Worldwide Internal Soliton Criteria

Gus Jeans  Oceanalysis
Mark Calverley  Fugro GEOS
William Jeffery  Fugro NPA
Chris Jackson  Global Ocean Associates
Vasily Vlasenko  University of Plymouth
Al Osborne  Nonlinear Waves Research Corporation

Oceanology International Conference
14 March 2012
Presentation Structure

Motivation

Project Team

Data Sources

Deliverables
Soliton Impact
Project Motivation

• Prediction
• Quantification
• Enhance soliton desk studies
• Enhance early warning system
• Clarify in-situ measurement recommendations
• Derive more information from satellite data
• Apply recent modelling advances
• OGP Metocean Brainstorming
### Levels of Interest

<table>
<thead>
<tr>
<th>Interest Level</th>
<th>Development Phase</th>
<th>Recommended Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asset Appraisal</td>
<td>Preliminary soliton activity desk study</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GIS soliton atlas and Metocean strategy</td>
</tr>
<tr>
<td>2</td>
<td>Seismic Exploration</td>
<td>Soliton quantification and predictability desk study</td>
</tr>
<tr>
<td>3</td>
<td>Exploration Drilling</td>
<td>Soliton quantification and predictability desk study</td>
</tr>
<tr>
<td></td>
<td>Operations</td>
<td>In-situ soliton analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rig operability desk study</td>
</tr>
<tr>
<td>4</td>
<td>Engineering Design</td>
<td>In-situ soliton analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soliton Design Criteria</td>
</tr>
</tbody>
</table>
## Project Team Roles

<table>
<thead>
<tr>
<th>Organization</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fugro GEOS</td>
<td>Joint Industry Project Management</td>
</tr>
<tr>
<td></td>
<td>In-situ Measurement &amp; Analysis</td>
</tr>
<tr>
<td>Fugro NPA</td>
<td>Oil &amp; Gas Satellite Database</td>
</tr>
<tr>
<td>Global Ocean Associates</td>
<td>Internal Wave Atlas</td>
</tr>
<tr>
<td>University of Plymouth</td>
<td>Internal Wave Modelling</td>
</tr>
<tr>
<td>Nonlinear Waves Research</td>
<td>Soliton Theory &amp; Analysis</td>
</tr>
<tr>
<td>Oceanalysis</td>
<td>Analysis &amp; Review</td>
</tr>
</tbody>
</table>
Fugro GEOS: Soliton Desk Study Andaman Sea

Goff et al (2008)

218 satellite images with 77 images subjected to detailed analysis

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

Generation zone identified

Confirmed need for a SEWS

Identified best locations for SEWS moorings
Fugro GEOS: Soliton Early Warning System

- Oceanor Wavescan Buoy
- Iridium data transmission
- TRDI 75kHz Longranger ADCP
- Aanderaa DCS3900
- 3 x Seabird SBE-37 CT Sensors
Fugro GEOS: Soliton Early Warning System

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?
Fugro GEOS: Soliton Analysis

Solitons observed at SEWS#2

Current Velocity (m/s)

Northward Velocity (m/s)

Eastward Velocity (m/s)

Temperature (°C)

Oceanology International Conference 14 March 2012 Worldwide Internal Soliton Criteria
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.
The number of solitons at SEWS#1 peaked 2-hours after High Water with solitons occurring at SEWS#2 9-hours after High Water.

As expected, solitons were more frequent with higher magnitude around spring tides.
Fugro NPA: Global Satellite Database
Fugro NPA: Sulu Sea
Fugro NPA: South China Sea
An Atlas of Internal Solitary-like Waves and their Properties

Second Edition
February 2004

Prepared under contract with the Office of Naval Research Code 322PO

Please direct comments, suggestions and inquiries to:

Global Ocean Associates
goal@internalwaveatlas.com
Global Ocean Associates: New Sightings

Internal wave detection using the Moderate Resolution Imaging Spectroradiometer (MODIS)

Christopher Jackson

Figure 1. Location of internal waves observed in MODIS imagery from August 2002 through May 2004 along with the geographic boundary for the 15 regions listed in Table 1. The survey identified a total number of 3581 wave occurrences which combine to create 2774 distinct region, area, and date occurrences. Well-known occurrence sites are shown in gray, new areas of activity are shown in red, and areas of geographically expanded activity are shown in blue.
FIG. 1. Mode-1 linear internal wave phase speed as a function of depth for the northern South China Sea. The data are derived from temperature and salinity profiles acquired during ship surveys in the region between April 2005 and July 2007. Data are distinguished for quarter and year by symbol and shading, respectively. The dashed line is the nonlinear internal wave phase speed from the empirical model solution presented in Table 1.
Fig. 2. Internal wave signatures in the South China Sea from satellite imagery (gray) with the wave front locations from the empirical model (black). There are 141 internal wave signatures from 73 satellite images acquired on 61 days between April 2003 and December 2006. The shape and orientation of the model wave fronts agree well with the satellite signatures.
University of Plymouth: A Generation Story

Jeans (1998) A Nonlinear Internal Tide on the Portuguese Shelf
WISC Tier One Workflow

Satellite

Fugro NPA

GOA

Oceanalysis

Fugro GEOS

Plymouth

Literature

Fugro NPA

GIS Atlas

Fugro GEOS

Participants

Modelling
WISC Tier One

Applications:

• Asset appraisal
• Exploration planning
• Seismic exploration
• Exploration drilling

Data Sources:

• Literature review
• Satellite data screening and analysis
• Simple internal wave generation models
WISC Tier One Global Deliverables

• GIS Atlas covering offshore oil and gas regions worldwide
• Stand alone ESRI readable product and shapefiles
• Satellite image footprints showing internal wave activity
• Regions of theoretical internal wave generation potential
WISC Tier One Focus Region Deliverables

- Representative set of satellite images illustrating key characteristics
- Identification of likely generation sites and propagation directions
- Engineering focussed description of soliton activity in the region
- Summary of measured soliton current speeds*
- Soliton predictability relative to time of local high water*
- Soliton predictability relative to spring-neaps cycle*
- Assessment of seasonal trends and correlation with stratification*
- Recommended metocean strategy including sampling intervals
- A list of references used in the literature review

* if available
WISC Tier One Global Region Definition
WISC Tier Two

Applications:

• Preliminary engineering
• Engineering design

Data Sources:

• In-situ measurement
• Three dimensional non-linear, non-hydrostatic modelling
• Nonlinear Fourier Analysis
MITgcm Modelling

Grid in horizontal directions
\[ \Delta x = 250 \text{ m}; \Delta y = 1000 \text{ m} \]

Grid in vertical direction:
\[ \Delta z = 10 \text{ m} \text{ in upper 500 m} \]
\[ \Delta z = 50 \text{ m} \text{ in the rest of water} \]
Nonlinear Fourier Analysis

(a) $t = 0\ s$

Propagation Level

(b) $t = 380000\ s$

Propagation Level

Intermediate Spectrum

Spectral Amplitude - m

Soliton Spectrum

Radiation Spectrum

Modulus

Frequency - Hz
Summary

• Solitons represent a major hazard to offshore operations
• Impact remains incompletely understood in some regions
• World class project team assembled for WISC
• Tier One to provide global summary with detail in focus regions
• Overlay literature review, satellite data and generation model in GIS
• Tier Two to consider engineering design