



International Symposium  
Qualification of dynamic analyses of dams and their equipments  
and of probabilistic assessment seismic hazard in Europe

31th August - 2nd September 2016 - Saint-Malo

# Spatial variability of the seismic ground motion on the dam - foundation rock interface

E. Koufoudi

E. Chaljub

F. Dufour

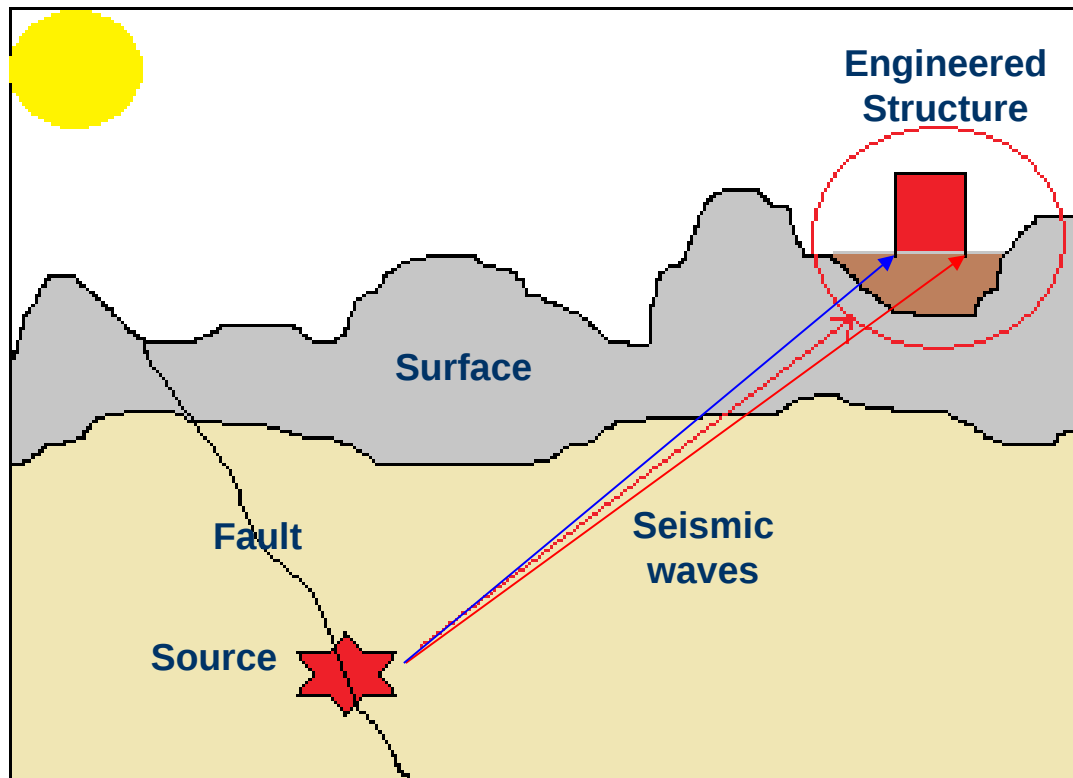
N. Humbert

E. Robbe

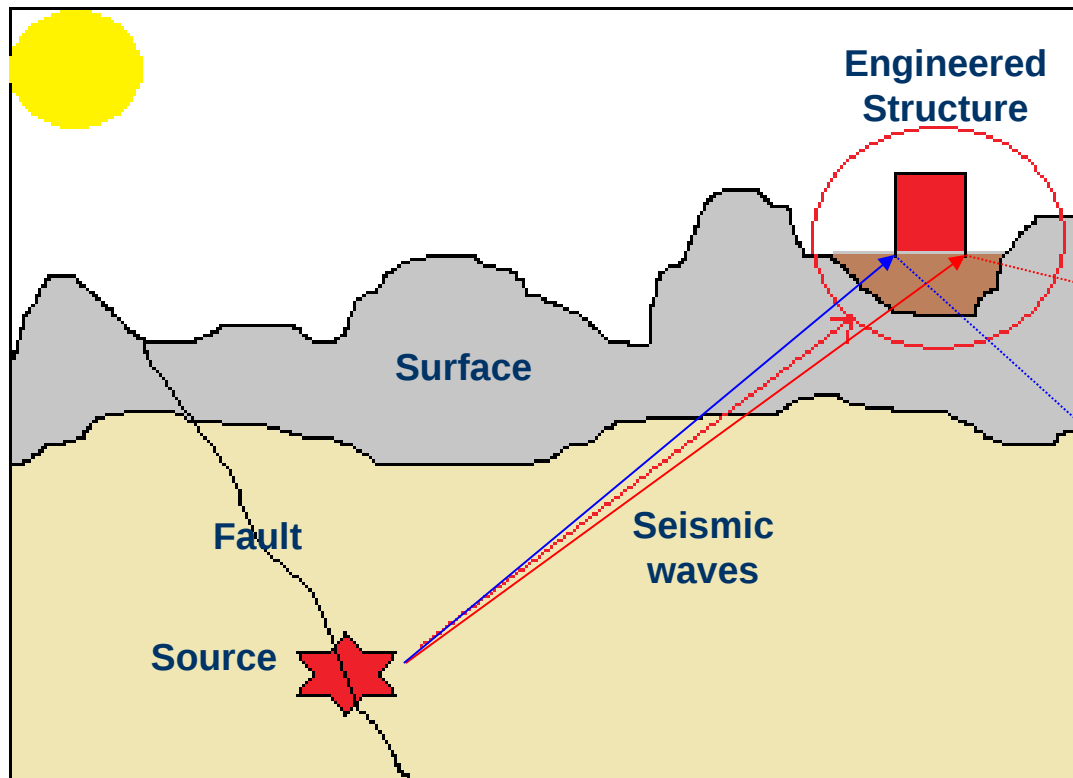
E. Bourdarot



# Spatial variability of the seismic ground motion

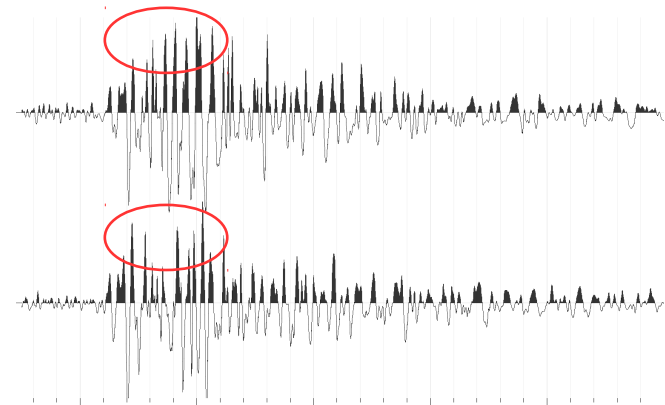


# Spatial variability of the seismic ground motion

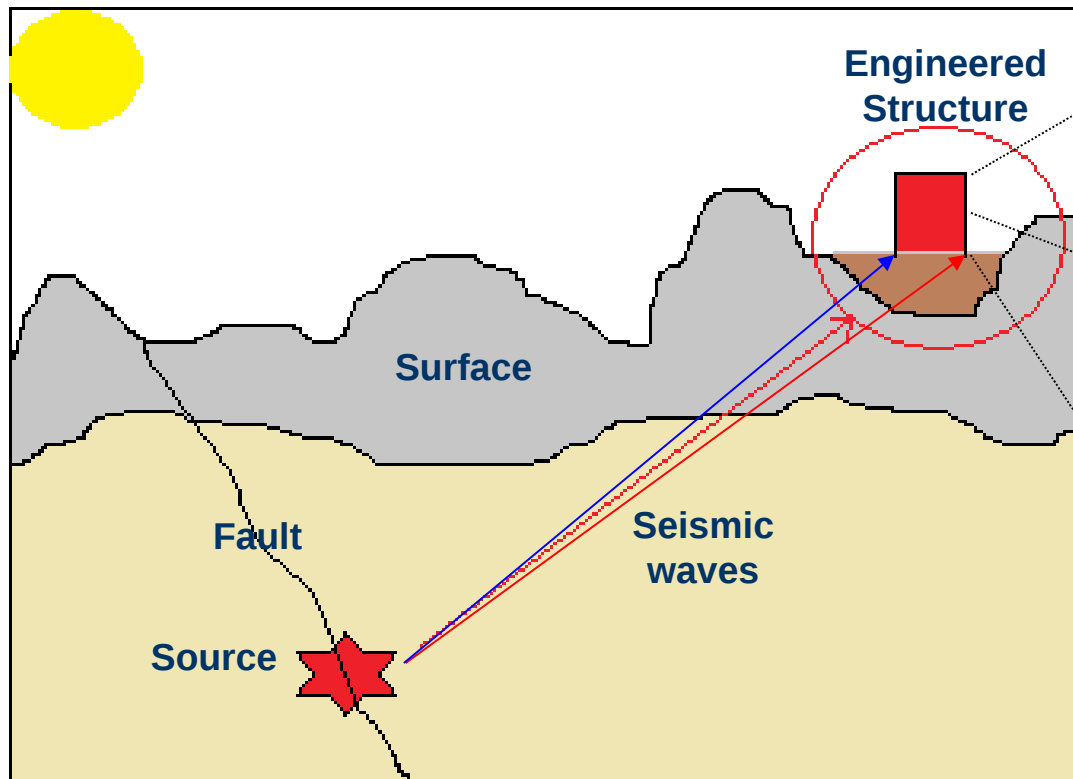


Differences between 2 time series :

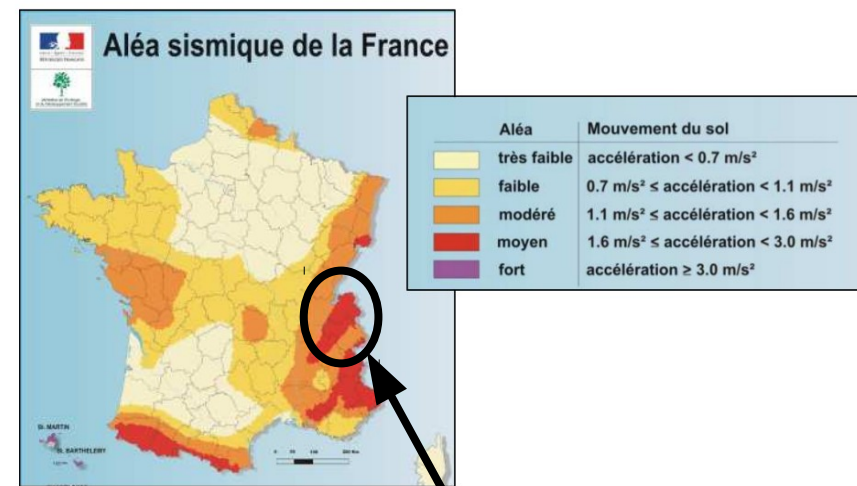
- **Amplitude**
- **Phase content**



# Spatial variability of the seismic ground motion



# SUMMARY



## Dense seismological array in Saint-Guérin site

Instrumentation

Earthquake recordings databank

## Spatial variability analysis

Phase variability

Amplitude variability

## Conclusions - Perspectives



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# Configuration of the seismological array



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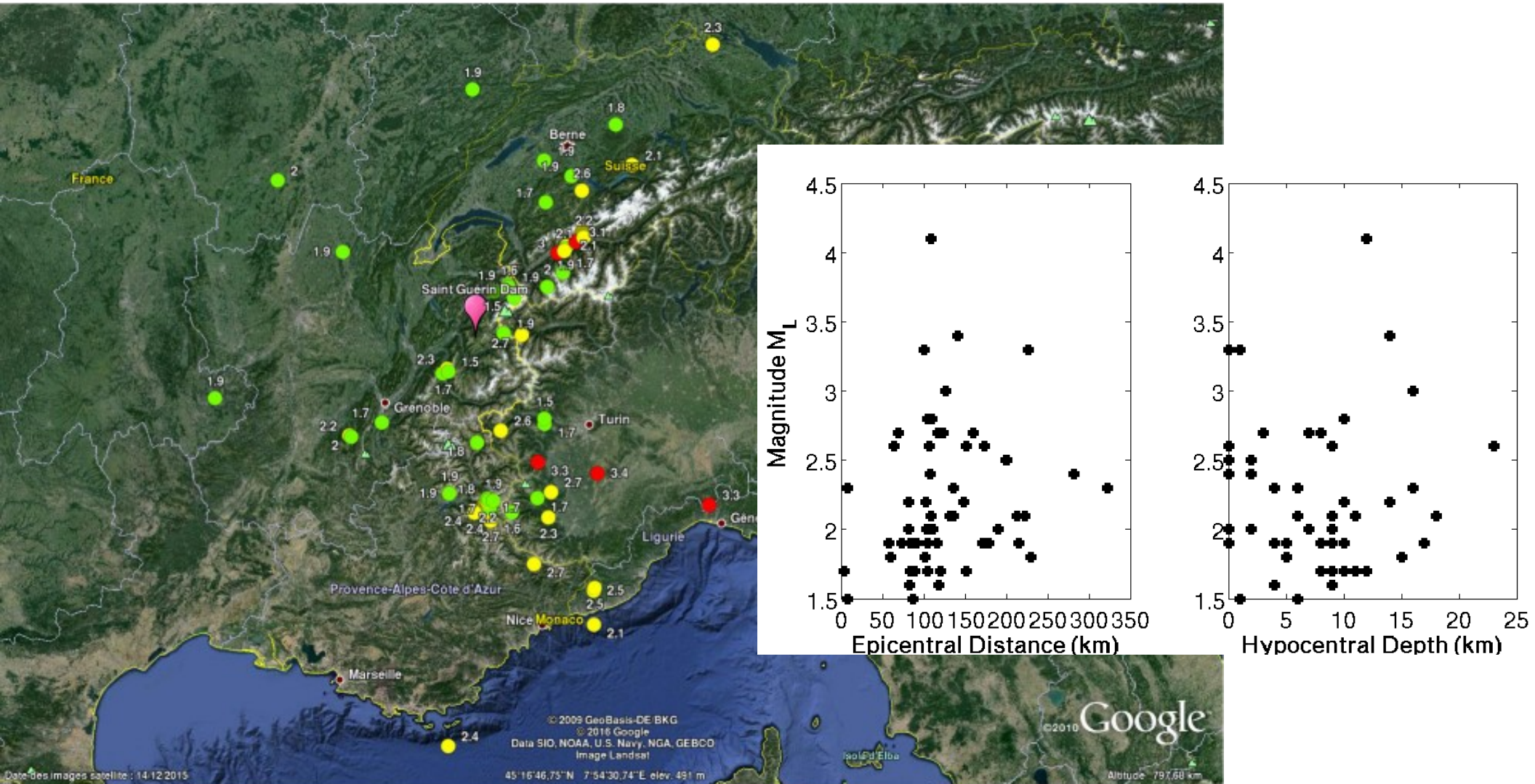
## **Conclusions - Perspectives**



# Subset of events : 58 (6 months)

$M_L > 1.5$  et  $D < 350$  km

Signal/Noise  $> 3$  in [1 20] Hz



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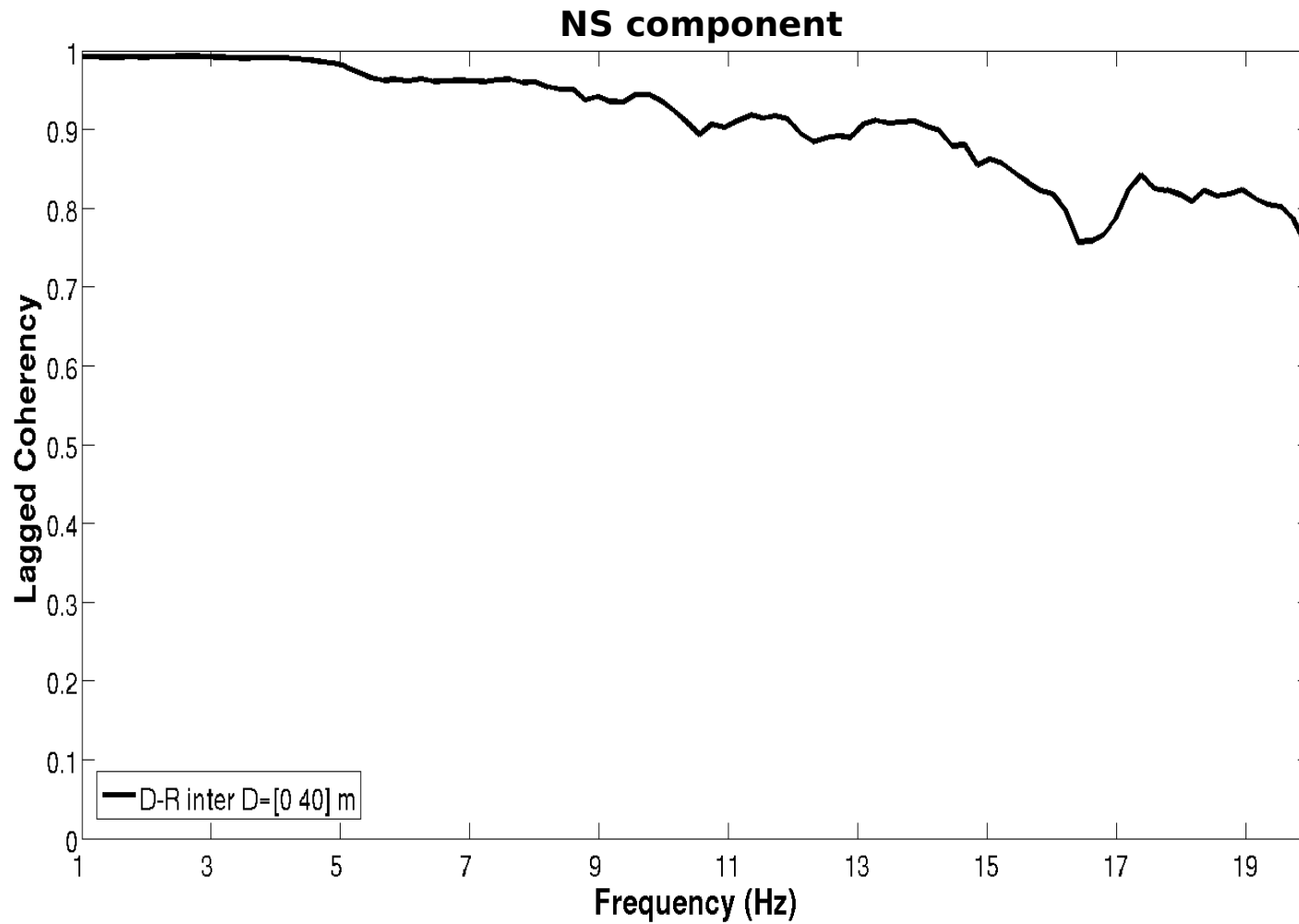
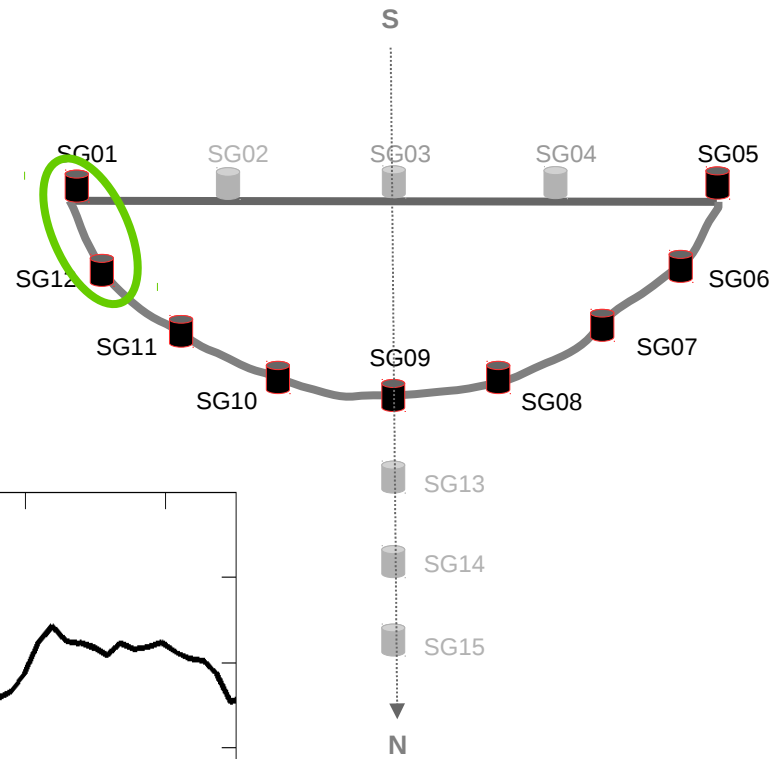
Phase variability

Amplitude variability

## **Conclusions - Perspectives**

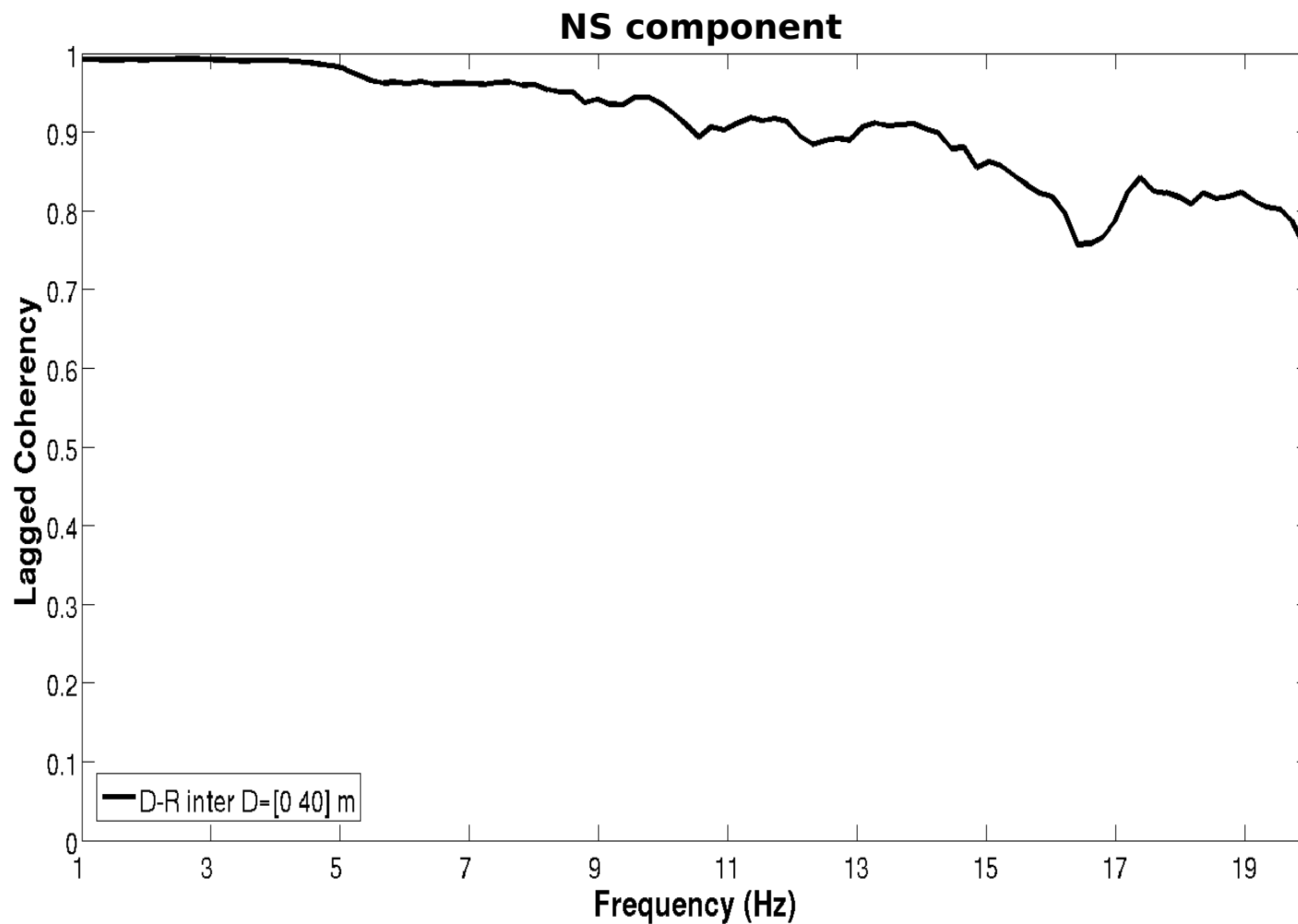
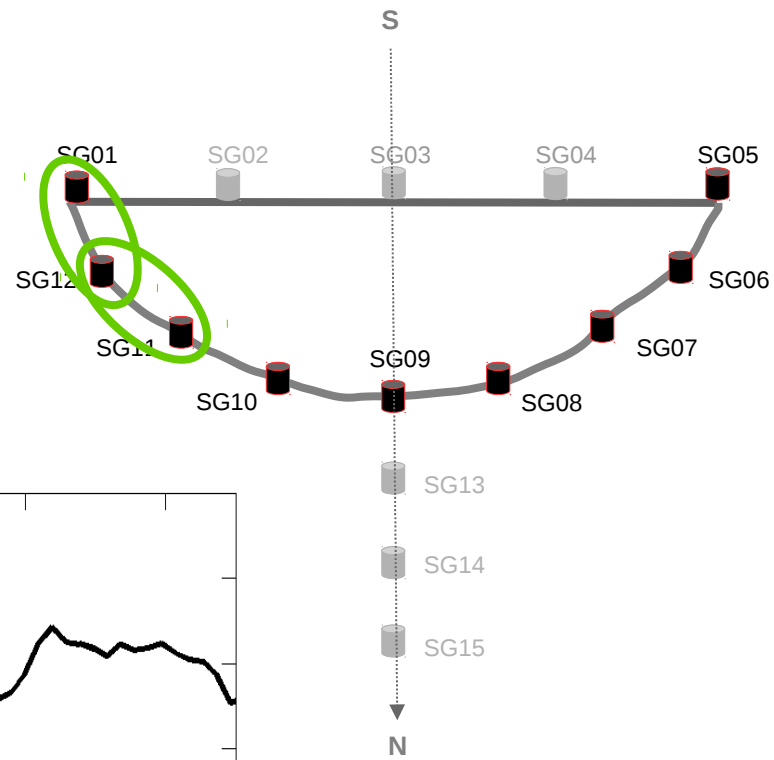
# Phase Variability

## Lagged Coherency



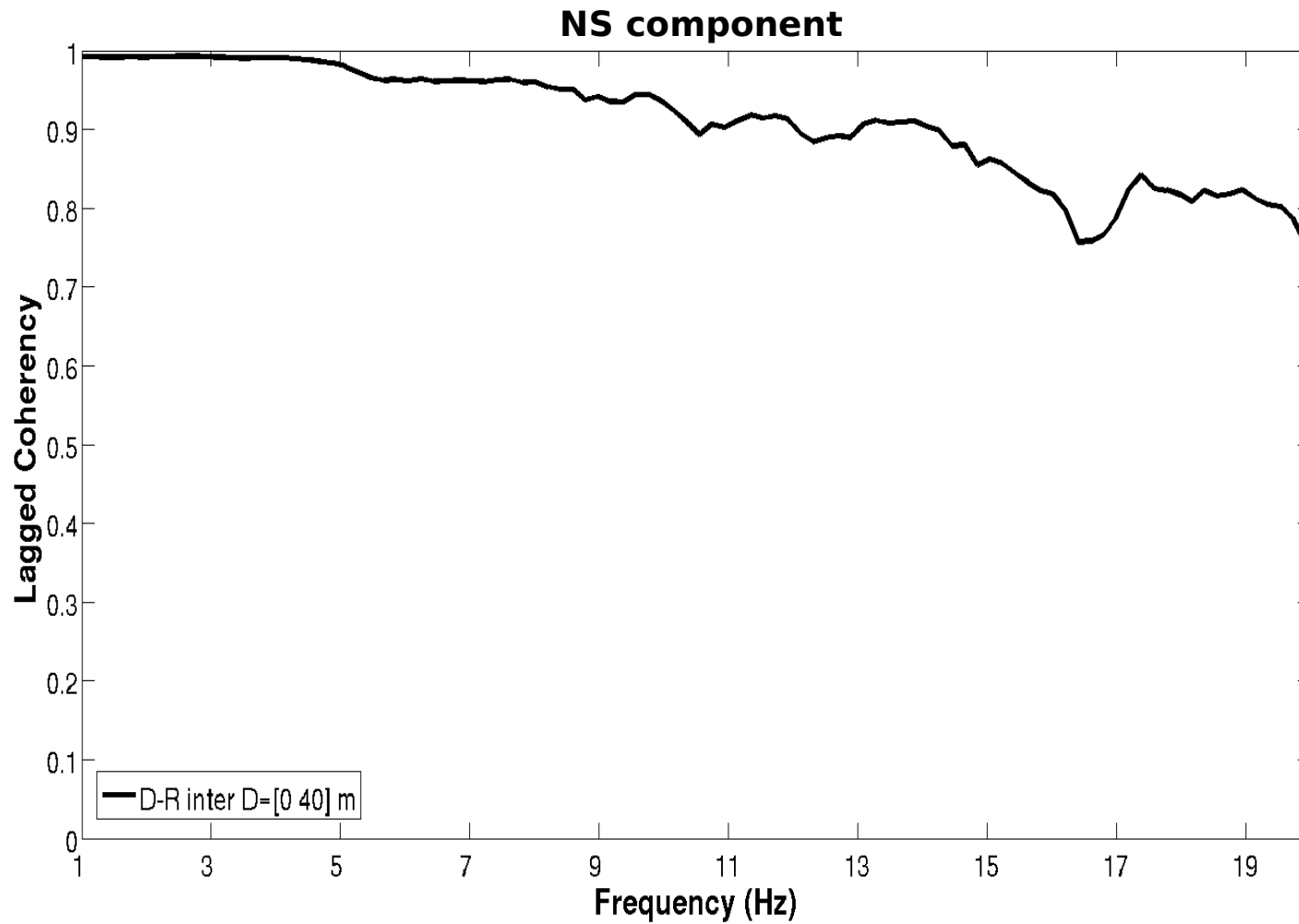
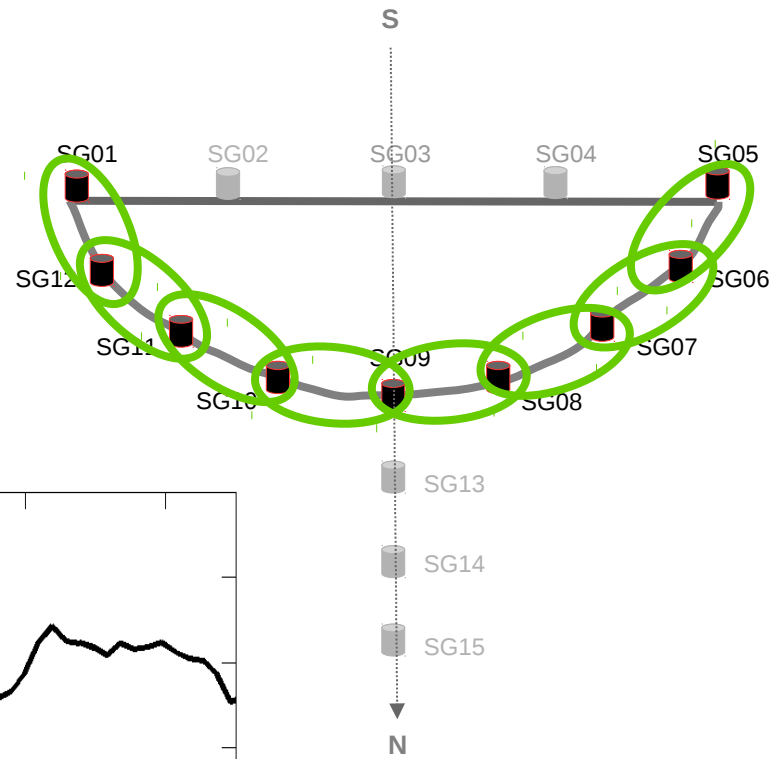
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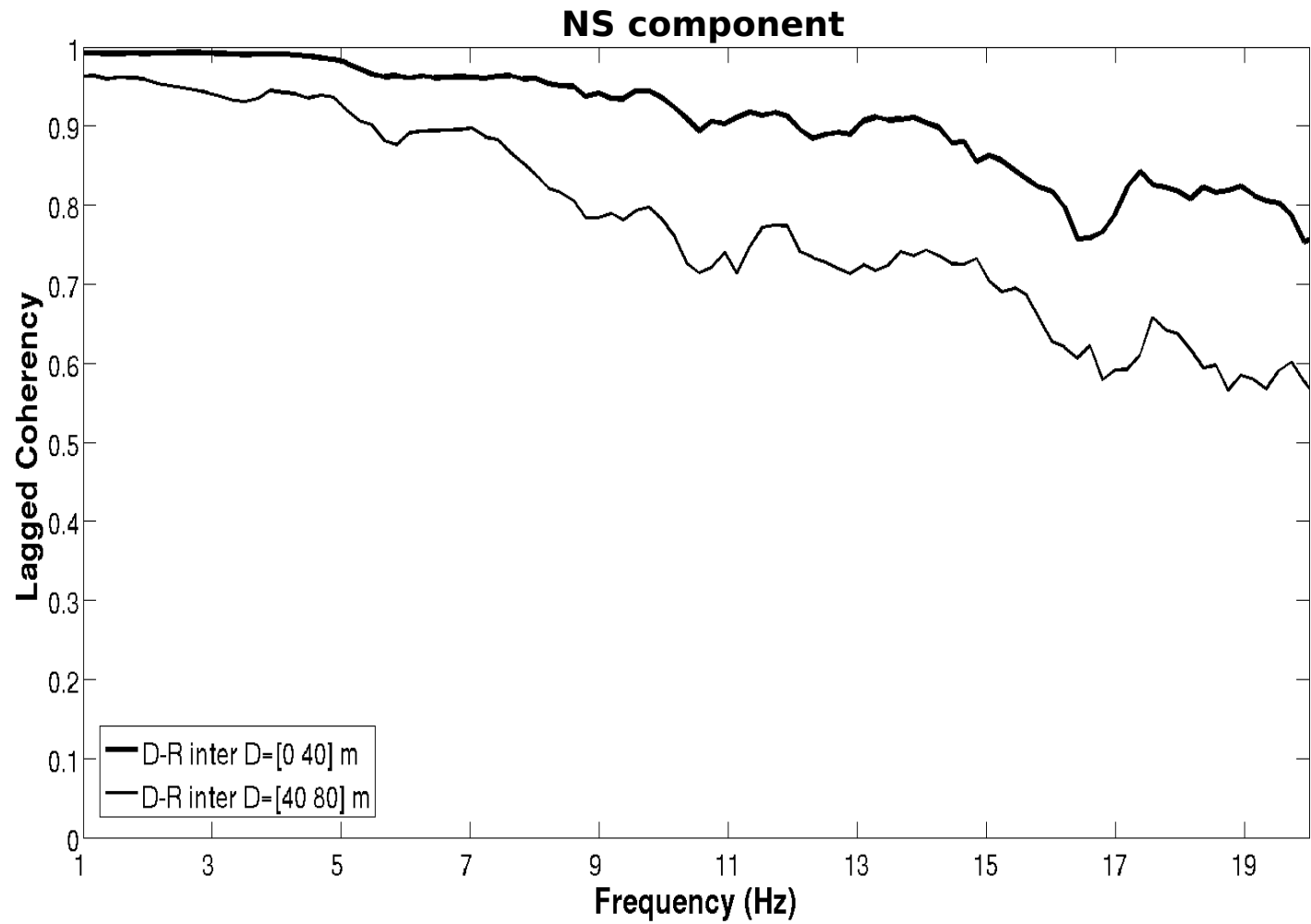
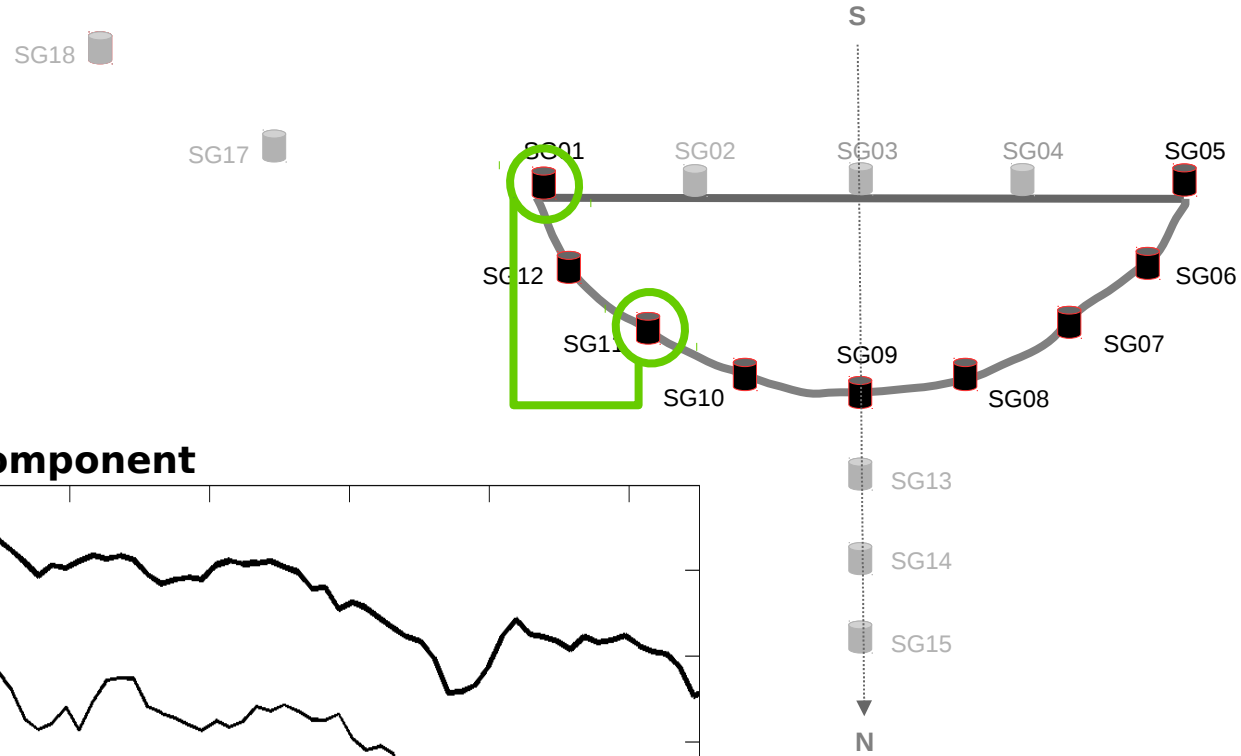
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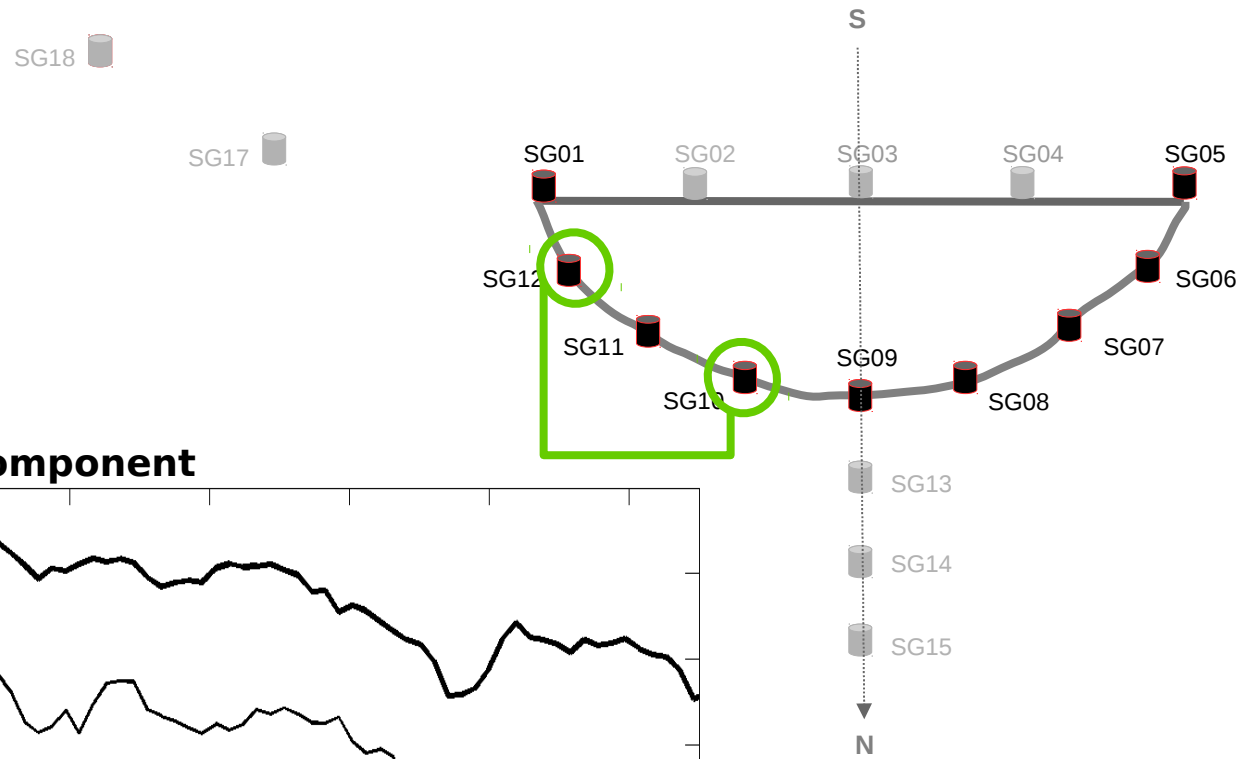
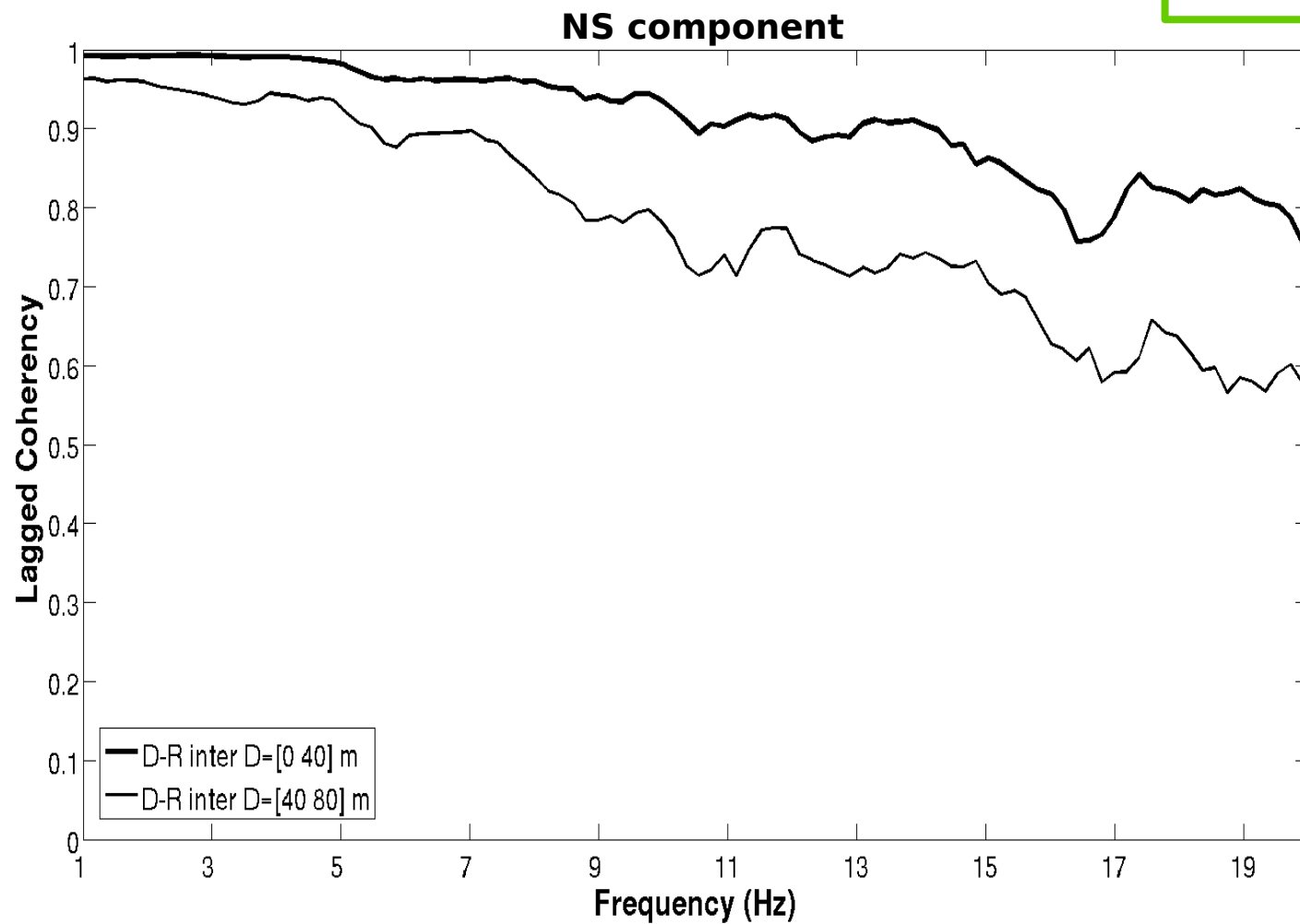
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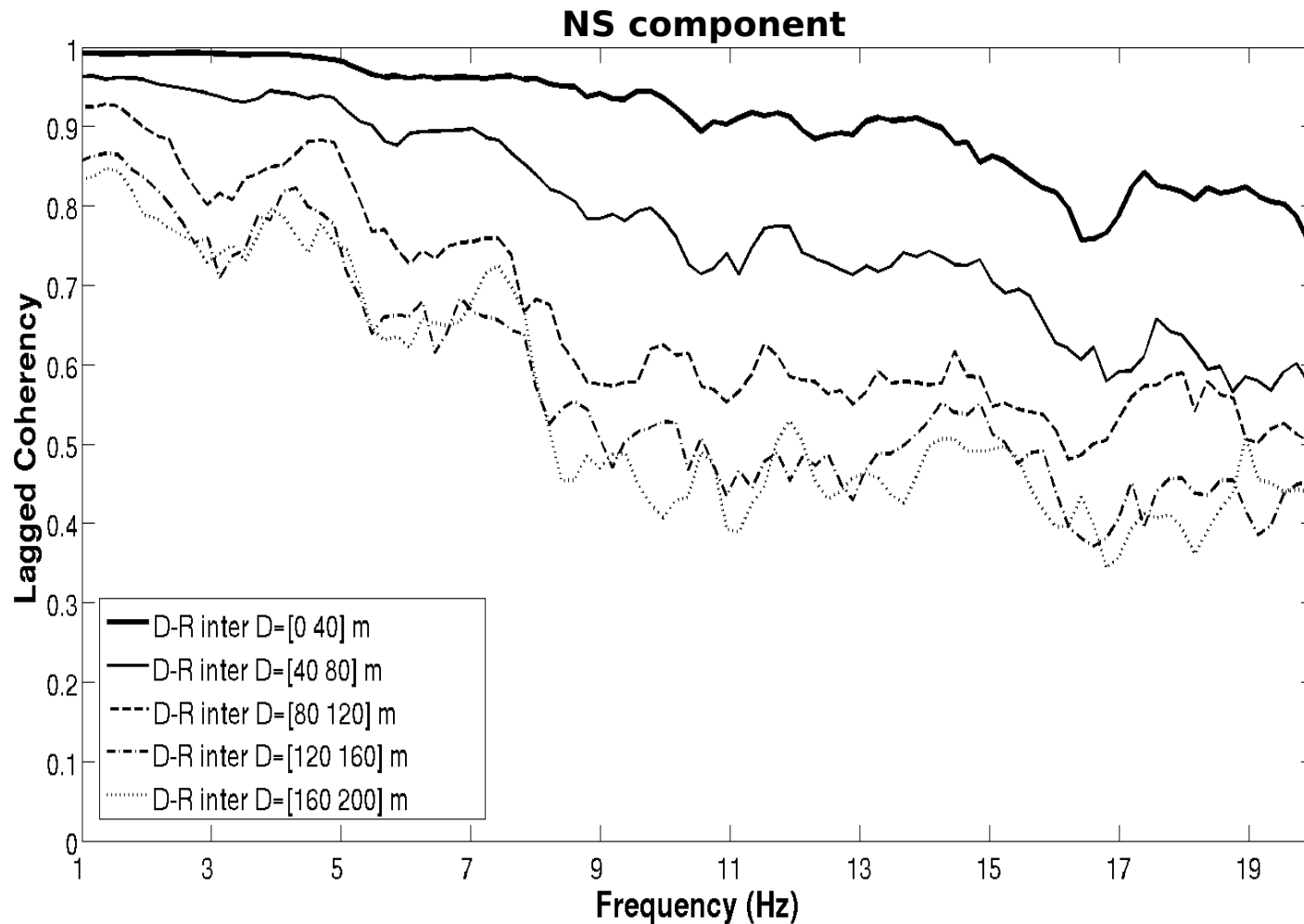
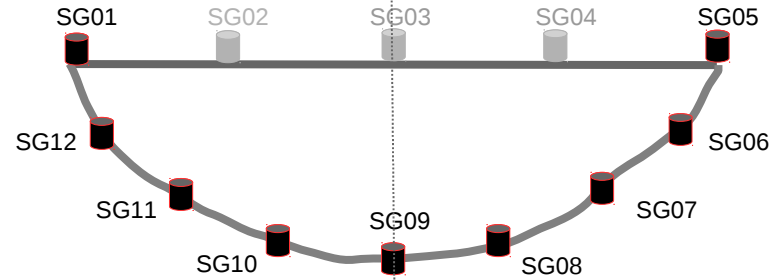


# Phase Variability

## Lagged Coherency

SG18

SG17



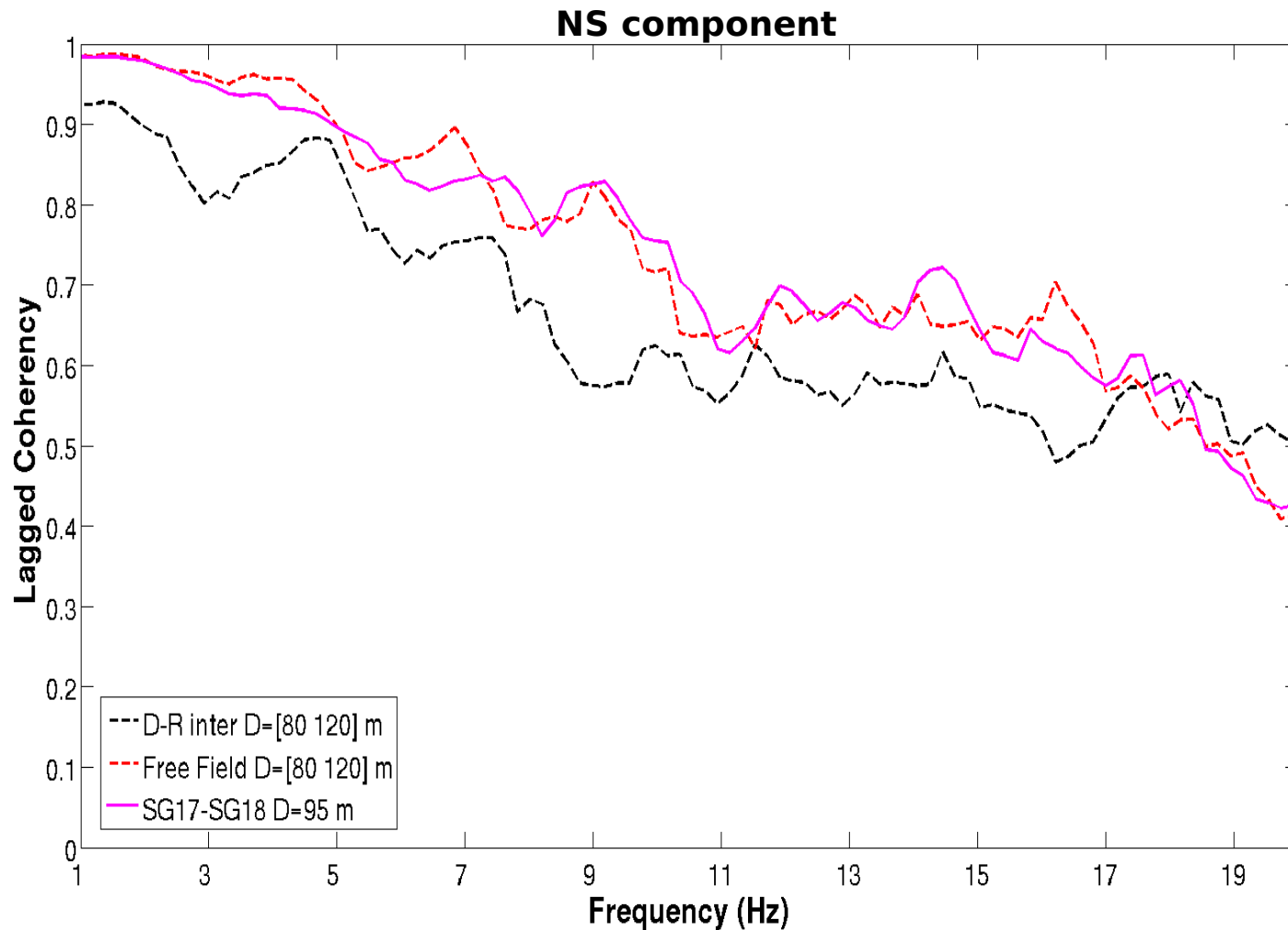
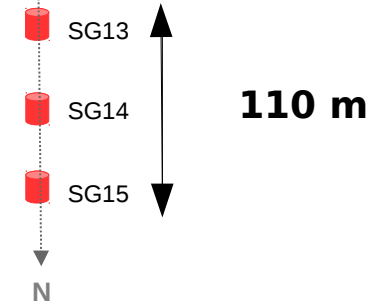
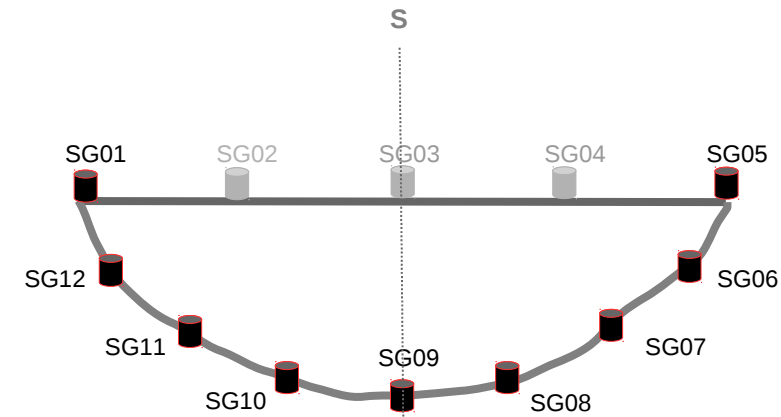
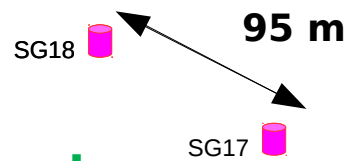
No dependency on source parameters :

- magnitude
- distance
- azimuth

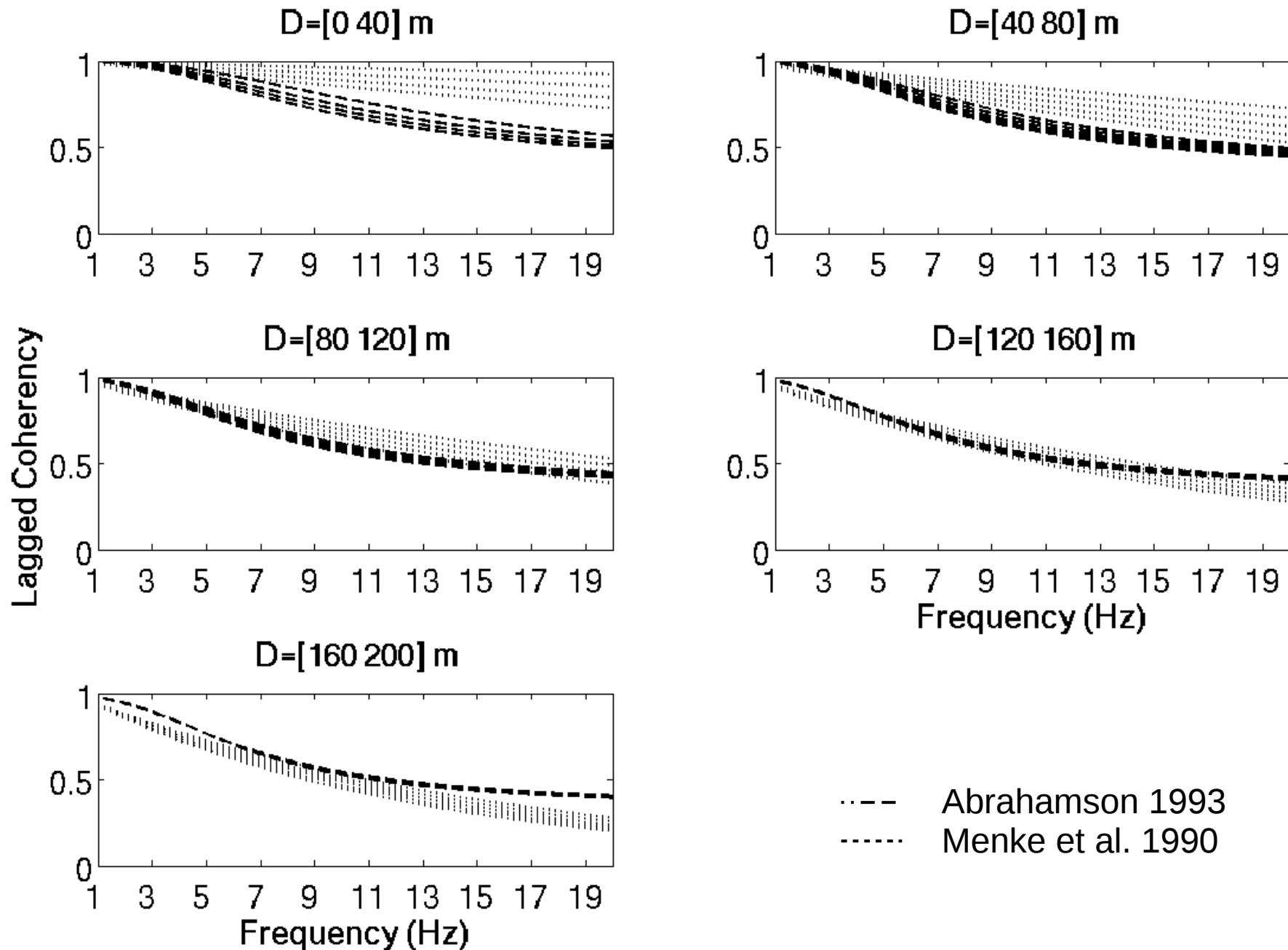


# Phase Variability

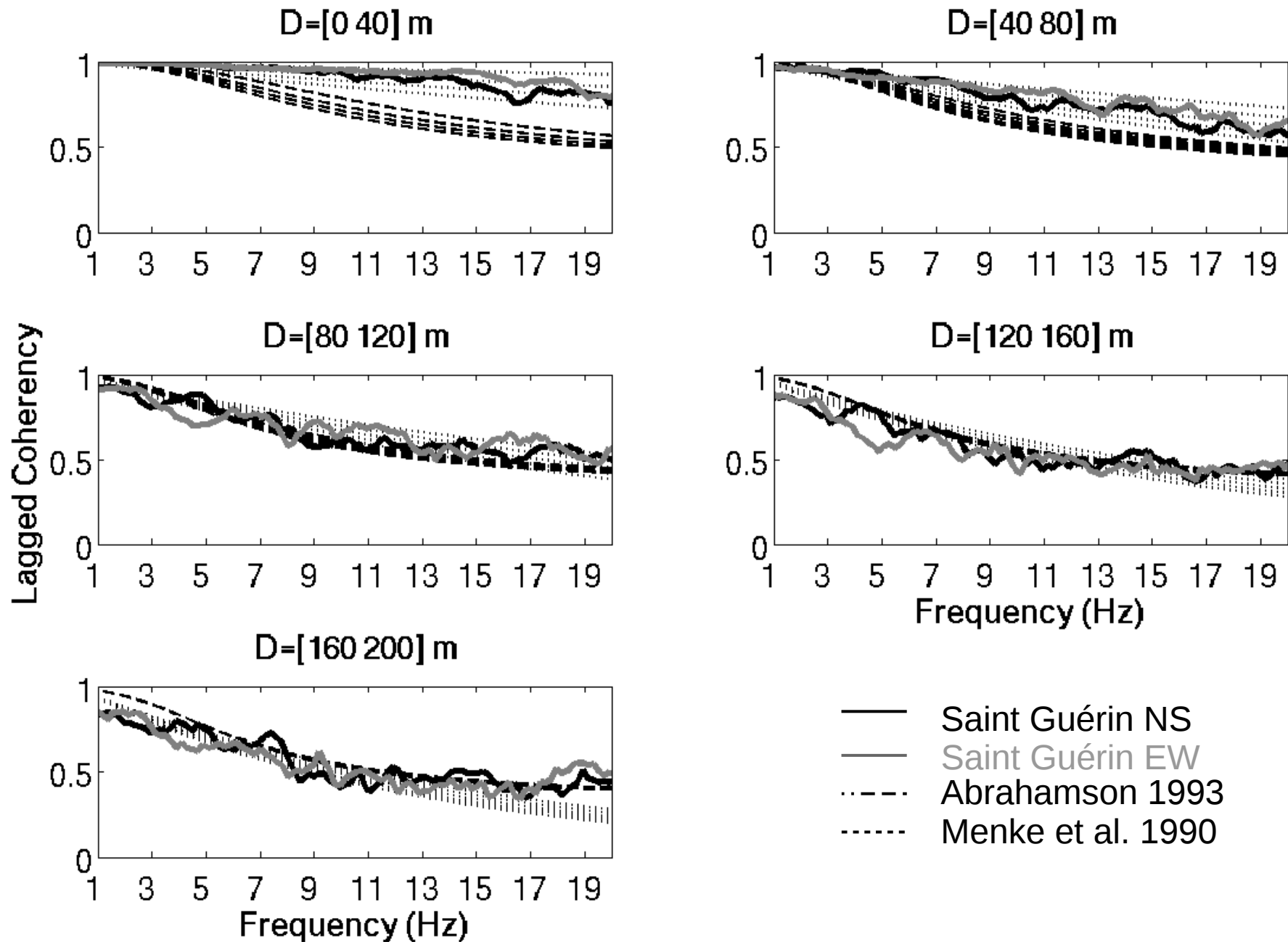
## Comparison with Free Field coherency



# Comparison with existing coherency models



# Comparison with existing coherency models



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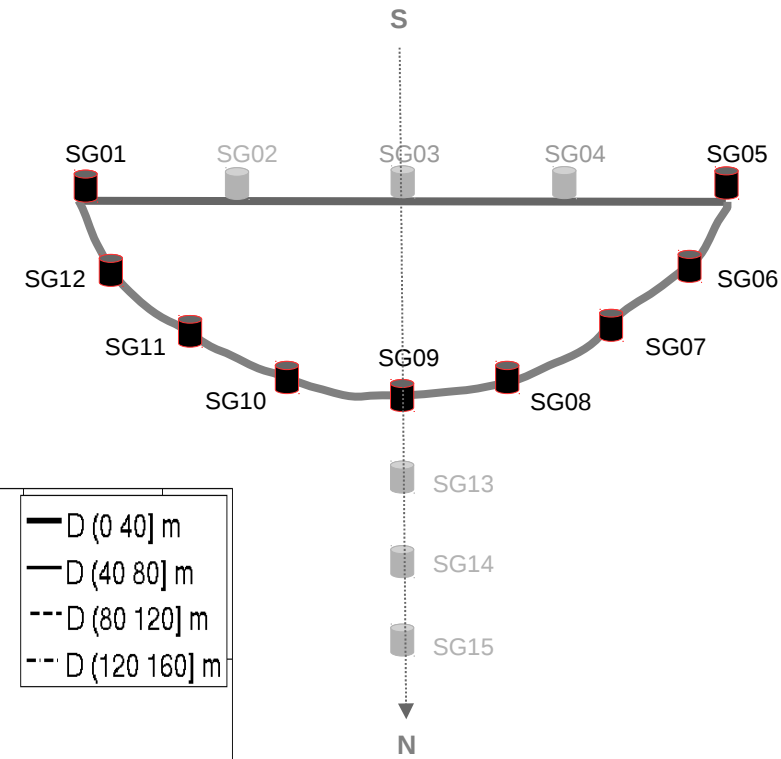
Phase variability

Amplitude variability

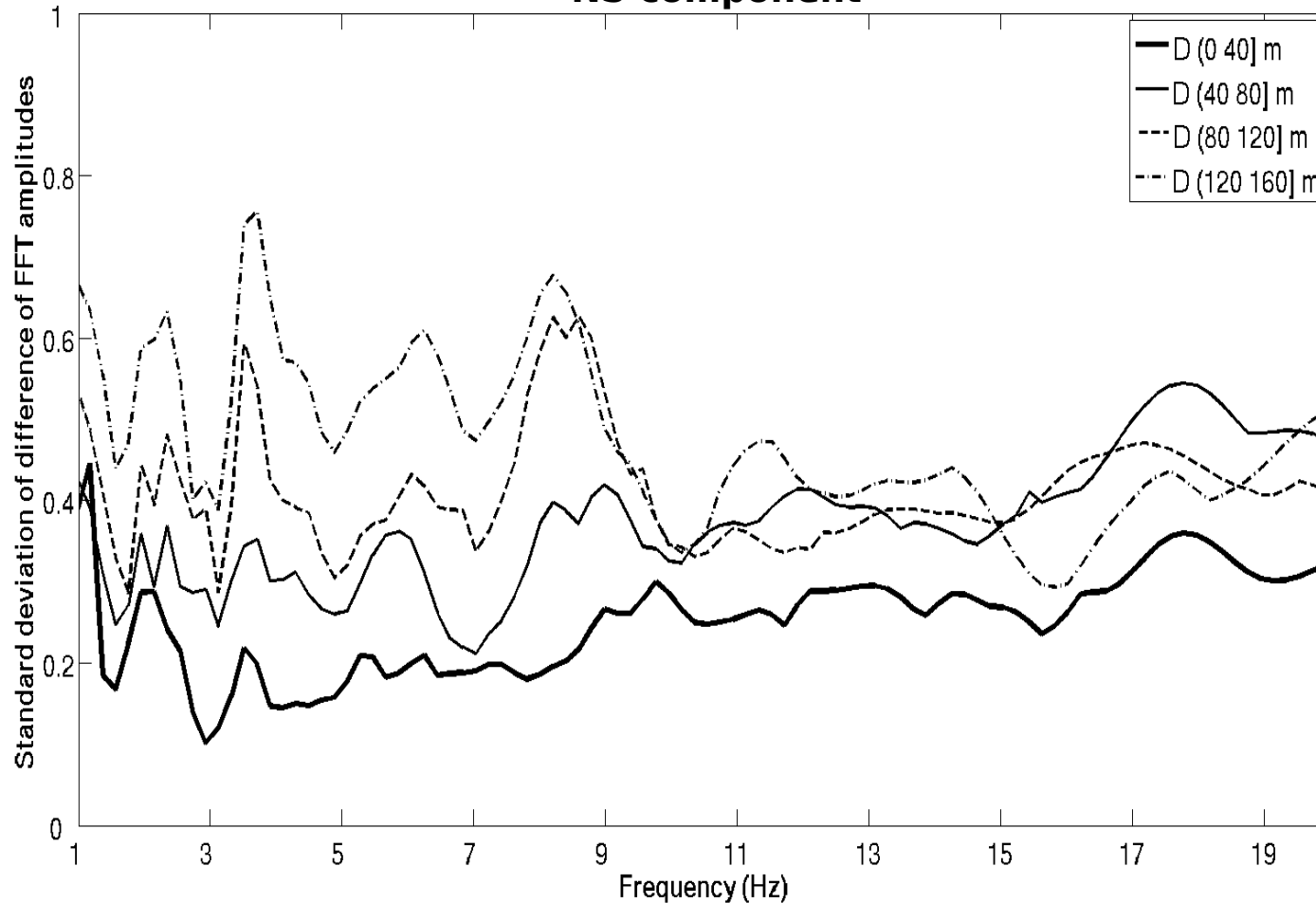
## **Conclusions - Perspectives**

# Amplitude Variability

Standard deviation of difference of log FFT amplitudes



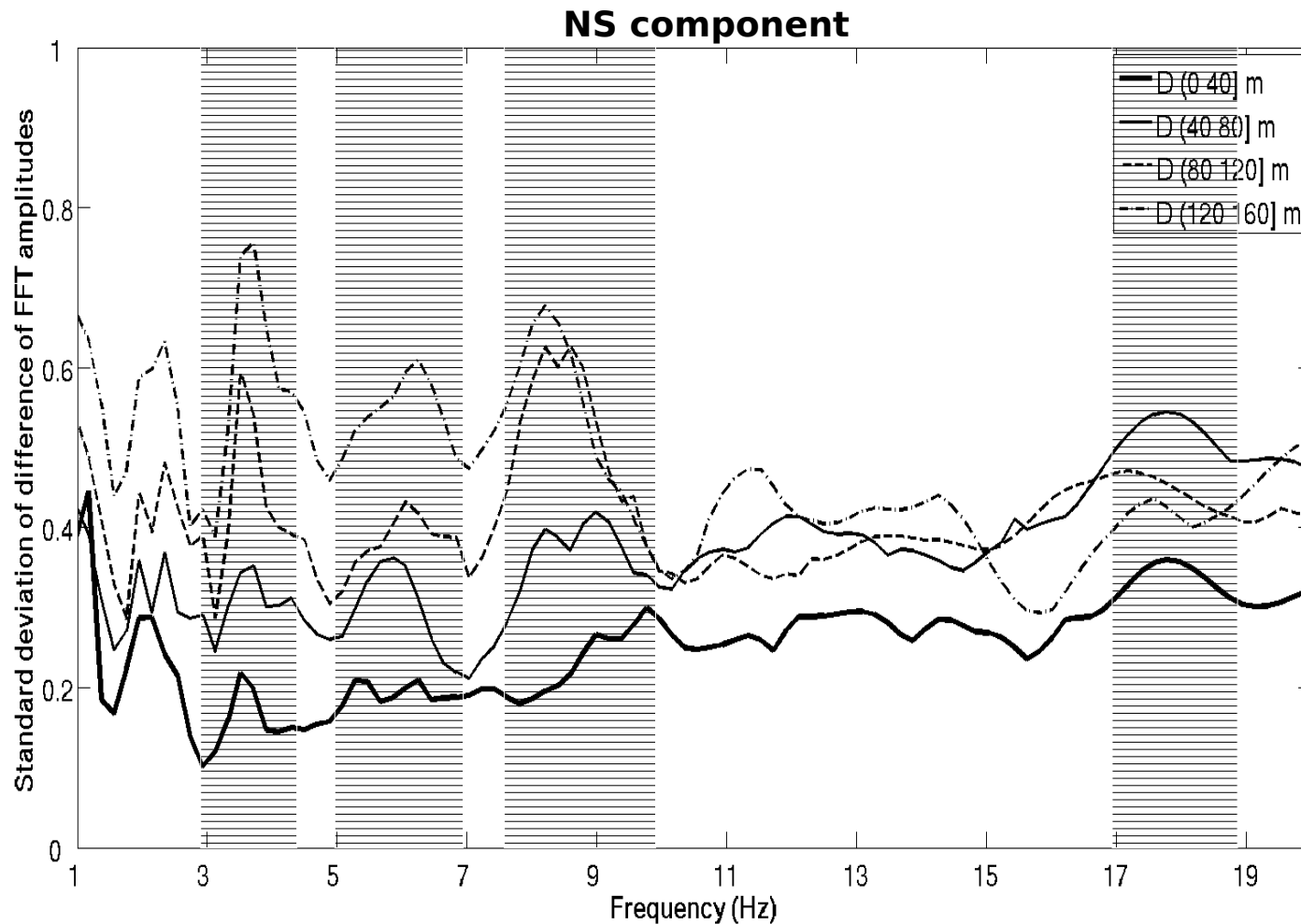
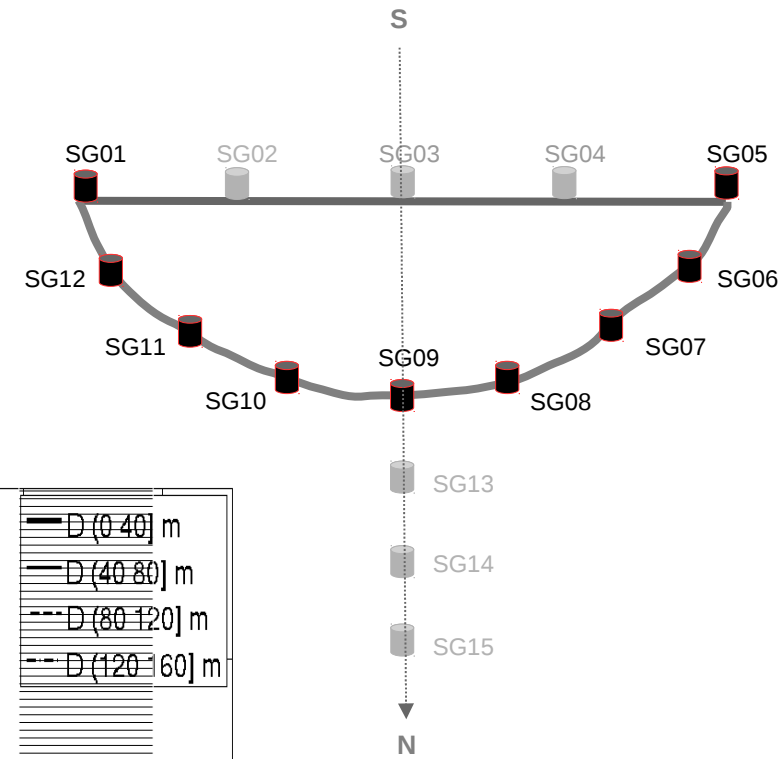
NS component



No dependency on source parameters :  
- magnitude  
- distance  
- azimuth

# Amplitude Variability

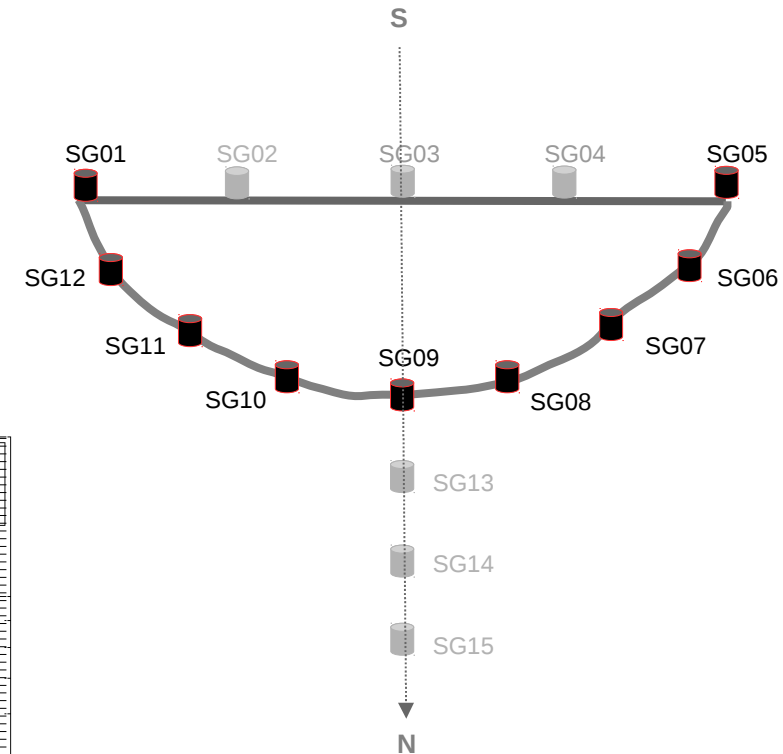
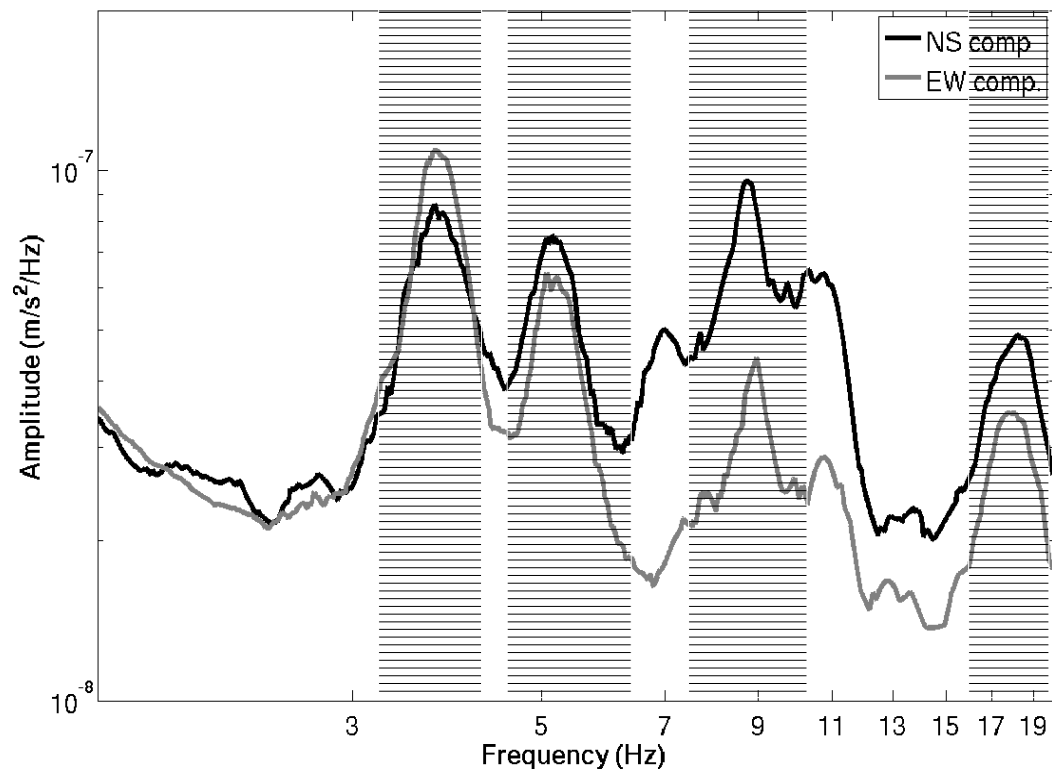
Standard deviation of difference of log FFT amplitudes



No dependency on source parameters :  
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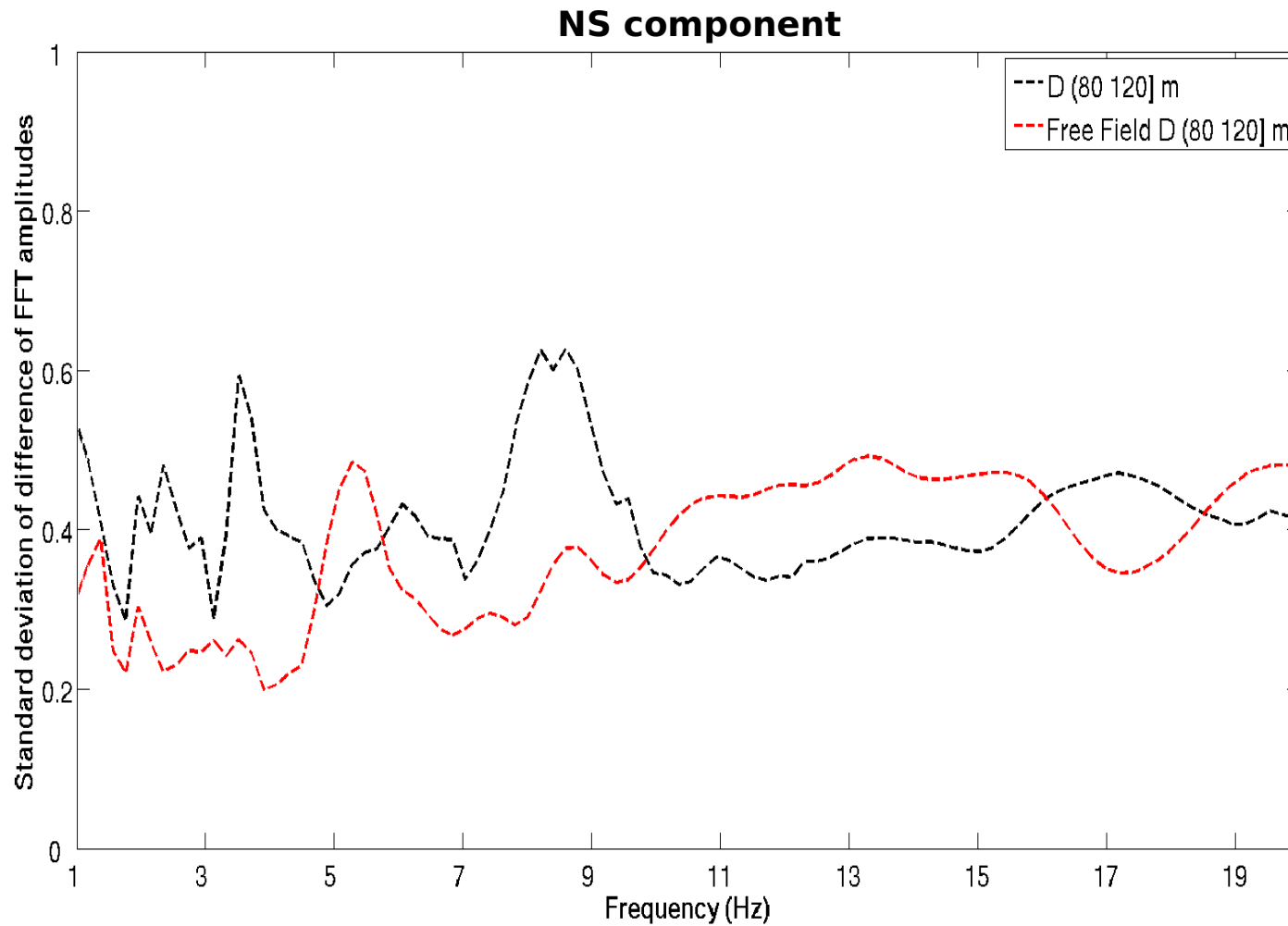
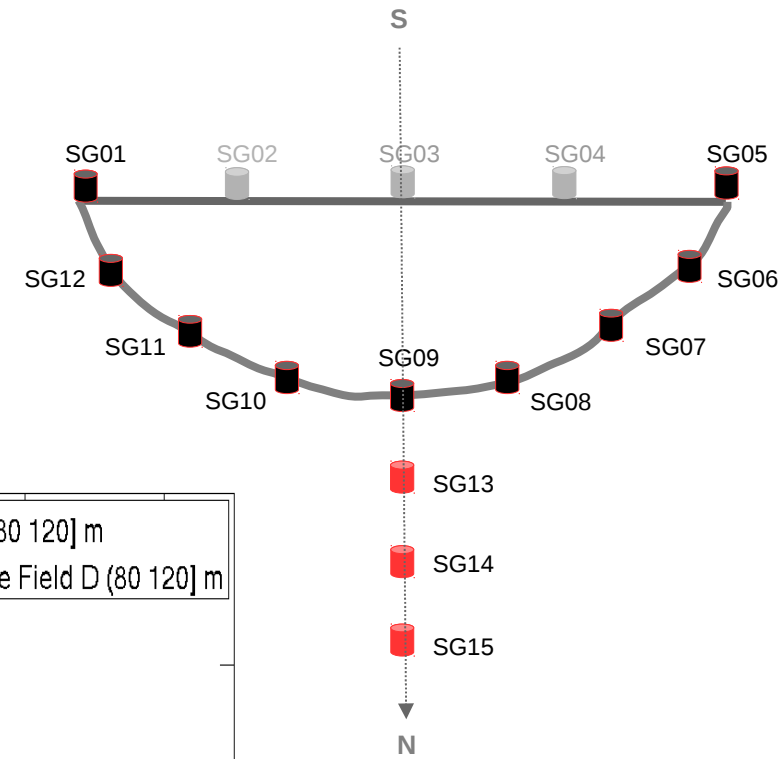
# Frequencies of vibration of the dam

(20 minute-long ambient noise records 2 hours before the seismic events)



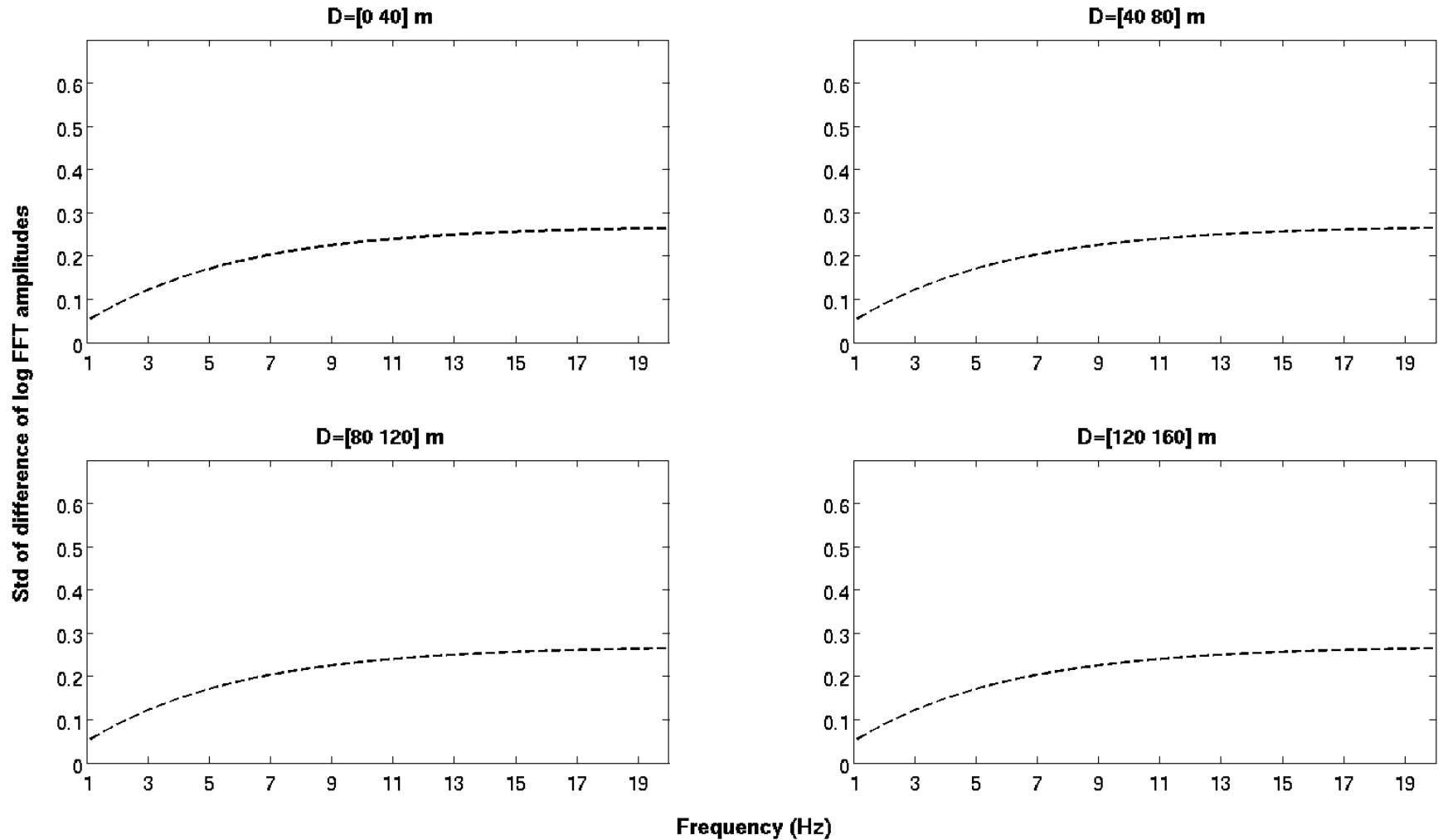
# Amplitude Variability

## Comparison with Free Field amplitude variability



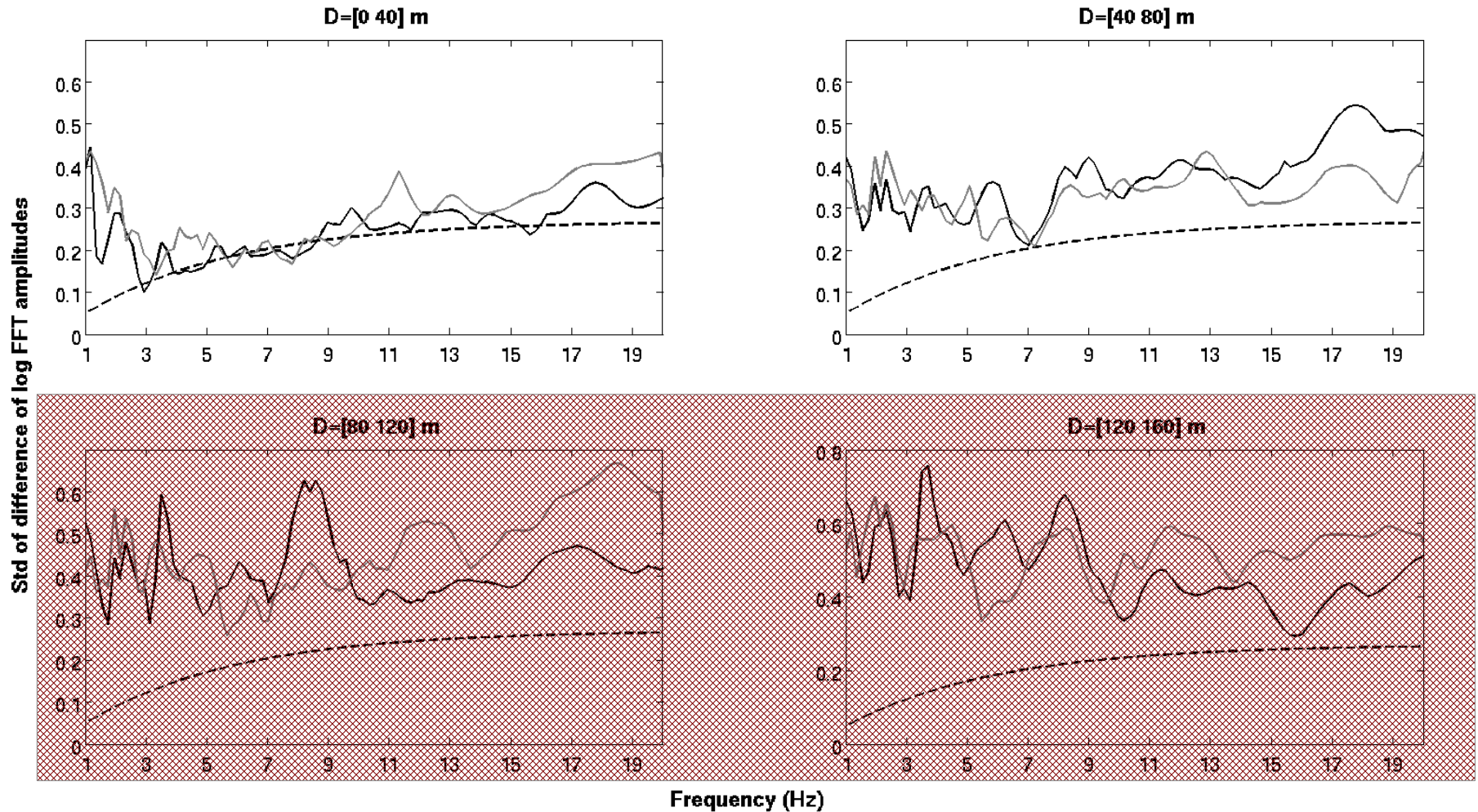


# Comparison with existing amplitude variability model



— — — Schneider et al. 1992

# Comparison with existing amplitude variability model



- Saint Guérin NS
- Saint Guérin EW
- - - Schneider et al. 1992

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## **Spatial variability analysis**

Frequencies of vibration of the dam

Phase variability

Amplitude variability

## **Conclusions - Perspectives**

# Conclusions - Perspectives

- Seismological Instrumentation of the Saint Guérin site (arch dam and surrounding area)
- Creation of a seismological catalog

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- Seismological Instrumentation of the Saint Guérin site (arch dam and surrounding area)
- Creation of a seismological catalog
- Quantification of spatial variability of the ground motion
  - Phase and amplitude variability increases with increasing frequency and station separation distance
  - Higher phase and amplitude variability on the dam-foundation rock interface with respect to the free field (Topography + Presence of the structure)?
  - Higher amplitude variability around the vibration frequencies of the structure (Presence of the structure)?

# Conclusions - Perspectives

- Seismological Instrumentation of the Saint Guérin site (arch dam and surrounding area)
- Creation of a seismological catalog
- Quantification of spatial variability of the ground motion
  - Phase and amplitude variability increases with increasing frequency and station separation distance.
  - Higher phase and amplitude variability on the dam-foundation rock interface with respect to the free field (Topography + Presence of the structure)?
  - Higher amplitude variability around the vibration frequencies of the structure (Presence of the structure)?
- Satisfactory fit of empirical coherency models of Menke et al. 1990 (and Abrahamson 1993 for longer separation distances) with the observations on the dam-foundation rock interface
- Satisfactory fit of amplitude variability model of Schnieder et al. 1992 with the observations on the dam-foundation rock interface only for short separation distances

THANK YOU FOR  
YOUR  
ATTENTION



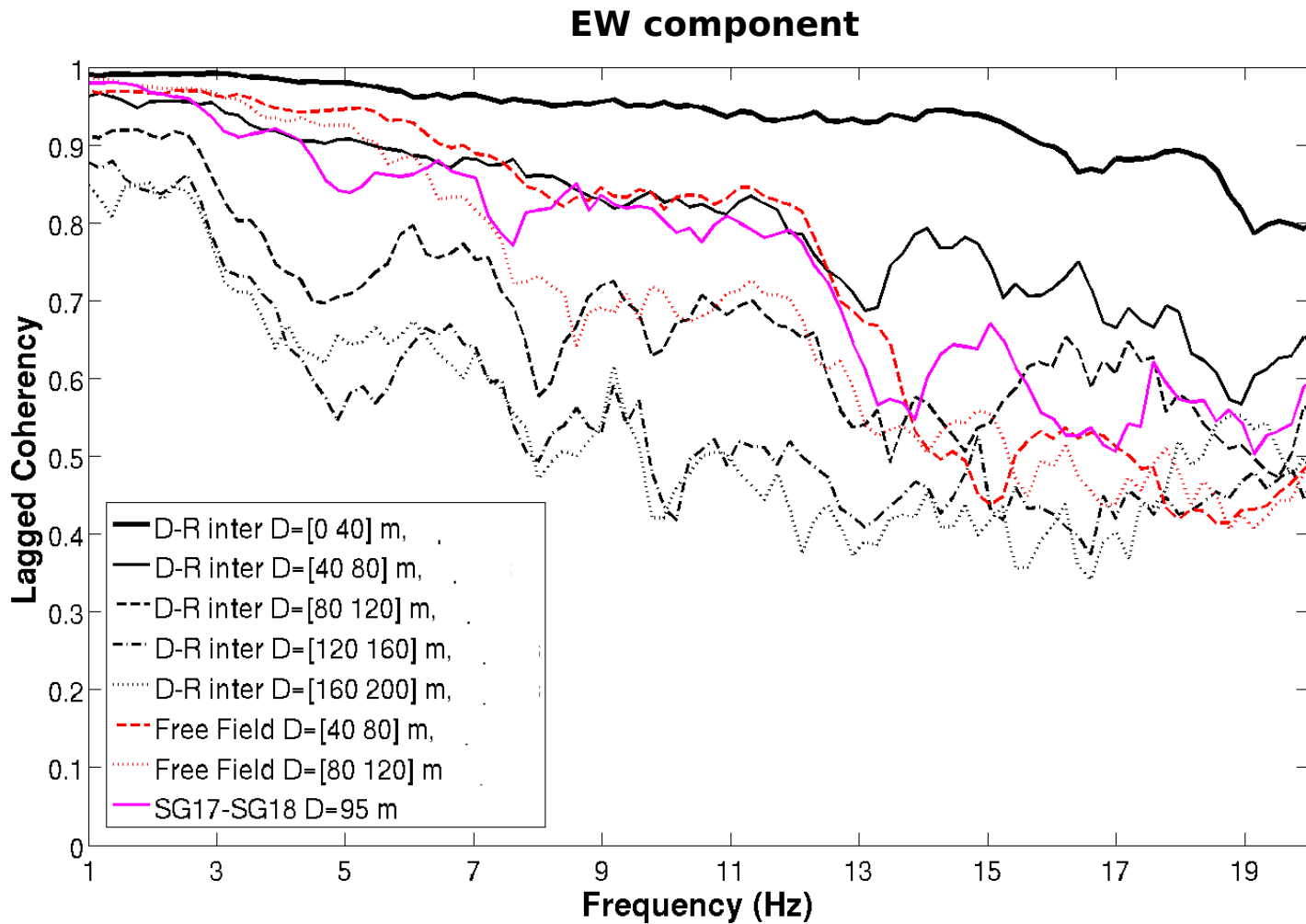
# Availability of Records

Period	Availability of Records																			
	SG01	SG02	SG03	SG04	SG05	SG06	SG07	SG08	SG09	SG10	SG11	SG12	SG13	SG14	SG15	SG17	SG18	SG19	SG20	
18/06/15-01/07/15	Red	Green	Green	Green	Green	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red
01/07/15-21/07/15	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
21/07/15-28/08/15	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green
28/08/15-25/09/15	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
25/09/15-20/10/15	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
20/10/15-03/12/15	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
03/12/15-16/12/15	Green	Green	Red	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Red	Green	Green	Green	Green	Green	Green	Green
16/12/15-05/01/16	Green	Green	Green	Red	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Green	Green	Green	Green	Green	Red	Green	Green
05/01/16-12/01/16	Green	Green	Green	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Green	Green	Green	Grey	Green	Red	Red	Red
12/01/16-21/01/16	Green	Green	Green	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Green	Green	Green	Grey	Green	Green	Green	Red
21/01/16-09/02/16	Green	Green	Green	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Green	Green	Green	Grey	Green	Green	Green	Green
09/02/16-08/03/16	Green	Green	Green	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Green	Green	Green	Grey	Green	Green	Green	Green
08/03/16-08/04/16	Green	Green	Green	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Green	Green	Green	Grey	Green	Green	Green	Green
08/04/16-13/05/16	Green	Green	Green	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Green	Green	Green	Grey	Green	Green	Green	Red
13/05/16-30/06/16	Green	Green	Green	Green	Green	Grey	Grey	Green	Grey	Grey	Grey	Green	Red	Green	Green	Grey	Green	Green	Green	Red



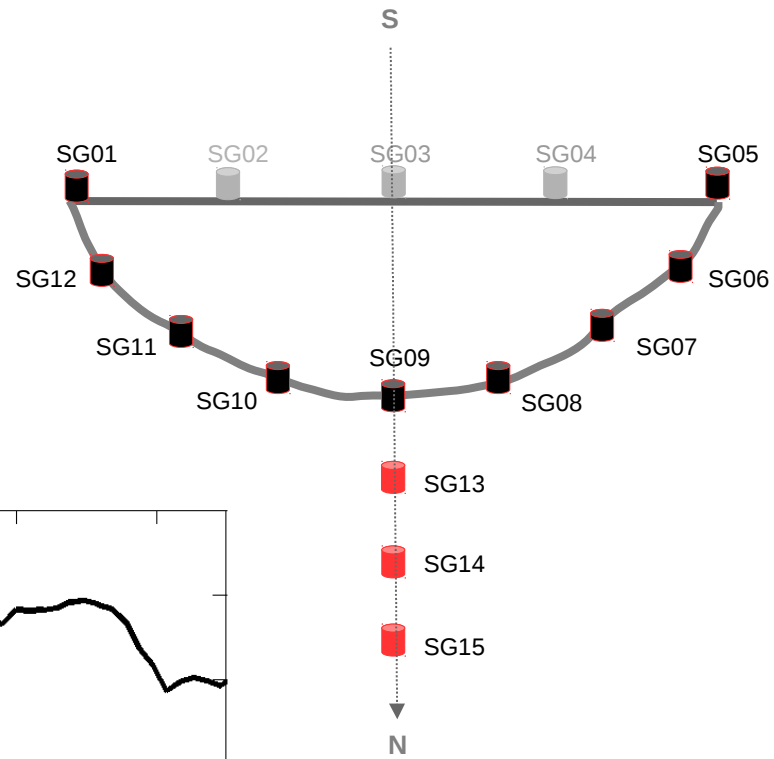
# Phase Variability

## Lagged Coherency



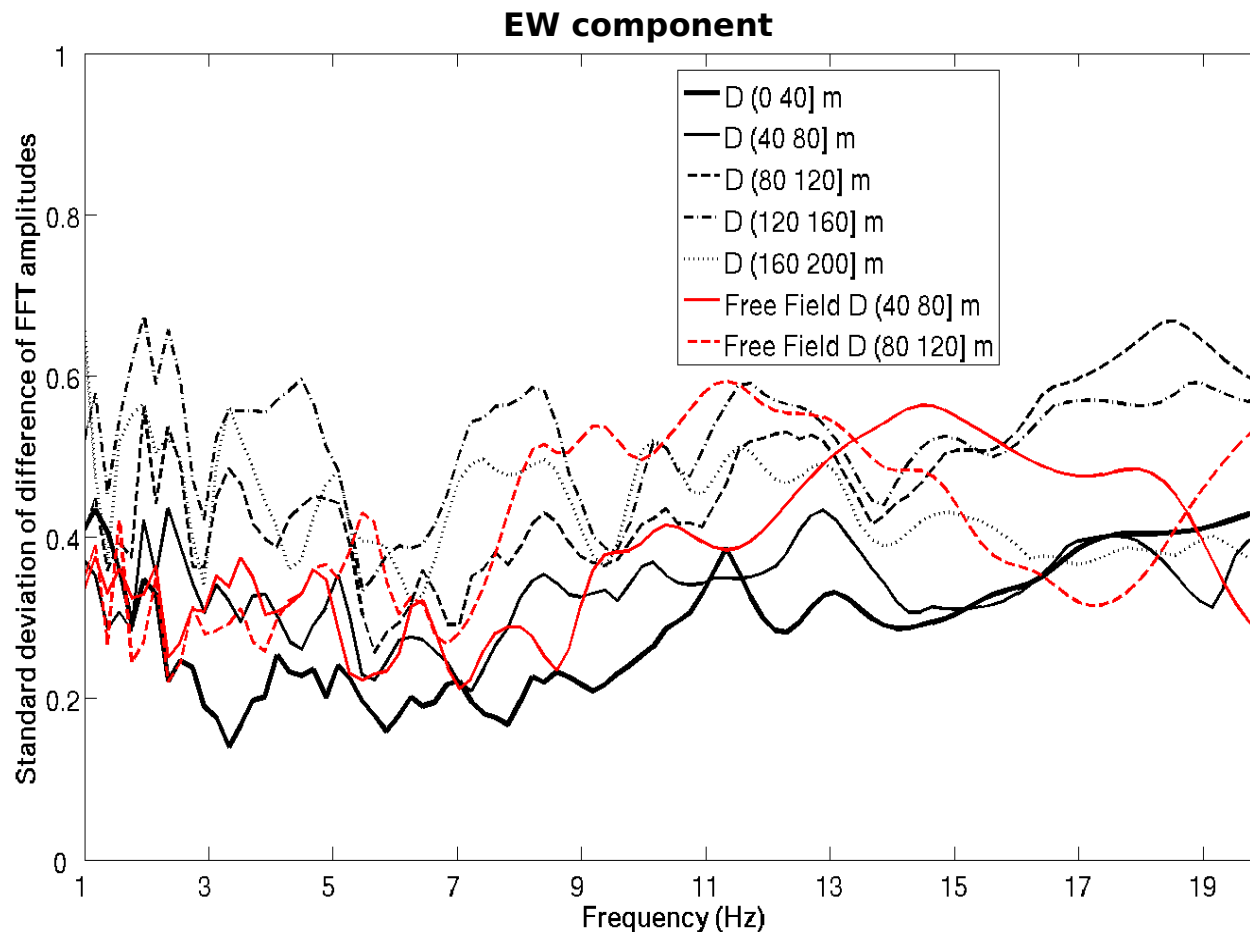
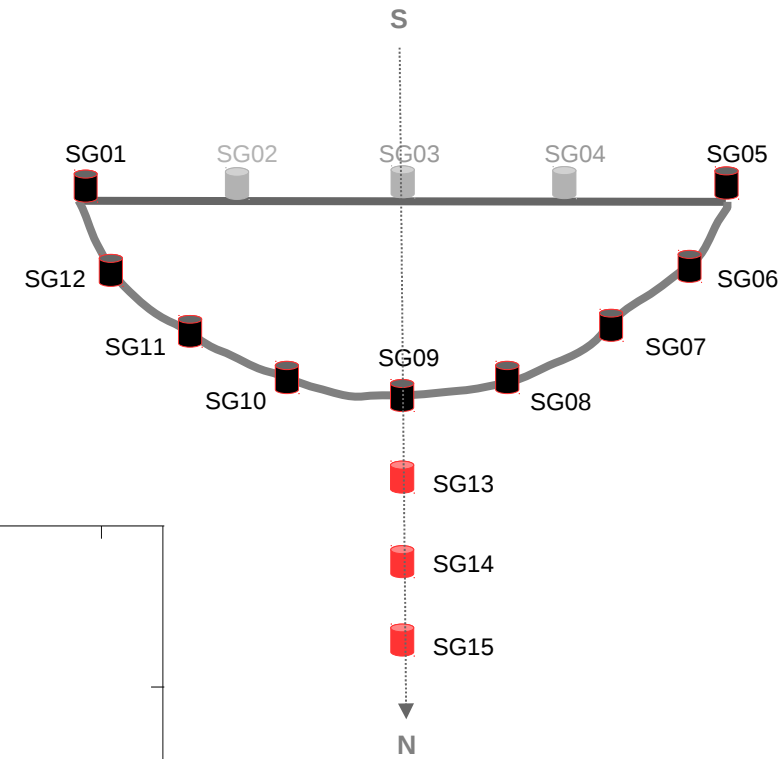
SG18

SG17



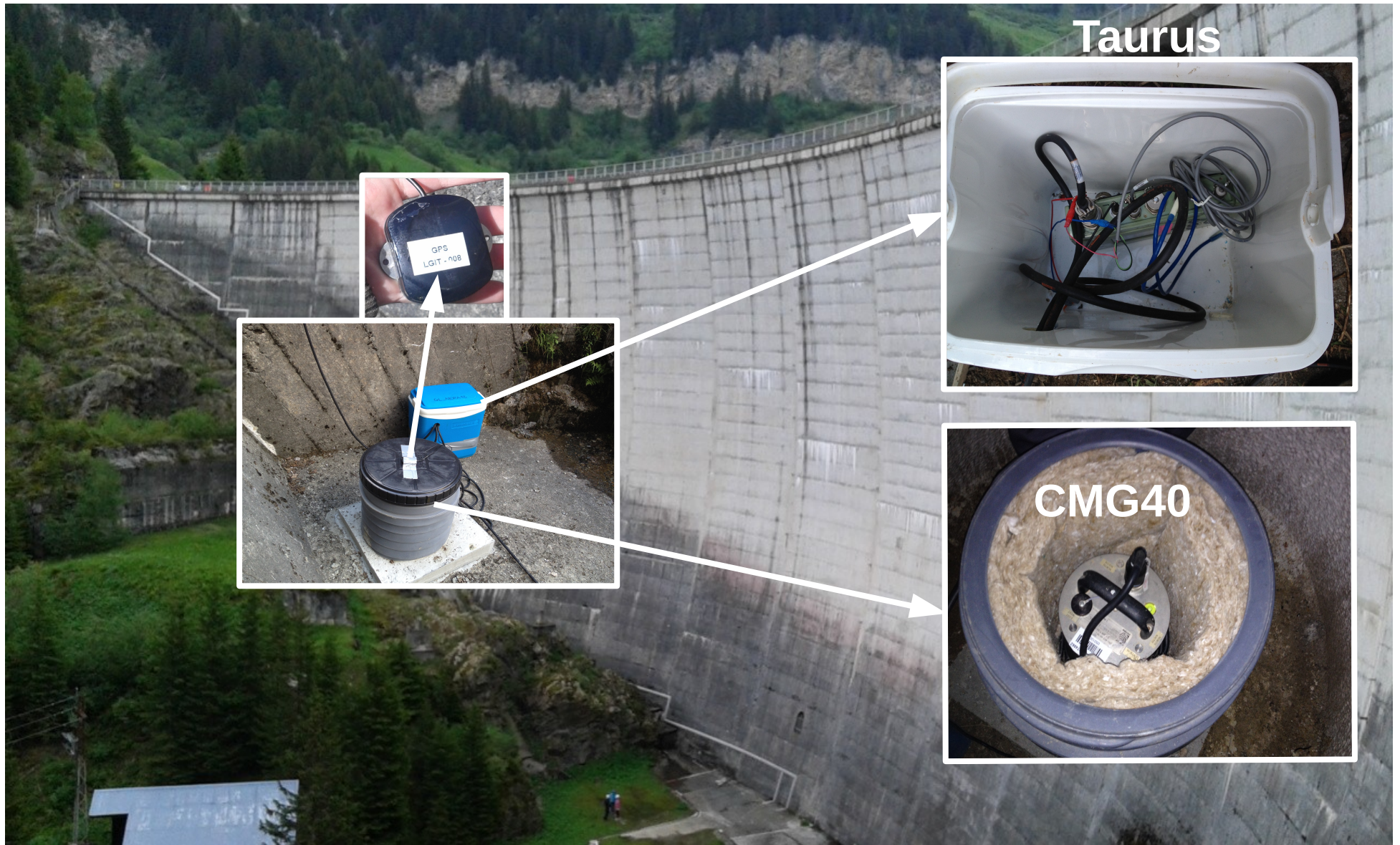
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Standard deviation of difference of log FFT amplitudes



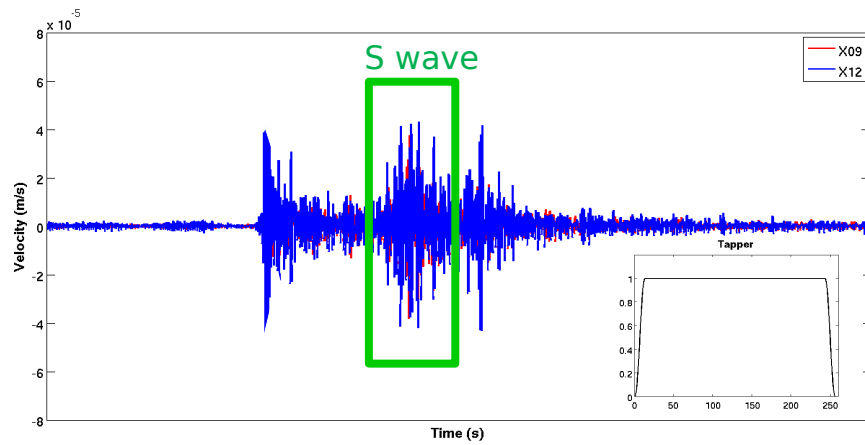
No dependency on source parameters :  
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# Configuration of the seismological array



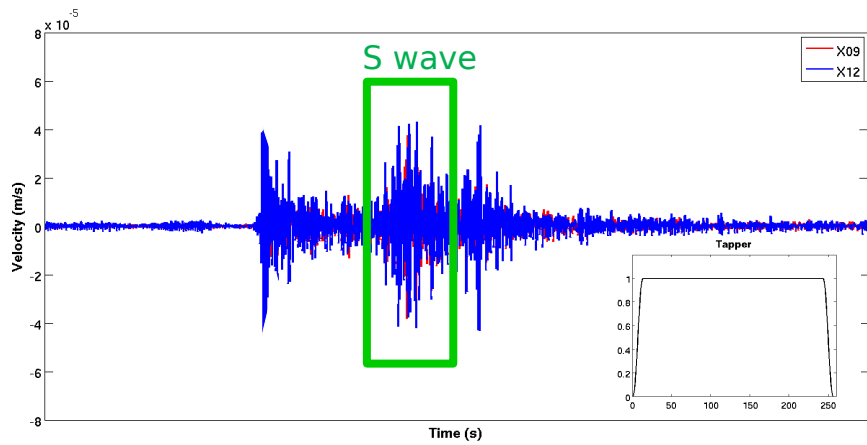
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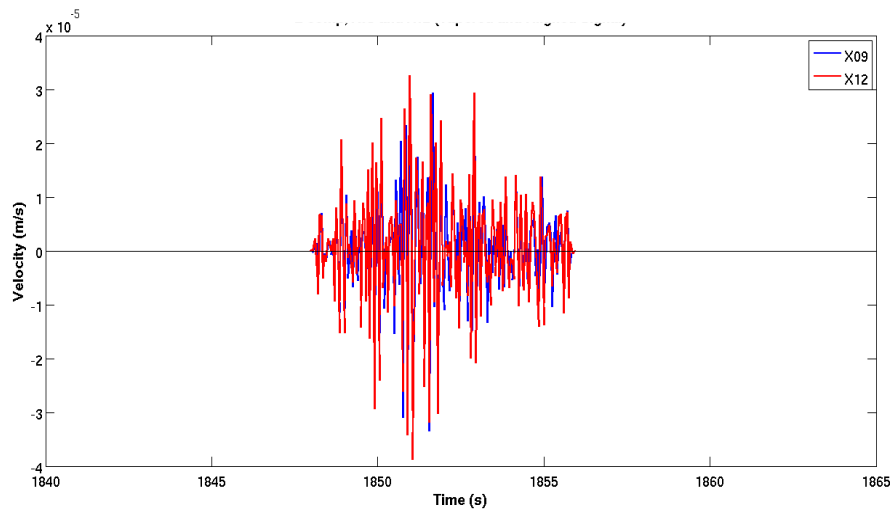


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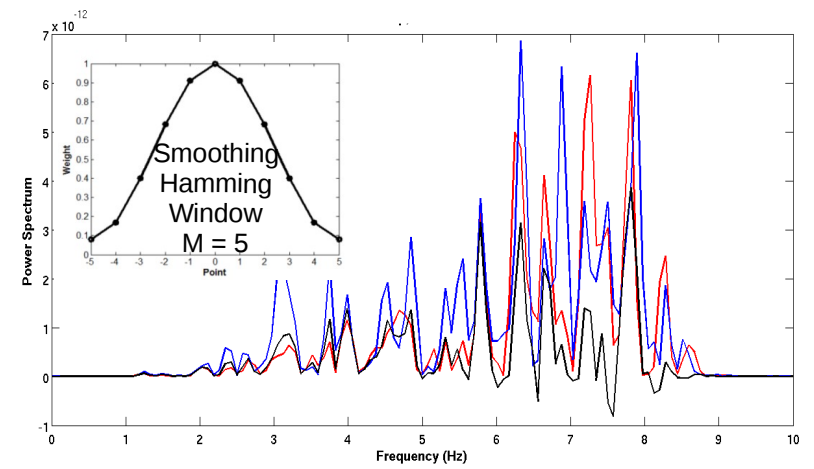
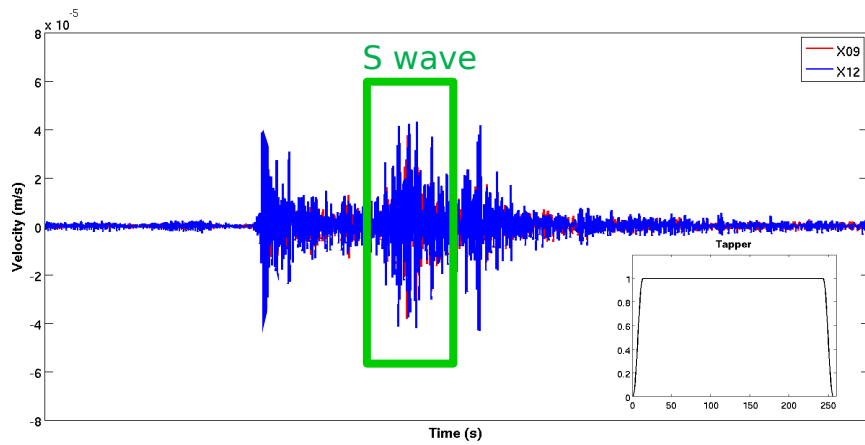


Arias Intensity (after Abrahamson, 2007):  
S wave window

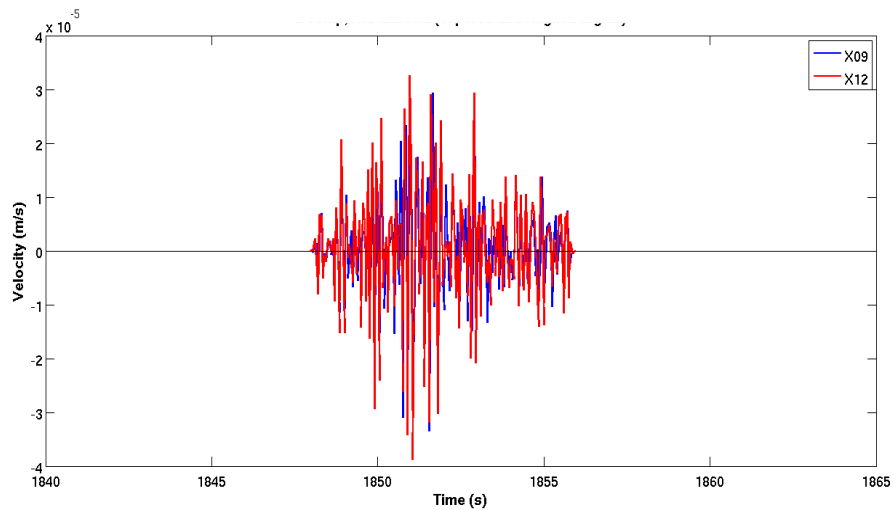


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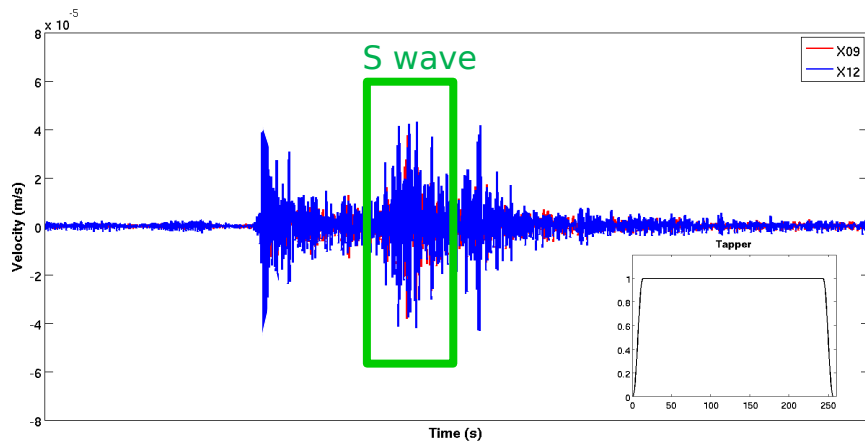


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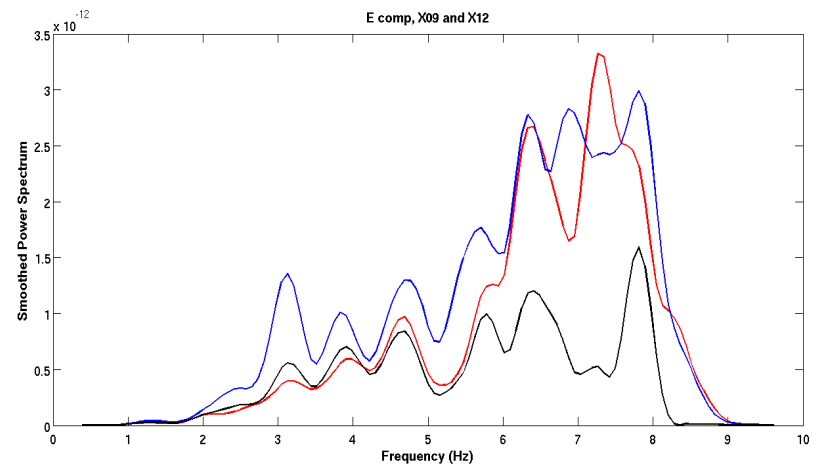
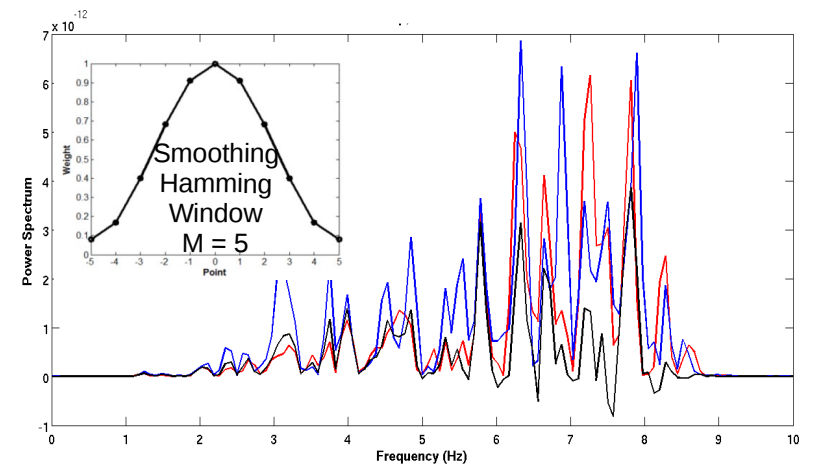
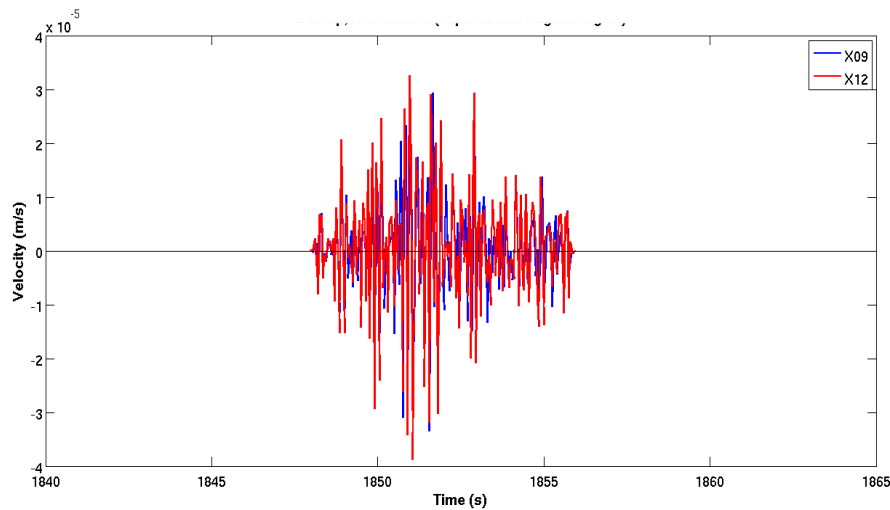


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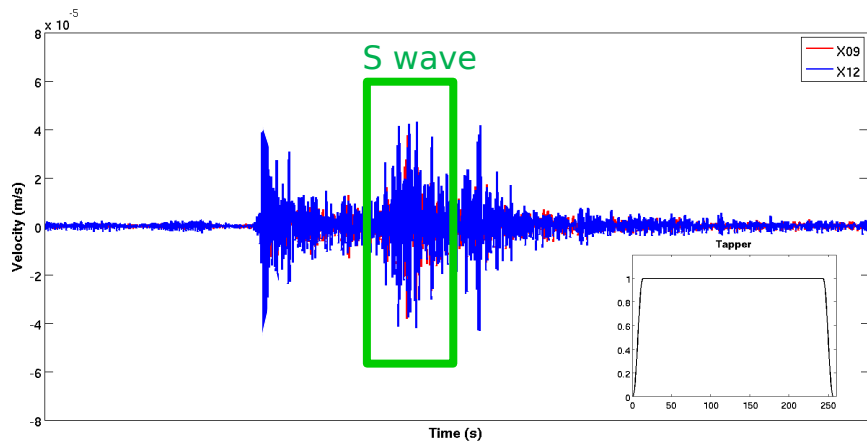


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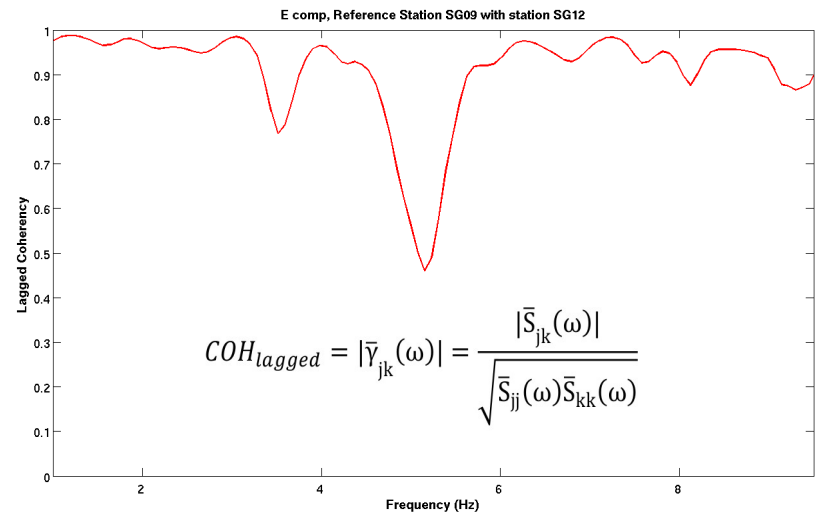
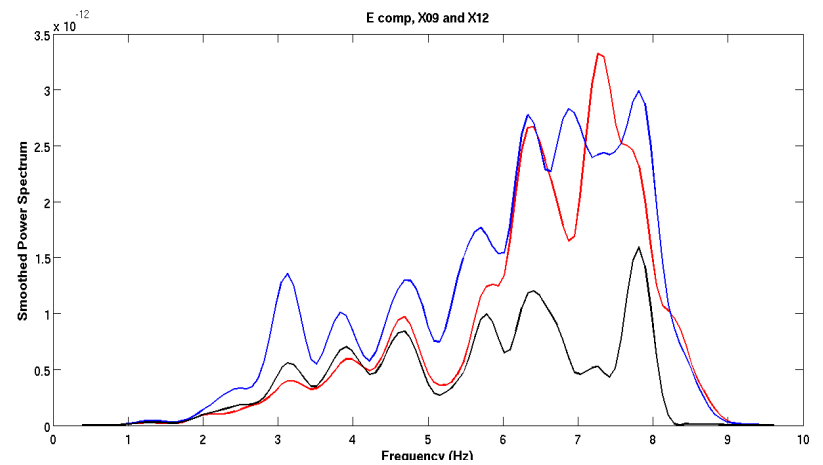
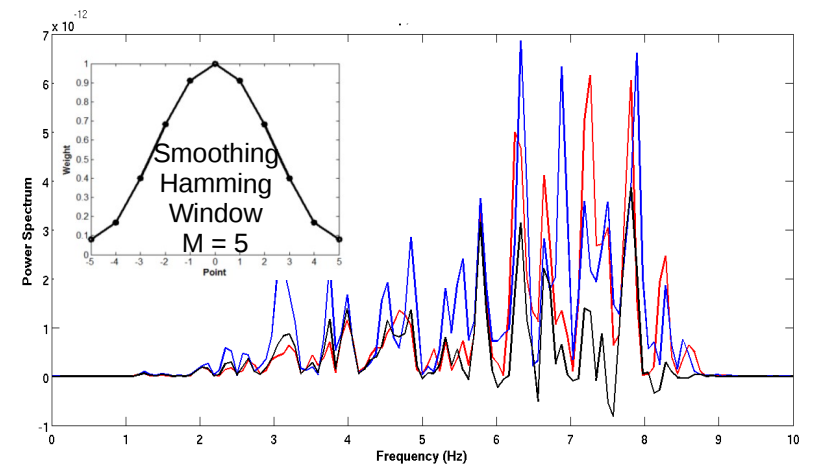
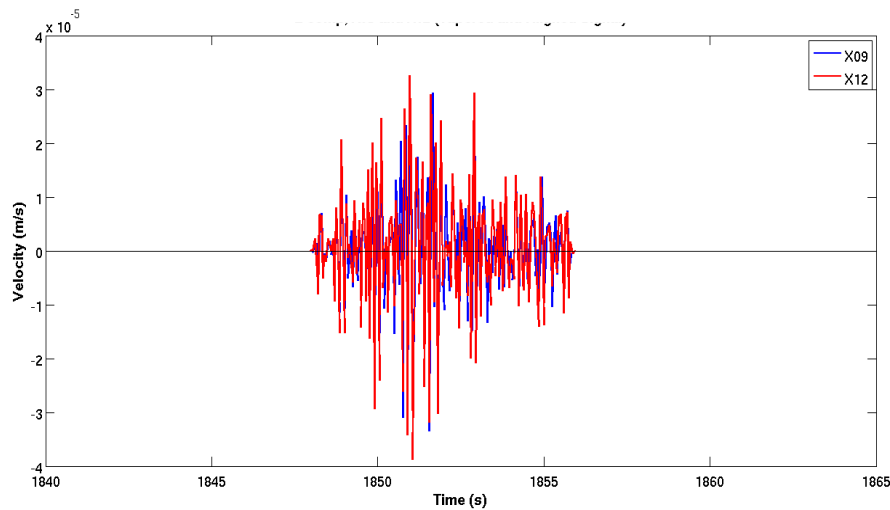


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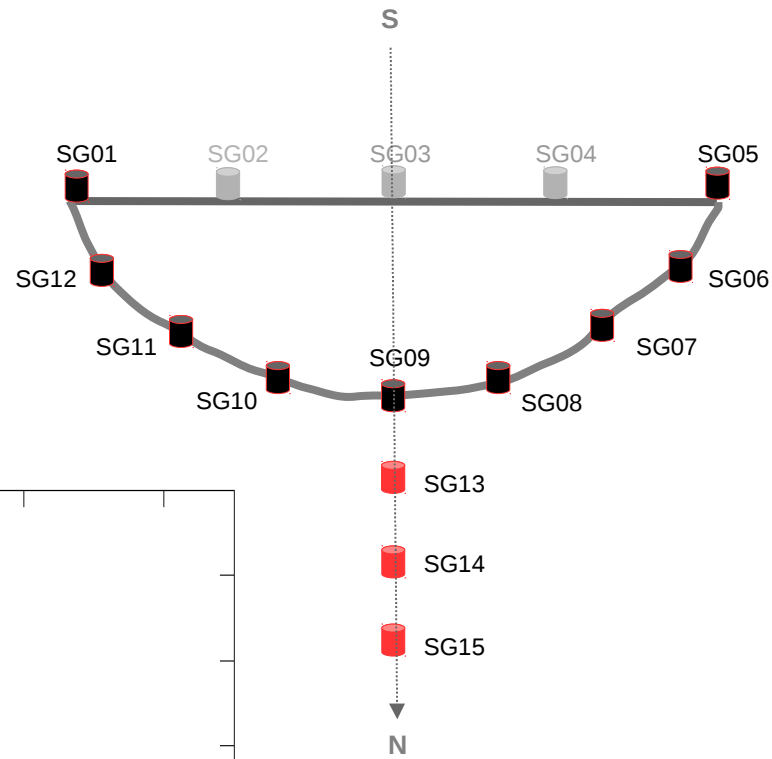


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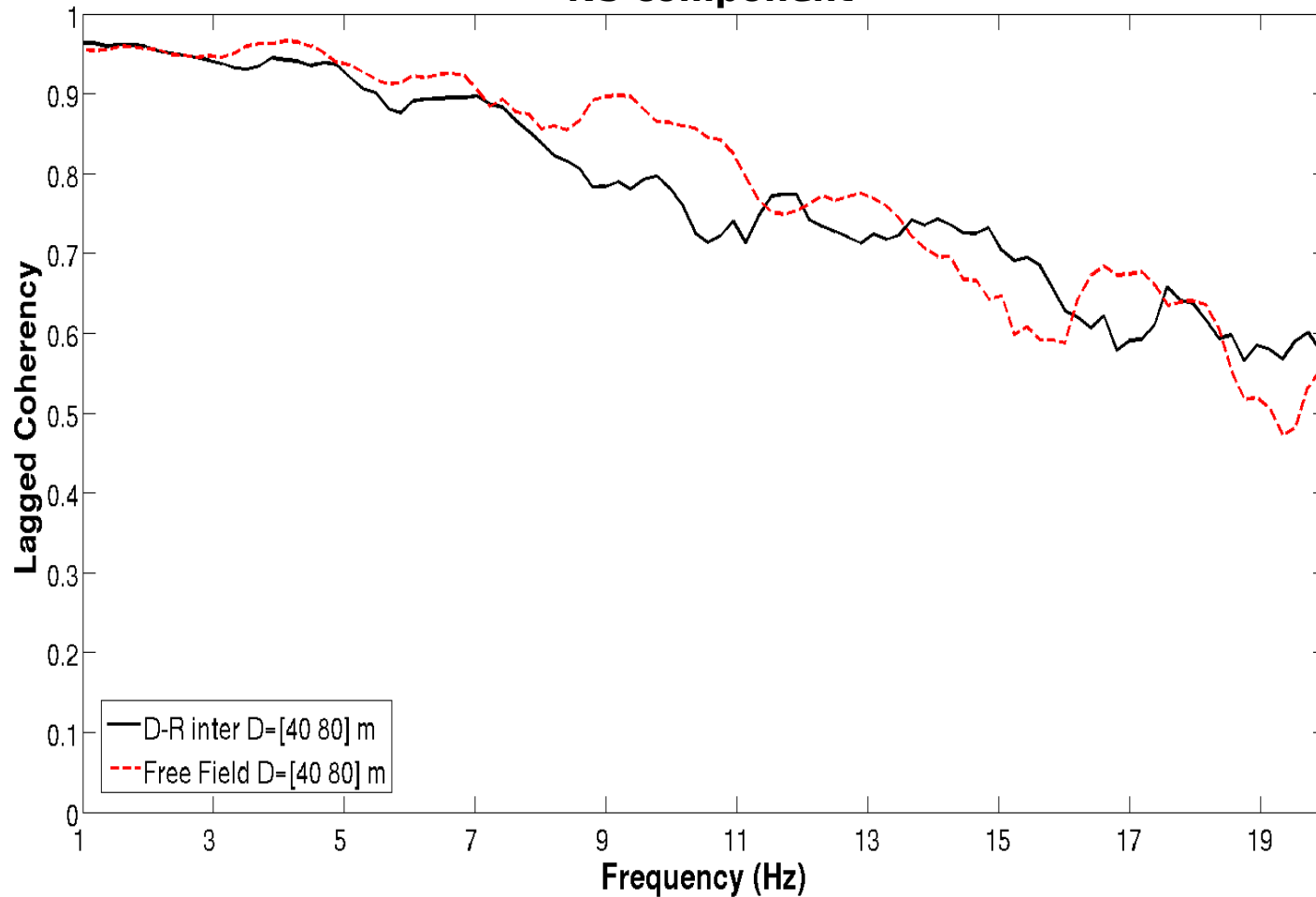
## Comparison with Free Field coherency

SG18

SG17



NS component



# Amplitude Variability

## Comparison with Free Field amplitude variability

