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# 2<sup>nd</sup> Workshop in Signal Processing for Marine and Seismic Data

*Abril 27-28, 2009*

*Unidad de Tecnología Marina, CSIC*

*Pg Marítim de la Barceloneta, 37-49*

*08012 Barcelona*

*SPAIN*

## **Organizers**

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Carine Simon

Juan Jose Dañobeitia

# Workshop program

## *Procesado de la Señal Aplicado a Datos Marinos y Sísmicos*

### 27<sup>th</sup> April

#### Morning

- 11h30 Welcoming and presentation of the UTM, *Juanjo Dañobeitia*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain
- 11h40 Group presentation and objectives of the workshop, *Carine Simon*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain

#### Microwave, synthetic aperture systems

- 11h50 Spatial Resolution Enhancement of SMOS Data: a Deconvolution-based Approach, *María Piles*  
Remote Sensing Laboratory, Dept. Teoria del Senyal i Comunicacions, Universitat Politècnica de Catalunya, Barcelona, Spain  
SMOS Barcelona Expert Centre, CMIMA, Barcelona, Spain
- 12h20 Scatterometer wind inversion, *Marcos Portabella*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain
- 12h50 Contributive processing methods integrated in a robust tool for ocean monitoring from SAR imagery, *Marivi Tello*  
Remote Sensing Laboratory, Signal Theory and Communications Department. Universitat Politècnica de Catalunya, Barcelona, Spain
- 13h20 Processing and Application, *Enrique Coiras*  
S&T Department, NATO Undersea Research Center
- 13h50 Discussions
- 14h15 Lunch break

#### Afternoon: biology

- 15h30 Permanent observing systems for biological studies. Opportunities and challenges for technological research, *Jaume Piera*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain
- 16h Derivative analysis of hyperspectral remote-sensing reflectances, identification of phytoplankton pigment assemblages, *Elena Torrecilla*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain
- 16h30 Dimensionality reduction techniques for hyperspectral data using wavelets, *Sergi Pons*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain
- 17h Coffee break
- 17h20 Applications of Non-Linear Physics methods for the extraction of dynamic quantities in remote-sensing data, *Antonio Turiel*.  
Instituto de Ciencias del Mar, CSIC, Barcelona, Spain
- 18h 2D and 3D image surface descriptors for fish otoliths classification, *Ramon Reig Bolaño*  
Departament d'Electrònica i Telecomunicacions, Universitat de Vic, Vic, Spain.
- 18h30 Adaptive nonlinear growth demodulation and time warping of otolith intensity profiles, *Vicenç Parisi*  
Departament d'Enginyeria Electrònica, Superior, Universitat Politècnica de Catalunya, Vilanova i la Geltrú, Spain.
- 19h Discussions

## 28<sup>th</sup> April

### Geophysics

- 9h30 Processing of EM data, *Xavier Garcia*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain
- 10h Vector sensor array processing for seismic data, *Jérôme Mars*  
GIPSA-Lab/ Dept. Images Signal, Grenoble, France
- 10h45 New trends for shallow water acoustic tomography, *Jérôme Mars*  
GIPSA-Lab/ Dept. Images Signal, Grenoble, France
- 11h15 Coffee break
- 11h35 Acoustic imaging enhancement by application of phase coherence factors, *Jorge Camacho*  
Instituto de Automática Industrial – CSIC, Madrid, Spain
- 12h05 Velocity adaptive filters in the time-scale domain, *Sergi Ventosa*  
Unidad de Tecnología Marina, CSIC, Barcelona, Spain
- 12h35 Detection, Characterization and Origin of Polarized Microseismic Noise, *Martin Schimmel*  
Institute of Earth Sciences Jaume Almera – CSIC, Barcelona, Spain
- 13h05 Discussions
- 13h45 Lunch

# Abstracts

## Microwave, synthetic aperture systems

### **Spatial Resolution Enhancement of SMOS Data: a Deconvolution-based Approach**

*María Piles, Mercè Vall-llossera, Adriano Camps, and Marco Talone*

Remote Sensing Laboratory, Dept. Teoria del Senyal i Comunicacions, Universitat Politècnica de Catalunya, Barcelona, Spain

SMOS Barcelona Expert Centre, CMIMA, Barcelona, Spain

A deconvolution-based model has been developed to improve the spatial resolution of future Soil Moisture and Ocean Salinity (SMOS) data. This presentation is devoted to the analysis and evaluation of this approach: a comparative study of different algorithms has been performed over brightness temperatures images obtained from an upgraded version of the SMOS End-to-end Performance Simulator (SEPS). Particular emphasis is made on the use of least-squares-derived Lagrangian methods on the Fourier and Wavelet domains. The possibility of suitably adding auxiliary information in the reconstruction process has also been addressed. Results indicate that with these techniques it is feasible to obtain a good agreement between spatial resolution enhancement and radiometric sensitivity upholding.

### **Scatterometer wind inversion**

*M. Portabella<sup>1</sup>, A. Stoffelen<sup>2</sup>, M. Belmonte<sup>2</sup>, and J. Vogelzang<sup>2</sup>*

<sup>1</sup> Unidad de Tecnología Marina (UTM – CSIC), Pg. Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain.

<sup>2</sup> Royal Netherlands Meteorological Institute (KNMI), 3730 AE De Bilt, The Netherlands.

Scatterometers are real aperture radars, which are known to provide accurate mesoscale (25-50 km resolution) wind field information used in a wide variety of applications, including Numerical Weather Prediction (NWP) data assimilation, nowcasting, and climate studies. The radar antenna geometry, the measurement noise, as well as non-linearities in the relationship between the backscatter measurements and the wind vector (i.e., the Geophysical Model Function, GMF) complicate the wind inversion process.

In a quest for a generic unbiased scatterometer wind inversion method, the different inversion procedures currently in use are revisited in this paper. A careful examination of both the errors in the wind and in the measurement domain, combined with the non-linear shape of the GMF, leads to a generic and novel Bayesian wind retrieval approach in the measurement domain. In this approach the shape of the GMF solution manifold in measurement space is more important than the specified noise. This shape is related to the system wind direction sensitivity, and when this sensitivity is uniform, realistic and precise wind direction distributions are retrieved, even when measurements lie far from the GMF manifold. A simplified measurement space transformation that produces such uniform sensitivity for the European Remote Sensing Satellite (ERS) scatterometer is presented and shown to have reduced wind direction bias compared to the more traditional (measurement-noise normalized) inversion for ERS. Moreover, the simplified wind inversion reveals a similar performance to the current operational ERS wind inversion, but is potentially more generally applicable. The simplified method is then applied to SeaWinds but is ineffective. In this case the instrument geometry results in a low

sensitivity to wind direction at a few specific directions. As a consequence, certain wind direction solutions remain favoured in the SeaWinds inversion.

## **Contributive processing methods integrated in a robust tool for ocean monitoring from SAR imagery**

*Marivi Tello, Carlos Lopez-Martinez, Jordi J. Mallorqui*

Remote Sensing Laboratory, Signal Theory and Communications Department  
Universitat Politècnica de Catalunya (UPC), Barcelona, Spain

A number of experiments all over the world have proven that satellite borne SAR images constitute a valuable tool to monitor oceanic environment, preventing it from overexploitation or pollution matters and it can also help to evaluate the full implications of natural or man made hazards. Nonetheless, the understanding and subsequent exploitation of SAR images is difficult and specific data mining methods are still to be developed.

In the last two years, our group has studied, analyzed and validated several dedicated and automatic processing methods for different marine applications in SAR imagery: namely, ship detection [1], extraction and monitoring of temporal evolution of the coastline [2] and detection and rough classification of pollutants on the sea surface [2]. All of these methods rely in a multiscale time (or space) - frequency framework which it has been shown to be well suited for this purpose. In fact, the use of time - frequency tools allow the evaluation of statistical parameters of the imaged scene, while preserving spatial information. Furthermore, the time – frequency trade off can be adjusted thanks to the multiscale capability of this method, providing a sense of context, extremely helpful to understand the observed scene, with no a priori information about it.

Even if usually treated separately, the oceanic applications concerned (vessel monitoring, coastline extraction and spill detection) are very closely related to each other. For example, any algorithm for automatic ship detection requires a previous land mask step which is usually performed with maps available from other sources. This is a problematic and time consuming operation which could be rendered easier by applying a method for automatic coastline extraction sufficiently robust. Moreover, the constitutive peakiness of SAR images can be reduced with a slight evolution of the technique used for ship detection and this increases substantially the performance of the algorithms used for coastline extraction or for the analysis of textures involved in oil spill detection. Besides, the discrimination of large elongated patterns can drastically reduce false alarms when the objective is to perform ship detection. It can also be used to locate oil spills in the sea surface. Additionally, the automatic detection of oil slicks aims at revealing responsibilities and it is then deeply associated to ship detection. Hence, previous examples suggest that the most efficient exploitation of oceanic SAR images implies a simultaneous use for different but complementary applications.

The objective of this presentation is to separately describe the algorithms specifically designed for marine applications with SAR data and to suggest the benefits of using a global tool incorporating these algorithms, enhancing both global and individual results whereas saving computing cost.

[1] Tello, M.; López-Martínez, C.; Mallorqui, J. Automatic Vessel Monitoring with Single and Multidimensional SAR Images in the Wavelet Domain, ISPRS

[2] Tello, M.; López-Martínez, C.; Mallorqui, J. Automatic Detection of Spots and Extraction of Frontiers in SAR Images by Means of the Wavelet Transform: Application to Ship and Coastline Detection, Proceedings on IGARSS 06.

## **Sonar Image Processing and Applications**

*Enrique Coiras*

S&T Department, NATO Undersea Research Center

The latest generation of sonar sensors offers new opportunities for investigating the underwater environment. MUSCLE, the new Synthetic Aperture Sonar (SAS) system developed by NATO's Undersea Research Centre (NURC), is capable of producing images at 2.5cm resolution up to 200m range, enabling for unprecedented quality and coverage in the observation of the seabed. As a counterpart, the data flow associated to this new type of sensor is very high, and automated image processing tools are necessary to process mission results. This presentation gives an overview of the different image processing operations required to extract information from high-resolution side-looking sonars and their application to object detection, seabed classification and 3D reconstruction.

## **Biology**

### **Permanent observing systems for biological studies. Opportunities and challenges for technological research.**

*Jaume Piera*

Unidad de Tecnología Marina, CSIC, Barcelona, Spain

The talk will introduce the main research activities of our group at the UTM. Although it will be focused on biological related studies, within the framework of high resolution and permanent observatories, most of our activity can be easily related to other research lines of marine technology.

### **Derivative analysis of hyperspectral remote-sensing reflectances, identification of phytoplankton pigment assemblages**

*Elena Torrecilla*

Unidad de Tecnología Marina, CSIC, Barcelona, Spain

One of the major challenges of ocean color research is distinguishing phytoplankton groups from space to better study and understand some involved biochemical processes. In this framework, high spectral resolution measurements of the remote-sensing reflectance, hyperspectral  $R_{rs}(\lambda)$ , can potentially yield more information about the presence of diverse phytoplankton groups than can be gleaned from traditional analyses of single band-ratios at discrete wavelengths (multispectral measurements). We introduce and discuss the feasibility of performing derivative analysis of hyperspectral  $R_{rs}(\lambda)$  to improve the identification of phytoplankton populations in open ocean waters. This approach is explored considering a data set of measured and modeled optical properties collected along a north-to-south transect in the eastern Atlantic Ocean. Stations have been first classified using Hierarchical clustering algorithms (HCA) into differing phytoplankton assemblages based upon the ratios of dominant accessory pigments to chlorophyll a (HPLC measurements). Next, differences in each station  $R_{rs}(\lambda)$  have been further examined using tools such as derivative spectroscopy and cluster analysis. Results suggest that the application of these techniques to hyperspectral  $R_{rs}(\lambda)$  provides an effective means to potentially characterize phytoplankton biodiversity in open ocean environments.

### **Dimensionality reduction techniques for hyperspectral data using wavelets**

*Sergi Pons*

Unidad de Tecnología Marina, CSIC, Barcelona, Spain

Recently, the optical and bio-optical research has emphasized the use of optical measurements as instruments to characterize the hydrodynamic, biologic and geochemical processes on the ocean. From variations of the optical properties on the water mass, changes of composition,

concentration or distribution of the constituents of the water column can be inferred. A concrete optical sensor is the hyperspectral sensor. Hyperspectral sensing is the analysis of signals using a large number of optical channels (corresponding to spectrum intervals).

This study tests a methodology consisting on decomposing hyperspectral data using wavelet analysis and choosing the best resulting coefficients using an entropy criterion, to state if they are more suitable as an input for a decision system than raw data.

### **Applications of Non-Linear Physics methods for the extraction of dynamic quantities in remote-sensing data.**

*Antonio Turiel*

Instituto de Ciencias del Mar, CSIC, Barcelona, Spain

In the recent years, the development of new techniques issued from Nonlinear Physics and the theory of turbulent flows has given rise to many applications in the domain of signal processing of remote sensing maps. With the aid of a new theoretical framework, the Microcanonical Multifractal Formalism, many new dynamic quantities can be derived from maps of variables such as SST or Chlorophyll concentration. In this talk we will review the main theoretical aspects of this formalism and we will show applications to real data. Future directions of research will also be discussed.

### **2D and 3D image surface descriptors for fish otoliths classification**

*Ramon Reig Bolaño, Pere Martí Puig, Antoni Lombarte, Vicenç Parisi*

Departament d'Electrònica i Telecomunicacions, Universitat de Vic, Vic, Spain.

Departament d'Enginyeria Electrònica, Superior, Universitat Politècnica de Catalunya, Vilanova i la Geltrú, Spain

The information of the volumetric surface of the otolith in a 3D representation will provide many details for the classification process (i.e. the representation of the acoustic groove). This 3D approach to the problem requires choosing a volumetric descriptor simple and easy to use. The extension of contour descriptors to 3D superficies is thus a challenging task that is not straightforward from 2D radial descriptors. In this work we propose a new descriptor of contours on 2D images that can be easily extensible to 3D.

Typical approaches to contour descriptors like radial descriptors, with a polar representation of the contour radius are the most widely used representation for the contour-based otoliths classification. The automatic classification of otoliths species is frequently based on their image contours. Frequently a standard protocol is used for the positioning and the capture of these images.

Our contour descriptor is based on the reflection of a normalized closed contour, with a definite horizontal and vertical axis, used as a reference for the reflection, and followed by an extraction of a non redundant contour descriptor from this new duplicated contour image.

Moreover, in some preceding works it has been validated that the analysis of these contours in transformed domains, such as FFT, wavelets or wavelet packet are appropriate for achieving discriminative parameters.

The efficiency of this descriptors represented in the transformed domain has been tested with different species below to the Family mugilids (<http://aforo.cmima.csic.es>): *Chelon labrosus*, *Liza aurata*, *Liza ramada*, and *Mugil cephalus*. This group is characterized by a close external similarity between species, and a good and detailed shape analyses of their otoliths can help to identify and discriminate morphologically close species. First results are promising and motivate the use of these descriptors in future tools for otolith 3D identification based on wavelet parametrization.

## **Adaptive nonlinear growth demodulation and time warping of otolith intensity profiles**

*Vicenç Parisi, Pere Martí, Ramon Reig*

Departament d'Enginyeria Electrònica, Superior, Universitat Politècnica de Catalunya, Vilanova i la Geltrú, Spain

Automated fish ageing from otoliths is usually based on the classification of radials of otolith section images.

The intensity profiles of these radials show singularities (peaks and valleys), due to the seasonal (annual) growth structures that can serve to classify the fish age. Normally these intensity profiles contain noise and are very influenced by the exponential growth of the otolith.

Specifically, non linear growth causes that radials belonging to an otolith of a given age have the singularities distributed in a nonuniform manner. This phenomena affects negatively the classifier performance and all those preprocessing steps of the radials, such as the wavelet representation, that are non traslation invariant. Thus, in this paper we present two techniques that are designed to reduce the effects of exponential growth. First we show an adaptive non linear demodulator base on the Von Bertalanffy growth model and a entropy optimization scheme

to compute the best model parameters in order to align the singularities of a given set of radials/age. Then we propose an alternative based on a dynamic time warping, to align otolith singularities, independently of the growth model.

The validity of both approaches is tested using a database of calibrated otoliths.

## **Geophysics**

### **Processing of marine EM data**

*Xavier Garcia*

Unidad de Tecnología Marina, CSIC, Barcelona, SPAIN

Electromagnetic (EM) data processing consists in the extraction of electrical impedances from the electric and magnetic fields measured in the field. Processing starts with a visualization of the data to remove those segments that are more contaminated by noise and also the application of some sort of pre-conditioning of the data consisting in filtering, detrending, pre-whitening. The following step consists in the calculation of the spectra of the EM time series, and using a Least-squares method the impedances are calculated through an iterative process. The last step consists in the calculation of the confidence limits.

At Prosedams I will present the different approaches in each one of the processing steps that I follow to process data, and also show some of the problems that I am still facing.

### **Vector sensor array processing for seismic data.**

*J.I. Mars*

GIPSA-Lab/ Dept. Images Signal, 961 rue de la Houille Blanche - BP46, F-38402  
GRENOBLE Cedex

OVER the past few years, multicomponent data have been used increasingly in the development of oil and gas exploration projects, either for improved noise attenuation methods or for the additional information (polarization) that the multicomponent provides to the interpreter. Arrays of multicomponent sensors offer useful information about the nature of the propagated wavefields and allow a more complete description of the underground structures. The polarization information is very helpful to differentiate and characterize seismic waves, but the specific (multicomponent) nature of the datasets has to be taken into account in the processing.

Consequently, more advanced processing methods for this kind of data are required to recover polarization of the recorded wavefield.

We present a model for signals recorded on arrays of vector-sensors acquiring seismic vibrations in different directions of the 3D space. Such acquisition schemes allow the recording of the polarization of waves and the proposed filters ensure the effective use of polarization information in the processing. This leads to a substantial increase in the performances of the wavefield separation algorithms.

Here we present two processing algorithms for multicomponent dataset. The first one, derived from the classical Singular Value Decomposition is applied directly on multicomponent array dataset (HOSVD). To be efficient, this technique requires a pre-processing (velocity correction for selected wavefield). As SVD provides orthogonal matrices and due to the fact that there is no physical reason to consider the orthogonality of propagation vector, we present an ICA extension which imposes a stronger criterion (to be fourth order statistically independent). The second processing, based on eigenvalue decomposition, extends the spectral matrix filtering to the multicomponent case. This technique does not require velocity correction and takes into account jointly polarization and interactions between all the frequencies and all the components. We illustrate proposed algorithms on simulated and real dataset.

### **New trends for shallow water acoustic tomography**

*I. Iturbe<sup>1</sup>, B. Nicolas<sup>1</sup>, P. Roux<sup>2</sup>, & J.I. Mars<sup>1</sup>*

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Ocean Acoustic Tomography aims at estimating ocean celerity variations. Wave travel-time being related to ocean celerity, tomography aims to solve the inverse problem: estimate celerity variations, using measurements of travel-time variations. For this purpose, the estimation of the variations of the travel times of waves and the identification of each acoustic arrival with a theoretical ray path in the medium are necessary. When estimation and identification tasks are well performed for a given ray arrival, the arrival is said to be resolved.

A big number of resolved ray arrivals allow a more accurate tomography results. Indeed, the goal of

Signal Processing in ocean acoustic tomography is to develop processing tools that allows better estimation and identification results.

Due to multi-path propagation, the estimation and identification of ray arrivals is usually non-trivial on the recorded signals, due to interferences between different paths or to weak Signal to Noise Ratio. Consequently, two kinds of solutions have been proposed: the High Resolution estimation methods, based on a modeling of the wavefront; and the wave separation techniques, using transducer arrays. This work is about the second ones.

In classical case, where an array of sensors is used, beamforming is performed to separate the ray arrivals by their different propagation angles. In more recent underwater experiments, a double array of emitters and an array of receivers were used. Signal processing tool for this experimental configuration will be presented: It consist on performing double beamforming simultaneously on emitter array and on receive array, and it allows a better separation of waves and a better identification with theoretical raypath. These advantages will be illustrated on real data from the experiment FAF03 and we will present also a tomography results on real data to illustrate the benefit of the double beamforming.

### **Acoustic imaging enhancement by application of phase coherence factors.**

*J. Camacho, C. Fritsch, M. Parrilla*

Instituto de Automática Industrial – CSIC

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Acoustic Imaging using an array of transducers is a standard technique in many application fields as Non Destructive Evaluation (NDE), Medical Diagnosis or Underwater Exploration. Using an array of independent transducers for receiving the back-scattered echos, allows to discriminate the position of the reflectors and to compose an image of the insonicated zone. The quality of the acoustic image obtained with an array is mainly limited by the lateral resolution, the ratio of the main to side lobe levels and by the presence of grating lobe artifacts. The lateral resolution is determined by the main lobe width, which is inversely proportional to the aperture extent. Increasing the aperture size requires a higher number of array elements and processing channels or, alternatively, a larger inter-element spacing  $d$ . When  $d$  is above half a wavelength, grating lobe artifacts appear, especially for large beam steering angles, creating false indications and blurring the image.

Reducing grating lobes is a common objective in High Resolution Sonar systems. Most of the proposed methods are based on sparse apertures that cancel grating lobes, but only at the focus region. Recently, a new method for side and grating lobes reduction was presented [1], based on an analysis of the phase diversity of the aperture data. Although it was first proposed for ultrasound imaging, it can be also applied on other research fields. In this work, the Phase Coherence Imaging theory is presented along with some experimental results with ultrasound arrays and phantoms. Also its application to reduce grating lobes artifacts in high resolution side-sonar for underwater exploration is addressed by simulation.

[1] J. Camacho, M. Parrilla, C. Fritsch, "Phase Coherence Imaging", IEEE Trans. on Ultrason., Ferroelec. And Freq. Contr., 56, 5, (in press), 2009.

### **Velocity adaptive filters in the time-scale domain**

*S. Ventosa<sup>1</sup>, C. Simon<sup>1</sup>, M. Schimmel<sup>2</sup>*

1. Unidad de Tecnología Marina, CSIC, Barcelona, SPAIN

2. Instituto Jaume Almera, CSIC, Barcelona, SPAIN

Seismograms are a measure of complex wave fields. To improve the comprehension of these fields, several seismograms are grouped into what is known as a seismic record section. That way, it is possible to distinguish the signals that characterize a set of wavefronts that interfere WITH each other.

One of the characteristics of any wave field is the similarity of the waveforms along the wavefront. This high lateral coherence can be used to separate the waves of interest in function of their velocity and to analyze them with higher precision.

In geophysics, most of the coherence filters work in the frequency-wavenumber (f-k) or the Radon domains. The f-k domain allows to easily filter signals in a constant range of speeds through the record section but, as it is based on a 2-D Fourier transform, its space resolution is null. The Radon domain is suitable for signals whose wavefront have a known trajectory that varies smoothly with the distance.

With the aim of solving these limitations we propose the velocity adaptive filters in the time-scale domain. These filters can adapt automatically to the variations of the velocity of the wavefronts. In addition, the bigger flexibility that this domain provides gives us a higher degree of control in the filter design that allows an optimal adjustment of the velocity resolution at each frequency. It is hence possible to build velocity adaptive filters that do not distort the waveform of the processed seismic signals.

### **Detection, Characterization and Origin of Polarized Microseismic Noise**

*M. Schimmel (1), E. Stutzmann (2), J. Gallart (1)*

(1)Institute of Earth Sciences Jaume Almera – CSIC, Barcelona, Spain,

(2)Institute Physics of the Earth – IPEGP, Paris, France.

We present a frequency dependent polarization approach which we then use to detect polarized signals in the microseismic noise. The microseismic noise is the strongest known ambient noise. It hosts informations on the Earth structure, and on atmospheric and oceanic processes at different scales. It is observed everywhere on the globe and is strongest between 0.04 - 1 Hz. The precise source mechanisms are still under debate but related to atmospheric perturbations and ocean infra-gravity and gravity waves. The microseisms are split into two, primary and secondary microseisms. We show that the microseisms contain polarized signals which we use to characterize the noise as function of time and frequency. We find that this noise is stronger polarized than noise in other frequency bands and use this property to measure the directions of the polarized noise at individual stations all over the world. We analyse a data base of 7 years of continuous seismograms from the GEOSCOPE network. Our measurements are used to locate the sources of microseisms and to show their characteristics at global scale. We prove the global seasonal forcing of microseisms and show that the sources are not restricted to near-coastal locations. The latter are attributed, at global scale, to opposing swell from seasonal storms.