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Container Drift Assessment

IROISE Sea Experiment

Sar-Drift Project

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Novembre 2008

SUMMARY

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1. Introduction

The SAR-DRIFT project [1] aims at developing a forecast system for localisation of drifting objects, as well as decision aid tools for Maritime Search and Rescue. Its basic principle is to predict the position of drifting objects, when combining environmental measurements and forecast through sophisticated stochastic modelling.

Among the different tasks of the project, one is to assess the hydrodynamic behaviour of various objects drifting at sea when submitted to the joint action of wind, waves and currents.

Thousands of cargo containers are reported to fall overboard each year. A significant part of these containers will stay afloat from several hours to several weeks and represent a major hazard to navigation.

In order to evaluate the drift coefficients of such cargo containers, trials were conducted at sea during which a 20 feet container was let adrift for 24 hours while measuring environmental parameters.

Experimental set-up and operational process are described in this report. Main results on evaluation of the behaviour of the drifting container are also presented.

2. Experimental set-up

2.1. Container

Trials were carried out with a regular 20 feet cargo container (Maisondieu, 2008).

The container was equipped with 24 PEHD barrels, fixed under the ceiling, to guarantee its buoyancy. Total additional buoyancy was 5.75 m^3.

440 kg of weights were added and evenly placed on the floor for stability.

Apertures were made on both floor and ceiling in order to allow water filling when dropping the container. Total area of apertures on the floor was 1.5 m2, about 10% of the total floor surface. Such size of apertures would allow quick water filling of the container while minimizing water flow in and out of the container as well as alteration of dynamic pressure on the bottom.

With such an arrangement, the container was set to float horizontally with a draught of about 2m (80% of total height).

Additionally, the container was equipped with a canister containing electronic devices, batteries and recorders for the measurement of its dynamics and of the environmental parameters. This canister was placed at ceiling level.

Figure 1 : Container's buoyancy

Main characteristics of the equipped container are summarized in table 1 hereafter.

Net weight (kg)	2272
Total weight (kg)	2897
Zg (m) in water (from bottom)	1.29
Length (m)	6.06
Beam (m)	2.44
Height (m)	2.59

Table 1: Main characteristics of the container

2.2. AIS Transponder

The container was equipped with a Class B AIS transponder (Trueheading CTRX) which provides position over ground, measured by GPS. The Automatic Identification System was chosen for the trial because not only it permits the continuous recording of the container's position but also it allows all vessels in the surroundings to be aware of the presence of the object, preventing as much as possible collision hazard (AIS signal was reported by Ouessant RCC on Tuesday 23rd in the morning as distance was about 18 nautical miles).

Position was recorded at a rate of 1 Hz. Because of the small elevation of the antennas above sea surface accuracy on the container's position was about 10 m.

The sampling period used for analysis is 20 minutes. With such a period and considering an average drift speed of 0.7 knots, the maximum error on the container's drift is about 6 %.

MMSI number provided by the French navy for the duration of the trials was 2279955.

2.3. Currentmeter

Position over ground or speed over ground of the container provided by the AIS is not enough for drift evaluation. It is necessary, in order to evaluate the leeway, to measure the flow relative to the container, that is the drift component due to wind and waves.

In order to measure this flow, the container was equipped with a currentmeter (Nortek Aquadopp).

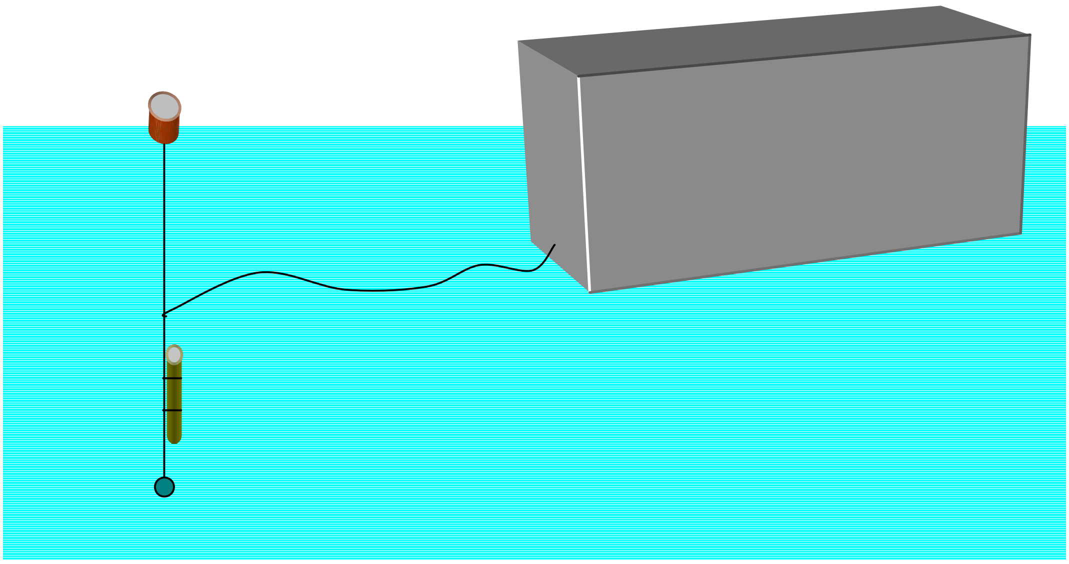


Figure 2 : currentmeter arrangement

The currentmeter was neutrally buoyant. It was attached to the container by a 20 m leash. It was mounted on a line ended by a float at its upper extremity and by a 3 kg weight at the bottom. Drag of the currentmeter was partially compensated by wind action on the buoy and could be anyway considered negligible compared to the container's inertia. Measurement cell of the currentmeter was approximately 3 m below mean water surface.

Only horizontal components of the flow were recorded. Measurement sampling period was 5s. Data were then averaged over 5 minutes intervals. Accuracy on flow velocity measurement is 1.1 cm/s.

2.4. Anemometer

Local wind was measured by mean of a sonic anemometer fixed to a rigid mast vertically mounted on top of the container.

The anemometer provides wind speed and direction in its own referential. In order to get the absolute wind direction, the anemometer was coupled with the compass of the Motion Record Unit embarked on-board the container.

Record sampling rate was 1 Hz. Wind data were then averaged over 10 minutes periods for analysis.

2.5. Motion Record Unit

The dynamics of the container was measured by mean of inertia sensors. Integrated 3D accelerometers and gyroscopic sensors allow measurement of the six degrees of freedom of the container for comparison with tests carried out on scaled models at the Ifremer wave tank.

Record sampling rate was 1 Hz.

Results regarding dynamics of the container are not presented in this report.

2.6. Argos beacons

In addition to the sensors placed on-board the container, a couple of marking devices were attached to the container. These markers basically consisted in Argos beacons placed on buoys leashed to the container and providing a record of the containers location every 20 mn.

Figure 3 : Instrumentation and markers

These markers were developed by the members of the "Lost cont" project and by the French navy. They provided a back-up to the AIS position record.

2.7. Additional safety equipment

The container was also equipped with flash lights and radar deflectors placed on the mast of the anemometer. Both systems proved not to be efficient enough for detecting the container in a long distance.

2.8. Additional environmental measurement

On top of the parameters recorded by the equipment placed on-board the container, current and wave data were obtained from two different measurement devices available on the site of the trials.

2.8.1. HF Radars

Trials were conducted over the Iroise sea area where HF radars owned by SHOM[1] are operated and processed by Actimar for operational oceanography purpose.

These radars provide real time measurements of surface currents and wind on ranges of more than 150 km**.**

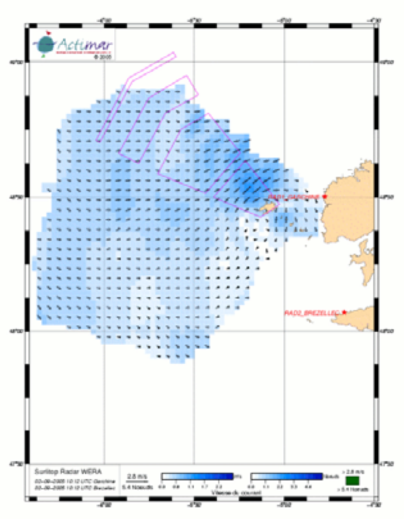


Figure 4 : Example of HF radars measurement area

Data provided by these radars were used for validation of the SAR-Drift forecast model.

[1] HF Radars data were used with the kind authorisation of SHOM (Service Hydrographique et Oceanographique de la Marine), owner of the radar system.

2.8.2. Wave Buoy “Les Pierres Noires”

Wave data was obtained from the Previmer datawell wave buoy « Les Pierres Noires » (02911) operated by CETMEF (www.previmer.org).

The buoy is located at the point : 48°17’25.8” N, 4°58’5.88” W

It provides spectral parameters every 30 minutes :

SWH : significant Wave Height (m),

Tp : Peak Period (s),

Tm : Mean Period (s),

Dir : Direction at peak frequency (°),

S : Directional spreading

3. Trials

Trials were carried out on September 22nd and 23rd 2008 in the Iroise sea.

3.1. Trials Site

Trials took place in the Iroise sea, off-shore Brest. This area was chosen for its vicinity to Brest harbour where the supply vessel used for the experiment is based and where all technical support was available for preparing the experiment.

Additional reasons for choosing this area is that it is covered by the HF radars for measurement of currents and wave data from a directional wave buoy was also available.

3.2. Supply vessel

Trials were conducted on-board BSAD Alcyon. This supply vessel is chartered by the French authorities for counter-pollution operations and is adequately fitted for deployment and recovery operations of the container. Main characteristics of the vessel are :

- Length : 53,01 mètres
- Beam : 13,31 mètres
- Draught : 6,75 mètres
- Displacement : 1.500 tons
- Speed : 14 knots
- Bollard pull : 64 tonnes
- Crane : 23 tons

Figure 5 : BSAD Alcyon

3.3. Deployment and recovery operations

Deployment of the container was a rather straightforward operation. Weather conditions were mild with a rather long swell travelling from northwest and light north-easterly wind (20 kts).

The container was placed on the aft deck of the Alcyon just at the edge of the open stern. A cable was then passed behind the container so that it would push it over-board when tensioned by a winch. It took about one minute for the container to fill up and stabilize at its nominal draught.

Figure 6 : Container on the aft deck before deployment

The container was deployed at the position 48°15’23.3”N, 5°9’48.63” W, at 13h00 UTC, in the southern part of the area covered by the radars, in order to stay away from the main shipping lanes around Ushant island.

Once the container in the water, Argos beacons were attached by mean of magnets. This operation was made by divers on-board the MOB and took about 15 mn. The container was then let free to drift.

For safety reasons, the supply vessel remained watching the container in close vicinity, especially at night, staying downwind in order to avoid wind masking.

Recovery operations were slightly more difficult. Sea-state conditions were slightly harsher than during deployment and wind over 25 knots.

Recovery operations required divers to hook towing lines to the lower corners of the container. This hooking operation was a rather difficult and risky task because of the large heaving amplitude of the container in waves (in order to avoid this problem in future trials, the container should preferably already be equipped with a cable or bridle to which the towing line could be hooked).

Once the line hooked, the container was towed and winched on-board the supply vessel. Apertures on the floor allowed quick lightering of the container which could be towed on the deck without bending.

Container was recovered on September 23rd at the position 48°13’04.80” N,

5° 25’29.99” W at 13h00 UTC. Total drift duration was 24 hours.

Figure 7 : Drifting container

Figure 8 : Container's recovery

4. Results

Main results of data analysis are presented in this chapter.

It must be noted that because of a leakage, the canister was partially filled with water and after about seven hours, part of the electronic was out of order. Thus, wind data from the anemometer and AIS position are only available for the first five hours. The full trajectory of the container over the 24 hours is then recovered by completing the AIS data set with records of the position provided by the SASEMAR Argos beacon.

The currentmeter, which was autonomous, worked well and provided data over the 24 hours of the trial.

4.1. Environmental data

4.1.1. Wind

Wind data retained for analysis is the one measured by the anemometer placed on-board the container. This measurement is only validated for the 5 first hours of the experiment because of problems with the electronics. Anemometer was fixed to a mast placed on top of the container, at an elevation of about 2.35m above the still sea surface. In the following, the wind velocity is adjusted to its equivalent value

at 10 m following Large&Pond (1981) formulation and averaged over 10 mn intervals.
The 10 m value is used in the definition of leeway coefficients because it is the parameter usually available from forecast models.

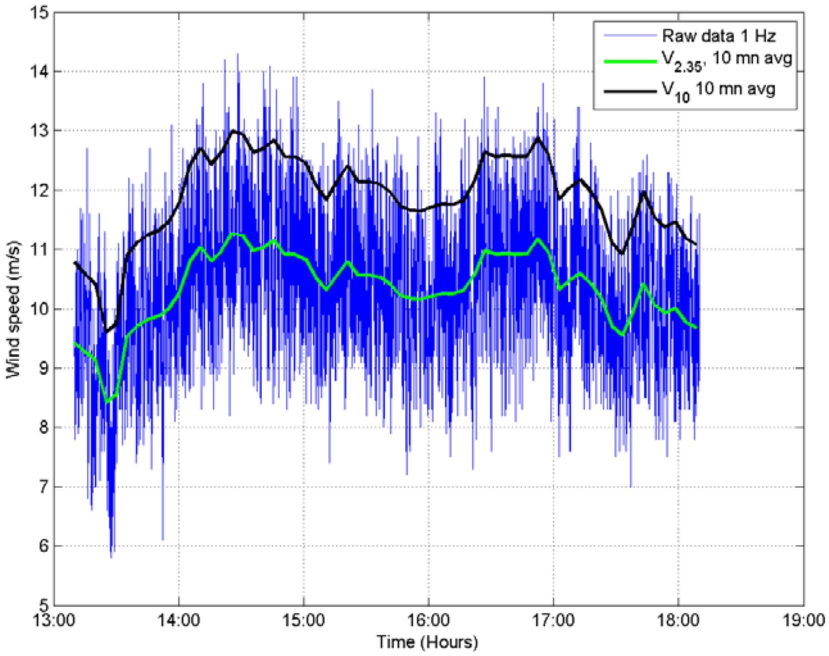


Figure 9 : wind velocity over 5 first hours

Wind speed (m/s)	Mean	Standard Dev.	Max	Min
Raw (1Hz)	10.35	1.176	14.3	5.8
$V_{2.35m\ 10mn\ avg}$	10.34	0.63	11.27	8.42
$V_{10m\ 10\ mn\ avg.}$	11.87	0.74	12.99	9.60

Table 2: Wind speed parameters

Wind dir (°)	Mean	Standard Dev.	Max	Min
Raw (1Hz)	71	11.1	111	24
$V_{20mn\ avg}$	71	4.4	77	60

Table 3 : Wind direction parameters

Wind was north-easterly and on average 23 knots (V_{10m}) during the 5 first hours, slightly lower during the deployment and the first hour.

From observations and logbook it was noted that wind direction remained north-easterly during the whole duration of the trial at about the same speed, slightly lower during the night and early morning on the 23rd.

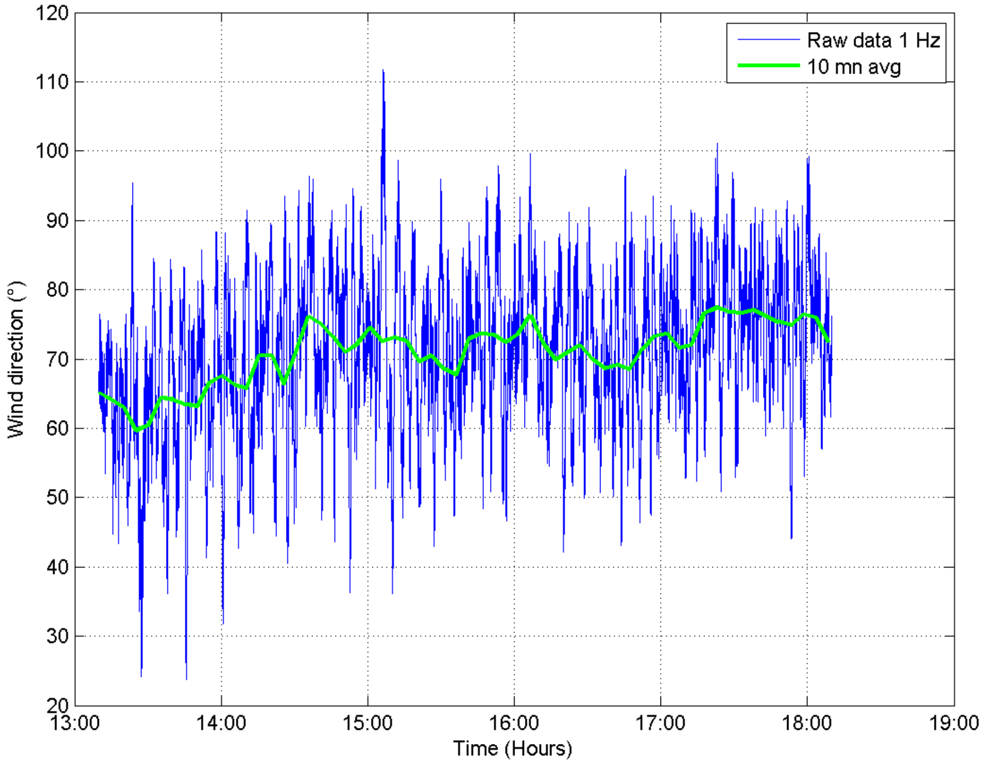


Figure 10 : Wind direction over 5 first hours

4.1.2. Wave data

Global sea-state parameters are obtained from spectral data recorded by buoy 02911.

Sea-state was dominated by a rather long swell (Average Peak period = 13.1 s) travelling from west-northwest (Average peak direction = 284°). Significant wave height was on average 1.5m over the duration of the trial. It was slightly below one meter during deployment and first hours and then grew up to about 1.8 m as the wind picked up in the afternoon, reaching a maximum of about two meters during the night.

The minimum observed in the peak period (Figure 11), coupled with a change in direction, at 14h50 UTC corresponds to a situation where the total spectrum is dominated by the north north-easterly wind sea (even though swell is still propagating).

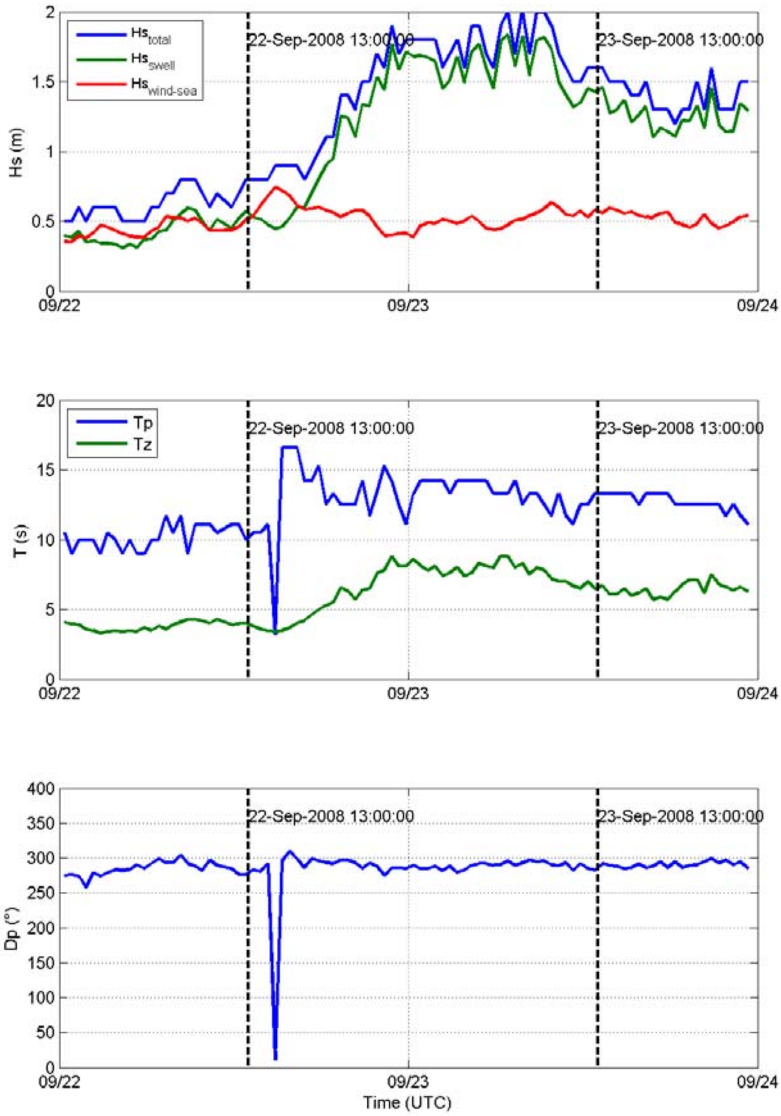


Figure 11: Wave parameters from buoy 02911

Analysis of power spectral densities at each time step over the duration of the trial shows that the sea-state is in fact the superimposition of a swell from west-northwest with an average significant wave height of about 1.33 m and a wind-sea, driven by the local north-easterly wind, with an average significant wave height of about 0.54 m. In this analysis and because whole directional spectra were not available, swell energy is associated with components at frequencies below 0.15 Hz (T>6.67 s) while wind-sea is constituted of components of higher frequencies, above 0.15 Hz.

This spectral depiction of the sea-state is in agreement with observations made on-board.

Power spectral densities plotted for different times on figure 12 show the existence of the wind sea part of the sea-state, in the range of the higher frequencies.

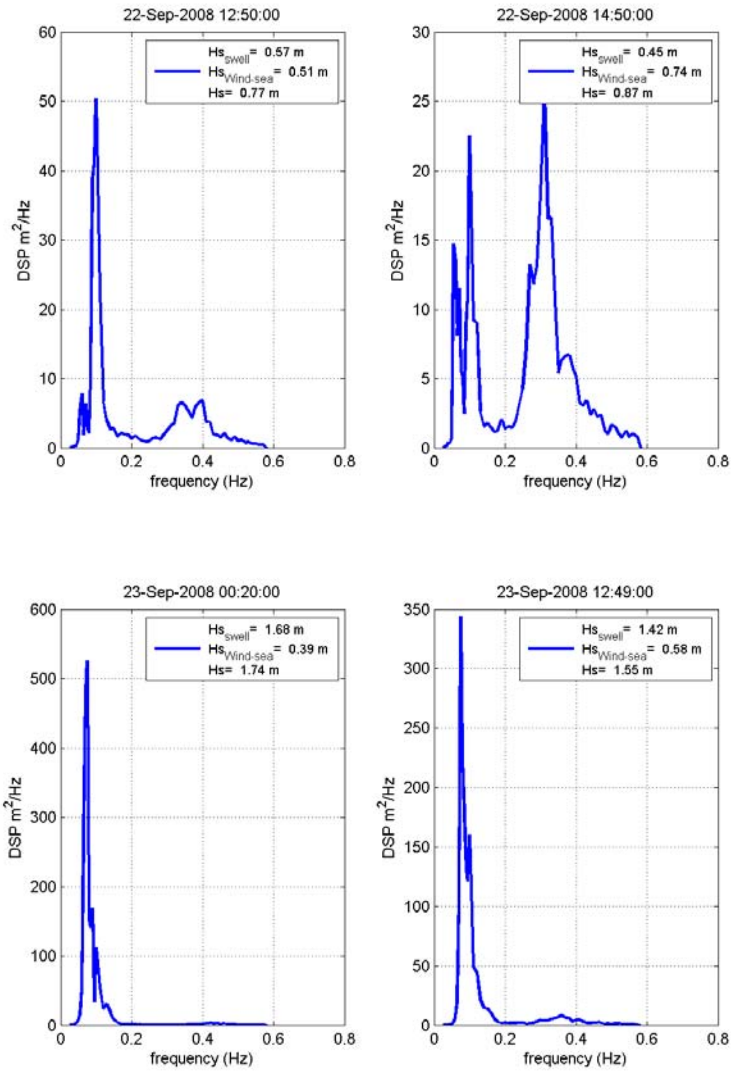


Figure 12 : Wave Spectra

4.2. Container's drift analysis

4.2.1. Container's trajectory

During the 24 hours of the trial, the container drifted for 16.83 nautical miles at an average speed of 0.7 knts (0.365 m/s).

As can be seen on figure 13, even though the main drift direction is towards the west, the trajectory is also influenced by tidal currents (tidal flow being globally oriented south during ebb and north during flood).

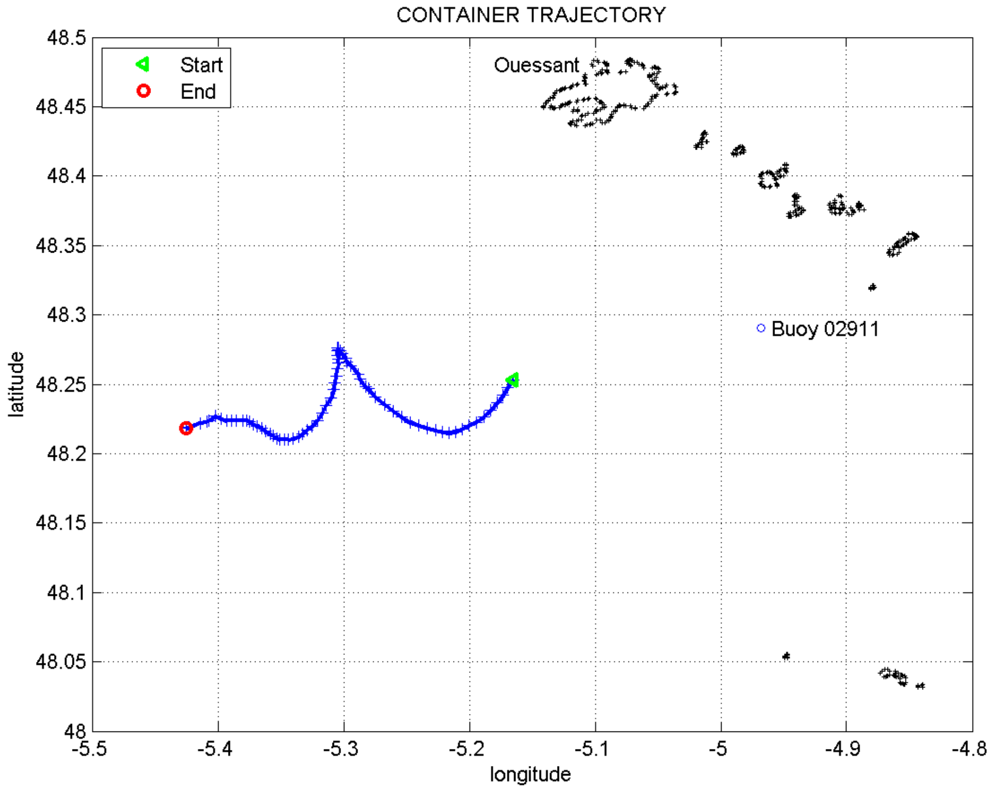


Figure 13 : Container's trajectory

Date	Latitude	Longitude
Start : 22-Sep-2008 13:10:33 (UTC)	48°15'11.21" N	5°09'55.43" W
End : 23-Sep-2008 13:00:00 (UTC)	48°13'04.80" N	5°25'29.99" W

Table 4: Drift starting and ending positions for analysis

This result is confirmed by figure 14 where total drift speed and leeway speed are superimposed.

Leeway speed is the speed of the container relative to the water, component of the drift due to the action of wind and waves on the container and counterbalanced by drag forces. Its amplitude is actually the one of the flow as measured by the currentmeter attached to the container.

Total drift speed is the speed over ground derived from the AIS positions.

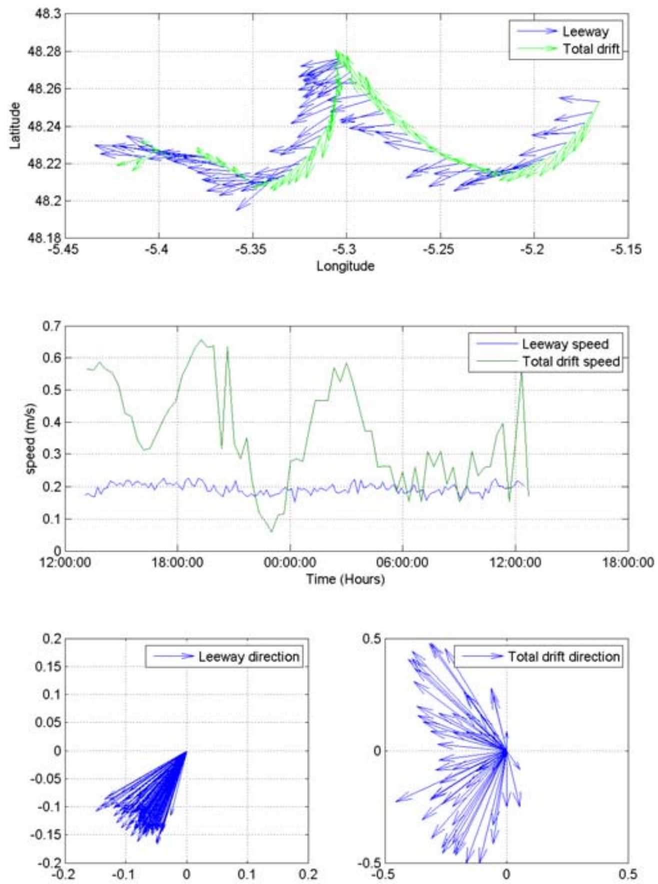


Figure 14 : Drift Speed

As can be seen on figure 14 (middle plot), leeway speed is relatively steady at an average value of 0.195 m/s (standard deviation : 0.016 m/s), while total speed oscillates with a larger amplitude (mean speed : 0.365 m/s, standard deviation : 0.16 m/s) and a periodicity of about six hours corresponding to the tidal mode.
Minimal drift velocity (0.059 m/s) is observed at 23h00. This corresponds to the time when the container reaches its northernmost position along the track.
It is observed that the average leeway speed is only 53 % of the average total speed.
Hodographs (lower plots) clearly show that leeway direction is restricted to the south to west quadrant as a result of the action of the northeasterly wind and wind-sea while total drift directions are spread all over the south to north sector because of the influence of the tidal currents.

4.2.2. Comparison with the SAR-Drift forecast model

A forecast model for drift of objects at sea was developed by the partners of the SAR-Drift project. Algorithms developed in this model are based on a stochastic approach and combine metocean forecast and climate data with advanced models of the hydrodynamic behaviour of drifting objects.
Details on drift computation methods are given in Pavec, 2008. What should be noted here is that the static method used in the model is different from the existing

Leeway method (Breivik, 2004) in the sense that drag forces and drift speed are evaluated at each time steps considering the object at equilibrium.
This model was already tested for a container using data from the Dourvarc'h experiment (Aoustin 1991, 1992) and for an oil drum using data from SAR-Drift Fedje experiment (Roth, 2008).

A calibration/validation study[1] of the SAR-Drift model was then carried out using drift data of the container recorded during the Iroise sea trial.

Trajectories of the container obtained from the model for different configurations are plotted on figure 15 together with the observed trajectory.

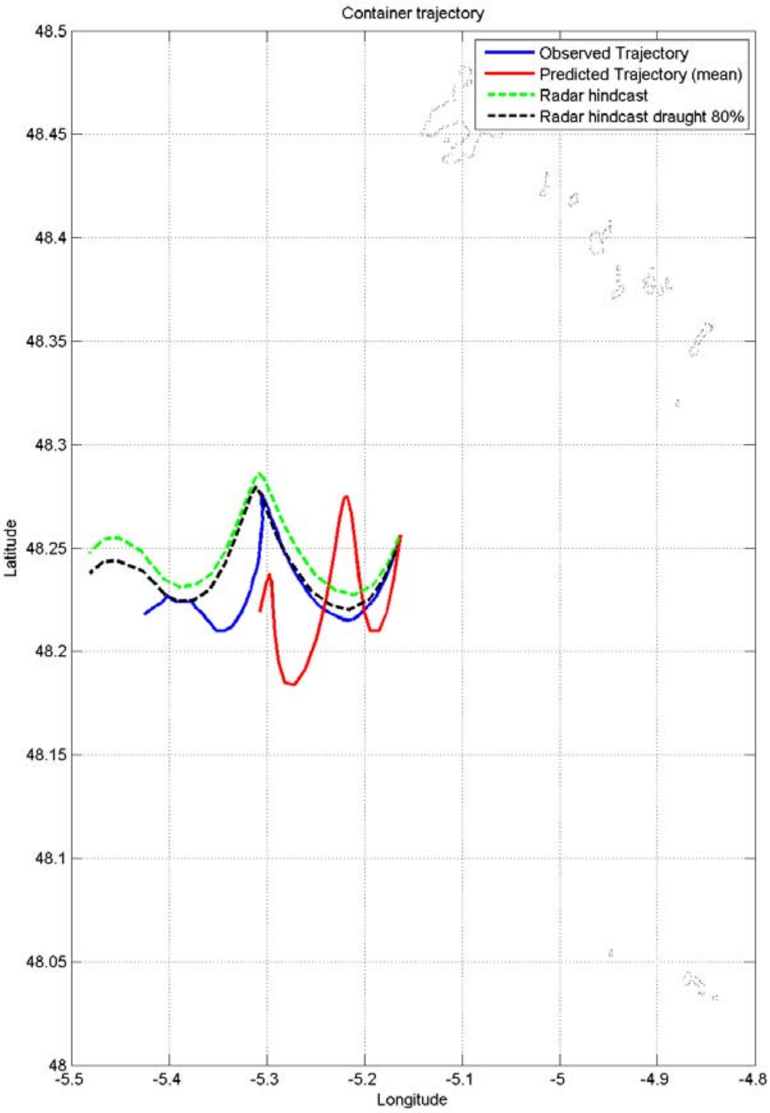


Figure 15 : Drift model trajectories

[1] All results from the forecast model presented in this document were provided by Actimar.

Stochastic approach used in the model is based on MonteCarlo method. Basically, each drift simulation is run for a large number of containers, each with slightly different characteristics depending on uncertainties on different parameters (such as initial time and location, draught…). The predicted trajectory is then obtained by evaluating at each time step the location corresponding to the highest probability of presence of the container (highest density).

A first simulation (red) is run using wind and current from weather forecast models. Comparison with observed trajectory (blue) show that even if influence of tidal currents is clearly visible, the model does not correctly predict the drift towards the west. Total distance covered by the container in the simulation is 18.13 nautical miles, 8% longer than the observed trajectory. Distance to observed location after 24 hours is 4.72 nautical miles (figure 16).

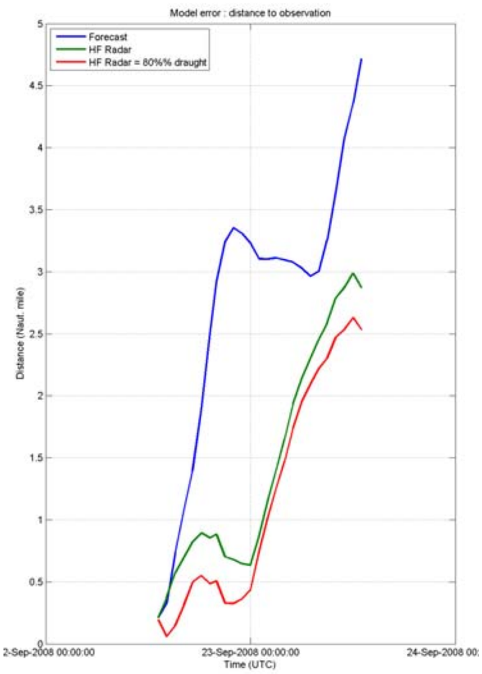


Figure 16 : Time evolution of distance to observation

A second simulation (green) is run replacing current forecast data with current data measured by HF radars. Even though this simulation can only be run in hindcast mode since radar data is only real-time or near real-time data, results are interesting because they show a great improvement in the evaluation of the container's trajectory, especially for the first 12 hours.

Finally a third simulation (black) is run using current data measured by HF radars (hindcast) and fixing the container's draught to its nominal value of 80% (no uncertainties on this parameter). Best agreement with observed trajectory is observed in this case, simulation being very accurate for the first 12 hours with an error less than 0.55 nautical mile. Error on position at the end of the trial is in this case reduced to 2.53 nautical miles.

It should be noted that for the present simulations, since deployment time and position were known, no uncertainty was applied on these parameters.

Environmental data used for the simulations were Previmer data for the current and Actimar (WRF model) for the wind.

4.2.3. Influence of draught

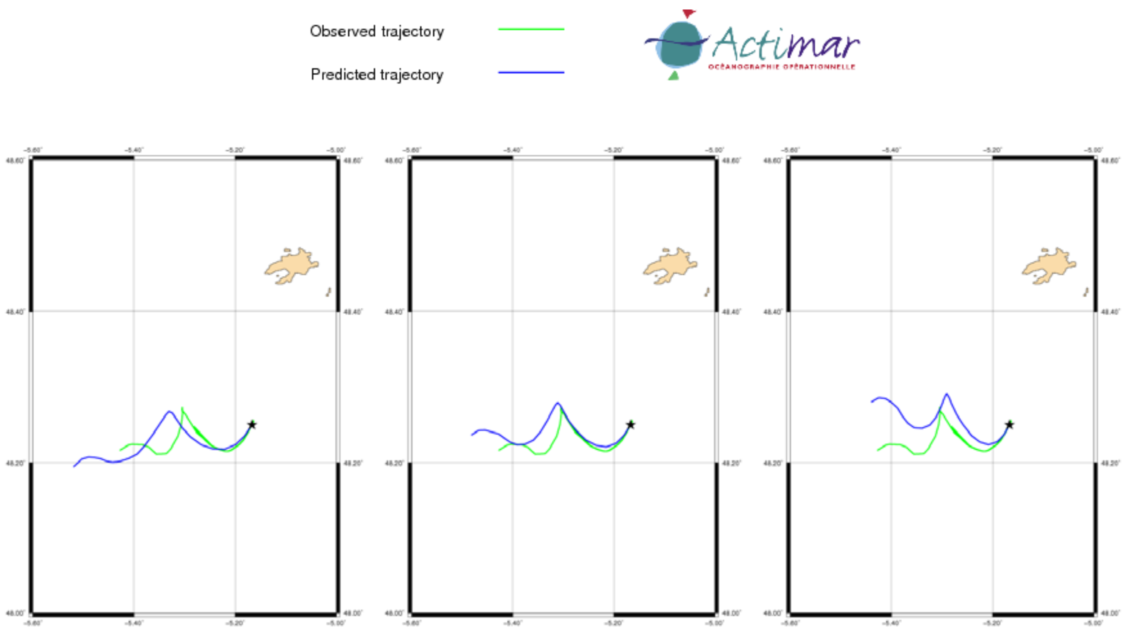
Container's draught is an important parameter for drift evaluation since it characterises ratio of wind forces to current/waves forces.

A study was carried out to evaluate the sensitivity of the forecast model to the draught.

Three simulations were executed using each time the same environmental input data (HF radar current) but fixing the draught to three different values, respectively 70%, 80% and 90% of the container's total height. 80% corresponding to the actual container's draught during the trial.

Results for the 3 simulations are plotted figure 17. In the 70% case, container's cross-section submitted to wind is larger. Forces due to the north-easterly wind are then stronger and the general trend of the drift is slightly more to the south than the observed trajectory. In the 90% case drift is dominated by currents and mean direction is orientated slightly more towards the north compared to observation.

80% case shows the best agreement with the observed trajectory.



Draught 70% Draught 80% Draught 90%

Figure 17 : Model sensitivity to container's draught

All these results show the ability of the model to correctly evaluate and describe the drift of a container submitted to combined action of wind, waves and currents and its sensitivity to parameters such as draught. They also point out the fact that good quality environmental forecast data is crucial for an accurate drift estimation.

4.3. Leeway parameters

Drift properties of an object are generally characterized by the leeway coefficients evaluated according to the leeway definition given by Allen & Plourde (1999) :

"Leeway is the velocity vector of the SAR object relative to the downwind direction at the search object as it moves relative to the surface current as measured between 0.3m and 1.0m depth caused by winds (adjusted to a reference height of 10m) and waves."

4.3.1. Assessment of leeway

Data set used for evaluation of leeway is built from records of AIS, anemometer and currentmeter on-board the container between 13h00 UTC and 18h10 UTC on September 22nd, before electronics break-down.

All data in this analysis are averaged over 10 mn from raw records. Wind velocity is adjusted to its equivalent value at 10 m following Large&Pond (1981) formulation.

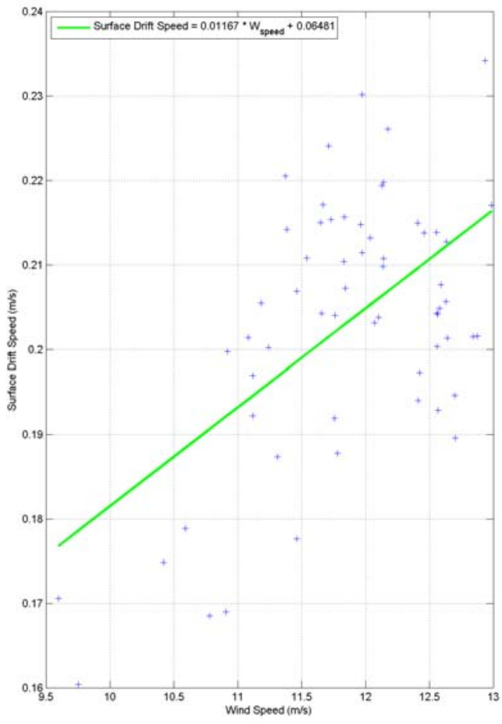


Figure 18 : Leeway speed

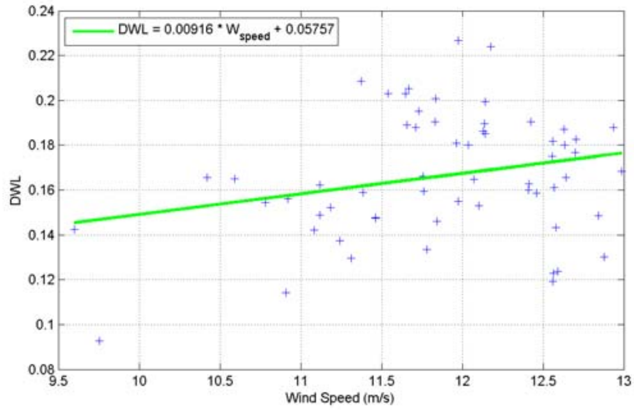
Over the range of wind velocities measured during the trial, which is rather narrow [9.5 m/s – 13 m/s] leeway speed is relatively scattered. One can still identify one linear relationship showing that leeway speed is only 1.16 % of wind speed, with a 6.48 cm/s off-set.

4.3.2. Leeway coefficients

Leeway coefficients are components of the leeway speed evaluated in the wind referential. These coefficients are to be implemented in the forecast drift model.

Results of evaluation of CWL and DWL as functions of wind speed are given figure 19.

$$CWL = L_{speed} * \sin(\theta) \qquad \theta = \theta_{drift} - \theta_{wind}$$
$$DWL = L_{speed} * \cos(\theta)$$



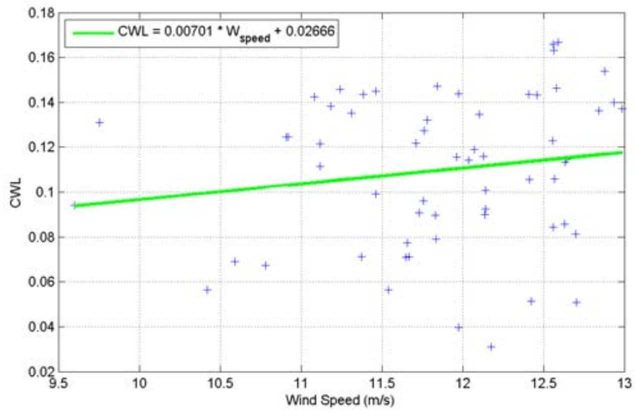


Figure 19 : Leeway coefficients

Leeway Speed		DWL		CWL	
Slope (%)	Off-set (m/s)	Slope (%)	Off-set (m/s)	Slope (%)	Off-set (m/s)
1.167	0.06481	0.916	0.05757	0.701	0.02666

Table 5: Leeway coefficients as functions of wind speed in m/s

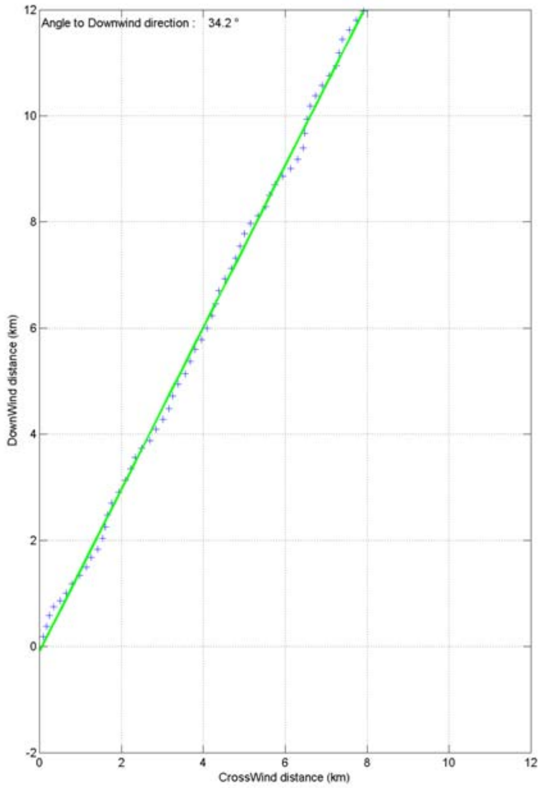


Figure 20 : Progressive Vector Diagram

The progressive vector diagram plotted figure 20 shows the trajectory of the container in the wind referential. This PVD shows that over the duration of the record, the container drifted in a steady direction at 34.2° on average to the downwind direction. Even though small changes in direction can be noticed, no jibing was observed during the trial.

5. Conclusions

Trials for evaluation of drift properties of a 20 feet container were conducted in the Iroise sea on 22nd and 23rd of September 2008.

A container equipped with measurement devices for recording of environmental parameters and position was let adrift for 24 hours.

Analysis of data allowed evaluation of leeway coefficients for the case of moderate winds to be implemented in drift forecast models.

Comparisons with results provided by the SAR-Drift forecast model showed the ability of the model to correctly predict container's drift providing that environmental forecast data are accurate. It also showed the sensitivity of the model to the draught of the container.

6. Acknowledgement

Partners of the SAR-Drift project whish to thank the partners of the LostCont Interreg project, for allowing to join their experiment program. Especially they would like to thank “Action de l’Etat en Mer” services, CEDRE and SASEMAR for their great support in the organisation and follow-up of the trials.

SAR-Drift partners also whish to thank the French navy for its operational, technical and administrative support, as well as the crew on-board BSAD Alcyon for their dedication and skills.

Les partenaires du projet SAR-Drift souhaitent remercier les partenaires du projet Européen Interreg LostCont pour leur avoir permis de se joindre à leur programme expérimental et plus particulièrement les services de l’Action de l’Etat en Mer, le CEDRE et SASEMAR pour leur important soutien dans l’organisation et la mise en œuvre de ces essais.

Les partenaires du projet SAR-Drift souhaitent également remercier la Marine Nationale pour son soutien tant administratif que technique et opérationnel, ainsi que l’équipage du BSAD Alcyon pour son accueil, sa compétence et son efficacité.

SAR-Drift project was supported by:

- French-Norwegian Foundation,
- Norwegian Research Council (NRC),
- Agence Nationale pour la recherche (ANR)
- OSEO/ANVAR

SAR-Drift partners are :

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