Hydroacoustic Research Group, Ocean Systems Laboratory

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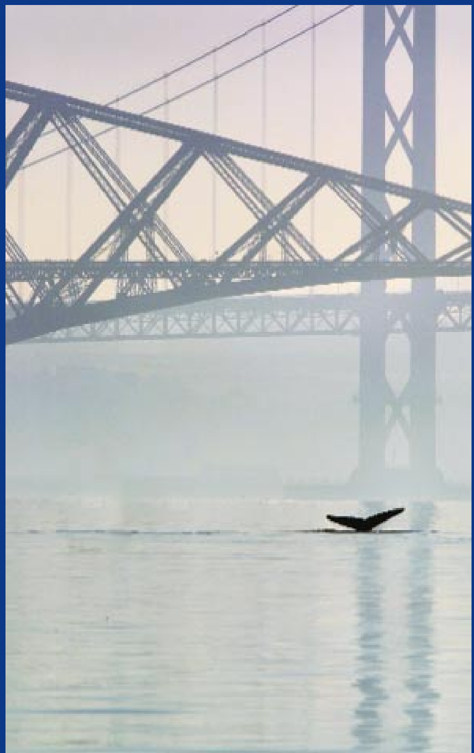
Ron McHugh



Environmental hydroacoustic monitoring
Passive Acoustic Monitoring (PAM)

Shallow-water environmental variability research
Shallow-water sonar signal performance
Multipath robust signal design
Sonar array (sparse) algorithm development

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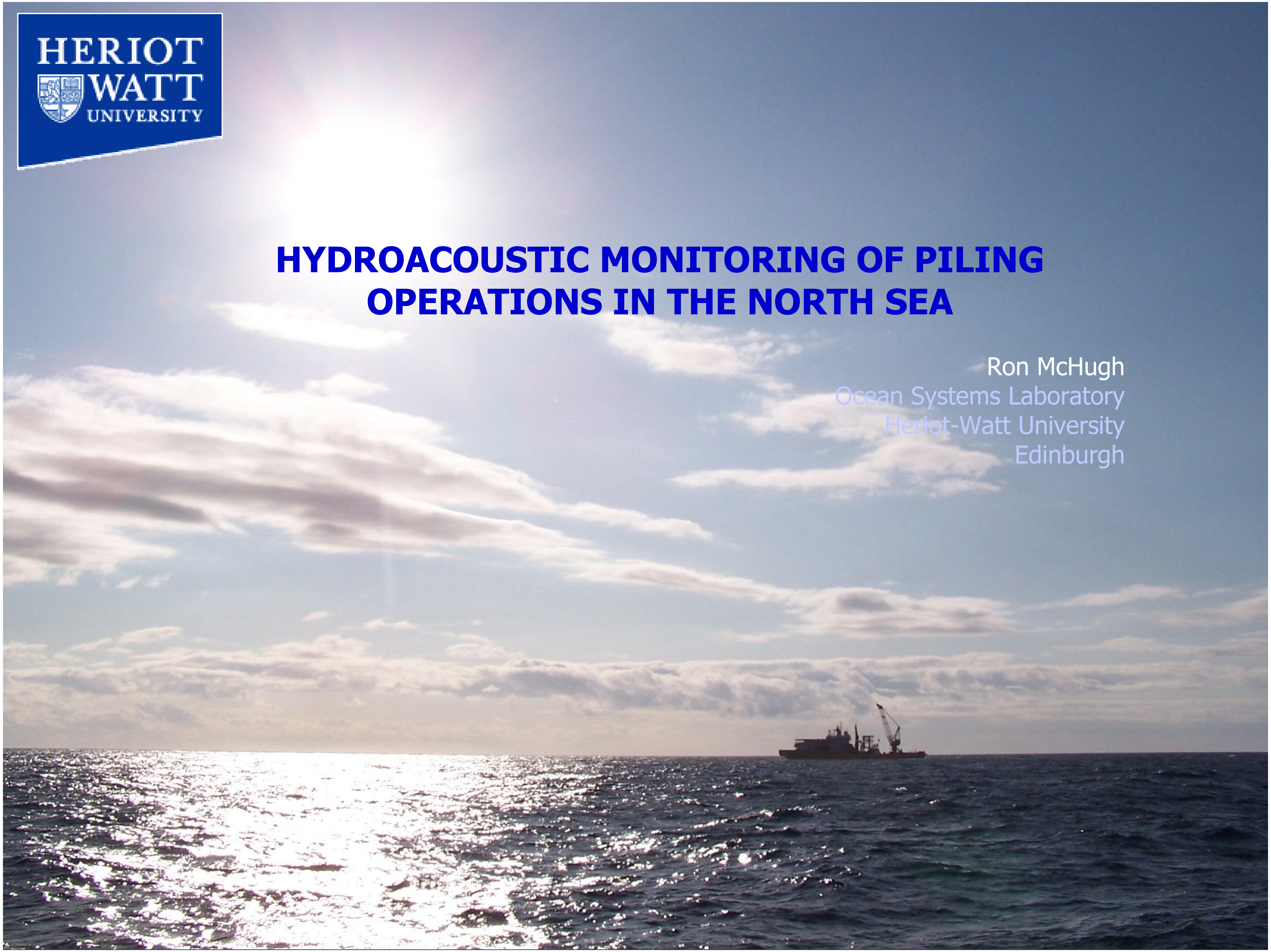


HYDROACOUSTIC MONITORING OF PILING OPERATIONS IN THE NORTH SEA

Ron McHugh
Ocean Systems Laboratory
Heriot-Watt University
Edinburgh

Overview

•Summer 2004, BP North Sea "Hot Tap" installation

•Future connection of Forties Pipeline to Encana Buzzard development

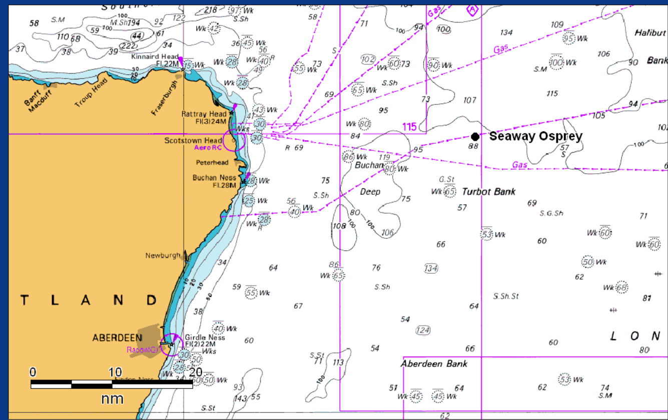
•Hot-Tap connection protective structure secured to sea bed by piles, depth:~100m

•Piles: 22m long, 0.75m diameter tubular steel

•BP underwent voluntary EIA

•HWU/Genesis contracted for hydroacoustic work

•Source level estimates through measurement/modelling



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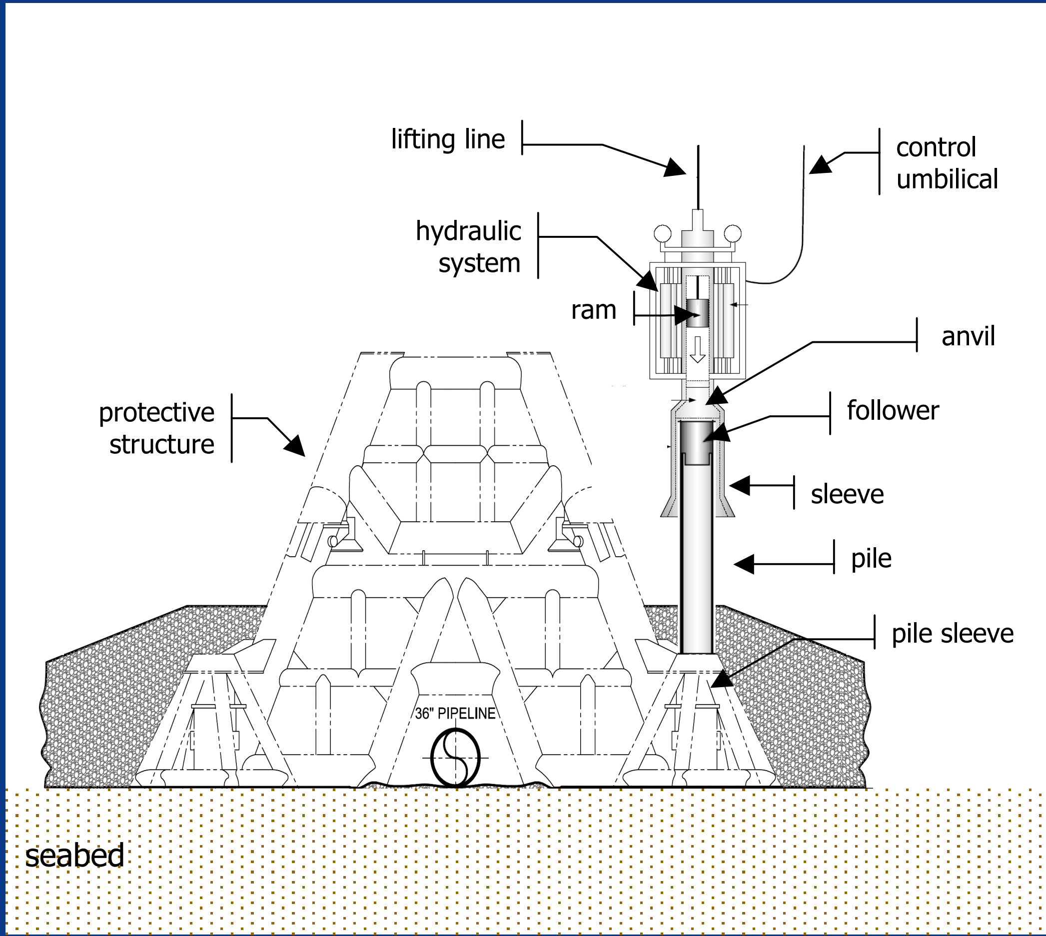
Piling operations

- four piles located at each corner of protective structure
- pile driver aligned with top of pile
- 10 tonne hammer + hydraulic charge
- several “single mode” blows to test penetration
- automatic mode: rapid blows



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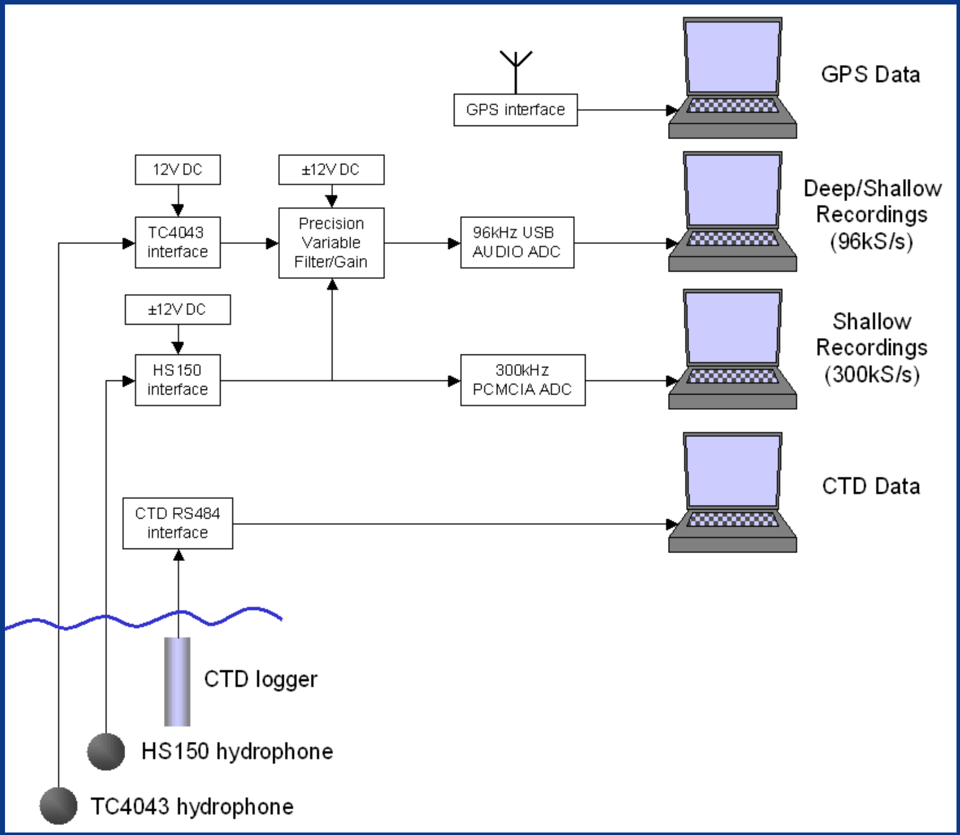
Methodology

- silent recording vessel
- July 04: ambient noise
- August 04: piling noise
- shallow hydrophone B=120kHz
- deep hydrophone B=45kHz
- CTD measurements
- GPS logging



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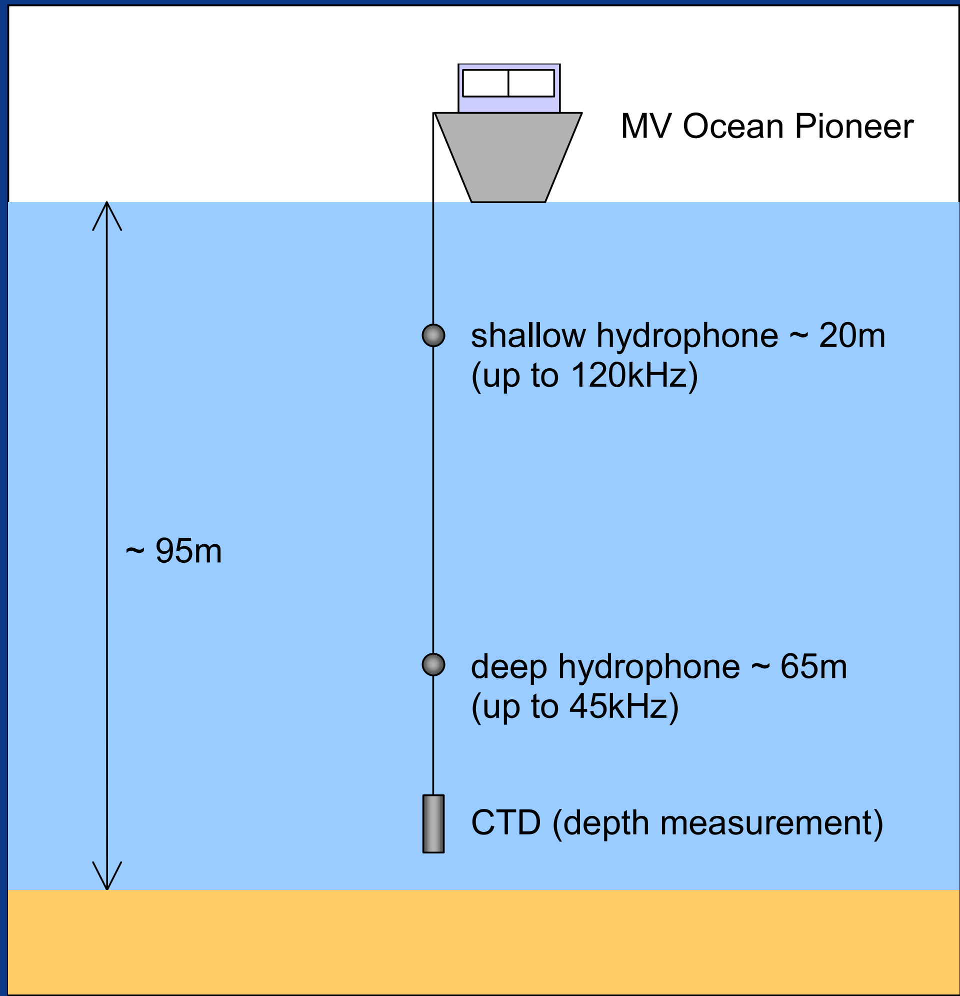

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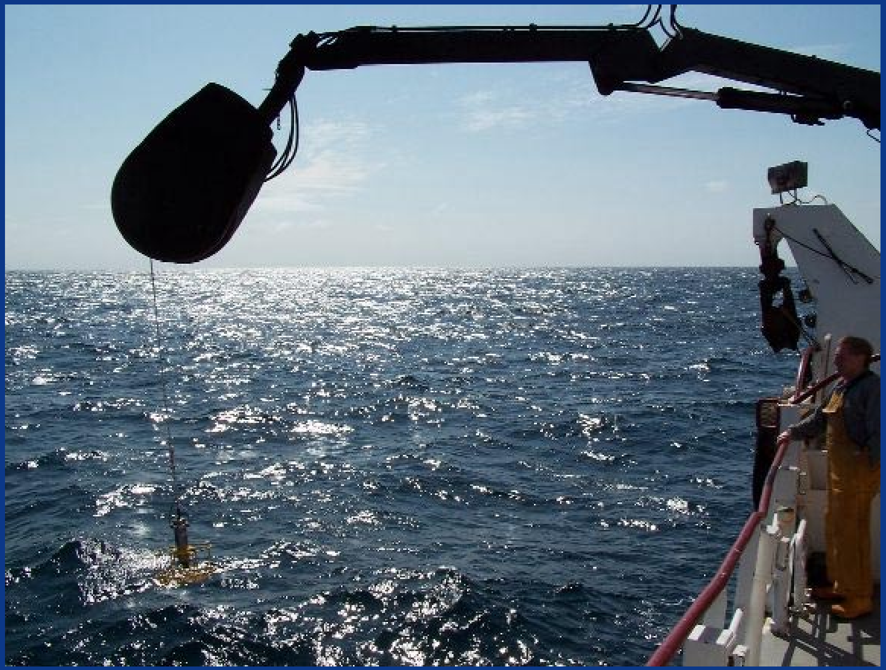
Environment: ambient recordings

- weather: good
- sea state: 2-3
- shipping:
  - seismic vessel @ 45km
  - fishing boat @ 3.5km
- sound speed profile
- white beaked dolphins present



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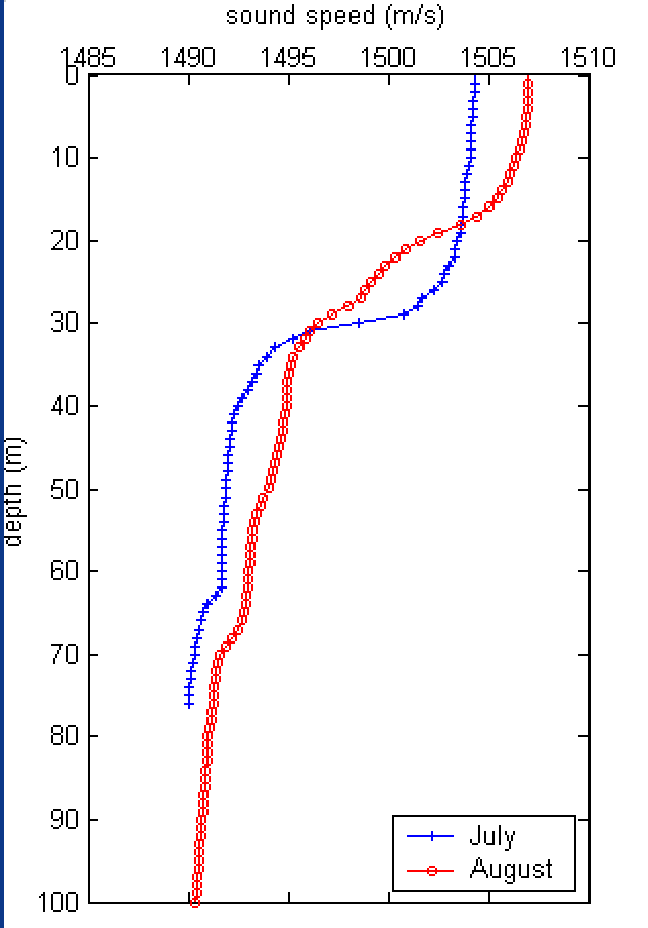

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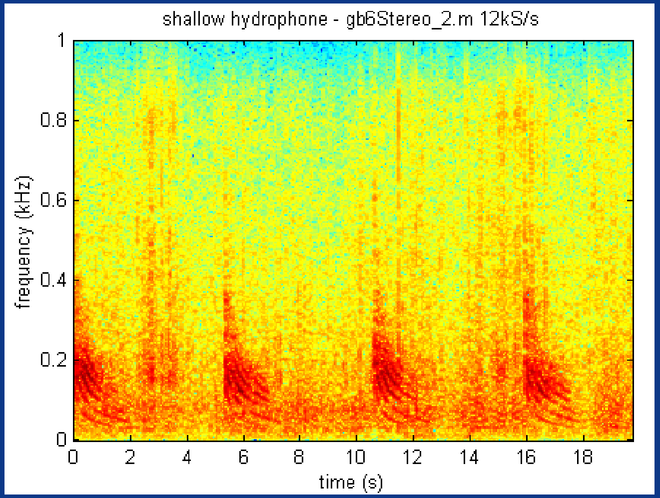
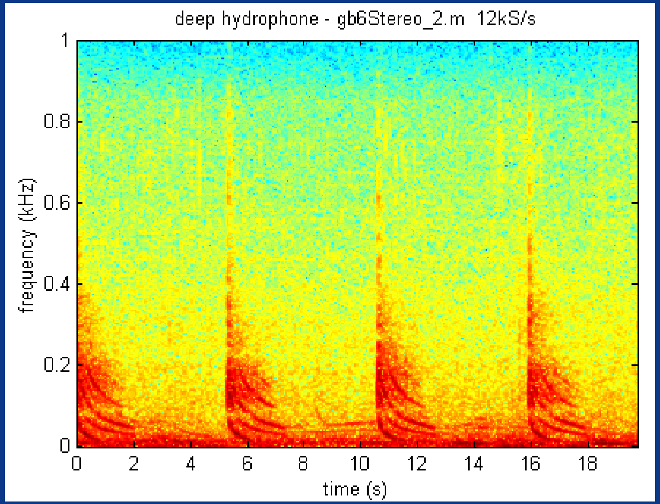
Results: ambient recordings

- seismic survey @ 45km – two vessels?
- seismic booms seen to feature sympathetic "downward chirps"
- geometrical dispersion of sounds undergoing multiple reflections
- wind-driven noise decreases with depth





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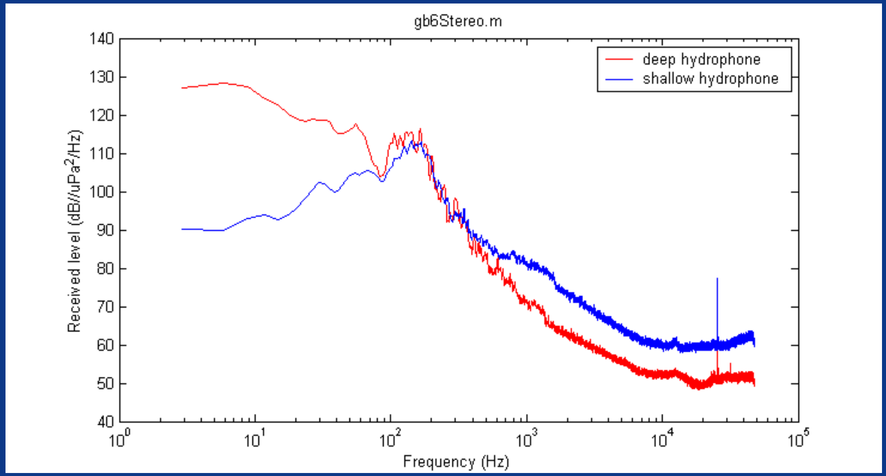
Results: ambient recordings

- Sound Pressure Density (SPD) spectra
- averaged over 1 minute
- $\Delta f \cong 3$Hz
- Θve gradient SSP ∴ energy concentrated in lower layers
- sub 100Hz: deep Rx 20-40dB > shallow
- above 1kHz: levels > due to agitation
- high levels compared to deep water Wenz curves



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Environment: piling recordings

- weather: good
- sea state: 2-3
- shipping:
  - 100m support ship
  - -diesel electric
  - -dynamic positioning
  - ROV
- no MMs observed

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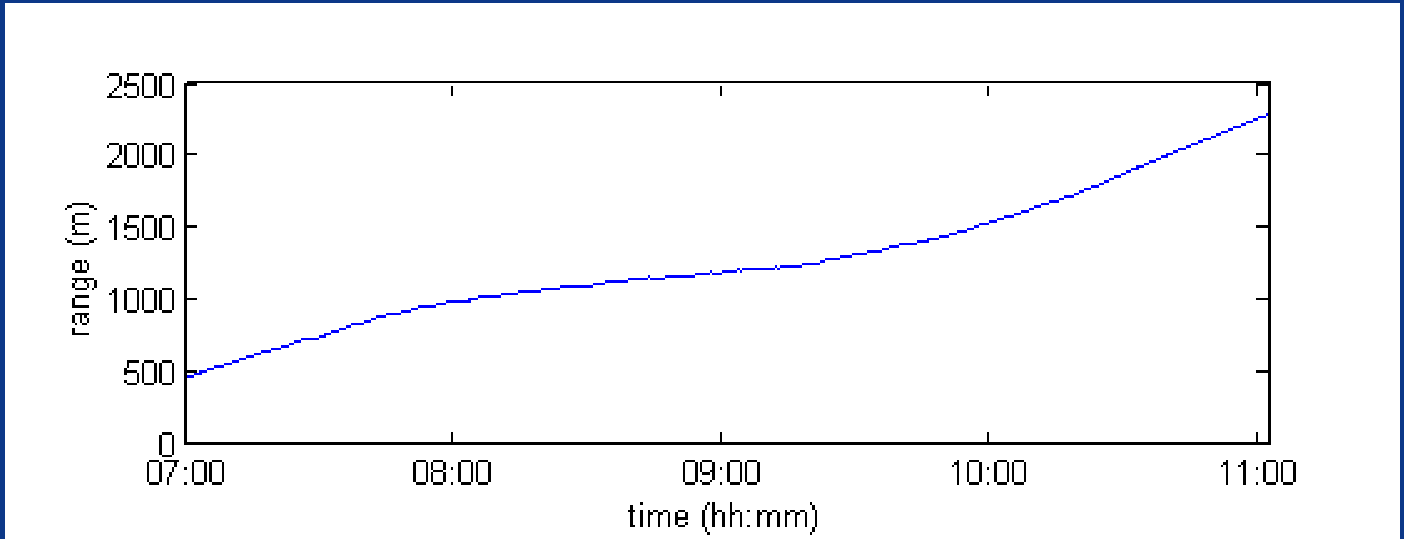
Methodology: piling recordings

- recording vessel downwind of ops
- drifts from <500m to >2000m over 4 hours
- 1600 pile hammer emissions recorded
- hydrophone depths logged



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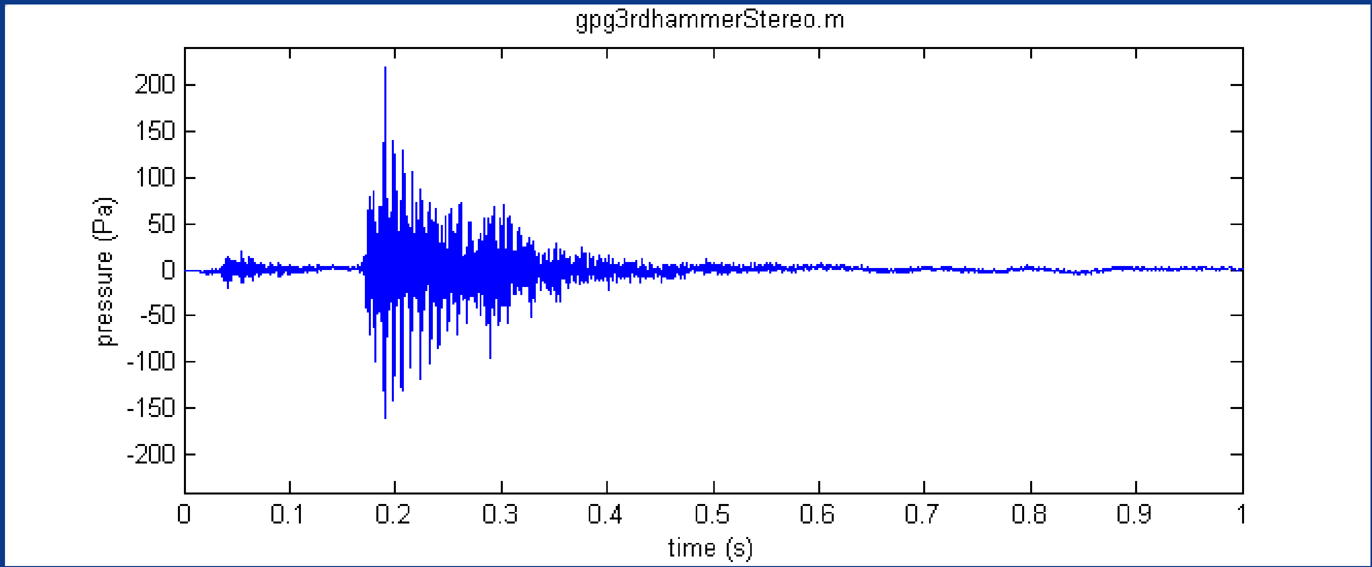
Results: piling recordings

- time-pressure series for a pile hammering operation
- smaller amplitude sound associated with hammer charging
- following this, impact of hammer against anvil/pile assembly



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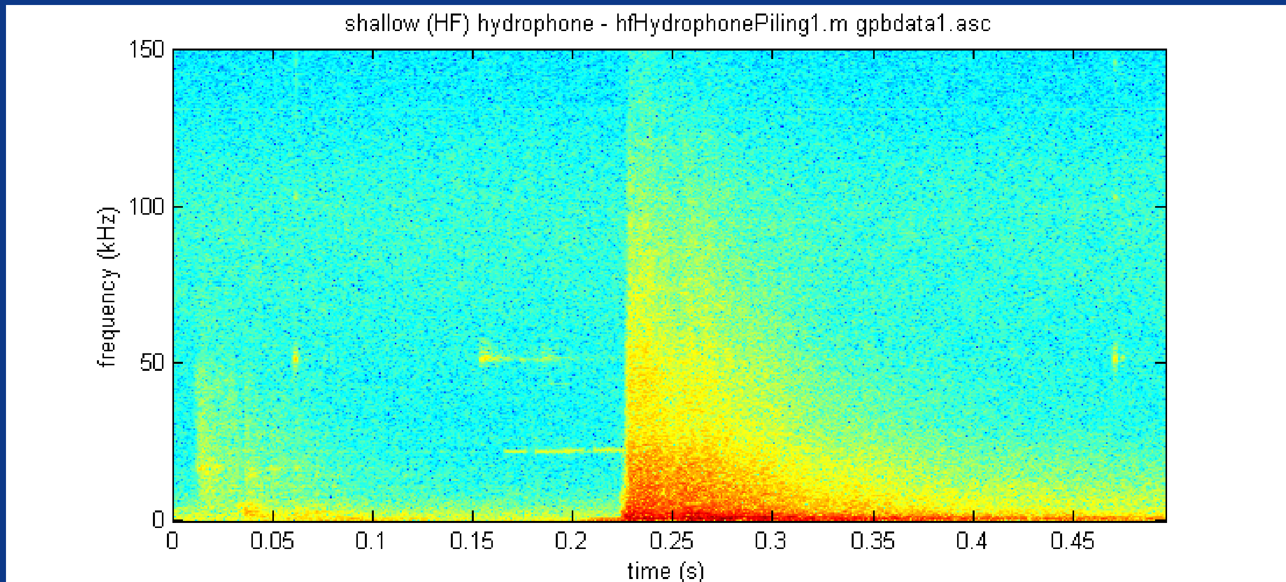
Results: piling recordings, spectral

- charging pulse & hammering pulse are broadband with low frequency bias
- hammering pulse energy extends to >100kHz



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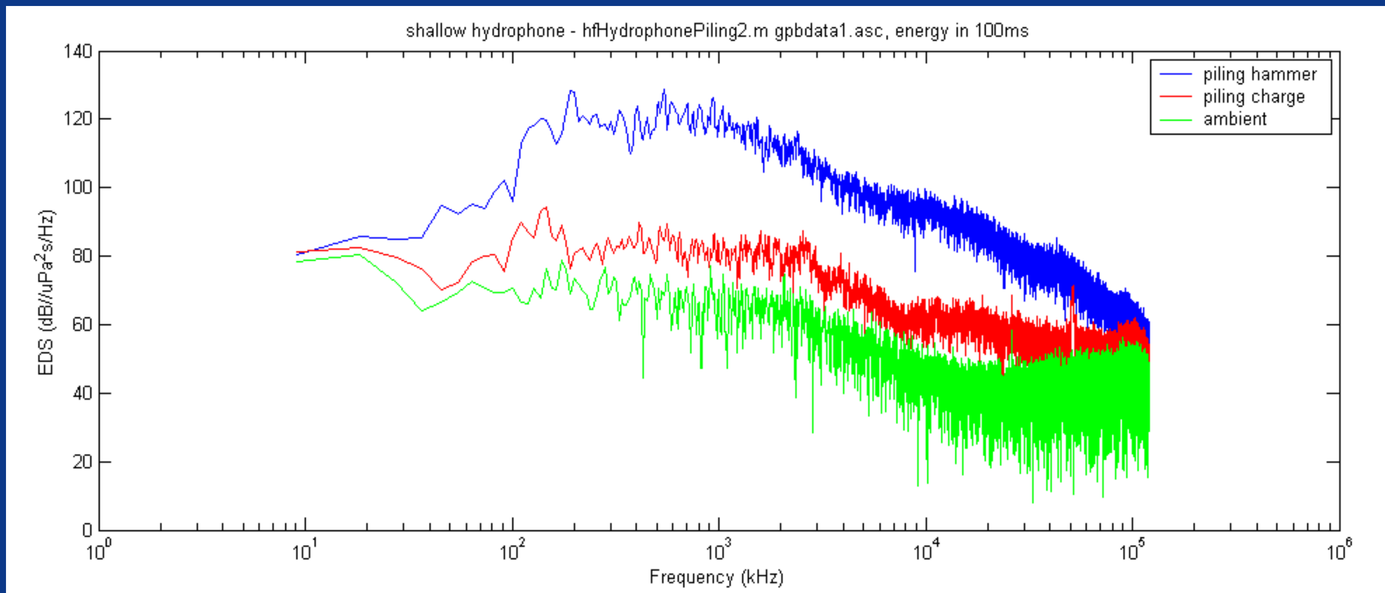
Results: piling recordings, spectral

- maximum difference between ambient and hammering: 55dB in 100Hz to 1kHz band
- at 120kHz: approximate increase of 10dB
- at 20Hz, a modest increase of 5dB *(100ms record, $\Delta f \cong 9$Hz)*



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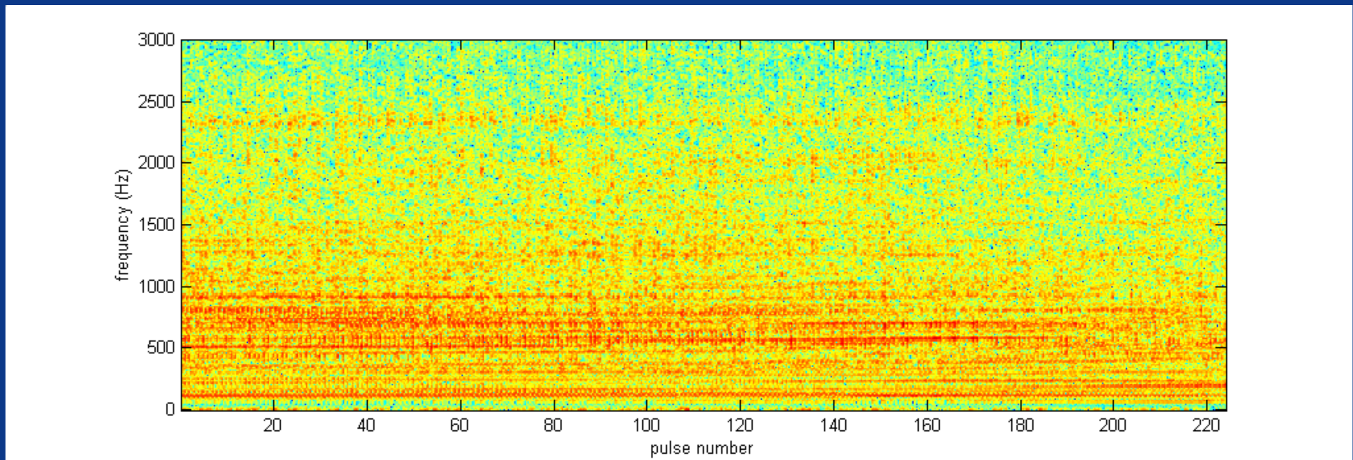
Results: piling recordings, spectral

- 82ms spectrogram "slices" for 224 hammer signatures concatenated
- taken from start of hammer signature
- no evidence of spectral line gradient increase with pile progress
- indicates that pile resonance is not the major component of signatures



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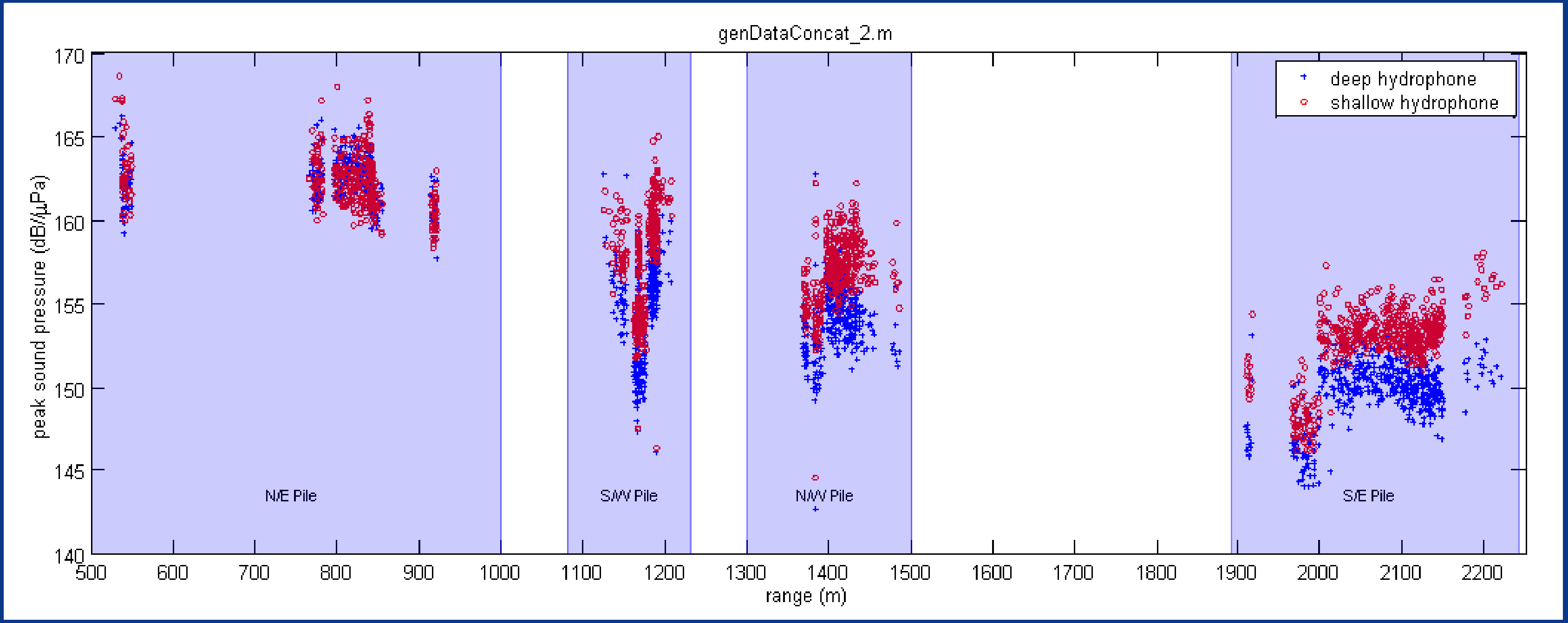
Results: piling recordings, peak SPL versus range

- maximum peak SPLs of 168 & 166 dB//µPa for shallow and deep RX @ 500m
- as R ⇑, relative increase in SPL between shallow & deep RX respectively – why?



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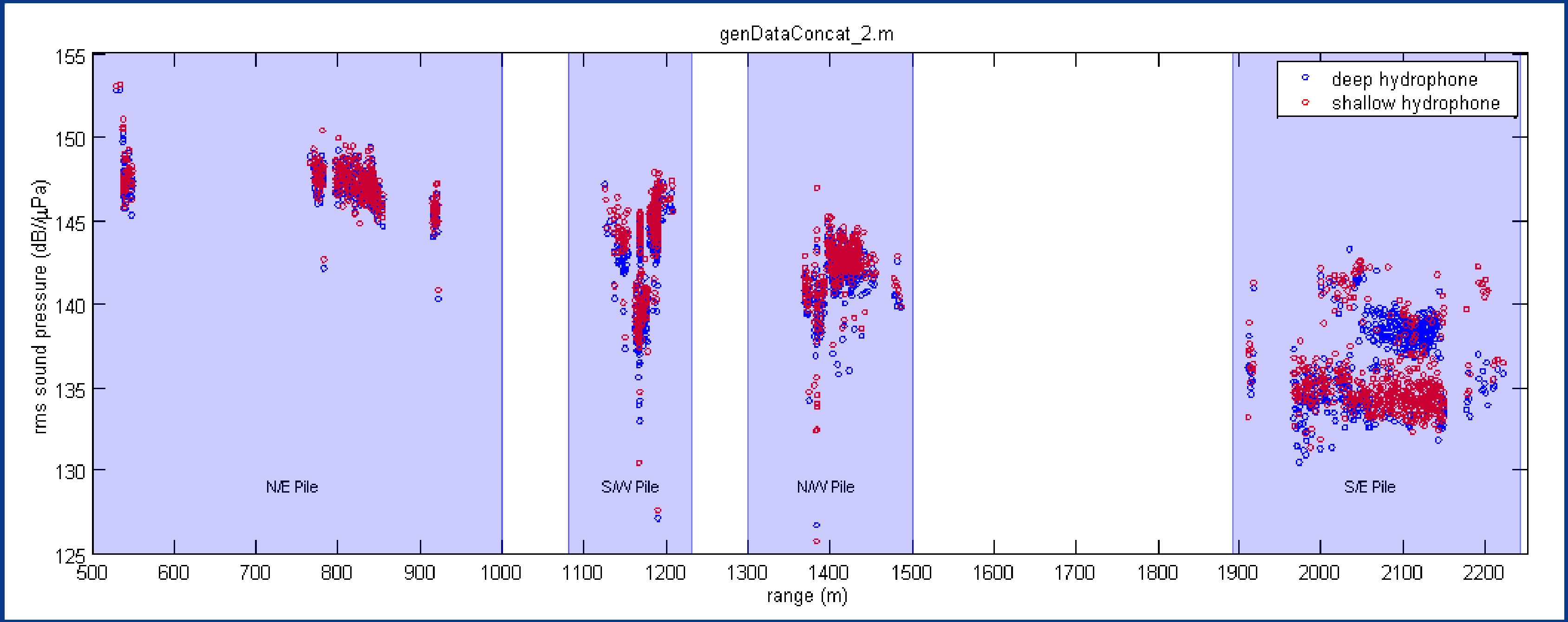
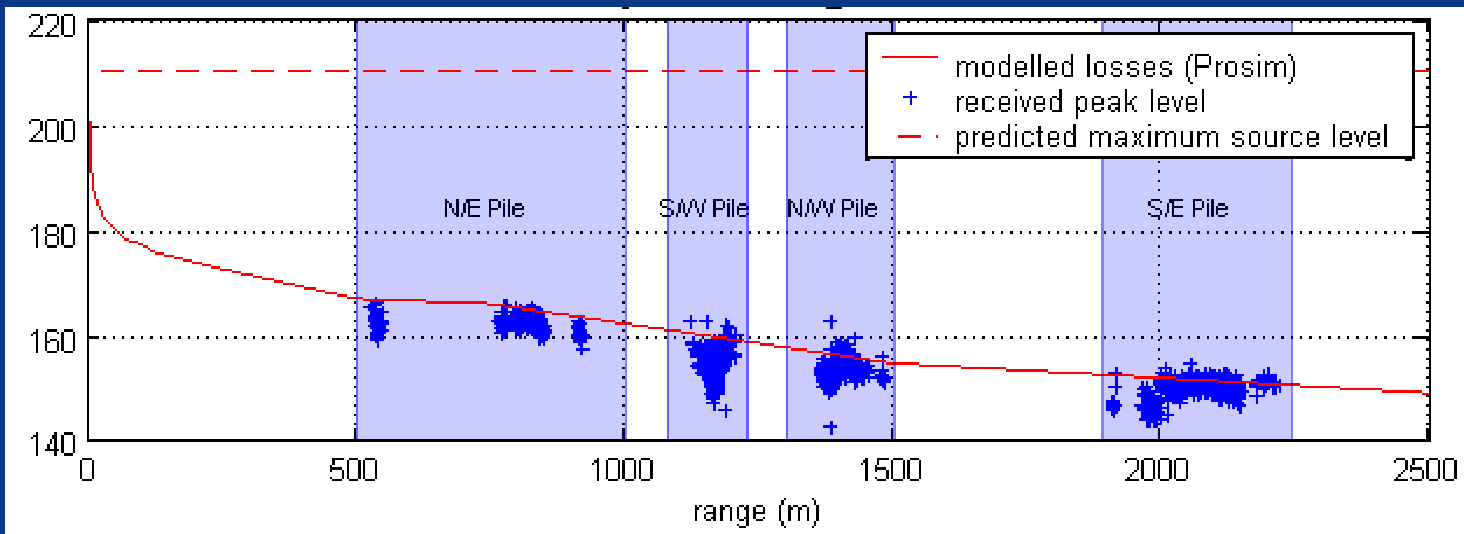
Results: piling recordings, rms SPL versus range

- rms pressure over peak-10% envelope
- maximum rms ≅ 153 dB//μPa
- deep/shallow comparable with range except for >2000m
- > 2000m, reverberation field in upper layer has less intensity



Modelling

- modelling allows estimation of source levels through extrapolation
- PROSIM broadband normal mode underwater acoustic model
- piling is modelled as a broadband (100-9000Hz) point source located 10m from floor
- inputs: smoothed CTD profile relative receiver positions
- peak source level estimation: 210dB//µPa@1m



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Conclusions and recommendations

- seismic noise may be considered part of the ‘normal’ noise climate
- acoustic data clearly indicates that the percussive piling dominates the sound field
- received signals are wideband with significant energy extending to over 100kHz
- at 500m range: peak and rms sound pressure levels of 168.6 and 153 dB//μPa
- propagation loss curve was generated using broadband normal mode acoustic model
- modelling exercise indicates a peak source level of 210dB//μPa@1m
- point source modelled, hence physical processes are not modelled in their entirety
- impulse spectra stable with pile progress: pile resonance is not a major contributor

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Conclusions and recommendations

- valuable addition to knowledge of anthropogenic sound pollution in the sea
- while acoustic processes present a complex modelling challenge, point-source modelling enables a valuable source level estimation
- Closer range measurements would further substantiate predictions (future work)
- Mitigation: further work required on impacts to marine life
- PRP, duty cycle may be key factors

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PART II

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PAMGUARD

THE PASSIVE ACOUSTIC MONITORING GUARDIANSHIP PROJECT

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School of Engineering and Physical Sciences

School of Mathematical and Computer Sciences

Heriot-Watt University
Edinburgh

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IRFC
Industry Research Funders Coalition

Methods of detecting marine mammals

Visual surveys

•operators employ teams of dedicated Marine Mammal Observers (MMOs)
•highly skilled at spotting animals which surface

Task of MMOs:

•minimise the probability of false detections
(costly to the operator)
•maximise the probability of true detections
(increased protection for MM)

Problems:

•Non-surfacing MMs
•Poor visibility
•Rough seas

Methods of detecting marine mammals

Passive Acoustic Monitoring (PAM)

- many marine mammals produce loud and distinctive vocalisations
- these can often be detected more reliably than visual cues

PAM:

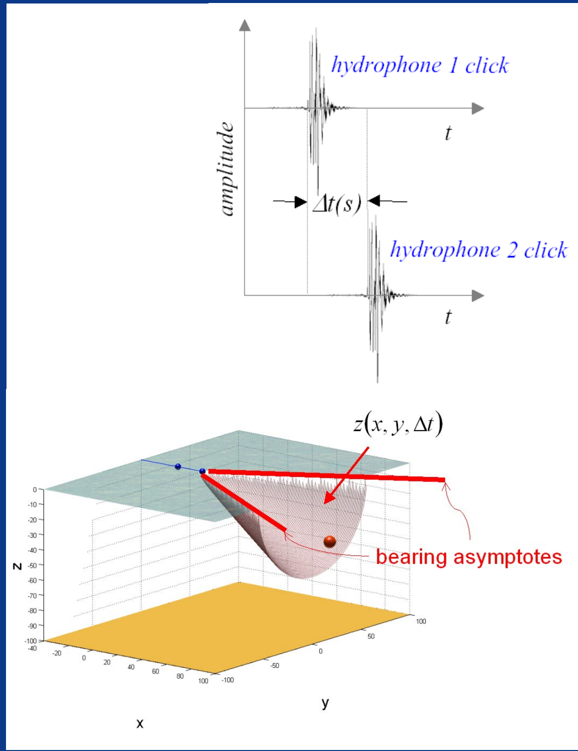
- offers an effective means of detection
- can detect creatures at ranges in excess of visual observation
- particularly useful for odontocetes, especially deep divers (sperm whales) and species that are difficult to spot (porpoises)

Existing PAM systems

Most commonly used freely available PAM software:

•IFAW suite

•"Rainbow Click" (medium freq. clicks), "Whistle" (whistles/tonals), "Porpoise" (HF clicks), "Logger" (logs detection/annotation/GPS data)
•two element array
•provides ambiguous hyperbolic bearing information rotational on array axis



ISHMAEL

•spectrogram viewer
•three acoustic localisation methods (including >2 element)
•three methods for automatic generic call detection (energy summation/matched filter/spectrogram correlation)

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PAMGUARD

The *vision* for the PAMGUARD initiative:

To address the fundamental limitations of existing cetacean passive acoustic monitoring (PAM) software capabilities by creating an <u>integrated PAM software infrastructure</u> that is <u>open source*</u> and <u>available to all PAM users</u> for the <u>benefit of the marine environment</u>.

www.pamguard.org

SOURCEFORGE.net

Open source* – publicly owned freely available

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PAMGUARD – software design

Platform independence

wide computing hardware/operating systems configuration options

Reusability

important for contributions from the PAMGUARD community

Generic behaviour of software components

captured in classes, which are extended into new capabilities/algorithms

"Infrastructure on which PAM can evolve"

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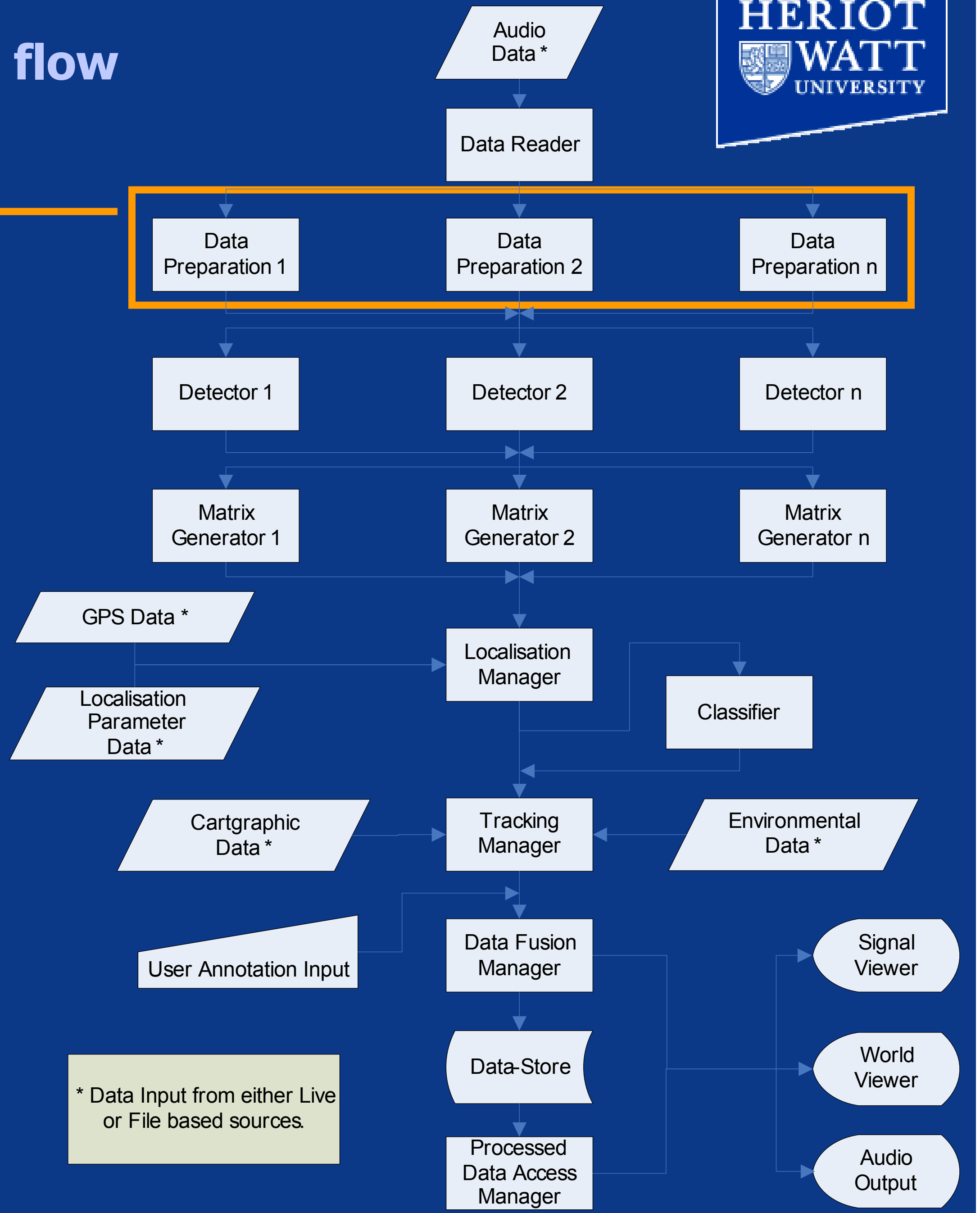
PAMGUARD data flow

Data Preparation objects

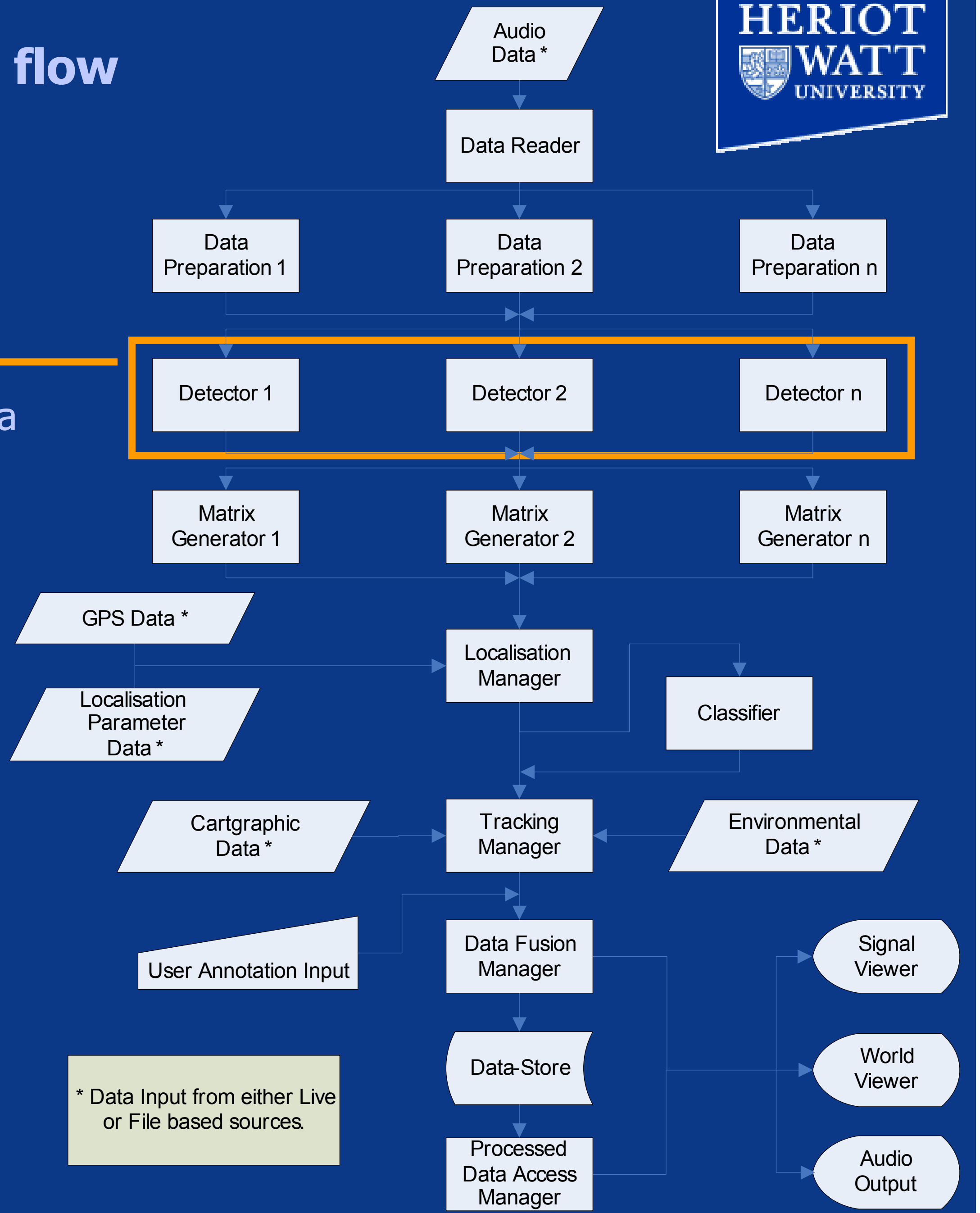
- receive acoustic data from Data Reader
- prepares data, e.g.:
- noise reduction,
- band pass filtering,
- down sampling,
- enveloping…



PAMGUARD data flow

Detector objects

- receive & process prepared acoustic data
- search for instances of acoustic signatures
- initially generic, e.g.:
- MF clicks (e.g. sperm whales)
- HF clicks (e.g. porpoises)
- whistles/tonals (e.g. dolphins)



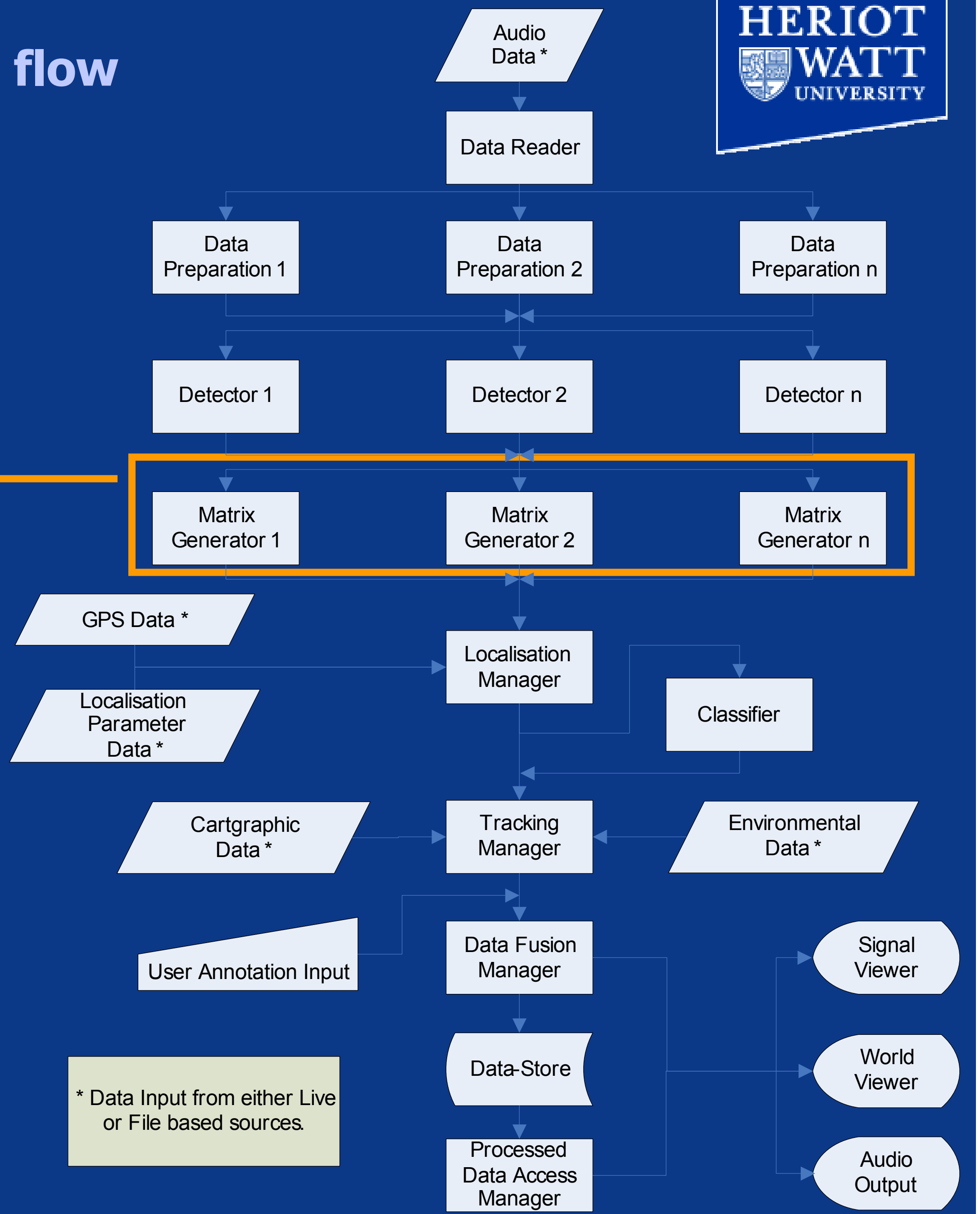
PAMGUARD data flow

Matrix Generator objects

•receive detection event objects

•build TDOA matrices

•cross examine multiple acoustic sources to find high confidence candidate matches for the same acoustic event



PAMGUARD data flow

Localisation objects

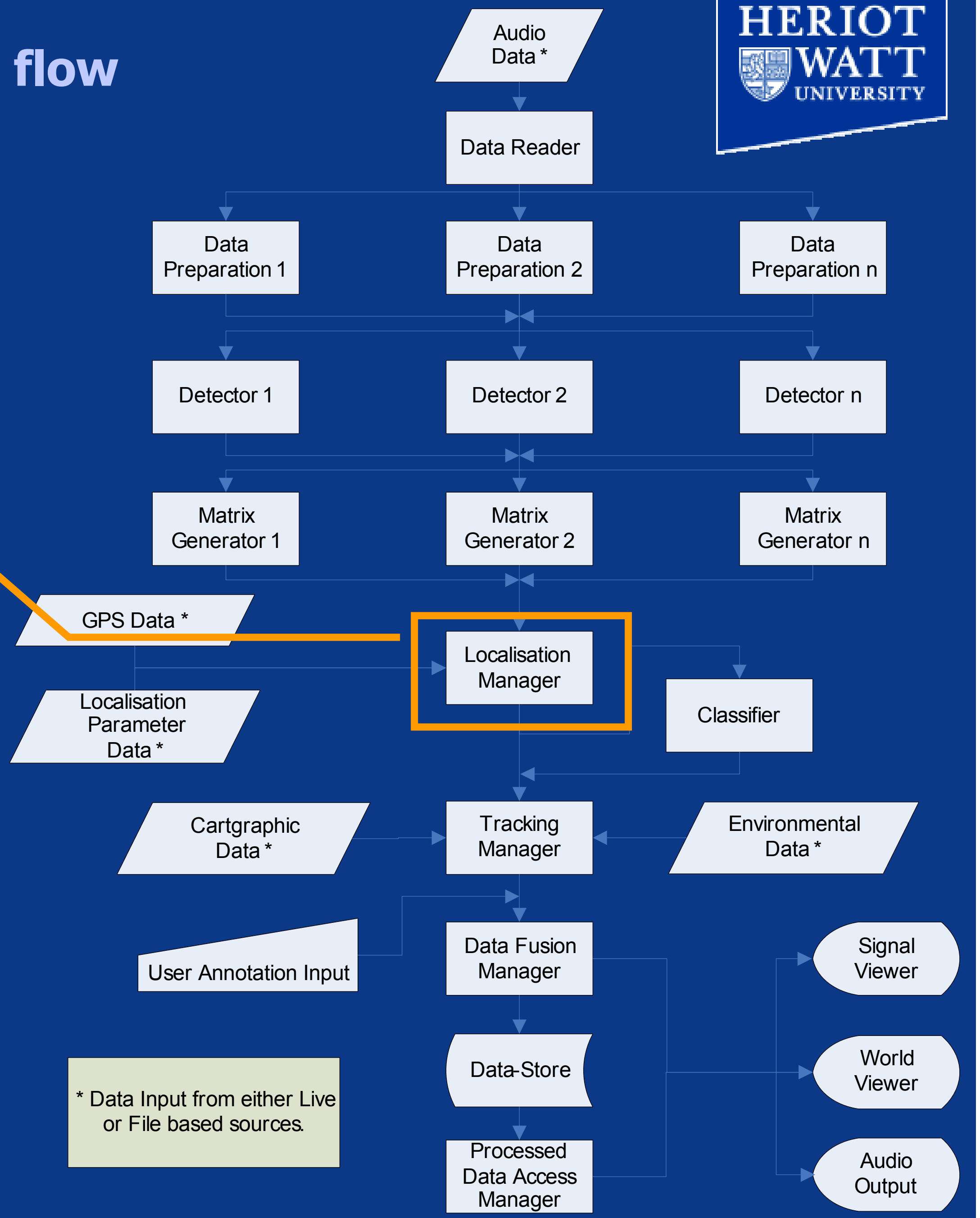
•uses TDOA matrices to place detection events in space

•draws upon:

GPS position

hydrophone array configuration

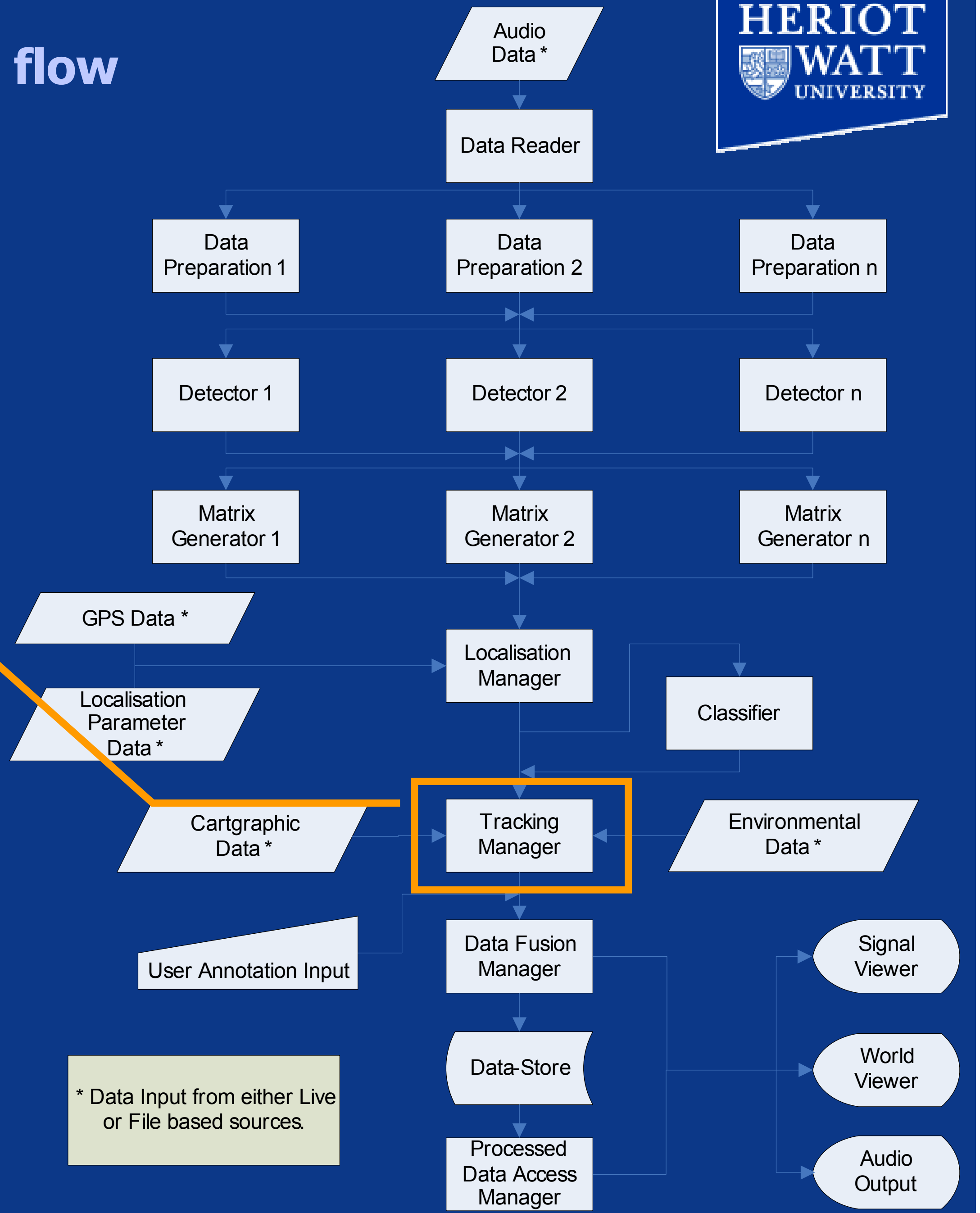
sound speed profiles



PAMGUARD data flow

Tracking object

- monitors detections, localisation classification information for evidence of individual animals



PAMGUARD data flow

Data Fusion Manager object

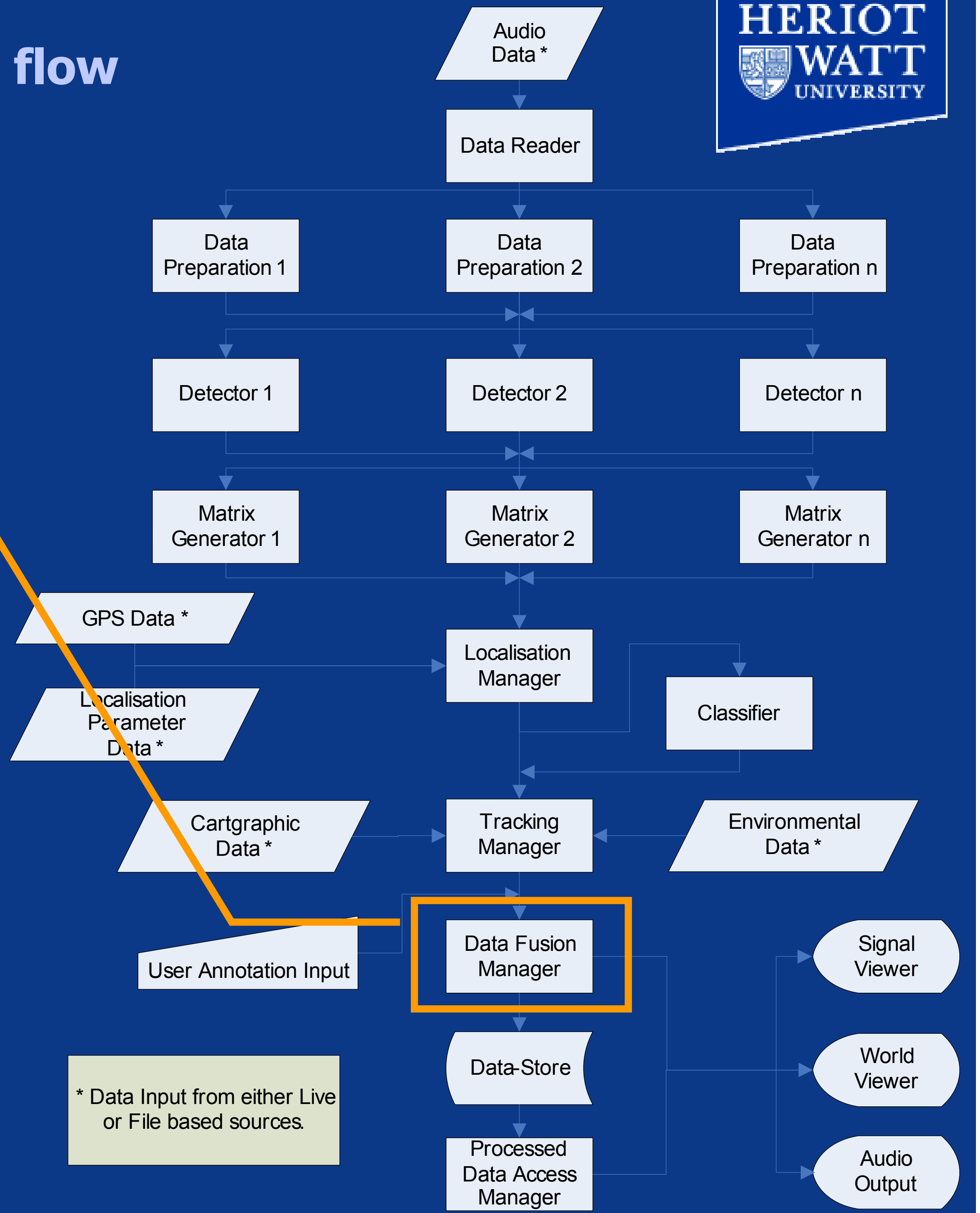
•collects event objects

•combines them with:

localisation information
user annotations
cartographic data
environmental conditions

•combined information is:

presented in GUI
stored in database



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How can you participate in the PAMGUARD venture?

If you wish to know more, please visit:

PAMGUARD web site: www.pamguard.org

SourceForge web site: https://sourceforge.net/projects/pamguard/

….and join us as a contributor to the PAMGUARD initiative.

First full prototype release due December 2005.

Demonstration system to be presented at 2nd International Workshop on Detection and Localisation of Marine Mammals using Passive Acoustics Monaco, 16-18 November 2005.

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