Project n° EVG1-CT-2000-00026 SESAME

European Commission – Research General Directorate

SESAME

Site EffectS assessment using AMbient Excitations

Final report

1 May 2001 – 31 October 2004

SESAME Partnership

1	**UJF**	University Joseph Fourier	Grenoble
2	**Resonance**	Résonance Ingénieurs-Conseils SA	Geneva
3	**UP**	University of Potsdam	Potsdam
4	**ULg**	University of Liège	Liège
5	**UiB**	University of Bergen	Bergen
6	**ETHZ**	Swiss Federal Institute of Technology	Zürich
7	**ITSAK**	Institute of Engineering Seismology and Earthquake Engineering	Thessaloniki
8	**ICTE/UL**	Institute of Earth and Space Sciences	Lisbon
9	**INGV**	National Institute of Geophysics and Volcanology	Roma
10	**CNR.GSAQ**	National Research Counsil	Milano
11	**GPISAS**	Geophysical Institute – Slovak Academy of Sciences	Bratislava
12	**CETE.Nice**	Center of Technical Studies	Nice
13	**CNRS-IRD**	National Center for Scientific Research – Institut de Recherche pour le Développement	Grenoble
14	**LCPC**	Central Laboratory for Bridges and Roads	Paris

Co-ordinator: Pierre-Yves BARD - LGIT, Observatoire de Grenoble, BP 53 - 38041 Grenoble Cedex – France

Content

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SESAME project rules

1. ***All the data lent by one of the SESAME project partners can only be used within the framework of the SESAME project. If one partner wants to use the data for another purpose, it is essential that he ask for an utilization agreement to the data owner.***
2. ***Each time the SESAME project partners make a presentation concerning the project SESAME, they must inform the co-ordinator of the project and as much as possible send a copy of the presentation. Moreover, each presentation on the SESAME project has the mandatory obligation to acknowledge the EC funding and mention the grant identification.***

Introduction

April 2001	***signature of the contract between the partners and the European Commission***	
1 May 2001	Beginning of the contract	
May 2001		
June 2001	***First payment of the EC (40%)***	
26-27 June 2001	Kick-off meeting in Grenoble, France	
July 2001		**Work on the field and in the laboratories on the different Tasks**
August 2001		
29-30 August 2001	Workshop for Task C in Zurich, Switzerland	
September 2001		
October 2001		
22-26 October 2001	Instrument workshop (TaskA-WP02) in Bergen, Norway	
November 2001		
A first progress report sent to the EC		
December 2001		
January 2002		
7-8 January 2002	Instrument workshop (TaskA-WP02) in Potsdam, Germany	
9-11 January 2002	Workshop (TaskA-WP03 & TaskB-WP06) in Potsdam, Germany	**Work on the field and in the laboratories on the different Tasks**
February 2002		
March 2002		
April 2002		
21-27 April 2002	Task A meeting during the EGS in Nice, France	
May2002		
29-30 May 2002	Task C meeting in Zurich, Switzerland	
A second progress report including Cost statements (= D03.01) and 2 deliverables (D01.02, D02.09) sent to the EC.		
June2002		
July 2002		
10 July 2002	Review meeting on seismic risk research in the EU	
August 2002		**Work on the field and in the laboratories on the different Tasks**
September 2002		
October 2002	***Second payment of the EC (37,99%)***	
22-24 October 2002	Work-package meetings in Roma, Italy	
25-26 October 2002	General SESAME meeting in Roma, Italy	
November 2002		
December 2002		
A third progress report and 4 deliverables D04.04 (draft), D05.06, D05.05, D07.05 sent to the EC.		
January 2003		
February 2003		**Work on the field and in the laboratories on the different Tasks**
3-14 February 2003	Task B meeting in Potsdam, Germany	
20-21 February 2003	Task C meeting in Bratislava, Slovakia	
March 2003		
April 2003		
7-11 April 2003	WP02 meeting during the EGS-AGU-EUG in Nice, France	
May 2003		
A fourth progress report including Cost statements (= D10.01) and 5 deliverables D08.02, D09.03, D13.08 (first part), D14.07, D15.06 and the final version of D04.04 sent to the EC.		
June 2003		
12-15 June 2003	WP03 & WP04 meeting in Thesssaloniki, Greece	

July 2003		
16-17 July 2003	Task C meeting in Grenoble, France	**Work in the laboratories**
August 2003		**on the different Tasks**
September 2003		
22-24 September 2003	SESAME Smolenice Workshop, Slovakia	
October 2003		
November 2003	***Third payment of the EC (7,01%)***	
December 2003		

A fifth progress report is sent to the EC.

January 2004		
February 2004		
8-13 February 2004	WP03 meeting in Lisbon, Portugal	**Work in the laboratories**
16-20 February 2004	Task C meeting in Potsdam, Germany	**on the different Tasks**
March 2004		
April 2004		
May 2004		
June 2004		

A sixth progress report and 5 deliverables
D16.04, D18.06, D20.04, D21.07 and the final version of D13.08 is sent to the EC.

July 2004		
August 2004		
1-6 August 2004	13th world conference in Earthquake Engineering, Vancouver, Canada	**Work in the laboratories**
September 2004		**on the different Tasks**
October 2004		**and meetings between the**
3-5 October 2004	SESAME General meeting, Les Houches, France	**partners to prepare the final**
31 October 2004	End of the contract	
November 2004		**results of the project**
22-23 November 2004	WP12 meeting in Geneva, Switzerland	
December 2004		
January 2005		

A final report is sent to the EC

with a copy of all the deliverables on a CD.

Progress of the Work and accomplishments

The following table shows the timetable of the SESAME project. This report presents a summary of the work done during the whole project.

TABLE: Project planning and time table

Phases	WP	Tasks	*Year 1*	*Year 2*	Year 3	**Deliverables** (finished)
P01			**xxxxxxxxxxxx**	**xxxxxxxxxxxx**	**xxxxxxxxxxxx**	
	WP01		xxxxxxxxxxxx	xxxxxxxxxxxx	xxxxxxxxxxxx	
		T01.01	xxxxxxxxxxxx			*D03.01**
		T02.01		xxxxxxxxxxxx		*D10.01**
		T03.01			xxxxxxxxxxxx	***(D25.01)***
P02 – Task A			**xxxxxxxxxxxx**	**xxxxxxxxxxxx**	**xxxxxx**	
Finished ←	WP02		xxxxxxxxxxxx	Xxxxxx		
		T01.02	xxxxxxxxxxxx			*D01.02**
		T02.02		xxxxxxxxxxxx		*D08.02**
Finished ←	WP03		xxxxxxxxx	Xxxxxxxxx		
		T01.03	xxxxxxxxx			
		T02.03		Xxxxxxxxx		*D09.03**
Finished ←	WP04		xxxxxx	xxxxxxxxxxxx	xxxxxx	
		T01.04	xxxxxx			
		T02.04		xxxxxxxxxxxx		*D04.04**
		T03.04			xxxxxx →	*D16.04 & D20.4**
P03 – Task B			**xxxxxxxxxxxx**	**xxxxxxxxxxxx**	**xxxxxxxx**	
Finished ←	WP05		xxxxxxxxxxxx	Xxxxxx		
		T01.05	xxxxxxxxxxxx			
		T02.05		Xxxxxx		*D06.05 & D07.05**
Finished ←	WP06		xxxxxxxxxxxx	xxxxxxxxxxxx	xxx	
		T01.06	xxxxxxxxxxxx			
		T02.06		xxxxxxxxxxxx		*D05.06*; D15.06**
		T03.06			xxx →	*D18.06** & **(D19.06)**
Finished ←	WP07		xxxxxxxxxxxx	xxxxxxxxxxxx	xxxxxxxx	
		T01.07	xxxxxxxxxxxx			
		T02.07		xxxxxxxxxxxx		*D14.07**
		T03.07			xxxxxxxx →	*D21.07**
P04 – Task C			**xxxxxxxxxxxx**	**xxxxxxxxxxxx**	**xxx**	
Finished ←	WP08		xxxxxxxxxxxx	xxxxxxxxxxxx		
		T01.08	xxxxxxxxxxxx			*D13.08**
		T02.08		xxxxxxxxxxxx	→	
Finished ←	WP09		xxxxxxxxxxxx	xxxxxxxxxxxx		
		T01.09	xxxxxxxxxxxx			*D02.09**
		T02.09		xxxxxxxxxxxx	→	**(D12.09)**
Finished ←	WP10			xxxxxxxxx	xxx	
		T01.10		xxxxxxxxx	→	
		T02.10			xxx	**(D11.10 & D17.10)**
P05 – Task D					**xxxxxxxxxxxx**	
	WP11				xxxxxxxxxxxx	
		T01.11			xxxxxxxxxxxx	**(D22.11)**
	WP12				xxxxxxxxxxxx	
		T01.12			xxxxxxxxxxxx	**(D23.12)**
	WP13				xxxxxxxxxxxx	
		T01.13			xxxxxxxxxxxx	**(D24.13 in Summer 05)**

*, the Deliverables in italic have already been sent to the EC with the previous reports;
the Deliverables in brackets are sent to the EC with this report.

I WP01 – T02.01: co-ordination – whole project

The co-ordination is followed by two persons:

Pierre-Yves Bard for the scientific part and Laurence Bourjot for the administrative and financial part.

TABLE 1: Persons involved in the project from May 2001 to February 2005

Partners	Name of the person		Partners	Name of the person	
1	Ebrahim Haghshenas	*S*			
1	Bruno Bettig	*S*	7	Petros Dimitriu	*R*
1	Fabien Blarel	*T*	7	Panagiotis Hatzidimitriou	*R*
1	Sylvette Bonnefoy	*S*	7	Areti Panou	*R*
1	Laurence Bourjot	*ACo*	7	Costantinos Papazachos	*R*
1	Cécile Cornou	*R*	7	Alekos Savvaidis	*R*
1	Fabrice Cotton	*R*	7	Nikos Theodulidis	*R*
1 (13)	Jean-Luc Chatelain	*R*	*7*	*Stratos Zacharopoulos*	*T*
1 (13)	François Dunand	*S*	*8*	*Antonio Borges*	*S*
1 (13)	Bertrand Guillier	*R*	*8*	*Catarina Paz*	*S*
1 (13)	Jérôme Noir	*S*	*8*	*Pedro Roquette*	*R*
1 (14)	Pierre-Yves Bard	*R*	*8*	*Gisela Viegas*	*S*
1 (14)	Philippe Guéguen	*R*	*8*	*Paula Teves-Costa*	*R*
2	Martin Koller	*R*	*9*	*Catello Acerra*	*T*
2	Corinne Lacave	*R*	*9*	*Riccardo Azzara*	*R*
2	Julien Rey	*R*	*9*	*Roberto Basili*	*R*
3	Matthias Ohrnberger	*R*	*9*	*Paola Bordoni*	*R*
3	Andreas Koehler	*S*	*9*	*Fabrizio Cara*	*R*
3	Gudrun Richter	*R*	*9*	*Giovanna Cultrera*	*R*
3	Frank Scherbaum	*R*	*9*	*Giuseppe di Giulio*	*R*
3	Estelle Schissele	*R*	*9*	*Fabrizio Marra*	*R*
3	Daniel Vollmer	*T*	*9*	*Sandro Rao*	*T*
3	Hans Havenith	*S*	*9*	*Antonio Rovelli*	*R*
4	Denis Jongmans	*R*	*9*	*Mario La Rocca*	*S*
4	Marc Wathelet	*S*	*9*	*Rosalba Maresca*	*S*
5	Kuvvet Atakan	*R*	*9*	*Gilberto Saccoroti*	*S*
5	Mathilde Bøttger	*S*	10	Rosastella Daminelli	*T*
5	Margaret Grandison	*S*	10	Roberto de Franco	*R*
5	Jens Havskov	*R*	10	Alberto Marcellini	*R*
5	Jose Asheim Ojeda	*S*	10	Antonio Morrone	*T*
5	Bladimir Moreno	*S*	10	Marco Pagani	*R*
5	Eirik Tvedt	*S*	10	Alberto Tento	*T*
5	Terje Utheim	*T*	11	Lucia Fojtikova	*S*
5	Katharina Wolff	*S*	11	Jozef Kristek	*R*
5	Gerardo Aguacil	*R*	11	Miriam Kristekova	*R*
6	Donat Fäh	*R*	11	Peter Moczo	*R*
6	Cécile Cornou	*R*	12	Anne-Marie Duval	*R*
6	*Philipp Kästli*	*R*	12	Etienne Bertrand	*R*
6	Fortunat Kind	*R*	12	Etor Querendez	*R*
6	Jörg Kirsch	*R*	12	Jean-François Vassiliades	*T*
6	Eva Spühler-Lanz	*R*	12	Sylvain Vidal	*T*
6	Ivo Oprsal	*R*			
6	Johannes Rippberger	*R*			
6	Daniel Roten	*R*			
6	*Thomas Schler*	*R*			
6	Jochen Woessner	*R*			

- *R = Researcher, S = Student, T = Technician, ACo = Assistant Coordinator*

During the whole year project, about 90 persons (researchers or engineers, students, technicians and 1 assistant-coordinator) have been involved in the project SESAME (**Table 1**).

❶ Since the beginning of the project, all these persons have met several times to exchange their work, to do experiments together and to work on the final results of the project.

- *26-27 June 2001* - Kick-off meeting in Grenoble (France)
- *29-30 August 2001* – Task C meeting in Zürich (Switzerland)
- *22-26 October 2001* – Instrument Workshop (TaskA-WP02) in Bergen (Norway)
- *7-8 January 2002* – Instrument Workshop (TaskA-WP02) in Postdam (Germany)
- *9-11 January 2002* – TaskA-WP03 Workshop in Postdam (Germany)
- *20-21 March 2002* – TaskC-Meeting in Bratislava (Slovakia)
- *21-27 April 2002* – Task A meeting in Nice (France)
- *30-31 May 2002* – Task C meeting in Zürich (Switzerland)
- *10 July 2002* – Review meeting on seismic risk research in the European Union.
- *22 October 2002* – Task C meeting in Roma (Italy)
- *23 October 2002* – WP04 Empirical evaluation meeting in Roma (Italy)
- *23-24 October 2002* – WP02 meeting in Roma (Italy)
- *24 October 2002* – WP03 Software development meeting in Roma (Italy)
- *25-26 October 2002* – General SESAME mid-term meeting in Roma (Italy)
- *3-14 February 2003* – Task B meeting in Potsdam (Germany)
- *20-21 February 2003* – Task C meeting in Bratislava (Slovekia)
- *7-11 April 2003* – WP02 meeting in Nice (France) during the EGS-AGU-EUG
- *12-15 June 2003* – WP03 & WP04 joint meeting in Thessaloniki (Greece)
- *16-17 July 2003* – Task C meeting in Grenoble (France)
- *22-24 September 2003* – SESAME Smolenice Workshop (Slovekia)
- *8-13 February 2004* – WP03 meeting in Lisbon (Portugal)
- *16-20 February 2004* – Task C meeting in Potsdam (Germany)
- *1-6 August 2004* – 13th world conference in Earthquake Engineering, Vancouver (Canada)
- *3-5 October 2004* – SESAME general meeting in Les Houches (France)
- *22-23 November 2004* – WP12 meeting in Geneva (Switzerland) : finalization of H/V user guidelines

❷ Since the beginning of the project, the partners, in parallel to their work on the project, have participated to different national or international meetings where they have presented a part of the scientific work done in the SESAME project. A total of 61 abstracts (posters or oral presentations) have been done within the framework of the project.

The most important international workshops, for the presentation of the results of the project was in
- August 2004, during the 13th World Conference on Earthquake Engineering in Vancouver (Canada), with a special session "Site Characterization for Site Effects Studies Using Ambient Vibrations",

and in
- September 2004, during the XXIXth European Seismological Commission in Potsdam (Germany) with a special session "Nature of noise wave field and recent developments in microzonation",

both partly devoted to the project SESAME.

- ***AGU*** in San Francisco (USA), 10-14 December 2001

  Ohrnberger M., F. Scherbaum, K.-G. Hinzen, S.-K. Reamer and B. Weber, 2001. Vibrations on the roll-Mana, a roll along array experiment to map local site effects across a fault system. *Eos. Trans. AGU 2001, Fall Meet. Suppl*., Abstract S21D-0606.

- ***Assemblea Hispano-Portuguesa de Geodesia y Geofisica*** in Valencia (Spain), 4-8 February 2002

  Teves-Costa P., C. Riedel, J.L. Gaspar, D. Vales, G. Queiroz, M.L. Senos, N. Wallenstei and F. M. Sousa e M. Escuer, 2002. Ensaios para a interpretação de anomalias de intensidades sísmicas nos Açores: estudos de ruído ambiental no Concelho da Povoação (ilha de S. Miguel) - Tests for the interpretation of seismic intensities anomalies at the Azores: Microtremor survey on Povoação County (S. Miguel island).

- ***EGS*** meeting in Nice (France), 21-27 April 2002

  Guillier B., K. Atakan, A-M. Duval, M. Ohrnberger, R. Azzara, F. Cara, J. Havskov, G. Alguacil, P. Teves-Costa, Nikos Theodulidis and the SESAME Project WP02-Team, 2002a. Influence of instruments on H/V spectra of ambien noise.

  Teves-Costa P., C. Riedel, D. Vales, N. Wallenstein, A. Borges, M.L. Senos, J.L. Gaspar and G. Queiroz, 2002a. Microtremor survey on Povoação County (S. Miguel island, Azores): data analysis and interpretation.

- ***III Coloquio sobre Microzonification Sismica*** in Caracas (Venezuela), 12-18 July 2002 (no abstract for these two *talks)*

  Bard P.-Y., 2002a. H/V Nogoshi-Nakamura's technique: Theoretical background, applications, limitations, and more, *Invited lecture, III Coloquio sobre Microzonificacion Sismica, Pre-coloquio sobre aplicaciones recientes en sismologia,* FUNVISIS, Caracas, 12-14 July, 2002.

  Bard P.-Y., 2002b. Important parameters for dynamic soil response, Invited magistral talk, *III Coloquio sobre Microzonificacion Sismica,* FUNVISIS, Caracas, 15-18 July, 2002.

- ***ESC (European Seismological Commission)*** in Genoa (Italy), 2-6 September 2002

  Bard P.-Y., 2002c. Site effects in urban areas, *Key-note lecture, XXVIII Assembly of the European Seismological Commission,* Genova, September 2-6, 2002.

  Guillier B., K. Atakan, A.-M. Duval, M. Ohrnberger, R. Azzara, F. Cara, J. Havskov, G. Alguacil, P. Teves-Costa, N. Theodulidis and the SESAME Project WP02 Team, 2002b. Influence of instruments on H/V spectra of ambien noise, *XXVIII Assembly of the European Seismological Commission,* Genova, September 2-6, 2002.

  Malischewsky P.G. and F. Scherbaum, 2002. "Love's formula and H/V ratios", *XXVIII Assembly of the European Seismological Commission,* Genova, September 2-6,2002.

  Ohrnberger M. and F. Scherbaum, 2002a. "Derivation of surface wave dispersion curves from array analysis of ambient vibrations", *XXVIII Assembly of the European Seismological Commission,* Genova, September 2-6, 2002.

  Scherbaum F., K.-G. Hinzen and M. Ohrnberger, 2002a. "Determination of shallow shear wave velocity profiles in the Cologne/Germany area using ambient vibration", *XXVIII Assembly of the European Seismological Commission,* Genova, September 2-6, 2002.

  Teves-Costa P., A. Borges, D. Vales, C. Riedel, J.-L. Gaspar and M.-L. Senos, 2002b. Investigation on H/V microtremor processing, *XXVIII Assembly of the European Seismological Commission,* Genova, September 2-6, 2002.

- ***Forum Katastrophenvorsorge und Gefahrentag***, Telegrafenberg Potsdam (GFZ), 7-9 October 2002

  Ohrnberger M., F. Scherbaum, F. Krüger, R. Pelzing and Sh.-K Reamer, 2002. How good are the shear wave velocity models in the Lower Rhine Embayment obtained from inversion of ambient vibrations? *Third Forum Katastrophenvorsorge und Gefahrentag, Telegrafenberg Potsdam (GFZ),* 7.-9. October, 2002.

- ***AGU*** in San Francisco (USA), December 2002

  Kristek J. and P. Moczo 2002. 3D 4th-order staggered-grid finite-difference modelling of seismic motion in viscoelastic media with material discontinuities. *Eos. Trans. AGU, 83 (47), Fall Meet. Suppl.,* Abstract S51C-01.

  Moczo, P., J. Kristek and M. Gális, 2002. Simulation of the planar free surface in media with near-surface lateral discontinuities in the 3D 4th-order staggered-grid finite-difference modeling of seismic motion. *Eos. Trans. AGU, 83 (47), Fall Meet. Suppl.*, Abstract S61B-1129.

Scherbaum, F., Ohrnberger, M., Savvaidis, A., Panou, A., Theodulidis, N., 2002a. Determination of Shallow Shear Wave Velocity Profiles Using Ambient Vibrations at Selected Sites in Greece. *Eos Trans. AGU, 83(47), Fall Meet. Suppl.*, Abstract S72A-1138.

- ***Associaçao Portuguesa de Meteorologica e Geofisica*** in Aveiro (Portugal), February 2003

Vales, D., P. Teves-Costa and A. Borges , 2003. Seismic noise analysis in Povoação county (in Portuguese). APMG, February, 2003.

Teves-Costa P., J. Almeida and I. Rio, 2003a. Seismic noise analysis in Lagos historical centre (in Portuguese). APMG, Febuary, 2003.

- ***EGS-AGU-EUG Joint assembly*** in Nice (France), 7-11 April 2003

Bonnefoy-Claudet S., P.-Y. Bard and F. Cotton 2003a. Nature of seismic noise wavefield: a litteraure survey. *Geophys. Res. Abstracts*, 5, EGS-AGU-EUG Joint Assembly, Abstract EAE03-A- 09750.

Cara, F., G. Di Giulio, D. Galluzzo, L. Fojtíková, R. Maresca, P. Moczo and A. Rovelli, 2003. Predominant frequency variations in the ambient noise recorded in the Colfiorito basin (Umbria, Italy). *Geophys. Res. Abstracts*, 5, EGS-AGU-EUG Joint Assembly, Abstract EAE03-A-08644.

Cornou C., S. Bonnefoy-Claudet, J. Kristek, D. Fäh, P.-Y. Bard, P. Moczo and F. Cotton. Simulation of seismic ambient vibration: characteristics of noise sources and reliability of H/V and array processing techniques, *Geophys. Res. Abstracts*, 5, EGS-AGU-EUG Joint Assembly, Abstract EAE03-A-10125.

Moczo, P. & J. Kristek, 2003a. 3D staggered-grid FD modeling of seismic motion in viscoelastic media. *Geophys. Res. Abstracts*, 5, EGS-AGU-EUG Joint Assembly, Abstract EAE03-A-06199.

Panou A., Theodulidis N., Hatzidimitriou P., Savvaidis A. and Papazachos C. Horizontal to vertical spectral ratio of ambient noise for assessing site effects in Urban environment: the case of Thessaloniki city, Northern Greece. *Geophys. Res. Abstracts*, 5, EGS-AGU-EUG Joint Assembly, Abstract EAE03-A-xxxxx.

Teves-Costa P. and L. Senos, 2003b. Noise measurements in Angra do Heroismo (Terceira Island – Azores). *Geophys. Res. Abstracts*, 5, EGS-AGU-EUG Joint Assembly, Abstract EAE03-A-xxxxx.

- ***EAGE (Surface Wave Methods for near surface characterization)*** in Stavanger (Norway), 1 June 2003

Wathelet M. and D. Jongmans, 2003. Surface wave inversion using a direct search algorithm and its application to ambient vibrations measurements, EAGE, Stavanger (Norway), June, 2003.

- ***AFPS*** in Cachan (France), 1-4 July 2003

Bonnefoy-Claudet S., C. Cornou, D. Fäh, P.-Y. Bard, M. Wathelet and M. Ohrnberger, 2003b. Modélisation numérique du bruit de fond sismique: implication pour déterminer la nature du bruit. 6th seminar of the AFP (Association Française de Génie Parasismique), Cachan (France), July, 2003.

Chatelain J.-L., A.-M. Duval, E. Querendez, B. Guillier, F. Dunand, S. Bonnefoy-Claudet, F. Cara, P. Teves-Costa, D. Faeh, C. Cornou, K. Attakan et les autres membres de l'équipe du projet européen SESAME, 2003. Influence des conditions expérimentales de mesure du bruit de fond sismique dans l'application de la méthode « H/V ». 6th seminar of the AFP (Association Française de Génie Parasismique), Cachan (France), July, 2003.

- ***IUGG (23rd International Union of Geophysic and Geodesy General Assembly)*** in Sapporo (Japon), 30 June-11 July 2003

Moczo, P., J. Kristek, C. Cornou, S. Bonnefoy-Claudet and P.-Y. Bard, 2003b. Finite-difference simulation of seismic noise in surface geologic structures, 23rd IUGG General Assembly, Sapporo (Japan), 30 June-11 July, SS04/07A/A03-11 1215**.**

Teves-Costa P. and L. Senos, 2003c. Looking for Site Effects in the Damage Distribution – Application to Angra do Heroismo (Azores) Using Microtremors Measurements, 23rd IUGG General Assembly, Sapporo (Japan), 30 June-11 July, SS04a/09P/D-049, B.504.

- ***ESG (Workshop on Effects of Surface Geology on Seismic Motion)*** in Sapporo (Japon), 11 July 2003

Bard P.-Y. and the SESAME team, 2003. The EU SESAME project: presentation, latest results and perspectives, Workshop on Effects of Surface Geology on Seismic Motion, Sapporo (Japan), 11 July, 2003.

- ***EEGS (Surface Wave Methods for near surface characterization)*** in Prague (Czech Republic), September 2003

Wathelet M., M. Ohrnberger, D. Jongmans, T. Cameelbeeck and F. Scherbaum, 2003. Non linear inversion of noise array measurements for determining S-wave velocity vertical profile, EEGS, Prague (Czech Republic), September 2003.

- ***GNGTS (XXII National Conference of Gruppo Nazionale di Geofisica della Terra Solida - C.N.R.)*** in Italy, 2003

  Cultrera G., A. Tento, R.M. Azzara, F. Cara, G. Di Giulio, A. Marcellini, M. Pagani, A. Rovelli, 2003. Rumore sismico ed effetti di sito: il contributo italiano al progetto SESAME (Site EffectS assessment using AMbient Excitations) - Seismic noise and site effects: the Italian contribution to the SESAME (Site EffectS assessment using AMbient Excitations) project.

- ***ICSDEE & ICEGE (11th International Conference on Soil Dynamics & Earthquake Engineering - 3rd International Conference on Earthquake Geotechnical Engineering)*** in Berkeley (CA, USA), 7-9 January 2004

  Atakan K., A-M. Duval, N. Theodulidis, P-Y. Bard and the SESAME-Team, 2004a. On the reliability of the H/V Spectral Ratio Technique, *in Proceedings of ICSDEE & ICEGE 2004* (11th International Conference on Soil Dynamics & Earthquake Engineering and 3rd International Conference on Earthquake Geotechnical Engineering), Berkeley CA, 7-9th January 2004, Volume 2, pp. 1-8.

  Duval A.-M., J.-L. Chatelain, B. Guillier and the SESAME WP02 team, 2004a. Influence of experimental conditions on H/V determination using ambient vibrations (noise), *in Proceedings of ICSDEE & ICEGE 2004* (11th International Conference on Soil Dynamics & Earthquake Engineering and 3rd International Conference on Earthquake Geotechnical Engineering), Berkeley CA, 7-9th January 2004, Volume 2, pp. 149-156

- ***HPGG (4ª Assembleia Luso Espanhola de Geodesia e Geofísica)*** in Figueira da Foz (Portugal), February 2004

  Teves-Costa P and M.L. Senos, 2004a. *Angra do Heroísmo seismic zonation using ambient vibrations*, AHPGG, Portugal, February 2004.

- ***DGG (Annual meeting of the German Geophysical Society)*** in Berlin (Germany), 8-12 March 2004

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❸ Since the beginning of the project, 21 papers have already been published, accepted or submitted and several are in preparation

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- Cara F., G. Di Giulio and A. Rovelli, 2003. A Study on Seismic Noise Variations at Colfiorito, Central Italy: Implications for the Use of H/V Spectral Ratios. *Geoph. Res. Lett.*, 30, n°18, 1972, doi:10.1029/2003GL017807.
- Fäh D., F. Kind and D. Giardini, 2003. Inversion of local S-wave velocity structures from average H/V ratios, and their use for the estimation of site effects. *Journal of Seismology*, **7**, 449-467.
- Kind F., D. Fäh, and D. Giardini, 2005. Array measurements of S-wave velocities from ambient vibrations. *Geophysical J. Int.*, 160, 114-126.
- Kristek K., P. Moczo and R. Archuleta, 2002. Efficient methods to simulate planar free surface in the 3D 4^{th} –order staggered-grid finite-difference schemes. *Studia Geophys. Geod.*, 46, 2002, 355-381.
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- Wathelet M., D. Jongmans and M. Ohrnberger, 2004. Surface wave inversion using a direct search algorithm and its application to ambient vibrations measurements. *Near Surface Geophysics*, 2, pp. 211-221.

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- Panou, A., N. Theodulidis, P. Hatzidimitriou, A. Savvaidis and C. Papazachos, 2004. Reliability of ambient noise H/V spectral ratio in urban environment: The case of Thessaloniki city (Northern Greece). *PAGEOPH* (in press).
- Panou, A., N. Theodulidis, P. Hatzidimitriou, A. Savvaidis and C. Papazachos and Stylianidis K. 2005a. Ambient noise H/V spectral ratio for assessing site effects in urban environments: The case of Thessaloniki city". *Bull. Geol. Soc. Greece, paper n° SE8_68* (in press).
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- Bonnefoy-Claudet S., C. Cornou, P.-Y. Bard, F. Cotton, P. Moczo, J. Kristek and D. Fäh, 2005a. H/V ratio: a tool for site effects evaluation. Results from 1D noise simulation, *Bull. Seism. Soc. Am.* (*to be submitted)*.
- Bonnefoy-Claudet S., F. Cotton and P.-Y. Bard, 2005b. Nature of noise wavefield: a literature review. *Earth-sciences Review* (*to be submitted)*.
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- SESAME WP04 Team, 2005, SESAME Database, Seism. Res. Letters (to be submitted).
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In addition,

→ two Ph.D thesis have been prepared within the SESAME project

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- Wathelet, M., 2005. *Array Recordings of ambient vibrations: surface wave inversion*. A thesis submitted for the degree of Doctor of Applied Sciences, University of Liège, February 2005, 161 pages (supervisor: D; Jongmans, Uni Liège).

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A copy of the papers can be asked to Pierre-Yves Bard

4 At the end of January 2005, 24 deliverables are available: see the following table

Del. N°	Deliverable names	WP N°	Lead Partner		Finish
	First progress report: May 01 – October 01	WP01		a report of 30 pages	Dec. 01
D01.02	Controlled instrumental specifications	WP02	AC12.1	a report of 34 pages + 5 appendices	June 02
D02.09	FD code to generate noise synthetics	WP09	CR11	in the form of a CD ROM with a report describing the flow chart of the software and canonical structural models	June 02
D03.01	Second progress report: year 1	WP01	CO1	a report of 41 pages + annexes on the financial aspect of the project	June 02
D04.04	Homogeneous data set of noise and earthquake recordings at many sites	WP04	CR7	a report of 55 pages + 1 appendix	Draft Dec.02 Final July 03
D05.06	Quality control software for in-situ checks	WP06	CR3	a report of 16 pages + 1 appendix	Dec. 02
D06.05	Array data set for different sites	WP05	CR3	a report of 33 pages + 1 appendix + 12 CD ROMs containing the data sets	Dec. 02
D07.05	Optimum deployment strategy and quality measure for array layout in view of obtaining surface wave	WP05	CR3	a report of 41 pages + 3 appendices. The complete report will be available on a CD Rom	Dec. 02
	Third progress report: May 02 – October 02	WP01		a report of 58 pages	Dec. 02
D08.02	Measurement guidelines	WP02	AC12.1	a report of 96 pages including 59 figures, accompanied by a DVD archiving all the test data and the corresponding results	July 03
D09.03	Multi-platform H/V processing software J-SESAME	WP03	CR5	a report of 37 pages describing the software + 1 CD ROM containing the software	July 03
D10.01	Fourth progress report: year 2	WP01	CO1	a report of 31 pages + annexes on the financial aspect of the project.	July 03
D11.10	Set of noise synthetics for H/V and array studies from simulation of real sites	WP10	CR6	included D17.10, a report of 62 pages	January 05
D12.09	Report on parameter studies	WP09	CR11	a report of 39 pages	January 05
D13.08	Report on the nature of noise	WP08	CO1	a report of 50 pages.	July 03/July 04
D14.07	Report on the inversion of velocity profile and Version 0 of the inversion software	WP07	CR4	a report of 40 pages + 2 appendixes including 45 figures	July 03
D15.06	Interface software	WP06	CR3	a report of 8 pages describing the software tool	July 03
	Fifth progress report: May 03 – December 03	WP01		a report of 25 pages	Jan. 04
D16.04	Comparisons of experimentally and theoretically estimated transfer functions with the (H/V) spectral ratio	WP04	CR7	a report of 62 pages + 3 appendixes.	July 04
D17.10	Overall comparison for test sites	WP10	CR6	included D11.10, a report of 62 pages	January 05
D18.06	Continuous array processing toolkit for ambient vibration array analysis	WP06	CR3	a report of 84 pages.	July 04
D19.06	Report on the FK/SPAC capabilities and limitations	WP06	CR3	a report of 43 pages	January 05
D20.04	Comparisons of damage distribution in modern urban areas with results from (H/V) spectral raios	WP04	CR7	a report of 73 pages.	July 04
D21.07	Array measurements: inversion of velocity profile	WP07	CR4	a report of 17 pages describing the software tool "Sesarray".	July 04
	Sixth progress report: year 3	WP01		a report of 20 pages	July 04
D22.11	Scientific papers (special issue in an international journal)	WP11	CO1	a special issue in an international journal	Summer 05
D23.12	Guidelines for the implementation of the H/V spectral ratio technique on ambient vibrations measurements, processing and interpretation	WP12	CR2	a guide of 62 pages	January 05
D24.13	Recommendations for array measurements and processing	WP13	CR4	a guide of 33 pages	March 05
D25.01	Final report	WP01	CO1	a report of 34 pages + one CD ROM	March 05

All the deliverables are available on the web site (except the CD ROMs with the data): http://SESAME-FP5.obs.ujf-grenoble.fr and on the appended CD

II WP02 – H/V technique – experimental conditions

Leader : Anne-Marie Duval (Partner 12 : CETEMED.LRE – Nice – France)

The aim of WP02 is to evaluate the influence of experimental parameters in stability and reproducibility of "H/V on ambient vibrations". To check the influence of various types of parameters, both in frequency and amplitude of the "H/V curves", an experimental and parametric survey is required. Results had to be gathered in a data-base.

Main results

1) Experimental test campaign: The first check to be performed concerned the recording instrument in itself. An experimental workshop was organized in UiB (Bergen, Norway) in October 2001, which allowed to compare the ability of numerous digitizers and sensors type to provide reliable result. Except some accelerometer, the main conclusion was that basically any equipment that has been tested can be used. Test and results are described in the first deliverable D01.02. Many other experimental parameters, related to filed conditions, that may influence H/V results, were identified. It was decided that each team would perform test near its own lab following a common procedure so that data could be integrated in a common data base latter. From May 2001 to February 2002, partners had intensive exchanges both to prepare an exhaustive list of experimental parameter to be tested, and to set common and rigorous experimental protocol, including common forms to be filled. Each parameter was to be tested separately at least by two teams, and each test was to be performed by changing only the tested parameter [whenever possible]. Two types of experimental conditions were distinguished: conditions related to the characteristics of the site itself and/or to the instrumentation (instrument and recording parameters, in situ soil-sensor coupling, modified soil-sensor coupling, nearby and underground structures) and conditions related to the variation of external conditions at the same place (weather, water table, time, noise sources). In 2002, from February to August, extensive measurements were performed and field form filled. As conclusions for many crucial parameters were different from one team to the other, a second series of tests have been performed until April 2003.

2) Processing tools: to achieve the evaluation, all data had to be processed with a single and validated tool (algorithm and default processing parameter). But this was the aim of WP03 and has not been validated until the end of the whole project. That is why partners began the processing with using their own usual software for their own data. In 2002 October, several partners tested the first JSESAME version and proposed a WP02 default processing parameter set. Finally, the whole set of data recorded for WP02 could not be processed with JSESAME within SESAME delays and the processing tools of one of the team (Grenoble) was applied to the whole data-base. Another required tool consisted in a common procedure to quantify the similarity of two H/V curves (tested and reference one). During the Roma meeting (2002 October) such a procedure was discussed: A Student test analysis was applied to all test results and the deviation from the reference records presented on individual "Technical Cards" for each tested parameter. This solution has finally been applied by Grenoble team for final analysis after many algorithm modification (last one in April 2003).

3) Data base compilation and analysis: a common data format SAF was designed (WP03) that allows homogeneous data compilation. Most of the raw records in SAF format, field form, H/V curves and conclusion reports were gathered in February 2003 (except for Thessaloniki and Grenoble ones). These results were synthesised and discussed in 2003 April together with respect to Grenoble ones. The lack of homogeneous procedure for computations and curves comparison prevented from drawing clear conclusion for most of the test, including the major ones. The amount of data had to be integrated in a statistical analysis to allow a definitive statement for the influence of each parameter. Grenoble team completed the compilation with their own data and performed a systematic analysis with their own software and parameters. Then a global analysis of student test results by parameter was performed. The second deliverable D08.02. presents the result of this analysis of more 596 test representing 60 experimental conditions. This report of 96 pages including 59 figures is accompanied by a DVD archiving all the test data and the corresponding results. Most of the experimental conditions tested are shown to be not influencing the H/V results, as long as the wind is not involved and, to a lesser extent, water in the most superficial layer of the ground. However, some experimental conditions would need to be tested more thoroughly. Another important conclusion is that no matter how strongly a tested experimental condition influences H/V amplitudes curves, the value of the frequency peak is usually not affected, with the noticeable exception of the wind.

All these results are compiled in the following deliverables:
D01.02: Controlled instrumental specifications
D08.02: Measurement guidelines

III WP03 – H/V technique – data processing

Leader : Kuvvet Atakan (Partner 5: UIB.ISI – Bergen – Norway)

The main objective of this work package was to develop a common, simple procedure to standardize the processing applied in the H/V spectral ratio technique and as a result a dedicated software J-SESAME is developed.

Main results

The J-SESAME is designed around a user-friendly graphical user interface (GUI), providing extensive functionality to the user. It is developed by using JAVA programming language to allow platform-free operation capability and is based on a modular architecture that consists of four main modules: the browsing module, window selection module, processing module and the display module. The main functionalities are integrated through the graphical user interface, which is part of the browsing module. The display module is also tightly connected to the browsing module, as there is close interaction between the two modules due to the integrated code development in Java. The window selection and H/V processing modules act independently and are called from the browsing module to perform specific computations based on user defined optional parameters. In addition to the parameter selection flexibility, a set of pre-defined recommended parameter settings are provided as default values to allow also the inexperienced users to conduct correct analysis. A simple new waveform data format (SAF) is defined in ASCII for easy data conversion from different acquisition systems. In addition, the widespread GSE-format is also supported.
Browsing module is entirely developed in Java, which is based on a graphical user interface that communicates with the window-selection and processing modules. The processed data is then visualized through the display module for manual inspection and different output options are provided. Once the data are organized under the project structure, the user then has the possibility to plot the waveform files (three components on the screen) for manual inspection. After the visual inspection, based on user defined (or default) parameters, user can select the time-windows either automatically or manually using the window selection module. The selected windows are then processed by the H/V processing module either as a single file or as a series of files usually corresponding to the same site. The H/V spectral ratios and the averages as well as other display options are then plotted using the display module.

Besides the manual selection, an automatic window selection module has been introduced for processing large amounts of data. The objective is to keep the most stationery parts of noise, and to avoid the transients often associated with specific sources. This is exactly the opposite of the usual goal of seismologists who want to detect signals, and have developed specific "trigger" algorithms to track the unusual transients. Asa consequence, we have used here an "antitrigger" algorithm based on the standard STA/LTA ratio of the signal.
Main processing module is developed in FORTRAN90. It conducts H/V spectral ratio computations and the other associated processing such as DC-offset removal, filtering, smoothing, merging of horizontal components, etc., on the selected windows for individual files or alternatively on several files as a batch process. The instrument response is assumed to be removed by the user (in the case of identical components H/V ratios should not be affected by the instrument response).
The display module allows the user to plot or save the results through a series of outputs which can be configured based on the definitions set by the user.

All these results are compiled in the following deliverable:
D09.03: Multi-platform H/V processing software J-SESAME
and
the J-SESAME software is available at http://sesame-fp5.obs.ujf-grenoble.fr for downloading free of charge for non-commercial use.

IV WP04 – H/V technique – empirical evaluation – year 3

Leader: Nikos Theodulidis (Partner 7 – IESEE – Thessaloniki – Greece)

The objective of the WP04 was to achieve a purely empirical, experimental assessment with respect to the meaning of the H/V spectral ratio, in order to enlighten the following issues:

- whether H/V spectral ratio provides a reliable estimate of the fundamental frequency at a given site;
- whether H/V spectral ratio indicates the frequency band over which the ground motion is amplified;
- *whether H/V spectral ratio provides a quantitative estimate of the corresponding amplification;*
- *whether we can learn something about the limitations in noise H/V technique related to non-linear soil behaviour;*
- whether H/V spectral ratio is correlated with earthquake damage distribution in modern cities.

Main results

To accomplish the Work Package 4 objective, all data available within the consortium were compiled and analysed in a common and homogeneous way. All the partners provided their earthquake and noise recordings obtained for site effect estimation at many different sites throughout Europe and elsewhere in the world in Standard Information Sheets (SIS). Additional noise recordings were acquired at sites where site effects have been reliably estimated, in particular at numerous strong motion sites where strong motion recordings were available. The data set created for experimental validation includes more than two hundred sites, information on noise and earthquake recordings in the SIS format - a number twice the initially foreseen- as well as data in a specific SESAME ASCII Format (SAF). In order to facilitate data selection with certain criteria, a SESAME Database management tool was constructed and a specific software was developed for easy access to data providing thus easy access to the users in choosing a desired sub-set of data.

Noise recordings compiled in the SESAME database were homogeneously processed with the technique developed in Work Package 3. The experimental site transfer functions obtained from earthquake recordings were compared with the H/V spectral ratios obtained from noise recordings, in terms of fundamental frequency and amplitude level. For the majority of examined sites good correlation between earthquake and noise fundamental frequency was found whereas this was not the case for the corresponding amplitudes. From these comparison statistics were derived and empirical conclusions were drawn as to the meaning of H/V spectral ratio concerning site conditions and site amplification. Due to the limited number of sites where strong motion data (say, PGA 0.15g) were available, quantitative relations between fundamental frequency of ambient noise H/V spectral ratio [Fon] and accelerograms [Fos] could not be established. However, qualitative correlation showed a shift of the strong-motion fundamental frequency [Fos] to lower values in comparison with Fon.

The experimental (H/V) spectral ratios were compared with seismic damage distribution in six modern cities of Europe: Thessaloniki and Kalamata *(Greece)*, Rome, Fabriano, and Palermo *(Italy)*, and Angra-do-Heroismo *(Portugal)*. Qualitative and quantitative correlation of (H/V) spectral ratio characteristics [fundamental frequency, corresponding amplitude] was attempted and showed from good to fuzzy and to no-correlation, thus indicating the complex character of the parameters involved. The individual studies performed in the aforementioned cities gave room for a variety of interpretations. Although in some cases there seems to be a positive correlation, in general it is agreed that the comparison to damage is a complex procedure. On the other hand comparison of (H/V) spectral ratio to the near-surface geology seems to be more consistent.

All these results are compiled in the following deliverables:

D04.04: Homogeneous Data Set of Noise and Earthquake Recordings at Many Sites.

D16.04: Comparisons of experimentally and theoretically estimated transfer functions with the (H/V) spectral ratio and evaluation of the applicability of the latter in cases of linear or/and non-linear soil behaviour.

D20.04: Comparisons of Damage Distribution in Modern Urban Areas with Results from (H/V) Spectral Ratio.

V WP05 – Instrument layout for array measurements

Leader: Frank Scherbaum (Partner 3 – UPOTS.GEO – Postdam – Germany)

The main objective within this WP was to assess the influence of experimental conditions on the array performance for phase velocity determination. In particular, the following experimental conditions were to be investigated: array geometry, aperture, number of sensors, sensor types and timing accuracy. The final goal consisted in finding a strategy for performing optimal array experiments for a given site situation.

Main results

Sensor calibration tests have been performed in comparison to a broadband sensor in order to assess the influence of phase delay characteristics on the phase velocity estimation procedure. It could be shown that the relative phase delays associated with instrumental effects may be large enough to cause non-negligible distortions on the phase velocity results. Therefore, a thorough sensor calibration is considered an important issue in ambient vibration array experiments and sensors have to be chosen such, that the corner period of the instruments is larger than the longest period of interest at the given site. We have further evaluated hardware timing errors with respect to their corresponding influence on dispersion estimates. We find that the usage of DCF-time decoders should be avoided. If DCF-equipment is to be used, antenna specific time lags have to be determined in the laboratory and need to be applied as correction values for array experiments.

Several field experiments have been performed in the second year of the project. In total, 21 sites in five distinct geological environments have been investigated. The data sets have been made available to the consortium and have been analysed (Cornou et al., 2004a, Köhler et al., 2004, Ohrnberger et al., 2004a, Scherbaum et al., 2002, Wathelet et al., 2004). Parts of the data are currently re-evaluated addressing questions related to 2D- and 3D- site effects.
In order to assess the reliability of dispersion curve estimates in dependence of the array geometry, two main procedures have been followed. First, for frequency wavenumber methods (f-k), the array response has been evaluated theoretically for simple, idealized wavefield situations. The obtained results confirm the known limitations of f-k techniques with respect to wavenumber resolution for longer wavelengths and spatial aliasing for shorter wavelengths (e.g. Tokimatsu, 1997). Secondly, we used ambient vibration simulations for 1D-velocity structures to investigate in detail the reliability of dispersion curve estimates in dependence of the array configuration and wavefield situation presented (Bonnefoy-Claudet et al., 2004, Cornou et al., 2004b, Ohrnberger et al., 2004b, Ohrnberger et al., 2004c).

From the simulation experiments, we find that for a restricted number of sensors: i) it is in general situations not possible, due to the limitations of f-k methods as indicated above, to find an optimal array layout, which allows the estimation of a high quality dispersion curve for the complete frequency band of interest; ii) for random wavefields containing signal arrivals from all directions, f-k techniques overestimate phase velocities for longer wavelengths due to their insufficient resolution capabilities; iii) the autocorrelation technique is advantageous with respect to the inherent resolution limits for longer wavelengths; iv) the autocorrelation technique results may introduce bias for wavefield situations with a dominant source contribution from a single direction.
From these findings we conclude the following:

- f-k and autocorrelation methods complement each other and should therefore be employed in combination to assure high-quality dispersion curve determination.
- A single optimal array layout for ambient vibration array analysis can not be established with a simple rule.
- In order to derive reliable phase velocity curves, it seems therefore most appropriate to construct wavenumber filters by choosing spatial array dimensions for narrow wavelength ranges. An iterative measurement strategy has been developed to accomplish these ideas and has been presented in WP13.

All these results are compiled in the following deliverables:

D06.05: Array data set for different sites.

D07.05: Optimum deployment strategy and quality measure for array layout in view of obtaining surface wave

Tokimatsu, K., 1997: *Geotechnical site characterization using surface waves*, in: Earthquake Geotechnical Engineering, Ishihara (ed.), pp. 1333-1368, Balkema, Rotterdam.
For the other references, see WP01 pages 7-13.

VI WP06 – array measurements – derivation of dispersion curves

Leader: Frank Scherbaum (Partner 3 – UPOTS.GEO – Postdam – Germany)

The main objective within this WP was the development of a semi-automatic processing system for array analysis of ambient vibrations. Besides the processing system itself, all necessary post-processing facilities for obtaining dispersion curves and a utility for rapid in-field quality control of the array performance had to be developed.

Main results

A new integrated software package (**CAP** – **C**ontinuous **A**rray **P**rocessing) was developed for the offline processing of ambient vibration array data. The waveform data acquired in ambient vibration array experiments can be accessed in various formats and three different database interfaces are available (Geopsy, Giant, based on filelists).
In particular, the following analysing methods have been integrated into CAP: **a)** semblance based conventional f-k technique CVFK (Kvaerna and Ringdahl, 1986); **b)** conventional f-k algorithm based on cross spectral matrix approach (standard beamformer); **c)** high resolution f-k algorithm after Capon (1969); **d)** multiple signal classification approach (MUSIC) after Schmidt (1981, 1986); **e)** modified spatial autocorrelation method after Bettig et al. (2001) based on original work of Aki (1957).
Besides the implementation of the algorithms, various pre- and post-processing facilities have been tested and implemented. Among those, there are e.g. energy criteria derived from time-frequency decomposition of the individual waveforms as pre-processing step, or coherency/energy criteria applied to individual analysis windows as a post-processing step. After processing, output files are written in ASCII formats and shell scripts are provided for calling the external post-processing utility fk2disp. Finally, the results of the dispersion analysis is plotted for visual control using the widely disseminated GMT software package (Wessel and Smith, 1998).
The dispersion curve/autocorrelation curve results are kept in simple ASCII output files and can further be interfaced with the inversion software package (NA_VIEWER) developed in WP07. A full integration of the array analysis package CAP and the inversion software package NA_VIEWER is therefore guaranteed allowing for an easy handling of the whole processing system. For a wider dissemination of the software package CAP, a documentation of the functionality and the procedures of operation have been provided in a user manual.
All of the provided software components have been tested with synthetic datasets computed within Tasks B and C of SESAME. Furthermore, all real waveform data sets acquired within the project (WP05) have been processed by this software package.

All these results are compiled in the following deliverables:

D05.06: Quality control software for in-situ checks. A utility has been developed for visual checking of waveform data (various formats).

D15.06: Interface software. A utility software program, which allows to extract individual waveforms from a GIANT database structure in GSE/SAF formats. This allows users involved in Task A to access the waveform data acquired in WP05 for H/V processing.

D18.06: FK/SPAC Continuous array processing software (laboratory post-processing): CAP documentation and user manual.

D19.06: Report on the FK/SPAC capabilities and limitations: Overview of performed tests and conclusions about FK/SPAC capabilities.

Aki, K., 1957: *Space and time spectra of stationary stochastic waves, with special reference to microtremors*, Bull. Earthquake Res. Inst. Tokyo Univ., 35, 415-456.

Bettig B., Bard P.-Y., Scherbaum F., Riepl J., and Cotton F., 2001: *Analysis of dense array noise measurements using the modified spatial auto-correlation method (SPAC). Application to the Grenoble area*, Bolletino di Geofisica Teorica ed Applicata, 42(3/4), 281-304.

Capon, J., 1969 : *High-resolution frequency-wavenumber spectrum analysis*, Proceedings of the IEEE, 57(8), 1408-1418.

Kvaerna, T., and Ringdahl, F., 1986: *Stability of various f-k estimation techniques*, Semmiannual technical summary, 1 October 1985 – 31 March 1986, NORSAR Scientific Report, 1-86/87, Kjeller, Norway, 29-40.

Schmidt, R.O., 1981: *A signal subspace approach to multiple emitter location and spectral estimation*, Ph.D. Dissertation, 201 pp., Stanford University, Stanford, California.

Schmidt, R.O., 1986: *Multiple emitter location and signal parameter estimation*, IEEE Trans. on Antennas and Propagation, 34, pp. 276-280.

Wessel, P., and W. H. F. Smith, 1998: *New, Improved Version of Generic Mapping Tools Released*, EOS Trans., AGU, 79 (47), p. 579.

VII WP07 – array measurements – inversion of velocity profile

Leader: Denis Jongmans (Partner 4 – ULGG.DGO – Liège – Belgium)

The main objective within this WP was the development of a flexible software allowing Vs and Vp vertical profiles to be retrieved from the dispersion curve in an easy and reliable way. A particular attention had to be paid to the introduction of prior information which can greatly help to constrain the model during the inversion process.

Main results

A new software was developed to invert the data outputting from the array analysis of ambient vibrations (WP6). It is fully integrated with this array processing system, making the whole processing chain easy to use and very flexible.

The inversion software (na_viewer) is built on the neighbourhood algorithm (Sambridge, 1999) which is a direct search inversion method randomly generating models inside a parameter space. To efficiently find the solutions of the problem, only the best promising parts of the parameters are densely sampled. As it is a random process the robustness of the results is estimated by launching several inversions with differing random seeds.
Compared to the classical linearized methods, this technique allows the whole parameter space to be investigated. On the other hand, it requires the computation of a large number of forward problems. A special attention was paid to the computation time which was drastically reduced by optimizing the calculation of the dispersion curve for a given model.

The main characteristics of the software are the following:
- inversion of Love or/and Rayleigh dispersion curves, for the fundamental or/and higher modes,
- direct inversion of autocorrelation curves (SPAC method), for the fundamental or/and higher modes,
- possible introduction of a velocity gradient (linear or power laws) within each layer, reducing the number of parameters,
- consideration of the data uncertainty for the misfit computations,
- easy introduction of prior information on the parameters (Vp, Vs, density, geometry) through the parameterization of the model,
- possibility of joint or separated inversion of dispersion, H/V and autocorrelation curves, allowing a great flexibility during processing and a crosschecking of different data.

All the software possibilities have been successfully tested by several partners on synthetic models (theoretical data curves), synthetic signals (ambient vibration modelling in 1D models) and real cases (test urban sites chosen at the beginning of the project).

All these results are compiled in the following deliverables:

D14.07: Report on the inversion of velocity profile and Version 0 of the inversion software.

D21.07: Array measurements: inversion of velocity profile.

The processing (*geopsy+cap*) and inversion (*na_viewer*) softwares are available on Linux, Mac OS X and Windows platforms.

Sambridge, M., 1999a: *Geophysical inversion with a neighbourhood algorithm: I. Searching a parameter space*, Geophys. J. Int., **138**, 479-484.

Sambridge, M., 1999b: *Geophysical inversion with a neighbourhood algorithm: II. Appraising the ensemble*, Geophys. J. Int., **138**, 727-746.

VIII WP08 – nature of noise wavefield

Leader: Pierre-Yves Bard (Partner 1 – UJF.LGIT – Grenoble – France)

The WP08 objectives were to clarify our knowledge about the physical nature of noise wavefield in urban areas. We thus investigated the nature of ambient seismic noise in order to define the reliability of the H/V and array techniques, which are deeply relying on the assumption that the noise wavefield is predominanlty consisting of

surface waves, or even Rayleigh waves. Through empirical, numerical and experimental approaches we tried to answer the following questions: what is the ambient noise? What is its origin? Which kind of waves composes the noise wavefield (Body waves, surface waves, …)?

Main results

The first step of this study has been devoted to update the literature survey in order to increase our knowledge on the actual consistency of the noise wavefield. Conclusions drawn by authors concerning the nature of noise show are consistent. Depending on the natural or anthropic origin (i.e. low frequency microseisms or higher frequency microtremor), characteristics of noise are different in both spectral and temporal domain. The spectral amplitude variations of microseisms are correlated with natural phenomena and there is an agreement that microseisms are due to oceanic and large scale meteorological conditions. On the opposite, spectral amplitude variations of microtremor present a clear correlation with human activities (daily and weekly variations), so microtremors are linked with human activities such as machineries, cars ... On the other hand, this literature overview highlights the lack of knowledge and the disagreement between authors about the composition of noise wavefield. Through this literature review, no suitable answers can be given to characterize noise. These results are included in the first part of the deliverable D13.08.

The second step of this study has been devoted to numerical simulations of seismic noise in order to analyze the structure of the noise wavefield, and more specifically to investigate the proportion of surface and body waves in microtremors, in relation to the H/V ratio peak frequencies. Because of the very heavy computational time requirements of the FD approach (see the previous SESAME progress reports for more details), a 1D numerical simulation method of urban noise has been used (Hisada, 1994, 1995). First, the influence of source parameters (time functions, distances, and depths) on the H/V ratio (in term of amplitude and frequency peak) and on the noise wavefield have been investigated for a well-known 1D structure (a strong impedance contrast sedimentary layer overlaying a bedrock). The main result of this study is the control of the vertical noise wavefield by the local surface sources. The H/V peak ratio located in the vicinity of the fundamental resonance frequency is mainly due to Rayleigh waves. This study is reviewed in the second part of the D13.08 deliverable. These results have been confirmed by various experimental continuous seismic noise measurements performed in urban areas.

The last step of the study consisted in analyzing the noise synthetics computed from 1D canonical models defined within WP09. The 1D canonical models set is constituted by 1) one sedimentary layer overlaying a bedrock with varying impedance contrasts and Poisson coefficients, 2) two sedimentary layers overlaying a bedrock with varying thickness and impedance contrasts, 3) one sedimentary layer overlaying a bedrock with varying S-wave velocity gradients. For all models, both H/V method and array analysis (in collaboration with Task B) were performed on noise synthetics. The array analysis (F-K conventional and CAPON) were performed on both vertical and horizontal components. This allowed to point out very clearly that the physical composition of the ambient noise wavefield, and thus the H/V peak origin, is influenced by the soil characteristic, especially the impedance contrast between sediment and bedrock.

One of the most important outcomes of this study is that despite the fact that the H/V peak may have several origins (Rayleigh waves ellipticity, Love waves Airy phase, or the S-wave resonance) depending on the site velocity structure and noise source locations, the peak frequency derived from H/V curves always gives a very satisfactory estimate of the fundamental resonance frequency (for a 1D sedimentary structure). Conversely, numerical simulations also show the limits of this H/V method to provide satisfactory estimates of the site amplification factor.

All these results are compiled in the following deliverables:

D13.08: Report on the nature of noise

Hisada, Y., 1994. An efficient method for computing Green's functions for a layered half-space with sources and receivers at close depths, *Bull. Seism. Soc. Am.,* 84-5, 1456-72.

Hisada, Y., 1995. An efficient method for computing Green's functions for a layered half-space with sources and receivers at close depths (part 2), *Bull. seism. Soc. Am.,* 85-4, 1080-93.

IX WP09 – numerical simulation of noise and parameter studies

Leader: Peter Moczo (Partner 11 – IGSAS.SD – Bratislava – Slovakia)

The main objectives within this work package were:
- development of computational method(s), algorithm(s), and computer codes for 3D, presumably/mainly finite-difference, modeling of seismic-noise wavefield for realistic models of source-structure configurations;
- numerical simulation of the seismic-noise wavefields and theoretical H/V ratios for a set of structural models representing the most typical and important geological situations, and for possible types of seismic noise generation;
- deduction of decisive factors determining peak H/V and HT (VT) frequencies and corresponding amplitudes in different geological situations.

Main results

The Fortran95 Program Package NOISE for numerical generation and simulation of seismic noise in 3D heterogeneous viscoelastic media has been developed. The package consists of two programs: RANSOURCE and FDSIM.
RANSOURCE is designed for random space-time generation of point sources of seismic noise and has to be run before the finite-difference (FD) simulation. The program generates two files for all delta-like sources and as many files as the number of generated pseudo-monochromatic sources. The output files serve as input files for the program FDSIM.
FDSIM is designed for the FD simulation of seismic wave propagation and seismic ground motion. The computational algorithm is based on the 4^{th}-order staggered-grid displacement-velocity-stress explicit heterogeneous FD scheme solving equations of motion in the heterogeneous viscoelastic medium with material discontinuities.
A set of canonical models for seismic noise simulations has been defined. The set represents basic relevant types of local surface sedimentary structures. The set served for simulations seismic noise. The synthetic noise was then analyzed for its relation to the structure.

An important improvement in the FD modeling of seismic motion has been achieved. In order to account properly for material discontinuities in attenuating media and, at the same time, be memory-efficient, (1) new anelastic functions were defined as material-independent, and (2) a new coarse spatial distribution of the anelastic functions was developed. The method has been implemented in the program package NOISE.

The need of simulation of seismic noise due to distant sources led to implementation of the option of a two-step computation in the program package NOISE. In the first step, the radiation of sources and wave propagation in the large-scale structure is simulated in a certain interval of frequencies. The wavefield is recorded at the borders of the so-called "excitation box". In the second step, the FD calculation is performed in a localized small-scale near-surface heterogeneous structure inside the excitation box.

This program has then been used to perform simulations both for a set of 1D, 2D and 3D "canonical models", and for several real sites (see the next section, WP10). The noise synthetics were then analysed with the H/V and array techniques, and the corresponding results could then be compared with the known model structure (fundamental frequencies, velocity profile) and/or with the actual field measurements. The results of this comparaison are very rich and partly summarized in Bonnefoy-Claudet (2004), Bonnefoy-Claudet et al., (2004) and Cornou et al. (2004). In a very brief and caricatural way, the main learnings may be summarized as follows:

Capabilities of H/V and array techniques for 1D structures

A number of simple 1D structures (with one or two homogeneous layers, or one gradient layer overlying a half-space) has been considered, with varying impedance contrasts and Poisson's ratio. In all cases, the application of the H/V technique on the noise synthetics did lead to the right value as to the fundamental frequency of the structure (within ± 20%). Very satisfactory results were also obtained with the array techniques, which did allow to derive satisfactory S-wave velocity profiles in most cases. The only cases where it did not work properly correspond to internal layering within the sediments with only moderate (i.e. < 50%) velocity contrast: array analysis techniques alone do not have a sufficient resolution to clearly identify slight velocity changes with depth, and provide good estimates only of the wave velocity value for the superficial layer. It was also shown

that the resolution on P-wave velocity, especially within the bedrock, is very poor, and that such information should probably be looked for with other geophysical techniques.

Capabilities of H/V and array techniques for 2D or 3D structures

Several "canonical" 2D and 3D structures were considered first: dipping layer (i.e., 2D valley edge with gentle subsurface slope), and deep alluvial valley. It was found that the resonance frequency given by the H/V technique generally slightly overestimates the theoretical 1D resonance frequency taking into account the local soil column, with a deviation range of about 20%. The H/V peaks, however, are much less clear on sites with rapidly varying thickness, for instance on valley edges. Similarly, the S-wave velocity profile inverted from virtual arrays located over underground slopes is basically related with the average thickness and S-wave velocity of the structure under the array, while, for areas where the underground structure does not present rapid lateral variations, the inverted velocity profiles are as satisfactory as in fully 1D structures.

Although these numerical investigations do point out some limitations for the array analysis techniques, their ability to give the superficial S-wave velocity is highlighted. One way to obtain the S-wave velocity profile of a complex structure over the whole depth interval (down to bedrock) could be to couple geophysical methods such as seismic refraction, which provids very good constraints on layer thickness.

Further investigations were also performed to try to derive additional information from the H/V curve, following the pioneering work of Fäh et al., 2002: sophisticated signal processing (based on wavelet analysis) proved succesful in extracting the Rayleigh wavelets from the synthetics (which in fact are a complex mixture of Love, Rayleigh and body waves), from which it was then possible to pick not only the H/V peak frequency, but also the Rayleigh wave ellipticity: it is then possible to invert this ellipticity curve in terms of velocity profile. More specifically, a Fortran95 code has been developed providing a time-frequency derivation for the H/V ratio, with 2 different methods of time-frequency analysis, windowed Fourier transform (WFT) and continuous wavelet transform (CWT). It has been found that CWT with a modified Morlet wavelet is better for determination of the ellipticity curve of the fundamental Rayleigh-wave mode than the classical H/V technique. In short, this new approach is based on a kind of “stacking” in the H/V-frequency plane instead of computing average curve from individual segments of the seismic noise recordings.

All these results are compiled in the following deliverables:
D02.09: FD code to generate noise synthetics
D12.09: Report on parameter studies

X WP10 – simulation of real sites

Leader: Donat Fäh (Partner 6 – ETHZ – Zürich – Switzerland)

This work package was dedicated to the finite-difference noise simulations for real sites and cross-checking between noise synthetics and actual noise simulations for a few well-known test-sites.

Main results

The work has first focused on testing and developing numerical codes that allow for the simulation of realistic ambient vibration wave-fields. This included the testing of the finite difference (FD) code developed during the SESAME project, and the adaptation of Hisada’s discrete wave number code to the ambient vibration problem using many sources and receivers in order to cross-check the results from the finite difference simulations. Tests on noise synthetics allowed to establish a correct parameter set needed for the numerical modelling. Canonical models were used to determine the effects of the source distribution (density, time function, spatial location) on H/V ratios and on spatial correlations. A good representation of observed noise in terms of H/V shape and spatial correlation could be achieved and a realistic configuration of seismic sources was established.

During the testing of the FD program for 3D structures, it has been recognized that the requirement in computation time is very high. For this reason, the Swiss Seismological Service has submitted a project to the Swiss Center for Scientific Computing (CSCS) in Manno. Two proposals were accepted in 2002 (33600 HCPU) and 2003 (22600 HCPU). Computation time restricted the number of models that could be studied within the

SESAME project. Therefore a selected number of models for real sites were established. This included models for Colfiorito, Basel and Grenoble, that have been encoded for the 3D modelling. The numerical modelling using the different 3D models provided a large data set of ambient vibration synthetics.

For the Grenoble site, synthetics were compared to measured noise and the work lead to the submission of two papers for the 13th World Conference on Earthquake Engineering (Bonnefoy-Claudet et al, 2004; Cornou et al., 2004a). Several canonical models were studied (large and narrow 2D valleys that have the same velocity structure as the Grenoble basin) in order to clarify the array analysis estimates obtained for the Grenoble basin by using observed ground motion and synthetic data. For the Colfiorito basin, the noise synthetics were analysed, and a comparison with the observed ambient noise has been performed. This included H/V spectral ratios computed for single stations and phase velocity curves obtained from array recordings. The preliminary results of this analysis were presented during the 13th World Conference on Earthquake Engineering (13WCEE) and during the European Seismological Commission conference that was held in Potsdam in September 2004 (Cornou et al., 2004a; Cornou et al., 2004b). For the analysis of the observed and synthetic ambient vibrations, the H/V software developed in WP03 and the array processing software developed in WP05 and WP06 were applied. In June 2004 the problems with numerical instabilities encountered during the modelling of the Basel model were solved and the computations were set up. At the present time, the noise computation is still running. Results are expected during the year 2005.

A special task of WP10 was concerned with the use of frequency-time analysis to compute H/V ratios (Kristekova and Fäh, 2004). The method is suitable for the extraction of Rayleigh wavelets, and allows the computation of the ellipticity of these wavelets. A wavelet transformation algorithm has been optimized and compared to classical H/V methods. Several tests have been performed with synthetic signals calculated for some canonical models.

All these results are compiled in the following deliverables:

D11.10: Set of noise synthetic for H/V and array studies from simulations of real sites.

D17.10: Overall comparison for test sites.

For the references, see WP01 page 7-13.

XI WP11 – scientific outcomes

Leader: Pierre-Yves Bard (Partner 1 – UJF-LGIT – Grenoble – France)

One important component of Task D "Dissemination of results", is to have the results of the project as widely disseminated as possible in the scientific and engineering community. In order to achieve that goal, extensive discussions during the general meetings (Roma, 2002; Somlenice Castle, 2003; Les Houches, 2004), and many email exchanges, indicated the following tracks to be followed:

- organization of a special session, at a ***world*** scale, on the occasion of the 13th World Conference of Earthquake Engineering in Vancouver (August 1-6, 2004);
- organization of a special session, at a ***European*** scale, on the occasion of the XXIXth European Sesimological Commission held in Potsdam (September 12-17, 2004);
- looking for a special issue in a scientific journal allowing to reach the various communities involved in earthquake engineering, to present the main results and products in a synthetic way;
- publishing more focused scientific papers in peer reviewed journals.

The following lines briefly describe what has been achieved regarding each of these 4 tracks.

Special session at XIII WCEE Vancouver

The Conference organizers answered positively to our request to have a special session devoted to "Sesame-related" topic. This session, entitled "*Site Characterization for Site Effects Studies Using Ambient Vibrations*",

has taken place on Wednesday, August 4, afternoon. A total of 34 communications has been presented in this session, out of which 13 presented various aspects of the SESAME project; in particular, the first half of the session consisted of 5 "SESAME" oral presentations, the first one with an overall presentation of the SESAME project, and the 4 others presenting successively the results and accomplishments for each of the 4 tasks.
All the papers (10 to 15 pages long each) have been distributed on site in the Conference Proceedings on an electronic support (CD).

SESAME oral presentations

[1] Bard P.-Y., and SESAME participants, 2004. The SESAME project: an overview and main results. Proceedings of the 13th World Conference in Earthquake Engineering, Vancouver, August 2004, Paper # 2207.
[2] Atakan K., A.-M. Duval, N. Theodulidis, B. Guillier, J.-L. Chatelain, P.-Y. Bard and SESAME-Team, 2004. The H/V spectral ratio technique: experimental conditions, data processing and empirical reliability assessment. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 2268.
[3] Cornou C., J. Kristek, S. Bonnefoy-Claudet, D. Fäh, P.-Y. Bard, P. Moczo, M. Ohrnberger, M Wathelet, 2004. Simulation of seismic ambient vibrations: II. H/V and array techniques for real sites. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, Canada, August 2004,* Paper # 1130.
[4] Koller M., C. Lacave et al., 2004. Practical user guidelines and software for the implementation of the H/V ratio technique : measuring conditions, processing method and results interpretation, *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper #3132.
[5] Ohrnberger, M., E. Schissele, C. Cornou, M. Wathelet, A. Savvaidis, F. Scherbaum, D. Jongmans, and F. Kind, 2004. Microtremor array measurements for site effect investigations: comparison of analysis methods for field data crosschecked by simulated wavefields. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 940.

SESAME poster presentations

[6] Duval A.-M., J.-L. Chatelain, B.Guillier and SESAME Project WP02 Team, 2004. Influence of experimental conditions on H/V determination using ambient vibrations (noise), *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 306.
[7] Atakan K., P.-Y. Bard, F. Kind, B. Moreno, P. Roquette, A. Tento and SESAME-Team, 2004. J-SESAME: a standardized software solution for the H/V spectral ration technique. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper #2270.
[8] Theodulidis N., G. Cultrera, A. Tento, D. Faeh, K. Atakan, P.-Y. Bard, A. Panou and the SESAME-Team, 2004. Empirical evaluation of the horizontal-to-vertical spectral ratio technique: results from the SESAME project. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 2323.
[9] Cultrera G., R. Azzara, F. Cara, R. d'Anna, G. Di Giulio, M. S. Giammarinaro, G. Passafiume, A. Rovelli and P. Vallone, 2004. Microtremor Measurements in Palermo, Italy: a comparison with macroseismic intensity and earthquake ground motion. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 915.
[10] Teves-Costa, P., L. Senos and C.S. Oliveira, 2004. Correlation between damage distribution and soil behaviour estimated with ambient vibrations. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 1004.
[11] Ohrnberger M, E. Schissele, C. Cornou, S. Bonnefoy-Claudet, M. Wathelet, A. Savvaidis, F. Scherbaum and D. Jongmans, 2004. Frequency wavenumber and spatial autocorrelation methods for dispersion curve determination from ambient vibration recordings. *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 946.
[12] Lacave C. and J. Rey, 2004. Is the phase of the one-sided autocorrelogram of the horizontal components of ambient vibrations (Tokeshi's method) able to reveal the fondamental resonance frequency of a site ? *Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, August 2004,* Paper # 3120.
[13] Bonnefoy-Claudet S., C. Cornou, J. Kristek, M. Ohrnberger, M Wathelet, P.-Y. Bard, D. Fäh, P. Moczo, F. Cotton, 2004. Simulation of seismic ambient noise: I H/V and array techniques on canonical models. Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, Canada, August 2004, Paper # 1120.

Special session at XXIX ESC Potsdam

In this case also, the Conference organizers answered positively to our request; however, due to a very big pressure, the "noise" session was merged with others devoted to site effects and seismic microzonation, so that the final session title is *"Nature of noise wave field and recent developments in microzonation"*; it has taken place on Thursday afternoon, September 16th and Friday morning, September 17th. A total of 36 papers were presented in this session, out of which 6 come from the SESAME project. Only the abstracts have been distributed; no special paper has been written.

[1] Bonnefoy-Claudet S., C. Cornou, M. Ohrnberger, M. Wathelet, P.-Y. Bard P.-Y., F. Cotton F., D. Fäh 2004. Excitation of Rayleigh waves higher modes in seismic ambient noise. *XXIXth European Seismological Commission, Session F3, September 2004.*

[2] Cornou, C., G. Di Giulio, M. Ohrnberger, J. Kristek, M. Wathelet, 2004. Simulated Vs observed seismic ambient noise in the Colfiorito basin: site effect estimation and noise wavefield characteristics. *XXIXth European Seismological Commission, Session F3, September 2004.*

[3] K. Atakan, P-Y. Bard, F. Cara, J-L. Chatelain, G. Cultrera, A.M. Duval, B. Guillier, F. Kind, B. Moreno, P. Roquette, A. Tento, P. Teves-Costa, 2004. J-SESAME: a dedicated software for H/V spectral ratios. *XXIXth European Seismological Commission, Session F3, September 2004.*

[4] M. Kristeková, D. Fäh, 2004. Computation of the h/v ratio using time-frequency analysis with continuous wavelet transform. *XXIXth European Seismological Commission, Session F3, September 2004.*

[5] M. Ohrnberger, E. Schissele, C. Cornou, M. Wathelet, 2004. Reliability of dispersion curve estimates obtained from ambient vibration array analysis. *XXIXth European Seismological Commission, Session F3, September 2004.*

[6] A. Panou, C. Cornou, N. Theodulidis, P. Hatzidimitriou, P.-Y. Bard, and C.B. Papazachos, 2004. Modelling of ambient noise horizontal-to-vertical spectral ratio in laterally varying structures: the case of the city of Thessaloniki (Northern Greece). *XXIXth European Seismological Commission, Session F3, September 2004.*

Special issue in a Journal

A. Ansal, secretary general of the European Association of Earthquake Engineering (EAEE), attended the SESAME Smolenice castle meeting in Fall 2003, and offered to devote an issue of the EAEE journal "*Bulletin of Earthquake Engineering (BEE)*" to the SESAME project. As EAEE and BEE are touching a very wide community throughout Europe and Mediterranean basin, we accepted this proposal. The final decisions on the summary papers to be written in that issue were taken during the last SESAME plenary meeting in early October. It consists of:

1. A CD-ROM with the JSESAME H/V software, the user manual, and the interpretation guidelines
2. Two papers on the instrumental and experimental tests
    a. *Evaluation of the influence of experimental conditions on H/V results from ambient noise recordings* (J.-L. Chatelain, B. Guillier, F. Cara, A.-M. Duval, K.Atakan, P.-Y. Bard and the WP02 SESAME team).
    b. *Influence of instruments on the H/V spectral ratios of ambient vibrations* (B. Guillier, K. Atakan, J.-L. Chatelain, J. Havskov, M. Ohrnberger, F. Cara, A.-M. Duval, S. Zacharopoulos, P. Teves-Costa and the SESAME Team).
3. One paper on the physical background
    a. Physical background : noise wavefield and interpretation of the H/V ratio (P.-Y. Bard, D. Fäh, C. Cornou, S. Bonnefoy-Claudet, F. Cotton and the SESAME team)
4. One paper on the experimental assessment of the H/V technique
    a. Empirical evaluation of the microtremor H/V spectral ratio (E. Haghshenas, P.-Y. Bard, N. Theodulidis, and the SESAME team)
5. One paper on the comparison between H/V ratio and damage observations
6. One paper on the recommendations for the use of array techniques

As of January 31, 2005, contributions (1), (2a) and (2b) are written; first drafts of contributions(3) and (4) have been written and are under internal revision and improvements; contributions (5) and (6) have been somewhat delayed, mainly because the results came late; in particular, for the last one, the paper cannot be issued before M. Wathelet, a PhD student partly funded with the SESAME project, finishes to write down his PhD manuscript, which is scheduled for the end of February 2005. We therefore plan to submit the whole series of papers as a special issue for BEE in early Spring 2005.

Focused papers

During the Smolenice and Les Houches meetings, a plan was established and agreed upon on the various specific papers that could be written on the basis of SESAME results. The following lines are indicating, for each task, the list of papers that was considered in addition of those considered for the BEE special issue, as well as their present status of writing. Obviously, publications resulting directly from the SESAME work are not over, although the project is officially finished: while this is partly due to the fact that some work packages

were delayed (for instance those involving numerical simulation), it also witnesses the fact that the developed tools and methods and the obtained results are very rich, requiring a rather long maturing time and deserving many different papers with different view angles.

TASK A - Papers already written, at least as a first draft

A1 Cara F., G. Di Giulio and A. Rovelli, 2003. A Study on Seismic Noise Variations at Colfiorito, Central Italy: Implications for the Use of H/V Spectral Ratios. *Geoph. Res. Lett.*, vol. 30, N° 18, 1972, doi:10.1029/2003GL017807.

A2 Panou, A., N. Theodulidis, P. Hatzidimitriou, A. Savvaidis and C. Papazachos, 2004. Reliability of ambient noise H/V spectral ratio in urban environment: The case of Thessaloniki city (Northern Greece). *PAGEOPH* (in press).

A3 Panou A., N. Theodulidis, P. Hatzidimitriou, C. Papazachos and K. Stylianides, 2004. Ambient noise H/V spectral ratio for assessing site effects in urban environments: The case of Thessaloniki city". *Bull. Geol. Soc. Greece* Paper No. SE8_68, (in press).

A4 Panou A., N. Theodulidis, P. Hatzidimitriou, K. Stylianides and C. Papazachos, 2005. Ambient noise horizontal-to-vertical spectral ratio in site effects estimation and correlation with seismic damage distribution in urban environment: The case of the city of Thessaloniki (Northern Greece). *Soil Dyn. & Earthq. Eng.* (in press).

A5 Teves-Costa, P., C.S. Oliveira and M.L. Senos, 2004. Correlations of damage distribution with soil and building parameters in Angra do Heroismo, Azores. First draft written

TASK A - Papers still under preparation

A6 Theodulidis et al., 2005, (H/V) spectral ratio using strong motion and ambient noise data: The case of accelerometric network in Greece (in preparation).

A7 Theodulidis et al.,2005, SESAME database (in preparation, to be submitted to Seism. Res. Letters).

A8 JSESAME paper (to be submitted to SRL (electronic seismologist) or Computer Geosciences and/or Special Issue of the BEE (?)). This paper can be sent together with another paper about the WP04 database (an article in SRL). Still in preparation

A9 Theodulidis et al., 2005,: Correlation of ambient noise (H/V) ratios with earthquake damage in selected European cities (in preparation).

A10 Cara, Cultrera et al.: Comparison of H/V ratios with geology and observed damage in Palermo.

Task B - Already written and at least submitted

B1 Ohrnberger M., F. Scherbaum, F. Krüger, R. Pelzing and S.K. Reamer, 2004. How good are shear wave velocity models in the Lower Rhine Embayment (NW-Germany) obtained from inversion of ambient vibrations, *Bolletino di Geofisica Teorica ed Applicata*, 45(3), pp. 215-232.

B2 Wathelet M., D. Jongmans and M. Ohrnberger, 2004. Surface wave inversion using a direct search algorithm and its application to ambient vibrations measurements. *Near Surface Geophysics*, 2, pp. 211-221.

B3 Köhler, A., Ohrnberger, M., Scherbaum F., Stange. S., and Kind F., 2004: Ambient vibration measurements in the southern Rhine graben close to Basle, subm. to Annali di Geofisica.

Task B - Still in preparation

B4 Wathelet et al.: Direct inversion of SPAC

B5 Ohrnberger et al. : Comparison of different methods for the determination of dispersion curves (first version however published in Vancouver)

B6 Savaidis et al. : Determination of dispersion curves and comparison with those obtained from geotechnical models for the Greek data sets

B7 Schissele et al. : The influence of Pre/post selection

Task C - Already written, at least as a first draft

C1 Fäh D., F. Kind and D. Giardini, 2003. Inversion of local S-wave velocity structures from average H/V ratios, and their use for the estimation of site effects. *Journal of Seismology*, **7**, 449-467.

C2 Kristek K., P. Moczo and R. Archuleta, 2002. Efficient methods to simulate planar free surface in the 3D 4^{th} –order staggered-grid finite-difference schemes. *Studia Geophys. Geod.*, **46**, 2002, 355-381.

C3 Moczo P., J. Kristek, V. Vavrycuk, R. Archuleta and L. Halada, 2002. 3D heterogeneous staggered-grid finite-difference modeling of seismic motion with volume harmonic and arithmetic averaging of elastic moduli and densities. *Bull. Seism. Soc. Am.*, **92**, 3042-3066.

C4 Kristek J. and P. Moczo, 2003. Seismic wave propagation in viscoelastic media with material discontinuities – a 3D 4th-order staggered-grid finite-difference modelling. *Bull. Seism. Soc. Am.* (in press).

C5 Malischesky, P. and F. Scherbaum, 2004. Comparison between Rayleigh H/V ellipticity peak frequency, and fundamental S-wave resonance frequency, Wave motion, published.

C6 Roten, D., D. Fäh, C. Cornou and D. Giardini, 2004. 2D resonances in alpine valleys identified from ambient vibration wavefields (submitted)

C7 Bonnefoy-Claudet S., 2004. Nature du bruit de fond sismique: implications pour les etudes des effets de site. *PhD thesis, Joseph Fourier University, Grenoble, France. 241 pp.*

C8 Bonnefoy-Claudet S., F. Cotton and P.-Y. Bard, 2005. Nature of noise wavefield: a literature review. *Ready to be submitted to Earth-sciences Review*.

C9 Bonnefoy-Claudet S., C. Cornou, P.-Y. Bard, F. Cotton, P. Moczo, J. Kristek and D. Fäh, 2005. H/V ratio: a tool for site effects evaluation. Results from 1D noise simulation. *Ready to be submitted to BSSA*.

C10 Panou, A.A., C. Cornou, N. Theodulidis, P. Hatzidimitriou, P.-Y. Bard, and C.B. Papazachos, 2005. Modelling of Ambient Noise horizontal-to-vertical spectral ratio in laterally varying structures: The case of the city of Thessaloniki (Northern Greece),

Task C - Still in preparation (should be completed between Spring 2005 and the end of 2005)

C11 Kristek J., Moczo P. and M. Kristeková. Finite-difference Simulation of Ambient Noise in 3D Surface Sedimentary Structures: Part 1 – Method (***First draft almost completed***).

C12 Di Giulio, G., C. Cornou, M. Ohrnberger, M. Wathelet and A. Rovelli, 2005. 2-D small aperture arrays for velocity profile estimation using ambient seismic noise in a small-size alluvial basin (Colfiorito, Italy). ***First draft under completion***

C13 Cornou, C. et al., 2005. Canonical models / 3D models : Relevancy of H/V technique and array processing techniques for 3D structures. ***Still in preparation, but preliminary version already written for Vancouver***

C14 Cornou, C., S. Bonnefoy-Claudet et al., 2005. Comparison between observations and numerical simulations of ambient noise with the actual site structure for the Grenoble (France) site.

C15 Wathelet, M., et al., 2005. Comparison between observations and numerical simulations of ambient noise with the actual site structure for the Liège (Belgium) site.

C16 Cornou, C., D. Fäh et al., 2005. Comparison between observations and numerical simulations of ambient noise with the actual site structure for the Basel (Switzerland) site.

C17 Cornou, C., et al., 2005. Main lessons from the comparison between observed and modelled ambient vibrations for a series of known real sites. [Topics to be adressed : adequacy between the level of knowledge for each site and the requirements of modelling ; ? is more needed for noise modelling than for ground motion prediction ? Is 3D modelling of noise worth ? Are array measurements useful in 3D sites? Is it so cheap with respect to S-wave profiling? Is our noise generation model correct ?]

C18 Kristekova, M., and D. Fäh, 2005. Extraction of Rayleigh wavelets from ambient noise recordings using time frequency analysis. ***In preparation***

In addition to all these papers, several SESAME related papers including contributions from the SESAME partners, and funded with other sources, (German Research Council, French sources), have been written:

Hinzen, K.G., F. Scherbaum and B. Weber, 2003. On the resolution of H/V measurements to determine sediment thickness, a case study across a normal fault in the Lower Rhine Embayment, Germany, *Journal of Earthquake Engineering*, 8(6), 909- 926, 2004.

Diallo M.S., M. Holschneider, M. Kulesh, F. Scherbaum and F. Adler, 2003. Characterization of seismic waves polarization attributes using continuous wavelet transforms, *Geophysics* (submitted).

Holschneider, M., M.S. Diallo, M. Kulesh, F. Scherbaum, M. Ohrnberger and E. Lück, 2004. Characterization of dispersive surface waves using continuous wavelet transforms, *Geophys. J. Int.* (in review).

Köhler A., M. Ohrnberger, F. Scherbaum, S. Stange and F. Kind, 2004. Ambient vibration measurements in the southern Rhine graben close to Basle, *Annali di Geofisica* (submitted).

Dunand, F., P.-Y. Bard, Ph. Guéguen, J.-L. Chatelain, B. Guillier, T. Vassail, 2003. Caractérisation du comportement dynamique des sols et structures par mesures de vibrations ambiantes : Développements récents et questions en suspens, *Journée d'étude F²AS "Recalage calcul / Mesures" (25/03/2003, Paris), IPSI, Vol. XXVII, n°1, 15 pages (in French)*

One may also find the main practical learning's from these multiple experimental and numerical achievements, in the recommendations and/or guidelines for the use of the H/V (WP12) and array (WP13) techniques.

Given the incompressible delay corresponding first to the maturation of the results and secondly to the review process in international journals, we consider that:
- the direct outcomes of the SESAME project will certainly not be over before mid 2006,
and
- the indirect outcomes should last for another 2 or 3 years, at least, given the amount of synthetic waveforms, experimental recordings (several hundreds of Gigabytes) that were gathered and archived, and the scientific issues that came out of the passionate discussions up to the very last meeting .

XII WP12 – H/V user guidelines

Leader: Corinne Lacave (Partner 2 – Resonance – Genève – Switzerland)

The objective of this work package was to build the basis for practical application of the research results. To this aim, guidelines for single station ambient vibration measurements and their interpretation had to be elaborated. Minimum quality requirements for the practical use of the H/V technique are fixed, a standard processing software is provided on a CD-ROM with a user manual, and - as far as possible - scientific explanations are given on the basis of our latest results and interpretations

The WP12 is primarily based on the outcomes of task A (WP02, WP03, WP04), but also on the results of the other WP, in particular of WP08 (nature of noise wave field) and WP11 (scientific outcomes). The guidelines content consists of the following parts:

INTRODUCTION
PART I: QUICK FIELD REFERENCE AND INTERPRETATION GUIDELINES
1. EXPERIMENTAL CONDITIONS + MEASUREMENT FIELD SHEET
2. DIAGRAMS FOR INTERPRETATION OF H/V RESULTS

PART II: DETAILED TECHNICAL GUIDELINES
1. TECHNICAL REQUIREMENTS
2. DATA PROCESSING STANDARD: J-SESAME SOFTWARE
3. INTERPRETATION OF RESULTS

APPENDIX A: H/V DATA EXAMPLES
APPENDIX B: PHYSICAL EXPLANATIONS

The first draft version of the guidelines was completed and presented during a special theme session at the 13th World Conference on Earthquake Engineering (Vancouver, August 2004). Each part of the guidelines has been submitted to a group of internal reviewers for comments and suggestions for improvements. Then, the revised guidelines have been reviewed by international external experts, not involved in the SESAME research project.

In the end, a final writing meeting has been conducted to improve and complete the guidelines, in order to reach the final version, after 5 draft versions. The guidelines text, as well as a CD-Rom containing the J-SESAME software will be published in a special issue of the Bulletin of Earthquake Engineering. These documents are also available on the Sesame web-site and constitute the Deliverable D23.12.

It is hoped and anticipated that the elaborated guidelines *"Guidelines for the implementation of the H/V spectral ration technique on ambient vibrations: Measurements, processing and interpretation"* become an internationally accepted quality standard for single station ambient vibration measurements and their interpretation.

→ The guidelines can be load free of charge on the following site http://SESAME-FP5.obs.ujf-grenoble.fr.

XIII WP13 – Recommendations for quality array measurements and processing

Leader: Denis Jongmans (Partner 4 – ULGG.DGO – Liège – Belgium)

The objective of this WP was to draw conclusions and to propose recommendations on the use of array measurements for site characterisation in urban areas.

Main results

Array measurement techniques are attractive but complex to use. The experience gained during the SESAME project allows to give recommendations which have ensured a correct use of the method. As all the theoretical aspects are not yet fully understood and as the method was tested on a limited set of data, they do not have to be considered as strict and definitive guidelines. The main conclusions are the following:

- All the methods used and developed during the project SESAME assume that the investigated site is made of horizontal layers with velocity values only varying with depth. Before any deployment of a seismic array, the one-dimensional structure of the site has to be proved or checked from existing geological data or from the spatial stability of the H/V curves;
- The spectral energy content of the ambient vibrations has to be checked and the sensor type has to be adapted to the analysable frequency range. Only on one site (Liège, Belgium) it was possible to use 4.5 Hz geophones, due to the low depth of the bedrock. Usually, 5-second seismometers are recommended;
- Large time windows (duration greater than 25 cycles) are needed to improve the phase delay estimate and a large number of windows are necessary to obtain good statistics;
- There is no simple relation between the array geometry, the penetration depth and the usable frequency range of the dispersion curve. The best solution to this problem was found to define two wave number limits (kmin: resolution, kmax: aliasing) deduced from the theoretical array response computation. Tests on synthetic signals have shown that the dispersion curve estimations were reliable within this wavenumber range;
- A field measurement methodology has been proposed for the real time determination of the dispersion curve. The method is based on the repeated deployment of small arrays with increasing aperture in order to build up the dispersion curve piece by piece on narrow wavelength ranges;
- The introduction of a priori information (Vp, Vs, geometry), the joint inversion of the dispersion curve with the frequency of the H/V peak or the joint inversion of the dispersion curve branches obtained from passive and active experiments reduces the non-uniqueness of the solution;
- Most recommended processing methods are the conventional f-k method and the SPAC technique. The combination of different methods increases the confidence about the results and is highly recommended.

The main recommendations for array measurements and processing, based on Task C results and M. Wathelet's PhD thesis, will be written in a publication submitted to the special issue of the Bulletin of Earthquake Engineering, dedicated to ambient vibration measurements.

All these results are compiled in the following deliverables:

D24.13: Recommendations or array measurements and processing

SESAME important dates

	Months	Week 1	Week 2	Week 3	Week 4
1	*May 2001*				
2	*June 2001*				Kick-off Meeting-Grenoble
3	*July 2001*				
4	*Aug. 2001*				**Zürich – Aug 29-30** Task C meeting
5	*Sept. 2001*				
6	*Oct. 2001*				**Bergen – Oct 22-26** TaskA - WP02
7	***Nov. 2001***	**First progress report: 6th months report**			
8	*Dec. 2001*		(AGU)		
9	*Jan. 2002*	**Potsdam – Jan 7-8** TaskA-WP02	**Potsdam – Jan 9-11** TaskA-WP03 & TaskB-WP06		
10	*Feb. 2002*				
11	*March 2002*				
12	*April 2002*			**During the EGS – Nice – April 21-27** Task A- WP02- WP 03- WP 04 D1, D2 → sent with D3 in June 03	
13	*May 2002*			**Zürich** Task C meeting	D3: Progress report 1 (due on 30/06/02)
14	***June 2002***	**Second report: first year progress report + Deliverables D1, D2 & D3**			
15	*July 2002*				
16	*Aug. 2002*				
17	*Sept 2002*	(ECEE London) (ESC Genoa)			
18	*Oct. 2002*		**Roma – Oct 22-26** Oct 22-24: WP02, WP03, WP04, WP09-10 meetings Oct. 25-26: General SESAME meeting		D5, D6, D7 → sent with the third report
19	*Nov. 2002*				
20	*Dec. 2002*		(AGU)		D4 draft sent with the third report
	Dec. 2002	**Third report: 18th months report + Deliverables D5, D6, D7 & a draft of D4**			
21	*Jan. 2003*				
22	*Feb. 2003*	**Potsdam– Feb. 3-14** Task B meeting		**Bratislava– Feb. 20-21** Task C meeting	
23	*March 2003*				
24	*April 2003*		**During the EGS-AGU-EUG Nice – April 7-11** WP02 meeting		D8, D9, D13 (first part), D14, D15 → sent with the fourth report
25	*May 2003*				D10: Progress report 2 (due on 30/06/03)
26	*June 2003*		**Thessaloniki– June 12-13** WP03-WP04 meeting		
	July 2003	**Fourth report: 2nd year report + Deliverables D8, D9, D10, D13, D14 & D15**			
27	*July 2003*			**Grenoble– July 16-17** Task C meeting	
28	*Aug. 2003*				
29	*Sept. 2003*			**Smolenice – Sept 22-24** **Scientific Workshop**	
30	*Oct. 2003*				
31	*Nov. 2003*				
32	*Dec. 2003*		(AGU)		
	Jan 2004	**Fifth report: 32th months report**			
33	*Jan. 2004*				
34	*Feb. 2004*		**Lisbon– Feb. 8-13** WP03 meeting	**Potsdam– Feb. 16-20** Task C meeting	
35	*March 2004*				
36	*April 2004*				EGU – Nice (25-30 apr.)
37	*May 2004*				
38	*June 2004*				
39	*July 2004*				
	July 2004	**Sixth report: 38th months report + Deliverables D13, D16, D18, D20 & D21**			
40	*August 2004*		**Vancouver – August 1-6** 13th world conference in Earthquake Engineering		
41	*September 2004*		**Potsdam – September 13-17** ESC		
42	*October 2004*	**Les Houches – Oct. 3-5** Final Meeting			D11, D12, D17, D19, D22, D23, D24
43	*November 2004*			**Geneva - Nov. 22-23** WP12 meeting	
44	*December 2004*				D25: Final report

Concluding comments

When looking back at this nearly 4-year long period, I feel legitimate, on behalf of the numerous scientists who contributed to this project, to express our feeling to have done a pretty good job:

- ***New data sets*** have been obtained and/or gathered: experimental recordings of ambient vibrations on various sites (single point as well as array measurements), simulation synthetics for many different geological configurations, including both canonical models and real sites, a site effect data base gathering ambient vibration and earthquake recordings for about 200 sites. This huge data set (up to 100 Gbytes) has been carefully documented and archived, so that it may be used for further analysis or revisited with any new emerging technique; it may also constitute the basis of any larger data base (in particular the SIS data base is certainly worth being enlarged so as to become a reference data set for statistical studies).

- ***New methods*** have been developped and tested. Beyond the selection of various algorithms for the classical H/V technique, original developments for a much richer use of H/V curve (inverting the H/V ellipticity) have been proposed and tested. Concerning array processing techniques, the main contribution has not been the development of new methods, but the careful cross-comparison of each of them (at least the main ones), the underlining of their respective advantages and drawbacks, and their implementation in a common software. Major forward steps have been achieved for the inversion of velocity profiles, pinpointing the severe limitations of previous techniques (those which are presently widely used in commercial softwares), and outlining the confidence intervals for the results – as well as the importance of other reconnaissance techniques to bring additional constraints on some cirtical parameters. The general conditions for a relevant numerical simulation of noise are now better framed and, while some further developments are still welcome (excitation box for long period waves with an oceanic origin), they offer a very useful tool for testing the data processing techniques on well constrained "data".

- ***New softwares*** have been written for implementing some of these methods in "user-friendly", properly documented computer programs (3, while only two were promised in the proposal: JSESAME for the H/V technique, SES-ARRAY for array processing techniques, NOISE for noise simulation in 3D structures). Accompanying ***user manuals*** and ***interpretation guidelines*** have been carefully prepared in order to avoid their misuse, especially for the JSESAME one, which is totally free for a wide dissemination.

- Extensive field tests have allowed to end up with ***practical recommendations for field measurements*** concerning both the H/V and array techniques, which, hopefully, should provide future users with the lessons of the good and bad experience of all the SESAME participants.

- A large amount of ***scientific results*** could be achieved, as already witnessed by the number of contributions in International Conferences; the number of papers published in international journals is still relaticvely modest, but will drastically increase in 2005 and 2006, given the delays for a) the maturation of latest results and b) the reviewing process. A special issue of the Bulletin of Earthqauke Enginneering, the official journal of the European Association of Eathquake Engineering, planned for late 2005 early 2006, should widely disseminate the main results within the engineering community.

Such a success is intimately related with the excellent working atmosphere within the consortium, which allowed in-depth scientific discussions throughout the whole 3.5 year duration of the project, on the occasion of many meetings and through extensive email exchanges. This good atmosphere, together with the promising results about some unexpected developments (SESARRAY sofware, extraction of Rayleigh wavelets, SIS data base, use of horizontal components) and some other recent results on other applications of ambient vibrations,

led all the consortium to enthusiastically volunteer for a continuation / extension. Unfortunately, the emphasis put on huge projects, and the relative disinterest for earthquake related issues in FP6 calls and tools, did not offer, till now, any such opportunity. With the exception of a "JRA" (Joint Research Activity) included in the NERIES proposal submitted within the last I3 call.
This success was also made possible thanks to the additional funding provided from several agencies / countries, which were not scheduled initially, but proved necessary and beneficial during the life of the project, and were made possible by the excellent synergy between the teams: Switzerland offered very large computational facilities for the numerical simulation of ambient vibrations in 3D structures, Germany and France offered additional manpower for some parts of the project.

Five years ago, when writing the proposal, most of us were essentially interested in investigating the H/V technique, and one key objective was the world-wide, free dissemination of the H/V package including a platform-free software and user guidelines. Simultaneously, most of us (not all however !) felt somewhat sceptical about array measurements (and so were also the project reviewers !...). The results obtained after 3.5 years of exciting work, considerably raised our enthusiasm for these techniques which appear to be a very powerful geophysical exploration tool – as claimed years ago by our Japanese colleagues -, and would probably also deserve some "standard" software to avoid misuses.
This leads us to mention the only issue about which we worry a little bit: the "SES-ARRAY" software, a non-promised outcome of the project, proves to be very convenient and is very frequently asked by colleagues from all-over the world. The consortium agreed on a common policy in the last general meeting in Les Houches: it consists, for the next two years, in disseminating freely the software to all interested groups, provided that a) they have a formal cooperation agreement with one of the 14 SESAME partners, and b) they participate in a training course to learn how to properly use the software. However, this "wild deliverable" is not yet completely stabilized and debugged, and there is no money left to fund the final polishing of the software and the redaction of a user manual. We therefore plan to set up a fee for the training course, in order to raise a one-year grant for a specialist.

We are aware that a huge amount of work based on ambient vibration recordings has been simulatenously carried out by many teams throughout the world (Latin-America, Asia, Africa, Near-East, India / Indonesia, CEI, South Pacific, North America), and for sure we cannot claim to have definitely solved all the issues related with the use of ambient vibrations in earthquake engineering. We think however we have achieved a significant step forward, which makes us proud and happy with the efforts, work (and fun) shared throughout the 4 last years. We hope the results of this project will be an opportunity to fruitful exchanges allowing to reach a worldwide consensus regarding some sensitive issues such as the H/V technique – which might possibly be discussed within the framework of the IAEE/IASPEI joint working group on Effects of Surface Geology -, and that the SESAME project will thus help opening the door to sustainable development by offering a carefully assessed, low cost tool for safer urban planning and seismic design.