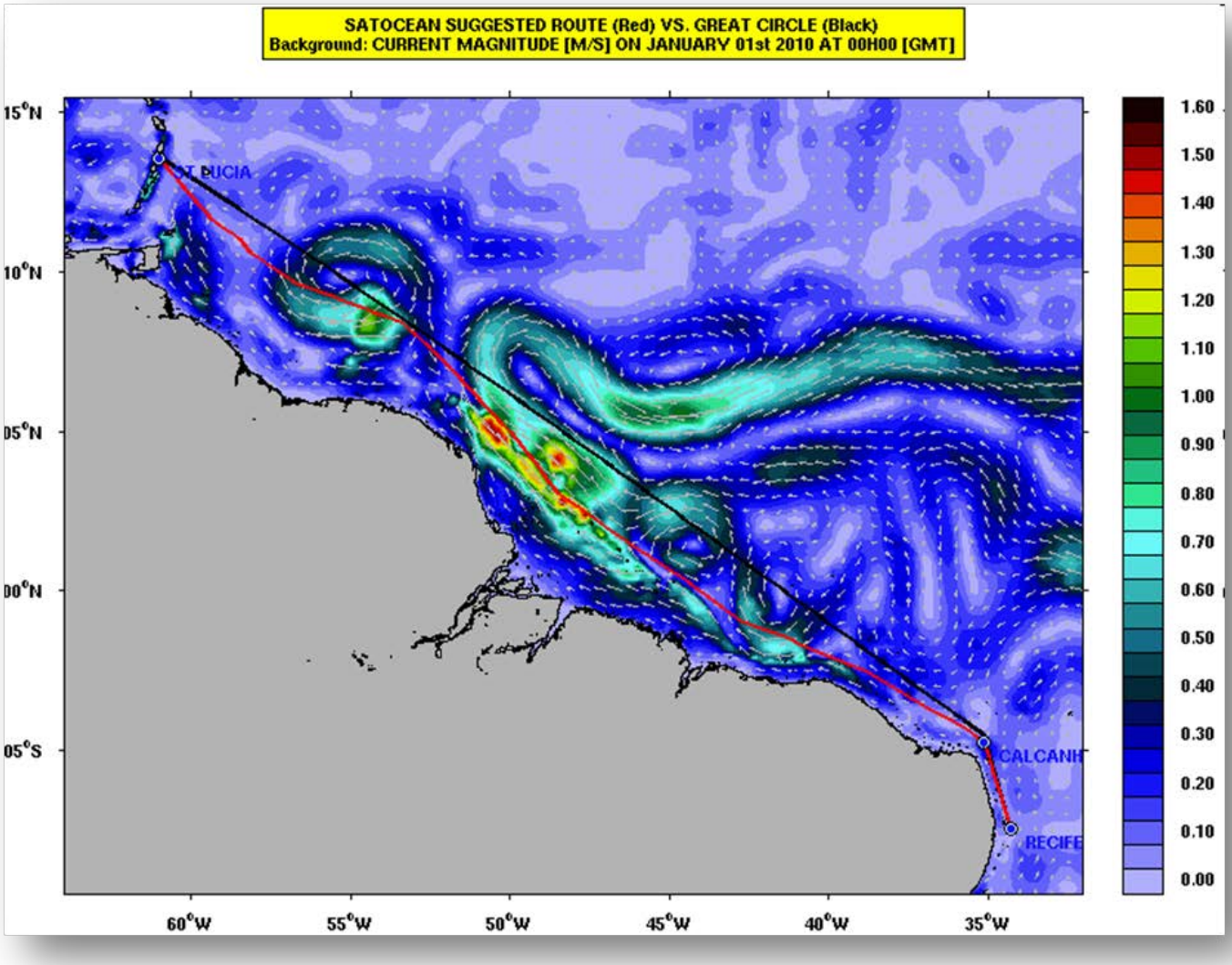
SAT-OCEAN'S SCOPE OF WORK FOR ROUTING SERVICES



1 Executive summary

SAT-OCEAN has developed an innovative routing service enabling for significant time and energy savings. This solution is going beyond traditional weather routing which is mainly concerned with winds and waves. The main differentiator lies in the inclusion of our own high resolution ocean current forecasts in the routing process. This enables both safety of the ships by taking into account the winds and waves forecast but also an average speed gain of between 0.3 and 1 knot with associated time and fuel savings.

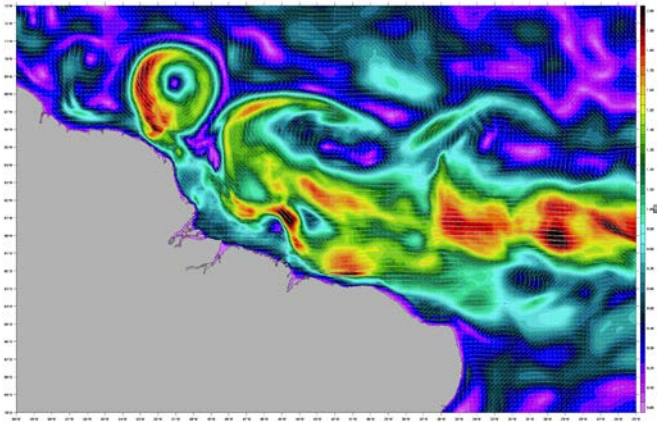
2 Principles of SAT-OCEAN service

The objective of SAT-OCEAN is very simple, to "use currents as the speed walk of the oceans". But to reach that objective, significant changes need to be made from the traditional approach to routing.

2.1 Real-time currents data

Rather than averaged values, SAT-OCEAN uses real-time current information, relying on daily updated satellite measurements to compute currents for the next 5 days. In practice, our ocean model is strongly forced with the collected temperature and altimetry data as well as high quality wind forecasts, which ensures a good representation of the ocean circulation.

This in turn represents a key enabler to provide very precise route advice as winds will among other factors generate variability in currents speed and direction. While pilot charts and climatology studies can be useful tools for pre departure route planning, only real-time currents, winds and waves data can provide a sound base for routing decisions at sea.



2.2 High resolution currents data

SAT-OCEAN operates a worldwide 1/8° (about 25km) global ocean currents system, which ensures an accurate representation of how the various currents interrelate and how the energy is transported in the worldwide ocean.

3 SAT-OCEAN services differentiators

3.1 "Current aware" routing

As explicated above, the main difference between SAT-OCEAN routing services is in its use of high-resolution real-time ocean current data in the routing algorithm. Through high resolution ocean currents forecasting, SAT-OCEAN delivers against the need to adapt in real time deep sea routes to the crossing of large scale currents and their eddies. This can yield significant differences as exemplified in the graph below.

In orange is presented the optimum route taking into account currents, wind and waves, in black the Great Circle route and in red the advised route taking only into accounts winds and waves. Quite clearly, the presence of strong winds in the South is well taken in consideration in the red route, which adopts an option to the North.

The orange route on the contrary stays longer in the South as the strong winds are compensated by favorable currents in that area. For that part, this is of course in general agreement with the description of the Agulhas current in the pilot charts. The exact trajectory as well as the subsequent deviations closer to Madagascar are however impossible to define by the sole reference to the pilot charts. They are basically a consequence of the actual ocean current conditions at the time of navigation.

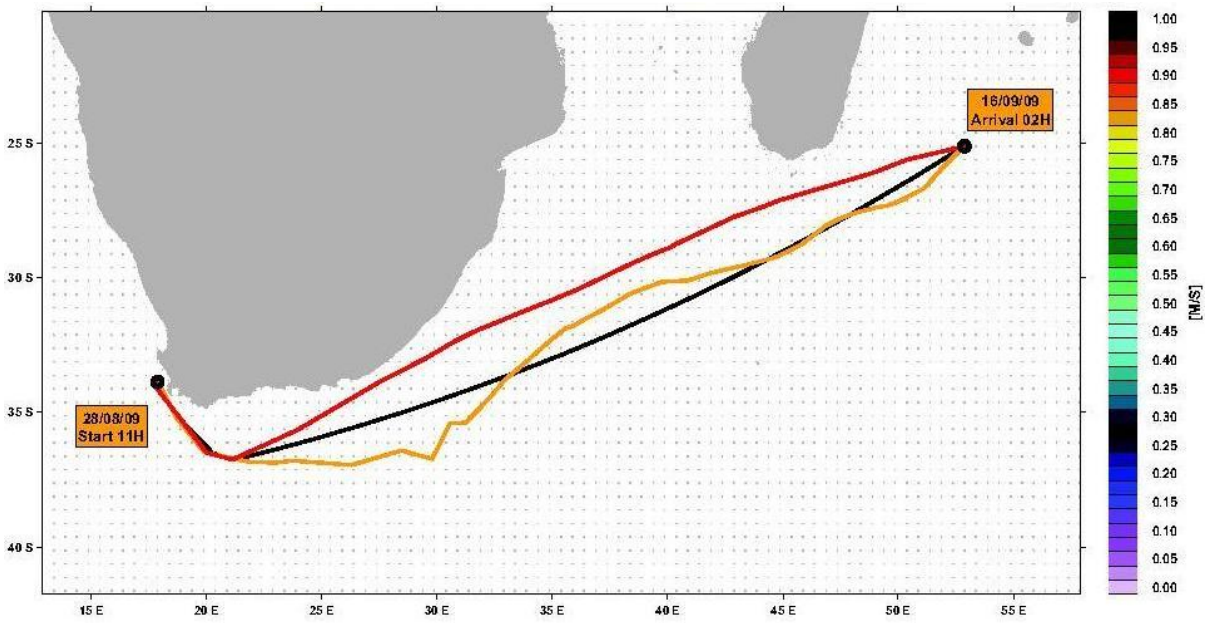


Figure 1: Classical weather routing vs SAT-OCEAN current-aware routing

Another interesting observation at this stage is to remark that while the red route is "linear" (reflecting the large scale of the lows that traditional weather routing seeks to avoid), taking into account currents lead to a more fragmented route. This is a direct consequence of the greater spatial variability of currents compared to winds and waves. In practice, "current aware" routing will thus tend to involve additional waypoints compared to traditional weather routing.

3.2 "Speed aware" routing

SAT-OCEAN routing service is in this area rejoining common sense which tells us that the impact of currents is magnified at constrained vessel speed. For this reason, our routing algorithm takes the average speed of the vessel as a key variable to compute the optimum route.

Based on various simulations and validation in customer projects, the results are striking: the slower the vessel goes, the longer the current optimum route will be and (despite the longer route) the higher the time and fuel savings.

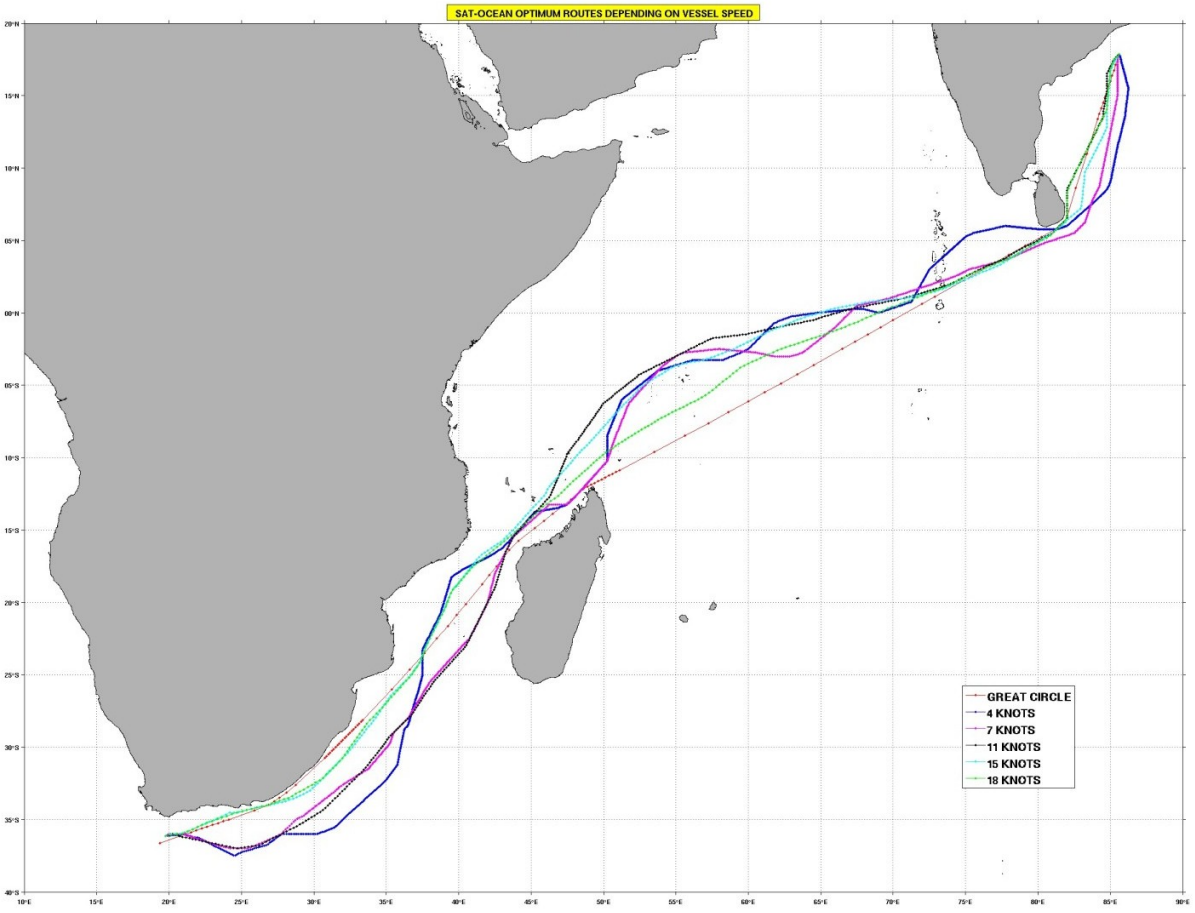


Figure 2: Influence of vessel speed on optimum route

3.3 Vessel / voyage specific routing

On top of currents, the wind influence on the vessel progression is computed, and the respective weight attributed to the winds and the currents derived from the drag of the vessel. Other Metocean constraints such as the maximum waves height and period are by default taken into account, and carry a penalty in the route selection process.

Moreover, our routing service incorporates vessel or voyage specific constraints such as the minimum depth of water or the minimum distance to shore. As a relative newcomer to the

field, SAT-OCEAN has had full freedom to develop a highly flexible system, and we can incorporate additional constraints into our system based on specific customer requirements.

4 Content of SAT-OCEAN service

4.1 Service description

SAT-OCEAN uses daily updated satellite measurements to compute winds, waves and currents forecasts. We then propose the most cost-effective route, for each vessel and each service. Our bulletins include comparisons between our suggested route and the Great Circle route, with information on the speed on the two routes, the estimated time saving and the conditions to be encountered.

Deliverables include on a daily basis:

- A dedicated secure web site for operation people onshore, presenting:

  - Wind (10m & 50m), waves, swell & air temperature forecasts
  - Atmospheric pressure maps & associated time series
  - Ocean current forecast maps centered on the vessel position for the next 4-5 days with a 3-hour time step and a spatial resolution of 1/8th of a degree
  - Suggested route plan and waypoints based on ocean currents, winds and waves conditions and in accordance with vessel's duly specified voyage constraints (see PDF example)

- An email with attached ocean current and wave maps along recommended route, statistics along SAT-OCEAN optimal route, an Excel spreadsheet of waypoints coordinates on the suggested route with Metocean conditions on each leg and a weather report.

- A post-voyage route replay analysis comparing vessel route with the Great Circle route.

The service is extremely flexible in that it requires no on-board installation and our e-mails are accepted by vessels’ systems. At the end of the voyage, we also perform 'a route replay' enabling to transparently quantify the benefits.

4.2 Examples of deliverables

	Statistics along Suggested route	Warning along Shortest path (latest pos. to arrival)
ETA [GMT]	2011-09-22 19:27	–
Duration	17 days 7 hrs	–
Max current	1.91 kts - 0.98 m/s	–
Max wave height	5.59 m (160% of max accept.)	5.56 m (159% of max accept.)
Max wind	28.4 kts (81% of max accept.)	27.5 kts (79% of max accept.)

Table 1: Statistics table along route - (*) Includes current and wind effect

	Shortest path (latest pos. to arrival)	Suggested route (latest pos. to arrival)	Statistics
Mean vel. estimated	+4.46 kts	+5.26 kts	+0.8 kts (+18.2%)
Duration estimated	20 days 7 hrs	17 days 7 hrs	14.7% saved
% downwind time (*)	44%	58%	+29%
Additionnal distance	–	31.7 nm	1% longer

Table 2: Comparison table - (*) Includes current and wind effect

	Parameters and environmental thresholds used for computation
Nominal speed	5 kts
Wind magnitude max.	35 kts
Waves height max.	3.5 m
Depth min.	> 25 m
Dist. to coast min.	> 35 nm

Figure 6: Daily summary of route

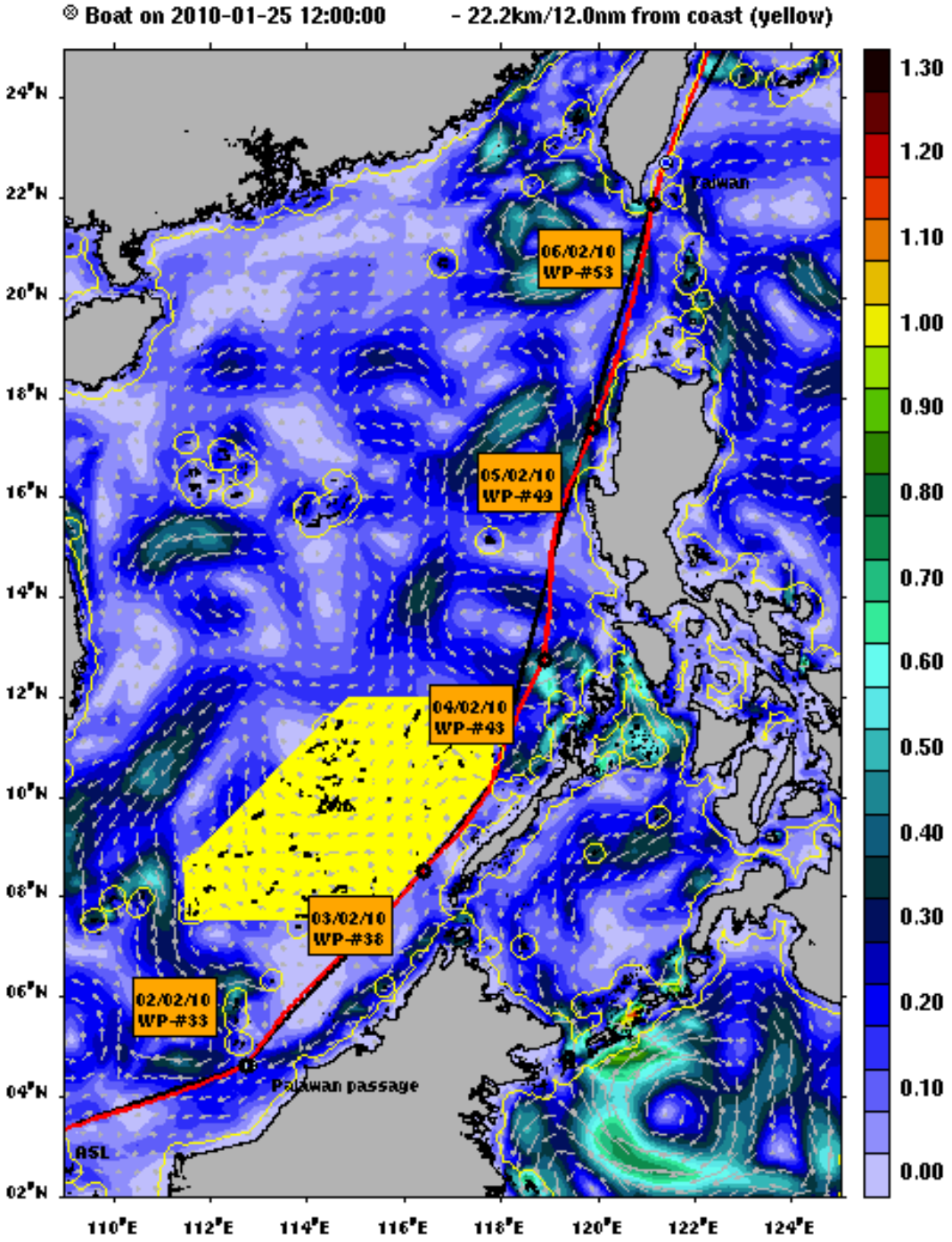


Figure 7: Route map and current forecast

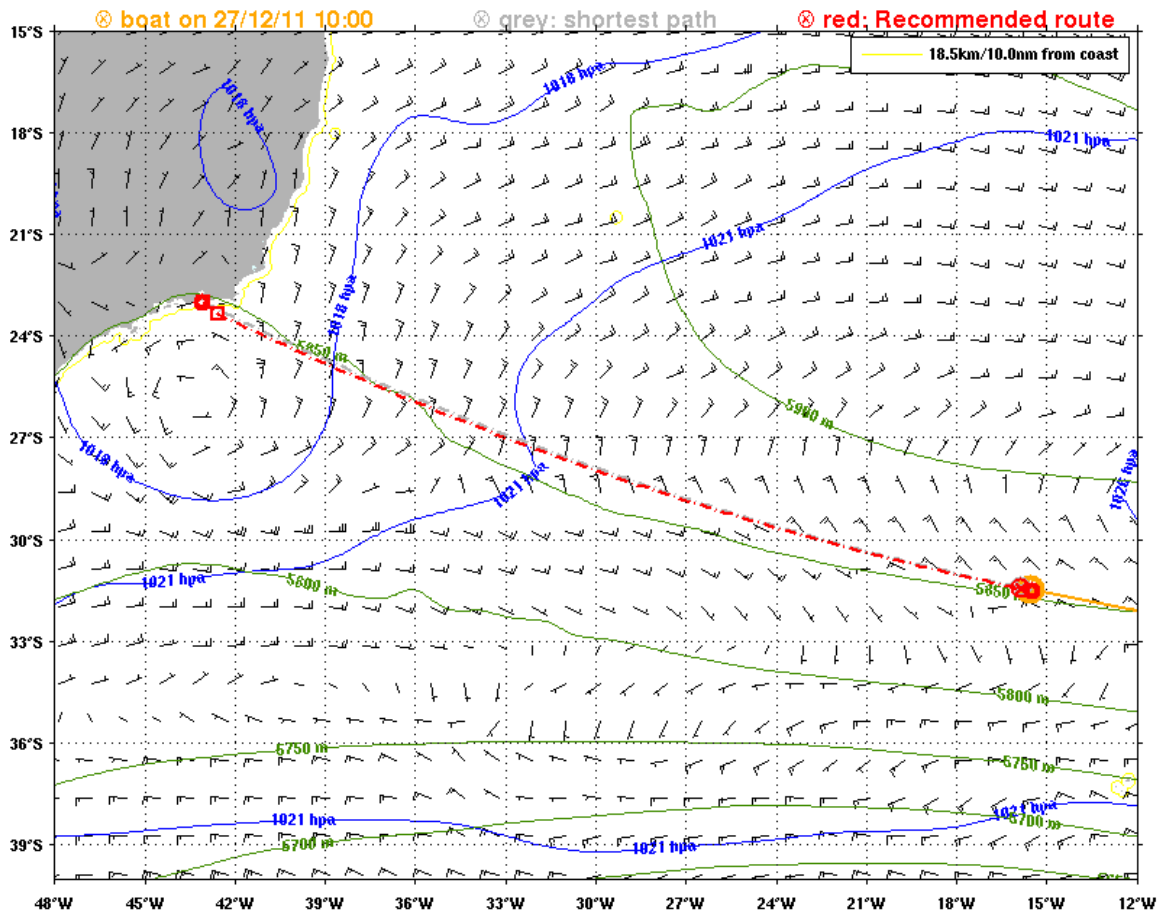


Figure 8: Wind and weather forecast along route

WP on Route day 2011-09-05	LATITUDE	LONGITUDE	TIME [UTC]	COURSE [° North]	DISTANCE (NM)
WP-1	32°00'S	115°00'E	12:00	339	102

Table 4: Detailed waypoints for day 05-Sep-2011

WP on Route day 2011-09-06	LATITUDE	LONGITUDE	TIME [UTC]	COURSE [° North]	DISTANCE (NM)
WP-2	30°23'S	114°17'E	13:44	341	28
WP-3	29°56'S	114°07'E	19:37	356	119

Table 5: Detailed waypoints for day 06-Sep-2011

WP on Route day 2011-09-07	LATITUDE	LONGITUDE	TIME [UTC]	COURSE [° North]	DISTANCE (NM)
WP-4	27°56'S	113°58'E	19:09	335	36

Figure 9: List of waypoints

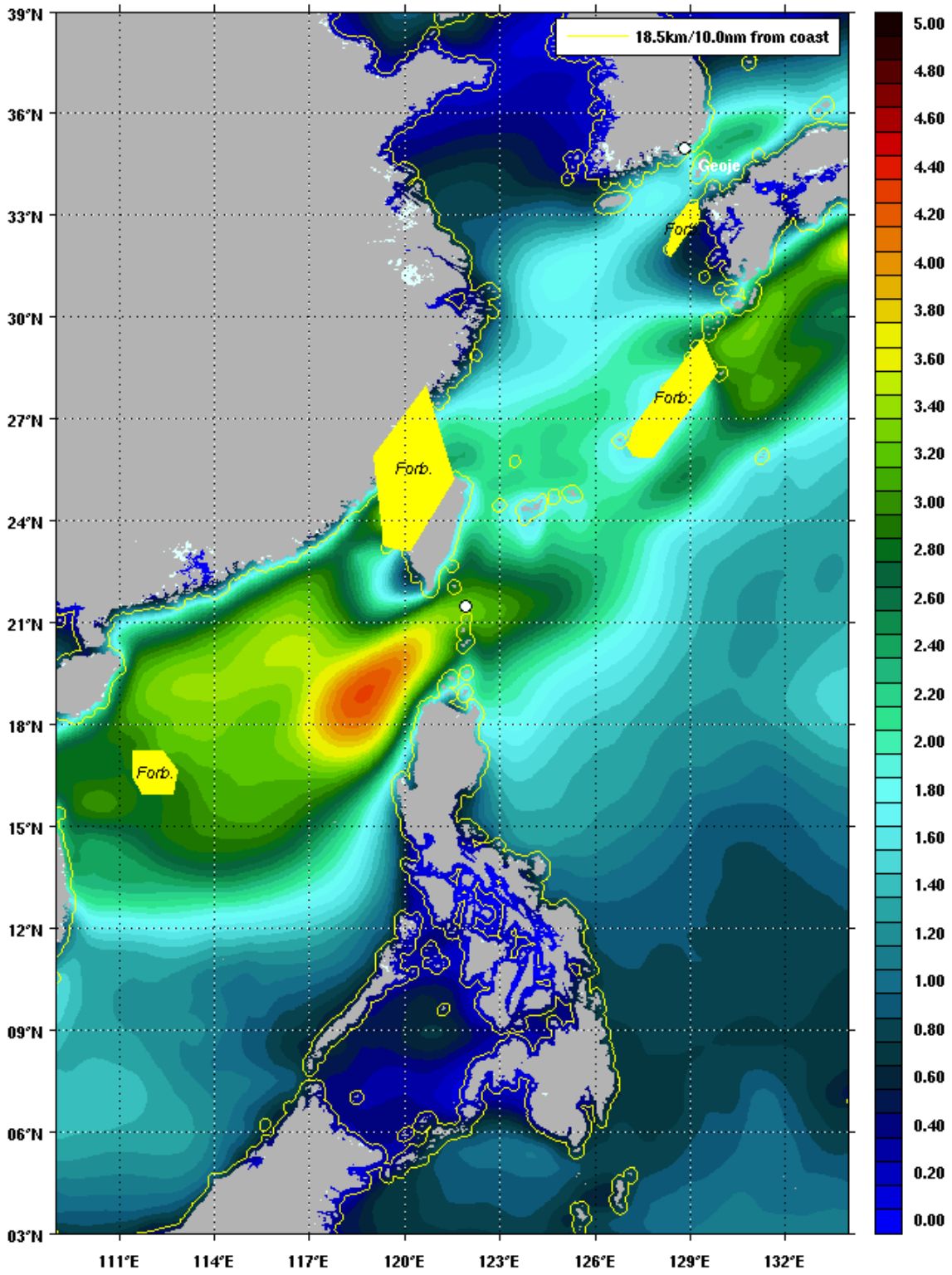


Figure 10: Wave forecast along route

APPENDIX 1: SAIPEM CASE STUDY

Background

Saipem is a world leader in the Oil & Gas contracting services sector, providing turnkey engineering, procurement, project management and construction services with distinctive capabilities in the design and the execution of large-scale offshore and onshore projects.
The Saipem 3000, a self propelled DP crane vessel, was contracted for offshore installation work in the West African Transform Margin area. This area, which extends nearly 1,500 km along the coasts of Ghana, Ivory Coast and Liberia, is becoming one of the most exciting production region in Africa. Recent oil discoveries now increase the likelihood that more reserves could exist in this region which has been the subject of limited exploration so far.

Project challenges

The West Africa Transform Margin oil reserves are positioned in the trajectory of the Guinea Current, an eastern ocean boundary current flowing at approximately 3°N along the western coast of Africa. Emanating from the North Equatorial Countercurrent (NECC) and the Canary Current, the Guinea Current's strength is affected by the seasonal instability of these two currents. It experiences a minimum during winter (November through February) and a maximum during summer (May through September). Its speed can also at times be higher in deep water than in coastal waters.

Saipem's experience further demonstrated that currents close to the jet's core were significantly undervalued by the monthly average statistics of the pilot charts: a pre-operation drift test completed by Saipem in 2009 had showed intensities eventually higher than the operability limits of the Saipem S3000. As a result Saipem asked SAT-OCEAN to provide a dataset covering the period of the drift test. The correlation between SAT-OCEAN currents and on-site data proved very good and confirmed that the SAT-OCEAN approach, solely relying on a combination of satellite measurements and advanced modeling, was capable of accurately representing the regional ocean circulation.

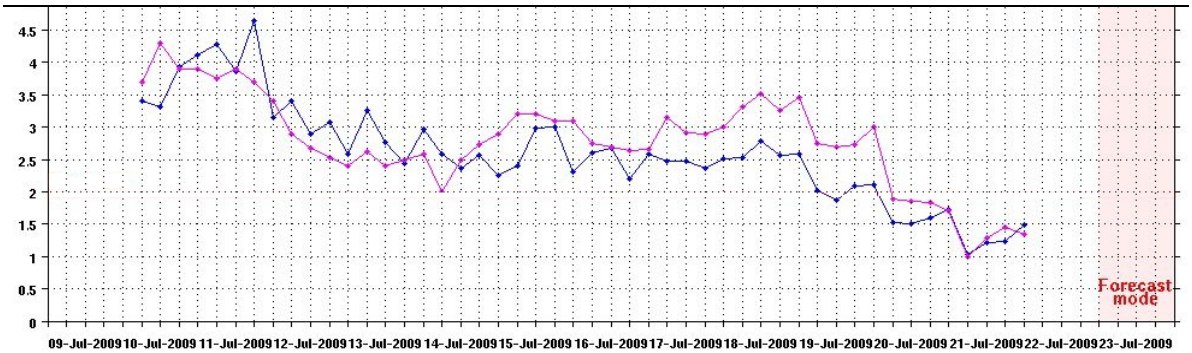


Figure 1: SAT-OCEAN magnitude (blue) vs. on-site measured magnitude [knots]

Downtime analysis

In order to carefully schedule its operations in the West African Transform Margin region, Saipem requested a Metocean statistic study from SAT-OCEAN. The objective was to define the most appropriate time window for the installation project. SAT-OCEAN used its worldwide archived data of hindcast currents to extract the relevant local time series, and delivered to Saipem operability statistics centered on the months of interest.

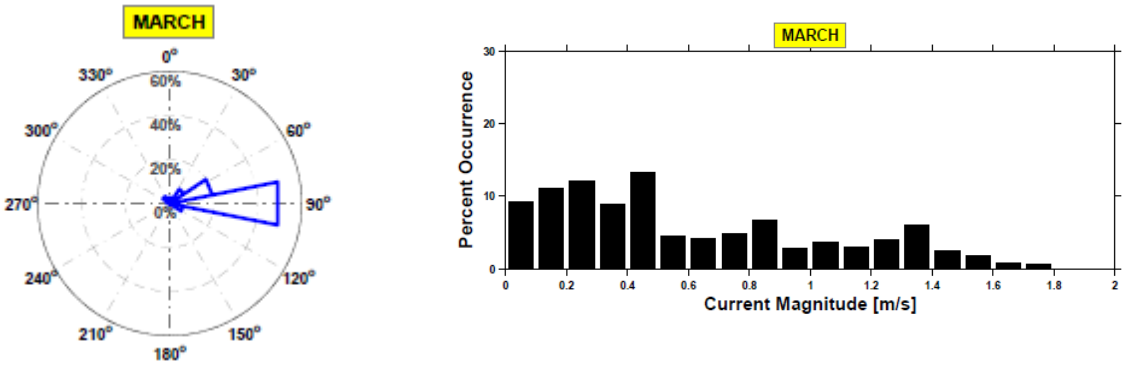


Figure 2: Current direction/magnitude distribution and occurrences

Once on site, Saipem needed to precisely monitor local current magnitude for the duration of two operations, the first one planned in February and the second one in March 2010. To that end, SAT-OCEAN provided a daily Metocean report including 5-day high resolution (1/32°) current forecasts. This service was used by the Saipem 3000 to fine-tune operations schedule and guarantee a safe execution.

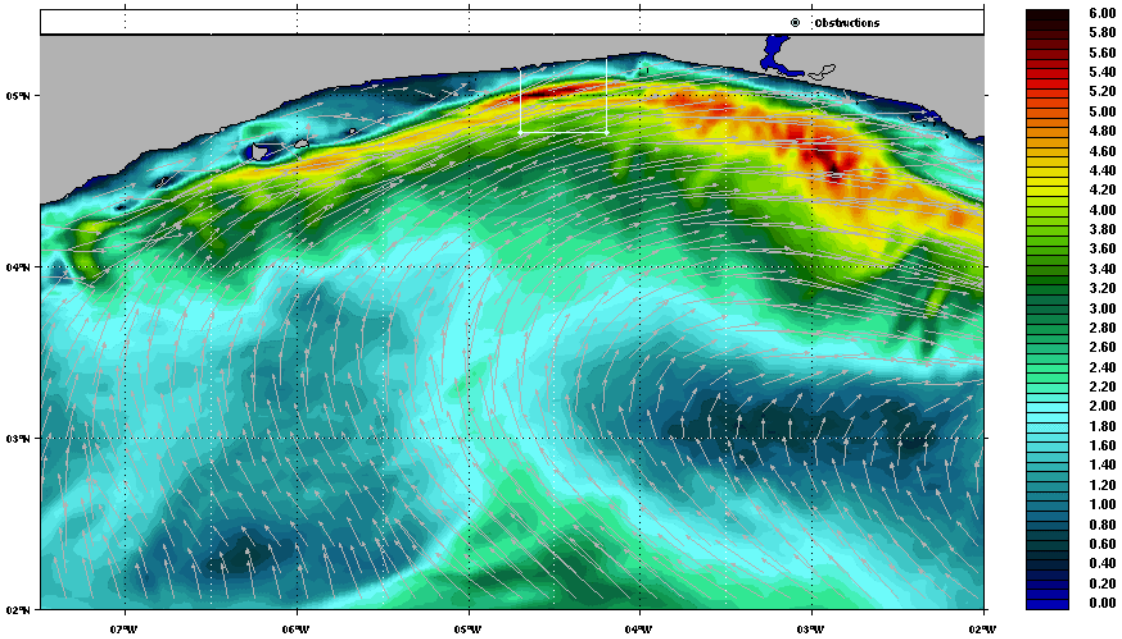


Figure 3: SAT-OCEAN surface currents (knots) predictions

Advanced routing services

For the mobilization of the Saipem 3000, SAT-OCEAN also delivered advanced routing services based on high resolution current forecasts. This innovative service consists in the daily computing of the most cost-effective route based on vessel characteristics and updated waves, winds and currents forecast. The ship receives every day a report including waypoints from last known position as well as complete route statistics (downwind, extreme conditions, ETA).

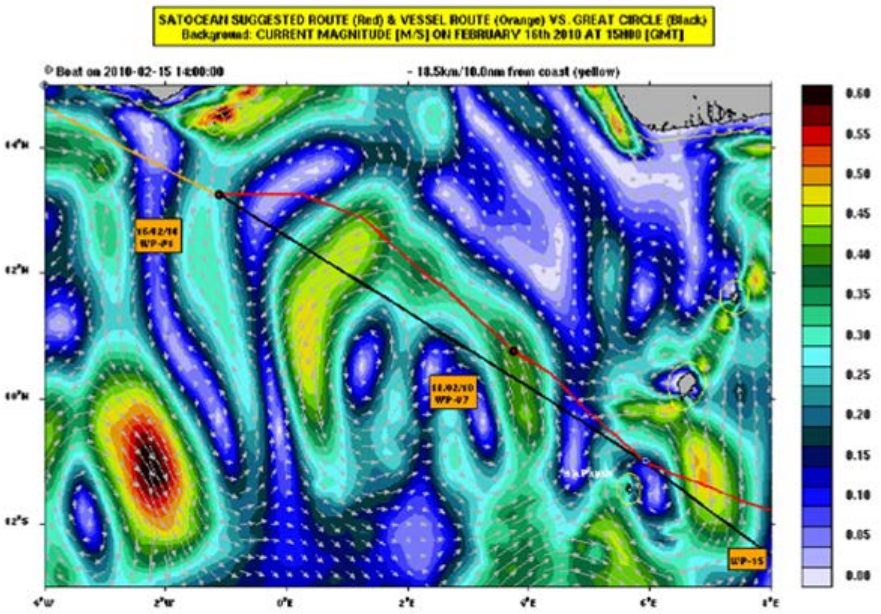


Figure 4: SAT-OCEAN suggested route in Gulf of Guinea

"The data provided by SAT-OCEAN proved very helpful, allowing us to steer clear of some unfavorable strong current pockets and take advantage of inline currents and winds" says Martin Amos, Master Saipem 3000.

The post voyage analysis comparing SAT-OCEAN suggested route to the Great Circle route showed a time saving of 17 hours for the voyage from Pointe Noire to Abidjan. Similar benefits were observed on the way back.

"For an installation in such a challenging offshore area, we clearly needed a trusted Metocean provider to support the operation planning and monitoring. SAT-OCEAN models proved quite accurate in the region. Furthermore, their capacity to also provide "current aware" routing for the various voyages of the S3000 in the Gulf of Guinea made them the perfect partner." says Guillaume Winckler, Project Manager – Saipem SA