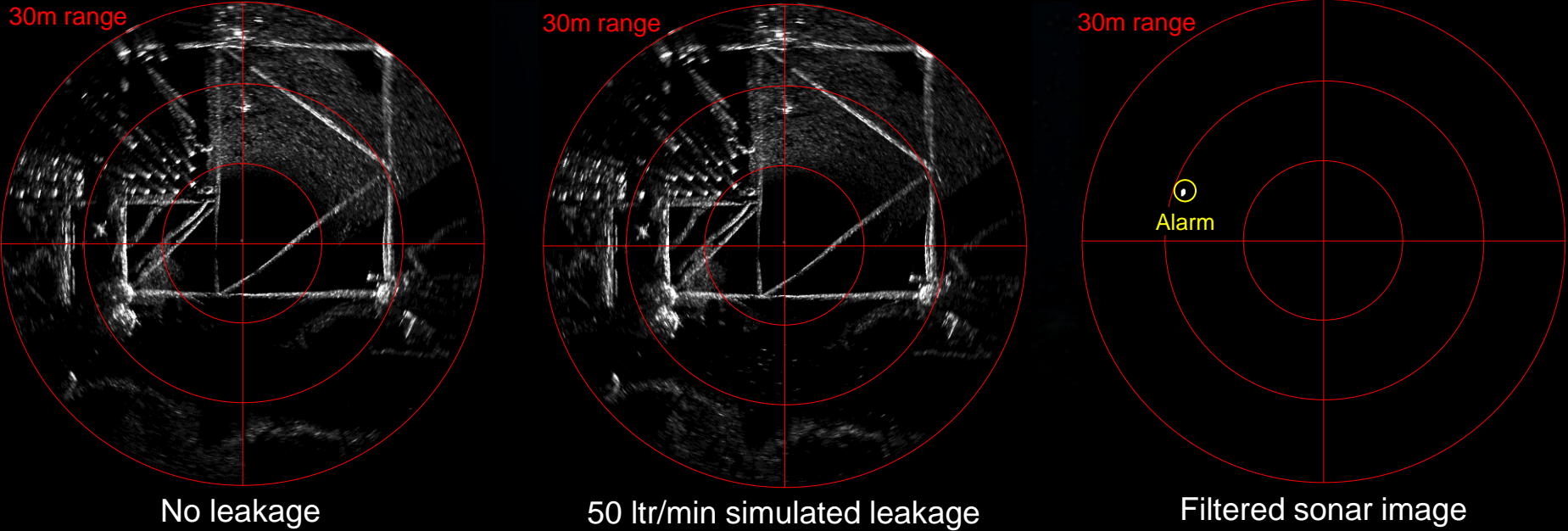
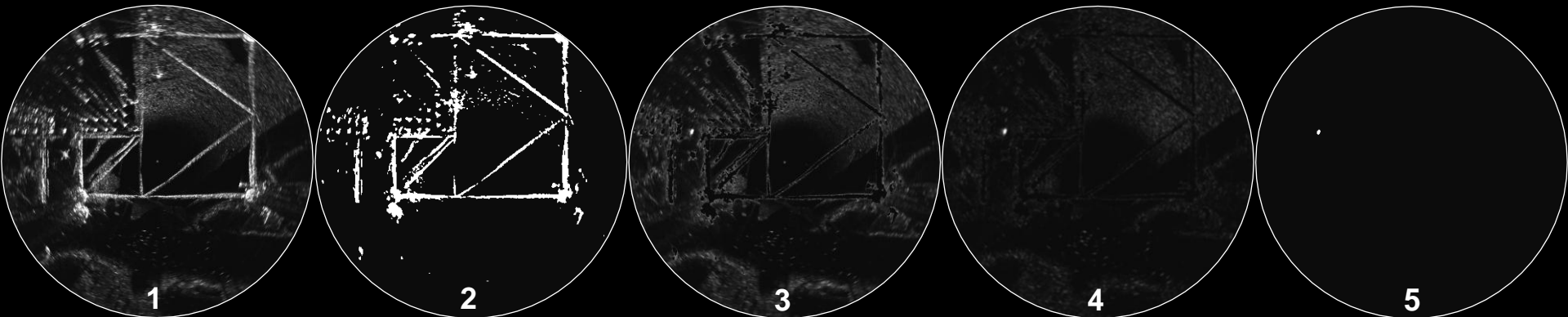
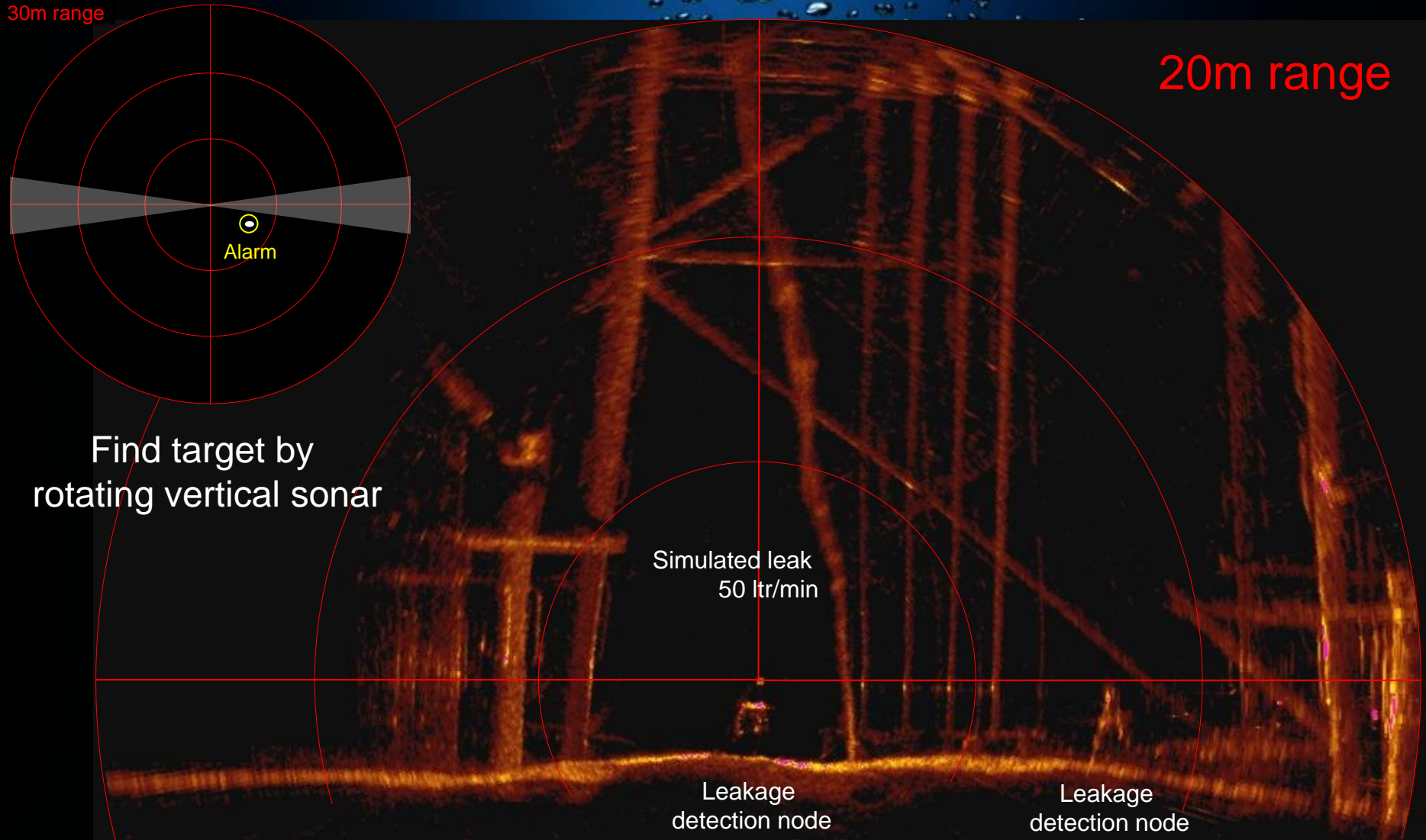


Image processing steps:



Horizontal scanning sonar images are processed on a continuous basis including coherence of multiple images for automatic detection

Alarm confirmation by vertical sonar



30m range

20m range

Alarm

Find target by rotating vertical sonar

Simulated leak
50 ltr/min

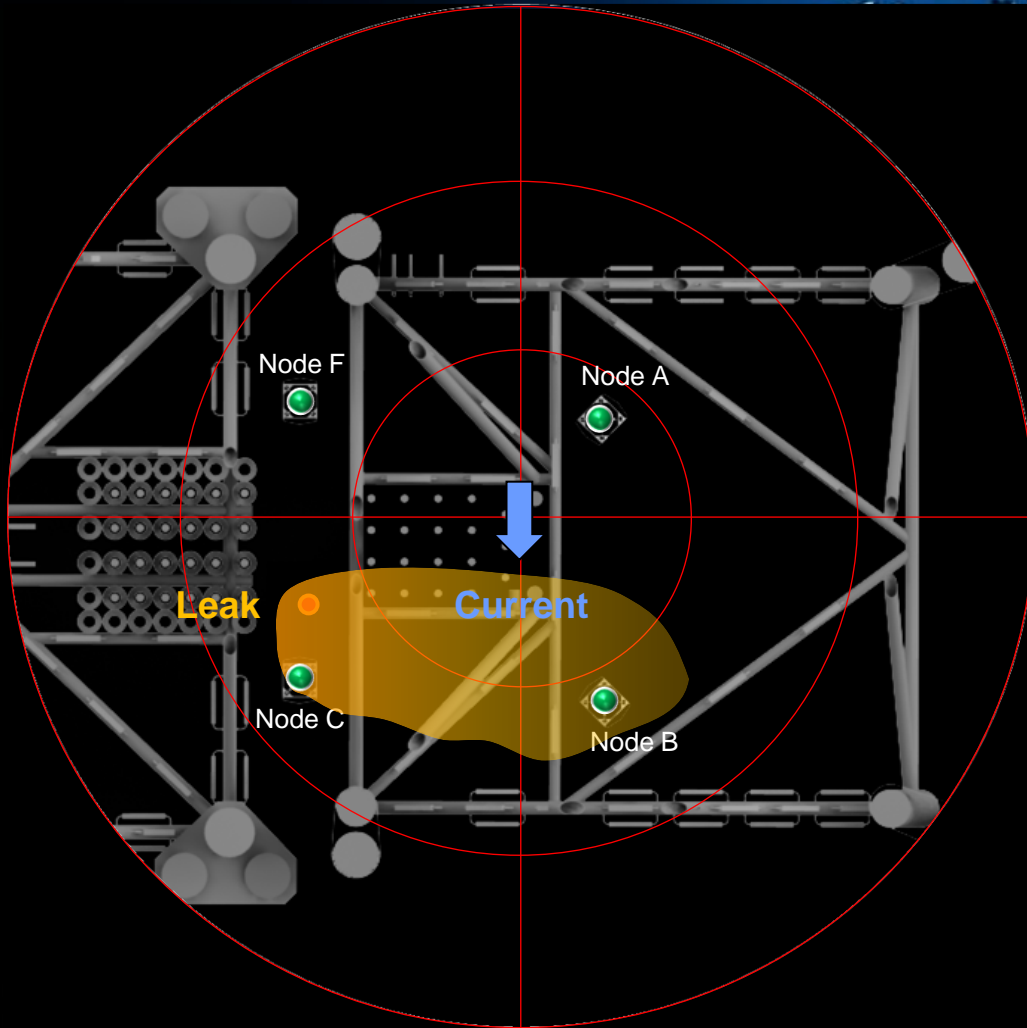
Leakage
detection node

Leakage
detection node

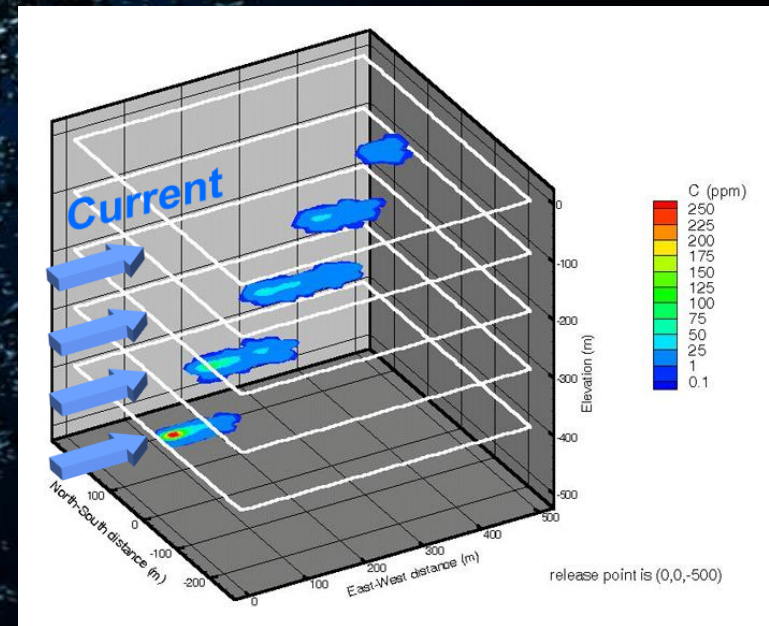


“Sniffers” and Current meters

Dissolved gas distributed by the water current

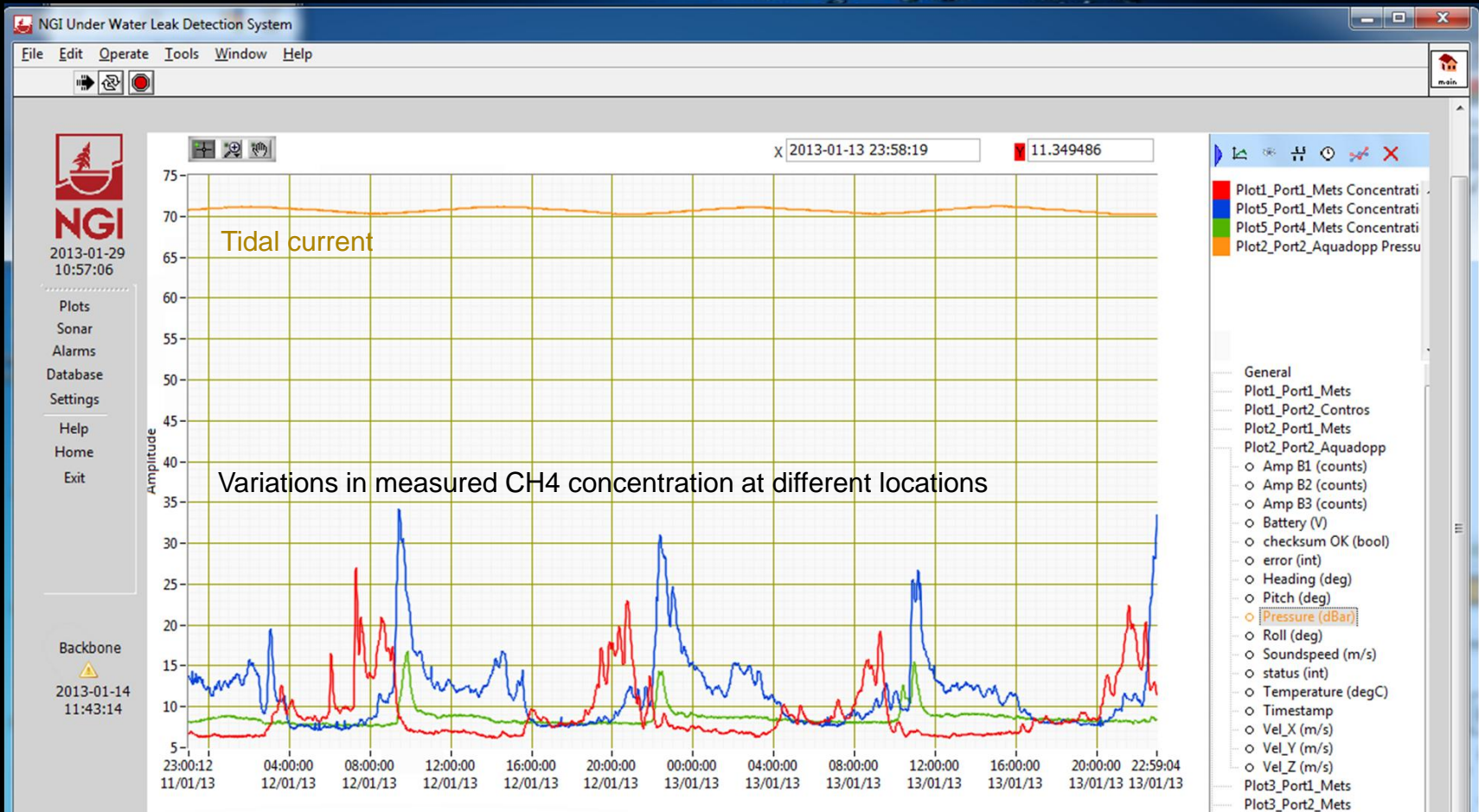


CDOG simulation of gas plume
Yapa and Zheng, (1997)



“Sniffers” and Current meters

Example showing CH4 variations related to tidal cycles



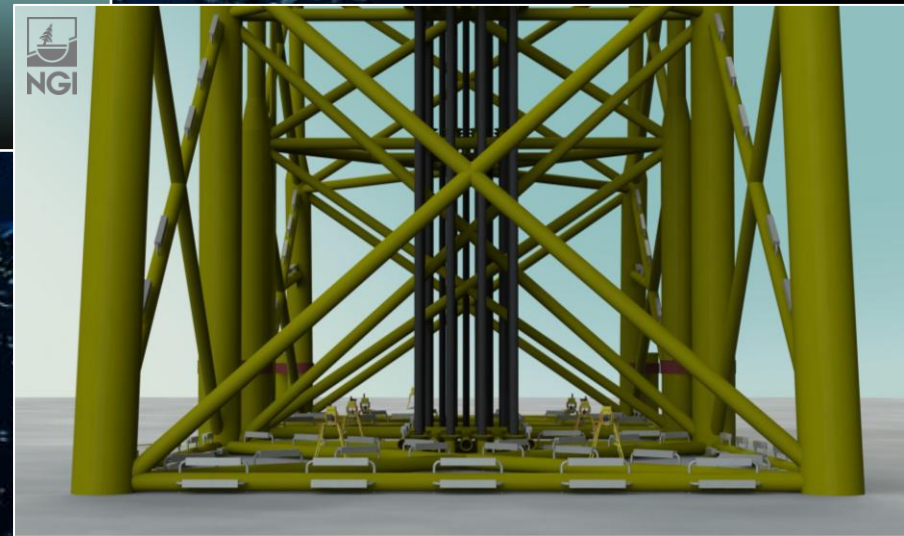
Note that measured concentrations are well below predicted response for a leakage



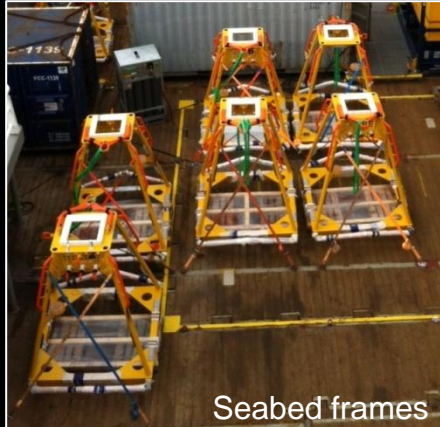
Prototype system in operation



An array of subsea leakage detection nodes including chemical sensors, active sonar's and current meters, has been installed at the seabed beneath an existing platform complex to monitor possible increased concentration of dissolved gas and detect possible leaks ranging from seeping bubbles (10 ltrs/min) to significant gas plumes. The objective is to provide early warning for conditions which may develop into critical leakage scenarios.



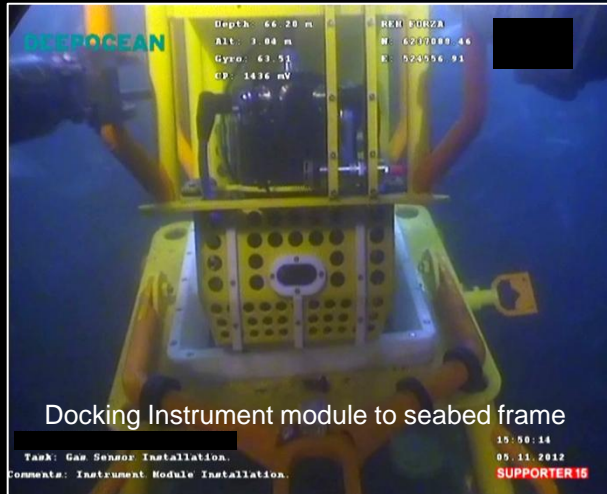
Prototype system installation



Seabed frames



Monitoring modules and riser umbilical



Docking Instrument module to seabed frame



Hooking up COM and power line



Subsea image: Stinger Technology AS

Subsea images: DeepOcean (responsible for subsea installation)



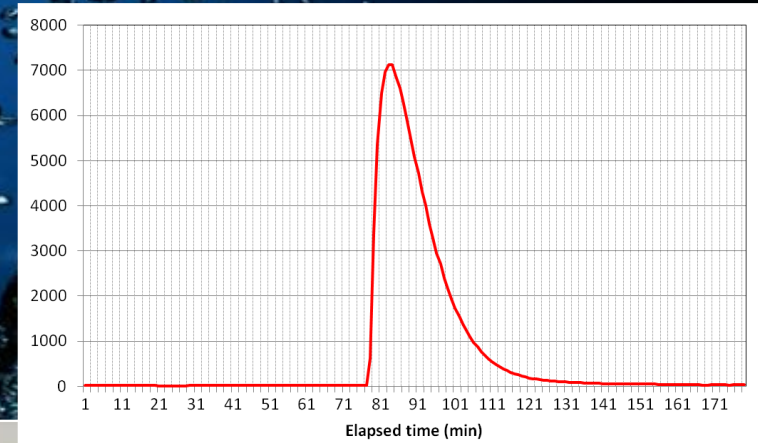
Insitu testing

Stinger Technology AS

Recorded in-situ response injecting 10ml Methane in seawater close to a Sniffer



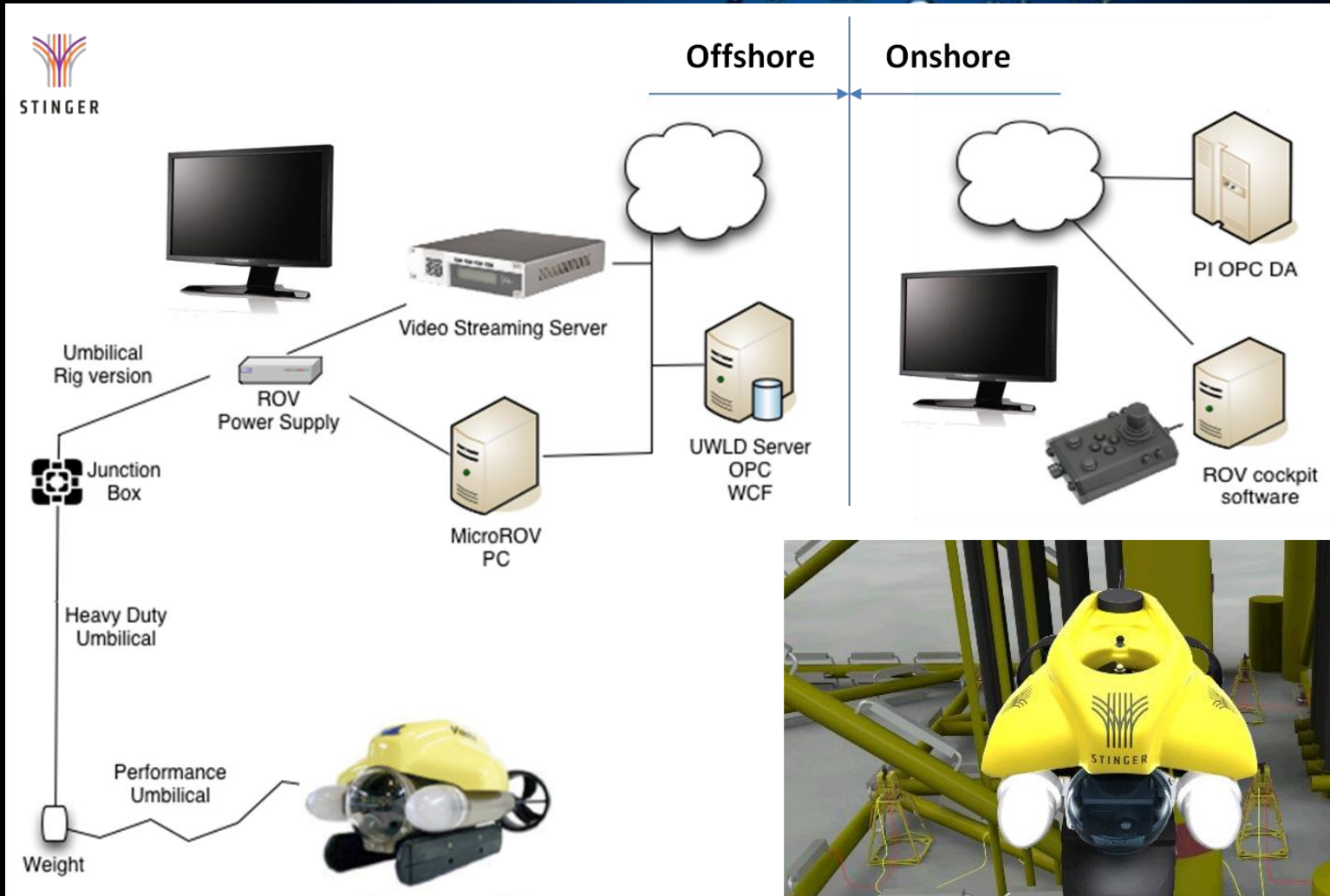
Seabed Gas leakage simulator



MicroROV with methane injector tubes

Remote operated "Watch dog"

Onshore remote operated MicroROV



Permanent Monitoring systems for Seabed Leakage Detection



Conclusions

What's next?



Sonar hugging Starfish

Thank You for the Attention!