# Soliton Early Warning System for Offshore Applications

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# Introduction

Offshore exploration and development operations are impacted by ocean currents, waves and adverse weather.

Internal waves (solitons) pose a specific risk to rigs, vessels, ROV and subsea operations.

USD$ Millions rig repositioning costs

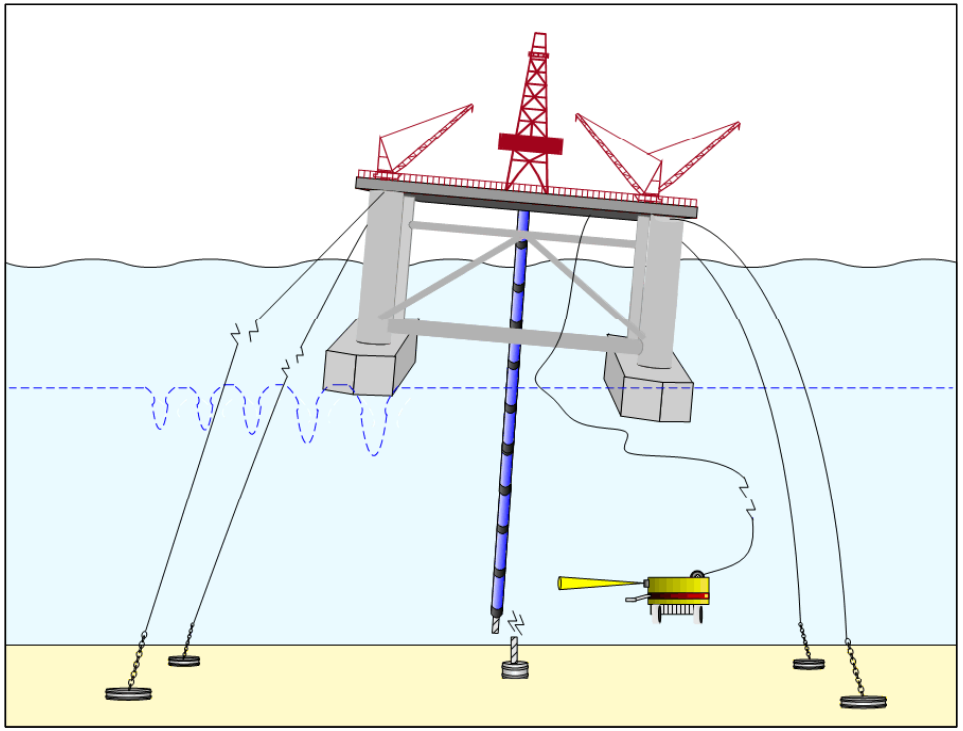
Broken drill strings

Supply vessels forced into rigs

Anchor chains parting

ROVs lost

Excessive rig listing



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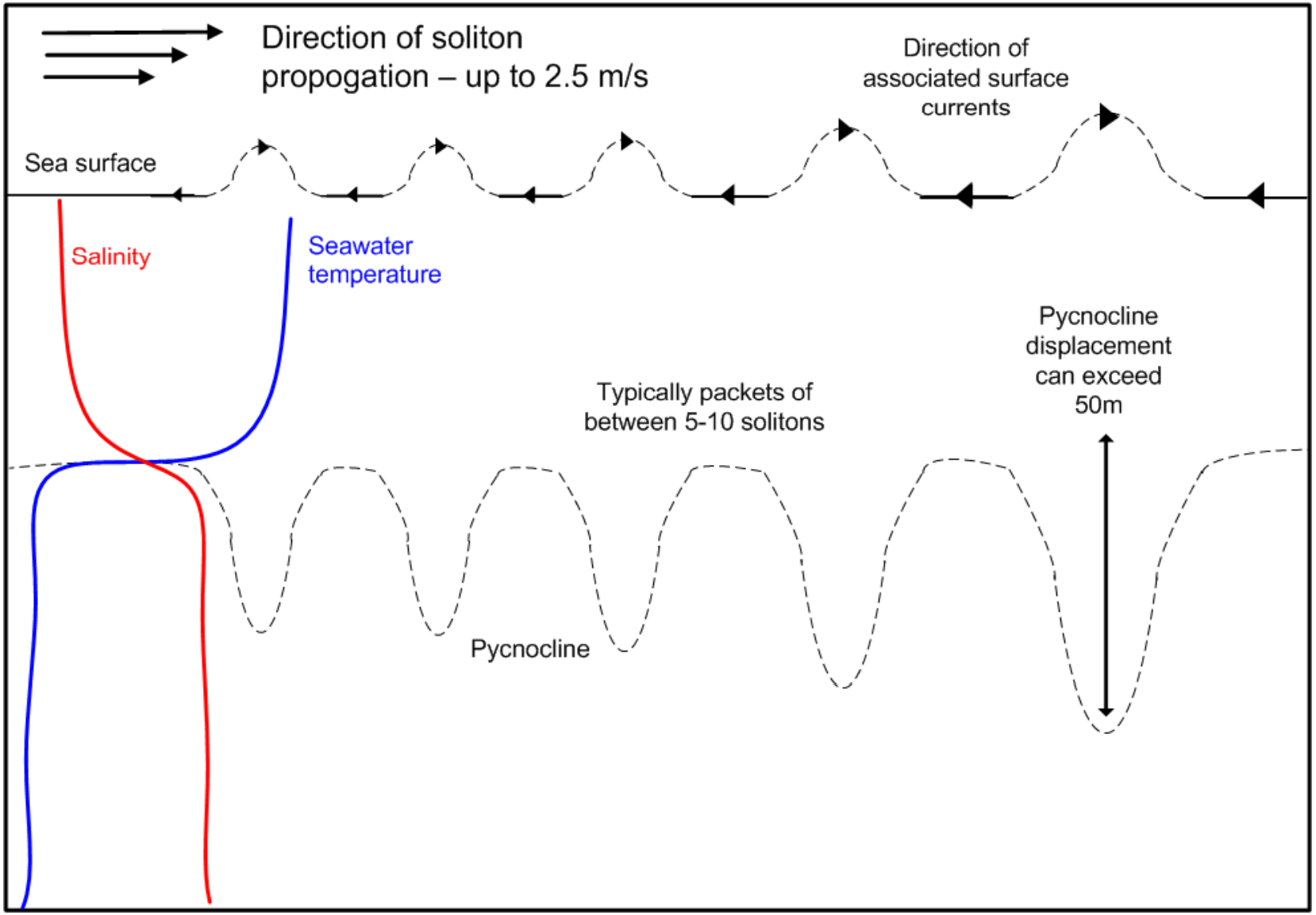
# Soliton Theory



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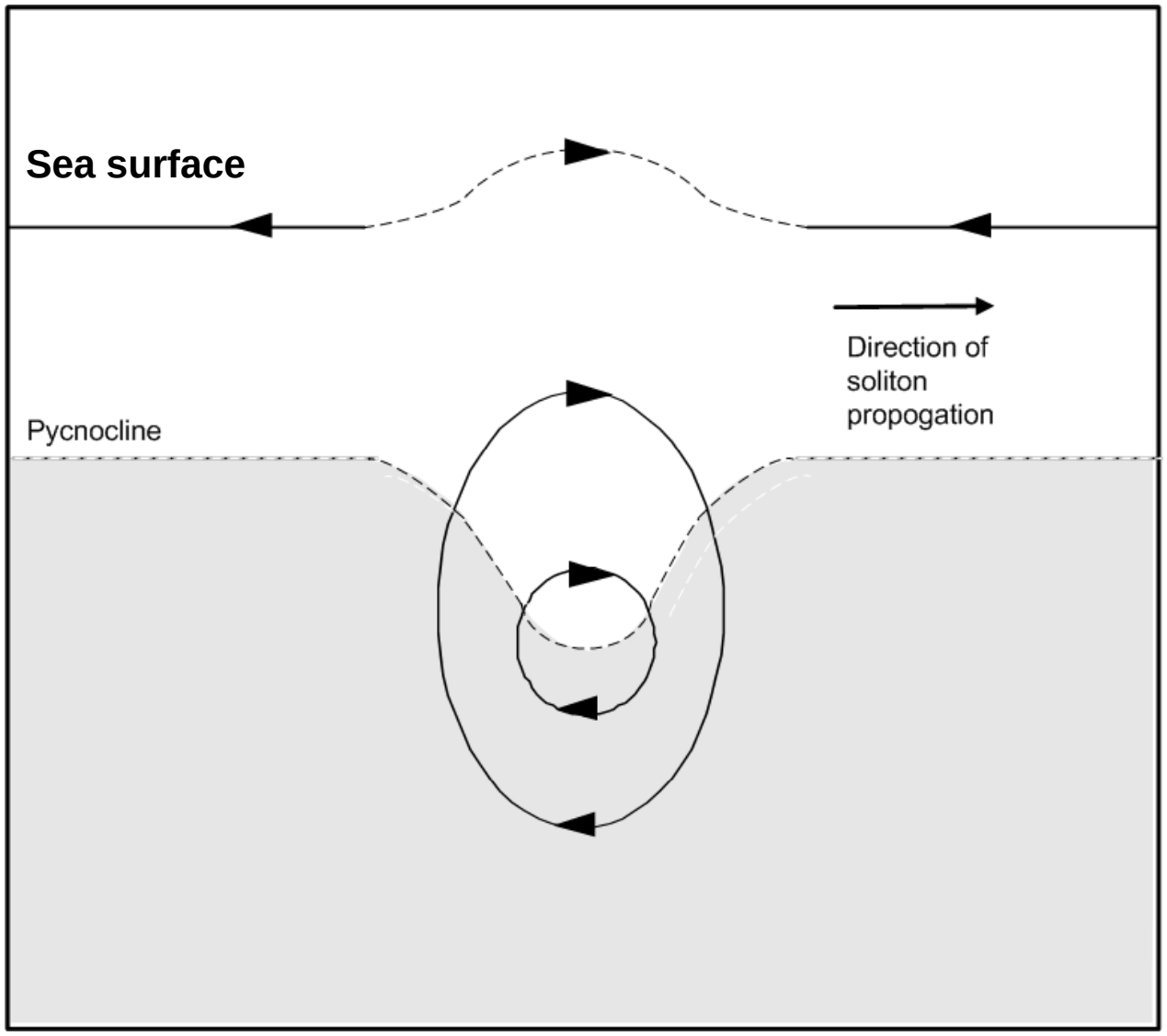

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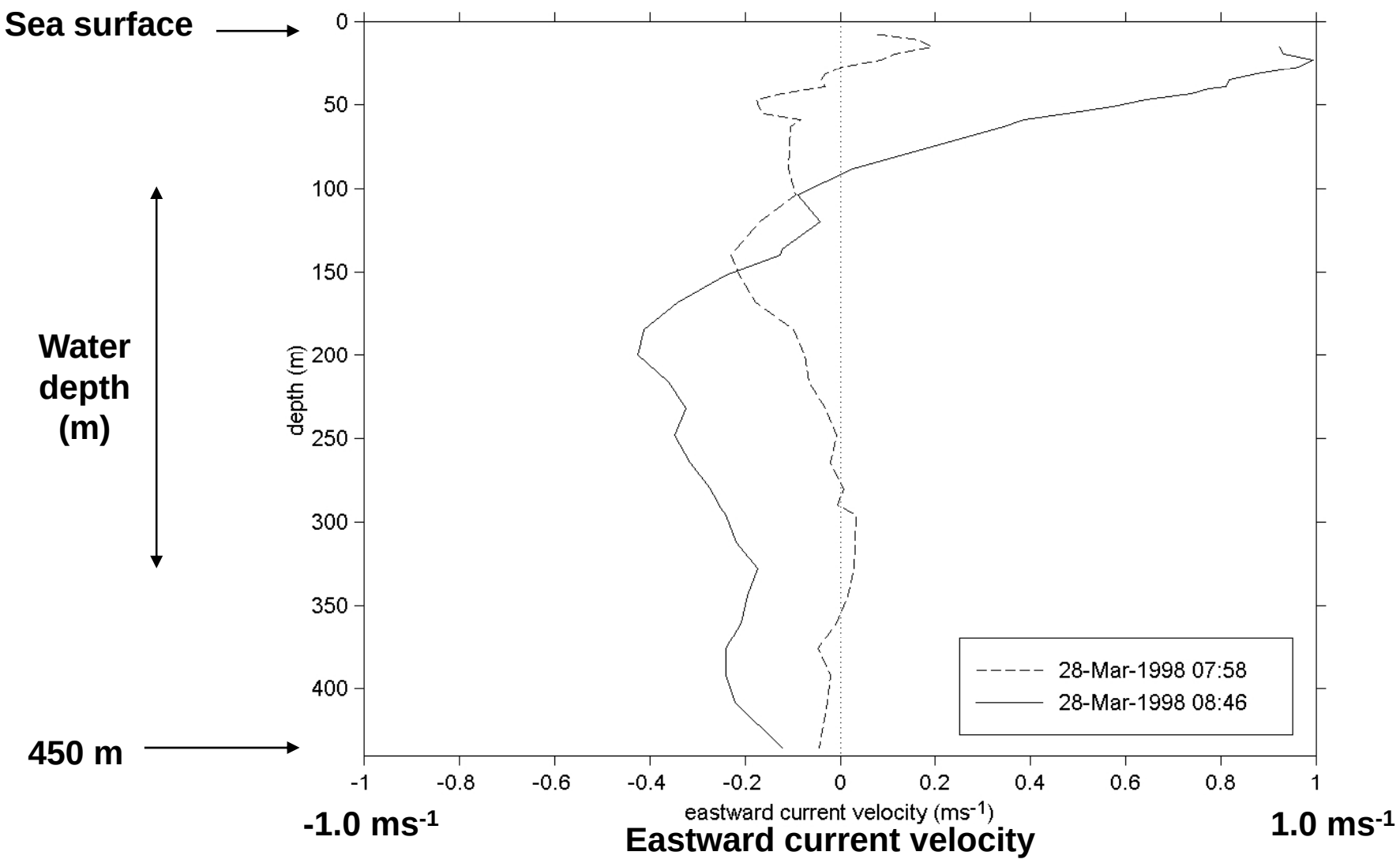

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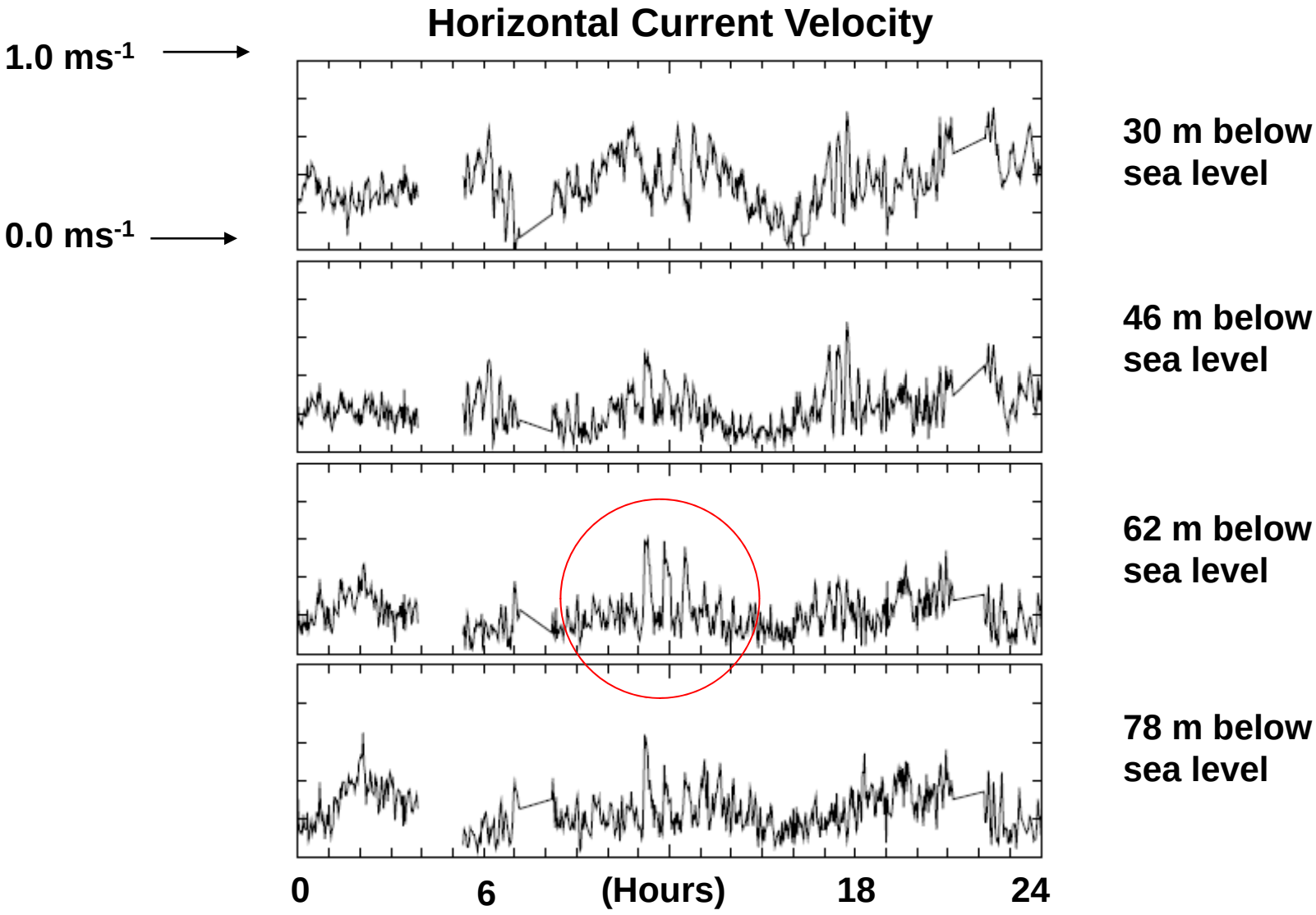

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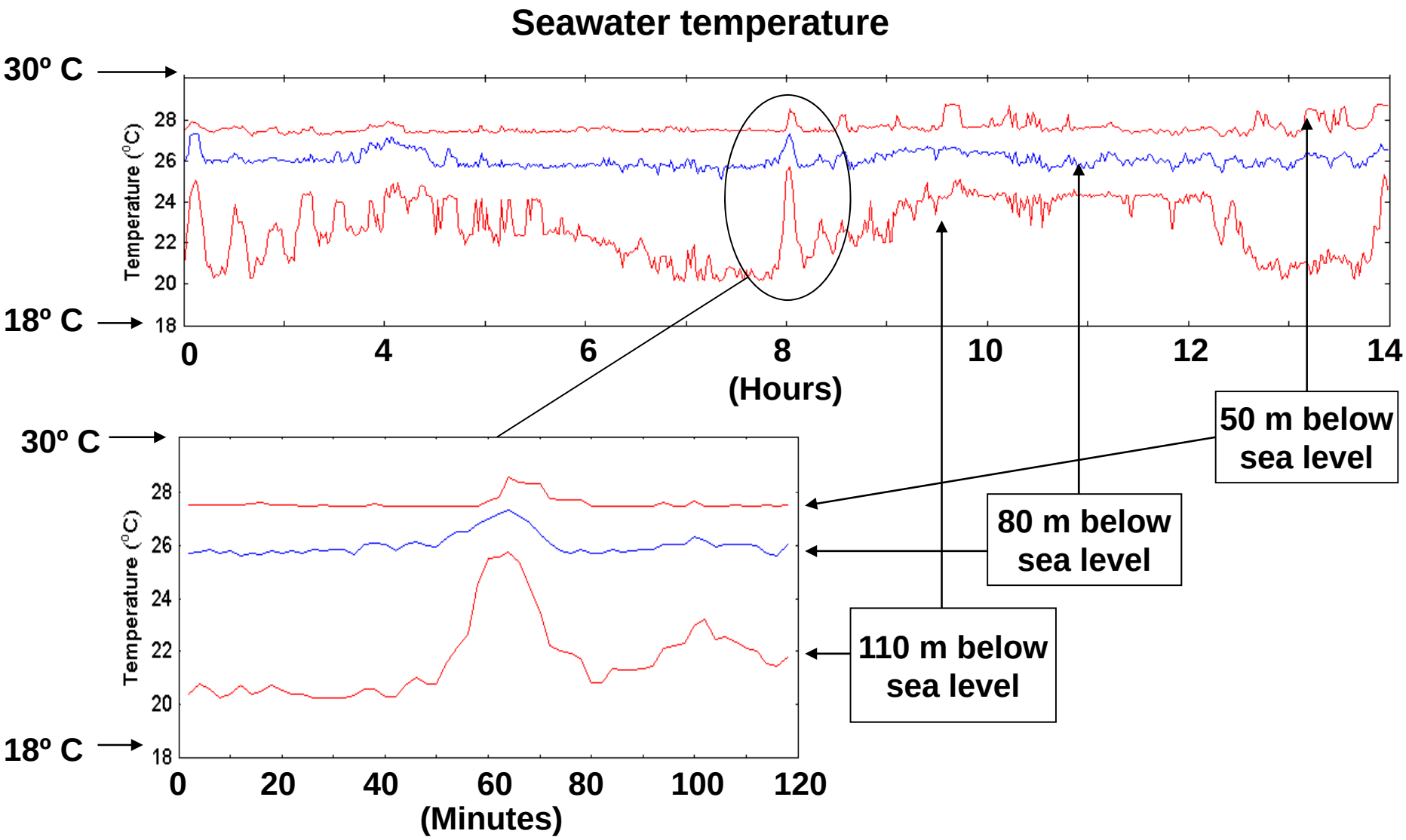

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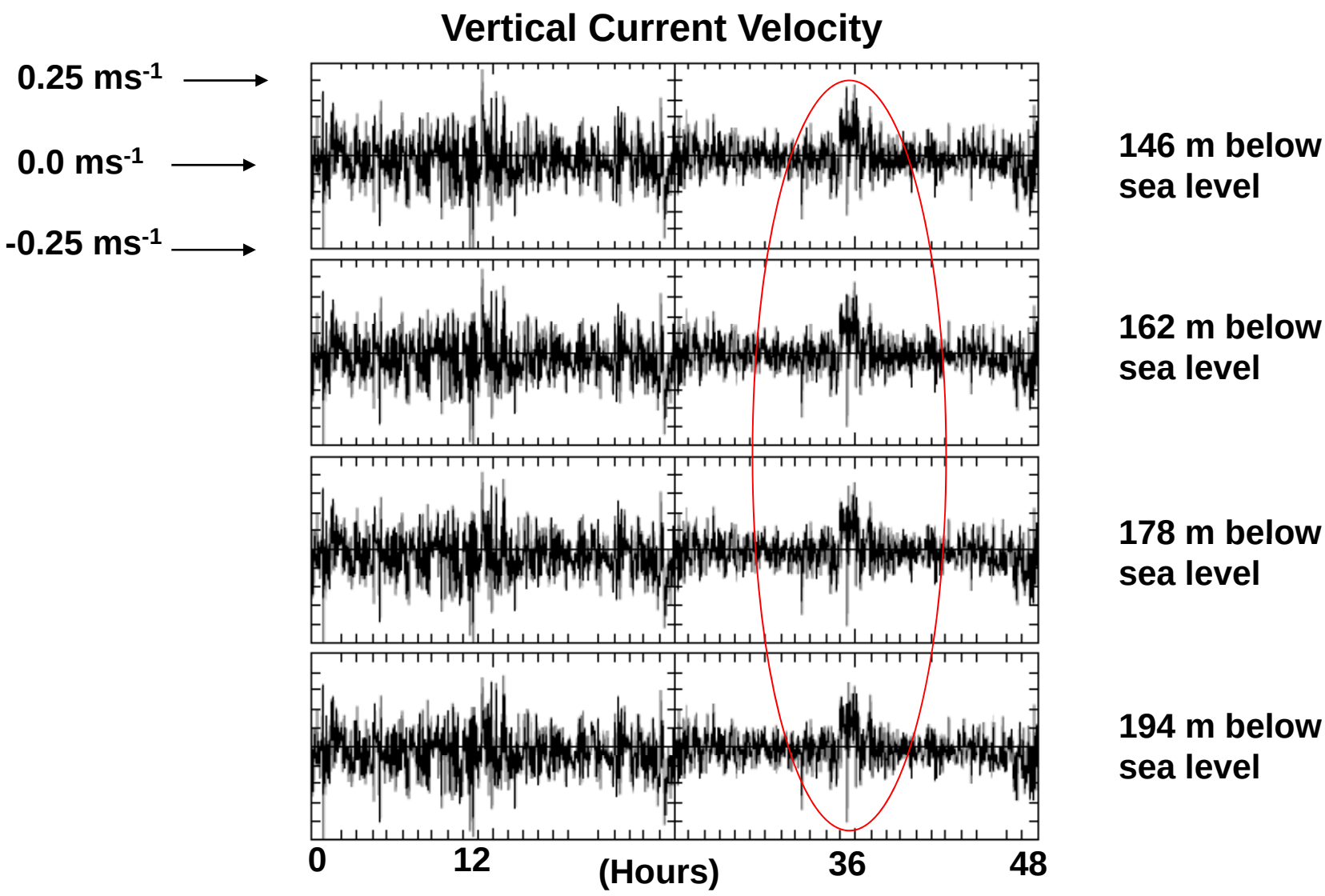

# Soliton Theory

**Solitons observed from an offshore platform – enhanced surface waves**

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# Soliton Early Warning System

ENI Krueng Mane Ltd (Indonesia) affected by solitons in a previous drilling campaign in the Andaman Sea.

Rig pushed off location 3 of 5 wells up to 189m

Drill pipe torn off at BOP

ENI required a Soliton Early Warning System (SEWS) for 2008/2009 drilling campaign in the Andaman Sea

Minimum of 10-hours warning period required

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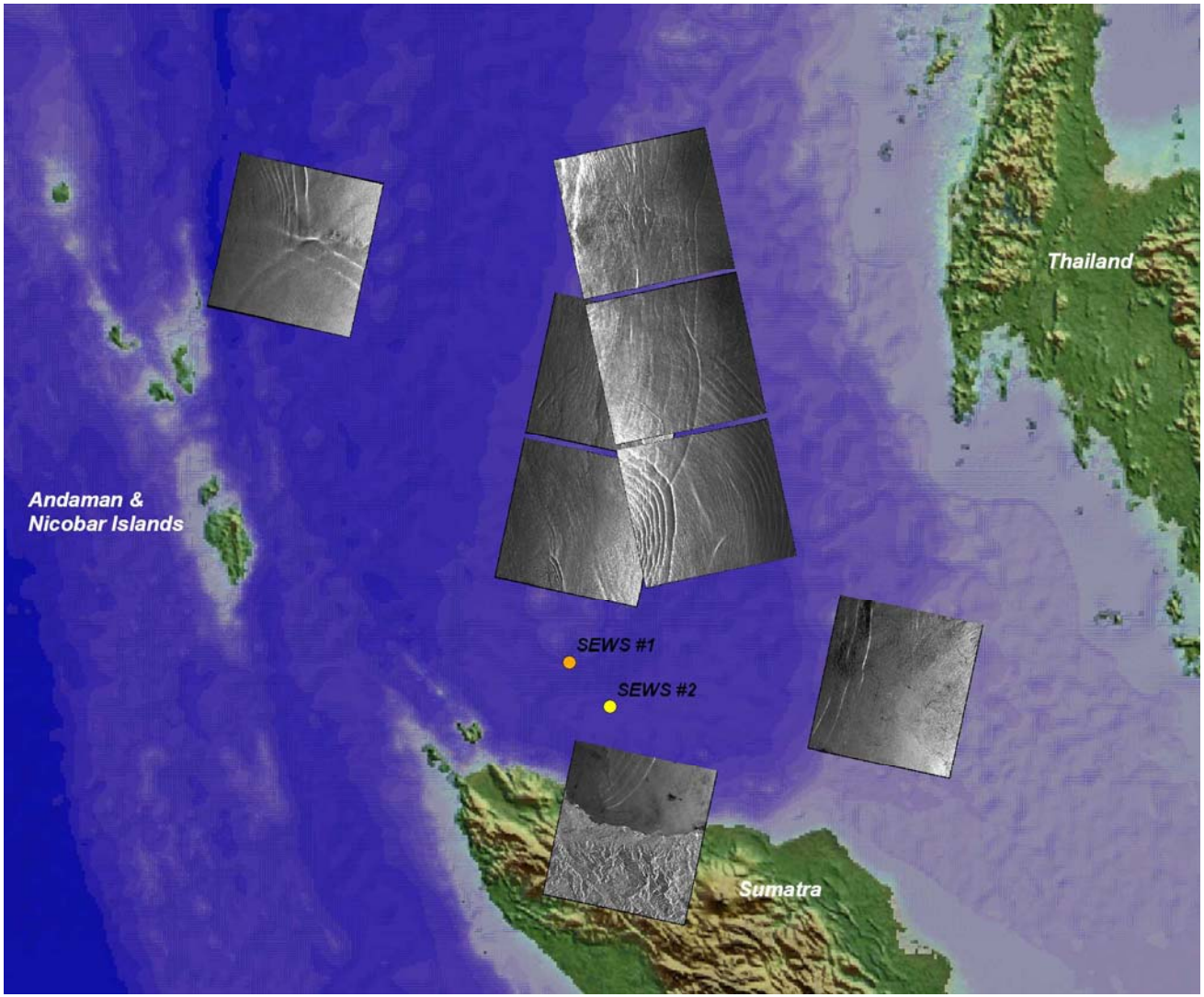
# Soliton Desk Study




218 satellite images with 77 images subjected to detailed analysis

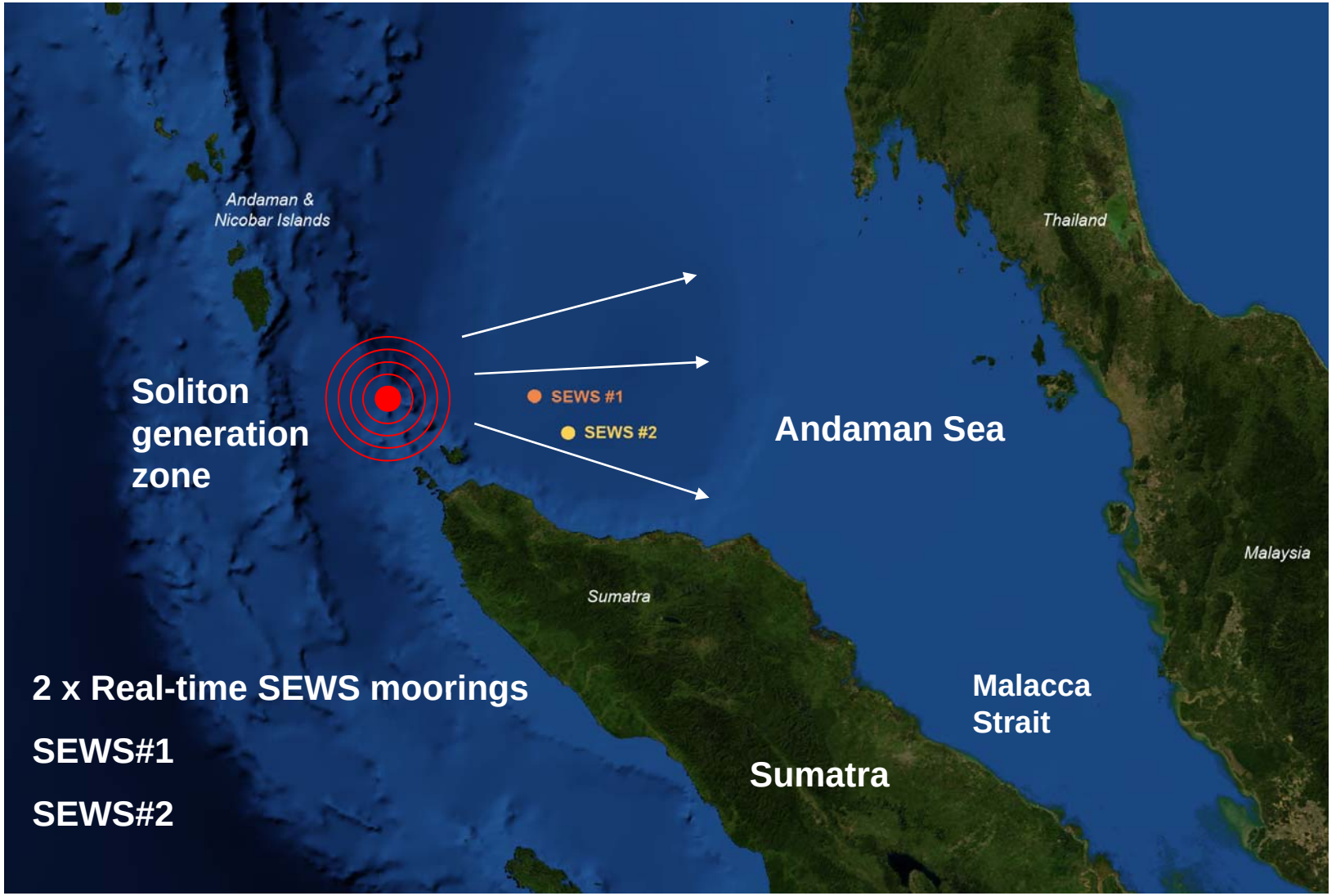
Propagation speed and direction calculated (1.7ms$^{-1}$)

Generation zone identified

Confirmed need for a SEWS

Identified best locations for SEWS moorings

# Real-time Warning System - Mooring Locations



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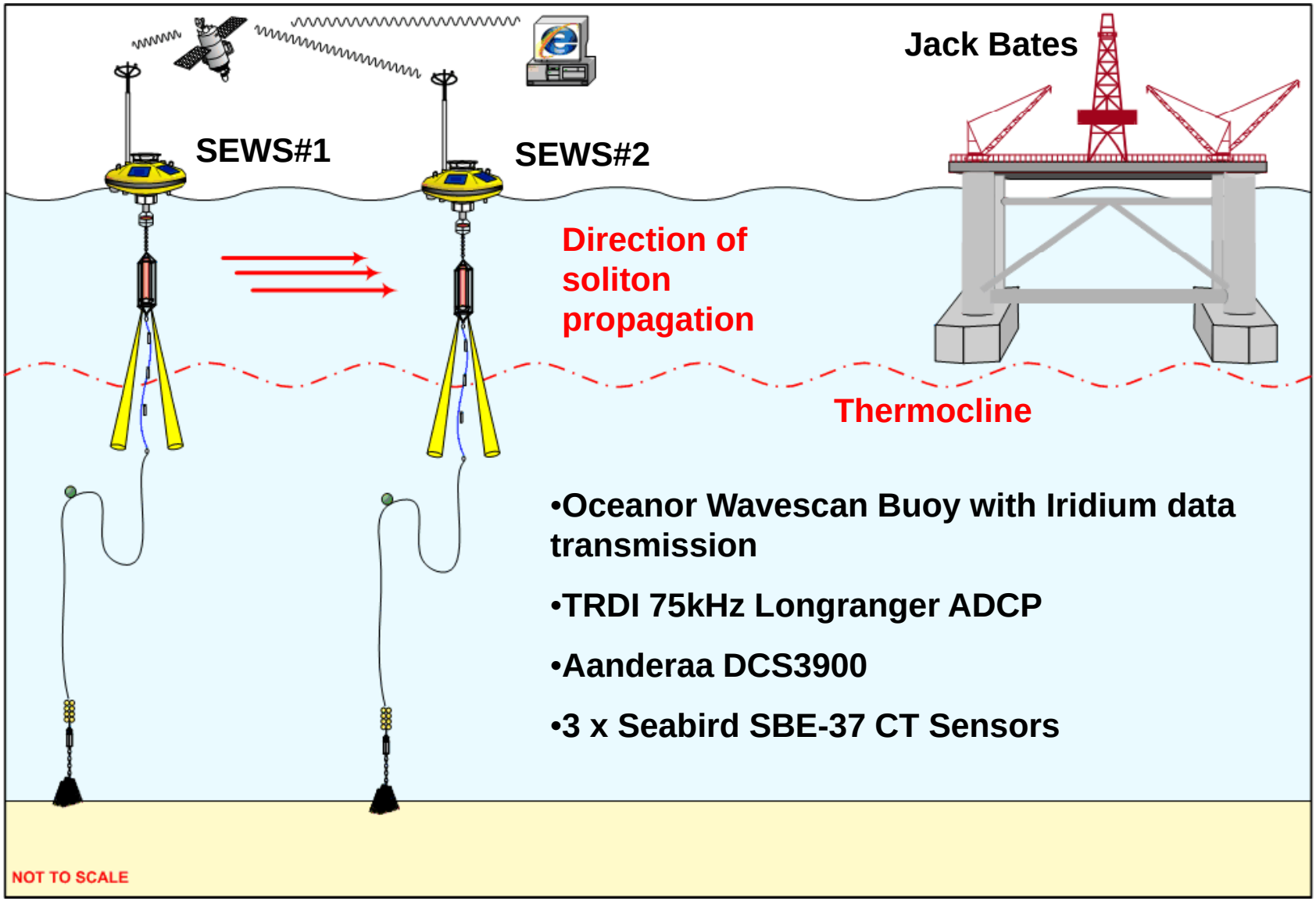
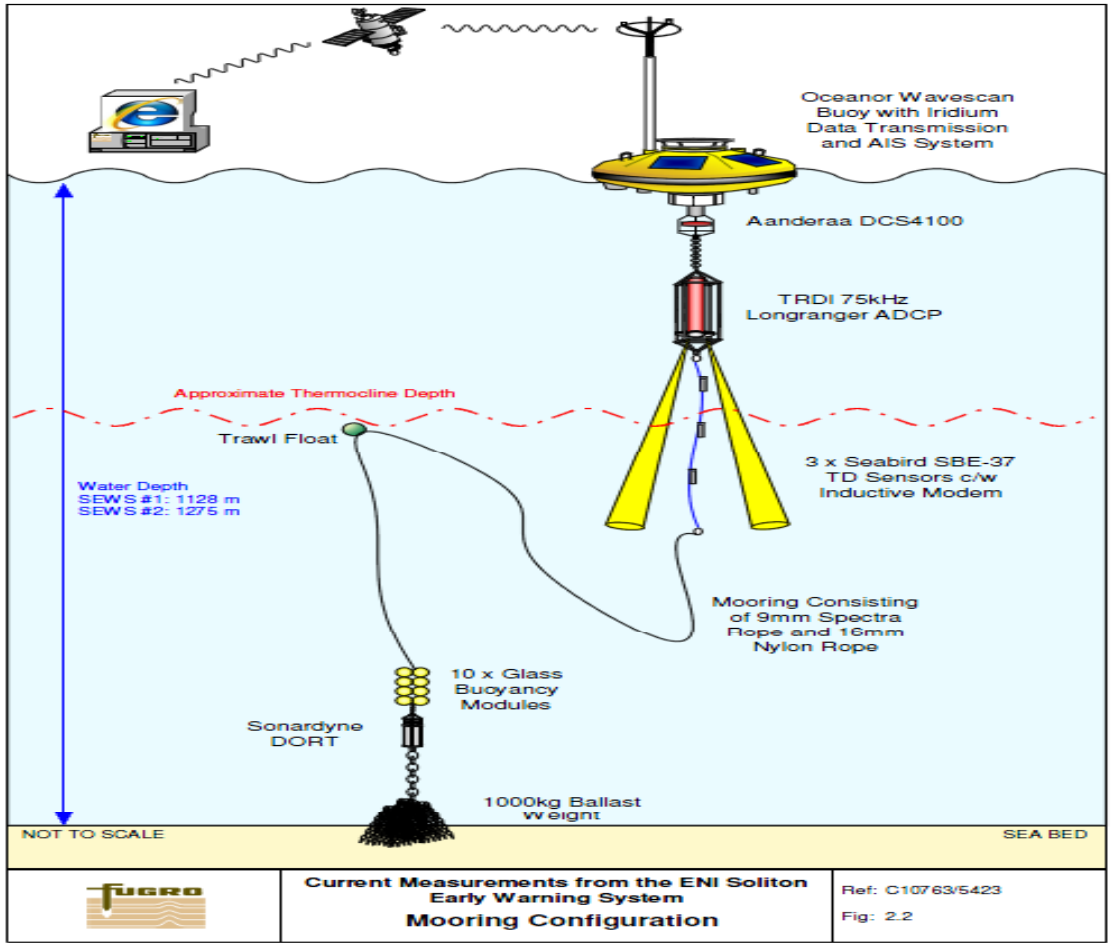
# Real-time Warning System - SEWS Moorings



# Real-time Warning System - SEWS Moorings

| | Proposed Mooring - 1350m Water Depth | | | | |
|---|---|---|---|---|---|
| | | | | | Updated 25-Sep-08 |
| | Mooring Component | LENGTH | HAB (METRES) | DEPTH | |
| 20m x 22mm Rope with Spliced Eyes Connected to LR Frame and Up to Wavescan Buoy | **Wavescan Buoy with DCS4100** | 1.70 | 1350.00 | 0 | |
| | 3.25T 4-Piece Crosby Bow shackle | 0.05 | 1348.25 | 1.75 | **Note: Shackle pins to be replaced** |
| | 5/8" chain | 8.00 | 1341.95 | 8.05 | |
| | 3.25T 4-Piece Crosby Bow shackle | 0.05 | | 8.10 | |
| | Master link | 0.10 | | 8.20 | |
| | 3.25T 4-Piece Crosby Bow shackle | 0.05 | | 8.25 | |
| | 5/8" chain | 1.00 | | 9.25 | |
| | 3.25T 4-Piece Crosby Bow shackle | 0.05 | | 9.30 | |
| | **LongRanger ADCP in frame** | 2.00 | | 11.30 | **Inductive Modem/Receiver** |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | | 11.35 | |
| | **Load Bearing Inductive Cable** | 100.00 | | 111.35 | **With Seabird SBE-37 IM CTs at** |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | | 111.40 | **Depths will be reconfirmed by on-** |
| | 3-Links HLZ-9 Chain | 0.15 | | 111.55 | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | | 111.60 | |
| | **14mm Wire Rope** | 160.00 | | 271.60 | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 1712.24 | 271.65 | |
| | 3-Links HLZ-9 Chain | 0.15 | 1712.19 | 271.80 | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 1712.04 | 271.85 | |
| | **16mm Nylon Rope** | 200.00 | 1711.99 | 471.85 | |
| | 3.25T 4-Piece Crosby Bow shackle | 0.05 | 1511.99 | 471.90 | |
| | **16mm Nylon Rope** | 200.00 | 1511.94 | 671.90 | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 1311.94 | 671.95 | |
| | 3-Links HLZ-9 Chain | 0.15 | 1311.89 | 672.10 | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 1311.74 | 672.15 | |
| | **9mm Spectra Rope** | 600.00 | 1311.69 | 1272.15 | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 711.69 | 1272.20 | |
| | **10 x 4kg Trawl Floats (Net Buoyancy of 40kg Required)** | | 711.64 | 1272.20 | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 711.64 | 1272.25 | |
| | **9mm Spectra Rope** | 600.00 | 711.59 | | |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 111.59 | | |
| | **9mm Spectra Rope** | 100.00 | 111.54 | | **Can be removed if water depth** |
| | 2T 4-Piece Crosby Bow shackle | 0.05 | 11.54 | | |
| | **5 Glass on HLZ-9 chain (In-line)** | 6.00 | 11.49 | | **Scope for adding more Spectra if** |
| | 1.5T Crosby Bow Shackle | 0.05 | 5.49 | | |
| Short Link Chain from Sonardyne Shackle Back up to 2T Shackle above DORT | 2T Crosby Bow Shackle | 0.05 | 5.44 | | |
| | **DORT** | 0.60 | 5.39 | | |
| | s/s Sonardyne shackle | 0.05 | 4.79 | | |
| | Short Link Chain Back up to 2T 4-Piece Crosby Bow Shackle | 0.05 | 4.74 | | |
| | Master link | 0.10 | 4.69 | | |
| | 2T Crosby Bow Shackle | 0.05 | 4.59 | | |
| | 1/2" Chain | 2.00 | 4.54 | | |
| | 2T Crosby Bow Shackle | 0.05 | 2.54 | | |
| | Master link | 0.10 | 2.49 | | |
| | 3 x 2TCrosby Bow Shackle | 0.05 | 2.39 | | |
| | loop of 1/2" SL chain | 0.50 | 2.34 | | |
| | **1500kg Ballast Chain** | 1.84 | 1.84 | | |
| | | | | | |
| | **Water Depth** | **1350.00** | | | |

# Real-time Warning System - SEWS Moorings



# Real-time Warning System - SEWS Moorings



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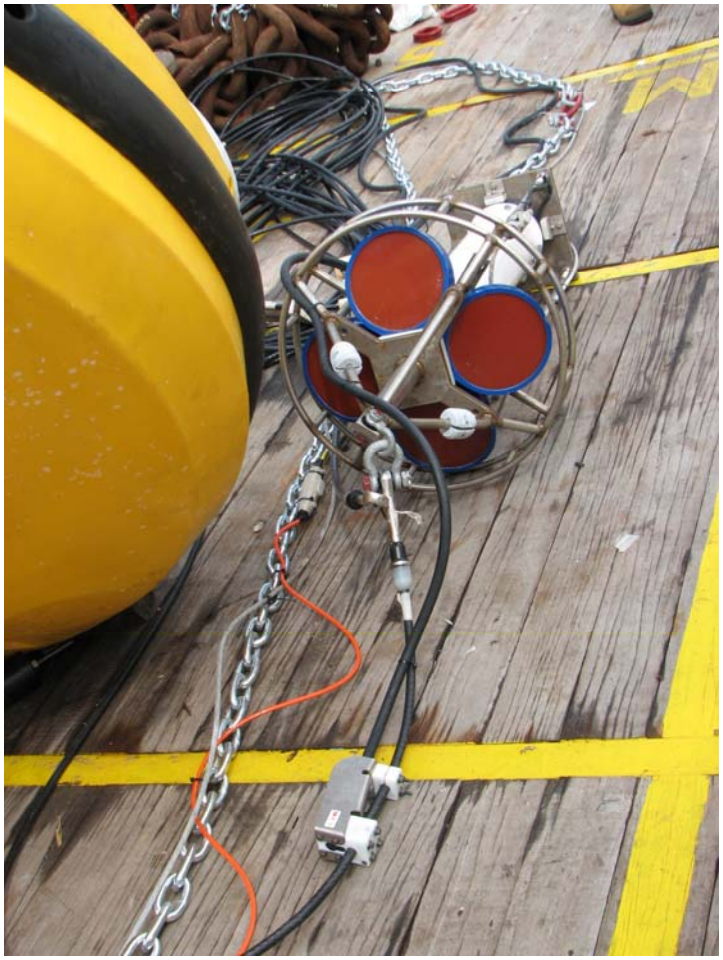
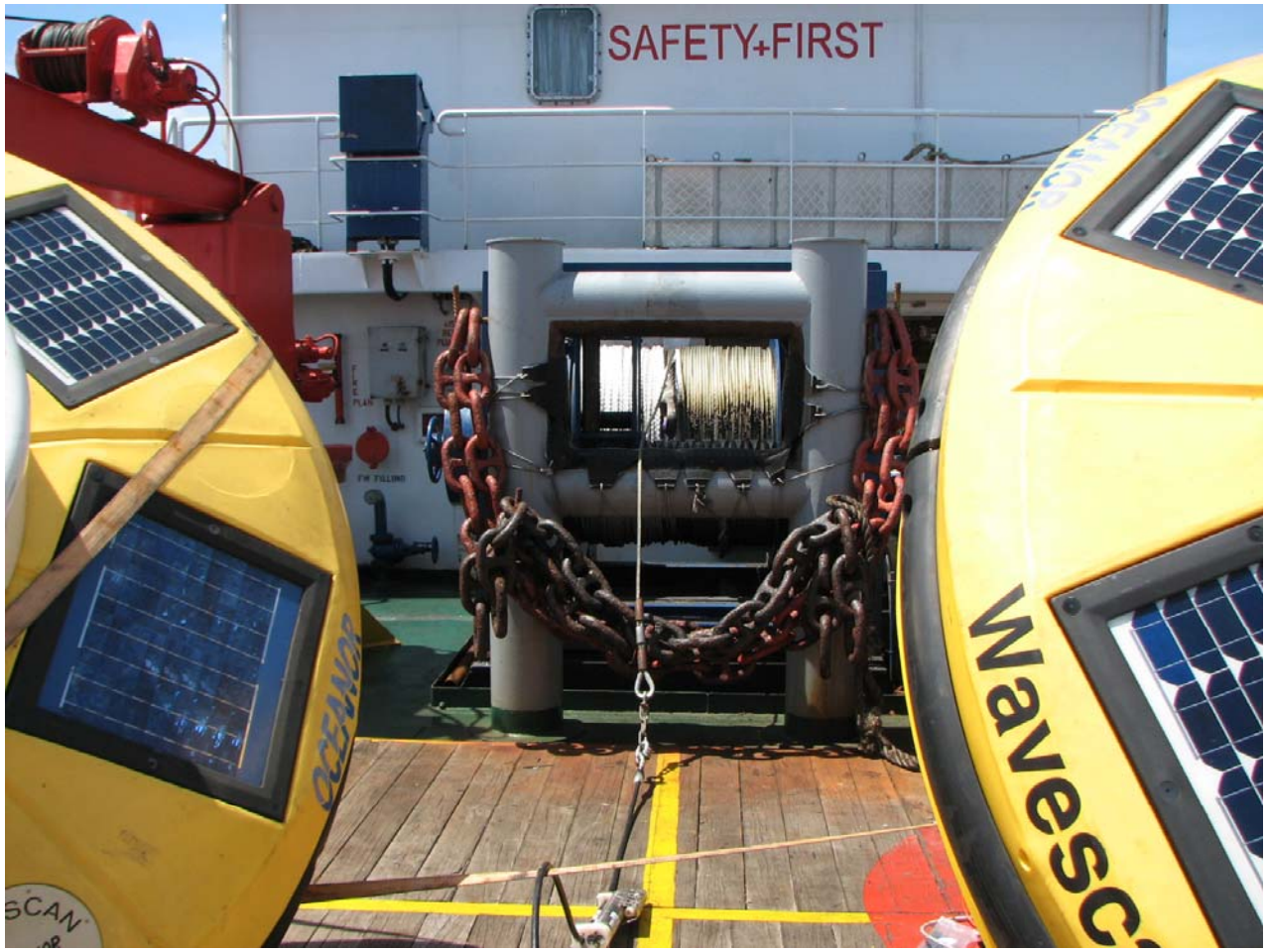


# Real-time Warning System - SEWS Moorings


Both SEWS buoys deployed 2-weeks prior to the Jack Bates' arrival on well location.

Soliton and current warnings required during the soliton sensitive rig tow and anchoring operations.

# Real Time Warning System



# Real-time Warning System

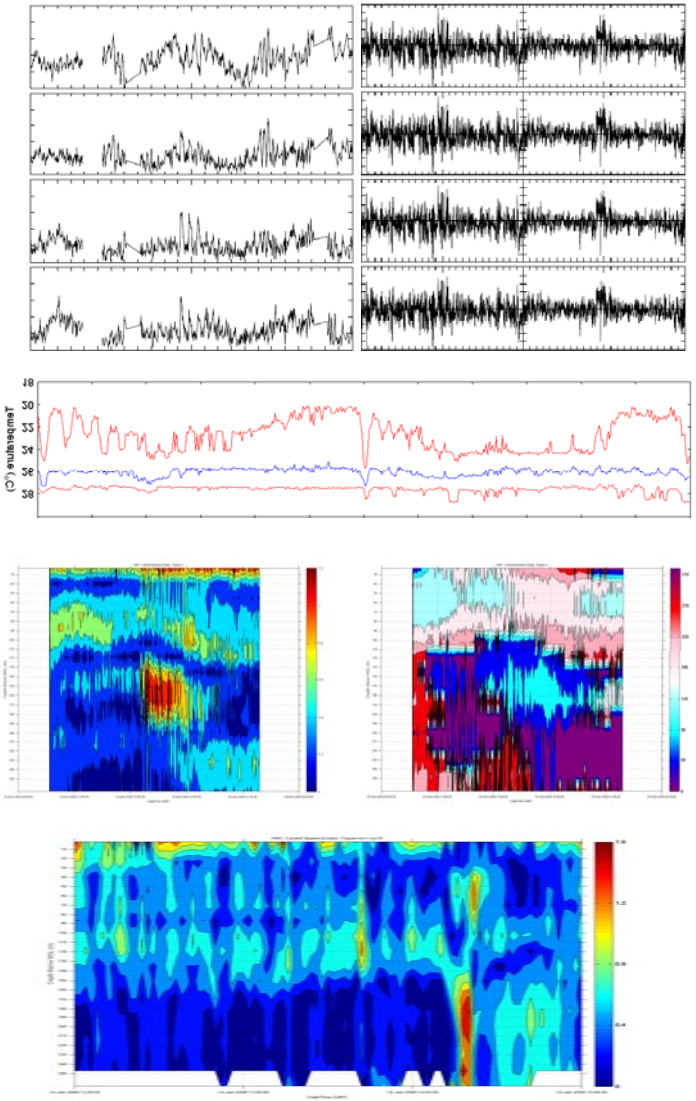
All sensors set to 2-minute sampling intervals.

Data transmitted to a web server hosted by Fugro Oceanor every 10-minutes.

Data displayed on a dedicated, password protected web display as time series plots and data tables.

Real-time data used to identify solitons:

- Pulses of increased horizontal and vertical current speed
- Immediate reversal in current direction
- Current shear
- High frequency oscillations in the thermocline



# Real-time Warning System - Soliton Monitoring

| Warning Level | Current Speed (knots) | Actions |
|---|---|---|
| LOW | < 1.5 | Record the solitons in daily 24-hour summary, but no warning required or action to be taken by the rig |
| MEDIUM | 1.5 to 2.0 | Issue soliton warning by email, but the rig will probably not take action |
| HIGH | 2.0 to 3.0 | Issue soliton warning by email and follow up by calling OIM. The rig will tighten anchor wires and standby |
| VERY HIGH | > 3.0 | Issue soliton warning by email and follow by calling OIM. Rig will prepare for possible disconnect |

# SOLITON WARNING LEVEL HIGH

Many solitons observed over the 3-month SEWS deployment, particularly during spring tides.

Most below the warning threshold, or later downgraded at SEWS#2

A packet of 5 solitons were observed at HIGH LEVEL warning threshold (2.0 to 3.0 knots). Soliton warning email issued, followed by a phone call to the OIM.

Approximately 12-hours later on the next tide, another packet of solitons were observed with similar current speeds.

The rig tightened the anchor wires facing into the solitons and loosened the anchor wires at the rear to avoid additional rig movement.

# Real-time Warning System - Soliton Monitoring

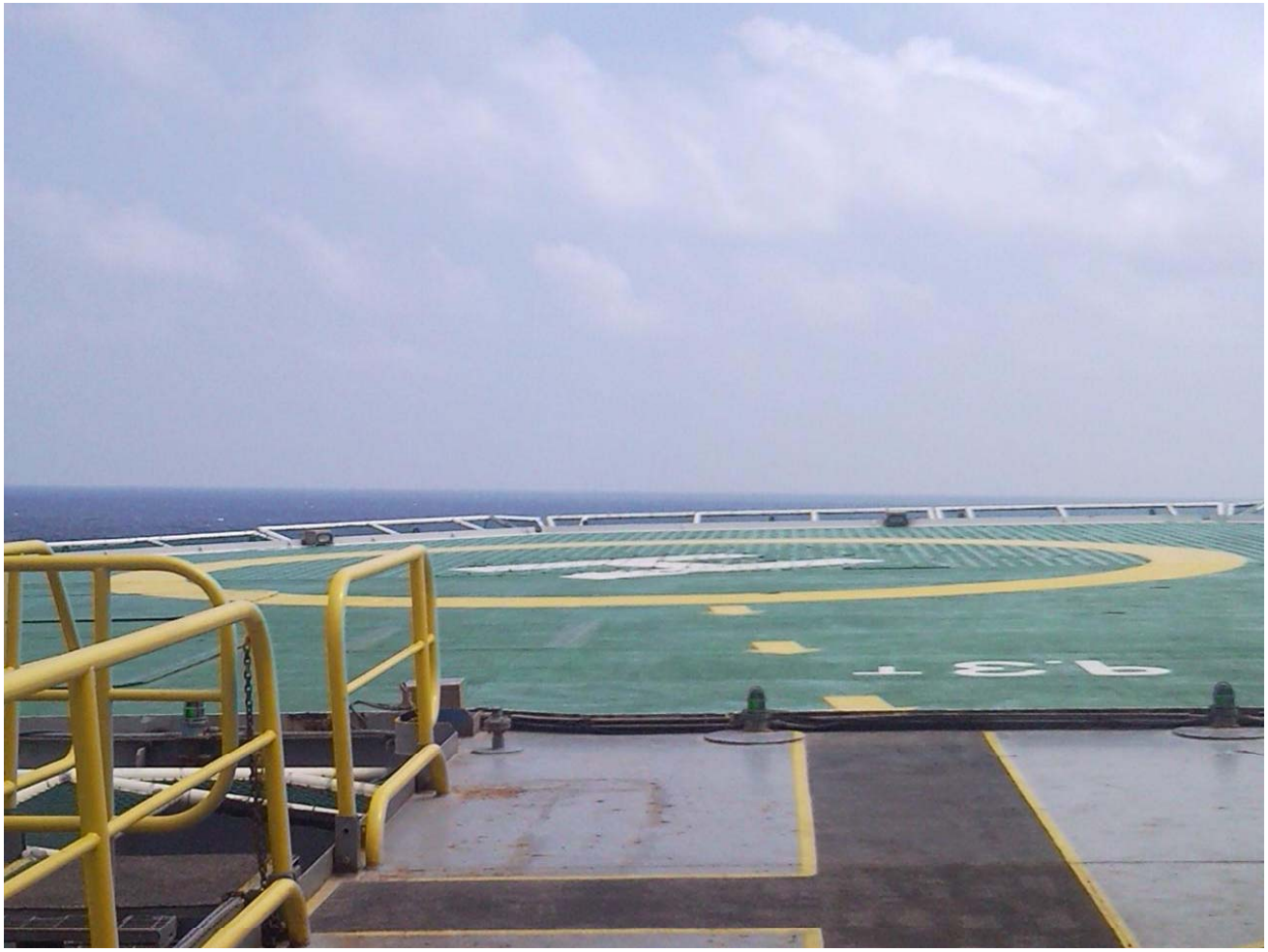
Jack Bates Radar – solitons approaching from northwest

Solitons observed approaching from the Jack Bates Helideck

# Real-time Warning System - Soliton Monitoring

Solitons approaching and passing the Jack Bates – seen as enhanced surface waves

# Real-time Warning System - Soliton Monitoring



Rig tilt observed from Helideck as solitons passed through

NOTE: this was AFTER appropriate action taken

Did the SEWS avoid the previous fate - pushed off location up to 189m and a broken drill string?

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# Soliton Analysis

All current profile and seawater temperature and salinity data downloaded for further data processing and analysis.

3-hour running means subtracted from 2-minute horizontal velocity data to identify short duration horizontal currents associated with solitons.

**327** individual soliton events were identified at SEWS#1

**207** at SEWS#2.

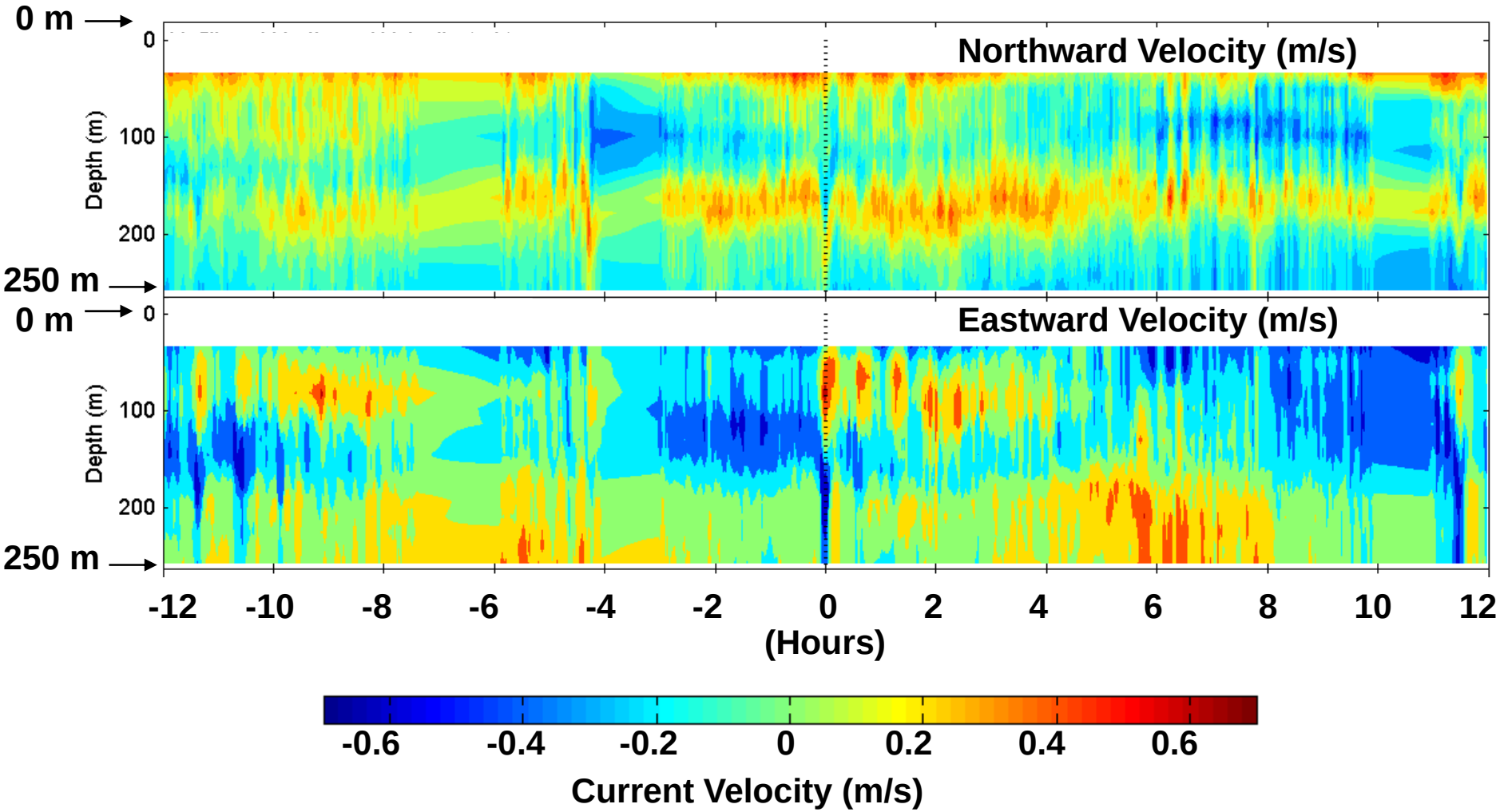
Soliton propagation speed calculated at **1.70ms$^{-1}$**, consistent with SAR desk study results and observations and forecasts during soliton monitoring.

Data available for future field development

More accurate predictions provided on when solitons were most likely to occur.

# Soliton Analysis

‘Classic’ soliton packet observed at SEWS#1



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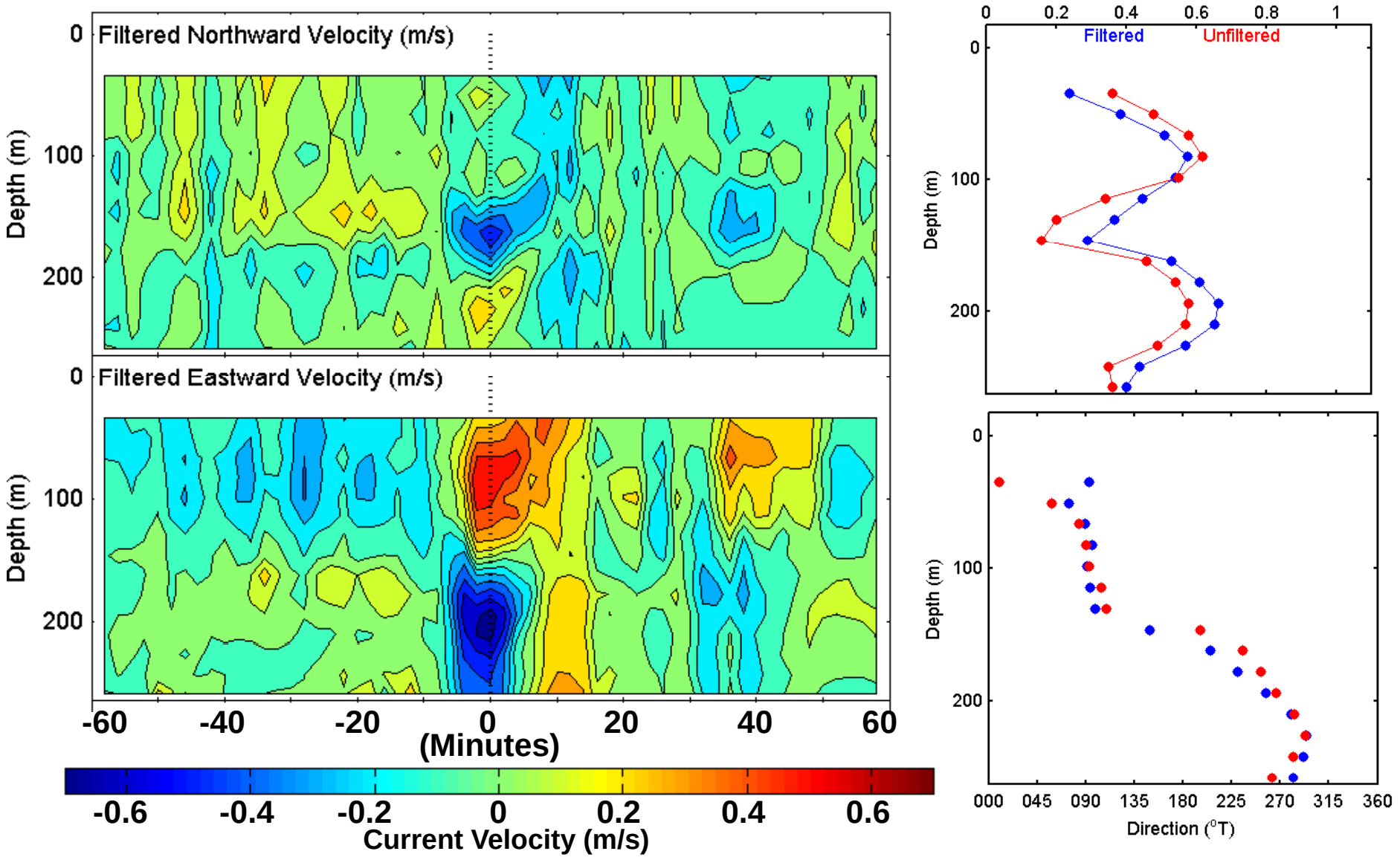

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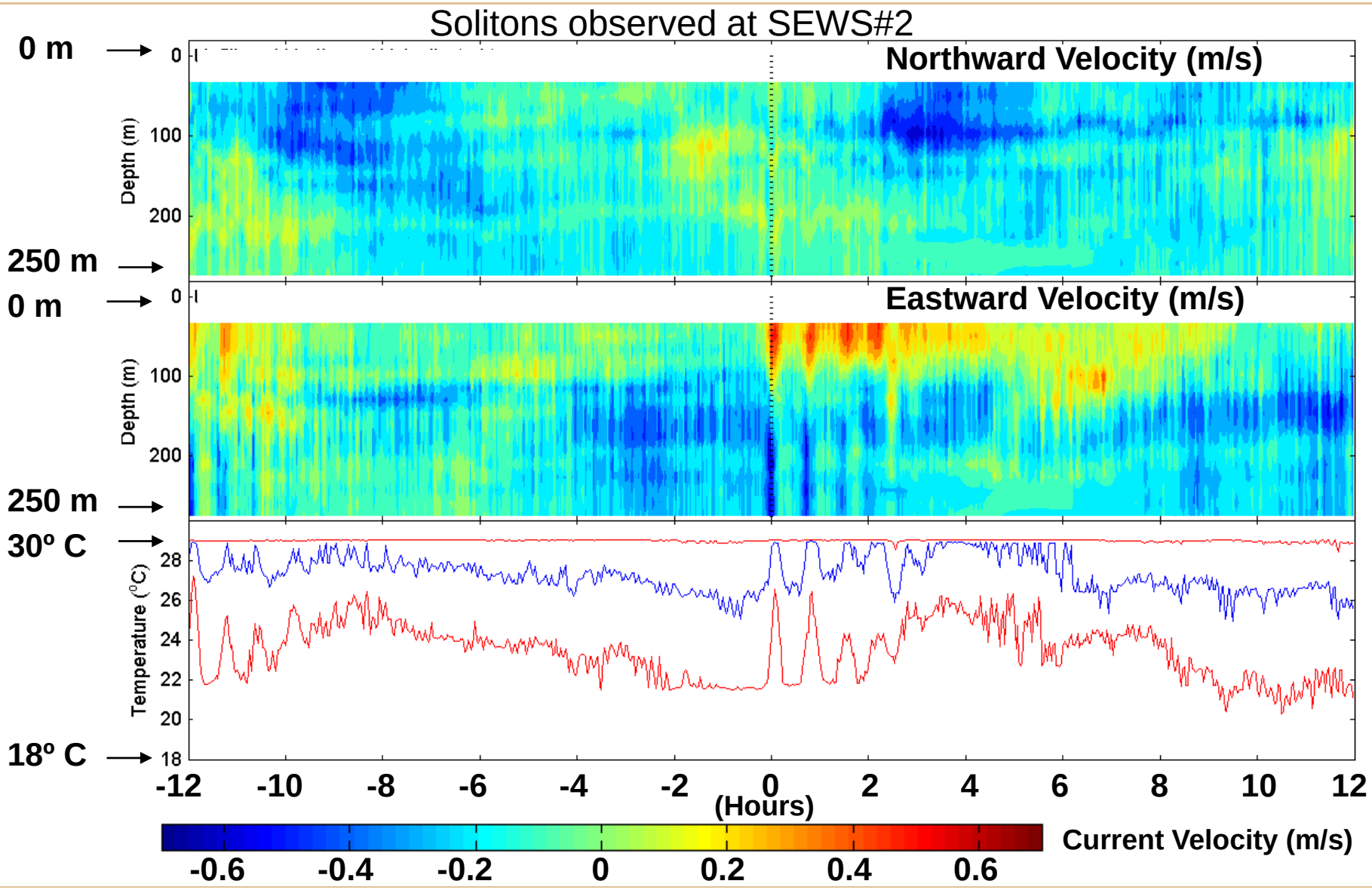

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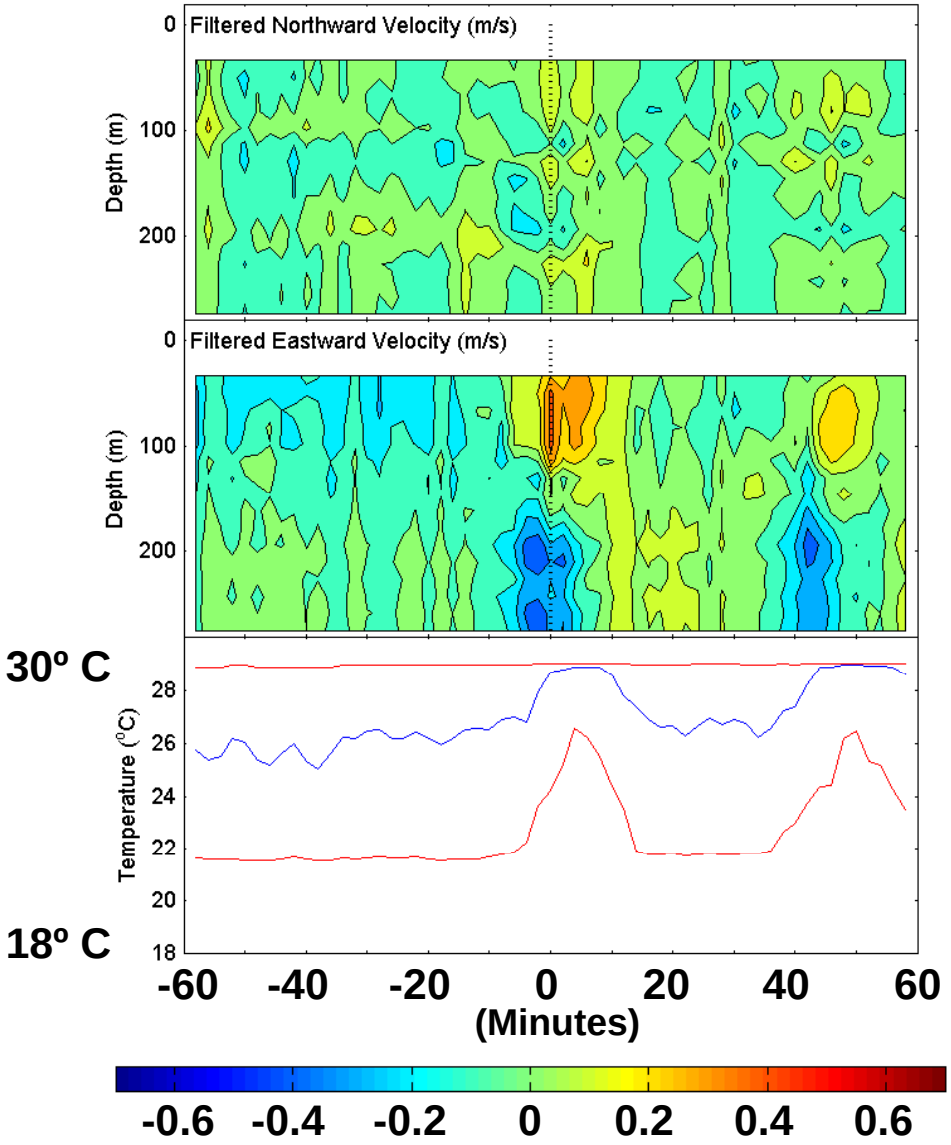


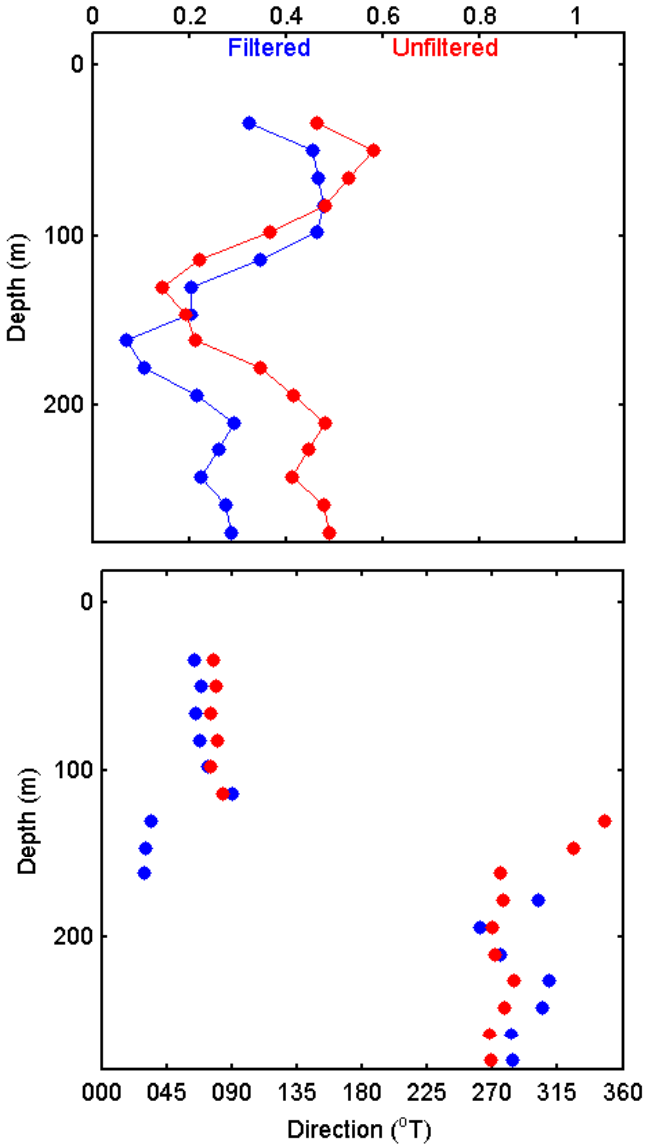

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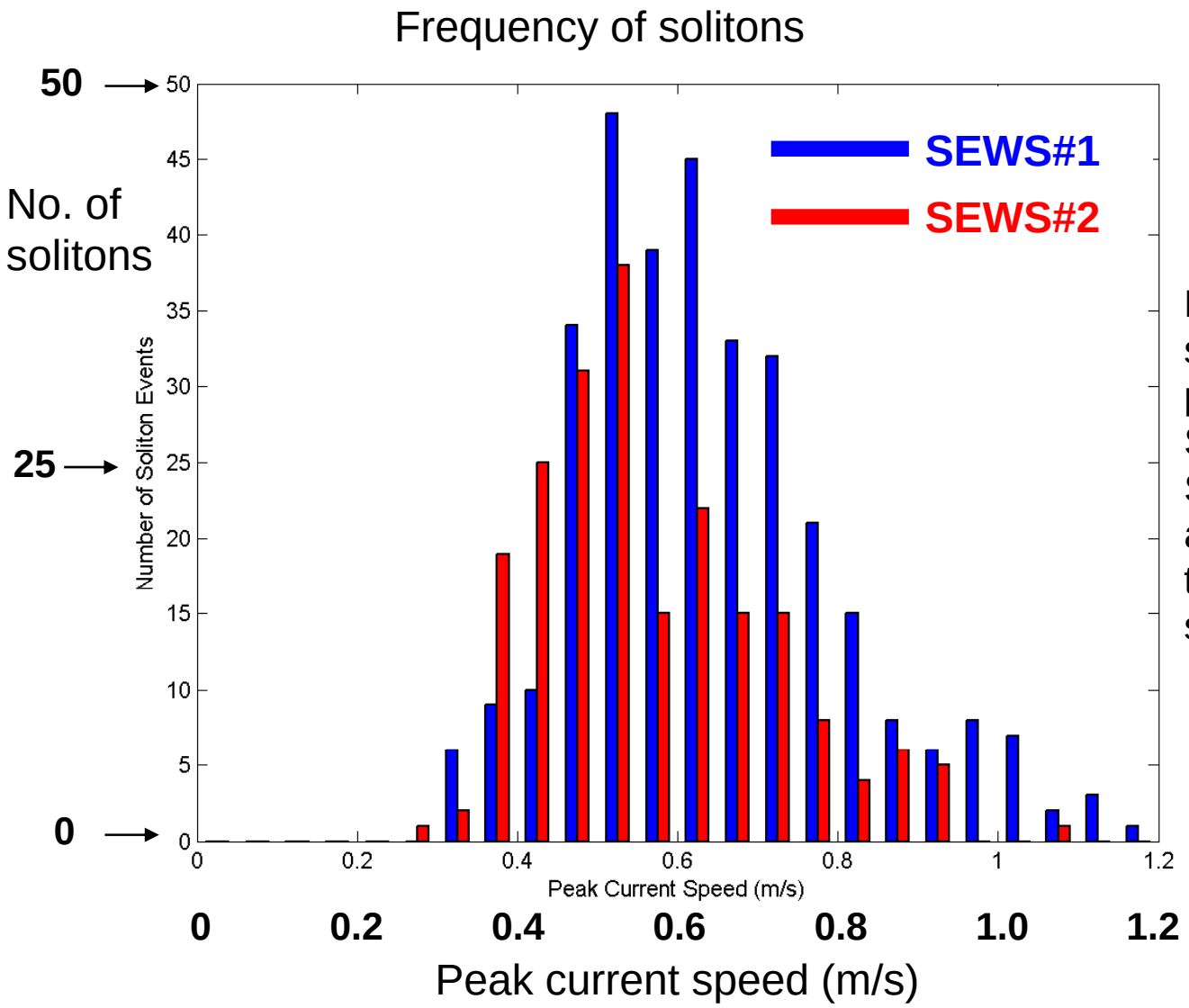


Peak soliton current speeds were predominantly higher at SEWS#1 than at SEWS#2 due to attenuation of energy over the distance travelled from soliton generation zone.

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# Conclusions

- Fugro GEOS were approached by ENI Krueng Mane Ltd to provide a soliton early warning system for drilling operations on the Jack Bates semi-submersible rig. A 10-hour minimum warning period was required.
- A combination of a SAR desk study, followed by real-time measurements across the thermocline and soliton monitoring provided this requirement.
- Solitons were successfully observed and when thresholds were exceeded, early warnings were issued. As a result the rig took the necessary action to avoid significant rig movement.
- Post processing and analysis of the data proved the SEWS effectiveness.
- ENI Well Operations Manager would have the SEWS again for soliton sensitive areas.

# Thank You