Important
Ce document, hors annexes, ne doit pas dépasser 40 pages, corps de texte en police de taille 11. Ce point constitue un critère de recevabilité de la proposition de projet. Les propositions de projets ne satisfaisant pas aux critères de recevabilité ne seront pas évaluées.

Nom et prénom du coordinateur / coordinator's name	**Jérôme WEISS**		
Acronyme / Acronym	**WaveSIMM**		
Titre de la proposition de projet	Etude de la banquise par analyse des ondes sismiques		
Proposal title	Waves in sea ice for monitoring and modelling		
Comité d'évaluation / Evaluation committee	SIMI 5/6		
Projet multidisciplinaire / multidisciplinary proposal	NON		
Type de recherche / Type of research	x Recherche Fondamentale / Basic Research x Développement Expérimental / Experimental Development		
Coopération internationale / International cooperation	OUI		
Aide totale demandée / Grant requested	551 105,36 €	**Durée de la proposition de projet / Proposal duration**	48 mois

1. RESUME DE LA PROPOSITION DE PROJET / PROPOSAL ABSTRACT

We propose a highly-integrated and multidisciplinary study of waves in sea ice. The proposed work builds on a successful bid to the European Science Foundation (ESF) by the one partner (LOV), based on the development of satellite-linked buoys for studying the changing Arctic (SATICE). Both projects share common goals to develop and prove novel observation techniques for modelling key ice and ocean parameters, in this time of rapid change. The work builds upon co-operation initiated under the EU DAMOCLES project and takes advantage of logistic opportunities provided to our project at no cost by the US/Canadian Beaufort Gyre study, aboard the icebreaker *Louis St Laurent*.

The over-arching objective of this project is to increase our knowledge and understanding of the Arctic sea ice cover. The ability of the project to significantly impact these fields of understanding comes from three main directions: (1) Novel cross-disciplinary application of analysis techniques, bringing solid-Earth methods to cryospheric studies; (2) Insight from the proposers' long experience of field measurement; (3) Technological advances, allowing us to build and deploy low-cost autonomous measurement platforms to actually make the required measurements for the first time. WaveSIMM will conduct ground-breaking investigations at the scales required by the generating processes. Specifically we will:

1. Demonstrate a validated monitoring system for local/regional-scale ice thickness, using noise cross-correlation techniques
2. Demonstrate a validated monitoring system for basin-scale ice thickness, using the thickness-dependent modification of travel time as waves cross the ice cover
3. Measure wave spectra in the summer Arctic Ocean and determine the importance of wave-induced mechanical forces on the breakup and retreat of Arctic sea ice
4. Explore the link between sea ice fracturing and regional deformation, hence develop modelling techniques to replace phenomenological parameters with realistic physics

Waves in sea ice have been measured for a long time (since at least the 1950s), but have, until recently, found little practical application. Technological advances - primarily the *Iridium* satellite data transmission system - prompted the proposers to initiate a new programme. This bore fruit as part of the DAMOCLES project, showing that long-period swell waves, generated by distant storms in the world oceans, could be used to diagnose ice thickness, by examining the *perturbation in travel time* of those waves caused by the ice. As a complement to the this method - which requires 'clean' wave arrivals from the deep ocean and applies over large scales – the solid-Earth seismic community has developed a technique which relies on the measured wavefield being random, and applies on an essentially local scale. This *noise cross-correlation* method has the potential to measure ice thickness within a relatively closely spaced array (scale from 1-100 km). The complementary methods thus promise to measure ice thickness at low cost at all scales of interest. The proposed work gives the exciting

possibility to ground-truth results and verify the methods, allowing them to take their place as part of a long-term ice thickness monitoring system.

The same GPS/wave measuring instruments will also be used to examine fracture of the ice cover. This discrete deformation, though actually how sea ice deforms, has previously been treated as a continuum process in models, which ascribe phenomenological viscous-plastic properties to the ice in order to make it computationally tractable. The limitations of this approach have been demonstrated, especially as the resolution of models is improving. Clearly, it would be preferable to model the real behaviour of the ice cover, especially since sea ice mechanics and its associated kinematics largely controls the sea ice thickness distribution, and fracturing has a major impact on sea-air exchanges through lead opening.

2. CONTEXTE, POSITIONNEMENT ET OBJECTIFS DE LA PROPOSITION / CONTEXT, POSITIONNING AND OBJECTIVES OF THE PROPOSAL

2.1. CONTEXTE DE LA PROPOSITION DE PROJET / CONTEXT OF THE PROPOSAL

The proposed work builds on successful collaboration between the partners as part of the EU DAMOCLES programme - centred around wave and seismic measurements from the schooner *Tara*, as it drifted across the Arctic Ocean – as well as participation in the SATICE project of the European Science Foundation (ESF) Polar Climate call by LOV (partner 2 in this proposal). It takes advantage of a major ongoing logistical effort in the Beaufort Sea region, by the joint U.S./Canadian Beaufort Gyre study, adding valuable collaboration in data, instruments, science and logistics (cruises aboard the icebreaker Louis St. Laurent) at essentially no cost. Collaborating institutions include Woods Hole Oceanographic Institute (WHOI), the International Arctic Research Centre (IARC), the Applied Physics Laboratory (APL) of the University of Washington and the International Arctic Buoy Programme (IAPB).

The proposed work brings novel methods to the study of the Arctic sea ice system from the solid-Earth seismic community. Seismic monitoring is the most classical and powerful tool to analyse fracturing and deformation of the Earth's crust, but seismic analyses of the sea ice cover to date are scarce and have been hampered by technological limitations. We therefore marry new sensors to state-of-the-art autonomous electronics systems, which were initially developed by the proposers and have been further developed under the SATICE programme, which includes participation from Spain (ICE-CSIC), Denmark (DTU-Space), Germany (AWI), Norway (NERSC), Scotland (SAMS) and France (LOV), as well as two Associated Partners from the US: Lamont-Doherty and Earth & Space Research.

The goal is to provide a low-cost, remotely-sensed, measures of ice thickness, at scales ranging from local (1-10 km) up to basin-scale (500 km+), by diverse methods using common instrumentation. The principles have been demonstrated alongside the schooner *Tara*, during the EU DAMOCLES project and we now seek to expand this pilot study into a full-scale demonstration of the capabilities.

The wave measuring instruments will also be used to address a major gap in our knowledge of the changing nature of the Arctic Ocean; specifically how the newly-exposed areas of open water, and the wind-generated waves which can now be generated there, impact the breakup and retreat of the sea ice. Floes broken by mechanical forces allow for greatly accelerated lateral melt processes. The Beaufort Sea is likely particularly prone to such effects, due to the long fetches of open water now occurring there. As well has having expected marked effects on the drifting pack, the newly-available mechanical energy also affects fast ice, and mid-season breakouts - previously unknown along the northern Alaska coast – are now becoming more common, often stranding indigenous hunters who have not adapted to the changing regime, exposing fragile coastlines to wave erosion and complicating access from shore to facilities. Data are urgently needed to model these effects, and we will collaborate with advanced wave modeling groups in New Zealand and Norway to ensure that these new data have the maximum benefit.

The work, as well as being a natural follow-on to the EU DAMOCLES programme, will make a major contribution to International programmes. These include the International Arctic Buoy Programme (IABP) – GPS buoy tracks will be made available to this programme in near-real-time from our drifting platforms – which provides data for real-time operational requirements and research purposes including support to the World Climate Research Programme (WCRP) and the World Weather Watch (WWW) Programme. Our measurements will also contribute to the Integrated Arctic Ocean Observing System (iAOOS), a long-term programme of the Arctic Ocean Sciences Board (AOSB).

2.2. ÉTAT DE L'ART ET POSITION DE LA PROPOSITION DE PROJET / STATE OF THE ART AND POSITIONNING OF THE PROPOSAL

Waves in sea ice have been measured for a long time (since at least the 1950s), mostly for understanding the origin of environmental noise in the Arctic and for determining in-situ the mechanical properties of the ice (including the ice thickness), e.g, Crary 1955, Hunkins 1960, Milne and Ganton 1964, Makris and Dyer 1986, Miller and Schmidt 1991, Dudko et al. 1998. Methods for estimating the ice thickness and rigidity have been developed, but always require active human intervention, in particular for generating seismic sources (hammer blows, or under-ice shots). They have therefore found little practical application for continuously surveying large-scale ice cover characteristics . Technological advances - primarily the *Iridium* satellite data transmission system - prompted the proposers (Wadhams & Doble) to initiate a new programme as part of the EU Framework-5 GreenICE project, with the goal of developing new techniques of measuring sea ice thickness on a large scale. Though technologically very successful, deployments of the tiltmeter buoys developed by that project were difficult to interpret, as the long-period waves studied had undergone many reflections before arriving at the measuring sites. An uninterrupted deep-water path was sought to demonstrate the developing theory and the EU Framework-6 DAMOCLES project provided the opportunity: alongside the schooner *Tara* as it drifted across the high Arctic Ocean. Relatively-large amplitude waves of a distinct and highly-peaked frequency spectrum were detected, located more than 1500 km inside the pack ice (**Figure 1**).

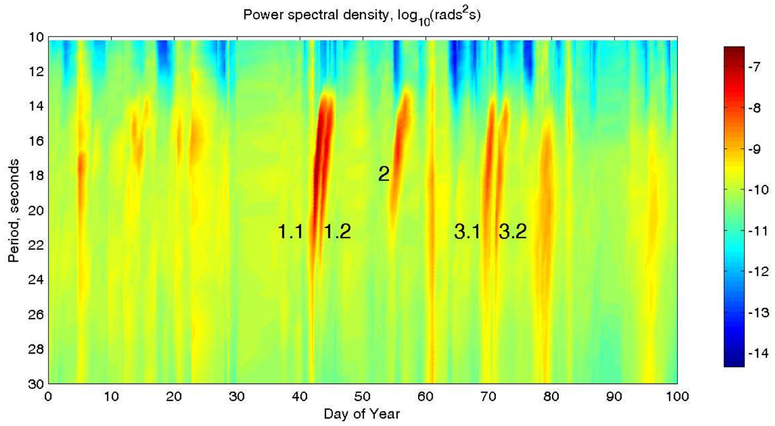


Figure 1: An example of the strong arrivals from lower-latitude storms, measured at *Tara*. The plot shows spectral power measured by the tiltmeter (log colour scale). The high-amplitude, highly-peaked, events stand out clearly, showing a clear progression from long to shorter periods.

The waves were shown to have been generated by large winter storms in the North Atlantic – identified using the European JASON satellite altimeter – and showed a linear increase of frequency with time, *i.e.* were dispersive. The presence of the ice cover modifies the **group velocity** of the waves from what would be expected in the open ocean: At the shortest periods observed (14 seconds) the ice would cause the waves to arrive at the tiltmeter over 7 hours earlier than in open water. It is this group velocity difference which can be exploited to 'remotely sense' the ice thickness between instruments (Wadhams & Doble, 2009).

The change in group velocity can be exploited to measure ice thickness over both (a) basin scales - measuring the significant decrease in travel time between widely-spaced instruments – and (b) local scales, determining the group velocity within an array.

It is suggested that the thickness derived by the method is the dominant (modal) thickness of the ice cover. As such, it is a climatological, or basin-scale, measure of the ice thickness – an extremely useful parameter when tracking the changes which the sea ice is currently undergoing.

For the long-scale method, the thickness of sea ice can be measured between two or more instruments for times when a clear storm driven signal propagates through the ice cover – events which our data have shown to occur regularly during wintertime (Wadhams & Doble, 2009). The single instrument deployed at Tara was, clearly, not able to determine an actual ice thickness value, and it is this final (multi-instrument) step that we seek to achieve in the current proposal.

The local scale technique is derived from established solid-Earth seismic techniques. In contrast to the above method, it relies on the measured wavefield being random, and applies on an essentially local scale. This "*noise cross-correlation*" method (Weaver and Lobkis 2001, Campillo and Paul 2003, Larose *et al.*, 2006) has the potential to perform ice thickness tomography within a relatively closely spaced array. The purpose of the noise correlation technique is to reconstruct the Green's function between two sensors, as if one was a source. The Green's function allows the dispersion relation to be determined and this in turn gives the ice thickness within the array, as before. The basic requirements for this technique to hold are that:

- The wavefield is random, because the noise sources are everywhere or, because there are lots of reflections all around.

- The record length is long enough to let the correlation converge to the Green's function: the recording time, *T*, must be much longer than the wave travel time between stations, *t*.

A first test of this method was conducted by ISTerre and LGGE as part of the DAMOCLES experiment, again using the schooner Tara as a base camp. Cross-correlations of three broad-band seismometers operating for about one month shows that the ice swell can be used as a natural, permanent source for calculating the dispersion of flexural waves, and therefore for estimating the ice thickness, see Figure 2. An estimated 2.5 m of ice was then estimated. The agreement of this estimate with drill-hole and electromagnetic induction survey (Haas et al., 2011) measurements (between 2.53 m and 2.73 m of mean ice thickness) conducted on profiles within or close to the seismic network proves the feasibility and rich potential of using seismic cross-correlation methods in this context. Further progress now requires the deployment of a seismic network to develop a ice thickness tomography at various scales, from the size of a floe (100 m to 1 km) to the regional scale (100 km and above).

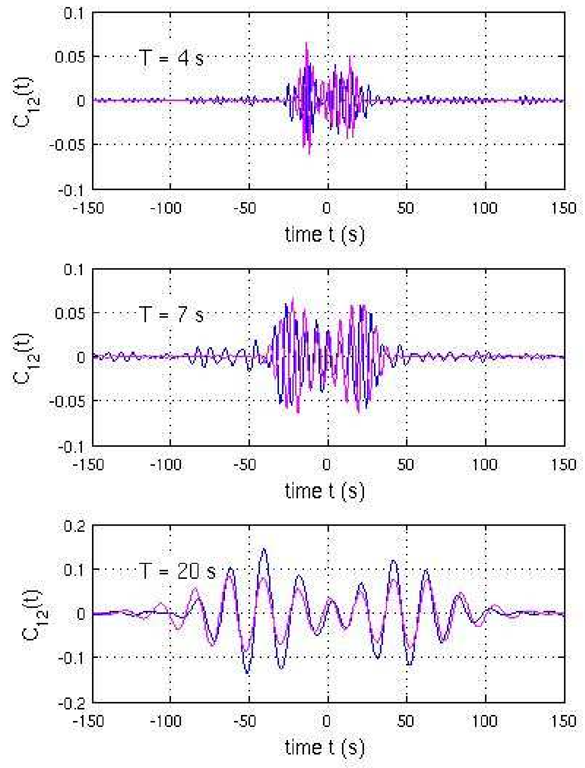


Figure 2 : observed (blue) and modeled (purple) cross-correlation functions, averaged over 1 month of data, between the vertical displacement rates casued by ice swell recorded at two stations separated by 640m during the Spring 2007 DAMOCLES experiment at Tara, near the North Pole. Three band-pass filters are used to analyze these cross-correlation functions, centered at 4, 7 and 20 s. This modeling then allows to estimate the ice thickness (here 2.5 m) by exploiting the dispersion of the ice swell (dependence of the propagation velocity with frequency).

The wave-measuring buoys will also greatly enhance our understanding of the effects of mechanical wave energy on the breakup and retreat of Arctic sea ice in summer. The increased prevalence of open water in the 'new Arctic' allows the generation of an appreciable wind-driven wave field. These locally-generated waves will likely be a major cause of breakup of the weak summer ice cover, increasing the lateral area of the ice and causing it to melt faster. The effect of waves is already being seen on fast-ice areas in the Beaufort Sea, which now experience mid-season breakouts, in contrast to the previous slow thermally-induced decay during summer. Current sea ice models do not parameterize this effect at all, since there is simply no data on the Arctic wave climate.

The same instruments can also be used to examine fracture of the ice cover. This discrete deformation, accommodated by the occurrence of fractures, lead opening and ice ridge events, has previously been treated as a continuum process in models, which ascribe phenomenological viscous-plastic properties to the ice in order to make it computationally tractable. Clearly, it would be preferable to model the real behaviour of the ice cover, and this is the thrust of recent work by the proposers (LGGE/ISTerre) – again bringing techniques from the solid-Earth community to sea ice research to gain new understanding (Weiss et al., 2007; Weiss et al., 2009; Girard et al., 2011). Examining drifting buoy records back to 1979, they demonstrated that Arctic sea ice thinning and decline has been accompanied, and most probably strengthened, by an acceleration of the drift speed and deformation of sea ice over the last three decades (Rampal et al., 2009). Such changes strengthen positive feedbacks on sea ice thickness through an intensification of fracturing-induced deformation of the sea ice cover. They imply an increase of lead opening, and therefore a decrease of the surface albedo, as well as an increase of sea ice export out of the basin. It is therefore crucial to properly understand the link between sea ice fracturing and deformation, as well as the feedbacks between sea ice thickness/concentration and sea ice rheology. As an example, sea ice mechanics and its associated kinematics largely controls the sea ice thickness distribution, whereas fracturing has a major impact on sea-air exchanges through lead opening.

Most of what is known about sea ice deformation and fracturing comes from large-scale (> 10 km) satellite observations, such as the RGPS (RADARSAT Geophysical Processor System) dataset (Kwok, 1998) or from the analysis of Lagrangian trajectories (buoys) (Rampal et al., 2008; Rampal et al., 2009). Although *in-situ* ice stress measurements furnished highly valuable information on sea ice mechanics (Richter-Menge and Elder, 1998; Richetr-menge et al., 2002; Weiss et al., 2007), other tools are needed to get a proper representation of sea ice fracturing and faulting from the local (<1km) to the regional scale (~100 km), and to analyse the mechanisms at work during the deformation events: e.g., what is the relative importance of rapid fracturing or slow, low-frequency events? Are shear and/or mode I instabilities dominant?

The seismic network deployed during the DAMOCLES experiment in Spring 2007 allowed the decomposition of the seismic signal into three main components: (i) The ice swell, as studied by the tiltmeters (ii) High-frequency (HF) icequakes with a spectrum spanning the 1-15 Hz range, which are a signature of mechanical and thermal fracturing at the local scale; (iii) Low-frequency (LF), horizontally-polarized wavetrains that can last several minutes, with peak period ranging between 30 to 40 s, that we think are the signature of remote, large-scale icequakes (Marsan et al., in press), cf. Figure 3. The configuration of the *Tara* instruments did not allow the localisation of these icequakes, but this LF seismic activity was clearly correlated to the regional deformation measured from an array of drifting buoys at the scale of 400 km, therefore suggesting that they are related to the activation of, and/or relative displacement across major and remote leads, in relation with episodes of large-scale deformation of the sea-ice cover. The deployment of a seismic network covering local (~1 km) to regional (~100 km) scales will allow us to localize these LF quakes and therefore to analyze in details the relationship between the activation of leads and deformation at different scales.

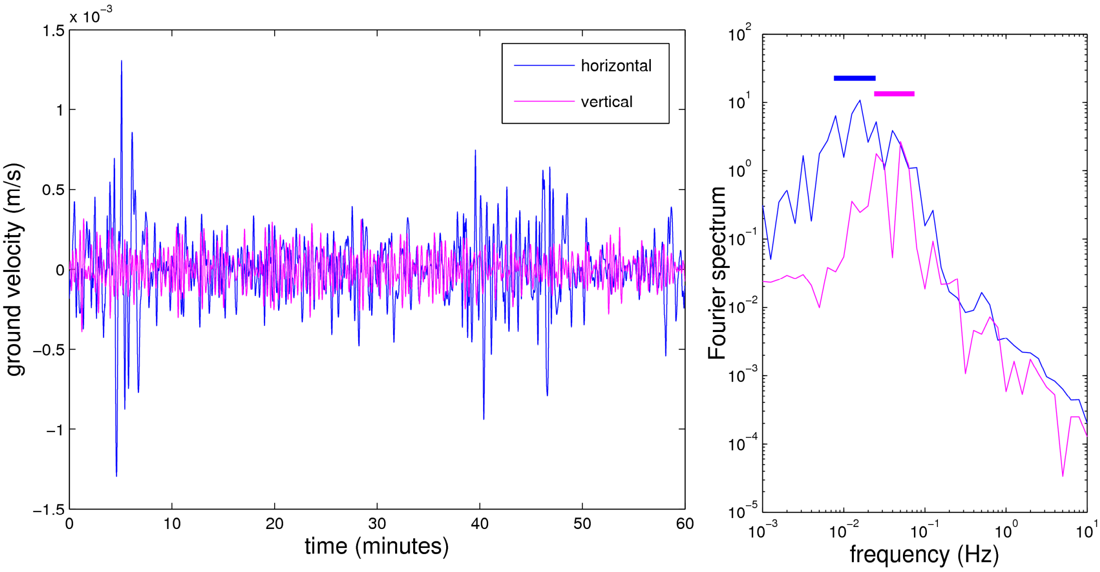


Figure 3: one hour of recording (1/5/2007, 02:00 - 03:00) for two channels (one horizontal, in blue, and the vertical, in purple) of a common station, and the associated Fourier spectra. The vertical channel is mostly affected by the ice swell, with dominant periods ranging from 14s to 42s, while the horizontal channel sees - on top of the swell - clear bursts of even lower frequency waves (dominant period from 40s to 130s, blue horizontal thick bar), likely caused by remote ice deformation episodes that propagate through the ice cover as horizontally-polarized (P and S) waves, hence with propagation speed much larger (typically x100) than ice swell propagation speed.

The deployment of the instrument array will contribute significantly to the International Arctic Buoy Programme (IABP) and the Arctic Ocean Observing Network (see attached letters of support).

This proposal is a reworking of our 2010 ANR Blanc submission, also titled *WaveSIMM*, updated with new fieldwork opportunities and adding work on the role of waves in Arctic sea ice retreat, and stressmeter investigations. The 2010 document was ranked very highly by the experts and committee « *because of its strongly innovative nature and because of the very important scientific content* ». The work was in fact recommended for funding, through no funds were actually received. It is hoped that our improved submission in 2011 will finally obtain the funding to allow this important work to take place.

2.3. OBJECTIFS ET CARACTERE AMBITIEUX ET/OU NOVATEUR DE LA PROPOSITION DE PROJET / OBJECTIVES, ORIGINALITY AND/OR NOVELTY OF THE PROPOSAL

The over-arching objective of this project is to increase our knowledge (through monitoring) and understanding (through modelling) of the Arctic sea ice cover in this time of rapid change. The techniques developed will also be fully applicable to the

Antarctic, allowing sensitive measurement of any changes which are occurring or will occur there.

The ability of the project to significantly impact these fields of understanding comes from three main directions: (1) Novel cross-disciplinary application of analysis techniques, bringing solid-Earth methods to cryospheric studies; (2) Insight from the proposers' long experience of field measurement; (3) Technological advances, allowing us to build and deploy low-cost autonomous measurement platforms to actually make the required measurements for the first time.

Scientific objectives can be divided into five main areas:

1. Demonstrate a validated monitoring system for local-scale ice thickness, applying the noise cross-correlation method
2. Demonstrate a validated monitoring system for basin-scale ice thickness, using the travel-time perturbation technique
3. Monitor the locally-generated wave field and determine its effects on summer ice breakup and retreat
4. Explore the link between sea ice fracturing and regional deformation, hence develop modelling techniques to replace phenomenological parameters with realistic physics
5. Examine dynamics and drift, in collaboration with IABP, AOOS and the Beaufort Gyre study

These aims share the framework of novel wave measurements on ice, using complementary techniques and common instrumentation. The scope of the work spans local (noise cross-correlation), regional (seismic arrays) and large (travel time) scales. Instruments will be deployed during a comprehensive in situ measurement campaign (ice and snow thickness) and will be co-deployed with CRREL/MetOcean Ice Mass Balance buoys (IMBs) to validate our thickness retrievals throughout our measuring period (see letter of support from IARC).

Though wave measurements on ice are relatively common, the mixture of duration and configuration required for the analyses proposed here has not previously been achieved. For the travel-time perturbation technique, deployments have either been in unsuitable regions (no deep-water path) or were single instruments. Previous seismic experiments on sea ice (such as carried out by the proposers from the *Tara*) suffered from several scientific and/or technical limitations, mainly related to demands of maintenance and data collection for non-autonomous instruments, requiring the installation of a network at the local scale only.

In this proposal, therefore, we will optimise the deployment to probe three distinct spatial scales: 1, 10

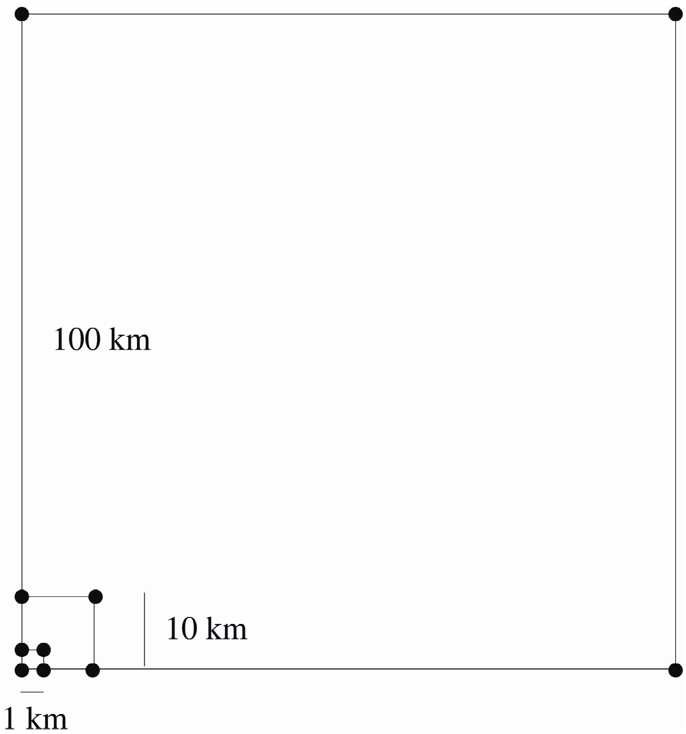


Figure 4: Layout of the seismic network

and 100 km (**Figure 4**). This is a unique experimental set-up for such studies on the sea-ice. It will allow (1) to test and validate the feasibility of conducting large-scale (>> 1 km) monitoring of the ice thickness with cross-correlation methods, and (2) to compare ice thicknesses at those distinct scales. Such a range of scales allows us to properly examine the wide range of wavelengths which we are studying. The very low frequency, horizontally-polarised wave-trains represent an entirely new phenomenon that has only very recently been observed (Marsan et al., in press), but that still needs to be fully characterized (i.e., what is its source?). Four vibrating-wires stressmeters will be associated to the seismometers constituting the diagonal of this array in order to analyse the links between internal ice stresses and seismicity.

Success of the project depends on mastery of technical, operational and scientific aspects. Success will be evaluated in four stages:

1. Development and construction of the autonomous wave-measuring instruments
2. Field operations demonstrating both optimal deployment of the instruments and obtaining fully validated ice thickness information from ground-truth measurements
3. Successful acquisition of scientific wave data from the various deployments
4. Success in using these data to serve the scientific aims

Though the scientific programme and the scope of the fieldwork are ambitious, the prior experience of the group in all aspects of the proposed work (see Table 1) means that we do not foresee any major problems, either technical or scientific. The work programme represents a natural evolution of our separate fields of expertise. Though the over-arching scope of the project is novel and ground-breaking – particularly in the broad range of applications of the wave data envisaged – that is achieved through manageable increments in our technical and scientific expertise in this highly-integrated, multi-disciplinary but very complementary project.

Table 1. Recent deployments of wave-measuring instruments by the proposers. Our instruments have proven their robustness at both poles, surviving both the harsh ice edge region of the Southern Ocean and reporting for over 3 years on Arctic sea ice

Partner	Location	Dates	Description	Funding
LOV	Weddell Sea	Apr – Dec 2000	Array of 6 drifting buoys deployed into pancake ice zone. Measured vertical acceleration, GPS, met.	NERC
LOV	Lincoln Sea	Apr. 2004 – Jul. 2007	5 tiltmeter buoys deployed from ice camp	EU FP5 GreenICE
LOV	Laptev Sea	Sep 2006 – Jan 2008	Single tiltmeter buoy deployed at Tara	EU FP6 DAMOCLES
LGEE – ISTerre	Storfjord (Spitzberg)	April 2005	Deployment of 8 Güralp CMG-30 EPSD broad-band seismic stations, associated to 30m-aperture vertical short-period seismic arrays	IPEV
LGGE –	Drifting	April –	Deployement of 5 Güralp	FP 6

ISTerre	near the North Pole (Tara schooner)	September 2007	CMG-30 EPSD broad-band seismic stations, and 4 30m-aperture vertical short-period seismic arrays	(DAMOCLES)

3. PROGRAMME SCIENTIFIQUE ET TECHNIQUE, ORGANISATION DE LA PROPOSITION DE PROJET / SCIENTIFIC AND TECHNICAL PROGRAMME, PROPOSAL ORGANISATION

3.1. PROGRAMME SCIENTIFIQUE, STRUCTURATION DE LA PROPOSITION DE PROJET/ SCIENTIFIC PROGRAMME, PROPOSAL STRUCTURE

The proposed work naturally divides into five Tasks:

1. Local- to regional-scale ice thickness tomography, using the noise cross-correlation technique
2. Large-scale ice thickness measurement, using the travel time perturbation method
3. Monitoring and modeling wave-induced breakup during summer
4. Linking fracture, internal stresses and deformation at the local and regional scales
5. Design and construction of the instruments

Tasks 1 & 2 are naturally complementary, exploiting opposite properties of the continuous flexural-gravity wavefield (simple/random). They both use the dispersion relation of waves in ice to derive the ice thickness, though on different scales (basin/local) and by very different techniques. Task 3 and 4 use the same instruments to examine fracture of the ice cover, whether by the waves themselves (Task 3) or from drift dynamics (Task 4). Whereas Task 1, 2 & 3 focus on the continuum of waves, Task 4 concentrates on the discontinuities, discrete events, though using the same raw data. In addition, the thickness data obtained from Tasks 1 and 2 will serve as a main input for a mechanical interpretation for Tasks 3 & 4.

Each Task will follow a similar path through the project, consisting of:

- Theoretic and algorithm development using existing data
- Initial deployment for engineering development & test
- Subsequent refinement of instrument design and sampling strategy
- Scientific deployment & data gathering
- Data analysis
- Theory refinement and demonstration of results

This pilot-development-deployment work structure has proven its worth in previous campaigns by the proposers, ensuring an unblemished record in successful Polar instrument deployments, even in the harshest conditions, as shown in Table 1.

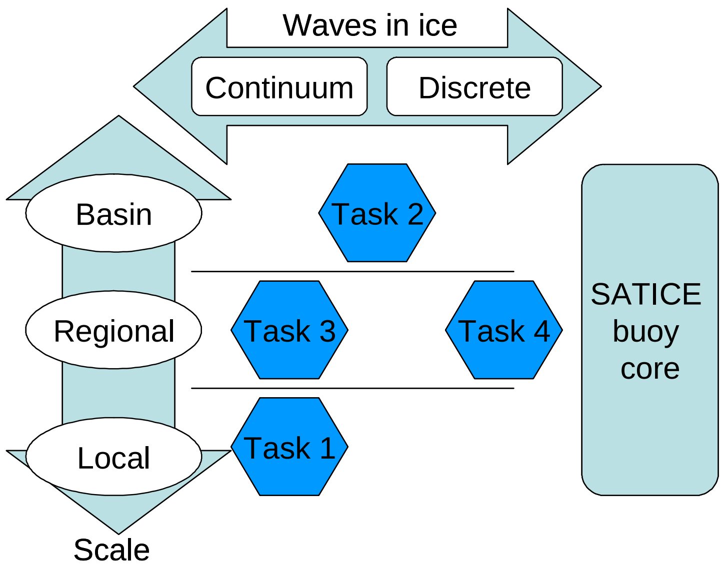


Figure 5: Diagram of the Tasks addressing the full range of processes and scales.

Instrument development and construction will form the first phase of the project and will be an ongoing process as lessons are learned from each field campaign. The buoy core, developed from LOV's proven design by the SATICE project, contains the processing, GPS and Iridium satellite communication equipment. Development under WaveSIMM will focus on integrating our main wave-sensing device: a Guralp broadband 3-axis seismometer to this core. Buoy cores will also be used with our tried-and-tested orthogonal tiltmeter sensors, vibrating wire stress-meters and accelerometers.

Detailed work plans following this structure are presented in the individual Task descriptions.

Logistically, the work is organized around cruises by the Canadian ice breaker *Louis St. Laurent* to the Beaufort Sea. The cruises will take place during the autumn (Sept./Oct.) of 2012 and 2013 as part of the Beaufort Gyre observational programme. The autumn timing is ideal to place instruments whose chief focus is over-winter and summer breakup. Chief Scientist is Dr. Andrey Proshutinsky and we enclose a letter of support from him. These field opportunities are provided to this proposed work at no cost.

We will join the 2012 cruise to (a) test our seismometer instruments, deploying a local array on floes alongside the ship for limited periods before recovering them; and (b) deploying a 'mature technology' array of 4 tiltmeter/accelerometer buoys. Data from the latter array will be used for Tasks 2-5 (including the ice retreat during summer 2013), as well as to optimize and finalise algorithms for the 2013 deployments of the seismometer-equipped instruments. The 2012 array will be in place for an expected underpass by a UK nuclear submarine cruise - in March 2013 - to further cross-validate our ice thickness results. We (LOV) also expect to take part in the April/May 2013 U.S. APLIS ice camp – a major field effort staged in the Beaufort Sea every few years (we attended the 2007 camp). This will provide further opportunities to make validated measurements, deploying (and recovering) the instruments and gaining maximum confidence in their operation prior to their final deployment in the autumn.

Figure 6 shows the area of icebreaker operations (circle) and approximate submarine cruise track (line) to the region of the APLIS 2013 ice camp. The background image shows the ice cover on October 1st 2010.

The 2013 cruise will deploy the full 10-buoy array shown in **Figure 4**, equipped with the optimal Guralp sensors. The array will provide the best-quality data for all Tasks, drifting during the winter of 2013/2014 and observing the summer 2014 ice retreat. The layout allows the seismic processes to be studied on 1, 10 and 100 km scales for the first time and is robust to instrument failure at all scales. Prior experience suggests that the arrays will survive for the duration of the project and beyond, until either the ice on which they are deployed melts or they succumb to mechanical failure induced by pressure ridging or curious polar bears.

The first phase of the project will also include data analysis and theoretical development, based on the Tara 2007 data. IsTerre will examine the noise cross-correlation technique in this context.

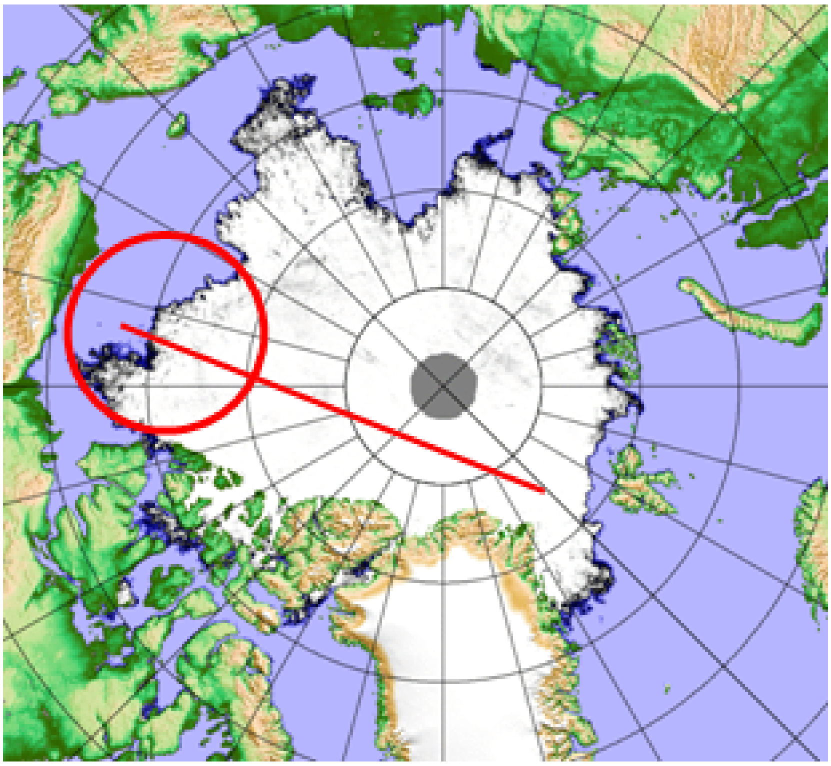


Figure 6: Area of icebreaker operations in autumn 2012 and 2013 (circle) and approximate 2013 submarine cruise track, superimposed on the AMSR ice concentration for October 1st 2010.

3.2. DESCRIPTION DES TRAVAUX PAR TACHE / DESCRIPTION BY TASK

3.2.1 TÂCHE 1 / TASK 1: ICE THICKNESS TOMOGRAPHY USING NOISE CROSS-CORRELATION (ISTERRE, LGGE, LOV)

Objectives
We will apply advanced mathematical techniques, developed for solid-Earth seismic investigations, to examine the potential for ice thickness tomography inside an array of seismic instruments. The technique exactly complements the travel-time technique described in Task 2, since it requires a high noise environment. We will use long duration measurements (long in comparison to travel time between instruments) to derive the dispersion relation for surface waves between instruments and hence the ice thickness within the array area.

Deployments
Instruments will use the SATICE buoy core (i.e. GPS, solar panels, microprocessor etc.), with a Guralp 3C broadband seismometer. The complete units used for this Task 1 are identical with those to be used in Task 4.

Following testing alongside the icebreaker during autumn 2012, autumn 2013 will see the autonomous array deployed on Beaufort Sea drift ice. This array will also form one vertex of the larger square seismic arrays, described in Task 4. The array will be used to track the ice thickness evolution as it drifts around the Beaufort Gyre, eventually exiting the Arctic through Fram Strait.

The convergence rate of the correlations toward the Green function was intensively studied over the last years (Larose *et al*., 2007), and was found to depend inversely on the square root of the distance and frequency, and proportionally to the square root of the duration of the record. This means that large distances between the sensors will slow the convergence. On the other hand, a dispersion study requires to separate arrival times of waves at different frequencies, which requires that sensors are far enough apart (a few tens of wavelengths). For the periods and wavelengths of interest, a spacing of 1-2 km between units would be appropriate to reconstruct the surface wave dispersion and deduce the ice thickness. We therefore propose to deploy an array of 4 sensors at this scale. Happily, this is exactly the same spatial scale and sampling regime as required by the seismic investigations at the local scale (see Task 4) and the same instruments will therefore be used for both purposes, maximising the science:cost ratio. We will moreover make the most of the wide aperture array (up to 100 km) to further test the feasibility of performing cross-correlation measurements of ice thickness at greater scales, in particular using the low frequency band. This will complement Task 2 for characterizing the regional scales.

During deployment, ice and snow thickness will be measured as part of an in situ campaign, and the evolution of ice and snow thickness will be followed by co-located IMBs, throughout the instruments' lives. We will also seek an overflight by NASA's "IceBridge" aircraft, carrying a scanning laser profilometer to characterize ice+snow freeboard over the whole local region. The same information will also be used by Tasks 2, 3 and 4. This will allow us to study whether the wavefield, multiply scattered by inhomogeneities in the ice thickness distribution, could also yield more information on this distribution than just an area-averaged estimate.

During daylight months (April-September) the units can record continuously, powered by solar panels as successfully demonstrated by the proposers' earlier experiences in 2004 and 2007 with similar units, though 'bursts' of 24 hour recording separated by 48 hour quiet periods (simply recording hourly GPS position) would be preferred, since this regime can also be followed during the Polar night. Units will be powered by Cyclon rechargeable gel batteries during the dark period, which have proven their reliability in temperatures down to -45°C in previous deployments.

Milestones

M1.1. Month 10/Sept 2012: Instrument test deployment in Beaufort Sea.
M1.2. Month 17/ April 2013: Testing at APLIS ice camp
M1.3. Month 22/ Sept. 2012: Final autonomous 10-buoy array deployed from Louis St. Laurent

Deliverables

D1.1. Month 15/ Feb. 2013: Report on 2012 field tests, demonstrating the technique, setting out autonomous sampling strategy & comparing results with in situ & IMB measurements.
D1.2. Month 48/ Nov. 2015: Synthesis Report on 2013 main deployment, tracking ice thickness within the array for the life of the instruments

3.2.2 TÂCHE 2 / TASK 2 MEASURING SEA ICE THICKNESS USING LONG-PERIOD WAVES (LOV)

Objectives

We will determine whether, as expected, the buoys are able to measure the path-integrated modal ice thickness between instruments, in support of International climatological monitoring programmes.

Methodology

The task will initially use the mature technology of our tiltmeter buoys to deploy an array of 4 buoys into the autumn Beaufort Sea in 2012, since we do not expect to have fully integrated and tested the seismometer buoys at this stage. This initial array will give us valuable data for the tasks not requiring the 3-axis seismometers (i.e. Tasks 2 & 3), while providing useful insight and data for the remaining Tasks (1 & 4) for which the seismometer data are best.

We will thus build 4 tiltmeter/accelerometer buoys and deploy them in 2012 from the Louis St. Laurent on a 100-500 km scale, depending on the exact cruise track, also making use of the ship's helicopter. 2013 deployments will use the same instruments as Task 1, *i.e.* the 10-buoy seismometer-equipped array.

For maximum scientific value, the ice between the tiltmeters should be profiled and the complete thickness profile compared to the wave-derived figure. Validation will be performed by in situ measurements during deployments and by co-locating the buoys with IMBs from the University of Alaska. The IMBs have thermistor strings embedded in the ice and sonic pingers above and below the ice, measuring ice and snow thickness, as well as temperature throught the ice/snow layer. We will also seek overflights by NASA's IceBridge programme, measuring ice+snow freeboard over wide regions. Data will also be compared with thickness retrievals from the European Cryosat-2 satellite and with overflights by the Alfred Wegener Institute's long-range *Polar-5* aircraft, equipped with an EM bird to measure ice+snow thickness. Finally, we will endeavour to obtain a complete sonar profile between the buoys as part of our ongoing submarine programme with the UK Royal Navy: the next cruise is scheduled to visit the Beaufort Sea in March 2013 and we will seek to direct its path under the updated positions of our instruments, providing the best possible validation of thickness from this novel method.

Milestones

M2.1. Month 10/ Sept 2012: First year's array deployed from Louis St Laurent.
M2.2. Month 16/ March. 2013: Validation of long-scale results by UK submarine underpass
M2.3. Month 22/ Sept. 2013: Main array deployed from Louis St. Laurent

Deliverables

D2.1. Month 19/June 2013: Data report from first winter season (Sept. 2012 – May 2013)
D2.2. Month 31/ June 2014: Data report from second winter season (Sept. 2013 – May 2014)
D2.3. Month 48/ Nov. 2015: Synthesis Report on ice thickness calculation using long period waves, compared with ice thickness from laser overflights and Cryosat-2. Recommendations for ongoing monitoring as part of iAOOS and IABP programmes.

3.2.3 TÂCHE 3 / TASK 3 : MONITORING AND MODELLING WAVE-INDUCED ICE BREAKUP IN THE SUMMER ARCTIC (LOV)

Objectives

To monitor the wave spectrum of the Arctic Ocean & examine the role of significant local wave generation on breakup and retreat of Arctic sea ice.

Methodology

The changing nature of the Arctic Ocean and the recent significant areas of open water – particularly in the Beaufort Sea region - means that winds within the Arctic basin itself can now generate waves which are capable of fracturing ice floes by mechanical forces. This is expected to have a significant impact on the retreat of the pack ice, since it greatly accelerates the lateral melt process, and hence the evolution of the Arctic and global climate systems. The trend also affects fast ice in the Arctic, and mid-season breakouts - previously unknown along the northern Alaska coast – are now becoming more common, often stranding indigenous hunters who have not adapted to the changing regime (Mahoney et al., 2007), exposing fragile coastlines to wave erosion and complicating access from shore to facilities (Dumas et al, 2005).

Despite the growing importance of wave-induced failure of fast- or drifting ice, and considerable progress on the theoretical side, very little data exist, primarily due to previous technological limitations: it has not previously been feasible to deploy suitable instruments for long periods required if the environment is to be characterized prior to breakup. The lack of data feeds forward into lage-scale modelling capabilities – no global models currently even crudely parameterize wave-related effects, since there is no data available to test any such parameterization.

The WaveSIMM instruments will therefore be used to:

- Provide a year-round data on wave energies in the Arctic Ocean
- Examine whether the observed wave energies are sufficiently high to break the floes, as we expect, through sophisticated modeling techniques
- Examine whether floe failure has taken place when predicted by the models, hence driving model improvements
- Hence map zones of wave-induced fracture and determine their importance to the mass balance of Arctic sea ice in summer

The seismometers and tiltmeters will likely be saturated once wave energies rise to a level, near the ice edge, where fracture of the floe is imminent. We will therefore incorporate a simple single-channel vertical accelerometer in the instruments to measure the expected high-energy events. This will be done using exactly the same hardware as done for our earlier Antarctic deployments, and thus is very low cost (hardware or development) and risk. Instruments fitted with the accelerometers will be housed in a large (1.25 m diameter) ionomer foam disc to provide floatation and ensure that the buoy can continue to transmit data once floe failure and even subsequent complete melt has occurred. Accelerometers/floatation will be fitted to the 4xtiltmeter buoys deployed in 2012 and to the 2013 seismometer-equipped buoys which do not include the stressmeters (6 buoys).

The retrieved wave spectra will be related to (a) distance from the ice edge (from AMSR passive microwave satellite data); (b) ice thickness (from other WPs and co-located IMBs); (c) thermal history of the ice (from co-located IMBs). Data will be used as input to the latest implementation of floe fracture models, implemented by our New Zealand-based collaborators NIWA (see attached letter of support), who are currently involved in implementing simple wave-based phenomena into global climate models for the first time, themselves in collaboration with Norwegian partners NERSC (Nansen Environmental Remote Sensing Centre), in Bergen. The aim is to map a likely zone of wave-influenced fracture at any time (including fast-ice zones), determine the resulting floe size distribution and thus the magnitude of the melt acceleration that might be expected as a result. Examination of the GPS motion of the buoys will also determine whether fracture of the floes has occurred when predicted by the models, and thus feed forward into model improvements.

Deliverables

- D3.1: Month 24/Nov. 2013: Report on results from 2012 array
- D3.2: Month 48/Nov. 2015: Report on importance of wave-induced breakup in the Beaufort Sea region

3.2.4 TÂCHE 4 / TASK 4 : LINKING FRACTURE AND DEFORMATION (LGGE, ISTERRE, LOV)

Objectives

The field campaigns represent a unique opportunity to extend and improve the seismic analysis of sea ice fracturing and deformation. The new technological and logistic opportunities under this programme will allow us to:

- Localise LF icequakes at the regional scale and estimate their relative magnitudes
- Hence investigate the link between fracturing and deformation, correlating LF seismic signals to GPS-observed deformation up to regional (100 km) scales

- Investigate the relationships between internal ice stresses (stressmeters) and fracturing and faulting events (LF seismicity)
- Determine feedbacks between ice thickness/concentration and rheology
- Hence introduce realistic brittle processes into deformation modelling

Interpretation of the seismic data will be performed in collaboration with the scientific partners of the SATICE project, as we raise closely linked questions such as: what is the link between sea ice fracturing and deformation? What is the relative contribution of wind and tides to sea ice fracturing? How does sea ice strength depend on ice thickness?

Methodology
Initial analysis will be performed on the 2012 tiltmeter array. The multi-scale seismic array deployed in autumn 2013 will be the main focus of our analysis, however. Units and data will be common to Task 1.

As set out in the description for Task 1, a comprehensive measurement programme will be performed in the area of the arrays, in both 2012 and 2013. For the seismic and deformation investigations, the map of freeboards from the scanning laser overflights will also serve as the baseline for subsequent deformation studies. Synthetic aperture radar images (e.g. Envisat ASAR) and satellite-derived motion products (such as RGPS) will be used to relate the seismic information and GPS buoy positions to the observed deformation on the large scale.

LF events will be detected by comparing the horizontal and the vertical recordings at very low frequencies (T > ice swell period, e.g., 25 to 40s). By cross-correlating LF waveforms between stations, we will be able to measure the time delays corresponding to the wave propagating from one station to the next. The delays will enable us to determine the direction of propagation from the source, and therefore to locate it. This procedure is made possible by the remarkably wide aperture of the array (100 km), a key characteristic of the proposed set-up that is a novelty for sea-ice seismological studies, which have always focused on much shorter (*e.g.* km) scales.

We will also study the much more local HF icequakes, that can be located within the 1-km array. This will bring additional information on sea-ice deformation, resolved at this small scale. In particular, we will investigate its time variability from the daily to the annual time scales:

(i) Is there a diurnal cycle related to thermal fracturing, as we observed during the *Tara*'s field campaign, in a region of very thick ice?
(ii) How does this diurnal cycle evolve throughout the year? During the *Tara* campaign, the strong diurnal cycle observed during spring disappeared during summer when thermal gradients within the ice cover vanished.
(iii) Is there a semi-diurnal cycle of seismic activity related to tidal forcing; i.e. what is the role of tidal forcing on sea ice fracturing?

The links between these LF and HF seismic activities and internal stress records will be also analyzed in details. Stressmeters have been deployed within sea ice for several years, but the interpretation of these data is still partly controversial: are these internal stress records dominated by a local signal, or set by regional-scale ice motion ? What are the processes associated to stress fluctuations ? The instrument array deployed within this project (Figure 3) will be a unique opportunity to answer to these questions, as well as to others such as: What is the relationship between the stress needed to activate a faulting event, and its size ? What is the amplitude of the stress drop following regional-scale LF icequake ? What is the exact relationship between thermal stresses and thermal fracturing (i.e. HF activity) at the local scale ?

Milestones

M4.1. Month 10/Sept.2012: Instrument test deployment in Beaufort Sea.
M4.2. Month 17/ April 2013: Testing at APLIS ice camp
M4.3. Month 22/ Sept. 2013: Autonomous arrays deployed in Beaufort Sea

Deliverables

D4.1. Month 15/ Feb. 2013: Report on 2012 field tests, demonstrating the technique, setting out autonomous sampling strategy & comparing results with previous DAMOCLES seismic data.
D4.2. Month 48/ Nov. 2015: Synthesis Report on 2013 main deployment, seismic and deformation analysis over the life of the instruments

3.2.5 TÂCHE 5 / TASK 5 : BUOY DEVELOPMENT AND CONSTRUCTION (LGGE, ISTERRE, LOV)

Objectives

Sophisticated autonomous wave-measuring systems will be developed and built, building on established reliable platforms already developed and deployed by the proposers. LOV and ISTERRE will collaborate closely with the SATICE partner SAMS (Scottish Association for Marine Science) to integrate the new sensors with the SATICE buoy core, using our expertise - in both hardware and software – gained from our GreenICE and DAMOCLES work.

Methodology

The proposers (Wadhams and Doble) instigated a new era of wave measuring on sea ice, with the development of autonomous instruments, reporting large volumes of data over the *Iridium* satellite system. The system was initially developed to measure the Southern Ocean waves in the Antarctic pancake ice zone, using a single vertical accelerometer as sensor, and proved to be very robust and successful, surviving the initial freeze-up period (April) where the buoys were subjected to 3+m significant wave heights while surrounded by heaving ice floes. Buoys in that 6-buoy array then froze into the Antarctic pack ice and drifted north, to break out the following Spring (December).

The instrument core was then adapted to handle orthogonal tiltmeter instruments, to allow us to sense extremely small long waves deep in the Arctic pack ice. A revolutionary stepper-motor-controlled self-levelling system was developed and a total of 14 buoys of various generations have now been deployed in the Arctic and Antarctic, in support of a wide variety of scientific aims, including fast-ice breakup and iceberg monitoring. Buoy lifetime has been determined simply by the survival of the ice on which they were deployed: the combination of solar panels (for daylight periods) and deep-cycle rechargeable batteries for the winter has proved very reliable. Our longest-surviving buoy was deployed in the Lincoln Sea, north of Greenland, passed through Nares Strait into Baffin Bay and finally ceased transmission more than 3 years later at 56°N, when the multi-year ridge on which it was deployed finally broke up.

The development task under WaveSIMM will use this proven technology and new sensors in a modular fashion. Primarily this will focus on sensitive 3-axis Guralp seismometers. These have been used extensively on ice by the Grenoble partners and are thus also "known and tested" in this context. Four of the buoys will also carry stressmeters in support of Task 4. Apart from electronic integration, inclusion of these new instruments will require significant additional power capacity and optimization of the data storage, on-board processing and transmission. We will add ionomer foam disc floatation to enable the instruments to survive floe melting, with the aim of continuing to monitor the Arctic wave field over the summer. Ionomer foam is an extremely tough material and it is hoped that floating units will survive the summer and refreeze the following autumn, though riming from freezing spray will be an issue. Units that remain on the ice are expected to continue operating in the normal way.

The buoy cores themselves are being updated and improved as part of the SATICE project, by SATICE partners SAMS (Scottish Association for Marine Science). Doble (LOV) instigated the design and programming of the original units when he worked there during the EU GreenICE project. To ensure a complete exhange of understanding for the development and construction of the instruments, we (Doble and ISTerre engineer) will travel to Scotland and work closely with the SAMS Marine Technology Group for a two-week period to ensure all the details of the buoy systems are properly understood by all concerned. Engineering development and construction will then take place at ISTerre.

Extensive testing of the new units will take place prior to their deployment, to ensure that our enviable performance record is maintained. Instrument development will make up the first phase of the project, in order to have test units ready for the Autumn 2012 cruise. These Guralp-equipped units will be deployed and tested for relatively short periods alongside the ship, during her ice stations, recovered and brought back to France for re-working as the final autonomous units. Further field tests will take place during the (winter/spring) APLIS 2013 ice camp (deployment approximately 2 weeks). Lessons from all these tests will be incorporated before the main array deployment in Autumn 2013. A subset of 4 proven tiltmeter units will be deployed in Autumn 2012 to provide data over that winter, be in place for the submarine underpass and monitor ice breakup in the summer of 2013.

Milestones

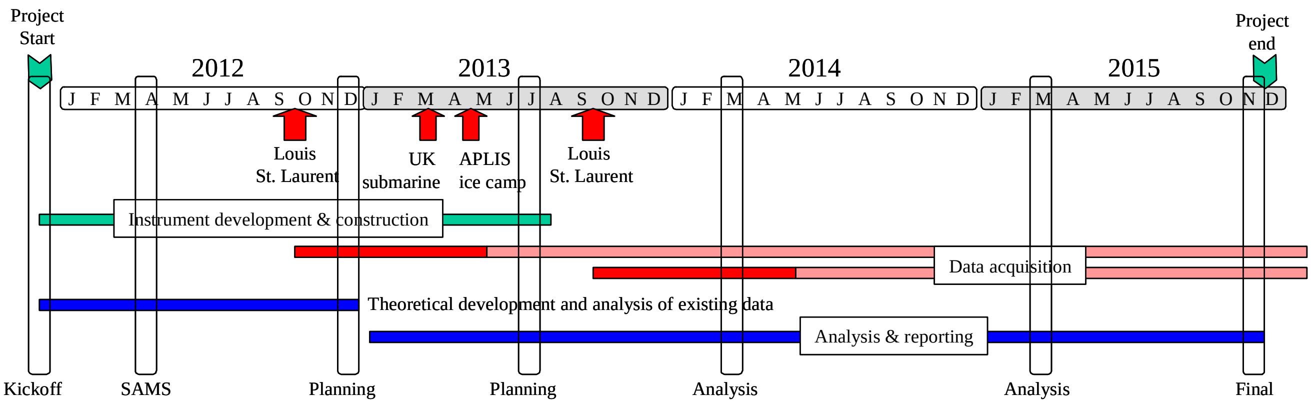
- M5.1: Month 8/July 2012: 4 tiltmeter units built and deployed
- M5.2: Month 8/July 2012: 4 initial test Guralp/stress units built
- M5.3: Month 16/March 2013: 4 final test Guralp/stress units built
- M5.4: Month 20/July 2013: 10 final Guralp + 4 Guralp/stress buoys built and shipped

3.3. CALENDRIER DES TACHES, LIVRABLES ET JALONS / TASKS SCHEDULE, DELIVERABLES AND MILESTONES

The Gantt chart below shows the timeline of the project, which is taken to start at the beginning of December 2011, following a funding decision in July, and run for 48 months. Fieldwork campaigns are indicated by arrows.The start of the project concentrates on instrument, algorithm and theoretical development, prior to the first tests/deployments in autumn 2012. Lessons will be incorporated into the final instrument programming & build, conducted in a timely manner. Analysis will be conducted as the data arrives on

our servers over the satellite link. Main winter acquisition periods are indicated in red, with expected continuing operation marked in pink, possibly beyond the life of the project.
Meetings are indicated as vertical bars :

- **Kickoff**
- **SAMS:** Travel to SATICE partner SAMS (2 weeks) to ensure full transfer of expertise on buoy cores
- **Planning 1** : Discuss initial tests and deployments, plan 2013 campaigns
- **Planning 2:** Detailed planning for main 2013 deployments
- **Analysis 1:** Examine results from main deployments, plan ongoing analysis & reporting
- **Analysis 2:** Continuing exchange of findings
- **Final:** Washup and plan remaining joint work and follow-up work arising from the findings



Deliverables

Task	Month	Description	Résp.
D1.1	15	Report on 2012 field tests	3
D1.2	48	Synthesis Report on 2013 main deployment	3
D2.1	19	Data report from first winter season (Sept. 2012 – May 2013)	2
D2.2	31	Data report from second winter season (Sept. 2013 – May 2014)	2
D2.3	48	Synthesis Report on ice thickness calculation using long period waves	2
D3.1	24	Report on results from 2012 array	2
D3.2	48	Report on importance of wave-induced breakup in the	2

		Beaufort Sea region	
D4.1	15	Report on 2012 field tests	1
D4.2	48	Synthesis Report on 2013 main deployment	1

4. STRATEGIE DE VALORISATION, DE PROTECTION ET D'EXPLOITATION DES RESULTATS / DISSEMINATION AND EXPLOITATION OF RESULTS, INTELLECTUAL PROPERTY

Dissemination of findings and results will be through standard scientific media and practice, i.e., presentations in international meetings such as AGU and EGU and publications in leading peer-reviewed journals such as AGU's Geophysical Research Letters (GRL) and Journal of Geophysical Research (JGR).

The kind of fieldwork that the project involves provides ample opportunities for production of impressive and meaningful outreach material of enormous societal interest. The partners have collaborated extensively with media on previous large Arctic field experiments, including the BBC, Discovery Channel, education/outreach organisations and reputable science journalists. We will seek similar co-operations during the extensive work proposed here. Additionally, the co-ordinating institute of SATICE, ICE/CSIC, is in the process of hiring a full-time scientific journalist. We intend to make use of the services of this professional to enhance communication between our project and the public through the use of that material and education videos, thus bridging between our science and society.

The main results of the project will be (a) the demonstration and validation of low-cost, ice thickness monitoring on local, regional and basin scales; (b) provide first results on the effect of wave energy on ther retreat of Arctic sea ice; (c) introduce realistic processes and rheology into large-scale ice modeling. These will have a large impact on our ability to monitor and model the response of the Arctic to ongoing change and therefore a priority for the project will be to work closely with the modeling community to ensure the advances are properly understood and communicated. Though scientific publications and conference presentations are the primary means of such communication, we will also ensure that the work is disseminated less formally through multiple ongoing collaborations, particularly by LGGE.

Once the thickness monitoring system has been demonstrated and validated by the proposed work, the intention is that the instruments and techniques will form a valuable long-term addition to our Arctic monitoring capabilities, in the framework of International collaborative arrangements, such as the International Arctic Buoy Programme (IABP) and the integrated Arctic Ocean Observing System (iAOOS). Our ice thickness measurements will be added to the new Unified Sea Ice Thickness Climate Data Record maintained at The Polar Science Center, University of Washington (http://psc.apl.uw.edu/sea_ice_cdr)

We will feed the results of our fracture mechanics investigations to the large-scale modeling community, particularly with reference to the LIM sea ice model and the NEMO GCM. These codes, used by several groups involved in IPCC assessments including LEGI, LPO, LOCEAN and LSCE in France, are among the highest resolution ocean/sea ice models of the Arctic region. Partners in this proposal maintain close links with the MEOM (Modélisation des Ecoulements Océaniques Multiéchelles) team at LEGI, a joint research unit of the CNRS, the University Joseph Fourier and the Institut National Polytechnique of Grenoble.

The project will therefore have important and long-term legacies in both monitoring and modeling applications.

5. DESCRIPTION DU PARTENARIAT / CONSORTIUM DESCRIPTION

5.1. DESCRIPTION, ADEQUATION ET COMPLEMENTARITE DES PARTENAIRES / PARTNERS DESCRIPTION AND RELEVANCE, COMPLEMENTARITY

This project is characterised by a strong interdisciplinarity, involving various aspects of geosciences including glaciology, solid earth geophysics, climate sciences and modelling, oceanology, and beyond with some fundamental aspects of fracture and damage mechanics, material science, statistical physics or turbulence. Its success depends therefore on a good cooperation between the different partners, whose respective strengths and competences are summarised below. Such collaborations between the partners are already active, developed during the major EU DAMOCLES project. The funding of this project would strengthen and perpetuate them into a small but active French sea ice mechanics and dynamics community.

Partner 1 (LGGE) has a ~15 years experience on sea ice mechanics, from the analysis of sea ice loads on offshore structures to the analysis of the dynamics, deformation and rheology of the Arctic sea ice cover as a whole. During the last 5 years, in collaboration with LGIT and the Polar Science Center in Seattle, LGGE developed an original analysis of the scaling properties of sea ice drift and deformation and their implications in terms of sea ice rheology. In 2005, LGGE coordinated a field research project on sea ice seismology in Svalbard, funded by IPEV. From 2006 to 2010, LGGE was a partner of the European project DAMOCLES and performed, in collaboration with LGIT, an analysis of sea ice seismology, fracturing and deformation during the drift of the polar schooner Tara. All this experience and the associated former collaborations will help to coordinate the present program. LGGE will be involved in all tasks of this project.

Partner 2 (LOV). Prof. Peter Wadhams & Dr. Martin Doble are in the forefront of this sea ice research, with a particular expertise in measuring and understanding waves in ice. Wave research by the team stems from the large-scale drifting ice camp days of MIZEX, CEAREX and AIWEX, in the 1980s and was recently revived with projects in the Antarctic (*Short Timescale Motion of Pancake Ice* (STiMPI), 1999-2002: Doble *et al*, 2003; Wadhams *et al*., 2004; Doble & Wadhams, 2006; Doble, 2009) and in the Arctic: *Greenland Arctic Shelf Ice and Climate Experiment* (GreenICE), 2002-2005, Doble *et al*. 2006; Haas *et al*., 2006; and DAMOCLES (2006-2010), Wadhams & Doble, 2009.

Partner 3 (ISTerre) has its main expertise in seismology and earthquake studies. The laboratory is located in two sites, Chambéry and Grenoble, which are involved in complementary domains related to the proposed research. For several years, LGIT (now ISTerre), in collaboration with LGGE, applied "solid earth" methodologies or concepts (seismology, faulting, damage) to sea ice mechanics, either in the field or in modelling. Also, the LGIT made early significant contributions to the development of the noise correlation technique, which allow to recontruct the Green's function between two passive sensors as if one was a source. ISTERRE is now recognized as a world leading laboratory for imaging with diffuse seismic waves and background noise.

The consortium is thus highly complementary. LOV (Wadhams/Doble) are one of the most experienced teams worldwide in conducting field experiments on sea ice, with over 50 years on-ice experience between them, particularly with innovative instruments and more particularly measuring waves in ice. Added to this solid base are the Grenoble groups, variously experienced in sea ice work, who bring new insights from their cross-disciplinary perspective of solid-Earth seismics. Such cross-fertilisation of ideas has great promise to move forward research, bringing new ideas and approaches, such as proposed here.

5.2. QUALIFICATION DU COORDINATEUR DE LA PROPOSITION DE PROJET/ QUALIFICATION OF THE PROPOSAL COORDINATOR

The co-ordinator (LGGE : J. Weiss) has long experience of sea ice projects. He was P.I. and member of the steering comitee of two E.U. projects on sea ice forces on offshore structures (LOLEIF (1996-2000) and STRICE (2000-2003)). Then, he co-ordinated an IPEV project in Svalbard that deployed a seismic array in Strofjord (2005), as well as a join CNRS-NSF project on sea ice deformation from 2002 to 2005, and was recently a partner of the E.U. project DAMOCLES, working, with LGIT, on sea ice seismicity and deformation. J. Weiss was also the leader of the Ice Mechanics Team of LGGE from 2002 to 2009.

5.3. QUALIFICATION, ROLE ET IMPLICATION DES PARTICIPANTS / QUALIFICATION AND CONTRIBUTION OF EACH PARTNER

Partenaire	Nom	Prénom	Emploi actuel	Discipline	Personne. mois	Rôle/Responsabilité dans le projet 4 lignes max
LGGE	WEISS	Jérôme	Directeur de Recherche	Ice mechanics	16	Co-ordination of the project. Stresssmeters measurements. Sea ice deformation and fracturing analysis.
LOV	WADHAMS	Peter	Professeur Associé de Recherche	Sea ice physics	12	Sea ice physics.
LOV	DOBLE	Martin	CDD	Sea ice physics	19.2	Oversee development & construction of instruments. Plan co-ordinate & carry out fieldwork. Analysis & exploitation of results for WP2,3,5
LGIT	MARSAN	David	Professeur	seismology	9	Processing of data for WP1 and WP4. Sea ice deformation and fracturing

						analysis.
LGIT	LAROSE	Eric	CNRS CR	Acoustics and seimsology	9	Ambiant noise and ocean wave correlation
ISTerre	X	X	CDD AI	Seismology	12	Development of seismometers, Iridium transmission
ISTerre	COUGOULAT	Glenn	IR CNRS	Seismology	4.5	Development and deployment of seismometers
ISTerre	BASCOU	Pascale	IE	Seismology	4.5	Development and deployment of seismometers and stressmeters

6. JUSTIFICATION SCIENTIFIQUE DES MOYENS DEMANDES / SCIENTIFIC JUSTIFICATION OF REQUESTED RESSOURCES

6.1. PARTENAIRE 1 / PARTNER 1 : LGGE

- *Équipement / Equipment*

4 ice biaxial stressmeters: 4000€ ×4 = 16000 €

- *Personnel / Staff*

6 months of gratification for a Master student working on Task 4 (linking seismicity and deformation), during year 4 of the project: 2388 €

- *Prestation de service externe / Subcontracting*

None

- *Missions / Travel*

Fieldwork :

- Autumn 2012 cruise of Louis St Laurent for 1 pers
  - Return flight to Prudhoe Bay, Alaska = 1600 €
  - Hotel/subsistence transit/joining/leaving cruise, 12 days total @ 150 € = 1800 €
- Autumn 2013 cruise of Louis St Laurent for 1 pers
  - Return flight to Prudhoe Bay, Alaska = 1600 €
  - Hotel/subsistence transit/joining/leaving cruise, 12 days total @ 150 € = 1800 €

- « Internal » WaveSIMM meetings : 1000 €
- Travel costs to 2 international conferences : 2400 €

- *Dépenses justifiées sur une procédure de facturation interne / Costs justified by internal invoicies*

None

- *Autres dépenses de fonctionnement / Other expenses*
  - Computer and software costs : 1500 €
  - Publication costs : 2000 €
  - shipping of stressmeters : 1500 €

6.2. Partenaire 2 / Partner 2 : LOV

- *Équipement / Equipment*

None: Buoy costs are not charged under 'equipment', since they will be deployed and not recovered.

- *Personnel / Staff*

Time is requested at 40% CDD for Dr. Martin Doble. His role will cover instrument development (WP5), planning and execution of the field programme, analysis of the large-scale data (WP2) and wave effects on ice retreat (WP3). His previous experience makes him ideally suited to the work (see CV in Section 7.2).

- *Prestation de service externe / Subcontracting*

None

- *Missions / Travel*

Fieldwork

- Autumn 2012 cruise of Louis St Laurent for 1 pers
    - Return flight to Prudhoe Bay, Alaska = 1600 €
    - Hotel/subsistence transit/joining/leaving cruise, 12 days total @ 150 € = 1800 €
- APLIS 2013 ice camp costs
    - Return flight to Prudhoe Bay, Alaska = 1600 €
    - Hotel/subsistence transit/joining/leaving cruise, 12 days total @ 150 € = 1800 €
- Autumn 2013 cruise of Louis St Laurent for 1 pers
    - Return flight to Prudhoe Bay, Alaska = 1600 €
    - Hotel/subsistence transit/joining/leaving cruise, 12 days total @ 150 € = 1800 €

Meetings

- 4x 2 day project meetings at Grenoble (of 6 total) = 1800 €
- Travel to SAMS for 2 week technology transfer session (13 nights @ 150 € + flights/transfer 400 €) = 2350 €
- 2x 2 pers international conferences to present results = 5200 €

- *Dépenses justifiées sur une procédure de facturation interne / Costs justified by internal invoicies*

None

- *Autres dépenses de fonctionnement / Other expenses*

Buoy costs are not charged under 'equipment', since they will be deployed and not recovered. Guralp seismometers are charged under ISTerre budget.

- 14x Component cost for total SATICE buoy cores (microprocessor, GPS, Iridium modem) @ 4600 € /unit = 64400 €
- 5x Applied Geomechanics tiltmeter sensors for fitting to above cores @ 2600 € = 13000 €
- Ionomer foam floatation discs for 10 units = 18400 €
- Iridium satellite data transmission costs @ 280 € / month/buoy (average 10 months/buoy expected) = 140 months = 39200 €
- Publication charges 2000 €
- Computing material 2000 €
- Shipping field eqpt to experiments 6300 €

6.3. PARTENAIRE 3 / PARTNER 3 : ISTERRE

- *Équipement / Equipment*

10 broad-band CMG 3 – EPSD Güralp stations, 120 s cut-off: 83675 €

- *Personnel / Staff*

The development and test of the seismic stations, and more particularly of the Iridium transmission, will be done in close collaboration with Partner 2 (LOV). This requires employing a full-time AI specialized in seismological instrumentation, for a 1 year duration: 33240 €.

- *Prestation de service externe / Subcontracting*

None

- *Missions / Travel*

Fieldwork

- Autumn 2012 cruise of Louis St Laurent for 2 pers
  - Return flight to Prudhoe Bay, Alaska = 3200 €
  - Hotel/subsistence transit/joining/leaving cruise, 12 days total @ 150 € = 3600 €
- Autumn 2013 cruise of Louis St Laurent for 1 pers
  - Return flight to Prudhoe Bay, Alaska = 1600 €
  - Hotel/subsistence transit/joining/leaving cruise, 12 days total @ 150 € = 1800 €

Visit to LOV

- Travel to and stay at Villefranche sur Mer (LOV) for implementing Iridium transmission on seismic stations (30 days in all) : 2715 €

- *Dépenses justifiées sur une procédure de facturation interne / Costs justified by internal invoicies*

Consumables for tests of seismic stations, documentation, 16523 €

- *Autres dépenses de fonctionnement / Other expenses*

  - Iridium satellite data transmission costs @ 280 € / month/station (average 12 months/station expected) and Iridum modems = 43600 €
  - Consumables for seismic stations (batteries, automatic leveling) @ 2900 € / station = 29000 €
  - Publication charges 2000 €
  - Computation costs (PCs, consummables) 5000 €
  - Shipping field equipment to experiments 2500 €

7. ANNEXES / ANNEXES

7.1. REFERENCES BIBLIOGRAPHIQUES / REFERENCES

From members of, and relevant to, the present project (recent publications):

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Doble, M.J.; Coon, M. D.; **Wadhams, P**. (2003). Pancake ice formation in the Weddell Sea, *J. Geophys. Res*. **108**(C7), 3209. doi: 10.1029/2002JC001373

Doble, M.J., and **P. Wadhams** (2006). Dynamical contrasts between pancake and pack ice, investigated with a drifting buoy array, *J. Geophys. Res*. **111**, C11S24, doi:10.1029/2005JC003320

Doble, M.J., Mercer, D.J.L. and D.T. Meldrum (2006). Wave measurements on sea ice: developments in instrumentation. *Ann. Glaciol.* **44,** 108-112

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Doble, M.J., Skourup, H., **Wadhams, P**. (2011). The relation between sea ice freeboard and draft in the Beaufort Sea: results from high resolution mapping using AUV sonar and a scanning laser profilometer. *Submitted to JGR OCeans*.

Girard, L., S. Bouillon, **J. Weiss**, D. Amitrano, T. Fichefet, V. Legat, 2011, A new modelling framework for sea ice ice mechanics based on elasto-brittle rheology, Annals Glaciol., **52**(57), 123-132

Haas, C., Hendricks, S. and **M.J. Doble** (2006). Comparison of the sea ice thickness distribution in the Lincoln Sea and adjacent Arctic Ocean in 2004 and 2005. *Ann. Glaciol.* **44**, 247-252

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Marsan, D., Weiss, J., Metaxian, J.P., Grangeon, J., Roux, P.F. and Haapala, J., Low frequency bursts of horizontally-polarized waves in the Arctic sea ice cover: a signature of remote regional-scale icequakes?, *J. Glaciol.*, in press

Marsan, D. and **J. Weiss**, 2010, Space/time coupling in brittle deformation at geophysical scales, *Earth Planet. Sci. Lett*.,, **296**, 353-359

Rampal, P., **Weiss, J**., **Marsan, D**., 2009. Positive trend in the mean speed and deformation rate of Arctic sea ice: 1979-2007. J. Geophys. Res. 114, C05013.

Rampal, P., **Weiss, J**., **Marsan, D**., Lindsay, R., Stern, H., 2008. Scaling properties of sea ice deformation from buoy dispersion analyses. J. Geophys. Res. 113, C03002.

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Wadhams, P. & **M.J.Doble** (2009). Sea ice thickness measurement using episodic infragravity waves from distant storms, *Cold Reg Sci.& Tech.* **56**, 98-101

Weiss, J., **Marsan, D**., Rampal, P., (2009). Space and time scaling laws induced by the multiscale fracturing of the Arctic sea ice cover, in: Borodich, F., (Ed), *IUTAM Symposium on Scaling in solid mechanics*, IUTAM Bookseries, Springer, pp. 101-109.

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Campillo, M. and Paul, A. (2003). Long-range correlation in the seismic coda. *Science*, 299, 547-549

Crary A. P. (1955), A brief study of ice tremors, Bull. Seismol. Soc. Am., 45, 1-9.

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Milne A. R., and J. H. Ganton (1964), Ambient noise under Arctic sea-ice, J. Acoust. Soc. Am., 36, 855-863.

Richter-Menge, J.A. and Elder, B.C. (1998). Characteristics of pack ice stress in the Alaskan Beaufort Sea. *J. Geophys. Res*. **103**, 21817-21829.
Richter-Menge, J.A., McNutt, S.L., Overland, J.E., Kwok, R., 2002. Relating arctic pack ice stress and deformation under winter conditions. *J. Geophys. Res*. **107**, 8040.
Weaver & Lobkis (2001). Ultrasonics without a source : Thermal fluctuations correlations at MHz frequencies. *Phys. Rev. Lett*. **87**, 134301.

7.2. Biographies / CV, resume

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Né le 1/1/1966, Marié, 3 enfants

Sujets de recherche: Fracturation et déformation plastique : des Sciences des matériaux aux Géosciences ; Systèmes complexes, lois d'échelles et criticalité; Dynamique et modélisation de la banquise

Cursus/Formation :

Thayer School of Engineering, Dartmouth College, Post-Doc, 1993
Ecole Nationale Supérieure des Mines de Paris, Doctorat en Sciences et Génie des Matériaux, 1992
Institut National Polytechnique de Lorraine, DEA, 1988
Ecole Nationale Supérieure de Géologie, Diplôme d'Ingénieur, 1988

Parcours professionnel :

2007 (Automne) Professeur invité, Université de Louvain-La-Neuve, Belgique
2005-présent Directeur de Recherche, LGGE/CNRS
2002-2009 Responsable de l'équipe "Matériau Glace", LGGE/CNRS
1994-2005 Chargé de Recherche, LGGE/CNRS

Production scientifique :

>70 publications dans revues ou ouvrages à comité de lecture, dont : 7 articles de revue sollicités , 2 *Nature*, 1 *Science*, 1 *Nature Materials*, 7 *J. Geophys. Res*., 2 *EPSL*, 2 *Phys. Rev. Lett.*, 2 *Phys. Rev. B*, 4 *Mat. Sci. Eng. A*, ..
23 conférences invitées

Diffusion des savoirs, enseignement :

3 articles de vulgarisation sur l'évolution de la banquise (Pour la Science, La Découverte, Pôle Nord &Sud)
10 conférences grand public, diverses interventions radio et télévision, ..
Responsable du cours « Complexité des objets géophysiques » de l'ED Terre-Univers-Environnement de l'UJF
Intervenant en M2R Terre-Univers-Environnement

5 Publications récentes (liées au projet) :

Marsan, D., Weiss, J., Metaxian, J.P., Grangeon, J., Roux, P.F. and Haapala, J., Low frequency bursts of horizontally-polarized waves in the Arctic sea ice cover: a signature of remote regional-scale icequakes?, *J. Glaciol.*, in press, 2011
Rampal, P., Weiss, J., Marsan, D. and Bourgoin, M., Arctic sea ice velocity field: general circulation and turbulent-like fluctuations, *J. Geophys. Res.*, **114**, C10014, 2009
Rampal, P., Weiss, J. and Marsan, D., Positive trend in the mean speed and deformation rate of Arctic sea ice, 1979-2007, *J. Geophys. Res*., **114**, C05013, 2009
Rampal, P., Weiss, J., Marsan, D., Lindsay, R., Stern, H., Scaling properties of sea ice deformation from buoy dispersion analysis, *J. Geophys. Res.*, **113**, C03002, 2008
Weiss, J., Schulson, E.M., Stern, H.L., Sea ice rheology from in-situ, satellite and laboratory observations: Fracture and friction, *Earth Planet. Sci. Lett*., **255**, 1-8, 2007

PETER WADHAMS MA PhD ScD est Professeur Associé de Recherche à l'Université Pierre et Marie Curie, en poste au Laboratoire d'Océanographie de Villefranche (LOV), et Professeur d'Océanographie Physique, Department of Applied Mathematics and Theoretical Physics (DAMTP), Université de Cambridge, Angleterre. Avec l'accord des deux universités il partage son temps de façon égale entre le LOV et DAMTP. Né le 14 mai 1948, il a un MA et PhD de l'Université de Cambridge et un ScD honoraire de Cambridge pour ses recherches. Il a passé plusieurs ans au Scott Polar Research Institute, Cambridge, où il était Directeur de 1987 à 1992. Il a la Médaille Polaire (H.M. la reine Elisabeth)(1987), le Prix Italgas pour la Recherche et l'Innovation dans les Sciences de l'Environnement (1990) et il est un membre étranger de l'Académie Finlandaise de la Science et des Lettres (2006). Il est un expert sur la glace de mer et l'océanographie polaire, et travaille avec les sous-marins arctiques et les AUV.

5 Publications récentes (liées au projet)

Wadhams, P. & M.J.Doble (2009). Sea ice thickness measurement using episodic infragravity waves from distant storms, *Cold Reg Sci.& Tech.* **56**(2-3), 98-101

Wadhams, P. & M.J. Doble (2008). Digital terrain mapping of the underside of sea ice from a small AUV, *Geophys. Res. Lett*. **35**, L01501, doi:10.1029/2007GL031921

Doble, M.J., and **P. Wadhams** (2006). Dynamical contrasts between pancake and pack ice, investigated with a drifting buoy array, *J. Geophys. Res*. **111**, C11S24, doi:10.1029/2005JC003320

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Martin Jonathan DOBLE

Situation professionnelle

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Cursus/formation

- Du 5/2001 au 9/2007 Doctorat (temps partiel) National Oceanography Centre.
- Du 9/96 au 9/97 M.Sc. Oceanography, Southampton Oceanography Centre.
- Du 9/85 au 6/88 B.Eng.Electrical and Electronic Engineering, Imperial College London

Parcours professionnel

- A partir de 01/03/2011, postdoc CDD (3 ans) à LOV implique d'un contrat européen FP-7
- Du 01/08/2006 au 31/02/2011, chercheur à l'Université de Cambridge, Department of Applied Mathematics and Theoretical Physics (DAMTP).
- Du 01/12/2002 au 31/07/2006, chercheur à la Scottish Association for Marine Science (SAMS), Oban, Ecosse.
- Du 01/10/1997 au 31/11/02, chercheur à l'Université de Cambridge, Scott Polar Research Institute (SPRI)
- Du 1/93 au 9/96, géophysique, Digital Exploration Ltd., U.K.
- Du 2/89 au 1/92, ingénieur, Services Techniques Schlumberger, Paris

5 Publications récentes (liées au projet) :

Doble, M.J. (2010). Ocean waves in sea ice: determining ice thickness between intermittently-recording buoys. *International Glaciology Society Symposium on Sea Ice in the Physical and Biochemical System*, Tromso, Norway, 31 May – 4 June 2010.

Doble, M.J. (2009). Simulating pancake and frazil ice growth in the Weddell Sea: A process model from freezing to consolidation. *J. Geophys. Res.* **114**, C09003, doi: 10.1029/2008JC004935

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Doble, M.J., Mercer, D.J.L. and D.T. Meldrum (2006). Wave measurements on sea ice: developments in instrumentation. *Ann. Glaciol.* **44,** 108-112

David MARSAN

né le 3/2/1970 (40 ans)

Institut des Sciences de la Terre (ISTerre) UMR CNRS – IRD – LCPC – UJF - UdS
Université de Savoie, Campus Scientifique, 73376 Le Bourget du Lac Cedex

Recherche :

- Déclenchement des séismes : observation, modélisation.
- Dynamique de la sismicité d'une zone de failles
- Mécanique de la banquise Arctique : déformation, fracturation, caractérisation.
- Fracturation des glaciers alpins

Cursus :

Depuis Septembre 2009 : **Professeur des Universités au LGIT – Université de Savoie**

- 2000-2009 : Maître de Conférences au LGIT – Université de Savoie
- 1997-2000 : post-doctorant au Département de Géologie de l'University College Dublin (Irlande)
- 1994-1997 : thèse de Physique Théorique au Laboratoire de Météorologie Dynamique et au Laboratoire de Modélisation en Mécanique (Université Paris 6), sur les « Multifractals espace-temps : dynamique et prédicibilité. Application aux champs de précipitations »
- 1993-1994 : DEA de Physique Théorique (Université Paris 6, ENS Paris).
- 1989-1993 : élève ingénieur à l'Ecole de Physique et Chimie Industrielles de la ville de Paris (ESPCI), spécialisation en physique.

Cinq publications :

- Marsan, D., H. Stern, R. Lindsay et J. Weiss, Scale dependence and localization of the deformation of Arctic sea ice, *Phys. Rev. Lett*., 93 (17), 178501, 2004.
- Roux P.-F., Marsan D., J.P. Métaxian, L. Moreau, et G. O'Brien, Microseismic activity within a serac zone in an Alpine glacier (glacier d'Argentière, Mont-Blanc, France), *Journal of Glaciology*, 54, 157-168, 2008.
- Marsan D., et O. Lengliné, Extending earthquake' reach through cascading, *Science*, 319, 2008.
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- Marsan D., Weiss J., Métaxian J.-P., Grangeon J., Roux P.-F., Haapala J., Low frequency bursts of horizontally-polarized waves in the Arctic sea-ice cover: A signature of remote, regional-scale icequakes?, J. Glaciol., sous presse.

Nombre total de publications dans les revues internationales et actes de congrés à comité de lecture:

41 (depuis 1996).

Autres :

Directeur-adjoint ISTerre (2007 – 2012).
Editeur Associé au Journal of Geophysical Research – Solid Earth depuis janvier 2008.
Actuellement coordinateur d'un projet ANR – JC « ASEISMIC » (fin décembre 2012).

Eric Larose
Chargé de Recherche (CR1) CNRS
ISTerre, Maison des Géosciences, BP 53, 38041 Grenoble Cedex 9
Né le 25 Janvier 1977 à Meudon (92)

- 1995 : Baccalauréat, série S.
- 1998 : Entrée à l'École Normale Supérieure (rue d'Ulm), concours Physique (D/S).
- 2001 : D.E.A. en Physique Statistique et Phénomènes non-Linéaires de l'ENS Lyon.
- 2005 : Doctorat en géophysique : *Diffusion multiple des ondes sismiques et expériences analogiques en ultrasons,* au LGIT (M. Campillo), et au Laboratoire Ondes Acoustiques (A. Derode).

Expériences Professionnelles après le doctorat:

- 15 sept. 2005 – 1 mai 2006 : Post-doctorat chez R. Weaver, University of Illinois at Urbana Champaign (USA)

Distinctions :

- Prix Edouard Branly 2010, remis par la F2S (SFP+SFO+SEE)
- Prix Coup de cœur « focus innovation » 2009 par le consortium régional GRAVIT.
- Lorand Eotvos Award 2008 from the European Associations of Geoscientists and Engineers (EAGE).
- Best paper award 2006 of the Society of Exploration Geophysicists (SEG).

Brevet :

"Localisation de défaut par suivi temporel d'ultrasons" FR0950612. Auteur E. Larose et V. Rossetto. Gestionaire : CNRS. Déposé le 30 janvier 2009.
Extension Europe et Etats-Unis effectuée en janvier 2010.

Cinq publications significatives :

E. Larose, T. Planes, V. Rossetto and L. Margerin: *Locating a small change in a multiple scattering environment*, Appl. Phys. Lett. **96** (20) (2010).

E. Larose, M. Campillo and L. Stehly: *Imaging the solid Earth with seismic noise*, J. Phys.: conf. ser. **118** 012003 (2008).

F. Brenguier, M. Campillo, C. Hadziioannou, N. M. Shapiro, R. M. Nadeau, and **E. Larose**: *Postseismic Relaxation Along the San Andreas Fault at Parkfield from Continuous Seismological Observations* Science **321**, 1478-1481 (2008).

E. Larose A.Derode, D. Clorennec, L. Margerin, M. Campillo : *Passive retrieval of Rayleigh waves in disordered elastic media,* Phys. Rev. E **72,** 046607 (2005).

E. Larose, A. Derode, M. Campillo, M. Fink : *Imaging from one-bit correlations of wide-band diffuse wavefields*, J. Appl. Phys. **95** (12), pp 8393-8399 (2004).

7.3. IMPLICATION DES PERSONNES DANS D'AUTRES CONTRATS / STAFF INVOLVMENT IN OTHER CONTRACTS

Part.	Nom de la personne participant au projet / name	Personne . Mois / PM	Intitulé de l'appel à projets, source de financement, montant attribué / Project name, financing institution, grant allocated	Titre du projet : Project title	Nom du coordinateur / coordinator name	Date début & Date fin / Start and end dates
N°1	Weiss Jérôme	3/an	Programme européen 72 k€ pour LGGE	DAMOCLES	Jean-Claude Gascard	2005-2010
N°1	Weiss Jérôme	4/an	ANR Blanc 120 k€ pour LGGE	EVOCRIT	Lev Truskinovsky	2008-2012
N°2	Martin DOBLE	37	EU FP7-OCEAN-2010, 458.848 €	ACCESS : Arctic Climate Change, Economy & Society	J-C Gascard	1/3/2011 – 31/2/2015
N°2	Peter WADHAMS	12	EU FP7-SPACE-2010-1, 382.749 €	SIDARUS : Sea ice downstream services for Arctic & Antarctic users and stakeholders	S. Sandven	1/1/2011 – 31/12/2013
N°2	Peter WADHAMS	16	EU FP7-OCEAN-2010, 458.848 €	ACCESS	J-C Gascard	1/3/2011 – 31/2/2015
N°3	Eric LAROSE	20	ERC Advanced Grant	WHISPER	M. Campillo	1/1/2010 – 31/12/2014
N°3	David MARSAN	4,8 / ans	ANR JC 192 k€	ASEISMIC	D. MARSAN	1/1/2009 – 31/12/2012