The Application of Internal Wave Physics to Offshore Engineering

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Large amplitude solitary internal waves cause strong, rapidly varying, currents that are a proven hazard to offshore oil and gas developments in several regions of the world. These phenomena are now commonly referred to within the industry as solitons, following the pioneering work by Osborne et al (1977). They described the engineering impact of these newly discovered features, responsible for expensive and potentially unsafe disruption to exploration drilling in the southern Andaman Sea. This industry application led to the classic paper by Osborne and Burch (1980), which became a key reference in the majority of subsequent internal wave research.

Despite subsequent extensive study, solitons remain a hazard to drilling in the same Andaman Sea region today. The associated risk was recently mitigated by the world's first successful Soliton Early Warning system, described by Goff et al (2010). Solitons have also been responsible for documented problems in the Northern Andaman Sea by Fraser (1998) and Fraser (1999). Another industry application led to the study soliton predictability in this region as described by Hyder et al (2005).

Soliton impact on exploration drilling has been noted in many other regions over recent decades, with key examples in other parts of Southeast Asia and offshore West Africa. Exploration drilling impacts include large tilts and horizontal displacements beyond the watch circle, excessive mooring line tensions and over compensation of dynamical positioning. Direct costs have included days of rig time and lost or damaged equipment. Additional risks to personnel and environment are more difficult to quantify.

Beyond exploration, solitons have proven seriously disruptive to other offshore operations, including installation, offloading and vessel manoeuvres. Hazards have been encountered offshore West Africa by various tandem vessels. The rapid onset of soliton currents has a potential impact on large floating structures akin to squall winds. Implications of strong vertical motions within complex hybrid riser systems remains poorly understood. Complex near bed currents associated with internal wave breaking present a challenge to pipelines and other seabed infrastructure.

All offshore structures require quantification of the long term distribution of currents throughout the water column for detailed engineering design. This is usually achieved via the specification of extreme current speeds at return periods of 100 years and greater. However solitons require rapidly sampled in-situ data for reliable quantification. Such measurement is typically of very short duration, compared to the time scales needed for reliable assessment of operability and especially extremes.

A range of modelling strategies, such as MITgcm, can be deployed to supplement short term in-situ data. However, high spatial and temporal resolution is required to resolve the critical features. Long term hindcasts, routinely used to quantify winds and waves, therefore remain impractical. Any soliton model would also require verification and perhaps calibration using in-situ measurement. This remains a challenge to the industry today. The continued need for an improved understanding of the risk posed by solitons prompted recent initiation of the Worldwide Internal Soliton Criteria project, described by Jeans et al (2012).

References

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