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PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

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0.2	26/11/2013	Update and correction	E. Greiner (CLS)

SUMMARY

The overall objective of SIDARUS is to develop and implement a set of sea ice downstream services in the area of Marine Safety, Marine and costal environment, and Climate and seasonal forecasting. The products to be developed are high-resolution sea ice and iceberg products from SAR, sea ice albedo, sea ice thickness, sea ice habitat conservation and ice forecasting.

The Icebergs Monitoring Service, as developed by CLS, is based on satellite technologies for iceberg detection, on numerical modeling for icebergs drifting, and GIS/web server for the visualization of the ice reports. In the proposed approach, the altimeter-based detections can be used as a first guess to identify possible icebergs infested areas which are then imaged by high resolution SAR images.

In this deliverable, the iceberg drift model is outlined and some examples in Antarctica and Arctic Sea are given.

SIDARUS CONSORTIUM

Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Nansen Environmental and Remote Sensing Center	NERSC	NO
2	Alfred Wegener Institute for Polar and Marine Research	AWI	D
3	Collecte Localisation Satellites SA	CLS	F
4	University of Bremen, Institute of Environmental Physics	UB	D
5	University of Cambridge, Department of Applied Mathematics and Theoretical Physics	UCAM	UK
6	Norwegian Meteorological Institute, Norwegian Ice Service	Met.no	NO

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPLICABLE DOCUMENTS

D5.3 “Report on SAR analysis”, WP5, SIDARUS project
D8.3 “Final report on integration and validation”, WP8, SIDARUS project
D9.11 “Report on demonstration no. 1 and service utility”, WP9, SIDARUS project

LIST OF REFERENCES

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Kubat I., Sayed M., Savge S.B., Carrieres T., Crocker G., ”An Operational Iceberg Deterioration Model”, Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference, Lisbon, July 1-6, 2007.

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N. Longépé, F. Mercier, E. Greiner, M. Sutton, F. Lefèvre, A. Salman, ”Iceberg Monitoring Service for Offshore Oil Rig Safety by Spaceborne Radar Technologies and Drift Modeling”, Society of Petroleum Engineers, Conf Russia Oct., 978-1-61399-284-5, 2013

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LIST OF ABBREVIATIONS

ASAR	Advanced Synthetic Aperture Radar
AVISO	Archiving, Validation and Interpretation of Satellite Oceanographic data
CLS	Collecte Localisation Satellites
CNES	French Space Agency
GIS	Geographic information system
MC	Monte Carlo
NIC	Naval Ice Center
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
SAR	Synthetic Aperture Radar

1 Introduction

The overall objective of SIDARUS is to develop and implement a set of sea ice downstream services that will extend the present GMES services with new satellite-derived sea ice products. All the SIDARUS products are to be validated with in situ or with data from other satellites. Some validation activities will be documented in the appropriate deliverables of WP4, WP5, WP6 and WP7. The objective of this document is to provide a status on the activities carried out in the frame of WP8 “Data integration and validation”.

Especially, SIDARUS should demonstrate new services and products in response to needs of users with responsibility to track iceberg in Antarctica and arctic seas. The Icebergs Monitoring Service, as developed by CLS (see Longépé et al. 2013), is based on satellite technologies for iceberg detection, on numerical modeling for icebergs drifting, and GIS/web server for the visualization of the ice reports. The idea is to provide on a regular basis an Icebergs Situation Map giving the icebergs conditions in real time and in a few days forecast. The chain is described in the SIDARUS deliverable D9.11. Three levels of surveillance are defined in the developed icebergs’ services depending on the user‘s requirements for ice management:

- Surveillance mode: monitor the whole area and provide a seasonal surveillance of the ice and icebergs conditions by using altimetry and medium-resolution SAR imagery every 2-3 days: production of weekly bulletin
- second level if icebergs are entering a Warning area closed to the area of interest by using daily medium-resolution SAR imagery: production of daily report
- Icebergs are entering the Critical area (e.g. 7-day interval between the icebergs and the platform): late SAR images programming enabled.

The drift model is a requisite for the implementation of the above surveillance levels, and is detailed in the following sections.

- Section 2 outlines the drift model and its main functionalities
- Section 3 shows how the drift modeling has been validated
- Section 4 explains the use of drift model in operational context
- Section 5 describes how iceberg simulation in Arctic seas could be used in near future to constrain SAR-based iceberg detection scheme.

2 Iceberg drift model

CLS has developed and maintains a suite of drift models named MOBIDRIFT, addressing 4 types of applications for Icebergs, Oil spills, Search and rescue and containers.

2.1 Introduction

MOBIDRIFT is an operational model, as demonstrated initially during the last Vendée-Globe (2008-2009) round the world sailing race, to forecast the movements of icebergs. The 2012 edition of the Vendée Globe showed again a great confidence in the CLS service using radar imagery and altimetry for iceberg detection and Mobidrift for the iceberg drift modelling.

MOBIDRIFT is able to model the following behavior of the iceberg: advection, thawing, rolling over, dislocation and generation.

The drift model is forced with environmental data to calculate the impact on the iceberg:

- Wind speed data
- Surface current and deep-layer current data
- Tidal current data (optional)
- Sea surface temperature data (for thawing)
- Sea state data (optional)
- Bathymetry data (for the particle grounding)

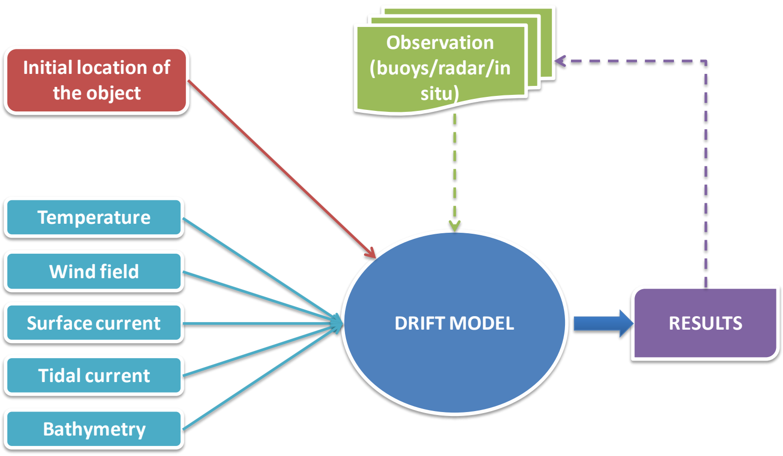

Figure 1 : Drift model schematic

MOBIDRIFT can be used with an ensemble mode (Monte-Carlo algorithm) which allows a probabilistic approach of drift modeling. The iceberg is then represented as an ensemble of probabilistic particles. There are two ways of activating the MC algorithm. First, perturbations can be added to the initial position, in case of uncertainty on the initial situation: range of initial time, uncertainty radius around the location. Secondly, perturbations can be added on the weather and oceanographic data, to account of the uncertainty on weather and ocean forecast models.

Real observations (in situ observations, satellites observations…) of the icebergs can be used in real time to re-adjust the icebergs positions during the model simulation (optional).

2.2 Parameterization of the drift model: Some thermo-dynamic aspects

All along their displacements, icebergs are degraded by external phenomena, decreasing their masses and as a result modifying their trajectories. Several processes should be parameterized to model their degradation: surface thawing by incoming solar fluxes, ”basal” and ”lateral” thawing, erosion from waves, calving, dislocation and stability. Each process, except calving, is modeled by a variation rate, its amplitude depending on iceberg morphology and temperature. In this model, the effect of solar radiation is neglected (few cm/day according to Veitch et Daley).

Basal melting can be associated to a convective heat transfer (Kubat, 2007), it impacts the bottom and lateral facets of the icebergs. It depends not only on the temperature difference between the iceberg and its surrounding water, but also on its relative speed. The faster an iceberg moves, the more its environment changes, loosing its ”protecting” cold skin.

Thawing due to convective force is relatively similar to basal thawing. The relative velocity between iceberg and oceanic current contributes to the thawing of the underwater portion of the iceberg. Wind effect, lateral thawing, erosion by waves and dislocation are also taken into account in the modeling.

2.3 General advection scheme

The advection of icebergs follows the below equation:

$$M\frac{dv_i}{dt} = -M.f \wedge v_i + F_a + F_w + F_s + F_p + F_r$$

with :

- M : its mass
- vi : its velocity
- M .f∧vi : Coriolis force
- Fa : drag force due to wind
- Fw : drag force due to oceanic current
- Fs : drag force due to sea ice

The detailed explanations of these parameters are beyond the scope of this deliverable and are not included this document.

From an initial location, a velocity and a given time interval, the iceberg is “advected” to its next location. For each iteration, the following steps are carried out:

- Temporal linear interpolation of metocean data (wind, current…)
- Computation of linear combination of the forces
- Spatial interpolation by cubic spline for each location
- Apply advection scheme
- Update iceberg morphology

3 Validation

There are two possibilities to validate iceberg drift modeling: a probabilistic approach with a climatological study at large scale and a deterministic approach using a dedicated ground truth (a set of consecutive SAR-based detections of the same iceberg, ARGOS deployment on icebergs…).

3.1 Ensemble simulation of icebergs in Antarctica and comparison with altimetry

One of the main difficulties in the validation process actually resides on the proper modeling of generation sites.

The modeling of iceberg drift around Antarctica implies the use of coastal current but also of under-ice current. But it is also important to have a correct generation of icebergs at the coast of Antarctica. Calving sites and volumes were carefully set in the model. As shown by Figure 2, the simulated trajectories of iceberg validate the calving process from Weddell Sea, Ross Sea and West ice shelf…

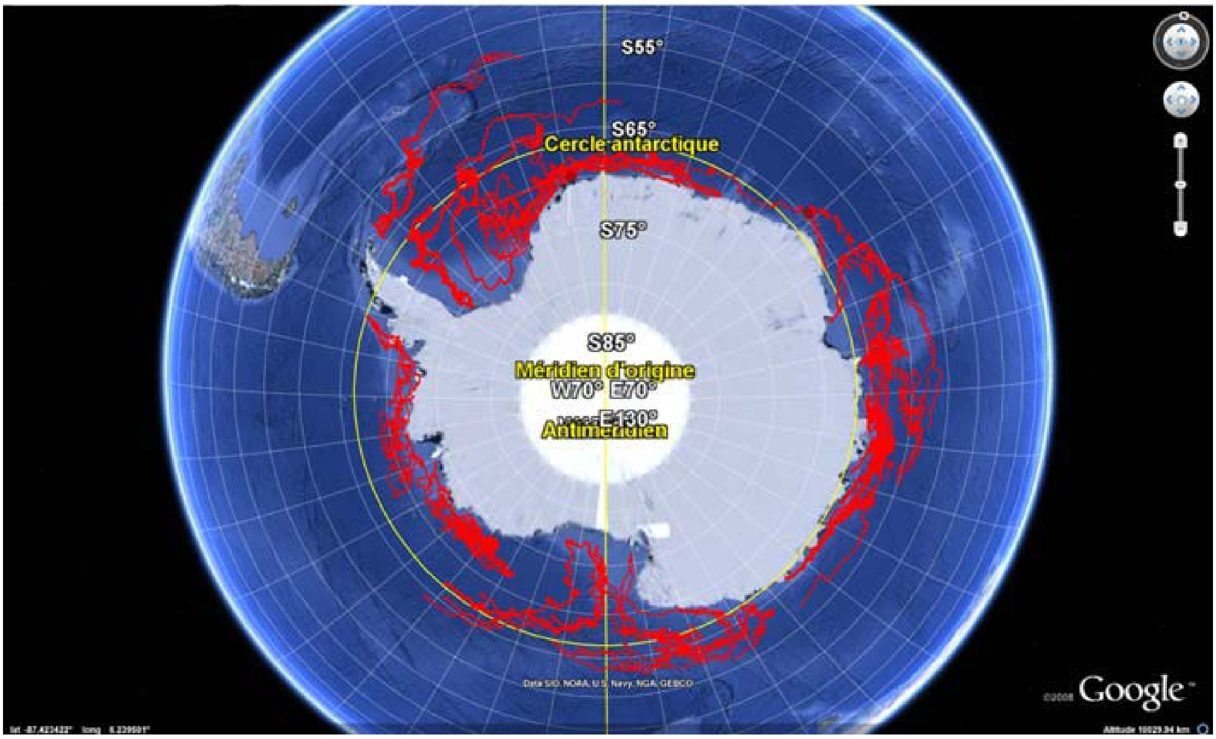

Figure 2 Drift modelling during 6 months

The simulations enable to compare the spatial densities of icebergs with altimeter-based observations (Tournadre *et al*. 2008 – see also deliverable D8.1 for additionnal details). To match the limitations of altimeter-based detections, only icebergs with height above sea surface below 25 meters are selected. Figure 3 shows the density of altimeter-based icebergs by 250x250 tile from November 2004 to December 2005. On the left panel, the number of detected echos has been normalized to account for the number of Jason data samples.

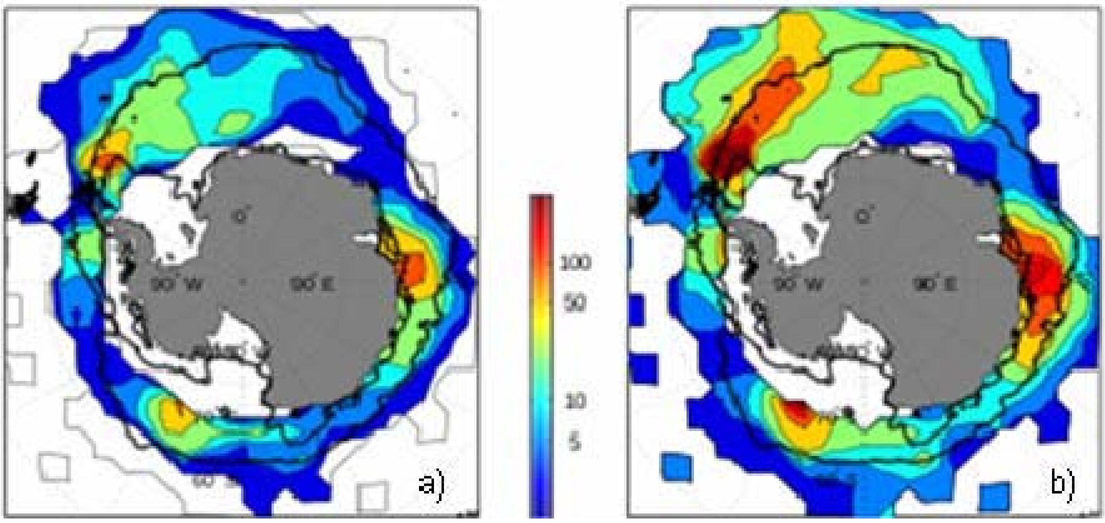

Figure 3 Left) Number of altimeter-based icebergs by 250x250 tile from November 2004 to December 2005 Right) Number ofdetected icebergs normalized by the number of Jason samples with respect to latitude. Color bar is logarithmic scaled, black lines correspond to the minimum and maximum extents of sea ice [from AMSR-E Ifremer/Cersat] (Tournadre et al., *2008).*

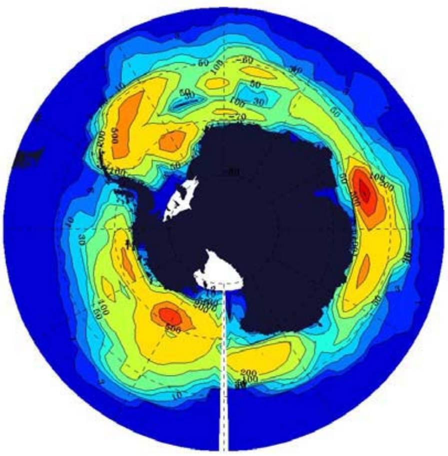

Figure 4 Density of simulated icebergs with height below 25m.

The 3 main sources of icebergs are in good agreement with the detections by altimetry. At this stage, it should be noted that Tournadre et al. 2008 focuses on open water only, which may explain some discrepancies within the sea ice extent. In addition, the swath coverage of altimeter system is about 13km and with an spatial distance of 20 km at 66° South, 100 km at 60° S and 135 km à 55° S. This aspect should be taken account when comparing the actual density values.

3.2 Deterministic validation (wind effect only)

In this document, we use two consecutive SAR images over the same iceberg to test and validate the impact of wind on the advection scheme. As shown in Figure 5, we can notice the simulated drifting iceberg is way on the East of the detected echo. The parameters of the drift modelling should be slighly adjusted to decrease the drift (wind and current effect).

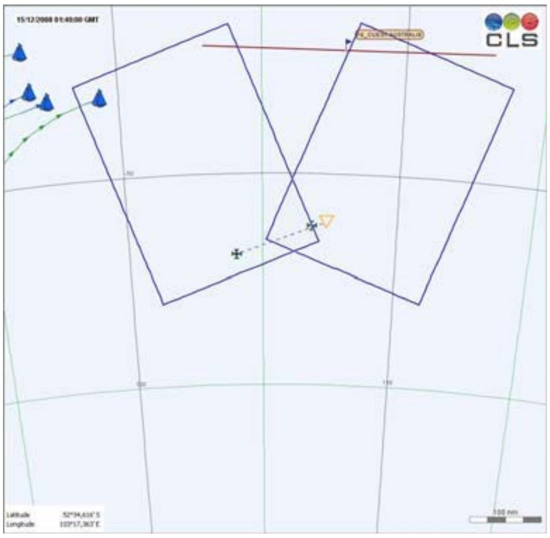

Figure 5 Two consecutive SAR images (7 and 15 December 2008), green dots correspond to detected echos, in orange the simulated drifting icebergs on the 15th of December

On the below figure, the effects of wind (wind effect rate) and current (new formulae for the current effect with both geostrophic and surface current components) are tested. A wind effect rate of 3% seems to provide the best results in terms of iceberg trajectories. Note that in that particular case, the wind decrease does not induce a significant decrease of the drift speed, but rather impact the trajectory.

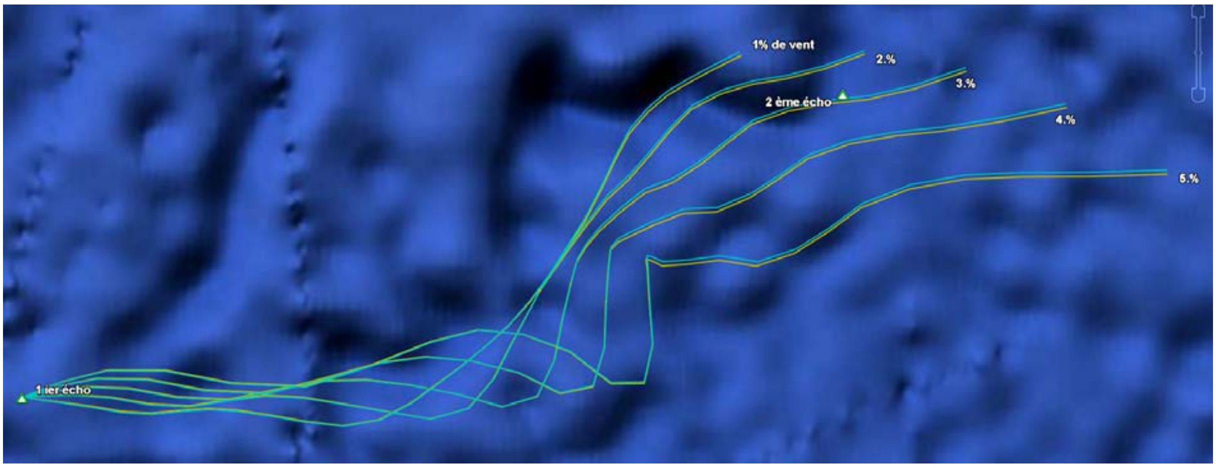

Figure 6 Drift simulationwith modification of wind effect rate (from 1 to 5%) and current effects with combination of geostrophic and surface currents (marron line, initial versio: green line)

4 Drift model in operational context

4.1 Run of drift model and ice report module

Once the icebergs observations have been collected (via atimetry or SAR imagery), and the metocean forecast acquired, the Mobidrift module is activated to produce the drift calculation. In the frame of this project, the calculation step has been set to 3 hours, and the outputs are stored daily. At every new drift simulation, the trajectories and icebergs positions are re-analysed for 10 days in the past and forecasted 3 days in the future. All the calculation parameters of Mobidrift are configurable.

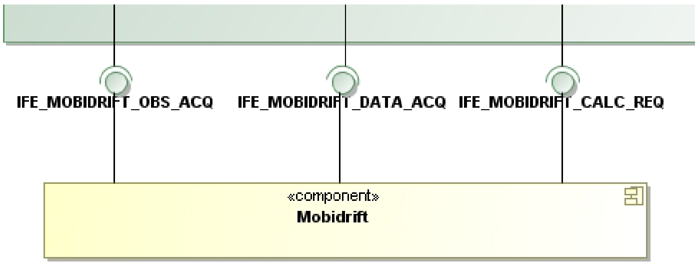

Figure 7 : Mobidrift module

The last step to be orchestrated is the Ice Report generation.

Mobidrift delivers a response file containing all the necessary information on the drift calculation: initial position of icebergs, source of observation (altimetry, radar...), intermediates iceberg positions at each time step, metocean data used...

From this response file, the processing chain, hereafter named BANQUIS, produces the Iceberg situation map for the end-user. This situation map is produced in a kmz format and then transformed to an ArcGis format using the arcgis python library.

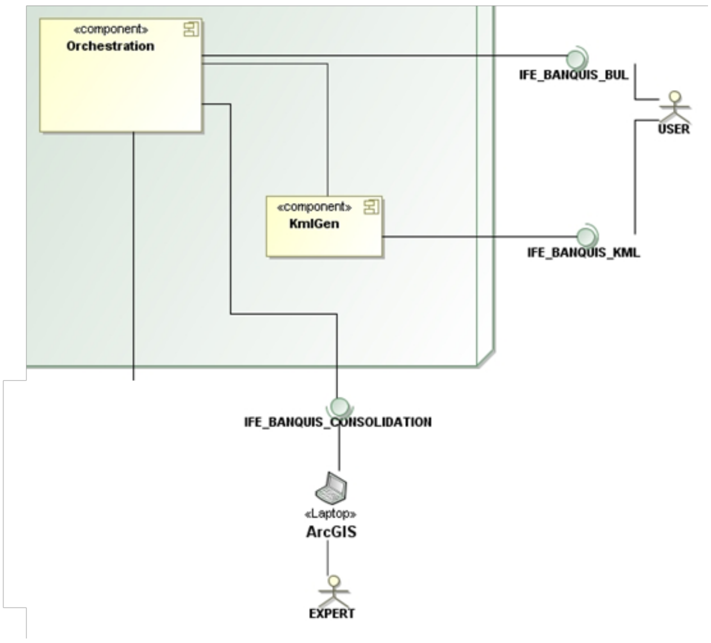

Figure 8 : Ice report module

4.2 Example of ice report in Arctic seas

The real-case demonstration is based on radar imagery acquired in July 2012. For this purpose, altimetry Cryosat data from July 2012 was analysed using the 3-peaks algorithm (see deliverable D8.1). 4 radar images were made available for the demonstration period and have been analysed by the CLS VIGISAT operators:

- 10/07/2012 05:45 : RADARSAT-2 image, ScanSAR Wide, HH, HV polarization
- 12/07/2012 04:46 : RADARSAT-2 image, ScanSAR Wide, HH, HV polarization
- 31/07/2012 05:32 : RADARSAT-2 image, ScanSAR Wide, HH, HV polarization
- 02/08/2012 04:33 : RADARSAT-2 image, ScanSAR Wide, HH, HV polarization

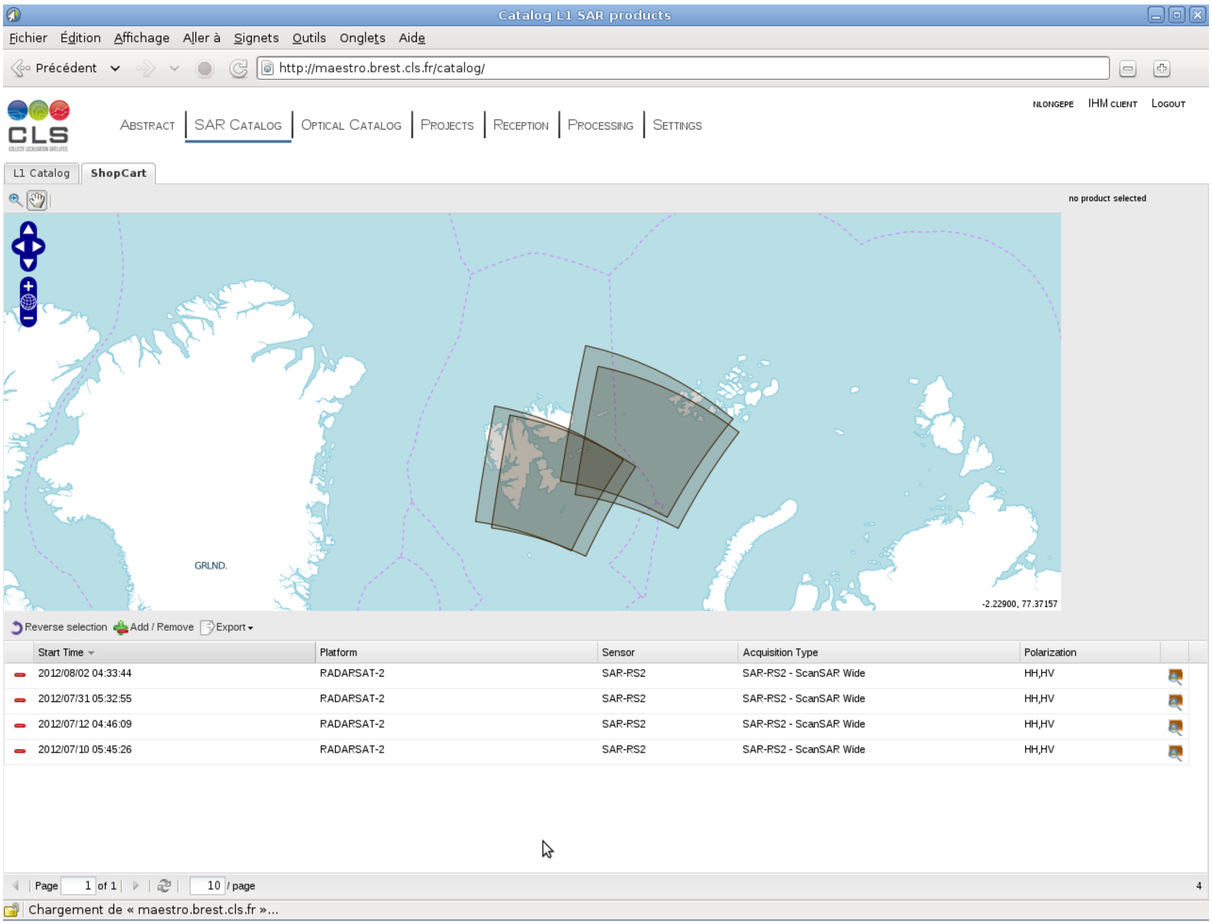

Figure 9 : Snapshot of SAR Catalog with the 4 radar images analysed

BANQUIS operational chain is activated in order to recreate the real conditions for this demonstration. Altimetry and SAR detection results for the demonstration period are ingested in the BANQUIS Observation Module. Oceanographic data are acquired for the period from 1st July to 5th August 2012 and the Mobidrift Module is run in simulating the real-time conditions.

Figure 10 presents an example of ice report generated for visualization in Google Earth. The ice report generated contains the following information:

- the latest SAR images analysed and the SAR contour;
- the positions of the latest icebergs observed with the SAR technology
- the positions of the latest icebergs observed with the altimetry technology

- the positions of the modelled icebergs up to x days in forecast
- the trajectories calculated by Mobidrift for the last x days and up to x days forecast
- the probability of presence of icebergs

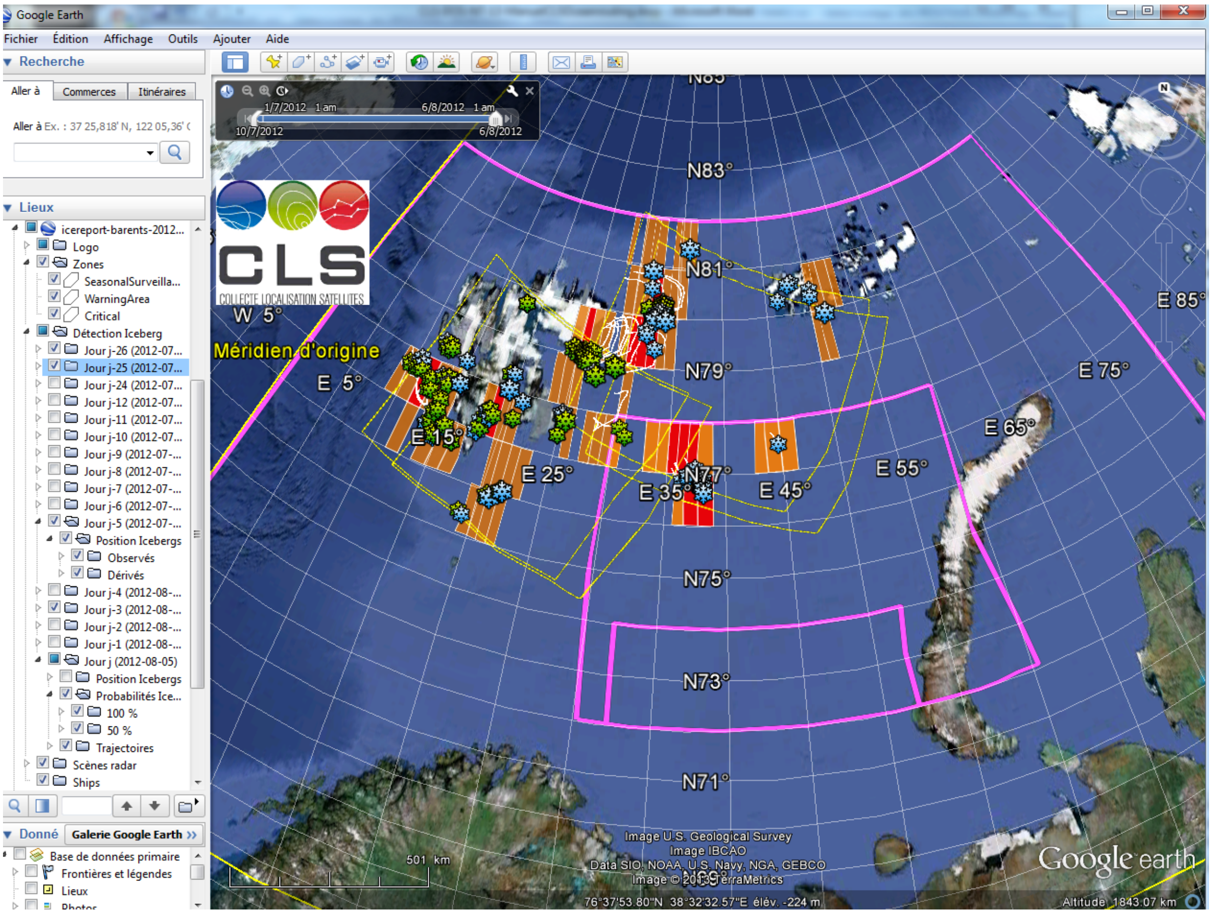

Figure 10 : Snapshot of an Ice report for visualization in Google Earth

The report may be presented by default for the D-day of report generation. Iceberg reports are provided for 12 days in the past and 3 days in forecast. Only the latest acquired radar scenes are exported in the report. The icebergs positions on the D-day are also displayed. Green flocks for model drifted icebergs from SAR observations, blue flocks for SAR observations (if any on the D-day), and purple for altimetry detections or model drifted from altimetry detection. Trajectories are displayed for the last 12 days on D-day, to show the icebergs direction of displacement. Furthermore, probability of presence of icebergs is also presented in the ice report. The probability of presence of icebergs is the result of the Monte Carlo algorithm activated in the Mobidrift simulation. Red squares show the area of 50% probability of occurrence of icebergs. Orange plus red squares show the area of 100% probability of occurrence of icebergs. Trajectories and probability grids are only given for the D-day and 3 days forecast of report.

5 Iceberg simulation for SAR- and altimeter-based detection scheme?

As stated in the deliverable of WP5 ”SAR data analysis”, iceberg detection in the ice pack can be very challenging. In this section, we have been initiating some activities of iceberg simulation in Barents sea to be further used in the detection scheme. The general idea is that knowing the a priori probability to have an iceberg in a given location may possibly help any SAR-based or altimetry-based detection process. This is especially true for the ”Constant False Alarm Rate” detection scheme which can be easily tuned via the False Alarm Probability parameters to adjust the number of actual detections with respect to the expected number of icebergs.

The icebergs are generated in a climatological manner for the various calving sites of Svalbard, Franz Joseph Land and Novaya Zemlya The known yearly volume of ice created from each island is dispatched among the various possible calving sites. In absence of proper observations, the distribution was made roughly proportional to the surface of the ice field shown by photos and maps (example below).

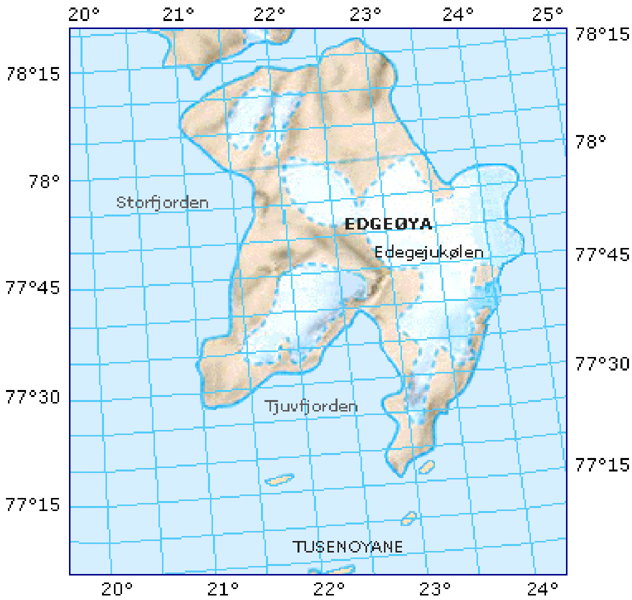

Figure 11 : Svalbard: edgeoya

There are a total of 28 calving sites (19 Spitzberg, 5 Franz Joseph Land, 4 Novaia Zemlia). All Svalbard glaciers are not useful for the Barents study, but it was easier to dispatch the whole ice volume among all the possible sites. Each iceberg is generated with a random size. On average, the size is chosen to be slightly larger than what is observed at large. The shape varies according to observed statistics. According to Kubyshkin & al. (Proceedings of the International Offshore and Polar Engineering, 2006), we impose a higher flow rate of the glacier in summer (shown below).

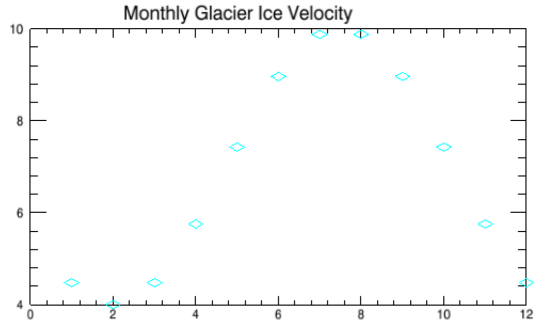

Figure 12 : Glacier flow rate with the month

More icebergs are generated in the summer, but they can be grounded for a while, and eventually melt in place, as observed in some fjords in Svalbard. Given this flow rate, in order to respect the mean observed dimensions, the generation is performed every 14 days. The precise number of iceberg is determined so that the correct volume is generated on a yearly basis.

Most of the icebergs generated on the western coast of Svalbard quickly go out of zone to the North. The map below show typical positions of generated icebergs:

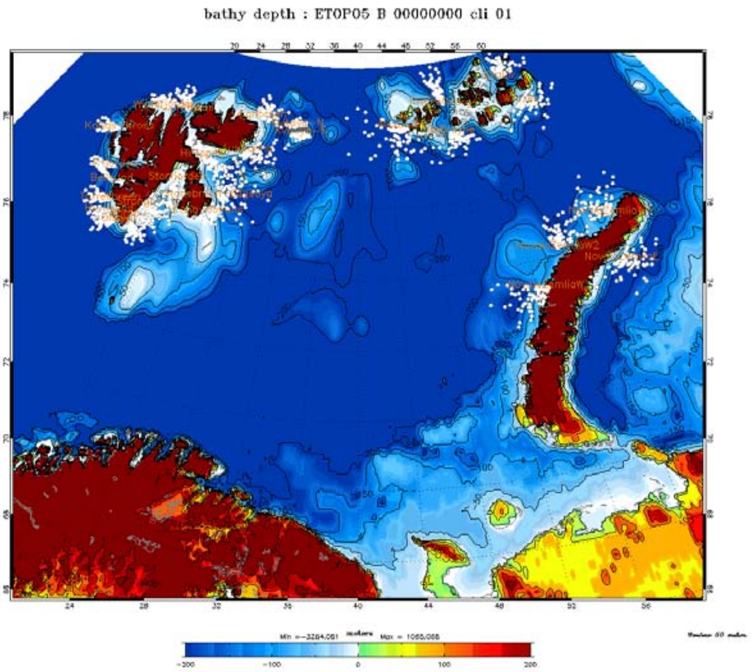

Figure 13 : Iceberg generation for a 14-day period

6 Conclusion

The aim of SIDARUS is to demonstrate new services and products in response to needs of users with responsibility to monitor icebergs in different regions of Arctic and Antarctic. In this deliverable, the iceberg drift model, as implemented by CLS in its Icebergs Monitoring Service is outlined. Some illustrations of its functionalities are given. The validation has been carefully carried out using a deterministic and a probabilistic approach. At this stage, it should be noted that a comprehensive drift validation has been also performed using ARGOS beacon deployed on icebergs. A demonstration of the service is given in the context of an Early Warning System for oil rig platform safety. Finally, some new perspectives on the use of iceberg drift model for iceberg detection are outlined.

END OF DOCUMENT