MINUTES of the SESAME Task B Meeting

Potsdam, 3-14 February 2003

I Partners attending the meeting

Cecile Cornou - Swiss Seismological Survey, ETHZ, Switzerland
Andreas Köhler -IGUP, Potsdam, Germany
Matthias Ohrnberger - IGUP, Potsdam, Germany
Gudrun Richter - IGUP, Potsdam, Germany
Alekos Savvaidis - ITSAK, Thessaloniki, Greece
Frank Scherbaum - IGUP, Potsdam, Germany
Estelle Schissele - IGUP, Potsdam, Germany
Marc Wathelet - UJF, Grenoble, France

II Schedule of the meeting

Monday, February 3, 2003:

After the participants arrival, a first meeting was held in the afternoon in order to define the main discussion points regarding the derivation of dispersion curves from ambient vibration array measurements. A list of discussion topics had been distributed in advance by e-mail to the participants:

1) Joining fk-analysis results with dispersion curve inversion
--- In case of non-negligible contribution of higher modes surfaces waves in the ambient noise wavefield: what is the expected influence on the array analysis result: problem of "apparent dispersion curves" - what do we really observe? can we expect to "see" single mode branches or do we actually observe a mixture of surface wave modes <-> implications for inversion scheme (involvement of Green's functions, source mechanism).
--- How to deal with uncertainties in the measurements? What are the errors due to experimental conditions, limitation of accuracy due to applied method and numerical errors? Can we account for those uncertainties ad how to estimate those. How should the errors incorporated into the inversion process?
--- Discussion of preliminary results obtained from array measurements
--- How can we include hazard relevant information into the inversion process <-> Is it possible to define a cost function adjusted to site response?
--- Technical details: interfacing between array analysis codes (e.g. "cap") and the inversion code (os_na, na_viewer).

2) How to improve the dispersion curve estimates from array analysis (resolution, reliability):
a) Preprocessing: automatic selection of appropriate windows for fk-analysis -
What do we consider as an appropriate window? Method dependency?
--- conventional fk-analysis:
time windows should contain a single dominant coherent signal, multiple signal arrivals are not resolvable for reasonable field setups (limited number of stations, feasible aperture size and station spacing which are limited by logistical constraints, heterogeneity of subsurface structure and time resolution of measurements).
--- SPAC: exclusion of single dominant signal arrivals? stationarity test?
--- MUSIC: rank limitation of covariance matrix? Choose windows with a few dominant signals? (experts must tell -> Cecile & Estelle).

b) Postprocessing: automatic selection of dispersion curve and uncertainties
---What implicit assumptions are made when extracting dispersion curves from fk-analysis?
Again: can we expect to observe single mode branches or do we have some apparent dispersion curves which results from mixing of different mode contributions to the wavefield.
--- Discussion about strategy for automatized dispersion curve determination, strongly dependent on method and technical issues (sampling in fk-space, statistics, threshold criteria, etc.)
--- Inversion of spatial autocorrelation curve to dispersion curve seems to be difficult for general situation. How can we approach this inversion task without any a priori knowledge of the site structure (i.e without a sufficiently good starting model?) - what is the influence of higher modes
on the autocorrelation curve observation - can higher modes be included into the inversion process?

c) Implementation of alternative array analysis methods for ambient vibration analysis:
- MUSIC

- Phase stack (complex trace analysis - instantaneous phase beamformer..)
- others??

d) Extensions of array analysis methods:
--- Using 3 component data
--- Incorporation of polarization analysis
--- Preselection of time windows according to wavefield separation (classification approach)

3) Analysis of array data sets for Liege/Uccle and sites in Greece
Use existing array processing software (cap) and inversion code (os_na, na_viewer) to obtain shallow shear wave velocity models. Data sets to be used are from Belgium and Greece.

While addressing the items of the list, a vivid discussion started about the advantages and disadvantages of certain array methods with respect to the tasks defined in the SESAME project. Mainly experiences with conventional f-k, and high-resolution methods (Capon, MUSIC) were reported and discussed. In order to proceed it was decided to dedicate the following day to presentations by M. Ohrnberger, M. Wathelet and C. Cornou to communicate the first preliminary results of array analysis and dispersion curve inversion for both synthetic and real data sets to the other participants.

Tuesday, February 4, 2003:

Morning: presentation of M. Ohrnberger about conventional FK array analysis applied to synthetic ambient noise simulations and real data sets. Comparison to results with Capon's method, resolution tests and limitations of methods in special situations.

Noon: Presentation of M. Wathelet about the nonlinear inversion of dispersion curve data into 1D velocity models. Introduction to the applied inversion method for this purpose (Neighborhood Algorithm NA, Sambridge, 1999a,b). Application to synthetic and real data sets within the SESAME project. Individual testing of the relevance of velocity model parameters on dispersion curves (forward problem) and implications for the inversion problem.

Afternoon: Presentation of C. Cornou about high resolution array analysis (MUISC) and H/V ratios for ambient noise wavefield investigations. Application to ambient noise data from deep sedimentary valleys. Examples of the influence of soil-structure interaction and meteorological conditions on the characteristics of the ambient noise wavefield.

The presentations were accompanied by discussions and at the end of the day, a list of priority tasks was defined which should be addressed in the following days:
- array processing on existing synthetic data sets (deep sedimentary structure, Cologne area, Germany) with existing array processing software (conventional FK, Capon and MUSIC) – comparison and test for different pre- and postprocessing strategies
- improvements to be implemented into existing code: apply spatial smoothing into Capon algorithm (similar to MUSIC) and search for secondary peaks (higher modes?) in fk-map.
- preprocessing strategies of data: coherence processing in adaptive time-frequency cells, energy criteria in time-frequency cells - Pass only those time-frequency cells to array processing which pass selected threshold of coherence or energy.
- stronger focus on horizontal component processing and polarization analysis for preselection of time windows. Needs as input 'full' synthetic wavefield. Existing synthetic datasets at Potsdam contained only Rayleigh wave surface waves. Thus, a computation of synthetic ambient noise data set with the wavenumber integration code of Hisada (brought by C. Cornou) should be performed. For the new computations of data sets, it was decided to use the canonical model for Liege and the array configurations which have been used during the measurements at this site in spring 2002.

Wednesday, February 5, 2003:

Work on data sets and computer codes in groups.

- Preprocessing issues and MUSIC: E. Schissele & C. Cornou
- Inversion code and testing: M. Wathelet & A. Savvaidis
- Spatial smoothing in Capon, interfacing of preprocessing information: M. Ohrnberger
- Work on existing synthetic datasets: all together
- Preparation of new synthetic dataset: C. Cornou

Thursday, February 6, 2003:

Continuation of work on program codes and data

Afternoon: presentation by A. Savvaidis: Evaluation of data sets from selected sites in Greece. Special focus on site Lefkas, Volvi and Thessaloniki. Comparison of preliminary results from Capon and conventional FK analysis obtained within the scope of SESAME to results of Apostilidis (2002) using the spatial autocorrelation method.

Presentation of video of the measurement campaign in summer 2002 by F. Scherbaum.

From the discussion the following propositions were made:
- evaluate H/V ratios from accelerometer stations of ITSAK at site Lefkas for ambient noise recordings, not earthquake recordings.
- forward computation of waveform synthetics for simplified model of site Lefkas in order to evaluate the resolution capabilities of the deployed array for the specific situation.
- comparison of site transfer functions for different models (geotechnical <-> inverted).
- try to obtain the waveform data of Apostilidis (2002) in order to re-evaluate the Autocorrelation curves and try to use improved inversion scheme.
- comparison of Apostilidis (2002) Autocorrelation curves with results obtained from MSPAC processing on datasets acquired within the SESAME project.

Friday, February 7, and Monday 10 to Friday 14, 2003:

Work on computer codes and testing on synthetic and real data sets.

Friday 14, 2003, noon: Closure of meeting, departure of participants.

III Summary

The SESAME task B meeting was held from February, 3rd to February 14th, 2003 in the University of Potsdam. The meeting covered two distinct aspects. First, preliminary results and the progress within the single workpackages (WP05, WP06 and WP07) were shared between the participants. Both scientific issues as well as technical details of the algorithm implementations were discussed and future actions were defined. Second, programming work on the existing computer codes, evaluations of the programs and specific tests have been performed. The main results of this meeting can be summarized as follows:

⇒ All of the investigated array methods so far (conventional FK, Capon, MUSIC, (M)SPAC) can be regarded as at least partially useful for the derivation of dispersion curves from ambient noise data. We will continue therefore the investigation of all array analysis methods with both synthetic and real data sets and focus on further improvement regarding the special application to the derivation of dispersion curves and shallow shear wave velocity structures from ambient noise data.

⇒ The MUSIC algorithm (Schmidt, 1986) is the preferred choice among the frequency wavenumber techniques in terms of its inherent resolution capability in the frequency wavenumber space. This characteristic is of special interest for separating the dispersion characteristics of individual surface wave modes from the ambient noise wavefield. However, there exist some limitation in the practical application. In order to achieve a stable and reliable result high expertise of the user is necessary and a careful analysis of the ambient noise wavefield is required. So far MUSIC based dispersion curve analysis from ambient noise data seems not to be suitable for automatic and fast processing schemes.

⇒ On the other hand, the conventional FK method (in our implementation similar to Kvaerna and Ringdahl, 1986) allows, for realistic array geometries, only limited resolution power. This is especially true for multiple source situations, which is mostly expected to be true for ambient noise data. However, the conventional FK has the striking advantage of being easily applicable without a priori knowledge of particularities of the data and provides robust phase velocity estimates for a wide range of real data sets. An interesting observation could be made from the preliminary results of ambient vibration data acquired within the SESAME project. In almost all 'real-world' data examples dominant directions of wave propagation exist at least within a restricted frequency band. In some cases we even observed distinct dominant directions for different frequency bands for one and the same data set at one site.

⇒ The high-resolution frequency wavenumber method after Capon (1969) shows an intermediate performance between conventional FK and MUSIC, allowing for higher resolution with respect to the conventional FK, but still stable enough to be applied ad hoc to real data sets thus allowing fast and effective automatic processing schemes.

⇒ So far the practical experience on the usefulness of the spatial autocorelation methods for real situations is still limited within task B. This is mostly due to the difficulties to derive stable and realistic (not overly smooth or other form restrictions) dispersion curve estimates via inversion from the autocorrelation curves (AC). Regarding this problem, an proposition has been made during the SESAME task B meeting for a new inversion strategy of velocity models from AC-data.

⇒ Instead of a two-step inversion procedure consisting in inverting DC-curves from the autocorrelation curves and further inverting a velocity model from this DC-curve, a direct one-step inversion based on the Neighborhood Algorithm (Sambridge, 1999a,b) from autocorrelation curves into velocity models will be implemented in the next months by M. Wathelet.

⇒ In order to allow a more quantitative comparison of the array methods, it has been decided to conduct further tests on synthetic waveform data for simple 1D velocity models. An unsolved question is the influence of higher mode surface waves on the estimate of dispersion curves and how to incorporate multi-modal dispersion information into the inversion procedure. With respect to the inversion of velocity structures from the derived dispersion curves, it has been agreed among the participants, that a focus should be laid on the quantification of uncertainties of phase velocity estimates. Furthermore, the extraction of dispersion curves from raw array measurements has to be revised. First order statistics in a postprocessing stage, as well as other pre- and postprocessing strategies for the array methods will be addressed in the next months.