

## ***Operational Oceanographic Needs for the Offshore Oil and Gas Industry***



Colin Grant, *BP Exploration, Upstream Technology Group, Sunbury-on-Thames, UK*

Chris Shaw, *Shell Global Solutions<sup>[1]</sup>, Rijswijk, Netherlands, & Chairman OGP Metocean committee*

### **Introduction**

Many offshore operations are critically dependent on the prevailing meteorological and oceanographic (metocean) conditions. To ensure that such operations are performed safely, efficiently, and economically, real time metocean data are required. Important metocean parameters for offshore operators include winds, waves, and currents. Recent trends in the offshore industry are to explore in ever-deeper waters and/or more hostile environments. These trends have brought their own additional metocean requirements. This paper addresses the provision and uses of metocean data, and how the move to deeper waters has increased the need for timely, accurate and relevant metocean information. It closes with some thoughts for providers of GOOS products and services.

<sup>[1]</sup>Shell Global Solutions is a network of technology companies of the Royal/Dutch Shell Group and provides technical services and consultancy to customers within and outside of Shell

January - March 2001

## ***Operational Oceanographic Needs for the Offshore Oil and Gas Industry***

*Colin Grant, BP Exploration, Upstream Technology Group, Sunbury-on-Thames, UK*

*Chris Shaw, Shell Global Solutions<sup>[1]</sup>, Rijswijk, Netherlands, & Chairman OGP Metocean committee*



### **Introduction**

Many offshore operations are critically dependent on the prevailing meteorological and oceanographic (metocean) conditions. To ensure that such operations are performed safely, efficiently, and economically, real time metocean data are required. Important metocean parameters for offshore operators include winds, waves, and currents. Recent trends in the offshore industry are to explore in ever-deeper waters and/or more hostile environments. These trends have brought their own additional metocean requirements. This paper addresses the provision and uses of metocean data, and how the move to deeper waters has increased the need for timely, accurate and relevant metocean information. It closes with some thoughts for providers of GOOS products and services.

#### **Overview of Requirements**

##### **1. Statutory Requirements**

One of the key requirements for real time data is to fulfil any statutory requirements imposed by the relevant authorities. For example, in the UK, the HSE's DCR regulations require monitoring of several parameters - wind speed and direction, air temperature, pressure, visibility, cloud base and cover. Mobile installations should also monitor the sea state and in the case of floating systems, the installation's roll, pitch, heave, yaw and heading. These requirements are the minimum deemed necessary for the safe

operation of fixed and mobile installations and are largely determined by the need for helicopters to land and take off.

## 2. *Operations support*

Real time information is needed on the installation for the purposes of keeping operations at the installation, and in the immediately surrounding area, within safety limits set by sea state, wind speed etc.

### 3. *Short Term Forecasts (usually up to 3 to 5 days)*

Local forecasts can be improved by the provision of real time data directly from the installation back to the offshore operator's forecast agency ashore.

### 4. *Design and Operational Planning*

Long-term climatological records are needed for use in the design of new structures, for re-certification, and for operations planning (e.g. as a basis for extreme values, percentage exceedence, persistence, and frequency of occurrence tables).

### 5. *Lifetime Performance Monitoring*

Metocean data is needed for the assessment and monitoring of the performance of structures and facilities during their operational life, which could be 20 years or more.

#### **Important Metocean Parameters in Real Time Monitoring**

The most important parameter for offshore operations is wave height. The term wave height is usually used to denote significant wave height, whether it be measured by an instrument, estimated visually by an observer, or part of a weather forecast issued by a meteorological agency. Specific wave height thresholds limit many operations, which for certain delicate operations can be less than 1 metre. Closely allied to wave height is the associated period. Usually the mean zero crossing period is used but, on occasions, spectral peak period ( $T_p$ ) is preferred. Certain operations can also take advantage of more detailed spectral wave information, such as the amount of wave energy at particular frequencies, and wave directionality which is nowadays obtainable from many systems. Fundamentally, the height and period combinations can be used to predict the response of many offshore systems, and whether particular operations can be performed safely. It should be noted that for long-term design work, knowledge of the distributions of maximum wave heights and crest elevations are critically important, being required to assess the overall structural loads and for setting deck levels.

Closely following wave height and period in importance is wind speed. Indeed, for certain operations, such as those involving helicopters and offshore cranes, the wind speed is of critical importance. Depending on the particular operation both mean speeds (e.g. hourly, 10 minute or 1 minute values) and gusts (typically 3 seconds) are required.

In many locations, assessment of the ocean current is required. This is particularly the case with exploration drilling rigs in deep water (usually 200 metres or more). Here, the rig is connected to the seabed wellhead using a marine "riser", a long, thin (0.5m diameter) cylindrical tube. The design and control of the riser, together with the drill string contained within it, are dependent on the applied forces. These include the waves and surface current near the rig, and the current profile through the water column. If strong enough, the current flow past the riser can create vortices which induce vibrations in the riser. Such "vortex induced vibrations" or "VIV" must be taken into account, as this can quickly cause fatigue of the subsea connections leading to damage and possible loss of the riser and associated well head.

As deeper waters are explored, drilling activities are often performed by "dynamically positioned" (dp) vessels (either drill ships or semi-submersible rigs). These dp vessels are not moored to the seabed and rely on powerful thrusters and sophisticated positioning systems to hold station over the well site. Knowledge of the ocean currents through depth, and forecasts of changes in the next few hours, are of great assistance to such operations.

Further marine parameters, which occasionally require real time monitoring offshore, are the water elevation (from which tide and surge data can be obtained), the temperature of the sea and air, visibility, cloud height and the presence of sea ice.

#### **Service Provision to the Offshore Industry**

Measurement systems on fixed platforms are typically owned by the oil company and operated by their staff. They are normally provided as part of the platform equipment during construction. During drilling operations on mobile rigs and drillships, it is quite common to add a system for current monitoring using an Acoustic Doppler Current Profiler (ADCP) with associated display equipment. These are often rented for the duration of a particular drilling programme from specialist contracting companies. The same is true of campaigns to monitor ocean currents and temperatures from fixed moorings ahead of drilling activity at a location. Specialist contractors tender for the services and usually provide all the necessary equipment together with the subsequent data processing and reporting.

Marine forecast services are typically provided by state meteorological agencies or private commercial companies – usually on contracts of a year or more for fixed installations. The requirement is typically for services twice per day with special additional services required during "critical" operations such as heavy lifts. Increasingly, such services use the latest in computer and communications technology to ensure timely delivery of a wide variety of textual and graphical products to the industry end-users. Most users do not

normally have specialist metocean knowledge hence the products sent must be user-friendly and easily interpretable. Such end users could be in onshore offices or control rooms on offshore rigs and platforms. In return, much of the industry measured data – particularly meteorological information, is fed back to the forecast providers in real-time in order to assist with the preparation of subsequent forecasts.

**Data Uses**

The following is a list of some of the main activities offshore which rely on real time metocean data (to a greater or lesser degree).

<p><b>Exploration Surveys</b> Seismic Site Investigation</p> <p><b>Exploration Drilling Campaigns</b> Rig operations</p> <p><b>Field Developments</b> Construction Float out, towing, warranty surveys Installation (lifting and piling) Pipeline and flowline installation</p>	<p><b>Field Operations</b> Helicopter transportation Supply Boats Diving and Maintenance Vessels Offshore hook-up and offloading</p> <p><b>Terminal Operations</b> Tanker berthing and offloading</p>
---	---

Initial studies of the hydrocarbon-bearing potential of the world's sedimentary basins rely on information gathered during seismic surveys. Typically a vessel tows astern a long "streamer" or series of streamers containing hydrophones. These operations are very dependent on seastate, particularly prevailing the relative direction and period of the swell and surface current conditions. Some seismic vessels now monitor the currents in real time with a hull mounted ADCP, and use the data to assist in the control of the streamer.

If prospects from the seismic results are encouraging, a drilling programme may be initiated. In shallow water, typically 50 metres or less, this will involve the use of jack-up rigs, whose legs penetrate the seabed. The towing of jack-up rigs between locations is particularly sensitive to seastate. Some tows use the hull of the jack up rig for buoyancy and tugs to provide propulsion whilst others use specialist vessels where the rig is loaded onto the deck.

In deeper waters (up to 2,000 metres or more) semi-submersible rigs or drill-ships are used, which move between locations under their own power. They are then either anchored or moored to the seabed, or use powerful thrusters to maintain station over the wellhead. All drilling programmes are sensitive to seastate. The moorings and motion responses of the rigs are particularly sensitive to swell conditions, and the riser connecting the rig to the seabed is also affected by the surface wave conditions as well as the variation of the current throughout the water column. In certain areas the wave climate will define seasons or "windows" when drilling usually takes place. However, the advent of more powerful and robust rigs, coupled with an improving knowledge of the metocean conditions, has resulted in the weather windows being steadily widened. For example, until recently, drilling activity to the West of the Shetlands in the UK was restricted to a season between approximately April and November. Now drilling activity is continuing year round.

Should a commercial prospect result from a drilling programme, it is possible that a jacket type structure will be installed. This supports the topsides equipment and accommodation facilities required to extract and process the hydrocarbons. The combination of jacket and topsides is termed a platform, and there are many hundreds installed throughout the world (nearly 3,500 in the Gulf of Mexico alone). The tow out and installation of the jacket is one of the most critical phases in the whole life of an offshore field, and one of the most weather sensitive. Accurate observations and forecasts are essential to ensure that the operation proceeds safely and efficiently. Offshore lifts up to nearly 12,000 metric tons are now being seen, using the latest offshore crane vessels. These heavy lifts typically require sea states below 1 or 2 metres for a period of several hours, with winds less than 10 metres/sec.

The installation of flowlines and pipelines, usually from specialised vessels, is also a critical and extremely weather sensitive phase in the development of an offshore field.



Certain offshore fields are developed using floating production facilities and the export route may be via tanker from a floating production, storage and offloading system (FPSO) or loading buoy, rather than via a pipeline. The berthing of large "shuttle" tankers on FPSOs and offshore loading buoys is very weather sensitive, with relatively low significant wave height thresholds for connection (3 to 4 metres) and

disconnection (5 to 6 metres).

Daily platform operations such as helicopter flights, crane operations and supply boat off loading are dependent on accurate real time metocean data and forecasts for their safe operation. Owing to several recent weather related incidents in the North Sea, certain operators have instigated formal "severe weather policies". These provide guidelines for those offshore activities which are in any sense "weather dependent". The policy includes details of the appropriate metocean parameter thresholds and the necessary decisions to be made when those thresholds are reached (or forecast to be reached).

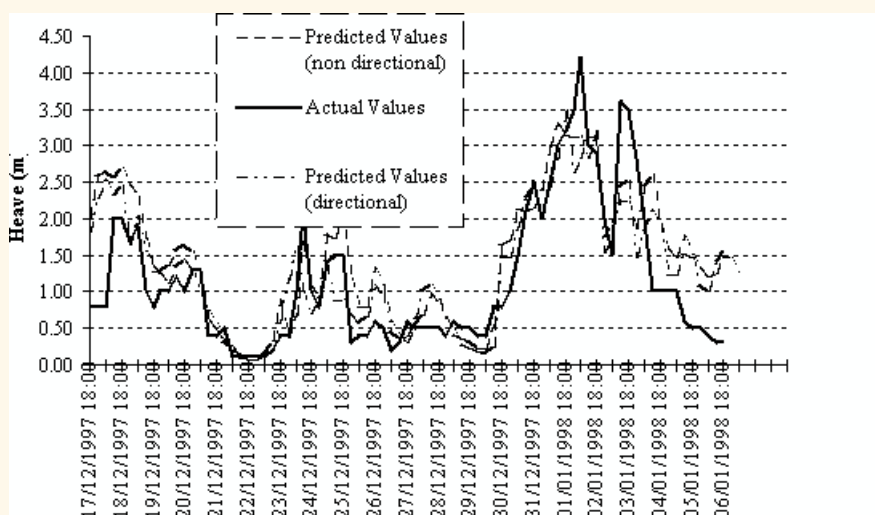
### Deep Water Considerations

In recent years there has been a trend in exploration and production activities towards deeper waters and, in some areas, more harsh and exposed environments. Examples are the Atlantic Margin off the UK, Ireland and Norway and offshore west Africa. UK production now includes the Foinaven and Schiehallion Fields to the West of Shetland in 500m and 390m water depths respectively. A detailed account of the development of the metocean design basis for these fields can be found in ref. 3 and a more general description of the approach used in developing global metocean design criteria in ref 5.

Why is there an increasing move to deeper waters and harsher environments? The principal reason is that the largest fields in the accessible shallow shelf seas have virtually all been discovered. For example, in the North Sea, fields like Brent, Forties, and Ekofisk have been in production for 20 years or more and are now in decline as their reservoirs are gradually exhausted. The discovery of similar very large fields - in excess of 1 billion barrels of oil - are anticipated in deeper waters (greater than 200m) on the continental slopes. Even with the advances being made in offshore technology, such huge field sizes will be required in order to develop such deep water discoveries economically.

Water depths of 1,000m or more are now routinely explored and the technology is under development to drill exploration wells in water depths up to 3,000m. Currently, the world record for exploration drilling is around 2,700m (8,860 feet) off Brazil. The deepest production field is also located offshore Brazil, where an FPSO system (Marlim Sul) is installed in a water depth of 1,420m. This facility has linked into it a production oil well in a water depth of 1,709m - the deepest producing well to date. Other important deep water areas include the Gulf of Mexico and West Africa. [The figure](#) shows the comparison of several deep water areas and their respective design metocean criteria.

Increasingly, it has been found that equipment and techniques which work successfully in shallow water areas such as the North Sea are not applicable in deep water areas where increased energy at long periods ("swell") is often present. Rig response in long period swell can be excessive, particularly "heave" - the vertical component of motion. A number of companies have developed methods for forecasting rig response, recent work by BP Amoco and the UK Met Office developed a technique for West of Shetland operations by using wave model output and knowledge of the rig response characteristics to produce real-time forecasts of rig heave out to 5 days ahead. (see ref. 4).

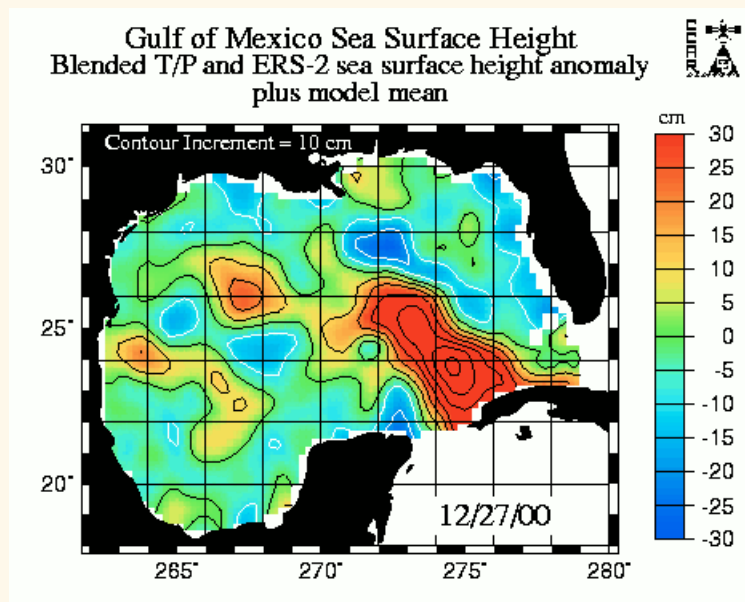


### Measured and Forecast Heave - Stena Forth at Bruce Field

Such an operational product is typical of the innovative collaboration necessary in order to achieve safe and economic operations in deep water areas. A related problem occurs for drilling vessels offshore West Africa, in locations off Nigeria, Gabon, and Angola. Here, the locally generated wave conditions are often benign, but swell generated in storms crossing the southern ocean, over 6,000 miles away, travels across the globe to impact these operations. Here wave spectral information is very important for offshore operations. Trials of a forecast swell service using a 3<sup>rd</sup> generation wave model have shown considerable skill in warning of swell events (the results are proprietary to the "WAX" joint industry project).

In addition to heave forecasts, assumptions concerning wave spectra which have proved acceptable for the design of jacket structures in shallow water areas are being re-examined for deeper water areas. In this area it is no longer economically or technically possible to have rigid steel jackets or platforms "fixed" to the seabed, such as commonly found in the Gulf of Mexico and North Sea. Now the industry is turning to floating systems in order to extract and produce the oil and gas reserves. Design concepts include FPSO's, tension leg platforms (TLP's) and spars. However, the design of such floating systems requires careful hydrodynamic assessment. Waves are usually the most important environmental parameter when designing a new offshore facility. This is due to the hydrodynamic load imposed in extreme events as well as from the fatigue (cyclic) loading which the wave environment causes over the life of the field - which can be from 10 to 70 years. The importance of understanding ocean wave spectra in deep water areas is vital if safe and economic structures are to be designed, constructed and operated. Issues such as multimodal spectra, directional considerations, wave spreading etc. all are increasingly important.

As noted previously, ocean currents can be a major issue for deep water operations. For example, significant downtime has been experienced on several Gulf of Mexico drilling programmes when the Loop Current, or one of its associated eddies, has crossed a drilling location. In some extreme circumstances, the down-time has lasted several weeks with significant economic consequences. This is one area of metocean technology that operational oceanography can significantly improve in the coming years. Although the industry has systems in place to monitor such events in real time (using ADCP's on the rigs) there are, as yet, only rudimentary forecast services available for ocean current prediction. These rely on satellite altimetry and 3D ocean current models, which although improving all the time, are not yet scientifically mature enough to contribute the type of accurate product and added value that ocean wave models are able to achieve. This position will improve dramatically with increasing availability of data from GOOS (for boundary and assimilation purposes), as well as scientific development of the models themselves.



#### Considerations for Providers of Operational Oceanographic Systems and Services

The offshore industry is relatively conservative in its application of new technology in metocean services. This is because the industry has developed an understanding of the traditional tools and techniques over many years. The present operational practices and design criteria have been developed from existing systems, and allowances for their shortcomings have been taken into account. Any novel technology or system that is proposed will, therefore, be compared with existing systems and services. This comparison will focus on both technical and commercial considerations. It is unlikely that a new system will be accepted until it has been in a comparative field trial with some or all of the alternative sensors or techniques.

The new system or service will usually have to provide at least the same level of information as existing technology, and then either provide additional (useful) data, or be significantly cheaper than the existing system. The important point to bear in mind is that the data must actually be usable by the operator. For a real-time system, that means that the processed results should be available almost instantaneously and capable of being displayed in a user-friendly format on the installation. It would be of little use for a real time system to provide data many minutes (or even hours) after the event.

The system should be capable of operating in the weather and seastate conditions likely to be experienced, and provide valid data across the range of anticipated conditions. For a real-time system, it is again of little use if the system performance degrades significantly with increasing seastate for example, such that during severe storms (when the data is most important) the system provides data that are meaningless.

When looking at commercial considerations, increasingly the life-cycle field costs are used. Therefore, it is not just the initial capital cost of a new piece of technology that is assessed, but also the costs to operate and maintain the unit or service over several years. In addition to the costs, the benefits of the new technology have to be identified, and wherever possible, quantified. This allows a proper comparison to be made over alternative systems and services.

## Offshore metocean technology developments

The recent oil price fluctuations have had an impact on companies in terms of focusing on in-house technology developments which have a reasonable chance of delivering results in the short-term. There has been a tendency to farm out non-strategic, longer-term technology into Joint Industry Projects (JIPs) where this is feasible.

Some of the technology projects in which the industry is involved are:

- SAFETRANS (A project aimed at defining criteria for long ocean tows)
- WACSIS (WAVE Crest Sensor Inter-comparison Study)
- "Response" based design criteria for offshore structures (fixed, floating and pipelines)
- Maximum wind gust speeds in squalls and tropical cyclones
- $10^{-4}$  (developing a better definition of very low probability events)
- ISO (development of international standards for the design of offshore structures (fixed steel, concrete, mobile jack-ups and floating systems))

During work on the ISO code, setting minimum deck elevations was identified as an area of major uncertainty and it was recognised that to resolve the issue required a better understanding of two aspects of the problem. Firstly, we needed to know the distribution of crest heights in storm conditions (and consequently an understanding of which datasets we could consider reliable). Secondly the new procedure for deck heights requires extrapolation of the distribution of crest heights to very low probabilities (return periods of 10,000 years). Hence the ISO work led on to the WACSIS and  $10^{-4}$  projects, the combined aims of which are to define a rational procedure, for use anywhere in the world, in defining the minimum air-gaps for fixed structures.

We expect that this trend to co-operate in developing non-strategic technology will continue in the future. However the recent oil company mergers have forced up the 'ticket price' for entering JIPs and consequently has made them more problematic to get started.

## The Offshore Industry's Aspirations for GOOS

Notwithstanding the comments in the previous section, the offshore industry believes that the improvements in operational oceanography, which will be forthcoming under the auspices of GOOS, will significantly influence and assist our operations round the globe. This is especially the case in the new deep water frontier areas such as the Atlantic Margin of Europe, the Gulf of Mexico and West Africa.

Developments in ocean modelling, coupled with data assimilation advances should lead to improvements in forecasts of key parameters such as ocean currents. At present, although real time monitoring of current speed and direction is possible using ADCP's, accurate forecasts to a few hours or days ahead are not available. Advances in marine weather forecasting generally will be beneficial, in particular for severe storms with their associated high waves. A related phenomenon is the so-called "rogue" wave. These occur infrequently but are usually significantly higher or steeper than other waves in the seastate. This can lead to operational problems including wave impact damage to offshore structures and facilities. Better knowledge and forecasts of such waves will be invaluable. In addition, refinements in operational wave models to include better descriptions of the spectral energy content of the seastate will be useful for both the operation of existing facilities and the design of new ones. This is especially the case for floating production systems. Spectral wave forecasts can be coupled directly to motion response algorithms, leading to forecasts of the key operational parameters for floating vessels such as heave, pitch and roll.

The industry is already working with parts of the global GOOS community to improve many of these areas. An example is the Offshore Weather Panel (OWP), a collaboration of members of the OGP metocean committee and representatives from weather forecasting consultants and agencies. It's remit is to improve the dialogue and address important issues at the interface between the offshore industry and the forecast providers. Another is the support for 3D current model development in the USA and Europe, including the close ties to the EU-funded DIADEM and TOPAZ projects.

### References

1. "Guidelines for the Specification and Design of Offshore Metocean Data Acquisition Systems", UK Offshore Operators Association, October 1992.
2. "Offshore Industry requirements for real time metocean data for operations," WMO/IOC Workshop on Operational Ocean Monitoring using Surface Based Radars, Geneva, 6-8 March 1995 (WMO/TD-No.694).
3. Grant, C.K., Dyer, R.C., and Leggett, I.M. (1995): "Development of a new metocean design basis for the NW Shelf of Europe", OTC 7685, Offshore Technology Conference, Houston, pp. 415-424.

4. Grant, C.K. Cornut, S., Dyer, R.C., Holt, M., and Mitchell, J. (1998): "Forecasting rig heave for drilling operations in harsh environments", in "Ocean wave kinematics, dynamics and loads on structures", Proceedings 1998 International OTRC Symposium, ASCE, pp. 225-232.
5. Shaw, C. J. (1999), Offshore industry requirements and recent metocean technology developments. CLIMAR 99 Conference, Vancouver

---

[1]Shell Global Solutions is a network of technology companies of the Royal/Dutch Shell Group and provides technical services and consultancy to customers within and outside of Shell